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Management of High Dynamic Range and Wide Color Gamut Standards Conversion Applications in

Since the earliest days of TV broadcasting, global viewers have wanted to watch programs from other countries — everything from live breaking news and international sporting events to entertainment and cultural programming. However, simple international program exchange has never been possible because of huge differences in TV standards around the world. Similarly, transferring movies to formats suitable for home-TV viewing inherently requires both format and frame rate conversion for audiences in all regions.

Standards converters solve these problems by changing the format and frame rate of the content to suit the required display specification. However, as technology advances and new formats and new production tools become available, more complications arise in the conversion workflow.

Whilst high dynamic range (HDR) and wide color gamut (WGC) increase the artistic choices available to content producers, converting that content for audiences watching on standard dynamic range (SDR)-only or

narrower-color-gamut displays can be problematic. Fortunately, a number of standards conversion manufacturers are starting to include tools supporting HDR and WGC in their products, but these tools must be used with care, as there are many pitfalls.

This article discusses conversion of content mastered with HDR and WGC, highlights some of the possible problems, and suggests solutions.

Dieser Artikel behandelt die Konvertierung von Inhalten, die mit HDR und WGC gemastert wurden, zeigt einige der möglichen Probleme auf und schlägt Lösungen vor.



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Introduction

Producers of UHD TV content have many new tools at their disposal to enhance programme-making, including high dynamic range (HDR) and wide color gamut (WGC). High dynamic range enables greater contrast ratios, such that fine variations in blacks can be accommodated

at the same time as very bright whites.

Wide color gamut, as defined in ITU-R BT.2020, extends the color space definition such that a larger range of colors can be represented in the scene. Figure 1 illustrates this concept.

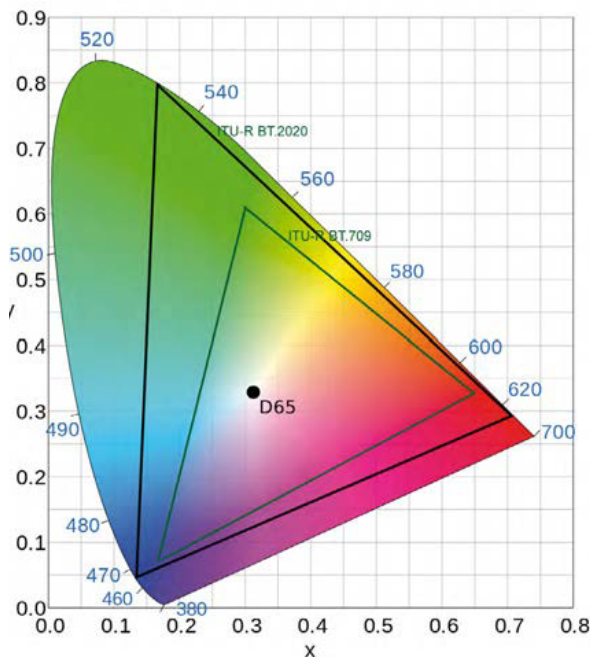


Figure 1: Illustration of color spaces BT.709 and BT.2020

Multiple HDR standards have been defined, and the ITU report BT.2408-1 titled "Operational practices in HDR television production"[1] presents in-depth guidance on the use of high dynamic range in television production using the Perceptual Quantization (PQ) and Hybrid Log-Gamma (HLG) methods specified in Recommendation ITU-R BT.2100[2]. Within the PQ standard, the producer will select a peak brightness level depending on

the expected viewing conditions — information that must be conveyed within the programme's metadata. HLG is described by the BBC (its originators) as a "scene-referenced signal," which means that it's possible to obtain the same artistic effect on any target display, independent of that display's inherent brightness, and no additional metadata are needed.

Note that producers of UHD content don't necessarily use HDR. It is equally common to find UHD content mastered at standard dynamic range (SDR), and, while most existing HD content will use SDR, producers of some newer HD content might have taken advantage of HDR production tools. Project information from the BBC[3] provides more detail on the opportunities HDR offers.

WCG is specifically defined in BT.2020 as applicable to UHD content. However, UHD content may equally be produced for the BT.709 color space, creating significant opportunity for confusion — and therefore downstream quality problems — when processing the content.

Conversion Applications

As broadcasters transition to UHD services, there are many situations in which SD — or, more commonly, HD — content needs to be integrated into a UHD production. In these cases, the SD or HD content might need frame rate conversion as well as resolution upconversion. Similarly, UHD content is often downconverted to HD for distribution on existing delivery networks, as illustrated in the simplified HD workflow of Figure 2.

If the UHD content was produced in HDR with BT.2020 color, but the HD workflow has been configured for SDR with BT.709 color, then clearly the Figure 2 example needs to be augmented with additional processing, as illustrated in Figure 3.

UHD frame rate conversion might also require HDR/WCG processing. For example, the incoming programme might have been mastered according to the PQ standard, but the output is required to be HLG. Therefore, in that case, the workflow needs a PQ-to-HLG transformation in

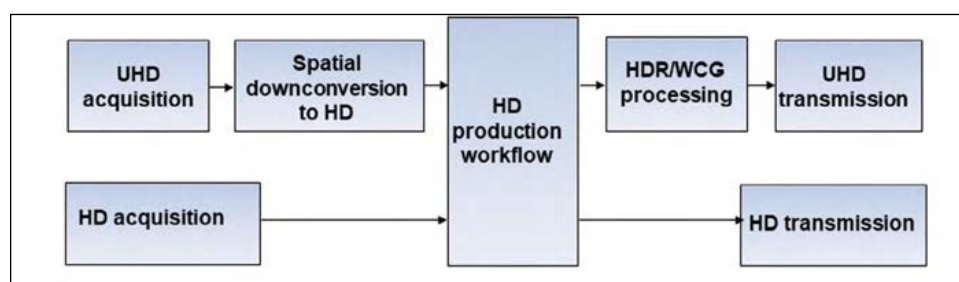


Figure 2: Example HD workflow

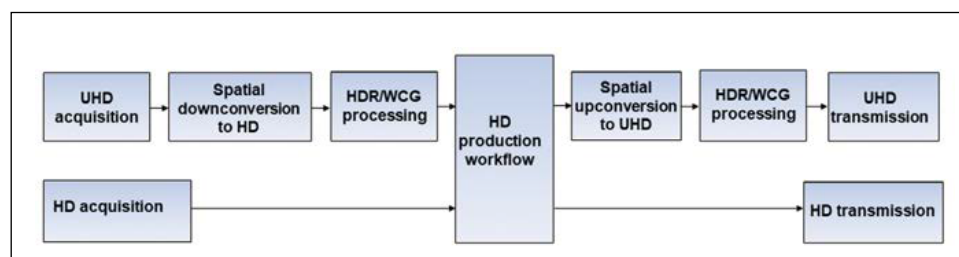


Figure 3: Example HD workflow with HDR/WCG processing

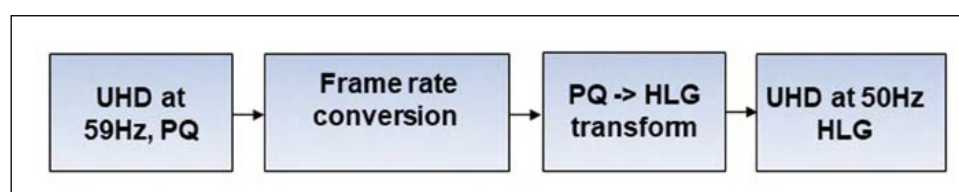


Figure 4: Example UHD frame rate conversion with HDR-HDR transform

addition to the frame rate conversion, as illustrated in the example of Figure 4.

When converting content as in the examples above, it is expected that the converter will examine the incoming metadata and make a decision about the required transforms. Such behaviour is normal in common conversion workflows, in which a user would ordinarily leave the converter in “automatic mode” on the input side. In that case, the converter detects the incoming signal’s format and frame rate and identifies important information from the metadata, such as colorimetry and dynamic range.

A typical user of standards conversion products would expect to have to set only the output parameters, i.e., the format and frame rate to which the output signal should conform. While doing that would typically work for most current converters and conversion applications, as will be shown below, it might not be the most appropriate course of action for content mastered using HDR and WCG.

Possible Conversion Problems

■ (A) COLOR SPACE CONVERSION

If the incoming video metadata are reliable and contain the color space descriptor, then allowing the converter to operate in an automatic mode on the input side will be successful. In that case, the converter interprets the incoming video according to the correct color space. Automatic input mode is still an option even if the input video metadata are unreliable or do not contain a color space descriptor; in that instance, the assumption is that SD content adheres to BT.601, HD follows BT.709, and UHD follows BT.2020.

Sometimes the user knows that the input video metadata relating to color space are erroneous or that the content does not follow the usual assumptions as in the “automatic” case. It is also possible that content being edited from multiple sources were mastered at different colorimetry standards. For these situations, it is recommended to manually force the converter to select the color space. Caution is advised to avoid quality problems, as will be illustrated in the following examples.

EXAMPLE 1: BT.2020 VIDEO ASSUMED TO BE BT.709
In this example, it is considered that UHD content was produced according to BT.2020 but either has incorrect metadata stating BT.709, or the user has overridden the correct metadata and instructed the converter to treat the video as BT.709.

If the user expects to view the output on a BT.2020-compliant monitor, as illustrated in Figure 5(i),

Figure 5: Illustration of BT.2020 content treated as BT.709



(i) BT.2020 video treated as BT.709

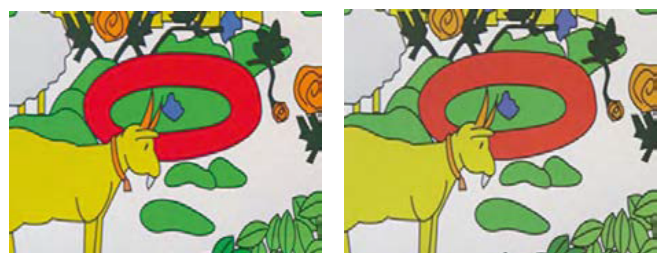
(ii) BT.2020 video treated correctly

then the result of a conversion will be that colors appear desaturated on the monitor used to view the output video. This result is most clear on the red post, which is correctly presented in Figure 5(ii).

EXAMPLE 2: BT.709 VIDEO ASSUMED TO BE BT.2020
In this example, it is considered that UHD content was produced according to BT.709 but either has incorrect metadata stating BT.2020, or the user has overridden the correct metadata and instructed the converter to treat the video as BT.2020.

As illustrated in Figure 6(i), the result of a conversion will be that colors will appear oversaturated on the monitor used to view the output video. Figure 6(ii) shows the correct color presentation.

Figure 6: Illustration of BT.709 content treated as BT.2020



(i) BT.709 video treated as BT.2020

(ii) BT.709 video treated correctly

■ (B) HIGH DYNAMIC RANGE

As discussed above, there are multiple standards for HDR, and the best results are obtained when one standard is used throughout capture, conversion, and display. However, using a single standard is not always possible, such as when a programme is shot in UHD HDR using PQ, but the user is viewing it on an HD SDR TV. Similarly, the programme might be shot in UHD using HLG but viewed on a PQ monitor.

If the source content is SDR but is incorrectly treated as HDR within the conversion process, then the resultant video will suffer unpleasant artefacts that make the video look over-enhanced. Figure 7(i) shows an example in which the detail in the lighter picture areas is lost in an unwanted “bloom.”

Figure 7: Illustration of SDR material treated as HDR



(i) SDR processed as HDR

(ii) SDR processed as SDR

EXAMPLE 2: HDR PROCESSED AS SDR

If the content is HDR but is treated as SDR during standards conversion, then the resultant video will tend to reduce the dynamic range, making the video appear somewhat flat. An example appears in Figure 8(i), where the HDR content processed as SDR appears much less bright than when correctly converted.

Figure 8: Illustration of HDR processed as SDR



(i) HDR processed as SDR

(ii) HDR correctly processed

Achieving the Best Results in Frame Rate and Format Conversion

Color space mapping

When converting video material between HD and UHD, or when converting frame rates between different UHD standards, it is important both to choose a converter with the appropriate HDR and WCG tools, and to set the required parameters carefully to match the incoming content and the expected final viewing conditions.

In the following examples, the FrameFormer software standards converter from InSync Technology Ltd is used to illustrate the proper choices required for correct conversion. FrameFormer is available as a component within the Zenium Workflow Designer that underlies Imagine Communications' SelenioFlex File transcoding solution.

The colorimetry settings are fairly straightforward. Figure 9 shows the controls available in the FrameFormer for SelenioFlex File window, which enable the converter to set explicit colorimetry for the incoming content.

If the incoming video metadata are reliable and contain the color space descriptor, then the recommendation is to select "Automatic." This selection ensures that the incoming video data are interpreted according to the correct color space. If the input video metadata are unreliable or do not contain a color space descriptor, then it is still

acceptable to use automatic mode. In that case, FrameFormer assumes that SD content adheres to BT.601, HD follows BT.709, and UHD follows BT.2020.

If the user knows that the input video metadata relating to color space are erroneous or that the content does not follow the usual assumptions as in the "automatic" case, then it is recommended to select the color space from one of the three options shown in Figure 9. However, it is essential to select the correct colorimetry to avoid quality problems, as discussed above.

On the output side, if any of the predefined SD, HD, or UHD output standards are chosen, then the assumptions as in the "automatic" case may be made. For example, an HD output will be assumed to require conformance to BT.709, or UHD to BT.2020.

If a different output color space is required, such as UHD content as BT.709, then it is necessary to select a "Custom" output from the output format drop-down menu. From there it's possible to select BT.709 or BT.2020.

HDR to HDR

Settings for HDR management are more complex. Metadata describing HDR parameters might be missing or incomplete, depending on the ability of upstream equipment to insert the required information. Furthermore, if the HDR format is PQ, then it is important to identify to the converter the peak or maximum brightness. Peak or maximum brightness (also called grading level) is an essential parameter in PQ HDR and is set by the program maker related to the expected viewing monitor. This parameter is only relevant for PQ content and is specified in nits (cd/m²) at four levels: 1,000, 2,000, 4,000, and 10,000.

If HDR metadata are missing, incomplete, or erroneous, then it is necessary to give the converter explicit instructions in identifying whether the content is SDR or HDR, what type of HDR, and the peak brightness in the case of PQ, as illustrated in Figure 10.

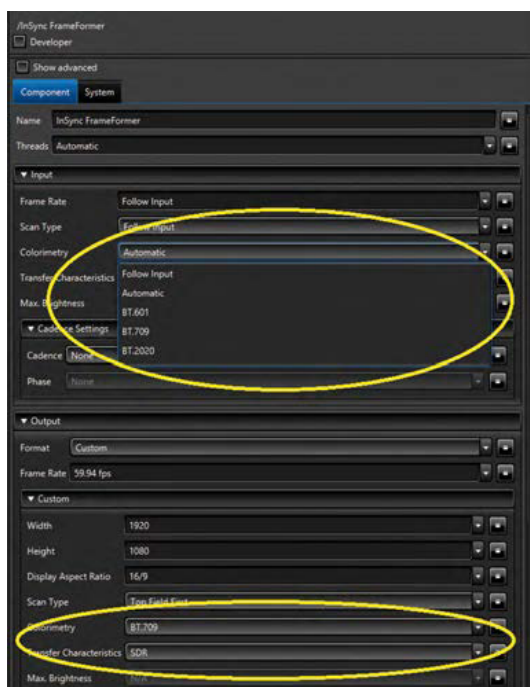


Figure 9: Example controls allowing color processing in standards conversion

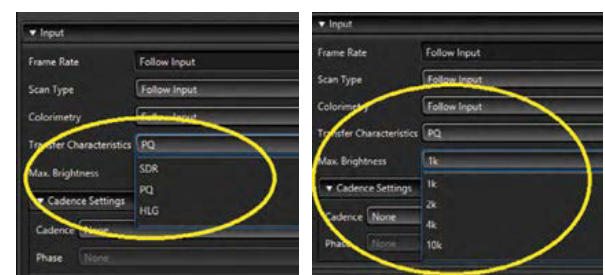


Figure 10: HDR selection for the input content

For HDR-to-HDR mappings, similar menus are available under the output controls to select the chosen format (see Figure 11).

A further choice is available in the output menu for HDR conversions in which the maximum supported output level is less than the source level. For these cases, clipping or limiting is applied (see Figure 12).

- Hard clipping means that high brightness levels not supported in the selected output format are hard-clipped to the maximum supported brightness level for that output format.

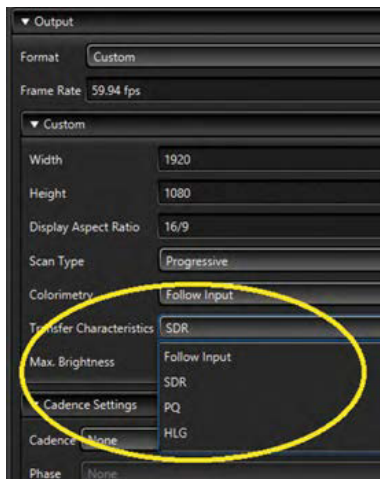


Figure 11: HDR selection for the output content

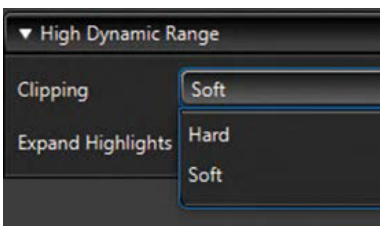


Figure 12: Hard/soft clip

- Soft clipping means that brightness levels close to the maximum supported levels in the selected output format are progressively attenuated to avoid an abrupt cut-off. A soft clip is an irreversible process.

HDR to SDR

For material that was mastered using HDR but is to be displayed on an SDR monitor, FrameFormer provides tools for HDR-to-SDR mapping. On the output menus, SDR should be selected (Figure 11). Doing so ensures that the FrameFormer software standards converter will carry out the correct mapping.

SDR to HDR

For content mastered in SDR but to be integrated into an HDR programme, FrameFormer offers SDR-to-HDR mapping. SDR should be selected from the Transfer Characteristic drop-down menu under the Input menu (Figure 10), and the required HDR format should be selected from the Transfer Characteristic drop-down menu under the Output menu (Figure 11).

FrameFormer offers a further menu option under High Dynamic Range, which is to allow the user to expand the highlights when mapping from SDR to HDR, as shown in Figure 13.

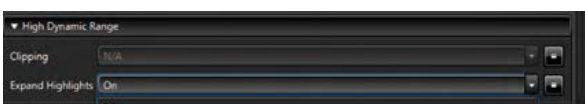


Figure 13: Expand highlights

Highlight expansion is explained in detail by the BBC in an April 2017 article[4]. In simple terms, the highlight expansion inverts the camera knee, which is a nonlinearity commonly applied during the camera-transfer function when the SDR content is acquired. This nonlinearity is applied because TV systems tend to operate within a smaller dynamic range than optical characteristics would allow. The camera knee compresses highlights

at the top of the dynamic range in order to be within the range of the TV system.

Because an HDR display can accommodate a much greater dynamic range than SDR, the BBC Highlights Expansion method allows all luminance values above a chosen breakpoint to be multiplied by a predefined parameter, which increases their value. This process expands the highlights back to more “normal” values with respect to midtones and shadows. As recommended by the BBC, FrameFormer uses a breakpoint of 80 percent of signal level and a multiplier of 2.0.

Using FrameFormer in SelenioFlex File

SelenioFlex File’s file-to-file media processing solutions seamlessly blend transcoding and workflow capabilities, supporting a comprehensive range of formats with superior quality for applications from post production and archive to multiscreen distribution. Built on the Imagine Communications Zenium pure microservices platform — an agile software engine that enables customizable foundational architectures — SelenioFlex File delivers a dynamic system management environment, allowing ready access to a catalog of features, functionalities, and licenses that are required at run time. This decision-based media processing workflow facilitates intelligent automation and exceptional scalability, and is easily managed from a single, intuitive, and consistent interface.

The FrameFormer software standards converter component for SelenioFlex File is a plug-in that enables content conversion from any frame rate and format to any other frame rate and format. Typical conversions will include UHD to HD downconversion and HD to UHD upconversion, as discussed in the applications above. Figure 14 shows the FrameFormer component in a typical workflow.

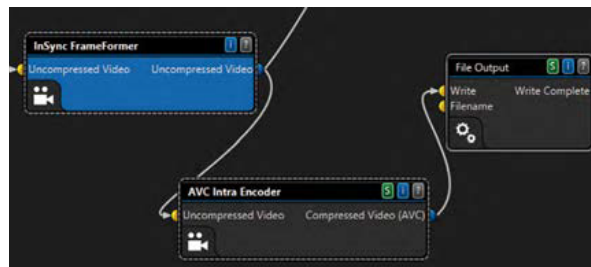


Figure 14: FrameFormer within a Zenium workflow

FrameFormer is available as a plug-in for popular editing software such as Final Cut Pro X or Adobe Premiere Pro on platforms such as Imagine Communications’ SelenioFlex File, or as a stand-alone application that can also be customised for integration into a bespoke workflow. www.insync.tv

References

- [1] Report BT.2408-1, “Operational practices in HDR television production,” April 2018, ITU.
- [2] Recommendation BT.2100-1, “Image parameter values for high dynamic range television for use in production and international programme exchange,” June 2017, ITU.
- [3] BBC R&D Projects website: <https://www.bbc.co.uk/rd/projects/high-dynamic-range>
- [4] Thomson S. “Conversion of conventional video for display on High Dynamic Range televisions,” SMPTE Motion Imaging Journal, April 2017, pp 23 – 28.