SMPTE ST 2067-21:2016
Revision of
SMPTE ST 2067-21:2014

SMPTE STANDARD

Interoperable Master Format — Application #2E

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Approved
May 18, 2016

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 its Standards Operations Manual.

SMPTE ST 2067-21 was prepared by Technology Committee 35PM.

Intellectual Property

At the time of publication no notice had been received by SMPTE claiming patent rights essential to the implementation of this Engineering Document. 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.

1 Scope

This specification extends IMF Application #2 with support for image frames with:

- colorimetry specified in IEC 61966-2-4 and Recommendation ITU-R BT.2020;
- color primaries specified in SMPTE RP 431-2;
- high-dynamic range using the transfer function specified in SMPTE ST 2084; and
- a maximum width and height of 4096 and 3112 pixels, respectively.

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.

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.

Unless otherwise specified, the order of precedence of the types of normative information in this document shall be as follows: Normative prose shall be the authoritative definition; Tables shall be next; followed by formal languages; then figures; and then any other language forms.

3 Normative References

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.

SMPTE ST 2067-20:2016, Interoperable Master Format — Application #2

SMPTE ST 2084:2014, High Dynamic Range Electro-Optical Transfer Function of Mastering Reference Displays

SMPTE ST 2086:2014, Mastering Display Color Volume Metadata Supporting High Luminance and Wide Color Gamut Images

CEA 861.3, CEA Standard, HDR Static Metadata Extensions (January 2015)

IEC 61966-2-4 Edition 1.0, Multimedia Systems and Equipment – Colour Measurement and Management — Part 2-4: Colour Management — Extended-Gamut YCC Colour Space for Video Applications — xvYCC

ISO/IEC 15444-1:2004/Amd.7:2015, Information Technology — JPEG 2000 Image Coding System: Core Coding System — Part 1 – Amendment 7: Profiles for an Interoperable Master Format (IMF)

ISO 11664-3:2012 (CIE S014-3/E:2011), Colorimetry — Part 3: CIE Tristimulus Values

Recommendation ITU-R BT.2020, Parameter Values for Ultra-High Definition Television Systems for Production and International Programme Exchange

4 Overall

4.1 General

The normative provisions of SMPTE ST 2067-20 shall apply in addition to those specified herein unless specified otherwise.

Note: A Composition that conforms to SMPTE ST 2067-20 also conforms to this specification.

4.2 Shim Parameters

Track Files conforming to this specification shall be associated with the shim parameter values specified in SMPTE ST 2067-20 with the exception of those specified in Table 1.

Table 1 – Shim Parameter Values Definitions

Shim Parameter	Value
shim_id	http://www.smpte-ra.org/schemas/2067-21/2016
picture_bitrate	ST 2067-21
picture_format	ST 2067-21

4.3 XML Schema and Namespace

XML elements defined by this specification shall conform to the XML schema definitions (see W3C XML Schema Part 1: Structures as referenced in SMPTE ST 2067-20) found in this specification. In the event of a conflict between schema definitions and the prose, the prose shall take precedence.

The XML schema root element shall be as defined in Table 2.

Table 2 – XML Schema root element definition

```
<xs:schema targetNamespace="http://www.smpte-ra.org/schemas/2067-21/2016"
                   xmlns:app2e="http://www.smpte-ra.org/schemas/2067-21/2016"
                  xmlns:xs="http://www.w3.org/2001/XMLSchema"
 elementFormDefault="qualified" attributeFormDefault="unqualified">

<!-- schema definitions found in this document -->

</xs:schema>
```

5 Image Essence

5.1 Constraints

Implementations shall support the combinations of image frame characteristics listed in Table 3.

The notation *a*..*b* indicates that any value between *a* and *b*, including *a* and *b*, is allowed. For instance, the range 1..4096 includes the value 3840 and the range 1..3112 includes the value 2160.

Table 3 – Image Characteristics

Characteristic	Constraint						
Image Frame Width	1..3840				1..4096		
Image Frame Height	1..2160				1..3112		
Colorimetry	COLOR.3	COLOR.4	COLOR.5	COLOR.7	COLOR.3	COLOR.5	COLOR.6 COLOR.7
Pixel Bit Depth	8 10		10 12	10 12 16	8 10	10 12	10 12 16
Frame Structure	Progressive						
Stereoscopy	Monoscopic Stereoscopic						
Frame Rate	24 24000/1001 25 30 30000/1001 50 60000/1001 60				24 24000/1001 25 30 30000/1001 50 60000/1001 60 120		
Sampling	4:2:2				4:4:4		
Quantization	QE.1				QE.1 QE.2		
Color Components	$Y'C'_BC'_R$				R'G'B'		

EXAMPLE 1: An image frame that combines COLOR.6 colorimetry with $Y'C'_BC'_R$ color components is not supported.

EXAMPLE 2: A monoscopic progressive R'G'B' 4:4:4 image frame with dimensions 3840x2160 that combines COLOR.7 colorimetry with 12-bit pixel bit depth, 60 Hz frame rate, and QE.2 quantization is supported.

Note 1: QE.1, QE.2 and COLOR.3 are defined in SMPTE ST 2067-20.

Note 2: This specification does not support the $Y'_CC'_{BC}C'_{RC}$ (constant luminance) color components specified in Recommendation ITU-R BT.2020.

Note 3: IEC 61966-2-4 uses $Y'C'_BC'_R$ and YCC (luma-chroma-chroma) interchangeably.

5.2 Colorimetry

Implementations shall support the mappings of component signals to red, green and blue tristimulus values listed in Table 4.

Table 4 – Colorimetry Systems

System	Description
COLOR.4	Mapped using method xvYCC709 as specified in IEC 61966-2-4
COLOR.5	Mapped as specified in Recommendation ITU-R BT.2020. R'G'B' components are mapped to $Y'C'_BC'_R$ components using the (non-constant luminance) derivation of Y' and colour difference signals specified in Table 4 of Recommendation ITU-R BT.2020.
COLOR.6	Mapped using the P3D65 color system color primaries and white point specified in Annex D, and the transfer function specified in SMPTE ST 2084
COLOR.7	R'G'B' components are mapped using the color primaries and white point specified in Recommendation ITU-R BT.2020 and the transfer function specified in SMPTE ST 2084. R'G'B' components are mapped to $Y'C'_BC'_R$ components using the (non-constant luminance) derivation of Y' and colour difference signals specified in Table 4 of Recommendation ITU-R BT.2020.

5.3 Encoding Profile

Implementations shall support the combinations of JPEG 2000 profiles (as specified in ISO/IEC 15444-1 Amd.7) and image frame dimensions listed in Table 5, which replaces Table 5 in ST 2067-20.

See Section 5.1 for a definition of the notation *a*…*b*.

Table 5 – JPEG 2000 Profiles

Image Frame Width	1..3840		1..2048		2049..4096	
Image Frame Height	1..2160		1..1556		1..3112	
JPEG 2000 Profile	Broadcast Contribution Single Tile Profile	Broadcast Contribution Multi-tile Reversible Profile	2k IMF single/multi-tile reversible profile	2k IMF Single Tile Lossy Profile	4k IMF single/multi-tile reversible profile	4k IMF Single Tile Lossy Profile
JPEG 2000 Operating Levels	Level 1 Level 2 Level 3 Level 4 Level 5	Level 6 Level 7	Mainlevel 1 Mainlevel 2 Mainlevel 3 Mainlevel 4 Mainlevel 5 Mainlevel 6		Mainlevel 1 Mainlevel 2 Mainlevel 3 Mainlevel 4 Mainlevel 5 Mainlevel 6 Mainlevel 7 Mainlevel 8	
JPEG 2000 Operating Sublevels	n/a		Sublevel 0 only	All allowed at a given Mainlevel with the exception of Sublevel 0	Sublevel 0 only	All allowed for a given Mainlevel with the exception of Sublevel 0

Note: The JPEG 2000 Broadcast Contribution profiles do not support either 16-bit Pixel Bit Depth or a Maximum Components Sampling Rate greater than $520 \cdot 10^6$ samples$\cdot s^{-1}$. In both cases, JPEG 2000 IMF Profiles are used instead.

6 Image Track Files

6.1 Generic Picture Essence Descriptor

6.1.1 Transfer Characteristic

The value of the Transfer Characteristic item shall be equal to:

- 06.0E.2B.34.04.01.01.0D.04.01.01.01.01.08.00.00 ["IEC 61966-2-4 xvYCC Transfer Characteristic" in SMPTE RP 224] if the COLOR.4 system is used.
- 06.0E.2B.34.04.01.01.0E.04.01.01.01.01.09.00.00 ["ITU-R.BT2020 Transfer Characteristic" in SMPTE RP 224] (see Annex B) if the COLOR.5 system is used.
- 06.0E.2B.34.04.01.01.0D.04.01.01.01.01.0A.00.00 ["SMPTE ST 2084 Transfer Characteristic" in SMPTE RP 224] (see Annex E) if the COLOR.6 or COLOR.7 systems are used.

6.1.2 Coding Equations

The value of the Coding Equations item shall be equal to:

- 06.0E.2B.34.04.01.01.01.04.01.01.01.02.02.00.00 ["Identifies ITU BT-709 Coding Equations" in SMPTE RP 224] if COLOR.4 system is used.
- 06.0E.2B.34.04.01.01.0D.04.01.01.01.02.06.00.00 ["Identifies ITU-R BT.2020 coding equations for non-constant luminance" in SMPTE RP 224] (see Annex F) if COLOR.5 or COLOR.7 system is used.

6.1.3 Color Primaries

The value of the Color Primaries item shall be equal to:

- 06.0E.2B.34.04.01.01.06.04.01.01.01.03.03.00.00 ["ITU-R.BT709 Color Primaries" in SMPTE RP 224] if the COLOR.4 system is used.
- 06.0E.2B.34.04.01.01.0D.04.01.01.01.03.04.00.00 ["ITU-R.BT2020 Color Primaries" in SMPTE RP 224] if the COLOR.5 or COLOR.7 systems are used.
- 06.0E.2B.34.04.01.01.0D.04.01.01.01.03.06.00.00 ["P3D65 Color Primaries" in SMPTE RP 224] (see Annex D.2) if the COLOR.6 system is used.

6.1.4 Picture Essence Coding

The value of the Picture Essence Coding item shall reflect the JPEG 2000 profile and operating level used to encode the image essence.

SMPTE RP 224 lists the labels corresponding to the JPEG 2000 profiles and operating levels listed in Section 5.3.

6.1.5 Mastering Display Color Volume Metadata

If COLOR.5, COLOR.6 or COLOR.7 system is used then

- either all or none of the items specified in Annex C shall be present;
- the items specified in Annex C should characterize the mastering display; and
- if the items specified in Annex C are absent, no ST 2086 metadata values are assumed.

If neither COLOR.5, COLOR.6 nor COLOR.7 system is used, then no item specified in Annex C shall be present.

Note: Annex C.6 contains selected examples values for Mastering Display Color Volume Metadata. Other values, not specified in these examples, are also permitted.

6.2 RGBA Picture Essence Descriptor

The values of the Component Max Ref and Component Min Ref items shall be set according to the pixel bit depth and quantization system used, as specified in Table 6 below and Table 10 in SMPTE ST 2067-20.

Table 6 – Component Max Ref and Component Min Ref values

System	*QE.1*		*QE.2*	
Pixel Bit Depth	12	16	12	16
Component Min Ref	256	4096	0	0
Component Max Ref	3760	60160	4095	65535

6.3 CDCI Picture Essence Descriptor

If COLOR.4, COLOR.5 or COLOR.7 is used, the values of the Black Ref Level, White Ref level and Color Range items shall be set according to Table 7.

Table 7 – Black Ref Level, White Ref level and Color Range values for COLOR.4, COLOR.5 and COLOR.7

Colorimetry	**COLOR.4**		**COLOR.5 COLOR.7**		
Pixel Bit Depth	**8**	**10**	**10**	**12**	**16**
Black Ref Level	16	64	64	256	4096
White Ref level	235	940	940	3760	60160
Color Range	254	1013	897	3585	57345

Note 1: The White Ref level item applies only to the Y' component, and the Color Range item to the C'_B and C'_R components.

Note 2: In the case of COLOR.7, "White Ref" is occasionally referred to as "Nominal Peak".

7 Composition

7.1 ApplicationIdentification

The ApplicationIdentification element (see SMPTE ST 2067-2 as referenced by SMPTE ST 2067-20) shall include the value listed in Table 8.

Table 8 – Application Identification

`http://www.smpte-ra.org/schemas/2067-21/2016`

7.2 MaxCLL and MaxFALL

If MainImage conforms to COLOR.6 or COLOR.7, the ExtensionProperties element of the Composition Playlist instance shall include

- zero or one instance of the MaxCLL element specified in Table 9; and
- zero or one instance of the MaxFALL element specified in Table 9.

Table 9 – MaxCLL and MaxFALL elements

```
<xs:element name="MaxCLL" type="xs:unsignedShort"/>
<xs:element name="MaxFALL" type="xs:unsignedShort"/>
```

The MaxCLL and MaxFALL values shall be calculated as specified in Annex A.1 and A.2 of CEA 861.3, respectively. This calculation shall use the MainImage Virtual Track image essence contained:

- within the area specified by the Active Area Rectangle; and
- only from the First Frame of Composition to the Last Frame of Composition, if specified.

If the MaxCLL (MaxFALL) value is unknown, then the MaxCLL (MaxFALL) element shall be (i) absent or (ii) set to 0.

The MaxCLL and MaxFALL values shall be represented in units of 1 cd/m^2.

Annex A Bibliography (Informative)

SMPTE RP 177:2003, Derivation of Basic Television Color Equations

SMPTE RP 224, SMPTE Labels Registry

SMPTE RP 431-2:2011, D-Cinema Quality — Reference Projector and Environment

Recommendation ITU-R BT.2035, A Reference Viewing Environment for Evaluation of HDTV Program Material or Completed Programmes

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

Recommendation ITU-T H.265 (04/2015), High Efficiency Video Coding

Annex B ITU-R.BT2020 Transfer Characteristic Label

Table B.1 – ITU-R.BT2020 Transfer Characteristic Label

Byte No.	Description	Value (hex)	Meaning
1-7	(see Transfer Characteristic node)		
8	Version Number	0Eh	Registry Version at the point of registration of this label
9-13	(see Transfer Characteristic node)		
14	ITU-R.BT2020 Transfer Characteristic	09h	Identifies ITU-R BT.2020 transfer characteristic
15-16		00h	

Annex C Mastering Display Color Volume Metadata

C.1 General

Table C.1 specifies optional items for the Generic Picture Essence Descriptor (see SMPTE ST 377-1) based on the metadata parameters specified in SMPTE ST 2086.

Table C.1 – Color Volume Metadata

Item Name	Item Symbol	Type	Len	Local Tag	Item UL	Req	Meaning	Default
Mastering Display Primaries	MasteringDisplayPrimaries	ThreeColorPrimaries	12	dyn	urn:smpte:ul:060e2b34.01010101.0e042004.01010000	Opt	Display Primaries metadata as specified in ST 2086	n/a
Mastering Display White Point Chromaticity	MasteringDisplayWhitePointChromaticity	ColorPrimary	4	dyn	urn:smpte:ul:060e2b34.01010101.0e042004.01020000	Opt	Chromaticity of White Point metadata as specified in ST 2086	n/a
Mastering Display Maximum Luminance	MasteringDisplayMaximumLuminance	UInt32	4	dyn	urn:smpte:ul:060e2b34.01010101.0e042004.01030000	Opt	Maximum Display Mastering Luminance metadata as specified in ST 2086	n/a
Mastering Display Minimum Luminance	MasteringDisplayMinimumLuminance	UInt32	4	dyn	urn:smpte:ul:060e2b34.01010101.0e042004.01040000	Opt	Minimum Display Mastering Luminance metadata as specified in ST 2086	n/a

Note: The quantization of the metadata parameters match that specified in Section D.2.27 of Recommendation ITU-T H.265.

C.2 Mastering Display Primaries

If present, the Mastering Display Primaries item shall be equal to the Display Primaries metadata specified in SMPTE ST 2086.

The ColorPrimary type shall consist of two UInt16 elements, in order, the normalized x and y chromaticity coordinates of the color primary in units of 0.00002.

EXAMPLE: The color primary characterized by the (x, y) chromaticity coordinates of (0.6800, 0.3200) is represented by a ColorPrimary value of {34000, 16000}.

Note 1: The elements of a ColorPrimary instance that conforms to the precision specified in ST 2086 (four decimal places) are multiples of 5 (0.0001 = 0.00002 · 5).

The ThreeColorPrimaries type shall be a fixed-size sequence of 3 instances of the ColorPrimary type, for a total of 12 bytes. The ColorPrimary instances should be ordered as follows: (i) instance with the largest x

chromaticity coordinate, (ii) instance with the largest y chromaticity coordinate, and (iii) instance with neither the largest y nor the largest x chromaticity coordinate.

Note 2: The recommended ordering of the ColorPrimary instances corresponds to RGB ordering in many common cases.

C.3 Mastering Display White Point Chromaticity

If present, the Mastering Display White Point Chromaticity item shall be equal to the Chromaticity of White Point metadata specified in SMPTE ST 2086.

The ColorPrimary type is specified in Annex C.

C.4 Mastering Display Maximum Luminance

If present, the Mastering Display Maximum Luminance item shall be equal to the Maximum Display Mastering Luminance metadata specified in SMPTE ST 2086.

The value Mastering Display Maximum Luminance item shall be expressed in units of 0.0001 candelas per square metre.

C.5 Mastering Display Minimum Luminance

If present, the Mastering Display Minimum Luminance item shall be equal to the Minimum Display Mastering Luminance metadata specified in SMPTE ST 2086.

The value Mastering Display Minimum Luminance item shall be expressed in units of 0.0001 candelas per square metre.

C.6 **Examples** (Informative)

Table C.2 lists example values for the items specified in Table C.1.

Table C.2 – Example values for the Mastering Display Color Volume Metadata

Item	Example Values	
Mastering Display White Point Chromaticity	Illuminant D65 specified in SMPTE RP 177	{ 15635, 16450 }
Mastering Display Primaries	Color primaries specified in Recommendation ITU-R BT.709	{ 32000, 16500 } { 15000, 30000 } { 7500, 3000 }
	Color primaries specified in Recommendation ITU-R BT.2020	{ 35400, 14600 } { 8500, 39850 } { 6550, 2300 }
	Color primaries of the P3D65 system specified in Annex D	{ 34000, 16000 } { 13250, 34500 } { 7500, 3000 }
Mastering Display Maximum Luminance	Reference white in Recommendation ITU-R BT.2035	1000000
	Mastering display with a maximum luminance of 4000 cd/m^2	40000000
Mastering Display Minimum Luminance	Reference black in Recommendation ITU-R BT.2035	100
	Mastering display with a minimum luminance of 0.005 cd/m^2	50

Annex D P3D65 Color System

D.1 Definition

The following defines the P3D65 color system with RGB component signals based on

- the color primaries specified in SMPTE RP 431-2, and
- the illuminant D65 specified in SMPTE RP 177.

The component signals of the color system shall be represented by red, green, and blue tristimulus values (RGB) whose colorimetric attributes are based upon reference primaries with the chromaticity coordinates specified in Table D.1.

Table D.1 – P3D65 Color System Color Primaries and White Point

	x	y
Red (R)	0.6800	0.3200
Green (G)	0.2650	0.6900
Blue (B)	0.1500	0.0600
White Point	0.3127	0.3290
The (x,y) coordinates are used as specified in ISO 11664-3.		

D.2 Color Primaries Label

Table D.2 – P3D65 Color Primaries Label

Byte No.	Description	Value (hex)	Meaning
1-7		(see Color Primaries node)	
8	Version Number	0Dh	Registry Version at the point of registration of this label
9-13		(see Color Primaries node)	
14	P3D65 Color Primaries	06h	Identifies P3D65 color primaries as specified in SMPTE ST 2067-21
15-16		00h	

Annex E SMPTE ST 2084 Transfer Characteristic Label

Table E.1 – SMPTE ST 2084 Transfer Characteristic Label

Byte No.	Description	Value (hex)	Meaning
1-7	(see Transfer Characteristic node)		
8	Version Number	0Dh	Registry Version at the point of registration of this label
9-13	(see Transfer Characteristic node)		
14	SMPTE ST 2084 Transfer Characteristic	0Ah	Identifies the transfer characteristics as specified in SMPTE ST 2084
15-16		00h	

Annex F ITU-R.BT2020 Non-Constant Luminance Coding Equations Label

Table F.1 – ITU-R.BT2020 Non-Constant Luminance Coding Equations Label

Byte No.	Description	Value (hex)	Meaning
1-7	(see Coding Equations node)		
8	Version Number	0Dh	Registry Version at the point of registration of this label
9-13	(see Coding Equations node)		
14	ITU-R BT.2020 Non-Constant Luminance Coding Equations	06h	Identifies ITU-R BT.2020 coding equations for non-constant luminance
15-16		00h	

Annex G Consolidated Schema (Informative)

This specification is accompanied by the following element, which is an XML schema document as specified in the XML Schema Part 1: Structures.

35PM-DP-ST-2067-21-revision-app-2e-20160411.xsd

This element collects the XML schema definitions defined in this specification. It is informative and, in case of conflict, this specification takes precedence.