Within the last few years, a number of new and competing video display interfaces have emerged. While each claims to have unique benefits, there is some overlap. This document describes and compares the main features and benefits of each interface.

**DisplayPort**

DisplayPort is a new digital display interface standard designed to simplify device interconnections while providing the performance scalability necessary in order to support the next generation of displays, which feature higher color depths, refresh rates and display resolutions. It is a license-free and royalty-free interface designed to connect audio and video between a computer and display monitor (PC), or a computer and home theatre system consumer electronics (CE) devices. Put forth by Video Electronics Standards Association (VESA), the standard was initially approved in May 2006 and updated to version 1.1 in April 2007.

DisplayPort uses small form factor connectors with an optional captive latch. Cable lengths are specified up to 15 meters. Up to four of the 20-pin DisplayPort connectors can be mounted on a standard full height PCI card bracket. Hot Plug and Play is supported, meaning connections can be made and reconfigured without needing to restart each device.

This digital display interface differs from others in that it uses a micro-packet architecture that carries video and audio data sent on up to four “lanes” in the DisplayPort cable. This supports variable color depths, refresh rates and display pixel formats, as well as up to eight channels of digital audio in a wide variety of different formats. A bi-directional auxiliary channel is used for transferring control and status information.

With the micro-packet architecture, multiple video streams can be sent over a single cable. For example: up to six 1080i or three 1080p video streams can be handled simultaneously. Two different data rates of 1.62 and 2.7 Gbit/s per lane are supported, providing a total of 6.48 or 10.8 Gbit/s, in addition to 1Mbit/s on the auxiliary “AUX” channel. The higher data rate is specified for short cables of up to 3 meters in length, and the lower data rate is for longer cables of up to 15 meters.

Video can be encoded in either RGB or YCbCr formats and at a variety of different bit depths from 6-16 bits per color component (18-48 bpp [bits per pixel]). In addition to not being limited to raster scan video data, the micro-packet architecture enables future extensibility to additional content types and applications. Switches and hubs may be used to route streams among multiple devices.

Video content protection protocols are implemented in between devices to prevent illegal copying. Video data is encrypted before being transmitted over the cable and each device must authenticate itself by exchanging cryptographic keys in order to decode and display video. DisplayPort supports two optional types of video content protection: DisplayPort Content Protection (DPCP) and High-Bandwidth Digital Content Protection (HDCP), which is also supported by Digital Visual Interface (DVI) and High-Definition Multimedia Interface (HDMI).

Power is provided over the cable in order to support devices such as repeaters and DisplayPort-to-legacy video converters.

The first DisplayPort video graphics adapter cards were introduced in late 2007, and the first commercially available displays supporting DisplayPort were announced at the beginning of 2008.

DisplayPort can also be used to transfer video internally within a portable notebook or laptop PC or similar device, replacing the current LVDS interconnection between the main board and display module. This simplifies the internal wiring and configuration. These features and the small connector are expected to help drive DisplayPort to become a standard on future portable devices.
DVI
DVI was developed by the Digital Display Working Group industry consortium and released in 1999. It supersedes the older analog VGA interface. The display interface features the capability of carrying both analog and uncompressed digital video in a single 29-pin connector.

The analog video bandwidth of DVI is higher than that of VGA so higher resolutions and refresh rates can be supported.

Digital video is transmitted using Transition Minimized Differential Signaling (TMDS) and is available in either a single or dual link format. A single link consists of four twisted pairs of wire (red, green, blue and clock) that transmit 24 bits per pixel. The picture is transmitted line-by-line with blanking intervals between each line and each frame. No compression or packetization is used, and there is no support for transmitting only changed parts of the image. This means that the entire video frame is constantly being transmitted.

A single link connection is limited to a maximum pixel clock frequency of 165 MHz, which can transmit a resolution of 1920x1200 @ 60Hz. However, the video resolution can be traded off with refresh rate. For example, the following resolutions can be supported using a single link connection:

- HDTV (1920x1080) @ 60 (131 MHz)
- UXGA (1600x1200) @ 60 (161 MHz)
- WUXGA (1920x1200) @ 60 Hz (154 MHz)
- SXGA+ (1440x900) @ 60 Hz (107 MHz)
- WQUXGA (3840x2400) @ 17 Hz (164 MHz)

The data capacity for transferring the digital video can be expanded by using a second digital link consisting of an additional three pairs for red, green and blue.

When more bandwidth is required than is possible with a single link, the second link can be enabled, and alternate pixels may be transmitted on each, allowing resolutions up to 4 megapixels at 60 Hz. The DVI specification mandates a fixed single link maximum pixel clock frequency of 165 MHz, where all display modes that require less than this must use single link mode, and all those that require more must switch to dual link mode. When both links are in use, the pixel rate on each may exceed 165 MHz. The second link can also be used when more than 24 bits per pixel is required, in which case it carries the least significant bits. The data pairs carry binary data at ten times the pixel clock reference frequency, maximum 1.65 Gbit/s x 3 data pairs for a single DVI link.

Dual link DVI can be used to accommodate higher resolutions and refresh rates than single link, or greater than 24 bits per pixel color depth, but not both.

As with single link, the video resolution can be traded off with refresh rate as in the following examples:

- QXGA (2048x1536) @ 75 Hz with GTF blanking (2x 170 MHz)
- HDTV (1920x1080) @ 85 Hz with GTF blanking (2x 126 MHz)
- WQXGA (2560x1600) @ 60 Hz with GTF blanking (2x 174 MHz)
- WQUXGA (3840x2400) @ 33 Hz with GTF blanking (2x 159 MHz)

The DVI connectors and cables are available in five different configurations:

- DVI-I (Single Link) Analog and digital video with a single link supporting 24 bits per color depth at resolutions up to 1920x1200 at 60Hz
- DVI-I (Dual Link) Analog and digital video with two links for supporting either higher resolutions and refresh rates or greater than 24 bits per pixel color depth
- DVI-D (Single Link) Digital-only video with a single link supporting 24 bits per color depth at resolutions up to 1920x1200 at 60Hz
- DVI-D (Dual Link) Digital-only video with two links for supporting either higher resolutions and refresh rates or greater than 24 bits per pixel color depth
- DVI-A Analog video only

The host (PC or other device) and display may support any of the five configurations. In cases where both devices support digital and analog, the display device informs the host of the preferred video format to output. In cases where one device only supports either digital or analog, the other device and interconnecting DVI cable must also support the same type, or both.

DVI does not have any support for transmitting audio signals.

Single-link DVI is forwards-compatible with HDMI, and a digital video DVI device can be connected using an inexpensive DVI to HDMI adapter.

DVI supports HDCP to encrypt video as it is transferred between
devices to prevent illegal copying. Each device must authenticate itself by exchanging cryptographic keys in order to decode and display video.

**HDMI**

This video interface standard was introduced in 2002 by HDMI LLC and its promoter companies. It is a licensable interface for digital audio and video connections and is aimed mainly at CE devices such as TVs, DVD players, video game consoles, set-top receivers etc.

It is aimed at replacing existing analog-based standards such as composite video, S-Video, component video and VGA. In addition, it is more consumer friendly than the much larger DVI connector.

HDMI uses the same TMDS (Minimized Differential Signaling) as DVI and is backward-compatible with the single-link DVI-carrying digital video (DVI-D or DVI-I, but not DVI-A) used on modern computer displays and graphics cards. This means that a DVI-D source can drive an HDMI display, or vice versa, by means of a suitable adapter or cable. HDMI cannot carry analog video signals like DVI-A and DVI-I can.

HDMI-specified connector types include:
Type A: This is the standard 19-pin connector used in most consumer devices. It supports a single digital link.
Type B: This is a larger connector with 29 pins that supports dual digital links, allowing support for higher resolutions such as WQSXGA (3200x2048). It is not in common use.
Type C: This is a mini connector with the same pins as the Type A connector but intended for small portable devices such as camcorders.

Two cable categories are defined:
Category 1: Sufficient to carry HDTV (74.25MHz/2.23Gbits/s)
Category 2: All supported HDMI rates 27-340MHz and beyond.

Starting with HDMI v1.3, higher color bit depths of 30, 36 and 48 bits per pixel in RGB or YCbCr can be accommodated. This feature, called "deep color," increases the number of possible colors from 16.7 million into the billions of colors. This eliminates color banding for smooth gradations and tone transitions and allows for increased contrast ratios with no banding artifacts.

Also starting with HDMI v1.3, an expanded color gamut called xvYCC is supported, which allows deeper saturated colors to be transferred (see detailed description later).

Digital audio is supported in a variety of different formats, with up to eight channels of uncompressed digital audio at 192 kHz sample rate with 24 bits per sample as well as any compressed stream such as Dolby Digital or DTS.

HDMI supports Consumer Electronics Control channel (CEC), which provides a method for consumer devices to inter-communicate over a bi-directional bus using an industry standard AV Link protocol.

This feature is used in two ways:
- To allow the user to command and control multiple CEC-enabled devices with one remote control.
- To allow individual CEC-enabled devices to command and control each other without user intervention.

An example of the latter would allow a DVD player, when the drawer is closed with a disc, to command the TV and the A/V receiver (all with CEC) to power up, select the appropriate HDMI ports and auto-negotiate the optimal video and audio modes. No remote control command is needed. Similarly, this type of equipment could be programmed to return to standby mode when the DVD ends.

A new feature in HDMI v1.3 called Lipsync Compensation allows the display to inform the host of its video and audio processing latencies. This can eliminate lip-sync issues due to the increased processing delays in sophisticated displays and switching devices.

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### HDMI Versions

<table>
<thead>
<tr>
<th>Feature</th>
<th>HDMI 1.0</th>
<th>HDMI 1.1</th>
<th>HDMI 1.2</th>
<th>HDMI 1.3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maximum Resolution</strong></td>
<td>1920x1080p@60Hz</td>
<td>1920x1080p@60Hz</td>
<td>1920x1080p@60Hz</td>
<td>2560x1600@60Hz</td>
</tr>
<tr>
<td><strong>Bandwidth</strong></td>
<td>4.8Gbits/s (165MHz)</td>
<td>4.8Gbits/s (165MHz)</td>
<td>4.8Gbits/s (165MHz)</td>
<td>10.2Gbits/s (340MHz)</td>
</tr>
<tr>
<td><strong>Consumer Electronic Control</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>8 channel 192kHz 24 bit audio</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>DVD Audio</strong></td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>SACD Audio</strong></td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Dolby TrueHD &amp; DTS-HD Audio</strong></td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>DeepColor (&gt; 24 bpp color)</strong></td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes (30, 36 and 48 bit color)</td>
</tr>
<tr>
<td><strong>xvYCC color space</strong></td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
VGA
The VGA standard has been in widespread use for almost 20 years and is still available on many desktop PCs and notebooks. It’s simple and royalty-free, and the relatively low cost of implementation has made VGA the de facto standard.

The DSUB15 “HD-15” connector carries analog red, green, blue and vertical and horizontal sync signals. Because there is no video pixel clock signal present, pixel-based displays such as LCDs and plasmas must accurately sample the analog video at the assumed pixel clock rate in order to correctly display the video signal.

The maximum resolution is limited by the connector bandwidth and cable quality and length. There is no provision for audio or video content protection.

An auxiliary data channel called Display Data Channel (DDC) is used by the display to inform the host PC of the resolutions and video timings that it is capable of handling, as well as allowing, remote adjustments and querying of the display device.

USB Video (DisplayLink)
Recently a method of transferring digital video over USB to a compatible display was introduced by Cambridge-based DisplayLink Corp. This has become possible due to the increased bandwidth of USB 2.0.

A display monitor with the necessary DisplayLink hardware built in behaves as a virtual graphics adapter to the host system. Sophisticated software drivers emulate the actual video graphics adapter hardware.

DisplayLink provides an easy way to add additional displays to devices such as notebook PCs, media players etc. USB-to-VGA and DVI DisplayLink adapters are also available that can be used to connect existing display monitors that do not have DisplayLink support built in.

As with any USB device, it is entirely Plug and Play and even multiple displays can be connected to a host system for multi-monitor applications. The main limitation to the number of displays is the total available bandwidth of USB and the speed of the host PC.

Because all of the video graphics adapter hardware is emulated in software, the operation is heavily tied in with the host operating system. At this time, only 32-bit Windows-based PCs are supported, and the maximum resolution is limited to 1600x1200. Also, some 3-D hardware accelerated features are not available.

Due to the data transfer limitations of USB, this system cannot be used to display full-screen motion video. Also, as more displays are added, the overall screen update performance will be degraded.

This white paper was published in and based on information as of January 2008. Technical information is subject to change.

Color Spaces and Color Depth
VGA and DVI interfaces both transfer video only as RGB (red, green and blue) signals. DisplayPort and HDMI allow video to be encoded as YCbCr in addition to RGB. This is more suitable for TV video and CE type applications.

VGA and DVI interfaces do not define the colorspace (intended color gamut) of the video data being transferred. However, HDMI being targeted for consumer electronics devices does allow the colorspace to be specified for TV type applications. For example, when standard definition video is being transferred, the color space is BT.601-5, and BT.709-5 for high-definition video.

In addition, the HDMI v1.3 spec supports a new color space called xvYCC, which has a much larger color gamut than either BT.601-5 or BT.709-5. This allows much richer and more saturated colors to be transmitted. This is done by utilizing the unused video levels of traditional digital YCbCr video to expand the range of available colors to outside the range of BT.601-5, and BT.709-5. While active video of YCbCr is normally limited to levels 16-235 (16-240 for Cb and Cr signals) for 8-bit video, xvYCC allows levels 1-255 to be used. xvYCC can be combined with higher bit depths such as 10, 12 and 16 bits per color component (30, 36 and 48 bits per pixel), known as “DeepColor” on HDMI.
<table>
<thead>
<tr>
<th>Video Display Interface Comparison Summary</th>
<th>DisplayPort</th>
<th>DVI</th>
<th>HDMI</th>
<th>VGA</th>
<th>USB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maximum Resolution</strong></td>
<td>2560x1600 @ 70Hz and higher</td>
<td>1920x1200 @ 60Hz (single link)</td>
<td>2560x1600 @ 60 Hz w/ HDMI v1.3</td>
<td>Limited by cable, DAC speeds</td>
<td>1600x1200</td>
</tr>
<tr>
<td><strong>Analog support</strong></td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>Content Protection</strong></td>
<td>DPCP or HDCP (optional)</td>
<td>HDCP (optional)</td>
<td>HDCP (optional)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Audio support</strong></td>
<td>Yes (8 channels x 192kHz/24bits)</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Auxiliary Communications channel</strong></td>
<td>1Mbps AUX Ch</td>
<td>DDC</td>
<td>DDC</td>
<td>DDC</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Connector</strong></td>
<td>Latching (20 pin)</td>
<td>Captive (29 pin)</td>
<td>Non-captive (19 pin Types A &amp; C, 29 pin &quot;Type B&quot;)</td>
<td>Captive (15 pin DSUB15)</td>
<td>Non-captive (4 pin)</td>
</tr>
<tr>
<td><strong>Max Cable Length</strong></td>
<td>15m</td>
<td>5m spec but up to 30m possible</td>
<td>15 maximum practical maximum</td>
<td>100m practical maximum</td>
<td>5m</td>
</tr>
<tr>
<td><strong>Max Bit Depth per Pixel</strong></td>
<td>48 bits</td>
<td>24 bits (single link)</td>
<td>24 bits (48 bits with HDMI v1.3 <em>DeepColor</em>)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Pixel Encoding</strong></td>
<td>RGB, YCbCr</td>
<td>RGB</td>
<td>RGB</td>
<td>RGB</td>
<td>RGB</td>
</tr>
<tr>
<td><strong>Defined Colorspaces</strong></td>
<td>BT.601-5 for SDTV</td>
<td>None</td>
<td>BT.601-5 for SDTV</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td><strong>Consumer Electronic Control</strong></td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>