SMPTE STANDARD

Interoperable Master Format — Application SMPTE ST 2019-1 (VC-3)

Table of Contents

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Approved August 21, 2024

Foreword

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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 clause 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; then formal languages; then figures; and then any other language forms.

Intellectual Property

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1 Scope

This document specifies an Application of the IMF framework specified in SMPTE ST 2067-2. The Application covers usage of the VC-3 codec as specified in SMPTE ST 2019-1.

2 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 379-2:2010, *Material Exchange Format (MXF) — MXF Constrained Generic Container*. https://doi.org/10.5594/smpte.st379-2.2010

SMPTE ST 2019-1:2016, *VC-3 Picture Compression and Data Stream Format*. https://doi.org/10.5594/smpte.st2019-1.2016

SMPTE ST 2019-4:2016, *Mapping VC-3 Coding Units into the MXF Generic Container*. https://doi.org/10.5594/smpte.st2019-4.2016

SMPTE ST 2019-4:2016 Am1:2024, *Mapping VC-3 Coding Units into the MXF Generic Container–Amendment 1*. https://doi.org/10.5594/SMPTE.ST2019-4.2016Amd1.2024

SMPTE ST 2067-2:2020, *Interoperable Master Format – Core Constraints*. https://doi.org/10.5594/smpte.st2067-2.2020

SMPTE ST 2067-5:2020, *Interoperable Master Format – Essence Component*. https://doi.org/10.5594/smpte.st2067-5.2020

SMPTE ST 2067-21:2023, *Interoperable Master Format – Application #2E*. https://doi.org/10.5594/smpte.st2067-21.2023

SMPTE ST 2067-101:2018, *Interoperable Master Format – Output Profile List – Common Image Definitions and Macros*. https://doi.org/10.5594/smpte.st2067-101.2018

SMPTE ST 2067-102:2022, *Common Image Pixel Color Schemes*. https://doi.org/10.5594/smpte.st2067-102.2022

W3C *XML Schema Part 1: Structures*

W3C *XML Schema Part 2: Datatypes*

3 Terms and Definitions

No terms and definitions are listed in this document.

4 General

All provisions of SMPTE ST 2067-2 shall apply.

5 Image Essence

5.1 Characteristics

Image frames shall conform to the combinations of characteristics allowed in Table 1. The notation [a, b] indicates that any value in the interval between a and b, including a and b, shall be allowed.

Table 1 — Image Characteristics

Characteristic	***Constraint***			
Image Frame Width	1920		[1, 16384]	
Image Frame Height	1080		[1, 16384]	
Frame Structure	Interlaced		Progressive	
Stereoscopy	Monoscopic		Monoscopic Stereoscopic	
Colorimetry	COLOR.3		COLOR.3 COLOR.5 COLOR.6 COLOR.7 COLOR.8	COLOR.3 COLOR.5 COLOR.7 COLOR.8
Sampling	4:4:4	4:2:2	4:4:4	4:4:4, 4:2:2, 4:2:0
Quantization	QE.1		QE.1, QE.2	QE.1, QE.2, QE.3
Color Components	R'G'B'	$Y'C'_BC'_R$	R'G'B'	$Y'C'_BC'_R$
Pixel Bit Depth	10	8,10	10,12	8, 10, 12

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 up to 16384x16384 that combines COLOR.6 colorimetry with 12-bit pixel bit depth, at any frame rate, and QE.2 quantization is supported.

NOTE 1 This specification does not constrain the frame rates allowed in SMPTE ST 2019-4:2016. Clause 7.4 specifies constraints required to conform with Clause 7.2 of SMPTE ST 2067-3:2020.

NOTE 2 The COLOR.n notation in the Colorimetry row represents the permitted Colorimetry Systems which are defined in Clause 5.2.

NOTE 3 The QE.n notation in the Quantization row represents the permitted Quantization Systems which are defined in Clause 5.3.

5.2 Colorimetry

This specification uses the definitions provided by Clause 5.3 of SMPTE ST 2067-21:2023.

Implementations shall support the Colorimetry Systems identified as COLOR.3, COLOR.5, COLOR.6, COLOR.7 and COLOR.8 from that clause.

5.3 Quantization

Implementations shall support R'G'B' or $Y'C'_BC'_R$ component signals being quantized according to one of the systems specified in Clause 5.4 of SMPTE ST 2067-21:2023, as well as the additional quantization system specified in Table 2.

Table 2 — Additional Quantization System

System	Component Triplet	Quantization equations (n is the pixel bit depth)
QE.3	$Y'C'_BC'_R$	$D'_Y = INT(Y' * (2^n-1))$ $D'_{CB} = INT (C'_B * (2^n-1) + 2^{n-1})$ $D'_{CR} = INT (C'_R * (2^n-1) + 2^{n-1})$

5.4 Coding

Each image frame shall consist of a single Compressed Frame as specified in SMPTE ST 2019-1.

Compression IDs 1244, 1258 and 1260 shall not be used.

Encoded alpha data shall not be present on the Main Image Virtual Track.

Bitstream Header Parameters shall be set in accordance with SMPTE ST 2019-1. For the parameters listed in Table 3 specific constraints shall apply in the context of this specification.

Table 3 — Bitstream Header Parameters

Bitstream Parameter	Constraint
HVN	**1, 2, 3**
MACF	**0** (not using adaptive macroblock coding)
ALPF/NAL	Shall be equal to Image Frame Height
SPL	Shall be equal to Image Frame Width
CompressionID	All identifiers permitted by SMPTE ST 2019-1 for HVN = [1, 3], except 1244, 1258 and 1260.
CLV	**0**: COLOR.3, **1**: COLOR.5, COLOR.8, COLOR.7, **3**: COLOR.6

NOTE 1 The frame rate is signaled in the Generic Picture Essence Descriptor of the Track File.

NOTE 2 The SBD value signals only the quantization precision DT coefficients, *after* the DCT. The actual Pixel Bit Depth is signaled in the Generic Picture Essence Descriptor of the Track File.

6 Image Track Files

6.1 General

Image Track Files shall conform to the provisions made in SMPTE ST 2067-2 and SMPTE ST 379-2.

6.2 Shim Parameters

Image Track Files are associated with the shim parameter values specified in Table 4.

Table 4 — Shim Parameter Values Definitions

Shim Parameter	Value
shim_id	*Value specified in Table 8*
gc_type	379-2-constrained-gc
picture_family	SMPTE ST 2019-1
picture_bitrate	SMPTE ST 2019-1
picture_format	SMPTE ST 2019-1
picture_custom_ANC	False
picture_render_ANC	False

6.3 Essence

Image Track Files shall contain image essence that conforms to Clause 5.

6.4 Wrapping

Image Track Files shall use the mapping defined in SMPTE ST 2019-4, applying the constraints provided by SMPTE ST 2067-5.

6.5 Picture Essence Descriptors

6.5.1 General

The Picture Essence Descriptor referenced by the Top-Level File Package of Image Track File shall be:

- A CDCI Picture Essence Descriptor if the decoded image uses $Y'C'_BC'_R$ color components
- An RGBA Picture Essence Descriptor if the decoded image essence uses R'G'B' color components.

The Generic Picture Essence Descriptor, the CDCI Picture Essence Descriptor and the RGBA Picture Essence Descriptor shall conform to Clause 9 of SMPTE ST 2019-4:2016.

6.5.2 Generic Picture Essence Descriptor

In addition to the provisions in SMPTE ST 2019-4 the following constraints shall apply as specified in Table 5.

Table 5 — Generic Picture Essence Descriptor items

Generic Picture Essence Descriptor item	Constraint
Signal Standard	Shall not be present.
Active Format Descriptor	Shall not be present.
Transfer Characteristic	Shall be present.
Video Line Map	Shall be ignored.
Alpha Transparency	Shall not be present.
Coding Equations	Shall be present if Y'C'$_B$C'$_R$ sampling is used. Should not be present if R'G'B' sampling is used. If present and if R'G'B' sampling is used, they shall be ignored.
Color Primaries	Shall be present.

6.5.3 CDCI Picture Essence Descriptor

In addition to the provisions in SMPTE ST 2019-4 the following constraints shall apply as specified in Table 6.

Table 6 — CDCI Picture Essence Descriptor items

CDCI Picture Essence Descriptor item	Constraint
Reversed Byte Order	Shall not be present
Alpha Sample Depth	Shall not be present for essence on the Main Image Virtual Track
Black Ref Level	Shall be present and set according to the chosen Quantization System.
White Ref Level	Shall be present and set according to the chosen Quantization System.
Color Range	Shall be present and set according to the chosen Quantization System.

6.5.4 RGBA Picture Essence Descriptor

In addition to the provisions in SMPTE ST 2019-4 the following constraints shall apply as specified in Table 7.

Table 7 — RGBA Picture Essence Descriptor items

RGBA Picture Essence Descriptor item	Constraint
Component Max Ref	Shall be present and set according to the chosen Quantization System.
Component Min Ref	Shall be present and set according to the chosen Quantization System.
Alpha Max Ref	Shall not be present
Alpha Min Ref	Shall not be present
ScanningDirection	Shall be present and shall be set to 0.
PixelLayout	Shall be present
Palette	Shall not be present
PaletteLayout	Shall not be present

7 Composition

7.1 Application Identification

The ApplicationIdentification element, as specified in SMPTE ST 2067-2, shall include exactly one instance of the value listed in Table 8.

Table 8 — Application Identification

`http://www.smpte-ra.org/ns/2067-70/2020`

7.2 Homogeneous Essence

Within a given composition, the following shall remain constant:

- All image essence characteristics specified in Clause 6.5.
- The compression ID specified in Clause 5.4.

7.3 Main Image Virtual Track

All Image Track Files referenced by the Main Image Virtual Track shall conform to Clause 7.2.

7.4 Segment Duration (Informative)

Please pay special attention to the provisions of Clause 7.3 of SMPTE ST 2067-3:2020. In order to comply with those provisions, the segment duration needs to be an integer multiple of the inverse of the audio sampling rate.

EXAMPLE: In case the Composition EditRate is 30000:1001, then the segment duration must be a multiple of 5.

In this example, a 48 kHz audio sampling rate implies 1601.6 samples per edit unit. For every 5 units, there is an integer sum of 8008 samples, which permits a perfect alignment between all tracks.

8 Pixel Color Schemes

Annex A defines Pixel Color Schemes, as specified in SMPTE ST 2067-101, for the use with IMF Application SMPTE ST 2019-1 (VC-3).

NOTE Annex A is for the sole purpose of enabling Output Profile List (OPL) processing of Application SMPTE ST 2019-1 (VC-3) IMF packages.

Annex A
(Normative)

Pixel Color Schemes Definition

A.1 XML Schema Definition

Annex A shall apply whenever a data structure is specified using XML schema definitions as specified in W3C XML Schema Part 1: Structures and W3C XML Schema Part 2: Datatypes.

In order to avoid duplication between text and schema, the cardinality and default values of elements are specified in the schema definitions only.

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 A.1.

Table A.1 — XML Schema root element definition

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema targetNamespace="http://www.smpte-ra.org/ns/2067-70/2020/opl-color-
                    scheme"
xmlns:oplcs="http://www.smpte-ra.org/schemas/2067-101/2018/color-schemes"
xmlns:vc3cs="http://www.smpte-ra.org/ns/2067-70/2020/opl-color-scheme"
xmlns:xs="http://www.w3.org/2001/XMLSchema"
elementFormDefault="qualified" attributeFormDefault="unqualified">
<xs:import namespace="http://www.smpte-ra.org/schemas/2067-101/2018/color-
                    schemes"/>
<!-- schema definitions found in Annex A of this document -->
</xs:schema>
```

A.2 APPVC3-QE3-YCbCr-8

The APPVC3-QE3-YCbCr-8 color scheme shall be as specified in Table A.2. The mathematical functions "floor(x)" and "clamp(a, b, x)" in Table A.2 shall be as defined in SMPTE ST 2067-102. The XML datatype Integer256TripletType shall be as defined in SMPTE ST 2067-102.

Table A.2 — APPVC3-QE3-YcbCr-8 Color Scheme

Name	APPVC3-QE3-YCbCr-8
URI	`http://www.smpte-ra.org/ns/2067-70/2020/opl-color-scheme#APPVC3-QE3-YCbCr-8`
Description	Y', C'_B and C'_R components as specified in Clause 5.3, using 8-bit bit depth and COLOR.3, COLOR.5, COLOR.7 or COLOR.8 colorimetry in Table 1.
Mapping from Reference Image Pixel	Y' = floor (255 * clamp (0, 1, P_1) + 0.5) C'_B = floor (255 * (clamp (-0.5, 0.5, P_2) + 0.5)) + 0.5) C'_R = floor (255 * (clamp (-0.5, 0.5, P_3) + 0.5)) + 0.5)
Mapping to Reference Image Pixel	P_1 = Y' / 255 P_2 = (C'_B – 128) / 255 P_3 = (C'_R – 128) / 255

Pixel Encoding Type	`<xs:complexType name="APPVC3-QE3-YCbCr-8-ColorEncodingType">`
	`  <xs:simpleContent>`
	`  <xs:restriction base="oplcs:ColorEncodingType">`
	`  <xs:simpleType>`
	`  <xs:restriction base="oplc:Integer256TripletType"/>`
	`  </xs:simpleType>`
	`  </xs:restriction>`
	`  </xs:simpleContent>`
	`</xs:complexType>`
	The three elements of the triplet shall correspond to the Y', C'_B and C'_R components.

A.3 APPVC3-QE3-YCbCr-10

The APPVC3-QE3-YCbCr-10 color scheme shall be as specified in Table A.3. The mathematical functions "floor(x)" and "clamp(a, b, x)" in Table A.3 shall be as defined in SMPTE ST 2067-102. The XML datatype Integer1024TripletType shall be as defined in SMPTE ST 2067-102.

Table A.3 — APPVC3-QE3-YcbCr-10 Color Scheme

Name	APPVC3-QE3-YCbCr-10
URI	`http://www.smpte-ra.org/ns/2067-70/2020/opl-color-scheme#APPVC3-QE3-YCbCr-10`
Description	Y', C'_B and C'_R components as specified in Clause 5.3, using 10-bit bit depth and COLOR.3, COLOR.5, COLOR.7 or COLOR.8 colorimetry in Table 1.
Mapping from Reference Image Pixel	Y' = floor (1023 * clamp (0, 1, P_1) + 0.5) C'_B = floor (1023 * (clamp (-0.5, 0.5, P_2) + 0.5)) + 0.5) C'_R = floor (1023 * (clamp (-0.5, 0.5, P_3) + 0.5)) + 0.5)
Mapping to Reference Image Pixel	P_1 = Y' / 1023 P_2 = (C'_B – 512) / 1023 P_3 = (C'_R – 512) / 1023

Pixel Encoding Type	`<xs:complexType name="APPVC3-QE3-YCbCr-10-ColorEncodingType">`
	`  <xs:simpleContent>`
	`  <xs:restriction base="oplcs:ColorEncodingType">`
	`  <xs:simpleType>`
	`  <xs:restriction base="oplc:Integer1024TripletType"/>`
	`  </xs:simpleType>`
	`  </xs:restriction>`
	`  </xs:simpleContent>`
	`</xs:complexType>`
	The three elements of the triplet shall correspond to the Y', C'_B and C'_R components.

A.4 APPVC3-QE3-YCbCr-12

The APPVC3-QE3-YCbCr-12 color scheme shall be as specified in Table A.4. The mathematical functions "floor(x)" and "clamp(a, b, x)" in Table A.4 shall be as defined in SMPTE ST 2067-102. The XML datatype Integer4096TripletType shall be as defined in SMPTE ST 2067-102.

Table A.4 — APPVC3-QE3-YcbCr-12 Color Scheme

Name	APPVC3-QE3-YCbCr-12
URI	`http://www.smpte-ra.org/ns/2067-70/2020/opl-color-scheme#APPVC3-QE3-YCbCr-12`
Description	Y', C'_B and C'_R components as specified in Clause 5.3, using 12-bit bit depth and COLOR.3, COLOR.5, COLOR.7 or COLOR.8 colorimetry in Table 1.
Mapping from Reference Image Pixel	Y' = floor (4095 * clamp (0, 1, P_1) + 0.5) C'_B = floor (4095 * (clamp (-0.5, 0.5, P_2) + 0.5)) + 0.5) C'_R = floor (4095 * (clamp (-0.5, 0.5, P_3) + 0.5)) + 0.5)
Mapping to Reference Image Pixel	P_1 = Y' / 4095 P_2 = (C'_B – 2048) / 4095 P_3 = (C'_R – 2048) / 4095

Pixel Encoding Type	`<xs:complexType name="APPVC3-QE3-YCbCr-12-ColorEncodingType">`
	`  <xs:simpleContent>`
	`  <xs:restriction base="oplcs:ColorEncodingType">`
	`  <xs:simpleType>`
	`  <xs:restriction base="oplc:Integer4096TripletType"/>`
	`  </xs:simpleType>`
	`  </xs:restriction>`
	`  </xs:simpleContent>`
	`</xs:complexType>`
	The three elements of the triplet shall correspond to the Y', C'_B and C'_R components.