

Digital video recording with video compression 12,65 mm type D-9 component format 525/60 and 625/50 (digital S)

The European Standard EN 62156:2001 has the status of a
British Standard

ICS 33.160.40

National foreword

This British Standard is the official English language version of EN 62156:2001. It is identical with IEC 62156:2001.

The UK participation in its preparation was entrusted to Technical Committee EPL/100, Audio, video and multimedia systems and equipment, which has the responsibility to:

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**Digital video recording with video compression 12,65 mm
type D-9 component format 525/60 and 625/50 (digital S)
(IEC 62156:2001)**

Enregistrement vidéo numérique
avec compression vidéo
sur bandes de 12,65 mm format
à composante 525/60 et 625/50
(numérique S) type D-9
(CEI 62156:2001)

Digitale Videoaufzeichnung
mit Videokompression 12,65 mm
D-9-Komponentenformat
525-60 und 625-50 (Digital-S)
(IEC 62156:2001)

This European Standard was approved by CENELEC on 2001-12-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

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CENELEC

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Foreword

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Annexes designated "normative" are part of the body of the standard.
In this standard, annex ZA is normative.
Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 62156:2001 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following note has to be added for the standard indicated:

IEC 60735	NOTE	Harmonized as EN 60735:1991 (not modified).
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DIGITAL VIDEO RECORDING WITH VIDEO COMPRESSION

12,65 mm TYPE D-9 COMPONENT FORMAT

525/60 AND 625/50 (DIGITAL S)

1 Scope

Intraframe bit rate reduction is applied to video data prior to recording.

This International Standard specifies the content, format and recording method of the data blocks containing video, audio, and associated data that form the helical records on 12,65 mm tape in cassettes.

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

One video channel and four independent audio channels are recorded in the digital format. Each of these channels is capable of independent editing.

The video channel records and reproduces a component television signal in the 525 line system with a frame frequency of 29,97 Hz (hereinafter referred to as the "525/60 system") and in the 625 line system with a frame frequency of 25,00 Hz (hereinafter referred to as the "625/50 system").

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

ITU-R BT.470-6, *Conventional television systems*

ITU-R BT.601-5, *Studio encoding parameters of digital television for standard 4:3 and wide-screen 16:9 aspect ratios*

SMPTE 12M-1999, *Television, Audio and Film – Time and Control Code*

3 Abbreviations

AAUX:	Audio auxiliary data
AP1:	Audio application ID
AP2:	Video application ID
AP3:	Subcode application ID
APT:	Track application ID
Arb:	Arbitrary
AS:	AAUX source pack
ASC:	AAUX source control pack
B/W:	Black and white flag
CGMS:	Copy generation management system
DBN:	DIF block number
DCT:	Discrete cosine transform
DIF:	Digital interface
DSF:	DIF sequence flag
ECC:	Error correction code
EFC:	Emphasis channel flag
EOB:	End of block
FSC:	DIF block set number
IDP:	ID parity
ITI:	Initial track information
LF:	Locked mode flag
MUB:	Main users binary group pack
OM:	Overwrite margin
QNO:	Quantization number
QU:	Quantization
Res:	Reserved for future use. Default value shall be set to "1"
SMP:	Sampling frequency
SSA:	Start sync area
SSYB:	Subcode sync block number
STA:	Status of the compressed macro block
STC:	Sub time code pack
SUB:	Sub users binary group pack
Syb:	Sync block number
TF:	Transmitting flag
TIA:	Track information area
Trp:	Track pair number
VAUX:	Video auxiliary data
VLC:	Variable length coding
VS:	VAUX source pack
VSC:	VAUX source control pack
VSM:	Vibrating sample magnetometre

4 Environment and test conditions

4.1 Environment

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

Temperature:	$(20 \pm 1) ^\circ\text{C}$
Relative humidity:	$(50 \pm 2) \%$
Barometric pressure:	from 86 kPa to 106 kPa
Tape conditioning:	not less than 24 h
Tape tension:	from 0,3 N to 0,45 N (Measured at the entrance of the drum)

4.2 Reference tape

Blank tape for reference recordings shall be available from any source producing tape meeting the tape characteristics as defined by this standard.

4.3 Calibration tape

The calibration tapes meeting the requirements of 4.3.1 and clause 5 should be available from manufacturers who produce digital tape recorders and players in accordance with this standard.

4.3.1 Record locations and dimensions

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

4.3.2 Calibration signals

Video, audio and cue channels shall be recorded on the calibration tape:

Video:	100/0/100/0 colour bars
Audio and cue:	1 kHz tone at 20 dB below full scale

5 Video tape cassette

5.1 General specifications

5.1.1 The dimensions of the cassette used for recording shall be in accordance with figures 1 to 17.

5.1.2 The magnetic coating on the tape shall face out of the cassette as specified in figure 12.

5.2 Datum plane

5.2.1 Datum plane Z is determined by datum areas A, B and C as specified in figure 7.

5.2.2 Datum plane Y shall be orthogonal to datum plane Z and shall run through the centre of datum hole (A) and datum hole (B) as specified in figures 4 and 5.

5.2.3 Datum plane X shall be orthogonal to both datum plane Y and datum plane Z and shall run through the centre of datum hole (A) as specified in figures 4 and 5.

5.3 Window and labels

Window and label areas shall be as specified in figures 2 and 3.

5.4 Colour

Window and reel upper flange: transparent

Cassette shell: A colour shall be selected so that overall light transmission of the cassette shell including wound tape is less than 2 % when the light onto the cassette upper surface is measured at the positions of the VTR light sensors. The VHS cassette optical tester VT-2M manufactured by JVC or equivalent measuring instrument shall be used.

5.5 Accidental erasure prevention hole

The dimensions and locations of the accidental erasure prevention hole are shown in figure 8. The function shall be defined as follows:

Open: total record lock out (audio, video, cue, time code, and control track)

Closed: possible to record

5.6 Video tape

5.6.1 Base

The base material shall be polyester or equivalent.

5.6.2 Width

The tape width shall be 12,650 mm $\pm$ 0,010 mm.

5.6.3 Width fluctuation

Width fluctuation of the video tape shall be less than 6 μ m.

5.6.4 Reference edge straightness

Maximum deviation of the reference edge straightness shall be 6 μ m peak-to-peak. Edge straightness fluctuation is measured at the edge of a moving tape positioned by three guides, having contact on the same edge of the tape. Distance between guides is 85 mm from the first to the second guide, and 85 mm from the second to the third guide. Edge measurements are averaged over a 10 m length of tape. Measurements are made at a point 5 mm in the direction towards the first guide from the midpoint between the first and second guide.

5.6.5 Tape thickness

The tape thickness shall be 14,4 μ m $\pm$ 0,5 μ m or 12,4 μ m $\pm$ 0,4 μ m.

5.6.6 Transmissivity

Transmissivity shall be less than 1,2 %, measured over the range of wavelength 800 nm to 1 000 nm.

5.6.7 Strength

Both of the following conditions A and B shall be fulfilled.

(A) Dynamic collapse strength (Sd) is greater than 0,6 N.

(B) Young's modulus (E) is greater than $10,3 \times 10^3 \text{ N/mm}^2$

$$E = E_l + E_t$$

El: Longitudinal direction Young's modulus(N/mm²)

Et: Transverse direction Young's modulus(N/mm²)

Sd is the force in the tape transverse direction that can cause tape edge buckling when the tape is pressed against the flange of the VTR guide roller. Sd shall be measured with the JVC VG-5 measuring instrument that simulates such tape edge buckling and measures the force in the transverse direction.

5.6.8 Yield strength

The yield strength shall be 18 N or more by the following test method:

Fix one end of a sample tape of length 200 mm and pull the other end at a speed of 100 mm/min. The yield strength is the force at which 5 % elongation is observed.

5.6.9 Magnetic coating

The magnetic layer of the tape shall consist of a coating of metal particles or equivalent, and the coercivity shall be a class of 1 800 (approximately 1 800 Oe / 143 000 A/m) with an applied field of 800 000 A/m (10 000 Oe) as measured by a vibrating sample magnetometer (VSM).

5.6.10 Length

Tape length and record time shall be as follows:

Record time min	Length m
124	437 ⁺³ ₀
104	370 ⁺³ ₀
64	230 ⁺³ ₀
34	125 ⁺³ ₀

5.7 Leader/trailer tape

5.7.1 The light path shall be as specified in figure 9.

5.7.2 The cassette shall include leader and trailer tape. When attached to the hub, the length between the splice point and the clamping point on the reel hub shall be 170 mm ± 20 mm.

5.7.3 The leader/trailer tape material shall be polyester or equivalent having transmissivity of at least 50 %. The light transmission shall be measured with a measuring instrument based on the following combination of devices:

Light source: 2 000 K halogen lamp

Light sensor: Photo diode having maximum sensitivity at 940 nm

The JVC VT-1M tape optical tester that conforms to the above condition shall be used to measure light transmission of leader/trailer tape.

5.7.4 The width of the leader/trailer tape shall be 12,65 mm $\pm$ 0,03 mm.

5.7.5 The thickness of the leader/trailer tape shall be 40 $^{+5}_{-25}$ μ m. The splicing tape used to attach the leader/trailer tape shall be applied to the back of the tape.

5.7.6 Length of splicing tape shall be 12 mm to 19 mm.

5.7.7 Splicing gap shall be 0 μ m to 70 μ m.

5.7.8 When attached to the hub, the leader/trailer tape shall not separate when subjected to a force of 30 N or less.

5.8 Reels

5.8.1 The dimensions of the reels and the relationship between the reels and the reel disks shall be as specified in figures 10 and 11.

5.8.2 The reels shall be locked automatically when the cassette is removed from the recorder/player.

5.8.3 When a cassette is inserted into the recorder/player, the reels shall be unlocked automatically as specified in figure 13. The force needed to release the reel lock shall be 0,7 N or less when the reel brake release pin is inserted 9,5 mm from the datum plane Z.

5.8.4 The reels shall be held in position by a reel spring with a force of 1,75 $^{+0,4}_{-0,2}$ N as specified in figure 11.

5.9 Lid

5.9.1 The lid shall be unlocked and opened by the recorder/player when the cassette is inserted. The force needed to unlock the lid shall be less than 0,15 N as specified in figure 14.

5.9.2 The front cover opening force shall be less than 1 N at the 27 mm opening distance as specified in figure 14.

5.9.3 The front cover shall be lifted by the recorder/player to the position shown in figure 14.

5.9.4 The rear cover shall be lifted by the recorder/player to the position shown in figure 15.

5.9.5 The minimum space within the cassette for the VTR loading mechanism shall be as shown in figure 16. The shaded area of figure 16 is intended to indicate the areas available for loading (threading) the tape. Note that the dimensions defining this space are not cassette dimensions.

6 Helical recording – physical characteristics

6.1 Tape speed

The tape speed shall be 57,737 mm/s for the 525/60 system and 57,795 mm/s for the 625/50 system.

The tolerance is $\pm 0,5$ %.

6.2 Sectors

Each recorded track contains ITI sectors, audio sectors, video sectors and a subcode sector.

6.3 Record location and dimensions

6.3.1 Record location and dimensions

Record location and dimensions for continuous recording shall be as specified in figure 18 and table 1. In recording, sector locations on each helical track shall be contained within the tolerance specified in figure 20 and in tables 2 and 3. Sector locations are derived from clause 6, figure 22 and the total length of the helical track (L).

The reference edge of the tape and dimensions specified in this standard shall be the lower edge as shown in figure 18. The magnetic coating, with the direction of tape travel as shown in figure 18, is on the side facing the observer.

6.3.2 Erasure

Full erasure is necessary prior to full recording. In addition, flying erasure is also required in insert editing.

6.3.3 Track pitch

As indicated in figure 18, the pitch between helical track pairs shall be 40 μm , with a guard band of a nominal 6 μm between track pairs. Track pairs consist of two nominally equal width tracks.

6.4 Helical track record tolerance zones

The lower edges of the upper heads of any two consecutive track pairs shall be contained within the pattern of the two tolerance zones defined in figure 20. Each zone is defined by two parallel lines which are inclined at an angle of $5,95892^\circ$ with respect to the tape reference edge. The centre lines of all zones shall be spaced in accordance with figure 20. These zones are established to contain track angle errors, track straightness errors and maintain vertical head offset tolerance.

6.5 Relative positions of recorded information

6.5.1 Relative positions of longitudinal tracks

Audio, video, control and cue tracks with information intended to be time coincident shall be positioned as shown in figures 18 and 19. Specifications in figure 18 and figure 19 are defined in tables 1, 2 and 3.

6.5.2 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 distance Y from the reference edge and the lower leading edge of the odd track (see figure 18).

The relationship between the reference point and programme track data is specified in 7.1.1.

6.6 Gap azimuth

6.6.1 Cue track, control track

The azimuth angle of the cue and control track head gaps used to produce longitudinal track recordings shall be 90° with respect to the track recording direction.

6.6.2 Helical track

The azimuth of the head gap 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 even track of every frame shall be oriented in the clockwise direction with respect to a line perpendicular to the helical track direction when viewed towards the face of tape with the magnetic coating.

6.7 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.

A possible configuration of the tape transport uses a scanner with an effective diameter of 62,00 mm. Scanner rotation is in the same direction as tape motion during normal playback mode. Data is recorded by two groups of heads mounted 180° apart. Figure 21 shows a possible mechanical configuration of the scanner. Table 4 shows the corresponding mechanical parameters.

Other mechanical configurations are allowed provided the same footprint of recorded information is produced on the tape.

7 Helical recording – electrical characteristics

7.1 Track contents

7.1.1 Track contents and duration

Each TV frame is recorded on 10 tracks for the 525/60 system or 12 tracks for the 625/50 system. The helical tracks contain digital data of the ITI sectors, video sector, audio sector, and subcode sector. The end of the pre-amble and beginning of SSA in the ITI 0 sector shall be recorded at the programme area reference point. The ITI sectors contain the start sync and track information. The subcode sector contains the subcode data.

Edit gaps between all sectors accommodate timing errors during editing. Figure 22 shows the arrangement of the ITI sectors, video and audio sectors and subcode sector on the tape.

7.1.2 Labelling convention

The most significant bit is written on the left and is the first recorded on the 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 a hexadecimal value.

7.2 Signal processing

7.2.1 General

The data to be recorded on the programme track shall be processed by the following operations.

- Randomization (except for sync patterns)
- Modulation (except for sync patterns and ID0)
- Pre-coding (except for sync patterns)

All pre-ambls, post-ambls, edit gaps, overwrite margins and ITI sectors are defined as bit streams after those dealt with in this standard.

7.2.2 Randomization

Bit stream data (except for sync patterns) shall be randomized. The randomizing is equivalent to performing the “exclusive-or” operation between the serial data stream and the serial stream generated by the polynomial function below:

$$X^7 + X^3 + 1$$

where X^i are place-keeping variables in GF(2), the binary field. The first term is the most significant and the first to enter the division computation. The randomization limits the run length of similar binary values.

7.2.3 24-25 modulation

As shown in figure 23, bit streams of randomized data shall be processed through 24-25 modulation by adding an extra bit at the beginning of the previously randomized three consecutive bytes.

A total of 25 bits of data are referred to as a code word. The extra bit shall satisfy three restrictions in a pre-coded bit stream as follows:

Priority 1
 Avoid duplicating the sync pattern as shown in 8.2.3.1 and 8.4.3.1.

Priority 2
 Make both of the maximum run length of “zeros” and “ones” less than ten. If the maximum run lengths are greater than nine for the extra bit = 0 or the extra bit = 1, the value of the extra bit shall be chosen to make the maximum run length shorter.

Priority 3
 If priority 2 is satisfied in a pre-coded bit stream, the value of the extra bit shall be chosen to make the frequency characteristics of the pre-coded bit stream nearer to being d.c. free.

7.2.4 Pre-coding

Pre-coding of the 24-25 modulated data stream shall be performed by converting it to interleaved NRZI as shown in figure 24.

7.3 Magnetization

7.3.1 Polarity

The recorder shall reproduce signals without regard to the polarity of the recorded flux on the helical tracks.

7.3.2 Record equalization

The record current should generate a record head gap flux which is constant within ± 1 dB between 0,55 MHz and 24,75 MHz.

7.3.3 Record level

The optimum recording current that flows through either of the heads should be higher by $3 \text{ dB} \pm 1 \text{ dB}$ than the level necessary to obtain maximum signal output level at 24,75 MHz.

7.3.4 Overwrite margin

In an original recording the overwrite margin shall be recorded with concatenations of run pattern A and run pattern B defined as follows:

	MSB	LSB
Run pattern A:	0 0 0 1 1 1 0 0 0 1 1 1 0 0 0 0 0 1 1 1 0 0 0 1 1	
Run pattern B:	1 1 1 0 0 0 1 1 1 0 0 0 1 1 1 1 1 0 0 0 1 1 1 0 0	

In overwriting whole sectors including ITI, an overwrite margin (OM) shall be recorded so as to erase old ITI 2 data.

However, the overwrite margin (OM) need not be recorded when insert editing by using the start sync area (SSA). Since the overwrite margin (OM) has no data, it need not be recorded or reproduced outside of the effective area.

8 Programme track data

8.1 ITI sector

8.1.1 Structure

The ITI sector contains the following elements:

- ITI pre-amble
- Start sync area (SSA)
- Track information area (TIA)
- ITI post-amble

The ITI sector is not overwritten during insert editing.

Figure 25 shows the structure of the ITI sector.

8.1.2 ITI pre-amble

Code word 1000101110 shall be recorded for 140 words as ITI pre-amble.

8.1.3 SSA

The bit stream shown in table 5 shall be recorded as SSA. The bit stream shown in table 5 serves only as the sync start-up pattern and it does not carry information.

8.1.4 TIA (track information area)

The bit stream specified in table 6 shall be recorded as TIA. Within each frame, the entire TIA bitstream pattern shall follow either that of table 6a or that of table 6b (but not both).

8.1.5 ITI post-amble

The code word 1000101110 shall be recorded 28 times as ITI post-amble.

8.2 Audio sector

8.2.1 Structure

The audio sector contains the following elements:

- Audio pre-amble,
- Audio sync block,
- Audio post-amble.

An audio sync block contains the following elements:

- Pre-sync block,
- Data sync block,
- Post-sync block.

Figure 26 shows the structure of an audio sector.

8.2.2 Audio pre-amble

The two types of audio pre-amble patterns are defined as shown below.

	MSB	LSB
Run pattern A:	0 0 0 1 1 1 0 0 0 1 1 1 0 0 0 0 0 1 1 1 0 0 0 1 1	
Run pattern B:	1 1 1 0 0 0 1 1 1 0 0 0 1 1 1 1 1 0 0 0 1 1 1 0 0	

The pattern to be recorded shall be chosen from the above two patterns according to the restrictions described in 7.2.3. The length of the audio pre-amble shall be 1 300 bits as recorded on tape.

8.2.3 Audio sync block

An audio sync block contains two pre-sync blocks followed by 14 data sync blocks, followed by one post-sync block. Each sync block contains two sync bytes, three ID bytes (ID0, ID1, IDP) and/or an area that can be composed either of 85 audio data bytes or an ID2 or ID3 byte. Byte position 5 of pre-sync and byte position 5 of post-sync are additional ID bytes (ID2, ID3). Figure 27 shows the structure of an audio sync block.

8.2.3.1 Sync

The two types of sync patterns after pre-coding are defined as follows.

	MSB	LSB
Sync pattern F:	0 0 0 1 1 1 1 1 1 1 1 1 1 0 0 0 1	
Sync pattern G:	1 1 1 0 0 0 0 0 0 0 0 0 0 1 1 1 0	

A sync pattern to be recorded shall be chosen from the above two patterns according to the priority 2 and priority 3 restrictions described in 7.2.3. The length of recorded sync shall be 17 bits.

8.2.3.2 ID

The ID sections consist of two ID data bytes (ID0, ID1) and one ID parity byte (IDP). ID data consists of application ID (AP1₂, AP1₁, AP1₀), sequence number (Seq₃, Seq₂, Seq₁, Seq₀), upper/lower flag (U/L), track pair number (Trp₂, Trp₁, Trp₀) and sync block number (Syb₇, Syb₆, Syb₅, Syb₄, Syb₃, Syb₂, Syb₁, Syb₀). See tables 8, 9 and 10.

-ID0

ID0 contains the information defined in table 7.

The track pair number shall be defined as given in table 9.

The sequence number shall be kept at the same value during one video frame and runs from 0 to 11 sequentially. Table 10 shows the sequence number.

-ID1

ID1 contains the sync block number defined as follows:

MSB							LSB
Syb ₇	Syb ₆	Syb ₅	Syb ₄	Syb ₃	Syb ₂	Syb ₁	Syb ₀

Sync block numbers run from 0 to 16 and are stored in ID1 in binary notation. Sync block number = 11111111b means no information.

The length of ID1 shall be 8 bits before the modulation.

-IDP

IDP is the parity byte of ID0 and ID1. The length of the IDP shall be 8 bits before the modulation.

IDP is defined as (12, 8, 3) BCH code for which the generator polynomial is $X^4 + X + 1$. ID code is divided into two ID code words (ID – CW0, ID – CW1) as follows:

ID – CW0: C14, C12, C10, C8, C6, C4, C2, C0, P6, P4, P2, P0

ID – CW1: C15, C13, C11, C9, C7, C5, C3, C1, P7, P5, P3, P1

The bit assignment of ID code words is shown in table 11.

Parity bits P0 to P7 are given by the following equations:

$$\begin{aligned} P4 &= C14 + C12 + C8 + C4 + C2 \\ P2 &= C14 + C12 + C10 + C6 + C2 + C0 \\ P0 &= C12 + C8 + C6 + C0 \\ P7 &= C15 + C11 + C7 + C5 \\ P5 &= C15 + C13 + C9 + C5 + C3 \\ P3 &= C15 + C13 + C11 + C7 + C3 + C1 \\ P1 &= C13 + C9 + C7 + C1 \end{aligned}$$

where + is the symbol of an “exclusive-or”.

Modulation shall be made together with ID1, IDP, ID2 or ID3, or first audio data.

8.2.3.3 Additional ID (ID2, ID3)

Byte position 5 of pre-sync block (ID2) shall be set to F0_h before the modulation.

Byte position 5 of post-sync block (ID3) shall be set to FF_h before the modulation.

Modulation shall be applied to three-byte sequences to include:

ID1, IDP, ID2, and ID1, IDP, ID3.

8.2.3.4 Composed audio data

Composed audio data containing the audio data, audio auxiliary data, inner error code and outer error code is shown in figure 27.

The length of the composed audio data shall be 85 bytes prior to the 24-25 modulation. By including the last two bytes of the ID, the length of the composed audio data shall be 87 bytes, divisible into three-byte length sections for 24-25 modulation.

8.2.4 Audio post-ambble

Audio post-ambble shall be the same as the audio pre-ambble described in 8.2.2 (except in length). The recorded length of the audio post-ambble shall be 1 500 bits.

8.3 Video sector

8.3.1 Structure

A video sector contains the following elements:

- Video pre-ambble
- Video sync block
- Video post-ambble

A video sync block contains the following elements:

- Pre-sync block
- Data sync block
- Post-sync block

Figure 28 shows the structure of the video sector.

8.3.2 Video pre-ambble

The video pre-ambble pattern shall be the same as the audio pre-ambble described in 8.2.2. The recorded length of the video pre-ambble shall be 1 300 bits.

8.3.3 Video sync block

The video sync block contains two pre-sync blocks followed by 149 data sync blocks, followed by one post-sync block. Each sync block contains sync of two bytes, ID of three bytes and compressed video data of 77 bytes. Figure 29 shows the structure of a video sync block. Byte positions 5 of pre-sync and 5 of post-sync are the additional ID (ID2, ID3).

8.3.3.1 Sync

Sync shall be same as audio sync described in 8.2.3.1. The recorded length of the sync shall be 17 bits.

8.3.3.2 ID

The ID consists of two data bytes (ID0, ID1) and one ID parity byte (IDP). ID data consists of the video application ID (AP2₂, AP2₁, AP2₀), sequence number (Seq₃, Seq₂, Seq₁, Seq₀), track pair number (Trp₃, Trp₂, Trp₁, Trp₀) and sync block number (Syb₇, Syb₆, Syb₅, ..., Syb₀).

-ID0

ID0 contains the information defined in table 12.

The video application ID is defined in table 13. The track pair number shall be the same as table 9. The sequence number is defined in table 10.

-ID1

ID1 contains the sync block number defined as follows:

MSB				LSB			
Syb ₇	Syb ₆	Syb ₅	Syb ₄	Syb ₃	Syb ₂	Syb ₁	Syb ₀

Sync blocks number from 17 to 168 and are stored in ID1 in binary notation.
 Sync block = FFh means no information.

-IDP

IDP shall be the same as in 8.2.3.2.

8.3.3.3 Additional ID (ID2, ID3)

Byte position 5 of the pre-sync block (ID2) shall be set to F0_h before the modulation.
 Byte position 5 of the post-sync block (ID3) shall be set to FF_h before the modulation.

8.3.3.4 Composed video data

Composed video data containing the video data, video auxiliary data, inner error code and outer error code are shown in figure 29. The length of the composed video data shall be 85 bytes before the modulation.

8.3.3.5 Video post-amble

Video post-amble shall be the same as audio post-amble as described in 8.2.4. The recorded length of the video post-amble shall be 1 500 bits.

8.4 Subcode sector

8.4.1 Structure

The subcode sector contains the following elements:

- Subcode pre-amble
- Subcode sync block
- Subcode post-amble

Figure 30 shows the structure of the subcode sector.

8.4.2 Subcode pre-amble

The subcode pre-amble pattern shall be the same as the audio pre-amble as described in 8.2.2. The recorded length of the subcode pre-amble shall be 1 300 bits.

8.4.3 Subcode sync block

The subcode sync block contains 12 sync blocks. Each sync block consists of a two-byte sync word, three ID bytes, five bytes of subcode data, followed by two parity bytes. Figure 31 shows the structure of the subcode sync block.

8.4.3.1 Sync

The two types of sync patterns after precoding are defined as follows:

	MSB	LSB
Sync pattern D:	0 0 0 0 0 1 1 1 1 1 1 1 1 1 0 1	
Sync pattern E:	1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 1 0	

A sync pattern to be recorded shall be chosen from the above two patterns according to the restrictions priority 2 and priority 3 described in 7.2.3. The length of recorded sync shall be 17 bits.

8.4.3.2 ID

The ID consists of two data bytes (ID0, ID1) and one ID parity byte (IDP). They are placed in sync block byte positions 2, 3, and 4. ID parity is the same as for the audio and video sectors. ID data consists of the subcode application ID (AP3₂, AP3₁, AP3₀), application ID for track (APT₂, APT₁, APT₀), first half ID (FRID), and sync block number (Syb₃, Syb₂, Syb₁, Syb₀). Figure 32 shows the structure of the ID data.

8.4.3.2.1 ID0

FR ID (first half ID)

FR ID is an identification for the first half or the second half of the video frame data.

- FR = 1: the first half of the video frame data
- FR = 0: the second half of the video frame data

AP3: Subcode application ID

The subcode application ID is defined in table 14.

APT_n: Application ID for track

APT_n shall be as defined in table 15. If the signal source is unknown, all bits for this data shall be set to "1". AP1, AP2, and AP3 shall be identical with APT.

8.4.3.2.2 ID1

Sync block number (Syb):

The sync block numbers run from 0 to 11, and are stored in Syb in binary notation. A sync block number = 1111 1111b means no information.

8.4.3.2.3 IDP

IDP shall be the same as in 8.2.3.2.

8.4.4 Subcode post-amble

The subcode post-amble shall be the same as the audio post-amble described in 8.2.4. The recorded length of subcode post-amble shall be 1 200 bits.

8.5 Edit gap

The space between areas on a track, reserved for accommodation of timing errors during editing, are referred to as the edit gap. In an original recording, the edit gap records concatenations of run pattern A and run pattern B defined as follows:

	MSB	LSB
Run pattern A:	0 0 0 1 1 1 0 0 0 1 1 1 0 0 0 0 0 1 1 1 0 0 0 1 1	
Run pattern B:	1 1 1 0 0 0 1 1 1 0 0 0 1 1 1 1 1 0 0 0 1 1 1 0 0	

During an edit, the edit gap may be partially rewritten with the above concatenations. The pre-amble and post-amble of adjacent unedited areas shall not be overwritten.

The choice of a run pattern between run patterns A and B depends only on the minimization of d.c. constants.

9 Longitudinal tracks

9.1 Control track

9.1.1 Method of recording

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

9.1.2 Flux polarity and control pulse reference edge

The polarities of the flux shall be as shown in figure 33.

9.1.3 Flux level

The control signal shall be recorded on the control track with sufficient current for saturation. The playback circuit shall not be impaired when the residual control signal is up to -10 dB as compared with the new (overwritten) control signal as shown in figure 34.

9.1.4 Pulse width

The period of the whole cycle of the recorded pulse shall be 33,37 ms (nominal) for the 525/60 system and 40 ms (nominal) for the 625/50 system. The rise time (10 % to 90 %) shall be less than 200 μ s.

9.1.5 Colourframe indication by non-symmetrical duty factor

525/60 system

When colourframe indication is required, the control track pulse duty factor shall be modified as indicated below.

ColourFrame A – $(67,5 \pm 0,5) \%$

ColourFrame B – $(52,5 \pm 0,5) \%$

When colourframe identification is not required, the control track pulse duty factor shall be $(62,5 \pm 0,5) \%$ or $(57,5 \pm 0,5) \%$.

A pulse with duty factor of $(20 \pm 0,5) \%$ can be used as the 0 frame pulse, indicating the last frame of a recorded cut.

625/50 system

When colourframe indication is required, the control track pulse duty factor shall be modified as indicated below.

Fields 1 and 2 -- $(70 \pm 0,5) \%$

Fields 3 and 4 -- $(50 \pm 0,5) \%$,

Fields 5 and 6 -- $(65 \pm 0,5) \%$

Fields 7 and 8 -- $(55 \pm 0,5) \%$.

When colourframe indication is not required, the control track pulse duty factor shall be $(60 \pm 0,5) \%$. A pulse with a duty factor of $(20 \pm 0,5) \%$ can be used as the 0 frame pulse, indicating the last frame of a recorded cut.

9.1.6 Servo reference pulse timing

The control pulse reference edge and the programme area reference point shall have the relation shown in figure 18.

9.2 Cue track

9.2.1 Method of recording

The signals shall be recorded using the non-hysteresis (a.c. bias) method.

9.2.2 Flux level

The recorded reference audio level shall correspond to an r.m.s. magnetic short-circuit flux level of 70 nWb/m (± 20 nWb/m) of track width at 1 000 Hz.

9.2.3 Relative timing

Cue information shall be recorded on the tape at a point referenced to the programme area reference point as defined by dimension P_2 of figure 18 and table 1.

10 Audio processing

10.1 Introduction

Four channels of audio data each of which corresponds to one video frame period are recorded in four audio blocks respectively. Each audio block is processed identically but independently. The audio block is composed of five audio sectors in five consecutive tracks for the 525/60 system, and six audio sectors in six consecutive tracks for the 625/50 system.

Each audio sector consists of audio data, audio auxiliary data (AAUX), and inner and outer parity data as shown in figure 27. Each audio sector is processed in a product block of dimension 77 columns by 9 rows. Audio data is shuffled prior to the addition of AAUX data and, after the addition of AAUX data, error correction data are added to the product block.

10.2 Encoding mode

One channel of audio signal shall be recorded in an audio block with the sampling frequency of 48 kHz. The encoded data are expressed by 2's complement representation with 16 linear bits.

10.2.1 Emphasis

Audio encoding is carried out with linear frequency characteristics or with first order pre-emphasis of 50/15 μ s.

NOTE For analog-input recording, emphasis should be off in the default state.

10.2.2 Audio error code

In audio encoded data, 8000h shall be assigned as the error code to indicate an invalid audio sample. This code corresponds to negative full scale value in ordinary 2's complement representation. When the encoded data includes 8000h, 8000h shall be converted to 8001h.

10.2.3 Sample to data byte conversion

Samples of 16 bits are defined as D_n ($n = 0, 1, 2, \dots$) and are shuffled by each D_n unit. The 16-bit encoded data is divided into two bytes as shown in figure 35.

10.3 Audio channel allocation

10.3.1 Audio block

The audio block is the physical recording channel for the audio signal on tape. Four audio blocks named CH1, CH2, CH3, CH4 are provided. The construction of these audio blocks is shown in table 16.

10.3.2 Channel allocation rule

Audio channels are defined such that all channels of audio blocks shall be recorded simultaneously. Encoded data for CH1, CH2, CH3 and CH4 correspond to encoded data X in figure 35.

10.4 Frame structure

10.4.1 Relative audio-video timing

The audio duration corresponding to one video frame duration is defined as one audio frame. The timing edge of the first pre-equalizing pulse of each video frame shall coincide with the audio frame within the tolerance of minus zero to plus 50 audio samples. The first pre-equalizing pulse timing edge is located at the beginning of line 1 in 525/60, and at the middle of line 623 in the 625/50 system.

10.4.2 Audio frame processing

This standard provides two types of audio frame processing modes, sequence locked mode and average locked mode. In sequence locked mode, each video frame within the five video frame duration is assigned with a fixed number of audio samples. In average locked mode, the number of audio samples per video frame may vary, although the long term average samples per video frame is kept constant. The machine shall be so designed as to accept both modes. The audio sampling frequency, f_s is locked to the video horizontal scan frequency, f_h as shown below:

$f_s = f_h \times 1144/375$ for the 525/60 system

$f_s = f_h \times 384/125$ for the 625/50 system

Sequence locked mode

The number of audio samples per frame keeps a regular sequence (525/60) or fixed value (625/50) as shown in table 17.

Average locked mode

The number of audio samples per frame is variable within the range between the maximum and the minimum as shown in table 18. The average number of audio samples per frame shall be the number shown in table 18.

In the average locked mode, the number of audio samples per frame is rounded to the nearest integer. For the lack of samples for filling the audio block, arbitrary values, "1", or "0", shall be recorded.

10.5 Audio shuffling

Audio samples are shuffled across tracks and data-sync blocks within a frame. Audio shuffling is accomplished by shuffling Dn data, a two-byte word, across sync blocks and tracks within the frame boundary.

Dn data (that is samples at n-th order ($n = 0, 1, 2, \dots$)) within a frame are located at the position derived from the following equations.

525/60 system

Track, sector number:

Sector 0 of track number $(\text{INT}(n/3) + 2 \times (n \bmod 3)) \bmod 5$	for CH1
Sector 1 of track number $(\text{INT}(n/3) + 2 \times (n \bmod 3)) \bmod 5 + 5$	for CH2
Sector 1 of track number $(\text{INT}(n/3) + 2 \times (n \bmod 3)) \bmod 5$	for CH3
Sector 0 of track number $(\text{INT}(n/3) + 2 \times (n \bmod 3)) \bmod 5 + 5$	for CH4

Sync block number: $2 + 3 \times (n \bmod 3) + \text{INT}((n \bmod 45)/15)$

Byte position number: $10 + 2 \times \text{INT}(n/45)$ for the upper byte
 $11 + 2 \times \text{INT}(n/45)$ for the lower byte
 Where $n = 0$ to 1619

625/50 system

Track, sector number:

Sector 0 of $(\text{INT}(n/3) + 2 \times (n \bmod 3)) \bmod 6$	for CH1
Sector 1 of $(\text{INT}(n/3) + 2 \times (n \bmod 3)) \bmod 6 + 6$	for CH2
Sector 1 of $(\text{INT}(n/3) + 2 \times (n \bmod 3)) \bmod 6$	for CH3
Sector 0 of $(\text{INT}(n/3) + 2 \times (n \bmod 3)) \bmod 6 + 6$	for CH4

Sync block number: $2 + 3 \times (n \bmod 3) + \text{INT}((n \bmod 54)/18)$

Byte position number: $10 + 2 \times \text{INT}(n/54)$ for the upper byte
 $11 + 2 \times \text{INT}(n/54)$ for the lower byte
 Where $n = 0$ to 1943

Audio shuffling patterns are shown in figure 36 for the 525/60 system and in figure 37 for the 625/50 system.

10.6 Audio auxiliary data (AAUX)

AAUX shall be added into each audio sync block, which has previously been loaded with the shuffled audio data, as shown in figure 27. Each AAUX packet of 5 bytes length, consists of a one byte packet header, followed by four bytes of packet data containing AAUX source pack (AS) and AAUX source control pack (ASC). As shown in figure 38, AAUX data for one audio sector consists of nine packs, audio pack numbers 0 through 8, located in the audio sync blocks 2 through 10.

AAUX data in CH1, CH2, CH3 and CH4 are defined independently. All data shall be set as correct values.

10.6.1 AAUX source pack (AS)

AAUX source pack shall be mapped as shown in table 21.

Where

- LF:** Locked mode flag

Locking condition of audio sampling frequency with video signal

0: Sequence locked mode
 1: Average locked mode

AF SIZE: Audio frame size

The number of audio samples per frame.

	525/60 system		625/50 system
000000	1580	000000	1896
101000	1620	110000	1944
	Res		Res
111111	Res	111111	Res

CHN: The number of audio channels within an audio block

- 00b: One channel per audio block
Others: Reserved

AUDIO MODE: The content of the audio signal in each sector

AUDIO MODE	CHN	
	00	01
0000	CH1(CH3)	Res
0001	CH2(CH4)	Res
0010 1110	Res	
1111	No information	

50/60:

- 0: 60-field system
- 1: 50-field system

STYPE: STYPE defines audio blocks per video frame.

STYPE	Audio blocks/frame
00000	4
00001	Res
11111	Res

EF: Emphasis flag

- 0: On
- 1: Off

SMP: Sampling frequency

- 000b: 48 kHz
- Others: Reserved

QU: Quantization

- 000b: 16 bits linear
- Others: Reserved

10.6.2 AAUX source control pack:

AAUX source control pack shall be mapped as shown in table 22.

Where

CGMS: Copy generation management system

CGMS	Possible copy generation
00	Free to copy
01	Res
10	
11	

IRF: Invalid recording flag

For CH1, CH2

- 0: Invalid recording
- 1: Valid recording

For CH3, CH4

- 0: Valid recording
- 1: Invalid recording

REC ST: Recording start frame flag

- 1: Recording start frame
- 0: Not recording start frame

The duration of the recording start frame flag shall be one audio block period for each recording channel.

REC END: Recording end frame flag

1: Recording end frame

0: Not recording end frame

The duration of the recording end frame flag shall be one audio block period for each recording channel.

DRF: Direction flag

1: Reverse direction

0: Forward direction

10.6.3 AAUX NO INFO pack

All AAUX packs that have no information shall be recorded with NO INFO packs as shown in table 23.

10.7 Error correction code addition

Audio data are protected by inner error correction code and outer error correction code.

10.7.1 Inner error correction code

The inner parity as shown in figure 27 is defined as a code word of an inner error correction code.

The inner error correction code is a (85, 77) Reed-Solomon code in GF(256) of which the field generator polynomial is:

$$X^8 + X^4 + X^3 + X^2 + 1$$

where X^i are place-keeping variables in GF(256), the binary field.

The generator polynomial of the code in GF(256) is

$$g_{in}(X) = (X + 1)(X + \alpha)(X + \alpha^2)(X + \alpha^3)(X + \alpha^4)(X + \alpha^5)(X + \alpha^6)(X + \alpha^7)$$

where " α " is given by 02h in GF(256).

Parities, $K_7, K_6, K_5, K_4, K_3, K_2, K_1, K_0$ are given by the equation:

$$K_7X^7 + K_6X^6 + K_5X^5 + K_4X^4 + K_3X^3 + K_2X^2 + K_1X + K_0,$$

which is the residue of $X^8D(X)$ divided by $g_{in}(X)$,

where the data polynomial $D(X)$ is defined as follows:

$$D(X) = D_{76}X^{76} + D_{75}X^{75} + \dots + D_2X^2 + D_1X + D_0,$$

and the code word polynomial is given by the following equation:

$$D_{76}X^{84} + D_{75}X^{83} + \dots + D_1X^9 + D_0X^8 + K_7X^7 + K_6X^6 + \dots + K_1X + K_0$$

where D_{76} through D_0 correspond to the data of byte positions 5 through 81, and K_7 through K_0 to the inner parity of byte positions 82 through 89 respectively.

10.7.2 Outer error correction code

The outer parity as shown in figure 27 is defined as a code word of an outer error correction code.

The outer error correction code is a (14, 9) Reed-Solomon code in GF(256) of which the field generator polynomial is:

$$X^8 + X^4 + X^3 + X^2 + 1$$

where X^i are place-keeping variables in GF(256), the binary field.

The generator polynomial of the code in GF(256) is

$$g_{\text{aout}}(X) = (X + 1)(X + \alpha)(X + \alpha^2)(X + \alpha^3)(X + \alpha^4)$$

where " α " is given by 02h in GF(256).

Parities K_4, K_3, K_2, K_1, K_0 are given by the equation:

$$K_4X^4 + K_3X^3 + K_2X^2 + K_1X + K_0$$

which is the residue of $X^5D(X)$ divided by $g_{\text{aout}}(X)$,

where the data polynomial $D(X)$ is defined as follows:

$$D(X) = D_8X^8 + D_7X^7 + \dots + D_2X^2 + D_1X + D_0$$

and the code word polynomial is given by the following equation:

$$D_8X^{13} + D_7X^{12} + \dots + D_1X^6 + D_0X^5 + K_4X^4 + K_3X^3 + \dots + K_1X + K_0$$

where D_8 through D_0 correspond to the data of sync blocks 2 through 10, and K_4 through K_0 to the outer parity of sync blocks 11 through 15 respectively.

11 Video processing

11.1 Introduction

Analog video component signals are sampled at 13,5 MHz for luminance (Y) and 6,75 MHz for colour difference (C_R, C_B) signals. The sampled data in the vertical blanking area and the horizontal blanking area are discarded.

The active video samples, mapped as a video frame of active horizontal samples by active vertical lines, are divided into DCT blocks. One DCT block contains 8 samples from each of 8 consecutive horizontal lines. Two luminance DCT blocks and two colour difference DCT blocks form a macro block. Five macro blocks, which are gathered from various areas in a frame by the rule shown in 11.2.6, form a video segment. A video segment is compressed to five compressed macro blocks by DCT and VLC processing.

The compressed macro blocks are re-ordered with the order defined in 11.8 when data sync blocks are formed.

Video auxiliary data (VAUX) are multiplexed with the compressed video data, and the multiplexed data are processed in a product block of dimension 77 columns by 138 rows. The data in the product block are protected with error correction data added to the product block. 24-25 modulation is applied prior to recording.

11.2 Video structure

11.2.1 Sampling structure

The sampling structure is the same as a sampling structure of 4:2:2 component television signals which is described in ITU-R BT. 601-5. Sampling structures of the luminance signal (Y) and two colour-difference signals (C_R , C_B) in the 4:2:2 method are described in table 24.

Pixel structure in one frame

For the 525/60 and 625/50 systems, 720 pixels of luminance signal per line shall be transmitted as shown in figures 39 and 40. For the 525/60 and 625/50 systems, 360 pixels of colour difference signal per line shall be transmitted as shown in figures 39 and 40.

The sampling starting point in the active period of C_R and C_B signals shall be the same as the sampling starting point in the active period of the Y signal. Each pixel has a value from -127 to 126, which is obtained by subtracting 128 from the input video signal level.

Line structure in one frame

For the 525/60 system, 240 lines shall be transmitted for Y, C_R and C_B signals from each field. For the 625/50 system, 288 lines shall be transmitted for Y, C_R and C_B signals from each field. The transmitted lines in the two fields are described in table 24.

11.2.2 DCT block

The Y, C_R and C_B pixels within a frame shall be divided into DCT blocks. As shown in figure 41, all DCT blocks are structured with a rectangular area of eight consecutive horizontal lines, and eight adjacent samples along a horizontal line, within a frame. The value of x shows the horizontal coordinate from the left. The value of y shows the vertical coordinate from the top. Odd lines of $y = 1, 3, 5, 7$ are the horizontal lines of field one, and even lines of $y = 0, 2, 4, 6$ are those of field two.

DCT block arrangement in one frame for 525/60 system

The horizontal arrangement of DCT blocks in one frame is shown in figure 42. The same horizontal arrangement is repeated for 60 DCT blocks in the vertical direction. Pixels in one frame are divided into 10 800 DCT blocks.

Y:	Vertical 60 DCT blocks x horizontal 90 DCT blocks = 5 400 DCT blocks
C_R :	Vertical 60 DCT blocks x horizontal 45 DCT blocks = 2 700 DCT blocks
C_B :	Vertical 60 DCT blocks x horizontal 45 DCT blocks = 2 700 DCT blocks

DCT block arrangement in one frame for 625/50 system

The horizontal arrangement of DCT blocks in one frame is shown in figure 42. The same horizontal arrangement is repeated to 72 DCT blocks in the vertical direction. Pixels in one frame are divided into 12 960 DCT blocks.

Y:	Vertical 72 DCT blocks x horizontal 90 DCT blocks = 6 480 DCT blocks
C_R :	Vertical 72 DCT blocks x horizontal 45 DCT blocks = 3 240 DCT blocks
C_B :	Vertical 72 DCT blocks x horizontal 45 DCT blocks = 3 240 DCT blocks

11.2.3 Macro block

Four DCT blocks form a macro block. Figure 43 shows the relationship between the macro block and the DCT blocks.

Each macro block consists of two luminance DCT blocks which are next to each other horizontally in the picture frame, and two chrominance DCT blocks for C_R and C_B respectively. Each of the chrominance blocks covers the same spatial area as the two luminance DCT blocks combined.

Macro block arrangement in one frame for 525/60 system

The arrangement of macro blocks in one frame is shown in figure 44. The smallest rectangles represent macro blocks. Pixels in one frame are divided into 2 700 macro blocks.

$$60 \text{ vertical macro blocks} \times 45 \text{ horizontal macro blocks} = 2\,700 \text{ macro blocks}$$

Macro block arrangement in one frame for 625/50 system

The arrangement of macro blocks in one frame is shown in figure 45. The smallest rectangles represent macro blocks. Pixels in one frame are divided into 3 240 macro blocks.

$$72 \text{ vertical macro blocks} \times 45 \text{ horizontal macro blocks} = 3\,240 \text{ macro blocks}$$

11.2.4 Super block

Each super block consists of 27 macro blocks

Super block arrangement in one frame for 525/60 system

The arrangement of super blocks in one frame is shown in figure 44. Each super block is structured with 27 adjacent macro blocks enclosed by a thick line. The pixels in one frame are divided into 100 super blocks.

$$20 \text{ vertical super blocks} \times 5 \text{ horizontal super blocks} = 100 \text{ super blocks}$$

Super block arrangement in one frame for 625/50 system

The arrangement of super blocks in one frame is shown in figure 45. Each super block is structured with 27 adjacent macro blocks enclosed by a thick line. The pixels in one frame are divided into 120 super blocks.

$$24 \text{ vertical super blocks} \times 5 \text{ horizontal super blocks} = 120 \text{ super blocks}$$

11.2.5 Definition of super block number, macro block number and value of the pixel

Super block number

The super block number in a frame is expressed as $S_{i,j}$ as shown in figures 44 and 45.

$S_{i,j}$ where i : the vertical order of the super block
 $i = 0, \dots, 19$ for the 525/60 system
 $i = 0, \dots, 23$ for the 625/50 system

j : the horizontal order of the super block
 $j = 0, \dots, 4$

Macro block number

The macro block number is expressed as $M_{i,j,k}$. The symbol k is the macro block order in the super block as shown in figure 46. The small rectangle in the figure shows a macro block, and the number in the small rectangle expresses k .

$M_{i,j,k}$ where i, j : the super block number
 k : the macro block order in the super block
 $k = 0, \dots, 26$

Pixel location

The value of the pixel is expressed as $P_{i,j,k,l}(x,y)$. The pixel is indicated by the suffixes $i,j,k,l(x,y)$. The symbol l is the DCT block order in a macro block as shown in figure 43. The rectangle in the figure shows a DCT block. The DCT number in the rectangle expresses l . The symbols x and y are the pixel coordinates in the DCT block as described in 11.2.2.

$P_{i,j,k,l}(x,y)$ where i, j, k : the macro block number
 l : the DCT block order in the macro block
 (x,y) : the pixel coordinates in the DCT block
 $x = 0, \dots, 7$
 $y = 0, \dots, 7$

11.2.6 Definition of video segment and compressed macro block

A video segment consists of five macro blocks which are gathered from various areas. Each video segment before bit rate reduction is expressed as $V_{i,k}$ which consists of $M_{a,2,k}$, $M_{b,1,k}$, $M_{c,3,k}$, $M_{d,0,k}$ and $M_{e,4,k}$.

where $a = (i + 4) \bmod n$
 where $b = (i + 12) \bmod n$
 where $c = (i + 16) \bmod n$
 where $d = (i + 0) \bmod n$
 where $e = (i + 8) \bmod n$

i : the vertical order of the super block

$i = 0, \dots, n - 1$

n : the number of vertical super blocks in a video frame

$n = 20$ for the 525/60 system

$n = 24$ for the 625/50 system

k : the macro block order in the super block

$k = 0, \dots, 26$

The bit rate reduction is executed from $M_{a,2,k}$ to $M_{e,4,k}$. The data in a video segment are compressed so that the total data is 385 bytes. One set of compressed video data consists of five compressed macro blocks. Each compressed macro block consists of 77 bytes and is expressed as CM. Each video segment after bit rate reduction is expressed as $CV_{i,k}$ which consists of $CM_{a,2,k}$, $CM_{b,1,k}$, $CM_{c,3,k}$, $CM_{d,0,k}$ and $CM_{e,4,k}$ as shown below (see also 11.7.1):

$CM_{a,2,k}$:

This block includes all parts or most parts of the compressed data of the macro block $M_{a,2,k}$ and may include the compressed data of the macro block $M_{b,1,k}$ or $M_{c,3,k}$ or $M_{d,0,k}$ or $M_{e,4,k}$.

$CM_{b,1,k}$:

This block includes all parts or most parts of the compressed data of the macro block $M_{b,1,k}$ and may include the compressed data of the macro block $M_{a,2,k}$ or $M_{c,3,k}$ or $M_{d,0,k}$ or $M_{e,4,k}$.

$CM_{c,3,k}$:

This block includes all parts or most parts (depending on the algorithm defined in 11.7.1) of the compressed data of the macro block $M_{c,3,k}$ and may include the compressed data of the macro block $M_{a,2,k}$ or $M_{b,1,k}$ or $M_{d,0,k}$ or $M_{e,4,k}$.

$CM_{d,0,k}$:

This block includes all parts or most parts of the compressed data of the macro block $M_{d,0,k}$ and may include the compressed data of the macro block $M_{a,2,k}$ or $M_{b,1,k}$ or $M_{c,3,k}$ or $M_{e,4,k}$.

CM_{e,4,k} :

This block includes all parts or most parts of the compressed data of the macro block M_{e,4,k} and may include the compressed data of the macro block M_{a,2,k} or M_{b,1,k} or M_{c,3,k} or M_{d,0,k}.

11.3 DCT processing

The DCT block is made up of pixels from two fields. It has a structure consisting of four horizontal lines and eight pixels per line per field. This subclause describes the DCT transforming method in a DCT block from 64 pixels with numbers i,j,k,l (x,y) to 64 coefficients with numbers i,j,k,l (h,v).

The value of the pixel is P_{i,j,k,l} (x,y) and the value of the coefficient is C_{i,j,k,l}(h,v).

When h = 0 and v = 0, the coefficient is called a "DC coefficient". Other coefficients are called "AC coefficients".

11.3.1 DCT mode

There are two DCT modes to improve the picture quality after the bit rate reduction, called 8-8-DCT mode and 2-4-8-DCT mode. 8-8-DCT mode should be selected when the difference between two fields is small. 2-4-8-DCT mode should be selected when the difference between two fields is significant.

The two DCT modes are defined as follows:

8-8-DCT mode

DCT:

$$C_{i,j,k,l}(h,v) = C(v)C(h) \sum_{y=0}^7 \sum_{x=0}^7 (P_{i,j,k,l}(x,y) \cos(\pi v(2y+1)/16) \cos(\pi h(2x+1)/16))$$

Inverse DCT:

$$P_{i,j,k,l}(x,y) = \sum_{v=0}^7 \sum_{h=0}^7 (C(v)C(h)C_{i,j,k,l}(h,v) \cos(\pi v(2y+1)/16) \cos(\pi h(2x+1)/16))$$

where

$$\begin{aligned} C(h) &= 0,5 / \sqrt{2} & \text{for } h = 0 \\ C(h) &= 0,5 & \text{for } h = 1 \text{ to } 7 \\ C(v) &= 0,5 / \sqrt{2} & \text{for } v = 0 \\ C(v) &= 0,5 & \text{for } v = 1 \text{ to } 7 \end{aligned}$$

2-4-8-DCT mode

DCT:

$$C_{i,j,k,l}(h,u) = C(u)C(h) \sum_{y=0}^3 \sum_{x=0}^7 ((P_{i,j,k,l}(x,2z) + P_{i,j,k,l}(x,2z+1)) KC)$$

$$C_{i,j,k,l}(h,u+4) = C(u)C(h) \sum_{y=0}^3 \sum_{x=0}^7 ((P_{i,j,k,l}(x,2z) - P_{i,j,k,l}(x,2z+1)) KC)$$

Inverse DCT:

$$P_{i,j,k,l}(x,2z) = \sum_{u=0}^3 \sum_{h=0}^7 ((C(u)C(h)C_{i,j,k,l}(h,u) + C_{i,j,k,l}(h,u+4))KC)$$

$$P_{i,j,k,l}(x,2z+1) = \sum_{u=0}^3 \sum_{h=0}^7 ((C(u)C(h)C_{i,j,k,l}(h,u) - C_{i,j,k,l}(h,u+4))KC)$$

Where

$$u = 0, \dots, 3$$

$$z = \text{INT}(y/2)$$

$$KC = \cos(\pi u(2z+1)/8) \cos(\pi h(2x+1)/16)$$

$$C(h) = 0,5 / \sqrt{2} \quad \text{for } h = 0$$

$$C(h) = 0,5 \quad \text{for } h = 1 \text{ to } 7$$

$$C(v) = 0,5 / \sqrt{2} \quad \text{for } v = 0$$

$$C(v) = 0,5 \quad \text{for } v = 1 \text{ to } 7$$

11.3.2 Weighting

DCT coefficients shall be weighted by the process as described below. $W(h,v)$ expresses the weighting factor for $C_{i,j,k,l}(h,v)$ of the DCT coefficient.

8-8-DCT mode

For $h = 0$ and $v = 0$

$$W(h,v) = 1/4$$

For others

$$W(h,v) = W(h)W(v)/2$$

2-4-8-DCT mode

For $h = 0$ and $v = 0$

$$W(h,v) = 1/4$$

For $v < 4$

$$W(h,v) = W(h)W(2v)/2$$

For others

$$W(h,v) = W(h)W(2(v-4))/2$$

where

$$W(0) = 1$$

$$W(1) = CS4/(4 \times CS7 \times CS2)$$

$$W(2) = CS4/(2 \times CS6)$$

$$W(3) = 1/(2 \times CS5)$$

$$W(4) = 7/8$$

$$W(5) = CS4/CS3$$

$$W(6) = CS4/CS2$$

$$W(7) = CS4/CS1$$

where

$$CSm = \cos(m\pi/16)$$

$$m = 1 \text{ to } 7$$

11.3.3 Output order

Figure 47 shows the output order of the weighted coefficients.

11.3.4 Tolerance of DCT with weighting

Output error between the output $Y_{ri}(h,v)$ of the reference DCT, and the output $Y_{ti}(h,v)$ of the tested DCT as shown in figure 48, should satisfy tolerance specifications for the following cases:

- Probability of occurrence of error
- Mean square errors for all coefficients
- Maximum value of mean square error for each DCT block
- When all input pixel values of a DCT block are the same

The error calculated with the method above should satisfy the following four tolerances:

- a) Occurrence probability, Pr , is less than or equal to 1×10^{-5} for the case of error value greater than one.

$$Pr(|Y_{ti}(h,v) - Y_{ri}(h,v)| > 1) \leq 1 \times 10^{-5}$$

$$\text{Where} \quad \begin{aligned} i &= 0, \dots, 9999 \\ h &= 0, \dots, 7 \\ v &= 0, \dots, 7 \end{aligned}$$

- b) Mean square errors for all coefficients are less than or equal to 0,125.

$$\sum_{i=0}^{9999} \sum_{h=0}^7 \sum_{v=0}^7 (Y_{ti}(h,v) - Y_{ri}(h,v))^2 / (64 \times 1000) \leq 0,125$$

- c) Maximum value of mean square error for each DCT block is less than or equal to 0,33.

$$\sum_{h=0}^7 \sum_{v=0}^7 (Y_{ti}(h,v) - Y_{ri}(h,v))^2 / 64 \leq 0,33$$

$$\text{where} \quad i = 0, \dots, 9999$$

- d) If all input pixel values of a DCT block are the same, all AC coefficients of the DCT block should be zero.

IDCT operation should be executed using a circuit with the same precision as the DCT that satisfies the above tolerances.

11.4 Quantization

11.4.1 Introduction

Weighted DCT coefficients are transformed into 9 bits. Then the 9-bit transformed data is divided by the quantization step in order to limit the amount of data in one video segment after bit rate reduction.

11.4.2 Bit assignment for quantization

Weighted DCT coefficients are represented as follows:

DC coefficient value (9 bits):	b8 b7 b6 b5 b4 b3 b2 b1 b0
	2's complement (-255 to 255)
AC coefficient value (10 bits):	s b8 b7 b6 b5 b4 b3 b2 b1 b0
	1 sign bit + 9 bits of absolute value (-511 to 511)

11.4.3 Class number

Each DCT block shall be defined by four classes as defined in table 25. The class number is used for selecting quantization steps. Both $c1$ and $c0$ express the class number and are stored in the DC coefficient of the compressed DCT block as described in 10.6. For reference, table 26 shows an example of classification.

11.4.4 Initial scaling

Initial scaling is an operation to transform AC coefficients from 10 bits to 9 bits. Initial scaling shall be done as follows:

For class number = 0, 1, 2:	
input data	s b8 b7 b6 b5 b4 b3 b2 b1 b0
output data	s b7 b6 b5 b4 b3 b2 b1 b0
For class number = 3:	
input data	s b8 b7 b6 b5 b4 b3 b2 b1 b0
output data	s b8 b7 b6 b5 b4 b3 b2 b1

11.4.5 Area number

The area number is used for selecting the quantization step. AC coefficients within a DCT block shall be classified into four areas with an area number as shown in figure 49.

11.4.6 Quantization step

The quantization step shall be decided by class number, area number and quantization number (QNO) as specified in table 27. The QNO is selected for each macro block in order to limit the amount of data in one video segment.

11.5 Variable length coding (VLC)

Variable length coding is an operation for transforming quantized AC coefficients to variable length codes. One or several successive AC coefficients within a DCT block are coded into one variable length code according to the order shown in figure 47.

Run length and amplitude are defined as follows.

Run length:	the number of successive AC coefficients quantized to "0" (run = 0, ..., 61)
Amplitude:	Absolute value just after successive AC coefficients quantized to "0" (amp = 0, ..., 255)
(run, amp):	The pair of run length and amplitude.

Table 28 shows the length of code words corresponding to (run, amp). In the table, the sign bit is not included in the length of code words. When the amplitude is not zero, the code length shall be greater by one bit, because the sign bit is needed. For an empty column, the code word for (run, amp) is coded by being divided into two codes of (run -1, 0) and (0, amp). The code of variable length coding shall be as shown in table 29. The left-most bit of code words is MSB and the right-most bit of code words is LSB. The LSB is followed by the MSB of the next code word.

Sign bit "s" shall be as follows:

For the quantized AC coefficients greater than zero:	s = 0
For the quantized AC coefficients less than zero:	s = 1

When the values of all of the remaining quantized coefficients are zero within a DCT block, the coding process is ended by adding the EOB (end of block) code word "0110b" just after the last code word.