SMPTE STANDARD

ANSI/SMPTE 251M-1996
Revision of
ANSI/SMPTE 251M-1991

for Television Analog Recording — 1/2-in Type M-2 — Electrical Parameters of Video, Audio, Time and Control Code and Tracking Control

1 Scope

1.1 This standard specifies the recording system for the video, audio, time and control code, and tracking-control signals for 1/2-in type M-2 helical-scan video tape recorders operating with video signals having a typical scanning structure of 525 lines, 59.94 fields/s, 2:1 interlace, and utilizing the video cassettes specified in ANSI/SMPTE 250M.

1.2 The audio frequency modulation (AFM) recording shown in this standard is optional. Pulse code modulation (PCM) audio recording mode with limited interchangeability, as defined in ANSI/SMPTE 249M, is a secondary audio recording mode which is specified in ANSI/SMPTE 252M.

1.3 Where nominal values are given without tolerances, the interchange performance will be limited by implementation accuracy.

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.

ANSI/SMPTE 12M-1995, Television, Audio and Film — Time and Control Code

ANSI/SMPTE 249M-1996, Television Analog Recording — 1/2-in Type M-2 — Records

ANSI/SMPTE 250M-1996, Television Analog Recording — 1/2-in Type M-2 — Tapes and Cassettes

ANSI/SMPTE 252M-1996, Television Analog Recording — 1/2-in Type M-2 — Pulse Code Modulation Audio

IEC 268-12 (1987), Part 12: Application of Connectors for Broadcast and Similar Use

3 Video signal recording

Type M-2 video tape recorders shall record component video signals and are intended to operate interchangeably in an NTSC environment. This component video recording system shall provide independent signal channels for the luminance and chrominance signals. These component signals shall be recorded on two independent tracks on the video tape as frequency modulated signals. The two separate tracks shall be designated as the Y track for the luminance signals and the C track for the chrominance signals. The chrominance signals, in the form of R-Y and B-Y color-difference signals, shall be recorded in the form of a time compressed and time division multiplexed signal on the C track. (The AFM audio signal recording shall be recorded in the form of a frequency multiplexed signal together with the FM color-difference signal on the C track.) The PCM audio signal shall be recorded using the luminance and chrominance heads on the luminance and chrominance tracks.

3.1 Luminance channel

3.1.1 Signal processing

A signal processing system, as specified in this standard, shall contain the following elements in the order of signal flow:

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1) Means for adding a timing burst signal to the luminance signal

2) Means for adding vertical interval subcarrier when appropriate

3) A luminance nonlinear preemphasis circuit

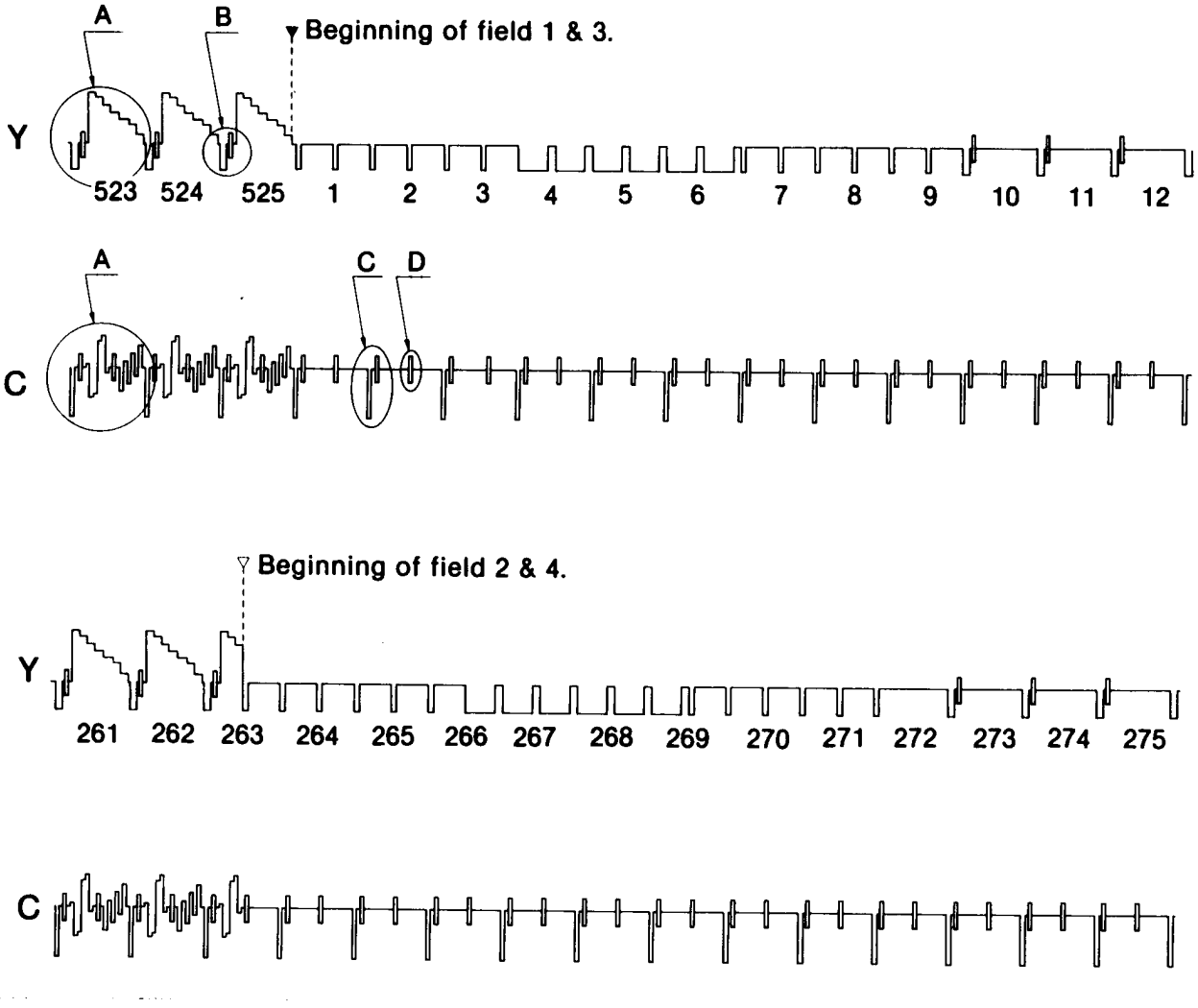
4) A luminance preemphasis network

5) Means for clipping the preemphasized luminance signal to the amplitude of the modulating frequencies

6) A linear frequency modulator having constant deviation with respect to the amplitude of the modulating frequencies

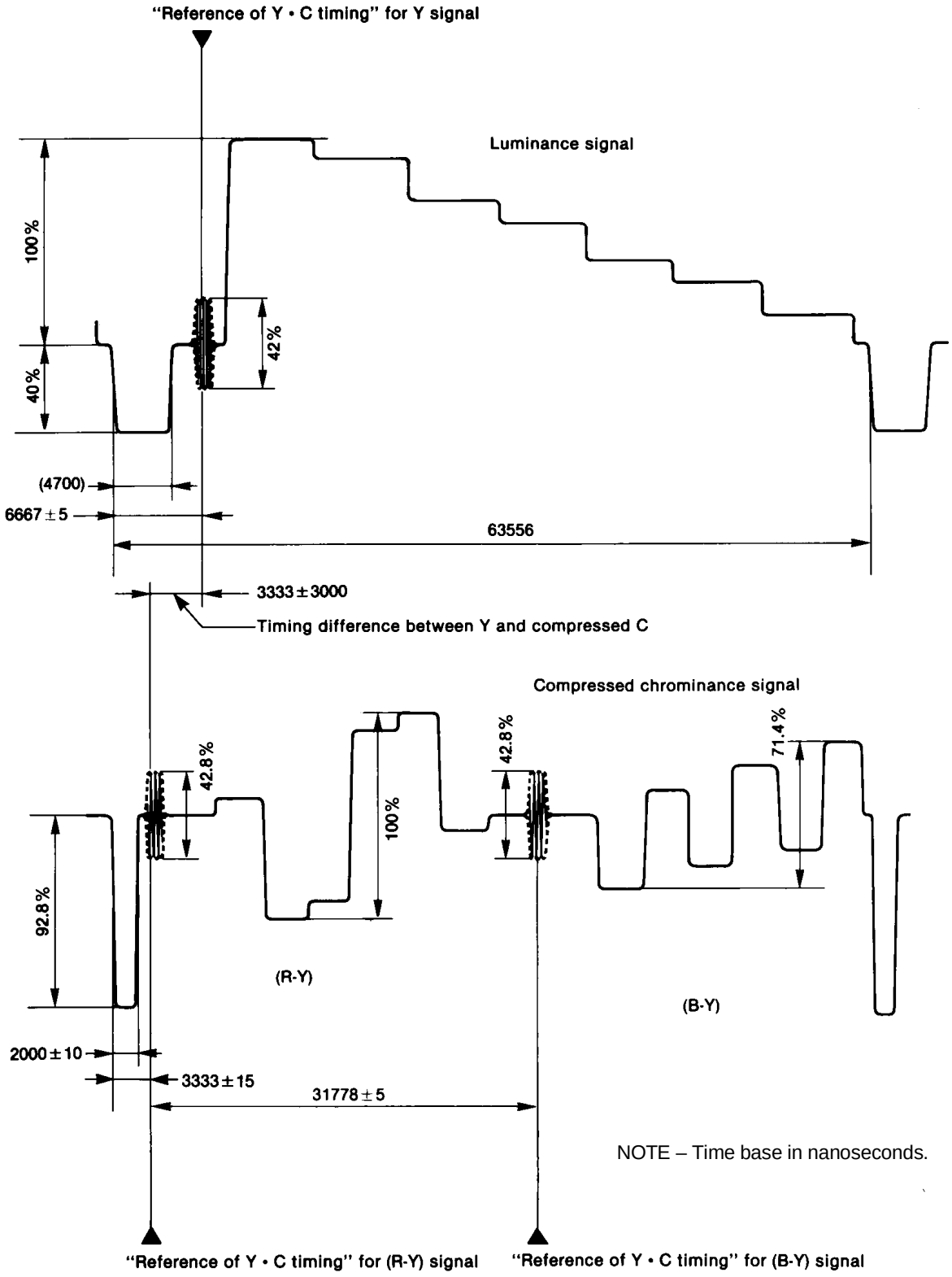
7) A circuit for mixing the PCM audio CH5 signal to the frequency modulated luminance signal

8) The recording current amplifier for the Y track video heads



NOTE – No burst signals are mixed during the 9H period of Y vertical blanking.

Figure 1 — Waveform of burst mixed luminance and burst and sync added chrominance signals



NOTE – Time base in nanoseconds.

Figure 2 – Luminance signal and compressed chrominance signals for 100/7.5/77/7.5 color bars (Details of figure 1A)

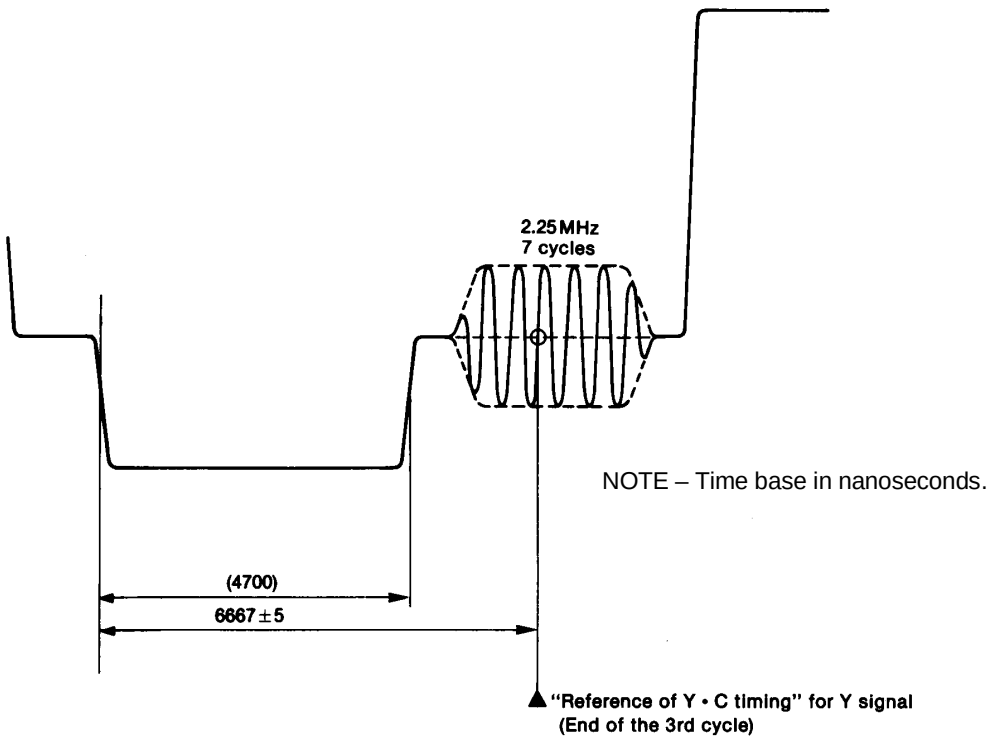


Figure 3 – Details of figure 1B

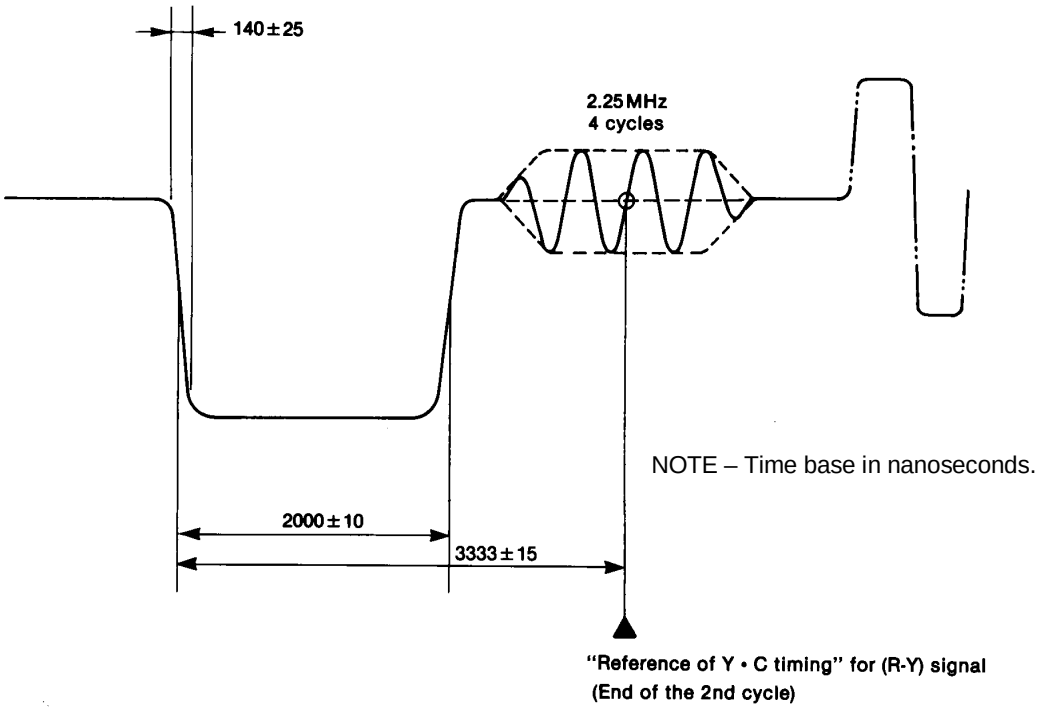
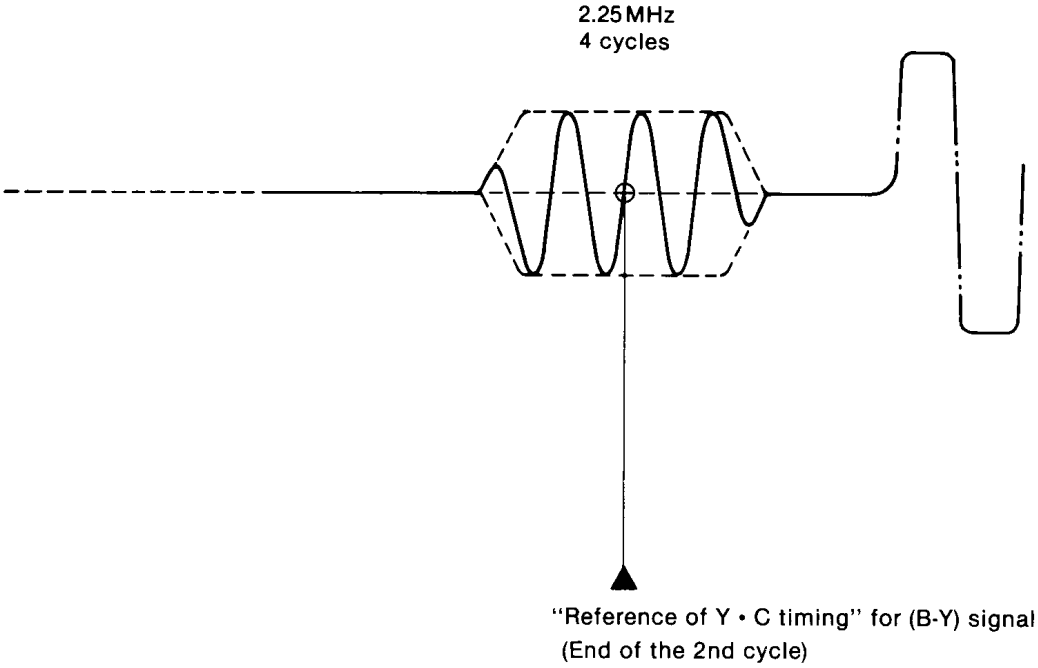
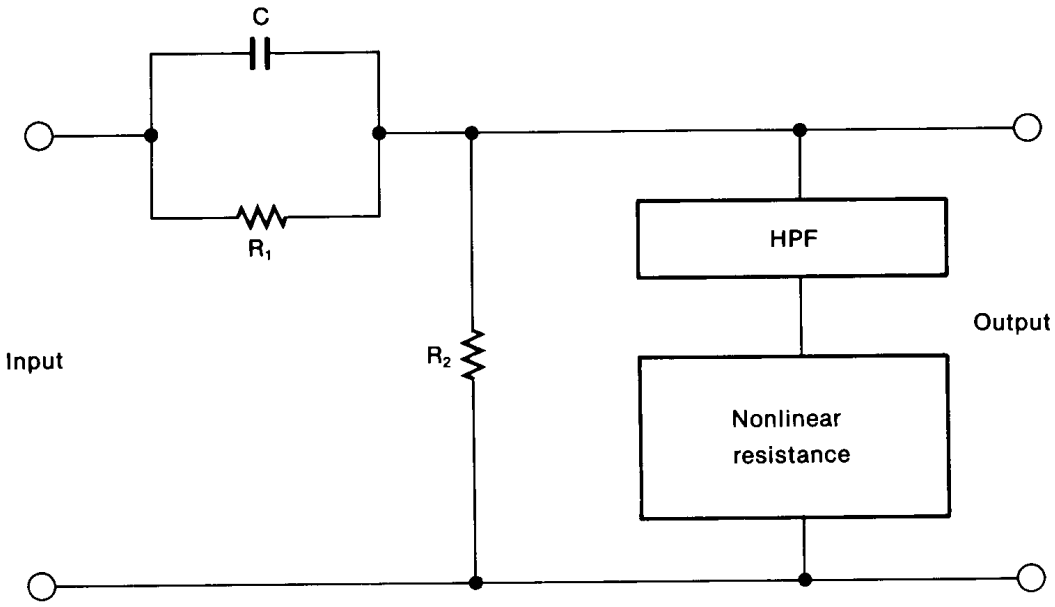


Figure 4 – Details of figure 1C



NOTE – Time base in nanoseconds.

Figure 5 – Details of figure 1D



NOTE – The input signals are fed from the zero impedance source, and the output signals are applied to the infinite impedance load.

Figure 6 – Luminance nonlinear preemphasis circuit

3.1.2 Burst signal addition

The resultant waveforms when the burst signal is added to the luminance signal shall be as shown in figures 1 to 3. Burst frequency (2.25 MHz) is locked to horizontal line frequency.

3.1.3 Luminance nonlinear preemphasis

The typical frequency characteristics of the nonlinear preemphasis circuit output signal are as shown in table 1.

Table 1 – Luminance nonlinear preemphasis circuit output signal

Frequency (MHz)	Relative input level (dB)		
	0	–10	–20
0.01	0	0	0
0.1	–0.1	–0.2	0.1
0.2	–0.4	0.1	0.4
0.5	–0.7	1.1	1.7
1.0	0	3.0	4.0
2.0	0.9	4.8	6.1
3.0	1.3	5.5	6.8
5.0	1.7	6.1	7.2

NOTES
1 A block diagram of a nonlinear preemphasis circuit is shown in figure 6.
2 Values are in decibels.

3.1.4 Luminance preemphasis

The network and circuit parameters shall be as shown in figure 7.

3.1.5 Amplitude clipping

For an input signal where blanking is at 0% and peak white at 100%, any positive or negative amplitude excursion exceeding the limits shown below shall be clipped:

– Positive excursion limit: + 338% (nominal)
+ 348% (maximum)

– Negative excursion limit: – 190% (nominal)
– 200% (maximum)

3.1.6 FM carrier frequency

Carrier frequencies corresponding to the reference video level shall be as follows:

– 100% white: 7.70 MHz (nominal)
– 50% level: 6.95 MHz (nominal)
– Blanking: 6.20 MHz ± 0.05 MHz
– Sync tip: 5.60 MHz (nominal)
– Video deviation: 1.50 MHz ± 0.05 MHz

3.1.7 Y track record head current

3.1.7.1 The amplitude of the record current for the Y track shall be such that the maximum level of remanent flux on the tape is produced when recording a Y signal with 50% average picture level.

3.1.7.2 The amplitude of the Y track record current shall decrease with increasing frequency according to a straight line in the range of 2 MHz to 10 MHz contained within limit lines as shown in figure 11.

3.2 Chrominance channel

3.2.1 Signal processing

A signal processing system, as specified by this standard, shall contain the following elements in the order of the signal flow:

1) Means for adding a horizontal sync pulse and the timing burst signals to the chrominance signal

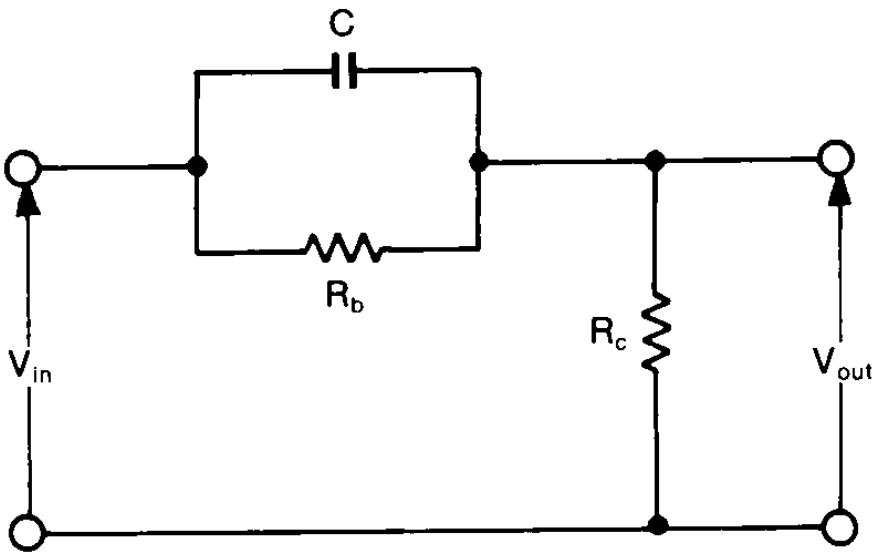
2) Means to individually adjust the R-Y and B-Y levels in the ratio specified

3) Means to perform the time compression and time-division multiplexing of the R-Y and B-Y color-difference signals

4) A chrominance nonlinear preemphasis circuit

5) A chrominance preemphasis network

6) Means for clipping the preemphasized chrominance signal



$T_Y = CR_b = 1.34\ \mu s$

$X_Y = R_b / R_c = 2.5$

$$\frac{V_{out}}{V_{in}} = \frac{1 + j\,\omega\,T_Y}{1 + X_Y + j\omega\,T_Y}$$

NOTE — Input source impedance = 0; output load impedance = ∞.

Figure 7 – Luminance preemphasis network

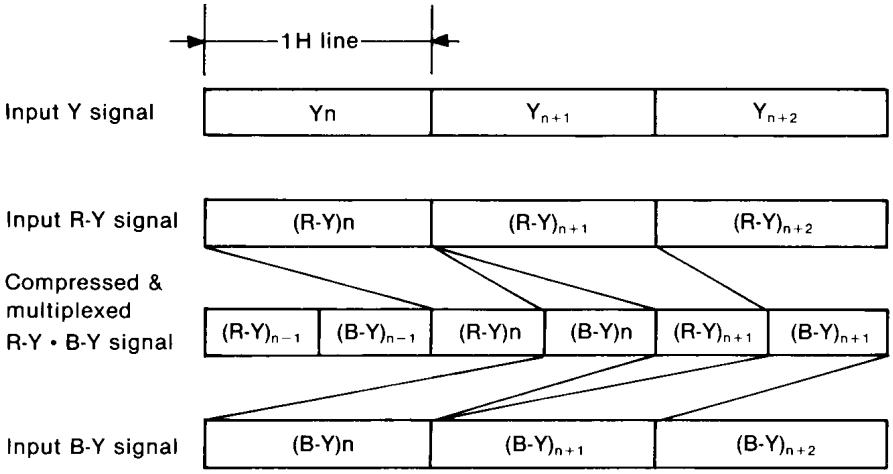


Figure 8 – Time-base compression and multiplexing

7) A linear frequency modulator having constant deviation with respect to the amplitude of the modulating frequencies

8) A high-pass filter to reduce the amplitude of low-frequency components to allow for the mixing of the optional AFM signals

9) A circuit to mix the optional AFM signals with the chrominance signal

10) A circuit for mixing the PCM audio CH6 signal to the frequency-modulated chrominance signal

11) A recording current amplifier for the C track video heads

3.2.2 Addition of burst and sync signals

Resultant signal waveforms shall be as shown in figures 1, 2, 4, and 5.

3.2.3 Time compression and multiplexing

The time compression factor shall be one half. The time compressed R-Y and B-Y signals shall be multiplexed alternately as shown in figure 8. The compressed and multiplexed R-Y and B-Y signals shall be delayed by one horizontal line with respect to the luminance signal.

3.2.4 Chrominance nonlinear preemphasis

A block diagram of a nonlinear preemphasis circuit is shown in figure 9. The typical frequency characteristics of this nonlinear preemphasis circuit output signal are as shown in table 2.

Table 2 – Chrominance nonlinear preemphasis circuit output signal

Frequency (MHz)	Relative input level (dB)		
	0	–10	–20
0.01	0	0	0
0.1	–0.3	–0.3	–0.1
0.2	–0.5	–0.1	0.2
0.5	–0.2	1.1	1.6
1.0	0.6	3.0	3.9
2.0	1.5	4.8	6.0
3.0	1.9	5.5	6.6

NOTE — Values are in decibels.

3.2.5 Chrominance preemphasis

The network and circuit parameters shall be as shown in figure 10.

3.2.6 Amplitude clipping

For an input signal of “100/7.5/77/7.5" color bars (100% level), any positive or negative amplitude excursion exceeding the limits shown below shall be clipped:

– Positive excursion limit: + 147.7% (nominal)
+ 157.7% (maximum)

– Negative excursion limit: – 180.2% (nominal)
– 190.2% (maximum)

3.2.7 FM carrier frequency

Carrier frequencies corresponding to reference video levels shall be as shown in table 3.

Table 3 – Carrier frequencies and reference video levels

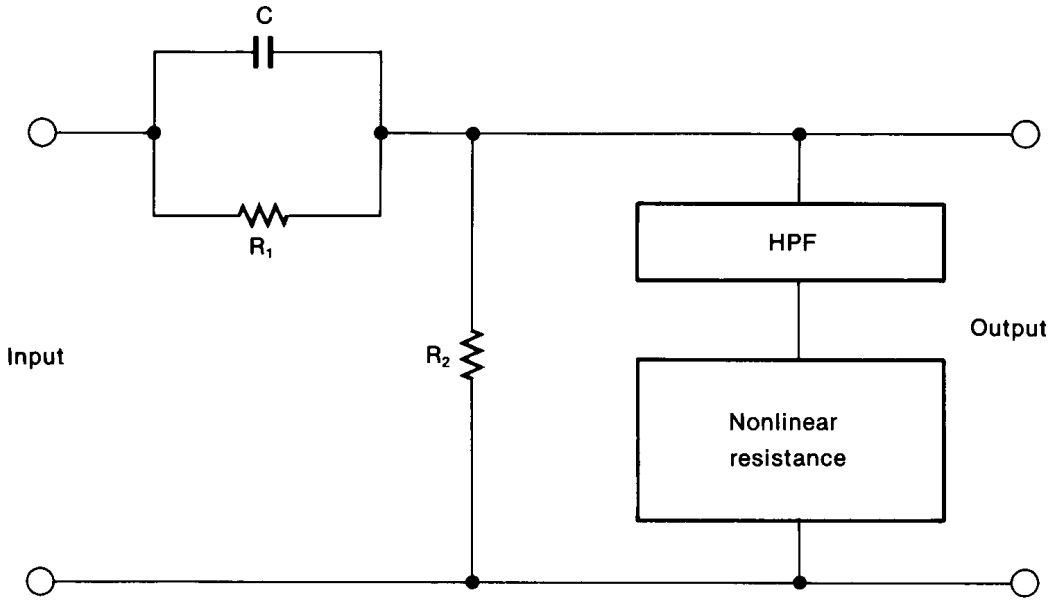
	100/7.5/77/7.5 color bar signal	
	R–Y	B–Y
Peak of positive excursion	6.20	6.00
Peak of negative excursion	4.80	5.00
Blanking	5.50	5.50
Sync-tip	4.20	—
Maximum p-p deviation	1.40	1.00
Deviation p-p tolerance	±0.02	±0.015
Blanking carrier tolerance	±0.05	±0.05

NOTE — Frequency in megahertz.

3.2.8 C track record head current

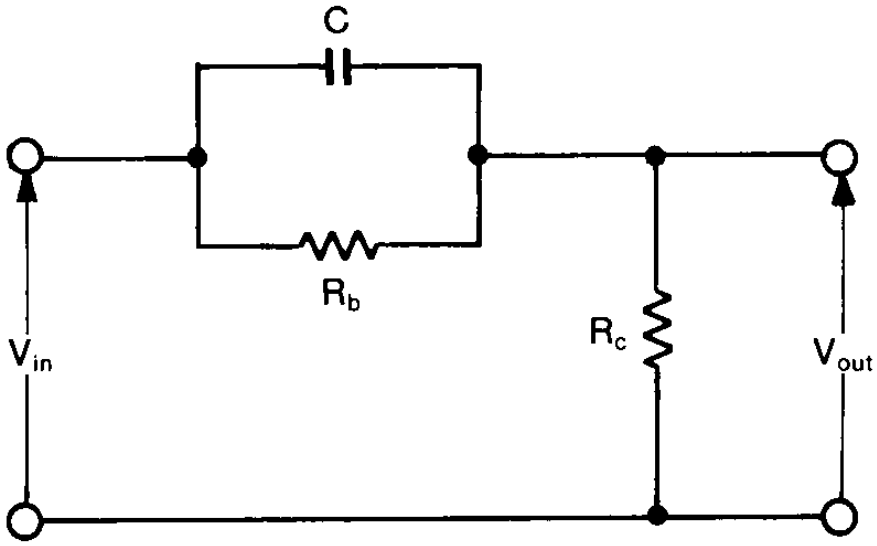
3.2.8.1 The amplitude of the record current for the C track shall be such that the maximum level of remanent flux on the tape is produced when recording the chrominance blanking level.

3.2.8.2 The amplitude of the C track record current shall decrease with increasing frequency according to a straight line in the range of 2 MHz to 10 MHz contained within limit lines as shown in figure 11.



NOTE — The input signals are fed from the zero impedance source and the output signals are applied to the infinite impedance load.

Figure 9 – Chrominance nonlinear preemphasis circuit



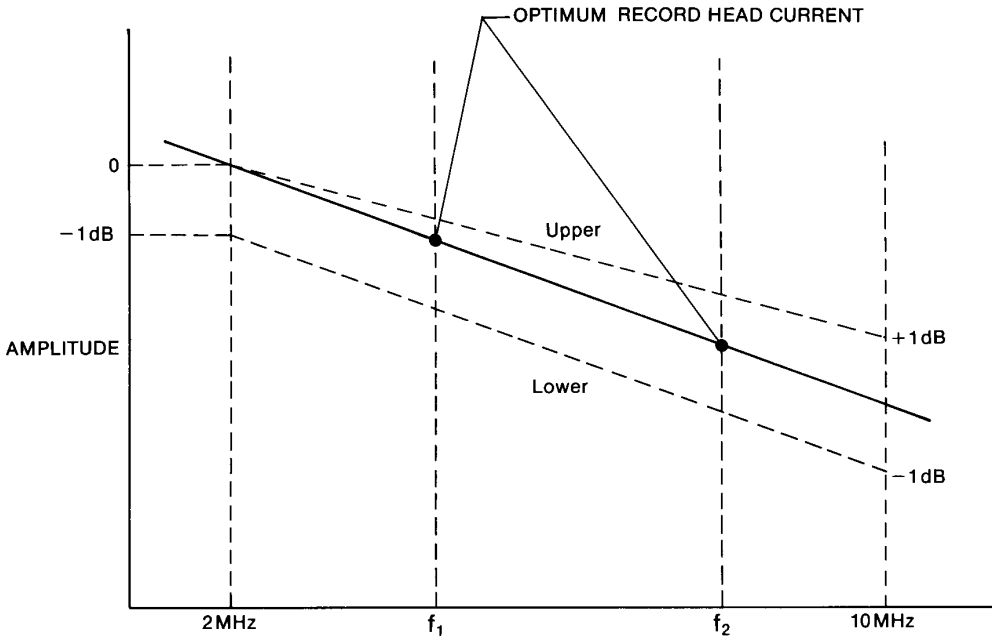
$T_c = CR_b = 0.60\ \mu s$

$X_c = R_b / R_c = 2.5$

$$\frac{V_{out}}{V_{in}} = \frac{1 + j\,\omega\,T_c}{1 + X_c + j\omega\,T_c}$$

NOTE – Input source impedance = 0; output load impedance = ∞.

Figure 10 – Chrominance preemphasis network



	Luminance channel	Chrominance channel
f_1	Blanking frequency	Minimum chroma frequency
f_2	100% white frequency	Maximum chroma frequency

Figure 11 — Record equalization

3.2.9 The frequency characteristics of the recording current shall be as shown in table 4.

Table 4 – Recording current characteristics

Frequency (MHz)	Relative level (dB)
0.4	Less than –30
0.7	Less than –30
2.0	0

3.3 Y-C timing

3.3.1 Reference of Y-C timing

The timing difference between the Y signal, the R-Y, and the B-Y signal before time compression shall not be more than 5 ns as shown in figure 12.

3.3.2 Tolerance of compressed Y-C timing

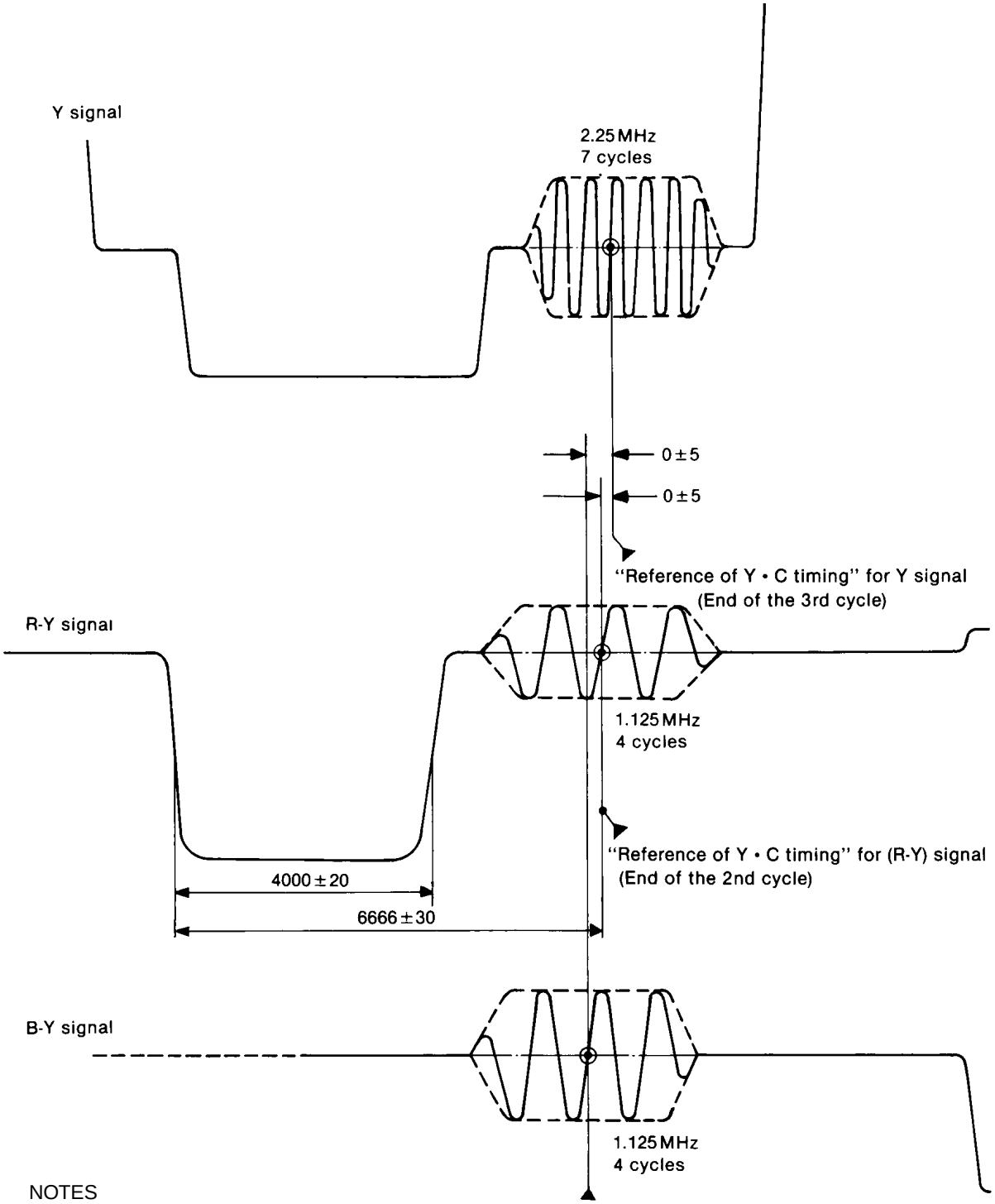
The timing difference between the luminance and the compressed chrominance signals shall be the value as shown in figure 2.

3.4 Vertical interval subcarrier (VISC)

3.4.1 VISC shall consist of one line of subcarrier inserted into each field of the Y signal as shown in figure 13. This signal shall only be present when the signal to be recorded is the result of decoding a composite NTSC signal with coherent subcarrier.

3.4.2 The frequency of the VISC signal shall be equal to the frequency of the subcarrier of the NTSC video signal.

3.4.3 The phase of the VISC signal shall be within $\pm 5°$ of the burst phase of the NTSC signal prior to decoding.



NOTES
1 Time base in nanoseconds.
2 Reference of Y–C timing shown displaced for illustrative purposes.

Figure 12 – Reference of Y-C timing

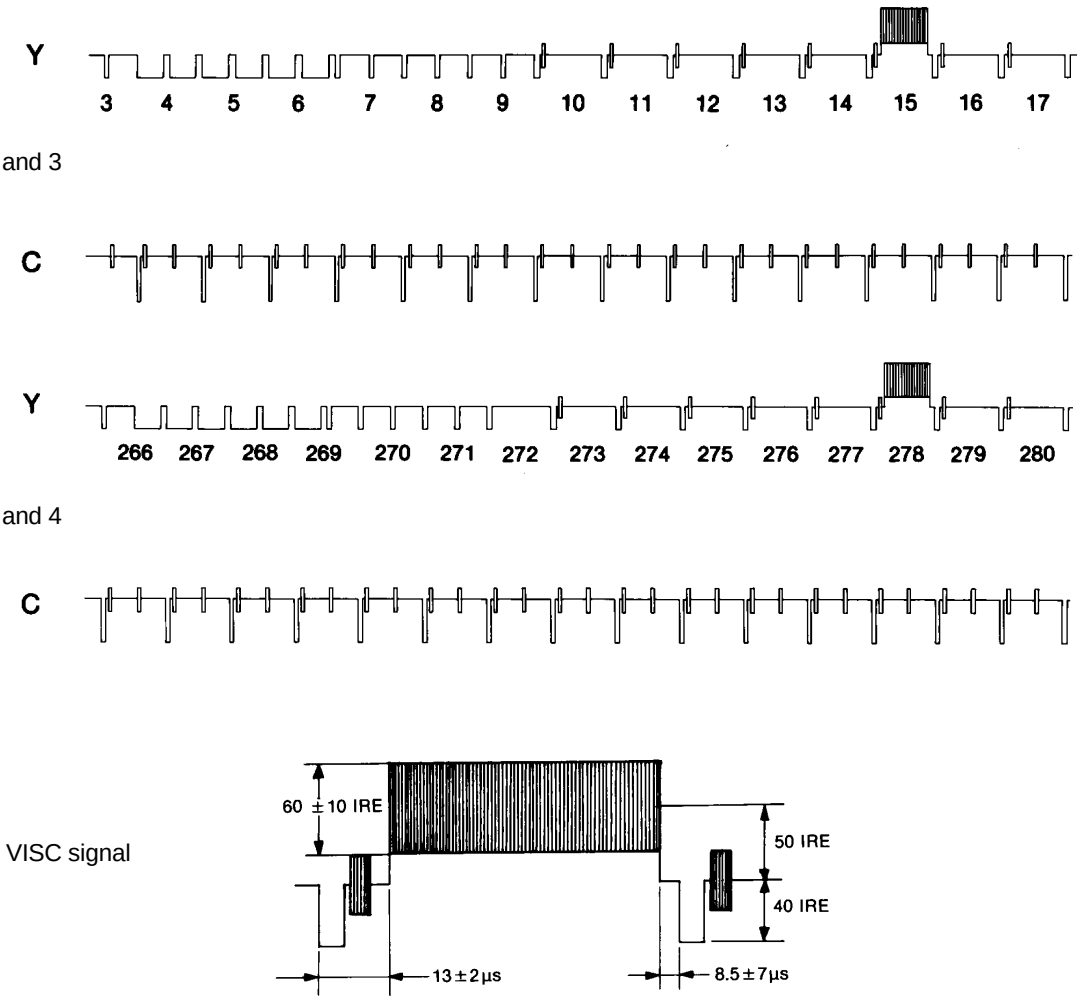


Figure 13 – Waveforms of VISC signal

4 Longitudinal audio signal recording

4.1 Recording method

Recordings shall be made by the anhysteretic (bias) method.

4.2 Recording/reproducing reference levels

4.2.1 Recording/reproducing level indicator

The audio recording and reproducing levels of this recorder shall be determined by using a standard volume indicator or its equivalent.

4.2.2 Recorder reference level

For a 1-kHz sinusoidal signal recording which yields an rms short circuit tape flux per unit track width on the record of 100 nWb/m ± 3 nWb/m, the recording volume indicator shall indicate its reference level scale mark.

4.2.3 Reproducer reference level

For the reproduction of a 1-kHz tape record which yields an rms short circuit tape flux per unit track width of 100 nWb/m, the reproducing volume indicator shall indicate its reference level scale mark.

4.3 Frequency characteristics

4.3.1 Record flux versus frequency characteristics

When a tape is recorded from a constant voltage applied to the input terminals, the short circuit tape flux level in the record versus frequency characteristics, $L\phi$ (f), shall be expressed by the following equation:

$$L\phi\,(f) = 10 \log_{10} \frac{1 + (F_l / f)^2}{1 + (f / F_h)^2} \quad (dB)$$

where $L\phi$ (f) is the relative tape flux level;
f is the frequency at which the response is calculated;
F_l is the low-frequency transition frequency, 50 Hz; and
F_h is the high-frequency transition frequency, 4681 Hz.

4.3.2 Reproduced flux versus frequency characteristics

When a tape record having a short-circuit tape flux level versus frequency characteristics given by 4.3.1 is reproduced, the output voltage level of the reproducer versus frequency characteristics shall remain constant.

4.3.3 Noise-reduction characteristics

A noise-reduction process, if applied, shall have the static encoding characteristics shown in table 5.

4.4 Track usage (common audio mode)

4.4.1 Nonstereo audio

The primary program audio channel shall be recorded on the audio 1 track.

4.4.2 Stereo audio

When separate channels are used for stereo audio, the left channel shall be recorded on the audio 1 track, and the right channel on the audio 2 track.

4.5 Program audio head phasing

When the same signal is recorded on audio 1 and audio 2 tracks, the tracks shall be so phased that, when reproduced with a head wide enough to sense the recorded flux on both records, the result will be additive.

4.6 Recording polarity

When a positive-going waveform is present on pin-2 of the input connector, as defined in IEC 268-12, the audio head gap shall produce the magnetic flux which flows out of the north pole and into the south pole. This flux flow shall be in the direction of the tape movement.

Table 5 – Longitudinal audio frequency response of noise reduction encoding level

Frequency (Hz)	Input level (dB)						
	0	–10	–20	–30	–40	–50	–60
100	0.2	0.9	2.7	2.9	2.9	2.9	2.9
200	0.1	1.5	5.3	8.0	8.1	8.1	8.1
300	0	1.6	6.1	10.7	12.0	12.0	12.0
500	0	1.7	6.3	11.8	15.6	16.2	16.2
1k	–0.3	1.5	5.9	11.4	16.2	19.4	19.6
3k	–1.6	–0.1	3.7	9.2	13.9	19.2	20.7
5k	–2.3	–0.6	2.9	8.4	13.5	18.7	20.4
10k	–3.5	–1.4	2.6	8.2	13.6	18.1	19.2
15k	–6.3	–3.3	1.5	7.3	12.2	15.0	15.0

NOTES
1 Input level is 0 dB, the reference input level at 1 kHz.
2 Encode level is 0 dB, the recorded reference level specified by 4.2.2.
3 Values are in decibels.

5 AFM signal recording (optional)

Audio signals of two channels shall frequency modulate two carriers. These frequency modulated carriers shall be located in the frequency region below the lower side band of the frequency modulated chrominance signal, which is specified by 3.2, in order to produce a frequency multiplex signal. The resultant multiplex signal shall be recorded on the chrominance track.

5.1 Signal processing

A signal processing system as specified by this standard shall contain the following elements:

5.1.1 An audio noise-reduction scheme incorporating compression

5.1.2 A linear frequency modulator having constant deviation with respect to the amplitude of the modulating frequencies

5.1.3 A means of adding the AFM signals to the chrominance signal in the ratios specified

5.2 Recording/reproducing reference levels

5.2.1 Recording/reproducing level indicator

The audio recording and reproducing levels of this recorder shall be determined by using a standard volume indicator or its equivalent.

5.2.2 Recorder reference level

When a 1-kHz sinusoidal signal recording is made with the reference deviation defined in 5.5.2, the recording volume indicator shall be adjusted to deflect to its reference level scale mark.

5.2.3 Reproducer reference level

When a 1-kHz tape record with the reference deviation defined in 5.5.2 is reproduced, the reproducing volume indicator shall deflect to its reference level scale mark.

5.3 Noise-reduction

5.3.1 Noise-reduction circuit

A noise-reduction circuit or its equivalent should be as shown in figure 14.

5.3.2 Compression ratio

The compression ratio shall be 2:1 in the logarithmic scale.

5.3.3 Transient response

The transient response shall be such that an attack time is 9.0 ms ± 3 ms and a recovery time is 90 ms ± 30 ms. Dynamic characteristics shall be as shown in figure 15.

5.4 Preemphasis

The output signal of the noise-reduction circuit specified in 5.3 shall be preemphasized before the frequency modulation by a network as shown in figure 16.

5.5 Frequency modulation

5.5.1 Carrier frequency

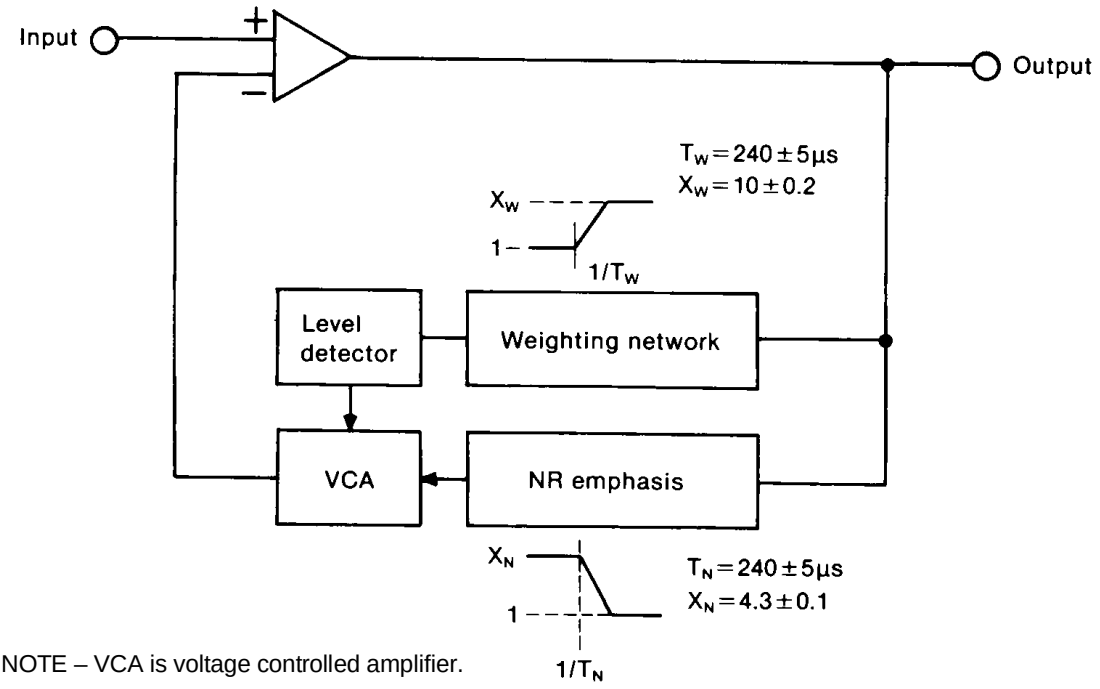
The left channel (CH3) signal frequency shall be 400 kHz ± 5 kHz. The right channel (CH4) signal frequency shall be 700 kHz ± 5 kHz.

5.5.2 Frequency deviation

The reference level deviation shall be 35 kHz ± 0.7 kHz at 1 kHz. The maximum deviation shall not exceed ± 105 kHz.

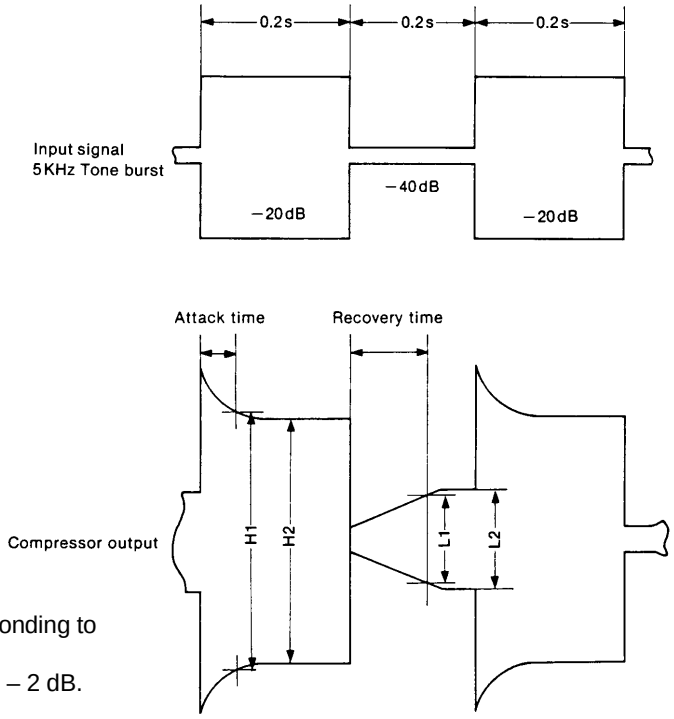
5.6 Recording head current

The recording head current level shall be adjusted at 20 dB ± 1 dB below the chrominance recording level defined in 3.2.8. The amplitude of the recording head current shall be constant over the frequency range from 300 kHz to 800 kHz.



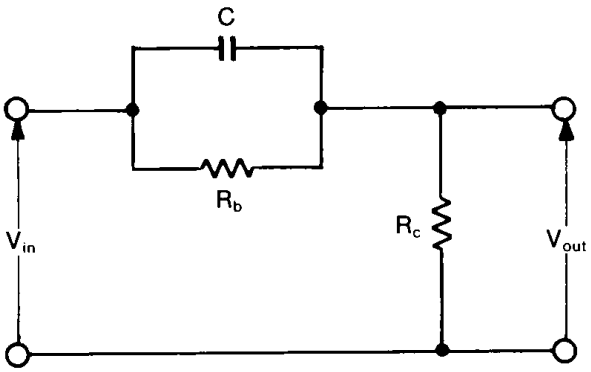
NOTE – VCA is voltage controlled amplifier.

Figure 14 – Noise-reduction circuit for AFM signals



NOTES
1 0 dB is input level corresponding to reference level.
2 $H_1 = H_2 + 2$ dB. $L_1 = L_2 - 2$ dB.

Figure 15 – Transient response of compressor for AFM noise reduction



$$T_D = CR_b = 56.0\ \mu s$$

$$X_D = \frac{R_b}{R_c} = 1.80$$

$$\frac{V_{out}}{V_{in}} = \frac{1 + j\omega T_D}{1 + X_D + j\omega T_D}$$

NOTE - Input source impedance = 0; output load impedance = ∞.

Figure 16 – Audio preemphasis network

6 Time and control code signal recording

6.1 Designated track for time and control code

The longitudinal track identified as the time and control code track shall be used for recording the code specified in ANSI/SMPTE 12M.

6.2 Recording method

The recording shall be made by the anhysteretic (bias) method.

6.3 Recording level

The recording level, as expressed in peak-to-peak short circuit tape flux per unit track width, shall be 250 nWb/m ± 50 nWb/m.

7 Tracking-control signal recording

7.1 Waveform and level

The recording waveform and level shall be a series of constant flux levels alternating in polarity at a field rate and completing one cycle per frame on the longitudinal track identified as shown in figure 17.

7.2 Polarity of remanent magnetization

During the time interval that video channel 1 is recording, the polarity of the tracking-control record flux shall be such that the S pole of the magnetic domain represents the direction of the tape travel.

7.3 Timing and period

The polarity of the flux described in 7.2 shall change to the opposite polarity when the recording of the next field is started by the channel 2 video heads. This opposite polarity interval shall continue until the beginning of the subsequent field recorded by the channel 1 video heads as shown in figure 17.

7.4 Optional framing information

If implemented, the color framing information shall be carried out by changing the timing of the polarity transition of the control signal recording as shown in figure 18.

7.5 Magnetization level

The magnitude of the tracking control recorded flux shall be at least 30 dB above the residual flux of any previous recordings.

7.6 Rise time

The rise time shall be the value shown in figure 17.

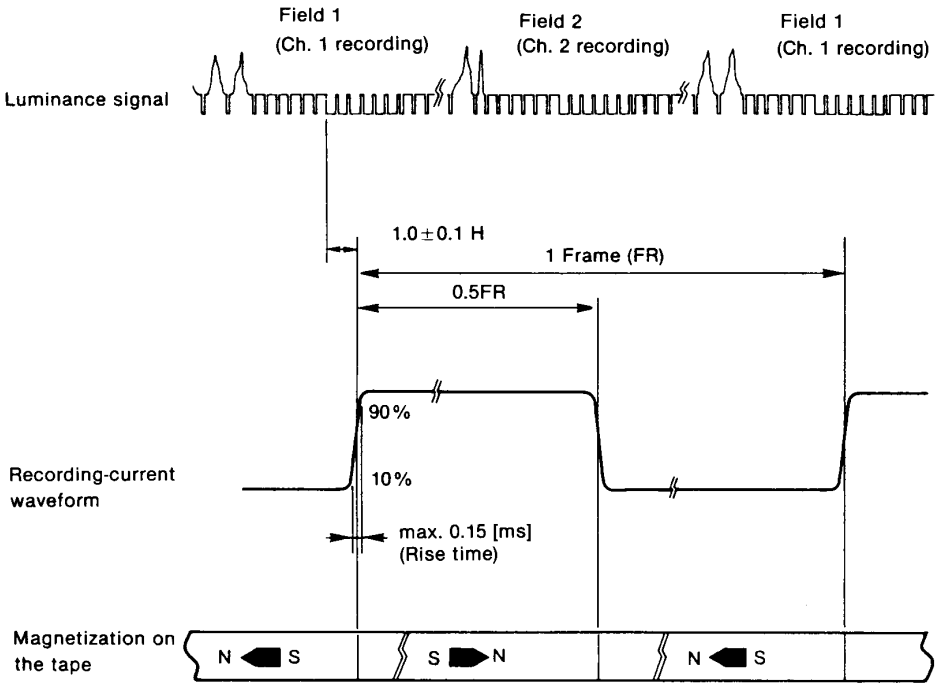


Figure 17 – Control-track signal waveforms and timing for component signal

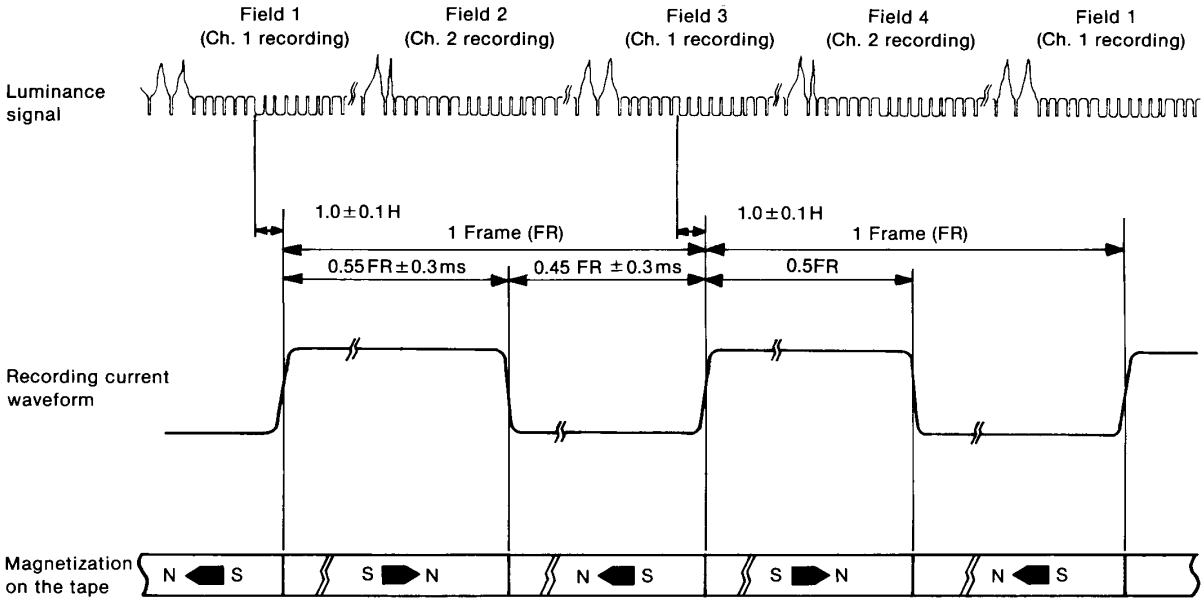


Figure 18 – Waveforms and timing of control-track signal with color framing information

Annex A (informative)
Bibliography

ITU-R BT.470-4, Television Systems