SMPTE ST 2036-1:2013
Revision of
SMPTE 2036-1-2009

SMPTE STANDARD

Ultra High Definition Television — Image Parameter Values for Program Production

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Approved
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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 Operations Manual.

SMPTE ST 2036-1 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.

1 Scope

1.1 This standard defines a family of progressive image sample structures of 3840 x 2160 or 7680 x 4320 with an aspect ratio of 16x9, called Ultra High Definition Television (UHDTV), as defined in Table 1. This standard specifies:

- R'G'B' color encoding and digital representation
- $Y'C'_BC'_R$ color encoding and digital representation.

1.2 This standard specifies multiple samples, line and frame rate formats for ten-bit and twelve-bit systems. It is not necessary for an implementation to support all formats to be compliant with this standard. However, an implementation must state which of the Systems are supported.

Table 1 – Image sample structures and frame rates of UHDTV systems

System category	System nomenclature	Luma or R' G' B' samples per line	Lines per frame	Frame rate (Hz)
UHDTV1	3840 x 2160/23.98/P	3840	2160	24/1.001
	3840 x 2160/24/P	3840	2160	24
	3840 x 2160/25/P	3840	2160	25
	3840 x 2160/29.97/P	3840	2160	30/1.001
	3840 x 2160/30/P	3840	2160	30
	3840 x 2160/50/P	3840	2160	50
	3840 x 2160/59.94/P	3840	2160	60/1.001
	3840 x 2160/60/P	3840	2160	60
	3840 x 2160/120/P	3840	2160	120
UHDTV2	7680 x 4320/23.98/P	7680	4320	24/1.001
	7680 x 4320/24/P	7680	4320	24
	7680 x 4320/25/P	7680	4320	25
	7680 x 4320/29.97/P	7680	4320	30/1.001
	7680 x 4320/30/P	7680	4320	30
	7680 x 4320/50/P	7680	4320	50
	7680 x 4320/59.94/P	7680	4320	60/1.001
	7680 x 4320/60/P	7680	4320	60
	7680 x 4320/120/P	7680	4320	120

Note: Throughout this standard, references to signals represented by a single primed letter (e.g., R', G' and B') refer to signals to which the transfer characteristics in Section 6.3 have been applied. Such signals are commonly described as being gamma corrected.

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 an Engineering 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

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]

SMPTE RP 177-1993, Derivation of Basic Television Color Equations

4 General

4.1 The specification of a system claiming compliance with this standard shall state:

- which of the systems of Table 1 are implemented;
- which of the signal representations are implemented (R’G’B’ or $Y'C'_BC'_R$);
- whether the digital representation employs uniformly quantized (linear), PCM, 10 bits or 12 bits;
- which of the primaries are implemented (UHDTV reference primaries or Conventional reference primaries).

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

5 Image Structure

5.1 The sampling lattice for UHDTV1 systems and UHDTV2 systems shall be uniformly spaced, shall be orthogonal and shall have a pixel aspect ratio of 1:1 (square pixels). The aspect ratio of the image shall be 16:9.

5.2 UHDTV1 systems shall consist of a pixel array 3840 x 2160, and UHDTV2 systems shall consist of a pixel array 7680 x 4320.

5.3 The image pixel array numbering shall be expressed with (0, 0) at the top left corner and the bottom right corner shall be represented by a pixel count of (3839, 2159) for UHDTV1 systems and (7679, 4319) for UHDTV2 systems.

5.4 For UHDTV1 systems, the center of the image shall be located at the center of the 3840 × 2160 pixel array, midway between horizontal pixel number of 1919 and 1920, and midway between lines 1079 and 1080. For UHDTV2 systems, the center of the image shall be located at the center of the 7680 × 4320 pixel array, midway between horizontal pixel number of 3839 and 3840, and midway between lines 2159 and 2160.

6 System Colorimetry

6.1 To be compliant with this standard, equipment shall be designed in accordance with the colorimetric analysis and opto-electronic transfer function defined in this section.

6.2 Picture information shall be linearly represented by red, green and blue tristimulus values (RGB), lying in the range 0 (reference black) to 1 (reference white), whose colorimetric attributes are based upon reference primaries with the following chromaticity coordinates (Table 2), whose reference white conforms to CIE D65 as defined by CIE S 014-2/E. Table 2 defines UHDTV reference primaries. Table 3 defines conventional reference primaries

Table 2 –UHDTV reference primaries and reference white[1]

	CIE x	CIE y
Red primary	0.708	0.292
Green primary	0.170	0.797
Blue primary	0.131	0.046
Reference white	0.3127	0.3290

Table 3 –Conventional reference primaries and reference white[2]

	CIE x	CIE y
Red primary	0.640	0.330
Green primary	0.300	0.600
Blue primary	0.150	0.060
Reference white	0.3127	0.3290

[1] These values are consistent with Recommendation ITU-R BT.2020.

[2] Conventional reference primaries may be optionally used by UHDTV1. These reference primaries are consistent with Recommendation ITU-R BT.709.

6.3 From the red, green and blue tristimulus values, three nonlinear primary components R', G' and B' shall be computed according to the opto-electronic transfer function as follows, where L denotes a tristimulus value and *V'* denotes a nonlinear primary signal:

$$V' = \begin{cases} 4.5L, & 0 \le L < \beta \\ \alpha L^{0.45} - (\alpha - 1), & \beta \le L \le 1 \end{cases}$$

For a 10-bit system $\alpha = 1.099$ and $\beta = 0.018$, and for a 12-bit system $\alpha = 1.0993$ and $\beta = 0.0181$ shall be used.

6.4 Signal levels shall be completely contained in the range specified between reference black and reference white specified in Section 7.5, except for overshoots and undershoots due to processing.

6.5 The Y' component shall be computed as a weighted sum of nonlinear R'G'B' primary components, using coefficients calculated from the reference primaries according to the method given in SMPTE RP 177:

$$Y' = 0.2627R' + 0.6780G' + 0.0593B'$$

UHDTV1 systems when using conventional reference primaries, the Y' component shall be computed using coefficients calculated as follows:

$$Y' = 0.2126R' + 0.7152G' + 0.0722B'$$

6.6 Color-difference component signals P'_B and P'_R having the same excursion as the Y' component shall be computed as follows:

$$P'_B = \frac{0.5}{1. - 0.0593}(B' - Y')$$
$$P'_R = \frac{0.5}{1. - 0.2627}(R' - Y')$$

UHDTV1 systems when using conventional reference primaries, the color-difference component signals P'_B and P'_R having the same excursion as the Y' component shall be computed as follows:

$$P'_B = \frac{0.5}{1. - 0.0722}(B' - Y')$$
$$P'_R = \frac{0.5}{1. - 0.2126}(R' - Y')$$

P'_B and P'_R may be coded as C'_B and C'_R components for digital transmission.

7 Digital Image Representation

7.1 Digital representation shall employ either R'G'B' or $Y'C'_BC'_R$ components as defined in Section 6, uniformly sampled.

7.2 The digital signals described here are assumed to have been appropriately filtered to reduce or prevent aliasing upon sampling.

7.3 R'G'B' signals and Y' signals shall have the same nominal bandwidth. In the case of a 4:4:4 systems, C'_B, C'_R shall have the same bandwidth as the associated Y' signal. For 4:2:2 systems, the C'_B, C'_R shall have bandwidth nominally half that of the associated Y' signal. In the case of 4:2:0 systems, C'_B, C'_R shall have bandwidth nominally quarter that of the associated Y' signal.

7.4 R'G'B' signals and Y' signal of the $Y'C'_BC'_R$ interface shall be sampled orthogonally, line- and picture-repetitive. R'G'B' samples shall be co-sited with each other.

7.5 Digital R'G'B' and Y' components shall be computed as follows:

$$L'_D = INT\left[219DL' + 16D\right]; \quad D = 2^{n-8}$$

where L' is the component value in abstract terms from 0 to 1.0, n takes the value 10 or 12 corresponding to the number of bits to be represented, and L_D' is the resulting digital code. The function INT[x] gives the value of 0 for fractional parts in the range of 0 to under 0.5, and +1 for fractional parts in the range from 0.5 to under 1.

Note: This scaling places the code words 040_h ($64_{(10)}$) and $3AC_h$ ($940_{(10)}$) in a 10-bit representation or the code words 100_h ($256_{(12)}$) and $EB0_h$ ($3760_{(12)}$) in a 12-bit representation for the signal level of 0% and 100% of R'G'B' and Y' as shown in Table 4.

Note: Throughout this section, subscript of "h" indicates the hexadecimal notation and subscript in parentheses with the integer decimal notation indicates the bit depth for video signal levels.

7.6 Digital C'_B and C'_R components of the $Y'C'_BC'_R$ set shall be computed as follows:

$$C'_D = INT\left[224DC' + 128D\right]; \quad D = 2^{n-8}$$

where C' is the component value in abstract terms from -0.5 to +0.5 and C'_D is the resulting digital code.

Note: This scaling places the code words 040_h ($64_{(10)}$) , 200_h ($512_{(10)}$) and $3C0_h$ ($960_{(10)}$) in a 10-bit representation or the code words 100_h ($256_{(12)}$), 800_h ($2048_{(12)}$) and $F00_h$ ($3840_{(12)}$) in a 12-bit representation for the signal level of –50%, 0% and +50% of C'_B and C'_R as shown in Table 4.

7.7 4:4:4 C'_B and C'_R signals shall each have the same number of samples as the Y' component 4:2:2 C'_B and C'_R signals shall be horizontally subsampled by a factor of two with respect to the Y' component. C'_B and C'_R samples shall be co-sited with even-numbered samples of Y'.

4:2:0 C'_B and C'_R shall be horizontally and vertically subsampled by a factor of two with respect to the Y' component. C'_B and C'_R samples shall be co-sited with even-numbered samples and lines of Y'.

7.8 Code values having the eight most-significant bits all 0 or all 1, that is 10-bit codes 000_h ($0_{(10)}$) through 003_h ($3_{(10)}$) and $3FC_h$ ($1020_{(10)}$) through $3FF_h$ ($1023_{(10)}$) in the case of a 10-bit system, and 12-bit codes 000_h ($0_{(12)}$) through $00F_h$ ($15_{(12)}$) and $FF0_h$ ($4080_{(12)}$) through FFF_h ($4095_{(12)}$) in the case of a 12-bit system as shown in Table 4, are employed for synchronizing purposes and shall be prohibited from video or ancillary data/signals.

7.9 A system having a 10-bit interface shall address the conversion of 12-bit video data to 10 bits with an appropriate process that minimizes video artifacts such as quantization noise. When converting 10-bit data to 12-bit data, the two least significant bits of the 12-bit word shall be set to 0.

7.10 For Y', R', G' and B' signals, undershoot and overshoot in video process may be accommodated by the use of code words 004_h ($4_{(10)}$) through $03F_h$ ($63_{(10)}$) and code words $3AD_h$ ($941_{(10)}$) through $3FB_h$ ($1019_{(10)}$) in a

10-bit system, code words 010_h ($16_{(12)}$) through $0FF_h$ ($255_{(12)}$) and code words $EB1_h$ ($3761_{(12)}$) through FEF_h ($4079_{(12)}$) in a 12-bit system as shown in Table 4.

For C'_B and C'_R signals, undershoot and overshoot in video process may be accommodated by the use of code words 004_h ($4_{(10)}$) through $03F_h$ ($63_{(10)}$) and code words $3C1_h$ ($961_{(10)}$) through $3FB_h$ ($1019_{(10)}$) in a 10-bit system, code words 010_h ($16_{(12)}$) through $0FF_h$ ($255_{(12)}$) and code words $F01_h$ ($3841_{(12)}$) through FEF_h ($4079_{(12)}$) in a 12-bit system as shown in Table 4.

Table 4 – Digital representation

Items		10-bit system	12-bit system	Note
R', G', B', Y'	Signal level of 100%	$3AC_h$ ($940_{(10)}$)	$EB0_h$ ($3760_{(12)}$)	Section 7.5
	Signal level of 0%	040_h ($64_{(10)}$)	100_h ($256_{(12)}$)	
	Headroom for Overshoot	$3AD_h$-$3FB_h$ ($941_{(10)}$-$1019_{(10)}$)	$EB1_h$-FEF_h ($3761_{(12)}$-$4079_{(12)}$)	Section 7.10
	Footroom for Undershoot	004_h-$03F_h$ ($4_{(10)}$-$63_{(10)}$)	010_h-$0FF_h$ ($16_{(12)}$-$255_{(12)}$)	
C'_B, C'_R	Signal level of 50%	$3C0_h$ ($960_{(10)}$)	$F00_h$ ($3840_{(12)}$)	Section 7.6
	Signal level of 0%	200_h ($512_{(10)}$)	800_h ($2048_{(12)}$)	
	Signal level of – 50 %	040_h ($64_{(10)}$)	100_h ($256_{(12)}$)	
	Headroom for Overshoot	$3C1_h$-$3FB_h$ ($961_{(10)}$-$1019_{(10)}$)	$F01_h$-FEF_h ($3841_{(12)}$-$4079_{(12)}$)	Section 7.10
	Footroom for Undershoot	004_h-$03F_h$ ($4_{(10)}$-$63_{(10)}$)	010_h-$0FF_h$ ($16_{(12)}$-$255_{(12)}$)	
Prohibited codes	Upper range	$3FC_h$-$3FF_h$ ($1020_{(10)}$-$1023_{(10)}$)	$FF0_h$-FFF_h ($4080_{(12)}$-$4095_{(12)}$)	Section 7.8
	Lower range	000_h-003_h ($0_{(10)}$-$3_{(10)}$)	000_h-$00F_h$ ($0_{(12)}$-$15_{(12)}$)	

Annex A Bibliography (Informative)

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.

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

SMPTE ST 2036-2:2008, Ultra High Definition Television — Audio Characteristics and Audio Channel Mapping for Program Production

SMPTE ST 2036-3:2012, Ultra High Definition Television — Mapping into Single-link or Multi-link 10 Gb/s Serial Signal/Data Interface

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

Recommendation ITU-R BT.1201-1 (03/04), Extremely High Resolution Imagery

Recommendation ITU-R BT.1361 (02/98), Worldwide Unified Colorimetry and Related Characteristics of Future Television and Imaging Systems

Recommendation ITU-R BT.1769 (07/06), Parameter Values for an Expanded Hierarchy of LSDI Image Formats for Production and International Programme Exchange

Recommendation ITU-R BT.1846 (10/08), Notation for video systems

Recommendation ITU-R BT.2020 (08/12), Parameter Values for Ultra-High Definition Television Systems for Production and International Programme Exchange