ARRI LogC4

Logarithmic Color Space

SPECIFICATION

Date: 1st May 2022

Document Version History		
Version	Author(s)	Change Note
2021-07-07	Harald Brendel Sean Cooper	Initial document version
2021-07-22	Sean Cooper	Clarify LogC4 Curve domain
2021-07-28	Sean Cooper	Pseudo-code update
2021-11-30	Sean Cooper	Mirrored LogC4 Curve and sensor-linear definition
2022-05-01	Sean Cooper	Negative handling in LogC4 Curve amended Matrices provided with higher precision Hardware encoding section expanded Reference code provided as CTL

Table of Contents

1 Introduction

This document describes the ARRI LogC4 logarithmic color space, hereinafter referred to as ARRI LogC4 or LogC4, and its use.

ARRI LogC4 was designed to optimize the encoding precision and production usability of the increased dynamic range[1] of the ALEV4 sensor. For detailed information about the naming convention and version history of ARRI camera encodings, please see Section 2 and 4.

The development of the transfer function was funded by the Horizon 2020 project HDR4EU[2] .

2 Version History

ARRI LogC4 is a direct successor to the prior LogC v3 encoding definition in use since 2011, and continues its version history. The prefix “ARRI” was adopted to ensure consistent naming across our cameras and provide a stable base for advancement into the future. The following table provides a historical overview of the versioning history for ARRI camera encodings:

ARRI Camera Encoding Version History				
Version	Cameras	SUP Version	Components	Status
1	D-20 D-21	N/A	Log C	Archived
2	ALEXA Classic ALEXA XT ALEXA SXT	SUP 1 SUP 2	ALEXA Log C v2	Archived
3	ALEXA Classic ALEXA XT ALEXA SXT ALEXA Mini ALEXA LF ALEXA Mini LF ALEXA 65 AMIRA	SUP $\geq$ 3	ALEXA LogC v3 ALEXA Wide Gamut RGB ALEXA LogC v3 Curve ——— ARRI LogC3 ARRI Wide Gamut 3 ARRI LogC3 Curve	Active
4	…	…	ARRI LogC4 ARRI Wide Gamut 4 ARRI LogC4 Curve	Active

Note: In technical or UI text, the version number must be included for full specificity, including the reduced form, e.g. ARRI LogC4 or LogC4.

[1] Ratio of full well capacity to read out noise

[2] See HDR4EU document D2.5 Real-time HDR to SDR conversion in a generic viewing environment

3 Hardware Encoding

This section outlines the LogC4 Hardware Encoding Curve as used in-camera. The hardware specification is provided as informative material pertaining to sensor signal encoding for LogC4, and is **not** intended to be implemented in software. Please see Section 4 for the specification intended for 3rd Party implementations of ARRI LogC4.

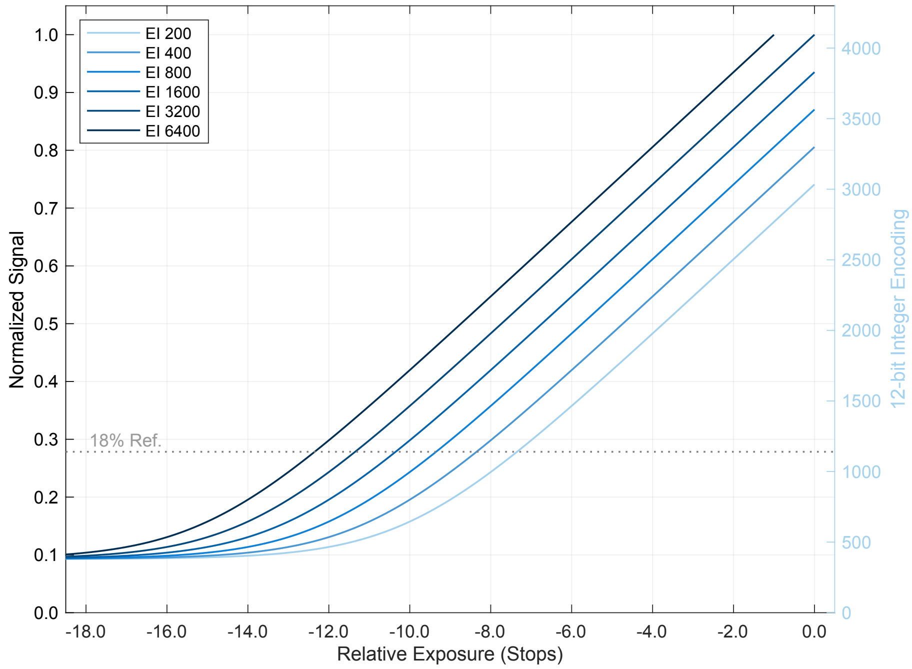

Figure 1: The LogC4 Hardware Encoding Curve at various exposure indices.

3.1 LogC4 Hardware Encoding Curve

The LogC4 Hardware Encoding Curve represents the logarithmic transform applied to linear sensor data in-camera. The most notable change from LogC3 is the constant "gamma" of the logarithmic curve which does not vary with exposure index, only the linear gain factor a_h changes.

The logarithmic encoding used by ALEV4 based cameras for LogC4 was optimized for 12-bit encoding, this allows for greater precision at each stop of sensor signal when compared to the 10-bit LogC3 encoding. The hardware encoding curve is defined as follows:

$$E' = min(\frac{log_2(a_h E_{sensor} + 64) - 6}{14} b + c \text{ , } 1.0 \text{)} \tag{1}$$

$$a_h = (2^{18} - 16) \frac{H_{EI}}{800} \tag{1a}$$

$$b = \frac{1023 - 95}{1023} \tag{1b}$$

$$c = \frac{95}{1023} \tag{1c}$$

where:

E_{sensor} = Normalized linear sensor signal.
E' = Normalized log signal.
a_h = Hardware encoding gain factor (EI dependent).
H_{EI} = User selected EI value.
b, c = Scaling and offset, equivalent to LogC3.

4 Specification

This section begins the formal definition of **ARRI LogC4**, the scene-referred logarithmic color space composed of the transfer function **ARRI LogC4 Curve** and the color primaries **ARRI Wide Gamut 4**.

4.1 ARRI LogC4 Curve

ARRI LogC4 Curve (LogC4 Curve) is the transfer function used in ARRI LogC4, it is a scene-referred logarithmic function defined by an encoding and decoding function.

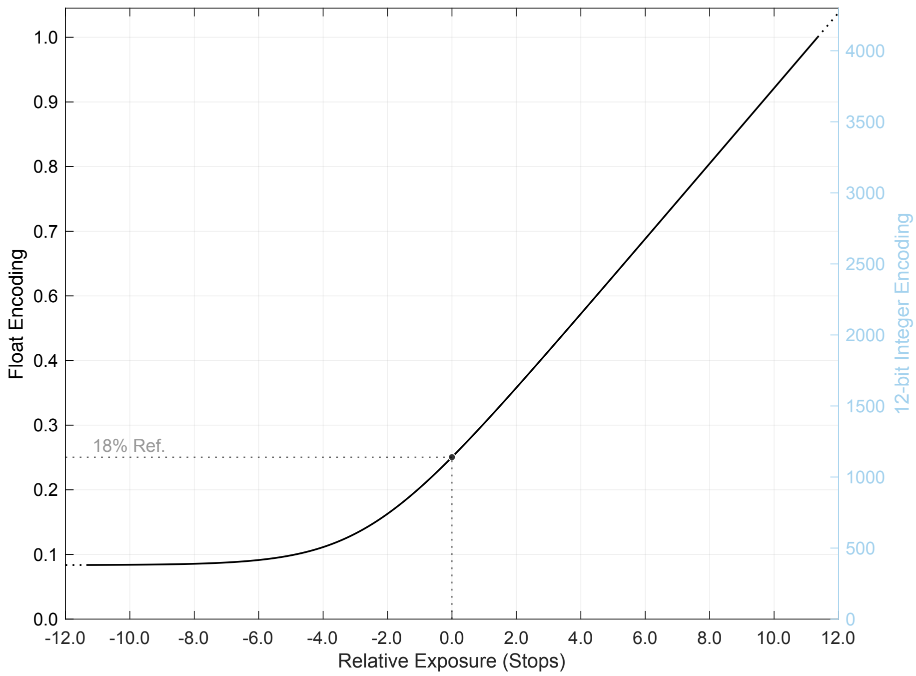

Figure 2: ARRI LogC4 Curve as normalized Float and 12-bit Integer signal.

The ARRI LogC4 Curve is exposure index independent, meaning, correct linearization of LogC4 encoded images does not depend on the user selected EI. This is a notable change from LogC3, and simplifies decoding of LogC4 encoded footage. This feature is enabled by the hardware encoding method described in Section 3.1.

Although ARRI cameras will not produce negative LogC4 values in internal processing or RAW data, negative LogC4 values may be introduced by intermediate processes in post-production software and colorimetric conversions. Negative handling is covered in the following definitions.

Note: The ARRI LogC4 Curve function was designed for 12-bit encoding as its minimum quantization level, 10-bit ARRI LogC4 encoded images should not be used for archival or interchange.

4.1.1 Encoding Function

The function for encoding relative scene linear values is defined as follows:

$$f(E_{scene}) = \begin{cases} \frac{log_2(aE_{scene}+64)-6}{14}b + c & E_{scene} \geq t \\ \frac{E_{scene}-t}{s} & E_{scene} < t \end{cases} \quad (2)$$

$$a = (2^{18} - 16)\frac{1}{117.45} \quad (2a)$$

$$s = \frac{7\ln(2)\ 2^{7-14c/b}}{ab} \quad (2b)$$

$$t = \frac{2^{(14\frac{-c}{b}+6)} - 64}{a} \quad (2c)$$

where:

f = ARRI LogC4 Curve encoding function.
E_{scene} = Relative scene linear signal.
a = Relative scene linear gain factor, see Equation 4.
s = Inverse slope at threshold t.
t = Relative scene linear threshold point.

Terms b and c are defined in Equations 1b, 1c respectively.

4.1.2 Decoding Function

The function for reconstructing relative scene linear values from ARRI LogC4 Curve encoded material, is defined as follows:

$$f^{-1}(E') = \begin{cases} \frac{2^{(14\frac{E'-c}{b}+6)}-64}{a} & E' \geq 0 \\ E's + t & E' < 0 \end{cases} \quad (3)$$

where:

f^{-1} = ARRI LogC4 Curve decoding function.
E' = ARRI LogC4 Curve encoded signal.

Terms a, b, c, s and t are defined in Equations 2a, 1b, 1c, 2b, 2c respectively.

The constant 117.45 found in the parameter a defined in Equation 2a is the relative scene linear gain factor derived by the following equation:

$$117.45 = 0.18/(400/260991) = Scene_{ref.}/(Signal_{ref.}/Signal_{max}) \quad (4)$$

The rounded version, as defined, should be used in all cases.

4.2 ARRI Wide Gamut 4

ARRI Wide Gamut 4 (AWG4) is the name of the color primaries used in ARRI LogC4. All chromaticity values are defined with CIE 1931 2 Degree Standard Observer Colorimetry.

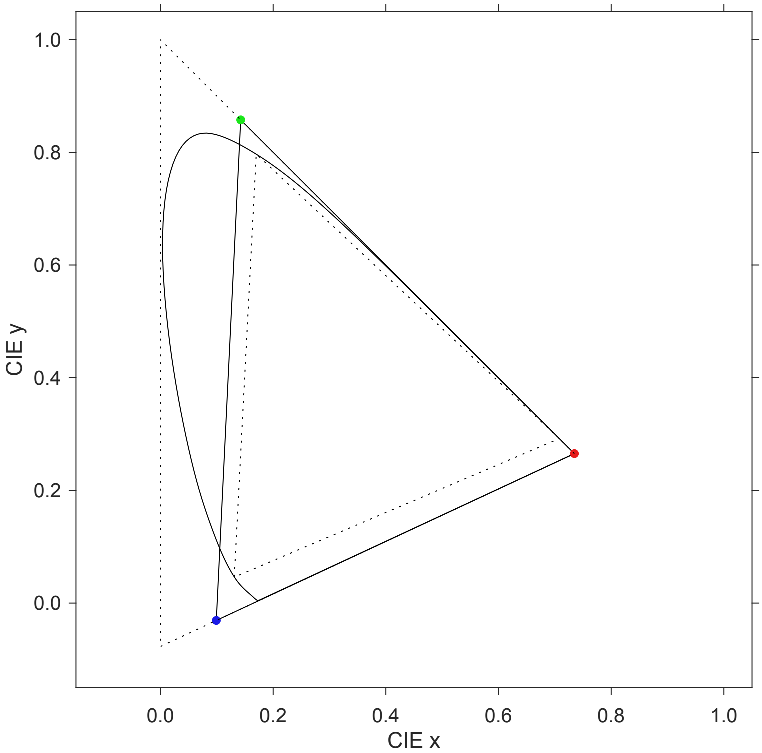

Figure 3: The 2D gamut bounded by ARRI Wide Gamut 4 in the CIE 1931 chromaticity diagram is shown as the solid line with colored markers. The larger and smaller gamuts with dotted lines are ACES AP0 (SMPTE ST 2065-1) and ITU-R BT.2020 respectively.

4.2.1 RGB Primaries

The RGB primaries of ARRI Wide Gamut 4, are defined as follows:

	CIE x	CIE y
Red	0.7347	0.2653
Green	0.1424	0.8576
Blue	0.0991	-0.0308

4.2.2 White Point

The White Point of ARRI Wide Gamut 4 is CIE Standard Illuminant D65, provided here for completeness:

	CIE x	CIE y
White	0.3127	0.3290

4.3 ARRI LogC4

ARRI LogC4 (LogC4) shall be defined as the logarithmic color space composed of the transfer function ARRI LogC4 Curve and the color primaries ARRI Wide Gamut 4.

4.3.1 ARRI LogC4 to CIE XYZ Conversion

The conversion from ARRI LogC4 to CIE 1931 XYZ is defined as follows:

$$XYZ_{D65} = M_{XYZ} \cdot f^{-1}(RGB_{LogC4}) \tag{5}$$

$$M_{XYZ} = \begin{bmatrix} 0.7048583204 & 0.1297602952 & 0.1158373115 \\ 0.2545241764 & 0.7814777327 & -0.0360019091 \\ 0.0000000000 & 0.0000000000 & 1.0890577508 \end{bmatrix} \tag{5a}$$

where:

f^{-1} = ARRI LogC4 Curve decoding function, defined in Equation 3.
M_{XYZ} = ARRI Wide Gamut 4 to CIE XYZ conversion matrix.

4.3.2 ARRI LogC4 to ACES Conversion

The conversion from ARRI LogC4 to AP0 (SMPTE ST 2065-1) is defined as follows:

$$RGB_{ACES} = M_{ACES} \cdot f^{-1}(RGB_{LogC4}) \tag{6}$$

$$M_{ACES} = \begin{bmatrix} 0.7509573628 & 0.1444227867 & 0.1046198505 \\ 0.0008218371 & 1.0073975849 & -0.0082194220 \\ -0.0004999521 & -0.0008541772 & 1.0013541294 \end{bmatrix} \tag{6a}$$

where:

f^{-1} = ARRI LogC4 Curve decoding function, defined in Equation 3.
M_{ACES} = ARRI Wide Gamut 4 to ACES AP0 conversion matrix.

Note: The above M_{ACES} matrix has been created with a CAT02 chromatic adaptation transform from CIE D65 to ACES D60. Which, despite the primaries being defined within the gamut of AP0, may produce negative values at the extreme border of ARRI Wide Gamut 4 in an ACES (ST 2065-1) container. Care should be used to preserve these values if a lossless round-trip conversion is required.

5 Contact

In case you have questions or comments, please contact: arriraw-dev@arri.de

Appendices

A Reference CTL Implementation

```
// Constants
const float a = (pow(2.0, 18.0) - 16.0) / 117.45;
const float b = (1023.0 - 95.0) / 1023.0;
const float c = 95.0 / 1023.0;
const float s = (7 * log(2) * pow(2.0, 7 - 14 * c / b)) / (a * b);
const float t = (pow(2.0, 14.0 * (-c / b) + 6.0) - 64.0) / a;

// LogC4 Curve Encoding Function
float relativeSceneLinearToNormalizedLogC4( float x) {

    if (x < t) {
        return (x - t) / s;
    }

    return (log2( a * x + 64.0) - 6.0) / 14.0 * b + c;
}

// LogC4 Curve Decoding Function
float normalizedLogC4ToRelativeSceneLinear( float x) {

    if (x < 0.0) {
        return x * s + t;
    }

    float p = 14.0 * (x - c) / b + 6.0;
    return (pow(2.0, p) - 64.0) / a;
}

void logC4ToACES
( input varying float rIn,
  input varying float gIn,
  input varying float bIn,
  input varying float aIn,
  output varying float rOut,
  output varying float gOut,
  output varying float bOut,
  output varying float aOut)
{

    float r_lin = normalizedLogC4ToRelativeSceneLinear(rIn);
    float g_lin = normalizedLogC4ToRelativeSceneLinear(gIn);
    float b_lin = normalizedLogC4ToRelativeSceneLinear(bIn);

    // Matrix AWG4 D65 --CAT02--> ACES AP0 D60
    rOut = r_lin *  0.7509573628 + g_lin *  0.1444227867 + b_lin *  0.1046198505;
    gOut = r_lin *  0.0008218371 + g_lin *  1.0073975849 + b_lin * -0.0082194220;
    bOut = r_lin * -0.0004999521 + g_lin * -0.0008541772 + b_lin *  1.0013541294;
    aOut = 1.0;

}
```

B Reference ARRI LogC4 Values

Description	ARRI LogC4 (R, G, B)	ACES 2065-1 (R, G, B)
Relative Scene Linear 0.0	0.0929, 0.0929, 0.0929	0.0000, 0.0000, 0.0000
Relative Scene Linear 0.18	0.2784, 0.2784, 0.2784	0.1800, 0.1800, 0.1800
LogC4 0.0	0.0000, 0.0000, 0.0000	-0.0181, -0.0181, -0.0181
ARRI LogC4 Hardware Max	1.0000, 1.0000, 1.0000	469.80, 469.80, 469.80