SMPTE ST 2067-40:2016

SMPTE STANDARD

Interoperable Master Format — Application #4 Cinema Mezzanine

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Foreword

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SMPTE Engineering Documents are drafted in accordance with the rules given in its Standards Operations Manual.

SMPTE ST 2067-40 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 document specifies compositions for IMF Application #4. IMF Application #4 is a specialization of the IMF Framework, and is intended to exchange content of cinematographic work after digital postproduction either sourced from film or from digital media and can be used in a preservation framework. It specifies:

- images encoded using 16-bit XYZ color primaries and a linear transfer function;
- maximum image frame width and height of 8192 and 6224 pixels, respectively; and
- a constrained Composition structure that mimics the segmentation of movie into individual reels.

To simplify implementation, IMF Application #4 reuses constraints from IMF Application #2 whenever appropriate.

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 RP 224, SMPTE Labels Registry

SMPTE ST 379-1:2009, Material Exchange Format (MXF) — MXF Generic Container

SMPTE ST 422:2014, Material Exchange Format — Mapping JPEG 2000 Codestreams into the MXF Generic Container

SMPTE ST 431-1:2006, D-Cinema Quality — Screen Luminance Level, Chromaticity and Uniformity

SMPTE ST 2067-2:2016, Interoperable Master Format — Core Constraints

SMPTE ST 2067-21:2016, Interoperable Master Format — Application 2E

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

ISO/IEC 15444-1:2004, Information Technology — JPEG 2000 Image Coding System: Core Coding System

ISO/IEC 15444-1:2004 AMD 7:2015, Information Technology — JPEG 2000 Image Coding System

4 Basic Constraints

4.1 General

All provisions of SMPTE ST 2067-2 shall apply.

4.2 Format

Track Files shall conform to SMPTE ST 379-1.

4.3 Shim Parameters

Track Files shall be associated with the shim parameter values specified in Table 1.

Table 1 – Shim Parameter Values Definitions

Shim Parameter	Value
shim_id	http://www.smpte-ra.org/schemas/2067-40/2016
gc_type	379-1-gc
picture_family	JPEG2000
picture_bitrate	ST 2067-40
picture_format	ST 2067-40
picture_custom_ANC	false
picture_render_ANC	false

5 Image Essence

5.1 General

Image essence shall consist of image frames, each a rectangular pixel array.

5.2 Constraints

Image frames shall conform to the combinations of characteristics allowed in Table 2.

Table 2 – Image Characteristics

Image Frame Width		1..2048	1..4096	1..8192
Image Frame Height		1..1556	1..3112	1..6224
Pixel Bit Depth n		16		
Frame Structure		Progressive		
Stereoscopy		Monoscopic Stereoscopic		
Frame Rate		16 200/11 20 240/11 24 25 30 48 50 60 100 120		
Sampling		4:4:4		
Quantization	§5.3.2	QE.APP4.1 (integer)		
Color Components	§5.3.1	XYZ		
Colorimetry	§5.3.1			

5.3 Characteristics

5.3.1 Color Components and Colorimetry

The Image Pixels shall be described using XYZ tristimulus values (color component triplet), as specified in ISO 11664-3.

XYZ values are deduced from the print element or from digital source. They should correspond to XYZ values measured off screen from a calibrated projection. Therefore the luminance of the maximum white on screen is 48 cd/m^2.

5.3.2 Quantization

The Image Pixels shall be described with XYZ component triplets quantized according to the system specified in Table 3.

For QE.APP4.1 the INT() operator returns the lower integer value for fractional parts in the range of 0 to 0.4999... and the closest higher integer for fractional parts in the range 0.5 to 0.9999..., i.e. it rounds up fractions above 0.5.

Table 3 – Quantization Systems

System	Component Triplet	Quantization equations
QE.APP4.1	XYZ	$D_X = INT(X \times 10^3)\ ;\ 0 \le X \le 52.37$ $D_Y = INT(Y \times 10^3)\ ;\ 0 \le Y \le 48.0$ $D_Z = INT(Z \times 10^3)\ ;\ 0 \le Z \le 52.37$

5.4 Encoding

5.4.1 General

5.4.2 Single Codestream

Each frame shall be a single codestream, as specified in ISO/IEC 15444-1.

5.4.3 Profile and Operating Levels

The JPEG 2000 profile and operating level (as specified in ISO/IEC 15444-1 Amendment 7) for each image frame dimension shall conform to Table 4. Table A.53 of the ISO/IEC 15444-1 Amendment 7 shall be used to select the Level/Sublevel.

Table 4 – JPEG 2000 Profiles

Image Frame Width	1..2048	1..4096	1..8192
Image Frame Height	1..1556	1..3112	1..6224
JPEG 2000 Profile	2k IMF single/multi-tile reversible profile	4k IMF single/multi-tile reversible profile	8k IMF single/multi-tile reversible profile
JPEG 2000 Operating Levels	Mainlevel 1 Sublevel 0 Mainlevel 2 Sublevel 0 Mainlevel 3 Sublevel 0 Mainlevel 4 Sublevel 0 Mainlevel 5 Sublevel 0 Mainlevel 6 Sublevel 0	Mainlevel 1 Sublevel 0 Mainlevel 2 Sublevel 0 Mainlevel 3 Sublevel 0 Mainlevel 4 Sublevel 0 Mainlevel 5 Sublevel 0 Mainlevel 6 Sublevel 0 Mainlevel 7 Sublevel 0 Mainlevel 8 Sublevel 0	Mainlevel 1 Sublevel 0 Mainlevel 2 Sublevel 0 Mainlevel 3 Sublevel 0 Mainlevel 4 Sublevel 0 Mainlevel 5 Sublevel 0 Mainlevel 6 Sublevel 0 Mainlevel 7 Sublevel 0 Mainlevel 8 Sublevel 0 Mainlevel 9 Sublevel 0 Mainlevel 10 Sublevel 0

The J2K profile should be selected such that its maximum supported image frame dimensions (as specified in Table 4) are the smallest encompassing the image frame dimensions. Similarly, the J2K operating level should be chosen such as no lower operating level would support the image essence.

5.4.4 Component Ordering

In a codestream, color components shall be ordered as specified in Table 5.

Table 5 – JPEG 2000 Color Component Ordering

Component Index	XYZ
0	X
1	Y
2	Z

6 Track Files

6.1 Image Track Files

6.1.1 Essence

Image Track Files shall contain image essence conforming to Section 5.

6.1.2 Wrapping

Image Track Files shall conform to SMPTE ST 422.

The image essence shall be wrapped according to mode P1 specified in SMPTE ST 422 ("Frame-wrapping".)

The Top-Level File Package of Image Track File shall reference an RGBA Picture Essence Descriptor.

6.1.2.1 Generic Picture Essence Descriptor

6.1.2.1.1 General

The Generic Picture Essence Descriptor items (including those specified in SMPTE ST 2067-2) shall be constrained as specified in Table 6.

Table 6 – Generic Picture Essence Descriptor Items

Generic Picture Essence Descriptor Item	Constraints
Sample Rate	See Annex A of SMPTE ST 422.
Signal Standard	Shall be ignored by the decoder.
Frame Layout	00h (FULL_FRAME)
Stored Width	Shall be equal to Image Frame Width. See Table 2.
Stored Height	Shall be equal to Image Frame Height. See Table 2.
StoredF2Offset	Shall not be present.
Sampled Width	Shall not be present or shall be equal to Stored Width.
Sampled Height	Shall not be present or shall be equal to Stored Height.
SampledXOffset	Shall not be present or shall be 0.
SampledYOffset	Shall not be present or shall be 0.
DisplayWidth	Shall not be present or shall be equal to Stored Width.
DisplayHeight	Shall not be present or shall be equal to Stored Height.
DisplayXOffset	Shall not be present or shall be 0.
DisplayYOffset	Shall not be present or shall be 0.
ActiveWidth	See Annex B for illustrative examples. Note: Unless explicitly set, the Active Area Rectangle is by default equal to the Display Rectangle – see SMPTE ST 2067-2.
ActiveHeight	
ActiveXOffset	
ActiveYOffset	
DisplayF2Offset	Shall not be present.
Aspect Ratio	Shall be present. See Annex B for illustrative examples.
Active Format Descriptor	Shall be ignored by the decoder
Video Line Map	Shall be ignored by the decoder.
Alpha Transparency	Shall not be present.
Transfer Characteristic	Shall be present. See Section 6.1.2.1.2.

Image Alignment Offset	Shall not be present.
Image Start Offset	Shall not be present.
Image End Offset	Shall not be present.
FieldDominance	Shall not be present.
Picture Essence Coding	Shall be present. See Section 6.1.2.1.4.
Coding Equations	Shall not be present.
Color Primaries	Shall be present. See Section 6.1.2.1.3.
Alternative Center Cuts	Shall be ignored by the decoder.
Mastering Display Primaries	May be present. See Section 6.1.2.1.5.
Mastering Display White Point Chromaticity	May be present. See Section 6.1.2.1.6.

Note: See Annex B in this specification and Annex H in SMPTE ST 2067-2 for examples of the use of active area rectangle.

6.1.2.1.2 Transfer Characteristic

The value of the Transfer Characteristic item shall be equal to:
06.0E.2B.34.04.01.01.01.04.01.01.01.01.06.00.00 ["Identifies a linear transfer characteristic" in SMPTE RP 224].

6.1.2.1.3 Encoding Color Primaries

The value of the Color Primaries item shall be equal to the label specified in Annex A.

6.1.2.1.4 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 5.4.3

6.1.2.1.5 Mastering Display Primaries

If the Mastering Display Primaries item defined in SMPTE ST 2067-21 is present, its value shall be one specified in Table 7.

Table 7 – Defined values of the Mastering Display Primaries item

Value	Notes

{
{ 34000, 16000 },
{ 13250, 34500 },
{ 7500, 3000 }
}
	Corresponds to the RGB color primaries, in order, of the reference projector defined in SMPTE RP 431-2 :
	Red (0.680, 0.320),
	Green (0.265,0.690),
	Blue (0.150,0.060)

If the Mastering Display Primaries item is absent, no information on the mastering display is available.

Note: The ColorPrimary type specified in SMPTE ST 2067-21 is expressed in units of 0.00002.

6.1.2.1.6 Chromaticity of the Mastering Display White Point Chromaticity

If the Chromaticity of the white point item defined in SMPTE ST 2067-21 is present, its value shall be one specified in Table 8.

Table 8 – Defined values of the Mastering Display White Point Chromaticity item

Value	Notes

{
{ 15700, 17550 }
}
	Corresponds to the white chromatic coordinates as defined in SMPTE ST 431-1 :
	White (0.314,0.351)

{
{ 15635, 16450 }
}
	Corresponds to the white chromatic coordinates as defined in SMPTE EG 432-1 :
	D65 White (0.3127, 0.3290)

{
{ 15990, 16800 }
}
	Corresponds to the white chromatic coordinates as defined in SMPTE EG 432-1 :
	D61 White {0.3198, 0.3360}

{
{ 16085, 16890 }
}
	Corresponds to the white chromatic coordinates as defined in SMPTE EG 432-1 :
	D60 White (0.3217,0.3378)

{
{ 16620, 17370 }
}
	Corresponds to the white chromatic coordinates as defined in SMPTE EG 432-1 :
	D55 White (0.3324,0.3474)

The mastering display white point is the one used during the validation process of the content.

Note: The ColorPrimary type specified in SMPTE ST 2067-21 is expressed in units of 0.00002.

6.1.2.2 RGBA Picture Essence Descriptor

6.1.2.2.1 General

The RGBA Picture Essence Descriptor items shall be constrained as specified in Table 9.

Table 9 – RGBA Essence Descriptor items

RGBA Picture Essence Descriptor Item	Constraints
Component Max Ref	Shall be present. See Section 6.1.2.2.2.
Component Min Ref	Shall be present. See Section 6.1.2.2.2.
Alpha Max Ref	Shall not be present.
Alpha Min Ref	Shall not be present.
ScanningDirection	Shall be present and shall be equal to 00h.
PixelLayout	Shall be present. See Section 6.1.2.2.3.
Palette	Shall not be present.
PaletteLayout	Shall not be present.

6.1.2.2.2 Component Max Ref and Component Min Ref

The values of the Component Max Ref and Component Min Ref items shall be as specified in Table 10.

Table 10 – Component Max Ref and Component Min Ref values

Integer	Component Min Ref	0
	Component Max Ref	$2^{16} - 1$

6.1.2.2.3 PixelLayout

The value of the PixelLayout item shall be equal to { D8h, 16, D9h, 16, DAh, 16, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0 }.

6.1.2.3 JPEG 2000 Picture Sub Descriptor

6.1.2.3.1 General

The Top-Level File Package of the Image Track File shall reference a JPEG 2000 Picture Sub Descriptor SMPTE ST 422 as constrained by Table 11.

Table 11 – JPEG 2000 Picture Subdescriptor items

JPEG 2000 Picture Subdescriptor Item	Constraints
Coding Style	Shall be present.
J2CLayout	Shall be present. See Section 6.1.2.3.2.

6.1.2.3.2 J2CLayout

The value of the J2CLayout item shall be equal to the PixelLayout item of the RGBA Descriptor (see Section 6.1.2.2.3).

6.2 Audio Track Files

Each Audio Track File shall contain at least one audio channel.

7 Composition

7.1 Segments

A Composition Segment should correspond to a single digitization unit, i.e. a reel or part of a reel from one scan pass.

7.2 Application Identification

The ApplicationIdentification element (as defined in SMPTE ST 2067-2) shall include exactly one instance of the value listed in Table 12.

Table 12 – Application Identification

`http://www.smpte-ra.org/schemas/2067-40/2016`

7.3 Homogenous Essence

Within a given a composition, the following shall remain constant:

- all image essence characteristics specified in Section 5.3.
- the codestream profile and level combination (see Section 5.4.1).

7.4 ContentKind

The ContentKind element shall be present in the Composition Playlist.

7.5 Creator

The Creator element shall be present in the Composition Playlist.

7.6 Issuer

The Issuer element shall be present in the Composition Playlist.

7.7 ContentVersion

At least one ContentVersion element shall be present in the Composition Playlist.

7.8 EntryPoint

EntryPoint should be either 0 or omitted from each Resource, unless EntryPoint indicates the active start of the element following all calibration or leader sequences present in the original film element. In the latter case, the EntryPoint should be equal on all resources referenced in a segment.

7.9 IntrinsicDuration

Within a Segment, all Resources belonging to MainImageSequence and MainAudioSequence Sequences shall have equal IntrinsicDuration.RepeatCount

RepeatCount for each Resource shall be omitted or shall be equal to 1.

7.10 Single Resource

A Sequence shall contain exactly one Resource.

7.11 Number of Audio Tracks

A Composition shall contain zero or more Audio Virtual Track, which shall consist of one or more MainAudioSequence elements.

Annex A XYZ Color Primaries

Table A.1 – XYZ Color Primaries

Name	Cinema Mezzanine Color Primaries
Symbol	ColorPrimaries_CinemaMezzanine
Namespace	http://www.smpte-ra.org/reg/400/2012
Item UL	060e2b34.0401010d.04010101.03080000
Definition	Identifies XYZ tristimulus values as specified in ISO 11664-3

Annex B Active Area Rectangle Examples (Informative)

Table B.1 provides examples of the use of active area and aspect ratio for selected image frame sizes.

Table B.1 – Example Image Frame Size

	1.85 aspect ratio image within a 2K container (with black bands)	1.85 aspect ratio image within a 4K container (with black bands)	16/9 aspect ratio image within a 2K container (without black bands)	2.39 aspect ratio image within a 2K container (without black bands)
Stored Width	2048	4096	1920	2048
Stored Height	1556	3112	1080	858
StoredF2FOffset	0	0	0	0
Sampled Width	2048	4096	1920	2048
Sampled Height	1556	3112	1080	858
Sampled X Offset	0	0	0	0
Sampled Y Offset	0	0	0	0
Display Width	2048	4096	1920	2048
Display Height	1556	3112	1080	858
Display X Offset	0	0	0	0
Display Y Offset	0	0	0	0
Aspect Ratio	2048/1556	4096/3112	16/9	1024/429
Active Width	2048	4096	1920	2048
Active Height	1106	2212	1080	858
Active X Offset	0	0	0	0
Active Y Offset	215	430	0	0

Bibliography (Informative)

SMPTE EG 432-1:2010, Digital Source Processing — Color Processing for D-Cinema

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