DisplayPort Technical Overview

IEEE International Conference on Consumer Electronics (ICCE)

Advances & Challenges in HD Interconnects

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DisplayPort Topics

- Quick Overview of Standard
- DisplayPort vs. existing standards
- Layered Protocol Approach
- Physical and Protocol Layers
- System Capabilities
- Usage Examples
- Future Developments

DisplayPort Quick Overview

Next Generation Display Interface for Personal Computer Products

- VGA and DVI are to be replaced by DisplayPort
  - The PC industry plans to phase out VGA and DVI over the next few years – DisplayPort will serve as the new interface for PC monitors and projectors
  - Now integrated into all main-stream GPU's and integrated GPU chip sets – DP receptacles appearing on new PC's and notebooks

- Being applied to other interface applications
  - Embedded DisplayPort (eDP) is the new interface for internal display panels, replacing LVDS
  - DisplayPort is being enabled in hand-held applications
    - The scalable electrical interface serves small and large devices and displays
    - DisplayPort is included in the PDMI (CE 2017-A) standard

DisplayPort Advantages for the Consumer

- Higher display performance
  - Resolution (up to 4K x 2K at 60 FPS and 24 bpp)
  - Refresh rate (up to 240 FPS for 1080p at 24 bpp)
  - Color Depth (up to 48 bpp, even at 2560 x 1600 at 60 FPS)
  - Color Accuracy (provides in-band color profile data)
- Multiple display support (up to 63 separate A/V streams supported)
- Integrated support for legacy video adapters
  - Power included at connector, protocol support included
- Power reduction, increased battery live
- Cable Consolidation
  - Auxiliary channel can be used for other data traffic

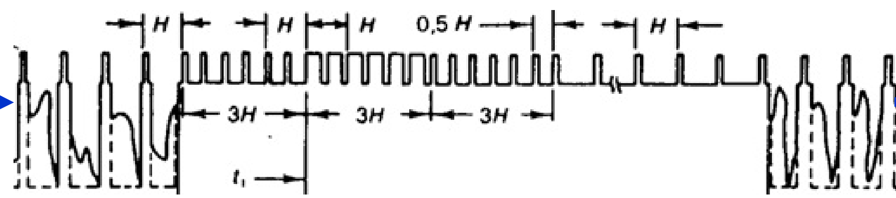
DisplayPort Advantages for the Industry

- Future extensible
  - Expandable packet-based protocol and link operation rates
- Provides addition data services and display control options
- Scalable for large and small devices, displays, and cables
  - Single-lane (twisted pair) can support 1680 x 1050 at 18 bpp
- Easier chip integration, simpler physical interface
  - Leads to lower system cost, lower power, sleeker designs
- Adaptable to other data interfaces (transport) types
  - Isosynchronous packet stream and control protocols can be embedded into other multi-use transport streams

The First Consumer Video Interface

NTSC (Introduced in 1941)

- Used directly as a display interface, or as a baseband signal for carrier modulation
- Consists of a single analog waveform that includes display synchronization (H-sync, V-sync) and pixel content
- Keeps display genlocked with video source

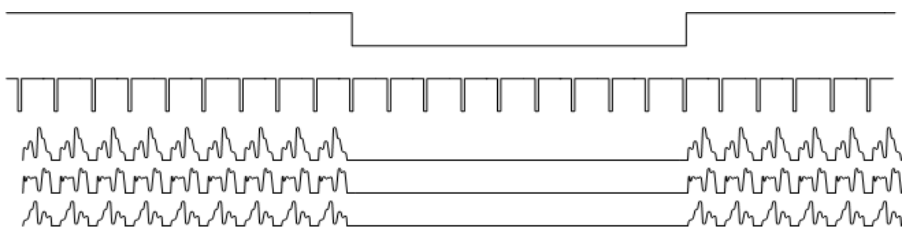


Physical interface includes A/V stream data and timing

Existing Interfaces use Similar Approach

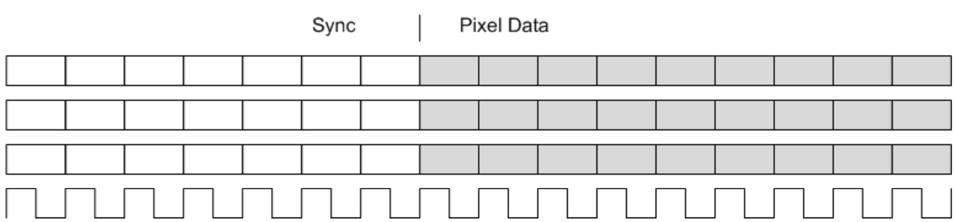
CGA (Introduced in 1981)
VGA (Introduced in 1987)

- Use Hsync and Vsync signaling
- Use 3 analog video signals (RGB)



DVI (Introduced in 1999)
HDMI™ (Introduced in 2003)

- Use dedicated pixel clock signal (variable frequency)
- Use Hsync and Vync symbols embedded in digital video stream



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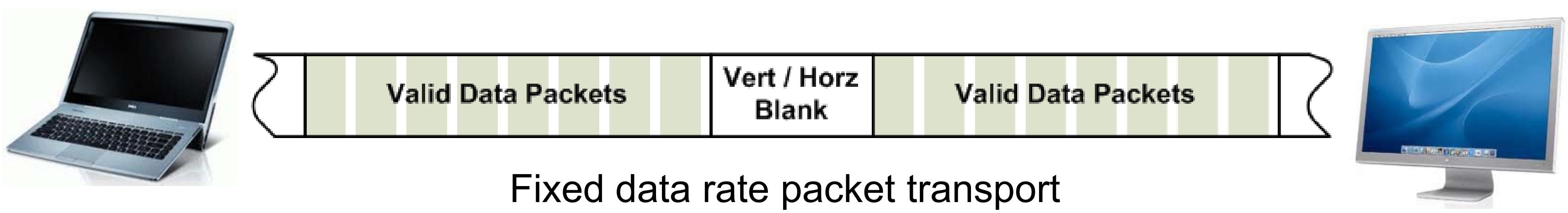
DisplayPort vs. Existing Display Interfaces

DisplayPort

DisplayPort™ (Introduced in 2008)

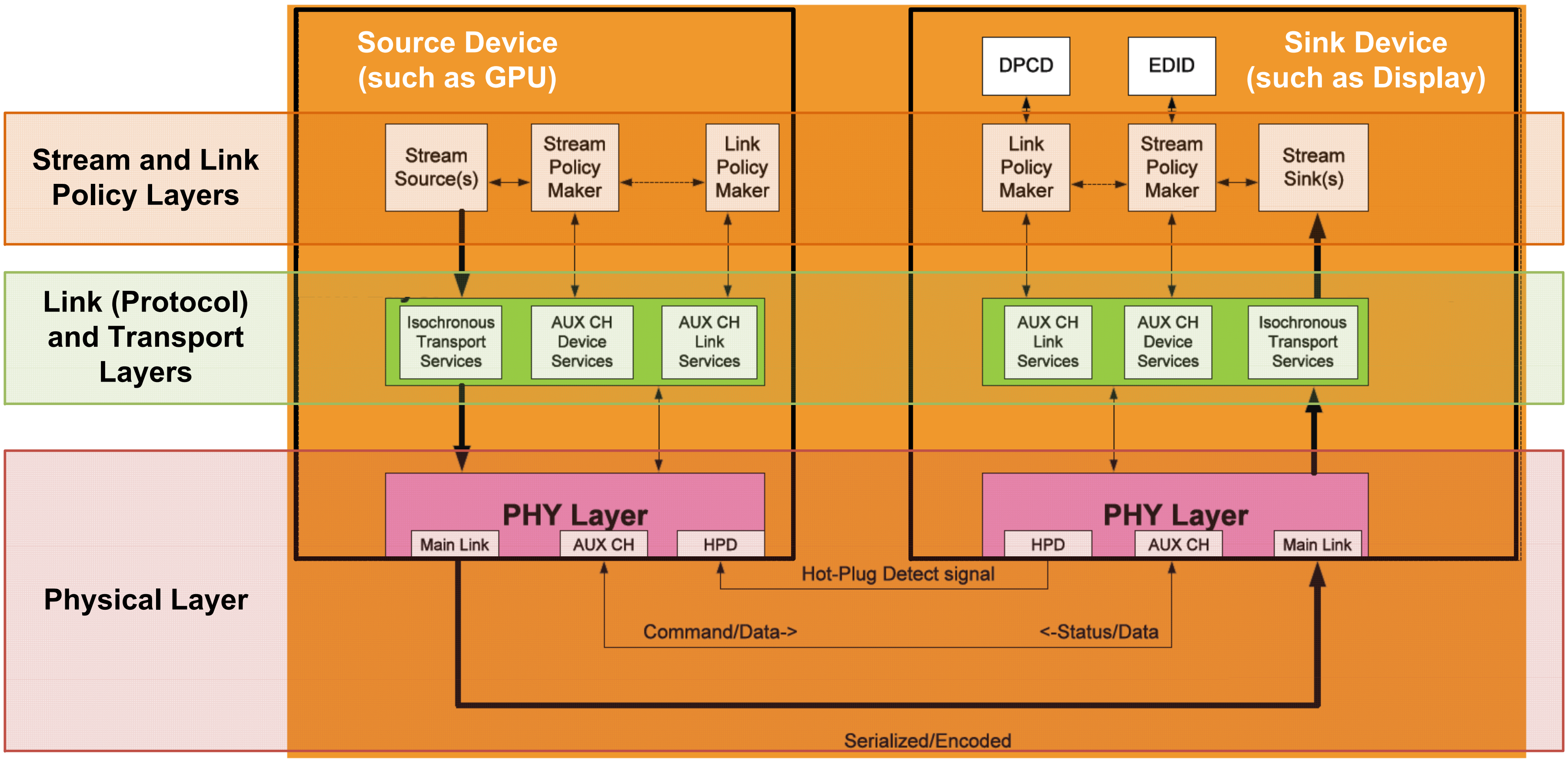
- Unlike other uncompressed data display interfaces, data packet utilization is similar to communication standards such Ethernet, PCI Express, USB, SATA
- Scalable interface fits a variety of system and display applications
- Future extensible to address new applications and system topologies
- Transport-adaptable display protocol
    - Designed for DisplayPort transport and (scalable) physical interface, but can be extended through other transport standards



Fixed data rate packet transport
(choice of link rates and interface lane count)

Overview of DisplayPort Transport Layers

DisplayPort uses a layered protocol for Isochronous AV Stream Transport



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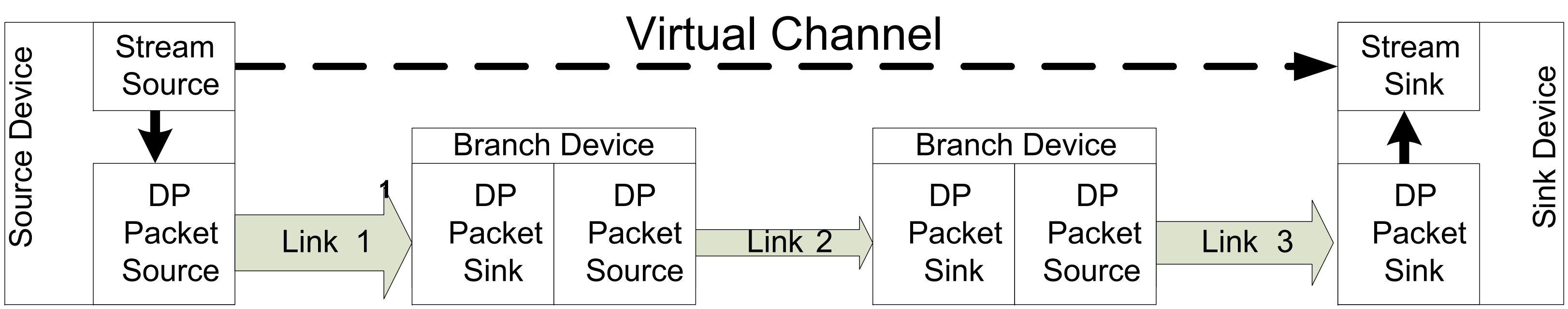
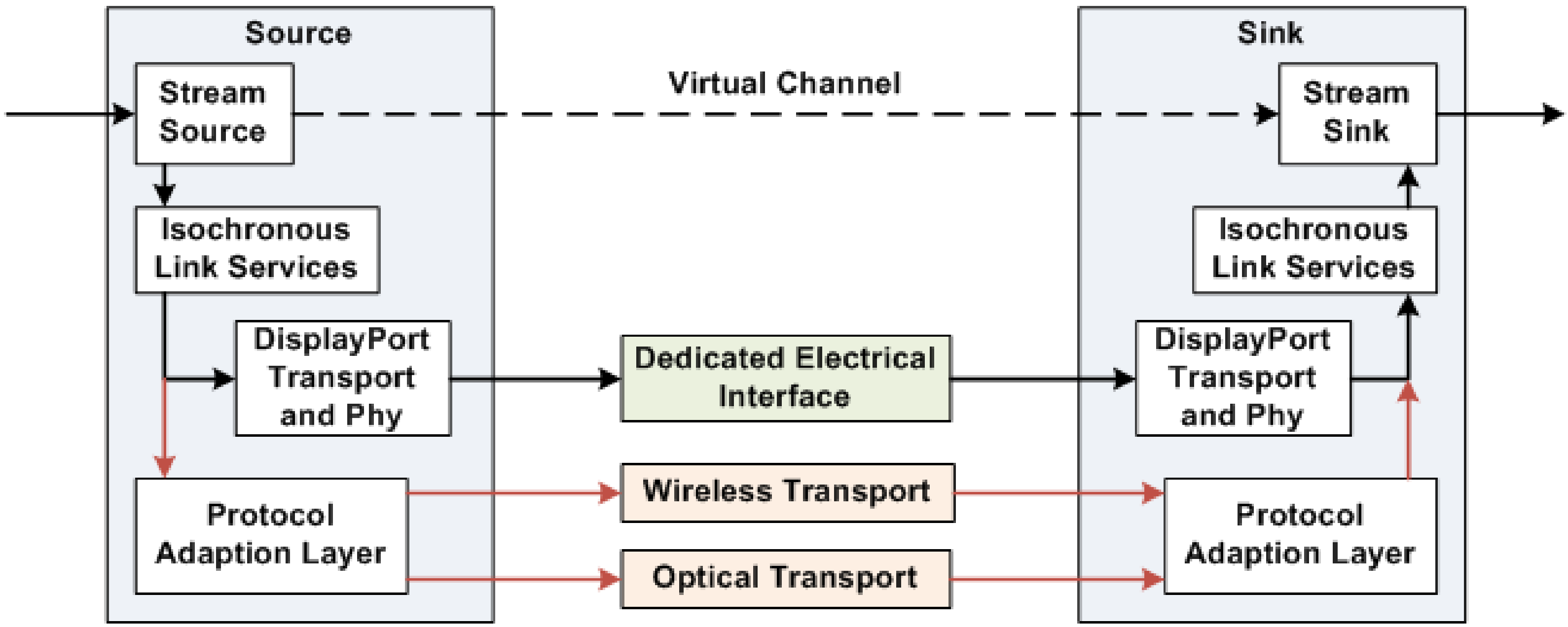
Overview of DisplayPort Transport Layers

- **A/V Streams are received by the Source and regenerated by the Sink**
- **The Stream Policy Maker manages the transport of the stream**
- **The Link Policy Maker is responsible for establishing the data path and keeping the link synchronized.**
- **The Transport Layer is the Source-to-Sink data interface including A/V data packetization and inclusion of other data**
- **The Physical Layer involves the electrical interface**



Overview of DisplayPort Transport Layers

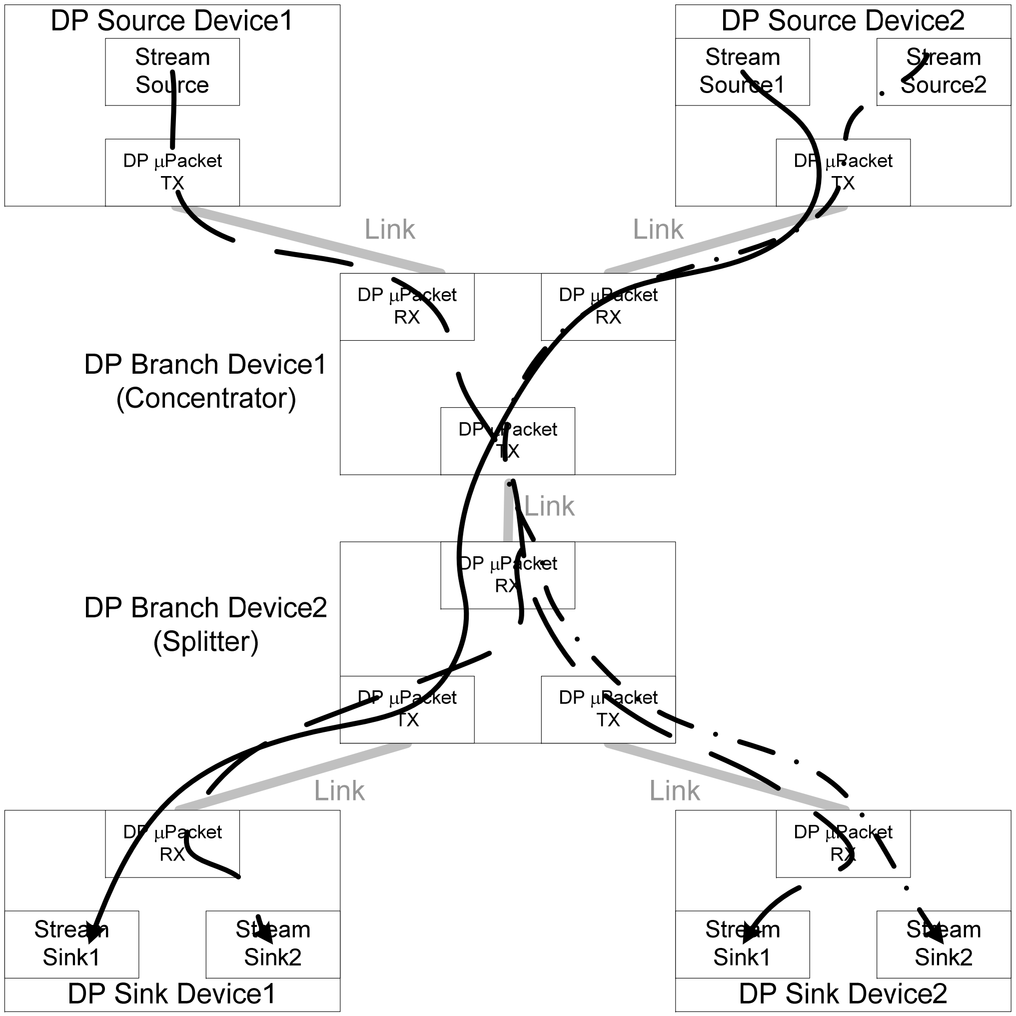
- The layered architecture of DisplayPort allows it to be extensible to other transport types
- The Isochronous AV Stream can sent be within a dedicated or shared transport
- VESA and the WiGig Alliance are currently working on the protocol adapter layer for DisplayPort over the WiGig interface



DisplayPort Transport Options

- DisplayPort 1.1a defined Single Stream Transport (SST) for use between a single Source and Sink Device.
- DisplayPort 1.2 added the Multi-Stream Transport (MST) option, allowing transport of up to 63 separate A/V streams across a single DisplayPort Connection.
- MST mode allows multiple Source and/or Sink devices to share a single connection

MST Example



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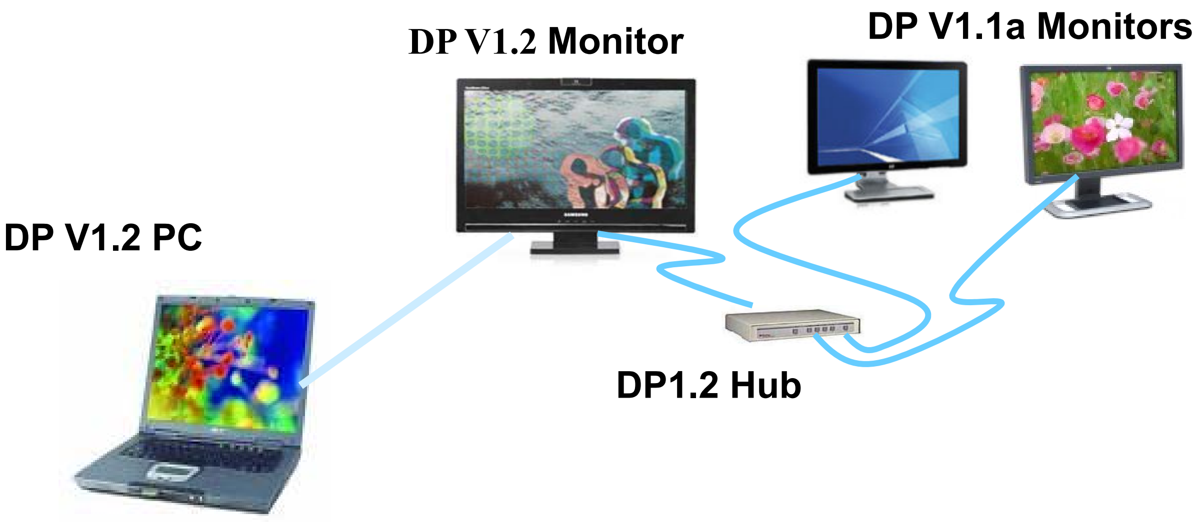
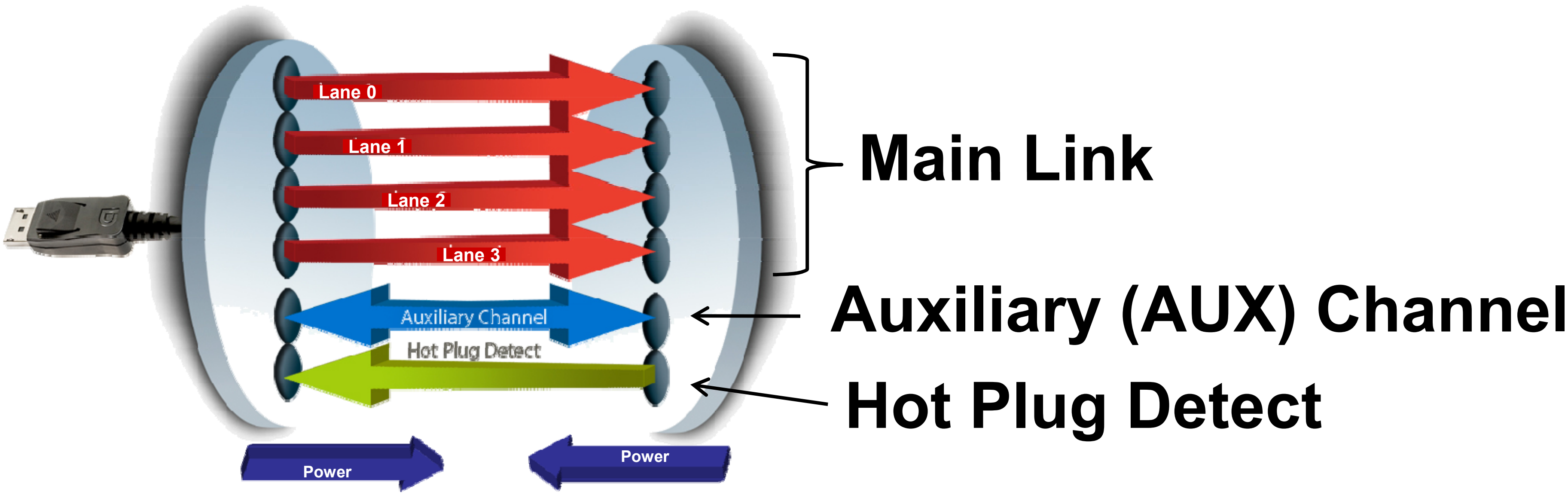
Multi-Stream Transport Application

- One useful MST application is multiple display support from a single connector
- This is particularly suited for portable devices that have limited connector space



DisplayPort Physical Layer Overview

Here we will review the DisplayPort Cable signals:



.and other connector configuration pins

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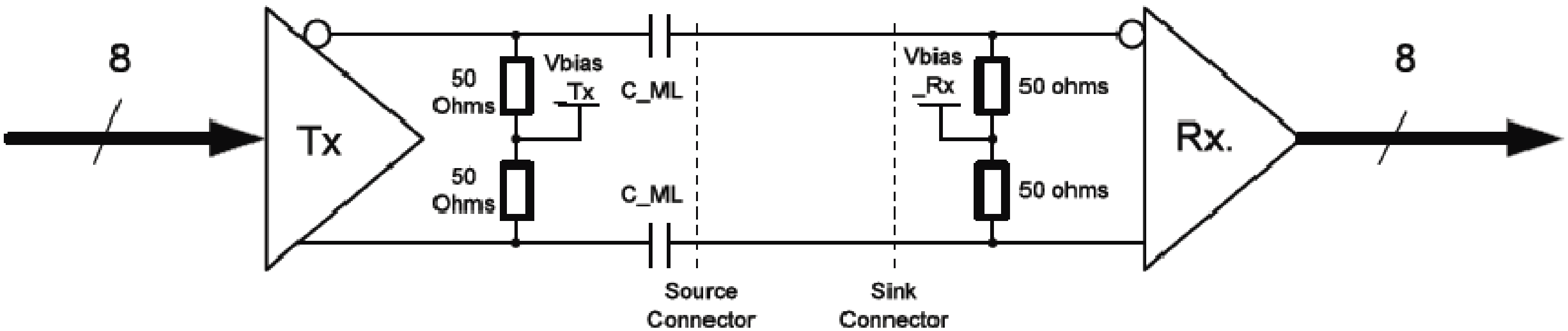
Main Link Signaling Characteristics



- Uses a low-voltage, AC coupled different signal
- Default signal amplitude at Source 400mV p-p
- Default signal pre-emphasis 0dB
- Signal amplitude and/or pre-emphasis can be increased as a result of link training (as directed by the Sink device)
  - Link training occurs during initial operation, or can be re-initiated after data errors detected.
  - Link training compensates for various connector / cable losses to assure an error-free data transport

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Main Link Signal coding and data rate

- Each main link lane uses 8B/10B encoding which provides an embedded clock
- Uses pseudo random code for EMI mitigation

- One of three fixed rates can be selected
  - 1.62 Gbps per lane (1.296 Gbps payload)
  - 2.7 Gbps per lane (2.16 Gbps payload)
  - 5.4 Gbps per lane (4.32 Gbps payload)*

    *Enable with DP 1.2

- Spread-spectrum clocking can be enabled for further EMI mitigation
  - All DP Source devices are designed to accept SSC

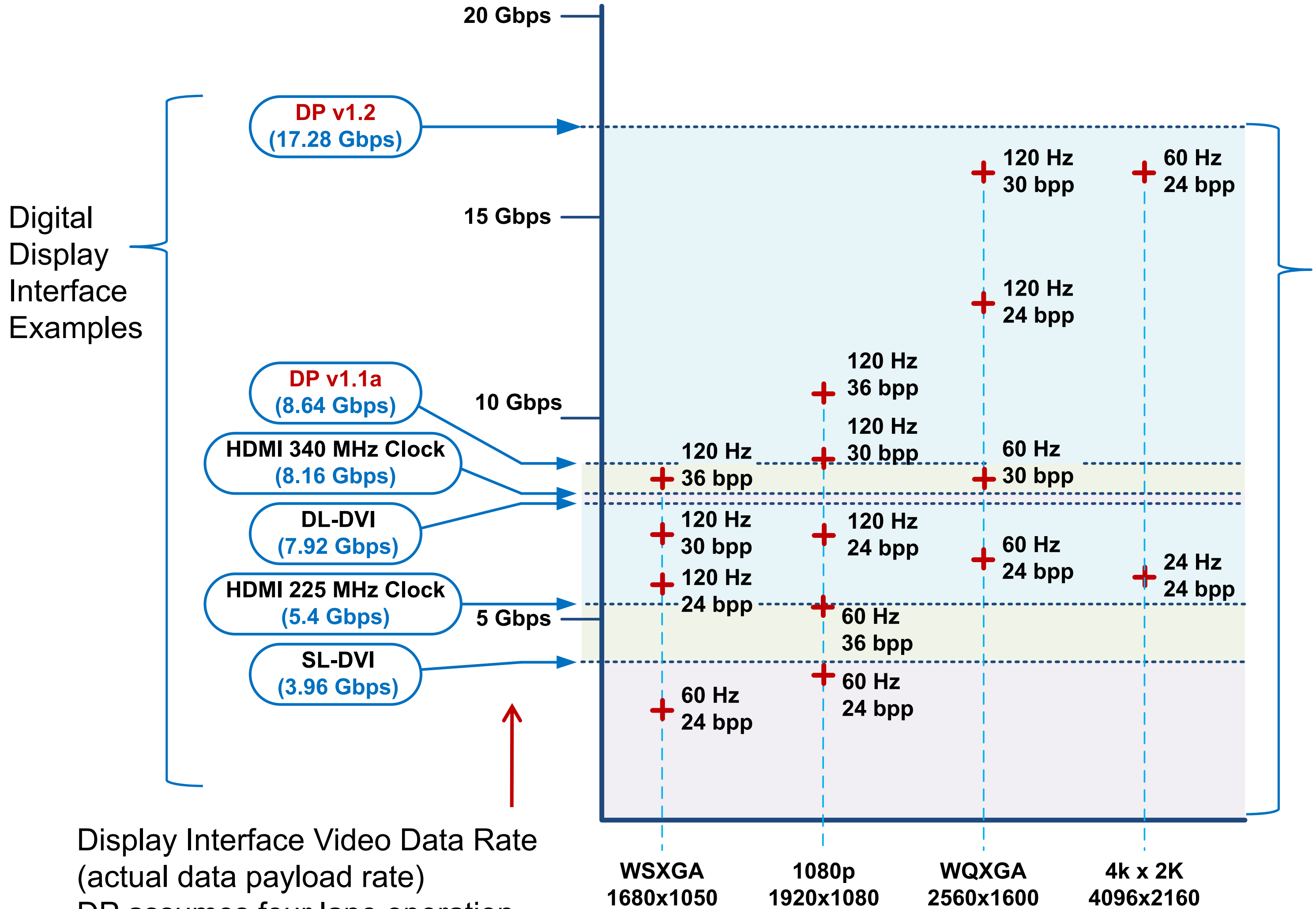
- 1, 2, or 4 lanes can be enabled depending on A/V stream requirements

Main Link Bit Rate Selections

Main Link Configuration	Raw Bit Rate (incl. coding overhead)	Application Bandwidth Throughput
1 lane	**1.62, 2.7, 5.4* Gbps**	**1.296, 2.16, 4.32* Gbps**
2 lanes	**3.24, 5.4, 10.8* Gbps**	**2.592, 4.32, 8.64* Gbps**
4 lanes	**6.48, 10.8, 21.6* Gbps**	**5.184, 8.64, 17.28* Gbps**

*New speed option Enabled by DisplayPort 1.2 Specification

Resolution Support vs. Interface Data Rate



Display Interface Video Data Rate (actual data payload rate)
DP assumes four lane operation

Standard VESA pixel clock rates assumed

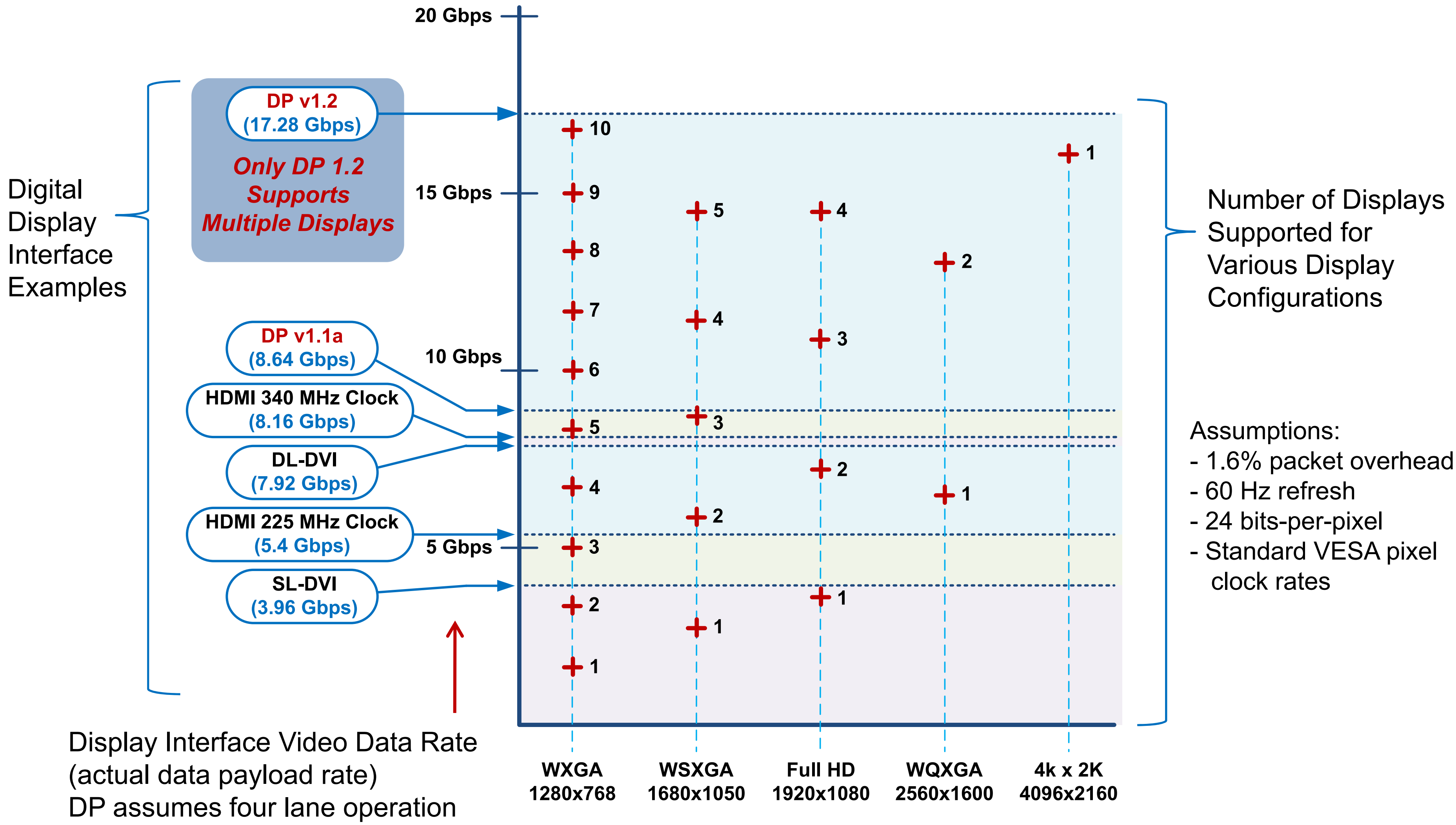
n Hz = refresh rate

120 Hz commonly used for 3D gaming

bpp = bits per pixel

DisplayPort Physical Layer Overview

Number of Monitors Supported vs. Interface Rate



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AUX Channel Signaling Method

~1Vpk-pk differential signal, AC coupled

- Bi-directional signal path

Default "AUX" mode:

- 1 Mbps transfer rate (either direction)
- Manchester encoded

"Fast AUX" mode (option defined by DP 1.2)

- 720 Mbps transfer rate (either direction)
- 8B/10B encoded
- Includes link training

Hot Plug Detect Signal Description

Signal provided by the Sink (display) to the Source (GPU)

Typically 0V or 3.3V signal (bi-level).

"High" signal (3.3V) indicates Sink presence.

"Low" signal (0V) > 2 msec indicates Sink absence

"Low" signal of 0.5 to 1ms indicates "interrupt" from Sink (request to read Sink DPCD registers)

DisplayPort Power Pin

DisplayPort Source and Sink receptacle includes a power pin

Provides 3.3V at 500 mA (1.5W)

- May include higher power option in the future

Used to power:

- Display Adapters (such as DP to VGA, DVI, HDMI)
- Active cables (for greater distance)
- Hybrid cables (Fiber optics, etc.)
- Display Hubs (for multi-monitor connection)
- Pico projectors?

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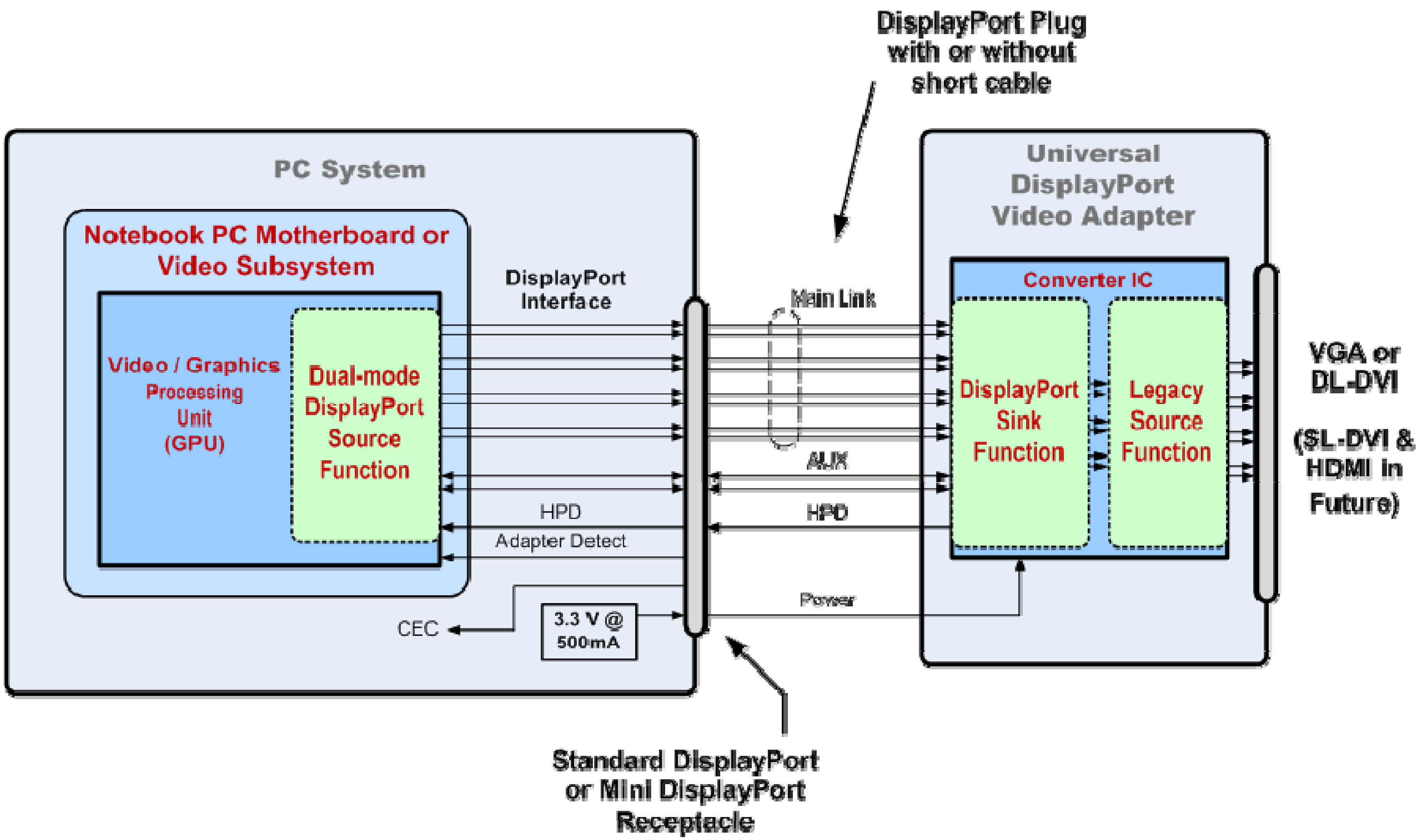
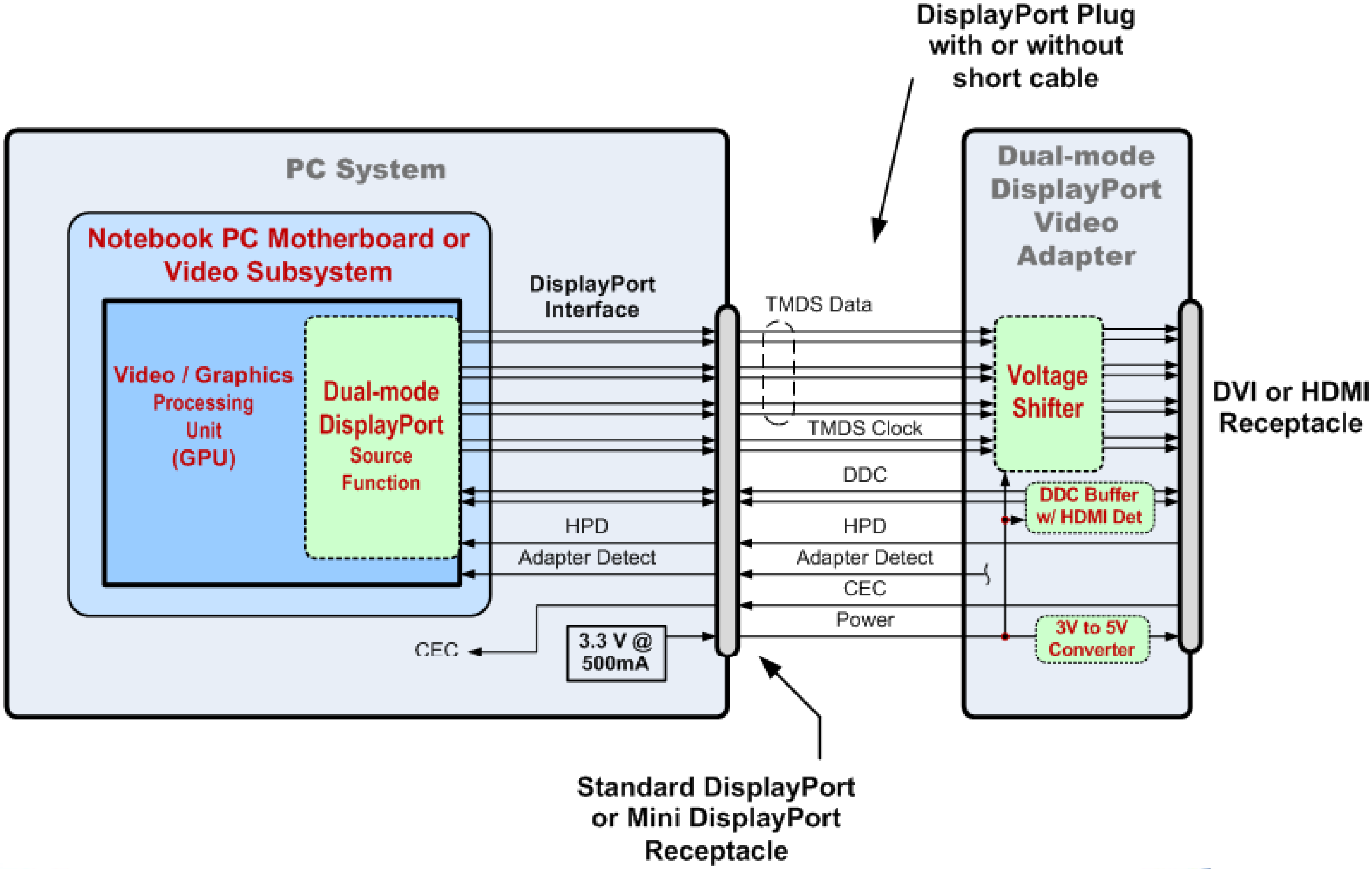
DisplayPort Physical Layer Overview

Connector Interface Pins Showing Power Pin Use



DisplayPort Physical Layer Overview

Interface Using Dual-mode adapter



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Cable and Connectors

Standard “high bandwidth” cables serve existing DP 1.1a and future DP 1.2 systems

“reduced bandwidth” passive cables (1.62 Gbps) are available in greater lengths to serve projector and digital signage applications

Higher bandwidth active cables and hybrid cables also available (utilize DP power pin)

Two connector types:

- Standard DisplayPort connector (USB size)
- Mini DisplayPort connector (introduced by Apple)
- Cable adapter, and adapter cables available

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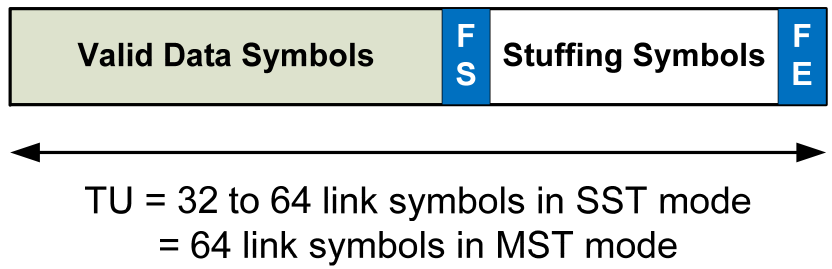
DisplayPort Link Layer Overview

Link Layer = Protocol Layer

Here we will review:

- Main Stream packet structure
- Auxiliary (AUX) Channel Operation

Micro-Packet "Transfer Unit" (TU)



- The DisplayPort transport layer is operated at a data rate above the stream data rate
- Stuffing symbols are used between valid data symbols

- When sending video display data (which is the usual application) the transfer units are stuffed in a means to distribute the video packets evenly over a display line interval
  - This means of data system distribution minimizes data buffering in the display
  - This is referred to Isochronous timing
- The Vertical and Horizontal Blanking periods are used to send other packet types

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DisplayPort Data Types in Main Link

- The Main Link is the high-speed forward data path
- DisplayPort 1.1a defined the use of a single main content stream, normally used for video
  - SST = Single Stream Transport
- DisplayPort 1.2 adds the option for multiple data stream (up to 53) within the Main Link
  - MST = Multi Stream Transport

Packet Types, for a given stream	**Description**
Main Content Stream	Transport format for sending a single stream of video or audio (which can be multi-channel)
Secondary Data Packet (SDP)	Secondary data transport packet for a video stream used for Audio, CEA 861 InfoFrames, main stream attribute data, and other types of data.
Framing symbols	Used to Identify beginning and end of video frame
Vertical Blank ID (VB-ID)	Blanking interval identification and status of audio and video channel
Copy Protection symbols	Used by video copy protection protocol.
Video Stream Configuration (VSC)	A type of SDP that contains additional 3D format information not declarable in the MSA field (introduced in DisplayPort v1.2)

Secondary Data Packet (SDP) Types

- Secondary Data Packets are sent during the vertical interval
- They are used for a variety of data types including the following:

Information Sent within SDP's	Description
Audio Stream	Inserted within video stream blanking period
Maud, Naud (6 Bytes),	Used for audio stream clock regeneration in the display or other Sink device
Audio Time Stamp	Sent once per video frame for audio-audio and audio-video synchronization
Audio Copy Management	C ontent protection for audio
Main Stream Attribute Data (MSA) (20 Bytes)	Describes video display timing and pixel clock rate as well as pixel format on color parameters
CEA-861-E InfoFrames	Sent once per video frame for each InfoFrame packet type
Compressed Video Data	Any type of information can be sent over SDP's

Audio Data Transport Capabilities

- A single stream can carry up to 8 LPCM channels at 192 KHz with 24 bit resolution
  - This represents ~0.1 Gbps payload, which is easily accommodated
- Supported compressed formats include DRA, Dolby MAT, DTS HD
- Options Added by DP 1.2
  - Multi-Stream Transport can extend the number of audio channels
  - Audio copy protection
  - GTC (Global Time Code) provides very precise time control of audio channel timing. Each audio channel can have an independent time delay adjustment between 0 and 4.3 seconds relative to a given Source, in 100 nano-second resolution. Used both for lip sync and speaker phase control.

Main Stream Attribute (MSA) Data

- MSA Data Packets are sent once per video frame during the vertical interval
- The MSA describes the format of the video with a given stream
- Some MSA data is optional

Packet Types, for a given stream	**Description**
Mvid (3 Bytes)	Used for video stream clock regeneration in the display
Nvid (3 Bytes)	Used for video stream clock regeneration in the display
Htotal (2 Bytes)	Total number of pixel in a horizontal line
Vtotal (2 Bytes)	Total number of lines in the video frame
HSP/HSW (2 Bytes)	Hsync polarity / Hsync width, in pixels
VSP/VSW (2 Bytes)	Vsync polarity / Vsync width, in lines
Hstart (2 Bytes)	Start of active video pixel s relative the Hsync
Vstart (2 Bytes)	Start of active video lines relative the Vsync
MISC1:0 (2 Byte)	Indentifies pixel color coding format, number of bits per pixel, color gamut, and other color profile information

Framing Symbols

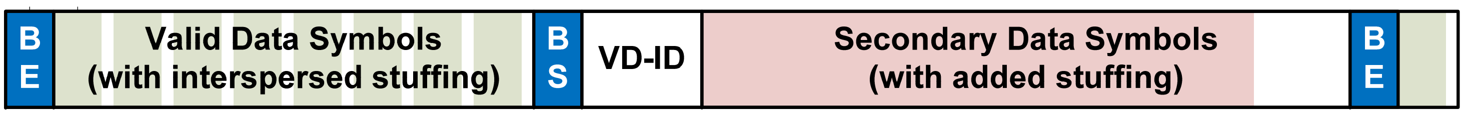
- Framing Symbols are used to identify the BEGINNING and END of:
  - Vertical Blanking (which thereby indentifies the beginning and end of each video frame)
  - A series of stuffing symbols
  - A "Secondary Data Packet", which can be used to transport and Audio stream and other types of information

- Other Framing symbols are used for data scrambler synchronization and copy protection

Basic DisplayPort Framing Symbols	**Abbreviation**	**Description**
Blanking Start	BS	Beginning of Vertical Blanking
Blanking End	BE	End of Vertical Blanking
Fill Start	FS	Beginning of stuffing symbols
Fill End	FE	End of stuffing symbols
Secondary-data Start	SS	Beginning of secondary data
Secondary-data End	SE	End of secondary data
Scrambler Reset	SR	Used to synchronize pseudo-ramdom main link data scrambler / descrambler between Source and Sink
Copy Protection BS	CPBS	For HDCP copy protection use
Copy Protection SR	CPSR	For HDCP copy protection use

Framing Symbols

Example



DisplayPort Link Layer Overview

AUX Channel – Data Formats

- Standard AUX transport format (Defined by DP 1.1a)
  - Manchester transport format
  - 1Mbps, Burst transfer = 16 data bytes max
  - Capable of establishing ~ 200Kbps full-duplex link

- Fast AUX transport format (New option defined in DP 1.2)
  - 720Mbps, Burst transfer = 64/1024 data bytes max
  - Capable of establishing ~ 200Mbps full-duplex link

DisplayPort Link Layer Overview

AUX Channel – Functions used to establish Link

- AUX is first used by the Source to Discover Sink Capabilities
  - Determines display rendering capabilities and preferences by reading display EDID (uses special I2C-over-AUX protocol)
  - The support of video content protection through HDCP key exchanges
  - Determines DisplayPort link transport capabilities by reading DPCD (DisplayPort Configuration Data) registers
- AUX is also used to discover interface topology
  - If MST is supported and what topology routing will be present
  - HDPC support through the virtual channel
- The stream and link policy makers use this information to determine stream and link configuration

DisplayPort Link Layer Overview

AUX Channel Functions During Normal Link Operation

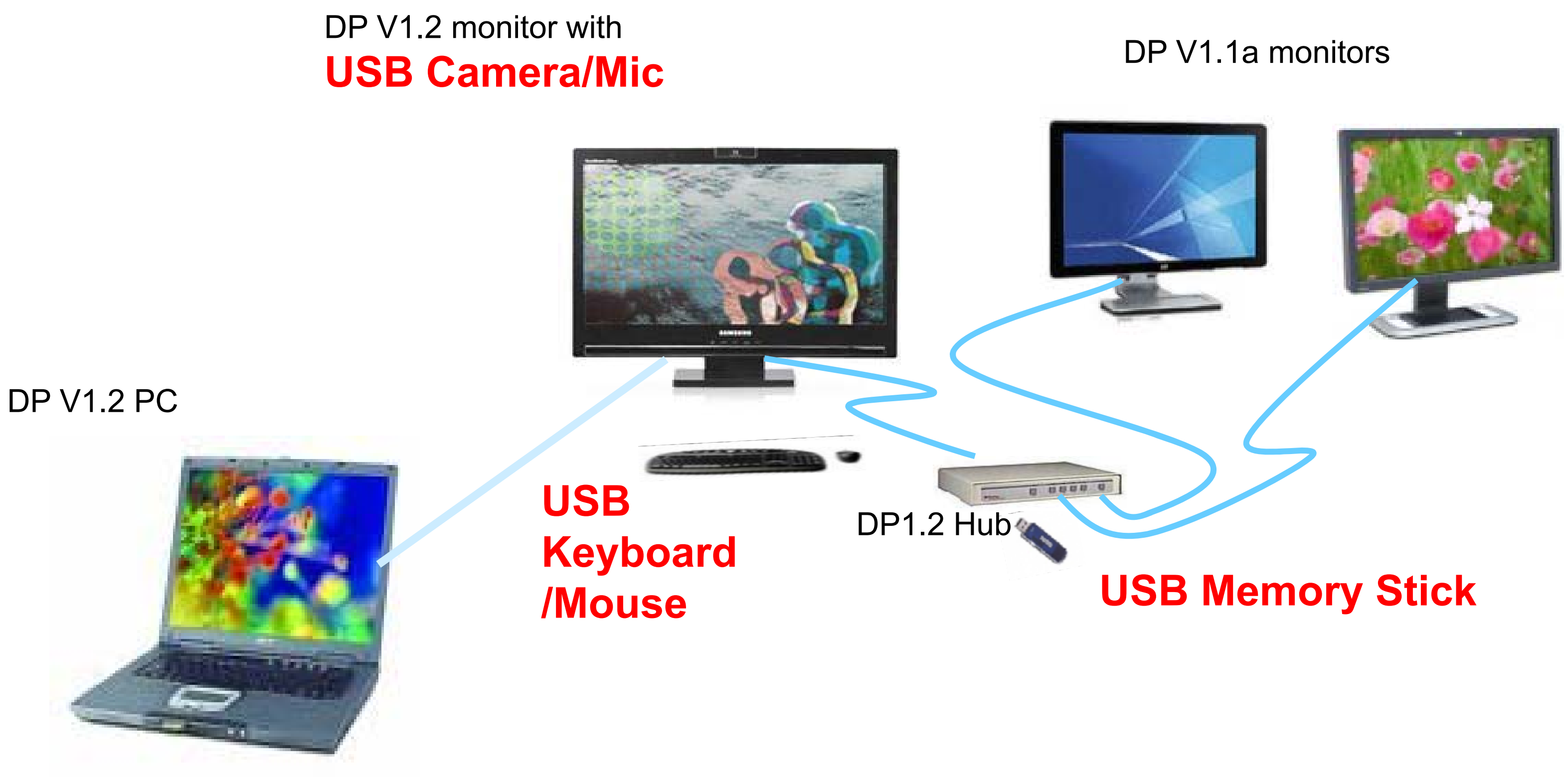
- AUX is used to maintain the link
  - Sink can notify Source that main link data corruption has occurred
  - Data and symbol lock, and optional ECC (Error Correction Code) can be used monitor link integrity
  - Source can reinitiate link training to re-establish link

- AUX can be used to transport auxiliary data, such as:
  - Camera and Microphone A/V data from Sink to Source for teleconferencing
  - Fast AUX mode can be used for USB 2.0 data to support USB hub in Display (cable consolidation)

- Display Control
  - AUX can be used to control display setting and operation
  - Can directly support MCCS using I2C-over-AUX protocol
  - Can also support dedicated display control DPCD registers as now used in Embedded DisplayPort (eDP)

DisplayPort Link Layer Overview

Example System Application Utilizing AUX Data Transport



State of Deployment

Many DP 1.1a devices are available from the top PC OEMs

- GPU Cards, Desktop PCs, and portable PC's
- Cables, video adapters
- Desktop displays

More DP 1.2 devices appearing in 2011

- GPU's with 5.4 Gbps main link now on market
  - Used for high-refresh stereo 3D support
  - Existing cables can be used
- Supporting 3D displays available
- Multi-stream capable Source devices, hubs and monitors expected later in year
- Protocol layer for USB over Fast AUX in development

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Other Resources

For more information about DisplayPort

www.displayport.org

www.vesa.org

Contact Information

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Thank You!

Q&A