High-Definition Multimedia Interface

Specification Version 1.4

Hitachi, Ltd.

Panasonic Corporation.

Philips Consumer Electronics, International B.V.

Silicon Image, Inc.

Sony Corporation

Thomson Inc.

Toshiba Corporation

June 5, 2009

CONFIDENTIAL

© 2009 HDMI Licensing, LLC. All rights reserved.

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.

Hitachi, Ltd., Panasonic Corporation, Philips Consumer Electronics International B.V., Silicon Image, Inc., Sony Corporation, Thomson Inc., Toshiba Corporation and HDMI Licensing, LLC disclaim all liability, including liability for infringement of any proprietary rights, relating to use of information in this specification.

Copyright © 2001-2009 by Hitachi, Ltd., Panasonic Corporation, Philips Consumer Electronics International, B.V., Silicon Image, Inc., Sony Corporation, Thomson Inc., and Toshiba Corporation. All rights reserved. No license, express or implied, by estoppel or otherwise, to any intellectual property rights is granted herein. Unauthorized use or duplication prohibited. “HDMI” and all associated logos are trademarks of HDMI Licensing, LLC. Third-party trademarks and servicemarks are property of their respective owners.

Document Revision History

1.4	2009/06/05	Significant enhancements: - Type D Connector (4.1.9.7, 4.1.9.8, 4.1.10.6) - Type E Connector and Cable (4.1.9.9, 4.1.9.10, 4.1.10.7, 4.1.10.8, 4.2.1, 4.2.3.2, 4.2.6) - Audio Return Channel Overview (7.12) - 3D and 4K x 2K video format (8.2.3, 8.3.2, Appendix H) - HDMI Ethernet and Audio Return Channel(HEAC) features(Supplement 2) Changed CEC supplement (see supplement 1 for details) Changed "Reserved" to Utility Line (4.2.11) Added Active, Passive and Converter cable types (4.2.6) Moved Passive Cable characteristics to 4.2.6. Added some features related to CEA-861 (6.3.2, 6.6, 6.7.2, 8.2, 8.3) Several minor editorials (throughout)
1.3a	2006/11/10	Cable and Sink modifications for Type C (Table 4-28, 4.2.6) Source termination recommendation (after Table 4-23) 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 ACR (7.3, 7.3.1, 7.3.2) Added Audio Rate Control Overview (7.11)
1.3	2006/06/22	Significant enhancements: - 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, 6.7.2.4, 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 (8.3.5) 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 (8.3.6) Loosened requirement for duplicated DTD declarations (8.3.6) 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 (8.3.5) 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

Intellectual Property Statement

Hitachi, Ltd., Panasonic Corporation, 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 1.4 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.

Table of Contents

PREFACE ..... **II**

NOTICE II
DOCUMENT REVISION HISTORY III
INTELLECTUAL PROPERTY STATEMENT V
CONTACT INFORMATION V
CONTRIBUTION V
ACKNOWLEDGEMENT V

1 INTRODUCTION **1**

1.1 PURPOSE AND SCOPE 1
1.2 NORMATIVE REFERENCES 1
1.3 INFORMATIVE REFERENCES 2
1.4 ORGANIZATION OF THIS DOCUMENT 2
1.5 USAGES AND CONVENTIONS 3

2 DEFINITIONS **5**

2.1 CONFORMANCE LEVELS 5
2.2 GLOSSARY OF TERMS 5
2.3 ACRONYMS AND ABBREVIATIONS 7

3 OVERVIEW **9**

4 PHYSICAL LAYER **11**

4.1 CONNECTORS AND CABLES 11
4.1.1 Overview of Connectors and Cables *11*
4.1.2 Connector Support Requirements *11*
4.1.3 Dual-Link *12*
4.1.4 Connector Pin Assignments *12*
4.1.5 Contact sequence *15*
4.1.6 Connector Mechanical Performance *16*
4.1.7 Connector Electrical Characteristics *20*
4.1.8 Connector Environmental Characteristics *22*
4.1.9 Connector Drawings – Mating Interface Dimensions *24*
4.1.10 Cable Adapter Specification *44*
4.2 ELECTRICAL SPECIFICATION 53
4.2.1 TMDS Overview *53*
4.2.2 TMDS System Operating Conditions *54*
4.2.3 TMDS Specification and Testing Overview *55*
4.2.4 HDMI Source TMDS Characteristics *58*
4.2.5 HDMI Sink TMDS Characteristics *60*
4.2.6 Cable Assembly TMDS Characteristics *62*
4.2.7 +5V Power Signal *71*
4.2.8 DDC *72*
4.2.9 Hot Plug Detect Signal (HPD) *73*
4.2.10 CEC Line *73*
4.2.11 Utility Line *74*
4.2.12 Robustness Requirements *75*

5 SIGNALING AND ENCODING **76**

5.1 OVERVIEW 76
5.1.1 Link Architecture 76
5.1.2 Operating Modes Overview 77
5.2 OPERATING MODES 78
5.2.1 Control Period 78
5.2.2 Video Data Period 80
5.2.3 Data Island Period 80
5.3 DATA ISLAND PACKET DEFINITIONS 84
5.3.1 Packet Header 84
5.3.2 Null Packet 85
5.3.3 Audio Clock Regeneration Packet 86
5.3.4 Audio Sample Packet 86
5.3.5 InfoFrame Packet 88
5.3.6 General Control Packet 89
5.3.7 Audio Content Protection Packet (ACP) 90
5.3.8 ISRC Packets 91
5.3.9 One Bit Audio Sample Packet 94
5.3.10 DST Audio Packet 95
5.3.11 High-Bitrate (HBR) Audio Stream Packet 96
5.3.12 Gamut Metadata Packet 96
5.4 ENCODING 100
5.4.1 Serialization 100
5.4.2 Control Period Coding 100
5.4.3 TERC4 Coding 101
5.4.4 Video Data Coding 101

6 VIDEO 105

6.1 OVERVIEW 105
6.2 VIDEO FORMAT SUPPORT 105
6.2.1 Format Support Requirements 105
6.2.2 Video Control Signals : HSYNC, VSYNC 106
6.2.3 Pixel Encoding Requirements 106
6.2.4 Color Depth Requirements 106
6.3 VIDEO FORMAT TIMING SPECIFICATIONS 107
6.3.1 Primary Video Format Timings 107
6.3.2 Secondary Video Format Timings 107
6.4 PIXEL-REPETITION 108
6.5 PIXEL ENCODINGS AND COLOR DEPTH 109
6.5.1 Pixel Encodings 109
6.5.2 Deep Color Pixel Packing 110
6.5.3 Deep Color Mode / Phase Indication 113
6.5.4 Pixel Repetition 115
6.6 VIDEO QUANTIZATION RANGES 116
6.7 COLORIMETRY 117
6.7.1 Default Colorimetry 117
6.7.2 Applicable Colorimetry Standards 117
6.7.3 Gamut-Related Metadata 118

7 AUDIO 119

7.1 RELATIONSHIP WITH IEC 60958/IEC 61937 119
7.2 AUDIO SAMPLE CLOCK CAPTURE AND REGENERATION 119
7.2.1 N parameter 121

7.2.2 CTS parameter *121*
7.2.3 Recommended N and Expected CTS Values *121*
7.2.4 L-PCM and IEC 61937 Compressed Audio ACR *124*
7.2.5 One Bit Audio ACR *124*
7.2.6 DST Audio ACR *124*
7.3 AUDIO SAMPLE RATES AND SUPPORT REQUIREMENTS 125
7.3.1 One Bit Audio Sample Rate Requirements *126*
7.3.2 DST Audio Sample Rate Requirements *126*
7.3.3 Video Dependency *127*
7.4 CHANNEL / SPEAKER ASSIGNMENT 128
7.5 AUDIO, VIDEO SYNCHRONIZATION 128
7.6 AUDIO DATA PACKETIZATION 128
7.6.1 One Bit Audio Packetization *130*
7.6.2 High-Bitrate Audio Stream Packetization *131*
7.6.3 DST Packetization *131*
7.7 ERROR HANDLING (INFORMATIVE) 131
7.8 PACKET DELIVERY RULES 131
7.8.1 Audio Sample Packets *131*
7.8.2 Audio Clock Regeneration Packets *132*
7.9 ONE BIT AUDIO USAGE OVERVIEW 132
7.10 DST USAGE OVERVIEW 132
7.11 AUDIO RATE CONTROL OVERVIEW 132
7.12 AUDIO RETURN CHANNEL OVERVIEW 133

8 CONTROL AND CONFIGURATION 134

8.1 OVERVIEW 134
8.2 INFOFRAMES 134
8.2.1 Auxiliary Video information (AVI) InfoFrame *134*
8.2.2 Audio InfoFrame *138*
8.2.3 HDMI Vendor Specific InfoFrame *140*
8.3 E-EDID DATA STRUCTURE 145
8.3.1 CEA Extension *146*
8.3.2 HDMI Vendor-Specific Data Block (HDMI VSDB) *146*
8.3.3 Colorimetry Data Block *150*
8.3.4 Video Capability Data Block (VCDB) *151*
8.3.5 DVI/HDMI Device Discrimination *151*
8.3.6 Audio and Video Details *152*
8.4 ENHANCED DDC 152
8.4.1 Timing *152*
8.4.2 Data Transfer Protocols *152*
8.4.3 Segment pointer *153*
8.4.4 Enhanced DDC Sink *153*
8.4.5 Enhanced DDC Source *153*
8.5 HOT PLUG DETECT SIGNAL 153
8.6 CONSUMER ELECTRONICS CONTROL (CEC) 154
8.7 PHYSICAL ADDRESS 154
8.7.1 Overview *154*
8.7.2 Physical Address Discovery *154*
8.7.3 Discovery Algorithm *156*
8.7.4 HDMI Sink Query *156*
8.8 ISRC HANDLING 156
8.9 AUTO LIPSYNC CORRECTION FEATURE 157

8.9.1 EDID Latency Info *157*
8.9.2 Compensation *158*
8.9.3 Supporting Dynamic Latency Changes *159*
8.9.4 Separate Audio and Video Paths *159*

9 CONTENT PROTECTION **160**

9.1 RECOMMENDATION 160
9.2 HDCP IMPLEMENTATIONS 160
9.3 USAGE OF AUDIO CONTENT PROTECTION (ACP) PACKETS 160
9.3.1 Requirements for Sink *160*
9.3.2 Requirements for Repeater *161*
9.3.3 Application to Generic Audio *161*
9.3.4 Application to IEC 60958-Identified Audio *161*
9.3.5 Application to DVD-Audio *161*
9.3.6 Application to Super Audio CD *162*

APPENDIX A REPEATER **164**

A.1 REPEATER FUNCTIONS 164
A.2 E-EDID READ TIMING (INFORMATIVE) 164

APPENDIX B TYPE B CONNECTOR USAGE **165**

B.1 EXCEPTION TO AUDIO FORMAT SUPPORT REQUIREMENT 165
B.2 HDMI DUAL-LINK ARCHITECTURE 165

APPENDIX C COMPATIBILITY WITH DVI **166**

C.1 REQUIREMENT FOR DVI COMPATIBILITY 166
C.2 HDMI SOURCE REQUIREMENTS 166
C.3 HDMI SINK REQUIREMENTS 167
C.4 TYPE A TO DVI ADAPTER CABLE [INFORMATIVE] 167
C.5 TYPE B TO DVI ADAPTER CABLE [INFORMATIVE] 169

APPENDIX D DEEP COLOR ADDITIONAL DETAIL **170**

D.1 STATE MACHINES 170
D.2 RECOMMENDED N AND EXPECTED CTS VALUES 171

APPENDIX E GAMUT-RELATED METADATA **175**

E.1 OVERVIEW 175
E.2 TRANSMISSION PROFILES 175
E.3 GAMUT BOUNDARY DESCRIPTION 175
E.4 DATA PACKING 178
E.5 EXAMPLE P0 DATA STRUCTURES 179

APPENDIX F VIDEO SCALING AUTO-CONFIGURATION **182**

APPENDIX G RESERVED **183**

APPENDIX H 3D VIDEO FORMATS EXTENSIONS **184**

H. 1 HDMI VENDOR SPECIFIC INFOFRAME EXTENSION 184
H. 2 3D VIDEO FORMATS STRUCTURE EXTENSION 188
H. 3 HDMI VENDOR-SPECIFIC DATA BLOCK (HDMI VSDB) EXTENSION 194

SUPPLEMENT 1 CONSUMER ELECTRONICS CONTROL (CEC) ..... CEC-I
SEE SUPPLEMENT FOR TABLE OF CONTENTS

SUPPLEMENT 2 HDMI ETHERNET AND AUDIO RETURN CHANNEL (HEAC) ..... HEAC-I
SEE SUPPLEMENT FOR TABLE OF CONTENTS

Figures

Figure 3-1 HDMI Block Diagram 9
Figure 4-1 Type A Receptacle Mating Interface Dimensions 24
Figure 4-2 Type A Plug Mating Interface Dimensions 26
Figure 4-3 Type A Receptacle and Plug Mated Condition 27
Figure 4-4 Type A Cable – Minimum Recommended Cable Bend 27
Figure 4-5 Type B Receptacle Mating Interface Dimensions 28
Figure 4-6 Type B Plug Mating Interface Dimensions 31
Figure 4-7 Type B Receptacle and Plug Mated Condition 31
Figure 4-8 Type C Receptacle Mating Interface Dimensions 32
Figure 4-9 Type C Plug Mating Interface Dimensions 33
Figure 4-10 Type C Receptacle and Plug Mated Condition 34
Figure 4-11 Type C Product Design Recommendations 34
Figure 4-12 Type D Receptacle Mating Interface Dimensions 35
Figure 4-13 Type D Plug Mating Interface Dimensions 36
Figure 4-14 Type D Receptacle and Plug Mated Condition 37
Figure 4-15 Type D Cable – Minimum Recommended Cable Bend 37
Figure 4-16 Type E Receptacle Mating Interface Dimensions 38
Figure 4-17 Type E Plug Mating Interface Dimensions 40
Figure 4-18 Type E Product Design Recommendations 41
Figure 4-19 Type E Receptacle and Plug Mated Condition 41
Figure 4-20 Type A Relay Receptacle Mating Interface Dimensions 42
Figure 4-21 Type A Relay Receptacle Design Recommendations 43
Figure 4-22 Conceptual Schematic for one TMDS differential pair 53
Figure 4-23 Single-ended Differential Signal 53
Figure 4-24 Differential Signal 54
Figure 4-25 TMDS Link Test Points 54
Figure 4-26 TMDS Link Test Points for Automotive (Relay Connection) 54
Figure 4-27 Gain of Reference Cable Equalizer 56
Figure 4-28 Gain of Reference Cable Equalizer for Automotive 57
Figure 4-29 Balanced Source Test Load 58
Figure 4-30 Eye Diagram Mask at TP1 for Source Requirements 59
Figure 4-31 HDMI Sink Test Points 60
Figure 4-32 Eye Diagram Mask at TP2 for Sink Requirements 62
Figure 4-33 Cable Assembly Test Points 63
Figure 4-34 Automotive CE Relay Cable Assembly Test Points (Relay Connection) 63
Figure 4-35 Automotive Relay Cable Assembly Test Points (Relay Connection) 63
Figure 4-36 Category 1 Cable Attenuation Limits – Sufficient Condition 65
Figure 4-37 Category 2 Cable Attenuation Limits – Sufficient Condition 65
Figure 4-38 Passive equalizer Cable Attenuation Limits – Sufficient Condition 67
Figure 4-39 Passive equalizer Cable Phase measurement method (explanation) 68
Figure 4-40 Passive equalize Cable Phase Limits – Sufficient Condition 68
Figure 4-41 Eye Diagram Mask at TP5 for CE Relay Cable 70
Figure 5-1 HDMI Encoder/Decoder Overview 76
Figure 5-2 Informative Example: TMDS periods in 720x480p video frame 77
Figure 5-3 TMDS Periods and Encoding 81
Figure 5-4 Data Island Packet and ECC Structure 83
Figure 5-5 Error Correction Code generator 84
Figure 5-6 Example P0 Transmission Sequence 98
Figure 5-7 TMDS Video Data Encode Algorithm 103

Figure 5-8 TMDS Video Decode Algorithm 104
Figure 6-1 Default pixel encoding: RGB 4:4:4, 8 bits/component 109
Figure 6-2 YC_BC_R 4:2:2 component 110
Figure 6-3 8-bit YC_BC_R 4:4:4 mapping 110
Figure 6-4 YC_BC_R 4:2:2 with Pixel-Doubling 116
Figure 7-1 Audio Clock Regeneration model 120
Figure 7-2 Optional Implementation: Audio Sink 120
Figure 7-3 Example Audio Sample Timing (Informative) 130
Figure 8-1 extended resolution format 143
Figure 8-2 extended resolution format (detailed timing) 143
Figure 8-3 3D structure (Frame packing) 144
Figure 8-4 Detailed timing parameters 145
Figure 8-5 CEC and DDC line connections 154
Figure 8-6 Typical HDMI cluster 155
Figure 8-7 Addresses within an HDMI cluster 155
Figure 8-8 ISRC/CCI and ISRC Status Handling 157

Tables

Table 4-1 Relation of the Cable category and the Supported functions (except Type B) 11
Table 4-2 Type A, Type E Connector Pin Assignment 12
Table 4-3 Type B Connector Pin Assignment 13
Table 4-4 Type C Connector Pin Assignment 14
Table 4-5 Type D Connector Pin Assignment 15
Table 4-6 Connector Contact Sequence 15
Table 4-7 Type A, Type C and Type D Plug and Receptacle Mechanical Performance 16
Table 4-8 Type E Plug and Receptacle Mechanical Performance 18
Table 4-9 Type E Cable Mechanical Performance 19
Table 4-10 Electrical Performance 20
Table 4-11 Connector Environmental Performance 22
Table 4-12 Type E Connector Environmental Performance 23
Table 4-13 Wire Categories 44
Table 4-14 Type A-to-Type A Cable Wire Assignment 45
Table 4-15 Type A-to-Type B Cable Wire Assignment 46
Table 4-16 Type B to Type B Cable Wire Assignment 47
Table 4-17 Type C-to-Type C Cable Wire Assignment 48
Table 4-18 Type C-to-Type A Cable Wire Assignment 49
Table 4-19 Type D-to-Type A Cable Wire Assignment 50
Table 4-20 Type E to Type E Cable Wire Assignment 51
Table 4-21 Type E-to-Type A Cable Wire Assignment 52
Table 4-22 Required Operating Conditions for HDMI Interface (see Figure 4-22) 55
Table 4-23 Source DC Characteristics at TP1 58
Table 4-24 Source AC Characteristics at TP1 59
Table 4-25 Sink Operating DC Characteristics at TP2 61
Table 4-26 Sink DC Characteristics When Source Disabled or Disconnected at TP2 61
Table 4-27 Sink AC Input Characteristics at TP2 61
Table 4-28 HDMI Sink Impedance Characteristics at TP2 62
Table 4-29 Cable Assembly TMDS Parameters 64
Table 4-30 Cable Assembly TMDS Parameters 66
Table 4-31 Automotive Cable Assembly TMDS Parameters (Direct Connection) 69
Table 4-32 CE Relay Cable Assembly TMDS Parameters (Relay Connection) 70
Table 4-33 Automotive Relay Cable Assembly TMDS Parameters (Relay Connection) 71
Table 4-34 +5V Power Pin Voltage 71
Table 4-35 Maximum Capacitance of DDC line 72
Table 4-36 Maximum Capacitance of DDC line for Automotive 72
Table 4-37 Pull-up Resistance on DDC Lines 72
Table 4-38 Required Output Characteristics of Hot Plug Detect Signal 73
Table 4-39 Required Detection Levels for Hot Plug Detect Signal 73
Table 4-40 CEC line Electrical Specifications for all Configurations 74
Table 4-41 Utility line Electrical Specifications (Recommendation) 74
Table 5-1 Encoding Type and Data Transmitted 78
Table 5-2 Preambles for Each Data Period Type 79
Table 5-3 TMDS Link Timing Parameters 80
Table 5-4 Extended Control Period Parameters 80
Table 5-5 Video Leading Guard Band Values 80
Table 5-6 Data Island Leading and Trailing Guard Band Values 82
Table 5-7 Packet Header 84
Table 5-8 Packet Types 85

Table 5-9 Null Packet Header 85
Table 5-10 Audio Clock Regeneration Packet Header 86
Table 5-11 Audio Clock Regeneration Subpacket 86
Table 5-12 Audio Sample Packet Header 87
Table 5-13 Audio Sample Subpacket 87
Table 5-14 InfoFrame Packet Header 88
Table 5-15 InfoFrame Packet Contents 88
Table 5-16 General Control Packet Header 89
Table 5-17 General Control Subpacket 89
Table 5-18 ACP Packet Header 90
Table 5-19 ACP Packet contents 90
Table 5-20 ISRC1 Packet Header 91
Table 5-21 ISRC1 Packet contents 92
Table 5-22 ISRC2 Packet Header 93
Table 5-23 ISRC2 Packet contents 93
Table 5-24 One Bit Audio Packet Header 94
Table 5-25 One Bit Audio Subpacket 95
Table 5-26 DST Audio Packet Header 95
Table 5-27 DST Audio Packet Body 96
Table 5-28 HBR Audio Stream Packet Header 96
Table 5-29 Gamut Boundary Description Metadata Profiles 97
Table 5-30 Gamut Metadata Packet Header 98
Table 5-31 Gamut Metadata Packet for P0 Transmission Profile 99
Table 5-32 Gamut Metadata Packet for P1 and Higher – 1st Packet of Sequence 100
Table 5-33 Gamut Metadata Packet for P1 and Higher – Remaining Packets 100
Table 5-34 Control-signal Assignment 101
Table 5-35 Encoding Algorithm Definitions 102
Table 6-1 Color Depth (CD field) Values 114
Table 6-2 Pixel Packing Phase (PP field) Values 115
Table 6-3 Video Color Component Ranges 116
Table 7-1 Recommended N and Expected CTS for 32kHz 122
Table 7-2 Recommended N and Expected CTS for 44.1kHz and Multiples 123
Table 7-3 Recommended N and Expected CTS for 48kHz and Multiples 124
Table 7-4 Allowed Values for Channel Status bits 24 to 27 126
Table 7-5 Max Sampling Frequency for 24-bit Video Format Timings* (Informative) 127
Table 7-6 Audio Packet Layout and Layout Value 129
Table 7-7 Valid Sample_Present Bit Configurations for Layout 0 129
Table 7-8 High Bitrate Audio Stream Packet Layout 131
Table 8-1 AVI InfoFrame Packet Header 135
Table 8-2 AVI InfoFrame Packet Contents 135
Table 8-3 Extended Colorimetry 136
Table 8-4 VIC AVI InfoFrame Packet Contents 137
Table 8-5 YCC Quantization Range 137
Table 8-6 Content Type 137
Table 8-7 Audio InfoFrame Packet Header 139
Table 8-8 Audio InfoFrame Packet contents 139
Table 8-9 LFE Playback Level Information 140
Table 8-10 HDMI Vendor Specific InfoFrame Packet Header 141
Table 8-11 HDMI Vendor Specific InfoFrame Packet Contents 141
Table 8-12 HDMI_Video_Format 141
Table 8-13 HDMI_VIC for extended resolution transmission 142
Table 8-14 3D transmission video formats 144

Table 8-15 HDMI-LLC Vendor-Specific Data Block (HDMI VSDB) 147
Table 8-16 Content Type 150
Table 8-17 Colorimetry Data Block 150
Table 8-18 Data Byte 3 Colorimetry Support flags 150
Table 8-19 Data Byte 4 Colorimetry Metadata Support flags 150
Table 8-20 Video Capability Data Block (VCDB) 151
Table 8-21 Quantization Range (Applies to YCC only) 151
Table 9-1 ACP_Type Dependent Fields for DVD-Audio Application 162
Table 9-2 ACP_Type Dependent Fields for Super Audio CD Application 163

1 Introduction

1.1 Purpose and Scope

This document constitutes the specification for the High-Definition Multimedia Interface (HDMI), version 1.4.

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, status and data 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

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 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”.

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 61966-2-1/Amendment 1,”Multimedia systems and equipment - Colour measurement and management - Part 2-1: Colour management - Default RGB colour space – sRGB”, 2003-01

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

IEC, IEC 61966-2-5, “Multimedia systems and equipment - Colour measurement and management - Part 2-5: Colour management - Optional RGB colour space – opRGB”.,Edition1.0 2007-11

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 1.4 (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.
- 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.
- Appendix G reserved.
- Appendix H describes additional 3D video formats.
- Supplement 1 describes use of the Consumer Electronics Control (CEC) line and protocol.
- Supplement 2 describes the functionality and use of the HDMI Ethernet and Audio Return Channel (HEAC).

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.

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, Chaudhuri, 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.

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.

$T_{character}$	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

ACR	Audio Clock Regeneration
ANSI	American National Standards Institute
ARC	Audio Return Channel
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
EDID	Extended Display Identification Data
EIA	Electronic Industries Alliance
HDCP	High-bandwidth Digital Content Protection
HDMI	High-Definition Multimedia Interface
HDTV	High-Definition Television
HEAC	HDMI Ethernet and Audio Return Channel
HEC	HDMI Ethernet Channel
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

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. The optional HDMI Ethernet and Audio Return Channel (HEAC) provides Ethernet compatible data networking between connected devices and an Audio Return Channel in the opposite direction from TMDS.

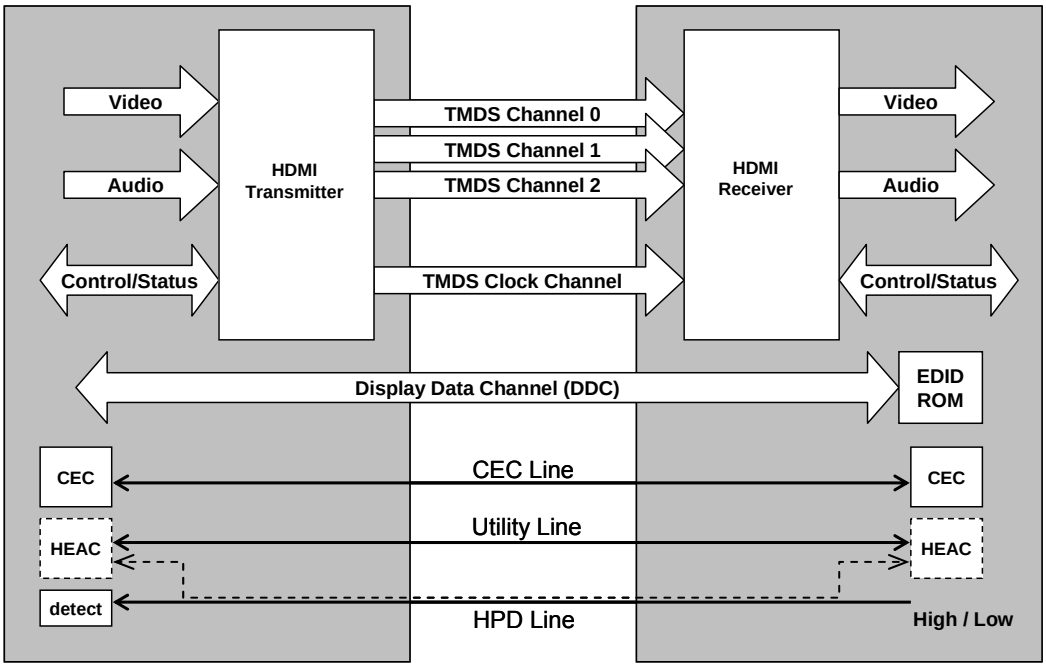


Figure 3-1 HDMI Block Diagram

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 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.

The Utility Line is used for extended optional features such as HEAC specified in Supplement 2.

4 Physical Layer

4.1 Connectors and Cables

4.1.1 Overview of Connectors and Cables

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

All five 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. The Type D connector carries the same signals as the Type A but is more compact than Type C. The Type E connector carries the same signals as the Type A and is intended for Automotive applications.

Cables are specified in two categories according to the supported clock frequency. Except for Automotive applications, both categories of cables specified here can also support HEAC applications after fulfilling the additional cable specifications in Supplement 2.

Table 4-1 Relation of the Cable category and the Supported functions (except Type B)

Cable Assembly	Maximum Clock frequency	Cable Adapters	Electrical Performance	Marketing name*
Category 1	74.25MHz	Type A – Type A/C/D Type C – Type C	See 4.2.6	Standard
Category 2	340MHz	Type A – Type A/C/D Type C – Type C	See 4.2.6	High Speed
Category 1 with HEAC	74.25MHz	Type A – Type A/C/D Type C – Type C	See 4.2.6 and Supplement 2	Standard with Ethernet
Category 2 with HEAC	340MHz	Type A – Type A/C/D Type C – Type C	See 4.2.6 and Supplement 2	High Speed with Ethernet
Category 1 Automotive	74.25MHz	Type E – Type E	See 4.2.6	(only for Automotive manufacturers)
		Type E – Type A Relay receptacle	See 4.2.6	
		Type A – Type A	See 4.2.6	Standard Automotive

4.1.2 Connector Support Requirements

All features and functions are equally available to all connectors except Type B and Type E.

* from "Adopted Trademark and Logo Usage Guidelines"

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.

4.1.4 Connector Pin Assignments

Table 4-2 Type A, Type E 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	Utility
16	SDA
18	+5V Power

Table 4-3 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

Table 4-4 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	Utility
18	+5V Power
19	Hot Plug Detect

Table 4-5 Type D Connector Pin Assignment

PIN	Signal Assignment
1	Hot Plug Detect
3	TMDS Data2+
5	TMDS Data2-
7	TMDS Data1 Shield
9	TMDS Data0+
11	TMDS Data0–
13	TMDS Clock Shield
15	CEC
17	SCL
19	+5V Power

PIN	Signal Assignment
2	Utility
4	TMDS Data2 Shield
6	TMDS Data1+
8	TMDS Data1-
10	TMDS Data0 Shield
12	TMDS Clock+
14	TMDS Clock–
16	DDC/CEC Ground
18	SDA

4.1.5 Contact sequence

Table 4-6 Connector Contact Sequence

Connection	Signals			
	Type A & C Connectors	Type B Connector	Type D Connector	Type E Connector
First Make	Connector shell	Connector shell	Connector shell	Connector shell
Second Make	Pins 1 - 17 and pin 19	Pins 1 - 27 and pin 29	Pins 1 – 18	Pins 1 - 19
Third Make	Pin18 (+5V Power)	Pin28 (+5V Power)	Pin19 (+5V Power)	

4.1.6 Connector Mechanical Performance

Table 4-7 Type A, Type C and Type D 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 and Type D: 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.

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 Type D: 5N minimum 25N maximum and after 5,000 cycles mating, 3N 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
Wrenching strength	Mated connectors, apply perpendicular forces to plug at a 15 mm distance from the edge of the receptacle covered by test fixture. Perform this test using virgin parts. Forces are to 4 directions (left, right, up, down).	appearance	Type D: 0-20N: No plug or receptacle damage. 20-40N: No receptacle damage.
Cable Pull-Out	Axial load to the cable for 1 minute. (ANSI/EIA-364-38c)	Discontinuity	Type D: 40N minimum

Table 4-8 Type E Plug and Receptacle Mechanical Performance

Item	Test Condition	Requirement	
Vibration	Values for test-condition: 5.0Hz-0.00200g^2/Hz 12.5Hz-0.24800g^2/Hz 77.5Hz-0.00320g^2/Hz 145.0Hz-0.00200g^2/Hz 200.0Hz-0.01180g^2/Hz 230.0Hz-0.00032g^2/Hz 1000.0Hz-0.00002g^2/Hz {Grms=1.81} Duration: 8 hours in each (Total of 24 hours) X, Y, Z axis. Electrical load: 100mA DC current shall be flowing during the test. (SAE/USCAR-2 5.4.6)	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: 10msec Waveform: half sine, 343m/s^2{35G}, 10strokes in each X, Y, Z axis (SAE/USCAR-2 5.4.6)	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 the following: Cycling: 10 cycles (SAE/USCAR-2 5.1.7)	Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell : Change from initial value: 50 milliohms maximum.
Drop	Drop onto a horizontal concrete surface from a height of 1m. Times: 3 times (SAE/USCAR-2 5.4.8)	Appearance	No Damage

Item	Test Condition	Requirement	
Connector-Connector Insertion/ Withdrawal Force	Insertion and withdrawal speed : 50mm/minute. (SAE/USCAR-2 5.4.2)	Insertion force	70N maximum
		Withdrawal force with the lock completely disengaged	70N maximum
		Withdrawal force with the lock fully engaged	100N minimum
Terminal-Connector Withdrawal Force	Withdrawal speed : 50mm/minute. (SAE/USCAR-2 5.4.1)	Withdrawal force with the secondary-lock fully engaged	90N minimum
Lock Disengagement Force	Disengagement speed : 50mm/minute. (SAE/USCAR-2 5.4.2)	Disengagement Force	50N maximum
Cable Flex	25 cycles in each of 2 planes Dimension X=6.4 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

Table 4-9 Type E Cable Mechanical Performance

Item	Test Condition	Requirement	
Thermal Deformation	Tempurature:100 °C Overloading : 2N (ISO-6722,7-1)	Dielectric Withstanding Voltage	Conform to item of dielectric withstanding voltage

4.1.7 Connector Electrical Characteristics

4.1.7.1 Electrical Performance

Table 4-10 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 Type A/B/C/E : 500 Volts AC(RMS) Type D : 250 Volts AC(RMS) between adjacent terminal or ground. Mated connector, apply Type A/B/C/E : 300 Volts AC(RMS.) Type D : 150 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)	Type A/B/C/E : 0.5 A minimum Type D: 0.3 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. Type E: Test unmated each connectors from 1 kVolt to 8 kVolts in 1 kVolt steps and 15 kVolts using 8mm ball probe. (IEC-801-2)	No evidence of Discharge to Contacts at 8 kVolts Type E : No evidence of Discharge to Contacts at 15 kVolts.

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/E: 100 ohms ±15% Type C/D: 100 ohms ±25% Transition Area : Type A /C/D:100 ohms ±15% Type E :100 ohms ±25% 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/D/E : 10% maximum

4.1.8 Connector Environmental Characteristics

4.1.8.1 Environmental Performance

Table 4-11 Connector Environmental Performance

Item	Test Condition		Requirement	
Thermal Shock	10 cycles of: a) -55°C for 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
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.

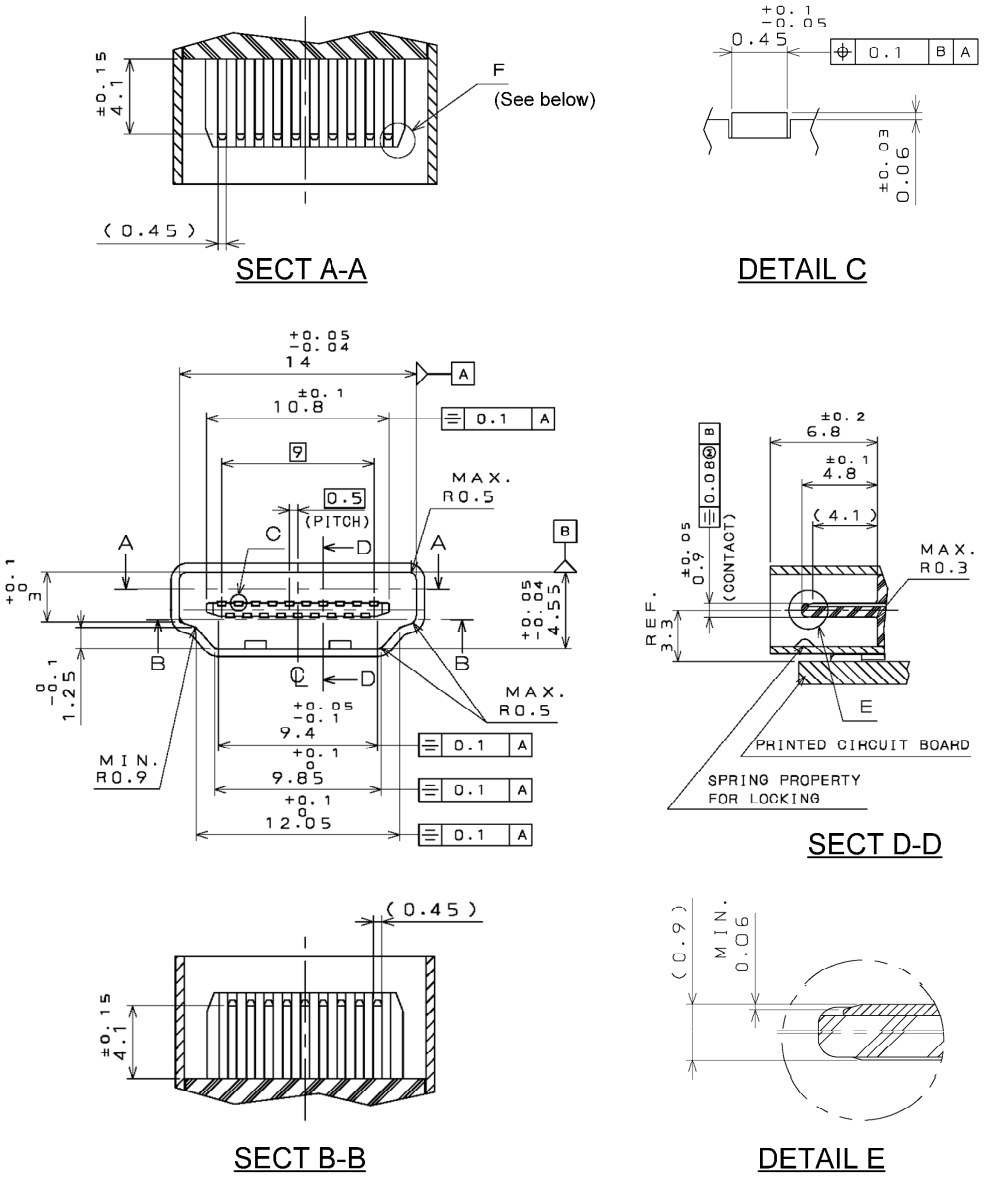
Table 4-12 Type E Connector Environmental Performance

Item	Test Condition		Requirement	
Thermal Shock	100 cycles of: a) −40 °C for 30 minutes b) +100 °C for 30 minutes (SAE/USCAR-2 5.6.1)		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: −40 ~ +100 °C Relative Humidity: 0 to 80% Duration: 40 cycles (320 hours) (SAE/USCAR-2 5.6.2)	Appearance	No Damage
			Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell : Change from initial value: 50 milliohms maximum.
	B	Unmate the connectors and perform the test as follows. Temperature: −40 ~ +100 °C Relative Humidity: 0 to 80% Duration: 40 cycles (320 hours) (SAE/USCAR-2 5.6.2)	Appearance	No Damage
			Dielectric Withstanding Voltage and Insulation Resistance	Conform to item of Dielectric Withstanding Voltage and Insulation Resistance
Thermal Aging	Mate connectors and expose to +100 °C for 1008 hours. (SAE/USCAR-2 5.6.3)		Appearance	No damage
			Contact Resistance	Contact : Change from initial value: 30 milliohms maximum. Shell : Change from initial value: 50 milliohms maximum.

4.1.9 Connector Drawings – Mating Interface Dimensions

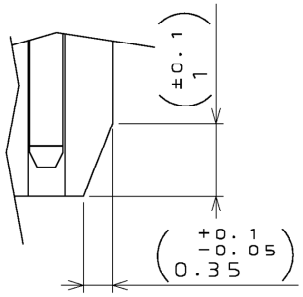
All dimensions in millimeters.

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

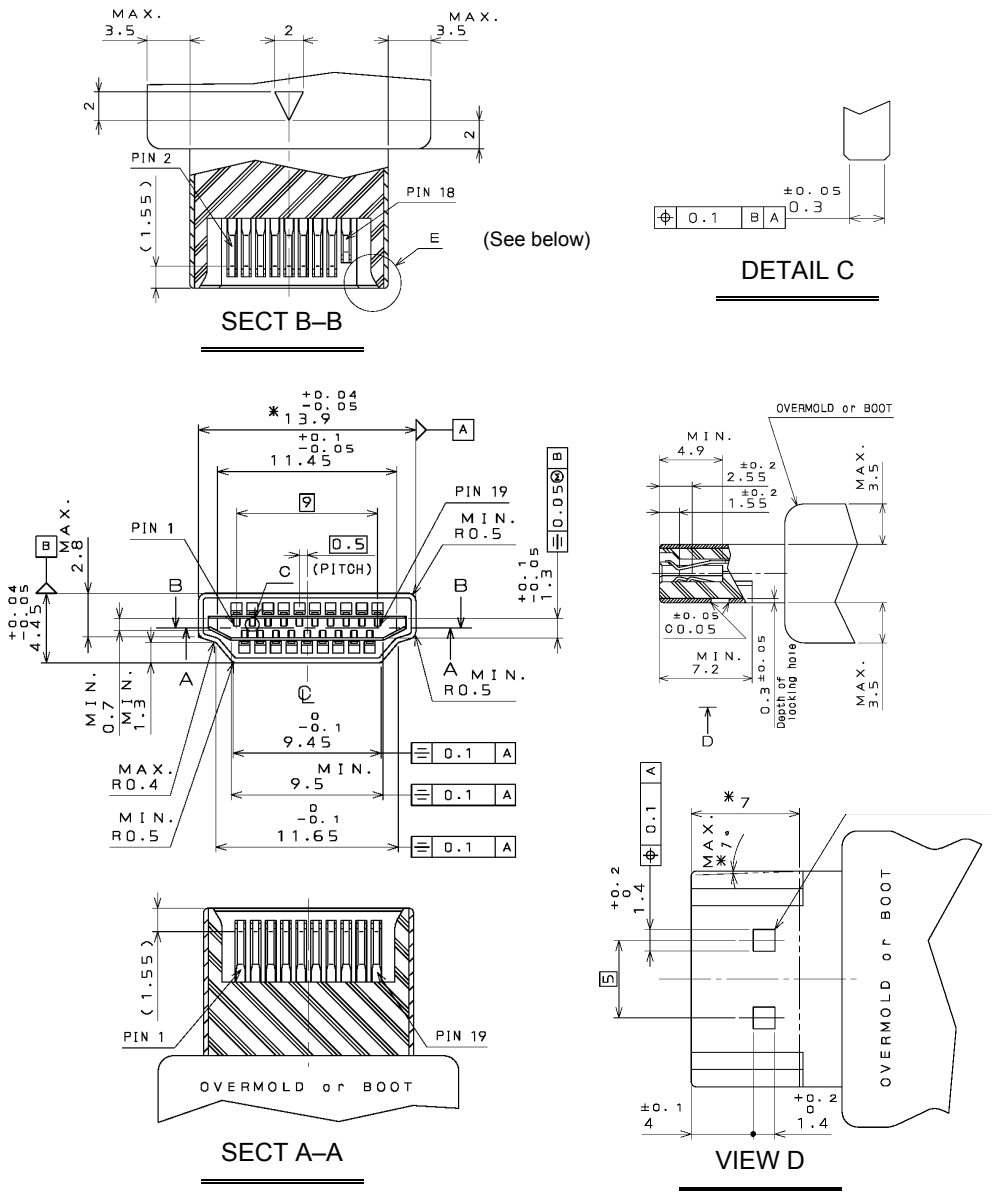


DETAIL F

- The form shown above is required. This feature will reduce the likelihood of damage to the receptacle insulator under rough operation.

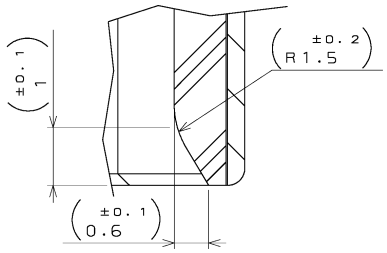
Figure 4-1–continued; Type A Receptacle, Detail F

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



- 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

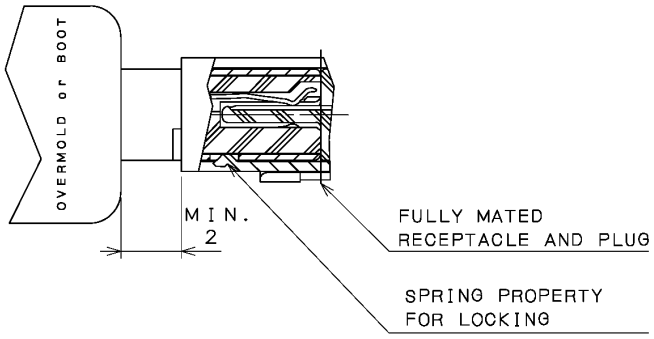


Figure 4-3 Type A Receptacle and Plug Mated Condition

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.

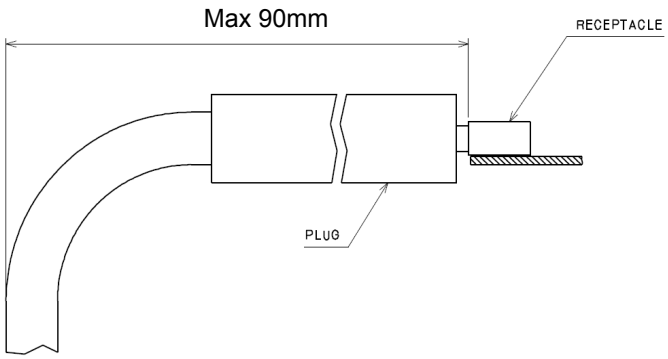
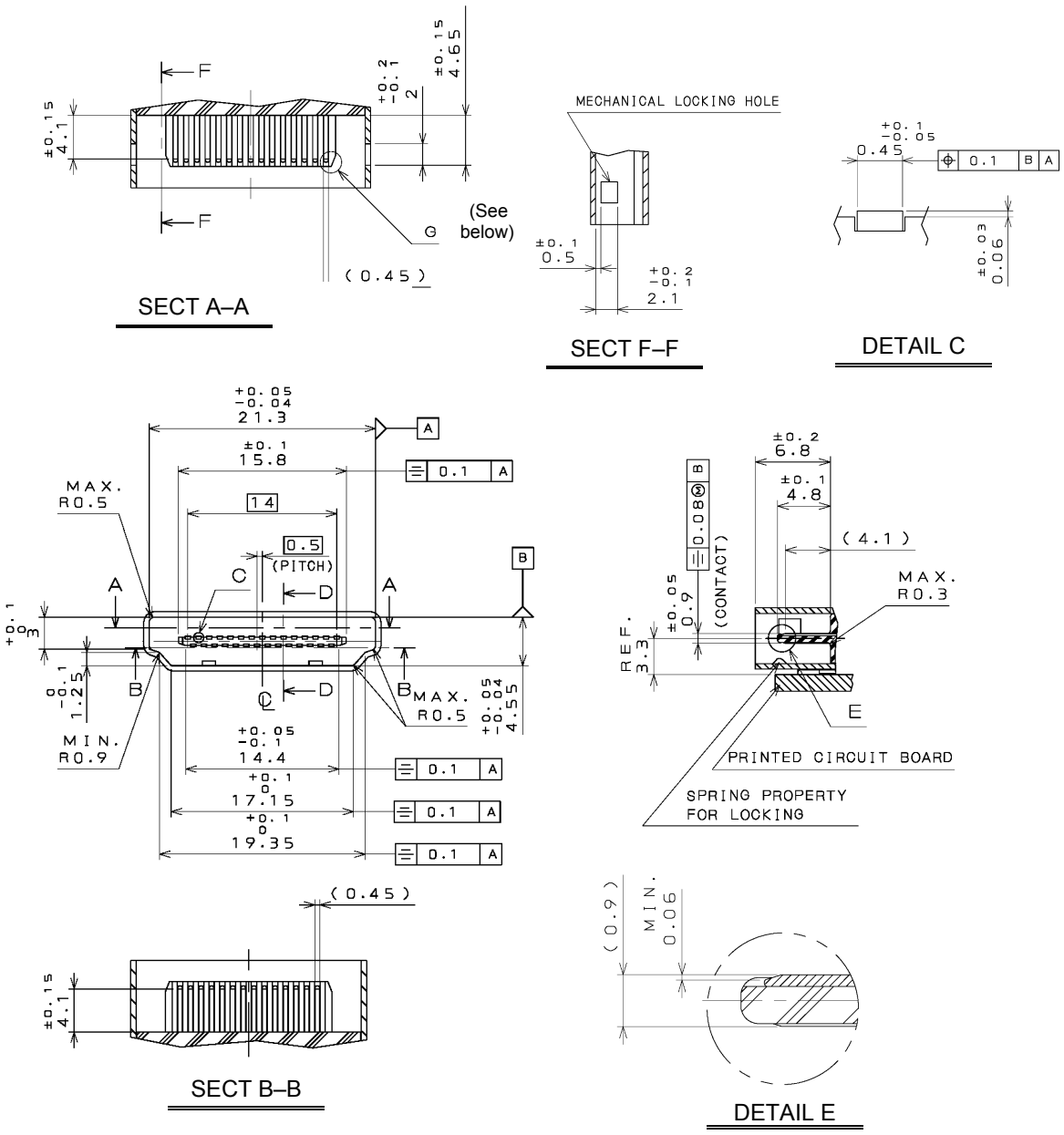


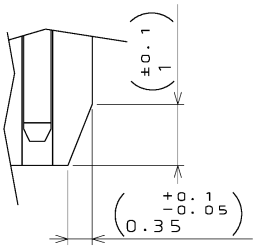
Figure 4-4 Type A Cable – Minimum Recommended Cable Bend

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

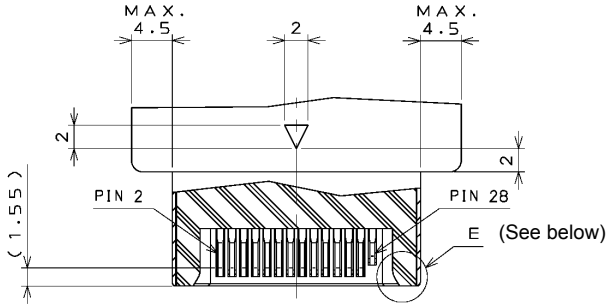


DETAIL G

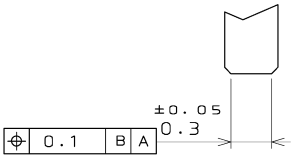
- The form shown above is required. This feature will reduce the likelihood of damage to the receptacle insulator under rough operation.

Figure 4-5-continued; Type B Receptacle, Detail G

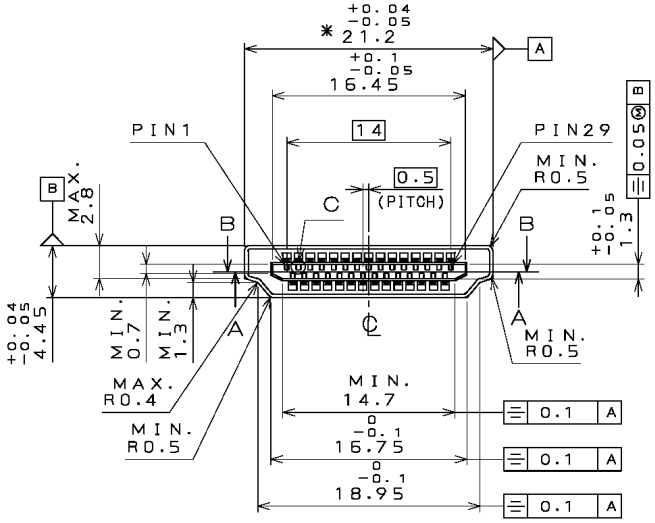
4.1.9.4 Type B Plug

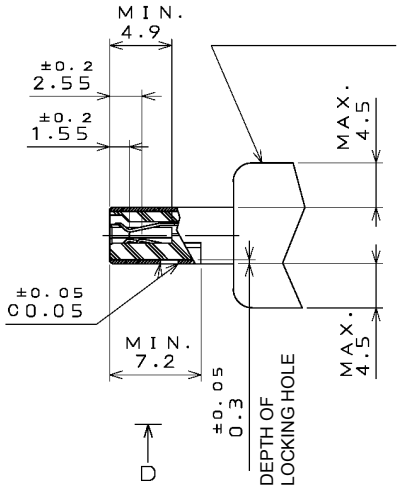


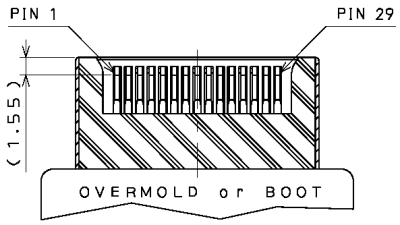
SECT B–B



DETAIL C



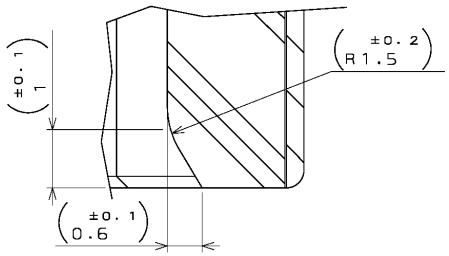




SECT A–A

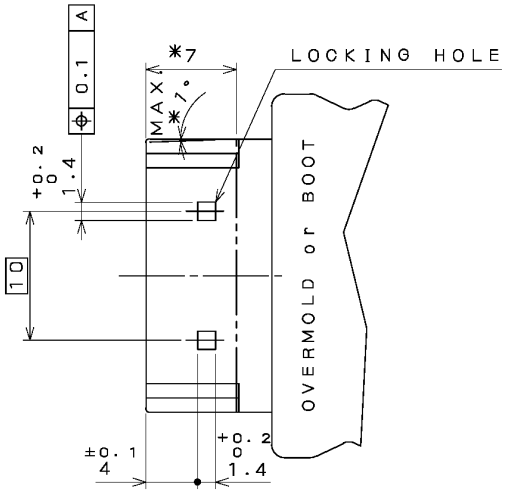
"VIEW D" → NEXT PAGE

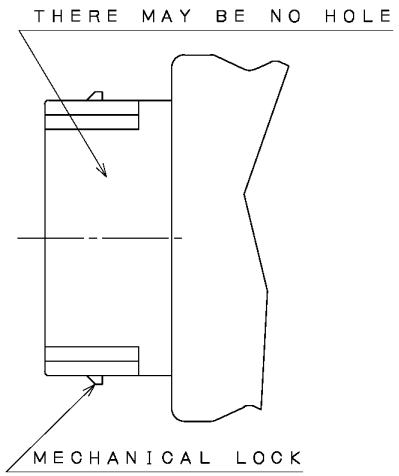
- The dimension of *21.2mm (+0.04 / -0.05) (on main section) should be measured at the point *7mm (on view D). The taper (on view D) shall be one degree max.
- The shell should not have a dimple other than the ones for locking.



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

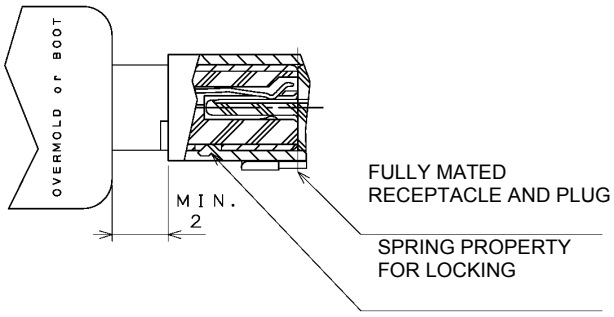
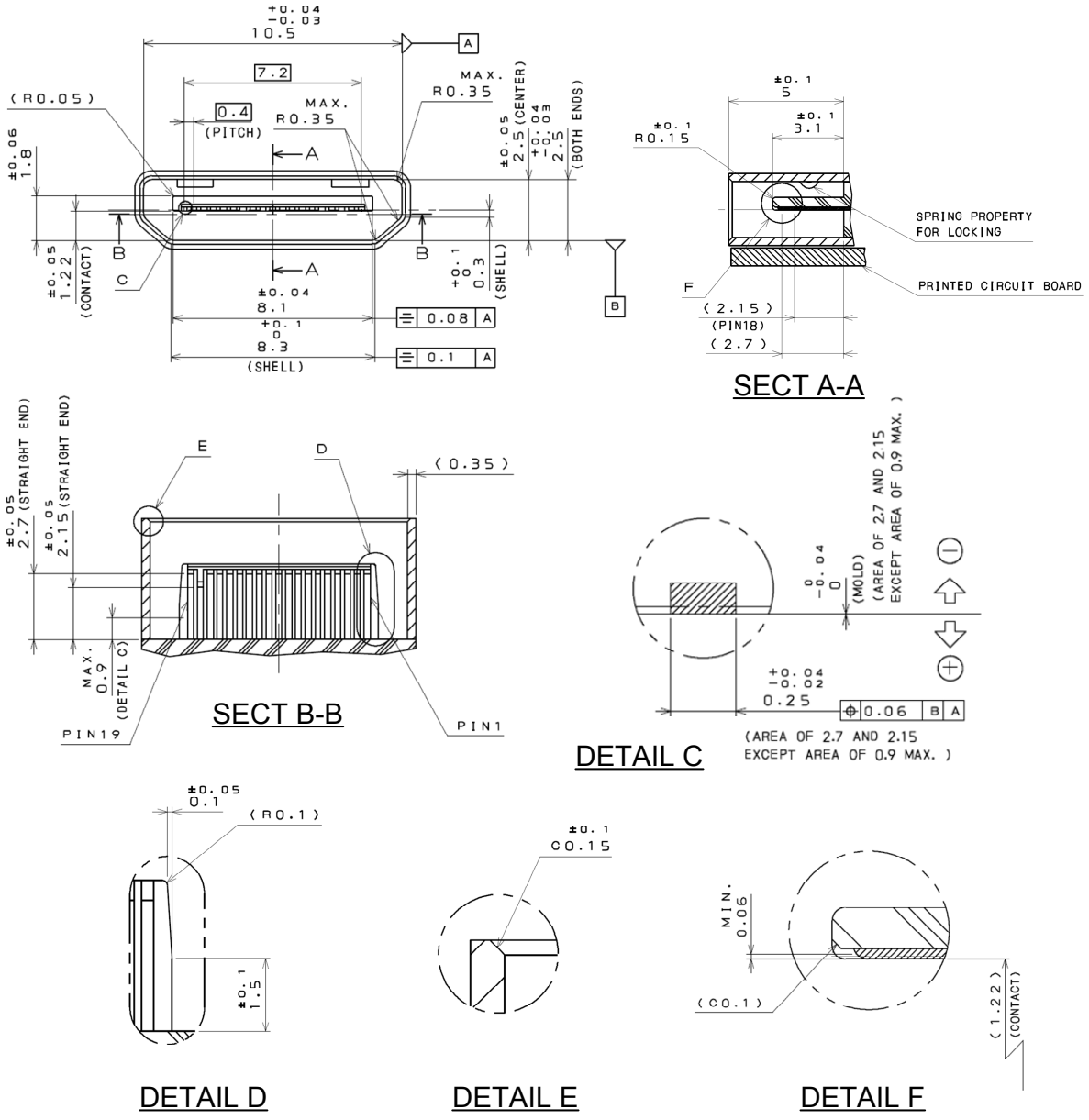


Figure 4-7 Type B Receptacle and Plug Mated Condition

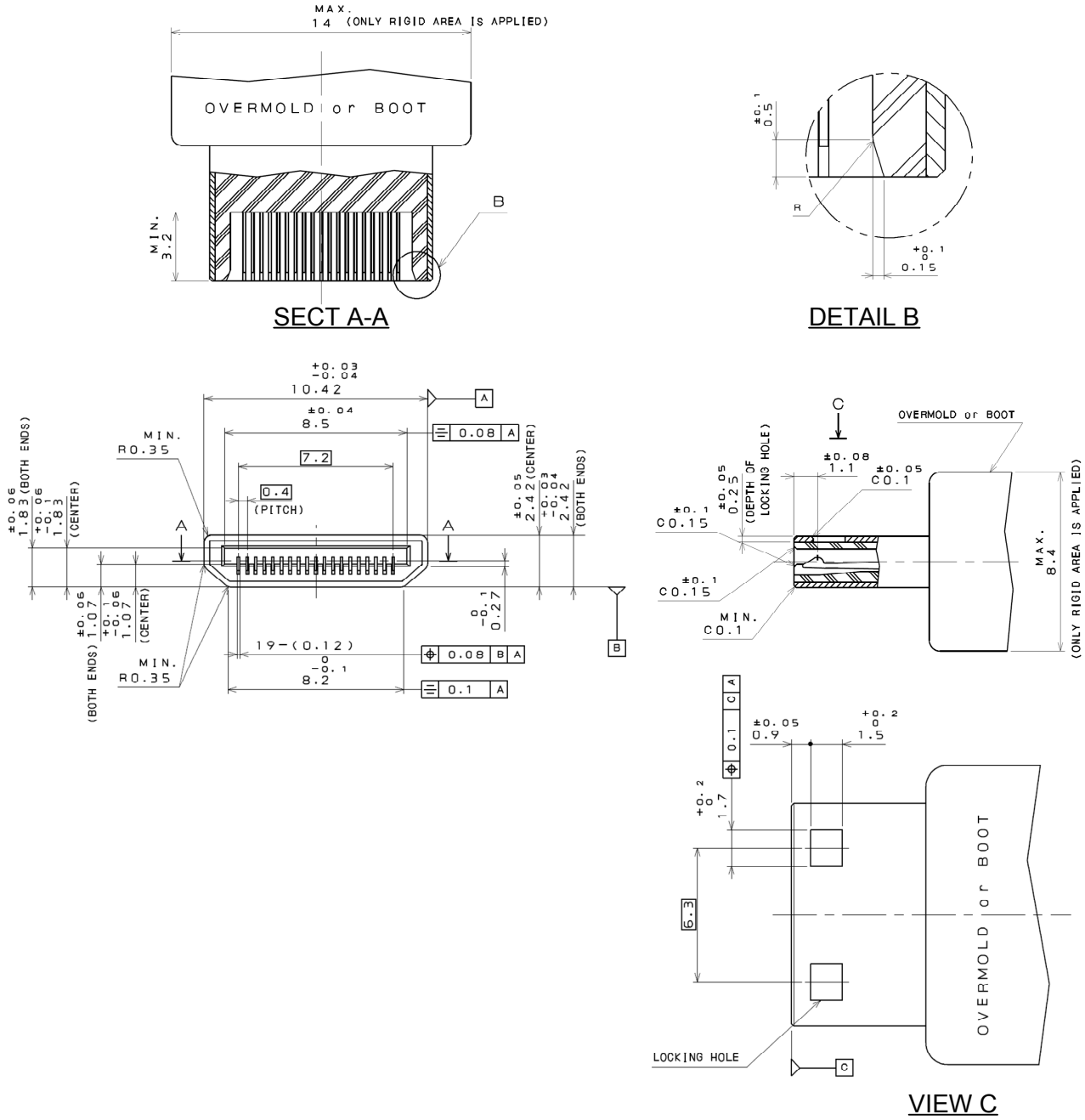
4.1.9.5 Type C Receptacle



- 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

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

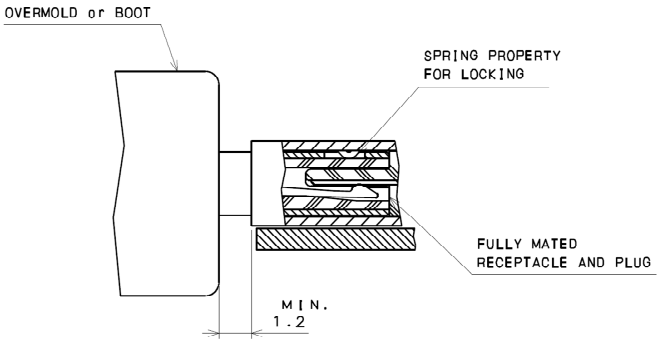


Figure 4-10 Type C Receptacle and Plug Mated Condition

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.

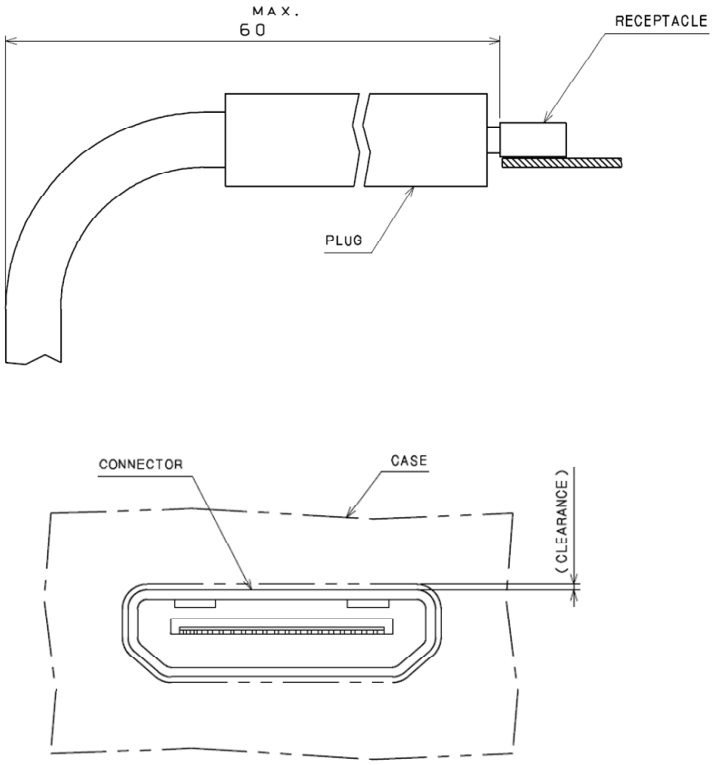
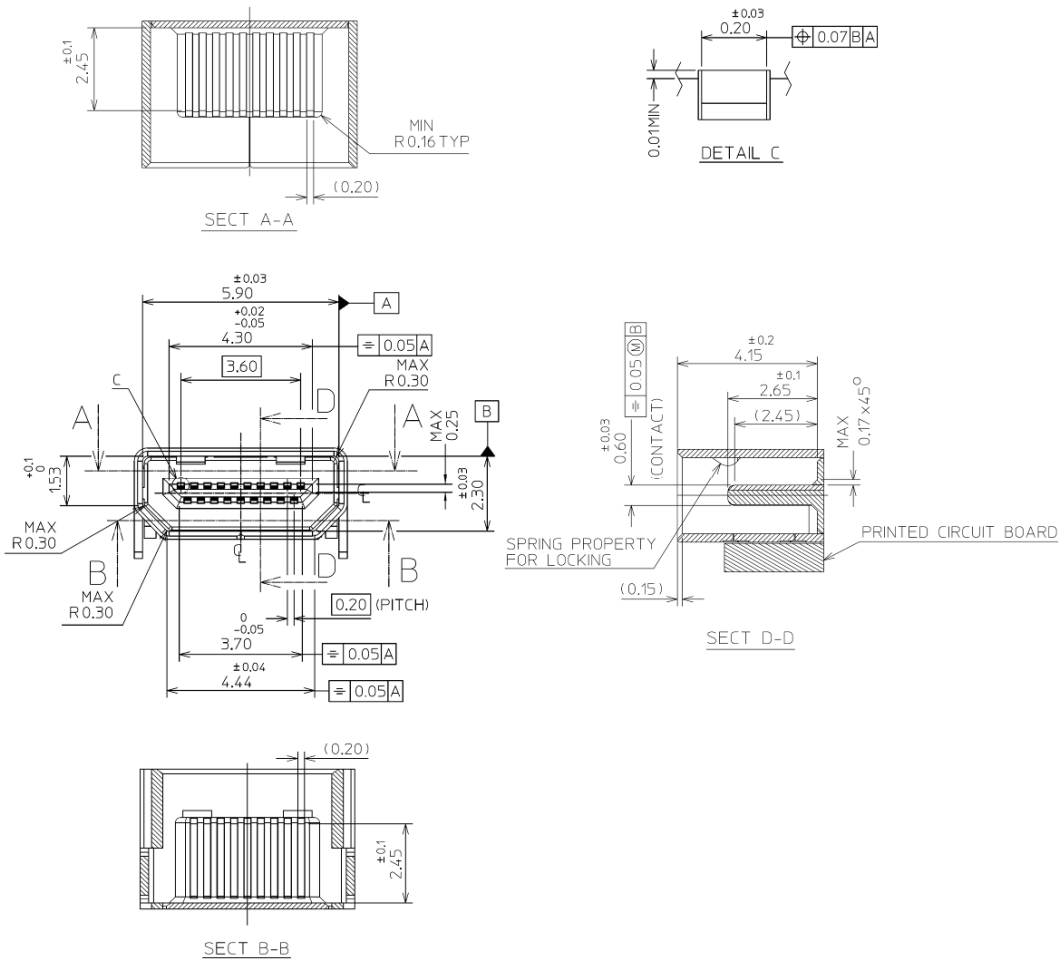


Figure 4-11 Type C Product Design Recommendations

4.1.9.7 Type D Receptacle



- The shell shall have a 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 4-12 Type D Receptacle Mating Interface Dimensions

4.1.9.8 Type D Plug

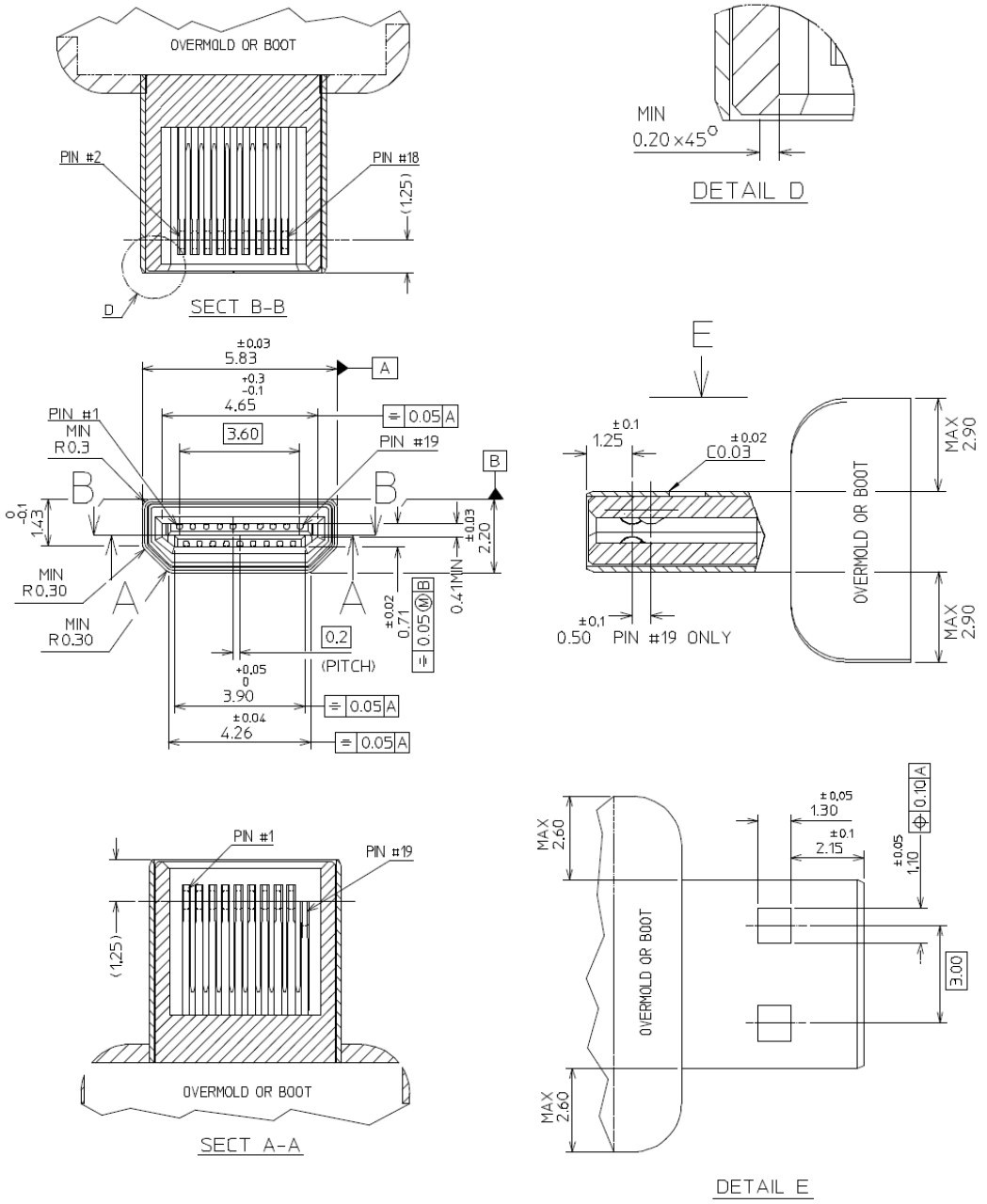


Figure 4-13 Type D Plug Mating Interface Dimensions

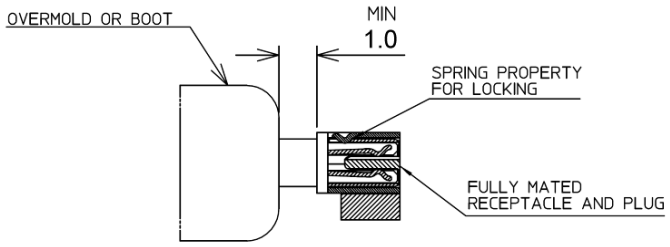


Figure 4-14 Type D Receptacle and Plug Mated Condition

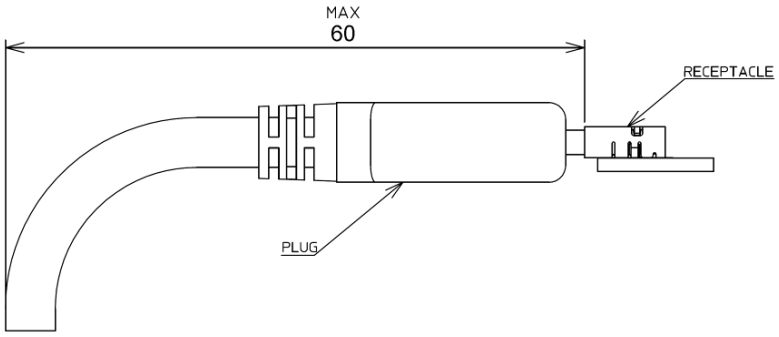


Figure 4-15 Type D Cable – Minimum Recommended Cable Bend

4.1.9.9 Type E Receptacle

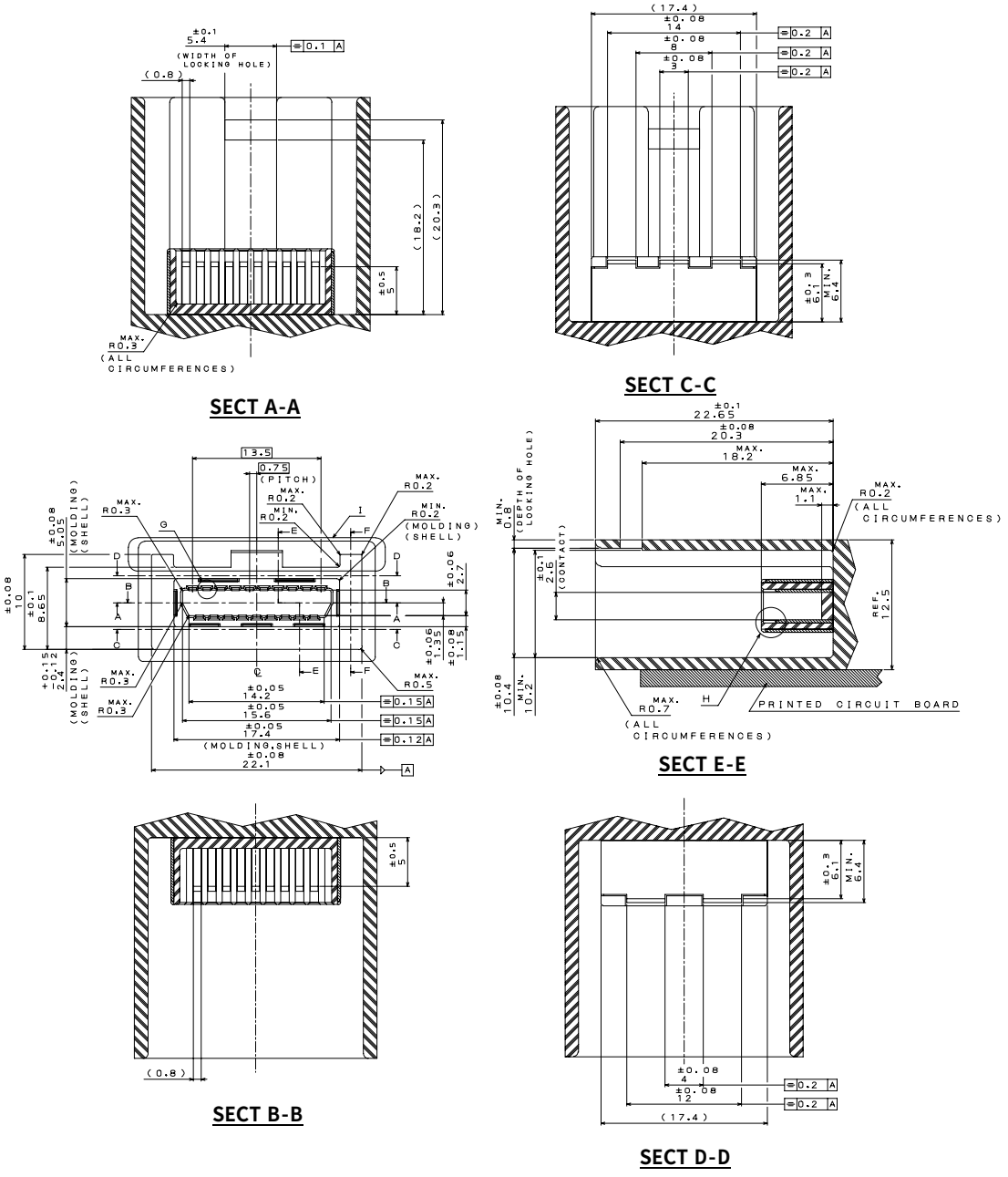
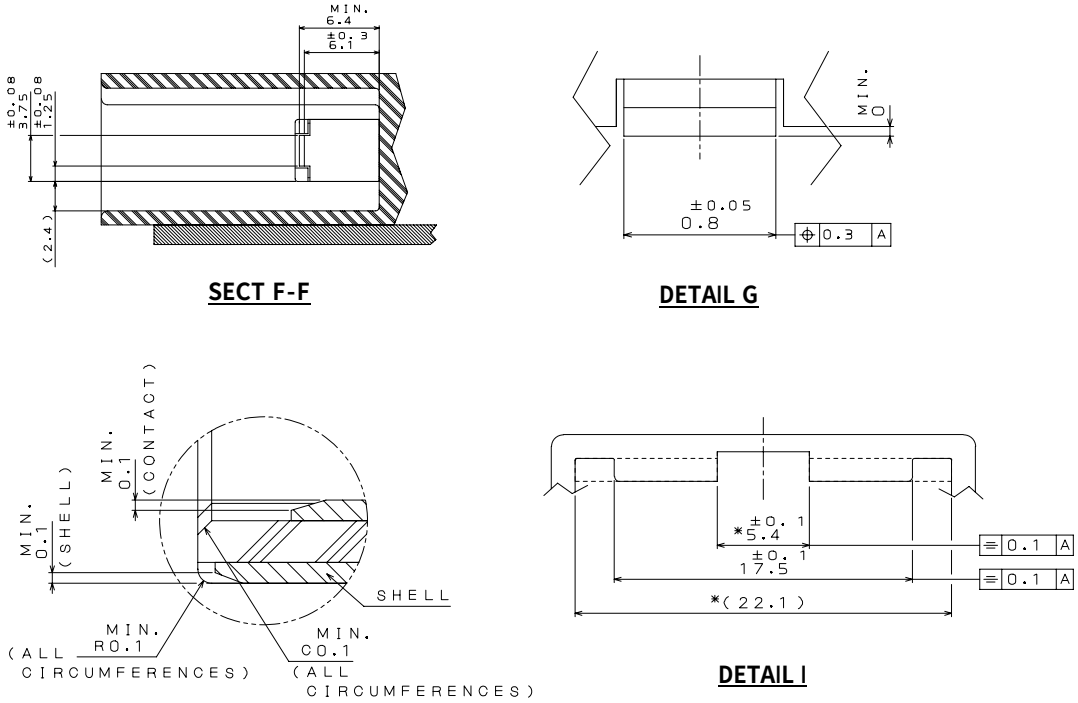


Figure 4-16 Type E Receptacle Mating Interface Dimensions



- The shell may be used for EMI reduction. It is the plug which may include the spring for EMI.
- The key shown above represents a standard key position. Position of the key may be varied between * (5.4) and * (22.1), (The area shown by dotted lines ; DETAIL I). For applications which require connector polarization, the key dimensions and location can be designed within this range.

Figure 4-16-Continued : Type E Receptacle Mating Interface Dimensions

4.1.9.10 Type E Plug

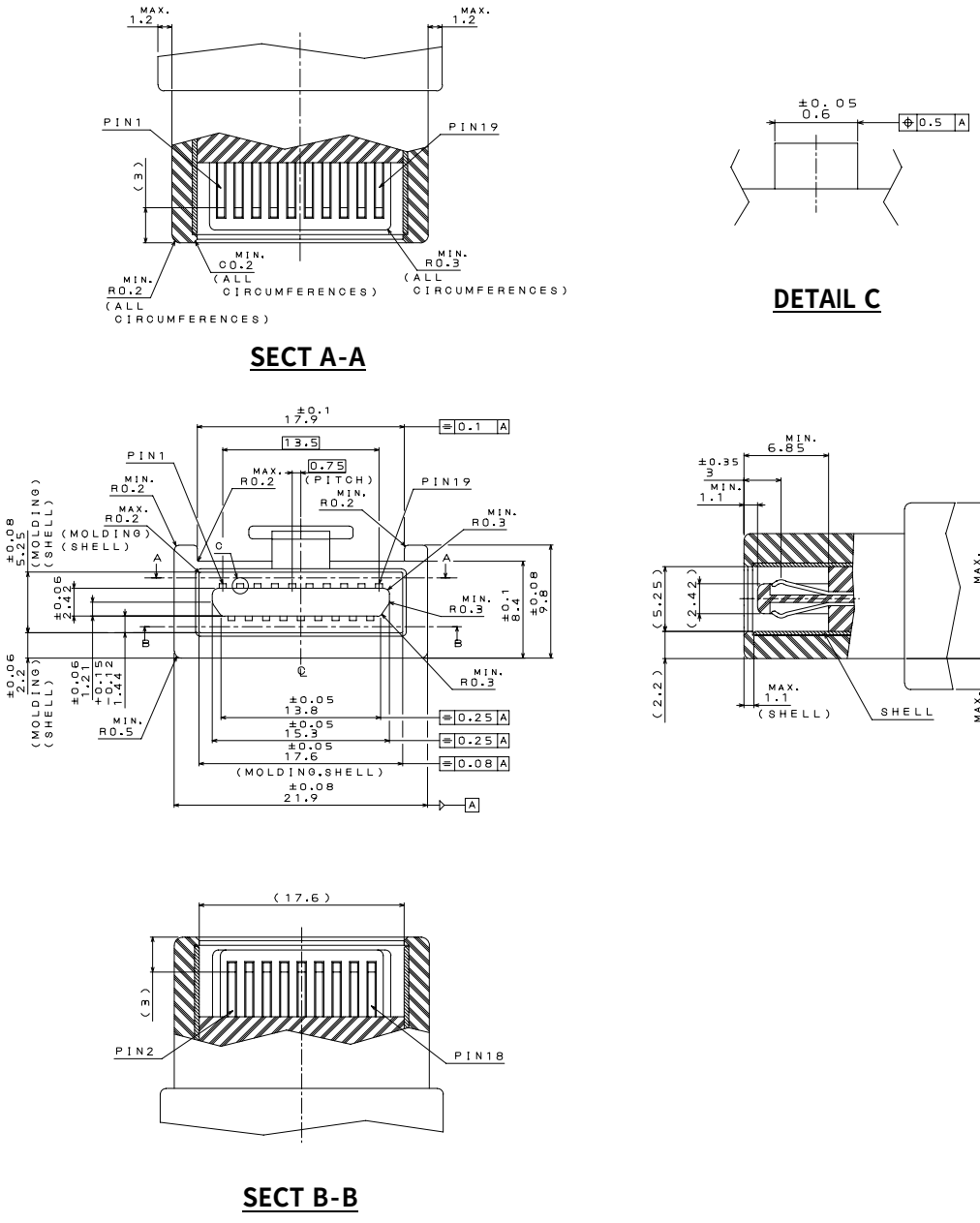
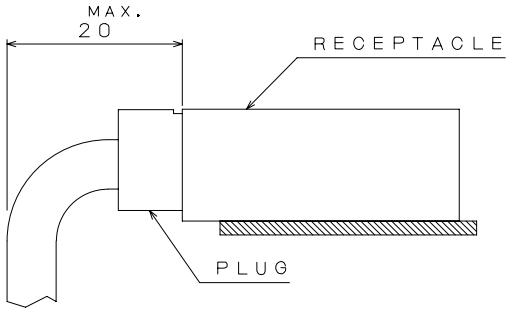


Figure 4-17 Type E Plug Mating Interface Dimensions



Minimum Recommended Cable Bend

- It is recommended that products using Type E connectors be designed to ensure that cable bends are not tighter than that shown in this Figure.

Figure 4-18 Type E Product Design Recommendations

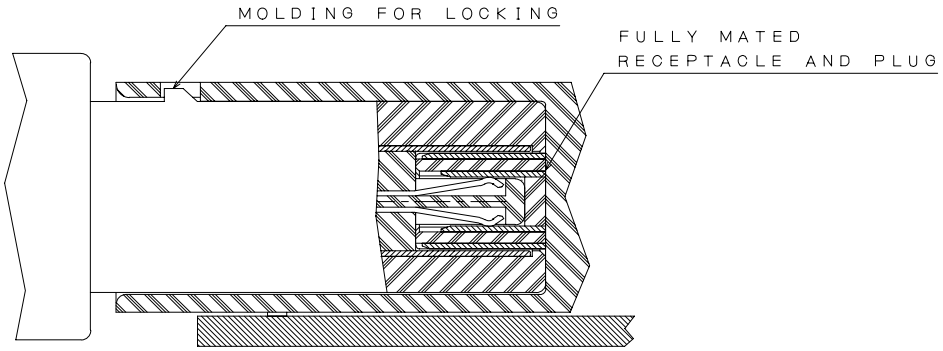
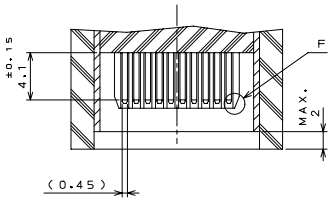
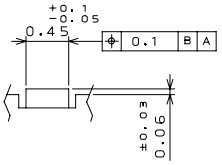


Figure 4-19 Type E Receptacle and Plug Mated Condition

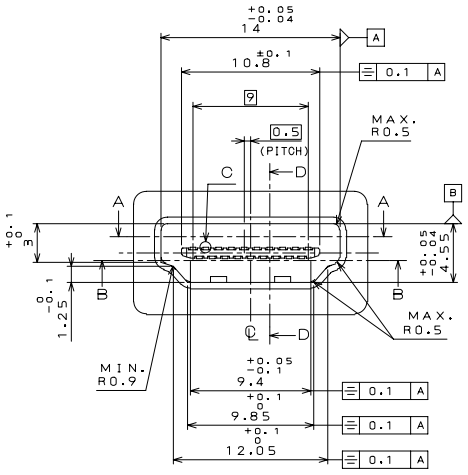
Type A Relay Receptacle

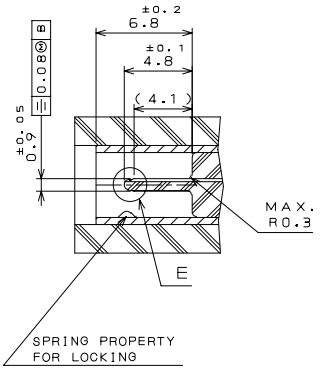


SECT A-A

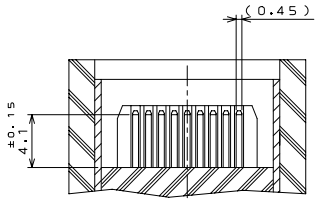


DETAIL C

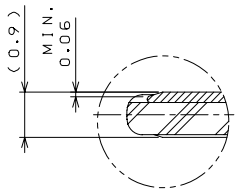




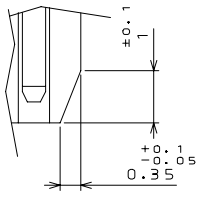
SECT D-D



SECT B-B



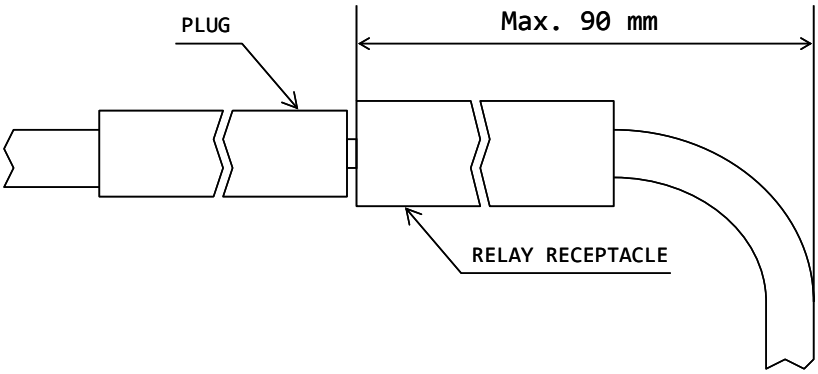
DETAIL E



DETAIL F

- 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.
- The Performance shall be conformed to the specification of “Type A”.
- The form shown above is required. This feature will reduce the likelihood of damage to the receptacle insulator under rough operation.

Figure 4-20 Type A Relay Receptacle Mating Interface Dimensions



Minimum Recommended Cable Bend

- It is recommended that products using the Type A relay receptacle be designed to ensure that cable bends are not tighter than that shown in the Figure.

Figure 4-21 Type A Relay Receptacle Design Recommendations

4.1.10 Cable Adapter Specification

Table 4-13 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

4.1.10.1 Type A Plug to Type A Plug

Table 4-14 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	Utility	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

4.1.10.2 Type A Plug to Type B Plug

Table 4-15 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

4.1.10.3 Type B Plug to Type B Plug

Table 4-16 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

4.1.10.4 Type C Plug to Type C Plug

Table 4-17 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	Utility	C	17
18	+5V Power	5V	18
19	Hot Plug Detect	C	19

4.1.10.5 Type C Plug to Type A Plug

Table 4-18 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	Utility	C	14
18	+5V Power	5V	18
19	Hot Plug Detect	C	19

4.1.10.6 Type D Plug to Type A Plug

Table 4-19 Type D-to-Type A Cable Wire Assignment

Type D pin	Signal Name	Wire	Type A pin
1	Hot Plug Detect	C	19
2	Utility	C	14
3	TMDS Data2+	A	1
4	TMDS Data2 Shield	B	2
5	TMDS Data2-	A	3
6	TMDS Data1+	A	4
7	TMDS Data1 Shield	B	5
8	TMDS Data1-	A	6
9	TMDS Data0+	A	7
10	TMDS Data0 Shield	B	8
11	TMDS Data0–	A	9
12	TMDS Clock+	A	10
13	TMDS Clock Shield	B	11
14	TMDS Clock–	A	12
15	CEC	C	13
16	DDC/CEC Ground	D	17
17	SCL	C	15
18	SDA	C	16
19	+5V Power	5V	18

4.1.10.7 Type E Plug to Type E Plug

Table 4-20 Type E to Type E Cable Wire Assignment

Type E pin	Signal Name	Wire	Type E 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	Utility	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

4.1.10.8 Type E Plug to Type A Relay Receptacle

Table 4-21 Type E-to-Type A Cable Wire Assignment

Type E 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	Utility	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

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 4-22. 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.

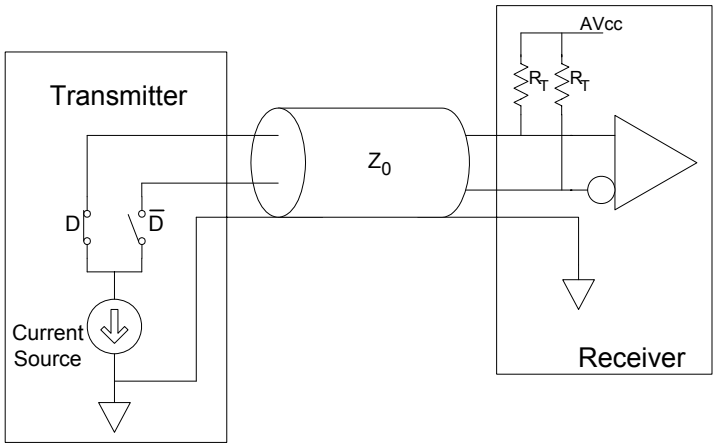


Figure 4-22 Conceptual Schematic for one TMDS differential pair

A single-ended differential signal, representing either the positive or negative terminal of a differential pair, is illustrated in Figure 4-23. 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 4-24, swings between positive V_{swing} and negative V_{swing}.

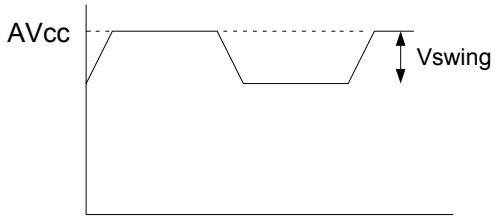


Figure 4-23 Single-ended Differential Signal

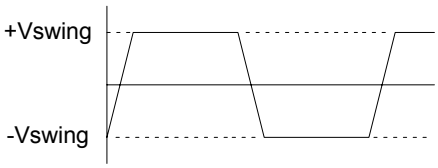


Figure 4-24 Differential Signal

The signal test points for a TMDS link are shown in Figure 4-25. 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. The TMDS link intermediate test point for the Automotive relay connection is shown as TP5 in Figure 4-26.

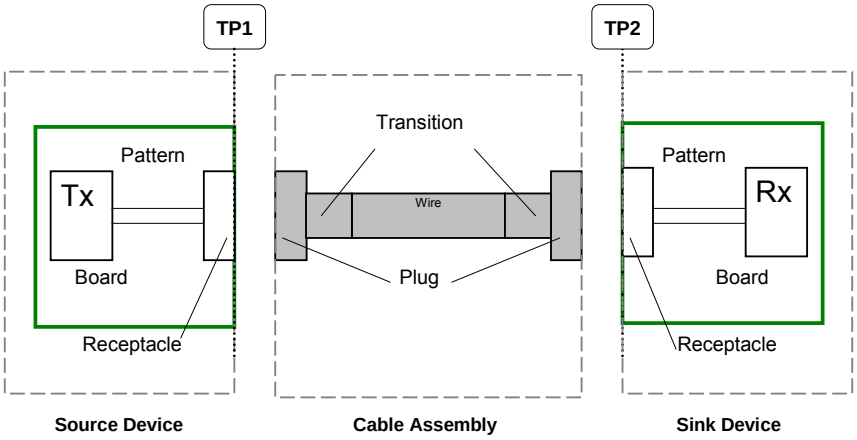


Figure 4-25 TMDS Link Test Points

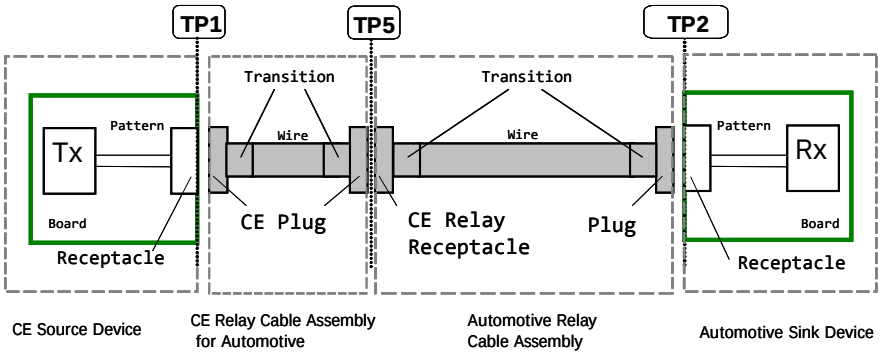


Figure 4-26 TMDS Link Test Points for Automotive (Relay Connection)

4.2.2 TMDS System Operating Conditions

The required operating conditions of the TMDS pairs are specified in Table 4-22.

Table 4-22 Required Operating Conditions for HDMI Interface (see Figure 4-22)

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 $\omega_0 = 2\pi F_0$, $F_0 = 4.0$ 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 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 4-27.

$$|H(j\omega)| = \begin{cases} e^{A*\omega^N} & (\omega < \omega_0) \\ e^{-B*(\omega-1.2*\omega_0)^2+C} & (\omega_0 < \omega < 1.4*\omega_0) \\ e^{-D*\omega+E} & (1.4*\omega_0 < \omega) \end{cases}$$

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

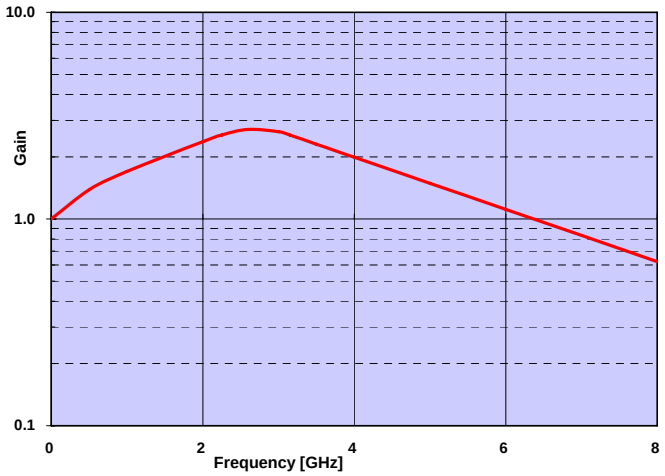


Figure 4-27 Gain of Reference Cable Equalizer

$$|H(j\omega)| = \begin{cases} e^{A*\omega^N} & (\omega < \omega_0) \\ e^{-B*(\omega-1.2*\omega_0)^2+C} & (\omega_0 < \omega < 1.4*\omega_0) \\ e^{-D*\omega+E} & (1.4*\omega_0 < \omega) \end{cases}$$

Where :

$$N = 0.7$$

$$\omega_0 = 2\pi * 0.7425GHz$$

$$A = 1.42E-7$$

$$B = \frac{7}{4} * A * \omega_0^{-1.3}$$

$$C = 1.07 * A * \omega_0^{0.7}$$

$$D = 0.7 * A * \omega_0^{-0.3}$$

$$E = 1.98 * A * \omega_0^{0.7}$$

Equation 4-3 Reference Cable Equalizer Function for Automotive

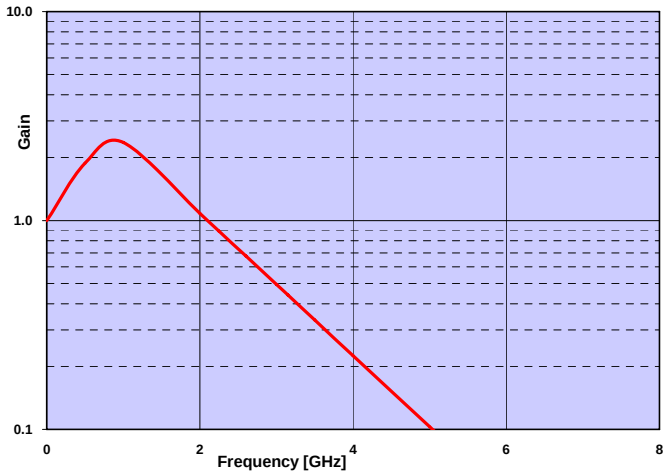


Figure 4-28 Gain of Reference Cable Equalizer for Automotive

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 4-29, with AV_{cc} set to 3.3V. TP1 represents the connection point of the receptacle.

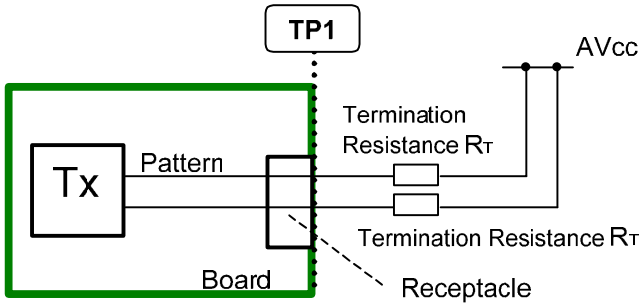


Figure 4-29 Balanced Source Test Load

The Source shall meet the DC specifications in Table 4-23 for all operating conditions specified in Table 4-22 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.

Table 4-23 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 4-24 across all operating conditions specified in Table 4-22. 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 4-24 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 4-29).

For all channels under all operating conditions specified in Table 4-22 and when terminated as shown in Figure 4-29, the Source shall have output levels at TP1 that meet the eye diagram requirements of Figure 4-30. 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 4-30 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.

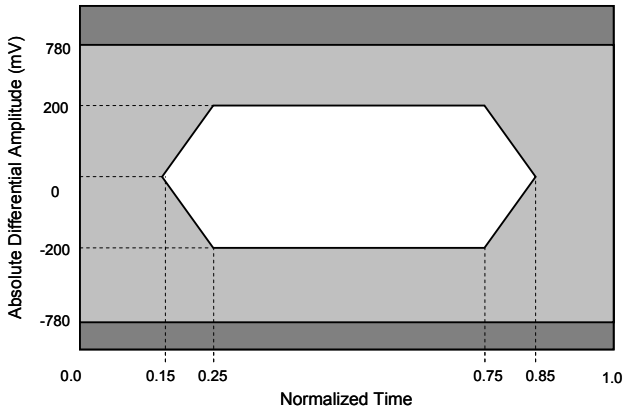


Figure 4-30 Eye Diagram Mask at TP1 for Source Requirements

Combining the single-ended swing voltage (V_{swing}) specified in Table 4-23 with a 15% overshoot (legacy) and the undershoot limits of Table 4-24, 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.

4.2.5 HDMI Sink TMDS Characteristics

HDMI Sink electrical testing shall be performed using a test signal generator as shown in Figure 4-31.

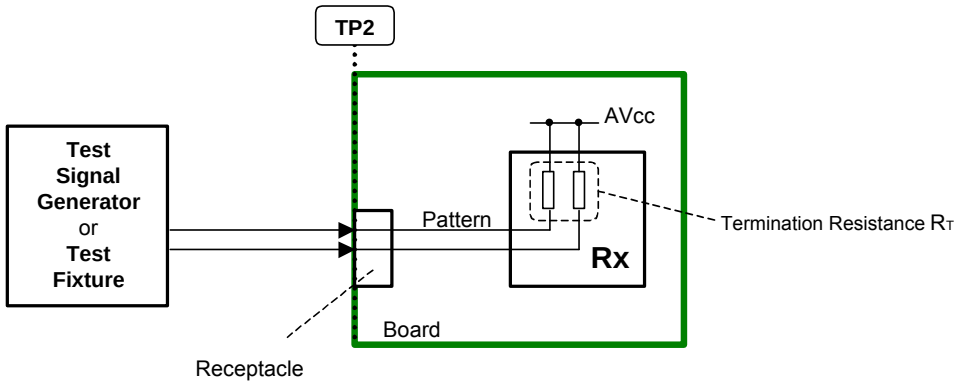


Figure 4-31 HDMI Sink Test Points

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 4-25, Table 4-26, and Table 4-27.

Table 4-25 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.

Table 4-26 Sink DC Characteristics When Source Disabled or Disconnected at TP2

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

Table 4-27 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 4-32.

- 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 4-32 after application of the Reference Cable Equalizer.

For Automotive

- For Automotive, 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 4-32 after application of the Reference Cable Equalizer for Automotive.
- Automotive cable parameters are specified only for Category 1 (up to 74.25MHz), so that the Automotive applications can be operated up to 74.25MHz.

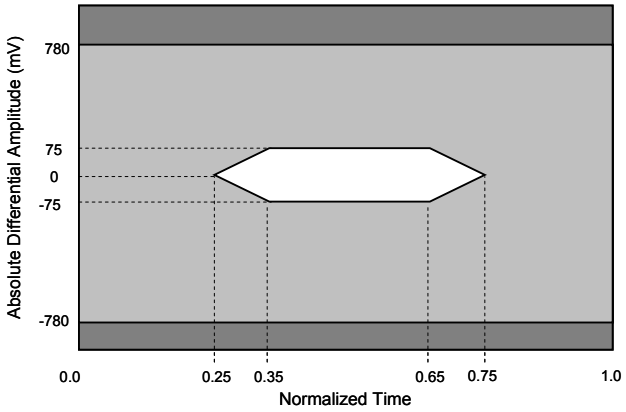


Figure 4-32 Eye Diagram Mask at TP2 for Sink Requirements

Table 4-28 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

Four types of cable assembly are defined based on the material of the cable itself:

- Wire: Wire-only construction with no circuit components (neither active nor passive).
- Passive: Wire plus passive circuit components. No active circuit components.
- Active: Contains active circuit components with equalizer function. Does not have Tx or Rx function.
- Converter: Contains Rx and Tx functions. Any transmission media like wireless, optical fiber, etc. may be used between the Rx and Tx functions. Acts as a 1to1 repeater where both ends are cable plugs.

HDMI cable assemblies are measured with respect to the test points TP3 and TP4 shown in Figure 4-33. 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. Similarly, TP6 is also used in place of TP5 as shown in Figure 4-34 and Figure 4-35.

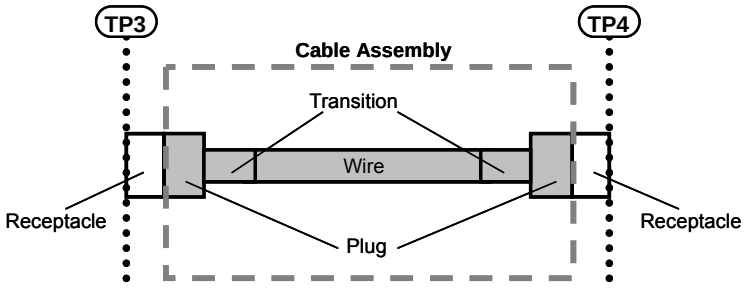


Figure 4-33 Cable Assembly Test Points

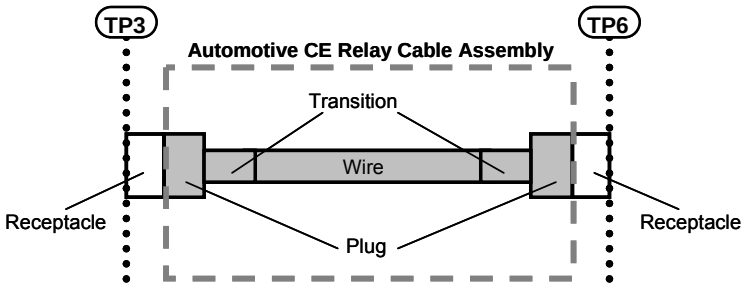


Figure 4-34 Automotive CE Relay Cable Assembly Test Points (Relay Connection)

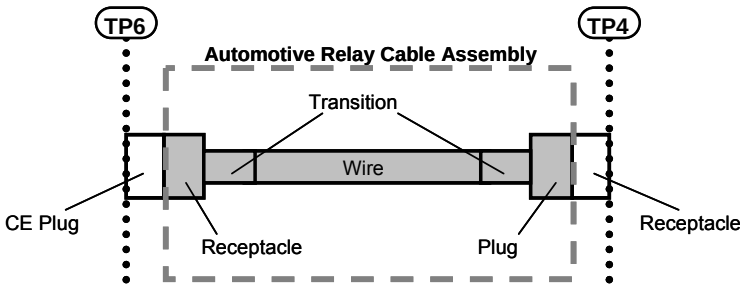


Figure 4-35 Automotive Relay Cable Assembly Test Points (Relay Connection)

HDMI cable assemblies shall support both V_{icm} ranges (V_{icm1} and V_{icm2}) given in Table 4-25.

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 4-30 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 4-32.
- Equalized eye diagram specification – when driven by any TMDS input waveform meeting the Source eye diagram mask requirements of Figure 4-30 at the tested TMDS clock frequency, the TMDS output waveform of the cable shall meet the post-equalized eye diagram mask of Figure 4-32 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 4-29, 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 4-29, or,
  B) all of:
    - the non-equalized eye diagram requirements at 165MHz and,
    - the equalized eye diagram requirements at 340MHz

Table 4-29 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 4-36	See Figure 4-37 (note) For cables with passive equalizer circuits, see the passive cable descriptions below.
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.*

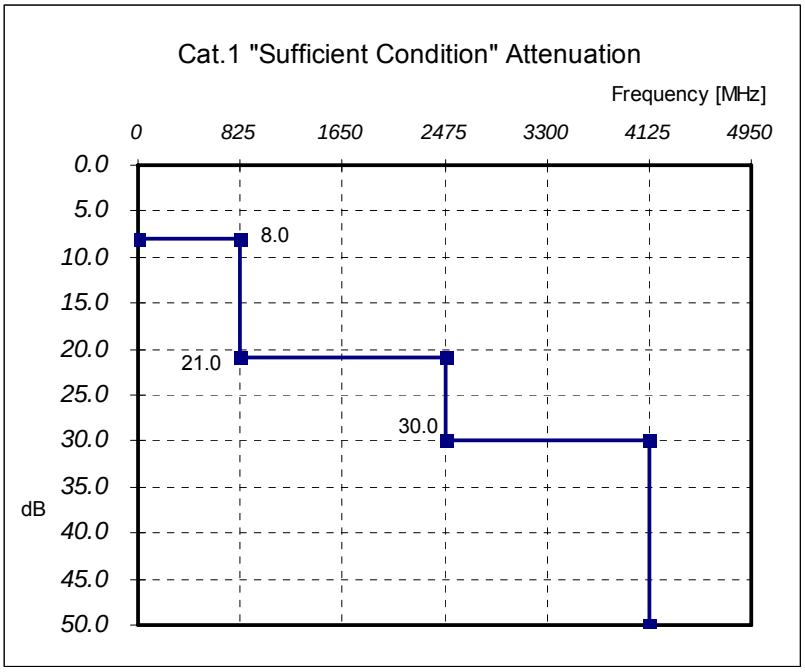


Figure 4-36 Category 1 Cable Attenuation Limits – Sufficient Condition

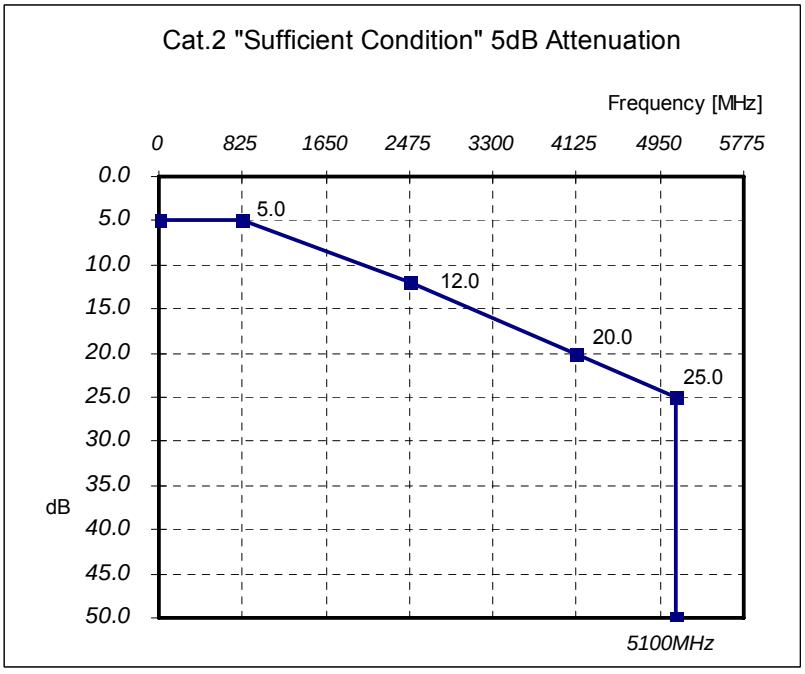


Figure 4-37 Category 2 Cable Attenuation Limits – Sufficient Condition

Passive Cables

Some HDMI cable assemblies include a passive equalizer circuit. In general, since the Passive cable can also be extracted as a set of S-parameter, this type of cable can be specified using the parametric values in the same manner as a normal copper cable. The only difference is a certain additional requirements are specified for parameters as shown below.

- Category 2 (TMDS clock up to 340MHz): Any passive equalizer circuit embedded in the cable shall meet either
  A) the parameters specified for Category 2 cables in Table 4-30 or,
  B) all of:
    - the non-equalized eye diagram requirements at 165MHz and,
    - the equalized eye diagram requirements at 340MHz and,

Table 4-30 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	See Figure 4-38	
Phase	See Figure 4-40	
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 duration less than 250psecs.*

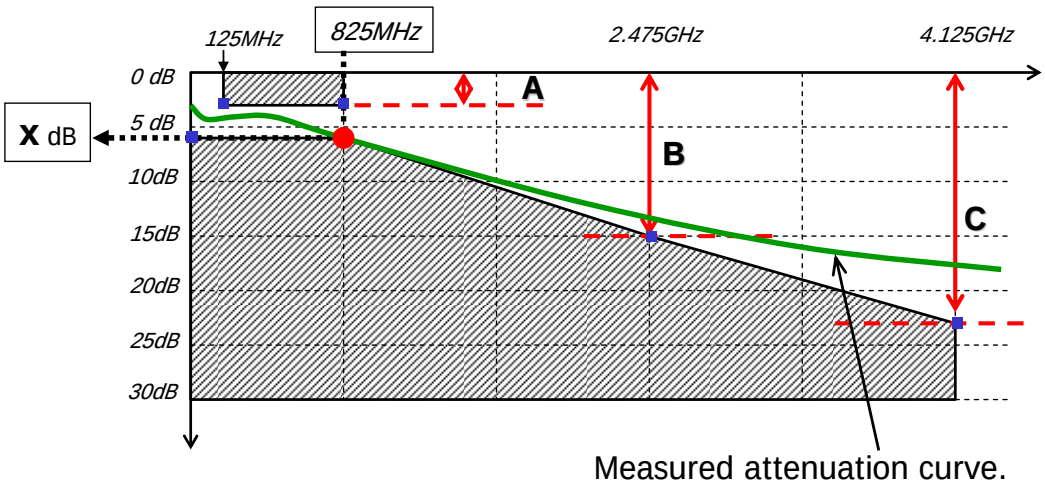


Figure 4-38 Passive equalizer Cable Attenuation Limits – Sufficient Condition

In Figure 4-38, 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 4-37 “Category 2 Cable Attenuation Limits – Sufficient Condition”.

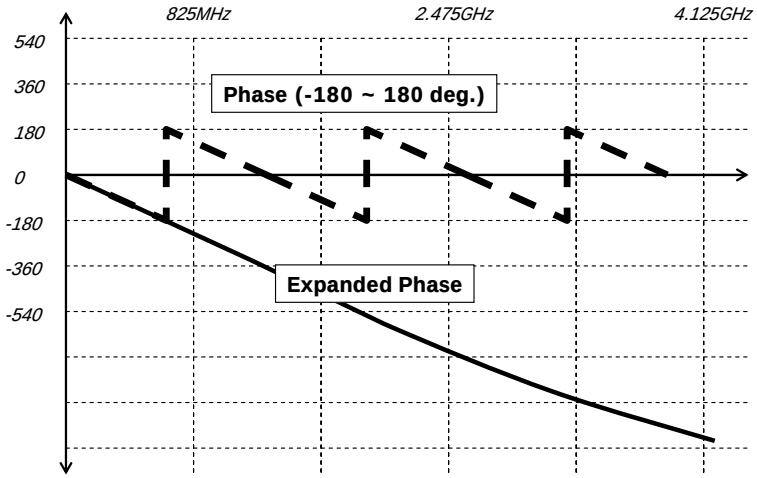


Figure 4-39 Passive equalizer Cable Phase measurement method (explanation)

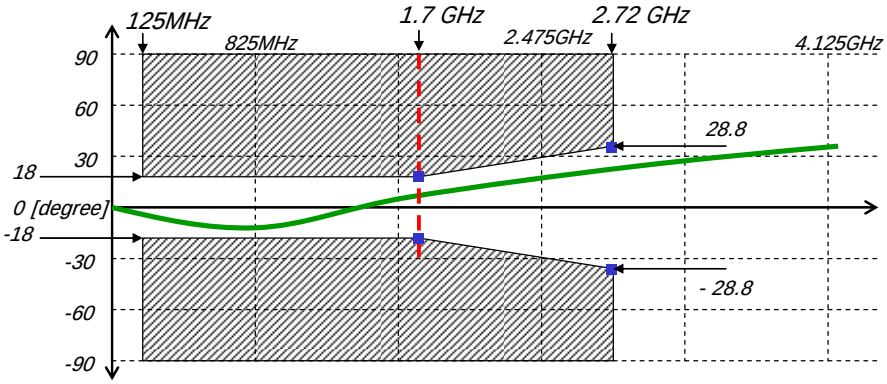


Figure 4-40 Passive equalize Cable Phase Limits – Sufficient Condition

The phase characteristic is plotted as the difference between the linear expanded phase line and the calculated linear approximated value by using “Ordinary Least Squares”.

In general, phase response is measured as a linear response shown in Figure 4-39. 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, and “m” is an incline parameter to be calculated. The frequency range used for calculation of “m” is from 300kHz to 1.7GHz).

Automotive Cable Assembly

Table 4-31 Automotive Cable Assembly TMDS Parameters (Direct Connection)

Parameter	Category 1 (up to 74.25MHz)
Maximum Cable Assembly Intra-Pair Skew	336psec
Maximum Cable Assembly Inter-Pair Skew	5.38nsec
Far-end Crosstalk	< -20dB
Attenuation	Eye Pattern with EQ for Automotive at TP2
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.*

Table 4-32 CE Relay Cable Assembly TMDS Parameters (Relay Connection)

Parameter	Category 1 (up to 74.25MHz)
Maximum Cable Assembly Intra-Pair Skew	101psec
Maximum Cable Assembly Inter-Pair Skew	1.61nsec
Far-end Crosstalk	< -20dB
Attenuation	Eye Pattern for Automotive at TP5
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.*

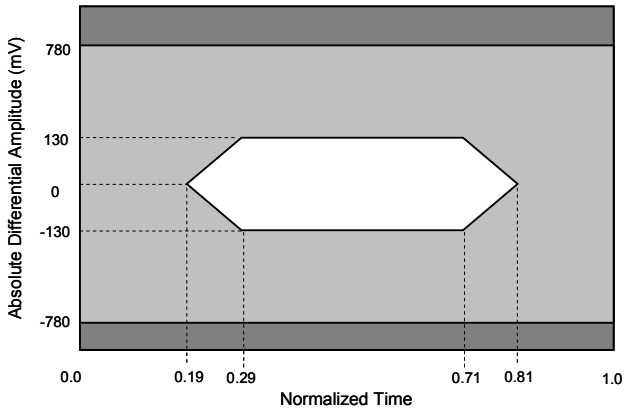


Figure 4-41 Eye Diagram Mask at TP5 for CE Relay Cable

Table 4-33 Automotive Relay Cable Assembly TMDS Parameters (Relay Connection)

Parameter	Category 1 (up to 74.25MHz)
Maximum Cable Assembly Intra-Pair Skew	235psec
Maximum Cable Assembly Inter-Pair Skew	3.77nsec
Far-end Crosstalk	< -20dB
Attenuation	Eye Pattern with EQ for Automotive at TP2
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.*

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 4-34. 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 4-34 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.

Table 4-34 +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 4-35, Table 4-36 and Table 4-37.

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 4-35 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 4-36 Maximum Capacitance of DDC line for Automotive

Item	HDMI Source	Cable Assembly			HDMI Sink
		Automotive Cable	CE Relay Cable	Automotive Relay Cable	
SDA – DDC/CEC Ground	50pF	700pF	210pF	490pF	50pF
SCL – DDC/CEC Ground	50pF	700pF	210pF	490pF	50pF

Table 4-37 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 4-38 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 4-39 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.

Table 4-40 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 such 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
	Maximum capacitance load of an Automotive Cable Assembly	700pF
	Maximum capacitance load of a CE Relay Cable Assembly	210pF
	Maximum capacitance load of an Automotive Relay Cable Assembly	490pF

4.2.11 Utility Line

This line may be used for multiple purposes (see HEAC as specified in Supplement 2). Its use is controlled using the Capability Discovery and Control protocol specified in Supplement 2 and the Consumer Electronics Control protocol specified in Supplement 1. The ground reference for the Utility signal is the DDC/CEC Ground signal.

Table 4-41 Utility line Electrical Specifications (Recommendation)

Item	Value
Impedance	55 ohms ± 35%

4.2.12 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.

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.

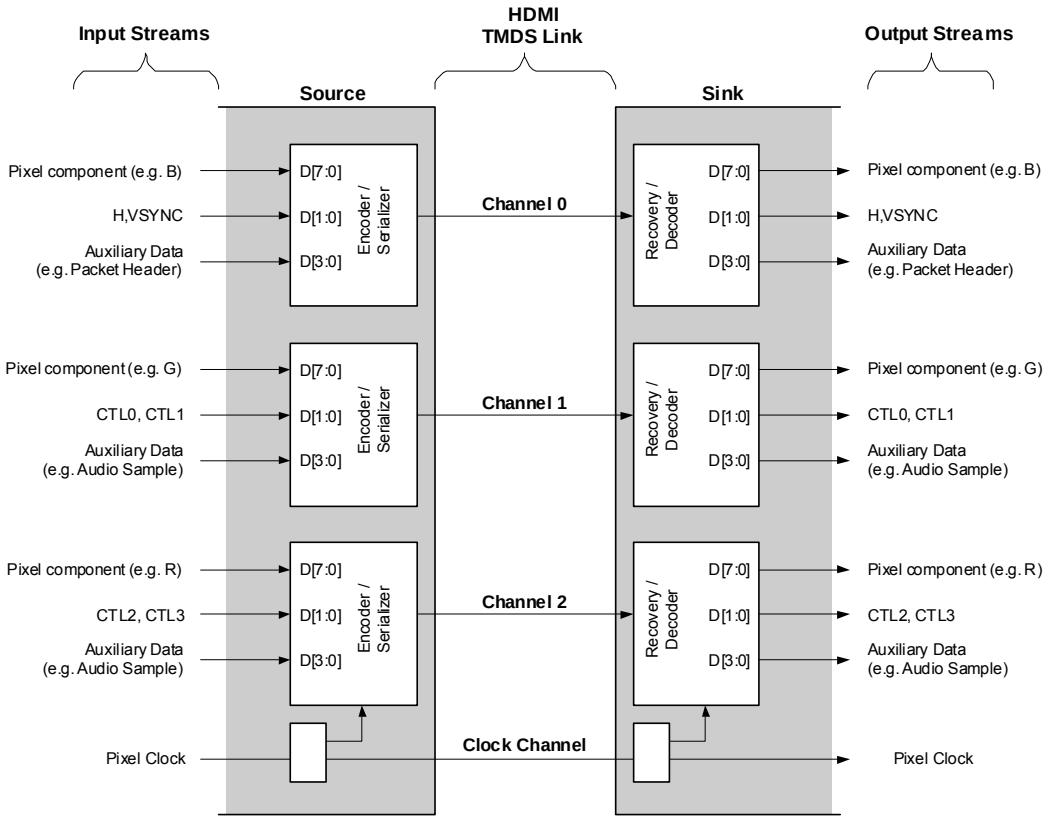


Figure 5-1 HDMI Encoder/Decoder Overview

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.

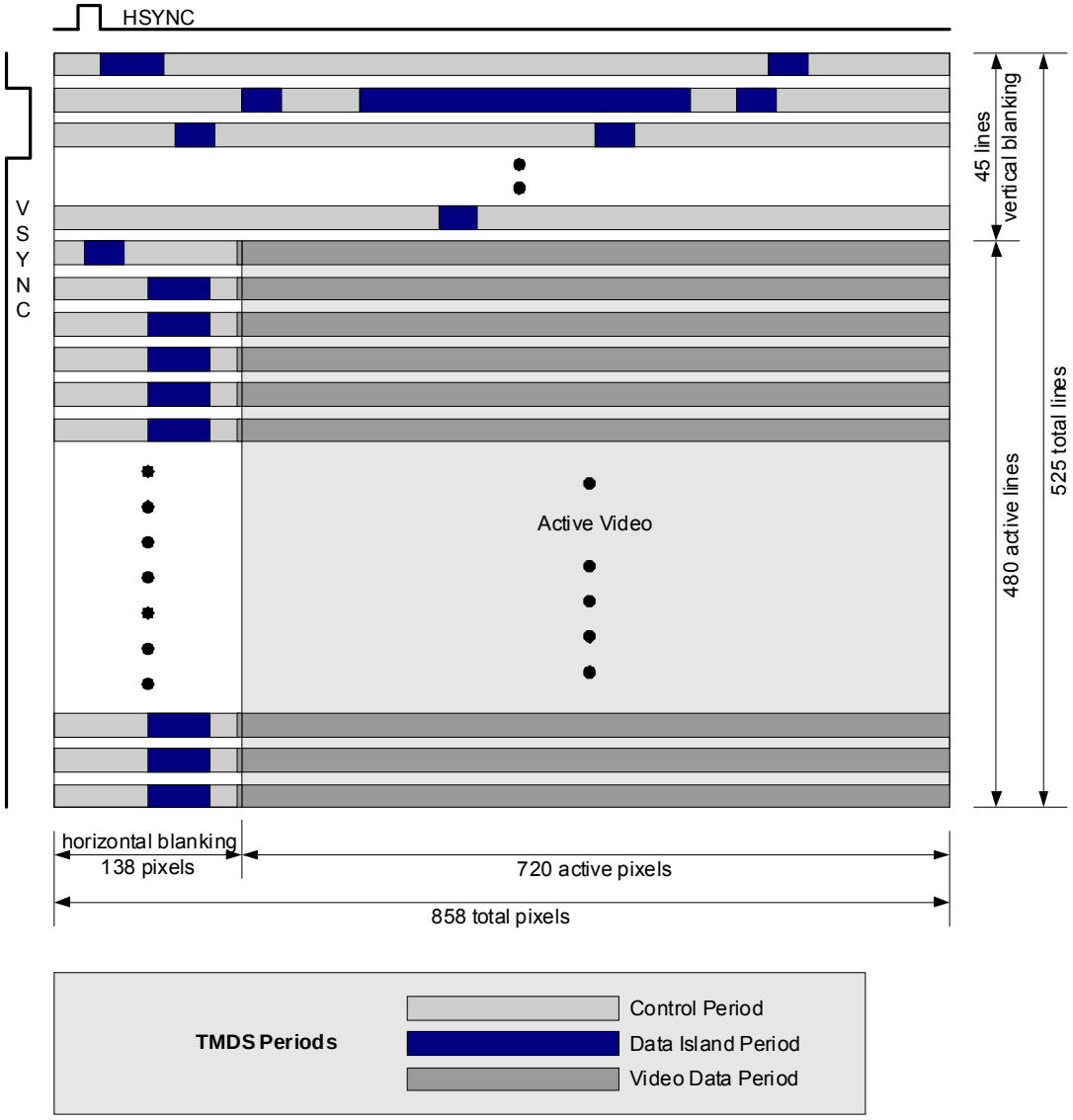


Figure 5-2 Informative Example: TMDS periods in 720x480p video frame

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.

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.

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.

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.

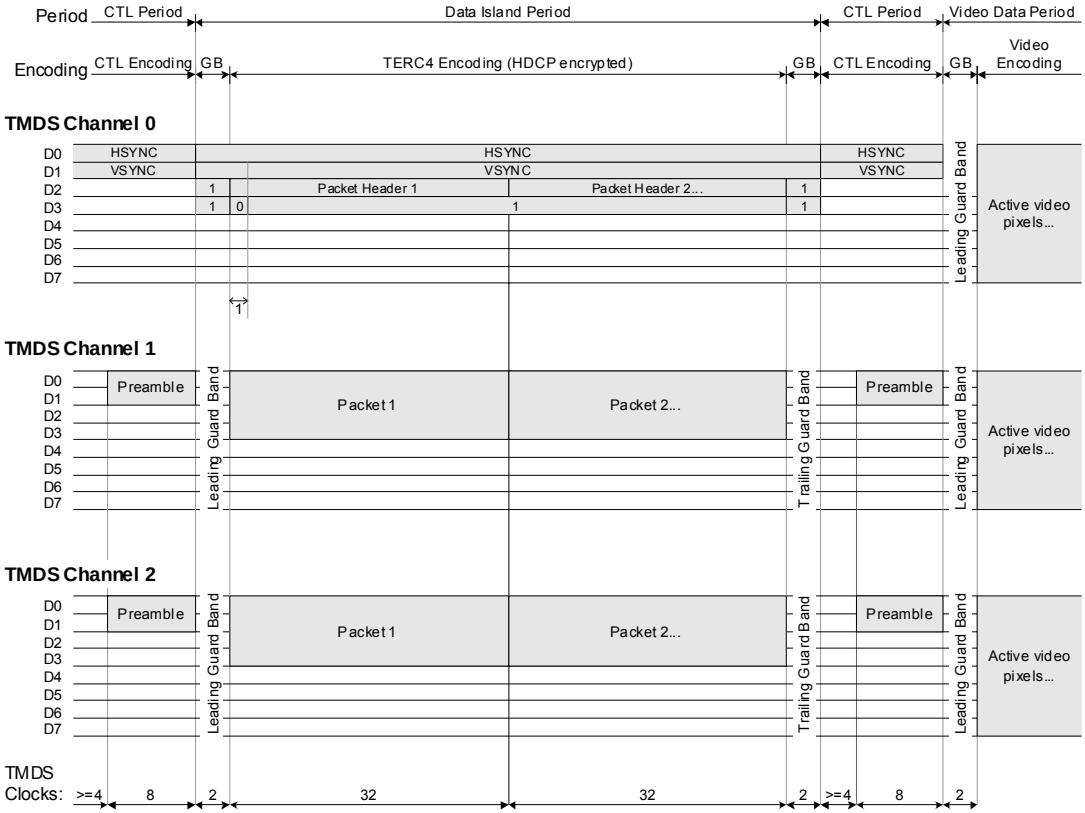


Figure 5-3 TMDS Periods and Encoding

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.

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).

This is illustrated in Figure 5-4.

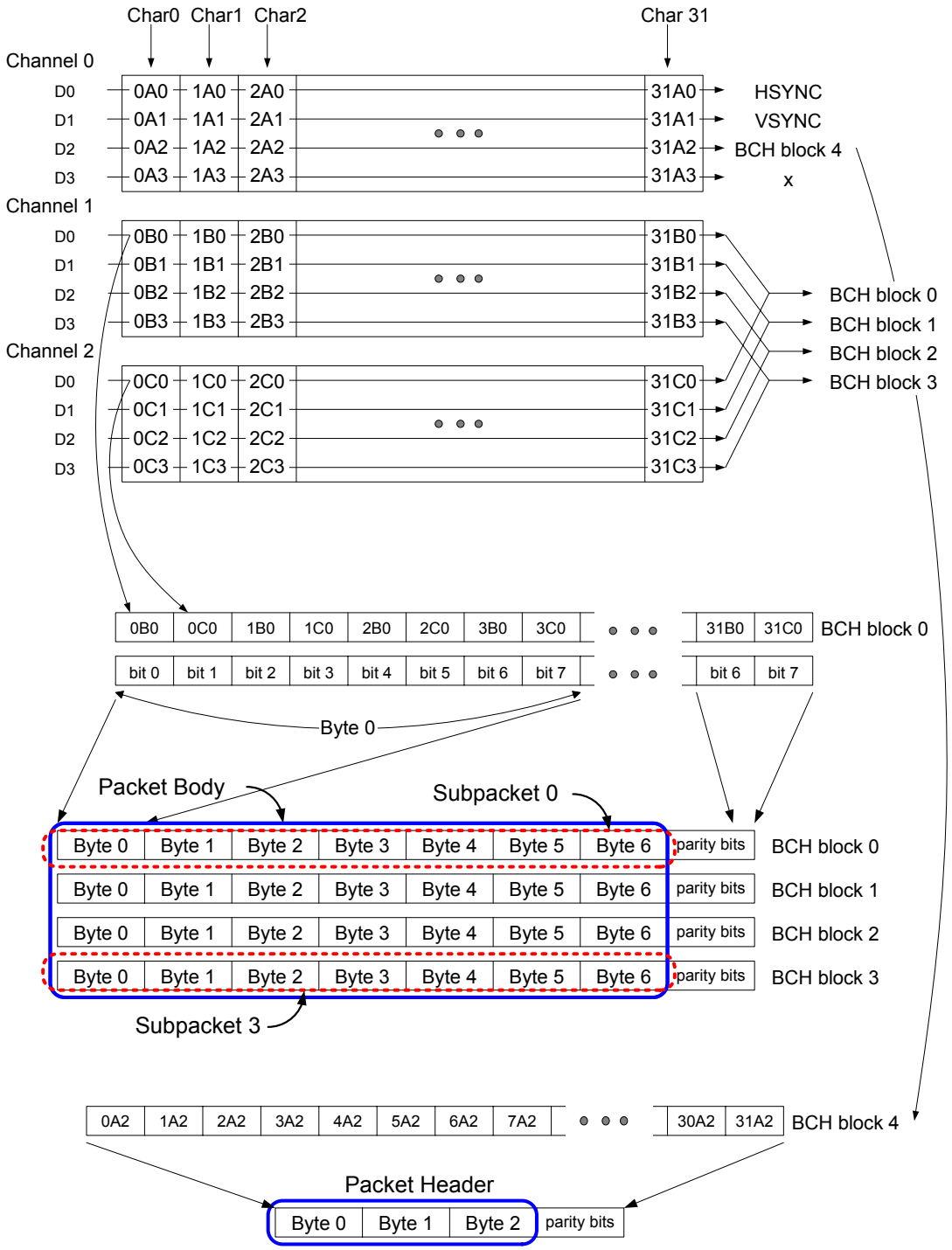


Figure 5-4 Data Island Packet and ECC Structure

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).

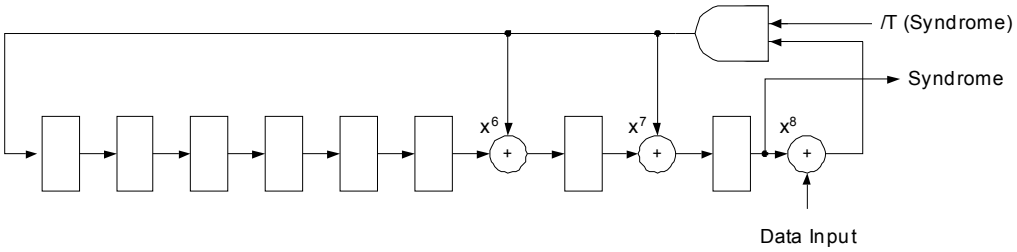


Figure 5-5 Error Correction Code generator

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.

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	8.2.3
	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

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*.

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)
- 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[1]. 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.
- 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.

[1] 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.

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.

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.

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.

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.

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.

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).

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.

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,

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.

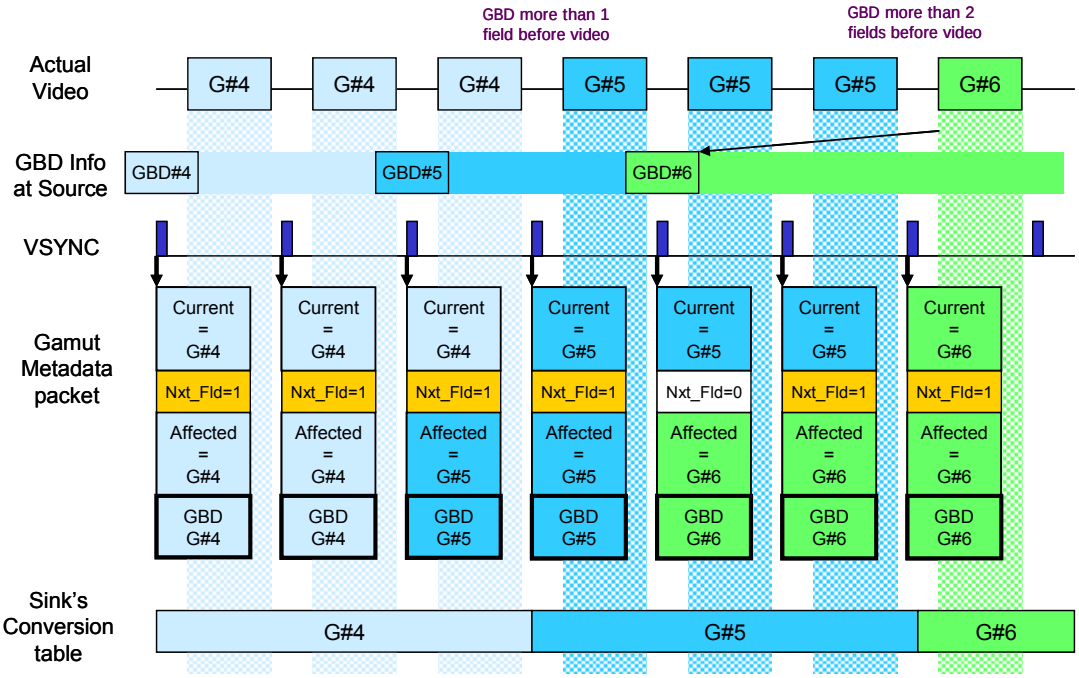


Figure 5-6 Example P0 Transmission Sequence

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.

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.

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.

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;
```

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.

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”

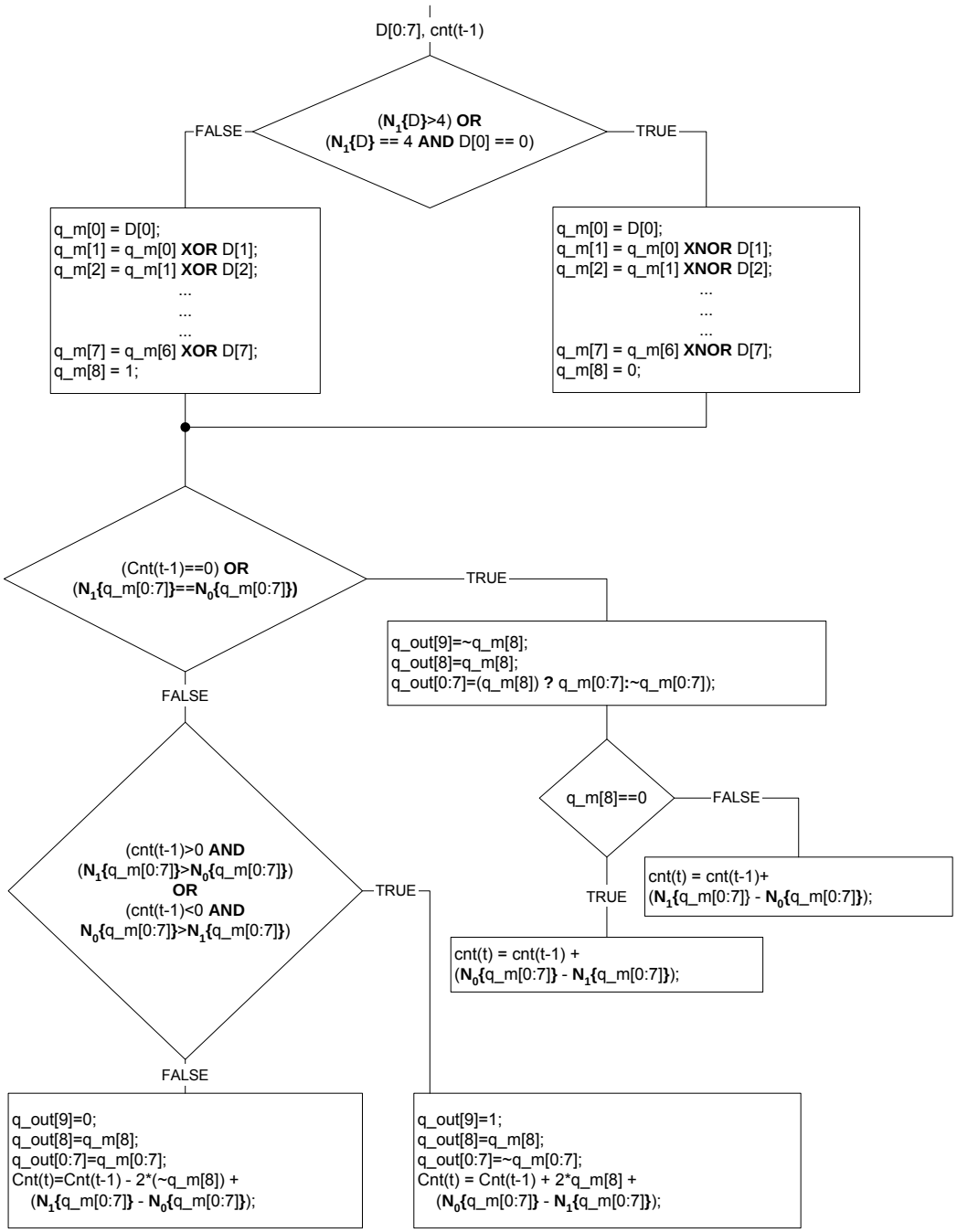


Figure 5-7 TMDS Video Data Encode Algorithm

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.

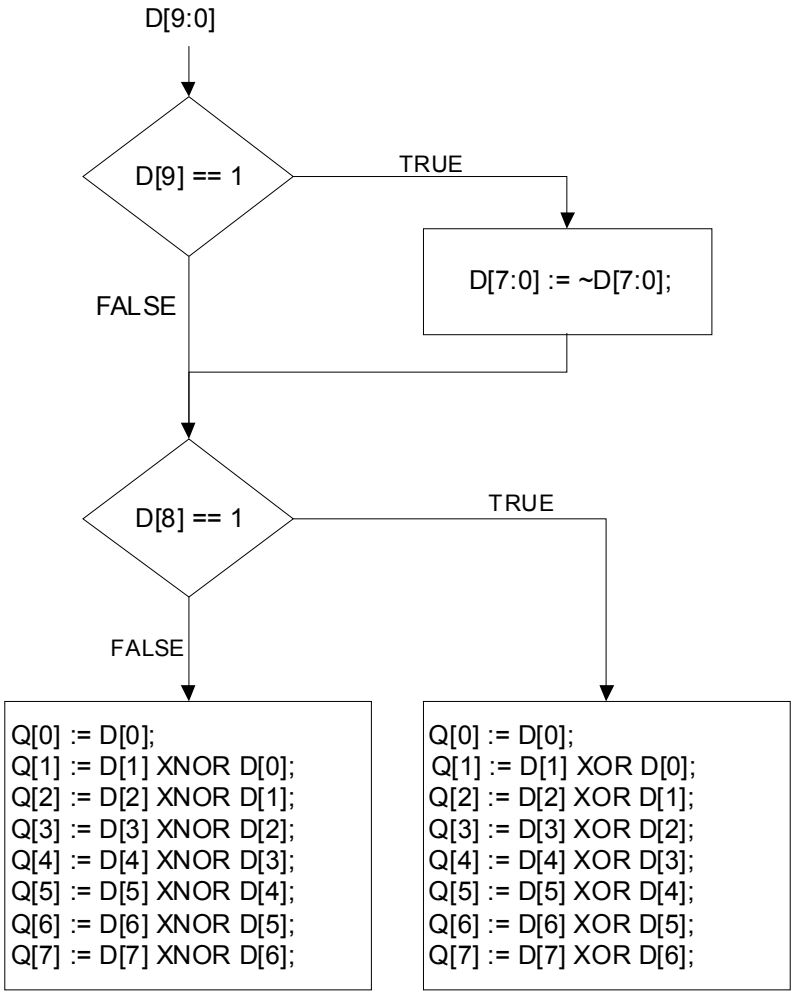


Figure 5-8 TMDS Video Decode Algorithm

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.
- 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 are 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.

Color depths greater than 24 bits per pixel are defined to be “Deep Color” and several Deep Color capability modes are defined in this Specification. 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 also 36-bit mode but does not require the further use of the Deep Color modes described in section 6.5.2 and 6.5.3.

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
- 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
- 1280x720p @ 23.98/24Hz
- 1280x720p @ 25Hz
- 1280x720p @ 29.97/30Hz
- 1920x1080p @ 119.88/120Hz
- 1920x1080p @ 100Hz

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.

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.

6.5.1 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.

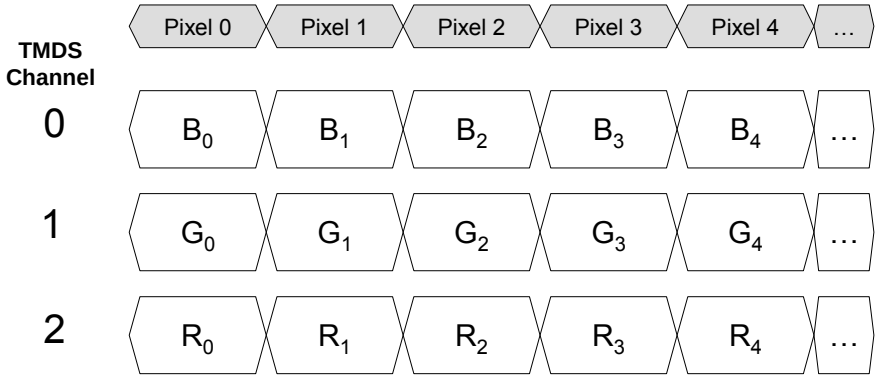


Figure 6-1 Default pixel encoding: RGB 4:4:4, 8 bits/component

Figure 6-2 shows the signal mapping and timing for transferring 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.

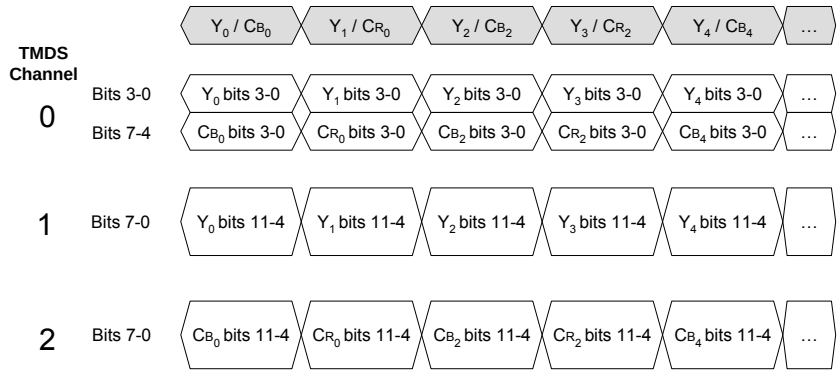


Figure 6-2 YC_BC_R 4:2:2 component

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.

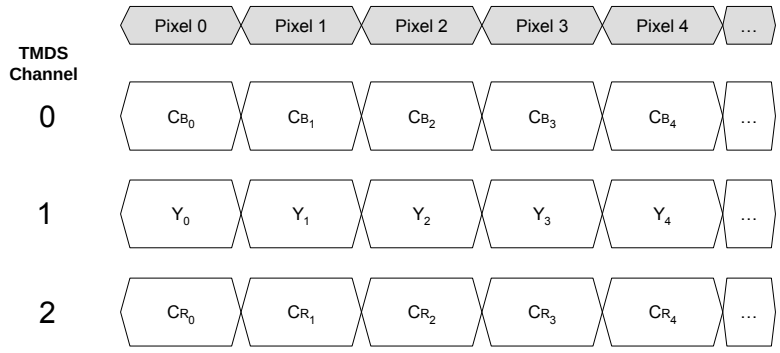


Figure 6-3 8-bit YC_BC_R 4:4:4 mapping

6.5.2 Deep Color Pixel Packing

There are four Color Pixel Packing modes supported: 24-, 30-, 36- and 48-bits per pixel, defined for RGB 4:4:4 and for YC_BC_R 4:4:4.

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 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.

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

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:

- 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).

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.

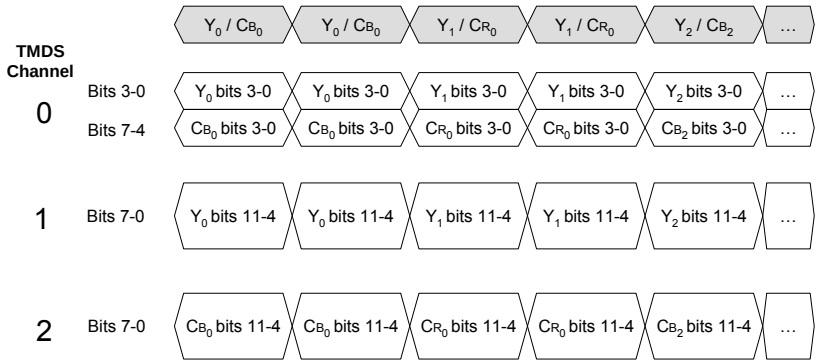


Figure 6-4 YC_BC_R 4:2:2 with Pixel-Doubling

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.” 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.

If the sink’s EDID declares a selectable YCC Quantization Range (QY=1), then it shall expect limited range pixel values if it receives AVI YQ=0 and it shall expect full range pixel values if it receives AVI YQ=1. For other values of YQ, the sink shall expect pixel values with the default range for the transmitted video format.

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)	Black level	Nominal Peak (White level)	Valid Range
Y	8	0	255	16	235	1 to 254
C_B / C_R		128	0 and 255	128	16 and 240	
Y	10	0	1023	64	940	4 to 1019
C_B / C_R		512	0 and 1023	512	64 and 960	
Y	12	0	4095	256	3760	16 to 4079
C_B / C_R		2048	0 and 4095	2048	256 and 3840	
Y	16	0	65535	4096	60160	256 to 65279
C_B / C_R		32768	0 and 65535	32768	4096 and 61440	

For component ranges for xvYCC, please refer to IEC 61966-2-4.

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 2, Section 3 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 2, Section 5.6 of ITU-R BT.709-5 and as summarized in Section 6.6 above.

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.

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.

6.7.2.4 IEC 61966-2-1 /Amendment 1 ($sYCC_{601}$)

The $sYCC_{601}$ color space is defined in Annex F of IEC 61966-2-1/Amendment 1. The ITU-R Rec. BT.601 color conversion matrix is used to transform RGB values to YCC values. The $sYCC_{601}$ color space can represent colors outside of the sRGB color gamut.

Refer to Chapter F.5 of IEC 61966-2-1/Amendment 1 for more details.

If the attached Sink does not support $sYCC_{601}$, then the Source shall not transmit $sYCC_{601}$-encoded video and shall not indicate $sYCC_{601}$ in the AVI InfoFrame.

6.7.2.5 IEC 61966-2-5 ($Adobe_{RGB}$, $Adobe_{YCC601}$)

The $Adobe_{RGB}$ (opRGB) color space is defined in IEC 61966-2-5. See also the Adobe RGB (1998) Color Image Encoding Specification.

The $Adobe_{YCC601}$ color space is defined in Annex A of IEC 61966-2-5. The ITU-R Rec. BT.601 color conversion matrix is used to transform RGB values to YCC values.

If the attached Sink does not support Adobe, then the Source shall not transmit Adobe-encoded video and shall not indicate $Adobe_{RGB}$ or $Adobe_{YCC601}$ 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.

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.

An HDMI Source or Sink may support an IEC 61937-compliant compressed audio format that has an Audio Format Code as specified per 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 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.

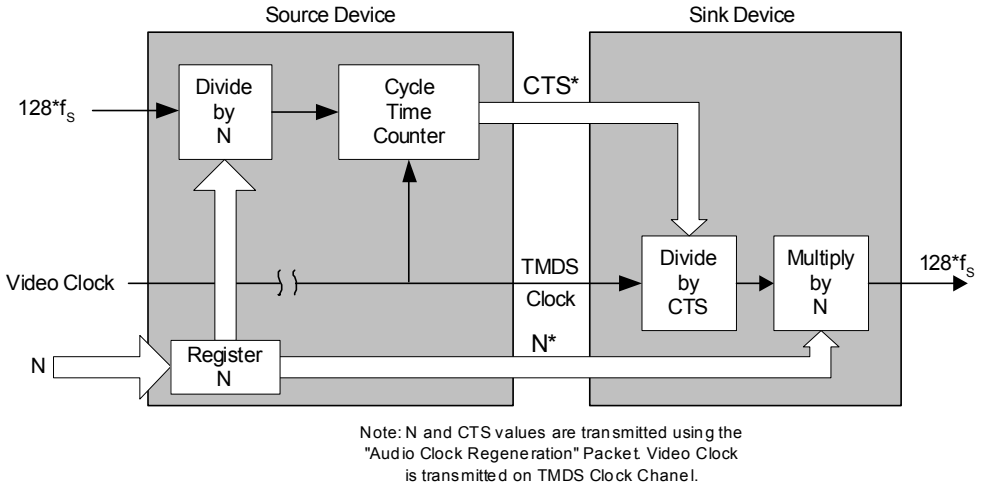


Figure 7-1 Audio Clock Regeneration model

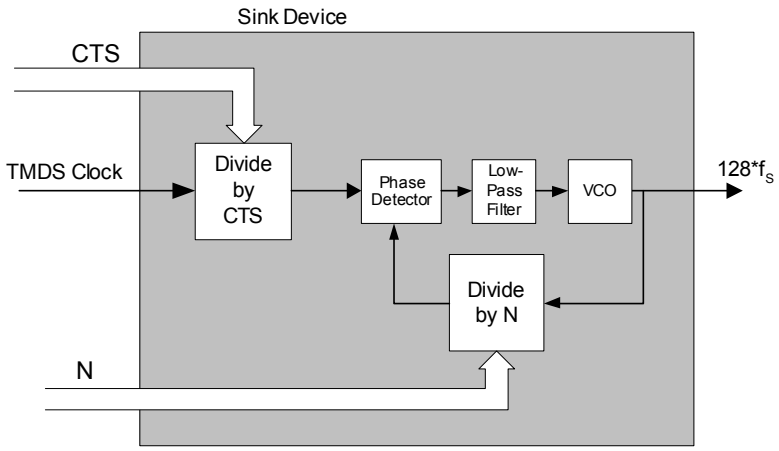


Figure 7-2 Optional Implementation: Audio Sink

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”.

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

	32 kHz	
TMDS 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
297 / 1.001	5824	421875
297	3072	222750
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

	44.1 kHz		88.2 kHz		176.4 kHz	
TMDS 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
297 / 1.001	4459	234375	8918	234375	17836	234375
297	4704	247500	9408	247500	18816	247500
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	
TMDS 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
297 / 1.001	5824	281250	11648	281250	23296	281250
297	5120	247500	10240	247500	20480	247500
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.

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.

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.

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	119.88/120	176.4	384	8
480p / 120Hz	720x480p	none	119.88/120	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

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 6.3 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.

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.

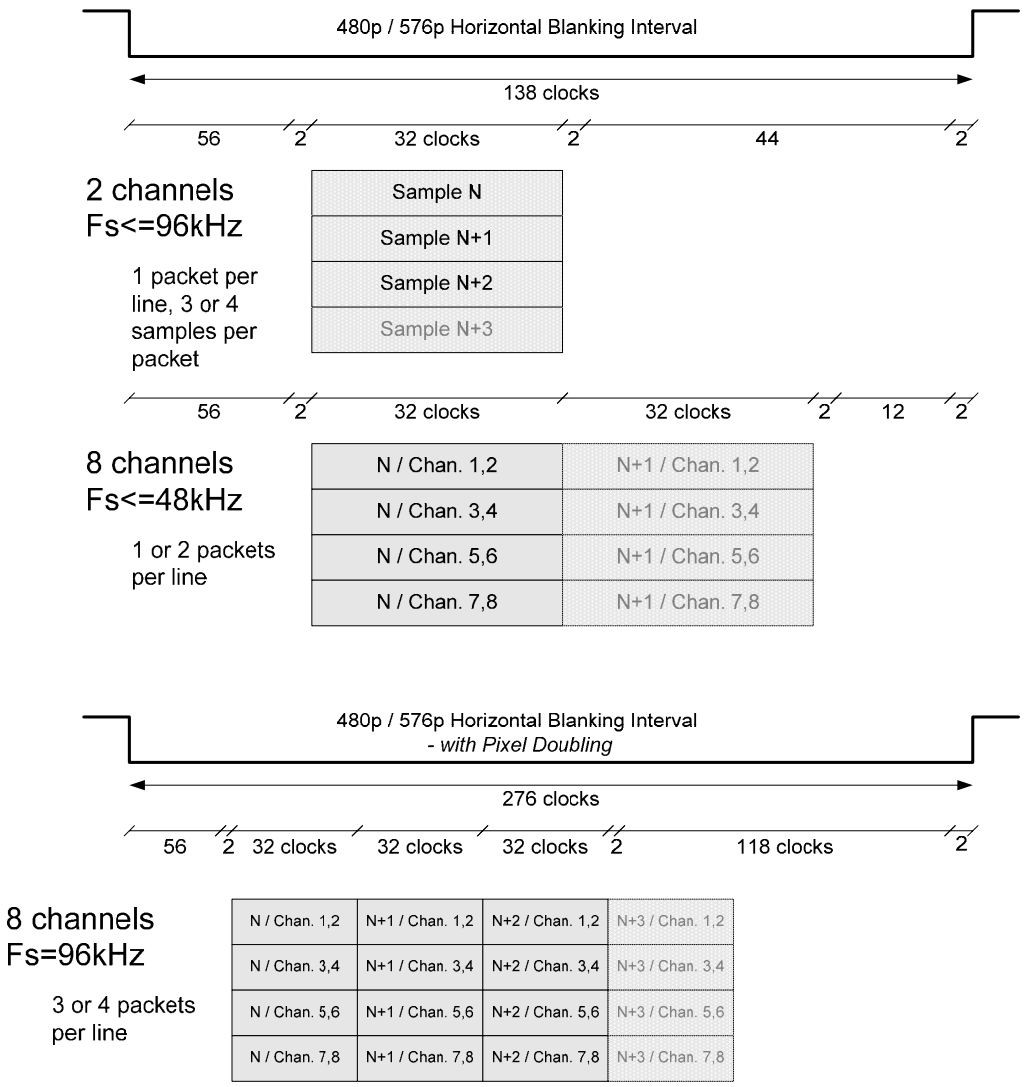


Figure 7-3 Example Audio Sample Timing (Informative)

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.

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.

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 8.3.6.

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 8.3.6.

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.

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.

7.12 Audio Return Channel Overview

The Audio Return Channel (ARC) feature allows an HDMI Sink to transmit an IEC 60958-1 audio stream in the reverse direction to the TMDS path to an HDMI Source or an HDMI Repeater. The Audio Return Channel is controlled by the use of CEC messages. Once activated through a CEC message, the Utility line alone (single Mode) or the Utility line in conjunction with the Hot Plug Detect line (common Mode) may be used for ARC transmission as specified in Supplement 2.

8 Control And Configuration

8.1 Overview

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

TMDS is used to carry 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.

HEC is optionally used as a high-speed bidirectional data channel, based on 100Base-TX. For further information see Supplement 2.

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 three 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 or,
- is ever capable of transmitting Content Type other than "no data" or,
- is ever capable of transmitting YCC Quantization Range.

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.

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	YQ1	YQ0	CN1	CN0	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.
- 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.
- 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.
- ITC IT Content. See Table 8-6 and CEA-861-D table 11 for details.
- EC0, EC1, EC2 Extended Colorimetry (IEC 61966-2-4 etc.). See CEA-861-D table 11 for details.
- Q0, Q1 Quantization range (Full vs. Limited, etc.). See CEA-861-D table 11 for details.
- SC0, SC1 Non-uniform Picture Scaling. See CEA-861-D table 11.
- VIC0...VIC6 Video Format Identification Code.
  When transmitting any 2D video format of section 6.3 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. The additional VIC values from 60 to 64 are defined in Table 8-4.
  When transmitting any 3D video format using the 3D_Structure field in the HDMI Vendor Specific InfoFrame, an HDMI Source shall set the AVI InfoFrame VIC field to satisfy the relation described in section 8.2.3.2.
  When transmitting any extended video format indicated through use of the HDMI_VIC field in the HDMI Vendor Specific InfoFrame or any other format which is not described in the above cases, an HDMI Source shall set the AVI InfoFrame VIC field to zero.
- YQ0, YQ1 YCC Quantization Range specified in Table 8-5.
- CN0, CN1 Content Type specified by Table 8-6.
- PR0...PR3 Pixel Repetition factor. See CEA-861-D table 13 and Table 8-4 for details.

Table 8-3 Extended Colorimetry

EC2	EC1	EC0	Extended Colorimetry
0	0	0	$xvYCC_{601}$
0	0	1	$xvYCC_{709}$
0	1	0	$sYCC_{601}$
0	1	1	$AdobeYCC_{601}$
1	0	0	$Adobe_{RGB}$
1	0	1	Reserved
1	1	0	Reserved
1	1	1	Reserved

Table 8-4 VIC AVI InfoFrame Packet Contents

VIC value	Formats	Field Rate	Pixel repeat value
60	720p (1280x720)	23.98 / 24	No Repetition
61	720p (1280x720)	25	No Repetition
62	720p (1280x720)	29.97 / 30	No Repetition
63	1080p (1920x1080)	119.88 / 120	No Repetition
64	1080p (1920x1080)	100	No Repetition

Table 8-5 YCC Quantization Range

YQ1	YQ0	YCC Quantization Range
0	0	Limited Range
0	1	Full Range
1	0	Reserved
1	1	Reserved

Table 8-6 *Content Type*

ITC	CN1,CN0	Content Type	Description
0	0,0	No Data	No Data
1	0,0	Graphics	Graphics (text). This indicates that content is composed according to common IT practice (i.e. without regard to Nyquist criterion) and is unsuitable for analog reconstruction or filtering.
X	0,1	Photo	The Photo type is indicated by the source to flag content derived from digital still pictures. When the Photo type is indicated, Extended Colorimetry bits should correctly indicate the content's color space.
X	1,0	Cinema	The Cinema type is indicated by the source to flag content derived from cinema material.
X	1,1	Game	The Game type is indicated by the source to flag content derived from game machine material.

"X" denotes don't care.

This Content Type value does not depend on the device category of the source. Only when the source knows the type of content being sent to the sink to be of Content Types Photo, Cinema, Game or Graphics, it may set the Content Type field accordingly. Otherwise the source shall set this field to (0, 0) with ITC=0.

When the source does not know the Content Type, then it shall set the Content Type to "No data". At all other times, the Content Type shall accurately indicate the type of content that the source is sending.

When sending content of a particular Content Type other than Graphics (Photo, Cinema, Game) and if the attached Sink has set the corresponding CNC flag (CNC1-3) in HDMI Vendor Specific

Data Block (section 8.3.2) to 0 (to indicate the absence of a processing mode for a particular Content Type), then the Source shall set ITC = 0 and CN as “no data”, i.e. CN = (0, 0).

When the source has content of Content Type Photo and/or Cinema and if the sink indicates that it has specific processing for that Content Type (by setting the relevant CNC bit to 1), then the source should pass through that content with minimal processing and set the Content Type to the corresponding value.

When the source has content of Content Type Game and if the sink indicates that it has specific processing for the Game Content Type (by setting the relevant CNC bit to 1), then the source should set the Content Type to the corresponding value.

When the source has content of Content Type Graphics, and the sink indicates that it has specific processing for that Content Type (by setting the CNC0 bit to 1), then the source should set ITC = 1 and CN=(0,0) to indicate this Content Type.

Note 1:
a source of version 1.4 or later cannot distinguish between a 1.3 sink and a 1.4 (or later) sink with CNC0 = 0 and CNC1-3 = all 0s. Therefore, in this case the source cannot check the CNC bit for type Graphics and can skip the check of CNC0=1 in the above paragraph.

Note 2:
when a sink of version 1.4 or later is connected to a source of version 1.3, the source will not check the sink’s CNC-bits and can set Content Type to Graphics even if the sink has set the corresponding CNC bit (CNC0) to 0.

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 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 8-7 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)				

Table 8-8 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	Rsvd (0)	LFEP BL1	LFEP BL0
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 being played from the disk. The DM_INH field value shall be set to zero in all cases other than DVD-Audio applications.
- LFEPBL0, LFEPBL1 LFE Playback level information.

Table 8-9 LFE Playback Level Information

LFEPBL1	LFEPBL0	Describes what value is used for the LFE playback level as compared to the other channels.
0	0	No information
0	1	0 dB playback
1	0	+ 10 dB playback
1	1	Reserved

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

8.2.3 HDMI Vendor Specific InfoFrame

This is a CEA-861 Vendor Specific InfoFrame containing a 24-bit IEEE Registration Identifier of 0x000C03, a value belonging to HDMI Licensing, LLC. The content of this InfoFrame is defined by this specification.

The transmission of this InfoFrame is optional for the source device. But if a source device outputs a video signal which is defined in this section 8.2.3, the source shall transmit this packet. Whenever this packet is transmitted, an accurate HDMI Vendor Specific InfoFrame shall be transmitted at least once per two Video Fields.

It is optional for a Sink to interpret this packet. If the Sink supports HDMI_VIC, then the HDMI_VIC value shall be used. Other data in the AVI InfoFrame packet remains valid even if the HDMI Vendor Specific InfoFrame is transmitted.

The packetization of this HDMI Vendor Specific InfoFrame is defined below.

Table 8-10 HDMI Vendor Specific InfoFrame Packet Header

Byte \ Bit #	7	6	5	4	3	2	1	0
HB0	Packet Type = 0x81							
HB1	Version = 0x01							
HB2	0	0	0	Length = Nv				

Table 8-11 HDMI Vendor Specific InfoFrame Packet Contents

Packet Byte #	7	6	5	4	3	2	1	0
PB0	Checksum							
PB1	24bit IEEE Registration Identifier (0x000C03) (least significant byte first)							
PB2								
PB3								
PB4	HDMI_Video_Format			Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)
PB5	HDMI_VIC							
	3D_Structure				Reserved(0)			
.. PB(Nv)	Reserved (0)							

- Length [5bits] This 5 bits field defines the length of HDMI vendor specific InfoFrame payload.
- HDMI_Video_Format [3bits] This value defines the structure of extended video formats exclusively defined within this HDMI specification.

Table 8-12 HDMI_Video_Format

Value [2…0]	description
000	No additional HDMI video format is presented in this packet.
001	Extended resolution format (e.g. used for 4K x 2K video) present. 1 byte of HDMI_VIC parameter value follows.
010	3D format indication present. 3D_Structure follows.
011 ~ 111	Reserved for future use

- HDMI_VIC [1byte] HDMI proprietary Video Format Identification Code. When transmitting any video format defined in this section 8.2.3.1, an HDMI Source shall set the HDMI_VIC field to the Video Code for that format. The HDMI_VIC value is defined in section 8.2.3.1.

- 3D_Structure [4bits] This 4 bit field defines the transmission format of 3D video data. The value of “0000” means the Frame packing structure described in this section. For other values, see Appendix H(Table H-2).

8.2.3.1 HDMI Video format Identification Code

In this section, HDMI video timing formats which are identified by HDMI_VIC numbers are defined. The following video formats shown in Table 8-13 are used for 4K x 2K video signal transmission. The meaning of each parameter in Table 8-13 is defined by Figure 8-1 and Figure 8-2.

Table 8-13 HDMI_VIC for extended resolution transmission

HDMI_VIC	Description	Pixel frequency (MHz)	Hactive	Hblank			
					Hfront	Hsync	Hback
0x00	Reserved	-	-	-	-	-	-
0x01	*4K x 2K 29.97, 30 Hz*	297.000 296.703	3840	560	176	88	296
0x02	*4K x 2K 25Hz*	297.000	3840	1440	1056	88	296
0x03	*4K x 2K 23.98, 24 Hz*	297.000 296.703	3840	1660	1276	88	296
0x04	*4K x 2K 24 Hz (SMPTE)*	297.000	4096	1404	1020	88	296
0x05..0xFF	Reserved	-	-	-	-	-	-

(Continued)

HDMI_VIC	Description	Vfreq (Hz)	Vactive	Vblank			
					Vfront	Vsync	Vback
0x00	Reserved	-	-	-	-	-	-
0x01	*4K x 2K 29.97, 30 Hz*	30.000 29.970	2160	90	8	10	72
0x02	*4K x 2K 25Hz*	25.000	2160	90	8	10	72
0x03	*4K x 2K 23.98, 24 Hz*	24.000 23.976	2160	90	8	10	72
0x04	*4K x 2K 24 Hz (SMPTE)*	24.000	2160	90	8	10	72
0x05..0xFF	Reserved	-	-	-	-	-	-

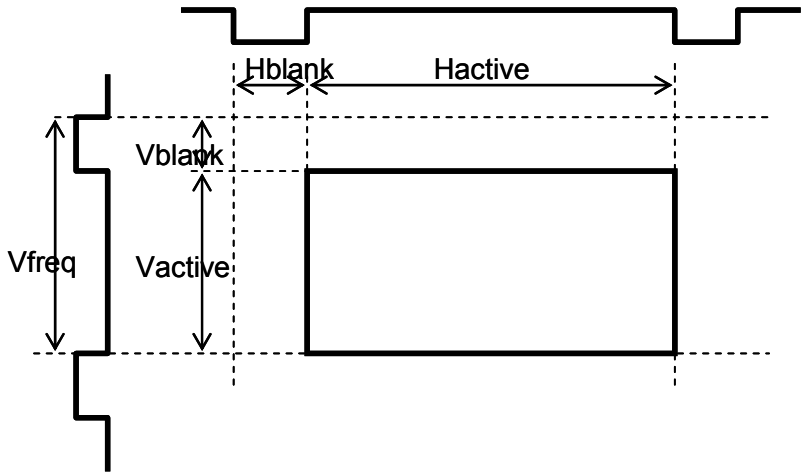


Figure 8-1 extended resolution format

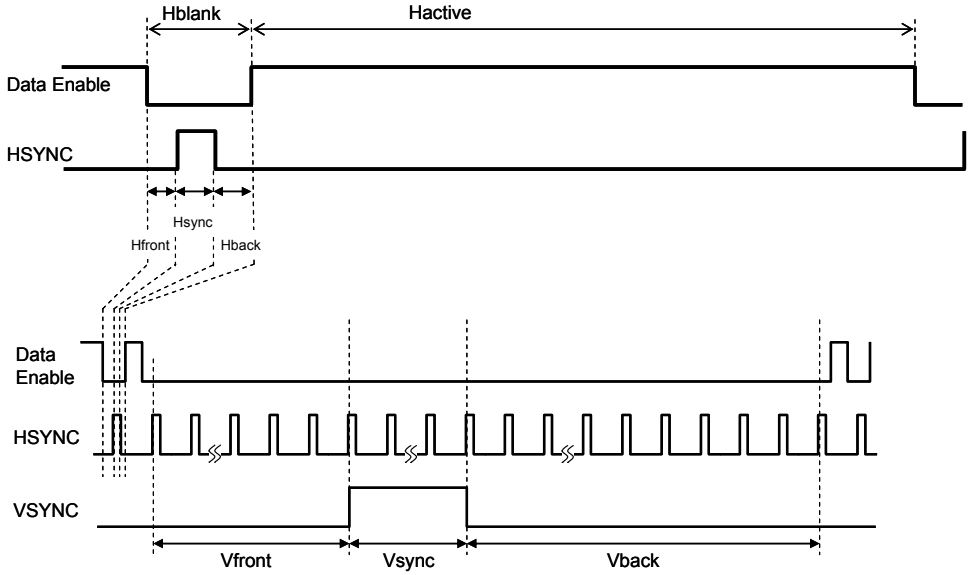


Figure 8-2 extended resolution format (detailed timing)

8.2.3.2 3D video format structure

The 3D video format is indicated using the VIC (Video Identification Code) in the AVI InfoFrame (indicating the video format of one of the 2D pictures, as defined in CEA-861-D or Table 8-4) in conjunction with the 3D_Structure field in the HDMI Vendor Specific InfoFrame (indicating the 3D structure).

Frame packing is one of the HDMI 3D video format structures indicated by the 3D_Structure field and is composed of two stereoscopic pictures: Left and Right, transmitted as shown in Figure 8-3.

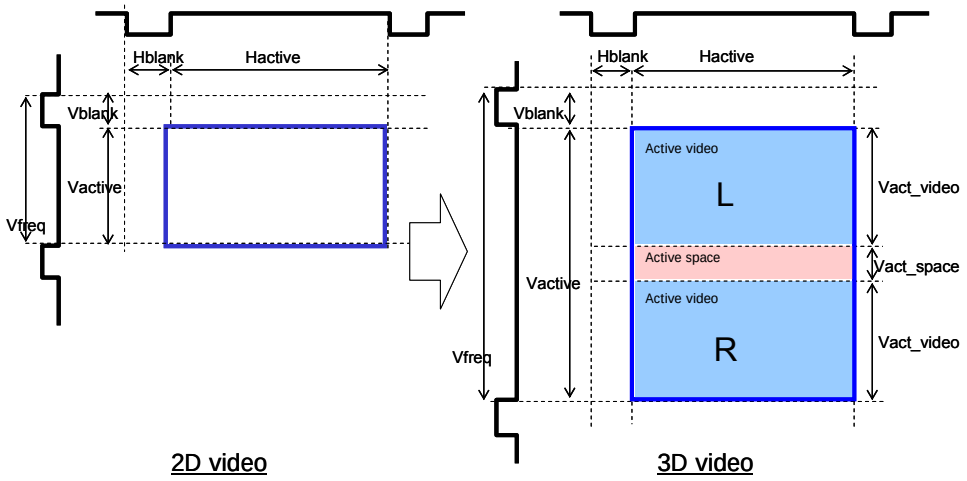


Figure 8-3 3D structure (Frame packing)

In this figure, the area inserted between the two Active video regions is designated as “Active space”. This Active space area shall be encoded in the same manner as the adjoining Active video regions. During the Active space, an HDMI Source shall transmit a constant pixel value. HDMI Sinks shall ignore all data received during the Active space regardless of the value.

Table 8-14 shows the detailed timing of the 3D video formats. Figure 8-4 shows the meaning of each parameter in Table 8-14.

Table 8-14 3D transmission video formats

3D _Structure	VIC	description	Hactive	Hblank			
					Hfront	Hsync	Hback
0000 (Frame packing)	32	1080p, 23.98 / 24Hz	1920	830	638	44	148
	4	720p, 59.94 / 60Hz	1280	370	110	40	220
	19	720p, 50Hz	1280	700	440	40	220

(Continued)

Vactive			Vblank				Pixel freq (MHz)	V freq (Hz)
	Vact_video	Vact_space		Vfront	Vsync	Vback		
2205	1080	45	45	4	5	36	148.35 / 148.50	23.976 / 24.000
1470	720	30	30	5	5	20	148.35 / 148.50	59.940 / 60.000
1470	720	30	30	5	5	20	148.50	50.000

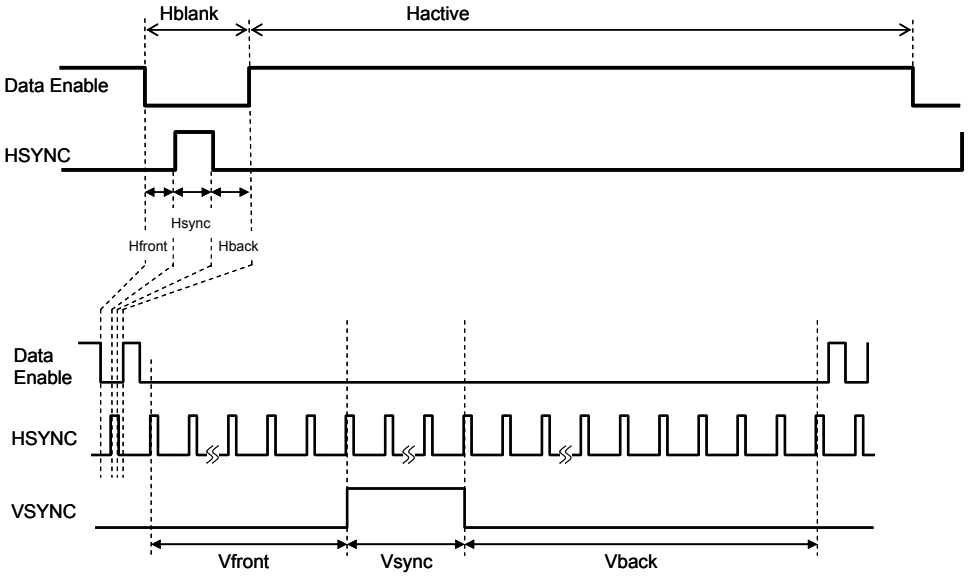


Figure 8-4 Detailed timing parameters

If an HDMI Source has the 3D Video Format capability, then the HDMI Source shall support transmission for at least one of the formats of Table 8-14. Note that for the Frame packing 3D structure, the frame frequencies 23.98 / 24Hz, 59.94 / 60Hz and 50Hz are specified here.

An HDMI Source shall not send any 3D video format to a Sink that does not indicate support for that format.

Additional 3D video formats will be specified in a future version. See Appendix H.

Note: The HDMI_VIC field in the HDMI Vendor Specific InfoFrame is not used for 3D transmission.

8.3 E-EDID Data Structure

All Sinks shall contain a 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 7.3) 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 8-15.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 8-15. 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.

Table 8-15 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	HDMI_Video_present	Rsvd (0)	CNC3	CNC2	CNC1	CNC0
(9)	Video_Latency							
(10)	Audio_Latency							
(11)	Interlaced_Video_Latency							
(12)	Interlaced_Audio_Latency							
(13)	3D_present	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)
(14)	HDMI_VIC_LEN			HDMI_3D_LEN				
(15)	(if HDMI_VIC_LEN > 0) HDMI_VIC_1							
…	…							
	HDMI_VIC_M							
9, 11, 13, 15, 11+M, 13+M, 15+M*. ...N	*Reserved (0)***							

extension fields ↓

* *The position of these bytes will depend upon the values of Latency_Fields_Present, I_Latency_Fields_Present and HDMI_Video_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).
- DC_48bit [1 bit] Set if Sink supports 48 bits/pixel (16 bits/color).
- DC_36bit [1 bit] Set if Sink supports 36 bits/pixel (12 bits/color).
- DC_30bit [1 bit] Set if Sink supports 30 bits/pixel (10 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.
- HDMI_Video_present [1bit] If set (=1) then additional video format capabilities are described by using the fields starting after the Latency area. This consists of 4 parts:
  - 1 byte with flag 3D_present
  - 1 byte with length fields HDMI_VIC_LEN and HDMI_3D_LEN
  - zero or more bytes for information about HDMI_VIC formats supported (length of this field is indicated by HDMI_VIC_LEN).
  - zero or more bytes for information about 3D formats supported (length of this field is indicated by HDMI_3D_LEN)
- CNC3…0 [4bits] Each of these bits indicates support for a particular Content Type. See Table 8-16.

- 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 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.
- 3D_present [1bit] If set (=1), The HDMI Sink supports 3D video formats. For further information, see Appendix H.
- HDMI_VIC_LEN [3bits] indicates the total length from HDMI_VIC_1 to HDMI_VIC_M.
- HDMI_3D_LEN [5bits] this field shall be zero, if HDMI Sink supports only the mandatory 3D formats. For further information, see Appendix H.
- HDMI_VIC_X [1 bytes] X means the index value from 1 to M. This field indicates the video formats which are supported by the Sink. The HDMI_VIC_X values are defined in section 8.2.3.1.

If 3D_present is set (=1), an HDMI Sink shall support 3D video formats per the following requirements.

- An HDMI Sink which supports at least one 59.94 / 60Hz 2D video format shall support both
  - 1920x1080p @ 23.98 / 24Hz Frame packing
  - 1280x720p @ 59.94 / 60Hz Frame packing
- An HDMI Sink which supports at least one 50Hz 2D video format shall support both
  - 1920x1080p @ 23.98 / 24Hz Frame packing
  - 1280x720p @ 50Hz Frame packing

  Setting 3D_present (=1) in the HDMI VSDB indicates support for the mandatory formats above and no further 3D video indication in the HDMI VSDB is required for the mandatory formats.

Additional 3D video formats will be specified in a future version. See Appendix H.

Table 8-16 Content Type

CNC3-0	Content Type	Description
CNC0	Graphics (text)	Set (=1) if the sink device can pass the pixel data without filtering and analog reconstruction because adjacent pixels are completely independent and should not interact.
CNC1	Photo	Set (=1) if the sink device has specific processing for still pictures.
CNC2	Cinema	Set (=1) if the sink device has specific processing for cinema content, e.g. film tone reproduction.
CNC3	Game	Set (=1) if the sink device has a specific processing mode with low Audio and Video latency.

When the source indicates that it is sending Graphics, Photo, Cinema or Game content, the sink is expected to use the corresponding processing specified in Table 8-16.

8.3.3 Colorimetry Data Block

The Colorimetry Data Block indicates support of specific extended colorimetry standards and gamut related, as yet undefined, metadata. Details regarding the contents of the Colorimetry Data Block are provided in Table 8-17, Table 8-18 and Table 8-19.
Byte 3 is allocated for Colorimetry data. The flags for bits 0 through 4 are defined for colorimetry based upon the IEC 61966-2 series of standards. The definitions of the colorimetry flags are shown in Table 8-18. Setting a colorimetry flag to one shall indicate that the sink is capable of displaying pictures encoded in that colorimetry.

Table 8-17 Colorimetry Data Block

	Bits							
Byte#	7	6	5	4	3	2	1	0
1	Tag Code = 0x07			Length of following data block (in bytes) = 0x03				
2	Extended Tag Code =0x05							
3	F37=0	F36=0	F35=0	$Adobe_{RGB}$	$Adobe_{YCC601}$	$sYCC_{601}$	$xvYCC_{709}$	$xvYCC_{601}$
4	F47=0	F46=0	F45=0	F44=0	MD3	MD2	MD1	MD0

Table 8-18 Data Byte 3 Colorimetry Support flags

Flag	Colorimetry
$xvYCC_{601}$	Standard Definition Colorimetry based on IEC 61966-2-4
$xvYCC_{709}$	High Definition Colorimetry based on IEC 61966-2-4
$sYCC_{601}$	Colorimetry based on IEC 61966-2-1/Amendment 1
$Adobe_{YCC601}$	Colorimetry based on IEC 61966-2-5, Annex A
$Adobe_{RGB}$	Colorimetry based on IEC 61966-2-5

Table 8-19 Data Byte 4 Colorimetry Metadata Support flags

Flag	Metadata
MD0	See Appendix E
MD1	Future metadata profile
MD2	Future metadata profile
MD3	Future metadata profile

8.3.4 Video Capability Data Block (VCDB)

The Video Capability Data Block (VCDB) allows a display to declare default, fixed, or InfoFrame controlled quantization range (see Table 8-20).

NOTE—The VCDB payload currently only contains a single byte in addition to the Extended Tag Code, while future versions may contain additional bytes. The source should ignore such additional bytes (when present) and continue to parse the single byte as defined in Table 8-20.

Table 8-20 Video Capability Data Block (VCDB)

	Bits							
Byte#	7	6	5	4	3	2	1	0
1	Tag Code = 0x07			Length of following data block (in bytes) = 0x02				
2	Extended Tag Code =0x00							
3	QY	QS	S_PT1	S_PT0	S_IT1	S_IT0	S_CE1	S_CE0

Table 8-21 Quantization Range (Applies to YCC only)

QY	Quantization Range (Applies to YCC only)
0	No Data
1	Selectable (via AVI YQ)

- QS Quantization Range (Applies to RGB only).
  See CEA-861-D table 43 for details.
- S_PT0…S_PT1 PT Overscan/underscan behavior (Applies to the preferred video format).
  See CEA-861-D table 43 for details.
- S_IT0…S_IT1 IT Overscan/underscan behavior (Applies to IT video formats).
  See CEA-861-D table 43 for details.
- S_CE0…S_CE1 CE Overscan/underscan behavior (Applies to CE video formats).
  See CEA-861-D table 43 for details.

8.3.5 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).

8.3.6 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 6.3, 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 6.7.2.4 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 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.

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 4-39 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 8-5.

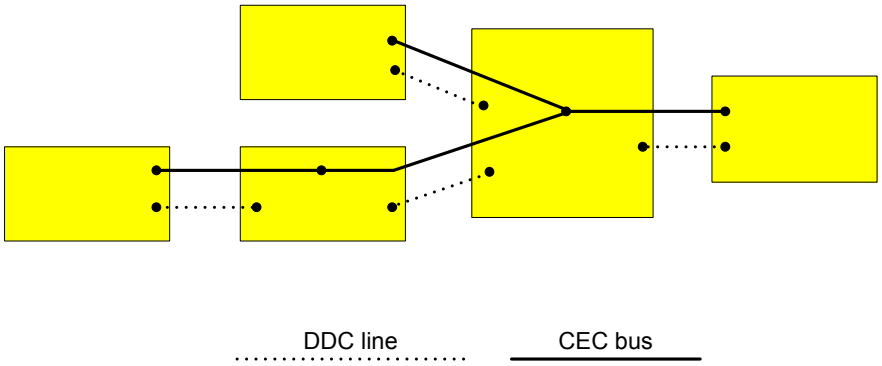


Figure 8-5 CEC and DDC line connections

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 8-7.

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.

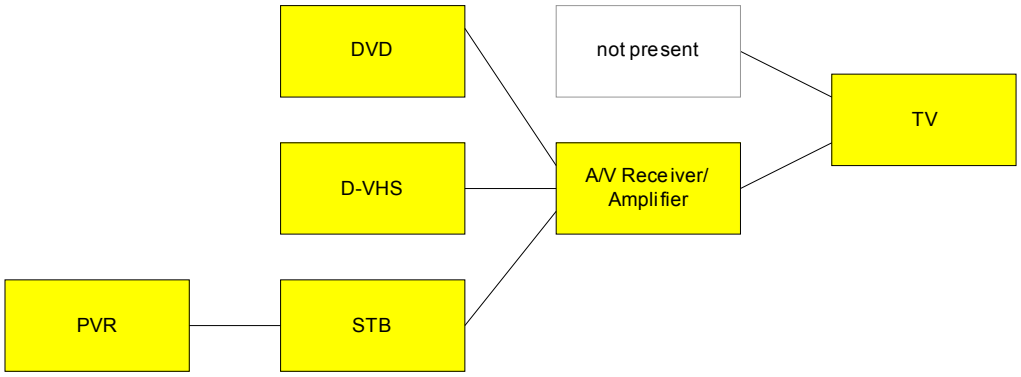


Figure 8-6 Typical HDMI cluster

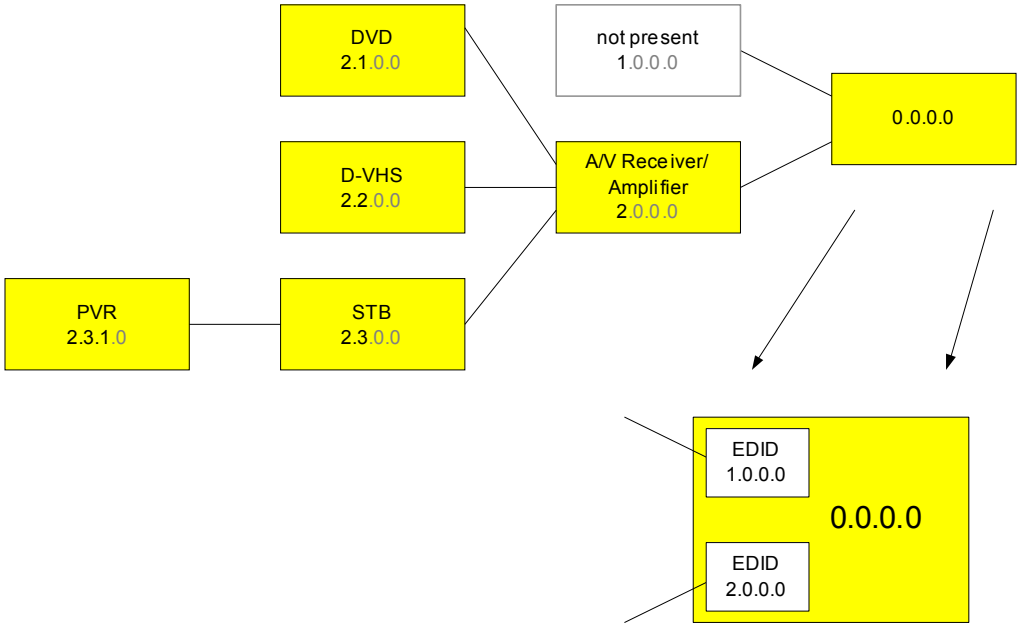


Figure 8-7 Addresses within an HDMI cluster

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.

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.

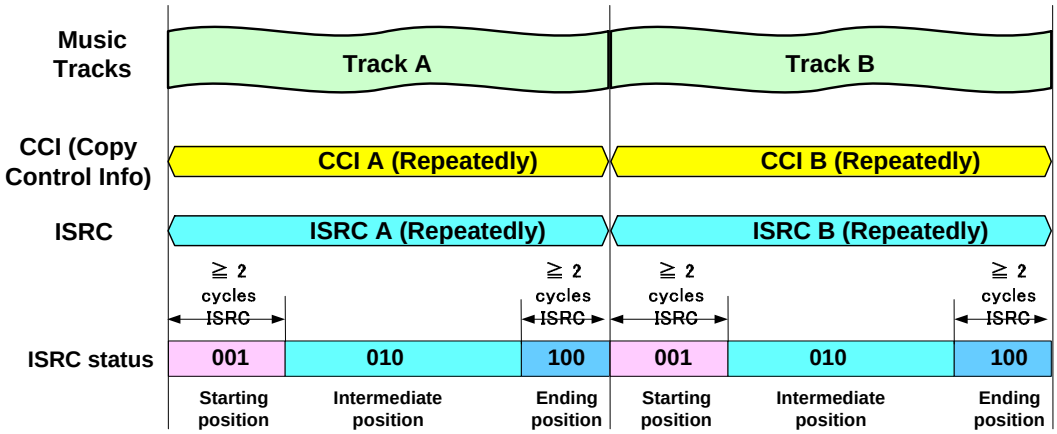


Figure 8-8 ISRC/CCI and ISRC Status Handling

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.

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.

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.

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 1.4.

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.

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:

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:

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.

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.

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.

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 8.3.5. 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.

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

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

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

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

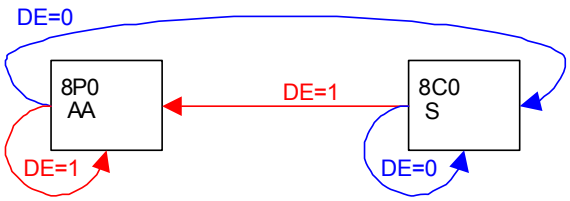
Type B pin	Pin Assignment	Wire	DVI-D pin
1	TMDS Data2+	A	2
2	TMDS Data2 Shield	B	3
3	TMDS Data2-	A	1
4	TMDS Data1+	A	10
5	TMDS Data1 Shield	B	11
6	TMDS Data1-	A	9
7	TMDS Data0+	A	18
8	TMDS Data0 Shield	B	19
9	TMDS Data0-	A	17
10	TMDS Clock+	A	23
11	TMDS Clock Shield	B	22
12	TMDS Clock-	A	24
13	TMDS Data5+	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

Appendix D Deep Color Additional Detail

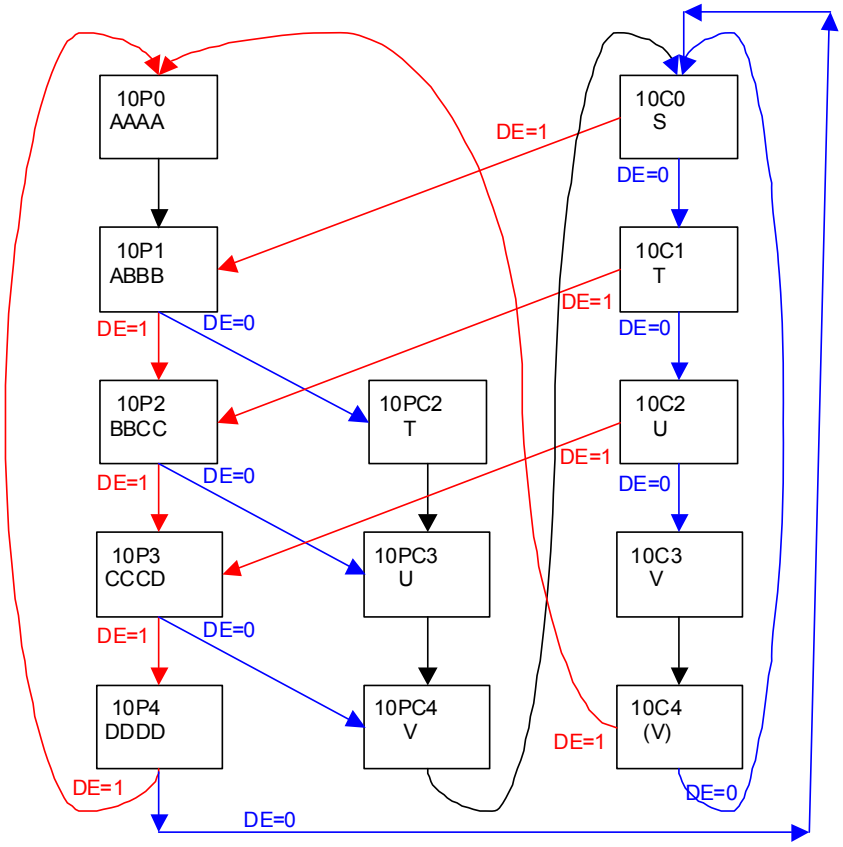
D.1 State Machines

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.

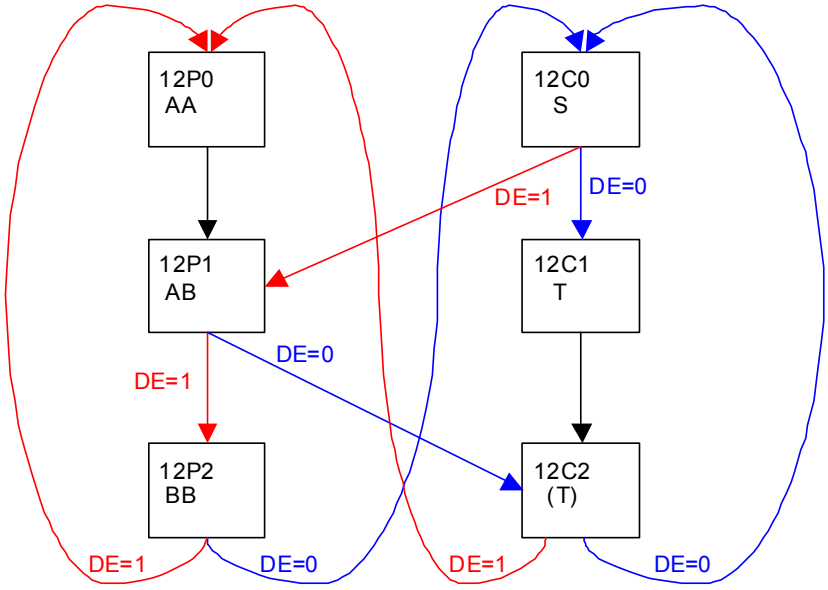
24 bit mode:



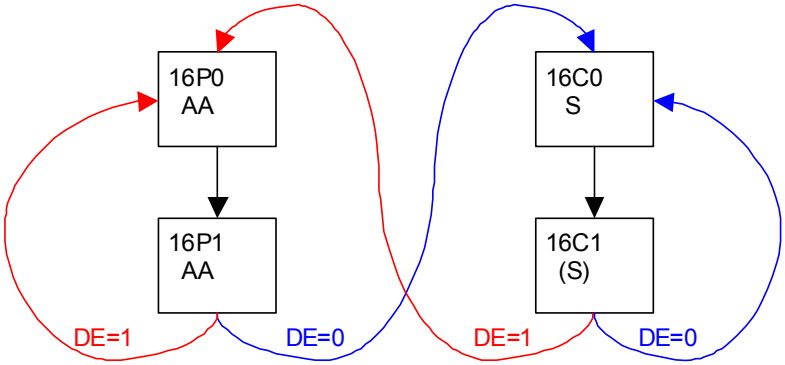
30 bit mode:



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”.

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	351562-351 563*	35672	351562-351 563*	71344	351562-351 563*
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.*

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	210937-210 938*	23296	210937-210 938*	46592	210937-210 938*
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

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

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 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

These values are not two's complement but instead, the integer and fraction are both absolute values. For instance, -0.853 (12-bit) is represented as 0x9B5 (sign=1, 0.853x512=437=0x1B5). Likewise, 0 = -0.0 or +0.0 = 0x000 or 0x800.

The value of a particular N-bit binary number of the range data representation is given by the following expression.

$N = \text{Color Precision}\,(8,\ 10\,\text{or}\,12)$

$b_i = \text{bit value}\,(\,\text{MSB is}\,b_{N-1},\ \text{LSB is}\,b_0\,)$

$\text{sign bit}: b_{N-1}\,|\,\text{integer}: b_{N-2}, b_{N-3}\,|\,\text{fraction}: b_{N-4}, \cdots, b_0$

$$\left(-1\right)^{b_{N-1}} / 2^{N-3} * \sum_{n=0}^{N-2} \left(2^n * b_n\right) = range\_data$$

The data structures for these two different formats are shown in Table E-1 and Table E-2 .

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.

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
  : :
  0b111 Reserved

  Note: RGB expression of $xvYCC_{601}$ coordinates should be processed as same as RGB expression of $xvYCC_{709}$ coordinates. RGB expression of $xvYCC_{601}$ coordinates in GBD_Color_Space is not defined in IEC 61966-2-4.

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.

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:

$$V_{WHITE} = V_{RED} + V_{GREEN} + V_{BLUE} - 2V_{BLACK}$$
$$V_{MAGENTA} = V_{RED} + V_{BLUE} - V_{BLACK}$$
$$V_{CYAN} = V_{GREEN} + V_{BLUE} - V_{BLACK}$$
$$V_{YELLOW} = V_{RED} + V_{GREEN} - V_{BLACK}$$

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)							

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							

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.

Appendix G Reserved

(This page is intended to be blank.)

Appendix H 3D video formats extensions

Note: The following is a preliminary draft subject to change without notice. Adopter may use this in its own discretion.

H. 1 HDMI Vendor Specific InfoFrame extension

In some cases, the HDMI Vendor Specific InfoFrame packet described in section 8.2.3 is extended as follows. When HDMI_Video_Format is set to 010, the 3D_Meta_present bit may be set (=1). If the 3D_Meta_present bit is set (=1), it indicates the presence of detailed information as defined in subsection "3D_Meta fields" below.

Table H-1 HDMI Vendor Specific InfoFrame Packet Contents

Packet Byte #	7	6	5	4	3	2	1	0
PB0	Checksum							
PB1	24bit IEEE Registration Identifier (0x000C03) (least significant byte first)							
PB2								
PB3								
PB4	HDMI_Video_Format			Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)
(PB5)	HDMI_VIC							
	3D_Structure				3D_Meta_present	Rsvd (0)	Rsvd (0)	Rsvd (0)
(PB6)	3D_Ext_Data				Reserved(0)			
(PB7)	3D_Metadata_type			3D_Metadata_Length (= N)				
(PB8)	3D_Metadata_1							
…	…							
(PB [7+N])	3D_Metadata_N							
PB[8+N] ~ [Nv]	Reserved (0)							

3D_Structure field

In addition to the Frame packing value "0000" specified in Section 8.2.3, additional values for 3D_Structure are defined below in Table H-2.

Table H-2 3D_Structure

Value	Meaning
0000	Frame packing
0001	Field alternative
0010	Line alternative
0011	Side-by-Side (Full)
0100	L + depth
0101	L + depth + graphics + graphics-depth
0110 ~ 0111	Reserved for future use.
1000	Side-by-Side (Half) (See Table H-3)
1001 ~ 1111	Reserved for future use.

3D_Ext_Data field

- 3D_Ext_Data [4bits] The meaning of this field depends on the 3D_Structure value. See Table H-3.
  If 3D_Structure is 1000 (Side-by-Side (Half)), the 3D_Ext_Data field is added in the HDMI Vendor Specific InfoFrame and indicates additional information about the 3D format.
  If 3D_Structure is 1001~1111, the 3D_Ext_Data field is also added and indicates additional information about the 3D format.
  If 3D_Structure is 0000~0111, the 3D_Ext_Data field shall not be present.

Table H-3 3D_Ext_Data –- Additional video format information for 3D_Structure = 1000

3D_Ext_Data	Meaning	
0000	Horizontal sub-sampling	Odd/Left picture, Odd/Right picture
0001		Odd/Left picture, Even/Right picture
0010		Even/Left picture, Odd/Right picture
0011		Even/Left picture, Even/Right picture
0100	Quincunx matrix	Odd/Left picture, Odd/Right picture
0101		Odd/Left picture, Even/Right picture
0110		Even/Left picture, Odd/Right picture
0111		Even/Left picture, Even/Right picture
1000 ~ 1111	Reserved	

For Side-by-Side (Half), the possible sub-sampling positions are defined in Table H-4. The description of “Odd” and “Even” is defined by the sampling position of the active video area in the first video line. See Figure H-1 and Figure H-2.

In the case of an interlaced video signal, the sampling position is defined by the first video line of the odd field. Figure H-1 and Figure H-2 are then regarded as field pictures.

If an HDMI Source supports Side-by-Side (Half), it shall support at least the horizontal sub-sampling with the odd sampling position for both Left and Right picture.

Table H-4 Relation of sub-sampling methods for the Side-by-Side (Half) 3D_Structure

Sub-sampling method	Meaning of sub-sampling method
Horizontal sub-sampling	The sub-sampling position is the same on each video line of the original full left and right pictures as shown in Figure H-1.
Quincunx matrix	The sub-sampling position interchanges on every line of the original full left and right pictures as shown in Figure H-2.

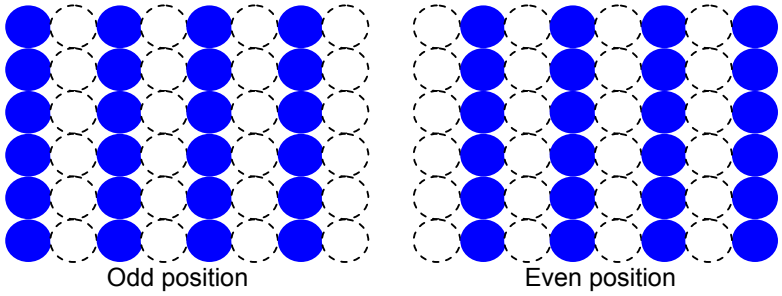


Figure H-1 Horizontal sub-sampling method and its position on the original full picture

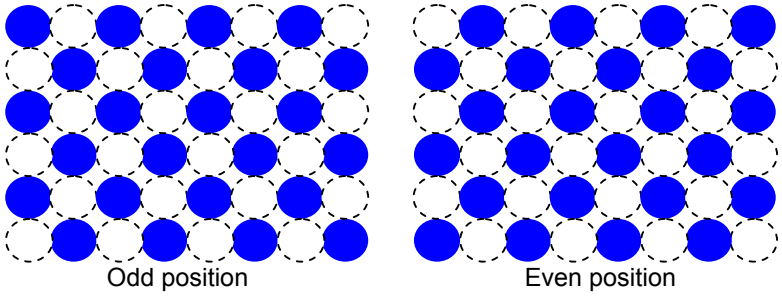


Figure H-2 Quincunx sub-sampling method and its position on the original full picture

3D_Meta field

- 3D_Meta_present [1bit] if set (=1) then a few additional bytes of 3D metadata (i.e. 3D_Metadata_type, 3D_Metadata_Length and 3D_Metadata_1…N) follow in the HDMI Vendor Specific InfoFrame.
- 3D_Metadata_type [3bits] These 3 bits define an optional metadata type that accompanies the stereoscopic video for correct rendering in the display. The semantics of the bytes 3D_Metadata1…N depend on the type of data as indicated in Table H-5.

Table H-5 3D_Metadata_type

Value	Meaning
000	The following 3D_Metadata_1…N contains the parallax information as defined in ISO23002-3 sections 6.1.2.2 and 6.2.2.2
001 ~ 111	Reserved for future use

- 3D_Metadata_Length [5 bits] These 5 bits show the length of following 3D_Metadata_1…N byte. In case of 3D_Metadata_type = 000, then 3D_Metadata_Length = 8 according to ISO23002-3 section 6.1.2.2.
- 3D_Metadata_1…N [N bytes] These bytes depend on 3D_Metadata_type value.
  In case of 3D_Metadata_type = 000, 3D_Metadata_1…8 is filled with following values:
  3D_Metadata_1 = parallax_zero[15…8]
  3D_Metadata_2 = parallax_zero[7…0]
  3D_Metadata_3 = parallax_scale [15…8]
  3D_Metadata_4 = parallax_scale [7…0]
  3D_Metadata_5 = dref [15…8]
  3D_Metadata_6 = dref [7…0]
  3D_Metadata_7 = wref[15…8]
  3D_Metadata_8 = wref[7…0]
  Regarding the parallax parameter, refer to ISO23002-3 section 6.2.2.2.

H. 2 3D video formats structure extension

Various 3D video formats may optionally be transmitted. The 3D video format is indicated by using the VIC field in the AVI InfoFrame in conjunction with one of the extended 3D_Structure values defined in Table H-2 in HDMI Vendor Specific InfoFrame.

The following table shows examples of 3D video formats. Other VICs can be used for 3D video formats.

Table H-6 3D transmission video size (example)

3D_structure	Corresponding figure	VIC	description	Hactive		Hblank		
						Hfront	Hsync	Hback
0000 (Frame packing)	Figure 8-3	*31*	1080p, 50Hz	1920	720	528	44	148
		16	1080p, 60Hz	1920	280	88	44	148
	Figure H-3	*5*	1080i, 60Hz	1920	280	88	44	148
		20	1080i, 50Hz	1920	720	528	44	148
0001 (Field alternative)	Figure H-4	*5*	1080i, 60Hz	1920	280	88	44	148
		20	1080i, 50Hz	1920	720	528	44	148
0010 (Line alternative)	Figure H-5	*16*	1080p, 60Hz	1920	280	88	44	148
		31	1080p, 50Hz	1920	720	528	44	148
0011 (Side-by-Side(Full))	Figure H-6	*16*	1080p, 60Hz	1920	280	88	44	148
		31	1080p, 50Hz	1920	720	528	44	148
0100 (L+depth)	Figure H-7	*19*	720p, 50Hz	1280	700	440	40	220
0101 (L+depth +Gfx +G-depth)	Figure H-8	*19*	720p, 50Hz	1280	700	440	40	220
1000 (Side-by-Side(Half))	Figure H-9 (note 2)	*16*	1080p, 60Hz	1920	280	88	44	148
		2, 3	480p, 60Hz	720	138	16	62	60

(Continued)

3D_Structure.	Vactive			Vblank				Pixel freq [MHz] (note 1)	V freq (Hz) (note 1)
		Vact_video	Vact_space		Vfront	Vsync	Vback		
0000	2205	1080	45	45	4	5	36	297.00	50
	2205	1080	45	45	4	5	36	297.00	60
	2228	540	Vact_space1=23 Vact_space2=22	22	2	5	15	148.50	60
	2228	540	Vact_space1=23 Vact_space2=22	22	2	5	15	148.50	50
0001	540	540	0	Vblank1=22	2	Vsync1=5	Vback1=15	148.50	60
				Vblank2=22	2	Vsync2=4.5	Vback2=15.5		
				Vblank3=23	-	-	-		
	540	540	0	Vblank1=22	2	Vsync1=5	Vback1=15	148.50	50
				Vblank2=22	2	Vsync2=4.5	Vback2=15.5		
				Vblank3=23	-	-	-		
0010	1080	1080	0	45	4	5	36	297.00	60
	1080	1080	0	45	4	5	36	297.00	50
0011	1080	1080	0	45	4	5	36	297.00	60
	1080	1080	0	45	4	5	36	297.00	50
0100	1470	720	30	30	5	5	20	148.50	50
0101	2970	720	30	30	5	5	20	297.00	50
1000	1080	1080	0	45	4	5	36	148.50	60
	480	480	0	45	9	6	30	27.00	60

1. V freq=60Hz and the corresponding Pixel freq include the variation of 1000/1001. The video timing for pixel and line is the same as 60Hz.
2. The Side-by-Side (Half) video timing format is shown in Figure H-9 where the two half-left/right pictures are aligned within 1-frame. The Side-by-Side (Half) transmission format is classified by the sub-sampling methods that are specified in Figure H-1 and Figure H-2. When sending the Side-by-Side (Half) format, the HDMI source shall send the 3D_Ext_Data byte set to an appropriate value.

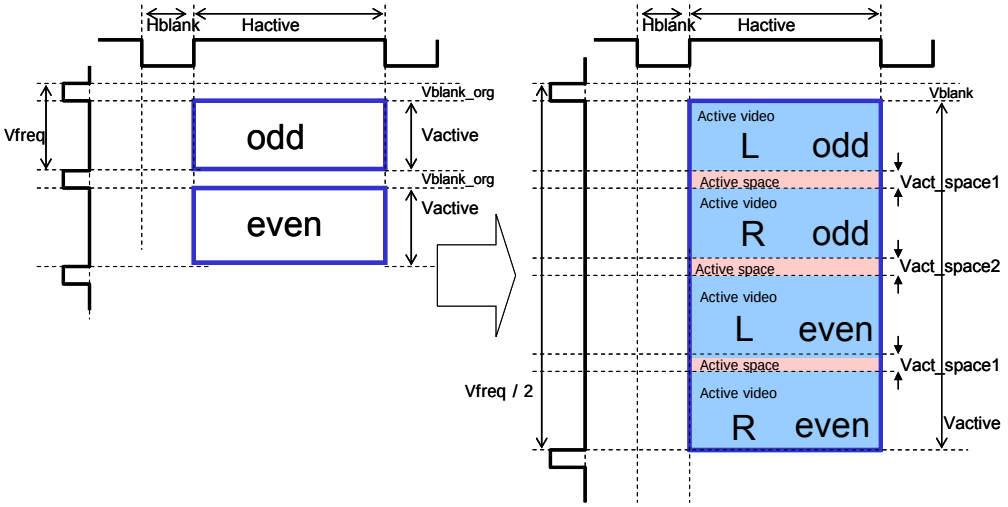


Figure H-3 3D video format (Frame packing for interlaced format)

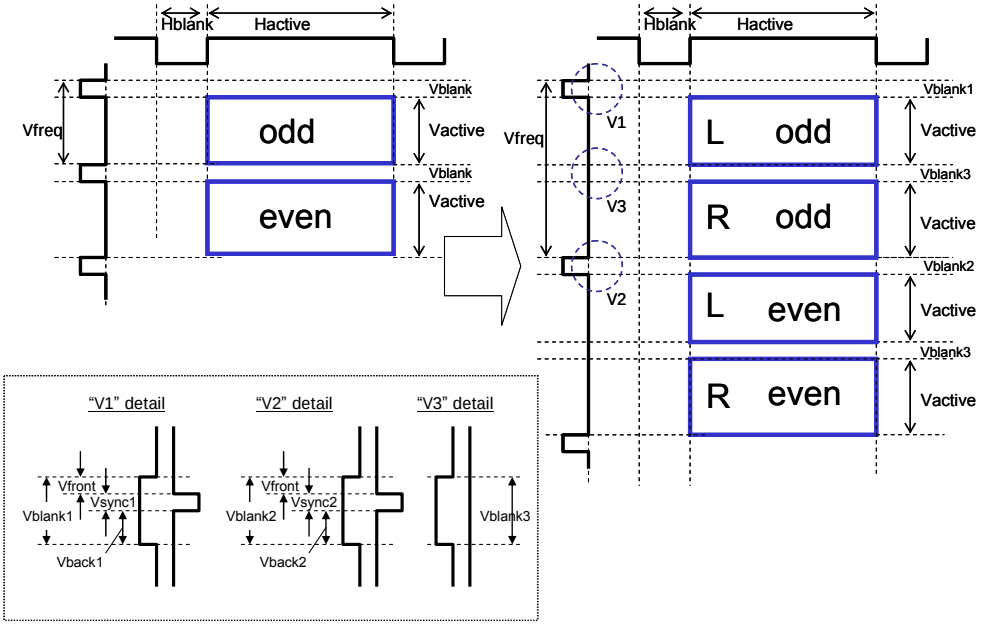


Figure H-4 3D video format (Field alternative)

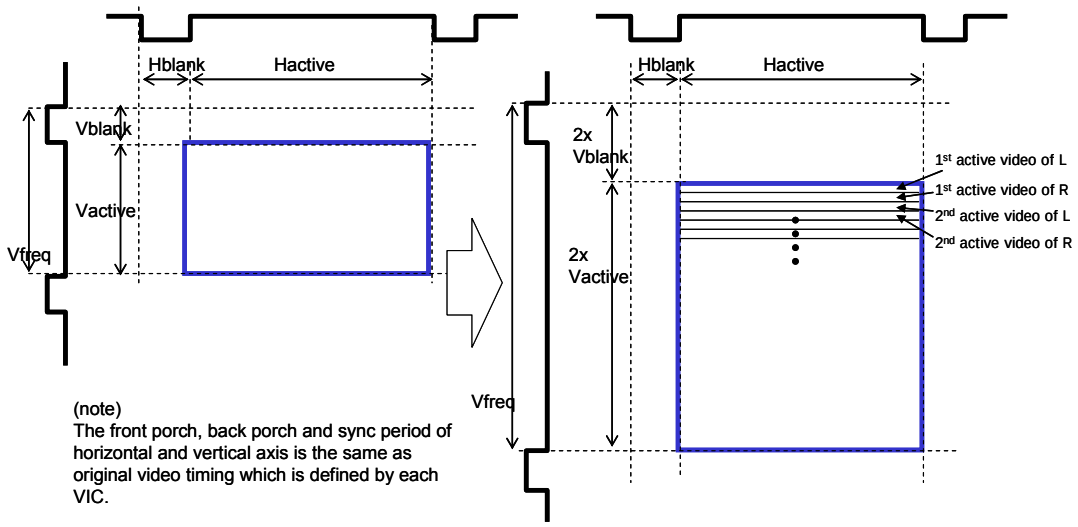


Figure H-5 3D video format (Line alternative)

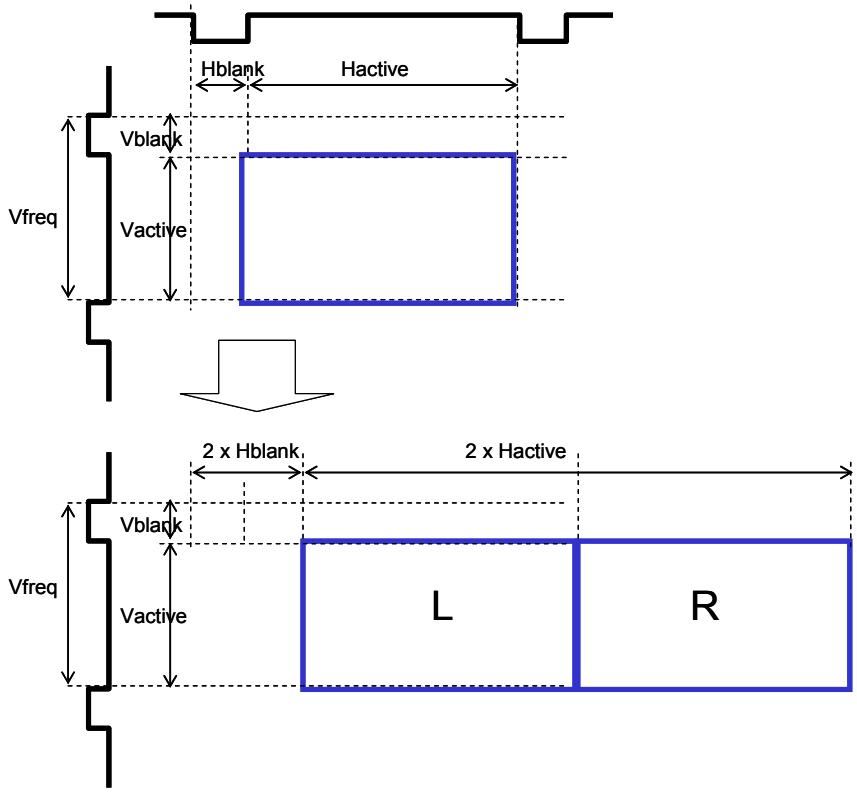


Figure H-6 3D video format (Side-by-Side (Full))

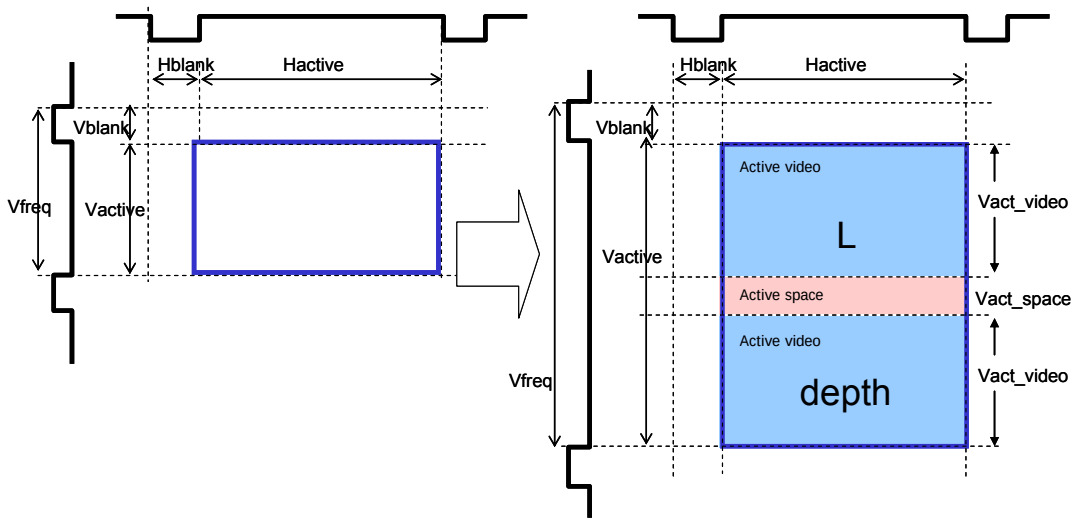


Figure H-7 3D video format (L + depth)

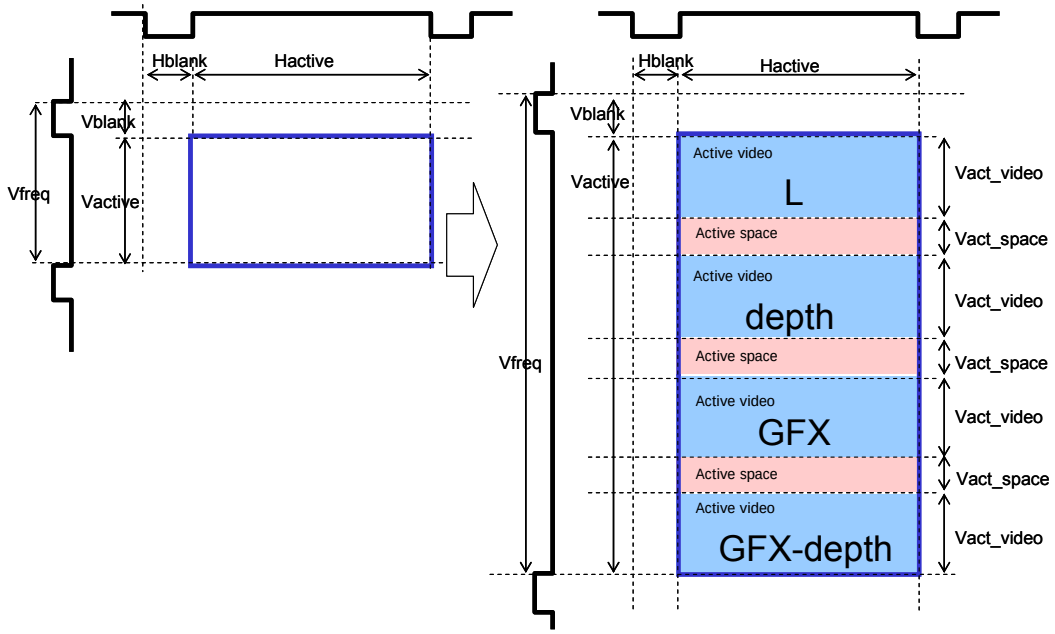


Figure H-8 3D video format (L + depth + Graphics + Graphics-depth)

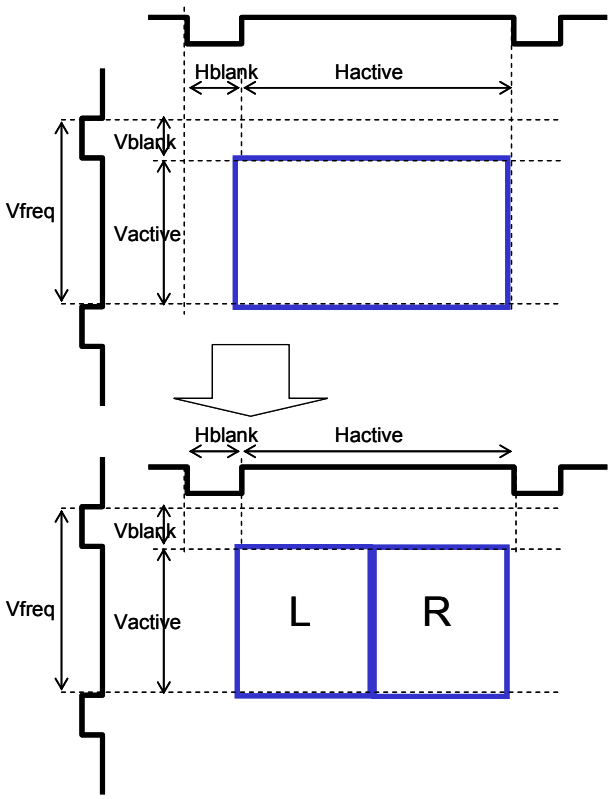


Figure H-9 3D video format (Side-by-Side (Half))

H. 3 HDMI Vendor-Specific Data Block (HDMI VSDB) extension

For some formats, additional fields in the HDMI Vendor Specific Data Block are defined.

Table H-7 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	HDMI_Video_present	Rsvd (0)	CNC3	CNC2	CNC1	CNC0
(9)	Video_Latency							
(10)	Audio_Latency							
(11)	Interlaced_Video_Latency							
(12)	Interlaced_Audio_Latency							
(13)	3D_present	3D_Multi_present	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	Rsvd (0)	
(14)	HDMI_VIC_LEN		HDMI_3D_LEN					
(15)	(if HDMI_VIC_LEN > 0) HDMI_VIC_1							
	…							
	HDMI_VIC_M							
	(if 3D_Multi_present = 01 or 10) 3D_Structure_ALL_15…8							

extension fields ↓

	3D_Structure_ALL_7…0	
	(if 3D_Multi_present = 10) 3D_MASK_15…8	
	3D_MASK_7…0	
	2D_VIC_order_1	3D_Structure_1
	3D_Detail_1 ***	Reserved(0) ***
	…	
	2D_VIC_order_L	3D_Structure_L
( )*…N	*Reserved (0)***	

** The position of these bytes will depend upon the values of Latency_Fields_Present, I_Latency_Fields_Present and HDMI_Video_present.*

*** No additional bytes are necessary but if present, they shall be zero.*

**** The bytes with 3D_Detail_X and Reserved(0) are present only for some values of 3D_Structure_X. See below for details.*

- HDMI_Video_present [1bit] If set (=1) then additional video format capabilities are described by using the fields starting after the latency related fields. This consists of 4 parts with the order described below:
  - 1 byte with flags “3D_present” and “3D_Multi_present”
  - 1 byte with length fields HDMI_VIC_LEN and HDMI_3D_LEN
  - zero or more bytes for information about HDMI_VIC formats supported (length of this field is indicated by HDMI_VIC_LEN)
  - zero or more bytes for information about 3D formats supported (length of this field is indicated by HDMI_3D_LEN) which are optionally composed of 3D_Structure_ALL_15...0, 3D_MASK_15...0, 2D_VIC_order_X, 3D_Structure_X and 3D_Detail_X field.

- 3D_present [1bit] This bit indicates 3D support by the HDMI Sink, including the mandatory formats. If set (=1), an HDMI Sink supports the 3D video formats that are mandatory formats, plus any additional formats indicated by combining the indications in both:
  - 3D_Structure_ALL_15…0 (if 3D_Multi_present = 01), or 3D_Structure_ALL_15…0 and 3D_MASK_15…0 (if 3D_Multi_present = 10); and
  - 2D_VIC_order_X, 3D_Structure_X and 3D_Detail_X (if these fields are present according to the HDMI_3D_LEN calculation).

- 3D_Multi_present [2bit]
  If 3D_Multi_present = 00
  3D_Structure_ALL_15…0 and 3D_MASK_15…0 fields are not present.
  If 3D_Multi_present = 01,
  3D_Structure_ALL_15…0 is present and assigns 3D formats to all of the VICs listed in the first 16 entries in the EDID.
  3D_MASK_15…0 is not present.
  If 3D_Multi_present = 10,
  3D_Structure_ALL_15…0 and 3D_MASK_15…0 are present and assign 3D formats to some of the VICs listed in the first 16 entries in

the EDID.
If 3D_Multi_present = 11
Reserved for future use.
Note: 3D_Structure_ALL_15…0 and 3D_MASK_15…0 are not present.

- HDMI_3D_LEN [5bits] indicates the total length of following 3D video format capabilities including 3D_Structure_ALL_15...0, 3D_MASK_15...0, 2D_VIC_order_X, 3D_Structure_X and 3D_Detail_X fields.

- 3D_Structure_ALL_15…0 [2 bytes]
  For each bit in this field which is set (=1), an HDMI Sink supports the corresponding 3D_Structure according to Table H-8 for all of the VICs listed in the first 16 entries in the EDID.
  By using this field, the 3D capabilities of an HDMI Sink can be concisely described.

Table H-8 3D_Structure_ALL

Bit	Meaning
3D_Structure_ALL_0	Sink supports “Frame packing” 3D formats.
3D_Structure_ALL_1	Sink supports “Field alternative” 3D formats which consists of field picture.
3D_Structure _ALL_2	Sink supports “Line alternative” 3D formats
3D_Structure _ALL_3	Sink supports Side-by-Side(Full) 3D formats
3D_Structure _ALL_4	Sink supports “L + depth” 3D formats
3D_Structure _ALL_5	Sink supports “L + depth + graphics + graphics-depth” 3D formats
3D_Structure_ALL_6…7	Reserved (Shall be 0)
3D_Structure _ALL_8	Sink supports “Side-by-Side(Half) with all sub-sampling methods” 3D formats
3D_Structure_ALL_9…15	Reserved (Shall be 0)

- 3D_MASK_15…0 [2 bytes] Where a bit is set (=1), for each corresponding VIC within the first 16 entries in the EDID, the Sink indicates 3D support as designated by the 3D_Structure_ALL_15…0 field.
  Where a bit is not set (=0), for each corresponding VIC, the Sink does not indicate 3D support using this field (whereas it may indicate 3D support by the 2D_VIC_order_X, 3D_Structure_X and 3D_Detail_X fields, if present).

  3D_MASK_0 = first VIC
  3D_MASK_1 = second VIC
  : : :
  3D_MASK_15 = 16th VIC

- 2D_VIC_order_X [4bits] X means the index value from 1 to L. The value of this field is a pointer to a particular VIC in the EDID based on the order in which the VICs are stored in the EDID. The value 0000 corresponds to the first VIC in the EDID, and the remaining values point to the rest of the first 15 VIC entries in the EDID in corresponding order.

  2D_VIC_order_X = 0000 corresponds to the first VIC in the EDID
  2D_VIC_order_X = 0001 corresponds to the second VIC in the EDID
  : : :
  2D_VIC_order_X = 1111 corresponds to the 16th VIC in the EDID

- 3D_Structure_X [4bits] X means the index value from 1 to L. This field indicates the 3D capability for the corresponding VIC code indicated by 2D_VIC_order_X. The value is defined in Table H-2.
- 3D_Detail_X [4bits] X means the index value from 1 to L. This field indicates additional detailed information for the related 3D_Structure_X field.
  If 3D_Structure_X is 0000~0111, this field and also the 4-bit reserved field in the same byte, shall not be present, so the X-th entry consists only of 2D_VIC_order_X and 3D_Structure_X (1 byte).
  If 3D_Structure_X is 1000~1111 (including Side-by-Side (Half)), this field and also the 4-bit reserved field in the same byte, shall be present, so the X-th entry consists of 2D_VIC_order_X, 3D_Structure_X and 3D_Detail_X (2 bytes).
  The values for 3D_Detail_X when 3D_Structure = 1000 are defined in Table H-9. In this case, 3D_Detail_X indicates the supported sub-sampling position(s). 3D_Detail_X = 0001 means that the Sink can handle all four sub-sampling positions for Horizontal sub-sampling and 0110 means that the Sink can handle all four sub-sampling positions for Quincunx matrix.

Table H-9 3D_Detail_X for Side-by-Side (Half)

3D_Detail_X	Meaning of supported sub-sampling position.	
0000	Support all eight combination of sub sampling position	
0001	Horizontal sub-sampling	Support all four combination of sub sampling position
0010		Odd/Left picture, Odd/Right picture
0011		Odd/Left picture, Even/Right picture
0100		Even/Left picture, Odd/Right picture
0101		Even/Left picture, Even/Right picture
0110	Quincunx matrix	Support all four combination of sub sampling position
0111		Odd/Left picture, Odd/Right picture
1000		Odd/Left picture, Even/Right picture
1001		Even/Left picture, Odd/Right picture
1010		Even/Left picture, Even/Right picture
1011 ~ 1111	Reserved	

If an HDMI Sink supports Side-by-Side (Half), it shall support at least the Horizontal sub-sampling with the odd sampling position for both Left and Right picture.

Note that the VICs which support 3D formats shall be listed in the first 16 entries in the EDID.

Supplement 1

Consumer Electronics Control (CEC)

CEC Table of Contents

CEC Page

CEC 1 INTRODUCTION 1

CEC 1.1 Normative references 1

CEC 1.2 Informative References 1

CEC 1.3 Document Revision History 1

CEC 2 DEFINITIONS 4

CEC 2.1 Conformance Levels 4

CEC 2.2 Glossary of Terms 4

CEC 2.3 Usages and Conventions 4
CEC 2.3.1 State Diagrams 4
CEC 2.3.2 Message Flow Diagrams 5
CEC 2.3.3 Notation 5

CEC 3 FEATURE OVERVIEW 6

CEC 3.1 End-User Features 6

CEC 3.2 Supporting Features 6

CEC 4 ELECTRICAL SPECIFICATION 7

CEC 5 SIGNALING AND BIT TIMINGS 9

CEC 5.1 CEC Line Usage 9

CEC 5.2 Bit Timing 9
CEC 5.2.1 Start Bit Timing 9
CEC 5.2.2 Data Bit Timing 9

CEC 6 FRAME DESCRIPTION 12

CEC 6.1 Header/Data Block description 12
CEC 6.1.1 EOM (End of Message) 12
CEC 6.1.2 ACK (Acknowledge) 13
CEC 6.1.3 Header Block Details 13

CEC 7 RELIABLE COMMUNICATION MECHANISMS 14

CEC 7.1 Frame Re-transmissions 14

CEC 7.2 Flow Control 14

CEC 7.3 Frame Validation 14

CEC 7.4 CEC Line Error Handling 14

CEC 8 PROTOCOL EXTENSIONS 16

CEC 9 CEC ARBITRATION 17

CEC 9.1 Signal Free Time 17

CEC 9.2 Message Time Constraints 17

CEC 10 DEVICE CONNECTIVITY AND ADDRESSING 18

CEC 10.1 Physical Address Discovery 18

CEC 10.2 Logical Addressing 18
CEC 10.2.1 Logical Address Allocation 20
CEC 10.2.2 Special Devices 21
CEC 10.2.3 Behavior with Earlier Versions 23

CEC 11 SWITCH REQUIREMENTS 24

CEC 11.1 CEC Switch 24

CEC 12 HIGH LEVEL PROTOCOL 26

CEC 12.1 Source Declaration 26

CEC 12.2 Protocol General Rules 26

CEC 12.3 Feature Abort 27

CEC 12.4 Abort 28

CEC 13 CEC FEATURES DESCRIPTION 29

CEC 13.1 One Touch Play 29
CEC 13.1.1 Messages 29
CEC 13.1.2 Feature Description 29
CEC 13.1.3 Behavior with Earlier Versions 30

CEC 13.2 Routing Control 30
CEC 13.2.1 Messages 30
CEC 13.2.2 Feature Description 31
CEC 13.2.3 Behavior with Earlier Versions 33

CEC 13.3 System Standby 33
CEC 13.3.1 Messages 33
CEC 13.3.2 Feature Description 33
CEC 13.3.3 Behavior with Earlier Versions 35

CEC 13.4 One Touch Record 35
CEC 13.4.1 Messages 35
CEC 13.4.2 Feature Description 35
CEC 13.4.3 Behavior with Earlier Versions 37

CEC 13.5 Timer Programming 37
CEC 13.5.1 Messages 37
CEC 13.5.2 Feature Description 38
CEC 13.5.3 Performing a Timed Recording using another device as source 39
CEC 13.5.4 Behavior with Earlier Versions 39

CEC 13.6 System Information 39
CEC 13.6.1 Messages 39
CEC 13.6.2 Feature Description 40

CEC 13.6.3 Additional Information....41
CEC 13.6.4 Behavior with Earlier Versions....41

CEC 13.7 Deck Control....41
CEC 13.7.1 Messages....41
CEC 13.7.2 Feature Description....42
CEC 13.7.3 Behavior with Earlier Versions....42

CEC 13.8 Tuner Control....43
CEC 13.8.1 Messages....43
CEC 13.8.2 Feature Description....43
CEC 13.8.3 Behavior with Earlier Versions....44

CEC 13.9 Vendor Specific Commands....44
CEC 13.9.1 Messages....44
CEC 13.9.2 Feature Description....44
CEC 13.9.3 Behavior with Earlier Versions....45

CEC 13.10 OSD Display....45
CEC 13.10.1 Messages....45
CEC 13.10.2 Feature Description....46
CEC 13.10.3 Behavior with Earlier Versions....46

CEC 13.11 Device OSD Name Transfer....46
CEC 13.11.1 Messages....46
CEC 13.11.2 Feature Description....46
CEC 13.11.3 Behavior with Earlier Versions....47

CEC 13.12 Device Menu Control....47
CEC 13.12.1 Messages....47
CEC 13.12.2 Feature Description....47
CEC 13.12.3 Behavior with Earlier Versions....48

CEC 13.13 Remote Control Pass Through....48
CEC 13.13.1 Messages....48
CEC 13.13.2 Feature Description....48
CEC 13.13.3 Press and Hold Operation....49
CEC 13.13.4 RC Key Forwarding Recommendations....51
CEC 13.13.5 Other uses of <User Control Pressed>....51
CEC 13.13.6 Deterministic UI Functions....51
CEC 13.13.7 Non-Deterministic Commands with Parameters....53
CEC 13.13.8 Behavior with Earlier Versions....53

CEC 13.14 Give Device Power Status....53
CEC 13.14.1 Messages....53
CEC 13.14.2 Feature Description....53
CEC 13.14.3 Behavior with Earlier Versions....54

CEC 13.15 System Audio Control....55
CEC 13.15.1 Messages....55
CEC 13.15.2 Feature Description....55
CEC 13.15.3 Discovering the Amplifier's Audio Format support....60
CEC 13.15.4 Further behavior....61
CEC 13.15.4.1 Operation with legacy Amplifier....61
CEC 13.15.4.2 Operation with TVs that do not support the Feature....61
CEC 13.15.4.3 Audio-only use....62
CEC 13.15.4.4 Power State Changes....62

CEC 13.15.4.5 Usage of remote control pass through 62
CEC 13.15.5 Behavior with Earlier Versions 63

CEC 13.16 Audio Rate Control 63
CEC 13.16.1 Messages 63
CEC 13.16.2 Feature Description 63
CEC 13.16.3 Behavior with Earlier Versions 64

CEC 13.17 Audio Return Channel Control 64
CEC 13.17.1 Messages 64
CEC 13.17.2 Feature description 64
CEC 13.17.2.1 Initiation and Termination from ARC Rx device 65
CEC 13.17.2.2 Request from ARC Tx device 65
CEC 13.17.3 Behavior with Earlier Versions 66

CEC 13.18 Capability Discovery and Control for HEC 67
CEC 13.18.1 Introduction and Messages 67
CEC 13.18.2 CDC only Device 67
CEC 13.18.3 CDC Device with CEC 67
CEC 13.18.4 Behavior with Earlier Versions 67

CEC 14 DEVICE STATES 68
CEC 14.1.1 Device States 68
CEC 14.1.2 State Changes 68
CEC 14.1.3 All Devices 68
CEC 14.1.4 TV 68
CEC 14.1.5 Recording Device 69
CEC 14.1.6 Playback Device 69
CEC 14.1.7 Menu Providing Device 70

CEC 15 MESSAGE DESCRIPTIONS 71

CEC 16 MESSAGE DEPENDENCIES 97

CEC 17 OPERAND DESCRIPTIONS 106

CEC APPENDIX A NON-CEC SWITCH (INFORMATIVE) 127

CEC Figures

CEC Page

CEC Figure 1 Example State Diagram 5
CEC Figure 2 Example Message Flow Diagram 5
CEC Figure 3 Start bit pulse format showing minimum and maximum tolerances 9
CEC Figure 4 Timing diagrams for both bit states 10
CEC Figure 5 Timing Diagram for Follower Asserted Bit (Logical 0) 11
CEC Figure 6 Block Structure 12
CEC Figure 7 Header Block 13
CEC Figure 8 Logical Address Allocation 21
CEC Figure 9 Examples of CEC systems with a “split architecture” TV 22
CEC Figure 10 Example of the use of a second TV 23
CEC Figure 11 A typical scenario illustrating the One Touch Play feature 29
CEC Figure 12 Example message flow, when a CEC Switch is manually switched 33
CEC Figure 13 A typical scenario for the broadcast (system) Standby feature 34
CEC Figure 14 A typical scenario for the Standby feature to a specific device 34
CEC Figure 15 A typical scenario for the One Touch Record feature 36
CEC Figure 16 A typical scenario for setting a Timer Record Block 38
CEC Figure 17 Message exchange when getting the TV’s menu Language 40
CEC Figure 18 A typical scenario when a menu language setting within the TV is modified 40
CEC Figure 19 A typical scenario for the Deck Control feature 42
CEC Figure 20 A typical scenario for selecting a new Service 43
CEC Figure 21 The messages sent in the Vendor Specific Commands feature 45
CEC Figure 22 A typical scenario where the user presses and quickly releases a key 48
CEC Figure 23 A typical scenario where the user presses and holds a key 49
CEC Figure 24 Initiator Repetition Time, Follower Safety Timeout and Press and Hold behavior 50
CEC Figure 25 A typical scenario for to discover the power status of a target device 54
CEC Figure 26 A typical scenario for initiating the System Audio Control feature from a TV 55
CEC Figure 27 A typical scenario for initiating the System Audio Control feature from an Amplifier 56
CEC Figure 28 A typical scenario for initiating the System Audio Control feature from a STB 57
CEC Figure 29 A typical scenario terminating the System Audio Control feature from a TV or STB 57
CEC Figure 30 A typical scenario terminating the System Audio Control feature from the Amplifier 58
CEC Figure 31 Typical Operation of the volume control where the user presses and quickly releases a key 58
CEC Figure 32 An example of TV and Amplifier implementing Press and Hold behavior 59
CEC Figure 33 An example of alternative connection link 60
CEC Figure 34 Typical Operation to discover the Audio Format capability of an Amplifier 61

CEC Figure 35 An example of topology with ARC link..... 64
CEC Figure 36 Initiation and Termination from ARC Rx device..... 65
CEC Figure 37 Request from ARC Tx device 66

CEC Tables

CEC Page

CEC Table 1 CEC Electrical Specifications during the fully powered-Off state 7
CEC Table 2 CEC Electrical Specifications except during the fully powered-Off state 8
CEC Table 3 Frame Description 12
CEC Table 4 Signal Free Time 17
CEC Table 5 Logical Addresses 20
CEC Table 6 Deterministic UI Functions 52
CEC Table 7 Non-deterministic UI commands with parameters 53
CEC Table 8 Message Descriptions for the One Touch Play Feature 72
CEC Table 9 Message Descriptions for the Routing Control Feature 73
CEC Table 10 Message Descriptions for the Standby Feature 75
CEC Table 11 Message Descriptions for the One Touch Record Feature 76
CEC Table 12 Message Descriptions for the Timer Programming Feature 77
CEC Table 13 Message Descriptions for the System Information Feature 79
CEC Table 14 Message Descriptions for the Deck Control Feature 81
CEC Table 15 Message Descriptions for the Tuner Control Feature 83
CEC Table 16 Message Descriptions for the Vendor Specific Commands Feature 84
CEC Table 17 Message Descriptions for the OSD Display Feature 86
CEC Table 18 Message Descriptions for the Device OSD Transfer Feature 87
CEC Table 19 Message Descriptions for the Device Menu Control Feature 88
CEC Table 20 Message Descriptions for the Remote Control Passthrough Feature 89
CEC Table 21 Message Descriptions for the Power Status Feature 90
CEC Table 22 Message Descriptions for General Protocol messages 91
CEC Table 23 Message Descriptions for the System Audio Control Feature 92
CEC Table 24 Message Descriptions for the Audio Rate Control Feature 94
CEC Table 25 Message Descriptions for the Audio Return Channel Control Feature 95
CEC Table 26 Message Descriptions for the Capability Discovery and Control Feature 96
CEC Table 27 Message dependencies when receiving a message 98
CEC Table 28 Message dependencies when sending a message 102
CEC Table 29 Operand Descriptions. 106
CEC Table 30 User Control Codes 124
CEC Table 31 Broadcast System 126

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

1.4 Clarification that a Follower ignores a message when EOM is zero and no further Data Blocks are received (CEC 6.1.1).
Recommendation to limit re-transmissions and clarification that frame re-transmission is only used for ACK errors (CEC 7.1).
Clarification of the use of Logical Address 14; clarification of allocation of Logical Addresses; clarification of "split architecture" and second TVs; addition of Device Type "Pure CEC Switch" and "Video Processor" (CEC 10.2).
Clarification of what a CEC Switch is (CEC 11.1).
Addition of [Abort Reason] "Unable to Determine" and clarification of what the abort reasons mean (CEC 12.3).
Better explanation of which messages are to be implemented and addition of references to the Message Description, Message Dependency and Operand tables (CEC 13).
Clarification that an Active Source loses its Active Source status when there is an <Active Source> message from another device (CEC 13.1.2).
Clarification that a device sends an <Active Source> message when it becomes the Active Source; removal of recommendation that a source may pause when it loses Active Source status (CEC 13.2.2).
Clarification of the difference between local and system standby (CEC 13.3.2).
Clarification that a recording device may take several seconds before it can send an accurate <Timer Status> or <Timer Cleared Status> message (CEC 13.5.2).
Allow Mobile devices and PCs not to change language if necessary; clarification that only a TV can change language; recommendation that non-TV devices accept a mixture of

upper- and lower-case characters; CEC Version is no longer linked to HDMI Version; (CEC 13.6.2 and 13.6.3).
Clarification that a device needs to discover CEC Version if it wishes to send a <Vendor Command> to a device from another vendor (CEC 13.9.2).
Better explanation of the [Display Control] parameter in OSD Display specifying how long an OSD is displayed; clarification that Display Control “Clear Previous Message” does not use any [OSD String] parameter (CEC 13.10.2).
Recommendation that an [OSD Name] of a device with multiple functionality refers to the complete product (CEC 13.11.2).
Addition of detailed description for Press and Hold operation; definition and specification of Initiator Repetition Time and Follower Safety Timeout; requirement to implement Follower Safety Timeout in all Followers implementing RC Passthrough; recommendation for Key Forwarding; clarification of other uses of <User Control Pressed> message; clarification of the use of the non-deterministic “Power” [UI Command]; addition of Select Broadcast Type and Select Sound Presentation non-deterministic UI commands with parameters (CEC 13.13.2 – CEC 13.13.7).
Clarification of operation, addition of missing items and corrections; addition of references to Audio Return Channel; addition of method to discover Audio Format Support of an Amplifier; addition of methods for ensuring the correct mute/unmute status of legacy amplifiers; addition of operation with TVs that do not support the Feature; addition of Audio-only use; clarification of behavior with Power State Changes; clarification of usage of RC Passthrough with System Audio Control (CEC 13.15.2 – CEC 13.15.4).
Addition of new Audio Return Channel Control section (CEC 13.17).
Addition of Capability Discovery and Control section, referencing Supplement 2 for details (CEC 13.18).
Clarification that “TV” refers to the device at Logical Address 0 in the message description tables CEC Table 8 to CEC Table 26; clarification that CDC only devices shall not implement messages in those tables.
Addition of new messages for Audio Return Channel and CDC in Tables CEC Table 25 and CEC Table 26.
Corrections and updates to Message Dependency tables CEC Table 27 and CEC Table 28.
Additions and corrections to Operand Description table CEC Table 29.
Addition of UI commands for Media Top Menu, Media Context Sensitive Menu, Number Entry Mode, Number 11, Number 12; clarification of notes to table (CEC Table 30).
Various editorial corrections throughout.

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.

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

1.2 Clarification of CEC line Standby behavior
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

CEC 2 Definitions

CEC 2.1 Conformance Levels

Because CEC is optional, the conformance level in this Supplement 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.

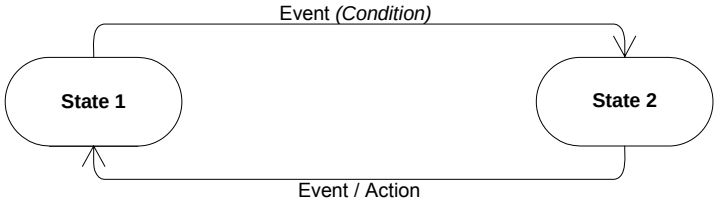
CEC 2.2 Glossary of Terms

Audio System	A device, which is not a TV, that has the ability to render audio, e.g. an audio Amplifier.
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 media such as DVD or Hard Disk.
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. an 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

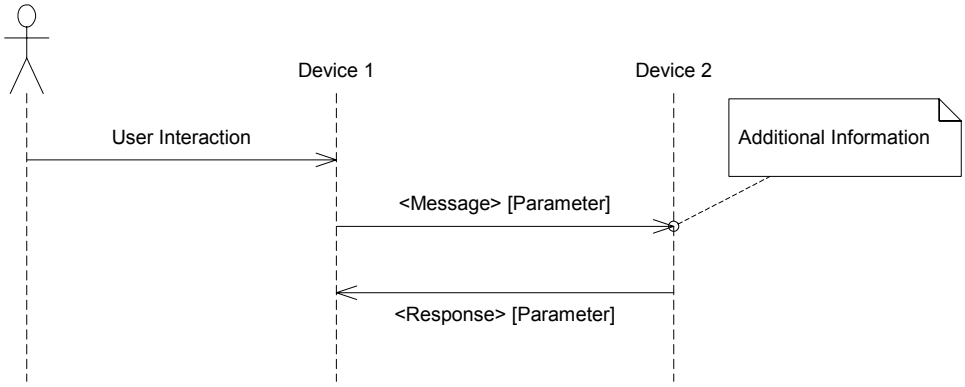
State diagrams describe behavior in terms of device states and events or actions. In these diagrams, the ovals represent device states and the arrows represent events and/or actions that move the device from one state to another state.



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.

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 the Standby state 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.

Audio Return Channel Control – Controls the Audio Return Channel (ARC) part of the HDMI Ethernet and Audio Return Channel (HEAC), which is fully specified in Supplement 2.

Capability Discovery and Control – Controls HDMI Ethernet Channel (HEC) part of HEAC, which is fully specified in Supplement 2.

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

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 (e.g. 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.

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.

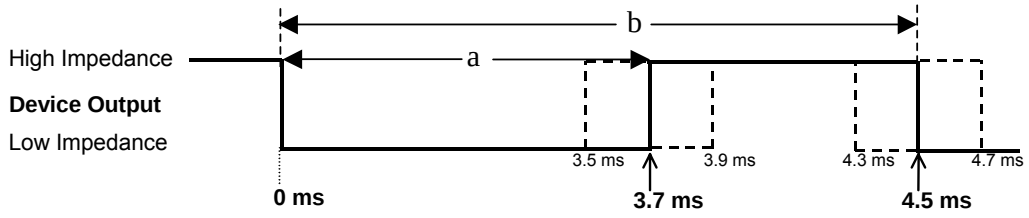
The Initiator provides bit timing and bit leading edges. Only one Initiator is allowed at any one time. A control signal line arbitration mechanism avoids conflict when more than one Initiator begins transmitting at the same time.

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).

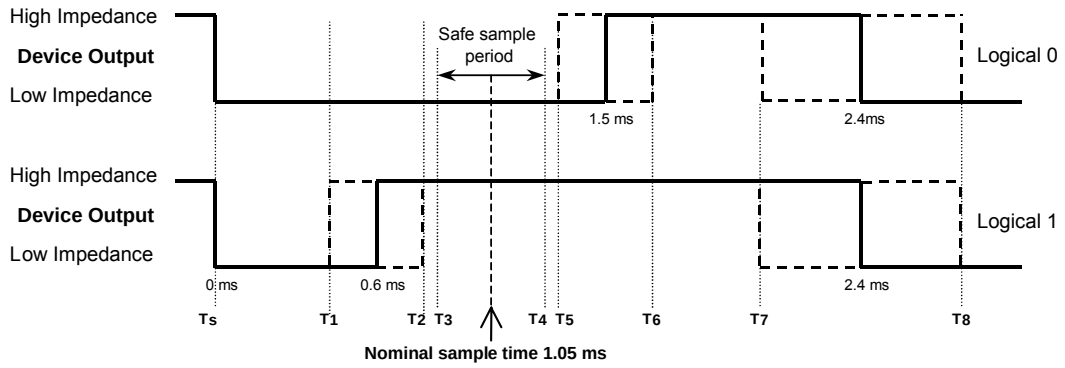


CEC Figure 3 Start bit pulse format showing minimum and maximum tolerances

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.

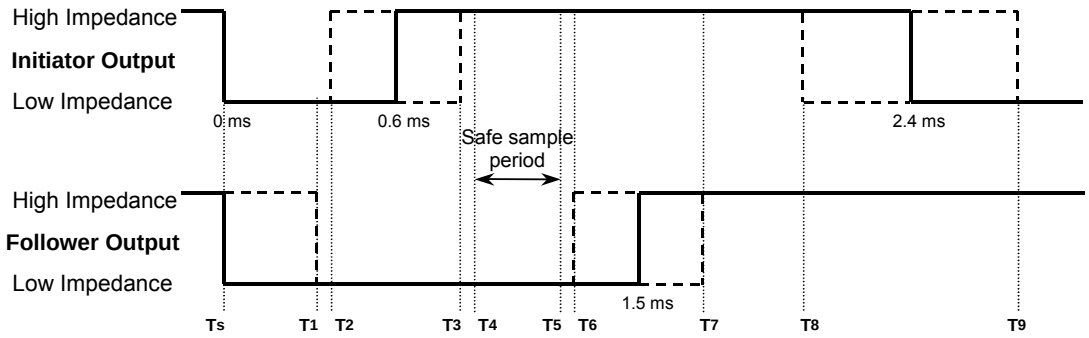
The high to low transition at the end of a data bit is the start of the next data bit and only occurs if there is a following data bit; after transmission of the final bit the CEC line remains high.



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.



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)

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.

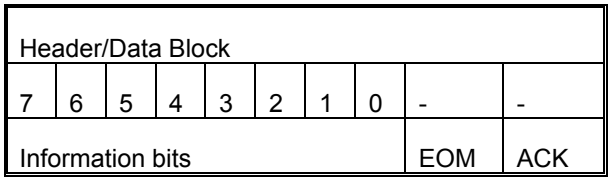
CEC Table 3 Frame Description

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 8 to CEC Table 26
Data Block 2 (operand blocks)	Operand(s) specific to opcode (optional, depending on opcode)	See CEC Table 29

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.



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.

In the event that EOM is zero and no further Data Blocks are received, the Follower shall ignore the entire message.

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:

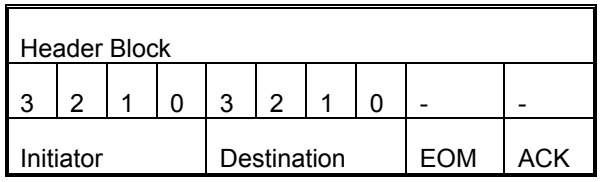
- A Follower that reads its own address in the Destination address field shall acknowledge with a '0' ACK bit.
- All other devices shall not assert the ACK bit to logical '0'.
- A '0' read by the Initiator therefore indicates a successful transmission of the data or Header Block.

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.



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.

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 Initiator device can assume this after 1 second.

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-transmission shall be after a signal free time as described in CEC Table 4. If the re-transmission is as a result of a <Polling Message> for a secondary task (see section CEC 12.2), then it is recommended to send only one re-transmission.

The Re-transmission mechanism shall only be used for transport errors such as frame not ACK'd (i.e. it has not been positively acknowledged or has been negatively acknowledged, according to message addressing, see above). It shall not be used for application errors, e.g. in response to a <Feature Abort> or an incorrect or unexpected application response - see section CEC 12.2, Protocol General Rules and section CEC 12.3, Feature Abort.

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 Data Blocks is less than the number specified for that opcode. Note that for some CEC messages, the number of Data Blocks can vary.

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 send a re-transmission later.

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.

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.

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 (except for devices using Logical Address 15, where several devices may take this address with reduced functionality). Except for Logical Addresses 14 and 15, the Logical Address defines a device type as well as being a unique identifier. These are specified in CEC Table 5.

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 as indicated in CEC Table 8 to CEC Table 26. If a physical device contains the mandatory functions of more than one device type then it should take the Logical Addresses for each of those device types. For example, 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). A home theater system (e.g. DVD Player with integrated Amplifier) may take one of the addresses 4, 8 or 11 (Playback Device) in addition to address 5 (Amplifier).

- If a device wants to advertise Amplifier functionality, it shall try to allocate the relevant ‘Audio System’ (5) Logical Address;
- If a device wants to advertise TV functionality and has Physical Address 0.0.0.0, it shall try to allocate the relevant ‘TV’ (0) Logical Address. If the 'TV'(0) Logical Address cannot be allocated it may try to allocate the 'Specific Use' (14) Logical Address (note that allocating the 'Specific Use' (14) Logical Address might result in reduced functionality being available);
  - A TV at a Physical Address other than 0.0.0.0 shall try to allocate the ‘Specific Use’ (14) address. If address 14 is already allocated it shall take the ‘Unregistered’ Logical Address (15).
- Else if the device can become an Active Source, then:
  - If it wants to advertise recording functionality (that can be controlled via CEC), it shall try to allocate one of the ‘Recording device’ Logical Addresses;
  - If it wants to advertise tuning functionality (that can be controlled via CEC), it shall try to allocate one of the ‘Tuner’ Logical Addresses;
  - Otherwise, it shall try to allocate one of the "Playback device" addresses;

- For a Special Device (see CEC 10.2.2) using a single CEC line (see CEC Figure 9A and CEC Figure 10A), or for the output (secondary CEC Line side) of a Special Device which has both primary and secondary CEC lines (see CEC Figure 9B and CEC Figure 10B):
  - If it wants to advertise being a second TV, then it shall try to allocate 'Specific Use' (14) Logical Address. Such a device uses "TV" for [Device Type] when sending a <Report Physical Address> message;
  - If it wants to advertise being a Video Processor (see CEC Table 29), then it shall try to allocate 'Specific Use' (14) Logical Address. Such a device uses "Video Processor" for [Device Type] when sending a <Report Physical Address> message;
  - Else if it wants to advertise any other functionality in the special device, such as a Tuner, it shall try to allocate a Logical Address for each device type that it wishes to advertise.
  - For a "Special Device" which has both primary and secondary CEC lines the input (primary CEC line) side shall try to allocate the relevant 'TV' (0) Logical Address.
- If a device is a pure CEC Switch or CDC-only device according to Supplement 2 or it does not want to advertise any functionality, it shall take the 'Unregistered' Logical Address (15).

'Specific Use' Logical Addresses (14) shall only be used for those cases described above.

It is allowed for a device to declare the functionality of another device type by using a different Logical Address. For example a recordable DVD device may take the address 4, 8 or 11 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' Logical 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.

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	Specific 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).

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.

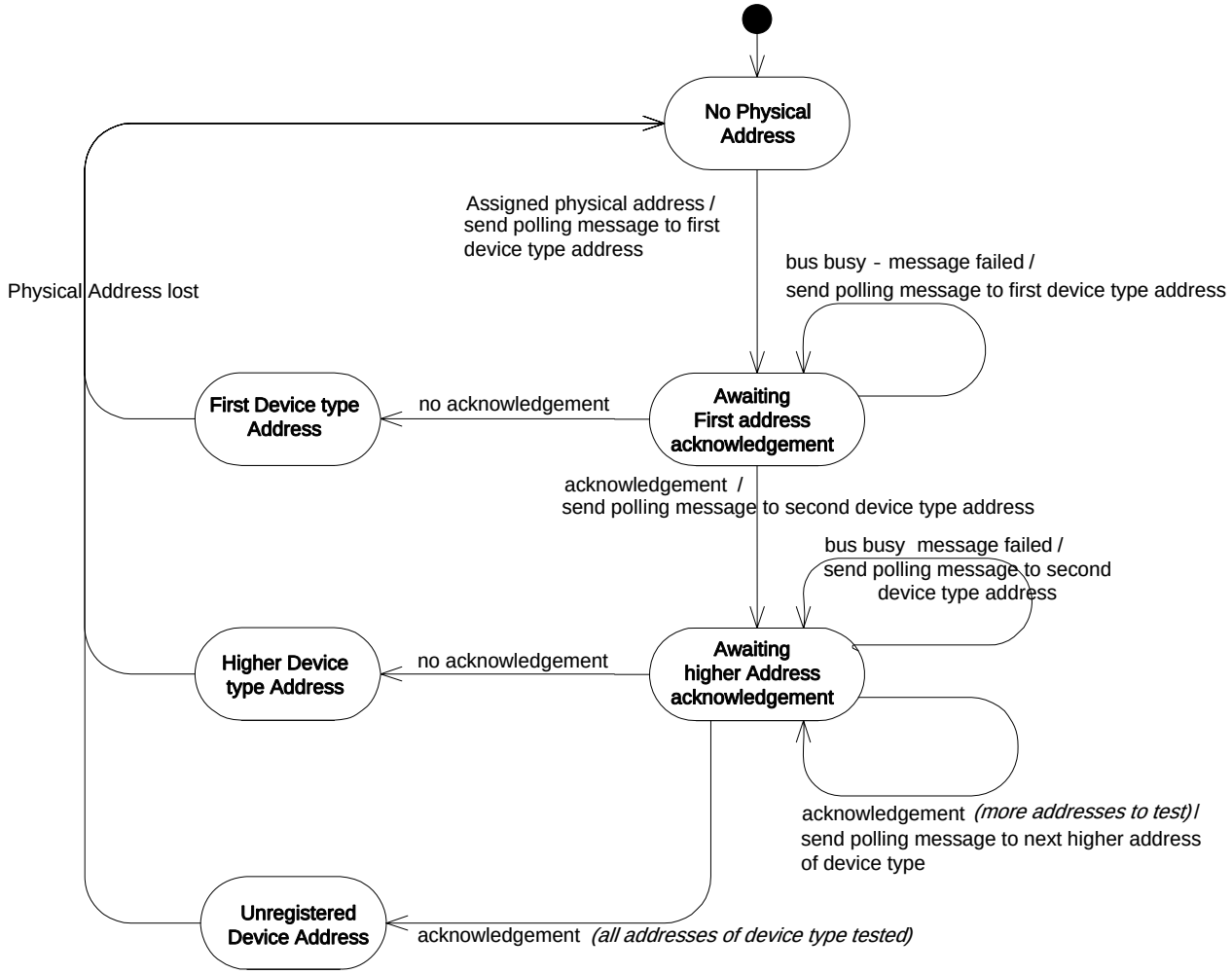
If the first address is acknowledged, then the device takes the next address for that device type and repeats the process (e.g. 'Tuner 2' → 'Tuner 2'). Again, if the message is not acknowledged, the device keeps that address.

This procedure continues until all possible 'type specific' Logical Addresses have been checked; if no 'type specific' Logical Addresses are available the device should take the unregistered address (15). Note that several physical devices might be sharing this address.

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.

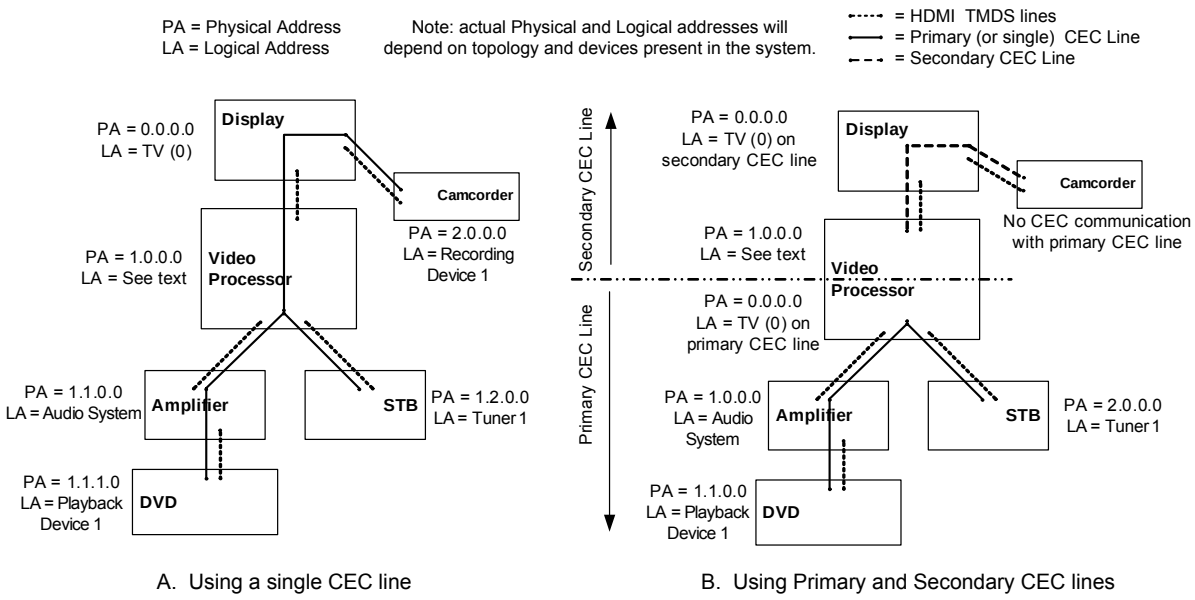
If a device loses its Physical Address at any time (e.g. it is unplugged) then its Logical Address should be set to ‘Unregistered’ (15).



CEC Figure 8 Logical Address Allocation

CEC 10.2.2 Special Devices

Some implementations, for instance a TV, may be implemented using “split architecture”, i.e. as two physically separate boxes consisting of the display device itself (such as an LCD panel) which is connected using HDMI and CEC to an associated Video Processor (also called control box or media receiver), which carries the HDMI inputs. The display (panel) takes Logical Address ‘TV’ (0).



A. Using a single CEC line

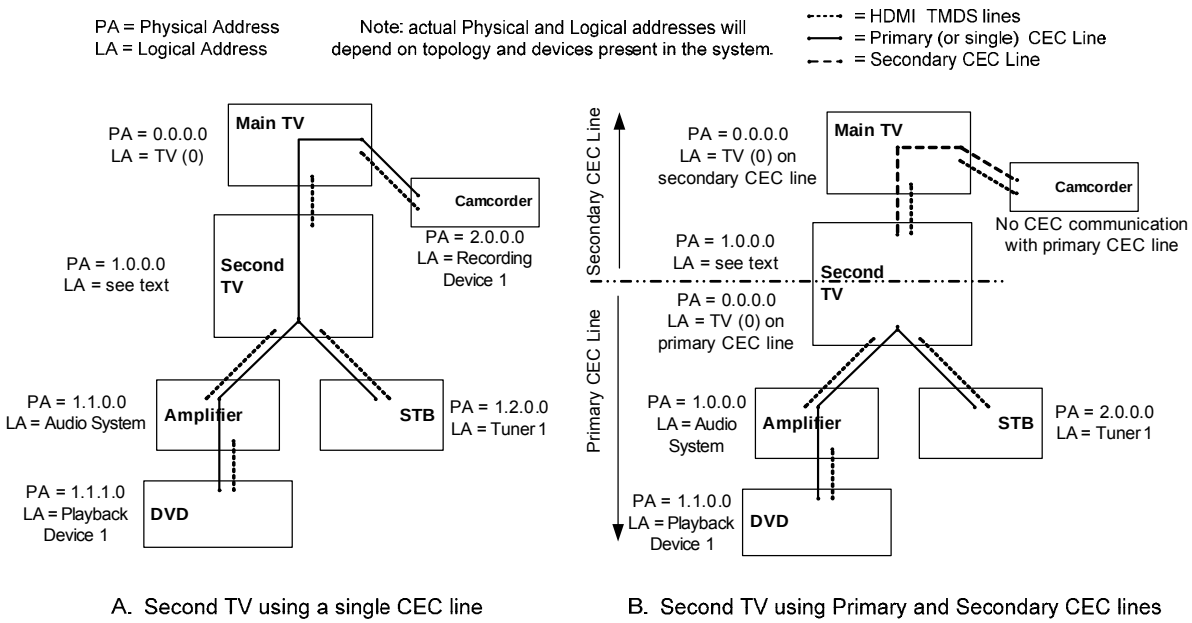
B. Using Primary and Secondary CEC lines

CEC Figure 9 Examples of CEC systems with a "split architecture" TV

In CEC Figure 9A, the CEC line is connected between the panel and the Video Processor using a single CEC line. A device directly connected to the panel (such as the camcorder in the example) can use CEC. If the Video Processor has other functionality (e.g. a Tuner) that is available for control via CEC, then it tries to take a Logical Address for that functionality. If it has no other such functionality, it takes the 'Unregistered' Logical Address (15), or tries to take the 'Specific Use' Logical Address (14) if it needs direct addressing – see CEC 10.2 for full details.

It is also possible to connect the display to the Video Processor using a secondary CEC line that is completely independent of the primary CEC line, i.e. the two CEC lines are not physically connected in the Video Processor, see CEC Figure 9B and section 4.2.10 of the HDMI specification. The primary CEC line is used to connect the Video Processor to all other HDMI devices. In this case also, the display panel takes Physical Address 0.0.0.0 and Logical Address 0 on the secondary CEC line. On the secondary CEC line the Video Processor is allocated Physical Address 1.0.0.0. If it has other functionality that is available for control via CEC on the secondary CEC line (e.g. a Tuner), it tries to take a Logical Address for that functionality. If it has no other functionality, it takes the 'Unregistered' Logical Address (15), or tries to take the 'Specific Use' Logical Address (14) if it needs direct addressing – see CEC 10.2 for full details. On the primary CEC line (connected to the other HDMI devices) the Video Processor takes Physical Address 0.0.0.0 with Logical Address 'TV' (0). Note that in this situation, it is not possible for any device connected using the secondary CEC line directly to the display to have CEC communications with devices using the primary CEC line.

CEC Figure 10 below shows how a second TV can be used. In both these examples, the second TV may take the Specific Use Logical Address (14) and/or the Logical Address of any other functionality in the TV, such as a Tuner – see CEC 10.2 for full details. In the example with both primary and secondary CEC lines, the second TV takes these addresses on the secondary CEC Line.



A. Second TV using a single CEC line

B. Second TV using Primary and Secondary CEC lines

CEC Figure 10 Example of the use of a second TV

CEC 10.2.3 Behavior with Earlier Versions

Version 1.4 allows the use of Logical Address 'Specific Use' (14) for devices which are not additional TVs and which also need direct addressing. Such use was not mentioned in Versions 1.3a and earlier and behavior with these devices is undefined.

Version 1.4 adds new values of "Video Processor" and "Pure CEC Switch" to [Device Type], see CEC Table 29. Behavior with devices conforming to Versions 1.3a and earlier is undefined.

Version 1.3a added new Logical Addresses of 'Tuner 4' and 'Playback Device 3': these will not be recognized by devices conforming to CEC specifications before Version 1.3a.

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. Although the TMDS connections are switched, the CEC line itself is not changed since all CEC lines are connected together internally in the device, see HDMI specification section 4.2.10.

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 CEC Switch, i.e. it allocates the address for devices connected to the inputs of the CEC Switch. This means that any device connected to the CEC Switch will always have a valid Physical Address (assuming the CEC Switch itself has a valid Physical Address). Therefore, any device below the CEC Switch may take a Logical Address and can react to CEC messages in a normal way. The CEC Switch is effectively transparent and will enable all standard CEC communications in its connected source devices.

A CEC Switch is defined as a device that has its own Physical Address, sends CEC messages and is controlled by receiving/monitoring CEC messages and has:

- only one HDMI input and has no internal sources and no non-HDMI inputs. This device has one HDMI output and e.g. is a Repeater or does video processing from input to output; or
- two or more HDMI inputs and can select between one of those inputs for HDMI output or rendering; or
- one or more HDMI inputs and can select between one of those HDMI inputs and some non-HDMI inputs or internal sources, for HDMI output or rendering. For example, the device may have, in addition to an HDMI input, a number of non-HDMI inputs, such as SPDIF, or an internal source such as a tuner or playback device. In this example, the CEC Switch can select between an HDMI input, an external SPDIF input, or an internal tuner or playback device, for HDMI output or rendering.

If a device does not have a Physical Address, then it is not a CEC Switch.

For further details of behavior and implementation for CEC Switches (as defined above), see CEC 13.2, Routing Control.

A CEC Switch can be part of another device, such as a TV or Amplifier. A device implementing CEC Switch functionality with such other functionality shall provide its advertised functionality (e.g. TV or Audio System) in addition to its CEC Switch functionality. In these cases, the CEC Switch takes the relevant address of its advertised functionality, i.e. 0 (‘TV’) or 5 (Audio System). The power control for the CEC Switch functionality should be separate from the power control for the other functionality so that the CEC Switch can be active even when the main functionality is in Standby – see CEC 13.2.2 for more details.

A device that is a “pure” CEC Switch and has no other functionality uses the ‘Unregistered’ Logical 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 CEC 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 CEC

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.

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 8 to CEC Table 26.

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>; or
- the message is a <Report Physical Address> or an <Active Source> (if the Follower wants to use); or
- the message is a CDC message that the Follower supports.

If a message was successfully received (i.e. was correctly ACK'd) but failed at the application level (e.g. <Feature Abort> or an incorrect or unexpected response), then the Initiator should limit the number of times it sends the same message (e.g. while waiting for a particular application state of the Follower).

If a <Polling Message> has not been ACK'd, the device is not present or is not in a state to respond, then repeated polling of these addresses should be limited.

If a device wishes to send a <Polling Message> for a secondary or background task, it should not disturb any primary or main tasks such as those tasks which have been initiated by the user. In this case such a secondary or background <Polling Message> (which is not the direct result of a user-initiated action or Logical Address allocation) should not be sent more frequently than once every 500ms.

If such a secondary <Polling Message> is not ACK'd, then the Initiator may send re-transmissions according to section CEC 7.1. In this case, it is recommended not to send more than one re-transmission.

For messages that return a response:

- Initiators should not rely on answers coming back in the same order as the requests that were sent out;
- Response messages might be interleaved with other messages initiated by the addressed device, or other devices;
- sending the same opcode (or the same vendor command contained in a <Vendor Command> or <Vendor Command with ID> message) to the same device more than once without first waiting for the reply may cause problems.

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 reasons for rejection are indicated in the [Abort Reason] Operand, which are specified in the individual Feature descriptions (see CEC 13). If no [Abort Reason] is specified in those sections, devices may use the following values to indicate the reason for rejection:

"Unrecognized opcode":	the device never recognizes or supports that opcode.
"Not in correct mode to respond":	the device recognizes and supports the opcode and any operands, but cannot perform that action in its current application mode. Some examples are: - the device supports a message when it is in the active state, but not during the Standby state; - it is currently recording.
"Cannot provide source":	the device recognizes and supports the opcode and any operands, but cannot provide the source signal.
"Invalid operand":	the device recognizes and supports the opcode, but does not recognize or support the operand.
"Refused":	the device recognizes and supports the opcode and operands, but is prevented from taking that action because of some other rules, such as copy protection or parental lock. Note that messages like <Record Status> provide more comprehensive information, whereas a <Feature Abort> "Refused" can be used in response to a Remote Control Passthrough command e.g. for recording.
"Unable to determine"	the device is in a state, such as Standby, where it cannot determine if the opcode or operands are supported by the device.

Note that if the device is in the Standby state it might not be able to respond with an accurate [Abort Reason] because full information may only be available when the device is active.

Note: Devices implementing Versions 1.3a or earlier will not respond with the "Unable to determine" code and are likely to respond with a "Not in correct mode to respond" code.The reaction to a faulty message by the Follower depends on whether 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 the <Feature Abort> [Abort Reason] was “Unrecognized opcode”, the Initiator should not send the same message to the same Follower again at that time to avoid saturating the bus. .

If the [Abort Reason] was other than “Unrecognized opcode”, the Initiator may send the message again. It is recommended that it waits for at least 200ms in order to 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.

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. Details of which messages are mandatory for each Feature are shown in CEC Table 8 to CEC Table 26. The support for some messages depends on which other messages are supported – for details see CEC Table 27 and CEC Table 28. Details of Operands for use with the messages are shown in CEC Table 29**.**

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>

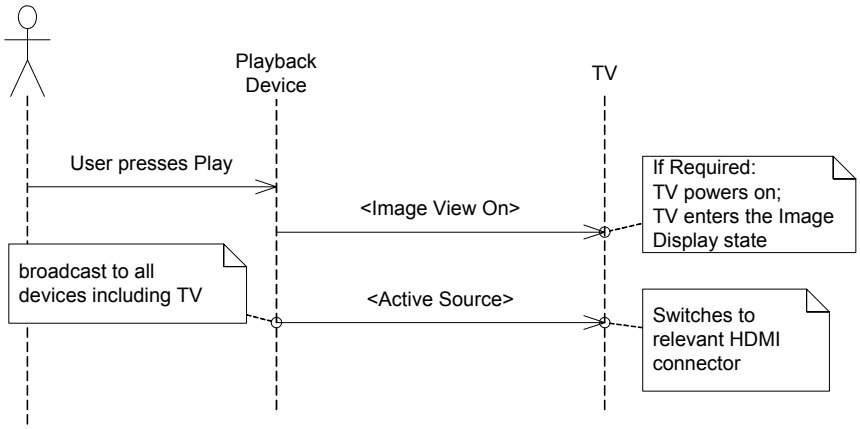
For details of which messages are mandatory, see CEC Table 8, CEC Table 27 and CEC Table 28.

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 11 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 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 active source it shall broadcast an <Active Source> message. The currently active source shall lose its active source status on receiving an <Active Source> message from another device.

Note: there is a special case when a TV switches to its internal tuner or to another non-HDMI source (e.g. 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 Behavior with Earlier Versions

There is no change in behavior for this Feature between Version 1.4 and Version 1.3a.

When sending this Message	From Version 1.3 or earlier Device	To Version 1.3a or later Device	Possible behavior
<Image View On>	Any source	TV	The TV might not keep its current menu on the screen
<Text View On>	Any source	TV	The TV might 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>

For details of which messages are mandatory, see CEC Table 9, CEC Table 27 and CEC Table 28.

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. CEC Switches shall not send a <Routing Change> message in this case. Devices which have other functionality and which also incorporate a CEC Switch, such as an Amplifier with several HDMI inputs, need only bring the CEC Switch part out of the Standby state as a response to the <Active Source> message, leaving the other functionality (e.g. Amplifier) still in the Standby state.

Whenever a device becomes the new active source it shall broadcast an <Active Source> message. The currently active source shall lose its active source status on receiving an <Active Source> message from another device.

When a device comes out of the Standby state 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 the Standby state some time after its source device(s). In this case it might not know the currently active source and it might not know which is the relevant connector to use (if the TV has multiple HDMI connectors), because it was in the Standby state or powering up when the device sent its <Active Source> message. Here, the <Request Active Source> message and the corresponding <Active Source> response are used to identify the relevant connector.

When the System Audio Control feature is started by an Amplifier (e.g. as a result of a local user command on the Amplifier), the <Request Active Source> message 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. CEC Switches shall not send a <Routing Change> message in this case. 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 the Standby state (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 (e.g. 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 the Standby state (e.g. 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.

The user may manually change a CEC Switch. When the user switches a CEC Switch:

- from one HDMI input to another HDMI input, it shall broadcast a <Routing Change> message. This will inform all devices in the network that the current active route below the CEC Switch has changed. The device that has been deselected by a CEC Switch loses its Active Source status.
- from an HDMI source to a non-HDMI source (e.g. to an internal tuner in the TV or Amplifier; or external SPDIF input on an Amplifier), then it should not send a <Routing Change> message.
  - if the CEC Switch wants to present stable video (which is originating from that non-HDMI source) via HDMI to the user and wants to act as a new Active Source, the CEC Switch shall broadcast an <Active Source> message with its own Physical Address.
  - if the TV is changed to its internal tuner or an external non-HDMI input connected directly to the TV, it shall broadcast an <Active Source> message with its own Physical Address.
- from a non-HDMI (or internal) source to an HDMI input, then the device should send a <Routing Change> message to determine the HDMI path below the CEC Switch.

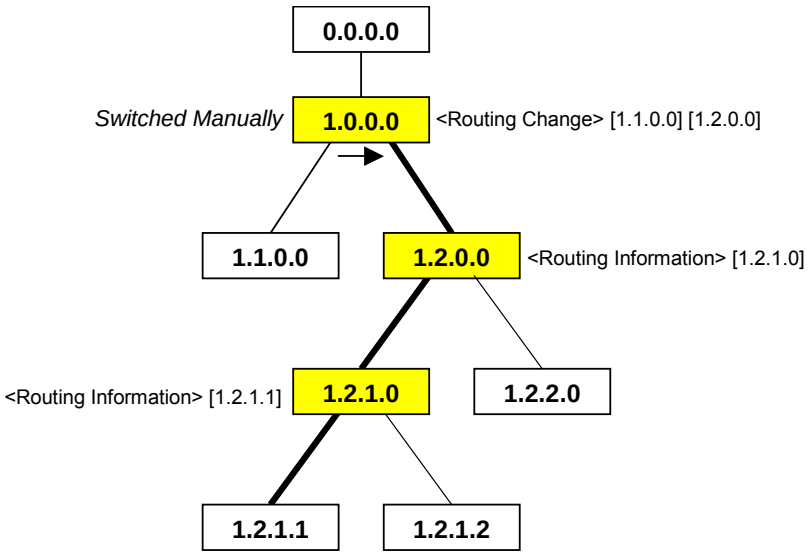
If a CEC Switch is at the new position indicated by the <Routing Change> message then it shall broadcast a <Routing Information> message with the Physical Address of its current active path. If a CEC Switch at the new position receives a <Routing Information> message then it shall broadcast a <Routing Information> message to indicate its 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.

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.

A TV (when it is the Root Device at Physical Address 0.0.0.0) does not implement the <Routing Information> message as an Initiator.

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 12 Example message flow, when a CEC Switch is manually switched

CEC 13.2.3 Behavior with Earlier Versions

There is no change in behavior for this Feature between Version 1.4 and Version 1.3a.

Some CEC Switches and TVs conforming to Version 1.3a or earlier might send a <Routing Change> message when they receive <Active Source> or <Set Stream Path> messages.

The <Inactive Source> message was new in Version 1.3a.

CEC 13.3 System Standby

CEC 13.3.1 Messages

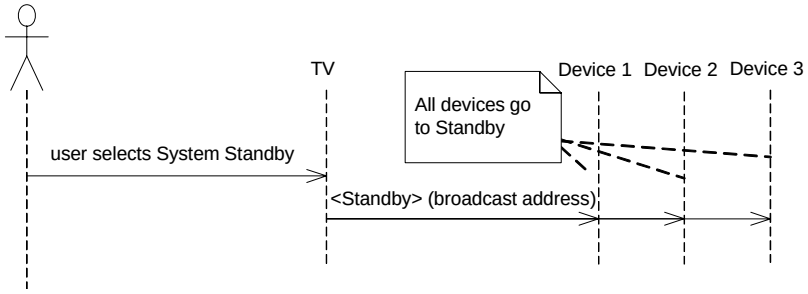
The following message is used for the System Standby feature:

<Standby>

For details of which messages are mandatory, see CEC Table 10, CEC Table 27 and CEC Table 28.

CEC 13.3.2 Feature Description

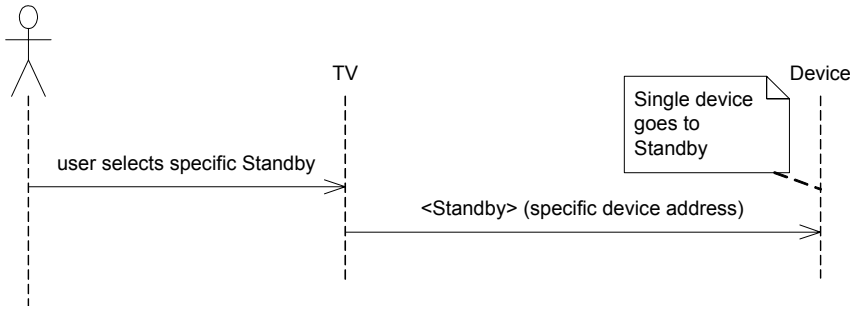
The broadcast message <Standby> can be used to switch all CEC devices to the Standby state. A typical scenario where the user sets the whole system to the Standby state is shown below:



CEC Figure 13 A typical scenario for the broadcast (system) Standby feature

The whole system may be set to the Standby state 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 the Standby state by sending the message <Standby> as a directly addressed message to it.



CEC Figure 14 A typical scenario for the Standby feature to a specific device

When a source device is put to Standby by the user (e.g. by its own remote control or local key), it shall not broadcast a system <Standby> message unless explicitly requested by the user.

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.

Devices can ignore <Standby> messages if they are in a state where going into the Standby state 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 Behavior with Earlier Versions

There is no change in behavior for this Feature between Version 1.4 and Version 1.3a.

When sending this Message	From Version 1.3a or later Device	To Version 1.3 or earlier Device	Possible behavior
<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:

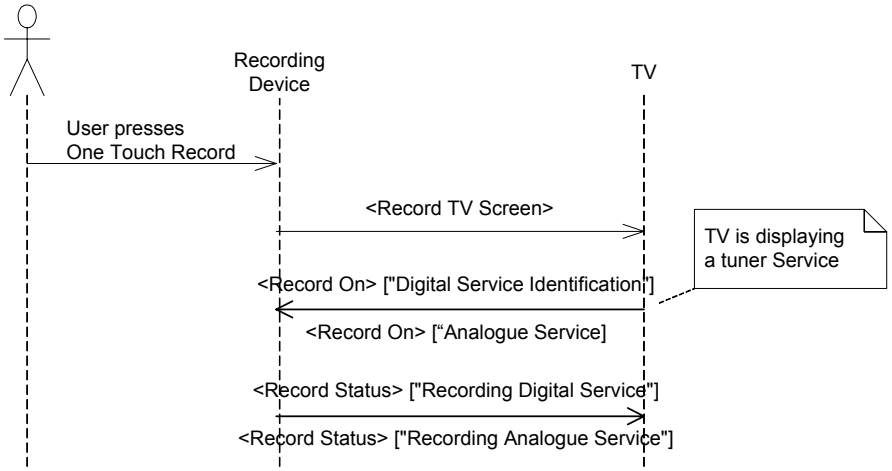
<Record Off>, <Record On>, <Record Status>, <Record TV Screen>

For details of which messages are mandatory, see CEC Table 11, CEC Table 27 and CEC Table 28.

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.



CEC Figure 15 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 (e.g. 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.

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 or more 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, e.g. 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' Logical Address (a future device type).

CEC 13.4.3 Behavior with Earlier Versions

There is no change in behavior for this Feature between Version 1.4 and Version 1.3a.

When sending this Message	From Version 1.3a or later Device	To Version 1.3 or earlier Device	Possible behavior
<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 was new in 1.3a

When sending this Message	From Version 1.3 or earlier Device	To Version 1.3a or later Device	Possible behavior
<Record On>	TV	Recording Device	<Feature Abort> as <Record On> is optional in 1.3a or later

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>

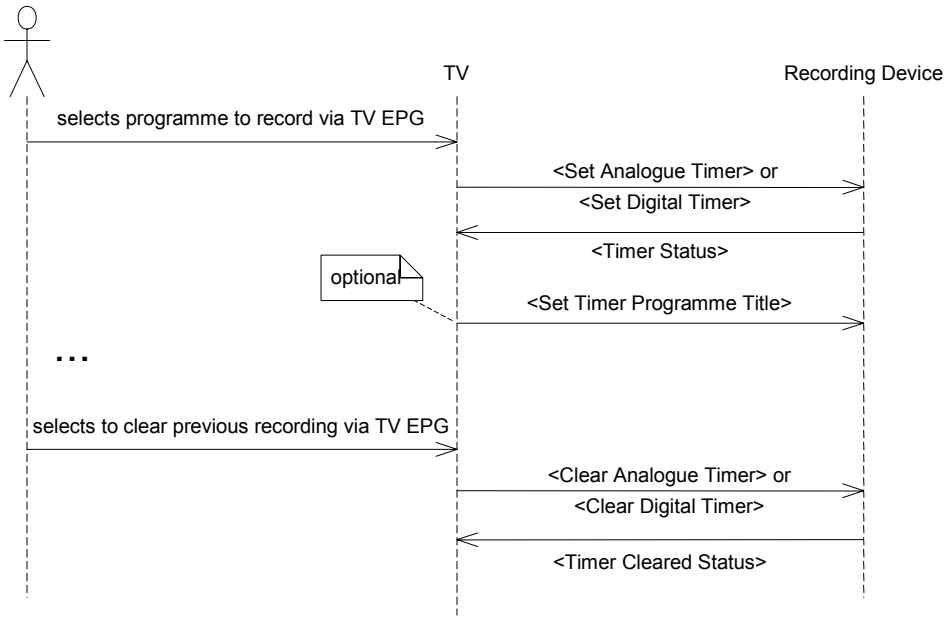
For details of which messages are mandatory, see CEC Table 12, CEC Table 27 and CEC Table 28.

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, 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 16 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 (e.g. transmission system and/or CA). Note that it may take several seconds or more before a recorder is able to send an accurate <Timer Status> or <Timer Cleared Status> after receiving the relevant Set Timer or Clear Timer message.

The Recording Device may optionally include an estimate of the duration available on the media when:

- There is not, or might not be, sufficient space available for recording; or
- The timer was not successfully programmed because the event already exists.

Note that duration estimate might 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 respond with a <Feature Abort> message to 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.

CEC 13.5.3 Performing a Timed Recording using another device as source

When recording using another source device, e.g. 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 (e.g. 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 (e.g. 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 (i.e. after receiving the <Record Off> message), unless it is the Active Source at the end of the recording.

CEC 13.5.4 Behavior with Earlier Versions

There is no change in behavior for this Feature between Version 1.4 and Version 1.3a.

This feature was introduced in Version 1.3a. Devices conforming to Version 1.3 or earlier will respond with a <Feature Abort> message to 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:

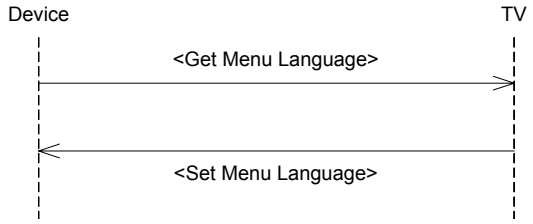
<CEC Version>, <Get CEC Version>, <Get Menu Language>, <Give Physical Address>, <Polling Message>, <Report Physical Address>, <Set Menu Language>.

For details of which messages are mandatory, see CEC Table 13, CEC Table 27 and CEC Table 28.

CEC 13.6.2 Feature Description

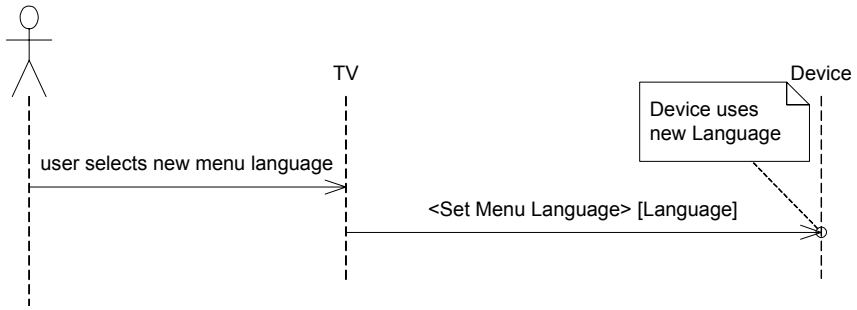
This feature allows devices to automatically use the same OSD and Menu language settings as the TV.

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 17 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 18 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. This message may be ignored by:

- devices where the user has specifically disabled this function; or
- Mobile Devices; or
- devices which are not able to change the language by CEC messages, e.g. a PC; or
- devices without OSD/ Menu generation capabilities.

If the device does not support the requested language, it shall ignore this <Set Menu Language> message.

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).

Devices which have Logical Addresses other than 0 (TV) or 14 (when a TV) shall send a <Feature Abort>[“Unrecognized opcode”] message in response to a <Get Menu Language> messages and shall not send <Set Menu Language> messages.

When identifying a language, the Bibliographic codes of ISO/FDIS 639-2 [ref 1n] shall be used. In accordance with this standard, only codes using strings of lower-case characters shall be used by a TV. For robustness reasons, non-TV devices should accept any mixture of upper- and lower-case characters.

Note that in the case of Chinese, both the Terminology code "zho" and the Bibliographic code "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 may ask another device to indicate which Version of CEC the target device supports. It shall do this by sending a <Get CEC Version> message. The target device should respond with a <CEC Version> message, which includes the relevant [CEC Version] operand.

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.

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 Behavior with Earlier Versions

<CEC Version> for devices conforming to Version 1.4 and later does not give any information about the HDMI Version used.

<Set Menu Language>: Non-TV devices conforming to Versions 1.3a and earlier may broadcast this message and might not accept a mixture of upper- and lower-case characters for [Language].

<Get Menu Language>: A TV conforming to Versions 1.3a and earlier may send this message.

<Get CEC Version> and <CEC Version> were new messages for 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>

For details of which messages are mandatory, see CEC Table 14, CEC Table 27 and CEC Table 28.

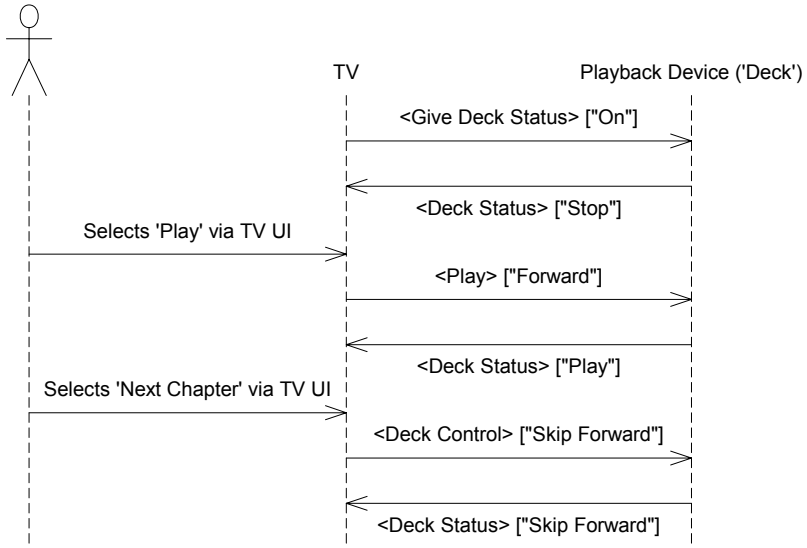
CEC 13.7.2 Feature Description

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 the Standby state 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 19 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 (e.g. 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 might 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 Behavior with Earlier Versions

There is no change in behavior for this Feature between Version 1.4 and Version 1.3a.

There are no differences for this Feature between a Version 1.3a device and a device implementing earlier versions of CEC.

CEC 13.8 Tuner Control

CEC 13.8.1 Messages

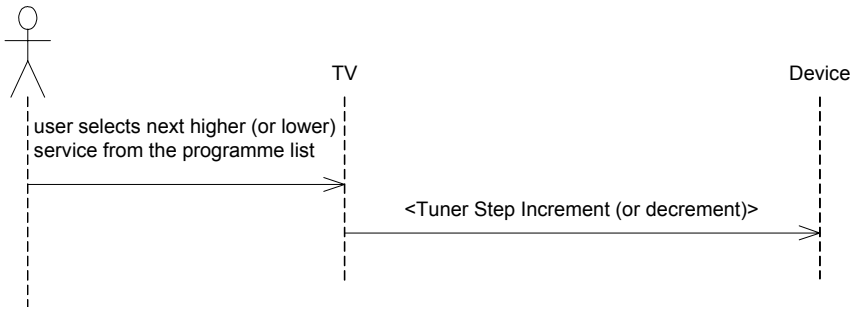
The following message are used for the Tuner Control feature:

<Give Tuner Device Status>, <Record On>, <Select Analogue Service>, <Select Digital Service>. <Tuner Step Decrement>, <Tuner Step Increment>, <Tuner Device Status>

For details of which messages are mandatory, see CEC Table 15, CEC Table 27 and CEC Table 28.

CEC 13.8.2 Feature Description

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



CEC Figure 20 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 Behavior with Earlier Versions

There is no change in behavior for this Feature between Version 1.4 and Version 1.3a.

<Select Analogue Service> was a new message for 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>

For details of which messages are mandatory, see CEC Table 16, CEC Table 27 and CEC Table 28.

CEC 13.9.2 Feature Description

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

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.

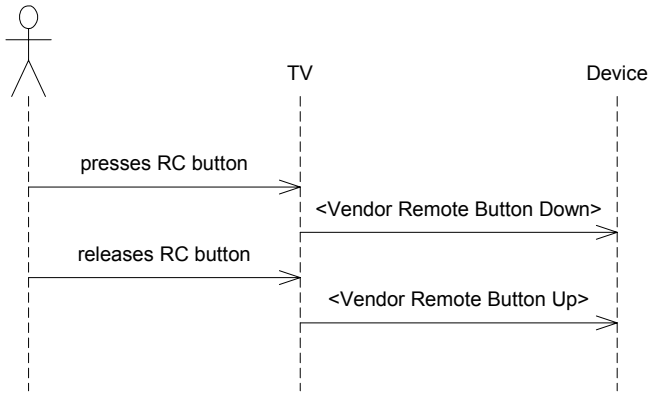
A Follower device may accept a <Vendor Command> from an Initiator of the same Vendor ID. With the agreement of the vendors involved, it is also possible for a device to accept a <Vendor Command> from devices made by other vendors. The Follower may accept a <Vendor Command> only if the Initiator's Vendor 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. This behavior was not allowed in Versions before 1.3a and so a device that wishes to send <Vendor Command> messages between different vendors in this way shall first discover whether the target conforms to Version 1.3a or later, by sending a <Get CEC Version> message. A Follower conforming to Version 1.3a or later and supporting such <Vendor Command> messages between different vendors shall respond with a <CEC Version> message. If the Follower responds with a CEC Version of 1.3a or later, then the Initiator device can continue by sending the required <Vendor Command>. Note that sending a <Get CEC Version> message does not need to be done every time a device wishes to send a <Vendor Command> to another device from a different vendor - if the Initiator already knows the CEC Version of the target then it is not necessary to send a <Get CEC Version> message.

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. These messages use the mechanism and timing, as described in section CEC 13.13.2 Remote Control Pass Through, for <User Control Pressed> and <User Control Released> messages.



CEC Figure 21 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 Behavior with Earlier Versions

There is no change in behavior for this Feature between Version 1.4 and Version 1.3a.

<Vendor Command With ID> was a new message for Version 1.3a.

In Version 1.3a or later, 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>

For details of which messages are mandatory, see CEC Table 17, CEC Table 27 and CEC Table 28.

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. The time that the OSD string is displayed on the TV is specified by the [Display Control] parameter:

- "Display for default time": the display is shown for a default period defined by the TV, e.g. 5 seconds, and then removed automatically;
- "Display until cleared": the string is displayed on the screen until it is explicitly cleared or its power is removed. When an Initiator uses this value it shall send a <Set OSD String> message containing a [Display Control] parameter of "Clear previous message" in order to clear the message after the user has had time to read the message;
- "Clear previous message" clears any displayed string. Note that when [Display Control] has this value, the [OSD String] parameter shall not be used.

The TV shall display the whole string unless it is in an unsuitable state or it cannot display the complete message, in which case it shall generate a <Feature Abort> message with relevant [Abort Reason], e.g. "not in correct mode to respond" or "invalid operand".

If a new <Set OSD String> message with a [Display Control] of "Display for default time" or "Display until cleared" 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 Behavior with Earlier Versions

TV's conforming to Version 1.3a or earlier might not respond with a <Feature Abort> message when they are not able to display the complete string.

There are no differences for this Feature between a 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>

For details of which messages are mandatory, see CEC Table 18, CEC Table 27 and CEC Table 28.

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 device's 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 device's name should then be used in on-screen references to it.

A device that implements more than one type of CEC functionality, e.g. a recorder with an internal tuner, and has more than one Logical Address (see CEC 10.2) should respond with the same [OSD Name] for each Logical Address. It is recommended that the [OSD Name] refers to the complete physical product, rather than the individual CEC functionality, in order to avoid user confusion. It is manufacturer-dependent how the individual CEC functionalities (e.g. the tuner or recorder in the above example) are presented to the user.

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

CEC 13.11.3 Behavior with Earlier Versions

Devices conforming to Version 1.3a or earlier with several Logical Addresses might respond with a different [OSD Name] for each implemented Logical Address.

A TV conforming to Version 1.3a or later might 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>

For details of which messages are mandatory, see CEC Table 19, CEC Table 27 and CEC Table 28.

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 the User Control messages and timing 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 Behavior with Earlier Versions

There is no change in behavior for this Feature between Version 1.4 and Version 1.3a.

There are no differences for this Feature between a Version 1.3a device and a device implementing earlier versions of CEC.

CEC 13.13 Remote Control Pass Through

CEC 13.13.1 Messages

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

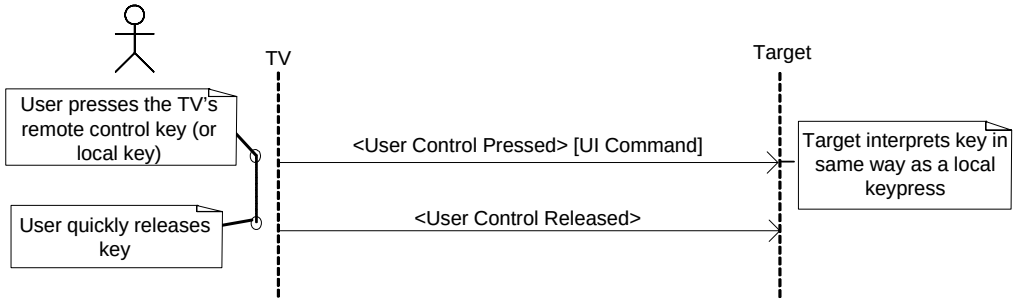
<User Control Pressed>, <User Control Released>

For details of which messages are mandatory, see CEC Table 20, CEC Table 27 and CEC Table 28.

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 typically pass the command through to the appropriate device, see section CEC 13.13.4.

The Initiator will send a <User Control Pressed> message when the remote control button is pressed. When the button is released, devices that do not implement Press and Hold operation (see CEC 13.13.3) should send a <User Control Released> message immediately. For devices that do implement Press and Hold operation, see section CEC 13.13.3.



CEC Figure 22 A typical scenario where the user presses and quickly releases a key

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, for example within the Initiator Repetition Time defined in CEC 13.13.3(1). This has the same effect as sending a <User Control Released> for the first button.

The <User Control Pressed> and <User Control Released> messages indicate that the user has pressed and released the relevant button on their remote control. For the non-Deterministic commands (i.e. those commands in CEC Table 30 which are not mentioned in Table 6), the response may be device-dependent and it is recommended that the Follower interprets those <User Control Pressed> and <User Control Released> messages in the same way as when a user presses and releases the corresponding buttons on device's own remote controller.

If a Follower does not receive a <User Control Released> message (or another <User Control Pressed> message) within an appropriate time period equal to the Follower Safety Timeout period, it shall assume that the button has been released and act accordingly. For details of the Follower Safety Timeout period see CEC 13.13.3 (2), which defines Press and Hold Operation,

A device that has initiated a <User Control Pressed> message shall ensure that it sends a <User Control Released> message before going into the Standby state, if the <User Control Pressed> message requires an associated <User Control Released> message. In the event that the Initiator of the message is powered off or its HDMI cable is disconnected before sending a <User Control Released> message, the Follower will never receive the <User Control Released> message.

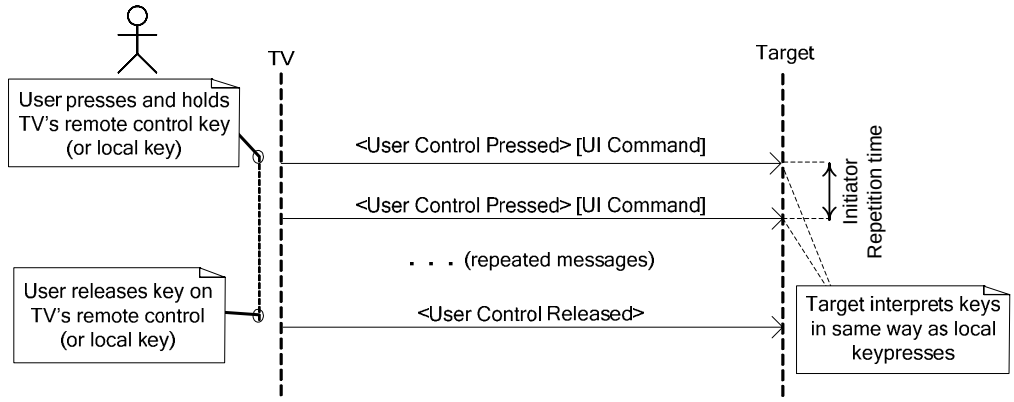
CEC 13.13.3 Press and Hold Operation

Press and Hold Operation is used in order to indicate to another device that the user presses and keeps pressing the same remote control button for a long time. A device supporting Press and Hold Operation as either an Initiator or a Follower shall follow the rules described in this subsection.

(1) Initiator Behavior

When the user presses and keeps pressing the same remote control button for a long time, the Initiator shall send repeated <User Control Pressed> messages containing the same [UI Command]. In this case, the Initiator does not interleave <User Control Released> messages, but it shall send a <User Control Released> message immediately when the user releases the key.

If the user presses and keeps pressing a key for a long time and then releases the first key and presses another key within the Initiator Repetition Time (see below), then it is not necessary to send a <User Control Released> message when the first key is released because the <User Control Pressed> with the second [UI Command] acts as the <User Control Released> message for the first key. If the second key is pressed after the Initiator Repetition Time, the Initiator shall send a <User Control Released> message.



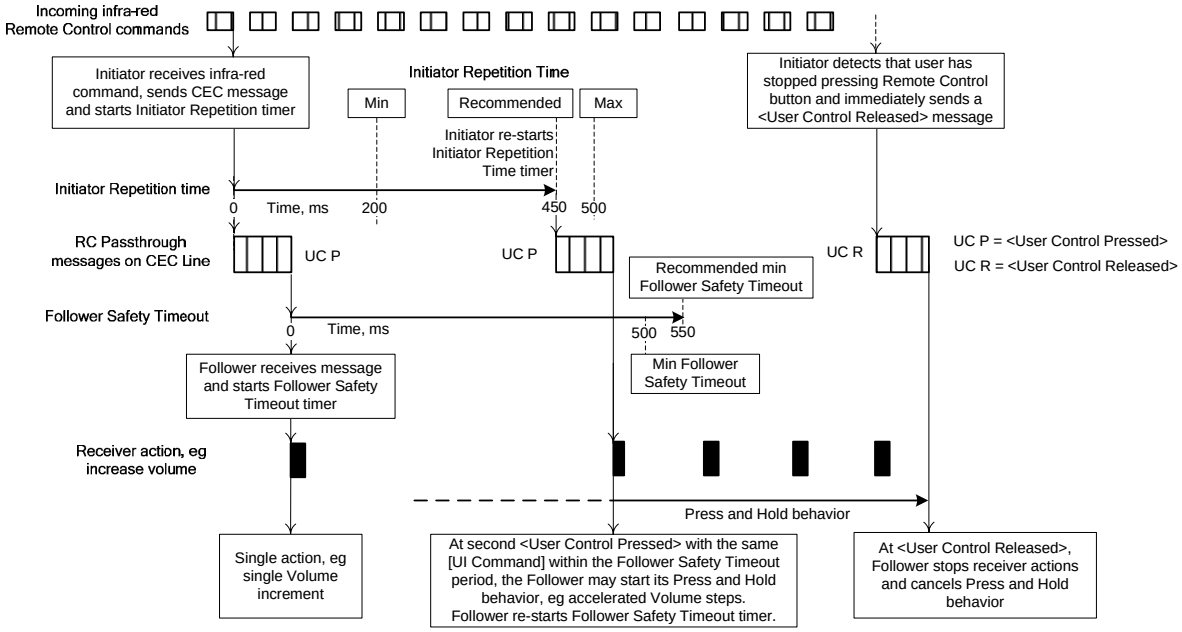
CEC Figure 23 A typical scenario where the user presses and holds a key

When the Initiator sends such repeated <User Control Pressed> messages, it shall send them using an Initiator Repetition Time with a minimum of 200ms and a maximum of 500ms. The recommended Initiator

Repetition Time is 450ms– see CEC Figure 24 below. Implementers should note that using timings near the maximum value may result in incorrect press and hold behavior (as this is very close to the Follower Safety Timeout period of the Follower) and that using timings near the minimum value places an unnecessarily heavy load on the CEC line.

The time between messages for the Initiator Repetition Time is measured from the same point on each message, e.g. between the first falling edge of the Start Bit in each message.

Note that many remote controls send their remote control commands, e.g. using infra-red, at high speeds which are too fast to be carried directly on the CEC line. It is important that the <User Control Pressed> messages shall not be sent using the minimum Initiator Repetition Time specified above.



CEC Figure 24 Initiator Repetition Time, Follower Safety Timeout and Press and Hold behavior

(2) Follower Behavior

The Follower Safety Timeout period of a Follower supporting Press and Hold operation should not be less than 500ms and is recommended to be at least 550ms. The time between messages for the Follower Safety Timeout period is measured from the end of the message, i.e. when the Follower receives a Data Block where the EOM bit is set to '1'.

The Follower shall start the Press and Hold behavior (see CEC Figure 24 above) when another <User Control Pressed> message containing the same [UI Command] is received within the Follower Safety Timeout period.

- The press and hold behavior (e.g. increment step, speed, etc) is defined by the Follower and should have the same behavior when using CEC as when one of the local keys are pressed or when using its own remote control;
- It is optional for the Follower to start Press and Hold behavior after the first <User Control Pressed> message has been received. Note that if the Press and Hold behavior starts at the first <User Control Pressed> message, then the Follower may make several increments before the user can release the key.

The Follower shall stop its Press and Hold behavior for the previous [UI Command] when:

- A <User Control Pressed> message containing a different (new) [UI Command] is received within the Follower Safety Timeout period; or
- The Follower Safety Timeout period has expired.

In the above two cases, the Follower should assume that it has received a <User Control Released> message.

The Follower shall stop its Press and Hold behavior for the previous [UI Command] before it handles the <User Control Pressed> message for a new [UI command].

It is the Follower's decision as to whether the forwarded [UI Command] is executed as a single-shot event or part of a Press and Hold sequence.

CEC 13.13.4 RC Key Forwarding Recommendations

In order to allow for "single remote control" system operation, whereby, for example, the TV's remote controller is used to control other devices by sending User Control messages, the TV should send to the appropriate device as many key presses as possible which the TV does not require itself or does not require in its current state, using <User Control Pressed> and associated <User Control Released> messages.

CEC 13.13.5 Other uses of <User Control Pressed>

The <User Control Pressed> message may also be sent in other cases which are not the direct result of a user interaction, nor directly mapped to a Remote Control key. For example, a TV might offer the user a way to access the root menu of connected devices from a menu in the TV UI. If the user selects that item in the TV UI, the TV will send a <User Control Pressed> ["Root Menu"] to the corresponding device. The Initiator (the TV in this example) should also send the corresponding <User Control Released> message.

If a Follower is not in a state where it can action those messages, e.g. it is in Standby, then it may send a <Feature Abort> message with an [Abort Reason] of "Not in correct mode to respond" (preferred) or "Unable to determine".

In order to deterministically change the power status of the target device, it is recommended to use the relevant deterministic functions 0x6D, 0x6C or 0x6B instead of ["Power"], 0x40, because 0x40 might not have predictable behavior. If it is necessary to deterministically change the power status of the target device by using 0x40, then the Initiator should first enquire the Power Status of the target device by sending a <Give Device Power Status> message. In this case, if the target device is already in the desired power state, then the Initiator shall not send a <User Control Pressed> ["Power"] message.

CEC 13.13.6 Deterministic UI Functions

In CEC Table 30, codes 0x60 to 0x6D are identified as Functions. Unlike the other codes, which just pass remote control presses to the target (often with device-specific results), the Functions are deterministic, i.e. 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 29.

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 device-specific.

2 During a recording or timed recording, a device may ask the user for confirmation of this action before executing it.

CEC 13.13.7 Non-Deterministic Commands with Parameters

Some non-deterministic commands have parameters. Unlike the deterministic Functions, the exact behavior of these commands is not fully specified. The following non-deterministic commands with parameters are defined:

CEC Table 7 Non-deterministic UI commands with parameters

UI Command Code	User Operation	Additional Operands
0x56	Select Broadcast Type	[UI Broadcast Type]
0x57	Select Sound Presentation	[UI Sound Presentation Control]

CEC 13.13.8 Behavior with Earlier Versions

Version 1.4 added [“Media Top Menu”], [“Media Context-sensitive Menu”], [“Number Entry Mode”], [“Number 11”], [“Number 12”], [“Select Broadcast Type”] and [“Select Sound Presentation”] UI commands. It also clarified the earlier [“Number 0”] to be [“Number 0 or Number 10”] (0x20).

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

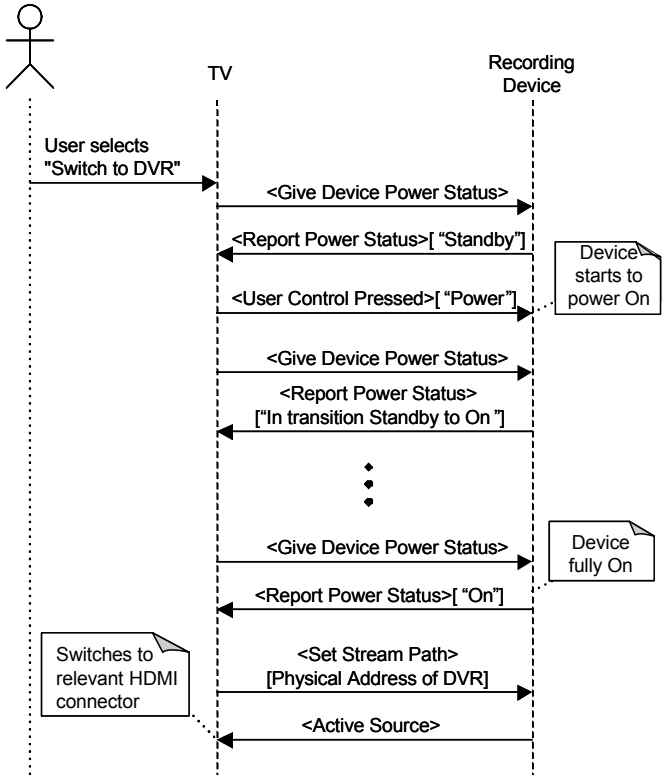
The following messages are used for the Give Device Power Status feature:

<Give Device Power Status>, <Report Power Status>

For details of which messages are mandatory, see CEC Table 21, CEC Table 27 and CEC Table 28.

CEC 13.14.2 Feature Description

Several messages, such as <Image View On> and <Play>, bring another device out of the Standby state. 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 25 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 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 Behavior with Earlier Versions

There is no change in behavior for this Feature between Version 1.4 and Version 1.3a.

When sending this Message	From Version 1.3a Device	To Version 1.2a or 1.3 Device	Possible behavior
<Give Device Power Status>	Any	Any (except CEC Switches)	Device may respond with a <Feature Abort> message 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>, <Report Short Audio

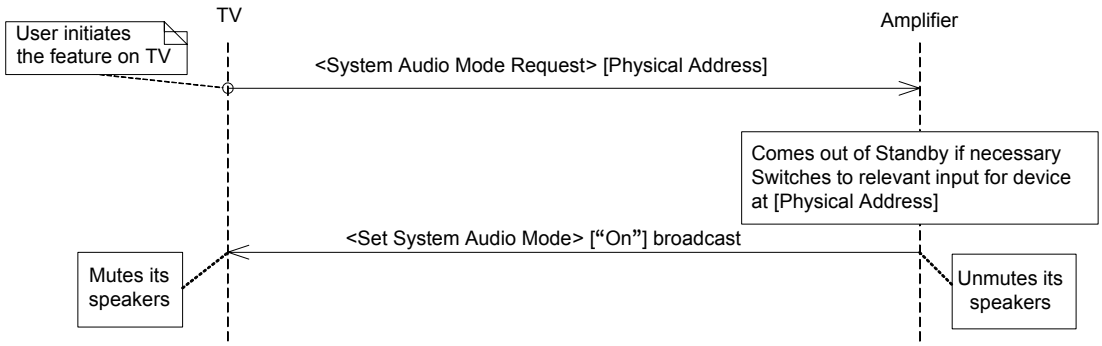
Descriptor>, <Request Short Audio Descriptor>, <Set System Audio Mode>, <System Audio Mode Request>, <System Audio Mode Status>, <User Control Pressed>, <User Control Released>.

For details of which messages are mandatory, see CEC Table 23, CEC Table 27 and CEC Table 28.

CEC 13.15.2 Feature Description

This feature allows an 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 (e.g. TV or STB) or the Amplifier. In the case of initiation by a device other than the Amplifier, that device sends a <System Audio Mode Request> message 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 the Standby state (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"] message – see below about addressing mode (direct or broadcast) of this command.



CEC Figure 26 A typical scenario for initiating the System Audio Control feature from a TV

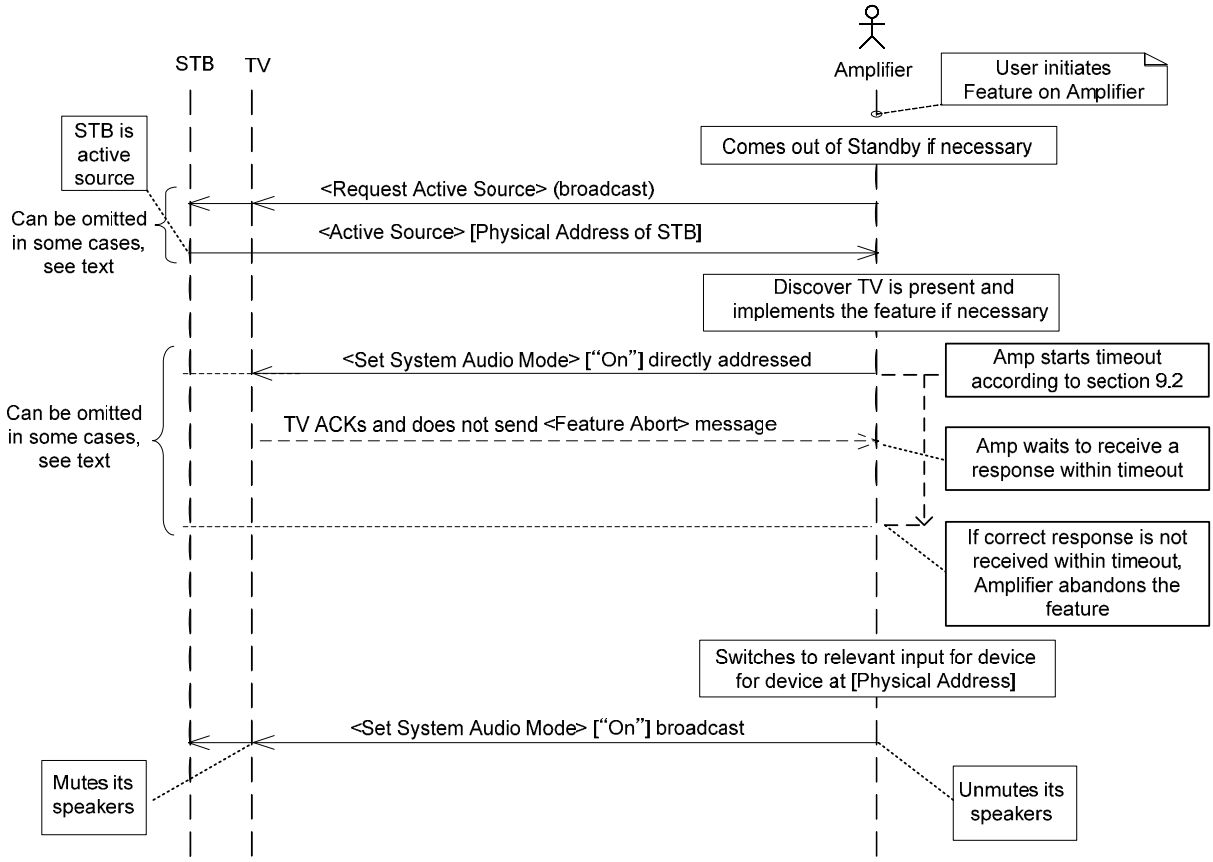
When the feature is initiated from the Amplifier, it shall come out of the Standby state (if necessary) and then shall discover which device is the currently active source, by broadcasting a <Request Active Source> message (note that it is not necessary for the Amplifier to send a <Request Active Source> message if the Amplifier already knows the source or 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 a broadcast or directly addressed <Set System Audio Mode> ["On"] message as described below.

The <Set System Audio Mode> ["On"] message shall initially be directly addressed to the TV when a device other than the TV (e.g. Amplifier or STB) has initiated the feature and if the Amplifier does not know and needs to confirm that the TV is present and that it supports the feature (for exception see CEC 13.15.4.2 - 3). Once the Amplifier has successfully discovered the TV and verified support for the Feature, the message does not need to be sent at the further initiations until the Amplifier is put into the Standby state.

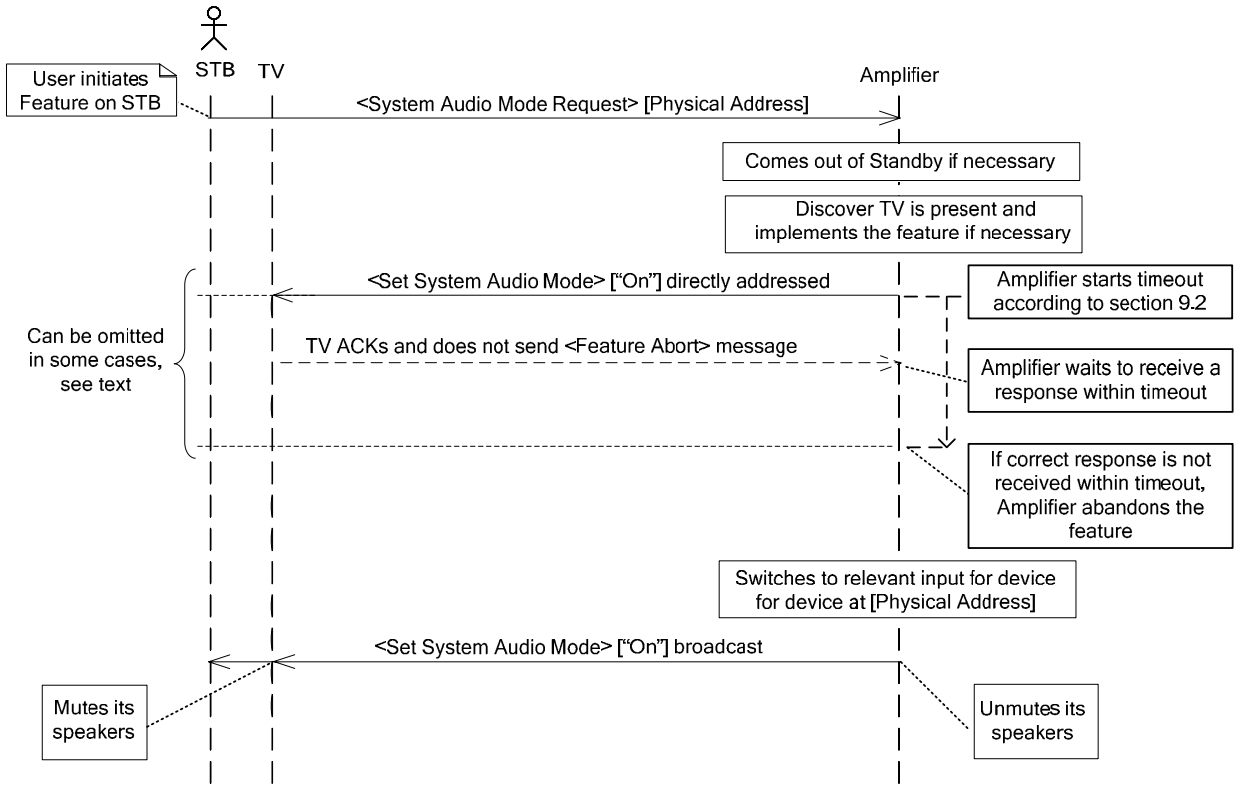
If the TV is not present or it does not implement the message (i.e. it does not ACK the message, or it replies with a <Feature Abort> [“Unrecognized opcode”] message, i.e., it does not implement this message), then the Amplifier does not proceed further with the feature (for exception see CEC 13.15.4.2 - 3). Note that the Amplifier needs to wait for the required maximum response time specified in CEC 9.2 before deciding that a response has not come from the TV.

Note: an Amplifier or a TV conforming to Version 1.4 or later is not required to change its mute/unmute state on receipt of a directly addressed <Set System Audio Mode> [“On”] message. A TV conforming to Version 1.3a may mute its speakers on receipt of a directly addressed <Set System Audio Mode> [“On”] message.

If the TV does not reply with a <Feature Abort> message, then the Amplifier broadcasts a <Set System Audio Mode> [“On”] message to inform any other devices (e.g. 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 27 A typical scenario for initiating the System Audio Control feature from an Amplifier

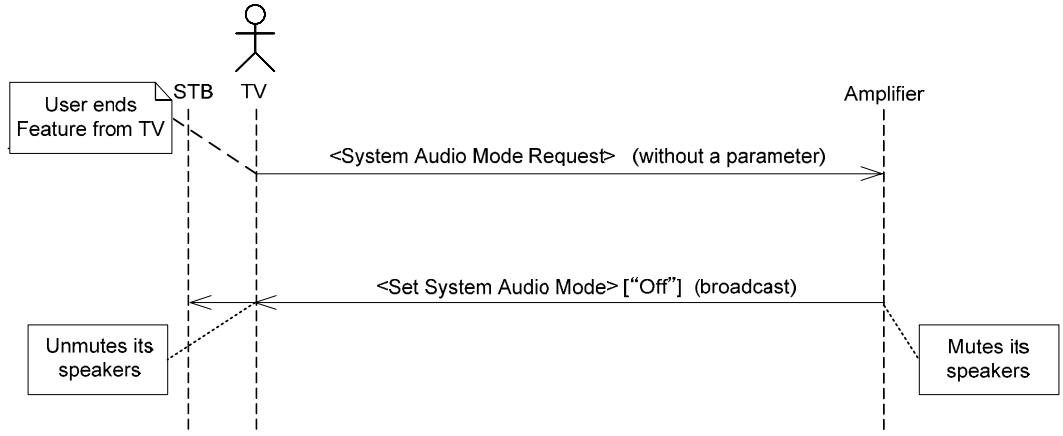


CEC Figure 28 A typical scenario for initiating the System Audio Control feature from a STB

When the Amplifier broadcasts the <Set System Audio Mode> ["On"] message, it shall unmute its speakers.

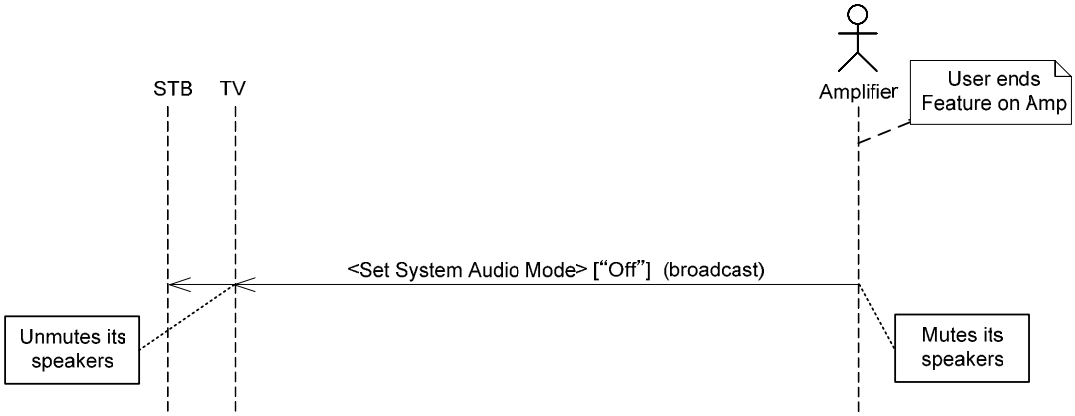
When the TV receives the <Set System Audio Mode> ["On"] broadcast message, it shall mute its speakers.

Stopping the feature can be initiated from the Amplifier or other device. When the non-Amplifier device (e.g. TV or STB) wants to stop the feature, it sends a <System Audio Mode Request> message without a parameter to the Amplifier. The Amplifier shall respond by broadcasting a <Set System Audio Mode> ["Off"] message.



CEC Figure 29 A typical scenario terminating the System Audio Control feature from a TV or STB

The Amplifier can terminate the feature by broadcasting a <Set System Audio Mode> [“Off”] message.

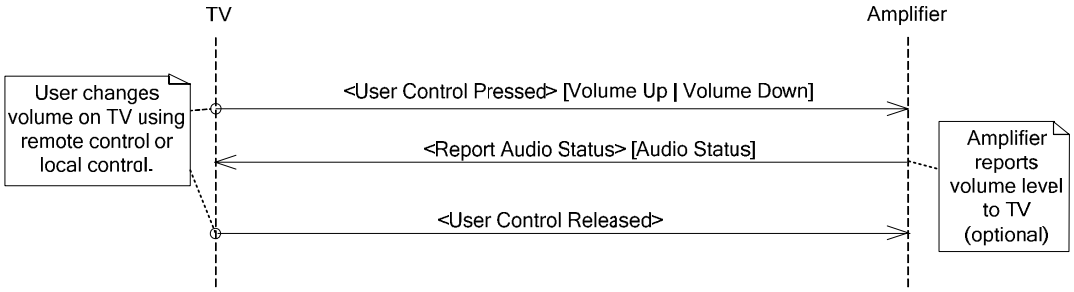


CEC Figure 30 A typical scenario terminating the System Audio Control feature from the Amplifier

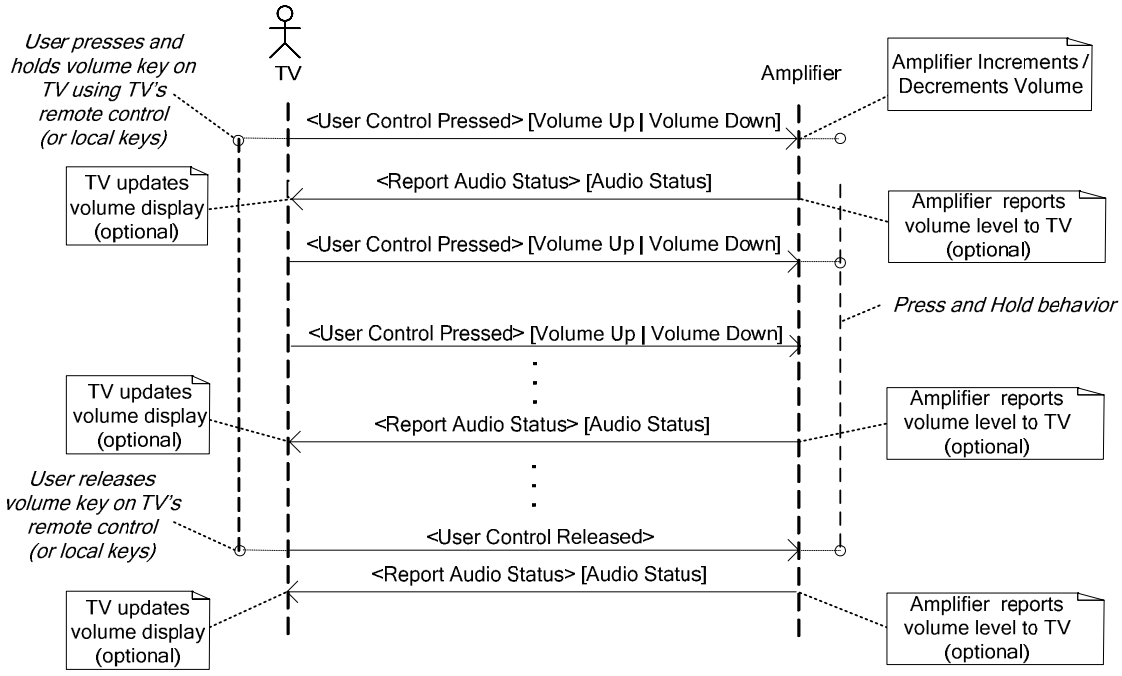
When the Amplifier broadcasts the <Set System Audio Mode> [“Off”] message, it shall mute its speakers.

When the TV receives the <Set System Audio Mode> [“Off”] broadcast message, it shall unmute its speakers.

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 (e.g. physical Volume + / - keys or a rotary style control). Similarly, the mute status of the Amplifier can be controlled by the relevant “mute” remote control button (or other controls) of the various devices.



CEC Figure 31 Typical Operation of the volume control where the user presses and quickly releases a key



CEC Figure 32 An example of TV and Amplifier implementing Press and Hold behavior

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, press and hold, timing, etc, see CEC 13.13.

Note that the behavior of the volume function 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 Pressed> message with an operand of ["Mute"]. The behavior of this ["Mute"] message is determined by the Amplifier. Alternatively, the device (such as a TV or STB) may send a <User Control Pressed> message with an operand of ["Mute Function"] or ["Restore Volume Function"] (see CEC 13.15.4.5 for further information).

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 level display. The <Give Audio Status > message is used to ask for the current audio status of a target Amplifier. The target device responds by sending a <Report Audio Status> message containing the Audio Status operand back to the device which sent the <Give Audio Status>.

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 updated volume indication 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 unmuted, it should send a <Report Audio Status> message so that the TV may display the updated 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.

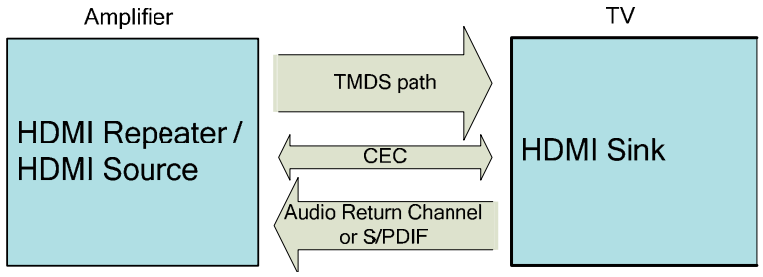
If the System Audio Mode is On, then the Amplifier shall send a <Set System Audio Mode> ["Off"] message just before it goes into the Standby state in order to restore the volume function back to the TV.

When a TV or other source which implements the System Audio Control feature comes out of Standby, or activates the feature, it shall request the current System Audio Mode status by sending a <Give System Audio Mode Status> message. The Amplifier, if active (i.e. 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.

A TV will connect its audio to the Amplifier via an alternative connection link such as analogue, S/PDIF or Audio Return Channel (see Supplement 2). 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 a <System Audio Mode Request> or an <Active Source> message) and map that address to the actual connection in use, i.e. 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 (e.g. analogue, Audio Return Channel 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.

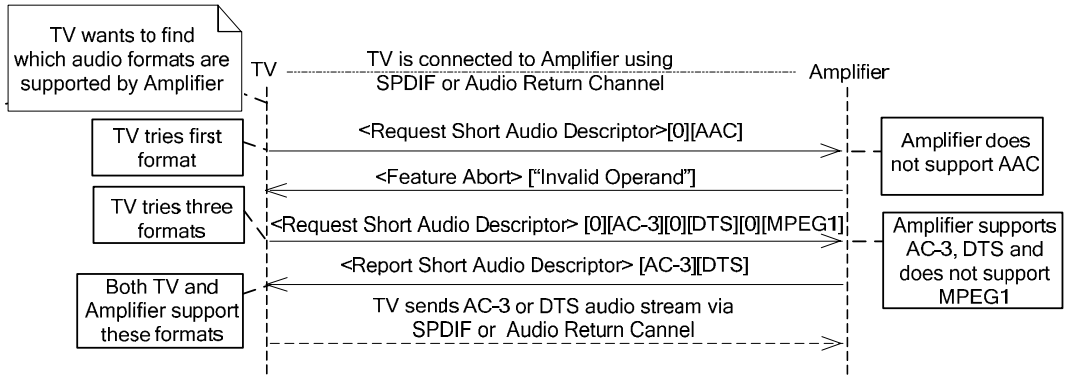
CEC 13.15.3 Discovering the Amplifier's Audio Format support

When using either an alternative link (e.g. S/PDIF) or the Audio Return Channel (see Supplement 2), the TV may enquire if the Amplifier supports a particular audio format by sending a <Request Short Audio Descriptor> message to the Amplifier which contains the [Audio Format ID] and [Audio Format Code] of the requested format. If the Amplifier supports this format, it responds with a <Report Short Audio Descriptor> message containing the relevant [Short Audio Descriptor]. If the Amplifier does not support that format, then it responds with a <Feature Abort> ["Invalid Operand"] message. The TV may attempt to discover if the Amplifier supports another audio format, until a common format is discovered.



CEC Figure 33 An example of alternative connection link

The TV may also enquire if an Amplifier supports multiple audio formats by using one <Request Short Audio Descriptor> message, up to a maximum of 4 formats. In this case, the Amplifier responds with a <Report Short Audio Descriptor> message indicating which of the audio formats it supports, from the list in the corresponding <Request Short Audio Descriptor> message.



CEC Figure 34 Typical Operation to discover the Audio Format capability of an Amplifier

If the TV receives <Feature Abort> ["Invalid Operand"] messages in response to all <Request Short Audio Descriptor> messages that it sent (since the Amplifier does not support the requested audio formats), then the TV selects default 2 channels LPCM audio format.

CEC 13.15.4 Further behavior

CEC 13.15.4.1 Operation with legacy Amplifier

Some Amplifiers conforming to Version 1.3a might not change the mute/unmute status of their own speakers automatically when the system audio mode is changed. It is optional for a TV's manufacturer to try and solve this using appropriate techniques, e.g. as in the following examples:

1. When a <Set System Audio Mode> ["On"] message is broadcast:

1-1) TV sends a <Give Audio Status> message to the Amplifier

1-2) If it is not acknowledged, or the Amplifier responds with a <Feature Abort> or the Amplifier does not respond with a <Report Audio Status> message within the time specified in section CEC 9.2, then the TV sends a <User Control Pressed> ["Restore Volume Function"] message to the Amplifier.

1-3) Else if the TV receives a <Report Audio Status> indicating "Audio Mute On", then the TV sends a <User Control Pressed> ["Mute"] message to the Amplifier.

2. When a <Set System Audio Mode> ["Off"] message is broadcast:

2-1) TV sends a <Give Audio Status> message to the Amplifier

2-2) If it is not acknowledged, or the Amplifier responds with a <Feature Abort> or the Amplifier doesn't respond with a <Report Audio Status> message within the time specified in section CEC 9.2, then the TV sends a <User Control Pressed> ["Mute Function"] message to the Amplifier.

2-3) Else if the TV receives a <Report Audio Status> indicating "Audio Mute Off", then the TV sends a <User Control Pressed> ["Mute"] message to the Amplifier.

CEC 13.15.4.2 Operation with TVs that do not support the Feature

In order to enable the System Audio Control feature when working with TV's that do not support the feature, it is possible for the Amplifier to mute or disable the audio part of the signal on its HDMI output towards the TV. In this case, if the System Audio Control Feature has been initiated by a device that is not the Amplifier and

the Amplifier is on the active path (i.e. it is on the path between the Active Source and the TV, or it is the Active Source), then the Amplifier may broadcast a <Set System Audio Mode> [“On”] message without first sending the directly addressed version first. However, implementers should note that when using this method it will not be possible to have the sound available on headphones connected to the TV. This will affect people with hearing difficulties who use headphones to hear the sound effectively.

In another case, if a non-Amplifier device such as an STB which is connected to the TV initiates a <System Audio Mode Request> message with a parameter, the Amplifier may broadcast a <Set System Audio Mode> ["On"] message confirming the audio signal connection from the STB through the TV. The Amplifier mutes the TV e.g. by sending <User Control Pressed>["Mute"] or <User Control Pressed>["Mute Function"].

CEC 13.15.4.3 Audio-only use

Some use cases do not require the TV to display video. Some examples are:

- listening to radio tuner (built in the Amplifier);

- a STB playing a radio channel which is connected to the Amplifier (either via HDMI, Audio Return Channel or an alternative connection) and where there is no suitable or interesting video to display;

If the user operates volume/mute controls of another device (e.g. TV or STB), it is recommended that these control events are sent to the Amplifier. To achieve this, in such "audio-only" use cases, the Amplifier needs to broadcast a <Set System Audio Mode> [“On”] message. This message informs the other devices of the state of System Audio Mode and helps them to determine the proper Destination for the volume control key events.

In these cases, the Amplifier needs to broadcast a <Set System Audio Mode> [“On”] message without first checking that the TV supports the System Audio Control Feature or not.

Note – this is an optional feature.

CEC 13.15.4.4 Power State Changes

If the Amplifier comes out of the Standby state as a result of an action other than receiving a <System Audio Mode Request> message, then it is a decision for the Amplifier's manufacturer as to whether the Amplifier starts the System Audio Mode or not.

For instance, the Amplifier manufacturer may decide that System Audio Mode is On because the user has turned on the Amplifier, or the Amplifier may remember the previous state before going to Standby, or the user has set startup states.

If the Amplifier decides to start the System Audio Mode (after checking that the TV supports the feature and is present as described in the above sections), the Amplifier shall broadcast a <Set System Audio Mode>["On"] message to inform the other devices.

If the Amplifier decides not to start System Audio Mode, the Amplifier may broadcast a <Set System Audio Mode>["Off"] message to confirm this state to the other devices.

CEC 13.15.4.5 Usage of remote control pass through

When a device such as TV or STB offers a deterministic mute control mechanism and the user operates this mechanism in order to deterministically 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 Pressed> message with an operand of [“Mute Function”] or ["Restore Volume Function"]. Note that the Amplifier shall support a <User Control Pressed> message with an operand of ["Mute"], and may support a <User Control Pressed> message with an operand of [“Mute Function”] and ["Restore Volume Function"].

If the System Audio Mode is Off and the Amplifier receives a volume control (i.e.. Volume Up, Volume Down or Mute) from its own remote control or local keypresses for, it is up to Amplifier manufacturer's implementation to either consume the keys in the Amplifier or forward the keypresses to the TV.

If a device such as a STB with volume control receives own remote control or local key keypresses for volume control, it is up to STB manufacturer's implementation to either consume the keys in the STB or forward the keypresses. This choice can be dependent upon the state of the STB. In case of forwarding the STB sends those keypresses either to the Amplifier or to the TV, depending on whether System Audio Mode is On (send to Amplifier) or Off (send to TV).

Note – when the System Audio Mode is Off, a TV might not support volume control using <User Control Pressed> messages (i.e. Volume Up, Volume Down or Mute).

CEC 13.15.5 Behavior with Earlier Versions

TVs and Amplifiers conforming to Version 1.3a may mute / unmute their speakers on receiving a directly addressed <Set System Audio Mode> message instead of the broadcast message.

Audio connection using ARC (Audio Return Channel) is new in Version 1.4.

<Request Audio Descriptor> and <Report Audio Descriptor> are new messages in Version 1.4 and Followers conforming to Version 1.3a or earlier will respond with a <Feature Abort> to these messages.

This feature was introduced in Version 1.3a. Devices conforming to Version 1.3 or earlier will respond with a <Feature Abort> to all directly addressed 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>

For details of which messages are mandatory, see CEC Table 24, CEC Table 27 and CEC Table 28.

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, e.g. from Standard Rate to Fast Rate.

CEC 13.16.3 Behavior with Earlier Versions

There is no change in behavior for this Feature between Version 1.4 and Version 1.3a.

This feature was introduced in Version 1.3a. Devices conforming to Version 1.3 or earlier will respond with a <Feature Abort> message to all messages sent by an Initiator for this feature.

CEC 13.17 Audio Return Channel Control

CEC 13.17.1 Messages

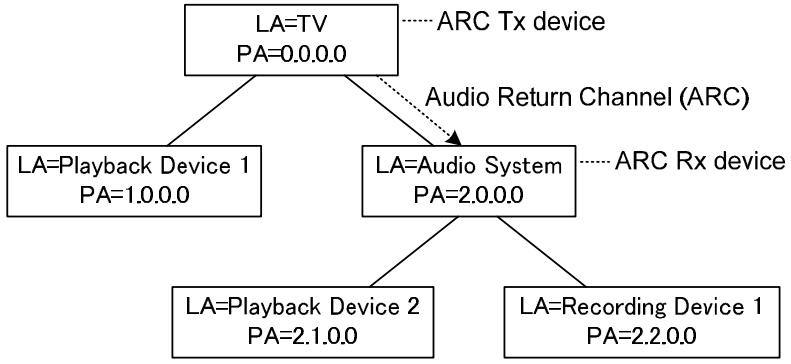
The following messages are used for the Audio Return Channel Control feature (see Supplement 2):

<Initiate ARC>, <Report ARC Initiated>, <Report ARC Terminated>, <Request ARC Initiation>, <Request ARC Termination>, <Terminate ARC>

For details of which messages are mandatory, see CEC Table 25, CEC Table 27 and CEC Table 28.

CEC 13.17.2 Feature description

This feature allows an Audio Return Channel receiver (ARC Rx) device to initiate or terminate an Audio Return Channel between an adjacent Audio Return Channel transmitter (ARC Tx) device and itself. In contrast, the ARC Tx device is allowed to request an adjacent ARC Rx device to initiate or terminate an Audio Return Channel between the devices. Both adjacent devices shall only utilize audio data transmissions via the Audio Return Channel between devices after the negotiation and confirmation between them has been successfully completed by following the procedures specified in this section.



CEC Figure 35 An example of topology with ARC link

If a Follower receives a message for this feature from a non-adjacent Initiator or never supports this feature with the Initiator on the relevant link (the Follower may support this feature on another link), then the Follower may respond with a <Feature Abort> [“Refused”] message.

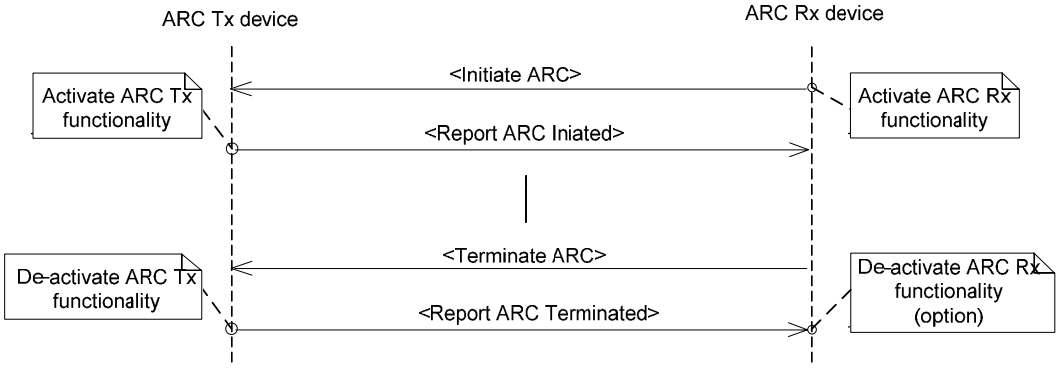
Note - Messages for Audio Return Channel Control provide connection functionality, and do not control selection of the audio source.

CEC 13.17.2.1 Initiation and Termination from ARC Rx device

In the case of initiation, an ARC Rx device shall send a directly addressed <Initiate ARC> message to an adjacent device after the ARC Rx functionality (see Supplement 2) has been activated. If the Follower sends a <Feature Abort> [“Unrecognized opcode”] message or no related message within the required maximum response time specified in CEC 9.2, then the ARC Rx device assumes that the Follower does not support the Audio Return Channel feature.

If the Follower is an ARC Tx device, it shall respond by sending a directly addressed <Report ARC Initiated> message or <Report ARC Terminated> message or <Feature Abort> message within the required maximum response time specified in CEC 9.2. Note – for example, if the Follower is an ARC Tx device, it may send a <Feature Abort> [“Cannot provide source”] message if there is no audio stream to output.

If the Follower responds with a directly addressed <Report ARC Initiated> message, the ARC Rx device knows that the Follower is an ARC Tx device, its ARC Tx functionality (see Supplement 2) has been activated and it transmits an audio stream via the Audio Return Channel. If the Follower responds with a directly addressed <Report ARC Terminated> message, the ARC Rx device knows the Follower is an ARC Tx device but its ARC Tx functionality has been deactivated and it is not transmitting an audio stream via the Audio Return Channel. In this case, the ARC Rx device may deactivate the ARC Rx functionality.



CEC Figure 36 Initiation and Termination from ARC Rx device

In the case of termination, the ARC Rx device shall send a directly addressed <Terminate ARC> message to the adjacent ARC Tx device. The ARC Tx device shall stop transmitting its audio stream, deactivate the ARC Tx functionality and respond with a directly addressed <Report ARC Terminated> message. In this case, the ARC Rx device may de-activate the ARC Rx functionality. If the ARC Rx device has not received a <Report ARC Terminated> message within the required maximum response time specified in CEC 9.2, the ARC Rx device may keep its ARC Rx functionality active or may de-activate the ARC Rx functionality by detecting the de-activation of the ARC Tx functionality, e.g. by loss of an audio signal.

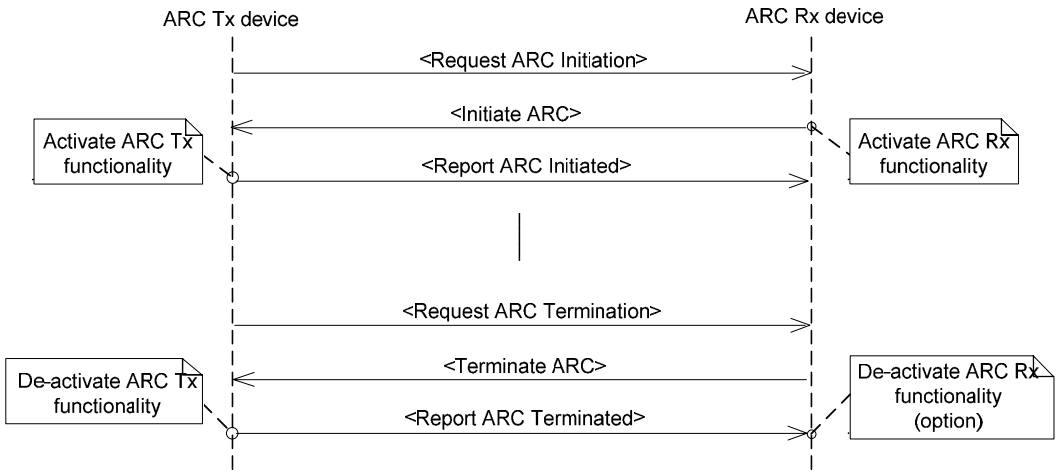
Also, in the case where the ARC Tx device has requested initiation to the adjacent ARC Rx device and the ARC Rx device has initiated the feature (see CEC 13.17.2.2), the ARC Rx device may at any time start to terminate the feature by sending a directly addressed <Terminate ARC> message to the ARC Tx device.

CEC 13.17.2.2 Request from ARC Tx device

In the case where an ARC Tx device wants to initiate an Audio Return Channel, then the ARC Tx device shall not send an <Initiate ARC> message. Instead, the ARC Tx device may request an adjacent device to initiate the Audio Return Channel by sending a directly addressed <Request ARC Initiation> message. If the

Follower sends a <Feature Abort> [“Unrecognized opcode”] message or no message within the required maximum response time specified in CEC 9.2, then the ARC Tx device assumes that the Follower does not support the Audio Return Channel feature. If the Follower sends a <Feature Abort> [“Not in correct mode to respond”] message, then the ARC Tx device assumes that the follower is an ARC Rx device and is not ready to initiate the Audio Return Channel feature.

If the Follower is an ARC Rx device, then when it is ready to initiate the feature it shall start the initiation sequence as described in CEC 13.17.2.1.



CEC Figure 37 Request from ARC Tx device

In the case where an ARC Tx device wants to terminate an Audio Return Channel, then the ARC Tx device shall not send a <Terminate ARC> message. Instead, the ARC Tx device may request the adjacent ARC Rx device to terminate the Audio Return Channel by sending a directly addressed <Request ARC Termination> message.

When the ARC Rx device is ready to terminate the Audio Return Channel, the ARC Rx device shall start the termination sequence as described in CEC 13.17.2.1.

If the ARC Rx device sends a <Feature Abort> message, or no related message is received within the required maximum response time specified in CEC 9.2, the ARC Tx device may de-activate the ARC Tx functionality.

If the ARC Tx device is temporarily entering a state where it cannot terminate the Audio Return Channel, it shall request termination before entering that state by sending a directly addressed <Request ARC Termination> message to the adjacent ARC Rx device.

Also, in the case where the ARC Rx device has initiated this feature (see CEC 13.17.2.1), the adjacent ARC Tx device may request termination of the feature to the ARC Rx device.

CEC 13.17.3 Behavior with Earlier Versions

This is a new Feature in Version 1.4. Devices conforming to Version 1.3a or earlier will respond with a <Feature Abort> to all messages sent by an Initiator for this feature.

CEC 13.18 Capability Discovery and Control for HEC

CEC 13.18.1 Introduction and Messages

Supplement 2 describes the HDMI Ethernet Channel (HEC). HEC needs some messages for control and discovery, called Capability Discovery and Control (CDC). These CDC messages are broadcast CEC messages and share a single CEC opcode. CDC messages may be used by both CDC only devices and CDC devices with CEC.

CEC 13.18.2 CDC only Device

A device that uses only CDC messages (but no further CEC messages) takes logical address 15 (Unregistered) as an initiator when it sends messages. Such a CDC only device does not need to implement the mandatory CEC messages, but adheres to the low level CEC protocol with some extensions, as specified in Supplement 2.

CEC 13.18.3 CDC Device with CEC

If a device implements CDC messages and at least one further CEC message, the device shall also implement all the mandatory CEC messages for its device type(s), see CEC Table 8 to CEC Table 26, CEC Table 27 and CEC Table 28, and shall attempt to allocate a relevant Logical Address according to section CEC 10.

CEC 13.18.4 Behavior with Earlier Versions

This is a new Feature in Version 1.4. Devices conforming to Version 1.3a or earlier will ignore all CDC messages (since CDC messages are broadcast, they will not respond with a <Feature Abort> message on receiving a CDC message).

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

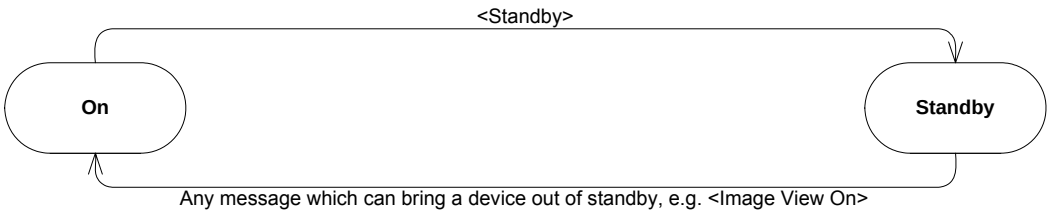
Playback Device: Deck Active, Deck Inactive

Menu Providing Device: Device Menu Active, Device Menu Inactive

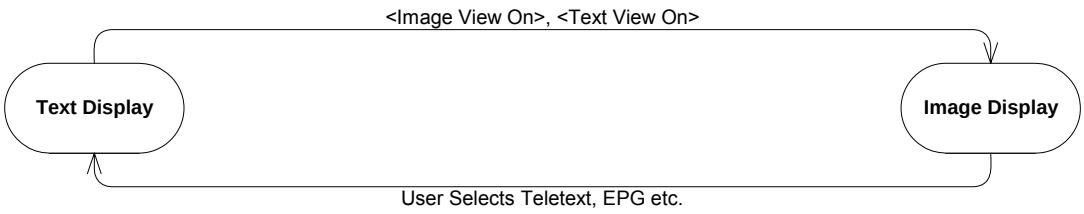
CEC 14.1.2 State Changes

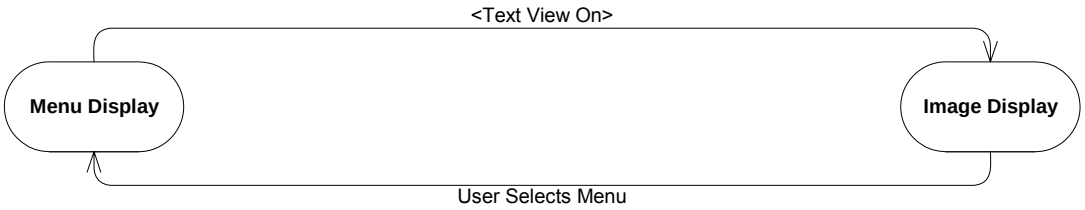
The following diagrams show the state transitions that are caused as a direct result of a device receiving a CEC message. Transitions between states that are not caused as a result of CEC messages are generally not shown, except where no CEC message can cause that transition.

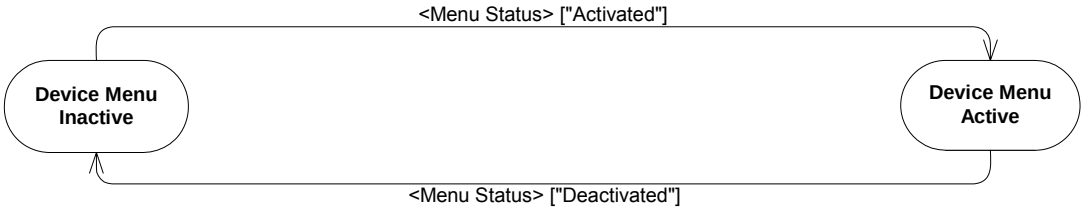
CEC 14.1.3 All Devices



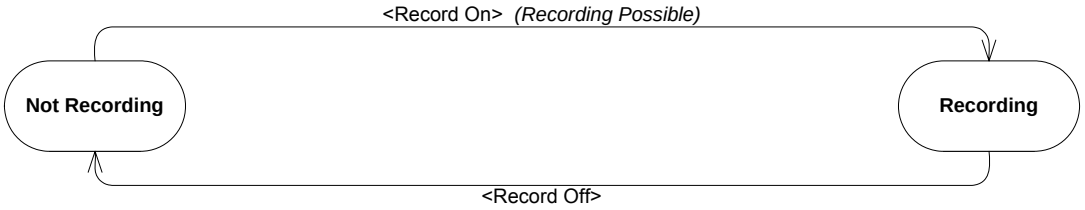
CEC 14.1.4 TV



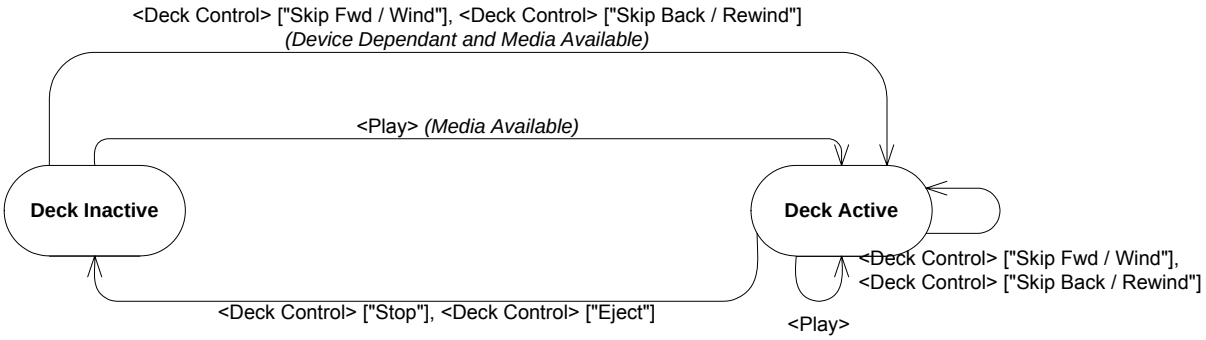




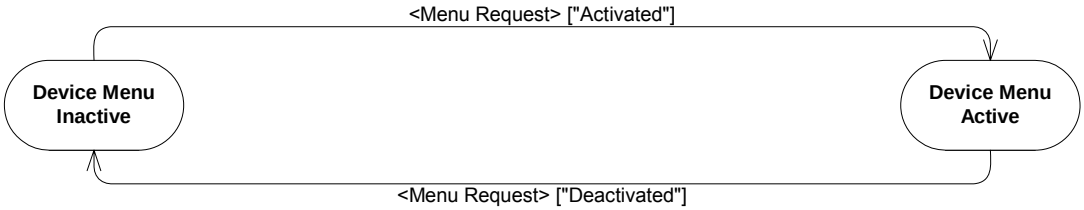
CEC 14.1.5 Recording Device



CEC 14.1.6 Playback Device



CEC 14.1.7 Menu Providing Device



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 8 to CEC Table 26 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 8 to CEC Table 26.

- **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 29 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.

In tables CEC Table 8 to CEC Table 26 "TV" refers to the device using Logical Address TV (0).

CDC only devices which do not implement other CEC messages (see section CEC 13.18.2), shall not implement messages that are indicated as Mandatory in CEC Table 8 to CEC Table 26. However, CDC devices with CEC shall implement the messages indicated in section CEC 13.18.3.

CEC Table 8 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 the Standby state 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

CEC Table 9 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 the Standby state 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 the Standby state 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 currently 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

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, except for root device at 0.0.0.0	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 the Standby state, stream its output and broadcast an <Active Source> message.		•		CEC Switches

CEC Table 10 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 the Standby state. 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 the Standby state. [3] Ignore the message if already in the Standby state.	•	•	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.

CEC Table 11 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 (i.e. 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.	•			

CEC Table 12 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.	•			

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		•			

CEC Table 13 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 version number of the CEC Specification which was used to design the device, in response to a <Get CEC Version>.	[CEC Version]	A value indicating the version number of the CEC Specification which was used to design the device.		•		[4]	[5]
<Get CEC Version>	0x9F	Used by a device to enquire which version number of the CEC Specification was used to design the Follower device.	None		The source responds with a <CEC Version> message indicating the version number of the CEC Specification which was used to design the Follower device.	•		[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 on the TV.	None		The TV 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 16 for requirements
[5] This message is also used in the Vendor Specific Command Feature - see CEC Table 16 for requirements
[6] This message is also used in the Vendor Specific Command Feature - see CEC Table 16 for requirements
[7] This message is also used in the Vendor Specific Command Feature - see CEC Table 16 for requirements

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 to indicate its currently selected menu language.	[Language]	TheTV's current menu language.	Set the menu language as specified, if possible.		•	TV	All, except for those devices mentioned in note below.

300

Note: <Set Menu Language> is Mandatory as a Follower except for the following: TV, CEC Switches, Mobile Devices, other devices which are not able to change the language by CEC messages, e.g. a PC, and devices without OSD/ Menu generation capabilities.

CEC Table 14 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 the Standby state and it 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 behavior 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 the Standby state, has media available and the parameter is ["Play Forward"] it should power on.	•			

302

CEC Table 15 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.	•			

CEC Table 16 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 version number of the CEC Specification which was used to design the device, in response to a <Get CEC Version>	[CEC Version]	A value indicating the version number of the CEC Specification which was used to design the device.		•		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 number of the CEC Specification was used to design the Follower device.	None		The source responds with a <CEC Version> message indicating the version number of the CEC Specification which was used to design the Follower device.	•		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

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	•	•		

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 17 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.	•			

306

CEC Table 18 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.	•			

CEC Table 19 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 30, 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. Can also be used as a command that is not directly initiated by the user.	[UI Command]	Required UI command issued by user.	Update display or perform an action, as required.	•			

[10] This message is also used in the RC Passthrough and System Audio Features

<User Control Released> [11]	0x45	Indicates that user released a remote control button (the last one indicated by the <User Control Pressed> message). Also used after a command that is not directly initiated by the user.	None		Update display or perform an action, as required.	•			

CEC Table 20 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. Can also be used as a command that is not directly initiated by the user.	[UI Command], plus any necessary Additional Operands specified in CEC Table 6 and CEC Table 7.	Required UI command.	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). Also used after a command that is not directly initiated by the user.	None		Update display or perform an action, as required.	•			

309

[11] This message is also used in the RC Passthrough and System Audio Features
[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

CEC Table 21 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)	

310

CEC Table 22 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

CEC Table 23 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		•			
<Report Short Audio Descriptor>	0xA3	Report Audio Capability.	[Short Audio Descriptor]	Up to 4 Short Audio Descriptor identifying supported audio format(s).		•			
<Request Short Audio Descriptor>	0xA4	Request Audio Capability.	[Audio Format ID] [Audio Format Code]	Up to 4 Audio Format ID(s) and Audio Format Code (s) (if needed) .	<Report Short Audio Descriptor>	•			
<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 unmutes its speakers. The TV or STB stop sending the volume-related <User Control Pressed> or <User Control Released> messages.	•	•		

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 (e.g. 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 the Standby state (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. Can also be used as a command that is not directly initiated by the user.	[UI Command] of “Volume Up”, “Volume Down” or “Mute” ,"Mute Function", "Restore Volume Function”.	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

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) . Also used after a command that is not directly initiated by the user.	None		Stop increasing or decreasing the volume	•			

CEC Table 24 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

CEC Table 25 Message Descriptions for the Audio Return Channel Control Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<Initiate ARC>	0xC0	Used by an ARC RX device to activate the ARC functionality in an ARC TX device.	None		The ARC functionality in the ARC TX device is activated	•		ARC Rx device	ARC Tx device
<Report ARC Initiated>	0xC1	Used by an ARC TX device to indicate that its ARC functionality has been activated.	None			•		ARC Tx device	ARC Rx device
<Report ARC Terminated>	0xC2	Used by an ARC TX device to indicate that its ARC functionality has been deactivated.	None			•		ARC Tx device	ARC Rx device
<Request ARC Initiation>	0xC3	Used by an ARC TX device to request an ARC RX device to activate the ARC functionality in the ARC TX device.	None		ARC RX device sends an <Initiate ARC> message	•			ARC Rx device
<Request ARC Termination>	0xC4	Used by an ARC TX device to request an ARC RX device to deactivate the ARC functionality in the ARC TX device.	None		ARC RX device sends a <Terminate ARC>	•			ARC Rx device
<Terminate ARC>	0xC5	Used by an ARC RX device to deactivate the ARC functionality in an ARC TX device.	None		The ARC functionality in the ARC TX device is deactivated	•		ARC Rx device	ARC Tx device

CEC Table 26 Message Descriptions for the Capability Discovery and Control Feature

Opcode	value	Description	Parameters	Parameter description	Response	Directly addressed	Broadcast	Mandatory for Initiator	Mandatory for Follower
<CDC Message>	0xF8	Used for Capability Discovery and Control, see Supplement 2	See Supplement 2	See Supplement 2	See Supplement 2		•	See Supplement 2	See Supplement 2

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 27 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 28 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 27 Message dependencies when receiving a message

If device does not <Feature Abort> the following message with "Unrecognized opcode" :	**It shall not <Feature Abort> the following message(s) with "Unrecognized opcode":**	**It shall be able to send the message(s):**
<CEC Version>	-	<Get CEC Version>
<Clear Analogue Timer>	<Set Analogue Timer>	<Timer Cleared Status>;
<Clear Digital Timer>	<Set Digital Timer>	<Timer Cleared Status>;
<Clear External Timer>	<Set External Timer>;	<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>
<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 Mode Status>	<System Audio Mode Request>, <User Control Pressed>["Volume Up" | "Down" | "Mute"], <User Control Released>	<Set System Audio Mode>, <System Audio Mode 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

If device does not <Feature Abort> the following message with "Unrecognized opcode" :	It shall not <Feature Abort> the following message(s) with "Unrecognized opcode":	It shall be able to send the message(s):
<Give Tuner Device Status>		<Tuner Device Status>
<Image View On>	<Active Source> [17]	-
<Inactive Source>	-	<Active Source>, <Set Stream Path>
<Initiate ARC>	<Terminate ARC>	<Report ARC Initiated>, <Report ARC Terminated>
<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>
<Request ARC Initiation>	<Request ARC Termination>	<Initiate ARC>, <Terminate ARC>
<Request ARC Termination>	<Request ARC Initiation>	<Initiate ARC>, <Terminate ARC>
<Request Short Audio Descriptor>		<Report Short Audio Descriptor>
<Routing Change>[19]	<Routing Information>	-
<Routing Information>[20]	<Routing Change>	-

[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.
[20] This message is broadcast and there is therefore no <Feature Abort>, but devices shall also accept the associated message.

If device does not <Feature Abort> the following message with "Unrecognized opcode" :	It shall not <Feature Abort> the following message(s) with "Unrecognized opcode":	It shall be able to send the message(s):
<Set Analogue Timer>	-	<Timer Status>
<Set Audio Rate>	-	-
<Set Digital Timer>	-	<Timer Status>
<Set External Timer>	-	<Timer 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>
<Terminate ARC>	<Initiate ARC>	<Report ARC Initiated>, <Report ARC Terminated>
<Text View On>	<Active Source>	-
<Timer Cleared Status>	<Timer Status>	-
<Tuner Device Status>	-	<Give Tuner Device Status>
<Timer Status>	-	-

[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.

If device does not <Feature Abort> the following message with "Unrecognized opcode" :	It shall not <Feature Abort> the following message(s) with "Unrecognized opcode":	It shall be able to send the message(s):
<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>

321

[22] This message can be broadcast and there might 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 might 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 might not be a <Feature Abort>, but devices shall also accept the associated messages and also be able to send the associated message.

CEC Table 28 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 following message(s) with "Unrecognized opcode":**
<CEC Version>	-	<Get CEC Version>
<Clear Analogue Timer>	<Set Analogue Timer>	<Timer Cleared Status>
<Clear Digital Timer>	<Set Digital Timer>	<Timer Cleared Status>
<Clear External Timer>	<Set External Timer>	<Timer Cleared 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>
<Image View On>	<Active Source>	-
<Inactive Source>	-	<Active Source>, <Set Stream Path>

[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.

If device ever sends the following message:	It shall be able to send the message(s):	It shall not <Feature Abort> the following message(s) with "Unrecognized opcode":
<Initiate ARC>	<Terminate ARC>	<Report ARC Initiated>, <Report ARC Terminated>, <Request ARC Initiation>, <Request ARC Termination>
<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>
<Report Short Audio Descriptor>		<Request Short Audio Descriptor>
<Request Active Source>	-	<Active Source>[28]
<Request ARC Initiation>	<Report ARC Terminated>, <Report ARC Initiated>	<Initiate ARC>, <Terminate ARC>
<Request ARC Termination>	<Report ARC Terminated>, <Report ARC Initiated>	<Initiate ARC>, <Terminate ARC>
<Routing Change>	<Routing Information> except for TV with Physical Address 0.0.0.0	-
<Set Analogue Timer>	-	<Timer Status>

[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.

If device ever sends the following message:	It shall be able to send the message(s):	It shall not <Feature Abort> the following message(s) with "Unrecognized opcode":
<Set Audio Rate>	-	-
<Set Digital Timer>	-	<Timer Status>
<Set External Timer>	-	<Timer 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>
<Terminate ARC>	<Initiate ARC>	<Report ARC Initiated>, <Report ARC Terminated>, <Request ARC Initiation>, <Request ARC Termination>
<Text View On>	<Active Source>	-
<Timer Cleared Status>	<Timer Status>	The relevant <Clear Analogue Timer>, <Clear Digital Timer> or <Clear External Timer>
<Timer Status>		The relevant <Set Analogue Timer>, <Set Digital Timer> or <Set External Timer>
<Tuner Device Status>	-	<Give Tuner Device Status>
<Tuner Step Decrement>	<Tuner Step Increment>	-

If device ever sends the following message:	It shall be able to send the message(s):	It shall not <Feature Abort> the following message(s) with "Unrecognized opcode":
<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>

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 29 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		
	“Unable to determine”	5		
[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 Format Code]	If [Audio Format ID] = 0,0x01≤N≤0x0F		6 bits	If [Audio Format ID]=0, Audio Format Code is defined in CEA-861-D for CEA Short Audio Descriptor.

Name	Range Description		Length	Purpose
[Audio Format ID]	0		2 bits	Indicates [Audio Format Code] and [Short Audio Descriptor] defined in CEA-861-D.
[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		
	“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

Name		Range Description		Length	Purpose
[Boolean]		"False"	0	1 byte	Flag
		"True"	1		
[Broadcast System]		0≤N≤31 – See CEC Table 31		1 byte	This specifies information about the color system, the sound carrier and the IF-frequency
[CEC Version]		Reserved	0x00 – 0x03	1 byte	Indicates the version number of the CEC Specification which was used to design the device.
		"Version 1.3a"	0x04		
		"Version 1.4"	0x05		
[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.

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		

Name	Range Description		Length	Purpose
[Device Type]	"TV"	0	1 byte	Used by a device to indicate its device type.
	"Recording Device"	1		
	Reserved	2		
	"Tuner"	3		
	"Playback Device"	4		
	"Audio System"	5		
	"Pure CEC Switch"	6		A device according to CEC 11.1 which has no other functionality or Device Type.
	"Video Processor"	7		A device with all the following properties: • cannot itself become an Active Source; • has an HDMI output and at least one input (HDMI or non-HDMI); • passes video from input to output modified or unmodified; • has its own Physical Address; • requires direct addressing; • has no other device type.
[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]

Name		Range Description			Length	Purpose
		"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		
			"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

[29] These formats are included for legacy devices. New devices shall use the Specific Formats starting at 0x08

Name		Range Description		Length	Purpose
		”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
		”Original_Network_ID”		2 bytes	The original_network_ID of the network carrying the transport stream for the required service
	[Channel data]	[Channel Identifier] [Reserved 2 bytes]}		6 bytes	Identifies the logical or virtual channel number of a service. See [Channel Identifier] for details.
[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		

<table>
<tr><th colspan="2">Name</th><th colspan="2">Range Description</th><th>Length</th><th>Purpose</th></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><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 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>
<tr><td colspan="2">[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 colspan="2">[Feature Opcode]</td><td colspan="2">0x00 ≤ N ≤ 0xFF (n is defined in CEC Table 8 to CEC Table 26)</td><td>1 byte</td><td>Defines command to be performed.</td></tr>
<tr><td colspan="2">[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 colspan="2" 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>
</table>

<table>
<tr><th>Name</th><th colspan="2">Range Description</th><th>Length</th><th>Purpose</th></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>
<tr><td>[OSD String]</td><td colspan="2">N {[ASCII]}, 1≤N ≤ 13</td><td>1 - 13 bytes</td><td>A string to be displayed on the display.</td></tr>
<tr><td>[Physical Address]</td><td colspan="2">4{[Port ID]}</td><td>2 bytes</td><td>Defines the path between the TV and a device – thus giving it a Physical Address within the cluster.</td></tr>
<tr><td>[Port ID]</td><td colspan="2">0x0≤n≤0xF</td><td>4 bits</td><td>Defines one ‘hop’ within the Physical Address relating to the physical connection of the device.</td></tr>
<tr><td rowspan="5">[Play Mode]</td><td>“Play Forward”</td><td>0x24</td><td rowspan="5">1 byte</td><td rowspan="5">The mode in which to play media.

Note: If a device does not support a particular play mode it should select the closest match.</td></tr>
<tr><td>“Play Reverse”</td><td>0x20</td></tr>
<tr><td>“Play Still”</td><td>0x25</td></tr>
<tr><td>“Fast Forward Min Speed”</td><td>0x05</td></tr>
<tr><td>“Fast Forward Medium Speed”</td><td>0x06</td></tr>
</table>

Name	Range Description		Length	Purpose
	"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		
[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]}, $1 \leq N \leq 14$		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.

Name		Range Description		Length	Purpose
	[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		
		“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		

Name	Range Description		Length	Purpose
	"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		
	"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.
	"Sunday"	0b0000001		
	"Monday"	0b0000010		
	"Tuesday"	0b0000100		

Name	Range Description		Length	Purpose
	"Wednesday"	0b0001000		[Recording Sequence] shall be set to 0x00 when the recording is not repeated. Bit 7 is reserved and shall be set to zero.
	"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.
[Short Audio Descriptor]	0x000000≤N≤0xFFFFFF		3 bytes	Indicates supported audio capability. If the requested [Audio Format ID]=0, Format of Short Audio Descriptor is defined in CEA-861-D as CEA Short Audio Descriptor.
[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		

Name		Range Description		Length	Purpose
		“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		
	[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 “Might 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		

Name		Range Description		Length	Purpose
		“Might 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		
		“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

Name		Range Description		Length	Purpose
	[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		
	[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 Broadcast Type]				1 byte	Indicates type of broadcast
		“Toggle through all available broadcast types”	0x00		
		“Digital / Analogue Toggle”	0x01		
		“Analogue”	0x10		
		“Analogue Terrestrial”	0x20		
		“Analogue Cable”	0x30		
		“Analogue Satellite”	0x40		
		“Digital”	0x50		
		“Digital Terrestrial”	0x60		
		“Digital Cable”	0x70		

Name	Range Description		Length	Purpose
	"Digital Satellite"	0x80		Broadcasting Satellite in the case of a Japanese TV or Recorder
	"Digital Communications Satellite"	0x90		
	"Digital Communications Satellite 2"	0x91		
	"IP"	0xA0		
[UI Command]	0x00≤n≤0xFF (n is defined in CEC Table 30)		1 byte	Indicates the command that the Follower is to perform. Note that some [UI Command] messages also have further operands following – see CEC Table 6 and CEC Table 7.
[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
[UI Sound Presentation Control]	Indicates requested Follower operation		1 byte	Indicates the selected command. Note: in order to toggle between available audio languages (audio streams) associated with the current video stream, use Sound Select, [UI Command] = 0x33.
	"Sound Mixing Mode (Dual Mono)"	0x20		Toggle between the dual-mono mixing modes available in the Follower (main, sub, main+sub).
	"Sound Mixing Mode (Karaoke)"	0x30		Toggle between the karaoke mixing modes available in the Follower (music only, voice only, music+voice, cancel vocal).
	"Select Audio Downmix Mode"	0x80		Toggle between the audio downmix modes available in the Follower (e.g. mono, stereo, multi-channel).

Name	Range Description		Length	Purpose
	"Select Audio Reverberation Processing" Mode	0x90		Toggle between the available reverberation processing (e.g. echo effects) available in the Follower.
	"Select Audio Equalizer Mode"	0xA0		Toggle between the equalizer settings available in the Follower.
	"bass step + "	0xB1		
	"bass neutral position"	0xB2		
	"bass step - "	0xB3		
	"treble step + "	0xC1		
	"treble neutral position"	0xC2		
	"treble step - "	0xC3		
[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.		≤11 or ≤14 bytes (see Purpose column)	The maximum length shall not exceed 14 Data Blocks for <Vendor Command>; or shall not exceed 11 Data Blocks for <Vendor Command with ID> 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)

CEC Table 30 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 - 0x0F	Reserved
0x10	Media Top Menu – See Note 3
0x11	Media Context-sensitive Menu – see Note 4
0x12 – 0x1C	Reserved
0x1D	**Number Entry Mode** – See Note 5
0x1E	**Number 11**
0x1F	**Number 12**
0x20	**Number 0 or Number 10**
0x21 - 0x29	**Numbers 1-9**
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
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
0x55	Initial Configuration
0x56	Select Broadcast Type
0x57	Select Sound Presentation
0x58 – 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 6
0x77 – 0xFF	Reserved

For notes, see following page.

Note 1: The elements identified in **bold** are the only ones which are forwarded as part of the device Menu Control feature, see section .CEC 13.12.

Note 2: This triggers 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 triggers the display of the main menu available for the currently playing media, e.g. DVD/BD Top Menu to select Language, Subtitle, Scene, Bonus, Start of Film, etc.

Note 4: This triggers the display of a context-sensitive media-related menu (e.g. DVD Menu or BD Popup Menu), typically containing functions to adapt the playback of the currently playing content.

Note 5: Selects an available Number Entry Mode that may be implemented on a device, such as: 1-12-key entry mode, 0-9-key entry mode, single or multiple digit entry.

Note 6: This is used, for example, to enter or leave a digital TV data broadcast application.

CEC Table 31 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.

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:

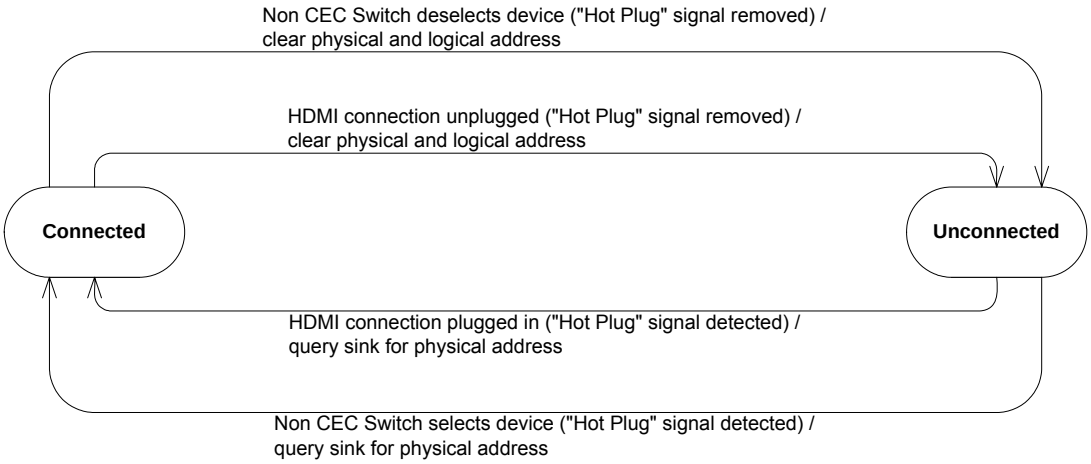
Note that the use of non-CEC Switches is deprecated, see CEC 11.

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.

Supplement 2

HDMI Ethernet and Audio Return Channel (HEAC)

Table of Contents

HEAC 1 Introduction 1
HEAC 1.1 Normative References 1
HEAC 1.2 Informative References 1
HEAC 1.3 Glossary of terms 2
HEAC 1.4 Acronyms and Abbreviations 2
HEAC 1.5 Document Revision History 3
HEAC 2 Physical Layer 4
HEAC 2.1 Connectors 4
HEAC 2.1.1 Overview of Connectors for HEAC 4
HEAC 2.1.2 Connector Pin Assignments for HEAC 4
HEAC 2.1.3 Cable Adapter Specification for HEAC 7
HEAC 2.1.3.1 Type A Plug to Type A Plug for HEAC 8
HEAC 2.1.3.2 Type C Plug to Type C Plug for HEAC 9
HEAC 2.1.3.3 Type C Plug to Type A Plug for HEAC 10
HEAC 2.1.3.4 Type D Plug to Type A Plug for HEAC 11
HEAC 2.2 Electrical Specification 12
HEAC 2.2.1 Overview 12
HEAC 2.3 System Operating Conditions 14
HEAC 2.4 Transmission Conditions 15
HEAC 2.5 Differential Signal Characteristics 15
HEAC 2.6 Common Mode Signal Characteristics 17
HEAC 2.7 Single Mode Signal Characteristics 20
HEAC 2.8 Receiver Performance 22
HEAC 2.9 Cable Assembly Characteristics 23
HEAC 3 Capability Discovery and Control 26
HEAC 3.1 Protocol General Rules 26
HEAC 3.1.1 Maximum Response Time 27
HEAC 3.1.2 Error Code 27

HEAC 3.1.3 Physical HPD pin 27
HEAC 3.2 Feature Description 28
HEAC 3.2.1 HDMI Ethernet Channel 28
HEAC 3.2.1.1 Messages 28
HEAC 3.2.1.2 Channels, Channel States and State Transitions 28
HEAC 3.2.1.3 HEC Capability Discovery 30
HEAC 3.2.1.4 HEC Control 33
HEAC 3.2.1.5 HEC Control for Adjacent Devices 40
HEAC 3.2.1.6 Best Practices 41
HEAC 3.2.2 CDC_HPD (CDC Hot Plug Detect signal) 42
HEAC 3.2.2.1 Messages 42
HEAC 3.2.2.2 Feature Description 42
HEAC 3.2.2.3 Additional Source Requirements 44
HEAC 3.3 Message Descriptions 47
HEAC 3.4 Message Dependencies 52
HEAC 3.5 Operand Descriptions 54
HEAC 4 Audio Return Channel 58
HEAC 4.1 Overview 58
HEAC 4.2 Relationship with IEC 60958/IEC 61937 58
HEAC 4.3 Functionality 58
HEAC 5 Networking 60
HEAC 5.1 Relationship Between HEC and 100Base-TX 60
HEAC 5.2 Layer Architecture 60
HEAC 5.3 Network Topology 61
HEAC 5.4 HEC Device Types 61
HEAC 5.5 Ethernet Switching Functionality 62
HEAC 5.6 Connection to Internet via Home Network 64
HEAC 5.7 Loop Detection and Loop Removal 64
HEAC 5.7.1 Loop Detection Requirements 65
HEAC 5.8 QoS 66

HEAC 6 Appendices 68
HEAC Appendix A MAC Frame Format (Informative) 68
HEAC Appendix B User Priority with Respect to Traffic Class Mapping (Informative) 69
HEAC Appendix C User Priority with Respect to Traffic Type Mapping 70
HEAC Appendix D Connection to the Home Network and Internet 71

Figures

HEAC Figure 2-1 Transmission Waveform 12
HEAC Figure 2-2 Illustration of Fundamental Structure (Differential mode and Common mode) 13
HEAC Figure 2-3 Illustration of ARC-only receiver (Single Mode/Common Mode) and Single Mode ARC-only transmitter 14
HEAC Figure 2-4 Illustration of the HEAC Differential Signal 16
HEAC Figure 2-5 Differential Signal Test Point 17
HEAC Figure 2-6 HEAC Common Mode Signal on each HEAC+/- Line 18
HEAC Figure 2-7 Common Mode Signal Test Point 20
HEAC Figure 2-8 ARC Single Mode Signal on HEAC+ 21
HEAC Figure 2-9 Single Mode Signal Test Point 22
HEAC Figure 2-10 Simultaneous Transmission Waveform 23
HEAC Figure 2-11 HEAC Signal-Line Differential Insertion Loss 25
HEAC Figure 3-1 CDC message frame 27
HEAC Figure 3-2 HEC Channel State Transition Diagram 30
HEAC Figure 3-3 Devices with different HEC Capabilities 31
HEAC Figure 3-4 Network example incorporating devices with different HEC Capabilities 32
HEAC Figure 3-5 Discovery of all HEC capable devices and their Capabilities 33
HEAC Figure 3-6 Capability Notification 33
HEAC Figure 3-7 HEC capability and state inquiry 34
HEAC Figure 3-8 Example for an HDMI network 36
HEAC Figure 3-9 Activation of an HDMI Ethernet Channel (HEC) 36
HEAC Figure 3-10 HDMI network example for multiple VHEC activation 37
HEAC Figure 3-11 Activation of multiple HDMI Ethernet Channel (HEC) 37
HEAC Figure 3-12 Deactivation of an AHEC by its Activator 38
HEAC Figure 3-13 Request deactivation of an AHEC by a device part of that AHEC 38
HEAC Figure 3-14 AHEC safety mechanism 39
HEAC Figure 3-15 Disable and Enable of reading EDID and restarting CP (1) 42
HEAC Figure 3-16 Disable and Enable of reading EDID and restarting CP (2) 44
HEAC Figure 3-17 A timing example of CDC_HPD messages and CP&EDID_HPD 45
HEAC Figure 3-18 A timing example of CDC_HPD messages and EDID_HPD 46
HEAC Figure 4-1 Audio Return Channel Overview 58
HEAC Figure 5-1 Layer Architecture 60
HEAC Figure 5-2 Example of an HEC Network 61
HEAC Figure 5-3 HEC Device Types 62
HEAC Figure 5-4 Example of a Connection to the Internet 64
HEAC Figure 5-5 Example of a Network Loop 65
HEAC Figure 5-6 Example of Three Device Cases with Respect to Conditions for Loop Detection and Removal Capability 66
HEAC Figure 6-1 MAC Frame Format 68
HEAC Figure 6-2 An Example of DLNA User Priority for Traffic Class Mapping 69
HEAC Figure 6-3 Examples of Connection to the Home Network and Internet 71

Tables

HEAC Table 2-1 Type A Connector Pin Assignment 4
HEAC Table 2-2 Type C Connector Pin Assignment 5
HEAC Table 2-3 Type D Connector Pin Assignment 6
HEAC Table 2-4 Wire Categories 7
HEAC Table 2-5 Type A-to-Type A Cable Wire Assignment 8
HEAC Table 2-6 Type C-to-Type C Cable Wire Assignment 9
HEAC Table 2-7 Type C-to-Type A Cable Wire Assignment 10
HEAC Table 2-8 Type D-to-Type A Cable Wire Assignment 11
HEAC Table 2-9 HEAC Operating Conditions 14
HEAC Table 2-10 Required Transmission Conditions 15
HEAC Table 2-11 Differential Transmission Characteristics at TP1 and TP2 16
HEAC Table 2-12 HEAC Common Mode Transmission Characteristics at TP2 18
HEAC Table 2-13 HEAC Common Mode Transmission Characteristics at TP1 19
HEAC Table 2-14 HEAC Single Mode Transmission Characteristics at TP2 21
HEAC Table 2-15 HEAC Single Mode Transmission Characteristics at TP1 21
HEAC Table 2-16 HEAC Impedance Characteristics 23
HEAC Table 2-17 HEAC+/- Lines Cable Assembly 24
HEAC Table 3-1 Possible HECs within a certain HDMI network 29
HEAC Table 3-2 HEC Channel States 29
HEAC Table 3-3 HEC Capability Definition 31
HEAC Table 3-4 Message Descriptions for the HDMI Ethernet Channel Feature 48
HEAC Table 3-5 Message Descriptions for the CDC_HPD Feature 51
HEAC Table 3-6 Message Dependencies when receiving a CDC message 52
HEAC Table 3-7 Message Dependencies when sending a CDC message 52
HEAC Table 3-8 Operand descriptions for CDC messages 54
HEAC Table 6-1 HEC Mapping for User Priority Traffic Type 70

HEAC 1 Introduction

HDMI Ethernet and Audio Return Channel (HEAC) enhances the HDMI standard through the addition of a high-speed bidirectional data communication link which is derived from the 100Base-TX IEEE 802.3 standard [4n] and audio data streaming which leverages the IEC60958-1 standard [1n].

HEAC provides a full duplex connection between HDMI devices which conforms to the 100Base-TX IEEE 802.3 standard. HEAC defines a Category 1 and 2 HDMI cable which is able to carry the high-speed data signals. This transmission is defined as the HDMI Ethernet Channel (HEC).

Furthermore, HEAC provides audio data streaming which conforms to the IEC 60958-1 standard from an HDMI Sink to an HDMI Source or Repeater. This transmission is defined as the Audio Return Channel (ARC).

HEAC 1.1 Normative References

[1n] IEC, IEC 60958-1, “Digital audio interface – Part 1: General”, Third edition 2008-09

[2n] IEC, IEC 61937-1, “Digital Audio - Interface for non-linear PCM encoded audio bitstreams applying IEC 60958 - Part 1: General”, Second edition 2007-01

[3n] IEC, IEC 61937-2, “Digital Audio - Interface for non-linear PCM encoded audio bitstreams applying IEC 60958 - Part 2: Burst-Info”, Second edition 2007-05

[4n] IEEE 802.3-2005, IEEE Standard for information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specification

[5n] IEEE 802.1D-2004, IEEE Standard for Information technology - Telecommunications and information exchange between systems - IEEE standard for local and metropolitan area networks - Common specifications - Media access control (MAC) Bridges

[6n] IEEE 802.1Q-2003, IEEE Standard for Information Technology - Telecommunications and information exchange between systems - IEEE standard for local and metropolitan area networks - Common specifications - Virtual Bridged Local Area Networks

HEAC 1.2 Informative References

[1i] DLNA Networked Device Interoperability Guidelines expanded: March 2006, Volume 1: Architectures and Protocols

[2i] IEC, IEC7498-1, "Information technology - Open Systems Interconnection - Basic Reference Model: The Basic Model", Second edition 1994-11

HEAC 1.3 Glossary of terms

Activator(s)	An Activator is a device which has successfully activated an HDMI Ethernet Channel. Note that a device acting only as an Activator is neither required to support the HEAC physical layer nor any of the HEAC features but it shall be fully compliant to HEAC CDC.
External Network	An External Network is a communication network connecting devices (usually IP based) without the usage of an HDMI Ethernet Channel. Devices supporting HEC might provide the possibility to connect to an External Network using an External Network Connection.
External Network Connection	Refer to HEAC Table 3-3 for a detailed definition.
HEC Functionality	Refer to HEAC Table 3-3 for a detailed definition.
Host Functionality	Refer to HEAC Table 3-3 for a detailed definition.
Layer 2 switch (L2 SW)	A device consisting of a single port or multiple ports and control logic. It includes Ethernet switching functionality on layer 2. Refer to [5n]
Maximum Response Time	The maximum time to respond to received messages (see HEAC 3.1.1).
MLT-3	The MLT-3 (multi-level signal) encoder receives the scrambled Non-Return to Zero (NRZ) data stream from the scrambler and encodes the stream. The output of the MLT-3 encoder has three levels. The 125 Mbps bit stream from the MLT-3 encoder is driven onto a cable by drivers. Refer to [4n]
Open System Interconnection (OSI) 7-layer reference model	The OSI Reference Model defines a seven-layer model for data communication with the physical transport at the lower layer and application protocols at the upper layers. Refer to [2i]
Terminating Device(s)	The Terminating Devices are the two devices at both ends of an HDMI Ethernet Channel. An HDMI Ethernet Channel can be fully identified by its Terminating Devices. See also HEAC 3.2.1.2.

HEAC 1.4 Acronyms and Abbreviations

AHEC	Active HDMI Ethernet Channel
ARC	Audio Return Channel
BPDU	Bridge Protocol Data Unit (Refer to [5n])
CDC	Capability Discovery and Control
CEC	Consumer Electronics Control
CP	Content Protection

HEAC	HDMI Ethernet and Audio Return Channel
HEC	HDMI Ethernet Channel
MRT	Maximum Response Time
PA	Physical Address
PHEC	Potential HDMI Ethernet Channel
VHEC	Verified HDMI Ethernet Channel

HEAC 1.5 Document Revision History

HEAC 2 Physical Layer

The following sections describe the fundamental architecture and requirements for the electrical and cable characteristics of HEAC.

Within Supplement 2, HEAC- denotes HPD/HEAC- and HEAC+ denotes Utility/HEAC+ respectively.

HEAC 2.1 Connectors

HEAC 2.1.1 Overview of Connectors for HEAC

HEAC utilizes the Utility and HPD lines for signal transmission. The pin assignments for Type A, Type C and Type D connectors and the cable adapters are defined in the following sections.

HEAC 2.1.2 Connector Pin Assignments for HEAC

HEAC Table 2-1 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	Utility / HEAC+
15	SCL	16	SDA
17	DDC/CEC Ground / HEAC Shield	18	+5V Power
19	Hot Plug Detect / HEAC-		

HEAC Table 2-2 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 / HEAC Shield
14	CEC
15	SCL
16	SDA
17	Utility / HEAC+
18	+5V Power
19	Hot Plug Detect / HEAC-

HEAC Table 2-3 Type D Connector Pin Assignment

PIN	Signal Assignment	PIN	Signal Assignment
1	Hot Plug Detect / HEAC-	2	Utility / HEAC+
3	TMDS Data2+	4	TMDS Data2 Shield
5	TMDS Data2–	6	TMDS Data1+
7	TMDS Data1 Shield	8	TMDS Data1–
9	TMDS Data0+	10	TMDS Data0 Shield
11	TMDS Data0–	12	TMDS Clock+
13	TMDS Clock Shield	14	TMDS Clock–
15	CEC	16	DDC/CEC Ground / HEAC Shield
17	SCL	18	SDA
19	+5V Power		

HEAC 2.1.3 Cable Adapter Specification for HEAC

HEAC Table 2-4 Wire Categories

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

HEAC 2.1.3.1 Type A Plug to Type A Plug for HEAC

HEAC Table 2-5 Type A-to-Type A Cable Wire Assignment

Type A pin	Signal Name	Wire (HEAC)	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	Utility / HEAC+	E	14
15	SCL	C	15
16	SDA	C	16
17	DDC/CEC Ground / HEAC Shield	F	17
18	+5V Power	5V	18
19	Hot Plug Detect / HEAC-	E	19

HEAC 2.1.3.2 Type C Plug to Type C Plug for HEAC

HEAC Table 2-6 Type C-to-Type C Cable Wire Assignment

Type C pin	Signal Name	Wire (HEAC)	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 / HEAC Shield	F	13
14	CEC	C	14
15	SCL	C	15
16	SDA	C	16
17	Utility / HEAC+	E	17
18	+5V Power	5V	18
19	Hot Plug Detect / HEAC-	E	19

HEAC 2.1.3.3 Type C Plug to Type A Plug for HEAC

HEAC Table 2-7 Type C-to-Type A Cable Wire Assignment

Type C pin	Signal Name	Wire (HEAC)	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 / HEAC Shield	F	17
14	CEC	C	13
15	SCL	C	15
16	SDA	C	16
17	Utility / HEAC+	E	14
18	+5V Power	5V	18
19	Hot Plug Detect / HEAC-	E	19

HEAC 2.1.3.4 Type D Plug to Type A Plug for HEAC

HEAC Table 2-8 Type D-to-Type A Cable Wire Assignment

Type D pin	Signal Name	Wire (HEAC)	Type A pin
1	Hot Plug Detect / HEAC-	E	19
2	Utility / HEAC+	E	14
3	TMDS Data2+	A	1
4	TMDS Data2 Shield	B	2
5	TMDS Data2-	A	3
6	TMDS Data1+	A	4
7	TMDS Data1 Shield	B	5
8	TMDS Data1-	A	6
9	TMDS Data0+	A	7
10	TMDS Data0 Shield	B	8
11	TMDS Data0-	A	9
12	TMDS Clock+	A	10
13	TMDS Clock Shield	B	11
14	TMDS Clock-	A	12
15	CEC	C	13
16	DDC/CEC Ground / HEAC Shield	F	17
17	SCL	C	15
18	SDA	C	16
19	+5V Power	5V	18

HEAC 2.2 Electrical Specification

HEAC 2.2.1 Overview

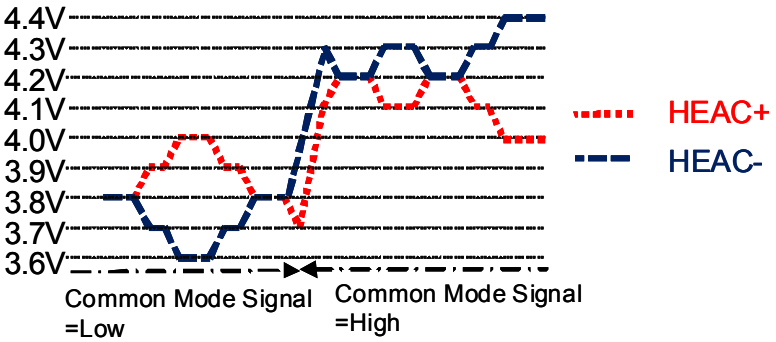
For HDMI Ethernet and Audio Return Channel (HEAC), the signal pair composed of the HEAC- and the HEAC+ lines or only the HEAC+ line is used for transmission.

The HEAC transmission is composed of HEC transmission and ARC transmission. HEC transmission employs MLT-3 signaling in differential mode. ARC transmission employs a single IEC 60958-1 signal in common mode or single mode. Each combination (HEC transmission only, ARC transmission only or HEC transmission with ARC transmission in common mode) is allowed.

For HEC transmission, Source and Sink exchange 100BASE-TX data through a differential pair with a 125 MSymbol/s (+/-50ppm) MLT-3 signal, which is simultaneously bidirectional (full-duplex). The signals are transmitted with attenuated amplitude compared to the normal 100BASE-TX Ethernet signal, and are transmitted on a set of biased lines. A single pair of wires is used to transmit in both directions simultaneously.

For ARC transmission, the HDMI Sink transmits a single IEC 60958-1 stream as a common mode component on the HEAC+/- differential pair with or without MLT-3 signals, or only the HEAC+ line is used for single mode transmission without MLT-3 signals, to an HDMI Source in the reverse direction from the TMDS signals.

When transmitting ARC in common mode, although it is possible to simultaneously transmit with MLT-3, it is not necessary to synchronize with that signal. In single mode ARC transmission it is not possible to transmit simultaneously with MLT-3. When simultaneously transmitting with MLT-3, transmission shall be performed in common mode. An HDMI Sink that supports ARC shall support either common mode or single mode transmission. An HDMI Source that supports ARC shall be capable to receive both common mode as well as single mode transmission. In HEAC Figure 2-1, examples of the HEC (differential mode) and ARC (common mode) simultaneous transmission waveforms are shown.

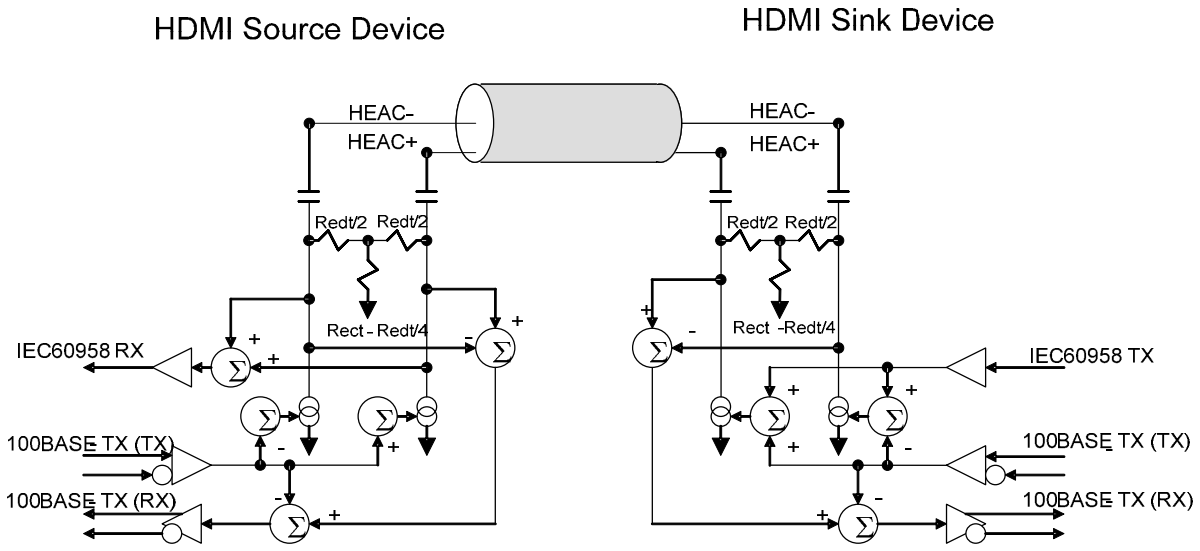


HEAC Figure 2-1 Transmission Waveform

The HEAC signal is transmitted in compliance with the HPD characteristics defined in section 4.2.9 of the main specification.

The HEC signal is the sum of the Tx and Rx MLT-3 signals onto a single pair with attenuated amplitude compared to 100BASE-TX Ethernet MLT-3 transmission.

HEAC Figure 2-2 shows HEAC's fundamental structure where HEC and ARC in common mode are both applied.



HEAC Figure 2-2 Illustration of Fundamental Structure (differential mode and common mode)

The differential lines shall be terminated by a resistor via AC coupling in both the Source and Sink. This Termination resistor and AC coupling is matched to the characteristic impedance of the cable with sufficient bandwidth to exchange MLT-3 signals between the devices.

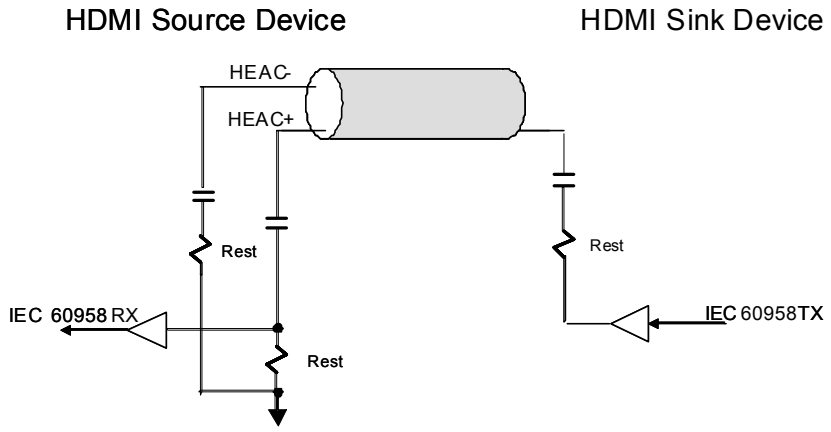
Full duplex bi-directional communication is performed by the HEAC transmitters in both Source and Sink. The transceiver consists of a high-impedance current driver that supplies current in proportion to the MLT-3 signal and IEC 60958-1 signal from the HDMI Sink side to the line pair and termination resistance in the connected device. A differential voltage sensor with a high impedance input is used in both Source and Sink to observe the differential voltage across the termination resistance, Redt.

When a Source and Sink are connected with a cable and the MLT-3 transmission is active, the differential voltage across the termination resistance, Redt, in one device is the sum of the driving MLT-3 signal of that device and the MLT-3 signal from the other device. The device is able to detect with its sensor the incoming MLT-3 signal by subtracting the detected differential signal from its current driver's outgoing MLT-3 signal. In addition, when the HDMI Sink is simultaneously transmitting ARC in common mode, the HDMI Source is capable of detecting with its sensor the IEC 60958-1 signal by summing the HEAC+ and HEAC- signals, to retrieve the common mode signal.

The differential impedance between the HEAC+/- lines and the DC bias of the HEAC+/- differential line provided by the Sink shall meet the specification in section HEAC 2.8. The Sink shall meet the DC bias specifications in section HEAC 2.3.

The HEAC+/- differential line in the cable shall meet the specifications for the characteristic impedance and insertion loss in section HEAC 2.9.

HEAC Figure 2-3 shows HEAC's fundamental structure where ARC in single mode is applied.



HEAC Figure 2-3 Illustration of ARC-only receiver (Single Mode/Common Mode) and Single Mode ARC-only transmitter

The single line shall be terminated by a resistor via AC coupling in both the Source and Sink. This Termination resistor is matched to the characteristic impedance of the cable with sufficient bandwidth to exchange the IEC 60958-1 signal.
The single mode impedance of the Sink shall meet the specification. The Sink shall meet the DC bias specifications.

HEAC 2.3 System Operating Conditions

The following HEAC Table 2-9 shows HEAC operating conditions:

HEAC Table 2-9 HEAC Operating Conditions

Item	Value
Operating DC voltage (HPD High condition), Veh differential and/or common mode transmission	4.0 Volts ±10% when +5V Power is high
Operating DC voltage , Vel Single mode only Transmission	0 ≦Vel ≦5.0 Volts
Termination differential resistance, Redt	100 ohms ±10%
Termination common mode resistance, Rect	30 ohms ± 20%
Termination single mode resistance, Rest	55 ohms ± 35%

The Operating DC Voltage may be derived from the +5V Power.

Redt is specified for HEC MLT-3 transmission. Rect is specified for ARC IEC 60958 transmission in common mode. Rest is specified for ARC IEC 60958 transmission in single mode.

HEAC 2.4 Transmission Conditions

It is possible to start HEC transmission once the conditions as described in section HEAC 3 Capability Discovery and Control are met, the following conditions for the bias voltage are met, and +5V Power is asserted high. If these conditions are not met, HEC transmission shall not be used.

It is possible to start ARC transmission once the conditions as described in CEC Section 13.17 Audio Return Channel Control are met, the following conditions for the bias voltage are met, and +5V Power is asserted high. If these conditions are not met, ARC transmission shall not be used.

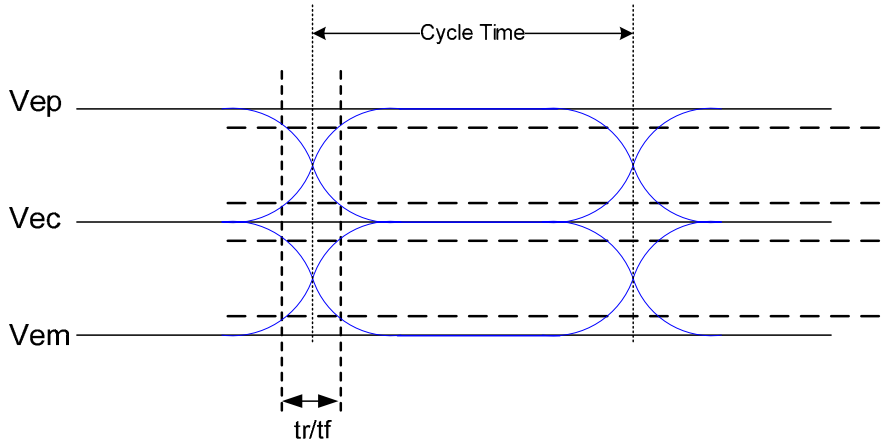
The High and Low voltage levels of the HEAC+/- lines used in this section are defined in Section 4.2.9, Hot Plug Detect Signal. When both HEAC+/- lines are biased to a High level and the other conditions mentioned above are met, an MLT-3 signal may be sent in the differential mode in both directions and an IEC-60958 signal may be sent in the common mode from Sink to Source. When both HEAC+/- lines are biased to a Low level or the HEAC+/- lines are at different bias levels, no MLT-3 differential signal or IEC-60958 common mode signal shall be transmitted. In single mode, ARC transmission is possible irrespective of the level of HPD. However, HPD should not be changed while the ARC single mode transmission is activated to prevent crosstalk noise from disturbing the HEAC+. HPD should not be changed while ARC common mode transmission is activated. For HPD requirements while HEC transmission is activated, see HEAC 3.1.3 and HEAC 3.2.2. Sources shall keep +5V Power at High level while HEC and/or ARC common mode transmission is activated.

HEAC Table 2-10 Required Transmission Conditions

Transmission Signal	Required Condition
HEC	HEAC+ = High , HEAC- = High, +5V Power = High
ARC (Common mode)	HEAC+ = High , HEAC- = High, +5V Power = High
ARC (Single mode)	HEAC+ = ARC (Single mode), HEAC- = normal HPD Signal, +5V Power = High

HEAC 2.5 Differential Signal Characteristics

For HEC, the input and output (I/O) drivers and differential lines are AC coupled. HEAC Figure 2-4 prescribes the eye pattern for the transmission line and also applies to the transmitter and receiver. Sink devices that are capable of transmitting an IEC 60958-1 signal in ARC Common Mode shall comply with these requirements when IEC 60958-1 transmission is on, and also when IEC 60958-1 transmission is off.



HEAC Figure 2-4 Illustration of the HEAC Differential Signal

The differential high level voltage for Vep and the low level voltage for Vem are shown in HEAC Figure 2-4. Vec is the midpoint voltage.

HEAC Table 2-11 Differential Transmission Characteristics at TP1 and TP2

Item	Value
High Level voltage, Vep	0.2 Volts ±10%
Low Level voltage, Ve_m	-0.2 Volts ±10%
Center Level voltage ,Vec	0 Volts ±20mV
Rise time / fall time (10%-90%)	3.0ns < Tr / Tf < 5.0ns
Jitter Max	1.4ns
Cycle time	8 ns ±0.125 ns

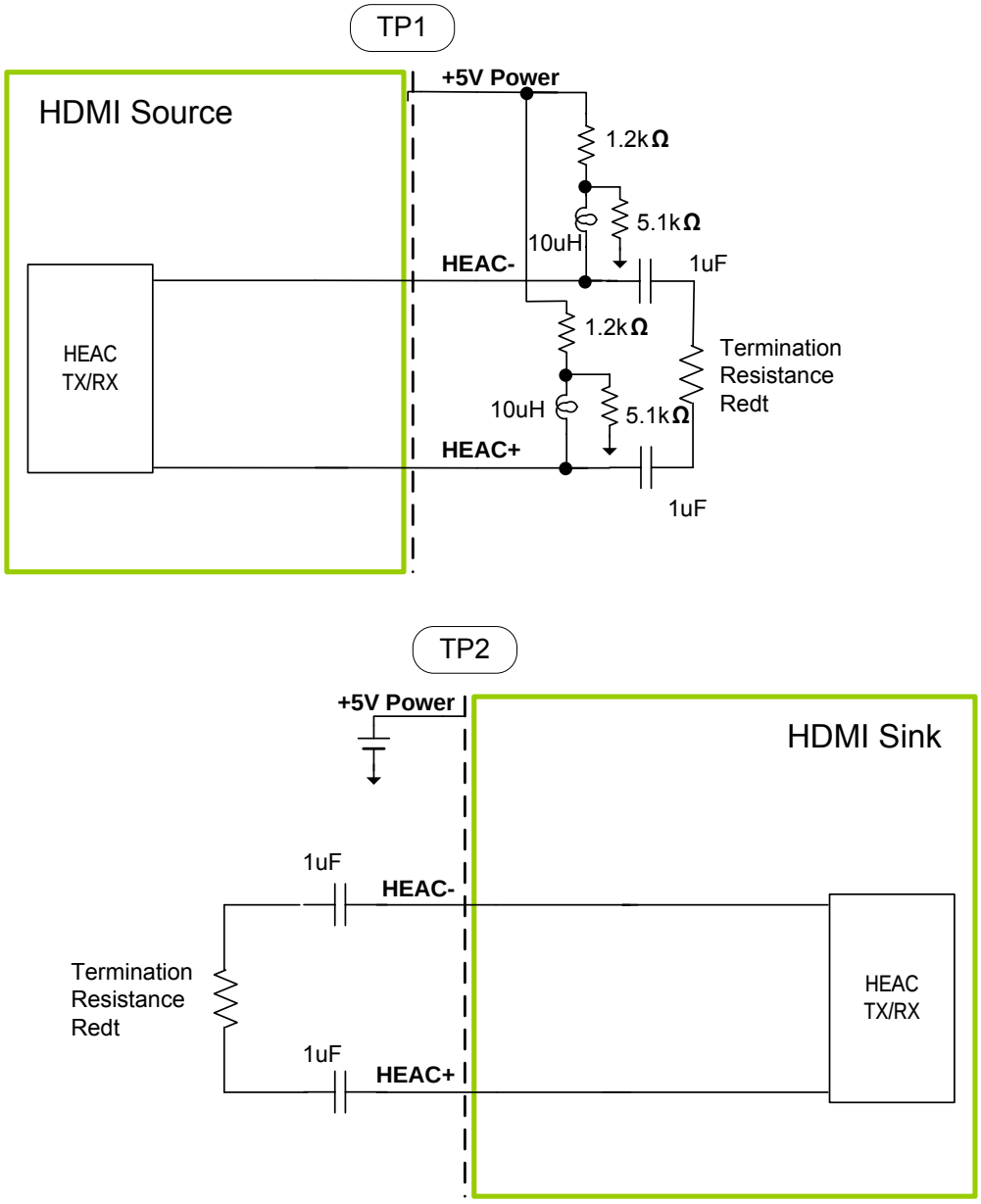
To verify the output signal at the transmitter meets the specification, subtract the reflected signal from the actual transmitted signal.

The waveform characteristics are measured at TP1 on the Source and are measured at TP2 on the Sink as shown in HEAC Figure 2-5. If the equipment is capable of transmitting in common mode, then during simultaneous differential mode and common mode signaling, the differential mode specification shall be met.

Rise/Fall times are defined as the signal transition time between 10% and 90% of Vec to Vep and Vec to Vem. The Jitter measurement is performed by measuring the center of Vep and Vec, and center of Vem and Vec.

Regarding the receiver waveform, the cable insertion loss lower limit from the cable assembly characteristics in section HEAC 2.9 is used and it may cause worst-case signal degradation.

The Actual Measurement Conditions are measured on the load condition in HEAC Figure 2-5.



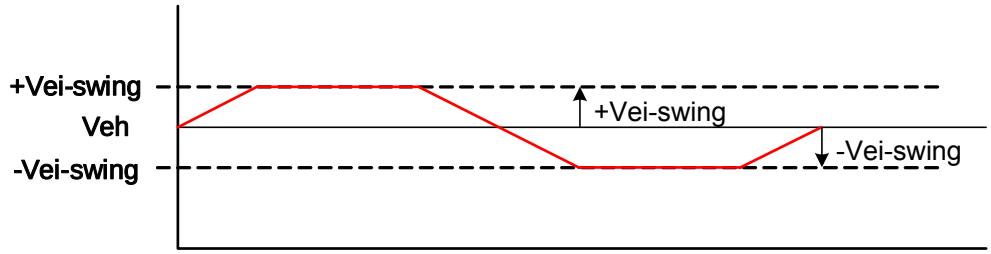
HEAC Figure 2-5 Differential Signal Test Point

HEAC 2.6 Common Mode Signal Characteristics

The common mode signal as defined in this section, regardless of how the differential signal was transmitted, shall be correctly received.

For ARC common mode transmission, the HDMI Sink transmits an IEC 60958-1 stream as a common mode signal component of the HEAC signal pair, in one direction (from HDMI Sink to HDMI Source), with some adaptations to the physical layer of the unbalanced line transmission format of IEC 60958-1 (such as

amplitude level, impedance and DC bias). This signal component shall comply with following requirements. Sink devices that are capable of transmitting an MLT-3 signal, shall comply with these requirements whether an MLT-3 signal exists or not. To verify that the output signal at the transmitter meets the specification, sum the signals from the actual transmitted HEAC+/- signals and multiply the amplitude of the sum by half. The differential signal as defined in section HEAC 2.4, regardless of how the common mode signal was transmitted, shall be correctly received.



HEAC Figure 2-6 HEAC Common Mode Signal on each HEAC+/- Line

HEAC Table 2-12 HEAC Common Mode Transmission Characteristics at TP2

Item	Value
Termination supply voltage, Veh	4.0 Volts ±10%
High level voltage, +Vei-swing	0.2 Volts ±20%
Low level voltage, -Vei-swing	-0.2 Volts ±20%
Rise time / fall time	When accompanied by MLT-3 signals; Min 10ns, Max See IEC 60958-1 When not accompanied by MLT-3 signals; Max See IEC 60958-1
Jitter Max	See IEC 60958-1
Clock frequency	4.096MHz ±1000 ppm, 5.6448MHz ±1000 ppm, 6.144MHz ±1000 ppm (Other frequencies defined in IEC 60958-3 are optional. Refer to HEAC 4.2.)

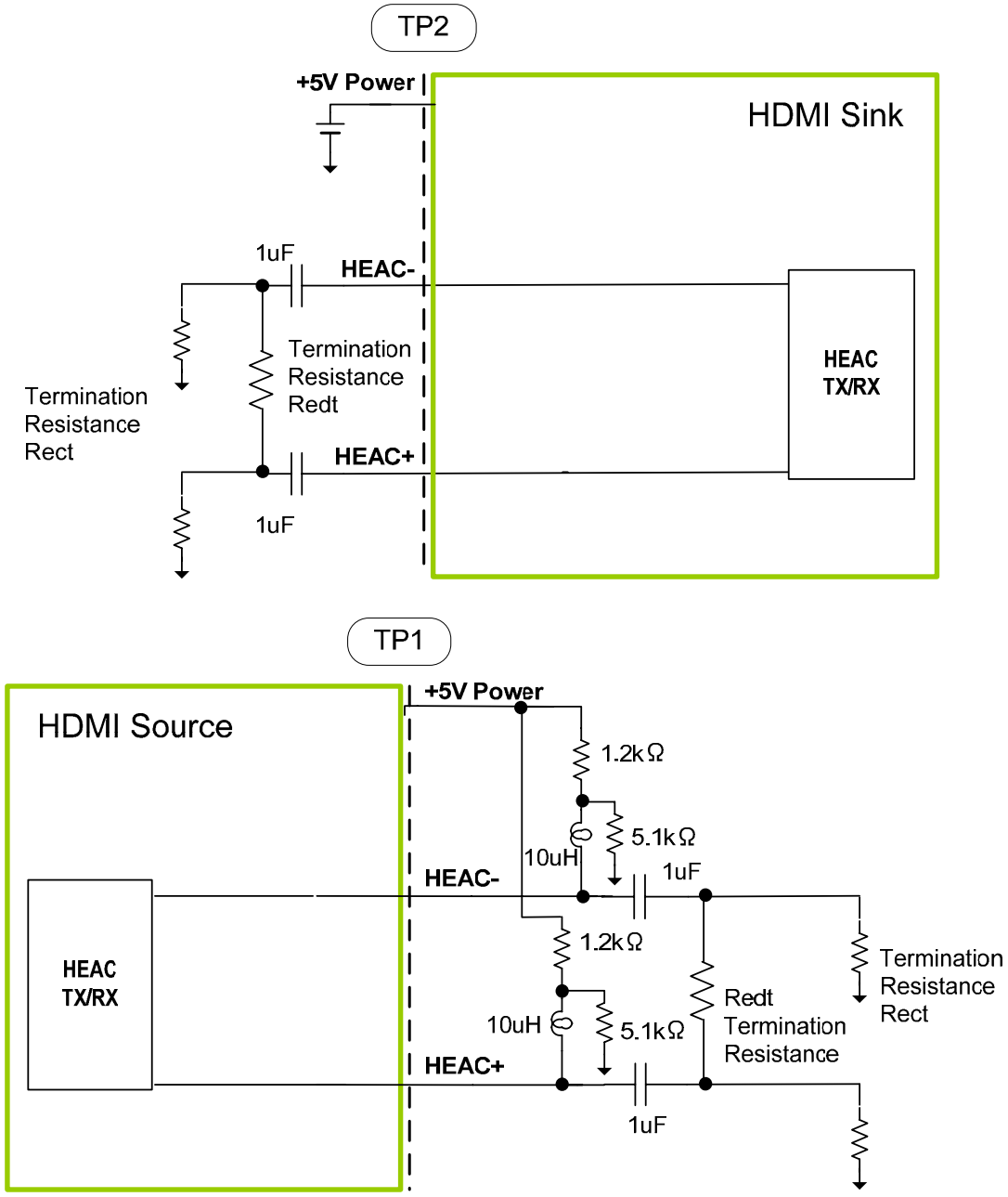
The waveform is measured at TP2 on the HDMI Sink as shown in HEAC Figure 2-7. If the equipment is capable of transmitting in differential mode, then also during simultaneous differential mode and common mode signaling, the common mode specification shall be met.

HEAC Table 2-12 specifies the output signal characteristics which are illustrated in HEAC Figure 2-6. HEAC Table 2-13 shows the input signal characteristics after the transmission path. ARC receivers shall be capable to receive the common mode input waveform's characteristics which are shown in HEAC Table 2-13. These waveform characteristics are defined at Source side TP1.

HEAC Table 2-13 HEAC Common Mode Transmission Characteristics at TP1

Item	Value
Input voltage level,	3.36 Volts <= Vheac <= 4.64 Volts
Minimum input (peak-to-peak)	160 mV (See IEC 60958-1 with Vmin=160mV)
Maximal input (peak-to-peak)	480 mV
Receiver jitter tolerance	See IEC 60958-1

The ground reference is the DDC/CEC Ground signal.

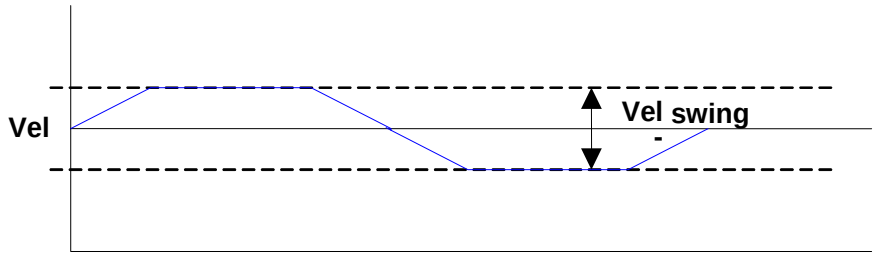


HEAC Figure 2-7 Common Mode Signal Test Point

HEAC 2.7 Single Mode Signal Characteristics

For ARC single mode transmission, the HDMI Sink transmits an IEC 60958-1 stream as a single mode component of the HEAC signal on the HEAC+ Line only, in one direction (from HDMI Sink to HDMI Source), with some adaptations to the physical layer of the unbalanced line transmission format of the IEC 60958-1

(such as impedance and DC bias). The single mode transmission case shall not be transmitted simultaneously with differential mode transmission.



HEAC Figure 2-8 ARC Single Mode Signal on HEAC+

HEAC Table 2-14 HEAC Single Mode Transmission Characteristics at TP2

Item	Value
Termination Supply Voltage, Vel	0 ≦Vel ≦5.0 Volts
Signal amplitude, Vel swing	0.5 Volts ± 0.1 Volts
Rise time / fall time	Max See IEC 60958-1
Output impedance, Rest	55 ohm ± 35% from 0.1 MHz to 128 times the maximum frame rate
Jitter Max	See IEC 60958-1
Clock frequency	4.096MHz ±1000 ppm, 5.6448MHz ±1000 ppm, 6.144MHz ±1000 ppm (Other frequencies defined in IEC 60958-3 are optional. Refer to HEAC 4.2.)

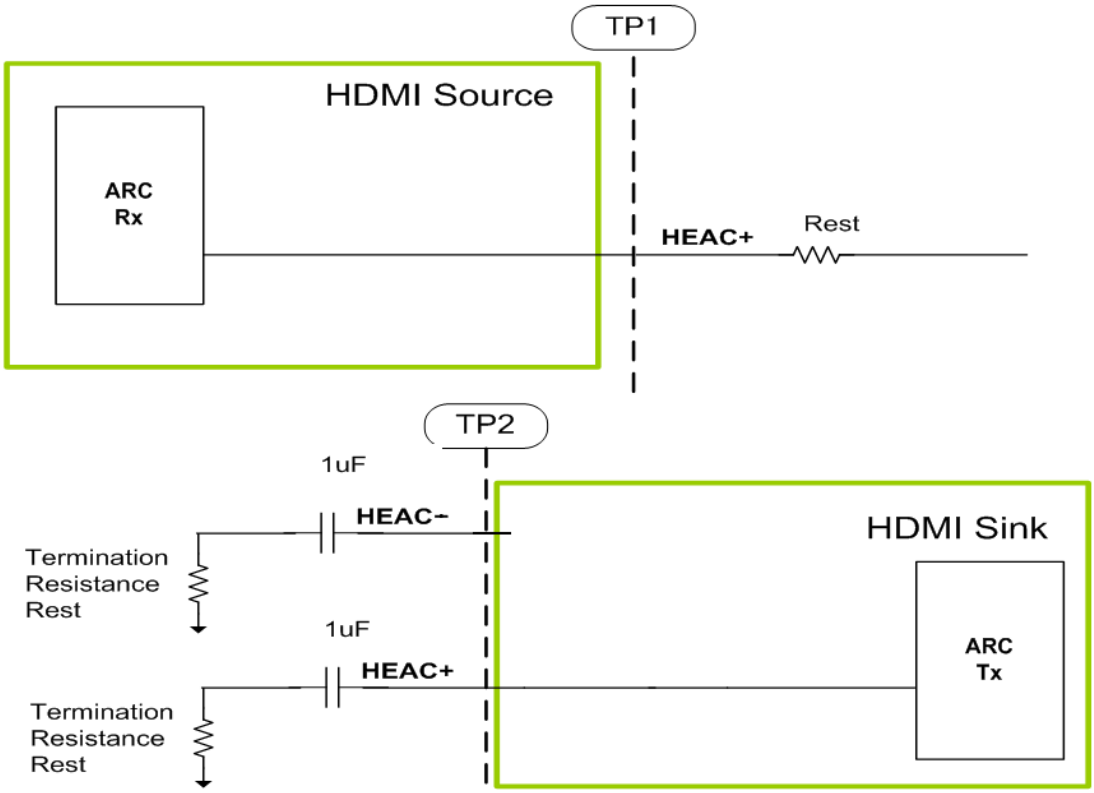
Measure the waveform at TP2 on the Sink as shown in HEAC Figure 2-9.

HEAC Table 2-14 specifies the output signal characteristics. HEAC Table 2-15 shows the received signal characteristics after the transmission path. ARC receivers shall be capable to receive the single mode input waveform's characteristics which are shown in HEAC Table 2-15. These waveform characteristics are defined at Source side TP1.

HEAC Table 2-15 HEAC Single Mode Transmission Characteristics at TP1

Item	Value
Input HEAC+ Voltage Level, Vheac+	-0.3 Volts <= Vheac+ <= 5.3 Volts
Minimum input (peak-to-peak)	See IEC 60958-1
Maximal input (peak-to-peak)	See IEC 60958-1
Receiver jitter tolerance	See IEC 60958-1

The ground reference is the DDC/CEC Ground signal.

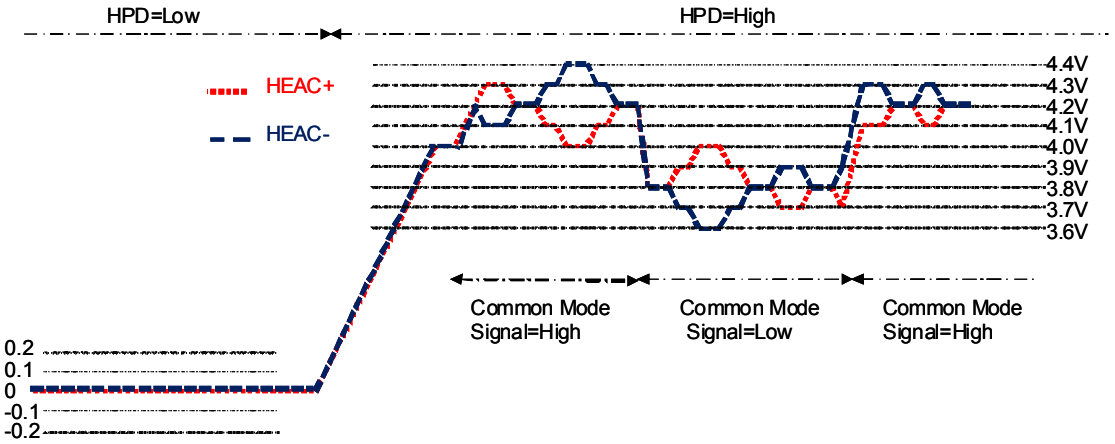


HEAC Figure 2-9 Single Mode Signal Test Point

HEAC 2.8 Receiver Performance

The HEAC signals are composed of MLT-3 signals in differential mode, a single IEC 60958-1 signal in common mode, or a single IEC 60958-1 signal in single mode.

Each allowed combination of transmission (HEC transmission only, ARC transmission only, or HEC transmission with ARC transmission in common mode) may be present. In an HDMI Source or Sink device that supports both HEC and ARC, during simultaneous common mode and differential mode signaling, common mode and differential mode signals shall be received by the HDMI Source and differential mode signals shall be received by the HDMI Sink. When transmitting differential and common mode signals simultaneously, a voltage waveform example is shown in HEAC Figure 2-10.



HEAC Figure 2-10 Simultaneous Transmission Waveform

A Source device with support for receiving ARC transmission shall be capable of receiving both common mode and single mode transmission. Given the cable characteristics as defined in HEAC 2.9, the worst case waveform at the input terminal is estimated, and the receiver shall be capable of receiving it.

For HEAC devices applying HEC, both the HDMI Source and Sink become input terminals, hence both devices shall meet the impedance specification for the HEAC +/- lines.

With the impedance measurement, there may be an impedance disturbance due to the connector. In comparison to a TDMS signal, which may become skewed, the HEAC signal line carrying an IEC 60958-1 signal is of a much lower frequency and the effect of the impedance fluctuation may be ignored.

HEAC Table 2-16 HEAC Impedance Characteristics

Item	Value
TDR Rise Time (10%-90%)	≤1ns
Through connection differential impedance except connector area*	100 ohms ±15%
At Termination differential impedance	100 ohms ±10%
At Termination common mode impedance	30 ohms ±20%
At Termination single mode impedance	55 ohms ±35%

* A single excursion is permitted out to a max/min of 100 ohms +/- 25% and of a duration less than 250 ps.

In HEAC Table 2-16, the differential impedance is specified for the DUT's MLT-3 transmission. The common mode impedance is specified for the DUT's IEC 60958 transmission in common mode. The single mode impedance is specified for the ARC Receiver DUT's IEC 60958 transmission for single mode. A device with support for receiving ARC transmission (ARC Rx) shall meet the common mode and single mode impedance specifications of HEAC Table 2-16.

HEAC 2.9 Cable Assembly Characteristics

This section describes the additional performance requirements for all Category cables with HEAC. A Category 1/2 HDMI cable with HEAC shall meet all cable specifications as specified in Sections 4.1 and 4.2.6 of the HDMI specification, as well as all requirements in this section. The Category 1/2 HDMI cable with HEAC is required when transmitting HEC only or HEC with common mode ARC, and is recommended for common

mode ARC without HEC. The HDMI Category 1/2 with HEAC cable specification fully satisfies the HDMI Category 1/2 cable specification; all requirements from the HDMI Category 1/2 cable specification shall be fulfilled.

The HEAC+/- lines are a shielded twisted pair in the cable and used as signal lines. This twisted pair uses the CEC/DDC ground as a shield.

With the cable impedance measurement, there may be an impedance disturbance due to the connector. In comparison to a TDMS signal, which may become skewed, the HEAC signal line carrying an IEC 60958-1 signal is of a much lower frequency and the effect of the connector's impedance perturbation may be ignored.

Common mode impedance is the impedance of the in-phase signal when applied to the HEAC+/- lines.

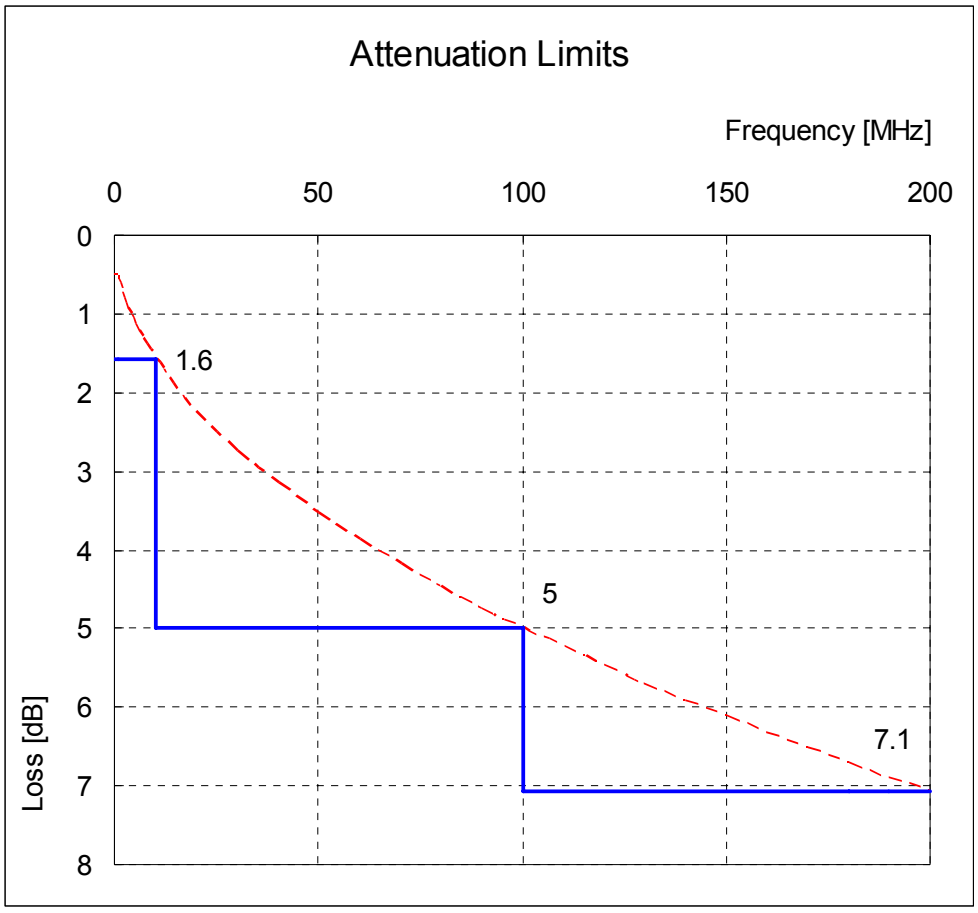
HEAC Table 2-17 HEAC+/- Lines Cable Assembly

Parameter	Value
Maximum Cable Assembly Intra-Pair Skew	111ps
Differential Attenuation	See HEAC Figure 2-11
300kHz - 10MHz	<1.6dB
10MHz – 100MHz	<5dB
100MHz – 200MHz	<7.1dB
Differential Impedance*	
Connection point and transition area: Up to 1ns	100 ohms ±15%*
Cable area: 1ns – 2.5ns	100 ohms ±10%
Common mode Impedance*	
Cable area: 1ns – 2.5ns	30 ohms ±20%

* A single excursion is permitted out to a max/min of 100 ohms +/- 25% and of a duration less than 250 ps.

The upper limit of the cable's differential insertion loss is shown in the formula below. The cable's maximum attenuation is shown in the formula below and the specification values shown in HEAC Table 2-17 shall be fulfilled. In HEAC Figure 2-11, the solid line indicates the specification's value. In HEAC Figure 2-11 the dashed line expresses the formula. The formula below shows the attenuation limit value. A cable which meets the differential attenuation requirements also satisfies necessary attenuation characteristics for common mode transmission.

$$ATTmax = \max\left(A \cdot \sqrt{\frac{f}{f_0}} , B \right) : A=5\ [dB],\ B=0.5\ [dB],\ f_0=100MHz$$



HEAC Figure 2-11 HEAC Signal-Line Differential Insertion Loss

HEAC 3 Capability Discovery and Control

In order to use the HDMI Ethernet Channel capabilities of HEAC, it is necessary to discover and control the capabilities of devices in the respective paths. This is done using CDC, Capability Discovery and Control messages carried by CEC (Supplement 1). A device with HDMI Ethernet Channel capability shall support CDC and shall not utilize HDMI Ethernet Channel data transmissions toward any HDMI devices without the procedures specified in this section.

HEAC 3.1 Protocol General Rules

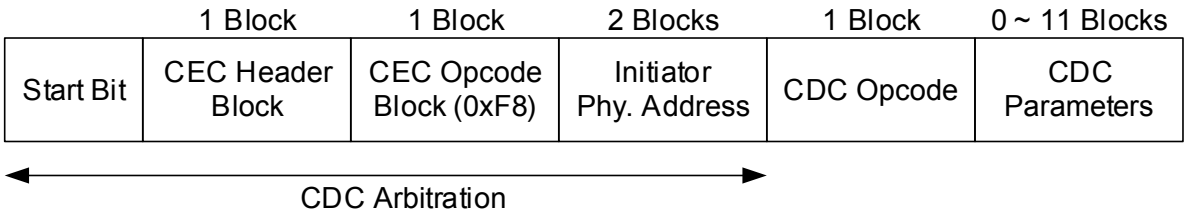
CDC devices shall be compliant with the CEC specification (Supplement 1) with the following exceptions:

- Devices implementing CDC only (CDC-only devices) shall not have a device-specific CEC Initiator Logical Address. Such devices shall use the Initiator CEC Unregistered Logical Address (15).
- Devices implementing CDC only (CDC-only devices) shall not implement any of the CEC Features.
- All CDC messages shall be broadcast using a Destination Logical Address of 15 (the CEC Broadcast Logical Address).
- CEC line arbitration for CDC messages commences with the leading edge of the Start Bit and continues until the end of the Initiator Physical Address within the second CEC operand block (see HEAC Figure 3-1). During this period the initiator shall monitor the CEC line and if whilst in high impedance state it detects low impedance at other than the Acknowledge bits then it shall assume that it has lost arbitration to a second initiator and it shall immediately stop transmitting and become a follower. The device shall then wait for the CEC line to be inactive for the signal free time period (see Supplement 1), before attempting to send another message. This process gives priority to the logical address with the most leading zeros. If the logical addresses are matching it gives priority to CEC broadcast messages over CDC messages; within CDC messages it gives higher priority to the initiator physical address with the most leading zeros.

A device that implements CEC as well as CDC shall use an Initiator Logical Address allocated according to Supplement 1 and shall implement at least the mandatory items described in the CEC specification (Supplement 1) in addition to the items described in this Supplement 2.

CDC messages shall be based on the CEC message frame with the following extensions (see HEAC Figure 3-1):

- CDC messages shall always use a CEC opcode value of 0xF8. This CEC opcode value for CDC messages is specified in the CEC specification (Supplement 1).
- CDC messages shall always incorporate the Initiator Physical Address in the first and the second operand block of the respective CEC message.
- CDC messages shall always incorporate the CDC opcode in the third operand block of the respective CEC message.
- Specific to the CDC opcode, CDC messages shall incorporate a minimum of 0 and a maximum of 11 CDC parameters in the fourth to the fourteenth operand block of the respective CEC message.



HEAC Figure 3-1 CDC message frame

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

All bit sequences are sent most significant bit first.

HEAC 3.1.1 Maximum Response Time

A certain Maximum Response Time to respond to received messages shall be obeyed at the application level. This Maximum Response Time has a desired maximum of 200ms and a required maximum of 1 second with one exception in the case where a device responds by sending a <CDC_HEC_Report_State> message and the CEC line is saturated by other CEC or CDC messages. In this case it is exceptionally allowed to respond at the first opportunity after 1 second has already passed. Note that devices waiting for incoming <CDC_HEC_Report_State> messages take appropriate measures to be able to receive also these late arriving messages.

HEAC 3.1.2 Error Code

A CDC message is a CEC broadcast message and therefore the CEC <Feature Abort> mechanism cannot be used. Alternatively CDC devices may report using the [CDC Error Code] field with the following errors:

- “Initiator does not have the requested Capability”: the device sending this message never supports this Capability.
- “Initiator is incapable to carry out the request in this state”: the device sending this message supports this Capability, but is incapable to carry out the request in the current state
- “Other Error”: the device sending this message discovered an error not covered by one of the above two responses.

These notifications are carried in the [CDC Error Code] fields in some CDC messages.

HEAC 3.1.3 Physical HPD pin

HDMI Sinks that support HEC shall meet the requirements of this section, since they shall support CDC (see introduction of HEAC 3). These Sinks maintain the physical HPD pin high in order not to disturb HEC transmission.

CDC can also be used in certain HDMI Sinks that do not support HEC, e.g. since they want to employ CDC_HPD.

The requirements in this section are relevant for both types of Sinks.

HDMI Sinks that support CDC hold the physical HPD pin high because an HDMI Source connected to the HDMI Sink utilizes CDC messages that depend on Physical Address.

HDMI Sinks that support CDC shall keep the physical HPD pin high,

- when connected to an HDMI Source that supports CDC messages,
  - The HDMI Sink shall verify such CDC support by sending at least one CDC message to the adjacent Source and detecting a CDC response within the Maximum Response Time.
- except as needed to meet the requirement that the Hot Plug Detect pin may be asserted only when the +5V Power line from the Source is detected (Section 8.5 of the main specification),
- with the additional exceptions that HDMI Sinks that do not support the CDC_HPD feature:
  - shall set the physical HPD-pin low while the E-EDID is not available for reading, and
  - shall set the physical HPD-pin low a short period that is at least 100 msec when the contents of the E-EDID is changed (see main specification Section 8.5),

  Note: In the current version of Supplement 2, all CDC devices support the CDC_HPD feature. In future releases, some CDC devices might not support the CDC_HPD feature.
- with the additional exceptions that HDMI Sinks that support the CDC_HPD feature shall set the physical HPD-pin low for a short period that is at least 100 msec (see main specification Section 8.5) in the following two cases:
  - it changes the Physical Address in the HDMI VSDB of its own EDID presented to the Source;
  - it receives no response or an Error response after sending a <CDC_HPD_SetState> message (see HEAC 3.2.2.2).

HEAC 3.2 Feature Description

HEAC 3.2.1 HDMI Ethernet Channel

HEAC 3.2.1.1 Messages

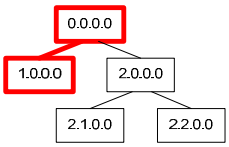
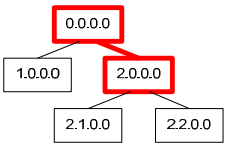
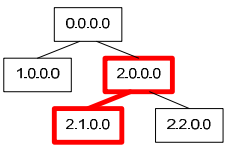
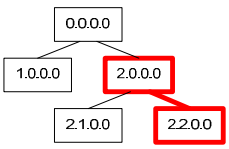
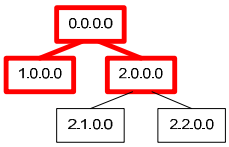
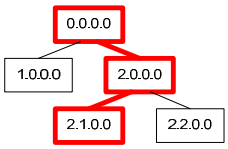
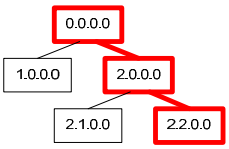
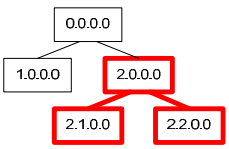
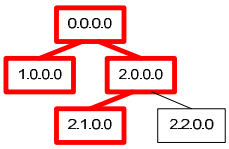
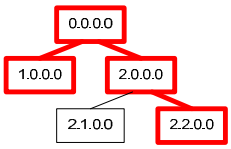
The following messages are used for the capability discovery and control of the HDMI Ethernet Channel (HEC) of HEAC. For details of which messages are mandatory, see HEAC Table 3-4, HEAC Table 3-6 and HEAC Table 3-7.

<CDC_HEC_InquireState>, <CDC_HEC_ReportState>, <CDC_HEC_SetState>, <CDC_HEC_RequestDeactivation>, <CDC_HEC_NotifyAlive>, <CDC_HEC_Discover>, <CDC_HEC_SetStateAdjacent>

HEAC 3.2.1.2 Channels, Channel States and State Transitions

Depending on the complexity of an HDMI network there are several possibilities to establish an HDMI Ethernet Channel between two or more devices within this network. HEAC Table 3-1 shows all possible HECs and the devices involved (red colored and bold) within a certain HDMI network. It is important to note that several of these possible HECs might be simultaneously active within one HDMI network. It is also important to note that the same possible HEC might be activated more than once by different Activators. An HEC is identified by the two devices at both ends of that HEC in the appropriate CDC messages. These two devices are referred to as the Terminating Devices of that HEC.

HEAC Table 3-1 Possible HECs within a certain HDMI network

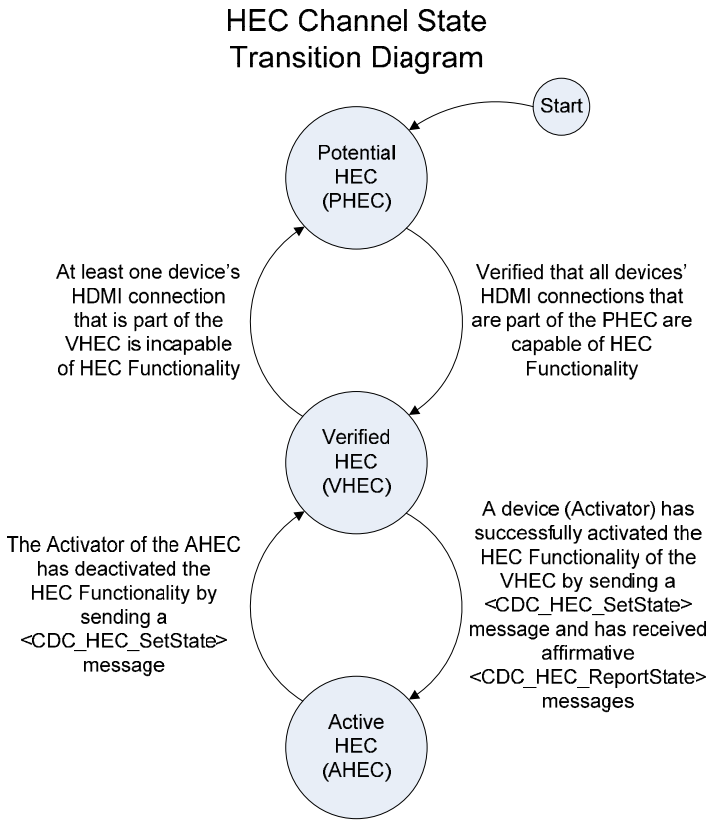
 Terminating Devices: 1.0.0.0 and 0.0.0.0	 Terminating Devices: 0.0.0.0 and 2.0.0.0	 Terminating Devices: 2.0.0.0 and 2.1.0.0	 Terminating Devices: 2.0.0.0 and 2.2.0.0	 Terminating Devices: 1.0.0.0 and 2.0.0.0
 Terminating Devices: 0.0.0.0 and 2.1.0.0	 Terminating Devices: 0.0.0.0 and 2.2.0.0	 Terminating Devices: 2.1.0.0 and 2.2.0.0	 Terminating Devices: 1.0.0.0 and 2.1.0.0	 Terminating Devices: 1.0.0.0 and 2.2.0.0

Each HEC channel may be in one of the states described in HEAC Table 3-2.

HEAC Table 3-2 HEC Channel States

HEC Channel State	Description
Potential HDMI Ethernet Channel (PHEC)	A Potential HDMI Ethernet Channel (PHEC) shall be considered as being a channel within an HDMI network that might provide an interconnect among two or more devices via HEC Functionality, regardless of whether or not all devices' HDMI connections that are part of this channel are capable of HEC Functionality. A device shall be considered to be part of a PHEC if it has at least one HDMI connection which is part of the PHEC. A maximum of two HDMI connections on a device may be part of the same PHEC.
Verified HDMI Ethernet Channel (VHEC)	A Potential HDMI Ethernet Channel (PHEC) shall be considered as a Verified HDMI Ethernet Channel (VHEC) after a successful capability inquiry of the PHEC or a capability discovery has shown that all devices' HDMI connections that are part of the PHEC are capable of HEC Functionality, regardless of whether or not the devices' HEC Functionality is activated or deactivated.
Active HDMI Ethernet Channel (AHEC)	A Verified HDMI Ethernet Channel (VHEC) shall be considered to be an Active HDMI Ethernet Channel (AHEC) after successful activation of the HEC Functionality of all devices' HDMI connections that are part of that VHEC. The Activator of a certain AHEC shall be the device that has sent the appropriate <CDC_HEC_SetState> message to activate the VHEC.

HEAC Figure 3-2 provides an overview about channel states and possible state transitions.



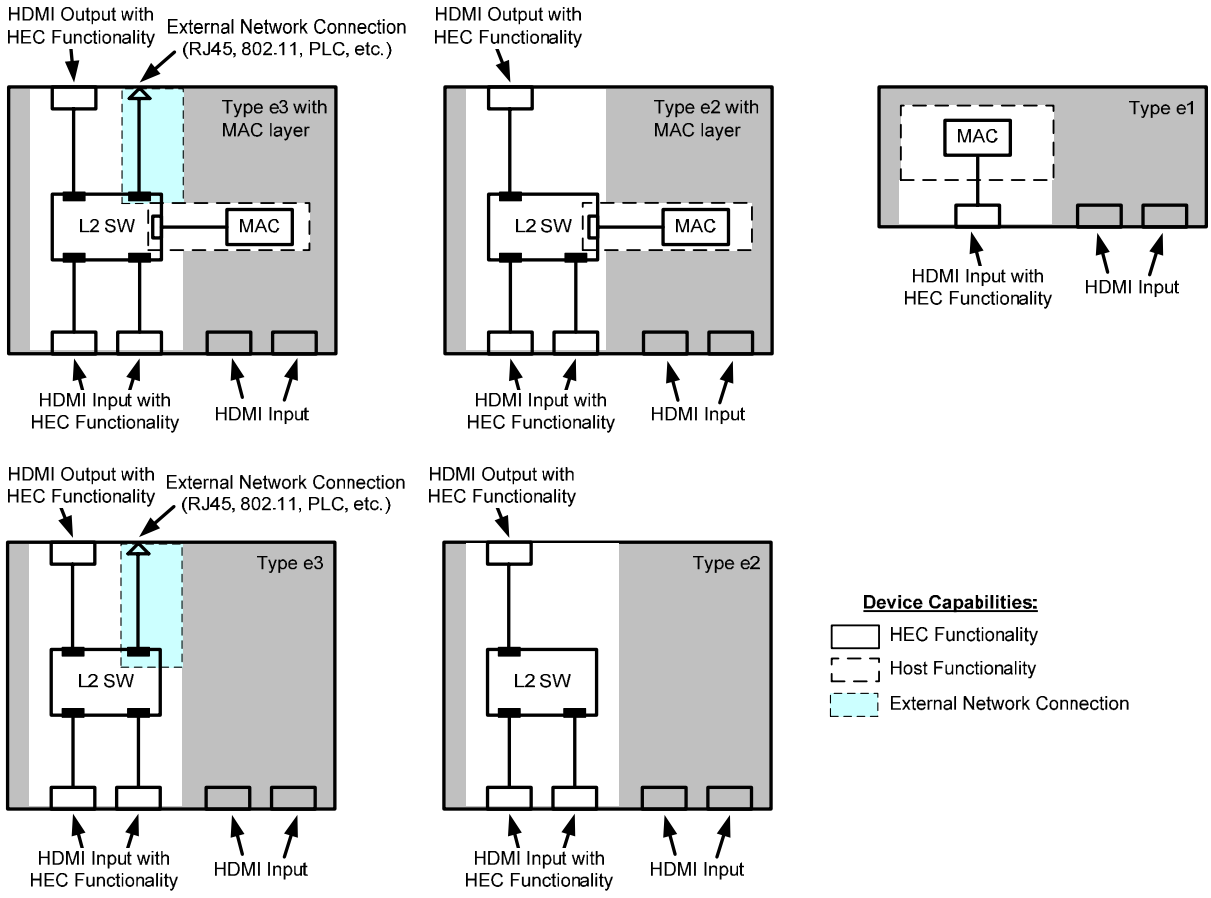
HEAC Figure 3-2 HEC Channel State Transition Diagram

HEAC 3.2.1.3 HEC Capability Discovery

All HDMI devices that support HEC Functionality shall distinguish between three different HEC Capabilities. The three different HEC Capabilities are HEC Functionality, Host Functionality and External Network Connection. They are defined in HEAC Table 3-3 and illustrated as part of different devices in HEAC Figure 3-3.

HEAC Table 3-3 HEC Capability Definition

HEC Capability	Definition
HEC Functionality	Describes the capability of a device to support communication with other devices based on an HDMI Ethernet Channel. Note that a device might not support HEC Functionality on all of its HDMI connections. Therefore all devices shall only claim HEC Functionality support for HDMI connections on which HEC Functionality is supported.
Host Functionality	Describes the capability of a device to receive or send MAC frames from or to a network based on HDMI Ethernet Channels. It can be assumed that there is a high possibility that a device with Host Functionality has an application layer which handles the appropriate messages incorporated in the MAC frames. A device shall not claim Host Functionality if it does not support HEC Functionality.
External Network Connection	Describes the capability of a device to interconnect a network based on HDMI Ethernet Channels with an External Network by MAC frame forwarding between both networks. A device shall not claim External Network Connection if it doesn't support HEC Functionality.



HEAC Figure 3-3 Devices with different HEC Capabilities

Note: Type e1, e2 and e3 are defined in HEAC 5.4.

A device within an HDMI network may discover the HEC Capabilities of all other devices within that HDMI network by sending a <CDC_HEC_Discover> message. It is important to note that the usage of

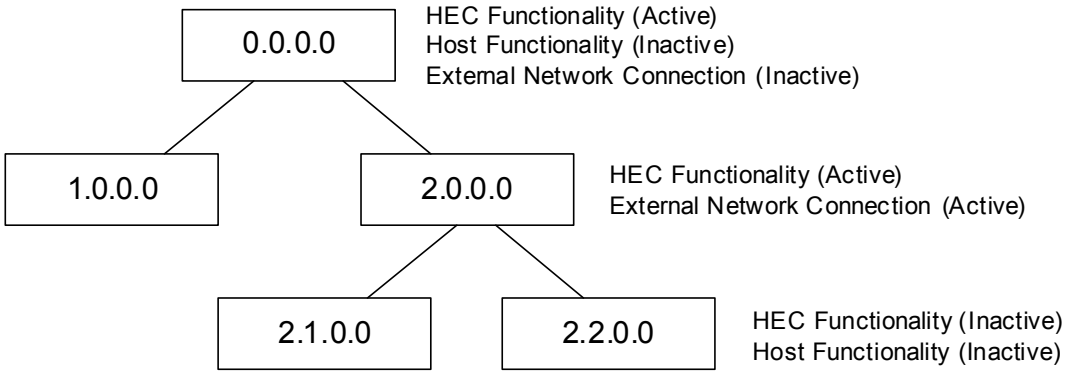
<CDC_HEC_Discover> messages might put a heavy load on the CEC bus. Therefore the HEC Capability Discovery should only be used in appropriate cases e.g. at service requests. Initiators of <CDC_HEC_Discover> messages shall not send these messages more often than once every 3 minutes with the exception of Frame Re-transmissions when a valid frame is considered lost (see Supplement 1).

On reception of a <CDC_HEC_Discover> message, all devices within the HDMI network shall check if they support HEC Functionality. All devices that do not support HEC Functionality (whether temporarily or never) shall not respond. All devices that support HEC Functionality on at least one HDMI connection shall respond with a <CDC_HEC_ReportState> message within the Maximum Response Time (see HEAC 3.1.1) to the discovering device, regardless of whether or not the HEC Functionality is active or inactive. Note that even if the discovering device supports HEC Functionality itself, it should not send a <CDC_HEC_ReportState> message in response to its own <CDC_HEC_Discover> message. The <CDC_HEC_ReportState> message shall incorporate the [HEC Support Field] parameter in order to indicate on which HDMI connections of the initiating device HEC Functionality is supported.

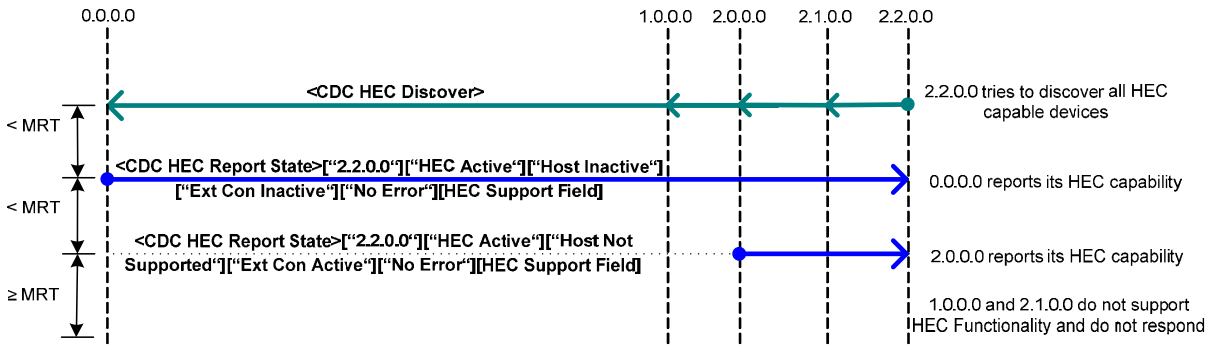
After sending the <CDC_HEC_Discover> message the discovering device shall monitor <CDC_HEC_ReportState> messages containing its [Physical Address] as the Target address for the Maximum Response Time and it shall continue to monitor for the Maximum Response Time (reset of timeout) after each reception of such a message until timeout or until the maximum monitoring time of 5 seconds is reached. After monitoring for the aforementioned messages the discovering device has gathered all information needed to determine the HEC Capabilities (see HEAC Table 3-3) of all other devices within the HDMI network. Note that the discovering device shall not rely on a certain order of incoming <CDC_HEC_ReportState> messages.

Unlike the response to a <CDC_HEC_InquireState> message which indicates HEC support only if all HDMI connections of a device that are part of the respective PHEC support HEC Functionality, the response to a <CDC_HEC_Discover> message indicates HEC Functionality if at least one HDMI connection of a device supports HEC Functionality. Therefore <CDC_HEC_ReportState> messages which are sent in response to a <CDC_HEC_Discover> message shall incorporate the [HEC Support Field] parameter that indicates on which HDMI connections of a device HEC Functionality is supported. After monitoring for <CDC_HEC_ReportState> messages as described above, the discovering device has gathered all information needed to determine if all devices within a particular PHEC are capable of HEC Functionality on all HDMI connections which are part of that particular PHEC. Only if all HDMI connections of all devices within a PHEC are capable of HEC Functionality that PHEC shall be considered as a Verified HEC (VHEC) and may be activated as described under HEAC 3.2.1.4.

HEAC Figure 3-4 and HEAC Figure 3-5 provide an example of a Capability Discovery used in a certain HDMI network incorporating devices with different HEC Capabilities.



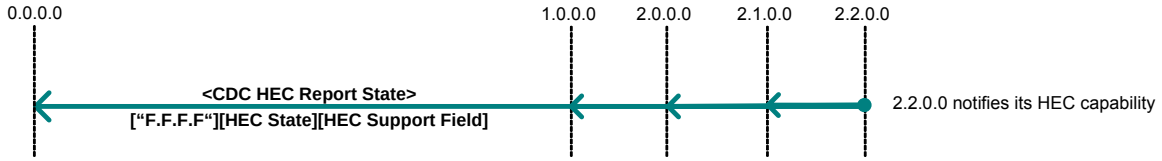
HEAC Figure 3-4 Network example incorporating devices with different HEC Capabilities



HEAC Figure 3-5 Discovery of all HEC capable devices and their Capabilities

CDC supports a Capability Notification to decrease the usage of <CDC_HEC_Discover> messages to only appropriate cases. All devices within an HDMI network that support HEC Functionality shall notify all other devices by sending <CDC_HEC_ReportState> messages with the physical address F.F.F.F as the Target address and with incorporated [HEC Support Field] parameter whenever it discovers a new Physical Address (e.g. at hot-plug or at mains-power-on) and whenever one of its HEC capabilities change in one of the following ways:

- [HEC State] changed from "HEC Not Supported" to either "HEC Inactive" or "HEC Active", or vice versa if possible (it might be not possible e.g. after unplugging the device's power or unplugging from the HDMI network by cable removal; see also HEAC Figure 3-14 regarding safety mechanism)
- [HEC State] changed in any way between "Ext Con Not Supported", "Ext Con Inactive" and "Ext Con Active"
- [HEC State] changed in any way between "Host Not Supported", "Host Inactive" and "Host Active"



HEAC Figure 3-6 Capability Notification

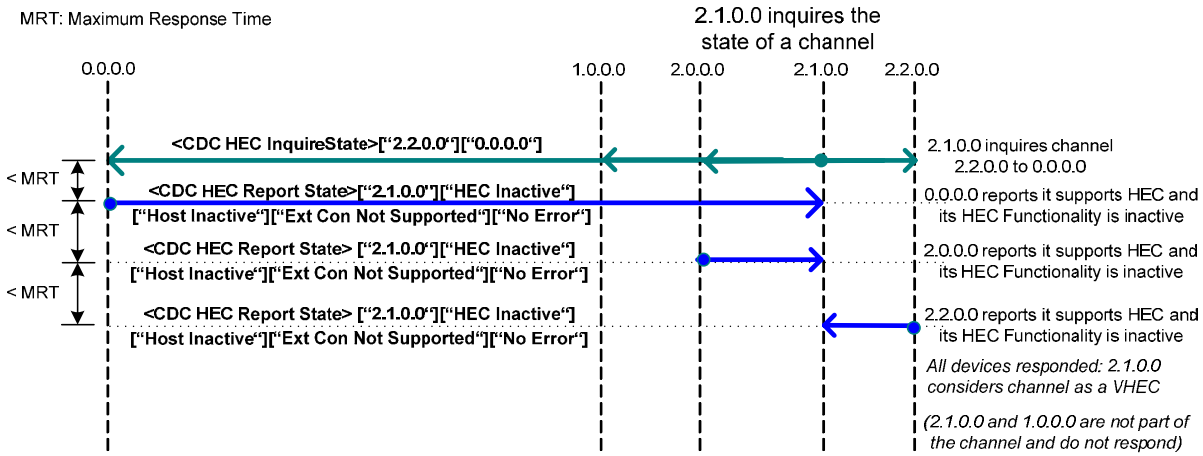
HEAC 3.2.1.4 HEC Control

Devices capable of HEC Functionality may make an inquiry of the capability of a Potential HDMI Ethernet Channel (PHEC) by sending a <CDC_HEC_InquireState> message. The PHEC that is inquired shall be indicated by the [Physical Address] parameters within the <CDC_HEC_InquireState> message. The physical address parameters shall define the Terminating Devices at both ends of the PHEC to be inquired whereas the order of the physical address parameters is not specified (i.e. <CDC_HEC_InquireState>["1.0.0.0"]["2.2.0.0"] and <CDC_HEC_InquireState>["2.2.0.0"]["1.0.0.0"] shall

inquire the same PHEC). A device which is part of a PHEC shall not inquire that PHEC if it is not capable of HEC Functionality on all HDMI connections that are part of the PHEC.

On reception of a <CDC_HEC_InquireState> message, all devices within the HDMI network that implement HEC Functionality shall check if they are part of the PHEC to be inquired. All devices which are not part of the PHEC to be inquired shall not respond. All devices which are part of the PHEC to be inquired shall respond with a <CDC_HEC_ReportState> message without the [HEC Support Field] parameter within the Maximum Response Time (see HEAC 3.1.1) to the inquiring device. The <CDC_HEC_ReportState> message indicates whether the device is capable of HEC Functionality, whether its HEC Functionality is active, or an error code. A device shall only respond as being capable of HEC Functionality if all its HDMI connections that are part of the PHEC are capable of HEC Functionality. Devices that do not respond with a <CDC_HEC_ReportState> message within the Maximum Response Time shall be considered as currently incapable of HEC Functionality. Note that even if the inquiring device is a part of the PHEC itself, it shall not send a <CDC_HEC_ReportState> message in response to its own <CDC_HEC_InquireState> message.

After sending the <CDC_HEC_InquireState> message, the inquiring device shall monitor <CDC_HEC_ReportState> messages containing its [Physical Address] as the Target address for the Maximum Response Time and it shall continue to monitor for the Maximum Response Time (reset of timeout) after each reception of such a message until timeout, until the maximum monitoring time of 5 seconds is reached, or until all devices which are part of the inquired PHEC have responded. After monitoring for the aforementioned messages the inquiring device has gathered all information needed to determine if all devices within the PHEC are capable of HEC Functionality. Only if all devices within the PHEC are capable of HEC Functionality the PHEC shall be considered as a Verified HEC (VHEC). Note that the inquiring device shall not rely on a certain order of incoming <CDC_HEC_ReportState> messages.



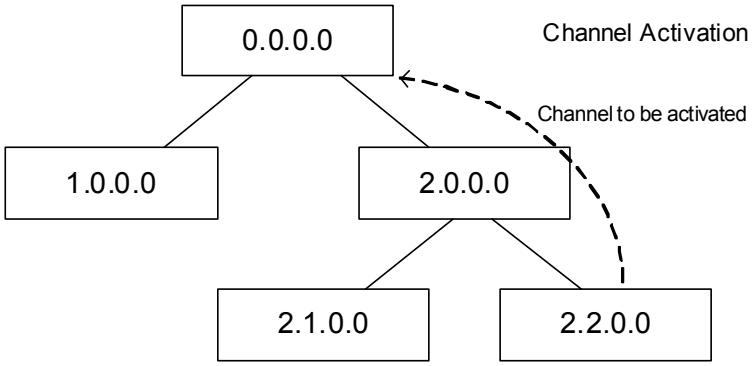
HEAC Figure 3-7 HEC capability and state inquiry

In some situations, e.g. after a service request, a device might want to activate one or more Verified HDMI Ethernet Channels (VHECs). A simultaneous activation of multiple VHECs usually decreases the time necessary for the activation as well as the load on the CEC bus in comparison to successive single activations of each VHEC. Therefore, if more than one VHEC shall be activated the Activator shall use an activation method which uses the lowest number of activation messages possible. Note that the activation method described in this section can activate a minimum of one and a maximum of four VHECs simultaneously. Also note that a simultaneous activation of VHECs is only possible in the case that all the VHECs share one common Terminating Device with the same physical address (e.g. device “0.0.0.0” in HEAC Figure 3-10).

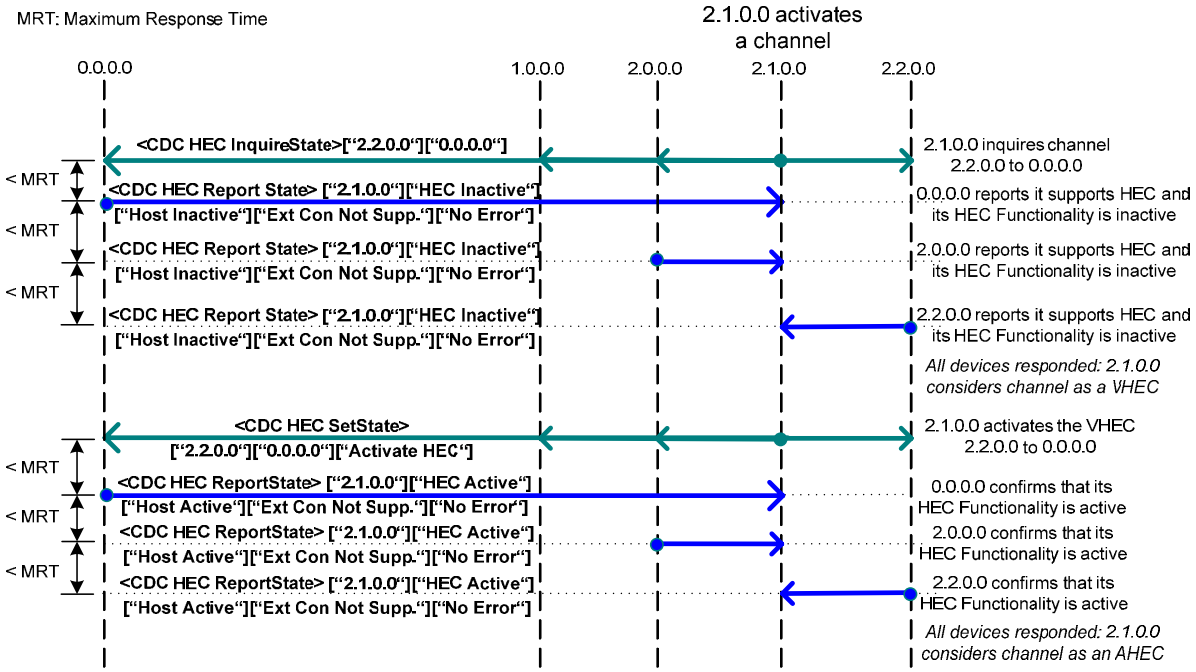
A device may only activate those PHECs that have been verified as VHECs and shall not try to activate PHECs that have not been verified as being VHECs nor just its own HEC Functionality. It shall activate one or more VHECs by sending a <CDC_HEC_SetState>[PA][PA]["Activate HEC"][PA][PA][PA] message. The VHECs to be activated shall be indicated by the physical address parameters. For each VHEC the first [PA] parameter in the message indicates the common Terminating Device. The other Terminating Device of each VHEC shall be indicated by the second through the last [PA] parameter. Note that the number of [PA] parameters in the <CDC_HEC_SetState> message indicates the number of VHECs to be activated (e.g. four [PA] parameters indicate three VHECs to be activated). Immediately after sending the activation message, if the activating device is part of one or more VHECs to be activated it shall activate its own HEC Functionality only on its HDMI connections that are part of the VHECs to be activated. A device shall not attempt to activate VHECs before the device has finished all previous activation attempts (with the exception of Frame Re-transmissions when a valid frame is considered lost (see Supplement 1)). Note that in this respect an activation attempt shall be considered finished after the Maximum Response Time corresponding to that activation has finally elapsed. A device shall not attempt to activate the same VHEC more than once without interleaving the activation attempts with deactivations of the active HEC (AHEC). A device which is part of a VHEC shall not activate that VHEC if it is not capable of activating its own HEC Functionality on all HDMI connections that are part of that VHEC.

On reception of a <CDC_HEC_SetState>[PA][PA]["Activate HEC"][PA][PA][PA] message all devices within the HDMI network which implement HEC Functionality shall check if they are part of at least one VHEC to be activated. All devices which are not part of at least one VHEC to be activated shall not respond. All devices that are part of one or more VHECs to be activated shall, immediately after activation message reception, activate their HEC Functionality only on the HDMI connections that are part of these VHECs (even when not fully powered-on e.g. in standby state) unless they are in an unsuitable error state. These devices shall then immediately respond to the activating device with a <CDC_HEC_ReportState> message without the [HEC Support Field] parameter, indicating its HEC Functionality status: HEC Functionality is activated, or an error code. All devices which are part of more than one VHEC to be activated and which have successfully activated their HEC Functionality regarding at least one VHEC, shall incorporate the [HEC Activation Field] parameter into the <CDC_HEC_ReportState> message and shall set the [HEC Functionality State] parameter to ["HEC Activation Field"]. Devices that have activated their HEC Functionality shall store the AHECs (physical addresses of both Terminating Devices) and the Activator (physical address of the Activator device). Devices which do not respond with a <CDC_HEC_ReportState> message within the Maximum Response Time (see also HEAC 3.1.1) shall be considered as currently incapable of HEC Functionality. Note that even if the Activator itself is part of a VHEC to be activated, it shall not send a <CDC_HEC_ReportState> message in response to its activation message. If a device's HEC Functionality is already activated at the activation message reception time, the device shall keep its HEC Functionality activated and if it is part of VHECs to be activated it shall store the appropriate AHECs (physical addresses of both Terminating Devices) and the Activator (physical address of the Activator device) in addition to previously stored AHECs and Activators.

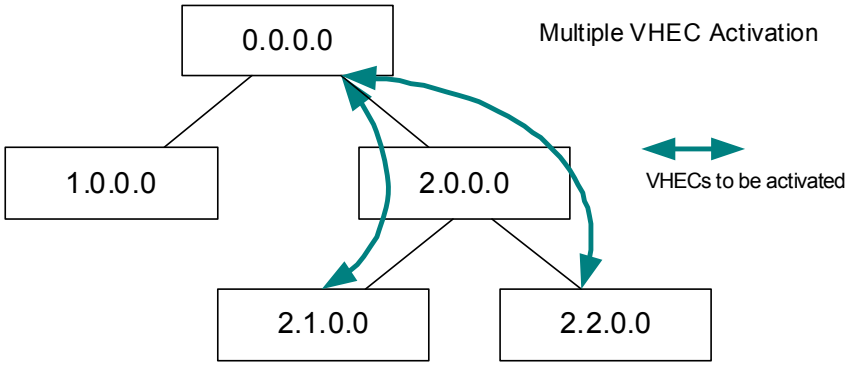
After sending the activation message, the Activator shall monitor the <CDC_HEC_ReportState> messages containing its [Physical Address] as the Target address for the Maximum Response Time and it shall continue to monitor for the Maximum Response Time (reset of timeout) after each reception of such a message until timeout, or until the maximum monitoring time of 5 seconds is reached, or until all devices which are part of the VHECs have responded. After monitoring for the aforementioned messages, the Activator has gathered all information required to determine if the activation of the VHECs has been successful. A VHEC that is successfully activated shall be considered as an Active HDMI Ethernet Channel (AHEC). The activation device of the AHEC shall be considered as the Activator and shall maintain its state as the Activator of that AHEC (physical addresses of both Terminating Devices). Note that all AHECs shall be considered as stand-alone AHECs even when simultaneously activated (as if they were activated by several activation messages containing single VHECs). If the activation of a VHEC has failed, e.g. it received a response with an error code, received a response with an [HEC Activation Field] parameter indicating that the HEC Functionality on at least one of the appropriate HDMI ports is not activated, or missed a response from at least one device, the Activator shall immediately send a <CDC_HEC_SetState>[PA][PA]["Deactivate HEC"] message for each VHEC that did not properly activate to inform all devices within each such VHEC. Note that the Activator shall not rely on a certain order of incoming <CDC_HEC_ReportState> messages.



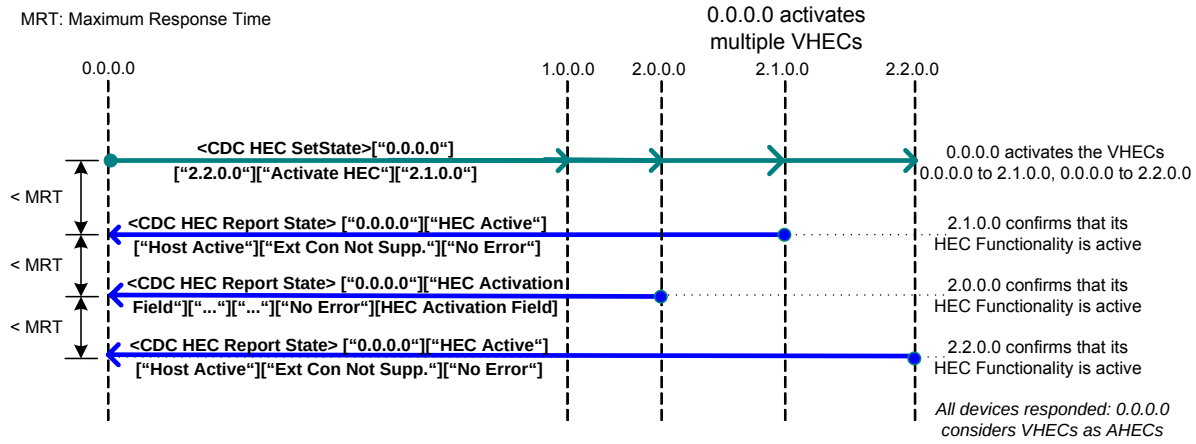
HEAC Figure 3-8 Example for an HDMI network



HEAC Figure 3-9 Activation of an HDMI Ethernet Channel (HEC)



HEAC Figure 3-10 HDMI network example for multiple VHEC activation

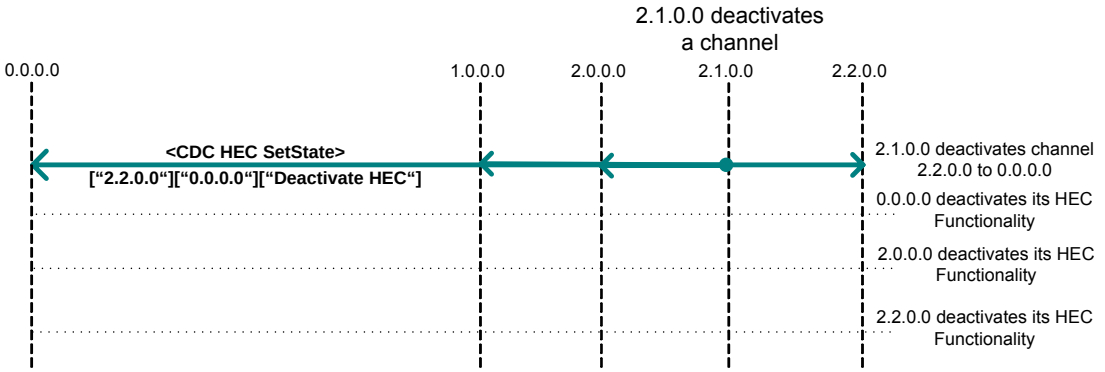


HEAC Figure 3-11 Activation of multiple HDMI Ethernet Channel (HEC)

A device may only deactivate active HECs (AHECs) and it shall neither try to deactivate non-active VHECs nor potential HECs (PHECs). Only the Activator of an AHEC shall be allowed to deactivate that AHEC. It shall deactivate that AHEC by sending a <CDC_HEC_SetState>[PA][PA]["Deactivate HEC"] message. The AHEC to be deactivated shall be indicated by the physical address parameters [PA][PA]. The physical address parameters shall define the Terminating Devices at both ends of the AHEC to be deactivated whereas the order of the physical address parameters is not specified (i.e. <CDC_HEC_SetState>["1.0.0.0"]["2.2.0.0"]["Deactivate HEC"] and <CDC_HEC_SetState>["2.2.0.0"]["1.0.0.0"]["Deactivate HEC"] shall deactivate the same AHEC). Immediately after sending the deactivation message, the deactivating (sending) device does not need and shall remove all states associated with the deactivated AHEC and its Activator and it shall deactivate its HEC Functionality on the HDMI connections that are part of the deactivated AHEC if the appropriate HDMI connection is not part of another AHEC. It shall not deactivate its HEC Functionality on an HDMI connection that is also part of another AHEC but it does not need and shall remove all states associated with the deactivated AHEC and its Activator.

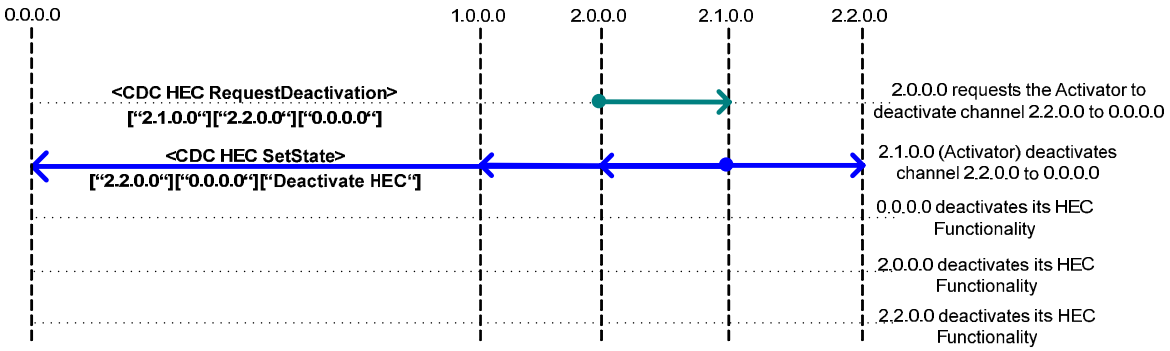
On reception of a <CDC_HEC_SetState>[PA][PA]["Deactivate HEC"] message each device within the HDMI network that implement HEC Functionality shall check if it is part of the deactivated AHEC and if the message has been sent by the device which has previously activated that AHEC, the Activator. The message shall be ignored if it has not been sent from the Activator of that AHEC. A device which is not part of the deactivated AHEC shall ignore the message. A device that is part of the deactivated AHEC and is not part of another

AHEC shall immediately deactivate its HEC Functionality on the HDMI connections that are part of the deactivated AHEC and does not need and shall remove all states associated with that AHEC and its Activator. A device that is part of the deactivated AHEC and is also part of another AHEC shall not deactivate its HEC Functionality on an HDMI connection that is also part of another AHEC but it does not need and shall remove all states associated with the deactivated AHEC and its Activator.



HEAC Figure 3-12 Deactivation of an AHEC by its Activator

A device that is part of an active HEC (AHEC) shall not autonomously deactivate its HEC Functionality (e.g. if it's switched to standby) in order to give the Activator the opportunity to reject the deactivation of the AHEC in case it is still needed for an important task. Instead, it may request deactivation of its HEC Functionality indirectly by requesting all Activators of all the AHECs that it is part of to deactivate their respective AHECs. The device shall request indirect deactivation by sending <CDC_HEC_RequestDeactivation> messages to all Activators of all AHECs that it is part of. Such a message shall be ignored if it has been sent to a device which is not the Activator of that AHEC. An Activator which receives a <CDC_HEC_RequestDeactivation> message from a device that is part of an AHEC that the Activator has activated shall check if it is appropriate to deactivate the AHEC (it might not be appropriate, e.g., if the AHEC is used for recording). If it is appropriate to deactivate the AHEC, the Activator shall immediately send a <CDC_HEC_SetState>[PA][PA]["Deactivate HEC"] message incorporating the same AHEC to inform all devices within the AHEC. If it is not appropriate to deactivate the AHEC, the Activator shall do nothing and the requestor shall not deactivate its HEC Functionality.

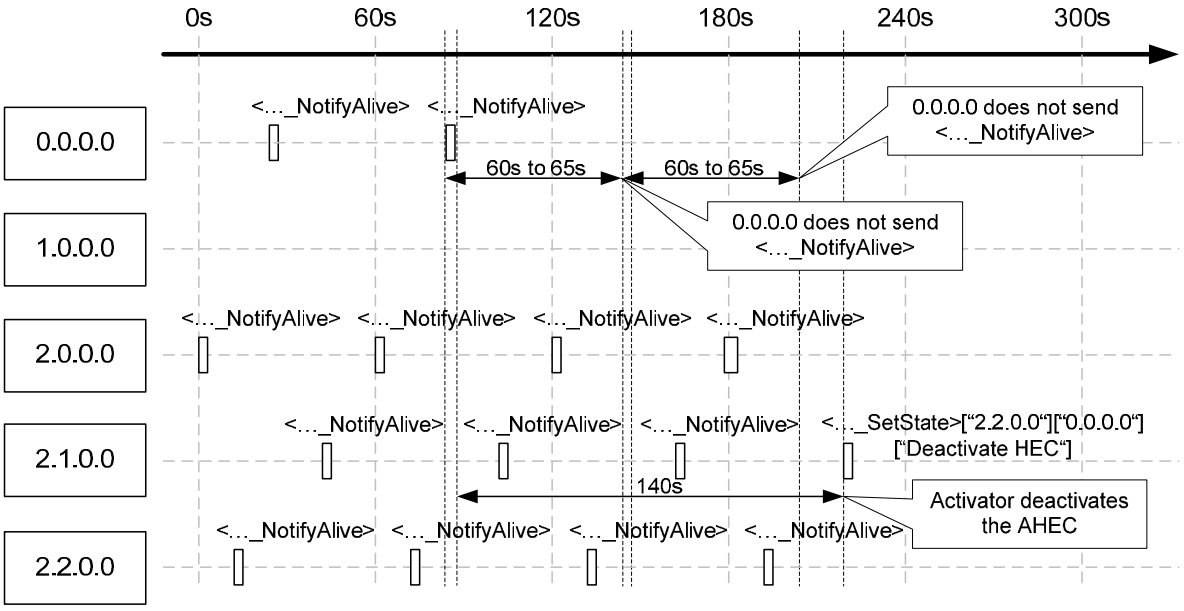


HEAC Figure 3-13 Request deactivation of an AHEC by a device part of that AHEC

It might be possible that a device is suddenly incapable of HEC Functionality, e.g. after unplugging the device's power or unplugging from the HDMI network by cable removal. In this case the device might be incapable of deactivating the active HECs (AHECs) that it is part of, or for which it is the Activator. To avoid a situation that an AHEC is incorrectly deactivated, all devices that are part of at least one AHEC or are an Activator of at least one AHEC shall send <CDC_HEC_NotifyAlive> messages every 60 to 65 seconds. Each device shall start sending the <CDC_HEC_NotifyAlive> messages randomly (it shall not always use the same timing) within the time frame of 10 to 50 seconds after activation of its HEC Functionality or after becoming an Activator. <CDC_HEC_NotifyAlive> messages shall not be sent more often than once every 60 seconds from the same initiator's physical address with the exception of Frame Re-transmissions when a valid frame is considered lost (see CEC Supplement 1). Note that even if a device is part of and/or Activator of multiple AHECs it shall send only one (not multiple) <CDC_HEC_NotifyAlive> messages in this period.

A device that is part of an active HEC (AHEC) shall check for regularly received <CDC_HEC_NotifyAlive> messages from the Activator of that AHEC. If no <CDC_HEC_NotifyAlive> message is received from the Activator within 140 seconds after the reception of the last <CDC_HEC_NotifyAlive> message from the Activator, the device shall designate the Activator as incapable of HEC Functionality and the AHEC is to be deactivated. Devices that are part of the AHEC and are not part of any other AHEC shall immediately deactivate their HEC Functionality on their HDMI connections that are part of the AHEC and do not need and shall remove all states associated with the AHEC and its Activator. If a device is also part of another AHEC, it shall not deactivate its HEC Functionality on an HDMI connection that is also part of another AHEC but it does not need and shall remove all states associated with the AHEC and its Activator.

A device that is the Activator of an AHEC shall check for regularly received <CDC_HEC_NotifyAlive> messages from all devices that are part of the AHEC. If at least one device that is part of that AHEC does not send a <CDC_HEC_NotifyAlive> message within 140 seconds after sending the last <CDC_HEC_NotifyAlive> message, then the Activator shall immediately deactivate the AHEC by sending a <CDC_HEC_SetState>[PA][PA][“Deactivate HEC”] message. It shall then immediately deactivate its HEC Functionality on the HDMI connections that are part of the deactivated AHEC if it is part of that AHEC and it does not need and shall remove all states associated with the AHEC and its Activator. If the device is also part of another AHEC, it shall not deactivate its HEC Functionality on an HDMI connection that is also part of another AHEC but it does not need and shall remove all states associated with the AHEC and its Activator. Note that the Activator shall not rely on a certain order of incoming <CDC_HEC_NotifyAlive> messages.



HEAC Figure 3-14 AHEC safety mechanism

HEAC 3.2.1.5 HEC Control for Adjacent Devices

In some situations and for some devices it might be appropriate to activate the HEC Functionality whenever this device joins an HDMI network, e.g. when it is powered-on or hot-plugged, and to keep the HEC Functionality active until the device is removed from the HDMI network, e.g. when powered-off or at cable removal. For such situations and devices it is possible to use the HEC Control for Adjacent Devices described within this section.

A device may try to activate an HEC (either it is a potential or a verified HEC) to an adjacent device by using a simplified method without previous verification that the HEC is a VHEC (note that the state diagram in HEAC Figure 3-2 is not applicable for this simplified method). Using the simplified method a device may try to activate an HEC to an adjacent device by sending a <CDC_HEC_SetStateAdjacent>[PA]["Activate HEC"] message. The Terminating Devices of the HEC to be activated shall be the initiating device of the message and the device indicated by the physical address parameter. A device shall not activate an HEC to an adjacent device if it is not capable of activating its own HEC Functionality on the HDMI connection that is part of that HEC. A device shall not attempt to activate the same HEC more than once without interleaving the activation attempts with deactivations of the active HEC (AHEC).

On reception of a <CDC_HEC_SetStateAdjacent>[PA]["Activate HEC"] message all devices within the HDMI network which implement HEC Control for Adjacent Devices shall check if they are part of the HEC to be activated and if the message has been initiated from an adjacent device. All devices which are not part of the HEC to be activated or which are not adjacent to the initiator shall not respond. A device that is part of the HEC to be activated and that is adjacent to the initiator shall immediately activate its HEC Functionality only on the HDMI connection that is part of that HEC after activation message reception (even when not fully powered-on e.g. in standby state) unless it is in an unsuitable error state. This device shall then immediately respond to the activating device with a <CDC_HEC_ReportState> message without the [HEC Support Field] parameter, indicating its HEC Functionality status: HEC Functionality is activated, or an error code. Devices which do not respond with a <CDC_HEC_ReportState> message within the Maximum Response Time (see also HEAC 3.1.1) shall be considered as currently incapable of HEC Functionality. Note that even if the Activator itself is part of the HEC to be activated, it shall not send a <CDC_HEC_ReportState> message in response to its activation message. If a device's HEC Functionality is already activated at the activation message reception time, the device shall keep its HEC Functionality activated (note that also in this case the device shall respond with a <CDC_HEC_ReportState> message).

After sending the activation message, the Activator shall monitor the <CDC_HEC_ReportState> messages containing its [Physical Address] as the Target address for the Maximum Response Time or until the adjacent device which is part of the HEC has responded. After monitoring for the aforementioned messages, the Activator has gathered all information required to determine if the activation of the HEC has been successful. If the activation of the HEC has been successful the Activator shall immediately activate its own HEC Functionality only on its HDMI connection that is part of the activated HEC.

Note that devices which are part of HECs which have been activated using the HEC Control for Adjacent Devices neither have to store the Terminating Devices and the Activators of these HECs nor do they have to send <CDC_HEC_NotifyAlive> messages (contrary to the mandatory <CDC_HEC_NotifyAlive> messages whenever a VHEC has been activated using the method described in HEAC 3.2.1.4). Note that devices which are part of HECs which have been activated using the HEC Control for Adjacent Devices shall send <CDC_HEC_NotifyAlive> messages as described under HEAC 3.2.1.4 if they are also part of or are an Activator of at least one AHEC which has been activated using the method described in HEAC 3.2.1.4.

Devices which are part of HECs which have been activated using the HEC Control for Adjacent Devices shall deactivate those HECs immediately when removed from the HDMI network, e.g. when powered-off, by sending <CDC_HEC_SetStateAdjacent>[PA]["Deactivate HEC"] messages. The Terminating Devices of the HEC to be deactivated shall be the initiating device of the message and the device indicated by the physical address parameter. Immediately after sending the deactivation message, the deactivating device shall

deactivate its HEC Functionality on the HDMI connection that is part of the HEC to be deactivated if the appropriate HDMI connection is not part of another AHEC. It shall not deactivate its HEC Functionality on an HDMI connection that is also part of another AHEC.

On reception of a <CDC_HEC_SetStateAdjacent>[PA]["Deactivate HEC"] message each device within the HDMI network that implements HEC Control for Adjacent Devices shall check if it is part of the HEC to be deactivated and if the message has been sent by an adjacent device. The message shall be ignored if it has not been sent by an adjacent device or if the HEC was not previously activated using the HEC Control for Adjacent Devices. A device which is not part of the HEC to be deactivated shall ignore the message. A device that is part of the HEC to be deactivated and is not part of another AHEC shall immediately deactivate its HEC Functionality on the HDMI connection that is part of the HEC to be deactivated. A device that is part of the HEC to be deactivated and is also part of another AHEC shall not deactivate its HEC Functionality on an HDMI connection that is also part of another AHEC.

In some cases, e.g. at cable removal, it might be impossible to correctly deactivate an HEC which has been activated using the HEC Control for Adjacent Devices. All devices supporting HEC Control for Adjacent Devices shall therefore be able to detect these cases, e.g. by monitoring the HPD and DDC lines, and they shall immediately deactivate their HEC Functionality on the HDMI connection that is part of the deactivated HEC at detection time.

HEAC 3.2.1.6 Best Practices

It is recommended that HEC devices provide support for an adequate number of AHECs depending on the number of HDMI connections with HEC Functionality. Devices which have reached the maximum support of AHECs (e.g. no further resources to store the physical addresses of the Terminating Devices and the Activator for additional AHECs) should reply to further activation attempts of the HEC Functionality by sending a <CDC_HEC_ReportState> message incorporating a [CDC Error Code] of ["Initiator is not capable to carry out the request in this state"].

HEAC 3.2.2 CDC_HPD (CDC Hot Plug Detect signal)

HEAC 3.2.2.1 Messages

The following messages are used for CDC_HPD. For details of which messages are mandatory, see HEAC Table 3-5, HEAC Table 3-6, HEAC Table 3-7 and HEAC 3.2.2.2.

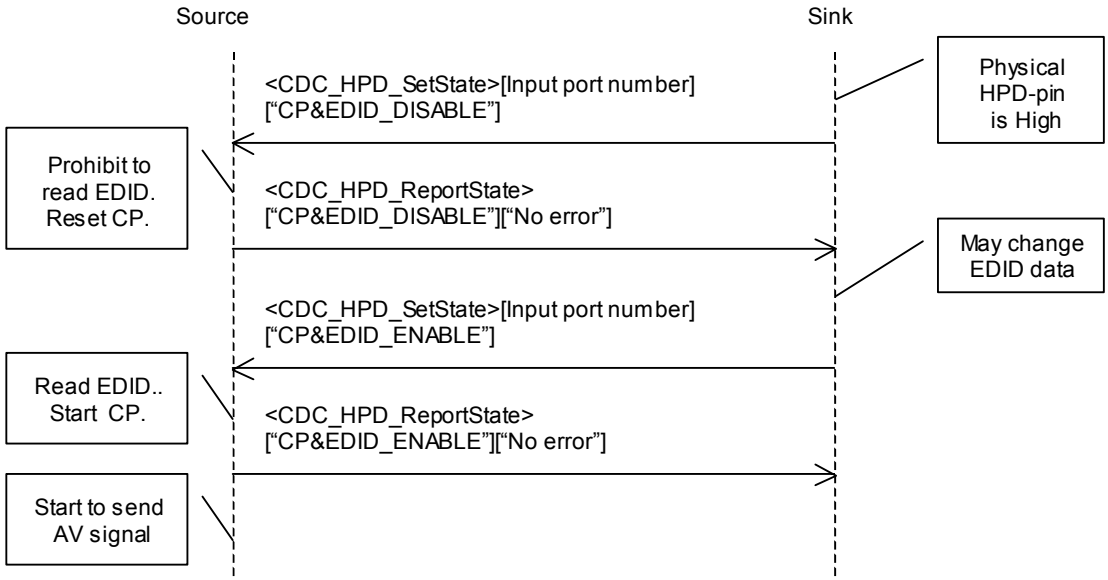
<CDC_HPD_SetState>, < CDC_HPD_ReportState>

HEAC 3.2.2.2 Feature Description

This feature allows an HDMI Sink device to enable/disable an adjacent HDMI Source device to read the EDID or initialize content protection while maintaining the physical HPD pin asserted.

HDMI Sinks which support HEC shall support the <CDC_HPD_SetState> message as an initiator and the <CDC_HPD_ReportState> message as a follower. HDMI Sources which support HEC shall support the <CDC_HPD_ReportState> message as an initiator and the <CDC_HPD_SetState> message as a follower.

HDMI Sinks that support the CDC_HPD feature shall use the <CDC_HPD_SetState> message to communicate the availability of the Sink's EDID for reading and to initiate a content protection reset in the Source instead of toggling the Physical HPD line. HDMI Sources that support the CDC_HPD feature shall correctly process <CDC_HPD_SetState> messages and respond with <CDC_HPD_ReportState> messages. The usage of these messages allows undisturbed transmission on the HEC.



HEAC Figure 3-15 Disable and Enable of reading EDID and restarting CP (1)

A Sink shall not send a <CDC_HPD_SetState> message with any of the following three parameters unless it supports content protection: [“CP&EDID_DISABLE”], [“CP&EDID_ENABLE”], [“CP&EDID_DISABLE_ENABLE”]. If a Source does not support content protection, it shall execute the equivalent EDID-only behavior on reception of a <CDC_HPD_SetState> message with any of the following three parameters: [“CP&EDID_DISABLE”], [“CP&EDID_ENABLE”], [“CP&EDID_DISABLE_ENABLE”].

After a <CDC_HPD_SetState> message reception, only the HDMI Source adjacent to and addressed by the initiator of that message shall respond with a <CDC_HPD_ReportState> message. If the HDMI Sink receives a CDC_HPD Error response or there is no response to that message within the Maximum Response Time, the HDMI Sink shall reset the Source by means of the physical HPD line. HDMI Sinks may attempt one re-try after receipt of a CDC_HPD Error response or when there is no response to that message within the Maximum Response Time prior to resetting the Source by means of the physical HPD line.

Note: A CDC_HPD Error response is a <CDC_HPD_ReportState> [HPD State] [“Other Errors”] message or a <CDC_HPD_ReportState> [HPD State] [“Initiator does not have the requested Capability”] message. A source shall not send a <CDC_HPD_ReportState> [HPD State] [“Initiator is not capable to carry out the request in this state”].

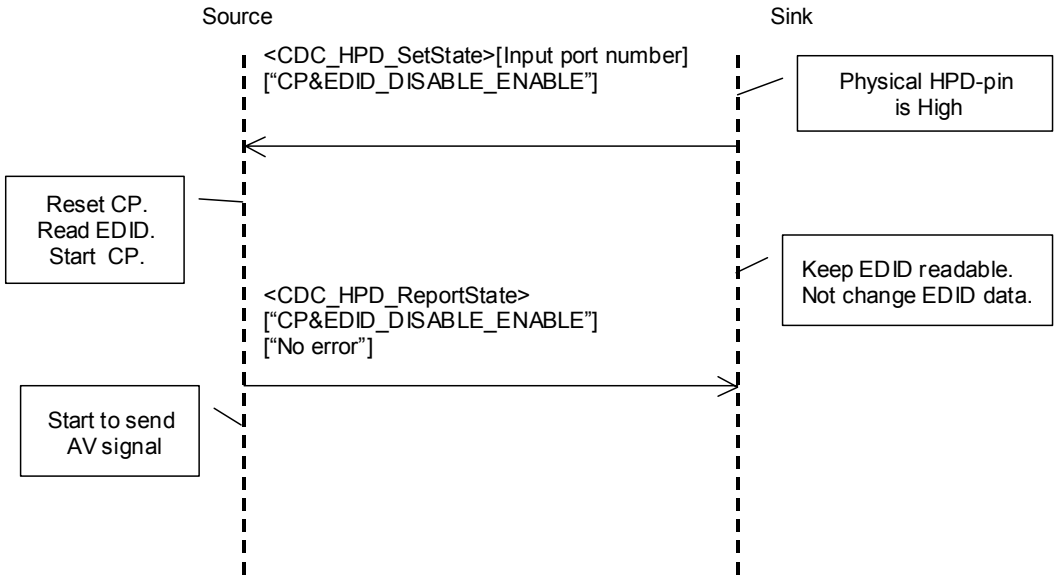
An HDMI sink shall keep its EDID readable until a <CDC_HPD_ReportState> [“CP&EDID_DISABLE”] [“No error”] message reception. After the reception of this message, the HDMI sink is permitted to transit to the EDID unreadable state and within this state it may change EDID data. Prior to sending a <CDC_HPD_SetState> [Input port number] [“CP&EDID_ENABLE”] message, the HDMI sink shall transit to the EDID readable state.

An HDMI sink shall keep its EDID readable until a <CDC_HPD_ReportState> [“EDID_DISABLE”] [“No error”] message reception. After the reception of this message, the HDMI sink is permitted to transit to the EDID unreadable state and within this state it may change EDID data. Prior to sending a <CDC_HPD_SetState> [Input number] [“EDID_ENABLE”] message, the HDMI sink shall transit to the EDID readable state.

If a Source with activated HEC Functionality does not send a TMDS video stream to the appropriate Sink, it should reply with a <CDC_HPD_ReportState>[HPD State] [“No Error, No video stream”] message after <CDC_HPD_SetState> message reception. In this case, the Sink should not resend the <CDC_HPD_SetState> message so frequently.

If a Source does not receive a <CDC_HPD_SetState> [Input port number] [“CP&EDID _ENABLE”] message within the Maximum Response Time after sending a <CDC_HPD_ReportState> [“CP&EDID_ DISABLE”][“No Error”] message, it may resend the <CDC_HPD_ReportState> [“CP&EDID_ DISABLE”] [“No Error”] message.

HEAC Figure 3-15 indicates the usage of the <CDC_HPD_SetState> [Input port number] [“CP&EDID_DISABLE”] and the <CDC_HPD_SetState> [Input port number] [“CP&EDID_ENABLE”] message and the related message sequence. In order to shorten this sequence, <CDC_HPD_SetState> [Input port number] [“CP&EDID_DISABLE_ENABLE”] may be used as indicated in HEAC Figure 3-16.



HEAC Figure 3-16 Disable and Enable of reading EDID and restarting CP (2)

A Sink shall keep its EDID readable even if it sends a <CDC_HPD_SetState> [Input port number] ["CP&EDID_DISABLE_ENABLE"] message.

Note: On sending the <CDC_HPD_SetState> [Input port number] ["CP&EDID_DISABLE_ENABLE"] message, a Sink may change the EDID data instantly while keeping the EDID readable, before the completion of this message transmission.

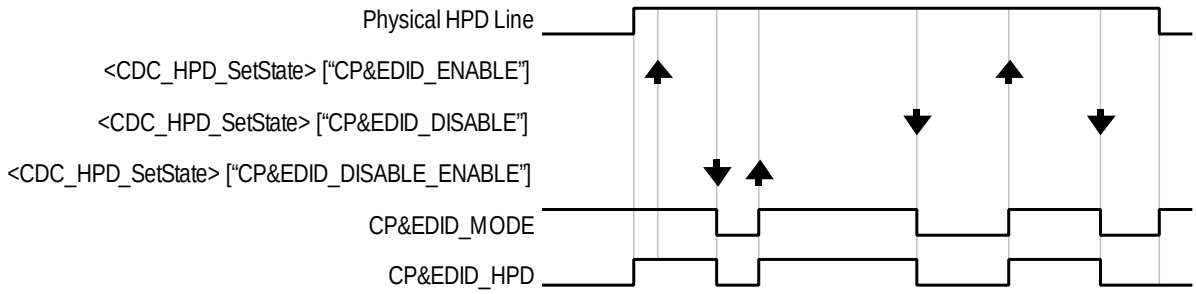
HEAC 3.2.2.3 Additional Source Requirements

Sources that support <CDC_HPD_SetState> and <CDC_HPD_ReportState> shall implement the behavior specified in this section to generate the CP&EDID_HPD signal (or state) for use by the Source's content protection logic. The CP&EDID_HPD signal (or state) is generated by combining state from the physical HPD line with received <CDC_HPD_SetState> messages as indicated below.

Sources that support <CDC_HPD_SetState> and <CDC_HPD_ReportState> and that support content protection shall maintain the state variable CP&EDID_MODE. CP&EDID_MODE shall be reset to the Enabled state (Enabled = "High") when the physical HPD line state is "Low." When the physical HPD line state is "High", CDC messages from the Sink which set the state of CP&EDID_MODE allow notification of the state of CP authentication and readability of the EDID to the Source device. When the physical HPD line state is "High", on receiving a <CDC_HPD_SetState> message with one of the following three parameters, Sources shall set CP&EDID_MODE as follows:

CP&EDID_ENABLE	Set CP&EDID_MODE to the Enabled state (Enabled = "High");
CP&EDID_DISABLE	Set CP&EDID_MODE to the Disabled state (Disabled = "Low");
CP&EDID_DISABLE_ENABLE	First set CP&EDID_MODE to the Disabled state then back to the Enabled state, with adequate time spent in the Disabled state to guarantee the required transitions in the Source content protection logic and to initiate a read of the Sink's EDID by the Source.

CP&EDID_HPD is a logical equivalent of the physical HPD line that causes the content protection logic of a Source device (or downstream output of a Repeater device) to evaluate and possibly initiate a state transition within the content protection logic as described in the relevant content protection specification. CP&EDID_HPD is also used to halt reads of the Sink's EDID (CP&EDID_HPD="Low") then subsequently to initiate a read of the Sink's EDID (CP&EDID_HPD transitions to "High"). The CP&EDID_HPD signal (or state) shall be generated by forming the logical AND of the state of the physical HPD line with the state of CP&EDID_MODE as shown in the following figure:

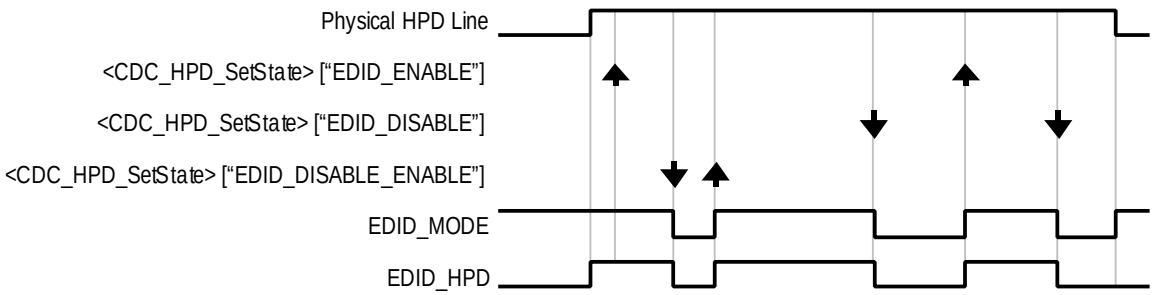


HEAC Figure 3-17 A timing example of CDC_HPD messages and CP&EDID_HPD

Sources that support <CDC_HPD_SetState> and <CDC_HPD_ReportState> shall maintain the state variable EDID_MODE. EDID_MODE shall be reset to the Enabled state (Enabled = "High") when the physical HPD line state is "Low." When the physical HPD line state is "High", CDC messages from the Sink which set the state of EDID_MODE allow notification of the state of readability of the EDID to the Source device. When the physical HPD line state is "High", on receiving a <CDC_HPD_SetState> message with one of the following three parameters, Sources shall set EDID_MODE as follows:

EDID_ENABLE	Set EDID_MODE to the Enabled state (Enabled = "High");
EDID_DISABLE	Set EDID_MODE to the Disabled state (Disabled = "Low");
EDID_DISABLE_ENABLE	First set EDID_MODE to the Disabled state then back to the Enabled state, with adequate time spent in the Disabled state to initiate a read of the Sink's EDID by the Source.

EDID_HPD is a logical equivalent of the physical HPD line that causes the Source device (or downstream output of a Repeater device) to halt reads of the Sink EDID (EDID_HPD="Low") then subsequently to initiate a read of the Sink's EDID (EDID_HPD transitions to "High"). The EDID_HPD signal (or state) shall be generated by forming the logical AND of the state of the physical HPD line with the state of EDID_MODE as shown in the following figure:



HEAC Figure 3-18 A timing example of CDC_HPD messages and EDID_HPD

HDMI Sources may read EDID data of the Sink device at any time while both CP&EDID_HPD and EDID_HPD are High, and shall not read EDID data of the Sink device when either CP&EDID_HPD or EDID_HPD is Low. Note that CP&EDID_MODE and EDID_MODE are controlled independently.

HEAC 3.3 Message Descriptions

The section defines the individual messages used in CDC. It describes and defines the parameters and expected responses of these messages. As CDC has no session layer, this section and the operands section HEAC 3.5 effectively define the complete messaging system. HEAC Table 3-4 to HEAC Table 3-7 show which messages are mandatory. If a manufacturer implements any of the optional messages, then they shall be implemented as described in HEAC 3.2.

The following list describes each heading within the message HEAC Table 3-4

- **CDC 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 HEAC Table 3-8 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.
- **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. 'HEC' indicates a device that supports HDMI Ethernet Channel.

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

HEAC Table 3-4 Message Descriptions for the HDMI Ethernet Channel Feature

CDC Opcode	Value	Description	Parameters	Parameter description	Response	Mandatory for Initiator	Mandatory for Follower
<CDC_HEC_InquireState>	0x00	Used to inquire the state of an HDMI Ethernet Channel	[Physical Address] [Physical Address]	Physical Adresses of channel's Terminating Devices. The order is not specified.	<CDC_HEC_ReportState>	HEC	HEC
<CDC_HEC_ReportState>	0x01	Used to report capabilities and states of a device that supports HEC Functionality	[Physical Address] [HEC State] [HEC Support Field] (shall be incorporated if and only if PA of Target is F.F.F.F or if the message is sent in response to a <CDC_HEC_Discover> message) [HEC Activation Field] (shall be incorporated if and only if the message is sent in response to a <CDC_HEC_SetState> message incorporating more than one VHEC)	PA of Target Indicates capabilities, current active status and Error status for an HDMI Ethernet Channel device. Indicates the HEC functionality of all HDMI ports independently. Indicates activation status for multiple VHECs.		HEC	HEC
<CDC_HEC_SetStateAdjacent>	0x02	Used to activate or de-activate an HDMI Ethernet Channel to an adjacent device	[Physical Address] [HEC Set State]	Physical Address to channel's Terminating device (not initiator's PA) Required State of the HEC	<CDC_HEC_ReportState>		

CDC Opcode	Value	Description	Parameters	Parameter description	Response	Mandatory for Initiator	Mandatory for Follower
<CDC_HEC_SetState>	0x03	Used to activate up to four or to de-activate one HDMI Ethernet Channel	[Physical Address] [Physical Address] [HEC Set State] [Physical Address] [Physical Address] [Physical Address] (The last three [PA] parameters shall not be incorporated if only one HEC shall be activated. The number of channels to be activated is the number of included [PA] parameters minus one.)	Physical Adresses of the first channel's Terminating Devices. The order is not specified if activating only one channel. When activating more than one channel, the first PA is common to all VHECs to be activated. Required State of the HEC(s) 1, 2 or 3 Physical Addresses of channels' Terminating Devices corresponding to the 2nd, 3rd, and 4th channels to be activated (only incorporated for multiple VHEC activation)	<CDC_HEC_ReportState>		HEC

CDC Opcode	Value	Description	Parameters	Parameter description	Response	Mandatory for Initiator	Mandatory for Follower
<CDC_HEC_RequestDeactivation>	0x04	Used to request the deactivation of an HDMI Ethernet Channel	[Physical Address] [Physical Address] [Physical Address]	Physical Address of Target (the channel's Activator) Physical Adresses of channel's Terminating Devices. The order is not specified.	<CDC_HEC_SetState>	HEC	HEC
<CDC_HEC_NotifyAlive>	0x05	Used to keep active HDMI Ethernet Channels active				HEC	HEC
<CDC_HEC_Discover>	0x06	Used to discover all HEC capabilities of devices within the HDMI network			<CDC_HEC_ReportState>		HEC

403

HEAC Table 3-5 Message Descriptions for the CDC_HPD Feature

CDC Opcode	Value	Description	Parameters	Parameter description	Response	Mandatory for Initiator	Mandatory for Follower
<CDC_HPD_SetState>	0x10	Used to substitute physical HPD pin signaling.	[Input port number] [HPD State]	The Sink's input port number for which the HPD state event is requested by the Initiator Note: Follower's upstream address is derived by combining the input port number into the relevant nibble of the adjacent Initiator's physical address.	<CDC_HPD_ReportState>	Sink with HEC	Source with HEC
<CDC_HPD_ReportState>	0x11	Used to report the state of a device using the CDC HPD signaling	[HPD State] [CDC_HPD_Error_Code]	HPD state event executed by an initiator. Note: Follower's downstream address is derived from Initiator's physical address.		Source with HEC	Sink with HEC

The Initiator and Follower utilizing these messages shall be directly connected by an HDMI Cable and shall only use destination physical addresses of the directly connected device.

HEAC 3.4 Message Dependencies

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

HEAC Table 3-6 describes the message dependencies when a device is capable of receiving a particular message.

HEAC Table 3-7 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.

HEAC Table 3-6 Message Dependencies when receiving a CDC message

If device responds to the following message:	**It shall not ignore the message(s):**	**It shall be capable of sending message(s):**
<CDC_HEC_InquireState>	<CDC_HEC_SetState>	<CDC_HEC_ReportState>
<CDC_HEC_SetStateAdjacent>		<CDC_HEC_ReportState>, <CDC_HEC_SetStateAdjacent>
<CDC_HEC_SetState>	<CDC_HEC_InquireState>	<CDC_HEC_ReportState>, <CDC_HEC_RequestDeactivation>
<CDC_HEC_RequestDeactivation>	<CDC_HEC_ReportState>	<CDC_HEC_SetState>
<CDC_HEC_Discover>	<CDC_HEC_SetState>	<CDC_HEC_ReportState>
<CDC_HPD_SetState>		<CDC_HPD_ReportState>

HEAC Table 3-7 Message Dependencies when sending a CDC message

If device ever sends the following message:	**It shall be capable to send the message(s):**	**It shall respond to the message(s):**
<CDC_HEC_InquireState>	<CDC_HEC_SetState>	<CDC_HEC_RequestDeactivation>
<CDC_HEC_SetStateAdjacent>		<CDC_HEC_SetStateAdjacent>
<CDC_HEC_SetState>	<CDC_HEC_InquireState>	<CDC_HEC_RequestDeactivation>

If device ever sends the following message:	It shall be capable to send the message(s):	It shall respond to the message(s):
<CDC_HEC_RequestDeactivation>	<CDC_HEC_ReportState>	<CDC_HEC_SetState>, <CDC_HEC_InquireState>, <CDC_HEC_Discover>
<CDC_HEC_ReportState>		<CDC_HEC_SetState>, <CDC_HEC_InquireState>, <CDC_HEC_Discover>
<CDC_HPD_ReportState>		<CDC_HPD_SetState>

406

HEAC 3.5 Operand Descriptions

In HEAC Table 3-8, 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 HEAC Table 3-8: those not shown shall be considered as “reserved”.

HEAC Table 3-8 Operand descriptions for CDC messages

Name	Range Description		Length	Purpose
[CDC Error Code]	“No Error”	0x00	2 bits	
	“Initiator does not have the requested Capability”	0x01		The device never supports this Capability
	“Initiator is not capable to carry out the request in this state”	0x02		The device supports this Capability, but is not capable to carry out the request in the current state
	”Other Error”	0x03		Another error occurred.
[HEC Activation]	“HEC Inactive”	0	1 bit	Indicates that HEC Functionality is inactive.
	“HEC Active”	1		Indicates that HEC Functionality is active.
[HEC Activation Field]	“Reserved (0x0)”	Bit 15	2 bytes	Reserved (shall be set to 0)
	[HEC Activation]	Bit 14		Indicates that HEC Functionality is either active or inactive on the device’s HDMI output.
	14{[HEC Activation]}	Bits 13-0		Indicates that HEC Functionality is either active or inactive on the respective HDMI input. HDMI 1 shall be indicated in bit 13 and HDMI 14 shall be indicated in the LSB (bit 0). The HDMI input number shall be defined to correspond to the respective physical address of the appropriate HDMI input. Note that the HDMI input number may be different in comparison to the label printed near the connector.
[HEC Support]	“HEC Not Supported”	0	1 bit	Indicates that HEC Functionality is not supported.

Name	Range Description		Length	Purpose
	"HEC Supported"	1		Indicates that HEC Functionality is supported.
[HEC Support Field]	"Reserved (0x0)"	Bit 15	2 bytes	Reserved (shall be set to 0)
	[HEC Support]	Bit 14		Indicates that HEC Functionality is either supported or not supported on the device's HDMI output.
	14{[HEC Support]}	Bits 13-0		Indicates that HEC Functionality is either supported or not supported on the respective HDMI input. HDMI 1 shall be indicated in bit 13 and HDMI 14 shall be indicated in the LSB (bit 0). The HDMI input number shall be defined to correspond to the respective physical address of the appropriate HDMI input. Note that the HDMI input number may be different in comparison to the label printed near the connector.

408

Name		Range Description		Length	Purpose
[HEC State]		[HEC Functionality State] [Host Functionality State] [ENC Functionality State] [CDC Error Code]		1 byte	
	[HEC Functionality State]	“HEC Not Supported”	0	2 bits	Indicates that HEC Functionality is not supported
		“HEC Inactive”	1		Indicates that HEC Functionality is supported but inactive
		“HEC Active”	2		Indicates that HEC Functionality is supported and active
		“HEC Activation Field”	3		Indicates that HEC Functionality is supported and active on at least one HDMI port. The activation state of each HDMI port is indicated in the [HEC Activation Field] parameter. This value shall only be used in response to a <CDC_HEC_SetState> message containing multiple VHECs.
	[Host Functionality State]	“Host Not Supported”	0	2 bits	Indicates that Host Functionality is not supported
		“Host Inactive”	1		Indicates that Host Functionality is supported but inactive
		“Host Active”	2		Indicates that Host Functionality is supported and active
	[ENC Functionality State]	“Ext Con Not Supported”	0	2 bits	Indicates that an External Network Connection is not supported (e.g. no cable connected)
		“Ext Con Inactive”	1		Indicates that an External Network Connection is supported but inactive
		“Ext Con Active”	2		Indicates that an External Network Connection is supported and active
[HEC Set State]		“Deactivate HEC”	0	1 byte	Sets the required HEC Functionality state of the HDMI Ethernet Channel
		“Activate HEC”	1		
[Input port number]		Initiator’s (Sink’s) input Port number	0 ≤ N ≤ 15	4 bits	The value of the nibble of the Initiator’s physical address that is different in the directly connected Follower’s physical address.

409

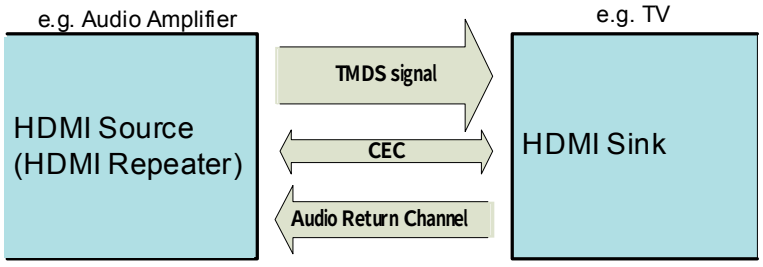
Name	Range Description		Length	Purpose	
[HPD_State]	"CP&EDID_DISABLE"	0x0	4 bits	Indicates CP&EDID_MODE transition to Disabled state	
	"CP&EDID_ENABLE"	0x1		Indicates CP&EDID_MODE transition to Enabled state	
	"CP&EDID_DISABLE_ENABLE"	0x2		Indicate CP&EDID_MODE transitions first to the Disabled state then back to the Enabled state	
	"EDID_DISABLE"	0x3		Indicates EDID_MODE transition to Disabled state.	
	"EDID_ENABLE"	0x4		Indicates EDID_MODE transition to Enabled state.	
	"EDID_DISABLE_ENABLE"	0x5		Indicate EDID_MODE transitions first to the Disabled state then back to the Enabled state	
	Reserved	0x6 - 0xF			
[CDC_HPD_Error_Code]	"No Error"	0x0	4 bits		Same Range as [CDC Error Code]
	"Initiator does not have the requested Capability"	0x1		The device never supports this Capability	
	"Initiator is not capable to carry out the request in this state"	0x2		The device supports this Capability, but is not capable to carry out the request in the current state Note: A Source shall not use this parameter	
	"Other Error"	0x3		Another error occurred.	
	"No Error, No Video Stream"	0x4		"No Error" response with additional indication that the Source is not sending a video stream	
	Reserved	0x5 – 0xF			

410

HEAC 4 Audio Return Channel

HEAC 4.1 Overview

The Audio Return Channel function allows delivery of a single IEC 60958-1 stream from an HDMI Sink to an adjacent HDMI Source/Repeater in the reverse direction to the TMDS signal (See HEAC 2) after negotiation using CEC Audio Return Channel Control (see CEC 13.17).



HEAC Figure 4-1 Audio Return Channel Overview

Typically, the Audio Return Channel function is used as a connection between a TV (HDMI Sink) and an audio Amplifier (HDMI Source/Repeater) to deliver an audio signal from the TV to the audio Amplifier, in conjunction with using the CEC System Audio Control Feature (see CEC 13.15).

HEAC 4.2 Relationship with IEC 60958/IEC 61937

The interface format of the Audio Return Channel is defined in IEC 60958-1.This IEC 60958-1 stream also shall comply with IEC 60958-3 or IEC 61937 specifications.

NOTE: Supplement 2 specifies a different physical specification from IEC 60958-1. (See Section HEAC 2)

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 of IEC 60958-3.

NOTE: the allowed rate values do not include the IEC 60958-3 specified “Sample frequency not indicated” value.

An HDMI device that has an Audio Return Channel receiver function shall support two- channel 16-bit L-PCM audio at sample rates of 32 kHz, 44.1 kHz, and 48 kHz defined in IEC 60958-3 on the ARC connection.

An HDMI device that has an Audio Return Channel transmitter function shall support two-channel 16-bit L-PCM audio at least one of these sample rates on the ARC connection.

NOTE: Clock frequencies correspond, respectively, to 4.096MHz, 5.6448MHz, and 6.144MHz.

Support of other audio formats as defined in IEC 60958-3 or compressed audio as defined in IEC 61937 (all parts) is optional. CEC messages may be used to discover the supported audio formats, see section CEC 13.15.3.

HEAC 4.3 Functionality

In order to use the Audio Return Channel feature, it is necessary to discover and control the capabilities of the devices in the respective paths, using CEC (Supplement 1). An Audio Return Channel device shall support

CEC and shall not utilize audio data transmissions via the Audio Return Channel towards any HDMI devices without the procedures specified in CEC 13.17. The discovery and control are identical for ARC common mode transmission and ARC single mode transmission, and performed with no discrimination between both modes.

The CEC messages activate or de-activate the Audio Return Channel and may enable power control of the Audio Return Channel transmitter (ARC Tx) and receiver (ARC Rx). When the Audio Return Channel is de-activated, the ARC Tx device and/or ARC Rx device may power down their ARC-related functionalities.

In the case where the ARC Tx device detects that the ARC Rx device has been unplugged from the ARC Tx device, the ARC Tx device shall stop audio data transmissions via the Audio Return Channel and deactivate its ARC Tx functionality on the port to which that ARC Rx device was connected.

The ARC Tx device is allowed to stop sending its audio signal via the Audio Return Channel temporarily while keeping the link active. The ARC Rx device should take appropriate measures to prevent an undesired noise on its audio output.

HEAC 5 Networking

Note: In this section, HEC means a bidirectional, full duplex, high speed differential transmission technology, which does not include common mode transmission. In addition, an HEC output means an HDMI output connector with HEC functionality. Likewise, a HEC input means the HDMI input connector with HEC functionality.

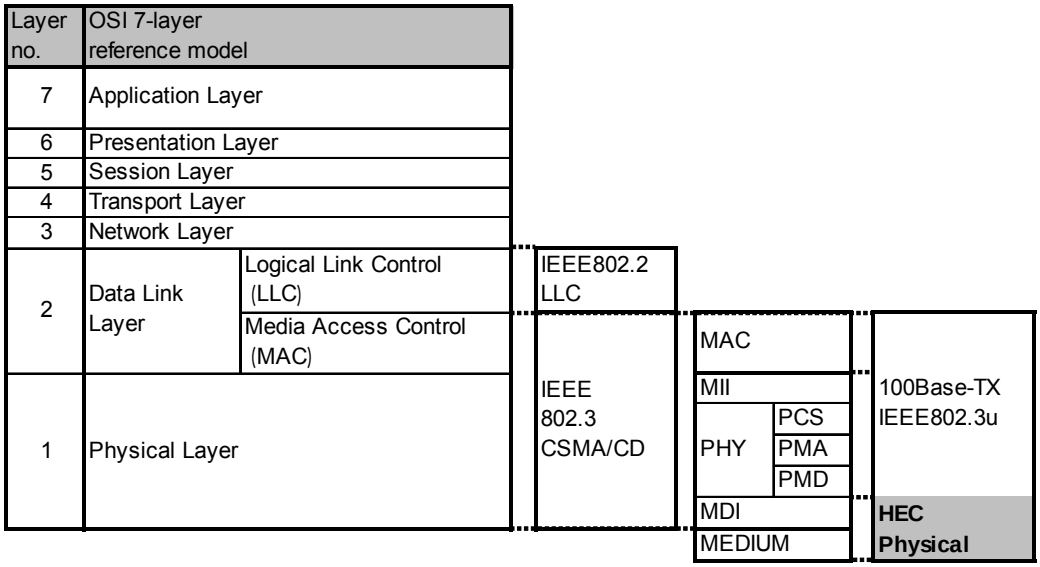
HEAC 5.1 Relationship Between HEC and 100Base-TX

Except for the following items, the physical layer of the HEC system is compatible with 100 Base-TX [4n]:

- Full duplex mode exclusively:
  Unnecessary to support CSMA/CD
- 100Mbps exclusively:
  No negotiation with 10Mbps and other transfer speeds.
- Different Physical Medium:
  A single pair of shielded twisted lines and hybrid circuits are used instead of two unshielded twisted pair lines.
- Different MDI:
  The RJ-45 connector is replaced by repurposing a pair of pins within the HDMI connector.

HEAC 5.2 Layer Architecture

HEAC Figure 5-1 shows the relationship between the Open System Interconnection (OSI) 7-layer reference model, IEEE 802.3 standard (Ethernet) and HEC Physical layer.



HEAC Figure 5-1 Layer Architecture

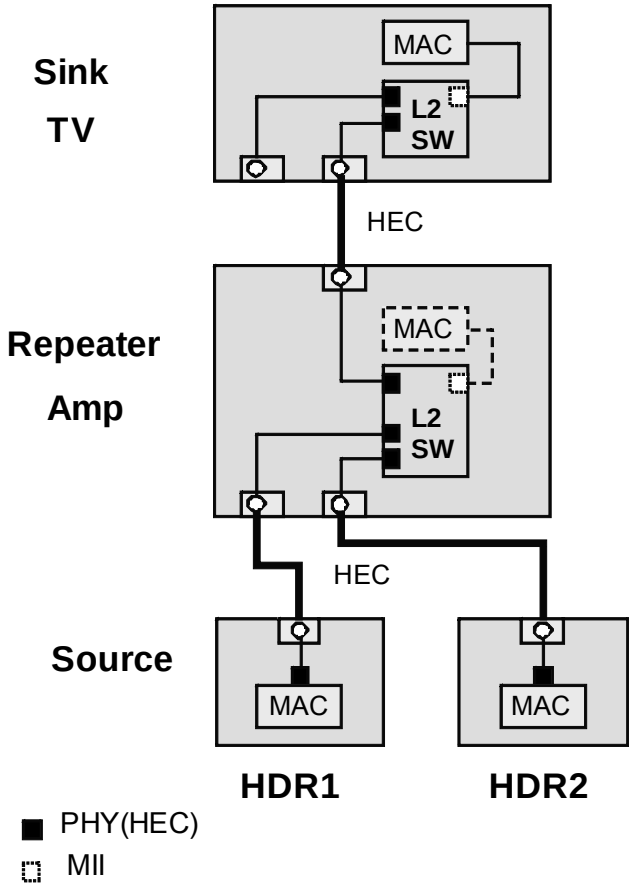
HEAC 5.3 Network Topology

The HEC network topology is star-type topology. HEAC Figure 5-2 illustrates a HEC network consisting of Sink, Repeater and Source devices interconnected by HEAC cables.

In this example, the devices are connected to each other; however there is no connection to a home network via wired Ethernet using RJ-45 connectors or to a wireless network like 802.11a/b/g. An example connection to a home network is shown later.

As precisely defined in HEAC 5.5, Sink, Repeater or Source devices which have at least two HEC connectors shall have an internal Layer 2 switch for forwarding the MAC frames (HEAC Appendix A) between its ports.

Note: the optional MAC layer is shown in the dashed-line boxes in HEAC Figure 5-2 through HEAC Figure 5-6.



HEAC Figure 5-2 Example of an HEC Network

HEAC 5.4 HEC Device Types

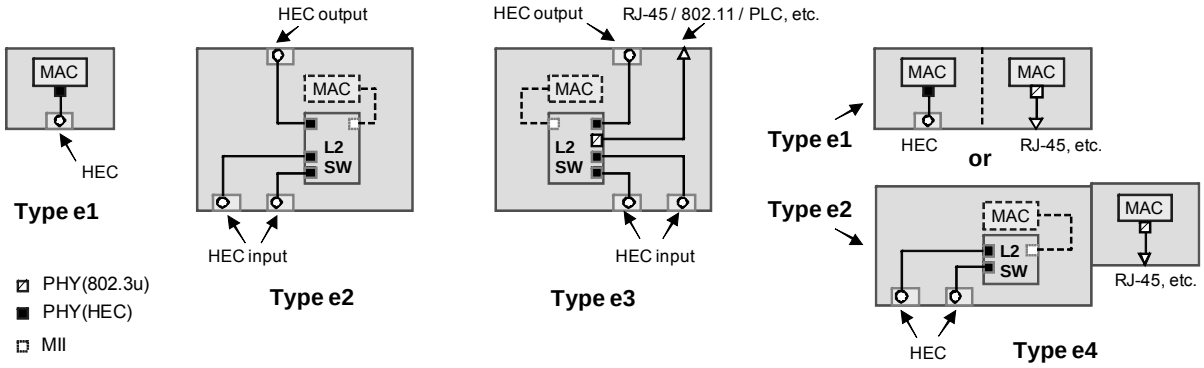
The following four types of HEC devices are identified with regard to network termination.

Type e1: HEC device with a single HEC input or output port and no network connection

Type e2: HEC device with multiple HEC input and/or output ports and no network connection

Type e3: HEC device with multiple HEC input and/or output ports and one or more network connection(s)

Type e4: HEC device with a single or multiple HEC ports and one or more other network connections, and no forwarding of MAC frames from the HEC port(s) to the other network connections (e.g. RJ45)



HEAC Figure 5-3 HEC Device Types

HEAC 5.5 Ethernet Switching Functionality

All HEC device types that have multiple HEC input and/or output ports and no network connection (Type e2), or multiple HEC input and/or output ports and one or more network connection(s) (Type e3), shall have a L2 SW which performs Ethernet switching functionality conforming to IEEE standards [4n] [5n] [6n]. Type e4 devices that have at least two HEC ports (see note below) shall have a L2 SW which performs Ethernet switching functionality between the HEC ports.

Ethernet switching functionality is briefly summarized as follows: Refer to [5n]

1. acquire the source address of an incoming MAC frame and the port number from where the MAC frame was sent.

2. search the filtering database for the destination address of the MAC frame and port number.

   - case1: if the MAC frame destination address does not exist within the filtering database, then forward the MAC frame to every port except to the port from where the MAC frame was sent.

   - case2: if the MAC frame destination address exists within the filtering database with a different port number, then forward the MAC frame to that port number (the different port number).

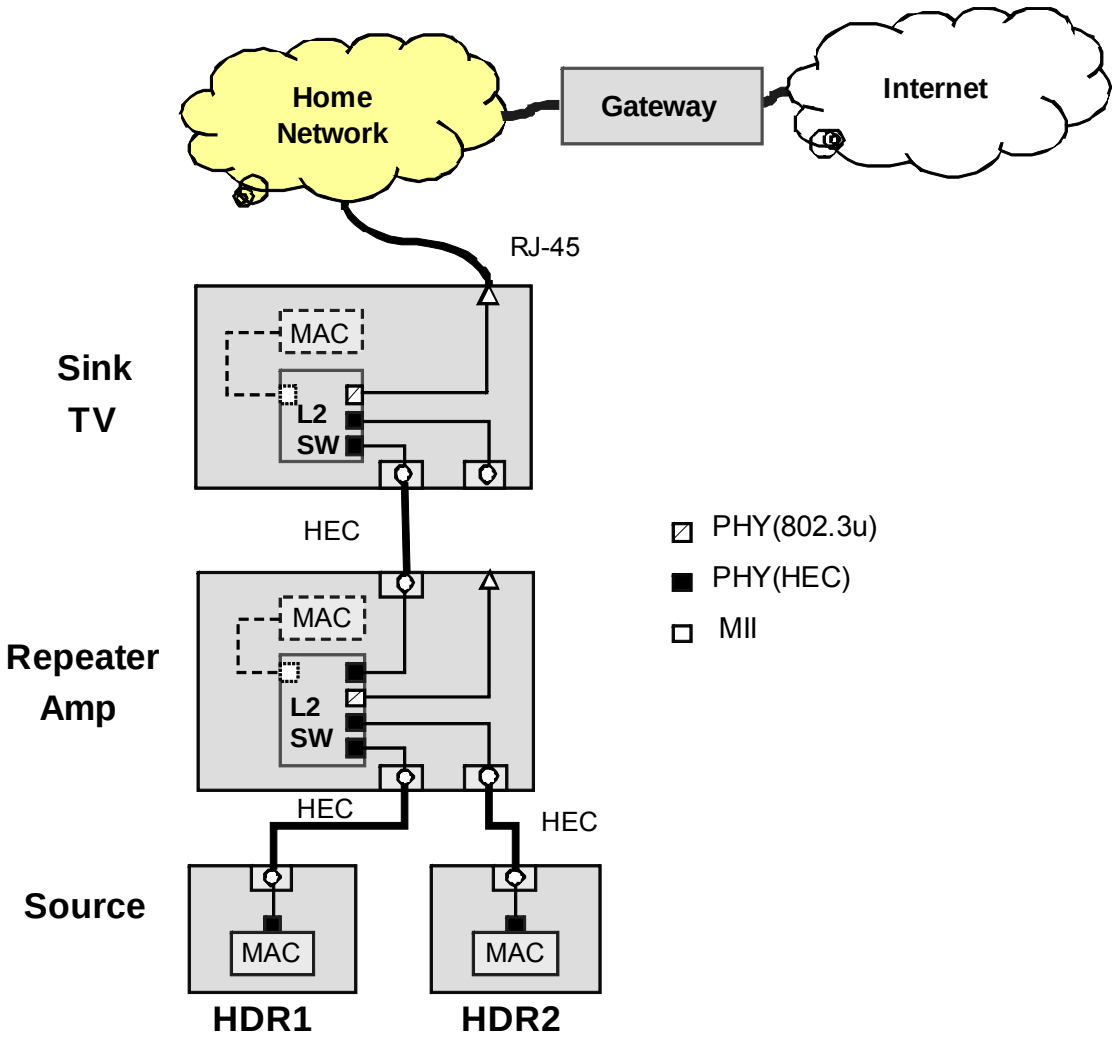
   - case 3: if the MAC frame destination address and port number exists within the filtering database, then filter the MAC frame.

3. the MAC frame's acquired source address and port number is registered with the filtering database.

Note that Ethernet switching functionality is mandatory for all Type e2 devices, Type e3 devices, and Type e4 devices with at least two HEC ports. For a Type e4 device with at least two HEC ports, Ethernet switching functionality is required between HEC ports but not from the HEC ports to the one or more network connection. If forwarding of MAC frames between these connections is added to a Type e4 device, this device then becomes a Type e3 device and Ethernet switching is then required.

HEAC 5.6 Connection to Internet via Home Network

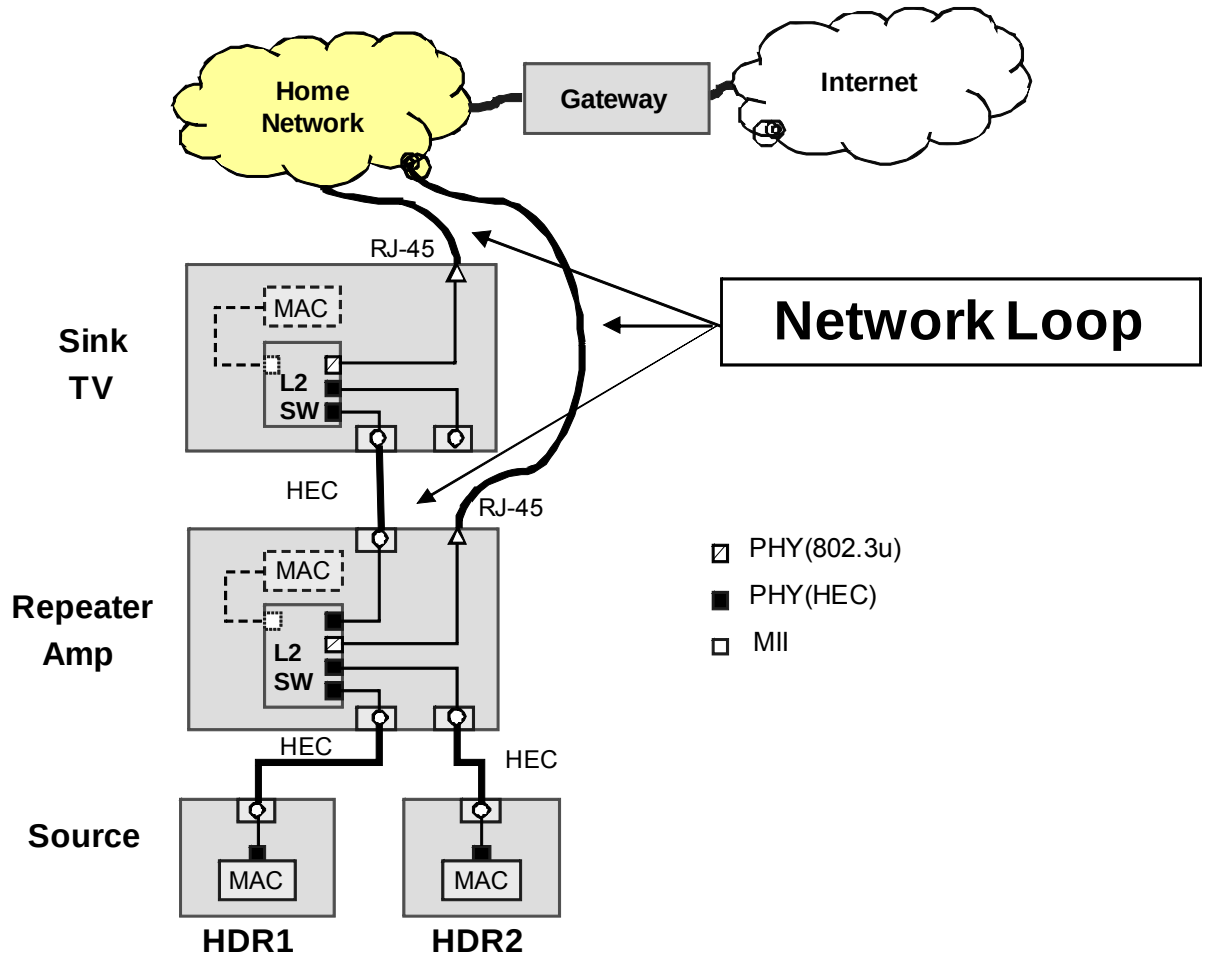
HEAC Figure 5-4 shows an example of a HEC network which is connected to the Internet via the Home Network. The connection to the Home Network may be implemented on any HEC device. Refer to HEAC Appendix D for recommendations related to connection to the Home Network and the Internet.



HEAC Figure 5-4 Example of a Connection to the Internet

HEAC 5.7 Loop Detection and Loop Removal

HEAC Figure 5-5 shows a situation where a network loop is formed. All HEC Sink, Repeater and Source devices that have an external network connection (e.g. RJ45, 802.11 or PLC) shall have loop detection and loop removal functionality to prevent traffic loops. Details are described below.



HEAC Figure 5-5 Example of a Network Loop

HEAC 5.7.1 Loop Detection Requirements

HEC devices that simultaneously fulfill the following conditions shall have loop detection capability.

condition (a): has multiple HEC outputs, or have at least one HEC output and an Ethernet or equivalent port (RJ45, 802.11, PLC, etc.).

condition (b): The MAC frame is forwarded from an HEC output port to another HEC output port or from an HEC output port to an Ethernet or equivalent port or from an Ethernet or equivalent port to a HEC output port.

These HEC devices shall also have a loop removal function. The loop removal function shall disable forwarding MAC frames to ports that are part of a loop.

The following method shall be used for loop detection and automatic loop removal:

- RSTP (Rapid Spanning Tree Protocol) [5n]

HEC devices that do not need to have loop detection capability and loop removal function, i.e. RSTP, according to the rules above, shall anyway forward the RSTP BPDUs [5n] to enable correct loop detection and loop removal operation in the system.

Note: if any (non-HEC) switches exist in the loop (e.g. as part of the home network) that do not forward RSTP messages, then the RSTP is not fully functional and automatic loop detection and removal is not always possible.

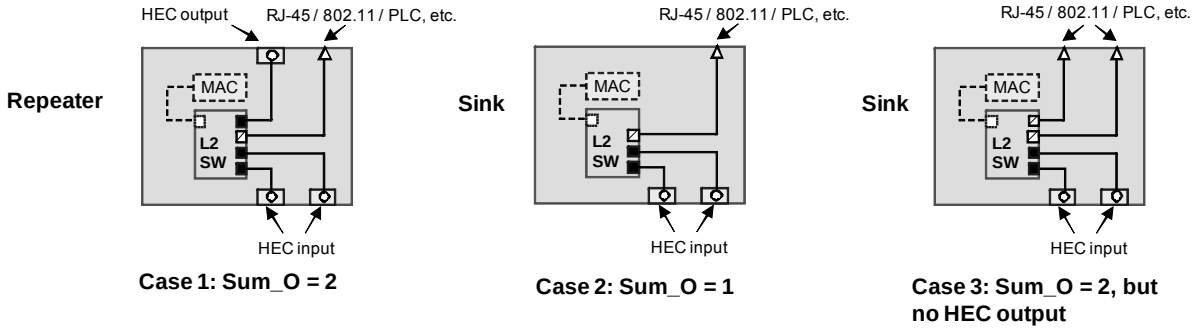
HEAC Figure 5-6 shows examples of an HEC Type e3 device that: in Case 1 meets the conditions requiring loop detection capability; in Case 2 does not meet the conditions requiring loop detection capability; in Case 3 device does not have any HEAC output. In these examples, the assumption is the device transfers MAC frames between each port (Type e3).

In these examples, Sum_O means the sum of the number of HEC outputs and the number of Ethernet or equivalent ports (RJ45, 802.11, PLC, etc.)

Case 1: Sum_O of this Repeater is 2, so the Repeater shall have loop detection capability and loop removal functionality.

Case 2: Sum_O of this Sink is 1, so the Sink does not need loop detection capability nor loop removal functionality. However it shall forward the BPDUs to enable correct loop detection and loop removal operation in other devices.

Case 3: Sum_O of this Sink is 2, and since this Sink does not have any HEC outputs, this case does not satisfy all the conditions described above, however it is recommended to have the capability for loop detection and removal functionality for such devices anyway.



HEAC Figure 5-6 Example of Three Device Cases with Respect to Conditions for Loop Detection and Removal Capability

HEAC 5.8 QoS

HEC uses conventional QoS mechanisms using VLAN priority tags (IEEE802.1Q [6n]) and queues.

For Ethernet packets which originate from outside the HEC network and which use VLAN Tag values, HEC devices should pass through those Ethernet packets and should use the same VLAN tag values already carried in those Ethernet packets. Ethernet packets which do not have VLAN tags shall be treated as best effort (priority 0, default).

For Ethernet packets which originate from within the HEC network, the mapping of traffic type or application type to user priority is typically defined by the application, e.g., DLNA [1i] (see also HEAC Appendix B), DVB. For Ethernet packets which originate within the HEC network and where there is no other applicable normative standard or specification to define the VLAN tags, the application shall use the Tag values defined in HEAC Appendix C.

The following functions shall be incorporated into each L2 switch within a HEC device for QoS control.

- Four or more queues for egress service

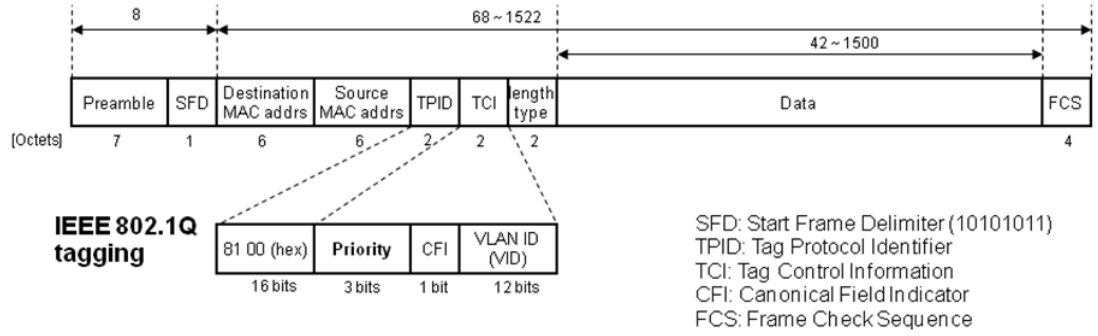
- Support for the MAC frame format with priority tags (See HEAC Appendix A)

The user priority is expressed by 3 bits in the TCI (Tag Control Information). The user priority to Ethernet packets class mapping defined in Table 7-2 in IEEE 802.1D [5n] shall be applied in the L2 switch.

HEAC 6 Appendices

HEAC Appendix A MAC Frame Format (Informative)

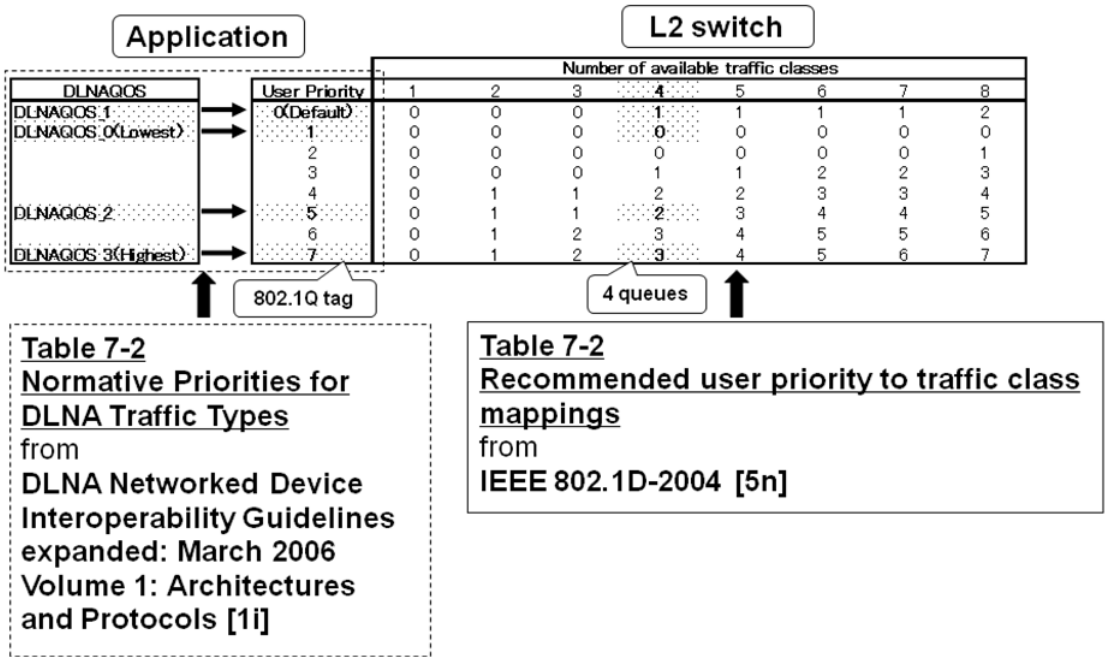
HEAC Figure 6-1 shows the MAC frame format (Fig 3-3 in IEEE802.3 [4n]) with tagging (IEEE802.1Q [6n]).



HEAC Figure 6-1 MAC Frame Format

HEAC Appendix B User Priority with Respect to Traffic Class Mapping (Informative)

HEAC Figure 6-2 shows the example of Traffic type to User priority to Traffic class mapping with four queues for DLNA. For other applications, Traffic type to User priority mapping may be different. It depends upon each application.



HEAC Figure 6-2 An Example of DLNA User Priority for Traffic Class Mapping

HEAC Appendix C User Priority with Respect to Traffic Type Mapping

If priority tagging for an application is not already specified by another standard or specification, then user priority which does not exceed the value in HEAC Table 6-1 shall be used.

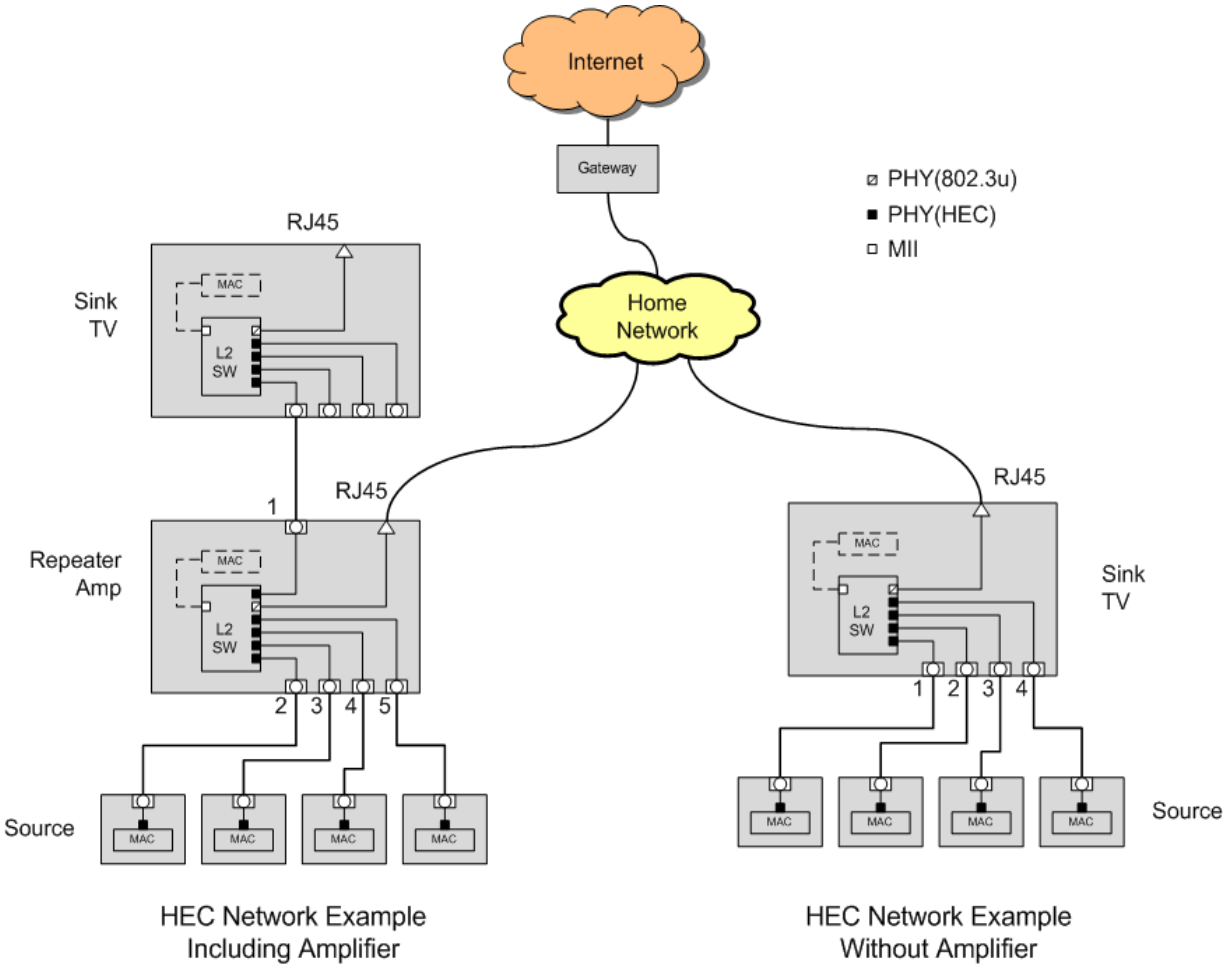
HEAC Table 6-1 HEC Mapping for User Priority Traffic Type

Traffic Type or Application Type	User Priority
Control	7
A/V Streaming	5
Data Services	2
Best Effort	0

HEAC Appendix D Connection to the Home Network and Internet

HEAC Figure 6-3 shows two examples of HEC networks which are connected to the Internet and to each other via the Home Network.

To provide for uplink connection and Layer 2 switching to the Home Network and Internet, it is recommended that HEC devices with two or more HEC ports support a minimum of one external network port. In the examples in HEAC Figure 6-3, the amplifier is shown with 5 HEC ports and the TV with 4 HEC ports, with each of these devices including an RJ45 external network port.



HEAC Figure 6-3 Examples of Connection to the Home Network and Internet

In the HEC network example without amplifier on the right side of HEAC Figure 6-3, the external port connection to the Home Network and Internet may be accessed by all HEC devices simultaneously. Each

HEC port (labeled 1 to 4) is capable of 100Mbps in each direction for an aggregate directional bandwidth of 400Mbps. To avoid uplink bandwidth congestion, it is recommended that the external port (and its associated internal switching logic) supports sufficient connection bandwidth to aggregate the bandwidth demands of the HEC ports:

$$\text{Upstream bandwidth} \geq \sum_{i=1}^{N} \text{HEC port}(i)$$

The device's internal host bandwidth requirements for the uplink should additionally be taken into account.

In the HEC network example including amplifier on the left side of HEAC Figure 5-4, this recommendation indicates for the amplifier to include an external port with a minimum directional bandwidth of 0.5Gbps to aggregate the HEC ports (labeled 1 to 5). By example, the criteria can be met by inclusion of a Gigabit Ethernet external network port. For this HEC network example, the connection to the Home Network and Internet is made from the amplifier to avoid the 100Mbps bandwidth limitation of the amplifier-to-TV HEC connection that would result if the TV uplink connection would have been used.