MIPI Automotive and A-PHY℠ Update

Matt Ronning
MIPI Automotive Working Group Chair, Sony

Raj Kumar Nagpal
MIPI A-PHY Subgroup Chair, Synopsys
Presentation Agenda

MIPI in Automotive
Matt Ronning
MIPI Automotive Working Group Chair

An Overview of MIPI A-PHY
Raj Kumar Nagpal
MIPI A-PHY Subgroup Chair
Auto Industry Transformation

Huge changes in the industry:

- Worldwide new car assessment program (government safety regulations such as FCWS, AEBS, RVS, LDWS, etc.)
- Aggressive fuel economy regulations
- Electrification of cars
- New OEMs, new business models, new alliances
- Autonomous driving systems
- Car connectivity

Honda and GM Partner to Develop Mass Produced, Driverless Cars
Source: October 4, 2018, Automotive News
NCAP Regulations Driving Sensors & Display Adoption

Surround sensors for driver assistance

- Worldwide NCAP ADAS standards driving adoption of multiple high data rate “surround sensors”
- Displays for driver viewing of assistance imaging and information also required

Source: Jabil, Inc
Fuel Economy a Market Force

- Fuel economy regulations drive auto tech: Mild hybrids, mirror replacement cameras (MRC), etc.
- MRCs weigh less and reduce side-mirror drag 2%~7%, resulting in improved fuel economy (with improved safety, too)
- Japan/EU regulatory approval for mirrorless cars as of 2016, U.S. approval pending
- Japan new vehicle 2023 projections:*
  - Digital rear-view mirrors: 29%
  - Digital side-view mirrors: 12%  

* Source: Ichikoh

“Today’s average car burns a full tank of fuel every year, just by transporting its mirrors.”

- Brad Duncan, Sr. Director, Exa Corp.
### Automotive Image Sensors

Source: MIPI AsG BoF Meetings

<table>
<thead>
<tr>
<th>Format</th>
<th>Hres (pixels)</th>
<th>Vres (pixels)</th>
<th>Res (Mpixs)</th>
<th>Fps</th>
<th>8 bit</th>
<th>10 bit</th>
<th>12 bit</th>
<th>14 bit</th>
<th>16 bit</th>
<th>20 bit</th>
<th>24 bit ('')</th>
</tr>
</thead>
<tbody>
<tr>
<td>1MP/720P</td>
<td>1280</td>
<td>720</td>
<td>0.92</td>
<td>30</td>
<td>0.22</td>
<td>0.28</td>
<td>0.33</td>
<td>0.39</td>
<td>0.44</td>
<td>0.55</td>
<td>0.66</td>
</tr>
<tr>
<td>1MP/720P</td>
<td>1280</td>
<td>720</td>
<td>0.92</td>
<td>60</td>
<td>0.44</td>
<td>0.55</td>
<td>0.66</td>
<td>0.77</td>
<td>0.88</td>
<td>1.11</td>
<td>1.33</td>
</tr>
<tr>
<td>2MP/1080P</td>
<td>1920</td>
<td>1080</td>
<td>2.07</td>
<td>30</td>
<td>0.50</td>
<td>0.62</td>
<td>0.75</td>
<td>0.87</td>
<td>1.06</td>
<td>1.29</td>
<td>1.48</td>
</tr>
<tr>
<td>2MP/1080P</td>
<td>1920</td>
<td>1080</td>
<td>2.07</td>
<td>60</td>
<td>1.00</td>
<td>1.24</td>
<td>1.48</td>
<td>1.74</td>
<td>1.95</td>
<td>2.49</td>
<td>2.99</td>
</tr>
<tr>
<td>4MP</td>
<td>2592</td>
<td>1458</td>
<td>3.78</td>
<td>30</td>
<td>0.91</td>
<td>1.13</td>
<td>1.36</td>
<td>1.59</td>
<td>1.81</td>
<td>2.27</td>
<td>2.72</td>
</tr>
<tr>
<td>4MP</td>
<td>2592</td>
<td>1458</td>
<td>3.78</td>
<td>60</td>
<td>1.81</td>
<td>2.27</td>
<td>2.72</td>
<td>3.17</td>
<td>3.63</td>
<td>4.55</td>
<td>5.44</td>
</tr>
<tr>
<td>4K Ultra HD</td>
<td>3840</td>
<td>2160</td>
<td>8.29</td>
<td>30</td>
<td>1.98</td>
<td>2.48</td>
<td>2.95</td>
<td>3.48</td>
<td>3.98</td>
<td>4.98</td>
<td>5.97</td>
</tr>
<tr>
<td>4K Ultra HD</td>
<td>3840</td>
<td>2160</td>
<td>8.29</td>
<td>60</td>
<td>3.98</td>
<td>4.98</td>
<td>5.97</td>
<td>6.97</td>
<td>7.96</td>
<td>9.95</td>
<td>11.94</td>
</tr>
<tr>
<td>10MP</td>
<td>4096</td>
<td>2304</td>
<td>9.44</td>
<td>30</td>
<td>2.76</td>
<td>3.83</td>
<td>4.40</td>
<td>4.96</td>
<td>5.52</td>
<td>6.60</td>
<td>8.14</td>
</tr>
<tr>
<td>10MP</td>
<td>4096</td>
<td>2304</td>
<td>9.44</td>
<td>60</td>
<td>4.50</td>
<td>5.66</td>
<td>6.79</td>
<td>7.93</td>
<td>9.06</td>
<td>11.32</td>
<td>13.58</td>
</tr>
</tbody>
</table>

**Link with 10Gbps could support:**
- Up to RAW16, 10MP 1 max exposure channel @ 60fps; 10MP 2 max exposure channel @ 30fps; 2MP 4 max exposure channel @ 60fps
- Up to RAW24, 10MP, 1 max exposure channel @ 30 fps

**Link with 5Gbps could support:**
- Up to RAW16, 2MP 2 max exposure channel @ 60fps
- Up to RAW24, 2MP, 1 max exposure channel @ 60 fps
Automotive Radar

- Data rate per RX channel ADC:
  - Min: 20MS/s, 12b resolution
  - Typical: 50MS/s, 12b resolution
  - Max: 80MS/s, 16b resolution

- Today: clusters of 4 channel transceiver

→ Required channel bandwidth for raw data transmission:
  - Min: 0.96Gbps
  - Typical: 2.40Gbps
  - Max: 5.12Gbps

<table>
<thead>
<tr>
<th></th>
<th>Samplerate [MS/s]</th>
<th>Resolution [bit]</th>
<th>1ch</th>
<th>2ch</th>
<th>4ch</th>
<th>8ch</th>
<th>16ch</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>assumption by 2022+</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>min</td>
<td>20</td>
<td>12</td>
<td>0.2</td>
<td>0.5</td>
<td>1.0</td>
<td>1.9</td>
<td>3.8</td>
</tr>
<tr>
<td>typ</td>
<td>50</td>
<td>12</td>
<td>0.6</td>
<td>1.2</td>
<td>2.4</td>
<td>4.8</td>
<td>9.6</td>
</tr>
<tr>
<td>max</td>
<td>80</td>
<td>16</td>
<td>1.3</td>
<td>2.6</td>
<td>5.1</td>
<td>10.2</td>
<td>20.5</td>
</tr>
</tbody>
</table>

Source: MIPI AsG BoF Meetings
Autonomous Driving System

**CENTRAL CHALLENGE:**

Transport raw image sensor and/or radar data to fusion processor, and processor/other generated data to the displays

**Data Rates**

*For image sensors*, 10Gbps link could support:
- RAW16 10MP 1 max exposure channel @ 60fps
- RAW 16 2MP 4 max exposure channel @ 60fps

*For radar*, 12.5Gbps link could support:
- Four “typical” 4-RX-channel (50MS/sec, 12b res)
- Two “max” 4-RX-channel (80MS/sec, 16b res)

*For display subsystems*, 16Gbps link could support:
- Ultra-HD 3840x2160 24-bits/pixel RGB 4:4:4 60 Hz
Why MIPI A-PHY for Automotive?

MIPI Alliance can provide auto OEMs with a standard I/F vs. current incompatible proprietary LVDS solutions, and enables the use/reuse of billions of instances of MIPI protocols like CSI-2.

MIPI asymmetric and low complexity automotive I/Fs complementary w/ automotive Ethernet solution:

Cautionary points:

- High market growth driving MIPI member interest
- Ability to leverage economies of scale from mobile -> automotive
- Physical layer investigations using auto channels (<15m) as targets indicate technically feasible

Migration from consumer to automotive not trivial
MIPI Alliance not trying to replace existing auto network standards: CAN, LIN, MOST, Auto Ethernet, etc.
MIPI C-/D-PHY\(^{\text{SM}}\), MIPI CSI-2\(^{\text{SM}}\), MIPI DSI-2\(^{\text{SM}}\) currently short range – board-level interface for automotive
AUTOMOTIVE REQUIREMENTS

Reliability  Zero Defects  Uninterrupted Supply  Security  Safety

Technology  Process & Packaging
Design  DFM, DFT
Validation  Qualification, Characterization
Production  Testing
Support  Supply Chain, FA, FQE

STANDARDS

ISO 26262  AEC-Q100  TS16949  MISRA-C*  Others

Over 50 Differences Between Automotive & Consumer Semiconductor Support Covered by Standards
MIPI Automotive Timeline

- Automotive activities began
- Automotive BoF formed
- ARD v0.56
- ARD v0.8
- ARD v0.9
- ARD v1.0.1
- ARD v1.1
- Specification work complete
- A-PHY available
- EMC testing

2017
- v0.56 Feb. 26, 2018
- v0.8 March 28, 2018

2018
- v0.9 May 30, 2018
- v1.0.1 July 21, 2018

2019
- v1.1 August 14, 2019

2020
EMC Testing Overview

PURPOSE:
To develop the noise and interference requirements in the automotive environment

TARGET EMC TEST:
• Focused on the following immunity and related tests:
  – ALSE RF Ingress (ISO11452-2)
  – BCI (ISO11452-4)
  – Transient Immunity (ISO7637-3)
  – Screening Attenuation (IEC62153-4)
• Testing focused on coax rather than STP or SPP, and was performed by Sony, Murata and Shikoku Cable.
• Additional interference sources covered by individual company and included the following sources:
  – PCB near end crosstalk (NEXT)
  – Alien crosstalk
  – Car noise

Cooperation with Other Companies

• Use of EMC facilities: Murata Manufacturing Company, Yokohama tech center
• Cable assembly: Shikoku Cable, Rosenberger Japan, MD Elektronik
• Use of equipment: BMW, Valens
• Comment and discussion: MIPI Automotive WG member companies including BMW, Microchip, NXP, Valens
Automotive PHY Requirements Overview

Miscellaneous Other Requirements

- Bit Error Rate shall be less than $10^{-12}$ for both data and control streams
- Latency (Data Link Layer to Data Link Layer) shall be less than 16 µSec
- Design shall support DC power over the data lines with a maximum current limit of 0.5 A
- System shall operate with GND voltage offsets of up to ±1.0 V
- A-PHY shall provide the following modes: Shutdown, Start-Up, Active, Sleep and Safe State
- The A-PHY Data Link Layer shall be agnostic to the higher-level protocols and with an overhead of 20% maximum
- Protocol Adaptation Layer shall support MIPI protocols w/ minimal changes needed
- It shall be possible to aggregate multiple links for increased HS data BW
- A-PHY solution shall support BIST and system diagnostics (e.g., link quality)
- A-PHY shall support system designs at the ASIL D level according to ISO26262:2018
- System clock shall be both embedded and asynchronous (i.e., decoupled from data rate clock)
- System cabling shall meet certain IL, RL and coupling requirements
- System operation shall be supported with specified automotive EMC requirements
An Overview of A-PHY

Raj Kumar Nagpal
MIPI A-PHY Subgroup Chair
What is A-PHY?

MIPI A-PHY is a physical layer specification targeted for advanced driver-assistance systems (ADAS) and autonomous driving systems (ADS) and other surround sensor applications in automotive (e.g., for displays, cameras), but also for other longer-reach applications such as IoT and industrial.

While most MIPI specifications are designed for shorter reaches for use within mobile devices, A-PHY will be capable of reaching up to 15 meters in the demanding automotive environment. A-PHY v1.0 will support speeds of 2-16 Gbps, with a roadmap to 24, 48 Gbps and beyond (e.g., 100 Gbps).
MIPI A-PHY: Solving the Long-Reach Challenge

Implementation of camera and display specifications with necessary bridging solutions vs. with A-PHY

Current implementation with proprietary bridging solutions

Implementation with A-PHY integrated into all components
Recognizing that IEEE 802.3ch Ethernet is an emerging network backbone, A-PHY will coexist in many implementations.

Illustration of concurrent use of asymmetric and symmetric data flows and interfaces.
A-PHY Data and Power Logical Structure

- Focus is on high throughput data to and from the system CPU over high-speed links with optimal wiring, cost and weight.
- The high-speed data, control data and optional power share the same physical wiring.
A-PHY High-Level Structure

A-PHY design includes a generic data link layer that will accommodate different protocol adaptation layers (both MIPI and non-MIPI)

Example use cases:

- Camera module to ECU
- Camera ECU to ECU
- Lidar, radar
- Display including touch and controls
- A-PHY links over PCB interconnect
A-PHY Cable Type & Topology

**MIPI Automotive Coax Topology “A”**

- 50 Ω Coax cable up to 15 m, with up to 4 inline connectors with minimum segment of 30 cm

**MIPI Automotive STP/SPP Topology “B”**

- 100 Ω SDP cable up to 10 m, with up to 4 inline connectors with minimum segment of 30 cm
A-PHY Vision

To address the complete market, A-PHY will:

• Provide options to suit various design needs
• Support speeds of **2-16 Gbps**, with a roadmap to **24, 48 Gbps and beyond** (e.g., 100 Gbps)
• Ensure **scalability** to stay ahead of growing bandwidth requirements
• **Serve the** broadest possible spectrum of OEMs, suppliers and vendors

*With this design, MIPI Alliance will offer a complete solution that addresses all speeds*
# A-PHY Profile Overview

**Profile 1**
- Focused toward lower speed applications
- Intended for lowest cost, low-design-complexity solutions and to speed time to market
- Expected upper speed will be about 8 Gbps at 15 meters
- Based on NRZ-8b10b

**Profile 2**
- Can be used for all speeds
- Interoperates with Profile 1
- Provides superior EMC performance
- Provides roadmap to higher speeds in future A-PHY revisions
- Based on PAM4/8/16 with PHY-level retransmission scheme (RTS) and narrowband interference cancellation (NBIC)

The two profiles interoperate to ensure compatibility, interoperability and system gradual scale-up
# A-PHY Channel Throughput

## Forward channel throughput and gear definition

<table>
<thead>
<tr>
<th>Gear</th>
<th>Raw Data Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>≤ 2 Gbps</td>
</tr>
<tr>
<td>2</td>
<td>≤ 4 Gbps</td>
</tr>
<tr>
<td>3</td>
<td>≤ 8 Gbps</td>
</tr>
<tr>
<td>4</td>
<td>≤ 12 Gbps</td>
</tr>
<tr>
<td>5</td>
<td>≤ 16 Gbps</td>
</tr>
</tbody>
</table>

Reverse channel, in full duplex with forward channel, will support the following data rates:

- **Low speed:** 25 Mbps  
  (Aimed for camera and sensor products)
- **High speed:** 125 Mbps  
  (Aimed for display and touchscreen products)
A-PHY Key Technical Advantages

- **Asymmetric-optimized architecture**
  A-PHY is designed from scratch for high-speed asymmetric-only transmission from cameras/sensors to ECU, and ECU to display, while providing concurrent low-speed bidirectional traffic for command and control. The optimized asymmetric architecture allows for design simplification and lower cost than other/symmetric architectures.

- **Mobile protocol reuse**
  After successful deployment in billions of smartphones and IOT devices, the MIPI protocols are well-proven for direct leverage into automotive.

- **Hardware-only protocol layers**
  As in mobile applications using C-PHY/D-PHY layering, A-PHY is tightly coupled with the CSI-2/DSI-2 protocol layers, thus essentially operating with hardware-only protocol layers without software intervention. This architecture is contrasted to other interfaces that are designed with more flexibility and utilize software layers to accomplish this flexibility.
A-PHY Key Technical Advantages

- **Optimized architecture for wiring, cost and weight**
  By its optimized asymmetric architecture and hardware protocol layering, A-PHY implementations achieve optimized cabling wiring, cost and weight requirements. This is increasingly important as the number of electronic components and their interface cabling increases on the road to autonomy.

- **Flexible link layer support of other protocols**
  MIPI Alliance expects to work with other organizations leveraging their native protocols into automotive. This includes VESA, which is adapting its DisplayPort protocol specification for automotive use. To accommodate these developing specifications, A-PHY includes a generic Data Link Layer that accommodates different protocol adaptation layers, with a plan to support VESA’s vehicular DisplayPort protocol.

- **High EMC immunity**
  MIPI has invested significantly to analyze and measure the harsh automotive channel, and has concluded that an architecture based on a Narrowband Interference Canceller (NBIC) and Retransmission system (RTS) provides the most robust performance, particularly for the applications requiring the higher data rates at longer distances.
More information can be found at:

- MIPI Alliance Advances Activities for ADAS, ADS and Other Automotive Applications (Press release, October 2019)
- Automotive Applications Drive MIPI A-PHY Development (Blog, May 2019)
- MIPI Alliance Meets the Needs of Autonomous Driving (DevCon presentation, October 2018)
- MIPI Alliance Extends Interface Standards to Support the Automotive Market (Webinar, April 2018)
- MIPI Alliance to Advance Autonomous Driving, other Automotive Applications with New Data Interface Specifications at 12-24 Gbps and Beyond (Press release, August 2018)
- MIPI Alliance Expands Reach with New Automotive Working Group (Press release, March 2018)

Download the new MIPI in Automotive white paper