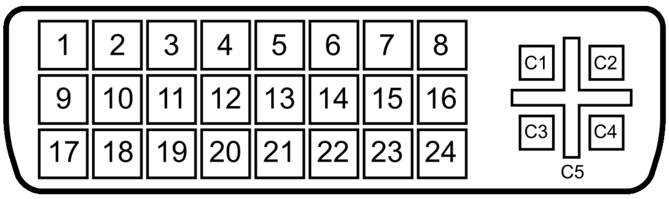
Digital Visual Interface

Digital Visual Interface (DVI)

A male DVI-D (single link) connector.

Type	Digital computer video connector
Production history	
Designer	Digital Display Working Group
Designed	April 1999
Produced	1999 to present
Superseded by	DisplayPort
General specifications	
Hot pluggable	Yes
External	Yes
Video signal	Digital video stream: (Single) WUXGA (1,920 × 1,200) @ 60 Hz (Dual) Limited by copper bandwidth limitations, DVI source limitations, and DVI sync limitations. Analog RGB video (−3 dB at 400 MHz)
Pins	29
Data	
Data signal	RGB data, clock, and display data channel
Bitrate	(Single link) 3.96 Gbit/s (Dual link) Limited only by copper bandwidth limitations, DVI source limitations, and DVI sync limitations.
Max. devices	1
Protocol	3 × transition minimized differential signaling data and clock
Pin out	



A female DVI-I socket from the front

Pin 1	TMDS data 2−	Digital red− (link 1)	
Pin 2	TMDS data 2+	Digital red+ (link 1)	

Pin 3	TMDS data 2/4 shield		
Pin 4	TMDS data 4−	Digital green− (link 2)	
Pin 5	TMDS data 4+	Digital green+ (link 2)	
Pin 6	DDC clock		
Pin 7	DDC data		
Pin 8	Analog vertical sync		
Pin 9	TMDS data 1−	Digital green− (link 1)	
Pin 10	TMDS data 1+	Digital green+ (link 1)	
Pin 11	TMDS data 1/3 shield		
Pin 12	TMDS data 3-	Digital blue− (link 2)	
Pin 13	TMDS data 3+	Digital blue+ (link 2)	
Pin 14	+5 V	Power for monitor when in standby	
Pin 15	Ground	Return for pin 14 and analog sync	
Pin 16	Hot plug detect		
Pin 17	TMDS data 0−	Digital blue− (link 1) and digital sync	
Pin 18	TMDS data 0+	Digital blue+ (link 1) and digital sync	
Pin 19	TMDS data 0/5 shield		
Pin 20	TMDS data 5−	Digital red− (link 2)	
Pin 21	TMDS data 5+	Digital red+ (link 2)	
Pin 22	TMDS clock shield		
Pin 23	TMDS clock+	Digital clock+ (links 1 and 2)	
Pin 24	TMDS clock−	Digital clock− (links 1 and 2)	
C1	Analog red		
C2	Analog green		
C3	Analog blue		
C4	Analog horizontal sync		
C5	Analog ground	Return for R, G, and B signals	

Digital Visual Interface (**DVI**) is a video display interface developed by the Digital Display Working Group (DDWG). The digital interface is used to connect a video source to a display device, such as a computer monitor.

DVI was developed to create an industry standard for the transfer of digital video content. The interface is designed to transmit uncompressed digital video and can be configured to support multiple modes such as DVI-D (digital only), DVI-A (analog only), or DVI-I (digital and analog). Featuring support for analog connections as well, the DVI specification provides optional compatibility with the VGA interface.[1] This compatibility along with other advantages led to widespread acceptance in the PC industry over other competing digital standards such as Plug and Display (P&D) and Digital Flat Panel (DFP).[2] Though predominantly found in computer devices, DVI is also present in some consumer electronics such as television sets.

Technical overview

DVI's digital video transmission format is based on PanelLink, a serial format devised by Silicon Image Inc. PanelLink uses transition minimized differential signaling (TMDS), a high-speed serial link developed by Silicon Image. Like modern analog VGA connectors, the DVI connector includes pins for the display data channel (DDC). A newer version of DDC called DDC2 allows the graphics adapter to read the monitor's extended display identification data (EDID). If a display supports both analog and digital signals in one DVI-I input, each input method can host a distinct EDID. Since the DDC can only support one EDID, there can be a problem if both the digital and analog inputs in the DVI-I port detect activity. It is up to the display to choose which EDID to send.

When a source and display are connected, the source first queries the display's capabilities by reading the monitor EDID block over an I²C link. The EDID block contains the display's identification, color characteristics (such as gamma level), and table of supported video modes. The table can designate a preferred mode or native resolution. Each mode is a set of CRT timing values that define the duration and frequency of the horizontal/vertical sync, the positioning of the active display area, the horizontal resolution, vertical resolution, and refresh rate.

For backward compatibility with displays using analog VGA signals, some of the contacts in the DVI connector carry the analog VGA signals. To ensure a basic level of interoperability, DVI compliant devices are required to support one baseline video mode, "low pixel format" (640×480 at 60 Hz). Digitally encoded video pixel data is transported using multiple TMDS links. At the electrical level, these links are highly resistant to electrical noise and other forms of analog distortion.

Single-link DVI

A single-link DVI connection consists of four TMDS links; each link transmits data from the source to the device over 1 twisted wire pair. Three of the links correspond to the RGB components of the video signal: red, green, blue (for a total of 24 bits per pixel.) The fourth link carries the pixel clock. The binary data is encoded using 8b10b encoding. The 8b10b encoding system serves several purposes: it preserves DC balance over time, it generates sufficient signal transitions to maintain receiver bit-alignment (pixel clock recovery), and it provides symbol (byte) alignment. Each TMDS link carries binary data at ten times the pixel clock reference frequency, for a maximum data rate of 1.65 Gbit/s × 3 data pairs for single-link DVI.

DVI does not use packetisation, but rather transmits the pixel data as if it were a rasterized analog video signal. As such, during each vertical refresh period, the complete frame is 'drawn' over the DVI link. The full active area of each frame is always transmitted; no data compression is used, and there is no support for only transmitting changed parts of the image. Video modes typically use horizontal and vertical refresh timings that are compatible with CRT displays, but this is not a requirement. The DVI specification (see below for link) does, however, include a paragraph on "Conversion to Selective Refresh" (under 1.2.2), suggesting this feature for future devices.

The DVI specification mandates a maximum pixel clock frequency of 165 MHz when running in single-link mode. With a single DVI link, the highest supported standard resolution is 2.75 megapixels (including blanking interval) at 60 Hz refresh. For practical purposes, this allows a maximum screen resolution at 60 Hz of 1,915 × 1,436 pixels (standard 4:3 ratio), 1,854 × 1,483 pixels (5:4 ratio), or 2,098 × 1,311 (widescreen 16:10 ratio).

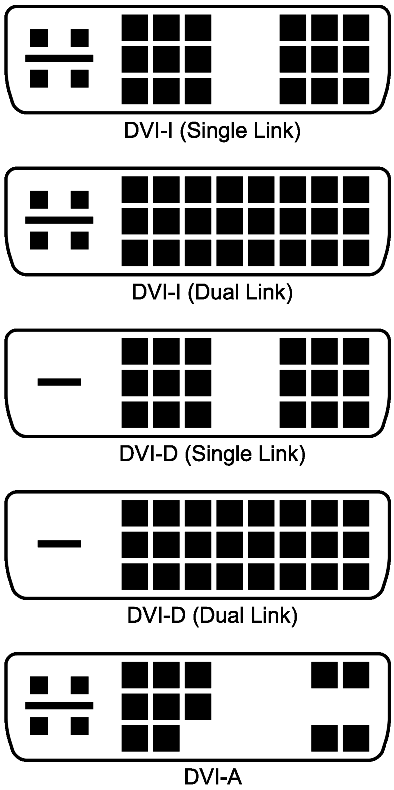
Dual-link DVI

To support display devices requiring higher video bandwidth, there is provision for a dual DVI link. A dual link doubles the number of TMDS pairs, effectively doubling video bandwidth at a given pixel clock frequency. The DVI specification mandates how the dual link may be used. All display modes that use a pixel clock below 165 MHz, and have at most 24 bits per pixel, are required to use single-link mode. All modes that require more than 24 bits per pixel, and/or 165 MHz pixel clock frequency must use dual-link mode. In modes where each pixel uses 24 bits of color data per pixel or less and dual-link mode is in use, the transmitter stripes pixel data across both links; each sequential video pixel is transmitted on alternate links. In modes with color depth greater than 24 bits per pixel, the second link carries the least significant bits of each pixel.

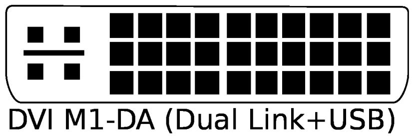
Cable length

The maximum length of DVI cables is not included in the specification since it is dependent on the pixel clock frequency, and hence the video mode's bandwidth requirements (which is a function of resolution and refresh rate). In general, cable lengths up to 4.5 m (15 ft) will work for displays at resolutions of 1,920 × 1,200. This resolution will work even up to 10 m (33 ft) if appropriate cable is used. Cable lengths up to 15 m (50 ft) can be used with displays at resolutions up to 1,280 × 1,024. For longer distances, the use of a DVI booster is recommended to mitigate signal degradation. DVI boosters may use an external power supply.

Connector



Male DVI connector pins (view of plug)



Male M1-DA connector pins (view of plug)

The DVI connector usually contains pins to pass the DVI-native digital video signals. In the case of dual link systems, additional pins provide increased bandwidth allowing higher resolutions and longer distances.[3] Dual link should not be confused with *dual display* (also known as *dual head*), which is a configuration that involves a single computer connected to two monitors.

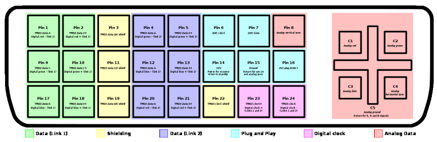
In addition to digital, the DVI connector includes pins that carry an analog signal. This allows a VGA monitor to be connected with a passive plug adapter and offers a universal solution for the DVI interface. The analog pins are the four that surround the flat blade as shown on the left-hand side of the diagrams for DVI-I and DVI-A. Some retail computers come with both a VGA and DVI-D video output. Without the four analog pins present on the DVI-D connector, a VGA source cannot be attached.

The DVI connector on a device is therefore given one of three names, depending on which signals it implements:

- *DVI-D* (digital only, both single-link and dual-link)
- *DVI-A* (analog only)
- *DVI-I* (integrated – digital and analog)

The DVI-D and DVI-I connector includes a provision for a second data link for resolutions up to 2560x1600 which is supported by many add-on graphic cards. The connector is sometimes referred to as DVI-DL (dual link).

The long flat pin on a DVI-I connector is wider than the same pin on a DVI-D connector, so it is not possible to connect a male DVI-I to a female DVI-D by removing the 4 analog pins. It is possible, however, to connect a male DVI-D cable to a female DVI-I connector. Many flat panel LCD monitors have only the DVI-D connection so that a DVI-D male to DVI-D male cable will suffice when connecting the monitor to a computer's DVI-I female connector.



Color coded female DVI connector with pin descriptions (Click image to see descriptions)

DVI is the only widespread video standard that includes analog and digital transmission options in the same connector.[4] Competing standards are exclusively digital: these include a system using low-voltage differential signaling (LVDS), known by its proprietary names FPD-Link (flat-panel display) and FLATLINK; and its successors, the LVDS Display Interface (LDI) and OpenLDI.

Some new DVD players, TV sets (including HDTV sets) and video projectors have DVI/HDCP connectors; these are physically the same as DVI connectors but transmit an encrypted signal using the HDCP protocol for copy protection. Computers with DVI video connectors can use many DVI-equipped HDTV sets as a display, but only computers whose graphics systems support High-bandwidth Digital Content Protection are currently able to play content that requires digital rights management.

USB signals are not incorporated into the connector, but were earlier incorporated into the VESA Plug and Display connector used by InFocus on their projector systems, and in the Apple Display Connector, which was used by Apple until 2005.

The DMS-59 connector is a way to combine two analog and two digital signals in one plug. It is commonly used when a single graphics card has two outputs. Note that this is *dual display* – it does not have the additional pins for the *dual link* TDMI signals.

M1-DA connectors are sometimes labeled as DVI-M1; they are used for the VESA Enhanced Video Connector and VESA Plug and Display schemes.

Specifications

Digital

A DVI-to-VGA adapter. Requires the analog signals provided by DVI-I.

- Minimum clock frequency: 25.175 MHz
- Single link maximum data rate including 8b/10b overhead is 4.95 Gbit/s @ 165 MHz. With the 8b/10b overhead subtracted, the maximum data rate is 3.96 Gbit/s.
- Dual link maximum data rate is limited only by the bandwidth limits of the copper the DVI cable is constructed of and by the DVI signal's source.
- Pixels per clock cycle: 1 (single link at 24 bits or less per pixel, and dual link at between 25 and 48 bits inclusively per pixel) or 2 (dual link at 24 bits or less per pixel)
- Bits per pixel:
  - 24 bits per pixel support is mandatory in all resolutions supported.
  - Less than 24 bits per pixel is optional.
  - Up to 48 bits per pixel are supported in dual link DVI, and is optional. If a mode greater than 24 bits per pixel is desired, the least significant bits are sent on the second link.
- Example display modes (*single link*):
  - HDTV (1,920 × 1,080) @ 60 Hz with CVT-RB blanking (139 MHz)
  - UXGA (1,600 × 1,200) @ 60 Hz with GTF blanking (161 MHz)
  - WUXGA (1,920 × 1,200) @ 60 Hz with CVT-RB blanking (154 MHz)
  - SXGA (1,280 × 1,024) @ 85 Hz with GTF blanking (159 MHz)
  - WXGA+ (1440 × 900) @ 60 Hz (107 MHz)

  - WQUXGA (3,840 × 2,400) @ 17 Hz (164 MHz)
- Example display modes (*dual link*):
  - QXGA (2,048 × 1,536) @ 75 Hz with GTF blanking (2 × 170 MHz)
  - HDTV (1,920 × 1,080) @ 85 Hz with GTF blanking (2 × 126 MHz)
  - WUXGA (1,920 × 1,200) @ 120 Hz with CVT-RB blanking (2 x 154 MHz)
  - WQXGA (2,560 × 1,600) @ 60 Hz with GTF blanking (2 × 174 MHz) (30-inch **/ unknown operator: u'strong'** mm Apple, Dell, Gateway, HP, NEC, Quinux, and Samsung LCDs)
  - WQXGA (2,560 × 1,600) @ 60 Hz with CVT-RB blanking (2 × 135 MHz) (30-inch **/ unknown operator: u'strong'** mm Apple, Dell, Gateway, HP, NEC, Quinux, and Samsung LCDs)
  - WQXGA (2,560 × 1,600) @ 60 Hz with CVT-RB blanking (269 MHz) (This is for high end monitors when operating at greater than 24 bits per pixel.)
  - WQUXGA (3,840 × 2,400) @ 33 Hz with GTF blanking (2 × 159 MHz)

Generalized Timing Formula (GTF) is a VESA standard which can easily be calculated with the Linux gtf utility. Coordinated Video Timings-Reduced Blanking (CVT-RB) is a VESA standard which offers reduced horizontal and vertical blanking for non-CRT based displays.[5]

Digital data encoding

One of the purposes of DVI stream encoding is to provide a DC balanced output stream. A DC balanced link reduces its Electromagnetic interference. This goal is achieved by using 10 bit symbols for 8 bit or less characters and using the extra bits for the DC balancing.

Like other ways of transmitting video, there are two differentiate regions: active region, where pixel data is sent, and control region, where synchronization signals are sent. Active region is encoded using Transition Minimized Differential Signaling scheme, where the control region is encoded with a fixed 2b/10b encoding. A more detailed explanation of both can be read at the Transition Minimized Differential Signaling wiki page. As the two schemes yield different 10 bit symbols, a receiver can fully differentiate between active and control regions.

The timing of the synchronization signals matches the equivalent analog video format, making the process of transforming from digital video to analog video, and vice-versa, a process that does not require extra memory. Please note that at the birth of DVI, most computer monitors were of the Cathode ray tube type ones that required the analog video synchronization signals. Memory was also expensive at the rates video signals work.

HDCP is an extra layer that transforms the 10 bit symbols before sending through the link. Only after correct authorization can the receiver undo the HDCP encryption. Control regions are not encrypted in order to let the receiver know when the active region starts.

Clock and data relationship

The DVI data channel operates at a bit-rate that is 10 times the frequency of the clock signal. In other words, in each DVI clock period there is a 10 bit symbol per channel. The set of three 10 bit symbol represents one complete pixel in single link mode and can represent either one or two complete pixels as set of six 10 bit symbols in dual link mode.

DVI links provides differential pairs for data and for the clock. The specification document allows the data and the clock to not be aligned. However, as the ratio between clock and bit rate is fixed at 1:10, the unknown alignment is kept over time. The receiver must recover the bits on the stream using any of the techniques of clock/data recovery and find then the correct symbol boundary. The DVI specification allows the input clock vary between 25MHz and 165MHz. This 1:6.6 ratio can make pixel recovery difficult, as Phase-locked loops, if used, need to work over a large frequency range. One benefit of DVI over other links is that it is relatively straightforward to transform the signal from digital domain into the analog one using a video DAC, as both clock and synchronization signals are sent over the link. Fixed frequency links, like DisplayPort, need to reconstruct the clock from the data sent over the link.

Display power management

The DVI specification includes signaling for reducing power consumption. Similar to the analog VESA display power management signaling (DPMS) standard, a connected device can turn a monitor off when the connected device is powered down, or programmatically if the display controller ("graphics card") of the device supports it. Devices with this capability can also attain Energy Star certification.

Analog

The analog section of the DVI specification document is brief and points to other specifications like VESA VSIS[6] for electrical characteristics and GTFS for timing information. The idea of the analog link is to keep compatibility with the previous VGA cables and connectors. HSync, Vsync and three video channels are available in both VGA and DVI connectors and are electrically compatible. Auxiliary links like DDC are also available. A passive adapter can be used in order to carry the analog signals between the two connectors.

DVI and HDMI compatibility

HDMI is a newer digital audio/video interface developed and promoted by the consumer electronics industry. DVI and HDMI have the same electrical specifications for their TMDS and VESA/DDC links. However, HDMI and DVI differ in several key ways.

- HDMI lacks VGA compatibility. The necessary analog signals are absent from the HDMI connector.
- DVI is limited to the RGB color space. HDMI supports RGB, but also supports YCbCr 4:4:4 and YCbCr 4:2:2. These spaces are widely used outside of computer graphics.
- HDMI supports the transport of packets, needed for digital audio, in addition to digital video. An HDMI source differentiates between a legacy DVI display and an HDMI-capable display by reading the display's EDID block.

To promote interoperability between DVI and HDMI devices, HDMI source components and displays support DVI signalling. An HDMI display can be driven by a single-link DVI-D source, since HDMI and DVI-D define an overlapping minimum set of supported resolutions and frame buffer formats. In the reverse scenario, a DVI monitor that lacks optional support for HDCP might be unable to display protected content, even though it is otherwise compatible with the HDMI source.

Features specific to HDMI, such as remote-control, audio transport, xvYCC, and deep-color, are not usable in devices that only support DVI signalling. However, many devices can output HDMI over a DVI output (examples: ATI 3000-series and NVIDIA GTX 200-series video cards),[7] and some multimedia displays accept HDMI (including audio) over a DVI input. Exact capabilities vary from product to product.

Proposed successors

- IEEE 1394 is proposed by High-Definition Audio-Video Network Alliance (HANA Alliance [8]) for all cabling needs, including video, over coax and/or 1394 cable as a combined data stream. However, this interface does not have enough throughput to handle uncompressed HD video, so it is unsuitable for applications that require uncompressed HD video like video games and interactive program guides.
- High-Definition Multimedia Interface (HDMI), a forward-compatible standard that also includes digital audio transmission
- Unified Display Interface (UDI) was proposed by Intel to replace both DVI and HDMI, but was deprecated in favor of DisplayPort.
- DisplayPort (a license-free standard proposed by VESA to succeed DVI that has DRM capabilities) / Mini DisplayPort / Thunderbolt

In December 2010, Intel, AMD, and several computer and display manufacturers announced they would stop supporting DVI-I, VGA and LVDS-technologies from 2013/2015, and instead speed up adoption of DisplayPort and

HDMI.[9] They also stated: "Legacy interfaces such as VGA, DVI and LVDS have not kept pace, and newer standards such as DisplayPort and HDMI clearly provide the best connectivity options moving forward. In our opinion, DisplayPort 1.2 is the future interface for PC monitors, along with HDMI 1.4a for TV connectivity."

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[8] http://hanaalliance.org/hana_solutions/use_cases

[9] Intel Newsrom (http://newsroom.intel.com/community/intel_newsroom/blog/2010/12/08/leading-pc-companies-move-to-all-digital-display-technology-phasing-out-analog) – *Leading PC Companies Move to All Digital Display Technology, Phasing out Analog* (8. December 2010)

Further reading

- DDWG promoters (1999-04-02) (PDF). *Digital Visual Interface* (http://www.ddwg.org/lib/dvi_10.pdf). Revision 1.0: Initial Specification Release. Digital Display Working Group.

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