An Overview of Current Display Interfaces

Table of Contents:

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, the DisplayPort (DP) connection 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 – 1600 x 900 to 1920 x 1080 resolution for widescreen displays in the 20-inch to 27-inch size range, with the top end of mainstream monitors at about 2560 x 1440 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 essentially all 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 in the short term but will begin losing market share to the newer alternatives. While the VGA connector currently remains the interface of choice for entry-level products, digital alternatives are starting to take hold. Due to content protection issues, the VGA connector will eventually be driven out of the market and by 2013 may be completely abandoned.
- The DVI connector has started to decline in favor of the newer DisplayPort standard as the PC industry's leading digital interface. By 2013, we expect the DVI interface to be essentially gone from the market. (Support for legacy products will be provided via adapters between dual-mode DisplayPort products and their older DVI counterparts.)

- The HDMI connector has completely displaced DVI 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 short term as a smaller DVI-compatible output for some notebook PCs.
- The DisplayPort connector started to show up in the PC market in early 2008, and its use has grown rapidly over the past few years. This growth has been at the expense of the DVI share of the PC market (that is, the DisplayPort interface is typically provided alongside the VGA connector). But 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 was published in 2010, and provides 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 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 almost 25 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 to the DisplayPort interface in PC applications and HDMI for TV/CE products) are the long-term solutions. Analog interfaces in general, and VGA in particular, are expected to decline in popularity over the next few years, especially as the industry faces the “analog sunset” requirements for the use of content-protected material (such as DVDs and Blu-ray discs).

Figure 1. VGA Connector

Table 1. VGA Connector Pinout

Pin	Signal	Pin)	Signal
1	Red video	9	+5 VDC
2	Green video	10	Sync return
3	Blue video	11	unused
4	unused (nc)	12	DDC Data (SDA)
5	Return	13	Horizontal sync
6	Red return	14	Vertical sync
7	Green return	15	DDC clock (SCL)
8	Blue return	--	--

Note: This 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 was at one time the most popular digital interface for monitors, but now its share is rapidly declining in favor of the DisplayPort interface for PC applications. DVI has already been virtually replaced in the CE/ TV market by HDMI.

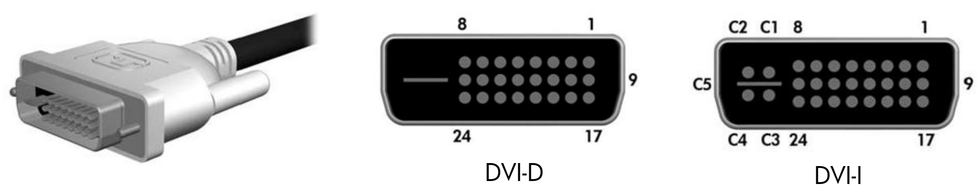

Figure 2. DVI Connector

Table 2. DVI Connector Pinout

Pin	Signal	Pin	Signal	Pin	Signal (DVI-I only)
1	TMDS Data 2-	13	TMDS Data 3+	C1	Red analog video
2	TMDS Data 2+	14	+5 VDC	C2	Green video analog
3	TMDS Data shield	15	Ground/return	C3	Blue analog video
4	TMDS Data 4-	16	Hot plug detect	C4	Horizontal sync
5	TMDS Data 4+	17	TMDS Data 0	C5	Common return
6	DDC clock	18	TMDS Data 0		
7	DDC data	19	TMDS Data shield		
8	Vert. sync (DVI_I)	20	TMDS Data 5-		
9	TMDS Data 1-	21	TMDS Data 5+		
10	TMDS Data 1+	22	TMDS Data shield		
11	TMDS Data shield	23	TMDS Clock +		
12	TMDS Data 3-	24	TMDS Clock -		

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

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 approximately doubled this capacity and also introduced a more compact version of the connector, for portable CE products, the HDMI-C. The most recent version, HDMI 1.4, provided some additional capacity increase and improved support for certain audio and video formats, including stereo ("3D") video.

Figure 3. HDMI Connector

Table 3. HDMI Connector Pinout

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

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 (VESA) 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 to the 1.1 version to better enable re-use of existing PCI-Express designs, and to support the Intel HDCP content-protection system. The current version of the specification is now DisplayPort 1.2.

DisplayPort uses a packetized communications protocol, which enables simple support of multiple data types and other features. Audio may be transferred – optionally – along with the digital video information, as well as other data types (text, etc.). 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, DisplayPort 1.1 provides about 10.8 Gb/s. of raw capacity. DisplayPort 1.2 released in 2010 doubled this capacity to 21.6 Gb/s while maintaining backward compatibility with the earlier standard, as well as providing support for increased functionality such as multiple audio and video streams (and so support for multiple displays) over a single physical connection.

Table 4. DisplayPort Connector Pinout

Source Pin	Sink Pin	Signal	Source Pin	Sink Pin	Signal
1	12	Lane 0+	11	2	Ground
2	11	Ground	12	1	Lane 3-
3	10	Lane 0-	13	13	Ground
4	9	Lane 1+	14	14	Ground
5	8	Ground	15	15	AUX Ch. +
6	7	Lane 1-	16	16	Ground
7	6	Lane 2+	17	17	AUX Ch. -
8	5	Ground	18	18	HPD
9	4	Lane 2-	19	19	Return
10	3	Lane 3+	20	20	DP Power

Note: Cable assemblies do not carry DP power

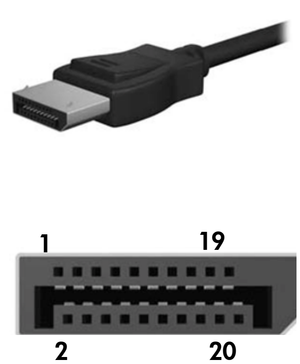

Figure 4. DisplayPort Connector

Display Interface Comparison Table

Table 5. 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, DVI-I adds 4-pin micro-cross section.	Unique 19-pin dual-row connector (HDMI-A)	Unique 20-pin dual-row connector with latch
Capacity/ Bandwidth	Undefined; usually ok to about 150 MHz pixel rates.	4.8 Gb/s (single link); 9.6 Gb/s (dual-llink)	4.8 Gb/s thru HDMI 1.2; up to 9.6 Gb/s HDMI 1.3 spec	Up to 10.8 Gb/s if all four lanes are used (21.6 Gb/s for DP 1.2)
Electrical layer	0.7 Vp-p analog video with separate TTL syncs	Silicon Image TMDS [1], 3 or 6 data pairs plus clock pair.	Silicon Image TMDS [1], 3 or 6 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 [2] (optional)	HDCP [2] (optional)	HDCP [2] (optional)
Other channels	Video Elect. Standards Association (VESA) Display Data Channel (DDC)	VESA DDC	VESA DDC, Consumer Electronics Control (CEC)	AUX channel (1 Mb/s, bi-directional general purpose; ~500 Mb/s in DP 1.2)
Controlling authority	None, DDC version was established by VESA	Digital display Working Group (defunct)	HDMI Founders; HDMI Licensing, LLC	VESA

NOTES:

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

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

652382-001, March 2011