An Overview of Current Display Interfaces

Introduction 2

The Future of Display Interfaces 2

- Monitor and TV Market Trends 2
- VGA 4
- DVI 6
- HDMI 9
- DisplayPort 11

Display Interface Comparison Table 13

Introduction

Concerns over image quality, the near-complete replacement of the CRT by LCDs and other new display technologies, and growing concerns over content protection are prompting significant changes in display interface technology. Although PCs will likely continue to use the VGA interface in the short run, long-term, the future is moving to all-digital.

Various proposals, including improved analog connectors, hybrid digital-plus-analog approaches, and several all-digital interfaces have been put forth since the early 1990s. One, the Digital Visual Interface (DVI), which is available in both analog plus digital and digital-only forms, has seen reasonable success in higher-end PC products, but has not managed to take the majority of the market from the VGA. Consumer HDTV products have started a migration from the various analog connections to the all-digital High Definition Multimedia Interface (HDMI) – but HDMI shows no signs of adoption in PCs, except for connection to TV products. Most recently, a pair of new PC-oriented standards, the Intel Unified Display Interface (UDI) and the VESA DisplayPort (DP) specification, have received some attention in the press as possible replacements for VGA. The UDI effort is now defunct, never having appeared on any actual hardware, while DisplayPort now appears to be the long-term future for the PC industry, and possibly the converged standard for both PC and CE products.

This paper gives an overview of the four leading display interfaces – VGA, DVI, HDMI, and DisplayPort – in the PC industry, and includes a brief history of each, their basic characteristics and pinouts, and provides a comparison of each interface's features and performance.

The Future of Display Interfaces

Monitor and TV Market Trends

The following trends seem likely over the next 3-5 years in the monitor and TV markets.

- While there will continue to be a trend to larger-sized monitors, the upper end of this market will not increase significantly in terms of size – the majority of desktop monitors will remain under 30-inch diagonal. Some increase in resolution (pixel formats) will likely occur, but most monitors will maintain the current norms – 1680 x 1050 to 1920 x 1200 resolution for widescreen displays in the 20-inch to 27-inch size range, with the top end of mainstream monitors at about 2560 x 1600 resolution.
- The trend in the TV market will be to larger sizes and a greater percentage of widescreen, HDTV-type displays, but in this particular application the pixel formats are constrained by television broadcast standards. The highest-definition format in normal use will remain at 1920 x 1080 pixels.
- There will continue to be growing pressure to provide content protection of copyrighted material (meaning the prevention of unauthorized viewing or copying of this material). As it is very difficult to provide adequate protection in the case of analog interfaces, this factor will likely accelerate the adoption of digital connections – and the displacement of their analog counterparts, such as the VGA connector in the PC market. Although content protection is of greatest importance in the consumer products market, the commercial sector may also be affected by this trend.
- There is also a growing desire, primarily on the consumer side of the PC market, for better interoperability between PC and digital TV products. Over the long term, this may lead to

convergence on a single digital interface standard for all such products, which would likely pull commercial users in the same direction.

- LCDs already account for the majority of the PC monitor market, and have a rapidly-growing share of the TV market. No other display technology is expected to displace the LCD from its top position over this time period.

These trends and the current state of the market will have the following effects on the predicted future of display interfaces.

- The long-lived VGA connector will continue on for the foreseeable future, but will continue to lose market share slowly to the newer alternatives. The VGA connector for now remains the interface of choice for entry-level products, and will almost certainly be the only connector used with CRT monitors. The VGA connector will eventually be driven out of the market due to content-protection issues, but not until some time in the 2010s.
- The DVI connector will continue to be used over the next 2-3 years as one of the PC market's standard digital interfaces. But starting in early 2008 DVI will begin to lose market share to the newer, smaller, more capable, and ultimately less expensive DisplayPort standard. This trend will accelerate over the next few years. (Support for legacy products will be provided via adapters between dual-mode DisplayPort products and their older DVI counterparts.)
- The HDMI connector has already displaced DVI, for the most part, in consumer HDTV gear. HDMI will continue to grow in popularity in the consumer market for both HD and digital SDTV equipment and start to displace the older analog-only TV interfaces (such as S-Video). HDMI, however, is very unlikely to see much use as a PC monitor connection or graphics output, except for TV connectivity purposes and in the near future as a smaller DVI-compatible output for some notebook PCs.
- The DisplayPort connector will start to show up in the PC market in early 2008, and its use will grow over the next several years. Initially, this growth will be at the expense of the DVI share of the PC market (that is, the DisplayPort interface will be provided alongside the VGA connector). Eventually DisplayPort will also displace VGA and become the dominant PC-market interface. DisplayPort brings advantages in performance, size, and eventually (as volumes mature) cost over the older DVI standard, and has much better extensibility for the future. (As noted in the DisplayPort section later in this document, a second-generation DisplayPort spec is expected around 2009 that will provide a significant capacity increase as well as adding additional features, while maintaining full backward compatibility with the original version.) DisplayPort is also the only one of these interfaces that is intended for use as a panel-level (internal) interface, permitting direct-drive monitor products that may be attractive in some markets.
- In the more distant future, it is at least possible that DisplayPort could also be adopted for CE-market products, and become the converged, common digital interface used by both CE and PC displays although HDMI currently shows no signs of decline in its CE-market dominance.

The following sections provide brief overviews of each of these standard interfaces.

VGA

The VGA connector – named for the Video Graphics Array standard introduced by IBM for the original Personal Computer products in 1987 has been the most successful PC monitor interface to date in the computer industry.

In use now for over 20 years, the VGA (also known as the 15HD connector, for15-pin high-density D-subminiature) remains the standard analog video interface of the PC industry, but is beginning to experience limitations. The D-subminiature connector family from which this connector was originally selected was never intended to handle very-high-frequency video, and VGA connections can often show the effects of low bandwidth, overall signal loss, and "ghosting" from impedance mismatches in the system. The use of cable extenders and switches often introduces additional problems of this nature. The popularity of the VGA connector continues primarily because it is inexpensive and has an enormous installed base – and the latter is not a minor concern as the industry tries to transition to newer, more capable interfaces. The analog section of the DVI-I standard carries VGA-compatible video, can interoperate with this standard, and will typically provide far better video performance, particularly for video timings and formats over 1280 x 1024 resolution. However, fully-digital interfaces (currently DVI-D or the digital section of DVI-I, but soon changing to the DisplayPort interface in PC applications and HDMI for TV/CE products) are the most probable long-term solutions.

Figure 1 VGA Connector

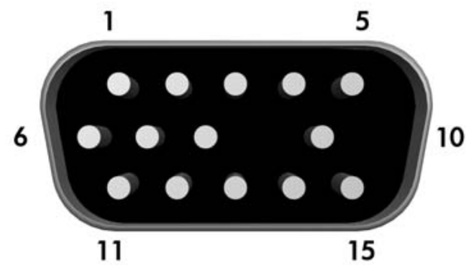

Figure 2 VGA Connector Pinout

Table 1 VGA Connector Pinout

Pin	Signal
1	Red video
2	Green video
3	Blue video
4	Unused (n.c.)
5	Return
6	Red return
7	Green return
8	Blue return
9	+5 VDC
10	Sync. return
11	Unused
12	DDC Data (SDA)
13	Horizontal sync (TTL)
14	Vertical sync (TTL)
15	DDC Clock (SCL)

NOTE: The above pinout refers to the VESA DDC (Display Data Channel) version of the VGA connector, which is currently the most widely used. It is identified by the blue color of the center part of the receptacle.

DVI

The Digital Visual Interface, or DVI, standard was published by the Digital Display Working Group (DDWG) in 1999. The DDWG was an ad-hoc consortium of seven PC-industry companies – HP, Compaq, Intel, IBM, NEC, Fujitsu, and Silicon Image (the developer of the Transition Minimized Differential Signaling or TMDS electrical interface on which the standard was based). DVI became the first reasonably-successful digital display interface for PC monitors. However, the DDWG group has not met for over five years, and may be considered defunct. Further development of the DVI specification is not expected.

DVI is available in two forms: DVI-I, which includes both a VGA-compatible set of analog video signals and a digital interface, and DVI-D, which is digital-only. The digital interface may provide either one or two links, depending on the data capacity needed. In DVI parlance, a single link consists of three differential data pairs and a clock pair, and provides 4.8 Gbits/second of raw data capacity. Dual-link versions of either DVI add three additional data pairs, for 9.6 Gbits/sec. total capacity. DVI-I and DVI-D may be distinguished by the four-pin Microcross™ section which carries the analog video signals; it is not present in DVI-D implementations.

DVI is currently the most popular digital interface for monitors, and will likely continue in use for several more years. However, due to the size and relatively high cost of the connector, it is now expected to lose PC market share to the newer DisplayPort standard, and has already been virtually replaced in the CE/TV market by HDMI.

Figure 3 DVI-D Connector

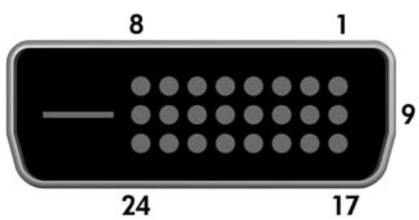

Figure 4 DVI-D Receptacle Connector

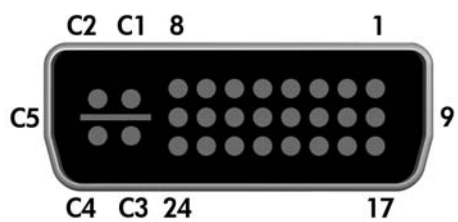

Figure 5 DVI-I Receptacle Connector

Table 2 DVI Pinout

Pin	Signal	Pin	Signal
1	TMDS Data 2-	14	+5 VDC
2	TMDS Data 2+	15	Ground/sync return
3	TMDS Data 2/4 shield	16	Hot plug detect (HPD)
4	TMDS Data 4-	17	TMDS Data 0-
5	TMDS Data 4+	18	TMDS Data 0+
6	DDC clock (SCL)	19	TMDS Data 0/5 field
7	DDC data (SDA)	20	TMDS Data 5-
8	Vertical sync (DVI-I only)	21	TMDS Data 5+
9	TMDS Data 1-	22	TMDS Clock shield
10	TMDS Data 1+	23	TMDS Clock+
11	TMDS Data 1/3 shield	24	TMDS Clock-
12	TMDS Data 3-		
13	TMDS Data 3+		

TMDS data pairs 3, 4, and 5 are only present or active in "dual-link" implementations.

Table 3 DVI-I (only) Pinout

Pin	Signal
C1	Red video (analog)
C2	Green video (analog)
C3	Blue video (analog)
C4	Horizontal sync (TTL)
C5	Common return

HDMI

After the DDWG failed to agree on a specification for a consumer version of the DVI specification, Silicon Image formed a new consortium to develop a digital interface specifically for the consumer TV market, this time with six leading CE companies. The result was the High Definition Multimedia Interface, or HDMI.

HDMI is essentially a single link of the TMDS electrical interface (as used in the DVI standard), plus a standard (and Silicon Image proprietary) method of carrying digital audio signals within the video data stream. Like DVI, HDMI also supports the Intel High Definition Content Protection (HDCP) copy-protection scheme. As in DVI, HDCP support is technically optional, but basically required for products in the CE market and HDMI implementations. HDMI is semi-compatible with single-link DVI, as DVI cannot provide the embedded audio features of HDMI and does not support HDMI's Consumer Electronics Control (CEC) channel, a one-line serial data bus for the control of CE products (such as DVD players, etc.) from the TV or other output device.

As was the case with DVI, HDMI (up to the 1.2 specification revision) provides support for up to 165 MHz pixel rates, or about 4.8 Gbit/sec. raw data capacity. The HDMI 1.3 spec is intended to approximately double this capacity, although it is unlikely that existing HDMI cables, etc., will support the higher rates. HDMI 1.3 also introduced a more compact version of the connector, for portable CE products, the HDMI-C.

The HDMI specification also includes a dual-link version, the HDMI-B connector, intended for PC use, but it has never been adopted by the PC industry. At this point PC usage of HDMI is limited to the HDMI-A, and then primarily for CE-connectivity purposes.

Figure 6 HDMI Receptacle

Figure 7 HDMI Receptacle Pinout

Table 4 HDMI Receptacle Pinout

Pin	Signal	Pin	Signal
1	TMDS Data 2+	17	DDC/CEC ground
2	TMDS Data 2 shield	18	+5 VDC
3	TMDS Data 2-	19	Hot plug detect (HPD)
4	TMDS Data 1+		
5	TMDS Data 1 shield		
6	TMDS Data 1-		
7	TMDS Data 0+		
8	TMDS Data 0 shield		
9	TMDS Data 0-		
10	TMDS Clock+		
11	TMDS Clock shield		
12	TMDS Clock-		
13	CEC		
14	Reserved (no connect)		
15	DDC clock (SCL)		
16	DDC data (SDA)		

DisplayPort

In late 2005, another consortium of computer and display electronics manufacturers – HP, Dell, Philips, NVIDIA, ATI (now AMD), Samsung, and Genesis Microchip – brought a new digital display interface specification to the Video Electronics Standards Association as a proposed new standard. About a year later, VESA published the original DisplayPort standard. Since then, the original group of promoters has expanded to include Intel and Lenovo, and the spec was revised slightly (to the current 1.1 version) to better enable re-use of existing PCI-Express designs, and to support the Intel HDCP content-protection system.

DisplayPort differs from the earlier TMDS-based interfaces (such as DVI and HDMI) in several significant ways. First, it uses a packetized communications protocol, which enables simple support of multiple data types and other features. Audio may be carried – optionally – along with the digital video information, as well as other data types (text, etc.), and later versions are expected to use the packetized protocol to enable support for multiple displays per physical connection, tiling, conditional update, etc., with full backward compatibility with the original spec. DisplayPort was also designed to be both an external (monitor, TV, etc.) connection as well as an internal (panel-level) interface, which will permit the development of such products as direct-drive monitors. Physically, the connector resembles HDMI in size, but differs in the shape of the shell and the thumb-operated latching mechanism.

DisplayPort source and sink (display) devices may use one, two, or four "lanes" (differential data pairs), depending on their data rate needs; the interface automatically configures itself to make the best use of the available capacity. With a full four lanes in use, it provides about 10.8 Gbit/sec. of raw capacity. The expected DisplayPort 2.0 release (planned for mid 2009) should double this capacity while maintaining backward compatibility.

Figure 8 DisplayPort Connector

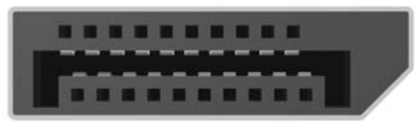

Figure 9 DisplayPort Connector Pinout

NOTE: Top row (from left) - pins 1, 3, 5 ... 19; Bottom row - pins 2, 4, 6 ... 20

Table 5 DisplayPort Connector Pinout

Pin			Pin		
Source	**Sink**	**Signal**	**Source**	**Sink**	**Signal**
1	12	Lane 0+	13	13	Ground
2	11	Ground	14	14	Ground
3	10	Lane 0-	15	15	AUX channel +
4	9	Lane 1+	16	16	Ground
5	8	Ground	17	17	AUX channel -
6	7	Lane 1-	18	18	Hot Plug Detect (HPD)
7	6	Lane 2+	19	19	Return
8	5	Ground	20	20	DP Power
9	4	Lane 2-			
10	3	Lane 3+			
11	2	Ground			
12	1	Lane 3-			

NOTE: Note difference in Lane 0-3 connections, source side vs. sink. Cable assemblies do not carry DP Power (pin 20), which is an output for both.

Display Interface Comparison Table

	VGA	DVI	HDMI	DisplayPort
Connector type	15-pin high-density D-subminiature; often with thumbscrews for latching.	Unique 24-pin, 3-row main field plus 4 pin MicroCross section if DVI-I	Unique 19-pin dual-row connector (HDMI-A)	Unique 20-pin dual-row connector with latch.
Capacity/ bandwidth	Indef.; usually OK to about 150+ MHz pixel rates.	4.8 Gbit/sec. (single-link); 9.6 Gbit/sec. (dual-link)	4.8 Gbit/sec. through HDMI 1.2; HDMI 1.3 spec to ~9.6 Gbit/sec.	Up to 10.8 Gbit/sec. if all four lanes used.
Electrical layer	0.7 Vp-p analog video with separate TTL syncs.	Silicon Image TMDS*, 3 or 6 data pairs plus clock pair.	Silicon Image TMDS*, 3 data pairs plus clock pair.	PCI-Express, 1, 2, or 4 data pairs ("lanes") with embedded clock.
Audio	No support	No support	Yes; effectively mandatory on HDMI-A	Optional
Content protection	None	HDCP** (opt.)	HDCP** (opt.)	HDCP** (opt.)
Other channels	VESA Display Data Channel (DDC)	VESA DDC	VESA DDC, Consumer Electronics Control (CEO)	AUX channel (1Mbit/sec., bidirectional gen. purpose)
Controlling authority	None; DDC version was established by VESA.	Digital Display Working Group (defunct)	HDMI Founders; HDMI Licensing, LLC	Video Elect. Standards Association (VESA)

** - TMDS - Transition Minimized Differential Signaling, a Silicon Image trademark for their proprietary differential-drive electrical layer.*

*** - HDCP - High Definition Content Protection, referring to a system developed by Intel and licensed by Digital Content Protection, LLC, see http://www.digital-cp.com/home for more information.*

NOTE: DisplayPort also supports DPCP, a content protection system developed for the interface by Philips Semiconductor. Neither HDCP or DPCP are mandated by the DisplayPort standard, and both specifications are separate and maintained by their respective originators. At this point, HDCP is expected to be the content-protection system of choice on all DisplayPort implementations.