Leveraging Video Compression within MIPI DSI-2\textsuperscript{SM} for High-Performance Displays

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26 May 2021
Product Display Bandwidth Trends
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[Graph showing trends in display bandwidth from 2008 to 2026, with lines for Displays, Auto, Tablets, and Mobiles, and arrows for Display and PHY Bandwidth growth.]
Product Display Bandwidth Trends

- VESA DSC Compression
- VESA VDC-M Compression

VESA® is a registered trademark of the Video Electronics Standards Association.
VES A Video Compression Codecs

• Incorporated in the MIPI Display Serial Interface (MIPI DSI-2SM)
• Guaranteed low-latency performance
• Visually lossless quality for all images and video

Which specification should you use?  
It depends on your target application & desired display features!
Image Quality Testing

• **Visually lossless subjective testing method:**
  – Expert analysis with image interleaving on high quality monitors
  – Non-expert random evaluation using the ISO/IEC CD 29170-2 procedure
    • Based on a “flicker test” and forced paradigm
  – All types of images tested

• **Test results:**
  – DSC at 8bpp vs. VDC-M at 6bpp: both are visually lossless
  – The two codecs have been tested with HDR content
  – Stereoscopic testing is also being done

Source: Hoffman & Stolitzka, 2015
Resources

Find out more about VESA’s image quality testing:

• VESA Display Stream Compression Whitepaper, 2014


• VESA DSC test results available for download: vesa.org/displayport-developer/presentations/
# DSC & VDC-M: Comparison of Key Features

<table>
<thead>
<tr>
<th></th>
<th>DSC</th>
<th>VDC-M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Encoding Block Structure</td>
<td>3x1 pixels</td>
<td>8x2 pixels</td>
</tr>
<tr>
<td>Encoding Tools</td>
<td>• Mid Point (MPP)</td>
<td>• Mid Point (MPP)</td>
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<tr>
<td></td>
<td>• Block Predictor (BP)</td>
<td>• Enhanced Block Predictor (BP)</td>
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<tr>
<td></td>
<td>• Modified Median Adaptive Predictor (MMAP)</td>
<td>• Transform (DCT &amp; Hadamard)</td>
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<tr>
<td></td>
<td>• Indexed Color History (ICH)</td>
<td>• Enhanced Quantization</td>
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<tr>
<td>IC Complexity</td>
<td>Low</td>
<td>Medium</td>
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<tr>
<td>Visually Lossless Performance</td>
<td>8 bpp (bits per pixel)</td>
<td>5-6 bpp (bits per pixel)</td>
</tr>
<tr>
<td>RAM Usage</td>
<td>Single line</td>
<td>2.5 lines</td>
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<tr>
<td>Latency (end-to-end)</td>
<td>&lt;0.5us</td>
<td>&lt;1.2us</td>
</tr>
<tr>
<td>Example: UHD 3840 x 2160</td>
<td>&lt;2H line</td>
<td>&lt;5H line</td>
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<tr>
<td>Pixels/Clock Architecture</td>
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<td>2</td>
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<tr>
<td>Encoder</td>
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<td>4</td>
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</table>

Source: VESA Website
Applications Using VESA Compression Codecs

• Mobiles
• Tablets
• Test equipment
• GPUs
• AR/VR devices
• Automotive video systems
• Video transport
• 8K TVs
• DTV set top boxes
• High-resolution monitors
# Video Compression: Application-Specific Benefits

<table>
<thead>
<tr>
<th>Market Trends</th>
<th>Compression Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Multiple or foldable displays</td>
<td>• Lower power consumption</td>
</tr>
<tr>
<td>• Ultra-high display resolutions</td>
<td>• Smaller footprint</td>
</tr>
<tr>
<td>• Ultra-high pixel density</td>
<td>• Lower cost</td>
</tr>
<tr>
<td>• High dynamic range (HDR) content</td>
<td>• Less pins</td>
</tr>
<tr>
<td>• Higher frame rates</td>
<td>• Lower switching frequencies</td>
</tr>
<tr>
<td>• Increased number of displays</td>
<td>• Reduced number of cables</td>
</tr>
<tr>
<td>• Higher display resolutions</td>
<td>• Lower weight &amp; labor costs</td>
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<tr>
<td>• Multiple video sources in parallel</td>
<td>• Lower EMI</td>
</tr>
<tr>
<td>• Multiple or foldable displays</td>
<td>• Lower power consumption</td>
</tr>
<tr>
<td>• Ultra-high display resolutions</td>
<td>• More reliable</td>
</tr>
<tr>
<td>• Ultra-high pixel density</td>
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<td>• Higher frame rates</td>
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Market Focus

Mobile
Mobile Market Trends

- Mobile devices need to be XR-ready
- Movement from LCD to OLED displays with sub-pixel rendering
  - Ultra-high resolutions and pixel density (up to 1500 ppi)
  - High dynamic range (HDR)
  - Higher frame rate
  - Optical compensation
  - Foldable, rollable displays
  - Lower power consumption
  - Non-uniformity compensation
- DDIC frame buffer going from 10 to 100 Mbits
- 5G increases EMI challenges

<table>
<thead>
<tr>
<th>Feature</th>
<th>2010</th>
<th>2020</th>
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<tr>
<td>Display Resolution</td>
<td>1280 x 720 HD</td>
<td>3840 x 2160 4K</td>
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<tr>
<td>Frame Rate</td>
<td>60 fps</td>
<td>120 fps</td>
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<tr>
<td>Pixel Depth</td>
<td>24 bits</td>
<td>30 bits</td>
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<tr>
<td>Interface</td>
<td>0.5 Gbps / lane</td>
<td>2.0 Gbps / lane With DSC</td>
</tr>
<tr>
<td>Display Bandwidth</td>
<td>1.3 Gbps</td>
<td>29.9 Gbps</td>
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23x
## VDC-M Allows Higher Resolutions

<table>
<thead>
<tr>
<th>Standard Resolution</th>
<th>FHD 1080x1920 24bpp/60fps</th>
<th>WQXGA 1600x2560 24bpp/60fps</th>
<th>UHD 2160x3840 24bpp/60fps</th>
<th>WQUXGA 2400x3840 24bpp/60fps</th>
<th>5K 2880x5120 24bpp/60fps</th>
<th>8K 4320x8192 30bpp/120fps</th>
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<tbody>
<tr>
<td><strong>Bandwidth</strong></td>
<td>3.58Gbps</td>
<td>7.08Gbps</td>
<td>14.33Gbps</td>
<td>15.93Gbps</td>
<td>25.48Gbps</td>
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<td><strong>D-PHY v1.1 1.5Gbps / lane</strong></td>
<td>3x compression</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>6</td>
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<td>4x compression</td>
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<tr>
<td></td>
<td>5x compression</td>
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<tr>
<td></td>
<td>4x compression</td>
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<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>5x compression</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td><strong>D-PHY v2.0 4.5Gbps / lane</strong></td>
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<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>4x compression</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>5x compression</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td><strong>D-PHY v2.1 6.5Gbps / lane short channel</strong></td>
<td>3x compression</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td></td>
<td>4x compression</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
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<td>N/A</td>
<td>N/A</td>
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</tr>
</tbody>
</table>
Display Resolution vs. Compression Technology

- FHD ←→ 4K@60fps > 4K@120fps
- VESA DSC
- VESA VDC-M

Display Bandwidth

- Gbps: 1000, 100, 10, 1

< FHD | FHD ↔ 4K@60fps | > 4K@120fps
DDIC Frame Buffer Subsystem:
UHD/4K Resolution 10bpc Use Case

- DDIC frame buffer subsystem includes the following three main components:
  - Display stream decoder core
  - SRAM used by the decoder core
  - Frame Buffer RAM
VDC-M vs. DSC for DDIC

• VDC-M offers attractive PPA (Power, Performance, Area) when compared to DSC:
  – Larger core gate count and internal SRAM is offset by a significant reduction in Frame Buffer RAM
  – Higher clock gating efficiency yields lower power
  – 4 pixels/clock decoder architecture allows for lower clock rates for the same throughput (Results in lower LVT usage)

• Overall VDC-M-based DDIC design will be:
  – 77% the area
  – 75-80% the power
  – Same throughput

• Additional savings will be obtained by the reduction in number or speed of MIPI PHY lanes
Market Focus

AR & VR
AR/VR Market

- **Challenges**
  - Requires two displays at higher resolution, higher ppi, higher refresh rates
  - Tethered Head-Mounted Display:
    - Cables are running out of bandwidth
  - Wireless Head-Mounted Display:
    - Bandwidth, power management, and miniaturization are huge obstacles
VDC-M to Fulfill Future AR/VR Requirements

Predicted industry trends:

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:
   - This is about **60 pixels per degree** for 273 degrees horizontally
   - 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
Use Case: AR Head-Mounted Display (HMD)

Compression could be applied to:
- Images captured by 3D camera
- Video and graphics processed by AR processor and GPU
- L/R video streams sent to micro-displays (DSI-2 Link)
- Video stored inside micro-display driver IC (Frame Buffer)

Benefits
- Lower bandwidth & EMI
- Smaller RAM buffers
- Power saving, longer battery life
- Low latency
Market Focus
Automotive
# Modern Automotive Cockpit Displays

<table>
<thead>
<tr>
<th>Display Type</th>
<th>Example Size (Inches)</th>
<th>Example Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left and Right-Side Mirror Displays</td>
<td>7”</td>
<td>1280x800</td>
</tr>
<tr>
<td>Driver Instrument Display</td>
<td>12.3”</td>
<td>3840x1440</td>
</tr>
<tr>
<td>Center Information Display</td>
<td>12.3”</td>
<td>3840x2160</td>
</tr>
<tr>
<td>Extended Co-Driver display</td>
<td>12.3”</td>
<td>3840x2160</td>
</tr>
<tr>
<td>Lower Control Display</td>
<td>12.4”</td>
<td>3840x2160</td>
</tr>
</tbody>
</table>
Modern Automotive Cockpit Displays

Rear Mirror Display

Left Rear Display

Right Rear Display
Digital Side View Mirror
More Displays Yes...
But 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)*
- Reliability, EMI, and signal integrity are major challenges
- On electric only vehicles, power consumption of video links must be minimized
- LESS cables reduces problems!

* Source: Delphi, Inc.
Benefits of using video compression:

- Reduced bandwidth for multiple feeds
- Enhance image quality (enabling HDR with same bandwidth)
- Savings on expensive cabling
- Lower EMI
- Reduce power
MASS: MIPI Automotive SerDes Solutions
A Vision for End-to-End Systems
MASS Display Use-Cases and Architecture

• MASS: MIPI Automotive SerDes Solutions
  – Foundation is the next generation MIPI Automotive-PHY specification (MIPI A-PHY<sup>SM</sup>)
    • 5 speed gears (2, 4, 8, 12 and 16 Gbps) with roadmap to 48 Gbps and beyond
  – Leverages MIPI low-power, low EMI display and camera protocols
  – Includes new end-to-end functional safety and security improvements
  – Includes and promotes standardized visually lossless compression (DSC/VDC-M) for displays
    • Low latency, low footprint & high visual quality

• MIPI whitepaper “Validating the Use of Compression for Automotive Displays”
  – A study verifying VDC-M's visually lossless compression properties demonstrates that MIPI DSI-2 offers a solution to the growing bandwidth challenges in next-generation vehicles
  – For automotive applications, VDC-M 6x compression is visually lossless
  – Download: [https://resources.mipi.org/download-mipi-whitepaper-automotive-display-compression](https://resources.mipi.org/download-mipi-whitepaper-automotive-display-compression)
# Automotive Display Bandwidth Requirements

<table>
<thead>
<tr>
<th>Display Config</th>
<th>Driver Instrument Display (DID) 12&quot;</th>
<th>Centre Information Display (CID) 10.2&quot;</th>
<th>Lower Control Display (CLD) 10.2&quot;</th>
<th>CoDriver Display (CDD) 12&quot;</th>
<th>Left Side Mirror 3.6&quot;</th>
<th>Right Side Mirror 3.6&quot;</th>
<th>Src 24-Bit</th>
<th>Src 30-bit</th>
<th>VDC-M Comp 24-bit (6:1)</th>
<th>VDC-M Comp 30-bit (6:1)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>1280x720</td>
<td>1280x720</td>
<td>None</td>
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<td>None</td>
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**Uncompressed Rates**
# Automotive Display Bandwidth Requirements

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**Compressed Rates**
Compression For Automotive Displays

Is it Safe?
Functional Safety in Display Applications

- Display systems, when involved in ADAS, are required to meet ASIL and ISO 26262 requirements

Safety Critical Information!
Functional Safety in Display Applications

• Safety Goals must be clearly defined

• There is no standardized definition of a display failure in a vehicle...
  – “Is a single pixel “glitch” ok?”
  – “Is a small portion of a frame corrupted for a second ok?”
  – “Is a complete frame corrupted for 1/60 sec ok?”
  – “Is a image showing darker than expected ok ?”
  – “Is it an issue if the video is frozen for ½ second?”

• For displays that contain safety critical information, no compromises are acceptable!
Functional Safety Assessment In a Nutshell

- **Failure Modes & Effects** are identified (how and where a failure occurs)
- **Diagnostic** mechanisms are added to detect when a failure happens
- For each failure mode, each diagnostic performance (fault coverage score in %) is determined for various types of fault: *Single Point Faults, Transient Faults, Latent Faults*, etc.
- This whole assessment is done through a complete **FMEDA (Failure Mode, Effects, and Diagnostics Analysis)**
- Required overall performance (for each type of fault) depends on the safety level required (ASIL A to ASIL D)
MIPI DSE℠ protocol adds Functional Safety (FuSa) features for displays:

- SEP
- Message Counters
- CRCs
**Additional Challenge with Video Compression**

- When compression is used, the compressed image payload and DSI-2 packets are protected by DSE FuSa, but not the image content itself.
- However...
  - Failures could occur during the encoding or decoding process.
  - Even when there is no failure, the decoded image is NOT identical to the original image (it is visually lossless but not bit exact).
FuSa with DSC & VDC-M Video Compression

- For DSC and VDC-M, the decoded image is generated during the encoding process

The integrity of the decompressed image in the display can be verified by comparing the CRC(s) of the decoded image generated by the encoder with the CRC(s) of the decoded image generated by the display.
FuSa with DSC & VDC-M Video Compression

• Benefits of the Decoded Image CRC(s) approach:
  — Easy to implement, **low area footprint**, removes the need for duplicated logic (a common technique for fault detection)
  — **Very high safety goal violation coverage** for both Single Point Faults (SPF) “Stuck bits” and Transient Faults (TF) “Glitches”, for the whole display subsystem
  — Using multiple CRC(s) per frame, a CRC value per “slice” helps to identify which parts of the image has corruption

• With the addition of Decoded Image CRC(s) when DSC or VDC-M compression is used, it becomes possible to meet the safety goals
Conclusions

• Video compression is essential for meeting the bandwidth requirements of current and future display applications

• VESA® DSC & VDC-M offer proven compatibility with the MIPI DSI-2\textsuperscript{SM} interface and visually lossless performance

• Integrating video compression into a design and achieving desired display features can be complex

• IP and IP subsystem solutions are available to help designers lower risk and achieve faster integration
Thank you....now time for questions

MIPI DSI-2 Homepage: www.mipi.org/specifications/dsi-2

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