H.264 Baseline/Main/High Profile Encoder on DM365/DM368

Overall Feature:

- **eXpressDSP Digital Media (XDM1.0 IVIDENC1) interface compliant**
- **Validated on the DM36x EVM**
- **H.264 Baseline/Main/High Profile up to level 5.0 compliant**
- **Supports resolutions up to 4096x4096 in Platinum mode and 2048x2048 in Version 1.1 backward compatible mode.**
- **YUV420 semi-planer input format for the frames supported**
- **Supports input resolution being multiples of 2**
- **Progressive and Interlaced encoding supported**
- **CAVLC and CABAC encoding supported**
- **Unrestricted Motion Vectors (UMV) supported**
- **Half Pel and Quarter Pel Interpolation for motion estimation supported**
- **Sequence scaling Matrix is supported**
- **Transform 8x8 and Transform 4x4 is supported**
- **Rate Control (CBR and VBR) supported**
- **Insertion of Buffering Period and Picture Timing Supplemental Enhancement Information (SEI) and Video Usability Information (VUI) supported**
- **Adaptive Intra Refresh (AIR)**
- **All 16x16, 8x8 and 4x4 Intra-Prediction Modes supported in I-Frame and INTRA16x16 DC is supported in P-frames**
- **Only single motion vector per macroblock**
- **Support for multiple slice with size specified in terms of Macroblock or Macroblock row**
- **Supports SVC-T up to four layers.**
- **Supports chain free P frames encoding.**
- **Supports Fixed slice size encoding feature.**
- **Supports ARF (Adaptive Reference field) and MRCRF (Most Recent Coded Reference field) encoding.**
- **Supports Constrained VBR Rate control (CVBR).**
- **Supports Fixed frame size Rate control.**
- **Supports configurable Scaling Matrix and VUI parameters encoding.**
- **Supports Gradual Decoder Refresh(GDR)**
- **Mega Pixels Support: Mega Pixel supports input video upto 4096x4096 pixels.**
- **Supports Adaptive Long-Term frame insertion**
- **Supports 1.1 backward compatible improved quality mode which has following features**
  - **4 motion vectors per Macroblock**
  - **All 16x16, 8x8 and 4x4 Intra-Prediction Modes supported in P-Frame**

Smart features supported

- **Region of Interest (ROI) supported**
- **Privacy Masking feature supported**
- **Simple Two Pass supported**

Support Low latency feature

- **Can be configured to provide output at NAL granularity or after entire frame is encoded**
- **Supports encoded output in NAL stream or Bytes stream format**

Not-supported features

- **Error Resilience features such as ASO/FMO and redundant slices**
- **B frames and weighted prediction**

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description

H.264 (from ITU-T, also called as H.264/AVC) is a popular video coding algorithm enabling high quality multimedia services on a limited bandwidth network. H.264 standard defines several profiles and levels which specify restrictions on the bit stream and hence limits the capabilities needed to decode the bit streams. This project is developed using Code Composer Studio version 3.3.81.6 and using the code generation tools version 4.5.2.

Performance measurement procedure

- Measured with program memory and I/O buffers in external memory, I/D cache enabled, ARM @297 MHz, DDR @ 270 MHz, Monta Vista Linux 5.0 for ID H264_ENC_01 and H264_ENC_03.
- Measured with program memory and I/O buffers in external memory, I/D cache enabled, ARM @ 432 MHz, DDR @ 340 MHz, Monta Vista Linux 5.0 for ID H264_ENV_02, H264_ENV_04, H264_ENV_05, H264_ENV_06, H264_ENV_07, H264_ENV_08 and H264_ENV_09.
- DM365 EVM with MV Linux is used to measure the performance numbers in this Data sheet.
- The process time is measured across algActivate/process/algDeactivate function call using *gettimeofday()* utility of linux.
- NFS File system is used as an environment in performance measurement.
- The performance numbers are measured at certain bit-rates. For larger bit-rates like more than 12mbps for 720p and more than 20mbps for 1080p, some degradation in performance numbers can be observed.

Summary of performance

This section describes performance of Standalone H.264 Encoder tested on DM365 EVM.

Table 1. Configuration Table

	CONFIGURATION	ID
Version 2.0 Platinum mode	H.264 High profile levels up to 5.0, UMV – ON, PRC – OFF,T8x8Inter – OFF and T8x8Intra – OFF, SM – ON, CABAC – ON, encoderPreset – XDM_HIGH_QUALITY, IntraPeriod-30, InputContentType-Progressive	H264_ENC_02
Version 2.0 Platinum mode	H.264 High profile levels up to 5.0, UMV – ON, PRC – OFF,T8x8Inter – OFF and T8x8Intra – OFF, SM – ON, CABAC – ON, encoderPreset – XDM_HIGH_QUALITY, IntraPeriod-30, InputContentType-Progressive With Different Feature Set (Refer Table 5)	H264_ENC_04
Version 1.1 backward compatible mode	H.264 High profile levels up to 5.0, UMV – ON, PRC – ON, T8x8Inter – OFF and T8x8Intra – ON, SM – ON, CABAC – ON, encoderPreset = XDM_USER_DEFINED, encQuality – 0, IntraPeriod-30, InputContentType-Progressive	H264_ENC_01
Version 1.1 backward compatible mode	H.264 High profile levels up to 5.0, UMV – OFF, PRC – ON, T8x8Inter – OFF and T8x8Intra – ON, SM – ON, CABAC – ON, encoderPreset = XDM_USER_DEFINED, encQuality – 0, IntraPeriod-30, InputContentType-Progressive With Different Feature Set (Refer 4)	H264_ENC_03
Version 2.0 Platinum mode	H.264 High profile levels up to 5.0, UMV – ON, PRC – OFF,T8x8Inter – OFF and T8x8Intra – OFF, SM – ON, CABAC – ON, encoderPreset – XDM_HIGH_QUALITY, IntraPeriod-30, InputContentType-InterlaceVideo	H264_ENC_05
Version 1.1 backward compatible mode	H.264 High profile levels up to 5.0, UMV – ON, PRC – ON, T8x8Inter – OFF and T8x8Intra – ON, SM – ON, CABAC – ON, encoderPreset = XDM_USER_DEFINED, encQuality – 0, IntraPeriod-30 , InputContentType-InterlaceVideo	H264_ENC_06

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Version 2.0 Platinum mode	H.264 High profile levels up to 5.0, UMV – ON, PRC – OFF,T8x8Inter – OFF and T8x8Intra – OFF, CABAC – ON, encoderPreset – XDM_HIGH_QUALITY, IntraPeriod-30, InputContentType- Progressive MegaPixel mode	H264_ENC_07
Version 2.0 Platinum mode	H.264 High profile levels up to 5.0,T8x8Inter – ON and T8x8Intra – ON, SM – ON, CABAC – ON, encoderPreset – XDM_HIGH_SPEED, IntraPeriod-30, InputContentType-Progressive, ROI_Type = PRIVACY_MASK used for last two configurations	H264_ENC_08
Version 2.0 Platinum mode	H.264 High profile levels up to 5.0, UMV – ON, PRC – OFF, T8x8Inter – ON and T8x8Intra – ON, SM – ON, CABAC – ON, encoderPreset = XDM_USER_DEFINED, encQuality – 1, IntraPeriod-30	H264_ENC_09

Table 2. Cycles Information for H264_ENC_01

INPUT NAME	PERFORMANCE STATISTICS FOR H264_ENC_01 SETTINGS						
	RESOLUTION	AVERAGE			PEAK		
		ARM 926 MHZ	ENCODE FRAME MHZ	FPS	ARM 926 MHZ	ENCODE FRAME MHZ	FPS
satonement_p1920x1056_24fps_420pl_60fr.yuv	1920x1056, 8mbps	0.18	17.32	17.32	0.19	23.50	12.76
parkrun_p1280x720_30fps_420pl_300fr.yuv	720p, 4mbps	0.15	8.16	36.78	0.17	9.99	30.02
shields_p720x480_25fps_420pl_252fr.yuv	D1, 2mbps	0.16	3.329	90.39	0.18	3.95	77.64
foreman_i640x480_30fps_420pl_300fr.yuv	VGA , 3mbps	0.34	3.49	85.99	2.42	14.73	20.36
akiyo_p352x288_30fps_420pl_300fr.yuv	CIF, 512kbps	0.14	1.13	265.51	0.19	1.38	216.64

Note:
1. Encode frame MHz depicts the cumulative the load on ARM926 and ARM968 separately.
2. Impact of SVC-T on performance number is negligible
3. They are measured in presence of linux without any system traffic . CE overhead is also excluded.
4. All numbers are collected (both average and peak) at frame-level processing for first 300 frames.
5. These performance numbers measured on DM36x platform with ARM @297 MHz, DDR @ 270, for other DM36x variants like ARM @432 MHz, DDR @ 340, these numbers will vary linearly based on DDR frequency ratio
6. The version of the code used to collect these numbers have the following features included:
   i. Interrupt mode of operation – one interrupt signal processing overhead per frame.
   ii. Resetting of vIMCOP and loading of code into ARM968 DTCM – once per Process call.

Table 3. Cycles Information for H264_ENC_02

INPUT NAME	PERFORMANCE STATISTICS FOR H264_ENC_02 SETTINGS						
	RESOLUTION	AVERAGE			PEAK		
		ARM 926 MHZ	ENCODE FRAME MHZ	FPS	ARM 926 MHZ	ENCODE FRAME MHZ	FPS
tractor_p1920x1080_30fps_420pl_493fr.yuv	1920x1080, 8mbps	0.30	12.8	32.88	0.9	14.69	27.6
parkrun_p1280x720_30fps_420pl_300fr.yuv	720p, 4mbps	0.23	5.7	72.46	0.69	6.8	57.59
xena_p640x480_30fps_420pl_443fr.yuv	VGA, 3mbps	0.21	2.02	193.34	0.29	2.91	132.35

Note:
1. The priority of all the ROI specified are kept same.
2. Impact of SVC-T on performance number is negligible
3. ROI_TYPE is kept as `BACKGROUND_OBJECT for all the region.`
4. These performance numbers measured on DM36x platform with ARM @432 MHz, DDR @ 340, for other DM36x variants like ARM @297 MHz, DDR @ 270, these numbers will vary linearly based on DDR frequency ratio

Table 4. Cycles Information for H264_ENC_03

INPUT NAME	PERFORMANCE STATISTICS FOR H264_ENC_03 SETTINGS (1,2,3)							
	RESOLUTION	FEATURES ENABLED	AVERAGE			PEAK		
			ARM 926 MHZ	ENCODE FRAME MHZ	FPS	ARM 926 MHZ	ENCODE FRAME MHZ	FPS
parkrun_p1280x720_30fps_420pl_300fr.yuv	720p, 4mbps	ROI = 0 Slices = 0	0.14	8.29	36.15	0.18	10.79	27.80
parkrun_p1280x720_30fps_420pl_300fr.yuv	720p, 4mbps	ROI = 5 Slices = 0	0.15	8.63	34.75	0.18	11.10	27.02
parkrun_p1280x720_30fps_420pl_300fr.yuv	720p, 4mbps	ROI = 0 Slices = 15	0.14	8.49	35.32	0.17	10.72	27.99

Note:
1. The priority of all the ROI specified are kept same.
2. ROI_TYPE is kept as `BACKGROUND_OBJECT for all the region.`
3. Each slice ends at row boundary whenever multiple slices are enabled.

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Table 5. Cycles Information for H264_ENC_04

INPUT NAME	PERFORMANCE STATISTICS H264_ENC_04 SETTINGS (1,2,3)							
	RESOLUTION	FEATURES ENABLED	AVERAGE			PEAK		
			ARM 926 MHZ	ENCODE FRAME MHZ	FPS	ARM 926 MHZ	ENCODE FRAME MHZ	FPS
tractor_p1920x1080_30fps_420pl_493fr.yuv	1920x1080, 8mbps	ROI = 0 Slices = 0	0.29	12.83	32.88	0.92	14.69	27.64
tractor_p1920x1080_30fps_420pl_493fr.yuv	1920x1080, 8mbps	ROI = 5 Slices = 0	0.55	12.8	32.26	0.85	14.7	27.76
tractor_p1920x1080_30fps_420pl_493fr.yuv	1920x1080, 8mbps	ROI = 0 Slices = 15	0.15	13.09	32.58	0.83	15.22	26.89
tractor_p1920x1080_30fps_420pl_493fr.yuv	1920x1080, 8mbps	1200 bytes per slice	0.40	16.4	26.33	1.04	23.57	18.32
tractor_p1920x1080_30fps_420pl_493fr.yuv	1920x1080, 8mbps	800 bytes per slice	0.42	18.02	23.96	1.06	25.81	16.7
parkrun_p1280x720_30fps_420pl_300fr.yuv	720p, 4mbps	1200 bytes per slice	0.30	7.3	59.07	0.36	15.5	27.7
parkrun_p1280x720_30fps_420pl_300fr.yuv	720p, 4mbps	800 bytes per slice	0.30	7.99	54.00	0.35	16.25	26.57

Note:

1. The priority of all the ROI specified are kept same.
2. ROI_TYPE is kept as BACKGROUND_OBJECT for all the region
3. Each slice ends at row boundary whenever multiple slices are enabled.

Table 6. Cycles Information for H264_ENC_05

INPUT NAME	PERFORMANCE STATISTICS FOR H264_ENC_05 SETTINGS						
	RESOLUTION	AVERAGE			PEAK		
		ARM 926 MHZ	ENCODE FRAME MHZ	FPS	ARM 926 MHZ	ENCODE FRAME MHZ	FPS
Parkjoy_i1920x1080_30fps_420pl_493fr.yuv	1920x1080, 8mbps	0.50	12.90	32.05	0.74	14.4	28.49
jcube_i720x480_30fps_420pl_260fr.yuv	720x480, 2mbps	0.48	2.5	148.45	0.62	3.21	112.5

Table 7. Cycles Information for H264_ENC_06

INPUT NAME	PERFORMANCE STATISTICS FOR H264_ENC_06 SETTINGS						
	RESOLUTION	AVERAGE			PEAK		
		ARM 926 MHZ	ENCODE FRAME MHZ	FPS	ARM 926 MHZ	ENCODE FRAME MHZ	FPS
Parkjoy_i1920x1080_30fps_420pl_493fr.yuv	1920x1080, 8mbps	0.39	18.08	23.89	1.73	20.06	20.9
jcube_i720x480_30fps_420pl_260fr.yuv	720x480, 2mbps	0.35	3.6	119.3	2.1	6.2	69.23

Table 8. Cycles Information for H264_ENC_07

INPUT NAME	PERFORMANCE STATISTICS FOR H264_ENC_07 SETTINGS						
	RESOLUTION	AVERAGE			PEAK		
		ARM 926 MHZ	ENCODE FRAME MHZ	FPS	ARM 926 MHZ	ENCODE FRAME MHZ	FPS
ParkJoy_p2592x1944_25fps_420pl_60fr.yuv	2592x1944 (5MP) 10mbps	0.22	33.11	12.96	0.87	39.16	10.79
CrowdRun_p3840x2748_25fps_420pl_60fr.yuv	3840x2748 (10MP) 10mbps	0.41	68.28	6.29	1.25	81.27	5.24

Note: 3480x2748 resolution (10MP) performance no. are measured at 3480x1368 resolutions because of EVM DDR footprint constraint and are up-scaled accordingly.

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Table 9. Cycles Information for H264_ENC_08

INPUT NAME	PERFORMANCE STATISTICS FOR H264_ENC_08 SETTINGS						
	RESOLUTION	AVERAGE			PEAK		
		ARM 926 MHZ	ENCODE FRAME MHZ	FPS	ARM 926 MHZ	ENCODE FRAME MHZ	FPS
tractor_p1920x1080_30fps_420pl_493fr.yuv	1920x1080, 8mbps	0.19	12.42	34.77	0.9	14.78	29.22
parkrun_p1280x720_30fps_420pl_300fr.yuv	720p, 4mbps	0.20	5.77	74.8	1.72	8.57	50.4
Intersection_720x480_420p.yuv	720x480, 2mbps	0.20	2.50	172.57	1.54	4.27	101.25
Croasswalk_p640x480_30fps_420pl_450fr.yuv	VGA, 1.5mbps	0.20	2.19	197.58	1.57	3.97	108.74
Foreman_352x288_300frames.yuv	CIF, 512kbps	0.19	0.99	436.39	1.47	2.37	182.14
pedestrian_p1920x1080_24fps_420pl_375fr.yuv	1920x1080,8mbps,ROI_Type = PRIVACY_MASK, 2 ROIs	0.19	12.68	34.06	1.00	14.92	28.95
pedestrian_p1920x1080_24fps_420pl_375fr.yuv	1920x1080,8mbps,ROI_Type = PRIVACY_MASK, 5 ROIs	0.19	12.75	33.87	1.16	15.10	28.62

Table 10. Cycles Information for H264_ENC_09

INPUT NAME	PERFORMANCE STATISTICS FOR H264_ENC_08 SETTINGS						
	RESOLUTION	AVERAGE			PEAK		
		ARM 926 MHZ	ENCODE FRAME MHZ	FPS	ARM 926 MHZ	ENCODE FRAME MHZ	FPS
foreman_p352x288_30fps_420pl_300fr.yuv	352x288, 512kbps	0.21	1.83	235.46	0.33	2.15	200.88
intotree_p720x480_25fps_420pl_250fr.yuv	720x480, 2mbps	0.21	5.52	78.25	0.22	5.79	74.61
stockholm_p1280x720_30fps_420pl_302fr.yuv	1280x720, 4mbps	0.21	14.14	30.55	0.37	14.67	29.44

pedestrian_p1920x1080_24fps_420pl_375fr.yuv	1920x1280, 8mbps	0.21	32.46	13.30	0.41	33.16	12.50
crowdrun_i1920x1080_25fps_420pl_250fr.yuv	1920x1080, 8mbps interlace input	0.40	33.87	12.90	0.50	34.73	12.53

Memory Statistics

COFIGURATION ID	MEMORY STATISTICS in bytes					
	PROGRAM MEMORY (Bytes)	DATA MEMORY				TOTAL
		CONSTANT (Bytes)	HEAP (Bytes)		STACK (Bytes)	
			PERSISTENT	SCRATCH		
H264_ENC_001 H264_ENC_002 H264_ENC_003 H264_ENC_004	494220	2372	14200392	73992	12288	14783264

[1]All these memory requirements are for ARM926 encoder library (including DMA library). They do not include any memory requirements from test application side. Stack, heap and code requirements for test-application are extra. Constant memory size requirements include code memory of ARM968 since it forms a constant table on ARM926 before transfer.
[2] The constant size is the sum of .cinit, .bss, and .const sections used by H.264 encoder library.

Table 11. Internal Data Memory Split-up

CONFIGURATION ID	DATA MEMORY – VICP AND HDVICP			
	HDVICP			VICP (BYTES)
	ARM968 ITCM (BYTES)	ARM968 DTCM (BYTES)	HDVICP BUFFERS (BYTES)	
H264_ENC_001 H264_ENC_002	**49152**	**32768**	**ALL**	**65535(2048x2048))**

Below are the details of codec's usage of memory via CMEM. Height' and 'Width' used in equations are the parameter specified at the creation time. The memory requirement calculation is theoretical worst case for a particular resolution.

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Table 12. DM365 H264 Encoder usage of Memory via CMEM

BUFFER	YUV420P
Input Buffer	**6291456 (for 2048x2048) (InputWidth * InputHeight * 1.5)**
Output Buffer	**3145728 (for 2048x2048) (worst case: InputBuffer/2)**
MEMTAB	**SIZE In Bytes**
Memtab 0	**1828**
Memtab 1	**5288**
Memtab 2	**5288**
Memtab 3	**20480**
Memtab 4	**2048**
Memtab 5	**13584384***
Memtab 6	**896**
Memtab 7	**52616**
Memtab 8	**52616**
Memtab 9	**67200**
Memtab 10	**131072**
Memtab 11	**262144**

Memtab 12	**640**
Memtab 13	**49152**
Memtab 14	**38912**
Memtab 15	**10240**

Notes:

- Memtab 5 size will be twice of those mentioned above for SVC-T
- When Adaptive Long Term frame feature is enabled Memtab5 size will become 20376576
- The above memtab sizes are measured for maxHeight = 2048 and maxWidth=2048.

Memtab 5 is calculated based on the resolution. Here is the formula

For interlace input sequence
uHeight = (maxHeight + 31) & (~0x1F) + (PAD_VERT << 2)
for progressive input sequence
uHeight = (maxHeight + 15) & (~0x0F) + (PAD_VERT << 1)
uWidth =(maxWidth + 63) & (~0x3F) + (PAD_HORIZ << 1)
uSize = (uHeight * uWidth * 3)

PAD_VERT = 26 for encoderPreset = XDM_USER_DEFINED and encQuality – 0
PAD_VERT = 48 for encoderPreset = XDM_USER_DEFINED and encQuality – 2 and 3
PAD_HORIZ = 32 for encoderPreset = XDM_USER_DEFINED and encQuality – 0, 2 and 3

Example:

For QCIF maxHeight = 144, maxWidth = 176 PAD_VERT - 26 and PAD_HORIZ – 32
uSize = (240*196*3) = 141120

notes

- HDVICP and MJCP
  - The entire HDVICP is a video resource and is used by the codec
  - The codec uses MJCP memory as scratch buffers and hence poses restriction on the usage of MJCP concurrently.
- DMA configuration

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Table13. DMA Configuration for encoderPreset = XDM_USER_DEFINED, encQuality – 0,

TC Q's	TC 0	TC 1	TC 2	TC 3	Total
Usage	Used by Codec	Used by Codec	Used by Codec	Reserved for system	-
Priority	1	1	2	0	-
EDMA channels	21	7	9	NA	37
PaRAM Entries	54	10	25	NA	89
QDMA channels	0	0	0	0	0/8

Table14. DMA Configuration for encoderPreset –XDM_HIGH_QUALITY

TC Q's	TC 0	TC 1	TC 2	TC 3	Total
Usage	Used by Codec	Used by Codec	Used by Codec	Reserved for system	-
Priority	1	1	2	0	-
EDMA channels	23	19	4	NA	46
PaRAM Entries	60	32	6	NA	98
QDMA channels	0	0	0	0	0/8

Table15. DMA Configuration for encoderPreset – XDM_HIGH_SPEED

TC Q's	TC 0	TC 1	TC 2	TC 3	Total
Usage	Used by Codec	Used by Codec	Used by Codec	Reserved for system	-
Priority	1	1	2	0	-
EDMA channels	18	22	6	NA	46
PaRAM Entries	28	38	33	NA	99
QDMA channels	0	0	0	0	0/8

Table16. DMA Configuration for encoderPreset = XDM_USER_DEFINED, encQuality – 1,

TC Q's	TC 0	TC 1	TC 2	TC 3	Total
Usage	Used by Codec	Used by Codec	Used by Codec	Reserved for system	-
Priority	1	1	2	0	-
EDMA	23	7	9	NA	39

channels					
PaRAM Entries	59	13	25	NA	97
QDMA channels	0	0	0	0	0/8

- The HDVICP/MJCP/EDMA resources are acquired using a generic resource manager known as Framework component. Please refer user guide for details.

- Code Placement
  - All the algorithm code are placed in external memory. The performance quoted is not sensitive to algorithm code placement.

references

- ISO/IEC 14496-10:2005 (E) Rec. - Information technology – Coding of audio-visual objects – H.264 (E) ITU-T Recommendation.
- *H.264 Baseline/Main/High Profile Encoder User's Guide* (SPRUEU9B).

glossary

Constants	Elements that go into .const memory section
Scratch	Memory space that can be reused across different instances of the algorithm
Shared	Sum of Constants and Scratch
Instance	Persistent-memory that contains persistent information - allocated for each instance of the algorithm

acronyms

ASO	Arbitrary Slice Order
CIF	Common Intermediate Format
D1	Video Resolution for PAL(720x576) and NTSC(720x480)
DMA	Direct Memory Access
DPB	Decoded Picture Buffer
EVM	Evaluation Module
FMO	Flexible Macro-block Ordering
NTSC	National Television System Committee
PAL	Phase Alternating Line
PRC	Perceptual Rate Control
PSNR	Peak Signal to Noise Ratio

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QCIF	Quarter Common Intermediate Format
QVGA	Quarter Video Graphics Array
RS	Redundant Slice
SEI	Supplementary Enhancement Information
SM	Scaling Matrix
SQCIF	Sub Quarter Common Intermediate Format
UMV	Unrestricted Motion Vectors
VGA	Video Graphics Array
vIMCOP	Video and Imaging Co-processor
VUI	Visual Usability Information
WVGA	Wide Video Graphics Array (864x480)
XDM	eXpressDSP Digital Media

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