SMPTE 293M-2003
Revision of
ANSI/SMPTE 293M-1996

SMPTE STANDARD

for Television — 720 x 483 Active Line at 59.94-Hz Progressive Scan Production — Digital Representation

Contents

1 Scope

1.1 This standard defines the digital representation of stationary or moving two-dimensional images for television production. The representation is sampled linearly in the spatial domain and sampled temporally at a constant frame rate. The scanned image has an aspect ratio of 16:9. The scanning format details are given in table 1. This standard includes both R',G',B' and Y',C'_B,C'_R expressions for the signal representation.

1.2 The principal application of this standard is for the production of content for EDTV-II, which employs an NTSC letterbox encoding scheme, compatible with SMPTE 170M.

NOTES

1 R'G'B' and Y'$C'_BC'_R$ refer to nonlinear "gamma" corrected signals derived from the linear components arising from the analysis of the image which are denoted as R,G,B, etc.

2 The signals C'_B,C'_R refer to digital expressions of the color-difference signals. The signals $P'_BP'_R$ refer to the analog color-difference signals. Although this standard defines the digital representation, references to analog signal representations are given where considered appropriate.

3 The primary purpose of this standard is to specify the parameters of the active area of the image. An additional set of parameters is included for real-time applications that consist of the frame rate, vertical and horizontal blanking, and total number of lines. The values of these parameters are included in table 1.

4 The term "line" in this standard refers to the digital line in the 483-line frame raster as described in figure B.1. In the case of an analog video signal, the word "analog line" is used. The line numbering is based on the 525 digital line numbers as described in figures 1 and B.1.

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February 7, 2003

Table 1 – Scanning system

System nomenclature	Samples per digital active line (S/AL)	Lines per active image	Frame rate	Sampling frequency fs (MHz)	Samples per total line	Total lines per frame	Colorimetry
720 x 483/59.94	720	483	60/1.001	27.0	858	525	SMPTE 170M

2 General

Digital code word values in this standard are expressed as decimal values in the ten-bit representation. An eight-bit system shall round or truncate to the most significant eight bits according to provisions described in 5.10.

3 Scanning

3.1 Scanning parameters are specified in terms of the reference clock frequency indicated in table 1. The clock frequency shall be maintained to a tolerance of ± 3 ppm.

3.2 A frame shall comprise the total lines per frame indicated in table 1. Each line is of equal duration, determined by the sampling frequency and the samples per total line (S/TL). Each line shall be scanned uniformly from left to right; lines in a frame shall be scanned uniformly from top to bottom. Lines are numbered in time sequence according to the raster structure described in annex B.

3.3 Each line shall be represented by the number of samples specified in table 1. These samples shall be equally spaced. Sample instants shall be defined with respect to a horizontal datum denoted by 0_H, which is also the sync reference instant for the analog signal. The timing of sample instants with respect to 0_H is shown in figure B.1.

4 System colorimetry and transfer characteristics

Signals in conformance with this standard shall be computed by the color analysis, optoelectronic transfer, scaling, and coding characteristics defined in annex A, unless indicated otherwise in an associated video index message (see SMPTE RP 186).

NOTE – The values indicated in annex A are identical to those of SMPTE 170M for NTSC production.

5 Digital representation

5.1 Signals may be expressed as either R',G',B' or Y',$C'_BC'_R$ digital component sets.

5.2 The digital signals described here are assumed to have been filtered to reduce or prevent aliasing upon sampling. Annex C provides additional information regarding such filtering.

5.3 R',G',B' signals and the Y' signals have a nominal bandwidth of 12 MHz. C'_B and C'_R signals shall have a bandwidth nominally one-half that of the associated Y' signal.

5.4 R',G',B' signals and the Y' signal of the Y',$C'_BC'_R$ set shall be sampled orthogonally, line and picture repetitive, at the reference clock frequency fs. The period of the sampling clock is denoted t = 1/fs. C'_B and C'_R signals shall be horizontally subsampled by a factor of two with respect to the Y' component. The C'_B and C'_R samples are cosited with even-numbered Y' samples (sample 0, sample 2, sample 4, etc.) of each line.

5.5 A sampling instant in a line is denoted in this standard by a sample number from zero through one less than the total number of samples in a line. Sample number 736 corresponds to the 0_H datum. The sample numbering is shown in figure 2 (for additional details, refer to figure B.1).

5.6 Sampled data at the interface shall be such that appropriate sin(x)/x correction occurs during conversion of the signal to the analog domain.

5.7 Digital R', G', B', and Y' components shall be computer as follows:

$$L'_d = INT\ (219DL' + 16D + 0.5);\ D = 2^{n-8}$$

where L' is the component value ($0 \leq L' \leq 1$), n takes the value 8 or 10 corresponding to the number of bits in the digital code word, and L'_d is the resulting digital code.

NOTE – This scaling places the peak values of the R',G',B' and Y' components at code words 64 and 940 in a ten-bit representation or code words 16 and 235 in an eight-bit representation.

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

$$C'_d = INT\ (224DC' + 128D + 0.5);\ D = 2^{n-8}$$

where C' is the component value ($-0.5 < C' < +0.5$), n takes the value 8 or 10 corresponding to the number of bits in the digital code word, and C'_d is the resulting digital code.

NOTE – This scaling places the peak values of the C'_B and C'_R components at code words 64 and 960 in a ten-bit representation or code words 16 and 240 in an eight-bit representation.

5.9 Code values having the eight most-significant bits all zeros or all ones — that is, ten-bit codes 0, 1, 2, 3, 1020, 1021, 1022, and 1023 — are employed for synchronizing purposes and shall be prohibited from video or ancillary data.

5.10 A system having an eight-bit code word precision may round video signals of 10-bit precision to eight bits and then discard the two least significant bits. The two least significant bits of all other data across the interface shall be truncated without rounding.

5.11 For Y', R', G', and B' signals, undershoot and overshoot in video processing may be accommodated by the use of code words 4 through 63 and code words 941 through 1019 in a ten-bit system, or code words 1 through 15 and code words 236 through 254 in an eight-bit system. For C'_B and C'_R signals, undershoot and overshoot in video processing may be accommodated by the use of code words 4 through 63 and code words 961 through 1019 in a ten-bit system, or code words 1 through 15 and code words 241 through 254 in an eight-bit system.

5.12 For Y', R', G', and B' signals, the data words occurring during the digital blanking intervals, that are not used for timing reference codes EAV, SAV, or for ancillary data/signal, shall be filled with the sequence of code word 64 (for 10-bit data) or 16 (for 8-bit data). For C'_B and C'_R color-difference signals, the code word shall be 512 (for 10-bit data) or 128 (for 8-bit data).

6 Raster structure

6.1 The details of the digital horizontal line are shown in figure 2. The figure also includes reference to the location of 0_H of the analog horizontal sync.

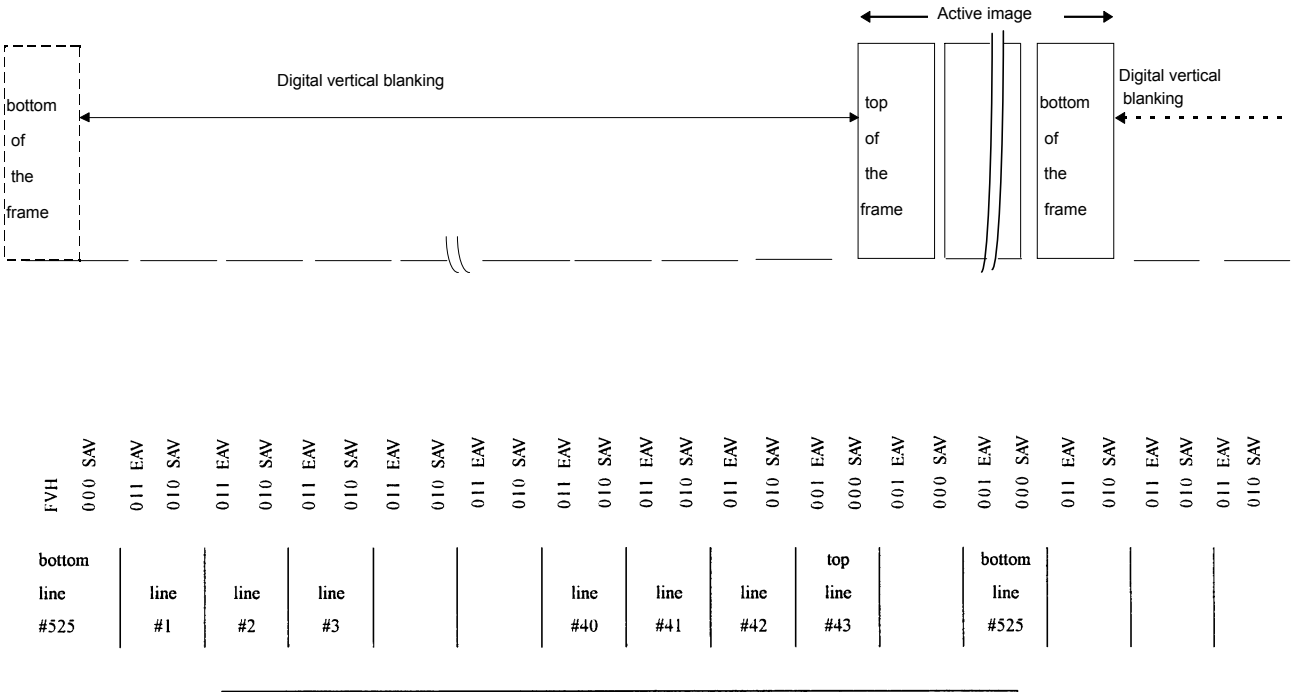
6.2 The details of the vertical scanning structure are shown in figure 1. The figure also includes the line-numbering definition and details of digital vertical blanking.

6.3 The production aperture is defined by the number of active lines and active pixels as shown in table 1.

6.4 The clean aperture shall extend vertically from line 44 to line 523, inclusive. Horizontally, the clean aperture shall extend from sample 6 to sample 713, inclusive. Analog blanking edges and other edge processing artifacts should be confined to the area outside the clear aperture.

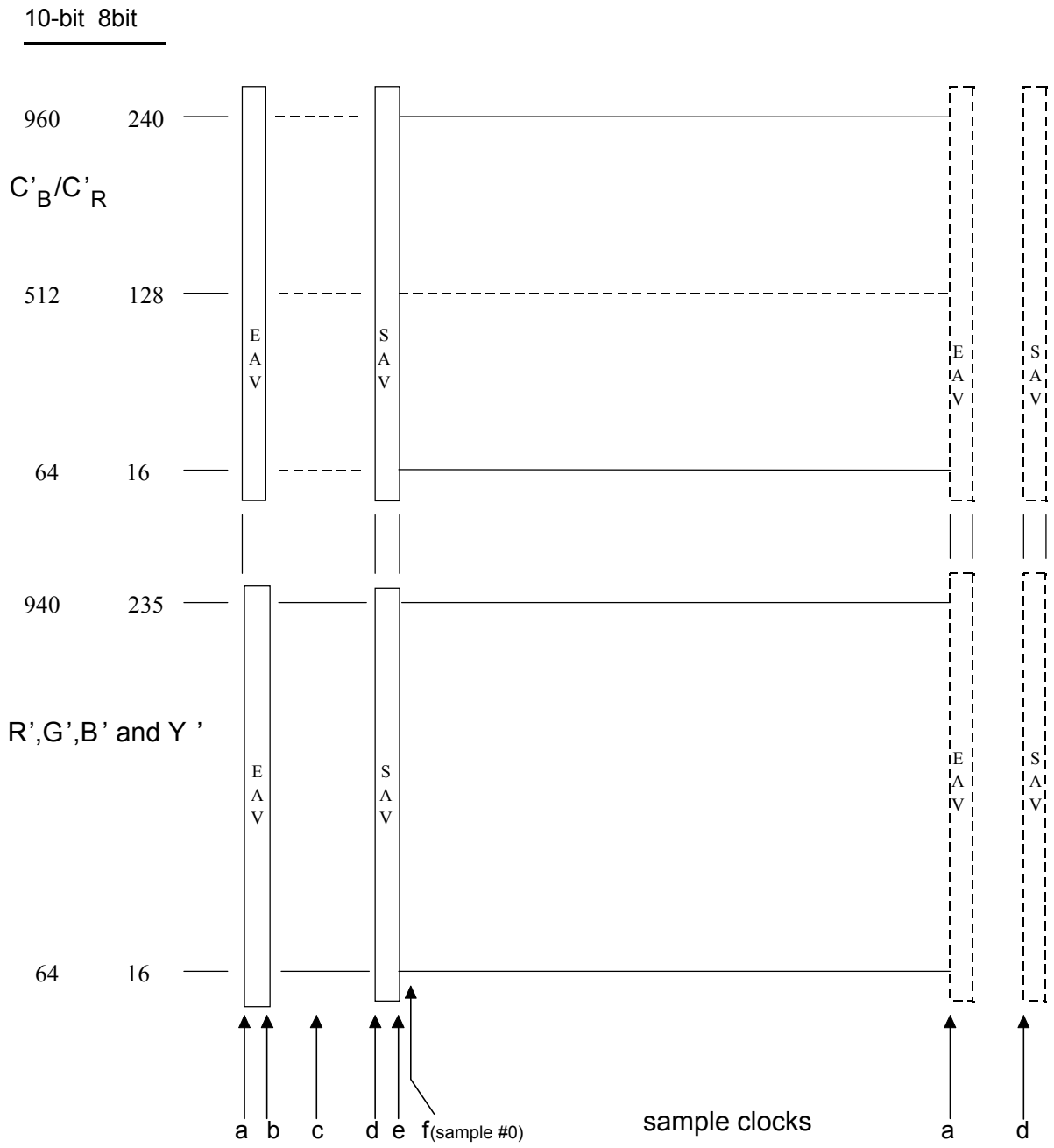
6.5 The center of the picture is defined as the center of the clean aperture. Vertically, the center of the picture lies between line 283 and line 284. Horizontally, the center of the picture lies between sample 359 and sample 360.

6.6 Each active line has a 4 sample/byte preamble, start of active video (SAV), and a postamble end of active video EAV), which are described in clause 7.



Total lines	Bottom line #	Top line #	Line #1	Lines available for data
525	525	43	Next to bottom line	42

Figure 1 – Vertical timing details specified in line numbers and the coding of EAV/SAV data



	Sample number for R', B' and Y' signals					
	a	b	c	d	e	f
Total samples per line	Start of EAV	End of EAV	Analog sync (0_H)	Start of SAV	End of SAV	Start of active line
858	720	723	736	854	857	0

Figure 2 – Horizontal timing details specified in sample numbers

7 Digital timing reference signals (SAV, EAV)

7.1 SAV (start of active video) and EAV (end of active video) timing reference signals delineate the active video data and may be used for synchronization across the digital interface. Figures 1 and 2 show the relationship of the SAV and EAV sequences to digital video. The corresponding relationship to analog video is shown in annex B.

7.2 An SAV or EAV sequence shall comprise four consecutive code words: a code word of all ones, a code word of all zeros, another code word of all zeros, and a code word including F, V, H (field, vertical, horizontal) activity indicators, and P3, P2, P1, and P0 (parity) bits. An SAV sequence shall be identified by having H = 0; EAV shall have H = 1. Tables 2 and 3 show details of the coding.

7.3 Each active line of video data (and, optionally, any blanked lines in the vertical interval) shall be preceded by a four-word SAV sequence and terminated by a four-word EAV sequence. The EAV sequence immediately preceding the 0H datum of line 1 shall be considered to be the start of the digital frame.

Table 2 – Video timing reference codes

Bit number		9	8	7	6	5	4	3	2	1	0
Word	Value	(MSB)									(LSB)
0	1023	1	1	1	1	1	1	1	1	1	1
1	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0
3	See table 3	1	F	V	H	P3	P2	P1	P0	0	0

Table 3 – Word 3, data and protection bits for SAV and EAV

Bit number		9	8	7	6	5	4	3	2	1	0
Function	Value	1 Fixed	F	V	H	P3	P2	P1	P0	0 Fixed	0 Fixed
SAV line numbers from 43 to 525	512	1	0	0	0	0	0	0	0	0	0
EAV line numbers from 43 to 525	628	1	0	0	1	1	1	0	1	0	0
SAV line numbers from 1 to 42	684	1	0	1	0	1	0	1	1	0	0
EAV line numbers from 1 to 42	728	1	0	1	1	0	1	1	0	0	0

NOTE – The value of F and V may be different in various interface standards. It will be assigned in corresponding interface documents.

8 Ancillary data

8.1 Ancillary data may be included optionally in the blanking intervals of a digital interface according to this standard.

8.2 Any horizontal blanking interval between EAV and SAV may be employed to convey ancillary data packets.

8.3 The interval between SAV and EAV of any line that is outside the vertical extent of the picture, and that is not employed to convey digitized ancillary signals, may be employed to convey ancillary data packets.

Annex A (normative)
System colorimetry, transfer characteristics and luminance coding

A.1 Picture information shall be represented by tristimulus (linear) red, green, and blue (R,G,B) primary components, lying in the range 0 (reference black) to +1 (reference white). The primary and reference white chromaticities (in the CIE S002 system) are as follows:

Chromaticities for primaries:

	x	y
Green	0.310	0.595
Blue	0.155	0.070
Red	0.630	0.340

Chromaticities for reference white:

	x	y
White	0.3127	0.3290

A.2 From the linear red, green, and blue tristimulus values, three nonlinear primary components, R', G', and B', shall be computed according to the optoelectronic transfer function of SMPTE 170M, where L denotes a tristimulus value and V' denotes a nonlinear primary signal:

$V' = 4.5L, \quad \text{for } 0 \leq L \leq 0.018$

$V' = 1.099L^{0.45} - 0.099 \quad \text{for } 0.018 \leq L \leq 1$

A.3 The Y' component shall be computed as a weighted sum of nonlinear R', G', and B' primary components, according to:

$Y' = 0.299R' + 0.587G' + 0.114B'$

NOTES

1 The Y' component is calculated in accordance with SMPTE 170M.

2 The Y' component, being a weighted sum of nonlinear R',G',B' components, has no simple relationship with the CIE luminance tristimulus component denoted Y used in color science. The choice of coefficients for Y' has no influence on color reproduction per se, but does have a small effect on the magnitude of the small errors in reproduced luminance and colors that are caused by the bandwidth limitation of the color-difference components.

A.4 Analog color-difference component signals P'_B and P'_R shall have the same 0.7 Vp-p excursion as the Y' component (figure B.3) and shall be computed as follows:

$$P'_B = \frac{0.5}{1 - 0.114}(B' - Y')$$

$$P'_R = \frac{0.5}{1 - 0.299}(R' - Y')$$

The digital components are coded as C'_B and C'_R components for digital transmission, as defined in clause 5.

A.5 To ensure the proper interchange of picture information between analog and digital representations, signal levels shall be completely contained in the range specified between reference black and reference white specified in clause 5, except for overshoots and undershoots due to processing, as noted.

Annex B (informative)
Analog representation of the sync waveforms and video levels for the systems included in this standard

This annex describes the relationship of the analog synchronizing signals to the digital data stream defined in this standard. The details are shown in figures B.1, B.2, and B.3.

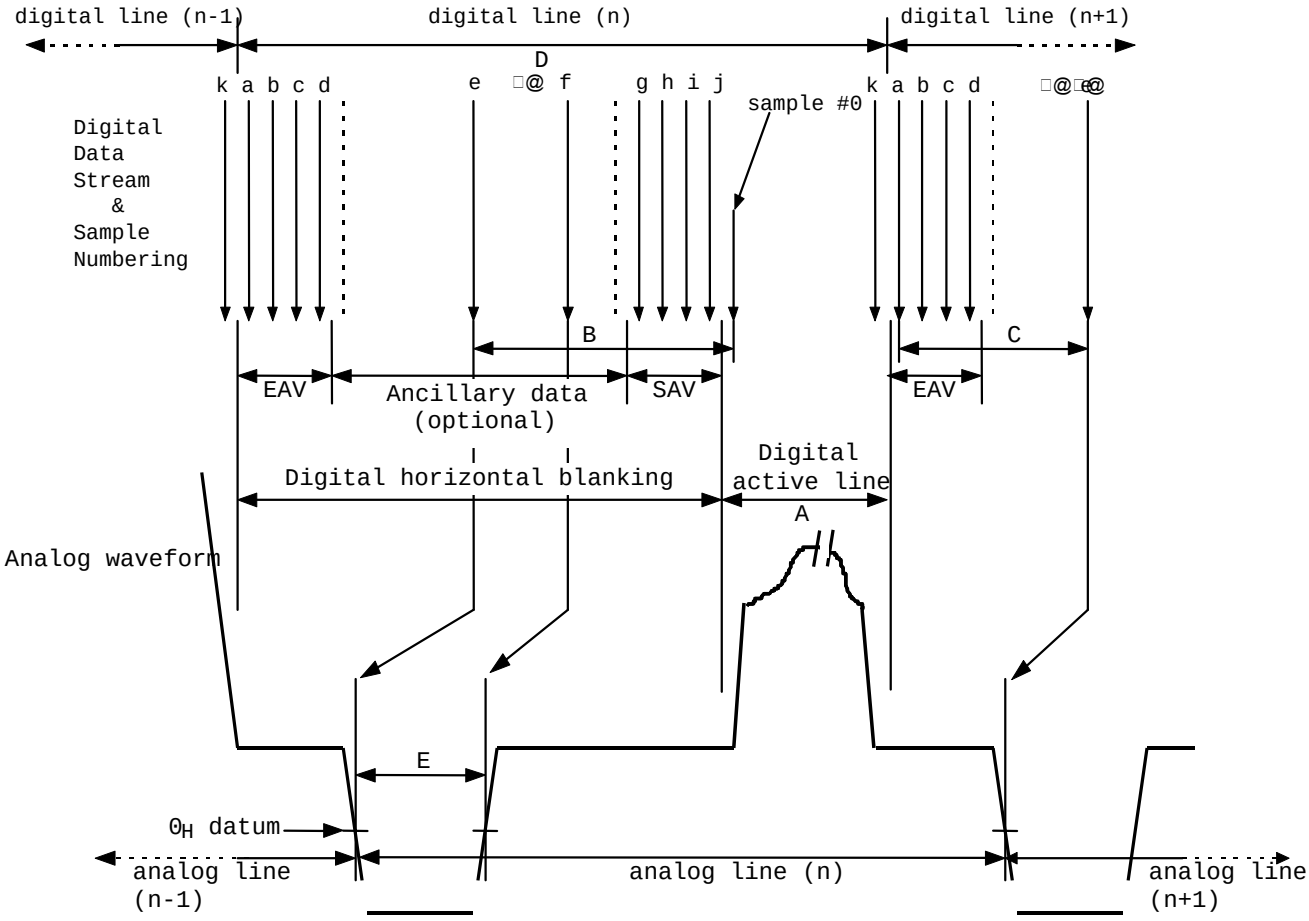
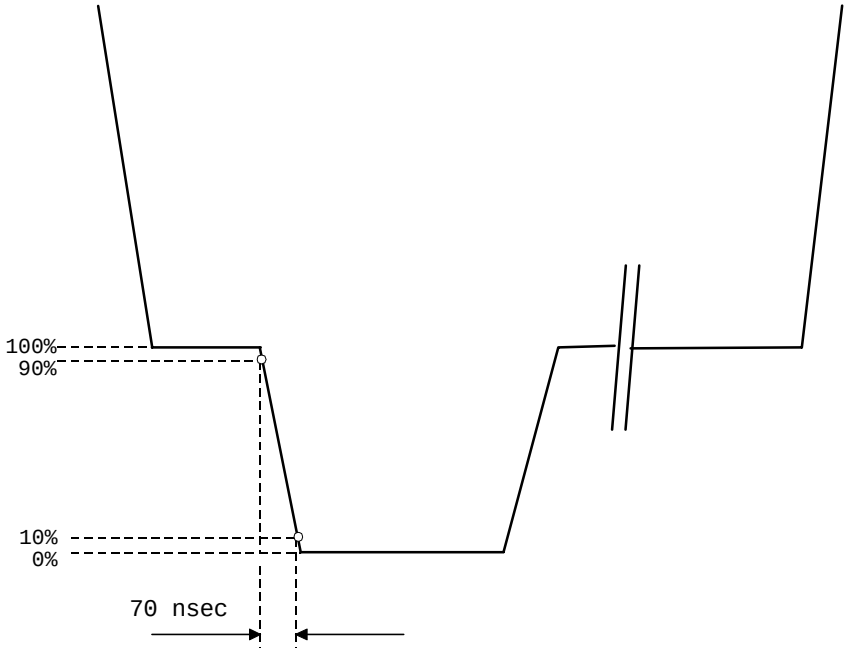


Figure B.1 - Relationship between digital data stream and analog waveform

Table B.1 – Sample numbering and signal duration for figure B.1

Sample numbering											
Total samples	a	b	c	d	e	f	g	h	i	j	k
858	720	721	722	723	736	799	854	855	856	857	719

Duration in reference clock periods				
A	B	C	D	E
720	122	16	858	63



NOTE – The sync pulse fall time for all analog signals shall be 70 ns ± 10 ns.

Figure B.1a – Sync pulse fall time

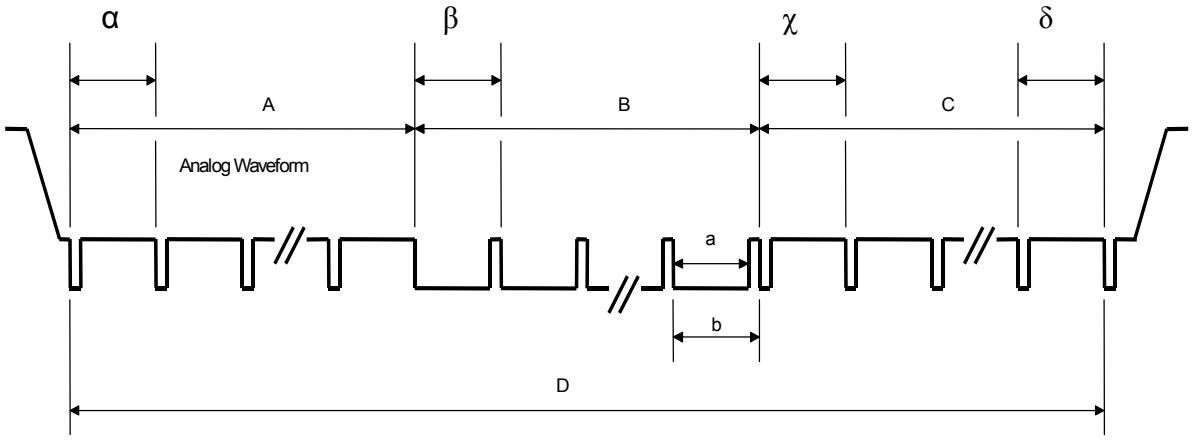


Figure B.2 – Vertical sync waveforms

Table B.2 – Vertical sync duration, pulse width and analog line numbering

	Duration in analog line intervals				Pluse width in clock periods		Analog line number			
Total analog lines	A	B	C	D	A	B	α	β	χ	δ
525	6	6	30	42	795	858	1	7	13	42

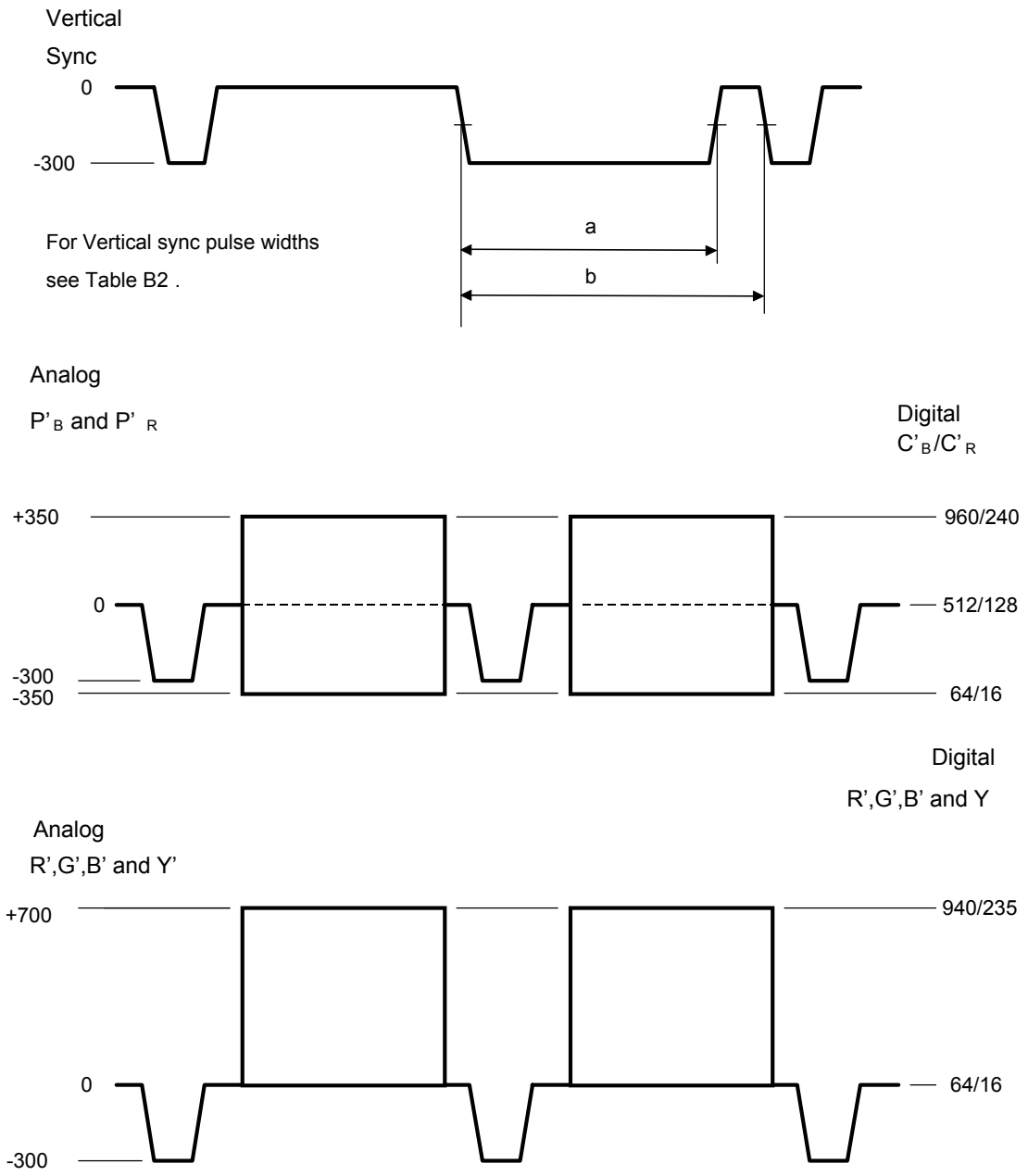


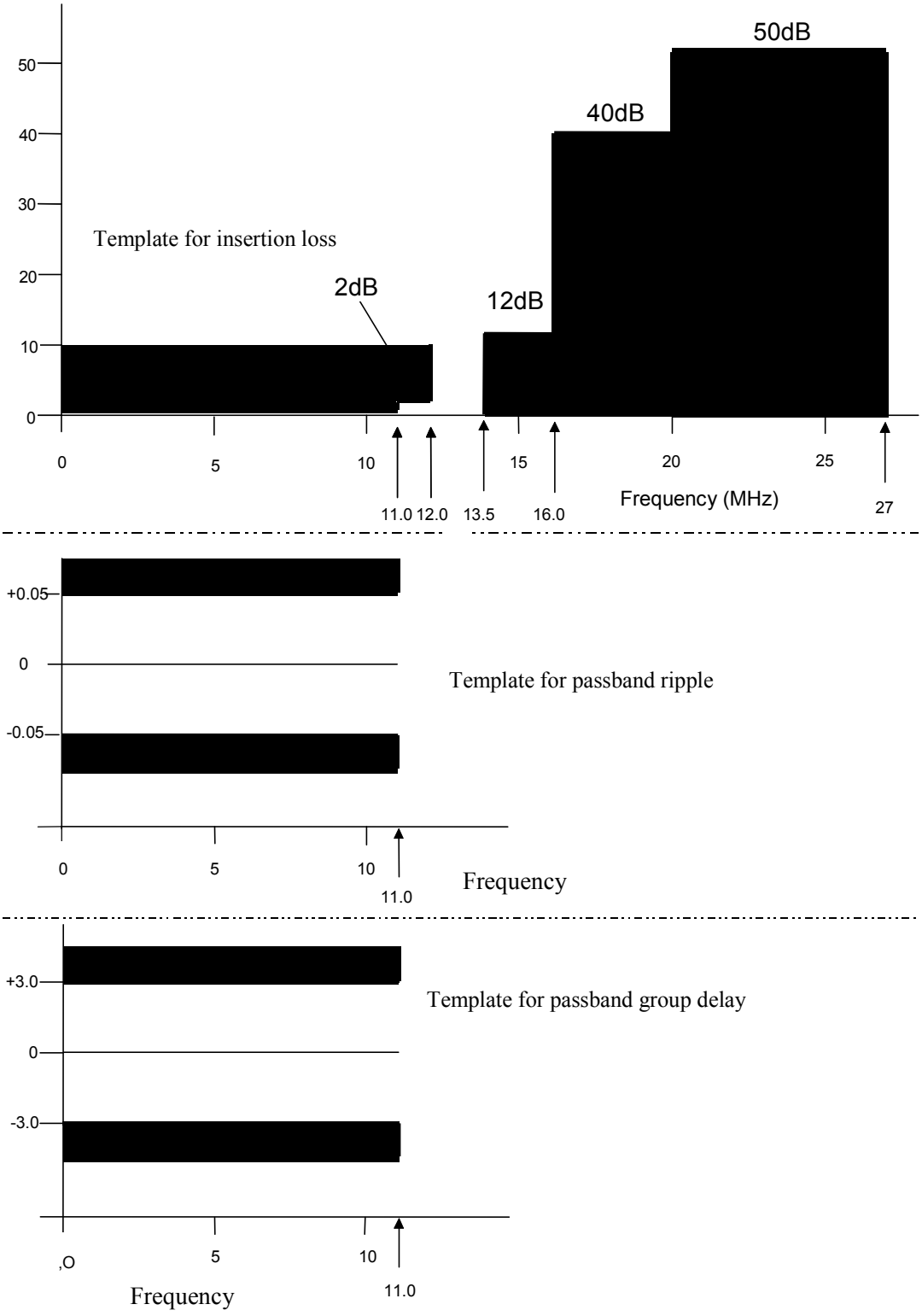
Figure B.3 – Analog signal levels in millivolts and their 8- and 10-bit digital values

Annex C (informative)
Recommended filter characteristics

C.1 Figure C.1 depicts filter characteristics for pre- and post-filtering of Y', R', G', and B' component signals. Figure C.2 depicts filter characteristics for pre-and post-filtering of P'_B and P'_R component signals.

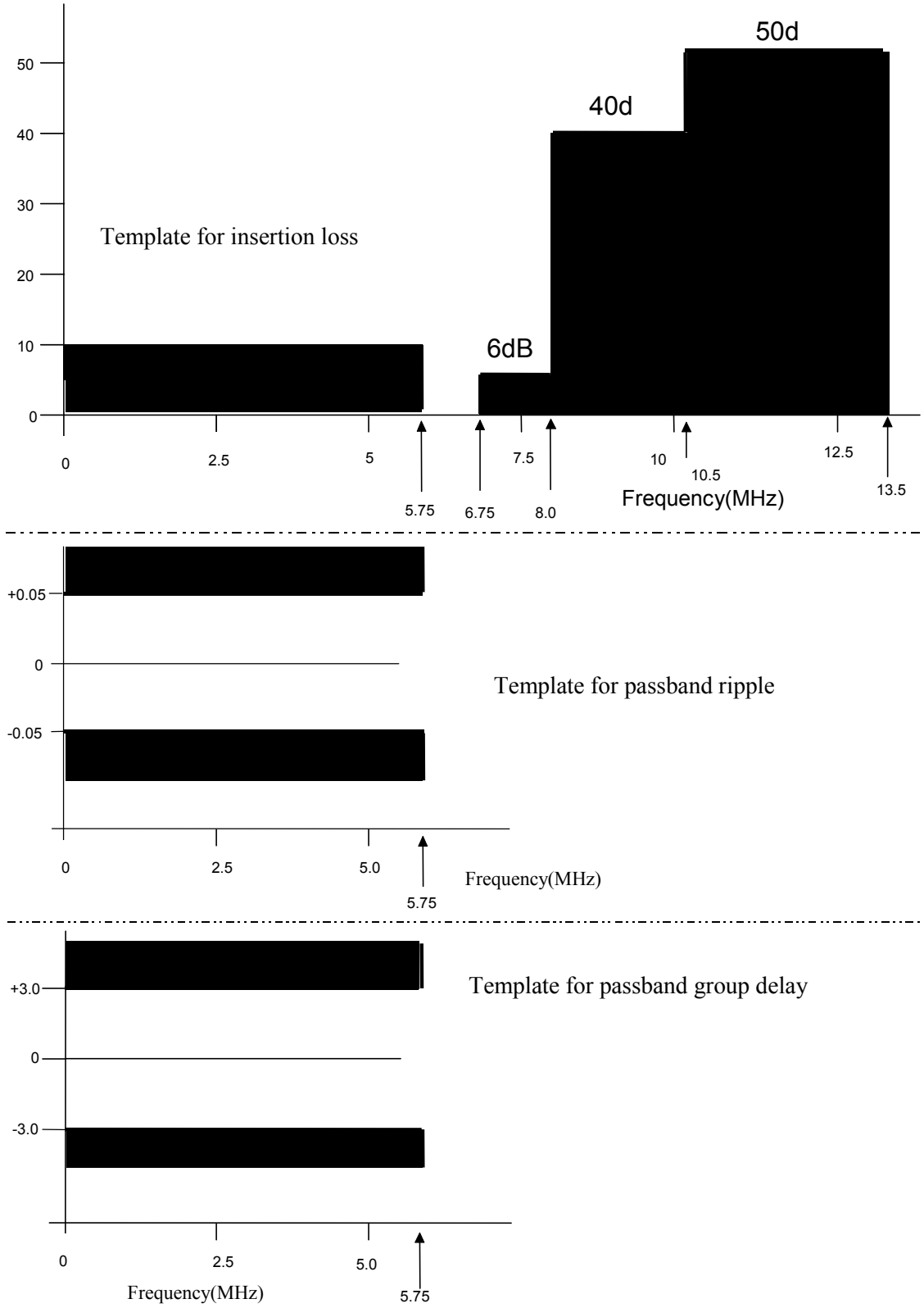
C.2 The value of the amplitude ripple tolerance in the passband is ± 0.05 dB relative to the insertion loss at 100 kHz.

C.3 The specifications for group delay in the filters are sufficiently tight to produce good performance while allowing practical implementation of the filters.



NOTE – All tolerances shown are relative to the value at 100 kHz.

Figure C.1 – Filter template for R', G', B' and Y' components



Note – All tolerances shown are relative to the value at 100 kHz.

Figure C.2 – Filter template for color-difference components

Annex D (informative)
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