Hi everyone, I’m James Goel, Chair of the MIPI Technical Steering Group and a Vice-Chair of the Display Working Group. Thank you for joining my MIPI DevCon 2020 virtual event.

Today I’m excited to talk about our new MIPI Automotive SerDes Solutions called MASS for short. This group of specifications is designed to work with our new Automotive-PHY we announced earlier this month.

I’m going to talk about recent automotive trends that are driving display architectures and how MASS can be used by engineers to solve difficult design challenges.

Before I begin, I’d like to point out this “deep diver” symbol that you will see on specific slides. It indicates that I have provided extra information in a supplementary presentation for you to review offline.

Also note that the audio transcript will be included in the notes under each slide of the PDF version.
Part I – MASS Display Use-Cases and Architecture

• Automotive displays undergoing rapid change driven by 5 new trends:
  – Connectivity, Over-the-Air Updates, Electrification, Autonomy and Ride Sharing
  – Increase in the number of displays
  – Increase in size
  – Increase in resolution

• **Massive increase in automotive display bandwidth** requirements.

• Countered with more stringent Power and RF interference constraints

It’s no surprise that the interior displays for next generation vehicles are evolving quickly.

Five new industry trends: Connectivity, Over-the-Air Feature Updates, Electrification, Autonomy and Car Sharing are increasing the number, size and resolution of automotive displays.

Consumers have become used to excellent mobile and television display quality and expect the same from their cars.

The net result is a massive increase in total automotive display bandwidth.

This increase does not come for free and is constrained by tight functional safety, security, power, weight and RF interference considerations.

Automotive engineers need new display systems solutions to address these difficult challenges.
Part I – MASS Display Use-Cases and Architecture
• Automotive engineers need new automotive display system solutions
• **MASS**: MIPI Automotive SerDes Solutions
  – Foundation is the next generation MIPI Automotive-PHY specification
  – Leverages MIPI low-power, low EMI display and camera protocols
  – Includes new End-to-end functional safety and security improvements
• Details in two new MASS Display and Compression whitepapers (Oct 2020)

MASS is a family of enhanced MIPI specifications upgraded to provide end-to-end protocols built upon the foundation of the new MIPI Automotive PHY.

MIPI Automotive SerDes Solutions combine A-PHY with enhanced low-power, low-EMI DSI-2 display and CSI-2 camera protocols. When used together, MASS provides an end-to-end solution capable of functional safety, security, data integrity across an automotive grade serial-deserializer.

More details of MASS and automotive display compression will be available in two new whitepapers to be published in October.
These 5 industry trends increase the total visual bandwidth resulting in a corresponding increase in the number, size and resolution of automotive displays.

The first trend, connectivity takes advantage of new 5G, V2V and V2X wireless communication standards to increase access to high bandwidth data streams for multimedia content like video, gaming and new automotive applications. Right now, many people use their cars as mobile offices to provide the freedom and flexibility to work anywhere and enhanced connectivity is becoming a requirement in modern cars.

The second trend, Over-the-Air Feature Updates, leverages this new connectivity to allow vehicle manufacturers to offer software subscription services that update the capabilities of vehicle after they have been purchased. These new software features take advantage of the advanced display hardware by providing user-customizable look-and-feel options for the car’s interior to match the tastes and preferences of each driver or passenger.

The third trend, Electrification, is well underway as vehicles transition from fossil fuels to renewal energy sources. This trend requires vehicle displays to minimize power consumption while maintaining very low electroco-magnetic compatibility (EMC) with communication and electrical systems.
The final two complementary trends, vehicle autonomy and car sharing combine to ease the driving task to the point where autonomous vehicles enable car sharing as a service. People that share vehicles will expect them to automatically switch to their personal display profiles to keep the interiors consistent from vehicle to vehicle.

All trends clearly point to more, higher, larger displays. Automotive display architects must adapt their next generation designs to accommodate this rapid increase in demand for visual bandwidth or face becoming uncompetitive as the automotive industry transitions.
This illustration contains multiple displays that will be found in next generation vehicles.

The Driver Instrument Cluster display is larger, brighter and higher resolution than current displays. It can be customized based on driver preference or upgraded with over the air features enabled by the trend for advanced connectivity.

The center information display contains navigation information and can be upgraded over-the-air with new features and applications as the automotive industry evolves. Below this is the lower-control display. All vehicle controls are configured through this touch sensitive display allowing the driver to make the user experience as detailed or as simple as desired.

The Co-Driver display allows the front passenger to customize their space, set their temperature controls and watch their own content including video, news and gaming.

The left and right-side mirror displays are based on the next generation of exterior sensors and more detail is provided on this application later in the presentation.
### 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 (DID)</td>
<td>12.3”</td>
<td>3840x1440</td>
</tr>
<tr>
<td>Center Information Display (CID)</td>
<td>12.3”</td>
<td>3840x2160</td>
</tr>
<tr>
<td>Extended Co-Driver display (CDD)</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>

On the right is an example table indicating the next generation of display sizes and resolutions taken from publicly available sources. Note how large these new displays have become along with an increase in display resolution compared to existing vehicles on the road today.

The key take-away is the obvious increase in total visual display bandwidth. Of course, these displays all need to meet stricter Electro-Magnetic Compatibility requirements to reduce interference for in-vehicle WiFi and 5G wireless communications. There is also the need to reduce power to ensure the longest possible distance on a single-battery charge all while maintaining functional safety and data integrity.
This slide shows rear screen displays that can be configured based on user profile and preferences. The rear-view mirror has been replaced by a display connected to a rear camera.

There are two important points illustrated on this slide:
1. It’s interesting to note the aerodynamic improvement in low profile side sensors compared to traditional external mirrors.
2. Displays are not necessarily close to an ECU mounted in the dashboard and often require longer cabling solutions to reach the rear of the vehicle.
Internal digital side view mirrors have a number of benefits over traditional external glass mirrors:
1. As we saw earlier, the lower-profile external sensors improve aerodynamic performance, reduce wind noise and increase night-time and poor weather visibility using advanced sensors and wide field-of-view optics.
2. Internal mirror displays enable instant zooming and customizable driver display positioning that is unaffected by weather.
3. ADAS lane departure, blind-spot and backup assist symbology is also supported.
Automotive Display Requirements

- Support multiple, high resolution displays from a single Electronic Control Unit (ECU)
  - Up to 15 meters with multiple simultaneous display channels
  - Low power, Electromagnetic Compatibility (EMC) and Ultra-low Packet Error Rate (PER) for safety and video compression support.
- Support scalable daisy-chain and hub-spoke topologies
  - Daisy Chain Topology
    - Best suited when central ECU drives multiple inline displays.
    - Dashboard applications
  - Hub-Spoke Topology
    - Best suited when central ECU drives multiple widely dispersed displays
    - Rear screen applications
- Side-view mirror use-case
  - External side-mirror camera sensor → ECU → side-mirror display
  - Functional Safety

We can divide these automotive display use-cases into three separate categories:
1. Short distance in-line dashboard displays
2. Long distance rear seat displays
3. Digital side and rear mirror displays using external sensors

* All use-cases feature support for multiple, high-resolution displays.
* The dashboard displays are typically in-line and only a short distance from the ECU, while rear displays and digital mirrors can require up to 15 meters of SERDES cable length as per the A-PHY specification
* In each case, displays may need to support functional safety, security, EMC and ultra-low packet error rates especially if display compression is required.

The dashboard use-case will be used to illustrate a daisy-chain display topology while the rear displays illustrate the hub-and-spoke system. I will go into detail for the daisy-chain system in this main presentation but the hub-and-spoke is covered in the deep dives section at the end.

The digital mirrors are interesting because they must maintain pixel integrity from the camera sensor to ECU to side mirror display. This is where MASS excels. Its protocols provide end-to-end solutions with functional safety, security and high data integrity.
This slide introduces the MASS or MIPI Automotive SerDes Solutions concept. MASS supports an end-to-end protocol chain with functional safety and security over the MIPI automotive PHY. In this diagram, the camera produces CSI-2 data streams with new functional safety and security information added to the protocol as indicated by the shield and lock icons. The CSI-2 data is transmitted over A-PHY to an automotive ECU for data verification and signal processing. Once ready, the ECU generates DSI-2 packets with functional safety and security for transmission over A-PHY to the display. Please note that MASS optionally supports HDCP for protection of high value content.
This slide illustrates MASS applied to the digital side mirror application.

The digital mirror display is a great application for MASS because it requires the camera sensor, ECU, and display to work together as an end-to-end system to ensure functional safety and pixel data integrity.

There are three levels in this diagram:

The top level illustrates how the external side camera sensor captures pixel data, and sends it to a MIPI A-PHY bridge chips using new CSI-2 functional safety and security protocols over a C-PHY or D-PHY physical connection. MASS specifications define the CSI-2 Camera Service Extensions and Protocol Adaptation Layer required to efficiently pack sensor pixels into A-PHY data frames used on both A-PHY Tx and Rx bridges.

The middle level illustrates how the ECU receives the camera data, verifies pixel integrity to ensure functional safety before signal processing. Once the image has been evaluated with proper graphics symbology overlay, the display generator sends display pixels out using the traditional DSI-2 protocol with Display Service Extensions and Protocol Adaptation layer specifications defining efficient A-PHY data frame packing. It is important to note that MASS CSI-2 and DSI-2 functional
safety and security specifications were designed to provide an end-to-end system solution that leverages A-PHY as the foundational Serial-Deserializer.

The lower level illustrates how the end display receives the A-PHY data frame from the Rx bridge and displays the picture using legacy C-Phy or D-PHY physical connections.

Some general Comments.

As mentioned earlier, the end-to-end FuSa and security are maintained by a series of MASS specifications designed to work together. The CSI-2 and DSI-2 protocols are not transcoded between the device and the A-PHY bridge. There are MIPI adaptation layer specifications that define how existing MIPI protocols are encapsulated for efficient A-PHY packet framing. MASS also supports GPIO and I2C/I3C adaptation layers for A-PHY to support existing CSI-2 and DSI-2 systems. The details of this will be in future whitepapers and DevCon presentations on MASS display details.
This slide illustrates a MASS Daisy chain topology for the dashboard display application shown here.

The ECU processor is embedded in the dashboard and these displays are physically in-line with each other as illustrated in the picture.

NOTE both digital side mirrors are at the end of the daisy chain and this is done on purpose. The architecture scales from the lowest auto trim-level with only the top three displays available up to the highest-trim where Co-Driver displays and digital mirrors are more popular.

The application processor generates all display content and uses MASS DSI-2 or VESA Display Port interfaces to connect an A-PHY bridge to the first display in the chain (Blue Arrow). MASS supports both a homogeneous and heterogeneous architecture with more details provided in the deep dive along with an alternate hub-and-spoke architecture.

Each subsequent display parses the required pixel stream and sends the remaining data down the chain. In this example the left side mirror and right-side mirror displays will require the least bandwidth because they are at the end of the chain.
MASS A-PHY supports the high pixel bandwidth required by the Blue Arrow and this is explored in the next section.
Part II – DSI-2 Display Bandwidth Compression

• Evaluate 7 different display automotive use-cases
• Calculate raw and compressed bandwidth requirements
  – Use the most aggressive VDC-M 6:1 compression ratio
  – 30-bits per pixel (bpp) uncompressed -> 5 bpp compressed
  – 24-bpp uncompressed -> 4 bpp compressed
• Explain MIPI Automotive Compression Study
• Analyze and report visual quality results

The first blue arrow connection shown in the previous slide contains all display content for the dashboard. The next section analyzes the bandwidth requirements of 7 different dashboard display configurations and applies the optional VDC-M 6:1 visually lossless compression to study the corresponding improvement in bandwidth.

The MIPI Display Working Group completed an expert study of VDC-M compression for automotive images and the results are presented in Part II of this DevCon presentation. More details available in the deeper dive.
This table summarizes the pixel bandwidth analysis for 7 different display configurations.

Each row calculates the display bandwidth requirements from the previous Daisy chain example for a fictional automotive trim-level.

Across the top of the table are the display parameters and then the total bandwidth required for all displays together.

This amount must be supported by the blue arrow in the previous diagram because the first connection in the daisy-chain.

The last set of columns indicate the number of lanes requires for the automotive-PHY, D-PHY and C-PHY bridge connections.

Let’s focus on the highlighted total bandwidth section.

The first 2 columns have different source pixel sizes. The source 24-bits means 8-bits per component and 30-bits per pixel that means 10 bits per component.

The calculations highlighted in blue indicate the total uncompressed data rates for
each of the 7 levels. These data rates can be reduced drastically using VDC-M compression.
### Automotive Display Bandwidth Requirements

<table>
<thead>
<tr>
<th>Display Config</th>
<th>Display Parameters</th>
<th>Total Bandwidth</th>
<th>MIPI PHY</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
<td>Compressed Rates</td>
<td>Minimum A-PHY Gear Required</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Comp 24-bit (6:1)</td>
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</tr>
<tr>
<td>Level 1</td>
<td>1280x720</td>
<td>2.846</td>
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<td></td>
<td>1280x720</td>
<td>3.558</td>
<td>1.068</td>
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<tr>
<td>Level 2</td>
<td>1920x720</td>
<td>6.405</td>
<td>5.577</td>
</tr>
<tr>
<td>Level 3</td>
<td>3840x1440</td>
<td>33.46</td>
<td>8.495</td>
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</tr>
<tr>
<td>Level 4</td>
<td>5120x2160</td>
<td>59.156</td>
<td>9.659</td>
</tr>
<tr>
<td>Level 5</td>
<td>7680x2800</td>
<td>78.954</td>
<td>98.89</td>
</tr>
</tbody>
</table>

**Compressed Rates**

The compressed rates highlighted on this slide indicate a 6:1 reduction in bandwidth.

This allows the design to reduce the required number of PHY lanes indicated in the last three columns.

In summary, the benefit of reduced bandwidth using VDC-M compression is a reduction in power, improved EMC and cost through interface savings.

VDC-M is a great technique when the compression quality meets the designer’s goal to be visually the same as the original uncompressed image. This is called visually lossless quality.

The next section of this presentation focuses on how MIPI evaluated the visual quality for example automotive images.
The MIPI Display Working Group asked the question:

Is VDC-M 6:1 compression visually lossless for automotive style images?

To answer this:

[HIGHLIGHT Step 1] MIPI created example automotive dashboard test images. These are available for MIPI members to download and evaluate.

[HIGHLIGHT Step 2] Select and use the internationally accepted 29170-2 standard protocol for testing high quality compression. This is publicly available from the ISO website.

Step 3: Seven visual quality experts followed the protocol and evaluated all automotive images.

Step 4: The results are summarized in a final quality report and posted for members to review. More details will be published in the October whitepaper.
The video on this slide illustrates the first static image testing protocol using an exaggerated compressed image.

The subject looks at these three images and selects the image on the bottom that matches the reference quality on the top. This is done many times over all the images with the bottom compressed image randomly positioned on the left or right. Over many trials, high quality compressed images will have the same 50% chance of selection as the uncompressed version.
The video on this slide illustrates the second dynamic flicker testing protocol using an exaggerated compressed test image.

You can see the compressed test image is alternating with the original and if the compressed image is different, it will become obvious to the tester which areas are not visually lossless.

The idea is to make it easy to expose visual differences with the flicker testing. This is done over many trials with randomly positioned flickering on either the right or left side.

Over these trials, high quality compressed images will have the same 50% chance of selection as the uncompressed version.
This slide contains 6 examples of the MIPI automotive test images commissioned for use in visual quality testing. These images also have day and night variants to simulate a change in contrast.

Low resolution versions of the complete image set are available in the deep dive section but the high resolution 4K versions must be downloaded from the MIPI website.
This slide illustrates specific areas of interest we evaluated on various images.

The shading background is covered in fine diagonal lines and this detailed area should be preserved in the compressed image.

We also evaluated the areas where text and graphics were close to the final lines.

Expert testing revealed that all areas of interest passed both static and dynamic evaluation.
These results come from gathering statistical results from 7 experts over multiple visual trials as described in the ISO quality standard.

A full trial would require many more subjects to be statistically accurate.

VDC-M 6:1 compression testing on these images was highly successful but automotive design teams still need to follow their own quality assessment protocols because the MIPI content will differ from their final production graphics.

The study report is available from the MIPI executive for those interested in following up on the details.
Summary

- Automotive displays are increasing in:
  - Number, Size and Resolution
- Driven by 5 new trends:
  - Connectivity, Over-the-Air Updates, Electrification, Autonomy and Ride Sharing
- Result: **Massive increase in automotive display bandwidth**
- **MASS**: MIPI Automotive SerDes Solutions
  - End-to-End Camera->ECU->Display Architecture
  - Leverages Display DSI-2 Compression
- **MIPI DSI-2 Compression for Automotive Display Study**
  - Compression for Visually Lossless Automotive MASS Displays

In Summary:

There are 5 new trends driving automotive displays to become larger, higher resolution and more numerous. This results in a massive increase in visual bandwidth. Automotive display architects are challenged to meet a variety of complex use-cases with existing SerDes solutions.

MIPI introduced MASS – The MIPI Automotive SerDes Solutions family of automotive specifications built upon the A-PHY.

MASS Displays support daisy chain and hub-and-spoke topologies for the use-cases discussed in this DevCon.

MASS DSI-2 display protocols support advanced VDC-M visually lossless compression and the latest MIPI 6:1 compression study explored the quality possible on a variety of available automotive images.

MASS provides excellent end-to-end support for functional safety and security display solutions. It is a great choice for next generation automotive display architectures.
Thank-you.
THANK YOU
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Deep Dive Sections

Deep Dive - MASS: MIPI Automotive SerDes Solutions
High-bandwidth Connected Displays

Deep Dive Part II - DSI-2 Display Bandwidth Compression
- Evaluate 7 different display automotive use-cases
  - Calculate raw and compressed bandwidth requirements
  - Use the most aggressive 800 M/s compression ratio
  - 10 bits per pixel (pp) uncompressed = 1.6 top compressed
  - 48 bpp uncompressed = 6.4 bpp compressed
- Explain MIPI Automotive Compression Study
- Analyze and report visual quality results

Deep Dive - Automotive Display Bandwidth Requirements

Deep Dive MIPI Automotive 4:1 Image Compression Study
1. MIPI automotive dashboard images
2. Selected DSC/PCI 29170-2:2015 Subjective Trials protocol
   - Standard for low bandwidth compression visual quality analysis
3. Expert reviewers evaluated images
4. Generated report results
   - All images pass a limited expert review
   - MIPI study images are available for member experimentation.
   - Please contact the MIPI executive team.

Deep Dive - Summary of MIPI Commissioned Test Images

Display Hub and Spoke Topology

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This diagram illustrates the basic concept behind mass as it is envisioned once it has matured and become fully integrated into the automotive ecosystem.

In this diagram all functional safety and security protocols have all been fully integrated into each electronic device in the MASS chain. MIPI recognizes this is not the current state of the automotive industry and it will take a while before this level of integration is achieved. MASS needs to be implemented with existing legacy solutions through the use of bridges chips and a slower evolutionary path as illustrated in the next diagram.
This version illustrates the inclusion of A-PHY Rx and Tx bridges as indicated by the circles.

These external bridges will support existing CSI-2, DSI-2 and VESA DisplayPort/eDP protocols to ease adoption of the MASS family of specifications.

MIPI expects this transition to be supported with A-PHY bridges for years given the required safety and security performance of automotive electronics.
This application requires two rear 4K resolution entertainment displays. One display is showing high value Hollywood content while the other display is not.

The block diagram illustrates one the use of MASS with VESA eDP/DP running HDCP content protection over A-PHY to support one display while the other supports DSI-2 without content protection.

This rear screen application requires multiple protocols and longer length A-PHY cables due to the physical distance between the dashboard ECU and the displays.

The next section discusses the hub-and-spoke topology best suited for this architecture.
Automotive Protocol Stack-up Diagram

Applications
- Camera / Radar / Lidar
- MIPI Protocol Layers
  - MIPI CCS
  - MIPI Camera Service Extensions (CSE)
  - MIPI CSI-2
  - MIPI PAL/CSI-2
  - Link Layer
  - Physical Layer

MIPI Display
- MIPI DCS
- MIPI Display Service Extensions (DSE)
- MIPI DSI-2
- MIPI PAL/DSI-2
- MIPI A-PHY Data Link Layer
- MIPI A-PHY SerDes — PHY Layer

VESA Display
- VESA DP/DP (SDP, MST, DP, HDCP)
- MIPI PAL/DP
- MIPI A-PHY SerDes — PHY Layer

Low Bandwidth Interfaces
- Various Controllers
  - PC
  - I3C
  - Future
  - GPIO
  - MIPI PALs for PC/I3C/GPIO

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This diagram illustrates the extent of MASS protocol specifications over the 5-layers from Application down to Physical Layer.

Mass currently covers four different interface categories: camera, display, VESA display, and low bandwidth interfaces.

Within each of these interface categories there are different MIPI protocol layers an adaptation layer specifications that cover various requirements and protocol additions to include functional safety, security, and protocol adaptation layer for a fee.

When used together, these specifications provide end to end data functional safety and security for the applications illustrated in this presentation.

All MASS protocols build upon the MIPI A-PHY and leverage the years of automotive/mobile protocol experience shipping in billions of devices.
Deep Dive Part II – DSI-2 Display Bandwidth Compression

- Evaluate 7 different display automotive use-cases
- Calculate raw and compressed bandwidth requirements
  - Use the most aggressive VDC-M 6:1 compression ratio
  - 30-bits per pixel (bpp) uncompressed -> 5 bpp compressed
  - 24-bpp uncompressed -> 4 bpp compressed
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## Deep Dive - Automotive Display Bandwidth Requirements

<table>
<thead>
<tr>
<th>Display Config</th>
<th>Driver Instrument Display (DID) 12”</th>
<th>Centre Information Display (CID) 10.2”</th>
<th>Lower Control Display (CLD) 10.2”</th>
<th>CoDriver Display (CDD) 12”</th>
<th>Left Side Mirror 3.6”</th>
<th>Right Side Mirror 3.6”</th>
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<th>Sc 30-bit</th>
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</tr>
</tbody>
</table>
## Panel Resolution vs Native Display Payload Data Rate

<table>
<thead>
<tr>
<th>Horizontal Resolution</th>
<th>Vertical Resolution</th>
<th>Frame Rate (Hz)</th>
<th>Display Interface Payload Data Rate (Gbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>24 bit Video</td>
</tr>
<tr>
<td>1920</td>
<td>720</td>
<td>60</td>
<td>2</td>
</tr>
<tr>
<td>2560</td>
<td>720</td>
<td>60</td>
<td>3</td>
</tr>
<tr>
<td>1920</td>
<td>1080</td>
<td>60</td>
<td>3</td>
</tr>
<tr>
<td>3840</td>
<td>1440</td>
<td>60</td>
<td>8</td>
</tr>
<tr>
<td>3840</td>
<td>2160</td>
<td>60</td>
<td>13</td>
</tr>
<tr>
<td>5120</td>
<td>2160</td>
<td>60</td>
<td>17</td>
</tr>
<tr>
<td>7680</td>
<td>2880</td>
<td>60</td>
<td>33</td>
</tr>
</tbody>
</table>

**Notes:**
- Video timing assumes use Reduced Blanking version 2 as per VESA CVT Spec 1.2
  - Uncompressed video transport (no DSC or VDC-M)
  - + 300ppm added to account for reference clock error
- Data rates are for single display; multiple display transport aggregation needs to be considered
- Data rates include Vertical blanking interval lines, and Horizon blanking interval pixels
  - Blanking interval lines and pixels will be used for transport of other data related to display support
  - Transport of blanking intervals also maintains plesiochronous timing of video stream, reducing buffer requirements
Gears and Profiles

- One Rate/line-code/modulation per Downlink Gear
- Single Uplink Gear
- Two Noise/Performance Profiles (with full inter-profile interoperability):
  - **Profile 1**: optimized for low cost/power implementations for the lower gears with lower Noise immunity and target PER of $10^{-5}$
  - **Profile 2**: optimized for Vehicle Life-span, link robustness for all Gears with high noise immunity and target PER of $10^{-19}$
- A-PHY Device supporting Gear N (N could be 1–5) shall support all lower gears.

<table>
<thead>
<tr>
<th>Gear Data Rate</th>
<th>Modulation [One modulation per Gear]</th>
<th>Symbol Rate [Gbaud]</th>
<th>Net Application Data Rate [Gbps]</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1 2 Gbps</td>
<td>NRZ-8b/10b</td>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td>G2 4 Gbps</td>
<td>NRZ-8b/10b</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>G3 8 Gbps</td>
<td>PAM4</td>
<td>4</td>
<td>7.2</td>
</tr>
<tr>
<td>G4 12 Gbps</td>
<td>PAM8</td>
<td>4</td>
<td>10.8</td>
</tr>
<tr>
<td>G5 16 Gbps</td>
<td>PAM16</td>
<td>4</td>
<td>14.4</td>
</tr>
<tr>
<td>Uplink, All Gears 100Mbps</td>
<td>NRZ-8b/10b</td>
<td>0.1</td>
<td>0.055 (55Mbps)</td>
</tr>
</tbody>
</table>
### Detailed Bandwidth Calculations

<table>
<thead>
<tr>
<th>MIPI PHY</th>
<th>Lane</th>
<th># Wires</th>
<th>Gsym/sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-PHY 2.0</td>
<td>1</td>
<td>4</td>
<td>4.5</td>
</tr>
<tr>
<td>D-PHY 2.0</td>
<td>2</td>
<td>6</td>
<td>4.5</td>
</tr>
<tr>
<td>D-PHY 2.0</td>
<td>3</td>
<td>8</td>
<td>4.5</td>
</tr>
<tr>
<td>D-PHY 2.0</td>
<td>4</td>
<td>10</td>
<td>4.5</td>
</tr>
<tr>
<td>C-PHY 2.0</td>
<td>1</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>C-PHY 2.0</td>
<td>2</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>A-PHY G1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>A-PHY G2</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>A-PHY G3</td>
<td>1</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>A-PHY G4</td>
<td>1</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>A-PHY G5</td>
<td>1</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>A-PHY G5</td>
<td>2</td>
<td>4</td>
<td>16</td>
</tr>
</tbody>
</table>
Deep Dive MIPI Automotive 6:1 Image Compression Study

1. MIPI automotive dashboard images
   - Optimized for low-impairment compression visual quality analysis
3. Expert reviewers evaluated images
4. Generated report results
   - All images passed a limited expert review
   • MIPI study images are available for member experimentation. Please contact the MIPI executive team.

The MIPI Display Working Group asked the question:

Is VDC-M 6:1 compression visually lossless for automotive style images?

To answer this:

[HIGHLIGHT Step 1] MIPI created example automotive dashboard test images. These are available for MIPI members to download and evaluate.

[HIGHLIGHT Step 2] Select and use the internationally accepted 29170-2 standard protocol for testing high quality compression. This is publicly available from the ISO website.

Step 3: Seven visual quality experts followed the protocol and evaluated all automotive images.

Step 4: The results are summarized in a final quality report and posted for members to review. More details will be published in the October whitepaper.
This slide contains 6 examples of the MIPI automotive test images commissioned for use in visual quality testing. These images also have day and night variants to simulate a change in contrast.

Low resolution versions of the complete image set are available in the in the deep dive section but the high resolution 4K versions must be downloaded from the MIPI website.
Link to original MIPI Automotive Images for use in quality trials

• Link to original MIPI Automotive Images for use in quality trials
• https://members.mipi.org/wg/All-Members/document/folder/13176
VDC-M Visually Lossless Quality Assessment

1. Uncompressed Source Image .ppm or .dpx
2. VDC-M Encoder
3. Compressed pixel stream .bits
4. VDC-M Decoder
5. Reconstructed Image .ppm or .dpx

Stage 1
Stage 2
Stage 3
Stage 4
Stage 5

Source Image CRC
Compressed Image CRC
Reconstructed Image CRC

VDC-M PPS Configuration Files .cfg
MIPI Test Image – Safety Icons and Telltales
MIPI Test Image – Driver Instrument Cluster

MIPI Alliance, Inc. 2020
MIPI Test Image – Center Information Display

62°F

Phone
Radio
Navigation
Climate

Users
Weather
Media
Settings

NOW PLAYING
Jazz Station

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MIPI Test Image – Rear Camera Day Display

Check surroundings for your safety.
Key Focus Areas

- Background Shading
- Detailed Text and Graphics
ISO Quality Results Report

- **Instrument Cluster**
  - Day: No TellTales
  - Night: White Ring
  - Obvious Artifacts: 100% Detectable
  - Visually Lossless: 50% Random Chance

- **Backup Camera**
  - Day: X
  - Night: X

- **Entertainment Cluster**
  - Day: X
  - Night: X

- **Navigation Map**
  - Day: X
  - Night: X

- **Virtual Event 2020**
Background

- **MASS: MIPI Automotive SerDes Solutions**
- Two key whitepapers provide much more detail (October 2020):
  - MASS Display Architecture Whitepaper
  - MASS Display DSI-2 VDC-M Compression Whitepaper

- **Citations**

- **Related Technical Standards**
  - ISO - Advanced image coding and evaluation — Part 2: Evaluation procedure for nearly lossless coding
    - ISO 15008:2017 - Road vehicles — Ergonomic aspects of transport information and control systems — Specifications and test procedures for in-vehicle visual presentation
  - ISO 2575:2010 - Road vehicles — Symbols for controls, indicators and tell-tales
  - SAE J1362 - Graphical Symbols for Operator Controls and Displays on Off-Road Self-Propelled Work Machines