

■ The present invention relates to image conversion and playback methods and devices for displaying high dynamic range (HDR) image signals on display devices such as televisions, projectors, tablets, and smartphones designed for standard dynamic range (SDR) signals (peak luminance: 100 nits).

■ Background

Until recently, efforts to improve video image quality have focused primarily on increasing the number of display pixels, leading to the widespread adoption of High Definition (HD) video with 1920 x 1080 pixels, an upgrade from Standard Definition (SD) video with 720 x 480 pixels.

To achieve even higher image quality, Ultra High Definition (UHD) at 3840 x 1920 pixels and so-called 4K video at 4096 x 1920 pixels have begun to be introduced in recent years.

Along with the introduction of 4K, efforts are underway to expand the dynamic range and color gamut, as well as to increase and improve frame rates.

In the case of dynamic range, HDR (High Dynamic Range) in particular has been attracting attention as a method for rendering bright light—such as specular reflections—with a luminance closer to reality while preserving shadow detail—something that cannot be achieved with current television signals. While conventional television signals, known as SDR (Standard Dynamic Range) signals, have a maximum luminance of 100 nits, HDR is expected to expand the maximum luminance to 1,000 nits or more, and standardization of specifications for mastering displays is currently underway at organizations such as SMPTE and ITU-R.

As with HD and UHD, HDR is expected to be used in broadcasting, packaged media (such as Blu-ray discs), and Internet streaming (see Figure 1).

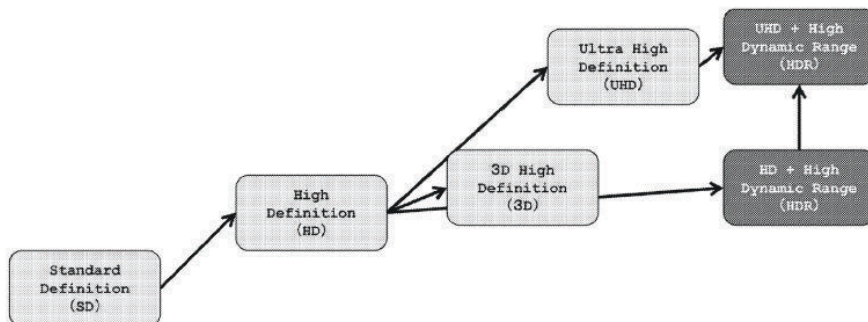


Figure 1: Evolution of Video Technology

· Overview of the Invention:

· When authoring content that includes visual data such as graphics in addition to video, a common master is used for non-video visual data in both HDR and SDR. For this reason, grading is performed so that the peak level in the master falls within the SDR luminance range.

· When playing back content, the system determines whether to output in HDR or SDR format based on whether the output device supports HDR, and performs remapping of the video and graphics from SDR to HDR or from HDR to SDR based on the output format. For graphics, a fixed-luminance remapping process is applied, in which the luminance values do not change before and after remapping. For video, a variable-luminance remapping process is applied, in which the luminance values may change before and after remapping.

· Effects:

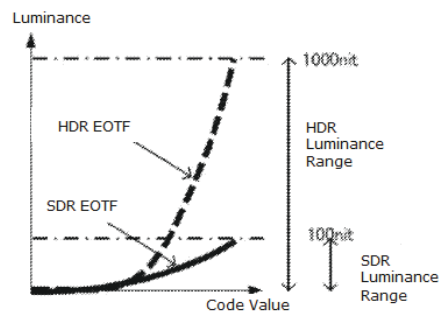
· Since masters other than those for video can be standardized for both HDR and SDR, the time required for master creation can be reduced.

· For graphics, since the luminance does not change before and after remapping, the image quality intended by the creator can be preserved.

Also, since there is no need to associate luminance values before and after EOTF conversion, the processing load associated with remapping is reduced.

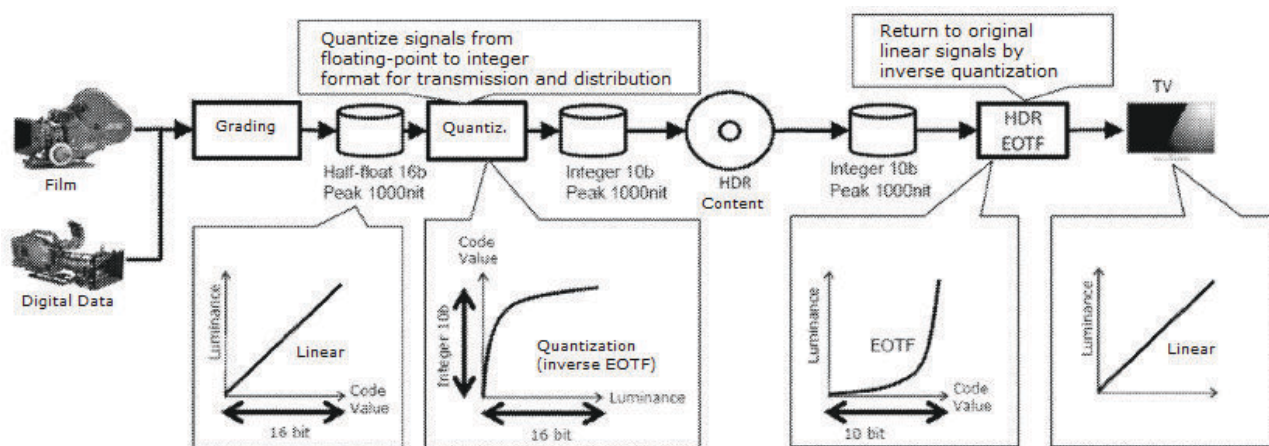
HDR EOTF:

· Figure 2 (a) shows examples of the EOTF (Electro-Optical Transfer Function) for HDR and SDR. The EOTF, commonly referred to as the gamma curve, converts luminance values into code values. For example, when representing SDR signals with 8 bits, the original signals are quantized up to 100 nits, and mapped to integer values ranging from 0 to 255. The HDR gamma curve allows for the representation of higher luminance values than SDR. In Figure 2 (a), the maximum luminance (peak luminance) is 1000 nits.



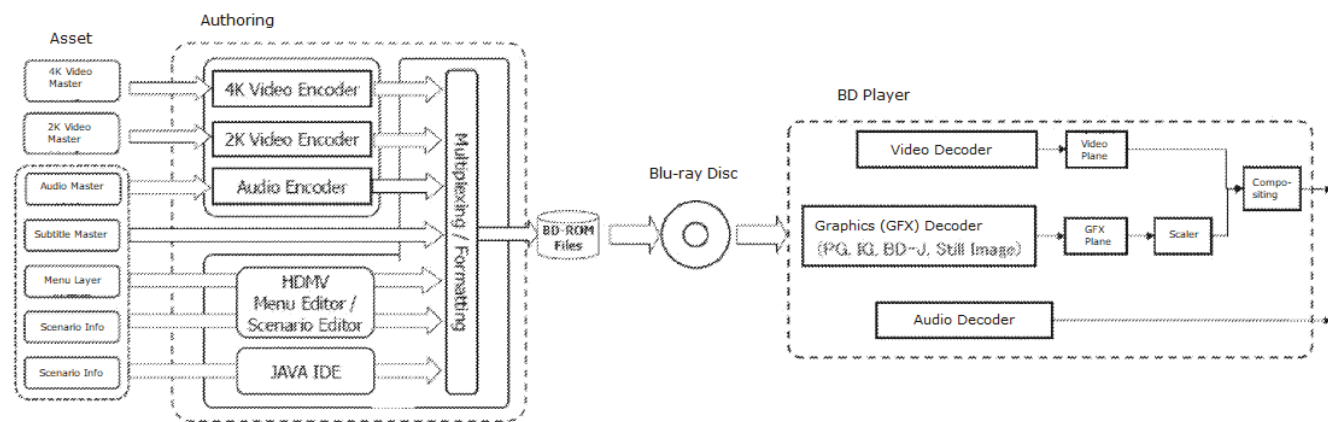
How to Use EOTF:

· Figure 3 (a) shows the method used to determine code values for the signals stored in the content, as well as the process of restoring luminance values from the code values during playback. In this example, the signals are HDR signals. The video after grading is quantized using the inverse function of the EOTF to determine the code bits corresponding to luminance. Based on these code values, video encoding and other processes are performed to generate elementary streams for video and graphics. During playback, the decoded elementary streams are subjected to EOTF-based inverse quantization to restore the luminance values for each pixel.



BD Stream Configuration:

Having previously noted that HDR may be used in optical discs such as Blu-ray discs or in broadcasts, we will now explain this using a BD (Blu-ray disc) as an example. Figure 4 (a) is a diagram used to explain the production of a BD and the player used to play it. The production process includes BD authoring and the creation of a Blu-ray disc containing the authored content. BD content includes not only video and audio but also graphics data for generating subtitles and menus, as well as scenario data for providing interactivity to menu displays and user operations. There are two types of scenario data: HDMV, which is controlled by predefined commands, and BD-J, which is controlled by Java programs. During authoring, video and audio are encoded, and these encoded streams, along with graphics such as subtitles and menus, are multiplexed into an M2TS-format transport stream. Additionally, management information necessary for playback control, such as frame lists and EP maps, is generated in the authoring process, and the resulting data is stored on the BD. A BD player references the management information to isolate, decode, and output the video and audio elementary streams, as well as the graphics data, required for playback. Here, subtitles and menus are outputted after their respective layers have been composited. If the resolutions of the video and graphics differ, the graphics are upscaled to match the video resolution before the video and graphics are composited.



Prior Art Problem 1:

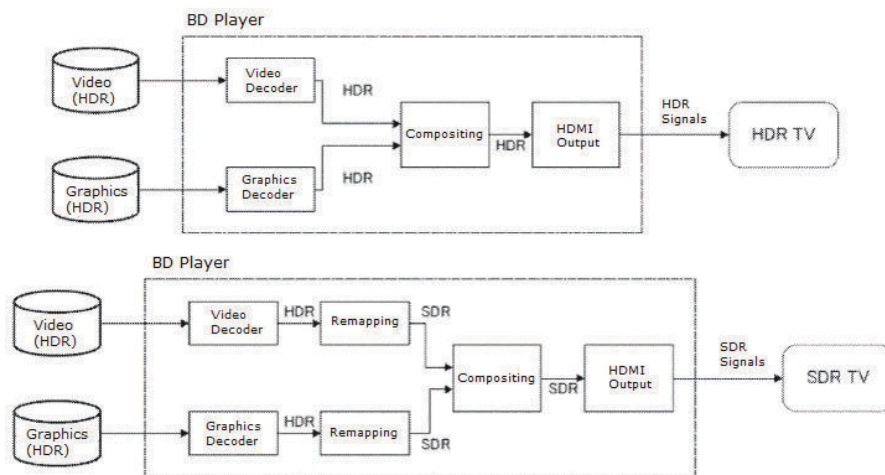
When creating video or graphics masters, a process called grading is needed to adjust the luminance and color tones of digital images captured by a camera or scanned film images to reflect the creator's intent. Grading requires advanced expertise and involves a tremendous amount of time. Therefore, it is desirable to keep the number of masters to a minimum. However, since HDR and SDR have different peak luminance levels, it is generally necessary to generate separate masters for each. Figure 4 (a) shows an example of HDR and SDR combinations when the content contains one video stream and one graphics stream. In this example, there are four possible combinations, and separate HDR and SDR masters are required for both the video and the graphics.

While the HDR effect is greatest in video content such as the main feature of a movie, and the effect on graphics such as subtitles is considered to be less significant compared to video, the first problem with the prior art is the heavy workload involved in content production, as creating both HDR and SDR masters for graphics is necessary, just as it is for video.

		Video Master	
		HDR	SDR
Graphics Master	SDR	✓	✓
	HDR	✓	✓

Prior Art Problem 2:

When playing back HDR content, the outputted signals from the playback device, such as a Blu-ray player, are displayed on a TV or other display. If the display supports HDR, the outputted signals remain in HDR. However, if the display does not support HDR, the outputted signals are converted to SDR. Figure 5 (a) and Figure 5 (b) show examples of a BD player connected to a TV via HDMI. Figure 5 (a) shows a case in which the TV supports HDR, and Figure 5 (b) shows a case in which the TV does not support HDR. In Figure 5 (a), the HDR data from the video and graphics is composited, and the HDR signals are outputted via HDMI to the HDR-compatible TV. In Figure 5 (b), since the TV does not support HDR, the video and graphics are remapped to the SDR EOTF before compositing, and composited as SDR signals. The SDR signals are then outputted via HDMI. Remapping is a process in which, when two types of EOTFs, namely, EOTF1 and EOTF2, exist, the code values in EOTF1 are converted to code values in EOTF2. In the conversion from HDR to SDR, the code values of the HDR EOTF are converted to the code values of the SDR EOTF. Since SDR cannot represent luminance values exceeding 100 nits, it is necessary to define mapping between HDR luminance values exceeding 100 nits and their corresponding SDR code values in advance, either using a predefined conversion table or through adaptive processing based on the luminance distribution of the image in the content. The need for different conversion rules is anticipated for data in which luminance values are critical, such as subtitles, and for video, and since the remapping occurs on a frame-by-frame basis, the processing load is particularly high for high-resolution images such as 4K. Also, since luminance values change before and after remapping, the remapped images may differ from the creator's intended images. However, when converting and outputting conventional HDR content to SDR, graphics require the same type of remapping as video. This not only results in a heavy processing load but also presents a second problem, namely, the possibility that the luminance values will be converted to levels not intended by the creator.



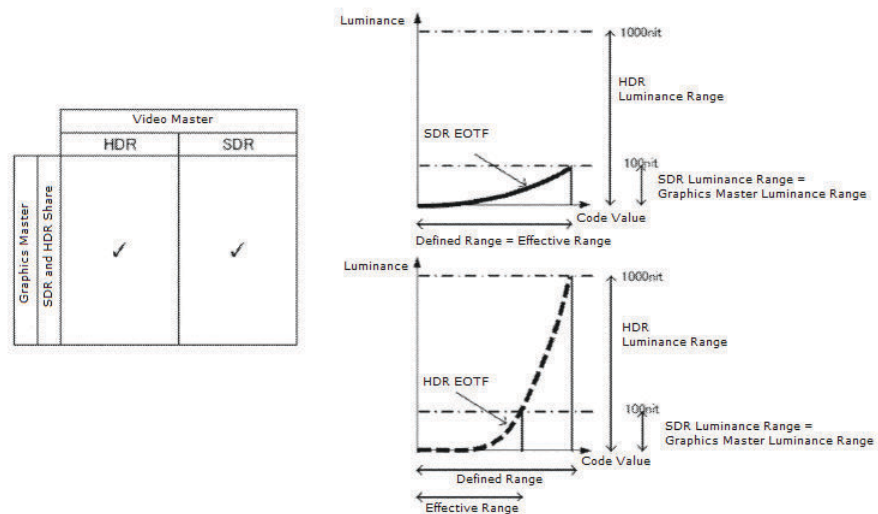
Content Generating Method:

When generating a graphics master in the present invention, the SDR and HDR masters are unified. To achieve this, the luminance range of the graphics master is made to match the SDR luminance range. Specifically, the peak luminance is set to be at or below the upper limit of the SDR luminance range. When the graphics data in the content is composed of SDR signals, the code value for each pixel is determined based on the SDR EOTF. When the content is composed of HDR signals, the code value for each pixel is determined based on the HDR EOTF. Figure 7 (b) shows a case in which the mapping is done to SDR signals. Since the SDR luminance range and the luminance range of the graphics master match, the entire range of code values in the SDR EOTF is valid. Figure 7 (c) shows a case in which mapping is done to HDR signals. In this case, only code values equal to or less than the code value corresponding to the SDR peak luminance are valid.

Note that when handling HDR signals, additional information indicating whether a signal falls within the SDR luminance range may be stored in the elementary stream, or in management information such as a playlist. In the remapping process, this identification information can be used to determine whether to apply either the fixed-luminance remapping or the variable-luminance remapping described later. When outputting is performed via an interface such as HDMI, this identification information may be stored as metadata for the output interface.

The EOTF for graphics can be determined based on the video. For example, if the video is HDR, the graphics data is also set to HDR, and if the video is SDR, the graphics data is also set to SDR. Alternatively, the graphics data may always be set to SDR.

This same approach can be applied when there are multiple video streams. For example, if there is a sub-video stream that is superimposed on or displayed side-by-side with the main video stream, the EOTF of the sub-video can be matched to that of the main video.

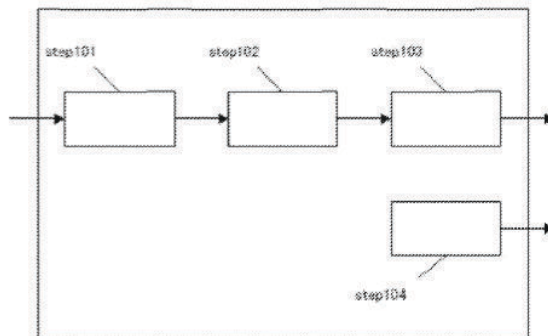
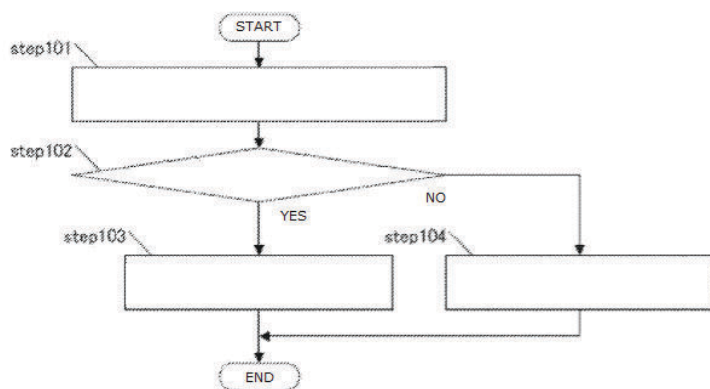


Data Generating Method and Device:

Figure 12 (a) is a flowchart used to explain the method for generating graphics signals in the authoring process of the present invention. In step 102, it is determined whether graphics are displayed with the video. For example, if there are subtitles, it is indicated that the video has superimposed subtitles.

For graphics that are not displayed with the video, such as a menu, the determination may be made based on whether the corresponding video is HDR or not. Note that since the graphics use the same format as that of conventional 2K content, the conversion can always be performed using the SDR EOTF. In this case, the determination process in step 102 may be omitted, and the process in step 104 may be performed directly.

Figure 12 (b) is a block diagram showing the configuration of the graphics signal generating unit in the authoring process of the present invention.



step 101: Grade graphics master to lower luminance value at or below SDR peak luminance
 step 102: Is video displayed at same time as graphics HDR?
 step 103: Convert luminance values of graphics to code values using HDR EOTF
 step 104: Convert luminance values of graphics to code values using SDR EOTF

step 101 processing: GFX grading means
 step 102 processing: Determining means
 step 103 processing: HDR signal generating means
 step 104 processing: SDR signal generating means

Data Playback Method and Device:

Figure 12 (a) is a flowchart of the remapping process for the video playback device in the present invention. The format for the outputted signals in step 201 is determined based on whether the display device (such as a TV) displaying the video is HDR-compatible. Alternatively, it may be determined so as to match the main video, such as the main feature. For the variable luminance remapping in step 203 and the fixed luminance remapping in step 204, tables showing the correspondence between HDR and SDR luminance values are prepared in advance. In these tables, the correspondence between code values in the HDR and SDR EOTFs may be described for each luminance value for which code values exist. Since a code value corresponding to the luminance values in the remapped EOTF always exists, there is no need to search for the code value closest to the given luminance value when no corresponding code value exists. Furthermore, in variable luminance remapping, it is possible to adaptively switch between multiple tables based on the luminance distribution within an image or per scene, or to sequentially create the optimal table for each piece of content.

Variable luminance remapping in step 203: (conversion from EOTF1 to EOTF2)

1. Determine the luminance values corresponding to the EOTF code values
2. Determine the EOTF2 luminance values corresponding to the luminance values determined in step 1
3. Determine the EOTF2 code value corresponding to the luminance values determined in step 2

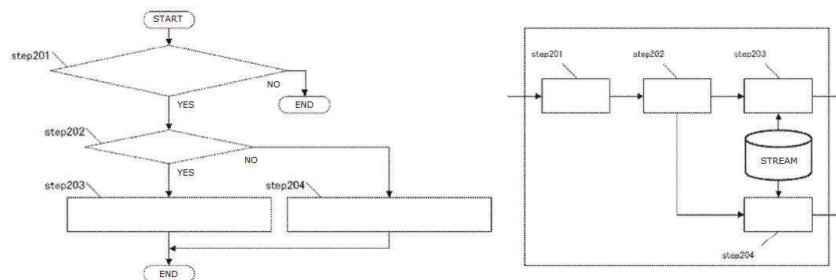
Fixed luminance value remapping in step 204: (conversion from EOTF1 to EOTF2)

1. Determine the luminance values corresponding to the EOTF code values
2. Determine the EOTF2 code values corresponding to the luminance values determined in step 1

* Since the luminance values do not change before and after remapping, the process described in step 2 above in step 203 is not necessary.

After the remapping process is complete, the video and graphics are composited and outputted. When outputting to a display device via an interface such as HDMI, information used to identify the EOTF of the outputted signals is sent as metadata.

Figure 12 (b) is a block diagram showing the configuration of the remapping processing unit in the image playback device of the present invention.



step 201: Is the EOTF of content signals and output signals different?

step 202: Is video the processing target?

step 203: Convert to signals corresponding to EOTF of output signals using variable luminance remapping

step 204: Convert to signals corresponding to EOTF of output signals using fixed luminance remapping

step 101 processing: EOTF determining means

step 102 processing: Processing target determining means

step 103 processing: Variable luminance remapping means

step 104 processing: Fixed luminance remapping means

Other:

Two types of outputted signal formats have been described: HDR and SDR. When outputting to HDMI etc., the output follows either the HDR or SDR standard. However, in cases such as when a Blu-ray player is built into a TV, when receiving and playing back broadcasts, or when viewing OTT services on a tablet, it is possible to output signals directly from the playback device to the display device. In such cases, if the peak luminance specified by the HDR standard differs from the peak luminance that can be displayed on the display device, the data in the content may be remapped according to the EOTF for the display device. SDR or HDR signals transmitted to the display device via HDMI may also be remapped again according to the EOTF corresponding to the display device's peak luminance.

In BD authoring, video, audio, or graphics can be specified on a play item-by-play item basis within the playlist. With interfaces such as HDMI, switching between HDR and SDR on a play item basis triggers a reset at the boundaries of play items, which may prevent seamless playback. Therefore, when HDR and SDR switch between play items that are connected seamlessly, a remapping process may be performed by a playback device, such as a BD player, to ensure that the EOTF of the outputted signals is identical to that of the immediately preceding play item. Alternatively, EOTF switching may be prohibited between seamlessly connected frames, and identification information indicating that the EOTF does not change may be stored in management information, such as a playlist.

The authoring and image playback methods of the present invention are applicable not only to storage media such as optical discs, but also to broadcasting and OTT (over-the-top) services. For example, in broadcasting, data broadcasts transmitted alongside the main program, as well as content acquired via communication networks, can be superimposed on the main video. In this case, it is expected that the main video will consist of a mix of HDR and SDR programs. Peak brightness limiting and remapping processing, as described above, can also be applied to the graphics and video in content acquired separately from the main program.

When introducing these new video formats (and increased pixel counts, etc.), the home entertainment masters used by video producers must be modified. Consequently, distribution methods, such as broadcasting, telecommunications, and packaged media, as well as display devices, such as televisions and projectors used to display video, must also be updated (see Figure 2).

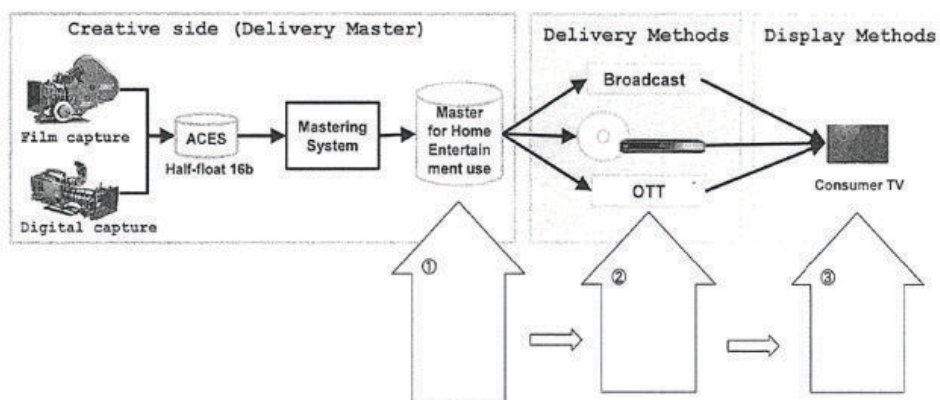
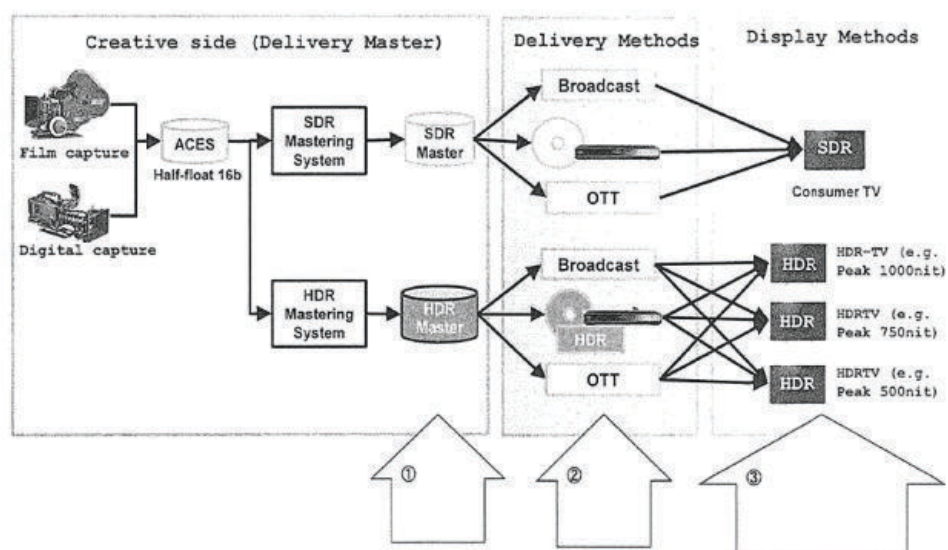


Figure 2: Relationship between the master, distribution method, and display device

For users to enjoy new high-luminance video content (HDR content) at home, both HDR-compatible distribution methods and HDR-compatible display devices must be introduced. This has been unavoidable during the transitions from SD to HD, HD to 3D, and HD to UHD (4K).

Consequently, changes in visual formats that require replacing TVs, which are expensive and difficult to replace due to their size and weight, often result in slow adoption. This is because neither the media nor content providers could make significant initial investments, relying instead on the widespread adoption of TVs with new features.

The same applies to HDR: to fully utilize the inherent capabilities of HDR, viewers must upgrade to an HDR-compatible TV (see Figure 3).

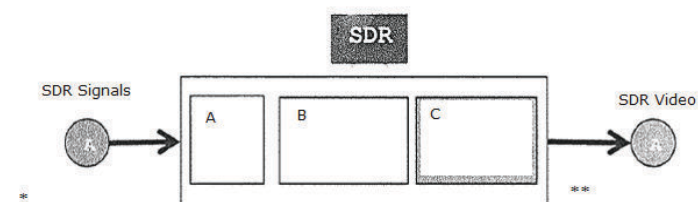


- ① HDR masters are required
- ② A distribution method for HDR masters is required
- ③ A display device for HDR masters is required. The widespread adoption of HDR-compatible TVs is key to the adoption of HDR.

Figure 3: Relationship between masters, distribution methods, and display devices at the time of introduction

Since standard SDR TVs have 100-nit input signals, their display capability should theoretically be sufficient at 100 nits. However, in practice, they are capable of displaying images at 200 nits or higher and can reproduce optimal picture quality for the viewing environment (for example, dark room: Cinema Mode; bright room: Dynamic Mode).

However, since the maximum luminance of the input signals is limited to 100 nits, the high-luminance video playback capability of SDR TVs cannot be utilized for HDR signal playback as long as that input interface is used (see Figures 4 (a) and 4 (b)).



A: SDR EOTF conversion

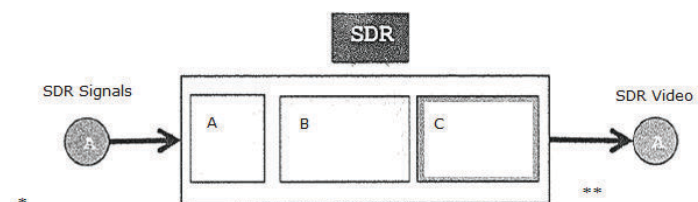
B: Mode-specific luminance conversion (100→ DPL)

C: Display device (maximum luminance: DPL nits)

*: SDR signals have a peak luminance of 100 nits

** : The peak luminance of the displayed video varies depending on the selected mode (can be displayed up to the maximum luminance of the display device)

Figure 4 (a) SDR display processing in an SDR TV



A: SDR EOTF conversion

B: Mode-specific luminance conversion

C: Display device (maximum luminance: 300 nits)

*: SDR signals have a peak luminance of 100 nits

** : For the displayed video, the display can be controlled so that, for example, the peak luminance is 300 nits in Dynamic Mode when viewed in a bright room, and the peak luminance is 100 nits in Cinema Mode when watching a movie in a dark room

Figure 4 (b) Example of SDR display processing on an SDR TV with a peak luminance of 300 nits

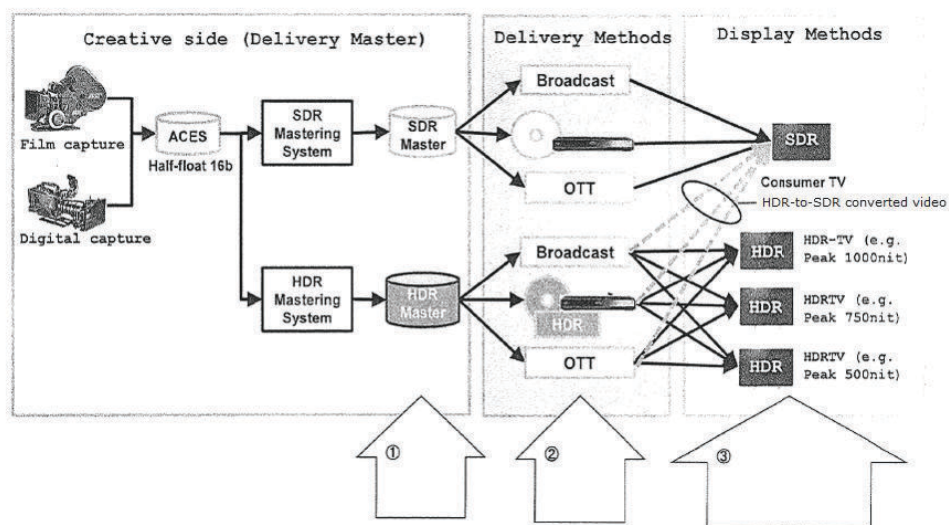
■ Conventional Example

In terms of distribution methods, an SDR TV may sometimes be connected to systems that distribute high-luminance video, such as HDR-compatible broadcasting, set-top box (STB) services, and HDR-compatible Blu-ray players for packaged media.

In these situations, SDR TVs are able to display HDR content properly by implementing an “HDR-to-SDR conversion function” that converts HDR signals into SDR video signals with a peak luminance of 100 nits (see Figure 5).

However, in these situations, users who have purchased HDR-compatible content (such as Blu-ray discs or HDR IPTV content) and HDR-compatible devices (such as Blu-ray players or HDR-compatible IPTV players) can only enjoy SDR video quality on an SDR TV.

Unless users purchase an HDR TV, they will not be able to appreciate the value of HDR, even if they purchase HDR content or transmission media. Therefore, the problem to be solved by this invention is to facilitate the spread of HDR content and HDR-compatible distribution methods at the same rate as the adoption of HDR TVs.



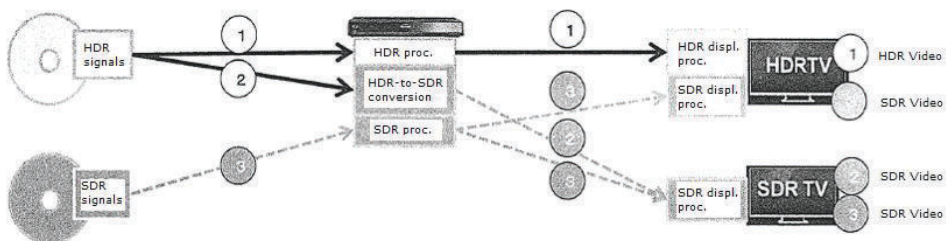
- ① HDR masters are required
- ② A distribution method for HDR masters is required
- ③ A display device for HDR masters is required. The widespread adoption of HDR-compatible TVs is key to the adoption of HDR.

Figure 5: When an HDR-to-SDR conversion feature is added to HDR distribution equipment

When transmitting HDR signals to a TV via a Blu-ray disc, two scenarios can be considered, as shown in Figure 6 below.

In both Case 1 and Case 2, even if users have purchased an HDR-compatible Blu-ray disc and an HDR-compatible Blu-ray player, they will only be able to enjoy SDR video unless they also have an HDR-compatible television. Therefore, an HDR-compatible television is required to view HDR video, and it will take time for HDR-compatible Blu-ray discs to become widely adopted.

Case 1: The HDR disc stores only HDR signals. When the Blu-ray player is connected to an SDR television, the HDR signals are converted to SDR signals through HDR-to-SDR conversion processing and sent to the SDR television.



Case 2: The HDR disc stores both HDR and SDR signals, and the Blu-ray player selects which signals to process based on the connected television.

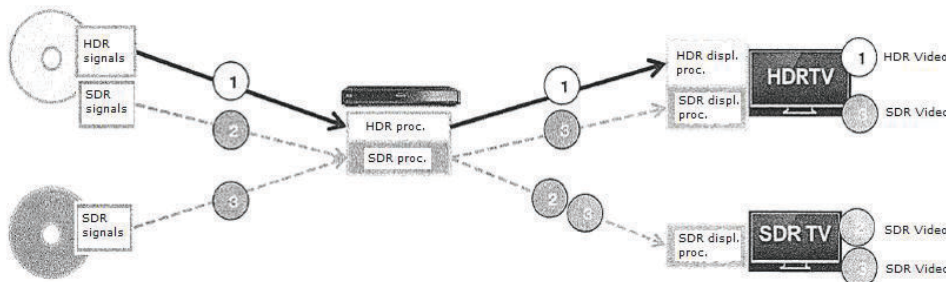
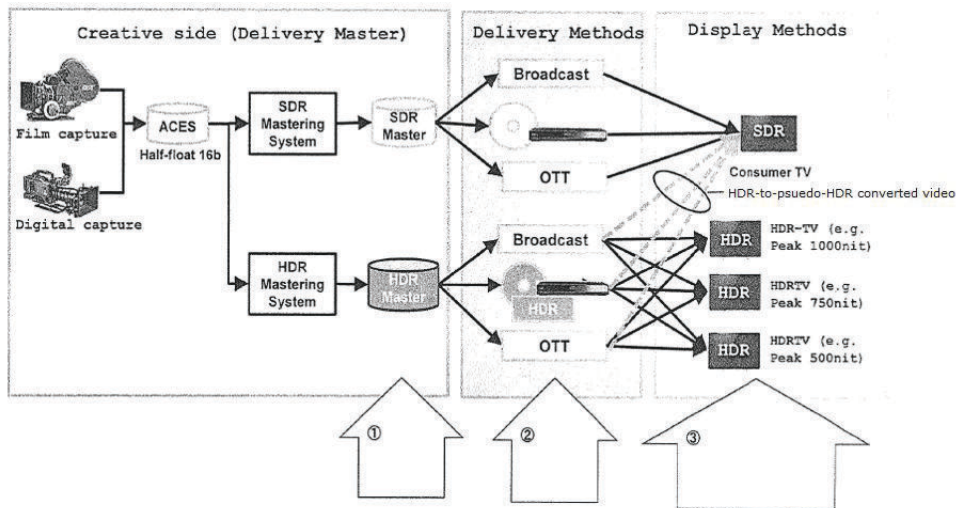


Figure 6: Two methods for implementing HDR-to-SDR conversion in HDR-compatible Blu-ray players

■ Problems to Be Solved by the Present Invention:

To promote the widespread adoption of HDR, it is important to advance the commercialization of HDR content and distribution methods without waiting for HDR TVs to become widespread. To achieve this, if HDR signals could be viewed on existing SDR televisions not as SDR video but as HDR video or pseudo-HDR video, users would be able to watch HDR-like video that is clearly distinct from SDR without having to purchase an HDR television, thereby creating an incentive to purchase HDR content and HDR playback devices (see Figure 7).

To achieve this, when playing HDR content on an SDR TV connected to an HDR streaming service, rather than converting the HDR signals to SDR video signals so that the SDR TV can display the image properly, it would be necessary to implement "HDR-to-pseudo-HDR conversion processing." This processing generates pseudo-HDR signals for a 100-nit peak video signal input to an SDR TV, enabling the SDR TV to utilize its video playback capability of 200 nits or more, and sends these signals to the SDR TV.



- ① HDR masters are required
- ② A distribution method for HDR masters is required
- ③ A display device for HDR masters is required. The widespread adoption of HDR-compatible TVs is key to the adoption of HDR.

Figure 7: When an HDR-to-pseudo-HDR conversion feature is added to the distribution system equipment

Figure 8 (a) shows the display processing inside an HDR TV that converts HDR signals to generate HDR video. Even if the TV is HDR-compatible, it cannot display HDR signals at peak luminance (HPL: for example, 1500 nits) without further processing. Therefore, after performing HDR EOTF conversion, luminance conversion must be performed on the resulting linear signals, and the luminance must be adjusted to the maximum luminance of the display device (DPL: for example, 750 nits). By inputting video signals converted in this way to the display device, the device can display HDR video at its maximum capability.

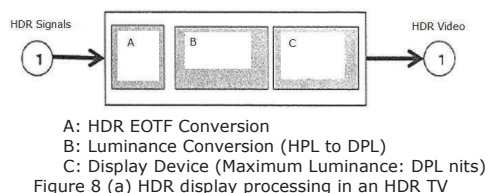


Figure 8 (a) HDR display processing in an HDR TV

When displaying HDR video on an SDR TV, if the peak luminance (DPL) of the SDR TV is 100 nits or higher, for example, 300 nits, "HDR-to-pseudo-HDR conversion" can be performed within the HDR-compatible Blu-ray player to perform "EOTF conversion" to the maximum luminance (DPL) of the SDR TV (for example, 300 nits), and by inputting these signals directly to the SDR TV, the same effect as an HDR TV can be achieved even when using an SDR TV.

However, since SDR TVs lack such a signal input method, this cannot be achieved.

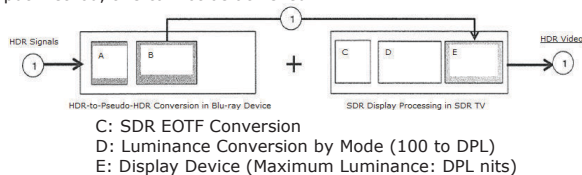


Figure 8 (b) HDR display processing using HDR-compatible equipment and an SDR TV

Figure 8 (c) shows that it is necessary to input signals ② that achieve the effect shown in Figure 8 (b), using a standard SDR TV interface (such as HDMI). To achieve this, it is necessary to perform "HDR EOTF conversion" and "luminance conversion" using the peak luminance of the SDR TV on signals passing through the SDR TV's input interface, in order to cancel out the "SDR EOTF conversion" and "luminance conversion by mode." This results in the same effect as if the signals immediately after "pseudo" luminance conversion had been input to the display device.

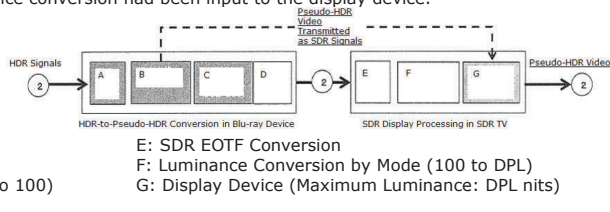


Figure 8 (c) HDR display processing in a configuration in which an HDR-compatible device is connected to an SDR TV via a standard interface

■ Summary of the Invention:

While standard SDR TVs have 100-nit input signals, they are capable of displaying images at 200 nits or higher depending on the viewing environment (for example, Cinema Mode for dark rooms, Dynamic Mode for bright rooms). However, because the upper limit on the luminance of input signals was conventionally capped at 100 nits, this capability could not be utilized directly.

When displaying HDR video on an SDR TV, rather than converting the HDR video to SDR video with a luminance of 100 nits or higher (typically 200 nits or higher), this technique—referred to as “HDR-to-pseudo-HDR conversion processing”—enables the display of HDR video on an SDR TV. Rather than converting the HDR video to SDR video with a luminance of 100 nits or less, the conversion preserves the tonal gradation in the 100-nit-and-above range to some extent, resulting in pseudo-HDR video that closely resembles the original HDR video.

When this “HDR-to-pseudo-HDR” technique is applied to a Blu-ray player, the HDR disc stores only HDR signals. When an SDR television is connected to a Blu-ray player, enabling the SDR television to display video with a pseudo-HDR effect. In this case, even if the SDR TV is not HDR-compatible, viewers can still enjoy pseudo-HDR video by purchasing HDR-compatible Blu-ray discs and an HDR-compatible Blu-ray player.

Therefore, while HDR compatibility is required to view true HDR video, pseudo-HDR video, which allows viewers to fully experience HDR-like effects, can be viewed on existing TVs. As a result, more widespread adoption of HDR-compatible Blu-ray discs can be expected.

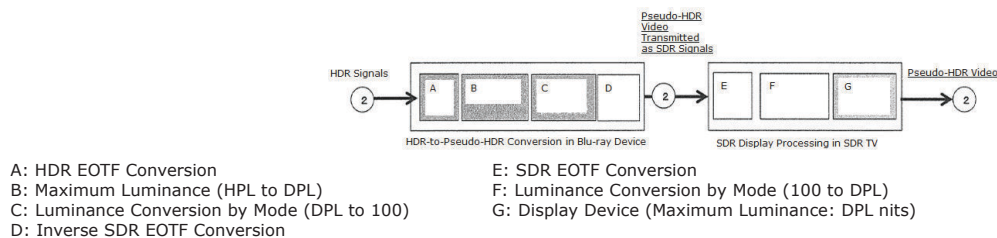
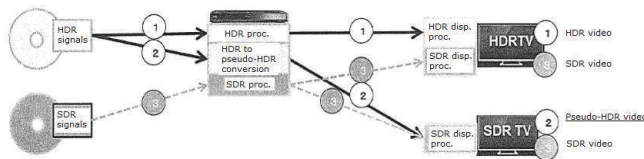


Figure 9: HDR display processing in a configuration where an HDR-compatible device is connected to an SDR TV via a standard interface



While the input signals for a standard SDR TV are 100-nit signals, the system is capable of displaying images at 200 nits or higher depending on the viewing environment (for example, dark room: Cinema Mode; bright room: Dynamic Mode).

■ Effects:

HDR signals transmitted via broadcast, packaged media such as Blu-ray, or Internet streaming services like OTT can be converted into pseudo-HDR signals through HDR-to-pseudo-HDR conversion processing, enabling the display of HDR signals as pseudo-HDR video on existing SDR TVs. For example, if HDR signals are stored on a Blu-ray disc and an SDR television is connected to a Blu-ray player, the HDR-to-pseudo-HDR conversion process inside the Blu-ray player converts the HDR signals into pseudo-HDR signals and sends them to the SDR television, enabling the SDR television to display video with a pseudo-HDR effect.

In this case, even if the television is not HDR-compatible, pseudo-HDR video can still be enjoyed by purchasing HDR-compatible Blu-ray discs and HDR-compatible Blu-ray players. Therefore, while true HDR video requires HDR compatibility, pseudo-HDR video—which allows users to fully experience HDR-like effects—can be viewed on existing TVs. As a result, we can expect HDR-compatible Blu-ray discs to become more widely adopted.

Figure 10

[Supplementary Explanation]

HDR EOTF:

- Figure 11 (a) shows examples of the input and output characteristics (EOTF: Electro-Optical Transfer Function) for HDR and SDR. The EOTF is generally referred to as the gamma curve and converts code values into luminance values.
- The inverse EOTF shown in Figure 11 (b) quantizes luminance values and converts them into code values. For example, when expressing HDR signals in 10 bits, signals up to 10,000 nits are quantized and mapped to integer values ranging from 0 to 1023.
- One example of HDR EOTF and inverse EOTF is SMPTE 2084, which has been standardized by the Society of Motion Picture and Television Engineers (SMPTE).
- EOTF and inverse EOTF for HDR enable signals to be represented with higher luminance values than with SDR. In Figure 11 (a) and Figure 11 (b), the maximum luminance (peak luminance) is 10,000 nits.

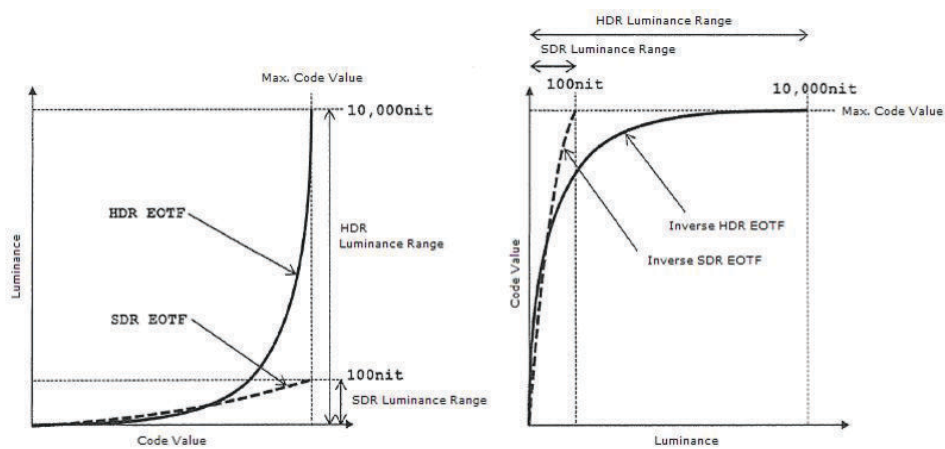


Figure 11 (a) EOTF

Figure 11 (b) Inverse EOTF

Figure 11

Proposed Method: Overall Configuration

· The workflow is explained on the next page

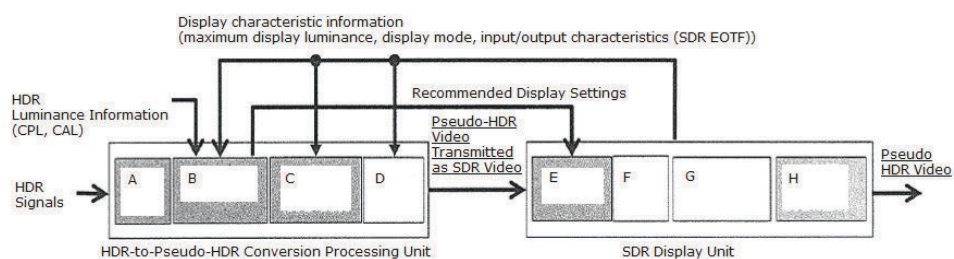


Figure 13 (a) Overall configuration

- A: HDR EOTF Conversion
- B: Luminance Conversion (HPL to DPL)
- C: Luminance Conversion by Mode (DPL to 100)
- D: Inverse SDR EOTF Conversion
- E: Display Settings
- F: SDR EOTF Conversion
- G: Luminance Conversion by Mode (100 to DPL)
- H: Display Device (Maximum Luminance: DFL nits)

HPL: HDR Peak Luminance
DPL: Display Peak Luminance
CPL: Content Peak Luminance
CAL: Content Average Luminance

Proposed Method: Overall Flow

[S101] The HDR-to-pseudo-HDR conversion unit acquires HDR video processed with an inverse HDR EOTF and converts it into linear signals by applying HDR EOTF processing. An example of an HDR EOTF is SMPTE 2084.

[S102] The linear signals are converted using display characteristic information and content luminance information. In this processing, luminance information ranging from 0 to HDR peak luminance (HPL) is converted to a range from 0 to the display peak luminance (DPL). Details are described below.

[S103] Inverse luminance conversion is performed in a mode-specific manner, converting luminance information in the range from 0 to DPL nits to a range from 0 to 100 nits. Details are described below.

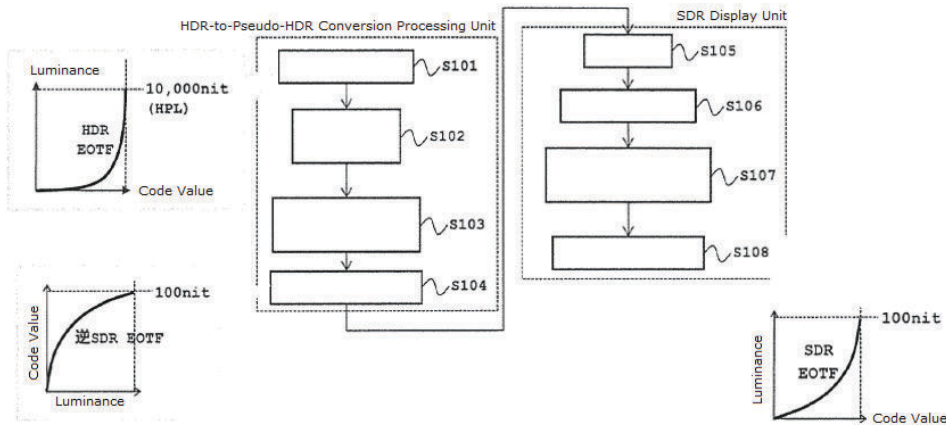
[S104] Inverse SDR EOTF processing is performed to generate pseudo-HDR video.

[S105] In an SDR display unit, display settings for the SDR display are configured using the recommended display setting information from the HDR-to-pseudo-HDR conversion processing unit. The recommended display settings information specifies how to apply the EOTF to the pseudo-HDR video and which settings to use to display high-quality video. These include, for example, the γ value specified in Rec. ITU-R BT.1886, display modes such as Living Mode and Dynamic Mode, and backlight (luminance) values. A message prompting the user to configure settings is also displayed on the SDR display. Details are described below.

[S106] SDR EOTF processing is performed on the pseudo-HDR video.

[S107] Luminance conversion is performed according to the display mode, converting signals in the range from 0 to 100 nits to the range from 0 to DPL nits. Details are described below.

[S108] Pseudo-HDR video is displayed on an SDR display.



S101: HDR EOTF conversion

S102: Luminance conversion (HPL to DPL)

S103: Inverse luminance conversion by mode (DPL to 100)

S104: Inverse SDR EOTF conversion

S105: Set display

S106: SDR EOTF conversion

S107: Luminance conversion by mode (100-to-DPL)

S108: Pseudo-HDR video display

Figure 14 (a) Overall Flow

Proposed Technique: Luminance Conversion (HPL to DPL)

[S102 Luminance Conversion (HPL to DPL) Details]

· Linear signals are converted to HDR signals using luminance information from HDR video content. This conversion is performed so that the linear signals do not exceed the display peak luminance (DPL). The DPL is determined using display characteristic information, such as the maximum luminance of the SDR display and the display mode. The display mode can include, for example, theater mode for viewing in dark environments and dynamic mode for viewing in bright environments. For example, the DPL is set to 750 nits when the maximum luminance of the SDR display is 1,500 nits and the display mode is set to 50% of the maximum luminance. Additionally, conversion processing is performed using the average luminance (CAL) of the HDR video in the luminance information, so that pixels at or below CAL are not converted from linear signals; only pixels at or above peak luminance (CPL) are converted. Furthermore, conversion is performed using the CPL of the HDR video in the luminance information so that the CPL pixels are set to the DPL mentioned above.

[S102 Luminance Conversion (Variation)]

· The linear signals in Figure 15 (b) may be clipped so as not to exceed DPL. This simplifies the processing, reduces the size of the device, consumes less power, and speeds up the processing.

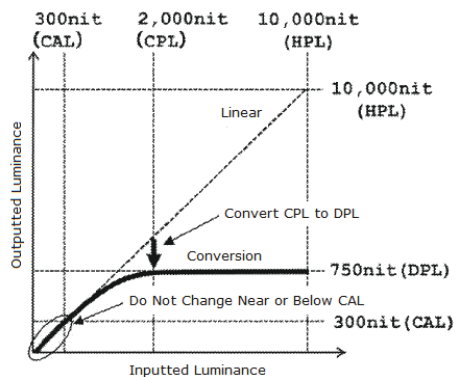


Figure 15 (a): Luminance Conversion (HPL to DPL)

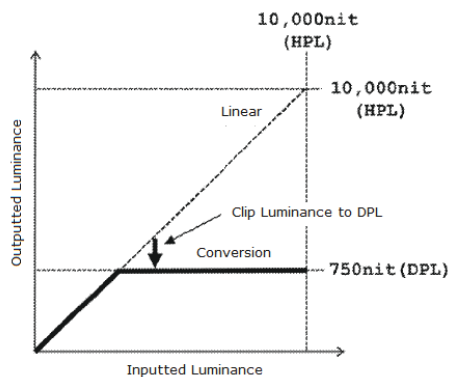


Figure 15 (b): Modified Luminance Conversion (HPL to DPL)

HPL: HDR peak luminance
DPL: Display peak luminance
CPL: Content peak luminance
CAL: Content average luminance

Figure 15

Proposed Technique: Luminance Conversion (HPL to DPL)

[S102 Luminance Conversion (HPL to DPL) Details]

· Linear signals are converted to HDR signals using luminance information from HDR video content. This conversion is performed so that the linear signals do not exceed the display peak luminance (DPL). The DPL is determined using display characteristic information, such as the maximum luminance of the SDR display and the display mode. The display mode can be, for example, mode information such as "theater mode" for viewing in dark environments and "dynamic mode" for viewing in bright environments. For example, the DPL is set to 750 nits when the maximum luminance of the SDR display is 1,500 nits and the display mode is set to 50% of the maximum luminance. Additionally, conversion processing is performed using the average luminance (CAL) of the HDR video in the luminance information, so that pixels at or below CAL are not converted from linear signals; only pixels at or above peak luminance (CPL) are converted. Furthermore, conversion is performed using the CPL of the HDR video in the luminance information so that the CPL pixels are set to the DPL mentioned above.

[S102 Luminance Conversion (Variation)]

· The linear signals in Figure 15 (b) may be clipped so as not to exceed DPL. This simplifies the processing, reduces the size of the device, consumes less power, and speeds up the processing.

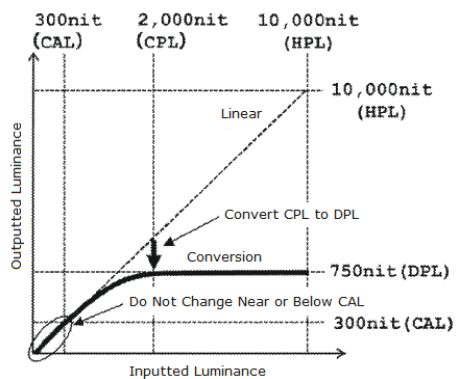


Figure 15 (a): Luminance Conversion (HPL to DPL)

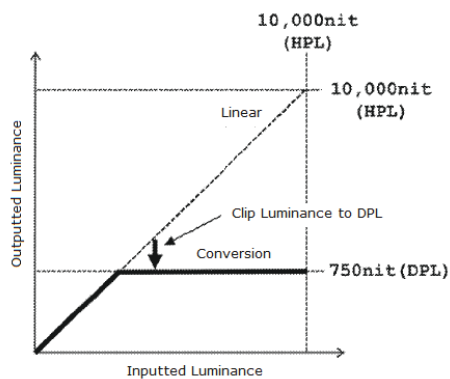


Figure 15 (b): Modified Luminance Conversion (HPL to DPL)

HPL: HDR peak luminance
DPL: Display peak luminance
CPL: Content peak luminance
CAL: Content average luminance

Figure 15

Proposed Technique: Inverse Luminance Conversion Per Mode (DPL to 100), Luminance Conversion Per Mode (100 to DPL)

[S103 Inverse Luminance Conversion Per Mode (DPL to 100) Details]

· Inverse luminance conversion per mode is performed on the 0 to DPL nit signals converted in the luminance conversion in S102. This processing can be used to obtain 0 to DPL nit signals after S102 processing using the mode-specific luminance conversion processing S107 in the SDR display. In this processing, the 0 to DPL nit signals fall within the SDR range of 0 to 100 nit.

· In this process, the conversion format switches based on the display mode. For example, in normal mode, the conversion standard is from 0 to DPL to 0 to 100 nit. In dynamic mode, where high-luminance pixels become brighter and low-luminance pixels become darker, inverse function processing is performed.

[S107 Luminance Conversion Per Mode (100 to DPL) Details]

· Here, 0 to 100 nit signals in the SDR range are converted to 0 to DPL nit based on the display mode. This processing is the inverse function of the per-mode inverse luminance conversion described in S103.

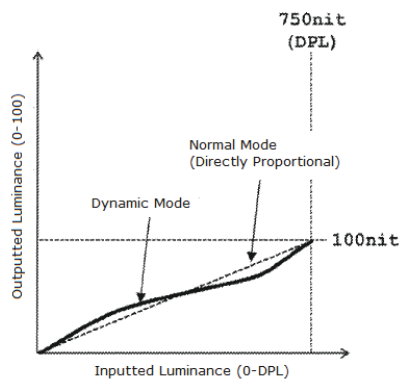


Figure 16 (a): Inverse Luminance Conversion (DPL to 100) per Mode S103

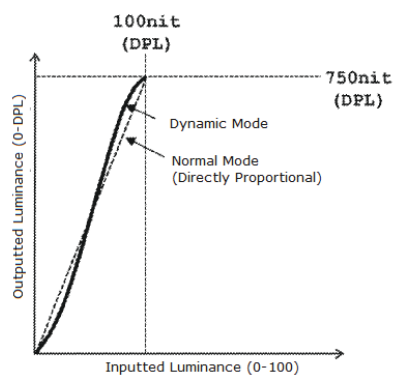


Figure 16 (B): Luminance Conversion (100 to DPL) per Mode S107

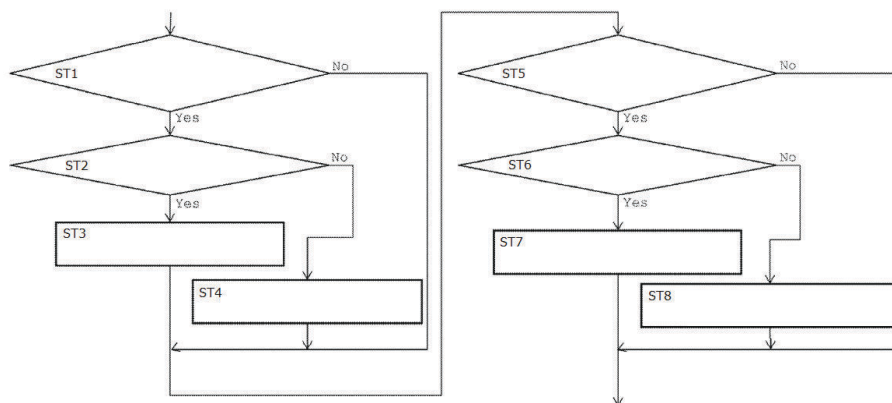
Figure 16

Proposed Technique: Display Settings

[S105 Display Settings Details]

· Using the recommended display settings information, the system determines whether the EOTF for the SDR display is aligned with pseudo HDR video. If they differ, the system determines whether the EOTF for the SDR display can be switched by the system. If switchable, the EOTF for the SDR display is switched using the recommended display settings. If the system cannot make the switch, a message is displayed on the screen prompting the user to manually make the switch. For example, a message may appear on the screen stating, "Please set the display gamma to 2.4."

· The pseudo-HDR video display unit displays pseudo-HDR video, but before doing so, it determines whether the display parameters for the SDR display conform to the recommended display settings specified in the recommended display settings information. If they differ, it determines whether the display parameters for the SDR display can be changed. If they can be changed, it adjusts the display parameters for the SDR display based on the recommended display settings. If the system cannot make the adjustment, a message appears on the screen prompting the user to manually adjust the display parameters. For example, a message may appear on the screen stating, "Please set the display mode to dynamic mode and set the backlight to maximum."



ST1: Does recommended display setting differ from EOTF for SDR display?
 ST2: Can EOTF for SDR display be switched?
 ST3: Switch EOTF for SDR display using recommended display setting
 ST4: Display message on screen prompting the user to change the EOTF manually

ST5: Does recommended display setting differ from display parameter?
 ST6: Can the display parameter be switched?
 ST7: Switch the display parameter for SDR display using recommended display setting
 ST8: Display message on screen prompting the user to change the display parameter manually

Figure 17 (a): Display Setting Flow

Proposed Technique: Notes

- The HDR video may be, for example, a video on a Blu-ray disc or a DVD, available on an online video streaming site, broadcast over the air, or stored on a hard disk drive (HDD).
- The HDR-to-pseudo-HDR conversion processor may be located in a disc player, disc recorder, set-top box, TV, personal computer, or smartphone. It may also be located in a server device on the Internet.
- The SDR display unit is, for example, a TV, personal computer, or smartphone.
- The display characteristic information to be acquired by the HDR-to-pseudo-HDR conversion processor may be obtained from an SDR display unit via an HDMI cable or LAN cable, or from SDR display model information available on the Internet. The user may manually configure the display characteristic information in the pseudo-HDR video generation unit. The HDR-to-pseudo-HDR conversion processor may acquire the display characteristic information immediately before generating pseudo-HDR video, or during the device's initial setup or connection. For example, the data may be extracted when the device is first connected via an HDMI cable.
- The HDR video content peak luminance (CPL) and content average luminance (CAL) may be specified for each bit of content or for each scene. The CPL and CAL may be found on the same medium (Blu-ray disc, DVD, etc.) as the HDR video or may be acquired from a separate location, such as over the Internet.
- In the HDR-to-pseudo-HDR conversion processor (HPL to DPL), CPL, CAL, and the display peak luminance (DPL) do not have to be used, or fixed values may be used. The fixed values may be adjustable from an external source. CPL, CAL, and DPL may be switched among several options. For example, there may be three options for DPL—namely, 200 nits, 400 nits, and 800 nits—and the value closest to the display's characteristic information may be used.
- The EOTF for HDR does not have to be SMPTE 2084; another EOTF based on HDR technology may be used. The maximum luminance of the HDR video (HPL) does not have to be 10,000 nits; it may be, for example, 4,000 nits or 1,000 nits.
- The bit width of the code values may be, for example, 16, 14, 12, 10, or 8 bits.
- Although the inverse EOTF conversion of SDR is determined based on the display characteristic information, a fixed conversion function (configurable externally) may be used. Inverse EOTF conversion of SDR may use, for example, a function specified in Rec. ITU-R BT.1886. The types of inverse EOTF conversion for SDR may be limited, and the type closest to the input-output characteristics of the SDR display unit may be selected and used.
- A fixed mode may be used for the display mode, and a display mode may not be included in the display characteristic information.
- The HDR-to-pseudo-HDR conversion processor does not have to transmit the setting information. The SDR display unit may use fixed display settings and may allow changes to those settings. In this case, a display setting unit is unnecessary. The setting information may consist of flag information indicating whether a video is a pseudo-HDR video; when a video is a pseudo-HDR video, the settings may be changed to the brightest display.

Figure 18

Proposed Technique: Notes (Continued)

· The luminance conversion (HPL to DPL) can be performed by the HDR-to-pseudo-HDR conversion processor using the following equation.

$$V = \begin{cases} L & \text{for } 0 \leq L < S1 \\ a \cdot \ln(L) + b & \text{for } S1 \leq L < S2 \\ M & \text{for } S2 \leq L \end{cases}$$

Here, L denotes a luminance value normalized to 0 to 1, and S1, S2, a, b, and M are values set based on CAL, CPL, and DPL. $\ln$ is the natural logarithm. V is a converted luminance value normalized to 0 to 1. As in the example shown in Figure 15 (a), when the average luminance is 300 nits, the maximum luminance is 2,000 nits, and the specified luminance is 750 nits, conversion is not performed until the average luminance plus 50 nits is reached, and conversion is performed at 350 nits or higher. The following values can be used.

S1 = 350/10,000
S2 = 2,000/10,000
M = 750/10,000
a = 0.023
b = S1 - a * $\ln(S1)$ = 0.112105

· Note that the numerical values, shapes, materials, components, arrangement of components, and connections between components are merely examples and are not intended to limit the present invention in any way.

Figure 19

Proposed Technique: Effects (Effects Other Than Those on Slide 9)

- By converting HDR video using information such as the content peak luminance and content average luminance of the HDR video, the conversion equation can be adjusted based on the content, and conversion can be performed to preserve the HDR gradation as much as possible. This helps prevent adverse effects such as areas that are too dark or too bright. Specifically, by mapping the content peak luminance of the HDR video onto the display peak luminance, gradation is preserved as much as possible. In addition, overall brightness is kept constant by not altering pixel values that are equal to or less than values in the vicinity of the average luminance.

- Furthermore, by using the peak luminance value and the display mode of the SDR display to convert HDR video, the conversion equation can be adjusted based on the display environment of the SDR display, allowing video with an HDR-like feel to be displayed in accordance with the SDR display's performance, with gradation and brightness similar to those of the original HDR video. Specifically, by determining the display peak luminance based on the maximum luminance and display mode of the SDR display, and by converting the HDR video so as not to exceed the peak luminance value, the HDR video is displayed with minimal loss of gradation from the original HDR video, up to the brightness level that the SDR display is capable of displaying. For brightness levels that cannot be displayed, the luminance value is reduced to a displayable brightness level. This makes it possible to reduce non-displayable brightness information and to display video in a form close to the original HDR video without reducing the gradation of displayable brightness. For example, for a display with a peak luminance of 1,000 nits, the overall brightness is maintained by converting the video to pseudo-HDR video with a peak luminance reduced to 1,000 nits, and the luminance value varies depending on the display mode. If the pseudo-HDR video contains luminance values greater than the display's peak luminance, these values may be replaced with the display's peak luminance. In this case, the display appears darker overall than the original HDR video. Conversely, if conversion is performed with a maximum luminance lower than the display's peak luminance, this luminance is replaced with the display's peak luminance, and the display appears brighter overall than the original HDR video. However, this does not fully utilize the display's gradation capabilities because the luminance is lower than the display's peak luminance.

- On the display side, pseudo-HDR video can be displayed more effectively by adjusting the display settings using configuration information. For example, when the brightness is set to a low level, high-luminance display is not possible, and the HDR effect is diminished. In this case, by changing the display settings or by displaying a message prompting the user to adjust them, the display can achieve its maximum performance, allowing for the display of high-gradation video.

Figure 20

Video and Graphics Compositing

In content such as Blu-ray content, video signals and graphics signals such as subtitles and menus are multiplexed as independent data streams. During playback, each stream is decoded and the decoded results are composited for display. Specifically, the subtitle and menu layers are superimposed on top of the video layer.

Here, even if the video signals are HDR, the graphics signals such as subtitles and menus may be SDR. Therefore, the following two approaches can be used for the HPL→DPL conversion of the video signals.

(a) HPL→DPL conversion after graphics compositing

1. Convert the graphics EOTF from SDR EOTF to HDR EOTF
2. Composite the graphics (after EOTF conversion) with the video
3. Perform HPL→DPL conversion on the composited result

(b) HPL→DPL conversion before compositing the graphics

1. Convert the graphics EOTF from SDR to HDR
2. Apply HPL→DPL conversion to the video
3. Composite the graphics after EOTF conversion with the video after DPL conversion

Note that the order of steps 1 and 2 may be reversed.

In both methods (a) and (b), the peak luminance of the graphics is 100 nits. However, if the DPL is at a high luminance level, such as 1,000 nits for example, keeping the graphics luminance at 100 nits may result in the graphics appearing darker relative to the video after HPL→DPL conversion. In particular, this could lead to undesirable effects such as subtitles superimposed on the video appearing too dark. Therefore, the brightness of the graphics may also be converted according to the DPL value. For example, the brightness of subtitles may be specified in advance, such as setting it to a certain multiple of the DPL value, and converted based on that setting. Graphics other than subtitles, such as menus, can be processed in the same manner.

Figure 21

Playback operations for HDR discs that store only HDR signals were described above.

Next, multiplex data stored on a dual disc that stores both HDR signals and SDR signals will be described with reference to Case 2 in Figure 6. On a dual disc, as shown in Figure 21 (b), HDR signals and SDR signals are stored as separate multiplex streams. For example, on an optical disc such as a Blu-ray disc, data for various media—including video, audio, subtitles, and graphics—is organized as a multiplex stream using an MPEG-2 TS-based multiplexing scheme known as M2TS. Several multiplex streams are referenced from metadata for playback control, such as a playlist. During playback, a player selects the multiplex stream to be played—which is stored within a multiplex stream—by analyzing metadata. This example illustrates a scenario in which a playlist for HDR and a playlist for SDR are stored separately, and each playlist references either HDR signals or SDR signals. Information indicating that both HDR signals and SDR signals are stored on the disc may be specified separately.

Although it would be possible to multiplex both HDR and SDR signals within the same multiplex stream, such multiplexing would have to comply with a buffer model, such as T-STD (System Target Decoder), as specified in MPEG-2 TS. In particular, it would be difficult to multiplex two high-bit-rate video streams within the limits of a predetermined data read rate. Therefore, separate multiplex streams are preferred. Data for audio, subtitles, graphics, etc., must be stored in each multiplex stream, and the data volume increases compared to single-stream multiplexing. However, the data volume for video can be reduced by using a video coding scheme with a high compression ratio. For example, switching from MPEG-4 AVC used in conventional Blu-ray devices to HEVC (High Efficiency Video Coding) is expected to improve the compression ratio by a factor of 1.6 to 2. Combinations that fit within the capacity of the optical disc may be used to store data on a dual disc, such as a combination of two 2K streams or a combination of a 4K stream and a 2K stream—including a combination of a 2K HDR stream and a 2K SDR stream, and a combination of a 4K SDR stream and a 2K HDR stream—with the storage of two 4K streams being prohibited.

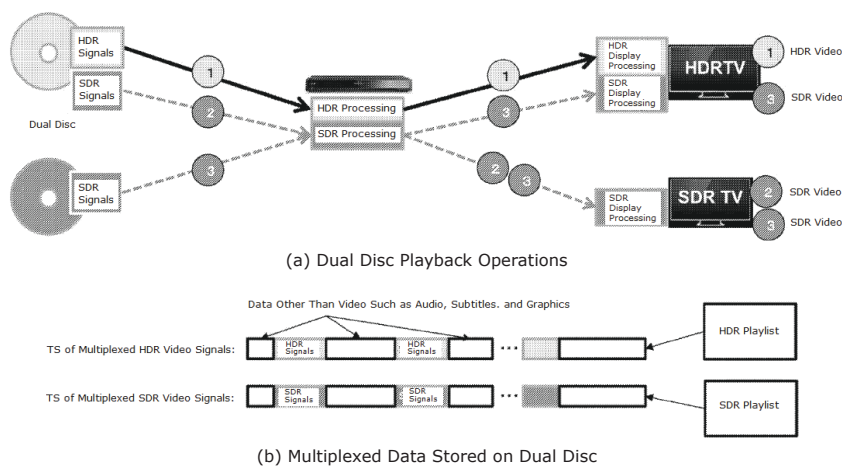


Figure 22

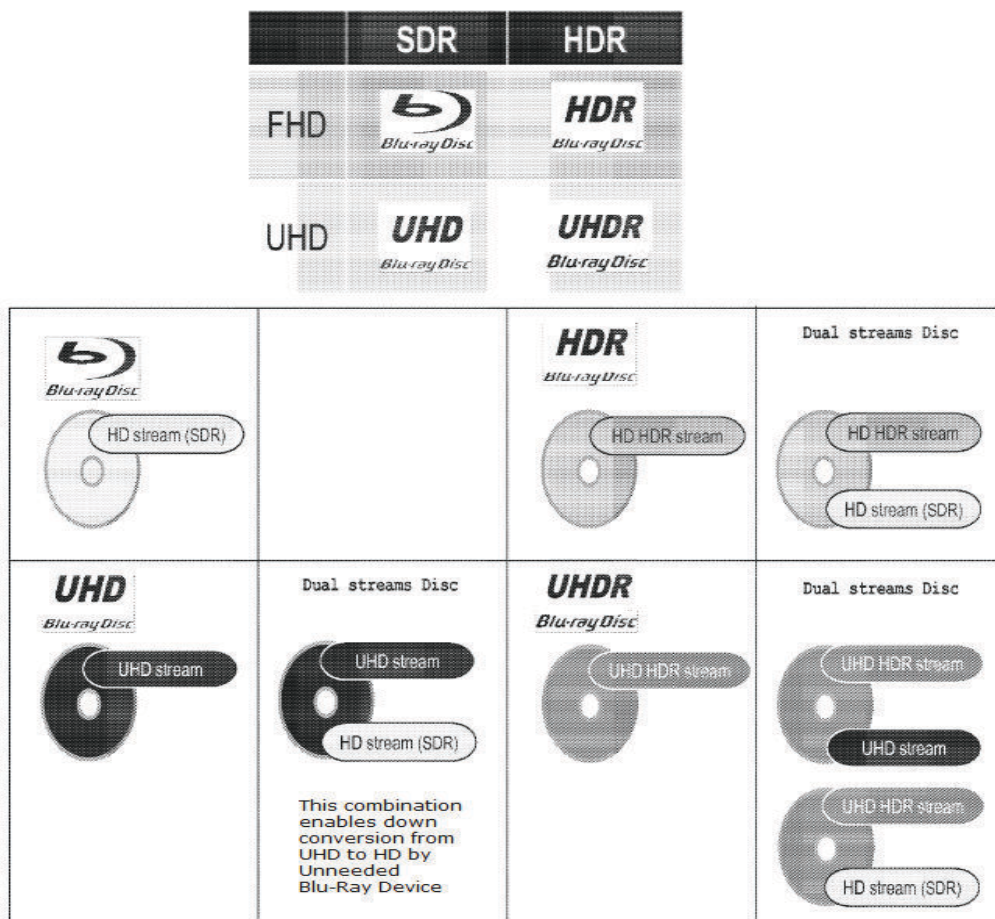


Figure 24: Example of a Dual-Stream Disc Combination

Figure 33: Examples of video and graphics stream combinations for individual Blu-ray discs and dual stream discs (Part 1)
 In these examples, all graphics are shared, on the assumption that both HD-to-UHD and HDR-to-SDR conversions are performed by Blu-ray devices to minimize production effort.

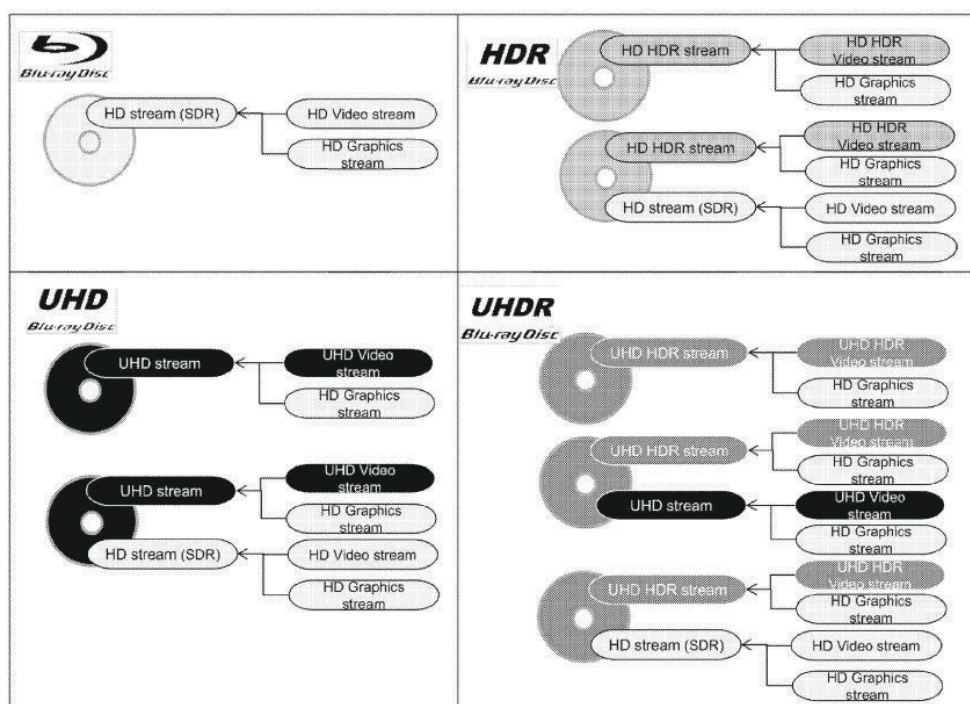


Figure 34: Examples of video stream and graphics stream combinations for individual Blu-ray discs and dual-stream discs (Part 1)
 In these examples, all graphics are shared, on the assumption that both HD-to-UHD and HDR-to-SDR conversions are performed by Blu-ray devices to minimize production effort.

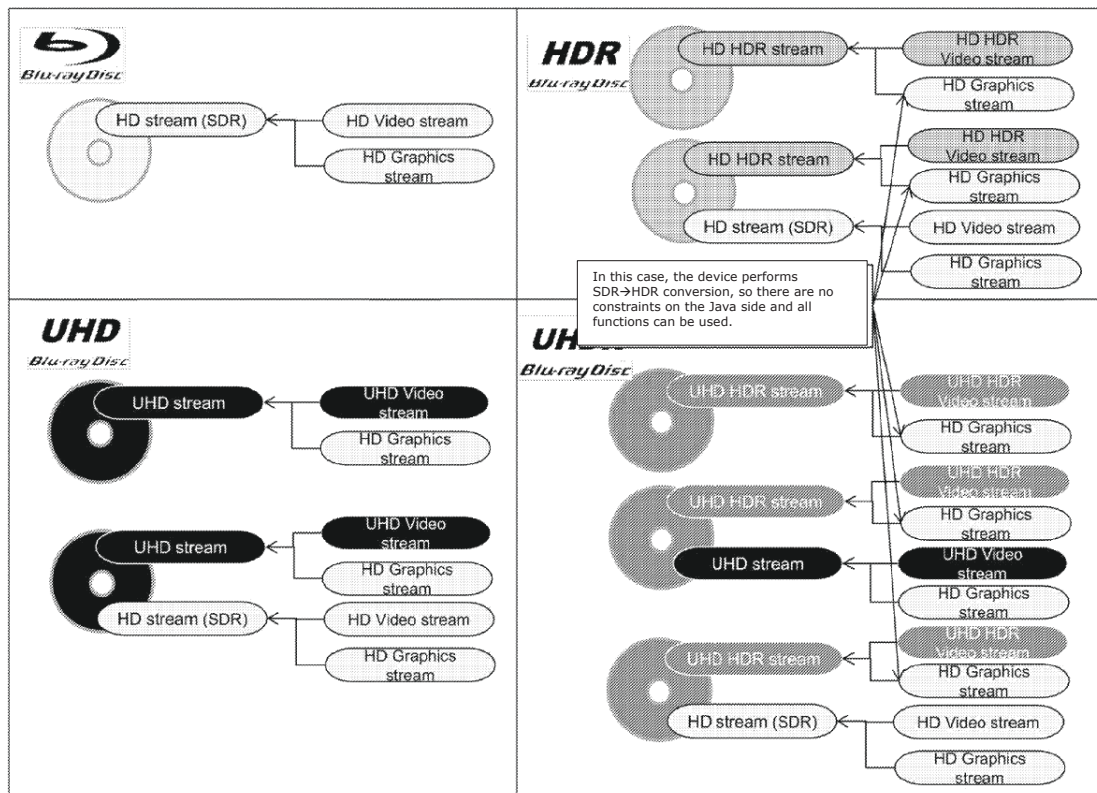


Figure 35 shows the details of the graphics stream in the combination of video and graphics streams for each Blu-ray disc and dual streams disc, as shown in Figure 33.

Since SDR graphics (PG, IG, Java Graphics, and Java Drawing) are used in HDR video streams, there are no constraints, including those on Java drawing commands.

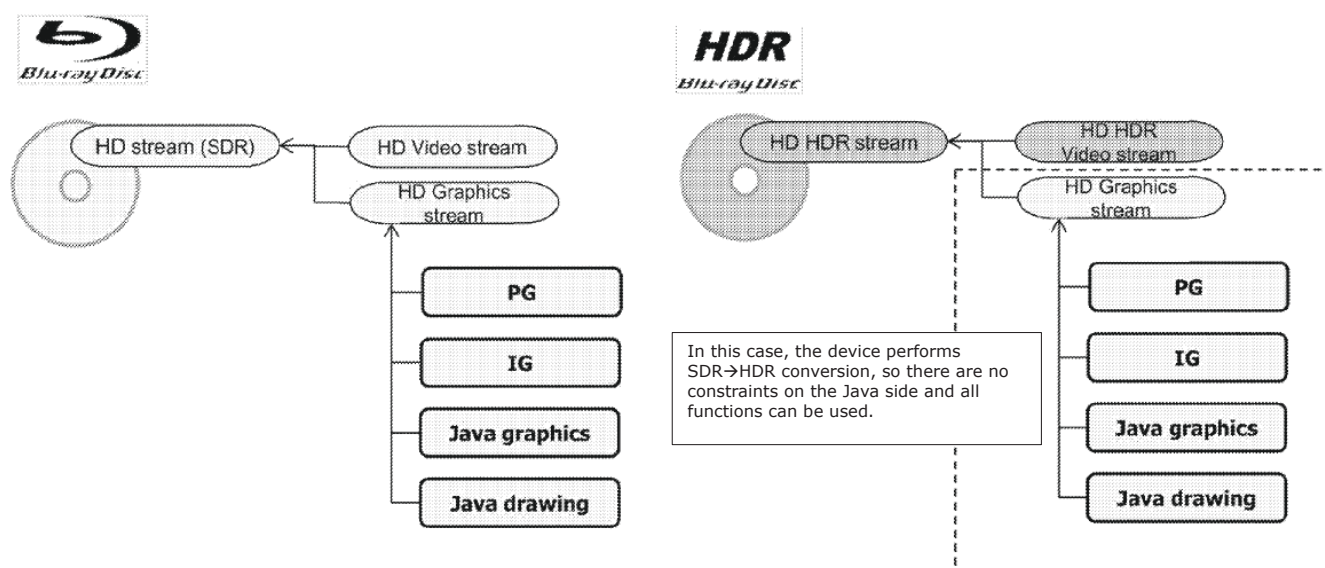


Figure 36: Examples of video stream and graphics stream combinations for Blu-ray discs and Dual Streams discs (Part 2)
 To reduce production effort, HD and UHD graphics are shared using HD graphics. However, in these examples, the graphics conversion from SDR to HDR is performed during production.

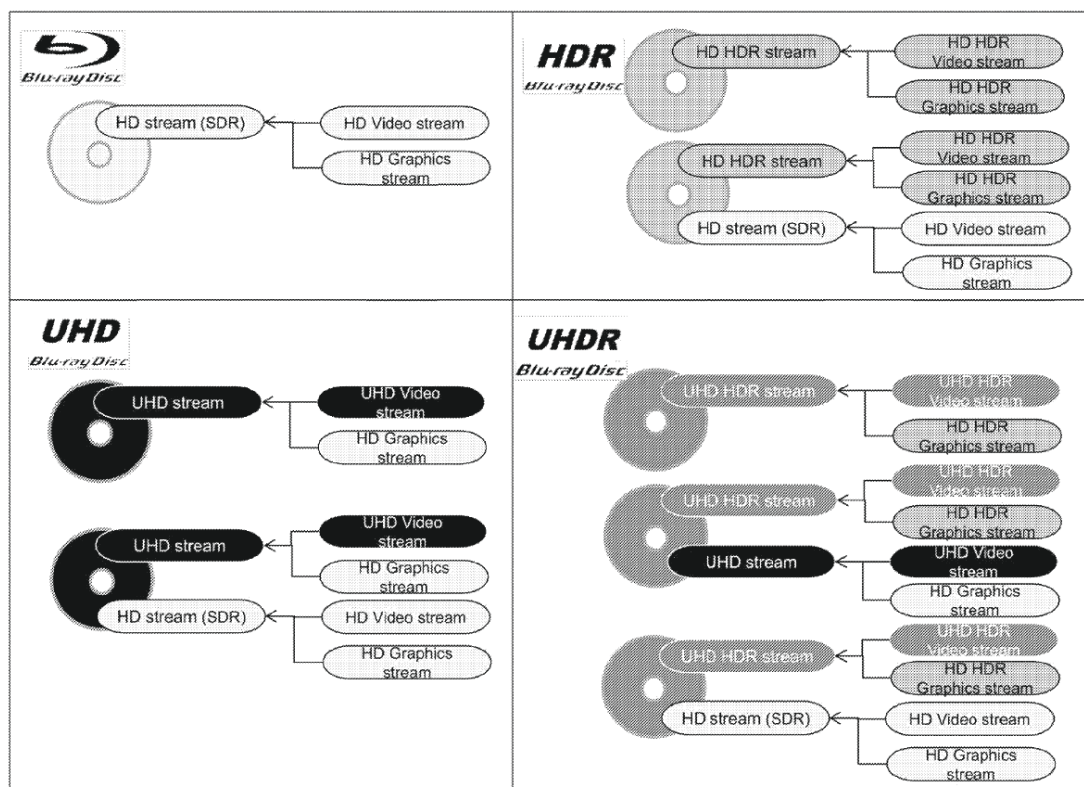


Figure 37 shows the details of the graphics stream in the combination of video and graphics streams for each Blu-ray disc and dual streams disc, as shown in Figure 36.

Although the basic graphics specifications are the same for SDR and HDR, the portions rendered using Java drawing commands cannot be used as-is due to constraints such as the Java color space (BT 2020 for UHD) and EOTF (EOTF for HDR). For this reason, Java rendering commands must be disabled on UHD, HDR, and UHD+HDR Blu-ray discs.

Therefore, to use Java drawing commands, color and brightness values can be specified based on the results of EOTF (SDR→ HDR) conversion, color space (BT709→ BT 2020) conversion, etc.

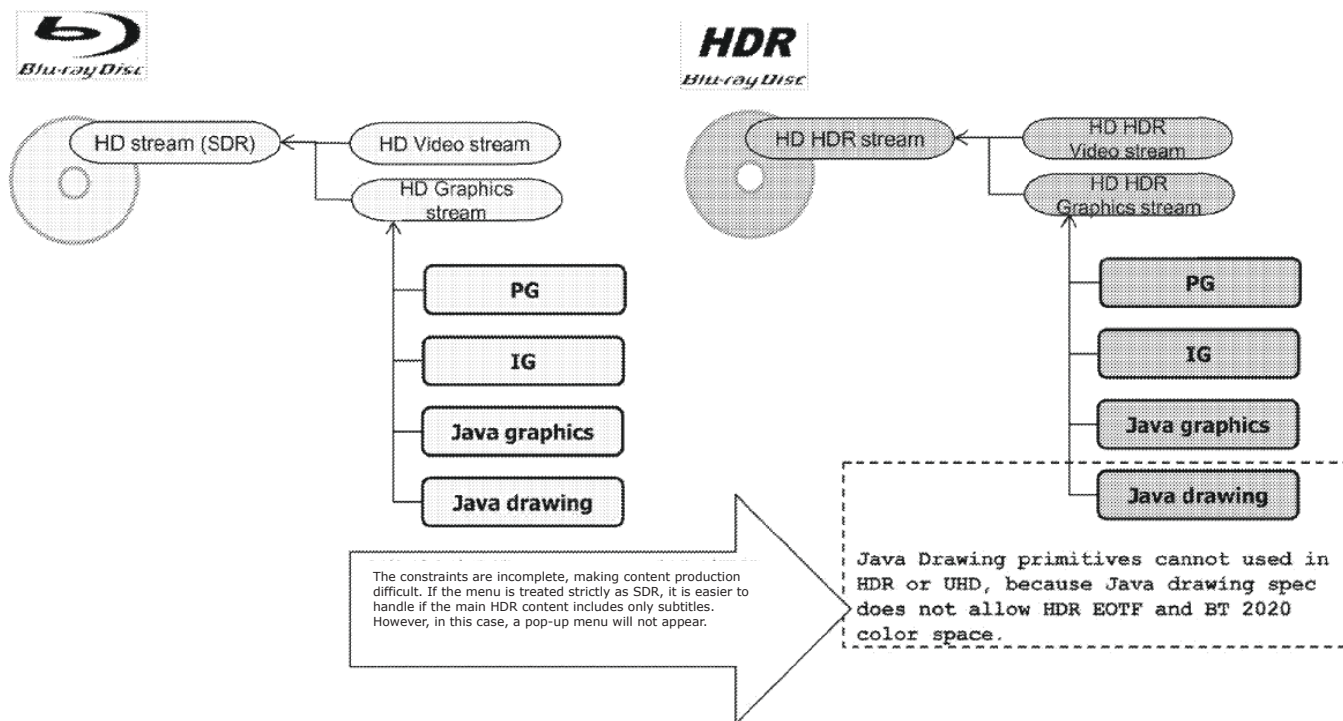


Figure 38 shows the details of the graphics stream in the combination of video and graphics streams for each Blu-ray disc and dual streams disc, as shown in Figure 36.

Prohibiting everything except subtitles makes authoring easier and is more intuitive for users.

However, in this case, the menu is displayed using Java as a standard display, overlaid on the video during the movie. Pop-up menus cannot be displayed.

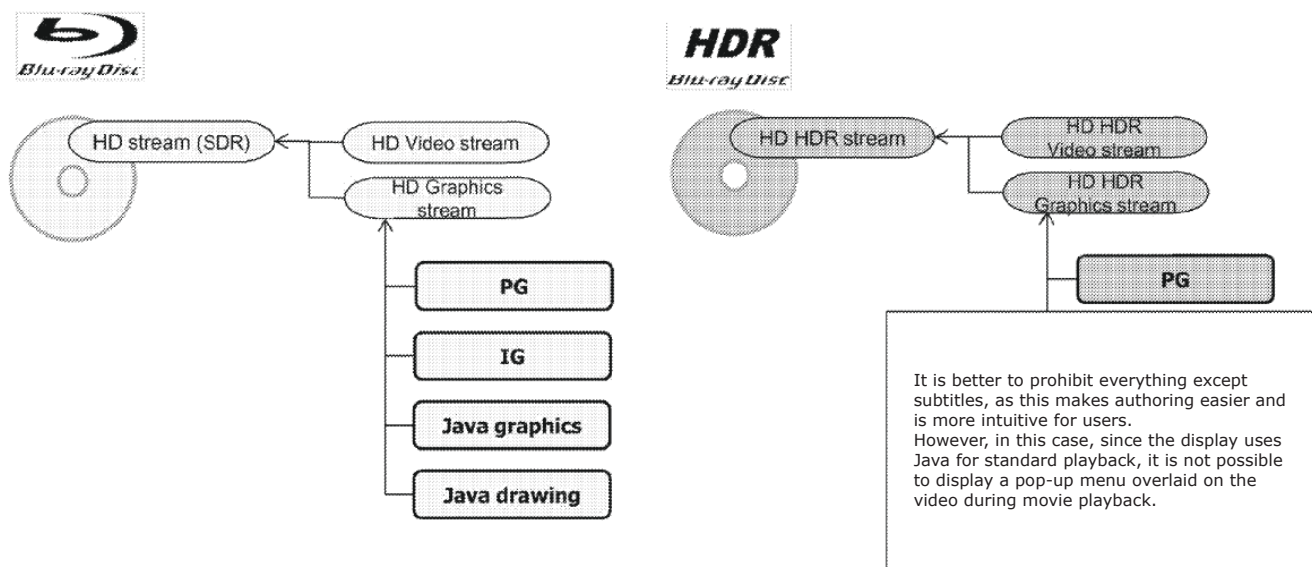


Figure 39: Examples of video stream and graphic stream combinations for Blu-ray discs and dual-stream discs (Part 2)
 In the case of an HD HDR graphics streams, restrictions on the Java side mean that only subtitles can be stored.

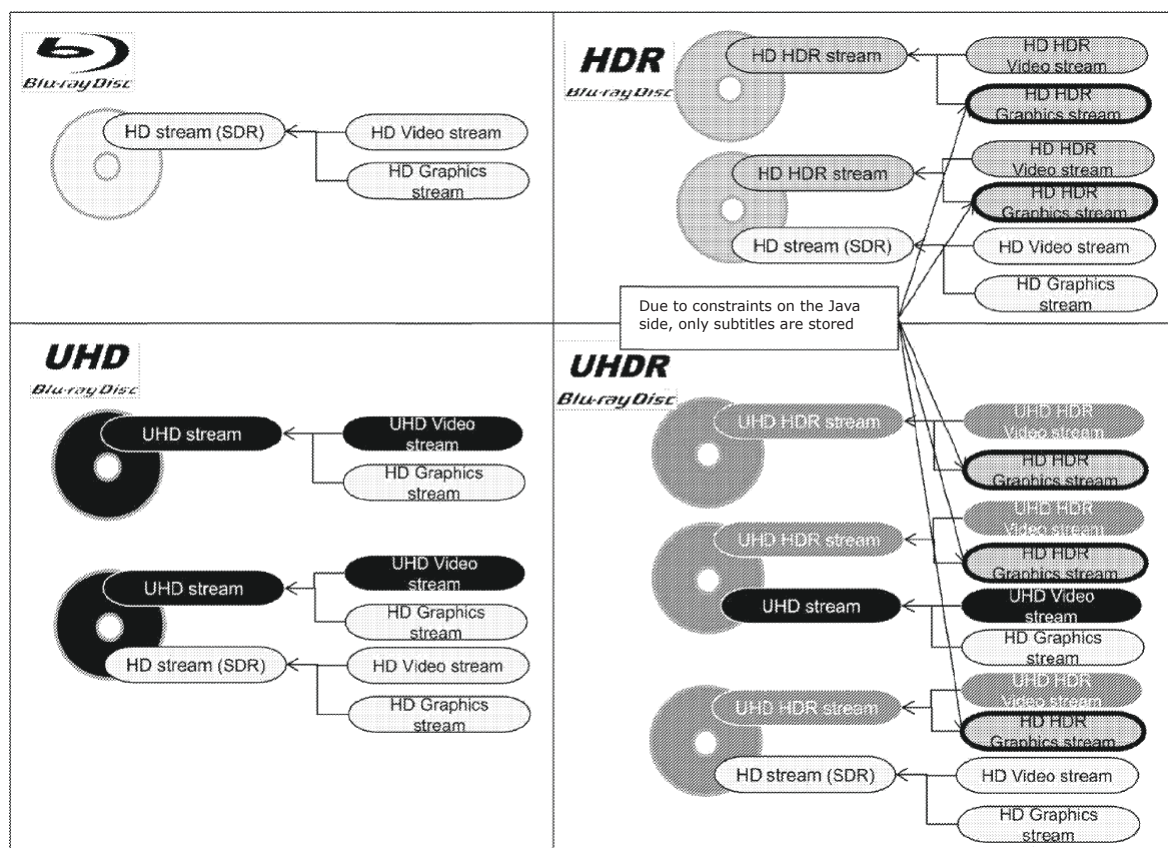
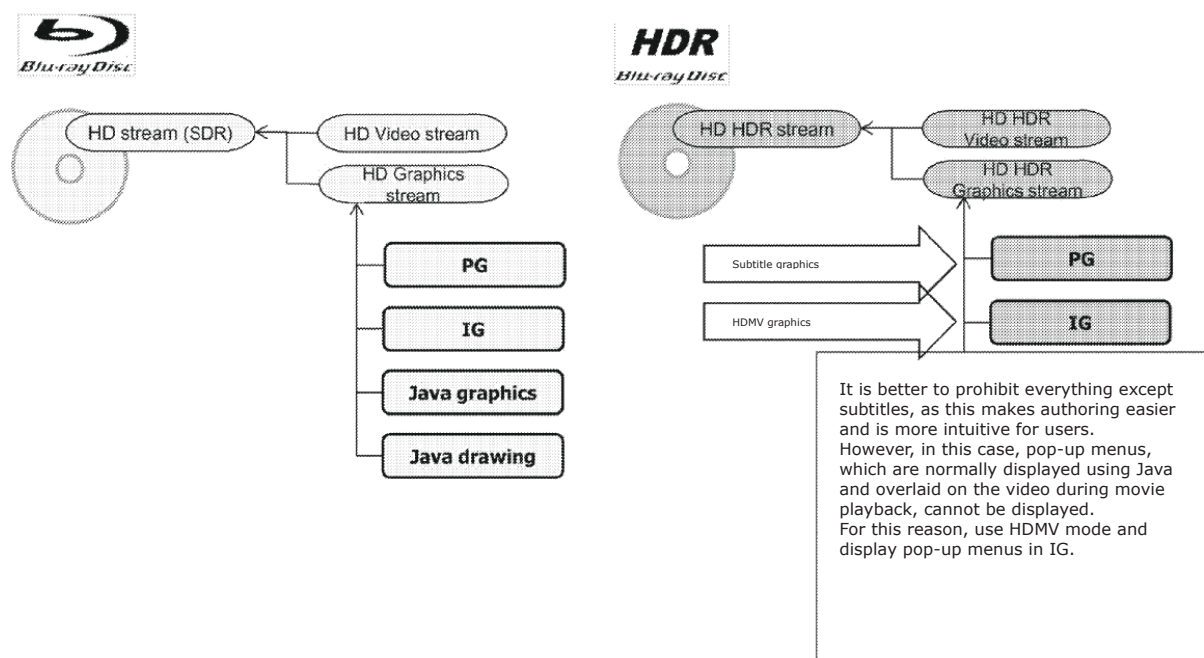


Figure 40 shows the details of the graphics stream in the combination of video and graphics streams for each Blu-ray disc and dual streams disc, as shown in Figure 27.

Prohibiting anything other than subtitles makes authoring easier and is more intuitive for users.

However, in this case, the subtitles are displayed using Java as a standard overlay on the video during movie playback. Pop-up menus cannot be displayed.

Therefore, instead of using Java, when playing HDR video in DVD-compatible mode, use HDMV mode and display pop-up menus in IG using the HDMV-specific interface.



While the video handles HDR signals, there are two types of players for handling the graphics for menus and subtitles superimposed on the video, namely, those with a built-in function to convert SDR signal graphics into HDR signal graphics, and those without this function.

In this case, players without the conversion and output function process the graphics as SDR signals, which can result in lower playback image quality or cause the brightness of menus and subtitles to be too low, making them difficult for users to see. To resolve this issue, content producers can prepare both HDR and SDR graphics content and provide them on a single Blu-ray Disc.

The player plays a menu written in a playback control programming language called BD-J or HDMV, presenting the user with a selection menu for the main feature. When the user selects to play the main program video in HDR, the player's register values are checked via the BD-J or HDMV program recorded on the disc. For example, the value in the 25th player register (a 32-bit register known as PSR25) can be checked to determine whether the player has the capability to convert SDR graphics to HDR graphics for output.

For players with the conversion output function, the playback control program plays Playlist #A, which has been prepared to convert SDR graphics into HDR graphics and output them. For players without the conversion output function, the BD-J or HDMV playback control program is written to play Playlist #B, which contains pseudo-HDR graphics that do not require conversion.

Blu-ray discs support three types of graphics, namely, subtitles (Presentation Graphics), graphics such as BD-J menus (BD-J Graphics), and graphics such as HDMV menus (Interactive Graphics). As described above, when selecting and playing a playlist based on whether the player supports conversion output, for playlists intended for players without conversion output capabilities, subtitles (Presentation Graphics) and HDMV-based menus (Interactive Graphics) can be designed to use a color look-up table (CLUT) defining numbers and corresponding colors. In this way, SDR signal graphics can use the CLUT prepared for SDR signals, while HDR signal graphics can use a separate CLUT prepared for HDR signals. This is a cost-effective means for avoiding the problem of menu and subtitle graphics being difficult to see, not only on players capable of converting SDR signal graphics to HDR signal graphics, but also on players that cannot perform such conversion.

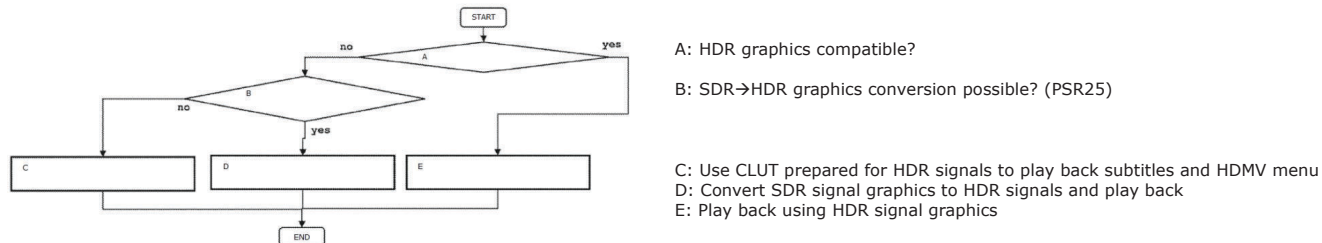


Figure 25

Key Points of the Invention

- In Blu-ray authoring and playback device design, in addition to standard Blu-ray (HD video), there are four types of video which require complex authoring work and internal processing by playback devices, namely, UHD video, HD video, HDR video, and UHD HDR video.
- In the case of Blu-ray discs containing HDR video, processing subtitles, menu graphics, Java graphics, and Java rendering as HDR content imposes constraints, such as the inability to display Java content due to the lack of a defined HDR color space for Java.
- In the present invention, cases are divided into those in which the player can perform SDR→HDR conversion for graphics-related tasks and those in which the player cannot. If conversion is possible, all graphics-related processing is performed on the SDR side. The results are then converted from SDR to HDR, and HDR video is composited, thus enabling all processing. If conversion is not possible, Java cannot process HDR content, so functions such as pop-up menus cannot be handled. Therefore, by calling the HDMV mode from Java and processing HDR graphics (subtitles, pop-up menus, etc.) in HDMV mode, a user experience similar to SDR can be provided using a simple authoring processes, even for HDR video.

Figure 24



TRANSLATOR CERTIFICATION

Date: July 1, 2026

To whom it may concern:

I, Frank McGee, a translator fluent in the Japanese and English languages, on behalf of Morningside Translations, do solemnly and sincerely declare that the following is, to the best of my knowledge and belief, a true and correct translation of the document(s) listed below in a form that reflects the intention and meaning of the original text.

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

The document is designated as:

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A handwritten signature in blue ink, appearing to read "Frank McGee", is written over a horizontal line.

Frank McGee