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Hardent

Next-Generation Mobile, AR/VR, & Automotive Displays With
VESA VDC-M & MIPI® DSI-2℠
Bandwidth Challenge for Video Connectivity
Gap between transport bandwidth and display requirements is increasing
Possible Solutions vs. Trade-offs

1. Add transport lanes
   - More pins/cables needed
   - Real estate increase
   - Weight increase
   - Cost increase
   - Power consumption increase
   - EMI noise increase
   - Potential visual artifacts
   - Greater design complexity
   - Increased latency

2. Use video compression
   - More pins/cables needed
   - Real estate increase
   - Weight increase
   - Cost increase
   - Power consumption increase
   - EMI noise increase
   - Potential visual artifacts
   - Greater design complexity
   - Increased latency
Industry Compression Timeline

- **Proprietary Compression Technologies**
- **DSC 1.1**
- **DSC 1.2a**
Display Stream Compression (DSC) Overview

- Visually lossless video compression standard
- Up to 3X compression (8 bpp) without any perceptible differences
- Extremely low latency (< 0.5 usec)
- Video quality excellent with all types of content
  - Natural and test images, text, and graphics
- Requires a single line of pixel storage + rate buffer

- Intra-frame Variable Bit Rate Encoder
- Constant Bit Rate (CBR) transmission
- Based on Delta Pulse Code Modulation (DPCM)
- Mid Point (MPP), Block Predictor (BP)
- Modified Median Adaptive Predictor (MMAP)
- Indexed Color History (ICH)

Source diagram: VESA DSC white paper
Transport Standards Using DSC

- MIPI DSI<sup>SM</sup> 1.3.1
- DisplayPort 1.4
- DisplayPort 2.0
- USB Type-C
- HDBT 2.0
- HDMI 2.1
- eDP 1.4b
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Applications Using DSC

- Mobiles
- Tablets
- GPUs
- AR/VR head-mounted displays
- In-car video systems
- Video transport
- UHD / 8K TVs
- DTV STBs
- High-resolution monitors

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Some Applications Require **Even More Bandwidth**

**Mobile Displays**
- Need to support gaming
- Need to be “AR/VR ready”
- Require higher display resolutions & frame rates

**AR/VR Displays**
- Need to drive two displays
- Require higher pixel density (ppi) & frame rates

**Automotive Displays**
- Are increasing rapidly
- Require higher display resolutions

![Images of mobile, AR/VR, and automotive displays]
Product Display Bandwidth Trends

VDC-M = VESA Display Compression for Mobile
## DSC vs. VDC-M

<table>
<thead>
<tr>
<th></th>
<th>DSC</th>
<th>VDC-M</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Encoding Block Structure</strong></td>
<td>3x1 pixels</td>
<td>8x2 pixels</td>
</tr>
<tr>
<td><strong>Encoding Tools</strong></td>
<td>Mid Point (MPP)</td>
<td>Mid Point (MPP)</td>
</tr>
<tr>
<td></td>
<td>Block Predictor (BP)</td>
<td>Enhanced Block Predictor (BP)</td>
</tr>
<tr>
<td></td>
<td>Modified Median Adaptive Predictor (MMAP)</td>
<td>Transform (DCT and Hadamard)</td>
</tr>
<tr>
<td></td>
<td>Indexed Color History (ICH)</td>
<td>Enhanced Quantization</td>
</tr>
<tr>
<td><strong>Visually Lossless Performance</strong></td>
<td>8 bpp (bits per pixel)</td>
<td>5-6 bpp (bits per pixel)</td>
</tr>
<tr>
<td><strong>IC Complexity</strong></td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>RAM Usage</strong></td>
<td>Single line</td>
<td>2.5 lines</td>
</tr>
<tr>
<td><strong>Latency (end-to-end) (UHD 3840x2160 example)</strong></td>
<td>&lt;0.5us</td>
<td>&lt;1.2us</td>
</tr>
<tr>
<td></td>
<td>&lt;2H line</td>
<td>&lt;5H line</td>
</tr>
<tr>
<td><strong>Pixels / Clock Architecture</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Encoder</strong></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Decoder</strong></td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
VDC-M Enhanced Block Prediction Mode

- Block prediction is performed on 2x1 or 2x2 partitions
  - One block prediction vector (BPV) for all color components of each partition

- Block prediction uses a large and regular search area
  - 64 potential BPVs for each partition

Search Range

Three example BPVs for a 2x2 partition

Three example BPVs for a 2x1 partition
VDC-M New Transform Mode

- Transforms residuals of best of 8 intra-predictors
  - DC, Vertical, Vertical Left, Vertical Right, Diagonal Left, Diagonal Right, Horizontal Left, Horizontal Right

- Transform is done for each color component on 8x2 block (or 4x2 block for YUV 4:2:x chroma)
  - Uses Butterfly DCT in horizontal direction and Hadamard transform in vertical direction
  - Separates higher frequencies (which the eye is less sensitive to) from lower frequencies
  - Similar transform to what is done in MPEG and JPEG encoding
Transport Standards Using VDC-M

- VDC-M was officially released in May 2018
- MIPI Alliance adopted VDC-M 1.2 as part of their new DSI-2 v1.1 specification
- VDC-M is now being considered by other transport specifications
Mobile Market Trends

- Mobile devices need to be VR-ready
- Movement from LCD to OLED displays
  - Ultra-high resolutions and pixel density (up to 1500 ppi)
  - High dynamic range
  - Higher frame rate
  - Optical compensation
  - Foldable,rollable displays
  - Lower power consumption
  - Non-uniformity compensation
- DDIC frame buffer going from 10 to 100 Mbits

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Display Resolution</td>
<td>1280 x 720 HD</td>
<td>3840 x 2160 4K</td>
</tr>
<tr>
<td>Frame Rate</td>
<td>60 fps</td>
<td>120 fps</td>
</tr>
<tr>
<td>Pixel Depth</td>
<td>24 bits</td>
<td>30 bits</td>
</tr>
<tr>
<td>Interface</td>
<td>0.5 Gbps / lane</td>
<td>2.0 Gbps / lane</td>
</tr>
<tr>
<td>Display Bandwidth</td>
<td>1.3 Gbps</td>
<td>29.9 Gbps</td>
</tr>
</tbody>
</table>

23x
Use Case: Mobile and Tablet Applications

- Application processor
- DDIC (Display Driver IC) and touch panel controller
- Benefits
  - Reduce bandwidth
  - Save power
  - Save on cost
  - Lower EMI
VDC-M Mobile/Tablet Use Case

- Additional DSI lane saving
- Power consumption saving
- Smaller SDRAM frame buffer

Examples

- WQUXGA Display (2400x3840) 24bpp 60fps
  - D-PHY$^{SM}$ 2.5Gbps: only 2 lanes required
  - SDRAM 4 times smaller

- UHD Display (2160x3840) 30bpp 120fps
  - D-PHY 2.5Gbps: only 3 lanes required
  - SDRAM 5 times smaller
AR/VR Market

• Console market
  – Oculus, HTC Vive, Sony Playstation, Windows MR,...
  – Cables are running out of bandwidth
    • Requires 2 displays at higher resolution, higher ppi, higher refresh rates

• Standalone market
  – Microsoft Hololens, Google Daydream, Oculus Go, HTC Vive Focus,...
  – Bandwidth, power management, and miniaturization are huge obstacles
  – Optimized silicon is emerging
    • Qualcomm Snapdragon XR, ARM Mali-D77, NVidia Tegra

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Use Case: AR/VR Head-Mounted Display

Applications
- Video capture
- Application processor and GPU
- Micro-display driver IC

Benefits
- Lower bandwidth
- Smaller RAM buffer
- Power and $ savings
- Low latency

Untethered AR System With Frame Buffer

Game Console - Wired VR System
VDC-M to Fulfill Future AR/VR Requirements

VESDA members AR/VR Task Group Survey Summary

1. Resolutions per eye will increase over time from 2K x 2K in 2019 to 8K x 8K in 2025

2. It is believed that very few people see a difference beyond 8K x 8K per eye
   a. This is about 60 pixels per degree for 273 degrees horizontally
   b. It allows 220 degrees plus 25 degrees of overlap between the eyes

3. Refresh rates required is between 120 to 240Hz to meet human perception limits

4. Pixel resolution of 12bpc will be required by 2025

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AR/VR Use Cases & VDC-M

- All resolutions/frame rates below are “per eye”

<table>
<thead>
<tr>
<th>Transport</th>
<th>Transport Bandwidth Available</th>
<th>DSC 8bpp</th>
<th>VDC-M 6bpp</th>
<th>VDC-M 5bpp</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 Gbits/sec</td>
<td>19.3 Gbits/sec</td>
<td>2.8Kx2.8K 120Hz</td>
<td>4Kx4K 100Hz</td>
<td>4Kx4K 120Hz</td>
</tr>
<tr>
<td>2 lanes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Gbits/sec</td>
<td>38.7 Gbits/sec</td>
<td>4Kx4K 120Hz</td>
<td>5Kx5K 120Hz</td>
<td>5Kx5K 120Hz</td>
</tr>
<tr>
<td>4 lanes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 Gbits/sec</td>
<td>38.7 Gbits/sec</td>
<td>4Kx4K 120Hz</td>
<td>5Kx5K 120Hz</td>
<td>5Kx5K 120Hz</td>
</tr>
<tr>
<td>2 lanes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 Gbits/sec</td>
<td>77.3 Gbits/sec</td>
<td>5Kx5K 120Hz</td>
<td>8Kx8K 100Hz</td>
<td>8Kx8K 120Hz</td>
</tr>
<tr>
<td>4 lanes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Digital Car Market

- Number of displays in cars is increasing rapidly
  - ADAS, infotainment, control panels, rear seat displays, head-up displays, side and rear view mirrors, ...
    - 1-3 displays → 10-12 displays
    - 1 camera → 5-10 cameras
    - 2-5 sensors → 10-20 sensors

<table>
<thead>
<tr>
<th>Display Type</th>
<th>Spatial Resolution</th>
<th>DPI (pix / inch)</th>
<th>Bandwidth Req. @ 60 Hz refresh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mid-range car</td>
<td>HD</td>
<td>1280 x 720</td>
<td>100</td>
</tr>
<tr>
<td>High-end car</td>
<td>FHD</td>
<td>1920 x 1080</td>
<td>200</td>
</tr>
<tr>
<td>Next-gen. car</td>
<td>UHD</td>
<td>3860 x 2160</td>
<td>400</td>
</tr>
</tbody>
</table>
Automotive Transport Link Technologies Today

• Several technologies available: Maxim GMSL, Inova APIX, Valens HDBaseT, TI FPD-Link

• Link speed ranges between 1.0 - 6.0 Gbps typically over a 15 meter coaxial or shielded twisted pair cable

• Automotive environment is demanding: higher bitrate (> 6 Gbps) adds significant challenges
  – Electromagnetic noise immunity, reliability, cost, etc.
  – Adoption/certification of high-speed serial link technology is a long & expensive process
  – Using multiple links per screen is expensive
More Cables Is NOT The Solution

• Wiring harness is the 3rd highest cost component in a car (behind engine and chassis) comprising 50% of the cost of labor for the entire car

• 3rd heaviest component (after the chassis and engine)*

• EMI and signal integrity is a major challenge

* Source: Delphi, Inc.
In-Car Video Applications

- Benefits
  - Smaller bandwidth for multiple feeds
  - Low latency
  - Save on expensive cabling
  - Lower EMI
Compressed Multi-Stream Transport

Cable #1
- Stream A - Frame 1
- Stream A - Frame 2
- Stream A - Frame 3

Cable #2
- Stream B - Frame 1
- Stream B - Frame 2
- Stream B - Frame 3

Cable #3
- Stream C - Frame 1
- Stream C - Frame 2
- Stream C - Frame 3

Single Cable
- Stream A - Frame 1
- Stream B - Frame 1
- Stream C - Frame 1
- Stream A - Frame 2
- Stream B - Frame 2
- Stream C - Frame 2
- Stream A - Frame 3
- Stream B - Frame 3
- Stream C - Frame 3

Packet Based

Video Compression

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VDC-M Automotive Use Case

• Number of displays in cars is increasing rapidly

• Display physical size may not increase due to car physical limitation, but resolution is increasing
  – High-end displays now support FHD (150-200 ppi)
  – Next-generation aiming at UHD (300-400 ppi)

• VDC-M extends life cycle of existing link technology
  – Limitations to increase transmission link speed between head unit and multiple displays
  – Automotive environment is demanding, higher bitrate (> 6Gbps) adds significant challenges
    • Electromagnetic noise immunity, reliability, cost, etc.
  – Adoption/certification of high-speed serial link technology is a long and expensive process
  – Using multiple links per screen is expensive
  – Potential use of self-healing ring cuts available link bandwidth

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Use Cases: Display / Link Compression Requirements

- Projected automotive link speed in the future = 12 Gbps
- Future display requirements:
  - 12 UHD displays
  - Bandwidth per display = 600 MPixels/sec = 14.4 Gbps for 24-bit pixels

<table>
<thead>
<tr>
<th>Compression</th>
<th>Target bpp</th>
<th>Comp. Factor</th>
<th>Bandwidth Req.</th>
<th># of UHD Displays / Links</th>
<th># of Links Required For 12 Displays</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncompressed</td>
<td>24</td>
<td>1X</td>
<td>14.4 Gbps*</td>
<td>1 or 2</td>
<td>12 or 24</td>
</tr>
<tr>
<td>VESA DSC</td>
<td>8</td>
<td>3X</td>
<td>4.8 Gbps</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>VESA VDC-M</td>
<td>6</td>
<td>4X</td>
<td>3.6 Gbps</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>4.8X</td>
<td>3.0 Gbps</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

* Slightly exceeds available bandwidth
Compression For Automotive Displays

Is it safe?

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## Automotive Functional Safety

- Governed by **ISO 26262** - Functional Safety for Road Vehicles standard
- 4 safety levels: ASIL A (lowest) to ASIL D (highest)

<table>
<thead>
<tr>
<th>Metric</th>
<th>ASIL B</th>
<th>ASIL C</th>
<th>ASIL D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Point Fault Metric</td>
<td>&gt; 90%</td>
<td>&gt; 97%</td>
<td>&gt; 99%</td>
</tr>
<tr>
<td>Latent Fault Metric</td>
<td>&gt; 60%</td>
<td>&gt; 80%</td>
<td>&gt; 90%</td>
</tr>
<tr>
<td>Probabilistic Metric for Hardware Failures</td>
<td>&lt; $10^{-7}$/h</td>
<td>&lt; $10^{-7}$/h</td>
<td>&lt; $10^{-8}$/h</td>
</tr>
</tbody>
</table>
Example: Head Unit Display

- Display shows a video coming from a backup camera

- **Safety Goals** for the end-to-end video path (hardware level):
  - Safety goal #1: stream displayed has **no corrupted pixels**
  - Safety goal #2: stream displayed has **no frozen frame**
Video Encoder Safety Mechanisms

- **Internal Safety Diagnostic Mechanisms**
  - Fault avoidance mechanism
    - Reset performed at the beginning of every frame
  - Additional circuits added to the compression IP core (**in blue**)
    - Self Check
    - Control output diagnostics (Output Check)
    - RAM ECC correctable and uncorrectable errors
    - Configuration register protection (Config Check)

- **External Safety Diagnostic Mechanisms**
  - Offers maximum reliability
  - Implemented to protect against faults not detected by the internal safety mechanisms, e.g.:
    - Interrupt pin validation
    - Frame start/done monitoring
    - Test of internal safety mechanisms
    - **Watermark video frames (detects frozen frames)**
Conclusion

• There is a clear need within the industry for the additional bandwidth savings offered by VDC-M compression

• VDC-M is already supported by MIPI DSI-2℠
  ─ VDC-M will be supported by other transport technologies in the future

• The VDC-M compression algorithm is complex
  ─ Each application has its own unique requirements

• Visit our demo in the exhibitor area to see a live VDC-M demo & find out more about using compression in your next design

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ADDITIONAL RESOURCES

• VESA Website
  https://vesa.org/vesa-display-compression-codecs

• MIPI Website
  https://www.mipi.org/specifications/dsi-2

• Hardent Website
  - https://www.hardent.com/ip-products-vdc-m/
THANK YOU