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WHITE PAPER

HDMI™: The Digital Display Link

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IDC OPINION

The transition of entertainment content from analog to digital form has sparked a revolution in the way that content is created, transported and consumed. This is true for every type of content—voice, images, music, TV, etc. —and the effect is profound for each player involved in providing and consuming this content. From the artists and studios creating the content, to service providers delivering it to homes and businesses, to consumer devices manufacturers and ultimately the consumer, the digital revolution presents exciting new opportunities as well as important challenges. Each of the players in this value chain is driven by the following common set of factors:

- *Quality*, primarily a function of new formats (resolution, color depth, refresh, lossless audio) and the quantum performance improvements they enable
- *Flexibility* in terms of the way content is distributed/obtained and played, exemplified by the way iTunes changed music and Tivo changed TV
- *Cost* reductions related to content delivery, such as not having to print film or other packaged media, or not having to drive to the video store

A critical enabler in this change is the mechanism by which devices that create, hold, playback or display this content are connected. The High-Definition Multimedia Interface™ (HDMI™) is a digital connectivity standard capable of carrying the highest quality, uncompressed high-definition digital video content, up to 8 separate channels of uncompressed digital audio and device command controls all on a single cable.

For consumers, HDMI means a simpler and higher-quality entertainment experience. For CE manufacturers, HDMI means a lower-cost, standardized way of interconnecting their devices that enables them to build differentiated products that deliver the best entertainment experience. For movie studios, HDMI in conjunction with HDCP (High-bandwidth Digital Copy Protection) represents a way to expand top-line growth by bringing the theater experience home—a key factor given that less than 20% of their revenue comes from theaters. Enhanced content protection represents another significant benefit for studios. For PC and monitor makers, HDMI is a means of bridging the gap between CE and PC video standards. Finally, for the market as a whole, the flexibility of the standard means that it can evolve to meet market needs, such as peripheral control of all attached devices.

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IN THIS WHITE PAPER

IDC examines the transition from analog to digital in the world of digital displays and connected devices and addresses critical implications of that change, particularly regarding connectivity standards. This White Paper examines these issues from the perspective of each player in the digital content value chain and the driving factors of quality, flexibility, ease of use and price. Within this context, we provide an overview of the HDMI (High-Definition Multimedia Interface) interface, which brings together all devices in the high-definition household value chain from set-top boxes and DVD players to flat-panel televisions and today's increasingly media-friendly consumer PCs, and even portable devices such as cameras and camcorders.

SITUATION OVERVIEW

Today's consumers are entranced with the wealth of high-definition content being made available to them and are eagerly snapping up flat-panel LCD and plasma televisions, as well as large rear-projection TVs (RPTVs) in order to view it. According to IDC's research, the worldwide LCD TV market is expected to grow by 41% in 2007 and plasma TVs should enjoy 40% growth. In some cases, purchases are being driven by a preference for thinner form factors. In others, they're driven by the desire for better picture quality or a combination of the two. In all cases, however, the underlying driver is the sweeping transition from analog to digital content. This transition has occurred on a number of highly visible fronts, from playback media (VCRs to DVDs) to TVs (analog to HDTV) to broadcasting (standard to digital). As it has unfolded, the costs associated with digital content delivery—both underlying semiconductors and the devices themselves—have predictably come down while their functionality and performance has steadily risen.

As a result of these developments, consumers have access to an entertainment experience that is both more stimulating and more simplified than was previously available. One of the promises of the digital revolution is more intelligent consumer electronics devices and systems that can automatically configure themselves, correct errors and free the user from having to manage these new technologies. Sadly, up until now, this promise has gone unfulfilled. HDMI delivers the framework for enabling this, not only by drastically simplifying cabling, but also by delivering the potential for system wide intelligence (such as allowing the use a single remote control to integrate multiple devices into a unified system for "one touch playback" and other functions). As discussed below, these capabilities of HDMI can make the experience of simultaneously using multiple digital entertainment devices much easier, while at the same time delivering the cost benefits that come from having a standardized method of connecting products digitally.

Connection History

Until recently, most video-based entertainment devices—such as DVD players, set-top boxes, and televisions—were limited to analog video connections. To make matters worse, audio connections, even though they moved to digital form several years back, have been separate from video. As a result, achieving a high-quality A/V experience is often a consumer nightmare fraught with multiple, incompatible connection standards, a complicated tangle of expensive add-on cables hidden behind the television set, and a slew of independent devices each with its own remote control. Gone are the days when setting up and watching TV simply meant plugging in a power cord and cable TV signal and using a single remote to turn everything on and off and select channels. Instead, complex interconnections lead to confused consumers and—because these connections tend to deliver lower resolution—an underutilization of today's high-quality source and display devices. Such factors have thwarted consumers in their quest for a truly fulfilling A/V experience.

The move to digital devices also drove the need for a digital connection standard. The first of these was the DVI (Digital Visual Interface) standard, which made its first appearance on PCs and LCD monitors in 1999 o. DVI is a high-quality digital replacement for the long-standing VGA connector that's been used with PC displays nearly since the first introduction of personal computers. With DVI, which only supports video, PCs and monitors can maintain an all digital-connection between the computer's graphic chips and the display, ensuring an extremely accurate, crisp, readable screen.

When the High-bandwidth Digital Content Protection (HDCP) specification was introduced for DVI in 2000 with the support of numerous content providers, some of the first consumer electronics devices started to offer digital video outputs and inputs. Since the DVI standard was a mature interface technology with industry endorsed content protection, many first-generation HDTV set-top boxes and HDTV-capable TVs began to feature DVI connections. But DVI was limited: the problem of multiple cables for audio and video remained, and DVI brought only limited intelligence to the system. As a result, a group of companies took the DVI framework and began to create a new standard that could carry both digital video and digital audio signals over a single cable and leverage the advantage of a digital connection for other control functions. Their other goal was to create a smaller, more consumer friendly connector. In December of 2002, those goals were realized as the HDMI 1.0 standard and the HDMI connector (see Figure 1).

FIGURE 1

Video Connectors: DVI and HDMI

Source: IDC, 2006

HDMI Basics

High-Definition Multimedia Interface, or HDMI, is a digital connection standard designed to provide the highest possible uncompressed video and audio quality over a thin, easy-to-use cable with a simple, consumer-friendly connector. HDMI can carry video signals at resolutions up to (and beyond) 1080p in full-color at full 60 Hz (and higher) refresh rates. It's also backwards compatible with DVI, requiring only a simple passive adaptor or cable to connect between the two interfaces. Most importantly, it adds support for up to 8 channels of full-resolution digital audio—all on a single cable. Since its inception, HDMI has offered the ability to transmit basic control codes from device to device, making the goal of system integration easier to achieve.

HDMI was created as a forward-looking specification with the ability to be updated as further market requirements became apparent. One of the advantages of HDMI is that it is an evolving standard that responds to market conditions and keeps pace with the latest technological innovations. This is a benefit to manufacturers, content providers and consumers in that HDMI continues to enable the highest quality consumer experience. As such, the specification has seen several major enhancements. In version 1.1, support for full definition DVD Audio was added, while version 1.2 offered support for SACD format high-definition audio and a number of enhancements to make the standard easier to use with PCs and PC monitors. Version 1.2a also added a host of new capabilities around the Consumer Electronics Controls (CEC) portion of the specification, which enables the control of multiple devices with a single remote. In June of 2006, version 1.3 was released.

HDMI 1.3 – New Capabilities

The most recent version, HDMI 1.3, more than doubles the bandwidth of the signaling from 4.95Gbps to 10.2Gbps. This increase in bandwidth enables support for even greater color depths (up to 16-bit per component), higher screen resolutions (1440p or WQXGA) and faster refresh rates (up to 120 Hz). Additionally, HDMI 1.3 supports the new xvYCC color space, adds support for the Dolby ® TrueHD and DTS-HD Master Audio standards, provides a mini-connector for use with portable devices (camcorders and digital still cameras), and supports the ability to automatically and accurately adjust the audio to maintain lip-sync with the video image. Table 1 summarizes the capabilities of current and historical versions of HDMI:

TABLE 1

HDMI Version History

HDMI 1. 0	HDMI 1. 1	HDMI 1. 2	HDMI 1. 3
Initial Specification	Added support for DVD Audio	Added support for SACD Audio	Increases bandwidth to 10.2Gbps (340MHz)
		Permitted PC applications to use only RGB color space	Offers support for 16-bit color, increased refresh rates (ex. 120 Hz), support for 1440p/WQXGA resolutions
		Supported low-voltage (AC-coupled sources) in PCs	Supports xvYCC color space standard
			Adds features to automatically correct audio video synchronization (lip sync)
			Adds mini connector
			Adds support for Dolby TrueHD and DTS-HD Master Audio standards

Source: IDC, 2006

The first products employing the HDMI interface were introduced to the market in the fall of 2003 and since then, over 75 million HDMI-equipped devices have shipped into the marketplace. By 2010, IDC expects that just over 1 billion HDMI-enabled TVs, DVD players, PCs, monitors and more devices will be in use in people's homes around the world.

Consumer Benefits

Underlying and driving the vigorous growth of the HDMI standard is a compelling set of benefits it makes possible. The improved visual and audio quality that an all-digital signal path enables is noticeable to most individuals and will only become more important as higher-resolution content becomes more widespread. Thanks to improvements in displays as well as increases in content resolution, consumers' expectations for audio and video quality have raised dramatically, as well as the need for an interconnection standard that delivers this experience reliably.

Today, people typically have at least 3 or 4 separate audio or video components (and some have many more—including PCs in their entertainment systems), hooked together via a number of different audio and video connection standards—each of which requires its own special kind of cabling—and the simple act of watching TV requires entering about 4-5 remote control commands on 3 or 4 different remotes. In addition, while older A/V equipment, such as VCRs, used analog signals, today's new set-top boxes, A/V receivers, DVD players and high-definition TVs all use digital signals to create a better quality visual and audio experience.

HDMI addresses the complexity issue by both reducing the cable count and easing the process of interconnecting the various devices that make up the typical home entertainment system. Instead of having to choose among RF, composite video, S-video and component video and optical digital audio or coax-based digital audio, everything can use a single HDMI connection. For example, in the case of a DVD Audio or SACD Audio capable DVD player, a single HDMI cable can replace up to 10 other connections (3 for analog component video, 1 for optical or coax digital audio and 6 for the 5.1 multichannel analog audio outputs). Added to this is the ability to simultaneously achieve the best possible audio and video quality due to the uncompressed all digital signaling of HDMI.

With PCs becoming an increasingly important part of home entertainment, the convergence of media-friendly PCs and entertainment devices is well served by HDMI because it can serve as a crossover interface—a means of connecting PCs to TVs or CE devices to PC monitors as new products in both categories are introduced. Since HDMI is functionally a compatible superset of DVI, a PC with HDMI maintains full connectivity to any DVI or HDMI display.

The standardization of device control protocols through HDMI's CEC feature enables consumers to reduce the number of remotes necessary to control their system, since CEC enables a single remote pointed at a single device to send commands to any other device (that supports CEC) connected by an HDMI cable. This means, for example, that a TV remote can be used to not only control the TV, but also the DVD player, set-top box or any other device with an HDMI connection, all without the need for consumers to perform manufacturer specific programming into that single remote.

CE Device Benefits

The benefits are equally strong for consumer electronics devices and the manufacturers who design and build those products. By having a single, worldwide standard for high-quality A/V connectivity, vendors can reduce their costs by focusing on a single standard that can be replicated in very high-volume and, therefore, low-cost parts. Unlike DVI, the HDMI standard also requires compliance testing, which is designed to ensure that any HDMI-enabled device built by one manufacturer will work seamlessly with a device from another manufacturer.

From the beginning, the HDMI specification was designed to offer the best quality A/V experience possible with both today's and tomorrow's entertainment hardware. This is seen in its initial support for 1080p signal resolutions at 60 Hz refresh rates and 8-bit 4:4:4 color depths. New improvements in version 1.3 of HDMI now enable 12- bit (billions of colors) or even 16-bit color depths (trillions of colors) at 1080p and higher resolutions, ensuring compatibility with the highest possible signal resolutions from next generation video sources, including Blu-ray and HD DVD players, the Sony Playstation 3 and HDMI-equipped PCs.

HDMI and Bandwidth Capabilities

To completely understand these capabilities, it's worth spending a bit of time explaining how digital video signals work and how they're sent from device to device. Any digital interface is ultimately limited by the bandwidth, or speed, of the connection. In the case of HDMI 1.3, that upper boundary is the 340MHz data rate per channel (for a total of 10.2Gbps of total bandwidth) at which the interface runs (though HDMI has the technical foundation to further increase speeds in the future). The DVI specification and versions of HDMI up through 1.2 support a maximum single-link bandwidth of 165MHz per channel (4.95Gbps). Within that limit, it's possible to use the bandwidth in various ways. The easiest way to understand this is by relating it to a simple mathematical analogy. You can reach the product of 10.2 by multiplying 5.1 x 2 or 1.2 x 10 or any number of other ways. So, too, can you use the bandwidth of HDMI to support different combinations of resolutions, refresh rates and color depths—it all boils down to a simple mathematical equation:

Signal Resolution * Refresh Rate * Color Depth = Necessary Bandwidth

Table 2 shows examples of possible combinations. Bear in mind that these rates are not user-selectable on either source or display devices—the display often sets them automatically. For example, an HD DVD or Blu-ray player may support a maximum of 1080p (some players and/or media may only support 1080i—which requires only half the refresh rate) and 8-bit color. Regardless, it's still clear from these figures that HDMI can easily support 1080p resolution signals, despite rumors to the contrary. As a baseline reference, a 720p or 1080i resolution signal at 60 Hz refresh and 8-bit color depth requires about 2.23Gbps of bandwidth. Increasing the resolution to 1080p, which is twice the resolution of 1080i, would require 2.23Gbps or 4.46Gbps. Increasing the color depth from 8-bit to 12-bit color requires 12/8 or 1.5 times more bandwidth. By remembering that the 720p/60Hz/8-bit baseline requires 2.23Gbps, it is easy to calculate how much bandwidth is needed when resolution, refresh rate, or

color depth is increased from this reference. As an example, the table below shows the required interface bandwidth for various common applications.

TABLE 2

HDMI Signal Combinations

Application	Signal Resolution	Color Depth	Frame Rate	Bandwidth Required
480p DVD Player or Game Console	480p	8-bit	60 Hz	0.81Gbps (27MHz)
HD Set-Top Box	720p/1080i	8-bit	60 Hz	2.23Gbps (74.25MHz)
Playstation 3	1080p	8-bit	60 Hz	4.46Gbps (148.5MHz)
	1080p	12-bit	60 Hz	6.68Gbps (222.75MHz)
HD DVD/Blu-ray	1080p	8-bit	60 Hz	4.46Gbps (148.5MHz)
	1080p	12-bit	60 Hz	6.68Gbps (222.75MHz)

Source: IDC, 2006

Device manufacturers also benefit from HDMI because it enables them to meet FCC mandates for HDTVs and HD set-top boxes. According to the US Federal Communications Commission (FCC) rules, for example, all Digital Cable Ready HDTVs of 25" and larger must have a DVI or HDMI connector as of July 1, 2006. All high-definition set-top boxes sold after July 1, 2005 must have either a DVI or HDMI output as well as an IEEE1394 connector. In Europe, the European Information & Communications Technology Industry Association (EICTA) rules stipulate that all HDTVs displaying the "HD Ready" logo must include DVI or HDMI inputs and support HDCP. In Asia, the Cable and Satellite Broadcast Association of Asia (CASBAA) began recommending in August 2005 that HDMI (or DVI) and HDCP "be included on every set-top box capable of outputting uncompressed high definition content."

Content Owner Benefits

HDMI also offers benefits to Hollywood studios and other organizations involved in creating entertainment content. The simplest and most important benefit is that it enables creative professionals to deliver their content in the highest possible quality. Not only can HDMI be used to deliver existing DVDs and digital set-top box video signals in their purest digital form, it is also the connector of choice for new high-definition DVD players (Blu-ray and HD DVD) and the next generation gaming consoles, such as Sony's Playstation 3.

Improved copy protection is another key benefit. Although HDMI does not require copy protection, the standard allows for it and—due to government regulations and the demands of trade associations and content providers—most devices implementing HDMI do offer HDCP (High-bandwidth Digital Copy Protection) which operates transparently to consumers in HDMI devices. As a result, HDMI helps reduce piracy and ensures that the highest quality content can be delivered to as wide an audience as possible. In addition, should new business models for content distribution arise that require new copy protection standards, the HDMI specification is flexible enough to support those changes. Content owners, therefore, can feel confident that their works will be widely distributed and yet needn't overly concern themselves with content theft via HDMI connections. Many Hollywood studios recognize this capability and have moved forward with their plans to develop and release high-definition digital content because of this comfort with the HDMI standard.

FUTURE OUTLOOK

HDMI has enjoyed robust adoption in the consumer electronics markets, particularly for flat-panel televisions and high-definition content sources. IDC expects this momentum to grow over time, with more than 55 million CE devices equipped with HDMI shipping in 2006, triple the number shipping in 2005. We also expect HDMI to find success in the consumer PC market. IDC also expects some of the first HDMI-equipped PC monitors to appear in 2006, with the number of desktop and notebook PCs equipped with HDMI growing from a tiny number in 2005 to over six million in 2007, particularly among consumer PCs. HDMI has been integrated into graphics products from ATI and NVIDIA, Intel motherboards, and appears in PC products from major OEM's such as Acer, HP, Samsung, Sony, Toshiba, etc. As a result, the influence of the HDMI specification is expected to grow over time in a variety of CE and PC markets. In particular, HDMI appears to be the digital interconnect that will be the basis for consumer PC-CE convergence. Already, consumers are starting to make TV and CE device purchase decisions on the appearance and number of HDMI connectors found on a device's jack pack.

We also believe the HDMI standard will continue to evolve, further addressing the needs of system integration in home entertainment systems and meeting the specific requirements of the PC industry, especially when it comes to even higher-resolution support.

CHALLENGES/OPPORTUNITIES

Despite its fast projected growth, HDMI presents a number of potential issues of relevance to consumers, device makers and content creators. First, not all devices that offer HDMI connections support the full capability of the specification. Most high-level HDMI functionality is optional, and manufacturers are free to choose the version that they will implement. So, when purchasing a component, consumers should not look for a particular version of HDMI, but rather for the functionality that they want the device to support (Deep Color, specific audio formats, etc.). Consumers can look for support for these features called out in the manufacturer's product information.

Moreover, in many cases, to take advantage of the benefits of new HDMI functionality (e.g., CEC), all devices in the consumer's system must support such functionality, and that is unlikely to occur for many years in most households. Similarly, HDMI cannot deliver functionality that does not exist in the system itself. If a DVD source or a TV sink does not support 1080p, there is no way that HDMI can deliver 1080p content to the consumer. All devices in the system must have the desired functionality. As a result, most consumers will only receive a sub-segment of the full potential of the new standard. If the standard evolves quickly to another version and adds more capabilities, this process could turn off consumers who never feel as if they can completely catch up. This problem is not unique to HDMI, as HDMI is only a reflection of the fast evolving CE market segment, where manufacturers are constantly increasing device performance to differentiate products.

The second challenge relates to ongoing industry efforts to create alternative digital display connection standards. The commercial PC industry, in particular, is hesitant to add even nominal royalty payments for the use of any technology, and developed the UDI (Unified Display Interface) as a potential alternative to HDMI. At this point, however, this new initiative, which does plan to offer backwards compatibility with HDMI, does not appear to be gaining wide acceptance in the PC industry. Instead, another standard within the VESA standards organization called DisplayPort is being developed as a challenge to HDMI. In fact, many major PC manufacturers, particularly market leader Dell, have expressed strong interest in pushing DisplayPort as their preferred digital display connector for the future. As a result, both Intel and AMD, who already offer HDMI solutions today, are expected to provide chipset-level system support for DisplayPort in the near future. However, we believe the momentum behind HDMI in the consumer market (not to mention the size of the installed base of HDMI-equipped devices at that point) will be difficult to overcome for consumers PCs. In the commercial PC market, however, DisplayPort will likely be a difficult competitor. As a result of this marketplace confusion, the inclusion of DisplayPort will likely to lead to higher costs for device manufacturers because of the need to support both new standards and existing standards for the installed base of devices.

CONCLUSION

As the convergence of consumer electronics and computing accelerates, the need for standards that help devices from these previously separate categories work together as a unified system has grown. The demand is particularly acute in the arena of digital display connectivity, especially with the growth in HDTV and other high-resolution video sources, such as Blu-ray and HD DVD players, and in media-centric PC's. HDMI addresses these needs by offering a single cable interface standard for the highest possible video quality (including 1080p and widescreen PC monitor resolutions), full resolution, multi-channel digital audio and a new set of machine controls that let you use a single remote to control multiple devices in an entertainment system. HDMI benefits multiple constituencies, including consumers, device manufacturers and content creators, in all cases enabling these different groups to enjoy the benefits of an all-digital world.

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