DisplayPort Technical Overview

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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 Quick Overview

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
DisplayPort vs. Existing Display Interfaces

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
DisplayPort vs. Existing Display Interfaces

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 Vsync symbols embedded in digital video stream
DisplayPort™ (Introduced in 2008)

- Unlike other uncompressed data display interfaces, data packet utilization is similar to communication standards such as 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
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 be sent 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.
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
Here we will review the DisplayPort Cable signals:

- Main Link
- Auxiliary (AUX) Channel
- Hot Plug Detect

...and other connector configuration pins
DisplayPort Physical Layer Overview

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
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

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

*New speed option Enabled by DisplayPort 1.2 Specification*
Resolution Support vs. Interface Data Data Rate

Data Rate Requirements for Example Display Configurations

Standard VESA pixel clock rates assumed

$n$ Hz = refresh rate

120 Hz commonly used for 3D gaming

bpp = bits per pixel

Display Interface Video Data Rate (actual data payload rate)

DP assumes four lane operation
DisplayPort Physical Layer Overview

Number of Monitors Supported vs. Interface Rate

Assumptions:
- 1.6% packet overhead
- 60 Hz refresh
- 24 bits-per-pixel
- Standard VESA pixel clock rates

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

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
DisplayPort Physical Layer Overview

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?
DisplayPort Physical Layer Overview

Connector Interface Pins Showing Power Pin Use
DisplayPort Physical Layer Overview

Interface Using Dual-mode adapter

DisplayPort Plug with or without short cable

PC System
Notebook PC Motherboard or Video Subsystem

Dual-mode DisplayPort Source Function

DisplayPort Interface

TMDS Data
TMDS Clock
DDC
HPD
Adapter Detect
CEC
Power

Voltage Shifter

3V to 5V Converter

DVI or HDMI Receptacle

Standard DisplayPort or Mini DisplayPort Receptacle

DisplayPort

VESA®
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
DisplayPort Link Layer Overview

Link Layer = Protocol Layer

Here we will review:

• Main Stream packet structure
• Auxiliary (AUX) Channel Operation
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.
DisplayPort Link Layer Overview

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

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

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

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.
DisplayPort Link Layer Overview

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

<table>
<thead>
<tr>
<th>Packet Types, for a given stream</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mvid (3 Bytes)</td>
<td>Used for video stream clock regeneration in the display</td>
</tr>
<tr>
<td>Nvid (3 Bytes)</td>
<td>Used for video stream clock regeneration in the display</td>
</tr>
<tr>
<td>Htotal (2 Bytes)</td>
<td>Total number of pixel in a horizontal line</td>
</tr>
<tr>
<td>Vtotal (2 Bytes)</td>
<td>Total number of lines in the video frame</td>
</tr>
<tr>
<td>HSP/HSW (2 Bytes)</td>
<td>Hsync polarity / Hsync width, in pixels</td>
</tr>
<tr>
<td>VSP/VSW (2 Bytes)</td>
<td>Vsync polarity / Vsync width, in lines</td>
</tr>
<tr>
<td>Hstart (2 Bytes)</td>
<td>Start of active video pixel s relative the Hsync</td>
</tr>
<tr>
<td>Vstart (2 Bytes)</td>
<td>Start of active video lines relative the Vsync</td>
</tr>
<tr>
<td>MISC1:0 (2 Bytes)</td>
<td>Identifies pixel color coding format, number of bits per pixel, color gamut, and other color profile information</td>
</tr>
</tbody>
</table>
DisplayPort Link Layer Overview

Framing Symbols

- Framing Symbols are used to identify the BEGINNING and END of:
  - Vertical Blanking (which thereby identifies 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

<table>
<thead>
<tr>
<th>Basic DisplayPort Framing Symbols</th>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blanking Start</td>
<td>BS</td>
<td>Beginning of Vertical Blanking</td>
</tr>
<tr>
<td>Blanking End</td>
<td>BE</td>
<td>End of Vertical Blanking</td>
</tr>
<tr>
<td>Fill Start</td>
<td>FS</td>
<td>Beginning of stuffing symbols</td>
</tr>
<tr>
<td>Fill End</td>
<td>FE</td>
<td>End of stuffing symbols</td>
</tr>
<tr>
<td>Secondary-data Start</td>
<td>SS</td>
<td>Beginning of secondary data</td>
</tr>
<tr>
<td>Secondary-data End</td>
<td>SE</td>
<td>End of secondary data</td>
</tr>
<tr>
<td>Scrambler Reset</td>
<td>SR</td>
<td>Used to synchronize pseudo-random main link data scrambler / descrambler between Source and Sink</td>
</tr>
<tr>
<td>Copy Protection BS</td>
<td>CPBS</td>
<td>For HDCP copy protection use</td>
</tr>
<tr>
<td>Copy Protection SR</td>
<td>CPSR</td>
<td>For HDCP copy protection use</td>
</tr>
</tbody>
</table>
DisplayPort Link Layer Overview

Framing Symbols

Example

<table>
<thead>
<tr>
<th>BE</th>
<th>Valid Data Symbols (with interspersed stuffing)</th>
<th>BS</th>
<th>VD-ID</th>
<th>BE</th>
<th>Secondary Data Symbols (with added stuffing)</th>
<th>BE</th>
</tr>
</thead>
</table>

DisplayPort™  

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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 to 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

DP V1.2 monitor with USB Camera/Mic

DP V1.2 PC

USB Keyboard /Mouse

USB Memory Stick

DP V1.2 Hub

DP V1.1a monitors

USB Memory Stick

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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
Other Resources

For more information about DisplayPort

www.displayport.org
www.vesa.org

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