

HDMI in HDV and AVCHD Camcorders

Introduction

HDMI (High Definition Multimedia Interface) is quickly becoming a common interface on HDV and AVCHD camcorders, as well as LCD and Plasma TVs and DVD players. New laptop computers, set-top boxes, and even the Sony PlayStation 3 will feature HDMI. This year, an estimated 60 million HDMI devices will ship worldwide. HDMI is clearly poised to become a ubiquitous standard interconnect for audio/video devices. But exactly what is HDMI?

This paper, by Convergent Design, explains HDMI and discusses how this exciting technology fits into HDV and AVCHD camcorders and decks. Applications such as all-digital live capture of “never-compressed” video/audio and low-cost conversion of HDMI to HD/SD-SDI are discussed. Finally, an analysis of the benefits of HDMI in NLE applications and how this technology can be used to effectively bypass the issues of Long-GOP formats such as HDV and especially AVCHD.

What is HDMI?

HDMI (High Definition Multimedia Interface), the successor of DVI, is projected to become the de-facto interconnect for TVs, set-top boxes, DVD players, consumer camcorders, and digital cameras. HDMI transmits uncompressed SD or HD video (up to 1080p) and up to 8 channels of high quality (192KHz) 24-bit audio over a single digital connection. Additionally, HDMI optionally includes digital content protection (known as HDCP) to eliminate unauthorized copying of DVDs and other programs.

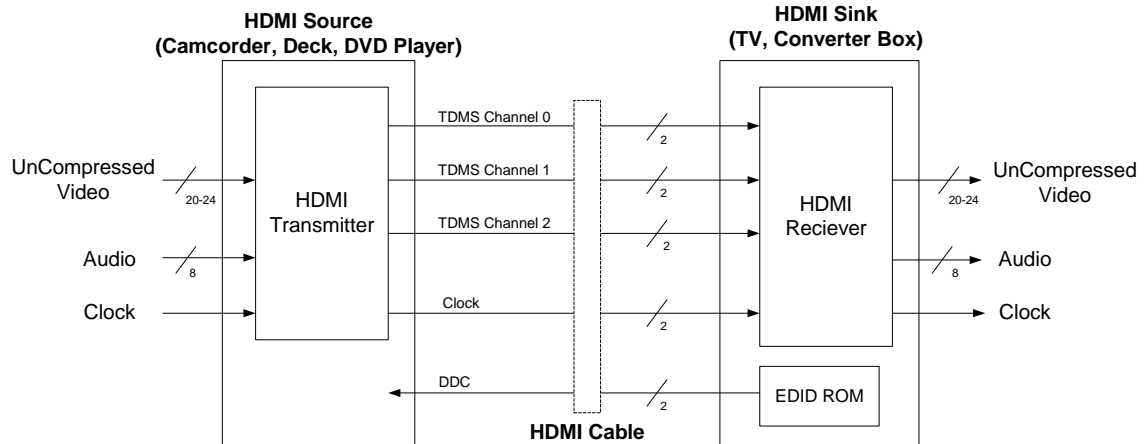
The original HDMI spec (1.0) was published in December 2002, by the founding members, including Hitachi, Panasonic, Philips, Silicon Images, Sony, Thompson, and Toshiba. HDMI is an open specification which has undergone numerous enhancements including the addition of deep color (greater than 24-bits per pixel), compressed audio, and Gamut metadata, among others. Revision 1.3 is the latest specification and can be downloaded at www.hdmi.org. Over 400 companies have now adopted HDMI.

HDMI can be thought of as DVI + audio + optional HDCP (High Definition Content Protection), with some significant improvements to potential video resolution and quality. HDMI uses the same electrical signaling as DVI, but with a smaller connector. Inside the HDMI cable 4-pairs of conductors carry video / audio and a clock. The interface uses a technique called TMDS (transition minimized differential signaling) to reduce EMI (electromagnetic interference) and possible transmission errors. Additionally, a 2-wire serial bus allows the transmitting device (such as a DVD player) to query the receiving device (such as an LCD TV) for its display capabilities (does it support 720p, 1080i, or 1080p?) and adjust the HDMI output accordingly. This is accomplished by reading a local memory inside the receiving device (using the DDC or data display channel), known as the E-EDID, the enhanced extended display interface data.

A simplified diagram of an HDMI connection is shown below.

HDMI in HDV and AVCHD Camcorders

HDMI Connection Diagram



The HDMI transmitter is essentially a parallel to serial converter, which accepts 24-bits of video data (and audio) and serializes this data over three TMDS channels. The HDMI receiver on the other hand is a serial to parallel converter which receives the three TMDS channels of data and de-serializes to 24-bits of video (and accompanying audio). Since the video data can be sent in RGB or YCbCr format, color space conversion may be performed on either end of the connection.

HDMI supports the following color space and quantization:

- 1) RGB 4:4:4 8-bit
- 2) YCbCr 4:2:2 8/10-bit
- 3) YCbCr 4:4:4 8-bit

HDMI supports over 35 different video formats, here's a list of the formats typically used in professional video.

- 1) 720 x 480 interlaced 4:3 at 59.94Hz (480i)
- 2) 720 x 576 interlaced 4:3 at 50Hz (576i)
- 3) 1280 x 720 progressive 16:9 at 59.95Hz (720p60)
- 4) 1280 x 720 progressive 16:9 at 50Hz (720p50)
- 5) 1920 x 1080 interlaced 16:9 at 59.94Hz (1080i60)
- 6) 1920 x 1080 interlaced 16:9 at 50Hz (1080i50)

Note that HDMI does not support 24p modes, which implies that the video decoder must automatically perform the required pull-down.

HDMI does include optional content protection, intended to prevent users from making illegal copies of DVDs, television programs, etc. This content protection is not a required part of the HDMI specification and has not been implemented on most camcorders/decks or other such personal video devices (where the video content is rightfully owned by the consumer and does not need to be protected).

Unlike 1394, HDMI receivers do not require complex (and costly) decoders (de-compressors) on the receiving side, since the video and audio are already uncompressed.

HDMI in HDV and AVCHD Camcorders

With few exceptions, 1394 A/V connections always carry a compressed stream, since 1394 bandwidth is limited to 800-Mbps or less (insufficient for uncompressed HD). So the 1394 receiver must include a decoder to decompress the A/V stream for display or further processing. HDMI's 4.95-Gbps bandwidth easily supports uncompressed 1080p video and 8-channels of accompanying audio eliminating the need to add a decoder for each type of compressed stream (HDV, AVCHD, DV, DVCPHD, etc). Using an uncompressed data link is simple and far less costly. (See Appendix A).

Compared to DVI, HDMI offers embedded audio (up to 8 channels of PCM or Dolby 5.1/7.1 compressed audio), and 10-Bit YCbCr 4:2:2 or 4:4:4 as compared to only 8-bit RGB 4:4:4 on DVI). Additionally, since the audio is embedded in HDMI, the inherent lip-sync problem with DVI monitors (due to the video latency in the LCD / Plasma panel) is eliminated. The audio and video in an HDMI monitor have exactly the same latency and are therefore always presented in sync.

In summary, HDMI offers the following advantages:

Industry wide support – HDMI has wide industry support from almost all major consumer electronics companies, as well as major motion picture producers (Fox, Universal & Disney - who use the HDCP content protection) and system operators (such as DirecTV and EchoStar). Over 400 companies have adopted HDMI.

High Quality HD Video and Audio – HDMI supports 8/10 bits per color in YCbCr 4:2:2 or 4:4:4 sampling as well as RGB 4:4:4. HDMI supports up to 8-channels of 192KHz 24-bit embedded audio, which is well above most audio implementations in broadcast studios.

Lower System Cost – Unlike a 1394 connection, the receiver does not require expensive MPEG2 or H.264 decoder, since the video / audio is already uncompressed. Compared to analog connections, HDMI transmitters and receivers are intrinsically lower cost than analog encoder and decoders and thus reduce product costs (see Appendix A).

100% Digital – HDMI avoids the losses inherent in all analog connections by eliminating the need to convert each signal from digital to analog (on the transmitting side) and then back to digital (on the receiving side). Softening of the video (due to bandwidth limitations in the analog conversion) as well as potential color shifts (due to voltage offsets between the transmitter and receiver) are eliminated.

Evolving Standard - HDMI 1.0 supported 1080p60 (1920x1080 @ 60 progressive frames per second). The current HDMI 1.3 spec now has about 3X the required bandwidth for 1080p60 video and audio. So, HDMI has headroom for future growth and expansion.

Ease-of-Use – Unlike analog component connections, which require 3 wires for the video and minimum of 2 more wires for the stereo audio, HDMI uses one simple cable to carry higher-quality video and up to 8-channels of audio. HDMI 1.3 offers

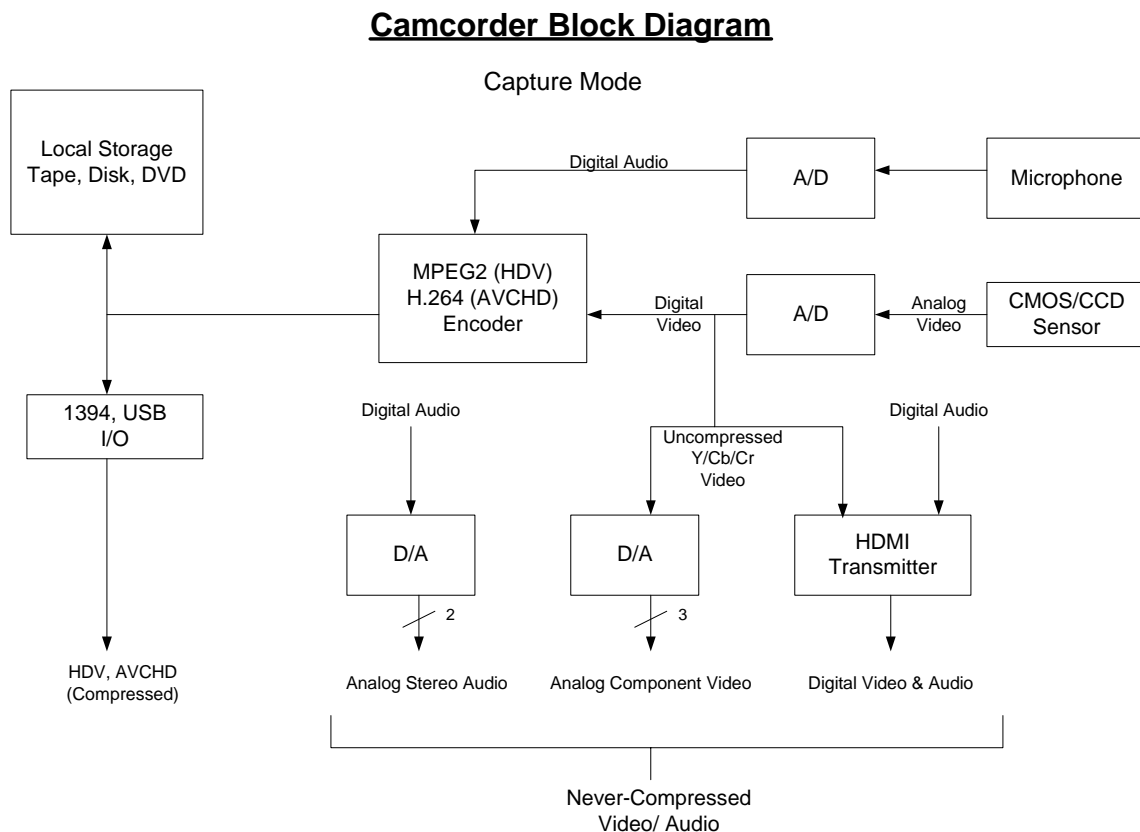
HDMI in HDV and AVCHD Camcorders

equivalent bandwidth than dual-link DVI without the hassle of separate audio connections.

What are the disadvantages of HDMI? Well, we can identify two shortcomings: 1) Cable lengths are limited to about 20 meters (65 feet) without the use of a repeater and 2) HDMI cable can be expensive compared to standard coax. HDMI cable is roughly 4x-8x the cost of coax (HDMI cable has 12 individual wires, compared to coax, which has only one).

HDMI in an HDV/AVCHD Camcorder (Acquisition)

Turning now to the implementation of HDMI in camcorders / decks, the diagram below shows a highly simplified view of the major processing blocks used in a camcorder during the capture of HDV or ACVHD video/audio.



Uncompressed video data is first captured off the CCD/CMOS sensors and converted to a digital format (using a very high quality A/D converter, typically 14-bit resolution). For most 1080i HDV cameras, which normally capture in 1440x1080 native resolution, there is a built-in horizontal up-scaler to expand the horizontal resolution from 1440 to 1920. For 720p HDV cameras with native 1280x720 resolution, no up-scaling is required.

HDMI in HDV and AVCHD Camcorders

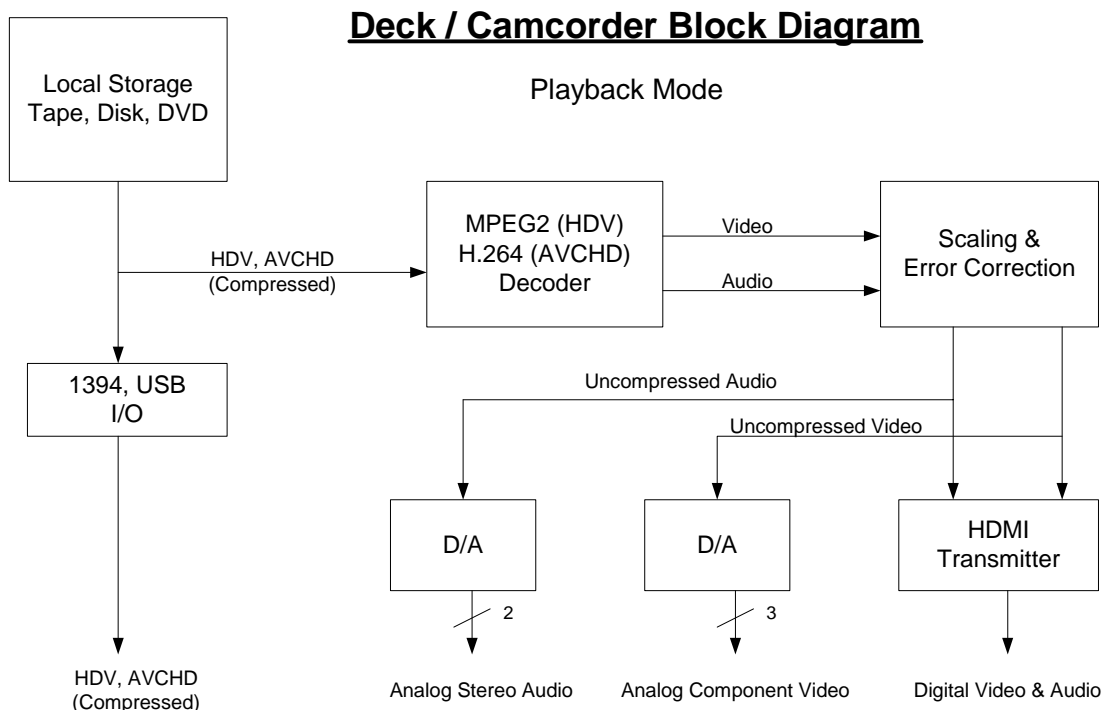
The digital data is then simultaneously sent to the MPEG2 (HDV) or H.264 (AVCHD) encoder, the analog component encoder (D/A) and the HDMI transmitter. In this live-capture mode, the video stream (and accompanying audio) to the HDMI transmitter and the video encoder have never been compressed and are limited in quality only by front-end CCD/CMOS sensors, optics, and associated electronics.

The compressed HDV or AVCHD data is stored locally on a DV tape, hard drive or DVD disk for future playback. The compressed stream is also sent over a 1394 connection (HDV camcorders only) for external capture or monitoring. (On AVCHD camcorders the compressed data is not streamed out the USB port, but is available for access as a data file).

The latency, or the time required to process the video/audio data, varies considerable between the HDMI/component port and the compressed (1394) port. The processing delay through HDMI port is imperceptible, while the delay through the MPEG2 / H.264 encoder can be up to ½ second! Therefore, the compressed stream generally cannot be used for live event monitoring. Whereas the output from the HDMI port is perfectly acceptable for live event capture and offers pristine never-compressed video/audio.

HDMI in an HDV/AVCHD Device (Playback)

The diagram below shows the data flow in a camcorder or deck when playing back recorded HDV/AVCHD footage.



HDMI in HDV and AVCHD Camcorders

During playback from a camcorder or deck, the compressed video/audio is streamed from the tape, disk or DVD simultaneously to the decoder (de-compressor) and to the 1394 (HDV) or USB (AVCHD) port. Uncompressed video and audio from the decoder is then sent to an error correction / scaling circuit where most tape dropout errors are removed and the video is scaled up or down as selected by the user. (Note: for 1080i HDV video, the horizontal line length is upscaled from 1440 to 1920 in this block. 720p HDV requires no such scaling). The scaled and error corrected video/audio is then sent simultaneously to the HDMI transmitter and the analog video/audio D/A converters.

One important distinction exists between the video/audio created from decoding the uncompressed stream out the 1394 port (using the software CODEC on your PC/MAC for example) and the hardware decoder inside the deck/camcorder. Inside the deck / camcorder is a hardware error correction unit which can remove many of the tape dropouts seen on mini-DV tapes. These colorful macroblock errors can be quite annoying at times and ruin otherwise useful footage. Additionally some camcorders introduce discontinuities at transition points (caused by pressing the record pause button). These transition points introduce errors in most software CODECs, which cause the clip to be split with possible time-code breaks. The error correction circuit in the camcorder/deck eliminates these issues, so the video out the HDMI / analog ports does not exhibit these problems.

In addition to error correction, this hardware video processing can cross convert the video from 1080i ↔ 720p or scale the video to SD resolution in anamorphic, edge-crop or letterbox formats. This hardware scaling can eliminate downstream software processing on the NLE system.

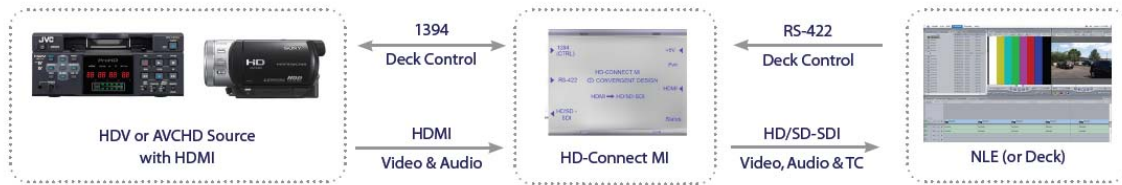
One of the most compelling reasons to consider using the uncompressed video / audio from the HDMI port for NLE ingest (or to copy HDV → HDCAM) is to eliminate all the rendering and playback issues associated with the Long-GOP HDV, AVCHD formats. Once the video/audio has been decoded into the uncompressed HDMI format, it can be captured into an I-Frame CODEC such as DVCProHD, JPEG or DNxHD and easily processed in most NLE programs. This transcode will become especially important with AVCHD camcorders as the decode of H.264 material is 4X the complexity of MPEG2, while the encode is 8X more complex. Native editing of HDV is already a difficult task on many computers - native AVCHD editing will be painfully slow.

HD-Connect MI and HDV, AVCHD and DV

So, how can I bring this high-quality, error-corrected HDMI video / audio stream into my NLE? Enter the HD-Connect MI from Convergent Design. The HD-Connect MI is a high-quality HDMI → HD/SD-SDI converter specially design to take advantage of the HDMI stream from HDV and AVCHD camcorders and decks. This affordable converter also includes RS-422 deck control for batch capture and online/offline workflows.

HDMI in HDV and AVCHD Camcorders

HD-Connect MI Connection Diagram



As shown in the diagram above, the HD-Connect MI connects from your HDMI-based camcorder / deck via the HDMI cable (uncompressed video / audio) and the 1394 cable (for deck control and time-code). The MI box accepts RS-422 deck control commands from the NLE and translates these to 1394. Uncompressed video and audio from the HDMI connection is multiplexed with the time-code and transmitted over coax using the industry-standard HD/SD-SDI format. Users can capture the uncompressed HD or SD video/audio into a CODEC on their NLE, or store in an uncompressed format on their hard drive.

In an exciting new application, HD-Connect MI can also be used to capture never-compressed video and audio out of an HDV/AVCHD camcorder during a live shoot. As discussed in the above section on camcorder acquisition, the HDMI video and audio out of a live shot has never been processed through an MPEG2 or H.264 compressor and therefore retains all the color information (4:2:2) and detail from the CCD/CMOS sensor.

The HD-Connect MI box creates an affordable connection between the HDMI output of the camcorder and the HD-SDI input of an NLE or deck. HDMI cable can be quite expensive and is limited to about 20 meters in length without a repeater (see Appendix A for comparisons). HD/SD-SDI coax cable, on the other hand, is relatively low-cost and can be used in lengths exceeding 100 meters (some tests indicate lengths up to 200 meters can be achieved). So, users can run a short HDMI cable from the camcorder to the HD-Connect MI box followed long low-cost coax cable (to carry the HD/SD-SDI signal) to their NLE system, display device, or router. (More information on the HD-Connect MI box is available at www.convergent-design.com)

Conclusions

HDMI is poised to become the de-facto standard interconnect for audio/video consumer devices and is quickly becoming a common interface on HDV and AVCHD camcorders. HDMI supports uncompressed HD and SD video in RGB 4:4:4 or YCbCr in 4:2:2 or 4:4:4 in resolutions up to 1080p. The HDMI output from a HDV/AVCHD device offers superior error-corrected video as compared to software NLE CODECs. Affordable HDMI → HD/SD-SDI converters, such as the HD-Connect MI, offer superior quality video and audio over analog conversion with simplified connection and integrated deck control. Live capture of never-compressed video/audio offers exciting low-cost opportunities for videographers to enjoy very high quality HD video from the new sub-\$5,000 HDV and AVCHD camcorders.

HDMI in HDV and AVCHD Camcorders

Appendix A - Video Connection Comparisons

	Component Analog	1394	SD-SDI	HD-SDI	DVI	HDMI
Bandwidth (Gbps)		0.8	0.27	1.485	4.95	4.95
Digital Video						
Compressed		√	(1)			
Uncompressed	√	(2)	√	√	√	√
Max Resolution	1080p		480i, 587i	1080i	1080p	1080p
RGB 4:4:4 8-Bit					√	√
YCbCr 4:2:2 8/10-Bit			√	√		√
YCbCr 4:4:4 8/10 Bit				(3)		√
Digital Audio						
Compressed		√				√
UnCompressed		√	√	√		√
Cables						
Number	5-11	1	1	1	1+2-8	1
Conductors inside	1	4	1	1	10	14
Max Length (m)	3-5	5	300	100	15	15
Cable Cost (\$/ft)	***	**	*	*	****	****
Embedded time-code						
Embedded time-code		√	√	√		
Routers, Switchers	N/A	Limited	Common	Common	N/A	N/A

Notes:

- 1) Compressed DV or MPEG2 can be transmitted over an SD-SDI connection using a standard known as SDTI or ASI.
- 2) Uncompressed SD video can be transmitted over 1394. However, 1394 does not have sufficient bandwidth for uncompressed HD.
- 3) Dual Link HD-SDI can transmit YCbCr 4:4:4 with 10-bit resolution. This requires two coax cables. There is also a new 3GHz HD-SDI standard which will support 1080p.
- 4) Both DVI and HDMI offer Dual Link options which double their bandwidth.
- 5) Since DVI does not have embedded audio, implementations require one DVI cable for video plus 2-8 cables for audio.
- 6) The high cost of DVI / HDMI cable is directly related to the large number of individual conductors inside the cable.
- 7) The latest HDMI spec (1.3) includes a provision for a 10Gbps Single Link connection.
- 8) SD-SDI and HD-SDI maximum cable length is shown according to SMPTE standards, actual applications have achieved 400 meters for SD-SDI and 200 meters for HD-SDI.

HDMI in HDV and AVCHD Camcorders

Appendix B – Video Bandwidth Requirement

Approximate Bandwidth requirements of common video formats

Compressed Formats:

AVCHD – 9 to 24 Mbps

DV – 25 Mbps

HDV (1080i) – 25 Mbps

HDV (720p) – 19 Mbps

DVCProHD – 100 Mbps

HDCAM – 143 Mbps

Uncompressed Formats:

480i, 576i (SD) – 210 Mbps (with audio)

720p (HD) – 1120 Mbps

1080i (HD) – 1250 Mbps

1080p (HD) – 2480 Mbps

DV and HDV are normally carried on a 400 MBit 1394 connection. SD (standard definition) video is transmitted over a 270 MBit SD-SDI cable, while HD (high definition) video is carried on a 1.485 GBit HD-SDI cable.

HDMI in HDV and AVCHD Camcorders

Glossary

A/D – **a**nalog to **d**igital converter, typically used inside an NLE capture card to convert incoming component analog video to a 8/10 bit digital format

AVCHD – advanced video codec for high definition (aka MPEG-4 AVC, H.264), a Long-GOP video/audio compression routine employed in new camcorders from Sony and Panasonic. (see www.avchd-info.org for more information)

D/A – **d**igital to **a**nalog converter, typically used inside a camcorder / deck to convert digital video or audio to analog.

DDC – **d**ata **d**isplay channel, carries the EDID information from the HDMI sink (TV, LCD panel, etc) to the HDMI source (camcorder, deck, etc)

Decode – The process of decompressing an HDV, DV or AVCHD stream to an uncompressed format

DCP – Digital Content Protection, the agency responsible for issuing HDCP keys (see www.digital-cp.com)

DVI – **D**igital **V**ideo **I**nterface, the predecessor to HDMI, widely used in PC graphics cards to connect to an external display.

EDID – **E**xtended **D**igital **I**nterface **D**isplay, the read only memory on the HDMI receiving device (TV, LCD screen, etc) that specifies the display capabilities to the HDMI source (camera, DVD, etc).

Embedded Audio – Audio which is carried on the same electrical connection as the accompanying video. Embedded audio is part of HDMI and HD/SD-SDI, but not available on DVI connections.

Embedded Time Code – Time Code which is carried on the same electrical connection as the accompanying video. Embedded time code is only available on HD/SD-SDI connections.

EMI – **E**lectromagnetic **I**nterference, radiated electrical noise, which can be greater minimized by differential transmission techniques used in DVI, HDMI and 1394.

Encode – The process of compressing video/audio. Typical formats include MPEG2 (HDV), MPEG4 (AVCHD), DV, and JPEG.

H.264 – the advanced audio/video compression used in AVCHD camcorders

HDCP – **H**igh **D**efinition **C**ontent **P**rotection, the protocol used to encrypt the audio/video stream sent over an HDMI connection

HDMI in HDV and AVCHD Camcorders

HDMI – **H**igh **D**efinition **M**ultimedia **I**nterface, the emerging standard interconnect for uncompressed HD/SD video (up to 1080p) and audio (up to 8-channels of 192 KHz, 24-bit). (see www.hdmi.org for more information)

I-Frame CODEC – a CODEC (compression / decompression) routine that utilizes only spatial compression techniques (no temporal compression). Video compressed with an I-Frame CODEC is generally far easier to edit as compared to MPEG compressed video, such as HDV or AVCHD. Common I-Frame CODECs include DVCProHD, DNxHD, DV and JPEG.

Latency – the delay through a system measured as an integral number of video frames. MPEG decoders typically have 1-3 frames of latency, while MPEG encoders may have over 8 frames of latency.

Long GOP – Long **G**roup of **P**ictures. A GOP is the basic cadence used in MPEG compression. A GOP usually starts with an I-Frame followed by a sequence of P (Predicted) and B (Bi-Directional) frames.

MPEG2 – an advanced video/audio compression algorithm which utilizes spatial (I-Frame) and temporal (P,B frames) compression techniques. MPEG typically produces a stream which is 1/3 to 1/8 the size compared to an I-Frame only CODEC

Never-Compressed – A video/audio stream which has never been compressed (encoded), thus yielding the highest possible quality for a given camera. Never-compressed video/audio is available from the HDMI port on a live camera shoot.

TMDS – **T**ransition **M**inimized **D**ifferential **S**ignaling. The transmission method used in DVI and HDMI connections. TMDS offers very low EMI with data-rates exceeding 1.5Gbps (per channel)