Specification

S-2014-003

ACEScc – A 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 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. It also uses color primaries closer to achievable display primaries for more natural control with typical color grading tools. This encoding, named ACEScc, provides compatibility with on-set look metadata, particularly ASC CDL, generated using ACESproxy encoding.

NOTICES

Revision History

Version	Date	Description
1.0	12/19/2014	Initial Version
1.0.1	04/24/2015	Formatting and typo fixes
	03/29/2016	Remove version number - to use modification date as UID
	07/18/2016	Change $ACEScclin$ to lin_{AP1}

Related Academy Documents

Document Name	Description
S-2008-001	Academy Color Encoding Specification (ACES)
S-2013-001	ACESproxy – An Integer Log Encoding of ACES Image Data
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 ACEScc.

Logarithmic encoding of ACES for use in 10-bit and 12-bit integer systems is known as ACESproxy and is specified in a separate document, "Academy S-2013-001." ACEScc provides compatibility for color grading systems with on-set look metadata generated using the ACESproxy specification. Both encodings use the same color primaries. ACESproxy has a restricted range of values; the minimum and maximum ACES values that can be represented in ACESproxy correspond to a range between 0.0 and 1.0 of ACEScc encoding. ACEScc, however, uses values above 1.0 and below 0.0 to encode the entire range of ACES values. ACEScc 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 ACEScc as the encoding is intended to be transient and internal to software or hardware systems, and is specifically not intended for interchange or archiving.

1 Scope

This document describes a 32-bit floating point encoding of ACES for use within color grading systems. It is intended to be compatible with on-set look metadata generated from systems using the ACESproxy encodings specified in "Academy S-2013-001." 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:

Academy S-2013-001, ACESproxy – An Integer Log Encoding of ACES Data

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 logarithmic encoding of ACES specified in Section 4.4 shall be known as ACEScc.

4.2 Color component value encoding

ACEScc 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

ACEScc uses a different set of primaries than ACES RGB primaries defined in SMPTE ST 2065-1. The CIE 1931 colorimetry of the ACEScc 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 – ACEScc 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 – ACES RGB white point chromaticity values

4.4 ACEScc

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

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 ACEScc values using Equation 1.

$$ACEScc = \begin{cases} \dfrac{\left(\log_2(2^{-16}) + 9.72\right)}{17.52}; & lin_{AP1} \leq 0 \\ \dfrac{\left(\log_2(2^{-16} + lin_{AP1} \times 0.5) + 9.72\right)}{17.52}; & lin_{AP1} < 2^{-15} \\ \dfrac{\left(\log_2(lin_{AP1}) + 9.72\right)}{17.52}; & lin_{AP1} \geq 2^{-15} \end{cases}$$

Equation 1 – lin_{AP1} to ACEScc

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 ACEScc 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}

NOTE 2: Clipping ACES values below 0 in the above function is not required. Implementers are encouraged to encode negative values or take care when clipping color outside the ACEScc gamut. See Appendix A for details.

4.4.2 Decoding Function

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

$$lin_{AP1} = \begin{cases} \left(2^{(ACEScc \times 17.52 - 9.72)} - 2.0^{-16}\right) \times 2.0; & ACEScc \leq \dfrac{(9.72-15)}{17.52} \\ 2^{(ACEScc \times 17.52 - 9.72)}; & \dfrac{(9.72-15)}{17.52} \leq ACEScc < \dfrac{\log_2(65504)+9.72}{17.52} \\ 65504; & ACEScc \geq \dfrac{\log_2(65504)+9.72}{17.52} \end{cases}$$

Equation 3 – ACEScc 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) 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 lin_{AP1} 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 ACEScc 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 ACEScc

Appendix A

(informative)

Encoding of negative values

Very small ACES scene referred values below $7\,^{1}/_{4}$ stops below 18% middle gray are encoded as negative ACEScc values. These values should be preserved per the encoding in Section 4.4 so that all positive ACES values are maintained.

When ACES values are matrixed into the smaller ACEScc color space, colors outside the ACEScc gamut can generate negative values even before the log encoding. If these values are clipped, a conversion back to ACES will not restore the original colors. A specific method of preserving negative values produced by the transformation matrix has not been defined in part to help ease adoption across various color grading systems that have different capabilities and methods for handling negative values. Clipping these values has been found to have minimal visual impact when viewed through the Reference Rendering Transform (RRT) and an appropriate Output Device Transform (ODT) on currently available display technology. However to preserve creative choice in downstream processing and to provide the highest quality archival master, developers implementing ACEScc encoding are encouraged to adopt a method of preserving negative values so that a conversion from ACES to ACEScc and back can be made lossless. Alternatively, a gamut mapping algorithm may be applied to minimize hue shifts resulting from clipping negative ACEScc values. Specific methods for handling negative values may be added to the ACEScc specification in the future.

Appendix B

(informative)

Application of ASC CDL parameters to ACEScc image data

American Society of Cinematographers Color Decision List (ASC CDL) slope, offset, power, and saturation modifiers can be applied directly to ACEScc image data. ASC CDL color grades created on-set with ACESproxy images per the ACESproxy specification will reproduce the same look when applied to ACEScc images. ACEScc images however arent limited to the ACESproxy range. To preserve the extended range of ACEScc values, no limiting function should be applied with ASC CDL parameters. The power function, however, should not be applied to any negative ACEScc values after slope and offset are applied. Slope, offset, and power are applied with the following function.

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

Where:

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

ASC CDL Saturation is also applied with no limiting function:

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

Appendix C

(informative)

Reference ACES and ACEScc values

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

Description	ACES (R,G,B)	ACEScc (R,G,B)
ACES min non-zero (2^{-24})	0.000000059605, 0.000000059605, 0.000000059605	-0.35828683, -0.35828683, -0.35828683
ACESproxy min (10-bit CV 64)	0.0011854, 0.0011854, 0.0011854	-0.000023420209, -0.000023420209, -0.000023420209
ACESproxy mid gray (10-bit CV 426)	0.1792, 0.1792, 0.1792	0.4132216, 0.4132216, 0.4132216
ACES middle gray 18%	0.18, 0.18, 0.18	0.4135884, 0.4135884, 0.4135884
ACESproxy max (10-bit CV 940)	222.88, 222.88, 222.88	1.000007, 1.000007, 1.000007
ACES max	65504, 65504, 65504	1.4679964, 1.4679964, 1.4679964
ColorChecker Blue	0.08731, 0.07443, 0.27274	0.30893183, 0.3139529, 0.44770366
ColorChecker Green	0.15366, 0.25692, 0.09071	0.39450577, 0.45037976, 0.35672173
ColorChecker Red	0.21743, 0.07070, 0.05130	0.45224518, 0.32502314, 0.31222793
ColorChecker Yellow	0.58921, 0.53944, 0.09157	0.52635247, 0.5099772, 0.3592168
ColorChecker Magenta	0.30904, 0.14818, 0.27426	0.46941227, 0.382433, 0.44858035
ColorChecker Cyan	0.14900, 0.23377, 0.35939	0.35056654, 0.43295938, 0.4702988