

SMPTE STANDARD

2048 × 1080 and 4096 × 2160

Digital Cinematography

Production Image Formats

FS/709



Table of Contents	Page
Foreword	2
Intellectual Property	2
Introduction.....	2
1 Scope	3
2 Conformance Notation	3
3 Normative References	4
4 General.....	4
5 Image Pixel Array and Mapping.....	4
5.1 2048 × 1080 Image Pixel Array	4
5.2 4096 × 2160 Image Pixel Array	5
6 System Colorimetry.....	7
6.1 FS Colorimetry	7
6.1.1 Encoding Primaries Free Scale Gamut(FS-Gamut)	7
6.1.2 FS-Log curve.....	7
6.1.3 Notation of parameter values	10
6.2 R'G'B' Colorimetry.....	10
6.3 Color VANC.....	11
7 Pixel Array Representation	20
7.1 FS-Log Pixel Array Representation	20
7.2 R'G'B' Pixel Array Representation	20
Annex A Conversion between FS-Gamut Primaries and ITU-R BT.709, CIE XYZ (Informative)	21
Annex B Flow Chart to Select Nonlinear Curve and Upper and Lower Three Coordinates of FS-Log Curve.....	22
Annex C Bibliography (Informative)	23
Annex D Document Road Map (Informative)	24

Foreword

SMPTE (the Society of Motion Picture and Television Engineers) is an internationally-recognized standards developing organization. Headquartered and incorporated in the United States of America, SMPTE has members in over 80 countries on six continents. SMPTE's Engineering Documents, including Standards, Recommended Practices, and Engineering Guidelines, are prepared by SMPTE's Technology Committees. Participation in these Committees is open to all with a bona fide interest in their work. SMPTE cooperates closely with other standards-developing organizations, including ISO, IEC and ITU.

SMPTE Engineering Documents are drafted in accordance with the rules given in Part XIII of its Administrative Practices.

SMPTE ST 2048-1 was prepared by Technology Committee 10E

Intellectual Property

At the time of publication no notice had been received by SMPTE claiming patent rights essential to the implementation of this Standard. However, attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. SMPTE shall not be held responsible for identifying any or all such patent rights.

Introduction

This section is entirely informative and does not form an integral part of this Engineering Document.

This standard defines 2048×1080 and 4096×2160 image formats primarily for D-Cinema content acquisition and creation. These image formats may also be used for acquisition and creation of high quality content for other D-Cinema applications.

This standard also defines the Color VANC which conveys the parameter values of user-defined color space and Log curve. This standard may be used in the creation of Computer Graphics and other D-Cinema applications related to the pre Digital Cinema Distribution Master (DCDM) creation.

1 Scope

1.1 This standard defines a family of progressive sample structures of 2048×1080 and 4096×2160 images for D-Cinema content creation as defined in Table 1 and Table 2 in Section 5. This standard specifies:

- $R'G'B'$ color encoding and digital representation¹
- $Y'C'_BC'_R$ color encoding and digital representation
- $R'_{FS}G'_{FS}B'_{FS}$ color encoding and digital representation

This standard also defines tristimulus values and reference white of Free Scale-Gamut (FS-Gamut), Free Scale-Log (FS-Log) curve and a Color VANC packet. The FS-Log curve has an affinity with the sensitivity of human eye and can specify a much wider dynamic range than the nonlinear curve defined in Recommendation ITU-R BT.709. The Color VANC carries tristimulus values, reference white and parameter values of the FS-Log curve.

An auxiliary component A may optionally accompany $R'G'B'$, $Y'C'_BC'_R$ and $R'_{FS}G'_{FS}B'_{FS}$; these interfaces are denoted $R'G'B'A$, $Y'C'_BC'_RA$ and $R'_{FS}G'_{FS}B'_{FSA}$. The "A" component if present, shall have the same characteristics as the G' , Y' or G'_{FS} channel.

Sampling structures supported by this standard include, 4:4:4:4, 4:4:4, and 4:2:2.

Note: FS-Gamut and FS-Log are identifying names of the defined color space and the Log curve in this standard.

2 Conformance Notation

Normative text is text that describes elements of the design that are indispensable or contains the conformance language keywords: "shall", "should", or "may". Informative text is text that is potentially helpful to the user, but not indispensable, and can be removed, changed, or added editorially without affecting interoperability. Informative text does not contain any conformance keywords.

All text in this document is, by default, normative, except: the Introduction, any section explicitly labeled as "Informative" or individual paragraphs that start with "Note:"

The keywords "shall" and "shall not" indicate requirements strictly to be followed in order to conform to the document and from which no deviation is permitted.

The keywords, "should" and "should not" indicate that, among several possibilities, one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required; or that (in the negative form) a certain possibility or course of action is deprecated but not prohibited.

The keywords "may" and "need not" indicate courses of action permissible within the limits of the document.

The keyword "reserved" indicates a provision that is not defined at this time, shall not be used, and may be defined in the future. The keyword "forbidden" indicates "reserved" and in addition indicates that the provision will never be defined in the future.

¹ Throughout this standard, references to signals represented by a single primed letter (e.g., R' , G' , B' , Y' , C'_B , C'_R and R'_{FS} , G'_{FS} , B'_{FS}) refer to signals to which the transfer characteristics in Section 6 have been applied. Such signals are commonly described as being gamma corrected.

A conformant implementation according to this document is one that includes all mandatory provisions ("shall") and, if implemented, all recommended provisions ("should") as described. A conformant implementation need not implement optional provisions ("may") and need not implement them as described.

3 Normative References

Note: All references in this document to other SMPTE documents use the current numbering style (e.g. SMPTE ST 274:2008) although, during a transitional phase, the document as published (printed or PDF) may bear an older designation (such as SMPTE 274M-2008). Documents with the same root number (e.g. 274) and publication year (e.g. 2008) are functionally identical.

The following standards contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of the standards indicated below.

CIE S 014-2/E:2006, Colorimetry Part 2: CIE standard illuminants [ISO 11664-2:2007]

IEEE Std 754-2008, IEEE Standard for Binary Floating-Point Arithmetic

Recommendation ITU-R BT.709-5 (04/02), Parameter Values for the HDTV Standards for Production and International Programme Exchange

SMPTE ST 274:2008, Television — 1920 x 1080 Image Sample Structure, Digital Representation and Digital Timing Reference Sequences for Multiple Picture Rates

SMPTE ST 291:2010, Ancillary Data Packet and Space Formatting

4 General

4.1 An implementation of a system claiming compliance with this standard shall state:

- which of the systems of Table 1 or Table 2 are implemented;
- which of the signal representations are implemented ($R'G'B'$, $Y'C'_B C'_R$, $R'G'B'A$, $Y'C'_B C'_R A$, $R'_{FS}G'_{FS}B'_{FS}$ or $R'_{FS}G'_{FS}B'_{FS} A$); and
- whether the digital representation employs 10 bits or 12 bits.

4.2 A 12-bit codeword, when converted to 10 bits, shall either be rounded or truncated. A 10-bit codeword, when converted to a 12-bit codeword, shall have two padding bits added.

4.3 The default values of the color space, reference white are defined in Table 3. Color VANC defined in Section 6.3 shall be used to carry user defined parameters of color primaries and FS-Log curve. ACT1 and ACT2 of the Color VANC indicate active color primaries, active nonlinear curve, active parameters of the FS-Log curve, etc.

5 Image Pixel Array and Mapping

5.1 2048 × 1080 Image Pixel Array

5.1.1 The sampling lattice shall be orthogonal and shall have a pixel aspect ratio of 1:1.

5.1.2 2048 × 1080 systems shall have the maximum number of 2048 horizontal pixels and the maximum number of 1080 vertical pixels per frame.

5.1.3 The data numbering in horizontal pixels shall be from left to right and vertical pixels shall be numbered from top to bottom of the image to be displayed. The data numbering shall begin with 0. The top left sampling data shall be expressed with (0, 0) and the bottom right sampling data shall be (2047, 1079) as shown in Figure 1.

5.1.4 The center of the image shall be located at the center of the 2048 × 1080 pixel array, midway between horizontal pixel number of 1023 and 1024, and midway between vertical pixel number of 539 and 540.

5.1.5 This standard specifies multiple frame rates as shown in Table 1 with pixel depths of 10 bits or 12 bits. It is not necessary for an implementation to support all formats to be compliant with this standard. However, an implementation shall state which of the formats are supported.

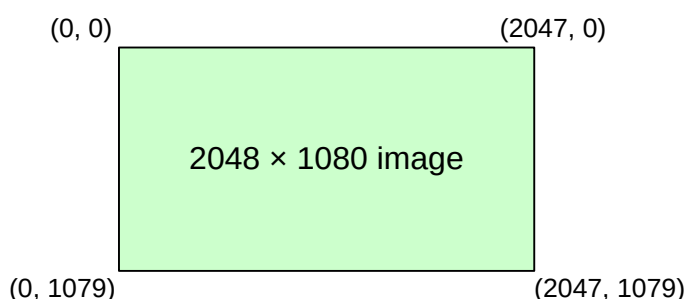


Figure 1 – Horizontal and vertical pixel numbering of 2048 × 1080 progressive images

Table 1 – 2048 × 1080 image pixel array and frame rates

System No.	System nomenclature	Frame rate (Hz)
1	2048 × 1080/60/P	60
2	2048 × 1080/59.94/P	$\frac{60}{1.001}$
3	2048 × 1080/50/P	50
4	2048 × 1080/48/P	48
5	2048 × 1080/47.95/P	$\frac{48}{1.001}$
6	2048 × 1080/30/P	30
7	2048 × 1080/29.97/P	$\frac{30}{1.001}$
8	2048 × 1080/25/P	25
9	2048 × 1080/24/P	24
10	2048 × 1080/23.98/P	$\frac{24}{1.001}$

5.2 4096 × 2160 Image Pixel Array

5.2.1 The sampling lattice shall be orthogonal and shall have a pixel aspect ratio of 1:1.

5.2.2 4096 × 2160 systems shall have maximum number of 4096 horizontal pixels and the maximum number of 2160 vertical pixels per frame.

5.2.3 The data numbering of the horizontal pixels shall be from left to right and vertical pixels shall be numbered from top to bottom of the image. The data numbering shall begin with 0. The top left sampling data shall be expressed with (0, 0) and the bottom right sampling data shall be (4095, 2159) as shown in Figure 2.

5.2.4 The center of the image shall be located at the center of the 4096 × 2160 pixel array, midway between horizontal pixel number of 2047 and 2048, and midway between vertical pixel number of 1079 and 1080.

5.2.5 This standard specifies multiple frame rate formats as shown in Table 2 with pixel depths of 10 bits or 12 bits. It is not necessary for an implementation to support all formats to be compliant with this standard. However, an implementation shall state which of the formats are supported.

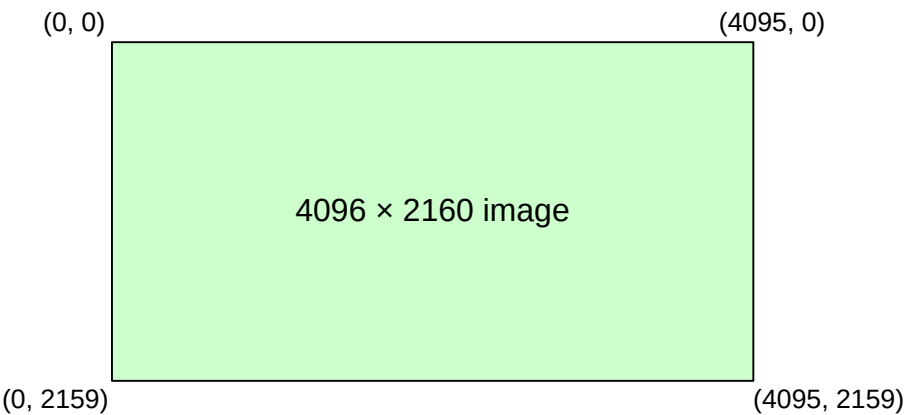


Figure 2 – Horizontal and vertical pixel numbering of 4096 × 2160 images

Table 2 – 4096 × 2160 image pixel array and frame rates

System No.	System nomenclature	Frame rate (Hz)
1	4096 × 2160/60/P	60
2	4096 × 2160/59.94/P	$\frac{60}{1.001}$
3	4096 × 2160/50/P	50
4	4096 × 2160/48/P	48
5	4096 × 2160/47.95/P	$\frac{48}{1.001}$
6	4096 × 2160/30/P	30
7	4096 × 2160/29.97/P	$\frac{30}{1.001}$
8	4096 × 2160/25/P	25
9	4096 × 2160/24/P	24
10	4096 × 2160/23.98/P	$\frac{24}{1.001}$

6 System Colorimetry

6.1 FS Colorimetry

6.1.1 Encoding Primaries Free Scale Gamut (FS-Gamut)

The FS colorimetry shall use the CIE XYZ tristimulus values defined in CIE S 014-2/E [ISO 11664-2] ranging from -2.00000 to $+2.00000$. Default values of the primaries and reference white shall be as defined in Table 3 and is defined as FS-Gamut.

Table 3 – Default values of FS-Gamut

	CIE x	CIE y
R_{FS} primary	0.73470	0.26530
G_{FS} primary	0.14000	0.86000
B_{FS} primary	0.10000	– 0.02985
Reference white D65	0.31272	0.32903

6.1.2 FS-Log curve

From the R_{FS} , G_{FS} , B_{FS} or user defined R_{user} , G_{user} , B_{user} tristimulus values, three nonlinear primary components R'_{FS} , G'_{FS} , B'_{FS} or R' , G' , B' shall be calculated according to the following FS-Log curve (Equation 1) — and if necessary — the upper and lower three coordinates defined in Table 4. Where nonlinear primary components L' shall be $0 \leq L' \leq 1$.

Table 4 – Definition of FS-Log curve

Exposure Range	Definition
$L_{C1} \leq L \leq L_{C3}$	Upper three coordinates (L_{C1} , L'_{C1}), (L_{C2} , L'_{C2}), (L_{C3} , L'_{C3})
$L_{B1} \leq L \leq L_{C1}$	$L' = \alpha \log_{10} (\beta L + \delta) + \epsilon$ (Equation 1)
$L_{B3} \leq L \leq L_{B1}$	Lower three coordinates (L_{B3} , L'_{B3}), (L_{B2} , L'_{B2}), (L_{B1} , L'_{B1})

Where, L shall be a linear tristimulus value multiplied by a k_{exp} factor as shown in Equation 2.

$$L = \text{Linear value} \times k_{exp}; \quad k_{exp} \text{ denotes the exposure value} \quad (\text{Equation 2})$$

“a linear value” shall mean that each value be linear relative to the amount of light. For example, $G_{FS} = 0.18000$ denotes an 18% Gray and $G_{FS} = 1.00000$ denotes light coming from a 100% reflector. The k_{exp} value shall denote the overexposure and the underexposure, i.e., the k_{exp} value of greater than 1 indicates the overexposure and the k_{exp} value of between 0 and 1 indicates the underexposure. The default value of the k_{exp} shall be 1.00000.

The FS-Log curve shall use the Equation 1 with L from L_{B1} to L_{C1} — and if necessary — in combination with two nonlinear curves connecting the upper three coordinates of (L_{C1}, L'_{C1}) , (L_{C2}, L'_{C2}) , (L_{C3}, L'_{C3}) with L from L_{C1} to L_{C3} and lower three coordinates of (L_{B1}, L'_{B1}) , (L_{B2}, L'_{B2}) , (L_{B3}, L'_{B3}) with L from L_{B3} to L_{B1} as shown in Figure 3. L_{B1} , L_{B2} , L_{B3} ($L_{B1} > L_{B2} > L_{B3}$) and L_{C1} , L_{C2} , L_{C3} ($L_{C1} < L_{C2} < L_{C3}$) shall indicate the linear values and L'_{B1} , L'_{B2} , L'_{B3} and L'_{C1} , L'_{C2} , L'_{C3} shall indicate the transformed nonlinear values, respectively.

Each of the two nonlinear curves shall be applied only when Equation 1 can not specify the nonlinear characteristics of primary components and shall be a smooth function connecting each of the upper and lower three coordinates as shown in Figure 4 and Figure 5.

Parameter values of α , β , δ , ε as well as the upper three coordinates of (L_{C1}, L'_{C1}) , (L_{C2}, L'_{C2}) , (L_{C3}, L'_{C3}) and lower three coordinates of (L_{B1}, L'_{B1}) , (L_{B2}, L'_{B2}) , (L_{B3}, L'_{B3}) shall be defined within the limitation of having the value of L' ranging from 0 to 1 and shall be carried within the Color VANC defined in Section 6.3.

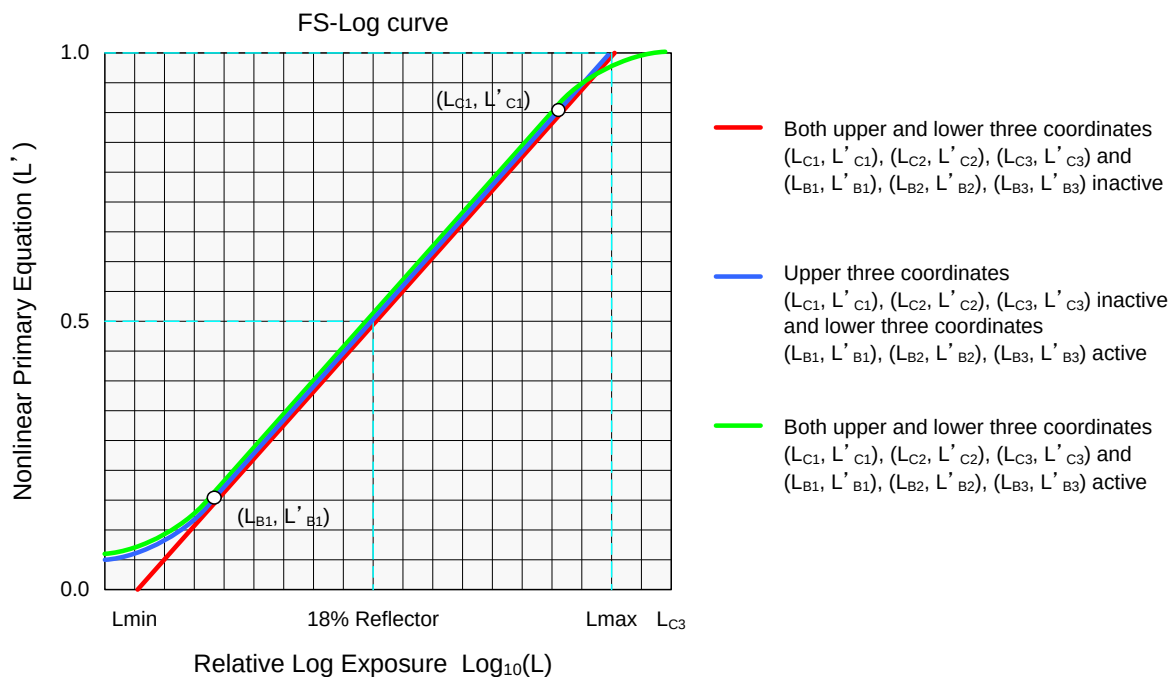


Figure 3 – FS-Log curve