INTERNATIONAL STANDARD

IEC 62330-1

First edition
2003-05

Helical-scan digital video cassette recording system using 12,65 mm (0,5 in) magnetic tape – Format HD-D5 –

Part 1: VTR specifications

Reference number
IEC 62330-1:2003(E)

Publication numbering

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International Electrotechnical Commission
Международная Электротехническая Комиссия

PRICE CODE XB

For price, see current catalogue

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

HELICAL-SCAN DIGITAL VIDEO CASSETTE RECORDING SYSTEM USING 12,65 mm (0,5 in) MAGNETIC TAPE – FORMAT HD-D5 –

Part 1: VTR specifications

FOREWORD

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International Standard IEC 62330-1 has been prepared by Technical Area 6: Higher data rate storage media and equipment of IEC technical committee 100: Audio, video and multimedia systems and equipment.

It was submitted to the national committees for voting under the Fast Track Procedure as the following documents:

CDV	Report on voting
100/504/CDV	100/603/RVC

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until 2008. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

IEC 62330 consists of the following parts, under the general title *Helical-scan digital video cassette recording system using 12,65 mm (0,5 in) magnetic tape – Format HD-D5*.

Part 1: VTR specifications

Part 2: Compression format

Part 3: Data stream format

This part 1 describes the VTR specifications which are tape, magnetization, helical recording, modulation method and basic system data for high definition video compressed data on 29,97 or 59,94 frame rate.

Part 2 describes the specifications for encoding process and data format for 1080i and 720p systems.

Part 3 describes the specifications for transmission of HD-D5 compressed video and audio data stream over 360 Mb/s serial digital interface.

HELICAL-SCAN DIGITAL VIDEO CASSETTE RECORDING SYSTEM USING 12,65 mm (0,5 in) MAGNETIC TAPE – FORMAT HD-D5 –

Part 1: VTR specifications

1 Scope

This part of IEC 62330 specifies the content, format, and recording method of the data blocks containing HD compressed video data defined in part 2, audio, and associated data which form the helical records on 12,65 mm (0,5 in) tape in cassettes as specified in IEC 61835.

In addition, this standard specifies the content, format, and recording method of the longitudinal record containing tracking information for the scanning head associated with the helical records, and also the longitudinal cue audio, and time and control code.

One video channel of HD compressed video data and four independent audio channels are recorded in the digital format. Each of these channels is designed to be capable of independent editing.

The HD compressed video data are derived from the following HD video signal:

- 1080 line / 59,94 Hz field frequency interlace system
- 720 line / 59,94 Hz frame frequency progressive system

Figure 1 and Figure 2 show block diagrams of the processes involved in the recorder.

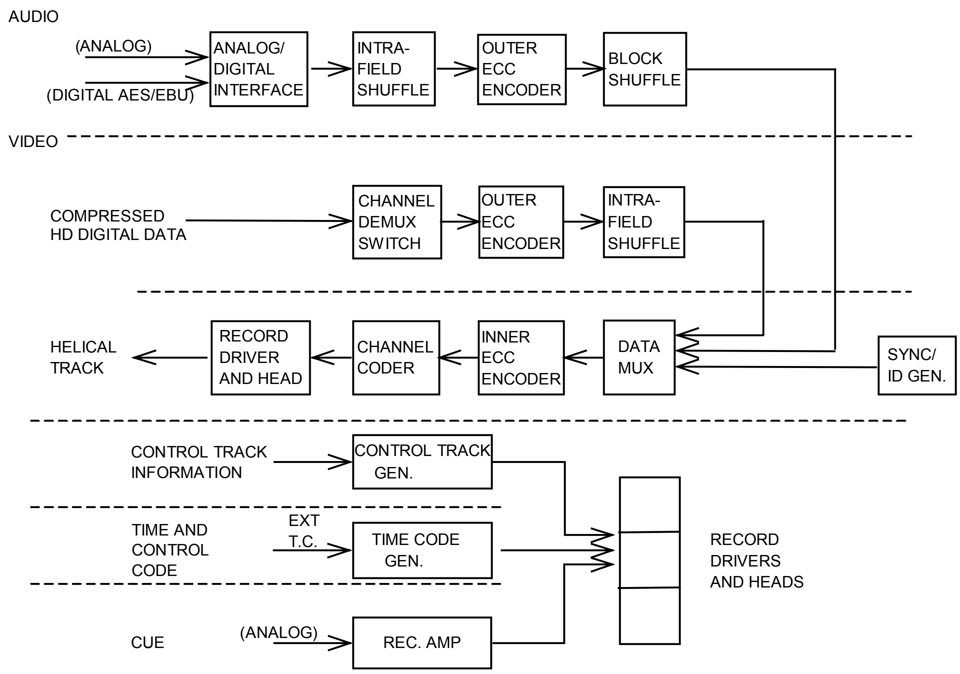


Figure 1 – Record block diagram

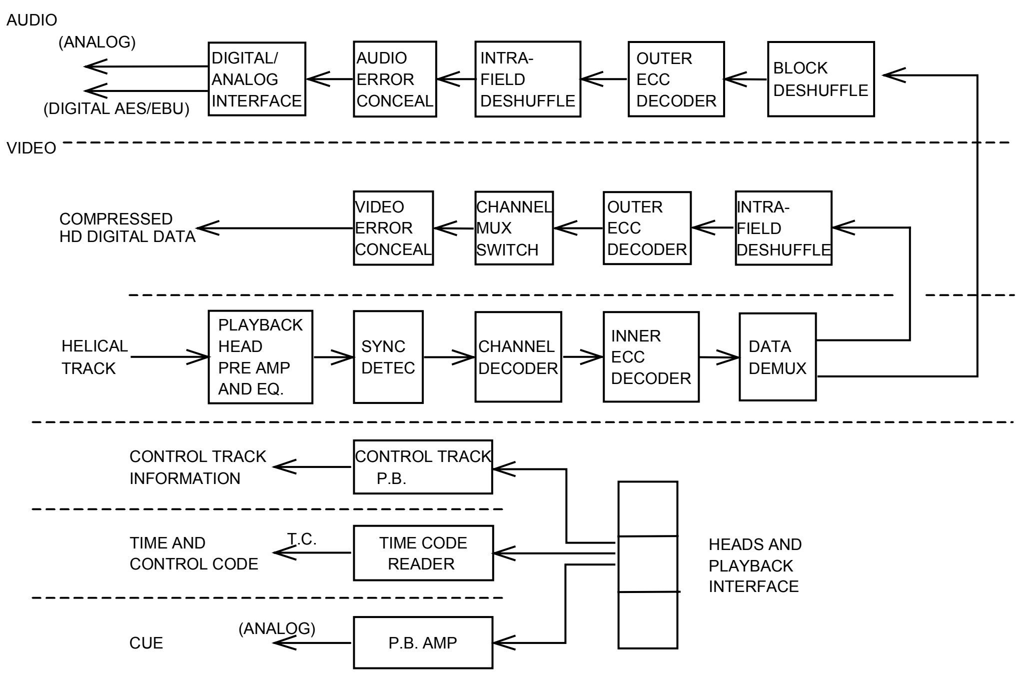


Figure 2 – Playback block diagram

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60461:2001, *Time and control code for video tape recorders*

IEC 60958, *Digital audio interface*

IEC 61835, *Helical-scan digital component video cassette recording system using 12,65 mm (0,5 in) magnet tape – Format D-5*

ITU-R BS. 647 *A digital audio interface for broadcasting studios*

SMPTE RP 155:1995, *Audio levels and Indicators for Digital Audio Records on Digital Television Tape Recorders*

3 Environment and test conditions

3.1 Environment

Tests and measurements made on the system to check the requirements of this standard shall be carried out under the following conditions:

Temperature	20 °C ±1 °C
Relative humidity	(50 ±2) %
Barometric pressure	from 86 kPa to 106 kPa
Tape conditioning	not less than 24 h
Centre tape tension	0,31 N ±0,05 N (see Annex A)

3.2 Reference tape

Blank tape for reference recordings should be available from any source meeting the tape characteristics as portrayed by this standard.

3.3 Calibration tape

The calibration tapes meeting the requirements of 3.3.1 and Clause 4 should be available from manufacturers who produce DTTRs and players in accordance with this standard.

3.3.1 Record locations and dimensions

Tolerances shown in Table 1 will be reduced by 50 %.

3.3.2 Calibration signals

Two sets of signals should be recorded on the calibration tape:

a) Video: 100 % colour bars
   Audio: 1 kHz tone at 20 dB below full scale on each of audio channels
   Cue: 1 kHz tone at reference level; 10 kHz tone at reference level

b) A signal of constant recorded frequency (i.e. one-half the Nyquist frequency) shall be recorded only on tracks of field 0, segment 0 for the purpose of mechanical alignment. Recording level should conform to 6.6.3.

4 Video tape

4.1 Base

The base material shall be polyester or equivalent.

4.2 Width

The tape width shall be 12,650 mm ±0,008 mm.

The tape, covered with glass, is measured without tension at a minimum of five different positions along the tape using a calibrated comparator having an accuracy of 0,001 mm (1 µm). The tape width is defined as the average of the five readings.

4.3 Width fluctuation

Tape width fluctuation shall not exceed 5 µm peak to peak. Measurement of tape width fluctuation shall be taken over a tape length of 900 mm. The value of tape width fluctuation shall be evaluated by measuring the tape width at 10 points, each separated by a distance of 100 mm.

4.4 Tape thickness

Two types of tape thickness shall be permitted by this standard. The first tape thickness shall be 10,2 µm to 11,0 µm (referred to as 11 µm); the second tape thickness shall be 13,0 µm to 14,0 µm (referred to as 14 µm).

4.5 Transmissivity

Transmissivity shall be less than 5 %, measured over the range of wavelengths 800 nm to 900 nm.

4.6 Offset yield strength

The offset yield strength shall be greater than 9 N for 11 µm tape and 10 N for 14 µm tape. The force required to produce 0,2 % elongation of a 1 000 mm test sample with a pull rate of a 10 mm per minute shall be used to confirm the offset yield strength. The line beginning at 0,2 % elongation parallel to the initial tangential slope is drawn and then read at the point of intersection of the line and the stress-strain curve.

4.7 Magnetic coating

The magnetic layer of the tape shall consist of a coating of metal particles or equivalent.

4.8 Coating coercivity

The coating coercivity shall be a class 1 800 (144 000 A/m) with an applied field of 400 000 A/m (5 000 Oe) as measured by a 50 Hz or 60 Hz B-H meter or vibrating sample magnetometer (VSM).

4.9 Particle orientation

The metal particles shall be longitudinally oriented.

5 Helical recordings

5.1 Tape speed

The tape speed shall be 167,228 mm/s. The tolerance shall be ±0,2 %.

5.2 Record location and dimensions

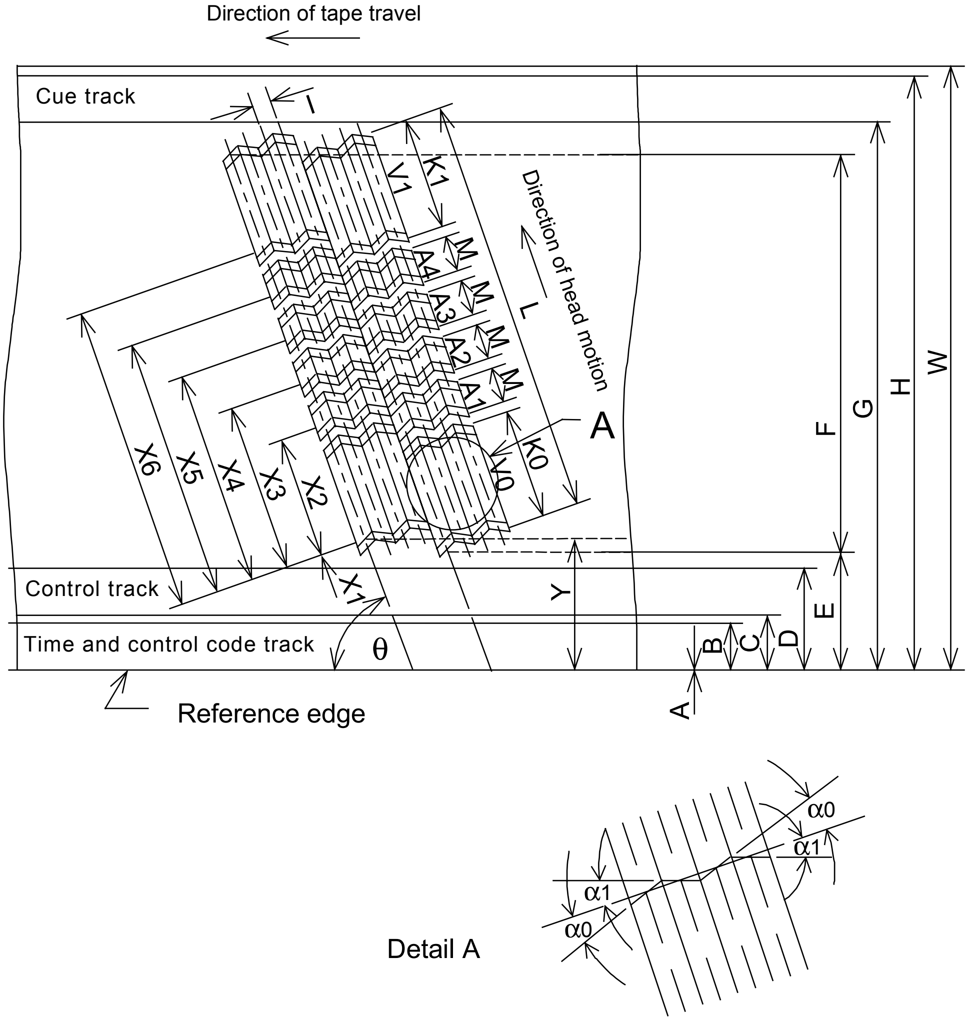
5.2.1 The format requires full-width erasure for continuous recording and flying erasure for insert editing.

5.2.2 Record location and dimensions for continuous recording shall be as specified in Figure 3, Figure 4 and Table 1. In recording, sector locations on each helical track shall be contained within the tolerance specified in Figure 3 and Table 1.

5.2.3 The reference edge of the tape for record location dimensions specified in this standard shall be the lower edge as shown in Figure 3. The magnetic coating, with the direction of tape travel as shown in Figure 3, is on the side facing the observer (measuring techniques are shown in Annex B).

5.2.4 As indicated in Figure 3, this standard anticipates a zero guard band between recorded tracks, and the record head width should be equivalent to the track pitch of 20 µm. The scanner head configuration should be chosen so that the recorded track widths are contained within the limits of 18 µm to 22 µm.

5.2.5 In insert editing, this standard provides a guard band of 2 µm (nominal) between the previously recorded track and the inserted track at editing points only. A typical track pattern for insert editing is shown in Figure C.1.



NOTE 1 A1, A2, A3, and A4 are audio sectors.

NOTE 2 V0 and V1 are video sectors.

NOTE 3 Tape viewed from magnetic coating side.

NOTE 4 Dimensions X1 to X6 are determined by the programme reference point as defined in Figure 4.

Figure 3 – Location and dimensions of recorded tracks

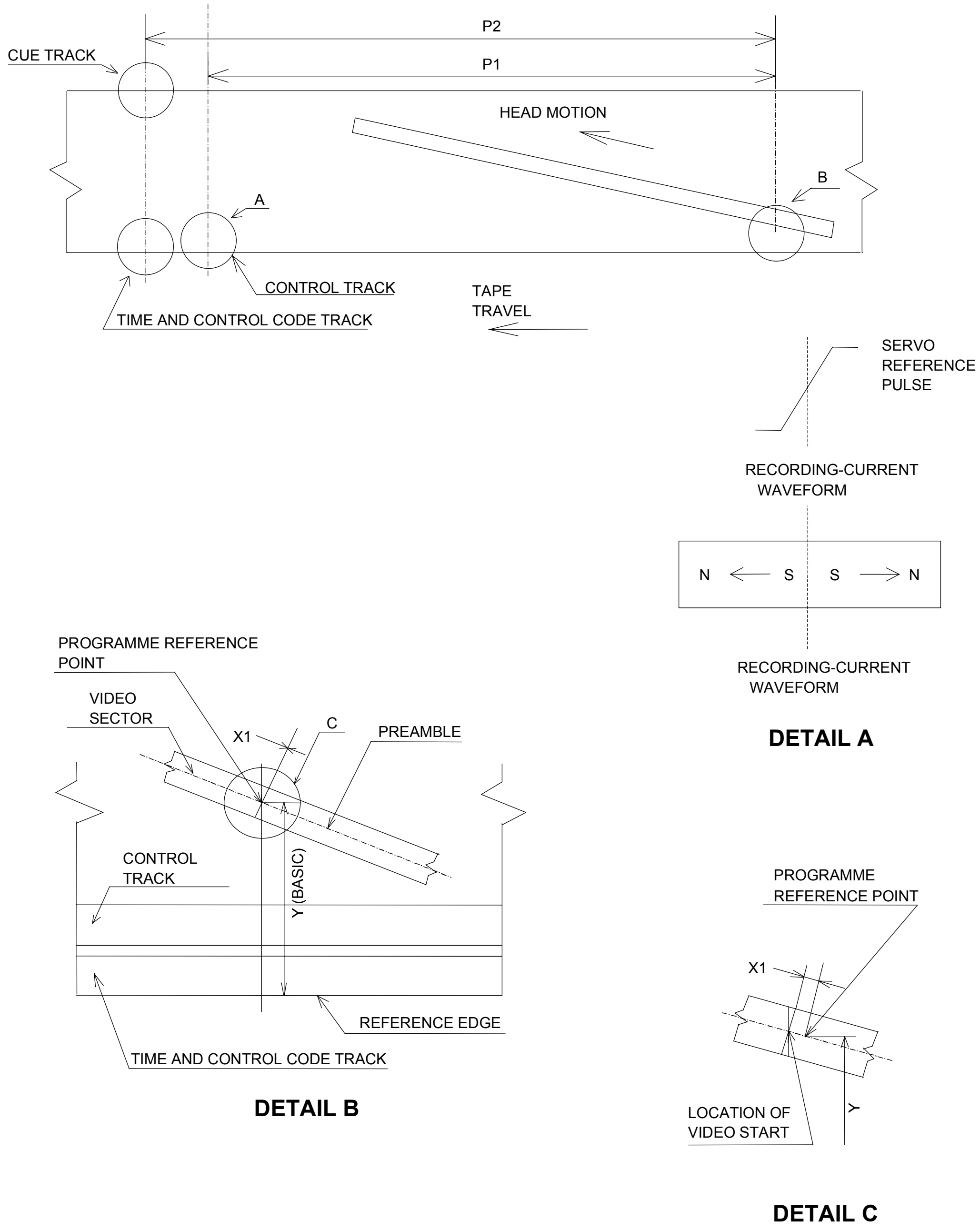


Figure 4 – Location of cue and time and control code track record

Table 1 – Record location and dimensions

Dimensions in millimetres

Dimensions		Nominal	Tolerance
A	Time and control code track lower edge	0	Basic
B	Time and control code track upper edge	0,450	±0,050
C	Control track lower edge	0,900	±0,050
D	Control track upper edge	1,300	±0,050
E	Programme area lower edge	1,629	Derived
F	Programme area width	10,020	Derived
G	Cue audio track lower edge	11,950	±0,050
H	Cue audio track upper edge	12,550	±0,050
I	Helical track pitch	0,0200	Ref
K0	Video sector 0 length	55,458	Derived
K1	Video sector 1 length	55,391	Derived
L	Helical track total length	116,397	Derived
M	Audio sector length	0,936	Derived
P1	Control track reference pulse to programme reference point (see Figure 4)	180,549	±0,050
P2	Cue/time and control code signal, start of code word, to programme reference point (see Figure 4)	183,400	±0,100
X1	Location of start of video sector V0	0	±0,050
X2	Location of start of audio sector A1[1)]	55,752	±0,050
X3	Location of start of audio sector A2[1)]	57,049	±0,050
X4	Location of start of audio sector A3[1)]	58,345	±0,050
X5	Location of start of audio sector A4[1)]	59,642	±0,050
X6	Location of start of video sector V1	60,938	±0,050
Y	Programme reference point	1,640	Basic
θ	Track angle	4,938 4 °	Basic
α0	Azimuth angle (track 0)	- 20,038 °	± 0,150 °
α1	Azimuth angle (track 1)	19,962 °	± 0,150 °

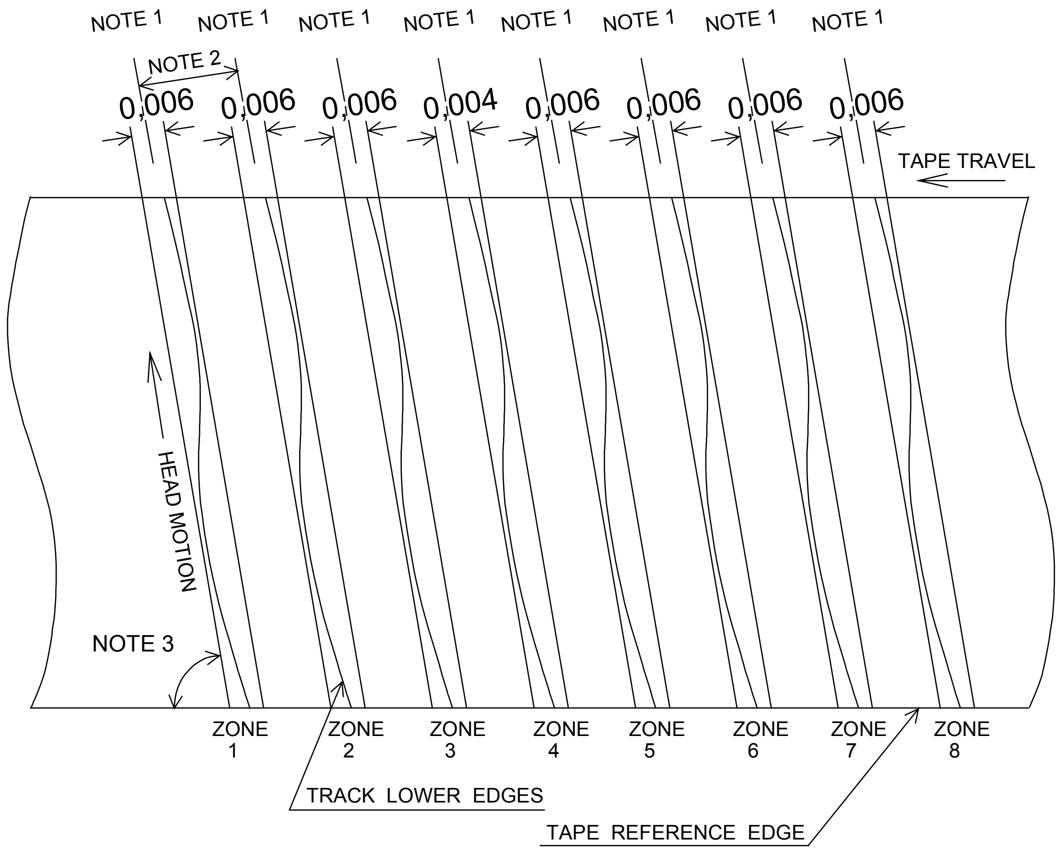
NOTE Measurements shall be made under the conditions specified in 3.1. The measurements shall be corrected to account for actual tape speed (see Figures B.1 and B.2).

1) Audio channel numbers vary.

5.3 Helical track record tolerance zones

The lower edges of any eight consecutive tracks starting at the first track in each video frame shall be contained within the pattern of the eight tolerance zones established in Figure 5. Each zone is defined by two parallel lines which are inclined with respect to the tape reference edge at an angle of 4,938 4° basic.

The centre lines of all zones shall be spaced apart 0,020 0 mm basic. The width of zones 1 to 3 and 5 to 8 shall be 0,006 mm basic. The width of zone 4 shall be 0,004 mm basic. These zones are established to contain track angle errors, track straightness errors, and vertical head offset tolerance (measuring technique is shown in Annex B).



NOTE 1 Tolerance zone centrelines.

NOTE 2 0,020 0

NOTE 3 4,938 4°

NOTE 4 All dimensions in millimetres.

Figure 5 – Location and dimensions of tolerance zones of helical track record

5.4 Relative positions of recorded information

5.4.1 Relative positions of longitudinal tracks

Audio, video, control track, time and control code, and cue track with information intended to be time coincident shall be positioned as shown in Figure 3 and Figure 4.

5.4.2 Programme area reference point

The programme area reference point is determined by the intersection of a line parallel to the reference edge of the tape at a distance Y from the reference edge and the centre line of the first track in each video field (segment 0, track 0). (See Figure 3 and Figure 4.)

The end of the preamble and start of the video sector are located at the programme area reference point, and the tolerance is dimension X1. The locations are shown in Figure 3 and Figure 4; dimensions X1 and Y are in Table 1. The relationship between sectors and contents of each sector is specified in Clause 6.

5.5 Gap azimuth

5.5.1 Cue track, control track, time code track

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

5.5.2 Helical track

The azimuth of the head gaps used for the helical track shall be inclined at angles α_0 and α_1 as specified in Table 1, with respect to a line perpendicular to the helical track. The azimuth of the first track of every field (segment 0, track 0) shall be oriented in the counterclockwise direction with respect to a line perpendicular to the helical track direction when viewed from the side of tape containing the magnetic record.

5.6 Transport and scanner

The effective drum diameter, tape tension, helix angle, and tape speed taken together determine the track angle. Different methods of design and/or variations in drum diameter and tape tension can produce equivalent recordings for interchange purposes.

One possible configuration of the transport uses a scanner with an effective diameter of 76,000 mm. Scanner rotation is in the same direction as tape motion during normal playback mode. Data is recorded by two groups of four heads mounted 180° apart. Figure 6 shows one possible mechanical configuration of the scanner, and Table 2 shows the corresponding mechanical parameters. Figure 7 shows the relationship between the longitudinal heads and the scanner. Other mechanical configurations are allowable provided the same footprint of recorded information is produced on tape.

Erase heads are described in 5.2.1 and Figure 6.

Table 2 – Parameters for a possible scanner design

Parameters		
Scanner rotation speed (rps)		90/1,001
Number of tracks per rotation		8
Drum diameter (mm)		76,000
Centre span tension (N)		0,31
Helix angle (degrees)		4,9000
Effective wrap angle (degrees)		176,9
Scanner circumferential speed (m/s)		21,5
H1,H3 over wrap head entrance (degrees)		14,1
H1,H3 over wrap head exit (degrees)		6
Angular relationship	H1 – H4:	13,570
(degrees)	H2 – H4:	9,047
	H3 – H4:	4,523
	H5 – H8:	13,570
	H6 – H8:	9,047
	H7 – H8:	4,523
	H4 – H8:	180,000
Vertical displacement	H1 – H4:	0,054
(mm)	H2 – H4:	0,036
	H3 – H4:	0,018
	H5 – H8:	0,054
	H6 – H8:	0,036
	H7 – H8:	0,018
Maximum tip projection (µm)		42,0
Record head track width (µm)		20

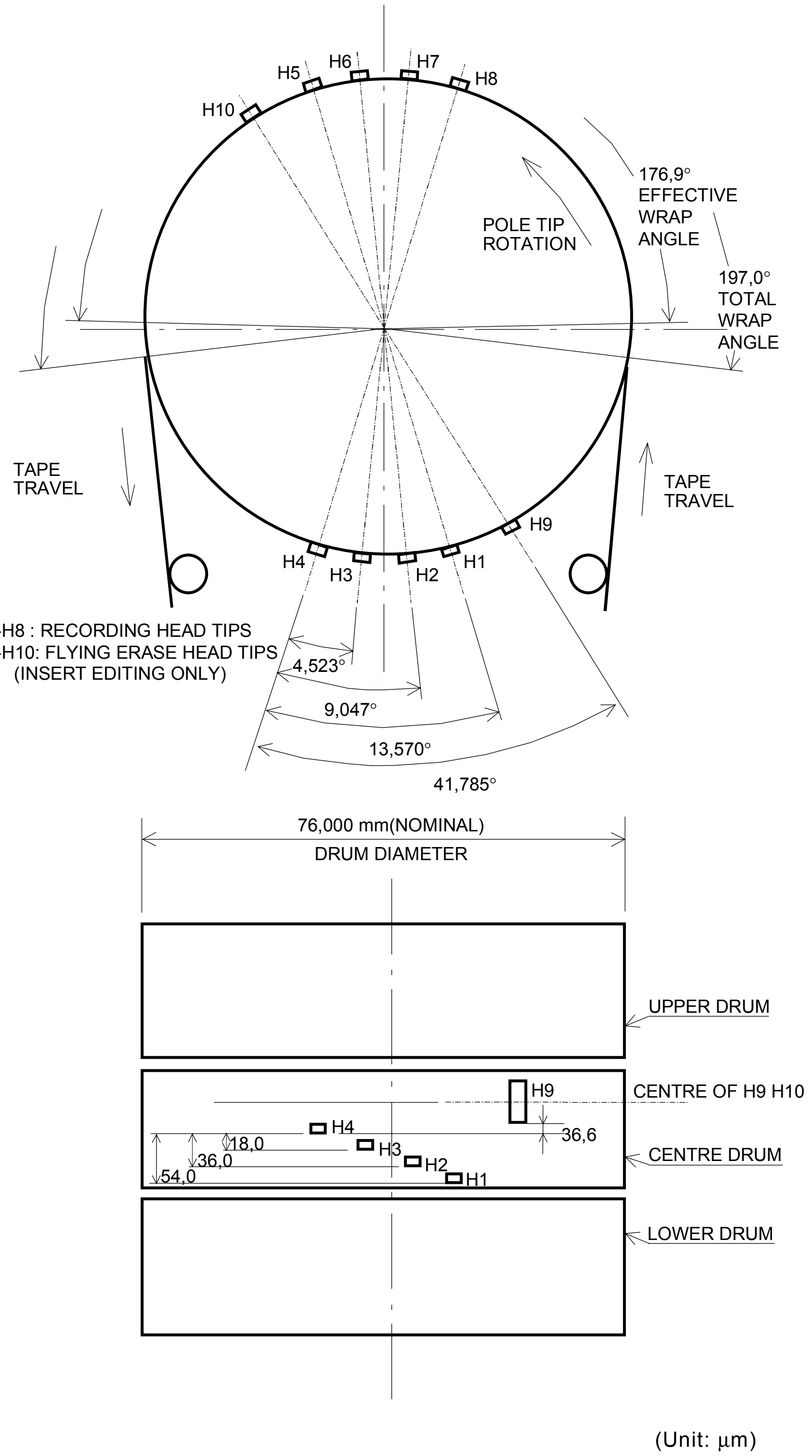


Figure 6 – A possible scanner configuration

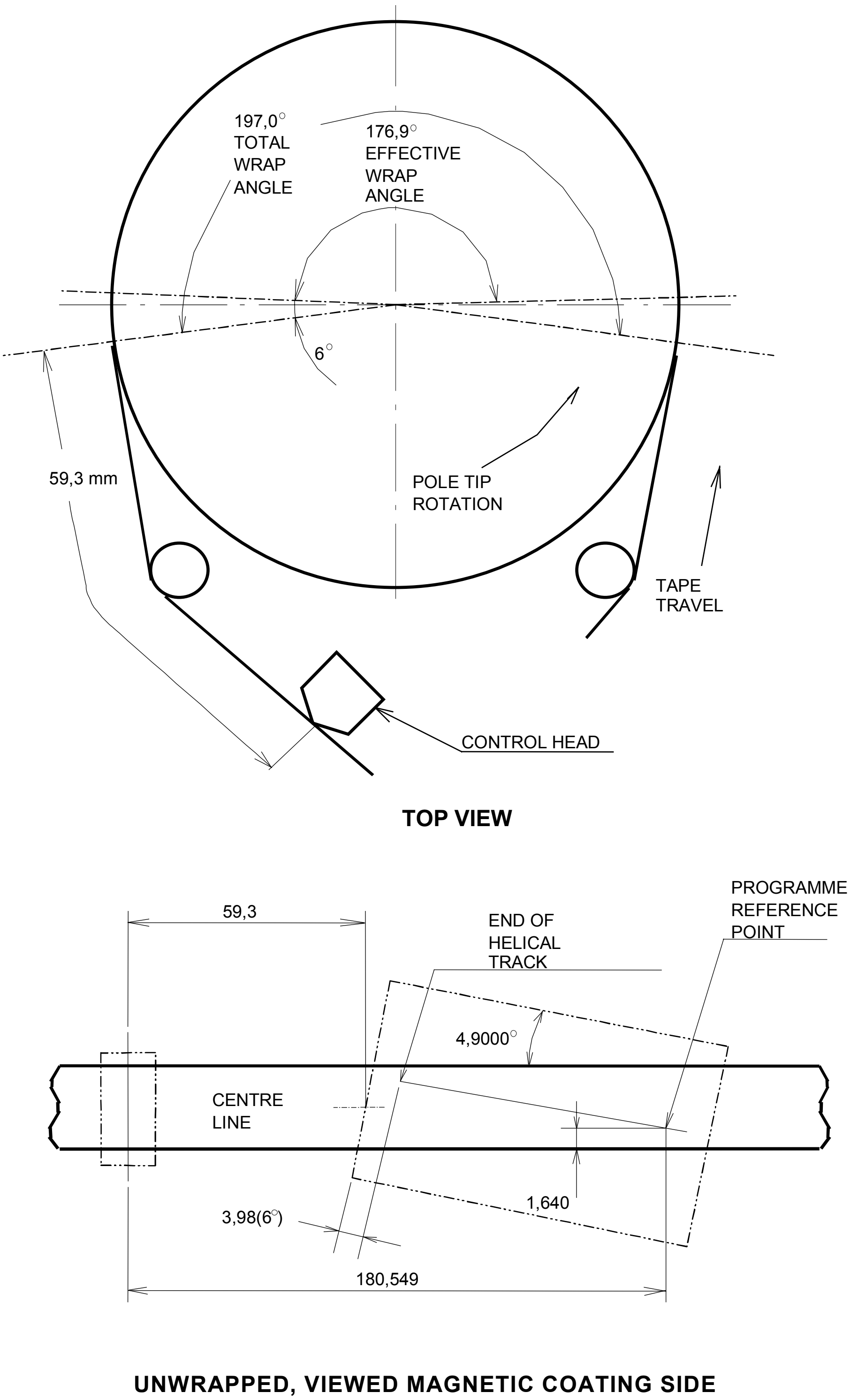


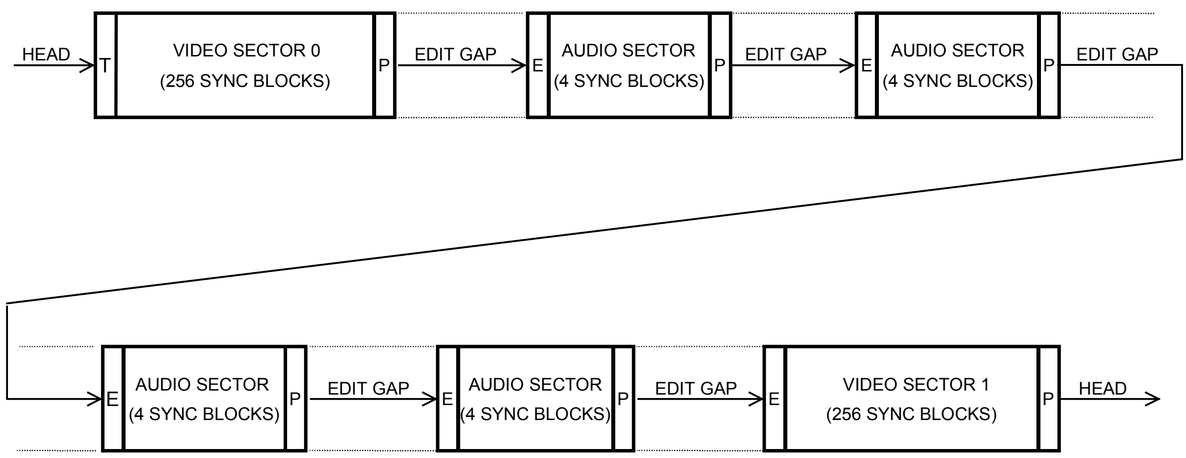
Figure 7 – A possible longitudinal head location and tape wrap

6 Programme track data

6.1 Introduction

Each HD TV field (1080/60i) or frame (720/60p) is recorded on 12 tracks.

The helical tracks contain digital data from the video channel and four audio channels. Each track contains a video sector followed by four audio sectors corresponding to four audio channels and followed by a second video sector, recorded in that order. An edit gap between sectors accommodates timing errors during editing. Figure 8 shows the arrangement of video and audio sectors on the tape.



T Track preamble (58 bytes)

E In-track preamble

P Postamble (4 bytes)

Sync block: 97 bytes

Edit gap: 162bytes nominal

Figure 8 – Sector arrangement on helical track

6.2 Labelling convention

The least significant bit is written on the left and first recorded to tape.

The lowest numbered byte is shown at the left/top and is the first encountered in the input data stream.

Byte values are expressed in hexadecimal notation unless otherwise noted. An h subscript indicates hexadecimal value.

6.3 Sector details

Each sector (audio or video) is divided into the following elements:

– preamble containing clock run-up sequence, sync pattern, identification pattern and fill pattern;

– sync blocks containing sync pattern and identification pattern, followed by a fixed length data block with error control;

– postamble containing sync pattern and identification pattern.

6.3.1 Sync block

The sync block format is common to both audio and video sectors. Each sync block contains a sync pattern (2 bytes) and an inner code block. Each inner block contains an identification pattern (2 bytes) and 85 data bytes of video, audio, or outer check bytes followed by 8 inner check bytes.

The inner code block contains the two bytes of the identification pattern together with 85 data bytes. Figure 9 shows the sync block format.

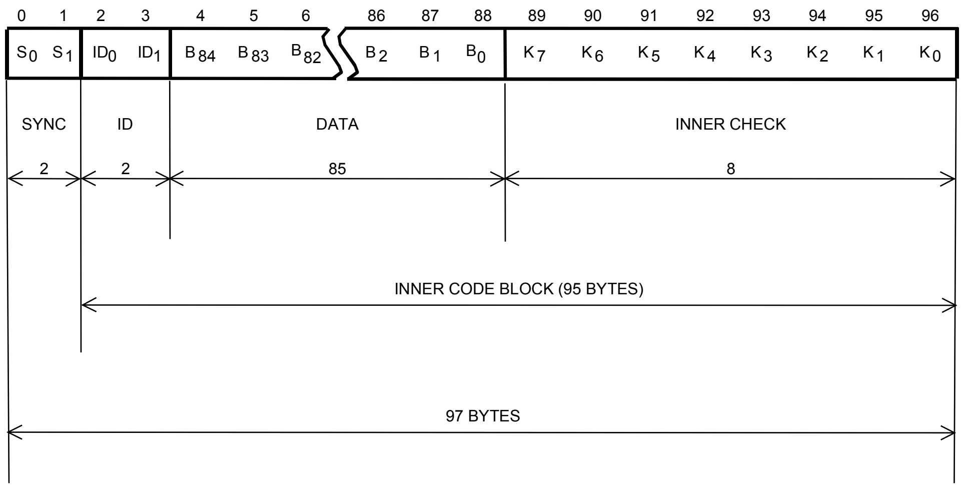


Figure 9 – Sync block format

6.3.2 Sync pattern

a) Length: 16 bits (2 bytes).

b) Pattern: 97F1 (in hexadecimal notation).

	LSB							MSB
Byte 0 -	1	1	1	0	1	0	0	1
Byte 1 -	1	0	0	0	1	1	1	1

c) Protection: none.

d) Randomization: none.

6.3.3 Identification pattern

As illustrated in Figure 10, the first two bytes of each inner block are used for identification of sync block, television field, segment (group of helical tracks scanned simultaneously), sector (portion of a track), and helical track. Bits 1 to 6 of the second byte (byte 3 of sync block) of the identification pattern identify the track. Bit 7 of the second byte (byte 3) identifies a sector on the helical track (see Figure 11).

a) Length: 16 bits (2 bytes).

b) Arrangement: the sync block number (byte 2 and the bit 0 of byte 3) follows a coded sequence along the track. Figure 12 shows the sequence of the sync block numbers.

   The sector ID (bits 1to7 of byte 3) identifies a particular sector.

The segment count is modulo 3. The field count for video sectors is modulo 4 (VF_2 = 0 in byte 3). The field count for audio sectors is modulo 4 (for AF_0 and AF_1 in byte 3) and AF_2 (in byte 3) is used for the identification of the five field sequences.

c) Video field identification: The field address VF_0, VF_1, VF_2 (bits 4, 5, and 6 of the byte 3) for video sync blocks shall identify the field sequence as shown below. In the case of composite signal input, the field address shall identify the four-field colour sequences as defined in ITU Report 624 and have the values as shown below:

Component signal input	**Composite signal**	**VF_0**	**VF_1**	**VF_2**
Field 1	Colour frame A, field I	0	0	0
Field 2	Colour frame A, field II	1	0	0
Field 1	Colour frame B, field III	0	1	0
Field 2	Colour frame B, field IV	1	1	0

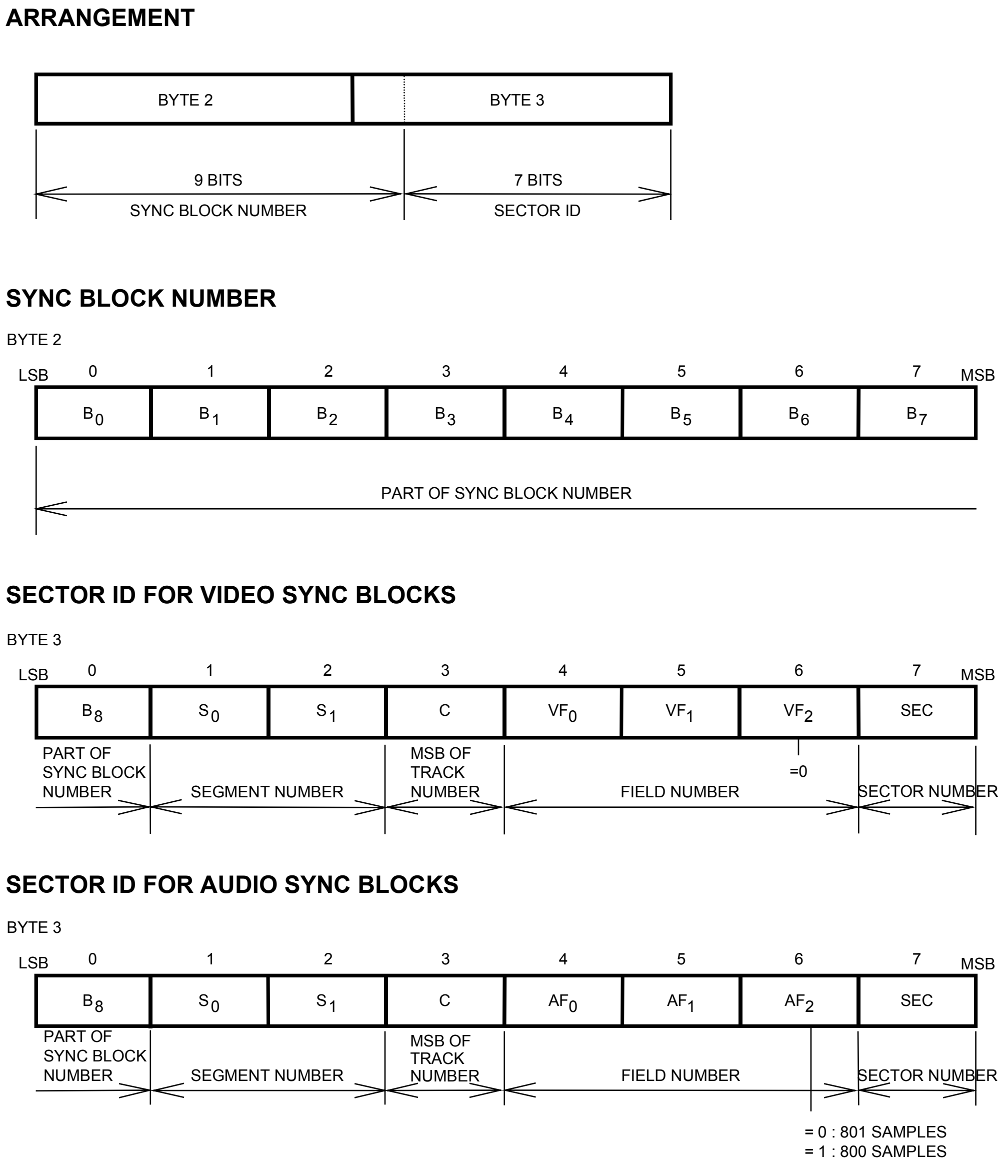
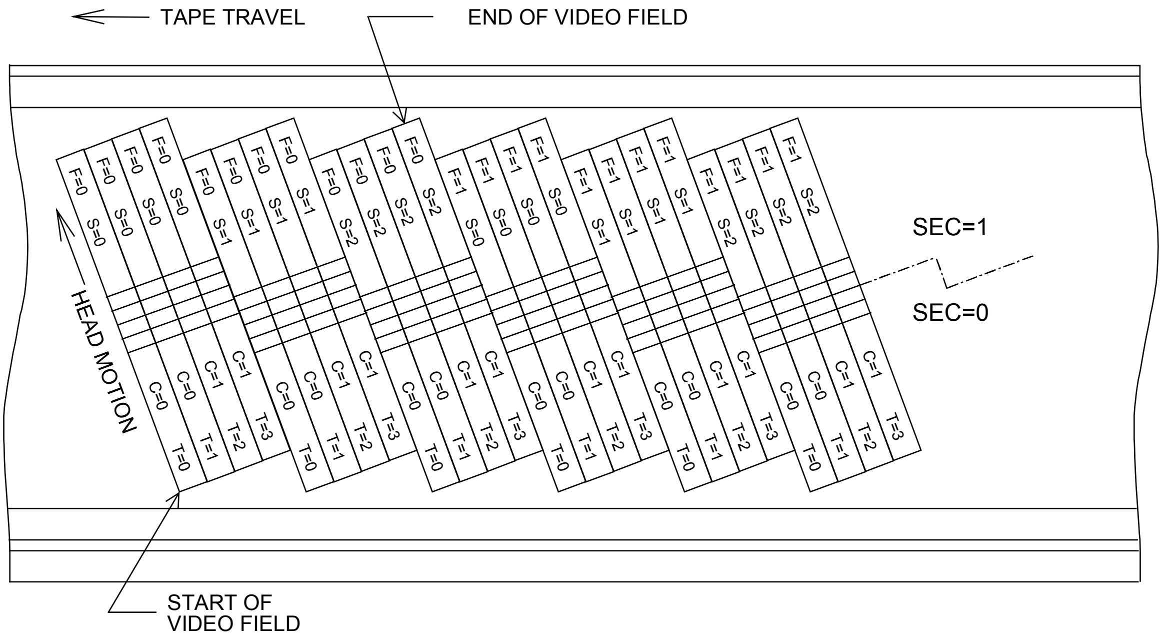


Figure 10 – Sync block identification format



NOTES

1 F = field number (0, 1, 2, 3).

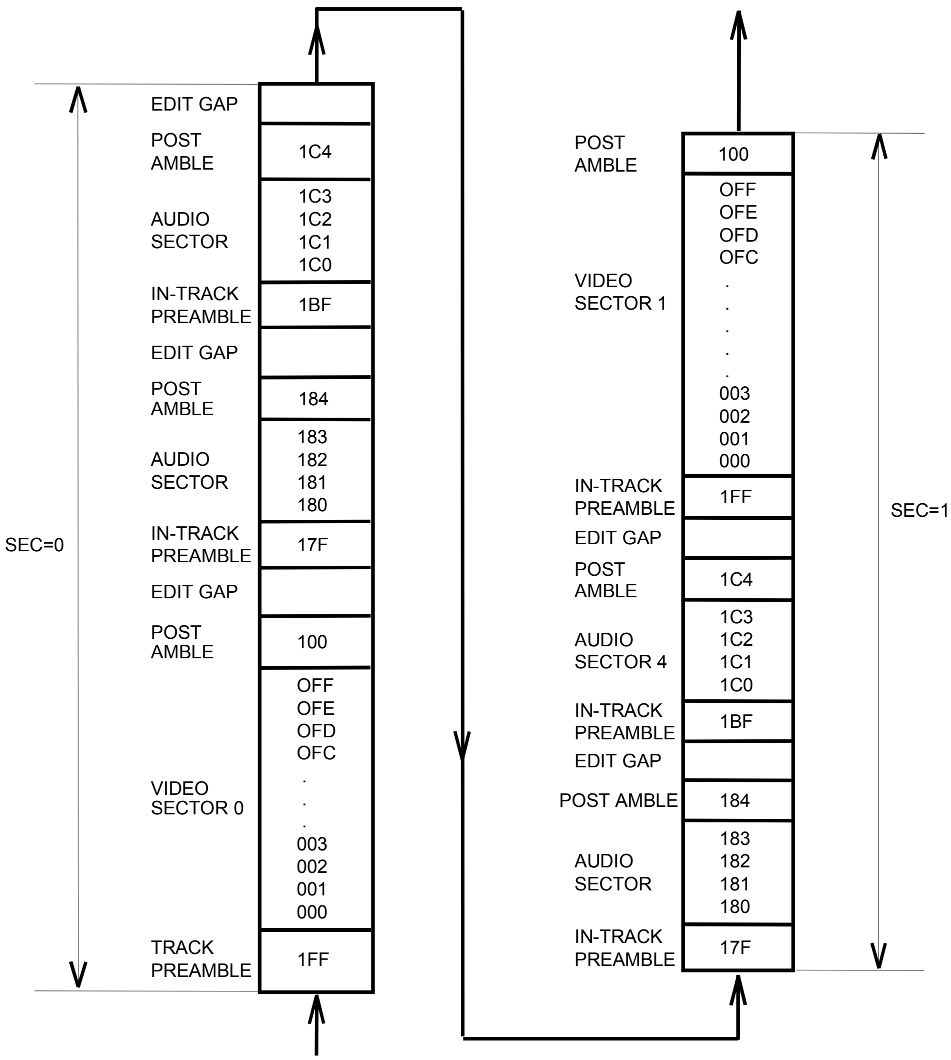
2 S = segment number (0, 1, 2).

3 SEC = sector number; C = MSB of track number (0, 1).

4 T = track number (0, 1, 2, 3). LSB of track number is identified by the azimuth angle.

5 Audio sectors are not shown.

Figure 11 – Track, segment and field numbers



NOTE Sync block number shows in hexadecimal notation.

Figure 12 – Sync block number

d) Audio field identification: The field address AF_0 and AF_1 of the audio sync block (bits 4 and 5 of byte 3) shall identify four-fields sequence as shown below. The sequence shall be identical for the system. When audio sectors are edited, the four-fields sequence shall be maintained.

Field	AF_0	AF_1
m	0	0
m+1	0	1
m+2	1	0
m+3	1	1

The field address AF_2 of the audio sync block (bit 6 of byte 3) shall identify a five-field sequence for the number of audio samples in the current field as shown below. When audio sectors are edited, the five-field sequence shall be maintained (see 10.3.6 d)).

Field	AF_2	Number of audio samples
n	0	801
n+1	0	801
n+2	0	801
n+3	0	801
n+4	1	800

e) Protection: the identification pattern is protected by an inner code block.

f) Randomization: the identification pattern is randomized before being channel coded.

The randomizing is equivalent to performing the exclusive-OR operation between the serial data stream and serial stream generated by the polynomial function

$$x^8 + x^4 + x^3 + x^2 + 1 \quad \text{(in GF(2))}$$

The first term is the most significant and the first to enter the division computation.

The polynomial generator noted above is preset to 15_h at the first byte of the identification pattern and continues to cycle until the end of the sync block.

6.3.4 Data field

This block is used for all video and audio data and the associated error correction data.

a) Length: 1 inner code block. The inner code block contains 95 bytes consisting of two identification pattern bytes, 85 data bytes (outer ECC check bytes are considered data), plus 8 inner ECC check bytes.

b) Arrangement: see Figure 9.

c) Interleaving: none.

d) Protection: inner ECC code.

Type: Reed-Solomon.

Galois Field: GF(256).

Field generator polynomial: $x^8 + x^4 + x^3 + x^2 + 1$,

where x^i are place keeping variables in GF(2), the binary field.

Order of use: left-most term is most significant, "oldest" in time computationally, and written to tape first.

Code Generator Polynomial in GF(256) is:

$G(x) = (x+1)(x+a)(x+a^2)(x+a^3)(x+a^4)(x+a^5)(x+a^6)(x+a^7)$

where

a is given by 02_h in GF(256).

Check characters: $K_7, K_6, K_5, K_4, K_3, K_2, K_1, K_0$

in $K_7x^7 + K_6x^6 + K_5x^5 + K_4x^4 + K_3x^3 + K_2x^2 + K_1x + K_0$ obtained as the remainder after dividing $x^8D(x)$ by G(x)

where

$D(x) = ID_0x^{86} + ID_1x^{85} + B_{84}x^{84} + . . . + B_2x^2 + B_1x + B_0$.

Polynomial of full code:

$ID_0x^{94} + ID_1x^{93} + B_{84}x^{92} + B_{83}x^{91} + . . . + B_1x^9 + B_0x^8$
$+ K_7x^7 + K_6x^6 + . . . + K_2x^2 + K_1x + K_0$.

e) Randomization: all data and error correction check characters are randomized before being channel coded. The randomization is equivalent to randomization as defined in item f) of 6.3.3.

6.3.5 Sector preamble

All sectors are preceded by a preamble consisting of a clock run-up sequence, sync pattern (2 bytes), identification pattern (2 bytes), and fill pattern (4 bytes). The clock run-up sequence varies in length depending on the sector. The remaining elements of the preamble have the same format for all sectors.

When a sector is edited, the appropriate preamble, including run-up sequence, shall be recorded.

6.3.5.1 Track preamble (T)

The track preamble precedes the first sector of every track. The total length of track preamble is 58 bytes and contains 50 bytes of run-up pattern "$2C_h$" which is followed by two bytes of sync pattern, two bytes of identification pattern, and four bytes of fill pattern "00_h".

LSB							MSB
0	0	1	1	0	1	0	0

a) Arrangement: see Figure 13 (a).

b) Total length: 58 bytes.

c) Run-up pattern: $2C_h$.

d) Sync pattern: see 6.3.2.

e) Identification pattern: see 6.3.3.

f) Fill pattern: 00_h.

g) Protection: none.

h) Randomization: only the identification pattern and fill pattern are randomized before being channel coded. The randomization is equivalent to randomization as defined in 6.3.3 f).

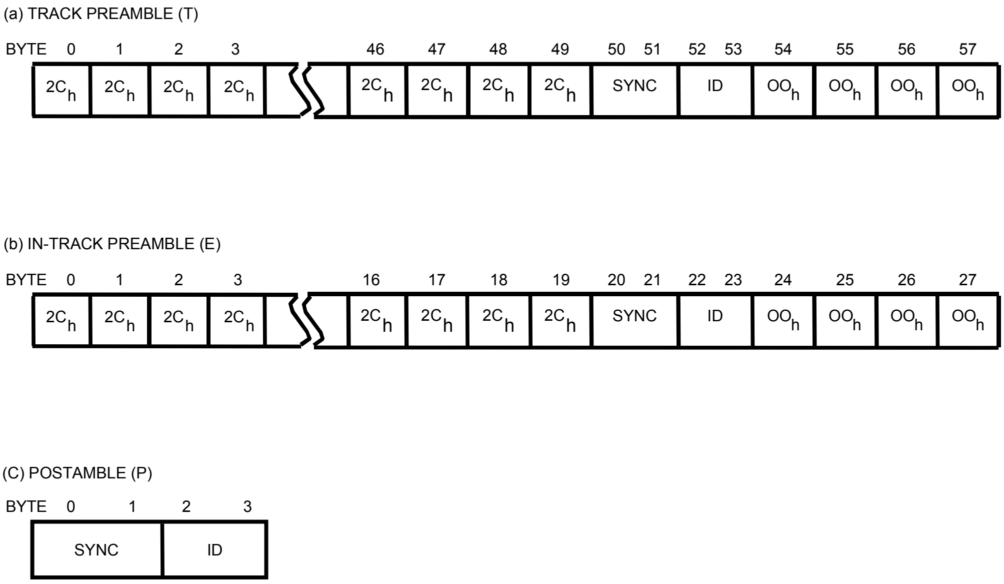


Figure 13 – Sector preamble and postamble

6.3.5.2 In-track preamble (E)

An in-track preamble precedes every sector except the first sector of a track. The total length is 28 bytes long and contains 20 bytes of run-up pattern "$2C_h$" followed by two bytes of sync pattern, two bytes of identification pattern, and four bytes of fill pattern "00_h".

a) Arrangement: see Figure 13 (b).

b) Total length: 28 bytes.

c) Run-up pattern: $2C_h$.

LSB							MSB
0	0	1	1	0	1	0	0

d) Sync pattern: see 6.3.2.

e) Identification pattern: refer to Figure 10.

f) Fill pattern: 00_h.

g) Protection: none.

h) Randomization: only the identification pattern and fill pattern are randomized before being channel coded. The randomization is equivalent to randomization as defined in 6.3.3 f).

6.3.6 Sector postamble (P)

All sectors are followed by a postamble. The total length is four bytes and contains two bytes of sync pattern and two bytes of identification pattern.

a) Arrangement: See Figure 13 (c).

b) Total length: 4 bytes.

c) Sync pattern: See 6.3.2.

d) Identification pattern: See 6.3.3.

e) Protection: none.

f) Randomization: only the identification pattern is randomized before being channel coded. The randomization is equivalent to randomization as defined in 6.3.3 f).

6.4 Edit gaps

The space between individual sectors of a track, exclusive of preamble and postamble, is nominally 167 bytes long.

The edit gap is used to accommodate timing errors during editing. In an original recording, the edit gap shall contain the pattern $2C_h$. During an edit, the edit gap may be partially overwritten with $2C_h$ code provided that the preamble and/or postamble of the adjacent unedited track sectors are not overwritten.

a) Protection: none.

b) Randomization: none.

6.5 Channel code

The channel code shall be an 8-14 modulation code which is defined by the following code rules.

NOTE 1 DSV is an abbreviation for digital sum variation and indicates the integral value which is counted from the beginning of the 8-14 modulated wave form, taking high level as 1 and low level as –1.

NOTE 2 CDS is an abbreviation for code word digital sum and indicates the DSV of one symbol modulation code.

NOTE 3 8-bit data entries in Tables 3 and 4 are in hexadecimal notation.

Selecting the current 14-bit code, the following steps shall be taken:

1) Select a 14-bit code satisfying the following conditions of (A) and (B) from Tables 3 and 4:
   a) The number of consecutive identical bits at the joint portion with the preceding 14-bit code is two to seven.
   b) The absolute value of the DSV at the end of the code (called end DSV hereinafter) is equal to or less than two.
2) When two or more 14-bit codes are selected at step (1), choose a 14-bit code that gives the smallest absolute value of the end DSV.
3) When two or more 14-bit codes are still chosen in step (2), select a 14-bit code by calculating the DSV for each bit of the code (called bit DSV hereinafter), determining the bit DSV the absolute value of which is minimum for each code, and choosing the code with the bit DSV whose minimum absolute value is smallest.
4) When two or more 14-bit codes are further found in step (3), select a 14-bit code by finding the maximum absolute value of the bit DSV of each code, and choosing a code with the bit DSV whose maximum absolute value is equal to or less than six.
5) When two or more codes are still found in step (4), select a 14-bit code satisfying the condition that the number of consecutive identical bits at the joint portion with the preceding 14-bit code is equal to or less than six.
6) When any codes selected in step (4) do not satisfy step (5), or two or more modulation codes satisfy step (5), select a 14-bit code satisfying the condition that the number of consecutive identical bits in that code is equal to or less than six.
7) When any codes selected in step (4) do not satisfy step (5) and step (6), or when any codes selected in step (5) do not satisfy step (6), or when two or more codes are further found in step (6), the following two steps shall be taken:
   a) When the end DSV of the code is –2, select a code of higher priority (corresponding to a smaller number in Table 5) according to Table 5. Likewise, when the end DSV of the code is +2, select a code of higher priority (corresponding to smaller number in Table 6) according to Table 6.

b) When two or more codes belonging to the equal highest priority are found in step (a), select all of them temporarily. When the end DSV is zero, select a code satisfying the last six bits except when 111111 or 000000 are in the code.

8) When any codes selected in step (4) do not satisfy steps (5), (6), and (7), or when any codes selected in step (5) do not satisfy step (6) and step (7), or when any codes selected in step (6) do not satisfy step (7), or when two or more codes are further found in step (7), select a code with the bit DSV whose maximum absolute value is smallest.

9) When two or more codes are still found in step (8), select a 14-bit code with the bit DSV whose minimum absolute value appears earliest in the bit string of the code.

10) When two or more codes are further found in step (9), select a 14-bit code whose bit will be reversed earliest after the joint portion with the preceding code.

The recorded data rate (for the scanner configuration defined in 5.6) and shortest recorded wavelength are given in Table 7, provided for reference only.

Table 3 – 8-14 modulation (CDS≥0)

Class	8-bit data	Modulation codes beginning with "0"	CDS	Class	8-bit data	Modulation codes beginning with "1"	CDS
1(A)	00	01111110000001	0	1(B)	00	10000001111110	0
	01	01111100110000	0		01	10000011001111	0
	02	01111100011000	0		02	10000011100111	0
	03	01111100001100	0		03	10000011110011	0
	04	01111100000110	0		04	10000011111001	0
	05	01111100000011	0		05	10000011111100	0
	06	01111001110000	0		06	10000110001111	0
	07	01111001100001	0		07	10000110011110	0
	08	01111000111000	0		08	10000111000111	0
	09	01111000110001	0		09	10000111001110	0
	0A	01111000011100	0		0A	10000111100011	0
	0B	01111000011001	0		0B	10000111100110	0
	0C	01111000001110	0		0C	10000111110001	0
	0D	01111000000111	0		0D	10000111111000	0
	0E	01110011110000	0		0E	10001100001111	0
	0F	01110011100001	0		0F	10001100011110	0
	10	01110011001100	0		10	10001100110011	0
	11	01110011000110	0		11	10001100111001	0
	12	01110011000011	0		12	10001100111100	0
	13	01110001111000	0		13	10001110000111	0
	14	01110001110001	0		14	10001110001110	0
	15	01110001100110	0		15	10001110011001	0
	16	01110001100011	0		16	10001110011100	0
	17	01110000111100	0		17	10001111000011	0
	18	01110000111001	0		18	10001111000110	0
	19	01110000110011	0		19	10001111001100	0
	1A	01110000011110	0		1A	10001111100001	0
	1B	01110000001111	0		1B	10001111110000	0
	1C	01100111110000	0		1C	10011000001111	0
	1D	01100111100001	0		1D	10011000011110	0
	1E	01100111001100	0		1E	10011000110011	0
	1F	01100111000110	0		1F	10011000111001	0
	20	01100111000011	0		20	10011000111100	0
	21	01100110011100	0		21	10011001100011	0
	22	01100110011001	0		22	10011001100110	0
	23	01100110001110	0		23	10011001110001	0
	24	01100110000111	0		24	10011001111000	0
	25	01100011111000	0		25	10011100000111	0
	26	01100011110001	0		26	10011100001110	0
	27	01100011100110	0		27	10011100011001	0
	28	01100011100011	0		28	10011100011100	0
	29	01100011001110	0		29	10011100110001	0
	2A	01100011000111	0		2A	10011100111000	0
	2B	01100001111100	0		2B	10011110000011	0
	2C	01100001111001	0		2C	10011110000110	0
	2D	01100001110011	0		2D	10011110001100	0
	2E	01100001100111	0		2E	10011110011000	0
	2F	01100000111110	0		2F	10011111000001	0
	30	01100000011111	0		30	10011111100000	0
	31	01111111001100	4		31	10000011111110	2
	32	01111111000110	4		32	10000110011111	2
	33	01111111000011	4		33	10000111001111	2
	34	01111110011100	4		34	10000111100111	2
	35	01111110011001	4		35	10000111110011	2
	36	01111110001110	4		36	10000111111001	2
	37	01111110000111	4		37	10000111111100	2
	38	01111100111100	4		38	10001100011111	2

Table 3 (*continued*)

Class	8-bit data	Modulation codes beginning with "0"	CDS	Class	8-bit data	Modulation codes beginning with "1"	CDS
1(A)	39	01111100111001	4	1(B)	39	10001100111110	2
	3A	01111100110011	4		3A	10001110001111	2
	3B	01111100011110	4		3B	10001110011110	2
	3C	01111100001111	4		3C	10001111000111	2
	3D	01111001111100	4		3D	10001111001110	2
	3E	01111001111001	4		3E	10001111100011	2
	3F	01111001110011	4		3F	10001111100110	2
	40	01111001100111	4		40	10001111110001	2
	41	01111000111110	4		41	10001111111000	2
	42	01111000011111	4		42	10011000011111	2
	43	01110011111100	4		43	10011000111110	2
	44	01110011111001	4		44	10011001100111	2
	45	01110011110011	4		45	10011001110011	2
	46	01110011100111	4		46	10011001111001	2
	47	01110011001111	4		47	10011001111100	2
	48	01110001111110	4		48	10011100001111	2
	49	01110000111111	4		49	10011100011110	2
	4A	01100111111100	4		4A	10011100110011	2
	4B	01100111111001	4		4B	10011100111001	2
	4C	01100111110011	4		4C	10011100111100	2
	4D	01100111100111	4		4D	10011110000111	2
	4E	01100111001111	4		4E	10011110001110	2
	4F	01100110011111	4		4F	10011110011001	2
	50	01100011111110	4		50	10011110011100	2
	51	01111111000001	2		51	10011111000011	2
	52	01111110011000	2		52	10011111000110	2
	53	01111110001100	2		53	10011111001100	2
	54	01111110000110	2		54	10011111100001	2
	55	01111110000011	2		55	10011111110000	2
	56	01111100111000	2		56	10001111001111	4
	57	01111100110001	2		57	10001111100111	4
	58	01111100011100	2		58	10001111110011	4
	59	01111100011001	2		59	10011001111110	4
	5A	01111100001110	2		5A	10011100111110	4
	5B	01111100000111	2		5B	10011110001111	4
	5C	01111001111000	2		5C	10011110011110	4
	5D	01111001110001	2		5D	10011111000111	4
	5E	01111001100110	2		5E	10011111001110	4
	5F	01111001100011	2		5F	10011111100011	4
	60	01111000111100	2		60	10011111100110	4
	61	01111000111001	2	2(B)	61	11000111100111	4
	62	01111000110011	2		62	11000111110011	4
	63	01111000011110	2		63	11000000111111	2
	64	01111000001111	2		64	11000001111110	2
	65	01110011111000	2		65	11000011001111	2
	66	01110011110001	2		66	11000011100111	2
	67	01110011100110	2		67	11000011110011	2
	68	01110011100011	2		68	11000011111001	2
	69	01110011001110	2		69	11000011111100	2
	6A	01110011000111	2		6A	11000110001111	2
	6B	01110001111100	2		6B	11000110011110	2
	6C	01110001111001	2		6C	11000111000111	2
	6D	01110001110011	2		6D	11000111001110	2
	6E	01110001100111	2		6E	11000111100011	2
	6F	01110000111110	2		6F	11000111100110	2
	70	01110000011111	2		70	11000111110001	2

Table 3 (*continued*)

Class	8-bit data	Modulation codes beginning with "0"	CDS	Class	8-bit data	Modulation codes beginning with "1"	CD S
	71	01100111111000	2		71	11000111111000	2
	72	01100111110001	2		72	11001100001111	2
	73	01100111100110	2		73	11001100011110	2
	74	01100111100011	2		74	11001100110011	2
	75	01100111001110	2		75	11001100111001	2
	76	01100111000111	2		76	11001100111100	2
1(A)	77	01100110011110	2		77	11001110000111	2
	78	01100110001111	2		78	11001110001110	2
	79	01100011111100	2		79	11001110011001	2
	7A	01100011111001	2		7A	11001110011100	2
	7B	01100011110011	2		7B	11001111000011	2
	7C	01100011100111	2		7C	11001111000110	2
	7D	01100011001111	2		7D	11001111001100	2
	7E	01100001111110	2		7E	11001111100001	2
	7F	01100000111111	2		7F	11001111110000	2
	80	00111111100000	0		80	11000000011111	0
	81	00111111000001	0		81	11000000111110	0
	82	00111110011000	0		82	11000001100111	0
	83	00111110001100	0		83	11000001110011	0
	84	00111110000110	0		84	11000001111001	0
	85	00111110000011	0		85	11000001111100	0
	86	00111100111000	0		86	11000011000111	0
	87	00111100110001	0		87	11000011001110	0
	88	00111100011100	0		88	11000011100011	0
	89	00111100011001	0		89	11000011100110	0
	8A	00111100001110	0	2(B)	8A	11000011110001	0
	8B	00111100000111	0		8B	11000011111000	0
	8C	00111001111000	0		8C	11000110000111	0
	8D	00111001110001	0		8D	11000110001110	0
	8E	00111001100110	0		8E	11000110011001	0
	8F	00111001100011	0		8F	11000110011100	0
	90	00111000111100	0		90	11000111000011	0
	91	00111000111001	0		91	11000111000110	0
	92	00111000110011	0		92	11000111001100	0
2(A)	93	00111000011110	0		93	11000111100001	0
	94	00111000001111	0		94	11000111110000	0
	95	00110011111000	0		95	11001100000111	0
	96	00110011110001	0		96	11001100001110	0
	97	00110011100110	0		97	11001100011001	0
	98	00110011100011	0		98	11001100011100	0
	99	00110011001110	0		99	11001100110001	0
	9A	00110011000111	0		9A	11001100111000	0
	9B	00110001111100	0		9B	11001110000011	0
	9C	00110001111001	0		9C	11001110000110	0
	9D	00110001110011	0		9D	11001110001100	0
	9E	00110001100111	0		9E	11001110011000	0
	9F	00110000111110	0		9F	11001111000001	0
	A0	00110000011111	0		A0	11001111100000	0
	A1	00111111100001	2		A1	11001100111110	4
	A2	00111111001100	2		A2	11001110011110	4
	A3	00111111000110	2		A3	11001111000111	4
	A4	00111111000011	2		A4	11001111001110	4
	A5	00111110011100	2		A5	11001111100011	4
	A6	00111110011001	2		A6	11001111100110	4

Table 3 (*continued*)

Class	8-bit data	Modulation codes beginning with "0"	CDS	Class	8-bit data	Modulation codes beginning with "1"	CDS
2(A)	A7	00111110001110	2	3(B)	A7	11100001111110	4
	A8	00111110000111	2		A8	11100011100111	4
	A9	00111100111100	2		A9	11100011110011	4
	AA	00111100111001	2		AA	11100011111100	4
	AB	00111100110011	2		AB	11100110011110	4
	AC	00111100011110	2		AC	11100111000111	4
	AD	00111100001111	2		AD	11100111001110	4
	AE	00111001111100	2		AE	11100111100011	4
	AF	00111001111001	2		AF	11100111100110	4
	B0	00111001110011	2		B0	11100111111000	4
	B1	00111001100111	2		B1	11100000011111	2
	B2	00111000111110	2		B2	11100000111110	2
	B3	00111000011111	2		B3	11100001100111	2
	B4	00110011111100	2		B4	11100001110011	2
	B5	00110011111001	2		B5	11100001111001	2
	B6	00110011110011	2		B6	11100001111100	2
	B7	00110011100111	2		B7	11100011000111	2
	B8	00110011001111	2		B8	11100011001110	2
	B9	00110001111110	2		B9	11100011100011	2
	BA	00110000111111	2		BA	11100011100110	2
	BB	00111111100110	4		BB	11100011110001	2
	BC	00111111100011	4		BC	11100011111000	2
	BD	00111111001110	4		BD	11100110000111	2
	BE	00111111000111	4		BE	11100110001110	2
	BF	00111110011110	4		BF	11100110011001	2
	C0	00111110001111	4		C0	11100110011100	2
	C1	00111100111110	4		C1	11100111000011	2
	C2	00111100011111	4		C2	11100111000110	2
	C3	00111001111110	4		C3	11100111001100	2
	C4	00111000111111	4		C4	11100111100001	2
	C5	00110011111110	4		C5	11100111110000	2
3(A)	C6	00011111110000	0		C6	11100000001111	0
	C7	00011111100001	0		C7	11100000011110	0
	C8	00011111001100	0		C8	11100000110011	0
	C9	00011111000110	0		C9	11100000111001	0
	CA	00011111000011	0		CA	11100000111100	0
	CB	00011110011100	0		CB	11100001100011	0
	CC	00011110011001	0		CC	11100001100110	0
	CD	00011110001110	0		CD	11100001110001	0
	CE	00011110000111	0		CE	11100001111000	0
	CF	00011100111100	0		CF	11100011000011	0
	D0	00011100111001	0		D0	11100011000110	0
	D1	00011100110011	0		D1	11100011001100	0
	D2	00011100011110	0		D2	11100011100001	0
	D3	00011100001111	0		D3	11100011110000	0
	D4	00011001111100	0		D4	11100110000011	0
	D5	00011001111001	0		D5	11100110000110	0
	D6	00011001110011	0		D6	11100110001100	0
	D7	00011001100111	0		D7	11100110011000	0
	D8	00011000111110	0		D8	11100111000001	0
	D9	00011000011111	0		D9	11100111100000	0
	DA	00011111110001	2	4(B)	DA	11110001111100	4
	DB	00011111100110	2		DB	11110011111000	4
	DC	00011111100011	2		DC	11110000001111	2
	DD	00011111001110	2		DD	11110000011110	2

Table 3 (*continued*)

Class	8-bit data	Modulation codes beginning with "0"	CDS	Class	8-bit data	Modulation codes beginning with "1"	CDS
	DE	00011111000111	2		DE	11110000110011	2
	DF	00011110011110	2		DF	11110000111001	2
	E0	00011110001111	2		E0	11110000111100	2
	E1	00011100111110	2		E1	11110001100011	2
	E2	00011100011111	2		E2	11110001100110	2
3(A)	E3	00011001111110	2		E3	11110001110001	2
	E4	00011000111111	2		E4	11110001111000	2
	E5	00011111110011	4		E5	11110011000011	2
	E6	00011111100111	4		E6	11110011000110	2
	E7	00011111001111	4		E7	11110011001100	2
	E8	00011110011111	4	4(B)	E8	11110011100001	2
	E9	00011100111111	4		E9	11110011110000	2
	EA	00001111111000	0		EA	11110000000111	0
	EB	00001111110001	0		EB	11110000001110	0
	EC	00001111100110	0		EC	11110000011001	0
	ED	00001111100011	0		ED	11110000011100	0
	EE	00001111001110	0		EE	11110000110001	0
	EF	00001111000111	0		EF	11110000111000	0
	F0	00001110011110	0		F0	11110001100001	0
	F1	00001110001111	0		F1	11110001110000	0
4(A)	F2	00001100111110	0		F2	11110011000001	0
	F3	00001100011111	0		F3	11110011100000	0
	F4	00001111111001	2		F4	11111000000111	2
	F5	00001111110011	2		F5	11111000001110	2
	F6	00001111100111	2		F6	11111000011001	2
	F7	00001111001111	2		F7	11111000011100	2
	F8	00001110011111	2		F8	11111000110001	2
	F9	00001100111111	2	5(B)	F9	11111000111000	2
	FA	00000111111100	0		FA	11111001100001	2
	FB	00000111111001	0		FB	11111001110000	2
	FC	00000111110011	0		FC	11111000001100	0
5(A)	FD	00000111100111	0		FD	11111000011000	0
	FE	00000111001111	0		FE	11111000110000	0
	FF	00000110011111	0		FF	11111001100000	0

Table 4 – 8-14 modulation (CDS≤0)

Class	8-bit data	Modulation codes beginning with "0"	CDS	Class	8-bit data	Modulation codes beginning with "1"	CDS
	00	01111110000001	0		00	10000001111110	0
	01	01111100110000	0		01	10000011001111	0
	02	01111100011000	0		02	10000011100111	0
	03	01111100001100	0		03	10000011110011	0
	04	01111100000110	0		04	10000011111001	0
	05	01111100000011	0		05	10000011111100	0
	06	01111001110000	0		06	10000110001111	0
	07	01111001100001	0		07	10000110011110	0
	08	01111000111000	0		08	10000111000111	0
	09	01111000110001	0		09	10000111001110	0
	0A	01111000011100	0		0A	10000111100011	0
	0B	01111000011001	0		0B	10000111100110	0
	0C	01111000001110	0		0C	10000111110001	0
	0D	01111000000111	0		0D	10000111111000	0
	0E	01110011110000	0		0E	10001100001111	0
	0F	01110011100001	0		0F	10001100011110	0
	10	01110011001100	0		10	10001100110011	0
	11	01110011000110	0		11	10001100111001	0
	12	01110011000011	0		12	10001100111100	0
	13	01110001111000	0		13	10001110000111	0
	14	01110001110001	0		14	10001110001110	0
	15	01110001100110	0		15	10001110011001	0
	16	01110001100011	0		16	10001110011100	0
	17	01110000111100	0		17	10001111000011	0
	18	01110000111001	0		18	10001111000110	0
	19	01110000110011	0		19	10001111001100	0
	1A	01110000011110	0		1A	10001111100001	0
	1B	01110000001111	0		1B	10001111110000	0
1(C)	1C	01100111110000	0	1(D)	1C	10011000001111	0
	1D	01100111100001	0		1D	10011000011110	0
	1E	01100111001100	0		1E	10011000110011	0
	1F	01100111000110	0		1F	10011000111001	0
	20	01100111000011	0		20	10011000111100	0
	21	01100110011100	0		21	10011001100011	0
	22	01100110011001	0		22	10011001100110	0
	23	01100110001110	0		23	10011001110001	0
	24	01100110000111	0		24	10011001111000	0
	25	01100011111000	0		25	10011100000111	0
	26	01100011110001	0		26	10011100001110	0
	27	01100011100110	0		27	10011100011001	0
	28	01100011100011	0		28	10011100011100	0
	29	01100011001110	0		29	10011100110001	0
	2A	01100011000111	0		2A	10011100111000	0
	2B	01100001111100	0		2B	10011110000011	0
	2C	01100001111001	0		2C	10011110000110	0
	2D	01100001110011	0		2D	10011110001100	0
	2E	01100001100111	0		2E	10011110011000	0
	2F	01100000111110	0		2F	10011111000001	0
	30	01100000011111	0		30	10011111100000	0
	31	01111100000001	-2		31	10000000110011	-4
	32	01111001100000	-2		32	10000000111001	-4
	33	01111000110000	-2		33	10000000111100	-4
	34	01111000011000	-2		34	10000001100011	-4
	35	01111000001100	-2		35	10000001100110	-4
	36	01111000000110	-2		36	10000001110001	-4
	37	01111000000011	-2		37	10000001111000	-4
	38	01110011100000	-2		38	10000011000011	-4

Table 4 (*continued*)

Class	8-bit data	Modulation codes beginning with "0"	CDS	Class	8-bit data	Modulation codes beginning with "1"	CDS
1(C)	39	01110011000001	-2	1(D)	39	10000011000110	-4
	3A	01110001110000	-2		3A	10000011001100	-4
	3B	01110001100001	-2		3B	10000011100001	-4
	3C	01110000111000	-2		3C	10000011110000	-4
	3D	01110000110001	-2		3D	10000110000011	-4
	3E	01110000011100	-2		3E	10000110000110	-4
	3F	01110000011001	-2		3F	10000110001100	-4
	40	01110000001110	-2		40	10000110011000	-4
	41	01110000000111	-2		41	10000111000001	-4
	42	01100111100000	-2		42	10000111100000	-4
	43	01100111000001	-2		43	10001100000011	-4
	44	01100110011000	-2		44	10001100000110	-4
	45	01100110001100	-2		45	10001100001100	-4
	46	01100110000110	-2		46	10001100011000	-4
	47	01100110000011	-2		47	10001100110000	-4
	48	01100011110000	-2		48	10001110000001	-4
	49	01100011100001	-2		49	10001111000000	-4
	4A	01100011001100	-2		4A	10011000000011	-4
	4B	01100011000110	-2		4B	10011000000110	-4
	4C	01100011000011	-2		4C	10011000001100	-4
	4D	01100001111000	-2		4D	10011000011000	-4
	4E	01100001110001	-2		4E	10011000110000	-4
	4F	01100001100110	-2		4F	10011001100000	-4
	50	01100001100011	-2		50	10011100000001	-4
	51	01100000111100	-2		51	10000000111110	-2
	52	01100000111001	-2		52	10000001100111	-2
	53	01100000110011	-2		53	10000001110011	-2
	54	01100000011110	-2		54	10000001111001	-2
	55	01100000001111	-2		55	10000001111100	-2
	56	01110000110000	-4		56	10000011000111	-2
	57	01110000011000	-4		57	10000011001110	-2
	58	01110000001100	-4		58	10000011100011	-2
	59	01100110000001	-4		59	10000011100110	-2
	5A	01100011000001	-4		5A	10000011110001	-2
	5B	01100001110000	-4		5B	10000011111000	-2
	5C	01100001100001	-4		5C	10000110000111	-2
	5D	01100000111000	-4		5D	10000110001110	-2
	5E	01100000110001	-4		5E	10000110011001	-2
	5F	01100000011100	-4		5F	10000110011100	-2
	60	01100000011001	-4		60	10000111000011	-2
	61	00111000011000	-4		61	10000111000110	-2
2(C)	62	00111000001100	-4		62	10000111001100	-2
	63	00111111000000	-2		63	10000111100001	-2
	64	00111110000001	-2		64	10000111110000	-2
	65	00111100110000	-2		65	10001100000111	-2
	66	00111100011000	-2		66	10001100001110	-2
	67	00111100001100	-2		67	10001100011001	-2
	68	00111100000110	-2		68	10001100011100	-2
	69	00111100000011	-2		69	10001100110001	-2
	6A	00111001110000	-2		6A	10001100111000	-2
	6B	00111001100001	-2		6B	10001110000011	-2
	6C	00111000111000	-2		6C	10001110000110	-2
	6D	00111000110001	-2		6D	10001110001100	-2
	6E	00111000011100	-2		6E	10001110011000	-2
	6F	00111000011001	-2		6F	10001111000001	-2
	70	00111000001110	-2		70	10001111100000	-2

Table 4 (*continued*)

Class	8-bit data	Modulation codes beginning with "0"	CDS	Class	8-bit data	Modulation codes beginning with "1"	CDS
	71	00111000000111	-2		71	10011000000111	-2
	72	00110011110000	-2		72	10011000001110	-2
	73	00110011100001	-2		73	10011000011001	-2
	74	00110011001100	-2		74	10011000011100	-2
	75	00110011000110	-2		75	10011000110001	-2
	76	00110011000011	-2		76	10011000111000	-2
	77	00110001111000	-2	1(D)	77	10011001100001	-2
	78	00110001110001	-2		78	10011001110000	-2
	79	00110001100110	-2		79	10011100000011	-2
	7A	00110001100011	-2		7A	10011100000110	-2
	7B	00110000111100	-2		7B	10011100001100	-2
	7C	00110000111001	-2		7C	10011100011000	-2
	7D	00110000110011	-2		7D	10011100110000	-2
	7E	00110000011110	-2		7E	10011110000001	-2
	7F	00110000001111	-2		7F	10011111000000	-2
	80	00111111100000	0		80	11000000011111	0
	81	00111111000001	0		81	11000000111110	0
	82	00111110011000	0		82	11000001100111	0
	83	00111110001100	0		83	11000001110011	0
	84	00111110000110	0		84	11000001111001	0
	85	00111110000011	0		85	11000001111100	0
	86	00111100111000	0		86	11000011000111	0
	87	00111100110001	0		87	11000011001110	0
	88	00111100011100	0		88	11000011100011	0
	89	00111100011001	0		89	11000011100110	0
2(C)	8A	00111100001110	0		8A	11000011110001	0
	8B	00111100000111	0		8B	11000011111000	0
	8C	00111001111000	0		8C	11000110000111	0
	8D	00111001110001	0		8D	11000110001110	0
	8E	00111001100110	0		8E	11000110011001	0
	8F	00111001100011	0		8F	11000110011100	0
	90	00111000111100	0		90	11000111000011	0
	91	00111000111001	0		91	11000111000110	0
	92	00111000110011	0		92	11000111001100	0
	93	00111000011110	0		93	11000111100001	0
	94	00111000001111	0	2(D)	94	11000111110000	0
	95	00110011111000	0		95	11001100000111	0
	96	00110011110001	0		96	11001100001110	0
	97	00110011100110	0		97	11001100011001	0
	98	00110011100011	0		98	11001100011100	0
	99	00110011001110	0		99	11001100110001	0
	9A	00110011000111	0		9A	11001100111000	0
	9B	00110001111100	0		9B	11001110000011	0
	9C	00110001111001	0		9C	11001110000110	0
	9D	00110001110011	0		9D	11001110001100	0
	9E	00110001100111	0		9E	11001110011000	0
	9F	00110000111110	0		9F	11001111000001	0
	A0	00110000011111	0		A0	11001111100000	0
	A1	00110011000001	-4		A1	11000000011110	-2
	A2	00110001100001	-4		A2	11000000110011	-2
	A3	00110000111000	-4		A3	11000000111001	-2
	A4	00110000110001	-4		A4	11000000111100	-2
	A5	00110000011100	-4		A5	11000001100011	-2
	A6	00110000011001	-4		A6	11000001100110	-2

Table 4 (*continued*)

Class	8-bit data	Modulation codes beginning with "0"	CDS	Class	8-bit data	Modulation codes beginning with "1"	CDS
	A7	00011110000001	-4		A7	11000001110001	-2
	A8	00011100011000	-4		A8	11000001111000	-2
	A9	00011100001100	-4		A9	11000011000011	-2
	AA	00011100000011	-4		AA	11000011000110	-2
	AB	00011001100001	-4		AB	11000011001100	-2
	AC	00011000111000	-4		AC	11000011100001	-2
	AD	00011000110001	-4		AD	11000011110000	-2
	AE	00011000011100	-4		AE	11000110000011	-2
	AF	00011000011001	-4		AF	11000110000110	-2
	B0	00011000000111	-4		B0	11000110001100	-2
	B1	00011111100000	-2		B1	11000110011000	-2
	B2	00011111000001	-2		B2	11000111000001	-2
	B3	00011110011000	-2		B3	11000111100000	-2
	B4	00011110001100	-2		B4	11001100000011	-2
	B5	00011110000110	-2	2(D)	B5	11001100000110	-2
	B6	00011110000011	-2		B6	11001100001100	-2
	B7	00011100111000	-2		B7	11001100011000	-2
	B8	00011100110001	-2		B8	11001100110000	-2
	B9	00011100011100	-2		B9	11001110000001	-2
	BA	00011100011001	-2		BA	11001111000000	-2
	BB	00011100001110	-2		BB	11000000011001	-4
	BC	00011100000111	-2		BC	11000000011100	-4
	BD	00011001111000	-2		BD	11000000110001	-4
3(C)	BE	00011001110001	-2		BE	11000000111000	-4
	BF	00011001100110	-2		BF	11000001100001	-4
	C0	00011001100011	-2		C0	11000001110000	-4
	C1	00011000111100	-2		C1	11000011000001	-4
	C2	00011000111001	-2		C2	11000011100000	-4
	C3	00011000110011	-2		C3	11000110000001	-4
	C4	00011000011110	-2		C4	11000111000000	-4
	C5	00011000001111	-2		C5	11001100000001	-4
	C6	00011111110000	0		C6	11100000001111	0
	C7	00011111100001	0		C7	11100000011110	0
	C8	00011111001100	0		C8	11100000110011	0
	C9	00011111000110	0		C9	11100000111001	0
	CA	00011111000011	0		CA	11100000111100	0
	CB	00011110011100	0		CB	11100001100011	0
	CC	00011110011001	0		CC	11100001100110	0
	CD	00011110001110	0		CD	11100001110001	0
	CE	00011110000111	0		CE	11100001111000	0
	CF	00011100111100	0		CF	11100011000011	0
	D0	00011100111001	0		D0	11100011000110	0
	D1	00011100110011	0		D1	11100011001100	0
	D2	00011100011110	0	3(D)	D2	11100011100001	0
	D3	00011100001111	0		D3	11100011110000	0
	D4	00011001111100	0		D4	11100110000011	0
	D5	00011001111001	0		D5	11100110000110	0
	D6	00011001110011	0		D6	11100110001100	0
	D7	00011001100111	0		D7	11100110011000	0
	D8	00011000111110	0		D8	11100111000001	0
	D9	00011000011111	0		D9	11100111100000	0
	DA	00001110000011	-4		DA	11100000001110	-2
	DB	00001100000111	-4		DB	11100000011001	-2
4(C)	DC	00001111110000	-2		DC	11100000011100	-2
	DD	00001111100001	-2		DD	11100000110001	-2

Table 4 (*continued*)

Class	8-bit data	Modulation codes beginning with "0"	CDS	Class	8-bit data	Modulation codes beginning with "1"	CDS
4(C)	DE	00001111001100	-2	3(D)	DE	11100000111000	-2
	DF	00001111000110	-2		DF	11100001100001	-2
	E0	00001111000011	-2		E0	11100001110000	-2
	E1	00001110011100	-2		E1	11100011000001	-2
	E2	00001110011001	-2		E2	11100011100000	-2
	E3	00001110001110	-2		E3	11100110000001	-2
	E4	00001110000111	-2		E4	11100111000000	-2
	E5	00001100111100	-2		E5	11100000001100	-4
	E6	00001100111001	-2		E6	11100000011000	-4
	E7	00001100110011	-2		E7	11100000110000	-4
	E8	00001100011110	-2		E8	11100001100000	-4
	E9	00001100001111	-2		E9	11100011000000	-4
	EA	00001111111000	0	4(D)	EA	11110000000111	0
	EB	00001111110001	0		EB	11110000001110	0
	EC	00001111100110	0		EC	11110000011001	0
	ED	00001111100011	0		ED	11110000011100	0
	EE	00001111001110	0		EE	11110000110001	0
	EF	00001111000111	0		EF	11110000111000	0
	F0	00001110011110	0		F0	11110001100001	0
	F1	00001110001111	0		F1	11110001110000	0
	F2	00001100111110	0		F2	11110011000001	0
	F3	00001100011111	0		F3	11110011100000	0
5(C)	F4	00000111111000	-2		F4	11110000000110	-2
	F5	00000111110001	-2		F5	11110000001100	-2
	F6	00000111100110	-2		F6	11110000011000	-2
	F7	00000111100011	-2		F7	11110000110000	-2
	F8	00000111001110	-2		F8	11110001100000	-2
	F9	00000111000111	-2		F9	11110011000000	-2
	FA	00000110011110	-2	5(D)	FA	11111000000011	0
	FB	00000110001111	-2		FB	11111000000110	0
	FC	00000111110011	0		FC	11111000001100	0
	FD	00000111100111	0		FD	11111000011000	0
	FE	00000111001111	0		FE	11111000110000	0
	FF	00000110011111	0		FF	11111001100000	0

Table 5 – Priority of modulation code selection (end DSV = –2)

Modulation codes	Priority
x x x x x x x x x x x x 0 0 1	4
x x x x x x x x x x x 0 0 1 1	1
x x x x x x x x x x 0 0 1 1 1	2
x x x x x x x x x 0 0 1 1 1 1	3
x x x x x x x x 0 0 1 1 1 1 1	8
x x x x x x x x x x x x 1 1 0	10
x x x x x x x x x x x 1 1 0 0	5
x x x x x x x x x x 1 1 0 0 0	6
x x x x x x x x x 1 1 0 0 0 0	7
x x x x x x x x 1 1 0 0 0 0 0	9
x x x x x x x 1 1 0 0 0 0 0 0	11

NOTE 1 "x" is a don't-care bit.

NOTE 2 This table shall be used in the case where DSV at the end of modulation code is –2

Table 6 – Priority of modulation code selection (end DSV = +2)

Modulation codes	Priority
x x x x x x x x x x x x 1 1 0	4
x x x x x x x x x x x 1 1 0 0	1
x x x x x x x x x x 1 1 0 0 0	2
x x x x x x x x x 1 1 0 0 0 0	3
x x x x x x x x 1 1 0 0 0 0 0	8
x x x x x x x x x x x x 0 0 1	10
x x x x x x x x x x x 0 0 1 1	5
x x x x x x x x x x 0 0 1 1 1	6
x x x x x x x x x 0 0 1 1 1 1	7
x x x x x x x x 0 0 1 1 1 1 1	9
x x x x x x x 0 0 1 1 1 1 1 1	11

NOTE 1 "x" is a don't-care bit.

NOTE 2 This table shall be used in the case where DSV at the end of modulation code is +2.

Table 7 – Data rate and wavelength

Parameter	
Total average data rate	300,6 Mb/s
Instantaneous channel data rate	76,5 Mb/s
Shortest recorded wavelength	0,64 μm

6.6 Magnetization

6.6.1 Polarity

Reproduction of the tape record shall be without regard to the polarity of the recorded flux on the helical tracks.

6.6.2 Recorded equalization

The record head current applied to a head should generate a constant magnetic flux level within a gap from the lowest recorded frequency (i.e. approximately one-third the Nyquist frequency) to the Nyquist frequency.

6.6.3 Record level

The level of the record head current applied to a head with a gap should be optimized for best reproduced signal-to-noise ratio at the highest constant recorded frequency (i.e. the Nyquist frequency of the channel). Other methods of setting the record level are permitted, providing they achieve the same results.

7 Video interface

The video signal interface conforms to the following:

Compressed video data Part 2

8 Audio interface

8.1 Encoding parameters

The digital audio signal is encoded according to the following parameters:

8.1.1 Sampling

a) The sampling frequency is 48,000 kHz and shall be related to the horizontal frequency as follows:

   48 kHz = $F_H \times 1\ 144 / 375$.

b) The resolution of each sample is 16 bits minimum, 20 bits maximum.

c) The coding is two's complement linear PCM.

8.1.2 Reference level

The recommended recorded audio levels should conform to SMPTE RP 155.

8.2 Digital signal interface

The principal mode of interface is analogue. The audio signal may also be input and output digitally in a bit-serial form. The bit-serial interface, if present, shall conform to IEC 60958 without error checking.

9 Video processing

9.1 Introduction

The purpose of the video processing operation is to transform the HD compressed video data into a form suitable for tape recording.

The HD compressed video data are reconfigured and supplemented with the Signal Format Information, and are distributed into 12 video blocks (4 channels, each channel with 3 video blocks).

For the data, randomization, column shuffling, outer error correction code addition, and interleaving operations are performed.

The ID is multiplexed with the interleaved data and applied to the Inner Error Correction Coder. A Sync Word is added to each code block to form a sync block, the smallest data block.

Prior to recording, randomization and 8-14 conversion are performed.

9.2 Recorded data

9.2.1 Reconfiguration of DIF data

The HD compressed video data is composed of 5 760 DIF blocks and each DIF block is composed of 85 bytes of data, defined in Part 2.

Each data D(DN,BN) of DIF blocks are reconfigured into a matrix as data P(S,L,H) (where S=0, 1, 2, 3,; L = 0, 1, ... , 254; H = 0, 1, ... , 959) as shown in Figure 14.

The rule for reconfiguration is described below:

$$S = (85 \times DN + BN) \bmod 4$$

$$L = (\text{int}((85 \times DN + BN) / 4)) \bmod 255$$

$$H = 8 \times ((\text{int}(DN/12)) \bmod 120) + 2 \times (\text{int}(DN/1\,440)) + \text{int}(S/3)$$

where

DN: DIF block number (DN = 0, 1, ... , 5 759)

BN: Byte location number in DIF block (BN = 0, 1, ... , 84)

9.2.2 Signal format information

To identify signal format, signal format information shown in Table 8 replaces the following five data. P(0,0,0) and P(1,0,0) are replaced by Byte0 of signal format information. P(3,0,1) is replaced by Byte1; P(1,0,2) is replaced by Byte2; P(3,0,3) is replaced by Byte3 of signal format information. These data exist at the first part of L = 0.

Table 8 – Signal format information

	Byte 0	Byte 1	Byte 2	Byte 3
1 080/60i	21 h	02 h	01 h	20 h
720/60p	23 h	01 h	01 h	20 h

If the remaining data P(S,0,H) of L=0 is not filled by other data, the rest of P(1,0,H) and P(3,0,H) shall be set to 10 $_h$, and the rest of P(0,0,H) and P(2,0,H) shall be set to 80 $_h$.

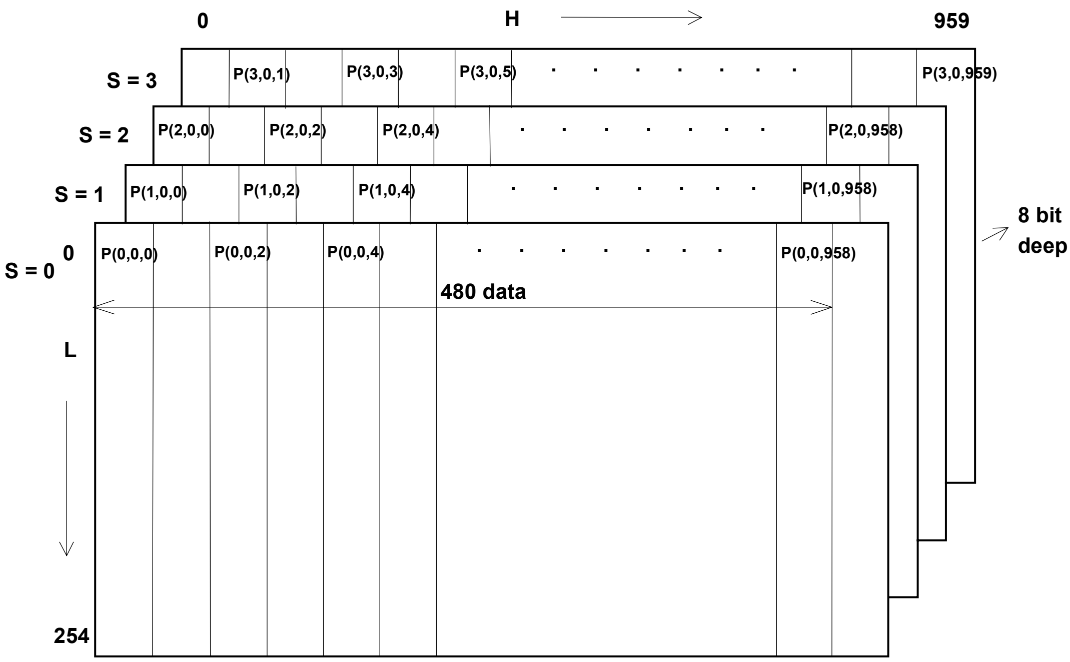


Figure 14 – Reconfigured data

9.3 Channel and video block distribution

The data P(S,L,H) shall be distributed by channel and segment as follows:

The actual index for channel distribution (Ch) and video block distribution (Vblk) is indicated below.

Ch = {int (H/2)} mod 4,

Vblk = int (H/320)

Spls means the data position of the horizontal direction of Figure 15.

Spls = {int (H/8)} mod 40

where

Spls = 0, 1, 2, ... 39

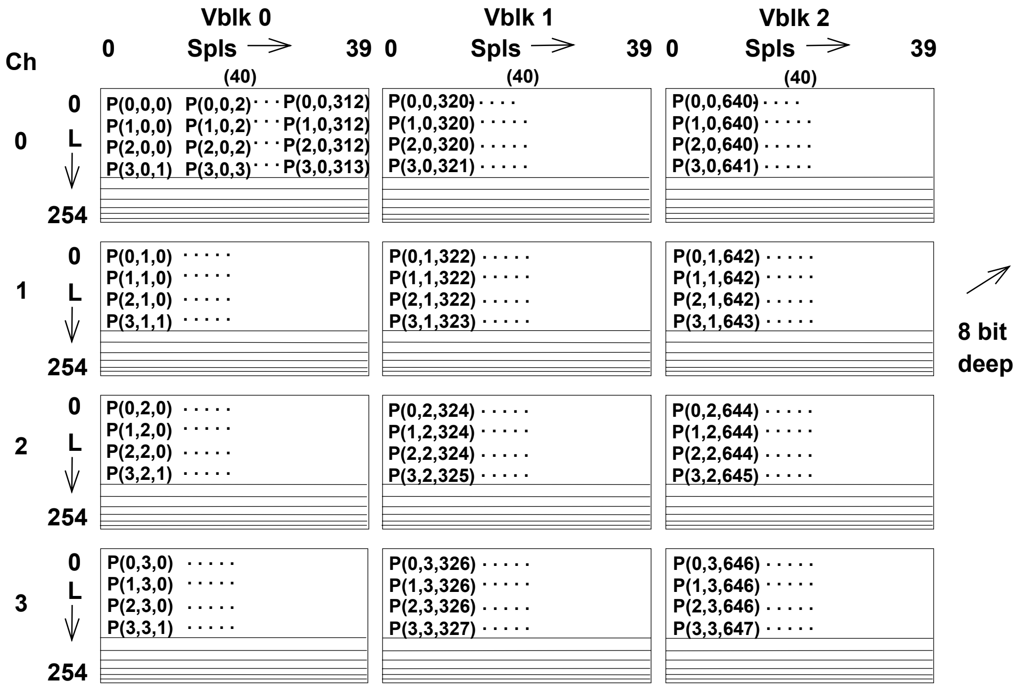


Figure 15 – Channel and video block distribution

9.4 Word data arrangement

Each data word consists of 8 bits.

Let Oc (= 0, 1, 2, 3) be the outer code number.

Oc = 0: for S=0

Oc = 1: for S=2

Oc = 2: for S=1

Oc = 3: for S=3

Let Splo be the sample number within an outer code block.

Splo = 40 $\times$ Vblk + Spls

Splo = 0, 1, ... 119

9.5 Video randomize

Video randomization is performed to further reduce the direct current content of the video data stream. It is done prior to the integration of the outer code. Each video data word (byte) is replaced by a new word produced by an exclusive-OR operation between the original video data stream and a random data stream generated by the following polynomial function:

$x^8 + x^4 + x^3 + x^2 + 1$, (in GF(2)).

The random data stream shall be pre-set to the following value for each line:

M0 = 128 + (L mod 128)

9.6 Outer error protection

Eight rows of each video field data array contain the error correction check data associated with each column of 8-bit bytes.

Type: Reed-Solomon.
Galois field: GF(256).

Field generator polynomial: $x^8 + x^4 + x^3 + x^2 + 1$,
where x^i are place-keeping variables in GF(2), the binary field.

Order of use: the left-most term is the most significant, and the oldest in time computationally.

Code generator polynomial in GF(256):
$G(x) = (x+1)(x+a)(x+a^2)(x+a^3)(x+a^4)(x+a^5)(x+a^6)(x+a^7)$,
where a is given by 02_h in GF(256).

Check characters: $K_7, K_6, K_5, K_4, K_3, K_2, K_1, K_0$ in $K_7x^7 + K_6x^6 + K_5x^5 + K_4x^4 + K_3x^3 + K_2x^2 + K_1x^1 + K_0$ are obtained as the remainder after dividing $x^8D(x)$ by G(x), where D(x) is thepolynomial given by $D(x) = B_{119}x^{119} + B_{118}x^{118} + \ldots + B_2x^2 + B_1x + B_0$.

Equation of full code is given by: $B_{119}x^{127} + B_{118}x^{126} + B_{117}x^{125} \ldots + B_1x^9 + B_0x^8 + K_7x^7 + K_6x^6 + K_5x^5 + K_4x^4 + K_3x^3 + K_2x^2 + K_1x + K_0$.

9.7 Field data array

The columns and rows for each field are 1 020 and 128 respectively.

The field data array is shown in Figure 16.

Column shuffling is the relocation of the column of the field data array.

The sample number of the data in the outer code block Oc, Splo, is written into the field memory at the coordinates shown below:

Row = Splo

Col = $4 \times L$ + B (Oc)

where B (0) = 0; B (1) = 1; B (2) = 2; B (3) = 3.

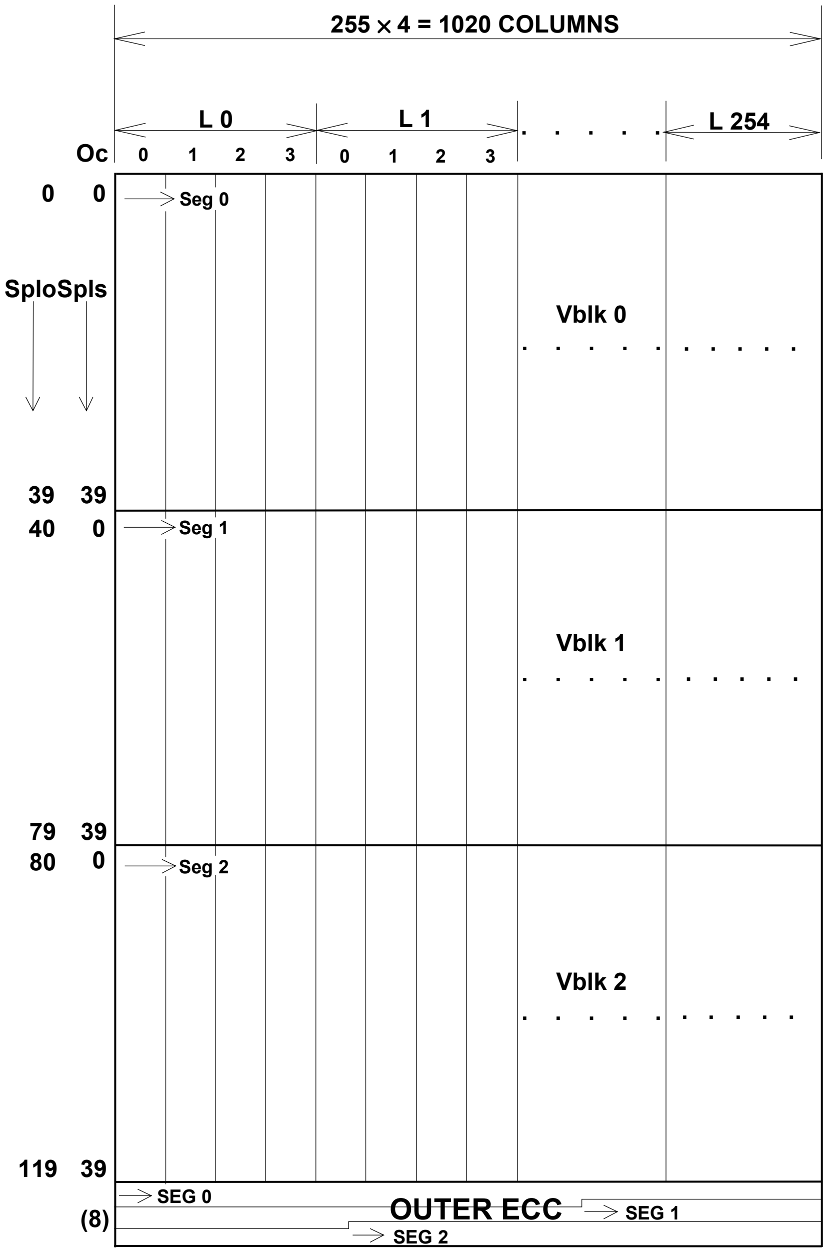


Figure 16 – Field data array

9.8 Order of transmission to inner coding

The field memory array data is written to tape first by ascending column order, then by ascending row order. Video data bytes and outer check bytes shall be divided into 3 segments. The outer check bytes are written to tape first and followed by data bytes.

Let Seg be the segment number within a video field:

Seg = 0, 1, 2

Let Fld be the field number within a colour frame:

Fld = 0, 1, 2, 3

The start point address number Xin of the field memory array is as follows:

For the outer check bytes:

Xin = 1 440 + 32 x Seg

For the outer data bytes:

Xin = 480 × Seg mod 1 440

The relationship between Xin and Row or Col of the field memory is:

Xin = 12 × Row + int (Col/85)

10 Audio processing

10.1 Introduction

Audio in each of the four channels is processed independently and identically into a product block for each channel of dimensions 85 × 3 columns by 8 rows. The audio samples of each channel are shuffled in a field before the addition of error correction data in the vertical (row) direction. Error correction in the horizontal (column) dimension is common with video data.

Auxiliary words are multiplexed with the audio data in the product block to provide housekeeping in the interface and in processing. Figure 17 shows the audio data block field array.

10.2 Source coding

Audio records that meet the requirements of ITU-R BS.647 are formed independently for each of four audio channels, from audio and ancillary data at the input interface. The data include audio data, channel status data (C), user data (U), and validity data (V). Parity bits are discarded. The remaining bit positions in the audio data words are reserved (R) for future use. Block sync marks for ancillary data are also processed. ITU-T J.17 pre-emphasis is not recognized.

Source data is defined as follows:

a) Audio data:
   - Sampling frequency: 48 kHz ± 3 parts in 10^6, synchronous with video
   - Word length: 20 bits
   - Coding: Two's complement linear PCM

b) Channel status data:

- Bit rate: 48 kbit/s (nominal)
- Word rate: 6 kByte/s
- Word length: 8 bits
- Block length: 192 bits, 24 words
- Coding: See IEC 60958

NOTE 1 Bytes 0 and 1 of AES status data are selected only for special processing in the DVTR. The contents of bytes 0 and 1 are shown in Tables 9 and 10, respectively.

NOTE 2 Bytes 22 and 23 of AES status data contain protection and validity information for bytes 0-21 and may be used in some source decoders.

c) User data:

- Bit rate: One bit associated with each audio word
- Coding: Undefined

d) Validity data:

- Bit rate: One bit associated with each audio word
- Coding: 0 = sample valid
  1 = sample defective

e) Parity bit:

- Bit rate: One bit associated with each audio word
- Coding: Even parity of associated word including audio, status, user, and validity data

			85 BYTES	85 BYTES	85 BYTES
AUDIO DATA (8 ROWS)	S=0	0	0	1	2
		1	3	4	5
		2	6	7	8
	S=1	3	9	10	11
		4	12	13	14
		5	15	16	17
	S=2	6	18	19	20
		7	21	22	23
OUTER CHECK (8 ROWS)	S=0	8	24	25	26
		9	27	28	29
		10	30	31	32
	S=1	11	33	34	35
		12	36	37	38
		13	39	40	41
	S=2	14	42	43	44
		15	45	46	47

Numeric table entries are audio sync block number.

S Segment number (0,1,2).

Figure 17 – Audio data block field array

Table 9 – AES status data (Byte 0)

LSB							MSB
0	1	2	3	4	5	6	7

Bit 0: 0 = Consumer use
1 = Professional use
Bit 1: 0 = Audio
1 = Data
Bit 2: Pre-emphasis 0
Bit 3: Pre-emphasis 1
Bit 4: Pre-emphasis 2
Bit 5: 0
Bit 6: Sampling frequency 0
Bit 7: Sampling frequency 1

NOTE – Bits 2, 3, and 4 of this byte are recorded in an auxiliary word.

Table 10 – AES status data (Byte 1)

LSB							MSB
0	1	2	3	4	5	6	7

Bit 0: Channel mode bit 0
Bit 1: Channel mode bit 1
Bit 2: Channel mode bit 2
Bit 3: Channel mode bit 3
Bit 4: Reserved
Bit 5: Reserved
Bit 6: Reserved
Bit 7: Reserved

Mode	0 1 2 3	Definition
0	0 0 0 0	Undefined-2 channel
1	0 0 0 1	2 Channel
2	0 0 1 0	Single channel
3	0 0 1 1	Primary/secondary 2 channel
4	0 1 0 0	Stereophonic
5	0 1 0 1	Reserved
	through	
F	1 1 1 1	Reserved

NOTE Bits 0, 1, and 3 of this byte are recorded in an auxiliary word.

10.3 Source processing

10.3.1 Introduction

Audio data is processed in fields. Each field contains 801 or 800 audio samples for an audio channel with associated status, user, and validity data. In addition, a number of control and user words are added to the data.

10.3.2 Relative audio-video timing

An audio field begins with the audio sample acquired 128 samples (±20 sample periods) before the first pre-equalizing pulse of the vertical interval of the input HD video signal.

10.3.3 Audio data in fields

Audio data in fields is processed into an audio block of 85 × 3 × 16, each corresponding to six audio sectors on tape. The data portion of the block is 85 × 3 × 8 bytes and the outer error check bytes portion of the block is also 85 × 3 × 8 bytes.

Audio data words: 801 or 800 words with
associated C, U, V, R bits (20 bits total per word).

Auxiliary data words: 15 words total (20 bits per word).

10.3.4 Intra-field shuffling

The audio data for each channel in each field is shuffled. The intrafield shuffling process operates identically for all fields.

Let Col be the column number within an audio field:

Col = 0, 1, . . . , 101.

Let Row be the row number within an audio field:

Row = 0, 1, . . . , 15

Row 8 to 15 contain the error correction data.

Let Oblk be the data block number:

$$\text{Oblk} = 3 \times \text{Row} + \text{int}(\text{Col} / 34)$$

The data block array is shown in Figure 18. Then sample number Smp within an audio field is obtained according to the following formula:

$$\text{Smp} = 24 \times (\text{Col mod } 34) + \text{int}(\text{Oblk} / 8) + 3 \times (\text{Oblk mod } 8)$$

When Smp is larger than 800, Smp = 801, 802, . . . , 815 are replaced by AUX 0, AUX 1, . . . , AUX 14.

Figure 18 shows the layout of the shuffled samples in a field array. Outer ECC codes are situated at Row = 8 to 15.

10.3.5 Block shuffling

The block shuffling process operates after the intrafield shuffling identically for all fields.
Let N be the recording order of the data block in an audio sector:

N = 0, 1, 2, 3

Let Seg be the segment number:

Seg = 0, 1, 2

Let Tr be the track number:

Tr = 0, 1, 2, 3

Then the data block Oblk within a field array is mapped according to the following formula:

$$\text{Oblk} = N' + Tr' + 8 \times \text{Seg} + 2 \times (12 - Tr') \times (N' \text{ mod } 2)$$

where

$N' = N + 4 \times \text{int}(Tr/2)$

$Tr' = Tr \bmod 2$

Figure 19 shows the data block arrangement of an audio channel in three pairs of sectors.

10.3.6 Audio data word processing

Input data are formed into words of 20 bits in the sequence:

a) assignment of the 20-bit word to audio and associated data is controlled by user input (see Table 11).

   The most significant bit of the audio word is in bit 19 and unused bits of lower significance are removed. The auxiliary word LNGH (four bits) signals the word mode selected;

b) each group of 20-bit words is divided into 8-bit bytes as shown in Figure 20 and arranged alternately by the MSB and the LSB of the first word of the word group;

c) each group is distributed into the product block in accordance with Figure 18;

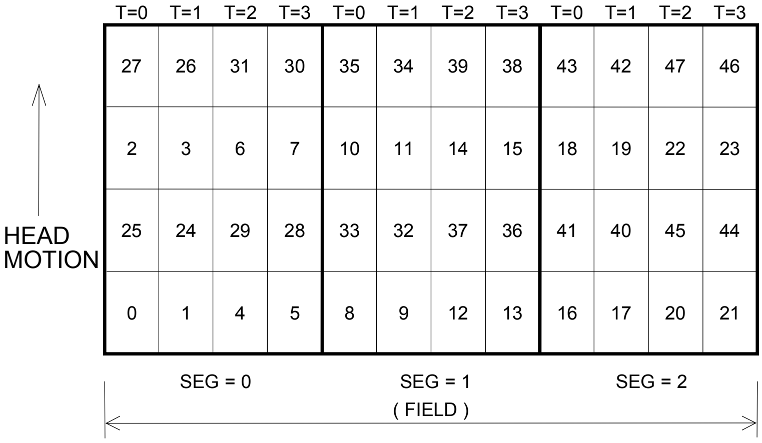
d) every fifth field shall contain 800 samples. All other fields shall contain 801 samples. The 5-field sequence of the number of audio samples begins at an arbitrarily chosen field. Continuity of the 5-field sequence shall be preserved throughout the recording, including editing. The 5-field sequence is indicated by the value of the auxiliary word FNCT, as defined in 10.4.5. Furthermore, every fifth field of 800 samples is identified by the field address AF_2 for audio sync blocks, as defined in 6.3.3.

		85bytes (34 words)							85bytes (34 words)							85bytes (34 words)						
		0							1							2						
AUDIO DATA 8 bytes	0	0	24	48	72	.....	768	792	3	27	51	75	.....	771	795	6	30	54	78	.....	774	798
	1	9	33	57	81	.....	777	AUX 0	12	36	60	84	.....	780	AUX 3	15	39	63	87	.....	783	AUX 6
	2	18	42	66	90	.....	786	AUX 9	21	45	69	93	.....	789	AUX 12	1	25	49	73	.....	769	793
	3	4	28	52	76	.....	772	798	7	31	55	79	.....	775	799	10	34	58	82	.....	778	AUX 1
	4	13	37	61	85	.....	781	AUX 4	16	40	64	88	.....	784	AUX 7	19	43	67	91	.....	787	AUX 10
	5	22	46	70	94	.....	790	AUX 13	2	26	50	74	.....	770	794	5	29	53	77	.....	773	797
	6	8	32	56	80	.....	776	800	11	35	59	83	.....	779	AUX 2	14	38	62	86	.....	782	AUX 5
	7	17	41	65	89	.....	785	AUX 8	20	44	68	92	.....	788	AUX 11	23	47	71	95	.....	791	AUX 14
OUTER CHECK 8 bytes	8	PV0	PV0	PV0	PV0	.....	PV0	PV0	PV0	PV0	PV0	PV0	.....	PV0	PV0	PV0	PV0	PV0	PV0	.....	PV0	PV0
	9	PV1	PV1	PV1	PV1	.....	PV1	PV1	PV1	PV1	PV1	PV1	.....	PV1	PV1	PV1	PV1	PV1	PV1	.....	PV1	PV1
	10	PV2	PV2	PV2	PV2	.....	PV2	PV2	PV2	PV2	PV2	PV2	.....	PV2	PV2	PV2	PV2	PV2	PV2	.....	PV2	PV2
	11	PV3	PV3	PV3	PV3	.....	PV3	PV3	PV3	PV3	PV3	PV3	.....	PV3	PV3	PV3	PV3	PV3	PV3	.....	PV3	PV3
	12	PV4	PV4	PV4	PV4	.....	PV4	PV4	PV4	PV4	PV4	PV4	.....	PV4	PV4	PV4	PV4	PV4	PV4	.....	PV4	PV4
	13	PV5	PV5	PV5	PV5	.....	PV5	PV5	PV5	PV5	PV5	PV5	.....	PV5	PV5	PV5	PV5	PV5	PV5	.....	PV5	PV5
	14	PV6	PV6	PV6	PV6	.....	PV6	PV6	PV6	PV6	PV6	PV6	.....	PV6	PV6	PV6	PV6	PV6	PV6	.....	PV6	PV6
	15	PV7	PV7	PV7	PV7	.....	PV7	PV7	PV7	PV7	PV7	PV7	.....	PV7	PV7	PV7	PV7	PV7	PV7	.....	PV7	PV7

Numeric table entries are audio sample numbers.

PV= to PV7 represent outer check corresponding to audio data of each column.

Figure 18 – Audio data block layout



Numeric entries are audio sync block numbers.

S Segment number (0, 1, 2).

T Track number (0, 1, 2, 3).

Figure 19 – Audio data block arrangement

Table 11 – Audio data word mode

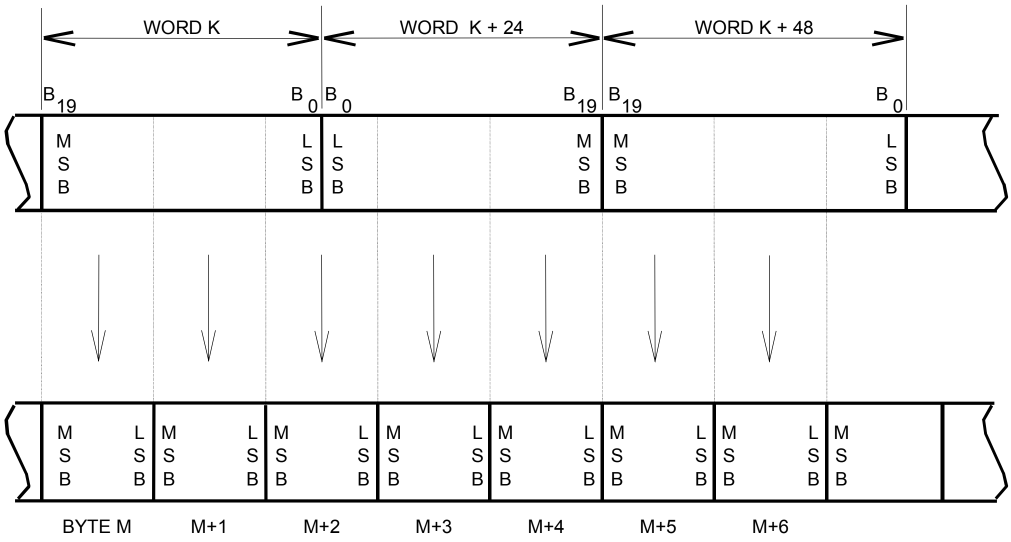
Word mode	Bit				
	0	1	2	3	4-19
0 (000)	C	U	V	R	Audio 0-15
1 (001)	C	U	V	Audio 0 (LSB)	Audio 1-16
2 (010)	C	V	Audio 0 (LSB)	Audio 1	Audio 2-17
3 (011)	C	U	Audio 0 (LSB)	Audio 1	Audio 2-17
4 (100)	C	Audio 0 (LSB)	Audio 1	Audio 2	Audio 3-18
5 (101)	V	Audio 0 (LSB)	Audio 1	Audio 2	Audio 3-18
6 (110)	U	Audio 0 (LSB)	Audio 1	Audio 2	Audio 3-18
7 (111)	Audio 0 (LSB)	Audio 1	Audio 2	Audio 3	Audio 4-19

NOTE 1 C = channel status bit, U = user bit, V = validity bit, R = reserved bit.

NOTE 2 Example, audio 1 represents bit 1 of audio sample.

NOTE 3 Audio data will be rounded from the 20-bit length of the interface word (auxiliary data truncated) to the length above with the elimination of the least significant bit(s).

NOTE 4 Modes 0, 3, and 7 are the recommended modes for general use.



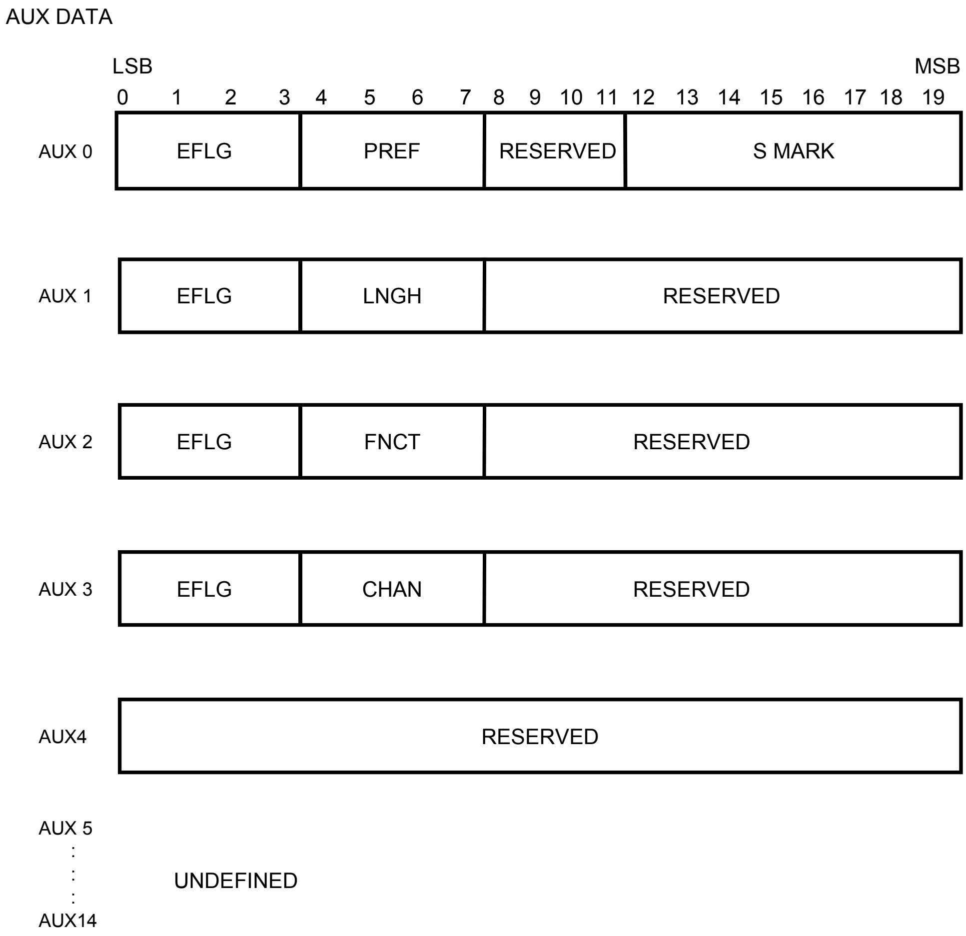
K 0, 9, 18, 4, 22, 8 and 17 in figures 17.

Figure 20 – Digital audio word to byte conversion

10.4 Auxiliary words

Auxiliary words are generated at the input interface from incoming data or user selection and serve to signal this information to the output interface. Auxiliary words are five words of four bits , plus one word of eight bits as defined in Figure 21. The word EFLG is written four times in each audio block.

Figure 21 shows the format of the auxiliary words in the audio data block.

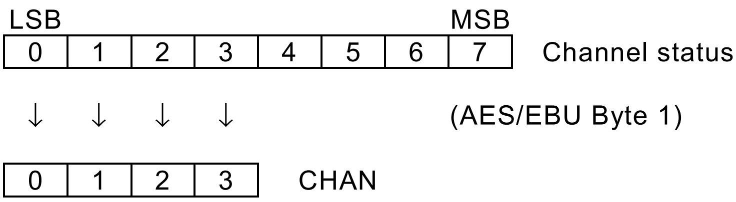


Reserved = 0_h or 000_h or 00000_h

Figure 21 – Audio data block auxiliary data

10.4.1 Channel use (CHAN)

This word is four bits and specifies the usage of the two input channels in an interface data stream. CHAN is derived from channel status byte 1. CHAN is inserted in bits 4-7 of AUX 3. (See Table 12)



Bit 0: Channel mode bit 0
Bit 1: Channel mode bit 1
Bit 2: Channel mode bit 2
Bit 3: Channel mode bit 3

Table 12 – Channel use control word

Mode	CHAN bit 0 1 2 3	Value
0	0 0 0 0	2 Channel-default
1	0 0 0 1	2 Channel
2	0 0 1 0	Single channel
3	0 0 1 1	Primary/secondary 2 channel
4	0 1 0 0	Stereophonic
5	0 1 0 1	Undefined
	through	
F	1 1 1 1	Undefined

10.4.2 Pre-emphasis (PREF)

This word is four bits and specifies the usage of pre-emphasis in the audio coding. PREF is derived from channel status byte 0. PREF is inserted in bits 4-7 of AUX 0 (see Table 13).

LSB MSB

0	1	2	3	4	5	6	7	Channel status
		↓	↓	↓	↓			(AES/EBU Byte 0)
		0	1	2	3			PREF

Bit 0: Pre-emphasis bit 0
Bit 1: Pre-emphasis bit 1
Bit 2: Pre-emphasis bit 2
Bit 3: 0

Table 13 – Pre-emphasis control word

Mode	PREF bit 0 1 2	Value
0	0 0 0	Pre-emphasis off – (default)
1	0 0 1	Reserved
2	0 1 0	Reserved
3	0 1 1	Reserved
4	1 0 0	Pre-emphasis off
5	1 0 1	Reserved
6	1 1 0	50/15 microsecond (CD type)
7	1 1 1	Reserved

10.4.3 Audio data word mode (LNGH)

This word is four bits and specifies the audio word length and the usage of the ancillary bits status, user, and validity. LNGH is derived from user control inputs and inserted in bits 4-7 of AUX 1 (see Table 14).

LSB MSB

0	1	2	3	LNGH

Bit 0: 0
Bit 1: LNGH 1 (LSB)
Bit 2: LNGH 2
Bit 3: LNGH 3 (MSB)

Table 14 – Word mode control word

Mode	LNGH bit 3 2 1	Audio Length	Ancillary bits C U V R
0	0 0 0	16 bits	X X X X
1	0 0 1	17 bits	X X X –
2	0 1 0	18 bits	X – X –
3	0 1 1	18 bits	X X – –
4	1 0 0	19 bits	X – – –
5	1 0 1	19 bits	– – X –
6	1 1 0	19 bits	– X – –
7	1 1 1	20 bits	– – – –
NOTE – "X" means the ancillary bit is recorded.			

10.4.4 Block sync location (S MARK)

S MARK is an 8-bit word. S MARK specifies the location of the block sync associated with channel status and user data, as defined in section 6.0 of ITU-R BS.647. S MARK contains the word count, in the current block, of the first block sync detected; i.e. the word address in the block pointing to the first sample after the block sync mark.

LSB							MSB	
0	1	2	3	4	5	6	7	S MARK

where

S MARK is from 00_h to BF_h inclusive.

S MARK = FF_h if no mark is found within the defined range.

S MARK is inserted in bits 12-19 of AUX 0.

10.4.5 Field number count (FNCT)

This word is four bits and specifies the number of audio samples in the current field. FNCT is inserted in bits 4-7 of AUX 2 (see Table 15).

LSB		MSB		
0	1	2	3	FNCT

Bit 0: FNCT 0 (LSB)
Bit 1: FNCT 1
Bit 2: FNCT 2 (MSB)
Bit 3: 0

Table 15 – FNCT mode

Number of samples	FNCT bit 2 1 0
801	0 0 0
801	0 0 1
801	0 1 0
801	0 1 1
800	1 0 0

10.4.6 Edit flag (EFLG)

This word is four bits and specifies the field associated with an edit transition. EFLG is inserted in bits 0-3 of AUX 0, AUX 1, AUX 2, and AUX 3.

LSB			MSB	
0	1	2	3	EFLG

EFLG = D_h for the first field of the edit
EFLG = 7_h for the last field of the edit
EFLG = 0_h otherwise

10.5 Outer error protection

Rows 8 through 15 of the data block, as shown in Figure 17, contain the error check bytes associated with each column.

Type: Reed-Solomon.

Galois field: GF(256).

Field generator polynomial:

$$x^8 + x^4 + x^3 + x^2 + 1,$$

where x^i are place-keeping variables in GF(2), the binary field.

Order of use: the left-most term is the most significant, "oldest" in time computationally, and written first to tape.

Code generator polynomial:

$$G(x) = (x+1)(x+a)(x+a^2)(x+a^3)(x+a^4)(x+a^5)(x+a^6)(x+a^7),$$

where a is given by 02_h in GF(256).

Check characters: K_7, K_6, K_5, K_4, K_3, K_2, K_1, K_0
(also identified respectively as PV_7, PV_6, PV_5, PV_4, PV_3, PV_2, PV_1, PV_0) in

$$K_7x^7 + K_6x^6 + K_5x^5 + K_4x^4 + K_3x^3 + K_2x^2 + K_1x + K_0$$

are obtained as the remainder after dividing the polynomial $x^8D(x)$ by G(x), where D(x) is the polynomial given by

$$D(x) = B_7x^7 + B_6x^6 + B_5x^5 + . . . + B_1x + B_0.$$

Polynomial of full code:

$$B_7x^{15} + B_6x^{14} + B_5x^{13} + . . . + B_1x^9 + B_0x^8 + K_7x^7 + K_6x^6 + . . . + K_2x^2 + K_1x + K_0.$$

Outer-code check characters in each column of the 85 x 3 x 8 blocks are calculated using the data order existing prior to the rearrangement into the pattern shown in Figure 18; i.e. in ascending sample order.

The check characters K_7 through K_0 are used as the vertical protection characters identified as PV_7 through PV_0, respectively.

10.6 Inner protection

The inner protection and sync block format are identical to that for video (see 6.3 and 6.4).

10.7 Order of transmission to inner coding

Audio data bytes (outer check bytes considered as data) are sent to the inner coder after the block shuffling.

10.8 Channel code

Channel code is identical to that for video (see 6.5).

10.9 Allocation of audio sectors

The data blocks of an audio channel are arranged in three groups of four sectors (12 sectors) as shown in Figure 19. A group of four sectors of each of the four audio channels is recorded according to Figure 22. Audio sectors labelled A1, A2, A3, and A4 correspond to audio input channels 1, 2, 3, and 4, respectively.
The allocation of a group of sectors is a four-field sequence. Field address AF_0, AF_1 of sector ID of four audio sync blocks is defined in 6.3.3.

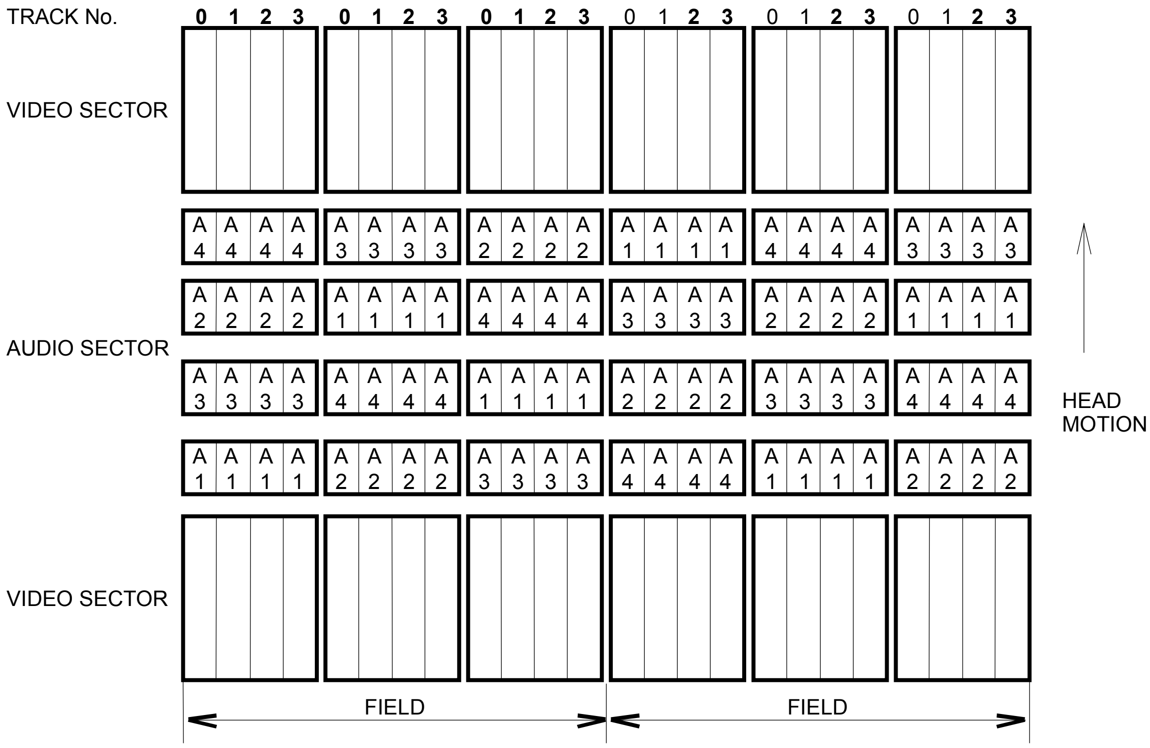


Figure 22 – Audio channel arrangement

11 Longitudinal tracks

11.1 Relative timing

11.1.1 Time and control code input

An external time and control code input that meets the specifications described in IEC 60461, or a time and control code that is internally generated within the recorder, shall be timed for recording as follows: The relationship between the "start of address" of the time and control code and the programme reference point of a track with an even-field address (count) for the video data is defined by Figure 4 and Table 1.

11.1.2 Time and control code information

The time and control code information shall refer to the video frame during which it is recorded.

11.1.3 Cue information

Cue information shall be recorded on the tape at a point referenced to the associated video information as defined by dimension P2 of Figure 4, and Table 1.

11.1.4 Control track servo pulse

Control track servo pulse record timing is described in 11.2.

11.2 Control track

11.2.1 Method of recording

The control track shall be recorded using the hysteresis (direct recording) method.

11.2.2 Servo reference pulse

The control track servo reference pulse, at the time of recording, shall be a series of pulses with a period of 11,122 ms ± 6 µs as shown in Figure 23.

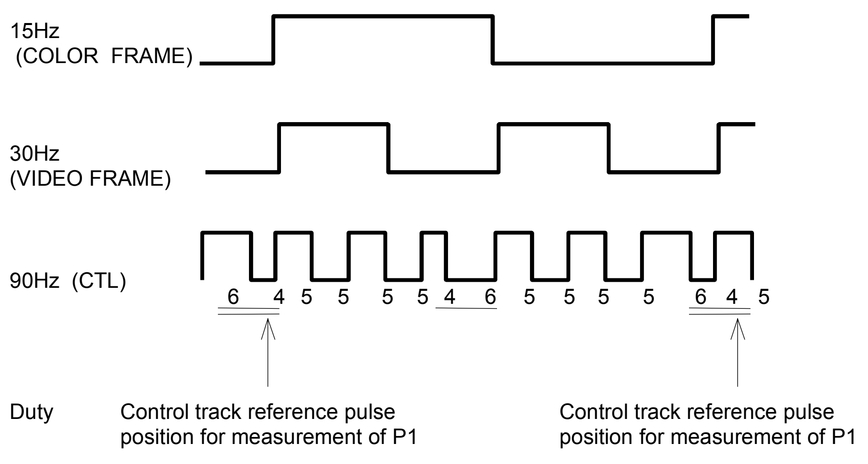


Figure 23 – Recorded control record waveform timing

11.2.3 Flux polarity

The polarities of the recorded flux shall be as shown in Figure 4.

11.2.4 Flux level

The recording shall attenuate any previous recording by at least 30 dB.

11.2.5 Pulse width

The recorded pulses shall have periods of 4T, 5T, or 6T where T equals 1,112 2 ms nominal. The rise and fall times of the record current (10 % to 90 % points) shall be less than 150 µs.

11.2.6 Servo reference pulse timing

The servo reference pulses and the data of the programme reference point, when recorded according to Figure 4, shall occur at the same time.

11.2.7 Colour frame pulse

A colour frame sequence at the time of the start of each recording shall be indicated by a pulse rising transition point which follows a sequence of 6T-4T duration pulses. The colour frame commences with colour frame A field 1. It shall be located at the rising point after the 6T-4T duration pulses, coinciding with a segment count and a field count of zero in the video sector identification pattern, as defined in 6.3.3.

11.2.8 Video frame pulse

The first segment of a video frame at the time of the start of each recording shall be indicated by a pulse rising transition point which follows a sequence of 6T-4T or 4T-6T duration pulses. It shall be located at the rising points after the 6T-4T or 4T-6T duration pulses, coinciding with a segment count and an even field count of zero in the video sector identification pattern, as defined in 6.3.3.

11.3 Cue record

11.3.1 Method of recording

The signals shall be recorded using the anhysteresis (ac bias) method.

11.3.2 Flux level

The recorded reference audio level shall correspond to an r.m.s. magnetic short circuit flux level of 125 nWb/m ± 3 nWb/m of track width at 1 000 Hz.

11.4 Time and control code record

11.4.1 Method of recording

The signals shall be recorded using the anhysteresis (ac bias) recording method.

11.4.2 Flux level

The recorded peak-to-peak flux shall correspond to a magnetic short circuit flux level of 250 nWb/m ± 20 nWb/m of track width.

11.4.3 Input signal

The signal recorded on this track shall be in accordance with IEC 60461.

Annex A
(normative)

Tape tension

The value measured with a tension monitor on the entrance side of the scanner may vary among manufacturers, but would typically be 0,31 N ± 0,05 N.

Annex B
(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 the distance between a minimum of 200 control track pitches. All measurements shall be made under the environmental conditions described in 3.1, except that the measurements are made without tape tension (see Table B.1). The tape is then mathematically stretched to account for tape tension (see Figure B.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 Table B.1 and Figure B.3).

Track location error, which is expressed by the lower edge error of the tracks, includes track angle errors, track straightness errors, and track pitch errors. The starting point for calculations and measurements is, for example, the cross point of the lower edge of the track containing the programme reference point and the line along the measurement path in Figure B.2. The values for every eighth 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 can be 20 samples per zone. A plot of the track location error against the track number must be computed (see Figure B.3). The peak-to-peak value shall lie within the tolerance zones specified in 5.3.

Table B.1 – Nomenclature and calculation of track location error

Y_0	Programme area reference (basic)	1,640 mm
θ	Track angle (basic)	4,938 4°
T	Tension	0,31 N
E	Young's modulus	8 000 N/mm²
A	Cross-sectional area	Thickness × Width
CTM	Distance of n control track pitches without tape tension	
CTM'	Distance of n control track pitches with tape tension	CTM' = CTM(1+ T/(A × E))
g	Longitudinal track pitch	g= CTM'/4n
i	Track number, i = 0 for track containing reference point	
Y_i	Measured position of track i at the recorded pattern	
Δ Y	Cross-section track pitch	$\Delta Y = g \times \tan \theta$
Y_{it}	Theoretical position of track i at the recorded pattern	$Y_{it} = Y_0 + i \times \Delta Y$
I	Track pitch	$I = g \times \sin \theta$
TLE	Track location error	$TLE = Y_i – Y_{it}$
Z	Tolerance zone	Z4 = 0,004 mm Z1, Z2, Z3, Z5, Z6, Z7, Z8 = 0,006 mm
NOTE For tolerance zone	Z1: i = … –8, 0, +8, +16, … Z2: i = … –9, –1, +7, +15, … Z3: i = … –10, –2, +6, +14, … Z4: i = … –11, –3, +5, +13, … Z5: i = … –12, –4, +4, +12, … 76: i = … –13, –5, +3, +11, … Z7: i = … –14, –6, +2, +10, … Z8: i = … –15, –7, +1, +9, …	

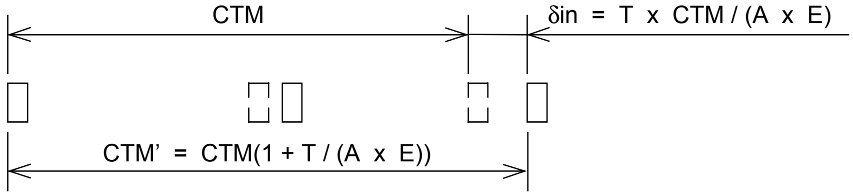
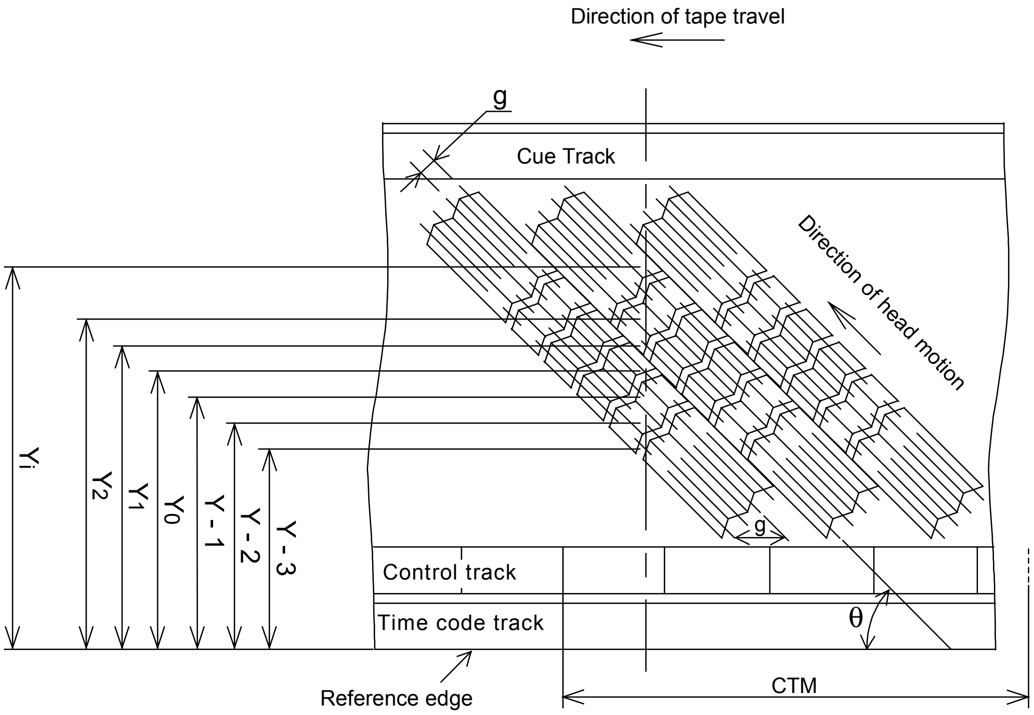


Figure B.1 – Correction factors (actual tape speed and tension)



NOTE The same head must be used for Yi measurement (i.e., every fourth track); CTM is the distance of n control track pitches (n = 200 minimum).

Figure B.2 – Cross-tape measurement technique

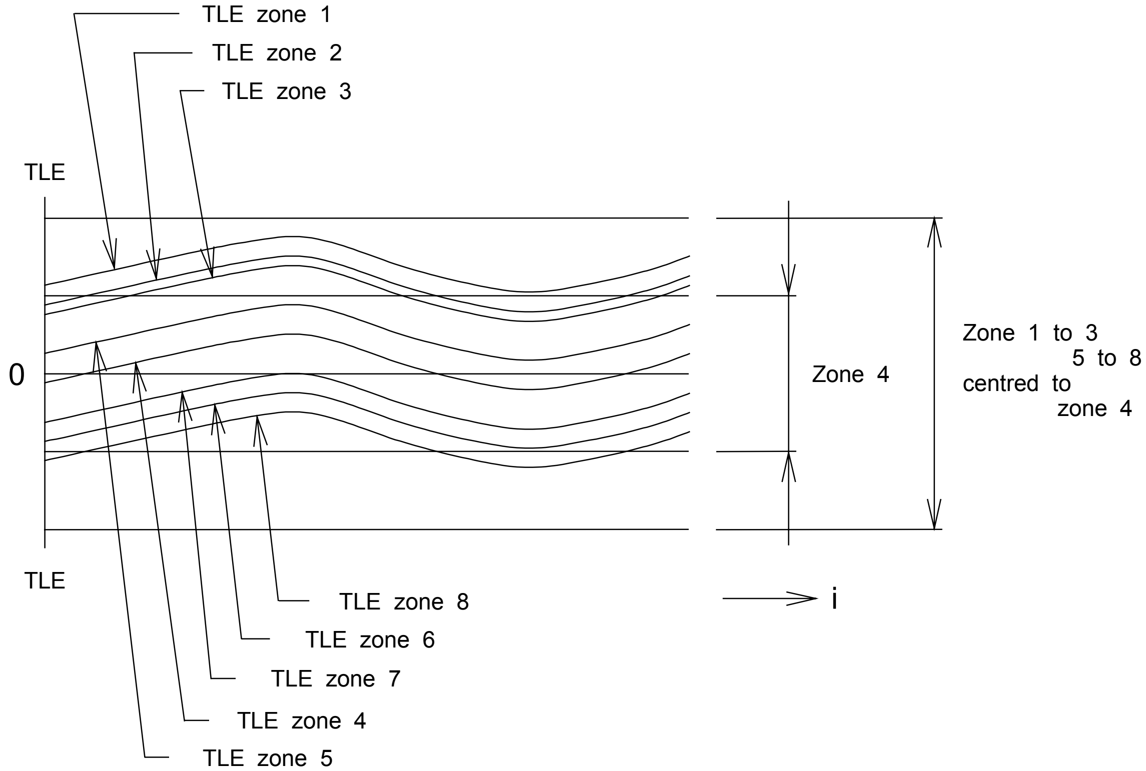
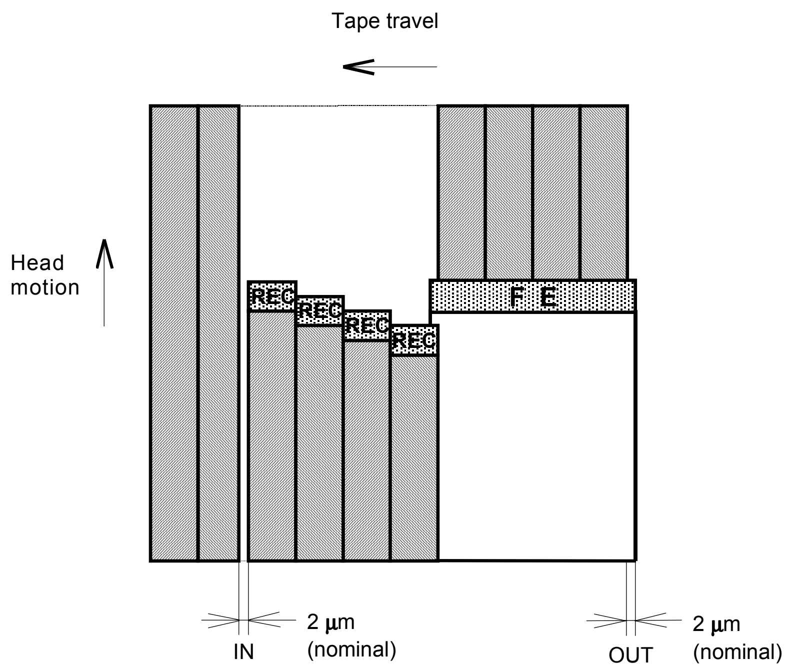


Figure B.3 – Track location error plot (example)

Annex C
(normative)

Track pattern during insert editing

A guard band of 2 µm (nominal) at editing points only is shown in Figure C.1.



REC is a recording head.

FE is a flying erase head.

Figure C.1 – A typical pattern during insert editing

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ICS 33.160.40; 35.240.99

Typeset and printed by the IEC Central Office
GENEVA, SWITZERLAND