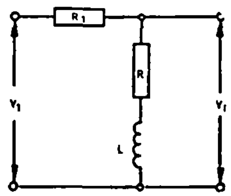
An approximately linear relationship exists between the magnetic flux emanating from the video head pole tips and the rf current flowing through the video head windings.



$$t_1 = \frac{L}{R_1 + R}$$

$$t_2 = \frac{L}{R}$$

$$\frac{V_0}{V_1} = \frac{j\omega t_2 + 1\, t_1}{j\omega t_1 + 1\, t_2}$$

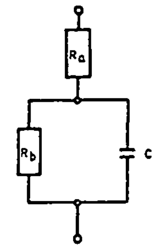
Figure A.1 – Preemphasis

The amplitude of the recording current in the video heads should be such as to produce maximum rf output in replay at the frequency corresponding to mid-gray level.

A.2 Definition of the playback chain

The deemphasis characteristic is introduced following the demodulator in the signal playback circuitry. (To obtain a flat input-to-output video response over the passband of interest, a complementary video preemphasis characteristic is introduced ahead of the frequency modulator stage during recording.)

The video deemphasis curves are defined as the normalized impedance of the two-terminal network, as shown in figure



$$t_1 = \frac{R_a R_b}{R_a + R_b} C$$

$$t_2 = R_b C$$

Figure A.2 – Deemphasis

A.2 where t_1 and t_2 are time constants in microseconds, R is resistance in ohms, and C is capacitance in microfarads.

The deemphasis network is introduced following the demodulator in the signal playback circuitry. (To obtain a flat input-to-output video response over the passband of interest, a complementary preemphasis network is introduced ahead of the frequency modulator stage during recording.)

This definition assumes that all preemphasis and deemphasis are placed in the video portion of the signal path and that the response of the rf portion of the signal path is flat over the passband of interest. Ideally, the magnitude of the remnant flux on a recorded tape should be independent of frequency over the frequency range of interest, but since there is no practical way of measuring it, the most practical approach is to ensure that the recording current in the video heads is independent of frequency over the passband of interest.

Annex B (informative)
Bibliography

ANSI/SMPTE 15M-1992, Television Analog Recording — 1-in Type B Helical Scan — Basic System Parameters

PROPOSED SMPTE STANDARD

SMPTE 154
Revision of ANSI/SMPTE 154-1988

for Motion-Picture Film (8-mm Type S) — Projectable Image Area and Projector Usage

1 Scope

1.1 This standard specifies the maximum dimensions of the film image area intended for projection and its relative position to the reference edge and the perforations of 8-mm type S motion-picture film, as specified in ANSI/SMPTE 149.

1.2 This standard also specifies the projection frame rate for 8-mm type S motion-picture film.

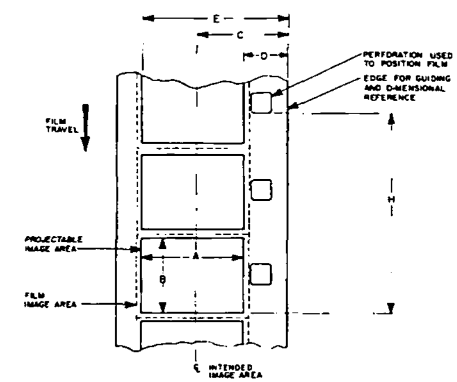
2 Emulsion and film position

2.1 For original reversal film, the emulsion side shall be toward the projection lens. For prints, the emulsion position is dependent upon the process of preparation and either emulsion-to-light-source or emulsion-to-projection-lens *orientation may be encountered*. The actual emulsion position should be indicated on the leader and film container by notation or diagram.

2.2 The perforation used for the film-positioning device shall be two perforations following the perforation adjacent to the projected aperture when the positioning device is at the end of its stroke (the minus-2 position). This location coincides with that of the positioning device required for 8-mm type S camera original films and thereby improves steadiness through cancellation.

3 Dimensions

The dimensions shall be as given in figure 1 and table 1.



NOTE – Film as seen from projector light source looking toward lens.

Figure 1 – Projectable image area

Table 1 – Specifications

Dimensions	Inches	Millimeters
A	0.209 ref	5.31 ref
B	0.158 max	4.01 max
C[1)]	0.170 ref	4.32 ref
D	0.063 min	1.60 min
E	0.278 max	7.06 max
H[2)]	0.389 nom	9.88 nom

1) See annex A.1.
2) See annex A.3.

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4 Projection frame rate

4.1 The standard frame rate for motion-picture projection is 24 frames per second. However, it is recognized that nonstandard frame rates are sometimes used for specific applications. For example, 24, 25, or 30 frames per second may be used for motion pictures intended for television, higher or lower frame rates may be used for special effects and analysis, and nonstandard rates may be used for special motion-picture systems. The use of nonstandard frame rates requires notification and agreement of all parties concerned with the use of the particular film.

4.2 A projection frame rate of 18 frames per second shall be used for nonprofessional films containing an audio record which was recorded for 18-frame projection.

Annex A (informative)
Additional data

A.1 The centerlines of the image area are given for convenience in interpreting the standard, facilitating such applications as the optical design of equipment, and assisting in the understanding of suitable mechanical embodiments related to projectable image area. Note that the centerline of the projectable image area is displaced from the centerline of the film by 0.013 in (0.33 mm) nominal.

A.2 Because of the increased intensity of illumination available in modern 8-mm projection systems, the industry has found it desirable to extend the flicker threshold by choosing as high a projection rate (and, therefore, as high a flicker frequency) as practicable. A projection rate of 18 frames per second and a corresponding flicker frequency of 54 Hz (obtained with a three-blade shutter) has been found by experience to be an acceptable compromise.

A.3 Dimension H is measured lengthwise along the path of the film from the bottom of the maximum image area projected by the aperture to the bottom of the frame-positioning perforation (two perforations following the perforation adjacent to the projected image).

A.4 Dimensions B, D, and E define the maximum image area on the film that is available for projection. They do not define the opening in the aperture plate of a projector. The size of this opening may differ from dimensions A and B, for example, because of the physical separation necessary between the aperture plate and the film to avoid scratching the film, the slant of the marginal rays accepted by the projection lens, etc.

A.5 This standard may be used as the basis for establishing picture areas from original photography for final viewing because it presents a description of the picture area on the projection print and is consistent with commercial practices specified in ANSI/SMPTE 153 and ANSI/SMPTE 157.

Annex B (informative)
Bibliography

ANSI/SMPTE 149-1988, Motion-Picture Film (8-mm Type S) — Perforated 1R

ANSI/SMPTE 153-1991, Motion-Picture Film (8-mm Type S) — 16-mm Film Perforated 8-mm Type S (1-4) — Printed Areas

ANSI/SMPTE 157-1988, Motion-Picture Film (8-mm Type S) — Camera Aperture Image and Usage

PROPOSED SMPTE STANDARD

SMPTE 244M

for Television — System M/NTSC Composite Video Signals — Bit-Parallel Digital Interface

1 Scope

1.1 This standard describes a bit-parallel composite video digital interface for systems operating according to the 525-line, 59.94-Hz NTSC standard, as described by SMPTE 170M, sampled at four times color subcarrier frequency. Sampling parameters for the digital representation of encoded video signals, the relationship between sampling phase and color subcarrier, and the digital levels of the video signal are defined.

1.2 This standard has application for use with shielded twisted 12-pair cable of conventional design over distances up to 50 m, without transmission equalization or any special equalization of the receiver. Longer cable lengths may be used, but with rapidly increasing requirement for care in the cable selection and possible receiver equalization or the use of active repeaters or both.

1.3 Digital composite video signals, as defined by this standard, are the signals conveyed by the composite implementation of the serial digital interface. It should be noted that additional information to that described by this standard is also carried by the serial digital interface.

The serial digital interface is the preferred method for the interconnection of composite digital equipments when cable lengths exceed 50 m.

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 170M, Television — Composite Analog Video Signal — NTSC for Studio Applications

ISO 2110:1989, Information Technology — Data Communication — 25-Pole DTE/DCE Interface Connector and Contact Number Assignments

CCIR Recommendation 471-1, Nomenclature and Description of Colour Bar Signals

3 General specifications

3.1 The analog signal shall be sampled at a rate of four times the color subcarrier frequency along the I and Q axes. The phase reference for the sample clock shall be color subcarrier (f_{sc}). Many systems will derive this phase reference from the burst of the analog signal.

3.2 Color subcarrier phase to horizontal sync timing (SC/H) in the digital domain shall be zero.

3.3 The quantization scale shall be uniformly quantized PCM at 10 bits per sample. Eight bits per sample video data may be carried across the interface by using the eight most significant bits and setting the two least significant bits to zero.

3.4 The bits of the digital words that describe the video signal are transmitted in a parallel arrangement using 10 conductor pairs. An eleventh conductor pair carries a clock signal at $4f_{sc}$ (14.31818 MHz).

3.5 The interface consists of one transmitter and one receiver in a point-to-point connection.

4 Sampling structure and quantization specifications

4.1 Sampling structure

Figure 1 depicts the line and field structure of the NTSC signal during the vertical blanking interval. Burst locked sinewave, shown in figure 1, is defined as a continuous sinewave at subcarrier frequency, with the same phase as burst.

4.1.1 There are 910 samples in a horizontal line period; 768 samples constitute the digital active video portion of each line. The remaining 142 samples comprise the digital horizontal blanking interval.

Each of the four samples during a color subcarrier period is described by the chrominance signal axis that it falls on. Figure 2 shows the derivation of the sample sequence.

Figure 3 depicts the sample numbering for a nominal NTSC signal. The half-amplitude point of the leading (falling) edge of the analog horizontal sync signal falls between samples 784 and 785.

The first of the 910 samples represents the first sample of the digital active line and is designated sample 0 for the purpose of reference. The 910 samples per line are, therefore, numbered 0 through 909. Samples 0 through 767 inclusive contain the digital active line video data.

4.1.2 The sample at sample 0, line 10, field 1, color frame A is an I axis (+123°) sample. (See figure 4.)

4.2 Quantization specifications

4.2.1 The digital video signal shall be quantized according to table 1.

Table 1 – Signal quantization

	8-bit system	10-bit system
White level	$C8_h$	320_h
Blanking level	$3C_h$	$0F0_h$
Sync tip level	04_h	010_h

Note - The "h" suffix indicates a hexidecimal value.

4.2.2 The amplitude relationship between the digital signal and an equivalent analog signal is shown in figure 5. The signal illustrated is a representation of 100% level, 7.5% setup (100/7.5/100/7.5) color bars.

4.2.3 The characteristics of the data word are based on the assumption that the location of any required (sin x)/x correction is at the point where the digital signal is converted to an analog form.

4.2.4 Data is represented in 8- or 10-bit words.

In an 8-bit system, 254 of the 256 levels (01 through FE) are used to express a quantized value.

In a 10-bit system, 1016 of the 1024 levels (004 through 3FB) are used to express a quantized value.

In an 8-bit system, levels 00 and FF are protected and are not permitted in the data stream.

In a 10-bit system, levels 000, 001, 002, 003 and 3FC, 3FD, 3FE, and 3FF are protected and are not permitted in the data stream.

The protected and permitted data levels are shown in table 2.

Table 2 – Permitted and protected values

8 bits		10 bits
00	Protected	000 001 002 003
01 — FE	Permitted	004 — 3FB
FF	Protected	3FC 3FD 3FE 3FF

4.2.5 Some models of composite digital video equipment allow the use of protected values in the video data. Designers of new equipment should consider the effects of such signals when detecting synchronizing patterns.

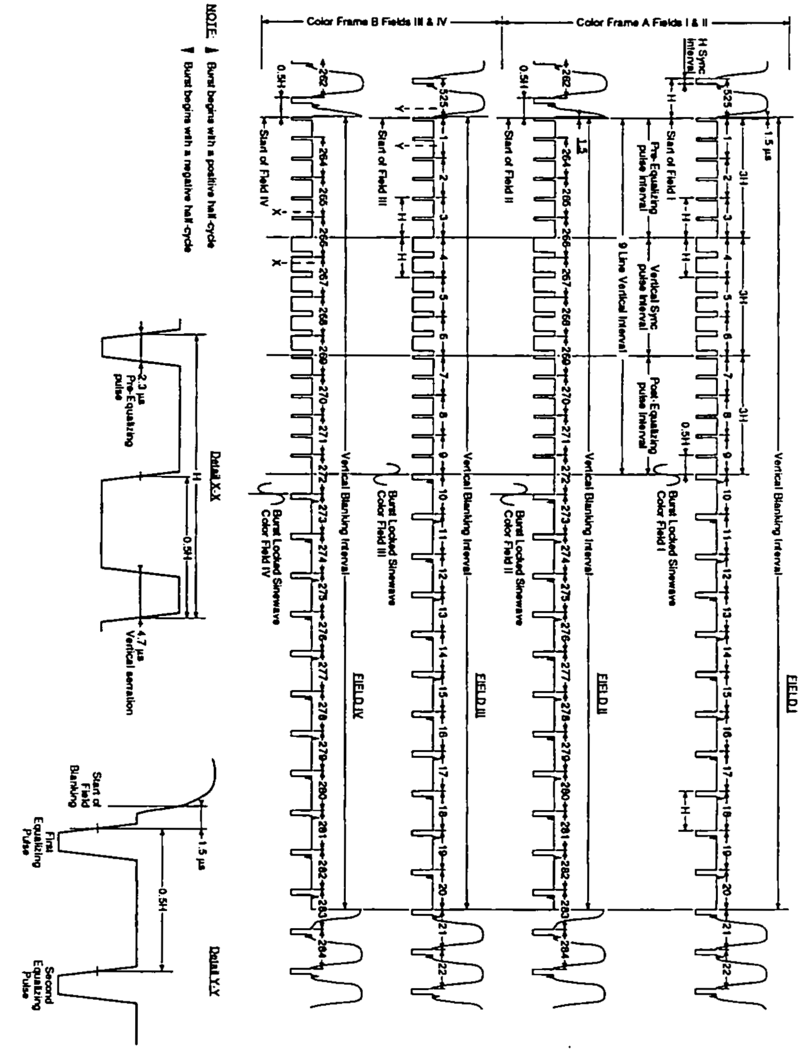


Figure 1 – Vertical blanking interval structure

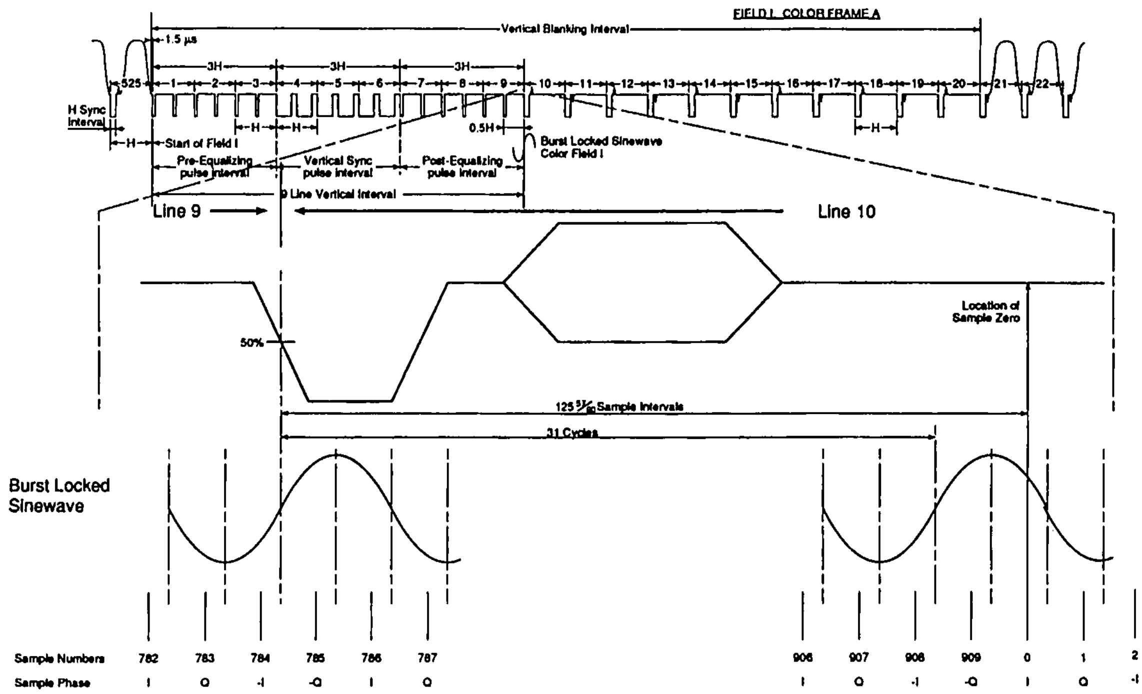
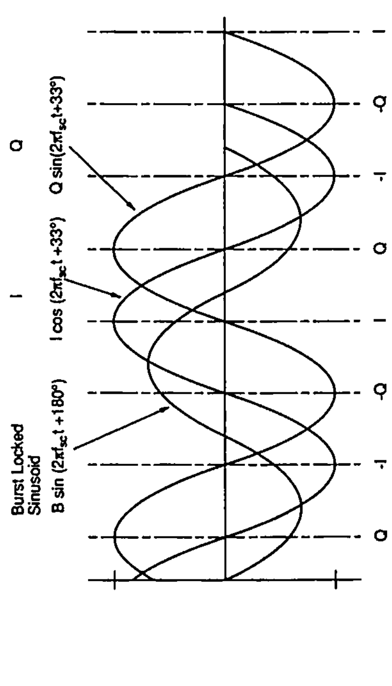


Figure 4 – Derivation of the sample zero sampling phase for line 10, field I, color frame A



NOTE – The equation for the chrominance signal is E = I cos ($2\pi f_{sc}t$ +33°) + Q sin ($2\pi f_{sc}t$ +33°).
The equation for the burst locked sinusoid is E = B sin ($2\pi f_{sc}t$ +180°).

Figure 2 – Derivation of sample sequence

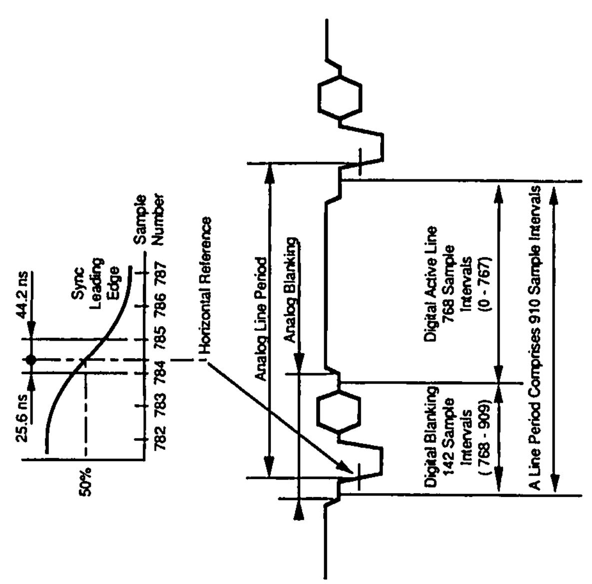


Figure 3 – Sample numbering for horizontal line period of nominal NTSC signal

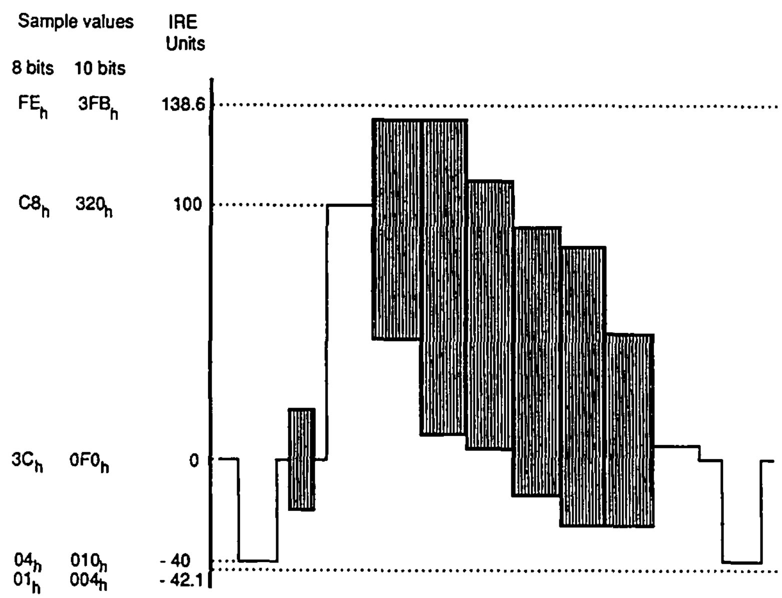


Figure 5 – Relationship between analog signal levels (IRE units) and digital sample values

4.3 Coding parameters

Sampling and quantization parameters are summarized in table 3.

Table 3 – Summary of coding parameters

Input signal	NTSC	
Number of samples/line period	910	
Sampling structure	Orthogonal	
Sampling frequency	$4f_{sc}$	
Sampling phase	I and Q axes (+123° and +33°)	
Form of coding	Uniformly quantized PCM, 8 or 10 bits per sample	
Quantization scale	8-bit system	10-bit system
White level	C8	320
Blanking level	3C	0F0
Sync tip level	04	010

5 Digital raster structure

Figure 6 depicts the digital raster structure and its relationship to the analog raster structure.

5.1 Digital active field

The digital active field duration exceeds that of the analog active field. The digital active field period is positioned to begin before and end after the analog video. Thus, the vertical blanking edges of the analog video are contained within the digital active picture space.

5.2 Digital active line

The digital active line duration exceeds that of the analog active line. The digital active line is positioned to begin before and end after analog video. Thus, the blanking edges of the analog video are contained within the digital active line period.

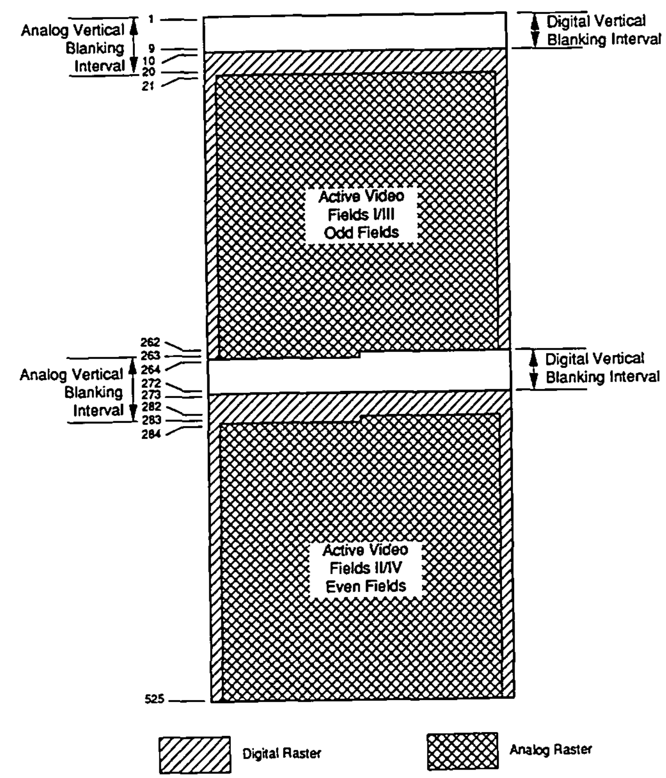


Figure 6 – Relationship between the analog and digital rasters

5.3 Analog blanking for digitally generated NTSC

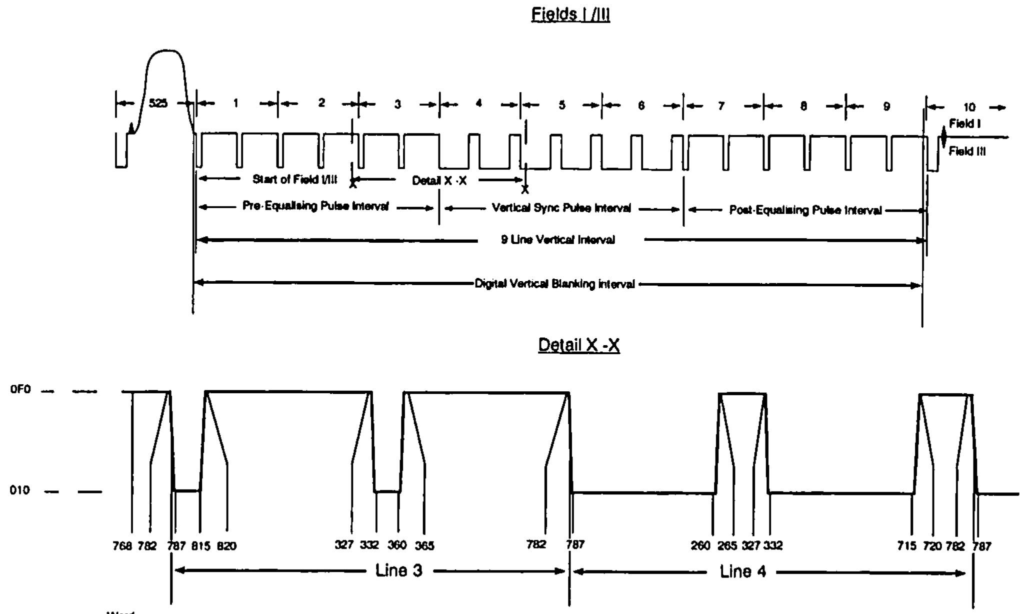
When NTSC signals are digitally generated, blanking edges and rise times appropriate for the analog waveform must be included as an integral part of the digital signal. The edges and timings shall be in accordance with those defined in SMPTE 170M.

5.4 Digital vertical blanking interval

5.4.1 The digital vertical blanking interval extends from line 525, sample 768 to line 9, sample 767 inclusive, for fields I and III and from line 263, sample 313 to line 272, sample 767 inclusive, for fields II and IV.

5.4.2 Digital data within the digital vertical blanking interval shall consist of a digital representation of an analog vertical interval. A 10-bit representation of the signal is preferred, although 8-bit values can be used. Suggested values are shown in table 4.

5.4.3 The location and magnitude of the samples during the digital vertical blanking intervals are shown in figure 7a and figure 7b.



Word Address (Decimal)	768	782	783	784	785	786	787	815	816	817	818	819	820	327	328	329	330	331	332	360	361	362	363	364	365
Sample Magnitude (10-Bit Hex)	0F0	0F0	0E9	0A4	044	011	010	010	017	05C	0BC	0EF	0F0	0F0	0E9	0A4	044	011	010	010	017	05C	0BC	0EF	0F0

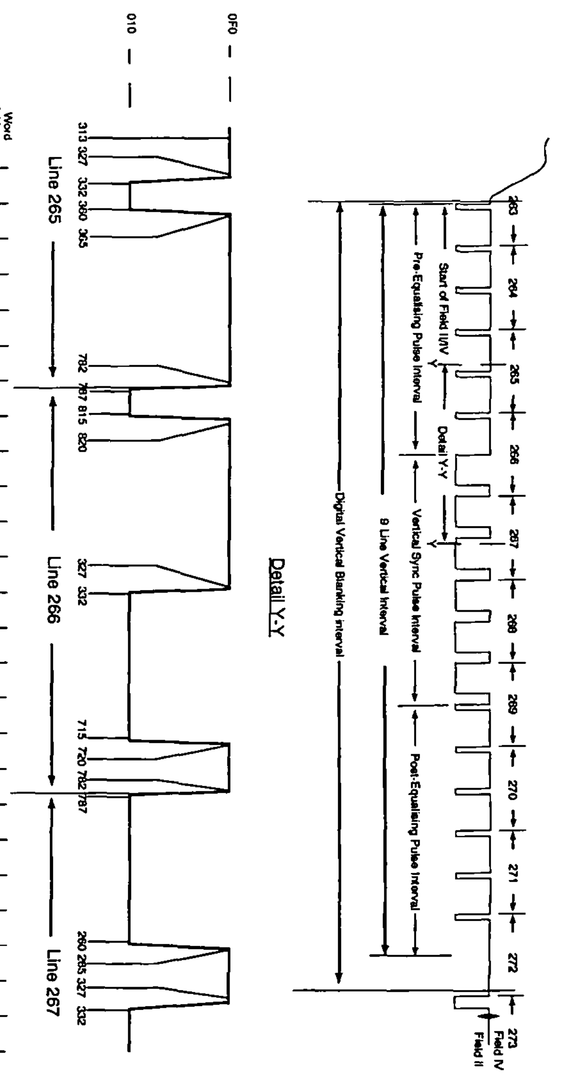
Word Address (Decimal)	260	261	262	263	264	265	327	328	329	330	331	332	715	716	717	718	719	720	782	783	784	785	786	787
Sample Magnitude (10-Bit Hex)	010	017	05C	0BC	0EF	0F0	0F0	0E9	0A4	044	011	010	010	017	05C	0BC	0EF	0F0	0F0	0E9	0A4	044	011	010

Figure 7a – Location and magnitude of 10-bit samples during digital vertical blanking interval of fields I and III

Table 4 – 10- and 8-bit hexadecimal values for the digital vertical blanking interval

Word	Fields I/III Sample values 10 bit	Fields I/III Sample values 8 bit	Word	Fields II/IV Sample values 10 bit	Fields II/IV Sample values 8 bit
Equalizing pulse interval values					
768–782	0F0	3C	313–327	0F0	3C
783	0E9	3A	328	0E9	3A
784	0A4	29	329	0A4	29
785	044	11	330	044	11
786	011	04	331	011	04
787–815	010	04	332–360	010	04
816	017	06	361	017	06
817	05C	17	362	05C	17
818	0BC	2F	363	0BC	2F
819	0EF	3C	364	0EF	3C
820–327	0F0	3C	365–782	0F0	3C
328	0E9	3A	783	0E9	3A
329	0A4	29	784	0A4	29
330	044	11	785	044	11
331	011	04	786	011	04
332–360	010	04	787–815	010	04
361	017	06	816	017	06
362	05C	17	817	05C	17
363	0BC	2F	818	0BC	2F
364	0EF	3C	819	0EF	3C
365–782	0F0	3C	820–327	0F0	3C
Vertical serration values					
782	0F0	3C	327	0F0	3C
783	0E9	3A	328	0E9	3A
784	0A4	29	329	0A4	29
785	044	11	330	044	11
786	011	04	331	011	04
787–260	010	04	332–715	010	04
261	017	06	716	017	06
262	05C	17	717	05C	17
263	0BC	2F	718	0BC	2F
264	0EF	3C	719	0EF	3C
265–327	0F0	3C	720–782	0F0	3C
328	0E9	3A	783	0E9	3A
329	0A4	29	784	0A4	29
330	044	11	785	044	11
331	011	04	786	011	04
332–715	010	04	787–260	010	04
716	017	06	261	017	06
717	05C	17	262	05C	17
718	0BC	2F	263	0BC	2F
719	0EF	3C	264	0EF	3C
720–782	0F0	3C	265–327	0F0	3C

Fields II/IV



Word Address (Decimal)	313	327	328	329	330	331	332	360	361	362	363	364	365	782	783	784	785	786	787	815	816	817	818	819	820
Sample Magnitude (10-Bit Hex)	0F0	0F0	0E9	0A4	044	011	010	010	017	05C	0BC	0EF	0F0	0F0	0E9	0A4	044	011	010	010	017	05C	0BC	0EF	0F0

Word Address (Decimal)	715	716	717	718	719	720	782	783	784	785	786	787	260	261	262	263	264	265	327	328	329	330	331	332
Sample Magnitude (10 Bit Hex)	010	017	05C	0BC	0EF	0F0	0F0	0E9	0A4	044	011	010	010	017	05C	0BC	0EF	0F0	0F0	0E9	044	044	011	010

Figure 7b – Location and magnitude of 10-bit samples during digital vertical blanking interval of fields II and IV

SMPTE 244M

5.4.4 Some models of digital composite video equipment may use values for the samples in the digital vertical blanking interval that differ from those listed in table 4. However, the range of values must conform to the tolerances laid down for the analog signal by SMPTE 170M. Designers of receivers for this interface should consider the effects of such changes when implementing detection circuits.

5.5 Digital horizontal blanking interval

5.5.1 The digital horizontal blanking interval extends from sample 768 to sample 909 inclusive, on all lines outside the digital vertical blanking interval.

5.5.2 Digital data within the digital horizontal blanking interval shall consist of a digital representation of an analog horizontal blanking interval, with a burst of 0 SC/H phase. A 10-bit representation is preferred. Where 8-bit values are used, the sample values are selected to maximize the accuracy of representation of the burst. Suggested values are shown in table 5.

5.5.3 The location and magnitude of the samples during the digital horizontal blanking region are shown in figure 8.

5.5.4 Some models of digital composite video equipment may use values for the samples in the digital horizontal blanking interval that differ from those listed in table 5. However, the range of values must conform to the tolerances laid down for the analog signal by SMPTE 170M and by this standard in respect of 0 SC/H phase. Designers of receivers for this interface should consider the effects of such changes when implementing detection circuits.

NOTE – There are two sets of values listed in the table for both the 10-bit and 8-bit sample values. The first value is designated as being 0° and represents the sample values that are used when the phase of the burst is positive. The second value is designated as being 180° and represents the sample values that are used when the phase of the burst is negative.

6 Electrical characteristics

6.1 Signal conventions

6.1.1 *The signals shall be transmitted via* balanced signal pairs. Although the use of ECL technology is not mandated, the line driver and receiver shall be ECL compatible to permit the use of standard ECL parts for either or both ends. In this standard, "standard ECL" refers to the 10,000 series of ECL logic.

6.1.2 The signalling sense of the voltage appearing across the interconnection cable is positive binary and defined as follows: The DATA terminal of the generator shall be positive (+) with respect to the RETURN terminal for a binary 1 (HIGH or H or ON) state. The DATA terminal of the generator shall be negative (-) with respect to the RETURN terminal for a binary 0 (LOW or L or OFF) state. *(See figure 9.)*

6.1.3 The data lines are designated DATA 0 through DATA 9. *DATA 9 is the most significant* bit.

6.2 Transmitter characteristics

6.2.1 The transmitter shall have a balanced out*put with a maximum impedance* of 110 ohms.

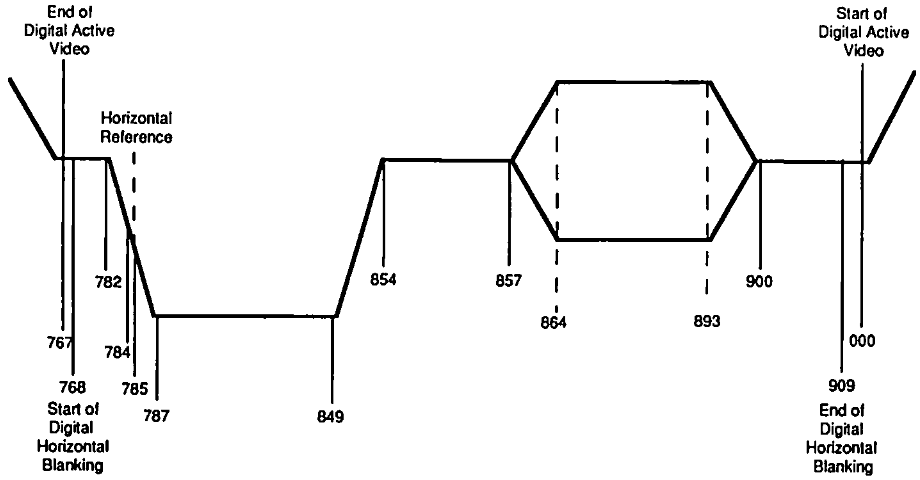
6.2.2 The common mode voltage of the line *driver shall be* -1.3 V ± 15% *with reference to the* ground terminals.

6.2.3 The generated *signal shall lie* between 0.8 V and 2.0 V peak-to-peak, measured across a 110-ohm resistor connected to the output terminals without any transmission line.

6.2.4 Rise and fall times shall be no longer *than 5 ns and differ by not more than 2 ns*, as measured between the 20% and 80% amplitude points, across a 110-ohm resistor connected to the output terminals without any transmission line.

6.3 Receiver characteristics

6.3.1 The cable shall be terminated by 110 ohms ± 10 ohms.



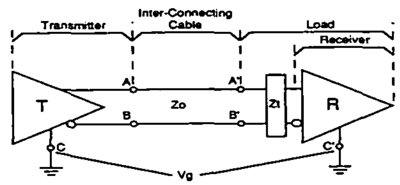
Word No.	768	782	783	784	785	786	787	849	850	851	852	853	854	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872
Burst Phase 0°	0F0	0F0	0E9	0A4	044	011	010	010	017	05C	0BC	0EF	0F0	0F0	0F4	0DC	0D6	12C	123	096	0B3	14E	12D	092	0B3	14E	12D	092	0B3
Burst Phase 180°	0F0	0F0	0E9	0A4	044	011	010	010	017	05C	0BC	0EF	0F0	0F0	0EC	104	10A	0B4	0BD	14A	12D	092	0B3	14E	12D	092	0B3	14E	12D

Word No.	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900	909
Burst Phase 0°	14E	12D	092	0B3	14E	12D	092	0B3	14E	12D	092	0B3	14E	12D	092	0B3	14E	12D	092	0B3	14E	129	0A6	0CD	112	0FA	0EC	0F0	0F0
Burst Phase 180°	092	0B3	14E	12D	092	0B3	14E	12D	092	0B3	14E	12D	092	0B3	14E	12D	092	0B3	14E	12D	092	0B7	13A	113	0CE	0E6	0F4	0F0	0F0

Figure 8 – Location and magnitude of 10-bit samples during digital horizontal blanking interval

Table 5 – 10- and 8-bit hexadecimal values for the digital horizontal blanking interval

Word	10-bit sample values 0°	10-bit sample values 180É	8-bit sample values 0°	8-bit sample values 180°	Word	10-bit sample values 0°	10-bit sample values 180°	8-bit sample values 0°	8-bit sample values 180°
768–782	0F0	0F0	3C	3C	874	12D	0B3	4B	2D
783	0E9	0E9	3A	3A	875	092	14E	25	53
784	0A4	0A4	29	29	876	0B3	12D	2D	4B
785	044	044	11	11	877	14E	092	53	25
786	011	011	4	4	878	12D	0B3	4B	2D
787–849	010	010	4	4	879	092	14E	25	53
850	017	017	6	6	880	0B3	12D	2D	4B
851	05C	05C	17	17	881	14E	092	53	25
852	0BC	0BC	2F	2F	882	12D	0B3	4B	2D
853	0EF	0EF	3C	3C	883	092	14E	25	53
854–856	0F0	0F0	3C	3C	884	0B3	12D	2D	4B
857	0F0	0F0	3C	3C	885	14E	092	53	25
858	0F4	0EC	3D	3B	886	12D	0B3	4B	2D
859	0DC	104	37	41	887	092	14E	25	53
860	0D6	10A	36	42	888	0B3	12D	2D	4B
861	12C	0B4	4B	2D	889	14E	092	53	25
862	123	0BD	49	2F	890	12D	0B3	4B	2D
863	096	14A	25	53	891	092	14E	25	53
864	0B3	12D	2D	4B	892	0B3	12D	2D	4B
865	14E	092	53	25	893	14E	092	53	25
866	12D	0B3	4B	2D	894	129	0B7	4A	2E
867	092	14E	25	53	895	0A6	13A	2A	4E
868	0B3	12D	2D	4B	896	0CD	113	33	45
869	14E	092	53	25	897	112	0CE	44	34
870	12D	0B3	4B	2D	898	0FA	0E6	3F	39
871	092	14E	25	53	899	0EC	0F4	3B	3D
872	0B3	12D	2D	4B	900–909	0F0	0F0	3C	3C
873	14E	092	53	25					



A, A' = Data line
B, B' = Return line
Zt = Cable termination
A, B = Transmitter interface points
A', B' = Load interface points
C = Transmitter circuit ground
C' = Load circuit ground
Vg = Ground potential difference
Zo = Cable characteristic impedance

Figure 9 – Balanced interface circuit

6.3.2 The line receiver must properly sense the binary data when connected directly to a line driver operating at the extreme voltage limits permitted by 6.2.3.

6.3.3 The receiver shall require a differential input voltage of no more than 185 mV to correctly attain the intended binary state.

6.3.4 The receiver shall operate correctly in the presence of common mode noise having a maximum amplitude of ± 0.5 V.

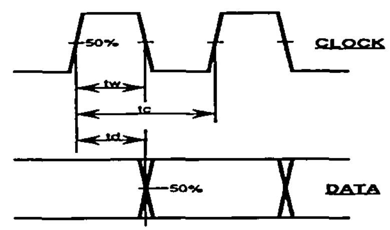
6.3.5 The receiver shall operate with a different delay between the received clock and any received data signals of up to 15 ns.

6.4 Clock signal

6.4.1 The clock signal is a $4f_{sc}$ square wave as shown in figure 10. The clock pulse width (Tw) is 35 ns ± 5 ns.

6.4.2 The peak-to-peak jitter between rising edges of the clock shall be within 5 ns of the average time of the rising edge computed over at least one television field.

6.4.3 The positive transition of the clock signal nominally occurs between the data transitions.



tw = 35 ns ± 5 ns

tc = $1/4f_{sc}$ (approximately 69.8 ns)

td = 35 ns ± 5 ns

Figure 10 – Digital interface clock waveform

7 Mechanical characteristics

7.1 General

This clause defines the mechanical specifications for the interface of digital video systems used in environments where the physical distance between the devices is limited and the general physical environment can be termed interior.

The majority of applications of this interface involve cable lengths of less than 50 m. For these lengths, cables with reasonable uniformity between pairs will, generally, give satisfactory results. For cable lengths greater than 50 m, cable specifications and termination characteristics become more critical and it is likely that equalization will be required.

7.2 Interconnecting cable

7.2.1 The interface is designed to operate with a nominal signal-pair impedance of 110 ohms.

7.2.2 The cable shall contain 12 pairs of conductors of which 11 pairs shall be used as signal lines. The remaining pair shall be used as system ground.

7.2.3 It is recommended that the cable be constructed to minimize the effects of crosstalk between signal lines, the susceptibility of the signal lines to external noise, and the transmission of interface signals to the external environment.

7.2.4 The cable shall have an outer shield, to minimize radiation, carried through the cable assembly. This shield shall be terminated via the chassis ground pin and the connector body at each end.

7.2.5 The cable shall be constructed to minimize the differential time delay between any two of the conductor pairs.

7.3 Connectors

7.3.1 The connectors shall have the mechanical characteristics conforming to the industry standard 25-pin subminiature type D, as described below. Additional information may be found in ISO 2110. (This interface will require that the connectors be inserted many times. ECL voltage and current levels are relatively low. Thus, the materials in the connector should be appropriate to the application.)

7.3.2 Cable connectors employ pin contacts and equipment connectors employ socket contacts (see figure 11).

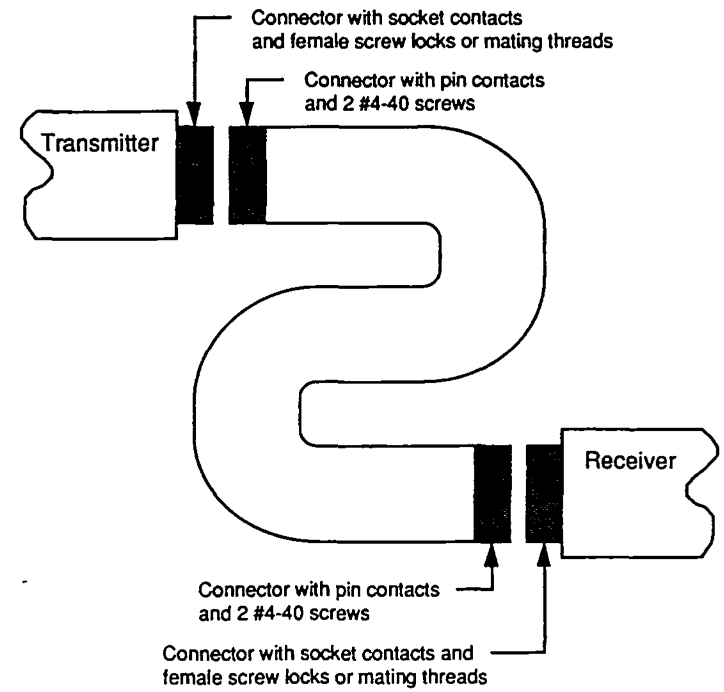


Figure 11 – Cable connector configuration

7.3.3 Cable connectors shall be provided with No. 4-40 mounting screws and equipment connectors shall be provided with female screw locks or mating threads. For further information, see annex A.

7.4 Connector contact assignments shall be in accord with table 6.

Table 6 – Connector contact assignments

Contact	Signal line	Contact	Signal line
1	CLOCK	14	CLOCK RETURN
2	SYSTEM GROUND	15	SYSTEM GROUND
3	DATA 9 (MSB)	16	DATA 9 RETURN
4	DATA 8	17	DATA 8 RETURN
5	DATA 7	18	DATA 7 RETURN
6	DATA 6	19	DATA 6 RETURN
7	DATA 5	20	DATA 5 RETURN
8	DATA 4	21	DATA 4 RETURN
9	DATA 3	22	DATA 3 RETURN
10	DATA 2	23	DATA 2 RETURN
11	DATA 1	24	DATA 1 RETURN
12	DATA 0 (LSB)	25	DATA 0 RETURN
13	CABLE SHIELD		

Annex A (informative)
Additional data

A.1 Connector characteristics

The interface employs a 25-pin subminiature type D connector with the connectors on the transmitter and receiver using socket contacts and the connectors on both ends of the cable using pin contacts.

Connectors are locked together by two No. 4-40 screws on the cable connectors, which mate with female screw locks mounted on the equipment connectors. Detailed dimensions are given in ISO 2110.

The relative position of the connector and the female screw lock are defined in figure A.1. The recommended minimum connector spacing is defined in figure A.2. It is recommended that the cable connectors employ a conductive backshell to maintain the shielding of the signal conductors. Care should be taken to select designs that are appropriate for use with the screw latching specified.

A.2 Cable shield pin

The cable shield (pin 13) is for the purpose of controlling electromagnetic radiation from the cable. It is recommended that pin 13 provide high-frequency continuity to the chassis ground at both ends and, in addition, provide DC continuity to the chassis ground at the transmit end.

A.3 Connector orientation

For either vertical or horizontal mounting, contact 1 should be uppermost.

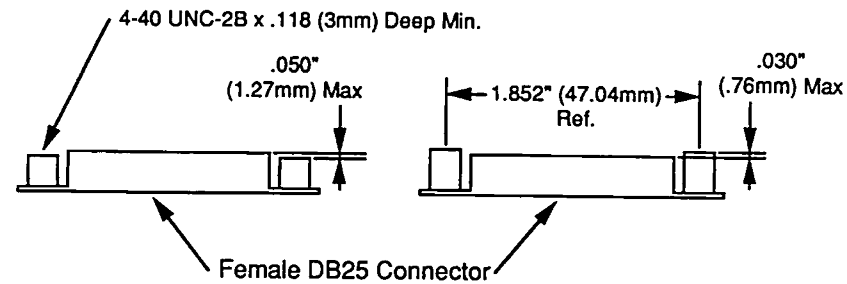


Figure A.1 – Female screw lock mounting detail

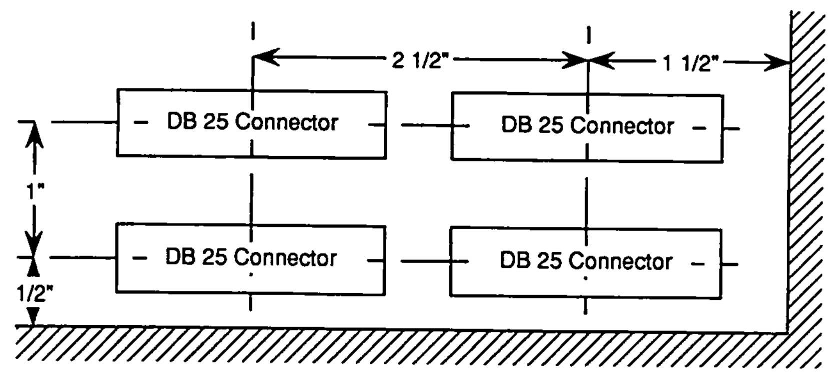


Figure A.2 – Minimum connector spacing

PROPOSED SMPTE STANDARD for Television Digital Recording — 19-mm Type D-2 Composite Format — Tape Record

1 Scope

This standard specifies the dimensions and location of the audio, video, ancillary data, cue track, time code, and control-track records for 19-mm type D-2 helical-scan composite digital cassette television tape recorders operating on the 525/60 television system encoded according to SMPTE 244M.

2 General specifications

2.1 Dimensions are in the metric system.

2.2 Tests and measurements made on the tape record to check the requirements of this standard shall be made under the following atmospheric conditions unless otherwise stated:

- Temperature 20°C ± 1°C
- Relative humidity (50 ± 2)%
- Barometric pressure 96 kPa ± 10 kPa
- Tape tension 0.70 N ± 0.05 N

2.3 Conditioning of the tape stock before recording and testing shall be as follows:

- Time of conditioning: Not less than 24 hours

- Environmental: Stabilized to the conditions specified in 2.2

- Tape tension: Wound on a reel at a tension of 0.6 N to 1.5 N

2.4 The reference edge of the tape for dimensions specified in this standard shall be the lower edge as shown in figure 1. The magnetic coating, with the direction of tape travel as shown in figure 1, is on the side facing the observer.

2.4.1 All dimensions in the table and figures shall be measured from an equivalent reference edge. The tape reference edge is a line through three points on the edge of tape constrained to lie in one straight line. This constraint may be a physical deformation or an equivalent mathematical transformation. The first and third points shall be separated by a measurement distance (MD) of 210 mm. The second point shall be located a distance 0.2 MD from the first point and 0.8 MD from the third point as shown in figure 3. The program reference point lies on a line perpendicular to the reference edge through the second point on the reference edge.

2.4.2 Measuring techniques are shown in annex A.

2.4.3 As indicated in figure 1, this standard anticipates the use of overlap recording by helical tape record heads of width greater than the track pitch.

3 Tape speed

The basic value for tape speed is 131.700 mm/s. The tape speed tolerance is ± 0.2%.

4 Record location and dimensions

4.1 Record location and dimensions for continuous recording shall be as specified in figures 1 and 2 and table 1.

4.2 In recording, sector locations on each helical track shall be contained within the tolerance specified in table 1 and figure 3.

4.3 The width and height tolerances of the heads used for recording shall be chosen so as to ensure

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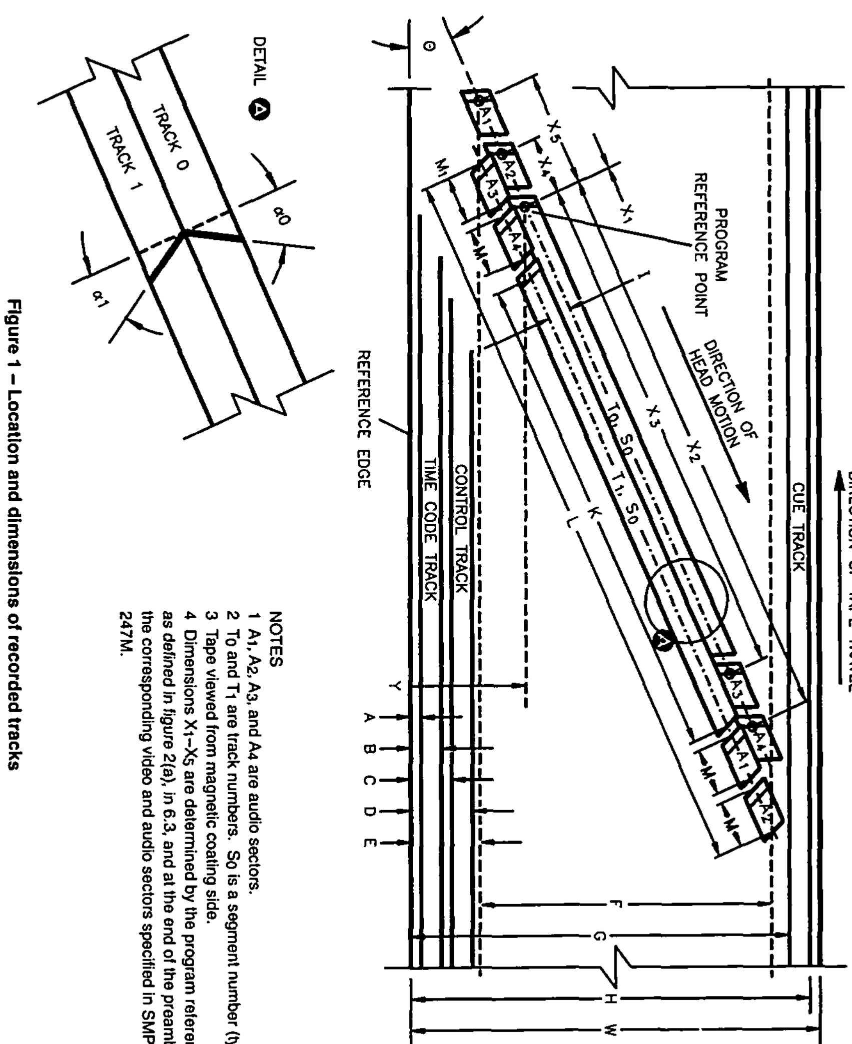


NOTES

1 A_1, A_2, A_3, and A_4 are audio sectors.

2 T_0 and T_1 are track numbers. S_0 is a segment number (typical).

3 Tape viewed from magnetic coating side.

4 Dimensions X_1–X_5 are determined by the program reference point as defined in figure 2(a), in 6.3, and at the end of the preambles of the corresponding video and audio sectors specified in SMPTE 247M.

Figure 1 – Location and dimensions of recorded tracks

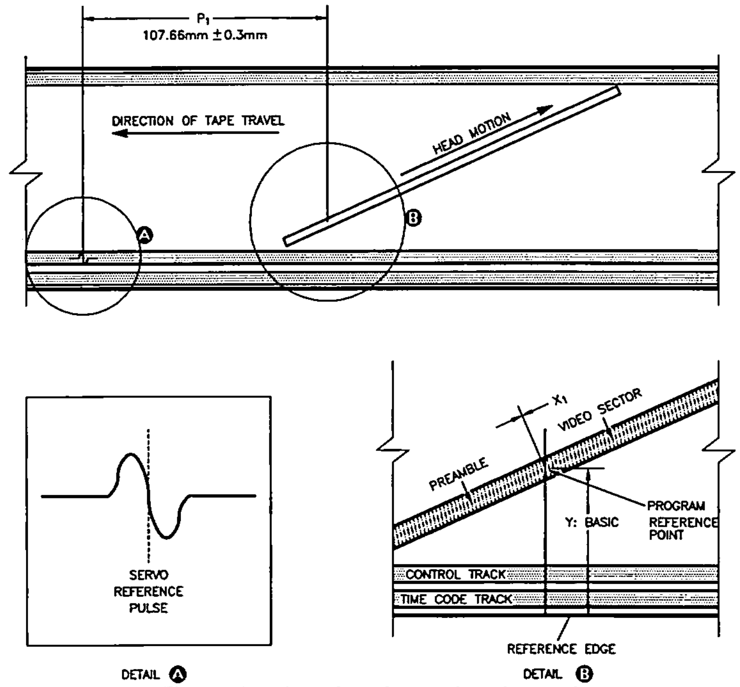


Figure 2(a) – Location of control track record

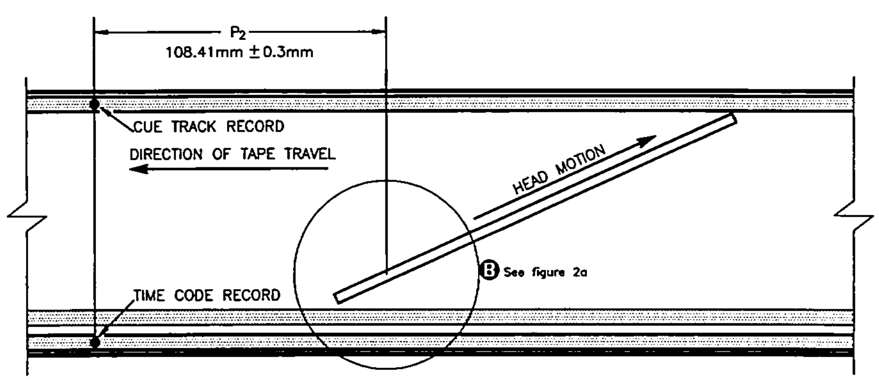


Figure 2(b) – Location of cue/time code record

Table 1 – Record location and dimensions

	Dimensions		Millimeters Nominal	Tolerance
A	Time code track lower edge		0.2	± 0.1
B	Time code track upper edge		0.7	± 0.1
C	Control track lower edge		1.0	± 0.1
D	Control track upper edge		1.50	± 0.05
E	Program area lower edge		1.807	Derived
F	Program area width		16.1	Derived
G	Cue track lower edge		18.2	± 0.1
H	Cue track upper edge		18.9	± 0.1
I	Helical track pitch		0.0391	± 0.0030
K	Video sector length		132.49	Derived
L	Helical track total length		150.78	Derived
M_1	Audio sector A_1 track 0 and A_3 track 1		4.13	Derived
M	All other audio sectors		4.01	Derived
P_1	Control pulse distance		107.66	± 0.30
P_2	Cue/time code distance		108.41	± 0.30
W	Tape width		19.010	± 0.015
X_1	Location of video sector		0	± 0.10
X_2	Location of start of audio sector A_4		137.57	± 0.10
X_3	Location of start of audio sector A_3		133.03	± 0.10
X_4	Location of start of audio sector A_2		4.54	± 0.10
X_5	Location of start of audio sector A_1		9.08	± 0.10
Y	Program reference point		2.80	Basic
θ	Track angle	6.1296°		
α0	Track 0 azimuth angle	+14.97° ± 0.17°		
α1	Track 1 azimuth angle	−15.03° ± 0.17°		

NOTE – Above dimensions shall apply under the conditions specified in 2.2.

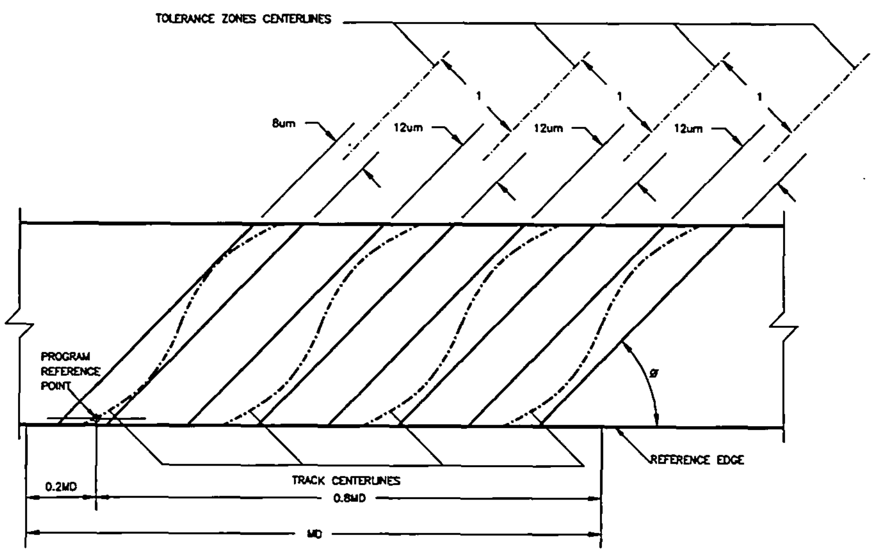
zero guard band between recorded tracks. If a guard band is present it shall not exceed 4 μm nor contain any previously recorded information. The minimum track width after recording is 35 μm measured across the track in a line perpendicular to the centerline of the tracks.

5 Helical track record curvature

5.1 The centerlines of any four consecutive tracks shall be contained within the pattern of the four tolerance zones established in figure 3.

5.2 Each zone is defined by two parallel lines which are inclined at an angle of 6.1296° basic with respect to the tape reference edge.

5.3 The centerlines of all zones shall be spaced 0.0391 mm basic apart. The width of the first zone shall be 0.008 mm basic. The width of zones 2 through 4 shall be 0.012 mm basic. These zones are established to contain track angle errors, track straightness errors, and track pitch errors. (See annex A.)



1 = HELICAL TRACK PITCH 0.0391mm
ß = TRACK ANGLE (BASIC) 6.1296°

Figure 3 – Location and dimensions of tolerance zones of helical track record

6 Relative positions of recorded signals

6.1 Audio, video, and ancillary data, tracking control, time code, and cue track, with information intended to be time coincident, shall be *positioned as shown in figures 1 and 2.*

6.2 The spatial relationship between the cue track record, time code record, control track record, and helical tracks is specified in figures 1 and 2.

6.3 The program reference point is determined by the intersection of a line parallel to the reference edge of the tape at the distance Y and the centerline of each track *in each video field (segment 0, track 0)*. The end of the preamble and the video sector shall be recorded at the program reference point and the tolerance is the dimension X_1. The locations are shown in figures 1 and 2. Dimensions X_1 and Y are given in table 1. The relationship between sectors and contents of each *sector is specified in* SMPTE 247M.

7. Gap azimuth

7.1 The cue, control track, and time code head gaps used to produce longitudinal track records shall be perpendicular to the track record.

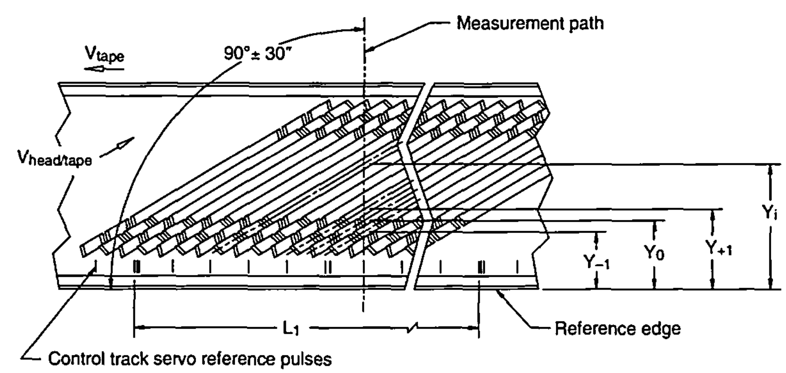
7.2 The azimuth of the head gaps used for the helical track recording shall be inclined at angles α0 and α1, as specified in table 1, perpendicular to the helical track record. The azimuth of the *first track of every field (segment 0, track 0) shall* be oriented in the clockwise direction with respect to the line perpendicular to the track direction when viewed from the side of the tape containing the magnetic record.

Annex A (normative)
Cross-tape track measurement technique

The cross-tape measuring technique utilizes the fact that all *tracks of a helical-scan* video recording, recorded by the same head at constant tape speed, have the same longitudinal track pitch, the same track angle, and the same track curvature.

From a ferrofluid development, measurements are made of the actual track positions and of the distance between a minimum of 201 control track servo reference pulses (200 *control track pitches minimum)* (see L_1, figure A.1). All measurements are made under the environmental conditions described in clause 2.2 except that the measurements are made without tape tension (see figure A.1). The tape is then mathematically stretched to account for tape tension (see figure A.2). The theoretical track position is calculated from the corrected longitudinal track pitch and the theoretical track angle. The track location error is calculated as the difference between the theoretical track position and the actual track position (see figure A.3).

Track location error includes track angle errors, track straightness errors, and track pitch errors. The starting point for calculations and measurements is, for example, the program reference point. The values for each fourth track are the errors for tolerance zone one; shifting one track, the second tolerance zone can be measured and so on. It is not necessary to measure all tracks; a suitable number is 20 samples per zone. A plot of the track location error against the track number shall be computed (see figure A.4). The peak-to-peak value shall lie within the tolerance zones according to clause 5.3.



NOTES
1 i is the track number (i = 0 for the track containing the program reference point).
2 Y_i is the actual track position (measured from the reference edge of the tape).
3 L_1 is the distance of n control track pitches (n = 200 minimum).

Figure A.1 – Measurement of ferrofluid tape development

The measured distance, L_1, must be corrected for tape tension. *The corrected tape length, L_2 (for n control track* pitches), is:

$L_2 = L_1 \times (1+T/(A \times E))$

where

T is the tape tension (0.7 N)
A is the tape cross section area (0.013 mm × 19.01 mm)
E is Young's modulus (10 000 N/mm^2).

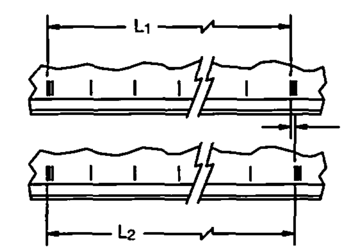
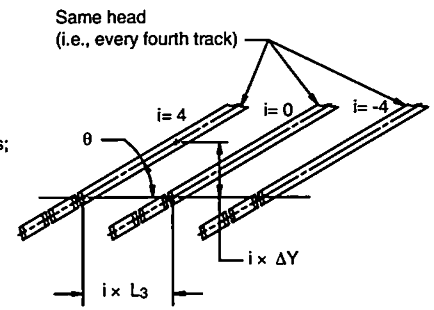


Figure A.2 – Correction for tape tension

The corrected longitudinal track pitch, L_3, is:
$L_3 = L_2/(n \times q)$
where
L2 is the corrected tape length for n control track pitches;
q is the number of tracks per control track pitch (2).

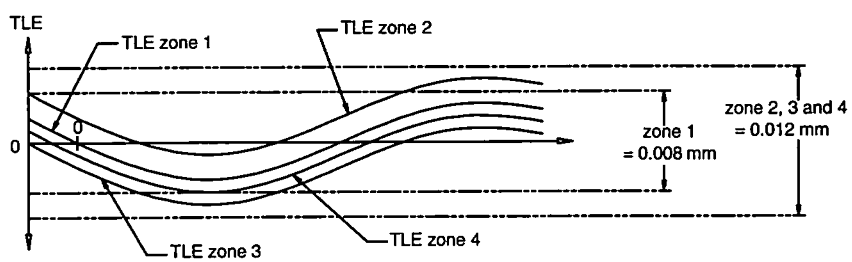
The cross track pitch, ΔY, is:
$\Delta Y = L_3 \times \tan(\theta)$
where
L_3 is the corrected track length;
θ is the theoretical track angle (6.1296°).



The theoretical track position, Y_{it}, to any track i is:
$Y_{it} = Y+(i \times \Delta Y)$
where
Y is the distance to the program reference point (2.80 mm);
i is the track number (i = 0 for the track containing the program reference point);
ΔY is the cross tape track pitch.

The track location error, TLE, is calculated as:
$TLE = Y_i - Y_{it}$
where
Y_i is the actual track position of track i;
Y_{it} is the theoretical track position of track i.

Figure A.3 – Calculation of track location error



NOTES
1 For tolerance zone 1: i = ... –4, 0, +4, +8 ....
2 For tolerance zone 2: i = ... –5, –1, +3, +7 ....
3 For tolerance zone 3: i = ... –6, –2, +2, +6 ....
4 For tolerance zone 4: i = ... –7, –3, +1, +5 ....

Figure A.4 – Example plot of track location error versus track number

Annex B (informative)
Bibliography

SMPTE 244M, Television — System M/NTSC Composite Video Signals — Bit-Parallel Digital Interface

SMPTE 246M, Television Digital Recording — 19-mm Type D-2 Composite Format — Magnetic Tape

SMPTE 247M, Television Digital Recording — 19-mm Type D-2 Composite Format — Helical Data and Control Records

SMPTE 248M, Television Digital Recording — 19-mm Type D-2 Composite Format — Cue Record and Time and Control Code Record

SMPTE EG 20, Tape Transport and Geometry Parameters for 19-mm Type D-2 Composite Format for Television Digital Recording

SMPTE EG 21, Nomenclature for Television Digital Recording, 19-mm Type D-1 Component and Type D-2 Composite Formats

PROPOSED SMPTE STANDARD

SMPTE 170M

for Television — Composite Analog Video Signal — NTSC for Studio Applications

Table of Contents

1 Scope

1.1 This standard describes the composite analog color video signal for studio applications: NTSC, 525 lines, 59.94 fields, 2:1 interlace with an aspect ratio of 4:3.

1.2 This standard specifies the interface for analog interconnection and serves as the basis for the digital coding necessary for digital interconnection of NTSC equipment.

NOTE – Parts of the NTSC signal defined in this standard differ from the final report of the Second National Television System Committee (NTSC 1953) due to changes in technology and studio operating practices.

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.

CIE S001 (1986), Colorimetric Illuminants

CIE S002 (1986), Colorimetric Observers

IEC 169-8 (1978), R.F. Coaxial Connectors with Inner Diameter of Outer Conductor 6.5 mm (0.256 in) with Bayonet Lock — Characteristic Impedance 50 Ohms (Type BNC)

3 General description of signal

The composite color video signal shall contain an electrical representation of the brightness and color of a scene being analyzed (the active picture area) along defined paths (scan lines). The signal shall also include synchronizing and color reference signals that allow the geometric and colorimetric aspects of the original scene to be correctly reconstituted at the display. The synchronizing and color reference signals shall be placed in parts of the composite color video signal that are not visible on a correctly adjusted display. Certain portions of the composite color video signal that do not contain active picture information shall be blanked (forced below black level) in order to allow retrace of scanning beams in some types of cameras and display devices.

3.1 The video signal representing the active picture area shall consist of:

– a wideband luminance (brightness) component with setup (see clauses 10 and 12), and no upper bandwidth limitation for studio applications;

– a pair of simultaneous chrominance (coloring) components, amplitude modulated on a pair of suppressed subcarriers of identical frequency (f_{sc} = 3.579545... MHz) in quadrature (i.e., with a 90° difference in phase).

3.2 The video signal representing the active picture area shall correspond to the scanning of the image at uniform velocities from left to right and from top to bottom. The velocities shall be such that the picture is repetitively scanned on 525 nominally horizontal lines, with alternate lines scanned on each vertical pass. This process is described as 2:1 interlace (see clauses 11 and 13).

3.3 The aspect ratio of the active picture area shall be four units horizontally to three units vertically.

3.4 The composite color video signal shall be produced by an NTSC encoder that functions as follows:

3.4.1 The input signals to an NTSC encoder shall be time-coincident green, blue, and red video signals (G B R), with no setup and of equal amplitude when conveying picture information with no color content (see clause 4). Horizontal and vertical synchronizing signals and reference subcarrier shall also be required.

NOTE – Throughout this standard, references to signals represented by a single letter, e.g., G, B, and R, are equivalent to the nomenclature in earlier documents of the form E_G', E_B', and E_R', which, in turn, refer to signals to which the transfer characteristics given in clause 5 have been applied. Such signals are commonly described as being gamma corrected.

3.4.2 Within the encoder, the green, blue, and red (G B R) video signals shall be matrixed to form one of two component sets, each comprising luminance (Y) and two color-difference signals (see clause 6); Y, B-Y, and R-Y or Y, I, and Q. The choice of component set is influenced by decisions regarding color component bandwidth; the final encoded signal shall be otherwise identical (see clause 7 and annex B).

3.4.3 After low-pass filtering, the color-difference signals (B-Y and R-Y or I and Q) shall be fed to balanced, quadrature-phase, subcarrier amplitude modulators.

3.4.4 The modulated subcarrier signals shall be added to the luminance signal, along with setup, blanking, sync, and burst (a color synchronizing signal) to form the composite output video signal.

3.5 There shall be a fixed frequency and phase relationship between the subcarrier in the burst signal, the subcarriers conveying the color-difference signals, and the horizontal and vertical synchronizing signals (see clauses 11 and 13).

3.6 The luminance and color-difference components of the composite color video signal at the encoder output shall be time-coincident.

4 Input signals

4.1 The green, blue, and red (G B R) input signals shall be suitable for a color display device having primary colors with the following chromaticities in the CIE S002 system of specifications:

		x	y
Green	(G)	0.310	0.595
Blue	(B)	0.155	0.070
Red	(R)	0.630	0.340

NOTES

1 The display primaries with the chromaticities specified above are commonly referred to as the SMPTE C set.

2 This specification does not preclude the continued use of equipment built to the color encoding/decoding parameters of the NTSC 1953 color television transmission standard for which the chromaticities in the CIE S002 system were specified at the following values:

		x	y
Green	(G)	0.21	0.71
Blue	(B)	0.14	0.08
Red	(R)	0.67	0.33

4.2 The system reference white is an illuminant which causes equal primary (input) signals to be produced by a reference camera and which is produced by a reference reproducer (display device) when driven by equal primary signals. For this system, the reference white is specified in terms of its CIE S002 chromaticity coordinates, which have been chosen to match those of CIE S001 illuminant D_{65}:

$$x = 0.3127 \qquad y = 0.3290$$

4.3 The input signals shall have no setup. Their amplitudes shall be equal for picture areas whose chromaticity corresponds to the system reference white. System nominal peak white shall be represented by input signals whose amplitudes are 100 IRE units for G, B, and R.

NOTE – IRE units are a linear scale for measuring the relative amplitudes of signals. An IRE unit has no absolute value, unless defined (see annex B).

5 Transfer characteristics

The reference reproducer for this system is representative of cathode ray tube displays, which have an inherently nonlinear electro-optical transfer characteristic. To achieve an overall system transfer characteristic that is linear, it is necessary to specify compensating nonlinearity elsewhere in the system. In the NTSC system, this is done at the signal source. For purposes of precision, particularly in digital signal processing applications, exactly inverse characteristics are specified for the reference camera and reproducer.

The respective transfer characteristics shall be as defined in 5.1 and 5.2. It is recognized that operating values may vary from the precise values given in order to meet operational requirements in practical systems.

5.1 Opto-electronic transfer characteristic of reference camera

$$V_C = 1.099 \times L_C^{(0.4500)} - 0.099 \quad \text{for } 0.018 \le L_C \le 1$$
$$V_C = 4.500 \times L_C \quad \text{for } 0 \le L_C < 0.018$$

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.

5.2 Electro-optical transfer characteristic of reference reproducer

$$L_T = [(V_r + 0.099)/1.099]^{(1/0.4500)} \quad \text{for } 0.0812 \le V_r \le 1$$
$$L_T = V_r/4.500 \quad \text{for } 0 \le V_r < 0.0812$$

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

NOTE – The description above is a more technically correct definition of the transfer function (gamma correction), particularly in dark areas of the picture, than the form used in older documents, viz., "having a transfer gradient (gamma exponent) of 2.2 associated with each primary" and "signals shall be gamma corrected through application of an exponential transfer gradient inverse to that assumed in the display; i.e., 1/2.2 (0.455...)."

6 Matrixing of the signals

The green, blue, and red (G B R) video signals shall be matrixed to form one of two baseband component sets of luminance (Y) and two color-difference signals: Y, B-Y, and R-Y or Y, I, and Q.

$$Y = +0.587G + 0.114B + 0.299R \quad \textbf{BASE EQUATION}$$
$$B\text{-}Y = -0.587G + 0.886B - 0.299R$$
$$R\text{-}Y = -0.587G - 0.114B + 0.701R$$

6.1 Luminance (Y) and the color-difference signals B-Y and R-Y can be matrixed from G, B, and R according to the following formulas:

6.2 The color-difference signals I and Q can be matrixed from color-difference signals B-Y and R-Y according to the following formulas:

$$I = -0.2680...(B\text{-}Y) + 0.7358...(R\text{-}Y)$$
$$Q = +0.4127...(B\text{-}Y) + 0.4778...(R\text{-}Y)$$
(...approximate values)

6.3 The color-difference signals I and Q can also be directly matrixed from G, B, and R video signals according to the following formulas:

$$I = -0.2746...G - 0.3213...B + 0.5959...R$$
$$Q = -0.5227...G + 0.3112...B + 0.2115...R$$
(...approximate values)

NOTE – This standard assumes input signals (G B R) to the encoder without setup. The luminance signal (Y) generated by the luminance equation above is, therefore, also without setup. Adjustment to achieve the required luminance signal, including setup, is performed in the encoding equations defined in clause 10.

It should be noted that this practice differs from the NTSC 1953 specification, which utilized input signals to the encoder having setup on them and, hence, not requiring the addition of setup in the encoder.

It should also be noted that the coefficients given for G, B, and R in the luminance base equation are precise values; i.e., 0.587 G = 587/1000 G, etc.

7 Filtering of signals

7.1 This standard does not impose a bandwidth restriction on the luminance part of the NTSC signal. Care should be taken to ensure that appropriate filtering is applied before the signal is fed to bandwidth-limited devices.

7.2 The color-difference signals shall be bandwidth limited prior to modulation as follows:

- less than 2 db down at 1.3 MHz;
- at least 20 db down at 3.6 MHz.

(See figure 1 for an example of the baseband, modulated carrier, and encoded [composite] signal passbands.)

7.3 The low-pass filters that are used with the baseband color-difference signals should have characteristics with a minimum of ringing and overshoot (Gaussian filter characteristics, for example).

NOTE to clause 7 – This standard does not preclude the continued use of equipment built to the NTSC 1953 color television transmission standard for which the I signal bandwidth is as specified in 7.2 and the Q signal bandwidth is limited as follows:

- at 0.4 MHz less than 2 db down;
- at 0.5 MHz less than 6 db down;
- at 0.6 MHz at least 6 db down.

When the overall bandwidth is not limited to less than 5 MHz, use of wideband, equiband chroma signals provides improved chroma resolution for signal processing in the studio.

When the composite NTSC signal is transmitted (or recorded on some types of video tape recorders), the overall bandwidth is normally limited to less than 5 MHz, typically 4.2 MHz as for broadcasting. In such cases, if it is desired to permit recovery at the receiver of the wideband I signal, as provided in the NTSC transmission specifications, it is necessary to decode and re-encode with the appropriate narrowband Q channel filter prior to transmission (or recording). (See SMPTE EG 27 for further information.)

This standard does not preclude the application of more sophisticated filtering techniques to any combination of the luminance, color-difference, or chrominance signals, provided care is taken not to degrade picture quality on display devices not equipped for operation with the sophisticated filtering techniques.

8 Subcarrier modulation

8.1 After low-pass filtering, the B-Y and R-Y (or I and Q) signals shall be fed to balanced, quadrature-phase, subcarrier amplitude modulators.

This process yields suppressed-carrier amplitude modulation in which the subcarrier chrominance signals (chroma) reduce to zero when the G B R input signals are of equal amplitude.

8.2 A gated and filtered signal derived from subcarrier, called the burst, shall be added in the horizontal blanking interval of each line, excluding the nine-line vertical sync interval, as a synchronizing signal and amplitude reference for the chrominance signals. The burst signal shall be inverted in phase from the reference subcarrier.

8.3 The modulated subcarrier signals (B-Y and R-Y or I and Q) shall be added to the luminance signal along with sync, blanking, setup, and burst to form the composite output video signal (N).

9 Timing

The input signals to the encoder shall be time coincident. Similarly, all the components that make up the encoded composite video signal (N) shall be time coincident at the output of the encoder (see figure 2). The recommended tolerance for time coincidence shall be ± 25 ns for any pair of nominally coincident signals.

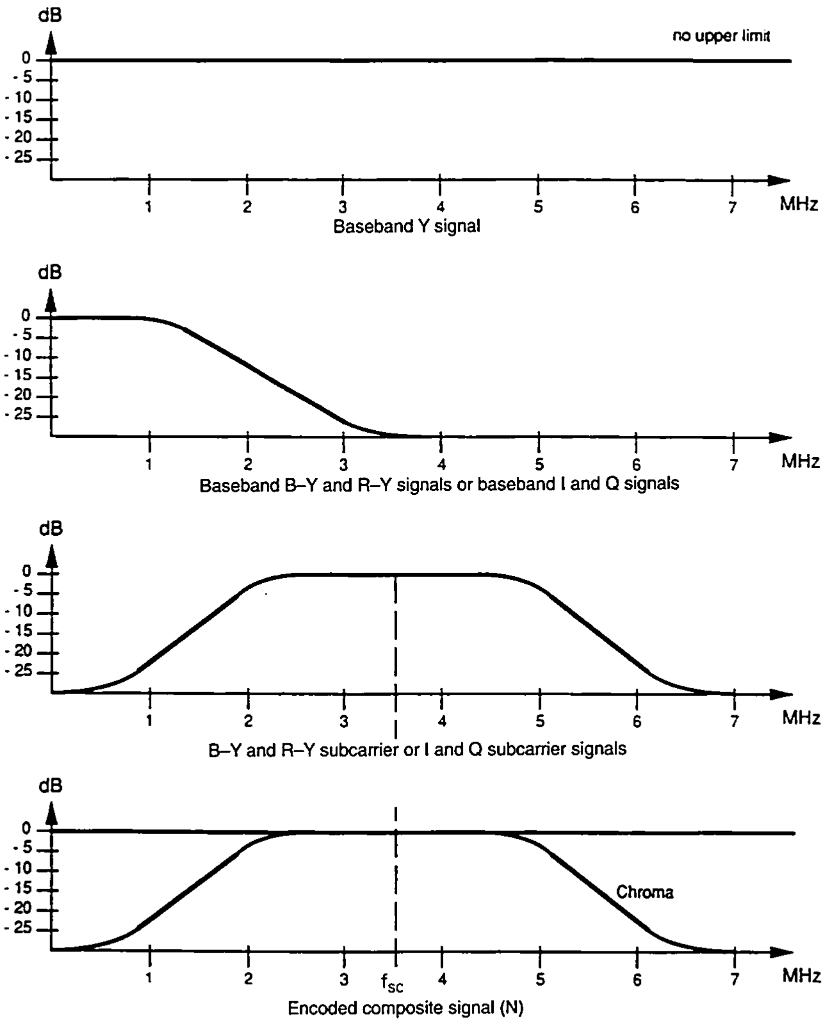


Figure 1 – Examples of signal passbands

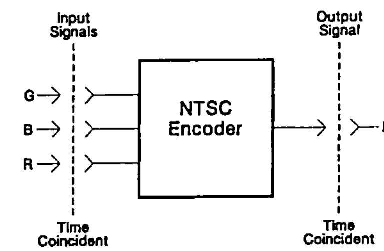


Figure 2 – Points of time coincidence

10 Encoded signal formulas

The encoded video signal (N), without sync, burst, and blanking, shall be defined by the following formulas (see figure 3). (These equations assume G B R inputs to the encoder of 100 IRE without setup).

Where Y, B-Y, and R-Y are used:

$N = 0.925(Y) + 7.5 + 0.4552...(B\text{-}Y) \sin(2\pi f_{sc} t)$
$+ 0.8115...(R\text{-}Y) \cos(2\pi f_{sc} t)$ **BASE EQUATION**

or, where Y, I, and Q are used:

$N = 0.925(Y) + 7.5 + 0.925(Q) \sin(2\pi f_{sc} t + 33°)$
$+ 0.925(I) \cos(2\pi f_{sc} t + 33°)$ **BASE EQUATION**

NOTES

1 The preceding formulas differ from those in the NTSC 1953 specification, which assumed a luminance signal (Y) that included setup. The 1953 luminance signal (Y) consisted of 92.5 IRE of signal excursion and 7.5 IRE of setup. The luminance signal used in this standard, as defined in clause 6, does not include setup and has a 100 IRE signal excursion. The encoding equations above apply a scaling factor of 0.925 (92.5%) to reflect the modern practice of adding setup in the encoder, while yielding output signals identical to the NTSC 1953 specification. For a detailed derivation of the encoding equations, see annex A.

2 The subcarrier phase reference in the equations above is the phase of the color burst +180°.

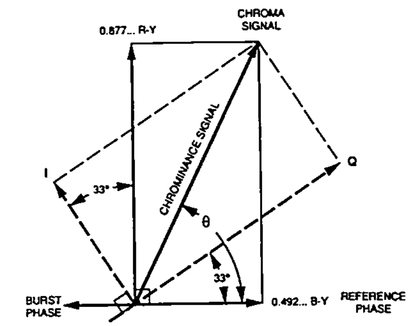


Figure 3 – Chrominance axis and burst phase

11 Frequency specifications

11.1 Color frequency (subcarrier)

$f_{SC} = 5\text{ MHz} \times \frac{63}{88} = 3.579545...\text{ MHz} \pm 10\text{ Hz}$

Recommended stability:

- drift < 1/10 Hz per second;
- jitter < 1 ns (p-p) over one horizontal line.

11.2 Line frequency (horizontal)

$f_H = \frac{2}{455} \times f_{SC} = 15{,}734.265...\text{ Hz}$

227.5 subcarrier cycles per video line

11.3 Field frequency (horizontal)

$f_V = \frac{2}{525} \times f_H = 59.94005994...\text{ Hz}$

525 lines per frame, 2:1 interlace

12 Video output waveform definitions

12.1 Composite video output signal amplitude without the two color-difference subcarrier signals shall be 140 IRE units peak-to-peak (see figure 4).

Table 1 – Video output waveform

Specification	Standard value	Recommended tolerance	Unit
White level	100	± 1	IRE
Black (setup) level	7.5	± 1	IRE
Blanking level	0.0	Reference	IRE
Burst amplitude (p-p)	40	± 1	IRE
Sync level	–40	± 1	IRE

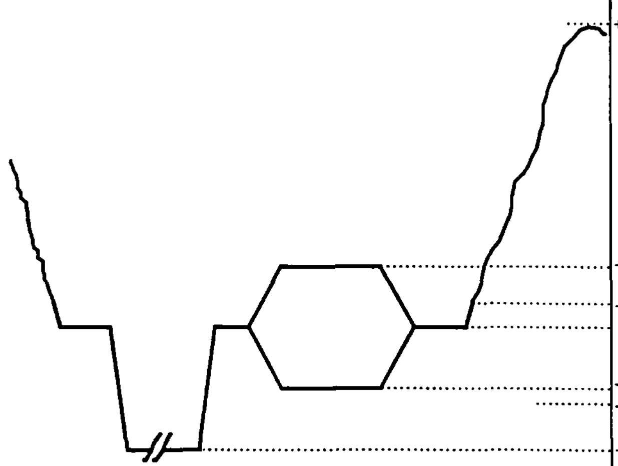


Figure 4 – Composite video signal amplitudes

12.2 Reference level shall be blanking level of 0 IRE units.

12.3 White (luminance), black (setup), blanking, burst, and sync signal levels shall be as given in table 1.

12.4 Maximum composite video output signal amplitude with the two color components (chroma) shall be 171 IRE units peak-to-peak (see figure 4).

13 Blanking intervals and synchronizing signals

The horizontal and vertical blanking intervals shall be the periods during which retrace occurs and in which the horizontal, vertical, and color synchronizing signals shall be located.

13.1 Horizontal blanking and synchronization

Each horizontal line outside the vertical blanking interval shall be divided into an active line period and a horizontal blanking interval. The horizontal blanking interval shall contain the negative-going horizontal sync pulse followed by the color synchronizing burst. The remainder of the horizontal blanking interval shall be at blanking level to properly space the synchronizing signals. Horizontal timing shall be as given in table 2 and figures 5 and 6. The horizontal reference point shall be as shown in figures 5 and 6.

Synchronization pulse and blanking edges should be skew symmetric. Raised cosine shaping is preferred.

13.2 Subcarrier phase to horizontal reference point

The term SC/H (subcarrier to horizontal) shall be used to define the phase relationship between the burst and the horizontal reference point (see figure 8).

Table 2 – Video signal horizontal timing (see figures 5 and 6)

Specification	Measurement points	Value	Recommended tolerance	Unit
Total line period (derived)		63.556		ms
Horizontal blanking rise time	10%–90%	140	± 20	ns
Sync rise time	10%–90%	140	± 20	ns
Burst envelope rise time	10%–90%	300	+ 200 – 100	ns
Horizontal blanking start to horizontal reference point	50%	1.5	± 0.1	µs
Horizontal sync	50%	4.70	± 0.10	µs
Horizontal reference point to burst start [1]	50%	19	Defined by SC/H	cycles
SC/H phase (see 13.2)	See 13.2	0	± 10	degrees
Horizontal reference point to horizontal blanking end	50%	9.20	+ 0.20 – 0.10	µs
Burst [1]	50%	9	± 1	cycles

[1] The start of burst shall be defined by the zero crossing (positive or negtive slope) that precedes the first half cycle of subcarrier that is 50% or greater of the burst amplitude. Its position is nominally 19 cycles of subcarrier from the horizontal reference point as shown in figure 6.

The end of burst shall be defined by the zero crossing (positive or negative slope) that follows the last half cycle of subcarrier that is 50% or greater of the burst amplitude.

Considered separately, the variations in level of each half envelope of the burst shall not exceed 0.5 IRE unit.

The burst signal shall not be present during the nine-line vertical blanking interval of each field, as shown in figure 7.

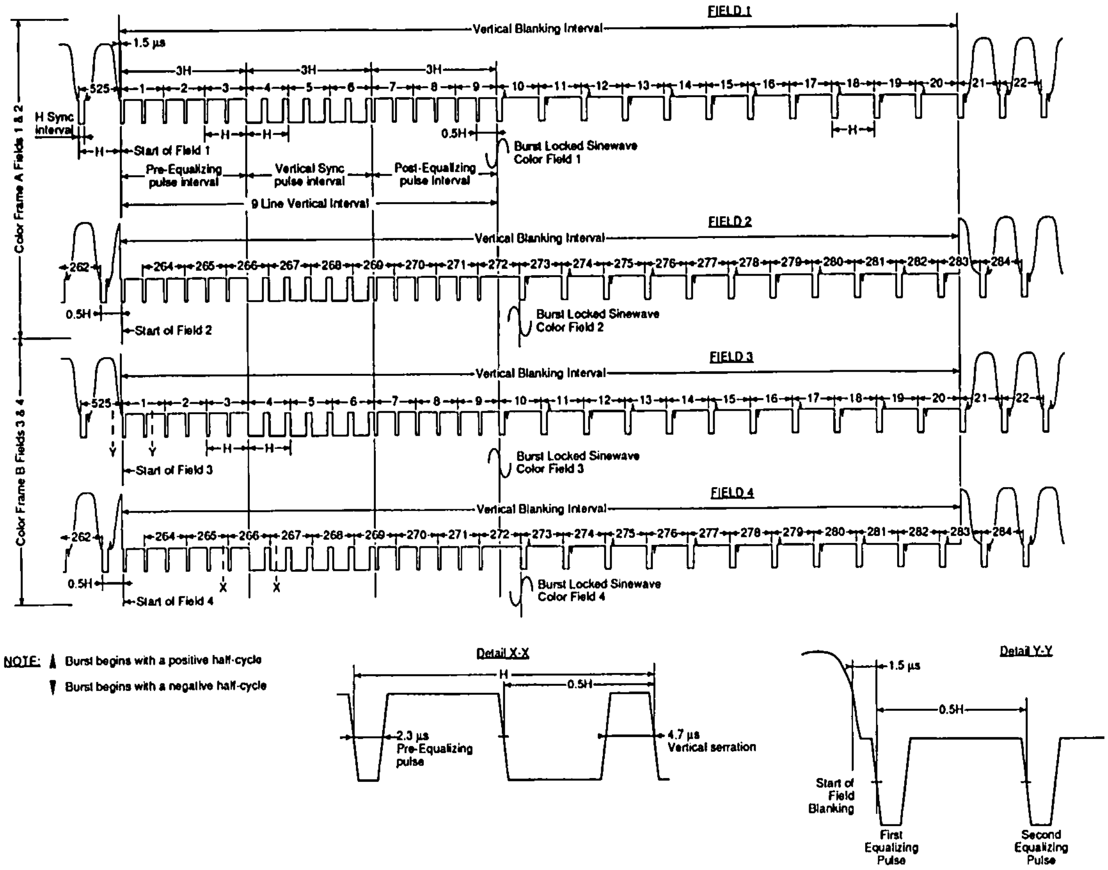


Figure 7 – Vertical (field) blanking interval

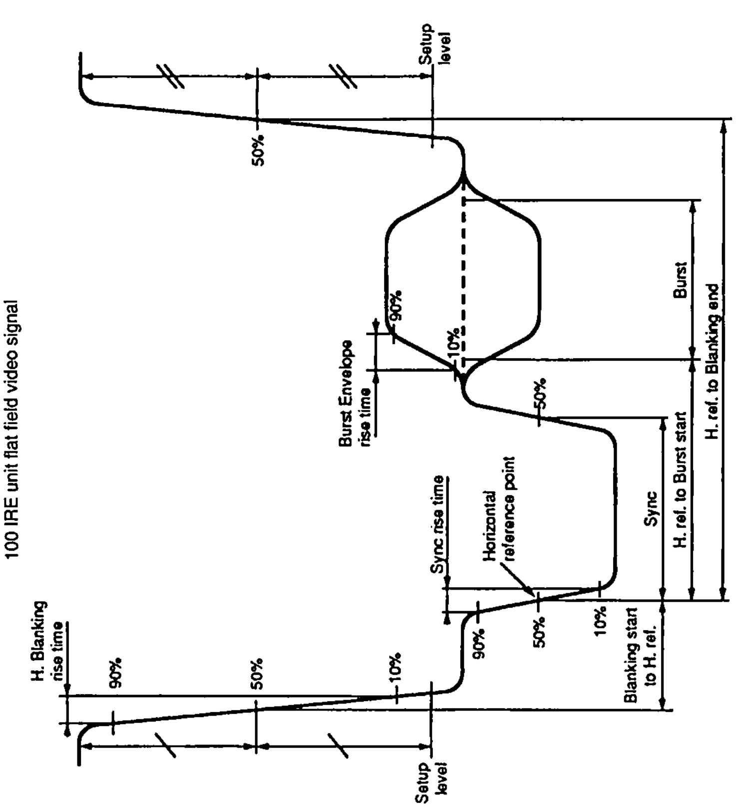


Figure 5 – Horizontal blanking interval

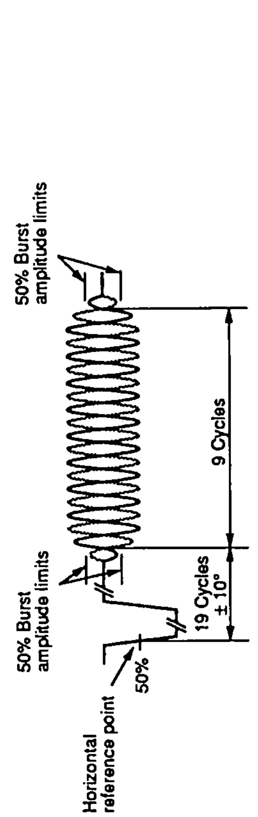


Figure 6 – Color burst

A zero SC/H signal shall be defined as a signal in which the horizontal reference point is coincident with the zero crossing point of a burst-locked sine wave (a continuous sine wave of the same phase as burst). The relationship between the subcarrier and the line frequency causes the direction of this zero crossing to alternate on successive lines. On any given line, the direction of this zero crossing shall be the same as the direction of the first zero crossing of the burst.

Field I shall be defined as that field in which the first zero crossing of burst on line 10 is positive going. The first zero crossing of burst on line 10 of field III shall be negative going. Color frame A shall be used to describe fields I and II. Color frame B shall be used to describe fields III and IV.

The data in table 2 defines the recommended tolerance for both burst position and SC/H.

13.3 Vertical blanking and synchronization

In an interlaced raster, each television frame (one complete scanning of the picture) is divided into two fields. The fields carry every other scan line in succession with the following field carrying the lines not scanned by the previous field.

In a color video signal, four fields (two monochrome frames) are required to complete one color video frame. The color video fields shall be numbered I through IV.

The color-difference subcarrier signals reverse phase, with reference to the horizontal synchronizing signals, every video line. Since this is a 525-line, 2:1 interlace system, four video fields are required to return to the starting phase relationship between the color-difference subcarrier signals and the horizontal and vertical synchronizing signals.

Each field shall be divided into an active picture area and a vertical blanking interval. The vertical blanking interval shall contain the vertical synchronizing information surrounded by blanking periods to properly position the vertical sync and by space allocated for special vertical interval signals.

The vertical synchronizing signal shall consist of a nine-line block divided into three three-line-long segments. The first of these segments shall contain six pre-equalizing pulses. The second segment shall contain the vertical synchronizing pulse with six serrations provided to maintain horizontal synchronization. The third segment shall contain six post-equalizing pulses. There shall be no color synchronizing burst carried during the nine-line block.

The remainder of the vertical blanking interval not used for the nine-line vertical sync block shall be available for special vertical interval signals. When such signals are carried on a particular line, the signal shall be confined to the active period between horizontal blanking intervals. When such signals are not carried on a particular line, the line shall be maintained at blanking level. Color synchronizing burst shall be applied to all lines following the vertical sync block whether they carry special vertical interval signals or only blanking level (see table 3).

14 NTSC encoders

Block diagrams of possible NTSC encoders using Y, B-Y, R-Y and Y, I, Q encoding are illustrated in figures 9a and 9b, respectively.

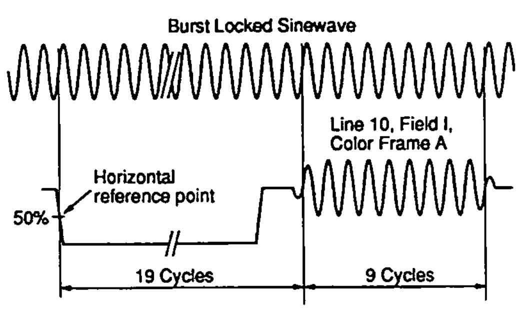


Figure 8 – Subcarrier phase to horizontal reference point

Table 3 – Video signal vertical timing (see figure 7)

Specification	Measurement point	Value	Recommended tolerance	Unit
Field period (derived)		16.6833		ms
Frame period (derived)		33.3667		ms
Vertical blanking start before first equalizing pulse	50%	1.50	± 0.10	µs
Vertical blanking (63.556...µs × 20 lines + 1.5 µs = 1272.62...µs (...approximate values) [see notes]		20 lines plus 1.5 µs [1]	± 0.1	lines µs
Pre-equalizing duration		3		lines
Pre-equalizing pulse width	50%	2.30	± 0.10	µs
Vertical sync duration		3		lines
Vertical serration pulse width	50%	4.70	± 0.10	µs
Post-equalizing duration		3		lines
Post-equalizing pulse width	50%	2.30	± 0.10	µs

[1] Some component equipment may not blank lines 20 and 282, resulting in 19-line (+ 1.5 µs) vertical blanking if signals from such equipment are directly encoded into NTSC.

NOTES

1 All pulse rise and fall times, unless otherwise specified, shall be 140 ns ± 20 ns measured from 10% to 90% amplitude points. All pulse widths shall be measured at 50% amplitude points, unless otherwise specified.

2 At some points in the signal, vertical and horizontal blanking overlap. Figure 7 shows the position of vertical blanking with reference to the synchronizing waveforms.

3 Data signals often found on line 21 (closed captioning for the hearing impaired) are part of the program material. These signals should not be removed (blanked), except when processing (editing, special effects, or time compression) will destroy their usability.

15 Analog interfaces

15.1 Cable

For analog interconnection of equipment using this standard, the interface signal shall be carried on an unbalanced coaxial cable.

15.2 Impedances

The source impedance shall be 75 Ω resistive.
The terminating impedance shall be 75 Ω resistive.
The cable impedance shall be 75 Ω nominal.

15.3 Connector

The preferred connector shall be a 75 Ω BNC type which mates in a nondestructive manner with the 50 Ω connector specified in IEC 169-8.

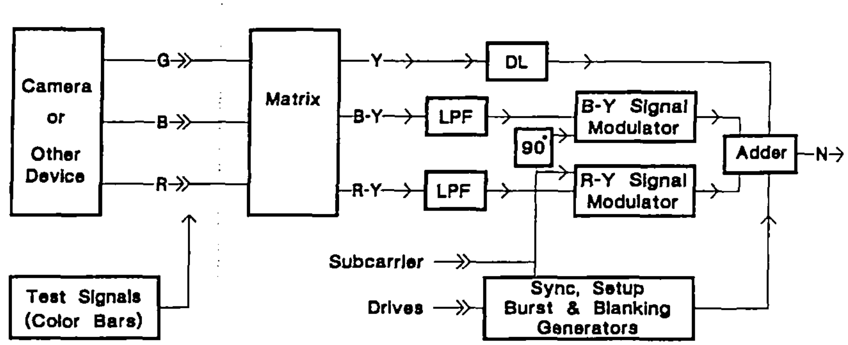
NOTE – The preferred connector listed above is described in Draft International Standard IEC 169-8 Amendment A.

15.4 Signal levels

The peak-to-peak amplitude of the luminance plus sync, measured from sync tip to white level, shall be 1 V. Excursions of color subcarrier may exceed this value.

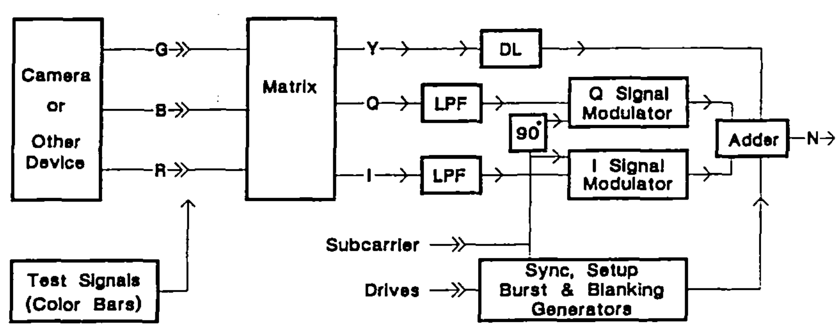
Clause 12 defines the amplitudes of the component parts of the signal and the permissible chroma excursions.

For signals crossing the interface, 140 IRE shall nominally equal 1 V. In dc-coupled systems, blanking level shall be nominally 0 V.



LPF = low pass filter
DL = delay line

Figure 9a – Block diagram of possible NTSC encoder using Y, B-Y, R-Y encoding



LPF = low pass filter
DL = *delay line*

Figure 9b – Block diagram of possible NTSC encoder using Y, I, Q encoding

Annex A (informative)
Derivation of SMPTE NTSC equations

This standard reflects modern *practice in the generation* of NTSC signals and, in some respects, differs from the original NTSC specification published in 1953. This annex addresses the differences and expains the relationship of the modern version to the original specification. The principal differences are in the areas of precision, handling of setup, and equiband color encoding.

A.1 Precision

The original definition of NTSC was based upon the luminance matrix of:

$$Y = 0.587G + 0.114B + 0.299R \quad (1)$$

and the corresponding expressions for B-Y and R-Y:

$$B\text{-}Y = -0.587G + 0.886B - 0.299R \quad (2)$$

$$R\text{-}Y = -0.587G - 0.114B + 0.701R \quad (3)$$

However, matrices of this precision were not generally *realizable in the early 1950s*, and most calculations were performed on slide rules. Accordingly, the NTSC specification was published using the lower precision version of the luminance matrix:

$$Y = 0.59G + 0.11B + 0.30R$$

Derived formulas were generally published to two-digit precision. The work underlying the published NTSC specification, however, was performed to a higher precision, and (with one small exception noted in A.3) this standard represents a recreation of the original work of NTSC.

This standard specifies the full precision version of the luminance matrix. Consequently, to ensure consistent results, it is also necessary to recalculate other NTSC equations to an appropriately higher precision. Coefficients used in this standard are quoted to a precision sufficient to ensure accuracy when color bar values are calculated to a precision of *0.1 IRE*.

A.2 Setup

In 1953, it was normal practice for GBR component signals to be distributed with a setup of 7.5 IRE, and the original NTSC equations assumed this form of input signal to the encoder. Modern practice is for GBR component signals to be distributed without setup, and for setup to be added in the NTSC encoder. This standard assumes GBR signals without setup, and the equations are modified accordingly.

Both documents equate the GBR input signals to 100 IRE. For this standard, this represents 100 IRE between black *and full amplitude for each component. In the original spec*ification, this represented 7.5 IRE of setup plus a signal excursion of 92.5 IRE between black and full amplitude for each component. This standard, therefore, contains values for Y, B-Y, and R-Y which are greater than those derived in the original specification. This discrepancy is eliminated in the SMPTE encoding equations by multiplying the values of Y, B-Y, and R-Y by 0.925, and by adding 7.5 IRE setup to *the luminance signal*. Because the luminance matrix is linear, the SMPTE equations yield the same signal as the original 1953 equations.

For example, consider the case where the blue input is at maximum, and red and green are each at *black level. For* the 1953 equations:

G = 7.5; B = 100; R = 7.5

from (1), (2), and (3):

$$\begin{aligned} Y &= 0.587\,(7.5) + 0.114\,(100) + 0.299\,(7.5) \\ &= 0.114\,(92.5) + (0.587 + 0.114 + 0.299)\,(7.5) \\ &= 10.545 + 7.5 \\ &= 18.045 \end{aligned}$$

$$\begin{aligned} B\text{-}Y &= -0.587\,(7.5) + 0.886\,(100) - 0.299\,(7.5) \\ &= 81.955 \end{aligned}$$

$$\begin{aligned} R\text{-}Y &= -0.587\,(7.5) + 0.114\,(100) + 0.701\,(7.5) \\ &= -10.545 \end{aligned}$$

For the SMPTE equations:

G = 0; B = 100; R = 0

$$\begin{aligned} Y &= 0.587\,(0) + 0.114\,(100) + 0.299\,(0) \\ &= 11.4 \end{aligned}$$

$$0.925Y + 7.5\ (\text{setup}) = 10.545 + 7.5 = 18.045$$

$$B\text{-}Y = -0.587\,(0) + 0.886\,(100) - 0.299\,(0) = 88.6$$

$$0.925\,(B\text{-}Y) = 81.955$$

$$R\text{-}Y = -0.587\,(0) - 0.114\,(100) + 0.701\,(0) = -11.4$$

$$0.925\,(R\text{-}Y) = -10.545$$

A.3 Reduction of (B-Y) and (R-Y)

If the base values of B-Y and R-Y as calculated above were used *to modulate the color subcarrier, the resulting compos*ite signal would have subcarrier excursions from approximately −66 IRE to +173 IRE. This signal would not have been compatible with transmitters and receivers existing at the time. It was determined experimentally that subcarrier excursions of 33.3% of the luminance signal excursion could be permitted above white and below black. This equated to a maximum positive excursion of 100 + (0.333 × 92.5) = 130.8025 IRE and a maximum negative excursion of 7.5 − (0.333 × 92.5) = 23.3025 IRE. This result was achieved by applying reduction factors to B-Y and R-Y. To the accuracy of the 1953 published equations, these factors resulted in maximum signal excursions for the yellow and cyan bars of a 75% color bar signal being 100 IRE, and this has become *the established reference for aligning NTSC encoders*. For the higher precision equations of this standard, this reference has been used in calculating the reduction coefficients.

The results are equivalent for calculations to an accuracy of 0.1 IRE: SMPTE equations give a maximum signal amplitude of 130.8333 IRE for 100% bars in place of the original 130.8025 IRE.

(It should be noted that there is an apparent error in the 1953 calculations of these reduction factors. Although the calculations were performed to a high degree of precision, a luminance matrix coefficient of 0.115 was used for blue instead of the correct 0.114. This resulted in values of 0.493 and 0.877 for B-Y and R-Y, respectively. These were normally approximated to 1/2.03 and 1/1.14, respectively. The error was not significant in the equations published to an accuracy of two significant figures, but it is significant for the higher precision equations used in this standard. The values quoted below and used in this standard are derived from the correct luminance matrix.) (Lower case is used to distinguish the reduced values:

$$b\text{-}y = 0.492111...(B\text{-}Y); \quad (4)$$

$$r\text{-}y = 0.877283...(R\text{-}Y).) \quad (5)$$

A.4 Equiband encoding

This standard reflects the modern practice of modulating the color subcarrier with equal bandwidth b-y and r-y signals. In the original NTSC specification, two different bandwidths were used for the signals modulating the subcarrier. The b-y and r-y signals may be considered as orthogonal components of a vector. To achieve the desired axes for nonequiband encoding, an alternative set of orthogonal components of the same vector are calculated; these components are rotated 33° counterclockwise with respect to b-y and r-y, and are known as I and Q. I and Q are defined in terms of the reduced b-y and r-y as:

$$I = -(b\text{-}y)\sin 33° + (r\text{-}y)\cos 33°$$

$$Q = (b\text{-}y)\cos 33° + (r\text{-}y)\sin 33°$$

or, in terms of the unreduced values B-Y and R-Y, as:

$$I = -0.26802288...(B\text{-}Y) + 0.73575162...(R\text{-}Y) \quad (6)$$

$$Q = 0.41271905...(B\text{-}Y) + 0.47780269...(R\text{-}Y) \quad (7)$$

or, in terms of GBR, as:

$$I = -0.274557...G - 0.321344...B + 0.595901...R \quad (8)$$

$$Q = -0.522736...G + 0.311200...B + 0.211537...R \quad (9)$$

A.5 Composite signal

If equiband encoding is employed, the composite signal may be derived from either B-Y and R-Y, or from I and Q. If nonequiband encoding is employed, the composite signal must be derived from I and Q; however, the B-Y and R-Y equations are valid for low chroma frequencies.

As discussed above, these equations assume GBR inputs of 100 IRE without setup.

$$N = 0.925(Y) + 7.5 + 0.925(b\text{-}y)\sin(2\pi f_{sc}t) + 0.925(r\text{-}y)\cos(2\pi f_{sc}t) \quad (10)$$

or:

$$N = 0.925(Y) + 7.5 + 0.455203...(B\text{-}Y)\sin(2\pi f_{sc}t) + 0.811487...(R\text{-}Y)\cos(2\pi f_{sc}t) \quad (11)$$

or:

$$N = 0.925(Y) + 7.5 + 0.925(Q)\sin(2\pi f_{sc}t + 33°) + 0.925(I)\cos(2\pi f_{sc}t + 33°) \quad (12)$$

A.6 Color bar signals

The color bar values resulting from the SMPTE NTSC equations are shown in tables A.1 – A.4. Values are shown for 100% and 75% bars, and are shown to four-decimal place accuracy, and rounded to one decimal place.

Table A.1 – 100/7.5/100/7.5 color bars (calculated to 10^{-4} IRE)

Bar	Luminance (IRE)	Chroma level (IRE)	Minimum chroma excursion (IRE)	Maximum chroma excursion (IRE)	Phase (degrees)
White	100.0000	0.0000			
Yellow	89.4550	82.7567	48.0767	130.8333	167.0812
Cyan	72.3425	116.9817	13.8517	130.8333	283.4558
Green	61.7972	109.2338	7.1806	116.4144	240.7098
Magenta	45.7025	109.2338	– 8.9144	100.3194	60.7098
Red	35.1575	116.9817	–23.3333	93.6483	103.4558
Blue	18.0450	82.7567	–23.3333	59.4233	347.0812
Black	7.5000	0.0000			

Table A.2 – 100/7.5/100/7.5 color bars (calculated to 10^{-1} IRE)

Bar	Luminance (IRE)	Chroma level (IRE)	Minimum chroma excursion (IRE)	Maximum chroma excursion (IRE)	Phase (degrees)
White	100.0	0.0			
Yellow	89.5	82.8	48.1	130.8	167.1
Cyan	72.3	117.0	13.9	130.8	283.5
Green	61.8	109.2	7.2	116.4	240.7
Magenta	45.7	109.2	– 8.9	100.3	60.7
Red	35.2	117.0	– 23.3	93.6	103.5
Blue	18.0	82.8	– 23.3	59.4	347.1
Black	7.5	0.0			

Table A.3 – 75/7.5/75/7.5 color bars (calculated to 10^{-4} IRE)

Bar	Luminance (IRE)	Chroma level (IRE)	Minimum chroma excursion (IRE)	Maximum chroma excursion (IRE)	Phase (degrees)
White	76.8750	0.0000			
Yellow	68.9663	62.0675	37.9325	100.0000	167.0812
Cyan	56.1319	87.7363	12.2638	100.0000	283.4558
Green	48.2231	81.9253	7.2605	89.1858	240.7098
Magenta	36.1519	81.9253	– 4.8108	77.1145	60.7098
Red	28.2431	87.7363	–15.6250	72.1113	103.4558
Blue	15.4088	62.0675	–15.6250	46.4425	347.0812
Black	7.5000	0.0000			

Table A.4 – 75/7.5/75/7.5 color bars (calculated to 10^{-1} IRE)

Bar	Luminance (IRE)	Chroma level (IRE)	Minimum chroma excursion (IRE)	Maximum chroma excursion (IRE)	Phase (degrees)
White	76.9	0.0			
Yellow	69.0	62.1	37.9	100.0	167.1
Cyan	56.1	87.7	12.3	100.0	283.5
Green	48.2	81.9	7.3	89.2	240.7
Magenta	36.2	81.9	– 4.8	77.1	60.7
Red	28.2	87.7	–15.6	72.1	130.5
Blue	15.4	62.1	–15.6	46.4	347.1
Black	7.5	0.0			

Annex B (informative)
IRE units

IRE units are a linear scale for measuring the relative amplitudes of the components of a television signal with the zero reference at blanking level.

The IRE scale is marked from +120 to −50. The reference white level corresponds to (plus) 100 units. Minus 40 IRE units corresponds to the level of the synchronizing pulses in the composite video signal (see figure B.1).

Since IRE units comprise a relative scale (they do not have a fixed voltage value), an oscilloscope may be calibrated to each particular video signal application. Nevertheless, important information can be communicated about the video signal levels.

Composite video systems are normally operated with 140 IRE units = 1.0 V p-p, while component video systems are normally operated with 100 IRE units = 0.7 V p-p.

Information on IRE units may be found in Federal Communications Commission ¶73.681.

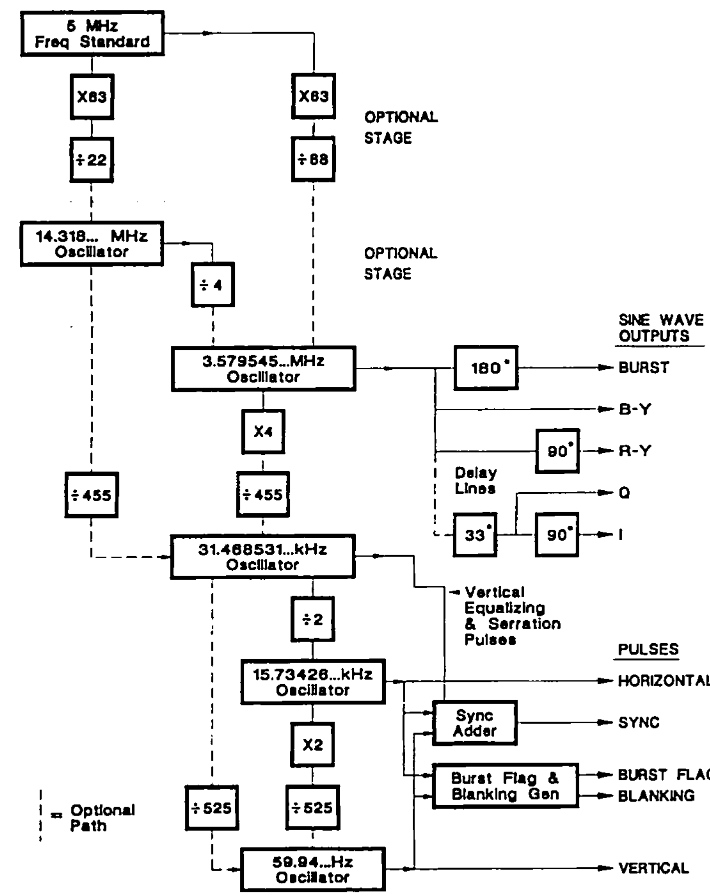
	IRE units	Percent of peak carrier amplitude	Composite video 1 V P-P	G–B–R video 0.7 V P-P
	120	0%		
	110	6.75%		
Reference white	100	12.5%	+0.714	+0.700
	80			
	60			
	40			
	20			
Blanking	0	75%	0.0	0.0
	−20			
Sync	−40	100%	−0.286	Sync not used with all GBR equipment. When used, sync is −0.300 V (−42.8 IRE)
	−50			

NOTE – Carrier amplitude is of the transmitter radio frequency carrier.

Figure B.1 – IRE scale

Annex C (informative)
Synchronizing signal timing

Figure C.1 represents the frequency relationship of the synchronizing signals and the phase relationship of the burst and the color-difference (sub)carriers. It is not meant to represent actual equipment.



NOTE – The sine wave carrier delay lines are normally part of the encoder.

Figure C.1 – Frequency and phase relationships