Specification

S-2016-001

ACEScct – A Quasi-Logarithmic Encoding of ACES Data for use within Color Grading Systems

The Academy of Motion Picture Arts and Sciences

Science and Technology Council

Academy Color Encoding System (ACES) Project Committee

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Summary: This document defines a quasi-logarithmic encoding of ACES data intended for use in color grading systems whose controls expect a log relationship to relative scene exposures for proper operation. The encoding uses color primaries closer to achievable display primaries for more natural control with typical color grading tools.

NOTICES

Revision History

Date	Description
07/06/2014	Initial Version

Related Academy Documents

Document Name	Description
S-2008-001	Academy Color Encoding Specification (ACES)
S-2013-003	ACEScc – A Logarithmic Encoding of ACES Data for use within Color Grading Systems
S-2014-004	ACEScg – A Working Space for CGI Render and Compositing

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Introduction

The Academy Color Encoding Specification (ACES) defines a common color encoding method using half-precision floating point values corresponding to linear exposure values encoded relative to a fixed set of extended-gamut RGB primaries. Many digital-intermediate color grading systems have been engineered assuming image data with primaries similar to the grading display and a logarithmic relationship between relative scene exposures and image code values.

This document describes a 32-bit single precision floating-point logarithm encoding of ACES known as ACEScct.

ACEScct uses values above 1.0 and below 0.0 to encode the entire range of ACES values. ACEScct values should not be clamped except as part of color correction needed to produce a desired artistic intent.

There is no image file container format specified for use with ACEScct as the encoding is intended to be transient and internal to software or hardware systems, and is specifically not intended for interchange or archiving.

For ACES values greater than 0.0078125, the ACEScct encoding function is identical to the pure-log encoding function of ACEScc. Below this point, the addition of a ”toe” results in a more distinct ”milking” or ”fogging” of shadows when a lift operation is applied when compared to the same operation applied in ACEScc. This difference in grading behavior is provided in response to colorist requests for behavior more similar to that of traditional legacy log film scan encodings.

1 Scope

This document describes a 32-bit floating point encoding of ACES for use within color grading systems.

Equivalent functions may be used for implementation purposes as long as correspondence of grading parameters to this form of log implementation is properly maintained. This document is intended as a guideline to aid developers who are integrating an ACES workflow into a color correction system.

2 References

The following standards, specifications, articles, presentations, and texts are referenced in this text:

SMPTE ST 2065-1:2012, Academy Color Encoding Specification (ACES)

SMPTE RP 177:1993, Derivation of Basic Television Color Equations

3 Terms and Definitions

The following terms and definitions are used in this document.

3.1 Academy Color Encoding Specification (ACES)

RGB color encoding for exchange of image data that have not been color rendered, between and throughout production and postproduction, within the Academy Color Encoding System. ACES is specified in SMPTE ST 2065-1.

3.2 American Society of Cinematographers Color Decision List (ASC CDL)

A set of file formats for the exchange of basic primary color grading information between equipment and software from different manufacturers. ASC CDL provides for Slope, Offset and Power operations applied to each of the red, green and blue channels and for an overall Saturation operation affecting all three.

4 Specification

4.1 Naming conventions

The quasi-logarithmic encoding of ACES specified in Section 4.4 shall be known as ACEScct.

4.2 Color component value encoding

ACEScct values are encoded as 32-bit floating-point numbers. This floating-point encoding uses 32 bits per component as described in IEEE 754.

4.3 Color space chromaticities

ACEScct uses a different set of primaries than ACES RGB primaries defined in SMPTE ST 2065-1. The CIE 1931 colorimetry of the ACEScct RGB primaries and white are specified below.

4.3.1 Color primaries

The RGB primaries chromaticity values, known as AP1, shall be those found in Table 1.

	R	G	B	CIE x	CIE y
Red	1.00000	0.00000	0.00000	0.713	0.293
Green	0.00000	1.00000	0.00000	0.165	0.830
Blue	0.00000	0.00000	1.00000	0.128	0.044

Table 1 – ACEScct RGB primaries chromaticity values

4.3.2 White Point

The white point shall be that found in Table 2.

	R	G	B	CIE x	CIE y
White	1.00000	1.00000	1.00000	0.32168	0.33767

Table 2 – ACEScct RGB white point chromaticity values

4.4 ACEScct

The following functions shall be used to convert between ACES values, encoded according to SMPTE ST 2065-1, and ACEScct.

4.4.1 Encoding Function

ACES R, G, and B values shall be converted to lin_{AP1} R, G, and B values using the transformation matrix (TRA_1) calculated and applied using the methods provided in Section 4 of SMPTE RP 177:1993.

lin_{AP1} R, G, and B values shall be converted to ACEScct values using Equation 1.

$$ACEScct = \begin{cases} 10.5402377416545 \times lin_{AP1} + 0.0729055341958355; & lin_{AP1} \leq 0.0078125 \\ \dfrac{\log_2(lin_{AP1}) + 9.72}{17.52}; & lin_{AP1} > 0.0078125 \end{cases}$$

Equation 1 – lin_{AP1} to ACEScct

NOTE: Equation 2 shows the relationship between ACES R, G, and B values and lin_{AP1} R, G, and B values. TRA_1, rounded to 10 significant digits, is derived from the product of NPM_{AP1} inverse and NPM_{AP0} calculated using methods provided in Section 3.3 of SMPTE RP 177:1993. AP0 are the primaries of ACES specified in SMPTE ST 2065-1. AP1 are the primaries of ACEScct specified in Section 4.3.

$$\begin{bmatrix} R_{lin_{AP1}} \\ G_{lin_{AP1}} \\ B_{lin_{AP1}} \end{bmatrix} = TRA_1 \cdot \begin{bmatrix} R_{ACES} \\ G_{ACES} \\ B_{ACES} \end{bmatrix}$$

$$TRA_1 = \begin{bmatrix} 1.4514393161 & -0.2365107469 & -0.2149285693 \\ -0.0765537734 & 1.1762296998 & -0.0996759264 \\ 0.0083161484 & -0.0060324498 & 0.9977163014 \end{bmatrix}$$

$$TRA_1 = NPM_{AP1}^{-1} \cdot NPM_{AP0}$$

Equation 2 – ACES to lin_{AP1}

4.4.2 Decoding Function

ACEScct R, G, and B values shall be converted to lin_{AP1} values using Equation 3.

$$lin_{AP1} = \begin{cases} \dfrac{(ACEScct - 0.0729055341958355)}{10.5402377416545}; & ACEScct \leq 0.155251141552511 \\ 2^{(ACEScct \times 17.52 - 9.72)}; & 0.155251141552511 \leq ACEScct < \dfrac{\log_2(65504) + 9.72}{17.52} \\ 65504; & ACEScct \geq \dfrac{\log_2(65504) + 9.72}{17.52} \end{cases}$$

Equation 3 – ACEScct to lin_{AP1}

lin_{AP1} R, G, and B values shall be converted to ACES R, G, and B values using the transformation matrix (TRA_2) calculated and applied using the methods provided in Section 4 of SMPTE RP 177:1993.

NOTE: Equation 4 shows the relationship between ACES R, G, and B values and ACEScct R, G, and B values. TRA_2, rounded to 10 significant digits, is derived from the product of NPM_{AP0} inverse and NPM_{AP1} calculated using methods provided in Section 3.3 of SMPTE RP 177:1993. AP0 are the primaries of ACES specified in SMPTE ST 2065-1. AP1 are the primaries of ACEScct specified in Section 4.3.

$$\begin{bmatrix} R_{ACES} \\ G_{ACES} \\ B_{ACES} \end{bmatrix} = TRA_2 \cdot \begin{bmatrix} R_{lin_{AP1}} \\ G_{lin_{AP1}} \\ B_{lin_{AP1}} \end{bmatrix}$$

$$TRA_2 = \begin{bmatrix} 0.6954522414 & 0.1406786965 & 0.1638690622 \\ 0.0447945634 & 0.8596711185 & 0.0955343182 \\ -0.0055258826 & 0.0040252103 & 1.0015006723 \end{bmatrix}$$

$$TRA_2 = NPM_{AP1}^{-1} \cdot NPM_{AP0}$$

Equation 4 – lin_{AP1} to ACES

Appendix A

(informative)

Application of ASC CDL parameters to ACEScct image data

American Society of Cinematographers Color Decision List (ASC CDL) slope, offset, power, and saturation modifiers can be applied directly to ACEScct image data. To preserve the extended range of ACEScct values, no limiting function should be applied with ASC CDL parameters. The power function, however, should not be applied to any negative ACEScct values after slope and offset are applied. Slope, offset, and power are applied with the following function.

NOTE: ACEScct is not compatible with ASC CDL values generated on-set using the ACESproxy encoding. If there is a need to reproduce a look generated on-set where ACESproxy was used, ACEScc must be used in the dailies and/or DI environment to achieve a match.

$$ACEScct_{out} = \begin{cases} ACEScct_{in} \times slope + offset; & ACEScct_{slopeoffset} \leq 0 \\ (ACEScct_{in} \times slope + offset)^{power}; & ACEScct_{slopeoffset} > 0 \end{cases}$$

Where:

$$ACEScct_{slopeoffset} = ACEScct_{in} \times slope + offset$$

ASC CDL Saturation is also applied with no limiting function:

$$luma = 0.2126 \times ACEScct_{red} + 0.7152 \times ACEScct_{green} + 0.0722 \times ACEScct_{blue}$$
$$ACEScct_{red} = luma + saturation \times (ACEScct_{red} - luma)$$
$$ACEScct_{green} = luma + saturation \times (ACEScct_{green} - luma)$$
$$ACEScct_{blue} = luma + saturation \times (ACEScct_{blue} - luma)$$

Appendix B

(informative)

Reference ACES and ACEScct values

The table below contains a series of reference ACES values and the corresponding ACEScct values for developers who wish to validate the accuracy of their implementation.

Description	ACES (R,G,B)	ACEScct (R,G,B)
ACES min non-zero (2^{-24})	0.000000059605, 0.000000059605, 0.000000059605	0.072906162, 0.072906162, 0.072906162
ACES middle gray 18%	0.18, 0.18, 0.18	0.4135884, 0.4135884, 0.4135884
ACES max	65504, 65504, 65504	1.4679964, 1.4679964, 1.4679964
ColorChecker Blue	0.08731, 0.07443, 0.27274	0.30893773, 0.31394949, 0.44770345
ColorChecker Green	0.15366, 0.25692, 0.09071	0.39450300, 0.45037864, 0.35672542
ColorChecker Red	0.21743, 0.07070, 0.05130	0.45224438, 0.32502256, 0.31222500
ColorChecker Yellow	0.58921, 0.53944, 0.09157	0.52635207, 0.50997715, 0.35921441
ColorChecker Magenta	0.30904, 0.14818, 0.27426	0.46941309, 0.38243160, 0.44857958
ColorChecker Cyan	0.14900, 0.23377, 0.35939	0.35056940, 0.43296115, 0.47029844