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HDMI: The Short and the Long of It

HDMI, or High Definition Multimedia Interface, is a digital A/V interface that supports high resolution computer-video and HDTV as well as multiple channels of audio on a single cable. It is prevalent in flat-panel displays and projectors as well as DVD players, Blu-ray Disc players, and even some laptops and PC graphics cards. HDMI enables a fully digital A/V pathway, avoiding the need for D/A and A/D signal conversion to deliver pristine, high quality computer graphics and HDTV with pixel perfect accuracy.

Though designed for consumer applications, HDMI is quickly finding its way into pro A/V alongside its predecessor, DVI - Digital Visual Interface. The thrust of this article is to bring into focus the primary advantages, or disadvantages depending on your point of view, of HDMI, the digital High Definition Multimedia Interface.

HDMI 1.3 Basic Performance Parameters

- ✓ Performance:
  - – DVI compatible
  - – 25 – 340 MHz
  - – Upward of 10.2 Gbps data speed
  - – Color depth: 24-bit, plus 30, 36, and 48-bit Deep Color
  - – Color space: ITU-R BT709-5, xvYCC
- ✓ Simple, plug and play connection
- ✓ Only one cable required
- ✓ Integrated video, audio, and content protection
- ✓ High level consumer control
- ✓ Auto lip sync

Table 1

HDMI Capabilities and Advantages

HDMI encompasses the original DVI electrical interface topology known within the electronics industry as TMDS, or Transition Minimized Differential Signaling. Consider HDMI as a superset which includes DVI along with multi-channel digital audio support in various formats, copyright protection, and consumer control—all packaged into a connector about half the physical size of the original DVI connector.

The HDMI consortium, www.hdmi.org, formed in 2002 and released the initial specification that same year. In 2004, version 1.1 of the specification released, followed by version 1.2 in 2005, and version 1.3 in 2006 with significant performance enhancements. Refer to Table 1 for HDMI 1.3 performance parameters.

The notion is that HDMI offers the consumer electronics industry a single interconnect solution which compacts all needed electrical interfaces into one small package consumers consider easy to use. HDMI mainly utilizes a 19-pin plug known as Type A, and offers a 19-pin mini-plug called Type C found on camcorders and other portable devices. A 29-pin plug, known as Type B and compatible with dual link DVI, is no longer part of the HDMI specification as of version 1.3.

HDMI supports both computer graphics and HDTV formats. Sufficient data bandwidth is available for HDTV up to 1080p, 60 Hz. HDMI versions up to 1.2 support computer graphics rates to at least 1920x1200/60 Hz. The latest specification for HDMI, version 1.3, significantly increases video capabilities for future applications beyond HDTV, with support for resolutions to WQXGA (2560x1600) at 60 or 75 Hz.

HDMI versions up to 1.2 as well as DVI offer 24-bit color depth. HDMI 1.3 adds Deep Color, which allows for significant increases in color depth, including 30, 36, and 48 bits. Deep Color expands the number of available colors, from millions to billions and even trillions. In order to fully support Deep Color as well as computer graphics resolutions up to WQXGA, HDMI 1.3 will require data speeds of 10.2 Gbps, a twofold increase over the 4.95 Gbps data speed supported by HDMI 1.2 and earlier. HDMI 1.3 also adds support for a significantly increased color gamut, known as xvYCC or Extended-gamut

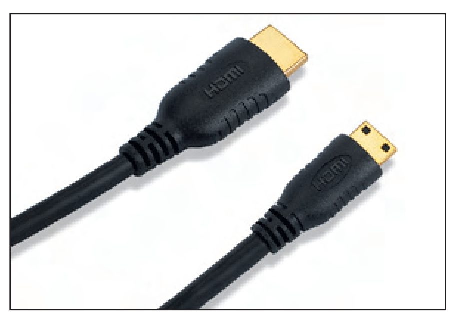

Figure 1: Relative size comparison between the Type A and Type C HDMI connectors. Type C is about 33% smaller.

YCC, or x.v.Color. Chapter 4.3 of the IEC standard describes xvYCC as an extension of ITU-R BT709-5 for sRGB and HDTV, but extends the gamut of that standard much wider. The concept is illustrated in Figure 2 where the outer boundary of the color space "wedge" represents the limits of human visual capacity and the triangles represent the available colors within a region defined by primary red, green, and blue tristimulus values for a given color space. The larger the triangle, the more vivid are the perceived colors.

For audio, HDMI supports up to eight channels of uncompressed audio at up to 24-bit/192 kHz, as well as the

SUPPORTED VIDEO FORMATS

DTV Formats
- SDTV – NTSC & PAL, EDTV & HDTV
- Interlaced 480i to 1080i
- Progressive 480p to 1080p at 60 Hz

Computer Formats
- VGA, UXGA, up to WQXGA (2560x 1600)
- Wide PC formats
- Any VESA or vendor-defined format

SUPPORTED AUDIO FORMATS

High Resolution Audio Formats
- Dolby TrueHD
- DTS-HD Master Audio
- DVD-Audio
- Super Audio CD

Compressed Audio Formats
- Dolby Digital
- DTS Digital Surround

Uncompressed Audio Formats
- Up to: 8 channels, 192 KHz, 24 bits
- CD-quality audio at base level
- 2-channel, 16-bit at 32, 44.1, or 48 KHz

Table 2

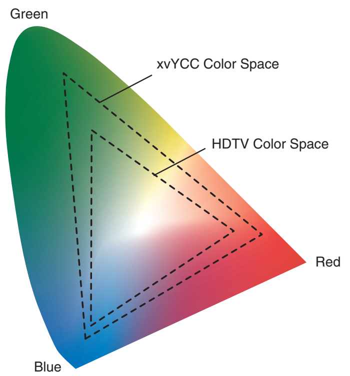

Figure 2: Conceptual presentation of the expanded xvYCC color space compared to the HDTV and sRGB color space (not to scale).

Dolby® Digital and DTS® compressed audio formats commonly used for DVDs, television broadcasts, and gaming. HDMI 1.3 adds the Dolby and DTS enhanced, lossless compression formats as part of Blu-ray Disc.

Implementation of Deep Color, xvYCC, and other enhancements is optional for HDMI 1.3-equipped products. Although xvYCC and/or Deep Color are promoted with many new LCD displays and projectors, they have yet to be widely implemented since they're not yet available with Blu-ray Disc and other source material. Refer to Table 2 for a complete listing of the video and audio support for HDMI up to version 1.3.

Promises in the Distance

Have you heard that HDMI promises longer cable length than DVI? Curiously, both the DVI specification and the HDMI specification contain the same electrical performance requirements between the source and the sink, or receiver. So, how is it that HDMI connectivity is promoted to work at greater distances than basic DVI? The answer is that the industry has learned how to make better cables for this type interface technology. Better cable manufacturing methods for precision shielded twisted pair cable coupled with consumer electronics volumes have made longer, low-cost HDMI cables a reality. In addition, technology has evolved with transmitter and receiver chipsets to ensure HDMI signal integrity over very long lengths of cable.

HDMI physical connections require precision shielded twisted pair cable. A cable is comprised of four shielded twisted pairs – one for the source clock signal and three for digital data – along with five individual wires for power, sub-communication functions, plus a ground reference for those functions. HDMI still requires the same encoding and data management protocol as DVI.

Run distance becomes critical due to particular timing tolerances that must be maintained within the DVI/HDMI specifications. Aside from the transmitter and receiver requirements where consistency should be straightforward, the cable becomes the largest variable

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affecting performance in the transmission system. Twisted pair cables, which DVI/HDMI uses, are subject to two types of skew which, when excessive, create timing errors and cause data dropouts. These parameters are: intra-pair skew, with time differential between the two wires making up the pair itself, and inter-pair skew, with time differential between separate twisted pair lines within the cable assembly.

The proper “shape” of the three TMDS signals – also known as the “eye” pattern, as well as their timing to the clock signal, is critical in ensuring proper HDMI or DVI image display. Refer to Figure 3. As shown in Figure 4, excessive skew, as well as attenuation due to long cable lengths, distorts the eye patterns and affects the ability of the receiving device to properly detect the signals, resulting in “sparkles” on-screen, or a complete loss of the image.

The HDMI specification only provides us with the electrical performance requirements for a functional interface. It does NOT specify cable design or cable length maximums. Manufacturers have but their own ingenuity using available raw cable materials and active electronics to solve the distance issues. However, version 1.3 does establish two classes of cable assemblies called Category 1 and Category 2. These "category" designations have nothing to do with the same nomenclature used for network cabling. Version 1.3 outlines detailed electrical design and testing requirements for both categories with Category 1, or Standard, cables supporting HDMI clock frequencies to 74.25 MHz and data speeds to 2.23 Gbps, and Category 2, or High Speed, cables supporting the entire specification through 340 MHz and 10.2 Gbps data speed.

So, what does this mean to us? HDTV rates through 1080i and 1080p at 30 Hz, operating at 24-bit color depth are serviced by the 74.25 MHz clock rate. This means that the supposedly cheaper, existing Category 1 cable will suffice. The higher performance Category 2 cable is therefore required to realize higher resolutions and any of the Deep Color rates. The 10.2 Gbps speed requirement makes it challenging for manufacturers to offer Category 2 cables at lengths comparable to Category 1.

Attenuation limit charts and eye diagram masks provide the tools to guide the cable designer between the two categories. It is obvious that, since cable length cannot be tied to the specification, we are highly dependent on the cable manufacturer to accurately design, test, and label the cable assemblies appropriately for the

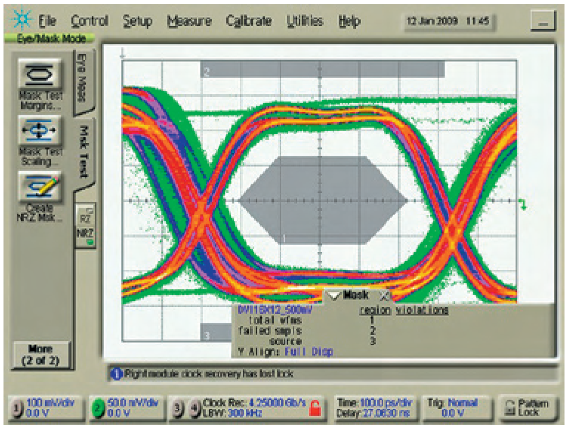

Figure 3: TMDS signals for the red, green, and blue channels, also known as the "eye" patterns. In this case, the eye pattern is “open” and clears the limit mask, shown in gray. This allows for reliable image display.

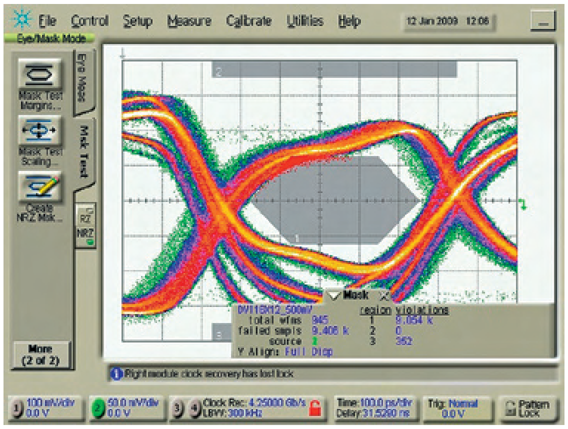

Figure 4: The eye pattern is distorted due to skew and attenuation losses from long cable lengths. It encroaches on the limit mask which potentially leads to erratic or no image display.

given length sold. While a short length of a particular cable type may perform to Category 2, it does not mean that a longer version of the same cable type will perform to Category 2. As cable length increases, we all know that attenuation effects limit performance rapidly. For critical applications, A/V designers should pre-test cables regardless of category labeling.

Arrest Fear, Not Pirates

HDCP is an acronym for High-Bandwidth Digital Content Protection, which is another subsystem of HDMI. Released in 2000 and mapped directly into the DVI standard, HDCP provides data security for the interface and is aimed to arrest the piracy concerns of digital content providers. HDCP protocol is implemented partly via a two-way communication link within the I^2C control interface used by the DDC - Data Display Channel and the high speed TMDS connections used to deliver image information. The DDC is a physical link in DVI and HDMI where the source graphics system communicates with the display device to determine its resolution capabilities.

HDCP rivals the complexity of TCP/IP TLS, or Transport Layer Security, used for Internet security. An authorized HDMI device may contain up to forty 56-bit secret key values along with a special identifier called the key selection vector, or KSV for short. These values, or codes, are provided by Digital Content Protection LLC, the designated third party set up to provide trusted keys to HDMI-licensed product manufacturers. Each time an HDMI device is connected in a system, a three-part authentication routine automatically occurs. First, shared values, or codes, between devices are exchanged; second, the KSV of each receiver is reported to the source; third, frame-by-frame ciphers are sent to the receivers that enable data decoding.

HDCP supports interconnection of devices via a hierarchy of sources, sinks, or receivers, and repeaters. All devices in an HDCP system communicate through a protocol designed to allow digital content to travel only to those devices which the source determines have the authorization to receive such content. The hierarchy supports seven levels of repeaters and up to a total of 128 devices. Repeaters are devices authorized to receive and re-transmit HDCP content. They must first be authenticated by the source, and then decrypt and re-encrypt HDCP content before sending it along to a sink or another repeater.

Significant changes are forthcoming with a new revision to HDCP. All of the aforementioned refers to HDCP versions 1.0 to 1.3, or simply 1.x. The latest version, HDCP 2.0, was released October 2008 to significantly bolster content protection and address well-known hacks into the current content security system. Instead of 56-bit key values, HDCP 2.0 calls for a more secure RSA system for authentication using 1024 and 3072-bit keys. Content encryption will be upgraded to the AES algorithm using 128-bit keys.
HDCP 2.0 is not only applicable to HDMI and DVI. It can be applied to any two-way digital communications scheme where content protection is needed, including DisplayPort, wireless, and IP. In addition to strengthening authentication and encryption requirements, HDCP 2.0 significantly reduces the total allowable number of interconnected devices, from 128 to just 32. Also, up to four levels of repeaters may be used, down from seven in HDCP 1.x. This will be important to take into account when designing future digital A/V systems with HDCP compliance.

HDCP 2.0 protocols will not be backward compatible with HDCP 1.x. To address this, converters will be made available to interface HDCP 1.x with newer HDCP 2.0 devices. Because these converters act as repeaters, they will be another important system design consideration, since only four repeaters will be permitted in an interconnected system.

CEC: Control Yourself

HDMI offers a whole new frontier of optional control capability for the consumer, as well as us A/V systems types. The embedded Consumer

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Electronics Control, or CEC, system provides various functions that orchestrate plug-and-play control among consumer products. The CEC function is handled via a separate wire connection within HDMI and contains its own protocol and quality of service, or QoS.

For example, in an installation where all devices use HDMI, its daisy-chain connection methodology may connect a DVD player through an A/V tuner/receiver to a television and, thereby, provide the consumer the ability to seamlessly turn on all downstream devices from the DVD player, signal them to switch to the appropriate input, and launch the movie by simply pressing the PLAY function on the DVD player.

Although it offers considerable flexibility and convenience for controlling multiple A/V devices, CEC has only been widely implemented in consumer electronics products since HDMI 1.3. Additionally, incompatibility issues have been reported with implementing CEC between products from different manufacturers.

Can You Say: Interoperability?

In order to promote consumer confidence and device compatibility, HDMI adopters are bound by the compliance agreement which requires successfully passing specified interoperability testing before a product may bear the HDMI logo.

The Authorized Testing Center - ATC, an independent organization, performs the initial product compliance tests for products within the designed product categories. Within the HDMI specification, a product falls into one of the following base categories: sink, source, repeater, or cable. Once tested by the ATC, all succeeding products of the same category may then be tested and self-certified by the manufacturer of the product.

Compliance to interoperability within the HDMI specification is mandated. However, full testing and validation for HDMI and HDCP compliance was not available until the release of HDMI 1.2. As a result, you may face compatibility issues with products having HDMI interfaces from generations prior to HDMI 1.2, as well as legacy displays with DVI ports. The issue of inoperability between some HDMI-equipped products across various manufacturers has been well-known in the electronics industry.

This incompatibility most often has been result of problems obtaining the necessary “handshake” between devices so that HDCP can be established. HDCP compliance testing has been optional as of HDMI 1.2, but is mandatory starting from HDMI 1.3. Therefore, HDMI product interoperability should substantially improve for new and future generation products.

Extending HDMI Signals

One of the major challenges for integrators working with HDMI, as has been the case for DVI, is to overcome distance limitations with cables. HDMI Licensing, LLC provides a rough guideline of 10 to 15 meters as the maximum length for Category 1 cables. For connections throughout a facility or residence, or even in a large home theater, 15 meters will not suffice.

However, sending HDMI signals long distances is certainly possible. As previously mentioned, advances in cable design have enabled longer runs of cable, to 150 to 200 feet (45 to 60 meters). Some designs use fiber optic cable with the transmitter and receiver built into the connectors. HDMI cable can also be used in conjunction with a cable equalizer, such as the Extron HDMI 101, to extend HDMI signals out to 200 feet (60 meters). This device features active equalization circuits that ensure the integrity of HDMI signals traveling through very long lengths of cables.

HDMI signals can also be sent over inexpensive CAT 5-type network cable, with runs possible up to about 200 feet (60 meters). This requires a specialized transmitter and receiver set, such as the Extron HDMI 201 or HDMI 201 A D Twisted Pair Extenders.

These current solutions mostly support HDMI 1.2 with a maximum pixel clock rate of 165 MHz and 4.95 Gbps data speed. Technologies for extending HDMI and DVI signals over standard cables as well as CAT 5-type cable continue to evolve, and will need to evolve to eventually support HDMI 1.3 with clock rates up to 340 MHz and speeds to 10.2 Gbps. CAT 7, or Class F transmission has the potential to extend HDMI 1.2 signals to 330 feet (100 meters) and deliver the performance capability that will be needed for full implementation of HDMI 1.3.

HDMI is Here to Stay

HDMI has become nearly ubiquitous in consumer and pro A/V displays as well as DVD and Blu-ray Disc players. Consumers have increasingly become aware of HDMI and are asking for it in stores and from residential installers. In our industry, we’re seeing more and more products with DVI or HDMI ports. The prospect of an all-digital video infrastructure offers great promise in terms of delivering high quality, pristine video and graphics at high resolutions with pixel-perfect integrity. Furthermore, an HDMI-based A/V infrastructure will be essential for presentation of copy-protected content such as Blu-ray Disc and HDTV broadcasts.

However, HDMI also has several important design considerations and potential challenges for you as an A/V systems designer. This article offers just an introduction to some of these, including HDCP, interoperability, and signal extension. Another important challenge is distributing HDMI signals and managing DDC communications. We’ll certainly explore all of these further in future issues of ExtroNews.