Encoding and displaying HDR content for cinema

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Introduction

The EclairColor project in its first phase is about bringing HDR images to a vast number of theaters in the world; we believe that a HDR technology must fit all cinemas: all movies, all screens, at reasonable cost so it can be broadly deployed.

From a content creation perspective, it is necessary to have a way to easily deliver multiple formats - for theaters, TV, OTT and mobile - as high and standard dynamic encodings.

Since Eclair provides theatrical delivery services, it would be unrealistic to create DCPs that are larger than the ones we deliver to theaters via satellite, broadband or hard drives. The amount of time required for delivery is shorter every day, therefore we need to work on the encoding/decoding of the images to keep the size of the DCPs reasonable, while keeping the quality pristine. We also need to use the current transport infrastructures for distribution.

To achieve these goals, we utilize proven technologies that are currently available and that provide an affordable, reliable and secure solution to the market: ACES color management and SMPTE DCP as a container.

HDR in the cinema

Originally, Digital Cinema offered a much better performance of image characteristics than TV: the sequential contrast ratio of a DLP projector could reach 2000:1 while LCD TVs would usually stay under 800:1.

Today, TV monitors use technologies such as dynamic backlighting of LCD displays, very high contrast OLED or Quantum Dots display that can achieve very high contrast, up to 1.000.000:1, while displaying DCI-P3 primaries or even Rec2020.

The next generation of cinemas, as a premium experience, should meet or exceed HDR TV performances. Currently available projectors allows for contrast of more than 6000:1, with Dolby Cinema claiming 1.000.000:1. Laser technologies also allows for use of a wider gamut of colors. These parameters have to be considered for a future-proof transport system.

State of the art

As for signal encoding and decoding, several options are available on the market:

DCI specifications

For image transport, digital cinema is using the specifications designed by the Digital Cinema Initiative workgroup. The DCI workgroup has issued these specifications in 2005 before the SMPTE created and developed the associated standards. These were the results of compromises largely based on technical performances and practices at that time.

The achievable color space chosen is larger than the one used by television at that time, known as Rec 709 color gamut. This new color gamut is called P3 and is using Red Green and Blue primaries than were achievable through filtering of the Xenon based lighting used for cinema projection.

The coding principle is based on the transmission of colors in the universal XYZ color space defined by CIE and by applying a transfer function in order to take advantage of the non-linear characteristic of the human visual perception.

The signal is encoded with an inverse gamma of 2.6, it is decoded with a transfer function that is a gamma curve of 2.6.

It is a proven system with great results for standard digital cinema, though it presents significant limitations in today's context:

- different technologies can have significantly different renderings of the same signal
- In the context of HDR, since most of the information sits in the regular tonal range, we need more codes in the dark luminance values
- Using X'Y'Z' encoding, which is useful to differentiate content from other RGB encoded content, but wastes a lot of code values.

ITU BT1886

ITU BT1886 was designed to provide better consistency across TV monitor rendering while showing SDR ITU Rec709 encoded content. It provides a way to consider the black level performance of the monitor and adapt its rendering to it.

Hybrid Log Gamma

HLG has been designed by the BBC and the NHK with the main purpose of carrying HDR information in SDR infrastructures.

SL-HDR1

A proposition by ST Microelectronics, Philips, CableLabs and Technicolor, SL-HDR1 relies on dynamic metadata to rebuild an HDR signal out of a SDR stream.

HDR10

The HDR10 Media Profile uses the SMPTE 2084 Perceptual Quantizer curve developed by Dolby Laboratories while using Rec2020 color space with a quantization over 10 bits.

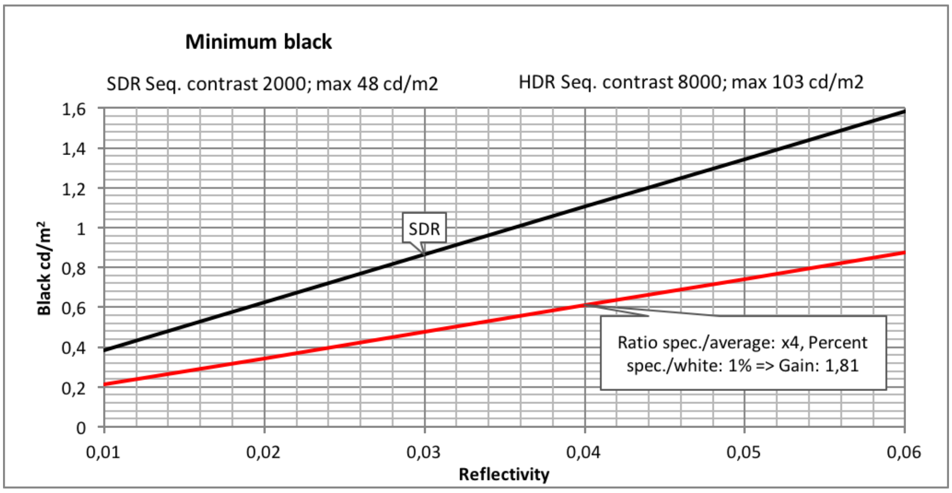
Dolby Vision

Dolby Vision is using a set of metadata on top of HDR10 to provide more details and address an even wider dynamic range. Using ICtCp color encoding it's capable of getting better encoding efficiency on compatible systems.

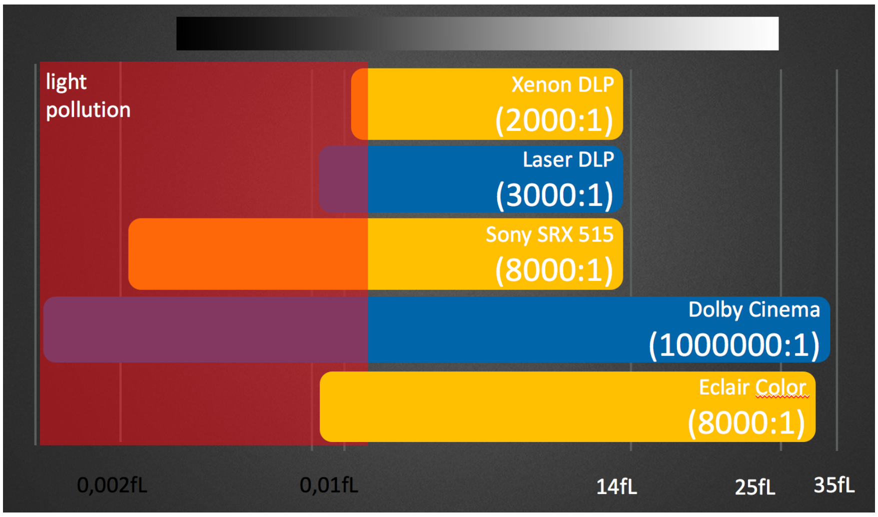
EclairColor

Mastering

EclairColor content is color graded with an HDR approach, which means that we keep diffuse white at a level comparable to the regular cinema standard (48 nits) and leave headroom for extra impact on specular lights, finer details like hair and textures, and also allow for more vivid colors as they can reach higher brightness. The peak white point is set to 103 nits (30 footlamberts), this value was chosen after testing, for the best compromise between peak brightness and the quality of black in a typical “optimized” theater environment. In purposely design theaters, better performance can be achieved for black level and reflectivity.



Black level in SDR vs HDR



Contrast ratio in theatrical environment

It is also important to keep the overall look consistent with the SDR version. Cinematographers don’t want to make another movie, they want to enhance details and get better emotional impact on what they consider the most important components in the image, by using more range for details in the highlights, the dark areas, and brighter colors. It is also important to consider that higher overall brightness of the picture can be problematic at 24 fps in a dark environment, showing stuttering effect. Using the ACES workflow, EclairColor is implemented through an Output Device Transform.

The most convenient way for the creative process is to start with the EclairColor version and then derive the SDR version. However, this is not always possible so we developed a remastering workflow used for catalog movies and movies color graded in other facilities. This process is validated by the client to make sure we fully respect the creative intent.

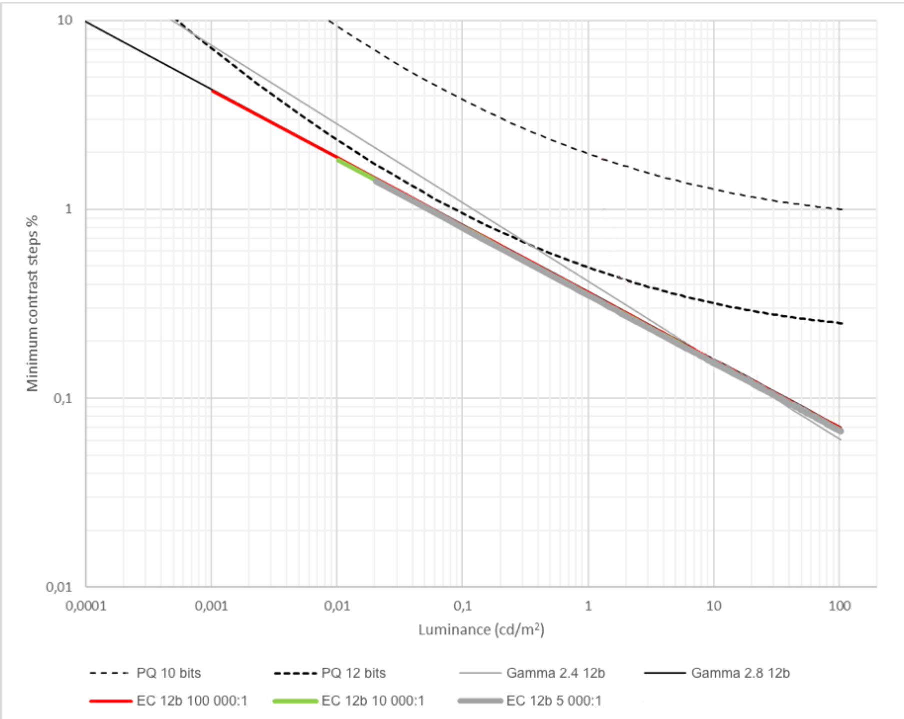
Signal encoding

In the context of EclairColor, we decided to comply with several constraints:

- Keeping the DCI infrastructure for delivery and playback of content
- Different projector technologies, with different sequential and intra-frame contrast ratio
- Potential for different mastering color gamuts (Rec709 to Rec2020)
- A peak white value set at 103 nits to allow for headroom while keeping a reasonable black value
- Higher brightness meaning more interaction with the room (reflectivity)
- Theaters optimized for HDR, but not necessarily built on purpose

We decided to use the SMPTE DCP and JPEG 2000 encoding, a robust platform for security and quality, as well as for metadata support.

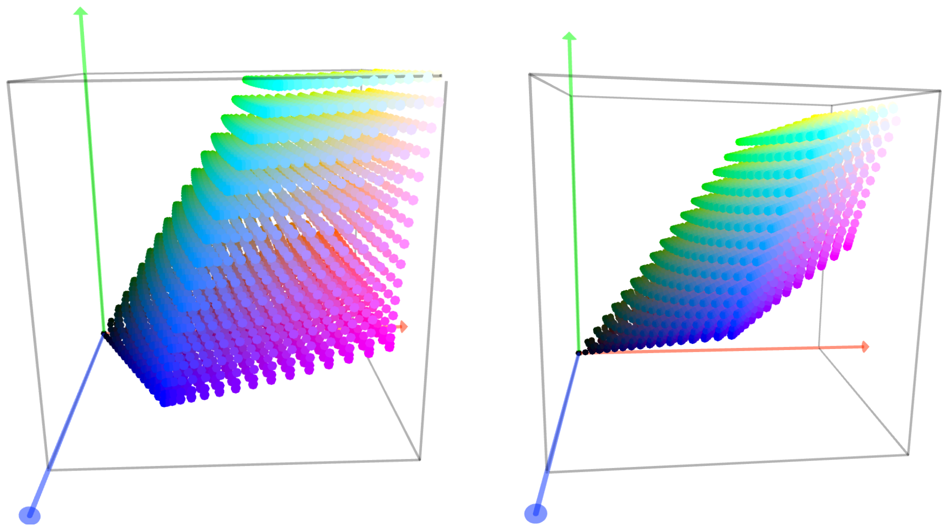
We chose gamma encoding, which has proven an efficient way to encode the image in the used dynamic range. The value of 2.8 gives sufficient codes in the dark areas while keeping the diffuse white about the same value as white in DCI (48 nits), which is a creative choice.



Measurement contrast steps in the theatrical dynamic range

Higher values and alternative curves tend to generate rounding errors in the dark areas, creating artifacts in JPEG encoding.

EclairColor use ACES AP1 primaries, which contains Rec2020 triangle but also other potential monochromatic primaries based color spaces while having a better usage of code values than X'Y'Z', resulting in smaller rounding errors. This results in better efficiency of the compression. We use the same virtual white point logic as DCI to allow for different creative white points.



DCI P3 encoded in ACES AP1 container (left) vs X'Y'Z' (right)

Signal decoding

For the electro optical transfer function, we took the logic of ITU BT1886 that provides a way to compensate for black performance, considering the variation in environment. We use a gamma of 2.8 in the equation and a reference peak white of 103 nits.

The rendering of the content would be using the EOTF as follow:

$$L_{proj} = \left(L_{pw}{}^{1/gamma} - L_b{}^{1/gamma}\right)^{gamma} (max[(V+b),0])^{gamma}$$

where :

b is given by $b = \frac{L_b{}^{1/gamma}}{L_{pw}{}^{1/gamma} - L_b{}^{1/gamma}}$

gamma is the power coefficient : 2.8

L_{pw} is the peak white of the projector: 103 nits

L_b is the black level of the room

L_{pw} is the luminance of peak white

L_{proj} is the luminance indicated by the output signal

V is the normalized by the input signal

This decoding allows for compensating the black level of the room. This makes the rendering of the image much closer to the original artistic intent and adaptable to the theater performance. It doesn't fully compensate for projector technology discrepancies, but the non-linearity of this parameter is comparable to the non-linearity of the room reflectivity, including attendance.

Conclusion

EclairColor is not only about HDR, it is meant to provide the moviegoer an experience as close as possible to what the creative team validated in the mastering room. To keep the EclairColor quality, theaters are certified by the validation of a set of specifications regarding room reflectivity. Constant monitoring and regular projector maintenance are also key in maintaining the quality of the big screen experience.

Contacts

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