UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

DELL INC., DELL TECHNOLOGIES INC., HP INC., AND LENOVO (UNITED STATES) INC.,

Petitioners

v.

UNIVERSAL CONNECTIVITY TECHNOLOGIES INC.,

Patent Owner.

DECLARATION OF STEVE VENUTI

Case No. IPR2024-01482
U.S. Patent No. 7,856,520

Mail Stop Patent Board
Patent Trial and Appeal Board
U.S. Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450

I, Steve Venuti, do hereby declare and state:

1. I am a citizen of the United States, and reside in Milpitas, California.

2. I make the following statements in this declaration based on my personal knowledge.

3. I first joined HDMI Licensing, LLC ("HDMI Licensing"), which is now HDMI Licensing Administrator, Inc., in September 2002. I retired from HDMI Licensing in March 2015. At the time of my retirement, I was serving as President of HDMI Licensing, a role that I had been in since April 2008. Prior to being President, from September 2005 to March 2008, I was the Vice President of Marketing of HDMI Licensing. From September 2002 to September 2005, I did not have an official title but worked in a marketing role to build a brand around HDMI by marketing the HDMI Specification.

4. This declaration relates to the publication and public accessibility of versions 1.0, 1.1, 1.3, and 1.3a of the HDMI Specification (generally, the "HDMI Specification"). A true and correct copy of versions 1.0, 1.1, 1.3, and 1.3a are attached to this declaration as Attachments A, J, B, and C, respectively. The HDMI Specification generally defines the features and functionality required to implement HDMI-compliant interfaces.

5. HDMI Licensing released the HDMI 1.0 Specification on December 9, 2002. This release was announced in a press release dated December 9, 2002. A

copy of that press release is contained in Attachment L (obtained from *https://hdmi.org/press/bodydetails/79*). At that time, I was serving in the role of marketing HDMI by marketing the HDMI specification for HDMI Licensing. The HDMI 1.0 Specification generally relates to an interface for transmitting digital audiovisual signals that can carry high quality multi-channel audio data, can carry all standard and high definition consumer electronics video formats, and can also carry control and status information in both directions.

6. HDMI Licensing released the HDMI 1.1 Specification on May 20, 2004. At that time, I was continuing to serve in the role of marketing HDMI by marketing the HDMI specification for HDMI Licensing. The HDMI 1.1 Specification generally relates to an interface for transmitting digital audiovisual signals that can carry high quality multi-channel audio data, can carry all standard and high definition consumer electronics video formats, and can also carry control and status information in both directions.

7. HDMI Licensing released the HDMI 1.3 Specification on June 22, 2006, and released the HDMI 1.3a Specification on November 10, 2006. At the time of those releases, respectively, I was the Vice President of Marketing of HDMI Licensing. The HDMI 1.3 Specification generally relates to an interface that combines uncompressed high-definition video, multi-channel audio, and data in a single digital interface to provide crystal-clear digital quality over a single cable.

The HDMI 1.3a Specification includes minor updates to the HDMI 1.3 Specification. Attachment D supports, and is consistent with, my recollection that version 1.3a of the HDMI Specification contains only minor revisions to version 1.3. Attachment D is the Internet Archive WayBack Machine copy of the December 17, 2008, version of the hdmi.org FAQ page. Attachment D explains that "[f]or consumers, there is no difference between HDMI version 1.3 and 1.3a….These minor revisions to the specification typically relate to manufacturing or testing issues and do not impact features or functionality." Attachment D at 2.

8. Since November 2002, HDMI Licensing has been the licensing agent responsible for administering the licensing of the HDMI Specification, promoting HDMI technology, and providing education on the benefits of the HDMI interface to retailers and consumers.

9. In my marketing role for marketing the HDMI Specification at HDMI Licensing, starting in September 2002, I was personally involved in promoting the adoption of version 1.0 of the HDMI Specification, and thus I am personally knowledgeable about the contents of this version. One of my responsibilities in that role was to encourage the adoption of version 1.0 of the HDMI Specification by consumer electronics and PC manufacturers worldwide, and I am personally knowledgeable about those efforts.

10. To encourage adoption of version 1.0 of the HDMI Specification, HDMI Licensing made the announcement available everywhere informing interested members of the public that version 1.0 was available to interested members of the public by way of the website at http://hdmi.org as of its release date of December 9, 2002. *See* Attachment L ("Parties interested in designing HDMI-based products may access the HDMI 1.0 Specification at www.hdmi.org."). I was personally responsible for the promotion of the HDMI 1.0 Specification, including by way of its distribution on the hdmi.org website, and thus have personal knowledge that the HDMI 1.0 Specification was available on http://hdmi.org to interested members of the public at least as of December 9, 2002.

11. Attachments E1 and E2 support, and are consistent with, my recollection that the HDMI 1.0 Specification was accessible to the public as of its December 9, 2002 release. Attachment E1 is the Internet Archive WayBack Machine copy of the February 1, 2003, version of the hdmi.org download instructions page[1] for the HDMI 1.0 Specification. Attachment E2 is the Internet Archive WayBack Machine copy of the February 2, 2003, version of the hdmi.org download page[2] that

[1] This page is accessible at https://web.archive.org/web/20030201085002/http://www.hdmi.org/download/download.asp

[2] This page is accessible at https://web.archive.org/web/20030202040735/http://www.hdmi.org/download/spec.asp

was presented upon the user clicking on the "**1.0 Spec**" link shown in the download instructions page in Attachment E1. As indicated in Attachment E1, dated February 1, 2003, "Version 1.0 of the HDMI specification is now available for download. Follow the steps below to gain access to the spec." As indicated in Attachment E1, interested members of the public only needed to submit two signed copies of an adopter agreement and make an annual fee payment to obtain a login name and password from HDMI Licensing that would allow them to download the HDMI 1.0 Specification. There were no other restrictions imposed on members of the public from accessing a copy of the HDMI 1.0 Specification. As indicated in Attachment E2, dated February 2, 2003, users would then enter their login name and password to download the HDMI 1.0 Specification from the website.

12. Attachment A contains a true and correct copy of version 1.0 of the HDMI specification, as initially released on December 9, 2002, and is a copy that I obtained from my archives that I maintained while I was employed by HDMI Licensing.

13. As shown in Attachment A, the HDMI 1.0 Specification included a "Confidential" footer at the time of its initial release. This footer was included merely to indicate that the HDMI 1.0 Specification was not to be distributed to individuals who had not signed the adopter agreement and paid the annual fee. As discussed, there were no other restrictions imposed on availability of the HDMI 1.0

Specification to interested members of the public. And this "Confidential" footer did not indicate that this was a confidential document internal to HDMI Licensing.

14. In my marketing role for marketing the HDMI Specification at HDMI Licensing, starting in September 2002, I was also personally involved in promoting the adoption of version 1.1 of the HDMI Specification, and thus I am personally knowledgeable about the contents of this version. One of my responsibilities in that role was to encourage the adoption of version 1.1 of the HDMI Specification by consumer electronics and PC manufacturers worldwide, and I am personally knowledgeable about those efforts.

15. To encourage adoption of version 1.1 of the HDMI Specification, HDMI Licensing made the announcement available everywhere informing interested members of the public that version 1.1 was available to interested members of the public by way of the website at http://hdmi.org as of its release date of May 20, 2004. I was personally responsible for the promotion of the HDMI 1.1 Specification, including by way of its distribution on the hdmi.org website, and thus have personal knowledge that the HDMI 1.1 Specification was available on http://hdmi.org to interested members of the public at least as of May 20, 2004.

16. Attachment K is consistent with my recollection that the HDMI 1.1 Specification was accessible to the public as of its May 20, 2004 release. Attachment K is the Internet Archive WayBack Machine copy of the June 12, 2004, version of

the hdmi.org download instructions page[3] for the HDMI 1.1 Specification. As indicated in Attachment K, dated June 12, 2004, "Version 1.1 of the HDMI Specification [is] available for download. In order to gain access to either of these specifications please register by filling out the form below." As shown in Attachment K, all interested members of the public had to do to be able to download the HDMI 1.1 Specification as of its release was to complete a form requesting biographical information from the user, such as name, title, phone number, email address, company, job function, etc. As Attachment K also indicates, once users submitted the form, they were able to download the HDMI 1.1 Specification for free. Attachment K ("Once you submit your completed form, you will be able to choose to download [] Version 1.1 of the HDMI Specification (FREE DOWNLOAD) . . ."). There were no other restrictions imposed on members of the public from accessing a copy of the HDMI 1.1 Specification. It merely required entry of basic information identifying the downloader. Activating the submit button would then provide a link from which the HDMI Specification could be directly downloaded. I was personally responsible for coordinating the development of this download functionality.

[3] This page is accessible at https://web.archive.org/web/20040612170926/http:/www.hdmi.org:80/download/download.asp

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17. Attachment J contains a true and correct copy of version 1.1 of the HDMI specification, as initially released on May 20, 2004, and is a copy that I obtained from my archives that I maintained while I was employed by HDMI Licensing.

18. In my role as Vice President of Marketing of HDMI Licensing from September 2005 through March 2008, I was personally involved in promoting the adoption of versions 1.3 and 1.3a of the HDMI Specification, and thus I am personally knowledgeable about the contents of these versions. One of my responsibilities in that role was to encourage the adoption of versions 1.3 and 1.3a of the HDMI Specification by consumer electronics and PC manufacturers worldwide, and I am personally knowledgeable about those efforts.

19. To encourage adoption of versions 1.3 and 1.3a of the HDMI Specification, HDMI Licensing made these versions freely available by way of the website at http://hdmi.org. I was personally responsible for the promotion of the HDMI 1.3 and 1.3a Specifications by way of their distribution on the hdmi.org website, and thus have personal knowledge that the HDMI 1.3 Specification was available on that website at least as of June 22, 2006 (when that version was released), and the HDMI 1.3a Specification was available on that website at least as of November 10, 2006 (when that version was released).

20. Attachment F supports, and is consistent with, my recollection that the HDMI 1.3 Specification was accessible to the public as of June 22, 2006. Attachment F is the Internet Archive WayBack Machine copy of the July 1, 2006, version of the hdmi.org download page[4] for the HDMI Specification. As noted above, by that time, the current version of the HDMI Specification was 1.3 and that version was available for download from the hdmi.org download page. Attachment F explains that "[t]he HDMI technical specification is available to HD device, display, component, and test equipment manufacturers at no charge." With respect to version 1.3, that statement is accurate, and was accurate as of June 22, 2006, when the HDMI 1.3 Specification was released. All that interested members of the public had to do to be able to download the HDMI 1.3 Specification was to complete the form requesting biographical information about the user, as indicated in Attachment F. There were no other restrictions on download. Activating the submit button would then provide a link from which the HDMI Specification could be directly downloaded. I was personally responsible for coordinating the development of this download functionality.

21. Attachment B contains a true and correct copy of version 1.1 of the HDMI specification, as initially released on June 22, 2006, and is a copy that I

[4] This page is accessible at: https://web.archive.org/web/20060701221246/http://www.hdmi.org:80/manufacturer/specification.asp

obtained from my archives that I maintained while I was employed by HDMI Licensing.

22. Attachment G supports, and is consistent with, my recollection that the HDMI 1.3a Specification was accessible to the public as of November 10, 2006. Attachment G is the Internet Archive WayBack Machine copy of the December 11, 2006, version of the hdmi.org download page[5] for the HDMI Specification. As noted above, by that time, the current version of the HDMI Specification was 1.3a and that version was available for download from the hdmi.org download page. Attachment G explains that "[t]he HDMI technical specification is available to HD device, display, component, and test equipment manufacturers at no charge." With respect to version 1.3a, that statement is accurate, and was accurate as of November 10, 2006, when the HDMI 1.3a Specification was released. All that interested members of the public had to do to be able to download the HDMI 1.3a Specification was to complete the form requesting biographical information about the user, as indicated in Attachment G. There were no other restrictions on download. Activating the submit button would then provide a link from which the HDMI Specification could be directly downloaded. I was personally responsible for coordinating the development of this download functionality.

[5] This page is accessible at: https://web.archive.org/web/20061211204205/http://www.hdmi.org:80/manufacturer/specification.asp

23. Attachment C contains a true and correct copy of version 1.3a of the HDMI specification, as initially released on November 10, 2006, and is a copy that I obtained from my archives that I maintained while I was employed by HDMI Licensing.

24. To encourage the adoption of the HDMI 1.0, 1.1, 1.3 and 1.3a Specifications, HDMI Licensing allowed the public, as of December 9, 2002, May 20, 2004, June 22, 2006, and November 10, 2006, respectively, to access the HDMI 1.0, 1.1, 1.3, and 1.3a Specifications via that website and download a copy. HDMI Licensing intended for the HDMI 1.0, 1.1, 1.3, and 1.3a Specifications to be distributed as widely as possible and thus placed no restrictions on such downloading or on the redistribution of the specification other than those specifically listed above.

25. Part of my responsibilities at HDMI Licensing was to make the relevant public aware of versions 1.0, 1.1, 1.3, and 1.3a of the HDMI Specification and their availability. We did this through several mechanisms—for example, through a tab on the hdmi.org website, through press releases, and through promotion of the availability of the versions of the HDMI Specification at industry events such as CES and DisplaySearch, as well as at HDMI Licensing press events.

26. In my role of encouraging the adoption of versions 1.0, 1.1, 1.3, and 1.3a of the HDMI Specification, I communicated with representatives from

consumer electronics and personal computer manufacturers who were interested in using the HDMI Specification to implement audiovisual interfaces in their products.

27. Around the time that versions 1.3 and 1.3a of the HDMI specification were released, there were already hundreds of HDMI adopters. Attachments H and I support, and are consistent with, my recollection concerning the number of HDMI adopters in the 2006 timeframe. Attachments H and I are Internet Archive WayBack Machine copies of the July 1, 2006, and November 29, 2006, versions of the hdmi.org adopters and founders page. As of July 1, 2006, this page listed 425 adopters. Attachment H. By November 29, 2006, this page listed 485 adopters, including many prominent consumer electronics manufacturers. Attachment I.

28. I am also personally aware of a number of people outside of HDMI Licensing, including at various manufacturers, who were aware of the availability of version 1.0 of the HDMI Specification on the hdmi.org website in the late 2002 and early 2003 timeframe after its release and who actually downloaded the HDMI Specification from the website. I am also personally aware of a number of people outside of HDMI Licensing, including at various manufacturers, who were aware of the availability of version 1.1 of the HDMI Specification on the hdmi.org website May 2004 timeframe after its release and who actually downloaded the HDMI Specification from the website. I am also personally aware of a number of people outside of HDMI Licensing, including at various manufacturers, who were aware of

the availability of versions 1.3 and 1.3a of the HDMI Specification on the hdmi.org website in the 2006 timeframe and who actually downloaded the HDMI Specification from the website.

29. Sometime in 2007, I personally made a request within HDMI Licensing for the number of downloads of the HDMI Specification from the hdmi.org website and learned that there had been more than 30,000 downloads of the HDMI 1.0-1.3a specifications as of that time in 2007.

30. As I discuss above, I was employed by HDMI Licensing until March 2015. In March 2015, I retired from my role as president of HDMI Licensing—a role I had held since April 2008. As president of HDMI Licensing, I would have viewed a dispute between Universal Connectivity Technologies, Inc. and HP, Dell, and Lenovo as a neutral event, and, as a matter of policy, would not have become involved without being issued a Court subpoena or similar legal document. At that time, I would not have provided, nor would I have authorized another HDMI Licensing employee to provide, a declaration such as this one.

31. I understand that in the current proceeding I may be deposed on the contents of this declaration, if requested, and I am willing to sit for any such deposition. I am being paid a flat fee of $2,500 for my time in connection with preparing this declaration, and an hourly fee of $500/hour for my time in connection with participating in any deposition in this proceeding. My compensation is in no

way dependent on the content of this declaration, nor is it dependent on the outcome of this proceeding.

32. I, Steve Venuti, declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, under Section 1001 of Title 18 of the United States Code.

Dated: September 30, 2024



Steve Venuti

ATTACHMENT A

High-Definition Multimedia Interface

Specification Version 1.0

Hitachi, Ltd.

Matsushita Electric Industrial Co., Ltd.

Philips Consumer Electronics, International B.V.

Silicon Image, Inc.

Sony Corporation

Thomson Inc.

Toshiba Corporation

CONFIDENTIAL

December 9, 2002

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Preface

Notice

THIS SPECIFICATION IS PROVIDED “AS IS” WITH NO WARRANTIES WHATSOEVER, EXPRESS OR IMPLIED, INCLUDING, WITHOUT LIMITATION, NO WARRANTIES OF MERCHANTABILITY, NONINFRINGEMENT, FITNESS FOR ANY PARTICULAR PURPOSE, OR ANY WARRANTY OTHERWISE ARISING OUT OF ANY PROPOSAL, SPECIFICATION, OR SAMPLE.

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Document Revision History

1.0	2002/12/09	Initial Release

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Intellectual Property Statement

Hitachi, Ltd., Matsushita Electric Industrial Co., Ltd., Philips Consumer Electronics International, B.V., Silicon Image, Inc., Sony Corporation, Thomson Inc., and Toshiba Corporation each may have patents and/or patent applications related to the High-Definition Multimedia Interface Specification. These companies intend to make available to the industry an Adopter Agreement that will include a limited, reciprocal patent license to certain of the electrical interfaces, mechanical interfaces, signals, signaling and coding protocols, and bus protocols described in the mandatory portions of the High-Definition Multimedia Interface Specification Release 1.0 published by HDMI Licensing, LLC.

Contact Information

The URL for the HDMI Founders web site is: http://www.HDMI.org.

Contribution

Silicon Image, Inc has made a significant contribution to this standard by editing the specification and developing the core technologies upon which this specification is based; including Transition Minimized Differential Signaling (TMDS®) technology.

Acknowledgement

HDMI founders acknowledge the concerted efforts of employees of Japan Aviation Electronics Industry, Limited and Molex Japan, who have made a significant contribution to this standard by developing the connector technology and the mechanical and electrical specifications for the required plugs and receptacles.

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1 Introduction

1.1 Purpose and Scope

This document constitutes the specification for the High-Definition Multimedia Interface (HDMI).

The High-Definition Multimedia Interface is provided for transmitting digital television audiovisual signals from DVD players, set-top boxes and other audiovisual sources to television sets, projectors and other video displays.

HDMI can carry high quality multi-channel audio data and can carry all standard and high-definition consumer electronics video formats. Content protection technology is available.

HDMI can also carry control and status information in both directions.

This specification completely describes the interface such that one could implement a complete transmission and interconnect solution or any portion of the interface. The underlying Transition Minimized Differential Signaling (TMDS)-based protocol and associated electrical signaling is described in detail. The mechanical specification of the connector and the signal placement within the connector are described.

A device that is compliant with this specification is interoperable with other compliant devices through the configuration and implementation provided for in this specification.

Mechanical, electrical, behavioral and protocol requirements necessary for compliance are described for sources, sinks and cables.

1.2 Normative References

The following standards contain provisions that, through reference in this text, constitute normative provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. If the referenced standard is dated, the reader is advised to use the version specified.

EIA, EIA/CEA-861B, “A DTV Profile For Uncompressed High Speed Digital Interfaces”[1]

VESA, VESA E-EDID Standard, ENHANCED EXTENDED DISPLAY IDENTIFICATION DATA STANDARD Release A, Revision 1, February 9, 2000

VESA, VESA E-DDC Standard, ENHANCED DISPLAY DATA CHANNEL STANDARD Version 1, September 2, 1999

Philips Semiconductors, The I^2C-bus Specification, Version 2.1, January 2000

ITU, ITU-R BT.601-5 Studio encoding parameters of digital television for standard 4:3 and wide-screen 16:9 aspect ratios (October 1995)

[1] All HDMI devices are required to comply with the requirements specified in EIA/CEA-861B except where specifically noted in this document.

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ITU, ITU-R BT.709-4 Parameter values for the HDTV standards for production and international programme exchange (March 2000)

IEC, IEC 60958-1, “Digital audio interface – Part 1: General”, First edition 1999-12

IEC, IEC 60958-3, “Digital audio interface – Part 3: Consumer applications”, First edition 1999-12

IEC, IEC 61937, “Digital Audio - Interface for non-linear PCM encoded audio bitstreams applying IEC 60958”, First edition 2000-04

DDWG, “Digital Visual Interface,” Revision 1.0, April 2, 1999 (DVI)

1.3 Informative References

The following documents contain information that is useful in understanding this standard. Some of these documents are drafts of standards that may become normative references in a future release of this standard.

Digital Content Protection LLC, “High-bandwidth Digital Content Protection System Specification”, Revision 1.10 (HDCP)

ANSI/SMPTE, SMPTE Standard 170M (1999) for Television – Composite Analog Video Signal – NTSC for Studio Applications

ANSI/SMPTE, SMPTE Standard 274M

ANSI/SMPTE, SMPTE Standard 296M

EIA, CEB14, “Recommend Practice for use of EDID with EIA/CEA-861”

1.4 Organization of this document

This specification is organized as follows:

- Chapter 1 introduces HDMI, describes the purpose and scope of this document, references, organization of the document and usages and conventions.
- Chapter 2 defines terms and acronyms used throughout this document.
- Chapter 3 provides a high-level overview of the operation of HDMI.
- Chapter 4 describes the details of the Physical Layer of HDMI including basic electrical specifications and mechanical specifications of cables and connectors.
- Chapter 5 describes the Signaling and Encoding used by HDMI including descriptions of the different periods and encoding types used to transmit audio, video, and control data types and packet definitions for audio and auxiliary data.
- Chapter 6 describes Video related issues including video format timings, pixel encodings (RGB, YC_BC_R), colorimetry and corresponding requirements.
- Chapter 7 describes Audio related issues including audio clock regeneration, placement of audio samples within packets, packet timing requirements, audio sample rates and requirements, and channel/speaker assignments.
- Chapter 8 describes Control and Configuration functions, mechanisms and requirements, including use of the E-EDID, and InfoFrames.

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- Chapter 9 describes the Content protection used for HDMI.
- Appendix A describes the usage of Repeaters and Switches.
- Appendix B describes restrictions related to the use of the Type B connector.
- Appendix C describes DVI compatibility.
- Supplement 1 describes use of the Consumer Electronics Control (CEC) line and protocol.

1.5 Usages and Conventions

bit N	Bits are numbered in little-endian format, i.e. the least-significant bit of a byte or word is referred to as bit 0.
D[X:Y]	Bit field representation covering bit X to bit Y (inclusive) of value or field D.
0xNN	Hexadecimal representation of base-16 numbers are represented using ‘C’ language notation, preceded by ‘0x’.
0bNN	Binary (base-2) numbers are represented using ‘C’ language notation, preceded by ‘0b’.
NN	Decimal (base-10) numbers are represented using no additional prefixes or suffixes.

Within this specification, any descriptions of data structures, values or sequences that occur on the HDMI interface should be interpreted only as data structures, values and sequences that are transmitted by the HDMI Source. Due to the possibility of errors during the transmission, these items should not be construed as data structures, values or sequences that are guaranteed to be detected by the HDMI Sink.

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2 Definitions

2.1 Conformance Levels

expected	A key word used to describe the behavior of the hardware or software in the design models *assumed* by this specification. Other hardware and software design models may also be implemented.
may	A key word that indicates flexibility of choice with *no implied preferenc*e.
shall	A key word indicating a mandatory requirement. Designers are *required* to implement all such mandatory requirements.
should	A key word indicating flexibility of choice with a strongly preferred alternative. Equivalent to the phrase *is recommended*.
reserved fields	A set of bits within a data structure that are defined in this specification as reserved, and are not otherwise used. Implementations of this specification shall zero these fields. Future revisions of this specification, however, may define their usage.
reserved values	A set of values for a field that are defined in this specification as reserved, and are not otherwise used. Implementations of this specification shall not generate these values for the field. Future revisions of this specification, however, may define their usage.

2.2 Glossary of Terms

(Audio) Channel	Audio data meant to be delivered to a single audio speaker.
(Audio) Sample Clock	Original clock related to the audio input samples at the Source or the generated clock used to time the output of audio samples.
BCH	Error correction technique named after the developers: Bose, Chauduri, and Hocquenghem.
Byte	Eight bits of data.
Data Stream Disparity	Integer indicating “DC-offset” level of link. A positive value represents the excess number of “1”s that have been transmitted. A negative value represents the excess number of “0”s that have been transmitted.
Downstream	In the direction of the primary audio and video data flow, i.e. towards the Sink (e.g. display).
(HDMI) Source	A device with an HDMI output.
(HDMI) Sink	A device with an HDMI input.
(HDMI) Repeater	A device with one or more HDMI inputs and one or more HDMI outputs. Repeater devices shall simultaneously behave as both an HDMI Sink and an HDMI Source.

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Multi-channel	Audio with more than 2 channels. Typically this term is applied to 6 (5.1) channel streams. Also called surround formats.
Pixel	Picture Element. Refers to the actual element of the picture and the data point in the digital video stream representing such an element. This term may also apply to the data that is carried across the HDMI link during a single TMDS (pixel) clock cycle, even if that data does not actually represent a picture element.
Pixel Encoding	Bit placement and sequencing for the components of a pixel for a particular color space and chroma sampling.
Root (Device)	A device, generally a display device, formally defined by the following rule: A device that has no HDMI output or, a device which has chosen to take the physical address 0.0.0.0 (see Section 8.7).
Receiver	A component that is responsible for receiving the four differential TMDS input pairs at the input to an HDMI Sink and converting those signals into a digital output indicating a 24 bit, 12 bit, or 6 bit TMDS decoded word and indicating the TMDS coding mode used to decode those bits. This digital output may be contained within a semiconductor device or may be output from a semiconductor device.
Stereo	2 channel audio.
Stream	A time-ordered set of digital data originating from one Source and terminating at zero or more Sinks. A stream is characterized by bounded bandwidth requirements.
T_{bit}	Time duration of a single bit carried across the TMDS data channels.
T_{pixel}	Time duration of a single pixel carried across the TMDS data channels. This is equal to $10 * T_{bit}$.
Transmitter	A component that is responsible for driving the four differential TMDS output pairs into an HDMI output and for clocking the data driven into those four output pairs.
Video Field	The period from one VSYNC active edge to the next VSYNC active edge.
Video Format	A video format is sufficiently defined such that when it is received at the monitor, the monitor has enough information to properly display the video to the user. The definition of each format includes a Video Format Timing, the picture aspect ratio, and a colorimetry space.
Video Format Timing	The waveform associated with a video format. Note that a specific Video Format Timing may be associated with more than one Video Format (e.g., 720X480p@4:3 and 720X480p@16:9).
YC_BC_R	Digital representation of any video signal using one of several luminance/color-difference color spaces.

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2.3 Acronyms and Abbreviations

ANSI	American National Standards Institute
AVI	Auxiliary Video Information
CEA	Consumer Electronics Association
CEC	Consumer Electronics Control
CTS	Cycle Time Stamp
DDC	Display Data Channel
DDWG	Digital Display Working Group
DTV	Digital Television
DVD	Digital Versatile Disc
DVI	Digital Visual Interface
E-DDC	Enhanced Display Data Channel
E-EDID	Enhanced Extended Display Identification Data
ECC	Error Correction Code
EDID	Extended Display Identification Data
EIA	Electronic Industries Alliance
HDCP	High-bandwidth Digital Content Protection
HDMI	High-Definition Multimedia Interface
HDTV	High-Definition Television
HPD	Hot Plug Detect
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ITU	International Telecommunications Union
L-PCM	Linear Pulse-Code Modulation
LSb	least significant bit
MPEG	Moving Picture Experts Group
MSb	most significant bit

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N.C.	No connect.
PCB	Printed Circuit Board
Rx	Receiver
SMPTE	Society of Motion Picture & Television Engineers
STB	Set-Top Box
TERC4	TMDS Error Reduction Coding – 4 bit
TMDS	Transition Minimized Differential Signaling
Tx	Transmitter
VESA	Video Electronics Standards Association
VSDB	Vendor-Specific Data Block

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3 Overview

HDMI system architecture is defined to consist of Sources and Sinks. A given device may have one or more HDMI inputs and one or more HDMI outputs. Each HDMI input on these devices shall follow all of the rules for an HDMI Sink and each HDMI output shall follow all of the rules for an HDMI Source.

As shown in *Figure 3-1 HDMI Block Diagram* the HDMI cable and connectors carry four differential pairs that make up the TMDS data and clock channels. These channels are used to carry video, audio and auxiliary data. In addition, HDMI carries a VESA DDC channel. The DDC is used for configuration and status exchange between a single Source and a single Sink. The optional CEC protocol provides high-level control functions between all of the various audiovisual products in a user's environment.

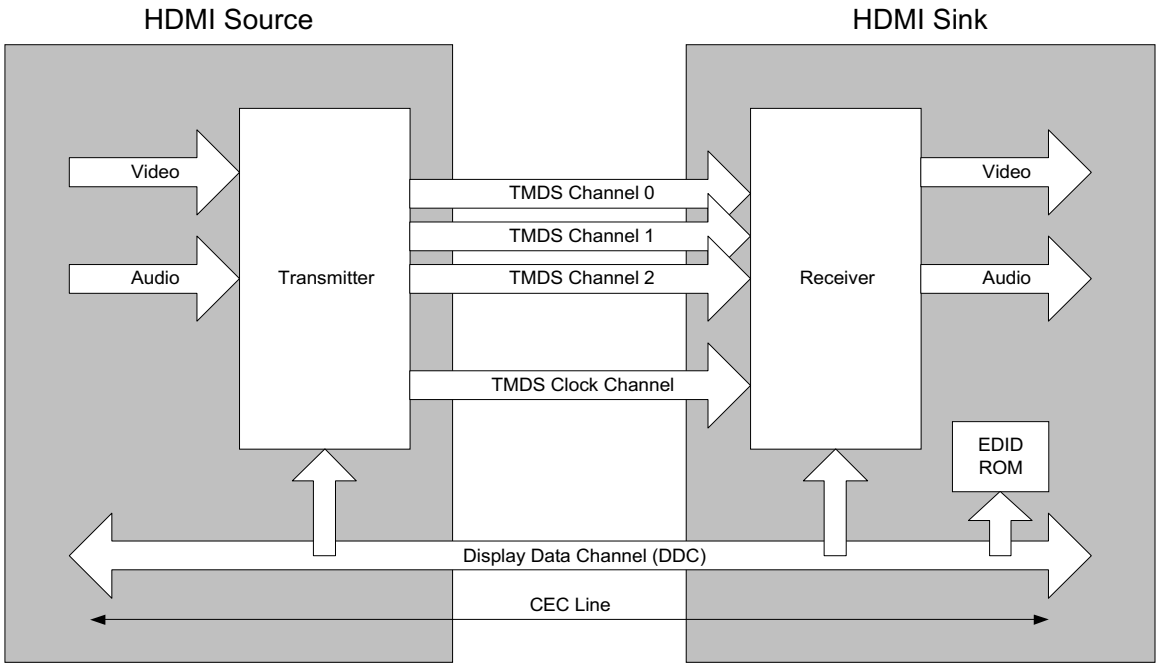


Figure 3-1 HDMI Block Diagram

Audio, video and auxiliary data is transmitted across the three TMDS data channels. The video pixel clock is transmitted on the TMDS clock channel and is used by the receiver as a frequency reference for data recovery on the three TMDS data channels.

Video data is carried as a series of 24-bit pixels on the three TMDS data channels. TMDS encoding converts the 8 bits per channel into the 10 bit DC-balanced, transition minimized sequence which is then transmitted serially across the pair at a rate of 10 bits per pixel clock period.

Video pixel rates can range from 25MHz to 165MHz. Video formats with rates below 25MHz (e.g. 13.5MHz for 480i/NTSC) can be transmitted using a pixel-repetition scheme. The video pixels can be encoded in either RGB, YC_BC_R 4:4:4 or YC_BC_R 4:2:2 formats. In all three cases, up to 24 bits per pixel can be transferred.

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In order to transmit audio and auxiliary data across the TMDS channels, HDMI uses a packet structure. In order to attain the higher reliability required of audio and control data, this data is protected with a BCH error correction code and is encoded using a special error reduction coding to produce the 10-bit word that is transmitted.

Basic audio functionality consists of a single IEC 60958 audio stream at sample rates of 32kHz, 44.1kHz or 48kHz. This can accommodate any normal stereo stream. Optionally, HDMI can carry a single such stream at sample rates up to 192KHz or from two to four such streams (3 to 8 audio channels) at sample rates up to 96KHz. HDMI can also carry IEC 61937 compressed (e.g. surround-sound) stream at sample rates up to 192kHz.

The DDC is used by the Source to read the Sink's Enhanced Extended Display Identification Data (E-EDID) in order to discover the Sink's configuration and/or capabilities.

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4 Physical Layer

4.1 Connectors and Cables

4.1.1 Overview of Connectors

A device's external HDMI connection shall be presented via one of the two specified HDMI connectors, Type A or Type B. This connector can be attached directly to the device or can be attached via a cable adapter that is shipped with the device.

The Type A connector carries all required HDMI signals, including a single TMDS link. The Type B connector is slightly larger and carries a second TMDS link which is necessary to support very high resolution computer displays requiring dual link bandwidth.

A passive cable adapter between Type A and Type B connectors is specified.

4.1.2 Connector Support Requirements

4.1.2.1 HDMI Sources

An HDMI Source connection using a Type A connector shall transmit only video format timings that are:

- Described in Section 6.3, or,
- Defined, per EDID Ver. 1.3, in the first, and only the first 18-byte timing descriptor of a concurrently attached HDMI compliant Sink.

An HDMI Source connection using a Type B connector may transmit any video format timing.

4.1.2.2 HDMI Sinks

An HDMI Sink connection using a Type A connector may define support, via E-EDID, only for video format timings that are:

- Described in Section 6.3, or,
- Defined within the first and only the first 18-byte timing descriptor found in the EDID 1.3 structure of this Sink.

An HDMI Sink connection using a Type B connector may define support for any video format timing, via any of the EDID 1.3 or EIA/CEA-861B mechanisms.

Beyond the specific video format timing restrictions defined in this section (above), no other video differences between Type A and Type B devices are defined in this specification.

4.1.3 Dual-Link

The Type A connector carries only a single TMDS link and is therefore only permitted to carry signals up to 165Mpixels/sec.

To support signals greater than 165Mpixels/sec, the dual-link capability of the Type B connector shall be used.

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HDMI dual-link architecture is compatible with DVI 1.0 dual-link architecture and is defined in Appendix B.

4.1.4 Connector Pin Assignments

Table 4-1 Type A Connector Pin Assignment

PIN	Signal Assignment	PIN	Signal Assignment
1	TMDS Data2+	2	TMDS Data2 Shield
3	TMDS Data2–	4	TMDS Data1+
5	TMDS Data1 Shield	6	TMDS Data1–
7	TMDS Data0+	8	TMDS Data0 Shield
9	TMDS Data0–	10	TMDS Clock+
11	TMDS Clock Shield	12	TMDS Clock–
13	CEC	14	Reserved (N.C. on device)
15	SCL	16	SDA
17	DDC/CEC Ground	18	+5V Power
19	Hot Plug Detect		

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Table 4-2 Type B Connector Pin Assignment

PIN	Signal Assignment	PIN	Signal Assignment
1	TMDS Data2+	2	TMDS Data2 Shield
3	TMDS Data2-	4	TMDS Data1+
5	TMDS Data1 Shield	6	TMDS Data1-
7	TMDS Data0+	8	TMDS Data0 Shield
9	TMDS Data0-	10	TMDS Clock+
11	TMDS Clock Shield	12	TMDS Clock-
13	TMDS Data5+	14	TMDS Data5 Shield
15	TMDS Data5-	16	TMDS Data4+
17	TMDS Data4 Shield	18	TMDS Data4-
19	TMDS Data3+	20	TMDS Data3 Shield
21	TMDS Data3-	22	CEC
23	Reserved (N.C. on device)	24	Reserved (N.C. on device)
25	SCL	26	SDA
27	DDC/CEC Ground	28	+5V Power
29	Hot Plug Detect		

4.1.5 Contact sequence

Table 4-3 Connector Contact Sequence

Connection	Signals	
	Type A Connector	Type B Connector
First Make	Connector shell	Connector shell
Second Make	Pins 1 - 17 and pin 19	Pins 1 - 27 and pin 29
Third Make	Pin18 (+5V Power)	Pin28 (+5V Power)

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4.1.6 Connector Mechanical Performance

Table 4-4 Type A Plug and Receptacle Mechanical Performance

Item	Test Condition	Requirement	
Vibration	Amplitude : 1.52mm P-P or 147m/s^2 {15G} Sweep time: 50-2000-50Hz in 20 minutes. Duration : 12 times in each (total of 36 Times) X, Y, Z axes. Electrical load : DC100mA current shall be Flowed during the test. (ANSI/EIA-364-28 Condition III Method 5A)	Appearance	No Damage
		Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell Part : Change from initial value: 50 milliohms maximum.
		Discontinuity	1 μsec maximum.
Shock	Pulse width: 11 msec., Waveform : half sine, 490m/s^2{50G}, 3 strokes in each X.Y.Z. axes (ANSI/EIA-364-27, Condition A)	Appearance	No Damage
		Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell : Change from initial value: 50 milliohms maximum.
		Discontinuity	1 μsec maximum.
Durability	Measure contact and shell resistance after Following. Automatic cycling : 10,000 cycles at 100 ± 50 cycles per hour	Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell : Change from initial value: 50 milliohms maximum.

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Item	Test Condition	Requirement	
Insertion / Withdrawal Force	Insertion and withdrawal speed : 25mm/minute. (ANSI/EIA-364-13)	Withdrawal force	9.8N {1.0kgf} minimum 39.2N {4.0kgf} maximum
		Insertion force	44.1N {4.5kgf} maximum
Cable Flex	100 cycles in each of 2 planes Dimension X = 3.7 x Cable Diameter. (ANSI/EIA-364-41, Condition I)	Discontinuity	1 μsec maximum.
		Dielectric Withstanding Voltage and Insulation Resistance	Conform to item of dielectric withstanding voltage and insulation resistance

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4.1.7 Connector Electrical Characteristics

4.1.7.1 Electrical Performance

Table 4-5 Electrical Performance

Item	Test Condition	Requirement
Contact Resistance	Mated connectors, Contact : measure by dry circuit, 20 mVolts maximum.,10mA. Shell : measured by open circuit, 5 Volts maximum ,100mA. (ANSI/EIA-364-06A-83)	Contact : 30 milliohms maximum. Shell : 50 milliohms maximum.
Dielectric Strength	Unmated connectors, apply 500 Volts AC(RMS.) between Adjacent terminal or ground. (ANSI/EIA 364-20,Method 301) Mated connector, apply 300 Volts AC(RMS.) between adjacent terminal and ground.	No Breakdown
Insulation Resistance	Unmated connectors, apply 500 Volts DC between adjacent terminal or ground. (ANSI/EIA 364-21,Method 302)	100 megaohms minimum (unmated)
	Mated connectors, apply 150 Volts DC between adjacent terminal or ground.	10 megaohms minimum (mated)
Contact Current Rating	55 °C, maximum ambient 85 °C, maximum temperature change (ANSI/EIA-364-70,TP-70)	0.5 A minimum
Applied Voltage Rating	40 Volts AC (RMS.) continuous maximum, on any signal pin with respect to the shield.	No Breakdown
Electrostatic Discharge	Test unmated each connectors from 1 kVolt to 8 kVolts in 1 kVolt steps using 8mm ball probe. (IEC-801-2)	No evidence of Discharge to Contacts at 8 kVolts

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Item	Test Condition	Requirement
TMDS Signals Time Domain Impedance	Rise time ≤ 200 psec (10%-90%). Signal to Ground pin ratio per HDMI designation. Differential Measurement Specimen Environment Impedance = 100 ohms differential Source-side receptacle connector mounted on a Controlled impedance PCB fixture. (ANSI/EIA-364-108 Draft Proposal)	Connector Area : 100 ohms ±15% Transition Area : 100 ohms ±15% Cable Area : 100 ohms ±10%
TMDS Signals Time Domain Cross talk FEXT	Rise time ≤ 200 psec (10%-90%). Signal to Ground pin ratio per HDMI designation. Differential Measurement Specimen Environment Impedance = 100 ohms differential. Source-side receptacle connector mounted on controlled impedance PCB fixture. Driven pair and victim pair. (ANSI/EIA-364-90 Draft Proposal)	5 % maximum

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4.1.8 Connector Environmental Characteristics

4.1.8.1 Environmental Performance

Table 4-6 Connector Environmental Performance

Item	Test Condition		Requirement	
Thermal Shock	10 cycles of: a) -55°Cfor 30 minutes b) +85°C for 30 minutes (ANSI/EIA-364-32, Condition I)		Appearance	No Damage
			Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell Part : Change from initial value: 50 milliohms maximum.
Humidity	A	Mate connectors together and perform the test as follows. Temperature : +25 to +85°C Relative Humidity : 80 to 95% Duration : 4 cycles (96 hours) Upon completion of the test, specimens shall be conditioned at ambient room conditions for 24 hours, after which the specified measurements shall be performed. (ANSI/EIA-364-31)	Appearance	No Damage
			Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell : Change from initial value: 50 milliohms maximum.
	B	Unmated each connectors and perform the test as follows. Temperature : +25 to +85°C Relative Humidity : 80 to 95% Duration : 4 cycles (96 hours) Upon completion of the test, specimens shall be conditioned at ambient room conditions for 24 hours, after which the specified measurements shall be performed. (ANSI/EIA-364-31)	Appearance	No Damage
			Dielectric Withstanding Voltage and Insulation Resistance	Conform to item of Dielectric Withstanding Voltage and Insulation Resistance

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Item	Test Condition	Requirement	
Thermal Aging	Mate connectors and expose to +105 ± 2°C for 250 hours. Upon completion of the exposure period, the test specimens shall be conditioned at ambient room conditions for 1 to 2 hours, after which the specified measurements shall be performed. (ANSI/EIA-364-17, Condition 4, Method A)	Appearance	No Damage
		Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell Part : Change from initial value: 50 milliohms maximum.

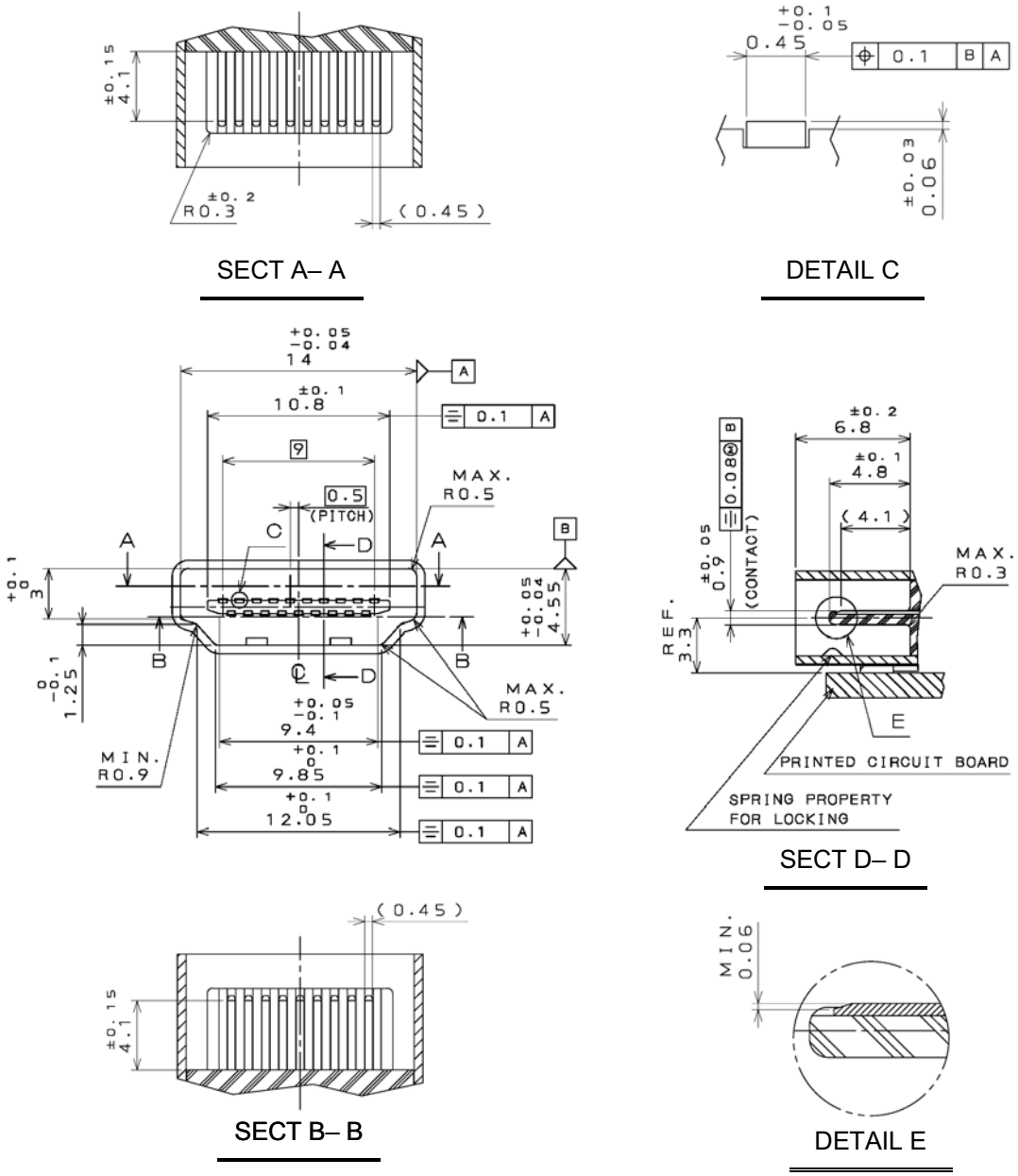
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4.1.9 Connector Drawings

All dimensions in millimeters.

4.1.9.1 Type A Receptacle

4.1.9.1.1 Mating Interface Dimensions



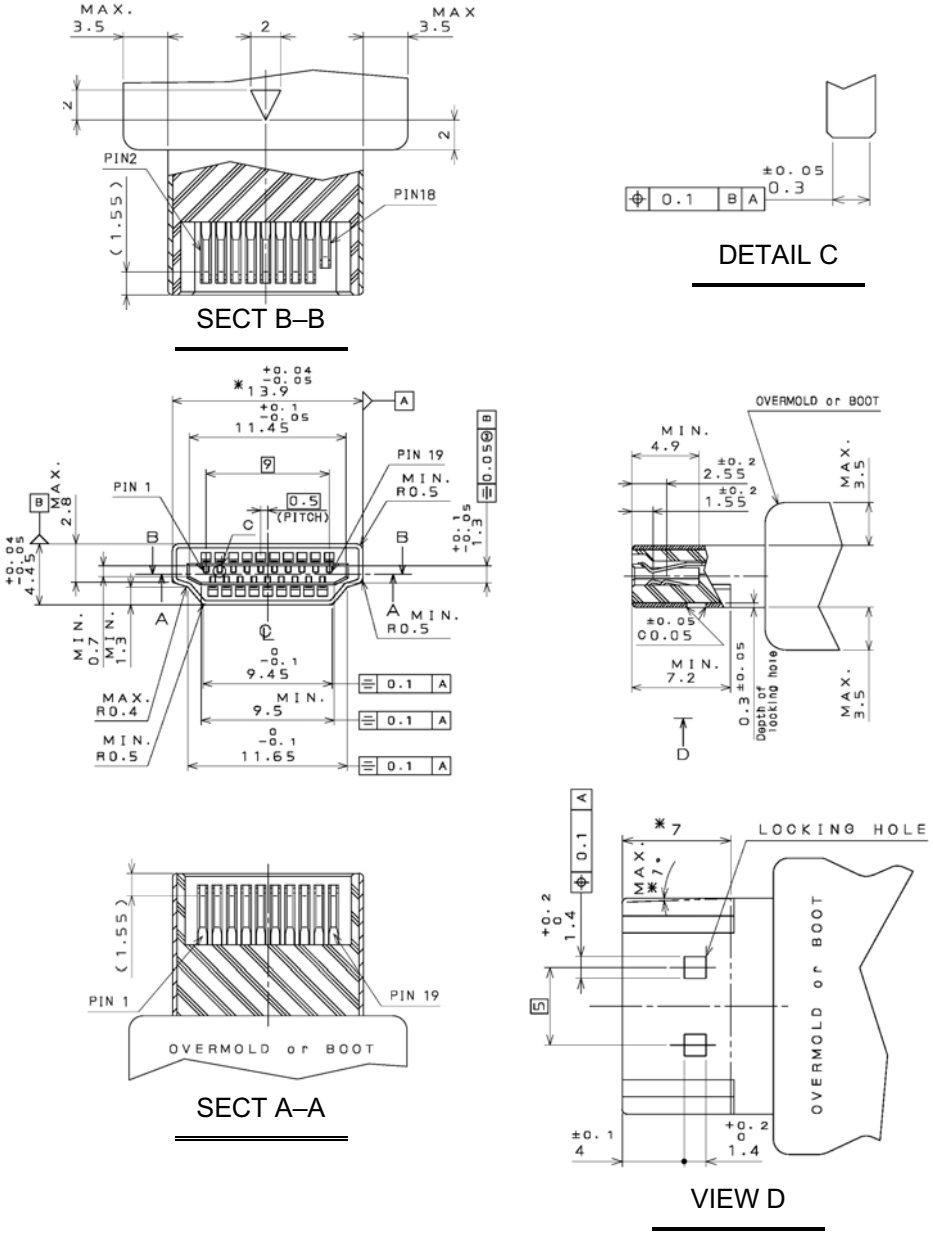
- The shell shall have springs for locking. Additional springs may be used for EMI reduction.
- The spring property for locking shall be activated by the locking hole of the plug shell.

Figure 4-1 Type A Receptacle Mating Interface Dimensions

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4.1.9.2 Type A Plug

4.1.9.2.1 Mating Interface Dimensions



- The dimension of *13.9mm (+0.04 / -0.05) (on main section) should be measured at the point *7mm (on view D). The taper (on view D) shall be one degree max.
- The shell should not have a dimple other than the ones for locking.

Figure 4-2 Type A Plug Mating Interface Dimensions

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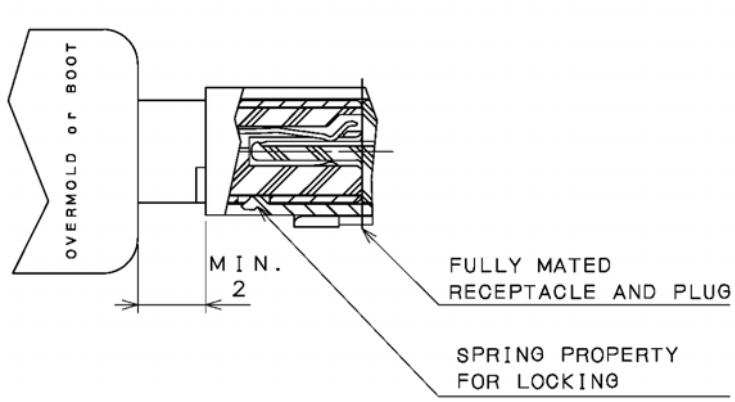
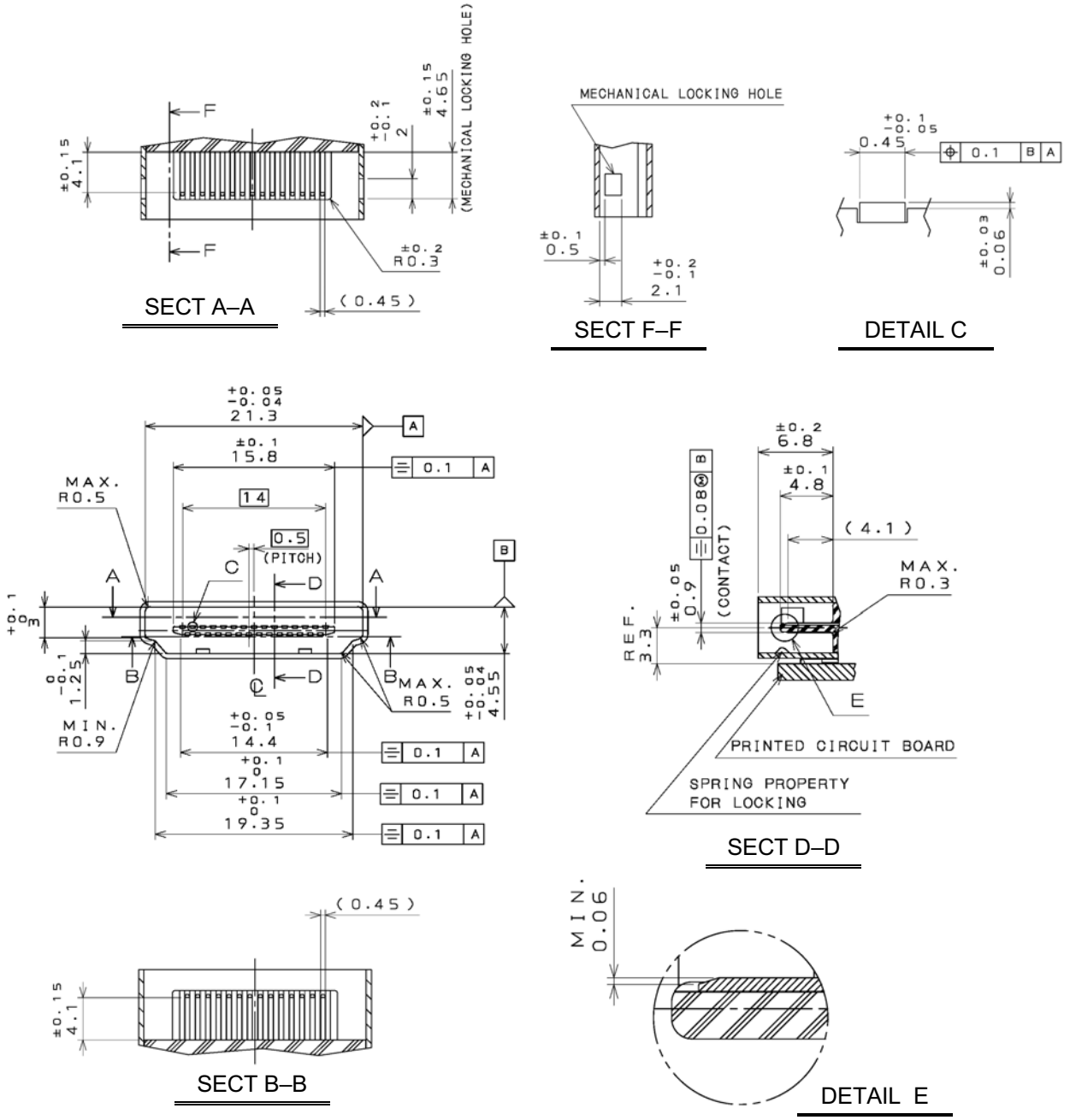


Figure 4-3 Type A Receptacle and Plug Mated Condition

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4.1.9.3 Type B Receptacle

4.1.9.3.1 Mating Interface Dimensions



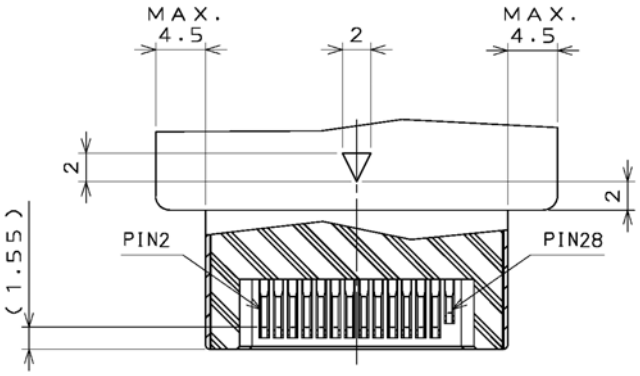
- The shell shall have springs for locking. Additional springs may be used for EMI reduction.
- The spring property for locking shall be activated by the locking hole of the plug shell.

Figure 4-4 Type B Receptacle Mating Interface Dimensions

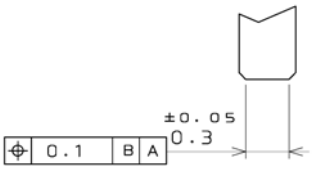
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4.1.9.4 Type B Plug

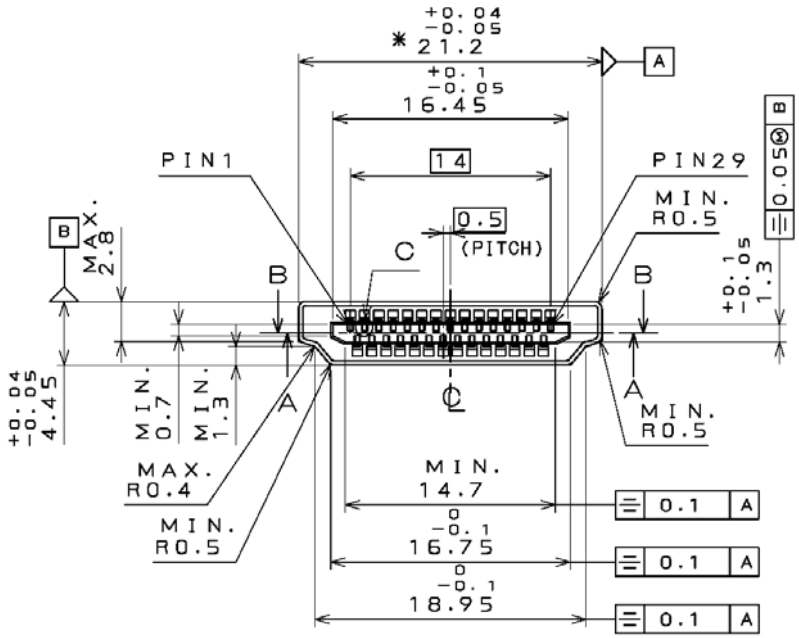
4.1.9.4.1 Mating Interface Dimensions

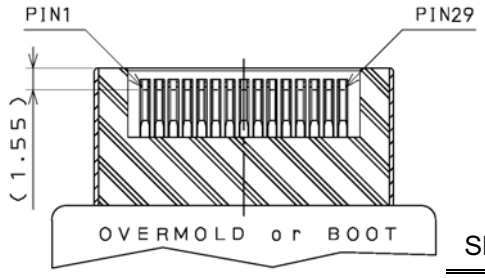


SECT B–B

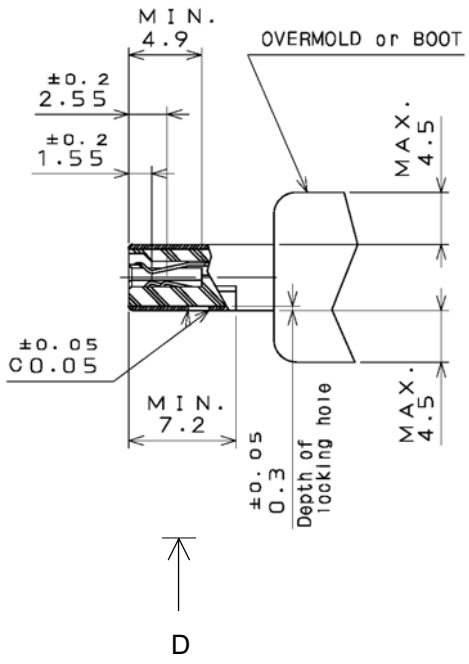


DETAIL C





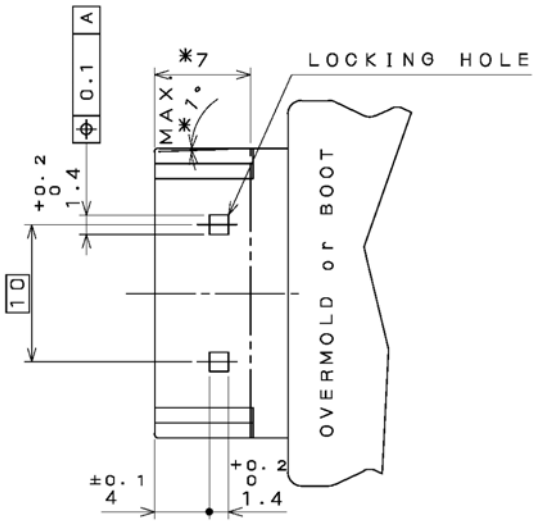
SECT A–A



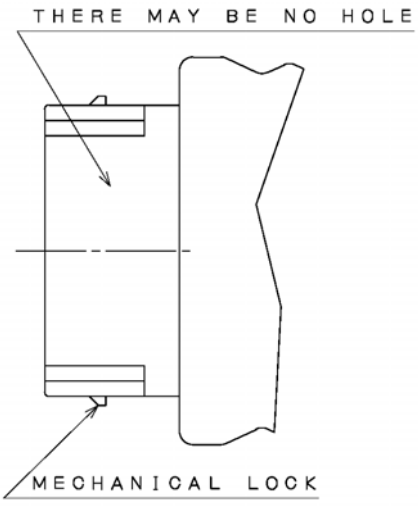
"VIEW D" → NEXT PAGE

- The dimension of *21.2mm (+0.04 / -0.05) (on main section) should be measured at the point *7mm (on view D). The taper (on view D) shall be one degree max.
- The shell should not have a dimple other than the ones for locking.

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FRICTION LOCK TYPE



MECHANICAL LOCK TYPE

The spring property for locking should be activated by the locking hole of the plug shell.

Figure 4-5 Type B Plug Mating Interface Dimensions

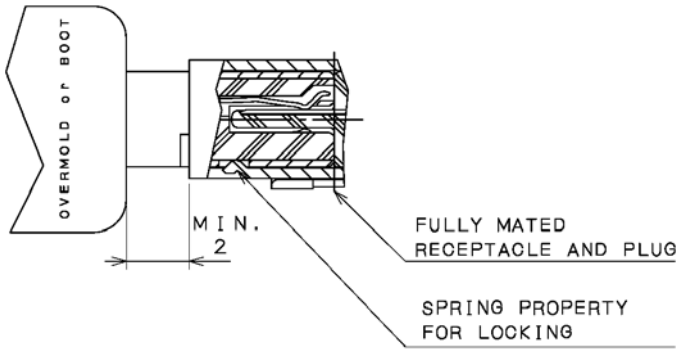


Figure 4-6 Type B Receptacle and Plug Mated Condition

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4.1.10 Cable Adapter Specification

Table 4-7 Wire Categories

Category	Description
A	TMDS Signal Wire
B	TMDS Shield
C	Control
D	Control Ground
N.C.	No connect (no wire)
5V	5 Volts Power Wire

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4.1.10.1 Type A Connector to Type A Connector

Type A Connector → Type A Connector



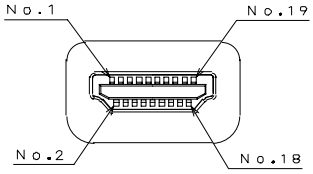
Table 4-8 Type A-to-Type A Cable Wire Assignment

Type A pin	Signal Name	Wire	Type A pin
1	TMDS Data2+	A	1
2	TMDS Data2 Shield	B	2
3	TMDS Data2–	A	3
4	TMDS Data1+	A	4
5	TMDS Data1 Shield	B	5
6	TMDS Data1–	A	6
7	TMDS Data0+	A	7
8	TMDS Data0 Shield	B	8
9	TMDS Data0–	A	9
10	TMDS Clock+	A	10
11	TMDS Clock Shield	B	11
12	TMDS Clock–	A	12
13	CEC	C	13
14	Reserved (in cable but N.C. on device)	C	14
15	SCL	C	15
16	SDA	C	16
17	DDC/CEC Ground	D	17
18	+5V Power	5V	18
19	Hot Plug Detect	C	19

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4.1.10.2 Type A Connector to Type B Connector

Type A Connector → Type B Connector



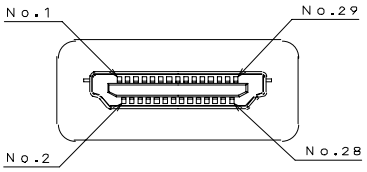


Table 4-9 Type A-to-Type B Cable Wire Assignment

Type A pin	Pin Assignment	Wire	Type B pin
1	TMDS Data2+	A	1
2	TMDS Data2 Shield	B	2
3	TMDS Data2-	A	3
4	TMDS Data1+	A	4
5	TMDS Data1 Shield	B	5
6	TMDS Data1-	A	6
7	TMDS Data0+	A	7
8	TMDS Data0 Shield	B	8
9	TMDS Data0-	A	9
10	TMDS Clock+	A	10
11	TMDS Clock Shield	B	11
12	TMDS Clock-	A	12
13	CEC	C	22
15	SCL	C	25
16	SDA	C	26
17	DDC/CEC Ground	D	27
18	+5V Power	5V	28
19	Hot Plug Detect	C	29
14	No connect	N.C.	
	No connect	N.C.	23
	No connect	N.C.	24

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4.1.10.3 Type B Connector to Type B Connector

Table 4-10 Type B to Type B Cable Wire Assignment

Type B pin	Pin Assignment	Wire	Type B pin
1	TMDS Data2+	A	1
2	TMDS Data2 Shield	B	2
3	TMDS Data2-	A	3
4	TMDS Data1+	A	4
5	TMDS Data1 Shield	B	5
6	TMDS Data1-	A	6
7	TMDS Data0+	A	7
8	TMDS Data0 Shield	B	8
9	TMDS Data0-	A	9
10	TMDS Clock+	A	10
11	TMDS Clock Shield	B	11
12	TMDS Clock-	A	12
13	TMDS Data5+	A	13
14	TMDS Data5 Shield	B	14
15	TMDS Data5-	A	15
16	TMDS Data4+	A	16
17	TMDS Data4 Shield	B	17
18	TMDS Data4-	A	18
19	TMDS Data3+	A	19
20	TMDS Data3 Shield	B	20
21	TMDS Data3-	A	21
22	CEC	C	22
25	SCL	C	25
26	SDA	C	26
27	DDC/CEC Ground	D	27
28	+5V Power	5V	28
29	Hot Plug Detect	C	29
23	No Connect	N.C.	
24	No Connect	N.C.	
	No Connect	N.C.	23
	No Connect	N.C.	24

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4.2 Electrical Specification

Some timing parameter values in this specification are based on the clock rate of the link while others are based on absolute values. For scalable timing parameters based on the clock rate, the time period of the clock is denoted as 'pixel time', or T_{pixel}. One tenth of the pixel time is called the bit time, or T_{bit}. The bit time is also referred to as one Unit Interval in the jitter and eye diagram specifications.

Schematic diagrams contained in this chapter are for illustration only and do not represent the only feasible implementation.

4.2.1 Overview

The conceptual schematic of one TMDS differential pair is shown in Figure 4-7. TMDS technology uses current drive to develop the low voltage differential signal at the Sink side of the DC-coupled transmission line. The link reference voltage AV_{cc} sets the high voltage level of the differential signal, while the low voltage level is determined by the current source of the HDMI Source and the termination resistance at the Sink. The termination resistance (R_T) and the characteristic impedance of the cable (Z_0) must be matched.

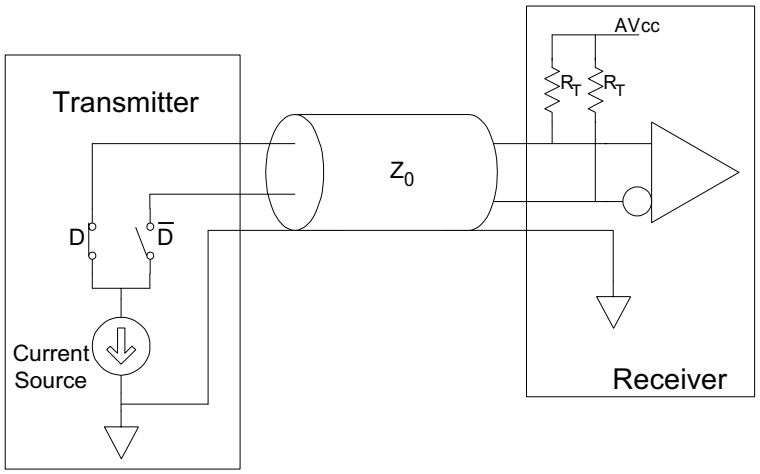


Figure 4-7 Conceptual Schematic for one TMDS differential pair

A single-ended differential signal, representing either the positive or negative terminal of a differential pair, is illustrated in Figure 4-8. The nominal high-level voltage of the signal is AV_{cc} and the nominal low-level voltage of the signal is (AV_{cc} - V_{swing}). Since the swing is differential on the pair, the net signal on the pair has a swing twice that of the single-ended signal, or $2*V_{swing}$. The differential signal, as shown in Figure 4-9, swings between positive V_{swing} and negative V_{swing}.

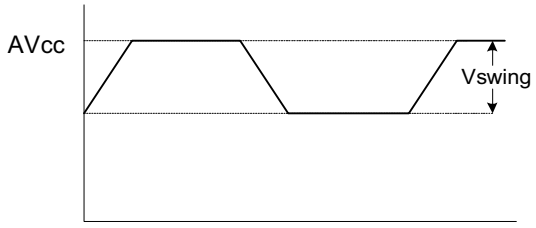


Figure 4-8 Single-ended Differential Signal

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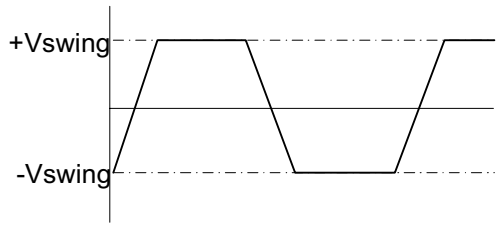


Figure 4-9 Differential Signal

The signal test points for a TMDS link are shown in Figure 4-10. TP1 is used for testing of HDMI Sources and Transmitter components. TP2 is used for testing of HDMI Sinks and Receiver components. TP1 and TP2 together are also used for testing of cables.

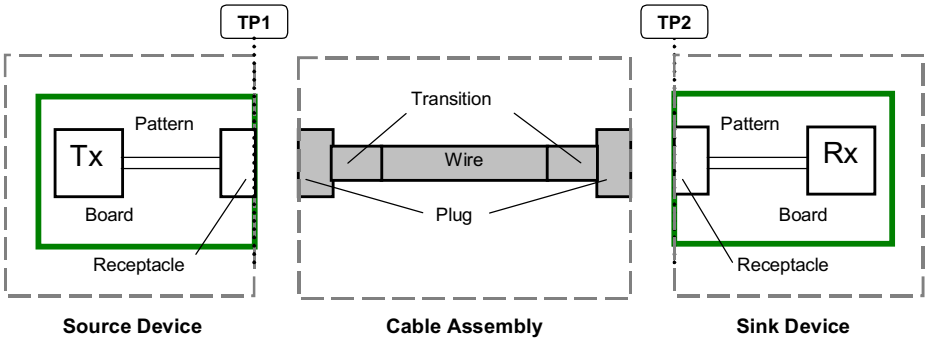


Figure 4-10 TMDS Link Test Points

4.2.2 System Operating Conditions

The required operating conditions of the TMDS pairs are specified in Table 4-11.

Table 4-11 Required Operating Conditions for HDMI Interface (see Figure 4-7)

Item	Value
Termination Supply Voltage, AV_{cc}	3.3 Volts ±5%
Termination Resistance, R_T	50 ohms ±10%

4.2.3 Jitter and Eye Measurements: Ideal Recovery Clock

All TMDS Clock and Data signal jitter specifications are specified relative to an Ideal Recovery Clock defined below. The Data jitter is not specified numerically, but instead, an HDMI device or cable shall adhere to the appropriate eye diagram(s) when the TMDS data signals are measured using an Ideal Recovery Clock as a trigger source.

The TMDS Clock signal may contain low-frequency jitter components, which can be tracked by a Sink's clock recovery circuitry, and high-frequency components, which are not typically tracked.

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The purpose of the Ideal Recovery Clock is to give an accurate representation of link performance when used as a trigger for eye diagram and clock jitter specifications.

For the purposes of jitter and eye diagram specification, the Ideal Recovery Clock is defined relative to the TMDS clock signal. The Ideal Recovery Clock shall be equivalent to the signal that would be derived by a perfect PLL with a jitter transfer function shown in Equation 4-1, when the TMDS clock signal were input into that PLL. This jitter transfer function has the behavior of a low pass filter with 20dB/decade rolloff and with a –3dB point of 4MHz.

For the purposes of compliance testing, a Clock Recovery Unit is used to generate a Recovered Clock, which is meant to approximate the Ideal Recovery Clock. This Recovered Clock is used for measurement of the jitter and eye diagram.

$$H(j\omega) = 1 / (1 + j\omega/\omega_0)$$

Where $\omega_0 = 2\pi F_0$, $F_0 = 4.0\text{MHz}$

Equation 4-1 Jitter Transfer Function of PLL for Ideal Recovery Clock Definition

4.2.4 HDMI Source TMDS Characteristics

HDMI requires a DC-coupled TMDS link. Source electrical testing shall be performed using the test load shown in Figure 4-11. TP1 represents the connection point of the receptacle.

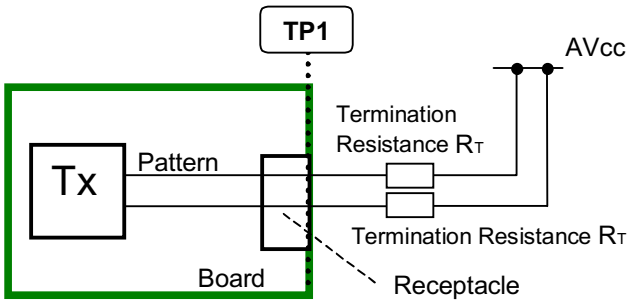


Figure 4-11 Balanced Source Test Load

The Source shall meet the DC specifications in Table 4-12 for all operating conditions specified in Table 4-11 when driving clock and data signals. The V_{swing} parameter identifies the minimum and maximum single-ended peak-to-peak signal amplitude that may be delivered by the Source into the test load.

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Table 4-12 Source DC Characteristics at TP1

Item	Value
Single-ended high level output voltage, V_H	AV_{cc} ±10mVolts
Single-ended low level output voltage, V_L	(AV_{cc} - 600mVolts) ≤ V_L ≤ (AV_{cc} - 400mVolts)
Single-ended output swing voltage, V_{swing}	400mVolts ≤ V_{swing} ≤ 600mVolts
Single-ended standby (off) output voltage, V_{OFF}	AV_{cc} ±10mVolts (Informative)
Single-ended standby (off) output current, I_{OFF}	| I_{OFF} | < 10uA

The Source shall meet the AC specifications in Table 4-13 across all operating conditions specified in Table 4-11. Rise and fall times are defined as the signal transition time between 20% and 80% of the nominal swing voltage (V_{swing}) of the device under test.

The Source intra-pair skew is the maximum allowable time difference (on both low-to-high and high-to-low transitions) as measured at TP1, between the true and complement signals of a given differential pair. This time difference is measured at the midpoint on the single-ended signal swing of the true and complement signals. The Source inter-pair skew is the maximum allowable time difference (on both low-to-high and high-to-low transitions) as measured at TP1, between any two single-ended data signals that do not constitute a differential pair.

Table 4-13 Source AC Characteristics at TP1

Item	Value
Rise time / fall time (20%-80%)	75psec ≤ Rise time / fall time ≤ 0.4 T_{bit}
Overshoot, max	15% of full differential amplitude (V_{swing}*2)
Undershoot, max	25% of full differential amplitude (V_{swing}*2)
Intra-Pair Skew at Source Connector, max	0.15 T_{bit}
Inter-Pair Skew at Source Connector, max	0.20 T_{pixel}
Clock duty cycle, min / average / max	40% / 50% / 60%
TMDS Differential Clock Jitter, max	0.25 T_{bit} (relative to Ideal Recovery Clock as defined in Section 4.2.3)

The design of a Source should take into account the differential impedance of the cable assembly and Sink of 100 ohms (see Table 4-17 and Table 4-18).

For all channels under all operating conditions specified in Table 4-11 and when terminated as shown in Figure 4-11, the Source shall have output levels at TP1, which meet the normalized eye diagram requirements of Figure 4-12. This requirement, normalized in both time and amplitude, specifies the minimum eye opening as well as the maximum overshoot and undershoot relative to the average differential swing voltage of the device under test. The time axis is normalized to the bit time at the testing frequency, while the amplitude axis is normalized to the average differential swing voltage.

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Determination of average swing voltage is made with transmission of the half clock test pattern. The average high-level and low-level amplitudes are determined at the point where signal ringing has subsided. These averages establish the swing voltage and are used to normalize the eye diagram.

The average differential swing voltage is defined as the difference between the average differential amplitude when driving a logic one and the average differential amplitude when driving a logic zero. The average logic one appears at positive 0.5 on the vertical axis, while the average logic zero appears at negative 0.5. The normalized amplitude limits in Figure 4-12 allow 15% (of the average differential swing voltage) maximum overshoot and 25% maximum undershoot, relative to the amplitudes determined to be logic one and zero.

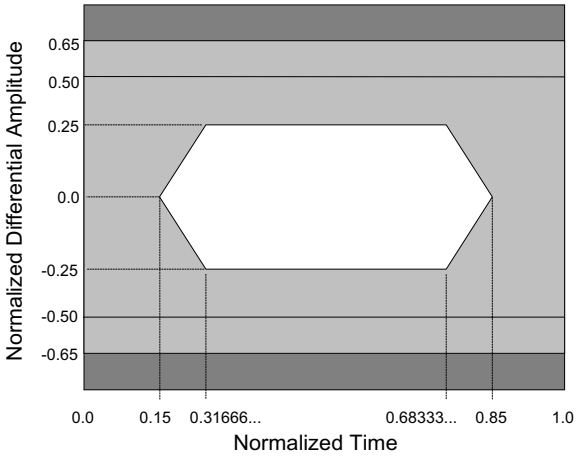


Figure 4-12 Normalized Eye Diagram Mask at TP1 for Source Requirements

Combining the single-ended swing voltage (V_{swing}) specified in Table 4-12 with the overshoot and undershoot requirements of Figure 4-12, it is possible to calculate the minimum and maximum high-level voltage (V_{high}) and low-level voltage (V_{low}) that is allowable on the interface.

V_{high} (max) = V_{swing} (max) + 15% * (2*V_{swing} (max)) = 600 + 180 = 780 mV

V_{high} (min) = V_{swing} (min) - 25% * (2*V_{swing} (min)) = 400 - 200 = 200 mV

V_{low} (max) = -V_{swing} (max) - 15% * (2*V_{swing} (max)) = -600 - 180 = -780 mV

V_{low} (min) = -V_{swing} (min) + 25% * (2*V_{swing} (min)) = -400 + 200 = -200 mV

Minimum opening at Source = V_{high} (min) - V_{low} (min) = 400 mV

Note that the combination of these extreme cases do not constitute a single valid eye.

Source eye diagram test procedures are defined in the HDMI Compliance Test Specification. The Source eye diagram mask of Figure 4-12 is not used for response time and clock jitter specifications, but specifies the clock to data jitter indirectly.

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4.2.5 HDMI Sink TMDS Characteristics

HDMI Sink electrical testing shall be performed using a test signal generator as shown in Figure 4-13.

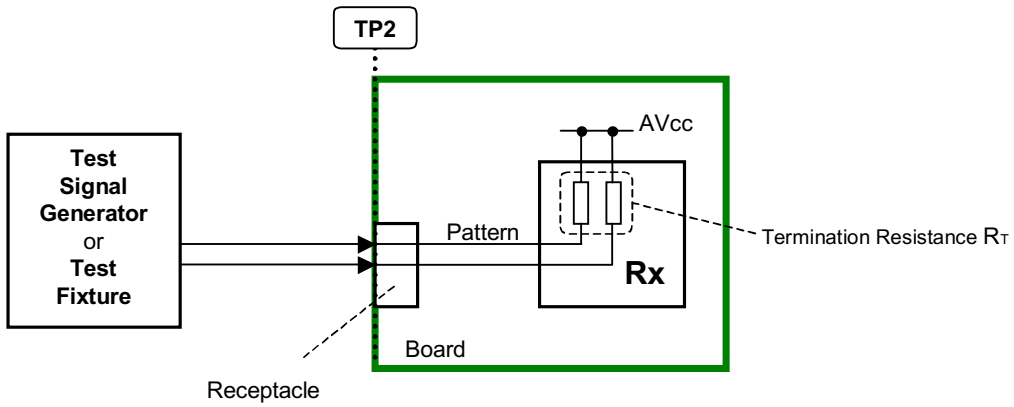


Figure 4-13 HDMI Sink Test Points

The Sink shall meet the signal requirements listed in Table 4-14, Table 4-15, and Table 4-16.

Table 4-14 Sink Operating DC Characteristics at TP2

Item	Value
Input Differential Voltage Level, V_{idiff}	$150 \le V_{idiff} \le 1200$ mVolts
Input Common Mode Voltage, V_{icm}	$(AV_{cc} - 300mVolts) \le V_{icm} \le (AV_{cc} - 37.5mVolts)$

Table 4-15 Sink DC Characteristics When Source Disabled or Disconnected at TP2

Item	Value
Differential Voltage Level	AV_{cc} ±10mVolts

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Table 4-16 Sink AC Characteristics at TP2

Item	Value
Minimum differential sensitivity (peak-to-peak)	150 mVolts
Maximum differential input (peak-to-peak)	1560 mVolts
Allowable Intra-Pair Skew at Sink Connector	0.4 T_{bit}
Allowable Inter-Pair Skew at Sink Connector	0.6 T_{pixel}
TMDS Clock Jitter	0.30 T_{bit} (relative to Ideal Recovery Clock as defined in Section 4.2.3)

Table 4-17 HDMI Sink Impedance Characteristics at TP2

Item	Value
TDR Rise Time at TP2 (10%-90%)	≤200 psec
Through connection impedance	100 ohms ±15%
At Termination impedance	100 ohms ±10%

For all channels under all operating conditions specified in this section, the Sink shall reproduce a test data stream, with video pixel error rate of 10^{-9} or better, when presented with input amplitude illustrated by the eye diagram of Figure 4-14.

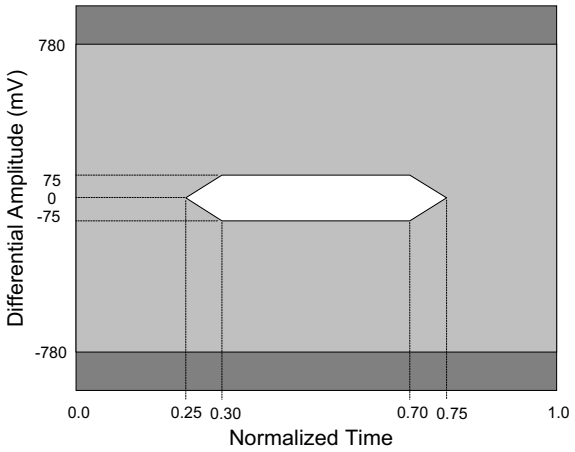


Figure 4-14 Absolute Eye Diagram Mask at TP2 for Sink Requirements

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4.2.6 Cable Assembly

The term “Cable assembly” includes all five parts listed below:

- Source-side plug
- Source-side transition (from plug to cable)
- Cable itself
- Sink-side transition
- Sink-side plug

HDMI cables are measured with respect to the test points TP3 and TP4 shown in Figure 4-15. TP1 and TP2 are not available because connection points between plug and receptacle cannot be accessed during testing. Therefore, TP3 and TP4 are used, even though the effects of receptacles at both ends are included in the test result.

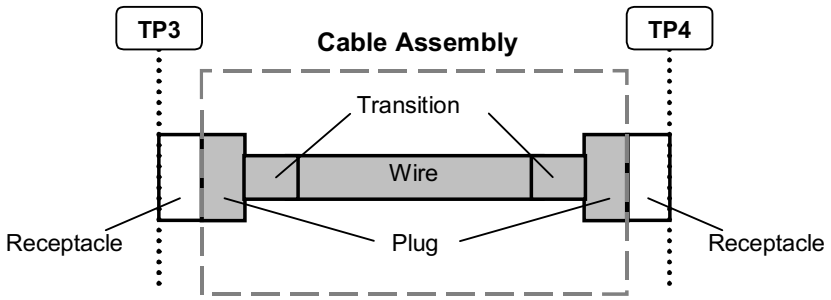


Figure 4-15 Cable Assembly Test Points

An HDMI cable assembly may be specified to operate up to a specified maximum pixel clock frequency. This specified maximum frequency shall be above 75MHz.

When driven by a TMDS input waveform meeting the Source eye diagram mask requirements of Figure 4-12 at the specified maximum pixel clock frequency, an HDMI cable assembly shall produce a TMDS output waveform that meets the Sink eye diagram mask of Figure 4-14.

In addition a cable should meet the specifications shown in Table 4-18.

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Table 4-18 Cable Assembly Parameters

Parameter	Value
Maximum Cable Assembly Intra-Pair Skew	151psec (0.25 T_{bit})
Maximum Cable Assembly Inter-Pair Skew	2.42nsec (0.4 T_{pixel})
Far-end Crosstalk	< -26dB
Attenuation	
300kHz - 825MHz	< 8dB
825MHz - 2.475GHz	< 21dB
2.475GHz - 4.125GHz	< 30dB
Differential Impedance	
Connection point and transition area: Up to 1nsec**	100 ohms ±15%
Cable area: 1nsec – 2.5nsec:**	100 ohms ±10%

** Measurement point for TDR measurement of impedance.

4.2.7 +5V Power Signal

The HDMI connector provides a pin allowing the Source to supply +5.0 Volts to the cable and Sink. All HDMI Sources shall assert the +5V Power signal whenever the Source is using the DDC, CEC, or TMDS signals. All HDMI Sources shall be able to supply a minimum of 55 mA to the +5V Power pin.

A Sink shall not draw more than 50 mA of current from the +5V Power pin. When the Sink is powered on, it can draw no more than 10mA of current from the +5V Power signal.

The return for the +5V Power signal is DDC/CEC Ground signal.

An HDMI Source shall have +5V Power signal over-current protection of no more than 0.5A.

Table 4-19 Power Pin Voltage

Item	Min	Max
TP1 voltage	4.95 Volts	5.05 Volts
TP2 voltage	4.80 Volts	5.20 Volts

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4.2.8 DDC

The Display Data Channel (DDC) I/Os and wires (SDA, SCL, DDC/CEC Ground), shall meet the requirements specified in the I^2C-bus Specification, version 2.1, Section 15 for "Standard-Mode" devices. Note that the discussions of high capacitance environments in the I^2C-bus Specification, section 17.2, "Switched pull-up circuit for Fast-mode I2C-bus", may be applied to the HDMI environment as well.

In the capacitance measurement, the DDC line ground (DDC/CEC Ground) shall be separated from the frame ground of the equipment. The exact method and measurement procedure is written in HDMI Compliance Test Specification. In some cases buffers, or I^2C "accelerators", may be inserted in the cable as long as all I^2C timing requirements are met.

Table 4-20 Maximum Capacitance of DDC line

Item	HDMI Source	Cable Assembly	HDMI Sink
SDA – DDC/CEC Ground	50pF	700pF	50pF
SCL – DDC/CEC Ground	50pF	700pF	50pF

Table 4-21 Pull-up Resistance on DDC Lines

Item	Value
Source Pull-up resistors for SCL and SDA signals	minimum 1.5k ohms, maximum 2.0k ohms
Sink Pull-up resistors for SCL signal	47k ohms, ±10%

4.2.9 Hot Plug Detect Signal (HPD)

The ground reference for the Hot Plug Detect signal is the DDC/CEC Ground pin.

Table 4-22 Required Output Characteristics of Hot Plug Detect Signal

Item	Value
High voltage level (Sink)	Minimum 2.4 Volts, Maximum 5.05 Volts
Low voltage level (Sink)	Minimum 0 Volts, Maximum 0.4 Volts
Output resistance	1000 ohms ±20%

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Table 4-23 Required Detection Levels for Hot Plug Detect Signal

Item	Value
High voltage level (Source)	Minimum 2.0 Volts, Maximum 5.05 Volts
Low voltage level (Source)	Minimum 0 Volts, Maximum 0.8 Volts

4.2.10 CEC Line

The following line characteristics are required for all products, including those that do not implement the CEC protocol. Further requirements for those devices which implement the CEC protocol are given in Supplement 1. The ground reference for the CEC signal is the DDC/CEC Ground signal.

Table 4-24 CEC line Electrical Specifications for all Configurations

Item	Rule / Description	Value
Line connectivity	In general, CEC lines from all HDMI inputs (if present) and a single HDMI output (if present) shall be interconnected. However, the following exceptions are allowed: A device which has no HDMI output is allowed to have separate CEC lines for each HDMI connector if that device takes a logical address of 0 on each CEC line. Due to the complexity of handling multiple active CEC lines, this is discouraged. A TV that is acting as the root shall not connect the CEC line to any HDMI output.	
Power-off characteristics	A device with power removed must not degrade communication between other CEC devices (e.g. the line must not be pulled down by the powered off device).	
Leakage current in standby/off	Maximum CEC line leakage current	1.8μA
CEC Line Capacitance	Maximum capacitance load of a device (excluding cable)	100pF
	Maximum capacitance load of a Cable Assembly	700pF

4.2.11 Robustness Requirements

No damage to the HDMI Source or Sink can result from the shorting of any combination of signals on any connector. If two HDMI Sources are connected together with a single cable, no damage can occur to either of the Sources. If two HDMI Sinks are connected together with a single cable, no damage can occur to either of the Sinks.

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5 Signaling And Encoding

5.1 Overview

5.1.1 Link Architecture

As shown in Figure 5-1, an HDMI link includes three TMDS Data channels and a single TMDS Clock channel. The TMDS Clock channel constantly runs at the pixel rate of the transmitted video. During every cycle of the TMDS Clock channel, each of the three TMDS data channels transmits a 10-bit character. This 10-bit word is encoded using one of several different coding techniques.

The input stream to the Source's encoding logic will contain video pixel, packet and control data. The packet data consists of audio and auxiliary data and associated error correction codes.

These data items are processed in a variety of ways and are presented to the TMDS encoder as either 2 bits of control data, 4 bits of packet data or 8 bits of video data per TMDS channel. The Source encodes one of these data types or encodes a Guard Band character on any given clock cycle.

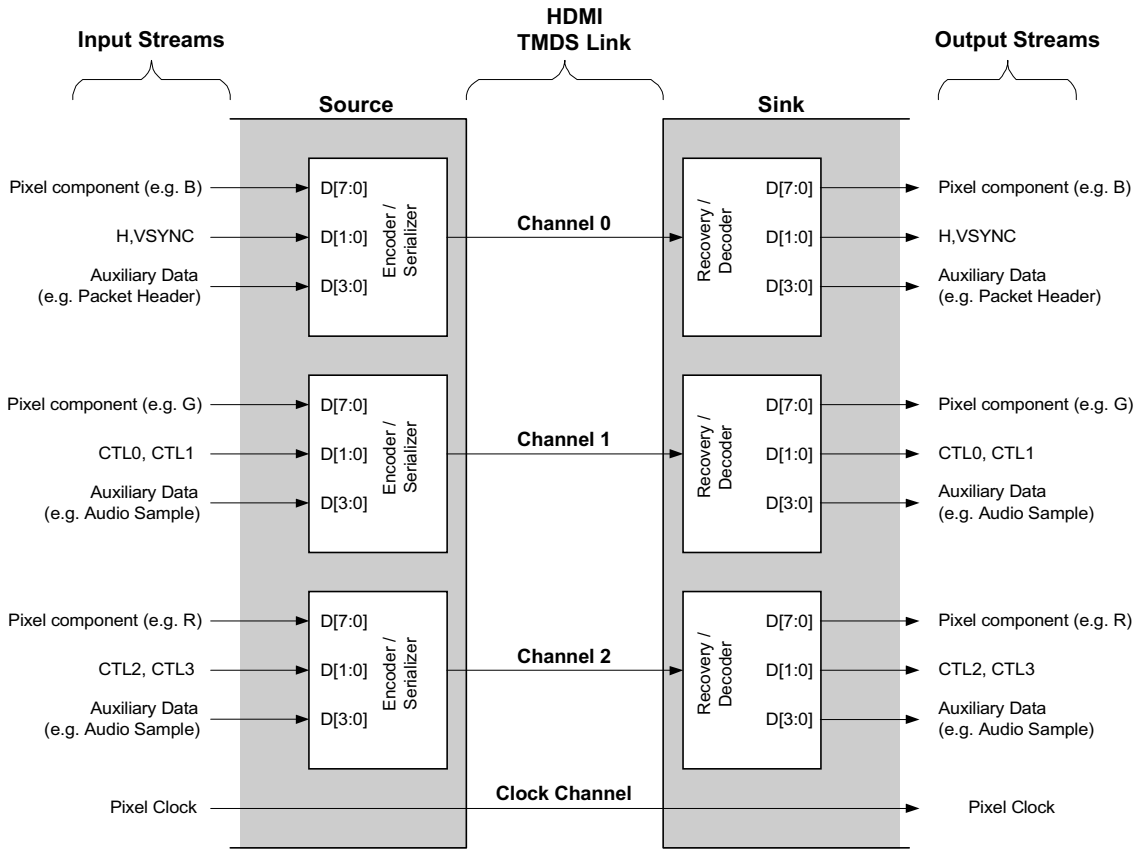


Figure 5-1 HDMI Encoder/Decoder Overview

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5.1.2 Operating Modes Overview

The HDMI link operates in one of three modes: Video Data Period, Data Island period, and Control period. During the Video Data Period, the active pixels of an active video line are transmitted. During the Data Island period, audio and auxiliary data are transmitted using a series of packets. The Control period is used when no video, audio, or auxiliary data needs to be transmitted. A Control Period is required between any other two periods.

An example of each period placement is shown in the following figure.

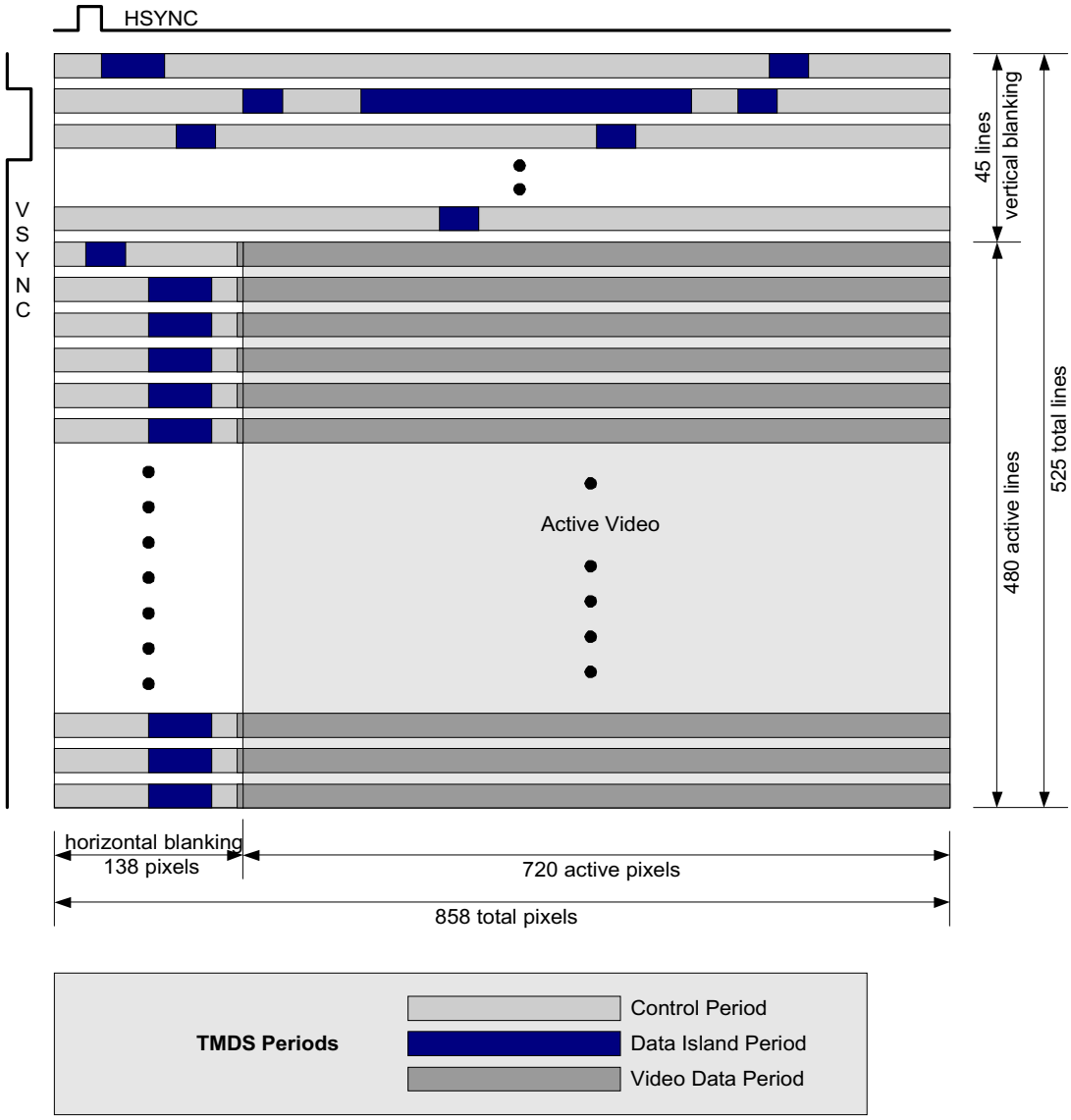


Figure 5-2 Informative Example: TMDS periods in 720x480p video frame

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Video Data Periods use transition minimized coding to encode 8 bits per channel, or 24 bits total per pixel.

Data Island Periods are encoded using a similar transition minimized coding, TMDS Error Reduction Coding (TERC4), which transmits 4 bits per channel, or 12 bits total per pixel clock period.

During Control Periods, 2 bits per channel, or 6 bits total are encoded per pixel clock using a transition maximized encoding. These 6 bits are HSYNC, VSYNC, CTL0, CTL1, CTL2 and CTL3. Near the end of every Control Period, a Preamble, using the CTLx bits, indicates whether the next Data Period is a Video Data Period or a Data Island Period.

Each Video Data Period and Data Island Period starts with a Leading Guard Band designed to provide robust determination of the transition from the Control Period to the Data Period. This Leading Guard Band consists of two special characters.

The Data Island Period is also protected by a Trailing Guard Band which is designed to provide a robust determination of the transition to Control Period.

The following table shows Encoding type used and data transmitted during each operating mode.

Table 5-1 Encoding Type and Data Transmitted

Period	Data Transmitted	Encoding Type
Video Data	Video Pixels	Video Data Coding (8 bits converted to 10 bits)
	(Guard Band)	(Fixed 10 bit pattern)
Data Island	Packet Data - Audio Samples - InfoFrames HSYNC, VSYNC	TERC4 Coding (4 bits converted to 10 bits)
	(Guard Band)	(Fixed 10 bit pattern)
Control	Control - Preamble - HSYNC, VSYNC	Control Period Coding (2 bits converted to 10 bits)

5.2 Operating Modes

5.2.1 Control Period

Control Period is used for transmission of the Preamble. The Control Period is also used by the Sink for character synchronization.

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5.2.1.1 Preamble

Immediately preceding each Video Data Period or Data Island Period is the Preamble. This is a sequence of eight identical Control characters that indicate whether the upcoming data period is a Video Data Period or is a Data Island. The values of CTL0, CTL1, CTL2, and CTL3 indicate the type of data period that follows. The remaining Control signals, HSYNC and VSYNC, may vary during this sequence.

There are only two legal Preamble characters:

Table 5-2 Preambles for Each Data Period Type

CTL0	CTL1	CTL2	CTL3	Data Period Type
1	0	0	0	Video Data Period
1	0	1	0	Data Island Period

The Video Data Period type indicates that the following data period contains video data, beginning with a Video Guard Band.

The Data Island type indicates that the following data period is an HDMI compliant Data Island, beginning with a Data Island Guard Band.

The transition from TMDS control characters to Guard Band characters following this sequence identifies the start of the Data Period.

5.2.1.2 Character Synchronization

The TMDS Sink needs to determine the location of character boundaries in the serial data streams. Once character boundaries are established on all data channels, the Sink is defined to be synchronized to the serial streams, and may recover TMDS characters from the data channels for decode. The TMDS data stream provides periodic cues for decoder synchronization.

The TMDS characters used during the Video Data Period and Data Island Period contain five or fewer transitions, while the TMDS characters used during the Control Period contain seven or more transitions. The high-transition content of the characters transmitted during the Control Period form the basis for character boundary synchronization at the decoder. While these characters are not individually unique in the serial data stream, they are sufficiently alike that the decoder may uniquely detect the presence of a succession of them during transmitted synchronization intervals. The exact algorithm for this detection is an implementation detail beyond the scope of this document, but minimum conditions for Sink synchronization are defined.

The Sink is required to establish synchronization with the data stream during any Control Period greater than or equal to $t_{S,min}$ (12) characters in length.

The Source is also required to occasionally transmit an Extended Control Period per Table 5-4.

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Table 5-3 TMDS Link Timing Parameters

Symbol	Description	Value	Unit
$t_{S,min}$	Minimum duration Control Period	12	T_{PIXEL}

Table 5-4 Extended Control Period Parameters

Symbol	Description	Value	Unit
t_{EXTS,max_delay}	Maximum time between Extended Control Periods	50	msec
$t_{EXTS,min}$	Minimum duration Extended Control Period	32	T_{PIXEL}

5.2.2 Video Data Period

Video data periods are used to carry the pixels of an active video line.

Each Video Data Period is preceded by a Preamble, described above.

Following the Preamble, the Video Data Period begins with a two pixel Video Leading Guard Band. There is no Trailing Guard Band for the Video Data Period.

During active video periods, 24 bits of pixel data are encoded using TMDS transition minimized encoding.

5.2.2.1 Video Guard Band

Table 5-5 Video Leading Guard Band Values

```
case (TMDS Channel Number):
       0:  q_out[9:0] = 0b1011001100;
       1:  q_out[9:0] = 0b0100110011;
       2:  q_out[9:0] = 0b1011001100;
endcase
```

5.2.3 Data Island Period

5.2.3.1 Data Island Overview

Data Islands are used to carry packets of audio sample data and auxiliary data. This auxiliary data includes EIA/CEA-861B InfoFrames and other data describing the active audio or video stream or describing the Source.

Each Data Island is preceded by a Preamble, described above.

Following the Preamble, each Island starts with a Leading Guard Band. The first packet of the Data Island then follows.

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During every pixel of the Data Island, including the Guard Band, bits 0 and 1 of TMDS Channel 0 transmit an encoded form of HSYNC and VSYNC.

Bit 2 of TMDS Channel 0 is used to transmit the Packet Header. All four bits of TMDS Channels 1 and 2 are used for the Packet data as shown in Figure 5-3. Each packet is 32 pixels long and is protected by BCH ECC for error correction and detection purposes.

During the Data Island, each of the three TMDS channels transmits a series of 10-bit characters encoded from a 4-bit input word, using TMDS Error Reduction Coding (TERC4). TERC4 significantly reduces the error rate on the link by choosing only 10-bit codes with high inherent error avoidance.

The last two characters of the Data Island, following the last packet, is the Trailing Guard Band.

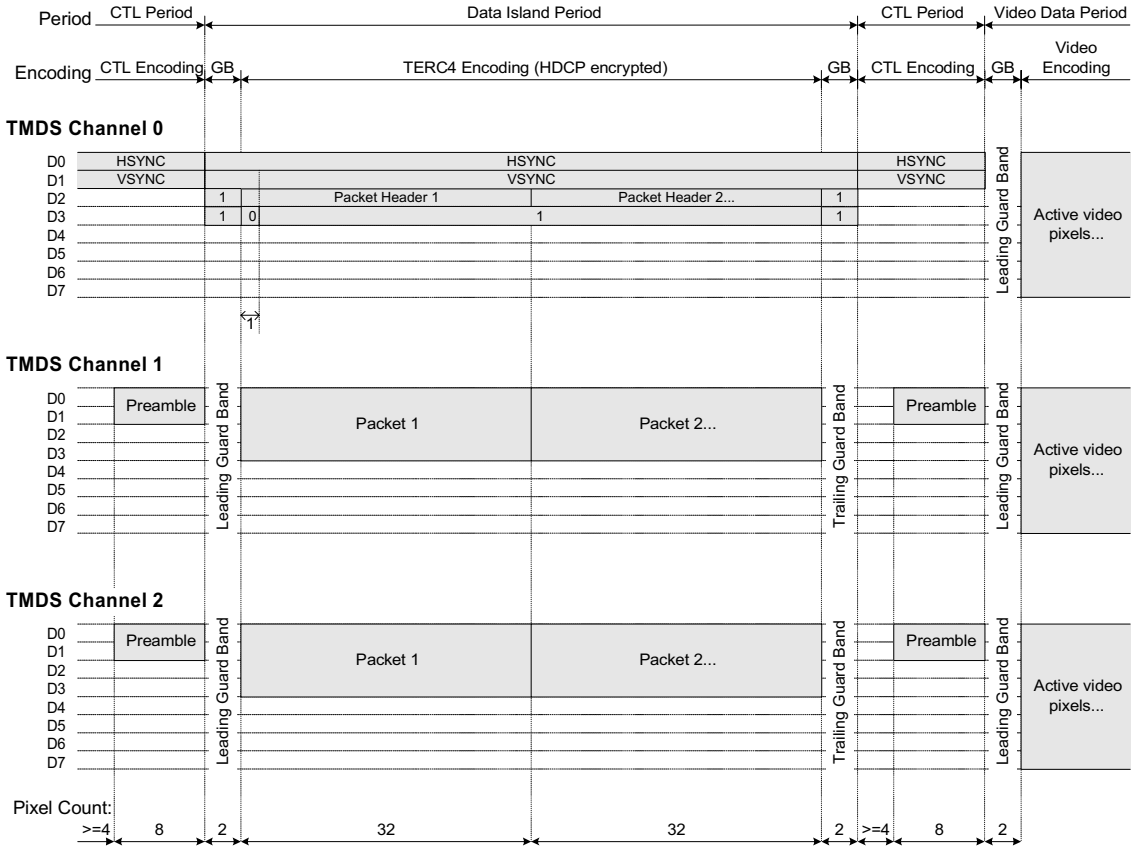


Figure 5-3 TMDS Periods and Encoding

Following the Data Island, all three channels revert to transmitting control characters.

5.2.3.2 Island Placement and Duration

The Source is required to determine the temporal placement and duration of the Data Island with respect to the video signal's horizontal and vertical blanking periods and synchronization signals. It shall do so following the rules stated below.

All TMDS Control Periods shall be at least $t_{S,min}$ (12) characters (pixels) long.

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The Data Island shall contain at least one packet, limiting its minimum size to 36 pixels.

Islands shall contain an integer number of packets. In order to assure the reliability of the data within the Data Island, they shall be limited to 18 packets or fewer.

Zero, one or more Data Islands can occur between subsequent video data periods.

While transmitting video, at least one Data Island shall be transmitted during every two video fields.

5.2.3.3 Data Island Guard Bands

The first two data characters within the Data Island are the Leading Guard Band. The last two data characters within the Data Island are the Trailing Guard Band.

During the Data Island Guard Bands, Channel 0 is encoded as one of four TERC4 values. These TERC4 values (D[3:0]) are 0xC, 0xD, 0xE and 0xF, depending upon the values of HSYNC and VSYNC.

Table 5-6 Data Island Leading and Trailing Guard Band Values

```
case (TMDS Channel Number):
       0:  q_out[9:0] = n.a.;
       1:  q_out[9:0] = 0b0100110011;
       2:  q_out[9:0] = 0b0100110011;
endcase
```

5.2.3.4 Data Island Packet Construction

All data within a Data Island is contained within 32 pixel Packets. Packets consist of a Packet Header, a Packet Body (consisting of four Subpackets), and associated error correction bits. Each Subpacket includes 56 bits of data and is protected by an additional 8 bits of BCH ECC parity bits.

Subpacket 0 plus its corresponding parity bits make up BCH Block 0. This block is mapped onto bit 0 of both Channel 1 and Channel 2. In this way, the 64 bits of BCH Block 0 are transferred over the course of 32 pixels. Likewise, BCH Block 1 (Subpacket 1 plus parity) is mapped onto bit 1 of both Channels 1 and 2.

In the tables below, Header bytes are indicated as HB0, HB1, and HB2 and Subpacket bytes are indicated as SB0 to SB6.

Subpacket 0 bytes 0 through 6 (SB0-SB6) are also designated Packet bytes 0 to 6 (PB0-PB6).

Subpacket 1 bytes 0 through 6 (SB0-SB6) are also designated Packet bytes 7 to 13 (PB7-PB13).

Subpacket 2 bytes 0 through 6 (SB0-SB6) are also designated Packet bytes 14 to 20 (PB14-PB20).

Subpacket 3 bytes 0 through 6 (SB0-SB6) are also designated Packet bytes 21 to 27 (PB21-PB27).

This is illustrated in Figure 5-4.

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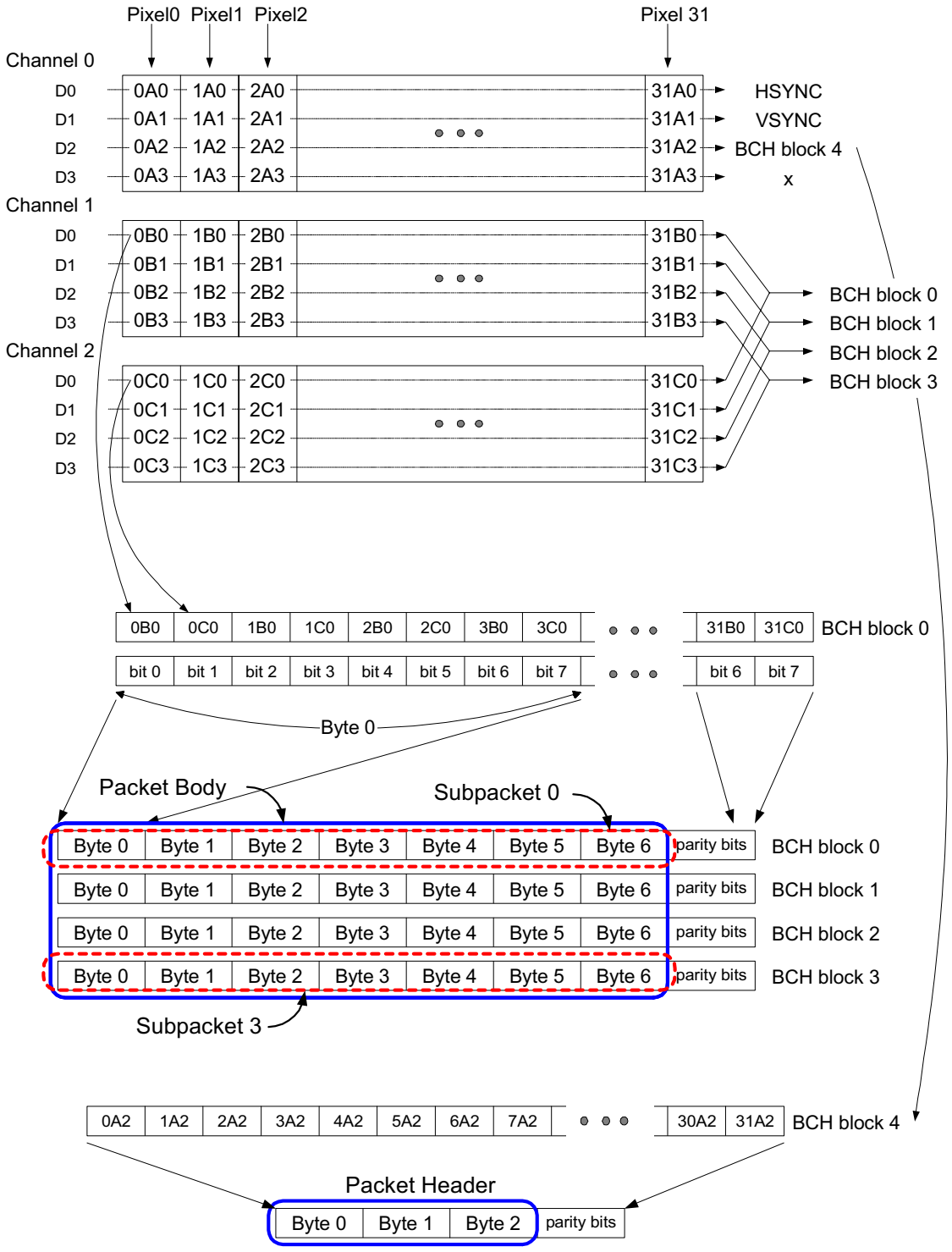


Figure 5-4 Data Island Packet and ECC Structure

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5.2.3.5 Data Island Error Correction

To improve the reliability of the data and to improve the detection of bad data, Error Correction Code (ECC) parity is added to each packet. BCH(64,56) and BCH(32,24) are generated by the polynomial G(x) shown in Figure 5-5.

$G(x)=1+x^6+x^7+x^8$ (127 count repetition cycle).

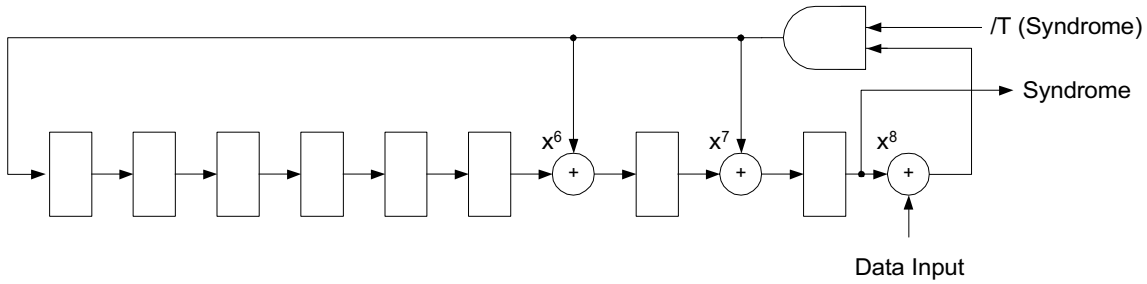


Figure 5-5 Error Correction Code generator

5.3 Data Island Packet Definitions

5.3.1 Packet Header

Packet Headers contain 24 data bits with an additional 8 bits of BCH(32,24) ECC parity. These parity bits are calculated over the 24 bits of the Packet Header.

A Packet Header includes an 8-bit Packet Type and 16 bits of packet-specific data.

Table 5-7 Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	Packet Type							
HB1	packet-specific data							
HB2	packet-specific data							

Table 5-8 shows the available packet types.

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Table 5-8 Packet Types

Packet Type Value	Packet Type
0x00	Null
0x01	Audio Clock Regeneration (N/CTS)
0x02	Audio Sample
0x80+InfoFrame Type	EIA/CEA-861B InfoFrame

5.3.2 Null Packet

Null packets can be used by the Source anytime. All bytes of a Null packet are undefined and shall contain only zero values. An HDMI Sink shall ignore bytes HB1 and HB2 of the Null Packet Header and all bytes of the Null Packet Body.

Table 5-9 Null Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	0	0	0	0	0	0	0	0
HB1	0	0	0	0	0	0	0	0
HB2	0	0	0	0	0	0	0	0

5.3.3 Audio Clock Regeneration Packet

Audio Clock Regeneration Packets contain both the N and CTS values used in the Audio Clock Regeneration process. The four Subpackets each contain the same Audio Clock Regeneration Subpacket. An HDMI Sink shall ignore bytes HB1 and HB2 of the Audio Clock Regeneration Packet header.

Table 5-10 Audio Clock Regeneration Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	0	0	0	0	0	0	0	1
HB1	0	0	0	0	0	0	0	0
HB2	0	0	0	0	0	0	0	0

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Table 5-11 Audio Clock Regeneration Subpacket

Byte \ Bit #	7	6	5	4	3	2	1	0
SB0	0	0	0	0	0	0	0	0
SB1	0	0	0	0	CTS.19	-	-	CTS.16
SB2	CTS.15	-	-	-	-	-	-	CTS.8
SB3	CTS.7	-	-	-	-	-	-	CTS.0
SB4	0	0	0	0	N.19	-	-	N.16
SB5	N.15	-	-	-	-	-	-	N.8
SB6	N.7	-	-	-	-	-	-	N.0

- N: value of audio clock regeneration “N” [20 bits]
- CTS: Cycle Time Stamp [20 bits]

CTS values of zero are used to indicate no new value of CTS.

5.3.4 Audio Sample Packet

Audio Sample Packets consist of one to four Audio Samples. These may be different samples or different partial samples (i.e. 2 of 6 channels). The configuration of the Subpackets is determined by the layout and sample_present bits in the header. This is described in detail in Section 7.6, *Audio Data Packetization*.

Table 5-12 Audio Sample Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	0	0	0	0	0	0	1	0
HB1	0	0	0	layout	sample_ present.sp3	sample_ present.sp2	sample_ present.sp1	sample_ present.sp0
HB2	B.3	B.2	B.1	B.0	sample_flat. sp3	sample_flat .sp2	sample_flat. sp1	sample_flat .sp0

- layout: indicates which of two possible Subpacket/audio sample layouts are used. See Section 7.6, *Audio Data Packetization*.
- sample_present.spX: indicates if Subpacket X contains an audio sample.
- sample_flat.spX: indicates if Subpacket X represents a “flatline” sample. Only valid if “sample_present.spX” is set.
- B.X: =1 if Subpacket X contains the first frame in an IEC 60958 block; = 0 otherwise

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Table 5-13 Audio Sample Subpacket

Byte \ Bit #	7	6	5	4	3	2	1	0
SB0	L.11	…	…	…	…	…	…	L.4
SB1	L.19	…	…	…	…	…	…	L.12
SB2	L.27	…	…	…	…	…	…	L.20
SB3	R.11	…	…					R.4
SB4	R.19	…	…	…	…	…	…	R.12
SB5	R.27	…	…	…	…	…	…	R.20
SB6	P_R	C_R	U_R	V_R	P_L	C_L	U_L	V_L

- L.X: Bit corresponding to Time Slot X from first (“left”) sub-frame per IEC 60958-1, page 15
- R.X: Bit corresponding to Time Slot X from second (“right”) sub-frame per IEC 60958-1, page 15
- V_L: Valid bit from first sub-frame
- V_R: Valid bit from second sub-frame
- U_L: User Data bit from first sub-frame
- U_R: User Data bit from second sub-frame
- C_L: Channel Status bit from first sub-frame
- C_R: Channel Status bit from second sub-frame
- P_L: Parity bit from first sub-frame (even parity)
- P_R: Parity bit from second sub-frame (even parity)

5.3.5 InfoFrame Packet

EIA/CEA-861B InfoFrames are carried across HDMI using the HDMI InfoFrame packet, with the following restrictions.

- Each InfoFrame shall be 30 bytes or less, including the Type Code (Packet Type), Version number and InfoFrame length fields.
- InfoFrame Type Codes shall be within the range of 0 to 127.
- Only InfoFrames defined in EIA/CEA-861B or in this specification may be transmitted.

InfoFrames are each carried in their own packet, as shown below.

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Table 5-14 InfoFrame Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	1	InfoFrame Type						
HB1	InfoFrame_version							
HB2	0	0	0	InfoFrame_length				

- InfoFrame Type: lower 7 bits of the InfoFrame type code as per EIA/CEA-861B.
- InfoFrame_version: version number of InfoFrame as per EIA/CEA-861B.
- InfoFrame_length: InfoFrame length in bytes as per EIA/CEA-861B. This length does not include any of the bytes in the Packet Header nor the checksum byte. The maximum value for this field is 27 (0x1B).

Table 5-15 InfoFrame Packet Contents

Byte \ Bit #	7	6	5	4	3	2	1	0
PB0	checksum							
PB1	Data Byte 1							
PB2	Data Byte 2							
PB3…PB26	…							
PB27	Data Byte 27							

- checksum: Checksum of the InfoFrame. The checksum shall be calculated such that a byte-wide sum of all three bytes of the Packet Header and all valid bytes of the InfoFrame Packet contents (determined by InfoFrame_length), plus the checksum itself, equals zero.
- Data Byte x: Data Byte X of the InfoFrame as defined in EIA/CEA-861B.

5.3.6 General Control Packet

The General Control packet header contains no data. Bytes HB1 and HB2 shall be ignored by the Sink. The General Control packet body shall contain four identical subpackets, defined in Table 5-17, below. The General Control packet may only be transmitted between the active edge of VSYNC and 384 pixels following this edge.

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Table 5-16 General Control Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	0	0	0	0	0	0	1	1
HB1	0	0	0	0	0	0	0	0
HB2	0	0	0	0	0	0	0	0

Table 5-17 General Control Subpacket

Byte \ Bit #	7	6	5	4	3	2	1	0
SB0	0	0	0	Clear_AVMUTE	0	0	0	Set_AVMUTE
SB1	0	0	0	0	0	0	0	0
SB2	0	0	0	0	0	0	0	0
SB3	0	0	0	0	0	0	0	0
SB4	0	0	0	0	0	0	0	0
SB5	0	0	0	0	0	0	0	0
SB6	0	0	0	0	0	0	0	0

- Set_AVMUTE: Set the AVMUTE flag. (See description below).
- Clear_AVMUTE: Clear the AVMUTE flag. (See description below).

A Source may not send a General Control Packet with the Clear_AVMUTE and Set_AVMUTE flags set simultaneously.

Source transmission of the General Control Packet is optional. Sinks may optionally interpret General Control Packet contents. Sinks shall be capable of receiving any General Control Packet.

The General Control packet's Set_AVMUTE and Clr_AVMUTE flags may be used by a Source to reduce the negative impact on the Sink of TMDS clock changes or interruptions. Use of the AVMUTE function may prevent spurious pops or noises in the audio during these clock changes.

When AVMUTE is set, the Sink may assume that no valid audio or video data is being received. The Sink may optionally apply a mute function to the audio data and/or a blank function to the video.

5.4 Encoding

5.4.1 Serialization

The stream of TMDS characters produced by the encoder is serialized for transmission on the TMDS data channel. In the discussions that follow, the least significant bit of each character (q_out[0]) is the first bit to be transmitted and the most significant bit (q_out[9]) is the last.

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5.4.2 Control Period Coding

Each TMDS channel has two control signals which are encoded into 10 bits during Control Periods. For each of the three channels these signals are shown in Table 5-18.

Table 5-18 Control-signal Assignment

TMDS Channel	D0	D1
0	HSYNC	VSYNC
1	CTL0	CTL1
2	CTL2	CTL3

The two Control signals for each of the three TMDS channels are encoded as follows:

```
case (D1, D0):
       0, 0:  q_out[9:0] = 0b1101010100;
       0, 1:  q_out[9:0] = 0b0010101011;
       1, 0:  q_out[9:0] = 0b0101010100;
       1, 1:  q_out[9:0] = 0b1010101011;
endcase;
```

5.4.3 TERC4 Coding

TMDS Error Reduction Coding (TERC4) is used during the Data Island period to encode 4 bits per channel into the 10 bits serialized and transmitted.

```
case (D3, D2, D1, D0):
    0000:  q_out[9:0] = 0b1010011100;
    0001:  q_out[9:0] = 0b1001100011;
    0010:  q_out[9:0] = 0b1011100100;
    0011:  q_out[9:0] = 0b1011100010;
    0100:  q_out[9:0] = 0b0101110001;
    0101:  q_out[9:0] = 0b0100011110;
    0110:  q_out[9:0] = 0b0110001110;
    0111:  q_out[9:0] = 0b0100111100;
    1000:  q_out[9:0] = 0b1011001100;
    1001:  q_out[9:0] = 0b0100111001;
    1010:  q_out[9:0] = 0b0110011100;
    1011:  q_out[9:0] = 0b1011000110;
    1100:  q_out[9:0] = 0b1010001110;
    1101:  q_out[9:0] = 0b1001110001;
    1110:  q_out[9:0] = 0b0101100011;
    1111:  q_out[9:0] = 0b1011000011;
endcase;
```


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5.4.4 Video Data Coding

5.4.4.1 Video Data Encoding

The following is a description of the encoding algorithm used during transmission of video data. A detailed description of an encoder is given. Other implementations are possible and are permitted but, given the same sequence of input characters, they are required to produce the same sequence of output (10-bit) characters that is generated by the described encoder.

During video data, where each 10-bit character represents 8 bits of pixel data, the encoded characters provide an approximate DC balance as well as a reduction in the number of transitions in the data stream. The encode process for the active data period can be viewed in two stages. The first stage produces a transition-minimized 9-bit code word from the input 8 bits. The second stage produces a 10-bit code word, the finished TMDS character, which will manage the overall DC balance of the transmitted stream of characters.

The 9-bit code word produced by the first stage of the encoder is made up of an 8-bit representation of the transitions found in the input 8 bits, plus a one-bit flag to indicate which of two methods was used to describe the transitions. In both cases the LSb of the output matches the LSb of the input. With a starting value established, the remaining 7 bits of the output word is derived from sequential exclusive OR (XOR) or exclusive NOR (XNOR) functions of each bit of the input with the previously derived bit. The choice between XOR and XNOR logic is made such that the encoded values contain the fewest possible transitions, and the ninth bit of the code word is used to indicate whether XOR or XNOR functions were used to derive the output code word. The decode of this 9-bit code word is simply a matter of applying either XOR or XNOR gates to the adjacent bits of the code, with the LSb passing from decoder input to decoder output unchanged.

The second stage of the encoder performs an approximate DC balance on the transmitted stream by selectively inverting the 8 data bits of the 9-bit code words produced by the first stage. A tenth bit is added to the code word, to indicate when the inversion has been made. The encoder determines when to invert the next character based on the running disparity between ones and zeros that it tracks in the transmitted stream, and the number of ones and zeros found in the current code word. If too many ones have been transmitted and the input contains more ones than zeros, the code word is inverted. This dynamic encoding decision at the Source is simply decoded at the Sink by the conditional inversion of the input code word based on the tenth bit of the TMDS character. The TMDS code mapping is specified by Figure 5-6 with the definitions of Table 5-19. The encoder produces one of 460 unique 10-bit characters. The encoder shall not generate any other 10-bit character during a Video Data Period.

Upon entering a Video Data Period, the data stream disparity (cnt) shall be considered to be zero by the encoder.

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Table 5-19 Encoding Algorithm Definitions

D	The encoder input data set. D is 8-bit pixel data
cnt	This is a register used to keep track of the data stream disparity. A positive value represents the excess number of “1”s that have been transmitted. A negative value represents the excess number of “0”s that have been transmitted. The expression cnt{t-1} indicates the previous value of the disparity for the previous set of input data. The expression cnt(t) indicates the new disparity setting for the current set of input data.
q_m	Intermediate value.
q_out	These 10 bits are the encoded output value.
N_1{x}	This operator returns the number of “1”s in argument “x”
N_0{x}	This operator returns the number of “0”s in argument “x”

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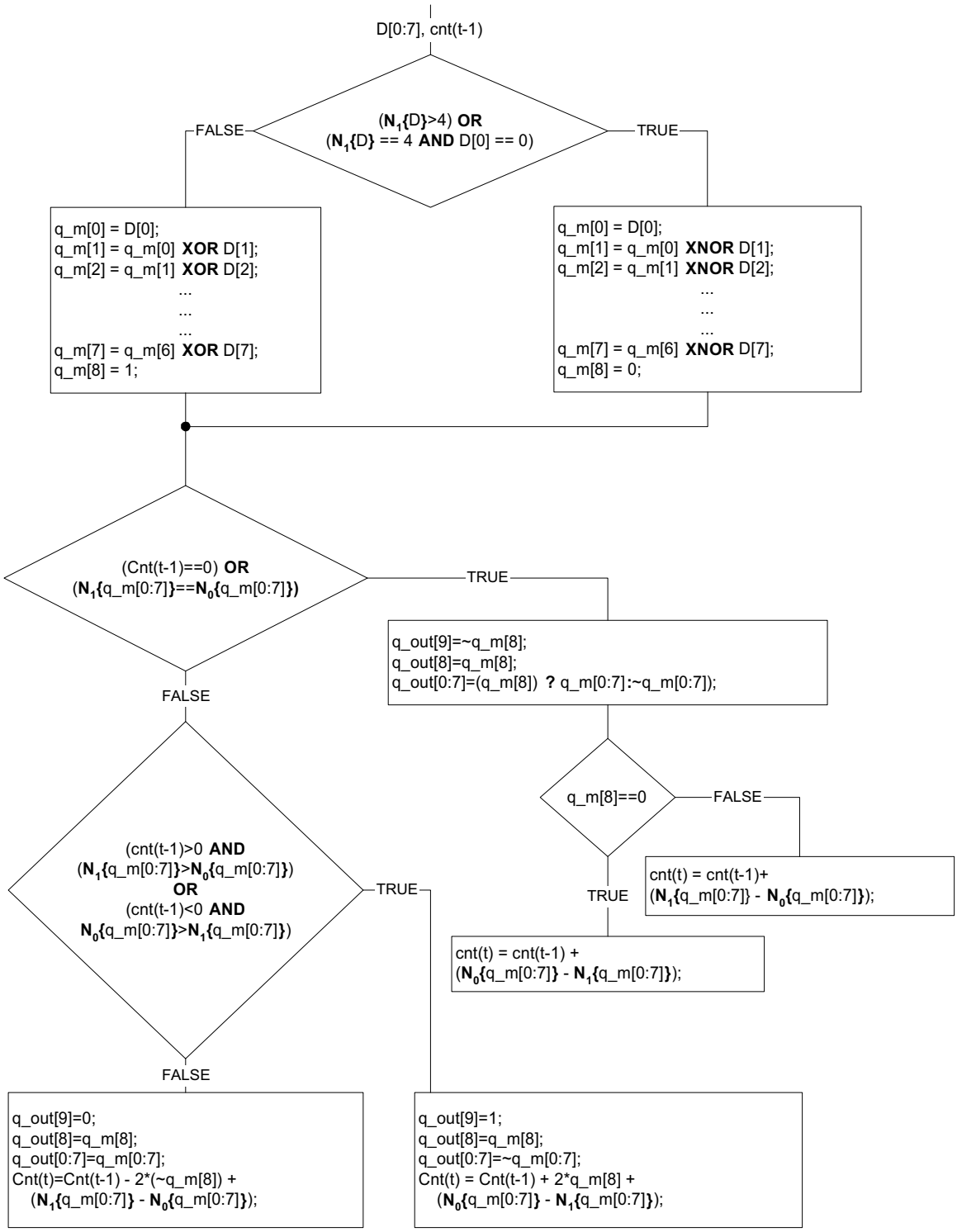


Figure 5-6 TMDS Video Data Encode Algorithm

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5.4.4.2 Video Data Decoding

The TMDS decode mapping is specified by Figure 5-7. Alternative implementations are possible but, given the same input data stream, they are required to generate the same output data stream as the described decoder algorithm.

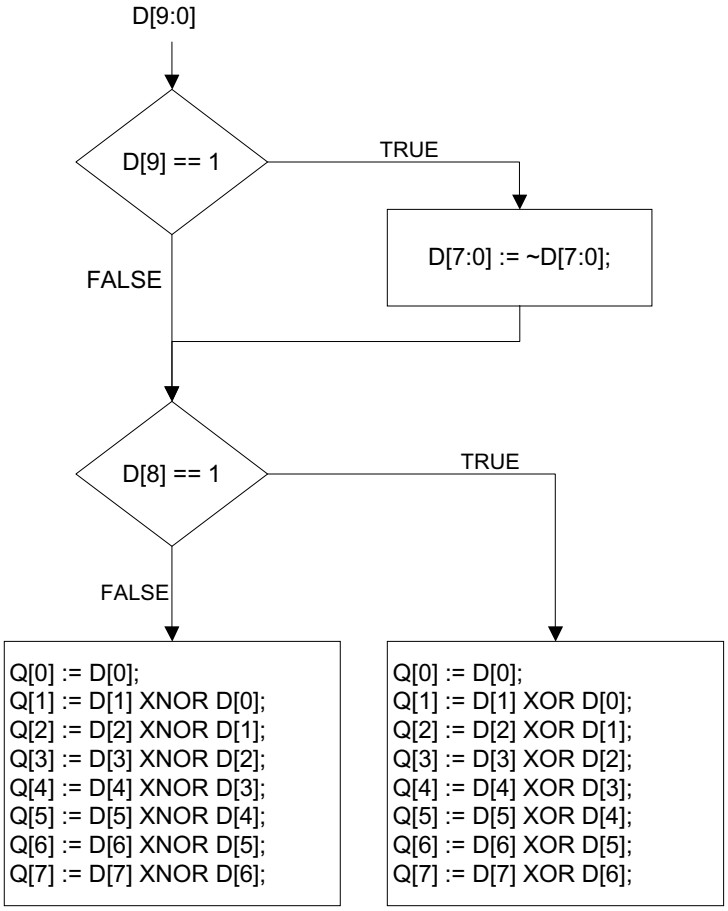


Figure 5-7 TMDS Video Decode Algorithm

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6 Video

6.1 Overview

HDMI allows a wide variety of explicitly defined video format timings to be transmitted and displayed. These video format timings define the pixel and line counts and timing, synchronization pulse position and duration, and whether the format is interlaced or progressive.

The video pixels carried across the link shall be in one of three different pixel encodings: RGB 4:4:4, YC_BC_R 4:4:4 or YC_BC_R 4:2:2.

The HDMI Source determines the pixel encoding and video format of the transmitted signal based on the characteristics of the source video, the format and pixel encoding conversions possible at the Source, and the format and pixel encoding capabilities and preferences of the Sink.

6.2 Video Format Support

In order to provide maximum compatibility between video Sources and Sinks, specific minimum requirements have been specified for Sources and Sinks.

6.2.1 Format Support Requirements

Some of the following support requirements are in addition to those specified in EIA/CEA-861B.

- An HDMI Source shall support at least one of the following video format timings:
  - 640x480p @ 59.94/60Hz
  - 720x480p @ 59.94/60Hz
  - 720x576p @ 50Hz
- An HDMI Source that is capable of transmitting any of the following video format timings using any other component analog or uncompressed digital video output, shall be capable of transmitting that video format timing across the HDMI interface.
  - 1280x720p @ 59.94/60Hz
  - 1920x1080i @ 59.94/60Hz
  - 720x480p @ 59.94/60Hz
  - 1280x720p @ 50Hz
  - 1920x1080i @ 50Hz
  - 720x576p @ 50Hz
- An HDMI Sink which accepts 60Hz video formats shall support the 640x480p @ 59.94/60Hz and 720x480p @ 59.94/60Hz video format timings.
- An HDMI Sink which accepts 50Hz video formats shall support the 640x480p @ 59.94/60Hz and 720x576p @ 50Hz video format timings.
- An HDMI Sink which accepts 60Hz video formats, and which supports HDTV capability, shall support 1280x720p @ 59.94/60Hz or 1920x1080i @ 59.94/60Hz video format timings.
- An HDMI Sink which accepts 50Hz video formats, and which supports HDTV capability, shall support 1280x720p @ 50Hz or 1920x1080i @ 50Hz video format timings.

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- An HDMI Sink that is capable of receiving any of the following video format timings using any other component analog or uncompressed digital video input, shall be capable of receiving that format across the HDMI interface.
  - 1280x720p @ 59.94/60Hz
  - 1920x1080i @ 59.94/60Hz
  - 1280x720p @ 50Hz
  - 1920x1080i @ 50Hz

6.2.2 Video Control Signals : HSYNC, VSYNC

During the Data Island period, HDMI carries HSYNC and VSYNC signals using encoded bits on Channel 0. During Video Data periods, HDMI does not carry HSYNC and VSYNC and the Sink should assume that these signals remain constant. During Control periods, HDMI carries HSYNC and VSYNC signals through the use of four different control characters on TMDS Channel 0.

6.2.3 Pixel Encoding Requirements

Only pixel encodings of RGB 4:4:4, YC_BC_R 4:2:2, and YC_BC_R 4:4:4 (as specified in Section 6.5) may be used on HDMI.

All HDMI Sources and Sinks shall be capable of supporting RGB 4:4:4 pixel encoding.

All HDMI Sources shall support either YC_BC_R 4:2:2 or YC_BC_R 4:4:4 pixel encoding whenever that device is capable of transmitting a color-difference color space across any other component analog or digital video interface.

All HDMI Sinks shall be capable of supporting both YC_BC_R 4:4:4 and YC_BC_R 4:2:2 pixel encoding when that device is capable of supporting a color-difference color space from any other component analog or digital video input.

If an HDMI Sink supports either YC_BC_R 4:2:2 or YC_BC_R 4:4:4 then both shall be supported.

An HDMI Source may determine the pixel-encodings that are supported by the Sink through the use of the E-EDID. If the Sink indicates that it supports YC_BC_R-formatted video data and if the Source can deliver YC_BC_R data, then it can enable the transfer of this data across the link.

6.3 Video Format Timing Specifications

All specified video line pixel counts and video field line counts (both active and total) and HSYNC and VSYNC positions and durations shall be adhered to when transmitting a specified video format timing.

For example, if a Source is processing material with fewer active pixels per line than required (i.e. 704 pixels vs. 720 pixels for standard definition MPEG2 material), it may add pixels to the left and right of the supplied material before transmitting across HDMI. AVI bar info may need to be adjusted to account for these added pixels.

Detailed timing is found in EIA/CEA-861B for the following primary and optional video format timings.

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6.3.1 Primary Video Format Timings

- 640x480p @ 59.94/60Hz
- 1280x720p @ 59.94/60Hz
- 1920x1080i @ 59.94/60Hz
- 720x480p @ 59.94/60Hz
- 720(1440)x480i @ 59.94/60Hz
- 1280x720p @ 50Hz
- 1920x1080i @ 50Hz
- 720x576p @ 50Hz
- 720(1440)x576i @ 50Hz

6.3.2 Optional Video Format Timings

- 720(1440)x240p @ 59.94/60Hz
- 2880x480i @ 59.94/60Hz
- 2880x240p @ 59.94/60Hz
- 1440x480p @ 59.94/60Hz
- 1920x1080p @ 59.94/60Hz
- 720(1440)x288p @ 50Hz
- 2880x576i @ 50Hz
- 2880x288p @ 50Hz
- 1440x576p @ 50Hz
- 1920x1080p @ 50Hz
- 1920x1080p @ 23.98/24Hz
- 1920x1080p @ 25Hz
- 1920x1080p @ 29.97/30Hz

6.4 Pixel-Repetition

Video formats with native pixel rates below 25 Mpixels/sec require pixel-repetition in order to be carried across a TMDS link. 720x480i and 720x576i video format timings shall always be pixel-repeated.

The HDMI Source indicates the use of pixel-repetition with the Pixel Repetition (PR0:PR3) field in the AVI InfoFrame. This field indicates to the HDMI Sink how many repetitions of each unique pixel are transmitted. In non-repeated formats, this value is zero.

For pixel-repeated formats, this value indicates the number of pixels that may be discarded by the Sink without losing real image content.

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The Source shall always accurately indicate the pixel repetition count being used. The use of the Pixel Repetition field is optional for HDMI Sink.

The use of this pixel-repetition count field is more fully described in EIA/CEA-861B.

6.5 Pixel Encodings

There are three different pixel encodings that may be sent across an HDMI cable: YC_BC_R 4:4:4, YC_BC_R 4:2:2 and RGB 4:4:4. Whichever encoding is used, it shall conform to one of the methods described in this section.

Figure 6-1 shows the default encoding, RGB 4:4:4. The R, G, and B components of the first pixel for a given line of video are transferred on the first pixel of the video data period following the Guard Band characters.

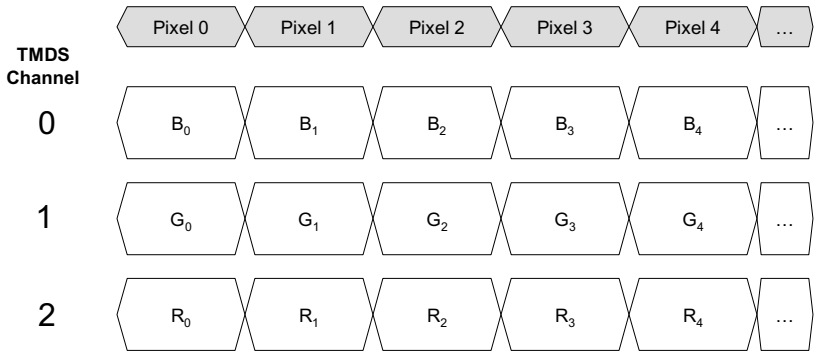


Figure 6-1 Default pixel encoding: RGB 4:4:4, 8 bits/component

Figure 6-2 shows the signal mapping and timing for transferring YC_BC_R 4:2:2 data across HDMI. Because 4:2:2 data only requires two components per pixel clock, more bits are allocated per component. The available 24 bits are split into 12 bits for the Y component and 12 bits for the C components.

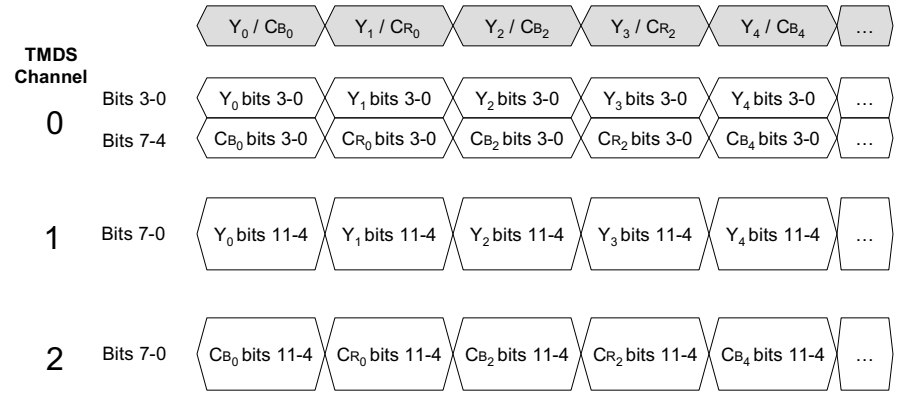


Figure 6-2 YC_BC_R 4:2:2 component

The YC_BC_R 4:2:2 pixel encoding on HDMI closely resembles standard ITU-R BT.601. The high-order 8 bits of the Y samples are mapped onto the 8 bits of Channel 1 and the low-order 4 bits

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are mapped onto the low-order 4 bits of Channel 0. If fewer than 12 bits are used, the valid bits shall be left-justified (i.e. MSb=MSb) with zeroes padding the bits below the LSb.

The first pixel transmitted within a Video Data Period contains three components, Y0, Cb0 and Cr0. The Y0 and Cb0 components are transmitted during the first TMDS pixel clock period while Cr0 is transmitted during the second TMDS pixel clock period. This second pixel clock period also contains the only component for the second pixel – Y1. In this way, the link carries one C_B sample for every two TMDS pixel clocks and one Cr sample for every two TMDS pixel clocks. These two components (C_B and C_R) are multiplexed onto the same signal paths on the link.

At the third TMDS pixel clock, this process is repeated with the Y and C_B components for the third pixel being transmitted, followed, on the next clock, by the C_R component of the third pixel and the Y component of the fourth pixel.

YC_BC_R 4:4:4 data is transferred using the scheme illustrated in Figure 6-3.

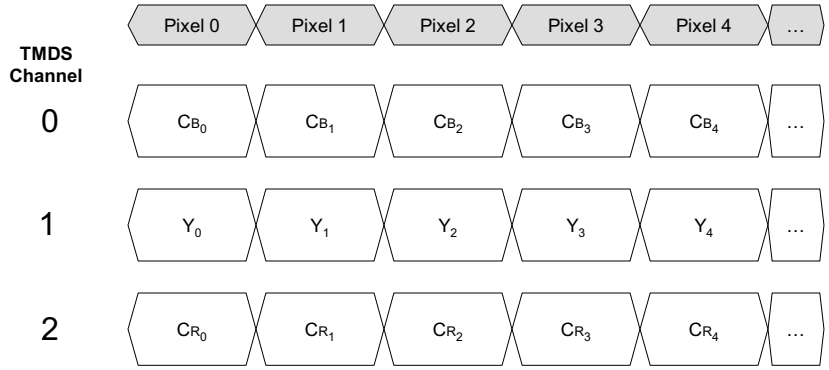


Figure 6-3 8-bit YC_BC_R 4:4:4 mapping

During pixel-doubling (Pixel_Repetition_Count = 1), all of the data sent across during the first pixel clock will be repeated during the second pixel clock. The third clock will then represent the second actual pixel and so on.

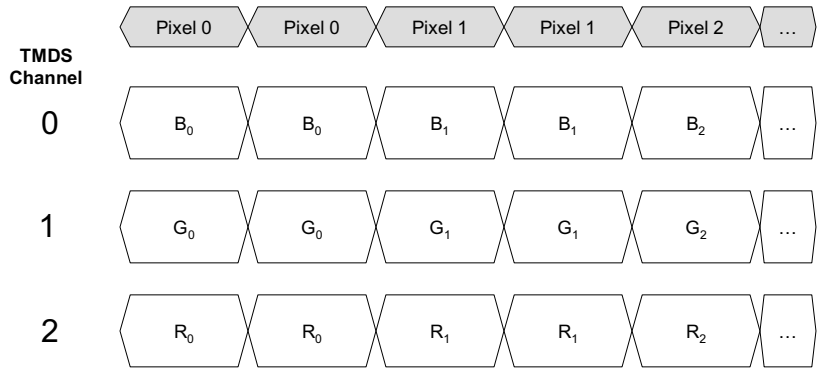


Figure 6-4 RGB with Pixel-Doubling

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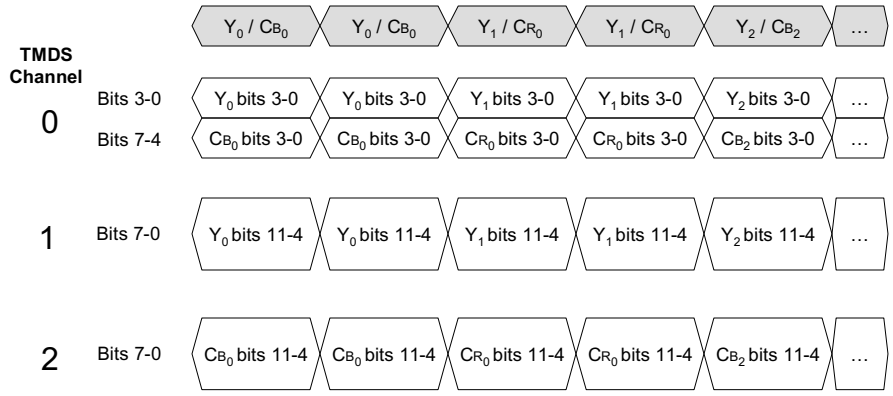


Figure 6-5 YC_BC_R 4:2:2 with Pixel-Doubling

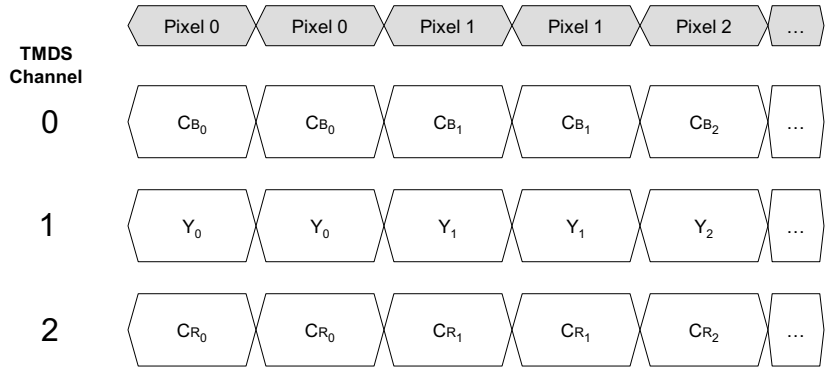


Figure 6-6 YC_BC_R 4:4:4 with Pixel-Doubling

6.6 Video Quantization Ranges

Black and white levels for video components shall be either “Full Range” or “Limited Range.” YC_BC_R components shall always be Limited Range while RGB components may be either Full Range or Limited Range. While using RGB, Limited Range shall be used for all video formats defined in EIA/CEA-861B, with the exception of VGA (640x480) format which requires Full Range.

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Table 6-1 Video Color Component Ranges

Color Space	Component Bit Depth	for Full range		for Limited range	
		Black level	White level	Black level	White level
R / G / B	8	0	255	16	235
Y / C_B / C_R	8	not allowed		16	235 (Y), 240 (C_B, C_R)
Y / C_B / C_R	10	not allowed		64	940 (Y), 960 (C_B, C_R)
Y / C_B / C_R	12	not allowed		256	3760 (Y), 3840 (C_B, C_R)

6.7 Colorimetry

6.7.1 480p, 480i, 576p, 576i, 240p and 288p

The 480-line, 576-line, 240-line, and 288-line video formats are typically transmitted with a color space based on SMPTE 170M.

ITU-R BT.601-5 Section 3.3 shall be used for any color space conversion needed in the course of processing unless a different colorimetry is specified in the AVI InfoFrame.

The encoding parameter values shall be as defined in Table 3 of ITU-R BT.601-5 and as summarized in Section 6.6.

6.7.2 1080i, 1080p and 720p

The high-definition video formats are typically transmitted with a color space based on ITU-R BT.709-4.

ITU-R BT.709-4 Part 1, Section 4 shall be used for any color space conversion needed in the course of processing unless a different colorimetry is specified in the AVI InfoFrame.

The digital representation shall be as defined in Part 1, Section 6.10 of ITU-R BT.709-4 and as summarized in Section 6.6.

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7 Audio

7.1 Relationship with IEC 60958/IEC 61937 (IEC)

Audio data is formatted in the Audio Sample Packet as a structure that closely resembles an IEC 60958 or IEC 61937 frame.

On HDMI, each IEC 60958 sub-frame is represented as a 28-bit word. There is no encoding of the preamble type which instead is replaced with a “B” bit (start-of-block) in each Audio Sample packet. The B bit shall be set for a “B, W” frame and shall be clear for an “M, W” frame. (IEC 60958-1 Section 4.1.2). No other sub-frame preamble combinations are allowed.

The behavior of all fields within the Audio Sample Subpackets shall follow the corresponding rules specified in the IEC 60958 or IEC 61937 specifications.

7.2 Audio Sample Clock Capture and Regeneration

Audio data being carried across the HDMI link, which is driven by a TMDS (video) clock only, does not retain the original audio sample clock. The task of recreating this clock at the Sink is called Audio Clock Regeneration.

There are a variety of clock regeneration methods that can be implemented in an HDMI Sink, each with a different set of performance characteristics. This specification does not attempt to define exactly how these mechanisms operate. It does however present a possible configuration and it does define the data items that the HDMI Source shall supply to the HDMI Sink in order to allow the HDMI Sink to adequately regenerate the audio clock. It also defines how that data shall be generated.

In many video source devices, the audio and video clocks are generated from a common clock (coherent clocks). In this situation, there exists a rational (integer divided by integer) relationship between these two clocks. The HDMI clock regeneration architecture can take advantage of this rational relationship and can also work in an environment where there is no such relationship between these two clocks, that is, where the two clocks are truly asynchronous or where their relationship is unknown.

Figure 7-1 Audio Clock Regeneration model, illustrates the overall system architecture model used by HDMI for audio clock regeneration. The Source shall determine the fractional relationship between the video clock and an audio reference clock (128 * audio sample rate) and shall pass the numerator and denominator for that fraction to the Sink across the HDMI link. The Sink may then recreate the audio clock from the TMDS clock by using a clock divider and a clock multiplier.

The exact relationship between the two clocks will be:

$$128 * f_S = f_{TMDS\_clock} * N / CTS.$$

The Source shall determine the value of the numerator N as specified in Section 7.2.1. Typically, this value N will be used in a clock divider to generate an intermediate clock that is slower than the $128 * f_S$ clock by the factor N. The Source will typically determine the value of the denominator CTS (Cycle Time Stamp) by counting the number of TMDS clocks in each of the $128 * f_S/N$ clocks.

If there is a constant fractional relationship between these two clocks, and the two clocks are exactly synchronous, then the CTS value will quickly come to a constant value. If the clocks are asynchronous, or there is some amount of jitter between the two clocks, then the CTS value will

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typically alternate between two or three different values. Greater variations are possible with larger jitter.

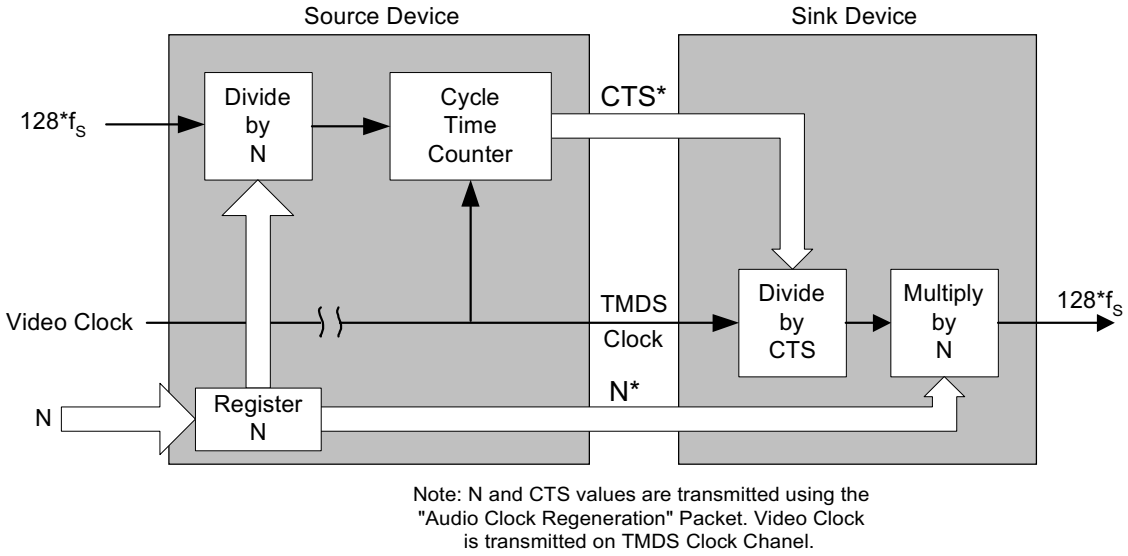


Figure 7-1 Audio Clock Regeneration model

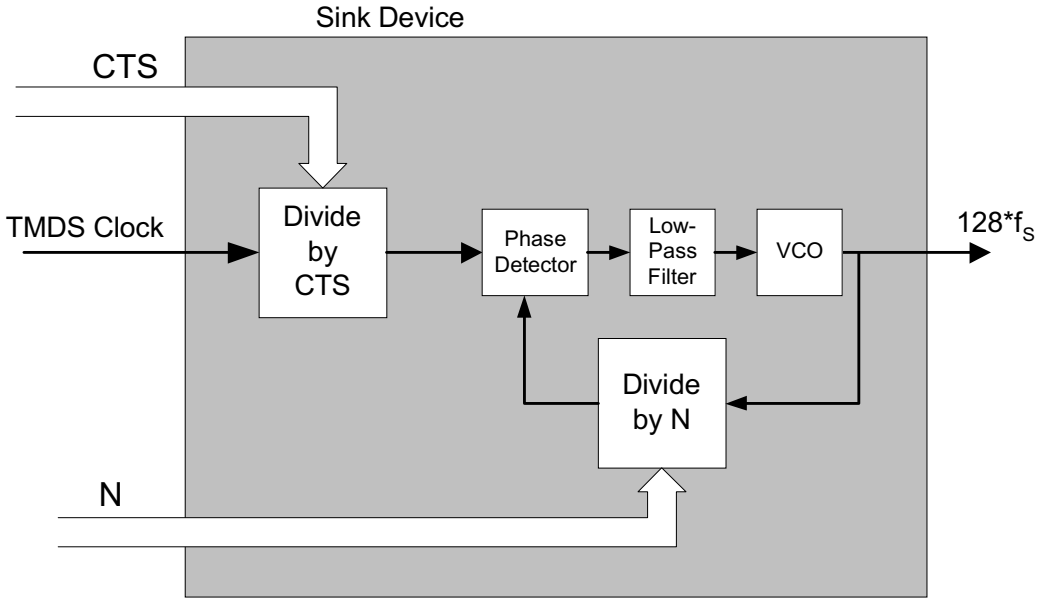


Figure 7-2 Optional Implementation: Audio Sink

It is expected that most Sinks will be implemented with an architecture similar to that shown in Figure 7-2, however, it is permitted and possible to devise an audio clock regeneration function that does not take advantage of the N or CTS values passed to the Sink.

7.2.1 N parameter

N shall be an integer number and shall meet the following restriction:

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$128 * f_S$ / 1500Hz ≤ N ≤ $128 * f_S$ / 300Hz

with a recommended optimal value of

$128 * f_S$ / 1000Hz approximately equals N

For coherent audio and video clock Sources, the tables below should be used to determine the value of N. For non-coherent Sources or Sources where coherency is not known, the equations above should be used.

7.2.2 CTS parameter

CTS shall be an integer number which satisfies the following:

(Average CTS value) = ($f_{TMDS\_clock} * N$) / ($128 * f_S$)

7.2.3 Recommended N and Expected CTS Values

The recommended value of N for several standard pixel clocks are given in Table 7-1, Table 7-2, and Table 7-3. It is recommended that Sources with non-coherent clocks use the values listed for a pixel clock of “Other”.

Table 7-1 Recommended N and Expected CTS for 32kHz Audio

	32 kHz	
Pixel Clock (MHz)	N	CTS
25.2 / 1.001	4576	28125
25.2	4096	25200
27	4096	27000
27 * 1.001	4096	27027
54	4096	54000
54 * 1.001	4096	54054
74.25 / 1.001	11648	210937-210938*
74.25	4096	74250
148.5 / 1.001	11648	421875
148.5	4096	148500
Other	4096	measured

*Note: This value will alternate because of restriction on N.

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Table 7-2 Recommended N and Expected CTS for 44.1kHz and Multiples

	44.1 kHz		88.2 kHz		176.4 kHz	
Pixel Clock (MHz)	N	CTS	N	CTS	N	CTS
25.2 / 1.001	7007	31250	14014	31250	28028	31250
25.2	6272	28000	12544	28000	25088	28000
27	6272	30000	12544	30000	25088	30000
27 * 1.001	6272	30030	12544	30030	25088	30030
54	6272	60000	12544	60000	25088	60000
54 * 1.001	6272	60060	12544	60060	25088	60060
74.25 / 1.001	17836	234375	35672	234375	71344	234375
74.25	6272	82500	12544	82500	25088	82500
148.5 / 1.001	8918	234375	17836	234375	35672	234375
148.5	6272	165000	12544	165000	25088	165000
Other	6272	measured	12544	measured	25088	measured

Table 7-3 Recommended N and Expected CTS for 48kHz and Multiples

	48 kHz		96 kHz		192 kHz	
Pixel Clock (MHz)	N	CTS	N	CTS	N	CTS
25.2 / 1.001	6864	28125	13728	28125	27456	28125
25.2	6144	25200	12288	25200	24576	25200
27	6144	27000	12288	27000	24576	27000
27 * 1.001	6144	27027	12288	27027	24576	27027
54	6144	54000	12288	54000	24576	54000
54 * 1.001	6144	54054	12288	54054	24576	54054
74.25 / 1.001	11648	140625	23296	140625	46592	140625
74.25	6144	74250	12288	74250	24576	74250
148.5 / 1.001	5824	140625	11648	140625	23296	140625
148.5	6144	148500	12288	148500	24576	148500
other	6144	measured	12288	measured	24576	measured

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7.3 Audio Sample Rates and Support Requirements

If an HDMI Source supports audio transmission across any output, then it shall support HDMI audio transmission. Exceptions to this rule for Sources with Type B connectors are found in Appendix B.

If an HDMI Source supports any HDMI audio transmission, then it shall support 2 channel L-PCM using an IEC 60958 Subpacket structure, with either 32kHz, 44.1kHz or 48kHz sampling rate and a sample size of 16 bits or more.

An HDMI Source is permitted to transmit L-PCM or encoded audio data at sample rates of 32kHz, 44.1kHz, 48kHz, 88.2kHz, 96kHz, 176.4kHz and 192kHz using either IEC 60958 format or IEC 61937 format.

If an HDMI Sink supports audio reception across any input, then it shall support audio reception from all HDMI inputs.

An HDMI Sink that is capable of accepting any audio format is required to accept two channel IEC 60958-formatted L-PCM audio at sample rates of 32kHz, 44.1kHz, and 48kHz.

For EIA/CEA-861B references to Sources, “Basic Audio” is defined as two channel L-PCM audio at sample rates of 32kHz, 44.1kHz, *or* 48kHz, with a sample size of at least 16 bits. For EIA/CEA-861B references to DTV devices, “Basic Audio” is defined as two channel L-PCM audio at sample rates of 32kHz, 44.1kHz, *and* 48kHz. There is no sample size usage restriction for DTV devices.

An HDMI Sink may optionally accept audio at sample rates of 88.2kHz, 96kHz, 176.4kHz and/or 192kHz using either IEC 60958 format or IEC 61937 format, and should indicate these capabilities in the E-EDID data structure.

An HDMI Repeater shall support HDMI audio reception and transmission.

Whenever transmitting a valid audio stream, HDMI Sources shall always include valid sample rate information in the Channel Status bits of the audio sample packets, per Table 7-4.

In some cases, pixel-repetition may be required to increase the available bandwidth for audio transmission. For instance, when transmitting a 720x480p video format timing, it is required to pixel double in order to transmit 6 channels @ 96kHz.

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Table 7-4 Channel Status Values for Audio Sample Frequencies

Channel Status Bit Number				Sample Frequency
24	25	26	27	
1	1	0	0	32 kHz
0	0	0	0	44.1 kHz
0	0	0	1	88.2 kHz
0	0	1	1	176.4 kHz
0	1	0	0	48 kHz
0	1	0	1	96 kHz
0	1	1	1	192 kHz

7.3.1 Video Dependency

Available audio bandwidth depends upon the pixel clock frequency, the video format timing, and whether or not content protection re-synchronization is needed.

Table 7-5 shows the available audio sample rates for 2-channel (Layout 0) and 8-channel (Layout 1) audio transmission at the various video format timings specified in EIA/CEA-861B, assuming that 58 clocks of the horizontal blanking interval is required for content protection re-synchronization.

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Table 7-5 Maximum Audio Sampling Frequency for all Video Format Timings (Informative)

Description	Format Timing	Pixel Repetition	Vertical Freq (Hz)	Max f_S 8 ch (kHz)	Max f_S 2 ch (kHz)
60Hz Formats					
VGA	640x480p	none	59.94/60	48	192
480i	1440x480i	2	59.94/60	48	192
480i	2880x480i	4	59.94/60	192	192
240p	1440x240p	2	59.94/60	48	192
240p	2880x240p	4	59.94/60	192	192
480p	720x480p	none	59.94/60	48	192
480p	1440x480p	2	59.94/60	96	192
720p	1280x720p	none	59.94/60	192	192
1080i	1920x1080i	none	59.94/60	192	192
1080p	1920x1080p	none	59.94/60	192	192
50Hz Formats					
576i	1440x576i	2	50	48	192
576i	2880x576i	4	50	192	192
288p	1440x288p	2	50	48	192
288p	2880x288p	4	50	192	192
576p	720x576p	none	50	48	192
576p	1440x576p	2	50	96	192
720p/50	1280x720p	none	50	192	192
1080i/50	1920x1080i	none	50	192	192
1080p/50	1920x1080p	none	50	192	192
1080p @ 24-30Hz					
1080p	1920x1080p	none	24	192	192
1080p	1920x1080p	none	25	192	192
1080p	1920x1080p	none	29.97/30	192	192

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7.4 Channel / Speaker Assignment

HDMI allows a Sink to indicate the configuration of attached speakers through the use of the Speaker Allocation Data Block described in EIA/CEA-861B page 84 and Table 36.

In addition, for multi-channel L-PCM audio streams, the Source may specify the speaker assignment for each of the channels in the audio stream delivered to the Sink. EIA/CEA-861B Section 6.3.2 specifies the available speaker assignments for active audio channels on HDMI. The indication of the current speaker assignment is carried in the Audio InfoFrame.

7.5 Audio, Video Synchronization

For a variety of reasons, an HDMI link may add a delay to the audio and/or video.

An HDMI Source is required to transmit audio and video data streams with no more than ±2 msec of audio delay relative to the video. Due to the uneven transmission of audio data, the delay shall be considered to be the average delay of all of the audio sample packets over the course of 3 steady-state video frames.

7.6 Audio Data Packetization

Each Subpacket of an Audio Sample Packet shall contain zero or one IEC 60958-defined "frames" of an IEC 60958 or IEC 61937 "block." There are two defined Subpacket layouts. No others are permitted.

Table 7-6 Audio Packet Layout and Layout Value

Layout Value	Max Num Channels	Samples	Subpkt 0	Subpkt 1	Subpkt 2	Subpkt 3
0	2	4	Chnl 1,2 Sample 0	Chnl 1,2 Sample 1	Chnl 1,2 Sample 2	Chnl 1,2 Sample 3
1	8	1	Chnl 1,2 Sample 0	Chnl 3,4 Sample 0	Chnl 5,6 Sample 0	Chnl 7,8 Sample 0

There are four sample_present bits in the Audio Sample Packet Header, one for each of the Subpackets. These indicate if that Subpacket contains an audio sample.

In addition, there are four sample_flat.spX bits which are set if no useful audio data was available at the Source during the time period represented by that sample. This may occur during sample rate changes or temporary stream interruptions. When sample_flat.spX is set, Subpacket X continues to represent a sample period but does not contain useful audio data. The sample_flat.spX bit is only valid when the corresponding sample_present.spX bit is set.

Layout 0 can carry up to four samples from a single IEC 61937 or a single 2-channel IEC 60958 stream of audio.

There are only five valid configurations of sample_present bits for a Layout 0 Audio Packet. They are shown in Table 7-7.

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Table 7-7 Valid Sample_Present Bit Configurations for Layout 0

SP0	SP1	SP2	SP3	Description
0	0	0	0	No Subpackets contain samples.
1	0	0	0	Only Subpacket 0 contains a sample.
1	1	0	0	Subpackets 0 and 1 contain samples.
1	1	1	0	Subpackets 0, 1, and 2 contain samples.
1	1	1	1	All Subpackets contain samples.

Layout 1 can carry only one sample with two to eight channels of L-PCM audio (i.e. one to four IEC 60958 streams) and is required for all stream groups with greater than 2 channels.

Valid combinations of sample_present bits for Layout 1 Audio Packets are determined by the permitted channel assignments as described in EIA/CEA-861B Section 6.3.2.

An HDMI Source shall place the data shown into the specified Subpackets and to identify the layout in the Audio Sample Packet Header.

The fields within a Subpacket with a corresponding sample_flat bit set or a sample_present bit clear, are not defined and can be any value.

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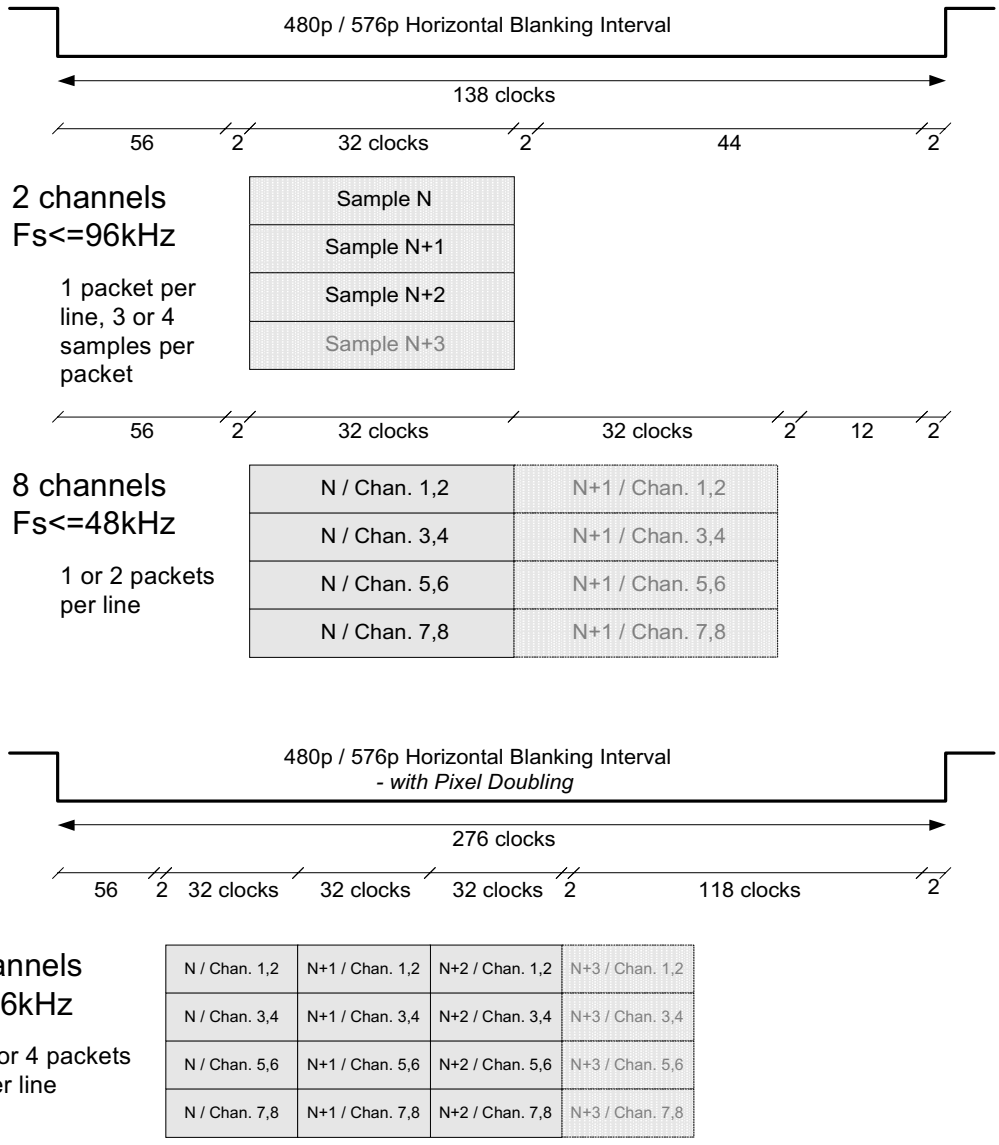


Figure 7-3 Example Audio Sample Timing (Informative)

7.7 Error Handling (Informative)

The behavior of the Sink after detecting an error is implementation-dependent. However, Sinks should be designed to prevent loud spurious noises from being heard. Sample repetition and interpolation are well known concealment techniques and are recommended.

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7.8 Packet Delivery Rules

7.8.1 Audio Sample Packets

All audio samples that are stored in a source buffer shall be sent as soon as possible while still fulfilling requirements for audio/video synchronization, and Data Island timing and placement. When using Layout 0 Audio Sample Packets, the Source shall transmit an Audio Sample Packet if at least one sample is stored in the source buffer.

Relative to an ideal constant-frequency clock, the jitter present in the Audio Sample Packet transmission timing shall not exceed one horizontal line period plus a single audio sample period.

7.8.2 Audio Clock Regeneration Packets

Nominally, Audio Clock Regeneration Packets with new (non-zero) CTS values will be transmitted at a rate of $128*f_S/N$. The Source shall transmit each new CTS data value as close as possible to the nominal transmission time for that value with the exception that priority must be given to Audio Sample packets to ensure that Audio Sample Packet delivery requirements are met.

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8 Control And Configuration

8.1 Overview

HDMI includes three separate communications channels: TMDS, DDC, and the optional CEC.

TMDS is used to carry all audio and video data as well as auxiliary data, including AVI and Audio InfoFrames that describe the active audio and video streams.

The DDC channel is used by an HDMI Source to determine the capabilities and characteristics of the Sink by reading the E-EDID data structure.

HDMI Sources are expected to read the Sink's E-EDID and to deliver only the audio and video formats which are supported by the Sink. Also, HDMI Sinks are expected to detect InfoFrames and to process the received audio and video data appropriately.

The CEC channel is optionally used for higher-level user functions such as automatic setup tasks or tasks typically associated with infrared remote control usage.

8.2 EIA/CEA-861B InfoFrames

An InfoFrame packet carries one InfoFrame. The InfoFrame provided by HDMI is limited to 30 bytes plus a checksum byte. HDMI Sources are recommended to use the AVI InfoFrame and Audio InfoFrame. Other InfoFrames specified in EIA/CEA-861B are optional.

All InfoFrames are described in detail in EIA/CEA-861B Section 6. The following describes how two of these InfoFrames are placed within the InfoFrame Packet structure and any areas where HDMI behavior is different than that specified in EIA/CEA-861B.

8.2.1 Auxiliary Video information (AVI) InfoFrame

Various aspects of the current video stream are indicated by the HDMI Source to the Sink with an Auxiliary Video information (AVI) InfoFrame.

The packetization of the AVI InfoFrame Version 2 is shown below.

Table 8-1 AVI InfoFrame Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	Packet Type = 0x82							
HB1	Version = 0x02							
HB2	0	0	0	Length = 13 (0x0D)				

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Table 8-2 AVI InfoFrame Packet Contents

Packet Byte #	EIA/CEA-861B Byte #	7	6	5	4	3	2	1	0
PB0	N. A.	Checksum							
PB1	Data Byte 1	Rsvd (0)	Y1	Y0	A0	B1	B0	S1	S0
PB2	Data Byte 2	C1	C0	M1	M0	R3	R2	R1	R0
PB3	Data Byte 3	Reserved (0)						SC1	SC0
PB4	Data Byte 4	Rsvd (0)	VIC6	VIC5	VIC4	VIC3	VIC2	VIC1	VIC0
PB5	Data Byte 5	Reserved (0)				PR3	PR2	PR1	PR0
PB6	Data Byte 6	Line Number of End of Top Bar (lower 8 bits)							
PB7	Data Byte 7	Line Number of End of Top Bar (upper 8 bits)							
PB8	Data Byte 8	Line Number of start of Bottom Bar (lower 8 bits)							
PB9	Data Byte 9	Line Number of start of Bottom Bar (upper 8 bits)							
PB10	Data Byte 10	Pixel Number of End of Left Bar (lower 8 bits)							
PB11	Data Byte 11	Pixel Number of End of Left Bar (upper 8 bits)							
PB12	Data Byte 12	Pixel Number of End of Right Bar (lower 8 bits)							
PB13	Data Byte 13	Pixel Number of End of Right Bar (upper 8 bits)							
PB14-PB27	Data Bytes 14-27	Reserved (0)							

- Y0, Y1 RGB or YC_BC_R indicator. See EIA/CEA-861B table 8 for details.
- A0 Active Information Present. See EIA/CEA-861B table 8 for details.
- B0, B1 Bar Info data valid. See EIA/CEA-861B table 8 for details.
- S0, S1 Scan Information (i.e. overscan, underscan). See EIA/CEA-861B table 8 for details.
- C0, C1 Colorimetry (ITU BT.601, BT.709 etc.). See EIA/CEA-861B table 9 for details.
- M0, M1 Picture Aspect Ratio (4:3, 16:9). See EIA/CEA-861B table 9 for details.
- R0…R3 Active Format Aspect Ratio. See EIA/CEA-861B table 10 and Annex H for details.
- VIC0…VIC6 Video Format Identification Code. See EIA/CEA-861B table 13 for details.
- PR0…PR3 Pixel Repetition factor. See EIA/CEA-861B table 14 for details.
- SC1, SC0 Non-uniform Picture Scaling. See EIA/CEA-861B table 11 and paragraph on page 58.

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Table 8-3 HDMI Valid Pixel Repeat Values for Each Format

Video Code	Video Description	EIA/CEA-861B Pixel Repeat Values	HDMI Pixel Repeat Values
1	640x480p @ 60Hz	No Repetition	No Repetition
2,3	720x480p @ 59.94/60Hz	No Repetition	No Repetition
4	1280x720p @ 59.94/60Hz	No Repetition	No Repetition
5	1920x1080i @ 59.94/60Hz	No Repetition	No Repetition
6,7	720(1440)x480i @ 59.94/60Hz	Pixel sent 2 times	Pixel sent 2 times
8,9	720(1440)x240p @ 59.94/60Hz	Pixel sent 2 times	Pixel sent 2 times
10,11	2880x480i @ 59.94/60Hz	Pixel sent 1 to 10 times	Pixel sent 1 to 10 times
12,13	2880x240p @ 59.94/60Hz	Pixel sent 1 to 10 times	Pixel sent 1 to 10 times
14,15	1440x480p @ 59.94/60Hz	No Repetition	Pixel sent 1 to 2 times**
16	1920x1080p @ 59.94/60Hz	No Repetition	No Repetition
17,18	720x576p @ 50Hz	No Repetition	No Repetition
19	1280x720p @ 50Hz	No Repetition	No Repetition
20	1920x1080i @ 50Hz	No Repetition	No Repetition
21,22	720(1440)x576i @ 50Hz	Pixel sent 2 times	Pixel sent 2 times
23,24	720(1440)x288p @ 50Hz	Pixel sent 2 times	Pixel sent 2 times
25,26	2880x576i @ 50Hz	Pixel sent 1 to 10 times	Pixel sent 1 to 10 times
27,28	2880x288 @ 50Hz	Pixel sent 1 to 10 times	Pixel sent 1 to 10 times
29,30	1440x576p @ 50Hz	No Repetition	Pixel sent 1 to 2 times**
31	1920x1080p @ 50Hz	No Repetition	No Repetition
32	1920x1080p @ 23.97/24Hz	No Repetition	No Repetition
33	1920x1080p @ 25Hz	No Repetition	No Repetition
34	1920x1080p @ 29.97/30Hz	No Repetition	No Repetition

** - Denotes change from EIA/CEA-861B valid values. Pixel repetition is required to support some audio formats at 720x480p and 720x576p video format timings. See Section 7.3.1

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8.2.2 Audio InfoFrame

A Source shall indicate characteristics of the active audio stream through the use of the IEC 60958 Channel Status bits and through the use of the Audio InfoFrame. Whenever an active audio stream is being transmitted, an accurate Audio InfoFrame shall be transmitted at least once per two video fields.

Upon the start of a new audio stream or upon any change in the audio stream that can be indicated by the Audio InfoFrame, a modified, accurate Audio InfoFrame shall be transmitted no later than one video field following the first affected non-silent audio sample. Preferably this would occur just before the first affected audio sample is transmitted.

The Audio InfoFrame transmission may occur at any time that a Data Island packet may be transmitted, including during any horizontal or vertical blanking period.

The following tables show the packetization of the Audio InfoFrame.

Table 8-4 Audio InfoFrame Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	Packet Type = 0x84							
HB1	Version Number = 0x01							
HB2	0	0	0	Length = 10 (0x0A)				

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Table 8-5 Audio InfoFrame Packet contents

Packet Byte #	EIA/CEA-861B Byte #	7	6	5	4	3	2	1	0
PB0	n. a.	checksum							
PB1	Data Byte 1	CT3	CT2	CT1	CT0	Rsvd	CC2	CC1	CC0
PB2	Data Byte 2	Reserved			SF2	SF1	SF0	SS1	SS0
PB3	Data Byte 3	Format depends on coding type (i.e. CT0…CT3)							
PB4	Data Byte 4	CA7	CA6	CA5	CA4	CA3	CA2	CA1	CA0
PB5	Data Byte 5	DM_INH	LSV3	LSV2	LSV1	LSV0	Reserved		
PB6	Data Byte 6	Reserved							
PB7	Data Byte 7	Reserved							
PB8	Data Byte 8	Reserved							
PB9	Data Byte 9	Reserved							
PB10	Data Byte 10	Reserved							
PB11-PB27	Data Byte 11-27	Reserved							

- CC0…CC2 Channel Count. See EIA/CEA-861B table 19 for details.
- CT0…CT3 Coding Type. See EIA/CEA-861B table 19 for details. The CT bits shall always be set to a value of 0, 0, 0, 0 (“Refer to Stream Header”).
- SS0…SS1 Sample Size. See EIA/CEA-861B table 20 for details. The SS bits shall always be set to a value of 0, 0 (“Refer to Stream Header”).
- SF0…SF2 Sample Frequency. See EIA/CEA-861B table 20 for details. The SF bits shall always be set to a value of 0, 0, 0 (“Refer to Stream Header”).
- CA0…CA7 Channel/Speaker Allocation. See EIA/CEA-861B Section 6.3.2 for details.
- LSV0…LSV3 Level Shift Value (for downmixing). See EIA/CEA-861B Section 6.3.2 and EIA/CEA-861B table 23 for details.
- DM_INH Downmix Inhibit. See EIA/CEA-861B Section 6.3.2 and table 24 for details. The DM_INH field is to be set only for DVD-Audio applications and corresponds to the value in the DM_INH field of the current audio stream being played from the disk. The DM_INH field value shall be set to zero in all cases other than DVD-Audio applications.

Data Byte 3 must always be set to a value of 0.

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8.3 E-EDID Data Structure

All Sinks shall contain an EIA/CEA-861B compliant E-EDID data structure accessible through the DDC.

A Source shall read the EDID 1.3 and first CEA EDID Timing Extension to determine the capabilities supported by the Sink. Additional extensions may be read to discover additional capabilities. The Source is responsible for any format conversions that may be necessary to supply audio and video in an understandable form to the Sink. However, it is permitted for a Source to transmit Basic Audio (see Section 7.3) to a Sink that does not indicate support for Basic Audio.

The overall structure of the E-EDID in the Sink shall conform to the E-EDID structure defined in the VESA E-EDID Standard Release A, Revision 1, but shall also meet the additional requirements specified herein.

The first 128 bytes of the E-EDID shall contain an EDID 1.3 structure. The contents of this structure shall also meet the requirements of EIA/CEA-861B.

8.3.1 EDID Timing Extension

The first E-EDID 'extension' shall contain a CEA EDID Timing Extension version 3, defined in EIA/CEA-861B section 7.5. Additional CEA EDID Timing Extensions may also be present. The E-EDID shall not contain an EDID Timing Extension version 1 or version 2.

EDID Timing Extension version 3 details are described in EIA/CEA-861B Section 7.5.

Further details on the requirements of the data structures in the E-EDID and implementation examples are given in EIA/CEA-861B.

8.3.2 HDMI Vendor-Specific Data Block (HDMI VSDB)

The first CEA EDID Timing Extension shall include an HDMI Vendor Specific Data Block (HDMI VSDB) shown in Table 8-6. This is an EIA/CEA-861B Vendor Specific Data Block (see EIA/CEA-861B tables 30, 31 and 32 for details) with a 24-bit IEEE Registration Identifier of 0x000C03 belonging to the HDMI Licensing, LLC.

Sinks shall contain an HDMI VSDB with a length field of 5, indicating the presence of a 2-byte Source Physical Address field following the 24-bit identifier. No other length field value is permitted.

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Table 8-6 HDMI-LLC Vendor-Specific Data Block (HDMI VSDB)

Byte #	7	6	5	4	3	2	1	0
0	Vendor-specific tag code (=3)			Length (=5)				
1	24-bit IEEE Registration Identifier (0x000C03) (least significant byte first)							
2								
3								
4	A				B			
5	C				D			

- A, B, C, D Components of Source Physical Address (A.B.C.D). See Section 8.7.

8.3.3 DVI/HDMI Device Discrimination

When an HDMI Source needs to determine if a sink is an HDMI device, it shall do so by checking the E-EDID for the presence of an HDMI Vendor Specific Data Block within the first CEA EDID Timing Extension version 3 or higher. Any device that contains this structure is an HDMI device. Future versions of HDMI may contain longer versions of this structure. Any device with an E-EDID that does not contain an HDMI VSDB (of any length) shall be treated as a DVI device (see Appendix C).

8.3.4 Audio and Video Details

Sink audio characteristics and support are indicated in the E-EDID. This data includes a list of audio encodings supported by the Sink and parameters associated with each of those encodings.

A Sink may indicate support for YC_BC_R pixel encodings. To indicate support, bits 4 and 5 of byte 3 of the EDID Timing Extension shall both be set to one (see Table 29 of EIA/CEA-861B). To indicate no support, bits 4 and 5 shall both be zero.

If a Sink is required to support a particular video format, video format timing, or pixel encoding, then the Sink shall indicate support for that video format, video format timing or pixel encoding in the E-EDID.

8.4 Enhanced DDC

Enhanced DDC described in this section is defined in VESA “ENHANCED DISPLAY DATA CHANNEL STANDARD Version 1 (September 2, 1999)”. All Sinks are required to support these enhanced DDC features. If a Sink’s E-EDID structure is longer than 256 bytes, it shall support the segment pointer.

8.4.1 Timing

Data is synchronized with the SCL signal and timing shall comply with the Standard Mode of the I^2C specification (100kHz clock).

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I^2C Bus is a standard two-wire (clock and data) serial data bus protocol. Refer to the I^2C specification for details.

Note that an HDMI Sink may hold off the DDC transaction by stretching the SCL line during the SCL-low period following the Acknowledge bit as permitted by the I^2C specification. All HDMI Sources shall delay the DDC transaction while the SCL line is being held low.

8.4.2 Data Transfer Protocols

The Source shall use I^2C commands to read information from a Sink's E-EDID with a slave address.

In Enhanced DDC, a segment pointer is used to allow addressing of the E-EDID outside of the normal 256-byte limit of the 0xA0/0xA1 address. The Enhanced DDC protocol sets the segment pointer before the remainder of the DDC command.

8.4.3 Segment pointer

Enhanced DDC allows access of up to 32 Kbytes of data. This is accomplished using a combination of the 0xA0/0xA1 address pair and a segment pointer. For each value of the segment pointer, 256 bytes of data are available at the 0xA0/0xA1 address pair. An unspecified segment pointer references the same data as when the segment pointer is zero.

Each successive value of the segment pointer allows access to the next two blocks of E-EDID (128 bytes each). The value of the segment pointer register cannot be read since it is reset at the completion of each command.

8.4.4 Enhanced DDC Sink

The Sink shall be Enhanced DDC read compliant.

The Sink shall be capable of responding with EDID 1.3 data and up to 255 extension blocks, each 128 bytes long (up to 32K bytes total E-EDID memory) whenever the Hot Plug Detect signal is asserted.

The Sink should be capable of providing E-EDID information over the Enhanced DDC channel whenever the +5V Power signal is provided. This should be available within 20msec after the +5V Power signal is provided.

8.4.5 Enhanced DDC Source

The Source shall use Enhanced DDC protocols.

The Source shall be capable of reading EDID 1.3 data at DDC address 0xA0.

The Source reads Enhanced EDID extensions data at DDC address 0xA0 using segment pointer 0x60.

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8.5 Hot Plug Detect Signal

An HDMI Sink shall not assert high voltage level on its Hot Plug Detect pin when the E-EDID is not available for reading. The Hot Plug Detect pin may be asserted only when the +5V Power line from the Source is detected. This will ensure that the Hot Plug Detect pin is not asserted before the Third Make of the connector (see Section 4.1.5).

A Source may use a high voltage level Hot Plug Detect signal to initiate the reading of E-EDID data.

An HDMI Sink shall indicate any change to the contents of the E-EDID by driving a low voltage level on the Hot Plug Detect pin for at least 100 msec.

8.6 Consumer Electronics Control (CEC)

The CEC line is used for high-level user control of HDMI-connected devices. The mandatory requirements for the CEC line are described in detail in Section 4.2.10, CEC Line. The optional CEC protocol is described in Supplement 1: Consumer Electronics Control (CEC).

8.7 Physical Address

8.7.1 Overview

In order to allow for CEC to be able to address specific physical devices and control switches, all devices must have a physical address. This connectivity has to be worked out whenever a new device is added to the cluster.

The CEC and DDC connections are shown in Figure 8-1.

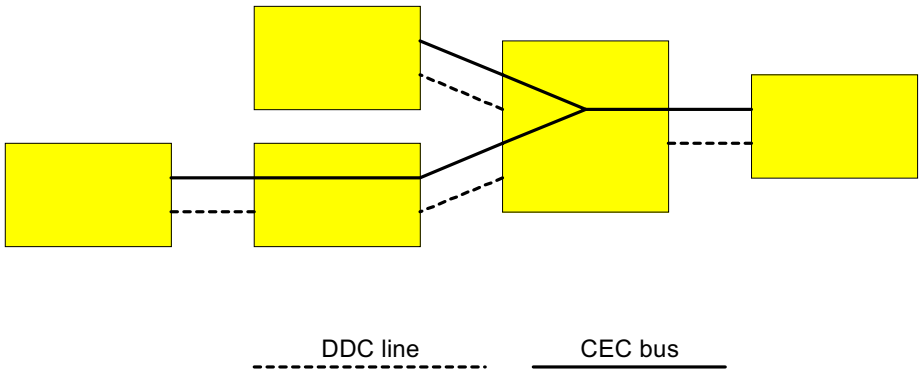


Figure 8-1 CEC and DDC line connections

The CEC line is directly connected to all nodes on the network. This gives a return channel for devices to transmit their physical and logical address across to all other devices, thus allowing any device to create a map of the network.

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8.7.2 Physical Address Discovery

The physical address of each node is determined through the physical address discovery process.

All addresses are 4 digits long allowing for a 5 deep device hierarchy. All are identified in the form of n.n.n.n in the following description. An example of this is given in Figure 8-3.

In order to allocate these addresses, an algorithm shall be used – this is described in the following section.

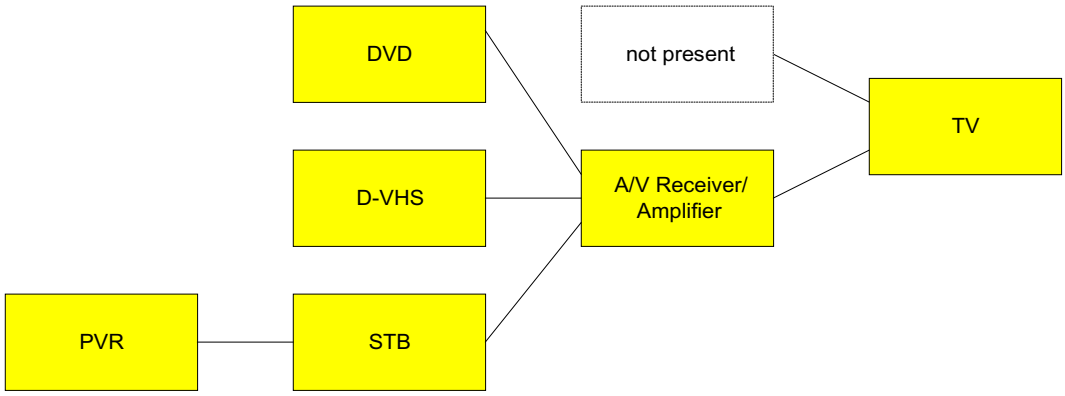


Figure 8-2 Typical HDMI cluster

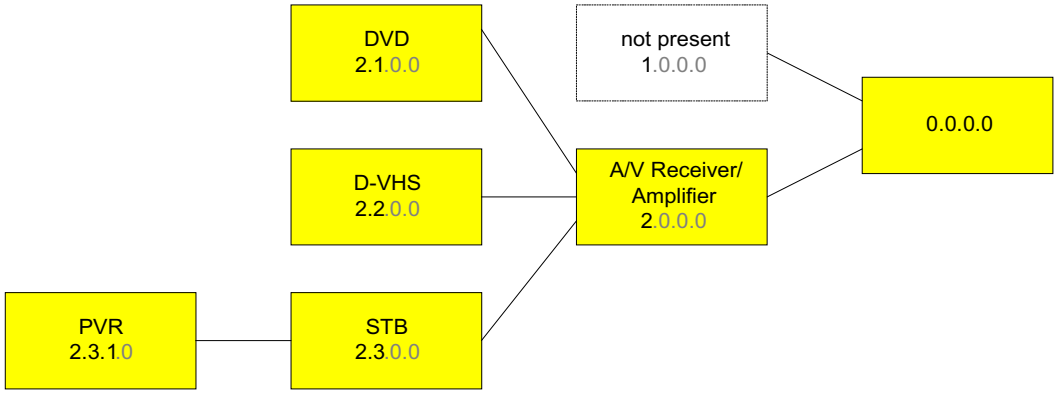


Figure 8-3 Addresses within an HMDI cluster

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8.7.3 Discovery Algorithm

The following algorithm is used to allocate the physical address of each device whenever HPD is de-asserted or upon power-up:

```
Disable assertion of HPD to all source (child) devices
Label all possible connections to source devices uniquely starting
    from connection_label = 1
If I am root
    Set my_address to 0.0.0.0
Else
    Wait for HPD from sink
    Query sink for my_address of my connection (Section 8.7.4)
    The device shall retain this physical address until HPD is
        removed (or the device is powered off).
End if
If device has connections for source (child) devices then
    If device has separate EDIDs for each source (child) connection then
        If my_address ends with 0 then
            Set all child_addresses to my_address with the first 0 being
                replaced with the appropriate connection_label.
        Else (i.e. beyond the fifth layer of the tree)
            Set all child_addresses to F.F.F.F
        End if
    Else
        Set all child_addresses to my_address
    End if
    Write child_address to HDMI VSDB in EDID for each source (child) connection
End if
Allow HPD to be asserted for source devices
```

8.7.4 HDMI Sink Query

A Source shall determine its physical address (my_address) by checking the HDMI Vendor Specific Data Block (see Section 8.3.2) within the EDID. The fourth and fifth bytes of this 5 byte structure contain the physical address (fields A, B, C, D).

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9 Content Protection

9.1 Recommendation

Content protection capability is recommended for all HDMI compliant devices. An HDMI compliant Source should protect all of the protected audiovisual data. Amongst adequate copy protection technologies which are compatible with HDMI, HDCP is available.

9.2 HDCP Implementations

HDCP implementations for HDMI shall adhere to HDCP specification version 1.10.

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Appendix A Repeater

A.1 Repeater Functions

A Repeater is defined as a device with one or more HDMI inputs and one or more HDMI outputs and a retransmission function.

A Repeater has at least one of following functions:

- Repeat function:
  Single-input, single-output devices. Used primarily for cable extension.
- Switch function:
  Multiple-input, single-output devices. Used primarily to select among multiple Sources.
- Distributor function:
  Single-input, multiple-output devices, where only one output is active. Used primarily to select among multiple displays or Sinks.
- Duplicator function:
  Single-input, multiple-output devices, where more than one output is active. Used for signal distribution.

Combinations of the above, for instance, multiple-input, multiple-output devices, incorporating both input selection and output selection or signal distribution are allowed.

In all cases, each HDMI input shall fulfill all of the requirements of an HDMI Sink when it is connected with an active sink device, and each HDMI output shall fulfill all of the requirements of an HDMI Source when it is connected with an active source.

The E-EDID presented by a Repeater should reflect the capabilities of the downstream Sink.

A.2 E-EDID Read Timing (Informative)

In terms of E-EDID handling, Repeaters will typically fall into one of the following categories.

- Stored E-EDID type: The Repeater stores an E-EDID data structure that typically consists of downstream Sink capabilities.
- Forwarding type: The Repeater does not store an E-EDID data structure. When an E-EDID read request comes from a Source, the Repeater forwards the read request to a Sink. The E-EDID data from the Sink is then forwarded back to the Source.

An HDMI cluster may have several Repeaters between a Source and a Sink. To minimize the impact to the E-EDID reading time, each Repeater in the chain should minimize the added delay.

For example, the delay added by a Forwarding type Repeater should be no more than 4 msec per 16-byte read.

A stored E-EDID type Repeater should be able to send a 256 byte E-EDID within 150 msec when a Source issues sixteen 16-byte read requests. This means that a 16-byte read request would be completed within approximately 10 msec.

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Appendix B Type B Connector Usage

B.1 Exception To Audio Format Support Requirement

Sources are not required to carry audio when all of the following conditions are met:

- Source is required by the HDMI Specification or associated agreements to use the Type B connector, and,
- Source has alternate default or user selectable audio outputs, and,
- Source can ensure that the appropriate audio stream is being delivered to the alternate audio outputs.

In order to guarantee rendering of video from Sources that do not fully support HDMI audio, the following condition shall be met:

- Sinks that are capable of supporting an HDMI video format when it is accompanied by audio shall also support that format when it is not accompanied by audio.

It is strongly recommended that a display device, when receiving an HDMI video signal without audio, temporarily indicate to the user that there is no audio accompanying the stream.

B.2 HDMI Dual-Link Architecture

HDMI dual-link architecture is compatible with DVI 1.0 dual-link architecture. Refer to section 3.1.5 of the DVI 1.0 specification.

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Appendix C Compatibility With DVI

C.1 Requirement for DVI Compatibility

All HDMI Sources shall be compatible with DVI 1.0 compliant sink devices (i.e. “monitors” or “displays”) through the use of a passive cable converter. Likewise, all HDMI Sinks shall be compatible with DVI 1.0 compliant sources (i.e. “systems” or “hosts”) through the use of a similar cable converter.

When communicating with a DVI device, an HDMI device shall operate according to the DVI 1.0 specification, with the following exception – these devices are not required to comply with DVI 1.0 rules regarding:

- Monitor scaling requirements [refer to Section 2.2.8.2 of the DVI specification – superceded by HDMI specifications]
- Physical Interconnect specifications [refer to Chapter 5 of the DVI specification – superceded by HDMI specifications]
- System Low Pixel Format Support Requirements [refer to Section 2.2.4 of the DVI specification – superceded by HDMI specifications]

Furthermore, for HDMI devices which would not otherwise have a “BIOS” or “operating system” there are the following additional exceptions:

- “BIOS” requirements [refer to Section 2.2.4 of the DVI specification]
- “Operating system” requirements [refer to Section 2.2.2 and Section 2.2.9 of the DVI specification]
- “System level event” requirements [refer to Section 2.2.9.1 of the DVI specification]
- Power management requirements [refer to Section 2.4 of the DVI specification]

C.2 HDMI Source Requirements

When communicating with a DVI sink device, an HDMI Source shall operate in a mode compatible with that device. This requires that the Source operate under the following limitations:

- Video pixel encoding shall be RGB.
- No Video Guard Bands shall be used.
- No Data Islands shall be transmitted.

An HDMI Source may only transmit Video Data Periods without Guard Bands when communicating to a DVI sink device or during the process of determining if the sink device is HDMI capable.

An HDMI Source, upon power-up, reset or detection of a new sink device, shall assume that the sink device operates under DVI 1.0 limitations. An HDMI Source shall determine if the sink device is an HDMI Sink by following the rule(s) described in Section 8.3.3. Upon detection of an HDMI Sink, the HDMI Source shall follow all of the HDMI Source-related requirements specified in this document.

All electrical and physical specifications in Section 4 shall be followed by the HDMI Source even when communicating with a DVI sink device.

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C.3 HDMI Sink Requirements

When connected to a DVI source device, an HDMI Sink shall operate as a DVI 1.0 compliant sink with the exceptions outlined in Section C.1 above.

A DVI source device will always be restricted in the following ways:

- Only RGB pixel encoding is used.
- There is no Guard Band on the Video Data Period.
- There are no Data Islands transmitted.

An HDMI Sink, upon power-up, reset or detection of a new source device, shall assume that the source device is limited to the above behavior. Upon the detection of an indication that the source is HDMI-capable, the HDMI Sink shall follow all of the HDMI Sink-related requirements specified in this document.

All electrical and physical specifications in Section 4 of the HDMI Specification shall be followed by the HDMI Sink even when communicating with a DVI source device.

C.4 Type A to DVI Adapter Cable [Informative]

Table C-1 Wire Categories

Category	Description
A	TMDS Signal Wire
B	TMDS Shield
C	Control
D	Control Ground
N.C.	No connect (no wire)
5V	5 Volts Power Wire

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Table C-2 Type A-to-DVI-D Cable Wire Assignment [Informative]

Type A pin	Signal Name	Wire	DVI-D pin
1	TMDS Data2+	A	2
2	TMDS Data2 Shield	B	3
3	TMDS Data2–	A	1
4	TMDS Data1+	A	10
5	TMDS Data1 Shield	B	11
6	TMDS Data1–	A	9
7	TMDS Data0+	A	18
8	TMDS Data0 Shield	B	19
9	TMDS Data0–	A	17
10	TMDS Clock+	A	23
11	TMDS Clock Shield	B	22
12	TMDS Clock–	A	24
15	SCL	C	6
16	DDC Data	C	7
17	DDC/CEC Ground	D	15
18	+5V Power	5V	14
19	Hot Plug Detect	C	16
13	CEC	N.C.	
14	Reserved (in cable but N.C. on device)	N.C.	
	TMDS Data 4-	N.C.	4
	TMDS Data 4+	N.C.	5
	TMDS Data 3-	N.C.	12
	TMDS Data 3+	N.C.	13
	TMDS Data 5-	N.C.	20
	TMDS Data 5+	N.C.	21
	No Connect	N.C.	8

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C.5 Type B to DVI Adapter Cable [Informative]

Table C-3 Type B to DVI-D Cable Wire Assignment [Informative]

Type B pin	Pin Assignment	Wire	DVI-D pin
1	TMDS Data2+	A	2
2	TMDS Data2 Shield	B	3
3	TMDS Data2-	A	1
4	TMDS Data1+	A	10
5	TMDS Data1 Shield	B	11
6	TMDS Data1-	A	9
7	TMDS Data0+	A	18
8	TMDS Data0 Shield	B	19
9	TMDS Data0-	A	17
10	TMDS Clock+	A	23
11	TMDS Clock Shield	B	22
12	TMDS Clock-	A	24
13	TMDS Data5+	A	21
14	TMDS Data5 Shield	B	19
15	TMDS Data5-	A	20
16	TMDS Data4+	A	5
17	TMDS Data4 Shield	B	3
18	TMDS Data4-	A	4
19	TMDS Data3+	A	13
20	TMDS Data3 Shield	B	11
21	TMDS Data3-	A	12
25	SCL	C	6
26	DDC Data	C	7
27	DDC/CEC Ground	D	15
28	+5V Power	5V	14
29	Hot Plug Detect	C	16
22	CEC	N.C.	
23	Reserved	N.C.	
24	Reserved	N.C.	
	No Connect	N.C.	8

END OF DOCUMENT

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Supplement 1
Consumer Electronics Control (CEC)

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CEC 1 Introduction

CEC is a protocol that provides high-level control functions between all of the various audiovisual products in a user's environment. This appendix describes the CEC protocol in the following order:

- An overview of the recommended features available in CEC.
- A Low Level Protocol Definition - Includes the electrical specification, signaling and bit timings and the frame description.
- A High Level Protocol Definition - Includes a detailed feature breakdown and individual message descriptions.

CEC 1.1 Normative references

[1n] ISO 639-1 Code for the representation of names of languages - Part 1: Alpha 2 code
http://xml.coverpages.org/languageIdentifiers.html - iso639

[2n] ITU-T E.164 – definition of country codes

CEC 1.2 Informative References

[1i] CENELEC, EN 50049-1:1997/A1:1998, Domestic and similar electronic equipment interconnection requirements: Peritelevision connector

[2i] CENELEC, EN 50157, Domestic and similar electronic equipment interconnection requirements: AV.link

EN 50157-1 : Part 1
EN 50157-2-1 : Part 2-1
EN 50157-2-2 : Part 2-2
EN 50157-2-3 : Part 2-3

[3i] IEEE std. 1394-1995 HIGH PERFORMANCE SERIAL BUS section 8.3.2.5.1 – example use of Company_id.

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CEC 2 Definitions

CEC 2.1 Conformance Levels

Because CEC is optional, the conformance level in this appendix is only effective when the device supports CEC. For example, the word "shall" indicates a mandatory requirement for the CEC supporting devices. However, within the Features section (CEC 13) "shall" only indicates a requirement if the feature is implemented.

CEC 2.2 Glossary of Terms

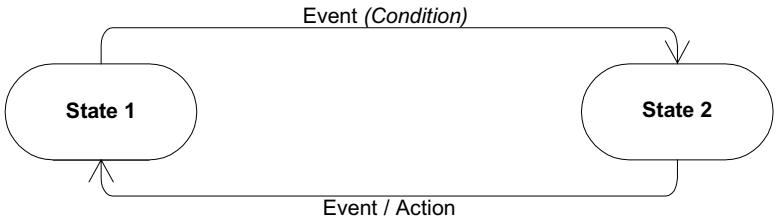
Broadcast Message	This is a message, sent to logical address 15, on which all devices are expected to receive.
Clear	Set to an empty/undefined state.
Deck	The part of a recording device or playback device that provides playback functionality usually from a removable media.
Destination	The target device for a CEC message.
Follower	A device that has just received a CEC message and is required to respond to it.
Initiator	The device that is sending, or has just sent, a CEC message and, if appropriate, is waiting for a follower to respond.
Logical address	A unique address assigned to each device (see section CEC 10.2)
Menu Providing Device	A non-display device that may render a menu on TV.
Playback device	A device that has the ability to play media, e.g. a DVD Player.
Recording device	A device that has the ability to record a source such as an internal preset or an external connection.
Source Device	A device that is currently providing an AV stream via HDMI.
Tuner Device	A device that contains a tuner, e.g. a STB or a Recording Device.
Timer Setting Device	A device that has the ability to set the record timer blocks of a recording device.
TV	A device with HDMI input that has the ability to display the input HDMI signal. Generally it has no HDMI output.

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CEC 2.3 Usages and Conventions

CEC 2.3.1 State Diagrams

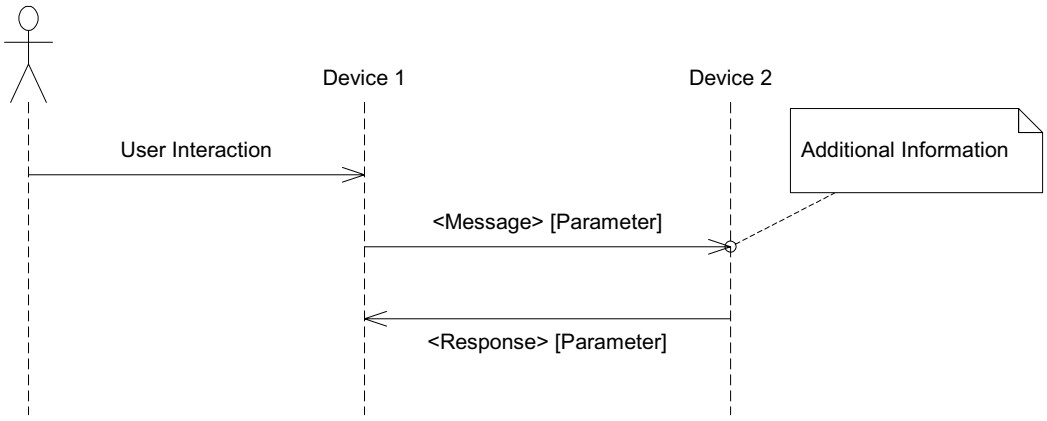
State diagrams describe behavior in terms of device states and events or actions. In these diagrams, the ovals represent device states and the arrows represent events and/or actions that move the device from one state to another state.



CEC Figure 1 Example State Diagram

CEC 2.3.2 Message Flow Diagrams

Message Flow Diagrams show sequences of messages that occur between 2 devices.



CEC Figure 2 Example Message Flow Diagram

CEC 2.3.3 Notation

Within the CEC specification there are a number of notations:

<xxx> xxx is an opcode for a message, which is defined in section CEC 15

[yyy] yyy is a data item, which is defined in section CEC 17.

“zzz” zzz is a constant and is a possible value for a data item in section CEC 17.

N{….} indicates the item within the braces is repeated N times, this is used mainly in section CEC 17.

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CEC 3 Feature Overview

CEC provides a number of recommended features designed to enhance the functionality and interoperability of devices within an HDMI system. This section gives an overview of these features.

- **One Touch Play** - Allows a device to be played and become the active source with a single button press.
- **System Standby** - Enables the user to switch all devices to standby with one button press.
- **Preset Transfer** - Enables any tuner device to download the same set of presets as the TV. It is used to auto configure a devices presets so no manual setup is required.
- **One Touch Record** - Offers a What You See Is What You Record (WYSIWYR) facility, meaning that whatever is shown on the TV screen is recorded on a selected recording device.
- **Timer Programming** - Allows a device (e.g. the TV) to set a timer recording on a recording device.
- **System Information** - Queries the system to determine device addresses and configurations (e.g. language and country)
- **Deck Control** - Enables a device to control (e.g. play, fast forward etc.) and interrogate a playback device (a deck).
- **Tuner Control** - Allows a device to control the tuner of another device.
- **Vendor Specific Commands** - Allows a set of vendor-defined commands to be used between devices of that vendor.
- **OSD Display** - Enables a device to use the on-screen display of the TV to display text strings.
- **Device Menu Control** - Enables a device to control the menu of another device by passing through user interface commands.
- **Routing Control** - Allows the control of CEC Switches for streaming of a new source device.
- **Remote Control Pass Through** - Enables remote control commands to be passed through to other devices within the system.
- **Device OSD Name Transfer** - Enables devices to upload their preferred OSD name to the TV. The TV can then use this name in any menus associated with that device.

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CEC 4 Electrical Specification

The electrical specifications define CEC such that a maximum of 10 devices may operate together in the worst-case scenario. In practice, many more may be expected to operate together as the worst case is highly improbable.

CEC Table 1 describes the electrical specifications for CEC.

CEC Table 1 CEC Electrical Specifications

Description	**Measurement Method**	**Value**
Maximum voltage slew rate	Open Circuit	$\frac{dv}{dt} \le \lvert 0.1 \rvert$ V/μs
	2700 ohms ± 5% load to 3.3V	
Maximum Output Voltage Logic ‘0’	2700 ohms ± 5% load to 3.3V	600 mV
Minimum Output Voltage Logic ‘0’	2700 ohms ± 5% load to 3.3V	0 V
Maximum Output Voltage Logic ‘1’	27k ohms ± 5% load to 2.7V	3.6 V
Minimum Output Voltage Logic ‘1’	27k ohms ± 5% load to 2.7V	2.5V
Input Voltage Threshold Logic ‘0’	CEC voltage set to 800mV	Logic ‘0’
Input Voltage Threshold Logic ‘1’	CEC voltage set to 2.0V	Logic ‘1’
Max rise time	From 10% to 90%	250 μs
Max fall time	From 90% to 10%	50 μs
Internal device pull-up to +3.3V ±10%		27k ohms ±10%

All values assume a nominal +3.3V signaling level.

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CEC 5 Signaling and Bit Timings

All transactions on the CEC line consist of an initiator and one or more followers. The initiator is responsible for sending the message structure and the data. The follower is the recipient of any data and is responsible for setting any acknowledgement bits.

The following sections describe the timing that is used by the initiator.

CEC 5.1 CEC line usage

A message is conveyed over the control signal line in a single frame; a frame is a self-contained unit consisting of a start bit followed by a number of data bits.

An initiator first has to test that the control signal line is free for use (described below). After that it generates a high to low transition on the CEC line, followed by a series of pulses comprising data bits whose starting point is defined by a high to low transition.

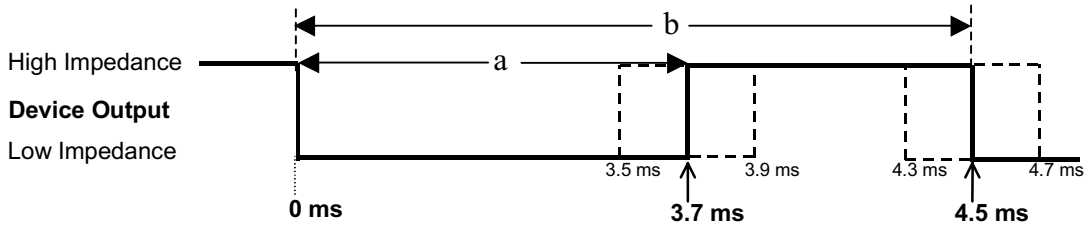
The initiator provides bit timing and bit leading edges. Only one initiator is allowed at any one time. A control signal line arbitration mechanism avoids conflict when more than one initiator begins transmitting at the same time.

CEC 5.2 Bit timing

CEC 5.2.1 Start bit timing

The pulse format of the start bit is shown in CEC Figure 3. It is unique and identifies the start of a frame.

The start bit has to be validated by its low duration (a) and its total duration (b).



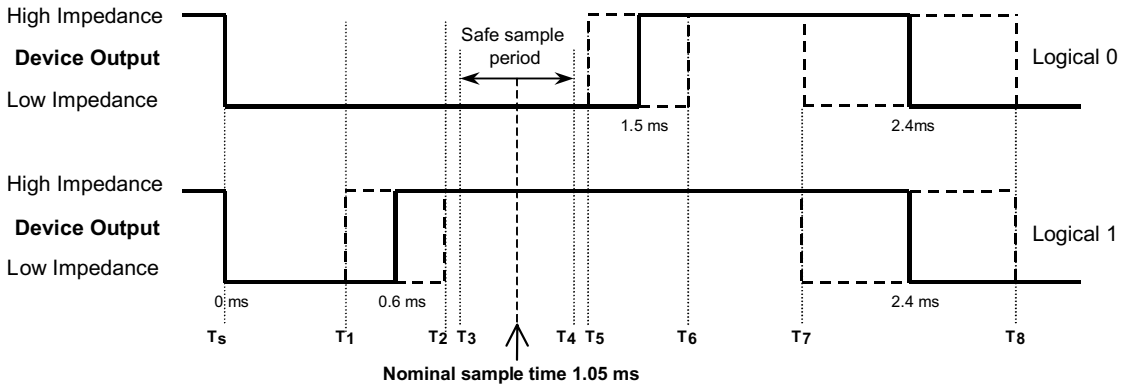
CEC Figure 3 Start bit pulse format showing minimum and maximum tolerances

CEC 5.2.2 Data bit timing

All remaining data bits in the frame, after the start bit, have consistent timing. There are, however, two types of bits; an initiator asserted bit and a follower asserted bit. All bits apart from the acknowledge bit are asserted by the initiator. CEC Figure 4 shows both logical 1 and logical 0 timing diagrams for an initiator asserted bit.

The high to low transition at the end of a data bit is the start of the next data bit and only occurs if there is a following data bit; after transmission of the final bit the CEC line remains high.

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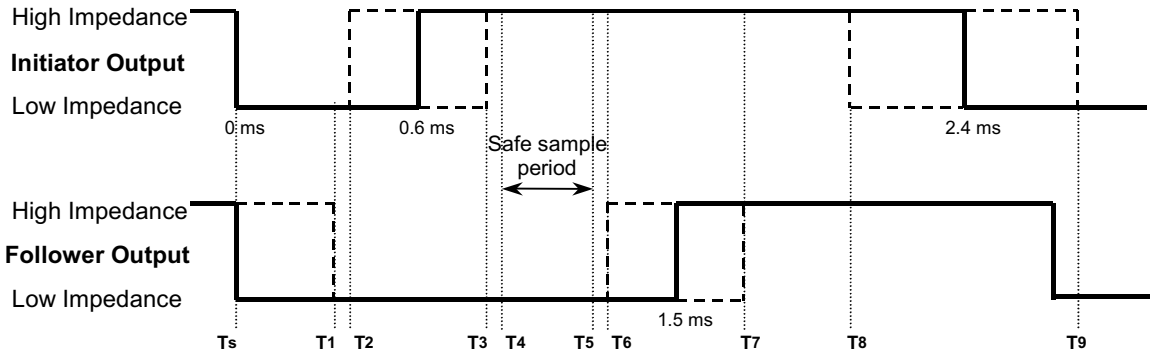


T_S	**0 ms**	The bit start event.
T_1	**0.4 ms**	The earliest time for a low - high transition when indicating a logical 1.
T_2	**0.8 ms**	The latest time for a low - high transition when indicating a logical 1.
T_3	**0.85 ms**	The earliest time it is safe to sample the signal line to determine its state.
T_4	**1.25 ms**	The latest time it is safe to sample the signal line to determine its state.
T_5	**1.3 ms**	The earliest time a device is permitted return to a high impedance state (logical 0).
T_6	**1.7 ms**	The latest time a device is permitted return to a high impedance state (logical 0).
T_7	**2.05 ms**	The earliest time for the start of a following bit.
T_8	**2.75 ms**	The latest time for the start of a following bit.

CEC Figure 4 Timing diagrams for both bit states

CEC Figure 5 shows an example bit with both initiator and follower where the follower may assert the bit to a logical 0 to acknowledge a data block. The initiator outputs a logical 1, thus allowing the follower to change the CEC state by pulling the control line low for the duration of the safe sample period.

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T_S	**0 ms**	The bit start event.
T_1	**0.35 ms**	The latest response time for a follower to go to the low impedance state.
T_2	**0.4 ms**	The earliest the initiator can return to high impedance when transmitting a logical 1.
T_3	**0.8 ms**	The latest the initiator can return to high impedance when transmitting a logical 1.
T_4	**0.85 ms**	The earliest time at which the bit state on the CEC line is valid for reading.
T_5	**1.25 ms**	The latest time at which the bit state on the CEC line is valid for reading.
T_6	**1.3 ms**	The earliest time the follower is permitted return to a high impedance state.
T_7	**1.7 ms**	The latest time the follower is permitted return to a high impedance state.
T_8	**2.05 ms**	The earliest time for the start of a following bit.
T_9	**2.75 ms**	The latest time for the start of a following bit.

CEC Figure 5 Timing Diagram for Follower Asserted Bit (Logical 0)

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CEC 6 Frame Description

The following table describes the complete CEC frame; the details of each block of the frame are given in the subsequent sections.

CEC Table 2 Frame Description

Name	Description	Value
Start	Special start 'bit'	N/A
Header Block	Source and destination addresses (see CEC Figure 7)	See CEC Table 4
Data Block 1 (op code block)	Op code (Optional)	See CEC Table 5
Data Block 2…. (operand blocks)	Operand(s) specific to op code (Optional, depending on op code)	See CEC Table 5 and CEC Table 8

CEC 6.1 Header/Data Block description

Both Data Block and Header Block have the same basic structure, as shown in CEC Figure 6.

<table>
<tr><td colspan="10">Header/Data Block</td></tr>
<tr><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>-</td><td>-</td></tr>
<tr><td colspan="8">Information bits</td><td>EOM</td><td>ACK</td></tr>
</table>

CEC Figure 6 Block Structure

The information bits are data, op codes or addresses, dependent on context. The control bits, EOM and ACK, are always present and always have the same usage.

CEC 6.1.1 EOM (End of Message)

The EOM bit is used to indicate if this is the final block in the message.

A '0' bit specifies that one or more data blocks follow.

A '1' bit specifies that the message is complete.

In the event that a message contains additional data blocks after an EOM is indicated, the follower should ignore the additional blocks.

CEC 6.1.2 ACK (Acknowledge)

The ACK bit is used by follower(s) to acknowledge the data or header block. It is always set to 1 by the initiator. It operates in one of two modes:

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For messages addressed to a single device:

- A follower that reads its own address in the destination address field shall acknowledge with a ‘0’ ACK bit.
- All other devices shall generate a ‘1’ ACK bit (i.e. do nothing).
- A ‘0’ read by the initiator therefore indicates a successful transmission of the data or header block.

For broadcast messages the sense of the ACK bit is inverted to allow for a single device to reject a message:

- All followers shall acknowledge with a ‘1’ ACK bit.
- A ‘1’ read by the initiator therefore indicates that no device has rejected the data or header block – the message transmission can therefore continue if required.
- A ‘0’ read by the initiator therefore indicates that one or more devices have rejected the message.

CEC 6.1.3 Header Block Details

The header block consists of the source logical address field, the destination logical address field, the end of message bit (EOM) and the acknowledge bit (ACK) as shown in CEC Figure 7. The addresses for the devices are specified in CEC Table 4.

Header Block									
3	2	1	0	3	2	1	0	-	-
Initiator				Destination				EOM	ACK

CEC Figure 7 Header Block

The initiator logical address field is used to identify the initiator of the current frame. The logical address of the initiator is written in this field (see CEC 10.2). The field consists of bits one to four of the header block, most significant bit first.

The destination logical address field is used to identify the destination of the current frame. The logical address of the destination is written in this field (see CEC 10.2). A special address (0b1111) is used for broadcast messages. The field consists of bits five to eight of the header block, most significant bit first.

A message with the EOM bit set in the Header Block can be used to ‘ping’ other devices, to ascertain if they are active.

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CEC 7 Reliable Communication Mechanisms

There are three mechanisms to provide a reliable communications medium for the transfer of frames:

- Frame re-transmissions increase the chance of a successful message transfer.
- Flow control ensures that communication only progresses as fast as the slowest follower.
- Frame validation.

Given these mechanisms and the active ACK method, a message transmitted and acknowledged should be assumed correctly received. A message that does not result in a <Feature Abort> can be assumed to have been acted upon. It is suggested that the receiving device can assume this after 1 second. Generally however, the <Feature Abort> will be received within around 100ms.

CEC 7.1 Frame Re-transmissions

A frame is considered lost and therefore may be re-transmitted under the following conditions:

- If a data block is not acknowledged in a directly addressed message.
- If a data block is negatively acknowledged in a broadcast message.
- If the initiator detects low impedance on the CEC line when it is transmitting high impedance and is not expecting a follower asserted bit.

Re-transmission can be attempted up to 5 times for a single message and shall be attempted at least once. The re-try shall be after a signal free time as described in CEC Table 3.

CEC 7.2 Flow Control

To provide flow control, a receiving device may negatively acknowledge any data or header block it is at present unable to process. A negative acknowledge will cause re-transmission by the initiator.

CEC 7.3 Frame Validation

A follower will ignore a frame if the number of operands is less than the number specified for that op code.

CEC 7.4 CEC Line Error Handling

It is the responsibility of all devices acting as followers to detect the existence of spurious pulses on the control signal line and notify all other devices (primarily the initiator) that a potential error has occurred.

An error is defined as a period between falling edges that is less than a minimum bit period (i.e. too short to be a valid bit).

Errors are notified by the follower generating a low bit period on the control signal line of 1.5 times the nominal data bit period. After such an error notification the original initiator should stop sending its current frame and re-try later.

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CEC 8 Protocol Extensions

In order to allow for extensions to the protocol in future releases of the specification, the current opcodes and parameters can be extended by adding further parameters onto them. If an older CEC node receives a message with more operands than expected, it should ACK the additional operands and simply ignore them, thus allowing extensions to already existing commands.

For entirely new commands, new opcodes can be allocated.

For entirely new device types, new addresses may be allocated.

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CEC 9 CEC arbitration

Arbitration for the CEC line ensures collisions are spotted and a reliable message layer can be achieved.

All devices that wish to transmit a frame onto the CEC line have to ensure that it has been inactive for the signal free time, see CEC Table 3.

A device that has lost arbitration shall stop transmitting and become a follower. The device shall then wait for the CEC line to be inactive for the signal free time period as specified in CEC Table 3, before attempting to send another message.

CEC line arbitration commences with the leading edge of the start bit and continues until the end of the initiator address bits within the header block. During this period the initiator shall monitor the CEC line and if whilst in high impedance state it detects low impedance then it shall assume that it has lost the arbitration to a second initiator.

It should be noted that this process gives priority to the logical address with the most leading zeros and, ultimately, the TV.

CEC 9.1 Signal Free Time

Before attempting to transmit or re-transmit a frame, a device shall ensure that the CEC line has been inactive for a number of bit periods. This signal free time is defined as the time since the start of the final bit of the previous frame.

The length of the required signal free time depends on the current status of the control signal line and the initiating device. The different signal free times required are summarized in the following table:

CEC Table 3 Signal Free Time

Precondition	**Signal Free Time**
Present initiator wants to send another frame immediately after its previous frame	7 bit periods
New initiator wants to send a frame	5 bit periods
Previous attempt to send frame unsuccessful	3 bit periods

CEC 9.2 Message Time Constraints

There are certain time constraints for messages that should be obeyed at application level. These are a desired maximum response time of 200ms and a required maximum response time of 1 second.

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CEC 10 Device Connectivity and Addressing

CEC is a protocol based on a bus system and therefore cannot alone ascertain the physical connectivity of the network. The mechanism defined in section 8.7 uses DDC to allocate physical addresses to devices in the network.

All CEC devices therefore have both a physical and logical address, whereas non-CEC devices only have a physical address.

CEC 10.1 Physical Address Discovery

The algorithm defined in 8.7.3 is used to allocate the physical address of each device.

Whenever a new physical address is discovered, a CEC device shall:

- allocate the logical address (see CEC 10.2.1)
- report the association between its logical and physical addresses by broadcasting <Report Physical Address>.

This process allows any node to create a map of physical connections to logical addresses.

CEC 10.2 Logical Addressing

Each device appearing on the control signal line has a unique logical address. This address defines a device type as well as being a unique identifier. These are specified in CEC Table 4.

If a physical device contains the functions of more than one logical device then it should take the logical addresses for each of those logical devices. It is allowed for a device to declare the functionality of another device by using a different logical address. For example a recordable DVD device may take the address 4 or 8 to expose only the functionality of a standard DVD device.

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CEC Table 4 Logical Addresses

Address	Device
0	TV
1	Recording Device 1
2	Recording Device 2
3	STB1
4	DVD1
5	Audio System
6	STB2
7	STB3
8	DVD2
9	Recording Device 3
10	Reserved
11	Reserved
12	Reserved
13	Reserved
14	Free Use
15	Unregistered (as initiator address) Broadcast (as destination address)

CEC 10.2.1 Logical Address Allocation

Note that a logical address should only be allocated when a device has a valid physical address.

Only the device at physical address 0.0.0.0 may take logical address TV (0). A TV at any other physical address must take either the ‘Free Use’ (14) or ‘Unregistered’ (15) logical addresses.

The ‘Free Use’ (14) address may be used for any device type.

Reserved addresses shall not be used at present and is reserved for future extensions to this specification.

Where more than one possible logical address is available for the given device type (e.g. STB1, STB2, etc.), an address allocation procedure shall be carried out by a newly connected device. The device takes the first allocated address and sends a polling message to the same address (e.g. STB1 STB1). If the polling message is not acknowledged, then the device stops the procedure and retains that address.

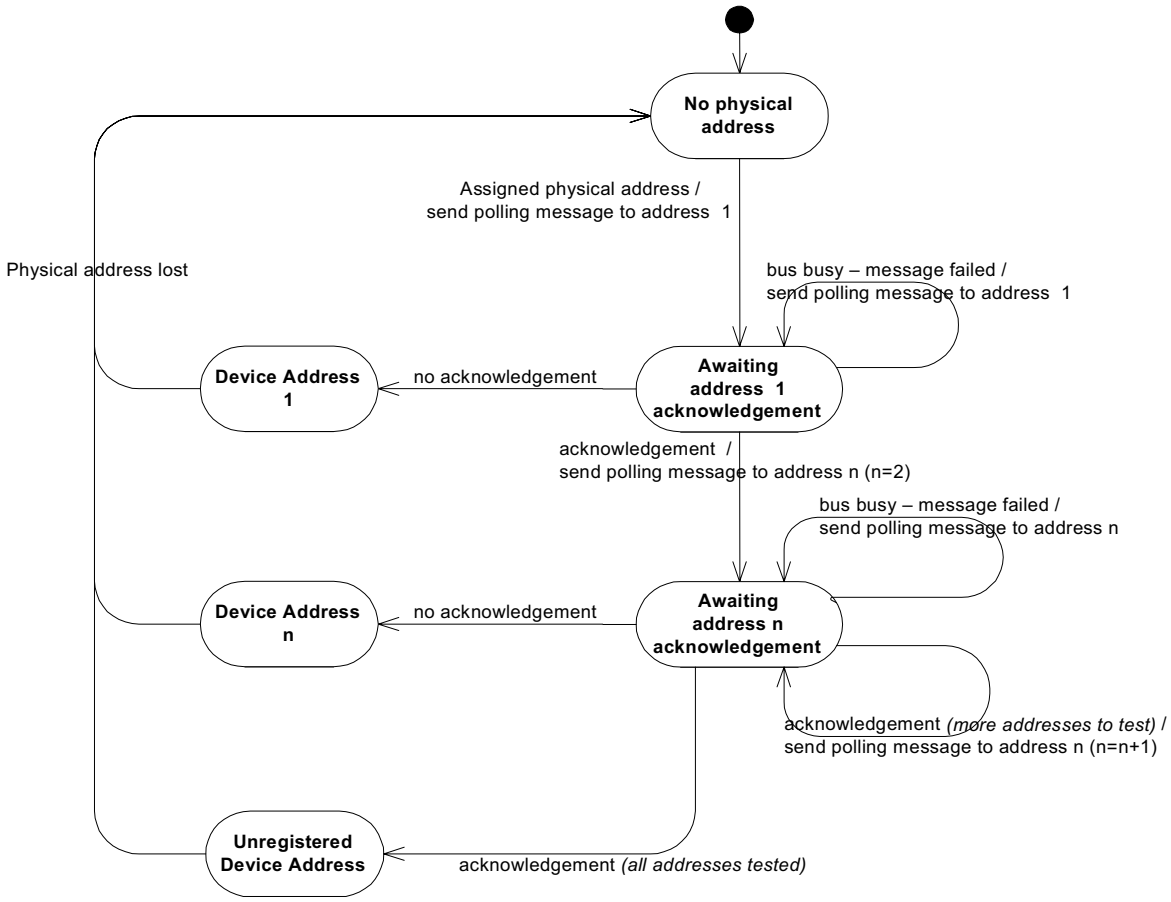
If the first address is acknowledged, then the device takes the next address and repeats the process (e.g. STB2 STB2). Again, if the message is not acknowledged, the device keeps that address.

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This procedure continues until all possible type specific addresses have been checked; if no free addresses are available the device should take the unregistered address (15).

A device may lose its logical address when it is disconnected or switched off. However, it may remember its logical address, so that the next time it is reconnected, it can begin the polling process at its previous logical address and try each other allowable logical address in sequence before taking the unregistered address. For example if an STB that was previously allocated address STB2 is reconnected, it would poll STB2, STB3 and STB1 before taking the unregistered address.

If a device loses its physical address at any time (e.g. it is unplugged) then its logical address shall be set to unregistered (15).



CEC Figure 8 Logical Address Allocation

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CEC 11 Switch Requirements

One of the major uses of the physical address identification is to allow a switch to be controlled in order to enable a specific device to stream to the TV. This places requirements on both CEC and non-CEC compliant switches.

All switches will consist of a single switched TMDS connection, and a fully wired CEC connection to each source device. There are significant differences between a CEC Switch and a non-CEC Switch, which are identified below.

CEC 11.1 CEC Switch

A CEC Switch allocates a unique child_address for every connection below the switch. This means that any device connected to the switch will always have a valid physical address (assuming the switch itself has a valid physical address). Therefore, any device below the switch may take a logical address and can react to CEC messages in a normal way. The switch is effectively transparent and will enable all standard CEC communications in its connected source devices.

For CEC compliant switches, there is a requirement to react on <Active Source> and <Set Stream Path> messages. Both of these messages require the switch to change the connected source device according to the physical AV stream path indicated by the CEC message. These mechanisms allow a source device to configure the switches between itself and the TV to ensure that its output is displayed, or for the TV to specifically receive the output from a given device.

A CEC compliant device that is only a switch does not need to take a logical address; it uses the unregistered address for any communications.

It is possible that a user may change a CEC Switch manually. In this instance a CEC Switch shall send a <Routing Change> message to inform other devices about the change.

CEC 11.2 Non-CEC Switch

There are two types of non-CEC switches, those which have only one EDID for all source devices (or simply reflect the sink EDID), and those which have a separate EDID for all source devices. The rules for the operation of these two types of switch are different:

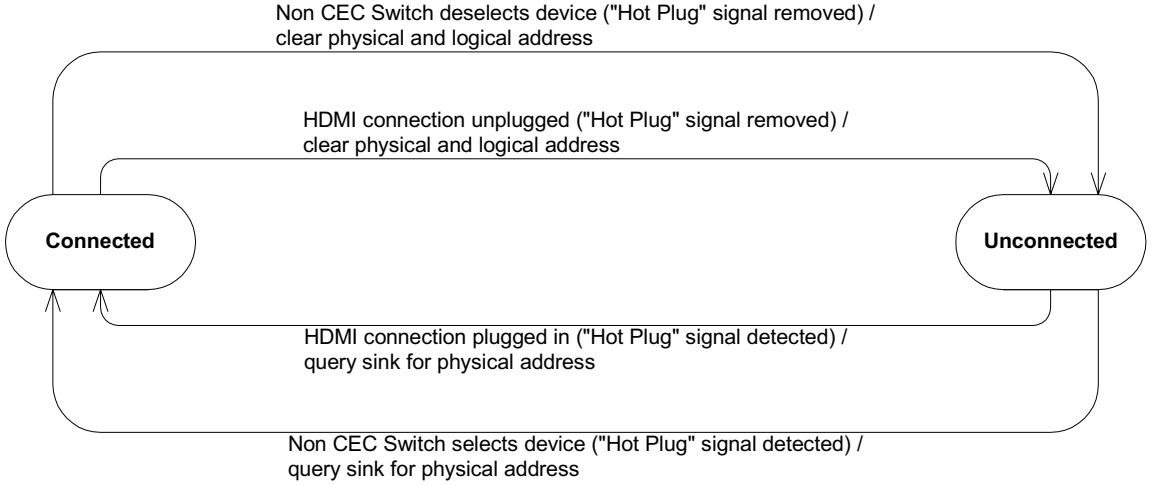
CEC 11.2.1 Switches with 1 EDID

A non-CEC-compliant switch may have a single child_address, which is always occupied by the currently switched device. Any other connected devices will have hot plug and so will have no physical address (and therefore can only use the unregistered logical address). These devices will, however, still see CEC messages as they will be connected to the CEC line and they may react to broadcast messages in the normal way (e.g. standby).

When a switch de-selects a device, that device will detect the removal of the ‘hot plug’ signal to indicate that its physical AV connection has been removed. It should immediately clear its physical and logical addresses. Each source device below the switch will detect the removal of the ‘hot plug’ signal to indicate they are no longer on the active AV Path and clear their addresses accordingly.

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When a switch selects a device, that device will detect the ‘hot plug’ signal. It can then obtain a valid physical address from its sink and subsequently a logical address. The device should activate the hot plug signal to its source (child) devices (if any) to indicate that they should now request a physical address.



CEC Figure 9 A device’s connection state when it is beneath a 1 EDID non-CEC Switch

CEC 11.2.2 Switches with Multiple EDIDs

These should operate as CEC switches except that they do not send messages on, or monitor, the CEC line.

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CEC 12 High Level Protocol

As described in the previous sections, messages consist of an op code and a number of parameters. This is the high level protocol.

This protocol can be described best by detailing the messages and the data types used for the parameters. These are detailed in CEC Table 5.

Although these tables explain the majority of the high level protocol, there are some special situations that require further explanation. These are given in the following sections.

CEC 12.1 Source Declaration

Before a device becomes a source, it should issue an <Active Source> message to declare its intention. Thus any presently active source can and should act appropriately.

CEC 12.2 Protocol general rules

A message that is defined as being valid only when directly addressed, shall be ignored if received as a broadcast message.

A message that is defined as being valid only when broadcast, shall be ignored if received as a directly addressed message.

All numbers greater than one byte are transmitted as bytes in big endian format.

All bit sequences are sent most significant bit first.

A follower shall respond to a message coming from any valid logical address between 0-14 unless otherwise stated.

A follower shall ignore a message coming from address 15 (unregistered), unless:

- that message invokes a broadcast response (e.g. <Start Preset Transfer>)
- the message has been sent by a CEC switch (a <Routing Change> or <Routing Information> message).
- the message is <standby>

CEC 12.3 Feature Abort

All devices shall support the message <Feature Abort>. It is used to allow devices to indicate if they do not support an op code that has been sent to them, if it is unable to deal with the message at present, of if there was something wrong with the transmitted frame at the high-level protocol layer.

Feature abort has two parameters, the opcode and a reason for its rejection of the frame.

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The reaction to a faulty message by the follower depends on if the message was directed or broadcast:

For a broadcast message:

- A follower that receives a broadcast message which it does not support, ignores the received message, and does not send a <Feature Abort>.

For a directly addressed message:

- <Feature abort> is used as a response to any failure.

If an initiator wishes to attempt retransmission after receiving a <Feature Abort> it is suggested that it waits for 200ms. This will allow time for the follower to recover from the state that caused the initial <Feature Abort> message.

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CEC 13 CEC Features Description

This section describes the message transfer and additional details for a number of common features enabled by CEC. Note that where a feature is supported, all messages within that feature should be implemented.

CEC 13.1 One Touch Play

CEC 13.1.1 Messages

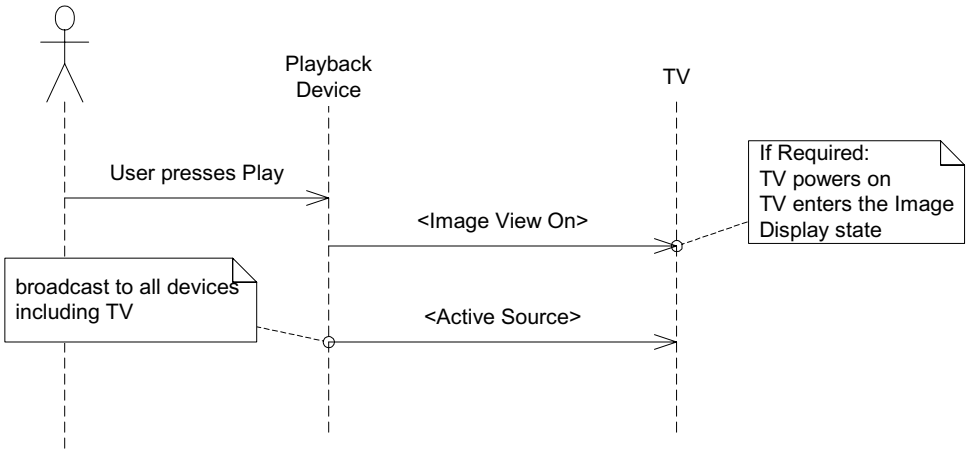
The following messages are used for the One Touch Play feature:

<Active Source>, <Image View On>, <Text View On>

CEC 13.1.2 Feature Description

The One Touch Play feature allows a device to be played and become the active source with a single button press.

A device shall send the message <Image View On> to the TV to indicate that its output should be displayed on the screen. If the TV is in a Text Display state (e.g. Teletext) it should switch to the Image Display state. If a menu is being displayed on the TV it shall remain on screen.



CEC Figure 10 A typical scenario illustrating the One Touch Play feature

A device may also send the message <Text View On>. This message has the same functionality as <Image View On> with the addition that any menus that the TV is displaying shall be removed.

Whenever a device becomes the new source device it should broadcast an <Active Source> message. The current active source device should then take appropriate action, for example, it may pause if it is playing media.

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CEC 13.2 System Standby

CEC 13.2.1 Messages

The following message is used for the System Standby feature:

<Standby>

CEC 13.2.2 Feature Description

The message <Standby> can be used to switch one or more CEC devices to standby.

The whole system may be set to standby by broadcasting the <Standby> message.

A device can switch another single device into standby by sending the message <Standby> as a directly addressed message to it. It should only switch a single device into standby if it previously activated that device (brought it out of standby).

CEC 13.2.3 Exceptions

Devices can ignore <Standby> messages if they are in a state where going into standby is not sensible. For example if the device is actively involved in a recording as either the source or recording device it should ignore any requests to go into standby. It is up to the device implementer how ‘sensible’ is defined.

CEC 13.3 Preset Download

CEC 13.3.1 Messages

The following messages are used for the Preset Download feature:

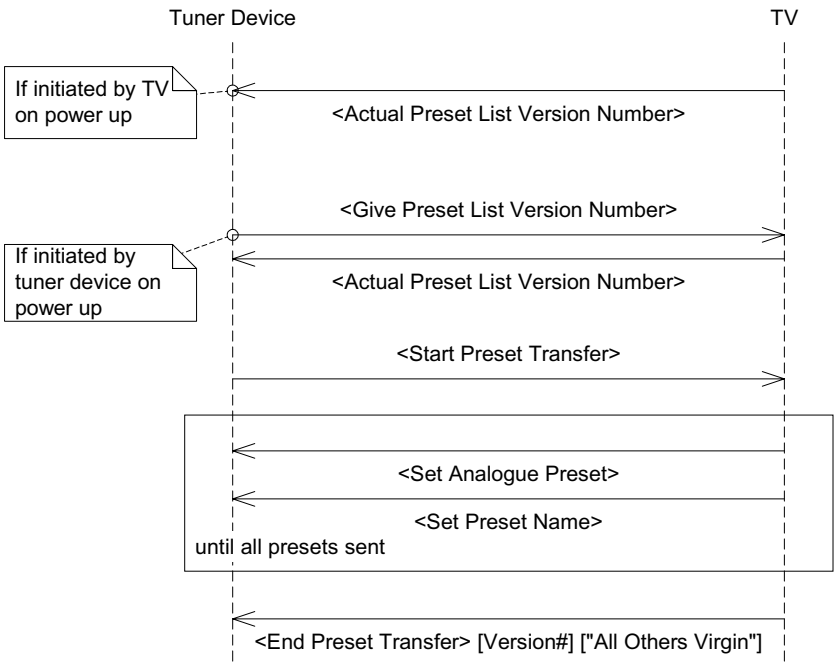
<Actual Preset List Version Number>, <End Preset Transfer>, <Give Preset List Version Number>, <Set Analogue Preset>, <Set Preset Name>, <Start Preset Transfer>, <Stop Preset Transfer>

CEC 13.3.2 Feature Description

This feature is used to ensure that any tuner device will have the same set of presets as the TV. It is used to auto configure device presets, thereby removing any manual set up process. This feature will provide a consistent channel line up to the user regardless of which device is in use.

All devices that store the presets do so with a version number of the preset list. The version number is a one-byte variable and is incremented modulo 256 by the TV whenever a change to the preset list occurs. If a tuner device (other than the TV) changes its presets locally it shall not change its version number, because the version number only refers to the preset list of the TV. It is the responsibility of the device to remember that its preset list differs from that of the TV.

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CEC Figure 11 The message exchange for the Preset Download feature

The feature can be initiated either by the TV or a tuner device on power up/connection. If the TV is the initiator it broadcasts the version number of the current list. If the device initiates the feature it requests the current version number from the TV.

If the device needs to download a new version of the list, it requests this from the TV. The preset information (e.g. channel and frequency) and optionally the preset name are sent to the device. This is repeated for all stored presets. The TV then informs the device when all set presets have been sent.

Note individual <Set Analogue Preset> and <Set Preset Name> messages can be used outside the above sequence to change small numbers of individual presets when a user has updated them in the TV. An <End Preset Transfer> message will always be sent once all presets have been transferred so that the device may update its version number.

In order to clear all the presets in another device (if for example all presets in the TV are cleared), the TV can send an <End Preset Transfer> [Version#] [“All others virgin”] message without first transmitting any <Set Analogue Preset> messages.

The preset download feature should be possible when the TV is in standby. It is up to the local specification if the TV should power on in order to download its presets. If an attempt is made to put a device into standby during a preset download it should either delay the standby until the preset download has completed, or continue with the preset download while in standby.

A device should ignore any of the following messages: <Actual Preset List Version Number>, <Set Analogue Preset>, <Set Preset Name> and <End Preset Transfer>, if they do not come from logical address 0 (the TV).

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CEC 13.3.3 Exceptions

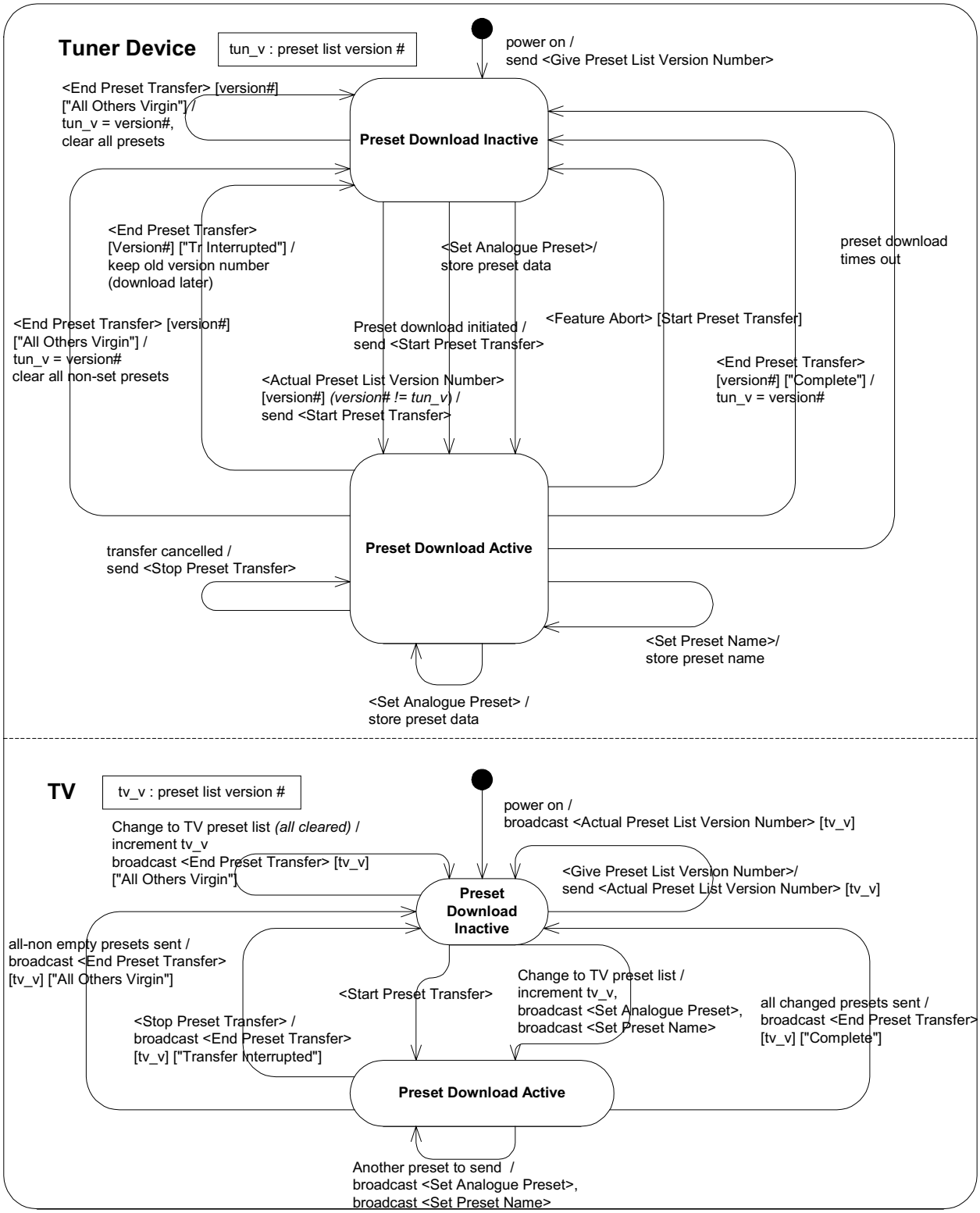
A device that initiates a <Start Preset Transfer> message can request that the transfer be stopped, by sending the message <Stop Preset Transfer>. The TV will then send an <End Preset Transfer> [Version#] [“Transfer interrupted”] message to indicate that transferring has been terminated. Any device that receives the [“Transfer interrupted”] parameter should remember that its preset table may be incomplete or out of date and should attempt a further download at a later time. The TV will ignore any <Stop Preset Transfer> messages from a device that did not initiate the transfer.

In the case of a partly transferred list, e.g. after a reshuffle of two presets, the device should check if the version number received in the <End Preset Transfer> message differs to its own value by more than 1. If it does then the device has missed an update and should initiate a full preset download. A partially transferred list will always have the [Preset List Info] parameter set to the value “Complete” (see [Preset List Info] in CEC Table 8).

A tuner device must be able to recover in the event that a preset download does not complete (no <End Preset Transfer> message is received). This can be detected by waiting for a sensible timeout after the last <Set Analogue Preset> or <Set Preset Name> message and if no subsequent message related to preset download is received the device should exit the Preset Download Active state.

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CEC 13.3.4 State Diagrams



CEC Figure 12 State transitions for the Preset Download feature

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CEC 13.4 One Touch Record

CEC 13.4.1 Messages

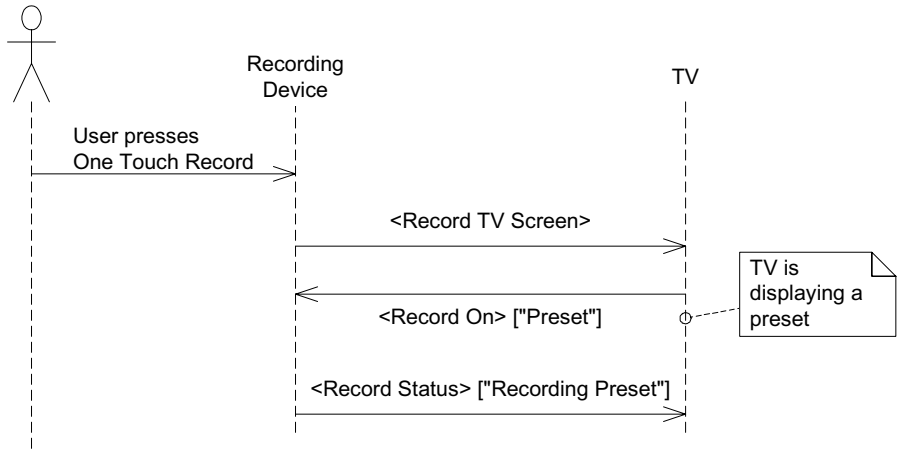
The following messages are used for the One Touch Record feature:

<Record Off>, <Record On>, <Record Status>, <Record TV Screen>

CEC 13.4.2 Feature Description

This feature allows the user to easily start a recording of the source that is being displayed on the TV, just by selecting a recording device and giving the record command. It is not always possible to carry out a One Touch Record as it depends on what source is currently being displayed. It is primarily used for the instant recording of a tuner preset, or the recording of another device (e.g. Camcorder) connected externally to the recording device

Either the TV or the recording device may initiate the One Touch Record Feature, for example by selecting a menu option on the TV or by pressing record on the recording device.



CEC Figure 13 A typical scenario for the One Touch Record feature

In the event of the recording device initiating the feature it will send a <Record TV Screen> message to the TV. On receipt of the <Record TV Screen> message by the TV, or if the user initiates the One Touch Record feature via the TV, the TV shall react as follows:

- It the TV is currently displaying an internal tuner preset, it shall respond with a <Record On> [“Preset”] [Preset Number] [Analogue Preset] message.
- If the Recording Device is the current active source device, then the TV shall respond with a <Record On> [“Own source”] message.
- If the TV is currently displaying some other source, it shall respond with a <Feature Abort> [“Cannot provide source”] message, or do nothing if initiated via the TV.

On receipt of a <Record On> message the recording device shall act as follows:

- If [“Preset”] is indicated and the devices local preset number matches the analogue preset information that was sent, the device shall change to that preset number and start recording. If the preset information does not match the preset number, the device should attempt to tune to the specified frequency and begin recording. If the device cannot support the required

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frequency/broadcast system, then it should respond with a <Record Status> ["No recording – invalid preset"].

- If ["Own source"] is indicated, then it shall attempt to record whatever it is currently displaying, e.g. an external connection such as a camcorder or the preset it is currently tuned to.

The recording device shall respond with the message <Record Status> to indicate if recording has begun, or a reason why recording has failed. If the TV initiated the recording, it may stop it at any time by sending a <Record Off> message. The recording device should then stop recording immediately.

The TV should ignore a <Record TV Screen> message that comes from a non-recording device address, however it may accept the message from a Reserved address (a future device type).

CEC 13.5 Timer Programming

CEC 13.5.1 Messages

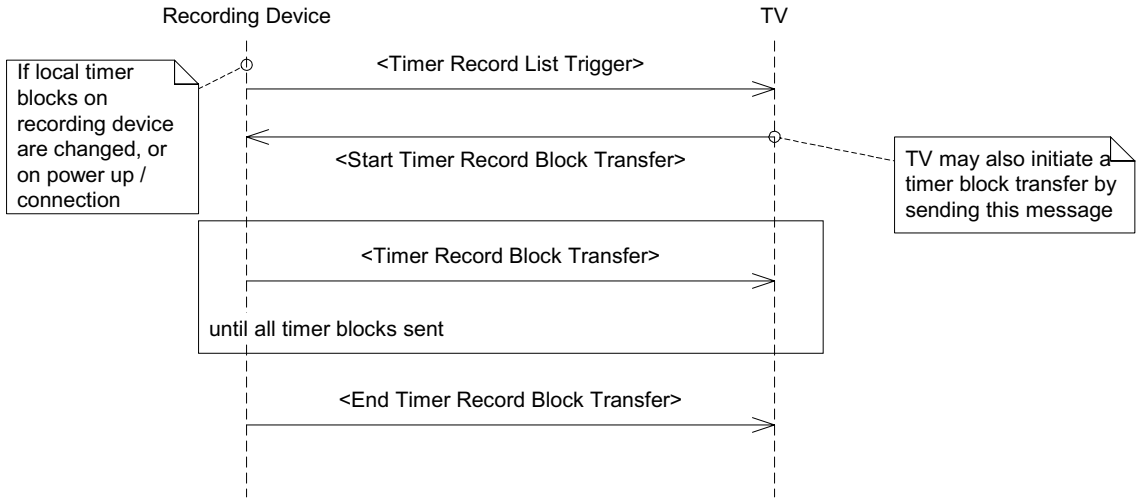
The following messages are used for the Timer Programming feature:

<Clear Timer>, <End Timer Record Block Transfer>, <Give Timer Options>, <Set Timer>, <Set Timer Program Title>, <Start Timer Record Block Transfer>, <Timer Cleared Status>, <Timer Options>, <Timer Record Block Transfer>, <Timer Record List Trigger>, <Timer Status>

CEC 13.5.2 Feature Description

This feature allows a device (e.g. the TV) to set a timer recording on a recording device. It may for example be used to set timer blocks of a recording device via a TV menu or via an EPG.

A device (e.g. the TV) may download the current list of timer blocks from the recording device as shown below.



CEC Figure 14 Message exchange for the Timer Record Block Transfer process

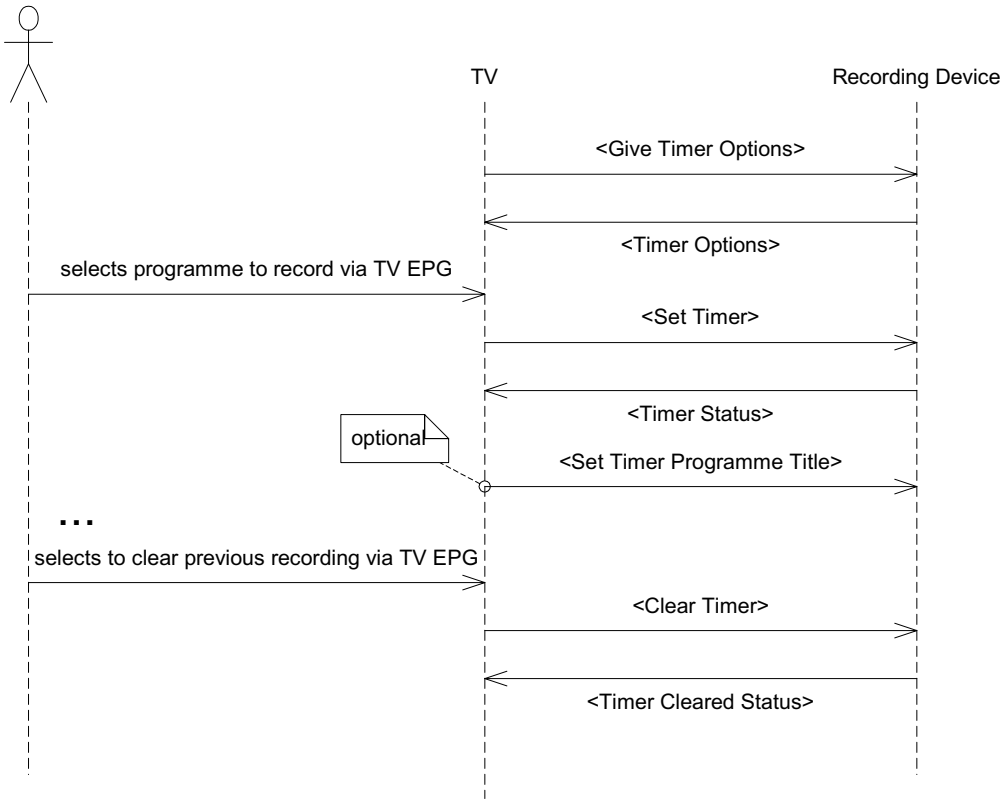
A recording device can inform other devices when its timer record list has changed (e.g. when a new timer record block is added locally) by sending a <Timer Record List Trigger> message.

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Recording devices should also send a <Timer Record List Trigger> message when powered on/connected to the system.

A device may query the recording device for information about its timer options by sending a <Give Timer Options> message. The recording device will respond with a <Timer Options> message, which describes information such as the number of free timer blocks and if high/low quality recording is supported.

A device may set or clear an individual timer block of a recording device. The recording device will respond to indicate if the timer was successfully set/cleared. It is also possible to transfer the program title of a timer block (where for instance a timer is set via an EPG). To achieve this a device may send a <Set Timer Program Title> message directly after sending <Set Timer>. The recording device may then store the program title along with the timer information. If the recording device does not support program titles, then it shall ignore an incoming <Set Timer Program Title> message.



CEC Figure 15 A typical scenario for setting a Timer Record Block

CEC 13.6 System Information

CEC 13.6.1 Messages

The following messages are used for the System Information feature:

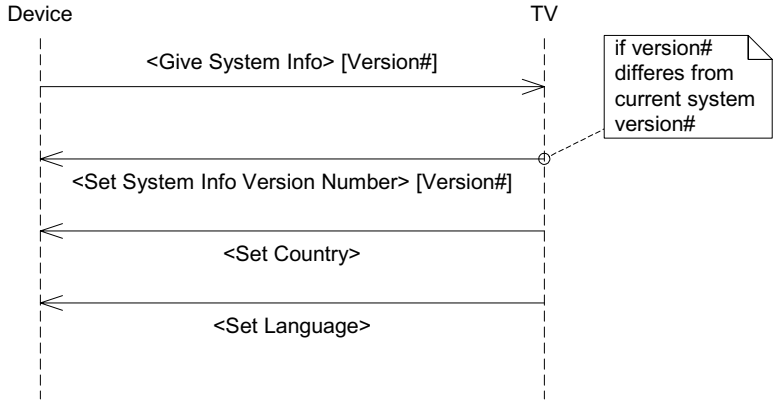
<Give Physical Address>, <Give System Info>, <Polling Message>, <Report Physical Address>, <Set Country>, <Set Language>, <Set System Info Version Number>

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CEC 13.6.2 Feature Description

This feature allows devices to automatically use the same country and language settings as the TV.

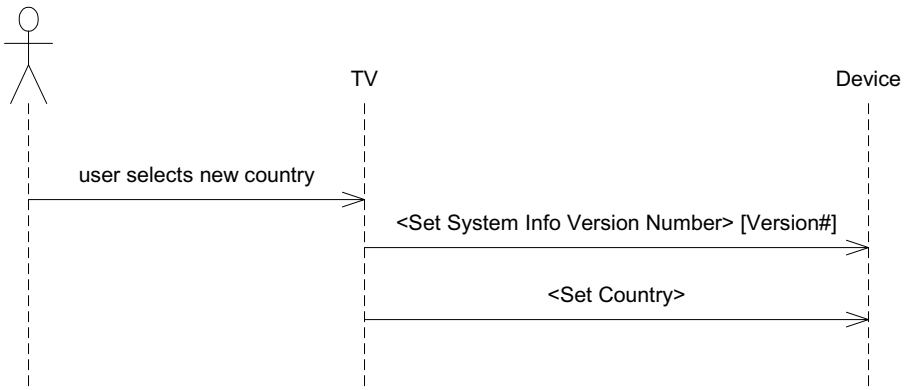
When a source device is powered on, it should send a <Give System Info> message to the TV. The TV will then respond as shown below if the version number is different to the current version number stored by the TV.



CEC Figure 16 Message exchange when downloading the TV's System Info

A device that supports the System Information feature shall support at least one of the <Set Country> and <Set Language> messages but is not required to support both. For example a device could have a configurable language setting, but no country setting.

When a change to a configuration setting occurs, the TV should increment its version number and broadcast a <Set System Info Version Number> message, followed by a message corresponding to the parameter that has changed as shown below.



CEC Figure 17 A typical scenario when a system setting within the TV is modified

A device receiving a <Set System Info Version Number> shall update its internal system info version number. A device may accept and act upon individual <Set Country> and <Set Language> messages, however the TV should always send a <Set System Info Version Number> message before sending either message. A device shall ignore any of the above messages that come from an initiator address other than 0 (the TV).

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CEC 13.6.3 Additional Information

The <Polling Message> is used to detect the presence or absence of a device within the system. It is used for allocating logical addresses as detailed in C.9.2.1.

The <Report Physical Address> message is used by a device to broadcast its physical address to all other devices in the system. By using the logical and physical addresses, any other device is able to derive the physical connectivity of the network. A device may request the physical address of another device by sending a directly addressed <Give Physical Address> message to it.

CEC 13.7 Deck Control

CEC 13.7.1 Messages

The following messages are used for the Deck Control feature:

<Deck Status>, <Give Deck Status>, <Deck Control>, <Play>

CEC 13.7.2 Feature Description

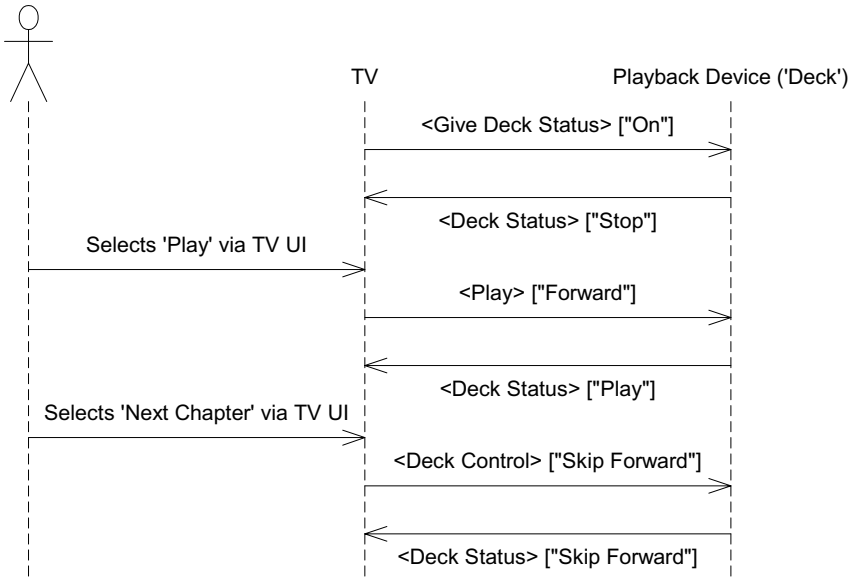
This feature allows a playback device (a deck) to be controlled by another device (e.g. the TV). Messages are also provided to allow a device to find out the status of the Deck; this allows, for example, a TV to keep its users interface synchronized with the status of the Deck.

A device may query the status of a deck with the <Give Deck Status> command. The deck should respond with a <Deck Status> message.

A device may control a Deck with the <Play> and <Deck Control> messages. These messages may be initiated after a user command. The Deck shall act upon the command that it receives within the messages <Play> and <Deck Control>. It is the equivalent of the user selecting the command local to the Deck. If the deck cannot carry out the command (e.g. it has no media when trying to play) it should respond with a <Feature Abort> [“Not in correct mode to respond”] message.

If the deck is in standby and receives a <Deck Control> [“Eject”] or <Play> [“Play Forward”] message, it should power on and act on the message. It is up to the local specification if the device should power on when receiving any other <Deck Control> or <Play> messages.

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CEC Figure 18 A typical scenario for the Deck Control feature

CEC 13.8 Tuner Control

CEC 13.8.1 Messages

The following message are used for the Tuner Control feature:

<Give Tuner Device Status>, <Select Preset>, <Tuner Step Decrement>, <Tuner Step Increment>, <Tuner Device Status>

CEC 13.8.2 Feature Description

This feature allows a device (e.g. the TV) to control another CEC devices tuner.

A device can select a preset number of a tuner device by sending the <Select Preset> message. The tuner device shall then attempt to tune to that preset number and stream its output on the HDMI connection. If the specified preset number is not set on the device then it should send a <Feature Abort> [“Invalid operand”] message. If the tuner device cannot change its preset number (e.g. if it is recording), it should respond with a <Feature Abort> [“Refused”] message.

A device can also control a CEC Devices tuner using the <Tuner Step Increment> and <Tuner Step Decrement> messages. If a device receives the <Tuner Step Increment> or <Tuner Step Decrement> message then it should increment or decrement the current preset that it is tuned to. The tuner device can interpret the messages as it chooses, for example, it may only cycle through channels included in the users list of favorites.

A device may query the status of a tuner device by sending a <Give Tuner Device Status> message. The tuner device shall respond by sending a <Tuner Device Status> message indicating if it is currently displaying its tuner and the preset number it is currently tuned to.

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CEC 13.9 Vendor Specific Commands

CEC 13.9.1 Messages

The following messages are used for the Vendor Specific Commands feature:

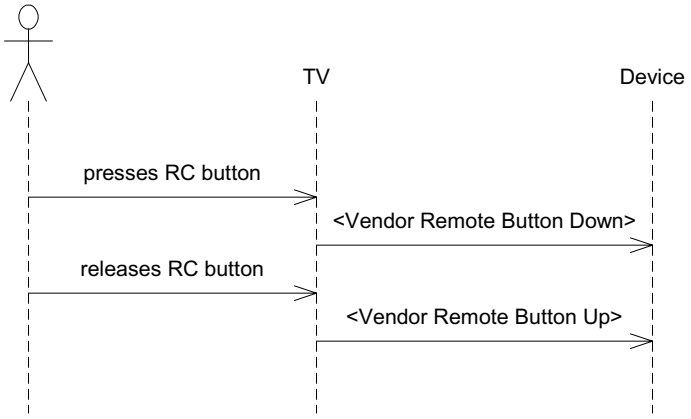
<Device Vendor ID>, <Give Device Vendor ID>, <Vendor Command>, <Vendor Remote Button Down>, <Vendor Remote Button Up>

CEC 13.9.2 Feature Description

This feature allows a set of vendor specific commands to be used to communicate between devices of a single vendor.

A device that supports vendor specific commands shall store a Vendor ID. A device shall broadcast a <Device Vendor ID> message after a successful initialization and address allocation to inform all other devices of its vendor ID. A device may request the Vendor ID of another device by sending a <Give Device Vendor ID> message to it. The follower shall respond by broadcasting a <Device Vendor ID> message. In this way any device can determine the vendor of another device. A device shall only attempt to transmit a vendor specific command to another device with the same vendor ID. If a device receives a vendor specific command from another device whose vendor ID it does not know, it shall assume that it is of the same vendor and respond accordingly.

It is possible to send vendor specific remote control commands using the <Vendor Remote Button Down> and <Vendor Remote Button Up> messages.



CEC Figure 19 The messages sent in the Vendor Specific Commands feature

In addition it is possible to send other (non remote control key) vendor specific messages using the <Vendor Command> message. The message parameter(s) can be used to communicate any additional (vendor defined) messages and data.

CEC 13.10 OSD Status Display

CEC 13.10.1 Messages

The following message is used for the OSD Status Display feature:

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<Set OSD String>

CEC 13.10.2 Feature Description

This feature allows a device to transfer a text string to the TV for On Screen Display. The <Set OSD String> message is used to transfer the text string to the TV.

A text string may be displayed for a default period (i.e. 5 seconds) or until explicitly cleared. In the latter case the device should send another <Set OSD String> message to clear the text when it is appropriate.

The TV should display the whole string unless it is in an unsuitable state, in which case it should generate a <Feature Abort> message.

If a new <Set OSD String> message is received when an OSD String is already being displayed, it should overwrite the existing string. OSD Strings generated locally within the TV may also overwrite any messages sent via the <Set OSD String> message.

CEC 13.11 Device Menu Control

CEC 13.11.1 Messages

The following messages are used for the Device Menu Control feature:

<User Control Pressed>, <User Control Released>, <Menu Request>, <Menu Status>

CEC 13.11.2 Feature Description

This feature allows device menus to be controlled via the TV remote control as if it was using its own remote control and allow the TV to be aware when another device has a menu on its display.

A device shall indicate that it is displaying a menu by sending a <Menu Status> [“Activated”] message to the TV. If the device leaves the menu it shall send a <Menu Status> [“Deactivated”] message to the TV. The TV should then handle incoming remote control commands internally (as it would normally).

The message <User Control Pressed> can be used to send incoming Remote Control commands from the TV to a device that it is displaying a menu. The <User Control Released> message should be sent on release of the RC button. If a device fails to acknowledge any <User Control> message when in the providing menu state then the TV shall assume that it has been removed from the system and act accordingly. For more information on <User Control> see the Remote Control Pass Through feature description (CEC 13.4).

The TV may initiate a device’s menu by sending a <Menu Request> [“Activate”] command. It may subsequently remove the menu by sending a <Menu Request> [“Deactivate”] message. The TV may also query a devices menu status by sending a <Menu Request> [“Query”]. The menu device shall always respond with a <Menu Status> command when it receives a <Menu Request>.

A new active source device shall send a <Menu Status> [“Activated”] message to the TV if it is displaying a menu. The TV shall assume that a new active source is not in a menu unless it receives this message after the <Active Source> message. The TV shall ignore a <Menu Status>

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message coming from a device that is not the current active source. A source device shall only send <Menu Status> commands when it is the current active source.

CEC 13.12 Routing Control

CEC 13.12.1 Messages

The following messages are used for the Routing Control feature:

<Active Source>, <Request Active Source>, <Set Stream Path>, <Routing Change>, <Routing Information>

CEC 13.12.2 Feature Description

This feature is used to control the routing of the HDMI network, by controlling CEC Switches.

In general whenever a device starts being streamed to the TV it should send an <Active Source> message. Any CEC Switches between the device and the TV should react to the <Active Source> message and switch (if required) to ensure the device at the physical address specified is on the active path. If another device was previously the active source then it should act accordingly, for example it may pause if it is playing media.

A device may broadcast a <Request Active Source> message to discover if any device is currently acting as the active source. The active source device will respond by broadcasting an <Active Source> message.

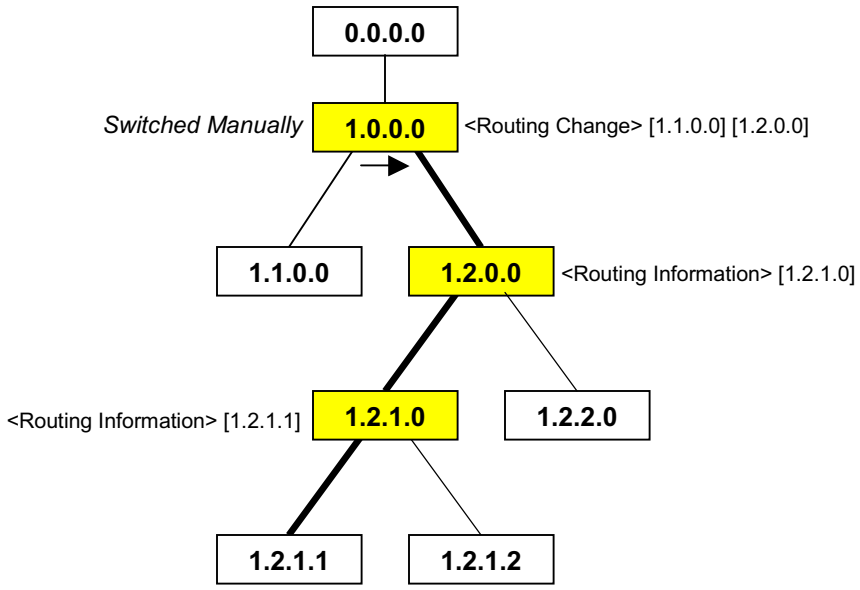
It is possible that the user may select a device to view via the TV user interface. In this case the TV should broadcast a <Set Stream Path> message with the physical address of the device it wishes to display as a parameter. Any CEC Switches between the device and TV should switch (if required) to ensure the device is on the active AV path. This feature ensures that non-CEC-compliant devices in the network can be switched to, if for instance they have been manually set up in the TV menu. A CEC device at the location specified by the <Set Stream Path> message should begin streaming its output and broadcast an <Active Source> message.

In the case that the user manually switches a CEC Switch it should broadcast a <Routing Change> message. This will inform all devices in the network that the current active route below the switch has changed. This enables, for instance, a device that has been deselected by a switch to pause if it is playing media.

If a CEC Switch is at the new position indicated by the <Routing Change> message then it should broadcast a <Routing Information> message with the physical address of its current active path. If a CEC Switch receives a <Routing Information> message then it should broadcast a <Routing Information> message to indicate it’s current active path. In this way the TV is aware of which device is on the current active path after the switch occurs. If the TV detects that the active source device has been de-selected by changing the switch it may either switch to an internal preset or send a <Set Stream Path> message to the device at the new location to indicate that it should become the new active source.

The following diagram shows an example of the message flow when a user manually switches a CEC Switch. (CEC Switches are shown filled).

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CEC Figure 20 Example message flow, when a CEC Switch is manually switched

CEC 13.13 Remote Control Pass Through

CEC 13.13.1 Messages

The following messages are used for the Remote Control Pass Through feature:

<User Control Pressed>, <User Control Released>

CEC 13.13.2 Feature Description

This feature is used to pass remote control commands received by one device (e.g. the TV) through to another device in the network.

The initiator shall decide on which device the remote command is for and send a directly addressed <User Control Pressed> message to it using the table of standard remote control pass though commands given in CEC Table 9.

The initiator will send a <User Control Pressed> message when the remote control button is pressed. When the button is released a <User Control Released> message should be sent by the initiator.

The initiator should not send repeated <User Control Pressed> messages for the same button press.

The initiator may send further <User Control Pressed> messages without interleaving <User Control Released> messages if a new button press occurs quickly after a button release.

A device that has initiated a <User Control Pressed> message shall ensure that it sends a <User Control Released> message before going into standby. In the event that the initiator of the

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message is powered off/disconnected before sending a <User Control Released> message, the follower will never receive the <User Control Released> message.

This method should not be used for sending commands other than true remote control pass through to another device as the actions taken by the other device are not defined in a consistent way.

CEC 13.14 Device OSD Name Transfer

CEC 13.14.1 Messages

The following messages are used for the Device OSD Name Transfer feature:

<Give OSD Name>, <Set OSD Name>

CEC 13.14.2 Feature Description

This feature is used to request the preferred name of a device to be used in any on screen display (e.g. menus), which reference that device. A device (e.g. the TV) may request another devices name by sending a directly addressed <Give OSD Name> message to it. If the device supports this feature it will respond with a <Set OSD Name> message. The devices name should then be stored and used in any future on screen references to it.

A TV shall send a <Give OSD Name> message whenever it discovers a new device that has been connected.

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CEC 14 Device states

This section shows how CEC messages can change the states of a device.

CEC 14.1.1 Device States

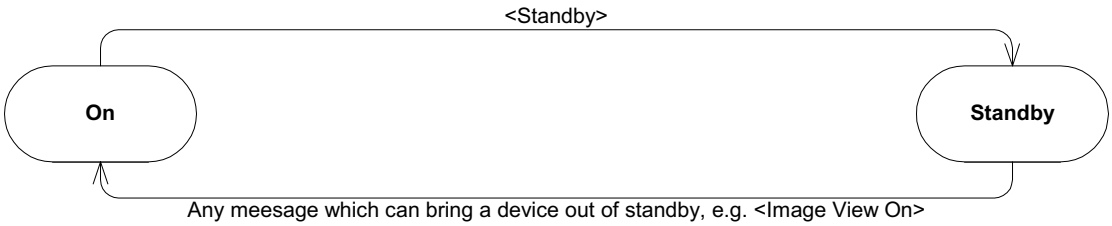
The following is a list of states that each device type can be in. Each device should be in one and only one state for each line shown below.

All Devices:	On, Standby, Off
TV:	Image Display, Menu Display, Text Display
	Preset Download Active, Preset Download Inactive
	Device Menu Active, Device Menu Inactive
Recording Device:	Recording, Not Recording
Playback Device:	Deck Active, Deck Inactive
Menu Providing Device:	Device Menu Active, Device Menu Inactive
Tuner Device:	Preset Download Active, Preset Download Inactive
Timer Setting Device:	Timer Block Transfer Active, Timer Block Transfer Inactive

CEC 14.1.2 State Changes

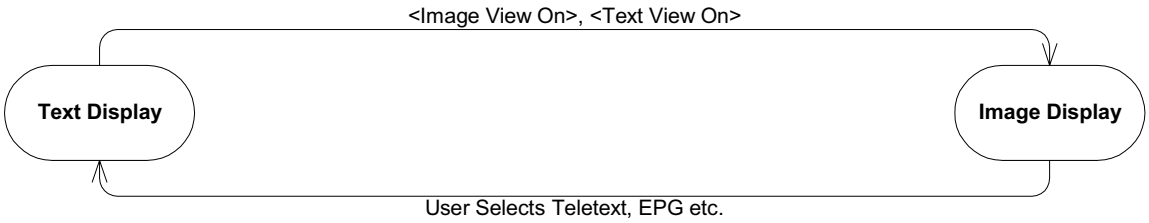
The following diagrams show the state transitions that are caused as a direct result of a device receiving a CEC message. Transitions between states that are not caused as a result of CEC messages are generally not shown, except where no CEC message can cause that transition.

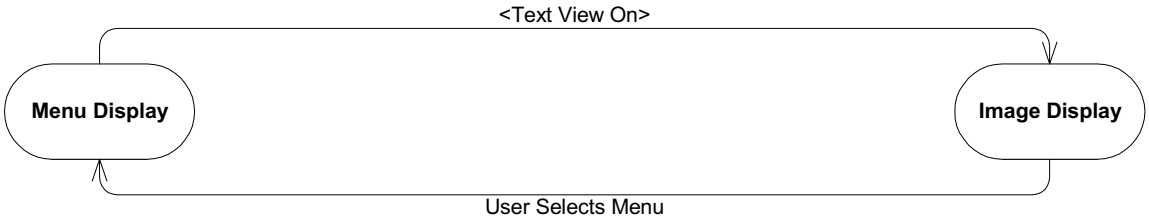
CEC 14.1.3 All Devices

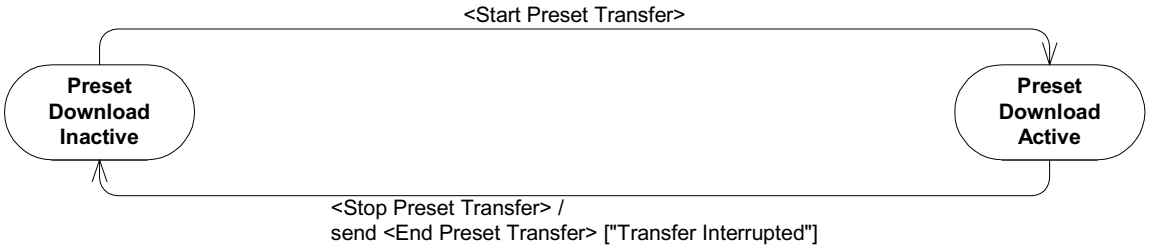


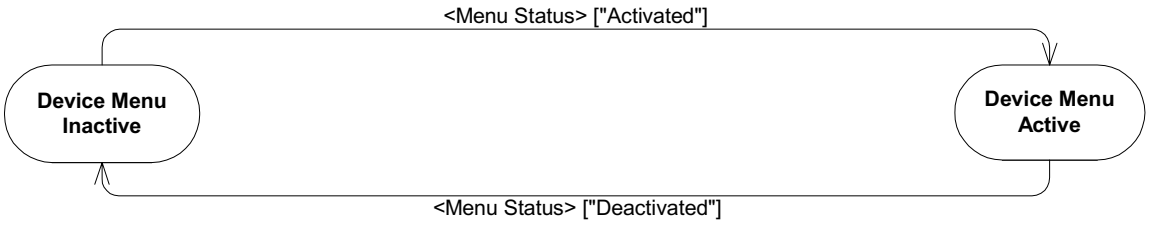
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CEC 14.1.4 TV



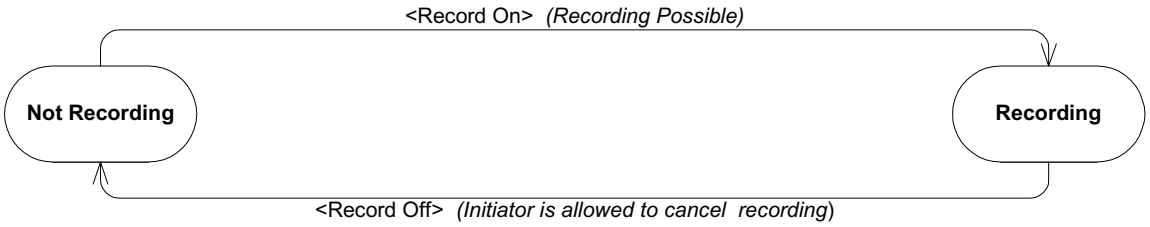




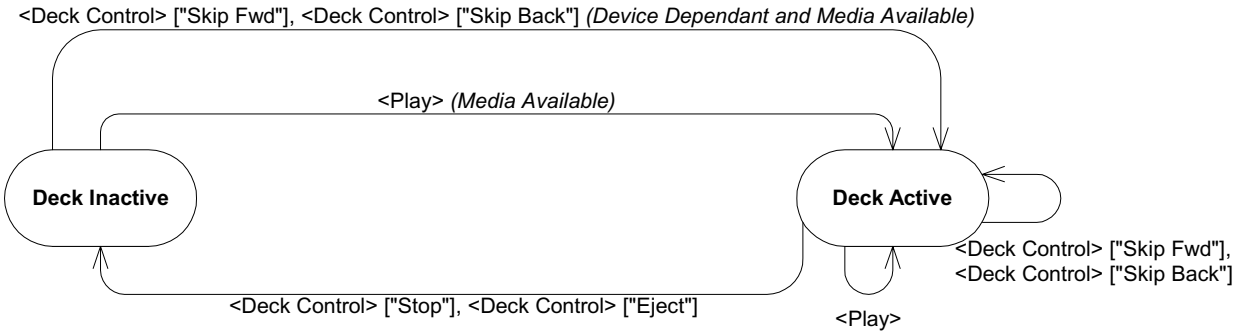


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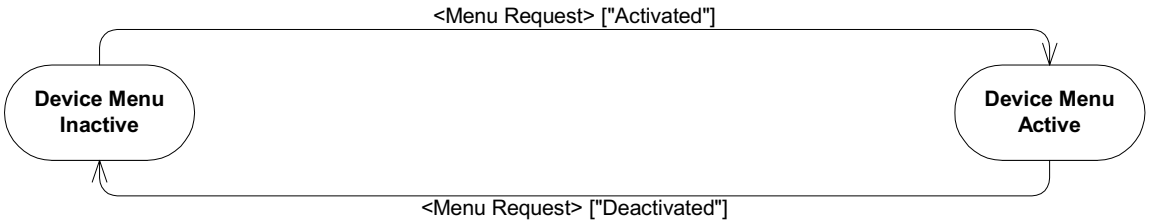
CEC 14.1.5 Recording Device



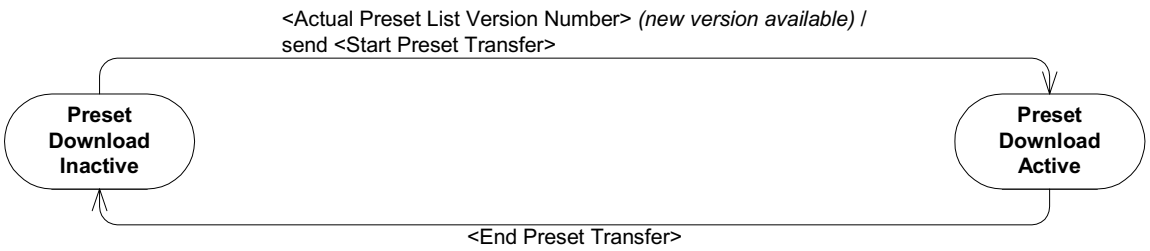
CEC 14.1.6 Playback Device



CEC 14.1.7 Menu Providing Device

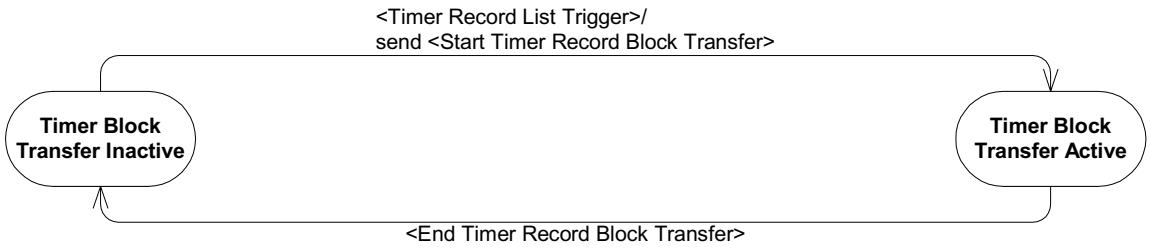


CEC 14.1.8 Tuner Device



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CEC 14.1.9 Timer Setting Device



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CEC 15 Message Descriptions

The section defines the individual messages used in CEC. It describes them and defines their parameters and expected responses. As CEC has no session layer, this section and the operands section (CEC 17) effectively define the complete messaging system. The use of this messaging system is clarified in the features description (CEC 13).

The following list describes each heading within the message table (CEC Table 5).

- **Opcode** – The name used to identify the message.
- **Value** – The unique identifier for the message.
- **Description** – A brief description of the message.
- **Parameters** – The set of parameters used by the message, refer to CEC Table 8 for individual descriptions.
- **Parameter Description** – A brief description of the parameters that the message uses.
- **Response** – Describes how a device should respond on receipt of the message.
- **Directly Addressed** – Indicates if the message may be directly addressed.
- **Broadcast** – Indicates if the message may be broadcast.
- **Mandatory** – Indicates if it is mandatory for a device to react and respond on receipt of the message. Note that where a message is indicated as being mandatory for 'All' devices, this excludes devices which act only as a CEC Switch.

Within the table some cells are intentionally left blank; this indicates that there is no associated requirements for the Opcode described.

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CEC Table 5 Message Descriptions

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Active Source>	0x82	Used by a new source to indicate that it has started to transmit a stream OR used in response to a <Request Active Source>	[Physical Address]	The physical address of the device.	A current active source should take appropriate action. Any CEC switches between source and root should switch to the appropriate input.			TV, CEC Switches
<Actual Preset List Version Number>	0x16	Used by the TV to inform all devices of the preset list version number. This is usually sent when the preset list has changed, or the TV has recently joined the network.	[Preset List Version Number]	The version number is incremented modulo 256 after every change to the preset table.	If the devices version number differs with that received it enters 'Preset Download Active' state and initiates a Preset Download by sending a <Start Preset Transfer> message to the TV.			
<Clear Timer>	0x33	Used to clear a timer block of a device.	See <Set Timer> message.	See <Set Timer> message.	Clear timer block if possible, then respond with <Timer Cleared Status>			
<Deck Control>	0x42	Used to control a device's tape/media functions.	[Deck Control Mode]	The deck control requested.	Perform the specified actions, or return a <Feature Abort> message. It is device dependant whether or not a Skip Fwd/Skip Back (Wind/Rewind) command is legal when in the 'Deck Inactive' state. If the device is in standby and receives an eject command, it should power on and eject its media.			Playback device

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Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Deck Status>	0x1B	Used to provide a deck's status to the initiator of the <Give Deck Status> message.	[Deck Info]	Information on the device's current status.				
<Device Vendor ID>	0x87	Reports the vendor ID of this device.	[Vendor ID]	The vendor ID of the device.	Any other interested device may store the vendor ID of the device.			
<End Preset Transfer>	0x03	Informs all devices that a preset transfer session has concluded.	[Preset List Version Number] [Preset List Info]	The version number of the preset list that has just been sent and its status.	Enter 'Preset Download Inactive' state. Store the new version number locally unless the parameter indicates the transfer was interrupted.			
<End Timer Record Block Transfer>	0x39	Used to indicate the end of the Timer Record Block transfer.	[Timer List Info]	Transfer and timer information.	Enter 'Timer Block Transfer Inactive' state.			
<Feature Abort>	0x00	Used as a response to indicate that the device does not support the requested message type, or that it cannot execute it at the present time.	[Feature Opcode] [Abort Reason]	The Opcode of the aborted message. The reason provides an indication as to whether the follower does not support the message, or does support the message but cannot respond at the present time.	Assume that request is not supported or has not been actioned.			All[1]

[1] Mandatory to accept this message on all devices and to generate it if a requested message is not supported.

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Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Give Deck Status>	0x1A	Used to request the status of a device, regardless of whether or not it is the current active source.	[Status Request]	Allows the initiator to request the status once or on all future state changes. Or to cancel a previous <Give Deck Status> [“On”] request.	<Deck Status>			Playback Device
<Give Device Vendor ID>	0x8C	Requests the Vendor ID from a device.	None		<Device Vendor ID>			
<Give OSD Name>	0x46	Used to request the preferred OSD name of a device for use in menus associated with that device.	None		<Set OSD Name>			
<Give Physical Address>	0x83	A request to a device to return its physical address.	None		<Report Physical Address>			All
<Give Preset List Version Number>	0x15	Used by a tuner device to request the TV’s preset list version number.	None.		<Actual Preset List Version Number>			TV[2]

[2] Only mandatory if TV contains tuner

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Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Give System Info>	0x52	Requests system information from the TV.	[System Info Version Number]	Version number of the system info.	TV sends: <Set System Info Version Number> and at least one of: <Set Country> and <Set Language> to the initiator. TV only responds if <System Info Version Number> is different to that given as a parameter within the request.			TV[3]
<Give Timer Options>	0x3E	Request for timer programming capabilities of a recording device.	None		<Timer Options>			
<Give Tuner Device Status>	0x08	Used to request the status of a tuner device.	[Status Request]	Allows the initiator to request the status once or on all future state changes, or to cancel a previous <Give Tuner Device Status> [“On”] message.	Respond with a <Tuner Device Status> message, or stop reporting changes on receipt of the [“Off”] message.			Tuner Device
<Image View On>	0x04	Sent by a source device to the TV whenever it enters the active state (alternatively it may send <Text View On>).	None		Turn on (if not on). If in ‘Text Display’ state then the TV enters ‘Image Display’ state. Displays output from initiator. Note: Don’t change TV menu or PIP status.			TV

[3] Only mandatory for information which the TV already holds for other purposes.

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Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Menu Request>	0x8D	A request from the TV for a device to show/remove a menu or to query if a device is currently showing a menu.	[Menu Request Type]	Indicates if the menu request is to activate or deactivate the devices menu, or to simply query the devices menu status.	May enter or exit the 'Device Menu Active' state if the parameter was "Activate" or "Deactivate" Send <Menu Status> to indicate the current status of the devices menu.			Menu Providing Device
<Menu Status>	0x8E	Used to indicate to the TV that the device is showing/has removed a menu and requests the remote control keys to be passed though.	[Menu State]	Indicates if the device is in the 'Device Menu Active' state or 'Device Menu Inactive' state.	If Menu State indicates activated, TV enters 'Device Menu Active' state and forwards those Remote control commands, shown in CEC Table 9, to the initiator. If deactivated, TV enters 'Device Menu Inactive' state and stops forwarding remote control commands.			TV
<Play>	0x41	Used to control the playback behaviour of a source device.	[Play Mode]	Play mode required.	Perform the specified actions, or return a <Feature Abort> message. If media is available the device enters 'Deck Active' state. If the device is in standby, has media available and the parameter is ["Play Forward"] it should power on.			Playback device
<Polling Message>	-	Used by any device for device discovery – similar to ping in other protocols.	None		Will set a low level ACK.			All

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Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Record Off>	0x0B	Requests a device to stop a recording.	None		Exit 'Recording' state and stop recording if the initiator is the same as the initiator of the <Record On> message which started this recording.			Recordin g Device
<Record On>	0x09	Attempt to record the specified source.	[Record Source]	Source to record, either preset number or own source.	Enter 'Recording' state and start recording if possible. Send the initiator <Record Status>.			Recordin g Device
<Record Status>	0x0A	Used by a recording device to inform the initiator of the message <Record On> about its status.	[Record Status Info]	The recording status of the device.				
<Record TV Screen>	0x0F	Request by the recording device to record the presently displayed source.	None		Initiate a recording using the <Record On> message, or send a <Feature Abort> ["Cannot provide source"] if the presently displayed source is not recordable.			
<Report Physical Address>	0x84	Used to inform all other devices of the mapping between physical and logical address of the initiator.	[Physical Address] [Device Type]	The device's physical address within the cluster.				
<Request Active Source>	0x85	Used by a new device to discover the status of the system.	None		<Active Source> from the present active source.			

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Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Routing Change>	0x80	Sent by a CEC Switch when it is manually switched to inform all other devices on the network that the active route to the sink below the switch has changed.	[Original Address] [New Address]	The previous child_address that the switch was switched to and the new child_address it has been moved to.	If a CEC Switch is at the new address, it sends a <Routing Information> message to indicate its current active route.			TV, CEC Switches
<Routing Information>	0x81	Sent by a CEC Switch to indicate the active route to the sink below the switch.	[Physical Address]	The current active route to the sink in the CEC Switch.	If a CEC Switch is at the specified address it should relay a <Routing Information> message to indicate its current active path.			CEC Switches
<Select Preset>	0x13	Used to allow one device to select a preset on another device that contains a tuner.	[Preset Number]	The preset number to be displayed.	Change to the selected preset, and stream its output on the HDMI connection. If the preset number is not set or the device cannot change preset, then it responds with a <Feature Abort>.			

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Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Set Analogue Preset>	0x01	Used to transfer an analogue preset.	[Preset Number] [Analogue Preset]	Preset number and details	Store the preset using the details indicated. If the device does not support the preset number, then it should ignore the message. If the device does not support the frequency or broadcast system, then it should clear the preset number			Tuner Device [4]
<Set Country>	0x31	Used by a TV to indicate the country setting to other devices	[Country]	The country code.	Set the country as specified, if possible			
<Set Language>	0x32	Used by a TV to indicate the menu & subtitle language settings to other devices	[Menu Language] [Subtitle Language]	The user's menu & subtitle language choices.	Set the menu & subtitle languages as specified, if possible.			
<Set OSD Name>	0x47	Used to set the preferred OSD name of a device for use in menus associated with that device.	[OSD Name]	The preferred name of the device.	Store the name and use it in any menus associated with that device.			
<Set OSD String>	0x64	Used to send a text message to output on a TV.	[Display Control] [OSD String]	Display timing. Text to be displayed.	TV displays the message.			

[4] Only mandatory on a device which initiates a <Start Preset Transfer>

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Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Set Preset Name>	0x0C	Used to transfer a preset name (only accepted if <Set Analogue Preset> has previously been received and accepted for this preset number). The preset name is optional, so this message may not be sent when transferring a preset.	[Preset Number] [Preset Name]	Preset number and name	Store the preset name indicated or ignore message.			
<Set Stream Path>	0x86	Used by the TV to request a streaming path from the specified physical address.	[Physical Address]	The physical address of the source device.	Any CEC switches between should switch inputs according to the path defined in [Physical Address]. The device at the new address should stream its output and broadcast an <Active Source> message.			CEC Switches
<Set System Info Version Number>	0x53	Used by a TV to indicate its system info version number.	[System Info Version Number]	The version of the system info.	Devices should update their system info version number accordingly.			
<Set Timer Program Title>	0x67	Used to set the name of a program associated with a timer block. Sent directly after sending a <Set Timer> message. The name is then associated with that timer block.	[Program Title String]	Program title	Recording device stores title for future reference. Ignore message if it is not the immediate next message from this initiator following a <Set Timer> message.			

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Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Set Timer>	0x34	Used to set a single timer block on a recording device.	[Preset Number] [Day of Month] [Month of Year] [Start Time] [Stop Time] [PIL Code] [Series Code] [Timer Related Data]	A complete set of timer information for one recording.	<Timer Status> message.			
<Standby>	0x36	Switches one or all devices into standby mode. Can be used as a broadcast message or be addressed to a specific device. It is recommended that a directly addressed message is only sent if the initiator originally brought the device out of standby.	None		Switch the device into standby. [5] Ignore the message if already in standby.			All
<Start Preset Transfer>	0x02	Request the current preset list from TV tuner.	None		TV enters 'Preset Download Active' state and starts transferring presets from its tuner.			TV[6]

[5] Can be ignored if actively engaged in a recording or providing a source stream for a recording.
[6] Only mandatory if TV contains a tuner.

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Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Start Timer Record Block Transfer>	0x37	Used to request transfer of all Timer Record Blocks from a recording device.	None		Enter 'Timer Block Transfer Active' state and broadcasts all occupied Timer Record Blocks using <Timer Record Block Transfer> messages.			
<Stop Preset Transfer>	0x10	Request from the initiator of <Start Preset Transfer> to stop transmitting presets. Ends a preset transfer session.	None		TV enters 'Preset Download Inactive' state and sends an <End Preset Transfer> ["Transfer interrupted"] message. No further presets are transmitted.			TV[6]
<Text View On>	0x0D	As <Image View On>, but also removes any text, menus and PIP windows from the TV's display.	None		As <Image View On>, but removes PIPs and menus from the screen. The TV enters 'Image Display' state regardless of its previous state.			TV
<Timer Cleared Status>	0x43	Used to give the status of a <Clear Timer> message.	[Timer Cleared Status Data]	Indicates if the timer was cleared successfully.	If the message indicates that the timer was not cleared because there was no matching entry, the device should remove the timer block locally or use <Start Timer Record Block Transfer> to ensure consistency with the recording device.			

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Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Timer Options>	0x3F	Used by a recording device to inform the initiator of the message <Give Timer Options> about its timer programming capabilities.	[# Timer Blocks] [# Free Timer Blocks] [Timer Options]	The total number and free number of timer blocks, with additional information about what programming features are supported.				
<Timer Record Block Transfer>	0x38	Used to transfer the data of a Timer Record Block.	[Preset Number] [Day of Month] [Month of Year] [Start Time] [Stop Time] [PIL Code] [Series Code] [Timer Block Related Data] [Recording Status]	As for <Set Timer>, except [Timer Block Related Data], [Recording Status] A complete set of timer information for one recording.				
<Timer Record List Trigger>	0x19	Used by a device to inform all followers that 1) its timer block list has changed; 2) it has been powered up.	None		May enter 'Timer Block Transfer Active' state and request to start the transfer of blocks by sending a <Start Timer Record Block Transfer> message.			
<Timer Status>	0x35	Used to send timer status to the initiator of a <Set Timer> message.	[Timer Status Data]	Indicates the timer status	.			

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Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Tuner Device Status>	0x07	Use by a tuner device to provide its status to the initiator of the <Give Tuner Device Status> message.	[Tuner Device Info]	Information on the tuner devices current status.				
<Tuner Step Decrement>	0x06	Used to decrement the preset used by a device's tuner. Can be used for PIP.	None		Follower decrements tuner preset.			
<Tuner Step Increment>	0x05	Used to increment the preset used by a device's tuner. Can be used for PIP.	None		Follower increments tuner preset.			
<User Control Pressed>	0x44	Used to indicate that the user pressed a remote control button or switched from one remote control button to another.	[UI Command]	UI command issued by user.	Update display or perform an action, as required.			
<User Control Released>	0x45	Indicates that user released a remote control button (the last one indicated by the <User Control Pressed> message)	None		Update display or perform an action, as required.			

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Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Vendor Command>	0x89	Allows vendor specific commands to be sent between two devices.	[Vendor Specific Data]	Vendor specific command or data. The maximum length of the [Vendor Specific Data] must not exceed 14 data blocks to avoid saturating the bus.	Vendor Specific			
<Vendor Remote Button Down>	0x8A	Indicates that a remote control button has been depressed.	[Vendor Specific RC Code]	The vendor specific Remote Control Code for the key pressed.	Vendor Specific			
<Vendor Remote Button Up>	0x8B	Indicates that a remote control button (the last button pressed indicated by the Vendor Remote Button Down message) has been released.	None		Vendor Specific			

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CEC 16 Message Dependencies

This section describes the dependencies between each message. This section is divided into two tables, which describe the following:

- CEC Table 6 describes the message dependencies when a device is capable of receiving a particular message (i.e. it does not <Feature Abort> indicating an [“Unrecognized opcode”] in response to the message).
- CEC Table 7 describes the message dependencies when a device is capable of sending a particular message.

Each table describes the additional messages that the device shall be capable of receiving and sending if a particular message is supported.

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CEC Table 6 Message dependencies when receiving a message

If device does not <Feature Abort> the following message:	**It shall not <Feature Abort> the message(s):**	**It shall be able to send the message(s):**
<Actual Preset List Version Number>	<End Preset Transfer>, <Set Analogue Preset>	<Give Preset List Version Number>, <Start Preset Transfer>, <Stop Preset Transfer>
<Clear Timer>	<Set Timer>	<Timer Cleared Status>, <Timer Status>
<Deck Control>	<Play>, <Give Deck Status>	<Deck Status>
<Deck Status>	-	<Give Deck Status>, <Play>, <Deck Control>
<Device Vendor ID>	-	<Give Device Vendor ID>
<End Preset Transfer>	<Actual Preset List Version Number>, <Set Analogue Preset>	<Give Preset List Version Number>, <Start Preset Transfer>, <Stop Preset Transfer>
<End Timer Record Block Transfer>	<Timer Record Block Transfer>, <Timer Record List Trigger>	<Start Timer Record Block Transfer>
<Give Deck Status>	<Play>, <Deck Control>	<Deck Status>
<Give Device Vendor ID>	-	<Device Vendor ID>
<Give OSD Name>	-	<Set OSD Name>
<Give Physical Address>	-	<Report Physical Address>
<Give Preset List Version Number>	<Start Preset Transfer>, <Stop Preset Transfer>	<Actual Preset List Version Number>, <Set Analogue Preset>, <End Preset Transfer>
<Give System Info>	-	<Set System Info Version Number>, At least one of: <Set Country>, <Set Language>
<Give Timer Options>	-	<Timer Options>

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If device does not <Feature Abort> the following message:	It shall not <Feature Abort> the message(s):	It shall be able to send the message(s):
<Give Tuner Device Status>	-	<Tuner Device Status>
<Image View On>	<Active Source>	-
<Menu Request>	<User Control Pressed>, <User Control Released>	<Menu Status>
<Menu Status>	-	<Menu Request>, <User Control Pressed>, <User Control Released>
<Play>	<Give Deck Status>, <Deck Control>	<Deck Status>
<Record Off>	<Record On>	<Record Status>
<Record On>	<Record Off>	<Record Status>
<Record Status>	-	<Record On>, <Record Off>
<Record TV Screen>	<Record Status>	<Record On>, <Record Off>
<Request Active Source>	-	<Active Source>
<Routing Change>	<Routing Information>	-
<Routing Information>	<Routing Change>	-
<Set Analogue Preset>	<End Preset Transfer>, <Actual Preset List Version Number>	<Start Preset Transfer>, <Stop Preset Transfer>, <Give Preset List Version Number>
<Set Country>	<Set System Info Version Number>	<Give System Info>
<Set Language>	<Set System Info Version Number>	<Give System Info>
<Set OSD Name>	-	<Give OSD Name>

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If device does not <Feature Abort> the following message:	It shall not <Feature Abort> the message(s):	It shall be able to send the message(s):
<Set OSD String>	-	-
<Set Preset Name>	<Set Analogue Preset>, <End Preset Transfer>, <Actual Preset List Version Number>	<Start Preset Transfer>, <Stop Preset Transfer>, <Give Preset List Version Number>
<Set Stream Path>	-	<Active Source> (not CEC Switches)
<Set System Info Version Number>	At least one of: <Set Country>, <Set Language>	<Give System Info>
<Set Timer Program Title>	<Set Timer>, <Clear Timer>	<Timer Status>, <Timer Cleared Status>
<Set Timer>	<Clear Timer>	<Timer Status>, <Timer Cleared Status>
<Start Preset Transfer>	<Give Preset List Version Number>, <Stop Preset Transfer>	<Set Analogue Preset>, <End Preset Transfer>, <Actual Preset List Version Number>
<Start Timer Record Block Transfer>	-	<End Timer Record Block Transfer>, <Timer Record Block Transfer>, <Timer Record List Trigger>
<Stop Preset Transfer>	<Start Preset Transfer>, <Give Preset List Version Number>	<Set Analogue Preset>, <End Preset Transfer>, <Actual Preset List Version Number>
<Text View On>	<Active Source>	-
<Timer Cleared Status>	<Timer Status>	<Clear Timer>, <Set Timer>
<Timer Options>	-	<Give Timer Options>
<Timer Record Block Transfer>	<Timer Record List Trigger>, <End Timer Record Block Transfer>	<Start Timer Record Block Transfer>
<Timer Record List Trigger>	<Timer Record Block Transfer>, <End Timer Record Block Transfer>	<Start Timer Record Block Transfer>

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If device does not <Feature Abort> the following message:	**It shall not <Feature Abort> the message(s):**	**It shall be able to send the message(s):**
<Timer Status>	<Timer Cleared Status>	<Set Timer>, <Clear Timer>
<Tuner Device Status>	-	<Give Tuner Device Status>
<Tuner Step Decrement>	<Tuner Step Increment>	-
<Tuner Step Increment>	<Tuner Step Decrement>	-
<User Control Pressed>	<User Control Released>	-
<User Control Released>	<User Control Pressed>	-
<Vendor Command>	<Device Vendor ID>	<Give Device Vendor ID>
<Vendor Remote Button Down>	<Vendor Remote Button Up>, <Device Vendor ID>	<Give Device Vendor ID>
<Vendor Remote Button Up>	<Vendor Remote Button Down>, <Device Vendor ID>	<Give Device Vendor ID>

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CEC Table 7 Message dependencies when sending a message

If device ever sends the following message:	**It shall be able to send the message(s):**	**It shall not <Feature Abort> the message(s):**
<Actual Preset List Version Number>	<End Preset Transfer>, <Set Analogue Preset>	<Give Preset List Version Number>, <Start Preset Transfer>, <Stop Preset Transfer>
<Clear Timer>	<Set Timer>	<Timer Cleared Status>, <Timer Status>
<Deck Control>	<Play>	-
<Deck Status>	-	<Give Deck Status>, <Play>, <Deck Control>
<Device Vendor ID>	-	<Give Device Vendor ID>
<End Preset Transfer>	<Actual Preset List Version Number>, <Set Analogue Preset>	<Give Preset List Version Number>, <Start Preset Transfer>, <Stop Preset Transfer>
<End Timer Record Block Transfer>	<Timer Record Block Transfer>, <Timer Record List Trigger>	<Start Timer Record Block Transfer>
<Give Deck Status>	<Play>, <Deck Control>	<Deck Status>
<Give Device Vendor ID>	-	<Device Vendor ID>
<Give OSD Name>	-	<Set OSD Name>
<Give Physical Address>	-	<Report Physical Address>
<Give Preset List Version Number>	<Start Preset Transfer>, <Stop Preset Transfer>	<Actual Preset List Version Number>, <Set Analogue Preset>, <End Preset Transfer>
<Give System Info>	-	<Set System Info Version Number>, At least one of: <Set Country>, <Set Language>
<Give Timer Options>	-	<Timer Options>

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If device ever sends the following message:	It shall be able to send the message(s):	It shall not <Feature Abort> the message(s):
<Give Tuner Device Status>	-	<Tuner Device Status>
<Image View On>	<Active Source>	-
<Menu Request>	<User Control Pressed>, <User Control Released>	<Menu Status>
<Menu Status>	-	<Menu Request>, <User Control Pressed>, <User Control Released>
<Play>	<Give Deck Status>, <Deck Control>	<Deck Status>
<Record Off>	<Record On>	<Record Status>
<Record On>	<Record Off>	<Record Status>
<Record Status>	-	<Record On>, <Record Off>
<Record TV Screen>	<Record Status>	<Record On>, <Record Off>
<Request Active Source>	-	<Active Source>
<Routing Change>	<Routing Information>	-
<Routing Information>	<Routing Change>	-
<Set Analogue Preset>	<End Preset Transfer>, <Actual Preset List Version Number>	<Start Preset Transfer>, <Stop Preset Transfer>, <Give Preset List Version Number>
<Set Country>	<Set System Info Version Number>	<Give System Info>
<Set Language>	<Set System Info Version Number>	<Give System Info>
<Set OSD Name>	-	<Give OSD Name>

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If device ever sends the following message:	It shall be able to send the message(s):	It shall not <Feature Abort> the message(s):
<Set Preset Name>	<Set Analogue Preset>, <End Preset Transfer>, <Actual Preset List Version Number>	<Start Preset Transfer>, <Stop Preset Transfer>, <Give Preset List Version Number>
<Set Stream Path>	-	<Active Source> (not CEC Switches)
<Set System Info Version Number>	At least one of: <Set Country>, <Set Language>	<Give System Info>
<Set Timer Program Title>	<Set Timer>, <Clear Timer>	<Timer Status>, <Timer Cleared Status>
<Set Timer>	<Clear Timer>	<Timer Status>, <Timer Cleared Status>
<Start Preset Transfer>	<Give Preset List Version Number>, <Stop Preset Transfer>	<Set Analogue Preset>, <End Preset Transfer>, <Actual Preset List Version Number>
<Start Timer Record Block Transfer>	-	<End Timer Record Block Transfer>, <Timer Record Block Transfer>, <Timer Record List Trigger>
<Stop Preset Transfer>	<Start Preset Transfer>, <Give Preset List Version Number>	<Set Analogue Preset>, <End Preset Transfer>, <Actual Preset List Version Number>
<Text View On>	<Active Source>	-
<Timer Cleared Status>	<Timer Status>	<Clear Timer>, <Set Timer>
<Timer Options>	-	<Give Timer Options>
<Timer Record Block Transfer>	<Timer Record List Trigger>, <End Timer Record Block Transfer>	<Start Timer Record Block Transfer>
<Timer Record List Trigger>	<Timer Record Block Transfer>, <End Timer Record Block Transfer>	<Start Timer Record Block Transfer>
<Timer Status>	<Timer Cleared Status>	<Set Timer>, <Clear Timer>

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If device ever sends the following message:	**It shall be able to send the message(s):**	**It shall not <Feature Abort> the message(s):**
<Tuner Device Status>	-	<Give Tuner Device Status>
<Tuner Step Decrement>	<Tuner Step Increment>	-
<Tuner Step Increment>	<Tuner Step Decrement>	-
<User Control Pressed>	<User Control Released>	-
<User Control Released>	<User Control Pressed>	-
<Vendor Command>	<Device Vendor ID>	<Give Device Vendor ID>
<Vendor Remote Button Down>	<Vendor Remote Button Up>, <Device Vendor ID>	<Give Device Vendor ID>
<Vendor Remote Button Up>	<Vendor Remote Button Down>, <Device Vendor ID>	<Give Device Vendor ID>

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CEC 17 Operand Descriptions

In the following table, Operand Descriptions are ordered alphabetically. Sub-operands, which only occur in a single parent operand, are grouped with their parent and are shown indented.

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CEC Table 8 Operand Descriptions.

Name	Range Description		Length	Purpose
[# Free Timer Blocks]	0x00 n 0xFF		1 byte	Indicates the number of timer blocks a device has free.
[# Timer Blocks]	0x00 n 0xFF		1 byte	Indicates the number of timer blocks a device can handle.
[Abort Reason]	“Unrecognized opcode”	0	1 byte	Reason for a <Feature Abort> response.
	“Not in correct mode to respond”	1		
	“Cannot provide source”	2		
	“Invalid operand”	3		
	“Refused”	4		
[Analogue Preset]	[Analogue Frequency] [Preset Related Data]		3 bytes	Identifies and specifies a particular tuner preset signal of an analogue tuner.
[Analogue Frequency]	0x0000<n<0xFFFF Frequency = 62.5n kHz		2 bytes	Used to specify the frequency used by an analogue terrestrial tuner.
[Preset Related Data]	[Reserved Bit] [Decoder Preset Indicator] [Favorite Indicator] [Broadcast System]		1 byte	Used to identify the data that is related to a tuner preset.
[Decoder Preset Indicator]	“Not present or not supported”	0	1 bit	Some tuner devices support the feature that a preset can be marked as a decoder present.
	”Decoder present and signal can be encoded”	1		
[Favorite Indicator]	“No”	0	1 bit	Some devices support the feature that a preset can be marked as a favorite preset. A follower is not required to use this information.
	”Yes or not supported”	1		

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Name	Range Description		Length	Purpose
[Broadcast System]	0 n 31 – See CEC Table 10		5 bits	This specifies information about the color system, the sound carrier and the IF-frequency.
[ASCII digit]	0x30 n 0x39		1 byte	Subset of [ASCII] representing a printable digit character.
[ASCII]	0x20 n 0x7F		1 byte	Represents a printable character.
[Boolean]	“False”	0	1 bit	Flag
	“True”	1		
[Country]	0x0000 n 0xFFFF (n is defined in ITU-T E.164 Assigned Country Codes)		2 bytes	Specify the country in which the device is operating.
[Day of Month]	1 n 31		1 byte	Day of month.
[Deck Control Mode]	“Skip Forward / Wind Forward”	1	1 byte	Used in <Deck Control>. Note: The “Skip Forward / Wind Forward” and ”Skip Backward / Wind Backward” values are used for example in a DVD as next chapter and previous chapter and in a VCR as wind and rewind.
	“Skip Backward / Rewind”	2		
	“Stop”	3		
	“Eject”	4		
[Deck Info]	“Play”	0x11	1 byte	Indicates the current status of a tape or disk deck.
	“Record”	0x12		
	“Play Reverse”	0x13		
	“Still”	0x14		
	“Slow”	0x15		

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Name	Range Description		Length	Purpose
	“Slow Reverse”	0x16		
	“Search Forward”	0x17		
	“Search Reverse”	0x18		
	“No Media”	0x19		
	“Stop”	0x1A		
	“Wind”	0x1B		
	“Rewind”	0x1C		
	“Index Search Forward”	0x1D		
	“Index Search Reverse”	0x1E		
	”Other Status”	0x1F		
[Device Type]	“TV”	0	1 byte	Allows additional devices, above the number allowed in the logical addressing mechanism, to indicate their device type.
	“Recording Device”	1		
	“STB”	3		
	“DVD”	4		
	“Audio System”	5		

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Name	Range Description			Length	Purpose
[Display Control]	bit 5 – bit 0 = 0			1 byte	To indicate the display mode for an on screen display message.
		bit 7	bit 6		
	"Display for default time"	0	0		
	"Display until cleared"	0	1		
	"Clear previous message"	1	0		
	Reserved for future use	1	1		
[Feature Opcode]	0x00 n 0xFF (n is defined in CEC Table 5)			1 byte	Defines command to be performed.
[High/Low Quality Timer Programming]	"High Quality" (i.e. Short Play)		0	1 bit	Indicates if recording should be in high or low quality mode.
	"Low Quality" (i.e. Long Play)		1		
[Language]	2 {[ASCII]} as defined in ISO/FDIS 639-1 [ref 1n]			2 bytes	Specify the language with which to interact with the user.
[Menu Language]	[Language]			2 bytes	Specify the language with which to interact with the user.
[Menu Request Type]	"Activate"		0	1 byte	Specifies whether to activate or deactivate a devices menu or simply query its current menu status.
	"Deactivate"		1		
	"Query"		2		
[Menu State]	"Activated"		0	1 byte	Specifies the state of a device menu
	"Deactivated"		1		

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Name	Range Description	Length	Purpose
[Month of Year]	1 n 12	1 byte	Month
[New Address]	[Physical Address]	2 bytes	The physical address of the new device selected by a CEC Switch.
[Original Address]	[Physical Address]	2 bytes	The physical address of the device de-selected by a CEC Switch.
[OSD Name]	N {[ASCII]}, 1≤N ≤ 8	1 - 8 bytes	The devices name - To be used in On Screen Display references to it.
[OSD String]	N {[ASCII]}, 1≤N ≤ 13	1 - 13 bytes	A string to be displayed on the display.
[Physical Address]	4{[Port ID]}	2 bytes	Defines the path between the TV and a device – thus giving it a physical address within the cluster.
[Port ID]	0x1 n 0xF	4 bits	Defines one 'hop' within the physical address relating to the physical connection of the device.
[PIL Code]	[PIL_High] [PIL_Mid] [PIL_Low]	3 bytes	The PIL number as defined in prETS300231 and is the time originally announced as the start of the program. Note PIL allocation is: bit 1 to bit 5 day bit 6 to bit 9 month bit 10 to bit 14 hour bit 15 to bit 20 minute Note: special code of 0b00000 11111 11111 11111 is used to indicate PDC/VPS off and that timing should therefore be done by the local timer.
[PIL_High]	PIL bit 1 to bit 8, bit 1 is MSb	1 byte	Part of PIL data.
[PIL_Mid]	PIL bit 9 to bit 16, bit 9 is MSb	1 byte	Part of PIL data.
[PIL_Low]	PIL bit 17 to bit 20, bit 17 is MSb bit 21 to bit 24 = 0b1111	1 byte	Part of PIL data.

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Name	Range Description		Length	Purpose
[Play Mode]	“Play Forward”	0x24	1 byte	The mode in which to play media. Note: If a device does not support a particular play mode it should select the closest match.
	“Play Reverse”	0x20		
	“Play Still”	0x25		
	“Scan Forward Min Speed”	0x05		
	“Scan Forward Medium Speed”	0x06		
	“Scan Forward Max Speed”	0x07		
	“Scan Reverse Min Speed”	0x09		
	“Scan Reverse Medium Speed”	0x0A		
	“Scan Reverse Max Speed”	0x0B		
	“Slow Forward Min Speed”	0x15		
	“Slow Forward Medium Speed”	0x16		
	“Slow Forward Max Speed”	0x17		
	“Slow Reverse Min Speed”	0x19		
	“Slow Reverse Medium Speed”	0x1A		
	“Slow Reverse Max Speed”	0x1B		

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Name	Range Description		Length	Purpose
[Preset List Info]	“Complete”	0	1 byte	The status of a preset transfer session at its completion.
	“All others virgin”	1		
	“Transfer interrupted”	2		
[Preset List Version Number]	0x00 n 0xFF		1 byte	The version number of a preset list (Modulo 256).
[Preset Name]	N {[ASCII]}, 1 ≤ N ≤ 12		1 - 12 bytes	The name of a preset.
[Preset Number]	0x0000 n 0xFFFF		2 bytes	The identifier for a tuner preset.
[Program Title String]	N {[ASCII]}, 1 ≤ N ≤ 14		1 - 14 bytes	Program title.
[Recording Sequence]	“One time”	0b00	2 bits	Indicates if recording is repeated and, if so, on what basis.
	“Weekly”	0b01		
	“Daily”	0b10		
	“Series”	0b11		
[Record Source]	[Record Source Type] | {[Record Source Type] [Preset Number] [Analogue Preset]}		-	To define the source for a recording.
[Record Source Type]	“Preset”	0	1 byte	Allows the record source to be specified for a recording.
	”Own source”	1		

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Name	Range Description		Length	Purpose
[Record Status Info]	“Recording preset”	0x00	1 byte	Indicates the status of a recording.
	“Recording own source”	0x01		
	“Reserved”	0x02		
	“Reserved”	0x03		
	“Reserved”	0x04		
	“Reserved”	0x05		
	“No recording - invalid preset”	0x09		
	“No recording - no media”	0x10		
	“No recording - playing”	0x11		
	“No recording - already recording”	0x12		
	“No recording - media protected”	0x13		
	“No recording - no source”	0x14		
	“No recording - media problem”	0x15		
	“No recording - other reason”	0x1F		

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Name	Range Description		Length	Purpose
[Recording Status]	bit 7 - bit 1: [Reserved Bit].		1 byte	Used in <Timer Record Block Transfer>.
		bit 0		
	”Recording of this block not busy”	0		
	“Recording of this block busy”	1		
[Reserved Bit]	0		1 bit	Used as padding bit for future extensions.
[Series Code]	0x00 n 0xFF		1 byte	Series code. (e.g. for PDC)
[Start Time]	[Time]		2 bytes	Indicates the start time for a timer based recording.
[Status Request]	“On”	1	1 byte	Contains the status request mode which can be report once or on all future state changes or reporting off.
	“Off”	2		
	“Once”	3		
[Stop Time]	[Time]		2 bytes	Indicates the end time for a timer based recording.
[Subtitle Language]	[Language]		2 bytes	Specify the language in which to supply sub-titles.
[System Info Version Number]	0x00 n 0xFF		1 byte	The version number of a system info stored in the TV (Modulo 256).
[Time]	[Hour][Minute]		2 bytes	Time of day
[Hour]	0 n 23		1 byte	Hours
[Minute]	0 n 59		1 byte	Minutes

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Name	Range Description		Length	Purpose
[Timer Block Related Data]	3{[Reserved Bit]} [High/Low Quality Timer Programming] [Controlled Record Start - Block] [Recording Sequence]		1 byte	Identifies data that is related to timer block.
[Controlled Record Start – Block]	"No controlled start used on this block"	0b00	2 bits	Indicates type of controlled record start used, if any.
	"PDC"	0b01		
	"Video Programming System"	0b10		
	"Either PDC or VPS"	0b11		
[Timer Cleared Status Data]	"Timer cleared" = 0b1xxxxxxx. "Timer not cleared" = 0b0xxxxxxx. Reason: No matching = 0b00000001		1 byte	Indicates status in a <Timer Cleared Status> message.
[Timer List Info]	"Transfer complete, free timer blocks left"	0	1 byte	Used in <End Timer Record Block Transfer> message.
	"Transfer complete, list empty"	1		
	"Transfer interrupted"	2		
	"Transfer complete, all timer blocks occupied"	3		
[Timer Options]	[Daily Programming type] [Series Programming Supported] [Daily Programming Supported] [Weekly Programming Supported] [Reserved] [VPS Supported] [PDC Supported] [Low Quality Supported]		1 byte	Describes the Timer functions available for a recording device

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Name	Range Description		Length	Purpose
[Daily Programming type]	"All 7 days of the week"	0	1 bit	Type of daily timer.
	"Only Monday to Friday"	1		
[Series Programming Supported]	[Boolean]		1 bit	Indicates if series programming is supported.
[Daily Programming Supported]	[Boolean]		1 bit	Indicates if daily repeat programming is supported.
[Weekly Programming Supported]	[Boolean]		1 bit	Indicates if weekly repeat programming is supported
[VPS Supported]	[Boolean]		1 bit	Indicates if VPS standard is supported
[PDC Supported]	[Boolean]		1 bit	Indicates if PDC standard is supported.
[Low Quality Supported]	[Boolean]		1 bit	Indicates if low quality (i.e. Long Play) is supported.
[Timer Related Data]	3{[Reserved Bit]} [High/Low Quality Timer Programming] [Controlled Record Start] [Recording Sequence]		1 byte	Identifies data that is related to timer programming.
[Controlled Record Start]	"Not supported"	0b00	2 bits	Indicates type of controlled record start to be used, if any.
	"PDC"	0b01		
	"Video Programming System"	0b10		
	"Reserved"	0b11		

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Name	Range Description		Length	Purpose
[Timer Status Data]	[High/Low Quality supported] [Timer overlap warning] [Media Info] [Timer Programmed Info]		1 byte	Used by a recoding device to respond to the initiator of a <Set Timer> message.
[High/Low Quality Supported]	“Not supported”	0	1 bit	Indicates if the recording device has used the High Quality/Low Quality setting as requested.
	”As requested”	1		
[Timer Overlap Warning]	“No overlap”	0	1 bit	Indicates is there is another timer block already set which overlaps with this new recording request.
	”Timer blocks overlap”	1		
[Media Info]	“Media present and not protected”	0b00	2 bits	Indicates if removable media is present and its write protect state.
	“Media present, but protected”	0b01		
	“Media not present”	0b10		
	Future Use	0b11		
[Timer Programmed Info]	[Programmed Indicator] {[Programmed Info] | [Not Programmed Error Info]}		4 bits	Gives information about how and if the programming request has been done. [Programmed Indicator] is used as a selector for the second parameter.
[Programmed Indicator]	“Not programmed”	0	1 bit	Selector for [Timer Programmed Info].
	”Programmed”	1		
[Programmed Info]	Future Use	0b0xx	3 bits	Information indicating any non-fatal issues with the programming request.
	“Media info not supported”	0b100		
	“Enough media available for recording”	0b101		

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Name	Range Description		Length	Purpose
	“Not enough media available for recording”	0b110		
	Future Use	0b111		
[Not Programmed Error Info]	Future Use	0b000	3 bits	Reason for programming failure.
	“Daily error”	0b001		
	“No free timer available”	0b010		
	“Illegal preset”	0b011		
	“Clock failure”	0b100		
	“Date out of range”	0b101		
	“Series programming not supported”	0b110		
	“Other reason”	0b111		
[Tuner Device Info]	[Tuner Display Info][Preset Number]		3 bytes	Indicates information about the tuner. Indicates the preset number that the tuner is set to, regardless of whether or not it is currently displaying the tuner.
[Tuner Display Info]	“Displaying tuner”	0	1 byte	Indicates if the device is currently displaying its tuner or not (it may for example be displaying an external source or media).
	“Not displaying tuner”	1		
[UI Command]	0x00 n 0xFF (n is defined in CEC Table 9)		1 byte	Indicates the remote control button pressed.

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Name	Range Description	Length	Purpose
[Vendor ID]	0x000 n 0xFFF (n is the 24-bit unique company ID [ref. 3i] obtained from the IEEE Registration Authority Committee (RAC)).	3 bytes	Identifier for a specific Vendor.

Notes: Items are transmitted in the order shown in the description.
All bit descriptions are done most significant bit first (i.e. first bit described is sent first)

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CEC Table 9 User Control Codes

Operation id	User Operation
0x00	**Select**
0x01	**Up**
0x02	**Down**
0x03	**Left**
0x04	**Right**
0x05	**Right-Up**
0x06	**Right-Down**
0x07	**Left-Up**
0x08	**Left-Down**
0x09	Root Menu
0x0A	Setup Menu
0x0B	Contents Menu
0x0C	Favorite Menu
0x0D	**Exit**
0x0E - 0x1F	Reserved
0x20 - 0x29	**Numbers 0-9**
0x2A	Dot
0x2B	Enter
0x2C	Clear
0x2D - 0x2F	Reserved
0x30	Channel Up
0x31	Channel Down

Operation id	User Operation
0x32	Previous Channel
0x33	Sound Select
0x34	Input Select
0x35	Display Information
0x36	Help
0x37	Page Up
0x38	Page Down
0x39 - 0x3F	Reserved
0x40	Power
0x41	Volume Up
0x42	Volume Down
0x43	Mute
0x44	Play
0x45	Stop
0x46	Pause
0x47	Record
0x48	Rewind
0x49	Fast forward
0x4A	Eject
0x4B	Forward
0x4C	Backward
0x4D - 0x4F	Reserved

Operation id	User Operation
0x50	Angle
0x51	Sub picture
0x52 - 0x5F	Reserved
0x60	Play Function
0x61	Pause-Play Function
0x62	Record Function
0x63	Pause-Record Function
0x64	Stop Function
0x65	Mute Function
0x66	Restore Volume Function
0x67	Tune Function
0x68	Select Disk Function
0x69	Select A/V Input Function
0x6A	Select Audio Input Function
0x6B - 0x70	Reserved
0x71	**F1 (Blue)**
0x72	**F2 (Red)**
0x73	**F3 (Green)**
0x74	**F4 (Yellow)**
0x75	**F5**
0x76 - 0x7F	Reserved

Note: The elements identified in **bold** are the only ones which are forwarded as part of the device menu control feature.

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CEC Table 10 Broadcast System

System	Value	Bits 43210	Sound Carrier	Sound Modulation	Video Modulation	Vertical Frequency	Color sub-carrier
PAL B/G	0	00000	5.5 MHz	FM	neg	50 Hz	4.43 MHz
SECAM L'	1	00001	6.5 MHz	AM	pos	50 Hz	[7]
PAL M	2	00010	4.5 MHz	FM	neg	60 Hz	3.5756MHz
NTSC M	3	00011	4.5 MHz	FM	neg	60 Hz	3.5795MHz
PAL I	4	00100	6.0 MHz	FM	neg	50 Hz	4.43 MHz
SECAM DK	5	00101	6.5 MHz	FM	neg	50 Hz	[7]
SECAM B/G	6	00110	5.5 MHz	FM	neg	50 Hz	[7]
SECAM L	7	00111	6.5 MHz	AM	pos	50 Hz	[7]
PAL DK	8	01000	6.5 MHz	FM	neg	50 Hz	4.43 MHz
Future use	9	01001					
..	..	..					
Future use	30	11110					
Other System [8]	31	11111					

[7] Color sub-carriers SECAM: f_{OB} 4.25 MHz, f_{OR} 4.406 MHz

[8] The system is not defined. The receiving device decides locally what to do.

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ATTACHMENT B

High-Definition Multimedia Interface

Specification Version 1.3

Hitachi, Ltd.

Matsushita Electric Industrial Co., Ltd.

Philips Consumer Electronics, International B.V.

Silicon Image, Inc.

Sony Corporation

Thomson Inc.

Toshiba Corporation

June 22, 2006

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Preface

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Document Revision History

1.3	2006/06/22	Significant new features: - Type C “Mini-Connector” (4.1.9.5, 4.1.9.6) - Cable Categories 1 and 2 (4.2.6) - Deep Color [4:4:4] (6.5, 8.3.2) - Reference Cable Equalizer (4.2.3.2, 4.2.5, 4.2.6) - Higher-speed single-link (4.1.2, 4.2.3,through 4.2.6, 8.3.2) - xvYCC Enhanced Colorimetry (6.7.2.3) - Gamut Metadata transmission (5.3.12, 6.7.3, Appendix E)) - DST audio format (5.3.10, 7.6.3) - High-bitrate compressed audio formats (5.3.11, 7.2.4, 7.3.3, 7.6.2) - Auto-Lipsync Correction feature (8.3.2, 8.9) Updated normative reference from CEA-861-B to –D (1.2, throughout). Updated Overview for new features (3) Several minor editorial (throughout)
1.2a	2005/12/14	Changes to CEC supplement (see supplement for details) Eliminated I_{OFF} and made V_{OFF} normative (4.2.4) Changed CEC resistance to 5 ohms (4.2.10) Clarified DVI device discrimination (8.3.3) Several minor editorial (throughout)
1.2	2005/08/22	Removed limitations on Type A connector usage (4.1.2, 6.1) Required new connector mechanical features, optional in 1.1 (4.1.9) Required Sink support for future AC-coupled Sources (4.2.5) Add note regarding maximum ratings of Sink (4.2.5) Clarified Cable Assembly use of +5V Power (4.2.7) Removed incorrect testing method for DDC capacitance (4.2.8) Clarified when separate CEC lines on inputs are allowed (4.2.10) Add maximum resistance spec for interconnected CEC line (4.2.10) Remove CEC leakage current limit while in standby (4.2.10) Relaxed YC_BC_R output requirement for RGB devices (6.2.3) Added support for additional video formats (6.2.4, and 7.3.3, 8.2.1) Corrected sample rate requirement from 1000 ppm to $\pm$1000 ppm (7.2.6) Clarified use of Speaker Allocation Data Block (7.4) Added support for One Bit audio (7.9, and throughout) Clarified exception for 640x480p (VGA) declaration in EDID (8.3.4) Loosened requirement for duplicated DTD declarations (8.3.4) Added recommendation for setting Supports_AI (9.2) Clarified the behavior of Repeater to Sink with Supports_AI (9.3.2) Clarified rule for DVD-Audio ACP Packet transmission (9.3.5) Additional minor editorial (throughout)
1.1	2004/05/20	Permitted multi-rate native format support on Type A Sinks (4.1.2) Changed connector mechanical spec (4.1.9) Changed connector electrical spec (4.1.7) Removed CEC / +5V Power dependency for Source (4.2.7) Loosened regulation requirements for +5V Power (4.2.7)

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		Made HPD voltages consistent with new +5V Power (4.2.9) Clarified CEC connection requirements (4.2.10) Restricted CTLx values allowed in non-Preamble periods (5.2.1) Added new Packet Types (5.3.1) Clarified InfoFrame Packet requirements (5.3.5) Added ACP and ISRC Packet definitions and usage (5.3.7, 8.8, 9.3) Specified recommended handling of non-Subpacket 0 CS blocks (7.1) Clarified audio sample rate requirements (7.2.6) Disallowed Layout 1 2-channel (7.6) Clarified AVI transmission requirements (8.2.1) Added extension fields and clarified HDMI VSDB (8.3.2) Clarified DVI/HDMI device discrimination (8.3.3) Clarified HPD behavior (8.5) Clarified EDID values of Physical Addresses (8.7) Made minor editorial changes (throughout)
1.0	2002/12/09	Initial Release

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Intellectual Property Statement

Hitachi, Ltd., Matsushita Electric Industrial Co., Ltd., Philips Consumer Electronics International, B.V., Silicon Image, Inc., Sony Corporation, Thomson Inc., and Toshiba Corporation each may have patents and/or patent applications related to the High-Definition Multimedia Interface Specification. These companies have made available to the industry an Adopter Agreement that includes a limited, reciprocal patent license to certain of the electrical interfaces, mechanical interfaces, signals, signaling and coding protocols, and bus protocols described in the mandatory portions of the High-Definition Multimedia Interface Specification Release 1.3 published by HDMI Licensing, LLC.

Contact Information

The URL for the HDMI Founders web site is: http://www.HDMI.org.

Contribution

Silicon Image, Inc has made a significant contribution to this standard by editing the specification and developing the core technologies upon which this specification is based; including Transition Minimized Differential Signaling (TMDS®) technology.

Acknowledgement

HDMI founders acknowledge the concerted efforts of employees of Japan Aviation Electronics Industry, Limited and Molex Japan, who have made a significant contribution to this standard by developing the connector technology and the mechanical and electrical specifications for the required plugs and receptacles.

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1 Introduction

1.1 Purpose and Scope

This document constitutes the specification for the High-Definition Multimedia Interface (HDMI), version 1.3.

The High-Definition Multimedia Interface is provided for transmitting digital television audiovisual signals from DVD players, set-top boxes and other audiovisual sources to television sets, projectors and other video displays.

HDMI can carry high quality multi-channel audio data and can carry all standard and high-definition consumer electronics video formats. Content protection technology is available.

HDMI can also carry control and status information in both directions.

This specification completely describes the interface such that one could implement a complete transmission and interconnect solution or any portion of the interface. The underlying Transition Minimized Differential Signaling (TMDS)-based protocol and associated electrical signaling is described in detail. The mechanical specification of the connector and the signal placement within the connector are described.

A device that is compliant with this specification is interoperable with other compliant devices through the configuration and implementation provided for in this specification.

Mechanical, electrical, behavioral and protocol requirements necessary for compliance are described for sources, sinks and cables.

1.2 Normative References

The following standards contain provisions that, through reference in this text, constitute normative provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. If the referenced standard is dated, the reader is advised to use the version specified.

CEA, CEA-861-D, “A DTV Profile For Uncompressed High Speed Digital Interfaces”[1]

VESA, VESA E-EDID Standard, ENHANCED EXTENDED DISPLAY IDENTIFICATION DATA STANDARD Release A, Revision 1, February 9, 2000

VESA, VESA E-DDC Standard, ENHANCED DISPLAY DATA CHANNEL STANDARD Version 1, September 2, 1999

Philips Semiconductors, The I^2C-bus Specification, Version 2.1, January 2000

[1] All HDMI devices are required to comply with the requirements specified in CEA-861-D except where specifically noted in this document. The CEA-861-D term “source” should be read as “(HDMI) Source” and the terms “Display”, “Monitor” or “DTV Monitor” should be read as “(HDMI) Sink”.

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ITU, ITU-R BT.601-5 Studio encoding parameters of digital television for standard 4:3 and wide-screen 16:9 aspect ratios (October 1995)

ITU, ITU-R BT.709-5 Parameter values for the HDTV standards for production and international programme exchange (2002)

IEC, IEC 60958-1, “Digital audio interface – Part 1: General”, First edition 1999-12

IEC, IEC 60958-3, “Digital audio interface – Part 3: Consumer applications”, Third edition 2006-05[pw9]

IEC, IEC 61937, “Digital Audio - Interface for non-linear PCM encoded audio bitstreams applying IEC 60958”, First edition 2000-04

IEC, IEC 61966-2-4: “Multimedia systems and equipment - Colour measurement and management - Part 2-4: Colour management - Extended-gamut YCC colour space for video applications – xvYCC”, January 2006

DDWG, “Digital Visual Interface,” Revision 1.0, April 2, 1999 (DVI)

DVD Forum, “DVD Specifications for Read-Only Disc”, “Part 4: AUDIO SPECIFICATIONS”, Version 1, March 1999.

DVD Forum, “DVD Specifications for Read-Only Disc”, “Part 4: AUDIO SPECIFICATIONS”, Version-up Information (from 1.1 to 1.2), May 2000.

Digital Content Protection LLC, “High-bandwidth Digital Content Protection System Specification”, Revision 1.10 (HDCP)

Royal Philips Electronics and SONY Corporation, “Super Audio CD System Description Version 2.0”

1.3 Informative References

The following documents contain information that is useful in understanding this standard. Some of these documents are drafts of standards that may become normative references in a future release of this standard.

ANSI/SMPTE, SMPTE Standard 170M (1999) for Television – Composite Analog Video Signal – NTSC for Studio Applications

ANSI/SMPTE, SMPTE Standard 274M

ANSI/SMPTE, SMPTE Standard 296M

1.4 Organization of this document

This specification is organized as follows:

- Chapter 1 introduces HDMI, describes the purpose and scope of this document, references, organization of the document and usages and conventions.
- Chapter 2 defines terms and acronyms used throughout this document.
- Chapter 3 provides a high-level overview of the operation of HDMI.

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- Chapter 4 describes the details of the Physical Layer of HDMI including basic electrical specifications and mechanical specifications of cables and connectors.
- Chapter 5 describes the Signaling and Encoding used by HDMI including descriptions of the different periods and encoding types used to transmit audio, video, and control data types and packet definitions for audio and auxiliary data.
- Chapter 6 describes Video related issues including video format timings, pixel encodings (RGB, YC_BC_R), colorimetry and corresponding requirements.
- Chapter 7 describes Audio related issues including audio clock regeneration, placement of audio samples within packets, packet timing requirements, audio sample rates and requirements, and channel/speaker assignments.
- Chapter 8 describes Control and Configuration functions, mechanisms and requirements, including use of the E-EDID, and InfoFrames.
- Chapter 9 describes the Content protection used for HDMI.
- Appendix A describes the usage of Repeaters and Switches.
- Appendix B describes restrictions related to the use of the Type B connector.
- Appendix C describes DVI compatibility.
- Appendix D describes additional details of Deep Color not covered in chapter 6, including example state machines and details of audio transmission in a Deep Color mode.
- Appendix E describes data structures and characteristics of gamut boundary descriptions, used when transmitting video using xvYCC colorimetry.
- Appendix F recommends a number of rules regarding a Sink's indication of video format support and automatic configuration of video output format for a Source.
- Supplement 1 describes use of the Consumer Electronics Control (CEC) line and protocol.

1.5 Usages and Conventions

bit N	Bits are numbered in little-endian format, i.e. the least-significant bit of a byte or word is referred to as bit 0.
D[X:Y]	Bit field representation covering bit X to bit Y (inclusive) of value or field D.
0xNN	Hexadecimal representation of base-16 numbers are represented using 'C' language notation, preceded by '0x'.
0bNN	Binary (base-2) numbers are represented using 'C' language notation, preceded by '0b'.
NN	Decimal (base-10) numbers are represented using no additional prefixes or suffixes.

Within this specification, any descriptions of data structures, values or sequences that occur on the HDMI interface should be interpreted only as data structures, values and sequences that are transmitted by the HDMI Source. Due to the possibility of errors during the transmission, these items should not be construed as data structures, values or sequences that are guaranteed to be detected by the HDMI Sink.

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2 Definitions

2.1 Conformance Levels

expected	A key word used to describe the behavior of the hardware or software in the design models *assumed* by this specification. Other hardware and software design models may also be implemented.
may	A key word that indicates flexibility of choice with *no implied preferenc*e.
shall	A key word indicating a mandatory requirement. Designers are *required* to implement all such mandatory requirements.
should	A key word indicating flexibility of choice with a strongly preferred alternative. Equivalent to the phrase *is recommended*.
reserved fields	A set of bits within a data structure that are defined in this specification as reserved, and are not otherwise used. Implementations of this specification shall zero these fields. Future revisions of this specification, however, may define their usage.
reserved values	A set of values for a field that are defined in this specification as reserved, and are not otherwise used. Implementations of this specification shall not generate these values for the field. Future revisions of this specification, however, may define their usage.

2.2 Glossary of Terms

(Audio) Channel	Audio data intended to be delivered to a single audio speaker.
(Audio) Sample Clock	Original clock related to the audio input samples at the Source or the generated clock used to time the output of audio samples.
BCH	Error correction technique named after the developers: Bose, Chauduri, and Hocquenghem.
Byte	Eight bits of data.
CEA Extension	A 128 byte EDID 1.3-compatible extension block defined in CEA-861-D, designed to allow declaration of audio formats, additional video formats (beyond those in the base EDID structure) and other characteristics of the Sink..
CEC Root (Device)	A device, generally a display (Sink) device, formally defined by the following rule: A device that has no HDMI output or, a device that has chosen to take the physical address 0.0.0.0 (see Section 8.7).
Compressed (Audio)	All audio formats carried by HDMI other than L-PCM and One Bit Audio.
Data Stream Disparity	Integer indicating “DC-offset” level of link. A positive value represents the excess number of “1”s that have been transmitted. A negative value represents the excess number of “0”s that have been transmitted.

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Direct Stream Transport	An audio format which is a lossless compression of Direct Stream Digital (DSD), as used in SuperAudio CD. DST is described in ISO/IEC 14496, part 3, Amendment 6: Lossless coding of oversampled audio.
Downstream	In the direction of the primary audio and video data flow, i.e. towards the Sink (e.g. display).
DVD-Audio	Disk format conforming to any version of “DVD Specifications for Read-Only Disc”, “Part 4: AUDIO SPECIFICATIONS”.
(HDMI) Source	A device with an HDMI output.
(HDMI) Sink	A device with an HDMI input.
(HDMI) Repeater	A device with one or more HDMI inputs and one or more HDMI outputs. Repeater devices shall simultaneously behave as both an HDMI Sink and an HDMI Source.
InfoFrame	A data structure defined in CEA-861-D that is designed to carry a variety of auxiliary data items regarding the audio or video streams or the source device and is carried from Source to Sink across HDMI.
Multi-channel	Audio with more than 2 channels. Typically this term is applied to 6 (5.1) channel streams. Also called surround formats.
One Bit Audio	1-bit Delta-Sigma modulated signal stream such as that used by Super Audio CD.
Pixel	Picture Element. Refers to the actual element of the picture and the data in the digital video stream representing such an element.
Pixel Encoding	Bit placement and sequencing for the components of a pixel for a particular color space and chroma sampling.
Receiver	A component that is responsible for receiving the four differential TMDS input pairs at the input to an HDMI Sink and converting those signals into a digital output indicating a 24 bit, 12 bit, or 6 bit TMDS decoded word and indicating the TMDS coding mode used to decode those bits. This digital output may be contained within a semiconductor device or may be output from a semiconductor device.
(TMDS) Character	A 10-bit TMDS-encoded value. One such value is carried on each of the three data channels for each cycle of the TMDS clock.
Stereo	2 channel audio.
Stream	A time-ordered set of digital data originating from one Source and terminating at zero or more Sinks. A stream is characterized by bounded bandwidth requirements.
Super Audio CD	Disk format of “Super Audio CD System Description”, see http://www.licensing.philips.com.
T_{bit}	Time duration of a single bit carried across the TMDS data channels.

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$T_{character}$	Time duration of a single TMDS character carried across the TMDS data channels. This is equal to $10*T_{bit}$.
Transmitter	A component that is responsible for driving the four differential TMDS output pairs into an HDMI output and for clocking the data driven into those four output pairs.
Video Field	The period from one VSYNC active edge to the next VSYNC active edge.
Video Format	A video format is sufficiently defined such that when it is received at the monitor, the monitor has enough information to properly display the video to the user. The definition of each format includes a Video Format Timing, the picture aspect ratio, and a colorimetry space.
Video Format Timing	The waveform associated with a video format. Note that a specific Video Format Timing may be associated with more than one Video Format (e.g., 720X480p@4:3 and 720X480p@16:9).
YC_BC_R	Digital representation of any video signal using one of several luminance/color-difference color spaces.

2.3 Acronyms and Abbreviations

ANSI	American National Standards Institute
AVI	Auxiliary Video Information
CEA	Consumer Electronics Association
CEC	Consumer Electronics Control
CTS	Cycle Time Stamp
DDC	Display Data Channel
DDWG	Digital Display Working Group
DST	Direct Stream Transport
DTD	Detailed Timing Descriptor
DTV	Digital Television
DVD	Digital Versatile Disc
DVI	Digital Visual Interface
E-DDC	Enhanced Display Data Channel
E-EDID	Enhanced Extended Display Identification Data
ECC	Error Correction Code

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EDID	Extended Display Identification Data
EIA	Electronic Industries Alliance
HDCP	High-bandwidth Digital Content Protection
HDMI	High-Definition Multimedia Interface
HDTV	High-Definition Television
HPD	Hot Plug Detect
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ITU	International Telecommunications Union
L-PCM	Linear Pulse-Code Modulation
LSb	least significant bit
MPEG	Moving Picture Experts Group
MSb	most significant bit
N.C.	No connect.
PCB	Printed Circuit Board
Rx	Receiver
SMPTE	Society of Motion Picture & Television Engineers
STB	Set-Top Box
SVD	Short Video Descriptor
TERC4	TMDS Error Reduction Coding – 4 bit
TMDS	Transition Minimized Differential Signaling
Tx	Transmitter
VESA	Video Electronics Standards Association
VSDB	Vendor-Specific Data Block

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3 Overview

HDMI system architecture is defined to consist of Sources and Sinks. A given device may have one or more HDMI inputs and one or more HDMI outputs. Each HDMI input on these devices shall follow all of the rules for an HDMI Sink and each HDMI output shall follow all of the rules for an HDMI Source.

As shown in *Figure 3-1,* the HDMI cable and connectors carry four differential pairs that make up the TMDS data and clock channels. These channels are used to carry video, audio and auxiliary data. In addition, HDMI carries a VESA DDC channel. The DDC is used for configuration and status exchange between a single Source and a single Sink. The optional CEC protocol provides high-level control functions between all of the various audiovisual products in a user's environment.

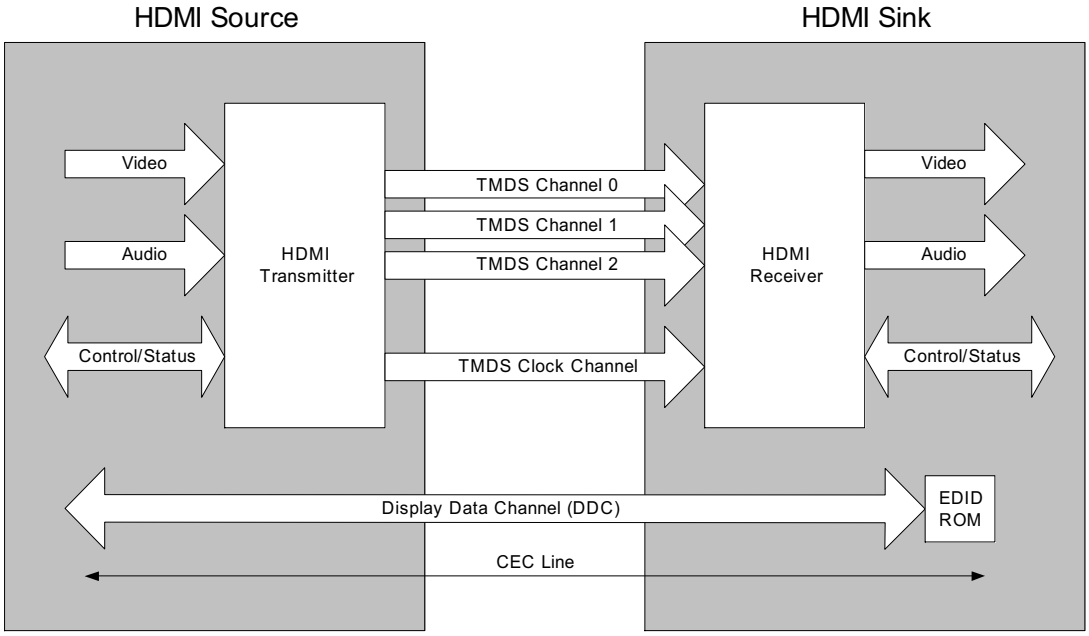


Figure 3-1 HDMI Block Diagram

Audio, video and auxiliary data is transmitted across the three TMDS data channels. A TMDS clock, typically running at the video pixel rate, is transmitted on the TMDS clock channel and is used by the receiver as a frequency reference for data recovery on the three TMDS data channels. At the source, TMDS encoding converts the 8 bits per TMDS data channel into the 10 bit DC-balanced, transition minimized sequence which is then transmitted serially across the pair at a rate of 10 bits per TMDS clock period.

Video data can have a pixel size of 24, 30, 36 or 48 bits. Video at the default 24-bit color depth is carried at a TMDS clock rate equal to the pixel clock rate. Higher color depths are carried using a correspondingly higher TMDS clock rate. Video formats with TMDS rates below 25MHz (e.g. 13.5MHz for 480i/NTSC) can be transmitted using a pixel-repetition scheme. The video pixels can be encoded in either RGB, YC_BC_R 4:4:4 or YC_BC_R 4:2:2 formats.

In order to transmit audio and auxiliary data across the TMDS channels, HDMI uses a packet structure. In order to attain the higher reliability required of audio and control data, this data is

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protected with a BCH error correction code and is encoded using a special error reduction coding to produce the 10-bit word that is transmitted.

Basic audio functionality consists of a single IEC 60958 L-PCM audio stream at sample rates of 32kHz, 44.1kHz or 48kHz. This can accommodate any normal stereo stream. Optionally, HDMI can carry such audio at sample rates up to 192KHz and with 3 to 8 audio channels. HDMI can also carry an IEC 61937 compressed (e.g. surround-sound) audio stream at bit rates up to 24.576Mbps. HDMI can also carry from 2 to 8 channels of One Bit Audio and a compressed form of One Bit Audio called DST.

The DDC is used by the Source to read the Sink's Enhanced Extended Display Identification Data (E-EDID) in order to discover the Sink's configuration and/or capabilities.

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4 Physical Layer

4.1 Connectors and Cables

4.1.1 Overview of Connectors

A device's external HDMI connection shall be presented via one of the three specified HDMI connectors, Type A, Type B or Type C. This connector can be attached directly to the device or can be attached via a cable adapter that is shipped with the device.

All three connectors carry all required HDMI signals, including a TMDS link. The Type B connector is slightly larger and carries a second TMDS link, which is necessary to support very high resolution displays using dual link. The Type C connector carries the same signals as the Type A but is more compact and intended for mobile applications.

Passive cable adapters between connector types are specified.

4.1.2 Connector Support Requirements

All features and functions are equally available to all three connectors.

4.1.3 Dual-Link

To support DVI signals greater than 165Mpixels/sec, the dual-link capability of the Type B connector shall be used. To support DVI signals less than or equal to 165Mpixels/sec, single-link operation shall be used.

To support very high-speed HDMI signals, the dual-link capability of the Type B connector is available. The single-link to dual-link crossover frequency for HDMI will be defined in a future specification and will be greater than 340Mpixels/sec. Dual-link cannot be used for formats below that crossover frequency.

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4.1.4 Connector Pin Assignments

Table 4-1 Type A Connector Pin Assignment

PIN	Signal Assignment
1	TMDS Data2+
3	TMDS Data2–
5	TMDS Data1 Shield
7	TMDS Data0+
9	TMDS Data0–
11	TMDS Clock Shield
13	CEC
15	SCL
17	DDC/CEC Ground
19	Hot Plug Detect

PIN	Signal Assignment
2	TMDS Data2 Shield
4	TMDS Data1+
6	TMDS Data1–
8	TMDS Data0 Shield
10	TMDS Clock+
12	TMDS Clock–
14	Reserved (N.C. on device)
16	SDA
18	+5V Power

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Table 4-2 Type B Connector Pin Assignment

PIN	Signal Assignment
1	TMDS Data2+
3	TMDS Data2-
5	TMDS Data1 Shield
7	TMDS Data0+
9	TMDS Data0-
11	TMDS Clock Shield
13	TMDS Data5+
15	TMDS Data5-
17	TMDS Data4 Shield
19	TMDS Data3+
21	TMDS Data3-
23	Reserved (N.C. on device)
25	SCL
27	DDC/CEC Ground
29	Hot Plug Detect

PIN	Signal Assignment
2	TMDS Data2 Shield
4	TMDS Data1+
6	TMDS Data1-
8	TMDS Data0 Shield
10	TMDS Clock+
12	TMDS Clock-
14	TMDS Data5 Shield
16	TMDS Data4+
18	TMDS Data4-
20	TMDS Data3 Shield
22	CEC
24	Reserved (N.C. on device)
26	SDA
28	+5V Power

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Table 4-3 Type C Connector Pin Assignment

PIN	Signal Assignment
1	TMDS Data2 Shield
2	TMDS Data2+
3	TMDS Data2-
4	TMDS Data1 Shield
5	TMDS Data1+
6	TMDS Data1-
7	TMDS Data0 Shield
8	TMDS Data0+
9	TMDS Data0-
10	TMDS Clock Shield
11	TMDS Clock+
12	TMDS Clock-
13	DDC/CEC Ground
14	CEC
15	SCL
16	SDA
17	Reserved
18	+5V Power
19	Hot Plug Detect

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4.1.5 Contact sequence

Table 4-4 Connector Contact Sequence

Connection	Signals	
	Type A & C Connectors	Type B Connector
First Make	Connector shell	Connector shell
Second Make	Pins 1 - 17 and pin 19	Pins 1 - 27 and pin 29
Third Make	Pin18 (+5V Power)	Pin28 (+5V Power)

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4.1.6 Connector Mechanical Performance

Table 4-5 Type A and Type C Plug and Receptacle Mechanical Performance

Item	Test Condition	Requirement	
Vibration	Amplitude : 1.52mm P-P or 147m/s^2 {15G} Sweep time: 50-2000-50Hz in 20 minutes. Duration : 12 times in each (total of 36 Times) X, Y, Z axes. Electrical load : DC100mA current shall be Flowed during the test. (ANSI/EIA-364-28 Condition III)	Appearance	No Damage
		Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell Part : Change from initial value: 50 milliohms maximum.
		Discontinuity	1 μsec maximum.
Shock	Pulse width: 11 msec., Waveform : half sine, 490m/s^2{50G}, 3 strokes in each X.Y.Z. axes (ANSI/EIA-364-27, Condition A)	Appearance	No Damage
		Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell : Change from initial value: 50 milliohms maximum.
		Discontinuity	1 μsec maximum.
Durability	Measure contact and shell resistance after Following. Automatic cycling : Type A: 10,000 cycles at 100 ± 50 cycles per hour Type C: 5,000 cycles at 100 ± 50 cycles per hour	Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell : Change from initial value: 50 milliohms maximum.

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Item	Test Condition	Requirement	
Insertion / Withdrawal Force	Insertion and withdrawal speed : 25mm/minute. (ANSI/EIA-364-13)	Withdrawal force	Type A: 9.8N {1.0kgf} minimum 39.2N {4.0kgf} maximum Type C: 7N minimum 25N maximum
		Insertion force	44.1N {4.5kgf} maximum
Cable Flex	100 cycles in each of 2 planes Dimension X = 3.7 x Cable Diameter. (ANSI/EIA-364-41C, Condition I)	Discontinuity	1 μsec maximum.
		Dielectric Withstanding Voltage and Insulation Resistance	Conform to item of dielectric withstanding voltage and insulation resistance

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4.1.7 Connector Electrical Characteristics

4.1.7.1 Electrical Performance

Table 4-6 Electrical Performance

Item	Test Condition	Requirement
Contact Resistance	Mated connectors, Contact : measure by dry circuit, 20 mVolts maximum.,10mA. Shell : measured by open circuit, 5 Volts maximum ,100mA. (ANSI/EIA-364-06B)	Initial Contact resistance excluding conductor resistance: 10 milliohms maximum . (Target design value)
Dielectric Strength	Unmated connectors, apply 500 Volts AC(RMS) between adjacent terminal or ground. Mated connector, apply 300 Volts AC(RMS.) between adjacent terminal and ground. (ANSI/EIA-364-20C, Method A)	No Breakdown
Insulation Resistance	Unmated connectors, apply 500 Volts DC between adjacent terminal or ground. (ANSI/EIA 364-21C)	100 megaohms minimum (unmated)
	Mated connectors, apply 150 Volts DC between adjacent terminal or ground.	10 megaohms minimum (mated)
Contact Current Rating	55 °C, maximum ambient 85 °C, maximum temperature change (ANSI/EIA-364-70A)	0.5 A minimum
Applied Voltage Rating	40 Volts AC (RMS.) continuous maximum, on any signal pin with respect to the shield.	No Breakdown
Electrostatic Discharge	Test unmated each connectors from 1 kVolt to 8 kVolts in 1 kVolt steps using 8mm ball probe. (IEC-801-2)	No evidence of Discharge to Contacts at 8 kVolts

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Item	Test Condition	Requirement
TMDS Signals Time Domain Impedance	Rise time ≤ 200 psec (10%-90%). Signal to Ground pin ratio per HDMI designation. Differential Measurement Specimen Environment Impedance = 100 ohms differential Source-side receptacle connector mounted on a controlled impedance PCB fixture. (ANSI/EIA-364-108)	Connector Area : Type A: 100 ohms ±15% Type C: 100 ohms ±25% Transition Area : 100 ohms ±15% Cable Area : 100 ohms ±10%
TMDS Signals Time Domain Cross talk FEXT	Rise time ≤ 200 psec (10%-90%). Signal to Ground pin ratio per HDMI designation. Differential Measurement Specimen Environment Impedance = 100 ohms differential. Source-side receptacle connector mounted on controlled impedance PCB fixture. Driven pair and victim pair. (ANSI/EIA-364-90)	Type A: 5% maximum Type C: 10% maximum

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4.1.8 Connector Environmental Characteristics

4.1.8.1 Environmental Performance

Table 4-7 Connector Environmental Performance

Item	Test Condition		Requirement	
Thermal Shock	10 cycles of: a) -55°Cfor 30 minutes b) +85°C for 30 minutes (ANSI/EIA-364-32C, Condition I)		Appearance	No Damage
			Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell Part : Change from initial value: 50 milliohms maximum.
Humidity	A	Mate connectors together and perform the test as follows. Temperature : +25 to +85°C Relative Humidity : 80 to 95% Duration : 4 cycles (96 hours) Upon completion of the test, specimens shall be conditioned at ambient room conditions for 24 hours, after which the specified measurements shall be performed. (ANSI/EIA-364-31B)	Appearance	No Damage
			Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell : Change from initial value: 50 milliohms maximum.
	B	Unmated each connectors and perform the test as follows. Temperature : +25 to +85°C Relative Humidity : 80 to 95% Duration : 4 cycles (96 hours) Upon completion of the test, specimens shall be conditioned at ambient room conditions for 24 hours, after which the specified measurements shall be performed. (ANSI/EIA-364-31B)	Appearance	No Damage
			Dielectric Withstanding Voltage and Insulation Resistance	Conform to item of Dielectric Withstanding Voltage and Insulation Resistance

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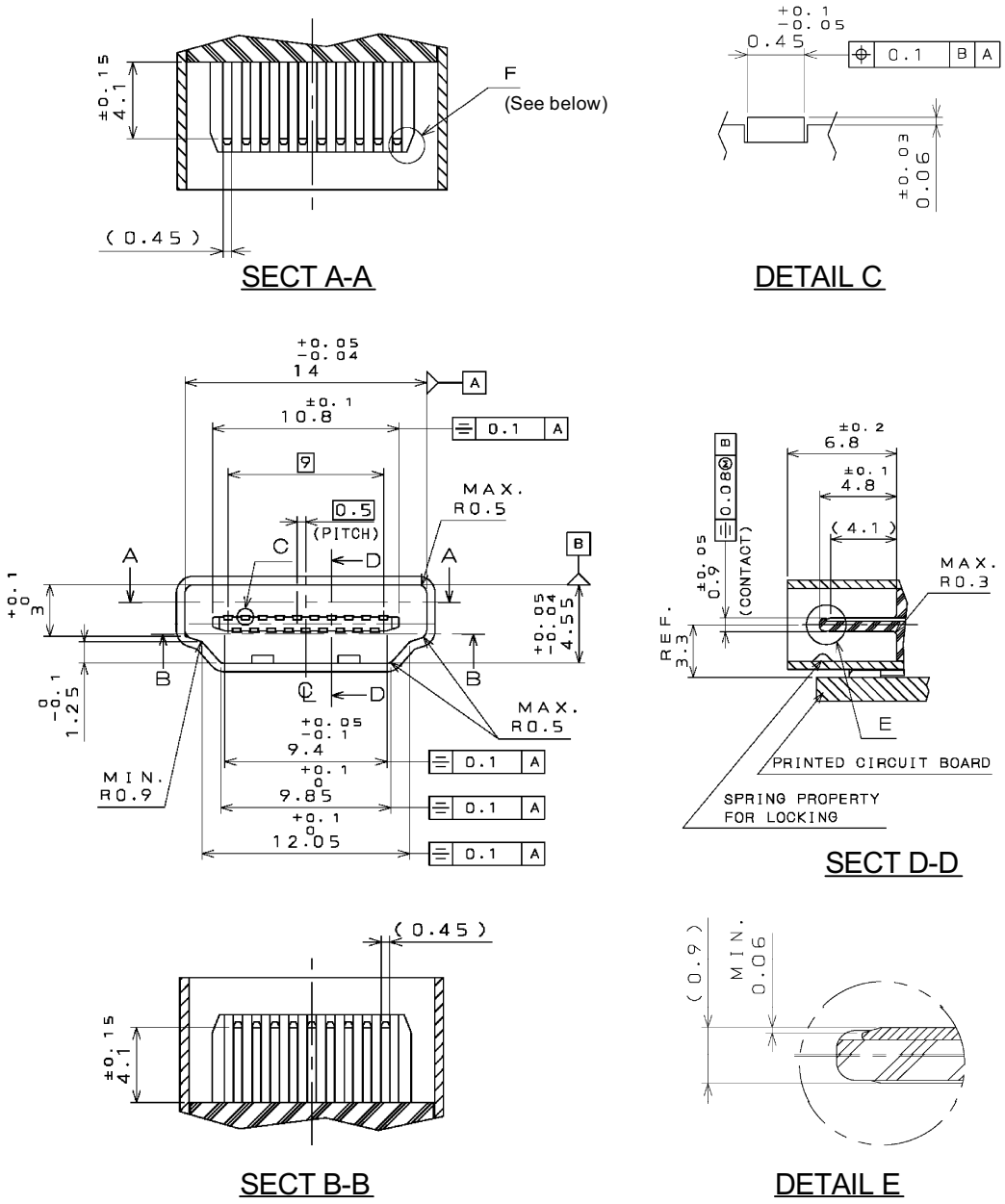
Item	Test Condition	Requirement	
Thermal Aging	Mate connectors and expose to +105 ± 2°C for 250 hours. Upon completion of the exposure period, the test specimens shall be conditioned at ambient room conditions for 1 to 2 hours, after which the specified measurements shall be performed. (ANSI/EIA-364-17B, Condition 4, Method A)	Appearance	No Damage
		Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell Part : Change from initial value: 50 milliohms maximum.

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4.1.9 Connector Drawings – Mating Interface Dimensions

All dimensions in millimeters.

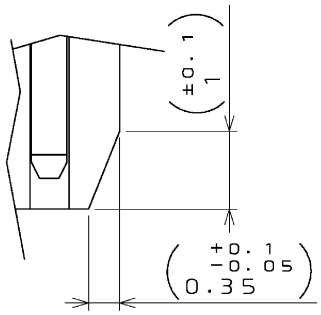
4.1.9.1 Type A Receptacle



- The shell shall have springs for locking. Additional springs may be used for EMI reduction.
- The spring property for locking shall be activated by the locking hole of the plug shell.

Figure 4-1 Type A Receptacle Mating Interface Dimensions

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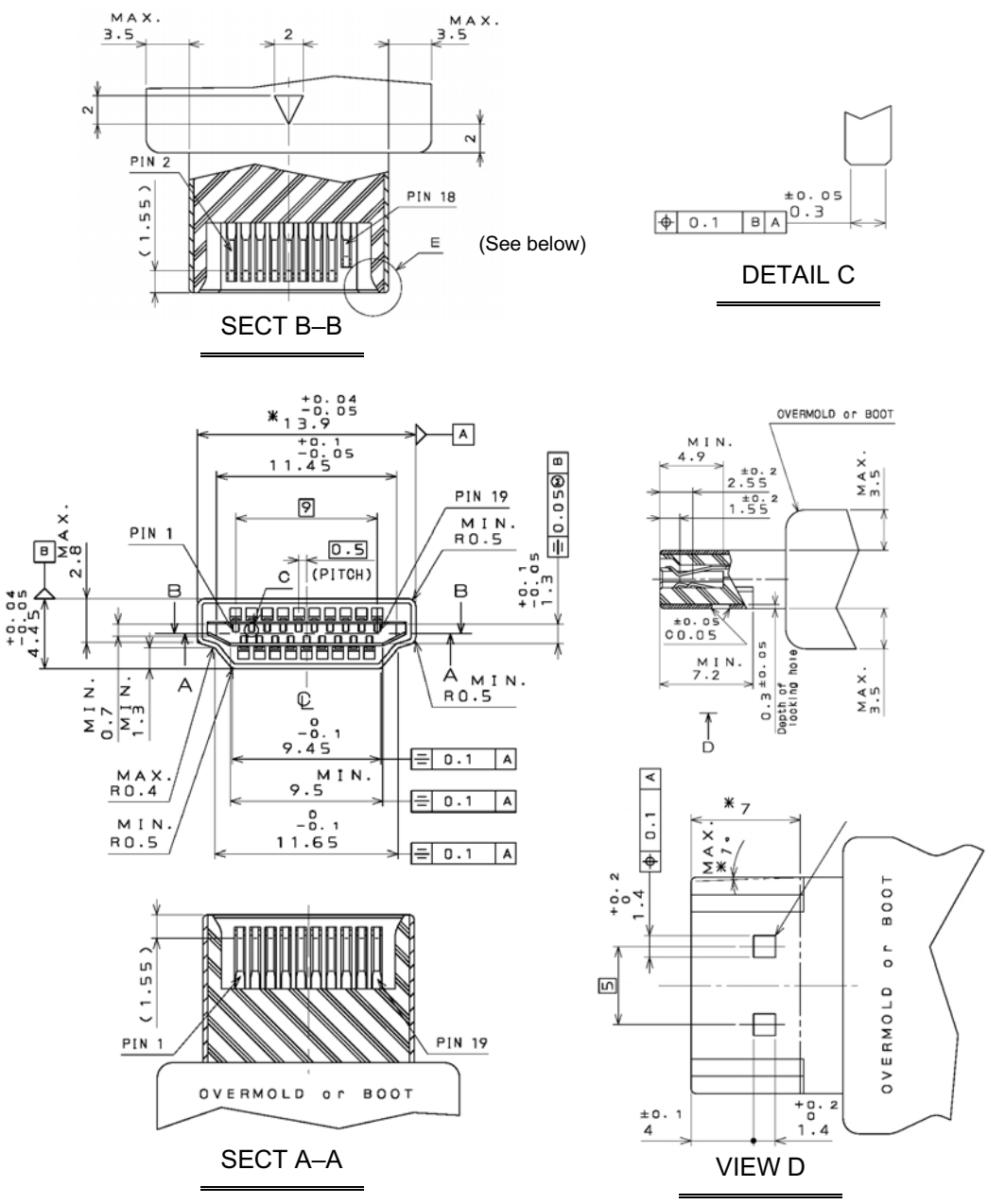
DETAIL F

- The form shown above is required. This feature will reduce the likelihood of damage to the receptacle insulator under rough operation.

Figure 4-1–continued; Type A Receptacle, Detail F

LENOVO EXHIBIT 1008 - 248/963

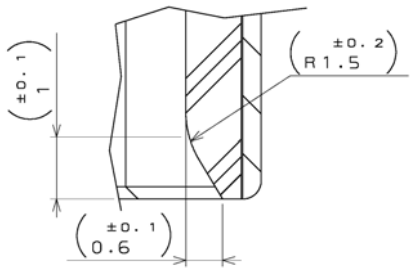
4.1.9.2 Type A Plug



- The dimension of *13.9mm (+0.04 / -0.05) (on main section) should be measured at the point *7mm (on view D). The taper (on view D) shall be one degree max.
- The shell should not have a dimple other than the ones for locking.

Figure 4-2 Type A Plug Mating Interface Dimensions

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DETAIL E

- The form shown above is required. This feature will reduce the likelihood of damage to the receptacle insulator under rough operation.

Figure 4-2-continued; Type A Plug, Detail E

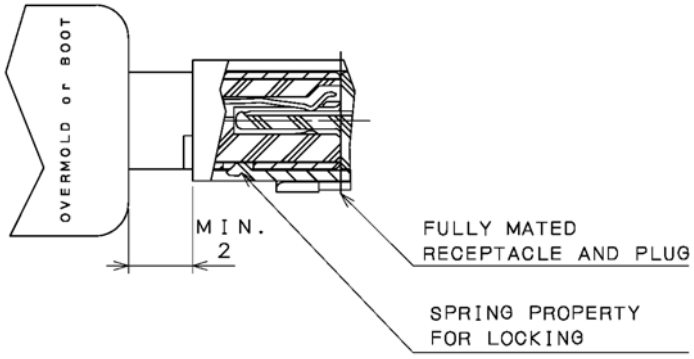


Figure 4-3 Type A Receptacle and Plug Mated Condition

It is recommended that products using Type A connectors be designed to ensure that cable bends are not tighter than that shown in Figure 4-4.

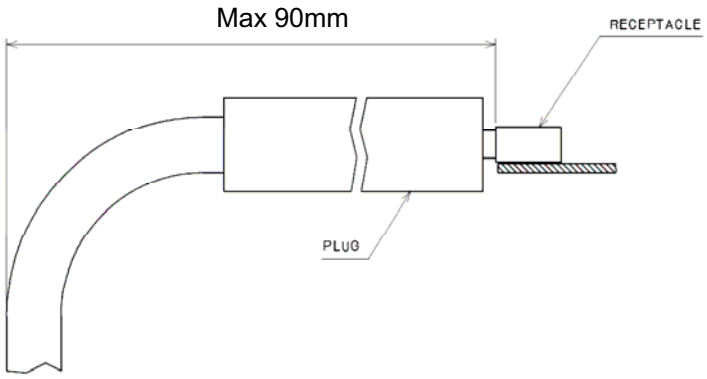
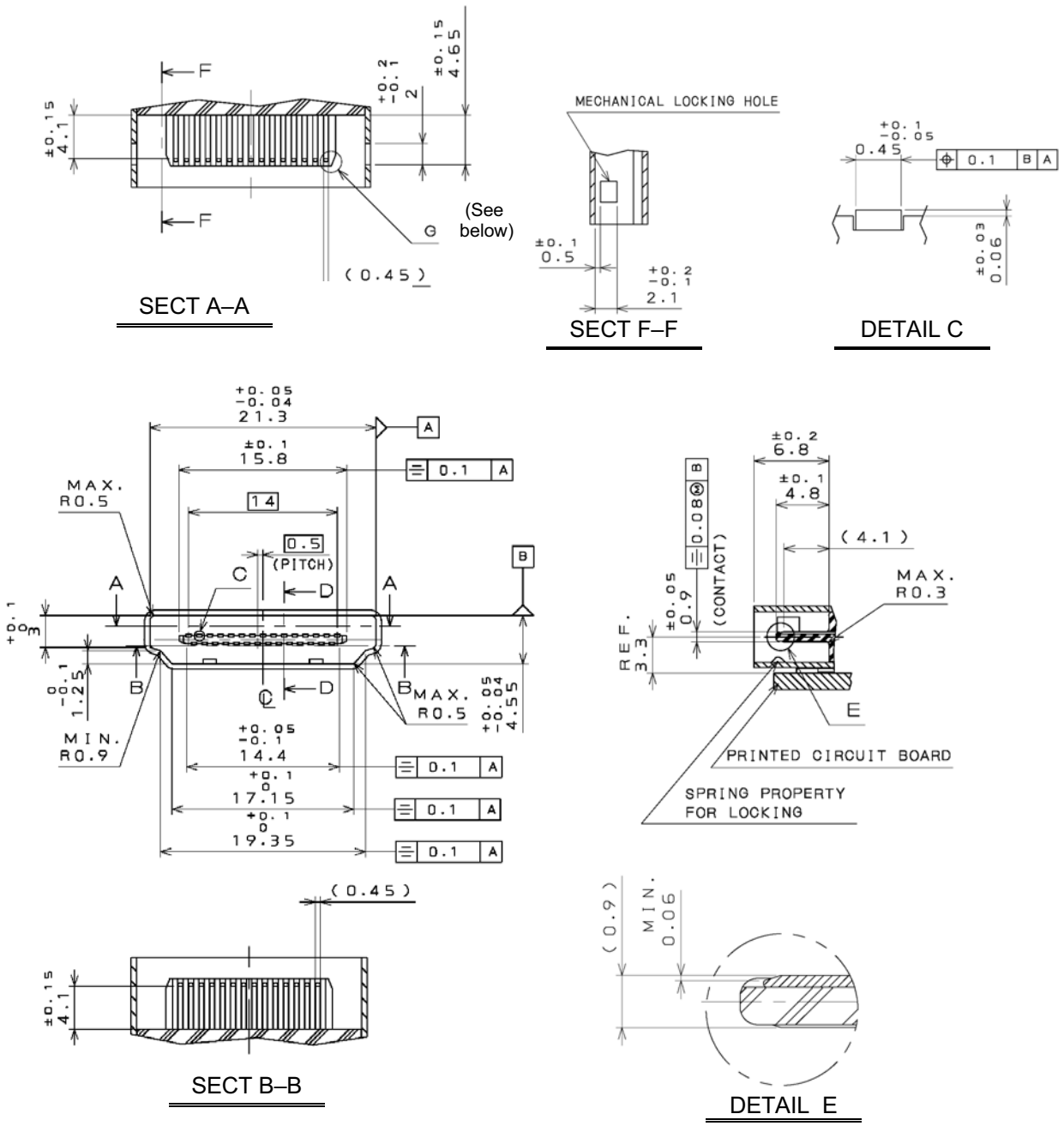


Figure 4-4 Type A Cable – Minimum Recommended Cable Bend

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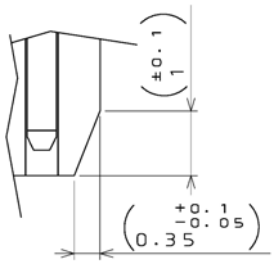
4.1.9.3 Type B Receptacle



- The shell shall have springs for locking. Additional springs may be used for EMI reduction.
- The spring property for locking shall be activated by the locking hole of the plug shell.

Figure 4-5 Type B Receptacle Mating Interface Dimensions

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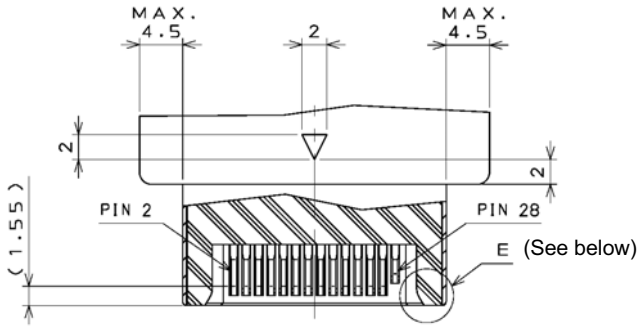
DETAIL G

- The form shown above is required. This feature will reduce the likelihood of damage to the receptacle insulator under rough operation.

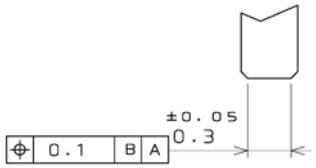
Figure 4-5-continued; Type B Receptacle, Detail G

LENOVO EXHIBIT 1008 - 252/963

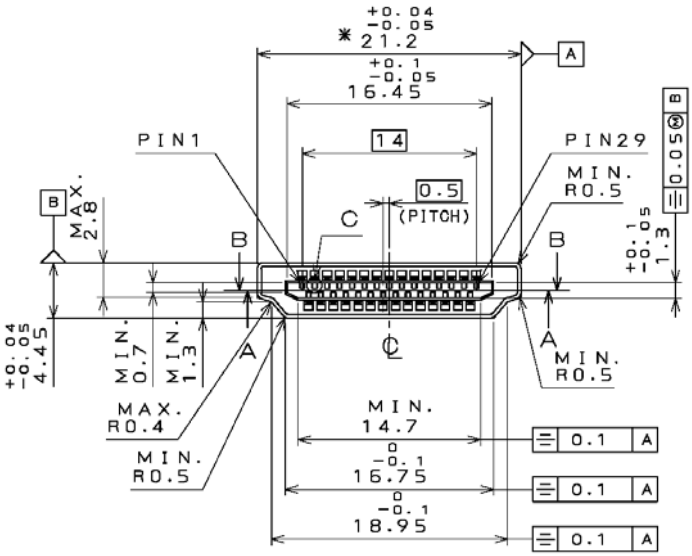
4.1.9.4 Type B Plug

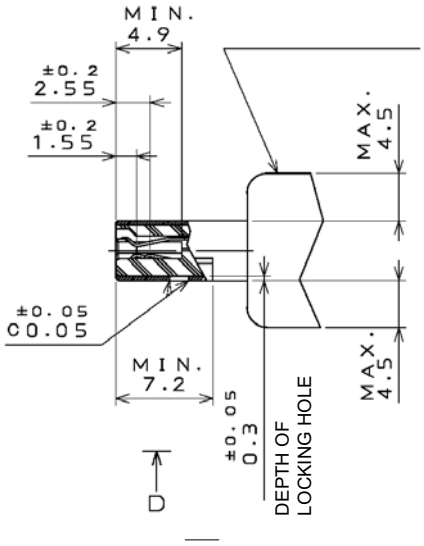


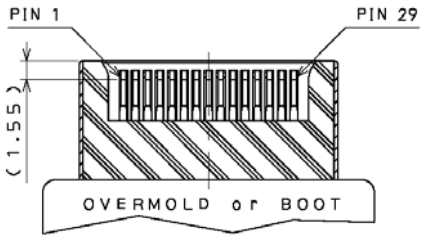
SECT B–B



DETAIL C





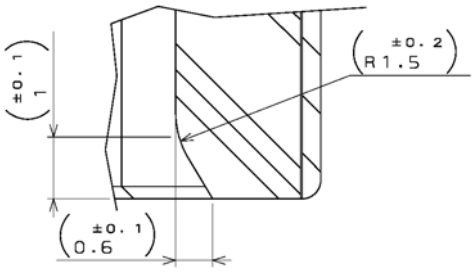


SECT A–A

"VIEW D" → NEXT PAGE

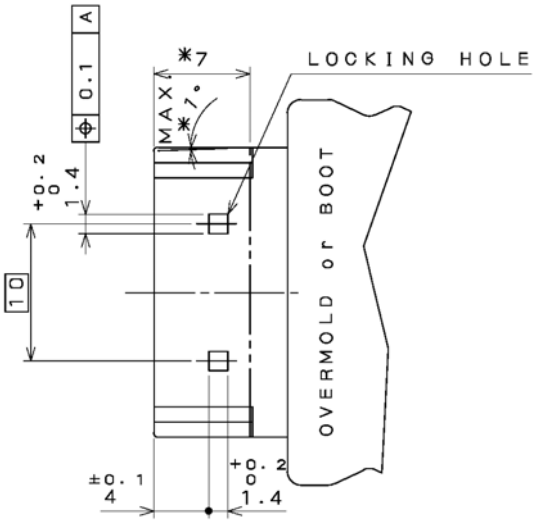
- The dimension of *21.2mm (+0.04 / -0.05) (on main section) should be measured at the point *7mm (on view D). The taper (on view D) shall be one degree max.
- The shell should not have a dimple other than the ones for locking.

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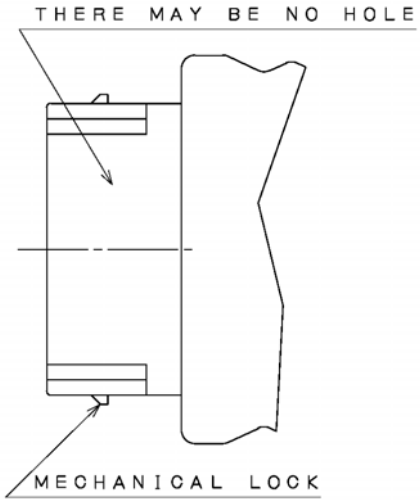


DETAIL E

- The form shown above is required. This feature will reduce the likelihood of damage to the receptacle insulator under rough operation.



FRICTION LOCK TYPE



MECHANICAL LOCK TYPE
The spring property for locking should be activated by the locking hole of the plug shell.

VIEW D

Figure 4-6 Type B Plug Mating Interface Dimensions

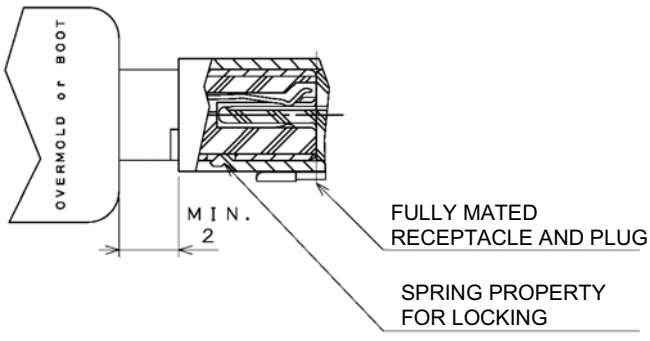
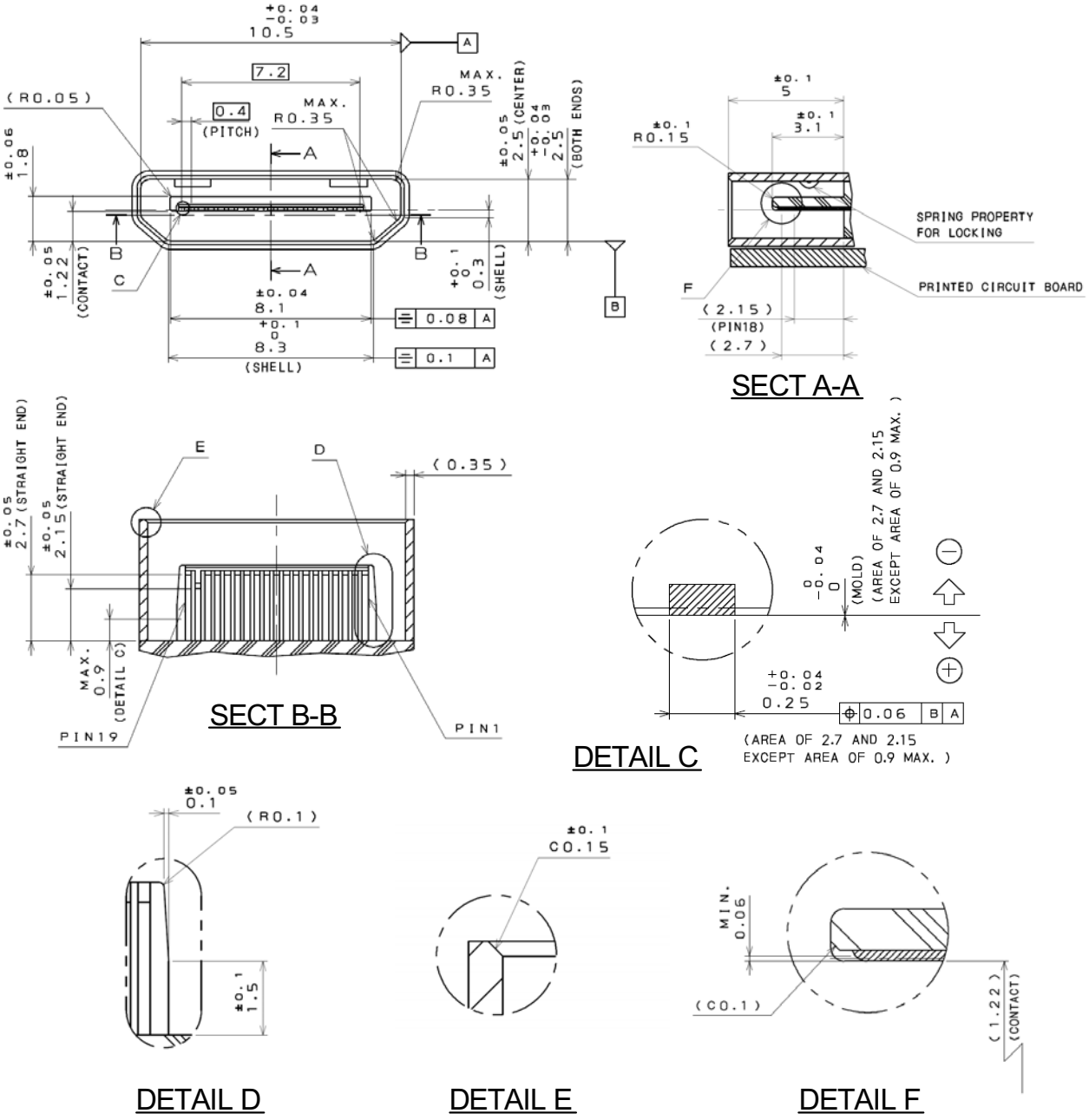


Figure 4-7 Type B Receptacle and Plug Mated Condition

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4.1.9.5 Type C Receptacle

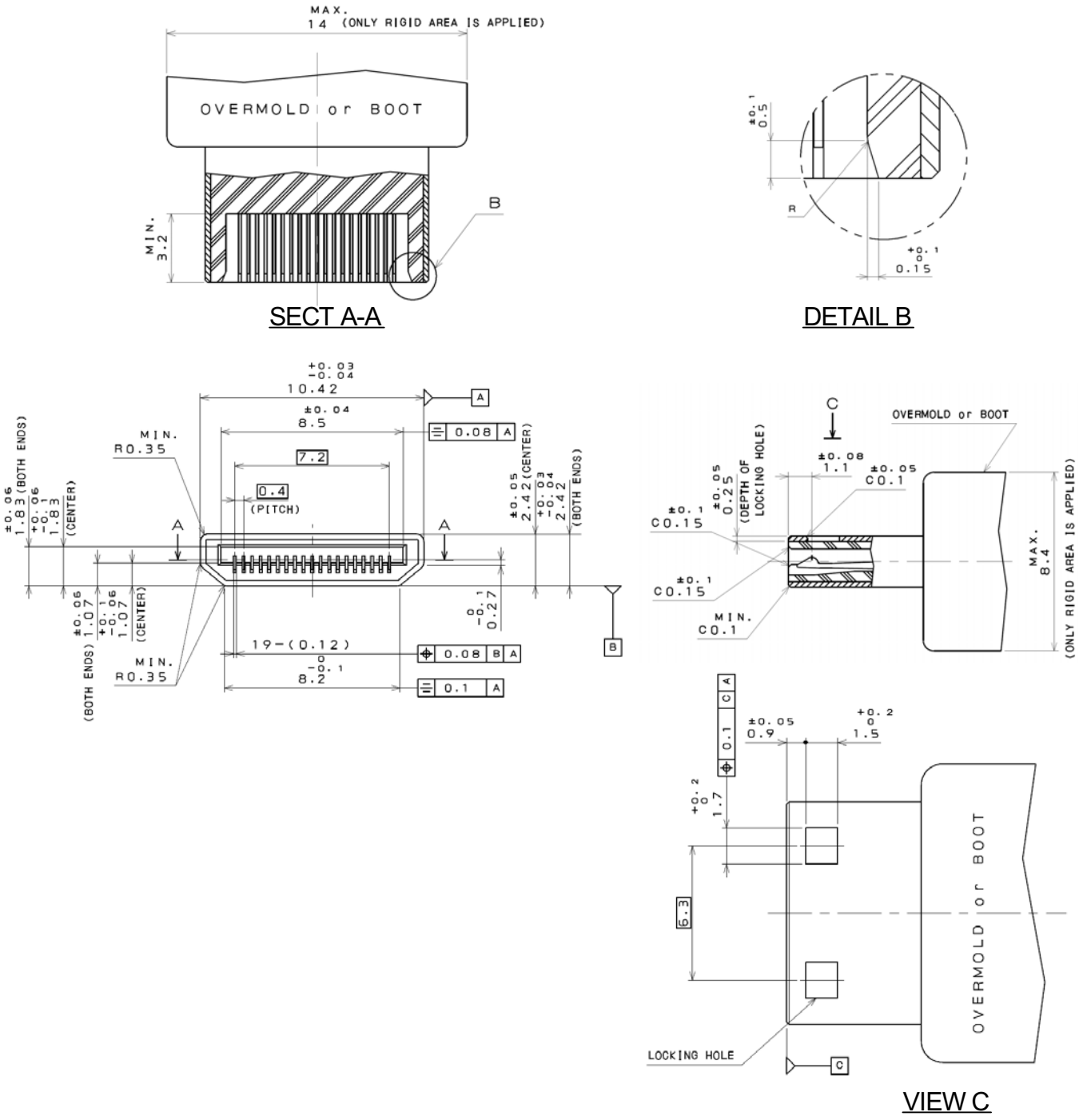


- The shell shall have spring for locking. Additional springs may be used for EMI reduction
- The spring property for locking shall be activated by the locking hole of the plug shell.

Figure 4-8 Type C Receptacle Mating Interface Dimensions

LENOVO EXHIBIT 1008 - 255/963

4.1.9.6 Type C Plug



- The shell should not have a dimple other than the ones for locking.
- The cable should have a maximum diameter of 7mm

Figure 4-9 Type C Plug Mating Interface Dimensions

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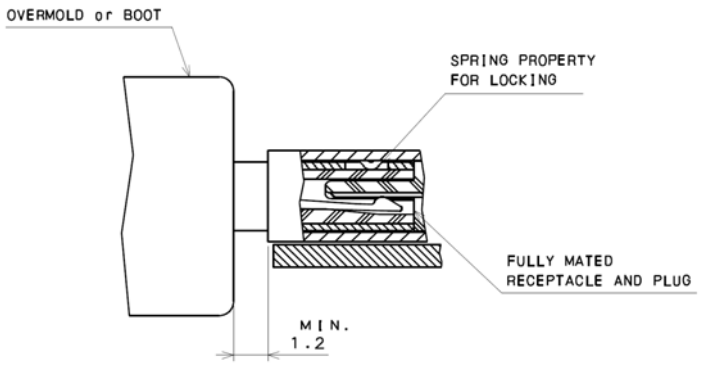


Figure 4-10 Type C Receptacle and Plug Mated Condition

It is recommended that products using Type C connectors be designed to ensure that cable bends that are not tighter than that shown in Figure 4-11. In addition, for strength, it is recommended that the shell flange and the case be fixed with a screw and that the clearance between the connector and the case be as narrow as possible.

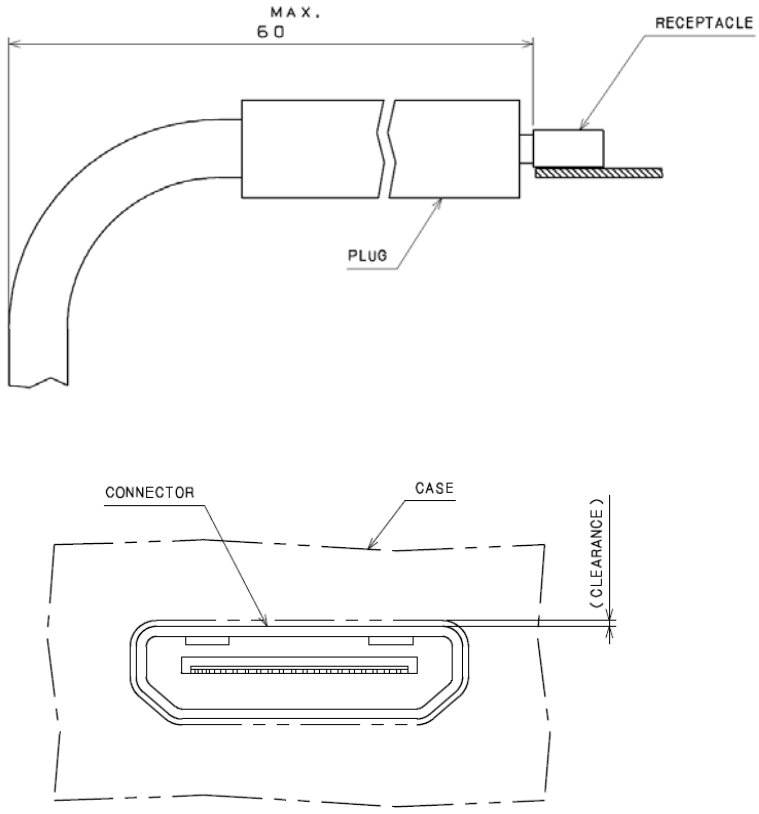


Figure 4-11 Type C Product Design Recommendations

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4.1.10 Cable Adapter Specification

Table 4-8 Wire Categories

Category	Description
A	TMDS Signal Wire
B	TMDS Shield
C	Control
D	Control Ground
N.C.	No connect (no wire)
5V	5 Volts Power Wire

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4.1.10.1 Type A Connector to Type A Connector

Table 4-9 Type A-to-Type A Cable Wire Assignment

Type A pin	Signal Name	Wire	Type A pin
1	TMDS Data2+	A	1
2	TMDS Data2 Shield	B	2
3	TMDS Data2–	A	3
4	TMDS Data1+	A	4
5	TMDS Data1 Shield	B	5
6	TMDS Data1–	A	6
7	TMDS Data0+	A	7
8	TMDS Data0 Shield	B	8
9	TMDS Data0–	A	9
10	TMDS Clock+	A	10
11	TMDS Clock Shield	B	11
12	TMDS Clock–	A	12
13	CEC	C	13
14	Reserved (in cable but N.C. on device)	C	14
15	SCL	C	15
16	SDA	C	16
17	DDC/CEC Ground	D	17
18	+5V Power	5V	18
19	Hot Plug Detect	C	19

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4.1.10.2 Type A Connector to Type B Connector

Table 4-10 Type A-to-Type B Cable Wire Assignment

Type A pin	Pin Assignment	Wire	Type B pin
1	TMDS Data2+	A	1
2	TMDS Data2 Shield	B	2
3	TMDS Data2-	A	3
4	TMDS Data1+	A	4
5	TMDS Data1 Shield	B	5
6	TMDS Data1-	A	6
7	TMDS Data0+	A	7
8	TMDS Data0 Shield	B	8
9	TMDS Data0-	A	9
10	TMDS Clock+	A	10
11	TMDS Clock Shield	B	11
12	TMDS Clock-	A	12
13	CEC	C	22
15	SCL	C	25
16	SDA	C	26
17	DDC/CEC Ground	D	27
18	+5V Power	5V	28
19	Hot Plug Detect	C	29
14	No connect	N.C.	
	No connect	N.C.	23
	No connect	N.C.	24

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4.1.10.3 Type B Connector to Type B Connector

Table 4-11 Type B to Type B Cable Wire Assignment

Type B pin	Pin Assignment	Wire	Type B pin
1	TMDS Data2+	A	1
2	TMDS Data2 Shield	B	2
3	TMDS Data2-	A	3
4	TMDS Data1+	A	4
5	TMDS Data1 Shield	B	5
6	TMDS Data1-	A	6
7	TMDS Data0+	A	7
8	TMDS Data0 Shield	B	8
9	TMDS Data0-	A	9
10	TMDS Clock+	A	10
11	TMDS Clock Shield	B	11
12	TMDS Clock-	A	12
13	TMDS Data5+	A	13
14	TMDS Data5 Shield	B	14
15	TMDS Data5-	A	15
16	TMDS Data4+	A	16
17	TMDS Data4 Shield	B	17
18	TMDS Data4-	A	18
19	TMDS Data3+	A	19
20	TMDS Data3 Shield	B	20
21	TMDS Data3-	A	21
22	CEC	C	22
25	SCL	C	25
26	SDA	C	26
27	DDC/CEC Ground	D	27
28	+5V Power	5V	28
29	Hot Plug Detect	C	29
23	No Connect	N.C.	
24	No Connect	N.C.	
	No Connect	N.C.	23
	No Connect	N.C.	24

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4.1.10.4 Type C Connector to Type C Connector

Table 4-12 Type C-to-Type C Cable Wire Assignment

Type C pin	Signal Name	Wire	Type C pin
1	TMDS Data2 Shield	B	1
2	TMDS Data2+	A	2
3	TMDS Data2-	A	3
4	TMDS Data1 Shield	B	4
5	TMDS Data1+	A	5
6	TMDS Data1-	A	6
7	TMDS Data0 Shield	B	7
8	TMDS Data0+	A	8
9	TMDS Data0-	A	9
10	TMDS Clock Shield	B	10
11	TMDS Clock+	A	11
12	TMDS Clock-	A	12
13	DDC/CEC Ground	D	13
14	CEC	C	14
15	SCL	C	15
16	SDA	C	16
17	Reserved (in cable but N.C. on device)	C	17
18	+5V Power	5V	18
19	Hot Plug Detect	C	19

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4.1.10.5 Type C Connector to Type A Connector

Table 4-13 Type C-to-Type A Cable Wire Assignment

Type C pin	Signal Name	Wire	Type A pin
1	TMDS Data2 Shield	B	2
2	TMDS Data2+	A	1
3	TMDS Data2-	A	3
4	TMDS Data1 Shield	B	5
5	TMDS Data1+	A	4
6	TMDS Data1-	A	6
7	TMDS Data0 Shield	B	8
8	TMDS Data0+	A	7
9	TMDS Data0-	A	9
10	TMDS Clock Shield	B	11
11	TMDS Clock+	A	10
12	TMDS Clock-	A	12
13	DDC/CEC Ground	D	17
14	CEC	C	13
15	SCL	C	15
16	SDA	C	16
17	Reserved (in cable but N.C. on device)	C	14
18	+5V Power	5V	18
19	Hot Plug Detect	C	19

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4.2 Electrical Specification

Some timing parameter values in this specification are based on the clock rate of the link while others are based on absolute values. For scalable timing parameters based on the TMDS clock rate, the time period of the clock is denoted as 'TMDS character time', or $T_{character}$. One tenth of the character time is called the bit time, or T_{bit}. The bit time is also referred to as one Unit Interval in the jitter and eye diagram specifications.

Schematic diagrams contained in this chapter are for illustration only and do not represent the only feasible implementation.

4.2.1 TMDS Overview

The conceptual schematic of one TMDS differential pair is shown in Figure 4-12. TMDS technology uses current drive to develop the low voltage differential signal at the Sink side of the DC-coupled transmission line. The link reference voltage AV_{cc} sets the high voltage level of the differential signal, while the low voltage level is determined by the current source of the HDMI Source and the termination resistance at the Sink. The termination resistance (R_T) and the characteristic impedance of the cable (Z_0) must be matched.

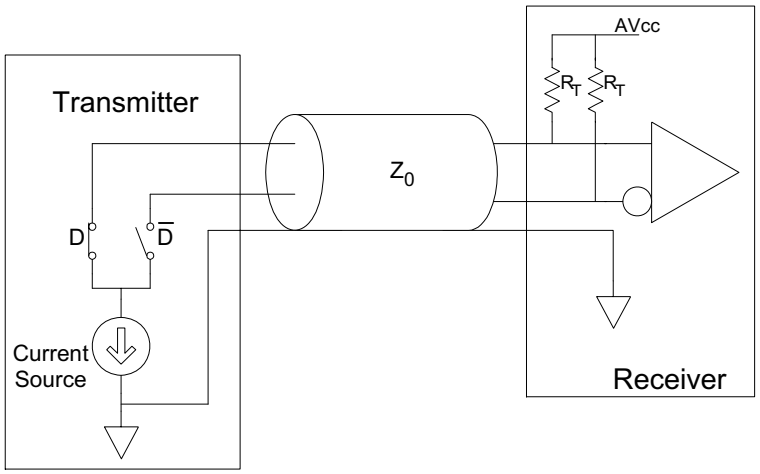


Figure 4-12 Conceptual Schematic for one TMDS differential pair

A single-ended differential signal, representing either the positive or negative terminal of a differential pair, is illustrated in Figure 4-13. The nominal high-level voltage of the signal is AV_{cc} and the nominal low-level voltage of the signal is (AV_{cc} - V_{swing}). Since the swing is differential on the pair, the net signal on the pair has a swing twice that of the single-ended signal, or $2*V_{swing}$. The differential signal, as shown in Figure 4-14, swings between positive V_{swing} and negative V_{swing}.

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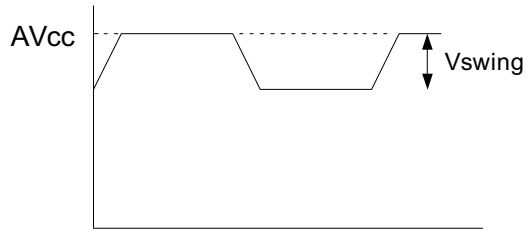


Figure 4-13 Single-ended Differential Signal

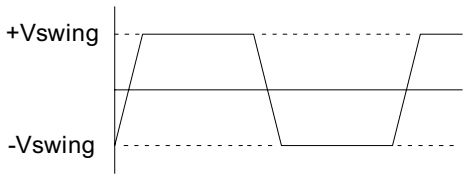


Figure 4-14 Differential Signal

The signal test points for a TMDS link are shown in Figure 4-15. TP1 is used for testing of HDMI Sources and Transmitter components. TP2 is used for testing of HDMI Sinks and Receiver components. TP1 and TP2 together are also used for testing of cables.

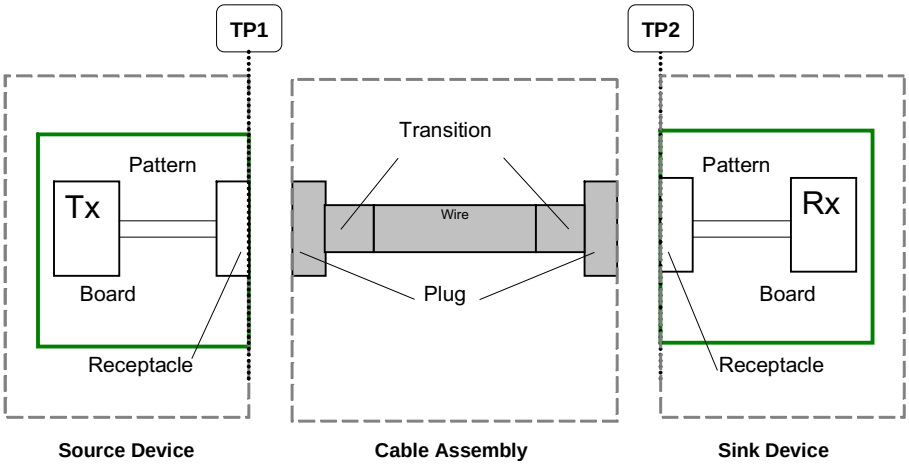


Figure 4-15 TMDS Link Test Points

4.2.2 TMDS System Operating Conditions

The required operating conditions of the TMDS pairs are specified in Table 4-14.

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Table 4-14 Required Operating Conditions for HDMI Interface (see Figure 4-12)

Item	Value
Termination Supply Voltage, AV_{cc}	3.3 Volts ±5%
Termination Resistance, R_T	50 ohms ±10%

4.2.3 TMDS Specification and Testing Overview

4.2.3.1 Jitter and Eye Measurements: Ideal Recovery Clock

All TMDS Clock and Data signal jitter specifications are specified relative to an Ideal Recovery Clock defined below. The Data jitter is not specified numerically, but instead, an HDMI device or cable shall adhere to the appropriate eye diagram(s) when the TMDS data signals are measured using an Ideal Recovery Clock as a trigger source.

The TMDS Clock signal may contain low-frequency jitter components, which can be tracked by a Sink's clock recovery circuitry, and high-frequency components, which are not typically tracked. The purpose of the Ideal Recovery Clock is to give an accurate representation of link performance when used as a trigger for eye diagram and clock jitter specifications.

For the purposes of jitter and eye diagram specification, the Ideal Recovery Clock is defined relative to the TMDS clock signal. The Ideal Recovery Clock shall be equivalent to the signal that would be derived by a perfect PLL (Ideal Clock Recovery Unit) with a jitter transfer function shown in Equation 4-1, when the TMDS clock signal were input into that PLL. This jitter transfer function has the behavior of a low pass filter with 20dB/decade roll-off and with a –3dB point of 4MHz.

For the purposes of compliance testing, a Clock Recovery Unit is used to generate a Recovered Clock, which is meant to approximate the Ideal Recovery Clock. This Recovered Clock is used for measurement of the jitter and eye diagram.

$$H(j\omega) = 1 / (1 + j\omega/\omega_0)$$

Where $\omega_0 = 2\pi F_0$, $F_0 = 4.0\text{MHz}$

Equation 4-1 Jitter Transfer Function of Ideal CRU for Ideal Recovery Clock Definition

4.2.3.2 Reference Cable Equalizer

The signal degradation introduced by typical passive cables increases with the frequency of the signal and the length of the cable. In order to accommodate passive copper cables of market-required lengths at the very high frequencies supported by HDMI, higher-speed HDMI Sinks are expected to support some sort of cable equalization function which allows them to recover data from such cables.

For lower-speed operation, the HDMI cable is specified with respect to the worst-case Source output eye (cable input eye) and the Sink input eye. For higher-speed operation, the HDMI cable

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specification also assumes application by the Sink of a cable equalization function approximating the performance implied by the Reference Cable Equalizer, which is a specified mathematical model of cable equalization.

The HDMI Sink is required to successfully recover the data stream from any compliant Sink input signal. At high frequencies, a compliant Sink input signal is any signal that, after application of the Reference Cable Equalizer to each of the differential TMDS signals, results in a signal that meets the Sink input eye requirements.

The definition of the Reference Cable Equalizer is given in Equation 4-2. The gain of this equation is shown in Figure 4-16.

$$|H(j\omega)| = \begin{cases} e^{A*\omega^N} & (\omega < \omega_0) \\ e^{-B*(\omega-1.2*\omega_0)^2+C} & (\omega_0 < \omega < 1.4*\omega_0) \\ e^{-D*\omega+E} & (1.4*\omega_0 < \omega) \end{cases}$$

Where:

$$N = 0.7$$

$$\omega_0 = 2\pi * 2.25GHz$$

$$A = 7.34E-8$$

$$B = \frac{7}{4} * A * \omega_0^{-1.3}$$

$$C = 1.07 * A * \omega_0^{0.7}$$

$$D = 0.7 * A * \omega_0^{-0.3}$$

$$E = 1.98 * A * \omega_0^{0.7}$$

Equation 4-2 Reference Cable Equalizer Function

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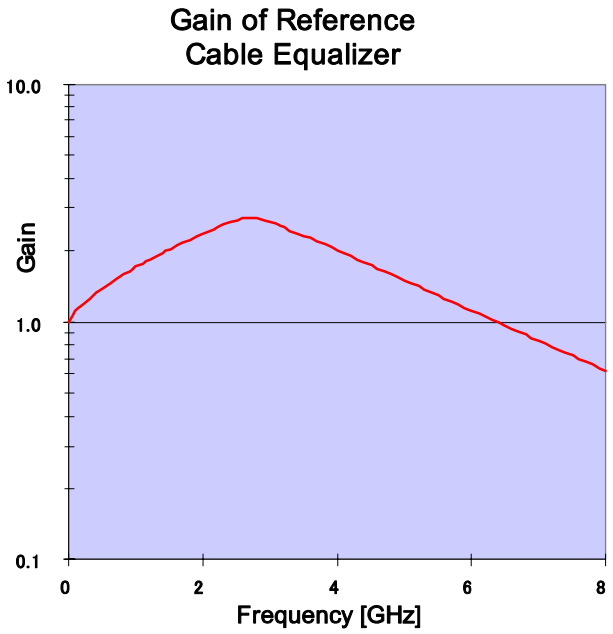


Figure 4-16 Gain of Reference Cable Equalizer

4.2.4 HDMI Source TMDS Characteristics

HDMI requires a DC-coupled TMDS link. Source electrical testing shall be performed using the test load shown in Figure 4-17, with AV_{cc} set to 3.3V. TP1 represents the connection point of the receptacle.

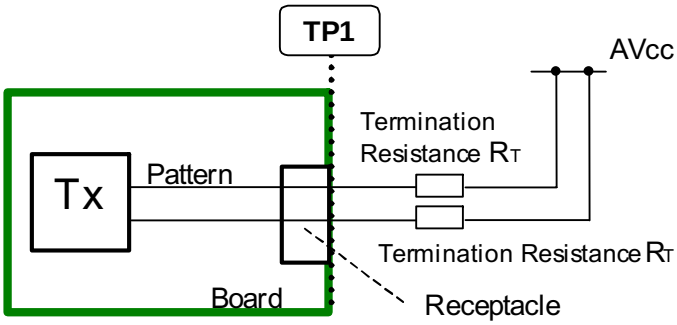


Figure 4-17 Balanced Source Test Load

The Source shall meet the DC specifications in Table 4-15 for all operating conditions specified in Table 4-14 when driving clock and data signals. The V_{swing} parameter is the difference between the single-ended most common high-level voltage (as would be revealed with a histogram measurement) and the most-common low-level voltage, after ringing has subsided.

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Table 4-15 Source DC Characteristics at TP1

Item	Value
Single-ended standby (off) output voltage, V_{OFF}	AV_{cc} ±10mVolts
Single-ended output swing voltage, V_{swing}	400mVolts ≤ V_{swing} ≤ 600mVolts
Single-ended high level output voltage, V_H	if attached Sink supports only <=165MHz : AV_{cc} ±10mVolts if attached Sink supports >165MHz : (AV_{cc} – 200mVolts) ≤ V_H ≤ (AV_{cc} + 10mVolts)
Single-ended low level output voltage, V_L	if attached Sink supports only <=165MHz : (AV_{cc} – 600mVolts) ≤ V_L ≤ (AV_{cc} – 400mVolts) if attached Sink supports >165MHz : (AV_{cc} – 700mVolts) ≤ V_L ≤ (AV_{cc} – 400mVolts)

It is recommended that Sources capable of higher speeds incorporate some amount of source termination. This termination will typically have the effect of lowering the average DC level of each single-ended signal. The relaxed V_H and V_L parameters permit such an implementation.

The Source shall meet the AC specifications in Table 4-16 across all operating conditions specified in Table 4-14. Rise and fall times are defined as the signal transition time between 20% and 80% of the nominal swing voltage (V_{swing}) of the device under test.

The Source intra-pair skew is the maximum allowable time difference (on both low-to-high and high-to-low transitions) as measured at TP1, between the true and complement signals of a given differential pair. This time difference is measured at the midpoint on the single-ended signal swing of the true and complement signals. The Source inter-pair skew is the maximum allowable time difference (on both low-to-high and high-to-low transitions) as measured at TP1, between any two single-ended data signals that do not constitute a differential pair.

Table 4-16 Source AC Characteristics at TP1

Item	Value
Rise time / fall time (20%-80%)	75psec ≤ Rise time / fall time ≤ 0.4 T_{bit}
Undershoot, max	25% of full differential amplitude (V_{swing}*2)
Intra-Pair Skew at Source Connector, max	0.15 T_{bit}
Inter-Pair Skew at Source Connector, max	0.20 $T_{character}$
Clock duty cycle, min / average / max	40% / 50% / 60%
TMDS Differential Clock Jitter, max	0.25 T_{bit} (relative to Ideal Recovery Clock as defined in Section 4.2.3)

The design of a Source should take into account the differential impedance of the cable assembly and Sink of 100 ohms (see Table 4-21).

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For all channels under all operating conditions specified in Table 4-14 and when terminated as shown in Figure 4-17, the Source shall have output levels at TP1that meet the normalized eye diagram requirements of Figure 4-18. This requirement, normalized in both time and amplitude, specifies the minimum eye opening relative to the average differential swing voltage as well as the absolute maximum and minimum voltages. The time axis is normalized to the bit time at the operating frequency, while the minimum eye amplitude is normalized to the average differential swing voltage.

Determination of average swing voltage is made with transmission of the half clock test pattern. The average high-level and low-level amplitudes are determined at the point where signal ringing has subsided. These averages establish the swing voltage and are used to normalize the eye diagram.

The average differential swing voltage is defined as the difference between the average differential amplitude when driving a logic one and the average differential amplitude when driving a logic zero. The average logic one appears at positive 0.5 on the vertical axis, while the average logic zero appears at negative 0.5. The normalized amplitude limits in Figure 4-18 allow 25% (of the average differential swing voltage) maximum undershoot, relative to the amplitudes determined to be logic one and zero. Overshoot limits are imposed only by the absolute max/min voltages of ±780mV shown above and below the normalized eye.

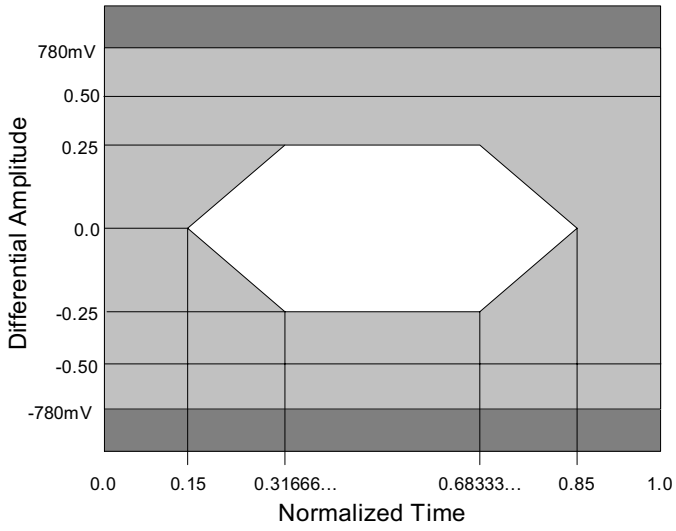


Figure 4-18 Eye Diagram Mask at TP1 for Source Requirements

Combining the single-ended swing voltage (V_{swing}) specified in Table 4-15 with a 15% overshoot (legacy) and the undershoot limits of Table 4-16, it is possible to calculate the minimum and maximum high-level voltage (V_{high}) and low-level voltage (V_{low}) that is allowable on the interface.

V_{high} (max) = V_{swing} (max) + 15% * (2*V_{swing} (max)) = 600 + 180 = 780 mV

V_{high} (min) = V_{swing} (min) - 25% * (2*V_{swing} (min)) = 400 - 200 = 200 mV

V_{low} (max) = -V_{swing} (max) - 15% * (2*V_{swing} (max)) = -600 - 180 = -780 mV

V_{low} (min) = -V_{swing} (min) + 25% * (2*V_{swing} (min)) = -400 + 200 = -200 mV

Minimum opening at Source = V_{high} (min) - V_{low} (min) = 400 mV

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Note that the combination of these extreme cases do not constitute a single valid eye.

Source eye diagram test procedures are defined in the HDMI Compliance Test Specification. The Source eye diagram mask of Figure 4-18 is not used for response time and clock jitter specifications, but specifies the clock to data jitter indirectly.

4.2.5 HDMI Sink TMDS Characteristics

HDMI Sink electrical testing shall be performed using a test signal generator as shown in Figure 4-19.

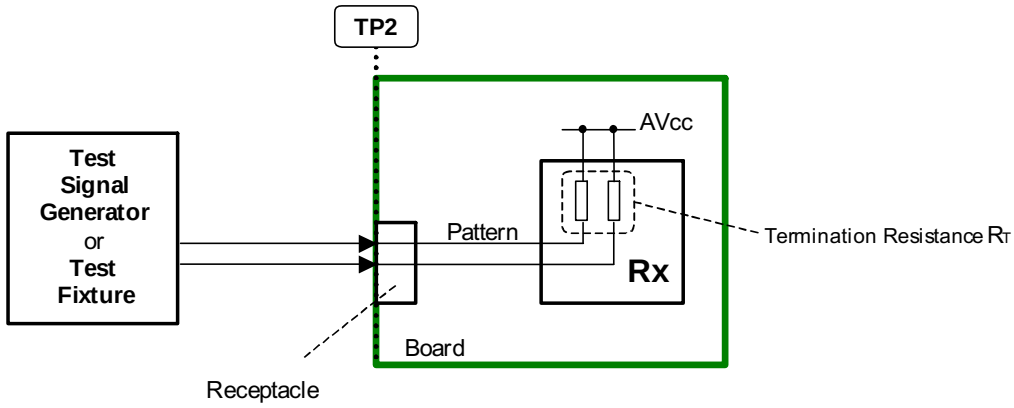


Figure 4-19 HDMI Sink Test Points

There may be a risk of source damage if the Sink asserts a very high or very low voltage, such as beyond the maximum ratings in the DVI 1.0 specification, on any TMDS line during power-on or other power transitions.

The Sink shall meet the signal requirements listed in Table 4-17, Table 4-18, and Table 4-19.

Table 4-17 Sink Operating DC Characteristics at TP2

Item		Value
Input Differential Voltage Level, V_{idiff}		$150 \le V_{idiff} \le 1200$ mVolts
Input Common Mode Voltage, V_{icm}	V_{icm1}	if Sink supports only <=165MHz : $(AV_{cc} - 300mVolts) \le V_{icm1} \le (AV_{cc} - 37.5mVolts)$ If Sink supports >165MHz : $(AV_{cc} - 400mVolts) \le V_{icm1} \le (AV_{cc} - 37.5mVolts)$
	V_{icm2}	AV_{cc} ±10mVolts

All Sinks are required to support both V_{icm} ranges (V_{icm1} and V_{icm2}). Sources are not yet permitted to operate in the V_{icm2} (AC-coupled) range. At higher speeds, Source devices may implement source termination, which may lower the DC-coupled V_{icm} (V_{icm1}) seen by the Sink.

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Table 4-18 Sink DC Characteristics When Source Disabled or Disconnected at TP2

Item	Value
Differential Voltage Level	AV_{cc} ±10mVolts

Table 4-19 Sink AC Input Characteristics at TP2

Item	Value
Minimum differential sensitivity (peak-to-peak)	150 mVolts
Maximum differential input (peak-to-peak)	1560 mVolts
Max Allowable Intra-Pair Skew at Sink Connector	For TMDS Clock rates 225MHz and below: 0.4 T_{bit} For TMDS Clock rates above 225MHz: 0.15 T_{bit} + 111psecs
Max Allowable Inter-Pair Skew at Sink Connector	0.2 $T_{character}$ + 1.78nsecs
TMDS Clock Jitter	0.30 T_{bit} (relative to Ideal Recovery Clock as defined in Section 4.2.3, for all TMDS clock rates >165MHz: after application of Reference Cable Equalizer given in Equation 4-2)

For each channel under all operating conditions specified in this section the following conditions shall be met. At TMDS clock frequencies less than or equal to 165MHz, the Sink shall recover data at a TMDS character error rate of 10^{-9} or better, when presented with any signal compliant to the eye diagram of Figure 4-20. At TMDS clock frequencies above 165MHz, the Sink shall recover data on each channel at a TMDS character error rate of 10^{-9} or better, when presented with any signal compliant to the eye diagram of Figure 4-20 after application of the Reference Cable Equalizer.

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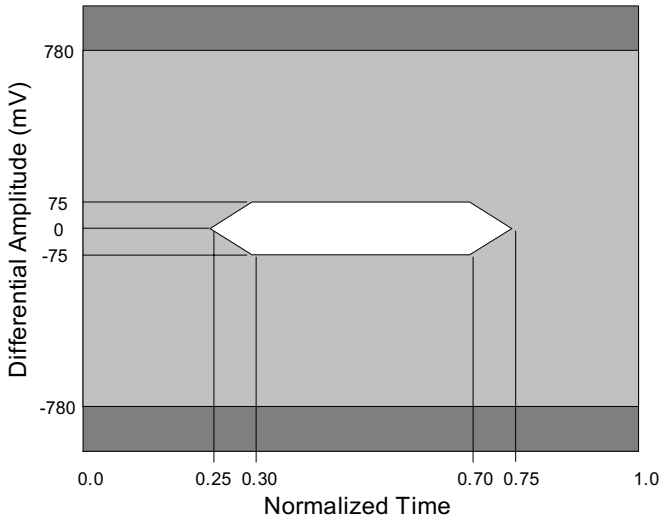


Figure 4-20 Eye Diagram Mask at TP2 for Sink Requirements

Table 4-20 HDMI Sink Impedance Characteristics at TP2

Item	Value
TDR Rise Time at TP2 (10%-90%)	≤200 psec
Through connection impedance	100 ohms ±15%
At Termination impedance (when V_{icm} is within V_{icm1} range)	100 ohms ±10%
At Termination impedance (when V_{icm} is within V_{icm2} range)	100 ohms ±35%

4.2.6 Cable Assembly TMDS Characteristics

The term “Cable assembly” includes all five parts listed below:

- Source-side plug
- Source-side transition (from plug to cable)
- Cable itself
- Sink-side transition
- Sink-side plug

HDMI cables are measured with respect to the test points TP3 and TP4 shown in Figure 4-21. TP1 and TP2 are not available because connection points between plug and receptacle cannot be accessed during testing. Therefore, TP3 and TP4 are used, even though the effects of receptacles at both ends are included in the test result.

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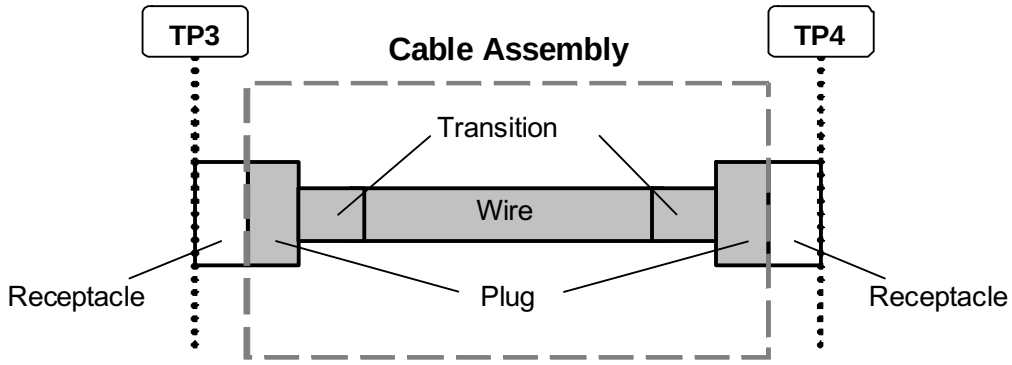


Figure 4-21 Cable Assembly Test Points

HDMI cable assemblies can fall into one of two categories: Category 1, supporting TMDS clock frequencies up to 74.25MHz and Category 2, supporting TMDS clock frequencies up to 340MHz.

HDMI cable assemblies are specified and tested using two different eye measurement procedures: “non-equalized” (without application of the Reference Cable Equalizer) and “equalized” (with application of the Reference Cable Equalizer).

- Non-equalized eye diagram specification – when driven by any TMDS input waveform meeting the Source eye diagram mask requirements of Figure 4-18 at the tested TMDS clock frequency, the HDMI cable assembly shall produce a TMDS output waveform that meets the Sink eye diagram mask of Figure 4-20.
- Equalized eye diagram specification – when driven by any TMDS input waveform meeting the Source eye diagram mask requirements of Figure 4-18 at the tested TMDS clock frequency, the TMDS output waveform of the cable shall meet the post-equalized eye diagram mask of Figure 4-20 after application of the Reference Cable Equalizer.

The application of these two different specifications depends upon the cables frequency rating:

- Category 1 (74.25MHz): The cable shall meet either:
  A) the parameters specified for Category 1 cables in Table 4-21, or,
  B) the non-equalized eye diagram requirements at 74.25MHz.
- Category 2 (>74.25MHz): The cable shall meet either
  A) the parameters specified for Category 2 cables in Table 4-21, or,
  B) all of:
    - the non-equalized eye diagram requirements at 165MHz and,
    - the equalized eye diagram requirements at 340MHz and,
    - the attenuation limits specified in Figure 4-24 if the cable is a passive copper cable or in Figure 4-25 if the cable has equalization circuitry embedded within.

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Table 4-21 Cable Assembly TMDS Parameters

Parameter	Category 1 (74.25MHz)	Category 2 (>74.25MHz)
Maximum Cable Assembly Intra-Pair Skew	151psec	111psec
Maximum Cable Assembly Inter-Pair Skew	2.42nsec	1.78nsec
Far-end Crosstalk	< -26dB	< -26dB
Attenuation	See Figure 4-22	See Figure 4-23
300kHz - 825MHz	< 8dB	< 5dB
825MHz - 2.475GHz	< 21dB	< 5dB...< 12dB
2.475GHz - 4.125GHz	< 30dB	< 12dB...< 20dB
4.125GHz – 5.1GHz	- -	< 20dB...< 25dB
Differential Impedance		
Connection point and transition area: Up to 1nsec**	100 ohms ±15%	
Cable area: 1nsec – 2.5nsec:**	100 ohms ±10%	

*** Measurement point for TDR measurement of impedance.*

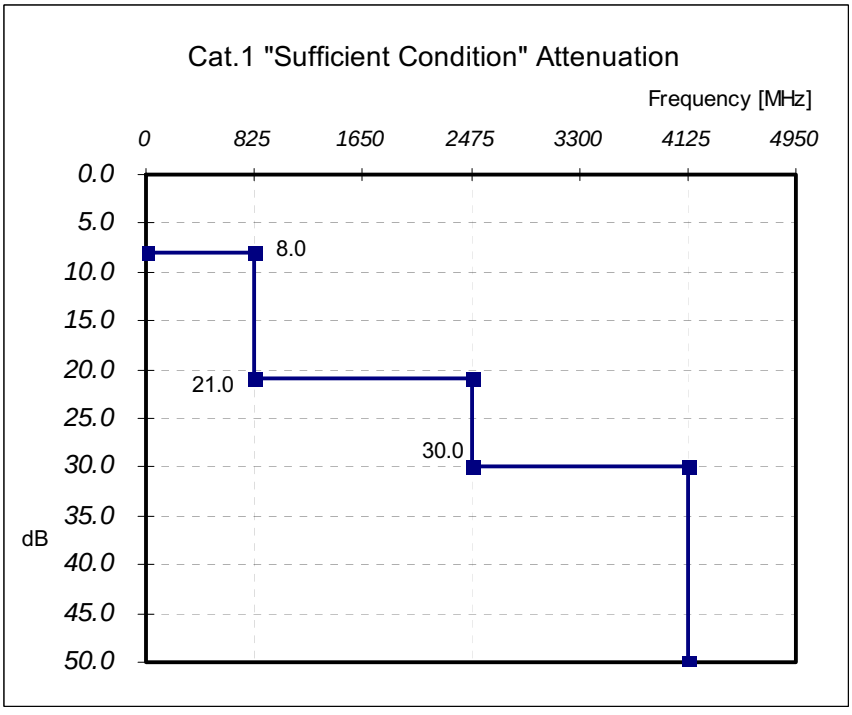


Figure 4-22 Category 1 Cable Attenuation Limits – Sufficient Condition

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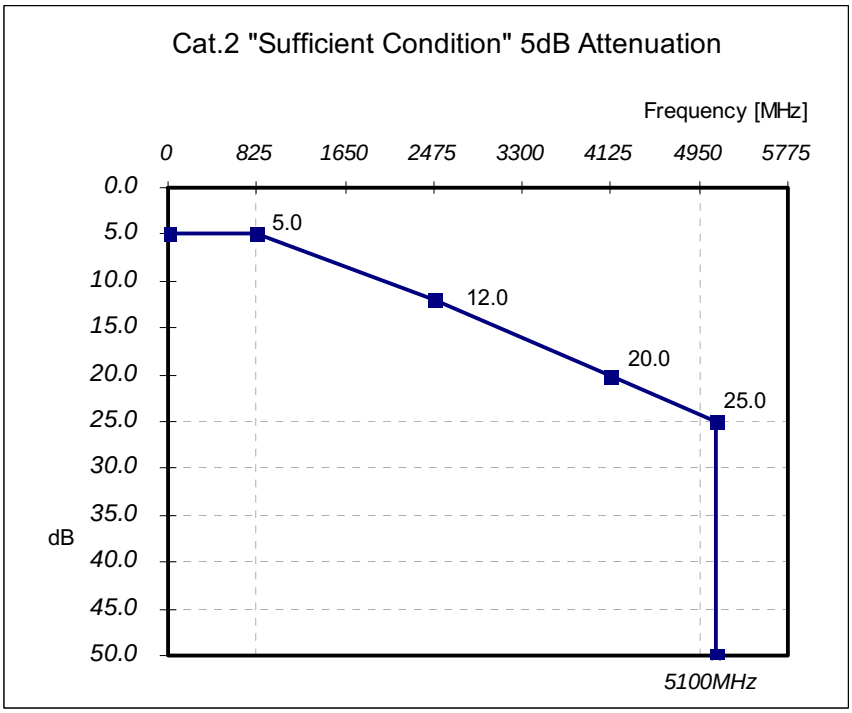


Figure 4-23 Category 2 Cable Attenuation Limits – Sufficient Condition

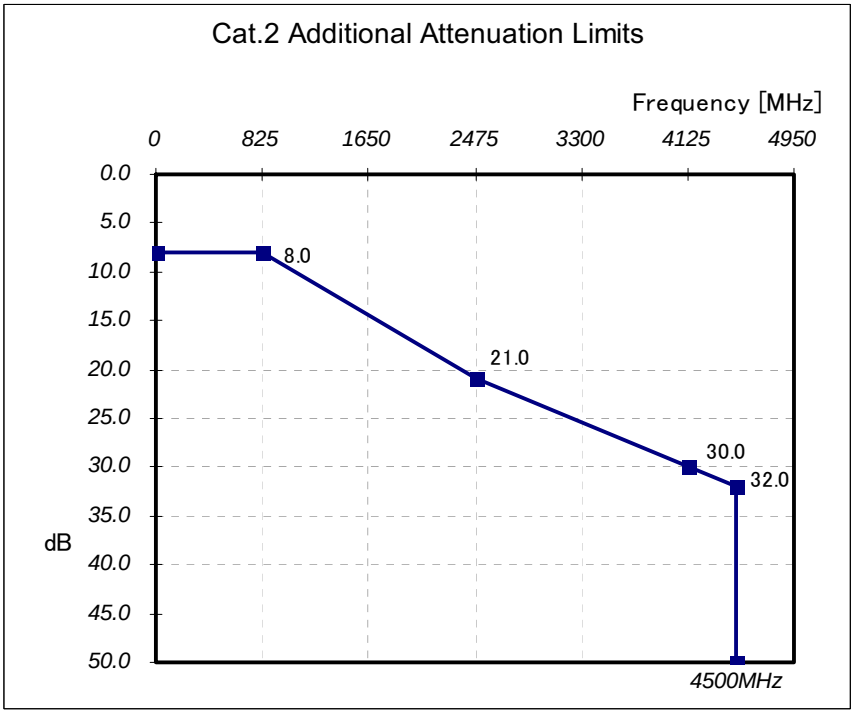


Figure 4-24 Category 2 Additional Attenuation Limits For Copper Cable

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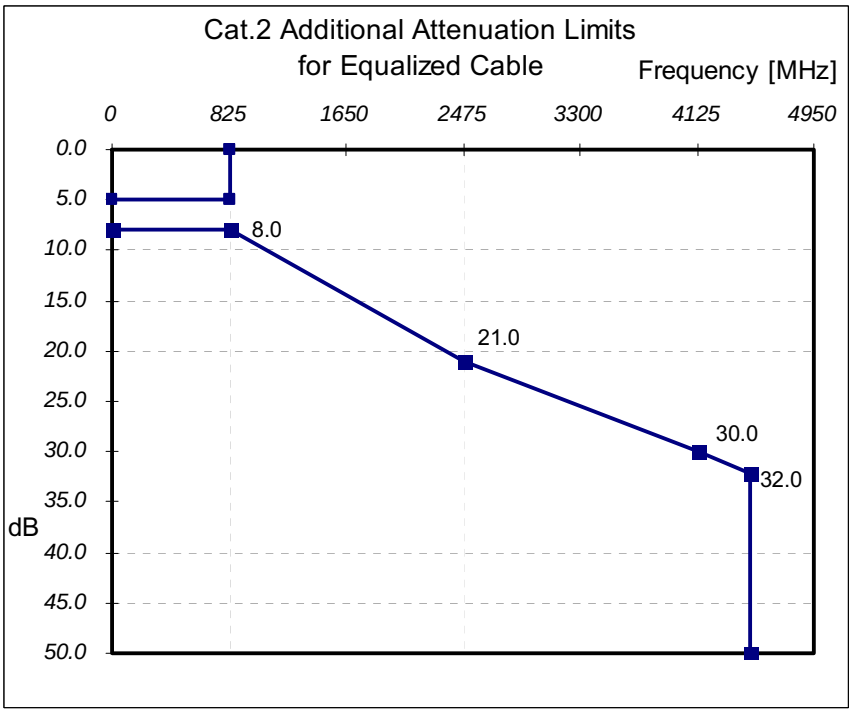


Figure 4-25 Category 2 Additional Attenuation Limits for Equalized Cable

4.2.7 +5V Power Signal

The HDMI connector provides a pin allowing the Source to supply +5.0 Volts to the cable and Sink.

All HDMI Sources shall assert the +5V Power signal whenever the Source is using the DDC or TMDS signals. The voltage driven by the Source shall be within the limits specified for TP1 voltage in Table 4-22. An HDMI Source shall have +5V Power signal over-current protection of no more than 0.5A.

All HDMI Sources shall be able to supply a minimum of 55 mA to the +5V Power pin.

A Sink shall not draw more than 50 mA of current from the +5V Power pin. When the Sink is powered on, it can draw no more than 10mA of current from the +5V Power signal. A Sink shall assume that any voltage within the range specified for TP2 voltage in Table 4-22 indicates that a Source is connected and applying power to the +5V Power signal.

A Cable Assembly shall be able to supply a minimum of 50mA to the +5V Power pin to a Sink, even when connected to a Source supplying no more than 55mA.

The return for the +5V Power signal is DDC/CEC Ground signal.

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Table 4-22 +5V Power Pin Voltage

Item	Min	Max
TP1 voltage	4.8 Volts	5.3 Volts
TP2 voltage	4.7 Volts	5.3 Volts

4.2.8 DDC

The Display Data Channel (DDC) I/Os and wires (SDA, SCL, DDC/CEC Ground), shall meet the requirements specified in the I^2C-bus Specification, version 2.1, Section 15 for "Standard-Mode" devices. Note that the discussions of high capacitance environments in the I^2C-bus Specification, section 17.2, "Switched pull-up circuit for Fast-mode I^2C-bus", may be applied to the HDMI environment as well.

HDMI devices shall have DDC electrical characteristics complying with the values shown in Table 4-23 and Table 4-24.

The exact method and measurement procedure is written in HDMI Compliance Test Specification. In some cases, buffers or I^2C "accelerators", may be inserted in the cable as long as all I^2C timing requirements are met.

Table 4-23 Maximum Capacitance of DDC line

Item	HDMI Source	Cable Assembly	HDMI Sink
SDA – DDC/CEC Ground	50pF	700pF	50pF
SCL – DDC/CEC Ground	50pF	700pF	50pF

Table 4-24 Pull-up Resistance on DDC Lines

Item	Value
Source Pull-up resistors for SCL and SDA signals	minimum 1.5k ohms, maximum 2.0k ohms
Sink Pull-up resistors for SCL signal	47k ohms, ±10%

4.2.9 Hot Plug Detect Signal (HPD)

The ground reference for the Hot Plug Detect signal is the DDC/CEC Ground pin.

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Table 4-25 Required Output Characteristics of Hot Plug Detect Signal

Item	Value
High voltage level (Sink)	Minimum 2.4 Volts, Maximum 5.3 Volts
Low voltage level (Sink)	Minimum 0 Volts, Maximum 0.4 Volts
Output resistance	1000 ohms ±20%

Table 4-26 Required Detection Levels for Hot Plug Detect Signal

Item	Value
High voltage level (Source)	Minimum 2.0 Volts, Maximum 5.3 Volts
Low voltage level (Source)	Minimum 0 Volts, Maximum 0.8 Volts

Note that many Sink devices simply connect the HPD signal to the +5V Power signal through a 1000 ohm resistor. It may therefore be necessary for a Source to pull-down the HPD signal in order to reliably differentiate between a floating (disconnected) HPD and a high voltage level HPD signal.

4.2.10 CEC Line

The following line characteristics are required for all products, including those that do not implement the CEC protocol. Further requirements for those devices that implement the CEC protocol are given in Supplement 1. The ground reference for the CEC signal is the DDC/CEC Ground signal.

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Table 4-27 CEC line Electrical Specifications for all Configurations

Item	Rule / Description	Value
Line connectivity	CEC lines from all HDMI inputs (if present) and a single HDMI output (if present) shall be interconnected. However, the following exceptions are allowed: A device that has no HDMI output is allowed to have separate CEC lines for each HDMI connector if that device implements CEC protocol and takes a logical address of 0 on each CEC line. Due to the complexity of handling multiple active CEC lines, this is discouraged. A device (typically a TV or media receiver box) that is acting as the CEC root device shall not connect the CEC line to any HDMI output. Maximum resistance of interconnected CEC line between any two HDMI connectors:	5Ω
Power-off characteristics	A device with power removed shall not degrade communication between other CEC devices (e.g. the line shall not be pulled down by the powered off device). Maximum CEC line leakage current in off (unpowered) state	1.8µA
CEC Line Capacitance	Maximum capacitance load of a device (excluding cable)	200pF
	Maximum capacitance load of a Cable Assembly	700pF

4.2.11 Robustness Requirements

No damage to the HDMI Source or Sink can result from the shorting of any combination of signals on any connector. If two HDMI Sources are connected together with a single cable, no damage can occur to either of the Sources. If two HDMI Sinks are connected together with a single cable, no damage can occur to either of the Sinks.

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5 Signaling And Encoding

5.1 Overview

5.1.1 Link Architecture

As shown in Figure 5-1, an HDMI link includes three TMDS Data channels and a single TMDS Clock channel. The TMDS Clock channel constantly runs at a rate proportional to the pixel rate of the transmitted video. During every cycle of the TMDS Clock channel, each of the three TMDS data channels transmits a 10-bit character. This 10-bit word is encoded using one of several different coding techniques.

The input stream to the Source's encoding logic will contain video pixel, packet and control data. The packet data consists of audio and auxiliary data and associated error correction codes.

These data items are processed in a variety of ways and are presented to the TMDS encoder as either 2 bits of control data, 4 bits of packet data or 8 bits of video data per TMDS channel. The Source encodes one of these data types or encodes a Guard Band character on any given clock cycle.

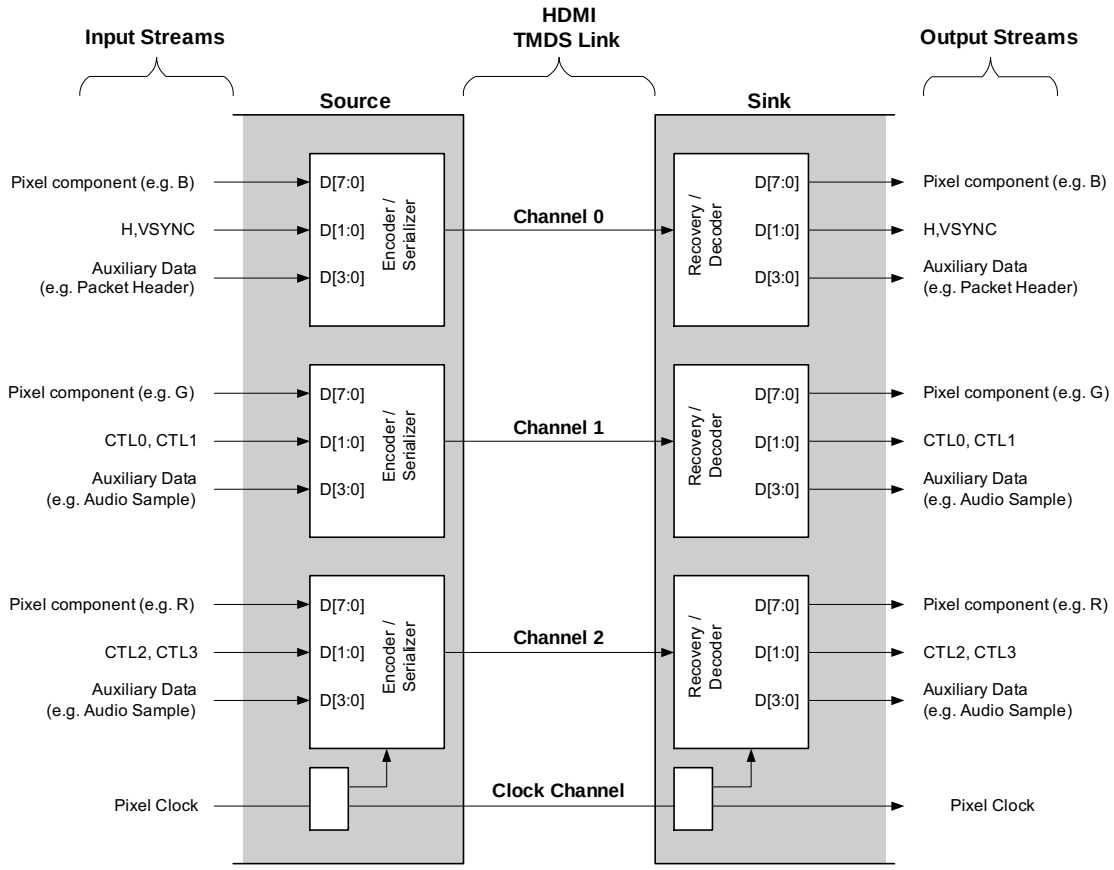


Figure 5-1 HDMI Encoder/Decoder Overview

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5.1.2 Operating Modes Overview

The HDMI link operates in one of three modes: Video Data Period, Data Island period, and Control period. During the Video Data Period, the active pixels of an active video line are transmitted. During the Data Island period, audio and auxiliary data are transmitted using a series of packets. The Control period is used when no video, audio, or auxiliary data needs to be transmitted. A Control Period is required between any two periods that are not Control Periods.

An example of each period placement is shown in the following figure.

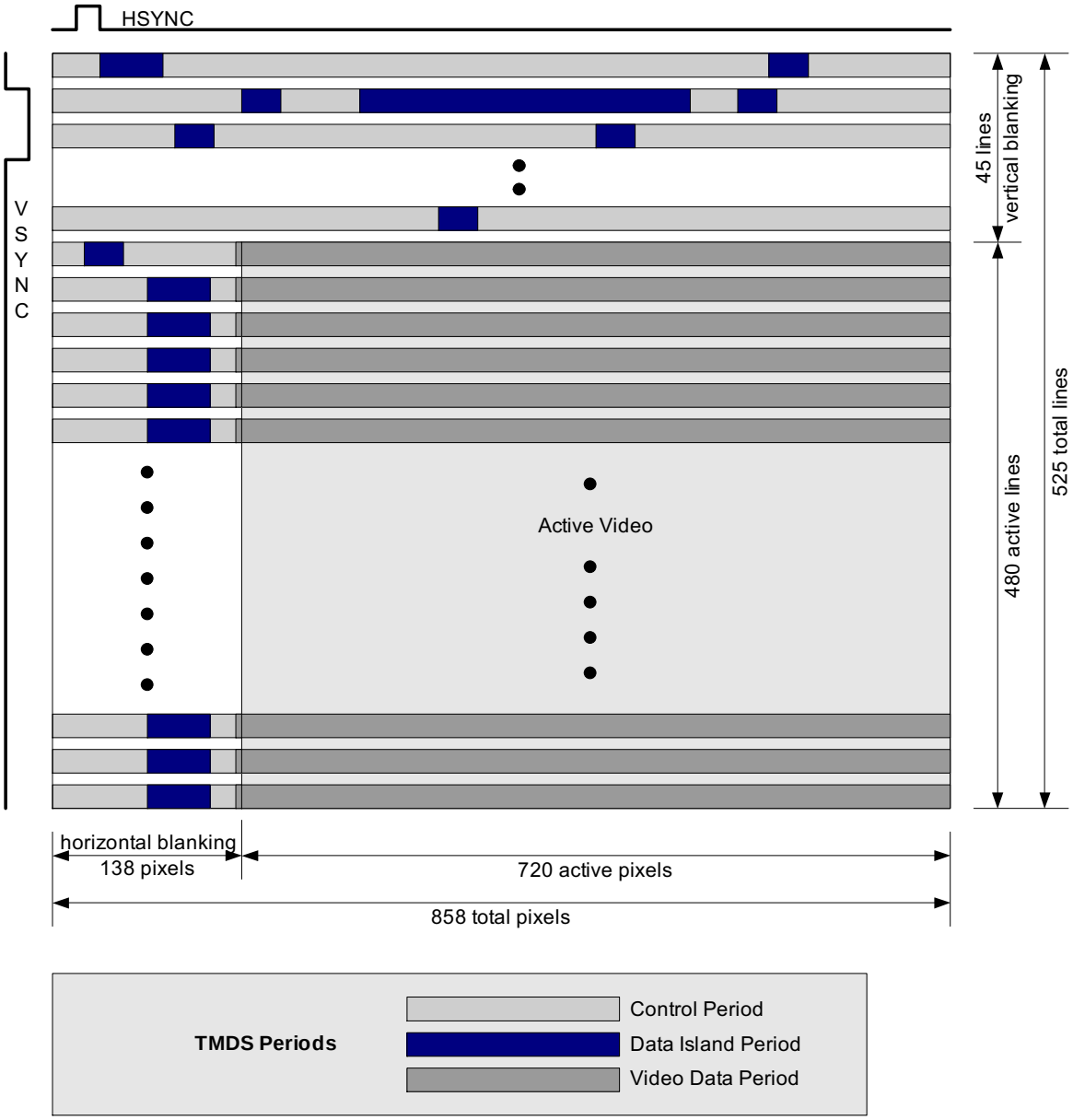


Figure 5-2 Informative Example: TMDS periods in 720x480p video frame

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Video Data Periods use transition minimized coding to encode 8 bits per channel, or 24 bits total per pixel.

Data Island Periods are encoded using a similar transition minimized coding, TMDS Error Reduction Coding (TERC4), which transmits 4 bits per channel, or 12 bits total per TMDS clock period.

During Control Periods, 2 bits per channel, or 6 bits total are encoded per TMDS clock using a transition maximized encoding. These 6 bits are HSYNC, VSYNC, CTL0, CTL1, CTL2 and CTL3. Near the end of every Control Period, a Preamble, using the CTLx bits, indicates whether the next Data Period is a Video Data Period or a Data Island Period.

Each Video Data Period and Data Island Period starts with a Leading Guard Band designed to provide robust determination of the transition from the Control Period to the Data Period. This Leading Guard Band consists of two special characters.

The Data Island Period is also protected by a Trailing Guard Band, which is designed to provide a robust determination of the transition to Control Period.

The following table shows Encoding type used and data transmitted during each operating mode.

Table 5-1 Encoding Type and Data Transmitted

Period	Data Transmitted	Encoding Type
Video Data	Video Pixels	Video Data Coding (8 bits converted to 10 bits)
	(Guard Band)	(Fixed 10 bit pattern)
Data Island	Packet Data - Audio Samples - InfoFrames HSYNC, VSYNC	TERC4 Coding (4 bits converted to 10 bits)
	(Guard Band)	(Fixed 10 bit pattern)
Control	Control - Preamble - HSYNC, VSYNC	Control Period Coding (2 bits converted to 10 bits)

5.2 Operating Modes

5.2.1 Control Period

Control Period is used for transmission of the Preamble. The Control Period is also used by the Sink for character synchronization.

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The HDCP-specified Enhanced Encryption Status Signaling ENC_EN code (CTL0:3=1001) shall not be used except as a correct ENC_EN during the HDCP-specified window of opportunity.

5.2.1.1 Preamble

Immediately preceding each Video Data Period or Data Island Period is the Preamble. This is a sequence of eight identical Control characters that indicate whether the upcoming data period is a Video Data Period or is a Data Island. The values of CTL0, CTL1, CTL2, and CTL3 indicate the type of data period that follows. The remaining Control signals, HSYNC and VSYNC, may vary during this sequence.

There are only two legal Preamble characters:

Table 5-2 Preambles for Each Data Period Type

CTL0	CTL1	CTL2	CTL3	Data Period Type
1	0	0	0	Video Data Period
1	0	1	0	Data Island Period

The Video Data Period type indicates that the following data period contains video data, beginning with a Video Guard Band.

The Data Island type indicates that the following data period is an HDMI compliant Data Island, beginning with a Data Island Guard Band.

The transition from TMDS control characters to Guard Band characters following this sequence identifies the start of the Data Period.

The Data Island Preamble control code (CTL0:3=1010) shall not be transmitted except for correct use during a Preamble period.

5.2.1.2 Character Synchronization

The TMDS Sink needs to determine the location of character boundaries in the serial data streams. Once character boundaries are established on all data channels, the Sink is defined to be synchronized to the serial streams, and may recover TMDS characters from the data channels for decode. The TMDS data stream provides periodic cues for decoder synchronization.

The TMDS characters used during the Video Data Period and Data Island Period contain five or fewer transitions, while the TMDS characters used during the Control Period contain seven or more transitions. The high-transition content of the characters transmitted during the Control Period form the basis for character boundary synchronization at the decoder. While these characters are not individually unique in the serial data stream, they are sufficiently alike that the decoder may uniquely detect the presence of a succession of them during transmitted synchronization intervals. The exact algorithm for this detection is an implementation detail beyond the scope of this document, but minimum conditions for Sink synchronization are defined.

The Sink is required to establish synchronization with the data stream during any Control Period greater than or equal to $t_{S,min}$ (12) characters in length.

The Source is also required to occasionally transmit an Extended Control Period per Table 5-4.

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Table 5-3 TMDS Link Timing Parameters

Parameter	Description	Value	Unit
$t_{S,min}$	Minimum duration Control Period	12	T_{PIXEL}

Table 5-4 Extended Control Period Parameters

Parameter	Description	Value	Unit
t_{EXTS,max_delay}	Maximum time between Extended Control Periods	50	msec
$t_{EXTS,min}$	Minimum duration Extended Control Period	32	T_{PIXEL}

5.2.2 Video Data Period

Video data periods are used to carry the pixels of an active video line.

Each Video Data Period is preceded by a Preamble, described above.

Following the Preamble, the Video Data Period begins with a two character Video Leading Guard Band. There is no Trailing Guard Band for the Video Data Period.

During active video periods, 24 bits of pixel data are encoded using TMDS transition minimized encoding during each TMDS clock period.

5.2.2.1 Video Guard Band

Table 5-5 Video Leading Guard Band Values

```
case (TMDS Channel Number):
       0:  q_out[9:0] = 0b1011001100;
       1:  q_out[9:0] = 0b0100110011;
       2:  q_out[9:0] = 0b1011001100;
endcase
```

5.2.3 Data Island Period

5.2.3.1 Data Island Overview

Data Islands are used to carry packets of audio sample data and auxiliary data. This auxiliary data includes InfoFrames and other data describing the active audio or video stream or describing the Source.

Each Data Island is preceded by a Preamble, described above.

Following the Preamble, each Island starts with a Leading Guard Band. The first packet of the Data Island then follows.

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During every TMDS clock period of the Data Island, including the Guard Band, bits 0 and 1 of TMDS Channel 0 transmit an encoded form of HSYNC and VSYNC.

Bit 2 of TMDS Channel 0 is used to transmit the Packet Header. All four bits of TMDS Channels 1 and 2 are used for the Packet data as shown in Figure 5-3. Each packet is 32 pixels long and is protected by BCH ECC for error correction and detection purposes.

During the Data Island, each of the three TMDS channels transmits a series of 10-bit characters encoded from a 4-bit input word, using TMDS Error Reduction Coding (TERC4). TERC4 significantly reduces the error rate on the link by choosing only 10-bit codes with high inherent error avoidance.

The last two characters of the Data Island, following the last packet, is the Trailing Guard Band.

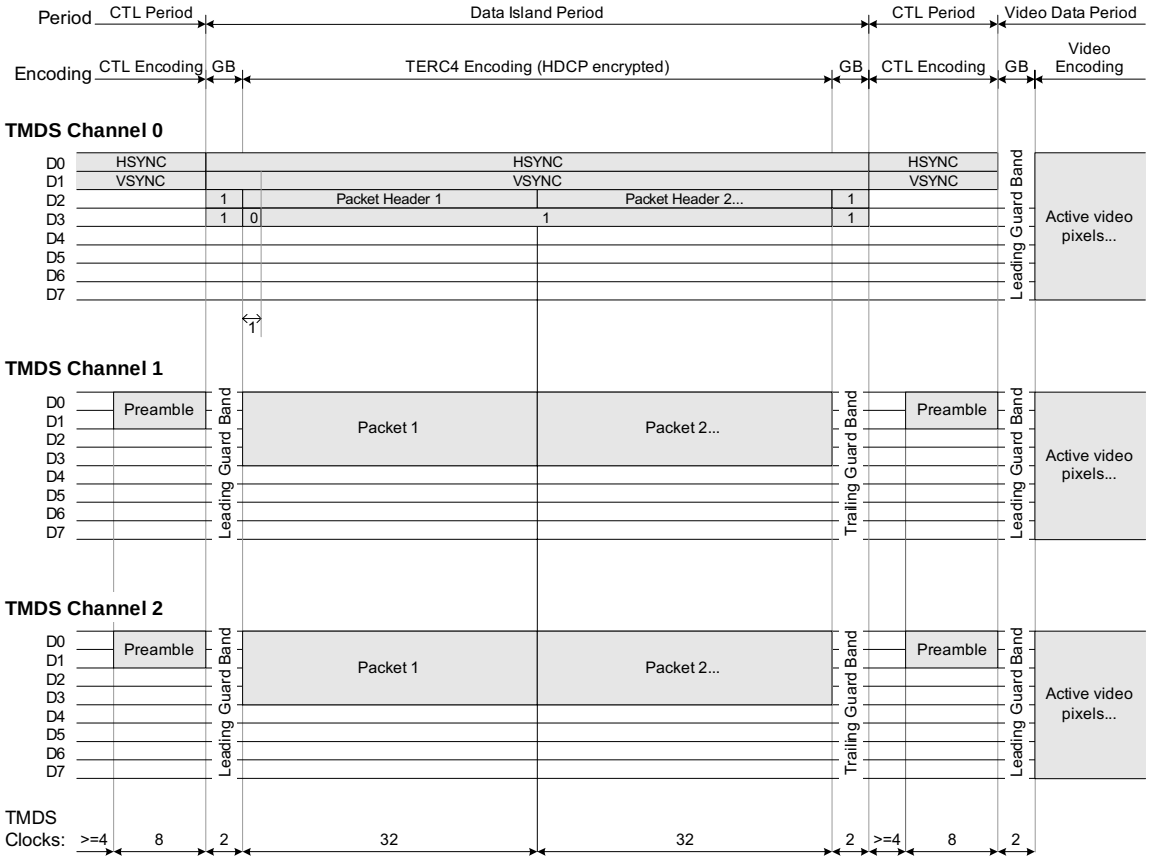


Figure 5-3 TMDS Periods and Encoding

Following the Data Island, all three channels revert to transmitting control characters.

5.2.3.2 Island Placement and Duration

The Source is required to determine the temporal placement and duration of the Data Island with respect to the video signal's horizontal and vertical blanking periods and synchronization signals. It shall do so following the rules stated below.

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All TMDS Control Periods shall be at least $t_{S,min}$ (12) characters (pixels) long.

The Data Island shall contain at least one packet, limiting its minimum size to 36 pixels.

Islands shall contain an integer number of packets. In order to assure the reliability of the data within the Data Island, they shall be limited to 18 packets or fewer.

Zero, one or more Data Islands can occur between subsequent video data periods.

While transmitting video, at least one Data Island shall be transmitted during every two video fields.

5.2.3.3 Data Island Guard Bands

The first two data characters within the Data Island are the Leading Guard Band. The last two data characters within the Data Island are the Trailing Guard Band.

During the Data Island Guard Bands, Channel 0 is encoded as one of four TERC4 values. These TERC4 values (D[3:0]) are 0xC, 0xD, 0xE and 0xF, depending upon the values of HSYNC and VSYNC.

Table 5-6 Data Island Leading and Trailing Guard Band Values

```
case (TMDS Channel Number):
       0:  q_out[9:0] = n.a.;
       1:  q_out[9:0] = 0b0100110011;
       2:  q_out[9:0] = 0b0100110011;
endcase
```

5.2.3.4 Data Island Packet Construction

All data within a Data Island is contained within 32 clock Packets. Packets consist of a Packet Header, a Packet Body (consisting of four Subpackets), and associated error correction bits. Each Subpacket includes 56 bits of data and is protected by an additional 8 bits of BCH ECC parity bits.

Subpacket 0 plus its corresponding parity bits make up BCH Block 0. This block is mapped onto bit 0 of both Channel 1 and Channel 2. In this way, the 64 bits of BCH Block 0 are transferred over the course of 32 pixels. Likewise, BCH Block 1 (Subpacket 1 plus parity) is mapped onto bit 1 of both Channels 1 and 2.

In the tables below, Header bytes are indicated as HB0, HB1, and HB2 and Subpacket bytes are indicated as SB0 to SB6.

Subpacket 0 bytes 0 through 6 (SB0-SB6) are also designated Packet bytes 0 to 6 (PB0-PB6).

Subpacket 1 bytes 0 through 6 (SB0-SB6) are also designated Packet bytes 7 to 13 (PB7-PB13).

Subpacket 2 bytes 0 through 6 (SB0-SB6) are also designated Packet bytes 14 to 20 (PB14-PB20).

Subpacket 3 bytes 0 through 6 (SB0-SB6) are also designated Packet bytes 21 to 27 (PB21-PB27).

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This is illustrated in Figure 5-4.

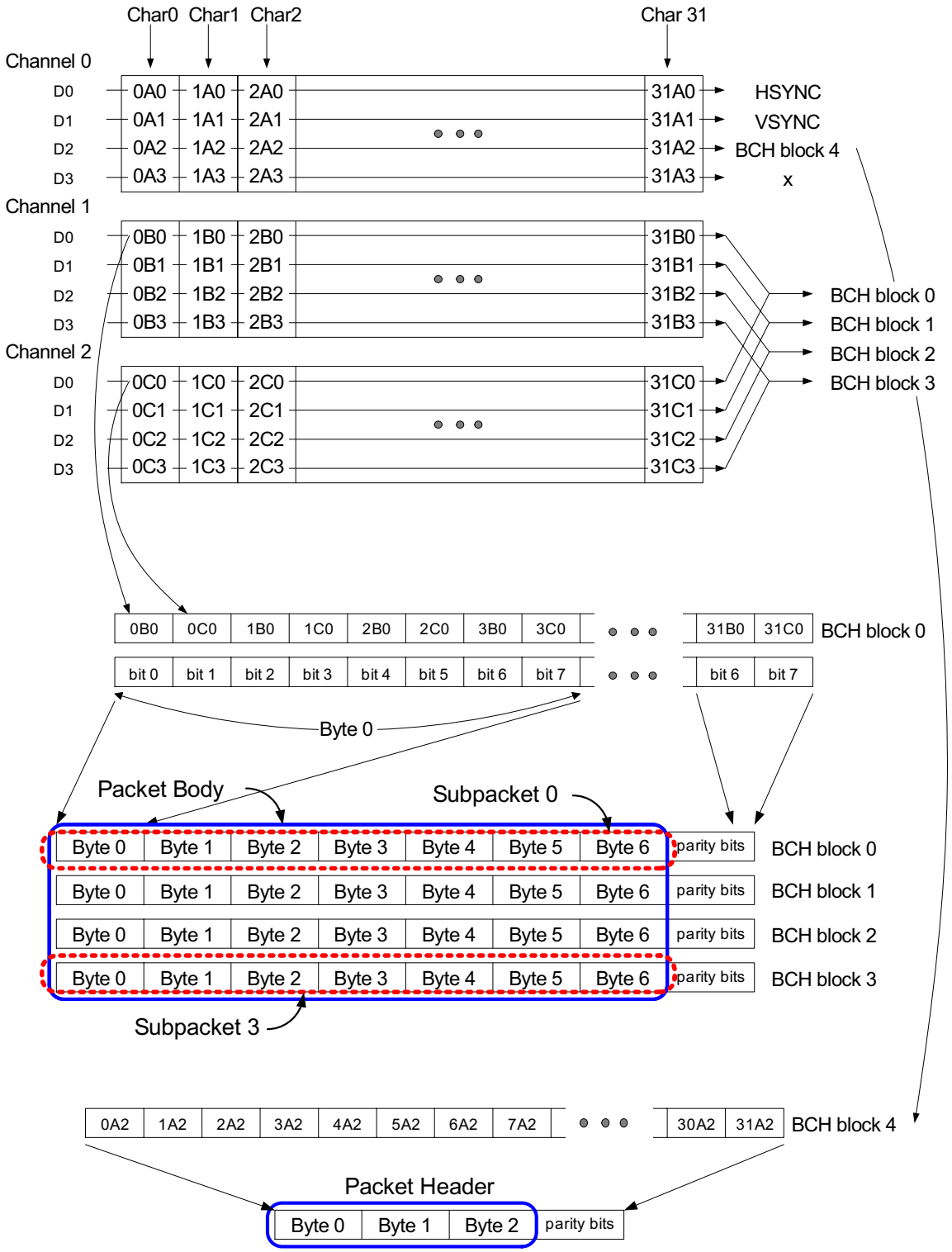


Figure 5-4 Data Island Packet and ECC Structure

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5.2.3.5 Data Island Error Correction

To improve the reliability of the data and to improve the detection of bad data, Error Correction Code (ECC) parity is added to each packet. BCH(64,56) and BCH(32,24) are generated by the polynomial G(x) shown in Figure 5-5.

$G(x)=1+x^6+x^7+x^8$ (127 count repetition cycle).

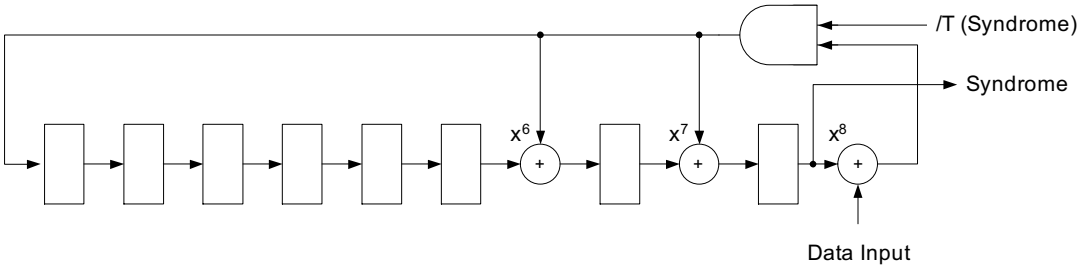


Figure 5-5 Error Correction Code generator

5.3 Data Island Packet Definitions

5.3.1 Packet Header

Packet Headers contain 24 data bits with an additional 8 bits of BCH(32,24) ECC parity. These parity bits are calculated over the 24 bits of the Packet Header.

A Packet Header includes an 8-bit Packet Type and 16 bits of packet-specific data.

A Sink shall be able to receive, with no adverse effects, any packet defined in the HDMI 1.0 specification including any InfoFrame Packet with an InfoFrame Type defined in CEA-861-D.

Table 5-7 Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	Packet Type							
HB1	packet-specific data							
HB2	packet-specific data							

Table 5-8 shows the available packet types.

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Table 5-8 Packet Types

Packet Type Value		Packet Type	Described in Section
0x00		Null	5.3.2
0x01		Audio Clock Regeneration (N/CTS)	5.3.3
0x02		Audio Sample (L-PCM and IEC 61937 compressed formats)	5.3.4
0x03		General Control	5.3.6
0x04		ACP Packet	5.3.7
0x05		ISRC1 Packet	5.3.8
0x06		ISRC2 Packet	"
0x07		One Bit Audio Sample Packet	5.3.9
0x08		DST Audio Packet	5.3.10
0x09		High Bitrate (HBR) Audio Stream Packet (IEC 61937)	5.3.11
0x0A		Gamut Metadata Packet	5.3.12
0x80+InfoFrame Type		InfoFrame Packet	5.3.5
	0x81	Vendor-Specific InfoFrame	- -
	0x82	AVI InfoFrame*	8.2.1
	0x83	Source Product Descriptor InfoFrame	- -
	0x84	Audio InfoFrame*	8.2.2
	0x85	MPEG Source InfoFrame	- -

** See Section 8.2 for the packet layout for these InfoFrames*

5.3.2 Null Packet

Null packets can be used by the Source anytime. All bytes of a Null packet are undefined and shall contain only zero values. An HDMI Sink shall ignore bytes HB1 and HB2 of the Null Packet Header and all bytes of the Null Packet Body.

Table 5-9 Null Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	0	0	0	0	0	0	0	0
HB1	0	0	0	0	0	0	0	0
HB2	0	0	0	0	0	0	0	0

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5.3.3 Audio Clock Regeneration Packet

Audio Clock Regeneration Packets contain both the N and CTS values used in the Audio Clock Regeneration process. The four Subpackets each contain the same Audio Clock Regeneration Subpacket. An HDMI Sink shall ignore bytes HB1 and HB2 of the Audio Clock Regeneration Packet header.

Table 5-10 Audio Clock Regeneration Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	0	0	0	0	0	0	0	1
HB1	0	0	0	0	0	0	0	0
HB2	0	0	0	0	0	0	0	0

Table 5-11 Audio Clock Regeneration Subpacket

Byte \ Bit #	7	6	5	4	3	2	1	0
SB0	0	0	0	0	0	0	0	0
SB1	0	0	0	0	CTS.19	-	-	CTS.16
SB2	CTS.15	-	-	-	-	-	-	CTS.8
SB3	CTS.7	-	-	-	-	-	-	CTS.0
SB4	0	0	0	0	N.19	-	-	N.16
SB5	N.15	-	-	-	-	-	-	N.8
SB6	N.7	-	-	-	-	-	-	N.0

- N [20 bits] value of audio clock regeneration “N”
- CTS [20 bits] Cycle Time Stamp

CTS values of zero are used to indicate no new value of CTS.

5.3.4 Audio Sample Packet

L-PCM and some IEC 61937 compressed audio formats are carried using Audio Sample Packets. Audio Sample Packets consist of one to four Audio Samples. These may be different samples or different partial samples (i.e. 2 of 6 channels). The configuration of the Subpackets is determined by the layout and sample_present bits in the header. This is described in detail in Section 7.6, *Audio Data Packetization*.

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Table 5-12 Audio Sample Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	0	0	0	0	0	0	1	0
HB1	0	0	0	layout	sample_ present.sp3	sample_ present.sp2	sample_ present.sp1	sample_ present.sp0
HB2	B.3	B.2	B.1	B.0	sample_flat .sp3	sample_flat .sp2	sample_flat .sp1	sample_flat .sp0

- layout: [1 bit] indicates which of two possible Subpacket/audio sample layouts are used. See Section 7.6, *Audio Data Packetization*.
- sample_present.spX [4 fields, 1 bit each] indicates if Subpacket X contains audio sample(s).
- sample_flat.spX [4 fields, 1 bit each] indicates if Subpacket X represents a “flatline” sample. Only valid if “sample_present.spX” is set.
- B.X [4 fields, 1 bit each] B.X =1 if Subpacket X contains the first frame in a 192 frame IEC 60958 Channel Status block; B.X = 0 otherwise

Table 5-13 Audio Sample Subpacket

Byte \ Bit #	7	6	5	4	3	2	1	0
SB0	L.11	-	-	-	-	-	-	L.4
SB1	L.19	-	-	-	-	-	-	L.12
SB2	L.27	-	-	-	-	-	-	L.20
SB3	R.11	-	-	-	-	-	-	R.4
SB4	R.19	-	-	-	-	-	-	R.12
SB5	R.27	-	-	-	-	-	-	R.20
SB6	P_R	C_R	U_R	V_R	P_L	C_L	U_L	V_L

- L.X: [24 fields, 1 bit each] Bit corresponding to Time Slot X from first (“left”) sub-frame per IEC 60958-1, page 15
- R.X: [24 fields, 1 bit each] Bit corresponding to Time Slot X from second (“right”) sub-frame per IEC 60958-1, page 15
- V_L: [1 bit] Valid bit from first sub-frame
- V_R: [1 bit] Valid bit from second sub-frame
- U_L: [1 bit] User Data bit from first sub-frame
- U_R: [1 bit] User Data bit from second sub-frame
- C_L: [1 bit] Channel Status bit from first sub-frame
- C_R: [1 bit] Channel Status bit from second sub-frame
- P_L: [1 bit] Parity bit from first sub-frame (even parity)

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- P_R: [1 bit] Parity bit from second sub-frame (even parity)

5.3.5 InfoFrame Packet

All InfoFrames defined in CEA-861-D may be carried across HDMI using the HDMI InfoFrame packet. InfoFrames not defined in CEA-861-D or in this specification shall not be transmitted.

Each HDMI InfoFrame Packet carries a single CEA InfoFrame, as shown below[2].[pw99] Note that HDMI places additional requirements on several InfoFrames that are not covered by CEA-861-D. For these additional details and restrictions, see Section 8.2.

Table 5-14 InfoFrame Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	1	InfoFrame Type						
HB1	InfoFrame_version							
HB2	0	0	0	InfoFrame_length				

- InfoFrame Type [7 bits] least significant 7 bits of the InfoFrame type code as per CEA-861-D.
- InfoFrame_version [1 byte] version number of InfoFrame as per CEA-861-D.
- InfoFrame_length [5 bits] InfoFrame length in bytes as per CEA-861-D. This length does not include any of the bytes in the Packet Header nor the checksum byte. The maximum value for this field is 27 (0x1B).

Table 5-15 InfoFrame Packet Contents

Byte \ Bit #	7	6	5	4	3	2	1	0
PB0	Checksum							
PB1	Data Byte 1							
PB2	Data Byte 2							
PB3...PB26	-							
PB27	Data Byte 27							

- Checksum [1 byte] Checksum of the InfoFrame. The checksum shall be calculated such that a byte-wide sum of all three bytes of the Packet Header and all valid bytes of the InfoFrame Packet contents (determined by InfoFrame_length), plus the checksum itself, equals zero.

[2] An earlier version of CEA-861-D, CEA-861B, had a method for encapsulating multiple CEA InfoFrames into a single CEA InfoPacket. HDMI has its own packet structure and therefore CEA Info*Packets* are not used.

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- Data Byte x [27 fields, 1 byte each] Data Byte X of the InfoFrame as defined in CEA-861-D. See [HDMI Specification] Section 8.2 for more information.

5.3.6 General Control Packet

The General Control packet header contains no data. Bytes HB1 and HB2 shall be ignored by the Sink. The General Control packet body shall contain four identical subpackets, defined in Table 5-17, below.

Table 5-16 General Control Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	0	0	0	0	0	0	1	1
HB1	0	0	0	0	0	0	0	0
HB2	0	0	0	0	0	0	0	0

Table 5-17 General Control Subpacket

Byte \ Bit #	7	6	5	4	3	2	1	0
SB0	0	0	0	Clear_AVMUTE	0	0	0	Set_AVMUTE
SB1	PP3	PP2	PP1	PP0	CD3	CD2	CD1	CD0
SB2	0	0	0	0	0	0	0	Default_Phase
SB3	0	0	0	0	0	0	0	0
SB4	0	0	0	0	0	0	0	0
SB5	0	0	0	0	0	0	0	0
SB6	0	0	0	0	0	0	0	0

- Set_AVMUTE [1 bit] Set the AVMUTE flag. (See description below).
- Clear_AVMUTE [1bit] Clear the AVMUTE flag. (See description below).
- PP [4 bits] Pixel Packing Phase. (See description in section 6.5.3.)
- CD [4 bits] Color Depth. (See description in section 6.5.3.)
- Default_Phase [1 bit] Default Phase. (See description in section 6.5.3.)

The General Control Packet contains fields for indicating AVMUTE information and color-depth information. Each transmitted GCP may contain valid indications for AVMUTE and/or color-depth or may contain no information (all fields zero).

General Control packets indicating Set_AVMUTE or Clear_AVMUTE may only be transmitted between the active edge of VSYNC and 384 pixels following this edge. A Source may not send a General Control Packet with the Clear_AVMUTE and Set_AVMUTE flags set simultaneously.

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Source transmission of the General Control Packet is optional. Sinks may optionally interpret General Control Packet contents. Sinks shall be capable of receiving any General Control Packet.

The General Control packet's Set_AVMUTE and Clear_AVMUTE flags may be used by a Source to reduce the negative impact on the Sink of TMDS clock changes or interruptions. Use of the AVMUTE function may prevent spurious pops or noises in the audio during these clock changes.

When AVMUTE is set, the Sink may assume that no valid audio or video data is being received. The Sink may optionally apply a mute function to the audio data and/or a blank function to the video.

5.3.7 Audio Content Protection Packet (ACP)

A Source may use the ACP Packet to convey content-related information regarding the active audio stream.

See Section 9.3 for rules regarding the use of the ACP packet.

The following tables show the packetization of the ACP Packet.

Table 5-18 ACP Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	Packet Type = 0x04							
HB1	ACP_Type							
HB2	Reserved (0)							

- ACP_Type [1 byte] Content protection type (see Section 9.3 for usage):
  0x00 = Generic Audio
  0x01 = IEC 60958-Identified Audio
  0x02 = DVD-Audio
  0x03 = Super Audio CD
  0x04...0xFF Reserved

Table 5-19 ACP Packet contents

Packet Byte #	7	6	5	4	3	2	1	0
PB0-PB27	ACP_Type_Dependent (Dependent upon ACP_Type value)							

- ACP_Type_Dependent [28 bytes] Contents are dependent upon ACP_Type field. See Section 9.3 for usage.

5.3.8 ISRC Packets

A Source may use the ISRC packets to transmit a UPC/EAN or ISRC code. See Section 8.8 for rules regarding the use of the ISRC packets.

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Table 5-20 ISRC1 Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	Packet Type = 0x05							
HB1	ISRC_ Cont	ISRC_ Valid	Reserved (0)			ISRC_Status		
HB2	Reserved (0)							

- ISRC_Cont [1 bit] ISRC Continued (in next packet). See Section 8.8 for usage.
- ISRC_Status [3 bits] See Section 8.8 for usage.
- ISRC Valid [1 bit]: This bit is set only when data located in ISRC_Status field and UPC_EAN_ISRC_xx field are valid. When Source cannot obtain complete data for these fields, ISRC_Valid may be 0.

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Table 5-21 ISRC1 Packet contents

Packet Byte #	7	6	5	4	3	2	1	0
PB0	UPC_EAN_ISRC_0							
PB1	UPC_EAN_ISRC_1							
PB2	UPC_EAN_ISRC_2							
PB3	UPC_EAN_ISRC_3							
PB4	UPC_EAN_ISRC_4							
PB5	UPC_EAN_ISRC_5							
PB6	UPC_EAN_ISRC_6							
PB7	UPC_EAN_ISRC_7							
PB8	UPC_EAN_ISRC_8							
PB9	UPC_EAN_ISRC_9							
PB10	UPC_EAN_ISRC_10							
PB11	UPC_EAN_ISRC_11							
PB12	UPC_EAN_ISRC_12							
PB13	UPC_EAN_ISRC_13							
PB14	UPC_EAN_ISRC_14							
PB15	UPC_EAN_ISRC_15							
PB16-PB27	Reserved (0)							

- UPC_EAN_ISRC_xx [16 fields, 1 byte each] UPC/EAN or ISRC byte xx. See Section 8.8 for usage.

Bytes PB16-PB27 shall be set to a value of 0.

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Table 5-22 ISRC2 Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	Packet Type = 0x06							
HB1	Reserved (0)							
HB2	Reserved (0)							

Table 5-23 ISRC2 Packet contents

Packet Byte #	7	6	5	4	3	2	1	0
PB0	UPC_EAN_ISRC_16							
PB1	UPC_EAN_ISRC_17							
PB2	UPC_EAN_ISRC_18							
PB3	UPC_EAN_ISRC_19							
PB4	UPC_EAN_ISRC_20							
PB5	UPC_EAN_ISRC_21							
PB6	UPC_EAN_ISRC_22							
PB7	UPC_EAN_ISRC_23							
PB8	UPC_EAN_ISRC_24							
PB9	UPC_EAN_ISRC_25							
PB10	UPC_EAN_ISRC_26							
PB11	UPC_EAN_ISRC_27							
PB12	UPC_EAN_ISRC_28							
PB13	UPC_EAN_ISRC_29							
PB14	UPC_EAN_ISRC_30							
PB15	UPC_EAN_ISRC_31							
PB16-PB27	Reserved (0)							

- UPC_EAN_ISRC_xx [16 fields, 1 byte each] UPC/EAN or ISRC byte xx.

Bytes PB16-PB27 shall be set to a value of 0.

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5.3.9 One Bit Audio Sample Packet

One Bit Audio streams are transmitted using the One Bit Audio Sample Packet.

One Bit Audio Packets consist of one to four One Bit Audio Subpackets. These may be different samples or different partial samples (e.g. 2 of 6 channels). The configuration of the Subpackets is determined by the layout and samples_present bits in the header. This is described in detail in Section 7.6, *Audio Data Packetization*.

It is optional for the Source, Sink and Repeater to support the One Bit Audio packet.

Table 5-24 One Bit Audio Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	0	0	0	0	0	1	1	1
HB1	Rsvd (0)	Rsvd (0)	Rsvd (0)	layout	samples_ present.sp3	samples_ present.sp2	samples_ present.sp1	samples_ present.sp0
HB2	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	samples_ invalid.sp3	samples_ invalid.sp2	samples_ invalid.sp1	samples_ invalid.sp0

- layout [1 bit] indicates which of two possible Subpacket/audio sample layouts are used. See Table 5-25 below and Section 7.6, *Audio Data Packetization*.
- samples_present.spX [4 fields, 1 bit each] indicates if Subpacket X contains audio sample data. Samples_present.spX = 1 if subpacket X contains sample data; else = 0.
- samples_invalid.spX [4 fields, 1 bit each] indicates if Subpacket X represents invalid samples. Samples_invalid = 1 if the samples in Subpacket X are invalid; else = 0. This bit is only valid if the relevant "samples_present.spX" is set.

Note that, for One Bit Audio, sample frequency information is carried in the Audio InfoFrame (see section 8.2.2).

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Table 5-25 One Bit Audio Subpacket

Byte \ Bit #	7	6	5	4	3	2	1	0
SB0	ChA.7	-	-	-	-	-	-	ChA.0
SB1	ChA.15	-	-	-	-	-	-	ChA.8
SB2	ChA.23	-	-	-	-	-	-	ChA.16
SB3	ChB.7	-	-	-	-	-	-	ChB.0
SB4	ChB.15	-	-	-	-	-	-	ChB.8
SB5	ChB.23	-	-	-	-	-	-	ChB.16
SB6	ChB.27	ChB.26	ChB.25	ChB.24	ChA.27	ChA.26	ChA.25	ChA.24

- ChA.X: [28 fields, 1 bit each] indicates consecutive One Bit Audio samples of the first channel. The most significant bit (ChA.27) is the first sampled bit of the consecutive 28-bit part in the One Bit Audio stream.
- ChB.X: [28 fields, 1 bit each] indicates consecutive One Bit Audio samples of the second channel. The most significant bit (ChB.27) is the first sampled bit of the consecutive 28-bit part in the One Bit Audio stream.

5.3.10 DST Audio Packet

DST (compressed DSD) audio streams are transmitted using the DST Audio Packet.

A DST Audio Packet contains a single DST Audio Packet Body which is filled as audio data becomes available. All identification of channels and other data is embedded in the stream. DST Audio Packet packing is described further in 7.6.3, *DST Packetization*.

It is optional for a Source, Sink or Repeater to support the DST Audio Packet.

Table 5-26 DST Audio Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	0	0	0	0	1	0	0	0
HB1	frame_ start	samples_ invalid	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	DST_normal _double
HB2	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)

- frame_start [1 bit] =1 indicates that this packet is the start of a DST frame; =0 otherwise.
- samples_invalid [1 bit] = 1 if the samples are not valid; = 0 if the samples are valid.
- DST_Normal_Double [1 bit] =0 (“DST_Normal”) indicates that the sample rate equals the transfer rate. =1 (“DST_Double”) indicates that the transfer rate is twice the sample rate. DST_Double rate is used when normal does not have sufficient bandwidth.

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Note that, for DST, sample frequency information is carried in the Audio InfoFrame (see section 8.2.2).

Each DST Audio Packet Body contains 224 bits (28 bytes) of DST data. DST stream data is taken in byte order and packed into the DST Audio Packet Body as shown in Table 5-27.

Table 5-27 DST Audio Packet Body

Byte \ Bit #	7	6	5	4	3	2	1	0
PB0	D.7	D.6	D.5	D.4	D.3	D.2	D.1	D.0
PB1	D.15	D.14	D.13	D.12	D.11	D.10	D.9	D.8
-	-	-	-	-	-	-	-	-
PB26	D.215	D.214	D.213	D.212	D.211	D.210	D.209	D.208
PB27	D.223	D.222	D.221	D.220	D.219	D.218	D.217	D.216

- D.X [224 fields, 1 bit each] DST bitstream, beginning with D.0.

5.3.11 High-Bitrate (HBR) Audio Stream Packet

High bitrate (>6.144Mbps) compressed audio streams conforming to IEC 61937 are carried using HBR Audio Stream Packets. Each packet carries four IEC 60958 frames which corresponds to (4x2x16 =) 128 contiguous bits of an IEC 61937 stream. This is described in more detail in Section 7.6.2, *High-Bitrate Audio Stream Packetization*.

Table 5-28 HBR Audio Stream Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	0	0	0	0	1	0	0	1
HB1	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)
HB2	B.3	B.2	B.1	B.0	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)

- B.X [4 fields, 1 bit each] B.X =1 if Subpacket X contains the first frame in a 192 frame IEC 60958 Channel Status block; B.X = 0 otherwise

The HBR Audio Stream Packet uses four subpackets which are identical to the Audio Sample Subpacket shown above in Table 5-13.

5.3.12 Gamut Metadata Packet

Gamut boundary descriptions (GBD) and other gamut-related metadata are carried using the Gamut Metadata Packet. Gamut metadata is further described in Appendix E.

One of several transmission profiles (P0, P1, P2, etc.) can be used when sending GBDs using this packet. The difference between the transmission profiles is primarily the transmission rate,

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specifically, the number of packets that may be sent per video field. The transmission profile is indicated in the field GBD_profile.

The lowest transmission profile (P0) also has a specific size limitation; it fits within a single Gamut Metadata Packet. Higher transmission profiles (P1, P2, etc.) can be larger, requiring many packets and possibly ten or more video fields for complete transmission.

Table 5-29 Gamut Boundary Description Metadata Profiles

Transmission Profile Name	EDID Colorimetry Data Block bit	Packets per Video Field	Total Packet Count
P0	MD0	1	1
P1	MD1	1	2-10
P2	MD2	2-10	11-100
P3	*	11-80	101-800

* *This bit will be defined in a future specification.*

Gamut metadata may be transmitted that describes the gamut of the currently transmitted video or that of upcoming video. Each time the gamut of the video stream changes in a way that requires transmission of new gamut metadata, a gamut sequence number is incremented. All metatdata packets include two fields, Affected_Gamut_Seq_Num and Current_Gamut_Seq_Num, that together indicate whether the metadata regards the current or the subsequent video stream. All Gamut Metadata Packets within a single video field (VSYNC active edge to VSYNC active edge) shall have the same Current_Gamut_Seq_Num field.

If a packet contains metadata for the currently transmitted video, Affected_Gamut_Seq_Num will be equal to Current_Gamut_Seq_Num. If the packet regards upcoming video, the Affected_Gamut_Seq_Num will be Current_Gamut_Seq_Num + 1 (mod 16). The field Affected_Gamut_Seq_Num shall never be beyond Current_Gamut_Seq_Num + 1, therefore, only current and next gamut may be described.

If it is known by the Source that a packet contains metadata that will be effective for the next video field then the Next_Field flag shall be set, whether or not the metadata is effective for the current video field.

Gamut metadata associated with upcoming video may be transmitted even when the current video has no associated metadata. In this situation, all Gamut Metadata packets transmitted shall indicate that the current stream has no associated metadata (i.e. colorimetry and gamut are described by the currently-valid AVI InfoFrame) by setting No_Current_GBD to 1. At least one such Gamut Metadata packet shall be transmitted in the VBLANK period. All Gamut Metadata packets within that same video field can carry metadata for the upcoming video.

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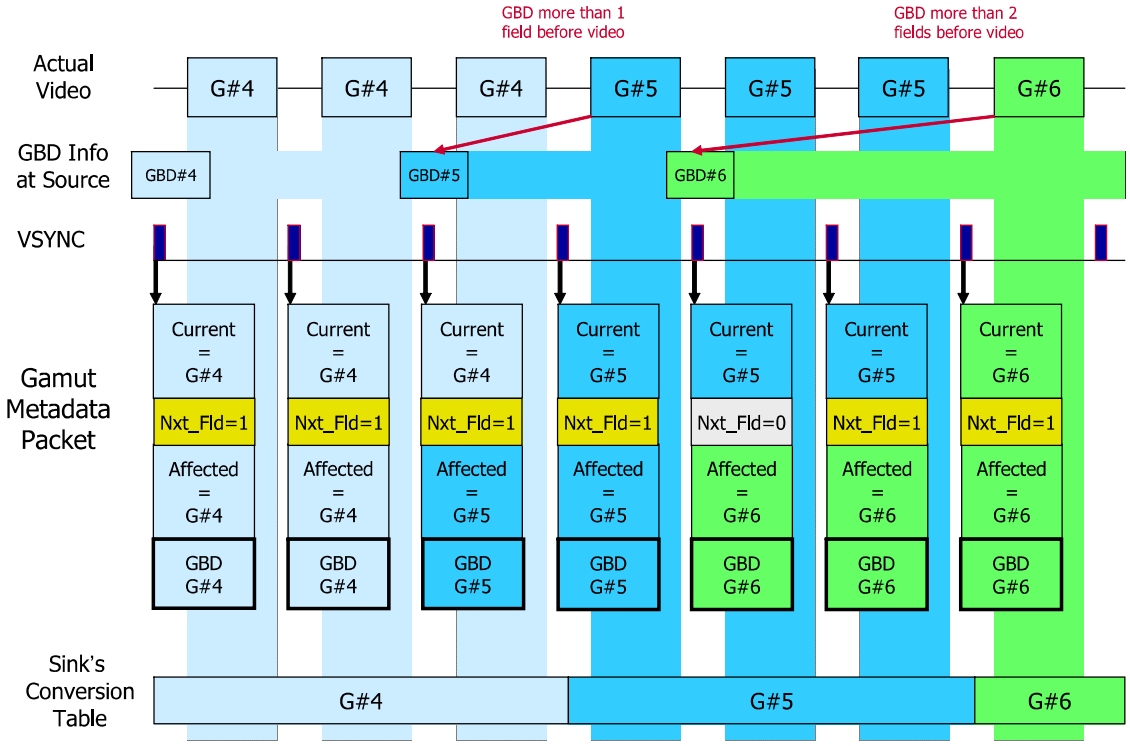


Figure 5-6 Example P0 Transmission Sequence

During the transmission of any video stream that is accompanied by or requires gamut metadata, at least one Gamut Metadata Packet containing a P0 transmission profile GBD shall be transmitted during each VBLANK. This transmission shall occur before the end of the first (VBLANK) video line following the active edge of VSYNC. If no Gamut Metadata Packet is transmitted during this period, then the colorimetry and gamut of the subsequent VACTIVE for that video field shall correspond to that described by the transmitted AVI InfoFrame.

If the Sink indicates support for P2 or higher transmission profiles then the Source may simultaneously transmit two GBDs. In this case, within each video field, the Source may transmit: a P0 profile containing the GBD for the current video and a portion of a higher profile containing the GBD for either the current or the upcoming video. Alternatively, the two simultaneous GBDs may be a P0 profile describing the current video and a P0 profile describing the upcoming video.

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Table 5-30 Gamut Metadata Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	0	0	0	0	1	0	1	0
HB1	Next_Field	GBD_profile			Affected_Gamut_Seq_Num			
HB2	No_Crnt _GBD	Rsvd (0)	Packet_Seq		Current_Gamut_Seq_Num			

- Next_Field [1 bit] Set to indicate that the GBD carried in this packet will be effective on the next video field. Specifically, the Affected_Gamut_Seq_Num for this packet will be equal to the Current_Gamut_Seq_Num for the next field. Next_Field should be set even if the GBD is already effective (e.g. Current=Affected).
- No_Current_GBD [1 bit] Set to indicate that there is no gamut metadata available for the currently transmitted video (i.e. current video has a standard colorimetry not requiring a GBD). When set, the field Current_Gamut_Seq_Num is meaningless and shall be ignored by the Sink.
- GBD_profile [3 bits] Transmission profile number:
  0: P0
  1: P1
  2: P2
  3: P3
  other values: reserved.
- Affected_Gamut_Seq_Num [4 bits] Indicates which video fields are relevant for this metadata.
- Current_Gamut_Seq_Num [4 bits] Indicates the gamut number of the currently transmitted video stream. All Gamut Metadata Packets transmitted within the same video field shall have the same Current_Gamut_Seq_Num, even if the Affected_Gamut_Seq_Num varies among the packets.
- Packet_Seq [2 bits] Indicates whether this packet is the only, the first, an intermediate or the last packet in a Gamut Metadata packet sequence.
  = 0 (0b00) Intermediate packet in sequence
  = 1 (0b01) First packet in sequence
  = 2 (0b10) Last packet in sequence
  = 3 (0b11) Only packet in sequence (i.e. P0)

The Gamut Metadata Packet Body differs depending upon transmission profile and whether the packet is the first of a sequence or one of the remaining packets in that sequence.

The packet body for a P0 transmission is defined in Table 5-31.

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Table 5-31 Gamut Metadata Packet for P0 Transmission Profile

Packet Byte #	7	6	5	4	3	2	1	0
PB00-PB27	GBD bytes 0 through 27							

When transmitting any GBD requiring more than one Gamut Metadata Packet for transmission, a packet containing the packet body shown in Table 5-32 shall be used. Subsequent packets in that sequence shall use the packet body shown in Table 5-33. If the GBD ends midway through a packet, the rest of the body shall be filled with zeroes by the Source and shall be ignored by the Sink.

Table 5-32 Gamut Metadata Packet for P1 and Higher – 1st Packet of Sequence

Packet Byte #	7	6	5	4	3	2	1	0
PB0	GBD_Length_H							
PB1	GBD_Length_L							
PB2	Checksum							
PB3-PB27	GBD bytes 0 through 24							

- GBD_Length(_H, _L) [2 bytes] Total length (in bytes) of gamut metadata, not including GBD_Length or Checksum.
- Checksum [1 byte] Checksum of every byte covered by GBD_Length field.

Table 5-33 Gamut Metadata Packet for P1 and Higher – Remaining Packets

Packet Byte #	7	6	5	4	3	2	1	0
PB00-PB27	Next 28 bytes of GBD							

5.4 Encoding

5.4.1 Serialization

The stream of TMDS characters produced by the encoder is serialized for transmission on the TMDS data channel. In the discussions that follow, the least significant bit of each character (q_out[0]) is the first bit to be transmitted and the most significant bit (q_out[9]) is the last.

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5.4.2 Control Period Coding

Each TMDS channel has two control signals, which are encoded into 10 bits during Control Periods. For each of the three channels these signals are shown in Table 5-34.

Table 5-34 Control-signal Assignment

TMDS Channel	D0	D1
0	HSYNC	VSYNC
1	CTL0	CTL1
2	CTL2	CTL3

The two Control signals for each of the three TMDS channels are encoded as follows:

```
case (D1, D0):
       0, 0:  q_out[9:0] = 0b1101010100;
       0, 1:  q_out[9:0] = 0b0010101011;
       1, 0:  q_out[9:0] = 0b0101010100;
       1, 1:  q_out[9:0] = 0b1010101011;
endcase;
```

5.4.3 TERC4 Coding

TMDS Error Reduction Coding (TERC4) is used during the Data Island period to encode 4 bits per channel into the 10 bits serialized and transmitted.

```
case (D3, D2, D1, D0):
    0000:  q_out[9:0] = 0b1010011100;
    0001:  q_out[9:0] = 0b1001100011;
    0010:  q_out[9:0] = 0b1011100100;
    0011:  q_out[9:0] = 0b1011100010;
    0100:  q_out[9:0] = 0b0101110001;
    0101:  q_out[9:0] = 0b0100011110;
    0110:  q_out[9:0] = 0b0110001110;
    0111:  q_out[9:0] = 0b0100111100;
    1000:  q_out[9:0] = 0b1011001100;
    1001:  q_out[9:0] = 0b0100111001;
    1010:  q_out[9:0] = 0b0110011100;
    1011:  q_out[9:0] = 0b1011000110;
    1100:  q_out[9:0] = 0b1010001110;
    1101:  q_out[9:0] = 0b1001110001;
    1110:  q_out[9:0] = 0b0101100011;
    1111:  q_out[9:0] = 0b1011000011;
endcase;
```


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5.4.4 Video Data Coding

5.4.4.1 Video Data Encoding

The following is a description of the encoding algorithm used during transmission of video data. A detailed description of an encoder is given. Other implementations are possible and are permitted but, given the same sequence of input characters, they are required to produce the same sequence of output (10-bit) characters that is generated by the described encoder.

During video data, where each 10-bit character represents 8 bits of pixel data, the encoded characters provide an approximate DC balance as well as a reduction in the number of transitions in the data stream. The encode process for the active data period can be viewed in two stages. The first stage produces a transition-minimized 9-bit code word from the input 8 bits. The second stage produces a 10-bit code word, the finished TMDS character, which will manage the overall DC balance of the transmitted stream of characters.

The 9-bit code word produced by the first stage of the encoder is made up of an 8-bit representation of the transitions found in the input 8 bits, plus a one-bit flag to indicate which of two methods was used to describe the transitions. In both cases, the LSb of the output matches the LSb of the input. With a starting value established, the remaining 7 bits of the output word is derived from sequential exclusive OR (XOR) or exclusive NOR (XNOR) functions of each bit of the input with the previously derived bit. The choice between XOR and XNOR logic is made such that the encoded values contain the fewest possible transitions, and the ninth bit of the code word is used to indicate whether XOR or XNOR functions were used to derive the output code word. The decode of this 9-bit code word is simply a matter of applying either XOR or XNOR gates to the adjacent bits of the code, with the LSb passing from decoder input to decoder output unchanged.

The second stage of the encoder performs an approximate DC balance on the transmitted stream by selectively inverting the 8 data bits of the 9-bit code words produced by the first stage. A tenth bit is added to the code word, to indicate when the inversion has been made. The encoder determines when to invert the next character based on the running disparity between ones and zeros that it tracks in the transmitted stream, and the number of ones and zeros found in the current code word. If too many ones have been transmitted and the input contains more ones than zeros, the code word is inverted. This dynamic encoding decision at the Source is simply decoded at the Sink by the conditional inversion of the input code word based on the tenth bit of the TMDS character. The TMDS code mapping is specified by Figure 5-7 with the definitions of Table 5-35. The encoder produces one of 460 unique 10-bit characters. The encoder shall not generate any other 10-bit character during a Video Data Period.

Upon entering a Video Data Period, the data stream disparity (cnt) shall be considered to be zero by the encoder.

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Table 5-35 Encoding Algorithm Definitions

D	The encoder input data set. D is 8-bit pixel data
cnt	This is a register used to keep track of the data stream disparity. A positive value represents the excess number of “1”s that have been transmitted. A negative value represents the excess number of “0”s that have been transmitted. The expression cnt{t-1} indicates the previous value of the disparity for the previous set of input data. The expression cnt(t) indicates the new disparity setting for the current set of input data.
q_m	Intermediate value.
q_out	These 10 bits are the encoded output value.
N_1{x}	This operator returns the number of “1”s in argument “x”
N_0{x}	This operator returns the number of “0”s in argument “x”

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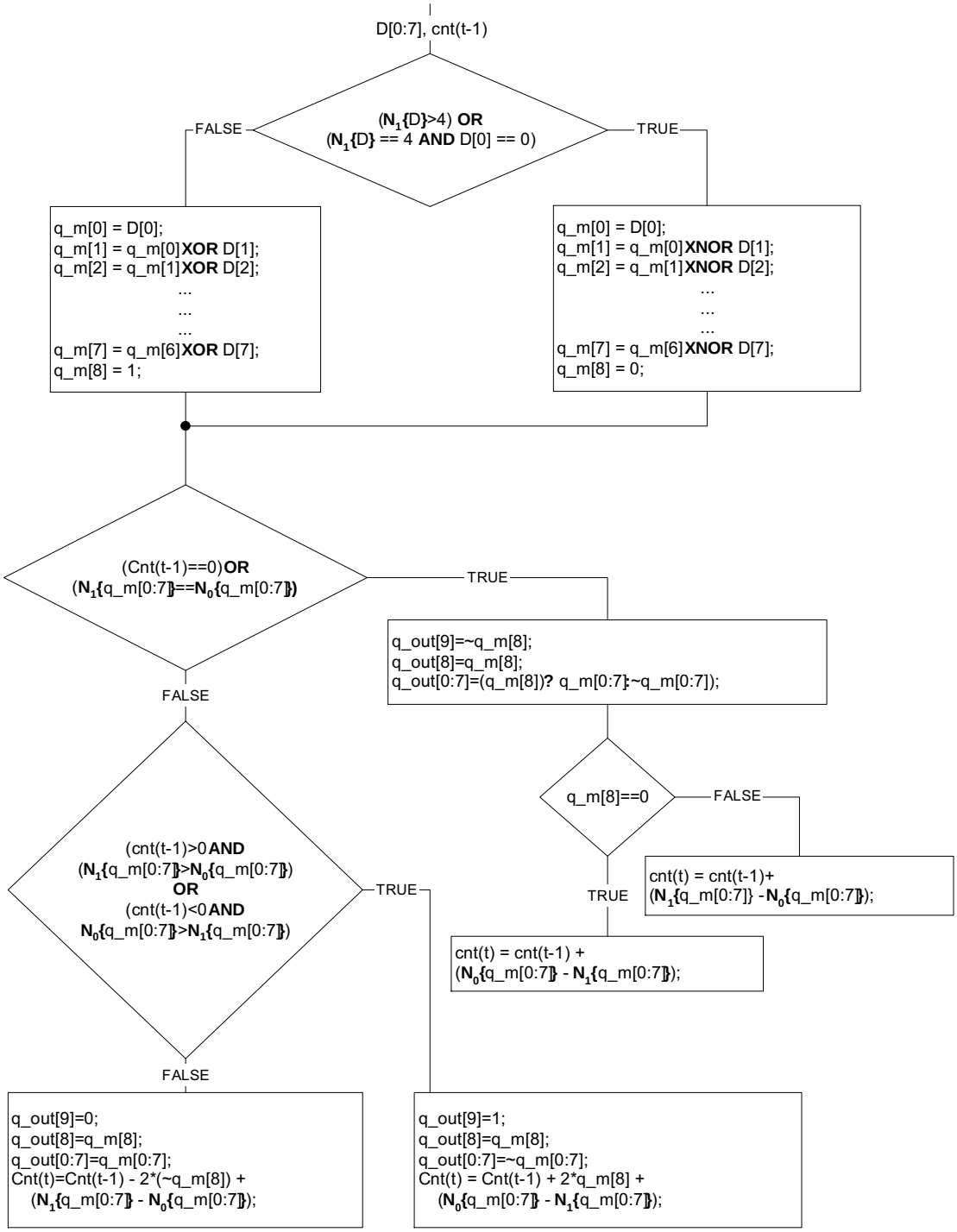


Figure 5-7 TMDS Video Data Encode Algorithm

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5.4.4.2 Video Data Decoding

The TMDS decode mapping is specified by Figure 5-8. Alternative implementations are possible but, given the same input data stream, they are required to generate the same output data stream as the described decoder algorithm.

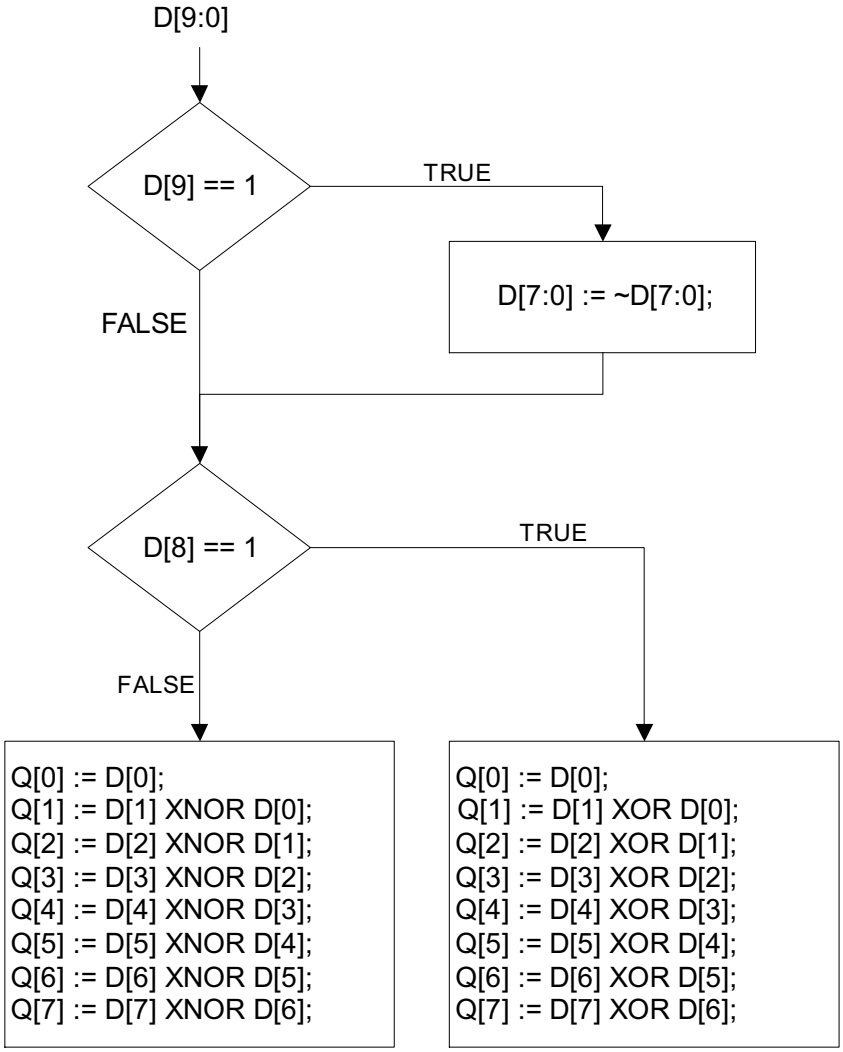


Figure 5-8 TMDS Video Decode Algorithm

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6 Video

6.1 Overview

HDMI allows any video format timing to be transmitted and displayed. To maximize interoperability between products, common DTV formats have been defined. These video format timings define the pixel and line counts and timing, synchronization pulse position and duration, and whether the format is interlaced or progressive. HDMI also allows vendor-specific formats to be used.

The video pixels carried across the link shall be in one of three different pixel encodings: RGB 4:4:4, YC_BC_R 4:4:4 or YC_BC_R 4:2:2.

The HDMI Source determines the pixel encoding and video format of the transmitted signal based on the characteristics of the source video, the format and pixel encoding conversions possible at the Source, and the format and pixel encoding capabilities and preferences of the Sink.

6.2 Video Format Support

In order to provide maximum compatibility between video Sources and Sinks, specific minimum requirements have been specified for Sources and Sinks.

6.2.1 Format Support Requirements

Some of the following support requirements are in addition to those specified in CEA-861-D.

- An HDMI Source shall support at least one of the following video format timings:
  - 640x480p @ 59.94/60Hz
  - 720x480p @ 59.94/60Hz
  - 720x576p @ 50Hz
- An HDMI Source that is capable of transmitting any of the following video format timings using any other component analog or uncompressed digital video output, shall be capable of transmitting that video format timing across the HDMI interface.
  - 1280x720p @ 59.94/60Hz
  - 1920x1080i @ 59.94/60Hz
  - 720x480p @ 59.94/60Hz
  - 1280x720p @ 50Hz
  - 1920x1080i @ 50Hz
  - 720x576p @ 50Hz

- An HDMI Sink that accepts 60Hz video formats shall support the 640x480p @ 59.94/60Hz and 720x480p @ 59.94/60Hz video format timings.
- An HDMI Sink that accepts 50Hz video formats shall support the 640x480p @ 59.94/60Hz and 720x576p @ 50Hz video format timings.

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- An HDMI Sink that accepts 60Hz video formats, and that supports HDTV capability, shall support 1280x720p @ 59.94/60Hz or 1920x1080i @ 59.94/60Hz video format timings.
- An HDMI Sink that accepts 50Hz video formats, and that supports HDTV capability, shall support 1280x720p @ 50Hz or 1920x1080i @ 50Hz video format timings.
- An HDMI Sink that is capable of receiving any of the following video format timings using any other component analog or uncompressed digital video input, shall be capable of receiving that format across the HDMI interface.
    - 1280x720p @ 59.94/60Hz
    - 1920x1080i @ 59.94/60Hz
    - 1280x720p @ 50Hz
    - 1920x1080i @ 50Hz

Additional recommendations for video format handling by Sources and Sinks is given in Appendix F.

6.2.2 Video Control Signals : HSYNC, VSYNC

During the Data Island period, HDMI carries HSYNC and VSYNC signals using encoded bits on Channel 0. During Video Data periods, HDMI does not carry HSYNC and VSYNC and the Sink should assume that these signals remain constant. During Control periods, HDMI carries HSYNC and VSYNC signals through the use of four different control characters on TMDS Channel 0.

6.2.3 Pixel Encoding Requirements

Only pixel encodings of RGB 4:4:4, YC_BC_R 4:2:2, and YC_BC_R 4:4:4 (as specified in Section 6.5) may be used on HDMI.

All HDMI Sources and Sinks shall be capable of supporting RGB 4:4:4 pixel encoding.

All HDMI Sources shall support either YC_BC_R 4:2:2 or YC_BC_R 4:4:4 pixel encoding whenever that device is capable of transmitting a color-difference color space across any other component analog or digital video interface except where that device would be required to convert RGB video to YC_BC_R in order to meet this requirement.

All HDMI Sinks shall be capable of supporting both YC_BC_R 4:4:4 and YC_BC_R 4:2:2 pixel encoding when that device is capable of supporting a color-difference color space from any other component analog or digital video input.

If an HDMI Sink supports either YC_BC_R 4:2:2 or YC_BC_R 4:4:4 then both shall be supported.

An HDMI Source may determine the pixel-encodings that are supported by the Sink through the use of the E-EDID. If the Sink indicates that it supports YC_BC_R-formatted video data and if the Source can deliver YC_BC_R data, then it can enable the transfer of this data across the link.

6.2.4 Color Depth Requirements

HDMI Sources and Sinks may support color depths of 24, 30, 36 and/or 48 bits per pixel. All HDMI Sources and Sinks shall support 24 bits per pixel.

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Color depths greater than 24 bits are defined to be “Deep Color” modes. All Deep Color modes are optional though if an HDMI Source or Sink supports any Deep Color mode, it shall support 36-bit mode.

For each supported Deep Color mode, RGB 4:4:4 shall be supported and optionally YC_BC_R 4:4:4 may be supported.

YC_BC_R 4:2:2 is not permitted for any Deep Color mode.

An HDMI Sink shall support all EDID-indicated Deep Color modes on all EDID-indicated video formats except if that combination exceeds the Max_TMDS_Clock indication.

An HDMI Source shall not send any Deep Color mode to a Sink that does not indicate support for that mode.

6.3 Video Format Timing Specifications

All specified video line pixel counts and video field line counts (both active and total) and HSYNC and VSYNC positions, polarities, and durations shall be adhered to when transmitting a specified video format timing.

For example, if a Source is processing material with fewer active pixels per line than required (i.e. 704 pixels vs. 720 pixels for standard definition MPEG2 material), it may add pixels to the left and right of the supplied material before transmitting across HDMI. AVI bar info may need to be adjusted to account for these added pixels.

Detailed timing is found in CEA-861-D or a later version of CEA-861 for the following video format timings.

6.3.1 Primary Video Format Timings

- 640x480p @ 59.94/60Hz
- 1280x720p @ 59.94/60Hz
- 1920x1080i @ 59.94/60Hz
- 720x480p @ 59.94/60Hz
- 720(1440)x480i @ 59.94/60Hz
- 1280x720p @ 50Hz
- 1920x1080i @ 50Hz
- 720x576p @ 50Hz
- 720(1440)x576i @ 50Hz

6.3.2 Secondary Video Format Timings

- 720(1440)x240p @ 59.94/60Hz
- 2880x480i @ 59.94/60Hz
- 2880x240p @ 59.94/60Hz

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- 1440x480p @ 59.94/60Hz
- 1920x1080p @ 59.94/60Hz
- 720(1440)x288p @ 50Hz
- 2880x576i @ 50Hz
- 2880x288p @ 50Hz
- 1440x576p @ 50Hz
- 1920x1080p @ 50Hz
- 1920x1080p @ 23.98/24Hz
- 1920x1080p @ 25Hz
- 1920x1080p @ 29.97/30Hz
- 2880x480p @ 59.94/60Hz
- 2880x576p @ 50Hz
- 1920x1080i (1250 total) @ 50Hz
- 720(1440)x480i @ 119.88/120Hz
- 720x480p @ 119.88/120Hz
- 1920x1080i @ 119.88/120Hz
- 1280x720p @ 119.88/120Hz
- 720(1440)x480i @ 239.76/240Hz
- 720x480p @ 239.76/240Hz
- 720(1440)x576i @ 100Hz
- 720x576p @ 100Hz
- 1920x1080i @ 100Hz
- 1280x720p @ 100Hz
- 720(1440)x576i @ 200Hz
- 720X576p @ 200Hz

6.4 Pixel-Repetition

Video formats with native pixel rates below 25 Mpixels/sec require pixel-repetition in order to be carried across a TMDS link. 720x480i and 720x576i video format timings shall always be pixel-repeated.

The HDMI Source indicates the use of pixel-repetition with the Pixel Repetition (PR0:PR3) field in the AVI InfoFrame. This field indicates to the HDMI Sink how many repetitions of each unique pixel are transmitted. In non-repeated formats, this value is zero.

For pixel-repeated formats, this value indicates the number of pixels that may be discarded by the Sink without losing real image content.

The Source shall always accurately indicate the pixel repetition count being used. The use of the Pixel Repetition field is optional for HDMI Sink.

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The use of this pixel-repetition count field is more fully described in CEA-861-D.

6.5 Pixel Encodings and Color Depth

There are three different pixel encodings that may be sent across an HDMI cable: YC_BC_R 4:4:4, YC_BC_R 4:2:2 and RGB 4:4:4. Whichever encoding is used, it shall conform to one of the methods described in this section.

There are four color depths supported: 24-, 30-, 36- and 48-bits per pixel. Only RGB 4:4:4 and YC_BC_R 4:4:4 are permitted at depths greater than 24-bits ("Deep Color" modes).

6.5.1 24-Bit Pixel Encodings

Figure 6-1 shows the default encoding, RGB 4:4:4 for 24-bit color depth. The R, G, and B components of the first pixel for a given line of video are transferred on the first pixel of the video data period following the Guard Band characters.

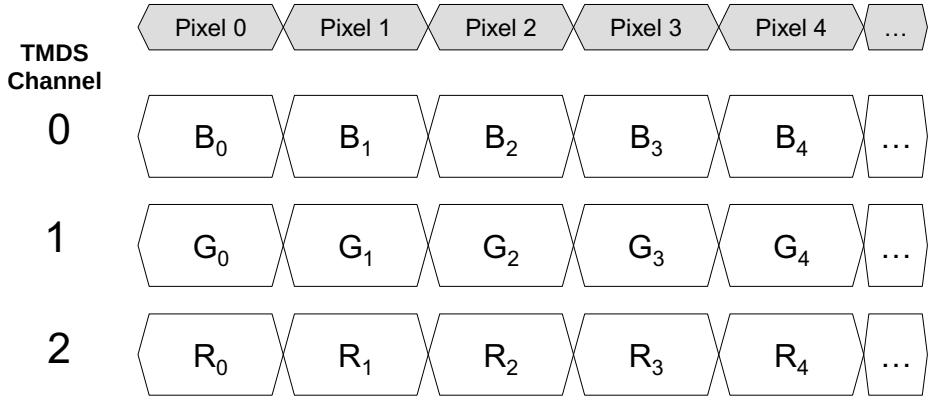
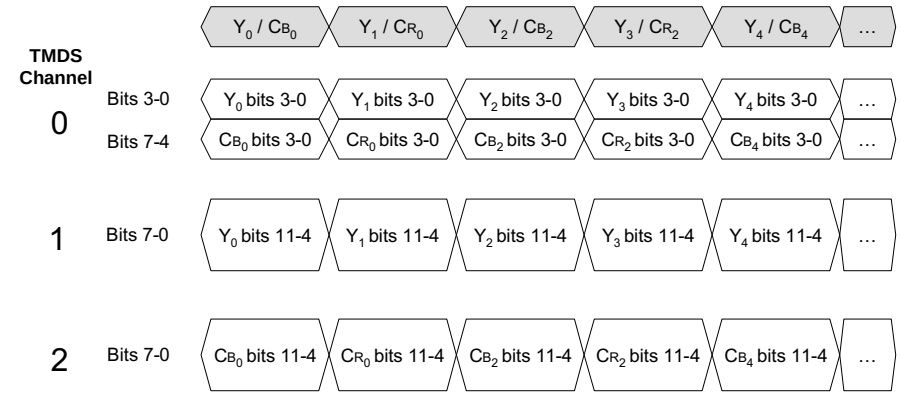


Figure 6-1 Default pixel encoding: RGB 4:4:4, 8 bits/component

Figure 6-2 shows the signal mapping and timing for transferring 24-bit YC_BC_R 4:2:2 data across HDMI. Because 4:2:2 data only requires two components per pixel, more bits are allocated per component. The available 24 bits are split into 12 bits for the Y component and 12 bits for the C components.



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Figure 6-2 YC_BC_R 4:2:2 component

The YC_BC_R 4:2:2 pixel encoding on HDMI closely resembles standard ITU-R BT.601. The high-order 8 bits of the Y samples are mapped onto the 8 bits of Channel 1 and the low-order 4 bits are mapped onto the low-order 4 bits of Channel 0. If fewer than 12 bits are used, the valid bits shall be left-justified (i.e. MSb=MSb) with zeroes padding the bits below the LSb.

The first pixel transmitted within a Video Data Period contains three components, Y0, Cb0 and Cr0. The Y0 and Cb0 components are transmitted during the first pixel period while Cr0 is transmitted during the second pixel period. This second pixel period also contains the only component for the second pixel – Y1. In this way, the link carries one C_B sample for every two pixels and one Cr sample for every two pixels. These two components (C_B and C_R) are multiplexed onto the same signal paths on the link.

At the third pixel, this process is repeated with the Y and C_B components for the third pixel being transmitted, followed, in the next pixel period, by the C_R component of the third pixel and the Y component of the fourth pixel.

YC_BC_R 4:4:4 data is transferred using the scheme illustrated in Figure 6-3.

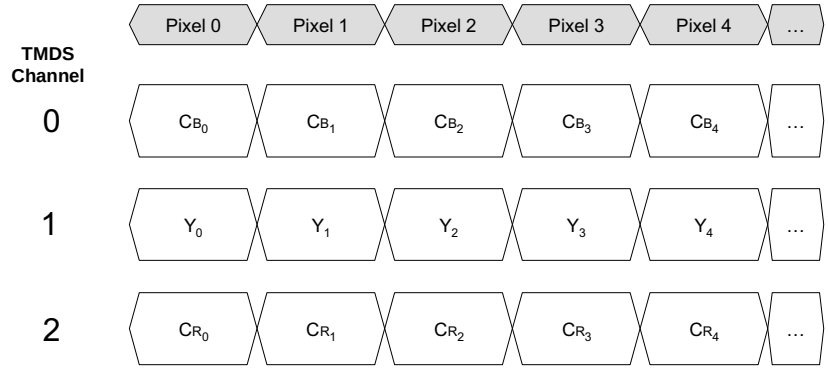


Figure 6-3 8-bit YC_BC_R 4:4:4 mapping

6.5.2 Deep Color Pixel Packing

For a color depth of 24 bits/pixel, pixels are carried at a rate of one pixel per TMDS clock. At deeper color depths, the TMDS clock is run faster than the source pixel clock providing the extra bandwidth for the additional bits. The TMDS clock rate is increased by the ratio of the pixel size to 24 bits:

- 24 bit mode: TMDS clock = 1.0 x pixel clock (1:1)
- 30 bit mode: TMDS clock = 1.25 x pixel clock (5:4)
- 36 bit mode: TMDS clock = 1.5 x pixel clock (3:2)
- 48 bit mode: TMDS clock = 2.0 x pixel clock (2:1)

When operating in a Deep Color mode, all video data (pixels) and signaling (HSYNC, VSYNC, DE transitions) are grouped into a series of packed Pixel Groups, each carrying the same number of pixels and each requiring the same number of TMDS clocks for transmission. On each TMDS

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clock, one Fragment of the Pixel Group is transmitted. The number of pixels per group and number of fragments per group depends on the pixel size:

- 24 bit mode: 1 pixel/group, 1 fragment/group
- 30 bit mode: 4 pixels/group, 5 fragments/group
- 36 bit mode: 2 pixels/group, 3 fragments/group
- 48 bit mode: 1 pixel/group, 2 fragments/group

During active video, the input pixel data is packed into these groups. During blanking, HSYNC and VSYNC are packed into these same groups. In this way, all video-related protocol elements are carried at a direct ratio to the pixel clock, thus ensuring no change to the relationship between the pixel clock and the pixel data, DE transitions and HSYNC or VSYNC transitions. This also allows any sequence of HSYNC, VSYNC, DE transitions, etc. that can be supported at 24 bits/pixel to be supported equally in any other pixel size.

All other HDMI protocol elements are unaffected by the Deep Color pixel packing. Data Islands, Video Guard Bands and Preambles occur as they do in normal (24-bit) mode – each Preamble is 8 TMDS clocks, each Data Island packet is 32 TMDS clocks, and each Guard Band is 2 TMDS clocks.

As shown above, a pixel group consists of 1, 2, or 4 pixels. Each pixel group is broken into 1, 2, 3 or 5 pixel fragments transmitted one fragment per TMDS clock.

Each TMDS character period (one TMDS clock) in the transmitted stream carries a single Fragment of a Pixel Group and so represents a particular Packing Phase of the group. It is necessary for the Sink to determine which character in the stream of characters represents the start of a new group, or phase 0, in order to synchronize its pixel unpacking state with the source's pixel packing state. To accomplish this, the source sends a packet indicating the packing phase of a specific pixel (see 6.5.3 for packet details). This packet is sent at least once per video field indicating the then-current packing phase. The sink uses this data to initially determine where each new group starts should also use this periodic update to verify that it is still synchronized or to recover from gross errors on the link.

The following tables specify all Pixel Encodings for all color depths. For each mode, the packing for each phase is described. Packing phases for active video are identified as "*m*P*n*" (10P0, 10P1, etc. while the packing phases for blanking are identified as "*m*C*n*" (10C0, 10C1, etc.).

24 bit mode: P (pixels/group) = 1 pixel; L (fragments/group) = 1 fragment (1 TMDS character). Standard HDMI format.

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Fragment	Phase	Pixels	8 bit HDMI pixel data code (to encoder)							
			Bit 0	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7
8P0	0	A	A0	A1	A2	A3	A4	A5	A6	A7

30 bit mode: P = 4 pixels; L = 5 fragments

Fragment	Phase	Pixels	8 bit HDMI pixel data code (to encoder)							
			Bit 0	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7
10P0	0	A	A0	A1	A2	A3	A4	A5	A6	A7
10P1	1	A+B	A8	A9	B0	B1	B2	B3	B4	B5
10P2	2	B+C	B6	B7	B8	B9	C0	C1	C2	C3
10P3	3	C+D	C4	C5	C6	C7	C8	C9	D0	D1
10P4	4	D	D2	D3	D4	D5	D6	D7	D8	D9

36 bit mode: P = 2 pixels; L = 3 fragments

Fragment	Phase	Pixels	8 bit HDMI pixel data code (to encoder)							
			Bit 0	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7
12P0	0	A	A0	A1	A2	A3	A4	A5	A6	A7
12P1	1	A+B	A8	A9	A10	A11	B0	B1	B2	B3
12P2	2	B	B4	B5	B6	B7	B8	B9	B10	B11

48 bit mode: P = 1 pixel; L = 2 fragments

Fragment	Phase	Pixels	8 bit HDMI pixel data code (to encoder)							
			Bit 0	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7
16P0	0	A	A0	A1	A2	A3	A4	A5	A6	A7
16P1	1	A	A8	A9	A10	A11	A12	A13	A14	A15

During blanking, one HSYNC and VSYNC value per pixel clock is carried in each Pixel Group. This provides one more HSYNC and VSYNC slot per group than is required (e.g. 5 TMDS clocks for 4 pixels) so the HSYNC and VSYNC values are simply repeated on the last TMDS clock of a group.

The following tables specify, for each mode, the group size and the sequence of HSYNC and VSYNC transmission within a group.

Source HSYNC/VSYNC values for each pixel are labeled S, T, U, V (as needed). Source HSYNC/VSYNC value S is the leftmost (earliest) code in the group.

- 24 bit mode:

Group size = 1 pixel; 1 fragment.

Fragment	HS/VS value
8C0	S

- 30 bit mode:

In 30-bit mode, if the Video Data Period ends before the pixel group boundary, the remaining fragments are filled using one or more steps from the 10PC*n* sequence listed in the table below until the group boundary is reached (step 10PC4). After that, the normal sequence is used (steps 10C*n*).

Group size = 4 pixels; 5 fragments.

Fragment	HS/VS value
10C0	S
10C1	T
10C2	U

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10C3	V
10C4	V

30-bit mode remnant (Falling Edge of DE occurs mid-group). Bridge states for transition from 10P*n* to 10C0 are named “10PC*n*”:

Fragment	HS/VS value
10PC2	T
10PC3	U
10PC4	V

- 36 bit mode:

Group size = 2 pixels; 3 fragment.

Fragment	HS/VS value
12C0	S
12C1	T
12C2	T

- 48 bit mode:

Group size = 1 pixel; 2 fragment.

Fragment	HS/VS value
16C0	S
16C1	S

6.5.3 Deep Color Mode / Phase Indication

When in a Deep Color mode, the Source and Sink each records the packing phase of the last pixel character of a Video Data period. The Source occasionally sends a General Control Packet (GCP) communicating the current color depth and the packing phase of the last pixel character sent prior to the GCP. This data is valid in the GCP whenever CD (CD0, CD1, CD2, CD3) is non-zero. Whenever the Sink receives a GCP with non-zero CD data, it should compare the receiver’s own color depth and phase with the CD data. If they do not match, the Sink should adjust its color depth and/or phase to match the CD data.

When transmitting Deep Color, the Source shall send a General Control Packet (GCP) with an accurate CD field indicating the current color depth and with the PP field (PP0, PP1, PP2, PP3) indicating the packing phase of the last pixel character (within the last Video Data Period) sent prior to the GCP. Sources shall only send GCPs with non-zero CD to Sinks that indicate support for Deep Color, and shall only select color depths supported by the Sink.

Once a Source sends a GCP with non-zero CD to a sink, it should continue sending GCPs with non-zero CD at least once per video field even if reverting to 24-bit color, as long as the Sink continues to support Deep Color.

If the Sink does not receive a GCP with non-zero CD for more than 4 consecutive video fields, it should exit deep color mode (revert to 24-bit color).

Color Depth field (CC) of SB1:

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- When CD is zero, no information about color depth is indicated. PP shall be zero.
- When CD is non-zero, the color depth is indicated and the packing phase bits (PP) are valid.

Table 6-1 Color Depth (CD field) Values

CD3	CD2	CD1	CD0	Color Depth
0	0	0	0	Color Depth not indicated
0	0	0	1	Reserved
0	0	1	0	Reserved
0	0	1	1	Reserved
0	1	0	0	24 bits per pixel
0	1	0	1	30 bits per pixel
0	1	1	0	36 bits per pixel
0	1	1	1	48 bits per pixel
All other values				Reserved

A CD field of zero (Color Depth not indicated) shall be used whenever the Sink does not indicate support for Deep Color. [pw130]This value may also be used in Deep Color mode to transmit a GCP indicating only non-Deep Color information (e.g. AVMUTE).

When the CD field indicates 24 bits per pixel, the PP field is invalid and should be ignored by the Sink.

Pixel Packing Phase field (PP) of SB1:

- When the CD field is zero, the PP field shall also be zero.
- When the CD field is non-zero, the PP field indicates the packing phase of the last fragment in the most recent Video Data Period (prior to the GCP message).

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Table 6-2 shows the specific PP values for each of the packing phases shown in the packing phase tables earlier.

Table 6-2 Pixel Packing Phase (PP field) Values

PP3	PP2	PP1	PP0	Pixel packing Phase
0	0	0	0	Phase 4 (10P4)
0	0	0	1	Phase 1 (10P1, 12P1, 16P1)
0	0	1	0	Phase 2 (10P2, 12P2)
0	0	1	1	Phase 3 (10P3)
0	1	0	0	Reserved
All other values				Reserved

Packing phase 0 does not need to be indicated using the PP bits. This is not necessary as phase 0 always represents only part of the first pixel of the group and therefore, no Video Data Period will end at phase 0. If the active video ended after the first pixel, then the final phase will be phase 1, containing the last bits of the first pixel.

If the transmitted video format has timing such that the phase of the first pixel of every Video Data Period corresponds to pixel packing phase 0 (e.g. 10P0, 12P0, 16P0), the Source may set the Default_Phase bit in the GCP. The Sink may use this bit to optimize it's filtering or handling of the PP field.

Default_Phase field of GCP SB2:

- When Default_Phase is 0, the PP bits may vary and the first pixel of each Video Data Period may vary.
- When Default_Phase is 1, the following will be true:
  - The first pixel of each Video Data Period shall always have a pixel packing phase of 0 (10P0, 12P0, 16P0).
  - The first pixel following each Video Data Period shall have a pixel packing phase of 0 (10C0, 12C0, 16C0).
  - The PP bits shall be constant for all GCPs and will be equal to the last packing phase (10P4, 12P2, 16P1).
  - The first pixel following every transition of HSYNC or VSYNC shall have a pixel packing phase of 0 (10C0, 12C0, 16C0).

6.5.4 Pixel Repetition

During pixel-doubling (Pixel_Repetition_Count = 1), all of the data sent across during the first pixel period will be repeated during the second pixel period. The third pixel period will then represent the second actual pixel and so on. This is shown below for YC_BC_R 4:2:2.

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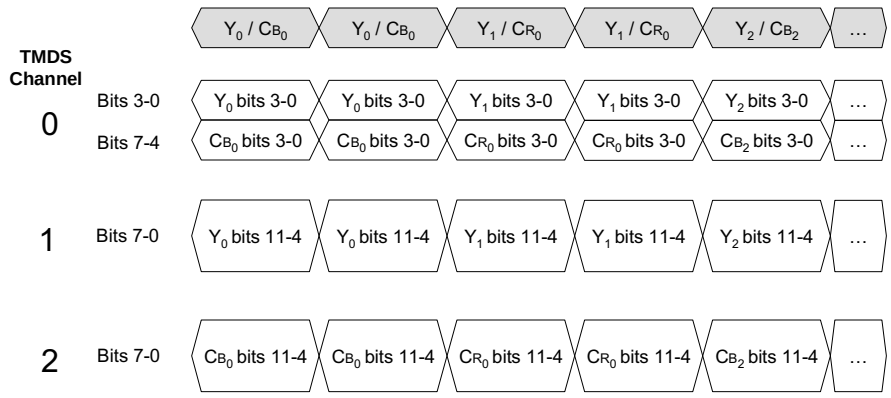


Figure 6-4 YC_BC_R 4:2:2 with Pixel-Doubling

Pixel repetition is permitted in conjunction with Deep Color modes. The Source replicates the pixels as described above prior to Deep Color packing into multiple fragments.

6.6 Video Quantization Ranges

Black and white levels for video components shall be either “Full Range” or “Limited Range.” YC_BC_R components shall always be Limited Range while RGB components may be either Full Range or Limited Range. While using RGB, Limited Range shall be used for all video formats defined in CEA-861-D, with the exception of VGA (640x480) format, which requires Full Range.

Table 6-3 Video Color Component Ranges

Color Components	Component Bit Depth	for Full range		for Limited range	
		Black level	Nominal Peak (White level)	Black level	Nominal Peak (White level)
R / G / B	8	0	255	16	235
R / G / B	10	0	1023	64	940
R / G / B	12	0	4095	256	3760
R / G / B	16	0	65535	4096	60160

Color Component	Bit Depth	for Full range	for Limited range		
			Black level	Nominal Peak	Valid range
Y	8	not allowed	16	235	1 to 254
C_B / C_R			-	16 and 240	
Y	10	not allowed	64	940	4 to 1019
C_B / C_R			-	64 and 960	
Y	12	not allowed	256	3760	16 to 4079
C_B / C_R			-	256 and 3840	
Y	16	not allowed	4096	60160	256 to 65279
C_B / C_R			-	4096 and 61440	

For component ranges for xvYCC, please refer to IEC 61966-2-4.

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6.7 Colorimetry

6.7.1 Default Colorimetry

Sources will typically use the specific default colorimetry for the video format being transmitted. If no colorimetry is indicated in the AVI InfoFrame's C field (C1, C0) then the colorimetry of the transmitted signal shall match the default colorimetry for the transmitted video format.

6.7.1.1 480p, 480i, 576p, 576i, 240p and 288p

The default colorimetry for all 480-line, 576-line, 240-line, and 288-line video formats described in CEA-861-D is based on SMPTE 170M.

6.7.1.2 1080i, 1080p and 720p

The default colorimetry for high-definition video formats (1080i, 1080p and 720p) described in CEA-861-D is based on ITU-R BT.709-5.

6.7.1.3 Other Formats

The default colorimetry of other video formats is sRGB.

6.7.2 Applicable Colorimetry Standards

6.7.2.1 SMPTE 170M / ITU-R BT.601

For any video categorized as SMPTE 170M, ITU-R BT.601-5 Section 3.5 shall be used for any color space conversion needed in the course of processing.

The encoding parameter values shall be as defined in Table 3 of ITU-R BT.601-5 and as summarized in Section 6.6.

6.7.2.2 ITU-R BT.709-5

For any video categorized as ITU-R BT.709, Part 1, Section 4 of that document shall be used for any color space conversion needed in the course of processing.

The digital representation shall be as defined in Part 1, Section 6.10 of ITU-R BT.709-5 and as summarized in Section 6.6.

6.7.2.3 IEC 61966-2-4 (xvYCC)

IEC 61966-2-4 defines the "Extended-gamut YCC color space for video applications". It is based on the YCC color encoding described in ITU-R BT.709-5 but extends its definition to a much wider gamut.

$xvYCC_{601}$ is based on the colorimetry defined in ITU-R BT.601, and $xvYCC_{709}$ is based on the colorimetry defined in ITU-R BT.709.

Refer to Chapter 4.3 of IEC 61966-2-4 for more details.

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Any Source transmission of xvYCC video (either $xvYCC_{601}$ or $xvYCC_{709}$) shall be accompanied by the transmission of valid gamut boundary metadata.

If the attached Sink does not support xvYCC or does not support Gamut Metadata Packets, then the Source should not transmit xvYCC-encoded video and shall not indicate $xvYCC_{601}$ or $xvYCC_{709}$ in the AVI InfoFrame.

6.7.3 Gamut-Related Metadata

HDMI has the ability to carry a description of the video gamut boundary using the Gamut Metadata Packet.

The Sink indicates support for specific transmission profiles by setting one or more of the MD0, MD1, etc. bits in the Colorimetry Data Block.

If the attached Sink's EDID does not include a Colorimetry Data Block then the Source shall not transmit Gamut Metadata Packets. Note that xvYCC colorimetry requires transmission of the gamut metadata.

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7 Audio

7.1 Relationship with IEC 60958/IEC 61937

L-PCM and IEC 61937 compressed audio data is formatted in the Audio Sample Packet or in the High Bitrate Audio Stream Packet as a structure that closely resembles an IEC 60958 frame. (Note: One Bit Audio and DST use a different mechanism – see the overview in sections 7.9.)

On HDMI, each IEC 60958 sub-frame is represented as a 28-bit word. There is no encoding of the preamble type, which instead is replaced with a “B” bit (start-of-block) in each Audio Sample packet. The B bit shall be set for a “B, W” frame and shall be clear for an “M, W” frame. (IEC 60958-1 Section 4.1.2). No other sub-frame preamble combinations are allowed.

Except where specifically indicated in this document, the behavior of all fields within the Audio Sample Subpackets shall follow the corresponding rules specified in the IEC 60958 or IEC 61937 specifications.

HDMI supports any IEC 61937 compressed audio format with a maximum bitrate of 6.144Mbps (frame rate of 192kHz) or less using Layout 0 of the Audio Sample Packet and higher bitrates using the HBR Audio Stream Packet (defined in section 5.3.11). See section 7.6 for more details.

Any IEC 61937-compliant compressed audio format may be supported by an HDMI Source or Sink if a published version of CEA-861 specifies an appropriate Audio Format Code for use in the EDID’s CEA Short Audio Descriptor (see CEA-861-D, table 37).

When receiving multi-channel audio, the Sink should not assume that Channel Status bits carried in Subpackets other than Subpacket 0 will have valid data.

7.2 Audio Sample Clock Capture and Regeneration

Audio data being carried across the HDMI link, which is driven by a TMDS clock running at a rate corresponding to the video pixel rate, does not retain the original audio sample clock. The task of recreating this clock at the Sink is called Audio Clock Regeneration.

There are a variety of clock regeneration methods that can be implemented in an HDMI Sink, each with a different set of performance characteristics. This specification does not attempt to define exactly how these mechanisms operate. It does however present a possible configuration and it does define the data items that the HDMI Source shall supply to the HDMI Sink in order to allow the HDMI Sink to adequately regenerate the audio clock. It also defines how that data shall be generated.

In many video source devices, the audio and video clocks are generated from a common clock (coherent clocks). In this situation, there exists a rational (integer divided by integer) relationship between these two clocks. The HDMI clock regeneration architecture can take advantage of this rational relationship and can also work in an environment where there is no such relationship between these two clocks, that is, where the two clocks are truly asynchronous or where their relationship is unknown.

Figure 7-1 Audio Clock Regeneration model, illustrates the overall system architecture model used by HDMI for audio clock regeneration. The Source shall determine the fractional relationship between the TMDS clock and an audio reference clock (128 * audio sample rate [f_s]) and shall pass the numerator and denominator of that fraction to the Sink across the HDMI link. The Sink

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may then recreate the audio clock from the TMDS clock by using a clock divider and a clock multiplier.

The exact relationship between the two clocks will be:

$$128*f_S = f_{TMDS\_clock} * N / CTS.$$

The Source shall determine the value of the numerator N as specified in Section 7.2.1. Typically, this value N will be used in a clock divider to generate an intermediate clock that is slower than the $128*f_S$ clock by the factor N. The Source will typically determine the value of the denominator CTS (Cycle Time Stamp) by counting the number of TMDS clocks in each of the $128*f_S/N$ clocks.

If there is a constant fractional relationship between these two clocks, and the two clocks are exactly synchronous, then the CTS value will quickly come to a constant value. If the clocks are asynchronous, or there is some amount of jitter between the two clocks, then the CTS value will typically alternate between two or three different values. Greater variations are possible with larger jitter.

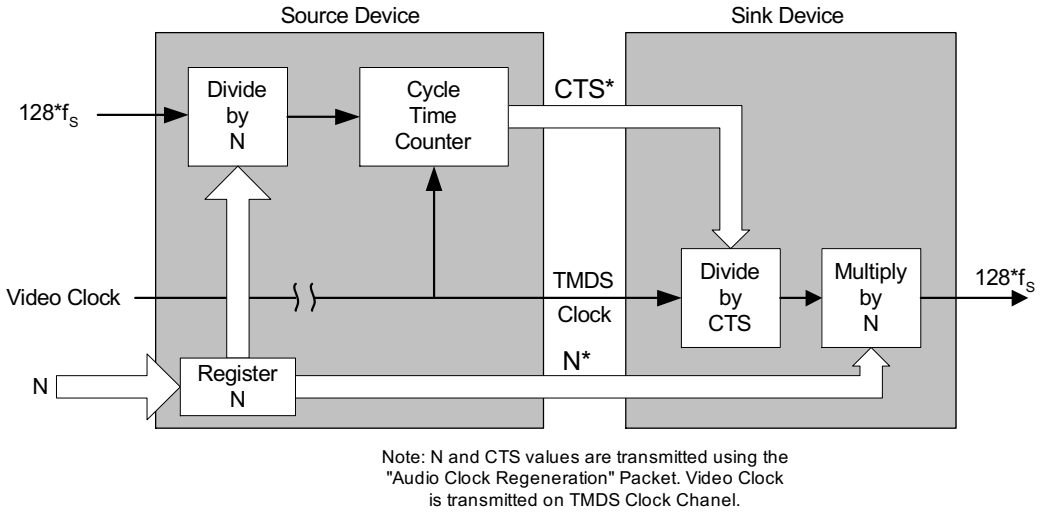


Figure 7-1 Audio Clock Regeneration model

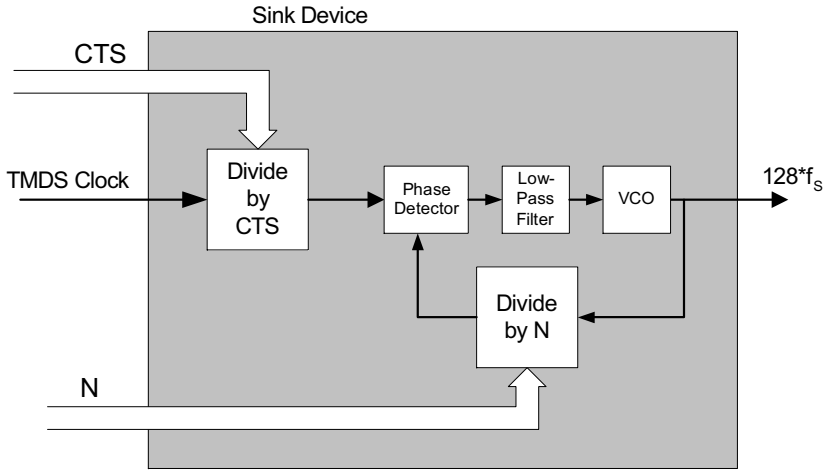


Figure 7-2 Optional Implementation: Audio Sink

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It is expected that most Sinks will be implemented with an architecture similar to that shown in Figure 7-2, however, it is permitted and possible to devise an audio clock regeneration function that does not take advantage of the N or CTS values passed to the Sink.

Note that the ACR mechanism uses the TMDS clock, not the pixel clock. When transmitting normal 24-bit pixels, the two are equivalent but when transmitting Deep Color modes, the TMDS clock, used for the ACR, will be running at a higher rate than the pixel clock.

It is recommended that Source devices be designed to support integer CTS values whenever possible.

7.2.1 N parameter

N shall be an integer number and shall meet the following restriction:

$$128 * f_S / 1500\text{Hz} \le N \le 128 * f_S / 300\text{Hz}$$

with a recommended optimal value of

$$128 * f_S / 1000\text{Hz} \text{ approximately equals } N$$

For coherent audio and video clock Sources, the tables in section 7.2.3 below should be used to determine the value of N. For non-coherent Sources or Sources where coherency is not known, the equations above should be used.

7.2.2 CTS parameter

CTS shall be an integer number that satisfies the following:

$$\text{(Average CTS value)} = (f_{TMDS\_clock} * N) / (128 * f_S)$$

7.2.3 Recommended N and Expected CTS Values

The recommended value of N for several standard TMDS clock rates are given in Table 7-1, Table 7-2, and Table 7-3. It is recommended that Sources with non-coherent clocks use the values listed for a TMDS clock of “Other”.

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Table 7-1 Recommended N and Expected CTS for 32kHz

TMDS Clock (MHz)	32 kHz	
	N	CTS
25.2 / 1.001	4576	28125
25.2	4096	25200
27	4096	27000
27 * 1.001	4096	27027
54	4096	54000
54 * 1.001	4096	54054
74.25 / 1.001	11648	210937-210938*
74.25	4096	74250
148.5 / 1.001	11648	421875
148.5	4096	148500
Other	4096	Measured

** Note: This value will alternate because of restriction on N.*

Table 7-2 Recommended N and Expected CTS for 44.1kHz and Multiples

TMDS Clock (MHz)	44.1 kHz		88.2 kHz		176.4 kHz	
	N	CTS	N	CTS	N	CTS
25.2 / 1.001	7007	31250	14014	31250	28028	31250
25.2	6272	28000	12544	28000	25088	28000
27	6272	30000	12544	30000	25088	30000
27 * 1.001	6272	30030	12544	30030	25088	30030
54	6272	60000	12544	60000	25088	60000
54 * 1.001	6272	60060	12544	60060	25088	60060
74.25 / 1.001	17836	234375	35672	234375	71344	234375
74.25	6272	82500	12544	82500	25088	82500
148.5 / 1.001	8918	234375	17836	234375	35672	234375
148.5	6272	165000	12544	165000	25088	165000
Other	6272	measured	12544	measured	25088	measured

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Table 7-3 Recommended N and Expected CTS for 48kHz and Multiples

TMDS Clock (MHz)	48 kHz		96 kHz		192 kHz	
	N	CTS	N	CTS	N	CTS
25.2 / 1.001	6864	28125	13728	28125	27456	28125
25.2	6144	25200	12288	25200	24576	25200
27	6144	27000	12288	27000	24576	27000
27 * 1.001	6144	27027	12288	27027	24576	27027
54	6144	54000	12288	54000	24576	54000
54 * 1.001	6144	54054	12288	54054	24576	54054
74.25 / 1.001	11648	140625	23296	140625	46592	140625
74.25	6144	74250	12288	74250	24576	74250
148.5 / 1.001	5824	140625	11648	140625	23296	140625
148.5	6144	148500	12288	148500	24576	148500
Other	6144	measured	12288	measured	24576	measured

7.2.4 L-PCM and IEC 61937 Compressed Audio ACR

For any L-PCM stream, the ACR f_S value shall be equal to the audio sample rate.

For any IEC 61937 compressed audio with an IEC 60958 frame rate at or below 192kHz, the ACR f_S value shall be equal to the frame rate. For any such stream with an IEC 60958 frame rate above 192kHz, the ACR f_S value shall be $1/4^{th}$ of the frame rate.

7.2.5 One Bit Audio ACR

For any One Bit Audio stream, the ACR f_S value shall be $1/64^{th}$ of the bit rate. For One Bit Audio data from Super Audio CD (2.8224MHz) the ACR f_S would therefore be 44.1kHz.

7.2.6 DST Audio ACR

For DST audio streams, the ACR f_S corresponds to the sample rate of the underlying compressed audio samples, which is typically 64*44.1kHz (2.8224MHz). This is true whether DST_Normal or DST_Double rate is used.

7.3 Audio Sample Rates and Support Requirements

If an HDMI Source supports audio transmission across any output, then it shall support HDMI audio transmission. Exceptions to this rule for Sources with Type B connectors are found in Appendix B.

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An HDMI Source is permitted to transmit L-PCM audio data at sample rates of 32kHz, 44.1kHz, 48kHz, 88.2kHz, 96kHz, 176.4kHz or 192kHz.

An HDMI Source is permitted to transmit IEC 61937 compressed audio at any IEC 60958 frame rate listed in Table 7-4.

If an HDMI Source supports any HDMI audio transmission, then it shall support 2 channel L-PCM (using an IEC 60958 Subpacket structure), with either 32kHz, 44.1kHz or 48kHz sampling rate and a sample size of 16 bits or more.

Transmitted audio shall have an audio sample rate (f_S) within ±1000 ppm of the sample rate indicated in Channel Status bits 24 through 27.

If an HDMI Sink supports audio reception from any input, then it shall support audio reception from all HDMI inputs.

An HDMI Sink may accept L-PCM audio at sample rates of 32kHz, 44.1kHz, 48kHz, 88.2kHz, 96kHz, 176.4kHz or 192kHz, and should indicate these capabilities in the E-EDID data structure.

An HDMI Sink may accept IEC 61937 compressed audio at any IEC 60958 frame rate listed in Table 7-4, and should indicate these capabilities in the E-EDID data structure.

An HDMI Sink that is capable of accepting any audio format is required to accept two channel (IEC 60958-formatted) L-PCM audio at sample rates of 32kHz, 44.1kHz, and 48kHz.

A Sink shall support the reception of an audio stream with correct sample rate indication in Channel Status bits 24 through 27 and with a sample rate (f_S) within ±1000 ppm of any supported sample rate. There is no sample size usage restriction for Sinks.

For CEA-861-D references to Sources, “Basic Audio” is defined as two channel L-PCM audio at sample rates of 32kHz, 44.1kHz, *or* 48kHz, with a sample size of at least 16 bits. For CEA-861-D references to DTV devices, “Basic Audio” is defined as two channel L-PCM audio at sample rates of 32kHz, 44.1kHz, *and* 48kHz.

An HDMI Repeater shall support HDMI audio reception and transmission.

Whenever transmitting a valid audio stream, HDMI Sources shall always include valid and correct information in Channel Status bits 24 through 27. For L-PCM audio, these bits shall indicate the audio sample frequency. For compressed audio formats, these bits shall indicate the IEC 60958 frame rate. An HDMI audio stream shall only indicate values shown in Table 7-4. Note that the allowed values do not include the IEC 60958-specified “Sample frequency not indicated” value.

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Table 7-4 Allowed Values for Channel Status bits 24 to 27

Channel Status Bit Number				Sample Frequency or Frame Rate
24	25	26	27	
1	1	0	0	32 kHz
0	0	0	0	44.1 kHz
0	0	0	1	88.2 kHz
0	0	1	1	176.4 kHz
0	1	0	0	48 kHz
0	1	0	1	96 kHz
0	1	1	1	192 kHz
1	0	0	1	768 kHz

Note that rates of 352.8 kHz, 384 kHz, 705.6 kHz are not yet supported by IEC 60958. When this happens, these rates may be supported by an HDMI Source or Sink.

In some cases, pixel-repetition may be required to increase the available bandwidth for audio transmission. For instance, when transmitting a 720x480p video format timing, it is required to pixel double in order to transmit 6 channels @ 96kHz.

7.3.1 One Bit Audio Sample Rate Requirements

A Source may transmit One Bit Audio at an f_S (1/64th of the bit rate) of 32kHz, 44.1kHz, 48kHz, 88.2kHz, 96kHz, 176.4kHz or 192kHz. Any Source capable of supporting One Bit Audio should support an f_S of 44.1kHz, corresponding to a bit rate of 2.8224MHz.

Transmitted One Bit Audio shall have an audio sample rate within ±1000 ppm of the targeted sample rate.

A Sink may accept One Bit Audio at an f_S (1/64th of the bit rate) of 32kHz, 44.1kHz, 48kHz, 88.2kHz, 96kHz, 176.4kHz or 192kHz. Any Sink capable of supporting One Bit Audio shall support an f_S of 44.1kHz, corresponding to a bit rate of 2.8224MHz.

For One Bit Audio, sample frequency information is carried in the Audio InfoFrame (see section 8.2.2).

7.3.2 DST Audio Sample Rate Requirements

All current DST streams carry compressed one bit audio samples with an actual (DAC) sampling frequency of 64*44.1kHz (2.8224MHz).

Any Source capable of supporting DST may transfer DST streams using either DST_Normal or DST_Double rate transmission.

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Transmitted DST shall have an audio sample rate within ±1000 ppm of the targeted sample rate.

Any Sink capable of supporting DST shall support streams with a sample rate of 64*44.1kHz (an f_S of 44.1kHz), and shall support reception of both DST_Normal and DST_Double rate.

7.3.3 Video Dependency

Available audio bandwidth depends upon the TMDS clock frequency, the video format timing, and whether or not content protection re-synchronization is needed.

Table 7-5 shows the available audio sample rates for 2-channel (Layout 0) and 8-channel (Layout 1) audio transmission at the various video format timings specified in CEA-861-D, assuming that 58 TMDS clocks of the horizontal blanking interval is required for content protection re-synchronization.

Table 7-5 Max Sampling Frequency for 24-bit Video Format Timings (Informative)*

Description	Format Timing	Pixel Repetition	Vertical Freq (Hz)	Max f_S 8 ch (kHz)	Max frame rate 2 ch, comp**	SuperAudio CD Channel Count
VGA	640x480p	none	59.94/60	48	192	2
480i	1440x480i	2	59.94/60	88.2	192	2
480i	2880x480i	4	59.94/60	192	768	8
240p	1440x240p	2	59.94/60	88.2	192	2
240p	2880x240p	4	59.94/60	192	768	8
480p	720x480p	none	59.94/60	48	192	2
480p	1440x480p	2	59.94/60	176.4	384	8
480p	2880x480p	4	59.94/60	192	768	8
720p	1280x720p	none	59.94/60	192	768	8
1080i	1920x1080i	none	59.94/60	192	768	8
1080p	1920x1080p	none	59.94/60	192	768	8
480i / 120Hz	1440x480i	2	119.9/120	176.4	384	8
480p / 120Hz	720x480p	none	119.9/120	96	384	8
50Hz Formats						
576i	1440x576i	2	50	88.2	192	2
576i	2880x576i	4	50	192	768	8
288p	1440x288p	2	50	88.2	192	2
288p	2880x288p	4	50	192	768	8
576p	720x576p	none	50	48	192	2
576p	1440x576p	2	50	176.4	384	8
576p	2880x576p	4	50	192	768	8

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720p/50	1280x720p	none	50	192	768	8
1080i/50	1920x1080i	none	50	192	768	8
1080p/50	1920x1080p	none	50	192	768	8
1080i, 1250 total	1920x1080i	none	50	192	768	8
576i / 100Hz	1440x576i	2	100	176.4	384	8
576p / 100Hz	720x576p	none	100	96	384	8
1080p @ 24-30Hz						
1080p	1920x1080p	None	24	192	768	8
1080p	1920x1080p	None	25	192	768	8
1080p	1920x1080p	None	29.97/30	192	768	8

** Note that formats listed in Section 6.2.4 but not listed above can carry 8 channels at 192kHz or 8 channels of One Bit Audio at the SuperAudio CD rate.*

*** Note that 2-channel PCM can never exceed 192kHz. Higher values in this column indicate higher frame rates that can be used for compressed streams. Note that 384kHz is not currently supported by IEC 60958.*

7.4 Channel / Speaker Assignment

HDMI allows a Sink to indicate the configuration of attached speakers through the use of the Speaker Allocation Data Block described in CEA-861-D section 7.5.3. Sinks supporting multi-channel L-PCM or multi-channel One Bit Audio shall include this Data Block.

In addition, for L-PCM or One Bit audio streams, the Source shall specify the speaker assignment for each of the channels in the audio stream delivered to the Sink. CEA-861-D section 6.6 specifies the available speaker assignments for active audio channels on HDMI. The indication of the current speaker assignment is carried in the CA field of the Audio InfoFrame.

7.5 Audio, Video Synchronization

For a variety of reasons, an HDMI link may add a delay to the audio and/or video.

An HDMI Source shall be capable of transmitting audio and video data streams with no more than ±2 msec of audio delay relative to the video. Due to the uneven transmission of audio data, the delay shall be considered to be the average delay of all of the audio sample packets over the course of 3 steady-state video frames.

7.6 Audio Data Packetization

Each Subpacket of an Audio Sample Packet shall contain zero or one IEC 60958-defined “frames” of an IEC 60958 or IEC 61937 “block.” There are two defined Subpacket layouts. No others are permitted.

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Table 7-6 Audio Packet Layout and Layout Value

Layout Value	Max Num Channels	Samples	Subpkt 0	Subpkt 1	Subpkt 2	Subpkt 3
0	2	4	Chnl 1,2 Sample 0	Chnl 1,2 Sample 1	Chnl 1,2 Sample 2	Chnl 1,2 Sample 3
1	8	1	Chnl 1,2 Sample 0	Chnl 3,4 Sample 0	Chnl 5,6 Sample 0	Chnl 7,8 Sample 0

There are four sample_present bits in the Audio Sample Packet Header, one for each of the Subpackets. These indicate if that Subpacket contains audio sample(s).

In addition, there are four sample_flat.spX bits which are set if no useful audio data was available at the Source during the time period represented by that sample. This may occur during sample rate changes or temporary stream interruptions. When sample_flat.spX is set, Subpacket X continues to represent a sample period but does not contain useful audio data. The sample_flat.spX bit is only valid when the corresponding sample_present.spX bit is set.

Layout 0 can be used to carry up to four samples from a single IEC 61937 or from a single 2-channel IEC 60958 stream of audio.

There are only five valid configurations of sample_present bits for a Layout 0 Audio Packet. They are shown in Table 7-7.

Table 7-7 Valid Sample_Present Bit Configurations for Layout 0

SP0	SP1	SP2	SP3	Description
0	0	0	0	No Subpackets contain audio samples.
1	0	0	0	Only Subpacket 0 contains audio samples.
1	1	0	0	Subpackets 0 and 1 contain audio samples.
1	1	1	0	Subpackets 0, 1, and 2 contain audio samples.
1	1	1	1	All Subpackets contain audio samples.

Layout 1 can be used to carry one audio sample with three to eight channels of L-PCM audio (i.e. two to four IEC 60958 streams).

Valid combinations of sample_present bits for Layout 1 Audio Packets are determined by the permitted channel allocations as described in CEA-861-D section 6.6.

An HDMI Source shall place the data shown into the specified Subpackets and to identify the layout in the Audio Sample Packet Header.

The fields within a Subpacket with a corresponding sample_flat bit set or a sample_present bit clear, are not defined and can be any value.

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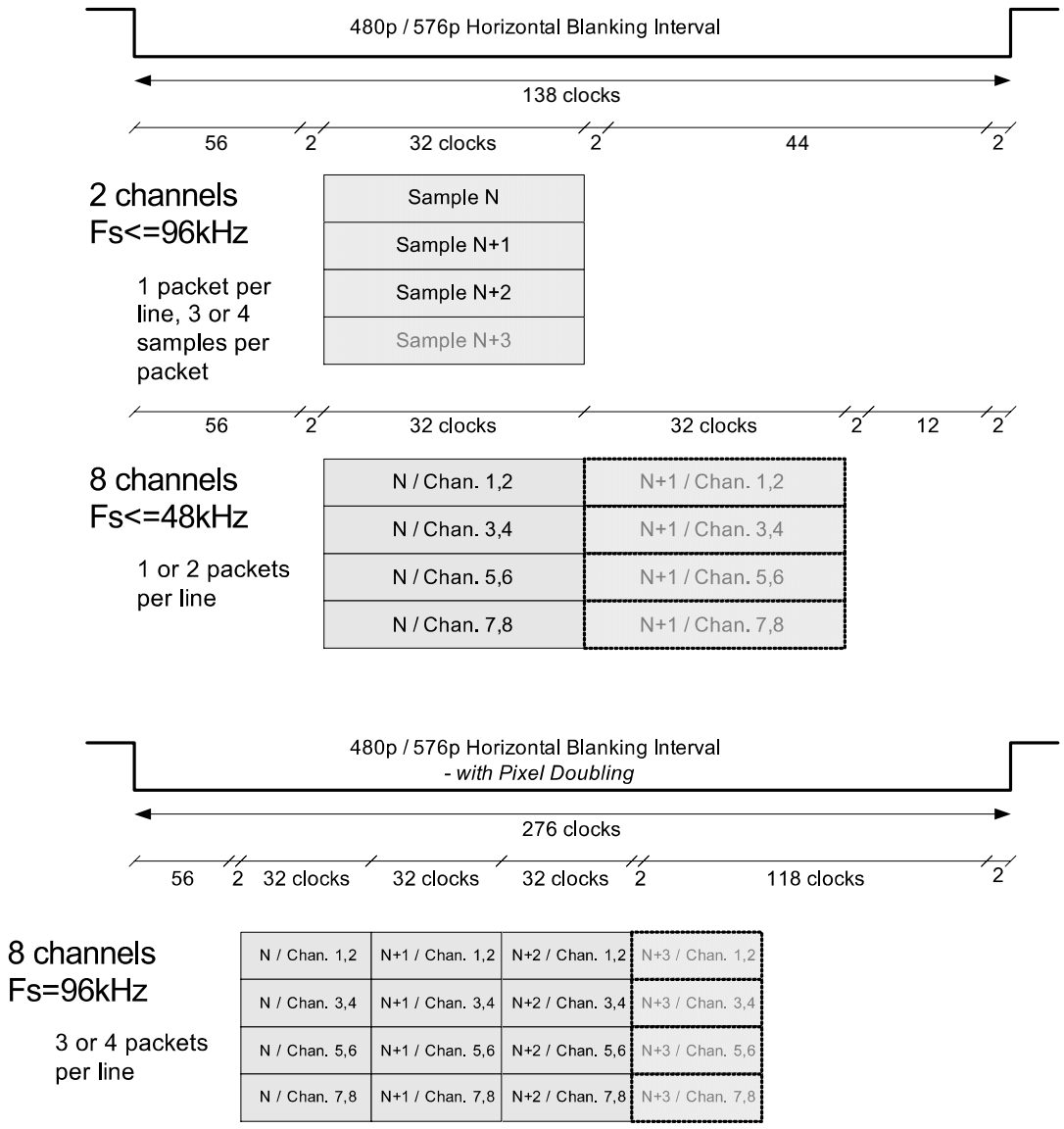


Figure 7-3 Example Audio Sample Timing (Informative)

7.6.1 One Bit Audio Packetization

When transmitting One Bit Audio, each Subpacket shall contain One Bit Audio bits for zero, one or two audio channels.

There are four sample_present bits in the One Bit Audio Sample Packet Header, one for each of the Subpackets. The corresponding bit is set if that Subpacket contains audio samples. There are four samples_invalid.spX bits which are set if no useful audio data was available at the Source during the time period represented by that sample. When samples_invalid.spX is set, Subpacket X continues to represent a sample period but does not contain any useful data.

Layout 0 can be used to carry 2 channels of One Bit Audio samples. Layout 1 can be used to carry from three to eight channels of One Bit Audio samples.

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Valid combinations of sample_present bits for Layout 1 Audio Packets are determined by the permitted channel allocations as described in section 7.6 above.

The fields within a Subpacket with a corresponding samples_invalid bit set or a sample_present bit clear, are not defined and can be any value.

7.6.2 High-Bitrate Audio Stream Packetization

When carrying IEC 61937 compressed audio at frame rates above 192kHz, the HBR Audio Stream packet shall be used.

For many high bitrate streams (e.g. DTS-HD Master Audio and Dolby MAT), the IEC 61937 data bursts will always have a repetition period that is a multiple of four frames, and so the Pa and Pb syncwords will always be found in the same subpacket. In such cases, the codec vendor may impose the additional constraint that Pa and Pb always appear in subpacket 0.

7.6.3 DST Packetization

The DST audio stream consists of a series of frames, each of which carries audio data for 1/75th of a second. Each DST frame will be transmitted using a number of DST Audio Packets. The end of a DST frame may occur within a DST Audio Packet. Any unused bits in such a DST Audio Packet shall be padded with “0”. In the time between the completion of one DST Audio Frame and the start of the next, DST Audio Packets containing all “0” shall be sent. A new DST Audio Packet with the frame_start bit set to “1” in the header shall be used when the next DST Audio Frame starts and the first bit of the new DST frame data shall be placed in D.0 of the packet body.

When samples_invalid in the DST Audio Packet is set to “1”, then the data in the DST Audio Packet is not valid or does not contain any useful data.

7.7 Error Handling (Informative)

The behavior of the Sink after detecting an error is implementation-dependent. However, Sinks should be designed to prevent loud spurious noises from being generated due to errors. Sample repetition and interpolation are well known concealment techniques and are recommended.

7.8 Packet Delivery Rules

7.8.1 Audio Sample Packets

All audio samples that are stored in a source buffer shall be sent as soon as possible while still fulfilling requirements for audio/video synchronization, and Data Island timing and placement. When using Layout 0 Audio Sample Packets, the Source shall transmit an Audio Sample Packet if at least one sample is stored in the source buffer.

Relative to an ideal constant-frequency clock, the jitter present in the Audio Sample Packet transmission timing shall not exceed one horizontal line period plus a single audio sample period.

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7.8.2 Audio Clock Regeneration Packets

Nominally, Audio Clock Regeneration Packets with newly generated CTS values will be transmitted at a rate of $128*f_S/N$. On average, the Source shall transmit CTS values at this rate precisely. The Source shall transmit each CTS data value as close as possible to the nominal transmission time for that value with the exception that priority must be given to Audio Sample packets to ensure that Audio Sample Packet delivery requirements are met.

7.9 One Bit Audio Usage Overview

One Bit Audio data is transmitted using the One Bit Audio packet defined in section 5.3.9 and described in section 7.6.1.

One Bit Audio clock regeneration uses the same mechanism used for all audio on HDMI and is described in section 7.2.4. One Bit Audio sample rate requirements are described in section 7.3.1.

A Sink may indicate its support for One Bit Audio with the Short Audio Descriptor as described in section **Error! Reference source not found.**.

One Bit Audio uses some fields within the Audio InfoFrame differently than L-PCM or compressed audio; these differences are described in section 8.2.2.

7.10 DST Usage Overview

DST data is transmitted using the DST Sample packet defined in section 5.3.10 and described in section 7.6.3.

DST clock regeneration uses the same mechanism used for all audio on HDMI and is described in section {7.2.5}. One Bit Audio sample rate requirements are described in section 7.3.2.

A Sink may indicate its support for DST with the Short Audio Descriptor as described in CEA-861-D.

In some cases, DST uses some fields within the Audio InfoFrame differently than L-PCM or IEC 61937 compressed audio; these differences are described in section 8.2.2.

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8 Control And Configuration

8.1 Overview

HDMI includes three separate communications channels: TMDS, DDC, and the optional CEC.

TMDS is used to carry all audio and video data as well as auxiliary data, including AVI and Audio InfoFrames that describe the active audio and video streams.

The DDC channel is used by an HDMI Source to determine the capabilities and characteristics of the Sink by reading the E-EDID data structure.

HDMI Sources are expected to read the Sink's E-EDID and to deliver only the audio and video formats that are supported by the Sink. In addition, HDMI Sinks are expected to detect InfoFrames and to process the received audio and video data appropriately.

The CEC channel is optionally used for higher-level user functions such as automatic setup tasks or tasks typically associated with infrared remote control usage.

8.2 InfoFrames

An InfoFrame packet carries one InfoFrame. The InfoFrame provided by HDMI is limited to 30 bytes plus a checksum byte. HDMI Sources are required, in some cases, to use the AVI InfoFrame and Audio InfoFrame and recommended in other cases. Other InfoFrames specified in CEA-861-D are optional.

All InfoFrames are described in detail in CEA-861-D. The following describes how two of these InfoFrames are placed within the InfoFrame Packet structure and any areas where HDMI behavior is different from that specified in CEA-861-D.

8.2.1 Auxiliary Video information (AVI) InfoFrame

Various aspects of the current video stream are indicated by the HDMI Source to the Sink with an Auxiliary Video information (AVI) InfoFrame.

A Source shall always transmit an AVI InfoFrame at least once per two video fields if the Source:

- is *ever* capable of transmitting an AVI InfoFrame or,
- is ever capable of transmitting YC_BC_R pixel encoding or,
- is ever capable of transmitting any colorimetry other than the transmitted video format's default colorimetry or,
- is ever capable of transmitting any xvYCC or future enhanced colorimetry or,
- is ever capable of transmitting any Gamut Metadata packet or,
- is ever capable of transmitting any video format with multiple allowed pixel repetitions.

The AVI InfoFrame shall be transmitted even while such a Source is transmitting RGB and non-pixel-repeated video. When a Source is not explicitly required to transmit AVI InfoFrames, it is recommended that the Source transmit AVI InfoFrames.

The packetization of the AVI InfoFrame Version 2 is shown below.

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Table 8-1 AVI InfoFrame Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	Packet Type = 0x82							
HB1	Version = 0x02							
HB2	0	0	0	Length = 13 (0x0D)				

Table 8-2 AVI InfoFrame Packet Contents

Packet Byte #	CEA-861-D Byte #	7	6	5	4	3	2	1	0
PB0	N. A.	Checksum							
PB1	Data Byte 1	Rsvd (0)	Y1	Y0	A0	B1	B0	S1	S0
PB2	Data Byte 2	C1	C0	M1	M0	R3	R2	R1	R0
PB3	Data Byte 3	ITC	EC2	EC1	EC0	Q1	Q0	SC1	SC0
PB4	Data Byte 4	Rsvd (0)	VIC6	VIC5	VIC4	VIC3	VIC2	VIC1	VIC0
PB5	Data Byte 5	Reserved (0)				PR3	PR2	PR1	PR0
PB6	Data Byte 6	Line Number of End of Top Bar (lower 8 bits)							
PB7	Data Byte 7	Line Number of End of Top Bar (upper 8 bits)							
PB8	Data Byte 8	Line Number of Start of Bottom Bar (lower 8 bits)							
PB9	Data Byte 9	Line Number of Start of Bottom Bar (upper 8 bits)							
PB10	Data Byte 10	Pixel Number of End of Left Bar (lower 8 bits)							
PB11	Data Byte 11	Pixel Number of End of Left Bar (upper 8 bits)							
PB12	Data Byte 12	Pixel Number of Start of Right Bar (lower 8 bits)							
PB13	Data Byte 13	Pixel Number of Start of Right Bar (upper 8 bits)							
PB14-PB27	n. a.	Reserved (0)							

See CEA-861-D section 6.4 for more information on the following fields:

- Y0, Y1 RGB or YC_BC_R indicator.
- A0 Active Information Present. Indicates whether field R0...R3 is valid. See CEA-861-D table 8 for details.
- B0, B1 Bar Info data valid. See CEA-861-D table 8 for details.

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- S0, S1 Scan Information (i.e. overscan, underscan). See CEA-861-D table 8 for details.
- C0, C1 Colorimetry (ITU BT.601, BT.709 etc.). See CEA-861-D table 9 for details.
- EC0, EC1, EC2 Extended Colorimetry (IEC 61966-2-4 etc.). See CEA-861-D table 11 for details.
- Q1, Q0 Quantization range (Full vs. Limited, etc.). See CEA-861-D table 11 for details.
- ITC IT Content. See CEA-861-D table 11 for details.
- M0, M1 Picture Aspect Ratio (4:3, 16:9). See CEA-861-D table 9 for details.
- R0...R3 Active Format Aspect Ratio. See CEA-861-D table 10 and Annex H for details.
- VIC0...VIC6 Video Format Identification Code. When transmitting any video format in section 6.2.4, above, an HDMI Source shall set the VIC field to the Video Code for that format. See CEA-861-D section 6.4 for details.
- PR0...PR3 Pixel Repetition factor. See CEA-861-D table 13 for details.
- SC1, SC0 Non-uniform Picture Scaling. See CEA-861-D table 11.

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Table 8-3 HDMI Valid Pixel Repeat Values for Each Video Format Timing

Video Code	Video Description		HDMI Pixel Repeat Values
1	640x480p @ 60Hz		No Repetition
2,3	720x480p @ 59.94/60Hz		No Repetition
4	1280x720p @ 59.94/60Hz		No Repetition
5	1920x1080i @ 59.94/60Hz		No Repetition
6,7	720(1440)x480i @ 59.94/60Hz		Pixel sent 2 times
8,9	720(1440)x240p @ 59.94/60Hz		Pixel sent 2 times
10,11	2880x480i @ 59.94/60Hz		Pixel sent 1 to 10 times
12,13	2880x240p @ 59.94/60Hz		Pixel sent 1 to 10 times
14,15	1440x480p @ 59.94/60Hz		Pixel sent 1 to 2 times
16	1920x1080p @ 59.94/60Hz		No Repetition
17,18	720x576p @ 50Hz		No Repetition
19	1280x720p @ 50Hz		No Repetition
20	1920x1080i @ 50Hz		No Repetition
21,22	720(1440)x576i @ 50Hz		Pixel sent 2 times
23,24	720(1440)x288p @ 50Hz		Pixel sent 2 times
25,26	2880x576i @ 50Hz		Pixel sent 1 to 10 times
27,28	2880x288 @ 50Hz		Pixel sent 1 to 10 times
29,30	1440x576p @ 50Hz		Pixel sent 1 to 2 times
31	1920x1080p @ 50Hz		No Repetition
32	1920x1080p @ 23.97/24Hz		No Repetition
33	1920x1080p @ 25Hz		No Repetition
34	1920x1080p @ 29.97/30Hz		No Repetition
35,36	2880x480p @ 59.94/60Hz		Pixel sent 1, 2 or 4 times
37,38	2880x576p @ 50Hz		Pixel sent 1, 2 or 4 times
39	1920x1080i (1250 total) @ 50Hz		No Repetition
40	1920x1080i @ 100Hz		No Repetition
41	1280x720p @ 100Hz		No Repetition
42,43	720x576p @ 100Hz		No Repetition
44,45	720(1440)x576i @ 100Hz		Pixel sent 2 times
46	1920x1080i @ 119.88/120Hz		No Repetition
47	1280x720p @ 119.88/120Hz		No Repetition
48,49	720x480p @ 119.88/120Hz		No Repetition
50,51	720(1440)x480i @ 119.88/120Hz		Pixel sent 2 times
52,53	720X576p @ 200Hz		No Repetition
54,55	720(1440)x576i @ 200Hz		Pixel sent 2 times
56,57	720x480p @ 239.76/240Hz		No Repetition
58,59	720(1440)x480i @ 239.76/240Hz		Pixel sent 2 times

8.2.2 Audio InfoFrame

A Source shall indicate characteristics of the active audio stream using the IEC 60958 Channel Status bits, IEC 61937 Burst Info and/or stream data (if present) and the Audio InfoFrame. Whenever an active audio stream is being transmitted, an accurate Audio InfoFrame shall be transmitted at least once per two video fields.

Upon the start of a new audio stream or upon any change in the audio stream that can be indicated by the Audio InfoFrame, a modified, accurate Audio InfoFrame shall be transmitted no later than one video field following the first affected non-silent audio sample. Preferably, this

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would occur just before the first affected audio sample is transmitted. For One Bit Audio streams, the Audio InfoFrame shall be transmitted before the first affected sample.

The Audio InfoFrame transmission may occur at any time that a Data Island packet may be transmitted, including during any horizontal or vertical blanking period.

Note that several of the fields permit a value of 0 (referred to in the CEA-861-D specification as “Refer to Stream Header”). A value of 0 signifies that the information associated with that field is actually indicated or implied by other items in the audio stream, for instance, by the IEC 60958 Channel Status bits or the IEC 61937 Burst Info.

The following tables show the packetization of the Audio InfoFrame.

Table 8-4 Audio InfoFrame Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	Packet Type = 0x84							
HB1	Version Number = 0x01							
HB2	0	0	0	Length = 10 (0x0A)				

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Table 8-5 Audio InfoFrame Packet contents

Packet Byte #	CEA-861-D Byte #	7	6	5	4	3	2	1	0
PB0	n. a.	Checksum							
PB1	Data Byte 1	CT3	CT2	CT1	CT0	Rsvd	CC2	CC1	CC0
PB2	Data Byte 2	Reserved (0)			SF2	SF1	SF0	SS1	SS0
PB3	Data Byte 3	Format depends on coding type (i.e. CT0...CT3)							
PB4	Data Byte 4	CA7	CA6	CA5	CA4	CA3	CA2	CA1	CA0
PB5	Data Byte 5	DM_INH	LSV3	LSV2	LSV1	LSV0	Reserved (0)		
PB6	Data Byte 6	Reserved (0)							
PB7	Data Byte 7	Reserved (0)							
PB8	Data Byte 8	Reserved (0)							
PB9	Data Byte 9	Reserved (0)							
PB10	Data Byte 10	Reserved (0)							
PB11-PB27	n. a.	Reserved (0)							

See CEA-861-D section 6.6 for more information on the following fields:

- CC0...CC2 Channel Count. See CEA-861-D table 17 for details.
- CT0...CT3 Coding Type. The CT bits shall always be set to a value of 0 (“Refer to Stream Header”).
- SS0...SS1 Sample Size. The SS bits shall always be set to a value of 0 (“Refer to Stream Header”).
- SF0...SF2 Sample Frequency. See CEA-861-D table 18 for details. For L-PCM and IEC 61937 compressed audio streams, the SF bits shall always be set to a value of 0 (“Refer to Stream Header”). For One Bit Audio and DST streams, the value indicated by the SF bits shall equal the ACR f_S value (see sections 7.2.5 and 7.2.6). For Super Audio CD, the SF bits are typically set to 0, 1, 0, to indicate a Sample Frequency of 2.8224MSamples/s (i.e. 64*44.1kHz).
- CA0...CA7 Channel/Speaker Allocation. See CEA-861-D Section 6.6.2 for details. The CA field is not valid for IEC 61937 compressed audio streams.
- LSV0...LSV3 Level Shift Value (for downmixing). See CEA-861-D Section 6.6.2 and CEA-861-D table 21 for details.
- DM_INH Downmix Inhibit. See CEA-861-D section 6.6.2 and table 22 for details. The DM_INH field is to be set only for DVD-Audio applications and corresponds to the value in the DM_INH field of the current audio stream

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being played from the disk. The DM_INH field value shall be set to zero in all cases other than DVD-Audio applications.

Data Byte 3 shall always be set to a value of 0.

8.3 E-EDID Data Structure

All Sinks shall contain an CEA-861-D compliant E-EDID data structure accessible through the DDC.

A Source shall read the EDID 1.3 and first CEA Extension to determine the capabilities supported by the Sink. Additional extensions may be read to discover additional capabilities. The Source is responsible for any format conversions that may be necessary to supply audio and video in an understandable form to the Sink. However, it is permitted for a Source to transmit Basic Audio (see Section 7.2.6) to a Sink that does not indicate support for Basic Audio.

The Source shall not transmit at TMDS clock rates higher than the maximum rate supported by the Sink, as determined by video format and Deep Color mode support indications but limited by the Max_TMDS_Clock field of the HDMI VSDB.

The overall structure of the E-EDID in the Sink shall conform to the E-EDID structure defined in the VESA E-EDID Standard Release A, Revision 1, but shall also meet the additional requirements specified herein.

The first 128 bytes of the E-EDID shall contain an EDID 1.3 structure. The contents of this structure shall also meet the requirements of CEA-861-D.

8.3.1 CEA Extension

The first E-EDID ‘extension’ shall contain a CEA Extension version 3, defined in CEA-861-D section 7.5. Additional CEA Extensions may also be present. The E-EDID shall not contain a CEA Extension version 1 or version 2.

CEA Extension version 3 details are described in CEA-861-D Section 7.5.

Further details on the requirements of the data structures in the E-EDID and implementation examples are given in CEA-861-D.

8.3.2 HDMI Vendor-Specific Data Block (HDMI VSDB)

The first CEA Extension shall include an HDMI Vendor Specific Data Block (HDMI VSDB) shown in Table 8-6. This is a CEA-861-D Vendor Specific Data Block (see CEA-861-D section 7.5.4 for details) containing a 24-bit IEEE Registration Identifier of 0x000C03, a value belonging to HDMI Licensing, LLC.

Sinks shall contain an HDMI VSDB minimally containing a 2-byte Source Physical Address field following the 24-bit identifier. An HDMI VSDB may have zero or more extension fields as shown in Table 8-6. The minimum value of N (length) is 5 and the maximum value of N is 31. A Sink that supports any function indicated by an extension field shall use an HDMI VSDB with a length sufficient to cover all supported fields.

The Source shall have the ability to handle an HDMI VSDB of any length. In future specifications, new fields may be defined. These additional fields will be defined such that a zero value indicates the same characteristics as is indicated if the field was not present. Sources should use the

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length field to determine which extension fields are present, and shall process the HDMI VSDB with no regard to non-zero values in fields defined as Reserved in this specification.

Table 8-6 HDMI-LLC Vendor-Specific Data Block (HDMI VSDB)

Byte #	7	6	5	4	3	2	1	0
0	Vendor-specific tag code (=3)				Length (=N)			
1	24-bit IEEE Registration Identifier (0x000C03) (least significant byte first)							
2								
3								
4	A				B			
5	C				D			
6	Supports_AI	DC_48bit	DC_36bit	DC_30bit	DC_Y444	Rsvd (0)	Rsvd (0)	DVI_Dual
7	Max_TMDS_Clock							
8	Latency_Fields_Present	I_Latency_Fields_Present	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)
(9)	Video_Latency							
(10)	Audio_Latency							
(11)	Interlaced_Video_Latency							
(12)	Interlaced_Audio_Latency							
9, 11 or 13...N*	*Reserved (0)***							

extension fields ↓

* *The position of these bytes will depend upon the values of Latency_Fields_Present and I_Latency_Fields_Present.*

** *No additional bytes are necessary but if present, they shall be zero.*

- A, B, C, D — [4 bits each] Components of Source Physical Address (A.B.C.D). See Section 8.7.
- Supports_AI — [1 bit] Set to 1 if the Sink supports at least one function that uses information carried by the ACP, ISRC1, or ISRC2 packets. If Supports_AI is set (=1), then the Sink shall accept and process any ACP, ISRC1 or ISRC2 packet with no regard to non-zero values in fields defined as Reserved in this specification. If the Sink does not support ACP, ISRC1 or ISRC2 packets, Supports_AI shall be clear (=0).
- DC_30bit — [1 bit] Set if Sink supports 30 bits/pixel (10 bits/color).
- DC_36bit — [1 bit] Set if Sink supports 36 bits/pixel (12 bits/color).

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- DC_48bit [1 bit] Set if Sink supports 48 bits/pixel (16 bits/color).
- DC_Y444 [1 bit] Set if Sink supports YC_BC_R 4:4:4 in Deep Color modes.

The three DC_XXbit bits above only indicate support for RGB 4:4:4 at that pixel size. Support for YC_BC_R 4:4:4 in Deep Color modes is indicated with the DC_Y444 bit. If DC_Y444 is set, then YC_BC_R 4:4:4 is supported for all modes indicated by the DC_XXbit flags. This provides the Sink the flexibility of supporting YC_BC_R formats for the standard color-depth (24-bits/pixel) while only supporting RGB for Deep Color modes.

- DVI_Dual [1 bit] Set if Sink supports DVI dual-link operation.
- Max_TMDS_Clock [1 byte] Indicates the maximum TMDS clock rate supported. Max rate = Max_TMDS_Clock * 5MHz. This field shall be set correctly and non-zero if the Sink supports TMDS clock frequencies above 165MHz or supports any Deep Color mode or supports DVI dual-link. A value of zero means that no clock rate is indicated.

The Max_TMDS_Clock field may be set by the Sink at a level below the TMDS clock rate corresponding to the maximum pixel clock rate at the maximum color depth. This allows the Sink to support higher color depths at lower resolutions than it can support at higher resolutions.

See section 8.9 for more detail on the following lipsync-related fields:

- Latency_Fields_Present [1 bit] If set (=1) then the Video_Latency and Audio_Latency fields are present. If clear (=0) then these fields are not present in the HDMI VSDB.
- I_Latency_Fields_Present [1 bit] If set (=1) then the latency fields total four bytes, two for video and audio latency information when progressive video formats are received and two for latency information when interlaced video formats are received. If clear (=0) then only two bytes are present, indicating the video and audio latency when any video format is received. I_Latency_Fields_Present shall be zero if Latency_Fields_Present is zero.
- Video_Latency [1 byte] Indicates the amount of video latency when receiving any video format or only when receiving progressive video formats; if I_Latency_Fields_Present flag == 1 then this field only indicates the latency while receiving progressive video formats, otherwise this field indicates the latency when receiving any video format. Value is number of (milliseconds / 2) + 1 with a maximum allowed value of 251 (indicating 500 millisecond duration). A value of 0 indicates that the field is not valid or that the latency is unknown. A value of 255 indicates that no video is supported in this device or downstream.
- Audio_Latency [1 byte] Indicates the amount of audio latency when receiving any video format or only when receiving progressive video formats; if I_Latency_Fields_Present flag == 1 then this field only indicates the latency while receiving progressive video formats, otherwise this field indicates the latency when receiving any video format. Value is number of (milliseconds / 2) + 1 with a maximum allowed value of 251 (indicating 500 millisecond duration). A value of 0 indicates that the field is not valid or that the latency is unknown. A value of 255 indicates that no audio is supported in this device or downstream.
- Interlaced_Video_Latency [1 byte] This field is only present if I_Latency_Fields_Present flag == 1. If present, the field indicates the amount of video latency when

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receiving an interlaced video format. Format is identical to Video_Latency field.

- Interlaced_Audio_Latency [1 byte] This field is only present if I_Latency_Fields_Present flag == 1. If present, the field indicates the amount of audio latency when receiving an interlaced video format. Format is identical to Audio_Latency field.

8.3.3 DVI/HDMI Device Discrimination

In order to determine if a sink is an HDMI device, an HDMI Source shall check the E-EDID for the presence of an HDMI Vendor Specific Data Block within the first CEA Extension. Any device with an HDMI VSDB of any valid length, containing the IEEE Registration Identifier of 0x000C03, shall be treated as an HDMI device.

Any device with an E-EDID that does not contain a CEA Extension or does not contain an HDMI VSDB of any valid length shall be treated by the Source as a DVI device (see Appendix C).

8.3.4 Audio and Video Details

Sink audio characteristics and support are indicated in a series of Short Audio Descriptors located in the CEA Extension's Data Block collection. This data includes a list of audio encodings supported by the Sink and parameters associated with each of those encodings, such as number of channels supported for that format. A Speaker Allocation Descriptor may also be included in the Data Block collection and is required for Sinks supporting multi-channel L-PCM or multi-channel One Bit Audio.

A Sink may indicate support for YC_BC_R pixel encodings. To indicate support, bits 4 and 5 of byte 3 of the CEA Extension shall both be set to one (see Table 27 of CEA-861-D). To indicate no support, bits 4 and 5 shall both be zero.

With the exception of 640x480p video format, if a Sink is required to support a particular video format, video format timing, or pixel encoding, then the Sink shall indicate support for that video format, video format timing or pixel encoding in the E-EDID. Explicit indication of 640x480p is optional but is not required because all Sinks are required to support that video format.

To indicate support for any video format in section 6.2.4, an HDMI Sink shall use a Short Video Descriptor (SVD) containing the Video Code for that format and may also use a Detailed Timing Descriptor (DTD).

If the Sink supports extended colorimetries (those beyond the default standard- and high-definition colorimetries) or supports the reception of gamut-related metadata, the Sink shall use a Colorimetry Data Block to indicate support for these colorimetries and metadata. See section 6.7.3 for more details.

8.4 Enhanced DDC

Enhanced DDC described in this section is defined in VESA "ENHANCED DISPLAY DATA CHANNEL STANDARD Version 1 (September 2, 1999)". All Sinks are required to support these

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enhanced DDC features. If a Sink's E-EDID structure is longer than 256 bytes, it shall support the segment pointer.

8.4.1 Timing

Data is synchronized with the SCL signal and timing shall comply with the Standard Mode of the I^2C specification (100kHz maximum clock rate).

I^2C Bus is a standard two-wire (clock and data) serial data bus protocol. Refer to the I^2C specification for details.

Note that an HDMI Sink may hold off the DDC transaction by stretching the SCL line during the SCL-low period following the Acknowledge bit as permitted by the I^2C specification. All HDMI Sources shall delay the DDC transaction while the SCL line is being held low.

8.4.2 Data Transfer Protocols

The Source shall use I^2C commands to read information from a Sink's E-EDID with a slave address.

In Enhanced DDC, a segment pointer is used to allow addressing of the E-EDID outside of the normal 256-byte limit of the 0xA0/0xA1 address. The Enhanced DDC protocol sets the segment pointer before the remainder of the DDC command.

8.4.3 Segment pointer

Enhanced DDC allows access of up to 32 Kbytes of data. This is accomplished using a combination of the 0xA0/0xA1 address pair and a segment pointer. For each value of the segment pointer, 256 bytes of data are available at the 0xA0/0xA1 address pair. An unspecified segment pointer references the same data as when the segment pointer is zero.

Each successive value of the segment pointer allows access to the next two blocks of E-EDID (128 bytes each). The value of the segment pointer register cannot be read since it is reset at the completion of each command.

8.4.4 Enhanced DDC Sink

The Sink shall be Enhanced DDC read compliant.

The Sink shall be capable of responding with EDID 1.3 data and up to 255 extension blocks, each 128 bytes long (up to 32K bytes total E-EDID memory) whenever the Hot Plug Detect signal is asserted.

The Sink should be capable of providing E-EDID information over the Enhanced DDC channel whenever the +5V Power signal is provided. This should be available within 20msec after the +5V Power signal is provided.

8.4.5 Enhanced DDC Source

The Source shall use Enhanced DDC protocols.

The Source shall be capable of reading EDID 1.3 data at DDC address 0xA0.

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The Source reads Enhanced EDID extensions data at DDC address 0xA0 using segment pointer 0x60.

8.5 Hot Plug Detect Signal

An HDMI Sink shall not assert high voltage level on its Hot Plug Detect pin when the E-EDID is not available for reading. This requirement shall be fulfilled at all times, even if the Sink is powered-off or in standby. The Hot Plug Detect pin may be asserted only when the +5V Power line from the Source is detected. This will ensure that the Hot Plug Detect pin is not asserted before the Third Make of the connector (see Section 0).

A Source may use a high voltage level Hot Plug Detect signal to initiate the reading of E-EDID data.

A Source shall assume that any voltage within the range specified for High voltage level in Table 4-26 indicates that a Sink is connected and that E-EDID is readable. It does not indicate whether or not the Sink is powered or whether or not the HDMI input on the Sink is selected or active.

An HDMI Sink shall indicate any change to the contents of the E-EDID by driving a low voltage level pulse on the Hot Plug Detect pin. This pulse shall be at least 100 msec.

8.6 Consumer Electronics Control (CEC)

The CEC line is used for high-level user control of HDMI-connected devices. The mandatory requirements for the CEC line are described in detail in Section 4.2.10, CEC Line. The optional CEC protocol is described in Supplement 1: Consumer Electronics Control (CEC).

8.7 Physical Address

8.7.1 Overview

In order to allow CEC to be able to address specific physical devices and control switches, all devices shall have a physical address. This connectivity has to be worked out whenever a new device is added to the cluster. The physical address discovery process uses only the DDC/EDID mechanism and applies to all HDMI Sinks and Repeaters, not only to CEC-capable devices.

The CEC and DDC connections are shown in Figure 8-1.

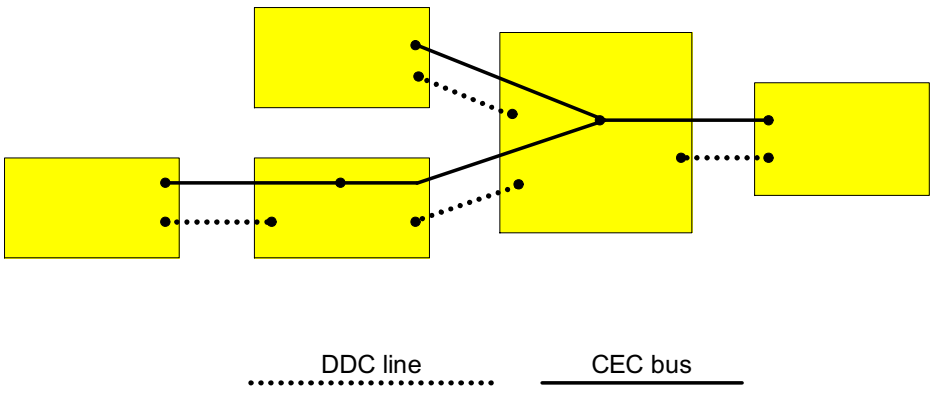


Figure 8-1 CEC and DDC line connections

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The CEC line is directly connected to all nodes on the network.

After discovering their own physical address, the CEC devices transmit their physical and logical addresses to all other devices, thus allowing any device to create a map of the network.

8.7.2 Physical Address Discovery

The physical address of each node is determined through the physical address discovery process. This process is dynamic in that it automatically adjusts physical addresses as required as devices are physically or electrically added or removed from the device tree.

All Sinks and Repeaters shall perform the steps of physical address discovery and propagation even if those devices are not CEC-capable. Sources are not required to determine their own physical address unless they are CEC-capable.

All addresses are 4 digits long allowing for a 5–device-deep hierarchy. All are identified in the form of n.n.n.n in the following description. An example of this is given in Figure 8-3.

A Sink or a Repeater that is acting as the CEC root device will generate its own physical address: 0.0.0.0. A Source or a Repeater reads its physical address from the EDID of the connected Sink. The CEC line may be connected to only one HDMI output so a device with multiple HDMI outputs will read its physical address from the EDID on the CEC-connected output. Each Sink and Repeater is responsible for generating the physical address of all Source devices connected to that device by appending a port number onto its own physical address and placing that value in the EDID for that port. The Source Address Field of the HDMI Vendor Specific Data Block (see Section 8.3.2) is used for this purpose.

Note that the values shown in the figures below represent the physical addresses for the devices themselves, not the Source physical addresses stored in the EDID within that device. In fact, for all devices shown, except the TV, those physical addresses are stored in the EDID of the connected Sink. An example is shown for the TV at physical address 0.0.0.0.

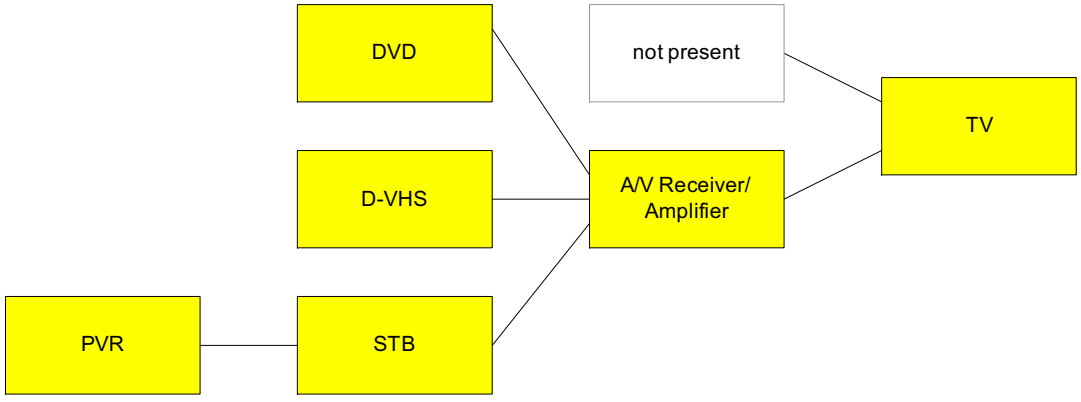


Figure 8-2 Typical HDMI cluster

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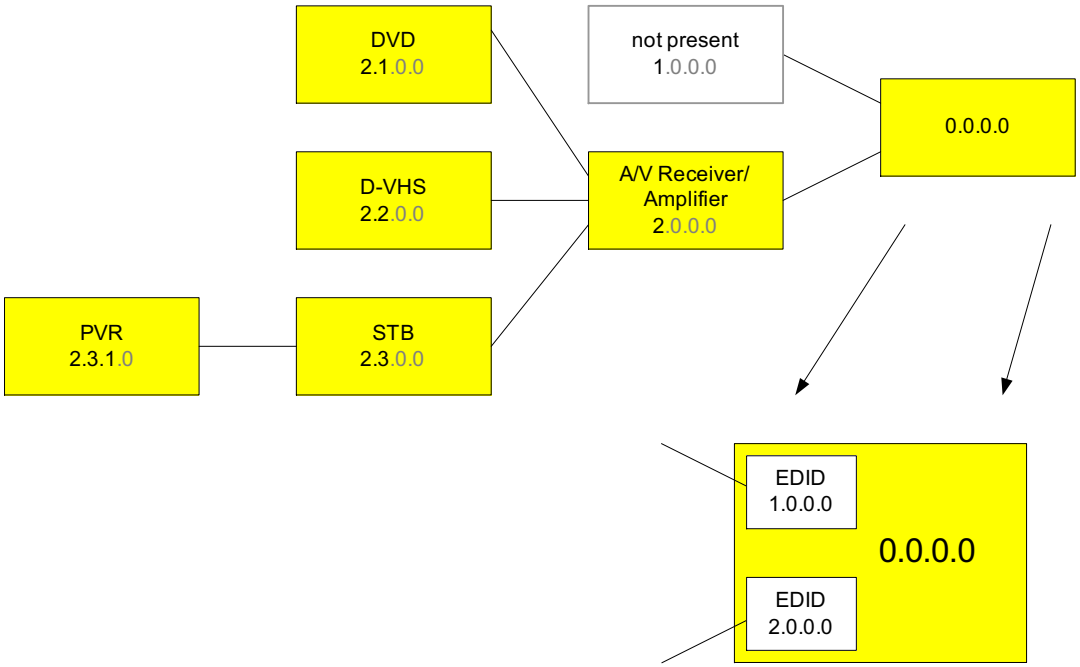


Figure 8-3 Addresses within an HDMI cluster

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8.7.3 Discovery Algorithm

The following algorithm is used to allocate the physical address of each device whenever HPD is de-asserted or upon power-up:

```
Disable assertion of HPD to all source devices
If I am CEC root
    Set my_address to 0.0.0.0
Else
    Wait for HPD from sink
    Query sink for my_address of my connection (Section 8.7.4)
    The device shall retain this physical address until HPD is
        removed (or the device is powered off).
End if
If device has connections for source devices then
    Label all possible connections to source devices uniquely starting
        from connection_label = 1 to the number of source input connections
    If device has separate EDIDs for each source connection then
        If my_address ends with 0 then
            Set each source_physical_address to my_address with the
                first 0 being replaced with connection_label.
        Else (i.e. beyond the fifth layer of the tree)
            Set each source_physical_address to F.F.F.F
        End if
    Else
        Set each source_physical_address to my_address
    End if
    Write source_physical_address to HDMI VSDB in EDID for each source
        connection
End if
Allow HPD to be asserted for source devices
```

8.7.4 HDMI Sink Query

A Source shall determine its physical address (my_address) by checking the HDMI Vendor Specific Data Block (see Section 8.3.2) within the EDID. The fourth and fifth bytes of this 5 byte structure contain the Source Physical Address (fields A, B, C, D).

8.8 ISRC Handling

A Source shall not transmit an ISRC1 or ISRC2 Packet to a Sink that does not have Supports_AI = 1.

A Source may handle an International Standard Recording Code (ISRC) and/or UPC/EAN describing the origin or owner details for each track of content on the medium. These values may be transmitted using the ISRC1 and ISRC2 packets.

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When fields UPC_EAN_ISRC_16 through 31 include effective data (i.e. not "reserved"), a subsequent ISRC2 Packet shall be transmitted. In other cases, the ISRC2 packet may optionally be transmitted.

When a subsequent ISRC2 Packet is transmitted, the ISRC_Cont field shall be set and shall be clear otherwise.

For further description of the UPC_EAN_ISRC fields, see "DVD Specifications for Read-Only Disc", Part 4: AUDIO SPECIFICATIONS Version 1.0, March 1999, Annex B".

Regarding usage of the ISRC_Status field, Source shall comply with "DVD Specifications for Read-Only Disc", "Part 4: AUDIO SPECIFICATIONS", Version-up Information (from 1.1 to 1.2), Table 7.2.3.1.1-2, May 2000. Following is a summary of the relevant rules from that specification:

- At the beginning of each track, at least two complete UPC_EAN_ISRC codes are transmitted with an ISRC_Status of 0b001.
- During the bulk of the track, continuous repetitions of the packet(s) are required, with an ISRC_Status of 0b010.
- Immediately before the end of each track, at least two complete UPC_EAN_ISRC codes are transmitted with an ISRC_Status of 0b100.

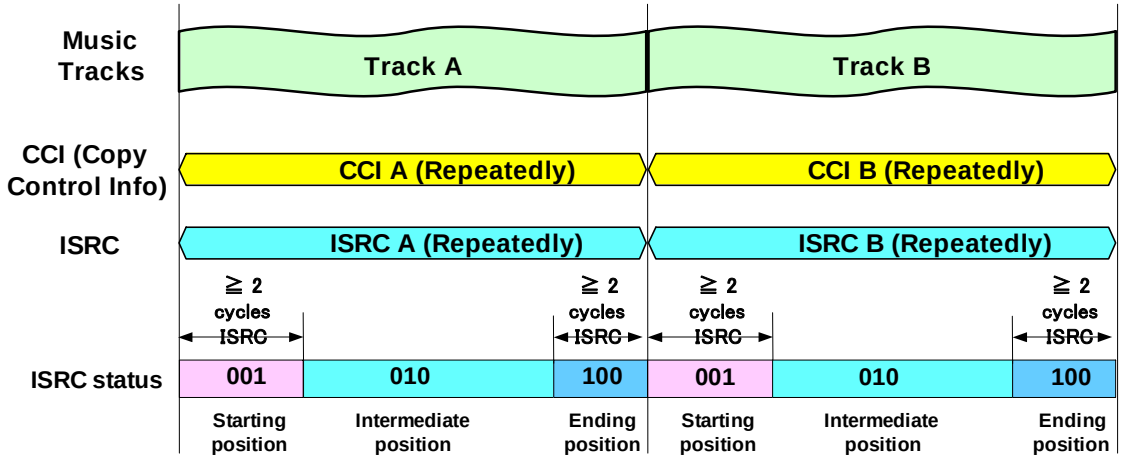


Figure 8-4 ISRC/CCI and ISRC Status Handling

8.9 Auto Lipsync Correction Feature

Some common home theater device configurations will render the audio in a device other than the TV. In these configurations, the video processing latency of the TV may cause perceptible lipsync issues to the user. These issues can be corrected by delaying the audio to compensate for the video processing latency. The HDMI Auto Lipsync Correction feature allows a Source or Repeater to automatically determine the necessary amount of audio delay before presentation or output of that audio signal.

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8.9.1 EDID Latency Info

HDMI Sinks and Repeaters may declare audio and video latency information in the EDID, allowing an HDMI Source or Repeater to determine how best to maintain synchronization between the rendered audio and video. These fields and other lipsync-related fields are in the HDMI VSDB (see section 8.3.2). The latency values within these fields indicate the amount of time between the video or audio entering the HDMI input to the actual presentation to the user (on a display or speakers), whether that presentation is performed by the device itself or by another device downstream.

Many TVs internally compensate for their own video processing latency by adding a delay to the audio stream that corresponds to the video latency. In this case, the EDID-indicated audio and video latencies will be equal. This delay will typically be applied for audio sent to internal speakers as well as audio sent to external S/PDIF (or other) audio outputs so that downstream amplifiers will also be in-sync.

A lipsync-aware Repeater will calculate the latency fields for its upstream EDID to indicate the overall video and audio latency from the reception by the Repeater to the eventual rendering by the Repeater or by downstream device(s). For instance, if the Repeater is a video processor the video data will be delayed by its internal processing before being passed downstream. In this case, the Repeater should indicate a video latency in the upstream EDID equal to the video latency found in the downstream device's EDID plus the Repeater's own internal video processing latency.

Likewise, if the Repeater is an audio amplifier which passes video through unmodified but which renders (amplifies) the audio directly (not passing it downstream), then the upstream audio latency will be equal to the Repeater's audio processing latency (only). If this amplifier adds an audio delay sufficient to compensate for the video latency of the downstream device, then the upstream audio and video latencies will be equal, whether that Repeater forwards the audio downstream or renders the audio directly.

8.9.1.1 Supporting a Range of Latency Values

If the video latency of a device differs significantly depending upon the video format or other factor, it is recommended that the video latency field indicate a latency that is between the extremes but skewed toward the longer latency. An audio/video mismatch is more perceptible if the audio leads the video than if the video leads the audio by a similar amount. Because of this effect, indicating a value that is closer to the maximum video delay may result in better overall user experience. For example, a value of roughly (2 * max_latency + min_latency)/3 may be used. The same is true for the audio latency but in this case, the indicated value should be skewed towards the minimum latency. For example, a value of roughly (max_latency + 2*min_latency)/3 may be used.

If the optimum indication for the video latency for interlaced video formats is significantly different than the optimum indication of latency for progressive formats, then the I_Latency_Fields_Present flag should be set, allowing the EDID to indicate separate latencies for these two categories of video formats. This approach may be used anytime but it is recommended in case the difference between the two latencies is more than roughly 30 msecs.

8.9.2 Compensation

A lipsync-aware Source or Repeater may delay the audio to compensate for the video latency of the downstream device(s), by an amount equal to the video_latency minus the audio_latency of the downstream (or rendering) devices.

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It may not be possible to determine the audio latency of non-HDMI audio outputs (e.g. S/PDIF or analog outputs). For uncompressed audio formats, typically the value will be close to zero and so the device can simply delay the audio by the amount of video latency in the downstream EDID. For compressed audio formats, the device may assume that the audio latency is near the standard decompression latency specified in the relevant IEC61937-x standard or in the codec vendor's documentation.

It is expected that an audio delay capability of 100msecs will support full compensation for almost all of the TV and video processor products on the market today.

If transmitting a progressive video format, the Video_Latency and Audio_Latency fields are used for this calculation. If transmitting an interlaced video format, either these same fields are used or, if I_Latency_Fields_Present == 1, then the Interlaced_Video_Latency and Interlaced_Audio_Latency fields are used.

8.9.3 Supporting Dynamic Latency Changes

A future version of the HDMI Spec will define a mechanism for Sinks to dynamically modify their latency information.

8.9.4 Separate Audio and Video Paths

If the Source or Repeater splits the audio and video stream for transmission to two separate outputs, the device should calculate the required audio delay for the audio path by subtracting the audio latency in the audio path's EDID from the video latency in the video path's EDID.

A Source may use the no-video value or the corresponding no-audio value (in the Audio_Latency fields) to automatically determine whether video or audio is supported on a particular signal path.

The no-video value of the Video_Latency fields allows a Sink to declare that it does no internal rendering of the video signal nor does it output the HDMI-received video stream on an HDMI or non-HDMI output. This may never be true for a TV but it may be true or may change dynamically for an audio amplifier with a video pass-through function depending upon whether any device is connected downstream of the video output port, for example.

For a Repeater that does no video rendering, if there is no downstream video device connected to the Repeater's output, then the Repeater should indicate no-video. If there are downstream device(s) connected but all of those device(s) have no-video value in the video latency field then the Repeater should also indicate no-video.

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9 Content Protection

9.1 Recommendation

Content protection capability is recommended for all HDMI compliant devices. An HDMI compliant Source should protect all of the protected audiovisual data. Amongst adequate copy protection technologies that are compatible with HDMI, HDCP is available.

9.2 HDCP Implementations

HDCP implementations for HDMI shall adhere to HDCP specification version 1.10.

Note that if the Sink has no digital audio outputs and has typical restrictions on its analog audio outputs (e.g. must be normal pitch) then it is recommended that Supports_AI be set. If this bit is clear then the Sink will not be able to receive audio content from DVD-Audio and Super Audio CD.

9.3 Usage of Audio Content Protection (ACP) Packets

A Source may use the ACP Packet to convey content-related information regarding the active audio stream.

Non-transmission of ACP Packets should be considered equivalent to transmission of an ACP Packet with an ACP_Type field of 0. If a Sink does not receive an ACP Packet within 600msecs, it shall revert to ACP_Type = 0 behavior.

Whenever a Source is required by other license agreements or specifications to transmit information related to the content protection requirements of the active audio stream, ACP Packets shall be transmitted at least once per 300msecs and an appropriate ACP_Type value shall be set.

When transmitting ACP Packets, upon the start of a new audio stream or upon any change in the audio stream that can be indicated by the ACP Packet, a modified, accurate ACP Packet shall be transmitted no later than 300msec following the transmission of the affected or relevant audio sample.

The ACP Packet transmission may occur at any time that a Data Island packet may be transmitted.

A Source shall not transmit an ACP Packet to a Sink that does not have Supports_AI = 1.

9.3.1 Requirements for Sink

A Sink that has any type of audio output and/or audio recording function shall be capable of receiving and appropriately handling the ACP Packet even if the Sink does not support any audio rendering functionality.

Whenever an HDCP-capable Sink detects an ACP Packet, it shall comply with the HDCP Audio Compliance Rules.

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Whenever an HDCP-capable Sink detects an ACP Packet with an unknown ACP_Type value, it shall comply with the HDCP Audio Compliance Rules for undefined content.

9.3.2 Requirements for Repeater

Any content that is received by a Repeater and is accompanied by an ACP Packet shall be accompanied with an identical ACP Packet and any concurrently received ISRC1 or ISRC2 packets when that content is transmitted to a Sink with Supports_AI = 1.

9.3.3 Application to Generic Audio

With regards to the control of copying and audio output permissions, transmission of an ACP Packet with an ACP_Type field of 0 is equivalent to no transmission of an ACP Packet.

ACP_Type = 0 : Generic Audio

ACP_Type_Dependent fields all Reserved (0).

9.3.4 Application to IEC 60958-Identified Audio

A Source may indicate that the Sink must support the proper output of SCMS bits by setting ACP_Type = 1 (Type 1 = IEC 60958-identified).

ACP_Type = 1 : IEC 60958-identified

ACP_Type_Dependent fields all Reserved (0).

9.3.5 Application to DVD-Audio

Whenever a Source is transmitting DVD-Audio content for which HDCP is required, an accurate ACP Packet, with ACP_Type = 2 shall be transmitted at least once per 300msec.

The UPC/EAN and/or ISRC values are recorded on the DVD-Audio disc with DVD audio data. When the Source transmits UPC/EAN and/or ISRC using ISRC packet, the time lag between the ISRC packet and the corresponding audio sample packet should be minimized.

ACP_Type = 2 : DVD-Audio

ACP_Type_Dependent Usage:

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Table 9-1 ACP_Type Dependent Fields for DVD-Audio Application

Packet Byte #	7	6	5	4	3	2	1	0
PB0	DVD-Audio_Type_Dependent_Generation							
PB1	Copy_Permission		Copy_Number			Quality		Transaction
PB2	Reserved (0)							
:								
PB27								

- DVD-Audio_Type_Dependent_Generation [8 bits] Identifies the generation of the DVD-Audio-specific ACP_Type_Dependent fields. Shall be set to 1. In the future version of this specification, currently reserved field(s) may be used to carry additional information. In such case, the value of this field may be incremented.
- Copy_Permission [2 bits] audio_copy_permission parameter.
- Copy_Number [3 bits] audio_copy_number parameter.
- Quality [2 bits] audio_quality parameter.
- Transaction [1 bit] audio_transaction parameter.

See “DVD Specifications for Read-Only Disc, Part 4: AUDIO SPECIFICATIONS”, Version 1.2, Table 7.2.3.1.1-2”, and “Supplement to Part 4: AUDIO SPECIFICATIONS Version 1.2 (February 2004)” for descriptions and use of the fields: audio_copy_permission, audio_copy_Number, audio_quality, and audio_transaction.

Any Source that supports DVD-Audio transmission on HDMI shall have the ability to transmit all valid channels of any multi-channel content.

9.3.6 Application to Super Audio CD

Whenever a Source is transmitting content originally derived from the HD Layer of a Super Audio CD, an accurate ACP Packet with ACP_Type = 3 shall be transmitted at least once per 300msec. See Super Audio CD System Description for “HD Layer Content”.

ACP_Type = 3 : Super Audio CD

ACP_Type_Dependent Usage:

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Table 9-2 ACP_Type Dependent Fields for Super Audio CD Application

Packet Byte #	7	6	5	4	3	2	1	0
PB0	CCI_1							
: :								
PB15								
PB16	Reserved (0)							
: :								
PB27								

CCI_1 [16 bytes] Additional content control information. See Super Audio CD System Description for details.

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Appendix A Repeater

A.1 Repeater Functions

A Repeater is defined as a device with one or more HDMI inputs, one or more HDMI outputs, and a retransmission function.

A Repeater has at least one of following functions:

- Repeat function:
  Single-input, single-output devices. Used primarily for cable extension.
- Switch function:
  Multiple-input, single-output devices. Used primarily to select among multiple Sources.
- Distributor function:
  Single-input, multiple-output devices, where only one output is active. Used primarily to select among multiple displays or Sinks.
- Duplicator function:
  Single-input, multiple-output devices, where more than one output is active. Used for signal distribution.

Combinations of the above, for instance, multiple-input, multiple-output devices, incorporating both input selection and output selection or signal distribution are allowed.

In all cases, each HDMI input shall fulfill all of the requirements of an HDMI Sink when it is connected with an active sink device, and each HDMI output shall fulfill all of the requirements of an HDMI Source when it is connected with an active source.

The E-EDID presented by a Repeater should reflect the capabilities of the downstream Sink.

A.2 E-EDID Read Timing (Informative)

In terms of E-EDID handling, Repeaters will typically fall into one of the following categories.

- Stored E-EDID type: The Repeater stores an E-EDID data structure that typically consists of downstream Sink capabilities.
- Forwarding type: The Repeater does not store an E-EDID data structure. When an E-EDID read request comes from a Source, the Repeater forwards the read request to a Sink. The E-EDID data from the Sink is then forwarded back to the Source.

An HDMI cluster may have several Repeaters between a Source and a Sink. To minimize the impact to the E-EDID reading time, each Repeater in the chain should minimize the added delay.

For example, the delay added by a Forwarding type Repeater should be no more than 4 msec per 16-byte read.

A stored E-EDID type Repeater should be able to send a 256 byte E-EDID within 150 msec when a Source issues sixteen 16-byte read requests. This means that a 16-byte read request would be completed within approximately 10 msec.

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Appendix B Type B Connector Usage

B.1 Exception To Audio Format Support Requirement

Sources are not required to carry audio when all of the following conditions are met:

- Source is required by the HDMI Specification or associated agreements to use the Type B connector, and,
- Source has alternate default or user selectable audio outputs, and,
- Source can ensure that the appropriate audio stream is being delivered to the alternate audio outputs.

In order to guarantee rendering of video from Sources that do not fully support HDMI audio, the following condition shall be met:

- Sinks that are capable of supporting an HDMI video format when it is accompanied by audio shall also support that format when it is not accompanied by audio.

It is strongly recommended that a display device, when receiving an HDMI video signal without audio, temporarily indicate to the user that there is no audio accompanying the stream.

B.2 HDMI Dual-Link Architecture

HDMI dual-link architecture is compatible with DVI 1.0 dual-link architecture. Refer to section 3.1.5 of the DVI 1.0 specification.

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Appendix C Compatibility With DVI

C.1 Requirement for DVI Compatibility

All HDMI Sources shall be compatible with DVI 1.0 compliant sink devices (i.e. “monitors” or “displays”) through the use of a passive cable converter. Likewise, all HDMI Sinks shall be compatible with DVI 1.0 compliant sources (i.e. “systems” or “hosts”) through the use of a similar cable converter.

When communicating with a DVI device, an HDMI device shall operate according to the DVI 1.0 specification, with the following exception – these devices are not required to comply with DVI 1.0 rules regarding:

- Monitor scaling requirements [refer to Section 2.2.8.2 of the DVI specification – superseded by HDMI specifications]
- Physical Interconnect specifications [refer to Chapter 5 of the DVI specification – superseded by HDMI specifications]
- System Low Pixel Format Support Requirements [refer to Section 2.2.4 of the DVI specification – superseded by HDMI specifications]

Furthermore, for HDMI devices that would not otherwise have a “BIOS” or “operating system” there are the following additional exceptions:

- “BIOS” requirements [refer to Section 2.2.4 of the DVI specification]
- “Operating system” requirements [refer to Section 2.2.2 and Section 2.2.9 of the DVI specification]
- “System level event” requirements [refer to Section 2.2.9.1 of the DVI specification]
- Power management requirements [refer to Section 2.4 of the DVI specification]

C.2 HDMI Source Requirements

When communicating with a DVI sink device, an HDMI Source shall operate in a mode compatible with that device. This requires that the Source operate under the following limitations:

- Video pixel encoding shall be RGB.
- No Video Guard Bands shall be used.
- No Data Islands shall be transmitted.

An HDMI Source may transmit Video Data Periods without Guard Bands only when communicating to a DVI sink device or during the process of determining if the sink device is HDMI capable.

An HDMI Source, upon power-up, reset or detection of a new sink device, shall assume that the sink device operates under DVI 1.0 limitations. An HDMI Source shall determine if the sink device is an HDMI Sink by following the rule(s) described in Section 8.3.3. Upon detection of an HDMI Sink, the HDMI Source shall follow all of the HDMI Source-related requirements specified in this document.

All electrical and physical specifications in Section 4 shall be followed by the HDMI Source even when communicating with a DVI sink device.

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C.3 HDMI Sink Requirements

When connected to a DVI source device, an HDMI Sink shall operate as a DVI 1.0 compliant sink with the exceptions outlined in Section C.1 above.

A DVI source device will always be restricted in the following ways:

- Only RGB pixel encoding is used.
- There is no Guard Band on the Video Data Period.
- There are no Data Islands transmitted.

An HDMI Sink, upon power-up, reset or detection of a new source device, shall assume that the source device is limited to the above behavior. Upon the detection of an indication that the source is HDMI-capable, the HDMI Sink shall follow all of the HDMI Sink-related requirements specified in this document.

All electrical and physical specifications in Section 4 of the HDMI Specification shall be followed by the HDMI Sink even when communicating with a DVI source device.

C.4 Type A to DVI Adapter Cable [Informative]

Table C-1 Wire Categories

Category	Description
A	TMDS Signal Wire
B	TMDS Shield
C	Control
D	Control Ground
N.C.	No connect (no wire)
5V	5 Volts Power Wire

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Table C-2 Type A-to-DVI-D Cable Wire Assignment [Informative]

Type A pin	Signal Name	Wire	DVI-D pin
1	TMDS Data2+	A	2
2	TMDS Data2 Shield	B	3
3	TMDS Data2–	A	1
4	TMDS Data1+	A	10
5	TMDS Data1 Shield	B	11
6	TMDS Data1–	A	9
7	TMDS Data0+	A	18
8	TMDS Data0 Shield	B	19
9	TMDS Data0–	A	17
10	TMDS Clock+	A	23
11	TMDS Clock Shield	B	22
12	TMDS Clock–	A	24
15	SCL	C	6
16	DDC Data	C	7
17	DDC/CEC Ground	D	15
18	+5V Power	5V	14
19	Hot Plug Detect	C	16
13	CEC	N.C.	
14	Reserved (in cable but N.C. on device)	N.C.	
	TMDS Data 4-	N.C.	4
	TMDS Data 4+	N.C.	5
	TMDS Data 3-	N.C.	12
	TMDS Data 3+	N.C.	13
	TMDS Data 5-	N.C.	20
	TMDS Data 5+	N.C.	21
	No Connect	N.C.	8

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C.5 Type B to DVI Adapter Cable [Informative]

Table C-3 Type B to DVI-D Cable Wire Assignment [Informative]

Type B pin	Pin Assignment	Wire	DVI-D pin
1	TMDS Data2+	A	2
2	TMDS Data2 Shield	B	3
3	TMDS Data2-	A	1
4	TMDS Data1+	A	10
5	TMDS Data1 Shield	B	11
6	TMDS Data1-	A	9
7	TMDS Data0+	A	18
8	TMDS Data0 Shield	B	19
9	TMDS Data0-	A	17
10	TMDS Clock+	A	23
11	TMDS Clock Shield	B	22
12	TMDS Clock-	A	24
13	TMDS Data5+	A	21
14	TMDS Data5 Shield	B	19
15	TMDS Data5-	A	20
16	TMDS Data4+	A	5
17	TMDS Data4 Shield	B	3
18	TMDS Data4-	A	4
19	TMDS Data3+	A	13
20	TMDS Data3 Shield	B	11
21	TMDS Data3-	A	12
25	SCL	C	6
26	DDC Data	C	7
27	DDC/CEC Ground	D	15
28	+5V Power	5V	14
29	Hot Plug Detect	C	16
22	CEC	N.C.	
23	Reserved	N.C.	
24	Reserved	N.C.	
	No Connect	N.C.	8

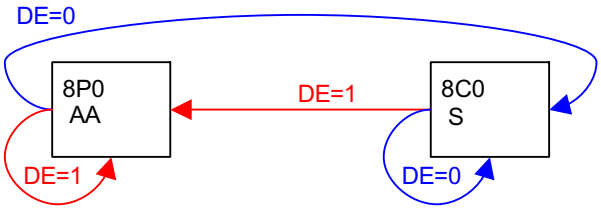
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Appendix D Deep Color Additional Detail

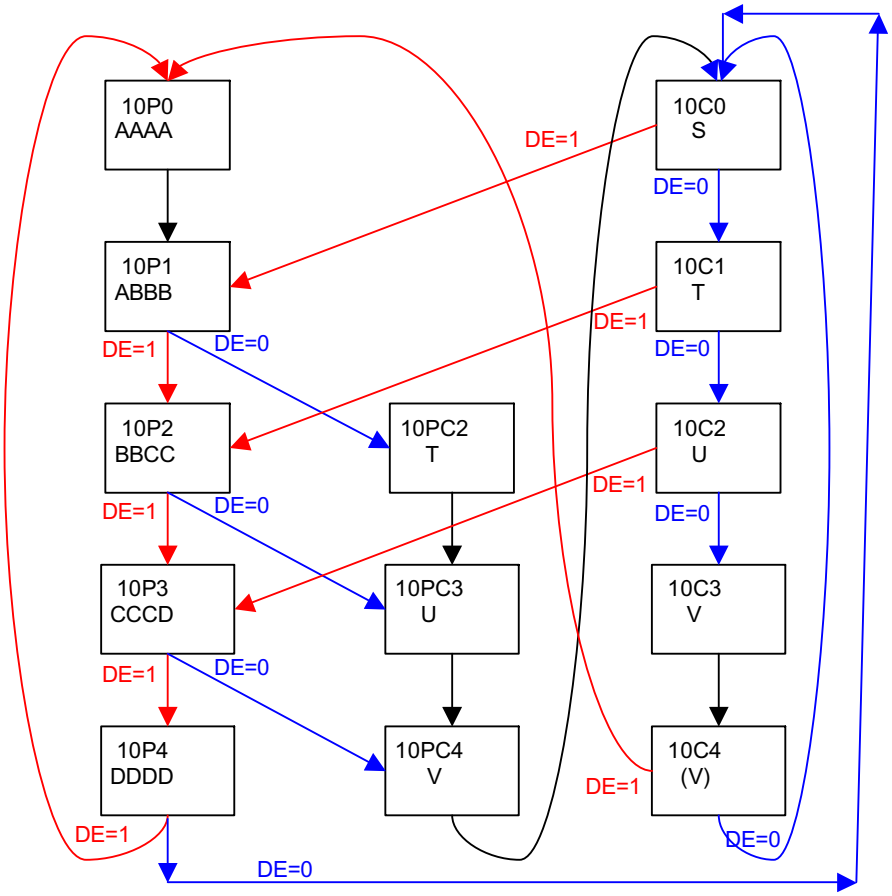
E.1 State Machines

The following state machine drawings are provided for informative purposes to provide better understanding of the Deep Color packing sequences. For each mode, the source sequence starts at phase 0, and then increments through the phases. While DE=1 (pixel data is available), pixel data fragments *m*P*n* are transmitted. While DE=0, blanking fragments *m*C*n* are transmitted.

24 bit mode:

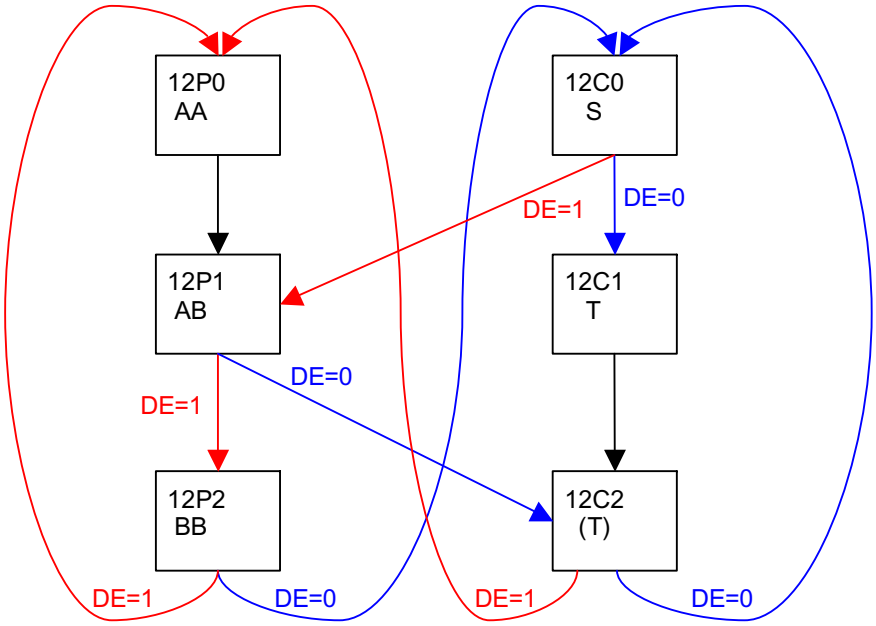


30 bit mode:

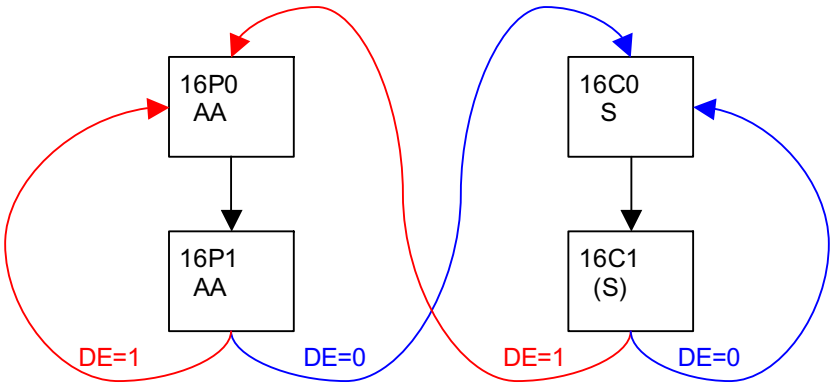


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36 bit mode:



48 bit mode:



D.2 Recommended N and Expected CTS Values

The recommended value of N for several standard pixel clock rates at several Deep Color modes are shown below. It is recommended that Sources with non-coherent clocks use the values listed for a TMDS clock of “Other”.

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Table D-1 36 bits/pixel: Recommended N and Expected CTS for 32kHz

	32 kHz	
TMDS Clock (MHz)	N	CTS
25.2 / 1.001	9152	84375
25.2	4096	37800
27	4096	40500
27 * 1.001	8192	81081
54	4096	81000
54 * 1.001	4096	81081
74.25 / 1.001	11648	316406-316407*
74.25	4096	111375
148.5 / 1.001	11648	632812-632813*
148.5	4096	222750
Other	4096	Measured

** Note: This value will alternate because of restriction on N.*

Table D-2 36 bits/pixel: Recommended N and Expected CTS for 44.1kHz and Multiples

	44.1 kHz		88.2 kHz		176.4 kHz	
TMDS Clock (MHz)	N	CTS	N	CTS	N	CTS
25.2 / 1.001	7007	46875	14014	46875	28028	46875
25.2	6272	42000	12544	42000	25088	42000
27	6272	45000	12544	45000	25088	45000
27 * 1.001	6272	45045	12544	45045	25088	45045
54	6272	90000	12544	90000	25088	90000
54 * 1.001	6272	90090	12544	90090	25088	90090
74.25 / 1.001	17836	351562-351563*	35672	351562-351563*	71344	351562-351563*
74.25	6272	123750	12544	123750	25088	123750
148.5 / 1.001	17836	703125	35672	703125	71344	703125
148.5	6272	247500	12544	247500	25088	247500
Other	6272	measured	12544	measured	25088	measured

** Note: This value will alternate because of restriction on N.*

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Table D-3 36 bits/pixel: Recommended N and Expected CTS for 48kHz and Multiples

TMDS Clock (MHz)	48 kHz		96 kHz		192 kHz	
	N	CTS	N	CTS	N	CTS
25.2 / 1.001	9152	56250	18304	56250	36608	56250
25.2	6144	37800	12288	37800	24576	37800
27	6144	40500	12288	40500	24576	40500
27 * 1.001	8192	54054	16384	54054	32768	54054
54	6144	81000	12288	81000	24576	81000
54 * 1.001	6144	81081	12288	81081	24576	81081
74.25 / 1.001	11648	210937-210938*	23296	210937-210938*	46592	210937-210938*
74.25	6144	111375	12288	111375	24576	111375
148.5 / 1.001	11648	421875	23296	421875	46592	421875
148.5	6144	222750	12288	222750	24576	222750
Other	6144	measured	12288	measured	24576	measured

** Note: This value will alternate because of restriction on N.*

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Table D-4 48 bits/pixel: Recommended N and Expected CTS for 32kHz

TMDS Clock (MHz)	32 kHz	
	N	CTS
25.2 / 1.001	4576	56250
25.2	4096	50400
27	4096	54000
27 * 1.001	4096	54054
54	4096	108000
54 * 1.001	4096	108108
74.25 / 1.001	11648	421875
74.25	4096	148500
148.5 / 1.001	11648	843750
148.5	4096	297000
Other	4096	Measured

Table D-5 48 bits/pixel: Recommended N and Expected CTS for 44.1kHz and Multiples

TMDS Clock (MHz)	44.1 kHz		88.2 kHz		176.4 kHz	
	N	CTS	N	CTS	N	CTS
25.2 / 1.001	7007	62500	14014	62500	28028	62500
25.2	6272	56000	12544	56000	25088	56000
27	6272	60000	12544	60000	25088	60000
27 * 1.001	6272	60060	12544	60060	25088	60060
54	6272	120000	12544	120000	25088	120000
54 * 1.001	6272	120120	12544	120120	25088	120120
74.25 / 1.001	17836	468750	35672	468750	71344	468750
74.25	6272	165000	12544	165000	25088	165000
148.5 / 1.001	8918	468750	17836	468750	35672	468750
148.5	6272	330000	12544	330000	25088	330000
Other	6272	measured	12544	measured	25088	measured

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Table D-6 48 bits/pixel: Recommended N and Expected CTS for 48kHz and Multiples

TMDS Clock (MHz)	48 kHz		96 kHz		192 kHz	
	N	CTS	N	CTS	N	CTS
25.2 / 1.001	6864	56250	13728	56250	27456	56250
25.2	6144	50400	12288	50400	24576	50400
27	6144	54000	12288	54000	24576	54000
27 * 1.001	6144	54054	12288	54054	24576	54054
54	6144	108000	12288	108000	24576	108000
54 * 1.001	6144	108108	12288	108108	24576	108108
74.25 / 1.001	11648	281250	23296	281250	46592	281250
74.25	6144	148500	12288	148500	24576	148500
148.5 / 1.001	5824	281250	11648	281250	23296	281250
148.5	6144	297000	12288	297000	24576	297000
Other	6144	measured	12288	measured	24576	measured

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Appendix E Gamut-Related Metadata

E.1 Overview

Unlike the classic colorimetry standards used for standard definition and high definition video, the enhanced colorimetry of xvYCC has a virtually unconstrained gamut, which does not easily map to the real-world gamut of existing or near-future display technologies. When transmitting such an enhanced colorimetry, it is necessary for the video source to also indicate the color gamut of the transmitted video. This metadata allows the display to map the gamut of the video stream more accurately and more predictably onto the gamut of the display.

The gamut describes all colors that are reproducible by a particular reference display or that are present in a given content. The color gamut can be described by a Gamut Boundary Description (GBD). When a given image content has a gamut larger or different from the gamut of the HDMI sink, the colors lying outside the aimed gamut need to be clipped or moved accordingly. This procedure is called gamut mapping. The gamut of the content is circumscribed by the gamut of the HDMI source color space. The display can then use the content's Gamut Boundary Description to perform accurate and predictable mapping onto its own gamut.

E.2 Transmission Profiles

There are several transmission profiles (P0, P1, etc.) for gamut related metadata. The difference between the transmission profiles is primarily the transmission rate, specifically, the number of packets that may be sent per video field. Because of the need to transmit the entire metadata within a short period of time, this transmission rate limits the maximum size of the profile as well. The maximum size of the metadata then also corresponds to the accuracy of the gamut boundary description.

The lowest speed transmission profile is P0, transmitting at a rate of one Gamut Metadata Packet per video field. P0 metadata fits completely within that one packet.

When transmitting GBD data, the Source shall send the GBD for an upcoming gamut change using P0 transmission profile if that GBD is available prior to transmission of the content. This P0 transmission should occur at least one full video field prior to the start of the new gamut video.

E.3 Gamut Boundary Description

The HDMI source gamut is described either by a set of R/G/B range limits or by a set of vertices with or without indexed facets. The Format_Flag field indicates which format is supplied:

- Format_Flag [1 bit] Identifies whether subsequent data describes gamut range boundary or gamut vertices boundary. A value of 0 indicates vertices/facets description. 1 indicates range description.

Two simple GBD data structures: one based on four vertices and the other based on R/G/B min/max range limits, are fully defined here and may be supported using the P0 transmission profile. Larger data structures carrying many more vertices as well as facets, will be defined in a future international specification, not necessarily the HDMI Specification. These data structures will require higher transmission speeds and sizes and therefore will require higher transmission profiles (P1**...**).

After those data structures are defined, a subsequent version of the HDMI Specification will permit HDMI devices to support them. Until that time, no HDMI Source may transmit a GBD with

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more than four vertices or containing facet data, nor may any Sink indicate support for transmission profiles other than P0 in the Colorimetry Data Block in the EDID.

Facet data descriptions below are informative only. The facet data structures and relationship between facets and vertices will be described in a future specification.

The size of each component of each vertex or range entry is indicated in the field GBD_Color_Precision:

- GBD_Color_Precision [2 bits] Color precision of GBD vertex and range data:
  0b00 8 bit
  0b01 10 bit
  0b10 12 bit

The definition of vertex data depends on the GBD_Color_Space field (see below) and is as follows:

- RGB: Unsigned integer. According to ITU-R 709-5 item 6.10 (8 bit), summarized in Section 6.6 (for 8**...**16 bit).
- xvYCC: Unsigned integer. According to IEC 61966-2-4 item 4.4, summarized in Section 6.6
- XYZ: Not valid. Future versions of this specification will further define XYZ tristimulus. Until that point, XYZ shall not be used for GBD data.

The precision of the facet data (Packed_GBD_Facets_Data in Table E-1) depends on the number of vertices (Number_Vertices) according to the following equation:

Precision [number of bits] of color facet data = ld(Number_Vertices)

Where ld() is the logarithm to the base of two. The format of color facet data is positive integer, each color facet data indicating the index of a vertex in the Packed_GBD_Vertices_data field. For example, the integer 0 indicates the first vertex in Packed_GBD_Vertices_data and the integer 1 indicates the second vertex in Packed_GBD_Vertices_data. Three consecutive facets data define one triangle with surface normal pointing outside the gamut.

The definition of 8/10/12-bit range data is as follows:

- 8-bit: signed fixed-point – 1 sign bit, 2 bits integer, 5 bits fraction
- 10-bit: signed fixed-point – 1 sign bit, 2 bits integer, 7 bits fraction
- 12-bit: signed fixed-point – 1 sign bit, 2 bits integer, 9 bits fraction

The data structures for these two different formats are shown in Table E-1 and Table E-2 .

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Table E-1 Vertices/Facets GBD Data Structure

Byte #	7	6	5	4	3	2	1	0
0	Format_ Flag = 0	Facet_ Mode	Rsvd(0)	GBD_Color_Precision		GBD_Color_Space		
1	Number_Vertices_H							
2	Number_Vertices_L							
3...VSIZE+2	Packed_GBD_Vertices_Data[0... VSIZE-1]							
VSIZE+3	Number_Facets_H							
VSIZE+4	Number_Facets_L							
VSIZE+5...	Packed_GBD_Facets_Data[0...FSIZE-2]							
VSIZE+FSIZE+4	Packed_GBD_Facets_Data[FSIZE-1]							

- Facet_Mode [1 bit] Indicates if Facets are also included in the GBD. Field is valid only when Format_Flag = 0. Reserved (0) when Format_Flag = 1.
- GBD_Color_Precision [2 bits] see above
- GBD_Color_Space [3 bits] Color space of GBD data:
  0b000 ITU-R BT.709 (using RGB)
  0b001 $xvYCC_{601}$ (IEC 61966-2-4 – SD) (using YC_BC_R)
  0b010 $xvYCC_{709}$ (IEC 61966-2-4 – HD) (using YC_BC_R)
  0b011 XYZ (see above)
- Number_Vertices(_H, _L) [2 bytes] Number of vertices described by following structure.
- Number_Facets(_H, _L) [2 bytes] Number of facets described by following structure.

VSIZE is the number of bytes in the Packed_GBD_Vertices_Data according to:

$$VSIZE = INT\left(3 \cdot Number\_Vertices \cdot GBD\_Color\_Precision / 8 + 0.99999\right)$$

Where, INT() is a function returning the integer part of the number (e.g. INT(3.99999...) = 3).

FSIZE is the number of bytes of Packed_GBD_Facets_Data and will be defined in a future specification.

The minimal number of vertices is 4. In this case, and only this case, the vertices have the following meaning, in this order: black point, red primary, green primary and blue primary. This convention allows constructing the white point and the secondary colors (magenta, cyan and yellow) without transmission.

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Table E-2 Range GBD Data Structure

Byte #	7	6	5	4	3	2	1	0
0	Format_ Flag = 1	Rsvd(0)	Rsvd(0)	GBD_Color_Precision		GBD_Color_Space		
1...N	Packed_Range_Data							

- Packed_Range_Data [N bytes] Packed range data according to following sequence:
  Min_Red_Data
  Max_Red_Data
  Min_Green_Data
  Max_Green_Data
  Min_Blue_Data
  Max_Blue_Data
- GBD_Color_Precision [2 bits] see above
- GBD_Color_Space [3 bits] Color space of GBD data:
  0b000 Reserved
  0b001 RGB expression of $xvYCC_{601}$ coordinates
  0b010 RGB expression of $xvYCC_{709}$ coordinates
  0b011 Reserved

E.4 Data Packing

GBD data is efficiently packed with each 8-, 10- and 12-bit value taking exactly 8-, 10- or 12-bits in the packet. The GBD_Color_Precision field specifies the packing and precision of the GBD data. Table E-3 and Table E-4 define the packing for 10- and 12-bit values using a representative sequence of values, A, B, C..., with A_low representing the low-order bits and A_high, the high-order bits of value A.

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Table E-3 10-bit Packing

	7	6	5	4	3	2	1	0
0	A_high							
1	A_low			B_high				
2	B_low				C_high			
3	C_low					D_high		
4	D_low							
5	E_high							
6	E_low			F_high				
7	F_low				G_high...			

Table E-4 12-bit Packing

	7	6	5	4	3	2	1	0
0	A_high							
1	A_low				B_high			
2	B_low							
3	C_high							
4	C_low				D_high			
5	D_low							

E.5 Example P0 Data Structures

A simple but useful vertex GBD data structure is defined in Table E-5 and can be transmitted using a single Gamut Metadata Packet, fitting within the P0 transmission profile.

The gamut is described in xvYCC$_{709}$ space at 8-bit. The GBD consists of black point as well as red, green and blue primaries.

This data structure has the minimum number of vertices. Following the specification, the correspondence of transmitted vertices and primaries and black point is given. To reconstruct the full gamut boundary description, the white point vertex V_{WHITE} and the secondary colors ($V_{MAGENTA}, V_{CYAN}, V_{YELLOW}$ for magenta, cyan and yellow, respectively) are generated from the first primaries as follows:

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$$V_{WHITE} = V_{RED} + V_{GREEN} + V_{BLUE} - 2V_{BLACK}$$
$$V_{MAGENTA} = V_{RED} + V_{BLUE} - V_{BLACK}$$
$$V_{CYAN} = V_{GREEN} + V_{BLUE} - V_{BLACK}$$
$$V_{YELLOW} = V_{RED} + V_{GREEN} - V_{BLACK}$$

Table E-5 P0 Vertices-Only Data – 8-bit Precision Example

Byte #	7	6	5	4	3	2	1	0
0	Format_ Flag = 0	Facet_ Mode = 0	Rsvd = 0	GBD_Color_Precision = 00		GBD_Color_Space = 010		
1	Number_Vertices_H = 0							
2	Number_Vertices_L = 4							
3	Black(Y)							
4	Black(C_B)							
5	Black(C_R)							
6	Red(Y)							
7	Red(C_B)							
8	Red(C_R)							
9	Green(Y)							
10	Green(C_B)							
11	Green(C_R)							
12	Blue(Y)							
13	Blue(C_B)							
14	Blue(C_R)							

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A typical range GBD data structure is shown in Table E-6 . This can be transmitted using a single Gamut Metadata Packet, fitting within the P0 transmission profile. The gamut is described in $xvYCC_{709}$ space at 12-bit. The GBD consists of min_red_data, max_red_data, min_green_data, max_green_data, min_blue_data, and max_blue_data

Table E-6 P0 Range Data – 12-bit Precision Example

Byte #	7	6	5	4	3	2	1	0
0	Format_ Flag = 1	Rsvd = 0	Rsvd = 0	GBD_Color_Precision = 10		GBD_Color_Space = 010		
1	Min_Red_Data_H							
2	Min_Red_Data_L				Max_Red_Data_H			
3	Max_Red_Data_L							
4	Min_Green_Data_H							
5	Min_Green_Data_L				Max_Green_Data_H			
6	Max_Green_Data_L							
7	Min_Blue_Data_H							
8	Min_Blue_Data_L				Max_Blue_Data_H			
9	Max_Blue_Data_L							

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Appendix F Video Scaling Auto-Configuration

Informative Appendix

In addition to any other mode that a source provides, it is highly recommended that it also provide a pass-through mode of operation. In the pass-through mode the source will pass video unprocessed to its output, if the format is supported by the display, without scaling or de-interlacing (except for performing any necessary field repeats, for instance to show 720p24Hz content on a display with only a 720p60Hz input capability).

In the case that the source cannot send the video in pass-through mode (because the format is not supported by the display), it should convert to the highest priority format as indicated by the DTDs and SVDs, with the first DTD (“Preferred”) being the highest priority.

In the case that the source cannot send the video in pass-through mode (format not supported by the display), and it can also not convert to the preferred video format, the source should select the highest resolution progressive video format supported by the display.

Note: in order to allow displays to indicate a wide range of supported video formats, the source must be able to read EDID information from all defined blocks and must read and understand DTDs and SVDs as defined in CEA-861-D.

The source may also provide a “film-mode” de-interlacer to convert interlaced format video to its original progressive format. It should then consider such converted video as progressive, for instance 480i 60Hz video should be considered as 480p 24Hz video after successful film mode conversion.

It is strongly recommended that displays that cannot perform film-mode de-interlacing on an interlaced video format do not list such an interlaced format as the preferred format but list such a format with a priority (in the list of DTDs and SVDs) that corresponds to the effective resolution. For instance, a display that cannot do film-mode de-interlacing on 1080i may list this format with a priority roughly equivalent to 540 progressive lines.

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Supplement 1

Consumer Electronics Control (CEC)

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CEC 1 Introduction

CEC is a protocol that provides high-level control functions between all of the various audiovisual products in a user's environment. This appendix describes the CEC protocol in the following order:

- An overview of the recommended features available in CEC.
- A Low Level Protocol Definition - Includes the electrical specification, signaling and bit timings and the frame description.
- A High Level Protocol Definition - Includes a detailed feature breakdown and individual message descriptions.

CEC 1.1 Normative references

[1n] ISO 639.2 Code for the representation of names of languages - Part 2: Alpha 3 code
http://www.loc.gov/standards/iso639-2/langhome.html

CEC 1.2 Informative References

[1i] CENELEC, EN 50049-1:1997/A1:1998, Domestic and similar electronic equipment interconnection requirements: Peritelevision connector

[2i] CENELEC, EN 50157, Domestic and similar electronic equipment interconnection requirements: AV.link
EN 50157-1 : Part 1
EN 50157-2-1 : Part 2-1
EN 50157-2-2 : Part 2-2
EN 50157-2-3 : Part 2-3

[3i] IEEE std. 1394-1995 HIGH PERFORMANCE SERIAL BUS section 8.3.2.5.1 – example use of Company_id.

CEC 1.3 Document Revision History

1.2 Clarification of CEC line Standby behaviour
Clarification of test conditions in Table 2
Addition of CEC line pull-up using a current source
Addition of Give Power Status message
Clarification of response to <Abort> message

1.2A Tolerance on internal pull-up resistance changed to ±5% in Table 2.
Removal of test conditions from Table 2,
Clarification of maximum message length.
Re-ordering of some Features in the text and splitting of message description table.
Update and clarification of mandatory and optional implementation status.
Clarification of rules with more explanations for Routing Control.
Additional examples and notes regarding the use of System Standby with recordings.
System Info simplified to language selection. <Set Language> now becomes <Set Menu Language> with a simplified mechanism. Removal of <Set System Info Version Number>, <Give System Info> and <Set Country>.
Removal of analogue tuning messages and addition of <Set Digital Service>.
Removal of Preset Download and Timer Programme Features.
Various editorial corrections throughout

1.3 No Changes.

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CEC 2 Definitions

CEC 2.1 Conformance Levels

Because CEC is optional, the conformance level in this appendix is only effective when the device supports CEC. For example, the word "shall" indicates a mandatory requirement for the CEC supporting devices. However, within the Features section (CEC 13) "shall" only indicates a requirement if the feature is implemented.

CEC 2.2 Glossary of Terms

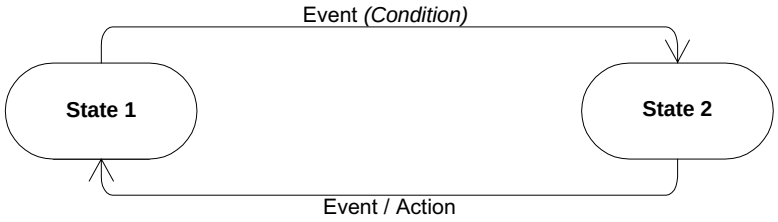
Broadcast Message	This is a message, sent to logical address 15, on which all devices are expected to receive.
Clear	Set to an empty/undefined state. When a physical address is cleared it takes the value F.F.F.F. When a logical address is cleared it takes the value 15.
Deck	The part of a recording device or playback device that provides playback functionality usually from a removable media.
Destination	The target device for a CEC message.
Follower	A device that has just received a CEC message and is required to respond to it.
Initiator	The device that is sending, or has just sent, a CEC message and, if appropriate, is waiting for a follower to respond.
Logical address	A unique address assigned to each device (see section CEC 10.2)
Menu Providing Device	A non-display device that may render a menu on TV.
Playback device	A device that has the ability to play media, e.g. a DVD Player.
Recording device	A device that has the ability to record a source such as an internal digital tuner or an external connection.
Source Device	A device that is currently providing an AV stream via HDMI.
Tuner Device	A device that contains a digital tuner, e.g. a STB or a Recording Device.
Timer Setting Device	A device that has the ability to set the record timer blocks of a recording device.
TV	A device with HDMI input that has the ability to display the input HDMI signal. Generally it has no HDMI output.

CEC 2.3 Usages and Conventions

CEC 2.3.1 State Diagrams

State diagrams describe behavior in terms of device states and events or actions. In these diagrams, the ovals represent device states and the arrows represent events and/or actions that move the device from one state to another state.

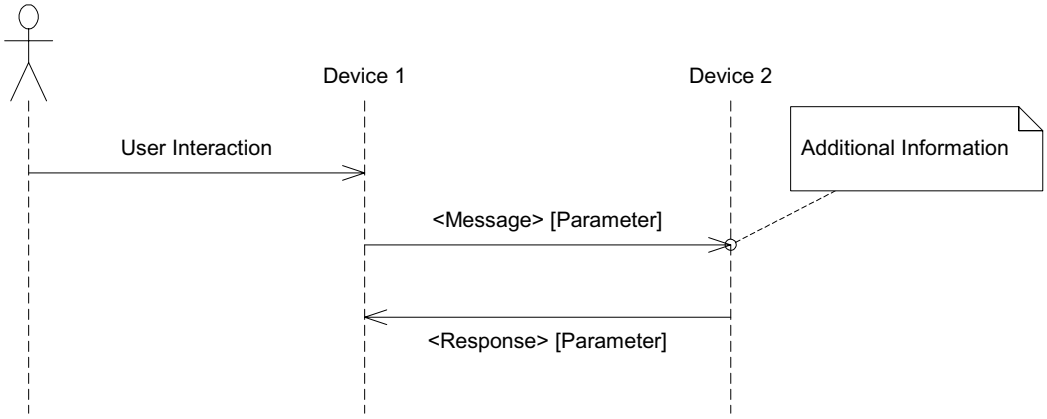
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CEC Figure 1 Example State Diagram

CEC 2.3.2 Message Flow Diagrams

Message Flow Diagrams show sequences of messages that occur between 2 devices.



CEC Figure 2 Example Message Flow Diagram

CEC 2.3.3 Notation

Within the CEC specification there are a number of notations:

<xxx> xxx is an opcode for a message, which is defined in section CEC 15

[yyy] yyy is a data item, which is defined in section CEC 17.

“zzz” zzz is a constant and is a possible value for a data item in section CEC 17.

N{….} indicates the item within the braces is repeated N times, this is used mainly in section CEC 17.

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CEC 3 Feature Overview

CEC provides a number of recommended features designed to enhance the functionality and interoperability of devices within an HDMI system. This section gives an overview of these features.

CEC 3.1 End-User Features

One Touch Play - Allows a device to be played and become the active source with a single button press.

System Standby - Enables the user to switch all devices to standby with one button press.

One Touch Record - Offers a What You See Is What You Record (WYSIWYR) facility, meaning that whatever is shown on the TV screen is recorded on a selected recording device.

Deck Control - Enables a device to control (e.g. play, fast forward etc.) and interrogate a playback device (a deck).

Tuner Control - Allows a device to control the tuner of another device.

Device Menu Control - Enables a device to control the menu of another device by passing through user interface commands.

Remote Control Pass Through - Enables remote control commands to be passed through to other devices within the system.

CEC 3.2 Supporting Features

Device OSD Name Transfer - Enables devices to upload their preferred OSD name to the TV. The TV can then use this name in any menus associated with that device.

Device Power Status – Allows the current power status of a device to be discovered.

OSD Display - Enables a device to use the on-screen display of the TV to display text strings.

Routing Control - Allows the control of CEC Switches for streaming of a new source device.

System Information - Queries the system to determine device addresses and language.

Vendor Specific Commands - Allows a set of vendor-defined commands to be used between devices of that vendor.

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CEC 4 Electrical Specification

The electrical specifications define CEC such that a maximum of 10 devices can interoperate in the worst-case scenario. In practice, many more may be expected to operate together as the worst case is highly improbable.

A device that implements CEC protocols, as described in this CEC supplement, and has enabled its CEC functionality, shall:

- Conform to Table 1 when it is powered-Off (e.g. power removed); or,
- Conform to Table 2 in all other power states. In these states, the device shall keep monitoring the CEC line for any messages addressing that device, including any messages that bring the device out of Standby, see CEC 14.1.3.

During the powered-Off state (e.g. power removed), the CEC line is not monitored.

CEC Table 1 CEC Electrical Specifications during the fully powered-Off state

Description	Value	Notes
Leakage current in powered-Off state	1.8μA max	1

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CEC Table 2 CEC Electrical Specifications except during the fully powered-Off state

Description	Value	Notes
Maximum Output Voltage Logic '0'	+0.6V	
Minimum Output Voltage Logic '0'	0V	
Maximum Output Voltage Logic '1'	+3.63 V	
Minimum Output Voltage Logic '1'	2.5V	
High to Low Input Voltage Threshold Logic '0'	V_{cecin}('0')≥+0.8V	
Low to High Input Voltage Threshold Logic '1'	V_{cecin}('1') ≤ +2.0V	
Typical Input hysteresis	+0.4 V	2
Maximum rise time (10% to 90%)	250 μs	
Maximum fall time (90% to 10%)	50 μs	
Internal device pull-up:	27k ohms ± 5% or equivalent (eg a current source)	

The device shall remain within specification under the full-range of load conditions.

Notes:

1 This effectively requires that the internal pull-up circuit shall be disconnected from the CEC line when the device is off. For example, this can be implemented by connecting an isolating diode between the CEC input pin and the internal pull-up circuit, such that diode is reverse-biased in the off state with an external device pulling-up the CEC line.

2 For information, input hysteresis is normally supplied by the microprocessor input circuit: in this circumstance, external hysteresis circuitry is not needed.

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CEC 5 Signaling and Bit Timings

All transactions on the CEC line consist of an initiator and one or more followers. The initiator is responsible for sending the message structure and the data. The follower is the recipient of any data and is responsible for setting any acknowledgement bits.

CEC 5.1 CEC Line Usage

A message is conveyed over the control signal line in a single frame; a frame is a self-contained unit consisting of a start bit followed by a number of data bits.

An initiator first has to test that the control signal line is free for use (described below). After that it generates a high to low transition on the CEC line, followed by a series of pulses comprising data bits whose starting point is defined by a high to low transition.

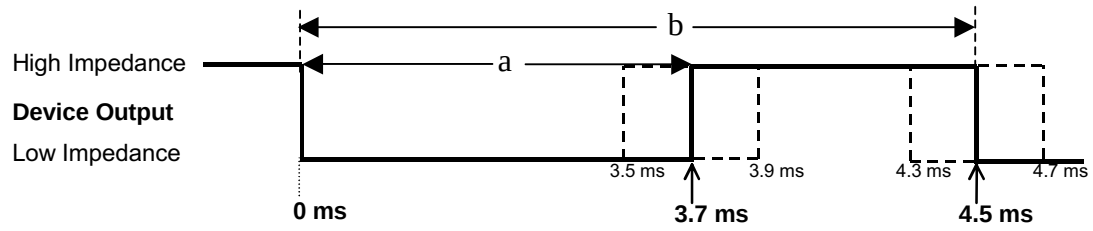
The initiator provides bit timing and bit leading edges. Only one initiator is allowed at any one time. A control signal line arbitration mechanism avoids conflict when more than one initiator begins transmitting at the same time.

CEC 5.2 Bit Timing

CEC 5.2.1 Start Bit Timing

The pulse format of the start bit is shown in CEC Figure 3. It is unique and identifies the start of a frame.

The start bit has to be validated by its low duration (a) and its total duration (b).



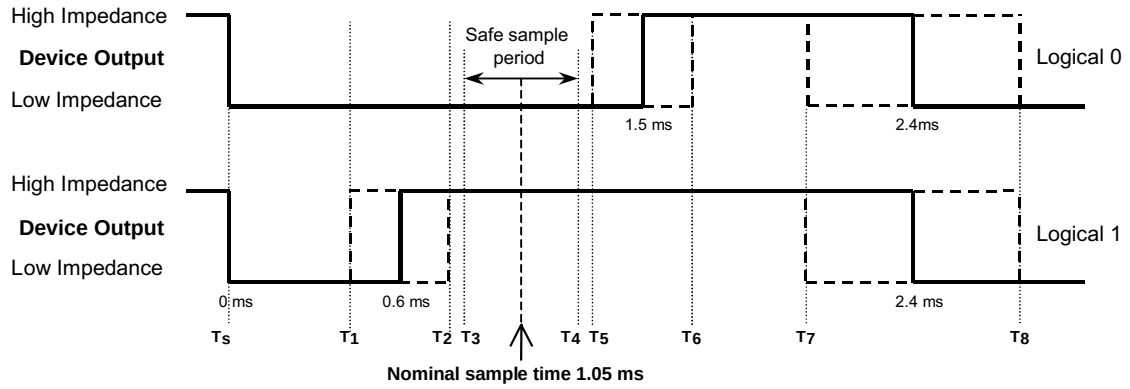
CEC Figure 3 Start bit pulse format showing minimum and maximum tolerances

CEC 5.2.2 Data Bit Timing

All remaining data bits in the frame, after the start bit, have consistent timing. There are, however, two types of bits; an initiator asserted bit and a follower asserted bit. All bits apart from the acknowledge bit are asserted by the initiator. CEC Figure 4 shows both logical 1 and logical 0 timing diagrams for an initiator asserted bit.

The high to low transition at the end of a data bit is the start of the next data bit and only occurs if there is a following data bit; after transmission of the final bit the CEC line remains high.

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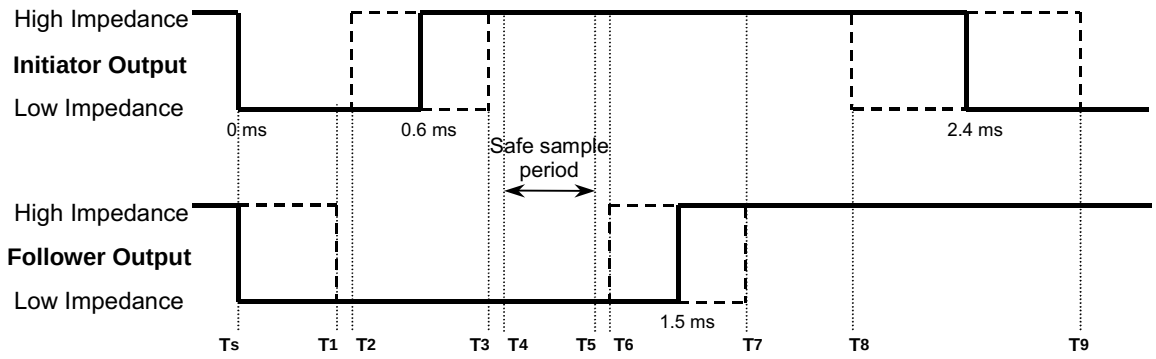


T_S	**0 ms**	The bit start event.
T_1	**0.4 ms**	The earliest time for a low - high transition when indicating a logical 1.
T_2	**0.8 ms**	The latest time for a low - high transition when indicating a logical 1.
T_3	**0.85 ms**	The earliest time it is safe to sample the signal line to determine its state.
T_4	**1.25 ms**	The latest time it is safe to sample the signal line to determine its state.
T_5	**1.3 ms**	The earliest time a device is permitted return to a high impedance state (logical 0).
T_6	**1.7 ms**	The latest time a device is permitted return to a high impedance state (logical 0).
T_7	**2.05 ms**	The earliest time for the start of a following bit.
	2.4ms	The nominal data bit period.
T_8	**2.75 ms**	The latest time for the start of a following bit.

CEC Figure 4 Timing diagrams for both bit states

CEC Figure 5 shows an example bit with both initiator and follower where the follower may assert the bit to a logical 0 to acknowledge a data block. The initiator outputs a logical 1, thus allowing the follower to change the CEC state by pulling the control line low for the duration of the safe sample period.

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T_S	**0 ms**	The bit start event.
T_1	**0.35 ms**	The latest response time for a follower to go to the low impedance state.
T_2	**0.4 ms**	The earliest the initiator can return to high impedance when transmitting a logical 1.
T_3	**0.8 ms**	The latest the initiator can return to high impedance when transmitting a logical 1.
T_4	**0.85 ms**	The earliest time at which the bit state on the CEC line is valid for reading.
T_5	**1.25 ms**	The latest time at which the bit state on the CEC line is valid for reading.
T_6	**1.3 ms**	The earliest time the follower is permitted return to a high impedance state.
T_7	**1.7 ms**	The latest time the follower is permitted return to a high impedance state.
T_8	**2.05 ms**	The earliest time for the start of a following bit.
	2.4ms	The nominal data bit period.
T_9	**2.75 ms**	The latest time for the start of a following bit.

CEC Figure 5 Timing Diagram for Follower Asserted Bit (Logical 0)

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CEC 6 Frame Description

The following table describes the complete CEC frame; the details of each block of the frame are given in the subsequent sections.

CEC Table 3 Frame Description

Name	Description	Value
Start	Special start 'bit'	N/A
Header Block	Source and destination addresses (see CEC Figure 7)	See CEC Table 5
Data Block 1 (opcode block)	Opcode (Optional)	See CEC Table 6 to CEC Table 18
Data Block 2…. (operand blocks)	Operand(s) specific to opcode (Optional, depending on opcode)	See CEC Table 6 and CEC Table 22

The maximum message size (opcode block plus operand blocks) is 16 * 10 bits

CEC 6.1 Header/Data Block description

All Data Blocks and Header Blocks are ten bits long and have the same basic structure, as shown in CEC Figure 6.

Header/Data Block									
7	6	5	4	3	2	1	0	-	-
Information bits								EOM	ACK

CEC Figure 6 Block Structure

The information bits are data, opcodes or addresses, dependent on context. The control bits, EOM and ACK, are always present and always have the same usage.

CEC 6.1.1 EOM (End of Message)

The EOM bit is used to indicate if this is the final block in the message.

A '0' bit specifies that one or more data blocks follow.

A '1' bit specifies that the message is complete.

In the event that a message contains additional data blocks after an EOM is indicated, the follower shall ignore the additional blocks.

CEC 6.1.2 ACK (Acknowledge)

The ACK bit is used by follower(s) to acknowledge the data or header block. It is always set to 1 by the initiator. It operates in one of two modes:

For messages addressed to a single device:

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- A follower that reads its own address in the destination address field shall acknowledge with a '0' ACK bit.
- All other devices shall generate a '1' ACK bit (i.e. do nothing).
- A '0' read by the initiator therefore indicates a successful transmission of the data or header block.

For broadcast messages the sense of the ACK bit is inverted to allow for a single device to reject a message:

- All followers shall acknowledge with a '1' ACK bit.
- A '1' read by the initiator therefore indicates that no device has rejected the data or header block – the message transmission can therefore continue if required.
- A '0' read by the initiator therefore indicates that one or more devices have rejected the message.

CEC 6.1.3 Header Block Details

The header block consists of the source logical address field, the destination logical address field, the end of message bit (EOM) and the acknowledge bit (ACK) as shown in CEC Figure 7. The addresses for the devices are specified in CEC Table 5.

Header Block									
3	2	1	0	3	2	1	0	-	-
Initiator				Destination				EOM	ACK

CEC Figure 7 Header Block

The initiator logical address field is used to identify the initiator of the current frame. The logical address of the initiator is written in this field (see CEC 10.2). The field consists of bits one to four of the header block, most significant bit first.

The destination logical address field is used to identify the destination of the current frame. The logical address of the destination is written in this field (see CEC 10.2). A special address (0b1111) is used for broadcast messages. The field consists of bits five to eight of the header block, most significant bit first.

A message with the EOM bit set in the Header Block can be used to 'ping' other devices, to ascertain if they are active.

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CEC 7 Reliable Communication Mechanisms

There are three mechanisms to provide a reliable communications medium for the transfer of frames:

- Frame re-transmissions increase the chance of a successful message transfer.
- Flow control ensures that communication only progresses as fast as the slowest follower.
- Frame validation.

Given these mechanisms and the active ACK method, a message transmitted and acknowledged should be assumed correctly received. A message that does not result in a <Feature Abort> can be assumed to have been acted upon. It is suggested that the receiving device can assume this after 1 second. Generally however, the <Feature Abort> will be received within around 100ms.

CEC 7.1 Frame Re-transmissions

A frame is considered lost and therefore may be re-transmitted under the following conditions:

- If a frame is not acknowledged in a directly addressed message.
- If a frame is negatively acknowledged in a broadcast message.
- If the initiator detects low impedance on the CEC line when it is transmitting high impedance and is not expecting a follower asserted bit.

Re-transmission can be attempted up to 5 times for a single message and shall be attempted at least once. The re-try shall be after a signal free time as described in CEC Table 4.

CEC 7.2 Flow Control

To provide flow control, a receiving device may negatively acknowledge any data or header block it is at present unable to process. A negative acknowledge will cause re-transmission by the initiator.

CEC 7.3 Frame Validation

A follower shall ignore a frame if the number of operands is less than the number specified for that opcode.

CEC 7.4 CEC Line Error Handling

It is the responsibility of all devices acting as followers to detect the existence of spurious pulses on the control signal line and notify all other devices (primarily the initiator) that a potential error has occurred.

An error is defined as a period between falling edges that is less than a minimum data bit period (i.e. too short to be a valid bit). Note that the start bit is excluded from CEC Line Error Handling.

Errors are notified by the follower generating a low bit period on the control signal line of 1.4-1.6 times the nominal data bit period. After such an error notification the original initiator should stop sending its current frame and re-try later.

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CEC 8 Protocol Extensions

In order to allow for extensions to the protocol in future releases of the specification, the current opcodes and parameters can be extended by adding further parameters onto them. If an older CEC node receives a message with more operands than expected, it should ACK the additional operands and simply ignore them, thus allowing extensions to already existing commands.

For entirely new commands, new opcodes can be allocated.

For entirely new device types, new addresses may be allocated.

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CEC 9 CEC Arbitration

Arbitration for the CEC line ensures collisions are spotted and a reliable message layer can be achieved.

All devices that wish to transmit a frame onto the CEC line have to ensure that it has been inactive for the signal free time, see CEC Table 4.

A device that has lost arbitration shall stop transmitting and become a follower. The device shall then wait for the CEC line to be inactive for the signal free time period as specified in CEC Table 4, before attempting to send another message.

CEC line arbitration commences with the leading edge of the start bit and continues until the end of the initiator address bits within the header block. During this period the initiator shall monitor the CEC line and if whilst in high impedance state it detects low impedance then it shall assume that it has lost the arbitration to a second initiator.

It should be noted that this process gives priority to the logical address with the most leading zeros and, ultimately, the TV.

CEC 9.1 Signal Free Time

Before attempting to transmit or re-transmit a frame, a device shall ensure that the CEC line has been inactive for a number of bit periods. This signal free time is defined as the time since the start of the final bit of the previous frame.

The length of the required signal free time depends on the current status of the control signal line and the initiating device. The different signal free times required are summarized in the following table:

CEC Table 4 Signal Free Time

Precondition	**Signal Free Time (nominal data bit periods)**
Present initiator wants to send another frame immediately after its previous frame	≥7 and <10
New initiator wants to send a frame	≥5 and <7
Previous attempt to send frame unsuccessful	≥3 and <5

CEC 9.2 Message Time Constraints

There are certain time constraints for messages that should be obeyed at application level. These are a desired maximum response time of 200ms and a required maximum response time of 1 second.

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CEC 10 Device Connectivity and Addressing

CEC is a protocol based on a bus system and therefore cannot alone ascertain the physical connectivity of the network. The mechanism defined in section 8.7 uses DDC to allocate physical addresses to devices in the network.

All CEC devices therefore have both a physical and logical address, whereas non-CEC devices only have a physical address.

CEC 10.1 Physical Address Discovery

The algorithm defined in 8.7.3 is used to allocate the physical address of each device.

Whenever a new physical address (other than F.F.F.F) is discovered, a CEC device shall:

- allocate the logical address (see CEC 10.2.1)
- report the association between its logical and physical addresses by broadcasting <Report Physical Address>.

This process allows any node to create a map of physical connections to logical addresses.

CEC 10.2 Logical Addressing

Each device appearing on the control signal line has a unique logical address. This address defines a device type as well as being a unique identifier. These are specified in CEC Table 5.

If a physical device contains the functions of more than one logical device then it should take the logical addresses for each of those logical devices. It is allowed for a device to declare the functionality of another device by using a different logical address. For example a recordable DVD device may take the address 4 or 8 to expose only the functionality of a standard DVD device.

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CEC Table 5 Logical Addresses

Address	Device
0	TV
1	Recording Device 1
2	Recording Device 2
3	STB1
4	DVD1
5	Audio System
6	STB2
7	STB3
8	DVD2
9	Recording Device 3
10	Reserved
11	Reserved
12	Reserved
13	Reserved
14	Free Use
15	Unregistered (as initiator address) Broadcast (as destination address)

CEC 10.2.1 Logical Address Allocation

Note that a logical address should only be allocated when a device has a valid physical address (i.e. not F.F.F.F), at all other times a device should take the 'Unregistered' logical address (15).

Only the device at physical address 0.0.0.0 may take logical address TV (0). A TV at any other physical address shall take the 'Free Use' (14) address. If address 14 is already allocated it shall take the 'Unregistered' address (15).

Reserved addresses shall not be used at present and are reserved for future extensions to this specification.

Where more than one possible logical address is available for the given device type (e.g. STB1, STB2, etc.), an address allocation procedure shall be carried out by a newly connected device. The device takes the first allocated address and sends a polling message to the same address (e.g. STB1 → STB1). If the polling message is not acknowledged, then the device stops the procedure and retains that address.

If the first address is acknowledged, then the device takes the next address and repeats the process (e.g. STB2 → STB2). Again, if the message is not acknowledged, the device keeps that address.

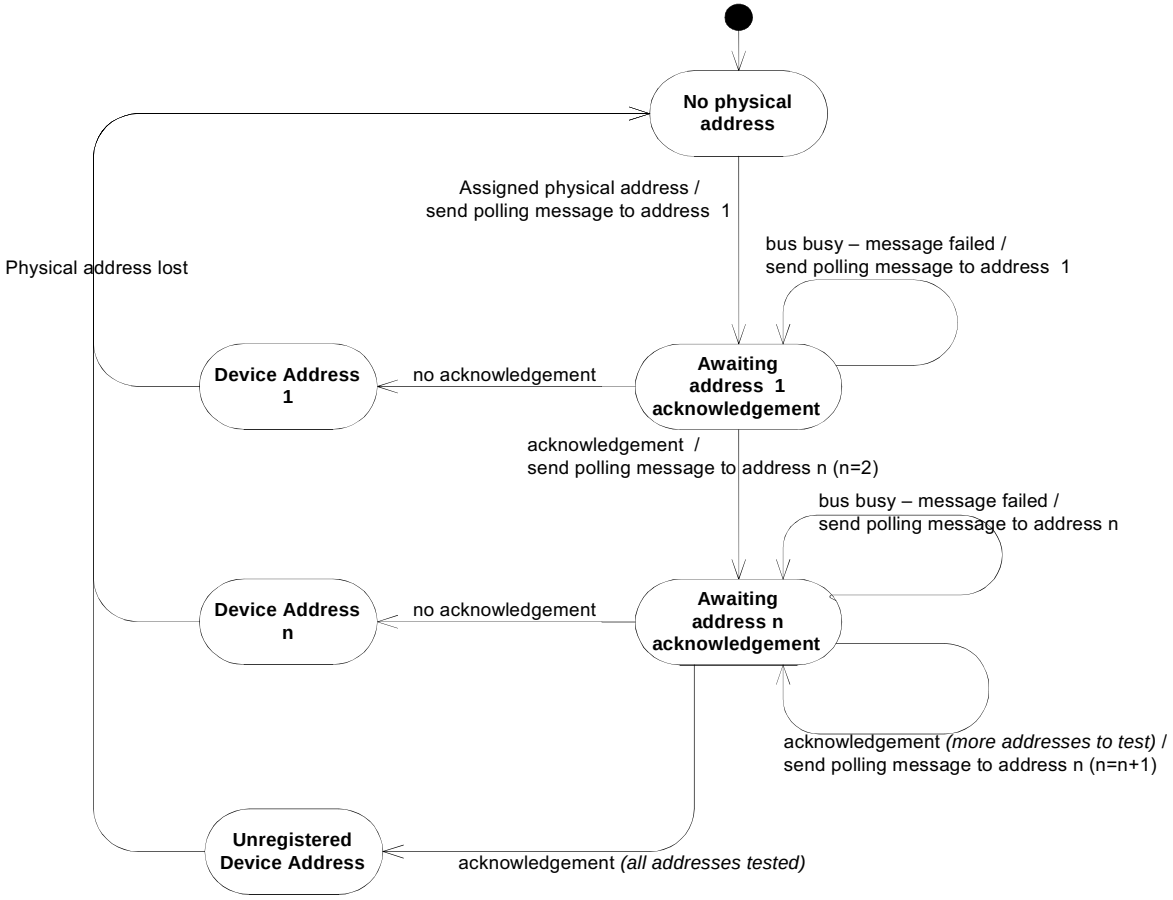
This procedure continues until all possible 'type specific' addresses have been checked; if no 'type specific' addresses are available the device should take the unregistered address (15).

A device may lose its logical address when it is disconnected or switched off. However, it may remember its previous logical address, so that the next time it is reconnected, it can begin the polling process at its

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previous logical address and try each other allowable logical address in sequence before taking the unregistered address. For example if an STB that was previously allocated address STB2 is reconnected, it would poll STB2, STB3 and STB1 before taking the unregistered address.

If a device loses its physical address at any time (e.g. it is unplugged) then its logical address shall be set to unregistered (15).



CEC Figure 8 Logical Address Allocation

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CEC 11 Switch Requirements

One of the major uses of the physical address identification is to allow a switch to be controlled in order to enable a specific device to stream to the TV. This places requirements on both CEC and non-CEC compliant switches.

All switches will consist of a single switched TMDS connection, and a fully wired CEC connection to each source device. There are significant differences between a CEC Switch and a non-CEC Switch, which are identified below.

CEC 11.1 CEC Switch

A CEC Switch allocates a unique child_address for every connection below the switch. This means that any device connected to the switch will always have a valid physical address (assuming the switch itself has a valid physical address). Therefore, any device below the switch may take a logical address and can react to CEC messages in a normal way. The switch is effectively transparent and will enable all standard CEC communications in its connected source devices.

For CEC compliant switches, there is a requirement to react on <Active Source> and <Set Stream Path> messages. Both of these messages require the switch to change the connected source device according to the physical AV stream path indicated by the CEC message. These mechanisms allow a source device to configure the switches between itself and the TV to ensure that its output is displayed, or for the TV to specifically receive the output from a given device.

A CEC compliant device that is only a switch does not need to take a logical address; it uses the unregistered address for any communications.

It is possible that a user may change a CEC Switch manually. In this instance a CEC Switch shall send a <Routing Change> message to inform other devices about the change.

CEC 11.2 Non-CEC Switch

There are two types of non-CEC switches, those which have only one EDID for all source devices (or simply reflect the sink EDID), and those which have a separate EDID for all source devices. The rules for the operation of these two types of switch are different:

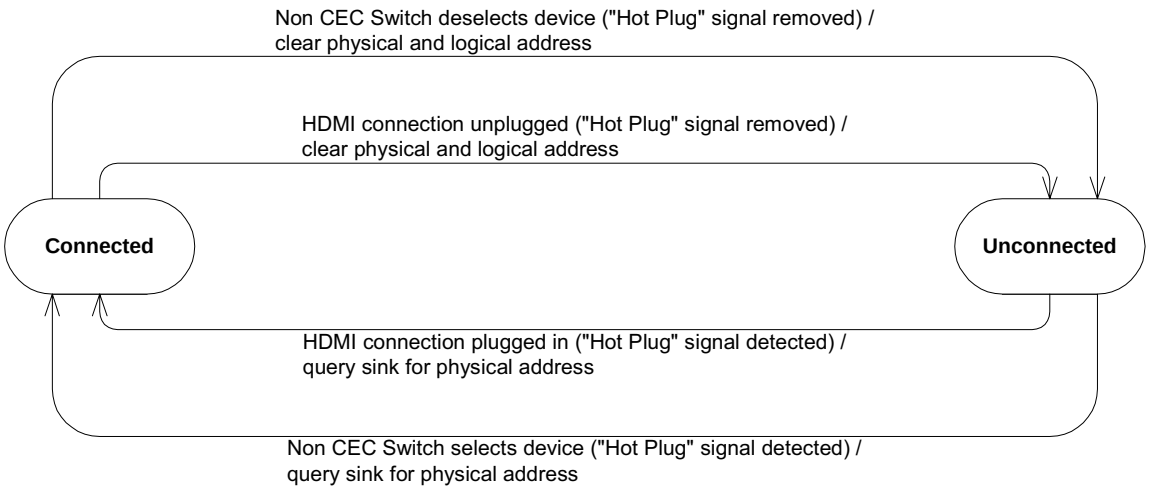
CEC 11.2.1 Switches with One EDID

A non-CEC-compliant switch may have a single child_address, which is always occupied by the currently switched device. Any other connected devices will have no hot plug signal and will therefore have an unallocated physical address (and can use only the unregistered logical address). These devices will, however, still see CEC messages as they will be connected to the CEC line and they may react to some broadcast messages in the normal way (e.g. standby).

When a switch de-selects a device, that device will detect the removal of the ‘hot plug’ signal to indicate that its physical AV connection has been removed. It should immediately clear its physical and logical addresses. Each source device below the switch will detect the removal of the ‘hot plug’ signal to indicate they are no longer on the active AV Path and clear their addresses accordingly.

When a switch selects a device, that device will detect the ‘hot plug’ signal. It can then obtain a valid physical address from its sink and subsequently a logical address. The device should activate the hot plug signal to its source (child) devices (if any) to indicate that they should now request a physical address.

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CEC Figure 9 Behavior when beneath a one EDID non-CEC Switch

CEC 11.2.2 Switches with Multiple EDIDs

These should operate as CEC switches except that they do not send messages on, or monitor, the CEC line.

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CEC 12 High Level Protocol

As described in the previous sections, messages consist of an opcode and a number of parameters. This is the high level protocol.

This protocol can be described best by detailing the messages and the data types used for the parameters. These are detailed in CEC Table 6.

Although these tables explain the majority of the high level protocol, there are some special situations that require further explanation. These are given in the following sections.

CEC 12.1 Source Declaration

Before a device becomes a source, it should issue an <Active Source> message to declare its intention. Thus any presently active source can and should act appropriately.

CEC 12.2 Protocol General Rules

A message that is defined as being valid only when directly addressed shall be ignored if received as a broadcast message.

A message that is defined as being valid only when broadcast shall be ignored if received as a directly addressed message.

All numbers greater than one byte are transmitted as bytes in big endian format.

All bit sequences are sent most significant bit first.

A follower shall respond to a message coming from any valid logical address from 0 to 14 unless otherwise stated.

A follower shall ignore a message coming from address 15 (unregistered), unless:

- that message invokes a broadcast response (e.g. <Get Menu Language >), or,
- the message has been sent by a CEC switch (a <Routing Change> or <Routing Information> message), or,
- the message is <standby>.

CEC 12.3 Feature Abort

All devices shall support the message <Feature Abort>. It is used to allow devices to indicate if they do not support an op code that has been sent to them, if it is unable to deal with the message at present, or if there was something wrong with the transmitted frame at the high-level protocol layer.

Feature abort has two parameters, the opcode and a reason for its rejection of the frame.

The reaction to a faulty message by the follower depends on if the message was directed or broadcast:

For a broadcast message:

- A follower that receives a broadcast message which it does not support, ignores the received message, and does not send a <Feature Abort>.

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For a directly addressed message:

- <Feature abort> is used as a response to any failure.

If an initiator wishes to attempt retransmission after receiving a <Feature Abort> it is suggested that it waits for 200ms. This will allow time for the follower to recover from the state that caused the initial <Feature Abort> message.

- <Feature Abort> is also used as a response to the <Abort> message during testing, see CEC 12.4

CEC 12.4 Abort

The <Abort> message shall be implemented as a Follower in all devices except CEC switches and is used during testing only. It shall be directly addressed to a specific device, which shall respond with a <Feature Abort> message. In this instance, any valid [Abort Reason] operand may be returned.

- A device shall ignore an <Abort> message which is broadcast.

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CEC 13 CEC Features Description

This section describes the message transfer and additional details for a number of common features enabled by CEC. Note that where a feature is supported, all messages within that feature should be implemented.

CEC 13.1 One Touch Play

CEC 13.1.1 Messages

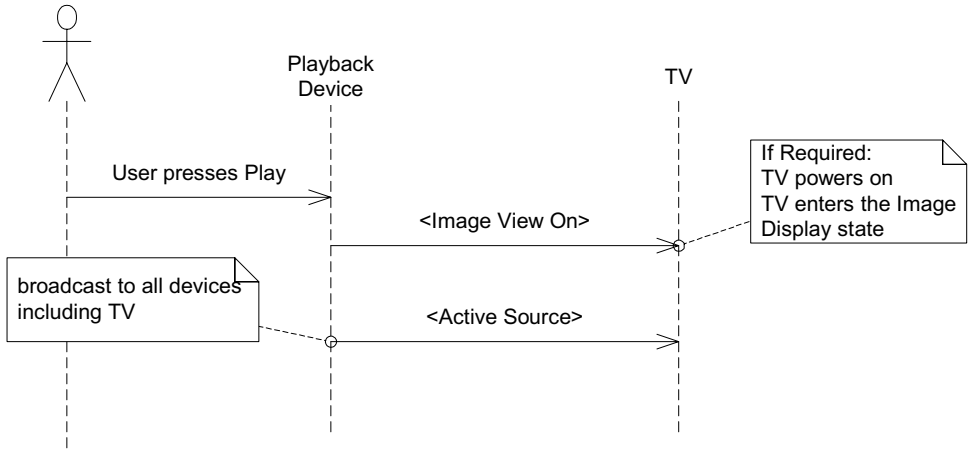
The following messages are used for the One Touch Play feature:

<Active Source>, <Image View On>, <Text View On>

CEC 13.1.2 Feature Description

The One Touch Play feature allows a device to be played and become the active source with a single button press.

A device shall send the message <Image View On> to the TV to indicate that its output should be displayed on the screen. If the TV is in a Text Display state (e.g. Teletext) it should switch to the Image Display state. If a menu is being displayed on the TV it shall remain on screen.



CEC Figure 10 A typical scenario illustrating the One Touch Play feature

A device may alternatively send the message <Text View On>. This message has the same functionality as <Image View On> with the addition that any menus that the TV is displaying shall be removed.

Whenever a device becomes the new source device it should broadcast an <Active Source> message. The current active source device should then take appropriate action, for example, it may pause if it is playing media.

Note: there is a special case when a TV switches to its internal tuner or to another non-HDMI source (eg Y/C, or a SCART socket on European market sets). In this case, it is the TV which broadcasts the <Active Source> message with address 0.0.0.0.

Note that it is mandatory for a source to implement at least one of <Image View On> or <Text View On>.

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CEC 13.2 Routing Control

CEC 13.2.1 Messages

The following messages are used for the Routing Control feature:

<Active Source>, <Request Active Source>, <Set Stream Path>, <Routing Change>, <Routing Information>

CEC 13.2.2 Feature Description

This feature is used to control the routing of the HDMI network, by controlling CEC Switches. In general whenever a device starts being streamed to the TV it should send an <Active Source> message (see One-Touch Play in section CEC 13.1).

On receiving an <Active Source> message, CEC Switches between the device and the TV shall come out of standby (if necessary) and switch (if required) to ensure the device at the physical address specified is on the active path.

If a device (other than a CEC switch) is currently the active source, then it shall lose its active source status on receiving an <Active Source> message from another device and should act accordingly, for example it may pause if it is playing media.

When a device comes out of standby or a (mains) off state, it may broadcast a <Request Active Source> message to discover if any other device is currently acting as the active source. On receiving a <Request Active Source> message, the active source device shall respond by broadcasting an <Active Source> message. A particular instance of this rule is when a TV comes out of standby some time after its source device(s). In this case, if the TV has multiple HDMI connectors, it will not know which is the correct connector for the currently active source (because it was in standby when that device sent its <Active Source> message). Here, the <Request Active Source> and the corresponding <Active Source> response are needed to identify the relevant connector.

The user may select a device to view via the TV user interface. In contrast to the <Active Source> message (which is sent by the current active source to the TV), the <Set Stream Path> is sent by the TV to the source device to request it to broadcast its path using an < Active Source> message. In this case, the TV should broadcast a <Set Stream Path> message with the physical address of the device it wishes to display as a parameter. Any CEC Switches between the device and TV shall switch (if required) to ensure the device is on the active AV path. This feature also ensures that non-CEC-compliant devices in the network can be switched to, if for instance they have been manually set up in the TV menu. A CEC device at the location specified by the <Set Stream Path> message shall broadcast an <Active Source> message and begin streaming its output.

Note: there is a special case when a TV switches to its internal tuner or to another non-HDMI source (eg Y/C, or a SCART socket on European market sets). In this case, it is the TV which broadcasts the <Active Source> message with address 0.0.0.0.

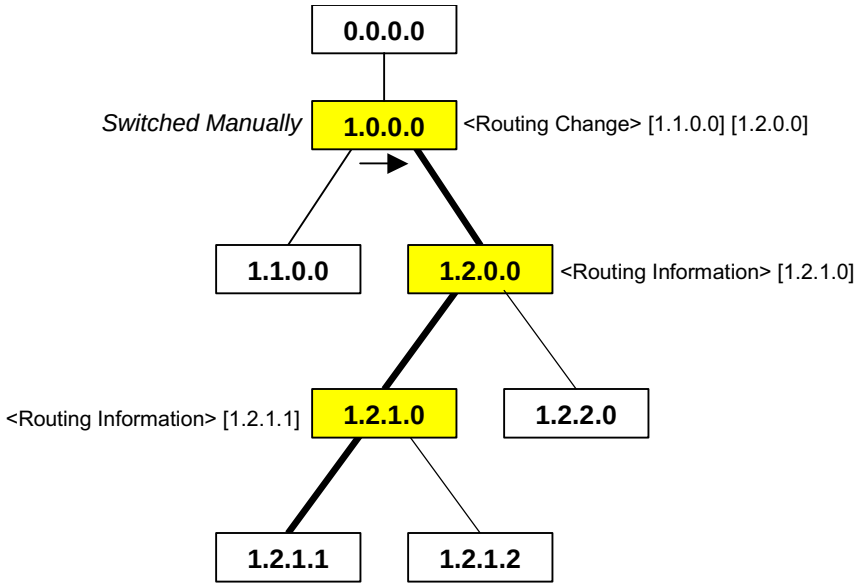
In the case that the user manually switches a CEC Switch it should broadcast a <Routing Change> message. This will inform all devices in the network that the current active route below the switch has changed. This enables, for instance, a device that has been deselected by a switch to pause if it is playing media.

If a CEC Switch is at the new position indicated by the <Routing Change> message then it shall broadcast a <Routing Information> message with the physical address of its current active path. If a CEC Switch receives a <Routing Information> message then it shall broadcast a <Routing Information> message to indicate it's current active path. In this way the TV is aware of which device is on the current active path after the switch occurs. If the TV detects that the active source device has been de-selected by changing the switch it may either switch to an internal digital service or send a <Set Stream Path> message to the device at the new location to indicate that it should become the new active source.

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The TV shall wait for a minimum of 7 nominal data bit periods before reacting to a <Routing Change> or <Routing Information> message to allow CEC switches to relay any <Routing Information> messages that are required.

The following diagram shows an example of the message flow when a user manually switches a CEC Switch. (CEC Switches are shown filled).



CEC Figure 11 Example message flow, when a CEC Switch is manually switched

CEC 13.3 System Standby

CEC 13.3.1 Messages

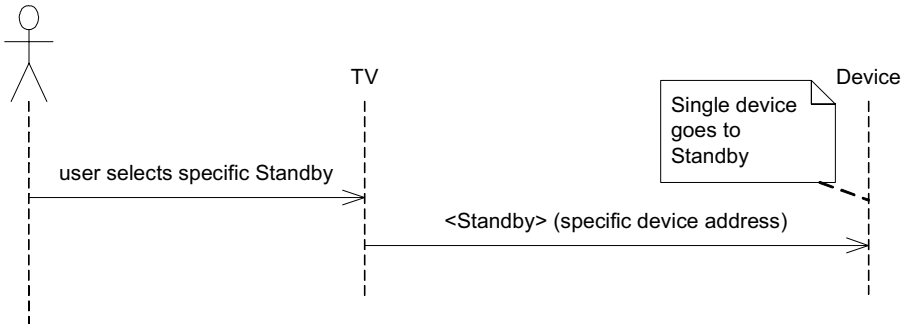
The following message is used for the System Standby feature:

<Standby>

CEC 13.3.2 Feature Description

The message <Standby> can be used to switch one or more CEC devices to standby. A typical scenario where the user sets a specific device to standby is shown below:

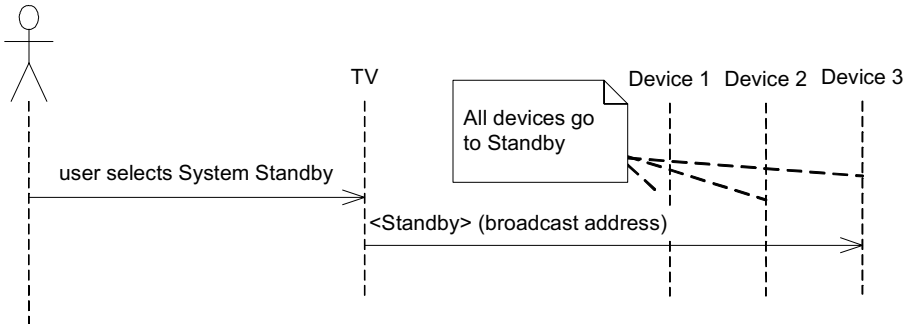
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CEC Figure 12 A typical scenario for the Standby feature to a specific device

A device can switch another single device into standby by sending the message <Standby> as a directly addressed message to it. It should only switch a single device into standby if it previously activated that device (brought it out of standby).

The whole system may be set to standby by broadcasting the <Standby> message. It is manufacturer dependent on how to differentiate between standby for a single device, e.g. a STB, and System Standby (broadcast to the whole system).



CEC Figure 13 A typical scenario for the broadcast (system) Standby feature

Note that whilst it is possible for a recorder to ignore a <Standby> message (see “Exceptions” below), it is not possible to identify the source for a recording device, e.g. a STB to a separate recorder. This implies that:

- With a specific <Standby> message, if the TV has brought a device (eg an STB) out of standby and it then sends a specific <Standby> to that STB (as a result of user interaction or when the TV goes to standby), this may upset a recording. It is therefore a manufacturer’s decision whether to send a specific <Standby> under these circumstances.
- The broadcast <Standby> message may cause the source of a recording to go to standby. Therefore, if the device is capable of sending a broadcast <Standby> message, then it should also provide a means for the user to select between the system (broadcast) <Standby> or the specific <Standby> message.
- It is also the manufacturer's decision if a source device goes into standby when it receives a system (broadcast) <Standby> message.

Devices can ignore <Standby> messages if they are in a state where going into standby is not sensible. For example if the device is actively involved in a recording it should ignore any requests to go into standby. It is up to the device implementer how ‘sensible’ is defined.

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CEC 13.4 One Touch Record

CEC 13.4.1 Messages

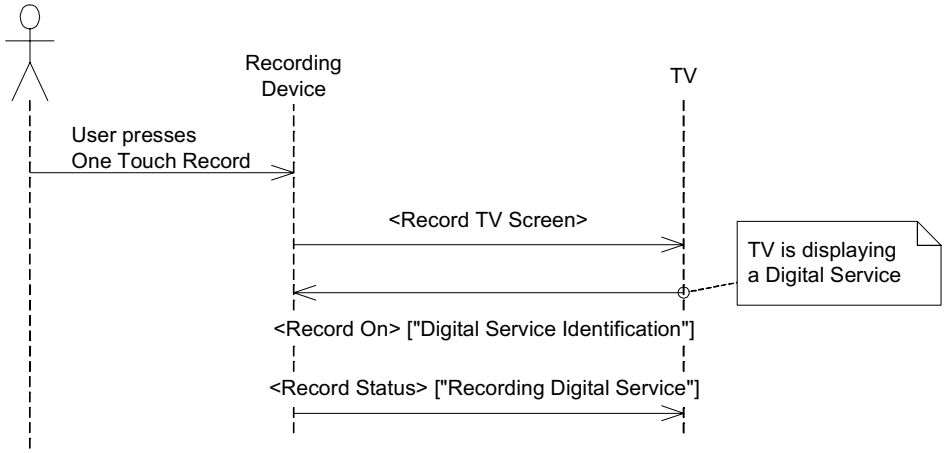
The following messages are used for the One Touch Record feature:

<Record Off>, <Record On>, <Record Status>, <Record TV Screen>

CEC 13.4.2 Feature Description

This feature allows the user to easily start a recording of the source that is being displayed on the TV, just by selecting a recording device and giving the record command. It is not always possible to carry out a One Touch Record as it depends on what source is currently being displayed. It is primarily used for the instant recording of a tuner preset, or the recording of another device (e.g. Camcorder) connected externally to the recording device

Either the TV or the recording device may initiate the One Touch Record Feature, for example by selecting a menu option on the TV or by pressing record on the recording device.



CEC Figure 14 A typical scenario for the One Touch Record feature

In the event of the recording device initiating the feature it will send a <Record TV Screen> message to the TV. On receipt of the <Record TV Screen> message by the TV, or if the user initiates the One Touch Record feature via the TV, the TV shall react as follows:

- It the TV is currently displaying an internal digital tuner service, it shall respond with a <Record On> [“Digital Service”] [Digital Service Identification] message.
- If the Recording Device is the current active source device, then the TV shall respond with a <Record On> [“Own source”] message.
- If the TV is currently displaying some other source, it shall respond with a <Feature Abort> [“Cannot provide source”] message, or do nothing if initiated via the TV.

On receipt of a <Record On> message the recording device shall act as follows:

- If [“Digital Service”] is indicated and the device can record the digital service using the Digital Service Information that was sent, the device shall change to that digital service and start recording. If the device cannot support the required digital service, then it should respond with a <Record Status> [“No recording –unable to record Digital Service”]. In this latter case, the TV should inform the user that the recording has failed, with the reason, or take other appropriate action.

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- If [“Own source”] is indicated, then it shall attempt to record whatever it is currently displaying, e.g. an external connection such as a camcorder or the digital service it is currently tuned to.

The recording device shall respond with the message <Record Status> to indicate if recording has begun, or a reason why recording has failed. If the TV initiated the recording, it may stop it at any time by sending a <Record Off> message. The recording device should then stop recording immediately.

The TV should ignore a <Record TV Screen> message that comes from a non-recording device address, however it shall accept the message from a ‘Reserved’ address (a future device type).

CEC 13.5 System Information

CEC 13.5.1 Messages

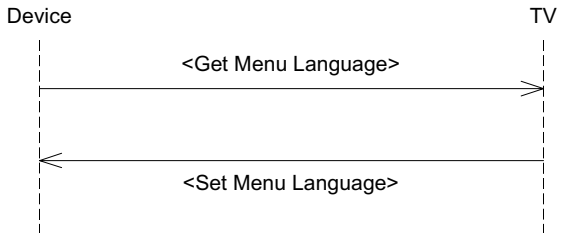
The following messages are used for the System Information feature:

<Get Menu Language>, <Give Physical Address>, <Polling Message>, <Report Physical Address>, <Set Menu Language>.

CEC 13.5.2 Feature Description

This feature allows devices to automatically use the same language settings as the TV and also for a TV to discover the current language when it is being installed.

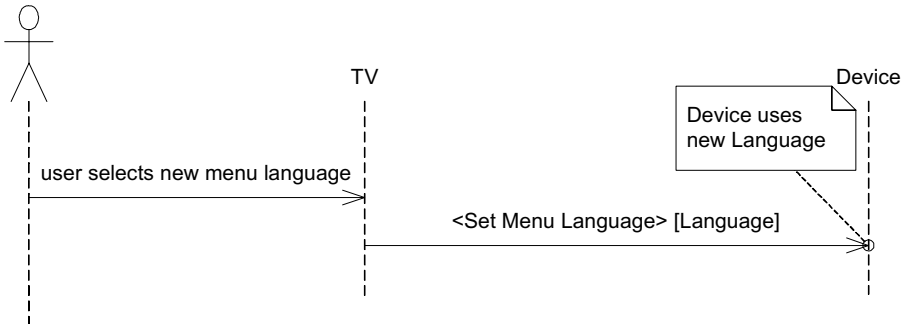
When a source device is powered on, it should send a <Get Menu Language> message to the TV. The TV shall then respond as shown below with a <Set Menu Language> message.



CEC Figure 15 Message exchange when getting the TV’s menu Language

When the user changes a menu language setting on the TV, it shall send a <Set Menu Language> message containing the currently selected menu [Language], as shown below.

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CEC Figure 16 A typical scenario when a menu language setting within the TV is modified

On receipt of the <Set Menu Language> message, the device shall attempt to use the newly selected [Language] for Menus and OSDs.

Note that a device might receive a <Set Menu Language> message even when the language has not been changed. A device shall ignore any of the above messages that come from an initiator address other than 0 (the TV).

During the installation of a TV, the <Get Menu Language> message may be sent by the TV to another device to discover what language has been set on that device.

CEC 13.5.3 Additional Information

The <Polling Message> is used to detect the presence or absence of a device within the system. It is used for allocating logical addresses as detailed in CEC 10.2.1.

The <Report Physical Address> message is used by a device to broadcast its physical address to all other devices in the system. By using the logical and physical addresses, any other device is able to derive the physical connectivity of the network. A device may request the physical address of another device by sending a directly addressed <Give Physical Address> message to it.

CEC 13.6 Deck Control

CEC 13.6.1 Messages

The following messages are used for the Deck Control feature:

<Deck Status>, <Give Deck Status>, <Deck Control>, <Play>

CEC 13.6.2 Feature Description

This feature allows a playback device (a deck or disc player or recorder) to be controlled by another device (e.g. the TV). Messages are also provided to allow a device to find out the status of the Deck; this allows, for example, a TV to keep its user interface synchronized with the status of the Deck.

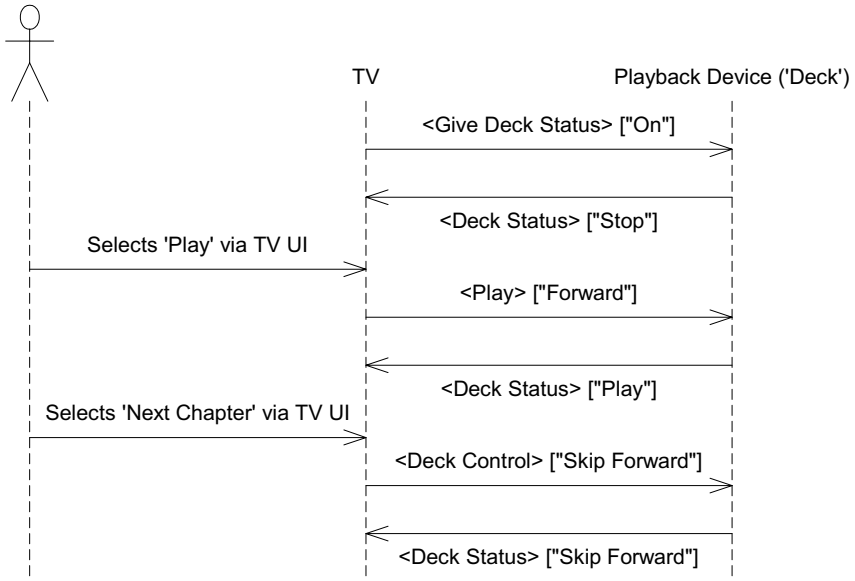
A device may query the status of a deck with the <Give Deck Status> command. The deck should respond with a <Deck Status> message.

A device may control a Deck with the <Play> and <Deck Control> messages. These messages may be initiated after a user command. The Deck shall act upon the command that it receives within the messages <Play> and <Deck Control>. It is the equivalent of the user selecting the command local to the Deck. If the

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deck cannot carry out the command (e.g. it has no media when trying to play) it should respond with a <Feature Abort> [“Not in correct mode to respond”] message.

If the deck is in standby and receives a <Deck Control> [“Eject”] or <Play> [“Play Forward”] message, it should power on and act on the message. It is up to the manufacturer to decide if the device should power on when receiving any other <Deck Control> or <Play> messages.



CEC Figure 17 A typical scenario for the Deck Control feature

Note that it is mandatory for a Deck to support <Play>[“Forward”] and <Deck Control>[“Stop”] only. The support of <Play> and <Deck Control> with other operands is optional.

CEC 13.7 Tuner Control

CEC 13.7.1 Messages

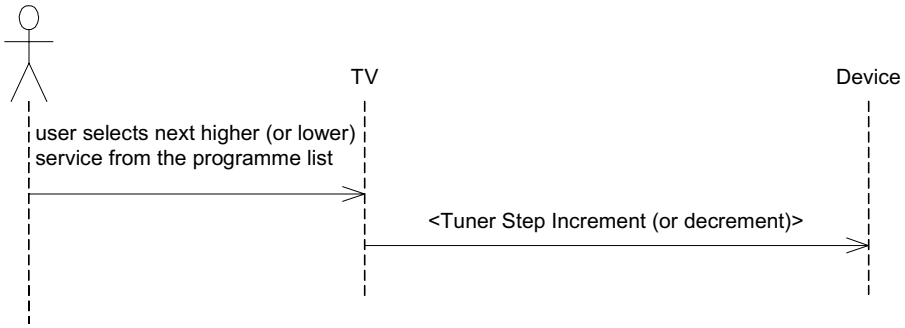
The following message are used for the Tuner Control feature:

<Give Tuner Device Status>, <Select Digital Service>. <Tuner Step Decrement>, <Tuner Step Increment>, <Tuner Device Status>

CEC 13.7.2 Feature Description

This feature allows a device (e.g. the TV) to control another CEC device’s tuner.

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CEC Figure 18 A typical scenario for selecting a new Digital Service

A device can select a digital service on a tuner device by sending the <Select Digital Service> message. The tuner device shall then attempt to tune to that digital service and stream its output on the HDMI connection. If the specified digital service is not supported on the device then it should send a <Feature Abort> ["Invalid operand"] message. If the tuner device cannot select that digital service (e.g. if it is recording), it should respond with a <Feature Abort> ["Refused"] message.

A device can also control a CEC Device's tuner using the <Tuner Step Increment> and <Tuner Step Decrement> messages. If a device receives the <Tuner Step Increment> or <Tuner Step Decrement> message then it should select the next highest or next lowest digital service in its service list. The tuner device can interpret the messages as it chooses, for example, it may only cycle through channels included in the user's list of favorites.

A device may query the status of a tuner device by sending a <Give Tuner Device Status> message. The tuner device shall respond by sending a <Tuner Device Status> message indicating if it is currently displaying its tuner and the digital service that is currently selected.

CEC 13.8 Vendor Specific Commands

CEC 13.8.1 Messages

The following messages are used for the Vendor Specific Commands feature:

<Device Vendor ID>, <Give Device Vendor ID>, <Vendor Command>, <Vendor Remote Button Down>, <Vendor Remote Button Up>

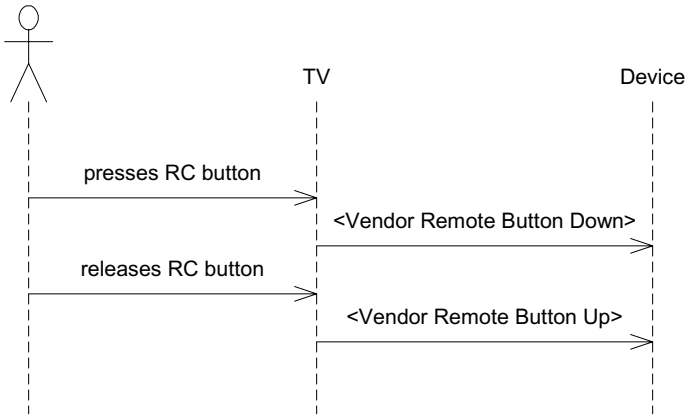
CEC 13.8.2 Feature Description

This feature allows a set of vendor specific commands to be used to communicate between devices of a single vendor.

A device that supports vendor specific commands shall store a Vendor ID. A device shall broadcast a <Device Vendor ID> message after a successful initialization and address allocation to inform all other devices of its vendor ID. A device may request the Vendor ID of another device by sending a <Give Device Vendor ID> message to it. The follower shall respond by broadcasting a <Device Vendor ID> message. In this way any device can determine the vendor of another device. A device shall only attempt to transmit a vendor specific command to another device that it knows has the same vendor ID. In this way a device receiving a vendor specific command can always assume that it came from a device of the same vendor and respond accordingly.

It is possible to send vendor specific remote control commands using the <Vendor Remote Button Down> and <Vendor Remote Button Up> messages.

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CEC Figure 19 The messages sent in the Vendor Specific Commands feature

In addition it is possible to send other (non remote control key) vendor specific messages using the <Vendor Command> message. The message parameter(s) can be used to communicate any additional (vendor defined) messages and data.

CEC 13.9 OSD Status Display

CEC 13.9.1 Messages

The following message is used for the OSD Status Display feature:

<Set OSD String>

CEC 13.9.2 Feature Description

This feature allows a device to transfer a text string to the TV for On Screen Display. The <Set OSD String> message is used to transfer the text string to the TV.

A text string may be displayed for a default period (i.e. 5 seconds) or until explicitly cleared. In the latter case the device should send another <Set OSD String> message to clear the text when it is appropriate.

The TV should display the whole string unless it is in an unsuitable state, in which case it should generate a <Feature Abort> message.

If a new <Set OSD String> message is received when an OSD String is already being displayed, it should overwrite the existing string. OSD Strings generated locally within the TV may also overwrite any messages sent via the <Set OSD String> message.

CEC 13.10 Device OSD Name Transfer

CEC 13.10.1 Messages

The following messages are used for the Device OSD Name Transfer feature:

<Give OSD Name>, <Set OSD Name>

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CEC 13.10.2 Feature Description

This feature is used to request the preferred name of a device to be used in any on screen display (e.g. menus), which reference that device. A device (e.g. the TV) may request another devices name by sending a directly addressed <Give OSD Name> message to it. If the device supports this feature it shall respond with a <Set OSD Name> message. The devices name should then be stored and used in any future on screen references to it.

A TV shall send a <Give OSD Name> message whenever it discovers a new device that has been connected.

CEC 13.11 Device Menu Control

CEC 13.11.1 Messages

The following messages are used for the Device Menu Control feature:

<User Control Pressed>, <User Control Released>, <Menu Request>, <Menu Status>

CEC 13.11.2 Feature Description

This feature allows device menus to be controlled via the TV remote control as if it was using its own remote control and allow the TV to be aware when another device has a menu on its display.

A device shall indicate that it is displaying a menu by sending a <Menu Status> [“Activated”] message to the TV. If the device leaves the menu it shall send a <Menu Status> [“Deactivated”] message to the TV. The TV should then handle incoming remote control commands internally (as it would normally).

The message <User Control Pressed> can be used to send incoming Remote Control commands from the TV to a device that it is displaying a menu. The <User Control Released> message should be sent on release of the RC button. If a device fails to acknowledge any <User Control Pressed> or <User Control Released> message when in the providing menu state, the TV shall assume that it has been removed from the system and act accordingly. For more information on <User Control> see the Remote Control Pass Through feature description (CEC 13.12).

The TV may initiate a device’s menu by sending a <Menu Request> [“Activate”] command. It may subsequently remove the menu by sending a <Menu Request> [“Deactivate”] message. The TV may also query a devices menu status by sending a <Menu Request> [“Query”]. The menu device shall always respond with a <Menu Status> command when it receives a <Menu Request>.

A new active source device shall send a <Menu Status> [“Activated”] message to the TV if it is displaying a menu. The TV shall assume that a new active source is not in a menu unless it receives this message after the <Active Source> message. The TV shall ignore a <Menu Status> message coming from a device that is not the current active source. A source device shall only send <Menu Status> commands when it is the current active source.

CEC 13.12 Remote Control Pass Through

CEC 13.12.1 Messages

The following messages are used for the Remote Control Pass Through feature:

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<User Control Pressed>, <User Control Released>

CEC 13.12.2 Feature Description

This feature is used to pass remote control commands received by one device (typically the TV) through to another device in the network. This feature will typically be used in situations where a TV offers a remote control with additional modes for controlling other devices within the system. The TV will receive the RC command and pass the command through to the appropriate device within the system.

The initiator shall decide on which device the remote command is for and send a directly addressed <User Control Pressed> message to it using the table of standard remote control pass through commands given in CEC Table 23. In a system where there is more than one of a particular device type present, the initiator should decide (as locally specified) a default device to pass remote control commands to.

The initiator will send a <User Control Pressed> message when the remote control button is pressed. When the button is released a <User Control Released> message should be sent by the initiator. The initiator should not send repeated <User Control Pressed> messages for the same button press.

The initiator may send further <User Control Pressed> messages without interleaving <User Control Released> messages if a new button press occurs quickly after a button release.

A device that has initiated a <User Control Pressed> message shall ensure that it sends a <User Control Released> message before going into standby. In the event that the initiator of the message is powered off/disconnected before sending a <User Control Released> message, the follower will never receive the <User Control Released> message.

This method should not be used for sending commands other than true remote control pass through to another device as the actions taken by the other device are not defined in a consistent way.

CEC 13.13 Give Device Power Status

CEC 13.13.1 Messages

The following messages are used for the Give Device Power Status feature:

<Give Device Power Status>, <Report Power Status>

CEC 13.13.2 Feature Description

Several messages, such as <Image View On> and <Play>, bring another device out of standby. The <Give Device Power Status> message is used to determine the current power status of a target device. The target device responds with a <Report Power Status> message containing the Power Status operand.

Some devices, such as TVs, may take some time before they have fully transitioned to the On state. A requesting device may poll the target device to determine when that device is fully On. In this case, the requesting device shall not send a <Give Device Power Status> message more frequently than once every 0.5 seconds. It is not recommended that a requesting device polls another device until the first device has transitioned to a stable state.

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CEC 14 Device States

This section shows how CEC messages can change the states of a device.

CEC 14.1.1 Device States

The following is a list of states that each device type can be in. Each device should be in one and only one state for each line shown below.

All Devices: On, Standby, Off

TV: Image Display, Menu Display, Text Display
Device Menu Active, Device Menu Inactive

Recording Device: Recording, Not Recording

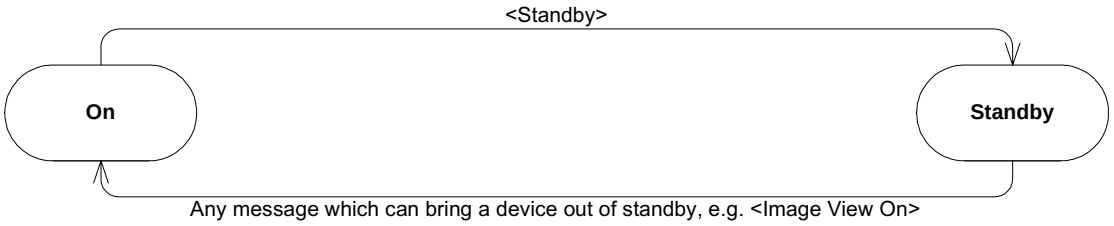
Playback Device: Deck Active, Deck Inactive

Menu Providing Device: Device Menu Active, Device Menu Inactive

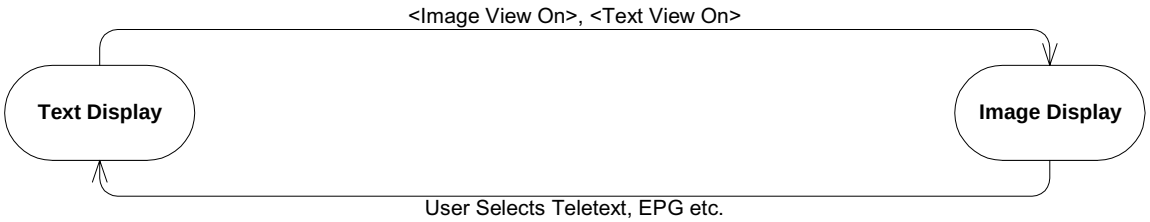
CEC 14.1.2 State Changes

The following diagrams show the state transitions that are caused as a direct result of a device receiving a CEC message. Transitions between states that are not caused as a result of CEC messages are generally not shown, except where no CEC message can cause that transition.

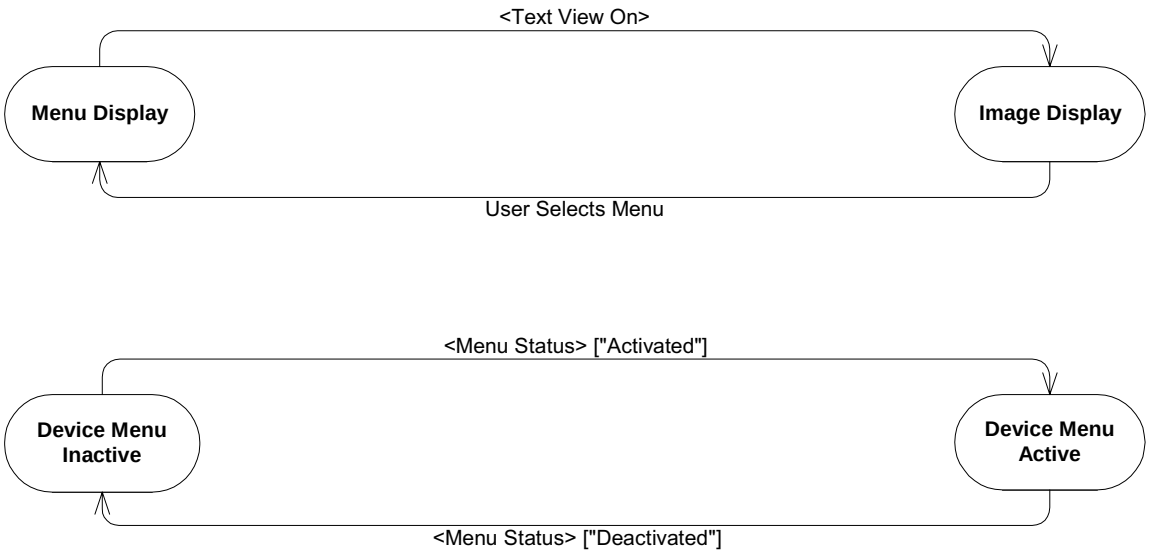
CEC 14.1.3 All Devices



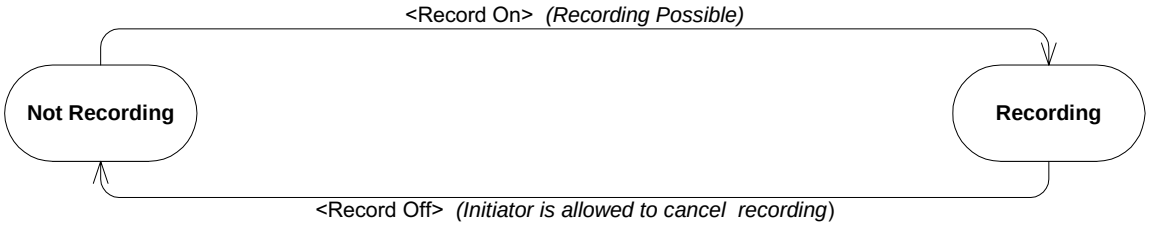
CEC 14.1.4 TV



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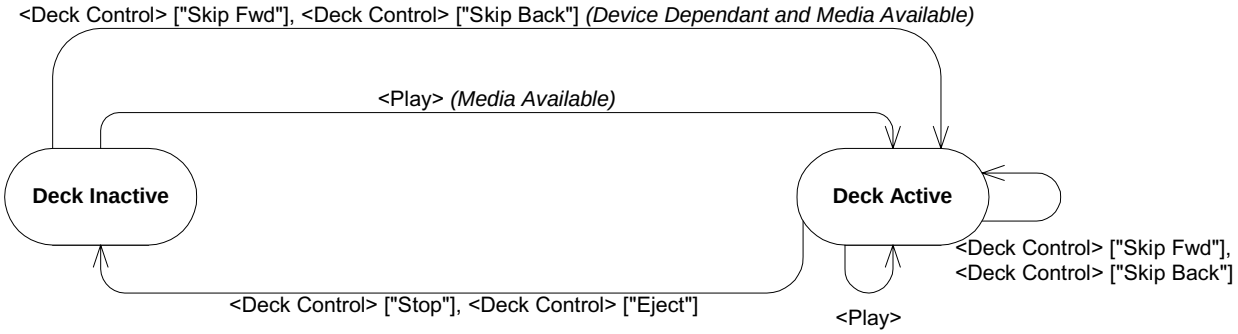


CEC 14.1.5 Recording Device

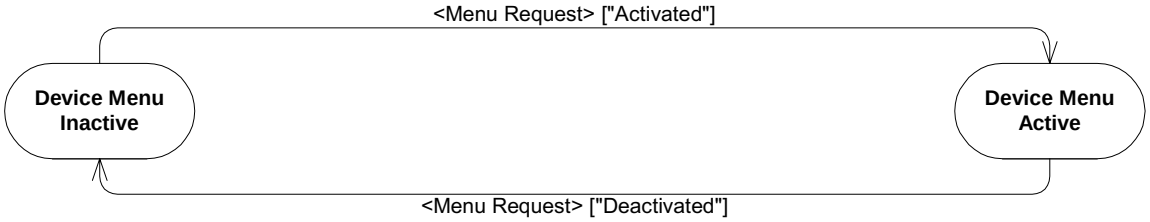


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CEC 14.1.6 Playback Device



CEC 14.1.7 Menu Providing Device



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CEC 15 Message Descriptions

The section defines the individual messages used in CEC. It describes them and defines their parameters and expected responses. As CEC has no session layer, this section and the operands section (CEC 17) effectively define the complete messaging system. Tables CEC Table 6 to CEC Table 18 show which messages are mandatory. If a manufacturer implements any of the optional messages, then they shall be implemented as described in CEC 13.

The following list describes each heading within the message tables CEC Table 6 to CEC Table 18.

- **Opcode** – The name used to identify the message.
- **Value** – The unique identifier for the message.
- **Description** – A brief description of the message.
- **Parameters** – The set of parameters used by the message, refer to CEC Table 22 for individual descriptions.
- **Parameter Description** – A brief description of the parameters that the message uses.
- **Response** – Describes how a device should respond on receipt of the message.
- **Directly Addressed** – Indicates if the message may be directly addressed.
- **Broadcast** – Indicates if the message may be broadcast.
- **Mandatory** – Indicates if it is mandatory for a device to react and respond on receipt of the message. Note that where a message is indicated as being mandatory for ‘All’ devices, this excludes devices which act only as a CEC Switch.

Within the table some cells are intentionally left blank; this indicates that there is no associated requirements for the Opcode described.

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CEC Table 6 Message Descriptions for the One Touch Play Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Active Source> [1]	0x82	Used by a new source to indicate that it has started to transmit a stream OR used in response to a <Request Active Source>	[Physical Address]	The physical address of the device.	A current active source should take appropriate action. TV should switch to the appropriate input. Any CEC switches between source and root should switch to the appropriate input and come out of standby if necessary.		•	All sources	TV, CEC Switches
<Image View On>	0x04	Sent by a source device to the TV whenever it enters the active state (alternatively it may send <Text View On>).	None		Turn on (if not on). If in 'Text Display' state then the TV enters 'Image Display' state. Note: Does not change TV menu or PIP status.	•		All sources shall implement at least one of <Image View On> or <Text View On>	TV
<Text View On>	0x0D	As <Image View On>, but also removes any text, menus and PIP windows from the TV's display.	None		As <Image View On>, but removes PIPs and menus from the screen. The TV enters 'Image Display' state regardless of its previous state.	•		All sources shall implement at least one of <Image View On> or <Text View On>	TV

[1] This message is also used in the Routing Control Feature

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CEC Table 7 Message Descriptions for the Routing Control Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Active Source> [2]	0x82	Used by a new source to indicate that it has started to transmit a stream OR used in response to a <Request Active Source>	[Physical Address]	The physical address of the device.	A current active source should take appropriate action. TV should switch to the appropriate input. Any CEC switches between source and root should switch to the appropriate input.		•	All sources	TV, CEC Switches
<Request Active Source>	0x85	Used by a new device to discover the status of the system.	None		<Active Source> from the present active source.		•		All except CEC Switches
<Routing Change>	0x80	Sent by a CEC Switch when it is manually switched to inform all other devices on the network that the active route below the switch has changed.	[Original Address] [New Address]	The previous child_address that the switch was switched to and the new child_address it has been moved to.	If a CEC Switch is at the new address, it sends a <Routing Information> message to indicate its current active route.		•	CEC Switches	CEC Switches
<Routing Information>	0x81	Sent by a CEC Switch to indicate the active route below the switch.	[Physical Address]	The current active route to the sink in the CEC Switch.	If a CEC Switch is at the specified address it should relay a <Routing Information> message to indicate its current active path.		•	CEC Switches	CEC Switches
<Set Stream Path>	0x86	Used by the TV to request a streaming path from the specified physical address.	[Physical Address]	The physical address of the source device.	Any CEC switches between should switch inputs according to the path defined in [Physical Address]. The device at the new address should stream its output and broadcast an <Active Source> message.		•		CEC Switches

[2] This message is also used in the One Touch Play Feature

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CEC Table 8 Message Descriptions for the Standby Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Standby>	0x36	Switches one or all devices into standby mode. Can be used as a broadcast message or be addressed to a specific device. It is recommended that a directly addressed message is only sent if the initiator originally brought the device out of standby. See section CEC 13.3 for important notes on the use of this message	None		Switch the device into standby. [3] Ignore the message if already in standby.	•	•		All

[3] Can be ignored if actively engaged in a recording or providing a source stream for a recording.

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CEC Table 9 Message Descriptions for the One Touch Record Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Record Off>	0x0B	Requests a device to stop a recording.	None		Exit 'Recording' state and stop recording if the initiator is the same as the initiator of the <Record On> message which started this recording.	•			Recording Device
<Record On>	0x09	Attempt to record the specified source.	[Record Source]	Source to record, either digital service or own source (ie currently selected source).	Enter 'Recording' state and start recording if possible. Send the initiator <Record Status>.	•			Recording Device, Own Source only
<Record Status>	0x0A	Used by a recording device to inform the initiator of the message <Record On> about its status.	[Record Status Info]	The recording status of the device.		•		Recording Device	Device Initiating a recording
<Record TV Screen>	0x0F	Request by the recording device to record the presently displayed source.	None		Initiate a recording using the <Record On> message, or send a <Feature Abort> ["Cannot provide source"] if the presently displayed source is not recordable.	•			

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CEC Table 10 Message Descriptions for the System Information Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Give Physical Address>	0x83	A request to a device to return its physical address.	None		<Report Physical Address>	•			All
<Get Menu Language>	0x91	Sent by a device capable of character generation (for OSD and Menus) to a TV in order to discover the currently selected Menu language. Also used by a TV during installation to discover the currently set menu language.	None		The addressed device responds with a <Set Menu Language> message	•			TV with OSD / Menu generation capabilities
<Polling Message>	-	Used by any device for device discovery – similar to ping in other protocols.	None		Shall set a low level ACK.	•		All except for TV and CEC Switches	
<Report Physical Address>	0x84	Used to inform all other devices of the mapping between physical and logical address of the initiator.	[Physical Address] [Device Type]	The device's physical address within the cluster.			•	All	TV
<Set Menu Language>	0x32	Used by a TV or anther device to indicate the menu language.	[Language]	The user's menu language choice.	Set the menu language as specified, if possible.		•	TV	All, except TV and CEC Switches

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CEC Table 11 Message Descriptions for the Deck Control Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Deck Control>	0x42	Used to control a device's media functions.	[Deck Control Mode]	The deck control requested.	Perform the specified actions, or return a <Feature Abort> message. It is device dependent whether or not a Skip Fwd/Skip Back (Wind/Rewind) command is legal when in the 'Deck Inactive' state. If the device is in standby and receives an eject command, it should power on and eject its media.	•			<Deck Control> ["Stop"] for a playback device
<Deck Status>	0x1B	Used to provide a deck's status to the initiator of the <Give Deck Status> message.	[Deck Info]	Information on the device's current status.		•			
<Give Deck Status>	0x1A	Used to request the status of a device, regardless of whether or not it is the current active source.	[Status Request]	Allows the initiator to request the status once or on all future state changes. Or to cancel a previous <Give Deck Status> ["On"] request.	<Deck Status>	•			
<Play>	0x41	Used to control the playback behaviour of a source device.	[Play Mode]	Play mode required.	Perform the specified actions, or return a <Feature Abort> message. If media is available the device enters 'Deck Active' state. If the device is in standby, has media available and the parameter is ["Play Forward"] it should power on.	•			<Play> ["Forward"] for a playback device

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CEC Table 12 Message Descriptions for the Tuner Control Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Give Tuner Device Status>	0x08	Used to request the status of a tuner device.	[Status Request]	Allows the initiator to request the status once or on all future state changes, or to cancel a previous <Give Tuner Device Status> [“On”] message.	Respond with a <Tuner Device Status> message, or stop reporting changes on receipt of the [“Off”] message.	•			
<Select Digital Service>	0x93	Directly selects a Digital TV, Radio or Data Broadcast Service	[Digital Service Identification]	Defines Digital TV system and necessary data to specify a service	Change to the selected digital service and stream its output on the HDMI connection. If the tuner device is not capable of selecting this service, respond with a <Feature Abort>	•			
<Tuner Device Status>	0x07	Use by a tuner device to provide its status to the initiator of the <Give Tuner Device Status> message.	[Tuner Device Info]	Information on the tuner devices current status.		•			
<Tuner Step Decrement>	0x06	Used to tune to next lowest service in a tuner’s service list. Can be used for PIP.	None		Follower tunes to next lowest service in its service list.	•		TV without Tuner and with Program Inc./ Dec. facility	Tuner Device
<Tuner Step Increment>	0x05	Used to tune to next highest service in a tuner’s service list. Can be used for PIP.	None		Follower tunes to next highest service in its service list.	•		TV without Tuner and with Program Inc./ Dec. facility	Tuner Device

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CEC Table 13 Message Descriptions for the Vendor Specific Commands Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Device Vendor ID>	0x87	Reports the vendor ID of this device.	[Vendor ID]	The vendor ID of the device.	Any other interested device may store the vendor ID of the device.		•	As needed for Devices supporting Vendor Specific Command	As needed for Devices supporting Vendor Specific Command
<Give Device Vendor ID>	0x8C	Requests the Vendor ID from a device.	None		<Device Vendor ID>	•		As needed for Devices supporting Vendor Specific Command	As needed for Devices supporting Vendor Specific Command
<Vendor Command>	0x89	Allows vendor specific commands to be sent between two devices.	[Vendor Specific Data]	Vendor specific command or data. The maximum length of the [Vendor Specific Data] shallnot exceed 14 data blocks to avoid saturating the bus.	Vendor Specific	•			
<Vendor Remote Button Down>	0x8A	Indicates that a remote control button has been depressed.	[Vendor Specific RC Code]	The vendor specific Remote Control Code for the key pressed.	Vendor Specific	•	•		
<Vendor Remote Button Up>	0x8B	Indicates that a remote control button (the last button pressed indicated by the Vendor Remote Button Down message) has been released.	None		Vendor Specific	•	•		

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CEC Table 14 Message Descriptions for the OSD Status Display Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Set OSD String>	0x64	Used to send a text message to output on a TV.	[Display Control] [OSD String]	Display timing. Text to be displayed.	TV displays the message.	•			

CEC Table 15 Message Descriptions for the Device OSD Transfer Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Give OSD Name>	0x46	Used to request the preferred OSD name of a device for use in menus associated with that device.	None		<Set OSD Name>	•			
<Set OSD Name>	0x47	Used to set the preferred OSD name of a device for use in menus associated with that device.	[OSD Name]	The preferred name of the device.	Store the name and use it in any menus associated with that device.	•			

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CEC Table 16 Message Descriptions for the Device Menu Control Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Menu Request>	0x8D	A request from the TV for a device to show/remove a menu or to query if a device is currently showing a menu.	[Menu Request Type]	Indicates if the menu request is to activate or deactivate the devices menu, or to simply query the devices menu status.	May enter or exit the 'Device Menu Active' state if the parameter was "Activate" or "Deactivate" Send <Menu Status> to indicate the current status of the devices menu.	•			
<Menu Status>	0x8E	Used to indicate to the TV that the device is showing/has removed a menu and requests the remote control keys to be passed though.	[Menu State]	Indicates if the device is in the 'Device Menu Active' state or 'Device Menu Inactive' state.	If Menu State indicates activated, TV enters 'Device Menu Active' state and forwards those Remote control commands, shown in CEC Table 23, to the initiator. If deactivated, TV enters 'Device Menu Inactive' state and stops forwarding remote control commands.	•			
<User Control Pressed> [4]	0x44	Used to indicate that the user pressed a remote control button or switched from one remote control button to another.	[UI Command]	UI command issued by user.	Update display or perform an action, as required.	•			
<User Control Released> [5]	0x45	Indicates that user released a remote control button (the last one indicated by the <User Control Pressed> message)	None		Update display or perform an action, as required.	•			

[4] This message is also used in the RC Passthrough Feature
[5] This message is also used in the RC Passthrough Feature

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CEC Table 17 Message Descriptions for the Remote Control Passthrough Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<User Control Pressed> [6]	0x44	Used to indicate that the user pressed a remote control button or switched from one remote control button to another.	[UI Command]	UI command issued by user.	Update display or perform an action, as required.	•			
<User Control Released> [7]	0x45	Indicates that user released a remote control button (the last one indicated by the <User Control Pressed> message)	None		Update display or perform an action, as required.	•			

CEC Table 18 Message Descriptions for the Power Status Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Give Device Power Status>	0x8F	Used to determine the current power status of a target device	None		<Report Power Status>	•			
<Report Power Status>	0x90	Used to inform a requesting device of the current power status	[Power Status]	The current power status		•			

[6] This message is also used in the Device Menu Control Feature
[7] This message is also used in the Device Menu Control Feature

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CEC Table 19 Message Descriptions for General Protocol messages

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Feature Abort>	0x00	Used as a response to indicate that the device does not support the requested message type, or that it cannot execute it at the present time.	[Feature Opcode] [Abort Reason]	The Opcode of the aborted message. The reason provides an indication as to whether the follower does not support the message, or does support the message but cannot respond at the present time.	Assume that request is not supported or has not been actioned.	•		Generate if a message is not supported	All
<Abort> Message	0xFF	This message is reserved for testing purposes.	None		A device shall never support this message, and shall always respond with a <Feature Abort> message containing any valid value for [Abort Reason]. CEC switches shall not respond to this message.	•			All, except for CEC switches

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CEC 16 Message Dependencies

This section describes the dependencies between each message. This section is divided into two tables, which describe the following:

- CEC Table 20 describes the message dependencies when a device is capable of receiving a particular message (i.e. it does not <Feature Abort> indicating an ["Unrecognized opcode"] in response to the message).
- CEC Table 21 describes the message dependencies when a device is capable of sending a particular message.
- Each table describes the additional messages that the device shall be capable of receiving and sending if a particular message is supported.

CEC Table 20 Message dependencies when receiving a message

If device does not <Feature Abort> the following message:	**It shall not <Feature Abort> the message(s):**	**It shall be able to send the message(s):**
<Deck Control>	<Play>	<Deck Status>
<Deck Status>	-	<Play>, <Deck Control>
<Device Vendor ID> [8]		<Give Device Vendor ID>
<Get Menu Language>	-	<Set Menu Language>
<Give Deck Status>	<Play>, <Deck Control>	<Deck Status>
<Give Device Power Status	-	<Report Power Status>
<Give Device Vendor ID>	-	<Device Vendor ID>
<Give OSD Name>	-	<Set OSD Name>

[8] This message is broadcast and there is therefore no <Feature Abort>, but devices accepting this message shall also be able to send the associated message

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If device does not <Feature Abort> the following message:	It shall not <Feature Abort> the message(s):	It shall be able to send the message(s):
<Give Physical Address>	-	<Report Physical Address>
<Give Tuner Device Status>	-	<Tuner Device Status>
<Image View On>	<Active Source> [9]	-
<Menu Request>	<User Control Pressed>, <User Control Released>	<Menu Status>
<Menu Status>	-	<Menu Request>, <User Control Pressed>, <User Control Released>
<Play>	<Deck Control>	<Deck Status>
<Record Off>	<Record On>	<Record Status>
<Record On>	<Record Off>	<Record Status>
<Record Status>	-	<Record On>, <Record Off>
<Record TV Screen>	<Record Status>	<Record On>, <Record Off>
<Request Active Source>[10]	-	<Active Source>
<Routing Change>[11]	<Routing Information>	-
<Routing Information>[12]	<Routing Change>	-
<Set Digital Service>	-	-
<Set Menu Language>	-	-
<Set OSD Name>	-	<Give OSD Name>
<Set OSD String>	-	-
<Set Stream Path>[13]	-	<Active Source> (not CEC Switches)

[9] This message is broadcast and there is therefore no <Feature Abort>, but devices shall also accept the associated message.
[10] This message is broadcast and there is therefore no <Feature Abort>, but devices accepting this message shall also be able to send the associated message.
[11] This message is broadcast and there is therefore no <Feature Abort>, but devices shall also accept the associated message.
[12] This message is broadcast and there is therefore no <Feature Abort>, but devices shall also accept the associated message.

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If device does not <Feature Abort> the following message:	It shall not <Feature Abort> the message(s):	It shall be able to send the message(s):
<Text View On>[14]	<Active Source>	-
<Tuner Device Status>	-	<Give Tuner Device Status>
<Tuner Step Decrement>	<Tuner Step Increment>	-
<Tuner Step Increment>	<Tuner Step Decrement>	-
<User Control Pressed>	<User Control Released>	-
<User Control Released>	<User Control Pressed>	-
<Vendor Command>[15]	<Device Vendor ID>	<Give Device Vendor ID>
<Vendor Remote Button Down> [16]	<Vendor Remote Button Up>, <Device Vendor ID>	<Give Device Vendor ID>
<Vendor Remote Button Up> [17]	<Vendor Remote Button Down>, <Device Vendor ID>	<Give Device Vendor ID>

[13] This message is broadcast and there is therefore no <Feature Abort>, but devices accepting this message shall also be able to send the associated message.
[14] This message is broadcast and there is therefore no <Feature Abort>, but devices shall also accept the associated message
[15] This message is broadcast and there is therefore no <Feature Abort>, but devices shall also accept the associated message and also be able to send the associated message.
[16] This message can be broadcast and there may not be a <Feature Abort>, but devices shall also accept the associated messages and also be able to send the associated message.
[17] This message can be broadcast and there may not be a <Feature Abort>, but devices shall also accept the associated messages and also be able to send the associated message.

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CEC Table 21 Message dependencies when sending a message

If device ever sends the following message:	**It shall be able to send the message(s):**	**It shall not <Feature Abort> the message(s):**
<Deck Control>	<Play>	-
<Deck Status>	-	<Give Deck Status>, <Play>, <Deck Control>
<Device Vendor ID>	-	<Give Device Vendor ID>
<Get Menu Language>	-	<Set Menu Language>[18]
<Give Deck Status>	<Play>, <Deck Control>	<Deck Status>
<Give Device Vendor ID>	-	<Device Vendor ID> [19]
<Give OSD Name>	-	<Set OSD Name>
<Give Physical Address>	-	<Report Physical Address> [20]
<Give Tuner Device Status>	-	<Tuner Device Status>
<Image View On>	<Active Source>	-
<Menu Request>	<User Control Pressed>, <User Control Released>	<Menu Status>
<Menu Status>	-	<Menu Request>, <User Control Pressed>, <User Control Released>
<Play>	<Deck Control>	-
<Record Off>	<Record On>	<Record Status>
<Record On>	<Record Off>	<Record Status>
<Record Status>	-	<Record On>, <Record Off>

[18] This message is broadcast and there is therefore no <Feature Abort>, but devices sending the associated message shall also be able to send this message.
[19] This message is broadcast and there is therefore no <Feature Abort>, but devices sending the associated message shall also be able to send this message.
[20] This message is broadcast and there is therefore no <Feature Abort>, but devices sending the associated message shall also be able to send this message.

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If device ever sends the following message:	It shall be able to send the message(s):	It shall not <Feature Abort> the message(s):
<Record TV Screen>	<Record Status>	<Record On>, <Record Off>
<Report Power Status>	-	<Give Device Power Status>
<Request Active Source>	-	<Active Source>[21]
<Routing Change>	<Routing Information>	-
<Routing Information>	<Routing Change>	-
<Set Menu Language>	-	<Get Menu Language>
<Set OSD Name>	-	<Give OSD Name>
<Set Stream Path>	-	<Active Source> (not CEC Switches)
<Text View On>	<Active Source>	-
<Tuner Device Status>	-	<Give Tuner Device Status>
<Tuner Step Decrement>	<Tuner Step Increment>	-
<Tuner Step Increment>	<Tuner Step Decrement>	-
<User Control Pressed>	<User Control Released>	-
<User Control Released>	<User Control Pressed>	-
<Vendor Command>	<Device Vendor ID>	<Give Device Vendor ID>
<Vendor Remote Button Down>	<Vendor Remote Button Up>, <Device Vendor ID>	<Give Device Vendor ID>
<Vendor Remote Button Up>	<Vendor Remote Button Down>, <Device Vendor ID>	<Give Device Vendor ID>

[21] This message is broadcast and there is therefore no <Feature Abort>, but devices sending the associated message shall also be able to send this message.

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CEC 17 Operand Descriptions

In the following table, Operand Descriptions are ordered alphabetically. Sub-operands, which only occur in a single parent operand, are grouped with their parent and are shown indented.

CEC Table 22 Operand Descriptions.

Name	Range Description		Length	Purpose
[Abort Reason]	"Unrecognized opcode"	0	1 byte	Reason for a <Feature Abort> response.
	"Not in correct mode to respond"	1		
	"Cannot provide source"	2		
	"Invalid operand"	3		
	"Refused"	4		
[ASCII digit]	0x30≤n≤0x39		1 byte	Subset of [ASCII] representing a printable digit character.
[ASCII]	0x20≤n≤0x7F		1 byte	Represents a printable character.
[Boolean]	"False"	0	1 bit	Flag
	"True"	1		
[Deck Control Mode]	"Skip Forward / Wind Forward"	1	1 byte	Used in <Deck Control>. Note: The "Skip Forward / Wind Forward" and "Skip Backward / Wind Backward" values are used for example in a DVD as next chapter and previous chapter and in a VCR as wind and rewind.
	"Skip Backward / Rewind"	2		
	"Stop"	3		
	"Eject"	4		

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Name	Range Description		Length	Purpose
[Deck Info]	“Play”	0x11	1 byte	Indicates the current status of a tape or disk deck.
	“Record”	0x12		
	“Play Reverse”	0x13		
	“Still”	0x14		
	“Slow”	0x15		
	“Slow Reverse”	0x16		
	“Search Forward”	0x17		
	“Search Reverse”	0x18		
	“No Media”	0x19		
	“Stop”	0x1A		
	“Wind”	0x1B		
	“Rewind”	0x1C		
	“Index Search Forward”	0x1D		
	“Index Search Reverse”	0x1E		
	”Other Status”	0x1F		

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Name			Range Description		Length	Purpose
[Device Type]			"TV"	0	1 byte	Allows additional devices, above the number allowed in the logical addressing mechanism, to indicate their device type.
			"Recording Device"	1		
			"STB"	3		
			"DVD"	4		
			"Audio System"	5		
[Digital Service Identification]			[Digital Broadcast System] [Service Identification]		7 bytes	Indicates Digital Broadcast System and the parameters to identify a specific service. Length of data depends on [Digital Broadcast System].
	[Digital Broadcast System]		"ARIB"	0x00	1 byte	Indicates the Digital Broadcast System of required service.
			"ATSC"	0x01		
			"DVB"	0x02		
	[Service Identification]		[ARIB data]		6 bytes	Specifies an ARIB digital service
			[ATSC data]		6 bytes	Specifies an ATSC digital service
			[DVB data]		6 bytes	Specifies a DVB digital service
	[ARIB data]		"Transport_stream_ID"		2 bytes	The transport_stream_ID of the transport stream carrying the required service
			"Service_ID"		2 bytes	The service_ID of the required service
			"Original_Network_ID"		2 bytes	The original_network_ID of the network carrying the transport stream for the required service
	[ATSC data]		"Transport_stream_ID"		2 bytes	The transport_stream_ID of the transport stream carrying the required service
			"Content_ID"		2 bytes	The content_ID of the required service
			"Reserved (0x0000)"		2 bytes	Reserved

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Name		Range Description			Length	Purpose
	[DVB data]	“Transport_stream_ID”			2 bytes	The transport_stream_ID of the transport stream carrying the required service
		”Service_ID”			2 bytes	The service_ID of the required service
		”Original_Network_ID”			2 bytes	The original_network_ID of the network carrying the transport stream for the required service
[Display Control]		bit 5 – bit 0 = 0			1 byte	To indicate the display mode for an on screen display message.
			bit 7	bit 6		
		“Display for default time”	0	0		
		“Display until cleared”	0	1		
		“Clear previous message”	1	0		
		Reserved for future use	1	1		
[Feature Opcode]		0x00≤n≤0xFF (n is defined in CEC Table 6)			1 byte	Defines command to be performed.
[Language]		3 {[ASCII]} as defined in ISO/FDIS 639-2 [ref 1n]			3 bytes	Specify the language with which to interact with the user.
[Menu Request Type]		“Activate”	0		1 byte	Specifies whether to activate or deactivate a devices menu or simply query its current menu status.
		“Deactivate”	1			
		“Query”	2			
[Menu State]		“Activated”	0		1 byte	Specifies the state of a device menu
		“Deactivated”	1			
[New Address]		[Physical Address]			2 bytes	The physical address of the new device selected by a CEC Switch.
[Original Address]		[Physical Address]			2 bytes	The physical address of the device de-selected by a CEC Switch.

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Name		Range Description		Length	Purpose
[OSD Name]		N {[ASCII]}, 1≤N ≤ 8		1 - 8 bytes	The devices name - To be used in On Screen Display references to it.
[OSD String]		N {[ASCII]}, 1≤N ≤ 13		1 - 13 bytes	A string to be displayed on the display.
[Physical Address]		4{[Port ID]}		2 bytes	Defines the path between the TV and a device – thus giving it a physical address within the cluster.
	[Port ID]	0x0≤n≤0xF		4 bits	Defines one 'hop' within the physical address relating to the physical connection of the device.
[Play Mode]		"Play Forward"	0x24	1 byte	The mode in which to play media. Note: If a device does not support a particular play mode it should select the closest match.
		"Play Reverse"	0x20		
		"Play Still"	0x25		
		"Scan Forward Min Speed"	0x05		
		"Scan Forward Medium Speed"	0x06		
		"Scan Forward Max Speed"	0x07		
		"Scan Reverse Min Speed"	0x09		
		"Scan Reverse Medium Speed"	0x0A		
		"Scan Reverse Max Speed"	0x0B		
		"Slow Forward Min Speed"	0x15		
		"Slow Forward Medium Speed"	0x16		
		"Slow Forward Max Speed"	0x17		
		"Slow Reverse Min Speed"	0x19		
		"Slow Reverse Medium Speed"	0x1A		
		"Slow Reverse Max Speed"	0x1B		

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Name		Range Description		Length	Purpose
[Power Status]		“On”	0x00	1 byte	Used to indicate the current power status of a device.
		“Standby”	0x01		
		“In transition Standby to On”	0x02		
		“In transition On to Standby”	0x03		
[Record Source]		[Record Source Type] | {[Record Source Type] [Digital Service Identification]}		-	To define the source for a recording.
	[Record Source Type]	”Own source”	1	1 byte	Allows the record source to be specified for a recording.
		“Digital Service”	2		
[Record Status Info]		“Recording own source”	0x01	1 byte	Indicates the status of a recording.
		“Recording Digital Service Service”	0x02		
		“Reserved”	0x03		
		“Reserved”	0x04		
		“No recording – unable to record Digital Service ”	0x05		
		“No recording - no media”	0x10		
		“No recording - playing”	0x11		
		“No recording - already recording”	0x12		
		“No recording - media protected”	0x13		
		“No recording - no source”	0x14		
		“No recording - media problem”	0x15		
		“No recording - other reason”	0x1F		

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Name		Range Description		Length	Purpose
[Reserved Bit]		0		1 bit	Used as padding bit for future extensions.
[Status Request]		"On"	1	1 byte	Contains the status request mode which can be report once or on all future state changes or reporting off.
		"Off"	2		
		"Once"	3		
[Tuner Device Info]		[Tuner Display Info][Digital Service Identification]]		8 bytes	Indicates information about the tuner. Indicates the digital service that the tuner is set to, regardless of whether or not it is currently displaying the tuner.
	[Tuner Display Info]	"Displaying tuner"	0	1 byte	Indicates if the device is currently displaying its tuner or not (it may for example be displaying an external source or media).
		"Not displaying tuner"	1		
[UI Command]		0x00≤n≤0xFF (n is defined in CEC Table 23)		1 byte	Indicates the remote control button pressed.
[Vendor ID]		0x000000≤n≤0xFFFFFF (n is the 24-bit unique company ID [ref. 3i] obtained from the IEEE Registration Authority Committee (RAC)).		3 bytes	Identifier for a specific Vendor.

Notes: Items are transmitted in the order shown in the description.
All bit descriptions are done most significant bit first (i.e. first bit described is sent first)

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CEC Table 23 User Control Codes

Operation id	User Operation
0x00	**Select**
0x01	**Up**
0x02	**Down**
0x03	**Left**
0x04	**Right**
0x05	**Right-Up**
0x06	**Right-Down**
0x07	**Left-Up**
0x08	**Left-Down**
0x09	Root Menu
0x0A	Setup Menu
0x0B	Contents Menu
0x0C	Favorite Menu
0x0D	**Exit**
0x0E - 0x1F	Reserved
0x20 - 0x29	**Numbers 0-9**
0x2A	Dot
0x2B	Enter
0x2C	Clear
0x2D - 0x2F	Reserved
0x30	Channel Up
0x31	Channel Down

Operation id	User Operation
0x32	Previous Channel
0x33	Sound Select
0x34	Input Select
0x35	Display Information
0x36	Help
0x37	Page Up
0x38	Page Down
0x39 - 0x3F	Reserved
0x40	Power
0x41	Volume Up
0x42	Volume Down
0x43	Mute
0x44	Play
0x45	Stop
0x46	Pause
0x47	Record
0x48	Rewind
0x49	Fast forward
0x4A	Eject
0x4B	Forward
0x4C	Backward
0x4D - 0x4F	Reserved

Operation id	User Operation
0x50	Angle
0x51	Sub picture
0x52 - 0x5F	Reserved
0x60	Play Function
0x61	Pause-Play Function
0x62	Record Function
0x63	Pause-Record Function
0x64	Stop Function
0x65	Mute Function
0x66	Restore Volume Function
0x67	Tune Function
0x68	Select Disk Function
0x69	Select A/V Input Function
0x6A	Select Audio Input Function
0x6B - 0x70	Reserved
0x71	**F1 (Blue)**
0x72	**F2 (Red)**
0x73	**F3 (Green)**
0x74	**F4 (Yellow)**
0x75	**F5**
0x76 - 0x7F	Reserved

Note: The elements identified in **bold** are the only ones which are forwarded as part of the device menu control feature.

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ATTACHMENT C

High-Definition Multimedia Interface

Specification Version 1.3a

Hitachi, Ltd.

Matsushita Electric Industrial Co., Ltd.

Philips Consumer Electronics, International B.V.

Silicon Image, Inc.

Sony Corporation

Thomson Inc.

Toshiba Corporation

November 10, 2006

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Preface

Notice

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Document Revision History

1.3a	2006/11/10	Cable and Sink modifications for Type C (Table 4-20, 4.2.6) Source termination recommendation (after Table 4-15) Removed undershoot and max rise/fall time limits (4.2.4). Modified slope of TP1 and TP2 eye diagrams (4.2.4, 4.2.5) HDMI cable assembly AC-coupling support required (4.2.6) CEC capacitance limits changed (4.2.10) Valid range for RGB video quantization added (6.6) Added audio sample rate exceptions for ARC (7.3, 7.3.1, 7.3.2) Added Audio Rate Control Overview (7.11)
1.3	2006/06/22	Significant new features: - Type C "Mini-Connector" (4.1.9.5, 4.1.9.6) - Cable Categories 1 and 2 (4.2.6) - Deep Color [4:4:4] (6.5, 8.3.2) - Reference Cable Equalizer (4.2.3.2, 4.2.5, 4.2.6) - Higher-speed single-link (4.1.2, 4.2.3,through 4.2.6, 8.3.2) - xvYCC Enhanced Colorimetry (6.7.2.3) - Gamut Metadata transmission (5.3.12, 6.7.3, Appendix E)) - DST audio format (5.3.10, 7.6.3) - High-bitrate compressed audio formats (5.3.11, 7.2.4, 7.3.3, 7.6.2) - Auto-Lipsync Correction feature (8.3.2, 8.9) Updated normative reference from CEA-861-B to –D (1.2, throughout). Updated Overview for new features (3) Several minor editorial (throughout)
1.2a	2005/12/14	Changes to CEC supplement (see supplement for details) Eliminated I_{OFF} and made V_{OFF} normative (4.2.4) Changed CEC resistance to 5 ohms (4.2.10) Clarified DVI device discrimination (8.3.3) Several minor editorial (throughout)
1.2	2005/08/22	Removed limitations on Type A connector usage (4.1.2, 6.1) Required new connector mechanical features, optional in 1.1 (4.1.9) Required Sink support for future AC-coupled Sources (4.2.5) Add note regarding maximum ratings of Sink (4.2.5) Clarified Cable Assembly use of +5V Power (4.2.7) Removed incorrect testing method for DDC capacitance (4.2.8) Clarified when separate CEC lines on inputs are allowed (4.2.10) Add maximum resistance spec for interconnected CEC line (4.2.10) Remove CEC leakage current limit while in standby (4.2.10) Relaxed YC_BC_R output requirement for RGB devices (6.2.3) Added support for additional video formats (6.2.4, and 7.3.3, 8.2.1) Corrected sample rate requirement from 1000 ppm to ±1000 ppm (7.2.6) Clarified use of Speaker Allocation Data Block (7.4) Added support for One Bit audio (7.9, and throughout) Clarified exception for 640x480p (VGA) declaration in EDID (8.3.4) Loosened requirement for duplicated DTD declarations (8.3.4)

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		Added recommendation for setting Supports_AI (9.2) Clarified the behavior of Repeater to Sink with Supports_AI (9.3.2) Clarified rule for DVD-Audio ACP Packet transmission (9.3.5) Additional minor editorial (throughout)
1.1	2004/05/20	Permitted multi-rate native format support on Type A Sinks (4.1.2) Changed connector mechanical spec (4.1.9) Changed connector electrical spec (4.1.7) Removed CEC / +5V Power dependency for Source (4.2.7) Loosened regulation requirements for +5V Power (4.2.7) Made HPD voltages consistent with new +5V Power (4.2.9) Clarified CEC connection requirements (4.2.10) Restricted CTLx values allowed in non-Preamble periods (5.2.1) Added new Packet Types (5.3.1) Clarified InfoFrame Packet requirements (5.3.5) Added ACP and ISRC Packet definitions and usage (5.3.7, 8.8, 9.3) Specified recommended handling of non-Subpacket 0 CS blocks (7.1) Clarified audio sample rate requirements (7.2.6) Disallowed Layout 1 2-channel (7.6) Clarified AVI transmission requirements (8.2.1) Added extension fields and clarified HDMI VSDB (8.3.2) Clarified DVI/HDMI device discrimination (8.3.3) Clarified HPD behavior (8.5) Clarified EDID values of Physical Addresses (8.7) Made minor editorial changes (throughout)
1.0	2002/12/09	Initial Release

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Intellectual Property Statement

Hitachi, Ltd., Matsushita Electric Industrial Co., Ltd., Philips Consumer Electronics International, B.V., Silicon Image, Inc., Sony Corporation, Thomson Inc., and Toshiba Corporation each may have patents and/or patent applications related to the High-Definition Multimedia Interface Specification. These companies have made available to the industry an Adopter Agreement that includes a limited, reciprocal patent license to certain of the electrical interfaces, mechanical interfaces, signals, signaling and coding protocols, and bus protocols described in the mandatory portions of the High-Definition Multimedia Interface Specification Release 1.3a published by HDMI Licensing, LLC.

Contact Information

The URL for the HDMI Founders web site is: http://www.HDMI.org.

Contribution

Silicon Image, Inc has made a significant contribution to this standard by editing the specification and developing the core technologies upon which this specification is based; including Transition Minimized Differential Signaling (TMDS®) technology.

Acknowledgement

HDMI founders acknowledge the concerted efforts of employees of Japan Aviation Electronics Industry, Limited and Molex Japan, who have made a significant contribution to this standard by developing the connector technology and the mechanical and electrical specifications for the required plugs and receptacles.

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1 Introduction

1.1 Purpose and Scope

This document constitutes the specification for the High-Definition Multimedia Interface (HDMI), version 1.3a.

The High-Definition Multimedia Interface is provided for transmitting digital television audiovisual signals from DVD players, set-top boxes and other audiovisual sources to television sets, projectors and other video displays.

HDMI can carry high quality multi-channel audio data and can carry all standard and high-definition consumer electronics video formats. Content protection technology is available.

HDMI can also carry control and status information in both directions.

This specification completely describes the interface such that one could implement a complete transmission and interconnect solution or any portion of the interface. The underlying Transition Minimized Differential Signaling (TMDS)-based protocol and associated electrical signaling is described in detail. The mechanical specification of the connector and the signal placement within the connector are described.

A device that is compliant with this specification is interoperable with other compliant devices through the configuration and implementation provided for in this specification.

Mechanical, electrical, behavioral and protocol requirements necessary for compliance are described for sources, sinks and cables.

1.2 Normative References

The following standards contain provisions that, through reference in this text, constitute normative provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. If the referenced standard is dated, the reader is advised to use the version specified.

CEA, CEA-861-D, “A DTV Profile For Uncompressed High Speed Digital Interfaces”[1]

VESA, VESA E-EDID Standard, ENHANCED EXTENDED DISPLAY IDENTIFICATION DATA STANDARD Release A, Revision 1, February 9, 2000

VESA, VESA E-DDC Standard, ENHANCED DISPLAY DATA CHANNEL STANDARD Version 1, September 2, 1999

Philips Semiconductors, The I^2C-bus Specification, Version 2.1, January 2000

[1] All HDMI devices are required to comply with the requirements specified in CEA-861-D except where specifically noted in this document. The CEA-861-D term “source” should be read as “(HDMI) Source” and the terms “Display”, “Monitor” or “DTV Monitor” should be read as “(HDMI) Sink”.

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ITU, ITU-R BT.601-5 Studio encoding parameters of digital television for standard 4:3 and wide-screen 16:9 aspect ratios (October 1995)

ITU, ITU-R BT.709-5 Parameter values for the HDTV standards for production and international programme exchange (2002)

IEC, IEC 60958-1, “Digital audio interface – Part 1: General”, First edition 1999-12

IEC, IEC 60958-3, “Digital audio interface – Part 3: Consumer applications”, Third edition 2006-05

IEC, IEC 61937, “Digital Audio - Interface for non-linear PCM encoded audio bitstreams applying IEC 60958”, First edition 2000-04

IEC, IEC 61966-2-4: “Multimedia systems and equipment - Colour measurement and management - Part 2-4: Colour management - Extended-gamut YCC colour space for video applications – xvYCC”, January 2006

DDWG, “Digital Visual Interface,” Revision 1.0, April 2, 1999 (DVI)

DVD Forum, “DVD Specifications for Read-Only Disc”, “Part 4: AUDIO SPECIFICATIONS”, Version 1, March 1999.

DVD Forum, “DVD Specifications for Read-Only Disc”, “Part 4: AUDIO SPECIFICATIONS”, Version-up Information (from 1.1 to 1.2), May 2000.

Digital Content Protection LLC, “High-bandwidth Digital Content Protection System Specification”, Revision 1.2 (HDCP)

Royal Philips Electronics and SONY Corporation, “Super Audio CD System Description Version 2.0”

1.3 Informative References

The following documents contain information that is useful in understanding this standard. Some of these documents are drafts of standards that may become normative references in a future release of this standard.

ANSI/SMPTE, SMPTE Standard 170M (1999) for Television – Composite Analog Video Signal – NTSC for Studio Applications

ANSI/SMPTE, SMPTE Standard 274M

ANSI/SMPTE, SMPTE Standard 296M

1.4 Organization of this document

This specification is organized as follows:

- Chapter 1 introduces HDMI, describes the purpose and scope of this document, references, organization of the document and usages and conventions.
- Chapter 2 defines terms and acronyms used throughout this document.
- Chapter 3 provides a high-level overview of the operation of HDMI.

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- Chapter 4 describes the details of the Physical Layer of HDMI including basic electrical specifications and mechanical specifications of cables and connectors.
- Chapter 5 describes the Signaling and Encoding used by HDMI including descriptions of the different periods and encoding types used to transmit audio, video, and control data types and packet definitions for audio and auxiliary data.
- Chapter 6 describes Video related issues including video format timings, pixel encodings (RGB, YC_BC_R), colorimetry and corresponding requirements.
- Chapter 7 describes Audio related issues including audio clock regeneration, placement of audio samples within packets, packet timing requirements, audio sample rates and requirements, and channel/speaker assignments.
- Chapter 8 describes Control and Configuration functions, mechanisms and requirements, including use of the E-EDID, and InfoFrames.
- Chapter 9 describes the Content protection used for HDMI.
- Appendix A describes the usage of Repeaters and Switches.
- Appendix B describes restrictions related to the use of the Type B connector.
- Appendix C describes DVI compatibility.
- Appendix D describes additional details of Deep Color not covered in chapter 6, including example state machines and details of audio transmission in a Deep Color mode.
- Appendix E describes data structures and characteristics of gamut boundary descriptions, used when transmitting video using xvYCC colorimetry.
- Appendix F recommends a number of rules regarding a Sink's indication of video format support and automatic configuration of video output format for a Source.
- Supplement 1 describes use of the Consumer Electronics Control (CEC) line and protocol.

1.5 Usages and Conventions

bit N	Bits are numbered in little-endian format, i.e. the least-significant bit of a byte or word is referred to as bit 0.
D[X:Y]	Bit field representation covering bit X to bit Y (inclusive) of value or field D.
0xNN	Hexadecimal representation of base-16 numbers are represented using 'C' language notation, preceded by '0x'.
0bNN	Binary (base-2) numbers are represented using 'C' language notation, preceded by '0b'.
NN	Decimal (base-10) numbers are represented using no additional prefixes or suffixes.

Within this specification, any descriptions of data structures, values or sequences that occur on the HDMI interface should be interpreted only as data structures, values and sequences that are transmitted by the HDMI Source. Due to the possibility of errors during the transmission, these items should not be construed as data structures, values or sequences that are guaranteed to be detected by the HDMI Sink.

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2 Definitions

2.1 Conformance Levels

expected	A key word used to describe the behavior of the hardware or software in the design models *assumed* by this specification. Other hardware and software design models may also be implemented.
may	A key word that indicates flexibility of choice with *no implied preferenc*e.
shall	A key word indicating a mandatory requirement. Designers are *required* to implement all such mandatory requirements.
should	A key word indicating flexibility of choice with a strongly preferred alternative. Equivalent to the phrase *is recommended*.
reserved fields	A set of bits within a data structure that are defined in this specification as reserved, and are not otherwise used. Implementations of this specification shall zero these fields. Future revisions of this specification, however, may define their usage.
reserved values	A set of values for a field that are defined in this specification as reserved, and are not otherwise used. Implementations of this specification shall not generate these values for the field. Future revisions of this specification, however, may define their usage.

2.2 Glossary of Terms

(Audio) Channel	Audio data intended to be delivered to a single audio speaker.
(Audio) Sample Clock	Original clock related to the audio input samples at the Source or the generated clock used to time the output of audio samples.
BCH	Error correction technique named after the developers: Bose, Chauduri, and Hocquenghem.
Byte	Eight bits of data.
CEA Extension	A 128 byte EDID 1.3-compatible extension block defined in CEA-861-D, designed to allow declaration of audio formats, additional video formats (beyond those in the base EDID structure) and other characteristics of the Sink..
CEC Root (Device)	A device, generally a display (Sink) device, formally defined by the following rule: A device that has no HDMI output or, a device that has chosen to take the physical address 0.0.0.0 (see Section 8.7).
Compressed (Audio)	All audio formats carried by HDMI other than L-PCM and One Bit Audio.
Data Stream Disparity	Integer indicating “DC-offset” level of link. A positive value represents the excess number of “1”s that have been transmitted. A negative value represents the excess number of “0”s that have been transmitted.

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Direct Stream Transport	An audio format which is a lossless compression of Direct Stream Digital (DSD), as used in SuperAudio CD. DST is described in ISO/IEC 14496, part 3, Amendment 6: Lossless coding of oversampled audio.
Downstream	In the direction of the primary audio and video data flow, i.e. towards the Sink (e.g. display).
DVD-Audio	Disk format conforming to any version of “DVD Specifications for Read-Only Disc”, “Part 4: AUDIO SPECIFICATIONS”.
(HDMI) Source	A device with an HDMI output.
(HDMI) Sink	A device with an HDMI input.
(HDMI) Repeater	A device with one or more HDMI inputs and one or more HDMI outputs. Repeater devices shall simultaneously behave as both an HDMI Sink and an HDMI Source.
InfoFrame	A data structure defined in CEA-861-D that is designed to carry a variety of auxiliary data items regarding the audio or video streams or the source device and is carried from Source to Sink across HDMI.
Multi-channel	Audio with more than 2 channels. Typically this term is applied to 6 (5.1) channel streams. Also called surround formats.
One Bit Audio	1-bit Delta-Sigma modulated signal stream such as that used by Super Audio CD.
Pixel	Picture Element. Refers to the actual element of the picture and the data in the digital video stream representing such an element.
Pixel Encoding	Bit placement and sequencing for the components of a pixel for a particular color space and chroma sampling.
Receiver	A component that is responsible for receiving the four differential TMDS input pairs at the input to an HDMI Sink and converting those signals into a digital output indicating a 24 bit, 12 bit, or 6 bit TMDS decoded word and indicating the TMDS coding mode used to decode those bits. This digital output may be contained within a semiconductor device or may be output from a semiconductor device.
(TMDS) Character	A 10-bit TMDS-encoded value. One such value is carried on each of the three data channels for each cycle of the TMDS clock.
Stereo	2 channel audio.
Stream	A time-ordered set of digital data originating from one Source and terminating at zero or more Sinks. A stream is characterized by bounded bandwidth requirements.
Super Audio CD	Disk format of “Super Audio CD System Description”, see http://www.licensing.philips.com.
T_{bit}	Time duration of a single bit carried across the TMDS data channels.

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$T_{character}$	Time duration of a single TMDS character carried across the TMDS data channels. This is equal to $10*T_{bit}$.
Transmitter	A component that is responsible for driving the four differential TMDS output pairs into an HDMI output and for clocking the data driven into those four output pairs.
Video Field	The period from one VSYNC active edge to the next VSYNC active edge.
Video Format	A video format is sufficiently defined such that when it is received at the monitor, the monitor has enough information to properly display the video to the user. The definition of each format includes a Video Format Timing, the picture aspect ratio, and a colorimetry space.
Video Format Timing	The waveform associated with a video format. Note that a specific Video Format Timing may be associated with more than one Video Format (e.g., 720X480p@4:3 and 720X480p@16:9).
YC_BC_R	Digital representation of any video signal using one of several luminance/color-difference color spaces.

2.3 Acronyms and Abbreviations

ANSI	American National Standards Institute
AVI	Auxiliary Video Information
CEA	Consumer Electronics Association
CEC	Consumer Electronics Control
CTS	Cycle Time Stamp
DDC	Display Data Channel
DDWG	Digital Display Working Group
DST	Direct Stream Transport
DTD	Detailed Timing Descriptor
DTV	Digital Television
DVD	Digital Versatile Disc
DVI	Digital Visual Interface
E-DDC	Enhanced Display Data Channel
E-EDID	Enhanced Extended Display Identification Data
ECC	Error Correction Code

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EDID	Extended Display Identification Data
EIA	Electronic Industries Alliance
HDCP	High-bandwidth Digital Content Protection
HDMI	High-Definition Multimedia Interface
HDTV	High-Definition Television
HPD	Hot Plug Detect
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ITU	International Telecommunications Union
L-PCM	Linear Pulse-Code Modulation
LSb	least significant bit
MPEG	Moving Picture Experts Group
MSb	most significant bit
N.C.	No connect.
PCB	Printed Circuit Board
Rx	Receiver
SMPTE	Society of Motion Picture & Television Engineers
STB	Set-Top Box
SVD	Short Video Descriptor
TERC4	TMDS Error Reduction Coding – 4 bit
TMDS	Transition Minimized Differential Signaling
Tx	Transmitter
VESA	Video Electronics Standards Association
VSDB	Vendor-Specific Data Block

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3 Overview

HDMI system architecture is defined to consist of Sources and Sinks. A given device may have one or more HDMI inputs and one or more HDMI outputs. Each HDMI input on these devices shall follow all of the rules for an HDMI Sink and each HDMI output shall follow all of the rules for an HDMI Source.

As shown in *Figure 3-1,* the HDMI cable and connectors carry four differential pairs that make up the TMDS data and clock channels. These channels are used to carry video, audio and auxiliary data. In addition, HDMI carries a VESA DDC channel. The DDC is used for configuration and status exchange between a single Source and a single Sink. The optional CEC protocol provides high-level control functions between all of the various audiovisual products in a user's environment.

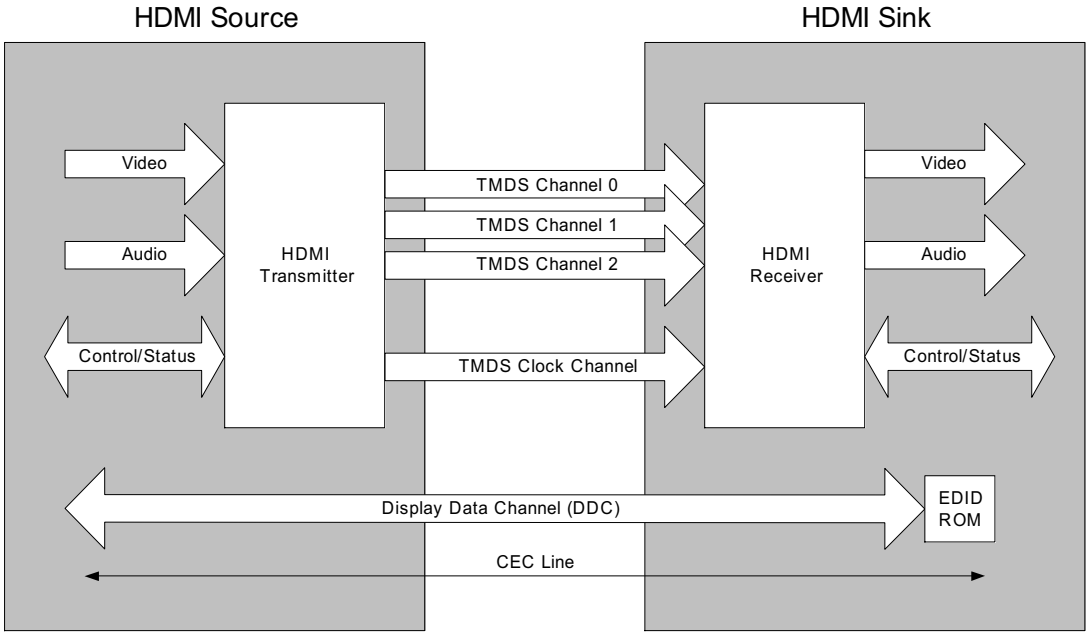


Figure 3-1 HDMI Block Diagram

Audio, video and auxiliary data is transmitted across the three TMDS data channels. A TMDS clock, typically running at the video pixel rate, is transmitted on the TMDS clock channel and is used by the receiver as a frequency reference for data recovery on the three TMDS data channels. At the source, TMDS encoding converts the 8 bits per TMDS data channel into the 10 bit DC-balanced, transition minimized sequence which is then transmitted serially across the pair at a rate of 10 bits per TMDS clock period.

Video data can have a pixel size of 24, 30, 36 or 48 bits. Video at the default 24-bit color depth is carried at a TMDS clock rate equal to the pixel clock rate. Higher color depths are carried using a correspondingly higher TMDS clock rate. Video formats with TMDS rates below 25MHz (e.g. 13.5MHz for 480i/NTSC) can be transmitted using a pixel-repetition scheme. The video pixels can be encoded in either RGB, YC_BC_R 4:4:4 or YC_BC_R 4:2:2 formats.

In order to transmit audio and auxiliary data across the TMDS channels, HDMI uses a packet structure. In order to attain the higher reliability required of audio and control data, this data is

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protected with a BCH error correction code and is encoded using a special error reduction coding to produce the 10-bit word that is transmitted.

Basic audio functionality consists of a single IEC 60958 L-PCM audio stream at sample rates of 32kHz, 44.1kHz or 48kHz. This can accommodate any normal stereo stream. Optionally, HDMI can carry such audio at sample rates up to 192KHz and with 3 to 8 audio channels. HDMI can also carry an IEC 61937 compressed (e.g. surround-sound) audio stream at bit rates up to 24.576Mbps. HDMI can also carry from 2 to 8 channels of One Bit Audio and a compressed form of One Bit Audio called DST.

The DDC is used by the Source to read the Sink's Enhanced Extended Display Identification Data (E-EDID) in order to discover the Sink's configuration and/or capabilities.

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4 Physical Layer

4.1 Connectors and Cables

4.1.1 Overview of Connectors

A device's external HDMI connection shall be presented via one of the three specified HDMI connectors, Type A, Type B or Type C. This connector can be attached directly to the device or can be attached via a cable adapter that is shipped with the device.

All three connectors carry all required HDMI signals, including a TMDS link. The Type B connector is slightly larger and carries a second TMDS link, which is necessary to support very high resolution displays using dual link. The Type C connector carries the same signals as the Type A but is more compact and intended for mobile applications.

Passive cable adapters between connector types are specified.

4.1.2 Connector Support Requirements

All features and functions are equally available to all three connectors.

4.1.3 Dual-Link

To support DVI signals greater than 165Mpixels/sec, the dual-link capability of the Type B connector shall be used. To support DVI signals less than or equal to 165Mpixels/sec, single-link operation shall be used.

To support very high-speed HDMI signals, the dual-link capability of the Type B connector is available. The single-link to dual-link crossover frequency for HDMI will be defined in a future specification and will be greater than 340Mpixels/sec. Dual-link cannot be used for formats below that crossover frequency.

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4.1.4 Connector Pin Assignments

Table 4-1 Type A Connector Pin Assignment

PIN	Signal Assignment
1	TMDS Data2+
3	TMDS Data2–
5	TMDS Data1 Shield
7	TMDS Data0+
9	TMDS Data0–
11	TMDS Clock Shield
13	CEC
15	SCL
17	DDC/CEC Ground
19	Hot Plug Detect

PIN	Signal Assignment
2	TMDS Data2 Shield
4	TMDS Data1+
6	TMDS Data1–
8	TMDS Data0 Shield
10	TMDS Clock+
12	TMDS Clock–
14	Reserved (N.C. on device)
16	SDA
18	+5V Power

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Table 4-2 Type B Connector Pin Assignment

PIN	Signal Assignment
1	TMDS Data2+
3	TMDS Data2-
5	TMDS Data1 Shield
7	TMDS Data0+
9	TMDS Data0-
11	TMDS Clock Shield
13	TMDS Data5+
15	TMDS Data5-
17	TMDS Data4 Shield
19	TMDS Data3+
21	TMDS Data3-
23	Reserved (N.C. on device)
25	SCL
27	DDC/CEC Ground
29	Hot Plug Detect

PIN	Signal Assignment
2	TMDS Data2 Shield
4	TMDS Data1+
6	TMDS Data1-
8	TMDS Data0 Shield
10	TMDS Clock+
12	TMDS Clock-
14	TMDS Data5 Shield
16	TMDS Data4+
18	TMDS Data4-
20	TMDS Data3 Shield
22	CEC
24	Reserved (N.C. on device)
26	SDA
28	+5V Power

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Table 4-3 Type C Connector Pin Assignment

PIN	Signal Assignment
1	TMDS Data2 Shield
2	TMDS Data2+
3	TMDS Data2-
4	TMDS Data1 Shield
5	TMDS Data1+
6	TMDS Data1-
7	TMDS Data0 Shield
8	TMDS Data0+
9	TMDS Data0-
10	TMDS Clock Shield
11	TMDS Clock+
12	TMDS Clock-
13	DDC/CEC Ground
14	CEC
15	SCL
16	SDA
17	Reserved
18	+5V Power
19	Hot Plug Detect

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4.1.5 Contact sequence

Table 4-4 Connector Contact Sequence

Connection	Signals	
	Type A & C Connectors	Type B Connector
First Make	Connector shell	Connector shell
Second Make	Pins 1 - 17 and pin 19	Pins 1 - 27 and pin 29
Third Make	Pin18 (+5V Power)	Pin28 (+5V Power)

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4.1.6 Connector Mechanical Performance

Table 4-5 Type A and Type C Plug and Receptacle Mechanical Performance

Item	Test Condition	Requirement	
Vibration	Amplitude : 1.52mm P-P or 147m/s^2 {15G} Sweep time: 50-2000-50Hz in 20 minutes. Duration : 12 times in each (total of 36 Times) X, Y, Z axes. Electrical load : DC100mA current shall be Flowed during the test. (ANSI/EIA-364-28 Condition III)	Appearance	No Damage
		Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell Part : Change from initial value: 50 milliohms maximum.
		Discontinuity	1 μsec maximum.
Shock	Pulse width: 11 msec., Waveform : half sine, 490m/s^2{50G}, 3 strokes in each X.Y.Z. axes (ANSI/EIA-364-27, Condition A)	Appearance	No Damage
		Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell : Change from initial value: 50 milliohms maximum.
		Discontinuity	1 μsec maximum.
Durability	Measure contact and shell resistance after Following. Automatic cycling : Type A: 10,000 cycles at 100 ± 50 cycles per hour Type C: 5,000 cycles at 100 ± 50 cycles per hour	Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell : Change from initial value: 50 milliohms maximum.

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Item	Test Condition	Requirement	
Insertion / Withdrawal Force	Insertion and withdrawal speed : 25mm/minute. (ANSI/EIA-364-13)	Withdrawal force	Type A: 9.8N {1.0kgf} minimum 39.2N {4.0kgf} maximum Type C: 7N minimum 25N maximum
		Insertion force	44.1N {4.5kgf} maximum
Cable Flex	100 cycles in each of 2 planes Dimension X = 3.7 x Cable Diameter. (ANSI/EIA-364-41C, Condition I)	Discontinuity	1 μsec maximum.
		Dielectric Withstanding Voltage and Insulation Resistance	Conform to item of dielectric withstanding voltage and insulation resistance

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4.1.7 Connector Electrical Characteristics

4.1.7.1 Electrical Performance

Table 4-6 Electrical Performance

Item	Test Condition	Requirement
Contact Resistance	Mated connectors, Contact : measure by dry circuit, 20 mVolts maximum.,10mA. Shell : measured by open circuit, 5 Volts maximum ,100mA. (ANSI/EIA-364-06B)	Initial Contact resistance excluding conductor resistance: 10 milliohms maximum . (Target design value)
Dielectric Strength	Unmated connectors, apply 500 Volts AC(RMS) between adjacent terminal or ground. Mated connector, apply 300 Volts AC(RMS.) between adjacent terminal and ground. (ANSI/EIA-364-20C, Method A)	No Breakdown
Insulation Resistance	Unmated connectors, apply 500 Volts DC between adjacent terminal or ground. (ANSI/EIA 364-21C)	100 megaohms minimum (unmated)
	Mated connectors, apply 150 Volts DC between adjacent terminal or ground.	10 megaohms minimum (mated)
Contact Current Rating	55 °C, maximum ambient 85 °C, maximum temperature change (ANSI/EIA-364-70A)	0.5 A minimum
Applied Voltage Rating	40 Volts AC (RMS.) continuous maximum, on any signal pin with respect to the shield.	No Breakdown
Electrostatic Discharge	Test unmated each connectors from 1 kVolt to 8 kVolts in 1 kVolt steps using 8mm ball probe. (IEC-801-2)	No evidence of Discharge to Contacts at 8 kVolts

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Item	Test Condition	Requirement
TMDS Signals Time Domain Impedance	Rise time ≤ 200 psec (10%-90%). Signal to Ground pin ratio per HDMI designation. Differential Measurement Specimen Environment Impedance = 100 ohms differential Source-side receptacle connector mounted on a controlled impedance PCB fixture. (ANSI/EIA-364-108)	Connector Area : Type A: 100 ohms ±15% Type C: 100 ohms ±25% Transition Area : 100 ohms ±15% Cable Area : 100 ohms ±10%
TMDS Signals Time Domain Cross talk FEXT	Rise time ≤ 200 psec (10%-90%). Signal to Ground pin ratio per HDMI designation. Differential Measurement Specimen Environment Impedance = 100 ohms differential. Source-side receptacle connector mounted on controlled impedance PCB fixture. Driven pair and victim pair. (ANSI/EIA-364-90)	Type A: 5% maximum Type C: 10% maximum

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4.1.8 Connector Environmental Characteristics

4.1.8.1 Environmental Performance

Table 4-7 Connector Environmental Performance

Item	Test Condition		Requirement	
Thermal Shock	10 cycles of: a) -55°Cfor 30 minutes b) +85°C for 30 minutes (ANSI/EIA-364-32C, Condition I)		Appearance	No Damage
			Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell Part : Change from initial value: 50 milliohms maximum.
Humidity	A	Mate connectors together and perform the test as follows. Temperature : +25 to +85°C Relative Humidity : 80 to 95% Duration : 4 cycles (96 hours) Upon completion of the test, specimens shall be conditioned at ambient room conditions for 24 hours, after which the specified measurements shall be performed. (ANSI/EIA-364-31B)	Appearance	No Damage
			Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell : Change from initial value: 50 milliohms maximum.
	B	Unmated each connectors and perform the test as follows. Temperature : +25 to +85°C Relative Humidity : 80 to 95% Duration : 4 cycles (96 hours) Upon completion of the test, specimens shall be conditioned at ambient room conditions for 24 hours, after which the specified measurements shall be performed. (ANSI/EIA-364-31B)	Appearance	No Damage
			Dielectric Withstanding Voltage and Insulation Resistance	Conform to item of Dielectric Withstanding Voltage and Insulation Resistance

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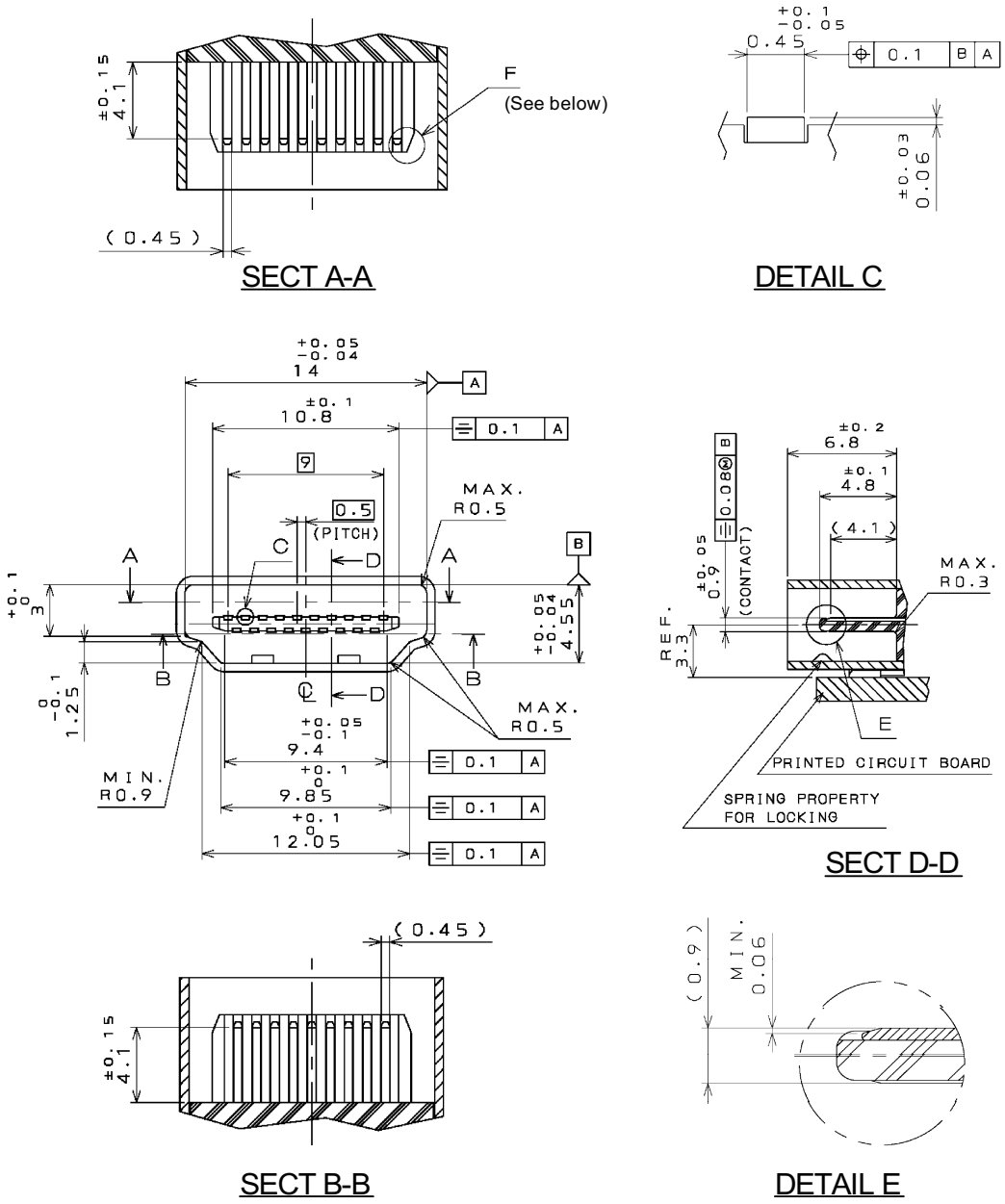
Item	Test Condition	Requirement	
Thermal Aging	Mate connectors and expose to +105 ± 2°C for 250 hours. Upon completion of the exposure period, the test specimens shall be conditioned at ambient room conditions for 1 to 2 hours, after which the specified measurements shall be performed. (ANSI/EIA-364-17B, Condition 4, Method A)	Appearance	No Damage
		Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell Part : Change from initial value: 50 milliohms maximum.

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4.1.9 Connector Drawings – Mating Interface Dimensions

All dimensions in millimeters.

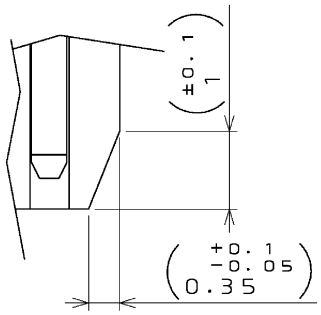
4.1.9.1 Type A Receptacle



- The shell shall have springs for locking. Additional springs may be used for EMI reduction.
- The spring property for locking shall be activated by the locking hole of the plug shell.

Figure 4-1 Type A Receptacle Mating Interface Dimensions

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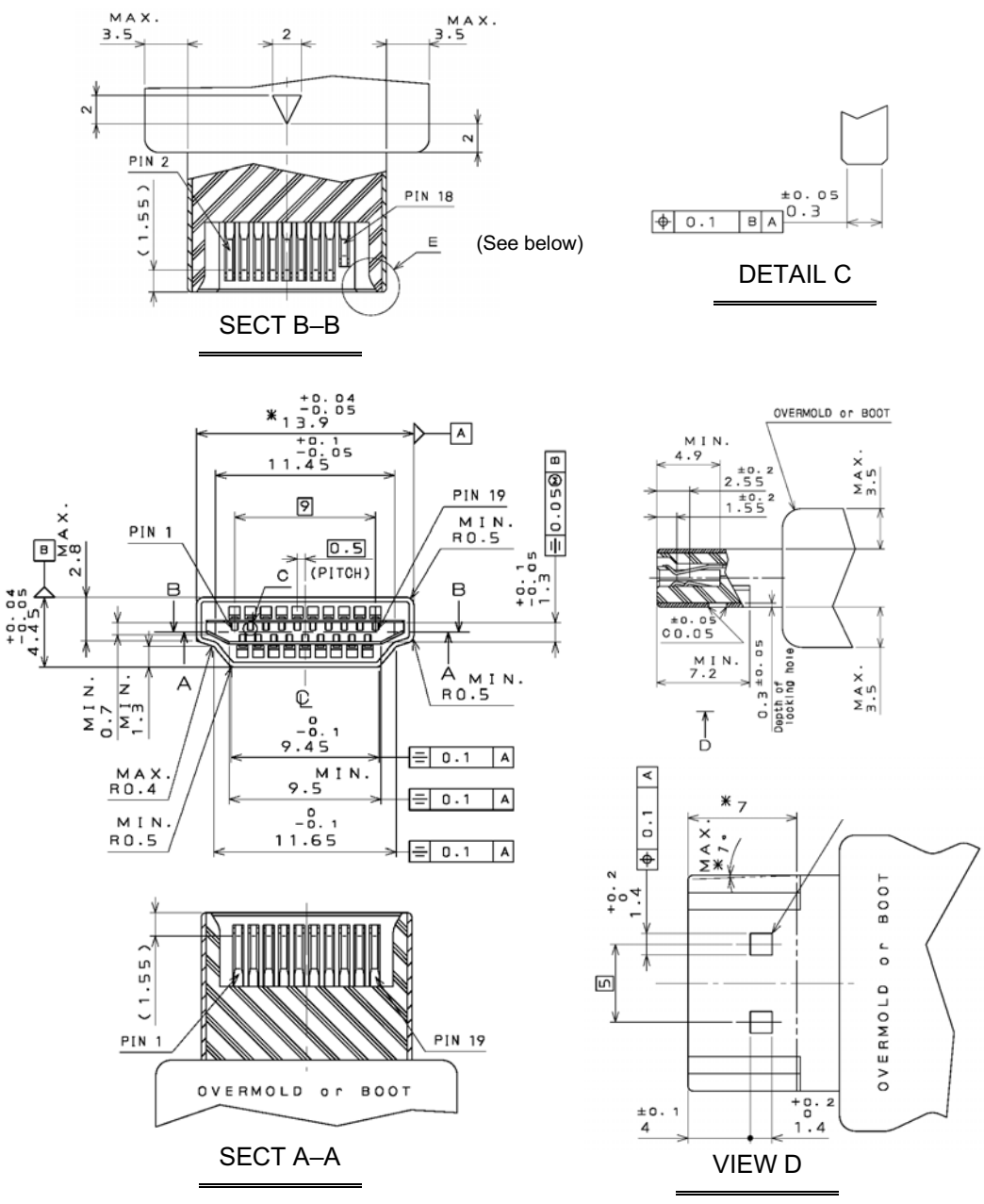
DETAIL F

- The form shown above is required. This feature will reduce the likelihood of damage to the receptacle insulator under rough operation.

Figure 4-1–continued; Type A Receptacle, Detail F

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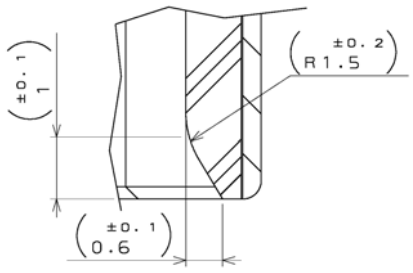
4.1.9.2 Type A Plug



- The dimension of *13.9mm (+0.04 / -0.05) (on main section) should be measured at the point *7mm (on view D). The taper (on view D) shall be one degree max.
- The shell should not have a dimple other than the ones for locking.

Figure 4-2 Type A Plug Mating Interface Dimensions

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DETAIL E

- The form shown above is required. This feature will reduce the likelihood of damage to the receptacle insulator under rough operation.

Figure 4-2-continued; Type A Plug, Detail E

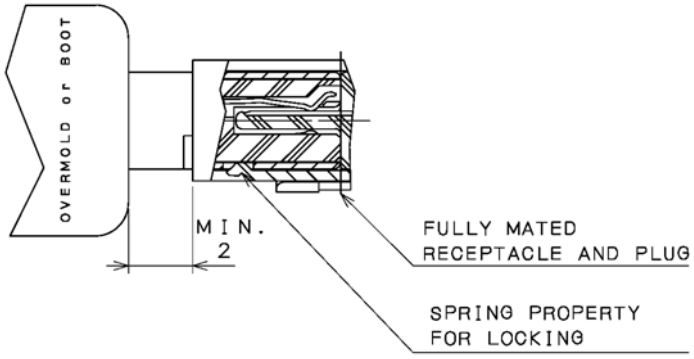


Figure 4-3 Type A Receptacle and Plug Mated Condition

It is recommended that products using Type A connectors be designed to ensure that cable bends are not tighter than that shown in Figure 4-4.

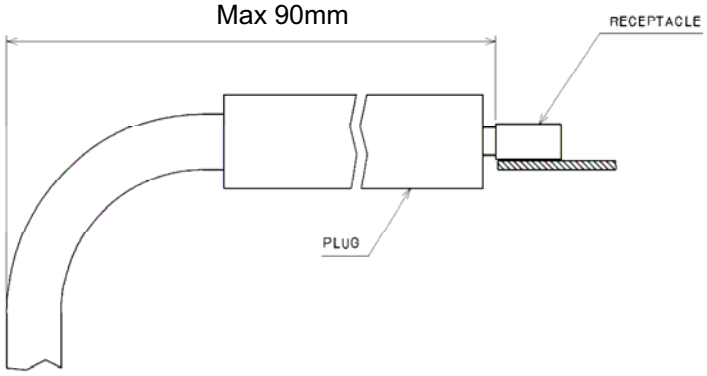
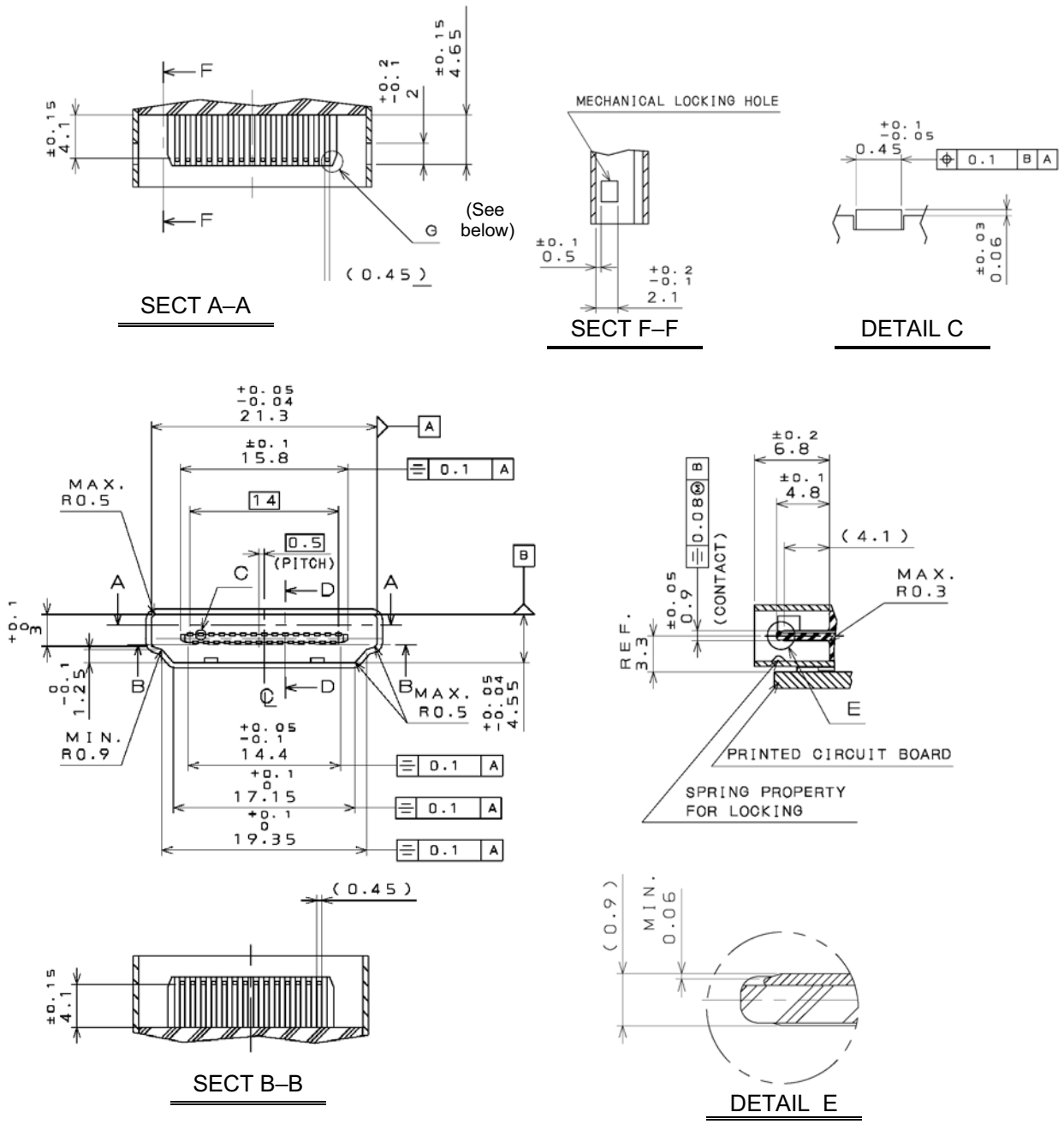


Figure 4-4 Type A Cable – Minimum Recommended Cable Bend

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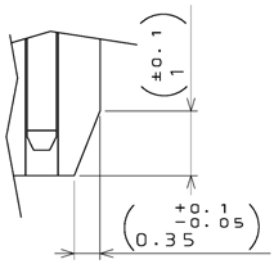
4.1.9.3 Type B Receptacle



- The shell shall have springs for locking. Additional springs may be used for EMI reduction.
- The spring property for locking shall be activated by the locking hole of the plug shell.

Figure 4-5 Type B Receptacle Mating Interface Dimensions

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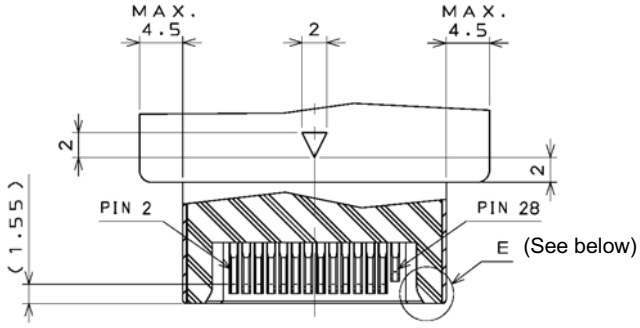
DETAIL G

- The form shown above is required. This feature will reduce the likelihood of damage to the receptacle insulator under rough operation.

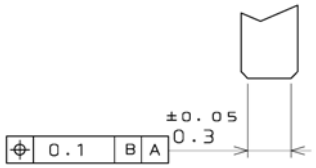
Figure 4-5-continued; Type B Receptacle, Detail G

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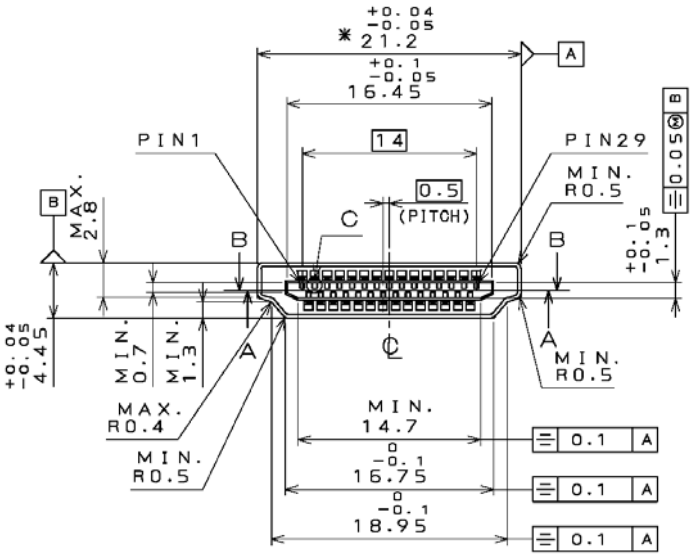
4.1.9.4 Type B Plug

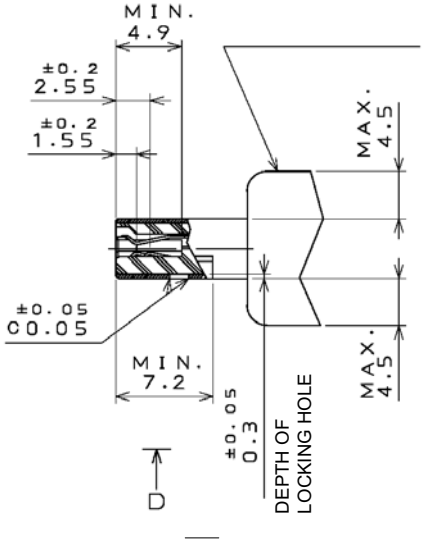


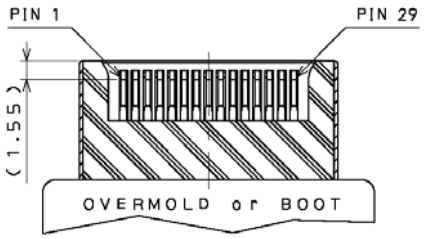
SECT B–B



DETAIL C





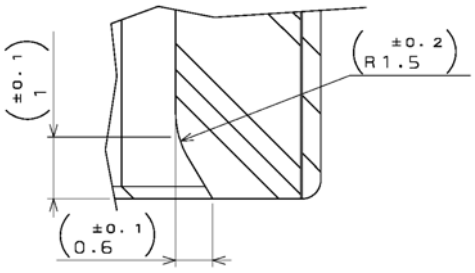


SECT A–A

"VIEW D" → NEXT PAGE

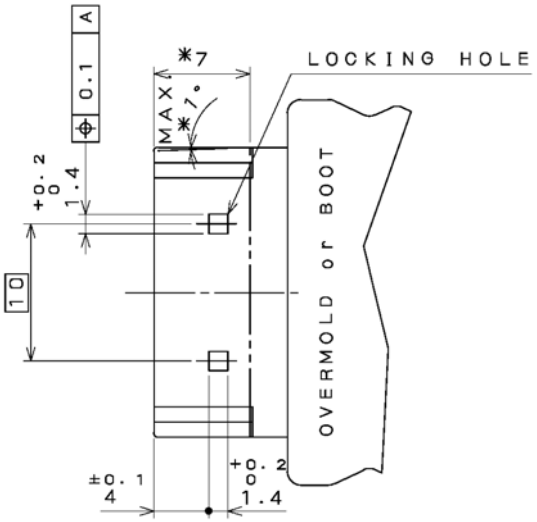
- The dimension of *21.2mm (+0.04 / -0.05) (on main section) should be measured at the point *7mm (on view D). The taper (on view D) shall be one degree max.
- The shell should not have a dimple other than the ones for locking.

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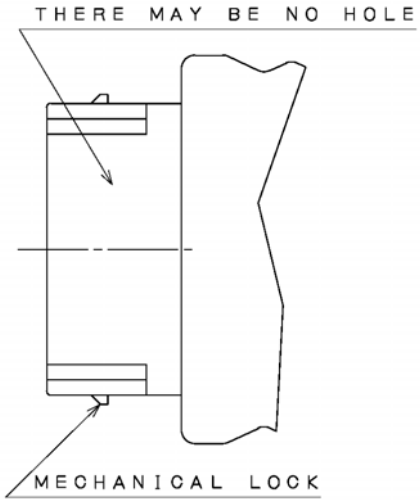


DETAIL E

- The form shown above is required. This feature will reduce the likelihood of damage to the receptacle insulator under rough operation.



FRICTION LOCK TYPE



MECHANICAL LOCK TYPE
The spring property for locking should be activated by the locking hole of the plug shell.

VIEW D

Figure 4-6 Type B Plug Mating Interface Dimensions

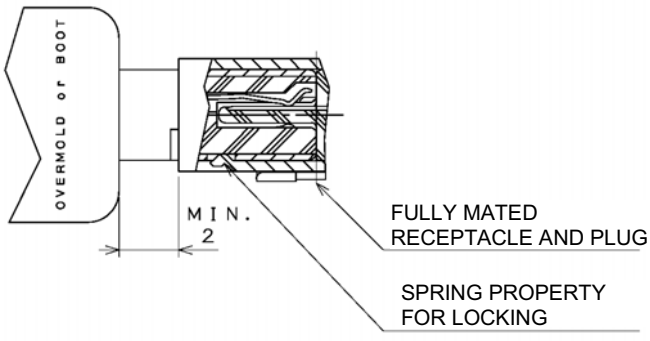
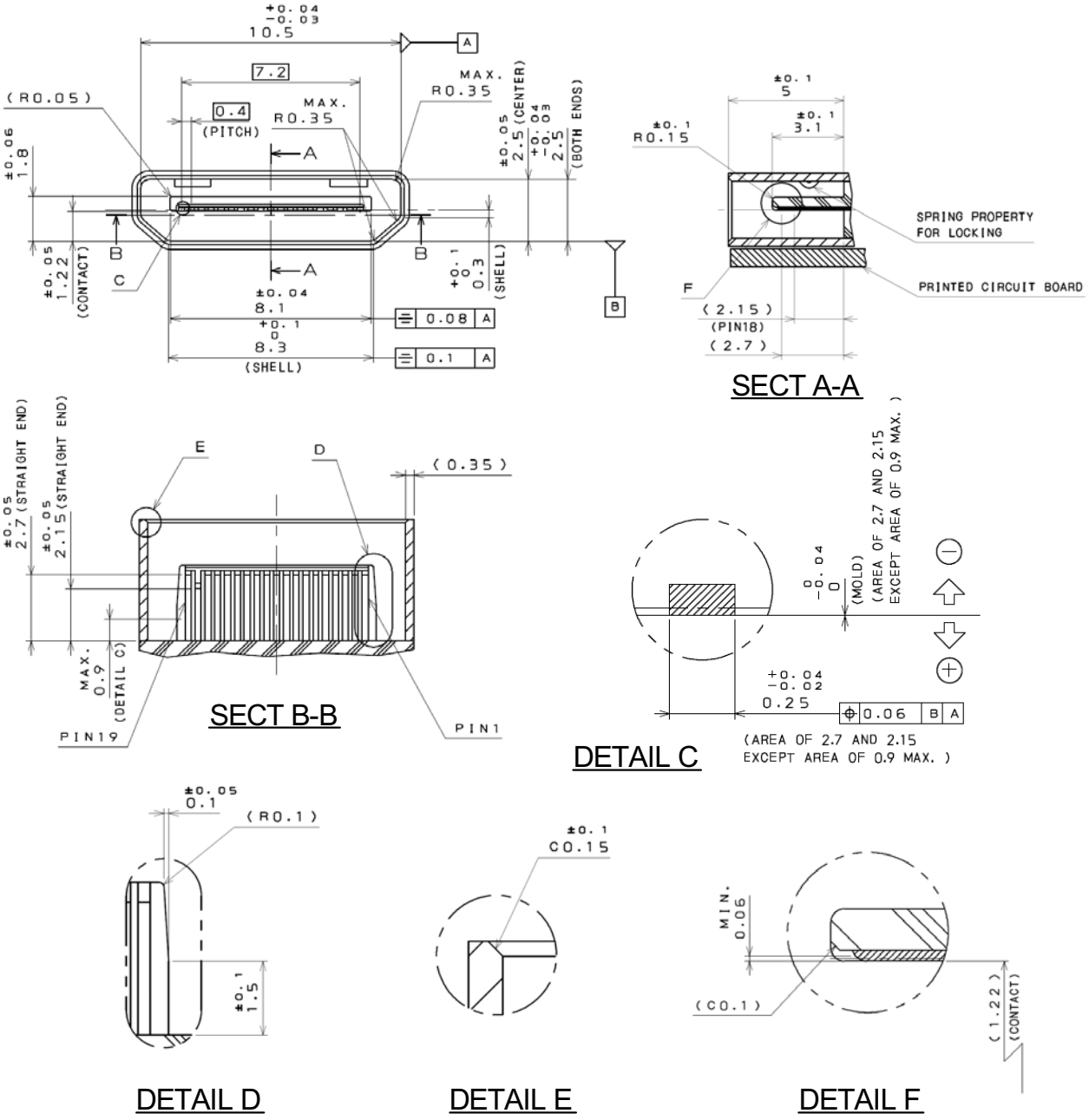


Figure 4-7 Type B Receptacle and Plug Mated Condition

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4.1.9.5 Type C Receptacle

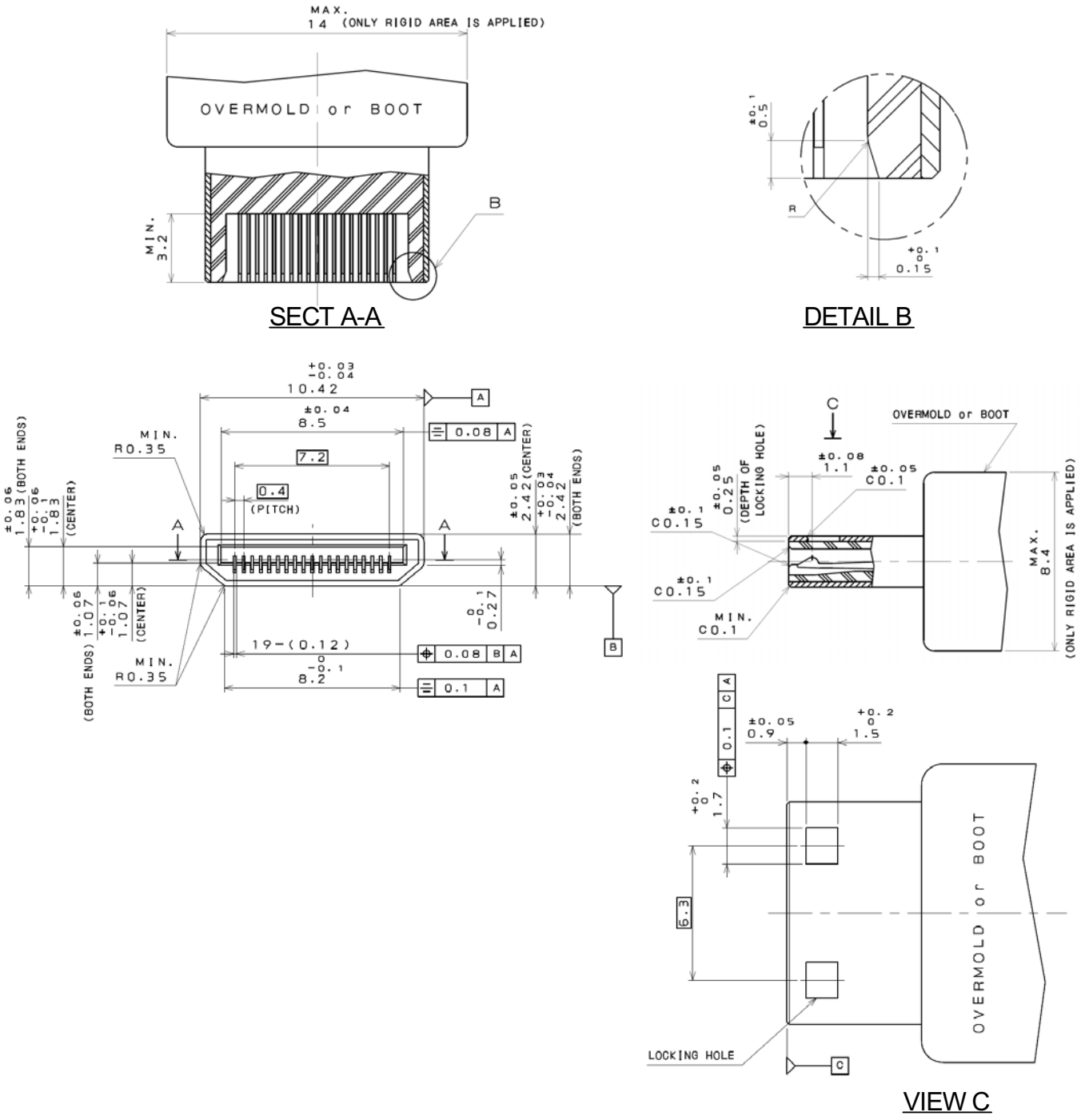


- The shell shall have spring for locking. Additional springs may be used for EMI reduction
- The spring property for locking shall be activated by the locking hole of the plug shell.

Figure 4-8 Type C Receptacle Mating Interface Dimensions

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4.1.9.6 Type C Plug



- The shell should not have a dimple other than the ones for locking.
- The cable should have a maximum diameter of 7mm

Figure 4-9 Type C Plug Mating Interface Dimensions

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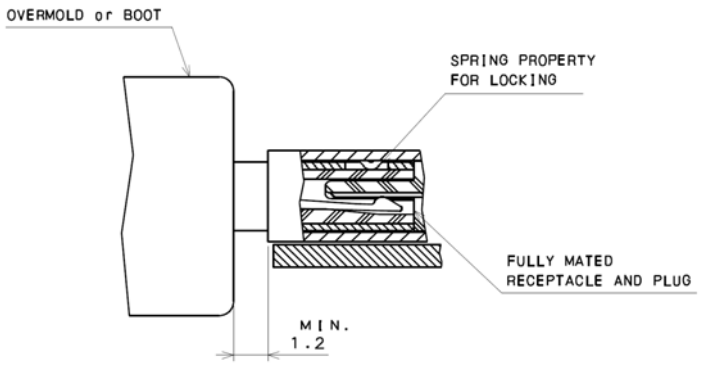


Figure 4-10 Type C Receptacle and Plug Mated Condition

It is recommended that products using Type C connectors be designed to ensure that cable bends are not tighter than that shown in Figure 4-11. In addition, for strength, it is recommended that the shell flange and the case be fixed with a screw and that the clearance between the connector and the case be as narrow as possible.

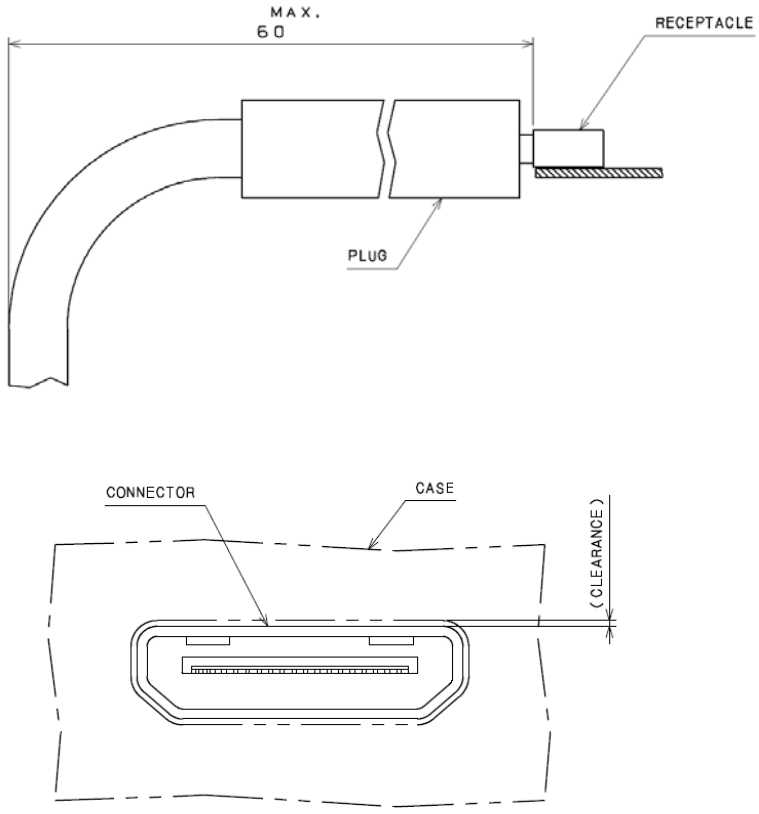


Figure 4-11 Type C Product Design Recommendations

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4.1.10 Cable Adapter Specification

Table 4-8 Wire Categories

Category	Description
A	TMDS Signal Wire
B	TMDS Shield
C	Control
D	Control Ground
N.C.	No connect (no wire)
5V	5 Volts Power Wire

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4.1.10.1 Type A Connector to Type A Connector

Table 4-9 Type A-to-Type A Cable Wire Assignment

Type A pin	Signal Name	Wire	Type A pin
1	TMDS Data2+	A	1
2	TMDS Data2 Shield	B	2
3	TMDS Data2–	A	3
4	TMDS Data1+	A	4
5	TMDS Data1 Shield	B	5
6	TMDS Data1–	A	6
7	TMDS Data0+	A	7
8	TMDS Data0 Shield	B	8
9	TMDS Data0–	A	9
10	TMDS Clock+	A	10
11	TMDS Clock Shield	B	11
12	TMDS Clock–	A	12
13	CEC	C	13
14	Reserved (in cable but N.C. on device)	C	14
15	SCL	C	15
16	SDA	C	16
17	DDC/CEC Ground	D	17
18	+5V Power	5V	18
19	Hot Plug Detect	C	19

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4.1.10.2 Type A Connector to Type B Connector

Table 4-10 Type A-to-Type B Cable Wire Assignment

Type A pin	Pin Assignment	Wire	Type B pin
1	TMDS Data2+	A	1
2	TMDS Data2 Shield	B	2
3	TMDS Data2-	A	3
4	TMDS Data1+	A	4
5	TMDS Data1 Shield	B	5
6	TMDS Data1-	A	6
7	TMDS Data0+	A	7
8	TMDS Data0 Shield	B	8
9	TMDS Data0-	A	9
10	TMDS Clock+	A	10
11	TMDS Clock Shield	B	11
12	TMDS Clock-	A	12
13	CEC	C	22
15	SCL	C	25
16	SDA	C	26
17	DDC/CEC Ground	D	27
18	+5V Power	5V	28
19	Hot Plug Detect	C	29
14	No connect	N.C.	
	No connect	N.C.	23
	No connect	N.C.	24

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4.1.10.3 Type B Connector to Type B Connector

Table 4-11 Type B to Type B Cable Wire Assignment

Type B pin	Pin Assignment	Wire	Type B pin
1	TMDS Data2+	A	1
2	TMDS Data2 Shield	B	2
3	TMDS Data2-	A	3
4	TMDS Data1+	A	4
5	TMDS Data1 Shield	B	5
6	TMDS Data1-	A	6
7	TMDS Data0+	A	7
8	TMDS Data0 Shield	B	8
9	TMDS Data0-	A	9
10	TMDS Clock+	A	10
11	TMDS Clock Shield	B	11
12	TMDS Clock-	A	12
13	TMDS Data5+	A	13
14	TMDS Data5 Shield	B	14
15	TMDS Data5-	A	15
16	TMDS Data4+	A	16
17	TMDS Data4 Shield	B	17
18	TMDS Data4-	A	18
19	TMDS Data3+	A	19
20	TMDS Data3 Shield	B	20
21	TMDS Data3-	A	21
22	CEC	C	22
25	SCL	C	25
26	SDA	C	26
27	DDC/CEC Ground	D	27
28	+5V Power	5V	28
29	Hot Plug Detect	C	29
23	No Connect	N.C.	
24	No Connect	N.C.	
	No Connect	N.C.	23
	No Connect	N.C.	24

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4.1.10.4 Type C Connector to Type C Connector

Table 4-12 Type C-to-Type C Cable Wire Assignment

Type C pin	Signal Name	Wire	Type C pin
1	TMDS Data2 Shield	B	1
2	TMDS Data2+	A	2
3	TMDS Data2-	A	3
4	TMDS Data1 Shield	B	4
5	TMDS Data1+	A	5
6	TMDS Data1-	A	6
7	TMDS Data0 Shield	B	7
8	TMDS Data0+	A	8
9	TMDS Data0-	A	9
10	TMDS Clock Shield	B	10
11	TMDS Clock+	A	11
12	TMDS Clock-	A	12
13	DDC/CEC Ground	D	13
14	CEC	C	14
15	SCL	C	15
16	SDA	C	16
17	Reserved (in cable but N.C. on device)	C	17
18	+5V Power	5V	18
19	Hot Plug Detect	C	19

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4.1.10.5 Type C Connector to Type A Connector

Table 4-13 Type C-to-Type A Cable Wire Assignment

Type C pin	Signal Name	Wire	Type A pin
1	TMDS Data2 Shield	B	2
2	TMDS Data2+	A	1
3	TMDS Data2-	A	3
4	TMDS Data1 Shield	B	5
5	TMDS Data1+	A	4
6	TMDS Data1-	A	6
7	TMDS Data0 Shield	B	8
8	TMDS Data0+	A	7
9	TMDS Data0-	A	9
10	TMDS Clock Shield	B	11
11	TMDS Clock+	A	10
12	TMDS Clock-	A	12
13	DDC/CEC Ground	D	17
14	CEC	C	13
15	SCL	C	15
16	SDA	C	16
17	Reserved (in cable but N.C. on device)	C	14
18	+5V Power	5V	18
19	Hot Plug Detect	C	19

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4.2 Electrical Specification

Some timing parameter values in this specification are based on the clock rate of the link while others are based on absolute values. For scalable timing parameters based on the TMDS clock rate, the time period of the clock is denoted as 'TMDS character time', or $T_{character}$. One tenth of the character time is called the bit time, or T_{bit}. The bit time is also referred to as one Unit Interval in the jitter and eye diagram specifications.

Schematic diagrams contained in this chapter are for illustration only and do not represent the only feasible implementation.

4.2.1 TMDS Overview

The conceptual schematic of one TMDS differential pair is shown in Figure 4-12. TMDS technology uses current drive to develop the low voltage differential signal at the Sink side of the DC-coupled transmission line. The link reference voltage AV_{cc} sets the high voltage level of the differential signal, while the low voltage level is determined by the current source of the HDMI Source and the termination resistance at the Sink. The termination resistance (R_T) and the characteristic impedance of the cable (Z_0) must be matched.

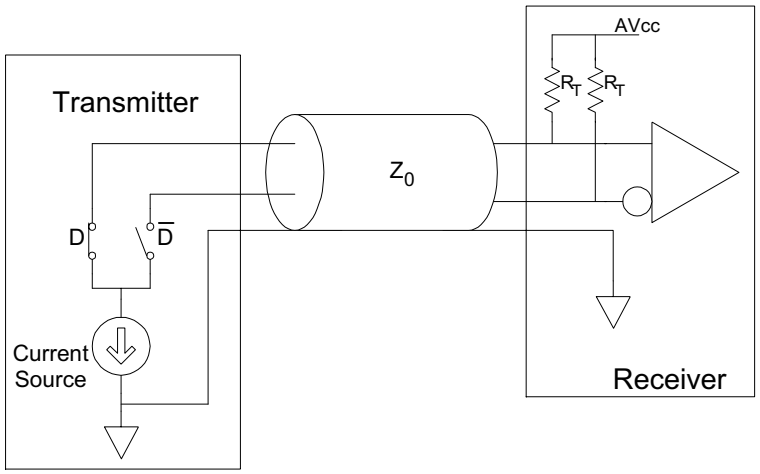


Figure 4-12 Conceptual Schematic for one TMDS differential pair

A single-ended differential signal, representing either the positive or negative terminal of a differential pair, is illustrated in Figure 4-13. The nominal high-level voltage of the signal is AV_{cc} and the nominal low-level voltage of the signal is (AV_{cc} - V_{swing}). Since the swing is differential on the pair, the net signal on the pair has a swing twice that of the single-ended signal, or $2*V_{swing}$. The differential signal, as shown in Figure 4-14, swings between positive V_{swing} and negative V_{swing}.

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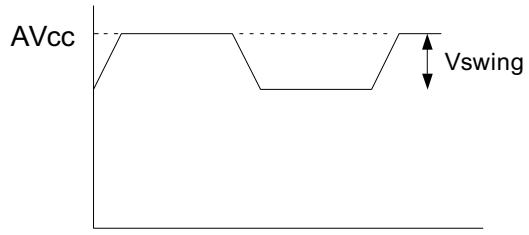


Figure 4-13 Single-ended Differential Signal

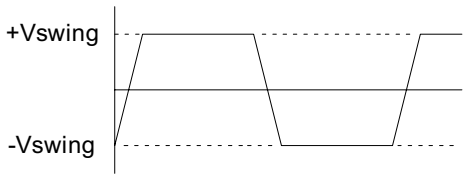


Figure 4-14 Differential Signal

The signal test points for a TMDS link are shown in Figure 4-15. TP1 is used for testing of HDMI Sources and Transmitter components. TP2 is used for testing of HDMI Sinks and Receiver components. TP1 and TP2 together are also used for testing of cables.

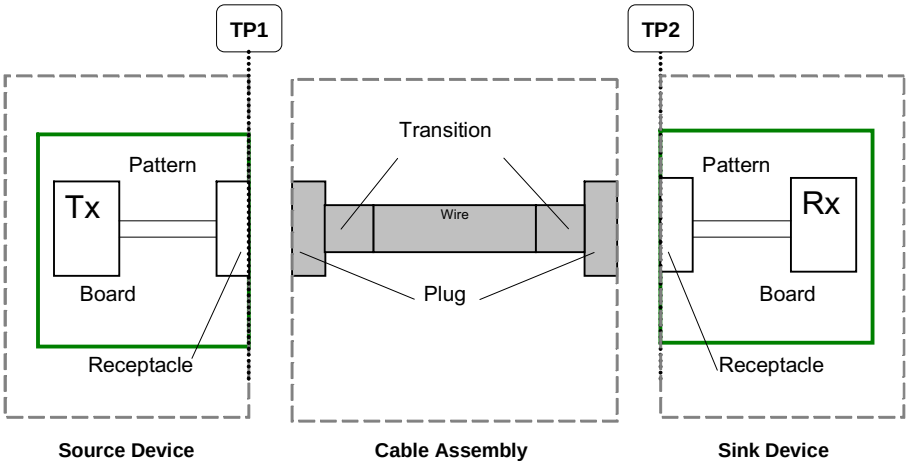


Figure 4-15 TMDS Link Test Points

4.2.2 TMDS System Operating Conditions

The required operating conditions of the TMDS pairs are specified in Table 4-14.

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Table 4-14 Required Operating Conditions for HDMI Interface (see Figure 4-12)

Item	Value
Termination Supply Voltage, AV_{cc}	3.3 Volts ±5%
Termination Resistance, R_T	50 ohms ±10%

4.2.3 TMDS Specification and Testing Overview

4.2.3.1 Jitter and Eye Measurements: Ideal Recovery Clock

All TMDS Clock and Data signal jitter specifications are specified relative to an Ideal Recovery Clock defined below. The Data jitter is not specified numerically, but instead, an HDMI device or cable shall adhere to the appropriate eye diagram(s) when the TMDS data signals are measured using an Ideal Recovery Clock as a trigger source.

The TMDS Clock signal may contain low-frequency jitter components, which can be tracked by a Sink's clock recovery circuitry, and high-frequency components, which are not typically tracked. The purpose of the Ideal Recovery Clock is to give an accurate representation of link performance when used as a trigger for eye diagram and clock jitter specifications. The relationship of clock jitter to data jitter is specified only indirectly by the eye mask.

For the purposes of jitter and eye diagram specification, the Ideal Recovery Clock is defined relative to the TMDS clock signal. The Ideal Recovery Clock shall be equivalent to the signal that would be derived by a perfect PLL (Ideal Clock Recovery Unit) with a jitter transfer function shown in Equation 4-1, when the TMDS clock signal were input into that PLL. This jitter transfer function has the behavior of a low pass filter with 20dB/decade roll-off and with a –3dB point of 4MHz.

For the purposes of compliance testing, a Clock Recovery Unit is used to generate a Recovered Clock, which is meant to approximate the Ideal Recovery Clock. This Recovered Clock is used for measurement of the jitter and eye diagram.

$$H(j\omega) = 1 / (1 + j\omega/\omega_0)$$

Where $\omega_0 = 2\pi F_0$, $F_0 = 4.0\text{MHz}$

Equation 4-1 Jitter Transfer Function of Ideal CRU for Ideal Recovery Clock Definition

4.2.3.2 Reference Cable Equalizer

The signal degradation introduced by typical passive cables increases with the frequency of the signal and the length of the cable. In order to accommodate passive copper cables of market-required lengths at the very high frequencies supported by HDMI, higher-speed HDMI Sinks are expected to support some sort of cable equalization function which allows them to recover data from such cables.

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For lower-speed operation, the HDMI cable is specified with respect to the worst-case Source output eye (cable input eye) and the Sink input eye. For higher-speed operation, the HDMI cable specification also assumes application by the Sink of a cable equalization function approximating the performance implied by the Reference Cable Equalizer, which is a specified mathematical model of cable equalization.

The HDMI Sink is required to successfully recover the data stream from any compliant Sink input signal. At high frequencies, a compliant Sink input signal is any signal that, after application of the Reference Cable Equalizer to each of the differential TMDS signals, results in a signal that meets the Sink input eye requirements.

The definition of the Reference Cable Equalizer is given in Equation 4-2. The gain of this equation is shown in Figure 4-16.

$$|H(j\omega)| = \begin{cases} e^{A*\omega^N} & (\omega < \omega_0) \\ e^{-B*(\omega-1.2*\omega_0)^2+C} & (\omega_0 < \omega < 1.4*\omega_0) \\ e^{-D*\omega+E} & (1.4*\omega_0 < \omega) \end{cases}$$

Where:

$$N = 0.7$$

$$\omega_0 = 2\pi * 2.25GHz$$

$$A = 7.34E-8$$

$$B = \frac{7}{4} * A * \omega_0^{-1.3}$$

$$C = 1.07 * A * \omega_0^{0.7}$$

$$D = 0.7 * A * \omega_0^{-0.3}$$

$$E = 1.98 * A * \omega_0^{0.7}$$

Equation 4-2 Reference Cable Equalizer Function

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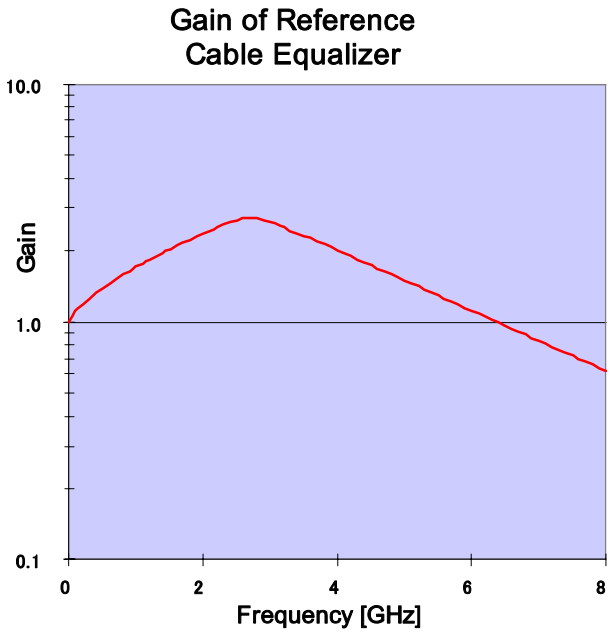


Figure 4-16 Gain of Reference Cable Equalizer

4.2.4 HDMI Source TMDS Characteristics

HDMI requires a DC-coupled TMDS link. Source electrical testing shall be performed using the test load shown in Figure 4-17, with AV_{cc} set to 3.3V. TP1 represents the connection point of the receptacle.

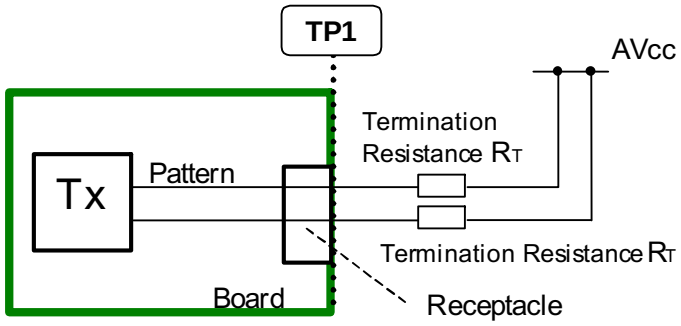


Figure 4-17 Balanced Source Test Load

The Source shall meet the DC specifications in Table 4-15 for all operating conditions specified in Table 4-14 when driving clock and data signals. The V_{swing} parameter is the difference between the single-ended most common high-level voltage (as would be revealed with a histogram measurement) and the most-common low-level voltage, after ringing has subsided.

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Table 4-15 Source DC Characteristics at TP1

Item	Value
Single-ended standby (off) output voltage, V_{OFF}	AV_{cc} ±10mVolts
Single-ended output swing voltage, V_{swing}	400mVolts ≤ V_{swing} ≤ 600mVolts
Single-ended high level output voltage, V_H	if attached Sink supports only <=165MHz : AV_{cc} ±10mVolts if attached Sink supports >165MHz : (AV_{cc} – 200mVolts) ≤ V_H ≤ (AV_{cc} + 10mVolts)
Single-ended low level output voltage, V_L	if attached Sink supports only <=165MHz : (AV_{cc} – 600mVolts) ≤ V_L ≤ (AV_{cc} – 400mVolts) if attached Sink supports >165MHz : (AV_{cc} – 700mVolts) ≤ V_L ≤ (AV_{cc} – 400mVolts)

It is recommended that Sources capable of higher speeds incorporate an effective amount of source termination, especially if using Type C connectors. This termination will typically have the effect of lowering the average DC level of each single-ended signal. The relaxed V_H and V_L parameters permit such an implementation.

The Source shall meet the AC specifications in Table 4-16 across all operating conditions specified in Table 4-14. Rise and fall times are defined as the signal transition time between 20% and 80% of the nominal swing voltage (V_{swing}) of the device under test.

The Source intra-pair skew is the maximum allowable time difference (on both low-to-high and high-to-low transitions) as measured at TP1, between the true and complement signals of a given differential pair. This time difference is measured at the midpoint on the single-ended signal swing of the true and complement signals. The Source inter-pair skew is the maximum allowable time difference (on both low-to-high and high-to-low transitions) as measured at TP1, between any two single-ended data signals that do not constitute a differential pair.

Table 4-16 Source AC Characteristics at TP1

Item	Value
Rise time / fall time (20%-80%)	75psec ≤ Rise time / fall time
Intra-Pair Skew at Source Connector, max	0.15 T_{bit}
Inter-Pair Skew at Source Connector, max	0.20 $T_{character}$
Clock duty cycle, min / average / max	40% / 50% / 60%
TMDS Differential Clock Jitter, max	0.25 T_{bit} (relative to Ideal Recovery Clock as defined in Section 4.2.3)

The design of a Source should take into account the differential impedance of the cable assembly and Sink of 100 ohms (see Table 4-21).

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For all channels under all operating conditions specified in Table 4-14 and when terminated as shown in Figure 4-17, the Source shall have output levels at TP1 that meet the eye diagram requirements of Figure 4-18. This requirement specifies the minimum eye opening as well as the absolute maximum and minimum voltages. The time axis is normalized to the bit time at the operating frequency.

The absolute amplitude limits in Figure 4-18 allow 25% (of the average differential swing voltage) maximum undershoot when the differential signal has a minimum swing (800mV) and greater undershoot for higher swings. Overshoot limits are imposed only by the absolute max/min voltages of ±780mV shown above and below the normalized eye.

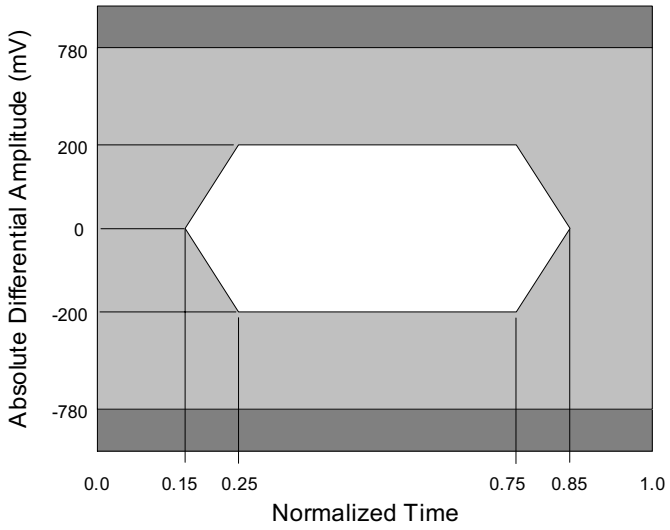


Figure 4-18 Eye Diagram Mask at TP1 for Source Requirements

Combining the single-ended swing voltage (V_{swing}) specified in Table 4-15 with a 15% overshoot (legacy) and the undershoot limits of Table 4-16, it is possible to calculate the minimum and maximum high-level voltage (V_{high}) and low-level voltage (V_{low}) that is allowable on the interface.

V_{high} (max) = V_{swing} (max) + 15% * (2*V_{swing} (max)) = 600 + 180 = 780 mV

V_{high} (min) = V_{swing} (min) - 25% * (2*V_{swing} (min)) = 400 - 200 = 200 mV

V_{low} (max) = -V_{swing} (max) - 15% * (2*V_{swing} (max)) = -600 - 180 = -780 mV

V_{low} (min) = -V_{swing} (min) + 25% * (2*V_{swing} (min)) = -400 + 200 = -200 mV

Minimum opening at Source = V_{high} (min) - V_{low} (min) = 400 mV

Note that the combination of these extreme cases do not constitute a single valid eye.

Source eye diagram test procedures are defined in the HDMI Compliance Test Specification.

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4.2.5 HDMI Sink TMDS Characteristics

HDMI Sink electrical testing shall be performed using a test signal generator as shown in Figure 4-19.

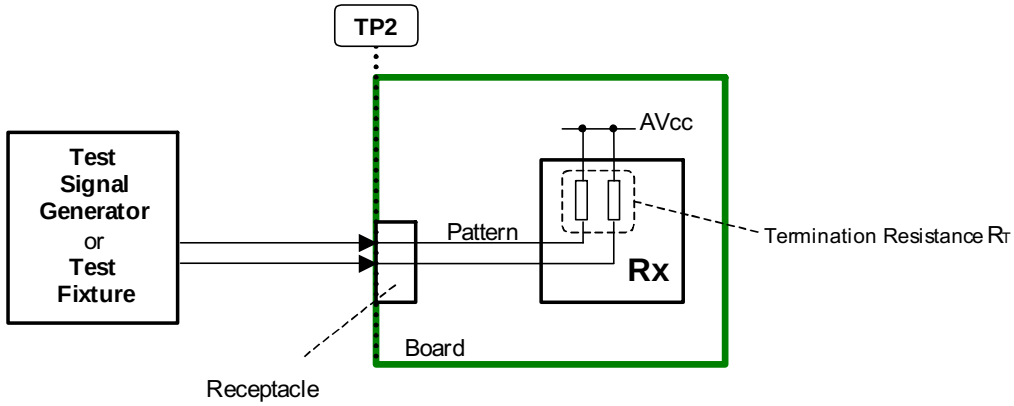


Figure 4-19 HDMI Sink Test Points

There may be a risk of source damage if the Sink asserts a very high or very low voltage, such as beyond the maximum ratings in the DVI 1.0 specification, on any TMDS line during power-on or other power transitions.

The Sink shall meet the signal requirements listed in Table 4-17, Table 4-18, and Table 4-19.

Table 4-17 Sink Operating DC Characteristics at TP2

Item		Value
Input Differential Voltage Level, V_{idiff}		$150 \le V_{idiff} \le 1200$ mVolts
Input Common Mode Voltage, V_{icm}	V_{icm1}	if Sink supports only <=165MHz : $(AV_{cc} - 300mVolts) \le V_{icm1} \le (AV_{cc} - 37.5mVolts)$ If Sink supports >165MHz : $(AV_{cc} - 400mVolts) \le V_{icm1} \le (AV_{cc} - 37.5mVolts)$
	V_{icm2}	$AV_{cc} \pm 10$mVolts

All Sinks are required to support both V_{icm} ranges (V_{icm1} and V_{icm2}). Sources are not yet permitted to operate in the V_{icm2} (AC-coupled) range. At higher speeds, Source devices may implement source termination, which may lower the DC-coupled V_{icm} (V_{icm1}) seen by the Sink.

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Table 4-18 Sink DC Characteristics When Source Disabled or Disconnected at TP2

Item	Value
Differential Voltage Level	AV_{cc} ±10mVolts

Table 4-19 Sink AC Input Characteristics at TP2

Item	Value
Minimum differential sensitivity (peak-to-peak)	150 mVolts
Maximum differential input (peak-to-peak)	1560 mVolts
Max Allowable Intra-Pair Skew at Sink Connector	For TMDS Clock rates 222.75MHz and below: 0.4 T_{bit} For TMDS Clock rates above 222.75MHz: 0.15 T_{bit} + 112psecs
Max Allowable Inter-Pair Skew at Sink Connector	0.2 $T_{character}$ + 1.78nsecs
TMDS Clock Jitter	0.30 T_{bit} (relative to Ideal Recovery Clock as defined in Section 4.2.3, and, for all TMDS clock rates >165MHz: after application of Reference Cable Equalizer given in Equation 4-2)

For each channel under all operating conditions specified in this section the following conditions shall be met.

- At TMDS clock frequencies less than or equal to 165MHz, the Sink shall recover data at a TMDS character error rate of 10^{-9} or better, when presented with any signal compliant to the eye diagram of Figure 4-20.
- At TMDS clock frequencies above 165MHz, the Sink shall recover data on each channel at a TMDS character error rate of 10^{-9} or better, when presented with any signal compliant to the eye diagram of Figure 4-20 after application of the Reference Cable Equalizer.

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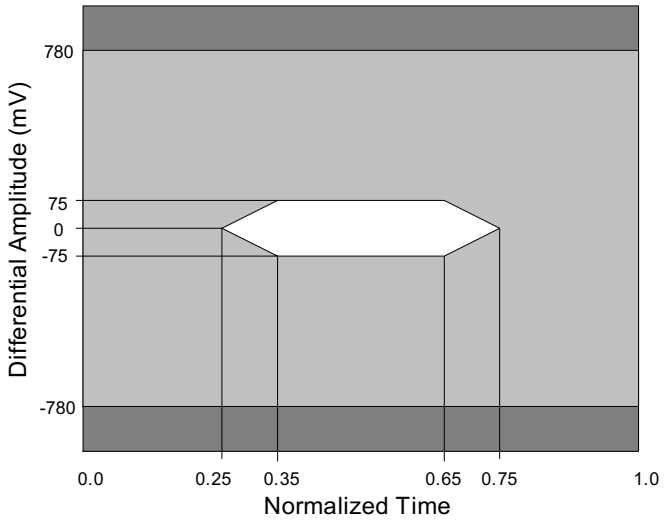


Figure 4-20 Eye Diagram Mask at TP2 for Sink Requirements

Table 4-20 HDMI Sink Impedance Characteristics at TP2

Item	Value
TDR Rise Time at TP2 (10%-90%)	≤200 psec
Through connection impedance	100 ohms ±15% *
At Termination impedance (when V_{icm} is within V_{icm1} range)	100 ohms ±10%
At Termination impedance (when V_{icm} is within V_{icm2} range)	100 ohms ±35%

** A single excursion is permitted out to a max/min of 100 ohms ±25% and of a duration less than 250psecs.*

4.2.6 Cable Assembly TMDS Characteristics

The term “Cable assembly” includes all five parts listed below:

- Source-side plug
- Source-side transition (from plug to cable)
- Cable itself
- Sink-side transition
- Sink-side plug

HDMI cables are measured with respect to the test points TP3 and TP4 shown in Figure 4-21. TP1 and TP2 are not available because connection points between plug and receptacle cannot be accessed during testing. Therefore, TP3 and TP4 are used, even though the effects of receptacles at both ends are included in the test result.

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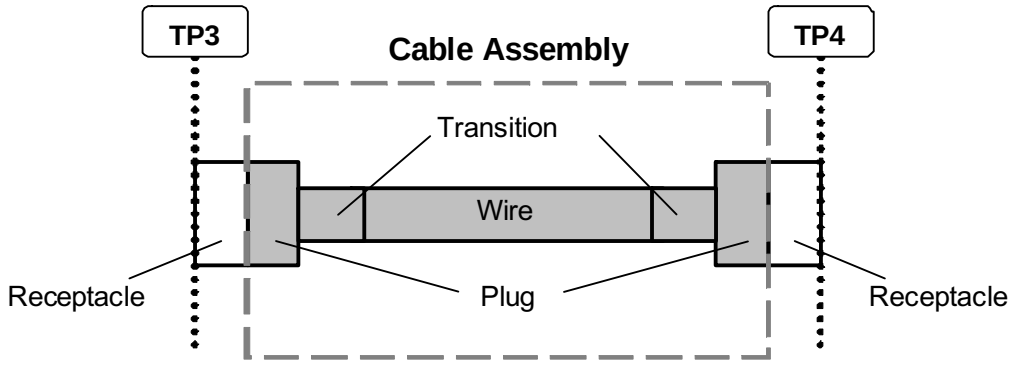


Figure 4-21 Cable Assembly Test Points

HDMI cable assemblies shall support both V_{icm} ranges (V_{icm1} and V_{icm2}) given in Table 4-17.

HDMI cable assemblies can fall into one of two categories: Category 1, supporting TMDS clock frequencies up to 74.25MHz and Category 2, supporting TMDS clock frequencies up to 340MHz.

HDMI cable assemblies are specified and tested using two different eye measurement procedures: “non-equalized” (without application of the Reference Cable Equalizer) and “equalized” (with application of the Reference Cable Equalizer).

- Non-equalized eye diagram specification – when driven by any TMDS input waveform meeting the Source eye diagram mask requirements of Figure 4-18 at the tested TMDS clock frequency, the HDMI cable assembly shall produce a TMDS output waveform that meets the Sink eye diagram mask of Figure 4-20.
- Equalized eye diagram specification – when driven by any TMDS input waveform meeting the Source eye diagram mask requirements of Figure 4-18 at the tested TMDS clock frequency, the TMDS output waveform of the cable shall meet the post-equalized eye diagram mask of Figure 4-20 after application of the Reference Cable Equalizer.

The application of these two different specifications depends upon the cables frequency rating:

- Category 1 (up to 74.25MHz): The cable shall meet either:
  A) the parameters specified for Category 1 cables in Table 4-21, or,
  B) the non-equalized eye diagram requirements at 74.25MHz.
- Category 2 (up to 340MHz): The cable shall meet either
  A) the parameters specified for Category 2 cables in Table 4-21, or,
  B) all of:
    - the non-equalized eye diagram requirements at 165MHz and,
    - the equalized eye diagram requirements at 340MHz

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Table 4-21 Cable Assembly TMDS Parameters

Parameter	Category 1 (up to 74.25MHz)	Category 2 (up to 340MHz)
Maximum Cable Assembly Intra-Pair Skew	151psec	112psec
Maximum Cable Assembly Inter-Pair Skew	2.42nsec	1.78nsec
Far-end Crosstalk	< -20dB	< -20dB
Attenuation	See Figure 4-22	See Figure 4-23 (note) For cables with passive equalizer circuits, see Appendix G.
Differential Impedance Connection point and transition area: Up to 1nsec*	100 ohms ±15% **	
Cable area: 1nsec – 2.5nsec:*	100 ohms ±10%	

** Measurement point for TDR measurement of impedance.*

*** A single excursion is permitted out to a max/min of 100 ohms ±25% and of a duration less than 250psecs.*

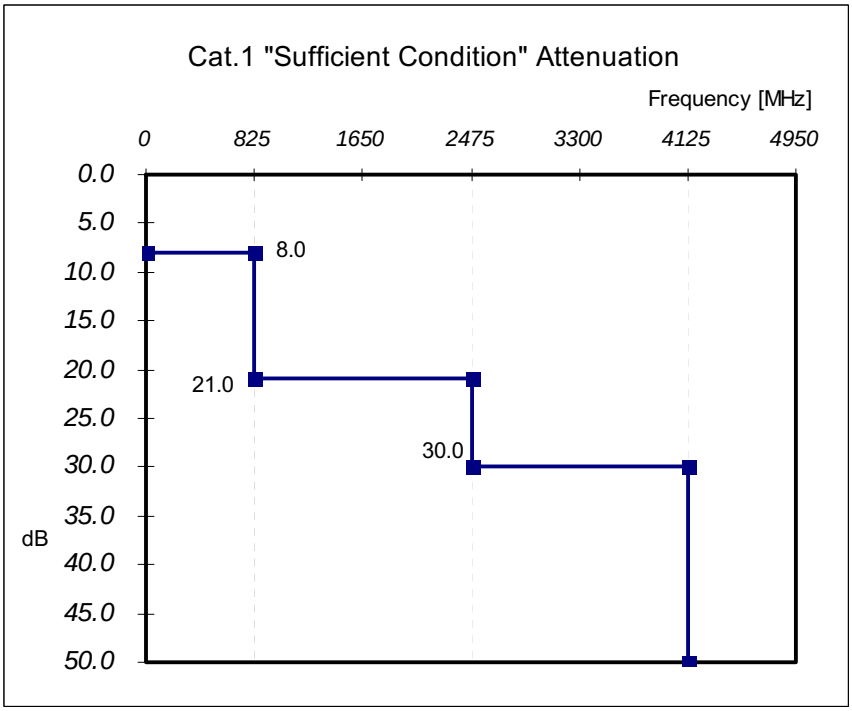


Figure 4-22 Category 1 Cable Attenuation Limits – Sufficient Condition

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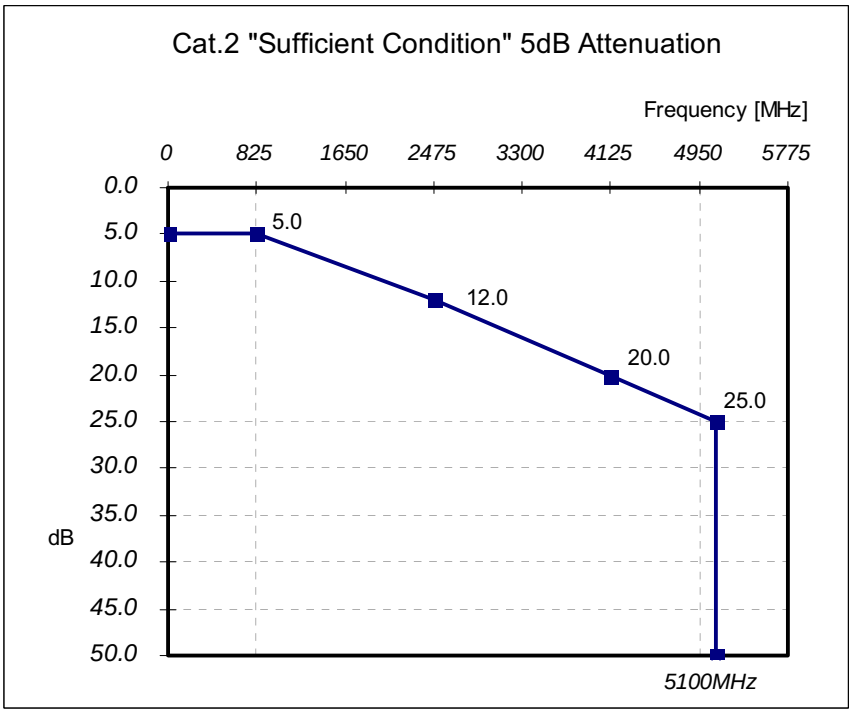


Figure 4-23 Category 2 Cable Attenuation Limits – Sufficient Condition

4.2.7 +5V Power Signal

The HDMI connector provides a pin allowing the Source to supply +5.0 Volts to the cable and Sink.

All HDMI Sources shall assert the +5V Power signal whenever the Source is using the DDC or TMDS signals. The voltage driven by the Source shall be within the limits specified for TP1 voltage in Table 4-22. An HDMI Source shall have +5V Power signal over-current protection of no more than 0.5A.

All HDMI Sources shall be able to supply a minimum of 55 mA to the +5V Power pin.

A Sink shall not draw more than 50 mA of current from the +5V Power pin. When the Sink is powered on, it can draw no more than 10mA of current from the +5V Power signal. A Sink shall assume that any voltage within the range specified for TP2 voltage in Table 4-22 indicates that a Source is connected and applying power to the +5V Power signal.

A Cable Assembly shall be able to supply a minimum of 50mA to the +5V Power pin to a Sink, even when connected to a Source supplying no more than 55mA.

The return for the +5V Power signal is DDC/CEC Ground signal.

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Table 4-22 +5V Power Pin Voltage

Item	Min	Max
TP1 voltage	4.8 Volts	5.3 Volts
TP2 voltage	4.7 Volts	5.3 Volts

4.2.8 DDC

The Display Data Channel (DDC) I/Os and wires (SDA, SCL, DDC/CEC Ground), shall meet the requirements specified in the I^2C-bus Specification, version 2.1, Section 15 for "Standard-Mode" devices. Note that the discussions of high capacitance environments in the I^2C-bus Specification, section 17.2, "Switched pull-up circuit for Fast-mode I^2C-bus", may be applied to the HDMI environment as well.

HDMI devices shall have DDC electrical characteristics complying with the values shown in Table 4-23 and Table 4-24.

The exact method and measurement procedure is written in HDMI Compliance Test Specification. In some cases, buffers or I^2C "accelerators", may be inserted in the cable as long as all I^2C timing requirements are met.

Table 4-23 Maximum Capacitance of DDC line

Item	HDMI Source	Cable Assembly	HDMI Sink
SDA – DDC/CEC Ground	50pF	700pF	50pF
SCL – DDC/CEC Ground	50pF	700pF	50pF

Table 4-24 Pull-up Resistance on DDC Lines

Item	Value
Source Pull-up resistors for SCL and SDA signals	minimum 1.5k ohms, maximum 2.0k ohms
Sink Pull-up resistors for SCL signal	47k ohms, ±10%

4.2.9 Hot Plug Detect Signal (HPD)

The ground reference for the Hot Plug Detect signal is the DDC/CEC Ground pin.

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Table 4-25 Required Output Characteristics of Hot Plug Detect Signal

Item	Value
High voltage level (Sink)	Minimum 2.4 Volts, Maximum 5.3 Volts
Low voltage level (Sink)	Minimum 0 Volts, Maximum 0.4 Volts
Output resistance	1000 ohms ±20%

Table 4-26 Required Detection Levels for Hot Plug Detect Signal

Item	Value
High voltage level (Source)	Minimum 2.0 Volts, Maximum 5.3 Volts
Low voltage level (Source)	Minimum 0 Volts, Maximum 0.8 Volts

Note that many Sink devices simply connect the HPD signal to the +5V Power signal through a 1000 ohm resistor. It may therefore be necessary for a Source to pull-down the HPD signal in order to reliably differentiate between a floating (disconnected) HPD and a high voltage level HPD signal.

4.2.10 CEC Line

The following line characteristics are required for all products, including those that do not implement the CEC protocol. Further requirements for those devices that implement the CEC protocol are given in Supplement 1. The ground reference for the CEC signal is the DDC/CEC Ground signal.

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Table 4-27 CEC line Electrical Specifications for all Configurations

Item	Rule / Description	Value
Line connectivity	CEC lines from all HDMI inputs (if present) and a single HDMI output (if present) shall be interconnected. However, the following exceptions are allowed: A device that has no HDMI output is allowed to have separate CEC lines for each HDMI connector if that device implements CEC protocol and takes a logical address of 0 on each CEC line. Due to the complexity of handling multiple active CEC lines, this is discouraged. A device (typically a TV or media receiver box) that is acting as the CEC root device shall not connect the CEC line to any HDMI output. Maximum resistance of interconnected CEC line between any two HDMI connectors:	5Ω
Power-off characteristics	A device with power removed shall not degrade communication between other CEC devices (e.g. the line shall not be pulled down by the powered off device). Maximum CEC line leakage current in off (unpowered) state	1.8µA
CEC Line Capacitance	Maximum capacitance load of a Source, or of a Repeater that is not a CEC root device	150pF
	Maximum capacitance load of a Sink or of a CEC root device	200pF
	Maximum capacitance load of a Cable Assembly	700pF

4.2.11 Robustness Requirements

No damage to the HDMI Source or Sink can result from the shorting of any combination of signals on any connector. If two HDMI Sources are connected together with a single cable, no damage can occur to either of the Sources. If two HDMI Sinks are connected together with a single cable, no damage can occur to either of the Sinks.

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5 Signaling And Encoding

5.1 Overview

5.1.1 Link Architecture

As shown in Figure 5-1, an HDMI link includes three TMDS Data channels and a single TMDS Clock channel. The TMDS Clock channel constantly runs at a rate proportional to the pixel rate of the transmitted video. During every cycle of the TMDS Clock channel, each of the three TMDS data channels transmits a 10-bit character. This 10-bit word is encoded using one of several different coding techniques.

The input stream to the Source's encoding logic will contain video pixel, packet and control data. The packet data consists of audio and auxiliary data and associated error correction codes.

These data items are processed in a variety of ways and are presented to the TMDS encoder as either 2 bits of control data, 4 bits of packet data or 8 bits of video data per TMDS channel. The Source encodes one of these data types or encodes a Guard Band character on any given clock cycle.

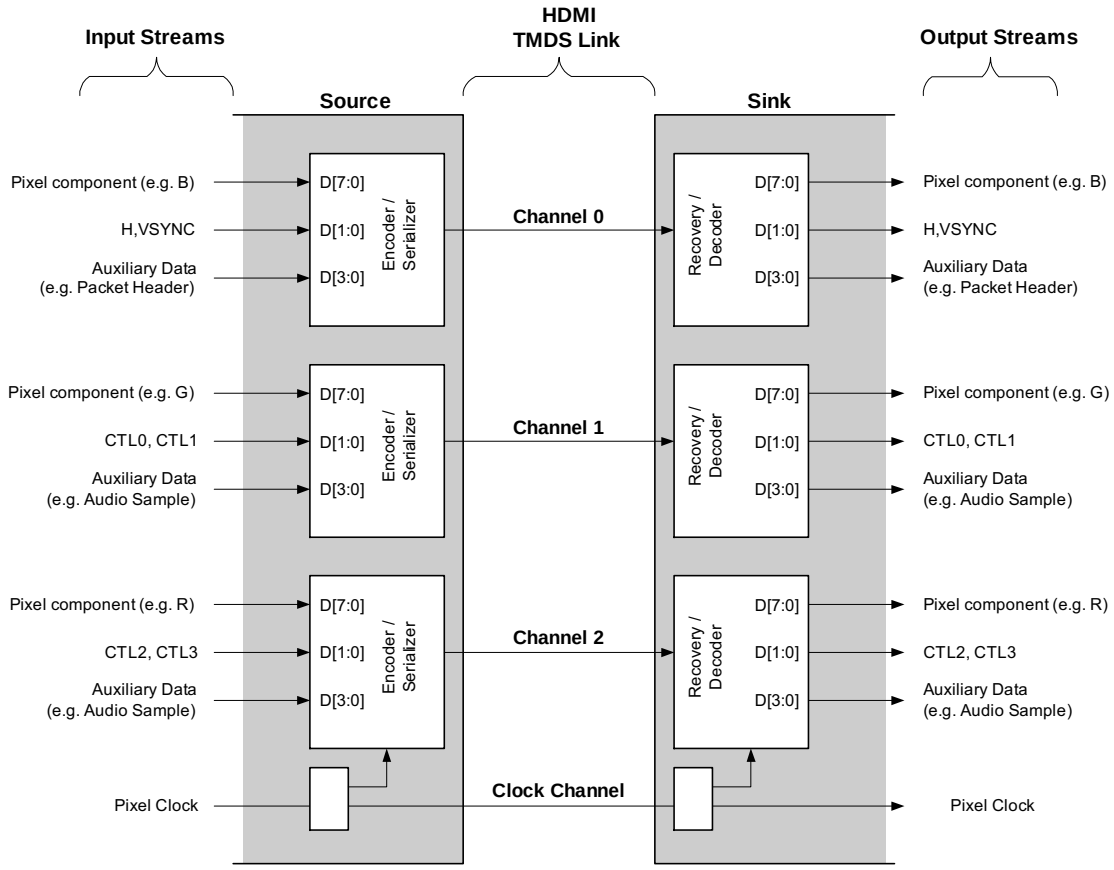


Figure 5-1 HDMI Encoder/Decoder Overview

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5.1.2 Operating Modes Overview

The HDMI link operates in one of three modes: Video Data Period, Data Island period, and Control period. During the Video Data Period, the active pixels of an active video line are transmitted. During the Data Island period, audio and auxiliary data are transmitted using a series of packets. The Control period is used when no video, audio, or auxiliary data needs to be transmitted. A Control Period is required between any two periods that are not Control Periods.

An example of each period placement is shown in the following figure.

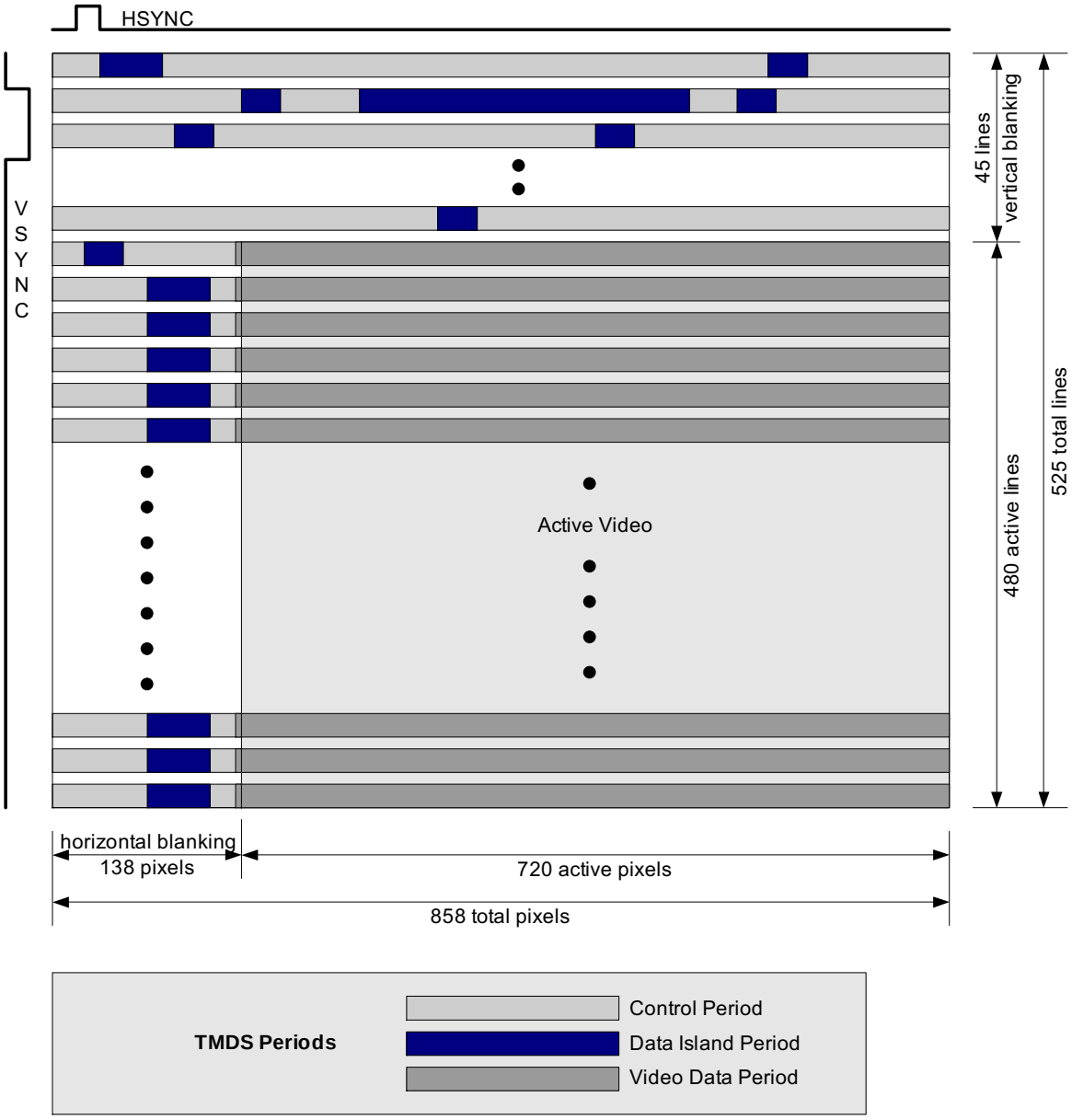


Figure 5-2 Informative Example: TMDS periods in 720x480p video frame

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Video Data Periods use transition minimized coding to encode 8 bits per channel, or 24 bits total per pixel.

Data Island Periods are encoded using a similar transition minimized coding, TMDS Error Reduction Coding (TERC4), which transmits 4 bits per channel, or 12 bits total per TMDS clock period.

During Control Periods, 2 bits per channel, or 6 bits total are encoded per TMDS clock using a transition maximized encoding. These 6 bits are HSYNC, VSYNC, CTL0, CTL1, CTL2 and CTL3. Near the end of every Control Period, a Preamble, using the CTLx bits, indicates whether the next Data Period is a Video Data Period or a Data Island Period.

Each Video Data Period and Data Island Period starts with a Leading Guard Band designed to provide robust determination of the transition from the Control Period to the Data Period. This Leading Guard Band consists of two special characters.

The Data Island Period is also protected by a Trailing Guard Band, which is designed to provide a robust determination of the transition to Control Period.

The following table shows Encoding type used and data transmitted during each operating mode.

Table 5-1 Encoding Type and Data Transmitted

Period	Data Transmitted	Encoding Type
Video Data	Video Pixels	Video Data Coding (8 bits converted to 10 bits)
	(Guard Band)	(Fixed 10 bit pattern)
Data Island	Packet Data - Audio Samples - InfoFrames HSYNC, VSYNC	TERC4 Coding (4 bits converted to 10 bits)
	(Guard Band)	(Fixed 10 bit pattern)
Control	Control - Preamble - HSYNC, VSYNC	Control Period Coding (2 bits converted to 10 bits)

5.2 Operating Modes

5.2.1 Control Period

Control Period is used for transmission of the Preamble. The Control Period is also used by the Sink for character synchronization.

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The HDCP-specified Enhanced Encryption Status Signaling ENC_EN code (CTL0:3=1001) shall not be used except as a correct ENC_EN during the HDCP-specified window of opportunity.

5.2.1.1 Preamble

Immediately preceding each Video Data Period or Data Island Period is the Preamble. This is a sequence of eight identical Control characters that indicate whether the upcoming data period is a Video Data Period or is a Data Island. The values of CTL0, CTL1, CTL2, and CTL3 indicate the type of data period that follows. The remaining Control signals, HSYNC and VSYNC, may vary during this sequence.

There are only two legal Preamble characters:

Table 5-2 Preambles for Each Data Period Type

CTL0	CTL1	CTL2	CTL3	Data Period Type
1	0	0	0	Video Data Period
1	0	1	0	Data Island Period

The Video Data Period type indicates that the following data period contains video data, beginning with a Video Guard Band.

The Data Island type indicates that the following data period is an HDMI compliant Data Island, beginning with a Data Island Guard Band.

The transition from TMDS control characters to Guard Band characters following this sequence identifies the start of the Data Period.

The Data Island Preamble control code (CTL0:3=1010) shall not be transmitted except for correct use during a Preamble period.

5.2.1.2 Character Synchronization

The TMDS Sink needs to determine the location of character boundaries in the serial data streams. Once character boundaries are established on all data channels, the Sink is defined to be synchronized to the serial streams, and may recover TMDS characters from the data channels for decode. The TMDS data stream provides periodic cues for decoder synchronization.

The TMDS characters used during the Video Data Period and Data Island Period contain five or fewer transitions, while the TMDS characters used during the Control Period contain seven or more transitions. The high-transition content of the characters transmitted during the Control Period form the basis for character boundary synchronization at the decoder. While these characters are not individually unique in the serial data stream, they are sufficiently alike that the decoder may uniquely detect the presence of a succession of them during transmitted synchronization intervals. The exact algorithm for this detection is an implementation detail beyond the scope of this document, but minimum conditions for Sink synchronization are defined.

The Sink is required to establish synchronization with the data stream during any Control Period greater than or equal to $t_{S,min}$ (12) characters in length.

The Source is also required to occasionally transmit an Extended Control Period per Table 5-4.

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Table 5-3 TMDS Link Timing Parameters

Parameter	Description	Value	Unit
$t_{S,min}$	Minimum duration Control Period	12	T_{PIXEL}

Table 5-4 Extended Control Period Parameters

Parameter	Description	Value	Unit
t_{EXTS,max_delay}	Maximum time between Extended Control Periods	50	msec
$t_{EXTS,min}$	Minimum duration Extended Control Period	32	T_{PIXEL}

5.2.2 Video Data Period

Video data periods are used to carry the pixels of an active video line.

Each Video Data Period is preceded by a Preamble, described above.

Following the Preamble, the Video Data Period begins with a two character Video Leading Guard Band. There is no Trailing Guard Band for the Video Data Period.

During active video periods, 24 bits of pixel data are encoded using TMDS transition minimized encoding during each TMDS clock period.

5.2.2.1 Video Guard Band

Table 5-5 Video Leading Guard Band Values

```
case (TMDS Channel Number):
       0:  q_out[9:0] = 0b1011001100;
       1:  q_out[9:0] = 0b0100110011;
       2:  q_out[9:0] = 0b1011001100;
endcase
```

5.2.3 Data Island Period

5.2.3.1 Data Island Overview

Data Islands are used to carry packets of audio sample data and auxiliary data. This auxiliary data includes InfoFrames and other data describing the active audio or video stream or describing the Source.

Each Data Island is preceded by a Preamble, described above.

Following the Preamble, each Island starts with a Leading Guard Band. The first packet of the Data Island then follows.

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During every TMDS clock period of the Data Island, including the Guard Band, bits 0 and 1 of TMDS Channel 0 transmit an encoded form of HSYNC and VSYNC.

Bit 2 of TMDS Channel 0 is used to transmit the Packet Header. All four bits of TMDS Channels 1 and 2 are used for the Packet data as shown in Figure 5-3. Each packet is 32 pixels long and is protected by BCH ECC for error correction and detection purposes.

During the Data Island, each of the three TMDS channels transmits a series of 10-bit characters encoded from a 4-bit input word, using TMDS Error Reduction Coding (TERC4). TERC4 significantly reduces the error rate on the link by choosing only 10-bit codes with high inherent error avoidance.

The last two characters of the Data Island, following the last packet, is the Trailing Guard Band.

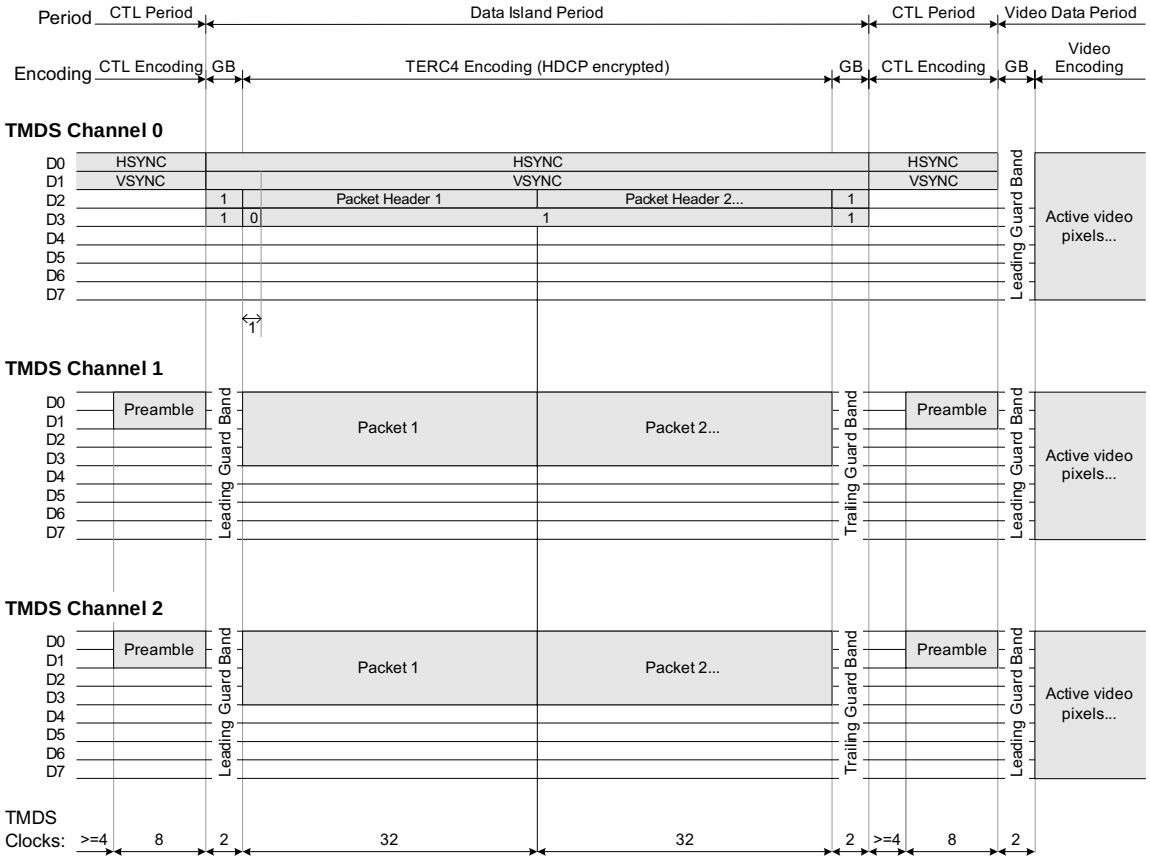


Figure 5-3 TMDS Periods and Encoding

Following the Data Island, all three channels revert to transmitting control characters.

5.2.3.2 Island Placement and Duration

The Source is required to determine the temporal placement and duration of the Data Island with respect to the video signal's horizontal and vertical blanking periods and synchronization signals. It shall do so following the rules stated below.

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All TMDS Control Periods shall be at least $t_{S,min}$ (12) characters (pixels) long.

The Data Island shall contain at least one packet, limiting its minimum size to 36 pixels.

Islands shall contain an integer number of packets. In order to assure the reliability of the data within the Data Island, they shall be limited to 18 packets or fewer.

Zero, one or more Data Islands can occur between subsequent video data periods.

While transmitting video, at least one Data Island shall be transmitted during every two video fields.

5.2.3.3 Data Island Guard Bands

The first two data characters within the Data Island are the Leading Guard Band. The last two data characters within the Data Island are the Trailing Guard Band.

During the Data Island Guard Bands, Channel 0 is encoded as one of four TERC4 values. These TERC4 values (D[3:0]) are 0xC, 0xD, 0xE and 0xF, depending upon the values of HSYNC and VSYNC.

Table 5-6 Data Island Leading and Trailing Guard Band Values

```
case (TMDS Channel Number):
       0:  q_out[9:0] = n.a.;
       1:  q_out[9:0] = 0b0100110011;
       2:  q_out[9:0] = 0b0100110011;
endcase
```

5.2.3.4 Data Island Packet Construction

All data within a Data Island is contained within 32 clock Packets. Packets consist of a Packet Header, a Packet Body (consisting of four Subpackets), and associated error correction bits. Each Subpacket includes 56 bits of data and is protected by an additional 8 bits of BCH ECC parity bits.

Subpacket 0 plus its corresponding parity bits make up BCH Block 0. This block is mapped onto bit 0 of both Channel 1 and Channel 2. In this way, the 64 bits of BCH Block 0 are transferred over the course of 32 pixels. Likewise, BCH Block 1 (Subpacket 1 plus parity) is mapped onto bit 1 of both Channels 1 and 2.

In the tables below, Header bytes are indicated as HB0, HB1, and HB2 and Subpacket bytes are indicated as SB0 to SB6.

Subpacket 0 bytes 0 through 6 (SB0-SB6) are also designated Packet bytes 0 to 6 (PB0-PB6).

Subpacket 1 bytes 0 through 6 (SB0-SB6) are also designated Packet bytes 7 to 13 (PB7-PB13).

Subpacket 2 bytes 0 through 6 (SB0-SB6) are also designated Packet bytes 14 to 20 (PB14-PB20).

Subpacket 3 bytes 0 through 6 (SB0-SB6) are also designated Packet bytes 21 to 27 (PB21-PB27).

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This is illustrated in Figure 5-4.

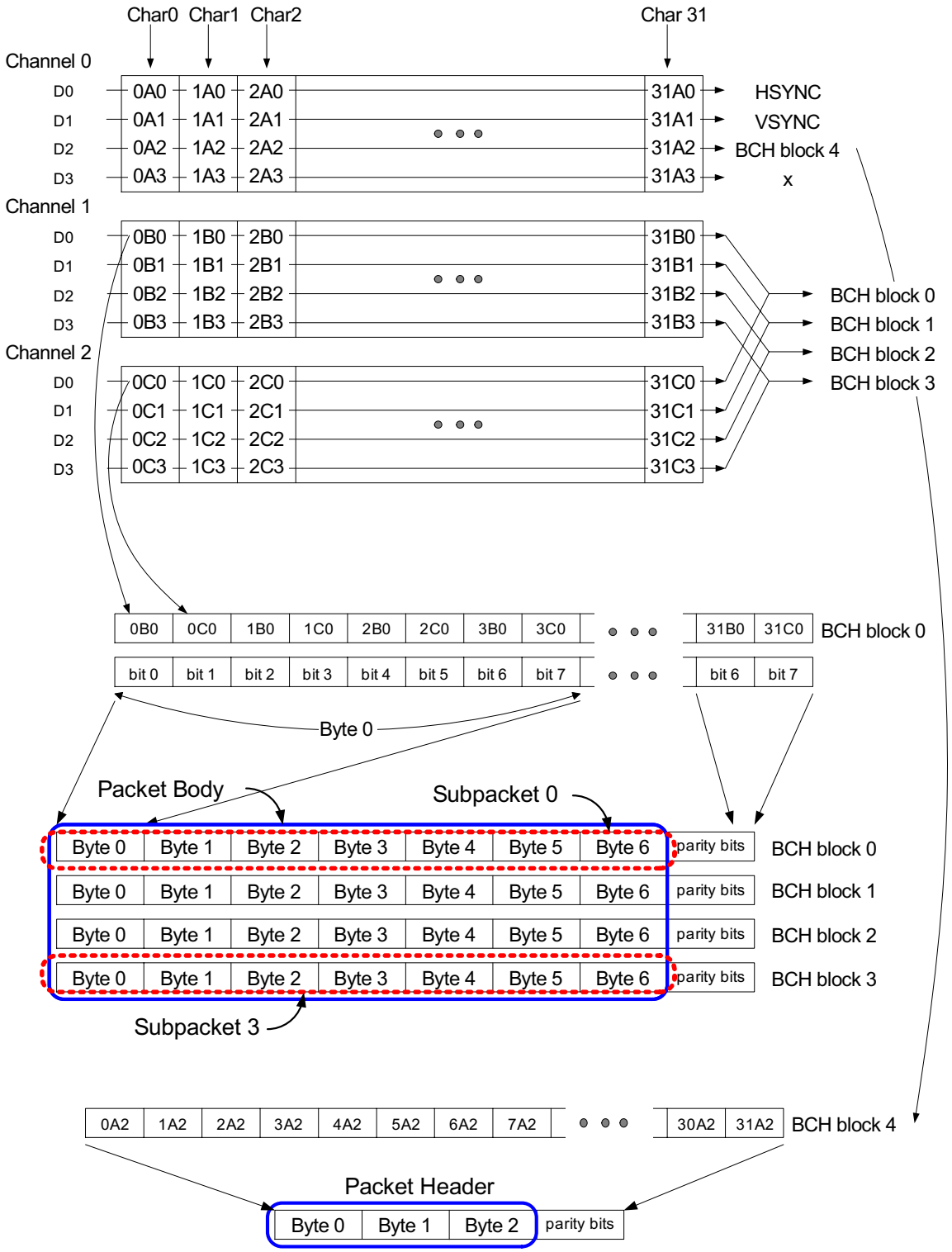


Figure 5-4 Data Island Packet and ECC Structure

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5.2.3.5 Data Island Error Correction

To improve the reliability of the data and to improve the detection of bad data, Error Correction Code (ECC) parity is added to each packet. BCH(64,56) and BCH(32,24) are generated by the polynomial G(x) shown in Figure 5-5.

$G(x)=1+x^6+x^7+x^8$ (127 count repetition cycle).

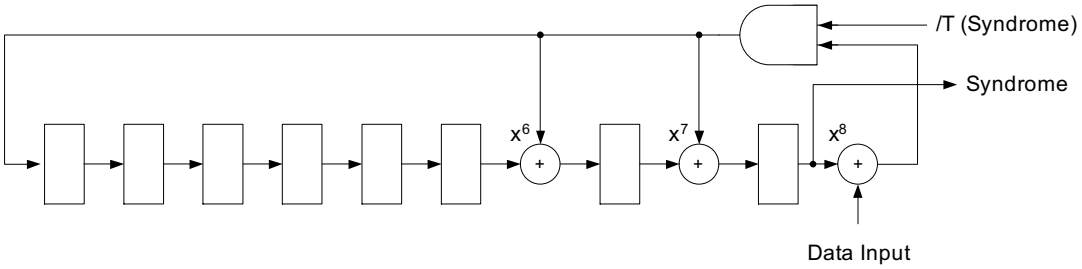


Figure 5-5 Error Correction Code generator

5.3 Data Island Packet Definitions

5.3.1 Packet Header

Packet Headers contain 24 data bits with an additional 8 bits of BCH(32,24) ECC parity. These parity bits are calculated over the 24 bits of the Packet Header.

A Packet Header includes an 8-bit Packet Type and 16 bits of packet-specific data.

A Sink shall be able to receive, with no adverse effects, any packet defined in the HDMI 1.0 specification including any InfoFrame Packet with an InfoFrame Type defined in CEA-861-D.

Table 5-7 Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	Packet Type							
HB1	packet-specific data							
HB2	packet-specific data							

Table 5-8 shows the available packet types.

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Table 5-8 Packet Types

Packet Type Value		Packet Type	Described in Section
0x00		Null	5.3.2
0x01		Audio Clock Regeneration (N/CTS)	5.3.3
0x02		Audio Sample (L-PCM and IEC 61937 compressed formats)	5.3.4
0x03		General Control	5.3.6
0x04		ACP Packet	5.3.7
0x05		ISRC1 Packet	5.3.8
0x06		ISRC2 Packet	"
0x07		One Bit Audio Sample Packet	5.3.9
0x08		DST Audio Packet	5.3.10
0x09		High Bitrate (HBR) Audio Stream Packet (IEC 61937)	5.3.11
0x0A		Gamut Metadata Packet	5.3.12
0x80+InfoFrame Type		InfoFrame Packet	5.3.5
	0x81	Vendor-Specific InfoFrame	- -
	0x82	AVI InfoFrame*	8.2.1
	0x83	Source Product Descriptor InfoFrame	- -
	0x84	Audio InfoFrame*	8.2.2
	0x85	MPEG Source InfoFrame	- -

** See Section 8.2 for the packet layout for these InfoFrames*

5.3.2 Null Packet

Null packets can be used by the Source anytime. All bytes of a Null packet are undefined and shall contain only zero values. An HDMI Sink shall ignore bytes HB1 and HB2 of the Null Packet Header and all bytes of the Null Packet Body.

Table 5-9 Null Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	0	0	0	0	0	0	0	0
HB1	0	0	0	0	0	0	0	0
HB2	0	0	0	0	0	0	0	0

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5.3.3 Audio Clock Regeneration Packet

Audio Clock Regeneration Packets contain both the N and CTS values used in the Audio Clock Regeneration process. The four Subpackets each contain the same Audio Clock Regeneration Subpacket. An HDMI Sink shall ignore bytes HB1 and HB2 of the Audio Clock Regeneration Packet header.

Table 5-10 Audio Clock Regeneration Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	0	0	0	0	0	0	0	1
HB1	0	0	0	0	0	0	0	0
HB2	0	0	0	0	0	0	0	0

Table 5-11 Audio Clock Regeneration Subpacket

Byte \ Bit #	7	6	5	4	3	2	1	0
SB0	0	0	0	0	0	0	0	0
SB1	0	0	0	0	CTS.19	-	-	CTS.16
SB2	CTS.15	-	-	-	-	-	-	CTS.8
SB3	CTS.7	-	-	-	-	-	-	CTS.0
SB4	0	0	0	0	N.19	-	-	N.16
SB5	N.15	-	-	-	-	-	-	N.8
SB6	N.7	-	-	-	-	-	-	N.0

- N [20 bits] value of audio clock regeneration “N”
- CTS [20 bits] Cycle Time Stamp

CTS values of zero are used to indicate no new value of CTS.

5.3.4 Audio Sample Packet

L-PCM and some IEC 61937 compressed audio formats are carried using Audio Sample Packets. Audio Sample Packets consist of one to four Audio Samples. These may be different samples or different partial samples (i.e. 2 of 6 channels). The configuration of the Subpackets is determined by the layout and sample_present bits in the header. This is described in detail in Section 7.6, *Audio Data Packetization*.

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Table 5-12 Audio Sample Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	0	0	0	0	0	0	1	0
HB1	0	0	0	layout	sample_ present.sp3	sample_ present.sp2	sample_ present.sp1	sample_ present.sp0
HB2	B.3	B.2	B.1	B.0	sample_flat .sp3	sample_flat .sp2	sample_flat .sp1	sample_flat .sp0

- layout: [1 bit] indicates which of two possible Subpacket/audio sample layouts are used. See Section 7.6, *Audio Data Packetization*.
- sample_present.spX [4 fields, 1 bit each] indicates if Subpacket X contains audio sample(s).
- sample_flat.spX [4 fields, 1 bit each] indicates if Subpacket X represents a “flatline” sample. Only valid if “sample_present.spX” is set.
- B.X [4 fields, 1 bit each] B.X =1 if Subpacket X contains the first frame in a 192 frame IEC 60958 Channel Status block; B.X = 0 otherwise

Table 5-13 Audio Sample Subpacket

Byte \ Bit #	7	6	5	4	3	2	1	0
SB0	L.11	-	-	-	-	-	-	L.4
SB1	L.19	-	-	-	-	-	-	L.12
SB2	L.27	-	-	-	-	-	-	L.20
SB3	R.11	-	-	-	-	-	-	R.4
SB4	R.19	-	-	-	-	-	-	R.12
SB5	R.27	-	-	-	-	-	-	R.20
SB6	P_R	C_R	U_R	V_R	P_L	C_L	U_L	V_L

- L.X: [24 fields, 1 bit each] Bit corresponding to Time Slot X from first (“left”) sub-frame per IEC 60958-1, page 15
- R.X: [24 fields, 1 bit each] Bit corresponding to Time Slot X from second (“right”) sub-frame per IEC 60958-1, page 15
- V_L: [1 bit] Valid bit from first sub-frame
- V_R: [1 bit] Valid bit from second sub-frame
- U_L: [1 bit] User Data bit from first sub-frame
- U_R: [1 bit] User Data bit from second sub-frame
- C_L: [1 bit] Channel Status bit from first sub-frame
- C_R: [1 bit] Channel Status bit from second sub-frame
- P_L: [1 bit] Parity bit from first sub-frame (even parity)

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- P_R: [1 bit] Parity bit from second sub-frame (even parity)

5.3.5 InfoFrame Packet

All InfoFrames defined in CEA-861-D may be carried across HDMI using the HDMI InfoFrame packet. InfoFrames not defined in CEA-861-D or in this specification shall not be transmitted.

Each HDMI InfoFrame Packet carries a single CEA InfoFrame, as shown below[2]. Note that HDMI places additional requirements on several InfoFrames that are not covered by CEA-861-D. For these additional details and restrictions, see Section 8.2.

Table 5-14 InfoFrame Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	1	InfoFrame Type						
HB1	InfoFrame_version							
HB2	0	0	0	InfoFrame_length				

- InfoFrame Type [7 bits] least significant 7 bits of the InfoFrame type code as per CEA-861-D.
- InfoFrame_version [1 byte] version number of InfoFrame as per CEA-861-D.
- InfoFrame_length [5 bits] InfoFrame length in bytes as per CEA-861-D. This length does not include any of the bytes in the Packet Header nor the checksum byte. The maximum value for this field is 27 (0x1B).

Table 5-15 InfoFrame Packet Contents

Byte \ Bit #	7	6	5	4	3	2	1	0
PB0	Checksum							
PB1	Data Byte 1							
PB2	Data Byte 2							
PB3...PB26	-							
PB27	Data Byte 27							

- Checksum [1 byte] Checksum of the InfoFrame. The checksum shall be calculated such that a byte-wide sum of all three bytes of the Packet Header and all valid bytes of the InfoFrame Packet contents (determined by InfoFrame_length), plus the checksum itself, equals zero.

[2] An earlier version of CEA-861-D, CEA-861B, had a method for encapsulating multiple CEA InfoFrames into a single CEA InfoPacket. HDMI has its own packet structure and therefore CEA Info*Packets* are not used.

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- Data Byte x [27 fields, 1 byte each] Data Byte X of the InfoFrame as defined in CEA-861-D. See [HDMI Specification] Section 8.2 for more information.

5.3.6 General Control Packet

The General Control packet header contains no data. Bytes HB1 and HB2 shall be ignored by the Sink. The General Control packet body shall contain four identical subpackets, defined in Table 5-17, below.

Table 5-16 General Control Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	0	0	0	0	0	0	1	1
HB1	0	0	0	0	0	0	0	0
HB2	0	0	0	0	0	0	0	0

Table 5-17 General Control Subpacket

Byte \ Bit #	7	6	5	4	3	2	1	0
SB0	0	0	0	Clear_AVMUTE	0	0	0	Set_AVMUTE
SB1	PP3	PP2	PP1	PP0	CD3	CD2	CD1	CD0
SB2	0	0	0	0	0	0	0	Default_Phase
SB3	0	0	0	0	0	0	0	0
SB4	0	0	0	0	0	0	0	0
SB5	0	0	0	0	0	0	0	0
SB6	0	0	0	0	0	0	0	0

- Set_AVMUTE [1 bit] Set the AVMUTE flag. (See description below).
- Clear_AVMUTE [1bit] Clear the AVMUTE flag. (See description below).
- PP [4 bits] Pixel Packing Phase. (See description in section 6.5.3.)
- CD [4 bits] Color Depth. (See description in section 6.5.3.)
- Default_Phase [1 bit] Default Phase. (See description in section 6.5.3.)

The General Control Packet contains fields for indicating AVMUTE information and color-depth information. Each transmitted GCP may contain valid indications for AVMUTE and/or color-depth or may contain no information (all fields zero).

General Control packets indicating Set_AVMUTE or Clear_AVMUTE may only be transmitted between the active edge of VSYNC and 384 pixels following this edge. A Source may not send a General Control Packet with the Clear_AVMUTE and Set_AVMUTE flags set simultaneously.

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Source transmission of the General Control Packet is optional. Sinks may optionally interpret General Control Packet contents. Sinks shall be capable of receiving any General Control Packet.

The General Control packet's Set_AVMUTE and Clear_AVMUTE flags may be used by a Source to reduce the negative impact on the Sink of TMDS clock changes or interruptions. Use of the AVMUTE function may prevent spurious pops or noises in the audio during these clock changes.

When AVMUTE is set, the Sink may assume that no valid audio or video data is being received. The Sink may optionally apply a mute function to the audio data and/or a blank function to the video.

5.3.7 Audio Content Protection Packet (ACP)

A Source may use the ACP Packet to convey content-related information regarding the active audio stream.

See Section 9.3 for rules regarding the use of the ACP packet.

The following tables show the packetization of the ACP Packet.

Table 5-18 ACP Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	Packet Type = 0x04							
HB1	ACP_Type							
HB2	Reserved (0)							

- ACP_Type [1 byte] Content protection type (see Section 9.3 for usage):
  0x00 = Generic Audio
  0x01 = IEC 60958-Identified Audio
  0x02 = DVD-Audio
  0x03 = Super Audio CD
  0x04...0xFF Reserved

Table 5-19 ACP Packet contents

Packet Byte #	7	6	5	4	3	2	1	0
PB0-PB27	ACP_Type_Dependent (Dependent upon ACP_Type value)							

- ACP_Type_Dependent [28 bytes] Contents are dependent upon ACP_Type field. See Section 9.3 for usage.

5.3.8 ISRC Packets

A Source may use the ISRC packets to transmit a UPC/EAN or ISRC code. See Section 8.8 for rules regarding the use of the ISRC packets.

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Table 5-20 ISRC1 Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	Packet Type = 0x05							
HB1	ISRC_ Cont	ISRC_ Valid	Reserved (0)			ISRC_Status		
HB2	Reserved (0)							

- ISRC_Cont [1 bit] ISRC Continued (in next packet). See Section 8.8 for usage.
- ISRC_Status [3 bits] See Section 8.8 for usage.
- ISRC Valid [1 bit]: This bit is set only when data located in ISRC_Status field and UPC_EAN_ISRC_xx field are valid. When Source cannot obtain complete data for these fields, ISRC_Valid may be 0.

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Table 5-21 ISRC1 Packet contents

Packet Byte #	7	6	5	4	3	2	1	0
PB0	UPC_EAN_ISRC_0							
PB1	UPC_EAN_ISRC_1							
PB2	UPC_EAN_ISRC_2							
PB3	UPC_EAN_ISRC_3							
PB4	UPC_EAN_ISRC_4							
PB5	UPC_EAN_ISRC_5							
PB6	UPC_EAN_ISRC_6							
PB7	UPC_EAN_ISRC_7							
PB8	UPC_EAN_ISRC_8							
PB9	UPC_EAN_ISRC_9							
PB10	UPC_EAN_ISRC_10							
PB11	UPC_EAN_ISRC_11							
PB12	UPC_EAN_ISRC_12							
PB13	UPC_EAN_ISRC_13							
PB14	UPC_EAN_ISRC_14							
PB15	UPC_EAN_ISRC_15							
PB16-PB27	Reserved (0)							

- UPC_EAN_ISRC_xx [16 fields, 1 byte each] UPC/EAN or ISRC byte xx. See Section 8.8 for usage.

Bytes PB16-PB27 shall be set to a value of 0.

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Table 5-22 ISRC2 Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	Packet Type = 0x06							
HB1	Reserved (0)							
HB2	Reserved (0)							

Table 5-23 ISRC2 Packet contents

Packet Byte #	7	6	5	4	3	2	1	0
PB0	UPC_EAN_ISRC_16							
PB1	UPC_EAN_ISRC_17							
PB2	UPC_EAN_ISRC_18							
PB3	UPC_EAN_ISRC_19							
PB4	UPC_EAN_ISRC_20							
PB5	UPC_EAN_ISRC_21							
PB6	UPC_EAN_ISRC_22							
PB7	UPC_EAN_ISRC_23							
PB8	UPC_EAN_ISRC_24							
PB9	UPC_EAN_ISRC_25							
PB10	UPC_EAN_ISRC_26							
PB11	UPC_EAN_ISRC_27							
PB12	UPC_EAN_ISRC_28							
PB13	UPC_EAN_ISRC_29							
PB14	UPC_EAN_ISRC_30							
PB15	UPC_EAN_ISRC_31							
PB16-PB27	Reserved (0)							

- UPC_EAN_ISRC_xx [16 fields, 1 byte each] UPC/EAN or ISRC byte xx.

Bytes PB16-PB27 shall be set to a value of 0.

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5.3.9 One Bit Audio Sample Packet

One Bit Audio streams are transmitted using the One Bit Audio Sample Packet.

One Bit Audio Packets consist of one to four One Bit Audio Subpackets. These may be different samples or different partial samples (e.g. 2 of 6 channels). The configuration of the Subpackets is determined by the layout and samples_present bits in the header. This is described in detail in Section 7.6, *Audio Data Packetization*.

It is optional for the Source, Sink and Repeater to support the One Bit Audio packet.

Table 5-24 One Bit Audio Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	0	0	0	0	0	1	1	1
HB1	Rsvd (0)	Rsvd (0)	Rsvd (0)	layout	samples_ present.sp3	samples_ present.sp2	samples_ present.sp1	samples_ present.sp0
HB2	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	samples_ invalid.sp3	samples_ invalid.sp2	samples_ invalid.sp1	samples_ invalid.sp0

- layout [1 bit] indicates which of two possible Subpacket/audio sample layouts are used. See Table 5-25 below and Section 7.6, *Audio Data Packetization*.
- samples_present.spX [4 fields, 1 bit each] indicates if Subpacket X contains audio sample data. Samples_present.spX = 1 if subpacket X contains sample data; else = 0.
- samples_invalid.spX [4 fields, 1 bit each] indicates if Subpacket X represents invalid samples. Samples_invalid = 1 if the samples in Subpacket X are invalid; else = 0. This bit is only valid if the relevant "samples_present.spX" is set.

Note that, for One Bit Audio, sample frequency information is carried in the Audio InfoFrame (see section 8.2.2).

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Table 5-25 One Bit Audio Subpacket

Byte \ Bit #	7	6	5	4	3	2	1	0
SB0	ChA.7	-	-	-	-	-	-	ChA.0
SB1	ChA.15	-	-	-	-	-	-	ChA.8
SB2	ChA.23	-	-	-	-	-	-	ChA.16
SB3	ChB.7	-	-	-	-	-	-	ChB.0
SB4	ChB.15	-	-	-	-	-	-	ChB.8
SB5	ChB.23	-	-	-	-	-	-	ChB.16
SB6	ChB.27	ChB.26	ChB.25	ChB.24	ChA.27	ChA.26	ChA.25	ChA.24

- ChA.X: [28 fields, 1 bit each] indicates consecutive One Bit Audio samples of the first channel. The most significant bit (ChA.27) is the first sampled bit of the consecutive 28-bit part in the One Bit Audio stream.
- ChB.X: [28 fields, 1 bit each] indicates consecutive One Bit Audio samples of the second channel. The most significant bit (ChB.27) is the first sampled bit of the consecutive 28-bit part in the One Bit Audio stream.

5.3.10 DST Audio Packet

DST (compressed DSD) audio streams are transmitted using the DST Audio Packet.

A DST Audio Packet contains a single DST Audio Packet Body which is filled as audio data becomes available. All identification of channels and other data is embedded in the stream. DST Audio Packet packing is described further in 7.6.3, *DST Packetization*.

It is optional for a Source, Sink or Repeater to support the DST Audio Packet.

Table 5-26 DST Audio Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	0	0	0	0	1	0	0	0
HB1	frame_ start	samples_ invalid	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	DST_normal _double
HB2	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)

- frame_start [1 bit] =1 indicates that this packet is the start of a DST frame; =0 otherwise.
- samples_invalid [1 bit] = 1 if the samples are not valid; = 0 if the samples are valid.
- DST_Normal_Double [1 bit] =0 (“DST_Normal”) indicates that the sample rate equals the transfer rate. =1 (“DST_Double”) indicates that the transfer rate is twice the sample rate. DST_Double rate is used when normal does not have sufficient bandwidth.

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Note that, for DST, sample frequency information is carried in the Audio InfoFrame (see section 8.2.2).

Each DST Audio Packet Body contains 224 bits (28 bytes) of DST data. DST stream data is taken in byte order and packed into the DST Audio Packet Body as shown in Table 5-27.

Table 5-27 DST Audio Packet Body

Byte \ Bit #	7	6	5	4	3	2	1	0
PB0	D.7	D.6	D.5	D.4	D.3	D.2	D.1	D.0
PB1	D.15	D.14	D.13	D.12	D.11	D.10	D.9	D.8
-	-	-	-	-	-	-	-	-
PB26	D.215	D.214	D.213	D.212	D.211	D.210	D.209	D.208
PB27	D.223	D.222	D.221	D.220	D.219	D.218	D.217	D.216

- D.X [224 fields, 1 bit each] DST bitstream, beginning with D.0.

5.3.11 High-Bitrate (HBR) Audio Stream Packet

High bitrate (>6.144Mbps) compressed audio streams conforming to IEC 61937 are carried using HBR Audio Stream Packets. Each packet carries four contiguous IEC 60958 frames which corresponds to (4x2x16 =) 128 contiguous bits of an IEC 61937 stream. This is described in more detail in Section 7.6.2, *High-Bitrate Audio Stream Packetization*.

Table 5-28 HBR Audio Stream Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	0	0	0	0	1	0	0	1
HB1	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)
HB2	B.3	B.2	B.1	B.0	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)

- B.X [4 fields, 1 bit each] B.X =1 if Subpacket X contains the first frame in a 192 frame IEC 60958 Channel Status block; B.X = 0 otherwise

The HBR Audio Stream Packet uses four subpackets which are identical to the Audio Sample Subpacket shown above in Table 5-13.

5.3.12 Gamut Metadata Packet

Gamut boundary descriptions (GBD) and other gamut-related metadata are carried using the Gamut Metadata Packet. Gamut metadata is further described in Appendix E.

One of several transmission profiles (P0, P1, P2, etc.) can be used when sending GBDs using this packet. The difference between the transmission profiles is primarily the transmission rate,

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specifically, the number of packets that may be sent per video field. The transmission profile is indicated in the field GBD_profile.

The lowest transmission profile (P0) also has a specific size limitation; it fits within a single Gamut Metadata Packet. Higher transmission profiles (P1, P2, etc.) can be larger, requiring many packets and possibly ten or more video fields for complete transmission.

Table 5-29 Gamut Boundary Description Metadata Profiles

Transmission Profile Name	EDID Colorimetry Data Block bit	Packets per Video Field	Total Packet Count
P0	MD0	1	1
P1	MD1	1	2-10
P2	MD2	2-10	11-100
P3	MD3 *	11-80	101-800

* *This bit will be defined in a future specification.*

Gamut metadata may be transmitted that describes the gamut of the currently transmitted video or that of upcoming video. Each time the gamut of the video stream changes in a way that requires transmission of new gamut metadata, a gamut sequence number is incremented. All metatdata packets include two fields, Affected_Gamut_Seq_Num and Current_Gamut_Seq_Num, that together indicate whether the metadata regards the current or the subsequent video stream. All Gamut Metadata Packets within a single video field (VSYNC active edge to VSYNC active edge) shall have the same Current_Gamut_Seq_Num field.

If a packet contains metadata for the currently transmitted video, Affected_Gamut_Seq_Num will be equal to Current_Gamut_Seq_Num. If the packet regards upcoming video, the Affected_Gamut_Seq_Num will be Current_Gamut_Seq_Num + 1 (mod 16). The field Affected_Gamut_Seq_Num shall never be beyond Current_Gamut_Seq_Num + 1, therefore, only current and next gamut may be described.

If it is known by the Source that a packet contains metadata that will be effective for the next video field then the Next_Field flag shall be set, whether or not the metadata is effective for the current video field.

Gamut metadata associated with upcoming video may be transmitted even when the current video has no associated metadata. In this situation, all Gamut Metadata packets transmitted shall indicate that the current stream has no associated metadata (i.e. colorimetry and gamut are described by the currently-valid AVI InfoFrame) by setting No_Current_GBD to 1. At least one such Gamut Metadata packet shall be transmitted in the VBLANK period. All Gamut Metadata packets within that same video field can carry metadata for the upcoming video.

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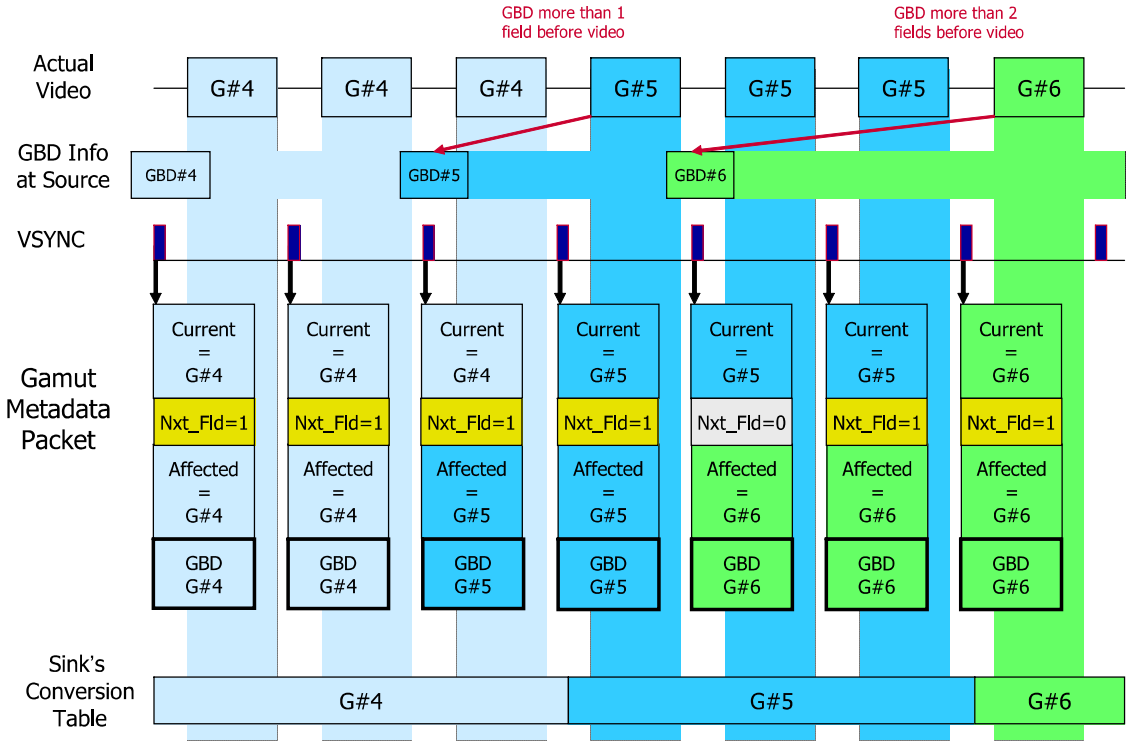


Figure 5-6 Example P0 Transmission Sequence

During the transmission of any video stream that is accompanied by or requires gamut metadata, at least one Gamut Metadata Packet containing a P0 transmission profile GBD shall be transmitted during each VBLANK. This transmission shall occur before the end of the first (VBLANK) video line following the active edge of VSYNC. If no Gamut Metadata Packet is transmitted during this period, then the colorimetry and gamut of the subsequent VACTIVE for that video field shall correspond to that described by the transmitted AVI InfoFrame.

If the Sink indicates support for P2 or higher transmission profiles then the Source may simultaneously transmit two GBDs. In this case, within each video field, the Source may transmit: a P0 profile containing the GBD for the current video and a portion of a higher profile containing the GBD for either the current or the upcoming video. Alternatively, the two simultaneous GBDs may be a P0 profile describing the current video and a P0 profile describing the upcoming video.

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Table 5-30 Gamut Metadata Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	0	0	0	0	1	0	1	0
HB1	Next_Field	GBD_profile			Affected_Gamut_Seq_Num			
HB2	No_Crnt _GBD	Rsvd (0)	Packet_Seq		Current_Gamut_Seq_Num			

- Next_Field [1 bit] Set to indicate that the GBD carried in this packet will be effective on the next video field. Specifically, the Affected_Gamut_Seq_Num for this packet will be equal to the Current_Gamut_Seq_Num for the next field. Next_Field should be set even if the GBD is already effective (e.g. Current=Affected).
- No_Current_GBD [1 bit] Set to indicate that there is no gamut metadata available for the currently transmitted video (i.e. current video has a standard colorimetry not requiring a GBD). When set, the field Current_Gamut_Seq_Num is meaningless and shall be ignored by the Sink.
- GBD_profile [3 bits] Transmission profile number:
  0: P0
  1: P1
  2: P2
  3: P3
  other values: reserved.
- Affected_Gamut_Seq_Num [4 bits] Indicates which video fields are relevant for this metadata.
- Current_Gamut_Seq_Num [4 bits] Indicates the gamut number of the currently transmitted video stream. All Gamut Metadata Packets transmitted within the same video field shall have the same Current_Gamut_Seq_Num, even if the Affected_Gamut_Seq_Num varies among the packets.
- Packet_Seq [2 bits] Indicates whether this packet is the only, the first, an intermediate or the last packet in a Gamut Metadata packet sequence.
  = 0 (0b00) Intermediate packet in sequence
  = 1 (0b01) First packet in sequence
  = 2 (0b10) Last packet in sequence
  = 3 (0b11) Only packet in sequence (i.e. P0)

The Gamut Metadata Packet Body differs depending upon transmission profile and whether the packet is the first of a sequence or one of the remaining packets in that sequence.

The packet body for a P0 transmission is defined in Table 5-31.

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Table 5-31 Gamut Metadata Packet for P0 Transmission Profile

Packet Byte #	7	6	5	4	3	2	1	0
PB00-PB27	GBD bytes 0 through 27							

When transmitting any GBD requiring more than one Gamut Metadata Packet for transmission, a packet containing the packet body shown in Table 5-32 shall be used. Subsequent packets in that sequence shall use the packet body shown in Table 5-33. If the GBD ends midway through a packet, the rest of the body shall be filled with zeroes by the Source and shall be ignored by the Sink.

Table 5-32 Gamut Metadata Packet for P1 and Higher – 1st Packet of Sequence

Packet Byte #	7	6	5	4	3	2	1	0
PB0	GBD_Length_H							
PB1	GBD_Length_L							
PB2	Checksum							
PB3-PB27	GBD bytes 0 through 24							

- GBD_Length(_H, _L) [2 bytes] Total length (in bytes) of gamut metadata, not including GBD_Length or Checksum.
- Checksum [1 byte] Checksum of every byte covered by GBD_Length field.

Table 5-33 Gamut Metadata Packet for P1 and Higher – Remaining Packets

Packet Byte #	7	6	5	4	3	2	1	0
PB00-PB27	Next 28 bytes of GBD							

5.4 Encoding

5.4.1 Serialization

The stream of TMDS characters produced by the encoder is serialized for transmission on the TMDS data channel. In the discussions that follow, the least significant bit of each character (q_out[0]) is the first bit to be transmitted and the most significant bit (q_out[9]) is the last.

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5.4.2 Control Period Coding

Each TMDS channel has two control signals, which are encoded into 10 bits during Control Periods. For each of the three channels these signals are shown in Table 5-34.

Table 5-34 Control-signal Assignment

TMDS Channel	D0	D1
0	HSYNC	VSYNC
1	CTL0	CTL1
2	CTL2	CTL3

The two Control signals for each of the three TMDS channels are encoded as follows:

```
case (D1, D0):
       0, 0:  q_out[9:0] = 0b1101010100;
       0, 1:  q_out[9:0] = 0b0010101011;
       1, 0:  q_out[9:0] = 0b0101010100;
       1, 1:  q_out[9:0] = 0b1010101011;
endcase;
```

5.4.3 TERC4 Coding

TMDS Error Reduction Coding (TERC4) is used during the Data Island period to encode 4 bits per channel into the 10 bits serialized and transmitted.

```
case (D3, D2, D1, D0):
    0000:  q_out[9:0] = 0b1010011100;
    0001:  q_out[9:0] = 0b1001100011;
    0010:  q_out[9:0] = 0b1011100100;
    0011:  q_out[9:0] = 0b1011100010;
    0100:  q_out[9:0] = 0b0101110001;
    0101:  q_out[9:0] = 0b0100011110;
    0110:  q_out[9:0] = 0b0110001110;
    0111:  q_out[9:0] = 0b0100111100;
    1000:  q_out[9:0] = 0b1011001100;
    1001:  q_out[9:0] = 0b0100111001;
    1010:  q_out[9:0] = 0b0110011100;
    1011:  q_out[9:0] = 0b1011000110;
    1100:  q_out[9:0] = 0b1010001110;
    1101:  q_out[9:0] = 0b1001110001;
    1110:  q_out[9:0] = 0b0101100011;
    1111:  q_out[9:0] = 0b1011000011;
endcase;
```


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5.4.4 Video Data Coding

5.4.4.1 Video Data Encoding

The following is a description of the encoding algorithm used during transmission of video data. A detailed description of an encoder is given. Other implementations are possible and are permitted but, given the same sequence of input characters, they are required to produce the same sequence of output (10-bit) characters that is generated by the described encoder.

During video data, where each 10-bit character represents 8 bits of pixel data, the encoded characters provide an approximate DC balance as well as a reduction in the number of transitions in the data stream. The encode process for the active data period can be viewed in two stages. The first stage produces a transition-minimized 9-bit code word from the input 8 bits. The second stage produces a 10-bit code word, the finished TMDS character, which will manage the overall DC balance of the transmitted stream of characters.

The 9-bit code word produced by the first stage of the encoder is made up of an 8-bit representation of the transitions found in the input 8 bits, plus a one-bit flag to indicate which of two methods was used to describe the transitions. In both cases, the LSb of the output matches the LSb of the input. With a starting value established, the remaining 7 bits of the output word is derived from sequential exclusive OR (XOR) or exclusive NOR (XNOR) functions of each bit of the input with the previously derived bit. The choice between XOR and XNOR logic is made such that the encoded values contain the fewest possible transitions, and the ninth bit of the code word is used to indicate whether XOR or XNOR functions were used to derive the output code word. The decode of this 9-bit code word is simply a matter of applying either XOR or XNOR gates to the adjacent bits of the code, with the LSb passing from decoder input to decoder output unchanged.

The second stage of the encoder performs an approximate DC balance on the transmitted stream by selectively inverting the 8 data bits of the 9-bit code words produced by the first stage. A tenth bit is added to the code word, to indicate when the inversion has been made. The encoder determines when to invert the next character based on the running disparity between ones and zeros that it tracks in the transmitted stream, and the number of ones and zeros found in the current code word. If too many ones have been transmitted and the input contains more ones than zeros, the code word is inverted. This dynamic encoding decision at the Source is simply decoded at the Sink by the conditional inversion of the input code word based on the tenth bit of the TMDS character. The TMDS code mapping is specified by Figure 5-7 with the definitions of Table 5-35. The encoder produces one of 460 unique 10-bit characters. The encoder shall not generate any other 10-bit character during a Video Data Period.

Upon entering a Video Data Period, the data stream disparity (cnt) shall be considered to be zero by the encoder.

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Table 5-35 Encoding Algorithm Definitions

D	The encoder input data set. D is 8-bit pixel data
cnt	This is a register used to keep track of the data stream disparity. A positive value represents the excess number of “1”s that have been transmitted. A negative value represents the excess number of “0”s that have been transmitted. The expression cnt{t-1} indicates the previous value of the disparity for the previous set of input data. The expression cnt(t) indicates the new disparity setting for the current set of input data.
q_m	Intermediate value.
q_out	These 10 bits are the encoded output value.
N_1{x}	This operator returns the number of “1”s in argument “x”
N_0{x}	This operator returns the number of “0”s in argument “x”

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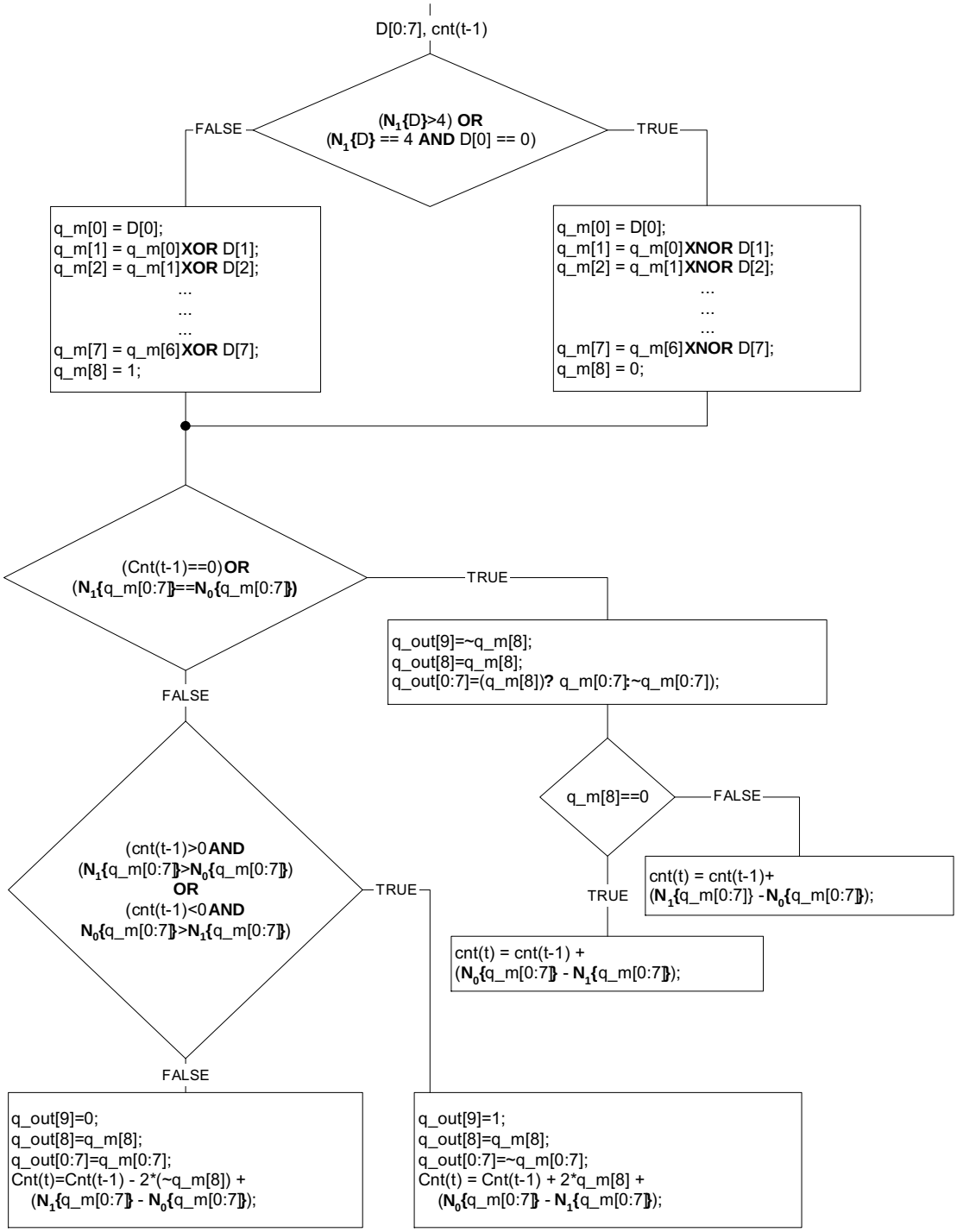


Figure 5-7 TMDS Video Data Encode Algorithm

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5.4.4.2 Video Data Decoding

The TMDS decode mapping is specified by Figure 5-8. Alternative implementations are possible but, given the same input data stream, they are required to generate the same output data stream as the described decoder algorithm.

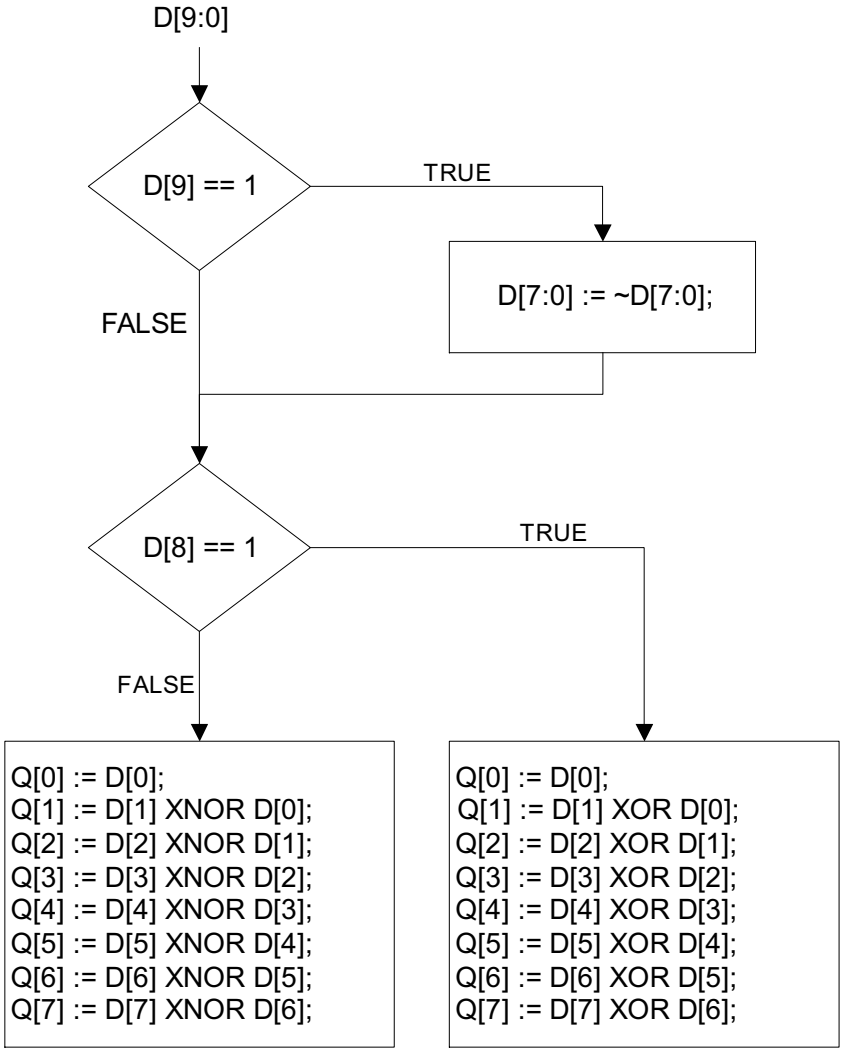


Figure 5-8 TMDS Video Decode Algorithm

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6 Video

6.1 Overview

HDMI allows any video format timing to be transmitted and displayed. To maximize interoperability between products, common DTV formats have been defined. These video format timings define the pixel and line counts and timing, synchronization pulse position and duration, and whether the format is interlaced or progressive. HDMI also allows vendor-specific formats to be used.

The video pixels carried across the link shall be in one of three different pixel encodings: RGB 4:4:4, YC_BC_R 4:4:4 or YC_BC_R 4:2:2.

The HDMI Source determines the pixel encoding and video format of the transmitted signal based on the characteristics of the source video, the format and pixel encoding conversions possible at the Source, and the format and pixel encoding capabilities and preferences of the Sink.

6.2 Video Format Support

In order to provide maximum compatibility between video Sources and Sinks, specific minimum requirements have been specified for Sources and Sinks.

6.2.1 Format Support Requirements

Some of the following support requirements are in addition to those specified in CEA-861-D.

- An HDMI Source shall support at least one of the following video format timings:
  - 640x480p @ 59.94/60Hz
  - 720x480p @ 59.94/60Hz
  - 720x576p @ 50Hz
- An HDMI Source that is capable of transmitting any of the following video format timings using any other component analog or uncompressed digital video output, shall be capable of transmitting that video format timing across the HDMI interface.
  - 1280x720p @ 59.94/60Hz
  - 1920x1080i @ 59.94/60Hz
  - 720x480p @ 59.94/60Hz
  - 1280x720p @ 50Hz
  - 1920x1080i @ 50Hz
  - 720x576p @ 50Hz

- An HDMI Sink that accepts 60Hz video formats shall support the 640x480p @ 59.94/60Hz and 720x480p @ 59.94/60Hz video format timings.
- An HDMI Sink that accepts 50Hz video formats shall support the 640x480p @ 59.94/60Hz and 720x576p @ 50Hz video format timings.

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- An HDMI Sink that accepts 60Hz video formats, and that supports HDTV capability, shall support 1280x720p @ 59.94/60Hz or 1920x1080i @ 59.94/60Hz video format timings.
- An HDMI Sink that accepts 50Hz video formats, and that supports HDTV capability, shall support 1280x720p @ 50Hz or 1920x1080i @ 50Hz video format timings.
- An HDMI Sink that is capable of receiving any of the following video format timings using any other component analog or uncompressed digital video input, shall be capable of receiving that format across the HDMI interface.
    - 1280x720p @ 59.94/60Hz
    - 1920x1080i @ 59.94/60Hz
    - 1280x720p @ 50Hz
    - 1920x1080i @ 50Hz

Additional recommendations for video format handling by Sources and Sinks is given in Appendix F.

6.2.2 Video Control Signals : HSYNC, VSYNC

During the Data Island period, HDMI carries HSYNC and VSYNC signals using encoded bits on Channel 0. During Video Data periods, HDMI does not carry HSYNC and VSYNC and the Sink should assume that these signals remain constant. During Control periods, HDMI carries HSYNC and VSYNC signals through the use of four different control characters on TMDS Channel 0.

6.2.3 Pixel Encoding Requirements

Only pixel encodings of RGB 4:4:4, YC_BC_R 4:2:2, and YC_BC_R 4:4:4 (as specified in Section 6.5) may be used on HDMI.

All HDMI Sources and Sinks shall be capable of supporting RGB 4:4:4 pixel encoding.

All HDMI Sources shall support either YC_BC_R 4:2:2 or YC_BC_R 4:4:4 pixel encoding whenever that device is capable of transmitting a color-difference color space across any other component analog or digital video interface except where that device would be required to convert RGB video to YC_BC_R in order to meet this requirement.

All HDMI Sinks shall be capable of supporting both YC_BC_R 4:4:4 and YC_BC_R 4:2:2 pixel encoding when that device is capable of supporting a color-difference color space from any other component analog or digital video input.

If an HDMI Sink supports either YC_BC_R 4:2:2 or YC_BC_R 4:4:4 then both shall be supported.

An HDMI Source may determine the pixel-encodings that are supported by the Sink through the use of the E-EDID. If the Sink indicates that it supports YC_BC_R-formatted video data and if the Source can deliver YC_BC_R data, then it can enable the transfer of this data across the link.

6.2.4 Color Depth Requirements

HDMI Sources and Sinks may support color depths of 24, 30, 36 and/or 48 bits per pixel. All HDMI Sources and Sinks shall support 24 bits per pixel.

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Color depths greater than 24 bits are defined to be “Deep Color” modes. All Deep Color modes are optional though if an HDMI Source or Sink supports any Deep Color mode, it shall support 36-bit mode.

For each supported Deep Color mode, RGB 4:4:4 shall be supported and optionally YC_BC_R 4:4:4 may be supported.

YC_BC_R 4:2:2 is not permitted for any Deep Color mode.

An HDMI Sink shall support all EDID-indicated Deep Color modes on all EDID-indicated video formats except if that combination exceeds the Max_TMDS_Clock indication.

An HDMI Source shall not send any Deep Color mode to a Sink that does not indicate support for that mode.

6.3 Video Format Timing Specifications

All specified video line pixel counts and video field line counts (both active and total) and HSYNC and VSYNC positions, polarities, and durations shall be adhered to when transmitting a specified video format timing.

For example, if a Source is processing material with fewer active pixels per line than required (i.e. 704 pixels vs. 720 pixels for standard definition MPEG2 material), it may add pixels to the left and right of the supplied material before transmitting across HDMI. AVI bar info may need to be adjusted to account for these added pixels.

Detailed timing is found in CEA-861-D or a later version of CEA-861 for the following video format timings.

6.3.1 Primary Video Format Timings

- 640x480p @ 59.94/60Hz
- 1280x720p @ 59.94/60Hz
- 1920x1080i @ 59.94/60Hz
- 720x480p @ 59.94/60Hz
- 720(1440)x480i @ 59.94/60Hz
- 1280x720p @ 50Hz
- 1920x1080i @ 50Hz
- 720x576p @ 50Hz
- 720(1440)x576i @ 50Hz

6.3.2 Secondary Video Format Timings

- 720(1440)x240p @ 59.94/60Hz
- 2880x480i @ 59.94/60Hz
- 2880x240p @ 59.94/60Hz

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- 1440x480p @ 59.94/60Hz
- 1920x1080p @ 59.94/60Hz
- 720(1440)x288p @ 50Hz
- 2880x576i @ 50Hz
- 2880x288p @ 50Hz
- 1440x576p @ 50Hz
- 1920x1080p @ 50Hz
- 1920x1080p @ 23.98/24Hz
- 1920x1080p @ 25Hz
- 1920x1080p @ 29.97/30Hz
- 2880x480p @ 59.94/60Hz
- 2880x576p @ 50Hz
- 1920x1080i (1250 total) @ 50Hz
- 720(1440)x480i @ 119.88/120Hz
- 720x480p @ 119.88/120Hz
- 1920x1080i @ 119.88/120Hz
- 1280x720p @ 119.88/120Hz
- 720(1440)x480i @ 239.76/240Hz
- 720x480p @ 239.76/240Hz
- 720(1440)x576i @ 100Hz
- 720x576p @ 100Hz
- 1920x1080i @ 100Hz
- 1280x720p @ 100Hz
- 720(1440)x576i @ 200Hz
- 720X576p @ 200Hz

6.4 Pixel-Repetition

Video formats with native pixel rates below 25 Mpixels/sec require pixel-repetition in order to be carried across a TMDS link. 720x480i and 720x576i video format timings shall always be pixel-repeated.

The HDMI Source indicates the use of pixel-repetition with the Pixel Repetition (PR0:PR3) field in the AVI InfoFrame. This field indicates to the HDMI Sink how many repetitions of each unique pixel are transmitted. In non-repeated formats, this value is zero.

For pixel-repeated formats, this value indicates the number of pixels that may be discarded by the Sink without losing real image content.

The Source shall always accurately indicate the pixel repetition count being used. The use of the Pixel Repetition field is optional for HDMI Sink.

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The use of this pixel-repetition count field is more fully described in CEA-861-D.

6.5 Pixel Encodings and Color Depth

There are three different pixel encodings that may be sent across an HDMI cable: YC_BC_R 4:4:4, YC_BC_R 4:2:2 and RGB 4:4:4. Whichever encoding is used, it shall conform to one of the methods described in this section.

There are four color depths supported: 24-, 30-, 36- and 48-bits per pixel. Only RGB 4:4:4 and YC_BC_R 4:4:4 are permitted at depths greater than 24-bits ("Deep Color" modes).

6.5.1 24-Bit Pixel Encodings

Figure 6-1 shows the default encoding, RGB 4:4:4 for 24-bit color depth. The R, G, and B components of the first pixel for a given line of video are transferred on the first pixel of the video data period following the Guard Band characters.

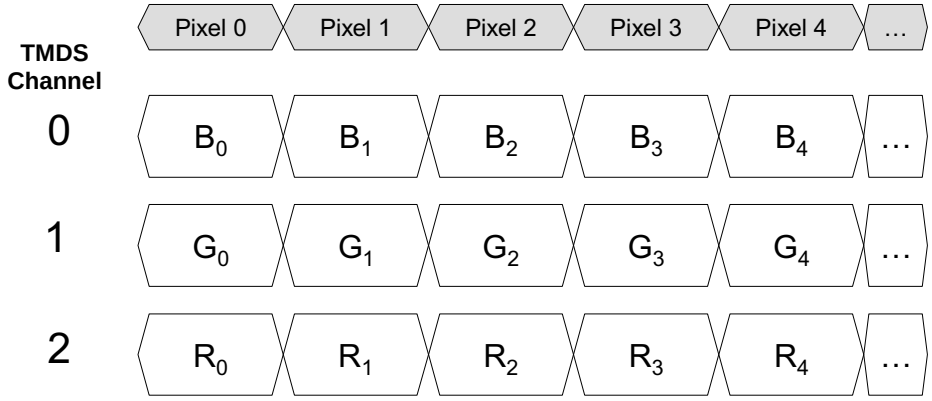
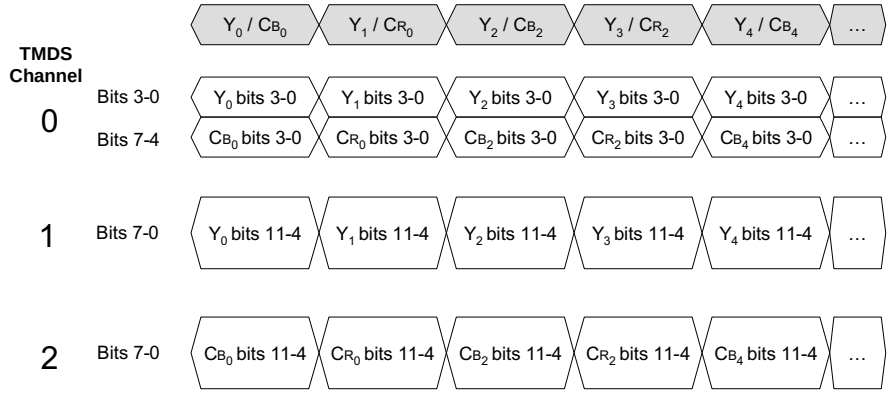


Figure 6-1 Default pixel encoding: RGB 4:4:4, 8 bits/component

Figure 6-2 shows the signal mapping and timing for transferring 24-bit YC_BC_R 4:2:2 data across HDMI. Because 4:2:2 data only requires two components per pixel, more bits are allocated per component. The available 24 bits are split into 12 bits for the Y component and 12 bits for the C components.



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Figure 6-2 YC_BC_R 4:2:2 component

The YC_BC_R 4:2:2 pixel encoding on HDMI closely resembles standard ITU-R BT.601. The high-order 8 bits of the Y samples are mapped onto the 8 bits of Channel 1 and the low-order 4 bits are mapped onto the low-order 4 bits of Channel 0. If fewer than 12 bits are used, the valid bits shall be left-justified (i.e. MSb=MSb) with zeroes padding the bits below the LSb.

The first pixel transmitted within a Video Data Period contains three components, Y0, Cb0 and Cr0. The Y0 and Cb0 components are transmitted during the first pixel period while Cr0 is transmitted during the second pixel period. This second pixel period also contains the only component for the second pixel – Y1. In this way, the link carries one C_B sample for every two pixels and one Cr sample for every two pixels. These two components (C_B and C_R) are multiplexed onto the same signal paths on the link.

At the third pixel, this process is repeated with the Y and C_B components for the third pixel being transmitted, followed, in the next pixel period, by the C_R component of the third pixel and the Y component of the fourth pixel.

YC_BC_R 4:4:4 data is transferred using the scheme illustrated in Figure 6-3.

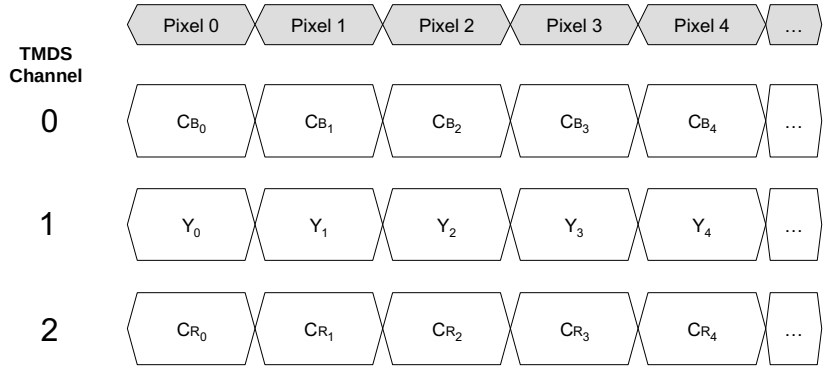


Figure 6-3 8-bit YC_BC_R 4:4:4 mapping

6.5.2 Deep Color Pixel Packing

For a color depth of 24 bits/pixel, pixels are carried at a rate of one pixel per TMDS clock. At deeper color depths, the TMDS clock is run faster than the source pixel clock providing the extra bandwidth for the additional bits. The TMDS clock rate is increased by the ratio of the pixel size to 24 bits:

- 24 bit mode: TMDS clock = 1.0 x pixel clock (1:1)
- 30 bit mode: TMDS clock = 1.25 x pixel clock (5:4)
- 36 bit mode: TMDS clock = 1.5 x pixel clock (3:2)
- 48 bit mode: TMDS clock = 2.0 x pixel clock (2:1)

When operating in a Deep Color mode, all video data (pixels) and signaling (HSYNC, VSYNC, DE transitions) are grouped into a series of packed Pixel Groups, each carrying the same number of pixels and each requiring the same number of TMDS clocks for transmission. On each TMDS

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clock, one Fragment of the Pixel Group is transmitted. The number of pixels per group and number of fragments per group depends on the pixel size:

- 24 bit mode: 1 pixel/group, 1 fragment/group
- 30 bit mode: 4 pixels/group, 5 fragments/group
- 36 bit mode: 2 pixels/group, 3 fragments/group
- 48 bit mode: 1 pixel/group, 2 fragments/group

During active video, the input pixel data is packed into these groups. During blanking, HSYNC and VSYNC are packed into these same groups. In this way, all video-related protocol elements are carried at a direct ratio to the pixel clock, thus ensuring no change to the relationship between the pixel clock and the pixel data, DE transitions and HSYNC or VSYNC transitions. This also allows any sequence of HSYNC, VSYNC, DE transitions, etc. that can be supported at 24 bits/pixel to be supported equally in any other pixel size.

All other HDMI protocol elements are unaffected by the Deep Color pixel packing. Data Islands, Video Guard Bands and Preambles occur as they do in normal (24-bit) mode – each Preamble is 8 TMDS clocks, each Data Island packet is 32 TMDS clocks, and each Guard Band is 2 TMDS clocks.

As shown above, a pixel group consists of 1, 2, or 4 pixels. Each pixel group is broken into 1, 2, 3 or 5 pixel fragments transmitted one fragment per TMDS clock.

Each TMDS character period (one TMDS clock) in the transmitted stream carries a single Fragment of a Pixel Group and so represents a particular Packing Phase of the group. It is necessary for the Sink to determine which character in the stream of characters represents the start of a new group, or phase 0, in order to synchronize its pixel unpacking state with the source's pixel packing state. To accomplish this, the source sends a packet indicating the packing phase of a specific pixel (see 6.5.3 for packet details). This packet is sent at least once per video field indicating the then-current packing phase. The sink uses this data to initially determine where each new group starts should also use this periodic update to verify that it is still synchronized or to recover from gross errors on the link.

The following tables specify all Pixel Encodings for all color depths. For each mode, the packing for each phase is described. Packing phases for active video are identified as "*m*P*n*" (10P0, 10P1, etc. while the packing phases for blanking are identified as "*m*C*n*" (10C0, 10C1, etc.).

24 bit mode: P (pixels/group) = 1 pixel; L (fragments/group) = 1 fragment (1 TMDS character). Standard HDMI format.

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Fragment	Phase	Pixels	8 bit HDMI pixel data code (to encoder)							
			Bit 0	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7
8P0	0	A	A0	A1	A2	A3	A4	A5	A6	A7

30 bit mode: P = 4 pixels; L = 5 fragments

Fragment	Phase	Pixels	8 bit HDMI pixel data code (to encoder)							
			Bit 0	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7
10P0	0	A	A0	A1	A2	A3	A4	A5	A6	A7
10P1	1	A+B	A8	A9	B0	B1	B2	B3	B4	B5
10P2	2	B+C	B6	B7	B8	B9	C0	C1	C2	C3
10P3	3	C+D	C4	C5	C6	C7	C8	C9	D0	D1
10P4	4	D	D2	D3	D4	D5	D6	D7	D8	D9

36 bit mode: P = 2 pixels; L = 3 fragments

Fragment	Phase	Pixels	8 bit HDMI pixel data code (to encoder)							
			Bit 0	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7
12P0	0	A	A0	A1	A2	A3	A4	A5	A6	A7
12P1	1	A+B	A8	A9	A10	A11	B0	B1	B2	B3
12P2	2	B	B4	B5	B6	B7	B8	B9	B10	B11

48 bit mode: P = 1 pixel; L = 2 fragments

Fragment	Phase	Pixels	8 bit HDMI pixel data code (to encoder)							
			Bit 0	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7
16P0	0	A	A0	A1	A2	A3	A4	A5	A6	A7
16P1	1	A	A8	A9	A10	A11	A12	A13	A14	A15

During blanking, one HSYNC and VSYNC value per pixel clock is carried in each Pixel Group. This provides one more HSYNC and VSYNC slot per group than is required (e.g. 5 TMDS clocks for 4 pixels) so the HSYNC and VSYNC values are simply repeated on the last TMDS clock of a group.

The following tables specify, for each mode, the group size and the sequence of HSYNC and VSYNC transmission within a group.

Source HSYNC/VSYNC values for each pixel are labeled S, T, U, V (as needed). Source HSYNC/VSYNC value S is the leftmost (earliest) code in the group.

- 24 bit mode:

Group size = 1 pixel; 1 fragment.

Fragment	HS/VS value
8C0	S

- 30 bit mode:

In 30-bit mode, if the Video Data Period ends before the pixel group boundary, the remaining fragments are filled using one or more steps from the 10PC*n* sequence listed in the table below until the group boundary is reached (step 10PC4). After that, the normal sequence is used (steps 10C*n*).

Group size = 4 pixels; 5 fragments.

Fragment	HS/VS value
10C0	S
10C1	T
10C2	U

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10C3	V
10C4	V

30-bit mode remnant (Falling Edge of DE occurs mid-group). Bridge states for transition from 10P*n* to 10C0 are named “10PC*n*”:

Fragment	HS/VS value
10PC2	T
10PC3	U
10PC4	V

- 36 bit mode:

Group size = 2 pixels; 3 fragment.

Fragment	HS/VS value
12C0	S
12C1	T
12C2	T

- 48 bit mode:

Group size = 1 pixel; 2 fragment.

Fragment	HS/VS value
16C0	S
16C1	S

6.5.3 Deep Color Mode / Phase Indication

When in a Deep Color mode, the Source and Sink each records the packing phase of the last pixel character of a Video Data period. The Source occasionally sends a General Control Packet (GCP) communicating the current color depth and the packing phase of the last pixel character sent prior to the GCP. This data is valid in the GCP whenever CD (CD0, CD1, CD2, CD3) is non-zero. Whenever the Sink receives a GCP with non-zero CD data, it should compare the receiver’s own color depth and phase with the CD data. If they do not match, the Sink should adjust its color depth and/or phase to match the CD data.

When transmitting Deep Color, the Source shall send a General Control Packet (GCP) with an accurate CD field indicating the current color depth and with the PP field (PP0, PP1, PP2, PP3) indicating the packing phase of the last pixel character (within the last Video Data Period) sent prior to the GCP. Sources shall only send GCPs with non-zero CD to Sinks that indicate support for Deep Color, and shall only select color depths supported by the Sink.

Once a Source sends a GCP with non-zero CD to a sink, it should continue sending GCPs with non-zero CD at least once per video field even if reverting to 24-bit color, as long as the Sink continues to support Deep Color.

If the Sink does not receive a GCP with non-zero CD for more than 4 consecutive video fields, it should exit deep color mode (revert to 24-bit color).

Color Depth field (CD) of SB1:

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- When CD is zero, no information about color depth is indicated. PP shall be zero.
- When CD is non-zero, the color depth is indicated and the packing phase bits (PP) are valid.

Table 6-1 Color Depth (CD field) Values

CD3	CD2	CD1	CD0	Color Depth
0	0	0	0	Color Depth not indicated
0	0	0	1	Reserved
0	0	1	0	Reserved
0	0	1	1	Reserved
0	1	0	0	24 bits per pixel
0	1	0	1	30 bits per pixel
0	1	1	0	36 bits per pixel
0	1	1	1	48 bits per pixel
All other values				Reserved

A CD field of zero (Color Depth not indicated) shall be used whenever the Sink does not indicate support for Deep Color. This value may also be used in Deep Color mode to transmit a GCP indicating only non-Deep Color information (e.g. AVMUTE).

When the CD field indicates 24 bits per pixel, the PP field is invalid and should be ignored by the Sink.

Pixel Packing Phase field (PP) of SB1:

- When the CD field is zero, the PP field shall also be zero.
- When the CD field is non-zero, the PP field indicates the packing phase of the last fragment in the most recent Video Data Period (prior to the GCP message).

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Table 6-2 shows the specific PP values for each of the packing phases shown in the packing phase tables earlier.

Table 6-2 Pixel Packing Phase (PP field) Values

PP3	PP2	PP1	PP0	Pixel packing Phase
0	0	0	0	Phase 4 (10P4)
0	0	0	1	Phase 1 (10P1, 12P1, 16P1)
0	0	1	0	Phase 2 (10P2, 12P2)
0	0	1	1	Phase 3 (10P3)
0	1	0	0	Reserved
All other values				Reserved

Packing phase 0 does not need to be indicated using the PP bits. This is not necessary as phase 0 always represents only part of the first pixel of the group and therefore, no Video Data Period will end at phase 0. If the active video ended after the first pixel, then the final phase will be phase 1, containing the last bits of the first pixel.

If the transmitted video format has timing such that the phase of the first pixel of every Video Data Period corresponds to pixel packing phase 0 (e.g. 10P0, 12P0, 16P0), the Source may set the Default_Phase bit in the GCP. The Sink may use this bit to optimize it's filtering or handling of the PP field.

Default_Phase field of GCP SB2:

- When Default_Phase is 0, the PP bits may vary and the first pixel of each Video Data Period may vary.
- When Default_Phase is 1, the following will be true:
  - The first pixel of each Video Data Period shall always have a pixel packing phase of 0 (10P0, 12P0, 16P0).
  - The first pixel following each Video Data Period shall have a pixel packing phase of 0 (10C0, 12C0, 16C0).
  - The PP bits shall be constant for all GCPs and will be equal to the last packing phase (10P4, 12P2, 16P1).
  - The first pixel following every transition of HSYNC or VSYNC shall have a pixel packing phase of 0 (10C0, 12C0, 16C0).

6.5.4 Pixel Repetition

During pixel-doubling (Pixel_Repetition_Count = 1), all of the data sent across during the first pixel period will be repeated during the second pixel period. The third pixel period will then represent the second actual pixel and so on. This is shown below for YC_BC_R 4:2:2.

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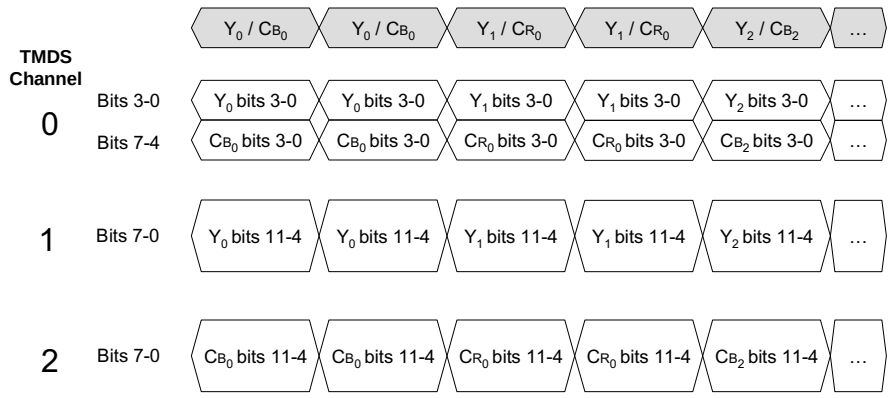


Figure 6-4 YC_BC_R 4:2:2 with Pixel-Doubling

Pixel repetition is permitted in conjunction with Deep Color modes. The Source replicates the pixels as described above prior to Deep Color packing into multiple fragments.

6.6 Video Quantization Ranges

Black and white levels for video components shall be either "Full Range" or "Limited Range." YC_BC_R components shall always be Limited Range while RGB components may be either Full Range or Limited Range. While using RGB, Limited Range shall be used for all video formats defined in CEA-861-D, with the exception of VGA (640x480) format, which requires Full Range.

Table 6-3 Video Color Component Ranges

Color Component	Component Bit Depth	for Full range		for Limited range		
		Black level	Nominal Peak (White level)	Black level	Nominal Peak (White level)	Valid Range
R / G / B	8	0	255	16	235	1 to 254
R / G / B	10	0	1023	64	940	4 to 1019
R / G / B	12	0	4095	256	3760	16 to 4079
R / G / B	16	0	65535	4096	60160	256 to 65279

Color Component	Component Bit Depth	for Full range	for Limited range		
			Black level	Nominal Peak (White level)	Valid Range
Y	8	not allowed	16	235	1 to 254
C_B / C_R			-	16 and 240	
Y	10	not allowed	64	940	4 to 1019
C_B / C_R			-	64 and 960	
Y	12	not allowed	256	3760	16 to 4079
C_B / C_R			-	256 and 3840	
Y	16	not allowed	4096	60160	256 to 65279
C_B / C_R			-	4096 and 61440	

For component ranges for xvYCC, please refer to IEC 61966-2-4.

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6.7 Colorimetry

6.7.1 Default Colorimetry

Sources will typically use the specific default colorimetry for the video format being transmitted. If no colorimetry is indicated in the AVI InfoFrame's C field (C1, C0) then the colorimetry of the transmitted signal shall match the default colorimetry for the transmitted video format.

6.7.1.1 480p, 480i, 576p, 576i, 240p and 288p

The default colorimetry for all 480-line, 576-line, 240-line, and 288-line video formats described in CEA-861-D is based on SMPTE 170M.

6.7.1.2 1080i, 1080p and 720p

The default colorimetry for high-definition video formats (1080i, 1080p and 720p) described in CEA-861-D is based on ITU-R BT.709-5.

6.7.1.3 Other Formats

The default colorimetry of other video formats is sRGB.

6.7.2 Applicable Colorimetry Standards

6.7.2.1 SMPTE 170M / ITU-R BT.601

For any video categorized as SMPTE 170M, ITU-R BT.601-5 Section 3.5 shall be used for any color space conversion needed in the course of processing.

The encoding parameter values shall be as defined in Table 3 of ITU-R BT.601-5 and as summarized in Section 6.6.

6.7.2.2 ITU-R BT.709-5

For any video categorized as ITU-R BT.709, Part 1, Section 4 of that document shall be used for any color space conversion needed in the course of processing.

The digital representation shall be as defined in Part 1, Section 6.10 of ITU-R BT.709-5 and as summarized in Section 6.6.

6.7.2.3 IEC 61966-2-4 (xvYCC)

IEC 61966-2-4 defines the "Extended-gamut YCC color space for video applications". It is based on the YCC color encoding described in ITU-R BT.709-5 but extends its definition to a much wider gamut.

$xvYCC_{601}$ is based on the colorimetry defined in ITU-R BT.601, and $xvYCC_{709}$ is based on the colorimetry defined in ITU-R BT.709.

Refer to Chapter 4.3 of IEC 61966-2-4 for more details.

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Any Source transmission of xvYCC video (either $xvYCC_{601}$ or $xvYCC_{709}$) shall be accompanied by the transmission of valid gamut boundary metadata.

If the attached Sink does not support xvYCC or does not support Gamut Metadata Packets, then the Source should not transmit xvYCC-encoded video and shall not indicate $xvYCC_{601}$ or $xvYCC_{709}$ in the AVI InfoFrame.

6.7.3 Gamut-Related Metadata

HDMI has the ability to carry a description of the video gamut boundary using the Gamut Metadata Packet.

The Sink indicates support for specific transmission profiles by setting one or more of the MD0, MD1, etc. bits in the Colorimetry Data Block.

If the attached Sink's EDID does not include a Colorimetry Data Block then the Source shall not transmit Gamut Metadata Packets. Note that xvYCC colorimetry requires transmission of the gamut metadata.

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7 Audio

7.1 Relationship with IEC 60958/IEC 61937

L-PCM and IEC 61937 compressed audio data is formatted in the Audio Sample Packet or in the High Bitrate Audio Stream Packet as a structure that closely resembles an IEC 60958 frame. (Note: One Bit Audio and DST use a different mechanism – see the overview in sections 7.9.)

On HDMI, each IEC 60958 sub-frame is represented as a 28-bit word. There is no encoding of the preamble type, which instead is replaced with a “B” bit (start-of-block) in each Audio Sample packet. The B bit shall be set for a “B, W” frame and shall be clear for an “M, W” frame. (IEC 60958-1 Section 4.1.2). No other sub-frame preamble combinations are allowed.

Except where specifically indicated in this document, the behavior of all fields within the Audio Sample Subpackets shall follow the corresponding rules specified in the IEC 60958 or IEC 61937 specifications.

HDMI supports any IEC 61937 compressed audio format with a maximum bitrate of 6.144Mbps (frame rate of 192kHz) or less using Layout 0 of the Audio Sample Packet and higher bitrates using the HBR Audio Stream Packet (defined in section 5.3.11). See section 7.6 for more details.

Any IEC 61937-compliant compressed audio format may be supported by an HDMI Source or Sink if a published version of CEA-861 specifies an appropriate Audio Format Code for use in the EDID’s CEA Short Audio Descriptor (see CEA-861-D, table 37).

When receiving multi-channel audio, the Sink should not assume that Channel Status bits carried in Subpackets other than Subpacket 0 will have valid data.

7.2 Audio Sample Clock Capture and Regeneration

Audio data being carried across the HDMI link, which is driven by a TMDS clock running at a rate corresponding to the video pixel rate, does not retain the original audio sample clock. The task of recreating this clock at the Sink is called Audio Clock Regeneration.

There are a variety of clock regeneration methods that can be implemented in an HDMI Sink, each with a different set of performance characteristics. This specification does not attempt to define exactly how these mechanisms operate. It does however present a possible configuration and it does define the data items that the HDMI Source shall supply to the HDMI Sink in order to allow the HDMI Sink to adequately regenerate the audio clock. It also defines how that data shall be generated.

In many video source devices, the audio and video clocks are generated from a common clock (coherent clocks). In this situation, there exists a rational (integer divided by integer) relationship between these two clocks. The HDMI clock regeneration architecture can take advantage of this rational relationship and can also work in an environment where there is no such relationship between these two clocks, that is, where the two clocks are truly asynchronous or where their relationship is unknown.

Figure 7-1 Audio Clock Regeneration model, illustrates the overall system architecture model used by HDMI for audio clock regeneration. The Source shall determine the fractional relationship between the TMDS clock and an audio reference clock (128 * audio sample rate [f_s]) and shall pass the numerator and denominator of that fraction to the Sink across the HDMI link. The Sink

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may then recreate the audio clock from the TMDS clock by using a clock divider and a clock multiplier.

The exact relationship between the two clocks will be:

$$128*f_S = f_{TMDS\_clock} * N / CTS.$$

The Source shall determine the value of the numerator N as specified in Section 7.2.1. Typically, this value N will be used in a clock divider to generate an intermediate clock that is slower than the $128*f_S$ clock by the factor N. The Source will typically determine the value of the denominator CTS (Cycle Time Stamp) by counting the number of TMDS clocks in each of the $128*f_S/N$ clocks.

If there is a constant fractional relationship between these two clocks, and the two clocks are exactly synchronous, then the CTS value will quickly come to a constant value. If the clocks are asynchronous, or there is some amount of jitter between the two clocks, then the CTS value will typically alternate between two or three different values. Greater variations are possible with larger jitter.

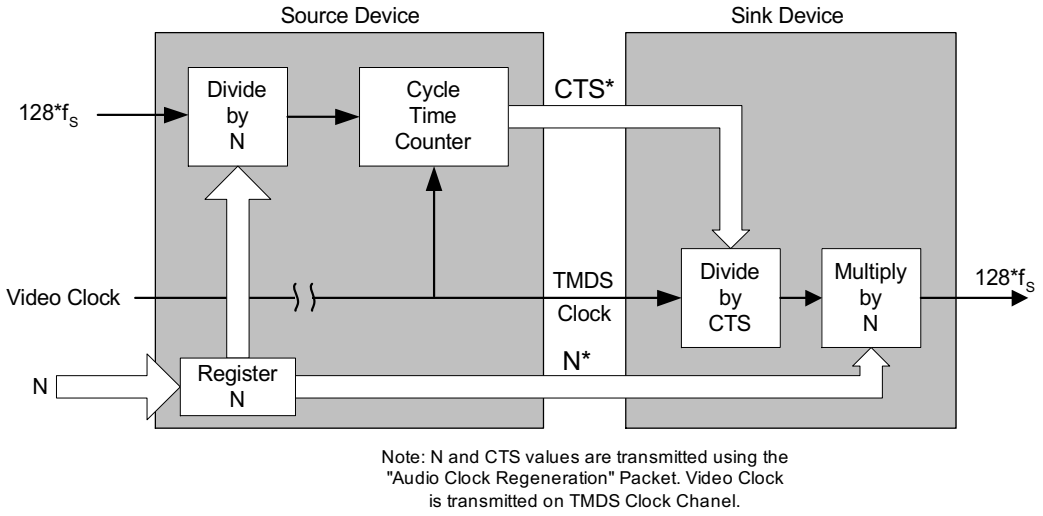


Figure 7-1 Audio Clock Regeneration model

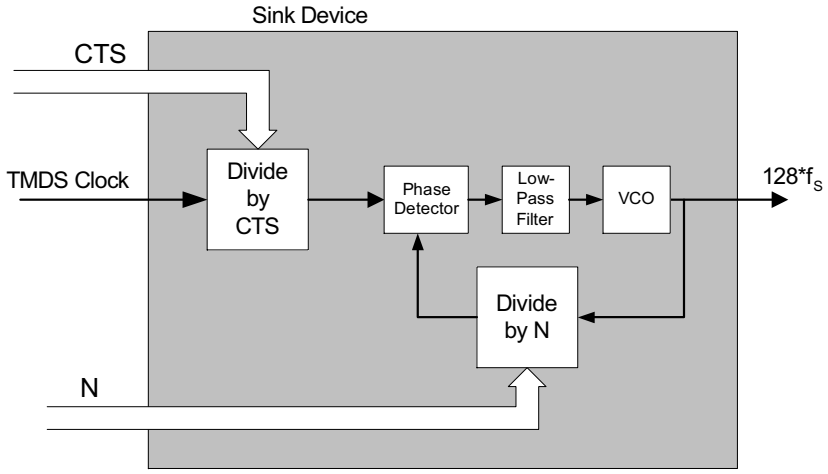


Figure 7-2 Optional Implementation: Audio Sink

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It is expected that most Sinks will be implemented with an architecture similar to that shown in Figure 7-2, however, it is permitted and possible to devise an audio clock regeneration function that does not take advantage of the N or CTS values passed to the Sink.

Note that the ACR mechanism uses the TMDS clock, not the pixel clock. When transmitting normal 24-bit pixels, the two are equivalent but when transmitting Deep Color modes, the TMDS clock, used for the ACR, will be running at a higher rate than the pixel clock.

It is recommended that Source devices be designed to support integer CTS values whenever possible.

7.2.1 N parameter

N shall be an integer number and shall meet the following restriction:

$$128 * f_S / 1500\text{Hz} \le N \le 128 * f_S / 300\text{Hz}$$

with a recommended optimal value of

$$128 * f_S / 1000\text{Hz} \text{ approximately equals } N$$

For coherent audio and video clock Sources, the tables in section 7.2.3 below should be used to determine the value of N. For non-coherent Sources or Sources where coherency is not known, the equations above should be used.

7.2.2 CTS parameter

CTS shall be an integer number that satisfies the following:

$$\text{(Average CTS value)} = (f_{TMDS\_clock} * N) / (128 * f_S)$$

7.2.3 Recommended N and Expected CTS Values

The recommended value of N for several standard TMDS clock rates are given in Table 7-1, Table 7-2, and Table 7-3. It is recommended that Sources with non-coherent clocks use the values listed for a TMDS clock of “Other”.

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Table 7-1 Recommended N and Expected CTS for 32kHz

TMDS Clock (MHz)	32 kHz	
	N	CTS
25.2 / 1.001	4576	28125
25.2	4096	25200
27	4096	27000
27 * 1.001	4096	27027
54	4096	54000
54 * 1.001	4096	54054
74.25 / 1.001	11648	210937-210938*
74.25	4096	74250
148.5 / 1.001	11648	421875
148.5	4096	148500
Other	4096	Measured

** Note: This value will alternate because of restriction on N.*

Table 7-2 Recommended N and Expected CTS for 44.1kHz and Multiples

TMDS Clock (MHz)	44.1 kHz		88.2 kHz		176.4 kHz	
	N	CTS	N	CTS	N	CTS
25.2 / 1.001	7007	31250	14014	31250	28028	31250
25.2	6272	28000	12544	28000	25088	28000
27	6272	30000	12544	30000	25088	30000
27 * 1.001	6272	30030	12544	30030	25088	30030
54	6272	60000	12544	60000	25088	60000
54 * 1.001	6272	60060	12544	60060	25088	60060
74.25 / 1.001	17836	234375	35672	234375	71344	234375
74.25	6272	82500	12544	82500	25088	82500
148.5 / 1.001	8918	234375	17836	234375	35672	234375
148.5	6272	165000	12544	165000	25088	165000
Other	6272	measured	12544	measured	25088	measured

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Table 7-3 Recommended N and Expected CTS for 48kHz and Multiples

TMDS Clock (MHz)	48 kHz		96 kHz		192 kHz	
	N	CTS	N	CTS	N	CTS
25.2 / 1.001	6864	28125	13728	28125	27456	28125
25.2	6144	25200	12288	25200	24576	25200
27	6144	27000	12288	27000	24576	27000
27 * 1.001	6144	27027	12288	27027	24576	27027
54	6144	54000	12288	54000	24576	54000
54 * 1.001	6144	54054	12288	54054	24576	54054
74.25 / 1.001	11648	140625	23296	140625	46592	140625
74.25	6144	74250	12288	74250	24576	74250
148.5 / 1.001	5824	140625	11648	140625	23296	140625
148.5	6144	148500	12288	148500	24576	148500
Other	6144	measured	12288	measured	24576	measured

7.2.4 L-PCM and IEC 61937 Compressed Audio ACR

For any L-PCM stream, the ACR f_S value shall be equal to the audio sample rate.

For any IEC 61937 compressed audio with an IEC 60958 frame rate at or below 192kHz, the ACR f_S value shall be equal to the frame rate. For any such stream with an IEC 60958 frame rate above 192kHz, the ACR f_S value shall be $1/4^{th}$ of the frame rate.

7.2.5 One Bit Audio ACR

For any One Bit Audio stream, the ACR f_S value shall be $1/64^{th}$ of the bit rate. For One Bit Audio data from Super Audio CD (2.8224MHz) the ACR f_S would therefore be 44.1kHz.

7.2.6 DST Audio ACR

For DST audio streams, the ACR f_S corresponds to the sample rate of the underlying compressed audio samples, which is typically 64*44.1kHz (2.8224MHz). This is true whether DST_Normal or DST_Double rate is used.

7.3 Audio Sample Rates and Support Requirements

If an HDMI Source supports audio transmission across any output, then it shall support HDMI audio transmission. Exceptions to this rule for Sources with Type B connectors are found in Appendix B.

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An HDMI Source is permitted to transmit L-PCM audio data at sample rates of 32kHz, 44.1kHz, 48kHz, 88.2kHz, 96kHz, 176.4kHz or 192kHz.

An HDMI Source is permitted to transmit IEC 61937 compressed audio at any IEC 60958 frame rate listed in Table 7-4.

If an HDMI Source supports any HDMI audio transmission, then it shall support 2 channel L-PCM (using an IEC 60958 Subpacket structure), with either 32kHz, 44.1kHz or 48kHz sampling rate and a sample size of 16 bits or more.

Transmitted audio shall have an audio sample rate (f_S) within ±1000 ppm of the sample rate indicated in Channel Status bits 24 through 27, except when the Source is Audio Rate Controlled by CEC (see section 7.11).

If an HDMI Sink supports audio reception from any input, then it shall support audio reception from all HDMI inputs.

An HDMI Sink may accept L-PCM audio at sample rates of 32kHz, 44.1kHz, 48kHz, 88.2kHz, 96kHz, 176.4kHz or 192kHz, and should indicate these capabilities in the E-EDID data structure.

An HDMI Sink may accept IEC 61937 compressed audio at any IEC 60958 frame rate listed in Table 7-4, and should indicate these capabilities in the E-EDID data structure.

An HDMI Sink that is capable of accepting any audio format is required to accept two channel (IEC 60958-formatted) L-PCM audio at sample rates of 32kHz, 44.1kHz, and 48kHz.

A Sink shall support the reception of an audio stream with correct sample rate indication in Channel Status bits 24 through 27 and with a sample rate (f_S) within ±1000 ppm of any supported sample rate. There is no sample size usage restriction for Sinks.

For CEA-861-D references to Sources, “Basic Audio” is defined as two channel L-PCM audio at sample rates of 32kHz, 44.1kHz, *or* 48kHz, with a sample size of at least 16 bits. For CEA-861-D references to DTV devices, “Basic Audio” is defined as two channel L-PCM audio at sample rates of 32kHz, 44.1kHz, *and* 48kHz.

An HDMI Repeater shall support HDMI audio reception and transmission.

Whenever transmitting a valid audio stream, HDMI Sources shall always include valid and correct information in Channel Status bits 24 through 27. For L-PCM audio, these bits shall indicate the audio sample frequency. For compressed audio formats, these bits shall indicate the IEC 60958 frame rate. An HDMI audio stream shall only indicate values shown in Table 7-4. Note that the allowed values do not include the IEC 60958-specified “Sample frequency not indicated” value.

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Table 7-4 Allowed Values for Channel Status bits 24 to 27

Channel Status Bit Number				Sample Frequency or Frame Rate
24	25	26	27	
1	1	0	0	32 kHz
0	0	0	0	44.1 kHz
0	0	0	1	88.2 kHz
0	0	1	1	176.4 kHz
0	1	0	0	48 kHz
0	1	0	1	96 kHz
0	1	1	1	192 kHz
1	0	0	1	768 kHz

Note that rates of 352.8 kHz, 384 kHz, 705.6 kHz are not yet supported by IEC 60958. When this happens, these rates may be supported by an HDMI Source or Sink.

In some cases, pixel-repetition may be required to increase the available bandwidth for audio transmission. For instance, when transmitting a 720x480p video format timing, it is required to pixel double in order to transmit 6 channels @ 96kHz.

7.3.1 One Bit Audio Sample Rate Requirements

A Source may transmit One Bit Audio at an f_S (1/64th of the bit rate) of 32kHz, 44.1kHz, 48kHz, 88.2kHz, 96kHz, 176.4kHz or 192kHz. Any Source capable of supporting One Bit Audio should support an f_S of 44.1kHz, corresponding to a bit rate of 2.8224MHz.

Transmitted One Bit Audio shall have an audio sample rate within ±1000 ppm of the targeted sample rate, except when the Source is Audio Rate Controlled by CEC (see section 7.11).

A Sink may accept One Bit Audio at an f_S (1/64th of the bit rate) of 32kHz, 44.1kHz, 48kHz, 88.2kHz, 96kHz, 176.4kHz or 192kHz. Any Sink capable of supporting One Bit Audio shall support an f_S of 44.1kHz, corresponding to a bit rate of 2.8224MHz.

For One Bit Audio, sample frequency information is carried in the Audio InfoFrame (see section 8.2.2).

7.3.2 DST Audio Sample Rate Requirements

All current DST streams carry compressed one bit audio samples with an actual (DAC) sampling frequency of 64*44.1kHz (2.8224MHz).

Any Source capable of supporting DST may transfer DST streams using either DST_Normal or DST_Double rate transmission.

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Transmitted DST shall have an audio sample rate within ±1000 ppm of the targeted sample rate, except when the Source is Audio Rate Controlled by CEC (see section 7.11).

Any Sink capable of supporting DST shall support streams with a sample rate of 64*44.1kHz (an f_S of 44.1kHz), and shall support reception of both DST_Normal and DST_Double rate.

7.3.3 Video Dependency

Available audio bandwidth depends upon the TMDS clock frequency, the video format timing, and whether or not content protection re-synchronization is needed.

Table 7-5 shows the available audio sample rates for 2-channel (Layout 0) and 8-channel (Layout 1) audio transmission at the various video format timings specified in CEA-861-D, assuming that 58 TMDS clocks of the horizontal blanking interval is required for content protection re-synchronization.

Table 7-5 Max Sampling Frequency for 24-bit Video Format Timings (Informative)*

Description	Format Timing	Pixel Repetition	Vertical Freq (Hz)	Max f_S 8 ch (kHz)	Max frame rate 2 ch, comp**	SuperAudio CD Channel Count
VGA	640x480p	none	59.94/60	48	192	2
480i	1440x480i	2	59.94/60	88.2	192	2
480i	2880x480i	4	59.94/60	192	768	8
240p	1440x240p	2	59.94/60	88.2	192	2
240p	2880x240p	4	59.94/60	192	768	8
480p	720x480p	none	59.94/60	48	192	2
480p	1440x480p	2	59.94/60	176.4	384	8
480p	2880x480p	4	59.94/60	192	768	8
720p	1280x720p	none	59.94/60	192	768	8
1080i	1920x1080i	none	59.94/60	192	768	8
1080p	1920x1080p	none	59.94/60	192	768	8
480i / 120Hz	1440x480i	2	119.9/120	176.4	384	8
480p / 120Hz	720x480p	none	119.9/120	96	384	8
50Hz Formats						
576i	1440x576i	2	50	88.2	192	2
576i	2880x576i	4	50	192	768	8
288p	1440x288p	2	50	88.2	192	2
288p	2880x288p	4	50	192	768	8

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576p	720x576p	none	50	48	192	2
576p	1440x576p	2	50	176.4	384	8
576p	2880x576p	4	50	192	768	8
720p/50	1280x720p	none	50	192	768	8
1080i/50	1920x1080i	none	50	192	768	8
1080p/50	1920x1080p	none	50	192	768	8
1080i, 1250 total	1920x1080i	none	50	192	768	8
576i / 100Hz	1440x576i	2	100	176.4	384	8
576p / 100Hz	720x576p	none	100	96	384	8
1080p @ 24-30Hz						
1080p	1920x1080p	None	24	192	768	8
1080p	1920x1080p	None	25	192	768	8
1080p	1920x1080p	None	29.97/30	192	768	8

** Note that formats listed in Section 6.2.4 but not listed above can carry 8 channels at 192kHz or 8 channels of One Bit Audio at the SuperAudio CD rate.*

*** Note that 2-channel PCM can never exceed 192kHz. Higher values in this column indicate higher frame rates that can be used for compressed streams. Note that 384kHz is not currently supported by IEC 60958.*

7.4 Channel / Speaker Assignment

HDMI allows a Sink to indicate the configuration of attached speakers through the use of the Speaker Allocation Data Block described in CEA-861-D section 7.5.3. Sinks supporting multi-channel L-PCM or multi-channel One Bit Audio shall include this Data Block.

In addition, for L-PCM or One Bit audio streams, the Source shall specify the speaker assignment for each of the channels in the audio stream delivered to the Sink. CEA-861-D section 6.6 specifies the available speaker assignments for active audio channels on HDMI. The indication of the current speaker assignment is carried in the CA field of the Audio InfoFrame.

7.5 Audio, Video Synchronization

For a variety of reasons, an HDMI link may add a delay to the audio and/or video.

An HDMI Source shall be capable of transmitting audio and video data streams with no more than ±2 msec of audio delay relative to the video. Due to the uneven transmission of audio data, the delay shall be considered to be the average delay of all of the audio sample packets over the course of 3 steady-state video frames.

7.6 Audio Data Packetization

Each Subpacket of an Audio Sample Packet shall contain zero or one IEC 60958-defined “frames” of an IEC 60958 or IEC 61937 “block.” There are two defined Subpacket layouts. No others are permitted.

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Table 7-6 Audio Packet Layout and Layout Value

Layout Value	Max Num Channels	Samples	Subpkt 0	Subpkt 1	Subpkt 2	Subpkt 3
0	2	4	Chnl 1,2 Sample 0	Chnl 1,2 Sample 1	Chnl 1,2 Sample 2	Chnl 1,2 Sample 3
1	8	1	Chnl 1,2 Sample 0	Chnl 3,4 Sample 0	Chnl 5,6 Sample 0	Chnl 7,8 Sample 0

There are four sample_present bits in the Audio Sample Packet Header, one for each of the Subpackets. These indicate if that Subpacket contains audio sample(s).

In addition, there are four sample_flat.spX bits which are set if no useful audio data was available at the Source during the time period represented by that sample. This may occur during sample rate changes or temporary stream interruptions. When sample_flat.spX is set, Subpacket X continues to represent a sample period but does not contain useful audio data. The sample_flat.spX bit is only valid when the corresponding sample_present.spX bit is set.

Layout 0 can be used to carry up to four samples from a single IEC 61937 or from a single 2-channel IEC 60958 stream of audio.

There are only five valid configurations of sample_present bits for a Layout 0 Audio Packet. They are shown in Table 7-7.

Table 7-7 Valid Sample_Present Bit Configurations for Layout 0

SP0	SP1	SP2	SP3	Description
0	0	0	0	No Subpackets contain audio samples.
1	0	0	0	Only Subpacket 0 contains audio samples.
1	1	0	0	Subpackets 0 and 1 contain audio samples.
1	1	1	0	Subpackets 0, 1, and 2 contain audio samples.
1	1	1	1	All Subpackets contain audio samples.

Layout 1 can be used to carry one audio sample with three to eight channels of L-PCM audio (i.e. two to four IEC 60958 streams).

Valid combinations of sample_present bits for Layout 1 Audio Packets are determined by the permitted channel allocations as described in CEA-861-D section 6.6.

An HDMI Source shall place the data shown into the specified Subpackets and to identify the layout in the Audio Sample Packet Header.

The fields within a Subpacket with a corresponding sample_flat bit set or a sample_present bit clear, are not defined and can be any value.

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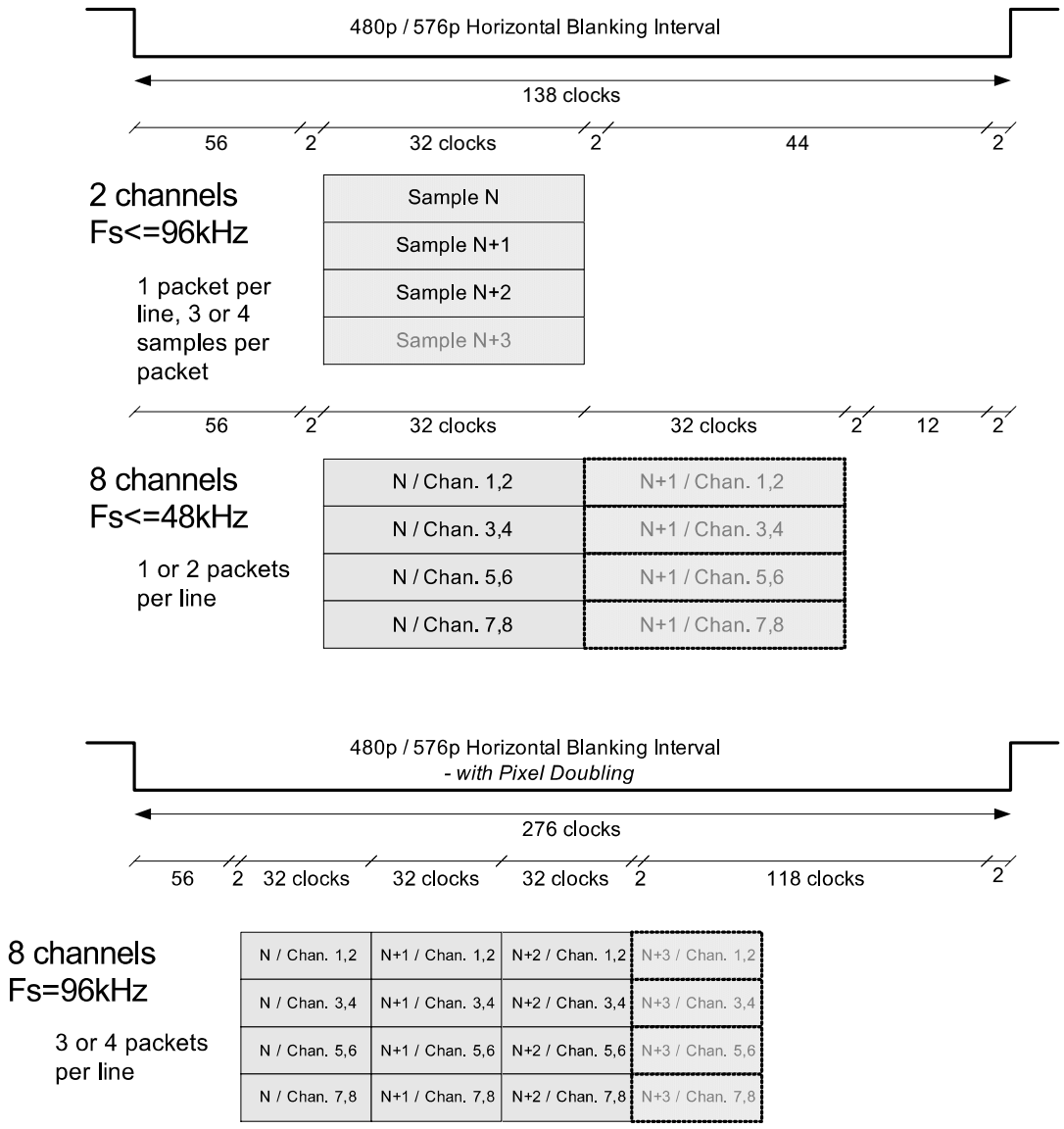


Figure 7-3 Example Audio Sample Timing (Informative)

7.6.1 One Bit Audio Packetization

When transmitting One Bit Audio, each Subpacket shall contain One Bit Audio bits for zero, one or two audio channels.

There are four sample_present bits in the One Bit Audio Sample Packet Header, one for each of the Subpackets. The corresponding bit is set if that Subpacket contains audio samples. There are four samples_invalid.spX bits which are set if no useful audio data was available at the Source during the time period represented by that sample. When samples_invalid.spX is set, Subpacket X continues to represent a sample period but does not contain any useful data.

Layout 0 can be used to carry 2 channels of One Bit Audio samples. Layout 1 can be used to carry from three to eight channels of One Bit Audio samples.

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Valid combinations of sample_present bits for Layout 1 Audio Packets are determined by the permitted channel allocations as described in section 7.6 above.

The fields within a Subpacket with a corresponding samples_invalid bit set or a sample_present bit clear, are not defined and can be any value.

7.6.2 High-Bitrate Audio Stream Packetization

When carrying IEC 61937 compressed audio at frame rates above 192kHz, the HBR Audio Stream packet shall be used.

Each Subpacket of a High-Bitrate Audio Stream Packet shall contain one IEC 60958-defined "frame" of an IEC 61937 bitstream.

Table 7-8 High Bitrate Audio Stream Packet Layout

Subpkt 0	Subpkt 1	Subpkt 2	Subpkt 3
Frame x+0	Frame x+1	Frame x+2	Frame x+3

For many high bitrate streams (e.g. DTS-HD Master Audio and Dolby MAT), the IEC 61937 data bursts will always have a repetition period that is a multiple of four frames, and so the Pa and Pb syncwords will always be found in the same subpacket. In such cases, the codec vendor may impose the additional constraint that Pa and Pb always appear in subpacket 0.

7.6.3 DST Packetization

The DST audio stream consists of a series of frames, each of which carries audio data for 1/75th of a second. Each DST frame will be transmitted using a number of DST Audio Packets. The end of a DST frame may occur within a DST Audio Packet. Any unused bits in such a DST Audio Packet shall be padded with "0". In the time between the completion of one DST Audio Frame and the start of the next, DST Audio Packets containing all "0" shall be sent. A new DST Audio Packet with the frame_start bit set to "1" in the header shall be used when the next DST Audio Frame starts and the first bit of the new DST frame data shall be placed in D.0 of the packet body.

When samples_invalid in the DST Audio Packet is set to "1", then the data in the DST Audio Packet is not valid or does not contain any useful data.

7.7 Error Handling (Informative)

The behavior of the Sink after detecting an error is implementation-dependent. However, Sinks should be designed to prevent loud spurious noises from being generated due to errors. Sample repetition and interpolation are well known concealment techniques and are recommended.

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7.8 Packet Delivery Rules

7.8.1 Audio Sample Packets

All audio samples that are stored in a source buffer shall be sent as soon as possible while still fulfilling requirements for audio/video synchronization, and Data Island timing and placement. When using Layout 0 Audio Sample Packets, the Source shall transmit an Audio Sample Packet if at least one sample is stored in the source buffer.

Relative to an ideal constant-frequency clock, the jitter present in the Audio Sample Packet transmission timing shall not exceed one horizontal line period plus a single audio sample period.

7.8.2 Audio Clock Regeneration Packets

Nominally, Audio Clock Regeneration Packets with newly generated CTS values will be transmitted at a rate of $128*f_S/N$. On average, the Source shall transmit CTS values at this rate precisely. The Source shall transmit each CTS data value as close as possible to the nominal transmission time for that value with the exception that priority must be given to Audio Sample packets to ensure that Audio Sample Packet delivery requirements are met.

7.9 One Bit Audio Usage Overview

One Bit Audio data is transmitted using the One Bit Audio packet defined in section 5.3.9 and described in section 7.6.1.

One Bit Audio clock regeneration uses the same mechanism used for all audio on HDMI and is described in section 7.2.4. One Bit Audio sample rate requirements are described in section 7.3.1.

A Sink may indicate its support for One Bit Audio with the Short Audio Descriptor as described in section 8.3.4.

One Bit Audio uses some fields within the Audio InfoFrame differently than L-PCM or compressed audio; these differences are described in section 8.2.2.

7.10 DST Usage Overview

DST data is transmitted using the DST Sample packet defined in section 5.3.10 and described in section 7.6.3.

DST clock regeneration uses the same mechanism used for all audio on HDMI and is described in section {7.2.5}. One Bit Audio sample rate requirements are described in section 7.3.2.

A Sink may indicate its support for DST with the Short Audio Descriptor as described in section 8.3.4.

In some cases, DST uses some fields within the Audio InfoFrame differently than L-PCM or IEC 61937 compressed audio; these differences are described in section 8.2.2.

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7.11 Audio Rate Control Overview

The Audio Rate Control feature allows a Sink to slightly and continuously adjust the audio clock rate of the Source in order to match the Sink's crystal-based audio clock. The Sink controls the Source's audio clock rate with the CEC <Set Audio Rate> command. See CEC Supplement section CEC 13.16 for details.

Source ACR behavior is not affected by Audio Rate Control. When Audio Rate Control is enabled the Source shall continue to generate correct ACR packets that accurately reflect the current (possibly adjusted) audio clock rate.

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8 Control And Configuration

8.1 Overview

HDMI includes three separate communications channels: TMDS, DDC, and the optional CEC.

TMDS is used to carry all audio and video data as well as auxiliary data, including AVI and Audio InfoFrames that describe the active audio and video streams.

The DDC channel is used by an HDMI Source to determine the capabilities and characteristics of the Sink by reading the E-EDID data structure.

HDMI Sources are expected to read the Sink's E-EDID and to deliver only the audio and video formats that are supported by the Sink. In addition, HDMI Sinks are expected to detect InfoFrames and to process the received audio and video data appropriately.

The CEC channel is optionally used for higher-level user functions such as automatic setup tasks or tasks typically associated with infrared remote control usage.

8.2 InfoFrames

An InfoFrame packet carries one InfoFrame. The InfoFrame provided by HDMI is limited to 30 bytes plus a checksum byte. HDMI Sources are required, in some cases, to use the AVI InfoFrame and Audio InfoFrame and recommended in other cases. Other InfoFrames specified in CEA-861-D are optional.

All InfoFrames are described in detail in CEA-861-D. The following describes how two of these InfoFrames are placed within the InfoFrame Packet structure and any areas where HDMI behavior is different from that specified in CEA-861-D.

8.2.1 Auxiliary Video information (AVI) InfoFrame

Various aspects of the current video stream are indicated by the HDMI Source to the Sink with an Auxiliary Video information (AVI) InfoFrame.

A Source shall always transmit an AVI InfoFrame at least once per two video fields if the Source:

- is *ever* capable of transmitting an AVI InfoFrame or,
- is ever capable of transmitting YC_BC_R pixel encoding or,
- is ever capable of transmitting any colorimetry other than the transmitted video format's default colorimetry or,
- is ever capable of transmitting any xvYCC or future enhanced colorimetry or,
- is ever capable of transmitting any Gamut Metadata packet or,
- is ever capable of transmitting any video format with multiple allowed pixel repetitions.

The AVI InfoFrame shall be transmitted even while such a Source is transmitting RGB and non-pixel-repeated video. When a Source is not explicitly required to transmit AVI InfoFrames, it is recommended that the Source transmit AVI InfoFrames.

The packetization of the AVI InfoFrame Version 2 is shown below.

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Table 8-1 AVI InfoFrame Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	Packet Type = 0x82							
HB1	Version = 0x02							
HB2	0	0	0	Length = 13 (0x0D)				

Table 8-2 AVI InfoFrame Packet Contents

Packet Byte #	CEA-861-D Byte #	7	6	5	4	3	2	1	0
PB0	N. A.	Checksum							
PB1	Data Byte 1	Rsvd (0)	Y1	Y0	A0	B1	B0	S1	S0
PB2	Data Byte 2	C1	C0	M1	M0	R3	R2	R1	R0
PB3	Data Byte 3	ITC	EC2	EC1	EC0	Q1	Q0	SC1	SC0
PB4	Data Byte 4	Rsvd (0)	VIC6	VIC5	VIC4	VIC3	VIC2	VIC1	VIC0
PB5	Data Byte 5	Reserved (0)				PR3	PR2	PR1	PR0
PB6	Data Byte 6	Line Number of End of Top Bar (lower 8 bits)							
PB7	Data Byte 7	Line Number of End of Top Bar (upper 8 bits)							
PB8	Data Byte 8	Line Number of Start of Bottom Bar (lower 8 bits)							
PB9	Data Byte 9	Line Number of Start of Bottom Bar (upper 8 bits)							
PB10	Data Byte 10	Pixel Number of End of Left Bar (lower 8 bits)							
PB11	Data Byte 11	Pixel Number of End of Left Bar (upper 8 bits)							
PB12	Data Byte 12	Pixel Number of Start of Right Bar (lower 8 bits)							
PB13	Data Byte 13	Pixel Number of Start of Right Bar (upper 8 bits)							
PB14-PB27	n. a.	Reserved (0)							

See CEA-861-D section 6.4 for more information on the following fields:

- Y0, Y1 RGB or YC_BC_R indicator.
- A0 Active Information Present. Indicates whether field R0...R3 is valid. See CEA-861-D table 8 for details.
- B0, B1 Bar Info data valid. See CEA-861-D table 8 for details.

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- S0, S1 Scan Information (i.e. overscan, underscan). See CEA-861-D table 8 for details.
- C0, C1 Colorimetry (ITU BT.601, BT.709 etc.). See CEA-861-D table 9 for details.
- EC0, EC1, EC2 Extended Colorimetry (IEC 61966-2-4 etc.). See CEA-861-D table 11 for details.
- Q1, Q0 Quantization range (Full vs. Limited, etc.). See CEA-861-D table 11 for details.
- ITC IT Content. See CEA-861-D table 11 for details.
- M0, M1 Picture Aspect Ratio (4:3, 16:9). See CEA-861-D table 9 for details.
- R0...R3 Active Format Aspect Ratio. See CEA-861-D table 10 and Annex H for details.
- VIC0...VIC6 Video Format Identification Code. When transmitting any video format in section 6.2.4, above, an HDMI Source shall set the VIC field to the Video Code for that format. See CEA-861-D section 6.4 for details.
- PR0...PR3 Pixel Repetition factor. See CEA-861-D table 13 for details.
- SC1, SC0 Non-uniform Picture Scaling. See CEA-861-D table 11.

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Table 8-3 HDMI Valid Pixel Repeat Values for Each Video Format Timing

Video Code	Video Description		HDMI Pixel Repeat Values
1	640x480p @ 60Hz		No Repetition
2,3	720x480p @ 59.94/60Hz		No Repetition
4	1280x720p @ 59.94/60Hz		No Repetition
5	1920x1080i @ 59.94/60Hz		No Repetition
6,7	720(1440)x480i @ 59.94/60Hz		Pixel sent 2 times
8,9	720(1440)x240p @ 59.94/60Hz		Pixel sent 2 times
10,11	2880x480i @ 59.94/60Hz		Pixel sent 1 to 10 times
12,13	2880x240p @ 59.94/60Hz		Pixel sent 1 to 10 times
14,15	1440x480p @ 59.94/60Hz		Pixel sent 1 to 2 times
16	1920x1080p @ 59.94/60Hz		No Repetition
17,18	720x576p @ 50Hz		No Repetition
19	1280x720p @ 50Hz		No Repetition
20	1920x1080i @ 50Hz		No Repetition
21,22	720(1440)x576i @ 50Hz		Pixel sent 2 times
23,24	720(1440)x288p @ 50Hz		Pixel sent 2 times
25,26	2880x576i @ 50Hz		Pixel sent 1 to 10 times
27,28	2880x288 @ 50Hz		Pixel sent 1 to 10 times
29,30	1440x576p @ 50Hz		Pixel sent 1 to 2 times
31	1920x1080p @ 50Hz		No Repetition
32	1920x1080p @ 23.97/24Hz		No Repetition
33	1920x1080p @ 25Hz		No Repetition
34	1920x1080p @ 29.97/30Hz		No Repetition
35,36	2880x480p @ 59.94/60Hz		Pixel sent 1, 2 or 4 times
37,38	2880x576p @ 50Hz		Pixel sent 1, 2 or 4 times
39	1920x1080i (1250 total) @ 50Hz		No Repetition
40	1920x1080i @ 100Hz		No Repetition
41	1280x720p @ 100Hz		No Repetition
42,43	720x576p @ 100Hz		No Repetition
44,45	720(1440)x576i @ 100Hz		Pixel sent 2 times
46	1920x1080i @ 119.88/120Hz		No Repetition
47	1280x720p @ 119.88/120Hz		No Repetition
48,49	720x480p @ 119.88/120Hz		No Repetition
50,51	720(1440)x480i @ 119.88/120Hz		Pixel sent 2 times
52,53	720X576p @ 200Hz		No Repetition
54,55	720(1440)x576i @ 200Hz		Pixel sent 2 times
56,57	720x480p @ 239.76/240Hz		No Repetition
58,59	720(1440)x480i @ 239.76/240Hz		Pixel sent 2 times

8.2.2 Audio InfoFrame

A Source shall indicate characteristics of the active audio stream using the IEC 60958 Channel Status bits, IEC 61937 Burst Info and/or stream data (if present) and the Audio InfoFrame. Whenever an active audio stream is being transmitted, an accurate Audio InfoFrame shall be transmitted at least once per two video fields.

Upon the start of a new audio stream or upon any change in the audio stream that can be indicated by the Audio InfoFrame, a modified, accurate Audio InfoFrame shall be transmitted no later than one video field following the first affected non-silent audio sample. Preferably, this

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would occur just before the first affected audio sample is transmitted. For One Bit Audio streams, the Audio InfoFrame shall be transmitted before the first affected sample.

The Audio InfoFrame transmission may occur at any time that a Data Island packet may be transmitted, including during any horizontal or vertical blanking period.

Note that several of the fields permit a value of 0 (referred to in the CEA-861-D specification as "Refer to Stream Header"). A value of 0 signifies that the information associated with that field is actually indicated or implied by other items in the audio stream, for instance, by the IEC 60958 Channel Status bits or the IEC 61937 Burst Info.

The following tables show the packetization of the Audio InfoFrame.

Table 8-4 Audio InfoFrame Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	Packet Type = 0x84							
HB1	Version Number = 0x01							
HB2	0	0	0	Length = 10 (0x0A)				

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Table 8-5 Audio InfoFrame Packet contents

Packet Byte #	CEA-861-D Byte #	7	6	5	4	3	2	1	0
PB0	n. a.	Checksum							
PB1	Data Byte 1	CT3	CT2	CT1	CT0	Rsvd	CC2	CC1	CC0
PB2	Data Byte 2	Reserved (0)			SF2	SF1	SF0	SS1	SS0
PB3	Data Byte 3	Format depends on coding type (i.e. CT0...CT3)							
PB4	Data Byte 4	CA7	CA6	CA5	CA4	CA3	CA2	CA1	CA0
PB5	Data Byte 5	DM_INH	LSV3	LSV2	LSV1	LSV0	Reserved (0)		
PB6	Data Byte 6	Reserved (0)							
PB7	Data Byte 7	Reserved (0)							
PB8	Data Byte 8	Reserved (0)							
PB9	Data Byte 9	Reserved (0)							
PB10	Data Byte 10	Reserved (0)							
PB11-PB27	n. a.	Reserved (0)							

See CEA-861-D section 6.6 for more information on the following fields:

- CC0...CC2 Channel Count. See CEA-861-D table 17 for details.
- CT0...CT3 Coding Type. The CT bits shall always be set to a value of 0 (“Refer to Stream Header”).
- SS0...SS1 Sample Size. The SS bits shall always be set to a value of 0 (“Refer to Stream Header”).
- SF0...SF2 Sample Frequency. See CEA-861-D table 18 for details. For L-PCM and IEC 61937 compressed audio streams, the SF bits shall always be set to a value of 0 (“Refer to Stream Header”). For One Bit Audio and DST streams, the value indicated by the SF bits shall equal the ACR f_S value (see sections 7.2.5 and 7.2.6). For Super Audio CD, the SF bits are typically set to 0, 1, 0, to indicate a Sample Frequency of 2.8224MSamples/s (i.e. 64*44.1kHz).
- CA0...CA7 Channel/Speaker Allocation. See CEA-861-D Section 6.6.2 for details. The CA field is not valid for IEC 61937 compressed audio streams.
- LSV0...LSV3 Level Shift Value (for downmixing). See CEA-861-D Section 6.6.2 and CEA-861-D table 21 for details.
- DM_INH Downmix Inhibit. See CEA-861-D section 6.6.2 and table 22 for details. The DM_INH field is to be set only for DVD-Audio applications and corresponds to the value in the DM_INH field of the current audio stream

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being played from the disk. The DM_INH field value shall be set to zero in all cases other than DVD-Audio applications.

Data Byte 3 shall always be set to a value of 0.

8.3 E-EDID Data Structure

All Sinks shall contain an CEA-861-D compliant E-EDID data structure accessible through the DDC.

A Source shall read the EDID 1.3 and first CEA Extension to determine the capabilities supported by the Sink. Additional extensions may be read to discover additional capabilities. The Source is responsible for any format conversions that may be necessary to supply audio and video in an understandable form to the Sink. However, it is permitted for a Source to transmit Basic Audio (see Section 7.2.6) to a Sink that does not indicate support for Basic Audio.

The Source shall not transmit at TMDS clock rates higher than the maximum rate supported by the Sink, as determined by video format and Deep Color mode support indications but limited by the Max_TMDS_Clock field of the HDMI VSDB.

The overall structure of the E-EDID in the Sink shall conform to the E-EDID structure defined in the VESA E-EDID Standard Release A, Revision 1, but shall also meet the additional requirements specified herein.

The first 128 bytes of the E-EDID shall contain an EDID 1.3 structure. The contents of this structure shall also meet the requirements of CEA-861-D.

8.3.1 CEA Extension

The first E-EDID ‘extension’ shall contain a CEA Extension version 3, defined in CEA-861-D section 7.5. Additional CEA Extensions may also be present. The E-EDID shall not contain a CEA Extension version 1 or version 2.

CEA Extension version 3 details are described in CEA-861-D Section 7.5.

Further details on the requirements of the data structures in the E-EDID and implementation examples are given in CEA-861-D.

8.3.2 HDMI Vendor-Specific Data Block (HDMI VSDB)

The first CEA Extension shall include an HDMI Vendor Specific Data Block (HDMI VSDB) shown in Table 8-6. This is a CEA-861-D Vendor Specific Data Block (see CEA-861-D section 7.5.4 for details) containing a 24-bit IEEE Registration Identifier of 0x000C03, a value belonging to HDMI Licensing, LLC.

Sinks shall contain an HDMI VSDB minimally containing a 2-byte Source Physical Address field following the 24-bit identifier. An HDMI VSDB may have zero or more extension fields as shown in Table 8-6. The minimum value of N (length) is 5 and the maximum value of N is 31. A Sink that supports any function indicated by an extension field shall use an HDMI VSDB with a length sufficient to cover all supported fields.

The Source shall have the ability to handle an HDMI VSDB of any length. In future specifications, new fields may be defined. These additional fields will be defined such that a zero value indicates the same characteristics as is indicated if the field was not present. Sources should use the

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length field to determine which extension fields are present, and shall process the HDMI VSDB with no regard to non-zero values in fields defined as Reserved in this specification.

Table 8-6 HDMI-LLC Vendor-Specific Data Block (HDMI VSDB)

Byte #	7	6	5	4	3	2	1	0
0	Vendor-specific tag code (=3)				Length (=N)			
1	24-bit IEEE Registration Identifier (0x000C03) (least significant byte first)							
2								
3								
4	A				B			
5	C				D			
6	Supports_AI	DC_48bit	DC_36bit	DC_30bit	DC_Y444	Rsvd (0)	Rsvd (0)	DVI_Dual
7	Max_TMDS_Clock							
8	Latency_Fields_Present	I_Latency_Fields_Present	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)
(9)	Video_Latency							
(10)	Audio_Latency							
(11)	Interlaced_Video_Latency							
(12)	Interlaced_Audio_Latency							
9, 11 or 13*...N	*Reserved (0)***							

extension fields ↓

* *The position of these bytes will depend upon the values of Latency_Fields_Present and I_Latency_Fields_Present.*

** *No additional bytes are necessary but if present, they shall be zero.*

- Length — [5 bits] Total length of data block, not including this byte. Shall be 5 (encompassing fields only up to C and D fields) or greater, to encompass additional fields.
- A, B, C, D — [4 bits each] Components of Source Physical Address (A.B.C.D). See Section 8.7.
- Supports_AI — [1 bit] Set to 1 if the Sink supports at least one function that uses information carried by the ACP, ISRC1, or ISRC2 packets. If Supports_AI is set (=1), then the Sink shall accept and process any ACP, ISRC1 or ISRC2 packet with no regard to non-zero values in fields defined as Reserved in this specification. If the Sink does not support ACP, ISRC1 or ISRC2 packets, Supports_AI shall be clear (=0).

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- DC_30bit [1 bit] Set if Sink supports 30 bits/pixel (10 bits/color).
- DC_36bit [1 bit] Set if Sink supports 36 bits/pixel (12 bits/color).
- DC_48bit [1 bit] Set if Sink supports 48 bits/pixel (16 bits/color).
- DC_Y444 [1 bit] Set if Sink supports YC_BC_R 4:4:4 in Deep Color modes.

The three DC_XXbit bits above only indicate support for RGB 4:4:4 at that pixel size. Support for YC_BC_R 4:4:4 in Deep Color modes is indicated with the DC_Y444 bit. If DC_Y444 is set, then YC_BC_R 4:4:4 is supported for all modes indicated by the DC_XXbit flags. This provides the Sink the flexibility of supporting YC_BC_R formats for the standard color-depth (24-bits/pixel) while only supporting RGB for Deep Color modes.

- DVI_Dual [1 bit] Set if Sink supports DVI dual-link operation.
- Max_TMDS_Clock [1 byte] Indicates the maximum TMDS clock rate supported. Max rate = Max_TMDS_Clock * 5MHz. This field shall be set correctly and non-zero if the Sink supports TMDS clock frequencies above 165MHz or supports any Deep Color mode or supports DVI dual-link. A value of zero means that no clock rate is indicated.

The Max_TMDS_Clock field may be set by the Sink at a level below the TMDS clock rate corresponding to the maximum pixel clock rate at the maximum color depth. This allows the Sink to support higher color depths at lower resolutions than it can support at higher resolutions.

See section 8.9 for more detail on the following lipsync-related fields:

- Latency_Fields_Present [1 bit] If set (=1) then the Video_Latency and Audio_Latency fields are present. If clear (=0) then these fields are not present in the HDMI VSDB.
- I_Latency_Fields_Present [1 bit] If set (=1) then the latency fields total four bytes, two for video and audio latency information when progressive video formats are received and two for latency information when interlaced video formats are received. If clear (=0) then only two bytes are present, indicating the video and audio latency when any video format is received. I_Latency_Fields_Present shall be zero if Latency_Fields_Present is zero.
- Video_Latency [1 byte] Indicates the amount of video latency when receiving any video format or only when receiving progressive video formats; if I_Latency_Fields_Present flag == 1 then this field only indicates the latency while receiving progressive video formats, otherwise this field indicates the latency when receiving any video format. Value is number of (milliseconds / 2) + 1 with a maximum allowed value of 251 (indicating 500 millisecond duration). A value of 0 indicates that the field is not valid or that the latency is unknown. A value of 255 indicates that no video is supported in this device or downstream.
- Audio_Latency [1 byte] Indicates the amount of audio latency when receiving any video format or only when receiving progressive video formats; if I_Latency_Fields_Present flag == 1 then this field only indicates the latency while receiving progressive video formats, otherwise this field indicates the latency when receiving any video format. Value is number of (milliseconds / 2) + 1 with a maximum allowed value of 251 (indicating 500 millisecond duration). A value of 0 indicates that the field is not valid or that the latency is unknown. A value of 255 indicates that no audio is supported in this device or downstream.

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- Interlaced_Video_Latency [1 byte] This field is only present if I_Latency_Fields_Present flag == 1. If present, the field indicates the amount of video latency when receiving an interlaced video format. Format is identical to Video_Latency field.
- Interlaced_Audio_Latency [1 byte] This field is only present if I_Latency_Fields_Present flag == 1. If present, the field indicates the amount of audio latency when receiving an interlaced video format. Format is identical to Audio_Latency field.

8.3.3 DVI/HDMI Device Discrimination

In order to determine if a sink is an HDMI device, an HDMI Source shall check the E-EDID for the presence of an HDMI Vendor Specific Data Block within the first CEA Extension. Any device with an HDMI VSDB of any valid length, containing the IEEE Registration Identifier of 0x000C03, shall be treated as an HDMI device.

Any device with an E-EDID that does not contain a CEA Extension or does not contain an HDMI VSDB of any valid length shall be treated by the Source as a DVI device (see Appendix C).

8.3.4 Audio and Video Details

Sink audio characteristics and support are indicated in a series of Short Audio Descriptors located in the CEA Extension's Data Block collection. This data includes a list of audio encodings supported by the Sink and parameters associated with each of those encodings, such as number of channels supported for that format. A Speaker Allocation Descriptor may also be included in the Data Block collection and is required for Sinks supporting multi-channel L-PCM or multi-channel One Bit Audio. See section 7.5.2 and 7.5.3 of CEA-861-D for details.

A Sink may indicate support for YC_BC_R pixel encodings. To indicate support, bits 4 and 5 of byte 3 of the CEA Extension shall both be set to one (see Table 27 of CEA-861-D). To indicate no support, bits 4 and 5 shall both be zero.

With the exception of 640x480p video format, if a Sink is required to support a particular video format, video format timing, or pixel encoding, then the Sink shall indicate support for that video format, video format timing or pixel encoding in the E-EDID. Explicit indication of 640x480p is optional but is not required because all Sinks are required to support that video format.

To indicate support for any video format in section 6.2.4, an HDMI Sink shall use a Short Video Descriptor (SVD) containing the Video Code for that format and may also use a Detailed Timing Descriptor (DTD).

If the Sink supports extended colorimetries (those beyond the default standard- and high-definition colorimetries) or supports the reception of gamut-related metadata, the Sink shall use a Colorimetry Data Block to indicate support for these colorimetries and metadata. See section 6.7.3 for more details.

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8.4 Enhanced DDC

Enhanced DDC described in this section is defined in VESA “ENHANCED DISPLAY DATA CHANNEL STANDARD Version 1 (September 2, 1999)”. All Sinks are required to support these enhanced DDC features. If a Sink’s E-EDID structure is longer than 256 bytes, it shall support the segment pointer.

8.4.1 Timing

Data is synchronized with the SCL signal and timing shall comply with the Standard Mode of the I^2C specification (100kHz maximum clock rate).

I^2C Bus is a standard two-wire (clock and data) serial data bus protocol. Refer to the I^2C specification for details.

Note that an HDMI Sink may hold off the DDC transaction by stretching the SCL line during the SCL-low period following the Acknowledge bit as permitted by the I^2C specification. All HDMI Sources shall delay the DDC transaction while the SCL line is being held low.

8.4.2 Data Transfer Protocols

The Source shall use I^2C commands to read information from a Sink’s E-EDID with a slave address.

In Enhanced DDC, a segment pointer is used to allow addressing of the E-EDID outside of the normal 256-byte limit of the 0xA0/0xA1 address. The Enhanced DDC protocol sets the segment pointer before the remainder of the DDC command.

8.4.3 Segment pointer

Enhanced DDC allows access of up to 32 Kbytes of data. This is accomplished using a combination of the 0xA0/0xA1 address pair and a segment pointer. For each value of the segment pointer, 256 bytes of data are available at the 0xA0/0xA1 address pair. An unspecified segment pointer references the same data as when the segment pointer is zero.

Each successive value of the segment pointer allows access to the next two blocks of E-EDID (128 bytes each). The value of the segment pointer register cannot be read since it is reset at the completion of each command.

8.4.4 Enhanced DDC Sink

The Sink shall be Enhanced DDC read compliant.

The Sink shall be capable of responding with EDID 1.3 data and up to 255 extension blocks, each 128 bytes long (up to 32K bytes total E-EDID memory) whenever the Hot Plug Detect signal is asserted.

The Sink should be capable of providing E-EDID information over the Enhanced DDC channel whenever the +5V Power signal is provided. This should be available within 20msec after the +5V Power signal is provided.

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8.4.5 Enhanced DDC Source

The Source shall use Enhanced DDC protocols.

The Source shall be capable of reading EDID 1.3 data at DDC address 0xA0.

The Source reads Enhanced EDID extensions data at DDC address 0xA0 using segment pointer 0x60.

8.5 Hot Plug Detect Signal

An HDMI Sink shall not assert high voltage level on its Hot Plug Detect pin when the E-EDID is not available for reading. This requirement shall be fulfilled at all times, even if the Sink is powered-off or in standby. The Hot Plug Detect pin may be asserted only when the +5V Power line from the Source is detected. This will ensure that the Hot Plug Detect pin is not asserted before the Third Make of the connector (see Section 4.1.5).

A Source may use a high voltage level Hot Plug Detect signal to initiate the reading of E-EDID data.

A Source shall assume that any voltage within the range specified for High voltage level in Table 4-26 indicates that a Sink is connected and that E-EDID is readable. It does not indicate whether or not the Sink is powered or whether or not the HDMI input on the Sink is selected or active.

An HDMI Sink shall indicate any change to the contents of the E-EDID by driving a low voltage level pulse on the Hot Plug Detect pin. This pulse shall be at least 100 msec.

8.6 Consumer Electronics Control (CEC)

The CEC line is used for high-level user control of HDMI-connected devices. The mandatory requirements for the CEC line are described in detail in Section 4.2.10, CEC Line. The optional CEC protocol is described in Supplement 1: Consumer Electronics Control (CEC).

8.7 Physical Address

8.7.1 Overview

In order to allow CEC to be able to address specific physical devices and control switches, all devices shall have a physical address. This connectivity has to be worked out whenever a new device is added to the cluster. The physical address discovery process uses only the DDC/EDID mechanism and applies to all HDMI Sinks and Repeaters, not only to CEC-capable devices.

The CEC and DDC connections are shown in Figure 8-1.

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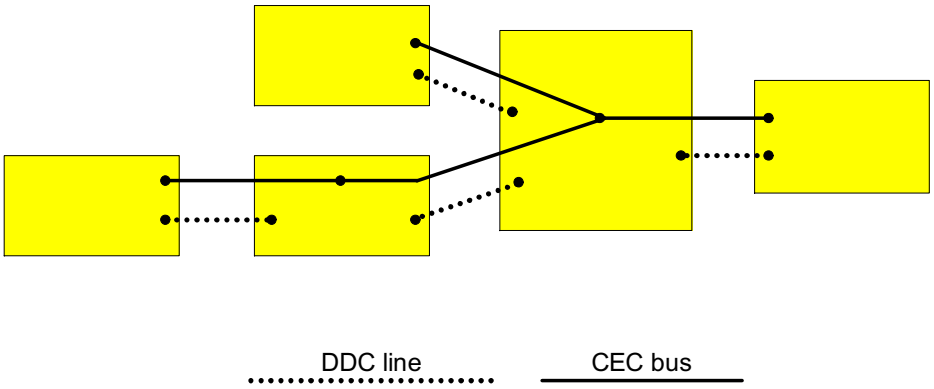


Figure 8-1 CEC and DDC line connections

The CEC line is directly connected to all nodes on the network.

After discovering their own physical address, the CEC devices transmit their physical and logical addresses to all other devices, thus allowing any device to create a map of the network.

8.7.2 Physical Address Discovery

The physical address of each node is determined through the physical address discovery process. This process is dynamic in that it automatically adjusts physical addresses as required as devices are physically or electrically added or removed from the device tree.

All Sinks and Repeaters shall perform the steps of physical address discovery and propagation even if those devices are not CEC-capable. Sources are not required to determine their own physical address unless they are CEC-capable.

All addresses are 4 digits long allowing for a 5–device-deep hierarchy. All are identified in the form of n.n.n.n in the following description. An example of this is given in Figure 8-3.

A Sink or a Repeater that is acting as the CEC root device will generate its own physical address: 0.0.0.0. A Source or a Repeater reads its physical address from the EDID of the connected Sink. The CEC line may be connected to only one HDMI output so a device with multiple HDMI outputs will read its physical address from the EDID on the CEC-connected output. Each Sink and Repeater is responsible for generating the physical address of all Source devices connected to that device by appending a port number onto its own physical address and placing that value in the EDID for that port. The Source Address Field of the HDMI Vendor Specific Data Block (see Section 8.3.2) is used for this purpose.

Note that the values shown in the figures below represent the physical addresses for the devices themselves, not the Source physical addresses stored in the EDID within that device. In fact, for all devices shown, except the TV, those physical addresses are stored in the EDID of the connected Sink. An example is shown for the TV at physical address 0.0.0.0.

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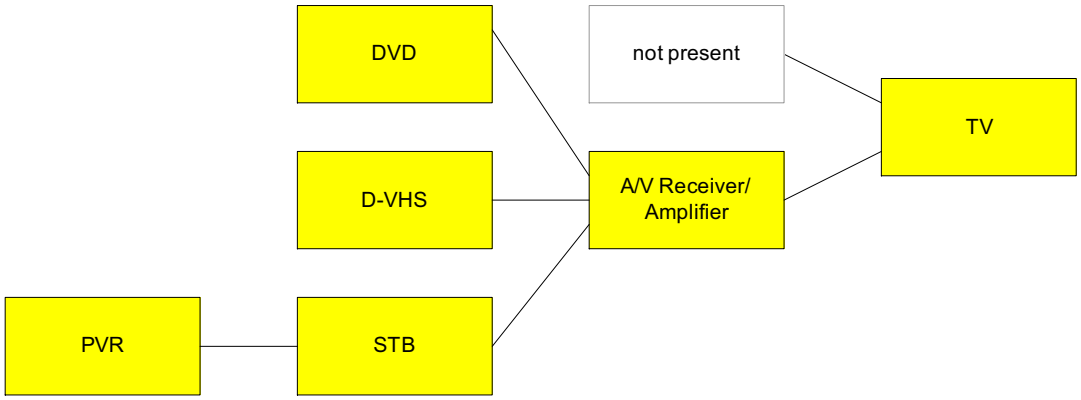


Figure 8-2 Typical HDMI cluster

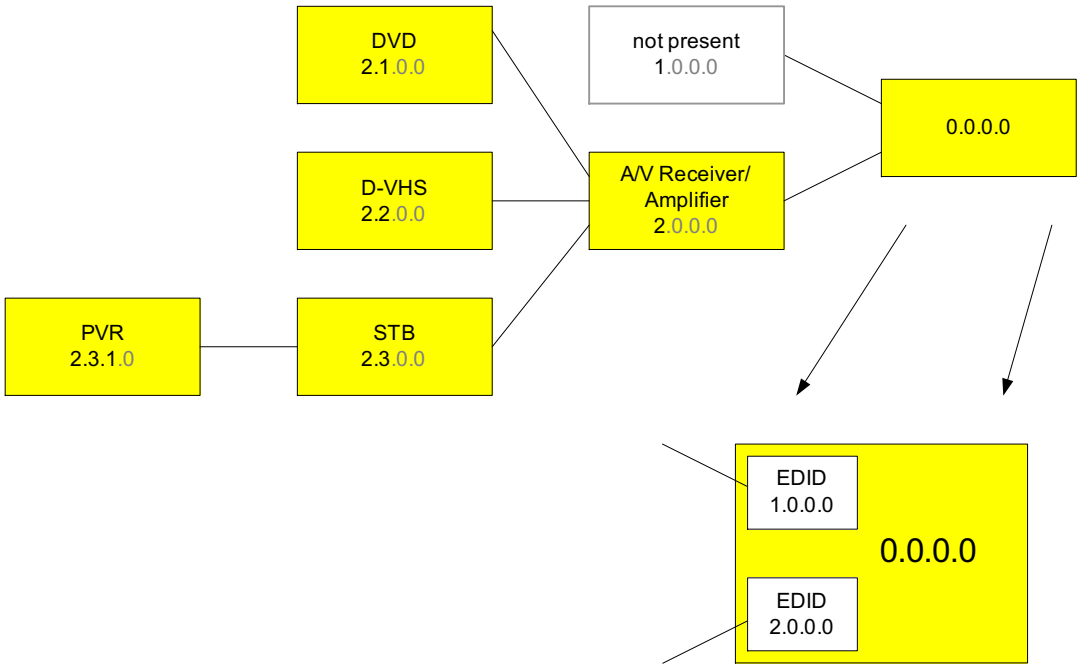


Figure 8-3 Addresses within an HDMI cluster

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8.7.3 Discovery Algorithm

The following algorithm is used to allocate the physical address of each device whenever HPD is de-asserted or upon power-up:

```
Disable assertion of HPD to all source devices
If I am CEC root
    Set my_address to 0.0.0.0
Else
    Wait for HPD from sink
    Query sink for my_address of my connection (Section 8.7.4)
    The device shall retain this physical address until HPD is
        removed (or the device is powered off).
End if
If device has connections for source devices then
    Label all possible connections to source devices uniquely starting
        from connection_label = 1 to the number of source input connections
    If device has separate EDIDs for each source connection then
        If my_address ends with 0 then
            Set each source_physical_address to my_address with the
                first 0 being replaced with connection_label.
        Else (i.e. beyond the fifth layer of the tree)
            Set each source_physical_address to F.F.F.F
        End if
    Else
        Set each source_physical_address to my_address
    End if
    Write source_physical_address to HDMI VSDB in EDID for each source
        connection
End if
Allow HPD to be asserted for source devices
```

8.7.4 HDMI Sink Query

A Source shall determine its physical address (my_address) by checking the HDMI Vendor Specific Data Block (see Section 8.3.2) within the EDID. The fourth and fifth bytes of this 5 byte structure contain the Source Physical Address (fields A, B, C, D).

8.8 ISRC Handling

A Source shall not transmit an ISRC1 or ISRC2 Packet to a Sink that does not have Supports_AI = 1.

A Source may handle an International Standard Recording Code (ISRC) and/or UPC/EAN describing the origin or owner details for each track of content on the medium. These values may be transmitted using the ISRC1 and ISRC2 packets.

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When fields UPC_EAN_ISRC_16 through 31 include effective data (i.e. not "reserved"), a subsequent ISRC2 Packet shall be transmitted. In other cases, the ISRC2 packet may optionally be transmitted.

When a subsequent ISRC2 Packet is transmitted, the ISRC_Cont field shall be set and shall be clear otherwise.

For further description of the UPC_EAN_ISRC fields, see "DVD Specifications for Read-Only Disc", Part 4: AUDIO SPECIFICATIONS Version 1.0, March 1999, Annex B".

Regarding usage of the ISRC_Status field, Source shall comply with "DVD Specifications for Read-Only Disc", "Part 4: AUDIO SPECIFICATIONS", Version-up Information (from 1.1 to 1.2), Table 7.2.3.1.1-2, May 2000. Following is a summary of the relevant rules from that specification:

- At the beginning of each track, at least two complete UPC_EAN_ISRC codes are transmitted with an ISRC_Status of 0b001.
- During the bulk of the track, continuous repetitions of the packet(s) are required, with an ISRC_Status of 0b010.
- Immediately before the end of each track, at least two complete UPC_EAN_ISRC codes are transmitted with an ISRC_Status of 0b100.

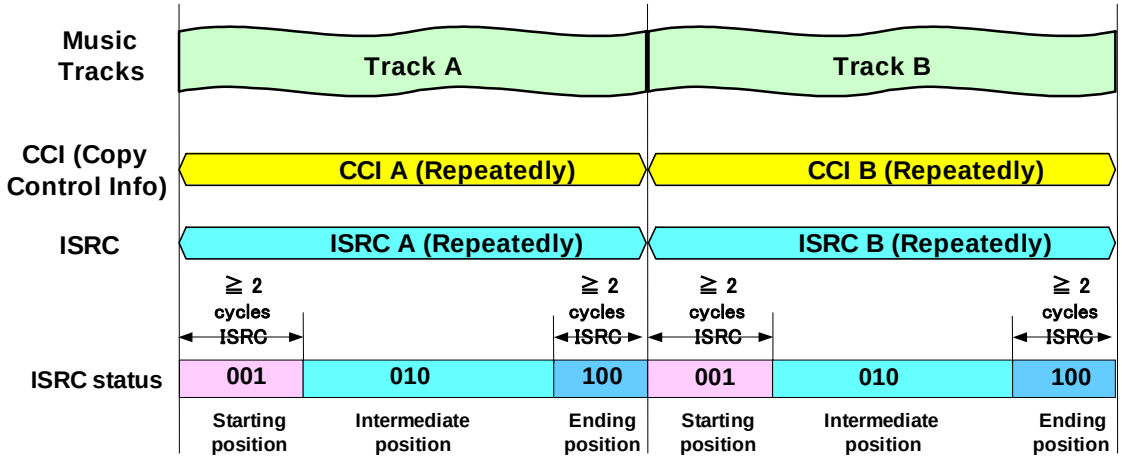


Figure 8-4 ISRC/CCI and ISRC Status Handling

8.9 Auto Lipsync Correction Feature

Some common home theater device configurations will render the audio in a device other than the TV. In these configurations, the video processing latency of the TV may cause perceptible lipsync issues to the user. These issues can be corrected by delaying the audio to compensate for the video processing latency. The HDMI Auto Lipsync Correction feature allows a Source or Repeater to automatically determine the necessary amount of audio delay before presentation or output of that audio signal.

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8.9.1 EDID Latency Info

HDMI Sinks and Repeaters may declare audio and video latency information in the EDID, allowing an HDMI Source or Repeater to determine how best to maintain synchronization between the rendered audio and video. These fields and other lipsync-related fields are in the HDMI VSDB (see section 8.3.2). The latency values within these fields indicate the amount of time between the video or audio entering the HDMI input to the actual presentation to the user (on a display or speakers), whether that presentation is performed by the device itself or by another device downstream.

Many TVs internally compensate for their own video processing latency by adding a delay to the audio stream that corresponds to the video latency. In this case, the EDID-indicated audio and video latencies will be equal. This delay will typically be applied for audio sent to internal speakers as well as audio sent to external S/PDIF (or other) audio outputs so that downstream amplifiers will also be in-sync.

A lipsync-aware Repeater will calculate the latency fields for its upstream EDID to indicate the overall video and audio latency from the reception by the Repeater to the eventual rendering by the Repeater or by downstream device(s). For instance, if the Repeater is a video processor the video data will be delayed by its internal processing before being passed downstream. In this case, the Repeater should indicate a video latency in the upstream EDID equal to the video latency found in the downstream device's EDID plus the Repeater's own internal video processing latency.

Likewise, if the Repeater is an audio amplifier which passes video through unmodified but which renders (amplifies) the audio directly (not passing it downstream), then the upstream audio latency will be equal to the Repeater's audio processing latency (only). If this amplifier adds an audio delay sufficient to compensate for the video latency of the downstream device, then the upstream audio and video latencies will be equal, whether that Repeater forwards the audio downstream or renders the audio directly.

8.9.1.1 Supporting a Range of Latency Values

If the video latency of a device differs significantly depending upon the video format or other factor, it is recommended that the video latency field indicate a latency that is between the extremes but skewed toward the longer latency. An audio/video mismatch is more perceptible if the audio leads the video than if the video leads the audio by a similar amount. Because of this effect, indicating a value that is closer to the maximum video delay may result in better overall user experience. For example, a value of roughly (2 * max_latency + min_latency)/3 may be used. The same is true for the audio latency but in this case, the indicated value should be skewed towards the minimum latency. For example, a value of roughly (max_latency + 2*min_latency)/3 may be used.

If the optimum indication for the video latency for interlaced video formats is significantly different than the optimum indication of latency for progressive formats, then the I_Latency_Fields_Present flag should be set, allowing the EDID to indicate separate latencies for these two categories of video formats. This approach may be used anytime but it is recommended in case the difference between the two latencies is more than roughly 30 msecs.

8.9.2 Compensation

A lipsync-aware Source or Repeater may delay the audio to compensate for the video latency of the downstream device(s), by an amount equal to the video_latency minus the audio_latency of the downstream (or rendering) devices.

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It may not be possible to determine the audio latency of non-HDMI audio outputs (e.g. S/PDIF or analog outputs). For uncompressed audio formats, typically the value will be close to zero and so the device can simply delay the audio by the amount of video latency in the downstream EDID. For compressed audio formats, the device may assume that the audio latency is near the standard decompression latency specified in the relevant IEC61937-x standard or in the codec vendor's documentation.

It is expected that an audio delay capability of 100msecs will support full compensation for almost all of the TV and video processor products on the market today.

If transmitting a progressive video format, the Video_Latency and Audio_Latency fields are used for this calculation. If transmitting an interlaced video format, either these same fields are used or, if I_Latency_Fields_Present == 1, then the Interlaced_Video_Latency and Interlaced_Audio_Latency fields are used.

8.9.3 Supporting Dynamic Latency Changes

A future version of the HDMI Spec will define a mechanism for Sinks to dynamically modify their latency information.

8.9.4 Separate Audio and Video Paths

If the Source or Repeater splits the audio and video stream for transmission to two separate outputs, the device should calculate the required audio delay for the audio path by subtracting the audio latency in the audio path's EDID from the video latency in the video path's EDID.

A Source may use the no-video value or the corresponding no-audio value (in the Audio_Latency fields) to automatically determine whether video or audio is supported on a particular signal path.

The no-video value of the Video_Latency fields allows a Sink to declare that it does no internal rendering of the video signal nor does it output the HDMI-received video stream on an HDMI or non-HDMI output. This may never be true for a TV but it may be true or may change dynamically for an audio amplifier with a video pass-through function depending upon whether any device is connected downstream of the video output port, for example.

For a Repeater that does no video rendering, if there is no downstream video device connected to the Repeater's output, then the Repeater should indicate no-video. If there are downstream device(s) connected but all of those device(s) have no-video value in the video latency field then the Repeater should also indicate no-video.

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9 Content Protection

9.1 Recommendation

Content protection capability is recommended for all HDMI compliant devices. An HDMI compliant Source should protect all of the protected audiovisual data. Amongst adequate copy protection technologies that are compatible with HDMI, HDCP is available.

9.2 HDCP Implementations

HDCP implementations for HDMI shall adhere to HDCP specification Revision 1.2.

Note that if the Sink has no digital audio outputs and has typical restrictions on its analog audio outputs (e.g. must be normal pitch) then it is recommended that Supports_AI be set. If this bit is clear then the Sink will not be able to receive audio content from DVD-Audio and Super Audio CD.

9.3 Usage of Audio Content Protection (ACP) Packets

A Source may use the ACP Packet to convey content-related information regarding the active audio stream.

Non-transmission of ACP Packets should be considered equivalent to transmission of an ACP Packet with an ACP_Type field of 0. If a Sink does not receive an ACP Packet within 600msecs, it shall revert to ACP_Type = 0 behavior.

Whenever a Source is required by other license agreements or specifications to transmit information related to the content protection requirements of the active audio stream, ACP Packets shall be transmitted at least once per 300msecs and an appropriate ACP_Type value shall be set.

When transmitting ACP Packets, upon the start of a new audio stream or upon any change in the audio stream that can be indicated by the ACP Packet, a modified, accurate ACP Packet shall be transmitted no later than 300msec following the transmission of the affected or relevant audio sample.

The ACP Packet transmission may occur at any time that a Data Island packet may be transmitted.

A Source shall not transmit an ACP Packet to a Sink that does not have Supports_AI = 1.

9.3.1 Requirements for Sink

A Sink that has any type of audio output and/or audio recording function shall be capable of receiving and appropriately handling the ACP Packet even if the Sink does not support any audio rendering functionality.

Whenever an HDCP-capable Sink detects an ACP Packet, it shall comply with the HDCP Audio Compliance Rules.

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Whenever an HDCP-capable Sink detects an ACP Packet with an unknown ACP_Type value, it shall comply with the HDCP Audio Compliance Rules for undefined content.

9.3.2 Requirements for Repeater

Any content that is received by a Repeater and is accompanied by an ACP Packet shall be accompanied with an identical ACP Packet and any concurrently received ISRC1 or ISRC2 packets when that content is transmitted to a Sink with Supports_AI = 1.

9.3.3 Application to Generic Audio

With regards to the control of copying and audio output permissions, transmission of an ACP Packet with an ACP_Type field of 0 is equivalent to no transmission of an ACP Packet.

ACP_Type = 0 : Generic Audio

ACP_Type_Dependent fields all Reserved (0).

9.3.4 Application to IEC 60958-Identified Audio

A Source may indicate that the Sink must support the proper output of SCMS bits by setting ACP_Type = 1 (Type 1 = IEC 60958-identified).

ACP_Type = 1 : IEC 60958-identified

ACP_Type_Dependent fields all Reserved (0).

9.3.5 Application to DVD-Audio

Whenever a Source is transmitting DVD-Audio content for which HDCP is required, an accurate ACP Packet, with ACP_Type = 2 shall be transmitted at least once per 300msec.

The UPC/EAN and/or ISRC values are recorded on the DVD-Audio disc with DVD audio data. When the Source transmits UPC/EAN and/or ISRC using ISRC packet, the time lag between the ISRC packet and the corresponding audio sample packet should be minimized.

ACP_Type = 2 : DVD-Audio

ACP_Type_Dependent Usage:

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Table 9-1 ACP_Type Dependent Fields for DVD-Audio Application

Packet Byte #	7	6	5	4	3	2	1	0
PB0	DVD-Audio_Type_Dependent_Generation							
PB1	Copy_Permission		Copy_Number			Quality		Transaction
PB2	Reserved (0)							
:								
PB27								

- DVD-Audio_Type_Dependent_Generation [8 bits] Identifies the generation of the DVD-Audio-specific ACP_Type_Dependent fields. Shall be set to 1. In the future version of this specification, currently reserved field(s) may be used to carry additional information. In such case, the value of this field may be incremented.
- Copy_Permission [2 bits] audio_copy_permission parameter.
- Copy_Number [3 bits] audio_copy_number parameter.
- Quality [2 bits] audio_quality parameter.
- Transaction [1 bit] audio_transaction parameter.

See “DVD Specifications for Read-Only Disc, Part 4: AUDIO SPECIFICATIONS”, Version 1.2, Table 7.2.3.1.1-2”, and “Supplement to Part 4: AUDIO SPECIFICATIONS Version 1.2 (February 2004)” for descriptions and use of the fields: audio_copy_permission, audio_copy_Number, audio_quality, and audio_transaction.

Any Source that supports DVD-Audio transmission on HDMI shall have the ability to transmit all valid channels of any multi-channel content.

9.3.6 Application to Super Audio CD

Whenever a Source is transmitting content originally derived from the HD Layer of a Super Audio CD, an accurate ACP Packet with ACP_Type = 3 shall be transmitted at least once per 300msec. See Super Audio CD System Description for “HD Layer Content”.

ACP_Type = 3 : Super Audio CD

ACP_Type_Dependent Usage:

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Table 9-2 ACP_Type Dependent Fields for Super Audio CD Application

Packet Byte #	7	6	5	4	3	2	1	0
PB0	CCI_1							
:								
PB15								
PB16	Reserved (0)							
:								
PB27								

CCI_1 [16 bytes] Additional content control information. See Super Audio CD System Description for details.

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Appendix A Repeater

A.1 Repeater Functions

A Repeater is defined as a device with one or more HDMI inputs, one or more HDMI outputs, and a retransmission function.

A Repeater has at least one of following functions:

- Repeat function:
  Single-input, single-output devices. Used primarily for cable extension.
- Switch function:
  Multiple-input, single-output devices. Used primarily to select among multiple Sources.
- Distributor function:
  Single-input, multiple-output devices, where only one output is active. Used primarily to select among multiple displays or Sinks.
- Duplicator function:
  Single-input, multiple-output devices, where more than one output is active. Used for signal distribution.

Combinations of the above, for instance, multiple-input, multiple-output devices, incorporating both input selection and output selection or signal distribution are allowed.

In all cases, each HDMI input shall fulfill all of the requirements of an HDMI Sink when it is connected with an active sink device, and each HDMI output shall fulfill all of the requirements of an HDMI Source when it is connected with an active source.

The E-EDID presented by a Repeater should reflect the capabilities of the downstream Sink.

A.2 E-EDID Read Timing (Informative)

In terms of E-EDID handling, Repeaters will typically fall into one of the following categories.

- Stored E-EDID type: The Repeater stores an E-EDID data structure that typically consists of downstream Sink capabilities.
- Forwarding type: The Repeater does not store an E-EDID data structure. When an E-EDID read request comes from a Source, the Repeater forwards the read request to a Sink. The E-EDID data from the Sink is then forwarded back to the Source.

An HDMI cluster may have several Repeaters between a Source and a Sink. To minimize the impact to the E-EDID reading time, each Repeater in the chain should minimize the added delay.

For example, the delay added by a Forwarding type Repeater should be no more than 4 msec per 16-byte read.

A stored E-EDID type Repeater should be able to send a 256 byte E-EDID within 150 msec when a Source issues sixteen 16-byte read requests. This means that a 16-byte read request would be completed within approximately 10 msec.

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Appendix B Type B Connector Usage

B.1 Exception To Audio Format Support Requirement

Sources are not required to carry audio when all of the following conditions are met:

- Source is required by the HDMI Specification or associated agreements to use the Type B connector, and,
- Source has alternate default or user selectable audio outputs, and,
- Source can ensure that the appropriate audio stream is being delivered to the alternate audio outputs.

In order to guarantee rendering of video from Sources that do not fully support HDMI audio, the following condition shall be met:

- Sinks that are capable of supporting an HDMI video format when it is accompanied by audio shall also support that format when it is not accompanied by audio.

It is strongly recommended that a display device, when receiving an HDMI video signal without audio, temporarily indicate to the user that there is no audio accompanying the stream.

B.2 HDMI Dual-Link Architecture

HDMI dual-link architecture is compatible with DVI 1.0 dual-link architecture. Refer to section 3.1.5 of the DVI 1.0 specification.

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Appendix C Compatibility With DVI

C.1 Requirement for DVI Compatibility

All HDMI Sources shall be compatible with DVI 1.0 compliant sink devices (i.e. “monitors” or “displays”) through the use of a passive cable converter. Likewise, all HDMI Sinks shall be compatible with DVI 1.0 compliant sources (i.e. “systems” or “hosts”) through the use of a similar cable converter.

When communicating with a DVI device, an HDMI device shall operate according to the DVI 1.0 specification, with the following exception – these devices are not required to comply with DVI 1.0 rules regarding:

- Monitor scaling requirements [refer to Section 2.2.8.2 of the DVI specification – superseded by HDMI specifications]
- Physical Interconnect specifications [refer to Chapter 5 of the DVI specification – superseded by HDMI specifications]
- System Low Pixel Format Support Requirements [refer to Section 2.2.4 of the DVI specification – superseded by HDMI specifications]

Furthermore, for HDMI devices that would not otherwise have a “BIOS” or “operating system” there are the following additional exceptions:

- “BIOS” requirements [refer to Section 2.2.4 of the DVI specification]
- “Operating system” requirements [refer to Section 2.2.2 and Section 2.2.9 of the DVI specification]
- “System level event” requirements [refer to Section 2.2.9.1 of the DVI specification]
- Power management requirements [refer to Section 2.4 of the DVI specification]

C.2 HDMI Source Requirements

When communicating with a DVI sink device, an HDMI Source shall operate in a mode compatible with that device. This requires that the Source operate under the following limitations:

- Video pixel encoding shall be RGB.
- No Video Guard Bands shall be used.
- No Data Islands shall be transmitted.

An HDMI Source may transmit Video Data Periods without Guard Bands only when communicating to a DVI sink device or during the process of determining if the sink device is HDMI capable.

An HDMI Source, upon power-up, reset or detection of a new sink device, shall assume that the sink device operates under DVI 1.0 limitations. An HDMI Source shall determine if the sink device is an HDMI Sink by following the rule(s) described in Section 8.3.3. Upon detection of an HDMI Sink, the HDMI Source shall follow all of the HDMI Source-related requirements specified in this document.

All electrical and physical specifications in Section 4 shall be followed by the HDMI Source even when communicating with a DVI sink device.

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C.3 HDMI Sink Requirements

When connected to a DVI source device, an HDMI Sink shall operate as a DVI 1.0 compliant sink with the exceptions outlined in Section C.1 above.

A DVI source device will always be restricted in the following ways:

- Only RGB pixel encoding is used.
- There is no Guard Band on the Video Data Period.
- There are no Data Islands transmitted.

An HDMI Sink, upon power-up, reset or detection of a new source device, shall assume that the source device is limited to the above behavior. Upon the detection of an indication that the source is HDMI-capable, the HDMI Sink shall follow all of the HDMI Sink-related requirements specified in this document.

All electrical and physical specifications in Section 4 of the HDMI Specification shall be followed by the HDMI Sink even when communicating with a DVI source device.

C.4 Type A to DVI Adapter Cable [Informative]

Table C-1 Wire Categories

Category	Description
A	TMDS Signal Wire
B	TMDS Shield
C	Control
D	Control Ground
N.C.	No connect (no wire)
5V	5 Volts Power Wire

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Table C-2 Type A-to-DVI-D Cable Wire Assignment [Informative]

Type A pin	Signal Name	Wire	DVI-D pin
1	TMDS Data2+	A	2
2	TMDS Data2 Shield	B	3
3	TMDS Data2–	A	1
4	TMDS Data1+	A	10
5	TMDS Data1 Shield	B	11
6	TMDS Data1–	A	9
7	TMDS Data0+	A	18
8	TMDS Data0 Shield	B	19
9	TMDS Data0–	A	17
10	TMDS Clock+	A	23
11	TMDS Clock Shield	B	22
12	TMDS Clock–	A	24
15	SCL	C	6
16	DDC Data	C	7
17	DDC/CEC Ground	D	15
18	+5V Power	5V	14
19	Hot Plug Detect	C	16
13	CEC	N.C.	
14	Reserved (in cable but N.C. on device)	N.C.	
	TMDS Data 4-	N.C.	4
	TMDS Data 4+	N.C.	5
	TMDS Data 3-	N.C.	12
	TMDS Data 3+	N.C.	13
	TMDS Data 5-	N.C.	20
	TMDS Data 5+	N.C.	21
	No Connect	N.C.	8

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C.5 Type B to DVI Adapter Cable [Informative]

Table C-3 Type B to DVI-D Cable Wire Assignment [Informative]

Type B pin	Pin Assignment	Wire	DVI-D pin
1	TMDS Data2+	A	2
2	TMDS Data2 Shield	B	3
3	TMDS Data2-	A	1
4	TMDS Data1+	A	10
5	TMDS Data1 Shield	B	11
6	TMDS Data1-	A	9
7	TMDS Data0+	A	18
8	TMDS Data0 Shield	B	19
9	TMDS Data0-	A	17
10	TMDS Clock+	A	23
11	TMDS Clock Shield	B	22
12	TMDS Clock-	A	24
13	TMDS Data5+	A	21
14	TMDS Data5 Shield	B	19
15	TMDS Data5-	A	20
16	TMDS Data4+	A	5
17	TMDS Data4 Shield	B	3
18	TMDS Data4-	A	4
19	TMDS Data3+	A	13
20	TMDS Data3 Shield	B	11
21	TMDS Data3-	A	12
25	SCL	C	6
26	DDC Data	C	7
27	DDC/CEC Ground	D	15
28	+5V Power	5V	14
29	Hot Plug Detect	C	16
22	CEC	N.C.	
23	Reserved	N.C.	
24	Reserved	N.C.	
	No Connect	N.C.	8

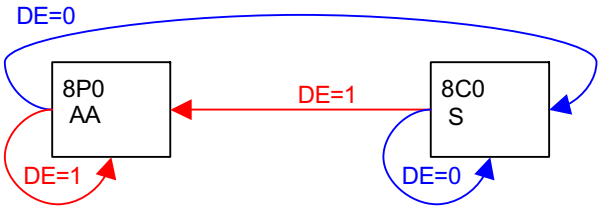
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Appendix D Deep Color Additional Detail

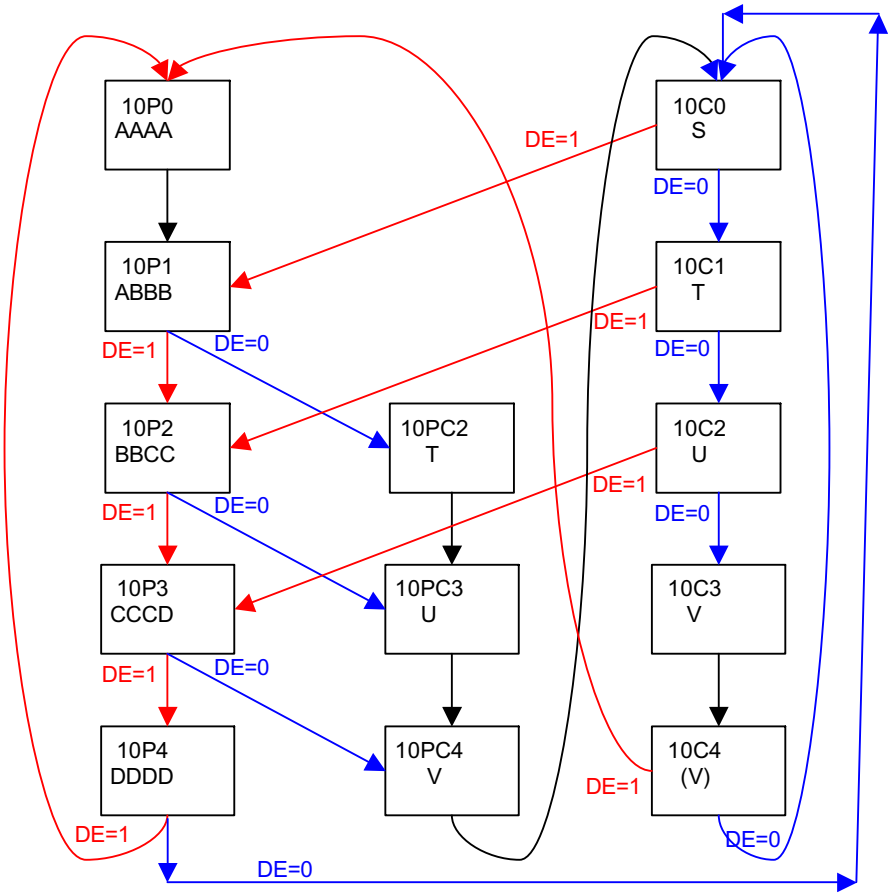
E.1 State Machines

The following state machine drawings are provided for informative purposes to provide better understanding of the Deep Color packing sequences. For each mode, the source sequence starts at phase 0, and then increments through the phases. While DE=1 (pixel data is available), pixel data fragments *m*P*n* are transmitted. While DE=0, blanking fragments *m*C*n* are transmitted.

24 bit mode:

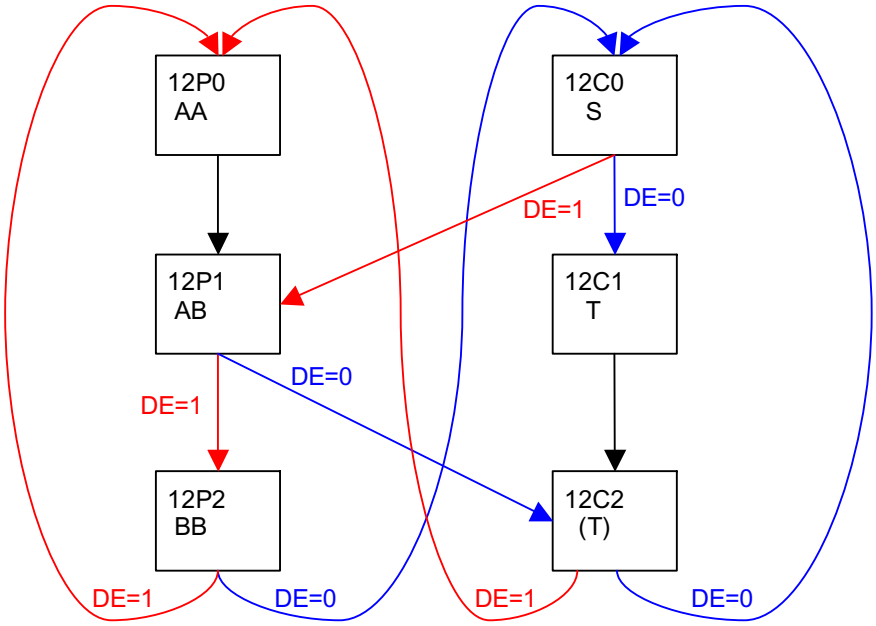


30 bit mode:

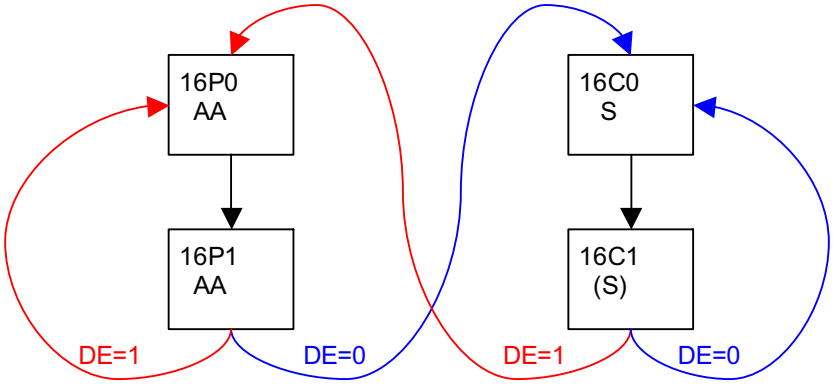


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36 bit mode:



48 bit mode:



D.2 Recommended N and Expected CTS Values

The recommended value of N for several standard pixel clock rates at several Deep Color modes are shown below. It is recommended that Sources with non-coherent clocks use the values listed for a TMDS clock of “Other”.

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Table D-1 36 bits/pixel: Recommended N and Expected CTS for 32kHz

	32 kHz	
Pixel Clock (MHz)	N	CTS
25.2 / 1.001	9152	84375
25.2	4096	37800
27	4096	40500
27 * 1.001	8192	81081
54	4096	81000
54 * 1.001	4096	81081
74.25 / 1.001	11648	316406-316407*
74.25	4096	111375
148.5 / 1.001	11648	632812-632813*
148.5	4096	222750
Other	4096	Measured

** Note: This value will alternate because of restriction on N.*

Table D-2 36 bits/pixel: Recommended N and Expected CTS for 44.1kHz and Multiples

	44.1 kHz		88.2 kHz		176.4 kHz	
Pixel Clock (MHz)	N	CTS	N	CTS	N	CTS
25.2 / 1.001	7007	46875	14014	46875	28028	46875
25.2	6272	42000	12544	42000	25088	42000
27	6272	45000	12544	45000	25088	45000
27 * 1.001	6272	45045	12544	45045	25088	45045
54	6272	90000	12544	90000	25088	90000
54 * 1.001	6272	90090	12544	90090	25088	90090
74.25 / 1.001	17836	351562-351563*	35672	351562-351563*	71344	351562-351563*
74.25	6272	123750	12544	123750	25088	123750
148.5 / 1.001	17836	703125	35672	703125	71344	703125
148.5	6272	247500	12544	247500	25088	247500
Other	6272	measured	12544	measured	25088	measured

** Note: This value will alternate because of restriction on N.*

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Table D-3 36 bits/pixel: Recommended N and Expected CTS for 48kHz and Multiples

	48 kHz		96 kHz		192 kHz	
Pixel Clock (MHz)	N	CTS	N	CTS	N	CTS
25.2 / 1.001	9152	56250	18304	56250	36608	56250
25.2	6144	37800	12288	37800	24576	37800
27	6144	40500	12288	40500	24576	40500
27 * 1.001	8192	54054	16384	54054	32768	54054
54	6144	81000	12288	81000	24576	81000
54 * 1.001	6144	81081	12288	81081	24576	81081
74.25 / 1.001	11648	210937-210938*	23296	210937-210938*	46592	210937-210938*
74.25	6144	111375	12288	111375	24576	111375
148.5 / 1.001	11648	421875	23296	421875	46592	421875
148.5	6144	222750	12288	222750	24576	222750
Other	6144	measured	12288	measured	24576	measured

** Note: This value will alternate because of restriction on N.*

Table D-4 48 bits/pixel: Recommended N and Expected CTS for 32kHz

	32 kHz	
Pixel Clock (MHz)	N	CTS
25.2 / 1.001	4576	56250
25.2	4096	50400
27	4096	54000
27 * 1.001	4096	54054
54	4096	108000
54 * 1.001	4096	108108
74.25 / 1.001	11648	421875
74.25	4096	148500
148.5 / 1.001	11648	843750
148.5	4096	297000
Other	4096	Measured

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Table D-5 48 bits/pixel: Recommended N and Expected CTS for 44.1kHz and Multiples

	44.1 kHz		88.2 kHz		176.4 kHz	
Pixel Clock (MHz)	N	CTS	N	CTS	N	CTS
25.2 / 1.001	7007	62500	14014	62500	28028	62500
25.2	6272	56000	12544	56000	25088	56000
27	6272	60000	12544	60000	25088	60000
27 * 1.001	6272	60060	12544	60060	25088	60060
54	6272	120000	12544	120000	25088	120000
54 * 1.001	6272	120120	12544	120120	25088	120120
74.25 / 1.001	17836	468750	35672	468750	71344	468750
74.25	6272	165000	12544	165000	25088	165000
148.5 / 1.001	8918	468750	17836	468750	35672	468750
148.5	6272	330000	12544	330000	25088	330000
Other	6272	measured	12544	measured	25088	measured

Table D-6 48 bits/pixel: Recommended N and Expected CTS for 48kHz and Multiples

	48 kHz		96 kHz		192 kHz	
Pixel Clock (MHz)	N	CTS	N	CTS	N	CTS
25.2 / 1.001	6864	56250	13728	56250	27456	56250
25.2	6144	50400	12288	50400	24576	50400
27	6144	54000	12288	54000	24576	54000
27 * 1.001	6144	54054	12288	54054	24576	54054
54	6144	108000	12288	108000	24576	108000
54 * 1.001	6144	108108	12288	108108	24576	108108
74.25 / 1.001	11648	281250	23296	281250	46592	281250
74.25	6144	148500	12288	148500	24576	148500
148.5 / 1.001	5824	281250	11648	281250	23296	281250
148.5	6144	297000	12288	297000	24576	297000
Other	6144	measured	12288	measured	24576	measured

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Appendix E Gamut-Related Metadata

E.1 Overview

Unlike the classic colorimetry standards used for standard definition and high definition video, the enhanced colorimetry of xvYCC has a virtually unconstrained gamut, which does not easily map to the real-world gamut of existing or near-future display technologies. When transmitting such an enhanced colorimetry, it is necessary for the video source to also indicate the color gamut of the transmitted video. This metadata allows the display to map the gamut of the video stream more accurately and more predictably onto the gamut of the display.

The gamut describes all colors that are reproducible by a particular reference display or that are present in a given content. The color gamut can be described by a Gamut Boundary Description (GBD). When a given image content has a gamut larger or different from the gamut of the HDMI sink, the colors lying outside the aimed gamut need to be clipped or moved accordingly. This procedure is called gamut mapping. The gamut of the content is circumscribed by the gamut of the HDMI source color space. The display can then use the content's Gamut Boundary Description to perform accurate and predictable mapping onto its own gamut.

E.2 Transmission Profiles

There are several transmission profiles (P0, P1, etc.) for gamut related metadata. The difference between the transmission profiles is primarily the transmission rate, specifically, the number of packets that may be sent per video field. Because of the need to transmit the entire metadata within a short period of time, this transmission rate limits the maximum size of the profile as well. The maximum size of the metadata then also corresponds to the accuracy of the gamut boundary description.

The lowest speed transmission profile is P0, transmitting at a rate of one Gamut Metadata Packet per video field. P0 metadata fits completely within that one packet.

When transmitting GBD data, the Source shall send the GBD for an upcoming gamut change using P0 transmission profile if that GBD is available prior to transmission of the content. This P0 transmission should occur at least one full video field prior to the start of the new gamut video.

E.3 Gamut Boundary Description

The HDMI source gamut is described either by a set of R/G/B range limits or by a set of vertices with or without indexed facets. The Format_Flag field indicates which format is supplied:

- Format_Flag [1 bit] Identifies whether subsequent data describes gamut range boundary or gamut vertices boundary. A value of 0 indicates vertices/facets description. 1 indicates range description.

Two simple GBD data structures: one based on four vertices and the other based on R/G/B min/max range limits, are fully defined here and may be supported using the P0 transmission profile. Larger data structures carrying many more vertices as well as facets, will be defined in a future international specification, not necessarily the HDMI Specification. These data structures will require higher transmission speeds and sizes and therefore will require higher transmission profiles (P1**...**).

After those data structures are defined, a subsequent version of the HDMI Specification will permit HDMI devices to support them. Until that time, no HDMI Source may transmit a GBD with

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more than four vertices or containing facet data, nor may any Sink indicate support for transmission profiles other than P0 in the Colorimetry Data Block in the EDID.

Facet data descriptions below are informative only. The facet data structures and relationship between facets and vertices will be described in a future specification.

The size of each component of each vertex or range entry is indicated in the field GBD_Color_Precision:

- GBD_Color_Precision [2 bits] Color precision of GBD vertex and range data:
  0b00 8 bit
  0b01 10 bit
  0b10 12 bit

The definition of vertex data depends on the GBD_Color_Space field (see below) and is as follows:

- RGB: Unsigned integer. According to ITU-R 709-5 item 6.10 (8 bit), summarized in Section 6.6 (for 8**...**16 bit).
- xvYCC: Unsigned integer. According to IEC 61966-2-4 item 4.4, summarized in Section 6.6
- XYZ: Not valid. Future versions of this specification will further define XYZ tristimulus. Until that point, XYZ shall not be used for GBD data.

The precision of the facet data (Packed_GBD_Facets_Data in Table E-1) depends on the number of vertices (Number_Vertices) according to the following equation:

Precision [number of bits] of color facet data = ld(Number_Vertices)

Where ld() is the logarithm to the base of two. The format of color facet data is positive integer, each color facet data indicating the index of a vertex in the Packed_GBD_Vertices_data field. For example, the integer 0 indicates the first vertex in Packed_GBD_Vertices_data and the integer 1 indicates the second vertex in Packed_GBD_Vertices_data. Three consecutive facets data define one triangle with surface normal pointing outside the gamut.

The definition of 8/10/12-bit range data is as follows:

- 8-bit: signed fixed-point – 1 sign bit, 2 bits integer, 5 bits fraction
- 10-bit: signed fixed-point – 1 sign bit, 2 bits integer, 7 bits fraction
- 12-bit: signed fixed-point – 1 sign bit, 2 bits integer, 9 bits fraction

The data structures for these two different formats are shown in Table E-1 and Table E-2 .

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Table E-1 Vertices/Facets GBD Data Structure

Byte #	7	6	5	4	3	2	1	0
0	Format_ Flag = 0	Facet_ Mode	Rsvd(0)	GBD_Color_Precision		GBD_Color_Space		
1	Number_Vertices_H							
2	Number_Vertices_L							
3...VSIZE+2	Packed_GBD_Vertices_Data[0... VSIZE-1]							
VSIZE+3	Number_Facets_H							
VSIZE+4	Number_Facets_L							
VSIZE+5...	Packed_GBD_Facets_Data[0...FSIZE-2]							
VSIZE+FSIZE+4	Packed_GBD_Facets_Data[FSIZE-1]							

- Facet_Mode [1 bit] Indicates if Facets are also included in the GBD. Field is valid only when Format_Flag = 0. Reserved (0) when Format_Flag = 1.
- GBD_Color_Precision [2 bits] see above
- GBD_Color_Space [3 bits] Color space of GBD data:
  0b000 ITU-R BT.709 (using RGB)
  0b001 xvYCC$_{601}$ (IEC 61966-2-4 – SD) (using YC$_B$C$_R$)
  0b010 xvYCC$_{709}$ (IEC 61966-2-4 – HD) (using YC$_B$C$_R$)
  0b011 XYZ (see above)
- Number_Vertices(_H, _L) [2 bytes] Number of vertices described by following structure.
- Number_Facets(_H, _L) [2 bytes] Number of facets described by following structure.

VSIZE is the number of bytes in the Packed_GBD_Vertices_Data according to:

$$VSIZE = INT\left(3 \cdot Number\_Vertices \cdot GBD\_Color\_Precision / 8 + 0.99999\right)$$

Where, INT() is a function returning the integer part of the number (e.g. INT(3.99999...) = 3).

FSIZE is the number of bytes of Packed_GBD_Facets_Data and will be defined in a future specification.

The minimal number of vertices is 4. In this case, and only this case, the vertices have the following meaning, in this order: black point, red primary, green primary and blue primary. This convention allows constructing the white point and the secondary colors (magenta, cyan and yellow) without transmission.

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Table E-2 Range GBD Data Structure

Byte #	7	6	5	4	3	2	1	0
0	Format_ Flag = 1	Rsvd(0)	Rsvd(0)	GBD_Color_Precision		GBD_Color_Space		
1...N	Packed_Range_Data							

- Packed_Range_Data [N bytes] Packed range data according to following sequence:
  Min_Red_Data
  Max_Red_Data
  Min_Green_Data
  Max_Green_Data
  Min_Blue_Data
  Max_Blue_Data
- GBD_Color_Precision [2 bits] see above
- GBD_Color_Space [3 bits] Color space of GBD data:
  0b000 Reserved
  0b001 RGB expression of $xvYCC_{601}$ coordinates
  0b010 RGB expression of $xvYCC_{709}$ coordinates
  0b011 Reserved

E.4 Data Packing

GBD data is efficiently packed with each 8-, 10- and 12-bit value taking exactly 8-, 10- or 12-bits in the packet. The GBD_Color_Precision field specifies the packing and precision of the GBD data. Table E-3 and Table E-4 define the packing for 10- and 12-bit values using a representative sequence of values, A, B, C..., with A_low representing the low-order bits and A_high, the high-order bits of value A.

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Table E-3 10-bit Packing

	7	6	5	4	3	2	1	0
0	A_high							
1	A_low			B_high				
2	B_low				C_high			
3	C_low					D_high		
4	D_low							
5	E_high							
6	E_low			F_high				
7	F_low				G_high...			

Table E-4 12-bit Packing

	7	6	5	4	3	2	1	0
0	A_high							
1	A_low				B_high			
2	B_low							
3	C_high							
4	C_low				D_high			
5	D_low							

E.5 Example P0 Data Structures

A simple but useful vertex GBD data structure is defined in Table E-5 and can be transmitted using a single Gamut Metadata Packet, fitting within the P0 transmission profile.

The gamut is described in xvYCC$_{709}$ space at 8-bit. The GBD consists of black point as well as red, green and blue primaries.

This data structure has the minimum number of vertices. Following the specification, the correspondence of transmitted vertices and primaries and black point is given. To reconstruct the full gamut boundary description, the white point vertex V_{WHITE} and the secondary colors ($V_{MAGENTA}, V_{CYAN}, V_{YELLOW}$ for magenta, cyan and yellow, respectively) are generated from the first primaries as follows:

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$$V_{WHITE} = V_{RED} + V_{GREEN} + V_{BLUE} - 2V_{BLACK}$$
$$V_{MAGENTA} = V_{RED} + V_{BLUE} - V_{BLACK}$$
$$V_{CYAN} = V_{GREEN} + V_{BLUE} - V_{BLACK}$$
$$V_{YELLOW} = V_{RED} + V_{GREEN} - V_{BLACK}$$

Table E-5 P0 Vertices-Only Data – 8-bit Precision Example

Byte #	7	6	5	4	3	2	1	0
0	Format_ Flag = 0	Facet_ Mode = 0	Rsvd = 0	GBD_Color_Precision = 00		GBD_Color_Space = 010		
1	Number_Vertices_H = 0							
2	Number_Vertices_L = 4							
3	Black(Y)							
4	Black(C_B)							
5	Black(C_R)							
6	Red(Y)							
7	Red(C_B)							
8	Red(C_R)							
9	Green(Y)							
10	Green(C_B)							
11	Green(C_R)							
12	Blue(Y)							
13	Blue(C_B)							
14	Blue(C_R)							

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A typical range GBD data structure is shown in Table E-6 . This can be transmitted using a single Gamut Metadata Packet, fitting within the P0 transmission profile. The gamut is described in $xvYCC_{709}$ space at 12-bit. The GBD consists of min_red_data, max_red_data, min_green_data, max_green_data, min_blue_data, and max_blue_data

Table E-6 P0 Range Data – 12-bit Precision Example

Byte #	7	6	5	4	3	2	1	0
0	Format_ Flag = 1	Rsvd = 0	Rsvd = 0	GBD_Color_Precision = 10		GBD_Color_Space = 010		
1	Min_Red_Data_H							
2	Min_Red_Data_L				Max_Red_Data_H			
3	Max_Red_Data_L							
4	Min_Green_Data_H							
5	Min_Green_Data_L				Max_Green_Data_H			
6	Max_Green_Data_L							
7	Min_Blue_Data_H							
8	Min_Blue_Data_L				Max_Blue_Data_H			
9	Max_Blue_Data_L							

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Appendix F Video Scaling Auto-Configuration

Informative Appendix

In addition to any other mode that a source provides, it is highly recommended that it also provide a pass-through mode of operation. In the pass-through mode the source will pass video unprocessed to its output, if the format is supported by the display, without scaling or de-interlacing (except for performing any necessary field repeats, for instance to show 720p24Hz content on a display with only a 720p60Hz input capability).

In the case that the source cannot send the video in pass-through mode (because the format is not supported by the display), it should convert to the highest priority format as indicated by the DTDs and SVDs, with the first DTD (“Preferred”) being the highest priority.

In the case that the source cannot send the video in pass-through mode (format not supported by the display), and it can also not convert to the preferred video format, the source should select the highest resolution progressive video format supported by the display.

Note: in order to allow displays to indicate a wide range of supported video formats, the source must be able to read EDID information from all defined blocks and must read and understand DTDs and SVDs as defined in CEA-861-D.

The source may also provide a “film-mode” de-interlacer to convert interlaced format video to its original progressive format. It should then consider such converted video as progressive, for instance 480i 60Hz video should be considered as 480p 24Hz video after successful film mode conversion.

It is strongly recommended that displays that cannot perform film-mode de-interlacing on an interlaced video format do not list such an interlaced format as the preferred format but list such a format with a priority (in the list of DTDs and SVDs) that corresponds to the effective resolution. For instance, a display that cannot do film-mode de-interlacing on 1080i may list this format with a priority roughly equivalent to 540 progressive lines.

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Appendix G Passive Equalized Cables

Note: The following is preliminary draft subject to change without notice. Adopter may use it by own discretion.

Some HDMI cable assembly includes passive equalizer circuit. In general, since the passive cable can also be extracted as a set of S-parameter, this types of cable can be specified using the parametric value in the same manner with a normal copper cable. The only difference is a certain requirement is specified additionally for parameter as shown below.

- Category 2 (TMDS clock up to 340MHz): Any cable passive equalizer circuit embedded shall meet either
  A) the parameters specified for Category 2 cables in Table G-1 or,
  B) all of:
     - the non-equalized eye diagram requirements at 165MHz and,
     - the equalized eye diagram requirements at 340MHz and,

Table G-1 Cable Assembly TMDS Parameters

Parameter	Category 1 (up to 74.25MHz)	Category 2 (up to 340MHz)
Maximum Cable Assembly Intra-Pair Skew	151psec	112psec
Maximum Cable Assembly Inter-Pair Skew	2.42nsec	1.78nsec
Far-end Crosstalk	< -20dB	
Attenuation and phase Phase	See Figure G-1 See Figure G-3	
Differential Impedance Connection point and transition area: Up to 1nsec * Cable area: 1nsec – 2.5nsec:*	 100 ohms ±15%** 100 ohms ±10%	

** Measurement point for TDR measurement of impedance.*

*** A single excursion is permitted out to a max/min of 100 ohms ±25% and of a duration less than 250psecs.*

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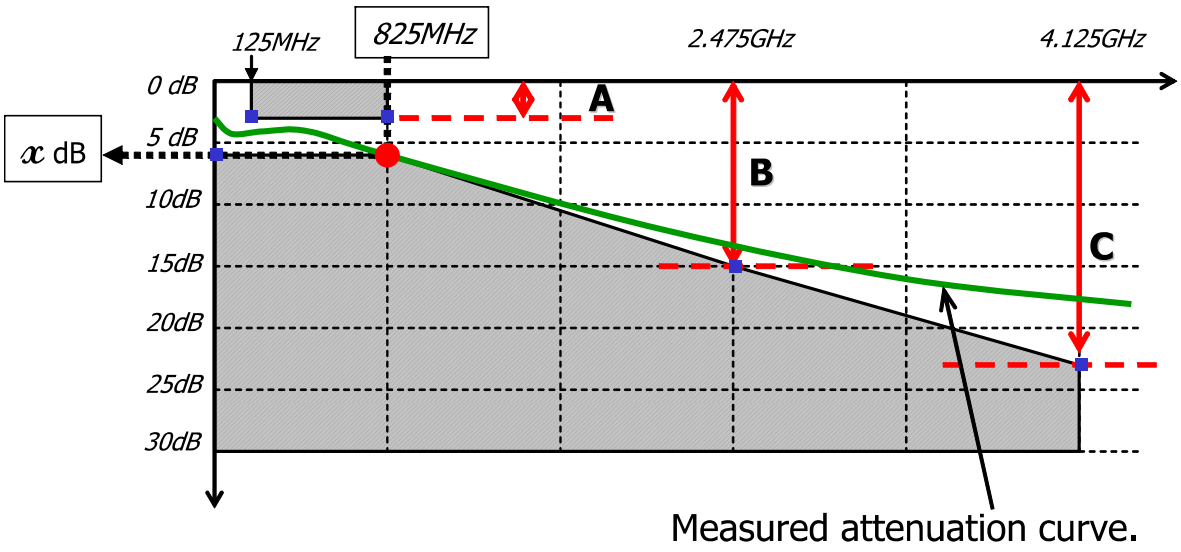


Figure G-1 Passive equalizer Cable Attenuation Limits – Sufficient Condition

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In Figure G-1, if measured attenuation and phase value cross the masked area, the cable DUT fails the parametric test. Here, the parameter A, B, C is calculated as

for (0 < x <5)
A= 0, B=12, C=20

for (5 < x < 8)
A= 2.5(x -5) +0.5, B= 3.0(x -5)+12, C= 10/3(x -5)+20

< The parameter x is a measured attenuation value at frequency 825MHz.>

(note)
if x=5, then the equation above becomes identically equal to Figure 4-23 “Category 2 Cable Attenuation Limits – Sufficient Condition”.

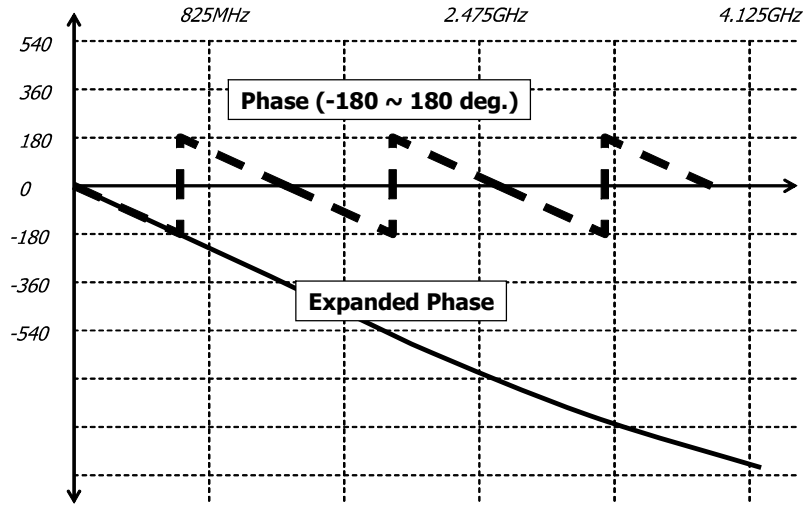


Figure G-2 Passive equalizer Cable Phase measurement method (explanation)

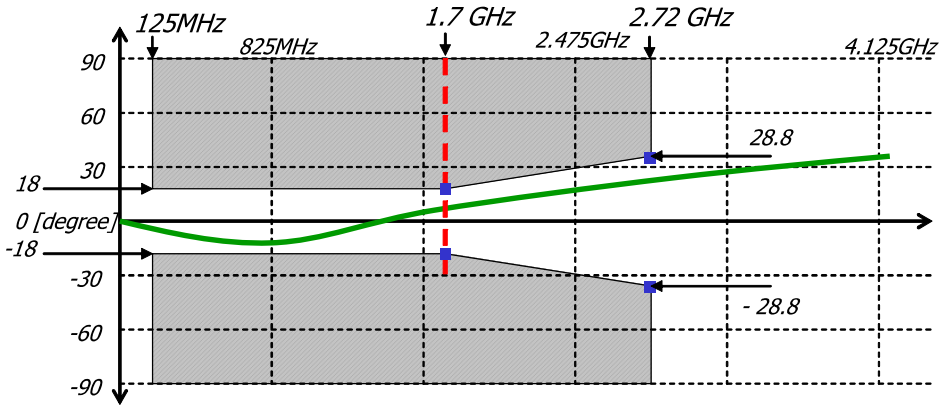


Figure G-3 Passive equalize Cable Phase Limits – Sufficient Condition

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The phase characteristic is plotted by the difference between the linear expanded phase line and calculated linear approximated value by using “Ordinary Least Squares”.

In general, phase response is measured as a linear response shown in Figure G-2. The phase tolerance is defined as a difference value of measured linear expanded phase and calculated approximated 1st order line.

The approximation model is “Ordinary Least Squares” of y=mx. (Here, “y” is the linear expanded phase value, “x” is frequency corresponding, “m” is a incline parameter to be calculated. The frequency range used for calculation of “m” is from 300kHz to 1.7GHz)

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Supplement 1

Consumer Electronics Control (CEC)

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CEC 1 Introduction

CEC is a protocol that provides high-level control functions between all of the various audiovisual products in a user's environment. This appendix describes the CEC protocol in the following order:

- An overview of the recommended features available in CEC.
- A Low Level Protocol Definition - Includes the electrical specification, signaling and bit timings and the frame description.
- A High Level Protocol Definition - Includes a detailed feature breakdown and individual message descriptions.

CEC 1.1 Normative references

[1n] ISO 639.2 Code for the representation of names of languages - Part 2: Alpha 3 code
http://www.loc.gov/standards/iso639-2/langhome.html

CEC 1.2 Informative References

[1i] CENELEC, EN 50049-1:1997/A1:1998, Domestic and similar electronic equipment interconnection requirements: Peritelevision connector

[2i] CENELEC, EN 50157, Domestic and similar electronic equipment interconnection requirements: AV.link
EN 50157-1 : Part 1
EN 50157-2-1 : Part 2-1
EN 50157-2-2 : Part 2-2
EN 50157-2-3 : Part 2-3

[3i] IEEE std. 1394-1995 HIGH PERFORMANCE SERIAL BUS section 8.3.2.5.1 – example use of Company_id.

CEC 1.3 Document Revision History

1.2 Clarification of CEC line Standby behaviour
Clarification of test conditions in Table 2
Addition of CEC line pull-up using a current source
Addition of Give Power Status message
Clarification of response to <Abort> message

1.2a Tolerance on internal pull-up resistance changed to ±5% in Table 2.
Removal of test conditions from Table 2,
Clarification of maximum message length.
Re-ordering of some Features in the text and splitting of message description table.
Update and clarification of mandatory and optional implementation status.
Clarification of rules with more explanations for Routing Control.
Additional examples and notes regarding the use of System Standby with recordings.
System Info simplified to language selection. <Set Language> now becomes <Set Menu Language> with a simplified mechanism. Removal of <Set System Info Version Number>, <Give System Info> and <Set Country>.
Removal of analogue tuning messages and addition of <Select Digital Service>.
Removal of Preset Download and Timer Programme Features.
Various editorial corrections throughout

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1.3a Clarification of pull-up resistance (for integrated implementations) and negative overshoot on CEC line.
Clarification of when CEC Line Error Checking is applied.
Clarification of Signal Free Time values.
Re-naming of addresses STB to Tuner and DVD to Playback device.
Allocation of Tuner 4 and Playback Device 3 Logical Addresses from reserved set.
<Image View On> and <Text View On>: change to mandatory behavior with displayed OSD/Menu
<Set Stream Path>: changes to mandatory behavior.
<Routing Change>: changes to mandatory behavior and addition of timing recommendation.
Standby: clarification of behavior.
Extension of <Record On> to tuners and addition of Analogue and External sources.
Addition of new Error Codes for <Record Status>.
Addition of Timer Programming Feature (Analogue, digital and external).
Addition of Analogue Tuning <Select Analogue Service> to Tuner.
Addition of Major/Minor and 4-digit Virtual Channel Identification
Addition of <Get CEC Version> and <CEC Version>.
Change of some names for [Play Mode] and [Deck status] codes to better indicate responses.
Allow <Vendor Command> to be shared between manufacturers in specific circumstances.
Addition of <Vendor Command With ID> message, which may also be broadcast.
Inconsistent Feature naming now unified to “OSD Display”.
Clarification and addition of recommendation for a timeout for the User Commands.
RC passthrough: Addition of Pause-Record, Data, Power (On, Off and toggle); clarification of <Root Menu>.
<Device Power Status> now made mandatory for an Initiator.
Addition of System Audio Control Feature.
Addition of Audio Rate Control Feature.
Updates to Message Dependencies and Operands tables as a result of above.
Correction to ASCII range.
Various editorial corrections throughout.

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CEC 2 Definitions

CEC 2.1 Conformance Levels

Because CEC is optional, the conformance level in this appendix is only effective when the device supports CEC. For example, the word "shall" indicates a mandatory requirement for the CEC supporting devices. However, within the Features section (CEC 13) "shall" only indicates a requirement if the feature is implemented.

CEC 2.2 Glossary of Terms

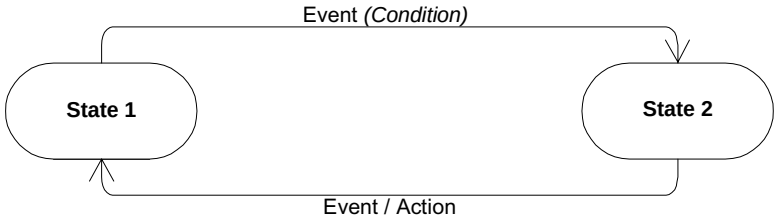
Broadcast Message	This is a message, sent to logical address 15, which all devices are expected to receive.
Clear	Set to an empty/undefined state. When a physical address is cleared it takes the value F.F.F.F. When a logical address is cleared it takes the value 15.
Deck	The part of a Recording Device or Playback Device that provides playback functionality e.g. from a removable media.
Destination	The target device for a CEC message.
Follower	A device that has just received a CEC message and is required to respond to it.
Initiator	The device that is sending, or has just sent, a CEC message and, if appropriate, is waiting for a follower to respond.
Logical address	A unique address assigned to each device (see section CEC 10.2)
Menu Providing Device	A non-display device that may render a menu on TV.
Playback device	A device that has the ability to play media, e.g. a DVD Player.
Recording device	A device that has the ability to record a source such as an internal tuner or an external connection.
Source Device	A device that is currently providing an AV stream via HDMI.
Tuner Device	A device that contains a tuner, e.g. a STB or a Recording Device.
Timer Setting Device	A device that has the ability to set the record timer blocks of a Recording Device.
TV	A device with HDMI input that has the ability to display the input HDMI signal. Generally it has no HDMI output.

CEC 2.3 Usages and Conventions

CEC 2.3.1 State Diagrams

State diagrams describe behavior in terms of device states and events or actions. In these diagrams, the ovals represent device states and the arrows represent events and/or actions that move the device from one state to another state.

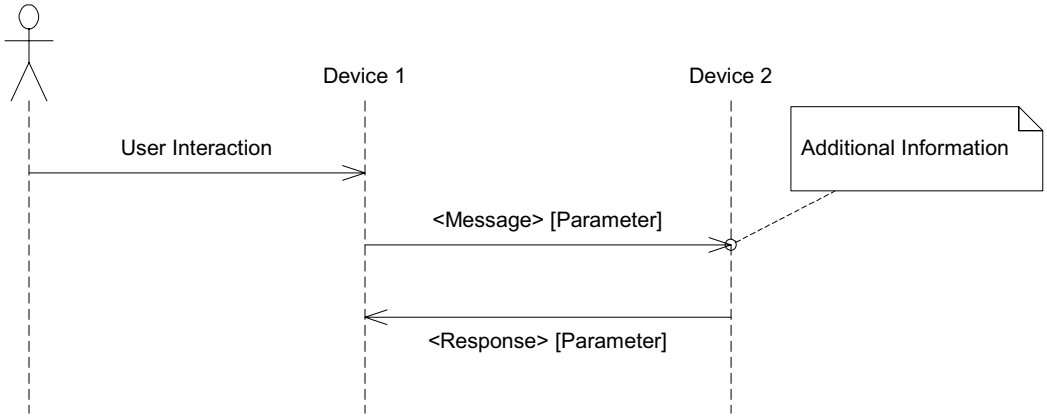
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CEC Figure 1 Example State Diagram

CEC 2.3.2 Message Flow Diagrams

Message Flow Diagrams show sequences of messages that occur between 2 devices.



CEC Figure 2 Example Message Flow Diagram

CEC 2.3.3 Notation

Within the CEC specification there are a number of notations:

<xxx> xxx is an opcode for a message, which is defined in section CEC 15

[yyy] yyy is a data item, which is defined in section CEC 17.

“zzz” zzz is a constant and is a possible value for a data item in section CEC 17.

N{….} indicates the item within the braces is repeated N times, this is used mainly in section CEC 17.

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CEC 3 Feature Overview

CEC provides a number of features designed to enhance the functionality and interoperability of devices within an HDMI system. This section gives an overview of these features.

CEC 3.1 End-User Features

One Touch Play - Allows a device to be played and become the active source with a single button press.

System Standby - Enables the user to switch all devices to standby with one button press.

One Touch Record - Offers a What You See Is What You Record (WYSIWYR) facility, meaning that whatever is shown on the TV screen is recorded on a selected Recording Device.

Timer Programming – Allows the user to program the timers in a Recording Device from an EPG running on a TV or STB.

Deck Control - Enables a device to control (e.g. play, fast forward etc.) and interrogate a Playback Device (a deck).

Tuner Control - Allows a device to control the tuner of another device.

Device Menu Control - Enables a device to control the menu of another device by passing through user interface commands.

Remote Control Pass Through - Enables remote control commands to be passed through to other devices within the system.

System Audio Control – Allows an Audio Amplifier / Receiver to be used with the TV. The volume can be controlled using any the remote controls of any suitably-equipped devices in the system.

CEC 3.2 Supporting Features

Device OSD Name Transfer - Enables devices to upload their preferred OSD name to the TV. The TV can then use this name in any menus associated with that device.

Device Power Status – Allows the current power status of a device to be discovered.

OSD Display - Enables a device to use the on-screen display of the TV to display text strings.

Routing Control - Allows the control of CEC Switches for streaming of a new source device.

System Information - Queries the system to determine device addresses and language.

Vendor Specific Commands - Allows a set of vendor-defined commands to be used between devices of that vendor.

Audio Rate Control – Allows an Amplifier to fractionally increase or decrease the playback rate of an audio source.

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CEC 4 Electrical Specification

The electrical specifications define CEC such that a maximum of 10 devices can interoperate in the worst-case scenario. In practice, many more may be expected to operate together as the worst case is highly improbable.

A device that implements CEC protocols, as described in this CEC supplement, and has enabled its CEC functionality, shall:

- Conform to Table 1 when it is powered-Off (e.g. power removed); or,
- Conform to Table 2 in all other power states. In these states, the device shall keep monitoring the CEC line for any messages addressing that device, including any messages that bring the device out of Standby, see CEC 14.1.3.

During the powered-Off state (e.g. power removed), the CEC line is not monitored.

CEC Table 1 CEC Electrical Specifications during the fully powered-Off state

Description	Value	Notes
Leakage current in powered-Off state	1.8μA max	1

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CEC Table 2 CEC Electrical Specifications except during the fully powered-Off state

Description	Value	Notes
Maximum Output Voltage Logic '0'	+0.6V	
Minimum Output Voltage Logic '0'	0V	3
Maximum Output Voltage Logic '1'	+3.63 V	
Minimum Output Voltage Logic '1'	2.5V	
High to Low Input Voltage Threshold Logic '0'	V_{cecin}('0') ≥ +0.8V	
Low to High Input Voltage Threshold Logic '1'	V_{cecin}('1') ≤ +2.0V	
Typical Input hysteresis	+0.4 V	2
Maximum rise time (10% to 90%)	250 μs	
Maximum fall time (90% to 10%)	50 μs	
Internal device pull-up:	27k ohms ± 5% or equivalent (eg a current source); or 26k ohms ± 10% when integrated.	

The device shall remain within specification under the full-range of load conditions.

Notes:

1 This effectively requires that the internal pull-up circuit shall be disconnected from the CEC line when the device is off. For example, this can be implemented by connecting an isolating diode between the CEC input pin and the internal pull-up circuit, such that diode is reverse-biased in the off state with an external device pulling-up the CEC line.

2 For information, input hysteresis is normally supplied by the microprocessor input circuit: in this circumstance, external hysteresis circuitry is not needed.

3 During transition from Logic '1' to Logic '0' a negative overshoot with maximum 300mV and up to 150μs duration is allowed.

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CEC 5 Signaling and Bit Timings

All transactions on the CEC line consist of an initiator and one or more followers. The initiator is responsible for sending the message structure and the data. The follower is the recipient of any data and is responsible for setting any acknowledgement bits.

CEC 5.1 CEC Line Usage

A message is conveyed over the control signal line in a single frame; a frame is a self-contained unit consisting of a start bit followed by a number of data bits.

An initiator first has to test that the control signal line is free for use (described below). After that it generates a high to low transition on the CEC line, followed by a series of pulses comprising data bits whose starting point is defined by a high to low transition.

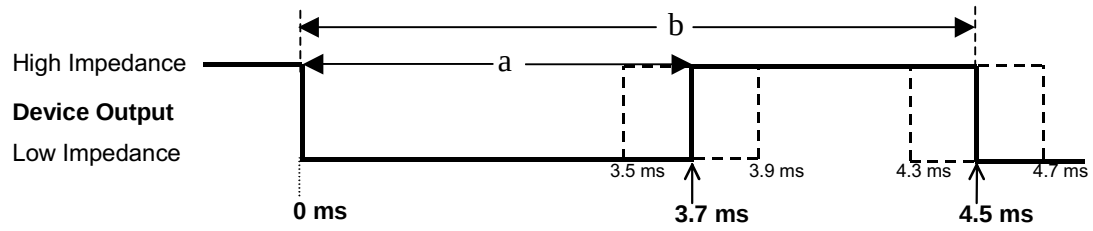
The initiator provides bit timing and bit leading edges. Only one initiator is allowed at any one time. A control signal line arbitration mechanism avoids conflict when more than one initiator begins transmitting at the same time.

CEC 5.2 Bit Timing

CEC 5.2.1 Start Bit Timing

The pulse format of the start bit is shown in CEC Figure 3. It is unique and identifies the start of a frame.

The start bit has to be validated by its low duration (a) and its total duration (b).



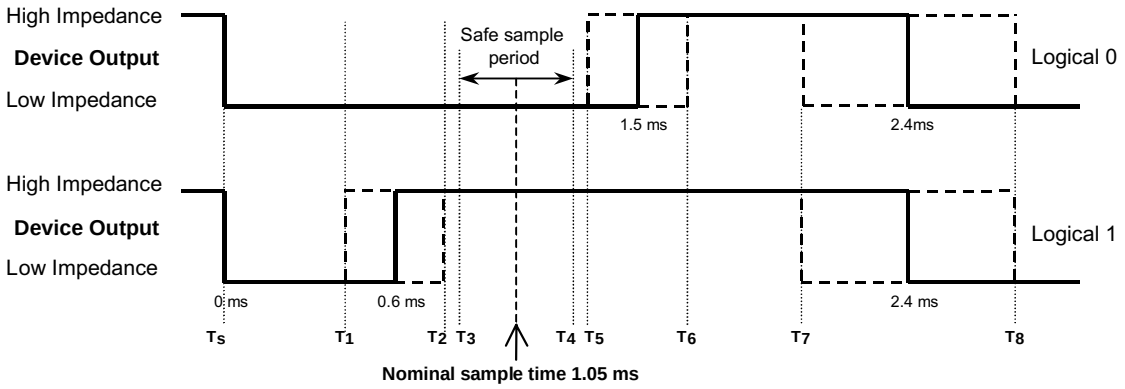
CEC Figure 3 Start bit pulse format showing minimum and maximum tolerances

CEC 5.2.2 Data Bit Timing

All remaining data bits in the frame, after the start bit, have consistent timing. There are, however, two types of bits; an initiator asserted bit and a follower asserted bit. All bits apart from the acknowledge bit are asserted by the initiator. CEC Figure 4 shows both logical 1 and logical 0 timing diagrams for an initiator asserted bit.

The high to low transition at the end of a data bit is the start of the next data bit and only occurs if there is a following data bit; after transmission of the final bit the CEC line remains high.

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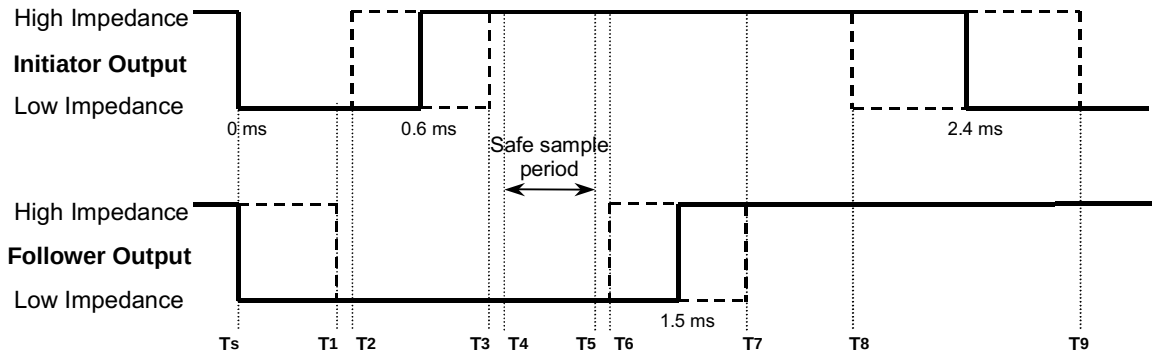


T_S	**0 ms**	The bit start event.
T_1	**0.4 ms**	The earliest time for a low - high transition when indicating a logical 1.
T_2	**0.8 ms**	The latest time for a low - high transition when indicating a logical 1.
T_3	**0.85 ms**	The earliest time it is safe to sample the signal line to determine its state.
T_4	**1.25 ms**	The latest time it is safe to sample the signal line to determine its state.
T_5	**1.3 ms**	The earliest time a device is permitted return to a high impedance state (logical 0).
T_6	**1.7 ms**	The latest time a device is permitted return to a high impedance state (logical 0).
T_7	**2.05 ms**	The earliest time for the start of a following bit.
	2.4ms	The nominal data bit period.
T_8	**2.75 ms**	The latest time for the start of a following bit.

CEC Figure 4 Timing diagrams for both bit states

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CEC Figure 5 shows an example bit with both initiator and follower where the follower may assert the bit to a logical 0 to acknowledge a data block. The initiator outputs a logical 1, thus allowing the follower to change the CEC state by pulling the control line low for the duration of the safe sample period.



T_S	**0 ms**	The bit start event.
T_1	**0.35 ms**	The latest response time for a follower to go to the low impedance state.
T_2	**0.4 ms**	The earliest the initiator can return to high impedance when transmitting a logical 1.
T_3	**0.8 ms**	The latest the initiator can return to high impedance when transmitting a logical 1.
T_4	**0.85 ms**	The earliest time at which the bit state on the CEC line is valid for reading.
T_5	**1.25 ms**	The latest time at which the bit state on the CEC line is valid for reading.
T_6	**1.3 ms**	The earliest time the follower is permitted return to a high impedance state.
T_7	**1.7 ms**	The latest time the follower is permitted return to a high impedance state.
T_8	**2.05 ms**	The earliest time for the start of a following bit.
	2.4ms	The nominal data bit period.
T_9	**2.75 ms**	The latest time for the start of a following bit.

CEC Figure 5 Timing Diagram for Follower Asserted Bit (Logical 0)

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CEC 6 Frame Description

The following table describes the complete CEC frame; the details of each block of the frame are given in the subsequent sections.

CEC Table 3 Frame Description

Name	Description	Value
Start	Special start 'bit'	N/A
Header Block	Source and destination addresses (see CEC Figure 7)	See CEC Table 5
Data Block 1 (opcode block)	Opcode (Optional)	See CEC Table 7 to Table 23
Data Block 2 (operand blocks)	Operand(s) specific to opcode (Optional, depending on opcode)	See CEC Table 26

The maximum message size (header block plus opcode block plus operand blocks) is 16 * 10 bits

CEC 6.1 Header/Data Block description

All Data Blocks and Header Blocks are ten bits long and have the same basic structure, as shown in CEC Figure 6.

Header/Data Block									
7	6	5	4	3	2	1	0	-	-
Information bits								EOM	ACK

CEC Figure 6 Block Structure

The information bits are data, opcodes or addresses, dependent on context. The control bits, EOM and ACK, are always present and always have the same usage.

CEC 6.1.1 EOM (End of Message)

The EOM bit is used to indicate if this is the final block in the message.

A '0' bit specifies that one or more data blocks follow.

A '1' bit specifies that the message is complete.

In the event that a message contains additional data blocks after an EOM is indicated, the follower shall ignore the additional blocks.

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CEC 6.1.2 ACK (Acknowledge)

The ACK bit is used by follower(s) to acknowledge the data or header block. It is always set to 1 by the initiator. It operates in one of two modes:

For messages addressed to a single device:

- A follower that reads its own address in the destination address field shall acknowledge with a '0' ACK bit.
- All other devices shall not assert the ACK bit to logical '0'.
- A '0' read by the initiator therefore indicates a successful transmission of the data or header block.

For broadcast messages the sense of the ACK bit is inverted to allow for a single device to reject a message:

- All followers that do not want to reject the message shall not assert the ACK bit to logical '0'.
- A '1' read by the initiator therefore indicates that no device has rejected the data or header block – the message transmission can therefore continue if required.
- A follower that wants to reject a broadcast message shall generate a "0" ACK bit.
- A '0' read by the initiator therefore indicates that one or more devices have rejected the message.

CEC 6.1.3 Header Block Details

The header block consists of the source logical address field, the destination logical address field, the end of message bit (EOM) and the acknowledge bit (ACK) as shown in CEC Figure 7. The addresses for the devices are specified in CEC Table 5.

Header Block									
3	2	1	0	3	2	1	0	-	-
Initiator				Destination				EOM	ACK

CEC Figure 7 Header Block

The initiator logical address field is used to identify the initiator of the current frame. The logical address of the initiator is written in this field (see CEC 10.2). The field consists of bits one to four of the header block, most significant bit first.

The destination logical address field is used to identify the destination of the current frame. The logical address of the destination is written in this field (see CEC 10.2). A special address (0b1111) is used for broadcast messages. The field consists of bits five to eight of the header block, most significant bit first.

A message with the EOM bit set in the Header Block can be used to 'ping' other devices, to ascertain if they are powered on. This is the <Polling Message> and the Initiator and Destination addresses will be different. It is also used in 10.2.1 for allocating Logical Addresses: in this case the Initiator and Destination addresses are the same.

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CEC 7 Reliable Communication Mechanisms

There are three mechanisms to provide a reliable communications medium for the transfer of frames:

- Frame re-transmissions increase the chance of a successful message transfer.
- Flow control ensures that communication only progresses as fast as the slowest follower.
- Frame validation.

Given these mechanisms and the active ACK method, a message transmitted and acknowledged should be assumed correctly received. A message that does not result in a <Feature Abort> can be assumed to have been acted upon. It is suggested that the receiving device can assume this after 1 second. Generally however, the <Feature Abort> will be received within around 100ms.

CEC 7.1 Frame Re-transmissions

A valid frame is considered lost and therefore may be re-transmitted under the following conditions:

- If a frame is not acknowledged in a directly addressed message.
- If a frame is negatively acknowledged in a broadcast message.
- If the initiator detects low impedance on the CEC line when it is transmitting high impedance and is not expecting a follower asserted bit.

Re-transmission can be attempted up to 5 times for a single message and shall be attempted at least once. The re-try shall be after a signal free time as described in CEC Table 4.

CEC 7.2 Flow Control

To provide flow control, a receiving device may negatively acknowledge any data or header block it is at present unable to process. A negative acknowledge will cause re-transmission by the initiator.

CEC 7.3 Frame Validation

A follower shall ignore a frame if the number of operands is less than the number specified for that opcode.

CEC 7.4 CEC Line Error Handling

It is the responsibility of all devices acting as followers to detect the existence of spurious pulses on the control signal line and notify all other devices (primarily the initiator) that a potential error has occurred.

An error is defined as a period between falling edges that is less than a minimum data bit period (i.e. too short to be a valid bit). Note that the start bit has different timing from normal data bits and is used to identify a valid CEC message. CEC Line Error checking shall start only after receiving a valid start bit.

Errors are notified by the follower generating a low bit period on the control signal line of 1.4-1.6 times the nominal data bit period. After such an error notification the original initiator should stop sending its current frame and re-try later.

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CEC 8 Protocol Extensions

In order to allow for extensions to the protocol in future releases of the specification, the current opcodes and parameters can be extended by adding further parameters onto them. If an older CEC node receives a message with more operands than expected, it should ACK the additional operands and simply ignore them, thus allowing extensions to already existing commands.

For entirely new commands, new opcodes can be allocated.

For entirely new device types, new addresses may be allocated.

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CEC 9 CEC Arbitration

Arbitration for the CEC line ensures collisions are spotted and a reliable message layer can be achieved.

All devices that want to transmit a frame onto the CEC line have to ensure that it has been inactive for the signal free time, see CEC Table 4.

A device that has lost arbitration shall stop transmitting and become a follower. The device shall then wait for the CEC line to be inactive for the signal free time period as specified in CEC Table 4, before attempting to send another message.

CEC line arbitration commences with the leading edge of the start bit and continues until the end of the initiator address bits within the header block. During this period the initiator shall monitor the CEC line and if whilst in high impedance state it detects low impedance then it shall assume that it has lost the arbitration to a second initiator.

It should be noted that this process gives priority to the logical address with the most leading zeros and, ultimately, the TV.

CEC 9.1 Signal Free Time

Before attempting to transmit or re-transmit a frame, a device shall ensure that the CEC line has been inactive for a number of bit periods. This signal free time is defined as the time since the start of the final bit of the previous frame.

The length of the required signal free time depends on the current status of the control signal line and the initiating device. The different signal free times required are summarized in the following table:

CEC Table 4 Signal Free Time

Precondition	**Signal Free Time (nominal data bit periods)**
Present initiator wants to send another frame immediately after its previous frame	≥7
New initiator wants to send a frame	≥5
Previous attempt to send frame unsuccessful	≥3

This means that there is an opportunity for other devices to gain access to the CEC line during the periods mentioned above to send their own messages after the current device has finished sending its current message.

CEC 9.2 Message Time Constraints

There are certain time constraints for messages that should be obeyed at application level. These are a desired maximum response time of 200ms and a required maximum response time of 1 second.

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CEC 10 Device Connectivity and Addressing

CEC is a protocol based on a bus system and therefore cannot alone ascertain the physical connectivity of the network. The mechanism defined in section 8.7 uses DDC to allocate physical addresses to devices in the network.

All CEC devices therefore have both a physical and logical address, whereas non-CEC devices only have a physical address.

CEC 10.1 Physical Address Discovery

The algorithm defined in 8.7.3 is used to allocate the physical address of each device.

Whenever a new physical address (other than F.F.F.F) is discovered, a CEC device shall:

- allocate the logical address (see CEC 10.2.1)
- report the association between its logical and physical addresses by broadcasting <Report Physical Address>.

This process allows any node to create a map of physical connections to logical addresses.

CEC 10.2 Logical Addressing

Each device appearing on the control signal line has a logical address which is allocated to only one device in the system. This address defines a device type as well as being a unique identifier. These are specified in CEC Table 5.

If a physical device contains the functions of more than one logical device then it should take the logical addresses for each of those logical devices. For example, a if a DVD recorder has a tuner, it may take one of the addresses 3, 6, 7 or 10 (Tuner) in addition to one of 1,2 or 9 (Recording Device).

It is allowed for a device to declare the functionality of another device by using a different logical address. For example a recordable DVD device may take the address 4 or 8 to expose only the functionality of a standard DVD Playback Device. In this case, the recording functionality will not be available or controllable via CEC.

A Recording Device with addresses 1,2 or 9 (Recording Device) shall not also take a Playback Device address as the playback functionality is also included in the recorder functionality.

If a device has multiple instances of a particular functionality, it should advertise only one instance. For instance, if a device has multiple tuners, it should only expose one for control via CEC. In this case, it is up to the device itself to manage multiple tuners.

A device shall advertise a function with a Logical Address, such as a Tuner, only if it supports at least the mandatory messages for that function.

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CEC Table 5 Logical Addresses

Address	Device
0	TV
1	Recording Device 1
2	Recording Device 2
3	Tuner 1
4	Playback Device 1
5	Audio System
6	Tuner 2
7	Tuner 3
8	Playback Device 2
9	Recording Device 3
10	Tuner 4
11	Playback Device 3
12	Reserved
13	Reserved
14	Free Use
15	Unregistered (as initiator address) Broadcast (as destination address)

CEC 10.2.1 Logical Address Allocation

Note that a logical address should only be allocated when a device has a valid physical address (i.e. not F.F.F.F), at all other times a device should take the 'Unregistered' logical address (15).

Only the device at physical address 0.0.0.0 may take logical address TV (0). A TV at any other physical address shall take the 'Free Use' (14) address. If address 14 is already allocated it shall take the 'Unregistered' address (15).

Reserved addresses shall not be used at present and are reserved for future extensions to this specification.

Where more than one possible logical address is available for the given device type (e.g. Tuner 1, Tuner 2, etc.), an address allocation procedure shall be carried out by a newly connected device. The device takes the first allocated address for that device type and sends a <Polling Message> to the same address (e.g. Tuner 1 → Tuner 1). If the <Polling Message> is not acknowledged, then the device stops the procedure and retains that address.

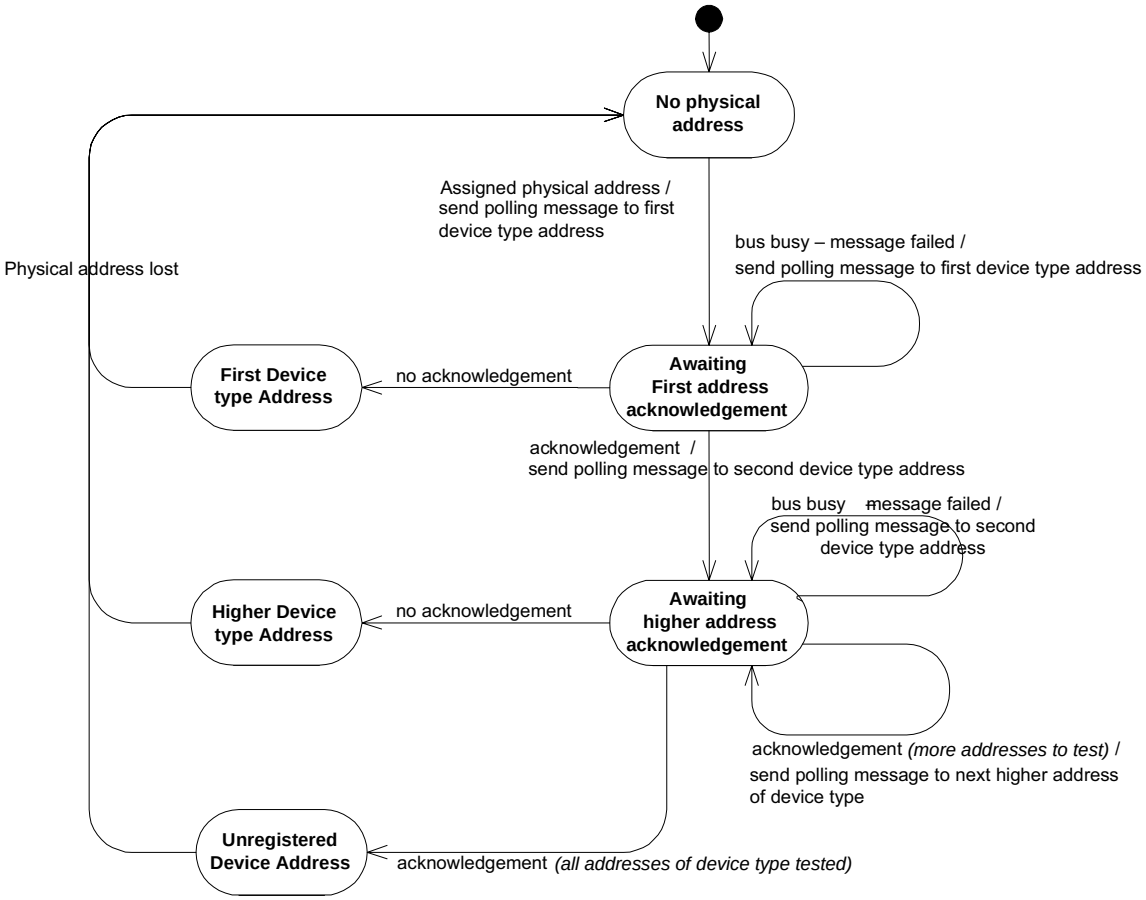
If the first address is acknowledged, then the device takes the next address for that device type and repeats the process (e.g. Tuner 2 → Tuner 2). Again, if the message is not acknowledged, the device keeps that address.

This procedure continues until all possible 'type specific' addresses have been checked; if no 'type specific' addresses are available the device should take the unregistered address (15). Note that several physical devices might be sharing this address.

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A device may lose its logical address when it is disconnected or switched off. However, it may remember its previous logical address, so that the next time it is reconnected or switched on, it can begin the polling process at its previous logical address and try each other allowable logical address in sequence before taking the unregistered address. For example if an STB that was previously allocated address Tuner 2 is reconnected, it would poll Tuner 2, Tuner 3, Tuner 4 and Tuner 1 before taking the unregistered address.

If a device loses its physical address at any time (e.g. it is unplugged) then its logical address should be set to unregistered (15).



CEC Figure 8 Logical Address Allocation

CEC 10.2.2 Behaviour with Earlier Versions

CEC Version 1.3a adds new Logical Addresses of Tuner 4 and Playback Device 3: these will not be recognized by devices conforming to CEC specifications before CEC version 1.3a.

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CEC 11 Switch Requirements

One of the major uses of the physical address identification is to allow a Switch to be controlled in order to enable a specific device to stream to the TV.

All Switches consist of a single switched TMDS connection, and a fully wired CEC connection to each source device. A CEC Switch can interpret and send CEC messages and can be switched by CEC messages.

The use of non-CEC Switches is deprecated. These do not interpret nor send CEC messages and cannot be switched by CEC messages. Non-CEC Switches stop the correct operation of many CEC Features including mandatory Features such as One Touch Play. They also prevent other CEC-compliant devices from operating correctly. Further information on non-CEC Switches can be found in CEC Appendix A.

CEC 11.1 CEC Switch

A CEC Switch allocates a unique child_address for every connection below the Switch, ie it allocates the address for devices connected to the inputs of the Switch. This means that any device connected to the Switch will always have a valid physical address (assuming the Switch itself has a valid physical address). Therefore, any device below the Switch may take a logical address and can react to CEC messages in a normal way. The Switch is effectively transparent and will enable all standard CEC communications in its connected source devices.

A CEC Switch can be part of another device, such as a TV or audio amplifier with two or more HDMI inputs. Such a device shall provide its advertised functionality (eg TV or Audio System) in addition to its CEC Switch functionality. In these cases, the Switch takes the relevant address of its advertised functionality, ie 0 (TV) or 5 (Audio System). The power control for the Switch functionality should be separate from the power control for the other functionality so that the Switch can be active even when the main functionality is in Standby – see CEC 13.2.2 for more details.

Note that if a device has only one HDMI input and a number of non-HDMI inputs, then that should not be considered to be a CEC Switch.

A device that is a “pure” CEC Switch and has no other functionality uses the Unregistered address (15) for communications.

For CEC Switches, there is a requirement to react on <Active Source> and <Set Stream Path> messages. Both of these messages require the Switch to change to the source device according to the physical AV stream path indicated by the CEC message. These mechanisms allow a source device to configure the Switches between itself and the TV to ensure that its output is displayed, or for the TV to specifically receive the output from a given device.

It is possible that a user may change a CEC Switch manually. In this instance a CEC Switch shall send a <Routing Change> message to inform other devices about the change –see section CEC 13.2.2.

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CEC 12 High Level Protocol

As described in the previous sections, messages consist of an opcode and a number of parameters. This is the high level protocol.

This protocol can be described best by detailing the messages and the data types used for the parameters. These are detailed in CEC Table 7 to Table 23.

Although these tables explain the majority of the high level protocol, there are some special situations that require further explanation. These are given in the following sections.

CEC 12.1 Source Declaration

For a device to act as a Source Device, it shall issue an <Active Source> message to declare its intention. Thus any presently active source shall act appropriately.

CEC 12.2 Protocol General Rules

A message that is defined as being valid only when directly addressed shall be ignored if received as a broadcast message.

A message that is defined as being valid only when broadcast shall be ignored if received as a directly addressed message.

All numbers greater than one byte are transmitted as bytes in big endian format.

All bit sequences are sent most significant bit first.

A follower shall respond to a message coming from any valid logical address from 0 to 14 unless otherwise stated.

A follower shall ignore a message coming from address 15 (unregistered), unless:

- that message invokes a broadcast response (e.g. <Get Menu Language>), or,
- the message has been sent by a CEC Switch (a <Routing Change> or <Routing Information> message), or,
- the message is <standby>.

CEC 12.3 Feature Abort

All devices shall support the message <Feature Abort>. It is used to allow devices to indicate if they do not support an opcode that has been sent to them, if it is unable to deal with the message at present, or if there was something wrong with the transmitted frame at the high-level protocol layer.

Feature abort has two parameters, the opcode and a reason for its rejection of the frame.

The reaction to a faulty message by the follower depends on if the message was directed or broadcast:

For a broadcast message:

- A follower that receives a broadcast message which it does not support, ignores the received message, and does not send a <Feature Abort>.

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For a directly addressed message:

- <Feature abort> is used as a response to any failure.

If an initiator wants to attempt retransmission after receiving a <Feature Abort> it is suggested that it waits for 200ms. This will allow time for the follower to recover from the state that caused the initial <Feature Abort> message.

- <Feature Abort> is also used as a response to the <Abort> message during testing, see CEC 12.4

CEC 12.4 Abort

The <Abort> message shall be implemented as a Follower in all devices except pure CEC Switches and is used during testing only. It shall be directly addressed to a specific device, which shall respond with a <Feature Abort> message. In this instance, any valid [Abort Reason] operand may be returned.

- A device shall ignore an <Abort> message which is broadcast.

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CEC 13 CEC Features Description

This section describes the message transfer and additional details for a number of common features enabled by CEC. Note that where a feature is supported, all messages within that feature should be implemented.

CEC 13.1 One Touch Play

CEC 13.1.1 Messages

The following messages are used for the One Touch Play feature:

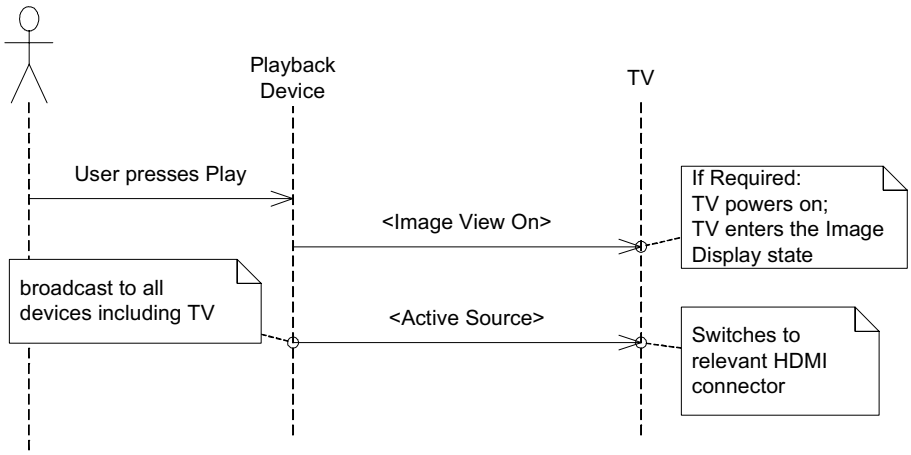
<Active Source>, <Image View On>, <Text View On>

CEC 13.1.2 Feature Description

The One Touch Play feature allows a device to be played and become the active source with a single button press.

A device shall send the message <Image View On> to the TV only when it needs to indicate that its output should be displayed on the screen. If the TV is in a Text Display state (e.g. Teletext) it should switch to the Image Display state. If a menu is being displayed on the TV it should remain on screen.

A device may alternatively send the message <Text View On>. This message has the same functionality as <Image View On> with the addition that any menus that the TV is displaying should be removed.



CEC Figure 9 A typical scenario illustrating the One Touch Play feature

When a source needs to display its output on the TV, it should send an <Image View On> message whenever it sends an <Active Source> message, as the source is not aware of the current Standby status of the TV.

The source shall send the associated <Active Source> message only when it has some stable video for display to the user.

If the TV is brought out of the Standby state by an <Image View On> message, it should buffer <Active Source> messages received while it is powering up so that it may select the correct input (if necessary). If

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this is not possible, or none were received, then it should enquire which device is the active source by sending a <Request Active Source> message.

Whenever a device becomes the new source device it shall broadcast an <Active Source> message. The currently active source device loses its active source status and should then take appropriate action, for example, it may pause if it is playing media.

Note: there is a special case when a TV switches to its internal tuner or to another non-HDMI source (eg Y/C, or a SCART socket on European market sets). In this case, it is the TV which broadcasts the <Active Source> message with address 0.0.0.0.

Note that it is mandatory for a source to implement at least one of <Image View On> or <Text View On>.

CEC 13.1.3 Behaviour with Earlier Versions

When sending this Message	From this HDMI Version 1.3 or 1.2a Device	To this HDMI Version 1.3a Device	Possible behaviour
<Image View On>	Any source	TV	The TV may not keep its current menu on the screen
<Text View On>	Any source	TV	The TV may not remove its current menu on the screen
<Active Source>	Any source	Any	The use of <Active Source> by devices before 1.3a was recommended, not mandatory.

CEC 13.2 Routing Control

CEC 13.2.1 Messages

The following messages are used for the Routing Control feature:

<Active Source>, <Inactive Source>, <Request Active Source>, <Set Stream Path>, <Routing Change>, <Routing Information>

CEC 13.2.2 Feature Description

This feature is used to control the routing of the HDMI network, by controlling CEC Switches. In general whenever a device starts being streamed to the TV it shall send an <Active Source> message (see One-Touch Play in section CEC 13.1).

On receiving an <Active Source> message, CEC Switches between the device and the TV shall become active (if necessary) and switch (if required) to ensure that there is an active path from the device at the physical address specified to the TV. Devices which have other functionality and which also incorporate a CEC Switch, such as a amplifier with several HDMI inputs, need only bring the Switch part out of the Standby state as a response to the <Active Source> message, leaving the other functionality (eg amplifier) still in the Standby state.

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If a device (other than a CEC Switch) is currently the active source, then it shall lose its active source status on receiving an <Active Source> message from another device and should act accordingly, for example it may pause if it is playing media.

When a device comes out of standby or a (mains) off state, it may broadcast a <Request Active Source> message to discover if any other device is currently acting as the active source, see One Touch Play in section CEC 13.1. On receiving a <Request Active Source> message, the active source device shall respond by broadcasting an <Active Source> message. A particular instance of this rule is when a TV comes out of standby some time after its source device(s). In this case it may not know the currently active source and it may not know which is the relevant connector to use (if the TV has multiple HDMI connectors), because it was in standby or powering up when the device sent its <Active Source> message. Here, the <Request Active Source> and the corresponding <Active Source> response are used to identify the relevant connector.

When the System Audio Control feature is started by an Amplifier (eg as a result of a local user command on the Amplifier), the <Request Active Source> shall be sent by the Amplifier to discover the currently active source in order present the relevant sound for the video (see CEC 13.15). This is not necessary when the System Audio Control feature is not active.

The user may select a device to view via the TV user interface. In contrast to the <Active Source> message (which is sent by the current active source to the TV), the <Set Stream Path> is sent by the TV to the source device to request it to broadcast its path using an <Active Source> message. In this case, the TV should broadcast a <Set Stream Path> message with the physical address of the device it wants to display as a parameter. Any CEC Switches between the device and TV shall switch (if required) to ensure the device is on the active AV path. This feature also ensures that non-CEC-compliant devices in the network can be switched to, if for instance they have been manually set up in the TV menu. A CEC device at the location specified by the <Set Stream Path> message should come out of standby (if necessary). If and when it has stable video to display, it shall broadcast an <Active Source> message and begin streaming its output.

Note: there is a special case when a TV switches to its internal tuner or to another non-HDMI source (eg Y/C, or a SCART socket on European market sets). In this case, it is the TV which broadcasts the <Active Source> message with address 0.0.0.0.

When the user has specifically sent the currently active device only to standby (eg as the result of a user action using the device's local control, such as its own remote controller), it should send an <Inactive Source> message with its own Physical Address as an operand. It is a manufacturer decision to decide the TV's response: it may, for example, display its own internal tuner, or select another device for display. In these cases, the TV should send a new <Active Source> message with its own physical address (0.0.0.0, when displaying its own internal tuner), or send a <Set Stream Path> to a new device for display. Note that an <Inactive Source> message can also be sent when the Source Device has no video to be presented to the user, even if the device is not in the standby state.

In the case that the user manually switches a CEC Switch it shall broadcast a <Routing Change> message (see below for exceptions with non-HDMI sources). This will inform all devices in the network that the current active route below the Switch has changed. The device that has been deselected by a Switch loses its active source status and enables it, for instance, to pause if it is playing media.

If a CEC Switch is at the new position indicated by the <Routing Change> message then it shall broadcast a <Routing Information> message with the physical address of its current active path. If a CEC Switch at the new position receives a <Routing Information> message then it shall broadcast a <Routing Information> message to indicate it's current active path. In this way the all CEC Switches are aware of the route to the new source and the last <Routing Information> message contains the complete route (address) to the new source.

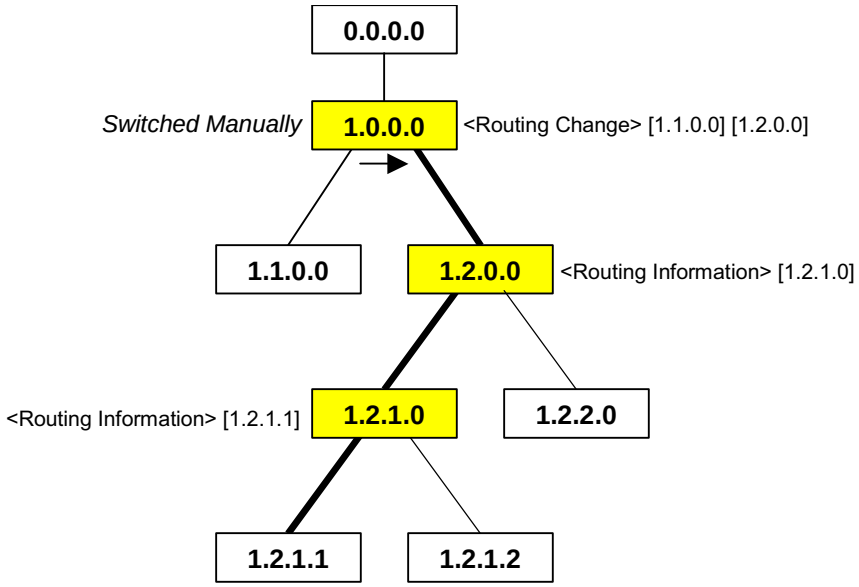
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When using non-HDMI sources:

- If a CEC Switch has non-HDMI inputs and the currently selected input is a non-HDMI source, the CEC Switch should not send a <Routing Information> message in response to a <Routing Change> or <Routing Information> message. For example, if the CEC Switch is already using an analogue input, then the CEC Switch should not send a <Routing Information> message in response to a <Routing Change> or <Routing Information> message.
- If a device (such as a TV or amplifier) with a CEC Switch is changed by the user from an HDMI source to a non-HDMI source (eg to the internal TV tuner or external SPDIF input on an Amplifier), then it should not send a <Routing Change> message.
- When switching from a non-HDMI source to an HDMI source, then the device should send a <Routing Change> message to determine the HDMI path below the Switch.

Optionally, if the TV detects that the active source device has been de-selected by changing the Switch it may either switch to an internal service or may send a <Set Stream Path> message to the device at the new location to indicate that it should become the new active source. In this case, the TV shall wait for a minimum of 7 nominal data bit periods and a recommended maximum of 500ms before reacting to a <Routing Change> or <Routing Information> message to allow CEC Switches to relay any <Routing Information> messages that are required.

The following diagram shows an example of the message flow when a user manually switches a CEC Switch. (CEC Switches are shown filled).



CEC Figure 10 Example message flow, when a CEC Switch is manually switched

CEC 13.2.3 Behaviour with Earlier Versions

The <Inactive Source> message is new in version 1.3a.

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CEC 13.3 System Standby

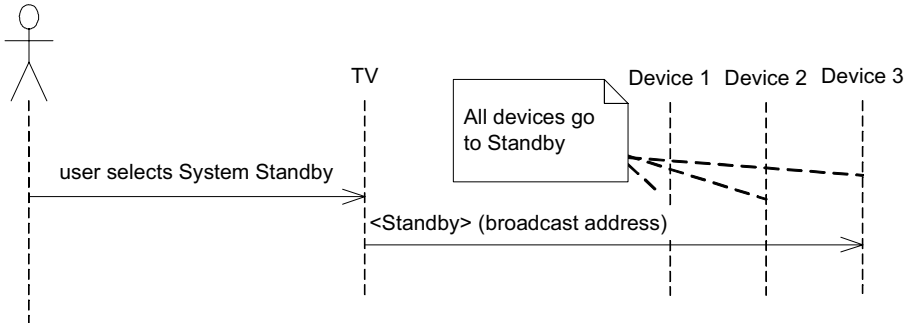
CEC 13.3.1 Messages

The following message is used for the System Standby feature:

<Standby>

CEC 13.3.2 Feature Description

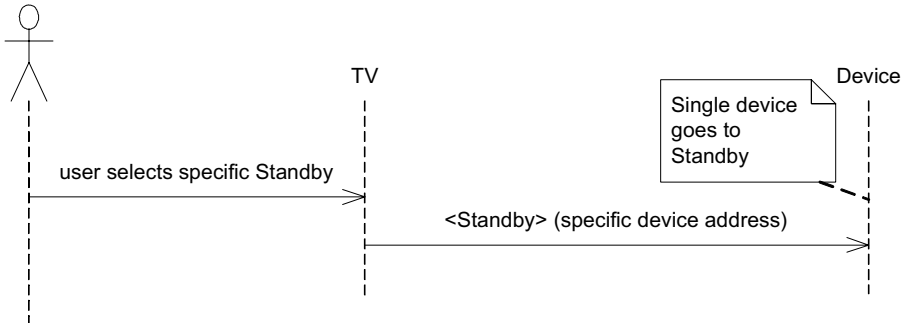
The broadcast message <Standby> can be used to switch all CEC devices to standby. A typical scenario where the user sets a the whole system to standby is shown below:



CEC Figure 11 A typical scenario for the broadcast (system) Standby feature

The whole system may be set to standby by broadcasting the <Standby> message. It is manufacturer dependent on how to differentiate between a standby message for a single device, e.g. a STB, and System Standby message (broadcast to the whole system). For example, the system or broadcast <Standby> message may be sent as the result of a long press on the local or remote control standby button.

A device can switch another single device into standby by sending the message <Standby> as a directly addressed message to it.



CEC Figure 12 A typical scenario for the Standby feature to a specific device

A <Standby> message is not a toggle and can only send a device to the Standby state: other messages shall be used to activate a device, i.e. bring a device out of the Standby state.

A <Standby> message should not interrupt any background tasks such as a recording - see Timed Recording, section CEC 13.5.3.

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Devices can ignore <Standby> messages if they are in a state where going into standby is not the appropriate action or due to device limitations it is not possible to go to the Standby state. For example:

- The device is recording;
- The device only has a mechanical power switch;
- It only provides limited facilities for external control of its power;
- The Standby function is disabled;
- It is a device, such as a PC, which is performing other functions that should be left running;
- High priority services, such as the reception of emergency announcements or similar, shall continue.

CEC 13.3.3 Behaviour with Earlier Versions

When sending this Message	From this HDMI Version 1.3a Device	To this HDMI Version 1.2a or 1.3 Device	Possible behaviour
<Standby>	Any	Source or recorder	When a <Standby> message is sent during a recording: - the target might not ignore the <Standby> message; - the target might not go to the Standby state after a recording. (These were manufacturer decisions clarified in 1.3a.)

CEC 13.4 One Touch Record

CEC 13.4.1 Messages

The following messages are used for the One Touch Record feature:

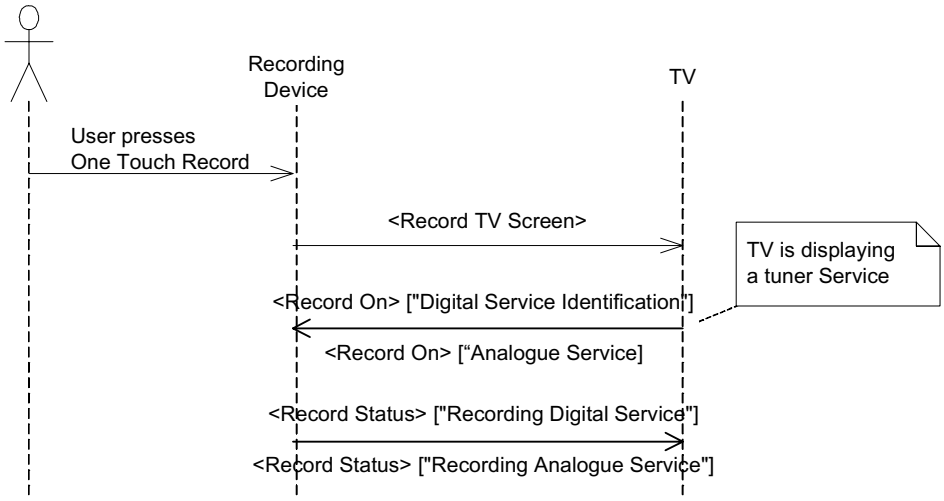
<Record Off>, <Record On>, <Record Status>, <Record TV Screen>

CEC 13.4.2 Feature Description

This feature allows the user to easily start a recording of the source that is being displayed on the TV, just by selecting a Recording Device and giving the record command. It is not always possible to carry out a One Touch Record as it depends on what source is currently being displayed. It is primarily used for the instant recording of a tuner service, or the recording of another device (e.g. Camcorder) connected externally to the Recording Device

Either the TV or the Recording Device may initiate the One Touch Record Feature, for example by selecting a menu option on the TV or by pressing record on the Recording Device.

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CEC Figure 13 A typical scenario for the One Touch Record feature

In the event of the Recording Device initiating the feature, it should send a <Record TV Screen> message to the TV. On receipt of the <Record TV Screen> message by the TV, or if the user initiates the One Touch Record feature via the TV, the TV shall react as follows:

- If the TV is currently displaying an internal tuner service, it shall respond with a <Record On> [“Digital Service”] [Digital Service Identification] message or a <Record On> [“Analogue Service”] [Analogue Broadcast Type] [Analogue Frequency] [Broadcast System] message.
- If the Recording Device is the current active source device, then the TV shall respond with a <Record On> [“Own source”] message.
- If the TV is currently displaying an external input and it knows the Physical Address of the external source (eg it has a map of which external devices are connected), then the TV may send a <Record On>[External Physical Address] message. The TV may alternatively send a <Record On>[External Plug Number] message if it knows the relevant plug number on the recorder for the external source.
- If the TV is currently displaying some other source, it shall respond with a <Feature Abort> [“Cannot provide source”] message, or do nothing if initiated via the TV.

On receipt of a <Record On> message the Recording Device shall act as follows:

- If [“Digital Service”] or [“Analogue Service”] is indicated and the device can record that service using the information that was sent, the device shall change to that service and start recording. If the device does not have the indicated type of tuner, then it should respond with a <Record Status> with an operand of [“No recording – unable to record Digital Service”] or [“No recording – unable to record Analogue Service”].
  If the recorder has a suitable tuner, but is not able to select a service because the requested parameters are invalid or out of the range of the tuner, then it should return “No recording – Unable to select required service”.
- If [“Own source”] is indicated, then it shall attempt to record whatever it is currently displaying, e.g. an external connection such as a camcorder or the service it is currently tuned to.
- If [“External Plug”] or [“External Physical Address”] is indicated, the recorder should switch to the connector indicated by the External Plug number, or the connector which has the input from the device identified by the external Physical Address, and return a status of “Recording External input”. If [External Plug] or the [External Physical Address] is invalid, the device should return “No recording – invalid External plug number” or “No recording – invalid External Physical Address” respectively.

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The Recording Device shall respond with the message <Record Status> to indicate if recording has begun, or a reason why recording has failed. If the recording failed to start, the TV should inform the user, with the reason, or take other appropriate action. Note that it may take several seconds before a recorder is able to send an accurate <Record Status> after receiving a <Record On> message.

A recording initiated by a <Record On> message may be stopped at any time by sending a <Record Off> message. The Recording Device should then stop recording immediately. The recorder may optionally send a <Record Status> message in response to a <Record Off> message. In this case, the recorder may indicate that the recording was terminated normally by the <Record Off> message, or that the recording had already terminated, eg because there was insufficient space available on the media.

When a recorder is making a recording, the system <Standby> message should not interrupt a recording in progress. If the recorder receives a <Standby> message during the recording, it should react to the <Standby> message when the recording has finished unless it is the Active Source at the end of the recording.

The TV should ignore a <Record TV Screen> message that comes from a non-Recording Device address, however it shall accept the message from a 'Reserved' address (a future device type).

CEC 13.4.3 Behaviour with Earlier Versions

When sending this Message	From this HDMI Version 1.3a Device	To this HDMI Version 1.2a or 1.3 Device	Possible behaviour
<Record ON>	TV	Recording Device	<Feature Abort>, when specifying a [Record Source] other than "Own Source"
<Record Status > after a <Record Off> message	Recording Device	TV	<Feature Abort> as sending a <Record Status> in this case is new in 1.3a

When sending this Message	From this HDMI Version 1.2a or 1.3 Device	To this HDMI Version 1.3aDevice	Possible behaviour
<Record ON>	TV	Recording Device	<Feature Abort> as <Record ON> is optional in 1.3a

CEC 13.5 Timer Programming

CEC 13.5.1 Messages

The following messages are used for the Timer Programming feature:

<Clear Analogue Timer>, <Clear Digital Timer>, <Clear External Timer>, <Set Analogue Timer>, <Set Digital Timer>, <Set External Timer>, <Set Timer Program Title>, <Timer Cleared Status>, <Timer Status>

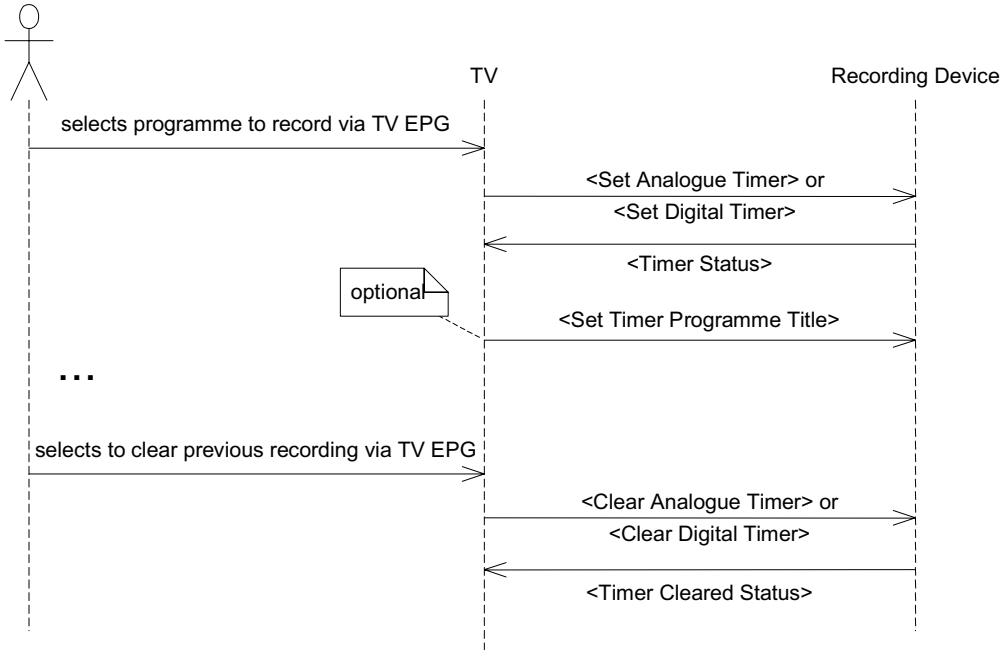
CEC 13.5.2 Feature Description

This feature allows a device (e.g. the TV) to set a timer recording on a Recording Device. It may for example be used to set timer blocks of a Recording Device via a TV menu or via an EPG.

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A device, such as the TV, may set or clear an individual timer block of a Recording Device. The Recording Device will respond to indicate if the timer was successfully set/cleared.

A timer block is set in the Recording Device by sending it a <Set Analogue Timer>, <Set Digital Timer> or a <Set External Timer> message, according to the type of service to be recorded.



CEC Figure 14 A typical scenario for setting a Timer Record Block

The Recording Device shall respond to the TV to indicate that a Timer was successfully programmed with a <Timer Status> message. For instance, there may be a conflict with an existing Timer, or the tuner in the Recording Device might not be of the correct Type (eg transmission system and/or CA).

The Recording Device may optionally include an estimate of the duration available on the media when:

- There is not, or may not be, sufficient space available for recording; or
- The timer was not successfully programmed because the event already exists.

Note that duration estimate may not be accurate with variable bitrate recordings, such as with a broadcast TV stream.

It is also possible to transfer the program title of a timer block (where for instance a timer is set via an EPG). To achieve this a device may send a <Set Timer Program Title> message directly after sending <Set Analogue Timer>, <Set Digital Timer> or <Set External Timer>. The Recording Device may then store the program title along with the timer information. If the Recording Device does not support program titles, then it shall Feature Abort an incoming <Set Timer Program Title> message.

When a recorder is making a recording, the system <Standby> message should not interrupt a recording in progress. If the recorder receives a <Standby> message during the recording, it should react to the <Standby> message when the recording has finished unless it is the Active Source at the end of the recording.

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CEC 13.5.3 Performing a Timed Recording using another device as source

When recording using another source device, eg recording a separate STB, the signal connection to the recorder will be made using another link such as an analogue connection or a SCART lead.

The <Set External Timer> message can be used to set a Timer in a Recording Device so that it uses an external (non-HDMI) connection as the source. There are two methods of specifying which connector the recorder should use: External Plug and External Physical Address, as specified in [External Source Specifier]:

- When “External Plug” has been specified, the recorder switches to the indicated plug number. Note that, in this case, the user (or an application in the TV) will have to supply the relevant External Plug number.
- When “External Physical Address” has been specified, the recorder switches to the relevant connector for the external device identified by the External Physical Address. Note that, in this case, the mapping of External Physical Address to recorder input connector is stored in the Recording Device. This mapping is usually made at installation time.

When the Recording Device starts a timed recording, it shall send a <Record On> message to the external tuner (STB) with the relevant operand to select the required service (analogue, digital or own source). Operation of this message is as described in the One Touch Record feature (see section CEC 13.4) and will cause the external device to come out of the Standby state if necessary. In this case, it shall do so “silently” without sending any <Image View On> or <Active Source> messages and shall provide an output on the separate link (eg SCART).

If the recorder initiated a recording using a <Record On> message to an external source, it shall also send a <Record Off> message to that source when the recording has finished, or when the recorder was unable to complete a recording for any reason (eg it has run out of media).

If the Source Device receives a <Standby> message during the recording, it shall ignore it for the duration of the recording and go to the Standby state after it has completed the recording (ie after receiving the <Record Off> message), unless it is the Active Source at the end of the recording.

CEC 13.5.4 Behaviour with Earlier Versions

This feature was introduced in HDMI version 1.3a. Devices conforming to HDMI version 1.3 or earlier will <Feature Abort> all messages sent by an Initiator for this feature.

CEC 13.6 System Information

CEC 13.6.1 Messages

The following messages are used for the System Information feature:

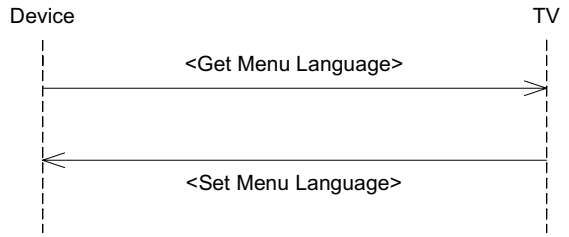
<CEC Version>, <Get CEC Version>, <Get Menu Language>, <Give Physical Address>, <Polling Message>, <Report Physical Address>, <Set Menu Language>.

CEC 13.6.2 Feature Description

This feature allows devices to automatically use the same OSD and Menu language settings as the TV and also for a TV to discover the current language when it is being installed.

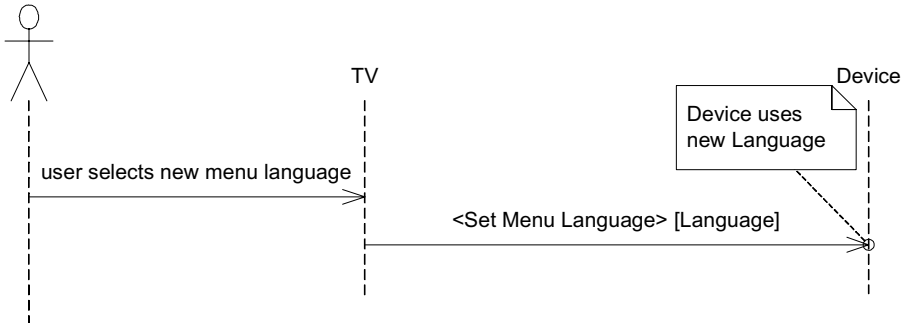
When a source device is powered on, it should send a <Get Menu Language> message to the TV. The TV shall then respond as shown below with a <Set Menu Language> message.

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CEC Figure 15 Message exchange when getting the TV's menu Language

When the user changes a menu language setting on the TV, it shall send a <Set Menu Language> message containing the currently selected menu [Language], as shown below.



CEC Figure 16 A typical scenario when a menu language setting within the TV is modified

On receipt of the <Set Menu Language> message, the device shall attempt to use the newly selected [Language] for Menus and OSDs.

Note that a device might receive a <Set Menu Language> message even when the language has not been changed. A device shall ignore any of the above messages that come from an initiator address other than 0 (the TV).

During the installation of a TV, the <Get Menu Language> message may be sent by the TV to another device to discover what language has been set on that device.

When identifying a language, the Bibliographic codes of ISO/FDIS 639-2 [ref 1n] shall be used.

In the case of Chinese, codes "zho" and "chi" are used. Where a device supports both Simple and Traditional characters, "zho" should be used for Simple characters and "chi" for Traditional characters. Where a device only supports one set (either Simple or Traditional), then the other code should default to the same character set. For example, if a device only supports Simple characters ("zho") it should also use these when the language is set to "chi" (Traditional).

A device can ask another device to indicate which version of CEC the target device supports, by sending a <Get CEC Version> message. The target device responds with a <CEC Version> message, which includes the relevant [CEC Version] operand. Note that the CEC version supported shall correspond with the relevant HDMI version, ie a device claiming support for CEC version 1.3a shall also support HDMI 1.3a.

CEC 13.6.3 Additional Information

The <Polling Message> is used to detect the presence or absence of a device within the system, see 6.1.3. It is also used for allocating logical addresses as detailed in CEC 10.2.1.

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The <Report Physical Address> message is used by a device to broadcast its physical address to all other devices in the system. By using the logical and physical addresses, any other device is able to derive the physical connectivity of the network. A device may request the physical address of another device by sending a directly addressed <Give Physical Address> message to it.

CEC 13.6.4 Behaviour with Earlier Versions

<Get CEC Version> and <CEC Version> are new messages for CEC Version 1.3a.

CEC 13.7 Deck Control

CEC 13.7.1 Messages

The following messages are used for the Deck Control feature:

<Deck Status>, <Give Deck Status>, <Deck Control>, <Play>

CEC 13.7.2 Feature Description

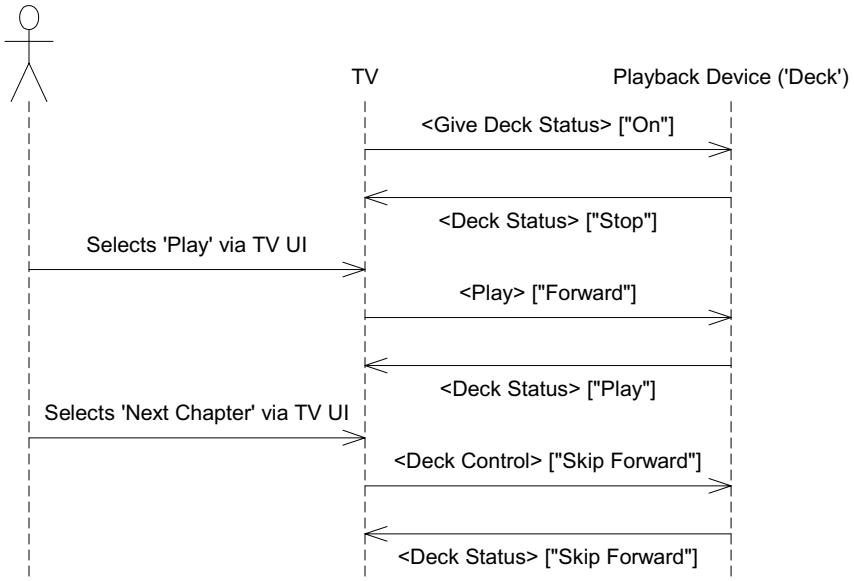
This feature allows a Playback Device (a deck or disc player or recorder) to be controlled by another device (e.g. the TV). Messages are also provided to allow a device to find out the status of the Deck; this allows, for example, a TV to keep its user interface synchronized with the status of the Deck.

A device may query the status of a deck with the <Give Deck Status> command. The deck should respond with a <Deck Status> message.

A device may control a Deck with the <Play> and <Deck Control> messages. These messages may be initiated after a user command. The Deck shall act upon the command that it receives within the messages <Play> and <Deck Control>. It is the equivalent of the user selecting the command local to the Deck. If the deck cannot carry out the command (e.g. it has no media when trying to play) it should respond with a <Feature Abort> [“Not in correct mode to respond”] message.

If the deck is in standby and receives a <Deck Control> [“Eject”] or <Play> [“Play Forward”] message, it should power on and act on the message. It is up to the manufacturer to decide if the device should power on when receiving any other <Deck Control> or <Play> messages.

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CEC Figure 17 A typical scenario for the Deck Control feature

The effect of the <Play> [Play Mode] operands "Fast Forward xx" and "Fast Reverse xx" will depend on the target device. For a disc-based sytem (eg DVD, Hard Disk), these will usually produce a picture at the required speed and direction. However, for a tape deck, the previous deck state may affect how this message is executed so that a picture may not always be available.

The effect of the <Deck Control> [Deck Control Mode] operands "Skip xx" will also depend on the target device. For a disc-based system, this will cause the disc to skip to the next Chapter. For a tape, this will cause the tape to go to the next marker without displaying a picture.

CEC 13.7.3 Behaviour with Earlier Versions

There are no differences between a CEC version 1.3a device and a device implementing earlier versions of CEC.

CEC 13.8 Tuner Control

CEC 13.8.1 Messages

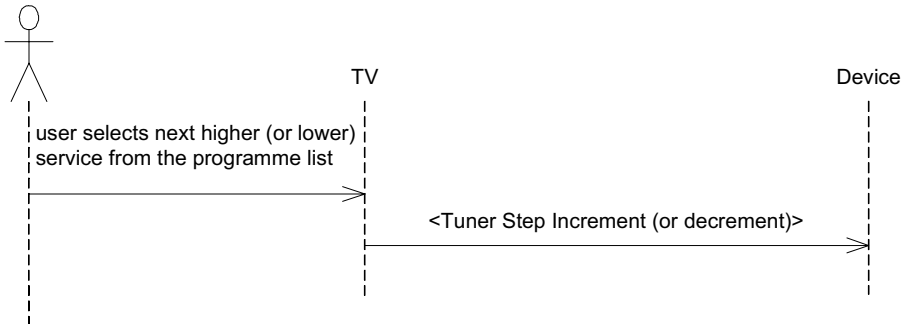
The following message are used for the Tuner Control feature:

<Give Tuner Device Status>, <Record On>, <Select Analogue Service>, <Select Digital Service>. <Tuner Step Decrement>, <Tuner Step Increment>, <Tuner Device Status>

CEC 13.8.2 Feature Description

This feature allows a device (e.g. the TV) to control another CEC device’s tuner.

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CEC Figure 18 A typical scenario for selecting a new Service

A device can control a CEC Device's tuner using the <Tuner Step Increment> and <Tuner Step Decrement> messages. If a device receives the <Tuner Step Increment> or <Tuner Step Decrement> message then it should select the next highest or next lowest service in its service list. The tuner device can interpret the messages as it chooses, for example, it may only cycle through channels included in the user's list of favorites.

A device can select a digital service on a tuner device by sending the <Select Digital Service> message. The tuner device shall then attempt to tune to that digital service and stream its output on the HDMI connection. If the specified digital service is not supported on the device then it should send a <Feature Abort> ["Invalid operand"] message. If the tuner device cannot select that digital service (e.g. if it is recording), it should respond with a <Feature Abort> ["Refused"] message. In a similar way, an analogue service may also be selected using the <Select Analogue Service> message.

A device may query the status of a tuner device by sending a <Give Tuner Device Status> message. The tuner device shall respond by sending a <Tuner Device Status> message indicating if it is currently displaying its tuner and the service that is currently selected.

A <Record On> message may be sent to a tuner when making an external recording. For details, see CEC 13.5.3.

CEC 13.8.3 Behaviour with Earlier Versions

<Select Analogue Service> is a new message for CEC Version 1.3a.

CEC 13.9 Vendor Specific Commands

CEC 13.9.1 Messages

The following messages are used for the Vendor Specific Commands feature:

<Device Vendor ID>, <Give Device Vendor ID>, <Vendor Command>, <Vendor Command With ID>, <Vendor Remote Button Down>, <Vendor Remote Button Up>

CEC 13.9.2 Feature Description

This feature allows a set of vendor specific commands to be used to communicate between devices.

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A device that supports vendor specific commands shall store a Vendor ID. A device shall broadcast a <Device Vendor ID> message after a successful initialization and address allocation to inform all other devices of its vendor ID. A device may request the Vendor ID of another device by sending a <Give Device Vendor ID> message to it. The follower shall respond by broadcasting a <Device Vendor ID> message. In this way any device can determine the vendor of another device.

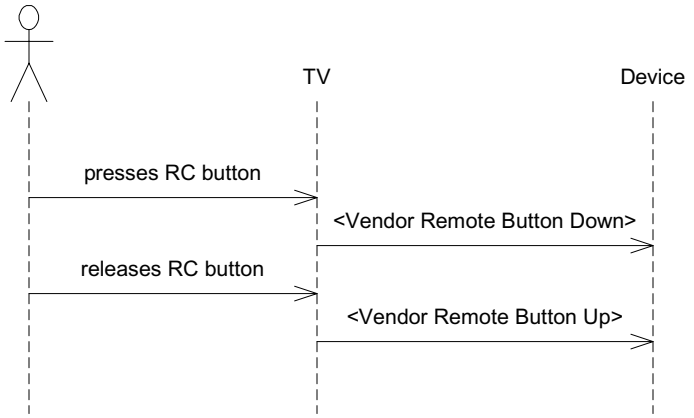
A device shall attempt to transmit a directly addressed <Vendor Command> to another device only if it has obtained or received the Vendor ID of that device and it recognizes that Vendor ID. A device should only send a <Vendor Command> if it has previously sent a <Device Vendor ID> message.

A follower device may accept a <Vendor Command> from an initiator of the same Vendor ID. With the agreement of the vendors involved, it is also possible for a device to accept a <Vendor Command> from devices made by other vendors. The follower may accept a <Vendor Command> only if the initiator's Vendor ID matches a Vendor ID on the follower's internal list of acceptable Vendor IDs. It should ignore all messages coming from devices with Vendor IDs which it does not recognize.

If an initiator device wants to send a <Vendor Command> and it does not know the Vendor ID of the follower device, the initiator device shall send a <Give Device Vendor ID> message to the follower device before it sends the <Vendor Command>. The follower device may respond to the received <Vendor Command>. It should only respond without previously sending a <Give Device Vendor ID> message if the follower device already knows the Vendor ID of the initiating device.

The <Vendor Command With ID> message may be broadcast as well as directly addressed. This differs from the <Vendor Command> in that the first 3 bytes of the payload carry a Vendor ID which identifies the vendor or entity which defined the command. Devices which receive the <Vendor Command With ID> and which do not accept the Vendor ID contained in the command shall ignore this command and shall respond with a <Feature Abort> if the message was directly addressed to that receiving device.

It is possible to send vendor specific remote control commands using the <Vendor Remote Button Down> and <Vendor Remote Button Up> messages.



CEC Figure 19 The messages sent in the Vendor Specific Commands feature

In addition it is possible to send other (non remote control key) vendor specific messages using the <Vendor Command> and <Vendor Command With ID> messages. The message parameter(s) can be used to communicate any additional (vendor defined) messages and data.

CEC 13.9.3 Behaviour with Earlier Versions

<Vendor Command With ID> is a new message for CEC Version 1.3a.

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In CEC Version 1.3a, by agreement of the vendors involved, <Vendor Command> messages may be used by devices which do not have the same Vendor ID.

CEC 13.10 OSD Display

CEC 13.10.1 Messages

The following message is used for the OSD Display feature:

<Set OSD String>

CEC 13.10.2 Feature Description

This feature allows a device to transfer a text string to the TV for On Screen Display. The <Set OSD String> message is used to transfer the text string to the TV.

A text string may be displayed for a default period (i.e. 5 seconds) or until explicitly cleared. In the latter case the device should send another <Set OSD String> message to clear the text when it is appropriate.

The TV should display the whole string unless it is in an unsuitable state, in which case it should generate a <Feature Abort> message.

If a new <Set OSD String> message is received when an OSD String is already being displayed, it should overwrite the existing string. OSD Strings generated locally within the TV may also overwrite any messages sent via the <Set OSD String> message.

CEC 13.10.3 Behaviour with Earlier Versions

There are no differences between a CEC version 1.3a device and a device implementing earlier versions of CEC.

CEC 13.11 Device OSD Name Transfer

CEC 13.11.1 Messages

The following messages are used for the Device OSD Name Transfer feature:

<Give OSD Name>, <Set OSD Name>

CEC 13.11.2 Feature Description

This feature is used to request the preferred name of a device to be used in any on screen display (e.g. menus), which reference that device. A device (e.g. the TV) may request another devices name by sending a directly addressed <Give OSD Name> message to it. If the device supports this feature it shall respond with a <Set OSD Name> message. The devices name should then be stored and used in any future on screen references to it.

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A TV may send a <Give OSD Name> message whenever it discovers a new device that has been connected.

CEC 13.11.3 Behaviour with Earlier Versions

A TV conforming to CEC Version 1.3a may not send a <Give OSD Name> message when it discovers a new device.

CEC 13.12 Device Menu Control

CEC 13.12.1 Messages

The following messages are used for the Device Menu Control feature:

<User Control Pressed>, <User Control Released>, <Menu Request>, <Menu Status>

CEC 13.12.2 Feature Description

This feature allows device menus to be controlled via the TV remote control as if it was using its own remote control and allow the TV to be aware when another device has a menu on its display.

A device shall indicate that it is displaying a menu by sending a <Menu Status> [“Activated”] message to the TV. If the device leaves the menu it shall send a <Menu Status> [“Deactivated”] message to the TV. The TV should then handle incoming remote control commands internally (as it would normally).

The message <User Control Pressed> can be used to send incoming Remote Control commands from the TV to a device that it is displaying a menu. The <User Control Released> message should be sent on release of the RC button. If a device fails to acknowledge any <User Control Pressed> or <User Control Released> message when in the providing menu state, the TV can assume that it has been removed from the system and act accordingly. For more information on <User Control> see the Remote Control Pass Through feature description (CEC 13.13).

The TV may initiate a device’s menu by sending a <Menu Request> [“Activate”] command. It may subsequently remove the menu by sending a <Menu Request> [“Deactivate”] message. The TV may also query a devices menu status by sending a <Menu Request> [“Query”]. The menu device shall always respond with a <Menu Status> command when it receives a <Menu Request>.

A new active source device shall send a <Menu Status> [“Activated”] message to the TV if it is displaying a menu. The TV shall assume that a new active source is not in a menu unless it receives this message after the <Active Source> message. The TV shall ignore a <Menu Status> message coming from a device that is not the current active source. A source device shall only send <Menu Status> commands when it is the current active source.

CEC 13.12.3 Behaviour with Earlier Versions

There are no differences between a CEC version 1.3a device and a device implementing earlier versions of CEC.

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CEC 13.13 Remote Control Pass Through

CEC 13.13.1 Messages

The following messages are used for the Remote Control Pass Through feature:

<User Control Pressed>, <User Control Released>

CEC 13.13.2 Feature Description

This feature is used to pass remote control commands received by one device (typically the TV) through to another device in the network. This feature will typically be used in situations where a TV offers a remote control with additional modes for controlling other devices within the system. The TV will receive the RC command and pass the command through to the appropriate device within the system. In a system where there is more than one of a particular device type present, the initiator should decide (as locally specified) a default device to pass remote control commands to.

The initiator will send a <User Control Pressed> message when the remote control button is pressed. When the button is released a <User Control Released> message should be sent by the initiator. The initiator should not send repeated <User Control Pressed> messages for the same button press.

The initiator may send further <User Control Pressed> messages without interleaving <User Control Released> messages if a new button press occurs quickly after a button release. This has the same effect as sending a <User Control Released> for the first button.

If a follower has received a <User Control Pressed> message and it did not receive a <User Control Released> message (or another <User Control Pressed> message with a different [UI Command]) within 500ms, then it is recommended that the receiving device should assume that the button has been released and act accordingly.

A device that has initiated a <User Control Pressed> message shall ensure that it sends a <User Control Released> message before going into standby. In the event that the initiator of the message is powered off/disconnected before sending a <User Control Released> message, the follower will never receive the <User Control Released> message.

The <User Control Pressed> and <User Control Released> messages indicate that the user has pressed or released the relevant button on their remote control. The receiving device determines the response to these messages. For the non-Deterministic functions, the response may be device-dependant.

This method should not be used for sending commands other than true remote control pass through to another device as the actions taken by the other device are not defined in a consistent way.

CEC 13.13.3 Deterministic UI Functions

In CEC Table 27, codes 0x60 to 0x6D are identified as Functions. Unlike the other codes, which just pass remote control presses to the target (often with manufacturer-specific results), the Functions are deterministic, ie they specify exactly the state after executing these commands. Several of these also have further operands, specifying the function in more detail, immediately following the relevant [UI Command] operand. For further information on the additional operands below, refer to Table 26.

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CEC Table 6 Deterministic UI Functions

UI Command Code	User Operation	Function	Additional Operands	Notes
0x60	Play Function	Specifies Play mode	[Play Mode]	1, 2
0x61	Pause-Play Function	Pauses playback. If repeated, the device shall remain in the paused state.		2
0x62	Record Function	Start recording. If repeated, the device shall remain in the record state without interrupting the recording.		2
0x63	Pause-Record Function	Pauses the recording. If repeated, the device shall remain paused.		2
0x64	Stop Function	Stops the media. If repeated, the device shall remain stopped.		2
0x65	Mute Function	Mutes audio output. If repeated, the audio shall stay muted.		
0x66	Restore Volume	Restores audio output to the value before it was muted.		
0x67	Tune Function	Identifies a broadcast channel number	[Channel Identifier]	1, 2
0x68	Select Media Function	Selects one Media within a device	[UI Function Media]	1, 2
0x69	Select A/V Input Function	Selects an A/V input	[UI Function Select A/V input]	1, 2
0x6A	Select Audio Input Function	Selects an Audio input	[UI Function Select Audio input]	1, 2
0x6B	Power Toggle Function	Toggles the device's power state (On / Standby)		2
0x6C	Power Off Function	Puts the device into the Standby state. If repeated, the device stays in the Standby state.		2
0x6D	Power On Function	Puts the device into the On (non-Standby) state. If repeated, the device stays in the active state		

Notes:

1 Functions with additional operands may also be used without the additional operand: in this case the behavior is manufacturer-specific.

2 During a recording or timed recording, a device may ask the user for confirmation of this action before executing it.

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CEC 13.13.4 Behaviour with Earlier Versions

CEC Version 1.3a added [Record Stop], [Record Pause], [Power Off Function], [Power On Function] and [Data] UI commands. It also clarified the earlier [Power Function] to be [Power Toggle Function] (0x6B).

CEC 13.14 Give Device Power Status

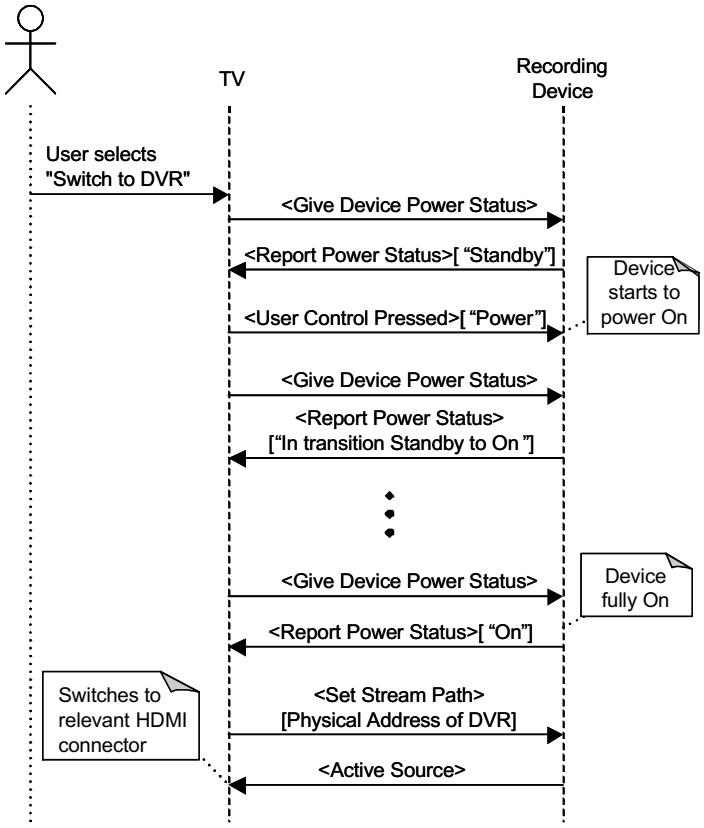
CEC 13.14.1 Messages

The following messages are used for the Give Device Power Status feature:

<Give Device Power Status>, <Report Power Status>

CEC 13.14.2 Feature Description

Several messages, such as <Image View On> and <Play>, bring another device out of standby. The <Give Device Power Status> message is used to determine the current power status of a target device. The target device responds with a <Report Power Status> message containing the Power Status operand.



CEC Figure 20 A typical scenario for to discover the power status of a target device

Some devices, such as a Recording Device, may take some time before they have fully transitioned to the On state. A requesting device may poll the target device to determine when that device is fully On. In this case, the requesting device shall not send a <Give Device Power Status> message more frequently than once

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every 0.5 seconds. It is not recommended that a requesting device polls another device until the first device has transitioned to a stable state.

CEC 13.14.3 Behaviour with Earlier Versions

When sending this Message	From this HDMI Version 1.3a Device	To this HDMI Version 1.2a or 1.3 Device	Possible behaviour
<Give Device Power Status>	Any	Any (except CEC Switches)	Device may <Feature Abort> as this was optional in 1.3 and before

CEC 13.15 System Audio Control

CEC 13.15.1 Messages

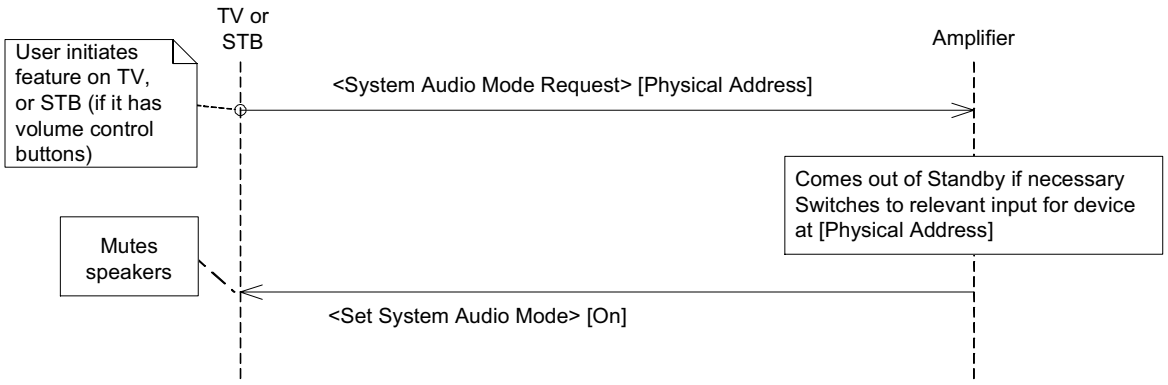
The following messages are used for the System Audio Control feature:

<Give Audio Status>, <Give System Audio Mode Status>, <Report Audio Status>, <Set System Audio Mode>, <System Audio Mode Request>, <System Audio Mode Status>, <User Control Pressed>, <User Control Released>.

CEC 13.15.2 Feature Description

This feature allows an audio amplifier to provide the audio for a source that is being displayed on a TV. When in this mode, the amplifier uses the same source as the video and provides the volume control function, instead of the TV, which mutes its speakers.

The feature can be initiated from a device (eg TV or STB) or the amplifier. In the case of initiation by a device other than the amplifier, that device sends an <System Audio Mode Request> to the amplifier, with the physical address of the device that it wants to use as a source as an operand. Note that the Physical Address may be the TV or STB itself. The amplifier comes out of standby (if necessary) and switches to the relevant input connector (see below concerning alternative connections). The amplifier shall then respond by sending a <Set System Audio Mode> [On] – see note below about addressing mode (direct or broadcast) of this command.

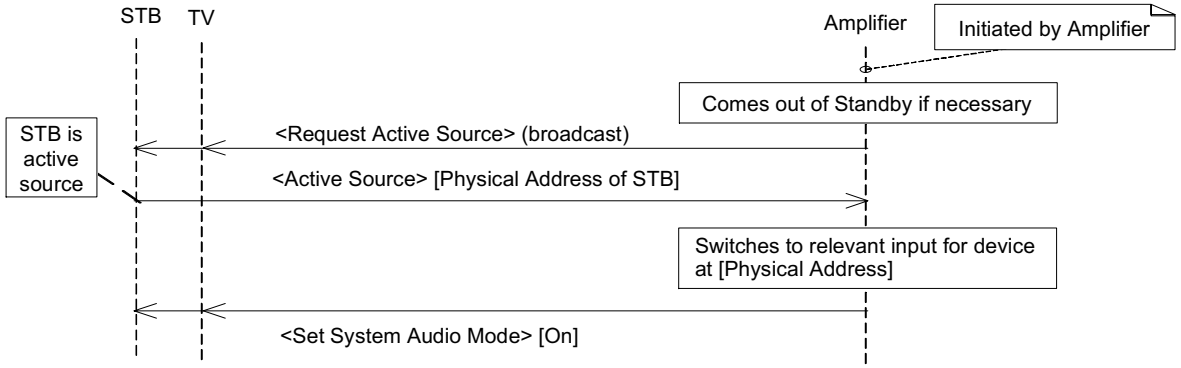


CEC Figure 21 A typical scenario for initiating the System Audio Control feature from a TV or STB

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When the feature is initiated from the amplifier, it shall come out of standby (if necessary) and then shall discover which device is the currently active source, by broadcasting a <Request Active Source> message (note that it is not necessary for the amplifier to send a <Request Active Source> message if System Audio Control is not required). The active device shall respond with an <Active Source> message with its physical address and the amplifier then selects the relevant input for that device. The amplifier then starts the feature by sending <Set System Audio Mode> [On] message.

The <Set System Audio Mode> [On] message shall initially be directly addressed to the TV when a device other than the TV (eg amplifier or STB) has initiated the feature. This also allows the amplifier to discover if the TV implements the System Audio Mode feature. If the TV replies with a <Feature Abort> [Unrecognized Opcode] message (ie, it does not implement this message), then the amplifier shall not proceed further with the feature. If the TV does not <Feature Abort> the message, then the amplifier broadcasts a <Set System Audio Mode> [On] message to inform any other devices (eg STBs) that the feature has been started. Further <Set System Audio Mode> [On] messages may use the broadcast address, until the amplifier is put into the standby state. It is not recommended for the amplifier to store the fact that a TV supports this feature since this does not allow the amplifier to detect if the TV has been changed to a device that does not support this feature.



CEC Figure 22 A typical scenario for initiating the System Audio Control feature from an amplifier

When the TV receives the <Set System Audio Mode> [On] message, it mutes its speakers.

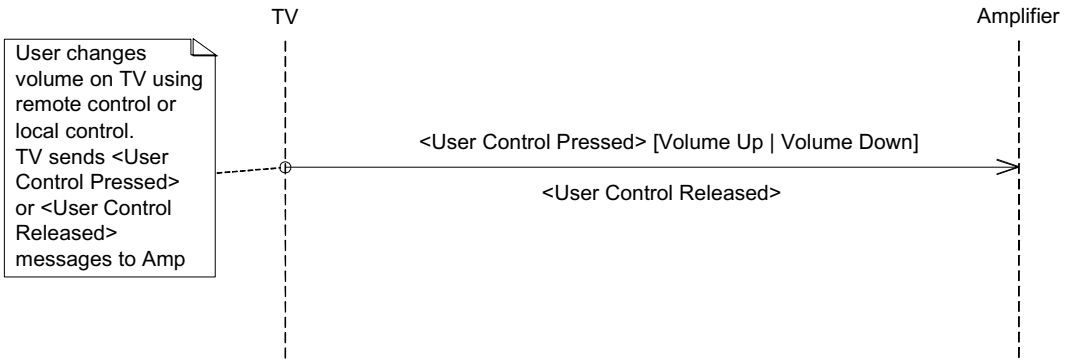
Stopping the feature can be initiated from the amplifier or other device. When the non-amplifier device (eg TV or STB) wants to stop the feature, it sends a <System Audio Mode Request> without a parameter to the amplifier. The amplifier shall respond by broadcasting a <Set System Audio Mode> [Off]. The amplifier can terminate the feature by broadcasting a <Set System Audio Mode> [Off].

When the TV receives the <Set System Audio Mode> [Off] message, it un-mutes its speakers.

Implementation of this feature shall be restricted to an amplifier and other devices that have volume control buttons such as a TV or STB.

When the System Audio Mode is On, the volume can be set using the volume control of the amplifier or other devices which have a volume control, such as the TV or a STB, using either the relevant user remote control or local controls on the device (eg physical Volume + / - keys or a rotary style control).

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CEC Figure 23 Typical Operation of the volume control

Whenever the volume is changed by one of the above methods and the System Audio Mode is On, the device that received the User's volume commands sends out a <User Control Pressed> with the relevant [Volume Up] or [Volume Down] operand to the amplifier. When the User releases the control, the device sends a <User Control Released> message to the amplifier. For further information on the User Control messages, see CEC 13.13.

Note that the behavior of the system volume will be determined by the behavior of the amplifier's volume control.

When the user requires to mute or unmute the amplifier's speakers while the System Audio Mode is On, the device (such as a TV or STB) sends a User Control message with an operand of [Mute]. The behavior of the mute message is determined by the amplifier.

The <Give Audio Status> and <Report Audio Status> messages are mainly used so that the TV can display the audio status of the external amplifier, for instance the current Mute status or a Volume bar display. The <Give Audio Status > message is used to ask for the current audio status of a target amplifier. The target device responds with a <Report Audio Status> message containing the Audio Status operand.

After the relevant <User Control Pressed> message has been sent to adjust the volume, the amplifier may send <Report Audio Status> messages so that the TV may display a moving bar as the volume changes. In this case, it is not recommended to send a <Report Audio Status> message more frequently than once every 500ms.

When the amplifier is muted or un-muted, it should send a <Report Audio Status> message so that the TV may display the mute status.

While System Audio Mode is On:

- the TV or source shall not change their own internal volume levels;
- the amplifier's local and remote controls shall also be active and able to control its volume.

If the System Audio Mode is On, then the amplifier shall send a <Set System Audio Mode>[Off] message just before it goes into the Standby state in order to restore the volume function back to the TV. If the amplifier is brought out of standby by a <System Audio Mode Request> from a TV or source, the System Audio Mode shall become On; otherwise the System Audio Mode is Off.

When a TV or other source which implements the System Audio Control feature joins the system or comes out of standby, it shall request the current System Audio Mode status by sending a <Give System Audio Mode Status>. The amplifier, if active (ie out of the Standby state), shall respond with a <System Audio Mode Status> message indicating the current status. The TV or source shall behave according to the current System Audio Mode status, as described in the paragraphs above.

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A TV will connect its audio to the amplifier via an alternative connection link such as analogue or S/PDIF. This is because the TV is at the end of an HDMI chain and so audio from the TV to the amplifier must be carried by the alternative link. It is also possible that other devices may connect their audio to the amplifier using an alternative link. In these cases it is the responsibility of the amplifier to switch to the device identified at a specified physical address (as indicated in an <System Audio Mode Request> or an <Active Source> message) and map that address to the actual connection in use, ie an HDMI connector or an alternative connector. In the case of a TV, the physical address of 0.0.0.0 will need to be mapped to the relevant alternative connector on the amplifier (eg analogue or S/PDIF). These mappings are usually made at installation time when the user identifies which connector and connection on the amplifier is used for each device.

CEC 13.15.3 Behaviour with Earlier Versions

This feature was introduced in HDMI version 1.3a. Devices conforming to HDMI version 1.3 or earlier will <Feature Abort> all messages sent by an Initiator for this feature.

CEC 13.16 Audio Rate Control

CEC 13.16.1 Messages

The following messages are used for the Audio Rate Control Feature:

<Set Audio Rate>

CEC 13.16.2 Feature Description

This feature allows the audio playback rate of a Source Device to be controlled by another device, e.g. an Audio System. A device may control the audio rate from a Source Device by sending a directly addressed <Set Audio Rate> message. Audio Rate Control is an exclusive function so that the Source Device can only be controlled by the one device that sent the <Set Audio Rate> message which started the Audio Rate Controlled function. It shall ignore any <Set Audio Rate> messages from other devices whilst it is in that state.

The audio rate controlled state is left when the controlling device sends a <Set Audio Rate> message with [Audio Rate] = “Rate Control Off” to the Source Device. The controlling device should send a <Set Audio Rate> command at least once every 2 seconds for active sensing. If a <Set Audio Rate> message is not received within 2 seconds or the status of the Source Device changes internally, then the Source Device shall quit the audio rate controlled mode. There are two control ranges, Wide and Narrow. When set to a specific range, the Source Device shall keep audio data streaming continuously even during a rate change transition, eg from Standard Rate to Fast Rate.

CEC 13.16.3 Behaviour with Earlier Versions

This feature was introduced in HDMI version 1.3a. Devices conforming to HDMI version 1.3 or earlier will <Feature Abort> all messages sent by an Initiator for this feature.

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CEC 14 Device States

This section shows how CEC messages can change the states of a device.

CEC 14.1.1 Device States

The following is a list of states that each device type can be in. Each device should be in one and only one state for each line shown below.

All Devices: On, Standby, Off

TV: Image Display, Menu Display, Text Display
Device Menu Active, Device Menu Inactive

Recording Device: Recording, Not Recording

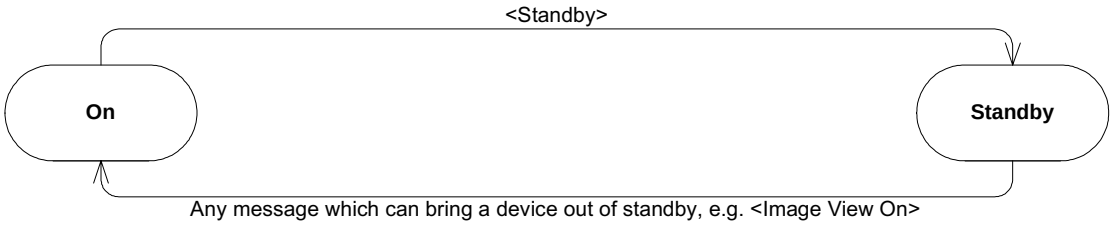
Playback Device: Deck Active, Deck Inactive

Menu Providing Device: Device Menu Active, Device Menu Inactive

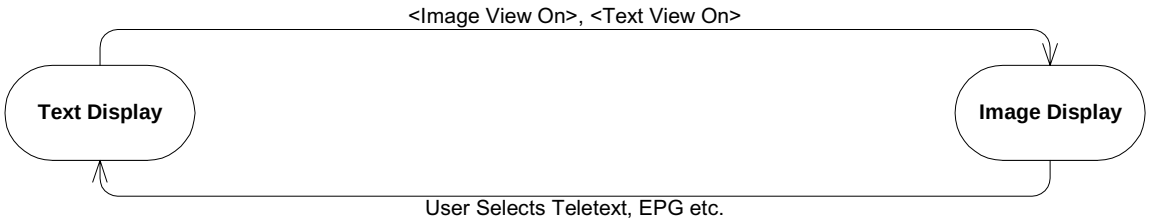
CEC 14.1.2 State Changes

The following diagrams show the state transitions that are caused as a direct result of a device receiving a CEC message. Transitions between states that are not caused as a result of CEC messages are generally not shown, except where no CEC message can cause that transition.

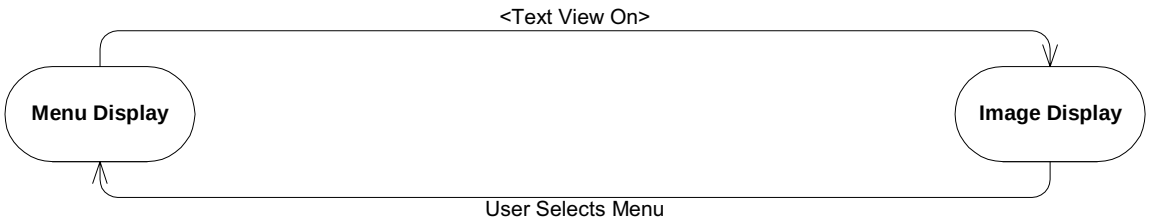
CEC 14.1.3 All Devices

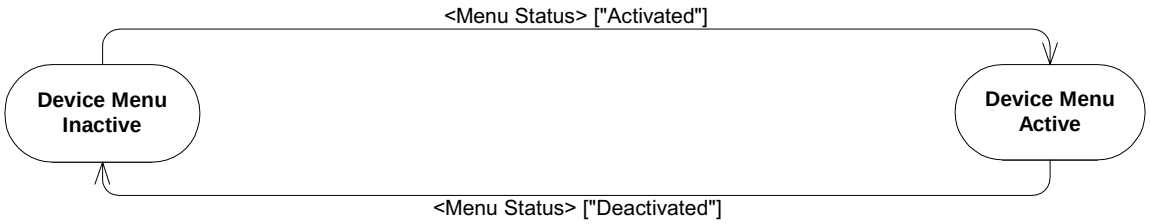


CEC 14.1.4 TV

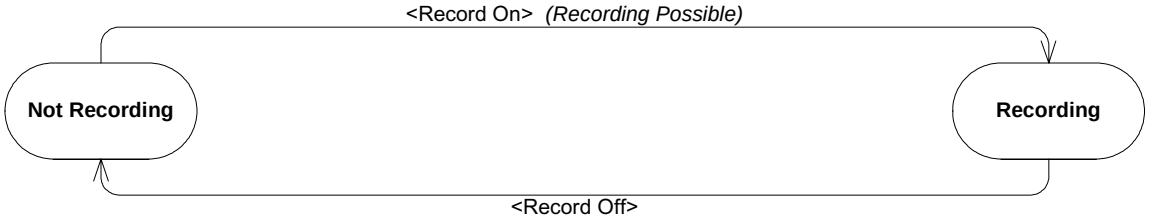


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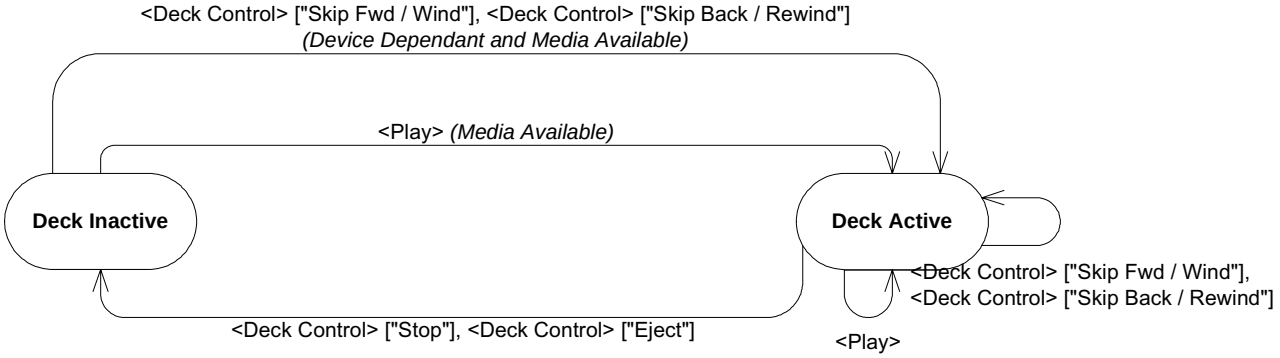




CEC 14.1.5 Recording Device

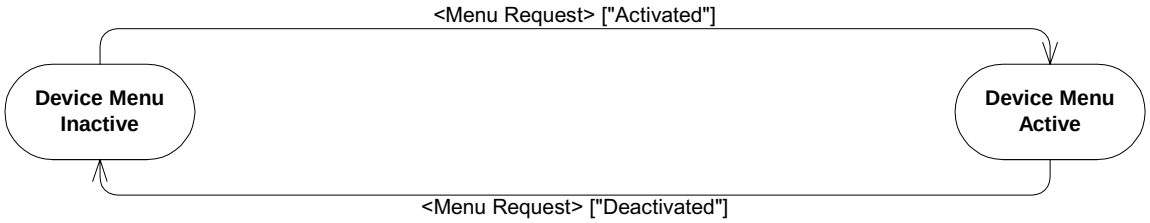


CEC 14.1.6 Playback Device



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CEC 14.1.7 Menu Providing Device



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CEC 15 Message Descriptions

The section defines the individual messages used in CEC. It describes them and defines their parameters and expected responses. As CEC has no session layer, this section and the operands section (CEC 17) effectively define the complete messaging system. Tables CEC Table 7 to CEC Table 20 show which messages are mandatory. If a manufacturer implements any of the optional messages, then they shall be implemented as described in CEC 13.

The following list describes each heading within the message tables CEC Table 7 to Table 23.

- **Opcode** – The name used to identify the message.
- **Value** – The unique identifier for the message.
- **Description** – A brief description of the message.
- **Parameters** – The set of parameters used by the message, refer to CEC Table 26 for individual descriptions.
- **Parameter Description** – A brief description of the parameters that the message uses.
- **Response** – Describes how a device should respond on receipt of the message.
- **Directly Addressed** – Indicates if the message may be directly addressed.
- **Broadcast** – Indicates if the message may be broadcast.
- **Mandatory** – Indicates if it is mandatory for a device to react and respond on receipt of the message. Note that where a message is indicated as being mandatory for ‘All’ devices, this excludes devices which act only as a CEC Switch.

Within the table some cells are intentionally left blank; this indicates that there are no associated requirements for the Opcode described.

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CEC Table 7 Message Descriptions for the One Touch Play Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Active Source> [1]	0x82	Used by a new source to indicate that it has started to transmit a stream OR used in response to a <Request Active Source>	[Physical Address]	The physical address of the device.	A current active source should take appropriate action. TV should switch to the appropriate input. Any CEC switches between source and root shall switch to the appropriate input and come out of standby if necessary.		•	All sources	TV, CEC Switches
<Image View On>	0x04	Sent by a source device to the TV whenever it enters the active state (alternatively it may send <Text View On>).	None		Turn on (if not on). If in 'Text Display' state then the TV enters 'Image Display' state. Note: Should not change TV menu or PIP status.	•		All sources shall implement at least one of <Image View On> or <Text View On>	TV
<Text View On>	0x0D	As <Image View On>, but should also remove any text, menus and PIP windows from the TV's display.	None		As <Image View On>, but should remove PIPs and menus from the screen. The TV enters 'Image Display' state regardless of its previous state.	•		All sources shall implement at least one of <Image View On> or <Text View On>	TV

[1] This message is also used in the Routing Control Feature

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CEC Table 8 Message Descriptions for the Routing Control Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Active Source> [2]	0x82	Used by a new source to indicate that it has started to transmit a stream OR used in response to a <Request Active Source>	[Physical Address]	The physical address of the device.	A current active source should take appropriate action. TV should switch to the appropriate input. Any CEC switches between source and root shall switch to the appropriate input and come out of standby if necessary.		•	All sources	TV, CEC Switches
<Inactive Source>	0x9D	Used by the currently active source to inform the TV that it has no video to be presented to the user, or is going into standby as the result of a local user command on the device.	[Physical Address]	The physical address of the device.	The TV may display its own internal tuner and shall send an <Active Source> with the address of the TV; or The TV may send <Set Stream Path> to another device for display.	•			
<Request Active Source>	0x85	Used by a new device to discover the status of the system.	None		<Active Source> from the present active source.		•		All, except for CEC Switches and devices which cannot become a source.

[2] This message is also used in the One Touch Play Feature

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Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Routing Change>	0x80	Sent by a CEC Switch when it is manually switched to inform all other devices on the network that the active route below the switch has changed.	[Original Address] [New Address]	The previous address that the switch was switched to and the new address it has been moved to.	If a CEC Switch is at the new address, it sends a <Routing Information> message to indicate its current active route.		•	CEC Switches and TV (with 2 or more HDMI inputs)	CEC Switches
<Routing Information>	0x81	Sent by a CEC Switch to indicate the active route below the switch.	[Physical Address]	The current active route to the sink in the CEC Switch.	If a CEC Switch is at the specified address it shall send a <Routing Information> message to indicate its current active path.		•	CEC Switches	CEC Switches
<Set Stream Path>	0x86	Used by the TV to request a streaming path from the specified physical address.	[Physical Address]	The physical address of the source device.	Any CEC switches between the TV and the source device shall switch inputs according to the path defined in [Physical Address]. A CEC device at the new address should come out of standby, stream its output and broadcast an <Active Source> message.		•		CEC Switches

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CEC Table 9 Message Descriptions for the Standby Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Standby>	0x36	Switches one or all devices into standby mode. Can be used as a broadcast message or be addressed to a specific device. See section CEC 13.3 for important notes on the use of this message	None		Switch the device into standby. [3] Ignore the message if already in standby.	•	•	TV (Broadcast Address)	All

[3] Can be ignored if actively engaged in a recording or providing a source stream for a recording. See also CEC 13.3 for other exceptions.

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CEC Table 10 Message Descriptions for the One Touch Record Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Record Off>	0x0B	Requests a device to stop a recording.	None		Exit 'Recording' state.	•		Device Initiating a recording	Recording Device if implementing <Record On>
<Record On>	0x09	Attempt to record the specified source.	[Record Source]	Source to record, either analogue service, digital service, external source or own source (ie currently selected source).	Enter 'Recording' state and start recording if possible. Send the initiator <Record Status>.	•			
<Record Status>	0x0A	Used by a Recording Device to inform the initiator of the message <Record On> about its status.	[Record Status Info]	The recording status of the device.		•		Recording Device if implementing <Record On>	Device Initiating a recording
<Record TV Screen>	0x0F	Request by the Recording Device to record the presently displayed source.	None		Initiate a recording using the <Record On> message, or send a <Feature Abort> ["Cannot provide source"] if the presently displayed source is not recordable.	•			

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CEC Table 11 Message Descriptions for the Timer Programming Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Clear Analogue Timer>	0x33	Used to clear an Analogue timer block of a device.	See <Set Analogue Timer> message.	See <Set Analogue Timer> message.	Clear timer block if possible, then respond with <Timer Cleared Status>	•			
<Clear Digital Timer>	0x99	Used to clear a Digital timer block of a device.	See <Set Digital Timer> message	See <Set Digital Timer> message	Clear timer block if possible, then respond with <Timer Cleared Status> message.	•			
<Clear External Timer>	0xA1	Used to clear an External timer block of a device.	See <Set External Timer> message	See <Set External Timer> message	Clear timer block if possible, then respond with <Timer Cleared Status> message.	•			
<Set Analogue Timer>	0x34	Used to set a single timer block on an Analogue Recording Device.	[Day of Month] [Month of Year] [Start Time] [Duration] [Recording Sequence] [Analogue Broadcast Type] [Analogue Frequency] [Broadcast System]	A complete set of Analogue timer information for one recording.	<Timer Status> message.	•			
<Set Digital Timer>	0x97	Used to set a single timer block on a Digital Recording Device.	[Day of Month] [Month of Year] [Start Time] [Duration] [Recording Sequence] [Digital Service Identification]	A complete set of Digital timer information for one recording.	<Timer Status> message.	•			

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Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Set External Timer>	0xA2	Used to set a single timer block to record from an external device.	[Day of Month] [Month of Year] [Start Time] [Duration] [Recording Sequence] [External Source Specifier] [External Plug] | [External Physical Address]	A complete set of External timer information for one recording.	<Timer Status> message.	•			
<Set Timer Program Title>	0x67	Used to set the name of a program associated with a timer block. Sent directly after sending a <Set Analogue Timer> or <Set Digital Timer> message. The name is then associated with that timer block.	[Program Title String]	Program title	Recording device stores title for future reference. Ignore message if it is not the immediate next message from this initiator following a <Set Analogue Timer> or <Set Digital Timer> message.	•			
<Timer Cleared Status>	0x43	Used to give the status of a <Clear Analogue Timer>, <Clear Digital Timer> or <Clear External Timer> message.	[Timer Cleared Status Data]	Indicates if the timer was cleared successfully.	If the message indicates that the timer was not cleared because there was no matching entry, the device should remove the timer block locally.	•			
<Timer Status>	0x35	Used to send timer status to the initiator of a <Set Timer> message.	[Timer Status Data]	Indicates the timer status		•			

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CEC Table 12 Message Descriptions for the System Information Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<CEC Version>	0x9E	Used to indicate the supported CEC version, in response to a <Get CEC Version>	[CEC Version]	A value indicating the supported CEC Version		•		[4]	[5]
<Get CEC Version>	0x9F	Used by a device to enquire which version of CEC the target supports	None		The source responds with a <CEC Version> message indicating the CEC version	•		[6]	[7]
<Give Physical Address>	0x83	A request to a device to return its physical address.	None		<Report Physical Address>	•			All, except for CEC Switches using logical address 15
<Get Menu Language>	0x91	Sent by a device capable of character generation (for OSD and Menus) to a TV in order to discover the currently selected Menu language. Also used by a TV during installation to discover the currently set menu language of other devices.	None		The addressed device responds with a <Set Menu Language> message	•			TV with OSD / Menu generation capabilities

[4] This message is also used in the Vendor Specific Command Feature - see CEC Table 15 for requirements
[5] This message is also used in the Vendor Specific Command Feature - see CEC Table 15 for requirements
[6] This message is also used in the Vendor Specific Command Feature - see CEC Table 15 for requirements
[7] This message is also used in the Vendor Specific Command Feature - see CEC Table 15 for requirements

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Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Polling Message>	-	Used by any device for device discovery – similar to ping in other protocols.	None		Shall set a low level ACK.	•		All except for CEC Switches	All except for CEC switches
<Report Physical Address>	0x84	Used to inform all other devices of the mapping between physical and logical address of the initiator.	[Physical Address] [Device Type]	The device's physical address within the cluster.			•	All	TV
<Set Menu Language>	0x32	Used by a TV or another device to indicate the menu language.	[Language]	The user's menu language choice.	Set the menu language as specified, if possible.		•	TV	All, except for TV, CEC Switches and devices without OSD/ Menu generation capabilities

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CEC Table 13 Message Descriptions for the Deck Control Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Deck Control>	0x42	Used to control a device's media functions.	[Deck Control Mode]	The deck control requested.	Perform the specified actions, or return a <Feature Abort> message. It is device dependent whether or not a Skip Forward/Wind or Skip Backward /Rewind command is legal when in the 'Deck Inactive' state. If the device is in standby and receives an eject command, it should power on and eject its media.	•			
<Deck Status>	0x1B	Used to provide a deck's status to the initiator of the <Give Deck Status> message.	[Deck Info]	Information on the device's current status.		•			
<Give Deck Status>	0x1A	Used to request the status of a device, regardless of whether or not it is the current active source.	[Status Request]	Allows the initiator to request the status once or on all future state changes. Or to cancel a previous <Give Deck Status> ["On"] request.	<Deck Status>	•			
<Play>	0x41	Used to control the playback behaviour of a source device.	[Play Mode]	Play mode required.	Perform the specified actions, or return a <Feature Abort> message. If media is available the device enters 'Deck Active' state. If the device is in standby, has media available and the parameter is ["Play Forward"] it should power on.	•			

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CEC Table 14 Message Descriptions for the Tuner Control Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Give Tuner Device Status>	0x08	Used to request the status of a tuner device.	[Status Request]	Allows the initiator to request the status once or on all future state changes, or to cancel a previous <Give Tuner Device Status> [“On”] message.	Respond with a <Tuner Device Status> message, or stop reporting changes on receipt of the [“Off”] message.	•			
<Select Analogue Service>	0x92	Directly selects an Analogue TV service	[Analogue Broadcast Type] [Analogue Frequency] [Broadcast System]	Defines Broadcast Type, Frequency and System for an Analogue TV service	Change to the selected analogue service and stream its output on the HDMI connection. If the tuner device is not capable of selecting this service, respond with a <Feature Abort>	•			
<Select Digital Service>	0x93	Directly selects a Digital TV, Radio or Data Broadcast Service	[Digital Service Identification]	Defines Digital TV system and necessary data to specify a service	Change to the selected digital service and stream its output on the HDMI connection. If the tuner device is not capable of selecting this service, respond with a <Feature Abort>	•			
<Tuner Device Status>	0x07	Use by a tuner device to provide its status to the initiator of the <Give Tuner Device Status> message.	[Tuner Device Info]	Information on the tuner devices current status.		•			
<Tuner Step Decrement>	0x06	Used to tune to next lowest service in a tuner’s service list. Can be used for PIP.	None		Follower tunes to next lowest service in its service list.	•			
<Tuner Step Increment>	0x05	Used to tune to next highest service in a tuner’s service list. Can be used for PIP.	None		Follower tunes to next highest service in its service list.	•			

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CEC Table 15 Message Descriptions for the Vendor Specific Commands Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<CEC Version> [8]	0x9E	Used to indicate the supported CEC version, in response to a <Get CEC Version>	[CEC Version]	A value indicating the supported CEC Version		•		All devices that want to be able to use the <Vendor Command> message from specific other vendors.	All devices that want to be able to use the <Vendor Command> message from specific other vendors.
<Device Vendor ID>	0x87	Reports the vendor ID of this device.	[Vendor ID]	The vendor ID of the device.	Any other interested device may store the vendor ID of the device.		•	As needed for Devices supporting Vendor Specific Commands	As needed for Devices supporting Vendor Specific Commands
<Get CEC Version> [9]	0x9F	Used by a device to enquire which version of CEC the target supports	None		The source responds with a <CEC Version> message indicating the CEC version	•		All devices that want to initiate a scenario with devices of specific other vendors using the <Vendor Command> message.	All devices that want to be able to use the <Vendor Command> message from specific other vendors.

[8] This message is also used in the System Information Feature
[9] This message is also used in the System Information Feature

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Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Give Device Vendor ID>	0x8C	Requests the Vendor ID from a device.	None		<Device Vendor ID>	•		As needed for Devices which initiate a scenario using the <Vendor Command> message	As needed for Devices supporting Vendor Specific Commands
<Vendor Command>	0x89	Allows vendor specific commands to be sent between two devices.	[Vendor Specific Data]	Vendor specific command or data. The maximum length of the [Vendor Specific Data] in this message shall not exceed 14 data blocks.	Vendor Specific	•			
<Vendor Command With ID>	0xA0	Allows vendor specific commands to be sent between two devices or broadcast.	[Vendor ID] [Vendor Specific data]	Vendor ID of the vendor or entity defining the command. Vendor specific command or data. The maximum length of [Vendor Specific Data] in this message shall not exceed 11 data blocks.	Vendor specific	•	•		
<Vendor Remote Button Down>	0x8A	Indicates that a remote control button has been depressed.	[Vendor Specific RC Code]	The vendor specific Remote Control Code for the key pressed. It is recommended to keep this to a minimum size. The maximum length shall not exceed 14 data blocks to avoid saturating the bus.	Vendor Specific	•	•		

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Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Vendor Remote Button Up>	0x8B	Indicates that a remote control button (the last button pressed indicated by the Vendor Remote Button Down message) has been released.	None		Vendor Specific	•	•		

CEC Table 16 Message Descriptions for the OSD Display Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Set OSD String>	0x64	Used to send a text message to output on a TV.	[Display Control] [OSD String]	Display timing. Text to be displayed.	TV displays the message.	•			

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CEC Table 17 Message Descriptions for the Device OSD Transfer Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Give OSD Name>	0x46	Used to request the preferred OSD name of a device for use in menus associated with that device.	None		<Set OSD Name>	•			
<Set OSD Name>	0x47	Used to set the preferred OSD name of a device for use in menus associated with that device.	[OSD Name]	The preferred name of the device.	Store the name and use it in any menus associated with that device.	•			

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CEC Table 18 Message Descriptions for the Device Menu Control Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Menu Request>	0x8D	A request from the TV for a device to show/remove a menu or to query if a device is currently showing a menu.	[Menu Request Type]	Indicates if the menu request is to activate or deactivate the devices menu, or to simply query the devices menu status.	May enter or exit the 'Device Menu Active' state if the parameter was "Activate" or "Deactivate" Send <Menu Status> to indicate the current status of the devices menu.	•			
<Menu Status>	0x8E	Used to indicate to the TV that the device is showing/has removed a menu and requests the remote control keys to be passed though.	[Menu State]	Indicates if the device is in the 'Device Menu Active' state or 'Device Menu Inactive' state.	If Menu State indicates activated, TV enters 'Device Menu Active' state and forwards those Remote control commands, shown in Table 26, to the initiator. If deactivated, TV enters 'Device Menu Inactive' state and stops forwarding remote control commands.	•			
<User Control Pressed> [10]	0x44	Used to indicate that the user pressed a remote control button or switched from one remote control button to another.	[UI Command]	UI command issued by user.	Update display or perform an action, as required.	•			
<User Control Released> [11]	0x45	Indicates that user released a remote control button (the last one indicated by the <User Control Pressed> message)	None		Update display or perform an action, as required.	•			

[10] This message is also used in the RC Passthrough and System Audio Features
[11] This message is also used in the RC Passthrough and System Audio Features

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CEC Table 19 Message Descriptions for the Remote Control Passthrough Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<User Control Pressed> [12]	0x44	Used to indicate that the user pressed a remote control button or switched from one remote control button to another.	[UI Command]	UI command issued by user.	Update display or perform an action, as required.	•			
<User Control Released> [13]	0x45	Indicates that user released a remote control button (the last one indicated by the <User Control Pressed> message)	None		Update display or perform an action, as required.	•			

CEC Table 20 Message Descriptions for the Power Status Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Give Device Power Status>	0x8F	Used to determine the current power status of a target device	None		<Report Power Status>	•			All (except CEC switches)
<Report Power Status>	0x90	Used to inform a requesting device of the current power status	[Power Status]	The current power status		•		All (except CEC switches)	

[12] This message is also used in the Device Menu Control and System Audio Features
[13] This message is also used in the Device Menu Control and System Audio Features

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CEC Table 21 Message Descriptions for General Protocol messages

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Feature Abort>	0x00	Used as a response to indicate that the device does not support the requested message type, or that it cannot execute it at the present time.	[Feature Opcode] [Abort Reason]	The Opcode of the aborted message. The reason provides an indication as to whether the follower does not support the message, or does support the message but cannot respond at the present time.	Assume that request is not supported or has not been actioned.	•		Generate if a message is not supported	All
<Abort> Message	0xFF	This message is reserved for testing purposes.	None		A device shall never support this message, and shall always respond with a <Feature Abort> message containing any valid value for [Abort Reason]. CEC switches shall not respond to this message.	•			All, except for CEC switches

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CEC Table 22 Message Descriptions for the System Audio Control Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Give Audio Status>	0x71	Requests an amplifier to send its volume and mute status	None		<Report Audio Status>	•			
<Give System Audio Mode Status>	0x7D	Requests the status of the System Audio Mode	None		Amplifier sends a <System Audio Mode Status> message indicating status (On or Off)	•			
<Report Audio Status>	0x7A	Reports an amplifier's volume and mute status	[Audio Status]	Volume and mute status		•			
<Set System Audio Mode>	0x72	Turns the System Audio Mode On or Off.	[System Audio Status]	Specifies if the System Audio Mode is On or Off.	If set to On, the TV mutes its speakers. The TV or STB sends relevant <User Control Pressed> or <User Control Released> as necessary. If set to Off, the TV un-mutes its speakers. The TV or STB stop sending the volume-related <User Control Pressed> or <User Control Released> messages.	•	•		

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Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<System Audio Mode Request>	0x70	A device implementing System Audio Control and which has volume control RC buttons (eg TV or STB) requests to use System Audio Mode to the amplifier	[Physical Address]	Source to be used is the device specified at this address.	The amplifier comes out of standby (if necessary) and switches to the relevant connector for device specified by [Physical Address]. It then sends a <Set System Audio Mode> [On] message. <System Audio Mode Request> sent without a [Physical Address] parameter requests termination of the feature. In this case, the amplifier sends a <Set System Audio Mode> [Off] message.	•			
<System Audio Mode Status>	0x7E	Reports the current status of the System Audio Mode	[System Audio Status]	Current system Audio Mode	If [On], the device requesting this information can send the volume-related <User Control Pressed> or <User Control Released> messages.	•			
<User Control Pressed>[14]	0x44	Used to indicate that the user pressed a remote control button or switched from one remote control button to another.	[UI Command] of “Volume Up”, “Volume Down” or “Mute”	Relevant UI command issued by user.	Increase or Decrease the volume of the amplifier, or mute/unmute the amplifier.	•			

[14] This message is also used in the Device Menu Control and RC Rassthrough Features

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Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<User Control Released>[15]	0x45	Indicates that user released a remote control button (the last one indicated by the <User Control Pressed> message)	None		Stop increasing or decreasing the volume	•			

CEC Table 23 Message Descriptions for the Audio Rate Control Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Set Audio Rate>	0x9A	Used to control audio rate from Source Device.	[Audio Rate]	The audio rate requested.	Perform the specified actions, or return a<Feature Abort> message.	•			

[15] This message is also used in the Device Menu Control and RC Rassthrough Features

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CEC 16 Message Dependencies

This section describes the dependencies between each message. This section is divided into two tables, which describe the following:

- CEC Table 24 describes the message dependencies when a device is capable of receiving a particular message (i.e. it does not <Feature Abort> indicating an ["Unrecognized opcode"] in response to the message).
- CEC Table 25 describes the message dependencies when a device is capable of sending a particular message.
- Each table describes the additional messages that the device shall be capable of receiving and sending if a particular message is supported.

CEC Table 24 Message dependencies when receiving a message

If device does not <Feature Abort> the following message:	**It shall not <Feature Abort> the message(s):**	**It shall be able to send the message(s):**
<CEC Version>	-	<Get CEC Version>
<Clear Analogue Timer>	<Set Analogue Timer>; and <Clear External Timer>, <Set External Timer> if Recording Device supports external recording	<Timer Status>, <Timer Cleared Status>;
<Clear Digital Timer>	<Set Digital Timer>; and <Clear External Timer>, <Set External Timer> if Recording Device supports external recording	<Timer Status>, <Timer Cleared Status>;
<Clear External Timer>	<Set External Timer>;	<Timer Status>, <Timer Cleared Status>;
<Deck Control>	<Play>	<Deck Status>
<Deck Status>	-	<Play>, <Deck Control>
<Device Vendor ID> [16]		<Give Device Vendor ID>
<Get CEC Version>	-	<CEC Version>
<Get Menu Language>	-	<Set Menu Language>
<Give Audio Status>	-	<Report Audio Status>

[16] This message is broadcast and there is therefore no <Feature Abort>, but devices accepting this message shall also be able to send the associated message

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If device does not <Feature Abort> the following message:	It shall not <Feature Abort> the message(s):	It shall be able to send the message(s):
<Give Deck Status>	<Play>, <Deck Control>	<Deck Status>
<Give Device Power Status>	-	<Report Power Status>
<Give Device Vendor ID>	-	<Device Vendor ID>
<Give OSD Name>	-	<Set OSD Name>
<Give Physical Address>	-	<Report Physical Address>
<Give System Audio Status>	<System Audio Mode Request>, <User Control Pressed>[Volume Up | Down | Mute], <User Control Released>	<Set System Audio Mode>, <System Audio Mode Status>
<Give Tuner Device Status>		<Tuner Device Status>
<Image View On>	<Active Source> [17]	-
<Inactive Source>	-	<Active Source>, <Set Stream Path>
<Menu Request>	<User Control Pressed>, <User Control Released>	<Menu Status>
<Menu Status>	-	<User Control Pressed>, <User Control Released>
<Play>	<Deck Control>	<Deck Status>
<Record Off>	<Record On>	<Record Status>
<Record On>	<Record Off>	<Record Status>
<Record Status>	-	<Record On>, <Record Off>
<Record TV Screen>	<Record Status>	<Record On>, <Record Off>
<Request Active Source>[18]	-	<Active Source>
<Routing Change>[19]	<Routing Information>	-

[17] This message is broadcast and there is therefore no <Feature Abort>, but devices shall also accept the associated message.
[18] This message is broadcast and there is therefore no <Feature Abort>, but devices accepting this message shall also be able to send the associated message.
[19] This message is broadcast and there is therefore no <Feature Abort>, but devices shall also accept the associated message.

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If device does not <Feature Abort> the following message:	It shall not <Feature Abort> the message(s):	It shall be able to send the message(s):
<Routing Information>[20]	<Routing Change>	-
<Set Analogue Timer>	<Clear Analogue Timer>; and <Clear External Timer> and <Set External Timer> if device supports external recording	<Timer Status>, <Timer Cleared Status>
<Set Audio Rate>	-	-
<Set Digital Timer>	<Clear Digital Timer>; and <Clear External Timer> and <Set External Timer> if device supports external recording	<Timer Status>, <Timer Cleared Status>
<Set External Timer>	<Clear External Timer>;	<Timer Status>, <Timer Cleared Status>
<Set System Audio Mode>	<System Audio Mode Status>	<System Audio Mode Request> <User Control Pressed>[Volume Up | Down | Mute], <User Control Released>
<Set Menu Language>	-	-
<Set OSD Name>	-	<Give OSD Name>
<Set OSD String>	-	-
<Set Stream Path>[21]	-	<Active Source> (not CEC Switches)
<System Audio Status>	<Set System Audio Mode>	<System Audio Mode Request>, <User Control Pressed>[Volume Up | Down | Mute], <User Control Released>
<System Audio Mode Request>	<Give System Audio Mode Status>, <User Control Pressed>[Volume Up | Down | Mute], <User Control Released>	<Set System Audio Mode>, <System Audio Mode Status>
<Text View On>	<Active Source>	-
<Timer Cleared Status>	<Timer Status>	

[20] This message is broadcast and there is therefore no <Feature Abort>, but devices shall also accept the associated message.
[21] This message is broadcast and there is therefore no <Feature Abort>, but devices accepting this message shall also be able to send the associated message.

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If device does not <Feature Abort> the following message:	It shall not <Feature Abort> the message(s):	It shall be able to send the message(s):
<Tuner Device Status>	-	<Give Tuner Device Status>
<Timer Status>	<Timer Cleared Status>	
<Tuner Step Decrement>	<Tuner Step Increment>	-
<Tuner Step Increment>	<Tuner Step Decrement>	-
<User Control Pressed>	<User Control Released>	-
<User Control Released>	<User Control Pressed>	-
<Vendor Command>	<Device Vendor ID>	<Give Device Vendor ID>
<Vendor Command With ID>[22]	<Device Vendor ID>	<Give Device Vendor ID>
<Vendor Remote Button Down> [23]	<Vendor Remote Button Up>, <Device Vendor ID>	<Give Device Vendor ID>
<Vendor Remote Button Up> [24]	<Vendor Remote Button Down>, <Device Vendor ID>	<Give Device Vendor ID>

[22] This message can be broadcast and there may not be a <Feature Abort>, but devices shall also accept the associated messages and also be able to send the associated message.
[23] This message can be broadcast and there may not be a <Feature Abort>, but devices shall also accept the associated messages and also be able to send the associated message.
[24] This message can be broadcast and there may not be a <Feature Abort>, but devices shall also accept the associated messages and also be able to send the associated message.

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CEC Table 25 Message dependencies when sending a message

If device ever sends the following message:	**It shall be able to send the message(s):**	**It shall not <Feature Abort> the message(s):**
<CEC Version>	-	<Get CEC Version>
<Clear Analogue Timer>	<Set Analogue Timer>; and <Set External Timer>, <Clear External Timer> if Recording Device supports External recording	<Timer Cleared Status>, <Timer Status>
<Clear Digital Timer>	<Set Digital Timer>; and <Set External Timer>, <Clear External Timer> if Recording Device supports External recording	<Timer Cleared Status>, <Timer Status>
<Clear External Timer>	<Set External Timer>	<Timer Cleared Status>, <Timer Status>
<Deck Control>	<Play>	-
<Deck Status>	-	<Give Deck Status>, <Play>, <Deck Control>
<Device Vendor ID>	-	<Give Device Vendor ID>
<Get CEC Version>	-	<CEC Version>
<Get Menu Language>	-	<Set Menu Language>[25]
<Give Deck Status>	<Play>, <Deck Control>	<Deck Status>
<Give Device Vendor ID>	-	<Device Vendor ID> [26]
<Give OSD Name>	-	<Set OSD Name>
<Give Physical Address>	-	<Report Physical Address> [27]
<Give Tuner Device Status>	-	<Tuner Device Status>

[25] This message is broadcast and there is therefore no <Feature Abort>, but devices sending the associated message shall also be able to send this message.
[26] This message is broadcast and there is therefore no <Feature Abort>, but devices sending the associated message shall also be able to send this message.
[27] This message is broadcast and there is therefore no <Feature Abort>, but devices sending the associated message shall also be able to send this message.

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If device ever sends the following message:	It shall be able to send the message(s):	It shall not <Feature Abort> the message(s):
<Image View On>	<Active Source>	-
<Inactive Source>	-	<Active Source>, <Set Stream Path>
<Menu Request>	<User Control Pressed>, <User Control Released>	<Menu Status>
<Menu Status>	-	<Menu Request>, <User Control Pressed>, <User Control Released>
<Play>	<Deck Control>	-
<Record Off>	<Record On>	<Record Status>
<Record On>	<Record Off>	<Record Status>
<Record Status>	-	<Record On>, <Record Off>
<Record TV Screen>	<Record Status>	<Record On>, <Record Off>
<Report Audio Status>	-	<Give Audio Status>
<Report Power Status>	-	<Give Device Power Status>
<Request Active Source>	-	<Active Source>[28]
<Routing Change>	<Routing Information>	-
<Routing Information>	<Routing Change>	-
<Set Analogue Timer>	<Clear Analogue Timer>; and <Set Digital Timer>, <Clear Digital Timer> if TV or STB has a Digital Tuner; and <Clear External Timer>, <Set External Timer>	<Timer Status>, <Timer Cleared Status>
<Set Audio Rate>	-	-

[28] This message is broadcast and there is therefore no <Feature Abort>, but devices sending the associated message shall also be able to send this message.

LENOVO EXHIBIT 1008 - 703/963

If device ever sends the following message:	It shall be able to send the message(s):	It shall not <Feature Abort> the message(s):
<Set Digital Timer>	<Clear Digital Timer>; and <Set Analogue Timer>, <Clear Analogue Timer> if TV or STB has an Analogue Tuner; and <Clear External Timer>, <Set External Timer>	<Timer Status>, <Timer Cleared Status>
<Set External Timer>	<Clear External Timer>; and <Set Analogue Timer>, <Clear Analogue Timer> if TV or STB has an Analogue Tumer>; and <Set Digital Timer>, <Clear Digital Timer> if TV or STB has a Digital Tuner	<Timer Status>, <Timer Cleared Status>
<Set System Audio Mode>	<System Audio Mode Status>	<Give System Audio Mode Status>, <User Control Pressed>[Volume Up | Down | Mute], <User Control Released>
<Set Menu Language>	-	<Get Menu Language>
<Set OSD Name>	-	<Give OSD Name>
<Set Stream Path>	-	<Active Source> (not CEC Switches)
<System Audio Mode Status>	<Set System Audio Mode>	<Give System Audio Mode Status>, <System Audio Mode Request>, <User Control Pressed>[Volume Up | Down | Mute], <User Control Released>
<System Audio Mode Request>	<User Control Pressed>[Volume Up | Down | Mute], <User Control Released>	<System Audio Mode Status>, <Set System Audio Mode>
<Text View On>	<Active Source>	-
<Timer Cleared Status>	<Timer Status>	<Clear Analogue Timer>, <Clear Digital Timer>, <Clear External Timer>
<Timer Status>	<Timer Cleared Status>	<Set Analogue Timer>, <Set Digital Timer>, <Set External Timer>
<Tuner Device Status>	-	<Give Tuner Device Status>
<Tuner Step Decrement>	<Tuner Step Increment>	-

LENOVO EXHIBIT 1008 - 704/963

If device ever sends the following message:	**It shall be able to send the message(s):**	**It shall not <Feature Abort> the message(s):**
<Tuner Step Increment>	<Tuner Step Decrement>	-
<User Control Released>	<User Control Pressed>	-
<Vendor Command>	<Device Vendor ID>	<Give Device Vendor ID>
<Vendor Command With ID>	<Device Vendor ID>	<Give Device Vendor ID>
<Vendor Remote Button Down>	<Vendor Remote Button Up>, <Device Vendor ID>	<Give Device Vendor ID>
<Vendor Remote Button Up>	<Vendor Remote Button Down>, <Device Vendor ID>	<Give Device Vendor ID>

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CEC 17 Operand Descriptions

In the following table, Operand Descriptions are ordered alphabetically. Sub-operands, which only occur in a single parent operand, are grouped with their parent and are shown indented.

Not all operand values are shown in the table: these shall be considered as “reserved”.

CEC Table 26 Operand Descriptions.

Name	Range Description		Length	Purpose
[Abort Reason]	“Unrecognized opcode”	0	1 byte	Reason for a <Feature Abort> response.
	“Not in correct mode to respond”	1		
	“Cannot provide source”	2		
	“Invalid operand”	3		
	“Refused”	4		
[Analogue Broadcast Type]	“Cable”	0x00	1 byte	Indicates the Analogue broadcast type
	“Satellite”	0x01		
	“Terrestrial”	0x02		
[Analogue Frequency]	0x0000<N<0xFFFF Frequency = 62.5n kHz		2 bytes	Used to specify the frequency used by an analogue tuner.
[ASCII digit]	0x30≤N≤0x39		1 byte	Subset of [ASCII] representing a printable digit character.
[ASCII]	0x20≤N≤0x7E		1 byte	Represents a printable character.
[Audio Rate]	“Rate Control Off”	0	1 byte	Control Off
	“Standard Rate”: 100% rate	1		Wide Range Control (IEEE 1394 compatible)
	“Fast Rate”: Max 101% rate	2		
	“Slow Rate”: Min 99% rate	3		

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Name		Range Description		Length	Purpose
		"Standard Rate": 100.0% rate	4		Narrow Range Control (HDMI Transparent)
		"Fast Rate": Max 100.1% rate	5		
		"Slow Rate": Min 99.9% rate	6		
[Audio Status]		[Audio Mute Status]	Bit 7	1 bit	Used to indicate the current audio status of a device.
		[Audio Volume Status]	Bits 6-0	7 bits	
	[Audio Mute Status]	"Audio Mute Off"	0	1 bit	Used to indicate the current audio mute status of a device.
		"Audio Mute On"	1		
	[Audio Volume Status]	0x00≤N≤0x64		7 bits	Used to indicate the current audio volume status of a device. N indicates audio playback volume, expressed as a percentage (0% - 100%). N=0 is no sound; N=100 is maximum volume sound level. The linearity of the sound level is device dependent. This value is mainly used for displaying a volume status bar on a TV screen.
		0x65≤N≤0x7E			Reserved
		0x7F			Current audio volume status is unknown
[Boolean]		"False"	0	1 byte	Flag
		"True"	1		
[Broadcast System]		0≤N≤31 – See CEC Table 28		1 byte	This specifies information about the color system, the sound carrier and the IF-frequency

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Name		Range Description		Length	Purpose
[CEC Version]		"Version 1.1"	0x00	1 byte	Indicates the supported CEC version
		"Version 1.2"	0x01		
		"Version 1.2a"	0x02		
		"Version 1.3"	0x03		
		"Version 1.3a"	0x04		
[Channel Identifier]		[Channel Number Format] [Major Channel Number] [Minor Channel Number]		4 bytes	Identifies a 1-part Logical or Virtual Channel Number or a 2-part Major and Minor channel combination
	[Channel Number Format]	"1-part Channel Number"	0x01	6 bits	Identifies Channel Format
		"2-part Channel Number"	0x02		
	[Major Channel Number]	If [Channel Number Format] is "2-part Channel Number", this operand represents a 3-digit Major channel number in hexadecimal format; if [Channel Number Format] is "1-part Channel Number" this operand shall be ignored.		10 bits	Major Channel Number (if Channel Number Format is 2-part)
	[Minor Channel Number]	If [Channel Number Format] is "1-part Channel Number" this operand represents a 1-part Channel Number in hexadecimal format; If [Channel Number Format] is "2-part Channel Number", this operand represents a Minor channel number in hexadecimal format		16 bits	1-part Channel Number, or a Minor Channel Number (if Channel Number Format is 2-part)
[Day of Month]		1≤N≤31		1 byte	Day of month.

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Name	Range Description		Length	Purpose
[Deck Control Mode]	“Skip Forward / Wind”	1	1 byte	Used in <Deck Control>. Note: The “Skip Forward / Wind” and ”Skip Reverse / Rewind” values are used for example in a DVD as next chapter and previous chapter and in a VCR as wind and rewind.
	“Skip Reverse / Rewind”	2		
	“Stop”	3		
	“Eject”	4		
[Deck Info]	“Play”	0x11	1 byte	Indicates the current status of a tape or disk deck.
	“Record”	0x12		
	“Play Reverse”	0x13		
	“Still”	0x14		
	“Slow”	0x15		
	“Slow Reverse”	0x16		
	“Fast Forward”	0x17		
	“Fast Reverse”	0x18		
	“No Media”	0x19		
	“Stop”	0x1A		
	“Skip Forward / Wind”	0x1B		
	“Skip Reverse / Rewind”	0x1C		
	“Index Search Forward”	0x1D		
	“Index Search Reverse”	0x1E		
	”Other Status”	0x1F		

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Name		Range Description			Length	Purpose
[Device Type]		"TV"		0	1 byte	Allows additional devices, above the number allowed in the logical addressing mechanism, to indicate their device type
		"Recording Device"		1		
		Reserved		2		
		"Tuner"		3		
		"Playback Device"		4		
		"Audio System"		5		
[Digital Service Identification]		[Service Identification Method] [Digital Broadcast System] [Service Identification]			7 bytes	Indicates Digital Broadcast System and the parameters to identify a specific service.
	[Service Identification Method]	"Service identified by Digital IDs"		0	1 bit	Indicates that a service is identified by digital service IDs
		"Service identified by Channel"		1		Indicates that a service is identified by a logical or virtual channel number
	[Digital Broadcast System]				7 bits	Indicates the Digital Broadcast System of required service. This is present irrespective of the state of [Service Identification Method]
		"ARIB generic"		0x00		Generic formats[29]
		"ATSC generic		0x01		
		"DVB generic"		0x02		
		"ARIB"	"ARIB-BS"	0x08		Specific Formats
			"ARIB-CS"	0x09		
			"ARIB-T"	0x0A		
		"ATSC"	"Cable"	0x10		

[29] These formats are included for legacy devices. New devices shall use the Specific Formats starting at 0x08

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Name		Range Description			Length	Purpose
			“Satellite”	0x11		
			“Terrestrial”	0x12		
		“DVB”	“DVB-C”	0x18		
			“DVB-S”	0x19		
			“DVB S2”	0x1A		
			“DVB-T”	0x1B		
	[Service Identification]	[ARIB data]			6 bytes	Specifies an ARIB digital service
		[ATSC data]				Specifies an ATSC digital service
		[DVB data]				Specifies a DVB digital service
		[Channel data]				When [Service Identification Method] is “Service identified by Channel”, this indicates the channel number
	[ARIB data]	“Transport_stream_ID”			2 bytes	The transport_stream_ID of the transport stream carrying the required service
		”Service_ID”			2 bytes	The service_ID of the required service
		”Original_Network_ID”			2 bytes	The original_network_ID of the network carrying the transport stream for the required service
	[ATSC data]	“Transport_stream_ID”			2 bytes	The transport_stream_ID of the transport stream carrying the required service
		“Program_number”			2 bytes	The Program_number of the required service
		“Reserved (0x0000)”			2 bytes	Reserved
	[DVB data]	“Transport_stream_ID”			2 bytes	The transport_stream_ID of the transport stream carrying the required service
		”Service_ID”			2 bytes	The service_ID of the required service

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<table>
<tr><th colspan="2">Name</th><th colspan="2">Range Description</th><th>Length</th><th>Purpose</th></tr>
<tr><td rowspan="2"></td><td></td><td colspan="2">”Original_Network_ID”</td><td>2 bytes</td><td>The original_network_ID of the network carrying the transport stream for the required service</td></tr>
<tr><td>[Channel data]</td><td colspan="2">[Channel Identifier] [Reserved 2 bytes]}</td><td>6 bytes</td><td>Identifies the logical or virtual channel number of a service. See [Channel Identifier] for details.</td></tr>
<tr><td colspan="2" rowspan="6">[Display Control]</td><td colspan="2">bit 5 – bit 0 = 0</td><td rowspan="6">1 byte</td><td rowspan="6">To indicate the display mode for an on screen display message.</td></tr>
<tr><td></td><td>Bit 7 Bit 6</td></tr>
<tr><td>“Display for default time”</td><td>0 0</td></tr>
<tr><td>“Display until cleared”</td><td>0 1</td></tr>
<tr><td>“Clear previous message”</td><td>1 0</td></tr>
<tr><td>Reserved for future use</td><td>1 1</td></tr>
<tr><td colspan="2">[Duration]</td><td colspan="2">[Duration Hours]
[Minute]</td><td>2 bytes</td><td></td></tr>
<tr><td></td><td>[Duration Hours]</td><td colspan="2">0≤N≤99</td><td>1 byte</td><td>Duration hours in BCD format:
<table>
<tr><th colspan="4">MS Byte</th><th colspan="4">LS Byte</th></tr>
<tr><td>b3</td><td>b2</td><td>b1</td><td>b0</td><td>b3</td><td>b2</td><td>b1</td><td>b0</td></tr>
</table></td></tr>
<tr><td colspan="2">[External Physical Address]</td><td colspan="2">[Physical Address]</td><td>2 bytes</td><td>Physical Address of device that is to be used as the source of a recording.
See CEC 13.5.3 for information on external connections.</td></tr>
<tr><td colspan="2">[External Plug]</td><td colspan="2">Plug number, 1 ≤ N ≤ 255</td><td>1 byte</td><td>External Plug number on the Recording Device.
See CEC 13.5.3 for information on external connections.</td></tr>
<tr><td colspan="2" rowspan="2">[External Source Specifier]</td><td>“External Plug”</td><td>4</td><td rowspan="2">1 byte</td><td rowspan="2">Indicates if External source is specified by the External plug number on the Recording Device, or by the External Physical Address of the required source</td></tr>
<tr><td>“External Physical Address”</td><td>5</td></tr>
</table>

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<table>
<tr><th>Name</th><th colspan="2">Range Description</th><th>Length</th><th>Purpose</th></tr>
<tr><td>[Hour]</td><td colspan="2">0 ≤ N ≤ 23</td><td>1 byte</td><td>Hour in BCD format:<table><tr><td colspan="4">MS Byte</td><td colspan="4">LS Byte</td></tr><tr><td>b3</td><td>b2</td><td>b1</td><td>b0</td><td>b3</td><td>b2</td><td>b1</td><td>b0</td></tr></table></td></tr>
<tr><td>[Feature Opcode]</td><td colspan="2">0x00 ≤ N ≤ 0xFF (n is defined in CEC Table 7 to CEC Table 23)</td><td>1 byte</td><td>Defines command to be performed.</td></tr>
<tr><td>[Language]</td><td colspan="2">3 {[ASCII]} as defined in ISO/FDIS 639-2 [ref 1n]</td><td>3 bytes</td><td>Specify the language with which to interact with the user.</td></tr>
<tr><td rowspan="3">[Menu Request Type]</td><td>“Activate”</td><td>0</td><td rowspan="3">1 byte</td><td rowspan="3">Specifies whether to activate or deactivate a devices menu or simply query its current menu status.</td></tr>
<tr><td>“Deactivate”</td><td>1</td></tr>
<tr><td>“Query”</td><td>2</td></tr>
<tr><td rowspan="2">[Menu State]</td><td>“Activated”</td><td>0</td><td rowspan="2">1 byte</td><td rowspan="2">Specifies the state of a device menu</td></tr>
<tr><td>“Deactivated”</td><td>1</td></tr>
<tr><td>[Minute]</td><td colspan="2">0≤N≤59</td><td>1 byte</td><td>Minute in BCD format:<table><tr><td colspan="4">MS Byte</td><td colspan="4">LS Byte</td></tr><tr><td>b3</td><td>b2</td><td>b1</td><td>b0</td><td>b3</td><td>b2</td><td>b1</td><td>b0</td></tr></table></td></tr>
<tr><td>[Month of Year]</td><td colspan="2">1≤N≤12</td><td>1 byte</td><td>Month</td></tr>
<tr><td>[New Address]</td><td colspan="2">[Physical Address]</td><td>2 bytes</td><td>The physical address of the new device selected by a CEC Switch.</td></tr>
<tr><td>[Original Address]</td><td colspan="2">[Physical Address]</td><td>2 bytes</td><td>The physical address of the device de-selected by a CEC Switch.</td></tr>
<tr><td>[OSD Name]</td><td colspan="2">N {[ASCII]}, 1≤N ≤ 14</td><td>1 - 14 bytes</td><td>The device’s name - to be used in On Screen Display references to it.</td></tr>
</table>

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Name		Range Description		Length	Purpose
[OSD String]		N {[ASCII]}, 1≤N ≤ 13		1 - 13 bytes	A string to be displayed on the display.
[Physical Address]		4{[Port ID]}		2 bytes	Defines the path between the TV and a device – thus giving it a physical address within the cluster.
	[Port ID]	0x0≤n≤0xF		4 bits	Defines one ‘hop’ within the physical address relating to the physical connection of the device.
[Play Mode]		“Play Forward”	0x24	1 byte	The mode in which to play media. Note: If a device does not support a particular play mode it should select the closest match.
		“Play Reverse”	0x20		
		“Play Still”	0x25		
		“Fast Forward Min Speed”	0x05		
		“Fast Forward Medium Speed”	0x06		
		“Fast Forward Max Speed”	0x07		
		“Fast Reverse Min Speed”	0x09		
		“Fast Reverse Medium Speed”	0x0A		
		“Fast Reverse Max Speed”	0x0B		
		“Slow Forward Min Speed”	0x15		
		“Slow Forward Medium Speed”	0x16		
		“Slow Forward Max Speed”	0x17		
		“Slow Reverse Min Speed”	0x19		
		“Slow Reverse Medium Speed”	0x1A		
		“Slow Reverse Max Speed”	0x1B		

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Name		Range Description		Length	Purpose
[Power Status]		“On”	0x00	1 byte	Used to indicate the current power status of a device.
		“Standby”	0x01		
		“In transition Standby to On”	0x02		
		“In transition On to Standby”	0x03		
[Program Title String]		N {[ASCII]}, 1 ≤ N ≤ 14		1 - 14 bytes	Program title.
[Record Source]		{[Record Source Type]} | {[Record Source Type] [Digital Service Identification]} | {[Record Source Type] [Analogue Broadcast Type] [Analogue Frequency] [Broadcast System]} | {[Record Source Type] [External Plug]} | {[Record Source Type] [External Physical Address]}		1 to 8 bytes (depends on source)	To define the source for a recording.
	[Record Source Type]	”Own source”	1	1 byte	Allows the record source to be specified for a recording.
		“Digital Service”	2		
		“Analogue Service”	3		
		“External Plug”	4		
		“External Physical Address”	5		
[Record Status Info]		“Recording currently selected source”	0x01	1 byte	Indicates the status of a recording.
		“Recording Digital Service”	0x02		
		“Recording Analogue Service”	0x03		
		“Recording External input”	0x04		

LENOVO EXHIBIT 1008 - 715/963

Name	Range Description		Length	Purpose
	"No recording – unable to record Digital Service "	0x05		No suitable tuner.
	"No recording – unable to record Analogue Service"	0x06		No suitable tuner.
	"No recording – unable to select required service"	0x07		Has suitable tuner, but the requested parameters are invalid or out of range for that tuner.
	"No recording – invalid External plug number"	0x09		
	"No recording – invalid External Physical Address"	0x0A		
	"No recording – CA system not supported"	0x0B		
	"No Recording – No or Insufficient CA Entitlements"	0x0C		
	"No recording – Not allowed to copy source"	0x0D		Source is "copy never".
	"No recording – No further copies allowed"	0x0E		
	"No recording – no media"	0x10		
	"No recording – playing"	0x11		
	"No recording – already recording"	0x12		
	"No recording – media protected"	0x13		
	"No recording – no source signal"	0x14		
	"No recording – media problem"	0x15		

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Name	Range Description		Length	Purpose
	"No recording – not enough space available"	0x16		
	"No recording – Parental Lock On"	0x17		
	"Recording terminated normally"	0x1A		Can optionally be sent in response to a <Record Off> message.
	"Recording has already terminated"	0x1B		Can optionally be sent in response to a <Record Off> message.
	"No recording – other reason"	0x1F		
[Recording Sequence]		b6……b0	8 bits	Indicates if recording is repeated and, if so, on which days. For repeated recordings, the recording sequence value is the bitwise OR of the days when recordings are required. [Recording Sequence] shall be set to 0x00 when the recording is not repeated. Bit 7 is reserved and shall be set to zero.
	"Sunday"	0b0000001		
	"Monday"	0b0000010		
	"Tuesday"	0b0000100		
	"Wednesday"	0b0001000		
	"Thursday"	0b0010000		
	"Friday"	0b0100000		
	"Saturday"	0b1000000		
	"Once only"	0b0000000		
	Bit 7, reserved	0		
[Reserved Bit]	0		1 bit	Used as padding bit for future extensions.

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Name		Range Description		Length	Purpose
[Status Request]		"On"	1	1 byte	Contains the status request mode which can be report once or on all future state changes or reporting off.
		"Off"	2		
		"Once"	3		
[Start Time]		[Time]		2 bytes	Indicates the start time for a timer based recording.
[System Audio Status]		"Off"	0	1 byte	Specifies if the System Audio Mode is On or Off
		"On"	1		
[Time]		[Hour][Minute]		2 bytes	Time of day
[Timer Cleared Status Data]		"Timer not cleared – recording"	0x00	1 byte	Indicates status in a <Timer Cleared Status> message.
		"Timer not cleared – no matching"	0x01		
		"Timer not cleared – no info available"	0x02		
		"Timer cleared"	0x80		
[Timer Status Data]		[Timer overlap warning] [Media Info] [Timer Programmed Info]		1 byte or 3 bytes	Used by a recoding device to respond to the initiator of a <Set Timer> message.
	[Timer Overlap Warning]	"No overlap"	0	1 bit	Indicates if there is another timer block already set which overlaps with this new recording request.
		"Timer blocks overlap"	1		
	[Media Info]	"Media present and not protected"	0b00	2 bits	Indicates if removable media is present and its write protect state.
		"Media present, but protected"	0b01		
		"Media not present"	0b10		
		Future Use	0b11		

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Name		Range Description		Length	Purpose
[Timer Programmed Info]		{[Programmed Indicator]} {[Programmed Info] [Duration Available]} | {[Not Programmed Error Info] [Duration Available]}		5 bits or 21 bits	Gives information about how and if the programming request has been done. [Programmed Indicator] is used as a selector for the second parameter. [Duration Available] can be optionally returned when: - [Programmed Info] is “Not enough space available” or “May not be enough space available”; or - [Not Programmed Info] is “Duplicate: already programmed” Note that the length depends on whether [Duration Available] is appended
	[Programmed Indicator]	“Not programmed”	0	1 bit	Selector for [Timer Programmed Info].
		”Programmed”	1		
	[Programmed Info]	Future Use	0b0xxx	4 bits	Information indicating any non-fatal issues with the programming request.
		“Enough space available for recording”	0b1000		
		“Not enough space available for recording”	0b1001		
		“May not be enough space available”	0b1011		
		“No Media info available”	0b1010		
	[Not Programmed Error Info]	Future Use	0b0000	4 bits	Reason for programming failure.
		“No free timer available”	0b0001		
		“Date out of range”	0b0010		
		“Recording Sequence error”	0b0011		Recording device does not support this recording sequence, or invalid data
		“Invalid External Plug Number”	0b0100		

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Name		Range Description		Length	Purpose
		"Invalid External Physical Address"	0b0101		
		"CA system not supported"	0b0110		
		"No or insufficient CA Entitlements"	0b0111		No or insufficient CA entitlements
		"Does not support resolution"	0b1000		Tuner does not support HD or recorder does not support HD
		"Parental Lock on"	0b1001		
		"Clock Failure"	0b1010		
		Reserved for Future Use	0b1011 to 0b1101		
		"Duplicate: already programmed"	0b1110		A timer block with identical details (of time and service) has already been programmed
	[Duration Available]	[Duration]		2 bytes	Optional parameter: Contains an estimate of the space left on the media, expressed as a time. This parameter may be returned when: - [Programmed Info] is "Not enough space available"; or - [Not Programmed Info] is "Duplicate: already programmed"
[Tuner Device Info]		[Recording Flag][Tuner Display Info] {[Analogue Broadcast Type] [Analogue Frequency][Broadcast System]} | [Digital Service Identification]}		5 bytes (analogue service); 8 bytes (digital service)	Indicates information about the tuner. Indicates the analogue or digital service that the tuner is set to, regardless of whether or not it is currently displaying the tuner. [Tuner Display Info] also indicates the data in the following bytes.
	[Recording Flag]	"Not being used for recording"	0	1 bit	Indicates if the tuner is being used as a source of a recording
		"Being used for recording"	1		

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Name		Range Description		Length	Purpose
	[Tuner Display Info]	"Displaying Digital Tuner"	0	7 bits	Indicates if the device is currently displaying its tuner or not (it may for example be displaying an external source or media).
		"Not displaying Tuner"	1		
		"Displaying Analogue tuner"	2		
[UI Command]		0x00≤n≤0xFF (n is defined in Table 27)		1 byte	Indicates the remote control button pressed. Note that some [UI Command] messages also have further operands following – see Table 6.
[UI Function Media]		Media number 1 ≤ N ≤ 255 N=0: Media number = current Media number + 1. If current Media number = maximum number in a device, then Media number =1.		1 byte	Number of the Media
[UI Function Select A/V input]		A/V input number 1 ≤ N ≤ 255 N=0: A/V input number = current A/V input number + 1. If current A/V input number = maximum number in a device, then A/V input number =1.		1 byte	Number of the A/V input
[UI Function Select Audio input]		Audio input number 1 ≤ N ≤ 255 N=0: Audio input number = current Audio input number + 1. If current Audio input number = maximum number in a device, then Audio input number = 1.		1 byte	Number of the Audio input
[Vendor ID]		0x000000≤N≤0xFFFFFF (n is the 24-bit unique company ID [ref. 3i] obtained from the IEEE Registration Authority Committee (RAC)).		3 bytes	Identifier for a specific Vendor.
[Vendor Specific Data]		Vendor specific command or data, as defined by the manufacturer.		≤14 bytes	The maximum length shall not exceed 14 data blocks to avoid saturating the bus.
[Vendor Specific RC Code]		Remote Control code, as defined by the manufacturer		≤14 bytes	It is recommended to keep this as small as possible to improve speed of response, as seen by the user. The maximum length shall not exceed 14 data blocks.

Notes: Items are transmitted in the order shown in the description.
All bit descriptions are sent most significant bit first (i.e. first bit described is sent first)

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CEC Table 27 User Control Codes

Operation id	User Operation
0x00	**Select**
0x01	**Up**
0x02	**Down**
0x03	**Left**
0x04	**Right**
0x05	**Right-Up**
0x06	**Right-Down**
0x07	**Left-Up**
0x08	**Left-Down**
0x09	Root Menu – see Note 2
0x0A	Setup Menu
0x0B	Contents Menu
0x0C	Favorite Menu
0x0D	**Exit**
0x0E - 0x1F	Reserved
0x20 - 0x29	**Numbers 0-9**
0x2A	Dot
0x2B	Enter
0x2C	Clear
0x2D - 0x2E	Reserved
0x2F	Next Favorite
0x30	Channel Up
0x31	Channel Down
0x32	Previous Channel
0x33	Sound Select
0x34	Input Select

Operation id	User Operation
0x35	Display Information
0x36	Help
0x37	Page Up
0x38	Page Down
0x39 - 0x3F	Reserved
0x40	Power
0x41	Volume Up
0x42	Volume Down
0x43	Mute
0x44	Play
0x45	Stop
0x46	Pause
0x47	Record
0x48	Rewind
0x49	Fast forward
0x4A	Eject
0x4B	Forward
0x4C	Backward
0x4D	Stop-Record
0x4E	Pause-Record
0x4F	Reserved
0x50	Angle
0x51	Sub picture
0x52	Video on Demand
0x53	Electronic Program Guide
0x54	Timer Programming

Operation id	User Operation
0x55	Initial Configuration
0x56 - 0x5F	Reserved
0x60	Play Function
0x61	Pause-Play Function
0x62	Record Function
0x63	Pause-Record Function
0x64	Stop Function
0x65	Mute Function
0x66	Restore Volume Function
0x67	Tune Function
0x68	Select Media Function
0x69	Select A/V Input Function
0x6A	Select Audio Input Function
0x6B	Power Toggle Function
0x6C	Power Off Function
0x6D	Power On Function
0x6E – 0x70	Reserved
0x71	**F1 (Blue)**
0x72	**F2 (Red)**
0x73	**F3 (Green)**
0x74	**F4 (Yellow)**
0x75	**F5**
0x76	Data – see Note 3
0x77 – 0xFF	Reserved

Note 1: The elements identified in **bold** are the only ones which are forwarded as part of the device menu control feature.

Note 2: This is the initial display that a device shows. It is device-dependent and can be, for example, a contents menu, setup menu, favorite menu or other menu. The actual menu displayed may also depend on the device's current state.

Note 3: This is used, for example, to enter or leave a digital TV data broadcast application.

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CEC Table 28 Broadcast System

System	Value	Bits 43210	Sound Carrier	Sound Modulation	Video Modulation	Vertical Frequency	Color sub-carrier
PAL B/G	0	00000	5.5 MHz	FM	neg	50 Hz	4.43 MHz
SECAM L'	1	00001	6.5 MHz	AM	Pos	50 Hz	[30]
PAL M	2	00010	4.5 MHz	FM	neg	60 Hz	3.5756MHz
NTSC M	3	00011	4.5 MHz	FM	neg	60 Hz	3.5795MHz
PAL I	4	00100	6.0 MHz	FM	neg	50 Hz	4.43 MHz
SECAM DK	5	00101	6.5 MHz	FM	neg	50 Hz	[30]
SECAM B/G	6	00110	5.5 MHz	FM	neg	50 Hz	[30]
SECAM L	7	00111	6.5 MHz	AM	pos	50 Hz	[30]
PAL DK	8	01000	6.5 MHz	FM	neg	50 Hz	4.43 MHz
Future use	9	01001					
..	..	..					
Future use	30	11110					
Other System [31]	31	11111					

[30] Color sub-carriers SECAM: f_{OB} 4.25 MHz, f_{OR} 4.406 MHz

[31] The system is not defined. The receiving device decides locally what to do.

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CEC Appendix A Non-CEC Switch (Informative)

There are two types of non-CEC Switches, those which have only one EDID for all source devices (or simply reflect the sink EDID), and those which have a separate EDID for all source devices. The rules for the operation of these two types of Switch are different:

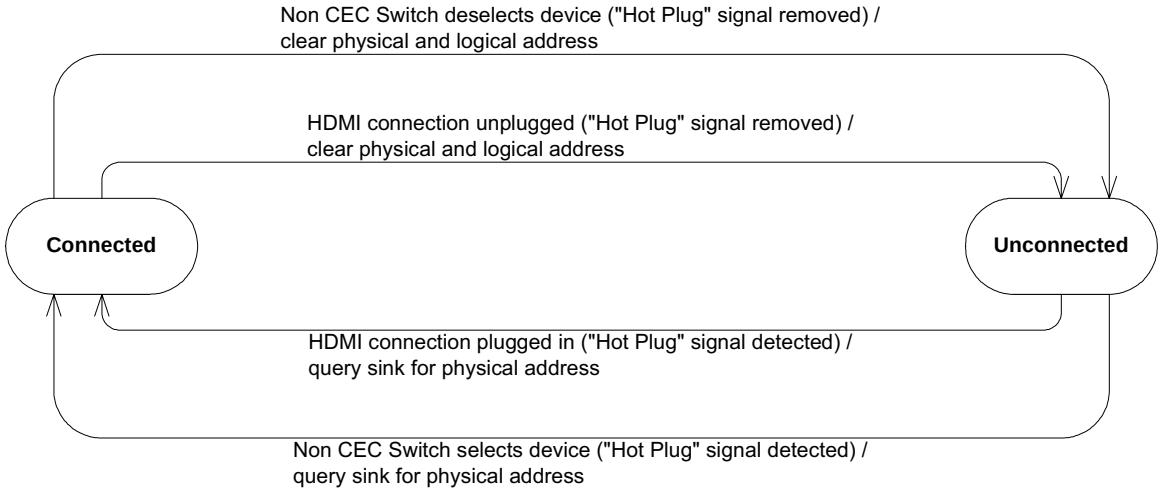
Note that the use of non-CEC Switches is deprecated, see CEC 11.

CEC A1 Switches with One EDID

A non-CEC-compliant Switch may have a single child_address, which is always occupied by the currently switched device. Any other connected devices will have no hot plug signal and will therefore have an unallocated physical address (and can use only the unregistered logical address). These devices will, however, still see CEC messages as they will be connected to the CEC line and they may react to some broadcast messages in the normal way (e.g. standby).

When a Switch de-selects a device, that device will detect the removal of the ‘hot plug’ signal to indicate that its physical AV connection has been removed. It should immediately clear its physical and logical addresses. Each source device below the Switch will detect the removal of the ‘hot plug’ signal to indicate they are no longer on the active AV Path and clear their addresses accordingly.

When a Switch selects a device, that device will detect the ‘hot plug’ signal. It can then obtain a valid physical address from its sink and subsequently a logical address. The device should activate the hot plug signal to its source (child) devices (if any) to indicate that they should now request a physical address.



CEC Figure A1 A device’s behavior when it is beneath a 1 EDID non-CEC Switch.

CEC A2 Switches with Multiple EDIDs

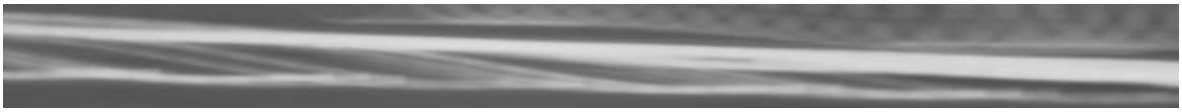
These should operate as CEC Switches except that they do not send messages on, or monitor, the CEC line.

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ATTACHMENT D

The Wayback Machine - https://web.archive.org/web/20081217013732/http://www.hdmi.org:80/learningcenter/faq.aspx

HIGH-DEFINITION MULTIMEDIA INTERFACE



FAQ

If you do not find your question listed here, please check the HDMI Knowledge Base.

Most Frequently Asked Questions

- **Q. What is the difference between HDMI 1.3 and HDMI 1.3a, or 1.3b?**
- **Q. Does HDMI support Closed Captioning?**
- **Q. What is HDMI?**
- **Q. Who supports HDMI?**

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- **Q. What are the advantages of HDMI over existing analog video interfaces such as composite, S-Video and component video?**
- **Q. What functionality was added to each version of HDMI?**
- **Q. Are all of the new HDMI versions backward compatible with previous versions?**
- **Q. What's new in the HDMI 1.3 Specification?**
- **Q. What testing is required?**
- **Q. Is HDMI backward compatible with DVI (Digital Visual Interface)?**
- **Q. Does HDMI accommodate long cable lengths?**
- **Q. How do I run HDMI cables longer than 10 meters?**
- **Q. How can I tell if a cable is an HDMI certified cable?**
- **Q. What is the difference between a "Standard" HDMI cable and a "High-Speed" HDMI cable?**
- **Q. Where can I find a copy of the Trademark and Logo Usage Guidelines?**
- **Q. Can I upgrade my existing HDMI version (1.X to v1.3)?**
- **Q. How can I tell the differences in each version of the HDMI specification?**
- **Q. Where can I get more information on becoming a HDMI Adopter?**
- **Q. What is the difference between DVI and HDMI?**
- **Q. How will HDMI change the way we interface with our entertainment systems?**
- **Q. What are the HDMI-related questions consumers should ask when shopping for a new CE or PC device?**
- **Q. As more and more devices converge, is HDMI an interface that can accommodate convergence between the PC and CE?**

Q. What is the difference between HDMI 1.3 and HDMI 1.3a, or 1.3b?

For consumers, there is no difference between HDMI version 1.3 and 1.3a or 1.3b. These minor revisions to the specification typically relate to manufacturing or testing issues and do not impact features or functionality. In addition, HDMI Licensing, LLC is actively working with manufacturers to reduce confusion for consumers by de-emphasizing version numbers and focusing instead on product features and functionality.

For Adopters, the latest HDMI Specification is v1.3a and the latest HDMI Compliance Test Specification (CTS) is 1.3c.

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Q. Does HDMI support Closed Captioning?
Close Captioning

The evolution from analog to digital TV has added some complexity to Close Captioning (CC). With one standard way of broadcasting/transmitting, decoding and displaying content NTSC or PAL, depending on region, analog TV made enabling CC fairly easy across CE devices since the TV was able to do all the CC decoding.

With the advent of digital TV and the introduction of digital HDTV services (cable, satellite, etc.) the responsibility of decoding CC has been taken away from the TVs and put into the various Set Top Boxes (STB) that are required for the majority of the digital HDTV services. Additionally, these STBs now have different ways of enabling CC making it complicated and creating confusion for consumers. All set-top boxes are required to support CC, however the implementation of CC can vary from one product to another. Enabling CC on a specific set-top box can be simple, or more difficult, depending on the implementation.

HDMI, LLC recommends contacting your TV service provider (cable, satellite, etc.) for the correct way to switch on its CC feature as a first step to resolve this issue. The second step is to contact the manufacturers directly for the correct way to enable the CC feature within your product.

HDMI and Close Captioning

All HDMI specifications support Close Captioning (CC) and enable the rendering of CC signals between CE devices. HDMI carries and delivers all the rendered data, in its entirety (including CC), produced from the source device to the display device.

HDMI, LLC is working with all CE vendors and service providers (cable, satellite, etc.) to make them aware of this issue. In addition, we are also encouraging these vendors and service providers to take steps that will address this CC problem which will deliver a more user friendly way for consumers to activate the CC feature.

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Q. What is HDMI?

HDMI (High-Definition Multimedia Interface) is the first and only industry-supported, uncompressed, all-digital audio/video interface. By delivering crystal-clear, all-digital audio and video via a single cable, HDMI dramatically simplifies cabling and helps provide consumers with the highest-quality home theater experience. HDMI provides an interface between any audio/video source, such as a set-top box, DVD player, or A/V receiver and an audio and/or video monitor, such as a digital television (DTV), over a single cable.

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HDMI supports standard, enhanced, or high-definition video, plus multi-channel digital audio on a single cable. It transmits all ATSC HDTV standards and supports 8-channel, 192kHz, uncompressed digital audio and all currently-available compressed formats (such as Dolby Digital and DTS), HDMI 1.3 adds additional support for new lossless digital audio formats Dolby® TrueHD and DTS-HD Master Audio™ with bandwidth to spare to accommodate future enhancements and requirements.

- **HDMI is the de facto standard digital interface for HD and the consumer electronics market:** More than 700 companies have become adopters, and nearly 200 million devices featuring HDMI are expected to ship in 2008, with an installed based of nearly one billion HDMI devices by 2010 (conservative estimates by In-Stat).
- **Convergence – HDMI is the interface for convergence of PC and consumer electronics devices:** HDMI enables PCs to deliver premium media content including high definition movies and multi-channel audio formats. HDMI is the only interface enabling connections to both HDTVs and digital PC monitors implementing the DVI and HDMI standards.
- **Evolving standard – HDMI is continually evolving to meet the needs of the market:** Products implementing new versions of the HDMI specification will continue to be fully backward compatible with earlier HDMI products.

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Q. Who supports HDMI?

The HDMI Founders include leading consumer electronics manufacturers Hitachi, Panasonic Corporation, Philips, Sony, Thomson (RCA), Toshiba, and Silicon Image. In addition, HDMI has the support of major motion picture producers Fox, Universal, Warner Bros. and Disney, and system operators DirecTV, EchoStar (Dish Network) as well as CableLabs.

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Q. What are the advantages of HDMI over existing analog video interfaces such as composite, S-Video and component video?

Quality: Because HDMI is a digital interface, it provides the best quality of the video since there are no lossy analog to digital conversions as are required for all analog connections (such as component or S-video). The difference is especially noticeable at higher resolutions such as 1080p. Digital video will be sharper than component, and eliminates the softness and ghosting found with component. Small, high contrast details such as text bring this difference out the most.

Ease-of-use: HDMI combines video and multi-channel audio into a single cable, eliminating the cost, complexity, and confusion of multiple cables currently used in A/V systems. This is particularly beneficial when equipment is being upgraded or added.

Intelligence: HDMI supports two-way communication between the video source (such as a DVD player) and the DTV, enabling new functionality such as automatic configuration and one-touch play. By using HDMI, devices automatically deliver the most effective format (e.g 480p vs 720p, 16:9 vs 4:3) for the display that it is connected to - eliminating the need for the consumer to scroll through all the format options to guess what looks best.

HD Content-Ready: HDMI devices supporting HDCP have the comfort of knowing they will have access to premium HD content now and in the future. HD-DVD and Blu-ray have delayed the activation of the image constraint token (a.k.a. content protection flag) with today's HD movies to help minimize potential issues caused by the transition, but are expected to activate this in a few years, meaning future HD movies will then not be viewable at HD resolutions over unprotected interfaces such as analog component.

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Q. What functionality was added to each version of HDMI?

The following provides an overview of major functionality added to each version of HDMI:

HDMI 1.1:

- Support for DVD Audio.

HDMI 1.2:

- Adds features and capabilities that increase HDMI's appeal for use in both the CE and PC industries. Specifically, the features and modifications for HDMI 1.2 include: Support for One Bit Audio format, such as SuperAudio CD's DSD (Direct Stream Digital), changes to offer better support for current and future PCs with HDMI outputs, including: availability of the widely-used HDMI Type A connector for PC sources and displays with full support for PC video formats, ability for PC sources to use their native RGB color space while retaining the option to support the YCbCr CE color space, requirement for HDMI 1.2 and later displays to support future low-voltage (i.e., AC-coupled) sources, such as those based on PCI Express I/O technology.

HDMI 1.2a:

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- Consumer Electronic Control (CEC) features and command sets and CEC compliance tests are now fully specified.
- Creation of version 1.2a of the HDMI Compliance Test Specification (CTS), which includes a CEC Supplement. HDMI CTS 1.2a has been updated for technical consistency with HDMI Specification 1.2a as well as to the recently released HDMI Specification 1.2.
- Significantly, CTS 1.2a contains additional cable and connector testing and Authorized Testing Center (ATC) submission requirements. Specifically, under CTS 1.2a, the Adopter shall submit for testing to the ATC any new HDMI cable whose length exceeds previously tested cables.
- Additionally, HDMI Licensing, LLC will maintain a list of approved connectors. For a device to pass CTS 1.2a testing at an ATC, all connectors on such device must appear on the approved connector list. To add a connector to this list, the vendor must submit to the ATC or HDMI Licensing, LLC full and passing testing results.

HDMI 1.3:

- **Higher speed:** HDMI 1.3 increases its single-link bandwidth to 340 MHz (10.2 Gbps) to support the demands of future HD display devices, such as higher resolutions, Deep Color and high frame rates. In addition, built into the HDMI 1.3 specification is the technical foundation that will let future versions of HDMI reach significantly higher speeds.
- **Deep Color:** HDMI 1.3 supports 10-bit, 12-bit and 16-bit (RGB or YCbCr) color depths, up from the 8-bit depths in previous versions of the HDMI specification, for stunning rendering of over one billion colors in unprecedented detail.
- **Broader color space:** HDMI 1.3 adds support for “x.v.Color™” (which is the consumer name describing the IEC 61966-2-4 xvYCC color standard), which removes current color space limitations and enables the display of any color viewable by the human eye.
- **New mini connector:** With small portable devices such as HD camcorders and still cameras demanding seamless connectivity to HDTVs, HDMI 1.3 offers a new, smaller form factor connector option.
- **Lip Sync:** Because consumer electronics devices are using increasingly complex digital signal processing to enhance the clarity and detail of the content, synchronization of video and audio in user devices has become a greater challenge and could potentially require complex end-user adjustments. HDMI 1.3 incorporates automatic audio synching capabilities that allows devices to perform this synchronization automatically with total accuracy.
- **New HD lossless audio formats:** In addition to HDMI’s current ability to support high-bandwidth uncompressed digital audio and all currently-available compressed formats (such as Dolby® Digital and DTS®), HDMI 1.3 adds additional support for new lossless compressed digital audio formats Dolby TrueHD and DTS-HD Master Audio™.

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Q. Are all of the new HDMI versions backward compatible with previous versions?

Yes, all HDMI versions are fully backward compatible with all previous versions.

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Q. What’s new in the HDMI 1.3 Specification?

- **Higher speed:** Although all previous versions of HDMI have had more than enough bandwidth to support all current HDTV formats, including full, uncompressed 1080p signals, HDMI 1.3 increases its single-link bandwidth to 340 MHz (10.2 Gbps) to support the demands of future HD display devices, such as higher resolutions, Deep Color and high frame rates. In addition, built into the HDMI 1.3 specification is the technical foundation that will let future versions of HDMI reach significantly higher speeds.
- **Deep Color:** HDMI 1.3 supports 10-bit, 12-bit and 16-bit (RGB or YCbCr) color depths, up from the 8-bit depths in previous versions of the HDMI specification, for stunning rendering of over one billion colors in unprecedented detail.
- **Broader color space:** HDMI 1.3 adds support for “x.v.Color™” (which is the consumer name describing the IEC 61966-2-4 xvYCC color standard), which removes current color space limitations and enables the display of any color viewable by the human eye.
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Q. What testing is required?

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Prior to mass producing or distributing any Licensed Product or component that claims compliance with the HDMI Specification (or allowing someone else to do such activities), each Adopter must test a representative sample for HDMI compliance. First, the Adopter must self test as specified in the then-current HDMI Compliance Test Specification. The HDMI Compliance Test Specification provides a suite of testing procedures, and establishes certain minimum requirements specifying how each HDMI Adopter should test Licensed Products for conformance to the HDMI Specification. Such compliance testing is limited to evaluation of a product's compliance with the HDMI Specification and is not designed to test the overall performance of any Licensed Product.

Second, each Adopter must submit the first product of each Licensed Product type (i.e. source, sink, repeater, or cable) to an HDMI Authorized Testing Center (ATC) for testing. Once an Adopter product of each type has passed testing, it is not required to submit to the ATC subsequent products of that type. However, Adopters must still self-test the products for compliance to the HDMI test specification. For example, once an Adopter's television has passed ATC testing, it is not required to submit another television or other display for ATC testing. However, to help ensure HDMI interoperability, we encourage Adopters to use the ATCs.

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Q. Is HDMI backward compatible with DVI (Digital Visual Interface)?

Yes, HDMI is fully backward compatible with DVI compliant devices. HDMI DTVs will display video received from existing DVI-equipped products, and DVI-equipped TVs will display video from HDMI sources. However, some older PCs with DVI are designed only to support computer monitors, not televisions. Consumers buying a PC with DVI should make sure that it specifically includes support for television formats and not just computer monitors.

Also, consumers may want to confirm that the DVI interface supports High-bandwidth Digital Content Protection (HDCP), as content that requires HDCP copy protection will require that both the HDMI and DVI devices support HDCP to properly view the video content.

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Q. Does HDMI accommodate long cable lengths?

Yes. HDMI technology has been designed to use standard copper cable construction at long lengths. In order to allow cable manufacturers to improve their products through the use of new technologies, HDMI specifies the required performance of a cable but does not specify a maximum cable length. We have seen cables pass "Standard Cable" HDMI compliance testing at lengths of up to a maximum of 10 meters without the use of a repeater. It is not only the cable that factors into how long a cable can successfully carry an HDMI signal, the receiver chip inside the TV or projector also plays a major factor. Receiver chips that include a feature called "cable equalization" are able to compensate for weaker signals thereby extending the potential length of any cable that is used with that device.

With any long run of an HDMI cable, quality manufactured cables can play a significant role in successfully running HDMI over such longer distances.

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Q. How do I run HDMI cables longer than 10 meters?

There are many HDMI Adopters working on HDMI solutions that extend a cable’s effective distance from the typical 10 meter range to much longer lengths. These companies manufacture a variety of solutions that include active cables (active electronics built into cables that boost and extend the cable’s signal), repeaters, amplifiers as well as CAT5/6 and fiber solutions.

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Q. How can I tell if a cable is an HDMI certified cable?

All HDMI products are required to be certified by the manufacturer as part of the HDMI Compliance Test Specification. However, there may be instances where cables bearing the HDMI logo are available but have not been properly tested. HDMI Licensing, LLC actively investigates these instances to ensure that the HDMI trademark is properly used in the market. We recommend that consumers buy their cables from a reputable source and a company that is trusted.

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Q. What is the difference between a “Standard” HDMI cable and a “High-Speed” HDMI cable?

Recently, HDMI Licensing, LLC announced that cables would be tested as Standard or High-Speed cables.

- Standard (or “category 1”) cables have been tested to perform at speeds of 75Mhz, which is the equivalent of a 1080i signal.

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- High Speed (or “category 2”) cables have been tested to perform at speeds of 340Mhz, which is the highest bandwidth currently available over an HDMI cable and can successfully handle 1080p signals including those at increased color depths and/or increased refresh rates. High-Speed cables are also able to accommodate higher resolution displays, such as WQXGA cinema monitors (resolution of 2560 x 1600).

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Q. Where can I find a copy of the Trademark and Logo Usage Guidelines?

The HDMI Trademark and Logo Usage Guidelines are posted on the HDMI website (http://www.hdmi.org) and can be found in the Manufacturer section.

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Q. Can I upgrade my existing HDMI version (1.X to v1.3)?

Currently, there are no provisions for doing such an upgrade. Because of the new enhanced feature set, any such conversion would require hardware and firmware upgrades. If there are such conversions, it would come from the manufacturer. Please check with them directly.

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Q. How can I tell the differences in each version of the HDMI specification?

Download a copy of the most recent specification of HDMI. At the beginning of the document, there is a section called "Revision History." In this section, you can view all of the the changes for each revision of the Specification.

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Q. Where can I get more information on becoming a HDMI Adopter?

On the home page of the www.hdmi.org website is a link to "Becoming an Adopter." Click on that link, and all the information you need, including the Adopter agreements and on-line registration, can be found there.

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Q. What is the difference between DVI and HDMI?

HDMI is DVI with the addition of:

- Audio (up to 8-channels uncompressed)
- Smaller Connector
- Support for YUV Color Space
- CEC (Consumer Electronics Control)
- CEA-861B InfoFrames

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Q. How will HDMI change the way we interface with our entertainment systems?

The most tangible and immediate way that HDMI changes the way we interface with our components is in the set-up. One cable replaces up to 11 analog cables, highly simplifying the setting up of a home theater as well as supporting the aesthetics of new component design with cable simplification.

Next, when the consumer turns on the HDMI-connected system, the video is of higher quality since the signal has been neither compressed nor converted from digital to analog and back.

Lastly, because of the two-way communication capabilities of HDMI, components that are connected via HDMI constantly talk to each other in the background, exchanging key profile information so that content is sent in the best format without the user having to scroll through set-up menus. The HDMI specification also includes the option for manufacturers to include CEC functionality (Consumer Electronics Control), a set of commands that utilizes HDMI’s two- way communication to allow for single remote control of any CEC-enabled devices connected with HDMI. For example, CEC includes one-touch play, so that one touch of play on the DVD will trigger the necessary commands over HDMI for the entire system to power on and auto-configure itself to respond to the command. CEC has a variety of common commands as part of its command set, and manufacturers who implement CEC must do so in a way that ensures that these common command sets interoperate amongst all devices, regardless of manufacturer.

CEC is an optional feature, however, so consumer interested in this functionality must look for CEC in the product feature list. Also, it is important to know that some manufacturers are creating their own proprietary names for their implementation of the CEC command set.

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Q. What are the HDMI-related questions consumers should ask when shopping for a new CE or PC device?

Several questions are key to evaluating HDMI on a CE component.

- How many inputs/outputs do I need?
    - We are seeing more and more inputs and outputs on components as more and more people are connecting with HDMI. It is common to see 3 and 4 inputs on an HDTV – many with one input on the side or front for connecting to game consoles or other portable devices such as digital still cameras or camcorders. Always think about the number of sources and displays (or projectors) that could become part of your home theater system, and make sure the device you are evaluating has the number of inputs and outputs to support your needs over the near and long term.
    - For those who have existing systems with one or two inputs, and are finding they need more, there are HDMI switches in the market that switch from multiple inputs (sources) to one output (to your display).
- Think features rather than HDMI version number.
    - HDMI is constantly evolving to meet the needs of the marketplace. The standard is constantly adding more and more features that manufacturers can implement if they desire. But HDMI does not require manufacturers to implement everything that HDMI can do. HDMI provides a menu of capabilities and allows the manufacturer to choose which of those features make sense for its product line.

      As a result, HDMI strongly recommends that consumers look for products with the features they want, rather than the version number of the HDMI components. Version numbers reflect capabilities, but do not correspond to product features. For example, if you want the new video features called Deep Color, look for Deep Color in the feature set rather than HDMI 1.3, the version of the specification that enabled Deep Color. Why? Because the version of the specification that enables Deep Color (1.3) does not mandate that Deep Color functionality be implemented.

      However, it is important to also note that all HDMI versions are backwards compatible, so it does not matter what version of HDMI is in the component, all HDMI-enabled components will work together at the highest level of shared functionality.

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Q. As more and more devices converge, is HDMI an interface that can accommodate convergence between the PC and CE?

Absolutely. HDMI was developed using the same technology as DVI (Digital Visual Interface), the digital connection standard for the PC environment. So, HDMI is fully compatible with all DVI-enabled PCs (since HDMI offers both audio and video over one cable, and DVI carried only video, DVI-HDMI connectivity requires a separate audio cable).

HDMI enables PCs to deliver premium media content including high definition movies and multi-channel audio formats. HDMI is the only interface enabling connections to both HDTVs and digital PC monitors implementing the DVI and HDMI standards – fully compatible with the hundreds of millions of DVI displays already in the market.

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- **FOUNDERS:**
- **HITACHI**
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- **PHILIPS**
- **SILICON IMAGE**
- **SONY**
- **THOMSON**
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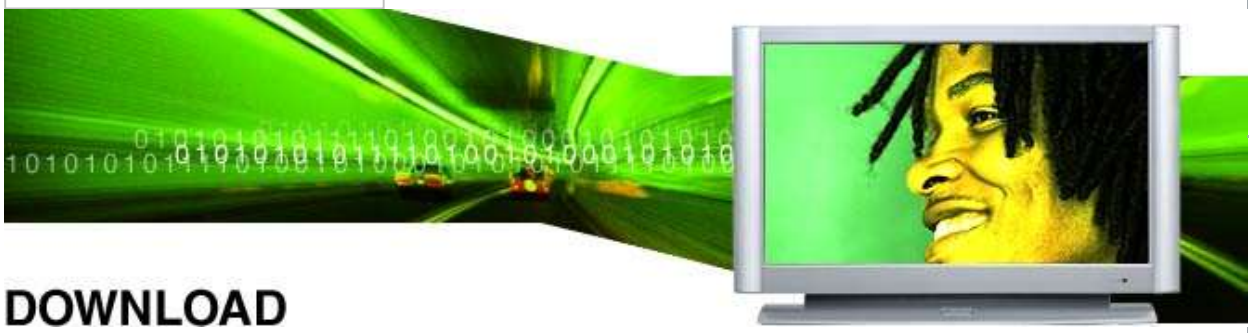
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ATTACHMENT E1

The Wayback Machine - https://web.archive.org/web/20030201085002/http://www.hdmi.org:80/download/download.asp

HDMI - high definition multimedia interface



DOWNLOAD

1.0 SPEC :: ADOPTER AGREEMENT



Version 1.0 of the HDMI specification is now available for download. Follow the steps below to gain access to the spec.

STEP 1 :: Download and sign the **Adopter Agreement**.

STEP 2 :: Submit annual fee payment (wire transfer only), and mail two signed copies of the Adopter Agreement to:

HDMI Licensing, LLC
1060 E. Arques Avenue, Suite 100
Sunnyvale, CA 94085
USA
t: 408.616.4199 (for delivery purposes)
e: **admin@hdmi.org**

STEP 1 Once payment and signed copies of the Adopter Agreement have been received, HDMI will send a login name and password to the registered email address in order to download the **1.0 Spec**.

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ATTACHMENT E2

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HDMI - high definition multimedia interface



DOWNLOAD :: 1.0 SPEC

1.0 SPEC :: ADOPTER AGREEMENT

To download the spec, please enter your login name and password in the fields below. You will receive your login information via email once we receive payment of the annual fee and two signed copies of the Adopter Agreement.

Please note that your login information is only valid for ONE DOWNLOAD. Please contact us if you need to download the spec more than once.

Login:
Password:
LOGIN



If you do not have a login and password, please do the following:

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STEP 2 :: Submit annual fee payment (wire transfer only) and mail two signed copies of the Adopter Agreement to:

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Becoming an Adopter
Adopter Extranet
Approved Connector List
Testing Policies
Authorized Test Centers
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Specification

The HDMI technical specification is available to HD device, display, component, and test equipment manufacturers at no charge. In order to download the specification, or become an HDMI Adopter, please complete the form that follows.

1. Last Name:
2. First Name:
3. Title:
4. Phone:
5. Email:
6. Job Function:
   - ◯ Director
   - ◯ Engineer
   - ◯ General Council/Legal
   - ◯ Legal
   - ◯ Manager
   - ◯ Marketing
   - ◯ Product Development
   - ◯ Sales
   - ◯ Vice President/Executive
   - ◯ Other
7. Company:
8. Company Address:

   City:

   Country: United States
9. Type of Company: (check all that apply)
   - ☐ Consumer Electronics Manufacturer
   - ☐ PC Manufacturer
   - ☐ Display Manufacturer
   - ☐ Semiconducter Manufacturer
   - ☐ System Operator (Satellite, Cable)
   - ☐ Test Equipment Maker
   - ☐ Content Provider
   - ☐ Broadcaster
   - ☐ Trade Association
   - ☐ Other

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Specification

The HDMI technical specification is available to HD device, display, component, and test equipment manufacturers at no charge. In order to download the specification, or become an HDMI Adopter, please complete the form that follows.

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2. First Name:
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5. Email:
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   - ◯ Engineer
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   - ◯ Legal
   - ◯ Manager
   - ◯ Marketing
   - ◯ Product Development
   - ◯ Sales
   - ◯ Vice President/Executive
   - ◯ Other
7. Company:
8. Company Address:
   City:
   Country: United States
9. Type of Company: (check all that apply)
   - ☐ Consumer Electronics Manufacturer
   - ☐ PC Manufacturer
   - ☐ Display Manufacturer
   - ☐ Semiconducter Manufacturer
   - ☐ System Operator (Satellite, Cable)
   - ☐ Test Equipment Maker
   - ☐ Content Provider
   - ☐ Broadcaster
   - ☐ Trade Association
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ATTACHMENT H

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Adopters & Founders

HDMI Founders

Hitachi, Ltd.
Matsushita Electric Industrial Co., Ltd. (Panasonic)
Philips Consumer Electronics International B.V.
Silicon Image, Inc.
Sony Corporation
Thomson, Inc.
Toshiba Corporation

HDMI Adopters

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2Wire Inc
3S Digital Co Ltd
A&R Cambridge Ltd (Arcam)
Across Techno Inc
Advance & Beyond-Tech Co Ltd
Advanced-Connectek Inc.
Advanced Digital Broadcast Polska Sp zoo
Advanced Display Lab Inc.
Advanced Knowledge Associates
Agilent Technologies Inc.
Akai Electric Co Ltd
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Avocent Corporation
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Krell Industries
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Digeo Interactive LLC
Digimedia Technology Co Ltd
Digital Device Inc
Digital Stream Technology Inc.
DigitalZone Co Ltd
D-Link Corporation
DM Technology Co Ltd
Motorola, Inc.
MovieBeam Inc
MSL Enterprises Corp
Mstar Semiconductor, Inc.
Murata Manufacturing Co.,Ltd.
Musco Sports Lighting LLC
NAD Electronics International
Nanjing Wanlida Technology Co Ltd
National Semiconductor
Neostar Technology Co Ltd
Netflix
Netgem
NexGen Mediatech Inc
Nice Fountain Industrial Co Ltd
NienYi Industrial Corp
Niketech Electronic Corp
Ningbo Broad Telecommunication Co Ltd
NINGBO SHUNSHENG COMMUNICATION APPARATUS CO.,LTD
Northstar System Corp
Nvidia
Oak Technology, Inc.
Onkyo Corporation
Ophit Co Ltd
OQO Inc
Orcom International Pte Ltd
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Orion Electric Co., Ltd.
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Parade Technologies Inc
Paradigm Electronics Inc
Park Electronics Co Ltd
PC Partner Ltd
Pericom Semiconductor
Pioneer Corporation
Pixel Magic Systems Ltd.
Pixelworks Inc.
Plastron Precision Co Ltd
Poker Quattro Spa
Power Communication Tech Co Ltd
Prime Electronics & Satellitics Inc
Princeton Technology Corp
Profilo Telra Elektronik San Ve Ticaret AS
Promax Electronica SA
Proton Electronic Industrial Co Ltd
Proview Group Limited
PT. Hit Electro Mechanics Indonesia
Pulse
Qingdao Haier Electronics Co Ltd
Qisheng International Ltd
Quanta Computer Inc
Quantum Data Inc.
Race Point Media LLC
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Dongguan Shinko Wire Co Ltd
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ATTACHMENT J

High-Definition Multimedia Interface

Specification Version 1.1

Hitachi, Ltd.

Matsushita Electric Industrial Co., Ltd.

Philips Consumer Electronics, International B.V.

Silicon Image, Inc.

Sony Corporation

Thomson Inc.

Toshiba Corporation

May 20, 2004

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Preface

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Document Revision History

1.1	2004/5/20	Permitted multi-rate preferred format support on Type A Sinks (4.1.2) Changed connector mechanical spec (4.1.9) Changed connector electrical spec (4.1.7) Removed CEC / +5V Power dependency for Source (4.2.7) Loosened regulation requirements for +5V Power (4.2.7) Made HPD voltages consistent with new +5V Power (4.2.9) Clarified CEC connection requirements (4.2.10) Restricted CTLx values allowed in non-Preamble periods (5.2.1) Added new Packet Types (5.3.1) Clarified InfoFrame Packet requirements (5.3.5) Added ACP and ISRC Packet definitions and usage (5.3.7, 8.8, 9.3) Specified recommended handling of non-Subpacket 0 CS blocks (7.1) Clarified audio sample rate requirements (7.3) Disallowed Layout 1 2-channel (7.6) Clarified AVI transmission requirements (8.2.1) Added extension fields and clarified HDMI VSDB (8.3.2) Clarified DVI/HDMI device discrimination (8.3.3) Clarified HPD behavior (8.5) Clarified EDID values of Physical Addresses (8.7) Made minor editorial changes (throughout)
1.0	2002/12/09	Initial Release

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Intellectual Property Statement

Hitachi, Ltd., Matsushita Electric Industrial Co., Ltd., Philips Consumer Electronics International, B.V., Silicon Image, Inc., Sony Corporation, Thomson Inc., and Toshiba Corporation each may have patents and/or patent applications related to the High-Definition Multimedia Interface Specification. These companies intend to make available to the industry an Adopter Agreement that will include a limited, reciprocal patent license to certain of the electrical interfaces, mechanical interfaces, signals, signaling and coding protocols, and bus protocols described in the mandatory portions of the High-Definition Multimedia Interface Specification Release 1.0 published by HDMI Licensing, LLC.

Contact Information

The URL for the HDMI Founders web site is: http://www.HDMI.org.

Contribution

Silicon Image, Inc has made a significant contribution to this standard by editing the specification and developing the core technologies upon which this specification is based; including Transition Minimized Differential Signaling (TMDS®) technology.

Acknowledgement

HDMI founders acknowledge the concerted efforts of employees of Japan Aviation Electronics Industry, Limited and Molex Japan, who have made a significant contribution to this standard by developing the connector technology and the mechanical and electrical specifications for the required plugs and receptacles.

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1 Introduction

1.1 Purpose and Scope

This document constitutes the specification for the High-Definition Multimedia Interface (HDMI).

The High-Definition Multimedia Interface is provided for transmitting digital television audiovisual signals from DVD players, set-top boxes and other audiovisual sources to television sets, projectors and other video displays.

HDMI can carry high quality multi-channel audio data and can carry all standard and high-definition consumer electronics video formats. Content protection technology is available.

HDMI can also carry control and status information in both directions.

This specification completely describes the interface such that one could implement a complete transmission and interconnect solution or any portion of the interface. The underlying Transition Minimized Differential Signaling (TMDS)-based protocol and associated electrical signaling is described in detail. The mechanical specification of the connector and the signal placement within the connector are described.

A device that is compliant with this specification is interoperable with other compliant devices through the configuration and implementation provided for in this specification.

Mechanical, electrical, behavioral and protocol requirements necessary for compliance are described for sources, sinks and cables.

1.2 Normative References

The following standards contain provisions that, through reference in this text, constitute normative provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. If the referenced standard is dated, the reader is advised to use the version specified.

EIA, EIA/CEA-861B, “A DTV Profile For Uncompressed High Speed Digital Interfaces”[1]

VESA, VESA E-EDID Standard, ENHANCED EXTENDED DISPLAY IDENTIFICATION DATA STANDARD Release A, Revision 1, February 9, 2000

VESA, VESA E-DDC Standard, ENHANCED DISPLAY DATA CHANNEL STANDARD Version 1, September 2, 1999

Philips Semiconductors, The I^2C-bus Specification, Version 2.1, January 2000

[1] All HDMI devices are required to comply with the requirements specified in EIA/CEA-861B except where specifically noted in this document. The EIA/CEA-861B term “source” should be read as “(HDMI) Source” and the terms “Display”, “Monitor” or “DTV Monitor” should be read as “(HDMI) Sink”.

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ITU, ITU-R BT.601-5 Studio encoding parameters of digital television for standard 4:3 and wide-screen 16:9 aspect ratios (October 1995)

ITU, ITU-R BT.709-4 Parameter values for the HDTV standards for production and international programme exchange (March 2000)

IEC, IEC 60958-1, “Digital audio interface – Part 1: General”, First edition 1999-12

IEC, IEC 60958-3, “Digital audio interface – Part 3: Consumer applications”, First edition 1999-12

IEC, IEC 61937, “Digital Audio - Interface for non-linear PCM encoded audio bitstreams applying IEC 60958”, First edition 2000-04

DDWG, “Digital Visual Interface,” Revision 1.0, April 2, 1999 (DVI)

DVD Forum, “DVD Specifications for Read-Only Disc”, “Part 4: AUDIO SPECIFICATIONS”, Version 1, March 1999.

DVD Forum, “DVD Specifications for Read-Only Disc”, “Part 4: AUDIO SPECIFICATIONS”, Version-up Information (from 1.1 to 1.2), May 2000.

1.3 Informative References

The following documents contain information that is useful in understanding this standard. Some of these documents are drafts of standards that may become normative references in a future release of this standard.

Digital Content Protection LLC, “High-bandwidth Digital Content Protection System Specification”, Revision 1.10 (HDCP)

ANSI/SMPTE, SMPTE Standard 170M (1999) for Television – Composite Analog Video Signal – NTSC for Studio Applications

ANSI/SMPTE, SMPTE Standard 274M

ANSI/SMPTE, SMPTE Standard 296M

EIA, CEB14, “Recommend Practice for use of EDID with EIA/CEA-861”

1.4 Organization of this document

This specification is organized as follows:

- Chapter 1 introduces HDMI, describes the purpose and scope of this document, references, organization of the document and usages and conventions.
- Chapter 2 defines terms and acronyms used throughout this document.
- Chapter 3 provides a high-level overview of the operation of HDMI.
- Chapter 4 describes the details of the Physical Layer of HDMI including basic electrical specifications and mechanical specifications of cables and connectors.
- Chapter 5 describes the Signaling and Encoding used by HDMI including descriptions of the different periods and encoding types used to transmit audio, video, and control data types and packet definitions for audio and auxiliary data.

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- Chapter 6 describes Video related issues including video format timings, pixel encodings (RGB, YC_BC_R), colorimetry and corresponding requirements.
- Chapter 7 describes Audio related issues including audio clock regeneration, placement of audio samples within packets, packet timing requirements, audio sample rates and requirements, and channel/speaker assignments.
- Chapter 8 describes Control and Configuration functions, mechanisms and requirements, including use of the E-EDID, and InfoFrames.
- Chapter 9 describes the Content protection used for HDMI.
- Appendix A describes the usage of Repeaters and Switches.
- Appendix B describes restrictions related to the use of the Type B connector.
- Appendix C describes DVI compatibility.
- Supplement 1 describes use of the Consumer Electronics Control (CEC) line and protocol.

1.5 Usages and Conventions

bit N	Bits are numbered in little-endian format, i.e. the least-significant bit of a byte or word is referred to as bit 0.
D[X:Y]	Bit field representation covering bit X to bit Y (inclusive) of value or field D.
0xNN	Hexadecimal representation of base-16 numbers are represented using ‘C’ language notation, preceded by ‘0x’.
0bNN	Binary (base-2) numbers are represented using ‘C’ language notation, preceded by ‘0b’.
NN	Decimal (base-10) numbers are represented using no additional prefixes or suffixes.

Within this specification, any descriptions of data structures, values or sequences that occur on the HDMI interface should be interpreted only as data structures, values and sequences that are transmitted by the HDMI Source. Due to the possibility of errors during the transmission, these items should not be construed as data structures, values or sequences that are guaranteed to be detected by the HDMI Sink.

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2 Definitions

2.1 Conformance Levels

expected	A key word used to describe the behavior of the hardware or software in the design models *assumed* by this specification. Other hardware and software design models may also be implemented.
may	A key word that indicates flexibility of choice with *no implied preferenc*e.
shall	A key word indicating a mandatory requirement. Designers are *required* to implement all such mandatory requirements.
should	A key word indicating flexibility of choice with a strongly preferred alternative. Equivalent to the phrase *is recommended*.
reserved fields	A set of bits within a data structure that are defined in this specification as reserved, and are not otherwise used. Implementations of this specification shall zero these fields. Future revisions of this specification, however, may define their usage.
reserved values	A set of values for a field that are defined in this specification as reserved, and are not otherwise used. Implementations of this specification shall not generate these values for the field. Future revisions of this specification, however, may define their usage.

2.2 Glossary of Terms

(Audio) Channel	Audio data meant to be delivered to a single audio speaker.
(Audio) Sample Clock	Original clock related to the audio input samples at the Source or the generated clock used to time the output of audio samples.
BCH	Error correction technique named after the developers: Bose, Chauduri, and Hocquenghem.
Byte	Eight bits of data.
Data Stream Disparity	Integer indicating “DC-offset” level of link. A positive value represents the excess number of “1”s that have been transmitted. A negative value represents the excess number of “0”s that have been transmitted.
Downstream	In the direction of the primary audio and video data flow, i.e. towards the Sink (e.g. display).
DVD-Audio	Disk format conforming to any version of “DVD Specifications for Read-Only Disc”, “Part 4: AUDIO SPECIFICATIONS”.
(HDMI) Source	A device with an HDMI output.
(HDMI) Sink	A device with an HDMI input.

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(HDMI) Repeater	A device with one or more HDMI inputs and one or more HDMI outputs. Repeater devices shall simultaneously behave as both an HDMI Sink and an HDMI Source.
Multi-channel	Audio with more than 2 channels. Typically this term is applied to 6 (5.1) channel streams. Also called surround formats.
Pixel	Picture Element. Refers to the actual element of the picture and the data point in the digital video stream representing such an element. This term may also apply to the data that is carried across the HDMI link during a single TMDS (pixel) clock cycle, even if that data does not actually represent a picture element.
Pixel Encoding	Bit placement and sequencing for the components of a pixel for a particular color space and chroma sampling.
Root (Device)	A device, generally a display (Sink) device, formally defined by the following rule: A device that has no HDMI output or, a device that has chosen to take the physical address 0.0.0.0 (see Section 8.7).
Receiver	A component that is responsible for receiving the four differential TMDS input pairs at the input to an HDMI Sink and converting those signals into a digital output indicating a 24 bit, 12 bit, or 6 bit TMDS decoded word and indicating the TMDS coding mode used to decode those bits. This digital output may be contained within a semiconductor device or may be output from a semiconductor device.
Stereo	2 channel audio.
Stream	A time-ordered set of digital data originating from one Source and terminating at zero or more Sinks. A stream is characterized by bounded bandwidth requirements.
T_{bit}	Time duration of a single bit carried across the TMDS data channels.
T_{pixel}	Time duration of a single pixel carried across the TMDS data channels. This is equal to 10 T_{bit} .
Transmitter	A component that is responsible for driving the four differential TMDS output pairs into an HDMI output and for clocking the data driven into those four output pairs.
Video Field	The period from one VSYNC active edge to the next VSYNC active edge.
Video Format	A video format is sufficiently defined such that when it is received at the monitor, the monitor has enough information to properly display the video to the user. The definition of each format includes a Video Format Timing, the picture aspect ratio, and a colorimetry space.
Video Format Timing	The waveform associated with a video format. Note that a specific Video Format Timing may be associated with more than one Video Format (e.g., 720X480p@4:3 and 720X480p@16:9).

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YC_BC_R	Digital representation of any video signal using one of several luminance/color-difference color spaces.

2.3 Acronyms and Abbreviations

ANSI	American National Standards Institute
AVI	Auxiliary Video Information
CEA	Consumer Electronics Association
CEC	Consumer Electronics Control
CTS	Cycle Time Stamp
DDC	Display Data Channel
DDWG	Digital Display Working Group
DTV	Digital Television
DVD	Digital Versatile Disc
DVI	Digital Visual Interface
E-DDC	Enhanced Display Data Channel
E-EDID	Enhanced Extended Display Identification Data
ECC	Error Correction Code
EDID	Extended Display Identification Data
EIA	Electronic Industries Alliance
HDCP	High-bandwidth Digital Content Protection
HDMI	High-Definition Multimedia Interface
HDTV	High-Definition Television
HPD	Hot Plug Detect
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ITU	International Telecommunications Union
L-PCM	Linear Pulse-Code Modulation
LSb	least significant bit
MPEG	Moving Picture Experts Group

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MSb	most significant bit
N.C.	No connect.
PCB	Printed Circuit Board
Rx	Receiver
SMPTE	Society of Motion Picture & Television Engineers
STB	Set-Top Box
TERC4	TMDS Error Reduction Coding – 4 bit
TMDS	Transition Minimized Differential Signaling
Tx	Transmitter
VESA	Video Electronics Standards Association
VSDB	Vendor-Specific Data Block

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3 Overview

HDMI system architecture is defined to consist of Sources and Sinks. A given device may have one or more HDMI inputs and one or more HDMI outputs. Each HDMI input on these devices shall follow all of the rules for an HDMI Sink and each HDMI output shall follow all of the rules for an HDMI Source.

As shown in *Figure 3-1 HDMI Block Diagram* the HDMI cable and connectors carry four differential pairs that make up the TMDS data and clock channels. These channels are used to carry video, audio and auxiliary data. In addition, HDMI carries a VESA DDC channel. The DDC is used for configuration and status exchange between a single Source and a single Sink. The optional CEC protocol provides high-level control functions between all of the various audiovisual products in a user's environment.

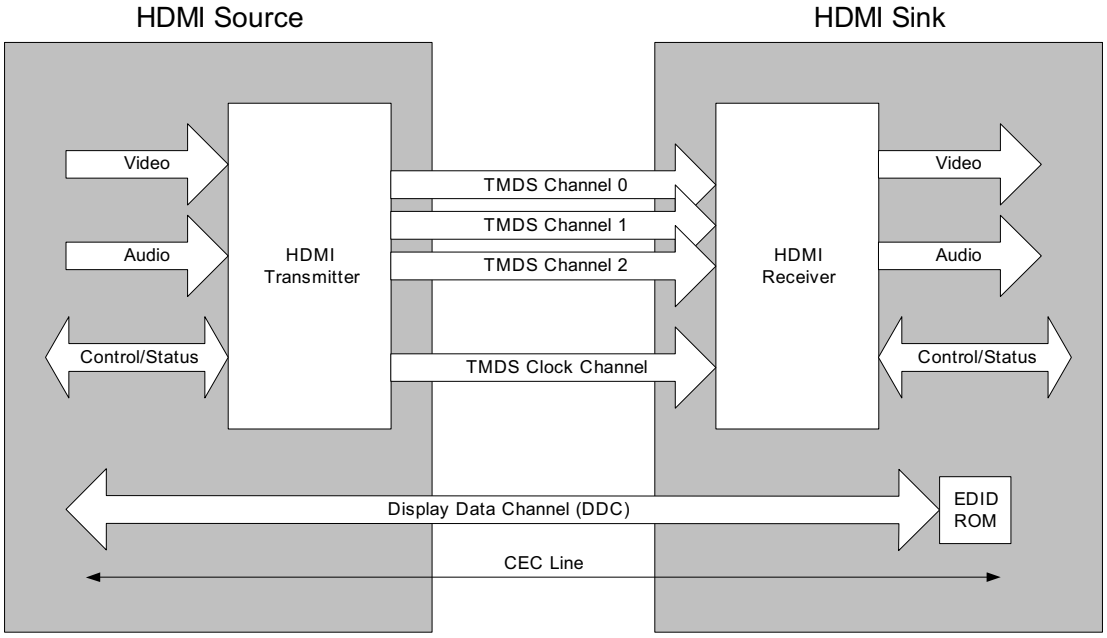


Figure 3-1 HDMI Block Diagram

Audio, video and auxiliary data is transmitted across the three TMDS data channels. The video pixel clock is transmitted on the TMDS clock channel and is used by the receiver as a frequency reference for data recovery on the three TMDS data channels.

Video data is carried as a series of 24-bit pixels on the three TMDS data channels. TMDS encoding converts the 8 bits per channel into the 10 bit DC-balanced, transition minimized sequence which is then transmitted serially across the pair at a rate of 10 bits per pixel clock period.

Video pixel rates can range from 25MHz to 165MHz. Video formats with rates below 25MHz (e.g. 13.5MHz for 480i/NTSC) can be transmitted using a pixel-repetition scheme. The video pixels can be encoded in either RGB, YC_BC_R 4:4:4 or YC_BC_R 4:2:2 formats. In all three cases, up to 24 bits per pixel can be transferred.

In order to transmit audio and auxiliary data across the TMDS channels, HDMI uses a packet structure. In order to attain the higher reliability required of audio and control data, this data is

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protected with a BCH error correction code and is encoded using a special error reduction coding to produce the 10-bit word that is transmitted.

Basic audio functionality consists of a single IEC 60958 audio stream at sample rates of 32kHz, 44.1kHz or 48kHz. This can accommodate any normal stereo stream. Optionally, HDMI can carry a single such stream at sample rates up to 192KHz or from two to four such streams (3 to 8 audio channels) at sample rates up to 96KHz. HDMI can also carry IEC 61937 compressed (e.g. surround-sound) stream at sample rates up to 192kHz.

The DDC is used by the Source to read the Sink's Enhanced Extended Display Identification Data (E-EDID) in order to discover the Sink's configuration and/or capabilities.

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4 Physical Layer

4.1 Connectors and Cables

4.1.1 Overview of Connectors

A device's external HDMI connection shall be presented via one of the two specified HDMI connectors, Type A or Type B. This connector can be attached directly to the device or can be attached via a cable adapter that is shipped with the device.

The Type A connector carries all required HDMI signals, including a single TMDS link. The Type B connector is slightly larger and carries a second TMDS link, which is necessary to support very high-resolution computer displays requiring dual link bandwidth.

A passive cable adapter between Type A and Type B connectors is specified.

4.1.2 Connector Support Requirements

4.1.2.1 HDMI Sources

An HDMI Source connection using a Type A connector shall transmit only video format timings that:

- are described in Section 6.3, or,
- are defined, per EDID Ver. 1.3, in the first Detailed (18-byte) Timing Descriptor of a concurrently attached HDMI compliant Sink, or,
- have horizontal and vertical active counts that match the Horizontal Active and Vertical Active fields of the first Detailed Timing Descriptor of a concurrently attached HDMI compliant Sink.

An HDMI Source connection using a Type B connector may transmit any video format timing.

4.1.2.2 HDMI Sinks

An HDMI Sink connection using a Type A connector may define support, via E-EDID, only for video format timings that:

- are described in Section 6.3, or,
- are defined within the first Detailed (18-byte) Timing Descriptor found in the EDID 1.3 structure of this Sink, or,
- are defined within subsequent Detailed Timing Descriptor(s) but only if the following fields of the subsequent DTD(s) are identical to the first DTD in the E-EDID:
    - Horizontal Active (byte 2 and top half of byte 4)
    - Vertical Active (byte 5 and top half of byte 7)
    - Horizontal Image Size (byte 12 and top half of byte 14)
    - Vertical Image Size (byte 13 and top half of byte 14)

An HDMI Sink connection using a Type B connector may define support for any video format timing, via any of the EDID 1.3 or EIA/CEA-861B mechanisms.

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Beyond the specific video format timing restrictions defined in this section (above), no other video differences between Type A and Type B devices are defined in this specification.

4.1.3 Dual-Link

The Type A connector carries only a single TMDS link and is therefore only permitted to carry signals up to 165Mpixels/sec.

To support signals greater than 165Mpixels/sec, the dual-link capability of the Type B connector shall be used.

HDMI dual-link architecture is compatible with DVI 1.0 dual-link architecture and is defined in Appendix B.

4.1.4 Connector Pin Assignments

Table 4-1 Type A Connector Pin Assignment

PIN	Signal Assignment	PIN	Signal Assignment
1	TMDS Data2+	2	TMDS Data2 Shield
3	TMDS Data2–	4	TMDS Data1+
5	TMDS Data1 Shield	6	TMDS Data1–
7	TMDS Data0+	8	TMDS Data0 Shield
9	TMDS Data0–	10	TMDS Clock+
11	TMDS Clock Shield	12	TMDS Clock–
13	CEC	14	Reserved (N.C. on device)
15	SCL	16	SDA
17	DDC/CEC Ground	18	+5V Power
19	Hot Plug Detect		

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Table 4-2 Type B Connector Pin Assignment

PIN	Signal Assignment
1	TMDS Data2+
3	TMDS Data2-
5	TMDS Data1 Shield
7	TMDS Data0+
9	TMDS Data0-
11	TMDS Clock Shield
13	TMDS Data5+
15	TMDS Data5-
17	TMDS Data4 Shield
19	TMDS Data3+
21	TMDS Data3-
23	Reserved (N.C. on device)
25	SCL
27	DDC/CEC Ground
29	Hot Plug Detect

PIN	Signal Assignment
2	TMDS Data2 Shield
4	TMDS Data1+
6	TMDS Data1-
8	TMDS Data0 Shield
10	TMDS Clock+
12	TMDS Clock-
14	TMDS Data5 Shield
16	TMDS Data4+
18	TMDS Data4-
20	TMDS Data3 Shield
22	CEC
24	Reserved (N.C. on device)
26	SDA
28	+5V Power

4.1.5 Contact sequence

Table 4-3 Connector Contact Sequence

Connection	Signals	
	Type A Connector	Type B Connector
First Make	Connector shell	Connector shell
Second Make	Pins 1 - 17 and pin 19	Pins 1 - 27 and pin 29
Third Make	Pin18 (+5V Power)	Pin28 (+5V Power)

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4.1.6 Connector Mechanical Performance

Table 4-4 Type A Plug and Receptacle Mechanical Performance

Item	Test Condition	Requirement	
Vibration	Amplitude : 1.52mm P-P or 147m/s^2 {15G} Sweep time: 50-2000-50Hz in 20 minutes. Duration : 12 times in each (total of 36 Times) X, Y, Z axes. Electrical load : DC100mA current shall be Flowed during the test. (ANSI/EIA-364-28 Condition III Method 5A)	Appearance	No Damage
		Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell Part : Change from initial value: 50 milliohms maximum.
		Discontinuity	1 μsec maximum.
Shock	Pulse width: 11 msec., Waveform : half sine, 490m/s^2{50G}, 3 strokes in each X.Y.Z. axes (ANSI/EIA-364-27, Condition A)	Appearance	No Damage
		Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell : Change from initial value: 50 milliohms maximum.
		Discontinuity	1 μsec maximum.
Durability	Measure contact and shell resistance after Following. Automatic cycling : 10,000 cycles at 100 ± 50 cycles per hour	Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell : Change from initial value: 50 milliohms maximum.

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Item	Test Condition	Requirement	
Insertion / Withdrawal Force	Insertion and withdrawal speed : 25mm/minute. (ANSI/EIA-364-13)	Withdrawal force	9.8N {1.0kgf} minimum 39.2N {4.0kgf} maximum
		Insertion force	44.1N {4.5kgf} maximum
Cable Flex	100 cycles in each of 2 planes Dimension X = 3.7 x Cable Diameter. (ANSI/EIA-364-41, Condition I)	Discontinuity	1 μsec maximum.
		Dielectric Withstanding Voltage and Insulation Resistance	Conform to item of dielectric withstanding voltage and insulation resistance

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4.1.7 Connector Electrical Characteristics

4.1.7.1 Electrical Performance

Table 4-5 Electrical Performance

Item	Test Condition	Requirement
Contact Resistance	Mated connectors, Contact : measure by dry circuit, 20 mVolts maximum.,10mA. Shell : measured by open circuit, 5 Volts maximum ,100mA. (ANSI/EIA-364-06)	Contact resistance excluding conductor resistance: 10 milliohms maximum. (Reference requirement)
Dielectric Strength	Unmated connectors, apply 500 Volts AC(RMS.) between Adjacent terminal or ground. (ANSI/EIA 364-20,Method 301) Mated connector, apply 300 Volts AC(RMS.) between adjacent terminal and ground.	No Breakdown
Insulation Resistance	Unmated connectors, apply 500 Volts DC between adjacent terminal or ground. (ANSI/EIA 364-21,Method 302)	100 megaohms minimum (unmated)
	Mated connectors, apply 150 Volts DC between adjacent terminal or ground.	10 megaohms minimum (mated)
Contact Current Rating	55 °C, maximum ambient 85 °C, maximum temperature change (ANSI/EIA-364-70,TP-70)	0.5 A minimum
Applied Voltage Rating	40 Volts AC (RMS.) continuous maximum, on any signal pin with respect to the shield.	No Breakdown
Electrostatic Discharge	Test unmated each connectors from 1 kVolt to 8 kVolts in 1 kVolt steps using 8mm ball probe. (IEC-801-2)	No evidence of Discharge to Contacts at 8 kVolts

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Item	Test Condition	Requirement
TMDS Signals Time Domain Impedance	Rise time 200 psec (10%-90%). Signal to Ground pin ratio per HDMI designation. Differential Measurement Specimen Environment Impedance = 100 ohms differential Source-side receptacle connector mounted on a Controlled impedance PCB fixture. (ANSI/EIA-364-108 Draft Proposal)	Connector Area : 100 ohms ±15% Transition Area : 100 ohms ±15% Cable Area : 100 ohms ±10%
TMDS Signals Time Domain Cross talk FEXT	Rise time 200 psec (10%-90%). Signal to Ground pin ratio per HDMI designation. Differential Measurement Specimen Environment Impedance = 100 ohms differential. Source-side receptacle connector mounted on controlled impedance PCB fixture. Driven pair and victim pair. (ANSI/EIA-364-90 Draft Proposal)	5 % maximum

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4.1.8 Connector Environmental Characteristics

4.1.8.1 Environmental Performance

Table 4-6 Connector Environmental Performance

Item	Test Condition		Requirement	
Thermal Shock	10 cycles of: a) -55°Cfor 30 minutes b) +85°C for 30 minutes (ANSI/EIA-364-32, Condition I)		Appearance	No Damage
			Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell Part : Change from initial value: 50 milliohms maximum.
Humidity	A	Mate connectors together and perform the test as follows. Temperature : +25 to +85°C Relative Humidity : 80 to 95% Duration : 4 cycles (96 hours) Upon completion of the test, specimens shall be conditioned at ambient room conditions for 24 hours, after which the specified measurements shall be performed. (ANSI/EIA-364-31)	Appearance	No Damage
			Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell : Change from initial value: 50 milliohms maximum.
	B	Unmated each connectors and perform the test as follows. Temperature : +25 to +85°C Relative Humidity : 80 to 95% Duration : 4 cycles (96 hours) Upon completion of the test, specimens shall be conditioned at ambient room conditions for 24 hours, after which the specified measurements shall be performed. (ANSI/EIA-364-31)	Appearance	No Damage
			Dielectric Withstanding Voltage and Insulation Resistance	Conform to item of Dielectric Withstanding Voltage and Insulation Resistance

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Item	Test Condition	Requirement	
Thermal Aging	Mate connectors and expose to +105 ± 2°C for 250 hours. Upon completion of the exposure period, the test specimens shall be conditioned at ambient room conditions for 1 to 2 hours, after which the specified measurements shall be performed. (ANSI/EIA-364-17, Condition 4, Method A)	Appearance	No Damage
		Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell Part : Change from initial value: 50 milliohms maximum.

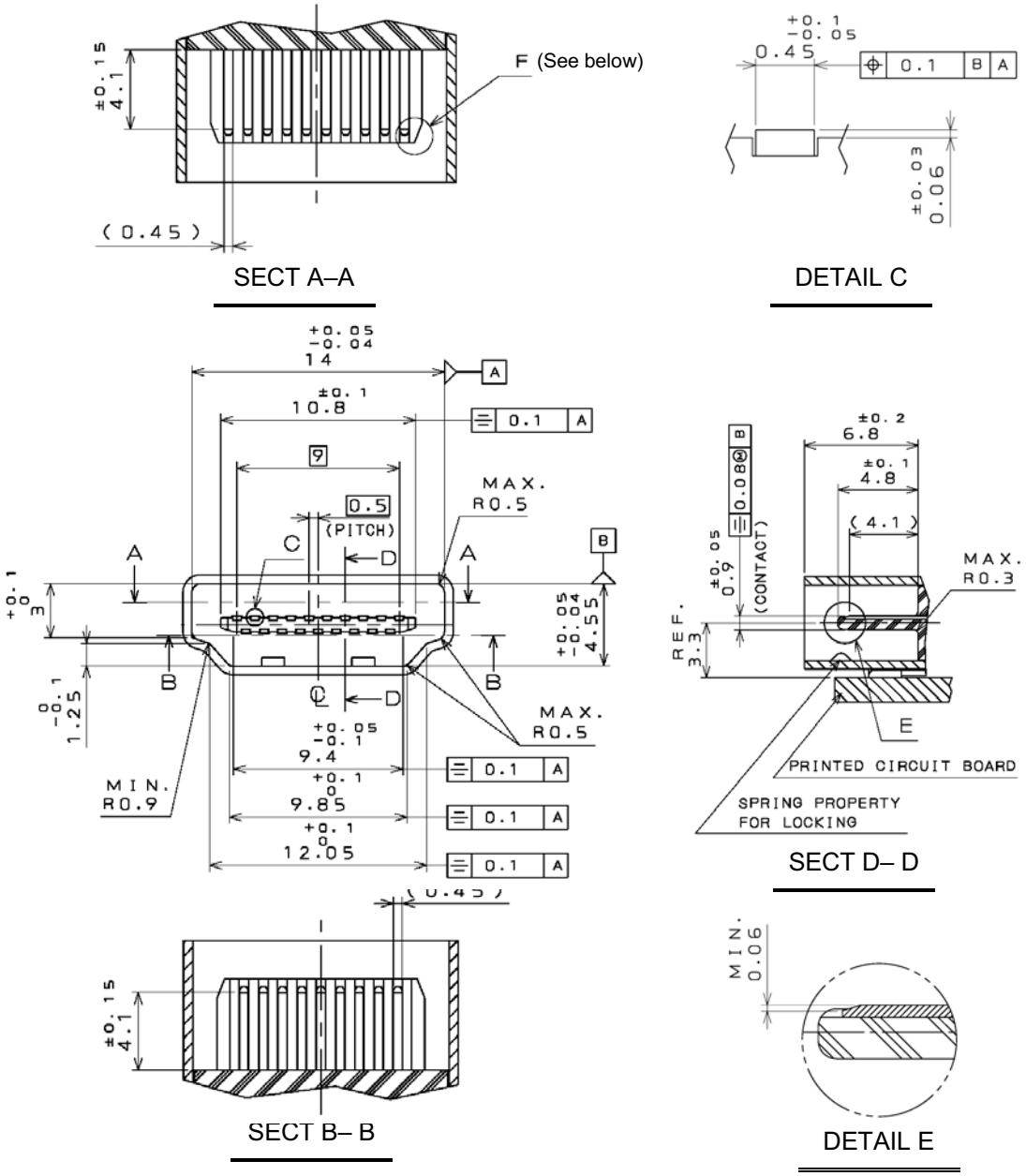
LENOVO EXHIBIT 1008 - 786/963

4.1.9 Connector Drawings

All dimensions in millimeters.

4.1.9.1 Type A Receptacle

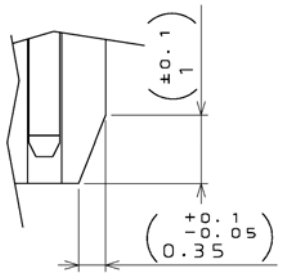
4.1.9.1.1 Mating Interface Dimensions



- The shell shall have springs for locking. Additional springs may be used for EMI reduction.
- The spring property for locking shall be activated by the locking hole of the plug shell.

Figure 4-1 Type A Receptacle Mating Interface Dimensions

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DETAIL F

- The form shown above is strongly recommended. This feature will reduce the likelihood of damage to the receptacle insulator under rough operation.[2]

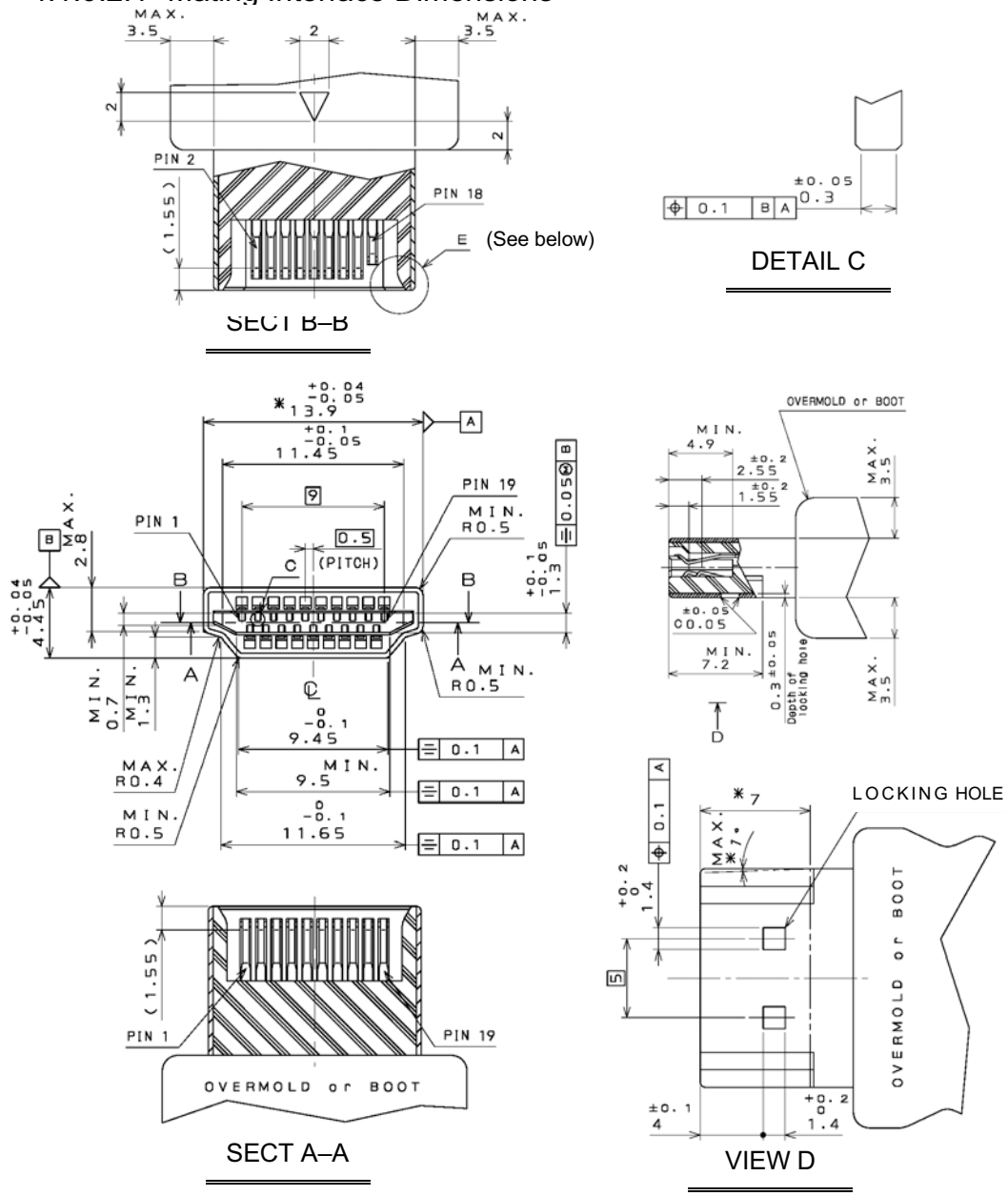
Figure 4-1–continued; Type A Receptacle, Detail F

[2] In the future, this form will be required.

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4.1.9.2 Type A Plug

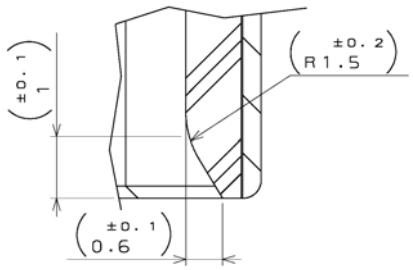
4.1.9.2.1 Mating Interface Dimensions



- The dimension of *13.9mm (+0.04 / -0.05) (on main section) should be measured at the point *7mm (on view D). The taper (on view D) shall be one degree max.
- The shell should not have a dimple other than the ones for locking.

Figure 4-2 Type A Plug Mating Interface Dimensions

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DETAIL E

- The form shown above is strongly recommended. This feature will reduce the likelihood of damage to the receptacle insulator under rough operation.[3]

Figure 4-2-continued; Type A Plug, Detail E

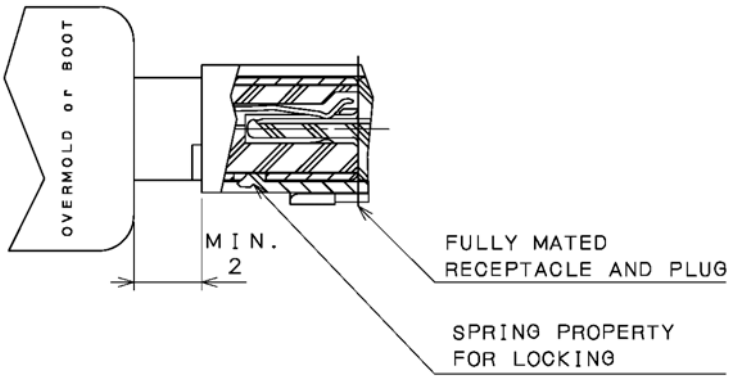


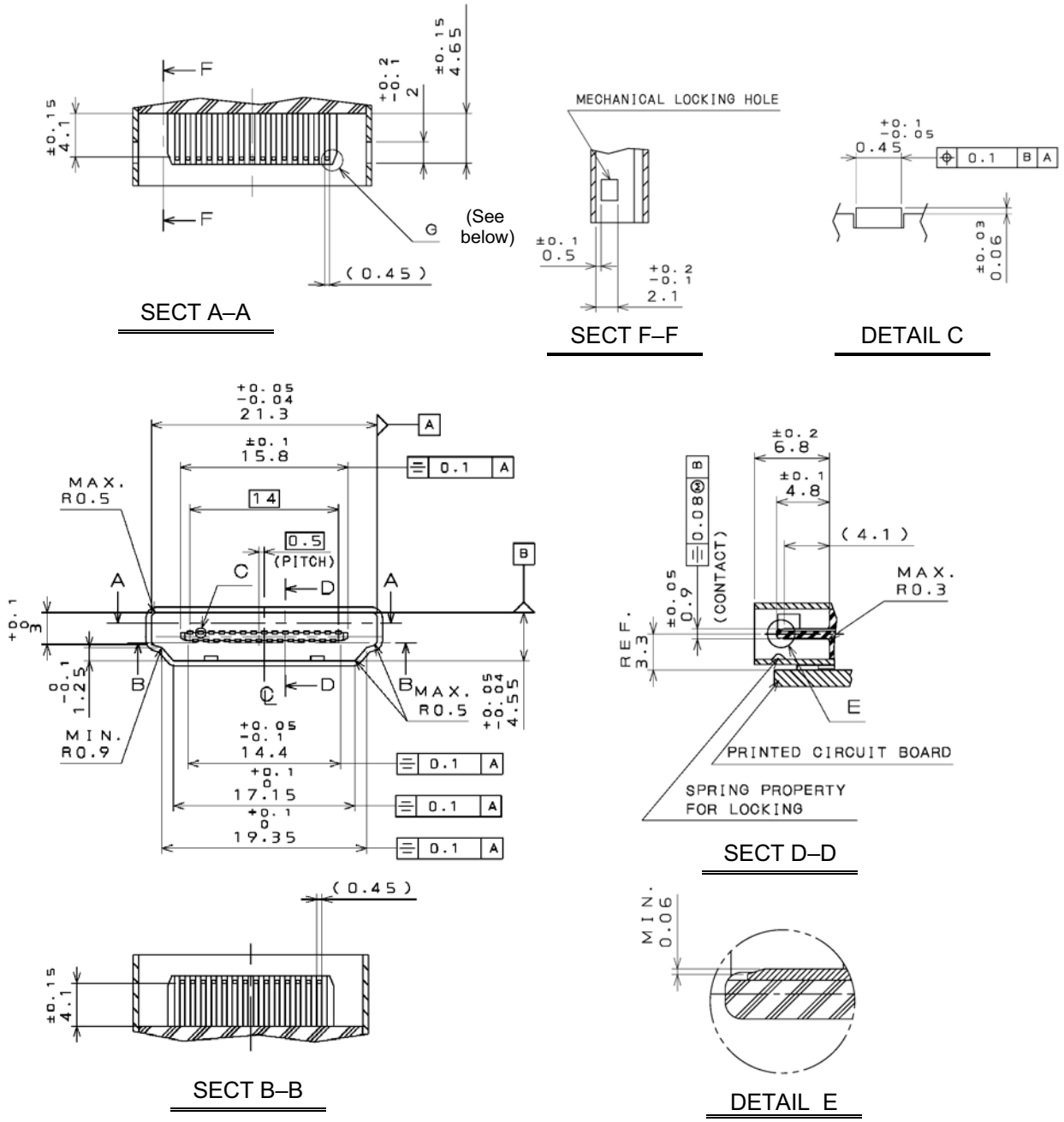
Figure 4-3 Type A Receptacle and Plug Mated Condition

[3] In the future, this form will be required.

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4.1.9.3 Type B Receptacle

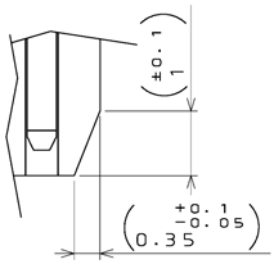
4.1.9.3.1 Mating Interface Dimensions



- The shell shall have springs for locking. Additional springs may be used for EMI reduction.
- The spring property for locking shall be activated by the locking hole of the plug shell.

Figure 4-4 Type B Receptacle Mating Interface Dimensions

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DETAIL G

- The form shown above is strongly recommended. This feature will reduce the likelihood of damage to the receptacle insulator under rough operation.[4]

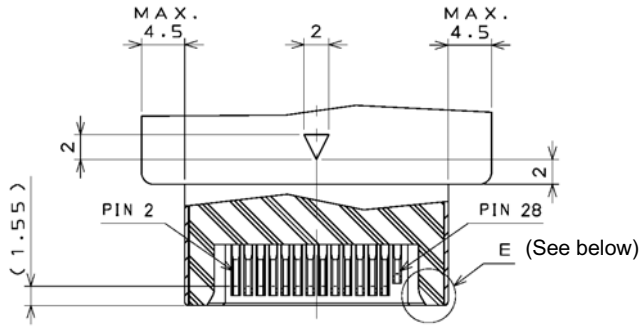
Figure 4-4-continued; Type B Receptacle, Detail G

[4] In the future, this form will be required.

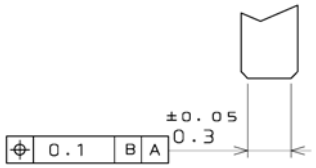
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4.1.9.4 Type B Plug

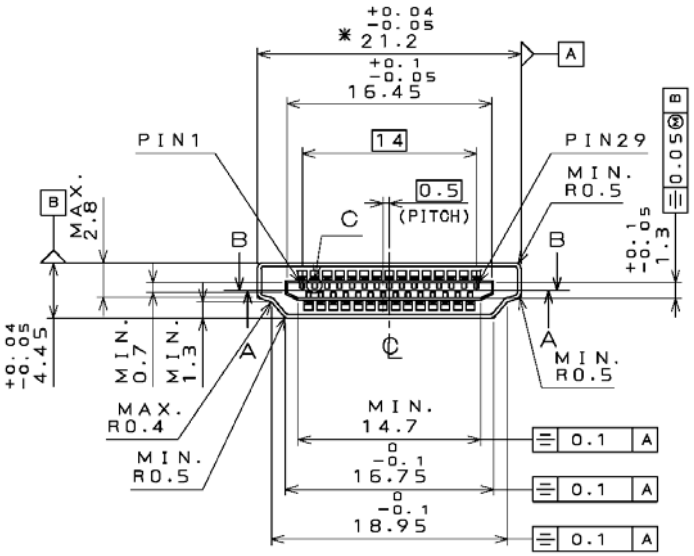
4.1.9.4.1 Mating Interface Dimensions

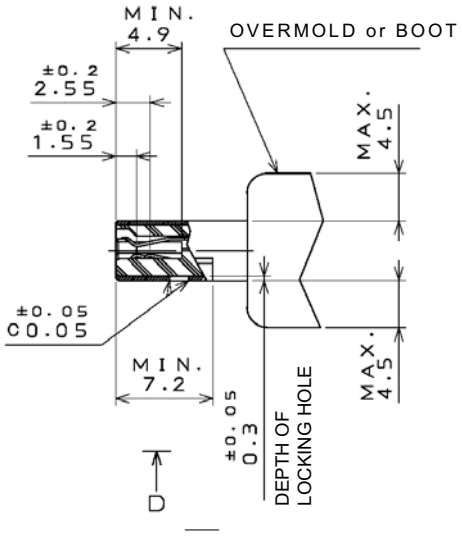


SECT B–B

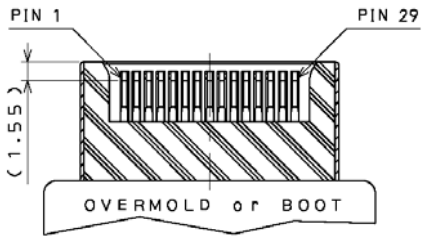


DETAIL C





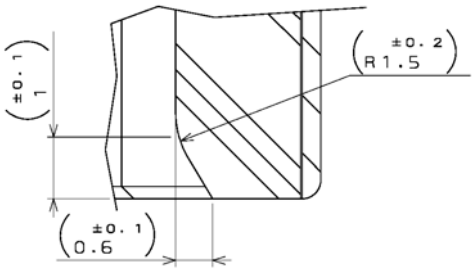
"VIEW D" → NEXT PAGE



SECT A–A

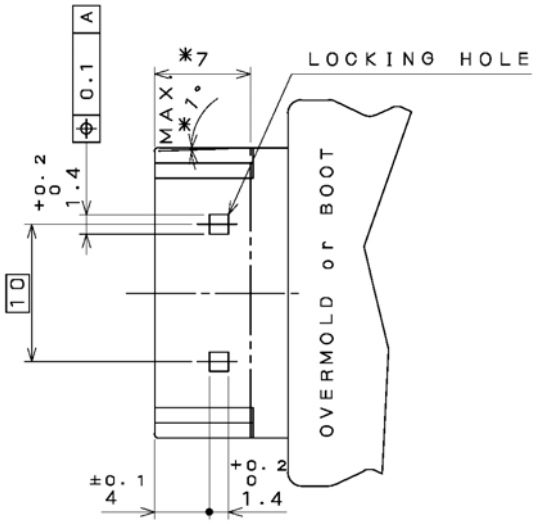
- The dimension of *21.2mm (+0.04 / -0.05) (on main section) should be measured at the point *7mm (on view D). The taper (on view D) shall be one degree max.
- The shell should not have a dimple other than the ones for locking.

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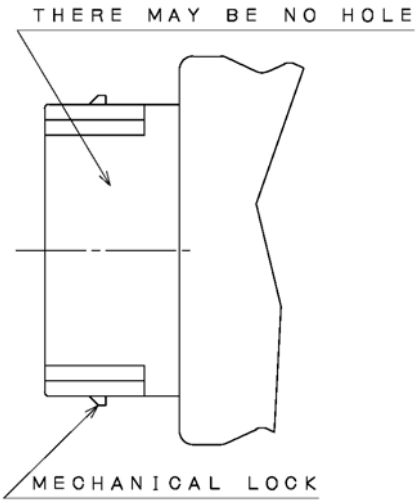


DETAIL E

- The form shown above is strongly recommended. This feature will reduce the likelihood of damage to the receptacle insulator under rough operation.[5]



FRICTION LOCK TYPE



MECHANICAL LOCK TYPE

The spring property for locking should be activated by the locking hole of the plug shell.

VIEW D

Figure 4-5 Type B Plug Mating Interface Dimensions

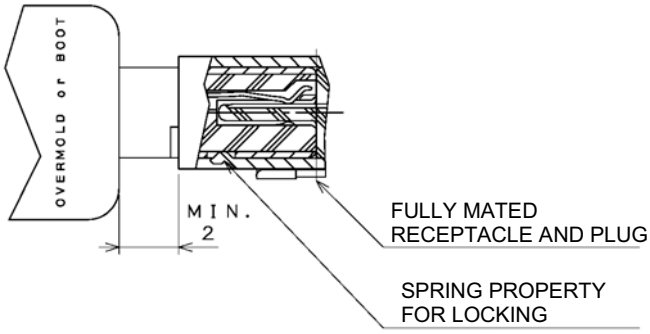


Figure 4-6 Type B Receptacle and Plug Mated Condition

[5] In the future, this form will be required.

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4.1.10 Cable Adapter Specification

Table 4-7 Wire Categories

Category	Description
A	TMDS Signal Wire
B	TMDS Shield
C	Control
D	Control Ground
N.C.	No connect (no wire)
5V	5 Volts Power Wire

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4.1.10.1 Type A Connector to Type A Connector

Type A Connector → Type A Connector



Table 4-8 Type A-to-Type A Cable Wire Assignment

Type A pin	*Signal Name*	*Wire*	*Type A pin*
1	*TMDS Data2+*	*A*	*1*
2	*TMDS Data2 Shield*	*B*	*2*
3	*TMDS Data2–*	*A*	*3*
4	*TMDS Data1+*	*A*	*4*
5	*TMDS Data1 Shield*	*B*	*5*
6	*TMDS Data1–*	*A*	*6*
7	*TMDS Data0+*	*A*	*7*
8	*TMDS Data0 Shield*	*B*	*8*
9	*TMDS Data0–*	*A*	*9*
10	*TMDS Clock+*	*A*	*10*
11	*TMDS Clock Shield*	*B*	*11*
12	*TMDS Clock–*	*A*	*12*
13	*CEC*	*C*	*13*
14	*Reserved (in cable but N.C. on device)*	*C*	*14*
15	*SCL*	*C*	*15*
16	*SDA*	*C*	*16*
17	*DDC/CEC Ground*	*D*	*17*
18	*+5V Power*	*5V*	*18*
19	*Hot Plug Detect*	*C*	*19*

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4.1.10.2 Type A Connector to Type B Connector

Type A Connector → Type B Connector



Table 4-9 Type A-to-Type B Cable Wire Assignment

Type A pin	*Pin Assignment*	*Wire*	*Type B pin*
1	*TMDS Data2+*	*A*	*1*
2	*TMDS Data2 Shield*	*B*	*2*
3	*TMDS Data2-*	*A*	*3*
4	*TMDS Data1+*	*A*	*4*
5	*TMDS Data1 Shield*	*B*	*5*
6	*TMDS Data1-*	*A*	*6*
7	*TMDS Data0+*	*A*	*7*
8	*TMDS Data0 Shield*	*B*	*8*
9	*TMDS Data0-*	*A*	*9*
10	*TMDS Clock+*	*A*	*10*
11	*TMDS Clock Shield*	*B*	*11*
12	*TMDS Clock-*	*A*	*12*
13	*CEC*	*C*	*22*
15	*SCL*	*C*	*25*
16	*SDA*	*C*	*26*
17	*DDC/CEC Ground*	*D*	*27*
18	*+5V Power*	*5V*	*28*
19	*Hot Plug Detect*	*C*	*29*
14	*No connect*	*N.C.*	
	No connect	*N.C.*	*23*
	No connect	*N.C.*	*24*

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4.1.10.3 Type B Connector to Type B Connector

Table 4-10 Type B to Type B Cable Wire Assignment

Type B pin	Pin Assignment	Wire	Type B pin
1	TMDS Data2+	A	1
2	TMDS Data2 Shield	B	2
3	TMDS Data2-	A	3
4	TMDS Data1+	A	4
5	TMDS Data1 Shield	B	5
6	TMDS Data1-	A	6
7	TMDS Data0+	A	7
8	TMDS Data0 Shield	B	8
9	TMDS Data0-	A	9
10	TMDS Clock+	A	10
11	TMDS Clock Shield	B	11
12	TMDS Clock-	A	12
13	TMDS Data5+	A	13
14	TMDS Data5 Shield	B	14
15	TMDS Data5-	A	15
16	TMDS Data4+	A	16
17	TMDS Data4 Shield	B	17
18	TMDS Data4-	A	18
19	TMDS Data3+	A	19
20	TMDS Data3 Shield	B	20
21	TMDS Data3-	A	21
22	CEC	C	22
25	SCL	C	25
26	SDA	C	26
27	DDC/CEC Ground	D	27
28	+5V Power	5V	28
29	Hot Plug Detect	C	29
23	No Connect	N.C.	
24	No Connect	N.C.	
	No Connect	N.C.	23
	No Connect	N.C.	24

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4.2 Electrical Specification

Some timing parameter values in this specification are based on the clock rate of the link while others are based on absolute values. For scalable timing parameters based on the clock rate, the time period of the clock is denoted as 'pixel time', or Tpixel. One tenth of the pixel time is called the bit time, or Tbit. The bit time is also referred to as one Unit Interval in the jitter and eye diagram specifications.

Schematic diagrams contained in this chapter are for illustration only and do not represent the only feasible implementation.

4.2.1 Overview

The conceptual schematic of one TMDS differential pair is shown in Figure 4-7. TMDS technology uses current drive to develop the low voltage differential signal at the Sink side of the DC-coupled transmission line. The link reference voltage AV_{cc} sets the high voltage level of the differential signal, while the low voltage level is determined by the current source of the HDMI Source and the termination resistance at the Sink. The termination resistance (R_T) and the characteristic impedance of the cable (Z_0) must be matched.

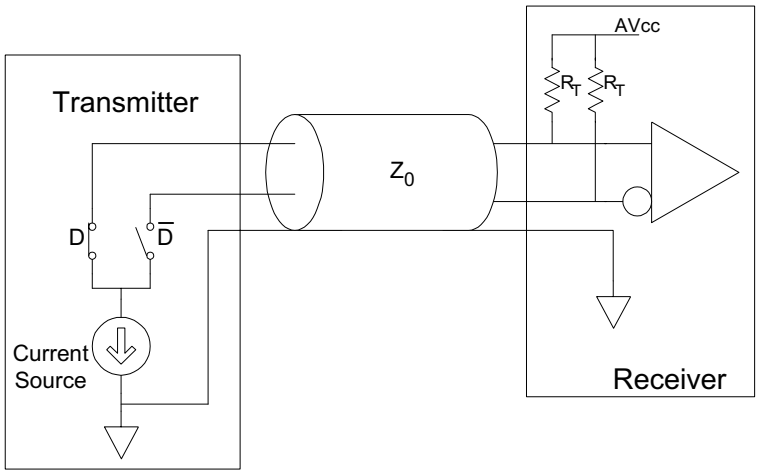


Figure 4-7 Conceptual Schematic for one TMDS differential pair

A single-ended differential signal, representing either the positive or negative terminal of a differential pair, is illustrated in Figure 4-8. The nominal high-level voltage of the signal is AV_{cc} and the nominal low-level voltage of the signal is (AV_{cc} - V_{swing}). Since the swing is differential on the pair, the net signal on the pair has a swing twice that of the single-ended signal, or 2 V_{swing}. The differential signal, as shown in Figure 4-9, swings between positive V_{swing} and negative V_{swing}.

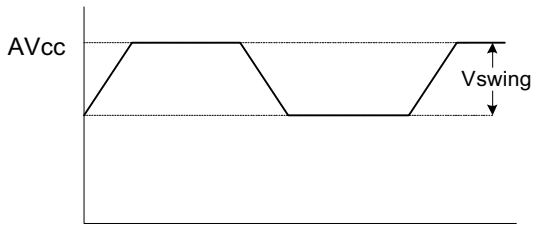


Figure 4-8 Single-ended Differential Signal

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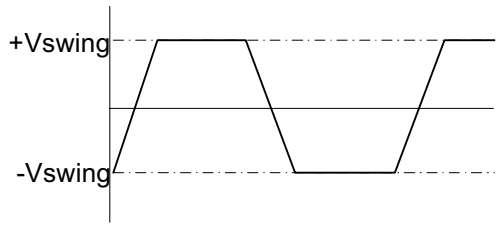


Figure 4-9 Differential Signal

The signal test points for a TMDS link are shown in Figure 4-10. TP1 is used for testing of HDMI Sources and Transmitter components. TP2 is used for testing of HDMI Sinks and Receiver components. TP1 and TP2 together are also used for testing of cables.

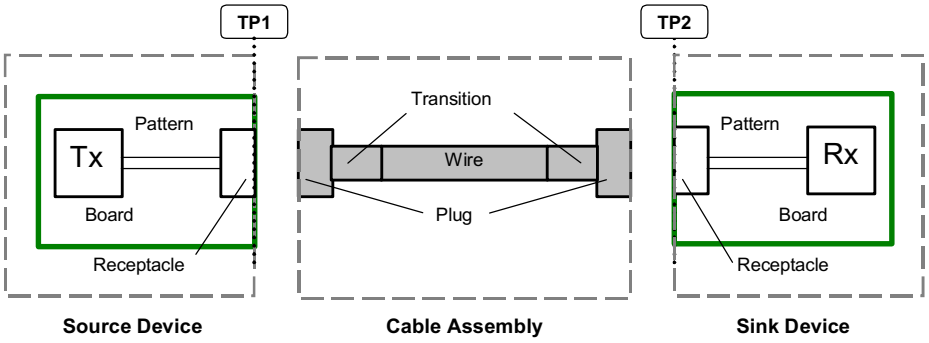


Figure 4-10 TMDS Link Test Points

4.2.2 System Operating Conditions

The required operating conditions of the TMDS pairs are specified in Table 4-11.

Table 4-11 Required Operating Conditions for HDMI Interface (see Figure 4-7)

Item	Value
Termination Supply Voltage, AV_{cc}	3.3 Volts ±5%
Termination Resistance, R_T	50 ohms ±10%

4.2.3 Jitter and Eye Measurements: Ideal Recovery Clock

All TMDS Clock and Data signal jitter specifications are specified relative to an Ideal Recovery Clock defined below. The Data jitter is not specified numerically, but instead, an HDMI device or cable shall adhere to the appropriate eye diagram(s) when the TMDS data signals are measured using an Ideal Recovery Clock as a trigger source.

The TMDS Clock signal may contain low-frequency jitter components, which can be tracked by a Sink's clock recovery circuitry, and high-frequency components, which are not typically tracked.

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The purpose of the Ideal Recovery Clock is to give an accurate representation of link performance when used as a trigger for eye diagram and clock jitter specifications.

For the purposes of jitter and eye diagram specification, the Ideal Recovery Clock is defined relative to the TMDS clock signal. The Ideal Recovery Clock shall be equivalent to the signal that would be derived by a perfect PLL with a jitter transfer function shown in Equation 4-1, when the TMDS clock signal were input into that PLL. This jitter transfer function has the behavior of a low pass filter with 20dB/decade rolloff and with a –3dB point of 4MHz.

For the purposes of compliance testing, a Clock Recovery Unit is used to generate a Recovered Clock, which is meant to approximate the Ideal Recovery Clock. This Recovered Clock is used for measurement of the jitter and eye diagram.

$$H(j\omega) = 1 / (1 + j\omega/\omega_0)$$

Where $\omega_0 = 2\pi F_0$, $F_0 = 4.0\text{MHz}$

Equation 4-1 Jitter Transfer Function of PLL for Ideal Recovery Clock Definition

4.2.4 HDMI Source TMDS Characteristics

HDMI requires a DC-coupled TMDS link. Source electrical testing shall be performed using the test load shown in Figure 4-11. TP1 represents the connection point of the receptacle.

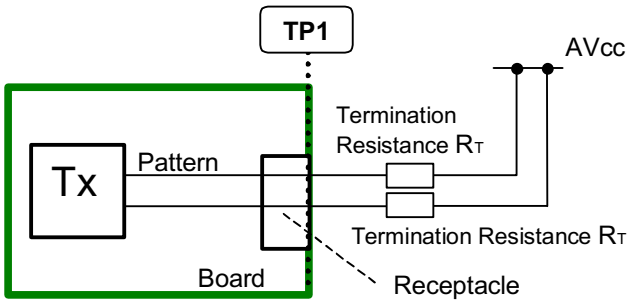


Figure 4-11 Balanced Source Test Load

The Source shall meet the DC specifications in Table 4-12 for all operating conditions specified in Table 4-11 when driving clock and data signals. The V_{swing} parameter identifies the minimum and maximum single-ended peak-to-peak signal amplitude that may be delivered by the Source into the test load.

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Table 4-12 Source DC Characteristics at TP1

Item	Value
Single-ended high level output voltage, V_H	AV_{cc} ±10mVolts
Single-ended low level output voltage, V_L	(AV_{cc} – 600mVolts) ≤ V_L ≤ (AV_{cc} – 400mVolts)
Single-ended output swing voltage, V_{swing}	400mVolts ≤ V_{swing} ≤ 600mVolts
Single-ended standby (off) output voltage, V_{OFF}	AV_{cc} ±10mVolts (Informative)
Single-ended standby (off) output current, I_{OFF}	| I_{OFF} | < 10uA

The Source shall meet the AC specifications in Table 4-13 across all operating conditions specified in Table 4-11. Rise and fall times are defined as the signal transition time between 20% and 80% of the nominal swing voltage (V_{swing}) of the device under test.

The Source intra-pair skew is the maximum allowable time difference (on both low-to-high and high-to-low transitions) as measured at TP1, between the true and complement signals of a given differential pair. This time difference is measured at the midpoint on the single-ended signal swing of the true and complement signals. The Source inter-pair skew is the maximum allowable time difference (on both low-to-high and high-to-low transitions) as measured at TP1, between any two single-ended data signals that do not constitute a differential pair.

Table 4-13 Source AC Characteristics at TP1

Item	Value
Rise time / fall time (20%-80%)	75psec ≤ Rise time / fall time ≤ 0.4 T_{bit}
Overshoot, max	15% of full differential amplitude (V_{swing} 2)
Undershoot, max	25% of full differential amplitude (V_{swing} 2)
Intra-Pair Skew at Source Connector, max	0.15 T_{bit}
Inter-Pair Skew at Source Connector, max	0.20 T_{pixel}
Clock duty cycle, min / average / max	40% / 50% / 60%
TMDS Differential Clock Jitter, max	0.25 T_{bit} (relative to Ideal Recovery Clock as defined in Section 4.2.3)

The design of a Source should take into account the differential impedance of the cable assembly and Sink of 100 ohms (see Table 4-17 and Table 4-18).

For all channels under all operating conditions specified in Table 4-11 and when terminated as shown in Figure 4-11, the Source shall have output levels at TP1that meet the normalized eye diagram requirements of Figure 4-12. This requirement, normalized in both time and amplitude, specifies the minimum eye opening as well as the maximum overshoot and undershoot relative to the average differential swing voltage of the device. The time axis is normalized to the bit time at the operating frequency, while the amplitude axis is normalized to the average differential swing voltage.

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Determination of average swing voltage is made with transmission of the half clock test pattern. The average high-level and low-level amplitudes are determined at the point where signal ringing has subsided. These averages establish the swing voltage and are used to normalize the eye diagram.

The average differential swing voltage is defined as the difference between the average differential amplitude when driving a logic one and the average differential amplitude when driving a logic zero. The average logic one appears at positive 0.5 on the vertical axis, while the average logic zero appears at negative 0.5. The normalized amplitude limits in Figure 4-12 allow 15% (of the average differential swing voltage) maximum overshoot and 25% maximum undershoot, relative to the amplitudes determined to be logic one and zero.

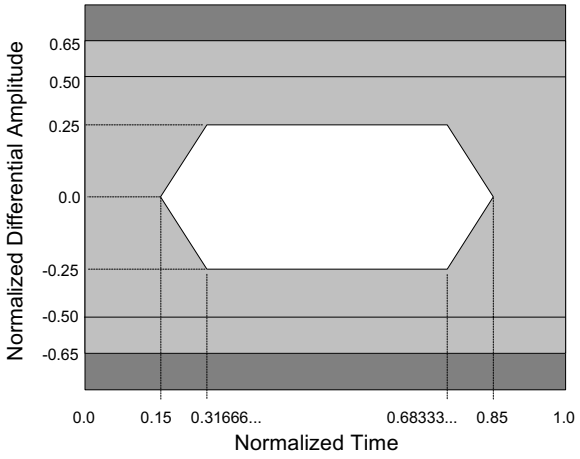


Figure 4-12 Normalized Eye Diagram Mask at TP1 for Source Requirements

Combining the single-ended swing voltage (V_{swing}) specified in Table 4-12 with the overshoot and undershoot limits of Figure 4-12, it is possible to calculate the minimum and maximum high-level voltage (V_{high}) and low-level voltage (V_{low}) that is allowable on the interface.

V_{high} (max) = V_{swing} (max) + 15% (2 V_{swing} (max)) = 600 + 180 = 780 mV

V_{high} (min) = V_{swing} (min) - 25% (2 V_{swing} (min)) = 400 - 200 = 200 mV

V_{low} (max) = -V_{swing} (max) - 15% (2 V_{swing} (max)) = -600 - 180 = -780 mV

V_{low} (min) = -V_{swing} (min) + 25% (2 V_{swing} (min)) = -400 + 200 = -200 mV

Minimum opening at Source = V_{high} (min) - V_{low} (min) = 400 mV

Note that the combination of these extreme cases do not constitute a single valid eye.

Source eye diagram test procedures are defined in the HDMI Compliance Test Specification. The Source eye diagram mask of Figure 4-12 is not used for response time and clock jitter specifications, but specifies the clock to data jitter indirectly.

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4.2.5 HDMI Sink TMDS Characteristics

HDMI Sink electrical testing shall be performed using a test signal generator as shown in Figure 4-13.

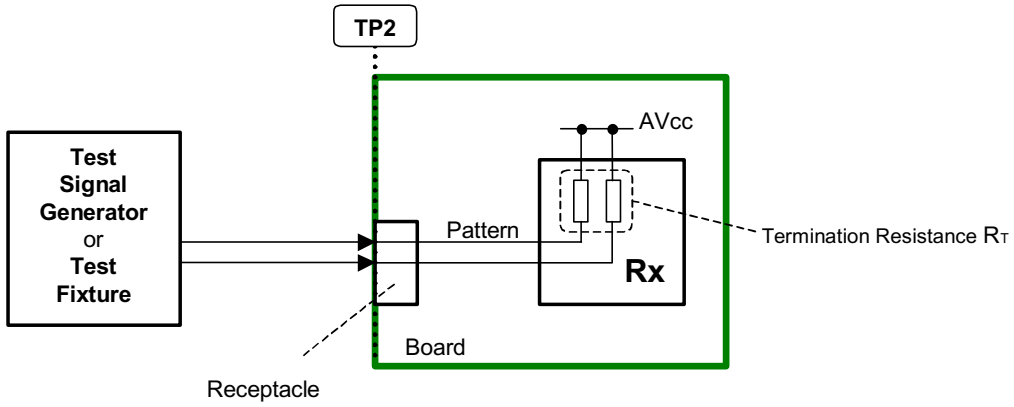


Figure 4-13 HDMI Sink Test Points

The Sink shall meet the signal requirements listed in Table 4-14, Table 4-15, and Table 4-16.

Table 4-14 Sink Operating DC Characteristics at TP2

Item	Value
Input Differential Voltage Level, V_{idiff}	$150 \le V_{idiff} \le 1200$ mVolts
Input Common Mode Voltage, V_{icm}	$(AV_{cc} - 300mVolts) \le V_{icm} \le (AV_{cc} - 37.5mVolts)$

Table 4-15 Sink DC Characteristics When Source Disabled or Disconnected at TP2

Item	Value
Differential Voltage Level	AV_{cc} ±10mVolts

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Table 4-16 Sink AC Characteristics at TP2

Item	Value
Minimum differential sensitivity (peak-to-peak)	150 mVolts
Maximum differential input (peak-to-peak)	1560 mVolts
Allowable Intra-Pair Skew at Sink Connector	0.4 T_{bit}
Allowable Inter-Pair Skew at Sink Connector	0.6 T_{pixel}
TMDS Clock Jitter	0.30 T_{bit} (relative to Ideal Recovery Clock as defined in Section 4.2.3)

Table 4-17 HDMI Sink Impedance Characteristics at TP2

Item	Value
TDR Rise Time at TP2 (10%-90%)	≤200 psec
Through connection impedance	100 ohms ±15%
At Termination impedance	100 ohms ±10%

For all channels under all operating conditions specified in this section, the Sink shall reproduce a test data stream, with video pixel error rate of 10^{-9} or better, when presented with input amplitude illustrated by the eye diagram of Figure 4-14.

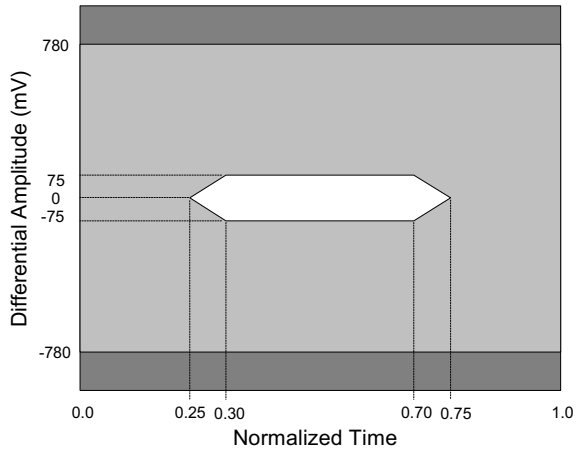


Figure 4-14 Absolute Eye Diagram Mask at TP2 for Sink Requirements

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4.2.6 Cable Assembly

The term “Cable assembly” includes all five parts listed below:

- Source-side plug
- Source-side transition (from plug to cable)
- Cable itself
- Sink-side transition
- Sink-side plug

HDMI cables are measured with respect to the test points TP3 and TP4 shown in Figure 4-15. TP1 and TP2 are not available because connection points between plug and receptacle cannot be accessed during testing. Therefore, TP3 and TP4 are used, even though the effects of receptacles at both ends are included in the test result.

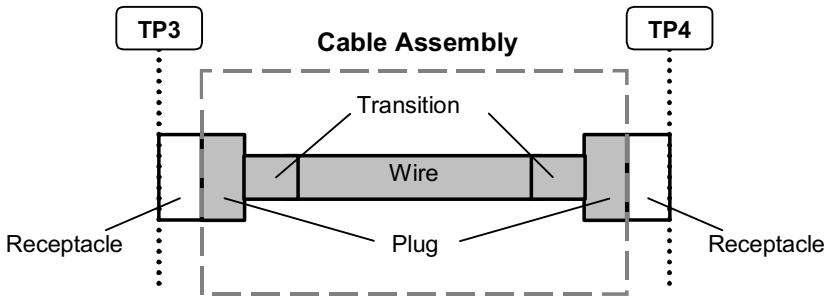


Figure 4-15 Cable Assembly Test Points

An HDMI cable assembly may be specified to operate up to a specified maximum pixel clock frequency. This specified maximum frequency shall be above 75MHz.

When driven by a TMDS input waveform meeting the Source eye diagram mask requirements of Figure 4-12 at the specified maximum pixel clock frequency, an HDMI cable assembly shall produce a TMDS output waveform that meets the Sink eye diagram mask of Figure 4-14.

In addition a cable should meet the specifications shown in Table 4-18.

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Table 4-18 Cable Assembly Parameters

Parameter	Value
Maximum Cable Assembly Intra-Pair Skew	151psec (0.25 T_{bit})
Maximum Cable Assembly Inter-Pair Skew	2.42nsec (0.4 T_{pixel})
Far-end Crosstalk	< -26dB
Attenuation	
300kHz - 825MHz	< 8dB
825MHz - 2.475GHz	< 21dB
2.475GHz - 4.125GHz	< 30dB
Differential Impedance	
Connection point and transition area: Up to 1nsec**	100 ohms ±15%
Cable area: 1nsec – 2.5nsec:**	100 ohms ±10%

** Measurement point for TDR measurement of impedance.

4.2.7 +5V Power Signal

The HDMI connector provides a pin allowing the Source to supply +5.0 Volts to the cable and Sink.

All HDMI Sources shall assert the +5V Power signal whenever the Source is using the DDC or TMDS signals. The voltage driven by the Source shall be within the limits specified for TP1 voltage in Table 4-19. An HDMI Source shall have +5V Power signal over-current protection of no more than 0.5A.

All HDMI Sources shall be able to supply a minimum of 55 mA to the +5V Power pin.

A Sink shall not draw more than 50 mA of current from the +5V Power pin. When the Sink is powered on, it can draw no more than 10mA of current from the +5V Power signal. A Sink shall assume that any voltage within the range specified for TP2 voltage in Table 4-19 indicates that a Source is connected and applying power to the +5V Power signal.

The return for the +5V Power signal is DDC/CEC Ground signal.

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Table 4-19 +5V Power Pin Voltage

Item	Min	Max
TP1 voltage	4.8 Volts	5.3 Volts
TP2 voltage	4.7 Volts	5.3 Volts

4.2.8 DDC

The Display Data Channel (DDC) I/Os and wires (SDA, SCL, DDC/CEC Ground), shall meet the requirements specified in the I^2C-bus Specification, version 2.1, Section 15 for "Standard-Mode" devices. Note that the discussions of high capacitance environments in the I^2C-bus Specification, section 17.2, "Switched pull-up circuit for Fast-mode I2C-bus", may be applied to the HDMI environment as well.

HDMI devices shall have DDC electrical characteristics complying with the values shown in Table 4-20 and Table 4-21.

In the capacitance measurement, the DDC line ground (DDC/CEC Ground) shall be separated from the frame ground of the equipment. The exact method and measurement procedure is written in HDMI Compliance Test Specification. In some cases, buffers or I^2C "accelerators", may be inserted in the cable as long as all I^2C timing requirements are met.

Table 4-20 Maximum Capacitance of DDC line

Item	HDMI Source	Cable Assembly	HDMI Sink
SDA – DDC/CEC Ground	50pF	700pF	50pF
SCL – DDC/CEC Ground	50pF	700pF	50pF

Table 4-21 Pull-up Resistance on DDC Lines

Item	Value
Source Pull-up resistors for SCL and SDA signals	minimum 1.5k ohms, maximum 2.0k ohms
Sink Pull-up resistors for SCL signal	47k ohms, ±10%

4.2.9 Hot Plug Detect Signal (HPD)

The ground reference for the Hot Plug Detect signal is the DDC/CEC Ground pin.

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Table 4-22 Required Output Characteristics of Hot Plug Detect Signal

Item	Value
High voltage level (Sink)	Minimum 2.4 Volts, Maximum 5.3 Volts
Low voltage level (Sink)	Minimum 0 Volts, Maximum 0.4 Volts
Output resistance	1000 ohms ±20%

Table 4-23 Required Detection Levels for Hot Plug Detect Signal

Item	Value
High voltage level (Source)	Minimum 2.0 Volts, Maximum 5.3 Volts
Low voltage level (Source)	Minimum 0 Volts, Maximum 0.8 Volts

Note that many Sink devices simply connect the HPD signal to the +5V Power signal through a 1000 ohm resistor. It may therefore be necessary for a Source to pull-down the HPD signal in order to reliably differentiate between a floating (disconnected) HPD and a high voltage level HPD signal.

4.2.10 CEC Line

The following line characteristics are required for all products, including those that do not implement the CEC protocol. Further requirements for those devices that implement the CEC protocol are given in Supplement 1. The ground reference for the CEC signal is the DDC/CEC Ground signal.

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Table 4-24 CEC line Electrical Specifications for all Configurations

Item	Rule / Description	Value
Line connectivity	In general, CEC lines from all HDMI inputs (if present) and a single HDMI output (if present) shall be interconnected. However, the following exceptions are allowed: A device that has no HDMI output is allowed to have separate CEC lines for each HDMI connector if that device takes a logical address of 0 on each CEC line. Due to the complexity of handling multiple active CEC lines, this is discouraged. A device (typically a TV or media receiver box) that is acting as the CEC root device shall not connect the CEC line to any HDMI output.	
Power-off characteristics	A device with power removed must not degrade communication between other CEC devices (e.g. the line must not be pulled down by the powered off device).	
Leakage current in standby/off	Maximum CEC line leakage current	1.8µA
CEC Line Capacitance	Maximum capacitance load of a device (excluding cable)	100pF
	Maximum capacitance load of a Cable Assembly	700pF

4.2.11 Robustness Requirements

No damage to the HDMI Source or Sink can result from the shorting of any combination of signals on any connector. If two HDMI Sources are connected together with a single cable, no damage can occur to either of the Sources. If two HDMI Sinks are connected together with a single cable, no damage can occur to either of the Sinks.

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5 Signaling And Encoding

5.1 Overview

5.1.1 Link Architecture

As shown in Figure 5-1, an HDMI link includes three TMDS Data channels and a single TMDS Clock channel. The TMDS Clock channel constantly runs at the pixel rate of the transmitted video. During every cycle of the TMDS Clock channel, each of the three TMDS data channels transmits a 10-bit character. This 10-bit word is encoded using one of several different coding techniques.

The input stream to the Source's encoding logic will contain video pixel, packet and control data. The packet data consists of audio and auxiliary data and associated error correction codes.

These data items are processed in a variety of ways and are presented to the TMDS encoder as either 2 bits of control data, 4 bits of packet data or 8 bits of video data per TMDS channel. The Source encodes one of these data types or encodes a Guard Band character on any given clock cycle.

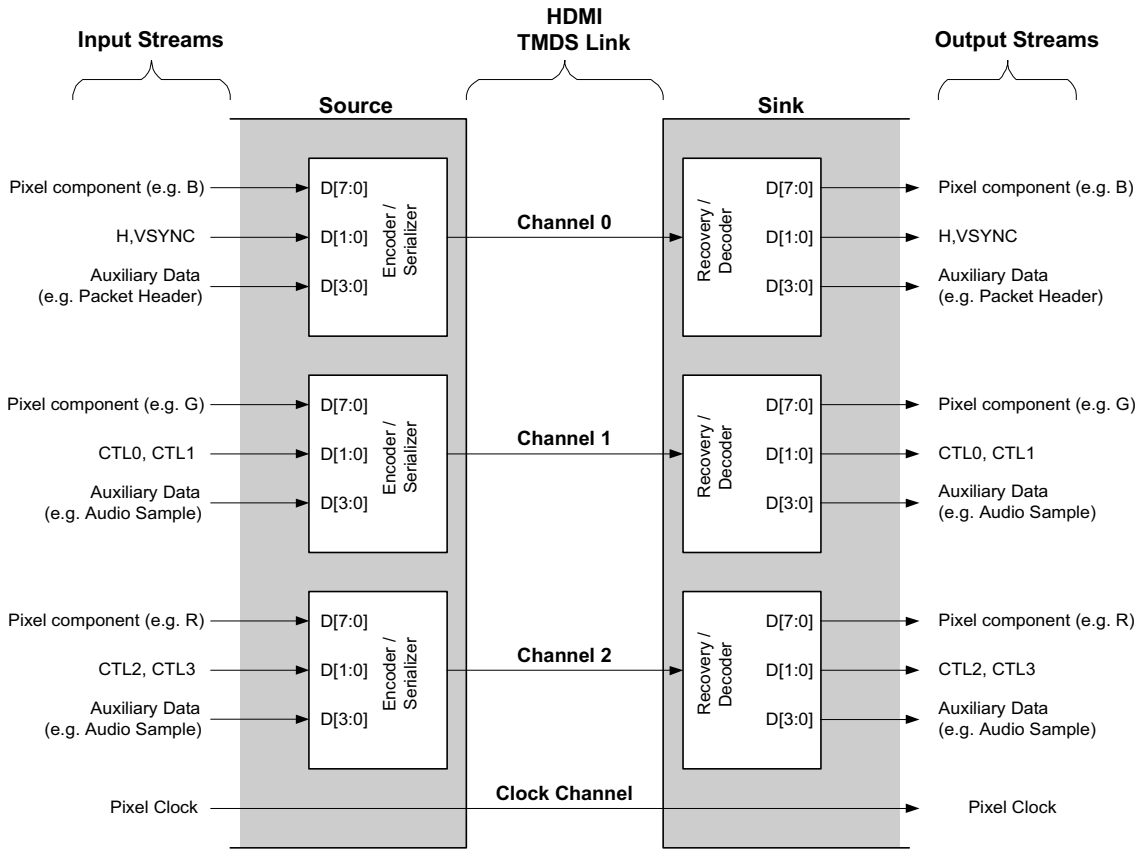


Figure 5-1 HDMI Encoder/Decoder Overview

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5.1.2 Operating Modes Overview

The HDMI link operates in one of three modes: Video Data Period, Data Island period, and Control period. During the Video Data Period, the active pixels of an active video line are transmitted. During the Data Island period, audio and auxiliary data are transmitted using a series of packets. The Control period is used when no video, audio, or auxiliary data needs to be transmitted. A Control Period is required between any two periods that are not Control Periods.

An example of each period placement is shown in the following figure.

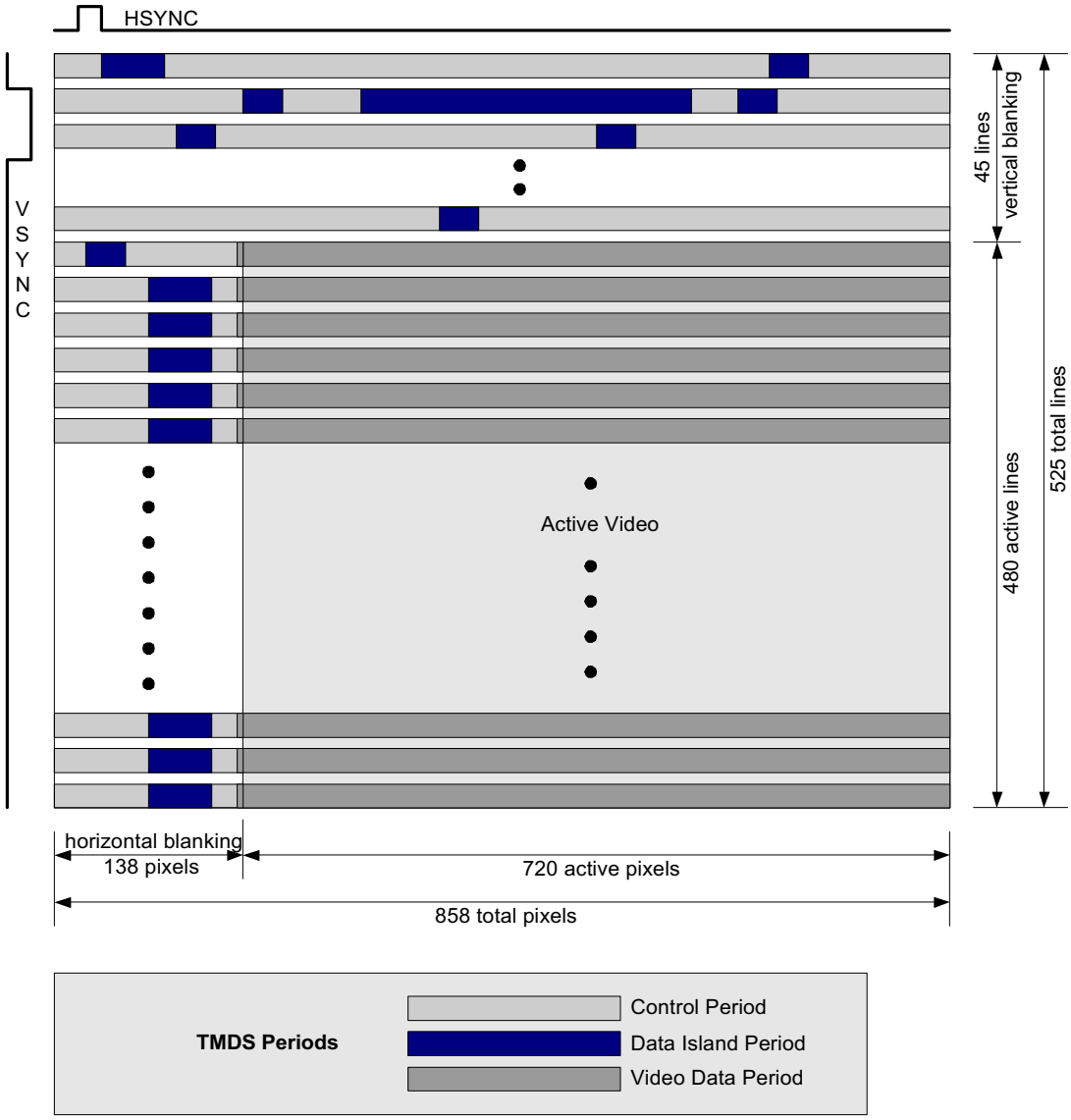


Figure 5-2 Informative Example: TMDS periods in 720x480p video frame

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Video Data Periods use transition minimized coding to encode 8 bits per channel, or 24 bits total per pixel.

Data Island Periods are encoded using a similar transition minimized coding, TMDS Error Reduction Coding (TERC4), which transmits 4 bits per channel, or 12 bits total per pixel clock period.

During Control Periods, 2 bits per channel, or 6 bits total are encoded per pixel clock using a transition maximized encoding. These 6 bits are HSYNC, VSYNC, CTL0, CTL1, CTL2 and CTL3. Near the end of every Control Period, a Preamble, using the CTLx bits, indicates whether the next Data Period is a Video Data Period or a Data Island Period.

Each Video Data Period and Data Island Period starts with a Leading Guard Band designed to provide robust determination of the transition from the Control Period to the Data Period. This Leading Guard Band consists of two special characters.

The Data Island Period is also protected by a Trailing Guard Band, which is designed to provide a robust determination of the transition to Control Period.

The following table shows Encoding type used and data transmitted during each operating mode.

Table 5-1 Encoding Type and Data Transmitted

Period	Data Transmitted	Encoding Type
Video Data	Video Pixels	Video Data Coding (8 bits converted to 10 bits)
	(Guard Band)	(Fixed 10 bit pattern)
Data Island	Packet Data - Audio Samples - InfoFrames HSYNC, VSYNC	TERC4 Coding (4 bits converted to 10 bits)
	(Guard Band)	(Fixed 10 bit pattern)
Control	Control - Preamble - HSYNC, VSYNC	Control Period Coding (2 bits converted to 10 bits)

5.2 Operating Modes

5.2.1 Control Period

Control Period is used for transmission of the Preamble. The Control Period is also used by the Sink for character synchronization.

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The HDCP-specified Enhanced Encryption Status Signaling ENC_EN code (CTL0:3=1001) shall not be used except as a correct ENC_EN during the HDCP-specified window of opportunity.

5.2.1.1 Preamble

Immediately preceding each Video Data Period or Data Island Period is the Preamble. This is a sequence of eight identical Control characters that indicate whether the upcoming data period is a Video Data Period or is a Data Island. The values of CTL0, CTL1, CTL2, and CTL3 indicate the type of data period that follows. The remaining Control signals, HSYNC and VSYNC, may vary during this sequence.

There are only two legal Preamble characters:

Table 5-2 Preambles for Each Data Period Type

CTL0	CTL1	CTL2	CTL3	Data Period Type
1	0	0	0	Video Data Period
1	0	1	0	Data Island Period

The Video Data Period type indicates that the following data period contains video data, beginning with a Video Guard Band.

The Data Island type indicates that the following data period is an HDMI compliant Data Island, beginning with a Data Island Guard Band.

The transition from TMDS control characters to Guard Band characters following this sequence identifies the start of the Data Period.

The Data Island Preamble control code (CTL0:3=1010) shall not be transmitted except for correct use during a Preamble period.

5.2.1.2 Character Synchronization

The TMDS Sink needs to determine the location of character boundaries in the serial data streams. Once character boundaries are established on all data channels, the Sink is defined to be synchronized to the serial streams, and may recover TMDS characters from the data channels for decode. The TMDS data stream provides periodic cues for decoder synchronization.

The TMDS characters used during the Video Data Period and Data Island Period contain five or fewer transitions, while the TMDS characters used during the Control Period contain seven or more transitions. The high-transition content of the characters transmitted during the Control Period form the basis for character boundary synchronization at the decoder. While these characters are not individually unique in the serial data stream, they are sufficiently alike that the decoder may uniquely detect the presence of a succession of them during transmitted synchronization intervals. The exact algorithm for this detection is an implementation detail beyond the scope of this document, but minimum conditions for Sink synchronization are defined.

The Sink is required to establish synchronization with the data stream during any Control Period greater than or equal to $t_{S,min}$ (12) characters in length.

The Source is also required to occasionally transmit an Extended Control Period per Table 5-4.

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Table 5-3 TMDS Link Timing Parameters

Symbol	Description	Value	Unit
$t_{S,min}$	Minimum duration Control Period	12	T_{PIXEL}

Table 5-4 Extended Control Period Parameters

Symbol	Description	Value	Unit
t_{EXTS,max_delay}	Maximum time between Extended Control Periods	50	msec
$t_{EXTS,min}$	Minimum duration Extended Control Period	32	T_{PIXEL}

5.2.2 Video Data Period

Video data periods are used to carry the pixels of an active video line.

Each Video Data Period is preceded by a Preamble, described above.

Following the Preamble, the Video Data Period begins with a two pixel Video Leading Guard Band. There is no Trailing Guard Band for the Video Data Period.

During active video periods, 24 bits of pixel data are encoded using TMDS transition minimized encoding.

5.2.2.1 Video Guard Band

Table 5-5 Video Leading Guard Band Values

```
case (TMDS Channel Number):
       0:  q_out[9:0] = 0b1011001100;
       1:  q_out[9:0] = 0b0100110011;
       2:  q_out[9:0] = 0b1011001100;
endcase
```

5.2.3 Data Island Period

5.2.3.1 Data Island Overview

Data Islands are used to carry packets of audio sample data and auxiliary data. This auxiliary data includes EIA/CEA-861B InfoFrames and other data describing the active audio or video stream or describing the Source.

Each Data Island is preceded by a Preamble, described above.

Following the Preamble, each Island starts with a Leading Guard Band. The first packet of the Data Island then follows.

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During every pixel of the Data Island, including the Guard Band, bits 0 and 1 of TMDS Channel 0 transmit an encoded form of HSYNC and VSYNC.

Bit 2 of TMDS Channel 0 is used to transmit the Packet Header. All four bits of TMDS Channels 1 and 2 are used for the Packet data as shown in Figure 5-3. Each packet is 32 pixels long and is protected by BCH ECC for error correction and detection purposes.

During the Data Island, each of the three TMDS channels transmits a series of 10-bit characters encoded from a 4-bit input word, using TMDS Error Reduction Coding (TERC4). TERC4 significantly reduces the error rate on the link by choosing only 10-bit codes with high inherent error avoidance.

The last two characters of the Data Island, following the last packet, is the Trailing Guard Band.

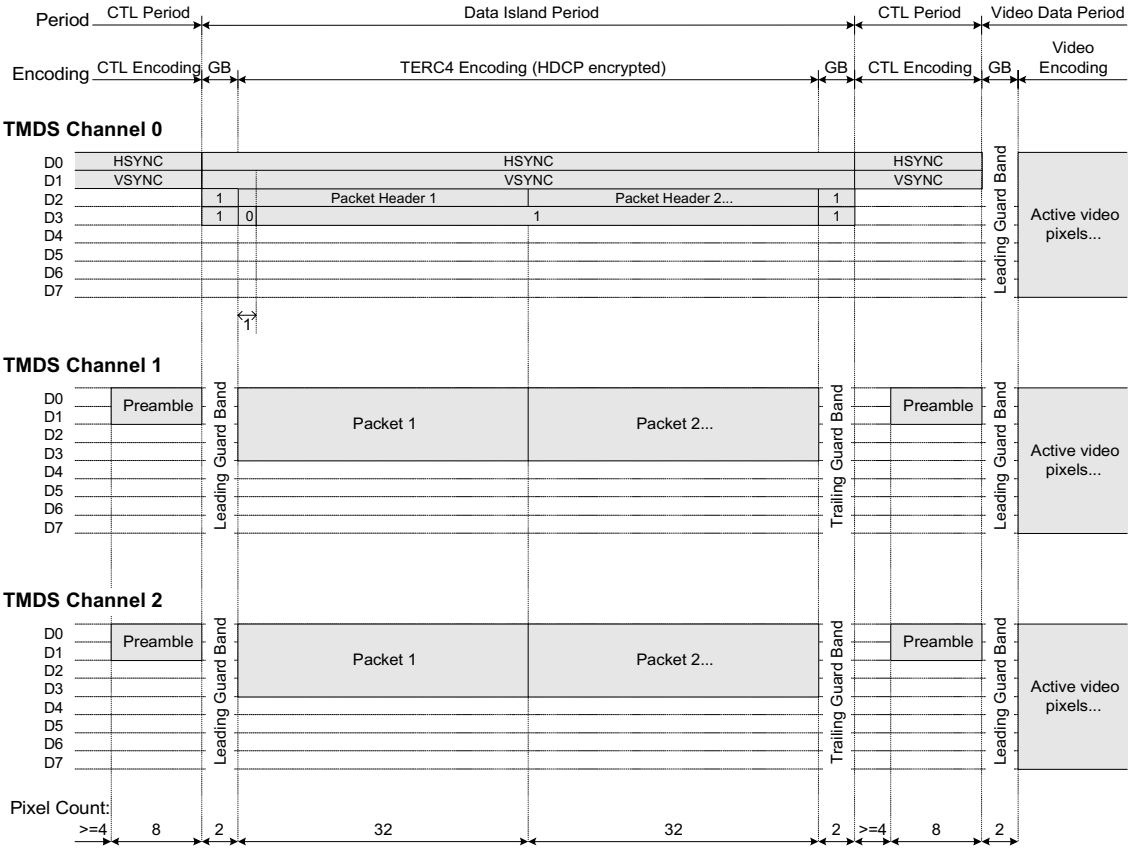


Figure 5-3 TMDS Periods and Encoding

Following the Data Island, all three channels revert to transmitting control characters.

5.2.3.2 Island Placement and Duration

The Source is required to determine the temporal placement and duration of the Data Island with respect to the video signal's horizontal and vertical blanking periods and synchronization signals. It shall do so following the rules stated below.

All TMDS Control Periods shall be at least $t_{S,min}$ (12) characters (pixels) long.

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The Data Island shall contain at least one packet, limiting its minimum size to 36 pixels.

Islands shall contain an integer number of packets. In order to assure the reliability of the data within the Data Island, they shall be limited to 18 packets or fewer.

Zero, one or more Data Islands can occur between subsequent video data periods.

While transmitting video, at least one Data Island shall be transmitted during every two video fields.

5.2.3.3 Data Island Guard Bands

The first two data characters within the Data Island are the Leading Guard Band. The last two data characters within the Data Island are the Trailing Guard Band.

During the Data Island Guard Bands, Channel 0 is encoded as one of four TERC4 values. These TERC4 values (D[3:0]) are 0xC, 0xD, 0xE and 0xF, depending upon the values of HSYNC and VSYNC.

Table 5-6 Data Island Leading and Trailing Guard Band Values

```
case (TMDS Channel Number):
       0:  q_out[9:0] = n.a.;
       1:  q_out[9:0] = 0b0100110011;
       2:  q_out[9:0] = 0b0100110011;
endcase
```

5.2.3.4 Data Island Packet Construction

All data within a Data Island is contained within 32 pixel Packets. Packets consist of a Packet Header, a Packet Body (consisting of four Subpackets), and associated error correction bits. Each Subpacket includes 56 bits of data and is protected by an additional 8 bits of BCH ECC parity bits.

Subpacket 0 plus its corresponding parity bits make up BCH Block 0. This block is mapped onto bit 0 of both Channel 1 and Channel 2. In this way, the 64 bits of BCH Block 0 are transferred over the course of 32 pixels. Likewise, BCH Block 1 (Subpacket 1 plus parity) is mapped onto bit 1 of both Channels 1 and 2.

In the tables below, Header bytes are indicated as HB0, HB1, and HB2 and Subpacket bytes are indicated as SB0 to SB6.

Subpacket 0 bytes 0 through 6 (SB0-SB6) are also designated Packet bytes 0 to 6 (PB0-PB6).

Subpacket 1 bytes 0 through 6 (SB0-SB6) are also designated Packet bytes 7 to 13 (PB7-PB13).

Subpacket 2 bytes 0 through 6 (SB0-SB6) are also designated Packet bytes 14 to 20 (PB14-PB20).

Subpacket 3 bytes 0 through 6 (SB0-SB6) are also designated Packet bytes 21 to 27 (PB21-PB27).

This is illustrated in Figure 5-4.

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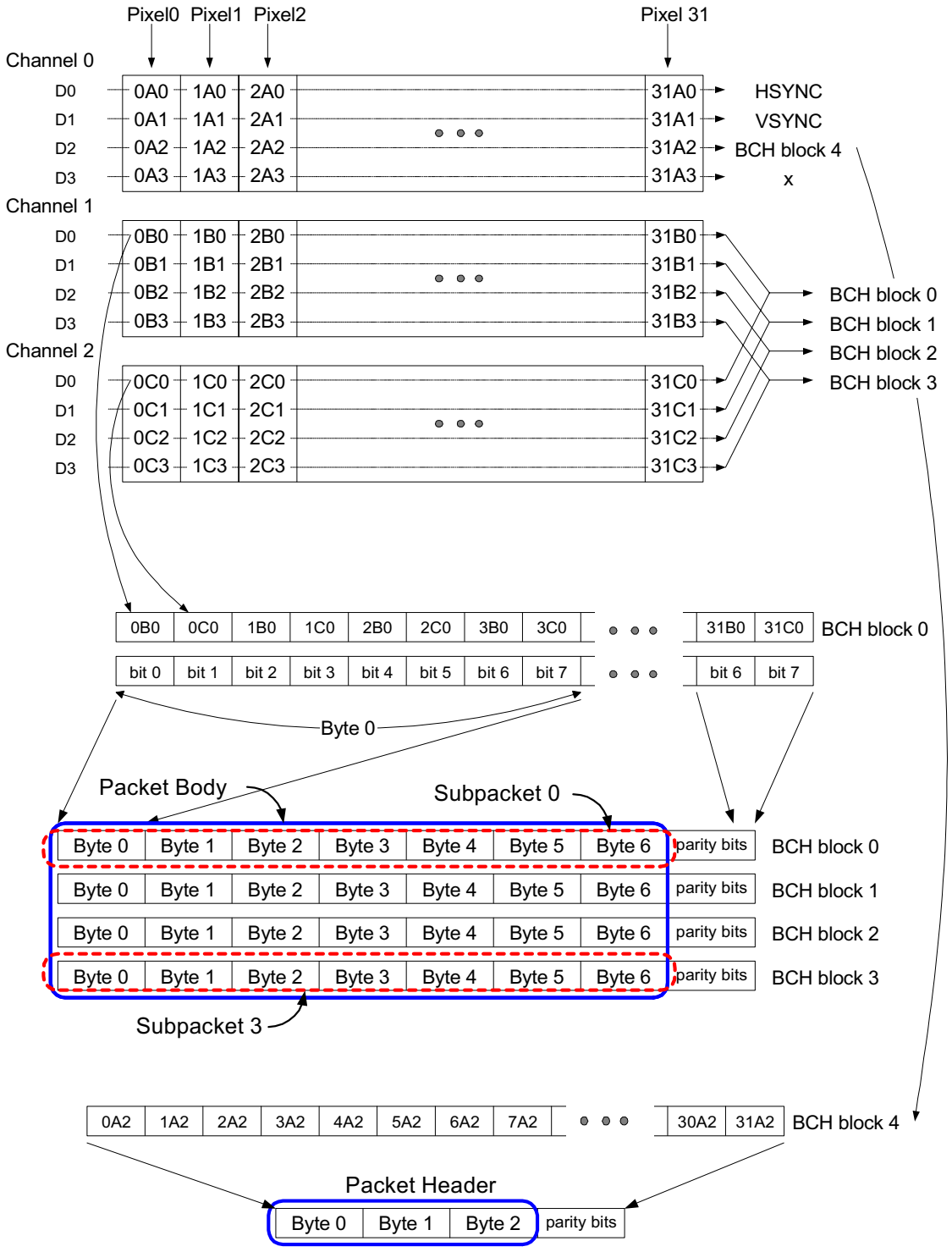


Figure 5-4 Data Island Packet and ECC Structure

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5.2.3.5 Data Island Error Correction

To improve the reliability of the data and to improve the detection of bad data, Error Correction Code (ECC) parity is added to each packet. BCH(64,56) and BCH(32,24) are generated by the polynomial G(x) shown in Figure 5-5.

$G(x)=1+x^6+x^7+x^8$ (127 count repetition cycle).

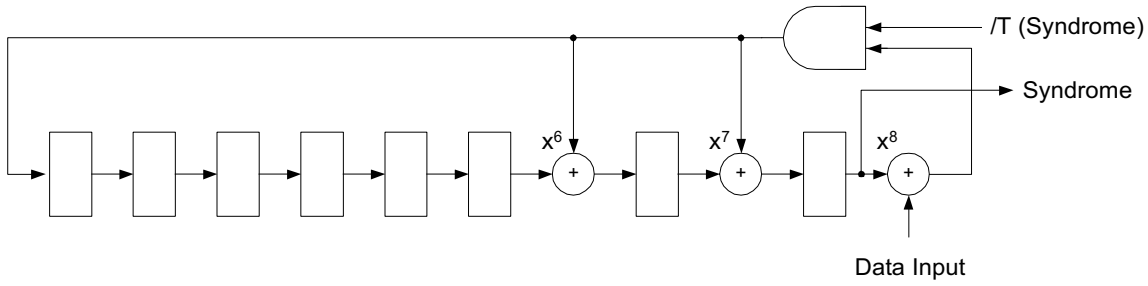


Figure 5-5 Error Correction Code generator

5.3 Data Island Packet Definitions

5.3.1 Packet Header

Packet Headers contain 24 data bits with an additional 8 bits of BCH(32,24) ECC parity. These parity bits are calculated over the 24 bits of the Packet Header.

A Packet Header includes an 8-bit Packet Type and 16 bits of packet-specific data.

A Sink shall be able to receive, with no adverse effects, any packet defined in the HDMI 1.0 specification including any InfoFrame Packet with an InfoFrame Type defined in EIA/CEA-861B.

Table 5-7 Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	Packet Type							
HB1	packet-specific data							
HB2	packet-specific data							

Table 5-8 shows the available packet types.

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Table 5-8 Packet Types

Packet Type Value		Packet Type
0x00		Null
0x01		Audio Clock Regeneration (N/CTS)
0x02		Audio Sample
0x03		General Control
0x04		ACP Packet
0x05		ISRC1 Packet
0x06		ISRC2 Packet
0x07		Reserved for DSD Packet
0x80+InfoFrame Type		EIA/CEA-861B InfoFrame
	0x81	*Vendor-Specific InfoFrame*
	0x82	*AVI InfoFrame*
	0x83	*Source Product Descriptor InfoFrame*
	0x84	*Audio InfoFrame*
	0x85	*MPEG Source InfoFrame*

5.3.2 Null Packet

Null packets can be used by the Source anytime. All bytes of a Null packet are undefined and shall contain only zero values. An HDMI Sink shall ignore bytes HB1 and HB2 of the Null Packet Header and all bytes of the Null Packet Body.

Table 5-9 Null Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	0	0	0	0	0	0	0	0
HB1	0	0	0	0	0	0	0	0
HB2	0	0	0	0	0	0	0	0

5.3.3 Audio Clock Regeneration Packet

Audio Clock Regeneration Packets contain both the N and CTS values used in the Audio Clock Regeneration process. The four Subpackets each contain the same Audio Clock Regeneration Subpacket. An HDMI Sink shall ignore bytes HB1 and HB2 of the Audio Clock Regeneration Packet header.

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Table 5-10 Audio Clock Regeneration Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	0	0	0	0	0	0	0	1
HB1	0	0	0	0	0	0	0	0
HB2	0	0	0	0	0	0	0	0

Table 5-11 Audio Clock Regeneration Subpacket

Byte \ Bit #	7	6	5	4	3	2	1	0
SB0	0	0	0	0	0	0	0	0
SB1	0	0	0	0	CTS.19	-	-	CTS.16
SB2	CTS.15	-	-	-	-	-	-	CTS.8
SB3	CTS.7	-	-	-	-	-	-	CTS.0
SB4	0	0	0	0	N.19	-	-	N.16
SB5	N.15	-	-	-	-	-	-	N.8
SB6	N.7	-	-	-	-	-	-	N.0

- N [20 bits] value of audio clock regeneration “N”
- CTS [20 bits] Cycle Time Stamp

CTS values of zero are used to indicate no new value of CTS.

5.3.4 Audio Sample Packet

Audio Sample Packets consist of one to four Audio Samples. These may be different samples or different partial samples (i.e. 2 of 6 channels). The configuration of the Subpackets is determined by the layout and sample_present bits in the header. This is described in detail in Section 7.6, *Audio Data Packetization*.

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Table 5-12 Audio Sample Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	0	0	0	0	0	0	1	0
HB1	0	0	0	layout	sample_ present.sp3	sample_ present.sp2	sample_ present.sp1	sample_ present.sp0
HB2	B.3	B.2	B.1	B.0	sample_flat .sp3	sample_flat .sp2	sample_flat .sp1	sample_flat .sp0

- layout: [1 bit] indicates which of two possible Subpacket/audio sample layouts are used. See Section 7.6, *Audio Data Packetization*.
- sample_present.spX [4 fields, 1 bit each] indicates if Subpacket X contains an audio sample.
- sample_flat.spX [4 fields, 1 bit each] indicates if Subpacket X represents a “flatline” sample. Only valid if “sample_present.spX” is set.
- B.X [4 fields, 1 bit each] B.X =1 if Subpacket X contains the first frame in an IEC 60958 block; B.X = 0 otherwise

Table 5-13 Audio Sample Subpacket

Byte \ Bit #	7	6	5	4	3	2	1	0
SB0	L.11	…	…	…	…	…	…	L.4
SB1	L.19	…	…	…	…	…	…	L.12
SB2	L.27	…	…	…	…	…	…	L.20
SB3	R.11	…	…					R.4
SB4	R.19	…	…	…	…	…	…	R.12
SB5	R.27	…	…	…	…	…	…	R.20
SB6	P_R	C_R	U_R	V_R	P_L	C_L	U_L	V_L

- L.X: [24 fields, 1 bit each] Bit corresponding to Time Slot X from first (“left”) sub-frame per IEC 60958-1, page 15
- R.X: [24 fields, 1 bit each] Bit corresponding to Time Slot X from second (“right”) sub-frame per IEC 60958-1, page 15
- V_L: [1 bit] Valid bit from first sub-frame
- V_R: [1 bit] Valid bit from second sub-frame
- U_L: [1 bit] User Data bit from first sub-frame
- U_R: [1 bit] User Data bit from second sub-frame
- C_L: [1 bit] Channel Status bit from first sub-frame
- C_R: [1 bit] Channel Status bit from second sub-frame
- P_L: [1 bit] Parity bit from first sub-frame (even parity)

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- P_R: [1 bit] Parity bit from second sub-frame (even parity)

5.3.5 InfoFrame Packet

All InfoFrames defined in EIA/CEA-861B may be carried across HDMI using the HDMI InfoFrame packet. InfoFrames not defined in EIA/CEA-861B or in this specification shall not be transmitted.

InfoFrames are each carried in their own packet, as shown below. Note that HDMI places additional requirements on several InfoFrames that are not covered by EIA/CEA-861B. For these additional details and restrictions, see Section 8.2.

Table 5-14 InfoFrame Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	1	InfoFrame Type						
HB1	InfoFrame_version							
HB2	0	0	0	InfoFrame_length				

- InfoFrame Type [7 bits] least significant 7 bits of the InfoFrame type code as per EIA/CEA-861B.
- InfoFrame_version [1 byte] version number of InfoFrame as per EIA/CEA-861B.
- InfoFrame_length [5 bits] InfoFrame length in bytes as per EIA/CEA-861B. This length does not include any of the bytes in the Packet Header nor the checksum byte. The maximum value for this field is 27 (0x1B).

Table 5-15 InfoFrame Packet Contents

Byte \ Bit #	7	6	5	4	3	2	1	0
PB0	checksum							
PB1	Data Byte 1							
PB2	Data Byte 2							
PB3…PB26	…							
PB27	Data Byte 27							

- Checksum [1 byte] Checksum of the InfoFrame. The checksum shall be calculated such that a byte-wide sum of all three bytes of the Packet Header and all valid bytes of the InfoFrame Packet contents (determined by InfoFrame_length), plus the checksum itself, equals zero.
- Data Byte x [27 fields, 1 byte each] Data Byte X of the InfoFrame as defined in EIA/CEA-861B. See Section 8.2 for more information.

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5.3.6 General Control Packet

The General Control packet header contains no data. Bytes HB1 and HB2 shall be ignored by the Sink. The General Control packet body shall contain four identical subpackets, defined in Table 5-17, below. The General Control packet may only be transmitted between the active edge of VSYNC and 384 pixels following this edge.

Table 5-16 General Control Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	0	0	0	0	0	0	1	1
HB1	0	0	0	0	0	0	0	0
HB2	0	0	0	0	0	0	0	0

Table 5-17 General Control Subpacket

Byte \ Bit #	7	6	5	4	3	2	1	0
SB0	0	0	0	Clear_AVMUTE	0	0	0	Set_AVMUTE
SB1	0	0	0	0	0	0	0	0
SB2	0	0	0	0	0	0	0	0
SB3	0	0	0	0	0	0	0	0
SB4	0	0	0	0	0	0	0	0
SB5	0	0	0	0	0	0	0	0
SB6	0	0	0	0	0	0	0	0

- Set_AVMUTE [1 bit] Set the AVMUTE flag. (See description below).
- Clear_AVMUTE [1bit] Clear the AVMUTE flag. (See description below).

A Source may not send a General Control Packet with the Clear_AVMUTE and Set_AVMUTE flags set simultaneously.

Source transmission of the General Control Packet is optional. Sinks may optionally interpret General Control Packet contents. Sinks shall be capable of receiving any General Control Packet.

The General Control packet's Set_AVMUTE and Clr_AVMUTE flags may be used by a Source to reduce the negative impact on the Sink of TMDS clock changes or interruptions. Use of the AVMUTE function may prevent spurious pops or noises in the audio during these clock changes.

When AVMUTE is set, the Sink may assume that no valid audio or video data is being received. The Sink may optionally apply a mute function to the audio data and/or a blank function to the video.

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5.3.7 Audio Content Protection Packet (ACP)

A Source may use the ACP Packet to convey content-related information regarding the active audio stream.

See Section 9.3 for rules regarding the use of the ACP packet.

The following tables show the packetization of the ACP Packet.

Table 5-18 ACP Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	Packet Type = 0x04							
HB1	ACP_Type							
HB2	Reserved (0)							

- ACP_Type [1 byte] Content protection type (see Section 9.3 for usage):
  0x00 = Generic Audio
  0x01 = IEC 60958-Identified Audio
  0x02 = DVD-Audio
  0x03 = Reserved for Super Audio CD (SACD)
  0x04…0xFF Reserved

Table 5-19 ACP Packet contents

Packet Byte #	7	6	5	4	3	2	1	0
PB0-PB27	ACP_Type_Dependent (Dependent upon ACP_Type value)							

- ACP_Type_Dependent [28 bytes] Contents are dependent upon ACP_Type field. See Section 9.3 for usage.

5.3.8 ISRC Packets

A Source may use the ISRC packets to transmit a UPC/EAN or ISRC code. See Section 8.8 for rules regarding the use of the ISRC packets.

Table 5-20 ISRC1 Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	Packet Type = 0x05							
HB1	ISRC_ Cont	ISRC_ Valid	Reserved (0)			ISRC_Status		
HB2	Reserved (0)							

- ISRC_Cont [1 bit] ISRC Continued (in next packet). See Section 8.8 for usage.

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- ISRC_Status [3 bits] See Section 8.8 for usage.
- ISRC Valid [1 bit]: This bit is set only when data located in ISRC_Status field and UPC_EAN_ISRC_xx field are valid. When Source can not obtain complete data for these fields, ISRC_Valid may be 0.

Table 5-21 ISRC1 Packet contents

Packet Byte #	7	6	5	4	3	2	1	0
PB0	UPC_EAN_ISRC_0							
PB1	UPC_EAN_ISRC_1							
PB2	UPC_EAN_ISRC_2							
PB3	UPC_EAN_ISRC_3							
PB4	UPC_EAN_ISRC_4							
PB5	UPC_EAN_ISRC_5							
PB6	UPC_EAN_ISRC_6							
PB7	UPC_EAN_ISRC_7							
PB8	UPC_EAN_ISRC_8							
PB9	UPC_EAN_ISRC_9							
PB10	UPC_EAN_ISRC_10							
PB11	UPC_EAN_ISRC_11							
PB12	UPC_EAN_ISRC_12							
PB13	UPC_EAN_ISRC_13							
PB14	UPC_EAN_ISRC_14							
PB15	UPC_EAN_ISRC_15							
PB16-PB27	Reserved (0)							

- UPC_EAN_ISRC_xx [16 fields, 1 byte each] UPC/EAN or ISRC byte xx. See Section 8.8 for usage.

Bytes PB16-PB27 shall be set to a value of 0.

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Table 5-22 ISRC2 Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	Packet Type = 0x06							
HB1	Reserved (0)							
HB2	Reserved (0)							

Table 5-23 ISRC2 Packet contents

Packet Byte #	7	6	5	4	3	2	1	0
PB0	UPC_EAN_ISRC_16							
PB1	UPC_EAN_ISRC_17							
PB2	UPC_EAN_ISRC_18							
PB3	UPC_EAN_ISRC_19							
PB4	UPC_EAN_ISRC_20							
PB5	UPC_EAN_ISRC_21							
PB6	UPC_EAN_ISRC_22							
PB7	UPC_EAN_ISRC_23							
PB8	UPC_EAN_ISRC_24							
PB9	UPC_EAN_ISRC_25							
PB10	UPC_EAN_ISRC_26							
PB11	UPC_EAN_ISRC_27							
PB12	UPC_EAN_ISRC_28							
PB13	UPC_EAN_ISRC_29							
PB14	UPC_EAN_ISRC_30							
PB15	UPC_EAN_ISRC_31							
PB16-PB27	Reserved (0)							

- UPC_EAN_ISRC_xx [16 fields, 1 byte each] UPC/EAN or ISRC byte xx.

Bytes PB16-PB27 shall be set to a value of 0.

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5.3.9 DSD Packet

This packet will be defined in a future version of the HDMI Specification.

5.4 Encoding

5.4.1 Serialization

The stream of TMDS characters produced by the encoder is serialized for transmission on the TMDS data channel. In the discussions that follow, the least significant bit of each character (q_out[0]) is the first bit to be transmitted and the most significant bit (q_out[9]) is the last.

5.4.2 Control Period Coding

Each TMDS channel has two control signals, which are encoded into 10 bits during Control Periods. For each of the three channels these signals are shown in Table 5-24.

Table 5-24 Control-signal Assignment

TMDS Channel	D0	D1
0	HSYNC	VSYNC
1	CTL0	CTL1
2	CTL2	CTL3

The two Control signals for each of the three TMDS channels are encoded as follows:

```
case (D1, D0):
       0, 0:  q_out[9:0] = 0b1101010100;
       0, 1:  q_out[9:0] = 0b0010101011;
       1, 0:  q_out[9:0] = 0b0101010100;
       1, 1:  q_out[9:0] = 0b1010101011;
endcase;
```

5.4.3 TERC4 Coding

TMDS Error Reduction Coding (TERC4) is used during the Data Island period to encode 4 bits per channel into the 10 bits serialized and transmitted.

```
case (D3, D2, D1, D0):
    0000:  q_out[9:0] = 0b1010011100;
    0001:  q_out[9:0] = 0b1001100011;
    0010:  q_out[9:0] = 0b1011100100;
    0011:  q_out[9:0] = 0b1011100010;
    0100:  q_out[9:0] = 0b0101110001;
    0101:  q_out[9:0] = 0b0100011110;
    0110:  q_out[9:0] = 0b0110001110;
    0111:  q_out[9:0] = 0b0100111100;
    1000:  q_out[9:0] = 0b1011001100;
    1001:  q_out[9:0] = 0b0100111001;
```


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```
    1010:  q_out[9:0] = 0b0110011100;
    1011:  q_out[9:0] = 0b1011000110;
    1100:  q_out[9:0] = 0b1010001110;
    1101:  q_out[9:0] = 0b1001110001;
    1110:  q_out[9:0] = 0b0101100011;
    1111:  q_out[9:0] = 0b1011000011;
endcase;
```

5.4.4 Video Data Coding

5.4.4.1 Video Data Encoding

The following is a description of the encoding algorithm used during transmission of video data. A detailed description of an encoder is given. Other implementations are possible and are permitted but, given the same sequence of input characters, they are required to produce the same sequence of output (10-bit) characters that is generated by the described encoder.

During video data, where each 10-bit character represents 8 bits of pixel data, the encoded characters provide an approximate DC balance as well as a reduction in the number of transitions in the data stream. The encode process for the active data period can be viewed in two stages. The first stage produces a transition-minimized 9-bit code word from the input 8 bits. The second stage produces a 10-bit code word, the finished TMDS character, which will manage the overall DC balance of the transmitted stream of characters.

The 9-bit code word produced by the first stage of the encoder is made up of an 8-bit representation of the transitions found in the input 8 bits, plus a one-bit flag to indicate which of two methods was used to describe the transitions. In both cases, the LSb of the output matches the LSb of the input. With a starting value established, the remaining 7 bits of the output word is derived from sequential exclusive OR (XOR) or exclusive NOR (XNOR) functions of each bit of the input with the previously derived bit. The choice between XOR and XNOR logic is made such that the encoded values contain the fewest possible transitions, and the ninth bit of the code word is used to indicate whether XOR or XNOR functions were used to derive the output code word. The decode of this 9-bit code word is simply a matter of applying either XOR or XNOR gates to the adjacent bits of the code, with the LSb passing from decoder input to decoder output unchanged.

The second stage of the encoder performs an approximate DC balance on the transmitted stream by selectively inverting the 8 data bits of the 9-bit code words produced by the first stage. A tenth bit is added to the code word, to indicate when the inversion has been made. The encoder determines when to invert the next character based on the running disparity between ones and zeros that it tracks in the transmitted stream, and the number of ones and zeros found in the current code word. If too many ones have been transmitted and the input contains more ones than zeros, the code word is inverted. This dynamic encoding decision at the Source is simply decoded at the Sink by the conditional inversion of the input code word based on the tenth bit of the TMDS character. The TMDS code mapping is specified by Figure 5-6 with the definitions of Table 5-25. The encoder produces one of 460 unique 10-bit characters. The encoder shall not generate any other 10-bit character during a Video Data Period.

Upon entering a Video Data Period, the data stream disparity (cnt) shall be considered to be zero by the encoder.

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Table 5-25 Encoding Algorithm Definitions

D	The encoder input data set. D is 8-bit pixel data
cnt	This is a register used to keep track of the data stream disparity. A positive value represents the excess number of “1”s that have been transmitted. A negative value represents the excess number of “0”s that have been transmitted. The expression cnt{t-1} indicates the previous value of the disparity for the previous set of input data. The expression cnt(t) indicates the new disparity setting for the current set of input data.
q_m	Intermediate value.
q_out	These 10 bits are the encoded output value.
N_1{x}	This operator returns the number of “1”s in argument “x”
N_0{x}	This operator returns the number of “0”s in argument “x”

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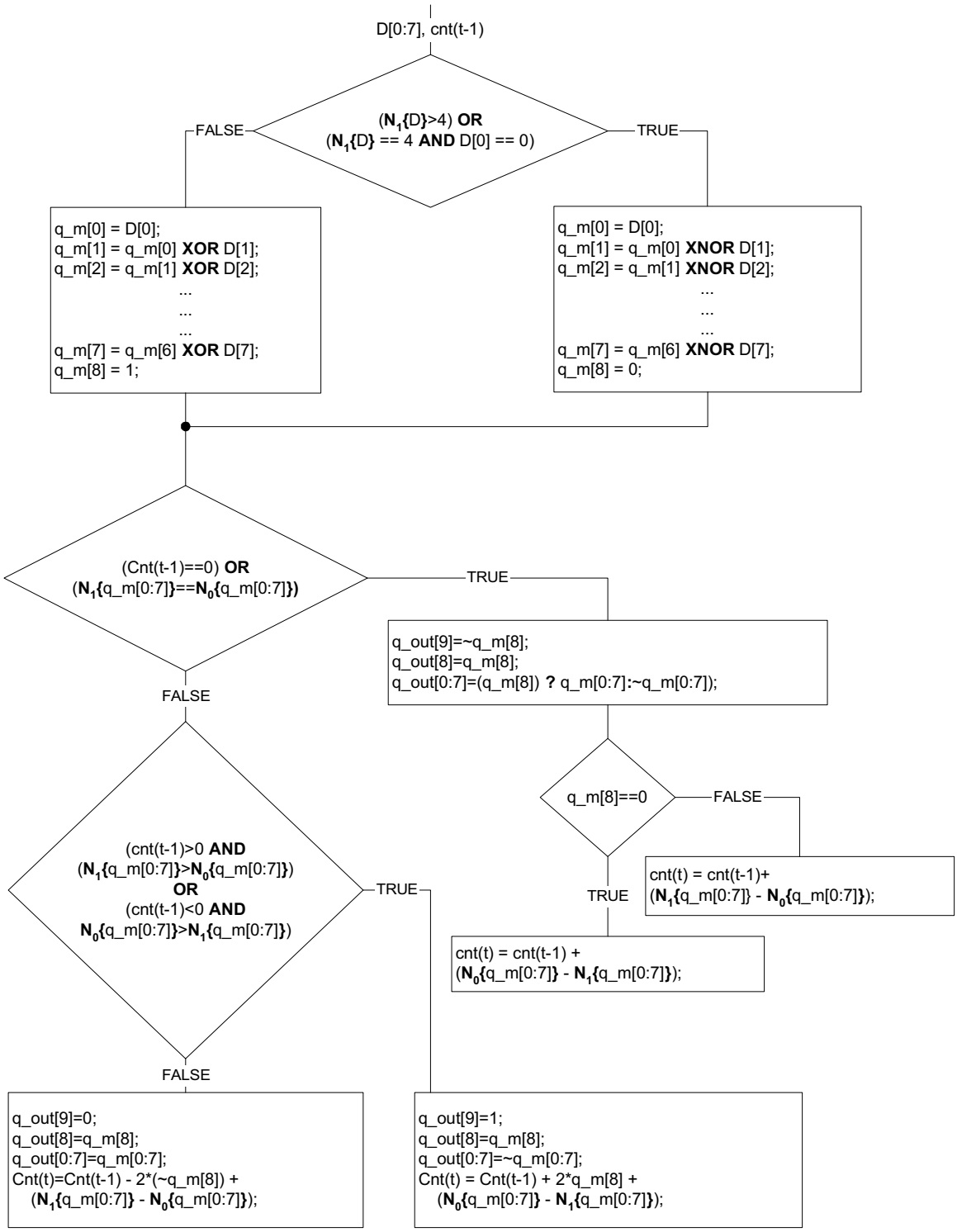


Figure 5-6 TMDS Video Data Encode Algorithm

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5.4.4.2 Video Data Decoding

The TMDS decode mapping is specified by Figure 5-7. Alternative implementations are possible but, given the same input data stream, they are required to generate the same output data stream as the described decoder algorithm.

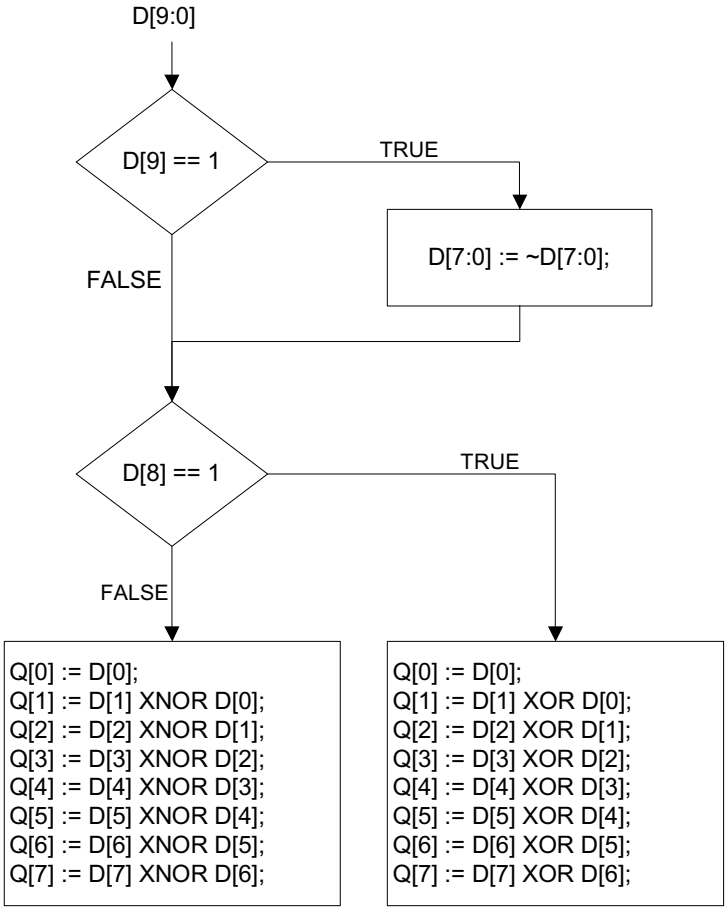


Figure 5-7 TMDS Video Decode Algorithm

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6 Video

6.1 Overview

HDMI allows a wide variety of explicitly defined video format timings to be transmitted and displayed. These video format timings define the pixel and line counts and timing, synchronization pulse position and duration, and whether the format is interlaced or progressive.

The video pixels carried across the link shall be in one of three different pixel encodings: RGB 4:4:4, YC_BC_R 4:4:4 or YC_BC_R 4:2:2.

The HDMI Source determines the pixel encoding and video format of the transmitted signal based on the characteristics of the source video, the format and pixel encoding conversions possible at the Source, and the format and pixel encoding capabilities and preferences of the Sink.

6.2 Video Format Support

In order to provide maximum compatibility between video Sources and Sinks, specific minimum requirements have been specified for Sources and Sinks.

6.2.1 Format Support Requirements

Some of the following support requirements are in addition to those specified in EIA/CEA-861B.

- An HDMI Source shall support at least one of the following video format timings:
  - 640x480p @ 59.94/60Hz
  - 720x480p @ 59.94/60Hz
  - 720x576p @ 50Hz
- An HDMI Source that is capable of transmitting any of the following video format timings using any other component analog or uncompressed digital video output, shall be capable of transmitting that video format timing across the HDMI interface.
  - 1280x720p @ 59.94/60Hz
  - 1920x1080i @ 59.94/60Hz
  - 720x480p @ 59.94/60Hz
  - 1280x720p @ 50Hz
  - 1920x1080i @ 50Hz
  - 720x576p @ 50Hz
- An HDMI Sink that accepts 60Hz video formats shall support the 640x480p @ 59.94/60Hz and 720x480p @ 59.94/60Hz video format timings.
- An HDMI Sink that accepts 50Hz video formats shall support the 640x480p @ 59.94/60Hz and 720x576p @ 50Hz video format timings.
- An HDMI Sink that accepts 60Hz video formats, and that supports HDTV capability, shall support 1280x720p @ 59.94/60Hz or 1920x1080i @ 59.94/60Hz video format timings.
- An HDMI Sink that accepts 50Hz video formats, and that supports HDTV capability, shall support 1280x720p @ 50Hz or 1920x1080i @ 50Hz video format timings.

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- An HDMI Sink that is capable of receiving any of the following video format timings using any other component analog or uncompressed digital video input, shall be capable of receiving that format across the HDMI interface.
  - 1280x720p @ 59.94/60Hz
  - 1920x1080i @ 59.94/60Hz
  - 1280x720p @ 50Hz
  - 1920x1080i @ 50Hz

6.2.2 Video Control Signals : HSYNC, VSYNC

During the Data Island period, HDMI carries HSYNC and VSYNC signals using encoded bits on Channel 0. During Video Data periods, HDMI does not carry HSYNC and VSYNC and the Sink should assume that these signals remain constant. During Control periods, HDMI carries HSYNC and VSYNC signals through the use of four different control characters on TMDS Channel 0.

6.2.3 Pixel Encoding Requirements

Only pixel encodings of RGB 4:4:4, YC_BC_R 4:2:2, and YC_BC_R 4:4:4 (as specified in Section 6.5) may be used on HDMI.

All HDMI Sources and Sinks shall be capable of supporting RGB 4:4:4 pixel encoding.

All HDMI Sources shall support either YC_BC_R 4:2:2 or YC_BC_R 4:4:4 pixel encoding whenever that device is capable of transmitting a color-difference color space across any other component analog or digital video interface.

All HDMI Sinks shall be capable of supporting both YC_BC_R 4:4:4 and YC_BC_R 4:2:2 pixel encoding when that device is capable of supporting a color-difference color space from any other component analog or digital video input.

If an HDMI Sink supports either YC_BC_R 4:2:2 or YC_BC_R 4:4:4 then both shall be supported.

An HDMI Source may determine the pixel-encodings that are supported by the Sink through the use of the E-EDID. If the Sink indicates that it supports YC_BC_R-formatted video data and if the Source can deliver YC_BC_R data, then it can enable the transfer of this data across the link.

6.3 Video Format Timing Specifications

All specified video line pixel counts and video field line counts (both active and total) and HSYNC and VSYNC positions, polarities, and durations shall be adhered to when transmitting a specified video format timing.

For example, if a Source is processing material with fewer active pixels per line than required (i.e. 704 pixels vs. 720 pixels for standard definition MPEG2 material), it may add pixels to the left and right of the supplied material before transmitting across HDMI. AVI bar info may need to be adjusted to account for these added pixels.

Detailed timing is found in EIA/CEA-861B for the following primary and optional video format timings.

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6.3.1 Primary Video Format Timings

- 640x480p @ 59.94/60Hz
- 1280x720p @ 59.94/60Hz
- 1920x1080i @ 59.94/60Hz
- 720x480p @ 59.94/60Hz
- 720(1440)x480i @ 59.94/60Hz
- 1280x720p @ 50Hz
- 1920x1080i @ 50Hz
- 720x576p @ 50Hz
- 720(1440)x576i @ 50Hz

6.3.2 Optional Video Format Timings

- 720(1440)x240p @ 59.94/60Hz
- 2880x480i @ 59.94/60Hz
- 2880x240p @ 59.94/60Hz
- 1440x480p @ 59.94/60Hz
- 1920x1080p @ 59.94/60Hz
- 720(1440)x288p @ 50Hz
- 2880x576i @ 50Hz
- 2880x288p @ 50Hz
- 1440x576p @ 50Hz
- 1920x1080p @ 50Hz
- 1920x1080p @ 23.98/24Hz
- 1920x1080p @ 25Hz
- 1920x1080p @ 29.97/30Hz

6.4 Pixel-Repetition

Video formats with native pixel rates below 25 Mpixels/sec require pixel-repetition in order to be carried across a TMDS link. 720x480i and 720x576i video format timings shall always be pixel-repeated.

The HDMI Source indicates the use of pixel-repetition with the Pixel Repetition (PR0:PR3) field in the AVI InfoFrame. This field indicates to the HDMI Sink how many repetitions of each unique pixel are transmitted. In non-repeated formats, this value is zero.

For pixel-repeated formats, this value indicates the number of pixels that may be discarded by the Sink without losing real image content.

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The Source shall always accurately indicate the pixel repetition count being used. The use of the Pixel Repetition field is optional for HDMI Sink.

The use of this pixel-repetition count field is more fully described in EIA/CEA-861B.

6.5 Pixel Encodings

There are three different pixel encodings that may be sent across an HDMI cable: YC_BC_R 4:4:4, YC_BC_R 4:2:2 and RGB 4:4:4. Whichever encoding is used, it shall conform to one of the methods described in this section.

Figure 6-1 shows the default encoding, RGB 4:4:4. The R, G, and B components of the first pixel for a given line of video are transferred on the first pixel of the video data period following the Guard Band characters.

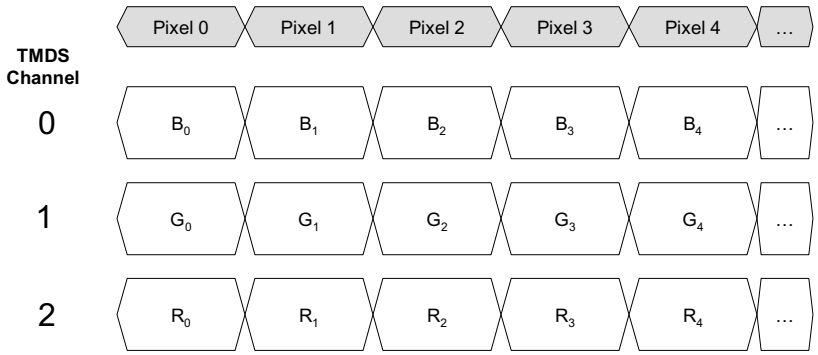


Figure 6-1 Default pixel encoding: RGB 4:4:4, 8 bits/component

Figure 6-2 shows the signal mapping and timing for transferring YC_BC_R 4:2:2 data across HDMI. Because 4:2:2 data only requires two components per pixel clock, more bits are allocated per component. The available 24 bits are split into 12 bits for the Y component and 12 bits for the C components.

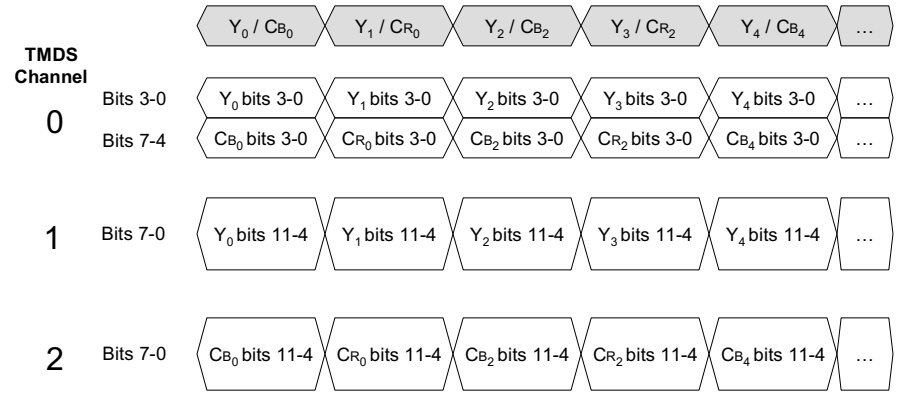


Figure 6-2 YC_BC_R 4:2:2 component

The YC_BC_R 4:2:2 pixel encoding on HDMI closely resembles standard ITU-R BT.601. The high-order 8 bits of the Y samples are mapped onto the 8 bits of Channel 1 and the low-order 4 bits

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are mapped onto the low-order 4 bits of Channel 0. If fewer than 12 bits are used, the valid bits shall be left-justified (i.e. MSb=MSb) with zeroes padding the bits below the LSb.

The first pixel transmitted within a Video Data Period contains three components, Y0, Cb0 and Cr0. The Y0 and Cb0 components are transmitted during the first TMDS pixel clock period while Cr0 is transmitted during the second TMDS pixel clock period. This second pixel clock period also contains the only component for the second pixel – Y1. In this way, the link carries one C_B sample for every two TMDS pixel clocks and one Cr sample for every two TMDS pixel clocks. These two components (C_B and C_R) are multiplexed onto the same signal paths on the link.

At the third TMDS pixel clock, this process is repeated with the Y and C_B components for the third pixel being transmitted, followed, on the next clock, by the C_R component of the third pixel and the Y component of the fourth pixel.

YC_BC_R 4:4:4 data is transferred using the scheme illustrated in Figure 6-3.

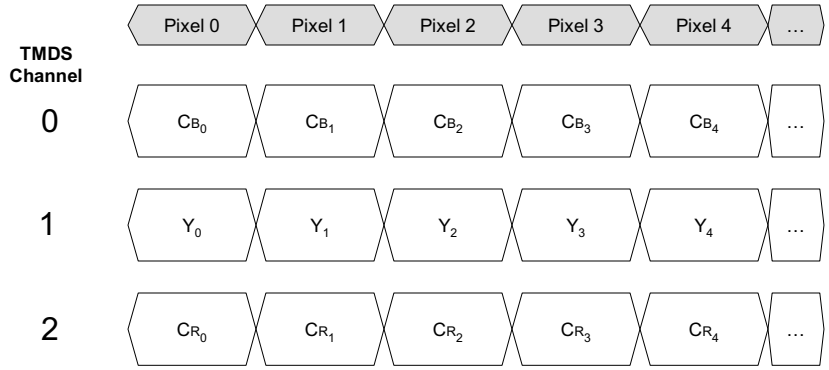


Figure 6-3 8-bit YC_BC_R 4:4:4 mapping

During pixel-doubling (Pixel_Repetition_Count = 1), all of the data sent across during the first pixel clock will be repeated during the second pixel clock. The third clock will then represent the second actual pixel and so on.

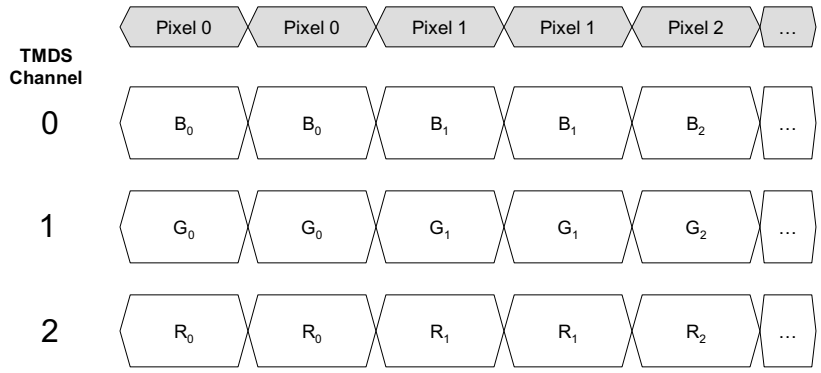


Figure 6-4 RGB with Pixel-Doubling

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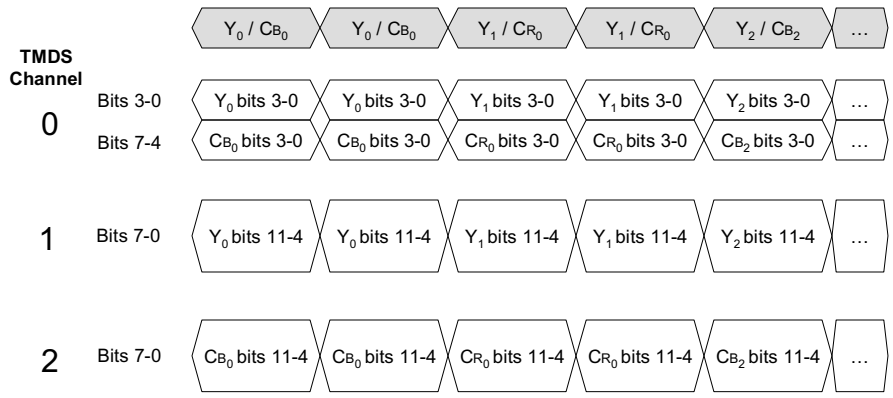


Figure 6-5 YC_BC_R 4:2:2 with Pixel-Doubling

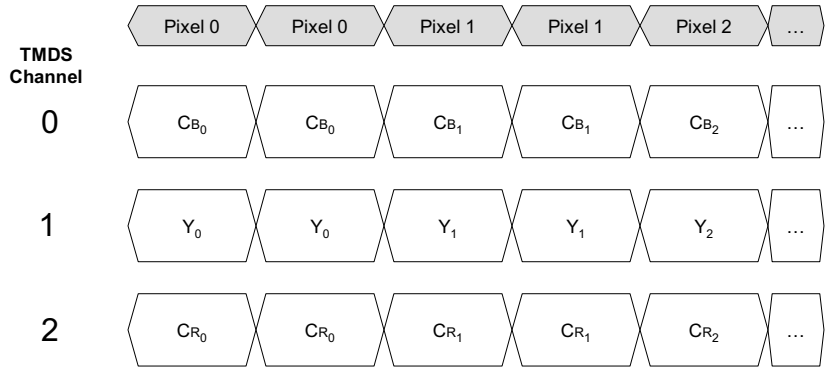


Figure 6-6 YC_BC_R 4:4:4 with Pixel-Doubling

6.6 Video Quantization Ranges

Black and white levels for video components shall be either “Full Range” or “Limited Range.” YC_BC_R components shall always be Limited Range while RGB components may be either Full Range or Limited Range. While using RGB, Limited Range shall be used for all video formats defined in EIA/CEA-861B, with the exception of VGA (640x480) format, which requires Full Range.

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Table 6-1 Video Color Component Ranges

Color Space	Component Bit Depth	for Full range		for Limited range	
		Black level	White level	Black level	White level
R / G / B	8	0	255	16	235
Y / C_B / C_R	8	not allowed		16	235 (Y), 240 (C_B, C_R)
Y / C_B / C_R	10	not allowed		64	940 (Y), 960 (C_B, C_R)
Y / C_B / C_R	12	not allowed		256	3760 (Y), 3840 (C_B, C_R)

6.7 Colorimetry

6.7.1 480p, 480i, 576p, 576i, 240p and 288p

The 480-line, 576-line, 240-line, and 288-line video formats are typically transmitted with a color space based on SMPTE 170M.

ITU-R BT.601-5 Section 3.3 shall be used for any color space conversion needed in the course of processing unless a different colorimetry is specified in the AVI InfoFrame.

The encoding parameter values shall be as defined in Table 3 of ITU-R BT.601-5 and as summarized in Section 6.6.

6.7.2 1080i, 1080p and 720p

The high-definition video formats are typically transmitted with a color space based on ITU-R BT.709-4.

ITU-R BT.709-4 Part 1, Section 4 shall be used for any color space conversion needed in the course of processing unless a different colorimetry is specified in the AVI InfoFrame.

The digital representation shall be as defined in Part 1, Section 6.10 of ITU-R BT.709-4 and as summarized in Section 6.6.

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7 Audio

7.1 Relationship with IEC 60958/IEC 61937 (IEC)

Audio data is formatted in the Audio Sample Packet as a structure that closely resembles an IEC 60958 or IEC 61937 frame.

On HDMI, each IEC 60958 sub-frame is represented as a 28-bit word. There is no encoding of the preamble type, which instead is replaced with a “B” bit (start-of-block) in each Audio Sample packet. The B bit shall be set for a “B, W” frame and shall be clear for an “M, W” frame. (IEC 60958-1 Section 4.1.2). No other sub-frame preamble combinations are allowed.

Except where specifically indicated in this document, the behavior of all fields within the Audio Sample Subpackets shall follow the corresponding rules specified in the IEC 60958 or IEC 61937 specifications.

When receiving multi-channel audio, the Sink should not assume that Channel Status bits carried in Subpackets other than Subpacket 0 will have valid data.

7.2 Audio Sample Clock Capture and Regeneration

Audio data being carried across the HDMI link, which is driven by a TMDS (video) clock only, does not retain the original audio sample clock. The task of recreating this clock at the Sink is called Audio Clock Regeneration.

There are a variety of clock regeneration methods that can be implemented in an HDMI Sink, each with a different set of performance characteristics. This specification does not attempt to define exactly how these mechanisms operate. It does however present a possible configuration and it does define the data items that the HDMI Source shall supply to the HDMI Sink in order to allow the HDMI Sink to adequately regenerate the audio clock. It also defines how that data shall be generated.

In many video source devices, the audio and video clocks are generated from a common clock (coherent clocks). In this situation, there exists a rational (integer divided by integer) relationship between these two clocks. The HDMI clock regeneration architecture can take advantage of this rational relationship and can also work in an environment where there is no such relationship between these two clocks, that is, where the two clocks are truly asynchronous or where their relationship is unknown.

Figure 7-1 Audio Clock Regeneration model, illustrates the overall system architecture model used by HDMI for audio clock regeneration. The Source shall determine the fractional relationship between the video clock and an audio reference clock (128 audio sample rate) and shall pass the numerator and denominator for that fraction to the Sink across the HDMI link. The Sink may then recreate the audio clock from the TMDS clock by using a clock divider and a clock multiplier.

The exact relationship between the two clocks will be:

$$128\ f_S = f_{TMDS\_clock}\ N / CTS.$$

The Source shall determine the value of the numerator N as specified in Section 7.2.1. Typically, this value N will be used in a clock divider to generate an intermediate clock that is slower than the 128 f_S clock by the factor N. The Source will typically determine the value of the denominator CTS (Cycle Time Stamp) by counting the number of TMDS clocks in each of the 128 f_S/N clocks.

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If there is a constant fractional relationship between these two clocks, and the two clocks are exactly synchronous, then the CTS value will quickly come to a constant value. If the clocks are asynchronous, or there is some amount of jitter between the two clocks, then the CTS value will typically alternate between two or three different values. Greater variations are possible with larger jitter.

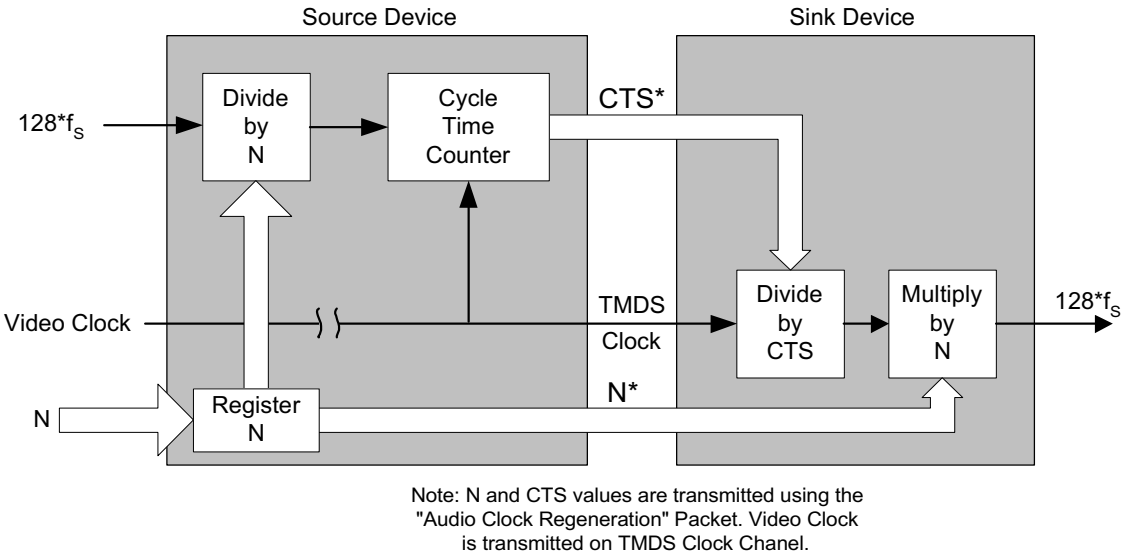


Figure 7-1 Audio Clock Regeneration model

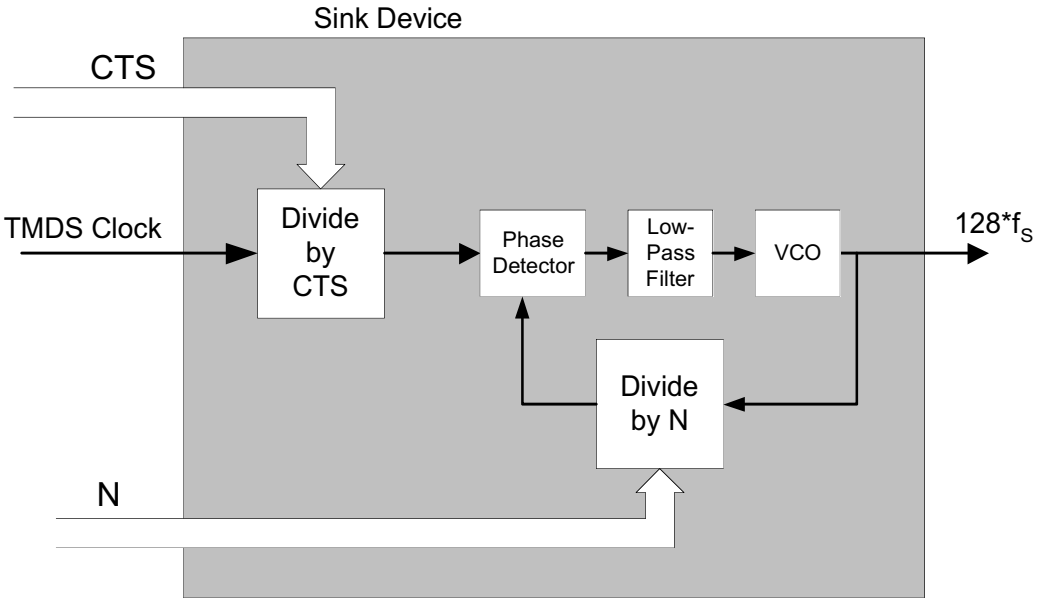


Figure 7-2 Optional Implementation: Audio Sink

It is expected that most Sinks will be implemented with an architecture similar to that shown in Figure 7-2, however, it is permitted and possible to devise an audio clock regeneration function that does not take advantage of the N or CTS values passed to the Sink.

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7.2.1 N parameter

N shall be an integer number and shall meet the following restriction:

$$128 \ f_S / 1500Hz \quad N \quad 128 \ f_S / 300Hz$$

with a recommended optimal value of

$$128 \ f_S / 1000Hz \text{ approximately equals } N$$

For coherent audio and video clock Sources, the tables below should be used to determine the value of N. For non-coherent Sources or Sources where coherency is not known, the equations above should be used.

7.2.2 CTS parameter

CTS shall be an integer number that satisfies the following:

$$\text{(Average CTS value)} = (f_{TMDS\_clock} \quad N) / (128 \quad f_S)$$

7.2.3 Recommended N and Expected CTS Values

The recommended value of N for several standard pixel clocks are given in Table 7-1, Table 7-2, and Table 7-3. It is recommended that Sources with non-coherent clocks use the values listed for a pixel clock of “Other”.

Table 7-1 Recommended N and Expected CTS for 32kHz Audio

	32 kHz	
Pixel Clock (MHz)	*N*	*CTS*
25.2 / 1.001	*4576*	*28125*
25.2	*4096*	*25200*
27	*4096*	*27000*
*27 * 1.001*	*4096*	*27027*
54	*4096*	*54000*
*54 * 1.001*	*4096*	*54054*
74.25 / 1.001	*11648*	*210937-210938**
74.25	*4096*	*74250*
148.5 / 1.001	*11648*	*421875*
148.5	*4096*	*148500*
Other	*4096*	*Measured*

*Note: This value will alternate because of restriction on N.

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Table 7-2 Recommended N and Expected CTS for 44.1kHz and Multiples

	44.1 kHz		88.2 kHz		176.4 kHz	
Pixel Clock (MHz)	N	CTS	N	CTS	N	CTS
25.2 / 1.001	7007	31250	14014	31250	28028	31250
25.2	6272	28000	12544	28000	25088	28000
27	6272	30000	12544	30000	25088	30000
27 * 1.001	6272	30030	12544	30030	25088	30030
54	6272	60000	12544	60000	25088	60000
54 * 1.001	6272	60060	12544	60060	25088	60060
74.25 / 1.001	17836	234375	35672	234375	71344	234375
74.25	6272	82500	12544	82500	25088	82500
148.5 / 1.001	8918	234375	17836	234375	35672	234375
148.5	6272	165000	12544	165000	25088	165000
Other	6272	measured	12544	measured	25088	measured

Table 7-3 Recommended N and Expected CTS for 48kHz and Multiples

	48 kHz		96 kHz		192 kHz	
Pixel Clock (MHz)	N	CTS	N	CTS	N	CTS
25.2 / 1.001	6864	28125	13728	28125	27456	28125
25.2	6144	25200	12288	25200	24576	25200
27	6144	27000	12288	27000	24576	27000
27 * 1.001	6144	27027	12288	27027	24576	27027
54	6144	54000	12288	54000	24576	54000
54 * 1.001	6144	54054	12288	54054	24576	54054
74.25 / 1.001	11648	140625	23296	140625	46592	140625
74.25	6144	74250	12288	74250	24576	74250
148.5 / 1.001	5824	140625	11648	140625	23296	140625
148.5	6144	148500	12288	148500	24576	148500
other	6144	measured	12288	measured	24576	measured

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7.3 Audio Sample Rates and Support Requirements

If an HDMI Source supports audio transmission across any output, then it shall support HDMI audio transmission. Exceptions to this rule for Sources with Type B connectors are found in Appendix B.

If an HDMI Source supports any HDMI audio transmission, then it shall support 2 channel L-PCM using an IEC 60958 Subpacket structure, with either 32kHz, 44.1kHz or 48kHz sampling rate and a sample size of 16 bits or more.

An HDMI Source is permitted to transmit L-PCM or encoded audio data at sample rates of 32kHz, 44.1kHz, 48kHz, 88.2kHz, 96kHz, 176.4kHz and 192kHz using either IEC 60958 format or IEC 61937 format.

Transmitted audio shall have an audio sample rate (f_S) within 1000 ppm of the sample rate indicated in Channel Status bits 24 through 27.

If an HDMI Sink supports audio reception across any input, then it shall support audio reception from all HDMI inputs.

An HDMI Sink that is capable of accepting any audio format is required to accept two channel IEC 60958-formatted L-PCM audio at sample rates of 32kHz, 44.1kHz, and 48kHz.

A Sink shall support the reception of an audio stream with correct sample rate indication in Channel Status bits 24 through 27 and with a sample rate (f_S) within 1000 ppm of any supported sample rate.

For EIA/CEA-861B references to Sources, “Basic Audio” is defined as two channel L-PCM audio at sample rates of 32kHz, 44.1kHz, *or* 48kHz, with a sample size of at least 16 bits. For EIA/CEA-861B references to DTV devices, “Basic Audio” is defined as two channel L-PCM audio at sample rates of 32kHz, 44.1kHz, *and* 48kHz. There is no sample size usage restriction for DTV devices.

An HDMI Sink may optionally accept audio at sample rates of 88.2kHz, 96kHz, 176.4kHz and/or 192kHz using either IEC 60958 format or IEC 61937 format, and should indicate these capabilities in the E-EDID data structure.

An HDMI Repeater shall support HDMI audio reception and transmission.

Whenever transmitting a valid audio stream, HDMI Sources shall always include valid and correct sample rate information in Channel Status bits 24 through 27 of the audio sample packets, per Table 7-4. An HDMI audio stream shall only indicate values shown in Table 7-4. Note that the allowed values do not include the IEC 60958-specified “Sample frequency not indicated” value.

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Table 7-4 Channel Status Values for Audio Sample Frequencies

Channel Status Bit Number				Sample Frequency
24	25	26	27	
1	1	0	0	32 kHz
0	0	0	0	44.1 kHz
0	0	0	1	88.2 kHz
0	0	1	1	176.4 kHz
0	1	0	0	48 kHz
0	1	0	1	96 kHz
0	1	1	1	192 kHz

In some cases, pixel-repetition may be required to increase the available bandwidth for audio transmission. For instance, when transmitting a 720x480p video format timing, it is required to pixel double in order to transmit 6 channels @ 96kHz.

7.3.1 Video Dependency

Available audio bandwidth depends upon the pixel clock frequency, the video format timing, and whether or not content protection re-synchronization is needed.

Table 7-5 shows the available audio sample rates for 2-channel (Layout 0) and 8-channel (Layout 1) audio transmission at the various video format timings specified in EIA/CEA-861B, assuming that 58 clocks of the horizontal blanking interval is required for content protection re-synchronization.

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Table 7-5 Maximum Audio Sampling Frequency for all Video Format Timings (Informative)

Description	*Format Timing*	*Pixel Repetition*	*Vertical Freq (Hz)*	*Max f_S 8 ch (kHz)*	*Max f_S 2 ch (kHz)*
60Hz Formats					
VGA	*640x480p*	*none*	*59.94/60*	*48*	*192*
480i	*1440x480i*	*2*	*59.94/60*	*48*	*192*
480i	*2880x480i*	*4*	*59.94/60*	*192*	*192*
240p	*1440x240p*	*2*	*59.94/60*	*48*	*192*
240p	*2880x240p*	*4*	*59.94/60*	*192*	*192*
480p	*720x480p*	*none*	*59.94/60*	*48*	*192*
480p	*1440x480p*	*2*	*59.94/60*	*96*	*192*
720p	*1280x720p*	*none*	*59.94/60*	*192*	*192*
1080i	*1920x1080i*	*none*	*59.94/60*	*192*	*192*
1080p	*1920x1080p*	*none*	*59.94/60*	*192*	*192*
50Hz Formats					
576i	*1440x576i*	*2*	*50*	*48*	*192*
576i	*2880x576i*	*4*	*50*	*192*	*192*
288p	*1440x288p*	*2*	*50*	*48*	*192*
288p	*2880x288p*	*4*	*50*	*192*	*192*
576p	*720x576p*	*none*	*50*	*48*	*192*
576p	*1440x576p*	*2*	*50*	*96*	*192*
720p/50	*1280x720p*	*none*	*50*	*192*	*192*
1080i/50	*1920x1080i*	*none*	*50*	*192*	*192*
1080p/50	*1920x1080p*	*none*	*50*	*192*	*192*
1080p @ 24-30Hz					
1080p	*1920x1080p*	*none*	*24*	*192*	*192*
1080p	*1920x1080p*	*none*	*25*	*192*	*192*
1080p	*1920x1080p*	*none*	*29.97/30*	*192*	*192*

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7.4 Channel / Speaker Assignment

HDMI allows a Sink to indicate the configuration of attached speakers through the use of the Speaker Allocation Data Block described in EIA/CEA-861B page 84 and Table 36.

In addition, for multi-channel L-PCM audio streams, the Source may specify the speaker assignment for each of the channels in the audio stream delivered to the Sink. EIA/CEA-861B Section 6.3.2 specifies the available speaker assignments for active audio channels on HDMI. The indication of the current speaker assignment is carried in the Audio InfoFrame.

7.5 Audio, Video Synchronization

For a variety of reasons, an HDMI link may add a delay to the audio and/or video.

An HDMI Source is required to transmit audio and video data streams with no more than ±2 msec of audio delay relative to the video. Due to the uneven transmission of audio data, the delay shall be considered to be the average delay of all of the audio sample packets over the course of 3 steady-state video frames.

7.6 Audio Data Packetization

Each Subpacket of an Audio Sample Packet shall contain zero or one IEC 60958-defined "frames" of an IEC 60958 or IEC 61937 "block." There are two defined Subpacket layouts. No others are permitted.

Table 7-6 Audio Packet Layout and Layout Value

Layout Value	Max Num Channels	Samples	Subpkt 0	Subpkt 1	Subpkt 2	Subpkt 3
0	2	4	Chnl 1,2 Sample 0	Chnl 1,2 Sample 1	Chnl 1,2 Sample 2	Chnl 1,2 Sample 3
1	8	1	Chnl 1,2 Sample 0	Chnl 3,4 Sample 0	Chnl 5,6 Sample 0	Chnl 7,8 Sample 0

There are four sample_present bits in the Audio Sample Packet Header, one for each of the Subpackets. These indicate if that Subpacket contains an audio sample.

In addition, there are four sample_flat.spX bits which are set if no useful audio data was available at the Source during the time period represented by that sample. This may occur during sample rate changes or temporary stream interruptions. When sample_flat.spX is set, Subpacket X continues to represent a sample period but does not contain useful audio data. The sample_flat.spX bit is only valid when the corresponding sample_present.spX bit is set.

Layout 0 can be used to carry up to four samples from a single IEC 61937 or from a single 2-channel IEC 60958 stream of audio.

There are only five valid configurations of sample_present bits for a Layout 0 Audio Packet. They are shown in Table 7-7.

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Table 7-7 Valid Sample_Present Bit Configurations for Layout 0

SP0	SP1	SP2	SP3	Description
0	0	0	0	No Subpackets contain samples.
1	0	0	0	Only Subpacket 0 contains a sample.
1	1	0	0	Subpackets 0 and 1 contain samples.
1	1	1	0	Subpackets 0, 1, and 2 contain samples.
1	1	1	1	All Subpackets contain samples.

Layout 1 can be used to carry one audio sample with three to eight channels of L-PCM audio (i.e. two to four IEC 60958 streams).

Valid combinations of sample_present bits for Layout 1 Audio Packets are determined by the permitted channel assignments as described in EIA/CEA-861B Section 6.3.2.

An HDMI Source shall place the data shown into the specified Subpackets and to identify the layout in the Audio Sample Packet Header.

The fields within a Subpacket with a corresponding sample_flat bit set or a sample_present bit clear, are not defined and can be any value.

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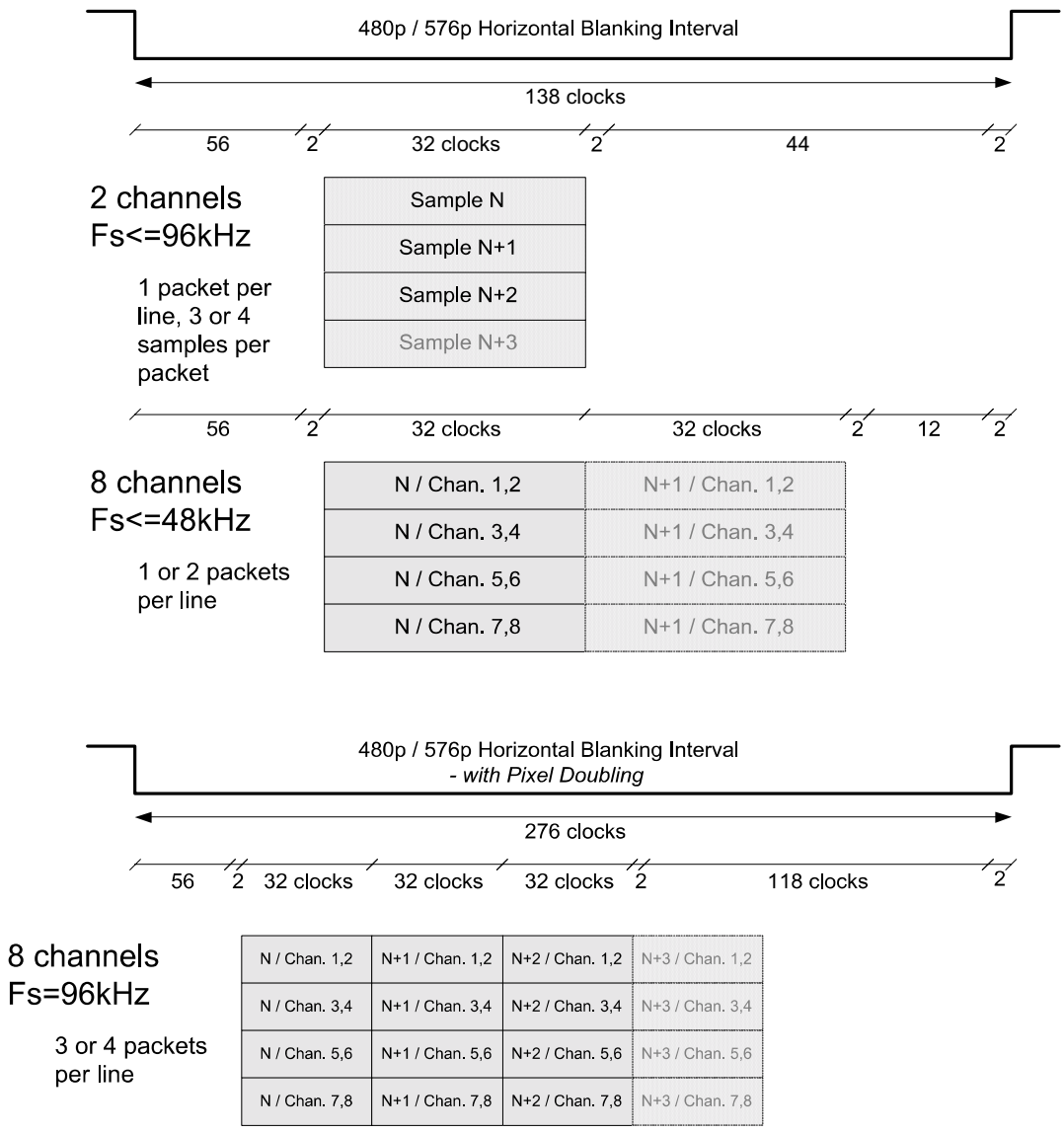


Figure 7-3 Example Audio Sample Timing (Informative)

7.7 Error Handling (Informative)

The behavior of the Sink after detecting an error is implementation-dependent. However, Sinks should be designed to prevent loud spurious noises from being generated due to errors. Sample repetition and interpolation are well known concealment techniques and are recommended.

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7.8 Packet Delivery Rules

7.8.1 Audio Sample Packets

All audio samples that are stored in a source buffer shall be sent as soon as possible while still fulfilling requirements for audio/video synchronization, and Data Island timing and placement. When using Layout 0 Audio Sample Packets, the Source shall transmit an Audio Sample Packet if at least one sample is stored in the source buffer.

Relative to an ideal constant-frequency clock, the jitter present in the Audio Sample Packet transmission timing shall not exceed one horizontal line period plus a single audio sample period.

7.8.2 Audio Clock Regeneration Packets

Nominally, Audio Clock Regeneration Packets with new (non-zero) CTS values will be transmitted at a rate of 128 f_S/N. The Source shall transmit each new CTS data value as close as possible to the nominal transmission time for that value with the exception that priority must be given to Audio Sample packets to ensure that Audio Sample Packet delivery requirements are met.

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8 Control And Configuration

8.1 Overview

HDMI includes three separate communications channels: TMDS, DDC, and the optional CEC.

TMDS is used to carry all audio and video data as well as auxiliary data, including AVI and Audio InfoFrames that describe the active audio and video streams.

The DDC channel is used by an HDMI Source to determine the capabilities and characteristics of the Sink by reading the E-EDID data structure.

HDMI Sources are expected to read the Sink's E-EDID and to deliver only the audio and video formats that are supported by the Sink. In addition, HDMI Sinks are expected to detect InfoFrames and to process the received audio and video data appropriately.

The CEC channel is optionally used for higher-level user functions such as automatic setup tasks or tasks typically associated with infrared remote control usage.

8.2 EIA/CEA-861B InfoFrames

An InfoFrame packet carries one InfoFrame. The InfoFrame provided by HDMI is limited to 30 bytes plus a checksum byte. HDMI Sources are required, in some cases, to use the AVI InfoFrame and Audio InfoFrame and recommended in other cases. Other InfoFrames specified in EIA/CEA-861B are optional.

All InfoFrames are described in detail in EIA/CEA-861B Section 6. The following describes how two of these InfoFrames are placed within the InfoFrame Packet structure and any areas where HDMI behavior is different from that specified in EIA/CEA-861B.

8.2.1 Auxiliary Video information (AVI) InfoFrame

Various aspects of the current video stream are indicated by the HDMI Source to the Sink with an Auxiliary Video information (AVI) InfoFrame.

A Source shall always transmit an AVI InfoFrame at least once per two video fields if the Source:

- is *ever* capable of transmitting an AVI InfoFrame or,
- is ever capable of transmitting YC_BC_R pixel encoding or,
- is ever capable of transmitting any video format with multiple allowed pixel repetitions.

The AVI InfoFrame shall be transmitted even while such a Source is transmitting RGB and non-pixel-repeated video. When a Source is not explicitly required to transmit an AVI InfoFrame, it is recommended that the Source transmit an AVI InfoFrame.

The packetization of the AVI InfoFrame Version 2 is shown below.

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Table 8-1 AVI InfoFrame Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	Packet Type = 0x82							
HB1	Version = 0x02							
HB2	0	0	0	Length = 13 (0x0D)				

Table 8-2 AVI InfoFrame Packet Contents

Packet Byte #	EIA/CEA-861B Byte #	7	6	5	4	3	2	1	0
PB0	N. A.	Checksum							
PB1	Data Byte 1	Rsvd (0)	Y1	Y0	A0	B1	B0	S1	S0
PB2	Data Byte 2	C1	C0	M1	M0	R3	R2	R1	R0
PB3	Data Byte 3	Reserved (0)						SC1	SC0
PB4	Data Byte 4	Rsvd (0)	VIC6	VIC5	VIC4	VIC3	VIC2	VIC1	VIC0
PB5	Data Byte 5	Reserved (0)				PR3	PR2	PR1	PR0
PB6	Data Byte 6	Line Number of End of Top Bar (lower 8 bits)							
PB7	Data Byte 7	Line Number of End of Top Bar (upper 8 bits)							
PB8	Data Byte 8	Line Number of start of Bottom Bar (lower 8 bits)							
PB9	Data Byte 9	Line Number of start of Bottom Bar (upper 8 bits)							
PB10	Data Byte 10	Pixel Number of End of Left Bar (lower 8 bits)							
PB11	Data Byte 11	Pixel Number of End of Left Bar (upper 8 bits)							
PB12	Data Byte 12	Pixel Number of End of Right Bar (lower 8 bits)							
PB13	Data Byte 13	Pixel Number of End of Right Bar (upper 8 bits)							
PB14-PB27	n. a.	Reserved (0)							

- Y0, Y1 RGB or YC_BC_R indicator. See EIA/CEA-861B table 8 for details.
- A0 Active Information Present. Indicates whether field R0…R3 is valid. See EIA/CEA-861B table 8 for details.
- B0, B1 Bar Info data valid. See EIA/CEA-861B table 8 for details.

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- S0, S1 Scan Information (i.e. overscan, underscan). See EIA/CEA-861B table 8 for details.
- C0, C1 Colorimetry (ITU BT.601, BT.709 etc.). See EIA/CEA-861B table 9 for details.
- M0, M1 Picture Aspect Ratio (4:3, 16:9). See EIA/CEA-861B table 9 for details.
- R0…R3 Active Format Aspect Ratio. See EIA/CEA-861B table 10 and Annex H for details.
- VIC0…VIC6 Video Format Identification Code. See EIA/CEA-861B table 13 for details.
- PR0…PR3 Pixel Repetition factor. See EIA/CEA-861B table 14 for details.
- SC1, SC0 Non-uniform Picture Scaling. See EIA/CEA-861B table 11 and paragraph on page 58.

Table 8-3 HDMI Valid Pixel Repeat Values for Each Format

Video Code	Video Description	EIA/CEA-861B Pixel Repeat Values	HDMI Pixel Repeat Values
1	640x480p @ 60Hz	No Repetition	No Repetition
2,3	720x480p @ 59.94/60Hz	No Repetition	No Repetition
4	1280x720p @ 59.94/60Hz	No Repetition	No Repetition
5	1920x1080i @ 59.94/60Hz	No Repetition	No Repetition
6,7	720(1440)x480i @ 59.94/60Hz	Pixel sent 2 times	Pixel sent 2 times
8,9	720(1440)x240p @ 59.94/60Hz	Pixel sent 2 times	Pixel sent 2 times
10,11	2880x480i @ 59.94/60Hz	Pixel sent 1 to 10 times	Pixel sent 1 to 10 times
12,13	2880x240p @ 59.94/60Hz	Pixel sent 1 to 10 times	Pixel sent 1 to 10 times
14,15	1440x480p @ 59.94/60Hz	No Repetition	Pixel sent 1 to 2 times**
16	1920x1080p @ 59.94/60Hz	No Repetition	No Repetition
17,18	720x576p @ 50Hz	No Repetition	No Repetition
19	1280x720p @ 50Hz	No Repetition	No Repetition
20	1920x1080i @ 50Hz	No Repetition	No Repetition
21,22	720(1440)x576i @ 50Hz	Pixel sent 2 times	Pixel sent 2 times
23,24	720(1440)x288p @ 50Hz	Pixel sent 2 times	Pixel sent 2 times
25,26	2880x576i @ 50Hz	Pixel sent 1 to 10 times	Pixel sent 1 to 10 times
27,28	2880x288 @ 50Hz	Pixel sent 1 to 10 times	Pixel sent 1 to 10 times
29,30	1440x576p @ 50Hz	No Repetition	Pixel sent 1 to 2 times**
31	1920x1080p @ 50Hz	No Repetition	No Repetition
32	1920x1080p @ 23.97/24Hz	No Repetition	No Repetition
33	1920x1080p @ 25Hz	No Repetition	No Repetition
34	1920x1080p @ 29.97/30Hz	No Repetition	No Repetition

** - Denotes change from EIA/CEA-861B valid values. Pixel repetition is required to support some audio formats at 720x480p and 720x576p video format timings. See Section 0

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8.2.2 Audio InfoFrame

A Source shall indicate characteristics of the active audio stream using the IEC 60958 Channel Status bits, IEC 61937 Burst Info and stream data (if present) and the Audio InfoFrame. Whenever an active audio stream is being transmitted, an accurate Audio InfoFrame shall be transmitted at least once per two video fields.

Upon the start of a new audio stream or upon any change in the audio stream that can be indicated by the Audio InfoFrame, a modified, accurate Audio InfoFrame shall be transmitted no later than one video field following the first affected non-silent audio sample. Preferably, this would occur just before the first affected audio sample is transmitted.

The Audio InfoFrame transmission may occur at any time that a Data Island packet may be transmitted, including during any horizontal or vertical blanking period.

The following tables show the packetization of the Audio InfoFrame.

Table 8-4 Audio InfoFrame Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	Packet Type = 0x84							
HB1	Version Number = 0x01							
HB2	0	0	0	Length = 10 (0x0A)				

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Table 8-5 Audio InfoFrame Packet contents

Packet Byte #	EIA/CEA-861B Byte #	7	6	5	4	3	2	1	0
PB0	n. a.	checksum							
PB1	Data Byte 1	CT3	CT2	CT1	CT0	Rsvd	CC2	CC1	CC0
PB2	Data Byte 2	Reserved (0)			SF2	SF1	SF0	SS1	SS0
PB3	Data Byte 3	Format depends on coding type (i.e. CT0…CT3)							
PB4	Data Byte 4	CA7	CA6	CA5	CA4	CA3	CA2	CA1	CA0
PB5	Data Byte 5	DM_INH	LSV3	LSV2	LSV1	LSV0	Reserved (0)		
PB6	Data Byte 6	Reserved (0)							
PB7	Data Byte 7	Reserved (0)							
PB8	Data Byte 8	Reserved (0)							
PB9	Data Byte 9	Reserved (0)							
PB10	Data Byte 10	Reserved (0)							
PB11-PB27	n. a.	Reserved (0)							

- CC0…CC2 Channel Count. See EIA/CEA-861B table 19 for details.
- CT0…CT3 Coding Type. See EIA/CEA-861B table 19 for details. The CT bits shall always be set to a value of 0, 0, 0, 0 (“Refer to Stream Header”). This value signifies that the Coding Type is indicated in the IEC 60958 Channel Status bits and/or the IEC 61937 Burst Info.
- SS0…SS1 Sample Size. See EIA/CEA-861B table 20 for details. The SS bits shall always be set to a value of 0, 0 (“Refer to Stream Header”).
- SF0…SF2 Sample Frequency. See EIA/CEA-861B table 20 for details. The SF bits shall always be set to a value of 0, 0, 0 (“Refer to Stream Header”).
- CA0…CA7 Channel/Speaker Allocation. See EIA/CEA-861B Section 6.3.2 for details.
- LSV0…LSV3 Level Shift Value (for downmixing). See EIA/CEA-861B Section 6.3.2 and EIA/CEA-861B table 23 for details.
- DM_INH Downmix Inhibit. See EIA/CEA-861B Section 6.3.2 and table 24 for details. The DM_INH field is to be set only for DVD-Audio applications and corresponds to the value in the DM_INH field of the current audio stream being played from the disk. The DM_INH field value shall be set to zero in all cases other than DVD-Audio applications.

Data Byte 3 shall always be set to a value of 0.

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8.3 E-EDID Data Structure

All Sinks shall contain an EIA/CEA-861B compliant E-EDID data structure accessible through the DDC.

A Source shall read the EDID 1.3 and first CEA EDID Timing Extension to determine the capabilities supported by the Sink. Additional extensions may be read to discover additional capabilities. The Source is responsible for any format conversions that may be necessary to supply audio and video in an understandable form to the Sink. However, it is permitted for a Source to transmit Basic Audio (see Section 7.3) to a Sink that does not indicate support for Basic Audio.

The overall structure of the E-EDID in the Sink shall conform to the E-EDID structure defined in the VESA E-EDID Standard Release A, Revision 1, but shall also meet the additional requirements specified herein.

The first 128 bytes of the E-EDID shall contain an EDID 1.3 structure. The contents of this structure shall also meet the requirements of EIA/CEA-861B.

8.3.1 EDID Timing Extension

The first E-EDID 'extension' shall contain a CEA EDID Timing Extension version 3, defined in EIA/CEA-861B section 7.5. Additional CEA EDID Timing Extensions may also be present. The E-EDID shall not contain an EDID Timing Extension version 1 or version 2.

EDID Timing Extension version 3 details are described in EIA/CEA-861B Section 7.5.

Further details on the requirements of the data structures in the E-EDID and implementation examples are given in EIA/CEA-861B.

8.3.2 HDMI Vendor-Specific Data Block (HDMI VSDB)

The first CEA EDID Timing Extension shall include an HDMI Vendor Specific Data Block (HDMI VSDB) shown in Table 8-6. This is an EIA/CEA-861B Vendor Specific Data Block (see EIA/CEA-861B tables 30, 31 and 32 for details) containing a 24-bit IEEE Registration Identifier of 0x000C03, a value belonging to HDMI Licensing, LLC.

Sinks shall contain an HDMI VSDB minimally containing a 2-byte Source Physical Address field following the 24-bit identifier. An HDMI VSDB may have zero or more extension fields as shown in Table 8-6. The minimum value of N (length) is 5 and the maximum value of N is 31. A Sink that supports any function indicated by an extension field shall use an HDMI VSDB with a length sufficient to cover all supported fields.

The Source shall have the ability to handle an HDMI VSDB of any length. In future specifications, new fields may be defined. These additional fields will be defined such that a zero value indicates the same characteristics as is indicated if the field was not present. Sources should use the length field to determine which extension fields are present, and shall process the HDMI VSDB with no regard to non-zero values in fields defined as Reserved in this specification.

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Table 8-6 HDMI-LLC Vendor-Specific Data Block (HDMI VSDB)

Byte #	7	6	5	4	3	2	1	0
0	Vendor-specific tag code (=3)				Length (=N)			
1	24-bit IEEE Registration Identifier (0x000C03) (least significant byte first)							
2								
3								
4	A				B			
5	C				D			
6	Supports_AI	Reserved (0)						
7…N-1	Reserved (0)							
N	Reserved (0)							

extension fields

- A, B, C, D [4 bits each] Components of Source Physical Address (A.B.C.D). See Section 8.7.
- Supports_AI [1 bit] Set to 1 if the Sink supports at least one function that uses information carried by the ACP, ISRC1, or ISRC2 packets. If Supports_AI is set (=1), then the Sink shall accept and process any ACP, ISRC1 or ISRC2 packet with no regard to non-zero values in fields defined as Reserved in this specification and shall receive, with no adverse effects, ACP packets with values in the ACP_Type field not defined in this specification. If the Sink does not support ACP, ISRC1 or ISRC2 packets, Supports_AI shall be clear (=0).

8.3.3 DVI/HDMI Device Discrimination

In order to determine if a sink is an HDMI device, an HDMI Source shall check the E-EDID for the presence of an HDMI Vendor Specific Data Block within the first CEA EDID Timing Extension. Any device with an HDMI VSDB of any valid length, containing the IEEE Registration Identifier of 0x000C03, shall be treated as an HDMI device.

Any device with an E-EDID that does not contain an HDMI VSDB of any valid length shall be treated by the Source as a DVI device (see Appendix C).

8.3.4 Audio and Video Details

Sink audio characteristics and support are indicated in the E-EDID. This data includes a list of audio encodings supported by the Sink and parameters associated with each of those encodings.

A Sink may indicate support for YC_BC_R pixel encodings. To indicate support, bits 4 and 5 of byte 3 of the EDID Timing Extension shall both be set to one (see Table 29 of EIA/CEA-861B). To indicate no support, bits 4 and 5 shall both be zero.

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If a Sink is required to support a particular video format, video format timing, or pixel encoding, then the Sink shall indicate support for that video format, video format timing or pixel encoding in the E-EDID.

8.4 Enhanced DDC

Enhanced DDC described in this section is defined in VESA “ENHANCED DISPLAY DATA CHANNEL STANDARD Version 1 (September 2, 1999)”. All Sinks are required to support these enhanced DDC features. If a Sink’s E-EDID structure is longer than 256 bytes, it shall support the segment pointer.

8.4.1 Timing

Data is synchronized with the SCL signal and timing shall comply with the Standard Mode of the I^2C specification (100kHz clock).

I^2C Bus is a standard two-wire (clock and data) serial data bus protocol. Refer to the I^2C specification for details.

Note that an HDMI Sink may hold off the DDC transaction by stretching the SCL line during the SCL-low period following the Acknowledge bit as permitted by the I^2C specification. All HDMI Sources shall delay the DDC transaction while the SCL line is being held low.

8.4.2 Data Transfer Protocols

The Source shall use I^2C commands to read information from a Sink’s E-EDID with a slave address.

In Enhanced DDC, a segment pointer is used to allow addressing of the E-EDID outside of the normal 256-byte limit of the 0xA0/0xA1 address. The Enhanced DDC protocol sets the segment pointer before the remainder of the DDC command.

8.4.3 Segment pointer

Enhanced DDC allows access of up to 32 Kbytes of data. This is accomplished using a combination of the 0xA0/0xA1 address pair and a segment pointer. For each value of the segment pointer, 256 bytes of data are available at the 0xA0/0xA1 address pair. An unspecified segment pointer references the same data as when the segment pointer is zero.

Each successive value of the segment pointer allows access to the next two blocks of E-EDID (128 bytes each). The value of the segment pointer register cannot be read since it is reset at the completion of each command.

8.4.4 Enhanced DDC Sink

The Sink shall be Enhanced DDC read compliant.

The Sink shall be capable of responding with EDID 1.3 data and up to 255 extension blocks, each 128 bytes long (up to 32K bytes total E-EDID memory) whenever the Hot Plug Detect signal is asserted.

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The Sink should be capable of providing E-EDID information over the Enhanced DDC channel whenever the +5V Power signal is provided. This should be available within 20msec after the +5V Power signal is provided.

8.4.5 Enhanced DDC Source

The Source shall use Enhanced DDC protocols.

The Source shall be capable of reading EDID 1.3 data at DDC address 0xA0.

The Source reads Enhanced EDID extensions data at DDC address 0xA0 using segment pointer 0x60.

8.5 Hot Plug Detect Signal

An HDMI Sink shall not assert high voltage level on its Hot Plug Detect pin when the E-EDID is not available for reading. This requirement shall be fulfilled at all times, even if the Sink is powered-off or in standby. The Hot Plug Detect pin may be asserted only when the +5V Power line from the Source is detected. This will ensure that the Hot Plug Detect pin is not asserted before the Third Make of the connector (see Section 4.1.5).

A Source may use a high voltage level Hot Plug Detect signal to initiate the reading of E-EDID data.

A Source shall assume that any voltage within the range specified for High voltage level in Table 4-23 indicates that a Sink is connected and that E-EDID is readable. It does not indicate whether or not the Sink is powered or whether or not the HDMI input on the Sink is selected or active.

An HDMI Sink shall indicate any change to the contents of the E-EDID by driving a low voltage level on the Hot Plug Detect pin for at least 100 msec.

8.6 Consumer Electronics Control (CEC)

The CEC line is used for high-level user control of HDMI-connected devices. The mandatory requirements for the CEC line are described in detail in Section 4.2.10, CEC Line. The optional CEC protocol is described in Supplement 1: Consumer Electronics Control (CEC).

8.7 Physical Address

8.7.1 Overview

In order to allow CEC to be able to address specific physical devices and control switches, all devices must have a physical address. This connectivity has to be worked out whenever a new device is added to the cluster. The physical address discovery process uses only the DDC/EDID mechanism and applies to all HDMI Sinks and Repeaters, not only to CEC-capable devices.

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The CEC and DDC connections are shown in Figure 8-1.

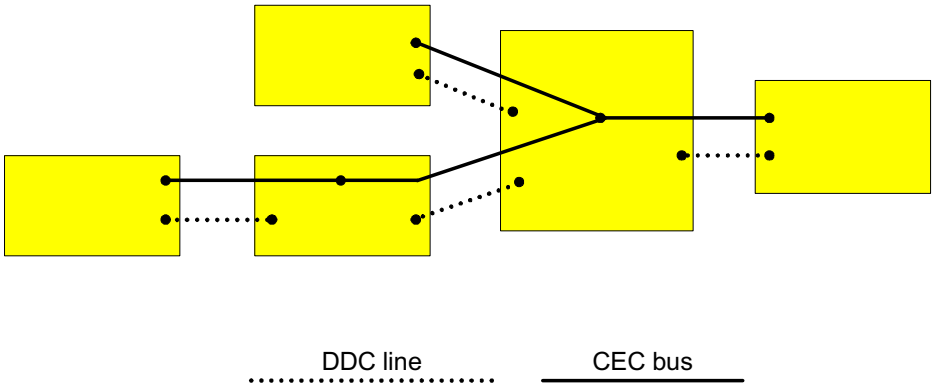


Figure 8-1 CEC and DDC line connections

The CEC line is directly connected to all nodes on the network.

After discovering their own physical address, the CEC devices transmit their physical and logical addresses to all other devices, thus allowing any device to create a map of the network.

8.7.2 Physical Address Discovery

The physical address of each node is determined through the physical address discovery process. This process is dynamic in that it automatically adjusts physical addresses as required as devices are physically or electrically added or removed from the device tree.

All Sinks and Repeaters shall perform the steps of physical address discovery and propagation even if those devices are not CEC-capable. Sources are not required to determine their own physical address unless they are CEC-capable.

All addresses are 4 digits long allowing for a 5–device-deep hierarchy. All are identified in the form of n.n.n.n in the following description. An example of this is given in Figure 8-3.

A Sink or a Repeater that is acting as the CEC root device will generate its own physical address: 0.0.0.0. A Source or a Repeater reads its physical address from the EDID of the connected Sink. The CEC line may be connected to only one HDMI output so a device with multiple HDMI outputs will read its physical address from the EDID on the CEC-connected output. Each Sink and Repeater is responsible for generating the physical address of all Source devices connected to that device by appending a port number onto its own physical address and placing that value in the EDID for that port. The Source Address Field of the HDMI Vendor Specific Data Block (see Section 8.3.2) is used for this purpose.

Note that the values shown in the figures below represent the physical addresses for the devices themselves, not the Source physical addresses stored in the EDID within that device. In fact, for all devices shown, except the TV, those physical addresses are stored in the EDID of the connected Sink. An example is shown for the TV at physical address 0.0.0.0.

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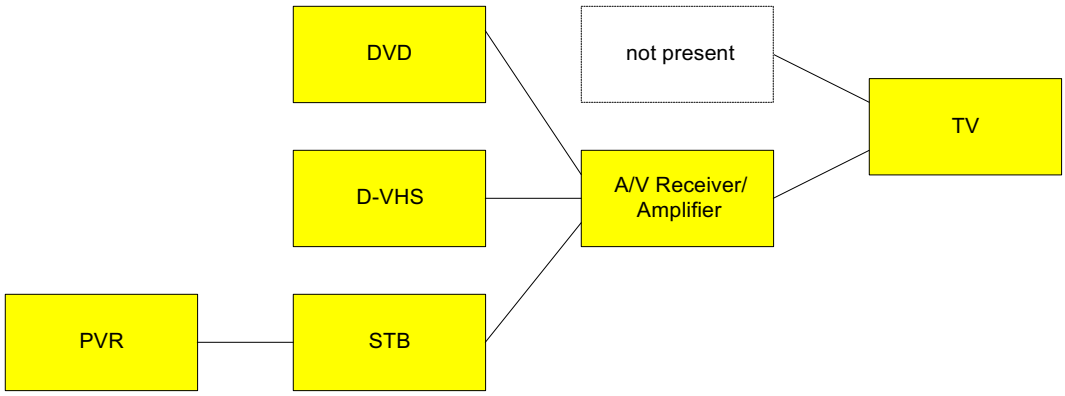


Figure 8-2 Typical HDMI cluster

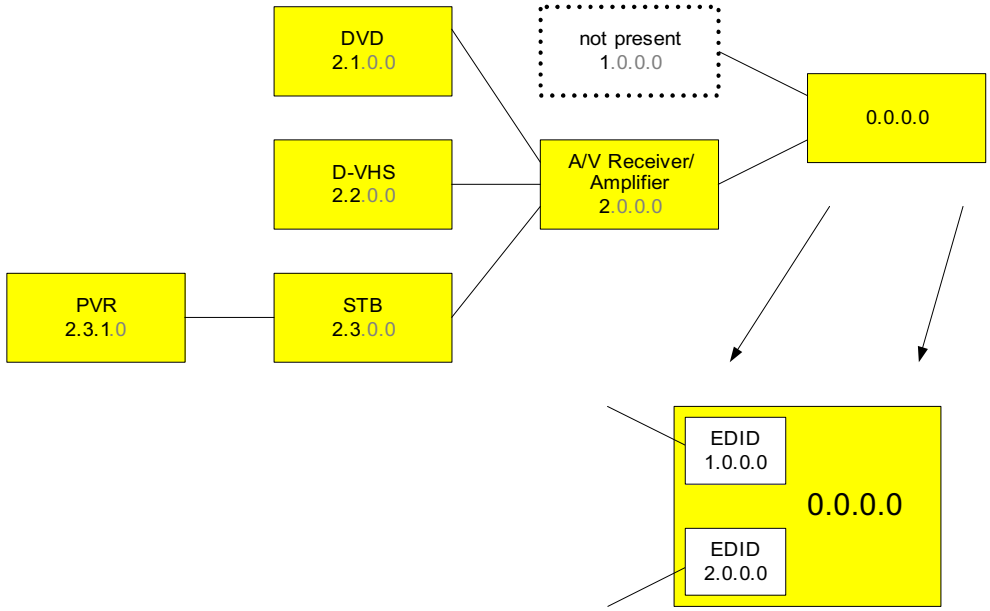


Figure 8-3 Addresses within an HDMI cluster

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8.7.3 Discovery Algorithm

The following algorithm is used to allocate the physical address of each device whenever HPD is de-asserted or upon power-up:

```
Disable assertion of HPD to all source devices
If I am root
    Set my_address to 0.0.0.0
Else
    Wait for HPD from sink
    Query sink for my_address of my connection (Section 8.7.4)
    The device shall retain this physical address until HPD is
        removed (or the device is powered off).
End if
If device has connections for source devices then
    Label all possible connections to source devices uniquely starting
        from connection_label = 1 to the number of source input connections
    If device has separate EDIDs for each source connection then
        If my_address ends with 0 then
            Set each source_physical_address to my_address with the
                first 0 being replaced with connection_label.
        Else (i.e. beyond the fifth layer of the tree)
            Set each source_physical_address to F.F.F.F
        End if
    Else
        Set each source_physical_address to my_address
    End if
    Write source_physical_address to HDMI VSDB in EDID for each source
        connection
End if
Allow HPD to be asserted for source devices
```

8.7.4 HDMI Sink Query

A Source shall determine its physical address (my_address) by checking the HDMI Vendor Specific Data Block (see Section 8.3.2) within the EDID. The fourth and fifth bytes of this 5 byte structure contain the Source Physical Address (fields A, B, C, D).

8.8 ISRC Handling

A Source shall not transmit an ISRC1 or ISRC2 Packet to a Sink that does not have Supports_AI = 1.

A Source may handle an International Standard Recording Code (ISRC) and/or UPC/EAN describing the origin or owner details for each track of content on the medium. These values may be transmitted using the ISRC1 and ISRC2 packets.

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When fields UPC_EAN_ISRC_16 through 31 include effective data (i.e. not "reserved"), a subsequent ISRC2 Packet shall be transmitted. In other cases, the ISRC2 packet may optionally be transmitted.

When a subsequent ISRC2 Packet is transmitted, the ISRC_Cont field shall be set and shall be clear otherwise.

For further description of the UPC_EAN_ISRC fields, see "DVD Specifications for Read-Only Disc", Part 4: AUDIO SPECIFICATIONS Version 1.0, March 1999, Annex B".

Regarding usage of the ISRC_Status field, Source shall comply with "DVD Specifications for Read-Only Disc", "Part 4: AUDIO SPECIFICATIONS", Version-up Information (from 1.1 to 1.2), Table 7.2.3.1.1-2, May 2000. Following is a summary of the relevant rules from that specification:

- At the beginning of each track, at least two complete UPC_EAN_ISRC codes are transmitted with an ISRC_Status of 0b001.
- During the bulk of the track, continuous repetitions of the packet(s) are required, with an ISRC_Status of 0b010.
- Immediately before the end of each track, at least two complete UPC_EAN_ISRC codes are transmitted with an ISRC_Status of 0b100.

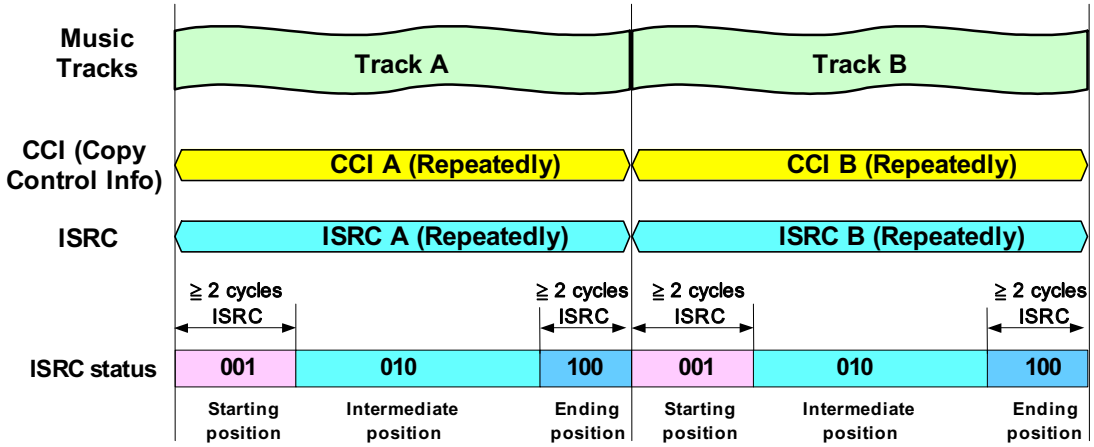


Figure 8-4 ISRC/CCI and ISRC Status Handling

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9 Content Protection

9.1 Recommendation

Content protection capability is recommended for all HDMI compliant devices. An HDMI compliant Source should protect all of the protected audiovisual data. Amongst adequate copy protection technologies that are compatible with HDMI, HDCP is available.

9.2 HDCP Implementations

HDCP implementations for HDMI shall adhere to HDCP specification version 1.10.

9.3 Usage of Audio Content Protection (ACP) Packets

A Source may use the ACP Packet to convey content-related information regarding the active audio stream.

Non-transmission of ACP Packets should be considered equivalent to transmission of an ACP Packet with an ACP_Type field of 0. If a Sink does not receive an ACP Packet within 600msecs, it shall revert to ACP_Type = 0 behavior.

Whenever a Source is required by other license agreements or specifications to transmit information related to the content protection requirements of the active audio stream, ACP Packets shall be transmitted at least once per 300msecs and an appropriate ACP_Type value shall be set.

When transmitting ACP Packets, upon the start of a new audio stream or upon any change in the audio stream that can be indicated by the ACP Packet, a modified, accurate ACP Packet shall be transmitted no later than 300msec following the transmission of the affected or relevant audio sample.

The ACP Packet transmission may occur at any time that a Data Island packet may be transmitted.

A Source shall not transmit an ACP Packet to a Sink that does not have Supports_AI = 1.

9.3.1 Requirements for Sink

A Sink that has any type of audio output and/or audio recording function shall be capable of receiving and appropriately handling the ACP Packet even if the Sink does not support any audio rendering functionality.

Whenever an HDCP-capable Sink detects an ACP Packet, it shall comply with the HDCP Audio Compliance Rules.

Whenever an HDCP-capable Sink detects an ACP Packet with an unknown ACP_type value, it shall comply with the HDCP Audio Compliance Rules for undefined content.

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9.3.2 Requirements for Repeater

Any content that is received by a Repeater and is accompanied by an ACP Packet shall be accompanied with an identical ACP Packet upon transmission to any Sink with Supports_AI = 1.

9.3.3 Application To Generic Audio

With regards to the control of copying and audio output permissions, transmission of an ACP Packet with an ACP_Type field of 0 is equivalent to no transmission of an ACP Packet.

ACP_Type = 0 : Generic Audio

ACP_Type_Dependent fields all Reserved (0).

9.3.4 Application To IEC 60958-Identified Audio

A Source may indicate that the Sink must support the proper output of SCMS bits by setting ACP_Type = 1 (Type 1 = IEC 60958-identified).

ACP_Type = 1 : IEC 60958-identified

ACP_Type_Dependent fields all Reserved (0).

9.3.5 Application To DVD-Audio

Whenever a Source is transmitting DVD-Audio content, an accurate ACP Packet, with ACP_Type = 2 shall be transmitted at least once per 300msec.

The UPC/EAN and/or ISRC values are recorded on the DVD-Audio disc with DVD audio data. When the Source transmits UPC/EAN and/or ISRC using ISRC packet, the time lag between the ISRC packet and the corresponding audio sample packet should be minimized.

ACP_Type = 2 : DVD-Audio

ACP_Type_Dependent Usage:

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Table 9-1 ACP_Type Dependent Fields for DVD-Audio Application

Packet Byte #	7	6	5	4	3	2	1	0
PB0	DVD-Audio_Type_Dependent_Generation							
PB1	Copy_Permission		Copy_Number			Quality		Transaction
PB2	Reserved (0)							
: :								
PB27								

- DVD-Audio_Type_Dependent_Generation [8 bits] Identifies the generation of the DVD-Audio-specific ACP_Type_Dependent fields. Shall be set to 1. In the future version of this specification, currently reserved field(s) may be used to carry additional information. In such case, the value of this field may be incremented.
- Copy_Permission [2 bits] audio_copy_permission parameter.
- Copy_Number [3 bits] audio_copy_number parameter.
- Quality [2 bits] audio_quality parameter.
- Transaction [1 bit] audio_transaction parameter.

See “DVD Specifications for Read-Only Disc, Part 4: AUDIO SPECIFICATIONS”, Version 1.2, Table 7.2.3.1.1-2”, and “Supplement to Part 4: AUDIO SPECIFICATIONS Version 1.2 (February 2004)” for descriptions and use of the fields: audio_copy_permission, audio_copy_Number, audio_quality, and audio_transaction.

Any Source that supports DVD-Audio transmission on HDMI shall have the ability to transmit all valid channels of any multi-channel content.

9.3.6 Application To Future CP Types

Future ACP_Type values may be defined in the HDCP license agreement and may be required by future source content license agreements.

Support for Super Audio CD will be defined in a future version of this specification.

ACP_Type = 3 : Reserved for Super Audio CD (SACD)

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Appendix A Repeater

A.1 Repeater Functions

A Repeater is defined as a device with one or more HDMI inputs, one or more HDMI outputs, and a retransmission function.

A Repeater has at least one of following functions:

- Repeat function:
  Single-input, single-output devices. Used primarily for cable extension.
- Switch function:
  Multiple-input, single-output devices. Used primarily to select among multiple Sources.
- Distributor function:
  Single-input, multiple-output devices, where only one output is active. Used primarily to select among multiple displays or Sinks.
- Duplicator function:
  Single-input, multiple-output devices, where more than one output is active. Used for signal distribution.

Combinations of the above, for instance, multiple-input, multiple-output devices, incorporating both input selection and output selection or signal distribution are allowed.

In all cases, each HDMI input shall fulfill all of the requirements of an HDMI Sink when it is connected with an active sink device, and each HDMI output shall fulfill all of the requirements of an HDMI Source when it is connected with an active source.

The E-EDID presented by a Repeater should reflect the capabilities of the downstream Sink.

A.2 E-EDID Read Timing (Informative)

In terms of E-EDID handling, Repeaters will typically fall into one of the following categories.

- Stored E-EDID type: The Repeater stores an E-EDID data structure that typically consists of downstream Sink capabilities.
- Forwarding type: The Repeater does not store an E-EDID data structure. When an E-EDID read request comes from a Source, the Repeater forwards the read request to a Sink. The E-EDID data from the Sink is then forwarded back to the Source.

An HDMI cluster may have several Repeaters between a Source and a Sink. To minimize the impact to the E-EDID reading time, each Repeater in the chain should minimize the added delay.

For example, the delay added by a Forwarding type Repeater should be no more than 4 msec per 16-byte read.

A stored E-EDID type Repeater should be able to send a 256 byte E-EDID within 150 msec when a Source issues sixteen 16-byte read requests. This means that a 16-byte read request would be completed within approximately 10 msec.

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Appendix B Type B Connector Usage

B.1 Exception To Audio Format Support Requirement

Sources are not required to carry audio when all of the following conditions are met:

- Source is required by the HDMI Specification or associated agreements to use the Type B connector, and,
- Source has alternate default or user selectable audio outputs, and,
- Source can ensure that the appropriate audio stream is being delivered to the alternate audio outputs.

In order to guarantee rendering of video from Sources that do not fully support HDMI audio, the following condition shall be met:

- Sinks that are capable of supporting an HDMI video format when it is accompanied by audio shall also support that format when it is not accompanied by audio.

It is strongly recommended that a display device, when receiving an HDMI video signal without audio, temporarily indicate to the user that there is no audio accompanying the stream.

B.2 HDMI Dual-Link Architecture

HDMI dual-link architecture is compatible with DVI 1.0 dual-link architecture. Refer to section 3.1.5 of the DVI 1.0 specification.

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Appendix C Compatibility With DVI

C.1 Requirement for DVI Compatibility

All HDMI Sources shall be compatible with DVI 1.0 compliant sink devices (i.e. “monitors” or “displays”) through the use of a passive cable converter. Likewise, all HDMI Sinks shall be compatible with DVI 1.0 compliant sources (i.e. “systems” or “hosts”) through the use of a similar cable converter.

When communicating with a DVI device, an HDMI device shall operate according to the DVI 1.0 specification, with the following exception – these devices are not required to comply with DVI 1.0 rules regarding:

- Monitor scaling requirements [refer to Section 2.2.8.2 of the DVI specification – superceded by HDMI specifications]
- Physical Interconnect specifications [refer to Chapter 5 of the DVI specification – superceded by HDMI specifications]
- System Low Pixel Format Support Requirements [refer to Section 2.2.4 of the DVI specification – superceded by HDMI specifications]

Furthermore, for HDMI devices that would not otherwise have a “BIOS” or “operating system” there are the following additional exceptions:

- “BIOS” requirements [refer to Section 2.2.4 of the DVI specification]
- “Operating system” requirements [refer to Section 2.2.2 and Section 2.2.9 of the DVI specification]
- “System level event” requirements [refer to Section 2.2.9.1 of the DVI specification]
- Power management requirements [refer to Section 2.4 of the DVI specification]

C.2 HDMI Source Requirements

When communicating with a DVI sink device, an HDMI Source shall operate in a mode compatible with that device. This requires that the Source operate under the following limitations:

- Video pixel encoding shall be RGB.
- No Video Guard Bands shall be used.
- No Data Islands shall be transmitted.

An HDMI Source may transmit Video Data Periods without Guard Bands only when communicating to a DVI sink device or during the process of determining if the sink device is HDMI capable.

An HDMI Source, upon power-up, reset or detection of a new sink device, shall assume that the sink device operates under DVI 1.0 limitations. An HDMI Source shall determine if the sink device is an HDMI Sink by following the rule(s) described in Section 8.3.3. Upon detection of an HDMI Sink, the HDMI Source shall follow all of the HDMI Source-related requirements specified in this document.

All electrical and physical specifications in Section 4 shall be followed by the HDMI Source even when communicating with a DVI sink device.

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C.3 HDMI Sink Requirements

When connected to a DVI source device, an HDMI Sink shall operate as a DVI 1.0 compliant sink with the exceptions outlined in Section C.1 above.

A DVI source device will always be restricted in the following ways:

- Only RGB pixel encoding is used.
- There is no Guard Band on the Video Data Period.
- There are no Data Islands transmitted.

An HDMI Sink, upon power-up, reset or detection of a new source device, shall assume that the source device is limited to the above behavior. Upon the detection of an indication that the source is HDMI-capable, the HDMI Sink shall follow all of the HDMI Sink-related requirements specified in this document.

All electrical and physical specifications in Section 4 of the HDMI Specification shall be followed by the HDMI Sink even when communicating with a DVI source device.

C.4 Type A to DVI Adapter Cable [Informative]

Table C-2 Wire Categories

Category	Description
A	TMDS Signal Wire
B	TMDS Shield
C	Control
D	Control Ground
N.C.	No connect (no wire)
5V	5 Volts Power Wire

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Table C-3 Type A-to-DVI-D Cable Wire Assignment [Informative]

Type A pin	*Signal Name*	*Wire*	*DVI-D pin*
1	*TMDS Data2+*	*A*	*2*
2	*TMDS Data2 Shield*	*B*	*3*
3	*TMDS Data2–*	*A*	*1*
4	*TMDS Data1+*	*A*	*10*
5	*TMDS Data1 Shield*	*B*	*11*
6	*TMDS Data1–*	*A*	*9*
7	*TMDS Data0+*	*A*	*18*
8	*TMDS Data0 Shield*	*B*	*19*
9	*TMDS Data0–*	*A*	*17*
10	*TMDS Clock+*	*A*	*23*
11	*TMDS Clock Shield*	*B*	*22*
12	*TMDS Clock–*	*A*	*24*
15	*SCL*	*C*	*6*
16	*DDC Data*	*C*	*7*
17	*DDC/CEC Ground*	*D*	*15*
18	*+5V Power*	*5V*	*14*
19	*Hot Plug Detect*	*C*	*16*
13	*CEC*	*N.C.*	
14	*Reserved (in cable but N.C. on device)*	*N.C.*	
	TMDS Data 4-	*N.C.*	*4*
	TMDS Data 4+	*N.C.*	*5*
	TMDS Data 3-	*N.C.*	*12*
	TMDS Data 3+	*N.C.*	*13*
	TMDS Data 5-	*N.C.*	*20*
	TMDS Data 5+	*N.C.*	*21*
	No Connect	*N.C.*	*8*

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C.5 Type B to DVI Adapter Cable [Informative]

Table C-4 Type B to DVI-D Cable Wire Assignment [Informative]

Type B pin	*Pin Assignment*	*Wire*	*DVI-D pin*
1	*TMDS Data2+*	*A*	*2*
2	*TMDS Data2 Shield*	*B*	*3*
3	*TMDS Data2-*	*A*	*1*
4	*TMDS Data1+*	*A*	*10*
5	*TMDS Data1 Shield*	*B*	*11*
6	*TMDS Data1-*	*A*	*9*
7	*TMDS Data0+*	*A*	*18*
8	*TMDS Data0 Shield*	*B*	*19*
9	*TMDS Data0-*	*A*	*17*
10	*TMDS Clock+*	*A*	*23*
11	*TMDS Clock Shield*	*B*	*22*
12	*TMDS Clock-*	*A*	*24*
13	*TMDS Data5+*	*A*	*21*
14	*TMDS Data5 Shield*	*B*	*19*
15	*TMDS Data5-*	*A*	*20*
16	*TMDS Data4+*	*A*	*5*
17	*TMDS Data4 Shield*	*B*	*3*
18	*TMDS Data4-*	*A*	*4*
19	*TMDS Data3+*	*A*	*13*
20	*TMDS Data3 Shield*	*B*	*11*
21	*TMDS Data3-*	*A*	*12*
25	*SCL*	*C*	*6*
26	*DDC Data*	*C*	*7*
27	*DDC/CEC Ground*	*D*	*15*
28	*+5V Power*	*5V*	*14*
29	*Hot Plug Detect*	*C*	*16*
22	*CEC*	*N.C.*	
23	*Reserved*	*N.C.*	
24	*Reserved*	*N.C.*	
	No Connect	*N.C.*	*8*

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Supplement 1
Consumer Electronics Control (CEC)

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CEC 1 Introduction

CEC is a protocol that provides high-level control functions between all of the various audiovisual products in a user's environment. This appendix describes the CEC protocol in the following order:

- An overview of the recommended features available in CEC.
- A Low Level Protocol Definition - Includes the electrical specification, signaling and bit timings and the frame description.
- A High Level Protocol Definition - Includes a detailed feature breakdown and individual message descriptions.

CEC 1.1 Normative references

[1n] ISO 639-1 Code for the representation of names of languages - Part 1: Alpha 2 code
http://xml.coverpages.org/languageIdentifiers.html - iso639

[2n] ITU-T E.164 – definition of country codes

CEC 1.2 Informative References

[1i] CENELEC, EN 50049-1:1997/A1:1998, Domestic and similar electronic equipment interconnection requirements: Peritelevision connector

[2i] CENELEC, EN 50157, Domestic and similar electronic equipment interconnection requirements: AV.link

EN 50157-1 : Part 1
EN 50157-2-1 : Part 2-1
EN 50157-2-2 : Part 2-2
EN 50157-2-3 : Part 2-3

[3i] IEEE std. 1394-1995 HIGH PERFORMANCE SERIAL BUS section 8.3.2.5.1 – example use of Company_id.

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CEC 2 Definitions

CEC 2.1 Conformance Levels

Because CEC is optional, the conformance level in this appendix is only effective when the device supports CEC. For example, the word "shall" indicates a mandatory requirement for the CEC supporting devices. However, within the Features section (CEC 13) "shall" only indicates a requirement if the feature is implemented.

CEC 2.2 Glossary of Terms

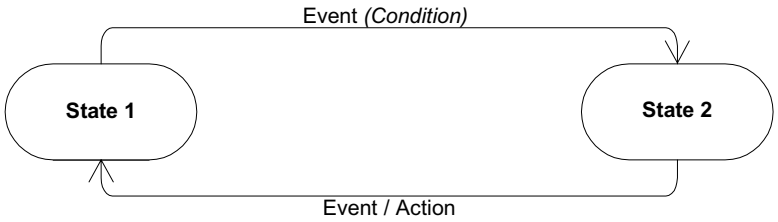
Broadcast Message	This is a message, sent to logical address 15, on which all devices are expected to receive.
Clear	Set to an empty/undefined state. When a physical address is cleared it takes the value F.F.F.F. When a logical address is cleared it takes the value 15.
Deck	The part of a recording device or playback device that provides playback functionality usually from a removable media.
Destination	The target device for a CEC message.
Follower	A device that has just received a CEC message and is required to respond to it.
Initiator	The device that is sending, or has just sent, a CEC message and, if appropriate, is waiting for a follower to respond.
Logical address	A unique address assigned to each device (see section CEC 10.2)
Menu Providing Device	A non-display device that may render a menu on TV.
Playback device	A device that has the ability to play media, e.g. a DVD Player.
Recording device	A device that has the ability to record a source such as an internal preset or an external connection.
Source Device	A device that is currently providing an AV stream via HDMI.
Tuner Device	A device that contains a tuner, e.g. a STB or a Recording Device.
Timer Setting Device	A device that has the ability to set the record timer blocks of a recording device.
TV	A device with HDMI input that has the ability to display the input HDMI signal. Generally it has no HDMI output.

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CEC 2.3 Usages and Conventions

CEC 2.3.1 State Diagrams

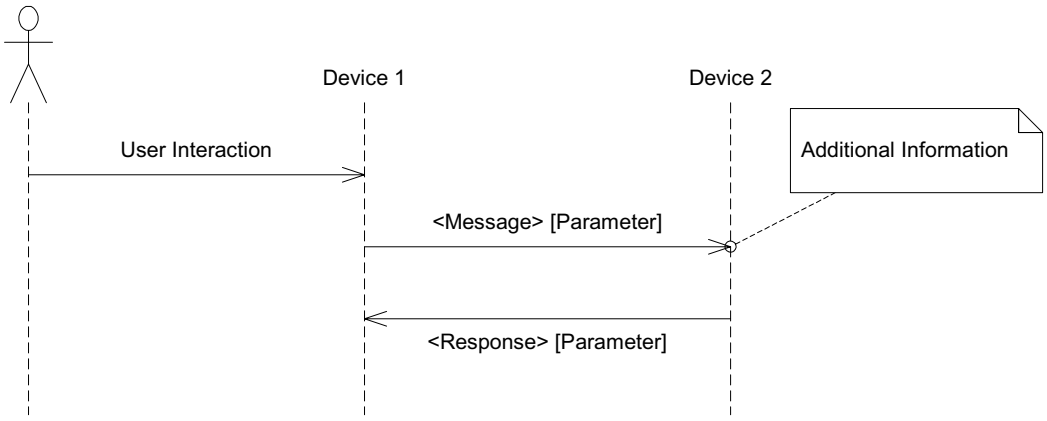
State diagrams describe behavior in terms of device states and events or actions. In these diagrams, the ovals represent device states and the arrows represent events and/or actions that move the device from one state to another state.



CEC Figure 1 Example State Diagram

CEC 2.3.2 Message Flow Diagrams

Message Flow Diagrams show sequences of messages that occur between 2 devices.



CEC Figure 2 Example Message Flow Diagram

CEC 2.3.3 Notation

Within the CEC specification there are a number of notations:

<xxx> xxx is an opcode for a message, which is defined in section CEC 15

[yyy] yyy is a data item, which is defined in section CEC 17.

“zzz” zzz is a constant and is a possible value for a data item in section CEC 17.

N{….} indicates the item within the braces is repeated N times, this is used mainly in section CEC 17.

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CEC 3 Feature Overview

CEC provides a number of recommended features designed to enhance the functionality and interoperability of devices within an HDMI system. This section gives an overview of these features.

- **One Touch Play** - Allows a device to be played and become the active source with a single button press.
- **System Standby** - Enables the user to switch all devices to standby with one button press.
- **Preset Transfer** - Enables any tuner device to download the same set of presets as the TV. It is used to auto configure a devices presets so no manual setup is required.
- **One Touch Record** - Offers a What You See Is What You Record (WYSIWYR) facility, meaning that whatever is shown on the TV screen is recorded on a selected recording device.
- **Timer Programming** - Allows a device (e.g. the TV) to set a timer recording on a recording device.
- **System Information** - Queries the system to determine device addresses and configurations (e.g. language and country)
- **Deck Control** - Enables a device to control (e.g. play, fast forward etc.) and interrogate a playback device (a deck).
- **Tuner Control** - Allows a device to control the tuner of another device.
- **Vendor Specific Commands** - Allows a set of vendor-defined commands to be used between devices of that vendor.
- **OSD Display** - Enables a device to use the on-screen display of the TV to display text strings.
- **Device Menu Control** - Enables a device to control the menu of another device by passing through user interface commands.
- **Routing Control** - Allows the control of CEC Switches for streaming of a new source device.
- **Remote Control Pass Through** - Enables remote control commands to be passed through to other devices within the system.
- **Device OSD Name Transfer** - Enables devices to upload their preferred OSD name to the TV. The TV can then use this name in any menus associated with that device.

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CEC 4 Electrical Specification

The electrical specifications define CEC such that a maximum of 10 devices may operate together in the worst-case scenario. In practice, many more may be expected to operate together as the worst case is highly improbable.

CEC Table 1 describes the electrical specifications for CEC.

CEC Table 1 CEC Electrical Specifications

Description	**Measurement Method**	**Value**
Maximum voltage slew rate	Open Circuit	$\frac{dv}{dt} \le \lvert 0.1 \rvert$ V/μs
	2700 ohms ± 5% load to 3.3V	
Maximum Output Voltage Logic ‘0’	2700 ohms ± 5% load to 3.3V	600 mV
Minimum Output Voltage Logic ‘0’	2700 ohms ± 5% load to 3.3V	0 V
Maximum Output Voltage Logic ‘1’	27k ohms ± 5% load to 2.7V	3.6 V
Minimum Output Voltage Logic ‘1’	27k ohms ± 5% load to 2.7V	2.5V
Input Voltage Threshold Logic ‘0’	CEC voltage set to 800mV	Logic ‘0’
Input Voltage Threshold Logic ‘1’	CEC voltage set to 2.0V	Logic ‘1’
Max rise time	From 10% to 90%	250 μs
Max fall time	From 90% to 10%	50 μs
Internal device pull-up to +3.3V ±10%		27k ohms ±10%

All values assume a nominal +3.3V signaling level.

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CEC 5 Signaling and Bit Timings

All transactions on the CEC line consist of an initiator and one or more followers. The initiator is responsible for sending the message structure and the data. The follower is the recipient of any data and is responsible for setting any acknowledgement bits.

The following sections describe the timing that is used by the initiator.

CEC 5.1 CEC line usage

A message is conveyed over the control signal line in a single frame; a frame is a self-contained unit consisting of a start bit followed by a number of data bits.

An initiator first has to test that the control signal line is free for use (described below). After that it generates a high to low transition on the CEC line, followed by a series of pulses comprising data bits whose starting point is defined by a high to low transition.

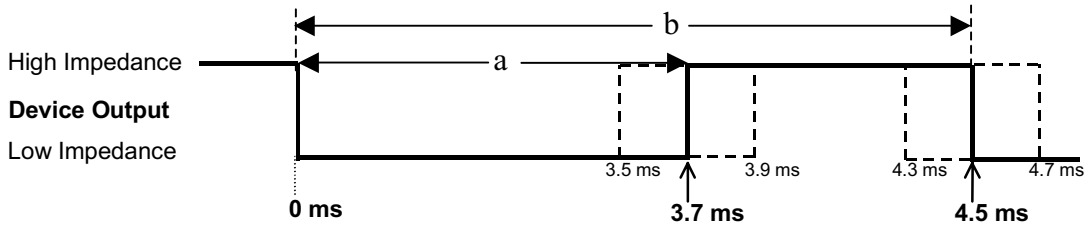
The initiator provides bit timing and bit leading edges. Only one initiator is allowed at any one time. A control signal line arbitration mechanism avoids conflict when more than one initiator begins transmitting at the same time.

CEC 5.2 Bit timing

CEC 5.2.1 Start bit timing

The pulse format of the start bit is shown in CEC Figure 3. It is unique and identifies the start of a frame.

The start bit has to be validated by its low duration (a) and its total duration (b).



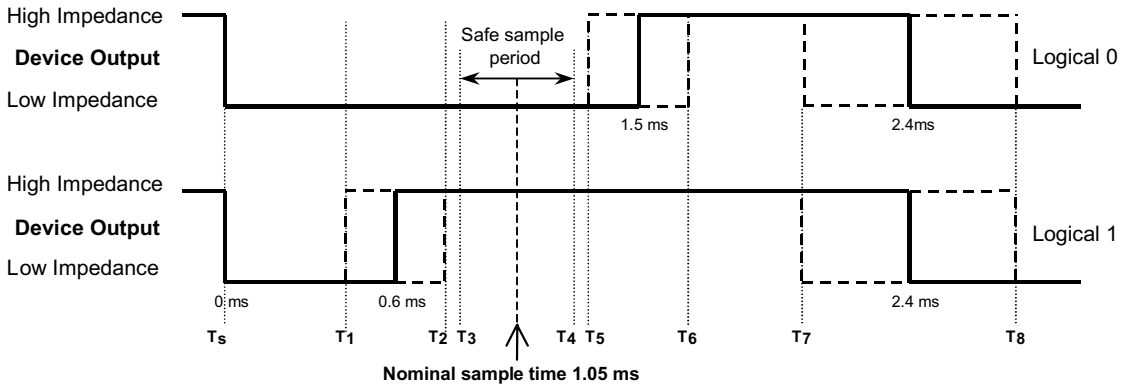
CEC Figure 3 Start bit pulse format showing minimum and maximum tolerances

CEC 5.2.2 Data bit timing

All remaining data bits in the frame, after the start bit, have consistent timing. There are, however, two types of bits; an initiator asserted bit and a follower asserted bit. All bits apart from the acknowledge bit are asserted by the initiator. CEC Figure 4 shows both logical 1 and logical 0 timing diagrams for an initiator asserted bit.

The high to low transition at the end of a data bit is the start of the next data bit and only occurs if there is a following data bit; after transmission of the final bit the CEC line remains high.

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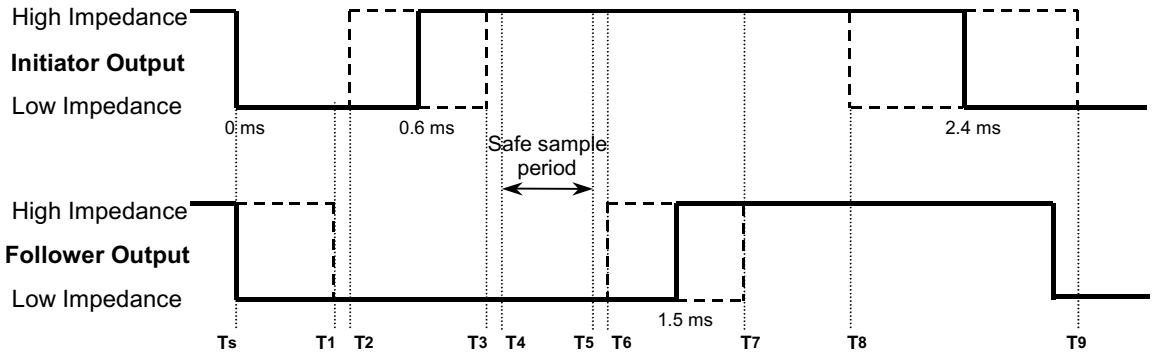


T_S	**0 ms**	The bit start event.
T_1	**0.4 ms**	The earliest time for a low - high transition when indicating a logical 1.
T_2	**0.8 ms**	The latest time for a low - high transition when indicating a logical 1.
T_3	**0.85 ms**	The earliest time it is safe to sample the signal line to determine its state.
T_4	**1.25 ms**	The latest time it is safe to sample the signal line to determine its state.
T_5	**1.3 ms**	The earliest time a device is permitted return to a high impedance state (logical 0).
T_6	**1.7 ms**	The latest time a device is permitted return to a high impedance state (logical 0).
T_7	**2.05 ms**	The earliest time for the start of a following bit.
	2.4ms	The nominal data bit period.
T_8	**2.75 ms**	The latest time for the start of a following bit.

CEC Figure 4 Timing diagrams for both bit states

CEC Figure 5 shows an example bit with both initiator and follower where the follower may assert the bit to a logical 0 to acknowledge a data block. The initiator outputs a logical 1, thus allowing the follower to change the CEC state by pulling the control line low for the duration of the safe sample period.

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T_S	**0 ms**	The bit start event.
T_1	**0.35 ms**	The latest response time for a follower to go to the low impedance state.
T_2	**0.4 ms**	The earliest the initiator can return to high impedance when transmitting a logical 1.
T_3	**0.8 ms**	The latest the initiator can return to high impedance when transmitting a logical 1.
T_4	**0.85 ms**	The earliest time at which the bit state on the CEC line is valid for reading.
T_5	**1.25 ms**	The latest time at which the bit state on the CEC line is valid for reading.
T_6	**1.3 ms**	The earliest time the follower is permitted return to a high impedance state.
T_7	**1.7 ms**	The latest time the follower is permitted return to a high impedance state.
T_8	**2.05 ms**	The earliest time for the start of a following bit.
	2.4ms	The nominal data bit period.
T_9	**2.75 ms**	The latest time for the start of a following bit.

CEC Figure 5 Timing Diagram for Follower Asserted Bit (Logical 0)

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CEC 6 Frame Description

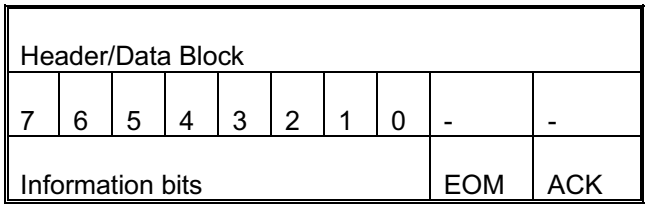
The following table describes the complete CEC frame; the details of each block of the frame are given in the subsequent sections.

CEC Table 2 Frame Description

Name	Description	Value
Start	Special start 'bit'	N/A
Header Block	Source and destination addresses (see CEC Figure 7)	See CEC Table 4
Data Block 1 (op code block)	Op code (Optional)	See CEC Table 5
Data Block 2…. (operand blocks)	Operand(s) specific to op code (Optional, depending on op code)	See CEC Table 5 and CEC Table 8

CEC 6.1 Header/Data Block description

Both Data Block and Header Block have the same basic structure, as shown in CEC Figure 6.



CEC Figure 6 Block Structure

The information bits are data, op codes or addresses, dependent on context. The control bits, EOM and ACK, are always present and always have the same usage.

CEC 6.1.1 EOM (End of Message)

The EOM bit is used to indicate if this is the final block in the message.

A '0' bit specifies that one or more data blocks follow.

A '1' bit specifies that the message is complete.

In the event that a message contains additional data blocks after an EOM is indicated, the follower should ignore the additional blocks.

CEC 6.1.2 ACK (Acknowledge)

The ACK bit is used by follower(s) to acknowledge the data or header block. It is always set to 1 by the initiator. It operates in one of two modes:

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For messages addressed to a single device:

- A follower that reads its own address in the destination address field shall acknowledge with a ‘0’ ACK bit.
- All other devices shall generate a ‘1’ ACK bit (i.e. do nothing).
- A ‘0’ read by the initiator therefore indicates a successful transmission of the data or header block.

For broadcast messages the sense of the ACK bit is inverted to allow for a single device to reject a message:

- All followers shall acknowledge with a ‘1’ ACK bit.
- A ‘1’ read by the initiator therefore indicates that no device has rejected the data or header block – the message transmission can therefore continue if required.
- A ‘0’ read by the initiator therefore indicates that one or more devices have rejected the message.

CEC 6.1.3 Header Block Details

The header block consists of the source logical address field, the destination logical address field, the end of message bit (EOM) and the acknowledge bit (ACK) as shown in CEC Figure 7. The addresses for the devices are specified in CEC Table 4.

Header Block									
3	2	1	0	3	2	1	0	-	-
Initiator				Destination				EOM	ACK

CEC Figure 7 Header Block

The initiator logical address field is used to identify the initiator of the current frame. The logical address of the initiator is written in this field (see CEC 10.2). The field consists of bits one to four of the header block, most significant bit first.

The destination logical address field is used to identify the destination of the current frame. The logical address of the destination is written in this field (see CEC 10.2). A special address (0b1111) is used for broadcast messages. The field consists of bits five to eight of the header block, most significant bit first.

A message with the EOM bit set in the Header Block can be used to ‘ping’ other devices, to ascertain if they are active.

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CEC 7 Reliable Communication Mechanisms

There are three mechanisms to provide a reliable communications medium for the transfer of frames:

- Frame re-transmissions increase the chance of a successful message transfer.
- Flow control ensures that communication only progresses as fast as the slowest follower.
- Frame validation.

Given these mechanisms and the active ACK method, a message transmitted and acknowledged should be assumed correctly received. A message that does not result in a <Feature Abort> can be assumed to have been acted upon. It is suggested that the receiving device can assume this after 1 second. Generally however, the <Feature Abort> will be received within around 100ms.

CEC 7.1 Frame Re-transmissions

A frame is considered lost and therefore may be re-transmitted under the following conditions:

- If a frame is not acknowledged in a directly addressed message.
- If a frame is negatively acknowledged in a broadcast message.
- If the initiator detects low impedance on the CEC line when it is transmitting high impedance and is not expecting a follower asserted bit.

Re-transmission can be attempted up to 5 times for a single message and shall be attempted at least once. The re-try shall be after a signal free time as described in CEC Table 3.

CEC 7.2 Flow Control

To provide flow control, a receiving device may negatively acknowledge any data or header block it is at present unable to process. A negative acknowledge will cause re-transmission by the initiator.

CEC 7.3 Frame Validation

A follower will ignore a frame if the number of operands is less than the number specified for that op code.

CEC 7.4 CEC Line Error Handling

It is the responsibility of all devices acting as followers to detect the existence of spurious pulses on the control signal line and notify all other devices (primarily the initiator) that a potential error has occurred.

An error is defined as a period between falling edges that is less than a minimum data bit period (i.e. too short to be a valid bit). Note that the start bit is excluded from CEC Line Error Handling.

Errors are notified by the follower generating a low bit period on the control signal line of 1.4-1.6 times the nominal data bit period. After such an error notification the original initiator should stop sending its current frame and re-try later.

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CEC 8 Protocol Extensions

In order to allow for extensions to the protocol in future releases of the specification, the current opcodes and parameters can be extended by adding further parameters onto them. If an older CEC node receives a message with more operands than expected, it should ACK the additional operands and simply ignore them, thus allowing extensions to already existing commands.

For entirely new commands, new opcodes can be allocated.

For entirely new device types, new addresses may be allocated.

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CEC 9 CEC arbitration

Arbitration for the CEC line ensures collisions are spotted and a reliable message layer can be achieved.

All devices that wish to transmit a frame onto the CEC line have to ensure that it has been inactive for the signal free time, see CEC Table 3.

A device that has lost arbitration shall stop transmitting and become a follower. The device shall then wait for the CEC line to be inactive for the signal free time period as specified in CEC Table 3, before attempting to send another message.

CEC line arbitration commences with the leading edge of the start bit and continues until the end of the initiator address bits within the header block. During this period the initiator shall monitor the CEC line and if whilst in high impedance state it detects low impedance then it shall assume that it has lost the arbitration to a second initiator.

It should be noted that this process gives priority to the logical address with the most leading zeros and, ultimately, the TV.

CEC 9.1 Signal Free Time

Before attempting to transmit or re-transmit a frame, a device shall ensure that the CEC line has been inactive for a number of bit periods. This signal free time is defined as the time since the start of the final bit of the previous frame.

The length of the required signal free time depends on the current status of the control signal line and the initiating device. The different signal free times required are summarized in the following table:

CEC Table 3 Signal Free Time

Precondition	**Signal Free Time (nominal data bit periods)**
Present initiator wants to send another frame immediately after its previous frame	7 and <10
New initiator wants to send a frame	5 and <7
Previous attempt to send frame unsuccessful	3 and <5

CEC 9.2 Message Time Constraints

There are certain time constraints for messages that should be obeyed at application level. These are a desired maximum response time of 200ms and a required maximum response time of 1 second.

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CEC 10 Device Connectivity and Addressing

CEC is a protocol based on a bus system and therefore cannot alone ascertain the physical connectivity of the network. The mechanism defined in section 8.7 uses DDC to allocate physical addresses to devices in the network.

All CEC devices therefore have both a physical and logical address, whereas non-CEC devices only have a physical address.

CEC 10.1 Physical Address Discovery

The algorithm defined in 8.7.3 is used to allocate the physical address of each device.

Whenever a new physical address (other than F.F.F.F) is discovered, a CEC device shall:

- allocate the logical address (see CEC 10.2.1)
- report the association between its logical and physical addresses by broadcasting <Report Physical Address>.

This process allows any node to create a map of physical connections to logical addresses.

CEC 10.2 Logical Addressing

Each device appearing on the control signal line has a unique logical address. This address defines a device type as well as being a unique identifier. These are specified in CEC Table 4.

If a physical device contains the functions of more than one logical device then it should take the logical addresses for each of those logical devices. It is allowed for a device to declare the functionality of another device by using a different logical address. For example a recordable DVD device may take the address 4 or 8 to expose only the functionality of a standard DVD device.

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CEC Table 4 Logical Addresses

Address	Device
0	TV
1	Recording Device 1
2	Recording Device 2
3	STB1
4	DVD1
5	Audio System
6	STB2
7	STB3
8	DVD2
9	Recording Device 3
10	Reserved
11	Reserved
12	Reserved
13	Reserved
14	Free Use
15	Unregistered (as initiator address) Broadcast (as destination address)

CEC 10.2.1 Logical Address Allocation

Note that a logical address should only be allocated when a device has a valid physical address (i.e. not F.F.F.F), at all other times a device should take the 'Unregistered' logical address (15).

Only the device at physical address 0.0.0.0 may take logical address TV (0). A TV at any other physical address shall take the 'Free Use' (14) address. If address 14 is already allocated it shall take the 'Unregistered' address (15).

Reserved addresses shall not be used at present and are reserved for future extensions to this specification.

Where more than one possible logical address is available for the given device type (e.g. STB1, STB2, etc.), an address allocation procedure shall be carried out by a newly connected device. The device takes the first allocated address and sends a polling message to the same address (e.g. STB1 STB1). If the polling message is not acknowledged, then the device stops the procedure and retains that address.

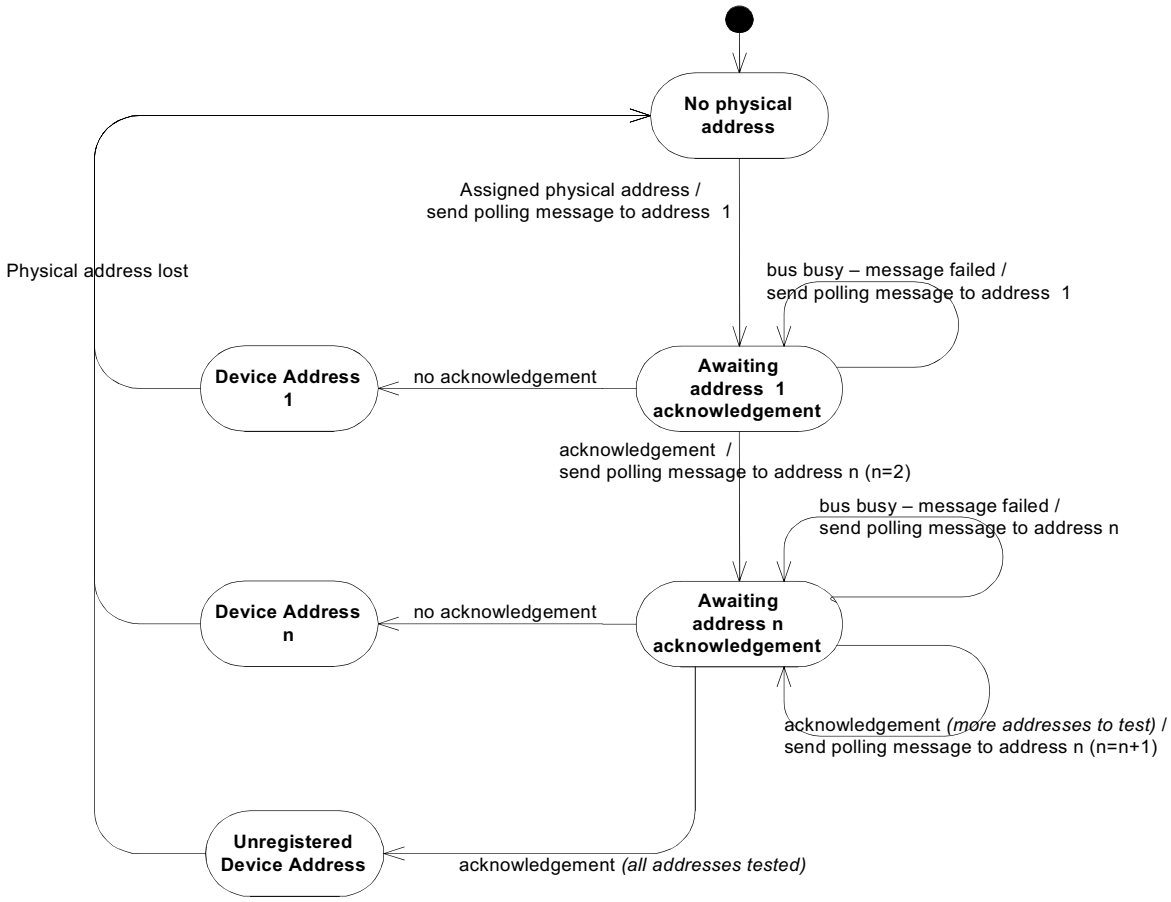
If the first address is acknowledged, then the device takes the next address and repeats the process (e.g. STB2 STB2). Again, if the message is not acknowledged, the device keeps that address.

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This procedure continues until all possible 'type specific' addresses have been checked; if no free addresses are available the device should take the unregistered address (15).

A device may lose its logical address when it is disconnected or switched off. However, it may remember its previous logical address, so that the next time it is reconnected, it can begin the polling process at its previous logical address and try each other allowable logical address in sequence before taking the unregistered address. For example if an STB that was previously allocated address STB2 is reconnected, it would poll STB2, STB3 and STB1 before taking the unregistered address.

If a device loses its physical address at any time (e.g. it is unplugged) then its logical address shall be set to unregistered (15).



CEC Figure 8 Logical Address Allocation

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CEC 11 Switch Requirements

One of the major uses of the physical address identification is to allow a switch to be controlled in order to enable a specific device to stream to the TV. This places requirements on both CEC and non-CEC compliant switches.

All switches will consist of a single switched TMDS connection, and a fully wired CEC connection to each source device. There are significant differences between a CEC Switch and a non-CEC Switch, which are identified below.

CEC 11.1 CEC Switch

A CEC Switch allocates a unique child_address for every connection below the switch. This means that any device connected to the switch will always have a valid physical address (assuming the switch itself has a valid physical address). Therefore, any device below the switch may take a logical address and can react to CEC messages in a normal way. The switch is effectively transparent and will enable all standard CEC communications in its connected source devices.

For CEC compliant switches, there is a requirement to react on <Active Source> and <Set Stream Path> messages. Both of these messages require the switch to change the connected source device according to the physical AV stream path indicated by the CEC message. These mechanisms allow a source device to configure the switches between itself and the TV to ensure that its output is displayed, or for the TV to specifically receive the output from a given device.

A CEC compliant device that is only a switch does not need to take a logical address; it uses the unregistered address for any communications.

It is possible that a user may change a CEC Switch manually. In this instance a CEC Switch shall send a <Routing Change> message to inform other devices about the change.

CEC 11.2 Non-CEC Switch

There are two types of non-CEC switches, those which have only one EDID for all source devices (or simply reflect the sink EDID), and those which have a separate EDID for all source devices. The rules for the operation of these two types of switch are different:

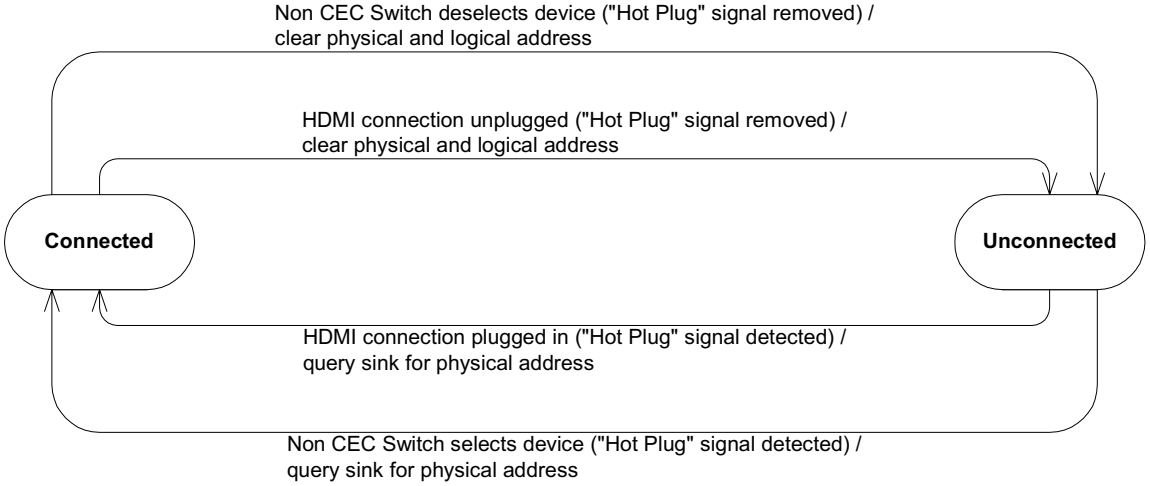
CEC 11.2.1 Switches with 1 EDID

A non-CEC-compliant switch may have a single child_address, which is always occupied by the currently switched device. Any other connected devices will have no hot plug signal and will therefore have an unallocated physical address (and can use only the unregistered logical address). These devices will, however, still see CEC messages as they will be connected to the CEC line and they may react to some broadcast messages in the normal way (e.g. standby).

When a switch de-selects a device, that device will detect the removal of the ‘hot plug’ signal to indicate that its physical AV connection has been removed. It should immediately clear its physical and logical addresses. Each source device below the switch will detect the removal of the ‘hot plug’ signal to indicate they are no longer on the active AV Path and clear their addresses accordingly.

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When a switch selects a device, that device will detect the ‘hot plug’ signal. It can then obtain a valid physical address from its sink and subsequently a logical address. The device should activate the hot plug signal to its source (child) devices (if any) to indicate that they should now request a physical address.



CEC Figure 9 A device’s connection state when it is beneath a 1 EDID non-CEC Switch

CEC 11.2.2 Switches with Multiple EDIDs

These should operate as CEC switches except that they do not send messages on, or monitor, the CEC line.

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CEC 12 High Level Protocol

As described in the previous sections, messages consist of an op code and a number of parameters. This is the high level protocol.

This protocol can be described best by detailing the messages and the data types used for the parameters. These are detailed in CEC Table 5.

Although these tables explain the majority of the high level protocol, there are some special situations that require further explanation. These are given in the following sections.

CEC 12.1 Source Declaration

Before a device becomes a source, it should issue an <Active Source> message to declare its intention. Thus any presently active source can and should act appropriately.

CEC 12.2 Protocol general rules

A message that is defined as being valid only when directly addressed, shall be ignored if received as a broadcast message.

A message that is defined as being valid only when broadcast, shall be ignored if received as a directly addressed message.

All numbers greater than one byte are transmitted as bytes in big endian format.

All bit sequences are sent most significant bit first.

A follower shall respond to a message coming from any valid logical address between 0-14 unless otherwise stated.

A follower shall ignore a message coming from address 15 (unregistered), unless:

- that message invokes a broadcast response (e.g. <Start Preset Transfer>)
- the message has been sent by a CEC switch (a <Routing Change> or <Routing Information> message).
- the message is <standby>

CEC 12.3 Feature Abort

All devices shall support the message <Feature Abort>. It is used to allow devices to indicate if they do not support an op code that has been sent to them, if it is unable to deal with the message at present, or if there was something wrong with the transmitted frame at the high-level protocol layer.

Feature abort has two parameters, the opcode and a reason for its rejection of the frame.

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The reaction to a faulty message by the follower depends on if the message was directed or broadcast:

For a broadcast message:

- A follower that receives a broadcast message which it does not support, ignores the received message, and does not send a <Feature Abort>.

For a directly addressed message:

- <Feature abort> is used as a response to any failure.

If an initiator wishes to attempt retransmission after receiving a <Feature Abort> it is suggested that it waits for 200ms. This will allow time for the follower to recover from the state that caused the initial <Feature Abort> message.

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CEC 13 CEC Features Description

This section describes the message transfer and additional details for a number of common features enabled by CEC. Note that where a feature is supported, all messages within that feature should be implemented.

CEC 13.1 One Touch Play

CEC 13.1.1 Messages

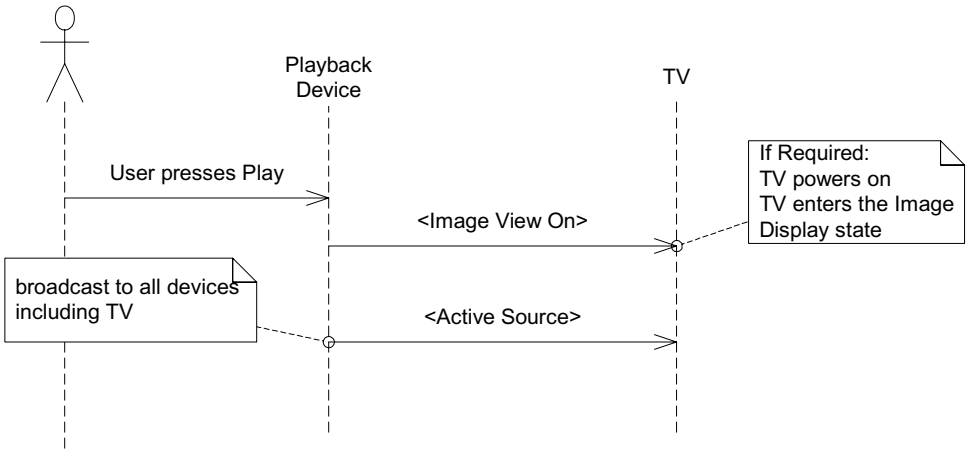
The following messages are used for the One Touch Play feature:

<Active Source>, <Image View On>, <Text View On>

CEC 13.1.2 Feature Description

The One Touch Play feature allows a device to be played and become the active source with a single button press.

A device shall send the message <Image View On> to the TV to indicate that its output should be displayed on the screen. If the TV is in a Text Display state (e.g. Teletext) it should switch to the Image Display state. If a menu is being displayed on the TV it shall remain on screen.



CEC Figure 10 A typical scenario illustrating the One Touch Play feature

A device may alternatively send the message <Text View On>. This message has the same functionality as <Image View On> with the addition that any menus that the TV is displaying shall be removed.

Whenever a device becomes the new source device it should broadcast an <Active Source> message. The current active source device should then take appropriate action, for example, it may pause if it is playing media.

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CEC 13.2 System Standby

CEC 13.2.1 Messages

The following message is used for the System Standby feature:

<Standby>

CEC 13.2.2 Feature Description

The message <Standby> can be used to switch one or more CEC devices to standby.

The whole system may be set to standby by broadcasting the <Standby> message.

A device can switch another single device into standby by sending the message <Standby> as a directly addressed message to it. It should only switch a single device into standby if it previously activated that device (brought it out of standby).

CEC 13.2.3 Exceptions

Devices can ignore <Standby> messages if they are in a state where going into standby is not sensible. For example if the device is actively involved in a recording as either the source or recording device it should ignore any requests to go into standby. It is up to the device implementer how ‘sensible’ is defined.

CEC 13.3 Preset Download

CEC 13.3.1 Messages

The following messages are used for the Preset Download feature:

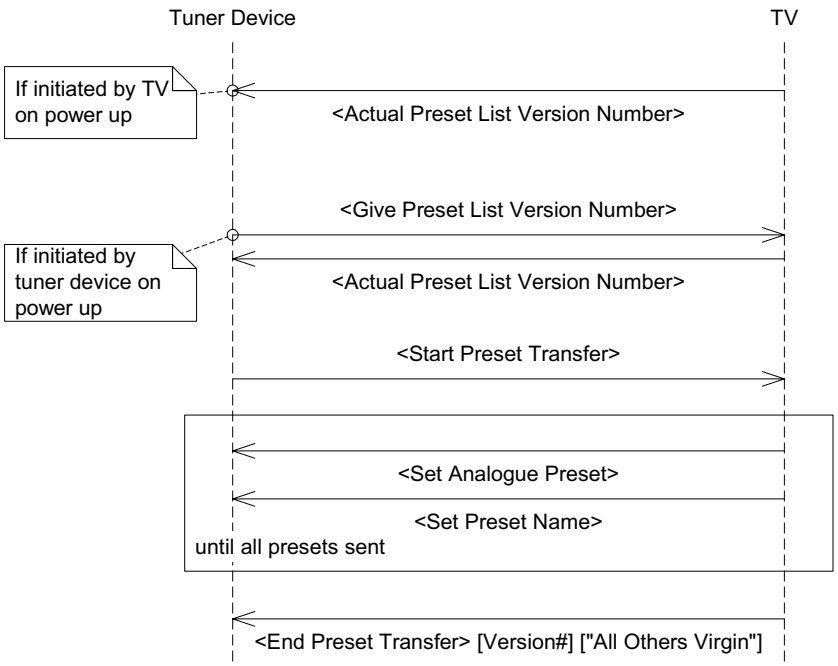
<Actual Preset List Version Number>, <End Preset Transfer>, <Give Preset List Version Number>, <Set Analogue Preset>, <Set Preset Name>, <Start Preset Transfer>, <Stop Preset Transfer>

CEC 13.3.2 Feature Description

This feature is used to ensure that any tuner device will have the same set of presets as the TV. It is used to auto configure device presets, thereby removing any manual set up process. This feature will provide a consistent channel line up to the user regardless of which device is in use.

All devices that store the presets do so with a version number of the preset list. The version number is a one-byte variable and is incremented modulo 256 by the TV whenever a change to the preset list occurs. If a tuner device (other than the TV) changes its presets locally it shall not change its version number, because the version number only refers to the preset list of the TV. It is the responsibility of the device to remember that its preset list differs from that of the TV.

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CEC Figure 11 The message exchange for the Preset Download feature

The feature can be initiated either by the TV or a tuner device on power up/connection. If the TV is the initiator it broadcasts the version number of the current list. If the device initiates the feature it requests the current version number from the TV.

If the device needs to download a new version of the list, it requests this from the TV. The preset information (e.g. channel and frequency) and optionally the preset name are sent to the device. This is repeated for all stored presets. The TV then informs the device when all set presets have been sent.

Note individual <Set Analogue Preset> and <Set Preset Name> messages can be used outside the above sequence to change small numbers of individual presets when a user has updated them in the TV. An <End Preset Transfer> message will always be sent once all presets have been transferred so that the device may update its version number.

In order to clear all the presets in another device (if for example all presets in the TV are cleared), the TV can send an <End Preset Transfer> [Version#] [“All others virgin”] message without first transmitting any <Set Analogue Preset> messages.

The preset download feature should be possible when the TV is in standby. It is up to the local specification if the TV should power on in order to download its presets. If an attempt is made to put a device into standby during a preset download it should either delay the standby until the preset download has completed, or continue with the preset download while in standby.

A device should ignore any of the following messages: <Actual Preset List Version Number>, <Set Analogue Preset>, <Set Preset Name> and <End Preset Transfer>, if they do not come from logical address 0 (the TV).

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CEC 13.3.3 Exceptions

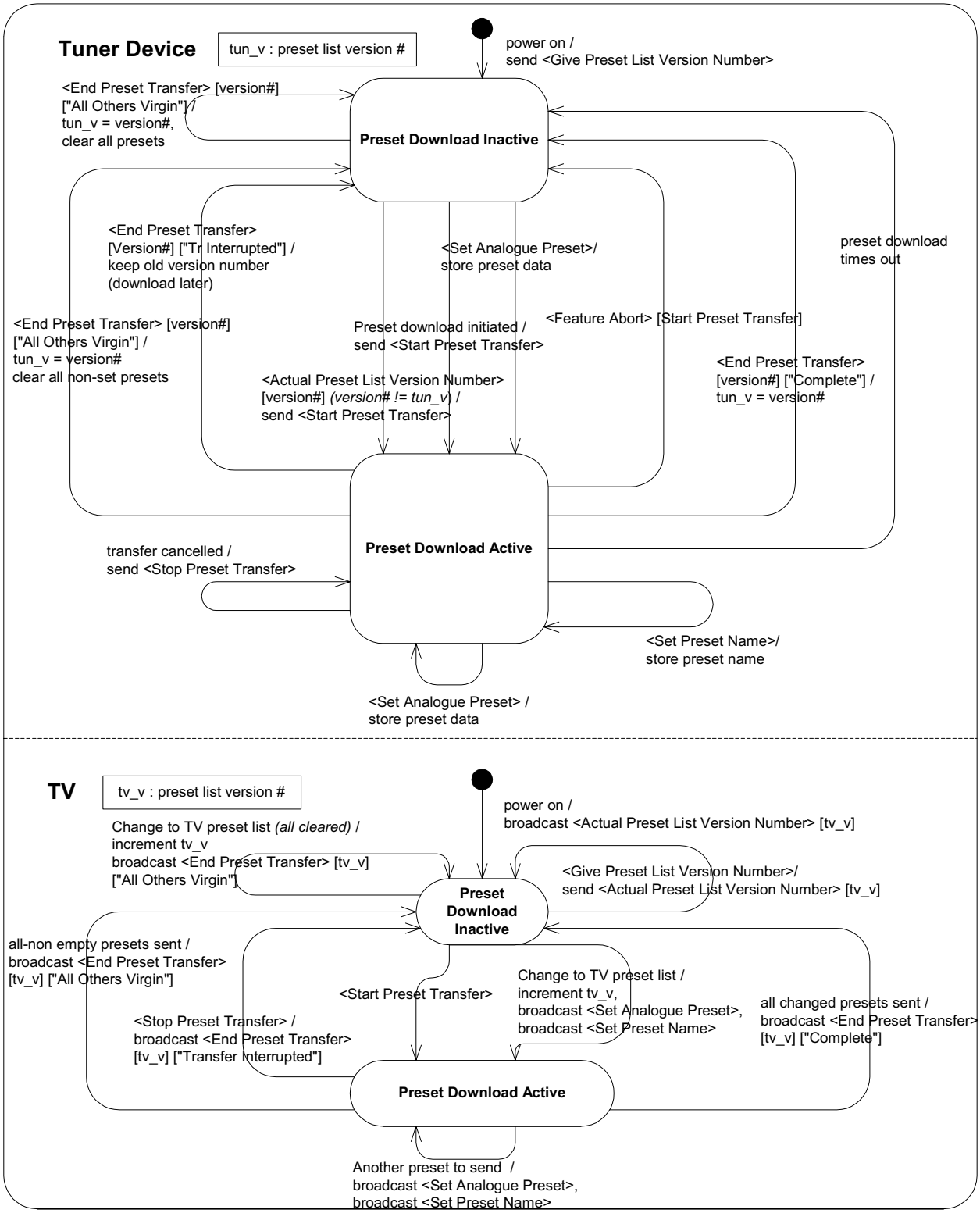
A device that initiates a <Start Preset Transfer> message can request that the transfer be stopped, by sending the message <Stop Preset Transfer>. The TV will then send an <End Preset Transfer> [Version#] [“Transfer interrupted”] message to indicate that transferring has been terminated. Any device that receives the [“Transfer interrupted”] parameter should remember that its preset table may be incomplete or out of date and should attempt a further download at a later time. The TV will ignore any <Stop Preset Transfer> messages from a device that did not initiate the transfer.

In the case of a partly transferred list, e.g. after a reshuffle of two presets, the device should check if the version number received in the <End Preset Transfer> message differs to its own value by more than 1. If it does then the device has missed an update and should initiate a full preset download. A partially transferred list will always have the [Preset List Info] parameter set to the value “Complete” (see [Preset List Info] in CEC Table 8).

A tuner device must be able to recover in the event that a preset download does not complete (no <End Preset Transfer> message is received). This can be detected by waiting for a sensible timeout after the last <Set Analogue Preset> or <Set Preset Name> message and if no subsequent message related to preset download is received the device should exit the Preset Download Active state.

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CEC 13.3.4 State Diagrams



CEC Figure 12 State transitions for the Preset Download feature

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CEC 13.4 One Touch Record

CEC 13.4.1 Messages

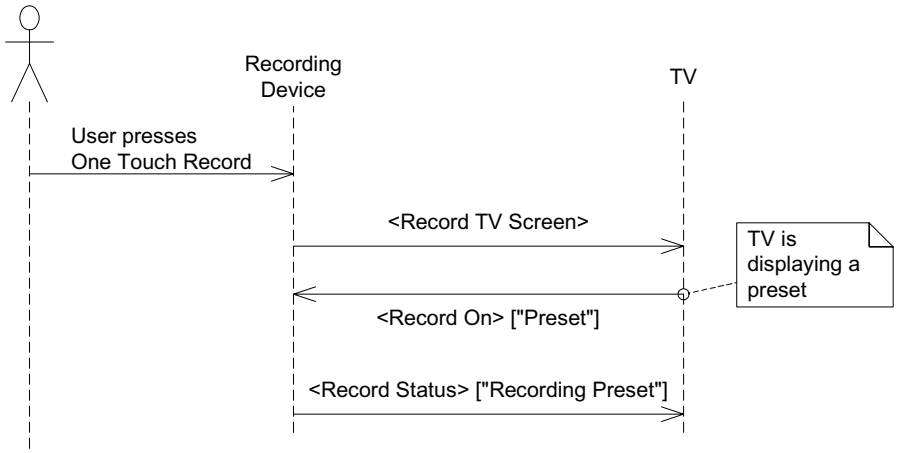
The following messages are used for the One Touch Record feature:

<Record Off>, <Record On>, <Record Status>, <Record TV Screen>

CEC 13.4.2 Feature Description

This feature allows the user to easily start a recording of the source that is being displayed on the TV, just by selecting a recording device and giving the record command. It is not always possible to carry out a One Touch Record as it depends on what source is currently being displayed. It is primarily used for the instant recording of a tuner preset, or the recording of another device (e.g. Camcorder) connected externally to the recording device

Either the TV or the recording device may initiate the One Touch Record Feature, for example by selecting a menu option on the TV or by pressing record on the recording device.



CEC Figure 13 A typical scenario for the One Touch Record feature

In the event of the recording device initiating the feature it will send a <Record TV Screen> message to the TV. On receipt of the <Record TV Screen> message by the TV, or if the user initiates the One Touch Record feature via the TV, the TV shall react as follows:

- It the TV is currently displaying an internal tuner preset, it shall respond with a <Record On> [“Preset”] [Preset Number] [Analogue Preset] message.
- If the Recording Device is the current active source device, then the TV shall respond with a <Record On> [“Own source”] message.
- If the TV is currently displaying some other source, it shall respond with a <Feature Abort> [“Cannot provide source”] message, or do nothing if initiated via the TV.

On receipt of a <Record On> message the recording device shall act as follows:

- If [“Preset”] is indicated and the devices local preset number matches the analogue preset information that was sent, the device shall change to that preset number and start recording. If the preset information does not match the preset number, the device should attempt to tune to the specified frequency and begin recording. If the device cannot support the required

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frequency/broadcast system, then it should respond with a <Record Status> ["No recording – invalid preset"].

- If ["Own source"] is indicated, then it shall attempt to record whatever it is currently displaying, e.g. an external connection such as a camcorder or the preset it is currently tuned to.

The recording device shall respond with the message <Record Status> to indicate if recording has begun, or a reason why recording has failed. If the TV initiated the recording, it may stop it at any time by sending a <Record Off> message. The recording device should then stop recording immediately.

The TV should ignore a <Record TV Screen> message that comes from a non-recording device address, however it shall accept the message from a 'Reserved' address (a future device type).

CEC 13.5 Timer Programming

CEC 13.5.1 Messages

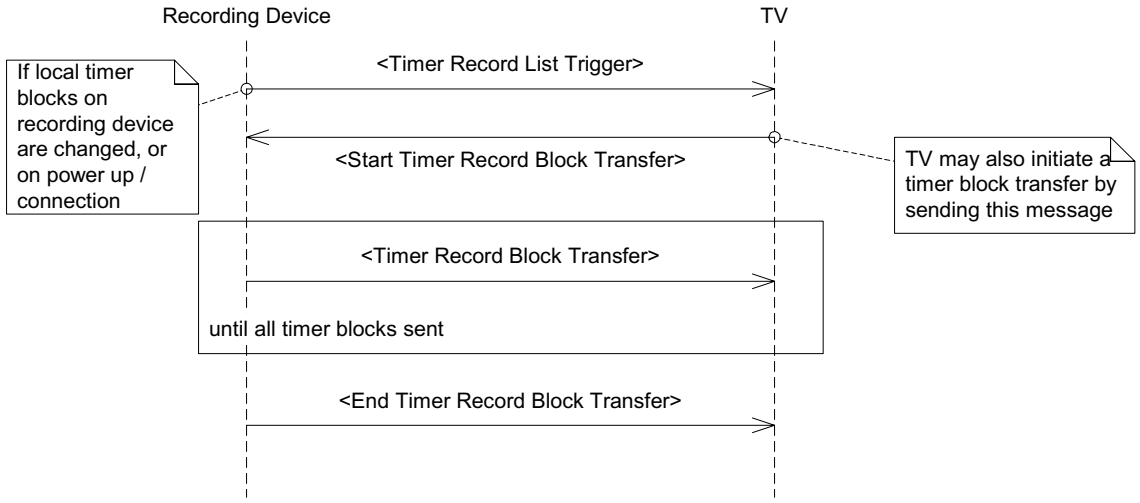
The following messages are used for the Timer Programming feature:

<Clear Timer>, <End Timer Record Block Transfer>, <Give Timer Options>, <Set Timer>, <Set Timer Program Title>, <Start Timer Record Block Transfer>, <Timer Cleared Status>, <Timer Options>, <Timer Record Block Transfer>, <Timer Record List Trigger>, <Timer Status>

CEC 13.5.2 Feature Description

This feature allows a device (e.g. the TV) to set a timer recording on a recording device. It may for example be used to set timer blocks of a recording device via a TV menu or via an EPG.

A device (e.g. the TV) may download the current list of timer blocks from the recording device as shown below.



CEC Figure 14 Message exchange for the Timer Record Block Transfer process

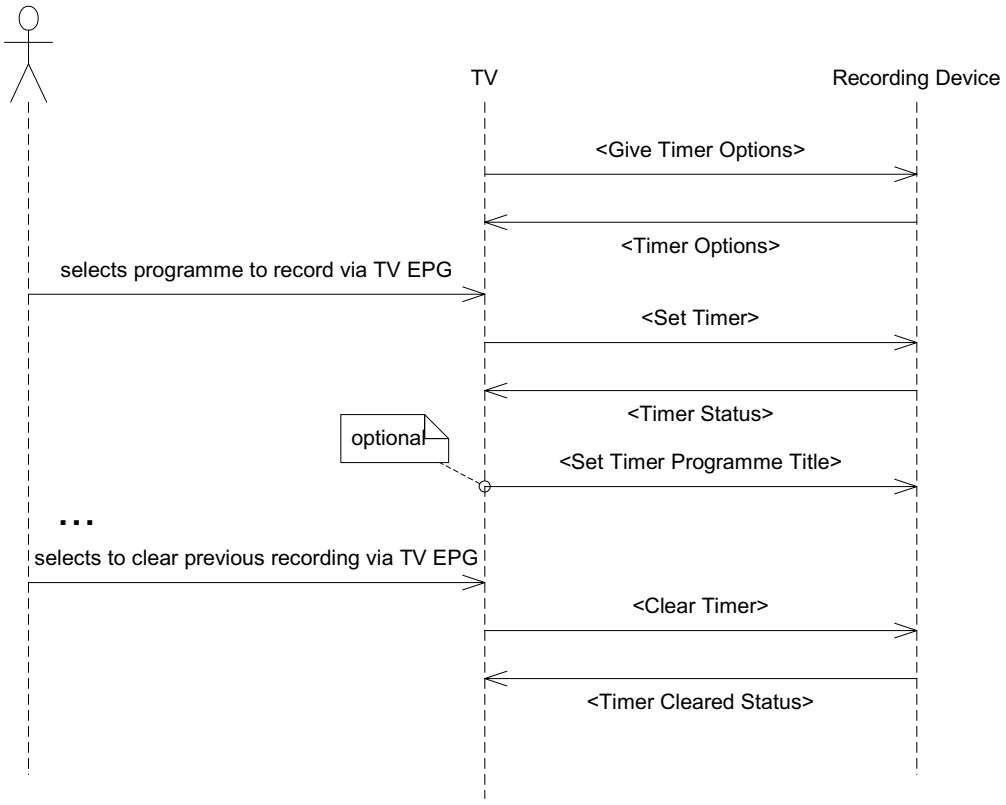
A recording device can inform other devices when its timer record list has changed (e.g. when a new timer record block is added locally) by sending a <Timer Record List Trigger> message.

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Recording devices should also send a <Timer Record List Trigger> message when powered on/connected to the system.

A device may query the recording device for information about its timer options by sending a <Give Timer Options> message. The recording device will respond with a <Timer Options> message, which describes information such as the number of free timer blocks and if high/low quality recording is supported.

A device may set or clear an individual timer block of a recording device. The recording device will respond to indicate if the timer was successfully set/cleared. It is also possible to transfer the program title of a timer block (where for instance a timer is set via an EPG). To achieve this a device may send a <Set Timer Program Title> message directly after sending <Set Timer>. The recording device may then store the program title along with the timer information. If the recording device does not support program titles, then it shall ignore an incoming <Set Timer Program Title> message.



CEC Figure 15 A typical scenario for setting a Timer Record Block

CEC 13.6 System Information

CEC 13.6.1 Messages

The following messages are used for the System Information feature:

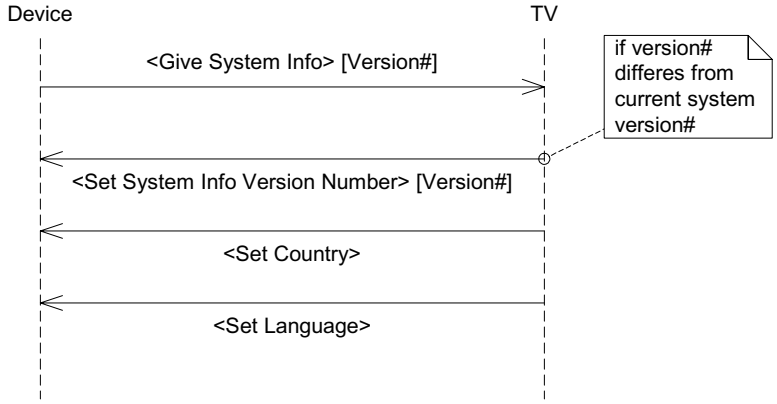
<Give Physical Address>, <Give System Info>, <Polling Message>, <Report Physical Address>, <Set Country>, <Set Language>, <Set System Info Version Number>

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CEC 13.6.2 Feature Description

This feature allows devices to automatically use the same country and language settings as the TV.

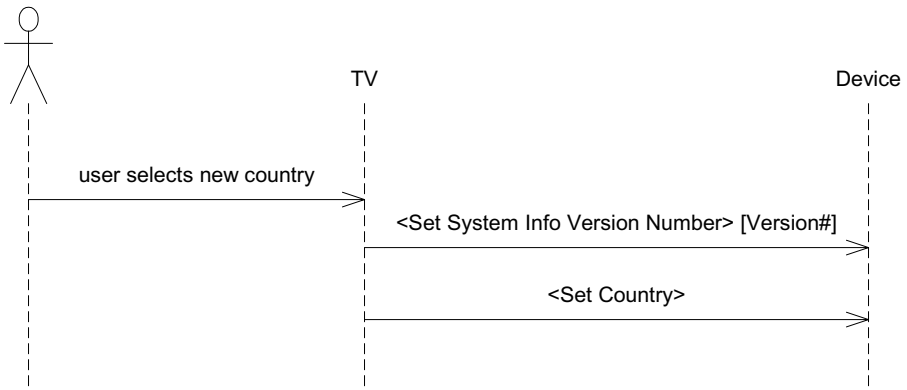
When a source device is powered on, it should send a <Give System Info> message to the TV. The TV will then respond as shown below if the version number is different to the current version number stored by the TV.



CEC Figure 16 Message exchange when downloading the TV's System Info

A device that supports the System Information feature shall support at least one of the <Set Country> and <Set Language> messages but is not required to support both. For example a device could have a configurable language setting, but no country setting.

When a change to a configuration setting occurs, the TV should increment its version number and broadcast a <Set System Info Version Number> message, followed by a message corresponding to the parameter that has changed as shown below.



CEC Figure 17 A typical scenario when a system setting within the TV is modified

A device receiving a <Set System Info Version Number> shall update its internal system info version number. A device may accept and act upon individual <Set Country> and <Set Language> messages, however the TV should always send a <Set System Info Version Number> message before sending either message. A device shall ignore any of the above messages that come from an initiator address other than 0 (the TV).

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CEC 13.6.3 Additional Information

The <Polling Message> is used to detect the presence or absence of a device within the system. It is used for allocating logical addresses as detailed in C.9.2.1.

The <Report Physical Address> message is used by a device to broadcast its physical address to all other devices in the system. By using the logical and physical addresses, any other device is able to derive the physical connectivity of the network. A device may request the physical address of another device by sending a directly addressed <Give Physical Address> message to it.

CEC 13.7 Deck Control

CEC 13.7.1 Messages

The following messages are used for the Deck Control feature:

<Deck Status>, <Give Deck Status>, <Deck Control>, <Play>

CEC 13.7.2 Feature Description

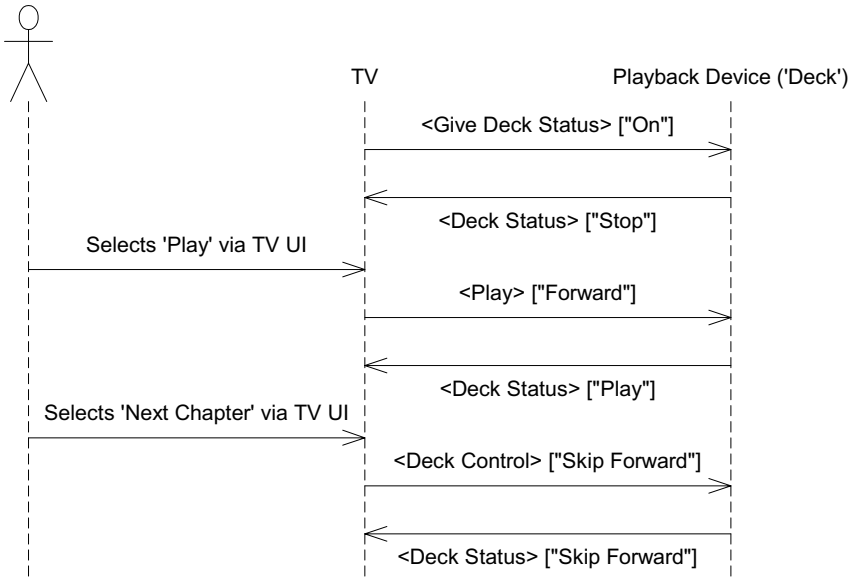
This feature allows a playback device (a deck) to be controlled by another device (e.g. the TV). Messages are also provided to allow a device to find out the status of the Deck; this allows, for example, a TV to keep its user interface synchronized with the status of the Deck.

A device may query the status of a deck with the <Give Deck Status> command. The deck should respond with a <Deck Status> message.

A device may control a Deck with the <Play> and <Deck Control> messages. These messages may be initiated after a user command. The Deck shall act upon the command that it receives within the messages <Play> and <Deck Control>. It is the equivalent of the user selecting the command local to the Deck. If the deck cannot carry out the command (e.g. it has no media when trying to play) it should respond with a <Feature Abort> [“Not in correct mode to respond”] message.

If the deck is in standby and receives a <Deck Control> [“Eject”] or <Play> [“Play Forward”] message, it should power on and act on the message. It is up to the local specification if the device should power on when receiving any other <Deck Control> or <Play> messages.

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CEC Figure 18 A typical scenario for the Deck Control feature

CEC 13.8 Tuner Control

CEC 13.8.1 Messages

The following message are used for the Tuner Control feature:

<Give Tuner Device Status>, <Select Preset>, <Tuner Step Decrement>, <Tuner Step Increment>, <Tuner Device Status>

CEC 13.8.2 Feature Description

This feature allows a device (e.g. the TV) to control another CEC devices tuner.

A device can select a preset number of a tuner device by sending the <Select Preset> message. The tuner device shall then attempt to tune to that preset number and stream its output on the HDMI connection. If the specified preset number is not set on the device then it should send a <Feature Abort> [“Invalid operand”] message. If the tuner device cannot change its preset number (e.g. if it is recording), it should respond with a <Feature Abort> [“Refused”] message.

A device can also control a CEC Devices tuner using the <Tuner Step Increment> and <Tuner Step Decrement> messages. If a device receives the <Tuner Step Increment> or <Tuner Step Decrement> message then it should increment or decrement the current preset that it is tuned to. The tuner device can interpret the messages as it chooses, for example, it may only cycle through channels included in the users list of favorites.

A device may query the status of a tuner device by sending a <Give Tuner Device Status> message. The tuner device shall respond by sending a <Tuner Device Status> message indicating if it is currently displaying its tuner and the preset number it is currently tuned to.

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CEC 13.9 Vendor Specific Commands

CEC 13.9.1 Messages

The following messages are used for the Vendor Specific Commands feature:

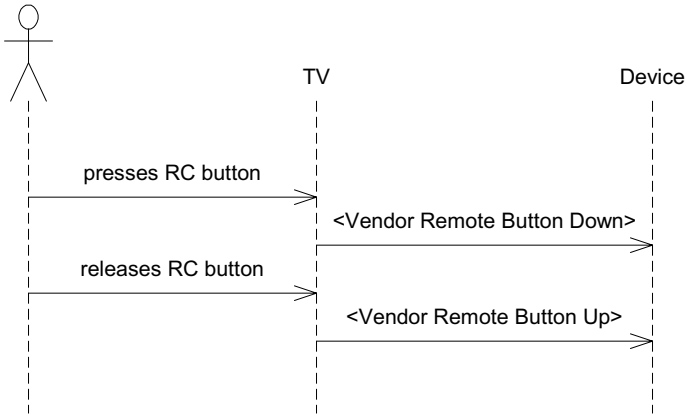
<Device Vendor ID>, <Give Device Vendor ID>, <Vendor Command>, <Vendor Remote Button Down>, <Vendor Remote Button Up>

CEC 13.9.2 Feature Description

This feature allows a set of vendor specific commands to be used to communicate between devices of a single vendor.

A device that supports vendor specific commands shall store a Vendor ID. A device shall broadcast a <Device Vendor ID> message after a successful initialization and address allocation to inform all other devices of its vendor ID. A device may request the Vendor ID of another device by sending a <Give Device Vendor ID> message to it. The follower shall respond by broadcasting a <Device Vendor ID> message. In this way any device can determine the vendor of another device. A device shall only attempt to transmit a vendor specific command to another device that it knows has the same vendor ID. In this way a device receiving a vendor specific command can always assume that it came from a device of the same vendor and respond accordingly.

It is possible to send vendor specific remote control commands using the <Vendor Remote Button Down> and <Vendor Remote Button Up> messages.



CEC Figure 19 The messages sent in the Vendor Specific Commands feature

In addition it is possible to send other (non remote control key) vendor specific messages using the <Vendor Command> message. The message parameter(s) can be used to communicate any additional (vendor defined) messages and data.

CEC 13.10 OSD Status Display

CEC 13.10.1 Messages

The following message is used for the OSD Status Display feature:

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<Set OSD String>

CEC 13.10.2 Feature Description

This feature allows a device to transfer a text string to the TV for On Screen Display. The <Set OSD String> message is used to transfer the text string to the TV.

A text string may be displayed for a default period (i.e. 5 seconds) or until explicitly cleared. In the latter case the device should send another <Set OSD String> message to clear the text when it is appropriate.

The TV should display the whole string unless it is in an unsuitable state, in which case it should generate a <Feature Abort> message.

If a new <Set OSD String> message is received when an OSD String is already being displayed, it should overwrite the existing string. OSD Strings generated locally within the TV may also overwrite any messages sent via the <Set OSD String> message.

CEC 13.11 Device Menu Control

CEC 13.11.1 Messages

The following messages are used for the Device Menu Control feature:

<User Control Pressed>, <User Control Released>, <Menu Request>, <Menu Status>

CEC 13.11.2 Feature Description

This feature allows device menus to be controlled via the TV remote control as if it was using its own remote control and allow the TV to be aware when another device has a menu on its display.

A device shall indicate that it is displaying a menu by sending a <Menu Status> [“Activated”] message to the TV. If the device leaves the menu it shall send a <Menu Status> [“Deactivated”] message to the TV. The TV should then handle incoming remote control commands internally (as it would normally).

The message <User Control Pressed> can be used to send incoming Remote Control commands from the TV to a device that it is displaying a menu. The <User Control Released> message should be sent on release of the RC button. If a device fails to acknowledge any <User Control Pressed> or <User Control Released> message when in the providing menu state, the TV shall assume that it has been removed from the system and act accordingly. For more information on <User Control> see the Remote Control Pass Through feature description (CEC 13.4).

The TV may initiate a device’s menu by sending a <Menu Request> [“Activate”] command. It may subsequently remove the menu by sending a <Menu Request> [“Deactivate”] message. The TV may also query a devices menu status by sending a <Menu Request> [“Query”]. The menu device shall always respond with a <Menu Status> command when it receives a <Menu Request>.

A new active source device shall send a <Menu Status> [“Activated”] message to the TV if it is displaying a menu. The TV shall assume that a new active source is not in a menu unless it receives this message after the <Active Source> message. The TV shall ignore a <Menu Status>

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message coming from a device that is not the current active source. A source device shall only send <Menu Status> commands when it is the current active source.

CEC 13.12 Routing Control

CEC 13.12.1 Messages

The following messages are used for the Routing Control feature:

<Active Source>, <Request Active Source>, <Set Stream Path>, <Routing Change>, <Routing Information>

CEC 13.12.2 Feature Description

This feature is used to control the routing of the HDMI network, by controlling CEC Switches.

In general whenever a device starts being streamed to the TV it should send an <Active Source> message. Any CEC Switches between the device and the TV should react to the <Active Source> message and switch (if required) to ensure the device at the physical address specified is on the active path. If another device was previously the active source then it should act accordingly, for example it may pause if it is playing media.

A device may broadcast a <Request Active Source> message to discover if any device is currently acting as the active source. The active source device will respond by broadcasting an <Active Source> message.

It is possible that the user may select a device to view via the TV user interface. In this case the TV should broadcast a <Set Stream Path> message with the physical address of the device it wishes to display as a parameter. Any CEC Switches between the device and TV should switch (if required) to ensure the device is on the active AV path. This feature ensures that non-CEC-compliant devices in the network can be switched to, if for instance they have been manually set up in the TV menu. A CEC device at the location specified by the <Set Stream Path> message should begin streaming its output and broadcast an <Active Source> message.

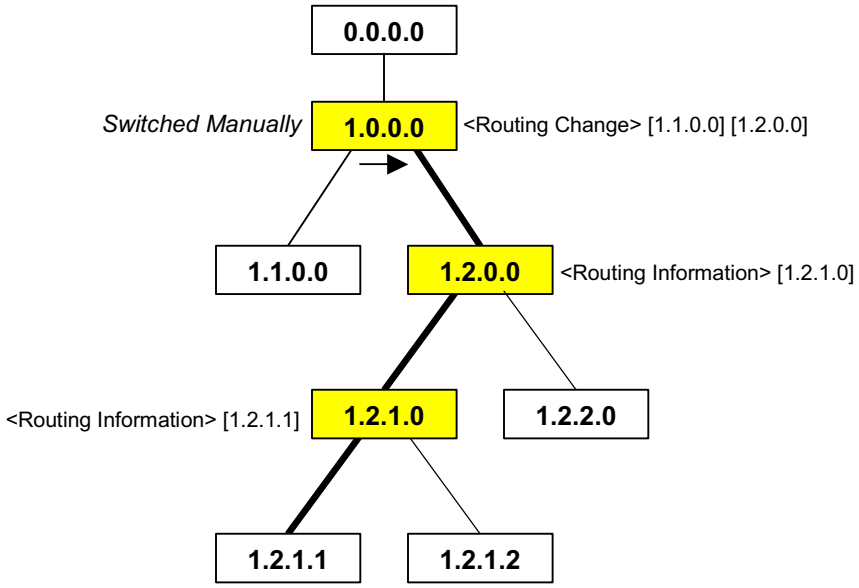
In the case that the user manually switches a CEC Switch it should broadcast a <Routing Change> message. This will inform all devices in the network that the current active route below the switch has changed. This enables, for instance, a device that has been deselected by a switch to pause if it is playing media.

If a CEC Switch is at the new position indicated by the <Routing Change> message then it should broadcast a <Routing Information> message with the physical address of its current active path. If a CEC Switch receives a <Routing Information> message then it should broadcast a <Routing Information> message to indicate it’s current active path. In this way the TV is aware of which device is on the current active path after the switch occurs. If the TV detects that the active source device has been de-selected by changing the switch it may either switch to an internal preset or send a <Set Stream Path> message to the device at the new location to indicate that it should become the new active source.

The TV shall wait for a minimum of 7 nominal data bit periods before reacting to a <Routing Change> or <Routing Information> message to allow CEC switches to relay any <Routing Information> messages that are required.

The following diagram shows an example of the message flow when a user manually switches a CEC Switch. (CEC Switches are shown filled).

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CEC Figure 20 Example message flow, when a CEC Switch is manually switched

CEC 13.13 Remote Control Pass Through

CEC 13.13.1 Messages

The following messages are used for the Remote Control Pass Through feature:

<User Control Pressed>, <User Control Released>

CEC 13.13.2 Feature Description

This feature is used to pass remote control commands received by one device (typically the TV) through to another device in the network. This feature will typically be used in situations where a TV offers a remote control with additional modes for controlling other devices within the system. The TV will receive the RC command and pass the command through to the appropriate device within the system.

The initiator shall decide on which device the remote command is for and send a directly addressed <User Control Pressed> message to it using the table of standard remote control pass through commands given in CEC Table 9. In a system where there is more than one of a particular device type present, the initiator should decide (as locally specified) a default device to pass remote control commands to.

The initiator will send a <User Control Pressed> message when the remote control button is pressed. When the button is released a <User Control Released> message should be sent by the initiator. The initiator should not send repeated <User Control Pressed> messages for the same button press.

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The initiator may send further <User Control Pressed> messages without interleaving <User Control Released> messages if a new button press occurs quickly after a button release.

A device that has initiated a <User Control Pressed> message shall ensure that it sends a <User Control Released> message before going into standby. In the event that the initiator of the message is powered off/disconnected before sending a <User Control Released> message, the follower will never receive the <User Control Released> message.

This method should not be used for sending commands other than true remote control pass through to another device as the actions taken by the other device are not defined in a consistent way.

CEC 13.14 Device OSD Name Transfer

CEC 13.14.1 Messages

The following messages are used for the Device OSD Name Transfer feature:

<Give OSD Name>, <Set OSD Name>

CEC 13.14.2 Feature Description

This feature is used to request the preferred name of a device to be used in any on screen display (e.g. menus), which reference that device. A device (e.g. the TV) may request another devices name by sending a directly addressed <Give OSD Name> message to it. If the device supports this feature it will respond with a <Set OSD Name> message. The devices name should then be stored and used in any future on screen references to it.

A TV shall send a <Give OSD Name> message whenever it discovers a new device that has been connected.

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CEC 14 Device states

This section shows how CEC messages can change the states of a device.

CEC 14.1.1 Device States

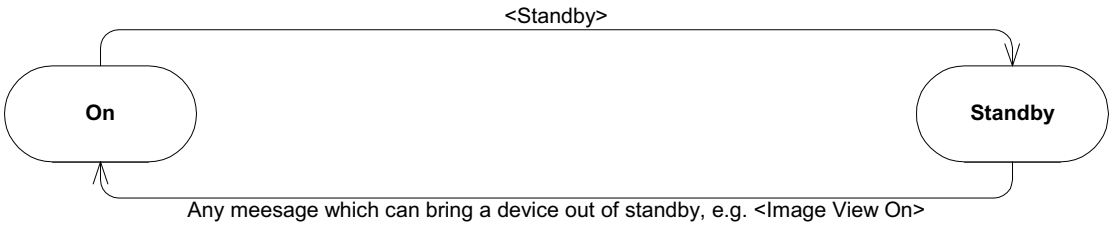
The following is a list of states that each device type can be in. Each device should be in one and only one state for each line shown below.

All Devices:	On, Standby, Off
TV:	Image Display, Menu Display, Text Display
	Preset Download Active, Preset Download Inactive
	Device Menu Active, Device Menu Inactive
Recording Device:	Recording, Not Recording
Playback Device:	Deck Active, Deck Inactive
Menu Providing Device:	Device Menu Active, Device Menu Inactive
Tuner Device:	Preset Download Active, Preset Download Inactive
Timer Setting Device:	Timer Block Transfer Active, Timer Block Transfer Inactive

CEC 14.1.2 State Changes

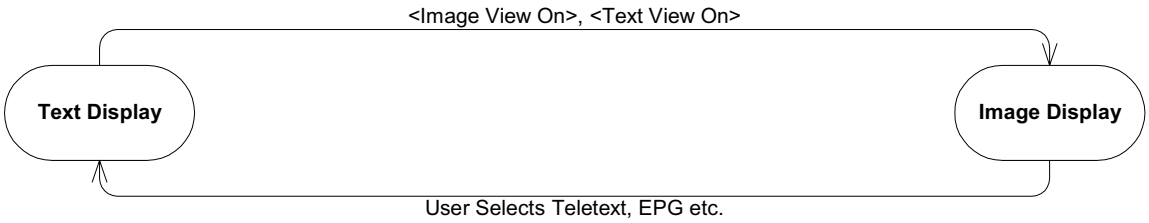
The following diagrams show the state transitions that are caused as a direct result of a device receiving a CEC message. Transitions between states that are not caused as a result of CEC messages are generally not shown, except where no CEC message can cause that transition.

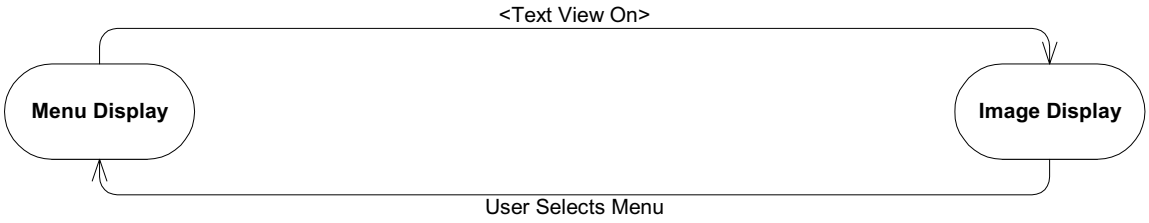
CEC 14.1.3 All Devices

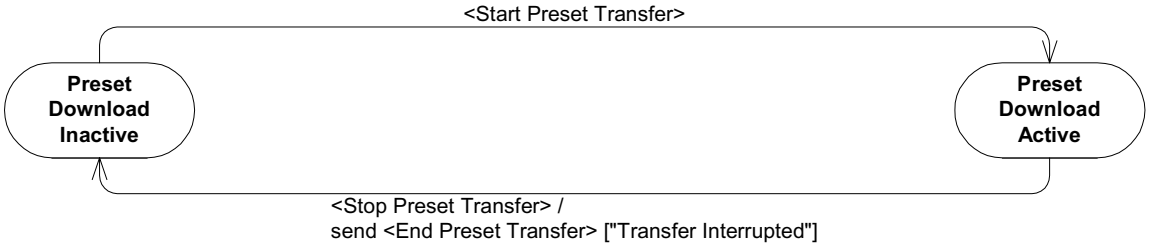


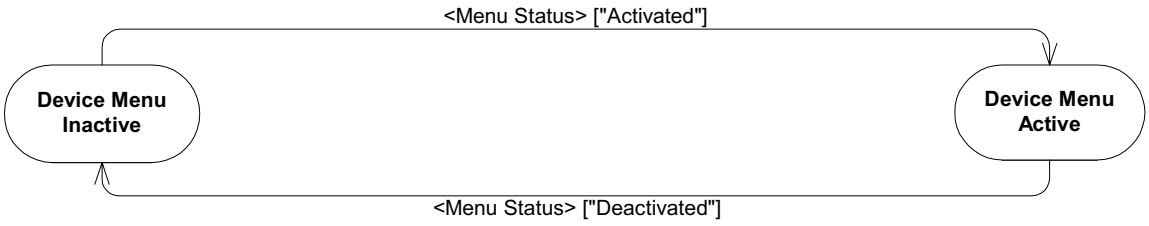
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CEC 14.1.4 TV



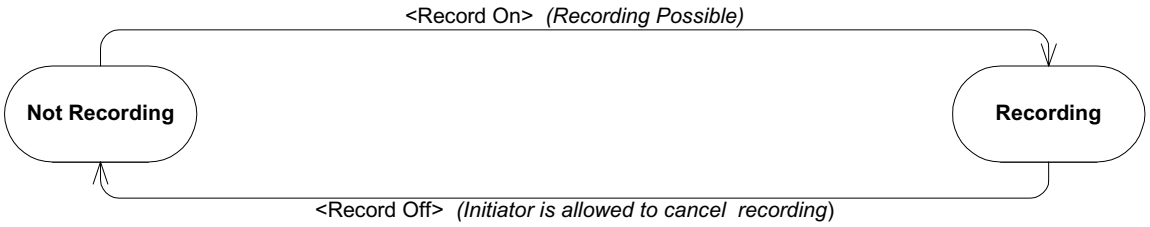




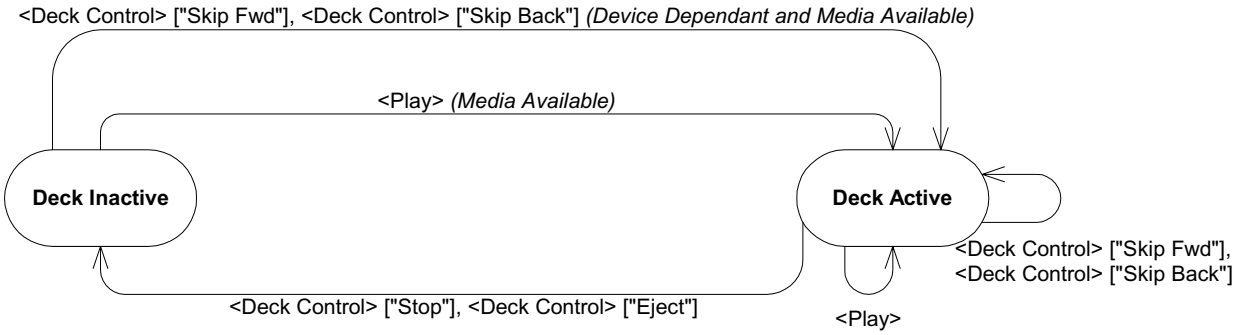


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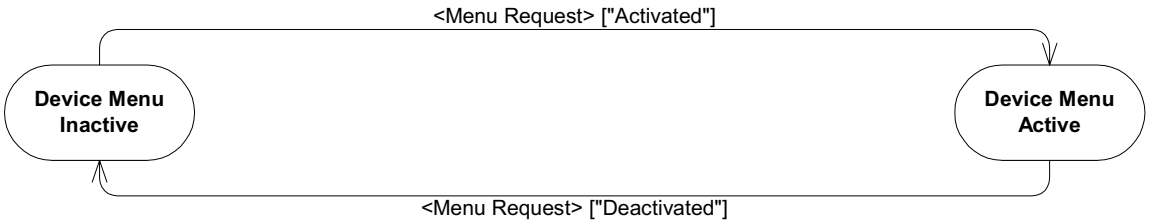
CEC 14.1.5 Recording Device



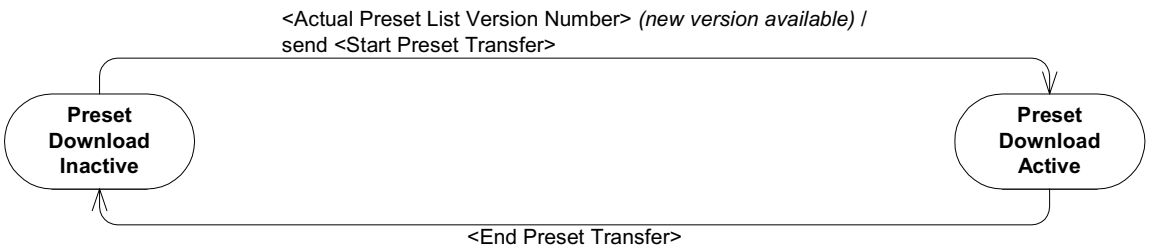
CEC 14.1.6 Playback Device



CEC 14.1.7 Menu Providing Device

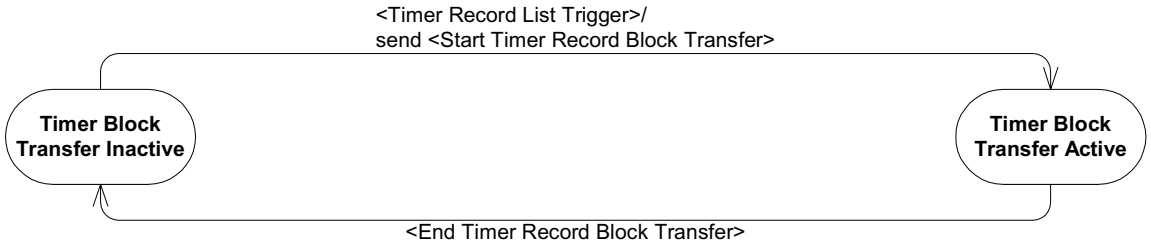


CEC 14.1.8 Tuner Device



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CEC 14.1.9 Timer Setting Device



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CEC 15 Message Descriptions

The section defines the individual messages used in CEC. It describes them and defines their parameters and expected responses. As CEC has no session layer, this section and the operands section (CEC 17) effectively define the complete messaging system. The use of this messaging system is clarified in the features description (CEC 13).

The following list describes each heading within the message table (CEC Table 5).

- **Opcode** – The name used to identify the message.
- **Value** – The unique identifier for the message.
- **Description** – A brief description of the message.
- **Parameters** – The set of parameters used by the message, refer to CEC Table 8 for individual descriptions.
- **Parameter Description** – A brief description of the parameters that the message uses.
- **Response** – Describes how a device should respond on receipt of the message.
- **Directly Addressed** – Indicates if the message may be directly addressed.
- **Broadcast** – Indicates if the message may be broadcast.
- **Mandatory** – Indicates if it is mandatory for a device to react and respond on receipt of the message. Note that where a message is indicated as being mandatory for 'All' devices, this excludes devices which act only as a CEC Switch.

Within the table some cells are intentionally left blank; this indicates that there is no associated requirements for the Opcode described.

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CEC Table 5 Message Descriptions

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Abort Message>	0xFF	This message is reserved for testing purposes.	None		A device should never support this message, and should always respond with a <Feature Abort>.			
<Active Source>	0x82	Used by a new source to indicate that it has started to transmit a stream OR used in response to a <Request Active Source>	[Physical Address]	The physical address of the device.	A current active source should take appropriate action. Any CEC switches between source and root should switch to the appropriate input.			TV, CEC Switches
<Actual Preset List Version Number>	0x16	Used by the TV to inform all devices of the preset list version number. This is usually sent when the preset list has changed, or the TV has recently joined the network.	[Preset List Version Number]	The version number is incremented modulo 256 after every change to the preset table.	If the devices version number differs with that received it enters 'Preset Download Active' state and initiates a Preset Download by sending a <Start Preset Transfer> message to the TV.			
<Clear Timer>	0x33	Used to clear a timer block of a device.	See <Set Timer> message.	See <Set Timer> message.	Clear timer block if possible, then respond with <Timer Cleared Status>			

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Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Deck Control>	0x42	Used to control a device's tape/media functions.	[Deck Control Mode]	The deck control requested.	Perform the specified actions, or return a <Feature Abort> message. It is device dependant whether or not a Skip Fwd/Skip Back (Wind/Rewind) command is legal when in the 'Deck Inactive' state. If the device is in standby and receives an eject command, it should power on and eject its media.			Playback device
<Deck Status>	0x1B	Used to provide a deck's status to the initiator of the <Give Deck Status> message.	[Deck Info]	Information on the device's current status.				
<Device Vendor ID>	0x87	Reports the vendor ID of this device.	[Vendor ID]	The vendor ID of the device.	Any other interested device may store the vendor ID of the device.			
<End Preset Transfer>	0x03	Informs all devices that a preset transfer session has concluded.	[Preset List Version Number] [Preset List Info]	The version number of the preset list that has just been sent and its status.	Enter 'Preset Download Inactive' state. Store the new version number locally unless the parameter indicates the transfer was interrupted.			

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Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<End Timer Record Block Transfer>	0x39	Used to indicate the end of the Timer Record Block transfer.	[Timer List Info]	Transfer and timer information.	Enter 'Timer Block Transfer Inactive' state.			
<Feature Abort>	0x00	Used as a response to indicate that the device does not support the requested message type, or that it cannot execute it at the present time.	[Feature Opcode] [Abort Reason]	The Opcode of the aborted message. The reason provides an indication as to whether the follower does not support the message, or does support the message but cannot respond at the present time.	Assume that request is not supported or has not been actioned.			All[1]
<Give Deck Status>	0x1A	Used to request the status of a device, regardless of whether or not it is the current active source.	[Status Request]	Allows the initiator to request the status once or on all future state changes. Or to cancel a previous <Give Deck Status> ["On"] request.	<Deck Status>			Playback Device
<Give Device Vendor ID>	0x8C	Requests the Vendor ID from a device.	None		<Device Vendor ID>			
<Give OSD Name>	0x46	Used to request the preferred OSD name of a device for use in menus associated with that device.	None		<Set OSD Name>			

[1] Mandatory to accept this message on all devices and to generate it if a requested message is not supported.

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Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Give Physical Address>	0x83	A request to a device to return its physical address.	None		<Report Physical Address>			All
<Give Preset List Version Number>	0x15	Used by a tuner device to request the TV's preset list version number.	None.		<Actual Preset List Version Number>			TV[2]
<Give System Info>	0x52	Requests system information from the TV.	[System Info Version Number]	Version number of the system info.	TV sends: <Set System Info Version Number> and at least one of: <Set Country> and <Set Language> to the initiator. TV only responds if <System Info Version Number> is different to that given as a parameter within the request.			TV[3]
<Give Timer Options>	0x3E	Request for timer programming capabilities of a recording device.	None		<Timer Options>			

[2] Only mandatory if TV contains tuner
[3] Only mandatory for information which the TV already holds for other purposes.

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Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Give Tuner Device Status>	0x08	Used to request the status of a tuner device.	[Status Request]	Allows the initiator to request the status once or on all future state changes, or to cancel a previous <Give Tuner Device Status> [“On”] message.	Respond with a <Tuner Device Status> message, or stop reporting changes on receipt of the [“Off”] message.			Tuner Device
<Image View On>	0x04	Sent by a source device to the TV whenever it enters the active state (alternatively it may send <Text View On>).	None		Turn on (if not on). If in ‘Text Display’ state then the TV enters ‘Image Display’ state. Displays output from initiator. Note: Don’t change TV menu or PIP status.			TV
<Menu Request>	0x8D	A request from the TV for a device to show/remove a menu or to query if a device is currently showing a menu.	[Menu Request Type]	Indicates if the menu request is to activate or deactivate the devices menu, or to simply query the devices menu status.	May enter or exit the ‘Device Menu Active’ state if the parameter was “Activate” or “Deactivate” Send <Menu Status> to indicate the current status of the devices menu.			Menu Providing Device
<Menu Status>	0x8E	Used to indicate to the TV that the device is showing/has removed a menu and requests the remote control keys to be passed though.	[Menu State]	Indicates if the device is in the ‘Device Menu Active’ state or ‘Device Menu Inactive’ state.	If Menu State indicates activated, TV enters ‘Device Menu Active’ state and forwards those Remote control commands, shown in CEC Table 9, to the initiator. If deactivated, TV enters ‘Device Menu Inactive’ state and stops forwarding remote control commands.			TV

LENOVO EXHIBIT 1008 - 924/963

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Play>	0x41	Used to control the playback behaviour of a source device.	[Play Mode]	Play mode required.	Perform the specified actions, or return a <Feature Abort> message. If media is available the device enters 'Deck Active' state. If the device is in standby, has media available and the parameter is ["Play Forward"] it should power on.			Playback device
<Polling Message>	-	Used by any device for device discovery – similar to ping in other protocols.	None		Will set a low level ACK.			All
<Record Off>	0x0B	Requests a device to stop a recording.	None		Exit 'Recording' state and stop recording if the initiator is the same as the initiator of the <Record On> message which started this recording.			Recordin g Device
<Record On>	0x09	Attempt to record the specified source.	[Record Source]	Source to record, either preset number or own source.	Enter 'Recording' state and start recording if possible. Send the initiator <Record Status>.			Recordin g Device
<Record Status>	0x0A	Used by a recording device to inform the initiator of the message <Record On> about its status.	[Record Status Info]	The recording status of the device.				

LENOVO EXHIBIT 1008 - 925/963

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Record TV Screen>	0x0F	Request by the recording device to record the presently displayed source.	None		Initiate a recording using the <Record On> message, or send a <Feature Abort> [“Cannot provide source”] if the presently displayed source is not recordable.			
<Report Physical Address>	0x84	Used to inform all other devices of the mapping between physical and logical address of the initiator.	[Physical Address] [Device Type]	The device’s physical address within the cluster.				
<Request Active Source>	0x85	Used by a new device to discover the status of the system.	None		<Active Source> from the present active source.			
<Routing Change>	0x80	Sent by a CEC Switch when it is manually switched to inform all other devices on the network that the active route to the sink below the switch has changed.	[Original Address] [New Address]	The previous child_address that the switch was switched to and the new child_address it has been moved to.	If a CEC Switch is at the new address, it sends a <Routing Information> message to indicate its current active route.			TV, CEC Switches
<Routing Information>	0x81	Sent by a CEC Switch to indicate the active route to the sink below the switch.	[Physical Address]	The current active route to the sink in the CEC Switch.	If a CEC Switch is at the specified address it should relay a <Routing Information> message to indicate its current active path.			CEC Switches

LENOVO EXHIBIT 1008 - 926/963

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Select Preset>	0x13	Used to allow one device to select a preset on another device that contains a tuner.	[Preset Number]	The preset number to be displayed.	Change to the selected preset, and stream its output on the HDMI connection. If the preset number is not set or the device cannot change preset, then it responds with a <Feature Abort>.			

LENOVO EXHIBIT 1008 - 927/963

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Set Analogue Preset>	0x01	Used to transfer an analogue preset.	[Preset Number] [Analogue Preset]	Preset number and details	Store the preset using the details indicated. If the device does not support the preset number, then it should ignore the message. If the device does not support the frequency or broadcast system, then it should clear the preset number			Tuner Device [4]
<Set Country>	0x31	Used by a TV to indicate the country setting to other devices	[Country]	The country code.	Set the country as specified, if possible			
<Set Language>	0x32	Used by a TV to indicate the menu & subtitle language settings to other devices	[Menu Language] [Subtitle Language]	The user's menu & subtitle language choices.	Set the menu & subtitle languages as specified, if possible.			
<Set OSD Name>	0x47	Used to set the preferred OSD name of a device for use in menus associated with that device.	[OSD Name]	The preferred name of the device.	Store the name and use it in any menus associated with that device.			
<Set OSD String>	0x64	Used to send a text message to output on a TV.	[Display Control] [OSD String]	Display timing. Text to be displayed.	TV displays the message.			

[4] Only mandatory on a device which initiates a <Start Preset Transfer>

LENOVO EXHIBIT 1008 - 928/963

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Set Preset Name>	0x0C	Used to transfer a preset name (only accepted if <Set Analogue Preset> has previously been received and accepted for this preset number). The preset name is optional, so this message may not be sent when transferring a preset.	[Preset Number] [Preset Name]	Preset number and name	Store the preset name indicated or ignore message.			
<Set Stream Path>	0x86	Used by the TV to request a streaming path from the specified physical address.	[Physical Address]	The physical address of the source device.	Any CEC switches between should switch inputs according to the path defined in [Physical Address]. The device at the new address should stream its output and broadcast an <Active Source> message.			CEC Switches
<Set System Info Version Number>	0x53	Used by a TV to indicate its system info version number.	[System Info Version Number]	The version of the system info.	Devices should update their system info version number accordingly.			
<Set Timer>	0x34	Used to set a single timer block on a recording device.	[Preset Number] [Day of Month] [Month of Year] [Start Time] [Stop Time] [PIL Code] [Series Code] [Timer Related Data]	A complete set of timer information for one recording.	<Timer Status> message.			

LENOVO EXHIBIT 1008 - 929/963

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Set Timer Program Title>	0x67	Used to set the name of a program associated with a timer block. Sent directly after sending a <Set Timer> message. The name is then associated with that timer block.	[Program Title String]	Program title	Recording device stores title for future reference. Ignore message if it is not the immediate next message from this initiator following a <Set Timer> message.			
<Standby>	0x36	Switches one or all devices into standby mode. Can be used as a broadcast message or be addressed to a specific device. It is recommended that a directly addressed message is only sent if the initiator originally brought the device out of standby.	None		Switch the device into standby. [5] Ignore the message if already in standby.			All
<Start Preset Transfer>	0x02	Request the current preset list from TV tuner.	None		TV enters 'Preset Download Active' state and starts transferring presets from its tuner.			TV[6]

[5] Can be ignored if actively engaged in a recording or providing a source stream for a recording.
[6] Only mandatory if TV contains a tuner.

LENOVO EXHIBIT 1008 - 930/963

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Start Timer Record Block Transfer>	0x37	Used to request transfer of all Timer Record Blocks from a recording device.	None		Enter 'Timer Block Transfer Active' state and broadcasts all occupied Timer Record Blocks using <Timer Record Block Transfer> messages.			
<Stop Preset Transfer>	0x10	Request from the initiator of <Start Preset Transfer> to stop transmitting presets. Ends a preset transfer session.	None		TV enters 'Preset Download Inactive' state and sends an <End Preset Transfer> ["Transfer interrupted"] message. No further presets are transmitted.			TV[6]
<Text View On>	0x0D	As <Image View On>, but also removes any text, menus and PIP windows from the TV's display.	None		As <Image View On>, but removes PIPs and menus from the screen. The TV enters 'Image Display' state regardless of its previous state.			TV
<Timer Cleared Status>	0x43	Used to give the status of a <Clear Timer> message.	[Timer Cleared Status Data]	Indicates if the timer was cleared successfully.	If the message indicates that the timer was not cleared because there was no matching entry, the device should remove the timer block locally or use <Start Timer Record Block Transfer> to ensure consistency with the recording device.			

LENOVO EXHIBIT 1008 - 931/963

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Timer Options>	0x3F	Used by a recording device to inform the initiator of the message <Give Timer Options> about its timer programming capabilities.	[# Timer Blocks] [# Free Timer Blocks] [Timer Options]	The total number and free number of timer blocks, with additional information about what programming features are supported.				
<Timer Record Block Transfer>	0x38	Used to transfer the data of a Timer Record Block.	[Preset Number] [Day of Month] [Month of Year] [Start Time] [Stop Time] [PIL Code] [Series Code] [Timer Block Related Data] [Recording Status]	As for <Set Timer>, except [Timer Block Related Data], [Recording Status] A complete set of timer information for one recording.				
<Timer Record List Trigger>	0x19	Used by a device to inform all followers that 1) its timer block list has changed; 2) it has been powered up.	None		May enter 'Timer Block Transfer Active' state and request to start the transfer of blocks by sending a <Start Timer Record Block Transfer> message.			
<Timer Status>	0x35	Used to send timer status to the initiator of a <Set Timer> message.	[Timer Status Data]	Indicates the timer status	.			

LENOVO EXHIBIT 1008 - 932/963

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Tuner Device Status>	0x07	Use by a tuner device to provide its status to the initiator of the <Give Tuner Device Status> message.	[Tuner Device Info]	Information on the tuner devices current status.				
<Tuner Step Decrement>	0x06	Used to decrement the preset used by a device's tuner. Can be used for PIP.	None		Follower decrements tuner preset.			
<Tuner Step Increment>	0x05	Used to increment the preset used by a device's tuner. Can be used for PIP.	None		Follower increments tuner preset.			
<User Control Pressed>	0x44	Used to indicate that the user pressed a remote control button or switched from one remote control button to another.	[UI Command]	UI command issued by user.	Update display or perform an action, as required.			
<User Control Released>	0x45	Indicates that user released a remote control button (the last one indicated by the <User Control Pressed> message)	None		Update display or perform an action, as required.			

LENOVO EXHIBIT 1008 - 933/963

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory
<Vendor Command>	0x89	Allows vendor specific commands to be sent between two devices.	[Vendor Specific Data]	Vendor specific command or data. The maximum length of the [Vendor Specific Data] must not exceed 14 data blocks to avoid saturating the bus.	Vendor Specific			
<Vendor Remote Button Down>	0x8A	Indicates that a remote control button has been depressed.	[Vendor Specific RC Code]	The vendor specific Remote Control Code for the key pressed.	Vendor Specific			
<Vendor Remote Button Up>	0x8B	Indicates that a remote control button (the last button pressed indicated by the Vendor Remote Button Down message) has been released.	None		Vendor Specific			

LENOVO EXHIBIT 1008 - 934/963

CEC 16 Message Dependencies

This section describes the dependencies between each message. This section is divided into two tables, which describe the following:

- CEC Table 6 describes the message dependencies when a device is capable of receiving a particular message (i.e. it does not <Feature Abort> indicating an [“Unrecognized opcode”] in response to the message).
- CEC Table 7 describes the message dependencies when a device is capable of sending a particular message.

Each table describes the additional messages that the device shall be capable of receiving and sending if a particular message is supported.

LENOVO EXHIBIT 1008 - 935/963

CEC Table 6 Message dependencies when receiving a message

If device does not <Feature Abort> the following message:	**It shall not <Feature Abort> the message(s):**	**It shall be able to send the message(s):**
<Actual Preset List Version Number>	<End Preset Transfer>, <Set Analogue Preset>	<Give Preset List Version Number>, <Start Preset Transfer>, <Stop Preset Transfer>
<Clear Timer>	<Set Timer>	<Timer Cleared Status>, <Timer Status>
<Deck Control>	<Play>, <Give Deck Status>	<Deck Status>
<Deck Status>	-	<Give Deck Status>, <Play>, <Deck Control>
<Device Vendor ID>	-	<Give Device Vendor ID>
<End Preset Transfer>	<Actual Preset List Version Number>, <Set Analogue Preset>	<Give Preset List Version Number>, <Start Preset Transfer>, <Stop Preset Transfer>
<End Timer Record Block Transfer>	<Timer Record Block Transfer>, <Timer Record List Trigger>	<Start Timer Record Block Transfer>
<Give Deck Status>	<Play>, <Deck Control>	<Deck Status>
<Give Device Vendor ID>	-	<Device Vendor ID>
<Give OSD Name>	-	<Set OSD Name>
<Give Physical Address>	-	<Report Physical Address>
<Give Preset List Version Number>	<Start Preset Transfer>, <Stop Preset Transfer>	<Actual Preset List Version Number>, <Set Analogue Preset>, <End Preset Transfer>
<Give System Info>	-	<Set System Info Version Number>, At least one of: <Set Country>, <Set Language>
<Give Timer Options>	-	<Timer Options>

LENOVO EXHIBIT 1008 - 936/963

If device does not <Feature Abort> the following message:	It shall not <Feature Abort> the message(s):	It shall be able to send the message(s):
<Give Tuner Device Status>	-	<Tuner Device Status>
<Image View On>	<Active Source>	-
<Menu Request>	<User Control Pressed>, <User Control Released>	<Menu Status>
<Menu Status>	-	<Menu Request>, <User Control Pressed>, <User Control Released>
<Play>	<Give Deck Status>, <Deck Control>	<Deck Status>
<Record Off>	<Record On>	<Record Status>
<Record On>	<Record Off>	<Record Status>
<Record Status>	-	<Record On>, <Record Off>
<Record TV Screen>	<Record Status>	<Record On>, <Record Off>
<Request Active Source>	-	<Active Source>
<Routing Change>	<Routing Information>	-
<Routing Information>	<Routing Change>	-
<Set Analogue Preset>	<End Preset Transfer>, <Actual Preset List Version Number>	<Start Preset Transfer>, <Stop Preset Transfer>, <Give Preset List Version Number>
<Set Country>	<Set System Info Version Number>	<Give System Info>
<Set Language>	<Set System Info Version Number>	<Give System Info>
<Set OSD Name>	-	<Give OSD Name>

LENOVO EXHIBIT 1008 - 937/963

If device does not <Feature Abort> the following message:	It shall not <Feature Abort> the message(s):	It shall be able to send the message(s):
<Set OSD String>	-	-
<Set Preset Name>	<Set Analogue Preset>, <End Preset Transfer>, <Actual Preset List Version Number>	<Start Preset Transfer>, <Stop Preset Transfer>, <Give Preset List Version Number>
<Set Stream Path>	-	<Active Source> (not CEC Switches)
<Set System Info Version Number>	At least one of: <Set Country>, <Set Language>	<Give System Info>
<Set Timer Program Title>	<Set Timer>, <Clear Timer>	<Timer Status>, <Timer Cleared Status>
<Set Timer>	<Clear Timer>	<Timer Status>, <Timer Cleared Status>
<Start Preset Transfer>	<Give Preset List Version Number>, <Stop Preset Transfer>	<Set Analogue Preset>, <End Preset Transfer>, <Actual Preset List Version Number>
<Start Timer Record Block Transfer>	-	<End Timer Record Block Transfer>, <Timer Record Block Transfer>, <Timer Record List Trigger>
<Stop Preset Transfer>	<Start Preset Transfer>, <Give Preset List Version Number>	<Set Analogue Preset>, <End Preset Transfer>, <Actual Preset List Version Number>
<Text View On>	<Active Source>	-
<Timer Cleared Status>	<Timer Status>	<Clear Timer>, <Set Timer>
<Timer Options>	-	<Give Timer Options>
<Timer Record Block Transfer>	<Timer Record List Trigger>, <End Timer Record Block Transfer>	<Start Timer Record Block Transfer>
<Timer Record List Trigger>	<Timer Record Block Transfer>, <End Timer Record Block Transfer>	<Start Timer Record Block Transfer>

LENOVO EXHIBIT 1008 - 938/963

If device does not <Feature Abort> the following message:	**It shall not <Feature Abort> the message(s):**	**It shall be able to send the message(s):**
<Timer Status>	<Timer Cleared Status>	<Set Timer>, <Clear Timer>
<Tuner Device Status>	-	<Give Tuner Device Status>
<Tuner Step Decrement>	<Tuner Step Increment>	-
<Tuner Step Increment>	<Tuner Step Decrement>	-
<User Control Pressed>	<User Control Released>	-
<User Control Released>	<User Control Pressed>	-
<Vendor Command>	<Device Vendor ID>	<Give Device Vendor ID>
<Vendor Remote Button Down>	<Vendor Remote Button Up>, <Device Vendor ID>	<Give Device Vendor ID>
<Vendor Remote Button Up>	<Vendor Remote Button Down>, <Device Vendor ID>	<Give Device Vendor ID>

LENOVO EXHIBIT 1008 - 939/963

CEC Table 7 Message dependencies when sending a message

If device ever sends the following message:	**It shall be able to send the message(s):**	**It shall not <Feature Abort> the message(s):**
<Actual Preset List Version Number>	<End Preset Transfer>, <Set Analogue Preset>	<Give Preset List Version Number>, <Start Preset Transfer>, <Stop Preset Transfer>
<Clear Timer>	<Set Timer>	<Timer Cleared Status>, <Timer Status>
<Deck Control>	<Play>	-
<Deck Status>	-	<Give Deck Status>, <Play>, <Deck Control>
<Device Vendor ID>	-	<Give Device Vendor ID>
<End Preset Transfer>	<Actual Preset List Version Number>, <Set Analogue Preset>	<Give Preset List Version Number>, <Start Preset Transfer>, <Stop Preset Transfer>
<End Timer Record Block Transfer>	<Timer Record Block Transfer>, <Timer Record List Trigger>	<Start Timer Record Block Transfer>
<Give Deck Status>	<Play>, <Deck Control>	<Deck Status>
<Give Device Vendor ID>	-	<Device Vendor ID>
<Give OSD Name>	-	<Set OSD Name>
<Give Physical Address>	-	<Report Physical Address>
<Give Preset List Version Number>	<Start Preset Transfer>, <Stop Preset Transfer>	<Actual Preset List Version Number>, <Set Analogue Preset>, <End Preset Transfer>
<Give System Info>	-	<Set System Info Version Number>, At least one of: <Set Country>, <Set Language>
<Give Timer Options>	-	<Timer Options>

LENOVO EXHIBIT 1008 - 940/963

If device ever sends the following message:	It shall be able to send the message(s):	It shall not <Feature Abort> the message(s):
<Give Tuner Device Status>	-	<Tuner Device Status>
<Image View On>	<Active Source>	-
<Menu Request>	<User Control Pressed>, <User Control Released>	<Menu Status>
<Menu Status>	-	<Menu Request>, <User Control Pressed>, <User Control Released>
<Play>	<Give Deck Status>, <Deck Control>	<Deck Status>
<Record Off>	<Record On>	<Record Status>
<Record On>	<Record Off>	<Record Status>
<Record Status>	-	<Record On>, <Record Off>
<Record TV Screen>	<Record Status>	<Record On>, <Record Off>
<Request Active Source>	-	<Active Source>
<Routing Change>	<Routing Information>	-
<Routing Information>	<Routing Change>	-
<Set Analogue Preset>	<End Preset Transfer>, <Actual Preset List Version Number>	<Start Preset Transfer>, <Stop Preset Transfer>, <Give Preset List Version Number>
<Set Country>	<Set System Info Version Number>	<Give System Info>
<Set Language>	<Set System Info Version Number>	<Give System Info>
<Set OSD Name>	-	<Give OSD Name>

LENOVO EXHIBIT 1008 - 941/963

If device ever sends the following message:	**It shall be able to send the message(s):**	**It shall not <Feature Abort> the message(s):**
<Set Preset Name>	<Set Analogue Preset>, <End Preset Transfer>, <Actual Preset List Version Number>	<Start Preset Transfer>, <Stop Preset Transfer>, <Give Preset List Version Number>
<Set Stream Path>	-	<Active Source> (not CEC Switches)
<Set System Info Version Number>	At least one of: <Set Country>, <Set Language>	<Give System Info>
<Set Timer Program Title>	<Set Timer>, <Clear Timer>	<Timer Status>, <Timer Cleared Status>
<Set Timer>	<Clear Timer>	<Timer Status>, <Timer Cleared Status>
<Start Preset Transfer>	<Give Preset List Version Number>, <Stop Preset Transfer>	<Set Analogue Preset>, <End Preset Transfer>, <Actual Preset List Version Number>
<Start Timer Record Block Transfer>	-	<End Timer Record Block Transfer>, <Timer Record Block Transfer>, <Timer Record List Trigger>
<Stop Preset Transfer>	<Start Preset Transfer>, <Give Preset List Version Number>	<Set Analogue Preset>, <End Preset Transfer>, <Actual Preset List Version Number>
<Text View On>	<Active Source>	-
<Timer Cleared Status>	<Timer Status>	<Clear Timer>, <Set Timer>
<Timer Options>	-	<Give Timer Options>
<Timer Record Block Transfer>	<Timer Record List Trigger>, <End Timer Record Block Transfer>	<Start Timer Record Block Transfer>
<Timer Record List Trigger>	<Timer Record Block Transfer>, <End Timer Record Block Transfer>	<Start Timer Record Block Transfer>
<Timer Status>	<Timer Cleared Status>	<Set Timer>, <Clear Timer>

LENOVO EXHIBIT 1008 - 942/963

If device ever sends the following message:	**It shall be able to send the message(s):**	**It shall not <Feature Abort> the message(s):**
<Tuner Device Status>	-	<Give Tuner Device Status>
<Tuner Step Decrement>	<Tuner Step Increment>	-
<Tuner Step Increment>	<Tuner Step Decrement>	-
<User Control Pressed>	<User Control Released>	-
<User Control Released>	<User Control Pressed>	-
<Vendor Command>	<Device Vendor ID>	<Give Device Vendor ID>
<Vendor Remote Button Down>	<Vendor Remote Button Up>, <Device Vendor ID>	<Give Device Vendor ID>
<Vendor Remote Button Up>	<Vendor Remote Button Down>, <Device Vendor ID>	<Give Device Vendor ID>

LENOVO EXHIBIT 1008 - 943/963

CEC 17 Operand Descriptions

In the following table, Operand Descriptions are ordered alphabetically. Sub-operands, which only occur in a single parent operand, are grouped with their parent and are shown indented.

LENOVO EXHIBIT 1008 - 944/963

CEC Table 8 Operand Descriptions.

Name	Range Description		Length	Purpose
[# Free Timer Blocks]	0x00≤n≤0xFF		1 byte	Indicates the number of timer blocks a device has free.
[# Timer Blocks]	0x00≤n≤0xFF		1 byte	Indicates the number of timer blocks a device can handle.
[Abort Reason]	“Unrecognized opcode”	0	1 byte	Reason for a <Feature Abort> response.
	“Not in correct mode to respond”	1		
	“Cannot provide source”	2		
	“Invalid operand”	3		
	“Refused”	4		
[Analogue Preset]	[Analogue Frequency] [Preset Related Data]		3 bytes	Identifies and specifies a particular tuner preset signal of an analogue tuner.
[Analogue Frequency]	0x0000<n<0xFFFF Frequency = 62.5n kHz		2 bytes	Used to specify the frequency used by an analogue terrestrial tuner.
[Preset Related Data]	[Reserved Bit] [Decoder Preset Indicator] [Favorite Indicator] [Broadcast System]		1 byte	Used to identify the data that is related to a tuner preset.
[Decoder Preset Indicator]	“Not present or not supported”	0	1 bit	Some tuner devices support the feature that a preset can be marked as a decoder present.
	”Decoder present and signal can be encoded”	1		
[Favorite Indicator]	“No”	0	1 bit	Some devices support the feature that a preset can be marked as a favorite preset. A follower is not required to use this information.
	”Yes or not supported”	1		

LENOVO EXHIBIT 1008 - 945/963

Name	Range Description		Length	Purpose
[Broadcast System]	0≤n≤31 – See CEC Table 10		5 bits	This specifies information about the color system, the sound carrier and the IF-frequency.
[ASCII digit]	0x30≤n≤0x39		1 byte	Subset of [ASCII] representing a printable digit character.
[ASCII]	0x20≤n≤0x7F		1 byte	Represents a printable character.
[Boolean]	“False”	0	1 bit	Flag
	“True”	1		
[Country]	0x0000≤n≤0xFFFF (n is defined in ITU-T E.164 Assigned Country Codes)		2 bytes	Specify the country in which the device is operating.
[Day of Month]	1≤n≤31		1 byte	Day of month.
[Deck Control Mode]	“Skip Forward / Wind Forward”	1	1 byte	Used in <Deck Control>. Note: The “Skip Forward / Wind Forward” and ”Skip Backward / Wind Backward” values are used for example in a DVD as next chapter and previous chapter and in a VCR as wind and rewind.
	“Skip Backward / Rewind”	2		
	“Stop”	3		
	“Eject”	4		
[Deck Info]	“Play”	0x11	1 byte	Indicates the current status of a tape or disk deck.
	“Record”	0x12		
	“Play Reverse”	0x13		
	“Still”	0x14		
	“Slow”	0x15		

LENOVO EXHIBIT 1008 - 946/963

Name	Range Description		Length	Purpose
	“Slow Reverse”	0x16		
	“Search Forward”	0x17		
	“Search Reverse”	0x18		
	“No Media”	0x19		
	“Stop”	0x1A		
	“Wind”	0x1B		
	“Rewind”	0x1C		
	“Index Search Forward”	0x1D		
	“Index Search Reverse”	0x1E		
	”Other Status”	0x1F		
[Device Type]	“TV”	0	1 byte	Allows additional devices, above the number allowed in the logical addressing mechanism, to indicate their device type.
	“Recording Device”	1		
	“STB”	3		
	“DVD”	4		
	“Audio System”	5		

LENOVO EXHIBIT 1008 - 947/963

Name	Range Description			Length	Purpose
[Display Control]	bit 5 – bit 0 = 0			1 byte	To indicate the display mode for an on screen display message.
		bit 7	bit 6		
	“Display for default time”	0	0		
	“Display until cleared”	0	1		
	“Clear previous message”	1	0		
	Reserved for future use	1	1		
[Feature Opcode]	0x00≤n≤0xFF (n is defined in CEC Table 5)			1 byte	Defines command to be performed.
[High/Low Quality Timer Programming]	“High Quality” (i.e. Short Play)		0	1 bit	Indicates if recording should be in high or low quality mode.
	”Low Quality” (i.e. Long Play)		1		
[Language]	2 {[ASCII]} as defined in ISO/FDIS 639-1 [ref 1n]			2 bytes	Specify the language with which to interact with the user.
[Menu Language]	[Language]			2 bytes	Specify the language with which to interact with the user.
[Menu Request Type]	“Activate”		0	1 byte	Specifies whether to activate or deactivate a devices menu or simply query its current menu status.
	“Deactivate”		1		
	“Query”		2		
[Menu State]	“Activated”		0	1 byte	Specifies the state of a device menu
	“Deactivated”		1		

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Name	Range Description	Length	Purpose
[Month of Year]	1≤n≤12	1 byte	Month
[New Address]	[Physical Address]	2 bytes	The physical address of the new device selected by a CEC Switch.
[Original Address]	[Physical Address]	2 bytes	The physical address of the device de-selected by a CEC Switch.
[OSD Name]	N {[ASCII]}, 1≤N ≤ 8	1 - 8 bytes	The devices name - To be used in On Screen Display references to it.
[OSD String]	N {[ASCII]}, 1≤N ≤ 13	1 - 13 bytes	A string to be displayed on the display.
[Physical Address]	4{[Port ID]}	2 bytes	Defines the path between the TV and a device – thus giving it a physical address within the cluster.
[Port ID]	0x1≤n≤0xF	4 bits	Defines one 'hop' within the physical address relating to the physical connection of the device.
[PIL Code]	[PIL_High] [PIL_Mid] [PIL_Low]	3 bytes	The PIL number as defined in prETS300231 and is the time originally announced as the start of the program. Note PIL allocation is: bit 1 to bit 5 day bit 6 to bit 9 month bit 10 to bit 14 hour bit 15 to bit 20 minute Note: special code of 0b00000 11111 11111 11111 is used to indicate PDC/VPS off and that timing should therefore be done by the local timer.
[PIL_High]	PIL bit 1 to bit 8, bit 1 is MSb	1 byte	Part of PIL data.
[PIL_Mid]	PIL bit 9 to bit 16, bit 9 is MSb	1 byte	Part of PIL data.
[PIL_Low]	PIL bit 17 to bit 20, bit 17 is MSb bit 21 to bit 24 = 0b1111	1 byte	Part of PIL data.

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Name	Range Description		Length	Purpose
[Play Mode]	“Play Forward”	0x24	1 byte	The mode in which to play media. Note: If a device does not support a particular play mode it should select the closest match.
	“Play Reverse”	0x20		
	“Play Still”	0x25		
	“Scan Forward Min Speed”	0x05		
	“Scan Forward Medium Speed”	0x06		
	“Scan Forward Max Speed”	0x07		
	“Scan Reverse Min Speed”	0x09		
	“Scan Reverse Medium Speed”	0x0A		
	“Scan Reverse Max Speed”	0x0B		
	“Slow Forward Min Speed”	0x15		
	“Slow Forward Medium Speed”	0x16		
	“Slow Forward Max Speed”	0x17		
	“Slow Reverse Min Speed”	0x19		
	“Slow Reverse Medium Speed”	0x1A		
	“Slow Reverse Max Speed”	0x1B		

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Name	Range Description		Length	Purpose
[Preset List Info]	“Complete”	0	1 byte	The status of a preset transfer session at its completion.
	“All others virgin”	1		
	“Transfer interrupted”	2		
[Preset List Version Number]	0x00≤n≤0xFF		1 byte	The version number of a preset list (Modulo 256).
[Preset Name]	N {[ASCII]}, 1 ≤ N ≤ 12		1 - 12 bytes	The name of a preset.
[Preset Number]	0x0000≤n≤0xFFFF		2 bytes	The identifier for a tuner preset.
[Program Title String]	N {[ASCII]}, 1 ≤ N ≤ 14		1 - 14 bytes	Program title.
[Recording Sequence]	“One time”	0b00	2 bits	Indicates if recording is repeated and, if so, on what basis.
	“Weekly”	0b01		
	“Daily”	0b10		
	“Series”	0b11		
[Record Source]	[Record Source Type] | {[Record Source Type] [Preset Number] [Analogue Preset]}		-	To define the source for a recording.
[Record Source Type]	“Preset”	0	1 byte	Allows the record source to be specified for a recording.
	”Own source”	1		

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Name	Range Description		Length	Purpose
[Record Status Info]	“Recording preset”	0x00	1 byte	Indicates the status of a recording.
	“Recording own source”	0x01		
	“Reserved”	0x02		
	“Reserved”	0x03		
	“Reserved”	0x04		
	“Reserved”	0x05		
	“No recording - invalid preset”	0x09		
	“No recording - no media”	0x10		
	“No recording - playing”	0x11		
	“No recording - already recording”	0x12		
	“No recording - media protected”	0x13		
	“No recording - no source”	0x14		
	“No recording - media problem”	0x15		
	“No recording - other reason”	0x1F		

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Name	Range Description		Length	Purpose
[Recording Status]	bit 7 - bit 1: [Reserved Bit].		1 byte	Used in <Timer Record Block Transfer>.
		bit 0		
	”Recording of this block not busy”	0		
	“Recording of this block busy”	1		
[Reserved Bit]	0		1 bit	Used as padding bit for future extensions.
[Series Code]	0x00≤n≤0xFF		1 byte	Series code. (e.g. for PDC)
[Start Time]	[Time]		2 bytes	Indicates the start time for a timer based recording.
[Status Request]	“On”	1	1 byte	Contains the status request mode which can be report once or on all future state changes or reporting off.
	“Off”	2		
	“Once”	3		
[Stop Time]	[Time]		2 bytes	Indicates the end time for a timer based recording.
[Subtitle Language]	[Language]		2 bytes	Specify the language in which to supply sub-titles.
[System Info Version Number]	0x00≤n≤0xFF		1 byte	The version number of a system info stored in the TV (Modulo 256).
[Time]	[Hour][Minute]		2 bytes	Time of day
[Hour]	0≤n≤23		1 byte	Hours
[Minute]	0≤n≤59		1 byte	Minutes

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Name	Range Description		Length	Purpose
[Timer Block Related Data]	3{[Reserved Bit]} [High/Low Quality Timer Programming] [Controlled Record Start - Block] [Recording Sequence]		1 byte	Identifies data that is related to timer block.
[Controlled Record Start – Block]	"No controlled start used on this block"	0b00	2 bits	Indicates type of controlled record start used, if any.
	"PDC"	0b01		
	"Video Programming System"	0b10		
	"Either PDC or VPS"	0b11		
[Timer Cleared Status Data]	"Timer cleared" = 0b1xxxxxxx. "Timer not cleared" = 0b0xxxxxxx. Reason: No matching = 0b00000001		1 byte	Indicates status in a <Timer Cleared Status> message.
[Timer List Info]	"Transfer complete, free timer blocks left"	0	1 byte	Used in <End Timer Record Block Transfer> message.
	"Transfer complete, list empty"	1		
	"Transfer interrupted"	2		
	"Transfer complete, all timer blocks occupied"	3		
[Timer Options]	[Daily Programming type] [Series Programming Supported] [Daily Programming Supported] [Weekly Programming Supported] [Reserved] [VPS Supported] [PDC Supported] [Low Quality Supported]		1 byte	Describes the Timer functions available for a recording device

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Name	Range Description		Length	Purpose
[Daily Programming type]	"All 7 days of the week"	0	1 bit	Type of daily timer.
	"Only Monday to Friday"	1		
[Series Programming Supported]	[Boolean]		1 bit	Indicates if series programming is supported.
[Daily Programming Supported]	[Boolean]		1 bit	Indicates if daily repeat programming is supported.
[Weekly Programming Supported]	[Boolean]		1 bit	Indicates if weekly repeat programming is supported
[VPS Supported]	[Boolean]		1 bit	Indicates if VPS standard is supported
[PDC Supported]	[Boolean]		1 bit	Indicates if PDC standard is supported.
[Low Quality Supported]	[Boolean]		1 bit	Indicates if low quality (i.e. Long Play) is supported.
[Timer Related Data]	3{[Reserved Bit]} [High/Low Quality Timer Programming] [Controlled Record Start] [Recording Sequence]		1 byte	Identifies data that is related to timer programming.
[Controlled Record Start]	"Not supported"	0b00	2 bits	Indicates type of controlled record start to be used, if any.
	"PDC"	0b01		
	"Video Programming System"	0b10		
	"Reserved"	0b11		

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Name	Range Description		Length	Purpose
[Timer Status Data]	[High/Low Quality supported] [Timer overlap warning] [Media Info] [Timer Programmed Info]		1 byte	Used by a recoding device to respond to the initiator of a <Set Timer> message.
[High/Low Quality Supported]	“Not supported”	0	1 bit	Indicates if the recording device has used the High Quality/Low Quality setting as requested.
	”As requested”	1		
[Timer Overlap Warning]	“No overlap”	0	1 bit	Indicates is there is another timer block already set which overlaps with this new recording request.
	”Timer blocks overlap”	1		
[Media Info]	“Media present and not protected”	0b00	2 bits	Indicates if removable media is present and its write protect state.
	“Media present, but protected”	0b01		
	“Media not present”	0b10		
	Future Use	0b11		
[Timer Programmed Info]	[Programmed Indicator] {[Programmed Info] | [Not Programmed Error Info]}		4 bits	Gives information about how and if the programming request has been done. [Programmed Indicator] is used as a selector for the second parameter.
[Programmed Indicator]	“Not programmed”	0	1 bit	Selector for [Timer Programmed Info].
	”Programmed”	1		
[Programmed Info]	Future Use	0b0xx	3 bits	Information indicating any non-fatal issues with the programming request.
	“Media info not supported”	0b100		
	“Enough media available for recording”	0b101		

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Name	Range Description		Length	Purpose
	“Not enough media available for recording”	0b110		
	Future Use	0b111		
[Not Programmed Error Info]	Future Use	0b000	3 bits	Reason for programming failure.
	“Daily error”	0b001		
	“No free timer available”	0b010		
	“Illegal preset”	0b011		
	“Clock failure”	0b100		
	“Date out of range”	0b101		
	“Series programming not supported”	0b110		
	“Other reason”	0b111		
[Tuner Device Info]	[Tuner Display Info][Preset Number]		3 bytes	Indicates information about the tuner. Indicates the preset number that the tuner is set to, regardless of whether or not it is currently displaying the tuner.
[Tuner Display Info]	“Displaying tuner”	0	1 byte	Indicates if the device is currently displaying its tuner or not (it may for example be displaying an external source or media).
	“Not displaying tuner”	1		
[UI Command]	0x00≤n≤0xFF (n is defined in CEC Table 9)		1 byte	Indicates the remote control button pressed.

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Name	Range Description	Length	Purpose
[Vendor ID]	0x000≤n≤0xFFF (n is the 24-bit unique company ID [ref. 3i] obtained from the IEEE Registration Authority Committee (RAC)).	3 bytes	Identifier for a specific Vendor.

Notes: Items are transmitted in the order shown in the description.
All bit descriptions are done most significant bit first (i.e. first bit described is sent first)

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CEC Table 9 User Control Codes

Operation id	User Operation
0x00	**Select**
0x01	**Up**
0x02	**Down**
0x03	**Left**
0x04	**Right**
0x05	**Right-Up**
0x06	**Right-Down**
0x07	**Left-Up**
0x08	**Left-Down**
0x09	Root Menu
0x0A	Setup Menu
0x0B	Contents Menu
0x0C	Favorite Menu
0x0D	**Exit**
0x0E - 0x1F	Reserved
0x20 - 0x29	**Numbers 0-9**
0x2A	Dot
0x2B	Enter
0x2C	Clear
0x2D - 0x2F	Reserved
0x30	Channel Up
0x31	Channel Down

Operation id	User Operation
0x32	Previous Channel
0x33	Sound Select
0x34	Input Select
0x35	Display Information
0x36	Help
0x37	Page Up
0x38	Page Down
0x39 - 0x3F	Reserved
0x40	Power
0x41	Volume Up
0x42	Volume Down
0x43	Mute
0x44	Play
0x45	Stop
0x46	Pause
0x47	Record
0x48	Rewind
0x49	Fast forward
0x4A	Eject
0x4B	Forward
0x4C	Backward
0x4D - 0x4F	Reserved

Operation id	User Operation
0x50	Angle
0x51	Sub picture
0x52 - 0x5F	Reserved
0x60	Play Function
0x61	Pause-Play Function
0x62	Record Function
0x63	Pause-Record Function
0x64	Stop Function
0x65	Mute Function
0x66	Restore Volume Function
0x67	Tune Function
0x68	Select Disk Function
0x69	Select A/V Input Function
0x6A	Select Audio Input Function
0x6B - 0x70	Reserved
0x71	**F1 (Blue)**
0x72	**F2 (Red)**
0x73	**F3 (Green)**
0x74	**F4 (Yellow)**
0x75	**F5**
0x76 - 0x7F	Reserved

Note: The elements identified in **bold** are the only ones which are forwarded as part of the device menu control feature.

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CEC Table 10 Broadcast System

System	Value	Bits 43210	Sound Carrier	Sound Modulation	Video Modulation	Vertical Frequency	Color sub-carrier
PAL B/G	0	00000	5.5 MHz	FM	neg	50 Hz	4.43 MHz
SECAM L'	1	00001	6.5 MHz	AM	pos	50 Hz	[7]
PAL M	2	00010	4.5 MHz	FM	neg	60 Hz	3.5756MHz
NTSC M	3	00011	4.5 MHz	FM	neg	60 Hz	3.5795MHz
PAL I	4	00100	6.0 MHz	FM	neg	50 Hz	4.43 MHz
SECAM DK	5	00101	6.5 MHz	FM	neg	50 Hz	[7]
SECAM B/G	6	00110	5.5 MHz	FM	neg	50 Hz	[7]
SECAM L	7	00111	6.5 MHz	AM	pos	50 Hz	[7]
PAL DK	8	01000	6.5 MHz	FM	neg	50 Hz	4.43 MHz
Future use	9	01001					
..	..	..					
Future use	30	11110					
Other System [8]	31	11111					

[7] Color sub-carriers SECAM: f_{OB} 4.25 MHz, f_{OR} 4.406 MHz

[8] The system is not defined. The receiving device decides locally what to do.

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ATTACHMENT K

The Wayback Machine - https://web.archive.org/web/20040612170926/http://www.hdmi.org:80/download/download.asp

HDMI - high definition multimedia interface



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