SMPTE STANDARD

for Television — Signal Parameters — 1125-Line High-Definition Production Systems

1 Scope

This standard defines the basic characteristics of the analog video signals associated with origination equipment operating in 1125-line high-definition television production systems. This standard defines systems operating at 60.00 Hz and 59.94 Hz field rates.

The digital representation of the signals described in this standard may be found in ANSI/SMPTE 260M. These two documents define between them both digital and analog implementations of 1125-line HDTV production systems.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the edition indicated was 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 standard indicated below.

ANSI/SMPTE 260M-1996, Television — Digital Representation and Bit-Parallel Interface — 1125/60 High-Definition Production System

3 Scanning parameters

The video signals represent a scanned raster with the characteristics shown in table 1.

4 System colorimetry and transfer function

The system is intended to create a metameric reproduction (visual color match) of the original scene as if lit by CIE illuminant D_{65}. To this end, the combination of a camera's optical spectral analysis and linear signal matrixing shall match the CIE color-matching functions (1931) of the reference primaries. Further, the combination of a reproducer's linear matrixing and reproducing primaries shall be equivalent to the reference primaries (see annex A.1).

Table 1 – Scanned raster characteristics

	1125/60 system	1125/59.94 system
Total scan lines per frame	1125	
Active lines per frame	1035	
Scanning format	Interlaced 2:1	
Aspect ratio	16:9	
Field repetition rate	60.00 Hz ± 10 ppm	59.94... Hz[1] ± 10 ppm
Line repetition rate (derived)	33750.00 Hz	33716.28... Hz[2]

[1]The 59.94... Hz notation denotes an approximate value. The exact value is $\frac{60}{1.001}$.

[2]The 33716.28... Hz notation denotes an approximate value. The exact value is $\frac{60 \times 1125}{2 \times 1.001}$.

American National Standard

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4.1 Chromaticity of reference primaries

The reference red, green, and blue primaries shall have CIE 1931 (*x,y*) chromaticities as follows:

	CIE *x*	CIE *y*
red	0.630	0.340
green	0.310	0.595
blue	0.155	0.070

4.2 Reference white

The system reference white is an illuminant which causes equal primary signals to be produced by the reference camera, and which is produced by the reference reproducer when driven by equal primary signals. For this system, the reference white is specified in terms of its 1931 CIE chromaticity coordinates, which have been chosen to match those of CIE illuminant D_{65}:

	CIE *x*	CIE *y*
white	0.3127	0.3290

4.3 Opto-electronic transfer characteristic of reference camera

The opto-electronic transfer function of the reference camera is defined to be:

$$V_c = \begin{cases} 4L_c & 0 \le L_c < 0.0228 \\ 1.1115\, L_c^{\,0.45} - 0.1115, & 0.0228 \le L_c \le 1 \end{cases}$$

where V_c is the video signal output of the reference camera normalized to the system reference white, and L_c is the light input to the reference camera normalized to the system reference white.

4.4 Electro-optical transfer characteristic of reference reproducer

The electro-optical transfer function of the reference reproducer is defined to be:

$$L_r = \begin{cases} \dfrac{V_r}{4}, & 0 \le V_r < 0.0913 \\ \left(\dfrac{V_r + 0.1115}{1.1115}\right)^{\left(\frac{1}{0.45}\right)}, & 0.0913 \le V_r \le 1 \end{cases}$$

where V_r is the video signal level driving the reference reproducer normalized to the system reference white, and L_r is the light output from the reference reproducer normalized to the system reference white.

5 Video signal definitions

The image is represented by three parallel, time-coincident video signals. Each incorporates a synchronizing waveform. The signals shall be either of the following sets:

Color primary set	Color difference set
E_G' -- green	E_Y' -- luma
E_B' -- blue	E_{PB}' -- blue color difference
E_R' -- red	E_{PR}' -- red color difference

where [E_G' E_B' E_R'] are the signals appropriate to directly drive the primaries of the reference reproducer (being nonlinearly related to light levels as specified in 4.3 and 4.4) and [E_Y' E_{PB}' E_{PR}'] can be derived from [E_G' E_B' E_R'] as follows:

The luma function is specified to be:

$$E_Y' = (0.701 \times E_G') + (0.087 \times E_B') + (0.212 \times E_R') \quad \text{[base equation]}$$

E_{PB}' is amplitude-scaled (E_B' – E_Y'), according to:

$$E_{PB}' = \frac{(E_B' - E_Y')}{1.826} \quad \text{[derived equation]}$$

and E_{PR}' is amplitude-scaled (E_R'– E_Y'), according to:

$$E_{PR}' = \frac{(E_R' - E_Y')}{1.576} \quad \text{[derived equation]}$$

where the scaling factors are derived from the signal levels given in 7.3.

(See annex A.3 for the derivation of the coefficients in the luma equation, and annex A.4 for a summary of the formulas for converting between the two sets).

6 Reference clock

Signal durations and timings in this standard are specified both in reference clock periods and in microseconds. The reference clock as defined in the following table is the fundamental timing reference in the system.

	1125/60 system	1125/59.94 system
Reference clock periods in total line	2200	2200
Reference clock period -- T (derived)	13.468...ns	13.481...ns
Reference clock frequency (derived)	74.25 MHz	74.17... MHz

NOTE -- The 74.17... MHz notation denotes an approximate value. The exact value is $\frac{60 \times 1125 \times 2200}{2 \times 1.001}$.

7 Video and synchronizing signal waveforms

The combined video and synchronizing signal shall be as shown in figure 1. For illustrative purposes, a video signal of the form E_Y', E_G', E_B', or E_R' is shown. The details of the synchronizing signal are identical for the E_{PB}' and E_{PR}' color-difference signals.

7.1 Timing

7.1.1 The timing of events within a horizontal line of video is illustrated in figure 1(a) and summarized in table 2. All event times are specified in terms of the reference clock period at the midpoint of the indicated transition.

The analog production aperture extends from the start-of-active video to the end-of-active video (see figure 1(a) and annex A.5).

7.1.2 The duration of the various portions of the video and sync waveforms are illustrated in figures 1(b), 1(c), and 1(d), and summarized in table 3.

7.2 Bandwidth

7.2.1 The color primary set [E_G' E_B' E_R'] comprises three equal-bandwidth signals whose nominal bandwidth is 30 MHz.

7.2.2 The color-difference set [E_Y' E_{PB}' E_{PR}'] comprises a luma signal E_Y' whose nominal bandwidth is 30 MHz, and color-difference signals E_{PB}' and E_{PR}' whose nominal bandwidth is 30 MHz for analog originating equipment, and 15 MHz for digital originating equipment.

7.3 Levels

The video signals are represented in analog form as follows:

E_Y', E_G', E_B', E_R' signals:

Reference black level	0	(mV)
Reference white level	700	(mV)
Synchronizing level	± 300	(mV)

E_{PB}', E_{PR}' signals:

Reference zero signal level	0	(mV)
Reference peak levels	± 350	(mV)
Synchronizing level	± 300	(mV)

All signals:

Sync pulse amplitude	300 ± 6	(mV)
Amplitude difference between positive- and negative going sync pulses	<6	(mV)

Table 2 -- Timing of events of a video line

	Reference clock periods
Rising edge of sync (timing reference)	0
Trailing edge of sync	44
Start of active video	192
End of active video	2112
Leading edge of sync	2156

Table 3 -- Duration of video and sync waveforms

		Reference clock periods	time (µs) 1125/60	time (µs) 1125/59.94	tolerance (µs)
a		44	0.593	0.593	± 0.040
b		88	1.185	1.186	-- 0.000 + 0.081
c		44	0.593	0.593	± 0.040
d		132	1.778	1.780	± 0.040
e		192	2.586	2.588	-- 0.000 + 0.081
f	(Sync rise time)	4	0.054	0.054	± 0.020
	Total line	2200	29.630	29.659	
	Active line	1920	25.859	25.884	+ 0 -- 0.162

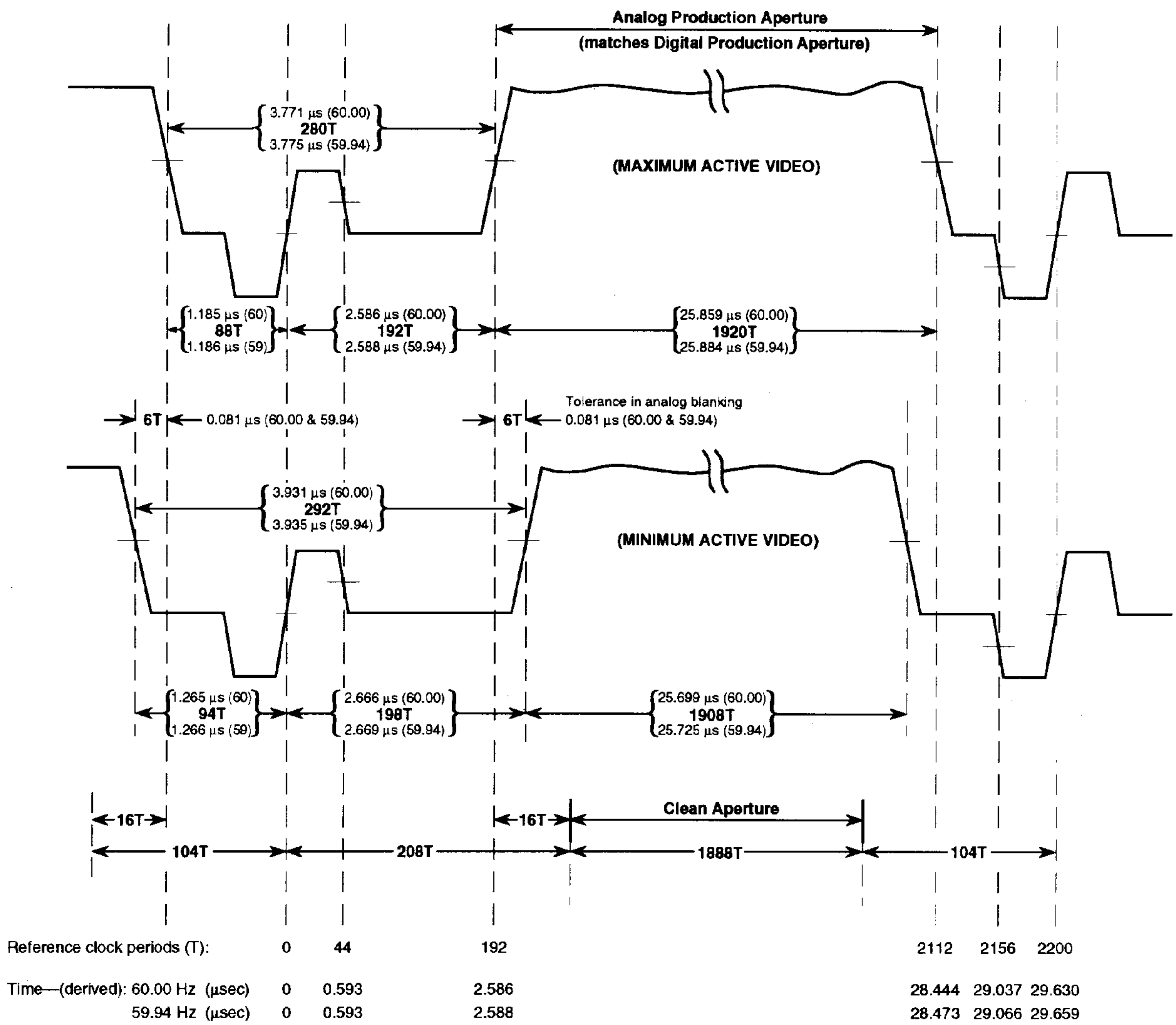

Figure 1(a) -- Timing of events within a video line

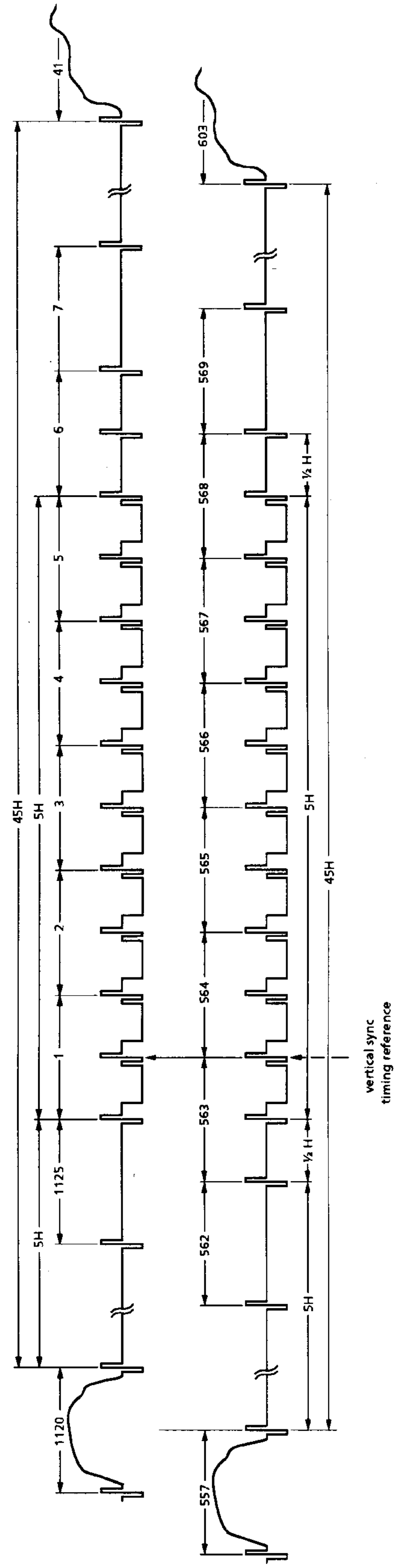

Figure 1(b) - -Detail of field blanking periods

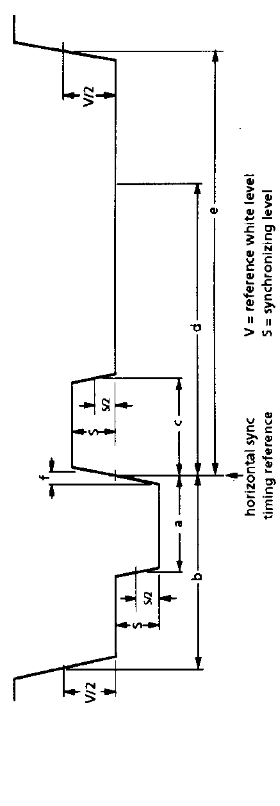

Figure 1(c) - -Detail of line blanking period

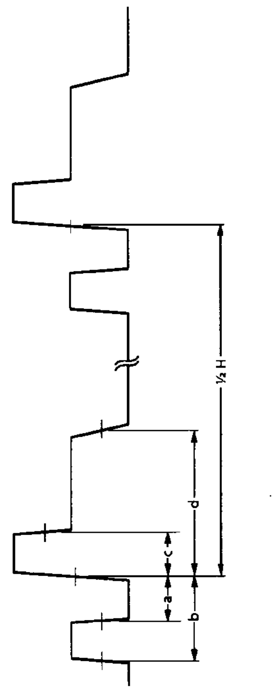

Figure 1(d) - -Detail of field synchronizing pulse

Annex A (informative)
Additional data

A.1 System colorimetry

The parameter values in clause 4 are based on current practice and technical constraints. It is recognized that the availability of a wider color gamut is highly desirable in an originating system. Furthermore, it is useful, for purposes of picture processing, to have available video signals proportional to light levels.

In order to obtain signals proportional to light levels, nonlinear processing is needed to remove the nonlinear characteristic given in 4.3. The equations given in 4.4 should be applied.

An approach to achieving the wider color gamut is under study which will involve retaining the reference primaries of 4.1 for the basic color coding and enlarging the color gamut by allowing negative RGB primary signals. (Consideration is also being given to the possibility of adopting the reference primaries specified in ITU-R BT.709, which are very close to the primaries specified in this standard.) The YP_bP_r signals derived from these extended-range RGB signals using the equations of clause 5 will fall within normal signal ranges.

A.2 Relationship between basic and derived parameters

Certain parameters have been determined as basic and fundamental system parameters. The values of all other system parameters can be derived from those chosen as basic, as shown in this annex.

Basic parameters:

- Field repetition rate (F) specified in clause 3.
- Total scan lines per frame (S) specified in clause 3.
- Reference clock periods in total line (R) specified in clause 6.

Computation of derived parameters:

- Line repetition rate (L): $L = S \times F/2$
- Reference clock frequency (C): $C = S \times R \times F/2$
- Reference clock period (T): $T = (S \times R \times F/2)^{-1}$

A.3 Derivation of the luma equation

A.3.1 Discussion of the luma function

It is common practice to encode the R,G,B component signals into a signal which conveys luminance information, and two signals which convey chrominance information. This was essential in the case of NTSC, PAL, and SECAM, where backwards compatibility with an existing monochrome system was required; and it is advantageous in modern systems, where the lower sensitivity of the eye to high-frequency chroma information can be exploited to reduce the bandwidth of the chroma signals.

The luminance function Y is defined by the CIE, and represents the brightness response of a standard observer. It is possible to determine the contributions of red, green, and blue light from a given phosphor set operating at a specified white point which are required to synthesize a true CIE luminance value for each scene element. The computation is summarized in A.3.2.

Because CRT phosphors do not respond linearly to electrical stimulation, the signals driving the phosphors must be preconditioned with an inverse nonlinearity. The preconditioning, usually called gamma correction, is normally done in the camera for several reasons. As a consequence, the RGB signals which are available for encoding are not linear with respect to light and cannot be linearly combined into a signal which represents true CIE luminance. The encoded signal which is produced will be called luma in order to permit clarity in terminology. Although the luma function does not represent the exact luminance of the scene element, it is common practice to encode it using the coefficient values derived for the luminance function.

For the purpose of this standard, the precise coefficient values are computed according to the method of A.3.2. The values are then rounded to three decimal places of accuracy, and those rounded values are defined as exact coefficient values in the specification of the luma equation in clause 5.

A.3.2 Luminance function coefficients for a phosphor set

The luminance function Y for a given phosphor set and white reference point is the mixture of the red, green, and blue lights (R,G,B) which represents the perceived brightness of scene elements.

The proportions of R,G,B which must be mixed to yield the correct value of Y can be calculated from the chromaticity coordinates of the reproducer primaries, and the chromaticity of reference white (i.e., the color reproduced when the reference reproducer is driven by equal primary signals), according to well-known methods.

Stated briefly, the equation for Y can be found as follows:

$$Y = \begin{bmatrix} J_r y_r & J_g y_g & J_b y_b \end{bmatrix} \bullet \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

where J_g, J_b, and J_r are derived according to:

$$\begin{bmatrix} J_r \\ J_g \\ J_b \end{bmatrix} = \begin{bmatrix} x_r & x_g & x_b \\ y_r & y_g & y_b \\ z_r & z_g & z_b \end{bmatrix}^{-1} \bullet \begin{bmatrix} \left(\frac{x_w}{y_w}\right) \\ 1 \\ \left(\frac{z_w}{y_w}\right) \end{bmatrix}$$

and x_r, y_r, z_r are the chromaticity coordinates of the red primary; x_g, y_g, z_g are the chromaticity coordinates of the green primary; x_b, y_b, z_b are the chromaticity coordinates of the blue primary; and x_w, y_w, z_w are the chromaticity coordinates of reference white.

A.4 Transformation between $[E_R' \; E_G' \; E_B']$ and $[E_Y' \; E_{PB}' \; E_{PR}']$

The transformations between the two sets are:

$$\begin{bmatrix} E_G' \\ E_B' \\ E_R' \end{bmatrix} = \begin{bmatrix} 1.000 & -0.227 & -0.477 \\ 1.000 & 1.826 & 0.000 \\ 1.000 & 0.000 & 1.576 \end{bmatrix} \begin{bmatrix} E_Y' \\ E_{PB}' \\ E_{PR}' \end{bmatrix}$$

$$\begin{bmatrix} E_Y' \\ E_{PB}' \\ E_{PR}' \end{bmatrix} = \begin{bmatrix} 0.701 & 0.087 & 0.212 \\ -0.384 & 0.500 & -0.116 \\ 0.445 & -0.055 & 0.500 \end{bmatrix} \begin{bmatrix} E_G' \\ E_B' \\ E_R' \end{bmatrix}$$

A.5 Picture boundaries

The production aperture defined by this standard comprises a picture made up of 1920 reference clock periods (T) horizontally by 1035 lines vertically. The 1920T width of this analog production aperture is specified at 50% video level, and represents the maximum active video permissible under this standard. It is good practice to adjust and operate all studio equipment with this minimal amount of blanking. This analog production aperture has identical dimensions to the digital production aperture of ANSI/SMPTE 260M.

In practical system implementations, blanking may be wider, up to the amount (6T at each end) specified by the tolerance in table 3. If the full amount of the tolerance is exercised at start and end of active picture, the minimum active video is obtained.

A.6 Reference reproducer and actual monitors

In 4.4, the electro-optical transfer characteristics of the reference reproducer are defined. This reference reproducer does not represent the transfer characteristics of a real monitor; rather, it is a mathematical description of a transfer function that is the exact inverse of the reference camera opto-electronic transfer function leading to a linear system that is convenient for many analyses. Experience has shown that, for the most pleasing subjective picture quality, television systems are often adjusted to have an overall light transfer characteristic represented by a power function whose exponent is slightly greater than unity. Therefore, real reproducers will often implement a transfer function whose power function exponent is somewhat greater than the value specified in this standard.

Annex B (informative)
Bibliography

ITU-R BT.709-2, Parameter Values for the HDTV Standards for Production and International Programme Exchange