SMPTE STANDARD

for Television —
Type D-11 Picture Compression and Data Stream Format

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1 Scope

This standard specifies the compression of a high-definition source format to a dual-channel packetized data stream format which is suitable for recording on disc and tape storage devices including type D-11 tape recorder. The specification includes a number of basic packetizing operations including the shuffling of the source data prior to compression both to aid compression performance and to allow error concealment processing in the decoder. The standard also includes the processes required to decode the compressed type D-11 packetized data format into a high-definition output signal.

This standard supports high-definition source formats using 1920*1080 pixels and the sampling structures specified in SMPTE 274M and SMPTE RP 211 at the following picture rates:

> 24÷1.001/PsF, 24/PsF, 25/PsF, 30÷1.001/PsF, 50/I and 60÷1.001/I
> (where PsF indicates progressive segmented frame and I indicates interlaced).

The data packet format specified by this standard is used as the source data stream for the associated document which maps this type D-11 packetized data stream format together with AES3 data over SDTI.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision,

Approved
March 28, 2002

and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of the standards indicated below.

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

SMPTE 274M-1998, Television — 1920 x 1080 Scanning and Analog and Parallel Digital Interfaces for Multiple Picture Rates

SMPTE 292M-1998, Television — Bit-Serial Digital Interface for High-Definition Television Systems

SMPTE RP 188-1999, Transmission of Time Code and Control Code in the Ancillary Data Space of a Digital Television Data Stream

SMPTE RP 211-2000, Implementation of 24P, 25P and 30P Segmented Frames for 1920 x 1080 Production Format

3 Introduction

This standard specifies the encoding and decoding of high-definition source formats via compression into a bit rate in the range 112~140 Mb/s for recording on a type D-11 digital tape recorder. The recorded bit rate is related to the source picture rate as given in table 1.

Table 1 – Data rates associated with source picture rates

Picture rate	Base data rate (Mb/s)
24÷1.001/PsF	111.863
24/PsF	111.975
25/PsF	116.640
30÷1.001/PsF	139.828
50/I	116.640
60÷1.001/I	139.828

Annex E gives the system overview of the documents which comprise the full type D-11 specification. This document specifies the parts identified by the number 1. The other documents identified as 2 and 3 specify, respectively, the following parts:

– The SDTI definition for direct data input and output from the type D-11 recorder.

– The mapping of the compressed data format from either this document or the data interface document onto the type D-11 helical tracks as the VTR format.

In common with other compression systems, the type D-11 encoding process uses intraframe coding (i.e., the coding is bound by the frame period) using the discrete cosine transform (DCT) to provide the data decorrelation required for efficient compression. The coefficients are quantized and variable length coded (VLC) to produce the basic output data format.

The source pictures are subsampled prior to compression coding. This reduces the number of coded pixels and allows the number of bits-per-pixel value to be raised in proportion. The luminance source sampling grid of 1920*1080 pixels is reduced to 1440*1080 pixels. For each chrominance channel, the source sampling grid of 960*1080 pixels is reduced to 480*1080 pixels. In the decoder, the output pixel sample grid is restored back to the source format of 1920*1080 pixels by interpolation following the compression decoding process.

The compressed data format specified by the output of the compression encoder is of a form which allows direct mapping into the basic block structure as defined in the type D-11 digital recorder document.

4 Encoding

4.1 Overview

The type D-11 source data for compression shall comprise only the production aperture area as defined by SMPTE 274M.

NOTE – The DCT coding uses a data block size which allows exactly 1080 lines to be coded.

The source formats comprise luminance (Y) and chrominance (C_B, C_R) component signals as defined by SMPTE 274M and SMPTE RP 211.

The type D-11 source picture rates for compression shall be constrained to the following values:

- 24÷1.001 frames per second in the segmented format as defined by SMPTE RP 211.
- 24 frames per second in the segmented format as defined by SMPTE RP 211.
- 25 frames per second in the segmented format as defined by SMPTE RP 211.
- 30÷1.001 frames per second in the segmented format as defined by SMPTE RP 211.
- 50 fields per second in the interlaced format (a.k.a. 50/I) as defined by SMPTE 274M.
- 60÷1.001 fields per second in the interlaced format (a.k.a. 60/I) as defined by SMPTE 274M.

The active picture data for compression shall be prefiltered and then subsampled from a source representation to a subsampled representation.

The reduced active data shall then be split into two identical channels for processing as shown in figure 1 and table 2.

The total picture data in each channel shall be divided into 20,250 8*8 blocks, each formed from 8 samples of 8 consecutive lines in a frame.

The 8*8 blocks for each channel shall then be shuffled within the frame boundary to produce 270 code blocks each comprising 45 luminance (Y) 8*8 blocks and 30 chrominance 8*8 blocks (15 C_B and 15 C_R).

The picture data in each code block shall be compressed by the application of the discrete cosine transform, quantization and VLC encoding. Each code block shall be separately encoded and there shall be no data sharing between code blocks. The data from the compression output shall be packed into the code block space of 1080 bytes.

Each code block shall be segmented into five basic blocks each comprising 216 compressed data bytes. Each basic block nominally contains the compressed data for 9 luminance 8*8 blocks and 6 chrominance 8*8 blocks (3 C_B and 3 C_R). Data overflow from one basic block can be shared with other basic blocks in the same code block.

NOTE – The 8*8 blocks may be coded by a single 8*8 DCT block, by two 8*4 DCT blocks, or by two 4*8 DCT blocks depending on the mode of operation (see 4.4).

The 270 code blocks for each channel shall be divided into six equal segments of 45 code blocks per segment. Each segment shall contain one auxiliary basic block prior to the compressed data basic blocks. All auxiliary basic blocks in one channel shall be identical with the exception of the segment identification number. The auxiliary basic block shall contain utility data for the segment. The distribution of a channel into code blocks and basic blocks is illustrated in figure 2.

All basic blocks shall have a total length of 219 bytes. The data for the basic blocks in a code block shall be 216 bytes in length, allowing 3 bytes for the basic block header. The data for the auxiliary basic block in each segment shall be 217 bytes in length, allowing 2 bytes for the basic block header.

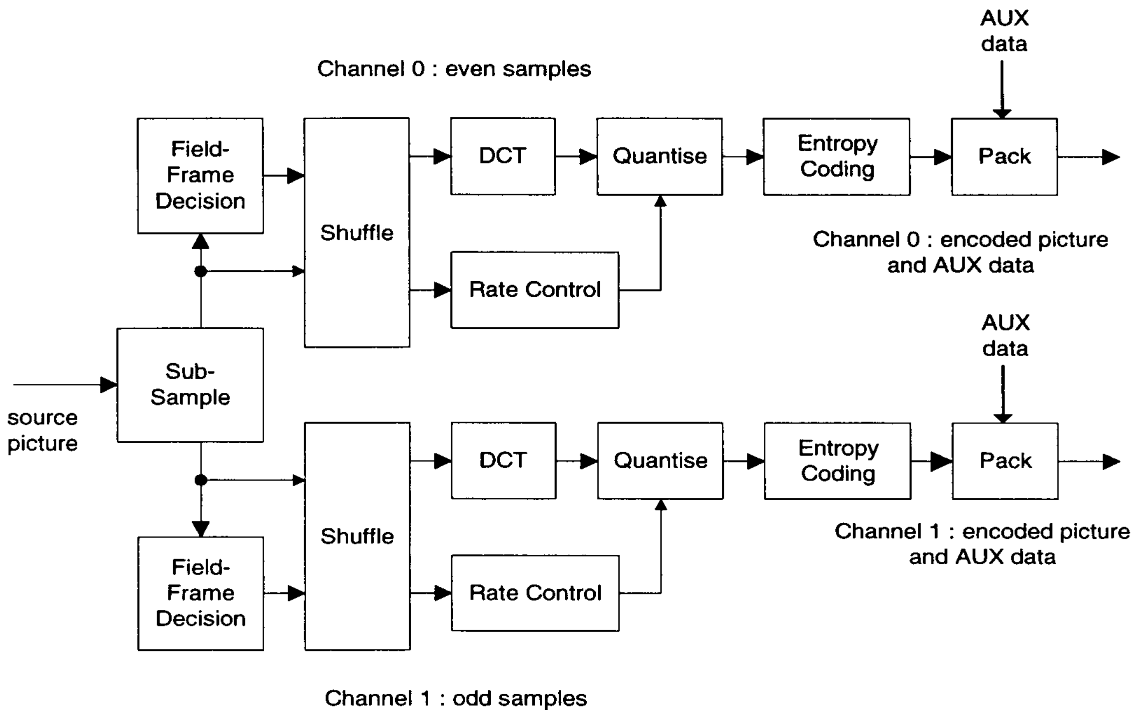


Figure 1 – Encoding block diagram

Table 2 – Definition of signal sampling parameters

Parameter		Source sampling	Subsampling	Channel division
Number of samples per line	Y	1920	1440	720
	C_B, C_R	960	480	240
Number of active lines per frame		1080	1080	1080
Quantization		10-bit (0..1023)	8-bit (0..255)	8-bit (0..255)
Sample levels	Peak range	4 to 1019	1 to 254	1 to 254
	Y	Peak white level: 940	Peak white level: 235	Peak white level: 235
		Black level: 64	Black level: 16	Black level: 16
		Total levels: 877	Total levels: 220	Total levels: 220
	C_B, C_R	Signal level: 512 ± 448	Signal level: 128 ± 112	Signal level: 128 ± 112
		Total levels: 897	Total levels: 225	Total levels: 225

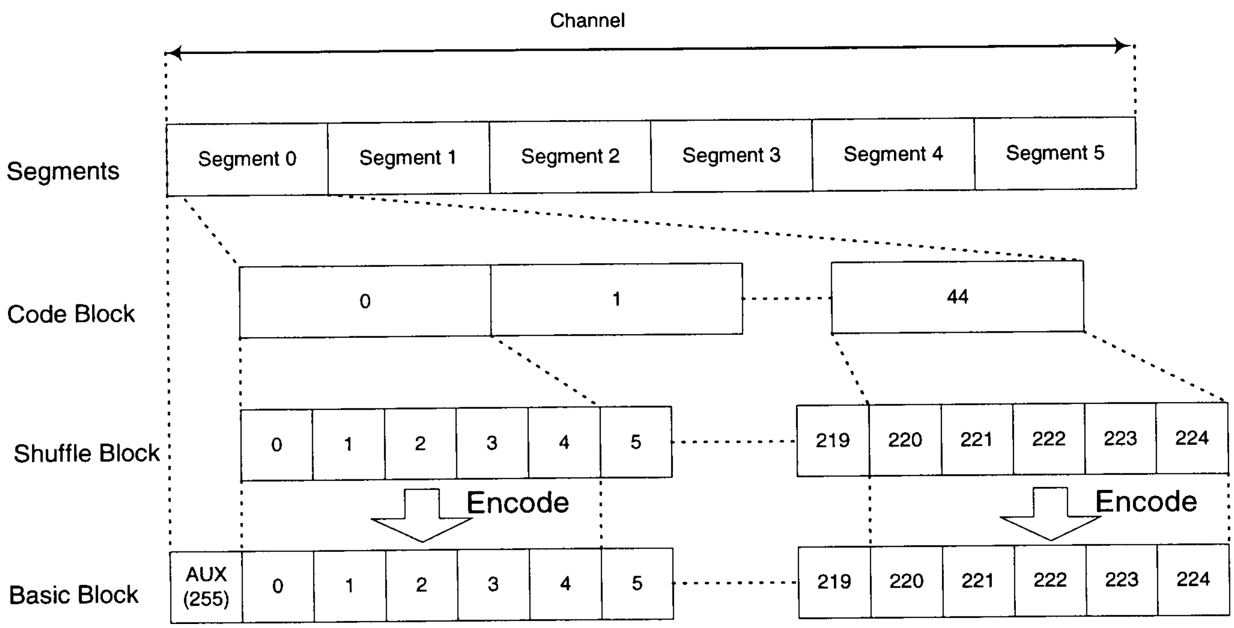


Figure 2 – Code blocks and basic blocks in channel

4.2 Preprocessing

The source picture shall be the production aperture as defined in SMPTE 274M having a luminance structure of 1920*1080 pixels and a multiplexed chrominance structure of 960*1080 pixels for each chrominance component.

The source interface has a sample resolution of 10 bits which shall be reduced to 8 bits after the horizontal subsampling process.

4.2.1 Vertical sampling process

For 1080/I systems, 540 lines for Y, C_B, C_R signals from each interlaced field shall be processed. The coding lines for each interlaced field are illustrated in figure 2.

For 1080/PsF systems, 1080 lines for Y, C_B, C_R signals from each whole frame shall be processed. The coding lines for the segmented frame are illustrated in figure 3.

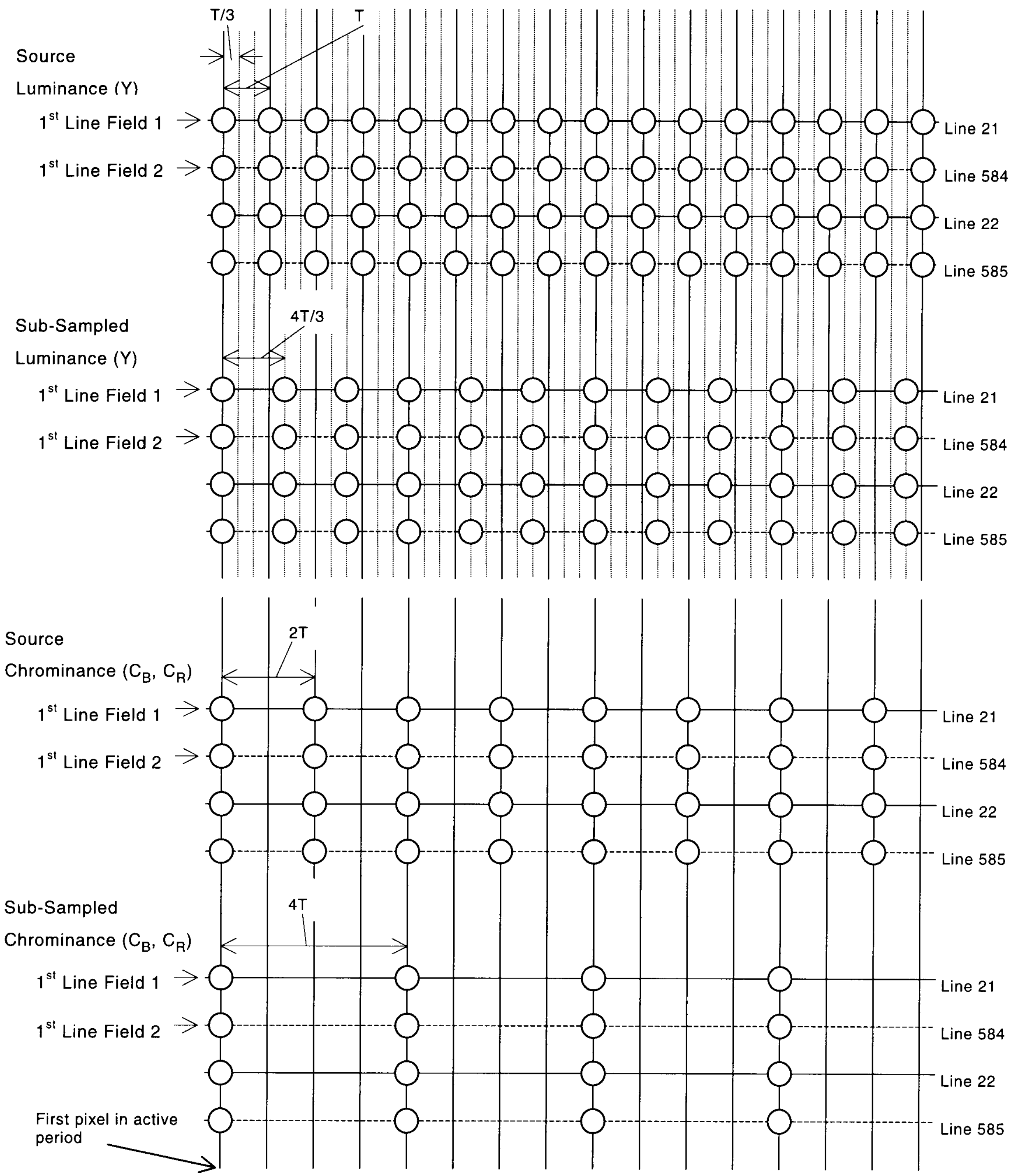
4.2.2 Horizontal subsampling process

For the luminance component, all 1920 active samples per line shall be subsampled to 1440 samples per line after a bandwidth limitation filtering process.

For each of the two chrominance components, all 960 active samples per line shall be subsampled to 480 samples per line after a bandwidth limitation filtering process.

The basic sample parameters for luminance (Y) and the two chrominance signals (C_B, C_R) of the source and subsampled component signals are described in table 2.

Figure 3 depicts the resampled spatial positions of the subsampled components for 1080/I and 1080/PsF line scanning systems.



NOTE – T is the period of the luminance horizontal sampling.

Figure 3 – Sampling relationships for 1080/I and 1080/PsF source and subsampled systems

The subsampled data in each frame shall be divided into two identical channels; an even sample channel and an odd sample channel as illustrated in figure 4.

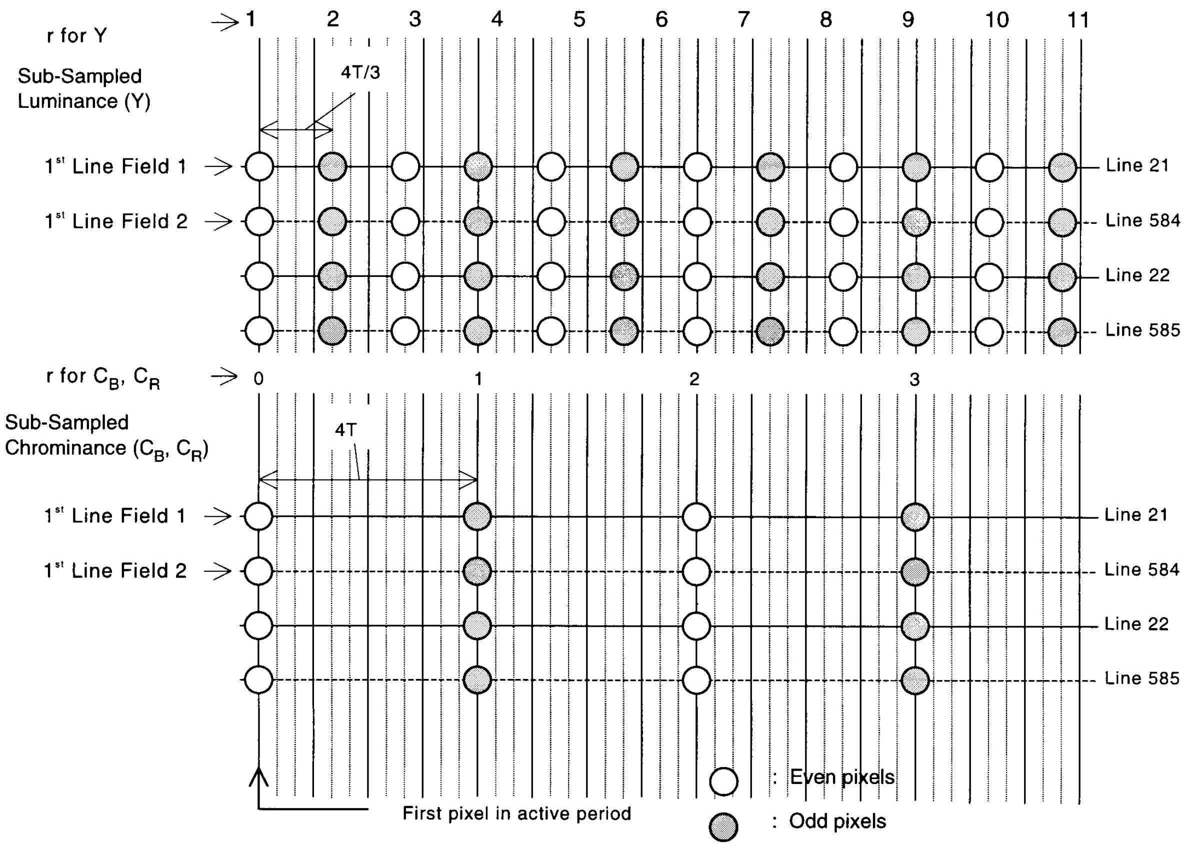


Figure 4 – Channel division of subsampled 1080/I and 1080/PsF signals

Let r be horizontal sample position number in the subsampled Y, C_B, C_R source.

For Y samples r = 0, 1, 2, 3, …. , 1439
For C_B, C_R samples r = 0, 1, 2, 3, …. , 479

Those samples that have r as an even number, depicted as a white circle in figure 4, shall be distributed to channel 0.

Those samples that have r as an odd number, depicted as a gray circle in figure 4, shall be distributed to channel 1.

Each luminance (Y) sample channel has a rectangular area of 720 samples by 1080 lines. Each chrominance (C_B, C_R) sample channel has a rectangular area of 240 samples by 1080 lines respectively as illustrated in figure 5.

Figure 4 shows the overall structure of the subsampling process.

To avoid alias artifacts, the source format shall be prefiltered with a filter operating in the horizontal dimension only. The templates for the overall filtering characteristics of the subsampling process are defined in annex A.

NOTE – The filtering and subsampling processes are implemented as one combined operation.

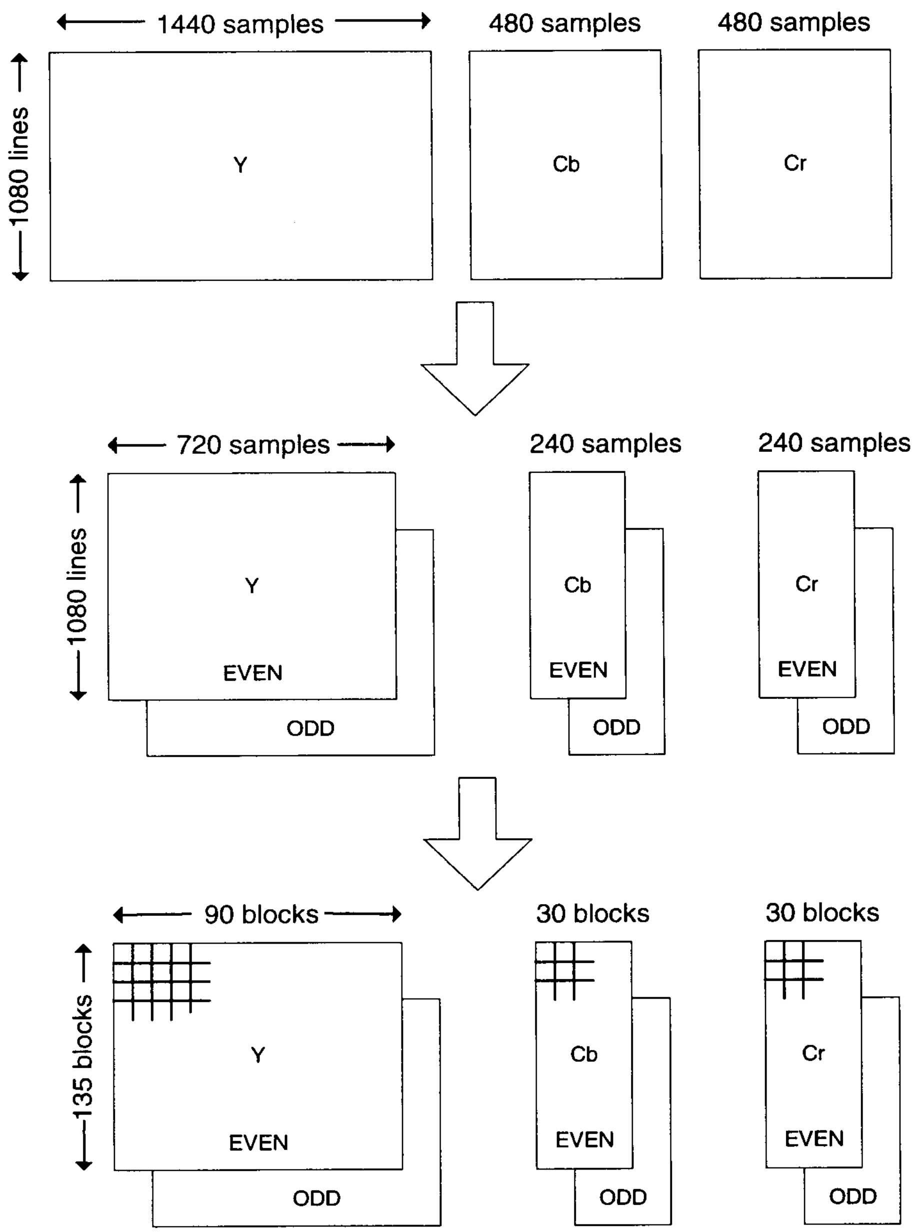


Figure 5 – Channel distribution

4.3 Shuffling

Each subsampled input picture shall be split into two channels each comprising 12,150 luminance (Y) and 8,100 chrominance (C_B and C_R) 8*8 blocks, as shown in figure 5. The 12,150 luminance blocks are taken from the array of 135*90 8*8 blocks. The 8,100 chrominance blocks are taken from the array of 135*30*2 8*8 blocks.

The input format prior to shuffling for both channels shall be as shown in figure 5. The shuffling rearranges the 8*8 blocks according to the algorithm defined in annex B.

After shuffling, the blocks for each channel shall be allocated to six segments each containing 45 code blocks. Each code block shall be subdivided into five shuffle blocks as shown in figure 2.

NOTE – The contents of the 5 shuffle blocks are uncompressed signal data. The data in the 5 shuffle blocks which form a code block are then compressed and packed into 5 corresponding basic blocks as described in 4.9.

Each shuffle block, defined at the output of the shuffle algorithm, comprises 3 header bytes, 9 luminance 8*8 blocks, and 6 chrominance 8*8 blocks, as shown in figure 6.

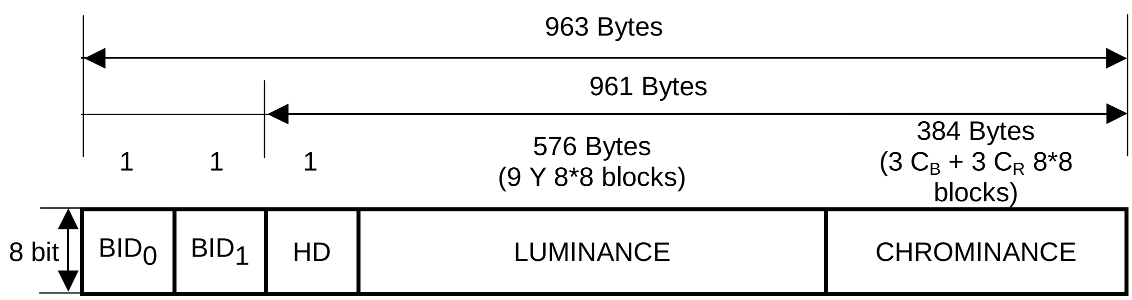


Figure 6 – Shuffle block format

The first header byte, BID_0, shall define the shuffle block number from figure 2 as an 8-bit unsigned integer in the range 0 to 224. Figure 7a defines the bit allocation for the shuffle block number.

The second byte (BID_1) defines the shuffle block mode information as shown in figure 7b.

Bit 7 (SPF) defines the shuffle pattern flag which identifies the two states specified in annex B.
Bit 6 shall be 0.
Bit 5 defines the field-frame mode flag as described in 4.4.
Bits 4 to 2 define the 3-bit segment number (values 0 to 5) with SG_2 as the MSB.
Bit 1 defines even channel (value 0) or odd channel (value 1).
Bit 0 shall be 0.

The third byte (HD) defines encoding information as shown in figure 7c.

Bit 7 shall have a default value of 0.
Bit 6 defines the overflow flag described in 4.9.
Bits 5 to 0 define the 6-bit quantizer base described in 4.6 with QB_5 as the MSB.

a) BID_0 byte

LSB	0	1	2	3	4	5	6	7	MSB
	SB_0	SB_1	SB_2	SB_3	SB_4	SB_5	SB_6	SB_7	
	Shuffle block number								

b) BID_1 byte

LSB	0	1	2	3	4	5	6	7	MSB
	0	CH	SG_0	SG_1	SG_2	FRM	0	SPF	
	Fixed	Chan	Segment number			Mode	Fixed	Pattern	

c) HD byte

LSB	0	1	2	3	4	5	6	7	MSB
	QB_0	QB_1	QB_2	QB_3	QB_4	QB_5	OVF	0	
	Quantizer base						Over	Fixed	

Figure 7 – Shuffle block header byte descriptions

4.4 Field-frame decision

4.4.1 Overview

The picture data in each channel shall be processed to select field or frame mode encoding, indicated by bit 5 of the BID_1 byte. Every shuffle block of any one channel comprising six segments shall be formatted as either field mode or frame mode as specified in 4.4.2 and 4.4.3.

4.4.2 Frame mode reformat

In frame mode encoding, bit 5 of BID_1 shall be set to the value 1. The nine luminance 8*8 blocks in each basic block shall not be reformatted and shall remain as nine $8_H x 8_V$ DCT blocks. The six chrominance 8*8 blocks shall be reformatted into three pairs of $4_H x 8_V$ C_B DCT blocks and three pairs of $4_H x 8_V$ C_R DCT blocks. The splitting of 8*8 blocks into $4_H x 8_V$ block pairs is shown in figure 8.

Input 8*8 C_B or C_R block

Samples 0..3	Samples 4..7
LN 0a	LN 0b
LN 1a	LN 1b
LN 2a	LN 2b
LN 3a	LN 3b
LN 4a	LN 4b
LN 5a	LN 5b
LN 6a	LN 6b
LN 7a	LN 7b

1st 4x8 DCT block

Samples 0..3
LN 0a
LN 1a
LN 2a
LN 3a
LN 4a
LN 5a
LN 6a
LN 7a

2^{nd} 4x8 DCT block

Samples 4..7
LN 0b
LN 1b
LN 2b
LN 3b
LN 4b
LN 5b
LN 6b
LN 7b

Figure 8 – Frame mode chrominance DCT block reformat

4.4.3 Field mode reformat

In field mode encoding, bit 5 of BID_1 shall be set to the value 0. The nine luminance 8*8 blocks in each shuffle block shall be reformatted into nine pairs of $8_H x 4_V$ luminance DCT blocks. This is achieved by placing the lines from field 1 in the first of a pair of $8_H x 4_V$ DCT blocks, and lines from field 2 in the second of the pair. The six chrominance 8*8 blocks shall be reformatted into three pairs of $8_H x 4_V$ C_B DCT blocks and three pairs of $8_H x 4_V$ C_R DCT blocks.

The splitting of 8*8 blocks into $8_H x 4_V$ block pairs is shown in figure 9.

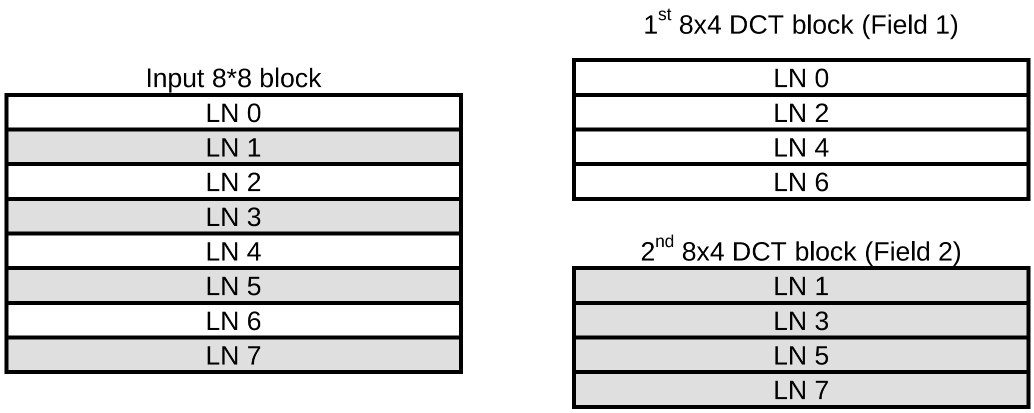


Figure 9 – Field mode DCT block reformat

4.5 Discrete cosine transform (DCT)

Prior to the DCT process, the MSB of each input sample shall be inverted.

This changes the luminance data from offset binary to twos complement form, and the chrominance from twos complement with MSB inversion to twos complement as shown in table 3.

Table 3 - Data representation

Luminance in		Luminance out		Chrominance in		Chrominance out	
0 to +255		-128 to +127		-128 to +127		-128 to +127	
+255	1111 1111	+127	0111 1111	+127	1111 1111	+127	0111 1111
+129	1000 0001	+1	0000 0001	+1	1000 0001	+1	0000 0001
+128	1000 0000	0	0000 0000	0	1000 0000	0	0000 0000
+127	0111 1111	-1	1111 1111	-1	0111 1111	-1	1111 1111
0	0000 0000	-128	1000 0000	-128	0000 0000	-128	1000 0000

The DCT process defined in annex C transforms each DCT block of luminance or chrominance samples to a single DC coefficient and a number of AC coefficients depending on the DCT block size.

Following the DCT process, the output coefficients shall be scaled to lie within the maximum range defined by a 16-bit twos complement number (see annex C).

4.6 Rate control

4.6.1 Overview

Each code block, comprising five shuffle blocks, shall be used to provide the basic unit for rate control.

The rate control process selects a quantizer base which is defined for each shuffle block in a code block and an individual quantizer offset which is defined for each DCT block.

The rate control process aims to fill, but not exceed, the available bit space of 8640 bits for each code block after compression encoding (see 4.9).

4.6.2 Quantizer base

Each shuffle block shall be allocated a 6-bit quantizer base as an unsigned integer which shall be stored in the third header byte (HD) as described in 4.3.

The quantizer base value 63 shall be selected when the target bit budget for the compressed data in a code block is exceeded and data must be discarded as described in 4.9. In this case, all shuffle blocks in the code block must take the quantizer base value of 63.

The quantizer base value 62 is reserved and shall not be used.

Otherwise the quantizer base may take values between 0 and 61.

4.6.3 Quantizer offset

The quantizer base for each shuffle block may be modified for each DCT block by a quantizer offset value.

The decision to apply quantizer offsets shall be made on a per-frame basis for each channel independently. Thus for both channels for a frame duration, quantizer offsets are either applied to every DCT block or to no DCT blocks.

If quantizer offsets are used, each offset value shall be a 6-bit signed twos complement number having the range: –32 and +31.

4.6.4 Quantizer index

The quantizer index for each DCT block is the sum of the quantizer base for the shuffle block and the quantizer offset for the DCT block.

If the result of this sum is less than 0, the quantizer index value shall be set to 0.

The quantizer offset value shall be limited to ensure that the quantizer index value does not exceed 89.

If quantizer offsets are not used, then the quantizer index value shall be equal to the quantizer base.

4.7 Quantization

The 16-bit DCT coefficients from the DCT process shall be divided by a divisor value. It is recommended that the division process include rounding.

The divisor value for DC coefficients shall be defined from the quantizer index value according to table 4.

The divisor value for AC coefficients shall be defined from the quantizer index value according to table 5.

Table 4 – DC quantization divisors

Quantizer index value (QI)	Divisor value
0	4
1	8
2 to 9	16
10 to 17	32
18 to 25	64
26 to 33	128
34 and above	256

Table 5 – AC quantization divisors

Quantizer index value (QI)	Divisor value
0	4
1	8
2 and above	$16 * 2^{((QI-2)/8)}$

In frame mode only (see 4.4) and following the quantization process, the chrominance DC coefficients from the second DCT block of each chrominance pair shall be DPCM coded as follows:

(2nd C_B DC coefficient for encoding) = (1st C_B DC coefficient) – (2nd C_B DC coefficient)
(2nd C_R DC coefficient for encoding) = (1st C_R DC coefficient) – (2nd C_R DC coefficient)

4.8 Entropy coding

4.8.1 Overview

DCT blocks containing quantized DCT coefficients shall be entropy encoded using a variable length code (VLC) to produce variable-length compressed data for each DCT block.

Quantizer offset information shall be encoded for each DCT block.

4.8.2 Quantizer offset encoding

The quantizer index of each DCT block is as described in 4.6. Any quantizer offset data for each DCT block shall be encoded before the associated DCT coefficients.

In each channel of a frame up to eight separate Y quantizer offset values, up to eight C_B quantizer offset values, and up to eight C_R quantizer offset values shall be selected from the total range of -32 to 31. Both channels of a frame shall use the same selected quantizer offset values.

The selected quantizer offset values shall be assigned a 3-bit offset index value in the range 0 to 7 for each Y, C_B and C_R component separately. The offset index values shall be assigned from 0 up to the number selected with a maximum value of 7. These selected offset index values and their corresponding quantizer offset values shall be defined for each component of each channel in the auxiliary basic blocks, as described in 4.10.

In frames where quantizer offset values are used, each DCT block shall be assigned an offset index value that defines the matching quantizer offset value.

Each shuffle block shall be assigned three independent 2-bit offset mode values for Y, C_B and C_R respectively. In frames where quantizer offsets are used, an offset mode value between 1 and 3 shall be selected depending on the number of offset index values. In frames where quantizer offsets are not used, the offset mode shall be 0.

Table 6 shows the relationship between the offset mode value and the number of offset index values supported. The first DCT block of each type (Y0, C_B0 and C_R0 in figures 11 and 12) shall include the associated 2-bit offset mode value as its first encoded data, MSB first.

Table 6 - Offset mode and offset index

Offset mode	Offset index bits	Offset index values
00	0	Not used
01	1	0 to 1
10	2	0 to 3
11	3	0 to 7

Table 6 shows that an offset mode of 0 requires no offset index bits; a mode of 1 requires one index bit; a mode of 2 requires two index bits; and a mode of 3 requires three index bits in each DCT block.

Each DCT block includes the number of bits that define the offset index value (MSB first). In the case of the first DCT block of each type (Y0, C_B0 and C_R0), these bits shall immediately follow the offset mode bits. In all remaining DCT blocks in a shuffle block, these bits shall be the first encoded data in the block.

4.8.3 Luminance DC coefficient encoding

Luminance DC coefficients shall be encoded using a fixed number of bits, depending on the quantization index of the DCT block selected by the rate control process (4.6). Any excess sign extension bits of the quantized DC coefficient value shall be discarded.

The number of bits allocated is shown in table 7.

Table 7 - DC coefficient fixed precision

Quantizer index value	Number of DC bits
0	14
1	13
2 to 9	12
10 to 17	11
18 to 25	10
26 to 33	9
34 and above	8

The luminance DC bits shall be presented MSB first and shall immediately follow any offset mode or offset index bits where present.

4.8.4 Luminance AC coefficient encoding

Luminance AC coefficients shall be coded using one of 22 VLC table groups, defined in annex D.1. These VLC table groups provide for several VLC options including:

- Provision for an end of block (EOB) code.
- Collapsing runs of zero coefficients with a terminating value of ± 1 into single codes.
- Collapsing other runs of zero coefficients into single codes.
- Provision of codes for single coefficient values.

The first luminance AC coefficient (or coefficient run) in each DCT block shall be coded using the appropriate VLC table group as defined in annex D.1.

Any subsequent luminance AC coefficient (or coefficient run) shall then be encoded using the appropriate VLC table group (called the current group) together with the VLC table group of the previous coefficient or coefficient run (called the previous group).

The current and previous group values shall be used to identify a VLC as defined in the luminance VLC tables in annex D.2. In the case of the first luminance AC coefficient (or coefficient run), the previous group shall be assigned the default value of 0.

Each VLC may be followed by a fixed length code (FLC) where the number of FLC bits for each group is defined in annex D.1. Annex D.4 describes the FLC data for each VLC table group.

Table 8 shows an informative example of DCT coefficient encoding.

Table 8 - Example luminance AC coefficient encoding

Coefficients	Previous group	Current group	VLC	FLC
0, 0, 0, +1	Default = 0	2	111100	11
0	2	7	11101	–
-2	7	14	0	01
+1	14	13	00	1
0, -1	13	1	100	0
EOB	1	0	1100	–
Final encoded AC data = 1111 0011 1110 1001 0011 0001 100 (27 bits)				

The luminance VLC and FLC bits shall be presented MSB first and immediately follow the luminance DC bits.

4.8.5 Chrominance coefficient encoding

NOTE – Chrominance coefficient encoding uses a technique similar to that for luminance AC coefficient encoding.

The first chrominance coefficient (or coefficient run) in each DCT block (including the DC coefficient) shall be coded using the appropriate VLC table group as defined in annex D.1.

Any subsequent chrominance coefficient (or coefficient run) shall then be encoded using the appropriate VLC table group (called the current group) together with the VLC table group of the previous coefficient or coefficient run (called the previous group).

The current and previous group values shall be used to identify a VLC as defined in the chrominance VLC tables in annex D.3. In the case of the first chrominance coefficient (or coefficient run), the previous group shall be assigned the default value of 0.

Each VLC may be followed by a fixed length code (FLC) where the number of FLC bits for each group is defined in annex D.1. Annex D.4 describes the FLC data for each VLC table group.

The chrominance VLC and FLC bits shall be presented MSB first and immediately follow any offset mode or offset index bits where present.

Figure 10 shows an example of the encoding order for the DCT blocks in a shuffle block. The Y cells are shown with a 3-bit offset index, C_B cells are shown with a 1-bit offset index, and C_R cells are shown with no quantizer offsets.

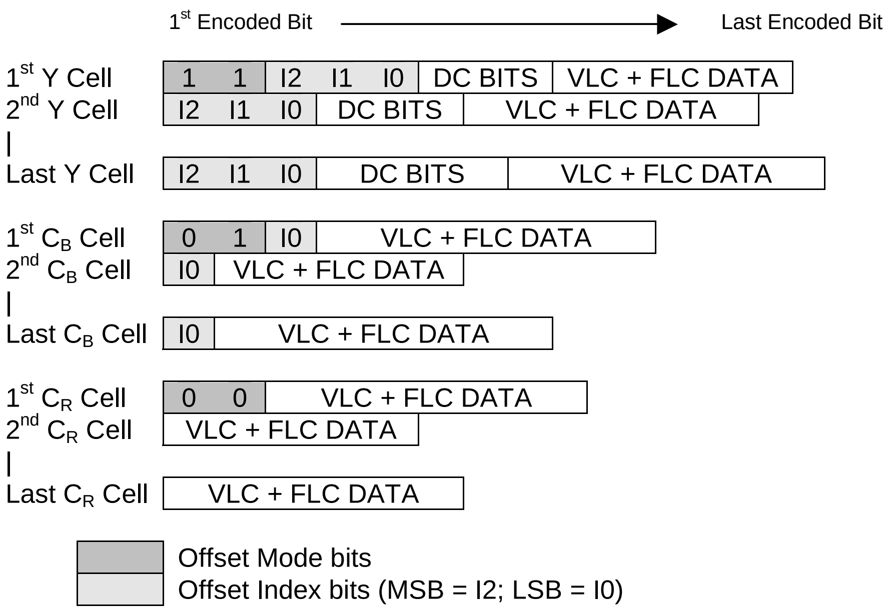


Figure 10 – DCT coefficient encoding example

4.9 Picture data packing

After entropy encoding, each DCT block consists of variable-length data representing the quantizer offset and the DCT coefficient data. The data from one code block (comprising five shuffle blocks) shall be packed into five basic blocks of the format described in figure 11.

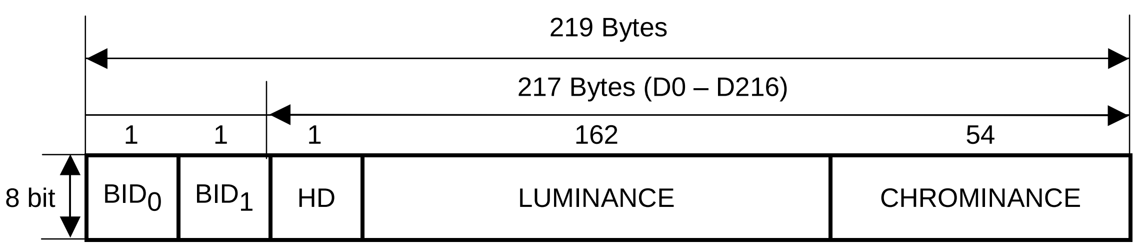


Figure 11 - Basic block format

The three header bytes, BID_0, BID_1, and HD, of each basic block shall be the same as those in the associated shuffle block (see figure 2). The header bytes are defined in 4.3.

4.9.1 Frame mode cell assignment

In frame mode, each basic block has 9 luminance cells of 18 bytes (162 bytes) and 12 chrominance cells of 4.5 bytes (54 bytes), corresponding to the luminance and chrominance DCT blocks as defined in 4.4.2. These cells are the nominal space assigned for the DCT block following compression. This is shown in figure 12 where the first DCT block of each chrominance pair shall be mapped to even cell numbers and the second DCT block of each chrominance pair shall be mapped to odd cell numbers.

For each pair of chrominance cells comprising 9 bytes, the first 4 bytes together with the 4 MSBs of the fifth byte shall be assigned to the first DCT block of the chrominance pair. The 4 LSBs of the fifth byte together with the last 4 bytes shall be assigned to the second DCT block of the chrominance pair.

→ Packing order

Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8
18 bytes	18 bytes	18 bytes	18 bytes	18 bytes	18 bytes	18 bytes	18 bytes	18 bytes

$C_B0 + C_B1$	$C_R0 + C_R1$	$C_B2 + C_B3$	$C_R2 + C_R3$	$C_B4 + C_B5$	$C_R4 + C_R5$
9 bytes	9 bytes	9 bytes	9 bytes	9 bytes	9 bytes

Figure 12 – Frame mode luminance and chrominance cells

4.9.2 Field mode cell assignment

In field mode, each basic block has 18 luminance cells of 9 bytes (162 bytes) and 12 chrominance cells of 4.5 bytes (54 bytes), corresponding to the luminance and chrominance DCT blocks as defined in 4.4.3. These cells are the nominal space assigned for the DCT block following compression. This is shown in figure 13 where the first DCT block of each luminance or chrominance pair shall be mapped to even cell numbers and the second DCT block of each luminance or chrominance pair shall be mapped to odd cell numbers

For each pair of chrominance cells comprising 9 bytes, the first 4 bytes together with the 4 MSBs of the fifth byte shall be assigned to the first DCT block of the chrominance pair. The 4 LSBs of the fifth byte together with the last 4 bytes shall be assigned to the second DCT block of the chrominance pair.

→ Packing order

Y0	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12	Y13	Y14	Y15	Y16	Y17
**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**

** = 9 bytes

$C_B0 + C_B1$	$C_R0 + C_R1$	$C_B2 + C_B3$	$C_R2 + C_R3$	$C_B4 + C_B5$	$C_R4 + C_R5$
9 bytes	9 bytes	9 bytes	9 bytes	9 bytes	9 bytes

Figure 13 – Field mode luminance and chrominance cells

4.9.3 Cell packing

The compressed data from each DCT block within a shuffle block shall be packed into an associated cell in a basic block until all the data are packed, or the cell is full. The data shall be packed in sequence from DCT blocks Y0 to C_R5 into cells from Y0 to C_R5 in the order shown in figure 12 for frame mode operation or figure 13 for field mode operation.

If the quantizer base value of the basic block is 63, any data remaining after packing shall be discarded and the OVF flag (HD byte, bit 6) shall be set to 0.

If the quantizer base value in the basic block is 61 or less, the following packing process shall be applied in the following sequence:

- Unpacked data from compressed DCT blocks that exceed the capacity of their cell shall be packed into unused space in other cells of the same basic block. The excess data from any compressed DCT blocks Y0 to C_R5 shall be packed into any remaining space of cells Y0 to C_R5 in the order shown in figure 12 for frame mode operation or figure 13 for field mode operation.

- Starting from the lowest numbered overflow basic block in a code block, any further excess data shall be packed first into any remaining space of the lowest numbered underflow basic block and then into any remaining space of subsequent underflow basic blocks contained within the code block. In each underflow basic block the excess data shall be packed into any remaining space of cells Y0 to C_R5 in the order shown in figure 12 for frame mode operation or figure 13 for field mode operation.

- Any remaining excess data shall be discarded.

If the data from the compressed DCT blocks Y0 to C_R5 fit within one basic block, the OVF flag (HD byte, bit 6) shall be set to 0 to indicate an underflow basic block.

If the data from the compressed DCT blocks Y0 to C_R5 exceed the capacity of one basic block, the OVF flag (HD byte, bit 6) shall be set to 1 to indicate an overflow basic block.

Figures 14 and 15 show the cell structure, packing order, and offset information (mode and index) positions for frame and field mode processing respectively.

Figures 16 and 17 show a simplified example of the packing process to aid understanding. In this example, a code block contains three shuffle blocks (SB0 to SB2). There are only five DCT blocks in each shuffle block (C0 to C4) and each cell in a basic block has a capacity of 5 bits.

Figure 16 shows the packing when the quantizer base has a value of 61 or less, and figure 17 shows the special case where a quantizer base value of 63 has been selected.

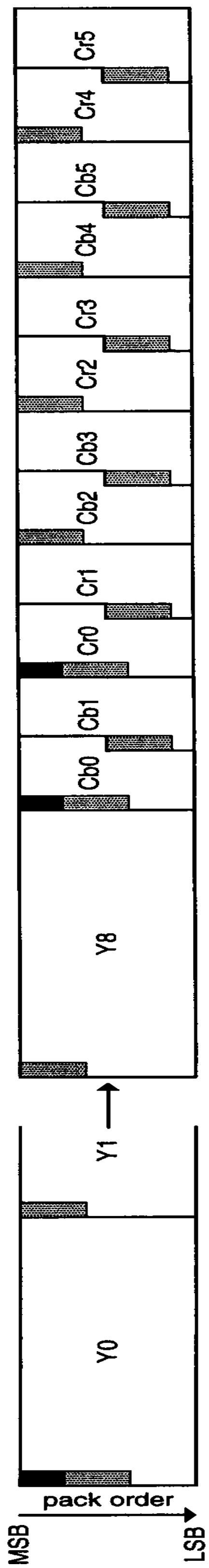
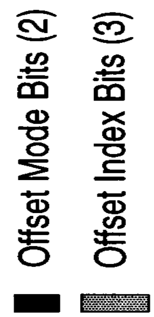


Figure 14 – Frame mode placement for offset mode and offset index bits



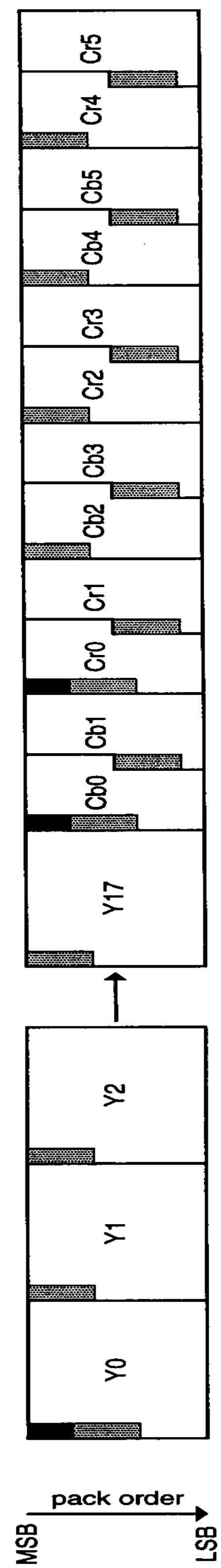


Figure 15 – Field mode placement for offset mode and offset index bits

DCT blocks before packing

SB									
SB0 (OVF=0)	C0	Aa0	Aa1	Aa2	Aa3	Aa4	Aa5	Aa6	
	C1	Ab0	Ab1	Ab2	Ab3				
	C2	Ac0	Ac1	Ac2	Ac3	Ac4	Ac5		
	C3	Ad0	Ad1	Ad2					
	C4	Ae0	Ae1						
SB1 (OVF=1)	C0	Ba0	Ba1	Ba2	Ba3				
	C1	Bb0	Bb1	Bb2	Bb3	Bb4	Bb5	Bb6	
	C2	Bc0	Bc1	Bc2					
	C3	Bd0	Bd1	Bd2	Bd3	Bd4	Bd5	Bd6	Bd7
	C4	Be0	Be1	Be2	Be3	Be4	Be5	Be6	
SB2 (OVF=0)	C0	Ca0	Ca1	Ca2	Ca3	Ca4			
	C1	Cb0	Cb1	Cb2	Cb3	Cb4	Cb5		
	C2	Cc0							
	C3	Cd0	Cd1	Cd2	Cd3	Cd4	Cd5		
	C4	Ce0	Ce1						

Packed Cells

Aa0	Aa1	Aa2	Aa3	Aa4
Ab0	Ab1	Ab2	Ab3	Aa5
Ac0	Ac1	Ac2	Ac3	Ac4
Ad0	Ad1	Ad2	Aa6	Ac5
Ae0	Ae1	Bd6	Bd7	Be5
Ba0	Ba1	Ba2	Ba3	Bb5
Bb0	Bb1	Bb2	Bb3	Bb4
Bc0	Bc1	Bc2	Bb6	Bd5
Bd0	Bd1	Bd2	Bd3	Bd4
Be0	Be1	Be2	Be3	Be4
Ca0	Ca1	Ca2	Ca3	Ca4
Cb0	Cb1	Cb2	Cb3	Cb4
Cc0	Cb5	Cd5	Be6	x
Cd0	Cd1	Cd2	Cd3	Cd4
Ce0	Ce1	x	x	x

NOTE – X indicates unused space in the code block.

Figure 16 – Packing when quantizer base = 61 or less

DCT blocks before packing

SB0 (OVF=0)	C0	Aa 0	Aa 1	Aa 2	Aa 3	Aa 4	Aa 5	Aa 6	
	C1	Ab 0	Ab 1	Ab 2	Ab 3				
	C2	Ac0	Ac1	Ac2	Ac3	Ac4	Ac5		
	C3	Ad 0	Ad 1	Ad 2					
	C4	Ae 0	Ae 1						
SB1 (OVF=0)	C0	Ba 0	Ba 1	Ba 2	Ba 3				
	C1	Bb 0	Bb 1	Bb 2	Bb 3	Bb 4	Bb 5	Bb 6	
	C2	Bc0	Bc1	Bc2					
	C3	Bd 0	Bd 1	Bd 2	Bd 3	Bd 4	Bd 5	Bd 6	Bd 7
	C4	Be 0	Be 1	Be 2	Be 3	Be 4	Be 5	Be 6	
SB2 (OVF=0)	C0	Ca 0	Ca 1	Ca 2	Ca 3	Ca 4			
	C1	Cb 0	Cb 1	Cb 2	Cb 3	Cb 4	Cb 5		
	C2	Cc 0							
	C3	Cd 0	Cd 1	Cd 2	Cd 3	Cd 4	Cd 5		
	C4	Ce 0	Ce 1						

Packed Cells

SB0 (OVF=0)	C0	Aa 0	Aa 1	Aa 2	Aa 3	Aa 4
	C1	Ab 0	Ab 1	Ab 2	Ab 3	x
	C2	Ac0	Ac1	Ac2	Ac3	Ac4
	C3	Ad 0	Ad 1	Ad 2	x	x
	C4	Ae 0	Ae 1	x	x	x
SB1 (OVF=0)	C0	Ba 0	Ba 1	Ba 2	Ba 3	x
	C1	Bb 0	Bb 1	Bb 2	Bb 3	Bb 4
	C2	Bc0	Bc1	Bc2	x	x
	C3	Bd 0	Bd 1	Bd 2	Bd 3	Bd 4
	C4	Be 0	Be 1	Be 2	Be 3	Be 4
SB2 (OVF=0)	C0	Ca 0	Ca 1	Ca 2	Ca 3	Ca 4
	C1	Cb 0	Cb 1	Cb 2	Cb 3	Cb 4
	C2	Cc 0	x	x	x	x
	C3	Cd 0	Cd 1	Cd 2	Cd 3	Cd 4
	C4	Ce 0	Ce 1	x	x	x

NOTE – X indicates unused space in the code block.

Figure 17 – Packing when quantizer base = 63

4.10 Auxiliary data

The compression process produces six segments for each channel, each segment comprising 225 basic blocks containing encoded data. Each segment shall be preceded by a single auxiliary basic block resulting in a total of 226 basic blocks.

The format of an auxiliary basic block is shown in figure 18.

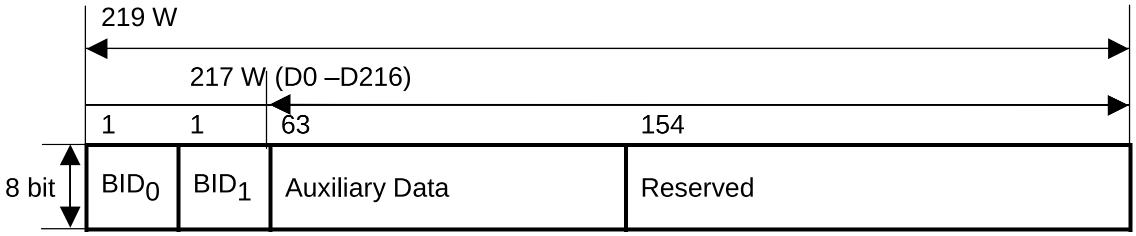


Figure 18 - Auxiliary basic block format

The auxiliary basic block contains two header bytes (BID_0 and BID_1), the quantizer offset values for the frame (described in 4.6 and 4.8.2), and extra data, as described in table 9.

The first header byte, BID_0, shall be set to the value 255. The second header byte, BID_1, shall contain the same information as the second header byte of a shuffle block, as described in 4.3.

The 6-bit, twos complement, quantizer offset values shall occupy the six LSBs of byte numbers D0 to D24. Any unused quantizer offset values shall be set to 0.

Any words or bits described as reserved in table 9 shall be set to 0.

The default value of any unassigned bits or bytes not identified as reserved in table 9 shall be 0.

Table 9 – Auxiliary basic block data

Byte	Bits	Description	Offset Index	Value
BID0	7..0	First header byte	-	Fixed value of 255
BID1	7..0	Second header byte	-	Described in 4.3
D0	5..0	Y quantizer offset value 0	0	-32 to +31 (6-bit twos complement)
D1	5..0	Y quantizer offset value 1	1	-32 to +31 (6-bit twos complement)
D2	5..0	Y quantizer offset value 2	2	-32 to +31 (6-bit twos complement)
D3	5..0	Y quantizer offset value 3	3	-32 to +31 (6-bit twos complement)
D4	5..0	Y quantizer offset value 4	4	-32 to +31 (6-bit twos complement)
D5	5..0	Y quantizer offset value 5	5	-32 to +31 (6-bit twos complement)
D6	5..0	Y quantizer offset value 6	6	-32 to +31 (6-bit twos complement)
D7	5..0	Y quantizer offset value 7	7	-32 to +31 (6-bit twos complement)
D8	5..0	C_B quantizer offset value 0	0	-32 to +31 (6-bit twos complement)
D9	5..0	C_B quantizer offset value 1	1	-32 to +31 (6-bit twos complement)
D10	5..0	C_B quantizer offset value 2	2	-32 to +31 (6-bit twos complement)
D11	5..0	C_B quantizer offset value 3	3	-32 to +31 (6-bit twos complement)
D12	5..0	C_B quantizer offset value 4	4	-32 to +31 (6-bit twos complement)
D13	5..0	C_B quantizer offset value 5	5	-32 to +31 (6-bit twos complement)
D14	5..0	C_B quantizer offset value 6	6	-32 to +31 (6-bit twos complement)
D15	5..0	C_B quantizer offset value 7	7	-32 to +31 (6-bit twos complement)
D16	5..0	C_R quantizer offset value 0	0	-32 to +31 (6-bit twos complement)
D17	5..0	C_R quantizer offset value 1	1	-32 to +31 (6-bit twos complement)
D18	5..0	C_R quantizer offset value 2	2	-32 to +31 (6-bit twos complement)
D19	5..0	C_R quantizer offset value 3	3	-32 to +31 (6-bit twos complement)
D20	5..0	C[illegible]	[illegible]	[illegible] complement)
D21	5..0	C[illegible]	[illegible]	[illegible] complement)
D22	5..0	C_R quantizer offset value 6	6	-32 to [illegible]

Table 9 – Auxiliary basic block data (concluded)

(continued)

D23	5..0	C_R quantizer offset value 7	7	-32 to +31 (6-bit twos complement)
D24	Bit 7	Shuffle pattern flag	-	Copy of BID1 bit 7 (SPF)
	Bit 6	Reserved	-	0
	Bit 5	Field-frame flag	-	Copy of BID1 bit 5 (FRM)
	4..0	Reserved	-	0
D25 to D35	7..0	Reserved	-	0
D36	7..0	VITC TC data (frame)	-	Described in figure 19
D37	7..0	VITC TC data (second)	-	Described in figure 19
D38	7..0	VITC TC data (minute)	-	Described in figure 19
D39	7..0	VITC TC data (hour)	-	Described in figure 19
D40	7..0	VITC UB data (frame)	-	Described in figure 19
D41	7..0	VITC UB data (second)	-	Described in figure 19
D42	7..0	VITC UB data (minute)	-	Described in figure 19
D43	7..0	VITC UB data (hour)	-	Described in figure 19
D44	7..0	Checksum	-	Bit inverted least significant byte of the summed bytes D36 to D43
D45	7..0	Reserved	-	0
D46	7..0	REC ID [7..0]	-	A random 16-bit number, unique to the frame.
D47	7..0	REC ID [15..8]	-	
D48 to D61	7..0	Reserved	-	0
D62	7..6	Reserved	-	0
	Bit 5	Interlace / sF	-	Interlace (value 0) or sF (value 1)
	4..3	Frame frequency	-	30 Hz (value 00) 25 Hz (value 01) 24 Hz (value 10)
	Bit 2	Input source	-	HD SDI (value 0) or SDTI dub (value 1)
	Bit 1	Active line number	-	1035 line (value 0) or 1080 line (value 1)
	Bit 0	Frame frequency divisor	-	1.001 (value 0) or 1.000 (value 1)
D63 to D216	7..0	Reserved	-	0

The format for each VITC data word shall be the same as defined in SMPTE RP 188. The least significant bit of each 4-bit VITC data word shall be aligned to bit 0 or bit 4 of the auxiliary data byte. Appropriate flag information defined by SMPTE 12M shall be inserted into the corresponding VITC time code data positions of figure 19.

NOTE – The fifth bit of each word, as described in SMPTE RP 188, is not recorded in the auxiliary data area, but is reproduced at the decoder output for compliance to SMPTE RP 188 at the interface.

The default value of any words described as reserved in figure 19 shall be set to 0.

Word	Bits 0–3 (LSB … MSB)	Bits 4–7 (LSB … MSB)
AUX 35	RESERVED	
AUX 36	LSB VITC TC DATA (units of frames) MSB	LSB VITC TC DATA (tens of frames+flags) MSB
AUX 37	LSB VITC TC DATA (units of seconds) MSB	LSB VITC TC DATA (tens of seconds+flag) MSB
AUX 38	LSB VITC TC DATA (units of minutes) MSB	LSB VITC TC DATA (tens of minutes+flag) MSB
AUX 39	LSB VITC TC DATA (units of hours) MSB	LSB VITC TC DATA (tens of hours+flags) MSB
AUX 40	LSB VITC UB DATA (binary group 1) MSB	LSB VITC UB DATA (binary group 2) MSB
AUX 41	LSB VITC UB DATA (binary group 3) MSB	LSB VITC UB DATA (binary group 4) MSB
AUX 42	LSB VITC UB DATA (binary group 5) MSB	LSB VITC UB DATA (binary group 6) MSB
AUX 43	LSB VITC UB DATA (binary group 7) MSB	LSB VITC UB DATA (binary group 8) MSB
AUX 44	CHECKSUM	
AUX 45	RESERVED	
AUX 46	REC ID	
AUX 47	REC ID	
AUX 48	RESERVED	
↓		
AUX 61	RESERVED	
AUX 62	VTR STATUS	
AUX 63	RESERVED	
↓		
AUX 216	RESERVED	

Figure 19 – Auxiliary data words

5 Decoding

5.1 Overview

The decoding process shall be the logical reverse of the encoding process, but without the field/frame decision or rate control functions.

In each channel the fixed length packed code blocks shall be unpacked to variable-length compressed DCT blocks.

These blocks shall be VLC decoded to fixed-length blocks of DCT coefficients, which shall be inverse quantized and transformed to 8*8 blocks of picture data by an inverse DCT process.

The two channels of 8*8 blocks shall be deshuffled to produce the even and odd samples of a subsampled frame. The subsampled frame shall be up-converted to produce a source sampled output frame.

Figure 20 shows the block diagram of the whole decoding process.

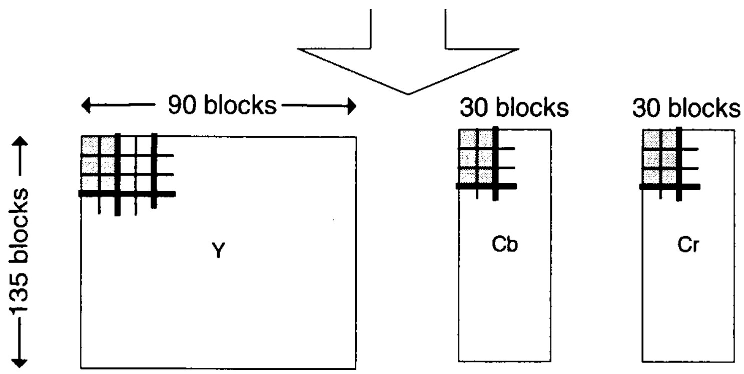


Figure 20 – Decoding block diagram

5.2 Unpacking

The compressed data, packed into five basic blocks, shall be unpacked to produce a code block containing variable-length compressed DCT-encoded data. This process shall perform the inverse of the packing process defined in 4.9.

The unpacking process also provides the quantizer base and other data from the header bytes of each basic block as defined in 4.3 and auxiliary data from the auxiliary basic blocks as defined in 4.10.

5.3 Entropy decoding

The variable-length data for each DCT block shall be decoded by performing the inverse of the entropy encoding process defined in 4.8. This process results in a DCT block containing quantized DC and AC coefficients together with the associated quantizer offset values.

5.4 Inverse quantization

The DPCM process defined in 4.7 for the chrominance DC coefficients shall be reversed using the equations as follows:

(2nd C_B DC coefficient for decoding) = (1st C_B DC coefficient) – (2nd C_B DC coefficient)
(2nd C_R DC coefficient for decoding) = (1st C_R DC coefficient) – (2nd C_R DC coefficient)

Each DCT coefficient shall then be recreated to its decoded value by simple multiplication of the coefficient value by the divisor value as defined in 4.7 using a value of quantizer index as defined in 4.6.

The value of each decoded DCT coefficient shall be limited to the range of a 16-bit twos complement number.

5.5 Inverse DCT

Following the inverse quantization process, the DCT coefficients shall be transformed to picture samples using the inverse DCT defined in annex C.

The samples out of the inverse DCT shall be limited to the range of an 8-bit twos complement number.

After the inverse DCT and limiting, the picture samples shall reverse the MSB inversion described in 4.5. Table 10 describes the data representations before and after this process.

Table 10 – MSB inversion

Luminance in		Luminance out		Chrominance in		Chrominance out	
-128 to +127		0 to +255		-128 to +127		-128 to +127	
+127	0111 1111	+255	1111 1111	+127	0111 1111	+127	1111 1111
+1	0000 0001	+129	1000 0001	+1	0000 0001	+1	1000 0001
0	0000 0000	+128	1000 0000	0	0000 0000	0	1000 0000
-1	1111 1111	+127	0111 1111	-1	1111 1111	-1	0111 1111
-128	1000 0000	0	0000 0000	-128	1000 0000	-128	0000 0000

5.6 Deshuffling

The picture samples in the DCT blocks produced by the inverse DCT process shall be reformatted and deshuffled, following the reverse of the processes described in 4.4 and 4.3 respectively.

5.7 Post-processing

The two channels of subsampled uncompressed picture samples shall be converted to the source sampled representation, using the vertical sampling process and reversing the horizontal subsampling process described in 4.2. The reverse of the subsampling process shall use a supersampling filter as defined in annex A. The output 10-bit samples from the supersampling filter shall be limited to the range 004_h to $3FB_h$ as defined in SMPTE 274M.

The full interface specification shall be recreated at the output digital interface according to SMPTE 292M.

Annex A (normative)
Subsampling filter

A digital filter shall be used for the sampling-rate conversion from source-sampled to subsampled luminance (Y) and chrominance (C_B,C_R) signals.

The template for the insertion-loss frequency characteristics of the luminance signal (Y) is defined in figure A.1. Figure A.2 defines the pass-band ripple tolerance.

NOTE – The sampling frequency, fs, used in figures A.1, A.2, A.3, and A.4 is that prior to subsampling.

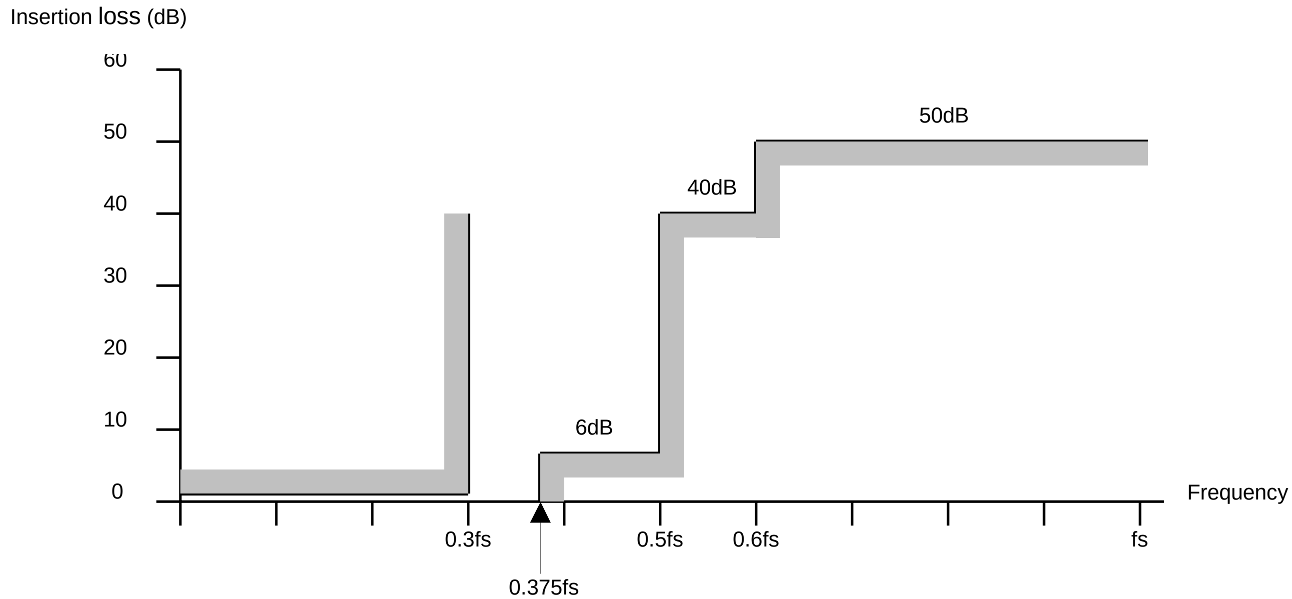


Figure A.1 – Template for insertion-loss frequency characteristic (Y)

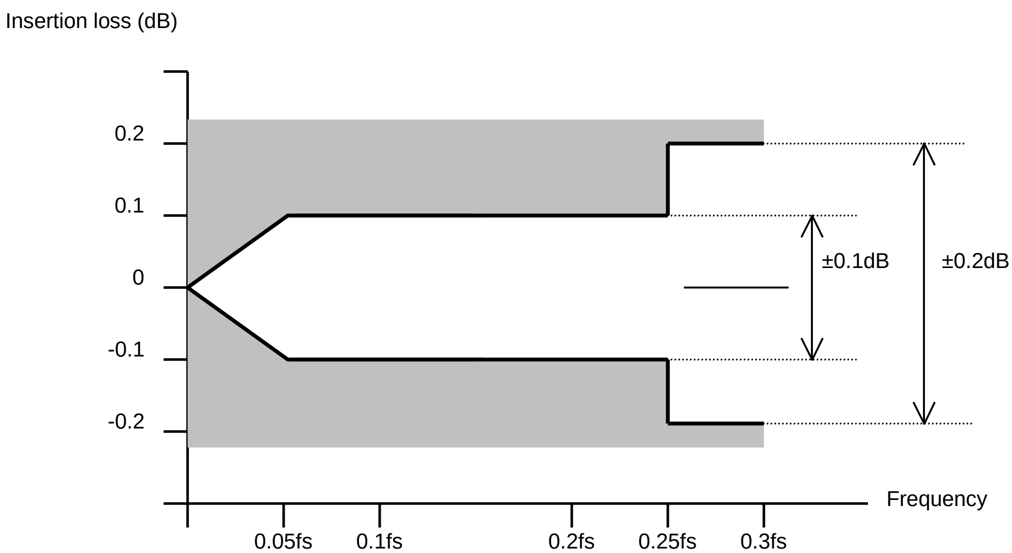


Figure A.2 – Pass-band ripple tolerance (Y)

The template for the insertion-loss frequency characteristics of the chrominance signals (C_B,C_R) is defined in figure A.3. Figure A.4 defines the pass-band ripple tolerance.

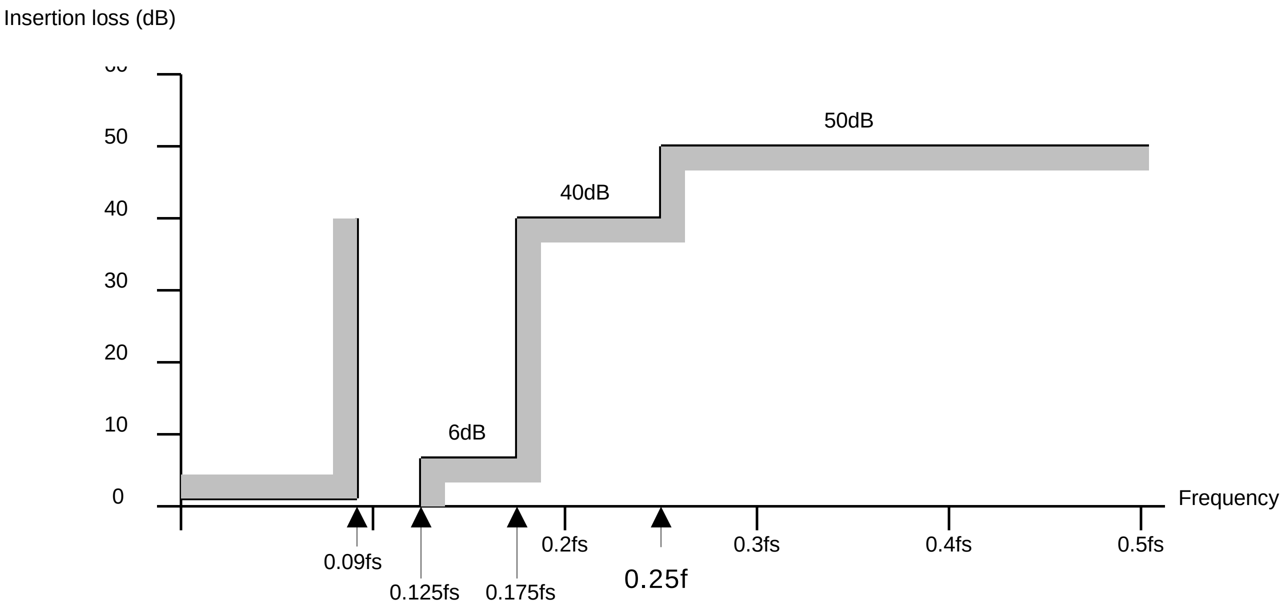


Figure A.3 – Template for insertion-loss frequency characteristic (C_B,C_R)

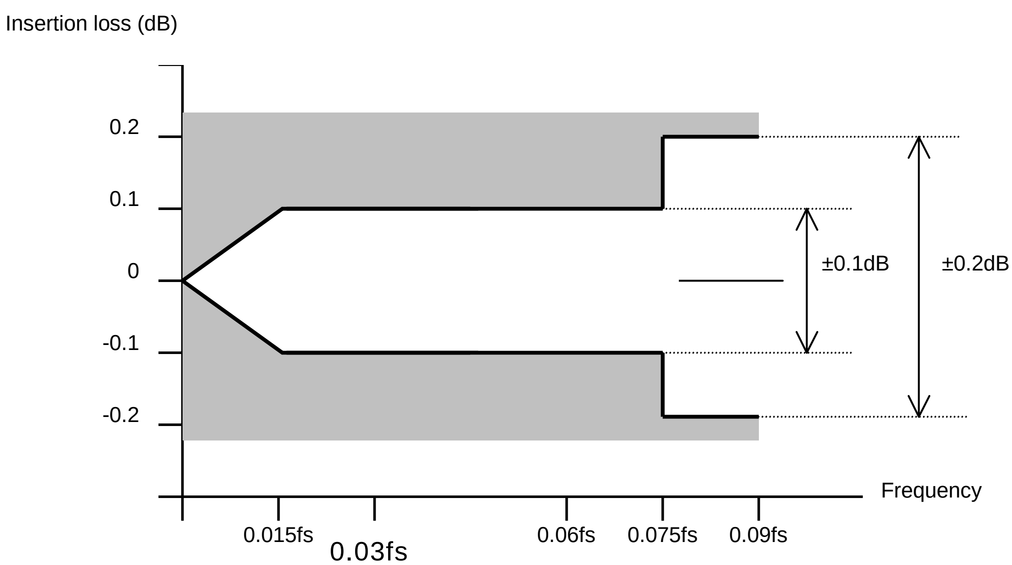


Figure A.4 – Pass-band ripple tolerance (C_B,C_R)

Annex B (normative)
Channel shuffling

Each channel processes a half frame of 90_Hx135_V luminance 8*8 blocks and 30_Hx135_V chrominance 8*8 block pairs (C_B and C_R) as shown in figure 5. The data shall be shuffled into six segments using one of two patterns defined by the shuffle pattern flag (SPF) in bit 7 of the BID_1 header byte as defined in 4.3.

Figure B.1 shows the segment numbers (in the range 0 to 5) assigned to a 6*6 array of 8*8 blocks for the luminance and chrominance data following the two shuffle patterns (identified by the SPF). This segment number is the same as that indicated in figure 2. The selected pattern, defined by the SPF, shall be repeated horizontally and vertically until all 8*8 blocks in each channel of a frame have been allocated to a segment.

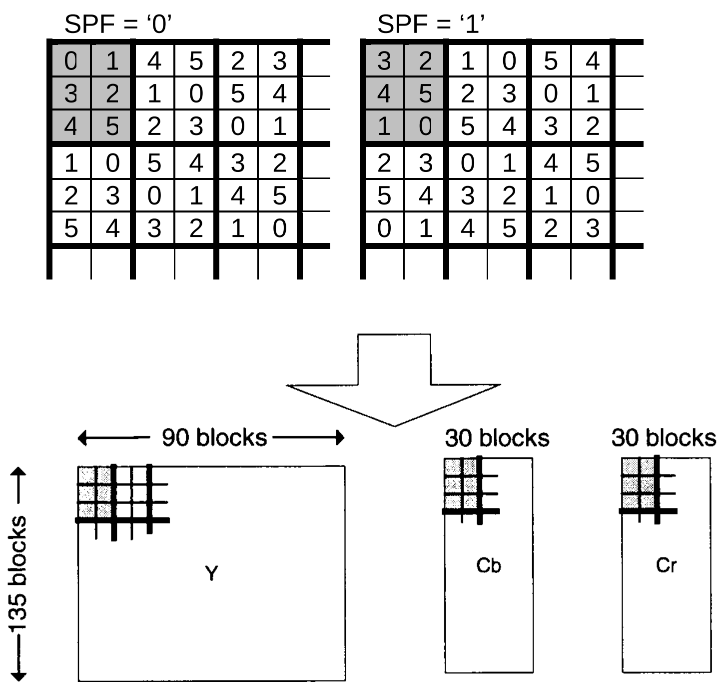


Figure B.1 – 8*8 block segmentation in each channel

For each channel, each segment then contains a total of 45_Hx45_V Y 8*8 blocks, 15_Hx45_V C_B 8*8 blocks, and 15_Hx45_V C_R 8*8 blocks.

These blocks shall then be further subdivided into 15 planes of 8*8 blocks, as shown in figure B.2, with 9 Y planes numbered P0 to P8, 3 C_B planes numbered P0 to P2, and 3 C_R planes numbered P0 to P2.

Each plane shall contain an array of 15_Hx15_V 8*8 blocks.

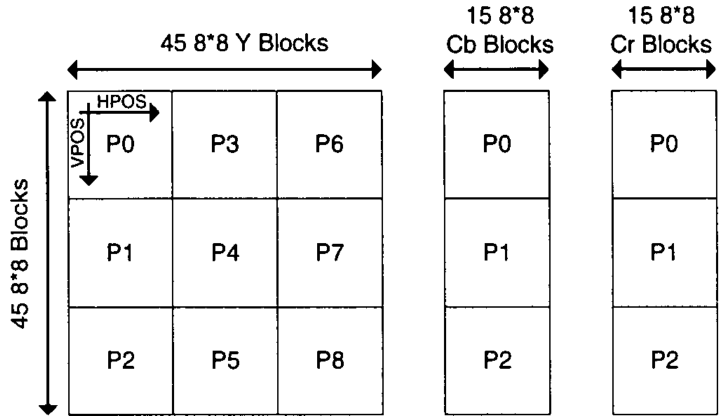


Figure B.2 – Block allocation within a segment

In each segment there are 225 shuffle blocks each containing 9 Y, 3 C_B, and 3 C_R 8*8 blocks. For each shuffle block, one 8*8 block shall be selected from each plane of $15_H x 15_V$ blocks in figure B.2.

The 8*8 blocks shall be selected from the planes P0 to P8 according to the equations below, where H_POS and V_POS are the horizontal and vertical block coordinates in the plane, with the top left block defined as (0,0).

H_POS = (START_OFFSET + TMP1) % 15
V_POS = ((START_OFFSET + TMP1) / 15) % 15

NOTE – The % symbol is used to denote the remainder after modulo division, and the / symbol is used to denote integer division.

The value of TMP1 is given in table B.1, and depends on the plane identifier (P0 to P8) from figure B.2 and the shuffle block number (SB), which is an integer from 0 to 224. This is the same value as defined in the BID_0 shuffle block header as illustrated in figure 7.

The values of START_OFFSET are given in tables B.2 and B.3, and depend on the segment number chosen from figure B.1 and the channel flag in bit 1 of the BID_1 header byte.

Table B.1 – Equation for TMP1

Plane identifier	Equation for TMP1
P0	(38*SB) % 225
P1	(8 + ((38*SB)%225) % 225
P2	(16 + ((38*SB)%225) % 225
P3	(180 + ((38*SB)%225) % 225
P4	(188 + ((38*SB)%225) % 225
P5	(196 + ((38*SB)%225) % 225
P6	(360 + ((38*SB)%225) % 225
P7	(368 + ((38*SB)%225) % 225
P8	(376 + ((38*SB)%225) % 225

Table B.2 – Values of START_OFFSET for luminance planes

Segment	Channel	START_OFFSET
0	0	35
1	0	170
2	0	50
3	0	140
4	0	20
5	0	155
0	1	60
1	1	150
2	1	75
3	1	165
4	1	45
5	1	180

Table B.3 – Values of START_OFFSET for chrominance planes

Segment	Channel	START_OFFSET
0	0	120
1	0	255
2	0	135
3	0	225
4	0	105
5	0	240
0	1	145
1	1	235
2	1	160
3	1	250
4	1	130
5	1	265

Annex C (normative)
Discrete cosine transform and zigzag scan

C.1 Discrete cosine transform

The $N_H x M_V$ two dimensional transform shall be defined as:

$$F(u,v)=\sqrt{\frac{2}{M}}\sqrt{\frac{2}{N}}.C(u).C(v).\sum_{y=0}^{y=M}\sum_{x=0}^{x=N} f(x,y).\cos\left(\frac{(2x+1)u\pi}{2N}\right).\cos\left(\frac{(2y+1)v\pi}{2M}\right)$$

where

x, y are spatial coordinates in the sample domain
u,v are spatial coordinates in the frequency domain

$$C(u),C(v)=\begin{cases}1/\sqrt{2} & \text{for u, v}=0\\ 1 & \text{otherwise}\end{cases}$$

The inputs to the forward transform are represented with 8 bits.

The coefficient values at the output of the transform are represented with a 16-bit signed number. All coefficients shall be scaled so that the worst case input occupies the dynamic ranges specified in table C.1.

In the $8_H x4_V$ and $4_H x8_V$ transforms, the DC coefficient shall be scaled so it occupies the same dynamic range as the DC coefficient produced by the $8_H x8_V$ transform.

$$F'(0,0)=\sqrt{2}.F(0,0)$$

The inverse transform shall be defined as:

$$f(x,y)=\sqrt{\frac{2}{M}}\sqrt{\frac{2}{N}}\sum_{v=0}^{v=M}\sum_{u=0}^{u=N} C(u).C(v).F(u,v).\cos\left(\frac{(2x+1)u\pi}{2N}\right).\cos\left(\frac{(2y+1)v\pi}{2M}\right)$$

The coefficient values at the input to the inverse transform shall be represented with a 16-bit signed number. The output from the inverse transform shall be represented with 8 bits.

In the $8_H x4_V$ and $4_H x8_V$ transforms, the DC sample shall be scaled to reverse the forward transform scaling.

$$f'(0,0)=\frac{1}{\sqrt{2}}.f(0,0)$$

The dynamic range of the DCT coefficients is given in hexadecimal form in table C.1.

Table C.1 – Dynamic range of coefficients

Transform	Coefficients	Minimum value	Maximum value
$8_H x8_V$	DC	8000	7F00
	AC	8000	7F00
$4_H x8_V$	DC	8000	7F00
	AC	A57E	59CD
$8_H x4_V$	DC	8000	7F00
	AC	A57E	59CD

C.1.1 Example

The coefficient values resulting from the transform of an $8_H x 8_V$, $8_H x 4_V$, or $4_H x 8_V$ DCT block containing samples of only one value are shown in table C.2.

Table C.2 – Coefficients for DC-only transforms

Sample value	8-bit data in	16-bit DC coefficient	16-bit AC coefficient
+1	01	0100	0000
-1	FF	FF00	0000
+127	7F	7F00	0000
-128	80	8000	0000

C.2 Zigzag scan

DCT coefficients in each DCT block shall be reordered after the DCT process as shown in tables C.3, C.4, and C.5, where the input and output data are sampled in a raster scan format.

Table C.3 – 8_H x 8_V zigzag scan

Input block

0	1	2	3	4	5	6	7
8	9	10	11	12	13	14	15
16	17	18	19	20	21	22	23
24	25	26	27	28	29	30	31
32	33	34	35	36	37	38	39
40	41	42	43	44	45	46	47
48	49	50	51	52	53	54	55
56	57	58	59	60	61	62	63

Output block

0	1	8	16	9	2	3	10
17	24	32	25	18	11	4	5
12	19	26	33	40	48	41	34
27	20	13	6	7	14	21	28
35	42	49	56	57	50	43	36
29	22	15	23	30	37	44	51
58	59	52	45	38	31	39	46
53	60	61	54	47	55	62	63

Table C.4 – 4_H x 8_V zigzag scan

Input block

0	1	2	3
4	5	6	7
8	9	10	11
12	13	14	15
16	17	18	19
20	21	22	23
24	25	26	27
28	29	30	31

Output block

0	1	4	8
5	2	3	6
9	12	16	13
10	7	11	14
17	20	24	21
18	15	19	22
25	28	29	26
23	27	30	31

Table C.5 – 8_H x 4_V zigzag scan

Input block

0	1	2	3	4	5	6	7
8	9	10	11	12	13	14	15
16	17	18	19	20	21	22	23
24	25	26	27	28	29	30	31

Output block

0	1	8	16	9	2	3	10
17	24	25	18	11	4	5	12
19	26	27	20	13	6	7	14
21	28	29	22	15	23	30	31

Annex D (normative)
VLC tables

Table D.1 – Group

VLC group	Number of FLC bits	Description
0	0	EOB code
1	1	(1)*0, ± 1
2	2	(2 to 3)*0, ± 1
3	3	(4 to 7)*0, ± 1
4	4	(8 to 15)*0, ± 1
5	5	(16 to 31)*0, ± 1
6	6	(32 to 63)*0, ± 1
7	0	(1)*0
8	1	(2 to 3)*0
9	2	(4 to 7)*0
10	3	(8 to 15)*0
11	4	(16 to 31)*0
12	5	(32 to 63)*0
13	1	± 1
14	2	-3 to –2, +2 to +3
15	3	-7 to –4, +4 to +7
16	4	-15 to –8, +8 to +15
17	5	-31 to –16, +16 to +31
18	6	-63 to –32, +32 to +63
19	7	-127 to –64, +64 to +127
20	8	-255 to –128, +128 to +255
21	14	-8192 to –256, +256 to +8191

NOTES
1 (x to y)*0, ± 1 means from x to y zero value coefficients followed by a coefficient of -1 or +1.
2 (x to y)*0 means from x to y zero value coefficients.

Table D.2 – Luminance VLC

Previous group	Current group	VLC
0	0	1100
0	1	11100
0	2	111100
0	3	111101
0	4	1111100
0	5	1111101
0	6	11111110
0	7	1101
0	8	111111110
0	9	1111111110
0	10	1111111111100
0	11	1111111111101
0	12	1111111111110
0	13	010
0	14	011
0	15	00
0	16	100
0	17	101
0	18	11101
0	19	1111110
0	20	11111111110
0	21	1111111111111

Previous group	Current group	VLC
1	0	11100
1	1	100
1	2	101
1	3	1100
1	4	111100
1	5	111111110
1	6	111111111110
1	7	11101
1	8	111101
1	9	1111110
1	10	1111111110
1	11	111111111111100
1	12	111111111111101
1	13	0
1	14	1101
1	15	111110
1	16	11111110
1	17	11111111110
1	18	1111111111110
1	19	111111111111110
1	20	1111111111111110
1	21	1111111111111111

Previous group	Current group	VLC
2	0	1100
2	1	00
2	2	100
2	3	101
2	4	11100
2	5	1111110
2	6	1111111110
2	7	11101
2	8	111100
2	9	111101
2	10	111111110
2	11	1111111111100
2	12	11111111111100
2	13	01
2	14	1101
2	15	111110
2	16	11111110
2	17	11111111110
2	18	1111111111101
2	19	11111111111101
2	20	11111111111110
2	21	11111111111111

Previous group	Current group	VLC
3	0	1100
3	1	00
3	2	100
3	3	101
3	4	1101
3	5	111100
3	6	11111110
3	7	111101
3	8	1111100
3	9	1111101
3	10	1111111110
3	11	1111111111100
3	12	1111111111101
3	13	01
3	14	1110
3	15	1111110
3	16	111111110
3	17	11111111110
3	18	11111111111100
3	19	11111111111101
3	20	11111111111110
3	21	11111111111111

(continued)

Table D.2 – Luminance VLC (continued**)**

Previous group	Current group	VLC	Previous group	Current group	VLC
4	0	010	5	0	00
4	1	011	5	1	010
4	2	100	5	2	011
4	3	101	5	3	100
4	4	110	5	4	101
4	5	11100	5	5	1110
4	6	1111100	5	6	11110
4	7	11101	5	7	11111000
4	8	1111101	5	8	111110100
4	9	111111100	5	9	111110101
4	10	111111101	5	10	111110110
4	11	111111111010	5	11	111110111
4	12	111111111011	5	12	111111000
4	13	00	5	13	110
4	14	11110	5	14	11111001
4	15	1111110	5	15	111111001
4	16	111111110	5	16	111111010
4	17	11111111100	5	17	111111011
4	18	111111111100	5	18	111111100
4	19	111111111101	5	19	111111101
4	20	111111111110	5	20	111111110
4	21	111111111111	5	21	111111111

Previous group	Current group	VLC	Previous group	Current group	VLC
6	0	0	7	0	Unused
6	1	11100	7	1	Unused
6	2	1100	7	2	Unused
6	3	100	7	3	Unused
6	4	101	7	4	Unused
6	5	11101	7	5	Unused
6	6	1111000	7	6	Unused
6	7	11110010	7	7	Unused
6	8	11110011	7	8	Unused
6	9	11110100	7	9	Unused
6	10	11110101	7	10	Unused
6	11	11110110	7	11	Unused
6	12	11110111	7	12	Unused
6	13	1101	7	13	Unused
6	14	11111000	7	14	0
6	15	11111001	7	15	10
6	16	11111010	7	16	110
6	17	11111011	7	17	1110
6	18	11111100	7	18	11110
6	19	11111101	7	19	111110
6	20	11111110	7	20	1111110
6	21	11111111	7	21	1111111

(continued)

Table D.2 – Luminance VLC (continued**)**

Previous group	Current group	VLC
8	0	Unused
8	1	Unused
8	2	Unused
8	3	Unused
8	4	Unused
8	5	Unused
8	6	Unused
8	7	Unused
8	8	Unused
8	9	Unused
8	10	Unused
8	11	Unused
8	12	Unused
8	13	Unused
8	14	0
8	15	10
8	16	110
8	17	1110
8	18	11110
8	19	111110
8	20	1111110
8	21	1111111

Previous group	Current group	VLC
9	0	Unused
9	1	Unused
9	2	Unused
9	3	Unused
9	4	Unused
9	5	Unused
9	6	Unused
9	7	Unused
9	8	Unused
9	9	Unused
9	10	Unused
9	11	Unused
9	12	Unused
9	13	Unused
9	14	0
9	15	10
9	16	110
9	17	1110
9	18	11110
9	19	111110
9	20	1111110
9	21	1111111

Previous group	Current group	VLC
10	0	Unused
10	1	Unused
10	2	Unused
10	3	Unused
10	4	Unused
10	5	Unused
10	6	Unused
10	7	Unused
10	8	Unused
10	9	Unused
10	10	Unused
10	11	Unused
10	12	Unused
10	13	Unused
10	14	0
10	15	10
10	16	110
10	17	1110
10	18	11110
10	19	111110
10	20	1111110
10	21	1111111

Previous group	Current group	VLC
11	0	Unused
11	1	Unused
11	2	Unused
11	3	Unused
11	4	Unused
11	5	Unused
11	6	Unused
11	7	Unused
11	8	Unused
11	9	Unused
11	10	Unused
11	11	Unused
11	12	Unused
11	13	Unused
11	14	00
11	15	01
11	16	100
11	17	101
11	18	110
11	19	1110
11	20	11110
11	21	11111

(continued)

Table D.2 – Luminance VLC (continued**)**

Previous group	Current group	VLC
12	0	Unused
12	1	Unused
12	2	Unused
12	3	Unused
12	4	Unused
12	5	Unused
12	6	Unused
12	7	Unused
12	8	Unused
12	9	Unused
12	10	Unused
12	11	Unused
12	12	Unused
12	13	Unused
12	14	00
12	15	01
12	16	100
12	17	101
12	18	110
12	19	1110
12	20	11110
12	21	11111

Previous group	Current group	VLC
13	0	111100
13	1	100
13	2	1100
13	3	1101
13	4	111101
13	5	111111110
13	6	111111111110
13	7	11100
13	8	111110
13	9	11111110
13	10	11111111110
13	11	1111111111111100
13	12	1111111111111101
13	13	0
13	14	101
13	15	11101
13	16	1111110
13	17	1111111110
13	18	1111111111110
13	19	11111111111110
13	20	1111111111111110
13	21	1111111111111111

Previous group	Current group	VLC
14	0	1111100
14	1	100
14	2	1100
14	3	11100
14	4	1111101
14	5	11111111110
14	6	111111111110
14	7	1101
14	8	11101
14	9	11111110
14	10	111111110
14	11	111111111111100
14	12	111111111111101
14	13	00
14	14	01
14	15	101
14	16	11110
14	17	1111110
14	18	1111111110
14	19	1111111111110
14	20	111111111111110
14	21	111111111111111

Previous group	Current group	VLC
15	0	11111111110
15	1	1100
15	2	111100
15	3	1111110
15	4	111111100
15	5	111111111110
15	6	111111111111100
15	7	1101
15	8	111101
15	9	111111101
15	10	1111111110
15	11	111111111111101
15	12	111111111111110
15	13	00
15	14	01
15	15	10
15	16	1110
15	17	111110
15	18	111111110
15	19	1111111111110
15	20	1111111111111110
15	21	1111111111111111

(continued)

Table D.2 – Luminance VLC (continued**)**

Previous group	Current group	VLC	Previous group	Current group	VLC

16	0	1111111110
16	1	11100
16	2	1111100
16	3	11111100
16	4	111111100
16	5	111111111110
16	6	11111111111100
16	7	11101
16	8	1111101
16	9	111111101
16	10	111111110
16	11	11111111111101
16	12	11111111111110
16	13	110
16	14	00
16	15	01
16	16	10
16	17	11110
16	18	11111101
16	19	11111111110
16	20	111111111111110
16	21	111111111111111

17	0	1111111100
17	1	11100
17	2	111100
17	3	11111100
17	4	1111111101
17	5	111111111100
17	6	111111111101
17	7	11101
17	8	111101
17	9	11111101
17	10	11111110
17	11	1111111111100
17	12	1111111111101
17	13	100
17	14	101
17	15	00
17	16	01
17	17	110
17	18	111110
17	19	1111111110
17	20	1111111111110
17	21	1111111111111

Previous group	Current group	VLC
18	0	1111111000
18	1	111100
18	2	1111100
18	3	1111111001
18	4	1111111010
18	5	1111111011
18	6	1111111100
18	7	111101
18	8	11100
18	9	1111101
18	10	11111100
18	11	1111111101
18	12	1111111110
18	13	100
18	14	101
18	15	110
18	16	00
18	17	01
18	18	11101
18	19	11111101
18	20	11111111110
18	21	11111111111

Previous group	Current group	VLC
19	0	1111000
19	1	111010
19	2	111011
19	3	1111001
19	4	11110110
19	5	11110111
19	6	11111000
19	7	1111010
19	8	11100
19	9	11111001
19	10	11111010
19	11	11111011
19	12	11111100
19	13	010
19	14	011
19	15	100
19	16	101
19	17	00
19	18	110
19	19	11111101
19	20	11111110
19	21	11111111

(continued)

Table D.2 – Luminance VLC (concluded**)**

Previous group	Current group	VLC
20	0	0000
20	1	0001

Previous group	Current group	VLC
21	0	0000
21	1	0001

20	2	0010
20	3	0011
20	4	0100
20	5	0101
20	6	0110
20	7	0111
20	8	1000
20	9	1001
20	10	10100
20	11	10101
20	12	10110
20	13	10111
20	14	11000
20	15	11001
20	16	11010
20	17	11011
20	18	11100
20	19	11101
20	20	11110
20	21	11111

21	2	0010
21	3	0011
21	4	0100
21	5	0101
21	6	0110
21	7	0111
21	8	1000
21	9	1001
21	10	10100
21	11	10101
21	12	10110
21	13	10111
21	14	11000
21	15	11001
21	16	11010
21	17	11011
21	18	11100
21	19	11101
21	20	11110
21	21	11111

Table D.3 – Chrominance VLC

Previous group	Current group	VLC
0	0	11100
0	1	11101
0	2	11111100
0	3	11111101
0	4	111111110
0	5	1111111110
0	6	11111111110
0	7	111110
0	8	111111111110
0	9	11111111111100
0	10	11111111111101
0	11	111111111111100
0	12	111111111111101
0	13	100
0	14	00
0	15	01
0	16	101
0	17	110
0	18	11110
0	19	11111110
0	20	111111111111110
0	21	111111111111111

Previous group	Current group	VLC
1	0	100
1	1	00
1	2	101
1	3	110
1	4	11100
1	5	111100
1	6	111101
1	7	11101
1	8	1111110
1	9	11111110
1	10	1111111110
1	11	1111111111010
1	12	1111111111011
1	13	01
1	14	111110
1	15	111111110
1	16	111111111100
1	17	1111111111100
1	18	1111111111101
1	19	1111111111110
1	20	11111111111110
1	21	11111111111111

Table D.3 – Chrominance VLC (continued) (continued)

Previous group	Current group	VLC
2	0	100
2	1	00

Previous group	Current group	VLC
3	0	010
3	1	011

2	2	101
2	3	110
2	4	1110
2	5	111100
2	6	111101
2	7	1111110
2	8	11111110
2	9	111111110
2	10	11111111110
2	11	11111111111000
2	12	11111111111001
2	13	01
2	14	111110
2	15	1111111110
2	16	11111111111010
2	17	11111111111011
2	18	11111111111100
2	19	11111111111101
2	20	11111111111110
2	21	11111111111111

3	2	100
3	3	101
3	4	110
3	5	1110
3	6	11110
3	7	1111110
3	8	111111100
3	9	111111101
3	10	1111111100
3	11	111111111000
3	12	111111111001
3	13	00
3	14	111110
3	15	1111111101
3	16	111111111010
3	17	111111111011
3	18	111111111100
3	19	111111111101
3	20	111111111110
3	21	111111111111

Previous group	Current group	VLC
4	0	00
4	1	010
4	2	011
4	3	100
4	4	101
4	5	1110
4	6	11110
4	7	1111100
4	8	11111100
4	9	11111101
4	10	11111110
4	11	11111111000
4	12	11111111001
4	13	110
4	14	1111101
4	15	11111111010
4	16	11111111011
4	17	11111111100
4	18	11111111101
4	19	11111111110
4	20	111111111110
4	21	111111111111

Previous group	Current group	VLC
5	0	00
5	1	010
5	2	011
5	3	100
5	4	101
5	5	1110
5	6	11110
5	7	111110110
5	8	111110111
5	9	11111010
5	10	1111100
5	11	111111000
5	12	111111001
5	13	110
5	14	111111010
5	15	111111011
5	16	111111100
5	17	111111101
5	18	1111111100
5	19	1111111101
5	20	1111111110
5	21	1111111111

(continued)

Table D.3 – Chrominance VLC (continued)

Previous group	Current group	VLC
6	0	0
6	1	100
6	2	101

Previous group	Current group	VLC
7	0	Unused
7	1	Unused
7	2	Unused

6	3	1100
6	4	1101
6	5	11110
6	6	111110010
6	7	111110011
6	8	111110100
6	9	111110101
6	10	11111000
6	11	111110110
6	12	111110111
6	13	1110
6	14	111111000
6	15	111111001
6	16	111111010
6	17	111111011
6	18	111111100
6	19	111111101
6	20	111111110
6	21	111111111

7	3	Unused
7	4	Unused
7	5	Unused
7	6	Unused
7	7	Unused
7	8	Unused
7	9	Unused
7	10	Unused
7	11	Unused
7	12	Unused
7	13	Unused
7	14	0
7	15	10
7	16	110
7	17	1110
7	18	11110
7	19	111110
7	20	1111110
7	21	1111111

Previous group	Current group	VLC
8	0	Unused
8	1	Unused
8	2	Unused
8	3	Unused
8	4	Unused
8	5	Unused
8	6	Unused
8	7	Unused
8	8	Unused
8	9	Unused
8	10	Unused
8	11	Unused
8	12	Unused
8	13	Unused
8	14	0
8	15	10
8	16	110
8	17	11100
8	18	11101
8	19	11110
8	20	111110
8	21	111111

Previous group	Current group	VLC
9	0	Unused
9	1	Unused
9	2	Unused
9	3	Unused
9	4	Unused
9	5	Unused
9	6	Unused
9	7	Unused
9	8	Unused
9	9	Unused
9	10	Unused
9	11	Unused
9	12	Unused
9	13	Unused
9	14	0
9	15	10
9	16	110
9	17	11100
9	18	11101
9	19	11110
9	20	111110
9	21	111111

(continued)

Table D.3 – Chrominance VLC (continued)

Previous group	Current group	VLC
10	0	Unused
10	1	Unused
10	2	Unused
10	3	Unused

Previous group	Current group	VLC
11	0	Unused
11	1	Unused
11	2	Unused
11	3	Unused

10	4	Unused
10	5	Unused
10	6	Unused
10	7	Unused
10	8	Unused
10	9	Unused
10	10	Unused
10	11	Unused
10	12	Unused
10	13	Unused
10	14	0
10	15	100
10	16	101
10	17	1100
10	18	1101
10	19	1110
10	20	11110
10	21	11111

11	4	Unused
11	5	Unused
11	6	Unused
11	7	Unused
11	8	Unused
11	9	Unused
11	10	Unused
11	11	Unused
11	12	Unused
11	13	Unused
11	14	00
11	15	01
11	16	100
11	17	101
11	18	110
11	19	1110
11	20	11110
11	21	11111

Previous group	Current group	VLC
12	0	Unused
12	1	Unused
12	2	Unused
12	3	Unused
12	4	Unused
12	5	Unused
12	6	Unused
12	7	Unused
12	8	Unused
12	9	Unused
12	10	Unused
12	11	Unused
12	12	Unused
12	13	Unused
12	14	00
12	15	01
12	16	100
12	17	101
12	18	110
12	19	1110
12	20	11110
12	21	11111

Previous group	Current group	VLC
13	0	010
13	1	011
13	2	100
13	3	101
13	4	11100
13	5	111100
13	6	111101
13	7	11101
13	8	1111110
13	9	11111110
13	10	1111111110
13	11	1111111111100
13	12	1111111111101
13	13	00
13	14	110
13	15	111110
13	16	111111110
13	17	11111111110
13	18	11111111111100
13	19	11111111111101
13	20	11111111111110
13	21	11111111111111

(continued)

Table D.3 – Chrominance VLC (continued)

Previous group	Current group	VLC
14	0	1010
14	1	100
14	2	1011
14	3	1100
14	4	111100

Previous group	Current group	VLC
15	0	1100
15	1	1101
15	2	11100
15	3	111100
15	4	1111100

14	5	11111110
14	6	1111100
14	7	1101
14	8	111101
14	9	1111101
14	10	11111111100
14	11	111111111100
14	12	111111111101
14	13	00
14	14	01
14	15	1110
14	16	1111110
14	17	111111110
14	18	11111111101
14	19	111111111110
14	20	1111111111110
14	21	1111111111111

15	5	11111100
15	6	11111101
15	7	100
15	8	111101
15	9	11111110
15	10	11111111100
15	11	11111111101
15	12	111111111100
15	13	00
15	14	01
15	15	101
15	16	11101
15	17	1111101
15	18	111111110
15	19	111111111101
15	20	111111111110
15	21	111111111111

Previous group	Current group	VLC
16	0	100
16	1	11100
16	2	11101
16	3	111100
16	4	1111100
16	5	11111100
16	6	11111101
16	7	1100
16	8	1111101
16	9	11111110
16	10	11111111100
16	11	11111111101
16	12	111111111100
16	13	00
16	14	01
16	15	101
16	16	1101
16	17	111101
16	18	111111110
16	19	111111111101
16	20	111111111110
16	21	111111111111

Previous group	Current group	VLC
17	0	010
17	1	11010
17	2	11011
17	3	11100
17	4	111100
17	5	1111100
17	6	1111101
17	7	11101
17	8	11111100
17	9	11111101
17	10	111111100
17	11	111111101
17	12	1111111100
17	13	00
17	14	011
17	15	100
17	16	101
17	17	1100
17	18	111101
17	19	1111111101
17	20	1111111110
17	21	1111111111

(continued)

Table D.3 – Chrominance VLC (concluded)

Previous group	Current group	VLC
18	0	1100
18	1	111010
18	2	111011
18	3	111100
18	4	1111010
18	5	11111000

Previous group	Current group	VLC
19	0	000
19	1	110110
19	2	110111
19	3	111000
19	4	111001
19	5	111010

18	6	11111001
18	7	11100
18	8	11111010
18	9	11111011
18	10	11111100
18	11	11111101
18	12	11111110
18	13	010
18	14	011
18	15	100
18	16	00
18	17	101
18	18	1101
18	19	1111011
18	20	111111110
18	21	111111111

19	6	111011
19	7	1111000
19	8	1111001
19	9	1111010
19	10	1111011
19	11	1111100
19	12	1111101
19	13	001
19	14	010
19	15	011
19	16	100
19	17	101
19	18	1100
19	19	11010
19	20	1111110
19	21	1111111

Previous group	Current group	VLC
20	0	0000
20	1	0001
20	2	0010
20	3	0011
20	4	0100
20	5	0101
20	6	0110
20	7	0111
20	8	1000
20	9	1001
20	10	10100
20	11	10101
20	12	10110
20	13	10111
20	14	11000
20	15	11001
20	16	11010
20	17	11011
20	18	11100
20	19	11101
20	20	11110
20	21	11111

Previous group	Current group	VLC
21	0	0000
21	1	0001
21	2	0010
21	3	0011
21	4	0100
21	5	0101
21	6	0110
21	7	0111
21	8	1000
21	9	1001
21	10	10100
21	11	10101
21	12	10110
21	13	10111
21	14	11000
21	15	11001
21	16	11010
21	17	11011
21	18	11100
21	19	11101
21	20	11110
21	21	11111

D.4 FLC table

The fixed length code of between 1 and 14 bits (defined in annex D.1) shall be generated according to table D.4.

The FLC bits column shall indicate the FLC associated with the current group as FLC[x:0], where x is the MSB and 0 is the LSB.

The FLC zero-run length column shall indicate the number of zero value coefficients encoded in the current group.

The FLC coefficient value column shall indicate the value of any non-zero coefficient encoded in the current group.

Table D.4 – FLC

Group number	FLC bits	FLC zero-run length	FLC coefficient value
0	-	-	-
1	FLC[0]	1	TVALUE(FLC[0])
2	FLC[1:0]	2 + FLC[1]	TVALUE(FLC[0])
3	FLC[2:0]	4 + FLC[2:1]	TVALUE(FLC[0])
4	FLC[3:0]	8 + FLC[3:1]	TVALUE(FLC[0])
5	FLC[4:0]	16 + FLC[4:1]	TVALUE(FLC[0])
6	FLC[5:0]	32 + FLC[5:1]	TVALUE(FLC[0])
7	-	-	-
8	FLC[0]	2 + FLC[0]	-
9	FLC[1:0]	4 + FLC[1:0]	-
10	FLC[2:0]	8 + FLC[2:0]	-
11	FLC[3:0]	16 + FLC[3:0]	-
12	FLC[4:0]	32 + FLC[4:0]	-
13	FLC[0]	-	VALUE(FLC[0])
14	FLC[1:0]	-	VALUE(FLC[1:0])
15	FLC[2:0]	-	VALUE(FLC[2:0])
16	FLC[3:0]	-	VALUE(FLC[3:0])
17	FLC[4:0]	-	VALUE(FLC[4:0])
18	FLC[5:0]	-	VALUE(FLC[5:0])
19	FLC[6:0]	-	VALUE(FLC[6:0])
20	FLC[7:0]	-	VALUE(FLC[7:0])
21	FLC[13:0]	-	SFLC[13:0]

NOTES

1 TVALUE(FLC[0]) is a code that returns a coefficient value which terminates a run of zeroes

– when FLC[0] takes the value 1 : coefficient = 1
– when FLC[0] takes the value 0 : coefficient = -1

2 VALUE(FLC[x:0]) is a code that returns a coefficient value which does not terminate a run of zeroes for x<13

– when FLC[x] takes the value 1 : coefficient = FLC[x:0]
– when FLC[x] takes the value 0 : coefficient = $-2^{(x+1)}$ + FLC[x:0] + 1

3 SFLC[13:0] means the twos complement value formed by bits 13 to 0.

Annex E (informative)
System overview

Figure E.1 describes the relationship between the compression processes described in the document and the associated specifications for a complete type D-11 specification.

1) is the compression specification, SMPTE 367M (this document);

2) is the SD-SDTI specification, SMPTE 369M;

3) is the VTR specification, SMPTE 368M.

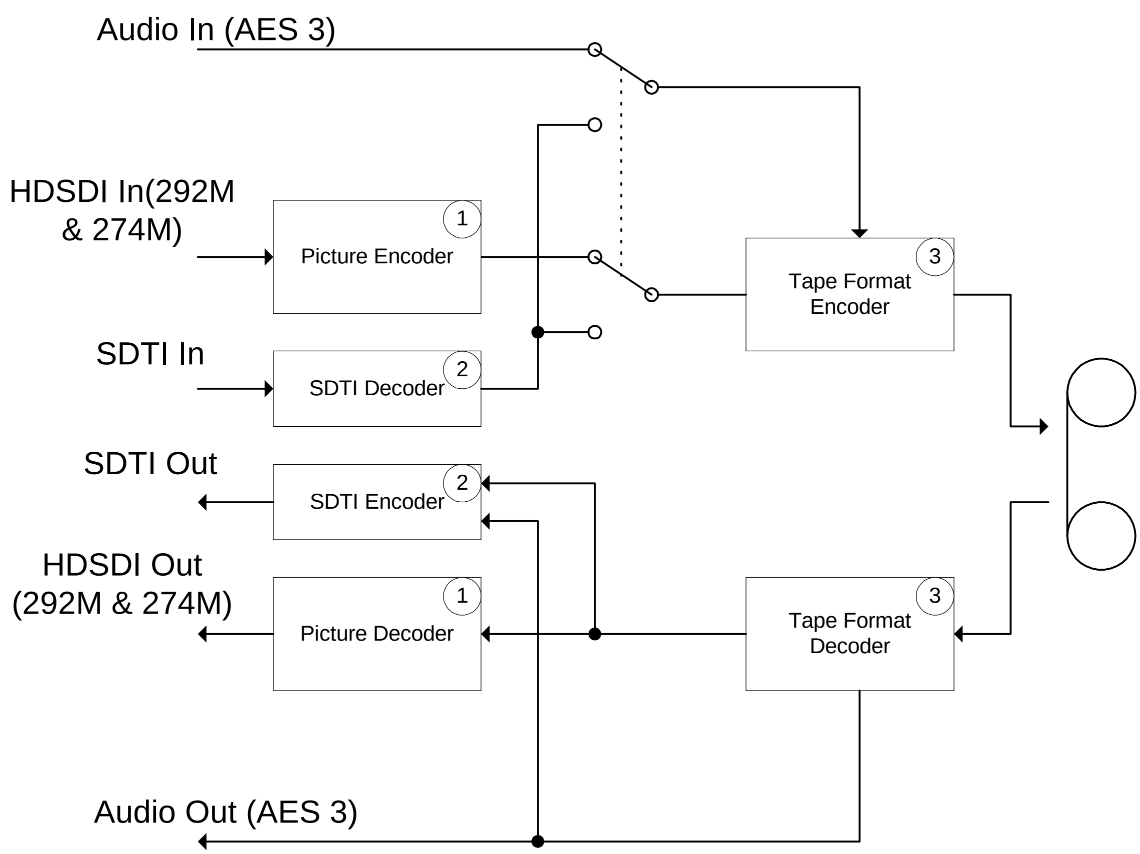


Figure E.1 – System overview

Annex F (informative)
Bibliography

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