LG-Cine Log White Paper

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Revision History

Document Version	Date	Comment
1.0	August 31, 2017	Initial release

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Tables

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1 What is LG-Cine Log?

LG-Cine log is a color profile which describes a high dynamic range and wide color gamut color space. It is designed to express the entire color volume of LG V30 with minimized loss. By using this profile, users can fully utilize the enhanced information in their color grading process. To import LG-Cine log footages correctly, dedicated scripts or LUTs are needed. The official files are released with this document.

Here are the brief characteristics of LG-Cine Log.

- 800% extended dynamic range toward the highlight compared to Rec. 709 [1]
- Able to handle the Rec. 2020 [2] color gamut
- Less color banding than other 8 bit log formats

2 Definition

LG-Cine Log is based on Rec. 2100 [3] with modifications on the OETF (Opto-Electro Transfer Function) and ICtCp matrix coefficients. The parameters and formulas are defined as follows. For details, refer to chapter 3.

2.1 Forward transformation

There are 4 steps to convert a scene-linear light X, Y, Z to a LG-Cine Log signal. Fig. 1 shows the block diagram of the process. Here, the formulas and coefficients of forward transformation are presented.

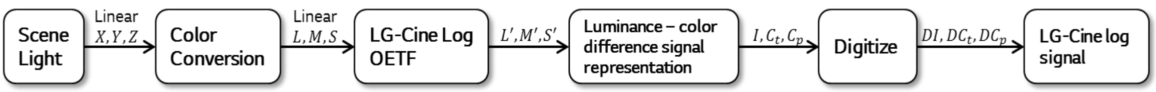

Figure 1. Foward transformation of the LG-Cine Log

2.1.1 Color conversion ($X, Y, Z \rightarrow L, M, S$)

$$\begin{pmatrix} L \\ M \\ S \end{pmatrix} = \begin{pmatrix} 0.359132 & 0.697604 & -0.03578 \\ -0.192188 & 1.10038 & 0.07554 \\ 0.006956 & 0.074916 & 0.84334 \end{pmatrix} \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}$$

2.1.2 LG-Cine Log OETF ($L, M, S \rightarrow L', M', S'$)

$$\{L', M', S'\} = \mathrm{OETF}(x),\ x = \{L, M, S\}$$

$$\mathrm{OETF}(x) = a \ln\left\{0.18 \exp\left(\log_2 \frac{x}{0.18}\right) + b\right\} + d$$

$$a = \frac{1}{9.4} \sim 0.1064$$

$$b = \frac{0.18}{\exp\left(\log_2 \frac{0.18}{8}\right)\{\exp(9.4) - 1\}} \sim 0.00355$$

$$d = -a \ln b \sim 0.6$$

2.1.3 Luminance and color difference signal representation ($L', M', S' \rightarrow I, C_t, C_p$)

$$\begin{pmatrix} I \\ C_t \\ C_p \end{pmatrix} = \begin{pmatrix} 0.5 & 0.5 & 0 \\ -0.3157 & -1.163242 & 1.478943 \\ 3.887175 & -4.103326 & 0.216151 \end{pmatrix} \begin{pmatrix} L' \\ M' \\ S' \end{pmatrix}$$

2.1.4 Digital representation ($\boldsymbol{I, C_t, C_p \rightarrow DI, DC_t, DC_p}$)

$$DI = \mathrm{MIN}[I \times (2^n - 1), 2^n - 1]$$
$$DC_t = \mathrm{MAX}\left[0, \mathrm{MIN}[C_t \times (2^{n-1} - 1) + 2^{n-1}, 2^n - 1]\right]$$
$$DC_p = \mathrm{MAX}\left[0, \mathrm{MIN}\left[C_p \times (2^{n-1} - 1) + 2^{n-1}, 2^n - 1\right]\right]$$
$$\mathrm{n} \geq 8$$

2.2 Inverse transformation

To obtain the scene-linear light X, Y, Z from a LG-Cine Log signal DI, DC_t, DC_p, apply the following steps.

2.2.1 Inverse of digital representation ($\boldsymbol{DI, DC_t, DC_p \rightarrow I, C_t, C_p}$)

$$I = \frac{DI}{(2^n - 1)}$$
$$C_t = \frac{DC_t - 2^{n-1}}{(2^{n-1} - 1)}$$
$$C_p = (DC_p - 2^{n-1})/(2^{n-1} - 1)$$

2.2.2 Inverse of luminance and color difference signal representation ($\boldsymbol{I, C_t, C_p \rightarrow L', M', S'}$)

$$\begin{pmatrix} L' \\ M' \\ S' \end{pmatrix} = \begin{pmatrix} 1 & -0.018579 & 0.127119 \\ 1 & 0.018579 & -0.127119 \\ 1 & 0.686805 & -0.072848 \end{pmatrix} \begin{pmatrix} I \\ C_t \\ C_p \end{pmatrix}$$

2.2.3 Inverse of LG-Cine Log OETF ($\boldsymbol{L', M', S' \rightarrow L, M, S}$)

$$\{L, M, S\} = \mathrm{OETF}^{-1}(X), \ X = \{L', M', S'\}$$
$$\mathrm{OETF}^{-1}(X) = 0.18 \times 2\text{^} \left(\frac{\exp\left(\frac{X - d}{a}\right) - b}{0.18} \right)$$

2.2.4 Inverse of color conversion ($\boldsymbol{L, M, S \rightarrow X, Y, Z}$)

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} 2.070508 & -1.326704 & 0.206681 \\ 0.365025 & 0.680458 & -0.045464 \\ -0.049504 & -0.049504 & 1.188095 \end{pmatrix} \begin{pmatrix} L \\ M \\ S \end{pmatrix}$$

3 Technical description

In this chapter, additional information of LG-Cine Log is provided.

3.1 Color primaries

LG-Cine Log uses the same LMS color primaries of Rec. 2100 (Hunt-Point-Estevez LMS color primaries normalized to a D65 white point [4] [5]). Since LG-Cine Log is targeted for use in camera, its color conversion matrix is defined to convert from X,Y,Z color primaries instead of R,G,B color primaries.

3.2 Transfer function

LG-Cine Log OETF has an input range of 0~8 and an output range of 0~1. The shape of OETF is presented in Fig. 2, compared to sRGB [6] and Rec. 709. The maximum input limit is extended to 800% while the output level of the middle gray (18% reflectance) is kept similar to Rec.709 (41.97%).

3.3 Luminance and color difference signal representation

LG-Cine Log uses an ICtCp type representation instead of a generic YCbCr representation. The matrix coefficients are modified from the original Rec. 2100 to fully cover the Rec. 2020 color gamut. The parameter differences of Rec. 2100 and LG-Cine Log are represented in Table 1. For details on alpha and scalar, see [7]. Fig. 3 shows the color gamut coverage of LG-Cine Log. It is notable that the LG-Cine Log covers the entire Pointer's gamut [8].

Table 1. Parameter differences of Rec. 2100 vs LG-Cine Log

Parameter	Rec. 2100	LG-Cine Log
alpha	$65°$	$83°$
scalar	$\begin{pmatrix} 1 & 1 & 1 \\ 1.4 & 1.4 & 1.4 \\ 1 & 1 & 1 \end{pmatrix}$	$\begin{pmatrix} 1 & 1 & 1 \\ 1.23 & 1.23 & 1.23 \\ 0.86 & 0.86 & 0.86 \end{pmatrix}$

3.4 Digital representation

LG-Cine Log uses the so-called full range format. By using a full range format, the banding effect can be reduced compared to using a narrow range format. The minimum bit depth is 8 bit. 10 bit or 12 bit representations are also allowed for future use.

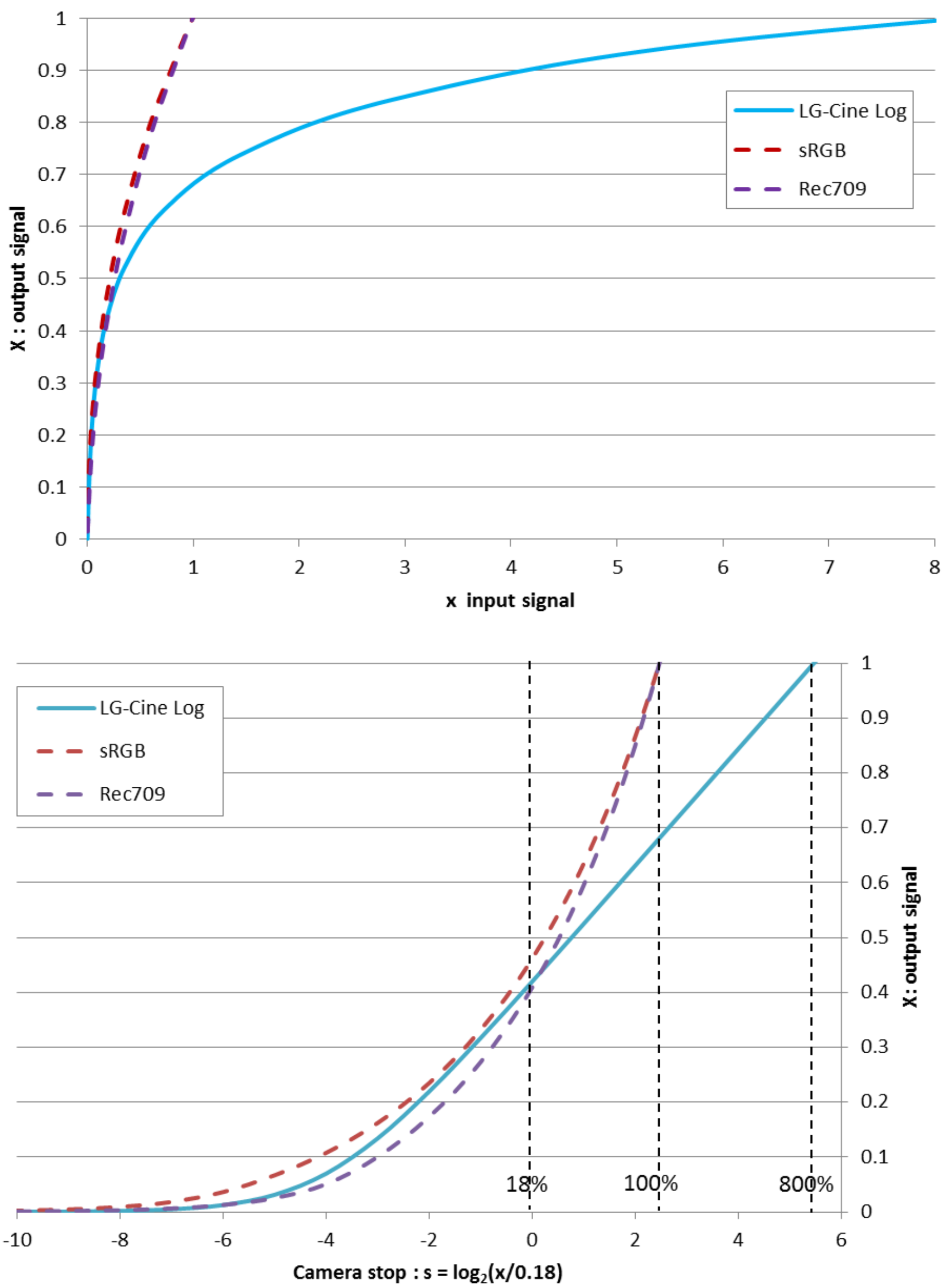

Figure 2. LG-Cine Log OETF. A linear-linear plot (top) and a camera stop-linear plot (bottom)

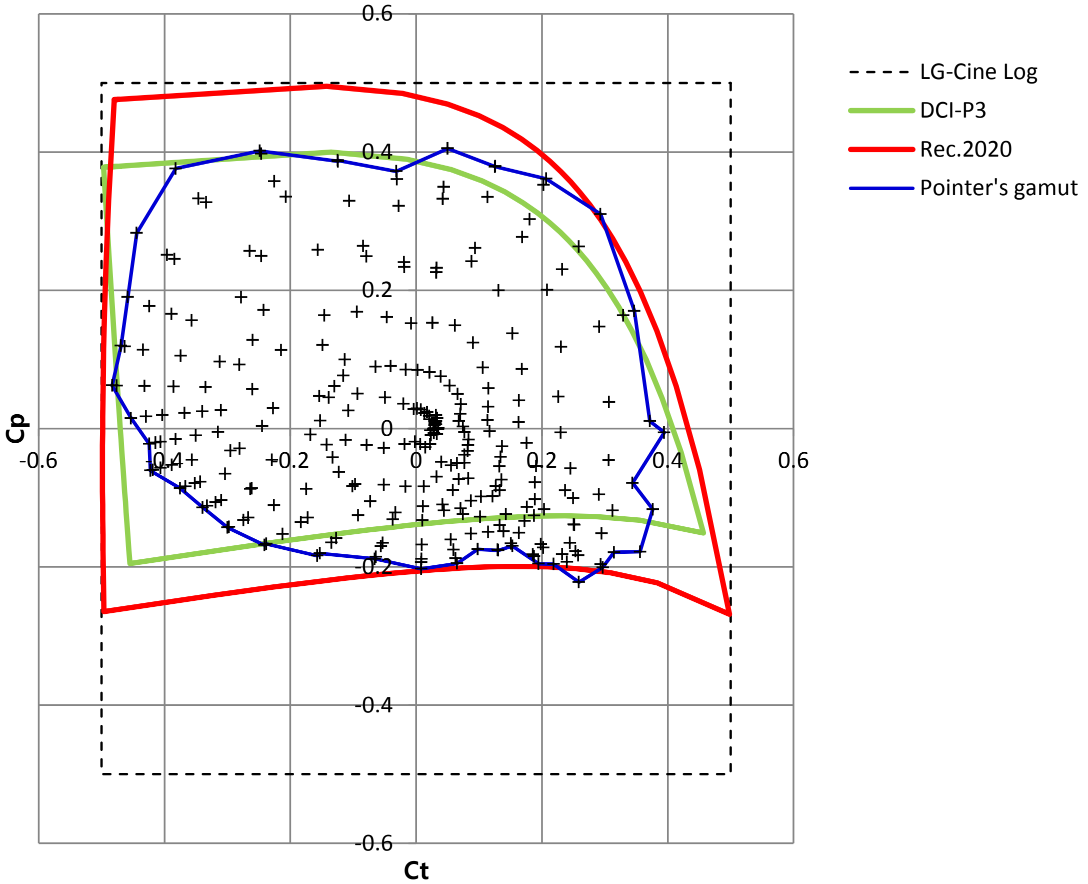

Figure 3. Gamut coverage of LG-Cine Log plotted on Ct-Cp plane

4 LG V30 implementation

This chapter explains the LG-Cine Log feature implemented in LG V30.

4.1 How to shoot

LG Cine-Log videos can be taken using the “Manual Video” mode of LG V30. Before the shooting, activate the “Save as LG-Cine Log” option in the setting menu.

4.2 Display LUT

When recording a log video on LG V30, a display LUT can be applied on the preview. By clicking the icon on the upper right corner, it is able to turn the LUT on and off.

When the display LUT is activated, it shows a Rec. 709 compatible look on the screen. To display the highlight area, a knee is applied on the LUT. This conversion is applied only on the preview, not on the saved file.

When the display LUT is not activated, it will show a unique LG-Cine Log look. Thanks to the ICtCp representation, the color is not much de-saturated like other log profiles. For this reason, it is easier to check the saturation of the highlight regions. The look comparison is shown on Fig. 4.

Figure 4. Look comparison of LG-Cine Log (left) and Rec. 709 (right)

4.3 File format

Table 2 represents the file format information of the LG-Cine Log videos recorded on LG V30. A dummy color space information "Rec. 601 [9] Full range" is inserted on the VUI metadata to avoid possible data loss.

Table 2. File format information

Item	Setting
Codec	AVC (H.264)
Bit depth	8 bit
Chroma subsampling	4:2:0
Color space metadata	Rec. 601 Full range

4.4 MPEG4 header

To distinguish the LG-Cine Log video files from other video files, the string "LG LP" is inserted on the "moov/udta" metadata of the MPEG4 header.

4.5 Avoiding "ghost" artifacts

Since LG V30 extends the dynamic range by combining long-exposure and short-exposure images, "ghost" artifacts can be seen when shooting dynamic scenes, especially using manual exposure settings. If the "ghost" becomes problematic, shortening the exposure time (e.g. set to under 1/120s) or increasing the ISO sensitivity would help to minimize the effect. Meanwhile, when using auto-exposure setting, the LG Cinema AE algorithm will choose optimized (least-artifact) pairs automatically.

4.6 Using light meter

Since the ISO value shown on the preview is not based on specific standards, caution is required when using a light meter. Although it may vary among light sources, +1 EV difference would happen if a light meter with k=1.3 (or K=14.03) is used. A possible solution is to add +1 EV offset on the light meter setting.

4.7 Image Processing

The LG-Cine Log video acquired from LG V30 is not a raw video stream. To enhance the overall quality, video processing (e.g. noise reduction) is applied. However, the detail enhancement is kept to minimum for usage afterward in post-production processes

5 For use in post-production

The LG-Cine Log videos can be utilized in post-production workflows including color grading processes. Its capability was tested with a digital intermediate studio, Dextor The Eye [10]. The color-grading results were applied to the "Cine video" mode of LG V30 as 15 kinds of "Cine effects".

In this chapter, additional advices on processing of LG-Cine Log videos are presented.

5.1 Official 3D-LUTs and scripts

To import LG-Cine Log videos correctly, dedicated 3D-LUTs (Look-Up Tables) or scripts are needed. It is available to download those files from the official website.

5.2 Selecting working color space

Since LG-Cine Log is designed for use as an input color space, it is recommended to perform color grading after converting the signals to another working color space. Selecting a narrow color space (e.g. Rec. 709) as the working color space may limit the flexibility. To maximize the flexibility, selecting a working color space greater than LG-Cine Log would be preferable. The ACES [11] is one of the promising choices.

5.3 Creating custom input LUTs

It is needed to consider the matrix mismatch when creating custom input LUTs or scripts. As defined in chapter 2, LG-Cine Log requires the dedicated ICtCp-type inverse matrix. However, in many systems, setting custom inverse matrix is not allowed. Those systems convert LG-Cine Log signals to RGB signals using their particular YCbCr-type inverse matrix, e.g. Rec. 709 narrow range matrix. This matrix mismatch problem can be solved by inserting an additional matrix in the first step of the conversion. Figure 5 shows an example flow. In this case, to cancel the mismatch, "Rec. 709 YCbCr conversion matrix" is inserted.

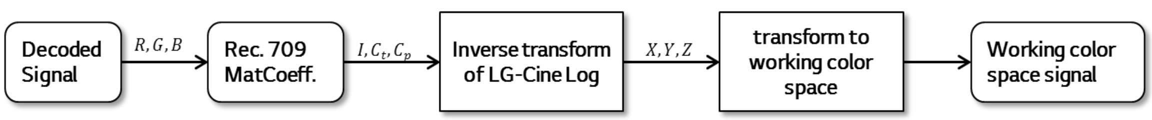

Figure 5. Example flow of converting a LG-Cine Log signal to a working color space signal

6 References

[1] International Telecommunication Union (ITU), “Parameter values for HDTV standards for production and international programme exchange,” *Recommendation ITU-R BT.709-6,* 2015.

[2] International Telecommunication Union (ITU), “Parameter values for ultra-high definition television systems for production and international programme exchange,” *Recommendation ITU-R BT.2020-0,* 2012.

[3] International Telecommunication Union (ITU), “Image Parameter values for high dynamic range for use in production and international programme exchange,” *Recommendation ITU-R BT.2100-0,* 2016.

[4] M. D. Fairchild, Color Appearance Models 2nd Edition, John Wiley & Sons Ltd, 2005.

[5] Dolby, “ICtCp Dolby White Paper,” Version 7.2, 2016.

[6] M. Stokes et all, "A Standard Default Color Space for the Internet - sRGB," Version 1.10, 1996.

[7] Dolby Laboratories, Inc, “Subsampling in ICtCp vs Y’Cb’Cr’,” 2016.

[8] M.R.Pointer, “The Gamut of Real Surface Colors,” *Color Research and Application 5,* 1980.

[9] International Telecommunication Union (ITU), “Studio encoding parameters of digital television for standard 4:3 and wide-screen 16:9 aspect ratios,” *Recommendation ITU-R BT.601-7,* 2011.

[10] Dextor studio, [Online]. Available: http://dexterstudios.com.

[11] SMPTE, “Academy Color Encoding Specification (ACES),” *ST 2065-1,* 2012.

7 Appendix

7.1 Derivation of LG-Cine Log OETF

Most log-type OETFs can be written as follows.

$$f(x) = a\log_2(x+b) + d \quad \text{(Equation 1)}$$

In contrast, LG-Cine Log OETF is based on a different formula, presented below.

$$f(s) = a\log_c(0.18c^s + b) + d \quad \text{(Equation 2)}$$

$$s = \log_2\left(\frac{x}{0.18}\right)$$

Eq. 2 is an expansion of Eq. 1, because it includes Eq. 1 as a special case when $c = 2$. By examining the limits of the camera stop domain, the implication of Eq. 2 can be made clear. When $s \to -\infty$ ($\because\ c^s \to 0$) and when $s \to +\infty$ ($\because\ 0.18c^s \gg b$),

$$s \to -\infty : f(s) = a\log_c(b) + d = \text{Const}$$
$$s \to +\infty : f(s) = a\log_c(0.18c^s) + d = as + \text{Const}$$

Therefore, Eq. 2 can be understood as a combination of two linear functions moderated by the parameter c. By changing c, it is able to change the curvature of the log OETF.

The parameters of LG-Cine Log OETF are determined as follows.
Firstly, a and c are given parameters.

$$a = 1/9.4,\ c = \exp(1)$$

b and d are derived using two boundary conditions.

$$f(x \to 0) = 0 \quad \rightarrow a\log_c b + d = 0\ ,\ \therefore d = -a\log_c b = -a\ln b$$

$$\begin{aligned} f(x = 8.0) = 1.0 \rightarrow\ & a\log_c\left\{0.18c^{\log_2\frac{8.0}{0.18}} + b\right\} + d \\ &= a\log_c\left\{0.18c^{\log_2\frac{8.0}{0.18}} + b\right\} - a\log_c b \\ &= a\log_c\frac{0.18c^{\log_2\frac{8.0}{0.18}} + b}{b} = 1.0 \end{aligned}$$

$$\therefore b = \frac{0.18c^{\log_2\frac{8.0}{0.18}}}{c^{1/a}-1} = \frac{0.18}{c^{\log_2\frac{0.18}{8.0}}(c^{1/a}-1)} = \frac{0.18}{\exp\left(\log_2\frac{0.18}{8}\right)\{\exp(9.4)-1\}}$$

7.2 LG V30 dynamic range test

The dynamic range test results are shown in Fig. 5. The images were captured with 6 cameras under the condition of various luminous intensity from -5 stop to +5 stop, while the exposure was fixed. As for the ISO settings, the minimum (or recommended) settings were used. For log-encoding capable cameras, Rec. 709 default LUTs of each maker were used to display. This result shows that LG V30 has the dynamic range extended toward the highlight, more than +2 stop compared to conventional SDR smartphone cameras.

Figure 6. Dynamic range test of 6 cameras including LG V30