S-Log: A new LUT for digital production mastering and interchange applications

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1. Introduction

Color correction tools, file formats, and capture devices are increasingly processing linear, high-dynamic range, color-component data, which is often stored in high-precision floating point formats. However, a wide variety of existing imaging and video formats as well as processing tools are designed to work with 10 / 12 bit integer data. A newly proposed look-up table, the S-Log LUT, is an attempt to bridge these worlds.

S-Log is a gamma function applied to Sony's electronic cinematography cameras, in a manner that digitally originated images can be post-processed with similar techniques as those employed for film originated materials. Since S-Log can reproduce the entire tonal range captured by a CCD or CMOS imager, the S-Log image can be described as the "Digital Negative" of the image acquisition process. Shooting in S-Log will enable the cinematographer to decide the exposure value by using a light meter, and offer a smooth transition from film acquisition to digital acquisition.

This paper will describe the technical characteristics of the S-Log Look Up Table for the handling of S-Log encoded camera original material in a Cine-based, 'film-centric', Digital Intermediate post production workflow.

2. S-Log Characteristics

The S-Log gamma function is optimized for digital motion picture cameras. This logarithmic curve was carefully designed by analyzing the noise floor characteristics and the tonal reproduction of the imaging device. Since negative film stock and the CCD or CMOS imager behave differently to incoming light, especially in the low-light and high-light region, the S-Log curve differs from log curves designed for film based images. CCD or CMOS imagers respond to incoming light in a far more linear fashion than film, thus there are no "toes" or "shoulders".

The S-Log curve provides sufficient quantization bits to offer exceptional tonal reproduction in both the low-light and high-light region. The appearance on a monitor is also taken into consideration, so that an S-Log image could be viewed acceptably using an appropriate display Look Up Table (LUT) (Film Print Emulation and/or S-Log to Rec. 709).

When shooting in S-Log, as distinct from ITU-R BT. 709 (Rec. 709) video gamma, a color grading process ('look management') is mandatory to establish a desired reference 'look' (color contrast) for dailies and editorial. This color graded 'look' should be related to a target output display, e.g., film print projection, or digital cinema projection. When viewing S-log encoded images on an HD reference monitor that are ultimately intended for cinema release via film print or D-Cinema projection, a display LUT should be applied that emulates film print or digital cinema color and contrast range within the constraints of the video monitor's gamut and contrast. Using the traditional photo-chemical analogy, S-Log is the "camera negative" and the final look of the "release print" and DCP (Digital Cinema Package) is ultimately defined during the final color grading in the Digital Intermediate, post production process.

When converted to a DPX Log File for a Digital Intermediate post workflow, S-Log encoded images require the transform function of an Input Conversion Transform (ICT) to adjust the slope/shape of its 'gamma curve' to be compatible with Cineon Print Density specifications, since the latter are based on scanned film negative as input source. This adjustment is necessary so that a film print emulation LUT can be applied, non-destructively, to S-Log encoded images for the final color grading intended for theatrical release.

Three examples of ICTs are:

- ASC CDL functions which include "Power" (gamma), "Offset" (lift), and "Slope" (gain). See overview description of ASC-CDL in appendix 7.2 of this paper.
- Sony LUT ('Kawada LUT' - 10bit S-Log to 12bit Cineon, as shown in Fig. 5 of this document). The purpose of this LUT is to conform S-Log DPX files to Cineon print density values for compatibility with a film print emulation display LUT for color grading.
- Image processing tool-sets internal to a color corrector as an ICT.

3. S-Log in Production

When capturing a wide dynamic range of scene tones is the priority, the recommended exposure index for the F35 (Sony's 35mm digital motion picture camera) is 500 ISO (MASTER GAIN 0dB). In order to achieve the widest dynamic range, the camera need to be set to Cine Mode (EXTEND mode) with S-Log. In this seating, the camera will resolve 5.3 T-stops of scene luminance above 18% neutral gray (800% in video terms) and 6.8 T-stops of scene luminance below 18%. See table 1 below.

Table 1 F35 Dynamic Range in Cine Mode

ISO	S/N	Exposure Latitude over18%	Exposure Latitude below 18%	Total Latitude (Dmin to Dmax)
450	54.5dB	+5.3 Stop	-6.8 Stop	12.1 Stops
500	53.6dB	+5.5 Stop	-6.6 Stop	12.1 Stops
640	51.5dB	+5.6 Stop	-6.3 Stop	11.9 Stops

Selecting the (EI) Exposure Index (ISO) setting for the F35 configured in Cine Mode S-Log

The selection of an optimal EI (ISO) setting for the F35 configured in Cine Mode S-Log is based on ensuring that a dynamic range of up to 12 stops of scene tone scale exposure values (scene luminance range from minimum shadow detail to maximum highlight detail carefully measured with a properly calibrated photometric spot meter) can be effectively captured ("Dmin" to "Dmax").

In general, an EI of 500 ISO should be used, but an EI of 640 ISO can also be effectively used as a ⅓ stop exposure latitude margin to further ensure that a scene's brightest highlight luminance(s) will be protected from possible clipping due to a potential error in spot meter reading and/or calibration drift of the photometer. Since the F35 configured in S-Log Cine Mode has greater exposure latitude under 18% (6.8 T-stops), reproduction of scene luminance(s) representing minimum shadow detail can be captured using an EI of 640 ISO without clipping.

Using Input Conversion Transform (ICT) to adjust S-Log gamma function to Cineon

When shooting in S-Log Cine Mode, actual digital code values that represent scene tone scale values do not directly correspond with code values that are calculated when using a conventional photographic exposure meter (which assumes film density code values). Such discrepancy between the recorded "density" and the exposure meter readings are caused by the characteristics of the S-Log digital gamma function, which is different from the film gamma function. When an appropiate ICT LUT is applied during on-set look management and/or in the post production process, the discrepancy will diminish. The basic characteristic of the S-Log gamma function (without ICT LUT treatment) is shown in Fig.1 and Table 2.

Fig. 1 Characteristic curve of S-Log

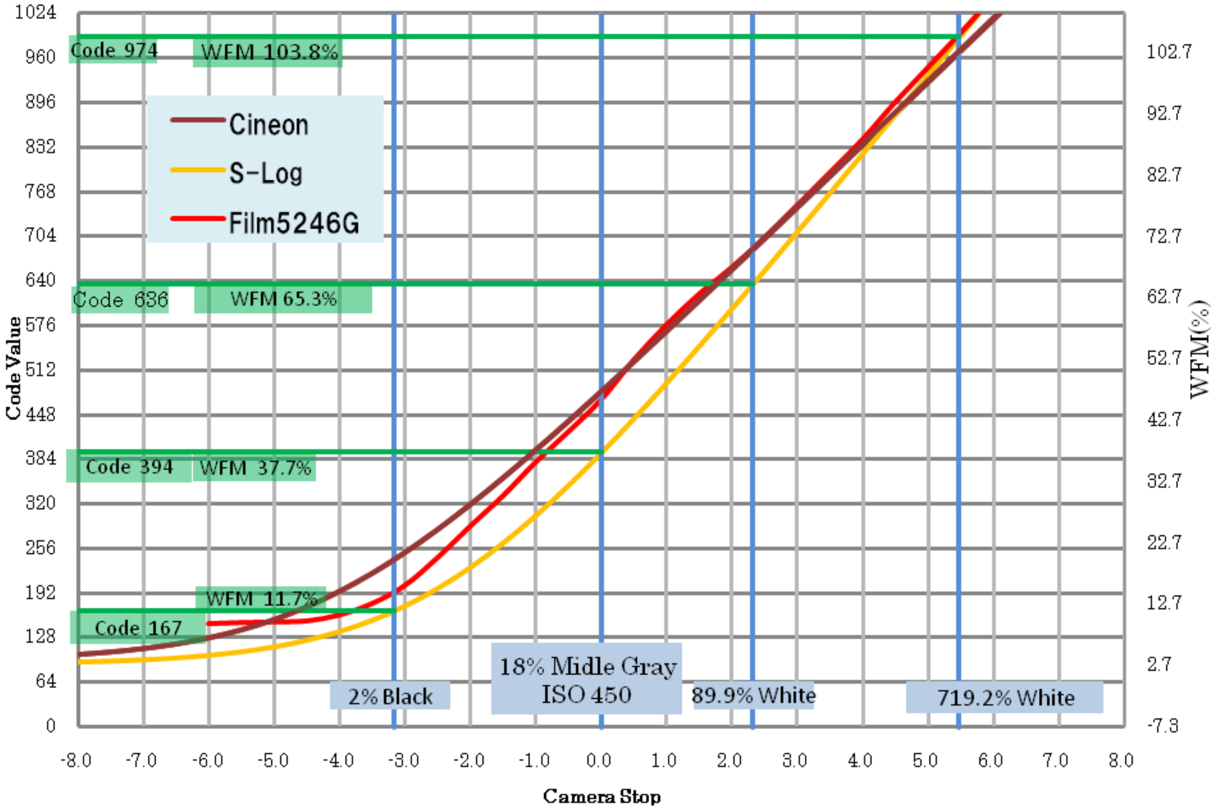


Table 2 S-Log Code Values

Chart Reflection (%)	ISO450 Video Input (%)	ISO450 Waveform Monitor (%)	ISO500 Video Input (%)	ISO500 Waveform Monitor (%)	ISO640 Video Input (%)	ISO640 Waveform Monitor (%)	Code Value
0.00	0.00	3.0	0.00	3.0	0.00	3.0	90
2.00	2.22	11.7	2.00	11.01	1.56	9.53	167
18.00	20.02	37.7	18.02	36.01	14.08	32.26	394
89.90	100.00	65.4	90.00	63.45	70.31	59.02	636
719.20	800.00	103.8					974
799.11			800.00	103.8			974
1022.86					800.00	103.82	974

Table 3 Cineon Code Values

Reflection (%)	Code Value
2	220
18	470
90	685

3.1 Changing the Sensitivity (Push Process / Pull Process)

The most common method is to adjust the MASTER GAIN of the camera as shown in Table 4. The image contrast that appears on camera viewfinders and the on-set displays will remain consistent, hence it is easier to monitor.

Table 4 F35 Sensitivity

MASTER GAIN	-6dB	-3dB	0dB	3dB
Latitude	400%	550%	800%	800%
Camera Stop	4.3	4.8	5.3	5.3

3.1.1 Normal Sensitivity

F35: ISO 500 Cine Mode, MASTER GAIN 0dB

3.1.2 Push Process

Increasing camera gain will improve camera sensitivity but will increase the camera noise floor. When extra dynamic range is required, the exposure value should be defined according to the light meter readings as in film.

3.1.3 Pull Process

Reducing the camera gain will improve the signal to noise ratio performance. This technique is suited for blue/green screen effects shots where pulling a clean key is of prime importance. It should be noted that the camera dynamic range will be reduced.

Chart 1. Comparing the Differences in Effects of Push/Pull Processing between S-Log and film

	Push Processing (+ve)			Pull Processing (-ve)		
	Contrast	**Latitude**	**Graininess**	**Contrast**	**Latitude**	**Graininess**
Film	Increases	Narrows	Increases	Reduces	Widens	Decreases
S-Log	No changes	No changes	Increases	No changes	Narrows	Decreases

3.2 On-set Monitoring

3.2.1 Camera Viewfinder

The camera viewfinder should be used for composition/framing only since it is not suitable for the display of reference quality images. Depending on the camera operator's preference, the viewfinder can display the S-Log images with no viewing LUT applied if the full dynamic range is to be seen while checking the camera framing and the acting performance. The viewfinder can also be set for a more 'normalized' contrast by using a display LUT if that is more important for accuracy of scene composition/framing.

3.2.2 Monitoring with the BVM-L230 and BVM-L231

For the director and/or the DP, the S-Log output signal can be fed to a Sony LCD master monitor (BVM-L series), or, the camera (processed) monitoring output signals can be fed to conventional (ITU-R BT.709) monitors.

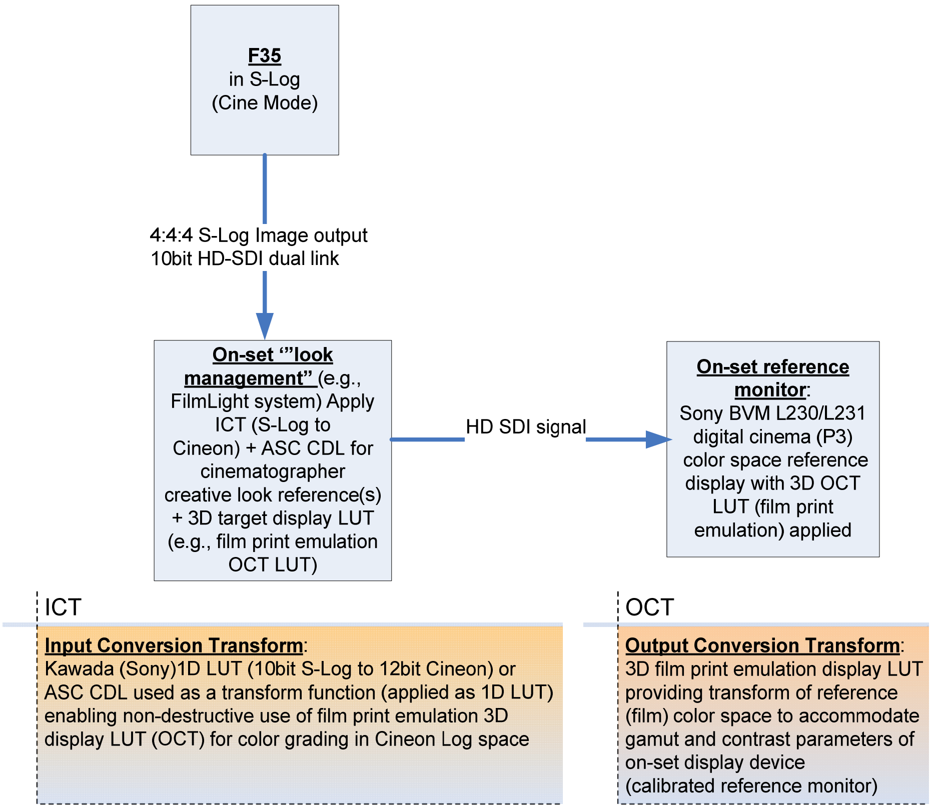
The BVM-L230 and BVM-L231 are equipped with two gamma function settings to monitor S-Log input signals. "S-Log Standard" converts the reflectance level of 90% gray to the BVM-L`s luminance level of 100%. The look of the image will be similar to that of video assist systems integrated into film cameras. The BVM-L230/L231 can reproduce highlights up to x1.32 times of 90% gray; however any further highlight information will be clipped. The overall image contrast will look close to how the human eye sees.

The "S-Log FULL" mode displays the full latitude (0% – 800%) of the S-Log signal. This setting should be selected when there is a need to check the entire dynamic range of the image that is being captured. Note that the displayed image will appear very dark on the BVM-L230/L231 as the camera's entire latitude is mapped within the monitor's 100% level.

3.2.3 Display LUT for on-set look management of image reference monitoring

For on-set look management reference monitoring (e.g., BVM-L231 or BVM-L230) of S-Log image output from the camera, a display LUT (Output Conversion Transform) should be applied to adjust contrast and color reproduction (within the gamut and contrast parameters of the on-set reference monitor) to more closely match the output of primary target display devices, i.e., Digital Cinema projection and Film Print Projection. See figure 3. It is important to note that creative looks made with an on-set look management system are intended as metadata look references for on-set display purpose only and should not be 'baked into' the original S-Log image capture. These on-set creative metadata look references can be applied to proxy images (of the original image capture) that are intended for dailies viewing and editorial.

Fig. 3 S-Log On-set Look Management workflow with ICT and viewing LUT (OCT) applied to target output display



4. S-Log material in Post production

Images captured in S-Log can be processed in various ways. The choice of the post production workflow depends on the final output of the project (TV, Film out, Digital Cinema release, & etc.), availability of the tool set, the viewing environment, preference of the colorist, and so on. When running a camera test, it is highly recommended to pay enough attention to the post production process, since it can significantly alter the test result. This paper addresses the way to handle extended range (Cine Mode) S-Log camera original material in a Cine-based (Cineon) 'film-centric' Digital Intermediate post production workflow designed for cinema release on both print film and digital cinema (DCP).

4.1 Working with S-Log in CINEON space

Very similar to how film based materials are scanned, ingested, and processed in Cineon Log space today, S-Log material can be directly processed by color grading systems that are capable of handling Cineon LOG based DPX image data files (see fig. 4) by first applying an Input Conversion Transform (ICT) function, e.g., Sony S-Log to Cineon LUT (see fig. 5) or another "pre-set" ICT LUT (the ASC CDL "Power", with optional "Offset" and "Slope" function(s) or by applying an internal color corrector transform), to conform S-Log gamma slope/shape for compatibility with the Cineon print density log curve. Since the resulting S-Log gamma characteristics with the appropriate ICT applied are very close to those of camera negative stocks, color grading can be performed by using a color corrector in a manner similar to a scanned film negative. This is a non-destructive process, where the S-Log camera original material will not be processed / rendered until the final color grading process has been approved. In order to make color grading decisions, an appropriate output display LUT for film print emulation, i.e. an Output Conversion Transform (OCT), needs to be applied within the system.

A film print emulation display LUT converts the S-Log DPX materials to film print color space and contrast.

LUT's can be applied within compositing tools such as the Autodesk Inferno system, in addition to the most frequently used color corrector systems, i.e., Autodesk Lustre, Quantel Pablo, Filmlight Baselight, DaVinci 2K, Resolve and Digital Vision Film Master.

Fig. 4 S-Log Workflow from Image Capture through DI

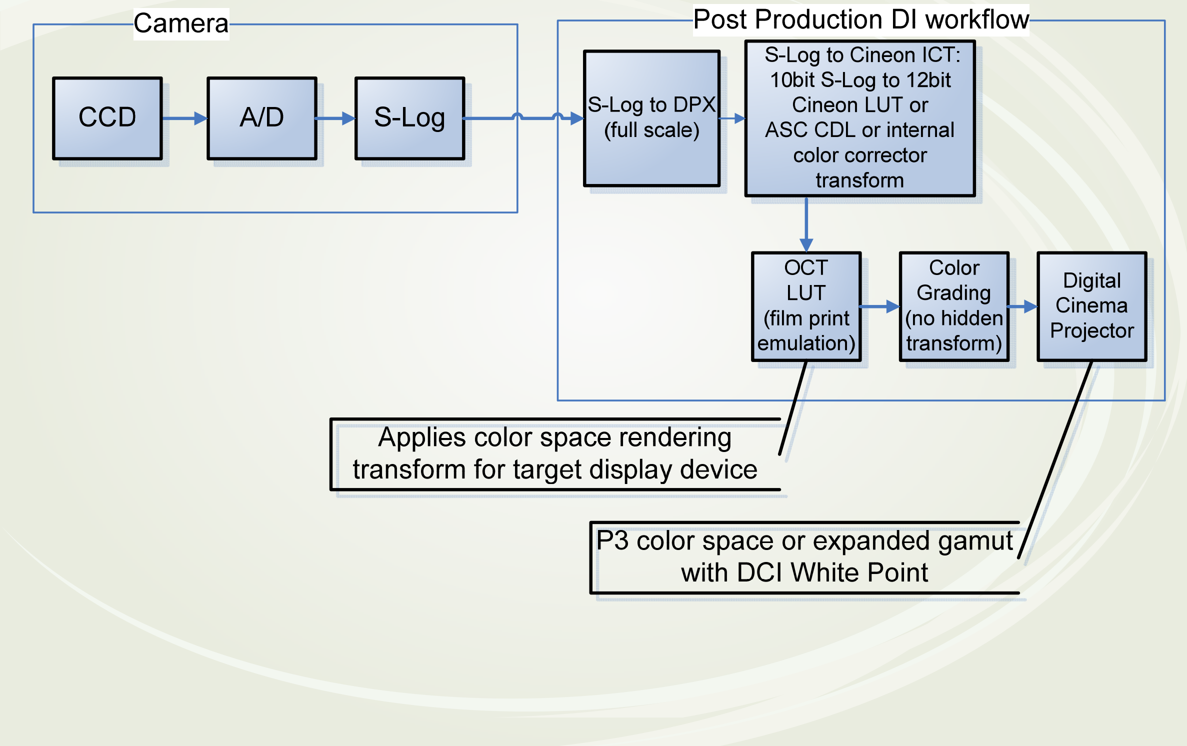
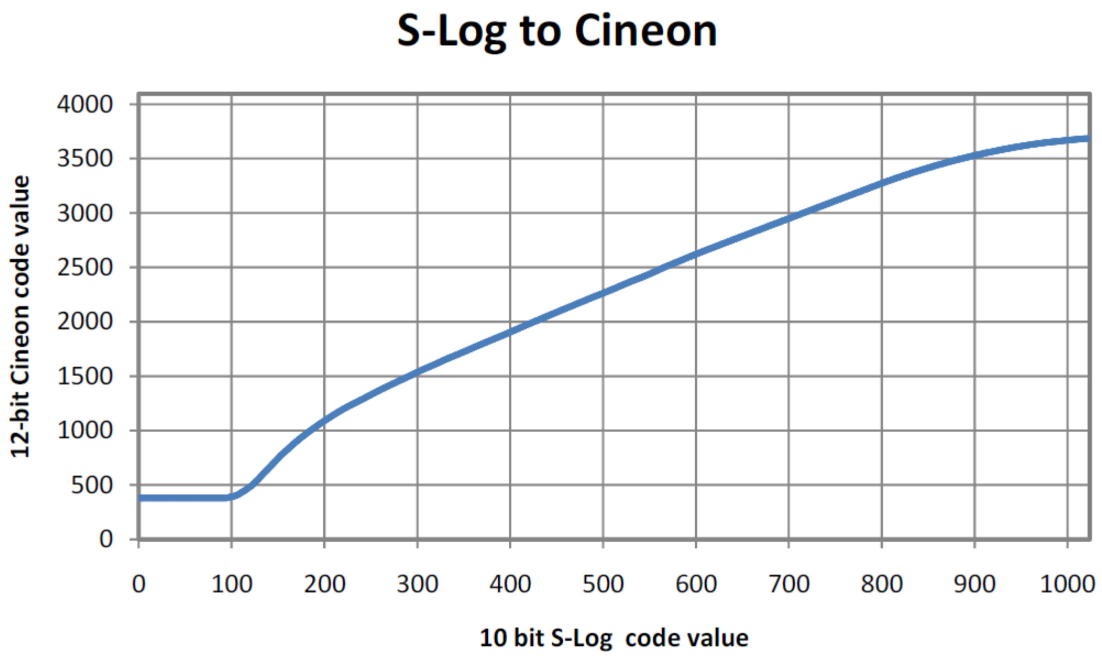


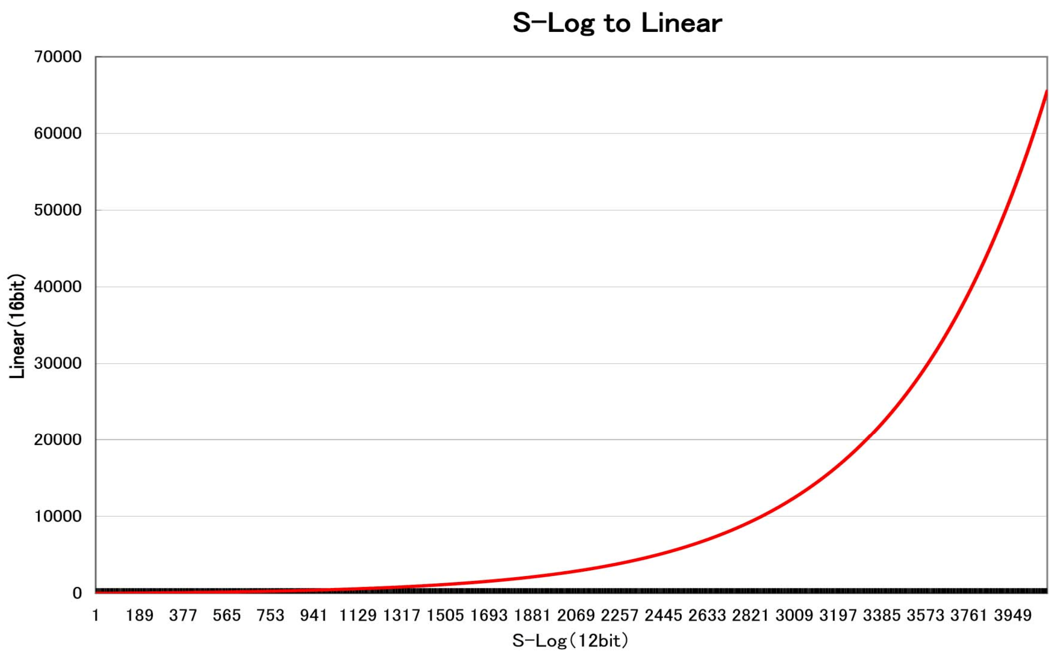
Fig. 5 below illustrates a LUT that converts 10bit S-Log to 12 bit Cineon.



4.2 Working in Linear Light Space

S-Log materials can be converted to linear data, which is linear to light, using a Capturing LUT as the files are stored into HDD (see Fig. 6).

Fig. 6 S-Log Capturing Interface (to Linear)



5. S-Log Equations

The formula representing the S-Log curve is as follow.

$$y = (0.432699 * \text{Log10}(t + 0.037584) + 0.616596) + 0.03$$

where t ranges from 0 to 10.0, representing 0 to 1000% input light level to a camera.
Multiply y by 100 to get the percentage.

The reverse curve is expressed as follow.

$$Y = \text{Power}(10.0, ((t - 0.616596 - 0.03) / 0.432699)) - 0.037584$$

where t has a range of 0 to 1.09, representing the camera output code of 0 to 109%.
Multiply Y by 100 to get the percentage.

Example for 14bit Input, 10bit Output;

INPUT
Bit Depth: 14bit
Gamma: 1.0 (linear light)
Black Level: 128
Reference White Level: 1880

OUTPUT
Bit Depth: 10bit
Gamma: S-Log A
Black Level: 90
Reference White Level: 636
Min. Output Value: 4
Max. Output Value: 1019

S-Log Formula

$$Y = 379.044 * \text{LOG10}(((X - 128) / 1752) + 0.037584) + 630$$

Anti S-Log Formula
(The formula to reconvert 10bit S-Log to 14bit Linear)

$$y = 1752 * (\text{POWER}(10.0, (X - 630) / 379.044) - 0.037584) + 128$$

Example Reverse S-Log 10bit Input reflection output.

x = 0 ~ 1023 (S-Log 10 bit code)
y = S-Log input reflection linear-light value (ex. 18% = 0.18)

y = (Power(10.0, ((((x / 4.0 - 16.0) / 219.0) - 0.616596 - 0.03) / 0.432699)) - 0.037584) * 0.9;

Video IRE value = y / 0.9;

6. Conclusion

This paper has described a new processing gamma function which is applied to Sony's electronic cinematography cameras for acquisition of motion picture imagery. The resulting digitally originated images can then be processed with post-production techniques similar as those employed for film originated materials. This logarithmic curve was carefully designed by analyzing the noise floor and the tonal reproduction characteristics of state-of-the-art CCD and CMOS imaging devices. The use of the S-Log curve results in an optimum allocation of the number of quantization levels for an exceptional handling of signal characteristics in both the low-light and high-light regions. A description is also given of Input and Output Conversion Transform functions to facilitate a look management of the captured images during production and post-production operations.

7. Appendix

7.1 S-Gamut (Color Space Conversion)

7.1.1 F900 Color Space

This color space should be used when users would like to match colors of images (like F23 and F35) to that of conventional Sony's camcorders representing the HDW-F900.
S-GAMUT to that for conventional cameras is shown below:

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1.306240 & -0.233075 & -0.073165 \\ -0.126851 & 1.178376 & -0.051526 \\ 0.000120 & -0.085649 & 1.085529 \end{bmatrix} \begin{bmatrix} R_w \\ G_w \\ B_w \end{bmatrix}$$

(Rw, Gw, Bw): RGB values for the original color space for S-Gamut

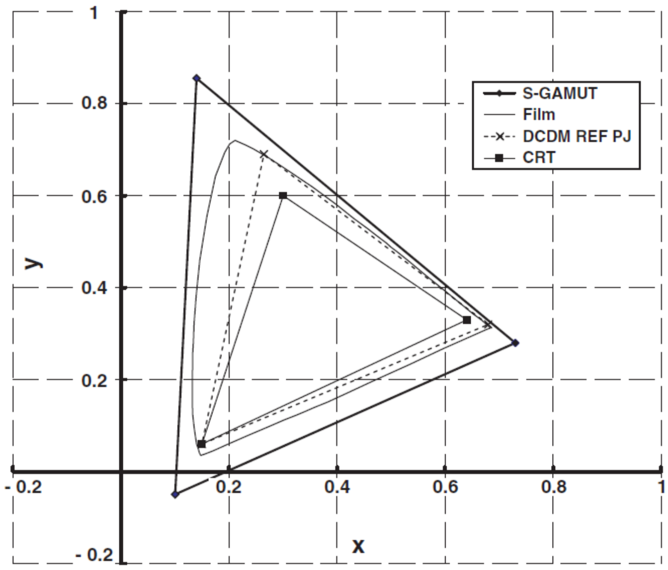
(R, G, B): Values after being converted to the color space for conventional cameras

7.1.2 S-Gamut Color Space

The chromaticities for the S-Gamut primaries are as follows:

	x	y
Red	0.73	0.28
Green	0.14	0.855
Blue	0.10	-0.05

In order to make the best use of the data capturing capability of S-Gamut (wider color space), the process that converts RGB values to the XYZ values is carried out by the following 3 x 3 matrix.



$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} \text{EMBED Equation.3} & \text{EMBED Equation.3} & \text{EMBED Equation.3} \\ \text{EMBED Equation.3} & \text{EMBED Equation.3} & \text{EMBED Equation.3} \\ \text{EMBED Equation.3} & \text{EMBED Equation.3} & \text{EMBED Equation.3} \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Where the reference white is D65 (x, y) = (0.3127, 0.3290).

7.2 ASC CDL overview description

The American Society of Cinematographers Color Decision List (ASC CDL) is a framework developed by the ASC Technology Committee that allows the interchange of basic RGB color-correction information between equipment and software made by different manufacturers.

Although the basic controls of most color correction systems are similar, they differ in specific implementation. The terms Lift (for dark tones), Gain (highlights), and Gamma (mid-tones) are commonly used by most color correction systems, but those definitions may vary in detail from system to system and manufacturer to manufacturer.
To avoid confusion and controversy, the ASC proposed a set of three defined transfer functions with unique names: Offset (lift), Slope (gain) and Power (gamma). Each function uses one number for the red channel, a second for the green and a third for the blue. Thus, the three transfer functions for the three color components can collectively be

described by nine parameters.

A tenth number, Saturation, was specified in Version 1.2 of the ASC CDL, and is applied to all three channels together.