

■ 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, up from Standard Definition (SD) video with 720 x 480 pixels.

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

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

In the case of dynamic range, HDR (High Dynamic Range) in particular has been attracting attention as a method for expressing bright light, such as specular reflections, with a luminance closer to reality while maintaining shadow detail—something that cannot be expressed by 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).

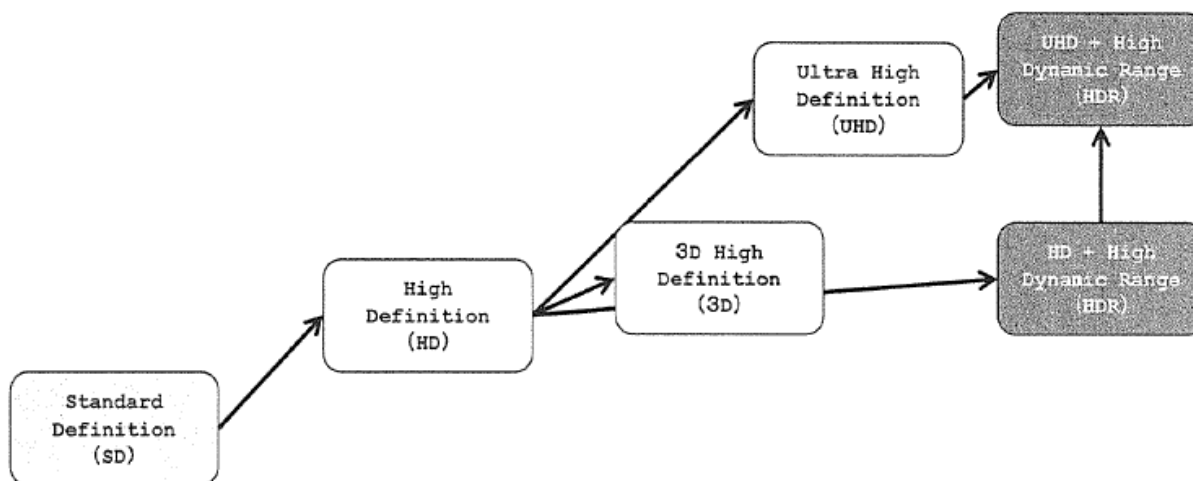


Figure 1: Evolution of Video Technology

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).

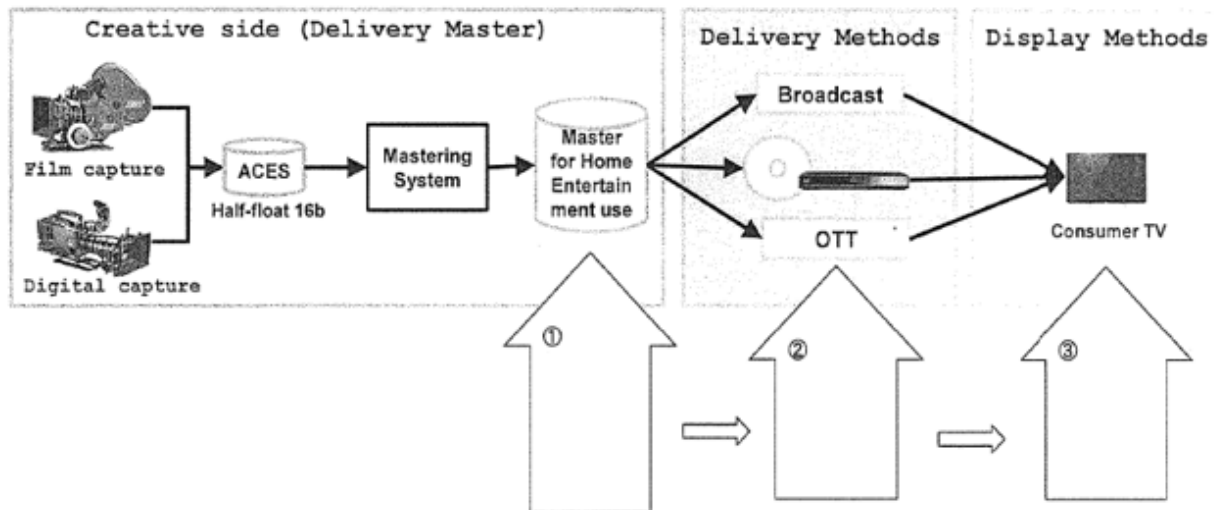
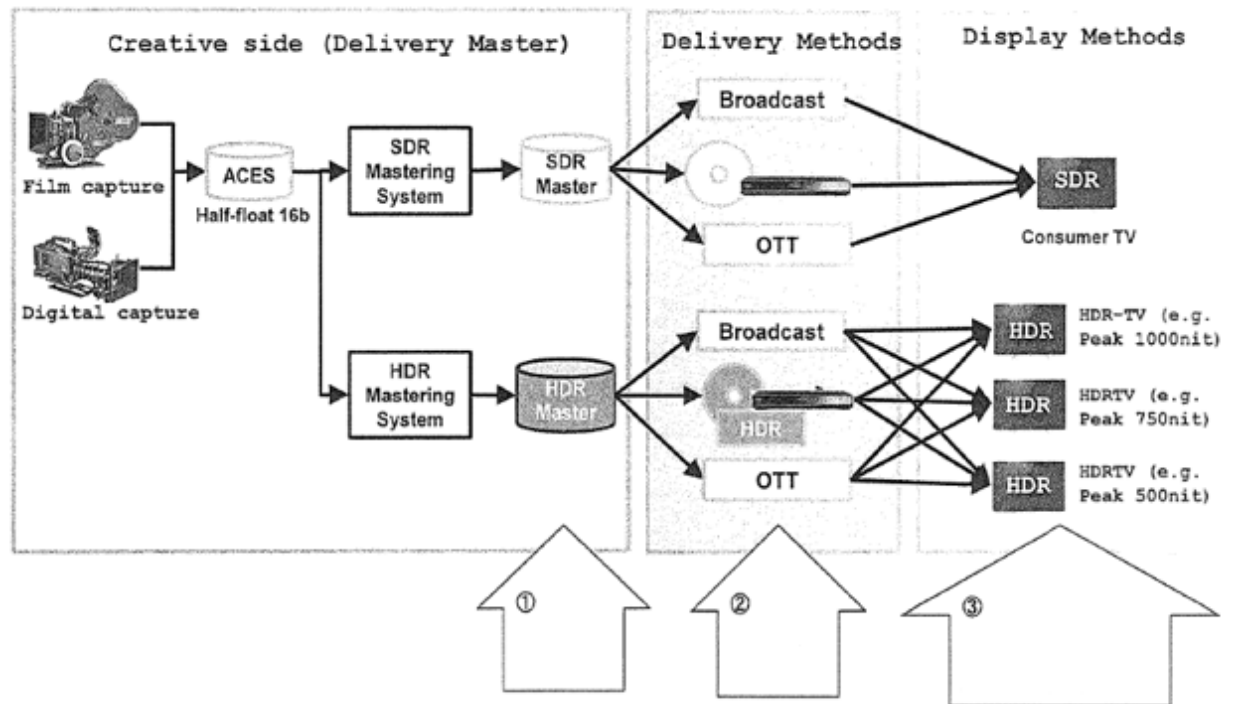


Figure 2: Relationship between the master, distribution method, and display device

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).

Thus, changes in visual formats that require replacing television sets, 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 television sets 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).

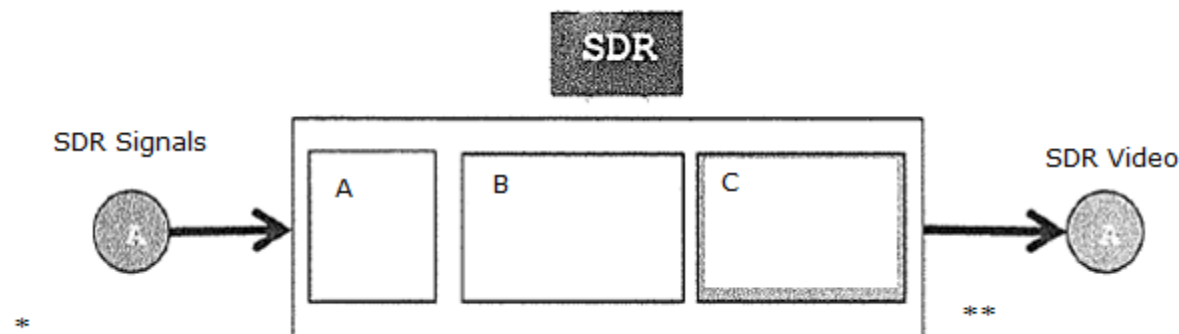


- ① HDR masters are required
- ② A distribution method for HDR masters is required
- ③ A display device for HDR masters is required. The widespread adoption of HDR-compatible TVs is key to the adoption of HDR

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

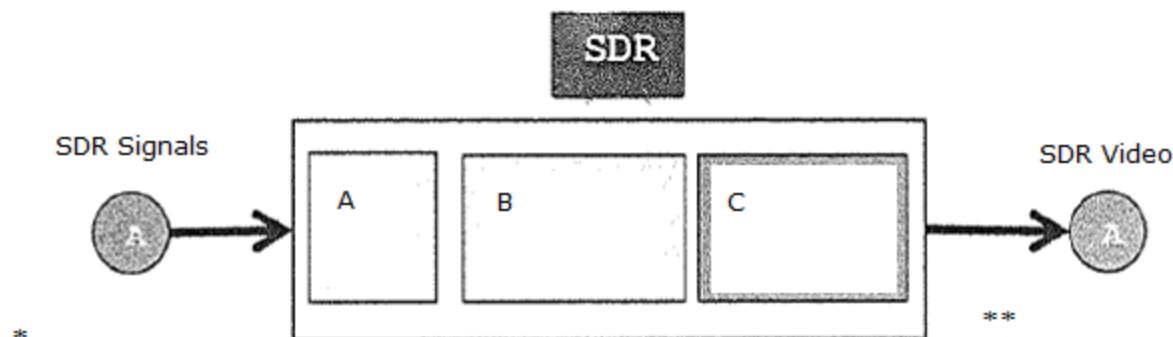
Since standard SDR television sets have 100-nit input signals, their display capability should theoretically be sufficient at 100 nits. However, in practice, they are capable of displaying images at 200 nits or higher and can reproduce optimal picture quality for the viewing environment (for example, 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 television sets 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 television set



- 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, control of the display is possible 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 television set with a peak luminance of 300 nits

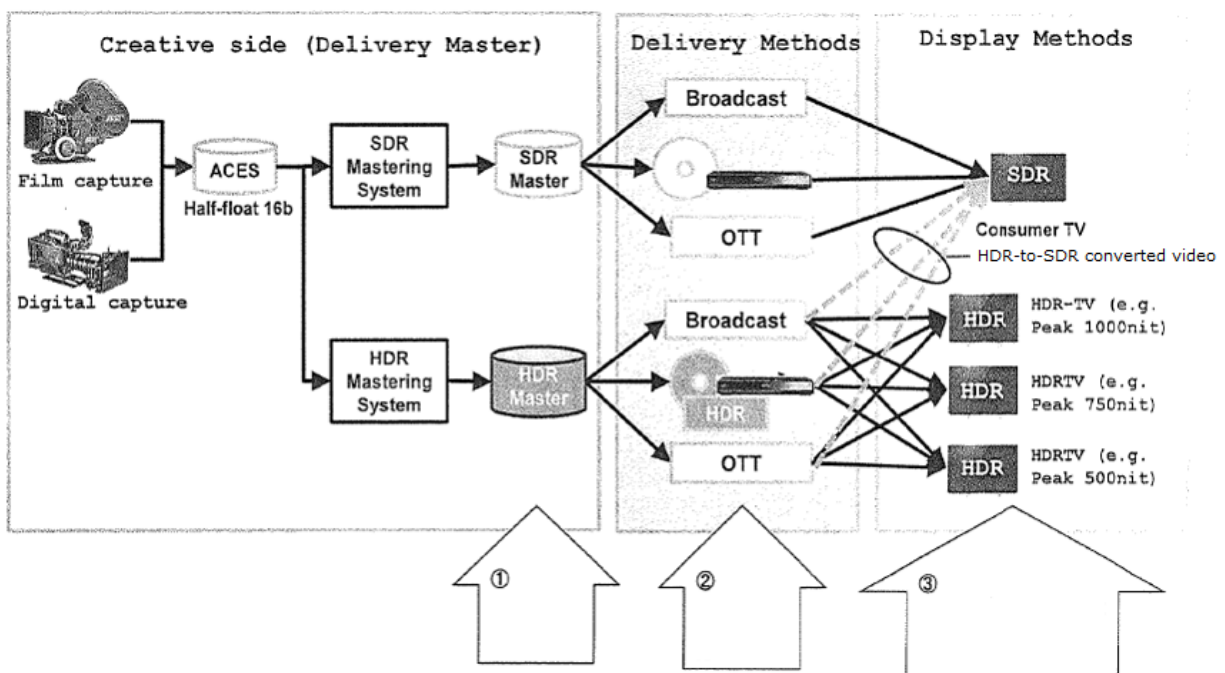
■ Conventional Example

As for the distribution method, an SDR television set may sometimes be connected to systems that distribute high-luminance video, such as HDR-compatible broadcasting, communication using set-top boxes (STBs), and HDR-compatible Blu-ray players for packaged media.

In these situations, SDR television sets 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 (for example, Blu-ray discs, HDR IPTV content) and HDR-compatible devices (for example, Blu-ray players, HDR-compatible IPTV players) can only enjoy SDR video quality on an SDR television set.

Unless users purchase an HDR television set, 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 rate at which HDR television sets become adopted.



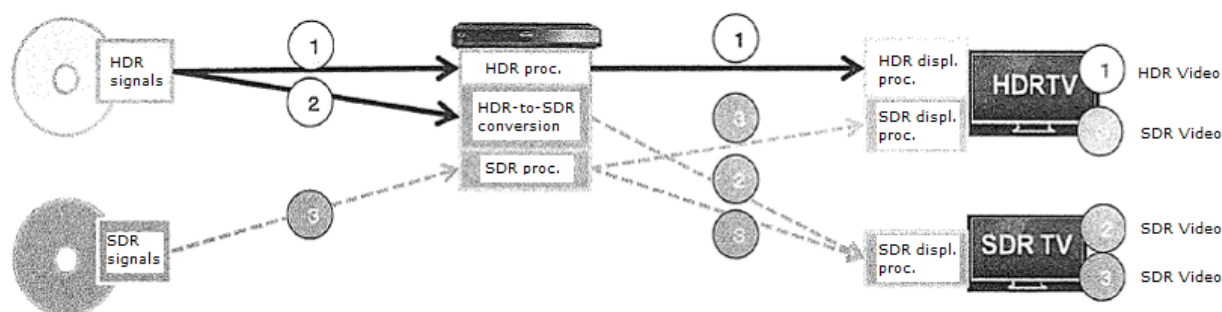
- ① HDR masters are required
- ② A distribution method for HDR masters is required
- ③ A display device for HDR masters is required. The widespread adoption of HDR-compatible TVs is key to the adoption of HDR

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

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

In both Case 1 and Case 2, even if an HDR-compatible Blu-ray disc and an HDR-compatible Blu-ray player have been purchased, users will only be able to enjoy SDR video unless they also have an HDR-compatible television set. Thus, an HDR-compatible television set 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 set, the HDR signals are converted to SDR signals via HDR-to-SDR conversion processing and sent to the SDR television set.



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 set.

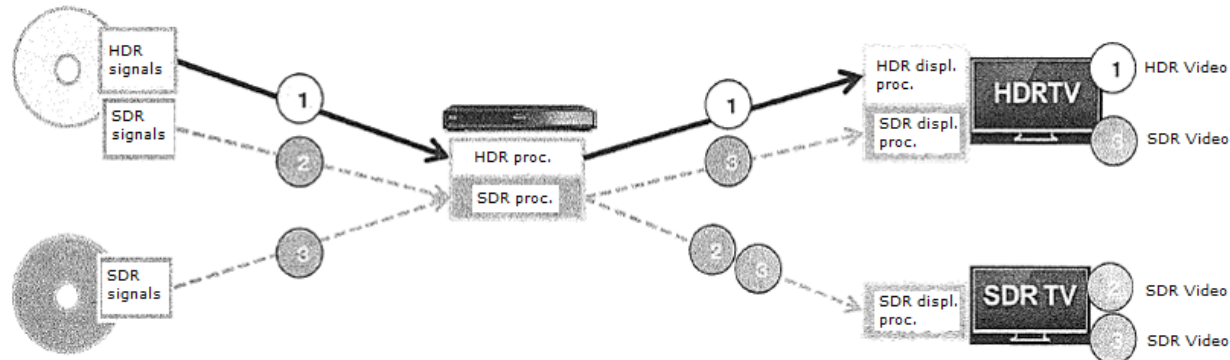
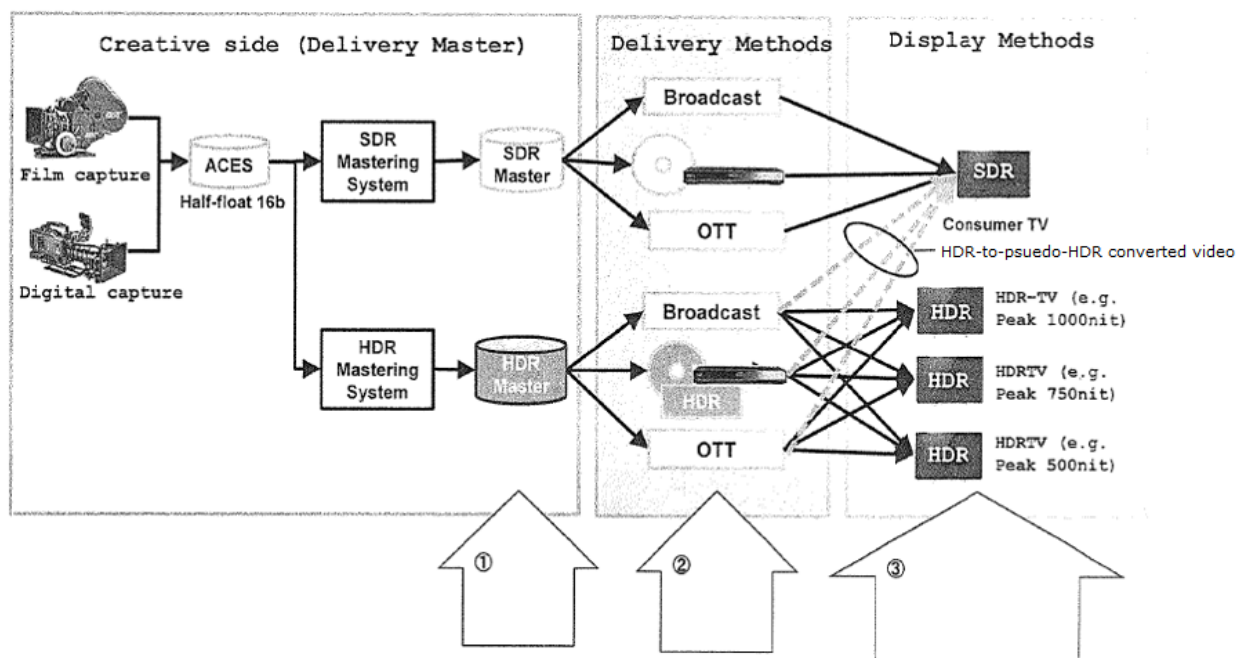


Figure 6: Two methods for implementing HDR-to-SDR conversion in HDR-compatible Blu-ray players

■ Problems to be Solved by the Present Invention:

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

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



- 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 television set is HDR-compatible, it cannot display HDR signals at peak luminance (HPL: for example, 1,500 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.

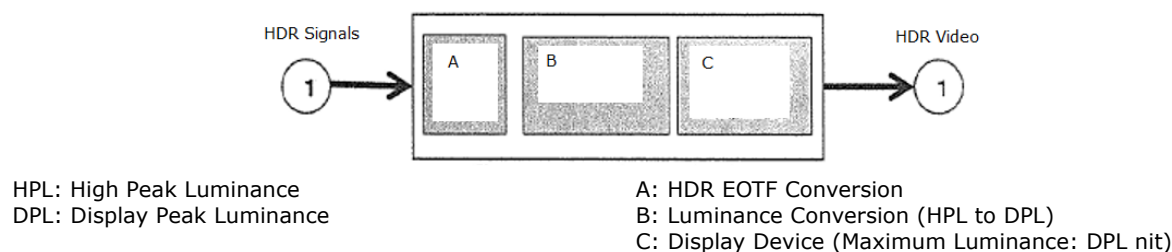


Figure 8 (a) HDR display processing in an HDR television set

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

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

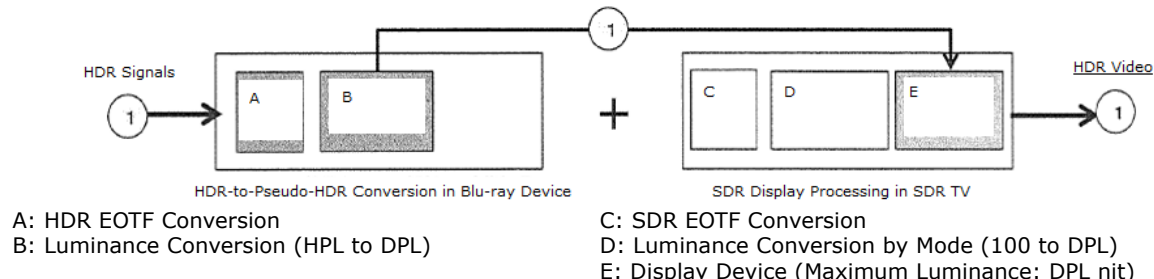


Figure 8 (b) HDR display processing using HDR-compatible equipment and an SDR television set

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 television set interface (such as HDMI). In order to achieve this, it is necessary to perform "HDR EOTF conversion" and "luminance conversion" using the peak luminance of the SDR television set on signals passing through the input interface of the SDR television set to be able to cancel the "SDR EOTF conversion" and "luminance conversion by mode." This results in the same effect as if the signals immediately after "luminance conversion" in a "pseudo" manner had been inputted to the display device.

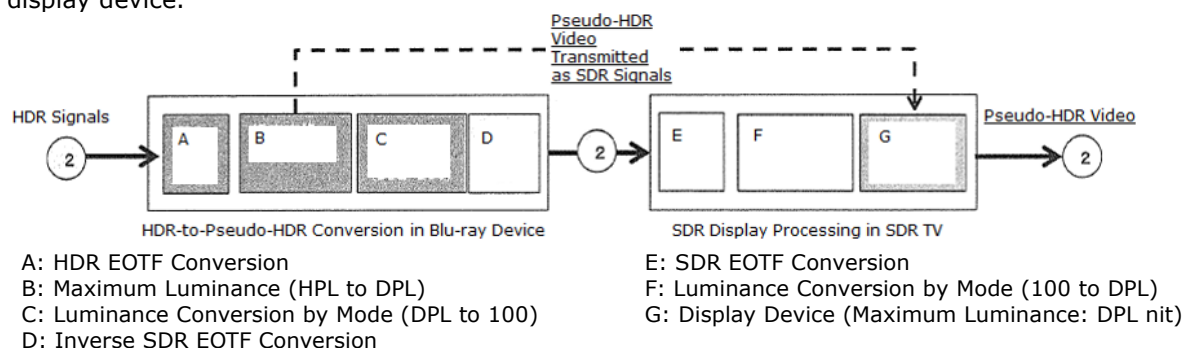


Figure 8 (c) HDR display processing in a configuration in which an HDR-compatible device is connected to a SDR television set via a standard interface

■ Summary of the Invention:

While standard SDR television sets 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 inputted signals was conventionally capped at 100 nits, this capability could not be utilized directly.

When displaying HDR video on an SDR television set, 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 television set. 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 set is connected to a Blu-ray player, the HDR-to-pseudo-HDR conversion processing converts the high-quality HDR signals into pseudo-HDR signals and sends them to the SDR television set, enabling the SDR television set to display video with a pseudo-HDR effect. In this case, even when the SDR television set is not HDR-compatible, pseudo-HDR video can still be enjoyed 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 television sets. As a result, more widespread adoption of HDR-compatible Blu-ray discs can be expected.

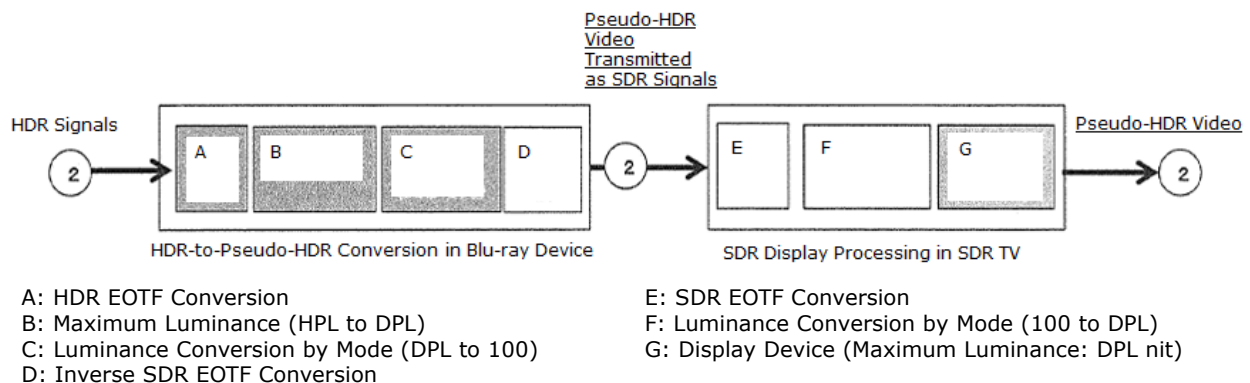
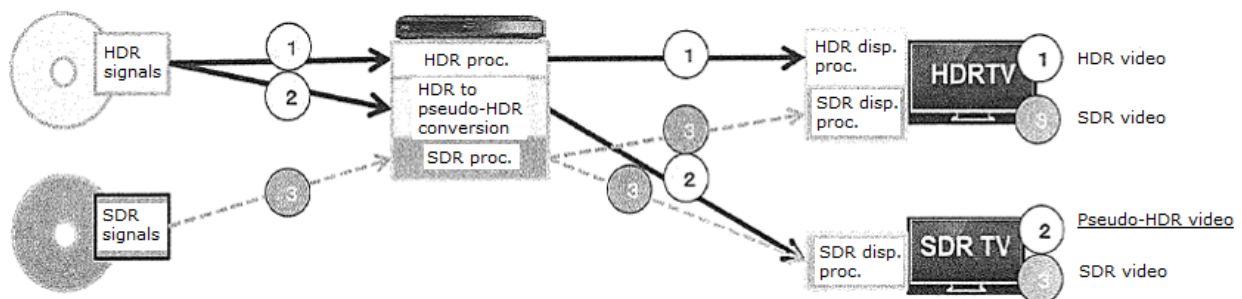


Figure 9: HDR display processing in a configuration in which an HDR-compatible device is connected to a SDR device via a standard interface



While the input signals for a standard SDR television set are 100-nit signals, the system has the capability to display 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 via HDR-to-pseudo-HDR conversion processing, enabling the display of HDR signals as pseudo-HDR video on existing SDR television sets. For example, if HDR signals are stored on a Blu-ray disc and an SDR television set 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 set, enabling the SDR television set to display video with a pseudo-HDR effect.

In this case, even if the television set 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 enables the user to fully experience HDR-like effects, can be viewed on existing television sets. As a result, the more widespread adoption of HDR-compatible Blu-ray discs can be expected.

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) conversely 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 enables signals to be expressed with higher luminance values than with SDR. In Figure 11 (a) and Figure 11 (b), the maximum luminance (peak luminance) is 10,000 nits.

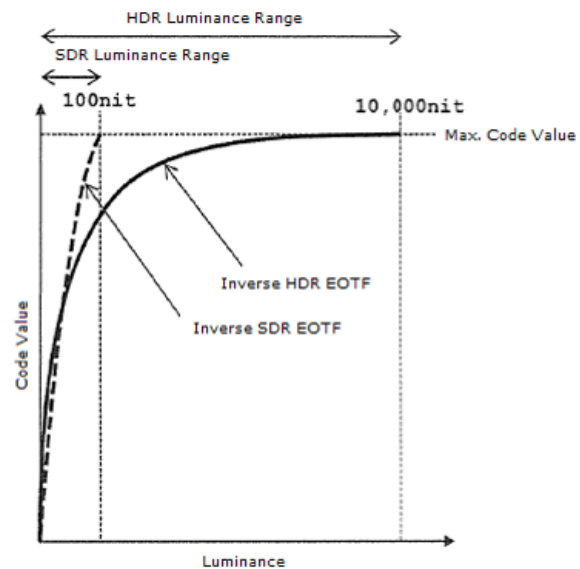
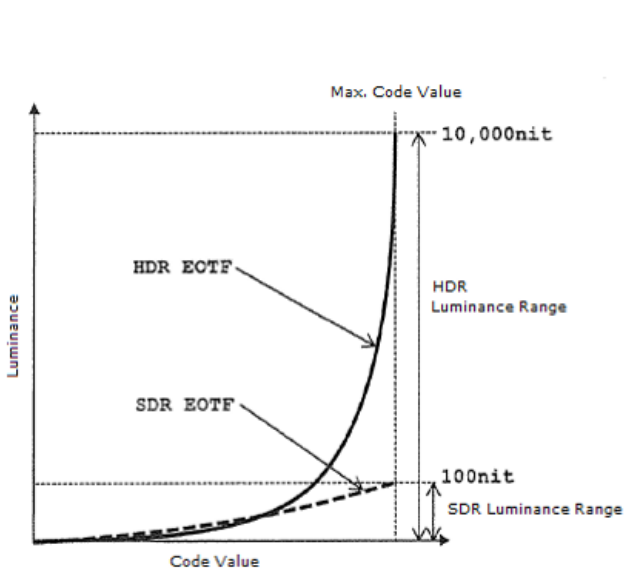


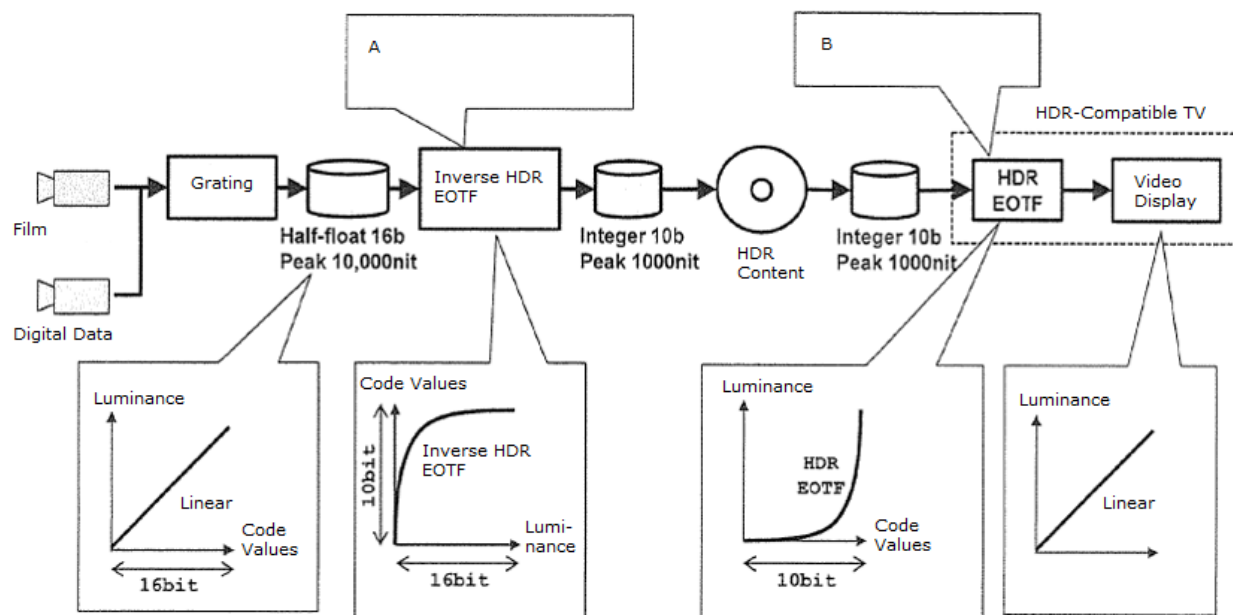
Figure 11

[Additional Information]

How EOTF is Used:

- Figure 12 (a) shows the method used to determine the code values of the signals stored in the content, as well as the process for restoring luminance values from these code values during playback.

The signals in this example are HDR signals. The video after grading is quantized using an inverse EOTF, and code values corresponding to luminance are determined. Based on these code values, video encoding, etc. is performed to generate a video stream. During playback, the luminance values for each pixel are restored by applying inverse quantization to the decoded stream based on EOTF.



- A: Quantization of signals from floating-point to integer for transmission/distribution
- B: Restoration to the original linear signals via inverse quantization

Figure 12 (a) Display Process

Figure 12

Proposed Method: Overall Architecture

- The flow is explained on the next page

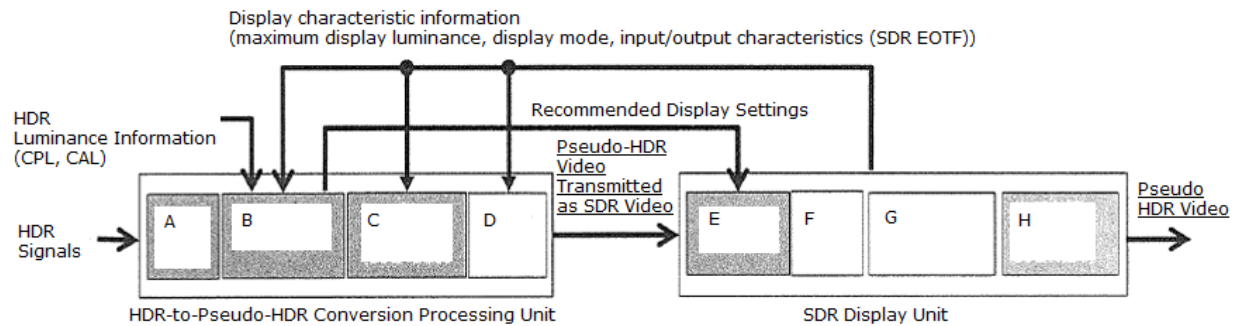


Figure 13 (a) Overall configuration

- 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 nit)

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 a range from 0 to DPL nits to a range from 0 to 100 nits. Details are described below.

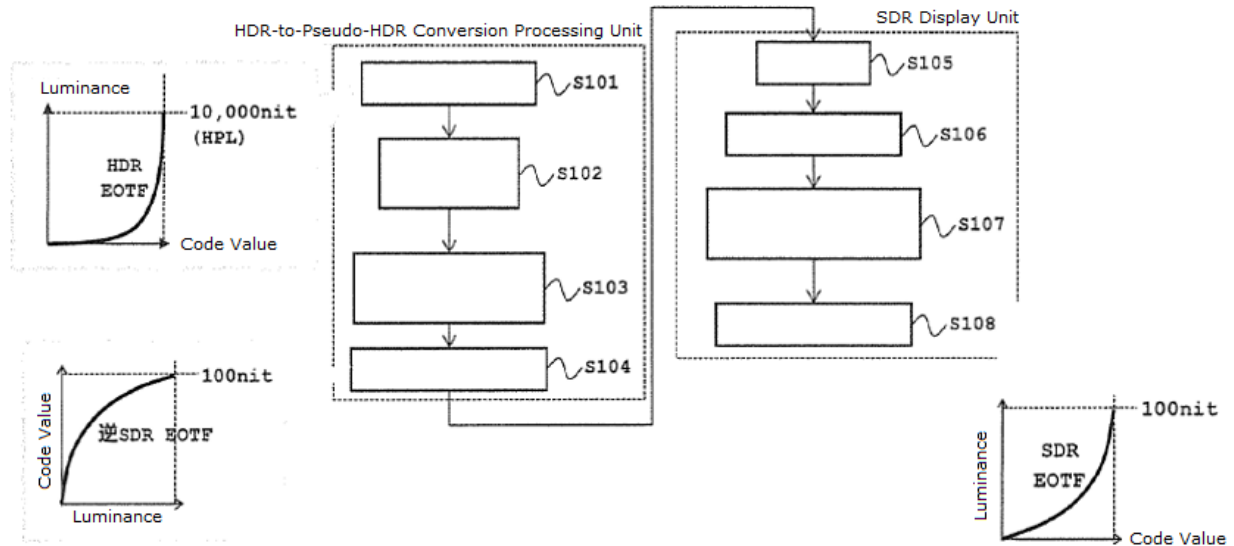
[S104] Inverse SDR EOTF processing is performed to generate pseudo-HDR video.

[S105] The display settings of the SDR display are set using the recommended display setting information from the HDR-to-pseudo-HDR conversion processing unit. The recommended display settings information indicates how to apply the EOTF to the pseudo-HDR video and which settings to use to display beautiful 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: Inversion 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 Method: Luminance Conversion (HPL to DPL)

[S102 Details of Luminance Conversion (HPL to DPL)]

· The linear signals are converted into HDR signals using display characteristics and the luminance information for the HDR content. This conversion is achieved by processing the linear signals so as not to exceed the display peak luminance (DPL). DPL is determined using the maximum luminance of the SDR display and the display mode, which is included among the display characteristics. The display mode refers to mode information such as Theater Mode, which displays images at a lower luminance, or Dynamic Mode, which displays images at a higher luminance. For example, if the maximum luminance of the SDR display is 1,500 nits and the display mode is set to 50% of the maximum luminance, the DPL is set to 750 nits. Using the average luminance (CAL) of the HDR video from the luminance information, pixels at or below the CAL are not converted from the linear signal, and conversion processing is performed only on pixels at or above the CAL. Additionally, using the peak luminance (CPL) of the HDR video from the luminance information, the signals are converted so that pixels at the CPL become the DPL.

[S102 Luminance Conversion (Variation)]

· As shown in Figure 15 (b), the linear signals may be clipped so as not to exceed the DPL. This simplifies the processing, leading to smaller devices, lower power consumption, and faster processing.

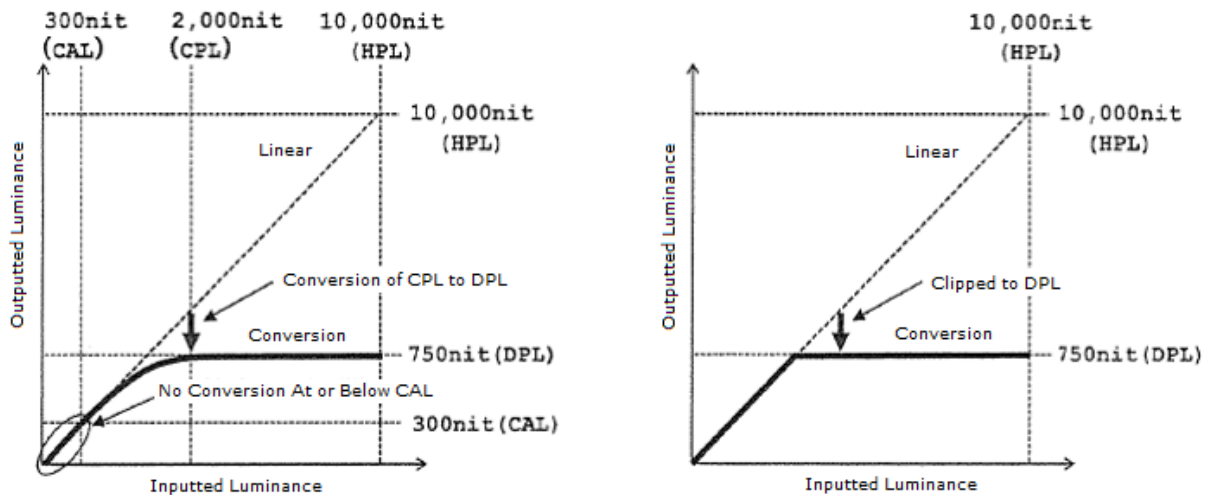


Figure 15 (a) Luminance Conversion (HPL-to-DPL) Figure 15 (b) Luminance Conversion (HPL-to-DPL) (Variation)

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

Figure 15

Proposed Method: Mode-specific inverse luminance transformation (DPL to 100), mode-specific luminance transformation (100 to DPL)

[S103 Details of mode-specific inverse luminance transformation (DPL to 100)]

- Mode-specific inverse luminance conversion is performed on the 0 to DPL nit signals converted in S102. This processing enables the mode-specific luminance conversion processing (S107) for the SDR display to obtain 0 to DPL nit signals resulting from the processing in S102. As a result of this processing, the 0 to DPL nit signals fall within the SDR range of 0 to 100 nits.
- This processing switches conversion equations depending on the display mode. For example, in Normal mode, it converts from 0 to DPL nits to from 0 to 100 nits in direct proportion. In Dynamic mode, which makes high-luminance pixels brighter and low-luminance pixels darker, the inverse function is applied.

[S107 Details of mode-specific luminance conversion (100 to DPL)]

- Signals within the SDR range of 0 to 100 nits are converted to 0 to DPL nits according to the display mode. This processing is performed so as to serve as the inverse function of the mode-specific inverse luminance conversion in S103.

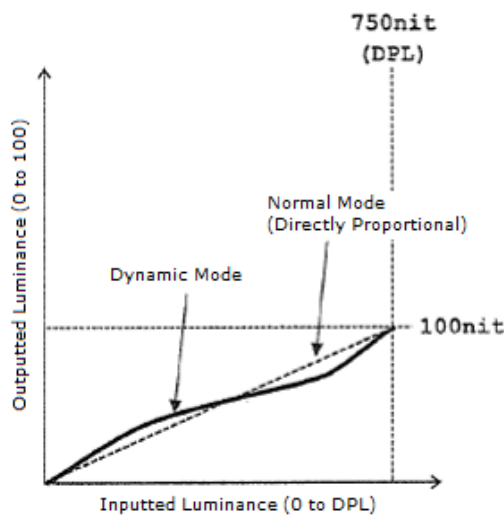


Figure 16 (a) Inverse luminance conversion by mode (DPL-to-100) S103

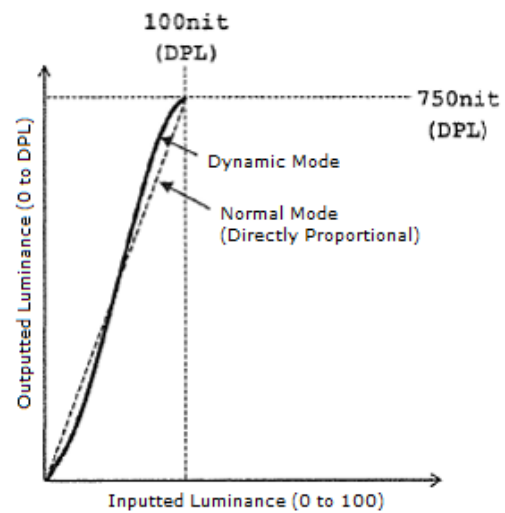
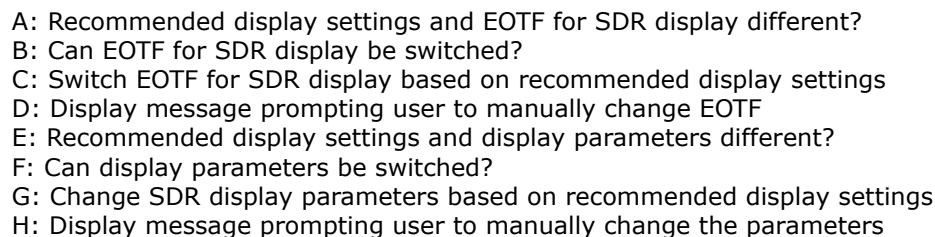


Figure 16 (b) Luminance conversion by mode (100-to-DPL) S107

Figure 16

[S105 Details on the display settings]

- The pseudo-HDR video display unit displays pseudo-HDR video. However, before display, the recommended display settings are used to determine whether the parameters of the SDR display match the recommended settings. If they do not match, it is determined whether the parameters of the SDR display can be switched. If switching is possible, the parameters of the SDR display are switched according to the recommended display settings. If the settings cannot be switched, a message is displayed on the screen prompting the user to manually change the display parameters. For example, a message such as "Please set the display mode to Dynamic Mode and set the backlight to maximum" is displayed on the screen.



17/24

Proposed Method: Notes

- HDR video includes, for example, video on Blu-ray discs, DVDs, video from streaming sites on the internet, video from broadcasts, and video stored on hard disk drives.
- The HDR-to-pseudo-HDR conversion processing unit may be located inside a disc player, disc recorder, set-top box, television, personal computer, or smartphone, or it may be located inside a server device on the internet.
- The SDR display unit may be, for example, a television, personal computer, or smartphone.
- The display characteristic information acquired by the HDR-to-pseudo-HDR conversion processing unit may be obtained from the SDR display unit via an HDMI cable or other cable, or it may be obtained from the internet based on the model information, etc. of the SDR display unit. Additionally, the user may manually set the display characteristic information in the pseudo-HDR video generating unit. Also, the HDR-to-pseudo-HDR conversion processing unit may acquire the display characteristic information immediately before generating the pseudo-HDR video, or at the time of initial device setup or display connection. For example, data may be exchanged when the device is first connected via an HDMI cable.
- The content peak luminance (CPL) and content average luminance (CAL) of HDR video may be provided as a single set on a per-content basis, or may be provided on a per-scene basis. Also, CPL and CAL may be included on the same medium as the HDR video (for example, Blu-ray disc, DVD), or may be obtained from a location separate from the HDR video, such as via the internet.
- In the luminance conversion (HPL to DPL) performed by the HDR-to-pseudo-HDR conversion unit, CPL, CAL, and display peak luminance (DPL) do not have to be used, and fixed values may be used instead. It may also be possible to allow these fixed values to be modified externally. In addition, it may be possible to switch between several types of HDR. For example, CPL, CAL, and DPL may be limited to only three values—200 nits, 400 nits, and 800 nits—or the value closest to the display characteristics may be used.
- The HDR EOTF does not have to be SMPTE 2084, and other HDR EOTF methods may be used. Also, the maximum luminance (HPL) of the HDR video 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.
- The inverse SDR EOTF transformation is determined based on display characteristics, but a fixed transformation function (which can be modified externally) may also be used. For example, the function specified in Rec. ITU-R BT.1886 may be used. Also, the types of inverse SDR EOTF transformations may be narrowed down to a few options, and the one closest to the input/output characteristics of the SDR display selected for use.
- A fixed display mode may be used, and this does not have to be included in the display characteristic information.
- The HDR-to-pseudo-HDR conversion processing unit does not have to transmit recommended display settings. The SDR display unit may use fixed display settings or may have display settings that cannot be changed at all. In such cases, a display settings unit is unnecessary. Also, the information regarding recommended display settings may consist simply of a flag indicating whether the video is pseudo-HDR. For example, if the video is pseudo-HDR video, the settings may simply be changed to display it at the brightest level.

Figure 18

Proposed Method: Notes (continued)

· The luminance conversion (HPL to DPL) using the HDR-to-pseudo-HDR conversion unit can be calculated, for example, 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 represents a luminance value normalized to the range from 0 to 1, and S1, S2, a, b, and M are values set based on CAL, CPL, and DPL. Also, ln is a natural logarithm, and v is the converted luminance value normalized to between 0 and 1. As in the example shown in Figure 15 (a), the average luminance is 300 nits, the maximum luminance of 2,000 nits, the specific luminance of 750 nits, no conversion is performed up to 50 nits above the average luminance, and conversion is performed on values of 350 nits or higher. In this case, the respective values can be, for example, the following.

```
S1 = 350/10000
S2 = 2000/10000
M  = 750/10000
a  = 0.023
b  = S1 - a*ln(S1) = 0.112105
```

· Note that the numerical values, shapes, materials, components, component arrangement, connection configuration, steps, and the order of steps are merely examples and are not intended to limit the scope of the present invention.

Figure 19

Proposed Method: Effects (effects other than those described in 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 according to the content, making it possible to perform conversion while preserving the HDR gradation as much as possible. Also, adverse effects such as the video being too dark or too bright can be suppressed. Specifically, by mapping the content peak luminance of the HDR video to the display peak luminance, the gradation is preserved as much as possible. Also, by leaving pixel values near or below the average luminance unchanged, the overall luminance does not change.
- Also, by converting HDR video using the peak luminance and display mode of the SDR display, the conversion equation can be adjusted and adapted to the SDR display (display environment), allowing video with an HDR-like feel to be displayed with the same tonal range and luminance as the original HDR video but tailored to the performance of the SDR display. Specifically, the display peak luminance is determined based on the maximum luminance and display mode of the SDR display. By converting the HDR video so that it does not exceed this peak luminance, the tonal range of the HDR video is displayed with virtually no loss up to the luminance level that the SDR display can handle, while luminance levels that cannot be displayed are reduced to a value within the range of the display. This makes it possible to reduce luminance information that cannot be displayed while maintaining the tonal range of the luminance that can be displayed, thereby displaying the content in a form close to the original HDR video. Simply put, for a display with a peak luminance of, for example, 1,000 nits, the video is converted into pseudo-HDR video with a peak luminance limited to 1,000 nits to maintain overall luminance. Since luminance values vary depending on the viewing mode of the display, adjustments are made accordingly. If the pseudo-HDR video allows for luminance levels higher than the peak luminance of the display, those high luminance levels may be replaced with the peak luminance of the display during playback, resulting in an overall darker image compared to the original HDR video. Conversely, if the video is converted with a maximum luminance lower than the peak luminance of the display, that lower luminance is substituted for the peak luminance of the display, resulting in an image that is brighter overall than the original HDR video. Because the luminance is lower than the peak luminance of the display, the gradation performance of the display is not being utilized to its fullest potential.
- In addition, by switching display settings using recommended display settings information, it becomes possible to display pseudo-HDR video more effectively. For example, if the luminance is set to a low level, high-luminance display is not possible, which compromises the HDR experience. In such cases, by displaying a message prompting the user to change the display settings, display performance can be maximized to enable the display of high-dynamic-range 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 is decoded separately, 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 signal is HDR, the graphics signals for subtitles and menus may be SDR. Therefore, the following two approaches can be used for HPL to DPL conversion of the video signals.

(a) Perform HPL to DPL conversion after compositing the graphics

1. Convert the graphics using an EOTF from an SDR EOTF to an HDR EOTF
2. Composite the graphics (after EOTF conversion) with the video
3. Perform HPL to DPL conversion on the composite results

(b) Perform HPL to DPL conversion before compositing the graphics

1. Convert graphics from an SDR EOTF to an HDR EOTF
 2. Perform HPL to DPL conversion on the video
 3. Composite the graphics subjected to EOTF conversion with the video subjected to DPL conversion
- Note that the order of steps 1 and 2 may be reversed.

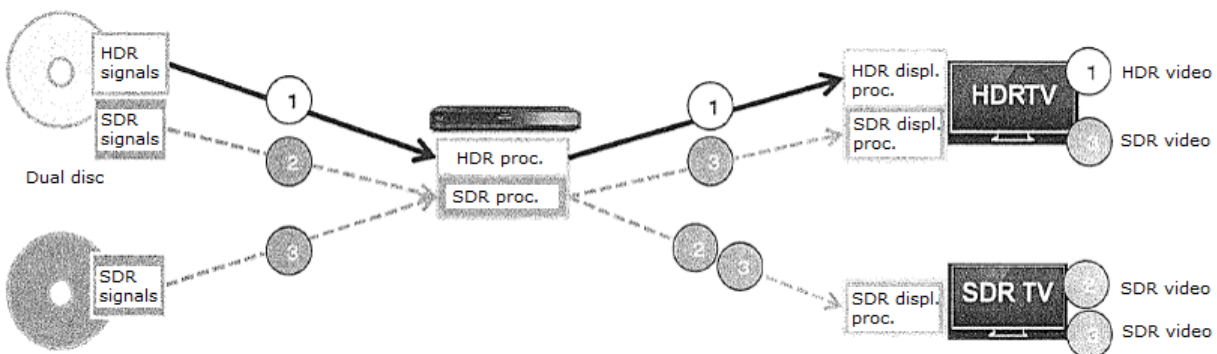
In either method (a) or (b), the peak luminance of the graphics is 100 nits. However, if the DPL is high, for example, 1,000 nits, keeping the graphics luminance at 100 nits may result in the graphics appearing darker relative to the video after HPL to DPL conversion. In particular, this could lead to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

Figure 21

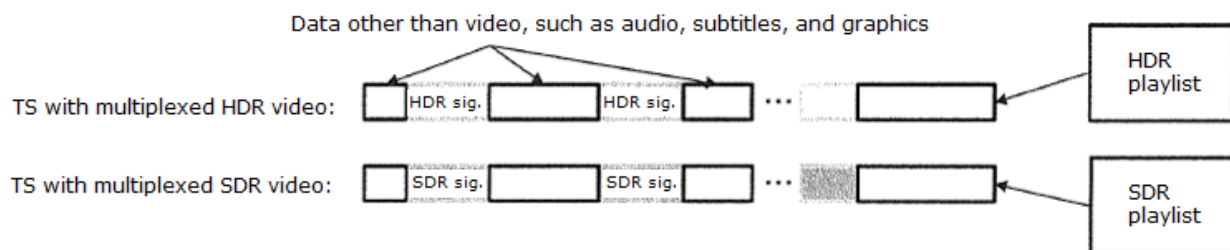
The playback operation for an HDR disc containing only HDR signals was described above.

Next, the playback operation for a dual disc containing both HDR signals and SDR signals, as shown in Case 2 of Figure 6, will be described. On a dual disc, as shown in Figure 21 (b), the HDR signals and the SDR signals are stored as separate multiplexed streams. For example, on optical discs such as Blu-ray discs, data for different media types, such as video, audio, subtitles, and graphics, is stored as a single multiplexed stream using an MPEG-2 TS-based multiplexing method called M2TS. These multiplexed streams are referenced via metadata used for playback control, such as playlists. During playback, the player analyzes the metadata to select the multiplexed stream to play, or to select specific language data stored among the multiplexed streams. In this example, playlists for HDR and SDR are stored separately, and each playlist references either the HDR signals or the SDR signals. Also, information indicating that both HDR and SDR signals are stored on the disc may be provided separately.

Although it is possible to multiplex both HDR-signals and SDR-signals into a single multiplexed stream, the multiplexing must comply with buffer models such as the T-STD (System Target Decoder) specified in MPEG-2 TS. Since it is particularly difficult to multiplex two high-bitrate video streams within a predetermined data readout rate range, they are preferably separated into different multiplexed streams. Data such as audio, subtitles, or graphics must be stored in their own multiplexed streams, which increases the data volume compared to multiplexing them into a single stream. However, this can be overcome by reducing the video data volume using a video encoding method with a high compression ratio. For example, replacing the MPEG-4 AVC used in conventional Blu-ray discs with HEVC (High Efficiency Video Coding) is expected to improve the compression ratio by a factor of 1.6 to 2. Also, regarding the content stored on a dual disc, combinations of two 2K tracks, a 2K track and a 4K track, and two 4K tracks, for example, 2K HDR and 2K SDR, or 4K SDR and 2K HDR may be used, provided that only combinations that fit within the capacity of the optical disc are allowed.



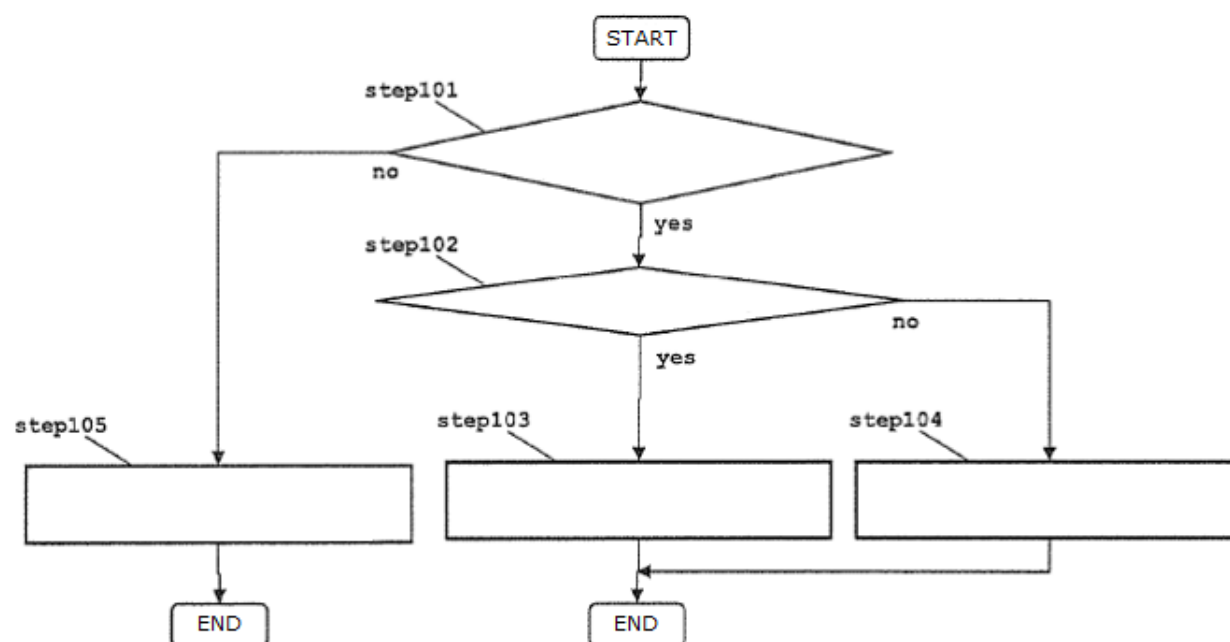
(a) Dual disc playback operations



(b) Multiplexed data stored on a dual disc

Figure 22

Figure 22 is a flowchart showing the playback operation for a dual disc. In step 101, it is determined whether or not the optical disc to be played back is a dual disc. If it is a dual disc, the processing proceeds to step 102. Next, in step 102, it is determined whether or not the television set receiving the output is an HDR television set or an SDR television set. If it is an HDR television set, the processing proceeds to step 103, and if it is an SDR television set, the processing proceeds to step 104. In step 103, HDR video signals are extracted from the multiplexed stream containing HDR signals on the dual disc, the extracted video signals are decoded, and the decoded video signals are outputted to the HDR television set. In step 104, SDR video signals are extracted from the multiplexed stream containing the SDR signals on the dual disc, the video signals are decoded, and the decoded video signals are outputted to the SDR television set. Note that if it is determined in step 101 that the playback target is not a dual disc, a determination of playback feasibility is performed using a predetermined method, and the playback method is determined based on the results of that determination.



Step 101: Is optical disc to be played a dual disc?

Step 102: Is the television set an HDR television set?

Step 103: Playback based on multiplexed stream containing HDR signals

Step 104: Playback based on multiplexed stream containing SDR signals

Step 105: Determine playback feasibility and playback method using a predetermined method

Figure 23

Key Features of the Invention

- When displaying HDR video on an SDR television set, rather than converting the HDR video to SDR video with a luminance of 100 nits or higher (typically 200 nits or higher), this "HDR-to-pseudo-HDR conversion process is implemented. Rather than converting the HDR video into SDR video with a luminance of 100 nits or less, the conversion preserves the tonal gradation in the 100-nit-or-higher range to some extent, resulting in pseudo-HDR video that closely resembles the original HDR, which can be displayed on a SDR television set.
- The conversion method for the "HDR-to-pseudo-HDR conversion processing" is switched based on the display characteristics of the SDR television set (maximum luminance, input/output characteristics, display mode)
 - Method for acquiring display characteristic information for the HDR-to-pseudo-HDR conversion processing unit
 - Method can be acquired automatically via HDMI or a network
 - Method can be generated based on user-inputted information such as maker name and model number
 - Method can be retrieved from the cloud or other source using information such as maker name and model number
 - Timing for acquiring display characteristic information for the HDR-to-pseudo-HDR conversion processing unit
 - Timing can be acquired immediately before performing pseudo-HDR conversion
 - Timing can be retrieved when first connecting to an SDR display (such as an SDR television set) (when the connection is established)
- Switches the conversion method for the HDR-to-pseudo-HDR conversion processing based on the luminance information for the HDR video (content average luminance, content peak luminance)
 - Method for acquiring HDR video luminance information in the HDR-to-pseudo-HDR conversion processing unit
 - Method can be acquired as metadata accompanying the HDR video
 - Method can be acquired by having the user enter the content title information
 - Method can be retrieved from the cloud or other sources using the information entered by the user
- Details of the conversion method
 - Converts the video so that it does not exceed the peak luminance of the display
 - Converts the content peak luminance to match the peak luminance of the display
 - Does not change the luminance levels at or below the content average luminance
 - Performs the conversion using a natural logarithm
 - Perform clipping based on the peak luminance of the display
- For HDR-to-pseudo-HDR conversion processing, it is also possible to transmit and switch the display mode and parameter settings of the SDR television set to enhance the pseudo-HDR effect
 - A message prompting the user to configure the settings may be displayed on the screen

Figure 24



TRANSLATOR CERTIFICATION

Date: June 11, 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 documents listed below in a form that reflects the intention and meaning of the original text.

Document designated as: US 62/010,096 filed 10 June 2014

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.

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

Frank McGee