MPEG-2

13818-1 : Systems
13818-2 : Video
13818-3 : Audio
13818-4 :Conformance
13818-5 :Software
13818-6 : Digital Storage Media -Command and Control (DSM-CC)

Two types of MPEG-2 streams

- ***Program Stream***
  - is MPEG-1 like and intended for error-free media.
  - Use a modify function syntax to support new function.
  - Typically employ long and variable -length packets for software based process
  - error free -environment (compressed data are stored on a disk)
- ***Transport stream***
  - differs from MPEG-1
  - offers robustness necessary for noisy channels as well as the ability to include multiple programs in a single stream
  - suitable for delivering compressed video & audio over error-prone channels

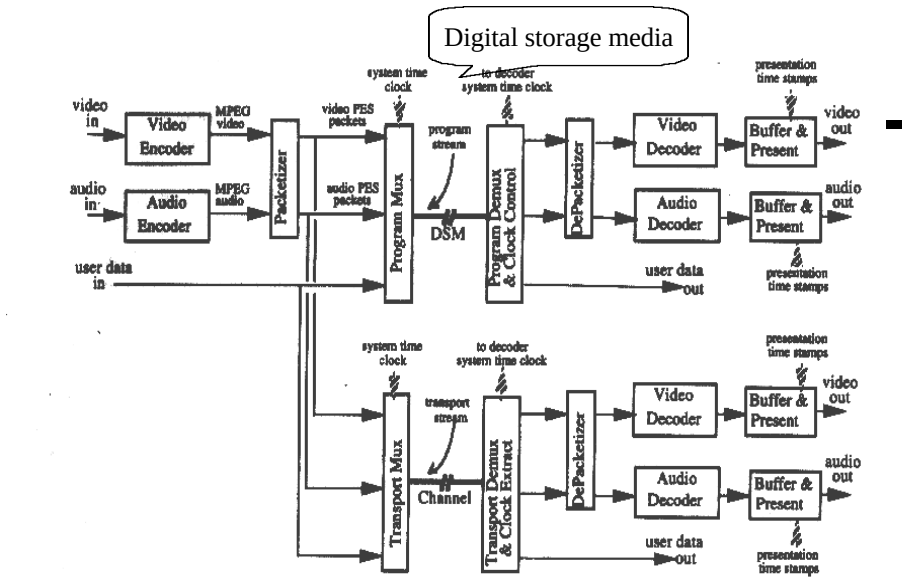


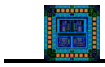
Fig. 2.1 MPEG-2 Systems Multiplex showing Program and Transport Streams.

MPEG-2 Systems

- Main function of system
  - to provide a means of combing, or multiplexing, several types of multimedia information into one stream.
- Methods for multiplexing
  - Time Division Multiplexing (TDM)
  - Packet multiplexing
    - constant bitrate (CBR)
    - variable bitrate (VBR)
    - statistical multiplexing

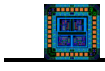
Synchronization

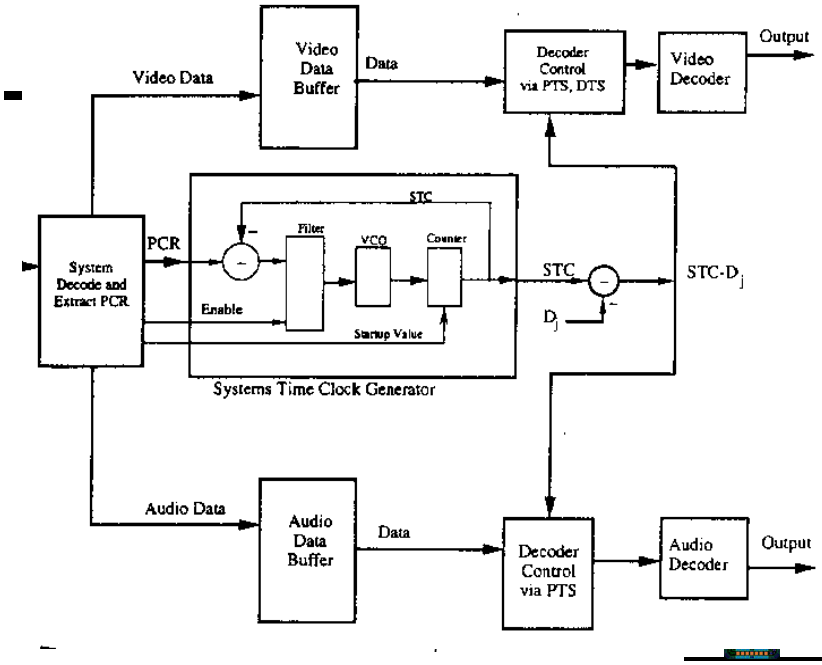
- Why?
  - Multimedia
  - Packetized systems
  - prepared & edited separated prior to multiplexing
- How?
  - Time stamps
    - Decoding Time Stamp (DTS)
    - Presentation Time Stamp (PTS)
  - Clock references
  - Systems Time Clock (STC)



Elementary Streams

- Packetized Elementary Stream (PES)
  - use for program and transport streams
- Compressed data from a single source
- Ancillary data
  - synchronization identification.
  - characterization of the source information.
- PES packet =header + stream data (payload)
- Start-Code
  - start_code_prefix(Psc) 000…001
  - Start-Code ID (PES: stream_id, 0xBD~0xFE)





MPEG-2
Video Coding & Compression

- ***Interlace Scan*** and progressive scan
- Color Subsampling --- 4:2:0, 4:2:2, 4:4:4
- Motion Compensation --- prediction and prime vectors
- Quantization --- more flexible for changing matrix and scale factor
- ***Profile & Level*** --- A profile is a defined subset of the entire bit stream syntax. With in profile, a level is defined as a set of constraints imposed on the parameters of the bit stream.
- ***Scalability*** ---
  - •Data partitioning -- for two channels available applications, ex. ATM
  - •SNR scalability
  - •Spatial Scalability
  - •Temporal Scalability

Profiles and Levels (1)

MPEG-2 defines coding parameters by profiles and levels

Profile defines sub-set of syntax

Level defines set of constrains

Main Profile @ Main Level (MP@ML)

Profile frame format: I, P, B
chrominance format: 4:2:0
scalability: No

Level 720x480, 30 f/sec, or 720x576, 25 f/sec
compressed bit rate: no more than 15Mbit/s

Profiles and Levels (2)

Level ↑

	Simple Nonscalable 4:2:0	Main Nonscalable 4:2:0	SNR Scalable 4:2:0	Spatial Scalable 4:2:0	High Nonscalable scalable 4:2:2/4:2:0
High 1920x1152x60		**MP@HL** (HDTV)			**HP@HL**
High1440 1440x1152x60		**MP@1440**		**SSP@H1440** (ED HDTV)	**HP@H1440**
Main 720x576x30	**SP@ML** DigitalCATV	**MP@ML** (DirecTV)	**SNP@ML**		**HP@ML**
Low 352x288x30		**MP@LL**	**SNP@LL**		

Profile →

Table 1 The MPEG2 profiles and levels

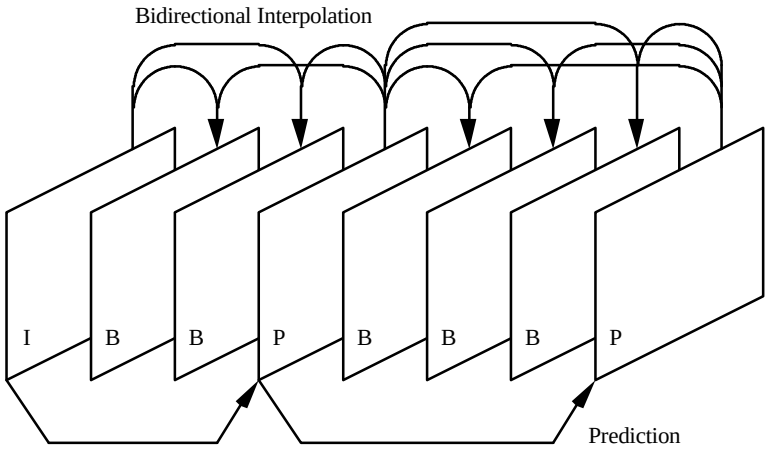
Level	Spatial resolution layer		Profile				
			Simple	Main	SNR	Spatial	High
High	Enhancement	samples/line		1920			1920
		lines/frame		1152			1152
		frames/sec		60			60
	Lower	samples/line					960
		lines/frame		-			576
		frames/sec					30
High-1440	Enhancement	samples/line		1440		1440	1440
		lines/frame		1152		1152	1152
		frames/sec		60		60	60
	Lower	samples/line				720	720
		lines/frame		-		576	576
		frames/sec				30	30
Main	Enhancement	samples/line	720	720	720		720
		lines/frame	576	576	576		576
		frames/sec	30	30	30		30
	Lower	samples/line					352
		lines/frame	-	-	-		288
		frames/sec					30
Low	Enhancement	samples/line		352	352		
		lines/frame		288	288		
		frames/sec		30	30		
	Lower	samples/line					
		lines/frame		-	-		
		frames/sec					
OTE - In the case of single layer or SNR scaled coding, the limits specified by 'Enhancement layer' apply							

MAIN PROFILE OVERVIEW

Table 8.1 Parameter Bounds for MPEG-2 Main Profile at Main Level (MP@ML) Video Streams.

Parameter	Bound
Samples/line	720
Lines/frame	576
Frames/second	30
Samples/second	10 368 000
Bitrate	15 Mbits/s
Buffer size	1 835 008 bits
Chroma format	4:2:0
Image aspect ratio	4:3, 16:9 and square pels

Structure of GOP



Ordering of GOP

At the encoder input,

1	2	3	4	5	6	7	8	9	10	11	12	13
I	B	B	P	B	B	P	B	B	I	B	B	P

At the encoder output, in the coded bitstream, and at the decoder input,

1	4	2	3	7	5	6	10	8	9	13	11	12
I	P	B	B	P	B	B	I	B	B	P	B	B

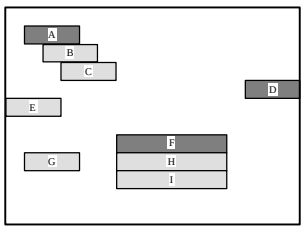
At the decoder output,

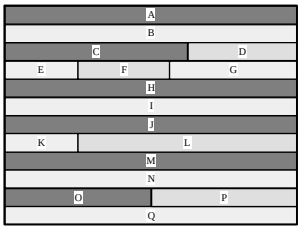
1	2	3	4	5	6	7	8	9	10	11	12	13

Non-constraint slice and Restricted Slice

some macroblock may not belong to any slice

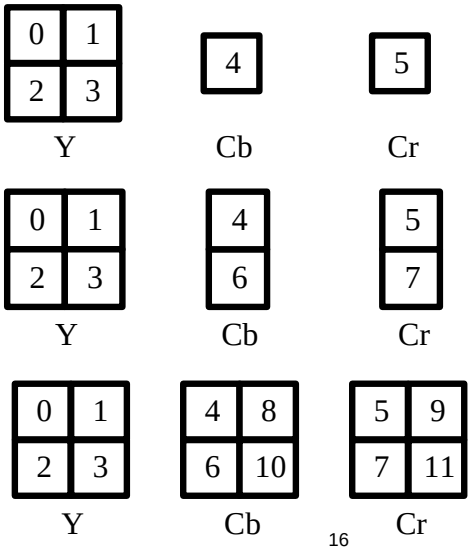
A **slice** is a series of an arbitrary number of consecutive macroblocks.
The first and last macroblocks of a slice shall not be skipped macroblocks.
Every slice shall contain at least one macroblock. Slices shall not overlap.
The position of slices may change from picture to picture.
The first and last macroblock of a slice shall be in the same horizontal row of macroblocks.
Slices shall occur in the bitstream in the order in which they are encountered, starting at the upper-left of the picture and proceeding by raster-scan order from left to right and top to bottom (illustrated in the Figures of this clause as alphabetical order).





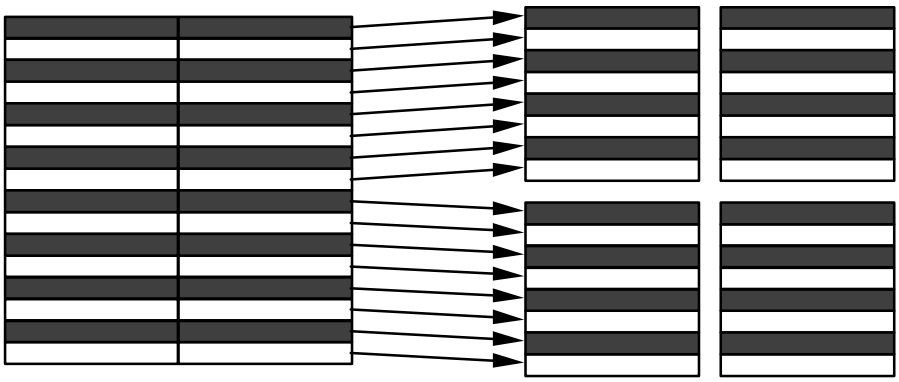
15

Macroblock structure



16

Luminance macroblock structure in frame DCT coding



17

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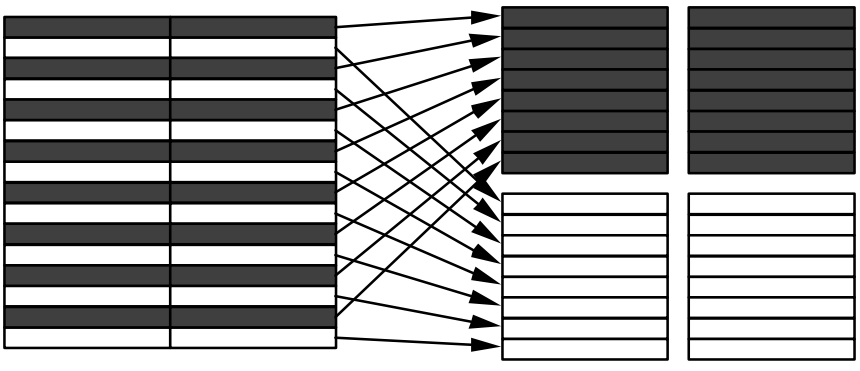
Luminance macroblock structure in field DCT coding



18

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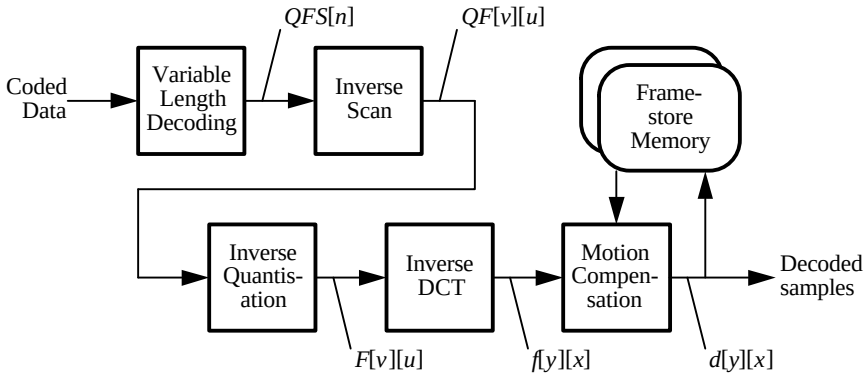
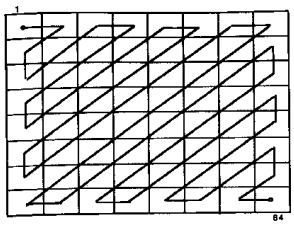
Simplified Video Decoding Process

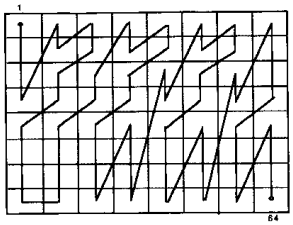


Exploiting Spatial Redundancy

- Interlace
  - provides interlace in Frame-pictures to reduce vertical correlation
- Scan
  - Alternate_scan vs. Zigzag scan



(a) Zigzag Scan



(b) Alternate Scan

Table 8.9 Luminance PSNR (dB) for DCT coefficient scans for frame-pictures. $M = 3, N = 15$, bitrate = 4 Mbits/s

Sequence	Zigzag Scan	Alternate Scan
Flowergarden	29.36	29.61 (+0.25)
Mobile & Cal	28.20	28.24 (+0.04)
Football	34.77	35.07 (+0.30)
Bus	31.35	31.57 (+0.22)
Carousel	29.57	29.68 (+0.11)

Quantizer Matrices

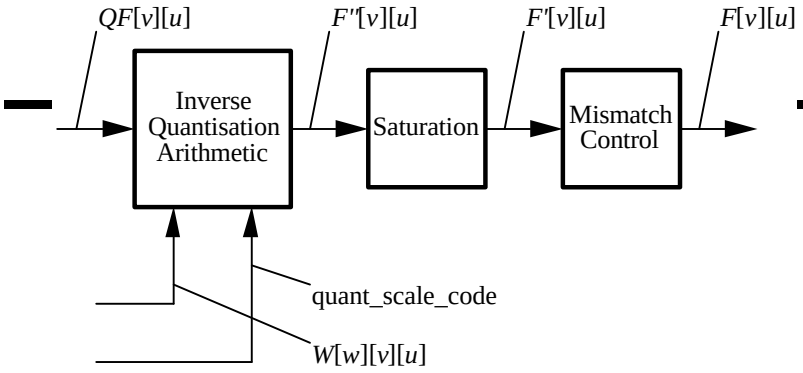
8	16	19	22	26	27	29	34
16	16	22	24	47	49	34	37
19	22	26	27	29	34	34	38
22	22	26	27	29	34	37	40
22	26	27	29	32	35	40	48
26	27	29	32	35	40	48	58
26	27	29	34	38	46	56	69
27	29	35	38	46	56	69	83

Intra

16	16	16	16	16	16	16	16
16	16	16	16	16	16	16	16
16	16	16	16	16	16	16	16
16	16	16	16	16	16	16	16
16	16	16	16	16	16	16	16
16	16	16	16	16	16	16	16
16	16	16	16	16	16	16	16
16	16	16	16	16	16	16	16

Inter

Note: For both Luminance and chrominance



$$F[v][u] = ((2 \times QF[v][u] + k) \times W[w][v][u] \times quantiser\_scale)/32$$

where :

$$k = \begin{cases} 0 & \text{intra blocks} \\ Sign(QF[v][u]) & \text{non-intra blocks} \end{cases}$$

$$F[v][u] = \begin{cases} 2047 & F[v][u] > 2047 \\ F[v][u] & -2048 \le F[v][u] \le 2047 \\ -2048 & F[v][u] < -2048 \end{cases}$$

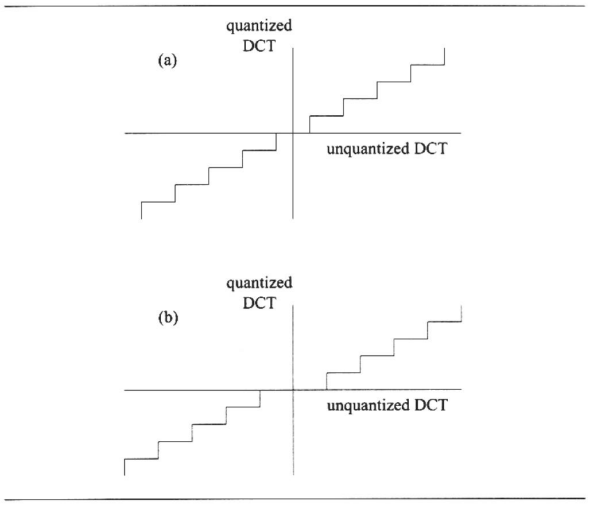


Figure 3.10: Rounding of quantized DCT coefficients for (a) intra coding and (b) nonintra coding. The nonintra rounding produces a dead zone around zero.

IDCT Mismatch

Since inter-coded blocks are added to previously reconstructed pels or data predicted from such pels, any differences between the IDCT used in the encoder and the IDCT used in the decoder will propagate until a block is intra coded. This difference is called IDCT mismatch error.

Oddification rules:

$$sum = \sum_{v=0}^{v<8} \sum_{u=0}^{u<8} F\,[v][u]$$

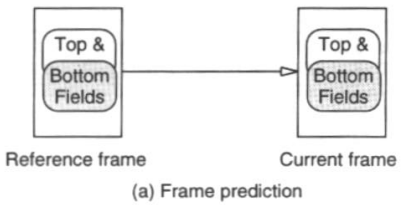
$$F[v][u] = F\,[v][u] \text{ for all } u, v \text{ except } u = v = 7$$

$$F[7][7] = \begin{cases} F\,[7][7] & \text{if } sum \text{ is odd} \\ \begin{cases} F\,[7][7]-1 & \text{if } F\,[7][7] \text{ is odd} \\ F\,[7][7]+1 & \text{if } F\,[7][7] \text{ is even} \end{cases} & \text{if } sum \text{ is even} \end{cases}$$

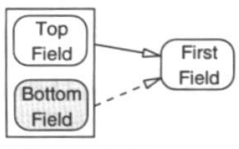
Exploiting Temporal Redundancy

Field and Frame Prediction Modes:

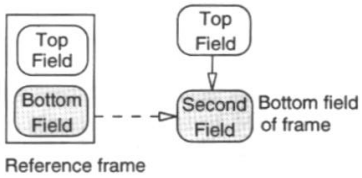
1. Frame prediction for frame pictures
2. Filed prediction for field pictures
3. Field prediction for frame pictures
4. Dual-prime for P-pictures (either frame/field)
5. 16x8 MC for field pictures



(a) Frame prediction



(b) Field prediction



(c) Field prediction

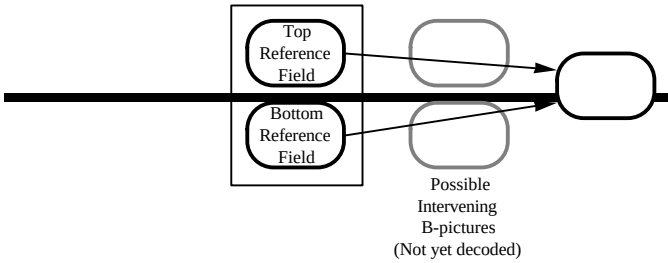


Figure 7-6. Prediction of the first field or field prediction in a frame-picture

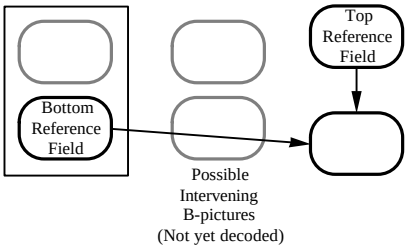


Figure 7-7. Prediction of the second field-picture when it is the bottom field

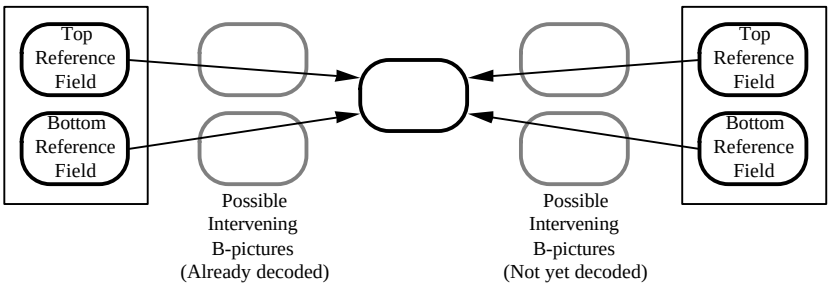
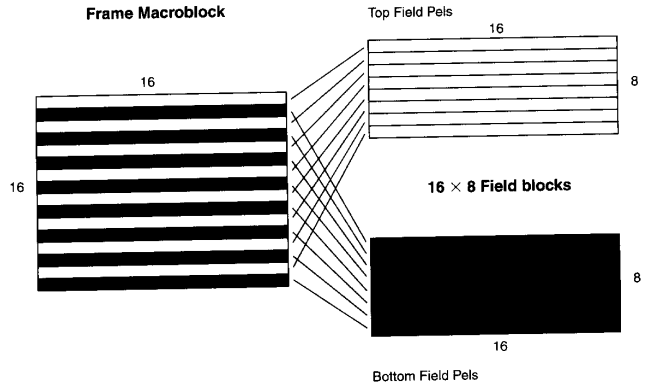


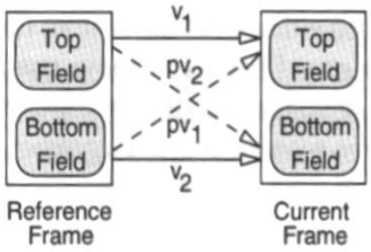
Figure 7-9. Field-prediction of B field pictures or B frame pictures

Filed prediction for frame-picture

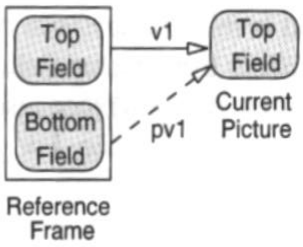


For P-frames, two motion vectors are assigned to each target MB.
For B-frames, two or four motion vectors are assigned to each target MB.

Dual-Prime Prediction Mode



(a) Field prediction in frame picture



(b) Field prediction in field picture

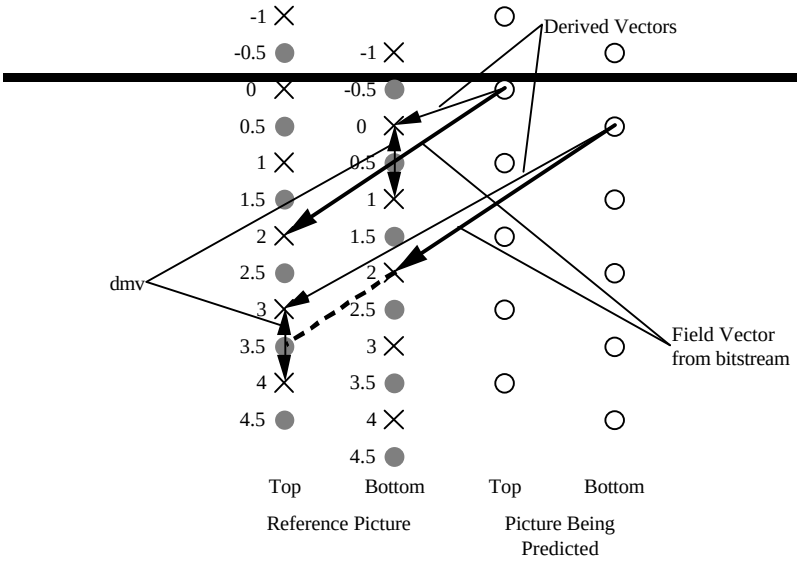


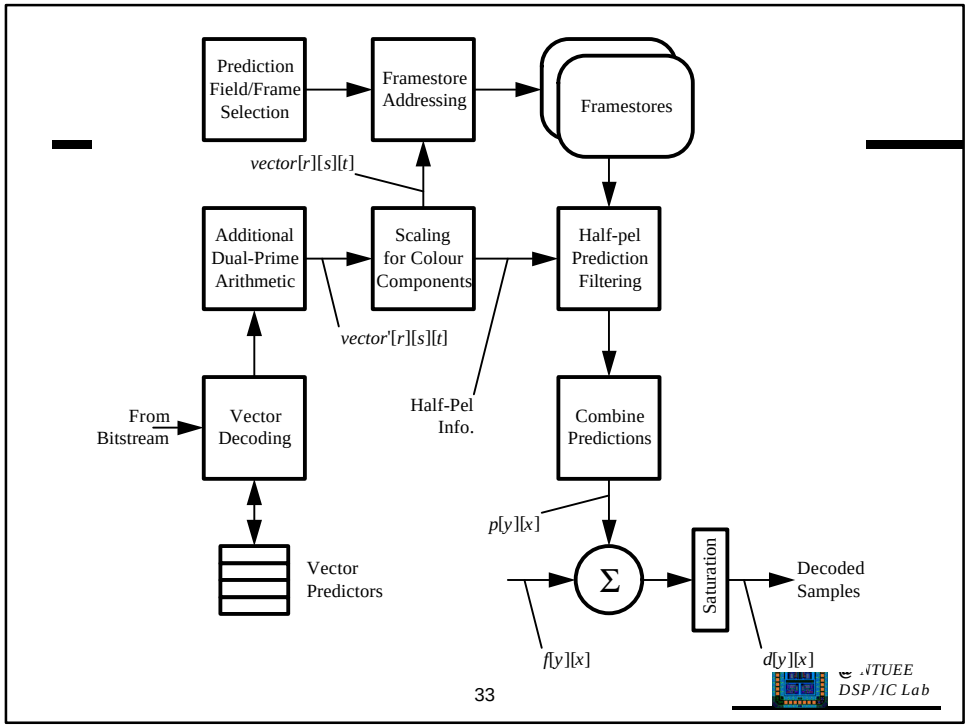
Figure 7-12. Scaling of motion vectors for dual prime prediction

16x8 MC for field Pictures

- The mode splits the Field picture MB into upper and lower half
- P-picture has 2 MV
- B-picture has 2 or 4 MV

Table 7.1 The five modes of motion compensation that can be used in MPEG-2.

Motion Compensation Mode	Use in Field Pictures?	Use in Frame Pictures?
Frame Prediction for Frame Pictures	No	Yes
Field Prediction for Field Pictures	Yes	No
Field Prediction for Frame Pictures	No	Yes
Dual-Prime for P-Pictures	Yes	Yes
16 × 8 MC for Field-Pictures	Yes	No


Prediction Field/Frame Selection
Framestore Addressing
Framestores
vector[r][s][t]
Additional Dual-Prime Arithmetic
Scaling for Colour Components
Half-pel Prediction Filtering
vector'[r][s][t]
From Bitstream
Vector Decoding
Half-Pel Info.
Combine Predictions
p[y][x]
Vector Predictors
Σ
Saturation
Decoded Samples
f[y][x]
d[y][x]
33
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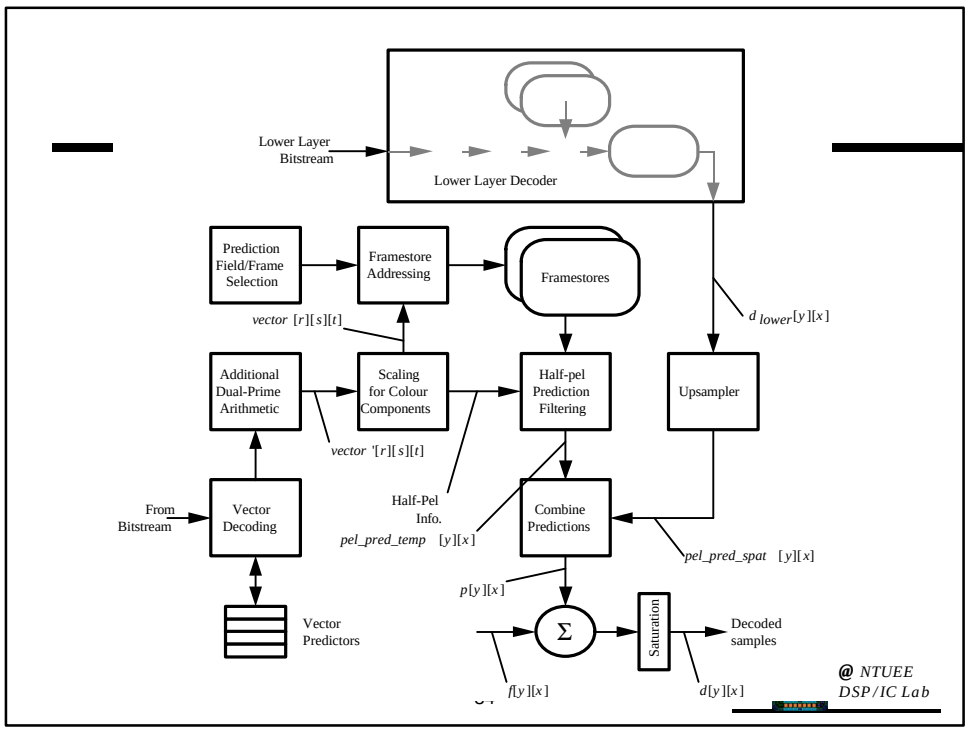
Lower Layer Bitstream
Lower Layer Decoder
Prediction Field/Frame Selection
Framestore Addressing
Framestores
vector [r][s][t]
d lower[y][x]
Additional Dual-Prime Arithmetic
Scaling for Colour Components
Half-pel Prediction Filtering
Upsampler
vector '[r][s][t]
From Bitstream
Vector Decoding
Half-Pel Info.
pel_pred_temp [y][x]
Combine Predictions
pel_pred_spat [y][x]
p[y][x]
Vector Predictors
Σ
Saturation
Decoded samples
f[y][x]
d[y][x]
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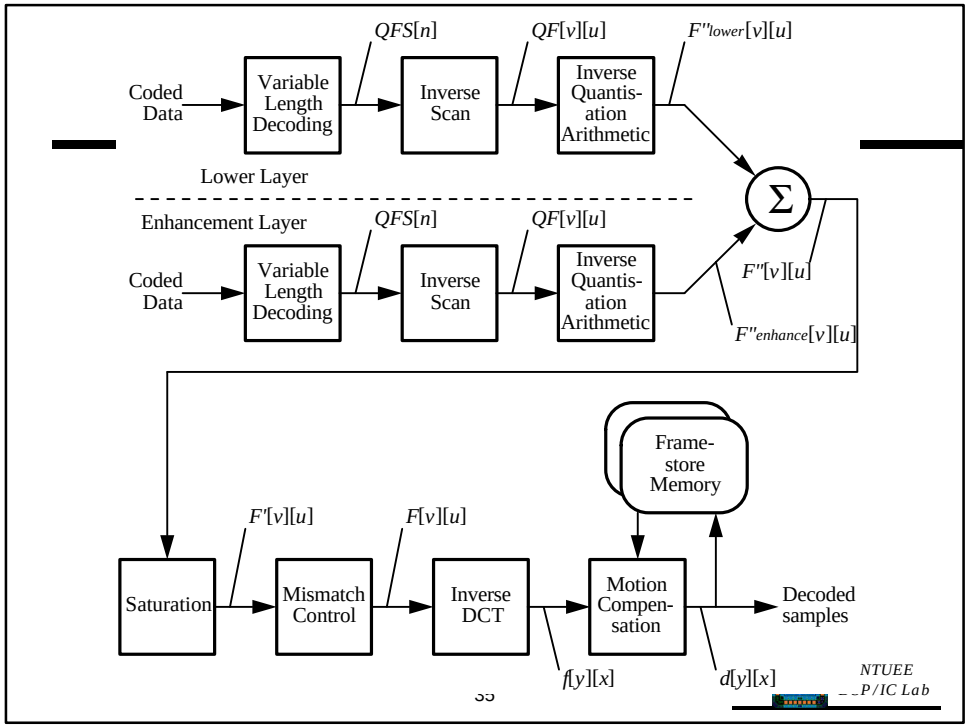


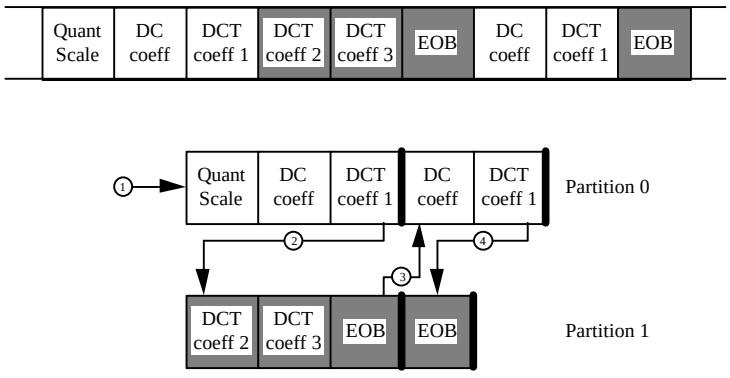


Figure 7-17 A segment from a bitstream with two partitions, with priority_breakpoint set to 64 (one (run, level) pair). The two partitions are shown, with arrows indicating how the decoder needs to switch between partitions

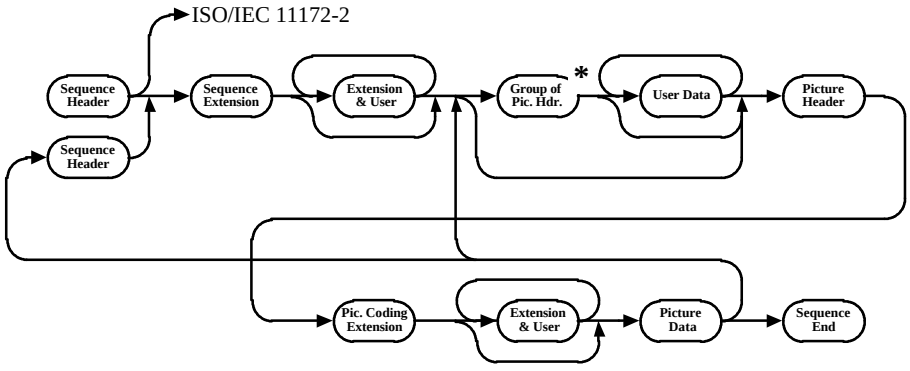
MPEG-2
VIDEO STREAM SYNTAX

- Syntax : a hierarchy of several Headers

Table 8.2 Six Headers of MPEG-2 Video Stream Syntax

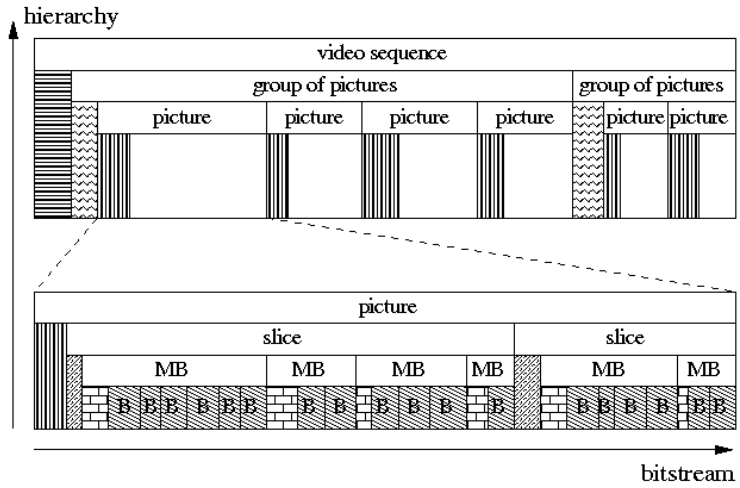
Syntax Header	Functionality
Sequence	Definition of entire video sequence
Group of Pictures	Enables random access in video stream
Picture	Primary coding unit
Slice	Resynchronization, refresh, and error recovery
Macroblock	Motion compensation unit
Block	Transform and compression unit

High level bitstream organisation



* After a GOP the first picture shall be an I-picture

MPEG-2 VIDEO STREAM SYNTAX



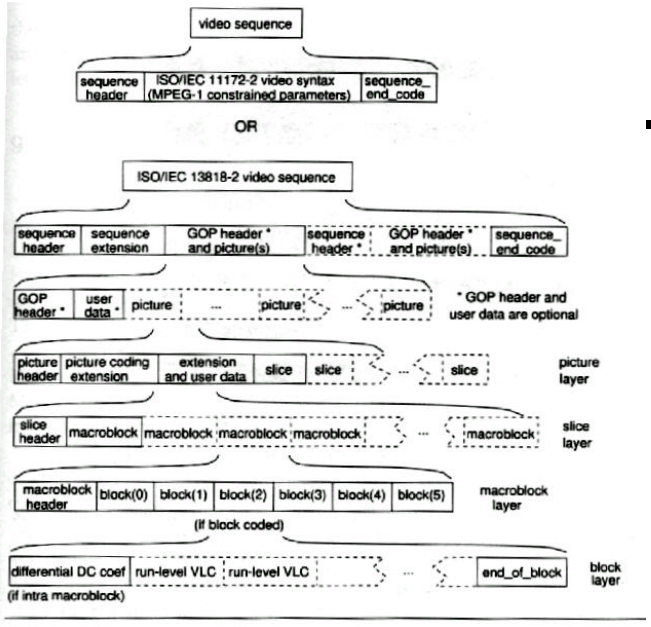
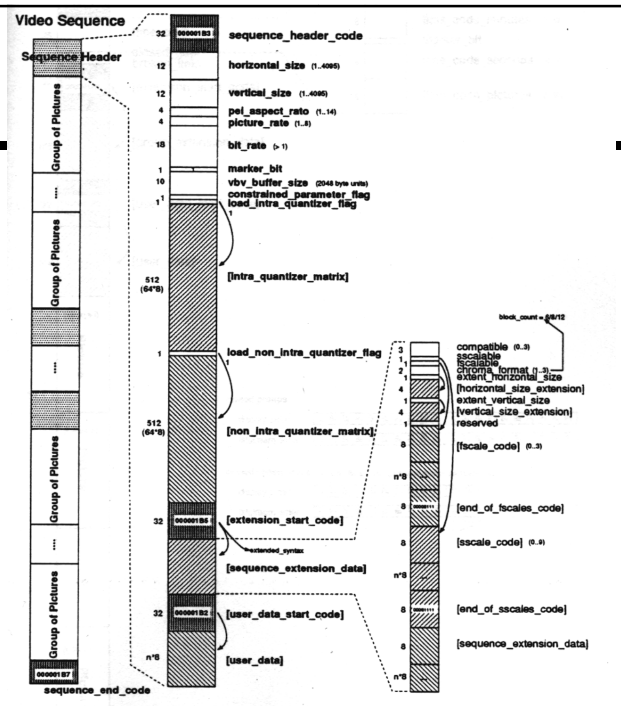


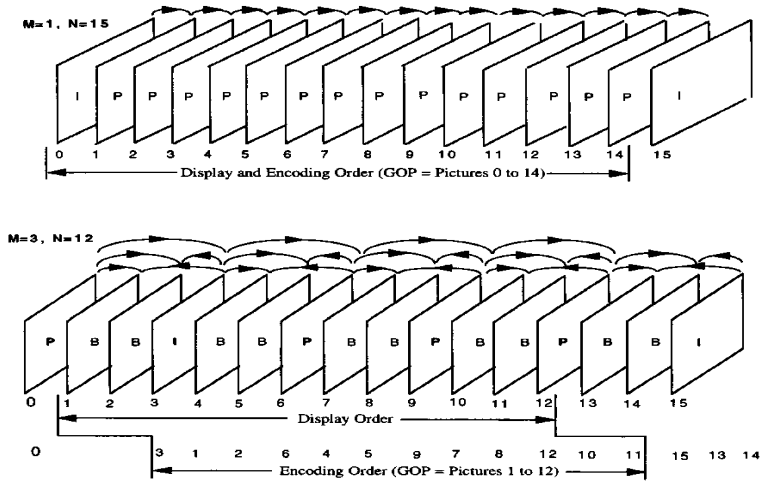
Figure 9.3: MPEG-2 main profile video sequence.



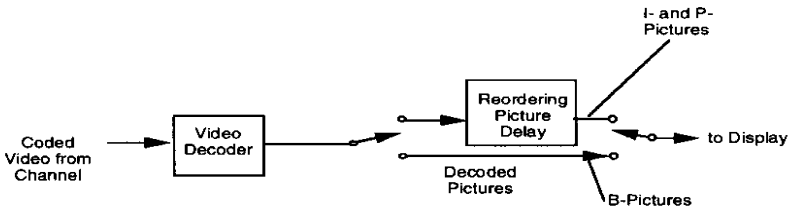
Group of pictures (GOP) Header

Time code
Editing flags
Random access, Fast search
    I-pictures
Editing
    the basic unit : GOP Header

Group of Pictures

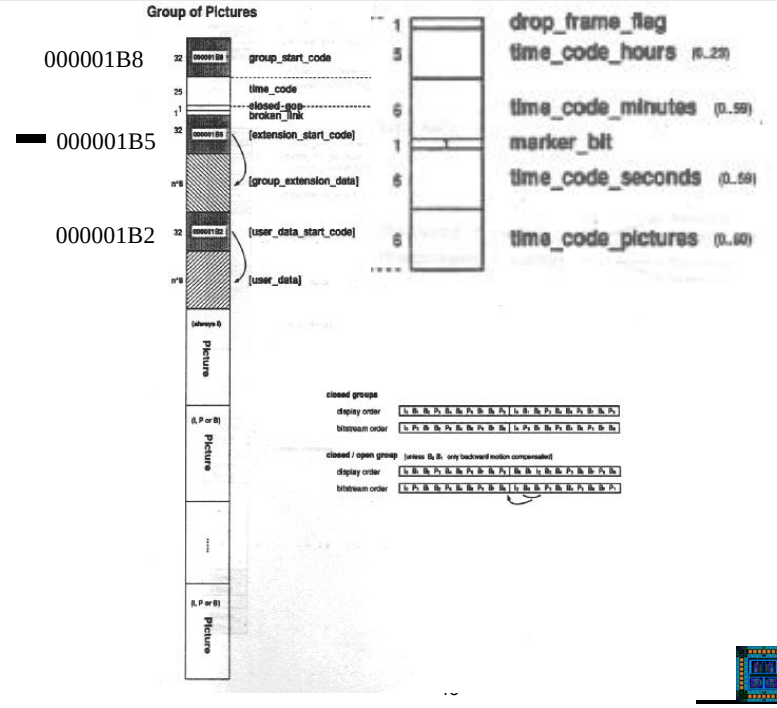


Ordering control



6.2.2.6 Group of pictures header

group_of_pictures_header() {	No. of bits	Mnemonic
group_start_code	32	bslbf
time_code	25	bslbf
closed_gop	1	uimsbf
broken_link	1	uimsbf
next_start_code()		
}		



Closed groups

Display order I0 B1 B2 P3 B4 B5 P6 B7 B8 P9 | I0 B1 B2 P3 B4 B5 P6 B7 B8 P9

bitstream order I0 P3 B1 B2 P6 B4 B5 P9 B7 B8 | I0 P3 B1 B2 P6 B4 B5 P9 B7 B8

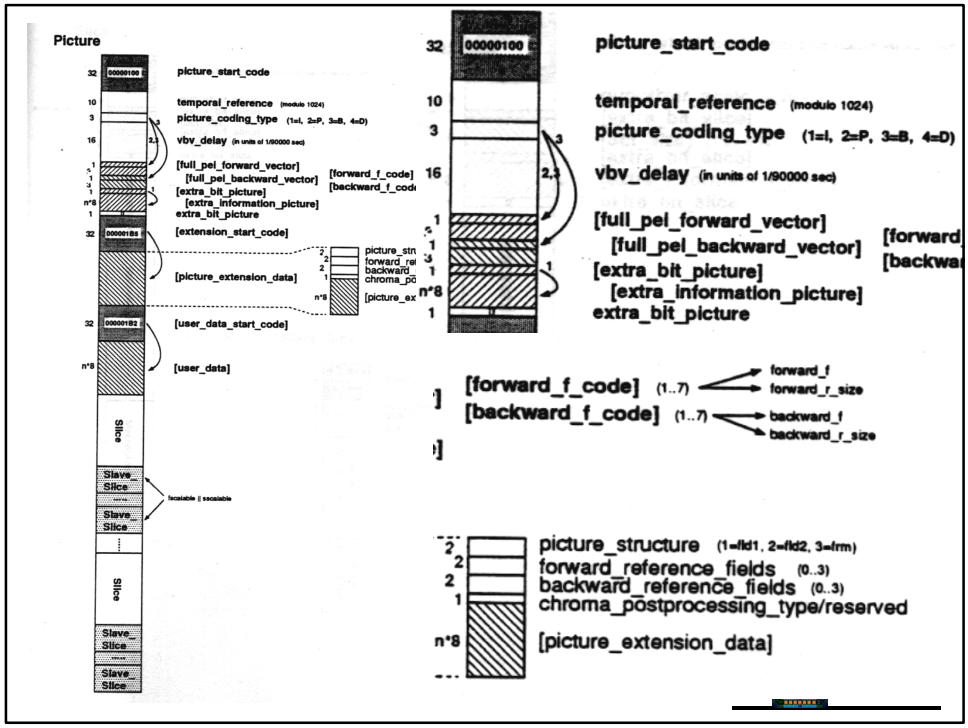
Closed / Open groups

Display order I0 B1 B2 P3 B4 B5 P6 B7 B8 P9 | B0 B1 I2 B3 B4 P5 B6 B7 P8 B9

bitstream order I0 P3 B1 B2 P6 B4 B5 P9 B7 B8 | I2 B0 B1 P5 B3 B4 P8 B6 B7 P1

6.2.3 Picture header

picture_header() {	**No. of bits**	**Mnemonic**
picture_start_code	32	bslbf
temporal_reference	10	uimsbf
picture_coding_type	3	uimsbf
vbv_delay	16	uimsbf
if (picture_coding_type == 2 || picture_coding_type == 3) {		
full_pel_forward_vector	1	bslbf
forward_f_code	3	bslbf
}		
if (picture_coding_type == 3) {		
full_pel_backward_vector	1	bslbf
backward_f_code	3	bslbf
}		
while (nextbits() == '1') {		
extra_bit_picture /* with the value '1' */	1	uimsbf
extra_information_picture	8	uimsbf
}		
extra_bit_picture /* with the value '0' */	1	uimsbf
next_start_code()		
}		



6.2.4 Slice

slice() {	No. of bits	Mnemonic
slice_start_code	32	bslbf
if (vertical_size > 2800)		
slice_vertical_position_extension	3	uimsbf
if (<*sequence_scalable_extension() is present in the bitstream*>) {		
if (scalable_mode == Ò dta partitioning")		
priority_breakpoint	7	uimsbf
}		
quantiser_scale_code	5	uimsbf
if (nextbits() == '1') {		
intra_slice_flag	1	bslbf
intra_slice	1	uimsbf
reserved_bits	7	uimsbf
while (nextbits() == '1') {		
extra_bit_slice /* with the value '1' */	1	uimsbf
extra_information_slice	8	uimsbf
}		
}		
extra_bit_slice /* with the value '0' */	1	uimsbf
do {		
macroblock()		
} while (nextbits() != '0000000000000000000000')		
next_start_code()		
}		

Slice Header

Function :

Resynchronization in the event of transmission bit error

Reset the prediction registers

Contain :

vertical position

quantizer_scale_code

indicator

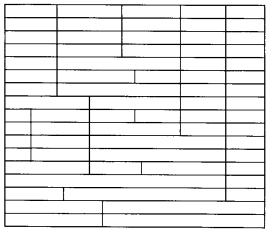


Fig. 8.7 Possible arrangement of Slices in which slice lengths vary throughout the picture. In MPEG-2 the left edge of the picture always starts a new slice.

6.2.5 Macroblock

macroblock() {	No. of bits	Mnemonic
while (nextbits() == '0000 0001 000')		
macroblock_escape	11	bslbf
macroblock_address_increment	1-11	vlclbf
macroblock_modes()		
if (macroblock_quant)		
quantiser_scale_code	5	uimsbf
if (macroblock_motion_forward ||		
(macroblock_intra && concealment_motion_vectors))		
motion_vectors(0)		
if (macroblock_motion_backward)		
motion_vectors(1)		
if (macroblock_intra && concealment_motion_vectors)		
marker_bit	1	bslbf
if (macroblock_pattern)		
coded_block_pattern()		
for (i=0; i<block_count; i++) {		
block(i)		
}		
}		

block(i) {	No. of bits	Mnemonic
if (pattern_code[i]) {		
if (macroblock_intra) {		
if (i<4) {		
dct_dc_size_luminance	2-9	vlclbf
if(dct_dc_size_luminance != 0)		
dct_dc_differential	1-11	uimsbf
} else {		
dct_dc_size_chrominance	2-10	vlclbf
if(dct_dc_size_chrominance !=0)		
dct_dc_differential	1-11	uimsbf
}		
} else {		
First DCT coefficient	2-24	
}		
while (nextbits() != End of block)		
Subsequent DCT coefficients	3-24	
End of block	2 or 4	vlclbf
}		
}		

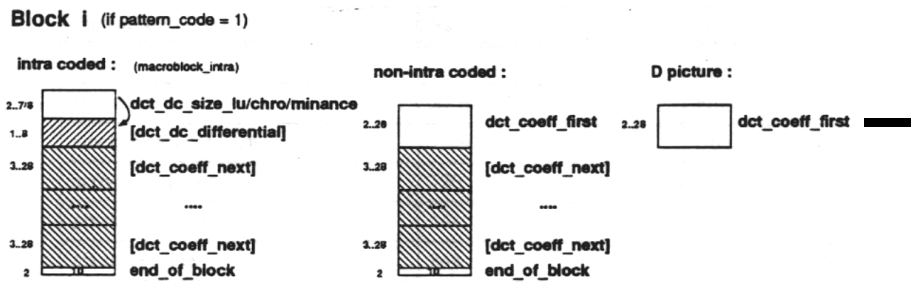


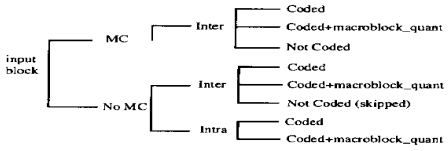
Table 8.3 **Macroblock_address-increment** Variable Length Code (VLC). The escape value is used for addresses larger than 33. N*0 means N zeros.

VLC Codeword	macroblock_ address-increment	VLC Codeword	macroblock_ address-increment
1	1	5*0 101 01	18
011	2	5*0 101 00	19
010	3	5*0 100 11	20
0011	4	5*0 100 10	21
0010	5	5*0 100 011	22
0001 1	6	5*0 100 010	23
0001 0	7	5*0 100 001	24
4*0 111	8	5*0 100 000	25
4*0 110	9	6*0 11 111	26
4*0 1011	10	6*0 11 110	27
4*0 1010	11	6*0 11 101	28
4*0 1001	12	6*0 11 100	29
4*0 1000	13	6*0 11 011	30
5*0 111	14	6*0 11 010	31
5*0 110	15	6*0 11 001	32
5*0 101 11	16	6*0 11 000	33
5*0 101 10	17	7*0 1 000	escape_word

- VLC Table for macroblock_type modes in I-pictures

macroblock _type	macroblock _quant	macroblock _motion _forward	macroblock _motion _backward	macroblock _pattern	macroblock _intra	VLC
Intra					1	1
Intra+macroblock_quant	1				1	01

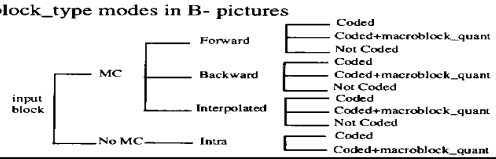
- macroblock_type modes in P-pictures



- VLC Table for macroblock_type modes in P-pictures

macroblock _type	macroblock _quant	macroblock _motion _forward	macroblock _motion _backward	macroblock _pattern	macroblock _intra	VLC
MC, Coded		1		1		1
No MC, Coded				1		01
MC, Not Coded		1				001
Intra					1	00011
MC, Coded+macroblock_quant	1	1		1		00010
No MC, Coded+macroblock_quant	1			1		00001
Intra+macroblock_quant	1				1	000001

- macroblock_type modes in B- pictures



ab

• VLC Table for macroblock_type modes in B- pictures

macroblock _type	macroblock _quant	macroblock _motion _forward	macroblock _motion _backward	macroblock _pattern	macroblock _intra	VLC
MC Interpolated, Not Coded		1	1			10
MC Interpolated, Coded		1	1	1		11
MC Backward, Not Coded			1			010
MC Backward, Coded			1	1		011
MC Forward, Not Coded		1				0010
MC Forward, Coded		1		1		0011
Intra					1	00011
MC Interpolated, Coded+macroblock_quant	1	1	1	1		00010
MC Forward, Coded+macroblock_quant	1	1		1		000011
MC Backward, Coded+macroblock_quant	1		1	1		000010
Intra+macroblock_quant	1				1	000001

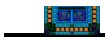


Table 8.5 Variable Length Codes (VLC) and Variable Length Integers (VLI) for quantized Intra DC differential values, which have a range of −1020 to 1020.

Range of Differential DC (DIFFs)	Size	Size VLC Luminance	Size VLC Chrominance	VLIs
−2047 to −1024	11	9*1	9*1 1	9*0 00 to 0 9*1 1
−1023 to −512	10	8*1 0	9*1 0	9*0 0 to 0 9*1
−511 to −256	9	7*1 0	8*1 0	9*0 to 0 8*1
−255 to −128	8	6*1 0	7*1 0	8*0 to 0 7*1
−127 to −64	7	5*1 0	6*1 0	7*0 to 0 6*1
−63 to −32	6	4*1 0	5*1 0	6*0 to 0 5*1
−31 to −16	5	1110	4*1 0	5*0 to 0 4*1
−15 to −8	4	110	1110	4*0 to 0111
−7 to −4	3	101	110	000 to 011
−3 to −2	2	01	10	00 to 01
−1	1	00	01	0
0	0	100	00	
1	1	00	01	1
2 to 3	2	01	10	10 to 11
4 to 7	3	101	110	100 to 111
8 to 15	4	110	1110	1000 to 4*1
16 to 31	5	1110	4*1 0	1 4*0 to 5*1
32 to 63	6	4*1 0	5*1 0	1 5*0 to 6*1
64 to 127	7	5*1 0	6*1 0	1 6*0 to 7*1
128 to 255	8	6*1 0	7*1 0	1 7*0 to 8*1
256 to 511	9	7*1 0	8*1 0	1 8*0 to 9*1
512 to 1023	10	8*1 0	9*1 0	1 9*0 to 9*1 1
1024 to 2048	11	9*1	9*1 1	1 9*0 0 to 9*1 11

N*0 means N zeros; N*1 means N ones

Table 8.6a VLC Table zero for RUNS of zero levels and nonzero LEVEL. It is used for NonIntra coefficients and for Intra AC coefficients if intra_vlc_format = 0. This VLC is the same as MPEG-1. The sign bit s is 0 for positive, and 1 for negative.

Run	Level	Code Word	Run	Level	Code Word
0	1	1s (if first inter coefficient)	4	1	0011 0s
0	1	11s (otherwise)	4	2	0000 0011 11s
0	2	0100 s	4	3	0000 0001 0010s
0	3	0010 1s	5	1	0001 11s
0	4	0000 110s	5	2	0000 0010 01s
0	5	0010 0110s	5	3	0000 0000 1001 0s
0	6	0010 0001s	6	1	0001 01s
0	7	0000 0010 10s	6	2	0000 0001 1110s
0	8	0000 0001 1101s	7	1	0001 00s
0	9	0000 0001 1000s	7	2	0000 0001 0101s
0	10	0000 0001 0011s	8	1	0000 111s
0	11	0000 0001 0000s	8	2	0000 0001 0001s
0	12	0000 0000 1101s	9	1	0000 101s
0	13	0000 0000 1100s	9	2	0000 0000 1000 1s
0	14	0000 0000 1100s	10	1	0010 0111 s
0	15	0000 0000 1011s	10	2	0000 0000 1000 0s
1	1	011s	11	1	0010 0011 s
1	2	0001 10s	12	1	0010 0010 s
1	3	0010 0101s	13	1	0010 0000 s
1	4	0000 0011 00s	14	1	0000 0011 10s
1	5	0000 0001 1011s	15	1	0000 0011 01s
1	6	0000 0000 1011 0s	16	1	0000 0010 00s
1	7	0000 0000 1010 1s	17	1	0000 0000 1111s
			18	1	0000 0001 1010s
2	1	0101 s			
2	2	0000 100s	19	1	0000 0001 1001s
2	3	0000 0010 11s	20	1	0000 0001 0111s
2	4	0000 0001 0100s	21	1	0000 0001 0110s
2	5	0000 0000 1010 0s	22	1	0000 0000 1111 1s
3	1	0011 1s	23	1	0000 0000 1111 0s
3	2	0010 0100s	24	1	0000 0000 1110 1s
3	3	0000 0001 1100s	25	1	0000 0000 1110 0s
3	4	0000 0000 1001 1s	26	1	0000 0000 1101 1s
EOB	10	Escape 0000 01			

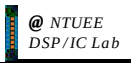


Table 8.6b VLC Table zero for RUNS and LEVELS. It is used for NonIntra coefficients and for Intra AC coefficients if intra_vlc_format = 0. This VLC is the same as MPEG-1. The sign bit s is 0 for positive, and 1 for negative.

Run	Level	Code Word	Run	Level	Code Word
0	16	8*0 0111 11s	1	8	8*0 0011 111s
0	17	8*0 0111 10s	1	9	8*0 0011 110s
0	18	8*0 0111 01s	1	10	8*0 0011 101s
0	19	8*0 0111 00s	1	11	8*0 0011 100s
0	20	8*0 0110 11s	1	12	8*0 0011 011s
0	21	8*0 0110 10s	1	13	8*0 0011 010s
0	22	8*0 0110 01s	1	14	8*0 0011 001s
0	23	8*0 0110 00s	1	15	8*0 0001 0011s
0	24	8*0 0101 11s	1	16	8*0 0001 0010s
0	25	8*0 0101 10s	1	17	8*0 0001 0001s
0	26	8*0 0101 01s	1	18	8*0 0001 0000s
0	27	8*0 0101 00s	6	3	8*0 0001 0100s
0	28	8*0 0100 11s	11	2	8*0 0001 1010s
0	29	8*0 0100 10s	12	2	8*0 0001 1001s
0	30	8*0 0100 01s	13	2	8*0 0001 1000s
0	31	8*0 0100 00s	14	2	8*0 0001 0111s
0	32	8*0 0011 000s	15	2	8*0 0001 0110s
0	33	8*0 0010 111s	16	2	8*0 0001 0101s
0	34	8*0 0010 110s	27	1	8*0 0001 1111s
0	35	8*0 0010 101s	28	1	8*0 0001 1110s
0	36	8*0 0010 100s	29	1	8*0 0001 1101s
0	37	8*0 0010 011s	30	1	8*0 0001 1100s
0	38	8*0 0010 010s	31	1	8*0 0001 1011s
0	39	8*0 0010 001s			
0	40	8*0 0010 000s			

8*0 = 0000 0000

MPEG-2 ERROR CONCEALMENT

- Typical way
  - replace with skipped MBs
- MPEG-2
  - Intra pictures may optionally contain coded motion vectors

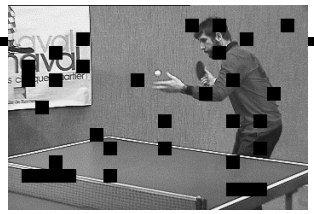
Subjective Quality

30 frames/sec Table Tennis Sequence

16x16 blocks

Loss Rate : 10%

Original



Damaged

Temporal Extrapolation

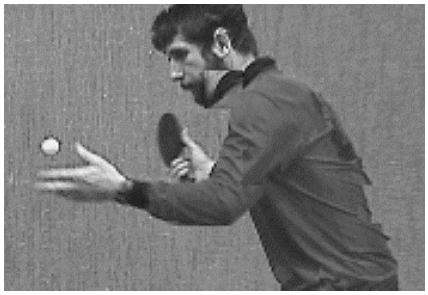
Side Match Only

Proposed

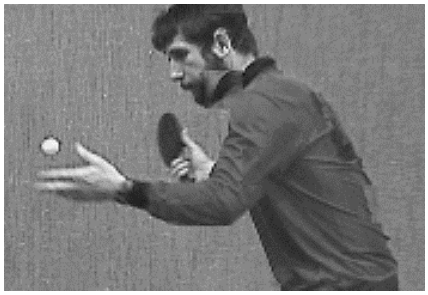
Side Match + Overlapped MC

Subjective Quality

Magnified Part Image



Side Match Only



Proposed

Side Match + Overlapped MC