Intel® Open Source HD Graphics Programmers' Reference Manual (PRM)

Volume 10: High Efficiency Video Coding (HEVC)

For the 2014-2015 Intel Atom™ Processors, Celeron™ Processors and Pentium™ Processors based on the "Cherry Trail/Braswell" Platform
(Cherryview/Braswell graphics)

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High Efficiency Video Coding (HEVC) Introduction

The HEVC Codec Pipeline (HCP) is a fixed function hardware video codec responsible for decoding HEVC (High Efficiency Video Coding) video streams.

Scope

The primary scope of the HCP BSpec document is to provide a description of the HCP commands processed by the Video Command Streamer (VCS). The secondary scope is to provide a description of the status registers on the Message Channel Interface to support decoding of the HEVC video format.

The BSpec sections include:

- Summary of Features
- Architecture Overview
- Commands
- Register Definitions
- Acronyms and Applicable Standards

Summary of Features

The following sections define the HEVC Decoder general features, and the features specific to HEVC decoding.

HCP Hardware Pipeline Features

- Supports decoder functions, setup on a per picture basis:
  - Hardware acceleration provides Ctb/CU level decode.
  - No context switch is supported within a frame process.
- Supports Video Command Streamer (VCS):
  - Shared with MFX HW pipeline, and at any one time, only one pipeline (MFX or HCP) and one operation (decoding or encoding) can be active.
- Supports Message Channel Interface:

Feature
Supports Tile-Y Legacy.

- Supports NV12 video buffer plane:
  - Supports 4:2:0, 8-bit per pixel component (Y, Cb and Cr) video.
- Supports 8Kx8K frame size.

HEVC Decoder Features

- Supports full-featured HEVC Main Profile standard, up to Level 6.2.
- Supports the long format HW decoding interface:
  - All headers (SPS, PPS, Slice Header) are parsed and decoded outside the HCP HW pipeline. They are then fed to the HW through a set of HCP state commands.
- Error detection/resiliency down to the Ctb/CU level.

HCP Command Summary

The HCP is configured for decoding through a set of batch commands defined in the following sections. The software driver builds a frame level workload using these commands and stores these workloads in graphics memory where they are fetched by the Video Command Streamer (VCS) and presented to the HCP for processing. The commands are processed by the Workload Parser within the HCP and the hardware is configured by the Workload Parser prior to each frame level decode. A workload is defined as a set of commands necessary to decode one frame.

The software driver is required to read the HCP disable fuse to determine if the HCP is enabled. If it is disabled, then the software driver must not enable HCP batch commands to be sent to the HCP or a hang event may occur. Only when the HCP is enabled through the fuse, should the batch commands be sent to the HCP.

Workload Command Model

DWord0 of each command is defined in HCP DWord0 Command Definition. The HCP is selected with the **Media Instruction Opcode "7h**" for all HCP Commands.

HCP DWord0 Command Definition

DWord	Bits	Description
0	31:29	**Command Type** = PARALLEL_VIDEO_PIPE = 3h
	28:27	**Pipeline Type** = 2h
	26:23	**Media Instruction Opcode = Codec/Engine Name** = HCP = 7h
	22:16	**Media Instruction Command** = *<see Workload Command Model>*
	15:12	**Reserved: MBZ**
	11:0	**Dword Length** (Excludes Dwords 0, 1) = *<command length>*

Each HCP command has assigned a media instruction command as defined in HCP Media Instruction Commands (Opcode=7h).

HCP Media Instruction Commands (Opcode=7h)

Media Instruction Command	Command DWord0 [22:16]	Mode	Scope
HCP_PIPE_MODE_SELECT	0h	Dec	Picture
HCP_SURFACE_STATE	1h	Dec	Picture
HCP_PIPE_BUF_ADDR_STATE	2h	Dec	Picture
HCP_IND_OBJ_BASE_ADDR_STATE	3h	Dec	Picture
HCP_QM_STATE	4h	Dec	Picture
Reserved	5h-Fh		
HCP_PIC_STATE	10h	Dec	Picture
HCP_TILE_STATE	11h	Dec	Picture
HCP_REF_IDX_STATE	12h	Dec	Slice
HCP_WEIGHTOFFSET	13h	Dec	Slice
HCP_SLICE_STATE	14h	Dec	Slice
Reserved	15h-1Fh		
Reserved	20h	Dec	Slice
Reserved	21h		
Reserved	22h		
Reserved	23h-7Fh		

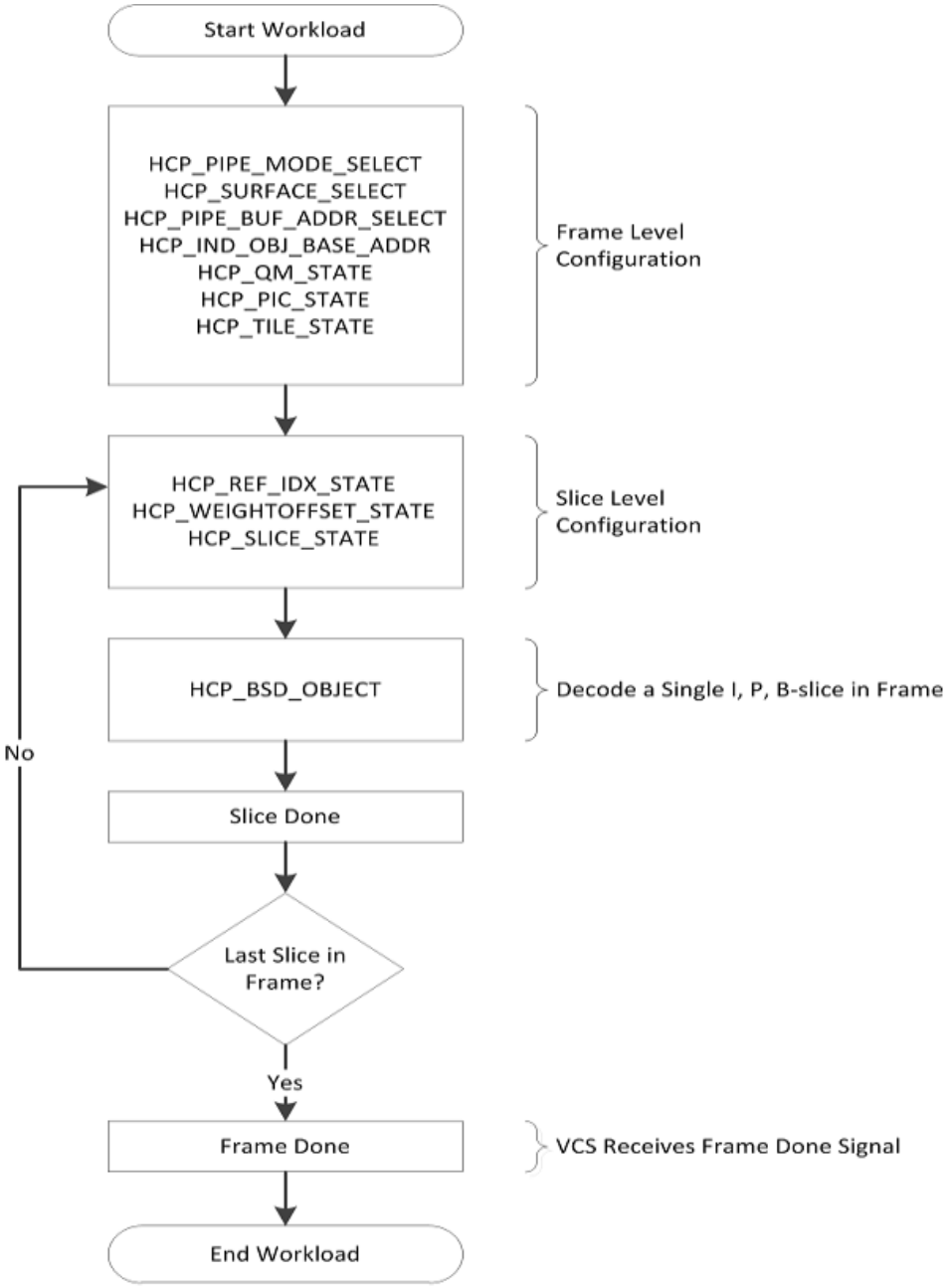
HCP Command Sequence Examples

This section is currently under development.

HCP Decoder Command Sequence

The long format workload for the HCP is based upon a single frame decode. There are no states saved between frame decodes in the HCP. Once the bit stream DMA is configured with the HCP_BSD_OBJECT command, and the bit stream is presented to the HCP, the frame decode will begin.

HCP Long Format Decode Workload Flowchart



Memory Address Attributes

This section defines the memory address attributes for the third DWord of the HCP command buffer address.

NOTE: The first DWord defines the lower address range and the second Dword defines the upper address range in the HCP command buffer address.

MemoryAddressAttributes

HCP Pipe Common Commands

The HCP Pipe Common Commands specify the HEVC Decoder pipeline level configuration.

HCP_PIPE_MODE_SELECT (VideoCS)

HCP_SURFACE_STATE (VideoCS)

HCP_PIPE_BUF_ADDR_STATE (VideoCS)

HCP_IND_OBJ_BASE_ADDR_STATE (VideoCS)

HCP_QM_STATE (VideoCS)

Buffer Size Requirements

HEVC Buffer Size Requirements

Buffer Name	Minimum Size in CLs	Notes
Deblocking Filter Line Buffer	((picture_width_in_pixels + 31) & (-32)) » 3	Eq. ensures multiple of 4
Deblocking Filter Tile Line Buffer	((picture_width_in_pixels + 31) & (-32)) » 3	Eq. ensures multiple of 4
Deblocking Filter Tile Column Buffer	((picture_height_in_pixels + 6*pic_height_in_ctb + 31) & (-32)) » 3	Eq. ensures multiple of 4
Metadata Line Buffer (all intra slices)	(picture_width_in_pixels + pic_width_in_lcu*8 + 1023) » 9	Eq. ensures multiple of 2
Metadata Tile Line Buffer (all intra slices)	(picture_width_in_pixels + pic_width_in_lcu *8 + 1023) » 9	Eq. ensures multiple of 2
Metadata Tile Column Buffer (all intra slices)	(picture_height_in_pixels + picture_height_in_lcu * 16 + 1023) » 9	Eq. ensures multiple of 2
Metadata Line Buffer (some inter slices)	(((picture_width_in_pixels+15)»4)*188 + pic_width_in_lcu * 9 + 1023) » 9	Eq. ensures multiple of 2
Metadata Tile Line Buffer (some inter slices)	(((picture_width_in_pixels +15)»4)*172 + pic_width_in_lcu * 9 + 1023) » 9	Eq. ensures multiple of 2
Metadata Tile Column Buffer (some inter slices)	(((picture_height_in_pixels +15)»4)*256 + picture_height_in_lcu * 9 + 1023) » 9	Eq. ensures multiple of 2
SAO Line Buffer	(((picture_width_in_pixels » 1) + pic_width_in_ctb * 3)+15) & (-16)) » 3	Eq. ensures multiple of 2
SAO Tile Line Buffer	(((picture_width_in_pixels » 1) + picture_width_in_ctb * 6)+15) & (-16)) » 3	Eq. ensures multiple of 2
SAO Tile Column Buffer	(((picture_height_in_pixels » 1) + pic_height_in_ctb * 6)+15) & (-16)) » 3	Eq. ensures multiple of 2
Current and Collocated Motion Vector Temporal Buffer (lcu=16x16)	(((picture_width_in_pixels+63)»6)*((picture_height_in_pixels+15)»4)	Eq. ensures multiple of 2
Current and Collocated Motion Vector Temporal Buffer (lcu>16x16)	(((picture_width_in_pixels+31)»5)*((picture_height_in_pixels+31)»5)	Eq. ensures multiple of 2
SSE Line Buffer	(Picture_width_in_lcu + 2) « 4	

HCP Common Commands

HCP_PIC_STATE (VideoCS)

HCP_TILE_STATE (VideoCS)

HCP_REF_IDX_STATE (VideoCS)

HCP_WEIGHTOFFSET_STATE (VideoCS)

HCP_SLICE_STATE (VideoCS)

HCP Commands

The HCP Commands specify the HEVC BSD object.

HCP_BSD_OBJECT (VideoCS)

HEVC Error Concealment

The HCP implements an error concealment policy, which is always enabled and cannot be disabled. The objective is that the HCP will always complete a frame/field workload by either decoding the bit stream normally until it finishes the workload or by concealing blocks until the slice or workload is completed. It should never be allowed to hang.

Error concealment, implemented by the HCP hardware, is configured for each slice in the HCP_BSD_OBJECT command. The following information in the HCP_BSD_OBJECT command is utilized for error concealment.

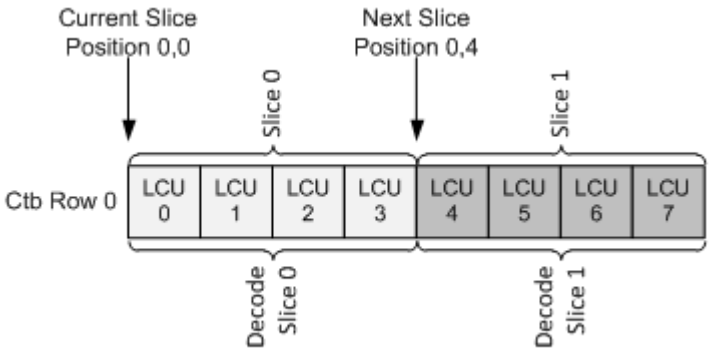
- **SliceStartCtbY, SliceStartCtbX:** The current slice position specified in Ctb coordinates.
- **NextSliceStartCtbY, NextSliceStartCtbX:** The next slice position specified in Ctb coordinates. If the current slice is the last slice in the picture, the next slice values are set to (0,0).
- **LastSliceofPic:** Indicates that the current slice is the last slice in the picture.
- **slice_type:** Indicates the picture type: I, P or B.

The host software will remove all extra slices in the picture. The HCP will not be given a workload that includes extra slices beyond the picture. The last slice in the picture will always be marked by the host software.

The host software will remove any overlapping slices in the picture. The HCP will not be given a workload that includes overlapping slices in the picture.

A HCP_BSD_OBJECT command will include the current slice position and the next slice position. For non-errored streams, it is guaranteed that the slice bit stream will be decoded by the HCP starting from the current slice position through to the Ctb (inclusive) adjacent to the Ctb indicated by the next slice position. *HEVC Error Concealment* illustrates the example of a non-errored stream decode starting with XXX.

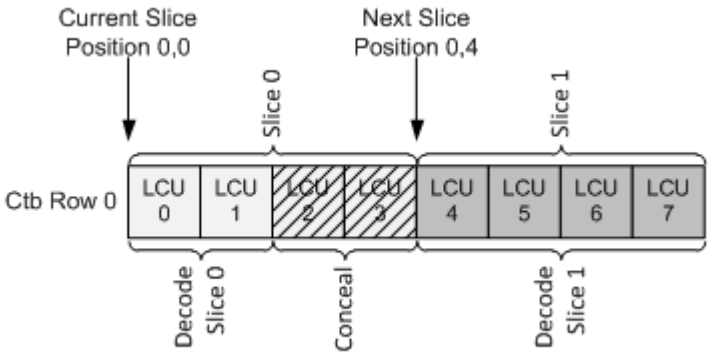
HEVC Slice Decode for Non-errored Stream Cases



For error stream cases where the next slice position does not align itself with the last successfully decoded Ctb in the current slice, the HCP will conceal Ctbs from the last decoded Ctb in the current slice through to the last Ctb prior to the Ctb indicated by the next slice position. If the error occurs such that the current decoded Ctb cannot be decoded, the HCP will ensure that the current Ctb is written out

by any means before writing out concealed Ctbs for the remaining Ctbs in the current slice. In the case of the last slice in a picture, the HCP will conceal Ctbs from the last decoded Ctb in the current slice through to the last Ctb position in the picture indicated by the resolution of the picture in the HCP_PICT_STATE command. *HEVC Error Concealment* illustrates the case described.

HEVC Slice Decode for Missing Blocks in a Slice



Since the host software removes overlapping slices, the next slice position will never be equal to or less than the current slice position.

A concealed Ctb for an I-slice is constructed by the HCP specifying the Intra_Planar prediction mode for the Ctb.

A concealed Ctb for a P-slice is constructed by the HCP specifying the skip_flag.

A concealed Ctb for a B-slice is constructed by the HCP specifying the skip_flag.

HEVC Register Definitions

The Message Channel Interface is a read-only bus used to access the HCP status register. All registers are 32 bits, where reserved bits return a value of zero and subtractive-decode is used to return 0x0000 for all register holes. The Unit ID is 28h. For HCP, the address range is 0x0001E900h to 0001E9FFh.

Register Attributes Description

Host Register Attributes gives the defined register tags and their description.

Host Register Attributes

Tag	Name	Description
R/W	Read/Write	Bit is read and writeable.
R/SW	Read/Special Write	Bit is readable. Write is only allowed once after a reset.
RO	Read Only	Bit is only readable, but writes have no effects.
WO	Write Only	Bit is only writeable, reads return zeros.
RV	Reserved	Bit is reserved and not visible. Reads will return 0, and writes have no effect.
NA	Not Accessible	This bit is not accessible.

HCP Decoder Register Map

Register	Address	Default	Description
HCP_DEC_STATUS	1E900h	00000000H	HCP decode status
HCP_CABAC_STATUS	1E904h	00000000H	HCP CABAC status
HCP_LAST_POSITION	1E908h	00000000H	Last row & column position of the decoder
HCP_PMU_STATUS	1E90Ch	00000000H	PMU counter overflow status
HCP_PMU_LUMA_CNTR	1E910h	00000000H	Luma cache miss event counter
HCP_PMU_CHROMA_CNTR	1E914h	00000000H	Chroma cache miss event counter
HCP_PMU_FRAME_DEC_ACT_CNTR	1E918h	00000000H	Frame decode active event counter
HCP_PICTURE_CHECKSUM_CIDX0	1E91Ch	00000000h	Picture checksum cIdx0
HCP_PICTURE_CHECKSUM_CIDX1	1E920h	00000000h	Picture checksum cIdx1
HCP_PICTURE_CHECKSUM_CIDX2	1E924h	00000000h	Picture checksum cIdx2

HCP Decoder Register Descriptions

The HCP implements the following MMIO registers. A description of the register including its address and DWord descriptions are provided.

HCPDecodeStatus (VideoCS)

HCPCABACStatus (VideoCS)

HCPLastPosition (VideoCS)

HCPPMUStatus (VideoCS)

HCPPMULumaCacheMissCounter (VideoCS)

HCPPMUChromaCacheMissCounter (VideoCS)

HCPPMUFrameDecodeActiveCounter (VideoCS)

HCPPictureChecksumcIdx0 (VideoCS)

HCPPictureChecksumcIdx1 (VideoCS)

HCPPictureChecksumcIdx2 (VideoCS)

Acronyms and Abbreviations

The table below defines acronyms and abbreviations used in this document.

Acronyms

Acronym	Meaning
AAC	Advanced Audio Coding — part of the MPEG specification, AAC is the latest development in audio compression. It provides higher-quality audio reproduction than MPEG-1 Layer 3 (MP3), while requiring nearly 50% less data. It is defined in ISO/IEC 13818-7.
ADSL	Asymmetrical Digital Subscriber Line — an asymmetrical DSL technology that takes advantage of the one-way nature of most multimedia communication, and provides much faster data rates for downstream (to the subscriber) then the upstream.
API	Application Programming Interface — a set of routines used by an application program to request and carry out low-level services performed by the operating system.
ARGB	Alpha Red Green Blue — color channel components.
ARIB	Association of Radio Industries and Business — designated by the Ministry of Public Management, Home Affairs, Posts and Telecommunications (MPHPT) in Japan. ARIB members include broadcasters, radio equipment manufacturers, telecommunication operators, and related organizations.
ASP	Advanced Simple Profile – MPEG4-2
ATSC	ATSC Advanced Television Systems Committee – an organization in US that establishes and promotes technical standards for advanced television systems, such as digital television (DTV).
BDU	Bit-stream Data Unit
BIST	Built In Self Test
BPP	Bits Per Pixel
BSD	Byte Stream Decoder
CA, CAM	Conditional Access, Conditional Access Module – the removable descrambling module implemented in digital cable or satellite television system. The data flows through the module, which can have any proprietary scrambling algorithm implemented, yet maintaining system interface compatibility. The CAMs are usually provided by the operators in the TV network.
CPU	Central Processing Unit
DAA	Direct Access Arrangement
DAC	Digital-to-Analog Converter
DDA	Digital Difference Analyzer
DDS	Direct Digital Synthesizer
DPB	Decoded Picture Buffer. This buffer holds the decoded pictures for reference and for output along with the currently decoding picture. This differs from the DPB in the standard, which only holds the decoded pictures for reference.
DVB	Digital Video Broadcasting — a set of open worldwide standards that define digital broadcasting using existing satellite, cable, and terrestrial infrastructures. It uses MPEG-2 specification as a universal foundation and expands it with DVB data structures and processes DVB-compliant digital broadcasting and equipment is widely available to consumers and is indicated with the DVB

Acronym	Meaning
	logo.
DVB-S	Satellite television DVB standards, based on QPSK and 8-DPSK modulation.
DVB-T	Terrestrial television DVB standards, based on 2k and 8k OFDM modulation.
DVD	Digital Versatile Disc
DVD-R	Recordable DVD. Since different disk formats are currently in use, including DVD-R,DVD+R, they are collectively mentioned as DVD-R in this document
DVI	Digital Visual Interface standard (EIA/CEA-861A). The standard defines a method for sending digital video signals over DVI and OpenLDI interface specifications. The standard is fully backward compatible with earlier DVI standards. New features include carrying auxiliary video information, such as aspect ratio and native video format information.
DSL xDSL	Digital Subscriber Line – transmission of data over copper telephone lines capable of bringing high-bandwidth to subscribers. Many flavors of DSL are currently in use, which are collectively called xDSL throughout the document.
DSP	Digital Signal Processor
DST	Destination
DWord	A 32-bit word
FIFO	First in First Out
FIR	Finite Impulse Response
FPU	Floating Point Unit
FW	Firmware running on the decoder controller, as used in Volume 4 of the *Olo River Plus Silicon EAS*
IDR	Instantaneous Decoding Refresh
IEEE 1394 1394	IEEE 1394 or iLink* or FireWire* An IEEE electronics industry standard for connecting multimedia and computing Up to 63 devices can be attached to your PC via a single plug-and-socket connection.
IEEE 802.11 802.11	The Institute for Electronics and Electrical Engineers (IEEE) wireless network specification. 802.11g and 802.11a networks can transmit payload at the rates in excess 34Mbits/s and allow for the wireless transmission at distances from several dozen to several hundred feet indoors.
IF	Intermediate Frequency — the fixed, relatively low-frequency carrier to which current programs are ported by the tuner.
GMCH	Graphics and Memory Control Hub — a chip that connects the IA processor to memory and other components in PC.
HDD	Hard Disk Drive — magnetic mass storage device used in media centers for audiovisual program recording.
HDMI	High Definition Multimedia Interface (HDMI). This interface is used between any audio/video source, such as a set-top box, DVD player, or A/V receiver, and an audio or video monitor, such as a DTV. HDMI supports standard, enhanced or high-definition video, plus multi-channel digital audio on a single cable. The format transmits all ATSC HDTV standards and supports eight-channel digital audio (at up to a 192kHz sampling rate), with bandwidth to spare for future enhancements.

Acronym	Meaning
HDTV	High-Definition Television — HDTV specifically refers to the highest-resolution formats of the 18 total DTV formats, true HDTV is generally considered to be 1,080-line interlaced (1080i) or 720-line progressive (720p).
HSR	Hidden Surface Removal
HW	Hardware
I/F	Interface
IEEE	IEEE 32-bit Floating Point number format representation
ISP	Image Synthesis Processor — A collective term to describe all components of the hidden surface removal operation within the PowerVR architecture.
LOD	Level Of Detail — used in texturing calculations.
LSB	Least Significant Bit
LUT	Look-up table
MBAFF	Block Adaptive Field Frame mode
MFD	Multi-Format Decoder
MMU	Memory Management Unit
MMMC	Multi-port, Multi-channel Memory Controller
MSA	Intel Micro Signal Architecture — microprocessor architecture combining the features of microcontroller and digital signal processor. MSA is used here as a synonym of the processor core used in Olo River Plus
MSB	Most Significant Bit
MPEG	Motion Picture Experts Group – Organization that develops standards for digital video and digital audio compression.
MPR	Inter Prediction Module
NAL	Network Abstraction Layer
NAL unit	Syntax structure in a H.264 stream
NTSC	National Television System Committee, North American 525-line analog broadcast TV standard.
NIM	Network Interface Module – the integrated tuner and digital demodulator in the (satellite) TV systems. The DVB NIMs output MPEG transport stream.
NOP	No operation
OEM	Original Equipment Manufacturer
OGL/OpenGL	Open GL application programming interface
PAL	Phase Alternation Line - TV standard used in Europe. PAL uses 625 lines per frame, a 25 frames per second update rate and YUV color encoding. The number of visible pixels for PAL video is 768 x 576.
PCI	Peripheral Component Interconnect bus, a bi-directional bus defined in PCI 2.x specification
PES	Packetized Elementary Streams — packetized streams are the ES streams arranged in data packets with PES header starting every packet. The syntax of the ES and PES is defined in MPEG. See definition for ES.
PIP	Picture In Picture display mode

Acronym	Meaning
POD	Point of Deployment conditional access module — the removable conditional access module defined in the OpenCable* specification in US.
PPS	Picture Parameter set
PTS	Presentation time stamp
PVR	Personal Video Recorder, also PDR or personal digital recorder — an interactive TV-recording device that records programs in digital format and allows users to search for/record shows based on type (for instance all basketball games or all episodes of a particular program). Users can also pause, rewind, stop, or fast-forward live programs with only a small time lag.
PWL	Piece-wise Linear
PXD	Pixel Decoder Module
RF	Radio Frequency – usually, modulated carriers which can be directly received by the tuners of TVs or radio receivers
RISC	Reduced Instruction Set Computer
RHW	Reciprocal Homogenous W — W is a 3-D coordinate representation like X Y Z
RSB	Row Store Buffer
RTL	Register Transfer Language/Level
SEI	Supplementary Enhancement Information
SIF	Semaphore Interface Module
SIMD	Single Instruction Multiple Data
SMPTE	Society of Motion Picture and Television Engineers
SOC	System on chip
SP	Simple Profile – MPEG4-2
SPS	Sequence Parameter set
SRC	Source
SDTV	Standard-Definition Television — a digital television system that is similar to current analog TV standards in picture resolution and aspect ratio. Typical SDTV resolution is 480i or 480p.
STB	Set Top Box — a device that effectively turns a television set into an interactive Internet device and/or allows the television to receive and decode digital television (DTV) broadcasts.
TA	Tile Accelerator
TS	MPEG-2 Transport Stream — a sequence of 188-byte packets carrying the multi-program audiovisual data
TSP	Texture Shading Processor — a collective term to describe all components of the texture, shading and pixel blending operations within the PowerVR architecture.
VCL	Video Coded Layer
VCXO	Voltage Controlled Crystal Oscillator
VGP/ VGP Lite	Vertex Geometry Processor
VLC	Variable length coded. This refers to the collection of coding techniques that are used in VC1, and include CABAC, CAVLC and Exp-Golomb.
VOL	Video Object Layer

Acronym	Meaning
VOP	Video Object Plane
WAN	Wide Area Network
WSS	Wide Screen Signaling
XDS	Extended Data Services — data services sending data in line 21/283 of the analog NTSC TV signal
XSI	Intel® XScale® System Interconnect
X, Y, Z, W	3-D coordinate representations
YUV	YUV texture format, primarily for video formats