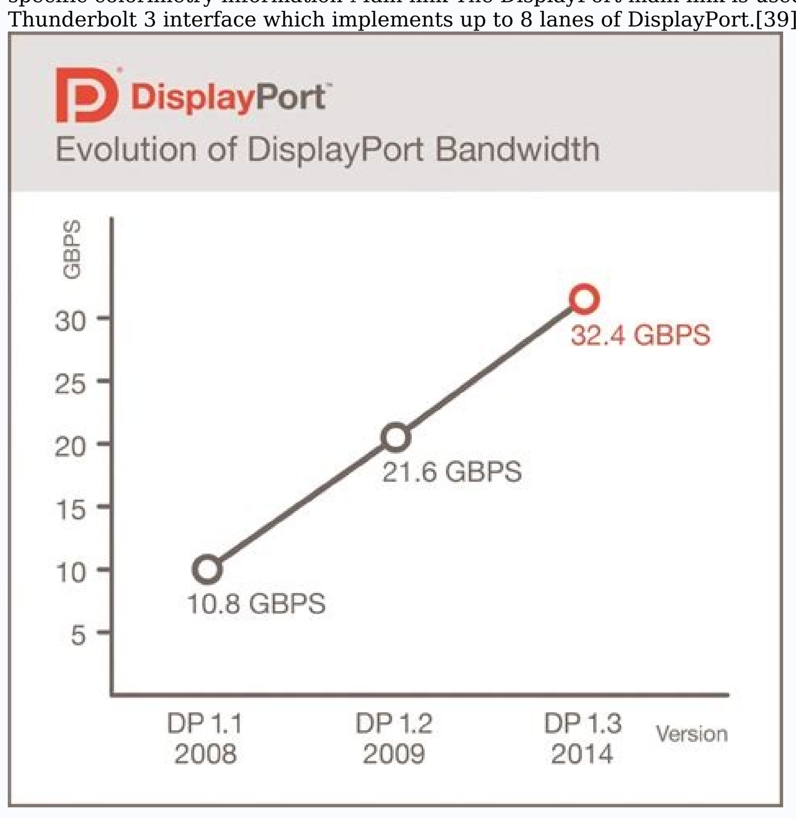
Displayport 1.2 specification pdf

Displayport 1.4a specification. Displayport 1.2 and 1.4 difference. Dp 1.2 spec. Dp 1.2a specs.

The ANX7750 is a SlimPort to DisplayPort lane converter. It takes a 1-lane SlimPort (@HBR2.5 rate) input and converts it to 4-lane DisplayPort (@HBR rate) output. ANX7750 works in conjunction with SlimPort transmitters, such as ANX7805, ANX7808, ANX7812, ANX7814, ANX7816, ANX7836, and more. ANX7750 is particularly suited for seamless plug-and-play to legacy DisplayPort (@HBR rate) HDTV, monitors, and projectors. ANX9807 is an ultra low power DP/eDP transmitter designed for motherboards. Any portable mobile device with an embedded ANX9807 device would be able to connect to any DP/eDP receiver through a passive cable as defined by DP/eDp specification. Digital display interface DisplayPort Type Digital audio/video connectorProduction historyDesigner VESADesigned May 2006Manufacturer VariousProduced 2008–presentSuperseded DVI, VGA, SCART, RGB ComponentSuperseded by NoneGeneral specificationsLength VariousHot pluggable YesExternal YesAudio signal Optional; 1–8 channels, 16 or 24-bit linear PCM; 32–192 kHz sampling rate; maximum bitrate 36,864 kbit/s (4,608 kB/s)Video signal Optional, maximum resolution limited by available bandwidthPins 20 pins for external connectors on desktops, notebooks, graphics cards, monitors, etc. and 30/20 pins for internal connections between graphics engines and built-in flat panels.ElectricalSignal +3.3 VMax. voltage 16.0 VMax. current 0.5 ADataData signal YesBitrate 1.62, 2.7, 5.4, 8.1, or 20 Gbit/s data rate per lane; 1, 2, or 4 lanes; (effective total 5.184, 8.64, 17.28, 25.92, or 77.37 Gbit/s for 4-lane link); 2 or 720 Mbit/s (effectively 1 or 576 Mbit/s) for the auxiliary channel.Protocol Micro-packetPinout External connector (source-side) on PCBPin 1 ML_Lane 0 (p)[a] Lane 0 (+)Pin 2 GND GroundPin 3 ML_Lane 0 (n)[a] Lane 0 (−)Pin 4 ML_Lane 1 (p)[a] Lane 1 (+)Pin 5 GND GroundPin 6 ML_Lane 1 (n)[a] Lane 1 (−)Pin 7 ML_Lane 2 (p)[a] Lane 2 (+)Pin 8 GND GroundPin 9 ML_Lane 2 (n)[a] Lane 2 (−)Pin 10 ML_Lane 3 (p)[a] Lane 3 (+)Pin 11 GND GroundPin 12 ML_Lane 3 (n)[a] Lane 3 (−)Pin 13 CONFIG1 Connected to ground[b]Pin 14 CONFIG2 Connected to ground[b]Pin 15 AUX CH (p) Auxiliary channel (+)Pin 16 GND GroundPin 17 AUX CH (n) Auxiliary channel (−)Pin 18 Hot plug Hot plug detectPin 19 Return Return for powerPin 20 DP_PWR Power for connector (3.3 V 500 mA) ^ a b c d e f g h This is the pinout for source-side connector, the sink-side connector pinout will have lanes 0–3 reversed in order; i.e., lane 3 will be on pin 1(n) and 3(p) while lane 0 will be on pin 10(n) and 12(p). ^ a b Pins 13 and 14 may either be directly connected to ground or connected to ground through a pulldown device. DisplayPort connector A DisplayPort port (top right) near an Ethernet port and a USB port DisplayPort (DP) is a digital display interface developed by a consortium of PC and chip manufacturers and standardized by the Video Electronics Standards Association (VESA). It is primarily used to connect a video source to a display device such as a computer monitor. It can also carry audio, USB, and other forms of data.[1] DisplayPort was designed to replace VGA, FPD-Link, and Digital Visual Interface (DVI). It is backward compatible with other interfaces, such as HDMI and DVI, through the use of either active or passive adapters.[2] It is the first display interface to rely on packetized data transmission, a form of digital communication found in technologies such as Ethernet, USB, and PCI Express. It permits the use of internal and external display connections. Unlike legacy standards that transmit a clock signal with each output, its protocol is based on small data packets known as micro packets, which can embed the clock signal in the data stream, allowing higher resolution using fewer pins.[3] The use of data packets also makes it extensible, meaning more features can be added over time without significant changes to the physical interface.[4] DisplayPort can be used to transmit audio and video simultaneously, although each can be transmitted without the other. The video signal path can range from six to sixteen bits per color channel, and the audio path can have up to eight channels of 24-bit, 192 kHz uncompressed PCM audio.[1] A bidirectional, half-duplex auxiliary channel carries device management and device control data for the Main Link, such as VESA EDID, MCCS, and DPMS standards. The interface is also capable of carrying bidirectional USB signals.[5] The interface uses a differential signal that is not compatible with DVI or HDMI. However, dual-mode DisplayPort ports are designed to transmit a single-link DVI or HDMI protocol (TMDS) across the interface through the use of an external passive adapter, enabling compatibility mode and converting the signal from 3.3 to 5 volts. For analog VGA/YPbPr and dual-link DVI, a powered active adapter is required for compatibility and does not rely on dual mode. Active VGA adapters are powered directly by the DisplayPort connector, while active dual-link DVI adapters typically rely on an external power source such as USB. Versions 1.0 to 1.1 The first version, 1.0, was approved by VESA on 3 May 2006.[6] Version 1.1 was ratified on 2 April 2007,[7] and version 1.1a was ratified on 11 January 2008.[8] DisplayPort 1.0–1.1a allow a maximum bandwidth of 10.8 Gbit/s (8.64 Gbit/s data rate) over a standard 4-lane main link. DisplayPort cables up to 2 meters in length are required to support the full 10.8 Gbit/s bandwidth.[8] DisplayPort 1.1 allows devices to implement alternative link layers such as fiber optic, allowing a much longer reach between source and display without signal degradation,[9] although alternative implementations are not standardized. It also includes HDCP in addition to DisplayPort Content Protection (DPCP). The DisplayPort 1.1a standard can be downloaded for free from the VESA website.[10] 1.2 DisplayPort version 1.2 was introduced on 7 January 2010.[11] The most significant improvement of this version is the doubling of the data rate to 17.28 Gbit/s in High Bit Rate 2 (HBR2) mode, which allows increased resolutions, higher refresh rates, and greater color depth, such as 3840 × 2160 at 60 Hz 10 bpc RGB. Other improvements include multiple independent video streams (daisy-chain connection with multiple monitors) called Multi-Stream Transport (MST), facilities for stereoscopic 3D, increased AUX channel bandwidth (from 1 Mbit/s to 720 Mbit/s), more color spaces including xvYCC, scRGB, and Adobe RGB 1998, and Global Time Code (GTC) for sub 1 μs audio/video synchronisation. Also Apple Inc.'s Mini DisplayPort connector, which is much smaller and designed for laptop computers and other small devices, is compatible with the new standard.[1][12][13][14] 1.2a DisplayPort version 1.2a was released in January 2013[15] and may optionally include VESA's Adaptive Sync.[16] AMD's FreeSync uses the DisplayPort Adaptive-Sync feature for operation. FreeSync was first demonstrated at CES 2014 on a Toshiba Satellite laptop by making use of the Panel-Self-Refresh (PSR) feature from the Embedded DisplayPort standard,[17] and after a proposal from AMD, VESA later adapted the Panel-Self-Refresh feature for use in standalone displays and added it as an optional feature of the main DisplayPort standard under the name "Adaptive-Sync" in version 1.2a.[18] As it is an optional feature, support for Adaptive-Sync is not required for a display to be DisplayPort 1.2a-compliant. 1.3 DisplayPort version 1.3 was approved on 15 September 2014.[19] This standard increases overall transmission bandwidth to 32.4 Gbit/s with the new HBR3 mode featuring 8.1 Gbit/s per lane (up from 5.4 Gbit/s with HBR2 in version 1.2), for a total data throughput of 25.92 Gbit/s after factoring in 8b/10b encoding overhead. This bandwidth is enough for a 4K UHD display (3840 × 2160) at 120 Hz with 24 bit/px RGB color, a 5K display (5120 × 2880) at 60 Hz with 30 bit/px RGB color, or an 8K UHD display (7680 × 4320) at 30 Hz with 24 bit/px RGB color. Using Multi-Stream Transport (MST), a DisplayPort port can drive two 4K UHD (3840 × 2160) displays at 60 Hz, or up to four WQXGA (2560 × 1600) displays at 60 Hz with 24 bit/px RGB color. The new standard includes mandatory Dual-mode for DVI and HDMI adapters, implementing the HDMI 2.0 standard and HDCP 2.2 content protection.[20] The Thunderbolt 3 connection standard was originally to include DisplayPort 1.3 capability, but the final release ended up with only version 1.2. The VESA's Adaptive Sync feature in DisplayPort version 1.3 remains an optional part of the specification.[21] 1.4 DisplayPort version 1.4 was published 1 March 2016.[22] No new transmission modes are defined, so HBR3 (32.4 Gbit/s) as introduced in version 1.3 still remains as the highest available mode. DisplayPort 1.4 adds support for Display Stream Compression 1.2 (DSC), Forward Error Correction, HDR10 metadata defined in CTA-861.3, including static and dynamic metadata and the Rec. 2020 color space, for HDMI interoperability,[23] and extends the maximum number of inline audio channels to 32.[24] 1.4a DisplayPort version 1.4a was published in April 2018.[25] VESA made no official press release for this version. It updated DisplayPort's DSC implementation from DSC 1.2 to 1.2a.[26] 2.0 On 26 June 2019, VESA formally released the DisplayPort 2.0 standard. VESA stated that version 2.0 is the first major update to the DisplayPort standard since March 2016, and provides up to a ≈3× improvement in data rate (from 25.92 to 77.37 Gbit/s) compared to the previous version of DisplayPort (1.4a), as well as new capabilities to address the future performance requirements of traditional displays. These include beyond 8K resolutions, higher refresh rates and high dynamic range (HDR) support at higher resolutions, improved support for multiple display configurations, as well as improved user experience with augmented/virtual reality (AR/VR) displays, including support for 4K-and-beyond VR resolutions. Products incorporating DisplayPort 2.0 are not projected by VESA to appear on the market until later in 2021.[27][28] According to a roadmap published by VESA in September 2016, a new version of DisplayPort was intended to be launched in "early 2017". It would have improved the link rate from 8.1 to 10.0 Gbit/s, a 23% increase.[29][30] This would have increased the total bandwidth from 32.4 Gbit/s to 40.0 Gbit/s. However, no new version was released in 2017, likely delayed to make further improvements after the HDMI Forum announced in January 2017 that their next standard (HDMI 2.1) would offer up to 48 Gbit/s of bandwidth.

According to a press release on 3 January 2018, "VESA is also currently engaged with its members in the development of the next DisplayPort standard generation, with plans to increase the data rate enabled by DisplayPort by two-fold and beyond. VESA plans to publish this update within the next 18 months."[31] At CES 2019, VESA announced that the new version would support 8K @ 60 Hz without compression and was expected to be released in the first half of 2019.[32] DP 2.0 configuration examples With the increased bandwidth enabled by DisplayPort 2.0, VESA offers a high degree of versatility and configurations for higher display resolutions and refresh rates. In addition to the above-mentioned 8K resolution at 60 Hz with HDR support, UHBR20 through USB-C as DisplayPort Alt Mode enables a variety of high-performance configurations: Single display resolutions One 16K (15360 × 8640) display @ 60 Hz with 10 bpc (30 bit/px, HDR) RGB/Y′CBCR 4:4:4 color (with DSC) One 10K (10240 × 4320) display @ 60 Hz and 8 bpc (24 bit/px, SDR) RGB/Y′CBCR 4:4:4 color (uncompressed) Dual display resolutions Two 8K (7680 × 4320) displays @ 120 Hz and 10 bpc (30 bit/px, HDR) RGB/Y′CBCR 4:4:4 color (with DSC) Two 4K (3840 × 2160) displays @ 144 Hz and 8 bpc (24 bit/px, SDR) RGB/Y′CBCR 4:4:4 color (uncompressed) Triple display resolutions Three 10K (10240 × 4320) displays @ 60 Hz and 10 bpc (30 bit/px, HDR) RGB/Y′CBCR 4:4:4 color (with DSC) Three 4K (3840 × 2160) displays @ 90 Hz and 10 bpc (30 bit/px, HDR) RGB/Y′CBCR 4:4:4 color (uncompressed) When using only two lanes on the USB-C connector via DP Alt Mode to allow for simultaneous SuperSpeed USB data and video, DP 2.0 can enable such configurations as:[28] Three 4K (3840 × 2160) displays @ 144 Hz and 10 bpc (30 bit/px, HDR) RGB/Y′CBCR 4:4:4 color (with DSC) Two 4K × 4K (4096 × 4096) displays (for AR/VR headsets) @ 120 Hz and 10 bpc (30 bit/px, HDR) RGB/Y′CBCR 4:4:4 color (with DSC) Three QHD (2560 × 1440) @ 120 Hz and 8 bpc (24 bit/px, SDR) RGB/Y′CBCR 4:4:4 color (uncompressed) One 8K (7680 × 4320) display @ 30 Hz and 10 bpc (30 bit/px, HDR) RGB/Y′CBCR 4:4:4 color (uncompressed) 2.1 VESA announced version 2.1 of the DisplayPort standard on 17 October 2022.[33] This version incorporates the new DP40 and DP80 cable certifications, which test DisplayPort cables for proper operation at the UHBR10 (40 Gbit/s) and UHBR20 (80 Gbit/s) speeds introduced in version 2.0. Additionally, it revises some of the electrical requirements for DisplayPort devices in order to improve integration with USB4.
In VESA's words: DisplayPort 2.1 has tightened its alignment with the USB Type-C specification as well as the USB4 PHY specification to facilitate a common PHY servicing both DisplayPort and USB4.

In addition, DisplayPort 2.1 has added a new DisplayPort bandwidth management feature to enable DisplayPort tunneling to coexist with other I/O data traffic more efficiently over the USB4 link. Specifications Main specifications   DisplayPort version 1.0–1.1a 1.2–1.2a 1.3 1.4–1.4a 2.0–2.1 Release date May 2006 (1.0)[34]Mar 2007 (1.1)[35]Jan 2008 (1.1a)[8] Jan 2010 (1.2)[11]May 2012 (1.2a)[35] Sep 2014[19] Mar 2016 (1.4)[22]Apr 2018 (1.4a)[25] Jun 2019 (2.0)[28]Oct 2022 (2.1)[33] Main link Transmission modes: RBR (1.62 Gbit/s per lane) Yes[36]:§1.6.1 Yes Yes Yes Yes HBR (2.70 Gbit/s per lane) Yes[36]:§1.6.1 Yes Yes Yes Yes HBR2 (5.40 Gbit/s per lane) No Yes[37]:§2.1.1 Yes Yes Yes HBR3 (8.10 Gbit/s per lane) No No Yes[19] Yes Yes UHBR 10 (10.0 Gbit/s per lane) No No No No Yes UHBR 13.5 (13.5 Gbit/s per lane) No No No No Yes UHBR 20 (20.0 Gbit/s per lane) No No No No Yes Number of lanes [8]:§1.7.1 4 4 4 4 4 Maximum total bandwidth[a] 10.80 Gbit/s 21.60 Gbit/s 32.40 Gbit/s 32.40 Gbit/s 80.00 Gbit/s Maximum total data rate[b] 8.64 Gbit/s 17.28 Gbit/s 25.92 Gbit/s 25.92 Gbit/s 77.37 Gbit/s Encoding scheme[c] [8]:§1.7.1 8b/10b 8b/10b 8b/10b 8b/10b 128b/132b Compression (optional) – – – DSC 1.2 (DP 1.4)DSC 1.2a (DP 1.4a) DSC 1.2a Auxiliary channel Maximum bandwidth [8]:Fig. 3-3 2 Mbit/s [37]:§3.4 720 Mbit/s 2 Mbit/s 2 Mbit/s 2 Mbit/s Maximum data rate [8]:§3.4 1 Mbit/s [37]:§3.4 576 Mbit/s 1 Mbit/s 1 Mbit/s 1 Mbit/s Encoding scheme [8]:§1.7.2 Manchester II [37]:§3.4 8b/10b Manchester II Manchester II Manchester II Color format support RGB Yes[36]:§1.6.1 Yes Yes Yes Yes Y′CBCR 4:4:4 Yes[36]:§1.6.1 Yes Yes Yes Yes Y′CBCR 4:2:2 Yes[36]:§1.6.1 Yes Yes Yes Yes Y′CBCR 4:2:0 No No Yes Yes Yes Y-only (monochrome) No Yes[37]:§2.2.4.3 Yes Yes Yes Color depth support 06 bpc (18 bit/px) Yes[36]:§1.6.1 Yes Yes Yes Yes 08 bpc (24 bit/px) Yes[36]:§1.6.1 Yes Yes Yes Yes 10 bpc (30 bit/px) Yes[36]:§1.6.1 Yes Yes Yes Yes 12 bpc (36 bit/px) Yes[36]:§1.6.1 Yes Yes Yes Yes 16 bpc (48 bit/px) Yes[36]:§1.6.1 Yes Yes Yes Yes Color space support ITU-R BT.601 Yes[8]:§2.2.4 Yes Yes Yes Yes ITU-R BT.709 Yes[8]:§2.2.4 Yes Yes Yes Yes sRGB No[d] Yes[37]:§2.2.4.3 Yes Yes Yes scRGB No Yes[37]:§2.2.4.3 Yes Yes Yes xvYCC No Yes[37]:§2.2.4.3 Yes Yes Yes Adobe RGB (1998) No Yes[37]:§2.2.4.3 Yes Yes Yes DCI-P3 No Yes[37]:§2.2.4.3 Yes Yes Yes Simplified color profile No Yes[37]:§2.2.4.3 Yes Yes Yes ITU-R BT.2020 No No Yes[38]:4 Yes Yes Audio specifications Max. sample rate [8]:§1.2.5 192 kHz [37]:§2.2.5.3 768 kHz 768 kHz [22] 1536 kHz ?
Max. sample size [8]:§1.2.5 24 bits 24 bits 24 bits 24 bits ? Maximum audio channels [8]:§1.2.5 8 8 8 32 ?   1.0–1.1a 1.2–1.2a 1.3 1.4–1.4a 2.0–2.1 DisplayPort version ^ Total bandwidth (the number of binary digits transmitted per second) is equal to the bandwidth per lane of the highest supported transmission mode multiplied by the number of lanes. ^ While the total bandwidth represents the number of physical bits transmitted across the interface, not all of the bits represent video data. Some of the transmitted bits are used for encoding purposes, so the rate at which video data can be transmitted across the DisplayPort interface is only a portion of the total bandwidth. ^ The 8b/10b encoding scheme uses 10 bits of bandwidth to send 8 bits of data, so only 80% of the bandwidth is available for data throughput. The extra 2 bits are used for DC balancing (ensuring a roughly equal number of 1s and 0s). They consume bandwidth, but do not represent any data. ^ In DisplayPort 1.0–1.1a, RGB images are simply sent without any specific colorimetry information Main link The DisplayPort main link is used for transmission of video and audio. The main link consists of a number of unidirectional serial data channels which operate concurrently, called lanes. A standard DisplayPort connection has 4 lanes, though some applications of DisplayPort implement more, such as the Thunderbolt 3 interface which implements up to 8 lanes of DisplayPort.[39]:4 In a standard DisplayPort connection, each lane has a dedicated set of twisted-pair wires, and transmits data across it using differential signaling.



This is a self-clocking system, so no dedicated clock signal channel is necessary.[8]:§1.7.1 Unlike DVI and HDMI, which vary their transmission speed to the exact rate required for the specific video format, DisplayPort only operates at a few specific speeds; any excess bits in the transmission are filled with "stuffing symbols".[8]:§2.2.1.4 In DisplayPort versions 1.0–1.4a, the data is encoded using ANSI 8b/10b encoding prior to transmission. With this scheme, only 8 out of every 10 transmitted bits represent data; the extra bits are used for DC balancing (ensuring a roughly equal number of 1s and 0s). As a result, the rate at which data can be transmitted is only 80% of the physical bitrate. The transmission speeds are also sometimes expressed in terms of the "Link Symbol Rate", which is the rate at which these 8b/10b-encoded symbols are transmitted (i.e. the rate at which groups of 10 bits are transmitted, 8 of which represent data). The following transmission modes are defined in version 1.0–1.4a: RBR (Reduced Bit Rate): 1.62 Gbit/s bandwidth per lane (162 MHz link symbol rate) HBR (High Bit Rate): 2.70 Gbit/s bandwidth per lane (270 MHz link symbol rate) HBR2 (High Bit Rate 2): 5.40 Gbit/s bandwidth per lane (540 MHz link symbol rate), introduced in DP 1.2 HBR3 (High Bit Rate 3): 8.10 Gbit/s bandwidth per lane (810 MHz link symbol rate), introduced in DP 1.3 DisplayPort 2.0 uses 128b/132b encoding; each group of 132 transmitted bits represents 128 bits of data.
This scheme has an efficiency of 96.96%.[40] In addition, a small amount of overhead is added for the link layer control packet and other miscellaneous operations, resulting in an overall efficiency of ≈96.7%.[41]:§3.5.2.18 The following transmission modes are added in DP 2.0: UHBR 10 (Ultra High Bit Rate 10): 10.0 Gbit/s bandwidth per lane UHBR 13.5 (Ultra High Bit Rate 13.5): 13.5 Gbit/s bandwidth per lane UHBR 20 (Ultra High Bit Rate 20): 20.0 Gbit/s bandwidth per lane The total bandwidth of the main link in a standard 4-lane connection is the aggregate of all lanes: RBR: 04 × 1.62 Gbit/s = 06.48 Gbit/s bandwidth (data rate of 5.184 Gbit/s or 648 MB/s with 8b/10b encoding) HBR: 04 × 2.70 Gbit/s = 10.80 Gbit/s bandwidth (data rate of 8.64 Gbit/s or 1.08 GB/s) HBR2: 4 × 5.40 Gbit/s = 21.60 Gbit/s bandwidth (data rate of 17.28 Gbit/s or 2.16 GB/s) HBR3: 4 × 8.10 Gbit/s = 32.40 Gbit/s bandwidth (data rate of 25.92 Gbit/s or 3.24 GB/s) UHBR 10: 4 × 10.0 Gbit/s = 40.00 Gbit/s bandwidth (data rate of 38.69 Gbit/s or 4.84 GB/s with 128b/132b encoding and FEC) UHBR 13.5: 4 × 13.5 Gbit/s = 54.00 Gbit/s bandwidth (data rate of 52.22 Gbit/s or 6.52 GB/s) UHBR 20: 4 × 20.0 Gbit/s = 80.00 Gbit/s bandwidth (data rate of 77.37 Gbit/s or 9.69 GB/s) The transmission mode used by the DisplayPort main link is negotiated by the source and sink device when a connection is made, through a process called Link Training. This process determines the maximum possible speed of the connection. If the quality of the DisplayPort cable is insufficient to reliably handle HBR2 speeds for example, the DisplayPort devices will detect this and switch down to a lower mode to maintain a stable connection.[8]:§2.1.1 The link can be re-negotiated at any time if a loss of synchronization is detected.[8]:§1.7.3 Audio data is transmitted across the main link during the video blanking intervals (short pauses between each line and frame of video data).[8]:§2.2.5.3 Auxiliary channel The DisplayPort AUX channel is a half-duplex (bidirectional) data channel used for miscellaneous additional data beyond video and audio, such as EDID (I2C) or CEC commands.[8]:§2.4 This bidirectional data channel is required, since the video lane signals are unidirectional from source to display. AUX signals are transmitted across a dedicated set of twisted-pair wires. DisplayPort 1.0 specified Manchester encoding with a 2 MBd signal rate (1 Mbit/s data rate).[8]:§3.4 Version 1.2 of the DisplayPort standard introduced a second transmission mode called FAUX (Fast AUX), which operated at 720 MBd with 8b/10b encoding (576 Mbit/s data rate),[37]:§3.4 but it was deprecated in version 1.3. Cables and connectors Cables Compatibility and feature support All DisplayPort cables are compatible with all DisplayPort devices, regardless of the version of each device or the cable certification level.[42] All features of DisplayPort will function across any DisplayPort cable. DisplayPort does not have multiple cable designs; all DP cables have the same basic layout and wiring, and will support any feature including audio, daisy-chaining, G-Sync/FreeSync, HDR, and DSC. DisplayPort cables differ in their transmission speed support. DisplayPort specifies seven different transmission modes (RBR, HBR, HBR2, HBR3, UHBR 10, UHBR 13.5, and UHBR 20) which support progressively higher bandwidths. Not all DisplayPort cables are capable of all seven transmission modes. VESA offers certifications for various levels of bandwidth. These certifications are optional, and not all DisplayPort cables are certified by VESA. Cables with limited transmission speed are still compatible with all DisplayPort devices, but may place limits on the maximum resolution or refresh rate available. DisplayPort cables are not classified by "version". Although cables are commonly labeled with version numbers, with HBR2 cables advertised as "DisplayPort 1.2 cables" for example, this notation is not permitted by VESA.[42] The use of version numbers with cables can falsely imply that a DisplayPort 1.4 display requires a "DisplayPort 1.4 cable", or that features introduced in version 1.4 such as HDR or DSC will not function with older "DP 1.2 cables". DisplayPort cables are classified only by their bandwidth certification level (RBR, HBR, HBR2, HBR3, etc.), if they have been certified at all. Cable bandwidth and certifications Not all DisplayPort cables are capable of functioning at the highest levels of bandwidth. Cables may be submitted to VESA for an optional certification at various bandwidth levels.

VESA offers four levels of cable certification: Standard, DP8K, DP40, and DP80.[41]:§4.1 These certify DisplayPort cables for proper operation at the following speeds: DisplayPort cable certifications Transmission mode Transmissionbit rate Minimum required cable certification RBR (Reduced Bit Rate) 6.48 Gbit/s Standard VESA-certified DisplayPort cable HBR (High Bit Rate) 10.80 Gbit/s HBR2 (High Bit Rate 2) 21.60 Gbit/s HBR3 (High Bit Rate 3) 32.40 Gbit/s DP8K DisplayPort cable UHBR10 (Ultra High Bit Rate 10) 40.00 Gbit/s DP40 cable UHBR13.5 (Ultra High Bit Rate 13.5) 54.00 Gbit/s DP80 cable UHBR20 (Ultra High Bit Rate 20) 80.00 Gbit/s In April 2013, VESA published an article stating that the DisplayPort cable certification did not have distinct tiers for HBR and HBR2 bandwidth, and that any certified standard DisplayPort cable—including those certified under DisplayPort 1.1—would be able to handle the 21.6 Gbit/s bandwidth of HBR2 that was introduced with the DisplayPort 1.2 standard.[42] The DisplayPort 1.2 standard defines only a single specification for High Bit Rate cable assemblies, which is used for both HBR and HBR2 speeds, although the DP cable certification process is governed by the DisplayPort PHY Compliance Test Standard (CTS) and not the DisplayPort standard itself.[37]:§5.7.1, §4.1 The DP8K certification was announced by VESA in January 2018, and certifies cables for proper operation at HBR3 speeds (8.1 Gbit/s per lane, 32.4 Gbit/s total).[43] In June 2019, with the release of version 2.0 of the DisplayPort Standard, VESA announced that the DP8K certification was also sufficient for the new UHBR10 transmission mode. No new certifications were announced for the UHBR13.5 and UHBR20 modes. VESA is encouraging displays to use tethered cables for these speeds, rather than releasing standalone cables onto the market.[40] It should also be noted that the use of Display Stream Compression (DSC), introduced in DisplayPort 1.4, greatly reduces the bandwidth requirements for the cable. Formats which would normally be beyond the limits of DisplayPort 1.4, such as 4K (3840 × 2160) at 144 Hz 8 bpc RGB/Y′CBCR 4:4:4 (31.4 Gbit/s data rate when uncompressed), can only be implemented by using DSC. This would reduce the physical bandwidth requirements by 2–3×, placing it well within the capabilities of an HBR2-rated cable.

This exemplifies why DisplayPort cables are not classified by "version"; although DSC was introduced in version 1.4, this does not mean it needs a so-called "DP 1.4 cable" (an HBR3-rated cable) to function. HBR3 cables are only required for applications which exceed HBR2-level bandwidth, not simply any application involving DisplayPort 1.4. If DSC is used to reduce the bandwidth requirements to HBR2 levels, then an HBR2-rated cable will be sufficient.

In version 2.1, VESA introduced the DP40 and DP80 cable certification tiers, which validate cables for UHBR10 and UHBR20 speeds respectively. Cable length The DisplayPort standard does not specify any maximum length for cables, though the DisplayPort 1.2 standard does set a minimum requirement that all cables up to 2 meters in length must support HBR2 speeds (21.6 Gbit/s), and all cables of any length must support RBR speeds (6.48 Gbit/s).[37]:§5.7.1, §4.1 Cables longer than 2 meters may or may not support HBR/HBR2 speeds, and cables of any length may or may not support HBR3 speeds or above. Connectors and pin configuration DisplayPort output on a computer DisplayPort cables and ports may have either a "full-size" connector or a "mini" connector. These connectors differ only in physical shape—the capabilities of DisplayPort are the same regardless of which connector is used. Using a Mini DisplayPort connector does not affect performance or feature support of the connection. Full-size DisplayPort connector The standard DisplayPort connector (now referred to as a "full-size" connector to distinguish it from the mini connector)[37]:§4.1.1 was the sole connector type introduced in DisplayPort 1.0. It is a 20-pin single-orientation connector with a friction lock and an optional mechanical latch. The standard DisplayPort receptacle has dimensions of 16.10 mm (width) × 4.76 mm (height) × 8.88 mm (depth).[8]:§4.2.1.7, p201 The standard DisplayPort connector pin allocation is as follows:[8]:§4.2.1 12 pins for the main link – the main link consists of four shielded twisted pairs. Each pair requires 3 pins; one for each of the two wires, and a third for the shield.[8]:§4.1.2, p183 (pins 1–12) 2 additional ground pins – (pins 13 and 14) 3 pins for the auxiliary channel – the auxiliary channel uses another 3-pin shielded twisted pair (pins 15–17) 1 pin for HPD – hot-plug detection (pin 18) 2 pins for power – 3.3 V power and return line (pins 19 and 20) Mini DisplayPort connector Mini DisplayPort plug The Mini DisplayPort connector was developed by Apple for use in their computer products.

It was first announced in October 2008 for use in the new MacBooks and Cinema Display. In 2009, VESA adopted it as an official standard, and in 2010 the specification was merged into the main DisplayPort standard with the release of DisplayPort 1.2. Apple freely licenses the specification to VESA. The Mini DisplayPort (mDP) connector is a 20-pin single-orientation connector with a friction lock.

Unlike the full-size connector, it does not have an option for a mechanical latch. The mDP receptacle has dimensions of 7.50 mm (width) × 4.60 mm (height) × 4.99 mm (depth).[44]:§2.1.3.6, pp27–31 The mDP pin assignments are the same as the full-size DisplayPort connector.[44]:§2.1.3 DP_PWR (pin 20) Pin 20 on the DisplayPort connector, called DP_PWR, provides 3.3 V (±10%) DC power at up to 500 mA (minimum power delivery of 1.5 W).[8]:§3.2 This power is available from all DisplayPort receptacles, on both source and display devices. DP_PWR is intended to provide power for adapters, amplified cables, and similar devices, so that a separate power cable is not necessary.

Standard DisplayPort cable connections do not use the DP_PWR pin. Connecting the DP_PWR pins of two devices directly together through a cable can create a short circuit which can potentially damage devices, since the DP_PWR pins on two devices are unlikely to have exactly the same voltage (especially with a ±10% tolerance).[45] For this reason, the DisplayPort 1.1 and later standards specify that passive DisplayPort-to-DisplayPort cables must leave pin 20 unconnected.[8]:§3.2.2 However, in 2013 VESA announced that after investigating reports of malfunctioning DisplayPort devices, it had discovered that a large number of non-certified vendors were manufacturing their DisplayPort cables with the DP_PWR pin connected: Recently VESA has experienced quite a few complaints regarding troublesome DisplayPort operation that ended up being caused by improperly made DisplayPort cables. These "bad" DisplayPort cables are generally limited to non-DisplayPort certified cables, or off-brand cables. To further investigate this trend in the DisplayPort cable market, VESA purchased a number of non-certified, off-brand cables and found that an alarmingly high number of these were configured improperly and would likely not support all system configurations. None of these cables would have passed the DisplayPort certification test, moreover some of these cables could potentially damage a PC, laptop, or monitor. The stipulation that the DP_PWR wire be omitted from standard DisplayPort cables was not present in the DisplayPort 1.0 standard. However, DisplayPort products (and cables) did not begin to appear on the market until 2008, long after version 1.0 had been replaced by version 1.1. The DisplayPort 1.0 standard was never implemented in commercial products.[46] Resolution and refresh frequency limits The tables below describe the refresh frequencies that can be achieved with each transmission mode. In general, maximum refresh frequency is determined by the transmission mode (RBR, HBR, HBR2, HBR3, UHBR 10, UHBR 13.5, or UHBR 20). These transmission modes were introduced to the DisplayPort standard as follows: RBR and HBR were defined in the initial release of the DisplayPort standard, version 1.0 HBR2 was introduced in version 1.2 HBR3 was introduced in version 1.3 UHBR 10, UHBR 13.5, and UHBR 20 were introduced in version 2.0 However, transmission mode support is not necessarily dictated by a device's claimed "DisplayPort version number". For example, older versions of the DisplayPort Marketing Guidelines allowed a device to be labeled as "DisplayPort 1.2" if it supported the MST feature, even if it didn't support the HBR2 transmission mode.[47]:9 Newer versions of the guidelines have removed this clause, and currently (as of the June 2018 revision) there are no guidelines on the usage of DisplayPort version numbers in products.[48] DisplayPort "version numbers" are therefore not a reliable indication of what transmission speeds a device can support. In addition, individual devices may have their own arbitrary limitations beyond transmission speed. For example, NVIDIA Kepler GK104 GPUs (such as the GeForce GTX 680 and 770) support "DisplayPort 1.2" with the HBR2 transmission mode, but are limited to 540 Mpx/s, only 3⁄4 of the maximum possible with HBR2.[49] Consequently, certain devices may have limitations that differ from those listed in the following tables. To support a particular format, the source and display devices must both support the required transmission mode, and the DisplayPort cable must also be capable of handling the required bandwidth of that transmission mode. (See: Cables and connectors) Refresh frequency limits for common resolutions The maximum limits for the RBR and HBR modes are calculated using standard data rate calculations.[50] For UHBR modes, the limits are based on the data efficiency calculations provided by the DisplayPort standard.[51]:§3.5.2.18 All calculations assume uncompressed RGB video with CVT-RB v2 timing. Maximum limits may differ if compression (i.e. DSC) or Y′CBCR 4:2:2 or 4:2:0 chroma subsampling are used.

Display manufacturers may also use non-standard blanking intervals rather than CVT-RB v2 to achieve even higher frequencies when bandwidth is a constraint. The refresh frequencies in the below table do not represent the absolute maximum limit of each interface, but rather an estimate based on a modern standardized timing formula. The minimum blanking intervals (and therefore the exact maximum frequency that can be achieved) will depend on the display and how many secondary data packets it requires, and therefore will differ from model to model. Video format Transmission mode / Maximum data rate Short-hand Resolution Colordepth(bpc) RBR HBR HBR2 HBR3 UHBR 10 UHBR 13.5 UHBR 20 5.184 Gbit/s 8.64 Gbit/s 17.28 Gbit/s 25.92 Gbit/s 38.68 Gbit/s 52.22 Gbit/s 77.37 Gbit/s Maximum refresh frequency with CVT-RB v2 timing uncompressed (Hz) 1080p 1920 × 1080 8 95 154 288 406 555 688 884 10 77 125 237 337 468 587 770 1440p 2560 × 1440 8 55 90 174 251 354 452 609 10 44 73 141 205 293 378 516 UWQHD 3440 × 1440 8 41 68 133 193 277 358 491 10 33 55 107 157 227 296 412 4K 3840 × 2160 8 41 81 120 174 229 323 10 33 65 97 142 187 267 5K 5120 × 2880 8 47 69 102 136 195 10 37 56 82 110 159 8K 7680 × 4320 8 31 47 63 92 10 37 50 74 Below 30 Hz 030–60 Hz 060–120 Hz 120–240 Hz Above 240 Hz Refresh frequency limits for standard video Color depth of 8 bpc (24 bit/px or 16.7 million colors) is assumed for all formats in these tables. This is the standard color depth used on most computer displays. Note that some operating systems refer to this as "32-bit" color depth—this is the same as 24-bit color depth. The 8 extra bits are for alpha channel information, which is only present in software. At the transmission stage, this information has already been incorporated into the primary color channels, so the actual video data transmitted across the cable only contains 24 bits per pixel. Limits for uncompressed RGB / Y′CBCR 4:4:4 video only Video format Transmission mode / maximum data rate[a] Shorthand Resolution Refreshrate (Hz) Data raterequired[b] RBR HBR HBR2 HBR3 UHBR 10 UHBR 13.5 UHBR 20 5.184 Gbit/s 8.64 Gbit/s 17.28 Gbit/s 25.92 Gbit/s 38.69 Gbit/s 52.22 Gbit/s 77.37 Gbit/s 1080p 1920 × 1080 60 3.20 Gbit/s Yes Yes Yes Yes Yes Yes Yes 85 4.59 Gbit/s Yes Yes Yes Yes Yes Yes Yes 120 6.59 Gbit/s No Yes Yes Yes Yes Yes Yes 144 8.00 Gbit/s No Yes Yes Yes Yes Yes Yes 240 14.00 Gbit/s No No Yes Yes Yes Yes Yes 1440p 2560 × 1440 30 2.78 Gbit/s Yes Yes Yes Yes Yes Yes Yes 60 5.63 Gbit/s No Yes Yes Yes Yes Yes Yes 85 8.07 Gbit/s No Yes Yes Yes Yes Yes Yes 120 11.59 Gbit/s No No Yes Yes Yes Yes Yes 144 14.08 Gbit/s No No Yes Yes Yes Yes Yes 165 16.30 Gbit/s No No Yes Yes Yes Yes Yes 240 24.62 Gbit/s No No No Yes Yes Yes Yes 4K 3840 × 2160 24 4.93 Gbit/s Yes Yes Yes Yes Yes Yes Yes 30 6.18 Gbit/s No Yes Yes Yes Yes Yes Yes 60 12.54 Gbit/s No No Yes Yes Yes Yes Yes 75 15.79 Gbit/s No No Yes Yes Yes Yes Yes 120 25.82 Gbit/s No No No Yes Yes Yes Yes 144 31.35 Gbit/s No No No No Yes Yes Yes 240 54.84 Gbit/s No No No No No Yes[c] Yes 5K 5120 × 2880 24 8.73 Gbit/s No Yes[c] Yes Yes Yes Yes Yes 30 10.94 Gbit/s No No Yes Yes Yes Yes Yes 60 22.18 Gbit/s No No No Yes Yes Yes Yes 120 45.66 Gbit/s No No No No No Yes Yes 144 55.44 Gbit/s No No No No No No Yes 180 70.54 Gbit/s No No No No No No Yes 240 96.98 Gbit/s No No No No No No No 8K 7680 × 4320 24 19.53 Gbit/s No No No Yes Yes Yes Yes 30 24.48 Gbit/s No No No Yes Yes Yes Yes 60 49.65 Gbit/s No No No No No Yes Yes 85 71.17 Gbit/s No No No No No No Yes 120 102.20 Gbit/s No No No No No No No RBR HBR HBR2 HBR3 UHBR 10 UHBR 13.5 UHBR 20 Transmission mode ^ Only a portion of DisplayPort's bandwidth is used for carrying video data.

DisplayPort versions 1.0–1.4a use 8b/10b encoding, which means that 80% of the bits transmitted across the link represent data, and the other 20% are used for encoding purposes. The maximum bandwidth of RBR, HBR, HBR2, and HBR3 (6.48, 10.8, 21.6, and 32.4 Gbit/s) therefore transport video data at rates of 5.184, 8.64, 17.28, and 25.92 Gbit/s. DisplayPort version 2.0 uses 128b/132b encoding, and therefore the maximum bandwidths of UHBR 10, 13.5, and 20 (40, 54, and 80 Gbit/s) transport data at rates of 38.69, 52.22, and 77.37 Gbit/s. ^ These data rates are for uncompressed 8 bpc (24 bit/px) color depth with RGB or YCBCR 4:4:4 color format and CVT-R2 timing. Uncompressed data rate for RGB video in bits per second is calculated as bits per pixel × pixels per frame × frames per second. Pixels per frame includes blanking intervals as defined by CVT-R2. ^ a b Although this format slightly exceeds the maximum data rate of this transmission mode with CVT-R2 timing, it is close enough to be achieved with non-standard timings Limits including compression and chroma subsampling Video format Transmission mode / maximum data rate[a] Shorthand Resolution Refreshrate (Hz) Data raterequired[b] RBR HBR HBR2 HBR3 UHBR 10 UHBR 13.5 UHBR 20 5.184 Gbit/s 8.64 Gbit/s 17.28 Gbit/s 25.92 Gbit/s 38.69 Gbit/s 52.22 Gbit/s 77.37 Gbit/s 1080p 1920 × 1080 60 3.20 Gbit/s Yes Yes Yes Yes Yes Yes Yes 85 4.59 Gbit/s Yes Yes Yes Yes Yes Yes Yes 120 6.59 Gbit/s DSC[c] or 4:2:2[d] Yes Yes Yes Yes Yes Yes 144 8.00 Gbit/s DSC or 4:2:0 Yes Yes Yes Yes Yes Yes 240 14.00 Gbit/s DSC DSC or 4:2:0 Yes Yes Yes Yes Yes 1440p 2560 × 1440 30 2.78 Gbit/s Yes Yes Yes Yes Yes Yes Yes 60 5.63 Gbit/s DSC or 4:2:2 Yes Yes Yes Yes Yes Yes 85 8.07 Gbit/s DSC or 4:2:0 Yes Yes Yes Yes Yes Yes 120 11.59 Gbit/s DSC DSC or 4:2:2 Yes Yes Yes Yes Yes 144 14.08 Gbit/s DSC DSC or 4:2:0 Yes Yes Yes Yes Yes 165 16.30 Gbit/s DSC + 4:2:2[e] DSC or 4:2:0 Yes Yes Yes Yes Yes 240 24.62 Gbit/s DSC + 4:2:0 DSC DSC or 4:2:2 Yes Yes Yes Yes 4K 3840 × 2160 24 4.93 Gbit/s Yes Yes Yes Yes Yes Yes Yes 30 6.18 Gbit/s DSC or 4:2:2 Yes Yes Yes Yes Yes Yes 60 12.54 Gbit/s DSC DSC or 4:2:2 Yes Yes Yes Yes Yes 75 15.79 Gbit/s DSC DSC or 4:2:0 Yes Yes Yes Yes Yes 120 25.82 Gbit/s DSC + 4:2:0 DSC DSC or 4:2:2 Yes Yes Yes Yes 144 31.35 Gbit/s DSC + 4:2:0 DSC + 4:2:2 DSC or 4:2:0 DSC or 4:2:2 Yes Yes Yes 240 54.84 Gbit/s No No DSC + 4:2:2 DSC DSC or 4:2:2 Yes[f] Yes 5K 5120 × 2880 24 8.73 Gbit/s DSC or 4:2:0 Yes[f] Yes Yes Yes Yes Yes 30 10.94 Gbit/s DSC DSC or 4:2:2 Yes Yes Yes Yes Yes 60 22.18 Gbit/s DSC + 4:2:2 DSC DSC or 4:2:2 Yes Yes Yes Yes 120 45.66 Gbit/s No DSC + 4:2:0 DSC DSC or 4:2:0 DSC or 4:2:2 Yes Yes 144 55.44 Gbit/s No No DSC + 4:2:2 DSC DSC or 4:2:2 DSC or 4:2:2 Yes 180 70.54 Gbit/s No No DSC + 4:2:2 DSC DSC or 4:2:0 DSC or 4:2:2 Yes 240 96.98 Gbit/s No No DSC + 4:2:0 DSC + 4:2:2 DSC or 4:2:0 DSC or 4:2:2 8K 7680 × 4320 24 19.53 Gbit/s DSC + 4:2:2 DSC DSC or 4:2:2 Yes Yes Yes Yes 30 24.48 Gbit/s DSC + 4:2:0 DSC DSC or 4:2:2 Yes Yes Yes Yes 60 49.65 Gbit/s No DSC + 4:2:0 DSC DSC or 4:2:0 DSC or 4:2:2 Yes Yes 85 71.17 Gbit/s No No DSC + 4:2:2 DSC DSC or 4:2:0 DSC or 4:2:2 Yes 120 102.20 Gbit/s No No DSC + 4:2:0 DSC + 4:2:2 DSC DSC or 4:2:0 DSC or 4:2:2 144 124.09 Gbit/s No No No DSC + 4:2:0 DSC + 4:2:2 DSC DSC or 4:2:0 240 217.10 Gbit/s No No No No DSC + 4:2:0 DSC + 4:2:2 RBR HBR HBR2 HBR3 UHBR 10 UHBR 13.5 UHBR 20 Transmission mode ^ Only a portion of DisplayPort's bandwidth is used for carrying video data. DisplayPort versions 1.0–1.4a use 8b/10b encoding, which means that 80% of the bits transmitted across the link represent data, and the other 20% are used for encoding purposes. The maximum bandwidth of RBR, HBR, HBR2, and HBR3 (6.48, 10.8, 21.6, and 32.4 Gbit/s) therefore transport video data at rates of 5.184, 8.64, 17.28, and 25.92 Gbit/s. DisplayPort version 2.0 uses 128b/132b encoding, and therefore the maximum bandwidths of UHBR 10, 13.5, and 20 (40, 54, and 80 Gbit/s) transport data at rates of 38.69, 52.22, and 77.37 Gbit/s. ^ These data rates are for uncompressed 8 bpc (24 bit/px) color depth with RGB or YCBCR 4:4:4 color format and CVT-R2 timing. Uncompressed data rate for RGB video in bits per second is calculated as bits per pixel × pixels per frame × frames per second. Pixels per frame includes blanking intervals as defined by CVT-R2. ^ This format can only be achieved with full RGB color if DSC (display stream compression) is used. ^ This format can only be achieved uncompressed if the YCBCR format with either 4:2:2 or 4:2:0 chroma subsampling (as noted) is used ^ This format can only be achieved if DSC is used together with either YCbCr 4:2:2 or 4:2:0 chroma subsampling (as noted) ^ a b Although this format slightly exceeds the maximum data rate of this transmission mode with CVT-R2 timing, it is close enough to be achieved with non-standard timings Refresh frequency limits for HDR video Color depth of 10 bpc (30 bit/px or 1.07 billion colors) is assumed for all formats in these tables. This color depth is a requirement for various common HDR standards, such as HDR10. It requires 25% more bandwidth than standard 8 bpc video. HDR extensions were defined in version 1.4 of the DisplayPort standard. Some displays support these HDR extensions, but may only implement HBR2 transmission mode if the extra bandwidth of HBR3 is unnecessary (for example, on 4K 60 Hz HDR displays).

Since there is no definition of what constitutes a "DisplayPort 1.4" device, some manufacturers may choose to label these as "DP 1.2" devices despite their support for DP 1.4 HDR extensions.[52] As a result, DisplayPort "version numbers" should not be used as an indicator of HDR support. Limits for uncompressed RGB / Y′CBCR 4:4:4 video only Video Format Transmission Mode / Maximum Data Rate[a] Shorthand Resolution RefreshRate (Hz) Data RateRequired[b] RBR HBR HBR2 HBR3 UHBR 10 UHBR 13.5 UHBR 20 5.184 Gbit/s 8.64 Gbit/s 17.28 Gbit/s 25.92 Gbit/s 38.69 Gbit/s 52.22 Gbit/s 77.37 Gbit/s 1080p 1920 × 1080 60 4.00 Gbit/s Yes Yes Yes Yes Yes Yes Yes 100 6.80 Gbit/s No Yes Yes Yes Yes Yes Yes 120 8.24 Gbit/s No Yes Yes Yes Yes Yes Yes 144 10.00 Gbit/s No No Yes Yes Yes Yes Yes 240 17.50 Gbit/s No No Yes[c] Yes Yes Yes Yes 1440p 2560 × 1440 30 3.47 Gbit/s Yes Yes Yes Yes Yes Yes Yes 60 7.04 Gbit/s No Yes Yes Yes Yes Yes Yes 75 8.86 Gbit/s No Yes[c] Yes Yes Yes Yes Yes 120 14.49 Gbit/s No No Yes Yes Yes Yes Yes 144 17.60 Gbit/s No No Yes[c] Yes Yes Yes Yes 200 25.12 Gbit/s No No No Yes Yes Yes Yes 240 30.77 Gbit/s No No No No Yes Yes Yes 4K 3840 × 2160 30 7.73 Gbit/s No Yes Yes Yes Yes Yes Yes 60 15.68 Gbit/s No No Yes Yes Yes Yes Yes 98 26.07 Gbit/s No No No Yes[c] Yes Yes Yes 120 32.27 Gbit/s No No No No Yes Yes Yes 144 39.19 Gbit/s No No No No Yes[c] Yes Yes 180 49.85 Gbit/s No No No No No Yes Yes 240 68.56 Gbit/s No No No No No No Yes 5K 5120 × 2880 30 13.67 Gbit/s No No Yes Yes Yes Yes Yes 50 22.99 Gbit/s No No No Yes Yes Yes Yes 60 27.72 Gbit/s No No No No Yes Yes Yes 85 39.75 Gbit/s No No No No Yes[c] Yes Yes 100 47.10 Gbit/s No No No No No Yes Yes 120 57.08 Gbit/s No No No No No No Yes 144 69.30 Gbit/s No No No No No No Yes 8K 7680 × 4320 24 24.41 Gbit/s No No No Yes Yes Yes Yes 30 30.60 Gbit/s No No No No Yes Yes Yes 50 51.47 Gbit/s No No No No No Yes Yes 60 62.06 Gbit/s No No No No No No Yes 75 78.13 Gbit/s No No No No No No Yes[c] RBR HBR HBR2 HBR3 UHBR 10 UHBR 13.5 UHBR 20 Transmission Mode ^ Only a portion of DisplayPort's bandwidth is used for carrying video data.

DisplayPort versions 1.0–1.4a use 8b/10b encoding, which means that 80% of the bits transmitted across the link represent data, and the other 20% are used for encoding purposes. The maximum bandwidth of RBR, HBR, HBR2, and HBR3 (6.48, 10.8, 21.6, and 32.4 Gbit/s) therefore transport video data at rates of 5.184, 8.64, 17.28, and 25.92 Gbit/s. DisplayPort version 2.0 uses 128b/132b encoding, and therefore the maximum bandwidths of UHBR 10, 13.5, and 20 (40, 54, and 80 Gbit/s) transport data at rates of 38.69, 52.22, and 77.37 Gbit/s. ^ These data rates are for uncompressed 10 bpc (30 bit/px) color depth with RGB or YCBCR 4:4:4 color format and CVT-R2 timing.

Uncompressed data rate for RGB video in bits per second is calculated as bits per pixel × pixels per frame × frames per second. Pixels per frame includes blanking intervals as defined by CVT-R2. ^ a b c d e f g Although this format slightly exceeds the maximum data rate of this transmission mode with CVT-R2 timing, it is close enough to be achieved with non-standard timings Limits including compression and chroma subsampling Video Format Transmission Mode / Maximum Data Rate[a] Shorthand Resolution RefreshRate (Hz) Data RateRequired[b] RBR HBR HBR2 HBR3 UHBR 10 UHBR 13.5 UHBR 20 5.184 Gbit/s 8.64 Gbit/s 17.28 Gbit/s 25.92 Gbit/s 38.69 Gbit/s 52.22 Gbit/s 77.37 Gbit/s 1080p 1920 × 1080 60 4.00 Gbit/s Yes Yes Yes Yes Yes Yes Yes 100 6.80 Gbit/s DSC[c] or 4:2:2[d] Yes Yes Yes Yes Yes Yes 120 8.24 Gbit/s DSC or 4:2:0 Yes Yes Yes Yes Yes Yes 144 10.00 Gbit/s DSC DSC or 4:2:2 Yes Yes Yes Yes Yes 240 17.50 Gbit/s DSC + 4:2:2[e] DSC or 4:2:0 Yes[f] Yes Yes Yes Yes 1440p 2560 × 1440 30 3.47 Gbit/s Yes Yes Yes Yes Yes Yes Yes 60 7.04 Gbit/s DSC or 4:2:2 Yes Yes Yes Yes Yes Yes 75 8.86 Gbit/s DSC or 4:2:0 Yes[f] Yes Yes Yes Yes Yes 120 14.49 Gbit/s DSC DSC or 4:2:0 Yes Yes Yes Yes Yes 144 17.60 Gbit/s DSC + 4:2:2 DSC or 4:2:0 Yes[f] Yes Yes Yes Yes 200 25.12 Gbit/s DSC + 4:2:0 DSC DSC or 4:2:2 Yes Yes Yes Yes 240 30.77 Gbit/s DSC + 4:2:0 DSC + 4:2:2 DSC or 4:2:0 DSC or 4:2:2 Yes Yes Yes 4K 3840 × 2160 30 7.73 Gbit/s DSC or 4:2:2 Yes Yes Yes Yes Yes Yes 60 15.68 Gbit/s DSC DSC or 4:2:0 Yes Yes Yes Yes Yes 75 19.74 Gbit/s DSC + 4:2:2 DSC DSC or 4:2:2 Yes Yes Yes Yes 98 26.07 Gbit/s DSC + 4:2:0 DSC DSC or 4:2:2 Yes[f] Yes Yes Yes 120 32.27 Gbit/s No DSC + 4:2:2 DSC or 4:2:0 DSC or 4:2:2 Yes Yes Yes 144 39.19 Gbit/s No DSC + 4:2:2 DSC DSC or 4:2:2 Yes Yes Yes 180 49.85 Gbit/s No DSC + 4:2:0 DSC DSC or 4:2:0 DSC or 4:2:2 Yes Yes 240 68.56 Gbit/s No No DSC + 4:2:2 DSC DSC or 4:2:0 DSC or 4:2:2 Yes 5K 5120 × 2880 30 13.67 Gbit/s DSC DSC or 4:2:0 Yes Yes Yes Yes Yes 50 22.99 Gbit/s DSC + 4:2:2 DSC DSC or 4:2:2 Yes Yes Yes Yes 60 27.72 Gbit/s DSC + 4:2:0 DSC + 4:2:2 DSC or 4:2:0 DSC or 4:2:2 Yes Yes Yes 100 47.10 Gbit/s No DSC + 4:2:0 DSC DSC or 4:2:0 DSC or 4:2:2 Yes Yes 120 57.08 Gbit/s No No DSC + 4:2:2 DSC DSC or 4:2:2 DSC or 4:2:2 Yes 144 69.30 Gbit/s No No DSC + 4:2:2 DSC DSC or 4:2:0 DSC or 4:2:2 Yes 240 121.23 Gbit/s No No No DSC + 4:2:0 DSC DSC or 4:2:0 8K 7680 × 4320 24 24.41 Gbit/s DSC + 4:2:0 DSC DSC or 4:2:2 Yes Yes Yes Yes 30 30.60 Gbit/s DSC + 4:2:0 DSC + 4:2:2 DSC or 4:2:0 DSC or 4:2:2 Yes Yes Yes 50 51.47 Gbit/s No DSC + 4:2:0 DSC DSC or 4:2:0 DSC or 4:2:2 Yes Yes 60 62.06 Gbit/s No No DSC + 4:2:2 DSC DSC or 4:2:0 DSC or 4:2:2 Yes 75 78.13 Gbit/s No No DSC + 4:2:2 DSC DSC or 4:2:0 DSC or 4:2:2 Yes[f] 120 127.75 Gbit/s No No No DSC + 4:2:0 DSC + 4:2:2 DSC DSC or 4:2:0 144 155.11 Gbit/s No No No DSC + 4:2:0 DSC + 4:2:2 DSC DSC or 4:2:0 240 271.37 Gbit/s No No No No No DSC + 4:2:0 DSC + 4:2:2 RBR HBR HBR2 HBR3 UHBR 10 UHBR 13.5 UHBR 20 Transmission Mode ^ Only a portion of DisplayPort's bandwidth is used for carrying video data. DisplayPort versions 1.0–1.4a use 8b/10b encoding, which means that 80% of the bits transmitted across the link represent data, and the other 20% are used for encoding purposes. The maximum bandwidth of RBR, HBR, HBR2, and HBR3 (6.48, 10.8, 21.6, and 32.4 Gbit/s) therefore transport video data at rates of 5.184, 8.64, 17.28, and 25.92 Gbit/s.

DisplayPort version 2.0 uses 128b/132b encoding, and therefore the maximum bandwidths of UHBR 10, 13.5, and 20 (40, 54, and 80 Gbit/s) transport data at rates of 38.69, 52.22, and 77.37 Gbit/s. ^ These data rates are for uncompressed 10 bpc (30 bit/px) color depth with RGB or YCBCR 4:4:4 color format and CVT-R2 timing. Uncompressed data rate for RGB video in bits per second is calculated as bits per pixel × pixels per frame × frames per second. Pixels per frame includes blanking intervals as defined by CVT-R2. ^ This format can only be achieved with full RGB color if DSC (display stream compression) is used. ^ This format can only be achieved uncompressed if the YCBCR format with either 4:2:2 or 4:2:0 chroma subsampling (as noted) is used ^ This format can only be achieved if DSC is used together with either YCbCr 4:2:2 or 4:2:0 chroma subsampling (as noted) ^ a b c d e Although this format slightly exceeds the maximum data rate of this transmission mode with CVT-R2 timing, it is close enough to be achieved with non-standard timings Features DisplayPort version 1.0 1.1–1.1a 1.2–1.2a 1.3 1.4–1.4a 2.0 Hot-pluggable Yes Yes Yes Yes Yes Yes Inline audio Yes Yes Yes Yes Yes Yes DisplayPort contentprotection (DPCP) DPCP 1.0[36]:§1.2.6 DPCP 1.0 DPCP 1.0 DPCP 1.0 DPCP 1.0 DPCP 1.0 High-bandwidth digitalcontent protection (HDCP) No HDCP 1.3[8]:§1.2.6 HDCP 1.3[37]:§1.2.6 HDCP 2.2[19] HDCP 2.2 HDCP 2.2 Dual-mode (DP++) No Yes Yes Yes Yes Yes Maximum DP++ bandwidth(TMDS Clock) — 4.95 Gbit/s(165 MHz) 9.00 Gbit/s(300 MHz) 18.00 Gbit/s(600 MHz) 18.00 Gbit/s(600 MHz) 18.00 Gbit/s(600 MHz) Stereoscopic 3D video No Yes Yes Yes Yes Yes Multi-stream transport (MST) No No Yes Yes Yes Yes High-dynamic-range video (HDR) No No No No Yes Yes Display stream compression (DSC) No No No No DSC 1.2 (DP 1.4)DSC 1.2a (DP 1.4a) DSC 1.2a Panel replay No No No No No Yes[40] DisplayPort dual-mode (DP++) This section needs additional citations for verification.

Please help improve this article by adding citations to reliable sources in this section. Unsourced material may be challenged and removed.Find sources: "DisplayPort" – news · newspapers · books · scholar · JSTOR (April 2022) (Learn how and when to remove this template message) Dual-mode DisplayPort logo Dual-mode pin mapping DisplayPort pins DVI/HDMI mode Main link lane 0 TMDS channel 2 Main link lane 1 TMDS channel 1 Main link lane 2 TMDS channel 0 Main link lane 3 TMDS clock AUX CH+ DDC clock AUX CH− DDC data DP_PWR DP_PWR Hot-plug detect Hot-plug detect Config 1 Cable adapter detect Config 2 CEC (HDMI only) DisplayPort Dual-Mode (DP++), also called Dual-Mode DisplayPort, is a standard which allows DisplayPort sources to use simple passive adapters to connect to HDMI or DVI displays. Dual-mode is an optional feature, so not all DisplayPort sources necessarily support DVI/HDMI passive adapters, though in practice nearly all devices do. Officially, the "DP++" logo should be used to indicate a DP port that supports dual-mode, but most modern devices do not use the logo. Devices which implement dual-mode will detect that a DVI or HDMI adapter is attached, and send DVI/HDMI TMDS signals instead of DisplayPort signals.

The original DisplayPort Dual-Mode standard (version 1.0), used in DisplayPort 1.1 devices, only supported TMDS clock speeds of up to 165 MHz (4.95 Gbit/s bandwidth). This is equivalent to HDMI 1.2, and is sufficient for up to 1920 × 1200 at 60 Hz. In 2013, VESA released the Dual-Mode 1.1 standard, which added support for up to a 300 MHz TMDS clock (9.00 Gbit/s bandwidth), and is used in newer DisplayPort 1.2 devices.

This is slightly less than the 340 MHz maximum of HDMI 1.4, and is sufficient for up to 1920 × 1080 at 120 Hz, 2560 × 1440 at 60 Hz, or 3840 × 2160 at 30 Hz. Older adapters, which were only capable of the 165 MHz speed, were retroactively termed "Type 1" adapters, with the new 300 MHz adapters being called "Type 2".[53] Dual-mode limitations A DisplayPort to DVI adapter after removing its enclosure. The chip on the board converts the voltage levels generated by the dual-mode DisplayPort device to be compatible with a DVI monitor. Limited adapter speed – Although the pinout and digital signal values transmitted by the DP port are identical to a native DVI/HDMI source, the signals are transmitted at DisplayPort's native voltage (3.3 V) instead of the 5 V used by DVI and HDMI. As a result, dual-mode adapters must contain a level-shifter circuit which changes the voltage. The presence of this circuit places a limit on how quickly the adapter can operate, and therefore newer adapters are required for each higher speed added to the standard. Unidirectional – Although the dual-mode standard specifies a method for DisplayPort sources to output DVI/HDMI signals using simple passive adapters, there is no counterpart standard to give DisplayPort displays the ability to receive DVI/HDMI input signals through passive adapters. As a result, DisplayPort displays can only receive native DisplayPort signals; any DVI or HDMI input signals must be converted to the DisplayPort format with an active conversion device. DVI and HDMI sources cannot be connected to DisplayPort displays using passive adapters. Single-link DVI only – Since DisplayPort dual-mode operates by using the pins of the DisplayPort connector to send DVI/HDMI signals, the 20-pin DisplayPort connector can only produce a single-link DVI signal (which uses 19 pins). A dual-link DVI signal uses 25 pins, and is therefore impossible to transmit natively from a DisplayPort connector through a passive adapter. Dual-link DVI signals can only be produced by converting from native DisplayPort output signals with an active conversion device. Unavailable on USB-C – The DisplayPort Alternate Mode specification for sending DisplayPort signals over a USB-C cable does not include support for the dual-mode protocol. As a result, DP-to-DVI and DP-to-HDMI passive adapters do not function when chained from a USB-C to DP adapter. Multi-Stream Transport (MST) Multi-Stream Transport is a feature first introduced in the DisplayPort 1.2 standard.

It allows multiple independent displays to be driven from a single DP port on the source devices by multiplexing several video streams into a single stream and sending it to a branch device, which demultiplexes the signal into the original streams. Branch devices are commonly found in the form of an MST hub, which plugs into a single DP input port and provides multiple outputs, but it can also be implemented on a display internally to provide a DP output port for daisy-chaining, effectively embedding a 2-port MST hub inside the display.[37]:Fig. 2-59[54] Theoretically, up to 63 displays can be supported,[37]:20 but the combined data rate requirements of all the displays cannot exceed the limits of a single DP port (17.28 Gbit/s for a DP 1.2 port, or 25.92 Gbit/s for a DP 1.3/1.4 port). In addition, the maximum number of links between the source and any device (i.e. the maximum length of a daisy-chain) is 7,[37]:§2.5.2 and the maximum number of physical output ports on each branch device (such as a hub) is 7.[37]:§2.5.1 With the release of MST, standard single-display operation has been retroactively named "SST" mode (Single-Stream Transport). Daisy-chaining is a feature that must be specifically supported by each intermediary display; not all DisplayPort 1.2 devices support it. Daisy-chaining requires a dedicated DisplayPort output port on the display. Standard DisplayPort input ports found on most displays cannot be used as a daisy-chain output. Only the last display in the daisy-chain does not need to support the feature specifically or have a DP output port. DisplayPort 1.1 displays can also be connected to MST hubs, and can be part of a DisplayPort daisy-chain if it is the last display in the chain.[37]:§2.5.1 The host system's software also needs to support MST for hubs or daisy-chains to work. While Microsoft Windows environments have full support for it, Apple operating systems currently do not support MST hubs or DisplayPort daisy-chaining as of macOS 10.15 ("Catalina").[55][56] DisplayPort-to-DVI and DisplayPort-to-HDMI adapters/cables may or may not function from an MST output port; support for this depends on the specific device.[citation needed] MST is supported by USB Type-C DisplayPort Alternate Mode, so standard DisplayPort daisy-chains and MST hubs do function from Type-C sources with a simple Type-C to DisplayPort adapter.[57] High dynamic range (HDR) Main article: High-dynamic-range television Support for HDR video was introduced in DisplayPort 1.4. It implements the CTA 861.3 standard for transport of static HDR metadata in EDID.[22] Content protection DisplayPort 1.0 includes optional DPCP (DisplayPort Content Protection) from Philips, which uses 128-bit AES encryption. It also features full authentication and session key establishment. Each encryption session is independent, and it has an independent revocation system. This portion of the standard is licensed separately. It also adds the ability to verify the proximity of the receiver and transmitter, a technique intended to ensure users are not bypassing the content protection system to send data out to distant, unauthorized users.[8]:§6 DisplayPort 1.1 added optional implementation of industry-standard 56-bit HDCP (High-bandwidth Digital Content Protection) revision 1.3, which requires separate licensing from the Digital Content Protection LLC.[8]:§1.2.6 DisplayPort 1.3 added support for HDCP 2.2, which is also used by HDMI 2.0.[19] Cost VESA, the creators of the DisplayPort standard, state that the standard is royalty-free to implement. However, in March 2015, MPEG LA issued a press release stating that a royalty rate of $0.20 per unit applies to DisplayPort products manufactured or sold in countries that are covered by one or more of the patents in the MPEG LA license pool, which includes patents from Hitachi Maxell, Philips, Lattice Semiconductor, Rambus, and Sony.[58][59] In response, VESA updated their DisplayPort FAQ page with the following statement:[60] MPEG LA is making claims that DisplayPort implementation requires a license and a royalty payment. It is important to note that these are only CLAIMS. Whether these CLAIMS are relevant will likely be decided in a US court. As of August 2019, VESA's official FAQ no longer contains a statement mentioning the MPEG LA royalty fees. While VESA does not charge any per-device royalty fees, VESA requires membership for access to said standards.[61] The minimum cost is presently $5,000 (or $10,000 depending on Annual Corporate Sales Revenue) annually.[62] Advantages over DVI, VGA and FPD-Link This article contains embedded lists that may be poorly defined, unverified or indiscriminate. Please help to clean it up to meet Wikipedia's quality standards.

Where appropriate, incorporate items into the main body of the article. (November 2010) In December 2010, several computer vendors and display makers including Intel, AMD, Dell, Lenovo, Samsung and LG announced they would begin phasing out FPD-Link, VGA, and DVI-I over the next few years, replacing them with DisplayPort and HDMI.[63][64][65] DisplayPort has several advantages over VGA, DVI, and FPD-Link.[66] Standard available to all VESA members[dubious – discuss] with an extensible standard to help broad adoption[67] Fewer lanes with embedded self-clock, reduced EMI with data scrambling and spread spectrum mode Based on a micro-packet protocol Allows easy expansion of the standard with multiple data types Flexible allocation of available bandwidth between audio and video Multiple video streams over single physical connection (version 1.2) Long-distance transmission over alternative physical media such as optical fiber (version 1.1a) High-resolution displays and multiple displays with a single connection, via a hub or daisy-chaining[68] HBR2 mode with 17.28 Gbit/s of effective video bandwidth allows four simultaneous 1080p60 displays (CEA-861 timings), two 2560 × 1600 × 30 bit @ 120 Hz (CVT-R timings), or 4K UHD @ 60 Hz[note 1] HBR3 mode with 25.92 Gbit/s of effective video bandwidth, using CVT-R2 timings, allows eight simultaneous 1080p displays (1920 × 1080) @ 60 Hz, stereoscopic 4K UHD (3840 × 2160) @ 120 Hz, or 5120 × 2880 @ 60 Hz each using 24 bit RGB, and up to 8K UHD (7680 × 4320) @ 60 Hz using 4:2:0 subsampling[69] Designed to work for internal chip-to-chip communication Aimed at replacing internal FPD-Link links to display panels with a unified link interface Compatible with low-voltage signaling used with sub-micron CMOS fabrication Can drive display panels directly, eliminating scaling and control circuits and allowing for cheaper and slimmer displays Link training with adjustable amplitude and preemphasis adapts to differing cable lengths and signal quality Reduced bandwidth transmission for 15-metre (49 ft) cable, at least 1920 × 1080p @ 60 Hz at 24 bits per pixel Full bandwidth transmission for 3 metres (9.8 ft) High-speed auxiliary channel for DDC, EDID, MCCS, DPMS, HDCP, adapter identification etc.

traffic Can be used for transmitting bi-directional USB, touch-panel data, CEC, etc. Self-latching connector Comparison with HDMI Although DisplayPort has much of the same functionality as HDMI, it is a complementary connection used in different scenarios.[70][71] A dual-mode DisplayPort port can emit an HDMI signal via a passive adapter.

As of 2008, HDMI Licensing, LLC charged an annual fee of US$10,000 to each high-volume manufacturer and a per-unit royalty rate of US$0.04 to US$0.15.[72][needs update] DisplayPort is royalty-free, but implementers thereof are not prevented from charging (royalty or otherwise) for that implementation.[73] DisplayPort 1.2 has more bandwidth at 21.6 Gbit/s[74] (17.28 Gbit/s with overhead removed) as opposed to HDMI 2.0's 18 Gbit/s[75] (14.4 Gbit/s with overhead removed). DisplayPort 1.3 raises that to 32.4 Gbit/s (25.92 Gbit/s with overhead removed), and HDMI 2.1 raises that up to 48 Gbit/s (42.67 Gbit/s with overhead removed), adding an additional TMDS link in place of clock lane. DisplayPort also has the ability to share this bandwidth with multiple streams of audio and video to separate devices. DisplayPort has historically had higher bandwidth than the HDMI standard available at the same time. The only exception is from HDMI 2.1 (2017) having higher transmission bandwidth @48 Gbit/s than DisplayPort 1.3 (2014) @32.4 Gbit/s. DisplayPort 2.0 (2019) retook transmission bandwidth superiority @80.0 Gbit/s. DisplayPort in native mode lacks some HDMI features such as Consumer Electronics Control (CEC) commands. The CEC bus allows linking multiple sources with a single display and controlling any of these devices from any remote.[8][76][77] DisplayPort 1.3 added the possibility of transmitting CEC commands over the AUX channel[78] From its very first version HDMI features CEC to support connecting multiple sources to a single display as is typical for a TV screen. The other way round, Multi-Stream Transport allows connecting multiple displays to a single computer source. This reflects the facts that HDMI originated from consumer electronics companies whereas DisplayPort is owned by VESA which started as an organization for computer standards. HDMI uses unique Vendor-Specific Block structure, which allows for features such as additional color spaces. However, these features can be defined by CEA EDID extensions.[79] Both HDMI and DisplayPort have published specification for transmitting their signal over the USB-C connector. For more details, see USB-C § Alternate Mode partner specifications. Market share Figures from IDC show that 5.1% of commercial desktops and 2.1% of commercial notebooks released in 2009 featured DisplayPort.[63] The main factor behind this was the phase-out of VGA, and that both Intel and AMD planned to stop building products with FPD-Link by 2013. Nearly 70% of LCD monitors sold in August 2014 in the US, UK, Germany, Japan, and China were equipped with HDMI/DisplayPort technology, up 7.5% on the year, according to Digitimes Research.[80] IHS Markit, an analytics firm, forecast that DisplayPort would surpass HDMI in 2019.[81] Companion standards Mini DisplayPort Main article: Mini DisplayPort Mini DisplayPort (mDP) is a standard announced by Apple in the fourth quarter of 2008.

Shortly after announcing Mini DisplayPort, Apple announced that it would license the connector technology with no fee. The following year, in early 2009, VESA announced that Mini DisplayPort would be included in the upcoming DisplayPort 1.2 specification. On 24 February 2011, Apple and Intel announced Thunderbolt, a successor to Mini DisplayPort which adds support for PCI Express data connections while maintaining backwards compatibility with Mini DisplayPort based peripherals.[82] Micro DisplayPort Micro DisplayPort would have targeted systems that need ultra-compact connectors, such as phones, tablets and ultra-portable notebook computers. This standard would have been physically smaller than the currently available Mini DisplayPort connectors. The standard was expected to be released by Q2 2014.[83] DDM Direct Drive Monitor (DDM) 1.0 standard was approved in December 2008.

It allows for controller-less monitors where the display panel is directly driven by the DisplayPort signal, although the available resolutions and color depth are limited to two-lane operation. Display Stream Compression Main article: Display Stream Compression Display Stream Compression (DSC) is a VESA-developed video compression algorithm designed to enable increased display resolutions and frame rates over existing physical interfaces, and make devices smaller and lighter, with longer battery life.[84] eDP Embedded DisplayPort (eDP) is a display panel interface standard for portable and embedded devices. It defines the signaling interface between graphics cards and integrated displays. The various revisions of eDP are based on existing DisplayPort standards. However, version numbers between the two standards are not interchangeable. For instance, eDP version 1.4 is based on DisplayPort 1.2, while eDP version 1.4a is based on DisplayPort 1.3. In practice, embedded DisplayPort has displaced LVDS as the predominant panel interface in modern laptops and modern smartphones. eDP 1.0 was adopted in December 2008.[85] It included advanced power-saving features such as seamless refresh rate switching. Version 1.1 was approved in October 2009 followed by version 1.1a in November 2009. Version 1.2 was approved in May 2010 and includes DisplayPort 1.2 HBR2 data rates, 120 Hz sequential color monitors, and a new display panel control protocol that works through the AUX channel.[12] Version 1.3 was published in February 2011; it includes a new optional Panel Self-Refresh (PSR) feature developed to save system power and further extend battery life in portable PC systems.[86] PSR mode allows the GPU to enter a power saving state in between frame updates by including framebuffer memory in the display panel controller.[12] Version 1.4 was released in February 2013; it reduces power consumption through partial-frame updates in PSR mode, regional backlight control, lower interface voltages, and additional link rates; the auxiliary channel supports multi-touch panel data to accommodate different form factors.[87] Version 1.4a was published in February 2015; the underlying DisplayPort version was updated to 1.3 in order to support HBR3 data rates, Display Stream Compression 1.1, Segmented Panel Displays, and partial updates for Panel Self-Refresh.[88] Version 1.4b was published in October 2015; its protocol refinements and clarifications are intended to enable adoption of eDP 1.4b in devices by mid-2016.[89] Version 1.5 was published in October 2021; adds new features and protocols, including enhanced support for Adaptive-Sync, that provide additional power savings and improved gaming and media playback performance.[90] iDP Internal DisplayPort (iDP) 1.0 was approved in April 2010. The iDP standard defines an internal link between a digital TV system on a chip controller and the display panel's timing controller.

It aims to replace currently used internal FPD-Link lanes with a DisplayPort connection.[91] iDP features a unique physical interface and protocols, which are not directly compatible with DisplayPort and are not applicable to external connection, however they enable very high resolution and refresh rates while providing simplicity and extensibility.[12] iDP features a non-variable 2.7 GHz clock and is nominally rated at 3.24 Gbit/s per lane, with up to sixteen lanes in a bank, resulting in a six-fold decrease in wiring requirements over FPD-Link for a 1080p24 signal; other data rates are also possible. iDP was built with simplicity in mind so doesn't have an AUX channel, content protection, or multiple streams; it does however have frame sequential and line interleaved stereo 3D.[12] PDMI Portable Digital Media Interface (PDMI) is an interconnection between docking stations/display devices and portable media players, which includes 2-lane DisplayPort v1.1a connection. It has been ratified in February 2010 as ANSI/CEA-2017-A. wDP Wireless DisplayPort (wDP) enables the bandwidth and feature set of DisplayPort 1.2 for cable-free applications operating in the 60 GHz radio band. It was announced in November 2010 by WiGig Alliance and VESA as a cooperative effort.[92] SlimPort A SlimPort-to-HDMI adapter, made by Analogix SlimPort, a brand of Analogix products,[93] complies with Mobility DisplayPort, also known as MyDP, which is an industry standard for a mobile audio/video Interface, providing connectivity from mobile devices to external displays and HDTVs. SlimPort implements the transmission of video up to 4K-UltraHD and up to eight channels of audio over the micro-USB connector to an external converter accessory or display device. SlimPort products support seamless connectivity to DisplayPort, HDMI and VGA displays.[94] The MyDP standard was released in June 2012,[95] and the first product to use SlimPort was Google's Nexus 4 smartphone.[96] Some LG smartphones in LG G series also adopted SlimPort. SlimPort is an alternative to Mobile High-Definition Link (MHL).[97][98] DisplayID Main article: DisplayID DisplayID is designed to replace the E-EDID standard. DisplayID features variable-length structures which encompass all existing EDID extensions as well as new extensions for 3D displays and embedded displays.

The latest version 1.3 (announced on 23 September 2013) adds enhanced support for tiled display topologies; it allows better identification of multiple video streams, and reports bezel size and locations.[99] As of December 2013, many current 4K displays use a tiled topology, but lack a standard way to report to the video source which tile is left and which is right. These early 4K displays, for manufacturing reasons, typically use two 1920×2160 panels laminated together and are currently generally treated as multiple-monitor setups.[100] DisplayID 1.3 also allows 8K display discovery, and has applications in stereo 3D, where multiple video streams are used. DockPort Main article: DockPort DockPort, formerly known as Lightning Bolt, is an extension to DisplayPort to include USB 3.0 data as well as power for charging portable devices from attached external displays. Originally developed by AMD and Texas Instruments, it has been announced as a VESA specification in 2014.[101] USB-C Main article: USB-C On 22 September 2014, VESA published the DisplayPort Alternate Mode on USB Type-C Connector Standard, a specification on how to send DisplayPort signals over the newly released USB-C connector. One, two or all four of the differential pairs that USB uses for the SuperSpeed bus can be configured dynamically to be used for DisplayPort lanes. In the first two cases, the connector still can carry a full SuperSpeed signal; in the latter case, at least a non-SuperSpeed signal is available. The DisplayPort AUX channel is also supported over the two sideband signals over the same connection; furthermore, USB Power Delivery according to the newly expanded USB-PD 2.0 specification is possible at the same time. This makes the Type-C connector a strict superset of the use-cases envisioned for DockPort, SlimPort, Mini and Micro DisplayPort.[102] VirtualLink Main article: VirtualLink VirtualLink is a proposal that allows the power, video, and data required to drive virtual reality headsets to be delivered over a single USB-C cable. Products A Dual-mode DisplayPort connector Since its introduction in 2006, DisplayPort has gained popularity within the computer industry and is featured on many graphic cards, displays, and notebook computers. Dell was the first company to introduce a consumer product with a DisplayPort connector, the Dell UltraSharp 3008WFP, which was released in January 2008.[103] Soon after, AMD and Nvidia released products to support the technology.

AMD included support in the Radeon HD 3000 series of graphics cards, while Nvidia first introduced support in the GeForce 9 series starting with the GeForce 9600 GT.[104][105] A Mini DisplayPort connector Later the same year, Apple introduced several products featuring a Mini DisplayPort.[106] The new connector – proprietary at the time – eventually became part of the DisplayPort standard, however Apple reserves the right to void the license should the licensee "commence an action for patent infringement against Apple".[107] In 2009, AMD followed suit with their Radeon HD 5000 Series of graphics cards, which featured the Mini DisplayPort on the Eyefinity versions in the series.[108] Nvidia launched NVS 810 with 8 Mini DisplayPort outputs on a single card on 4 November 2015.[109] Nvidia revealed the GeForce GTX 1080, the world's first graphics card with DisplayPort 1.4 support on 6 May 2016.[110] AMD followed with the Radeon RX 480 to support DisplayPort 1.3/1.4 on 29 June 2016.[111] The Radeon RX 400 Series will support DisplayPort 1.3 HBR and HDR10, dropping the DVI connector(s) in the reference board design. In February 2017, VESA and Qualcomm announced that DisplayPort Alt Mode video transport will be integrated into the Snapdragon 835 mobile chipset, which powers smartphones, VR/AR head-mounted displays, IP cameras, tablets and mobile PCs.[112] Support for DisplayPort Alternate Mode over USB-C See also: USB-C § Hardware support A Samsung Galaxy S8 plugged into a DeX docking station. Currently, DisplayPort is the most widely implemented alternate mode, and is used to provide video output on devices that do not have standard-size DisplayPort or HDMI ports, such as smartphones, tablets, and laptops. A USB-C multiport adapter converts the device's native video stream to DisplayPort/HDMI/VGA, allowing it to be displayed on an external display, such as a television set or computer monitor. Examples of devices that support DisplayPort Alternate Mode over USB-C include: MacBook, Chromebook Pixel, Surface Book 2, Samsung Galaxy Tab S4, iPad Pro (3rd generation), HTC 10/U Ultra/U11/U12+, Huawei Mate 10/20/30, LG V20/V30/V40*/V50, OnePlus 7 and newer, ROG Phone, Samsung Galaxy S8 and newer, Sony Xperia 1/5 etc.[113][114] Participating companies The following companies have participated in preparing the drafts of DisplayPort, eDP, iDP, DDM or DSC standards: Agilent Altera AMD Graphics Product Group Analogix[115] Apple Astrodesign BenQ Broadcom Corporation Chi Mei Optoelectronics Chrontel[116] Dell Display Labs Foxconn Electronics FuturePlus Systems Genesis Microchip[117] Gigabyte Technology Hardent Hewlett-Packard Hosiden Hirose Electric Group Intel intoPIX I-PEX Integrated Device Technology JAE Electronics Kawasaki Microelectronics (K-Micro) Keysight Technologies Lenovo LG Display Luxtera Molex NEC NVIDIA NXP Semiconductors Xi3 Corporation Parade Technologies Realtek Semiconductor Samsung[118] SMK STMicroelectronics Synaptics Inc. SyntheSys Research Inc. Teledyne LeCroy (QuantumData) Tektronix Texas Instruments TLi Tyco Electronics ViewSonic VTM The following companies have additionally announced their intention to implement DisplayPort, eDP or iDP: Acer ASRock[119] Biostar Chroma BlackBerry Circuit Assembly DataPro[120] Eizo Fujitsu Hall Research Technologies ITE Tech. Matrox Graphics Micro-Star International[121] MStar Semiconductor Novatek Microelectronics Corp. Palit Microsystems Ltd. Pioneer Corporation S3 Graphics Toshiba Philips Quantum Data Sparkle Computer Unigraf Xitrix See also HDBaseT HDMI List of video connectors Thunderbolt (interface) Notes ^ Dual-link DVI is limited in resolution and speed by the quality and therefore the bandwidth of the DVI cable, the quality of the transmitter, and the quality of the receiver; can only drive one monitor at a time; and cannot send audio data.

HDMI 1.3 and 1.4 are limited to effectively 8.16 Gbit/s or 340 MHz (though actual devices are limited to 225–300 MHz[citation needed]), and can only drive one monitor at a time. VGA connectors have no defined maximum resolution or speed, but their analog nature limits their bandwidth, though can provide long cabling only limited by appropriate shielding. References

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Retrieved 10 August 2009. ^ "DataPro DisplayPort Cables". ^ "MSI announces video adaptor with DisplayPort". 17 January 2008. Archived from the original on 19 December 2013. Retrieved 10 August 2009. External links DisplayPort – the official site operated by VESA Retrieved from " 2Display device For more information on 3D television, see 3D television. A boy studying with zSpace display, a type of 3D display A person wearing a virtual reality headset, a type of near-eye 3D display. A 3D display is a display device capable of conveying depth to the viewer. Many 3D displays are stereoscopic displays, which produce a basic 3D effect by means of stereopsis, but can cause eye strain and visual fatigue. Newer 3D displays such as holographic and light field displays produce a more realistic 3D effect by combining stereopsis and accurate focal length for the displayed content. Newer 3D displays in this manner cause less visual fatigue than classical stereoscopic displays. As of 2021, the most common type of 3D display is a stereoscopic display, which is the type of display used in almost all virtual reality equipment. 3D displays can be near-eye displays like in VR headsets, or they can be in a device further away from the eyes like a 3D-enabled mobile device or 3D movie theater.

The term “3D display” can also be used to refer to a volumetric display which may generate content that can be viewed from all angles. History The first 3D display was created by Sir Charles Wheatstone in 1832.[1] It was a stereoscopic display that had rudimentary ability for representing depth. Stereoscopic displays Main article: Stereoscopy Stereoscopic displays are commonly referred to as “stereo displays,” “stereo 3D displays,” “stereoscopic 3D displays,” or sometimes erroneously as just “3D displays.” The basic technique of stereo displays is to present offset images that are displayed separately to the left and right eye. Both of these 2D offset images are then combined in the brain to give the perception of 3D depth. Although the term "3D" is ubiquitously used, it is important to note that the presentation of dual 2D images is distinctly different from displaying a light field, and is also different from displaying an image in three-dimensional space. The most notable difference to real 3D displays is that the observer's head and eyes movements will not increase information about the 3D objects being displayed. For example, holographic displays do not have such limitations. It is an overstatement of capability to refer to dual 2D images as being "3D". The accurate term "stereoscopic" is more cumbersome than the common misnomer "3D", which has been entrenched after many decades of unquestioned misuse. Although most stereoscopic displays do not qualify as real 3D displays, all real 3D displays are often referred to as also stereoscopic displays because they meet the lower criteria of being stereoscopic as well. Based on the principles of stereopsis, described by Sir Charles Wheatstone in the 1830s, stereoscopic technology provides a different image to the viewer's left and right eyes. The following are some of the technical details and methodologies employed in some of the more notable stereoscopic systems that have been developed. Side-by-side images "The early bird catches the worm" Stereograph published in 1900 by North-Western View Co. of Baraboo, Wisconsin, digitally restored. Traditional stereoscopic photography consists of creating a 3D illusion starting from a pair of 2D images, a stereogram. The easiest way to enhance depth perception in the brain is to provide the eyes of the viewer with two different images, representing two perspectives of the same object, with a minor deviation exactly equal to the perspectives that both eyes naturally receive in binocular vision. If eyestrain and distortion are to be avoided, each of the two 2D images preferably should be presented to each eye of the viewer so that any object at infinite distance seen by the viewer should be perceived by that eye while it is oriented straight ahead, the viewer's eyes being neither crossed nor diverging. When the picture contains no object at infinite distance, such as a horizon or a cloud, the pictures should be spaced correspondingly closer together.

The side-by-side method is extremely simple to create, but it can be difficult or uncomfortable to view without optical aids. Stereoscope and stereographic cards Main article: Stereoscope A stereoscope is a device for viewing stereographic cards, which are cards that contain two separate images that are printed side by side to create the illusion of a three-dimensional image. Transparency viewers Main article: Slide viewer § Stereo slide viewer A View-Master Model E of the 1950s Pairs of stereo views printed on a transparent base are viewed by transmitted light.

One advantage of transparency viewing is the opportunity for a wider, more realistic dynamic range than is practical with prints on an opaque base; another is that a wider field of view may be presented since the images, being illuminated from the rear, may be placed much closer to the lenses. The practice of viewing film-based stereoscopic transparencies dates to at least as early as 1931, when Tru-Vue began to market sets of stereo views on strips of 35 mm film that were fed through a hand-held Bakelite viewer. In 1939, a modified and miniaturized variation of this technology, employing cardboard disks containing seven pairs of small Kodachrome color film transparencies, was introduced as the View-Master. Head-mounted displays Main articles: Head-mounted display and Virtual retinal display The user typically wears a helmet or glasses with two small LCD or OLED displays with magnifying lenses, one for each eye. The technology can be used to show stereo films, images or games. Head-mounted displays may also be coupled with head-tracking devices, allowing the user to "look around" the virtual world by moving their head, eliminating the need for a separate controller. Owing to rapid advancements in computer graphics and the continuing miniaturization of video and other equipment these devices are beginning to become available at more reasonable cost. Head-mounted or wearable glasses may be used to view a see-through image imposed upon the real world view, creating what is called augmented reality. This is done by reflecting the video images through partially reflective mirrors. The real world can be seen through the partial mirror. A recent development in holographic-waveguide or "waveguide-based optics" allows a stereoscopic images to be superimposed on real world without the uses of bulky reflective mirror.[2][3] Head-mounted projection displays Head-mounted projection displays (HMPD) is similar to head-mounted displays but with images projected to and displayed on a retroreflective screen, The advantage of this technology over head-mounted display is that the focusing and vergence issues didn't require fixing with corrective eye lenses. For image generation, Pico-projectors are used instead of LCD or OLED screens.[4][5] 3D glasses Active shutter systems Main article: Active shutter 3D system A pair of LCD shutter glasses used to view XpanD 3D films. The thick frames conceal the electronics and batteries. With the eclipse method, a shutter blocks light from each appropriate eye when the converse eye's image is projected on the screen. The display alternates between left and right images, and opens and closes the shutters in the glasses or viewer in synchronization with the images on the screen. This was the basis of the Teleview system which was used briefly in 1922.[6][7] A variation on the eclipse method is used in LCD shutter glasses. Glasses containing liquid crystal that will let light through in synchronization with the images on the cinema, television or computer screen, using the concept of alternate-frame sequencing.

This is the method used by nVidia, XpanD 3D, and earlier IMAX systems. A drawback of this method is the need for each person viewing to wear expensive, electronic glasses that must be synchronized with the display system using a wireless signal or attached wire. The shutter-glasses are heavier than most polarized glasses, though lighter models are no heavier than some sunglasses or deluxe polarized glasses.[8] However these systems do not require a silver screen for projected images. Liquid crystal light valves work by rotating light between two polarizing filters. Due to these internal polarizers, LCD shutter-glasses darken the display image of any LCD, plasma, or projector image source, which has the result that images appear dimmer and contrast is lower than for normal non-3D viewing. This is not necessarily a usage problem; for some types of displays which are already very bright with poor grayish black levels, LCD shutter glasses may actually improve the image quality. Anaglyph Main article: Anaglyph 3D The archetypal 3D glasses, with modern red and cyan color filters, similar to the red/green and red/blue lenses used to view early anaglyph films. In an anaglyph, the two images are superimposed in an additive light setting through two filters, one red and one cyan. In a subtractive light setting, the two images are printed in the same complementary colors on white paper. Glasses with colored filters in each eye separate the appropriate image by canceling the filter color out and rendering the complementary color black. A compensating technique, commonly known as Anachrome, uses a slightly more transparent cyan filter in the patented glasses associated with the technique. Process reconfigures the typical anaglyph image to have less parallax. An alternative to the usual red and cyan filter system of anaglyph is ColorCode 3-D, a patented anaglyph system which was invented in order to present an anaglyph image in conjunction with the NTSC television standard, in which the red channel is often compromised.

ColorCode uses the complementary colors of yellow and dark blue on-screen, and the colors of the glasses' lenses are amber and dark blue. Polarization systems Resembling sunglasses, RealD circular polarized glasses are now the standard for theatrical releases and theme park attractions. Main article: Polarized 3D system To present a stereoscopic picture, two images are projected superimposed onto the same screen through different polarizing filters. The viewer wears eyeglasses which also contain a pair of polarizing filters oriented differently (clockwise/counterclockwise with circular polarization or at 90 degree angles, usually 45 and 135 degrees,[9] with linear polarization). As each filter passes only that light which is similarly polarized and blocks the light polarized differently, each eye sees a different image. This is used to produce a three-dimensional effect by projecting the same scene into both eyes, but depicted from slightly different perspectives. Additionally, since both lenses have the same color, people with one dominant eye, where one eye is used more, are able to see the colors properly, previously negated by the separation of the two colors. Circular polarization has an advantage over linear polarization, in that the viewer does not need to have their head upright and aligned with the screen for the polarization to work properly. With linear polarization, turning the glasses sideways causes the filters to go out of alignment with the screen filters causing the image to fade and for each eye to see the opposite frame more easily. For circular polarization, the polarizing effect works regardless of how the viewer's head is aligned with the screen such as tilted sideways, or even upside down. The left eye will still only see the image intended for it, and vice versa, without fading or crosstalk. Polarized light reflected from an ordinary motion picture screen typically loses most of its polarization. So an expensive silver screen or aluminized screen with negligible polarization loss has to be used. All types of polarization will result in a darkening of the displayed image and poorer contrast compared to non-3D images. Light from lamps is normally emitted as a random collection of polarizations, while a polarization filter only passes a fraction of the light.

As a result, the screen image is darker. This darkening can be compensated by increasing the brightness of the projector light source. If the initial polarization filter is inserted between the lamp and the image generation element, the light intensity striking the image element is not any higher than normal without the polarizing filter, and overall image contrast transmitted to the screen is not affected. Interference filter technology Main article: Anaglyph 3D § Interference filter systems Dolby 3D uses specific wavelengths of red, green, and blue for the right eye, and different wavelengths of red, green, and blue for the left eye. Eyeglasses which filter out the very specific wavelengths allow the wearer to see a 3D image. This technology eliminates the expensive silver screens required for polarized systems such as RealD, which is the most common 3D display system in theaters. It does, however, require much more expensive glasses than the polarized systems. It is also known as spectral comb filtering or wavelength multiplex visualization The recently introduced Omega 3D/Panavision 3D system also uses this technology, though with a wider spectrum and more "teeth" to the "comb" (5 for each eye in the Omega/Panavision system). The use of more spectral bands per eye eliminates the need to color process the image, required by the Dolby system. Evenly dividing the visible spectrum between the eyes gives the viewer a more relaxed "feel" as the light energy and color balance is nearly 50-50. Like the Dolby system, the Omega system can be used with white or silver screens. But it can be used with either film or digital projectors, unlike the Dolby filters that are only used on a digital system with a color correcting processor provided by Dolby. The Omega/Panavision system also claims that their glasses are cheaper to manufacture than those used by Dolby.[10] In June 2012, the Omega 3D/Panavision 3D system was discontinued by DPVO Theatrical, who marketed it on behalf of Panavision, citing "challenging global economic and 3D market conditions".[citation needed] Although DPVO dissolved its business operations, Omega Optical continues promoting and selling 3D systems to non-theatrical markets. Omega Optical’s 3D system contains projection filters and 3D glasses. In addition to the passive stereoscopic 3D system, Omega Optical has produced enhanced anaglyph 3D glasses. The Omega’s red/cyan anaglyph glasses use complex metal oxide thin film coatings and high quality annealed glass optics. Other Main article: Stereoscopy The Pulfrich effect is a psychophysical percept wherein lateral motion of an object in the field of view is interpreted by the visual cortex as having a depth component, due to a relative difference in signal timings between the two eyes. Prismatic glasses make cross-viewing easier as well as over/under-viewing possible, examples include the KMQ viewer. Autostereoscopy Main article: Autostereoscopy The Nintendo 3DS uses parallax barrier autostereoscopy to display a 3D image. In this method, glasses are not necessary to see the stereoscopic image. Lenticular lens and parallax barrier technologies involve imposing two (or more) images on the same sheet, in narrow, alternating strips, and using a screen that either blocks one of the two images' strips (in the case of parallax barriers) or uses equally narrow lenses to bend the strips of image and make it appear to fill the entire image (in the case of lenticular prints). To produce the stereoscopic effect, the person must be positioned so that one eye sees one of the two images and the other sees the other. The optical principles of multiview auto-stereoscopy have been known for over a century.[11] Both images are projected onto a high-gain, corrugated screen which reflects light at acute angles. In order to see the stereoscopic image, the viewer must sit within a very narrow angle that is nearly perpendicular to the screen, limiting the size of the audience. Lenticular was used for theatrical presentation of numerous shorts in Russia from 1940 to 1948[12] and in 1946 for the feature-length film Robinzon Kruzo[13] Though its use in theatrical presentations has been rather limited, lenticular has been widely used for a variety of novelty items and has even been used in amateur 3D photography.[14][15] Recent use includes the Fujifilm FinePix Real 3D with an autostereoscopic display that was released in 2009. Other examples for this technology include autostereoscopic LCD displays on monitors, notebooks, TVs, mobile phones and gaming devices, such as the Nintendo 3DS. Volumetric display Main article: Volumetric display Volumetric 3D display Volumetric displays use some physical mechanism to display points of light within a volume.

Such displays use voxels instead of pixels. Volumetric displays include multiplanar displays, which have multiple display planes stacked up, and rotating panel displays, where a rotating panel sweeps out a volume. Other technologies have been developed to project light dots in the air above a device. An infrared laser is focused on the destination in space, generating a small bubble of plasma which emits visible light. Light field / holographic display A light field display tries to recreate a "light field" on the surface of the display. In contrast to a 2D display which shows a distinct color on each pixel, a light field display shows a distinct color on each pixel for each direction that the light ray emits to. This way, eyes from different positions will see different pictures on the display, creating parallax and thus creating a sense of 3D. A light field display is like a glass window, people see 3D objects behind the glass, despite that all light rays they see come from (through) the glass. The light field in front of the display can be created in two ways: 1) by emitting different light rays in different directions at each point on the display; 2) by recreating a wavefront in front of the display. Displays using the first method are called ray-based or light field displays. Displays using the second method are called wavefront-based or holographic displays. Wavefront-based displays work in the same way as holograms. Compared to ray-based displays, a wavefront-based display not only reconstructs the light field, but also reconstructs the curvature of the plane waves, and the phase differences of the waves in different directions.[16] Integral photography is one of the ray-based methods with full-parallax information. However, there are also ray-based techniques developed with horizontal-parallax-only.[16] Holographic displays Main articles: Holographic display and Computer-generated holography Holographic display is a display technology that has the ability to provide all four eye mechanisms: binocular disparity, motion parallax, accommodation and convergence. The 3D objects can be viewed without wearing any special glasses and no visual fatigue will be caused to human eyes. In 2013, a Silicon valley Company LEIA Inc started manufacturing holographic displays well suited for mobile devices (watches, smartphones or tablets) using a multi-directional backlight and allowing a wide full-parallax angle view to see 3D content without the need of glasses.[17] Their first product was part of a mobile phone (Red Hydrogen One) and later on in their own Android tablet.[citation needed] Integral imaging Main article: Integral imaging Integral imaging is an autostereoscopic or multiscopic 3D display, meaning that it displays a 3D image without the use of special glasses on the part of the viewer. It achieves this by placing an array of microlenses (similar to a lenticular lens) in front of the image, where each lens looks different depending on viewing angle.

Thus rather than displaying a 2D image that looks the same from every direction, it reproduces a 3D light field, creating stereo images that exhibit parallax when the viewer moves. Compressive light field displays A new display technology called "compressive light field" is being developed. These prototype displays use layered LCD panels and compression algorithms at the time of display. Designs include dual[18] and multilayer[19][20][21] devices that are driven by algorithms such as computed tomography and Non-negative matrix factorization and non-negative tensor factorization. Problems Each of these display technologies can be seen to have limitations, whether the location of the viewer, cumbersome or unsightly equipment or great cost. The display of artifact-free 3D images remains difficult.[citation needed] See also Autostereogram Wiggle stereoscopy References

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A 3D display is a display device capable of conveying depth to the viewer. Many 3D displays are stereoscopic displays, which produce a basic 3D effect by means of stereopsis, but can cause eye strain and visual fatigue. Newer 3D displays such as holographic and light field displays produce a more realistic 3D effect by combining stereopsis and accurate focal length for the displayed content. Newer 3D displays in this manner cause less visual fatigue than classical stereoscopic displays.

As of 2021, the most common type of 3D display is a stereoscopic display, which is the type of display used in almost all virtual reality equipment. 3D displays can be near-eye displays like in VR headsets, or they can be in a device further away from the eyes like a 3D-enabled mobile device or 3D movie theater. The term “3D display” can also be used to refer to a volumetric display which may generate content that can be viewed from all angles. History The first 3D display was created by Sir Charles Wheatstone in 1832.[1] It was a stereoscopic display that had rudimentary ability for representing depth. Stereoscopic displays Main article: Stereoscopy Stereoscopic displays are commonly referred to as “stereo displays,” “stereo 3D displays,” “stereoscopic 3D displays,” or sometimes erroneously as just “3D displays.” The basic technique of stereo displays is to present offset images that are displayed separately to the left and right eye. Both of these 2D offset images are then combined in the brain to give the perception of 3D depth. Although the term "3D" is ubiquitously used, it is important to note that the presentation of dual 2D images is distinctly different from displaying a light field, and is also different from displaying an image in three-dimensional space. The most notable difference to real 3D displays is that the observer's head and eyes movements will not increase information about the 3D objects being displayed. For example, holographic displays do not have such limitations. It is an overstatement of capability to refer to dual 2D images as being "3D". The accurate term "stereoscopic" is more cumbersome than the common misnomer "3D", which has been entrenched after many decades of unquestioned misuse. Although most stereoscopic displays do not qualify as real 3D displays, all real 3D displays are often referred to as also stereoscopic displays because they meet the lower criteria of being stereoscopic as well. Based on the principles of stereopsis, described by Sir Charles Wheatstone in the 1830s, stereoscopic technology provides a different image to the viewer's left and right eyes. The following are some of the technical details and methodologies employed in some of the more notable stereoscopic systems that have been developed. Side-by-side images "The early bird catches the worm" Stereograph published in 1900 by North-Western View Co. of Baraboo, Wisconsin, digitally restored. Traditional stereoscopic photography consists of creating a 3D illusion starting from a pair of 2D images, a stereogram. The easiest way to enhance depth perception in the brain is to provide the eyes of the viewer with two different images, representing two perspectives of the same object, with a minor deviation exactly equal to the perspectives that both eyes naturally receive in binocular vision. If eyestrain and distortion are to be avoided, each of the two 2D images preferably should be presented to each eye of the viewer so that any object at infinite distance seen by the viewer should be perceived by that eye while it is oriented straight ahead, the viewer's eyes being neither crossed nor diverging. When the picture contains no object at infinite distance, such as a horizon or a cloud, the pictures should be spaced correspondingly closer together.

The side-by-side method is extremely simple to create, but it can be difficult or uncomfortable to view without optical aids. Stereoscope and stereographic cards Main article: Stereoscope A stereoscope is a device for viewing stereographic cards, which are cards that contain two separate images that are printed side by side to create the illusion of a three-dimensional image. Transparency viewers Main article: Slide viewer § Stereo slide viewer A View-Master Model E of the 1950s Pairs of stereo views printed on a transparent base are viewed by transmitted light. One advantage of transparency viewing is the opportunity for a wider, more realistic dynamic range than is practical with prints on an opaque base; another is that a wider field of view may be presented since the images, being illuminated from the rear, may be placed much closer to the lenses. The practice of viewing film-based stereoscopic transparencies dates to at least as early as 1931, when Tru-Vue began to market sets of stereo views on strips of 35 mm film that were fed through a hand-held Bakelite viewer. In 1939, a modified and miniaturized variation of this technology, employing cardboard disks containing seven pairs of small Kodachrome color film transparencies, was introduced as the View-Master. Head-mounted displays Main articles: Head-mounted display and Virtual retinal display The user typically wears a helmet or glasses with two small LCD or OLED displays with magnifying lenses, one for each eye. The technology can be used to show stereo films, images or games. Head-mounted displays may also be coupled with head-tracking devices, allowing the user to "look around" the virtual world by moving their head, eliminating the need for a separate controller.

Owing to rapid advancements in computer graphics and the continuing miniaturization of video and other equipment these devices are beginning to become available at more reasonable cost. Head-mounted or wearable glasses may be used to view a see-through image imposed upon the real world view, creating what is called augmented reality. This is done by reflecting the video images through partially reflective mirrors. The real world can be seen through the partial mirror. A recent development in holographic-waveguide or "waveguide-based optics" allows a stereoscopic images to be superimposed on real world without the uses of bulky reflective mirror.[2][3] Head-mounted projection displays Head-mounted projection displays (HMPD) is similar to head-mounted displays but with images projected to and displayed on a retroreflective screen, The advantage of this technology over head-mounted display is that the focusing and vergence issues didn't require fixing with corrective eye lenses. For image generation, Pico-projectors are used instead of LCD or OLED screens.[4][5] 3D glasses Active shutter systems Main article: Active shutter 3D system A pair of LCD shutter glasses used to view XpanD 3D films. The thick frames conceal the electronics and batteries. With the eclipse method, a shutter blocks light from each appropriate eye when the converse eye's image is projected on the screen. The display alternates between left and right images, and opens and closes the shutters in the glasses or viewer in synchronization with the images on the screen. This was the basis of the Teleview system which was used briefly in 1922.[6][7] A variation on the eclipse method is used in LCD shutter glasses. Glasses containing liquid crystal that will let light through in synchronization with the images on the cinema, television or computer screen, using the concept of alternate-frame sequencing. This is the method used by nVidia, XpanD 3D, and earlier IMAX systems. A drawback of this method is the need for each person viewing to wear expensive, electronic glasses that must be synchronized with the display system using a wireless signal or attached wire. The shutter-glasses are heavier than most polarized glasses, though lighter models are no heavier than some sunglasses or deluxe polarized glasses.[8] However these systems do not require a silver screen for projected images. Liquid crystal light valves work by rotating light between two polarizing filters. Due to these internal polarizers, LCD shutter-glasses darken the display image of any LCD, plasma, or projector image source, which has the result that images appear dimmer and contrast is lower than for normal non-3D viewing. This is not necessarily a usage problem; for some types of displays which are already very bright with poor grayish black levels, LCD shutter glasses may actually improve the image quality. Anaglyph Main article: Anaglyph 3D The archetypal 3D glasses, with modern red and cyan color filters, similar to the red/green and red/blue lenses used to view early anaglyph films. In an anaglyph, the two images are superimposed in an additive light setting through two filters, one red and one cyan. In a subtractive light setting, the two images are printed in the same complementary colors on white paper. Glasses with colored filters in each eye separate the appropriate image by canceling the filter color out and rendering the complementary color black. A compensating technique, commonly known as Anachrome, uses a slightly more transparent cyan filter in the patented glasses associated with the technique.

Process reconfigures the typical anaglyph image to have less parallax. An alternative to the usual red and cyan filter system of anaglyph is ColorCode 3-D, a patented anaglyph system which was invented in order to present an anaglyph image in conjunction with the NTSC television standard, in which the red channel is often compromised. ColorCode uses the complementary colors of yellow and dark blue on-screen, and the colors of the glasses' lenses are amber and dark blue. Polarization systems Resembling sunglasses, RealD circular polarized glasses are now the standard for theatrical releases and theme park attractions. Main article: Polarized 3D system To present a stereoscopic picture, two images are projected superimposed onto the same screen through different polarizing filters. The viewer wears eyeglasses which also contain a pair of polarizing filters oriented differently (clockwise/counterclockwise with circular polarization or at 90 degree angles, usually 45 and 135 degrees,[9] with linear polarization). As each filter passes only that light which is similarly polarized and blocks the light polarized differently, each eye sees a different image. This is used to produce a three-dimensional effect by projecting the same scene into both eyes, but depicted from slightly different perspectives.

Additionally, since both lenses have the same color, people with one dominant eye, where one eye is used more, are able to see the colors properly, previously negated by the separation of the two colors. Circular polarization has an advantage over linear polarization, in that the viewer does not need to have their head upright and aligned with the screen for the polarization to work properly. With linear polarization, turning the glasses sideways causes the filters to go out of alignment with the screen filters causing the image to fade and for each eye to see the opposite frame more easily.

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Autostereoscopy Main article: Autostereoscopy The Nintendo 3DS uses parallax barrier autostereoscopy to display a 3D image. In this method, glasses are not necessary to see the stereoscopic image. Lenticular lens and parallax barrier technologies involve imposing two (or more) images on the same sheet, in narrow, alternating strips, and using a screen that either blocks one of the two images' strips (in the case of parallax barriers) or uses equally narrow lenses to bend the strips of image and make it appear to fill the entire image (in the case of lenticular prints). To produce the stereoscopic effect, the person must be positioned so that one eye sees one of the two images and the other sees the other. The optical principles of multiview auto-stereoscopy have been known for over a century.[11] Both images are projected onto a high-gain, corrugated screen which reflects light at acute angles. In order to see the stereoscopic image, the viewer must sit within a very narrow angle that is nearly perpendicular to the screen, limiting the size of the audience. Lenticular was used for theatrical presentation of numerous shorts in Russia from 1940 to 1948[12] and in 1946 for the feature-length film Robinzon Kruzo[13] Though its use in theatrical presentations has been rather limited, lenticular has been widely used for a variety of novelty items and has even been used in amateur 3D photography.[14][15] Recent use includes the Fujifilm FinePix Real 3D with an autostereoscopic display that was released in 2009. Other examples for this technology include autostereoscopic LCD displays on monitors, notebooks, TVs, mobile phones and gaming devices, such as the Nintendo 3DS. Volumetric display Main article: Volumetric display Volumetric 3D display Volumetric displays use some physical mechanism to display points of light within a volume. Such displays use voxels instead of pixels. Volumetric displays include multiplanar displays, which have multiple display planes stacked up, and rotating panel displays, where a rotating panel sweeps out a volume. Other technologies have been developed to project light dots in the air above a device. An infrared laser is focused on the destination in space, generating a small bubble of plasma which emits visible light.

Light field / holographic display A light field display tries to recreate a "light field" on the surface of the display.

In contrast to a 2D display which shows a distinct color on each pixel, a light field display shows a distinct color on each pixel for each direction that the light ray emits to. This way, eyes from different positions will see different pictures on the display, creating parallax and thus creating a sense of 3D. A light field display is like a glass window, people see 3D objects behind the glass, despite that all light rays they see come from (through) the glass. The light field in front of the display can be created in two ways: 1) by emitting different light rays in different directions at each point on the display; 2) by recreating a wavefront in front of the display. Displays using the first method are called ray-based or light field displays. Displays using the second method are called wavefront-based or holographic displays. Wavefront-based displays work in the same way as holograms. Compared to ray-based displays, a wavefront-based display not only reconstructs the light field, but also reconstructs the curvature of the plane waves, and the phase differences of the waves in different directions.[16] Integral photography is one of the ray-based methods with full-parallax information.

However, there are also ray-based techniques developed with horizontal-parallax-only.[16] Holographic displays Main articles: Holographic display and Computer-generated holography Holographic display is a display technology that has the ability to provide all four eye mechanisms: binocular disparity, motion parallax, accommodation and convergence. The 3D objects can be viewed without wearing any special glasses and no visual fatigue will be caused to human eyes. In 2013, a Silicon valley Company LEIA Inc started manufacturing holographic displays well suited for mobile devices (watches, smartphones or tablets) using a multi-directional backlight and allowing a wide full-parallax angle view to see 3D content without the need of glasses.[17] Their first product was part of a mobile phone (Red Hydrogen One) and later on in their own Android tablet.[citation needed] Integral imaging Main article: Integral imaging Integral imaging is an autostereoscopic or multiscopic 3D display, meaning that it displays a 3D image without the use of special glasses on the part of the viewer.

It achieves this by placing an array of microlenses (similar to a lenticular lens) in front of the image, where each lens looks different depending on viewing angle. Thus rather than displaying a 2D image that looks the same from every direction, it reproduces a 3D light field, creating stereo images that exhibit parallax when the viewer moves.

Compressive light field displays A new display technology called "compressive light field" is being developed. These prototype displays use layered LCD panels and compression algorithms at the time of display. Designs include dual[18] and multilayer[19][20][21] devices that are driven by algorithms such as computed tomography and Non-negative matrix factorization and non-negative tensor factorization.

Problems Each of these display technologies can be seen to have limitations, whether the location of the viewer, cumbersome or unsightly equipment or great cost. The display of artifact-free 3D images remains difficult.[citation needed] See also Autostereogram Wiggle stereoscopy References

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"Tensor Displays: Compressive Light Field Synthesis using Multilayer Displays with Directional Backlighting". ACM Transactions on Graphics (SIGGRAPH). Retrieved from " 4Display device For more information on 3D television, see 3D television. A boy studying with zSpace display, a type of 3D display A person wearing a virtual reality headset, a type of near-eye 3D display. A 3D display is a display device capable of conveying depth to the viewer. Many 3D displays are stereoscopic displays, which produce a basic 3D effect by means of stereopsis, but can cause eye strain and visual fatigue. Newer 3D displays such as holographic and light field displays produce a more realistic 3D effect by combining stereopsis and accurate focal length for the displayed content. Newer 3D displays in this manner cause less visual fatigue than classical stereoscopic displays. As of 2021, the most common type of 3D display is a stereoscopic display, which is the type of display used in almost all virtual reality equipment. 3D displays can be near-eye displays like in VR headsets, or they can be in a device further away from the eyes like a 3D-enabled mobile device or 3D movie theater. The term “3D display” can also be used to refer to a volumetric display which may generate content that can be viewed from all angles. History The first 3D display was created by Sir Charles Wheatstone in 1832.[1]

It was a stereoscopic display that had rudimentary ability for representing depth. Stereoscopic displays Main article: Stereoscopy Stereoscopic displays are commonly referred to as “stereo displays,” “stereo 3D displays,” “stereoscopic 3D displays,” or sometimes erroneously as just “3D displays.” The basic technique of stereo displays is to present offset images that are displayed separately to the left and right eye. Both of these 2D offset images are then combined in the brain to give the perception of 3D depth. Although the term "3D" is ubiquitously used, it is important to note that the presentation of dual 2D images is distinctly different from displaying a light field, and is also different from displaying an image in three-dimensional space. The most notable difference to real 3D displays is that the observer's head and eyes movements will not increase information about the 3D objects being displayed. For example, holographic displays do not have such limitations. It is an overstatement of capability to refer to dual 2D images as being "3D". The accurate term "stereoscopic" is more cumbersome than the common misnomer "3D", which has been entrenched after many decades of unquestioned misuse. Although most stereoscopic displays do not qualify as real 3D displays, all real 3D displays are often referred to as also stereoscopic displays because they meet the lower criteria of being stereoscopic as well. Based on the principles of stereopsis, described by Sir Charles Wheatstone in the 1830s, stereoscopic technology provides a different image to the viewer's left and right eyes. The following are some of the technical details and methodologies employed in some of the more notable stereoscopic systems that have been developed. Side-by-side images "The early bird catches the worm" Stereograph published in 1900 by North-Western View Co. of Baraboo, Wisconsin, digitally restored. Traditional stereoscopic photography consists of creating a 3D illusion starting from a pair of 2D images, a stereogram. The easiest way to enhance depth perception in the brain is to provide the eyes of the viewer with two different images, representing two perspectives of the same object, with a minor deviation exactly equal to the perspectives that both eyes naturally receive in binocular vision. If eyestrain and distortion are to be avoided, each of the two 2D images preferably should be presented to each eye of the viewer so that any object at infinite distance seen by the viewer should be perceived by that eye while it is oriented straight ahead, the viewer's eyes being neither crossed nor diverging. When the picture contains no object at infinite distance, such as a horizon or a cloud, the pictures should be spaced correspondingly closer together. The side-by-side method is extremely simple to create, but it can be difficult or uncomfortable to view without optical aids. Stereoscope and stereographic cards Main article: Stereoscope A stereoscope is a device for viewing stereographic cards, which are cards that contain two separate images that are printed side by side to create the illusion of a three-dimensional image.

Transparency viewers Main article: Slide viewer § Stereo slide viewer A View-Master Model E of the 1950s Pairs of stereo views printed on a transparent base are viewed by transmitted light.

One advantage of transparency viewing is the opportunity for a wider, more realistic dynamic range than is practical with prints on an opaque base; another is that a wider field of view may be presented since the images, being illuminated from the rear, may be placed much closer to the lenses. The practice of viewing film-based stereoscopic transparencies dates to at least as early as 1931, when Tru-Vue began to market sets of stereo views on strips of 35 mm film that were fed through a hand-held Bakelite viewer. In 1939, a modified and miniaturized variation of this technology, employing cardboard disks containing seven pairs of small Kodachrome color film transparencies, was introduced as the View-Master. Head-mounted displays Main articles: Head-mounted display and Virtual retinal display The user typically wears a helmet or glasses with two small LCD or OLED displays with magnifying lenses, one for each eye. The technology can be used to show stereo films, images or games.

Head-mounted displays may also be coupled with head-tracking devices, allowing the user to "look around" the virtual world by moving their head, eliminating the need for a separate controller. Owing to rapid advancements in computer graphics and the continuing miniaturization of video and other equipment these devices are beginning to become available at more reasonable cost. Head-mounted or wearable glasses may be used to view a see-through image imposed upon the real world view, creating what is called augmented reality. This is done by reflecting the video images through partially reflective mirrors.

The real world can be seen through the partial mirror.

A recent development in holographic-waveguide or "waveguide-based optics" allows a stereoscopic images to be superimposed on real world without the uses of bulky reflective mirror.[2][3] Head-mounted projection displays Head-mounted projection displays (HMPD) is similar to head-mounted displays but with images projected to and displayed on a retroreflective screen, The advantage of this technology over head-mounted display is that the focusing and vergence issues didn't require fixing with corrective eye lenses. For image generation, Pico-projectors are used instead of LCD or OLED screens.[4][5] 3D glasses Active shutter systems Main article: Active shutter 3D system A pair of LCD shutter glasses used to view XpanD 3D films. The thick frames conceal the electronics and batteries.

With the eclipse method, a shutter blocks light from each appropriate eye when the converse eye's image is projected on the screen. The display alternates between left and right images, and opens and closes the shutters in the glasses or viewer in synchronization with the images on the screen. This was the basis of the Teleview system which was used briefly in 1922.[6][7] A variation on the eclipse method is used in LCD shutter glasses. Glasses containing liquid crystal that will let light through in synchronization with the images on the cinema, television or computer screen, using the concept of alternate-frame sequencing. This is the method used by nVidia, XpanD 3D, and earlier IMAX systems. A drawback of this method is the need for each person viewing to wear expensive, electronic glasses that must be synchronized with the display system using a wireless signal or attached wire. The shutter-glasses are heavier than most polarized glasses, though lighter models are no heavier than some sunglasses or deluxe polarized glasses.[8] However these systems do not require a silver screen for projected images. Liquid crystal light valves work by rotating light between two polarizing filters. Due to these internal polarizers, LCD shutter-glasses darken the display image of any LCD, plasma, or projector image source, which has the result that images appear dimmer and contrast is lower than for normal non-3D viewing. This is not necessarily a usage problem; for some types of displays which are already very bright with poor grayish black levels, LCD shutter glasses may actually improve the image quality. Anaglyph Main article: Anaglyph 3D The archetypal 3D glasses, with modern red and cyan color filters, similar to the red/green and red/blue lenses used to view early anaglyph films. In an anaglyph, the two images are superimposed in an additive light setting through two filters, one red and one cyan. In a subtractive light setting, the two images are printed in the same complementary colors on white paper. Glasses with colored filters in each eye separate the appropriate image by canceling the filter color out and rendering the complementary color black. A compensating technique, commonly known as Anachrome, uses a slightly more transparent cyan filter in the patented glasses associated with the technique. Process reconfigures the typical anaglyph image to have less parallax.

An alternative to the usual red and cyan filter system of anaglyph is ColorCode 3-D, a patented anaglyph system which was invented in order to present an anaglyph image in conjunction with the NTSC television standard, in which the red channel is often compromised. ColorCode uses the complementary colors of yellow and dark blue on-screen, and the colors of the glasses' lenses are amber and dark blue. Polarization systems Resembling sunglasses, RealD circular polarized glasses are now the standard for theatrical releases and theme park attractions.

Main article: Polarized 3D system To present a stereoscopic picture, two images are projected superimposed onto the same screen through different polarizing filters. The viewer wears eyeglasses which also contain a pair of polarizing filters oriented differently (clockwise/counterclockwise with circular polarization or at 90 degree angles, usually 45 and 135 degrees,[9] with linear polarization). As each filter passes only that light which is similarly polarized and blocks the light polarized differently, each eye sees a different image. This is used to produce a three-dimensional effect by projecting the same scene into both eyes, but depicted from slightly different perspectives. Additionally, since both lenses have the same color, people with one dominant eye, where one eye is used more, are able to see the colors properly, previously negated by the separation of the two colors.

Circular polarization has an advantage over linear polarization, in that the viewer does not need to have their head upright and aligned with the screen for the polarization to work properly. With linear polarization, turning the glasses sideways causes the filters to go out of alignment with the screen filters causing the image to fade and for each eye to see the opposite frame more easily. For circular polarization, the polarizing effect works regardless of how the viewer's head is aligned with the screen such as tilted sideways, or even upside down. The left eye will still only see the image intended for it, and vice versa, without fading or crosstalk. Polarized light reflected from an ordinary motion picture screen typically loses most of its polarization. So an expensive silver screen or aluminized screen with negligible polarization loss has to be used. All types of polarization will result in a darkening of the displayed image and poorer contrast compared to non-3D images. Light from lamps is normally emitted as a random collection of polarizations, while a polarization filter only passes a fraction of the light. As a result, the screen image is darker. This darkening can be compensated by increasing the brightness of the projector light source. If the initial polarization filter is inserted between the lamp and the image generation element, the light intensity striking the image element is not any higher than normal without the polarizing filter, and overall image contrast transmitted to the screen is not affected. Interference filter technology Main article: Anaglyph 3D § Interference filter systems Dolby 3D uses specific wavelengths of red, green, and blue for the right eye, and different wavelengths of red, green, and blue for the left eye. Eyeglasses which filter out the very specific wavelengths allow the wearer to see a 3D image.

This technology eliminates the expensive silver screens required for polarized systems such as RealD, which is the most common 3D display system in theaters. It does, however, require much more expensive glasses than the polarized systems. It is also known as spectral comb filtering or wavelength multiplex visualization The recently introduced Omega 3D/Panavision 3D system also uses this technology, though with a wider spectrum and more "teeth" to the "comb" (5 for each eye in the Omega/Panavision system). The use of more spectral bands per eye eliminates the need to color process the image, required by the Dolby system. Evenly dividing the visible spectrum between the eyes gives the viewer a more relaxed "feel" as the light energy and color balance is nearly 50-50.

Like the Dolby system, the Omega system can be used with white or silver screens. But it can be used with either film or digital projectors, unlike the Dolby filters that are only used on a digital system with a color correcting processor provided by Dolby. The Omega/Panavision system also claims that their glasses are cheaper to manufacture than those used by Dolby.[10] In June 2012, the Omega 3D/Panavision 3D system was discontinued by DPVO Theatrical, who marketed it on behalf of Panavision, citing "challenging global economic and 3D market conditions".[citation needed] Although DPVO dissolved its business operations, Omega Optical continues promoting and selling 3D systems to non-theatrical markets.

Omega Optical’s 3D system contains projection filters and 3D glasses. In addition to the passive stereoscopic 3D system, Omega Optical has produced enhanced anaglyph 3D glasses. The Omega’s red/cyan anaglyph glasses use complex metal oxide thin film coatings and high quality annealed glass optics. Other Main article: Stereoscopy The Pulfrich effect is a psychophysical percept wherein lateral motion of an object in the field of view is interpreted by the visual cortex as having a depth component, due to a relative difference in signal timings between the two eyes. Prismatic glasses make cross-viewing easier as well as over/under-viewing possible, examples include the KMQ viewer.

Autostereoscopy Main article: Autostereoscopy The Nintendo 3DS uses parallax barrier autostereoscopy to display a 3D image. In this method, glasses are not necessary to see the stereoscopic image. Lenticular lens and parallax barrier technologies involve imposing two (or more) images on the same sheet, in narrow, alternating strips, and using a screen that either blocks one of the two images' strips (in the case of parallax barriers) or uses equally narrow lenses to bend the strips of image and make it appear to fill the entire image (in the case of lenticular prints). To produce the stereoscopic effect, the person must be positioned so that one eye sees one of the two images and the other sees the other. The optical principles of multiview auto-stereoscopy have been known for over a century.[11] Both images are projected onto a high-gain, corrugated screen which reflects light at acute angles. In order to see the stereoscopic image, the viewer must sit within a very narrow angle that is nearly perpendicular to the screen, limiting the size of the audience. Lenticular was used for theatrical presentation of numerous shorts in Russia from 1940 to 1948[12] and in 1946 for the feature-length film Robinzon Kruzo[13] Though its use in theatrical presentations has been rather limited, lenticular has been widely used for a variety of novelty items and has even been used in amateur 3D photography.[14][15] Recent use includes the Fujifilm FinePix Real 3D with an autostereoscopic display that was released in 2009. Other examples for this technology include autostereoscopic LCD displays on monitors, notebooks, TVs, mobile phones and gaming devices, such as the Nintendo 3DS. Volumetric display Main article: Volumetric display Volumetric 3D display Volumetric displays use some physical mechanism to display points of light within a volume. Such displays use voxels instead of pixels. Volumetric displays include multiplanar displays, which have multiple display planes stacked up, and rotating panel displays, where a rotating panel sweeps out a volume.

Other technologies have been developed to project light dots in the air above a device. An infrared laser is focused on the destination in space, generating a small bubble of plasma which emits visible light. Light field / holographic display A light field display tries to recreate a "light field" on the surface of the display. In contrast to a 2D display which shows a distinct color on each pixel, a light field display shows a distinct color on each pixel for each direction that the light ray emits to. This way, eyes from different positions will see different pictures on the display, creating parallax and thus creating a sense of 3D.

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