MIPI Automotive SerDes Solutions: New Developments in A-PHY® and the MASS™ Connectivity Framework
Agenda

• MIPI Automotive SerDes Solution (MASS)
• A-PHY Overview
• Next Generation A-PHY
• Summary
• Q&A
MIPI Automotive SerDes Solution (MASS)
MIPI Automotive SerDes Solutions (MASS)

A framework for integrating sensors and displays with functional safety and security built in

**Electronic Control Unit (ECU)**
- Advanced driver assistance system (ADAS) based on sensor feeds
- Produces display feeds

**Sensors**
- Camera
- Lidar

**Displays**
- Dashboard
- Console
- Side-view mirrors
- Entertainment

(Optional) A-PHY bridges
- Translates between short-range MIPI C-PHY℠ / D-PHY℠ & long-range MIPI A-PHY
MASS Guiding Principles

Service Extensions
- CSE℠: Camera Service Extensions
- DSE℠: Display Service Extensions
- CCISE℠: Command and Control Interface Service Extensions
- MIPI Security Specification

PALS: Protocol Adaptation Layers
- MIPI CSI-2®, MIPI DSI-2℠, I3C®
- VESA eDP/DP
- Ethernet, I2C, GPIO, SPI, Audio

A-PHY
- Robust PHY for Automotive
- MTBF of 1 error over the full vehicle life-span
- Long reach PHY (15m)
- Coax, SDP and STQ cables

MTBF: Meantime Between Failure  SDP: Shielded Differential Pair  STQ: Star Quad (shielded dual differential pair)
MASS Supported Topologies - Examples

Camera and Sensor Aggregation

- Multi-port A-PHY RX SerDes with CSI-2 Aggregator
- End-to-End Protection

Daisy Chaining of Heterogeneous Displays

- MIPI DSI-2 + VESA eDP over A-PHY
- End-to-End Protection

Other common topologies are also supported but not shown
MASS Stack – Framework nearly completed

- Updated Command Set for Automotive Control
- Protocol extensions for Safety and Security
- Updated mobile protocols
- Adaptation Layers
- Automotive Long reach PHY

- MIPI Protocol Layers
  - MIPI Functional Safety and Security
  - MIPI CCS
  - Camera Service Extensions (CSE)
  - Functional Safety
  - Security
  - HDMI
- MIPI DSI-2
- MIPI PAL/DSI-2
- MIPI A-PHY Data Link Layer
- MIPI A-PHY SerDes Physical Layer

- Camera / Lidar / Radar
  - MIPI CCS
  - Display Service Extensions (DSE)
  - Functional Safety
  - Security
  - HDCP
- MIPI DSI-2
- MIPI PAL/DSI-2
- MIPI A-PHY SerDes Physical Layer

- MIPI Display
  - MIPI DCS
  - Display Service Extensions (DSE)
  - Functional Safety
  - Security
  - HDCP
- MIPI DSI-2
- MIPI PAL/DSI-2
- MIPI A-PHY SerDes Physical Layer

- VESA Display
  - VESA eDP / DP
  - Functional Safety
  - Security
  - HDCP
- MIPI PAL/eDP-DP

- Supporting Interfaces
  - Ethernet
  - GPIO
  - MIPI I3C
  - I2C
  - SPI
  - Future Protocols

Under development
# MASS Status

## Adopted Specifications
- A-PHY v1.0
- A-PHY v1.1
- PAL/CSI-2 v1.0
- PAL/DSI-2 v1.0
- PAL/eDP/DP v1.0
- PAL/GPIO v1.0
- PAL/I2C v1.0
- PAL/Ethernet v1.0
- CSE v1.0
- DSE v1.0

## Under Development
- A-PHY v1.1.1 Inclusive Terminology
- A-PHY v2.0 Higher data-rate, Security
- PoA\textsuperscript{SM} v1.0 New specification
- PAL/SPI v1.0 New specification
- PAL/I2C v1.0.1 Inclusive Terminology
- PAL/ETH v1.1 Support for frame preemption
- PAL/I2C v1.0 New specification
- MIPI Security v1.0 New Specification
- CCISE v1.0 Command and Control Interface Service Extensions
- CSE v2.0 Security, FSED, Timestamping
- DSE v1.1 Advanced FuSa, FSED, Timestamping, Audio
- DSE v2.0 Security
- DCS\textsuperscript{SM} v2.0 Automotive related commands

## In Adoption Process
- PAL/CSI-2 v1.1
  - timestamping and synchronization

## Published Application Notes
- A-PHY Profile 1 and Profile 2

## Upcoming Application Notes
- A-PHY RTS and Retraining
- PoA: Power over A-PHY

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**RTS:** Retransmission  
**FuSa:** Functional Safety  
**FSED:** Frame Service Extensions Data
# Camera Service Extensions (CSE)

<table>
<thead>
<tr>
<th>CSE v1.0</th>
<th>CSE v2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>• End to End Functional Safety Services</td>
<td>• End to End Security Services: Encryption, Authentication</td>
</tr>
<tr>
<td>• Message-based Functional Safety protection</td>
<td>• FSED Protocol</td>
</tr>
<tr>
<td>• CSI-2 Packets are extended with SEP</td>
<td>• Frame-based protection</td>
</tr>
<tr>
<td>• Message Counter and CRC are added per SEP</td>
<td>• SEP per “multiple messages” protection</td>
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<tr>
<td>• Test pattern generation and Error Injection</td>
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<tr>
<td>• ESS-CCI Protocol for End to End Control Plane protection</td>
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<table>
<thead>
<tr>
<th>CCISE v1.0</th>
</tr>
</thead>
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<tr>
<td>• Separate specification</td>
</tr>
<tr>
<td>• End to End protection of the Control Plane</td>
</tr>
<tr>
<td>• Backwards compatible to ESS-CCI in CSE v1.0</td>
</tr>
<tr>
<td>• Adding Security Services</td>
</tr>
</tbody>
</table>

SEP: Service Extensions Packet  
FSED: Frame Service Extensions Data  
CRC: Cyclical Redundancy Check  
CCISE: Command and Control Interface Service Extensions  
ESS-CCI: Enhanced Safety and Security Camera Control Interface
SEP and FSED – Example with CSE / CSI-2

Source image frame with Embedded Data

CSI-2 Packets

- 1ST Packet (FP-1)
  - SP (VC0, FS, FN)
  - PH (VC0, DT1)
  - Middle Block Image Data
  - FP (VC0, DT1)
  - PF (VC0, DT1)

- 2ND Packet (FP-2)
  - SP (VC0, FS, FN)
  - PH (VC0, DT1)
  - Middle Block Image Data
  - FP (VC0, DT1)
  - PF (VC0, DT1)

- 3RD Packet (FP-3)
  - SP (VC0, FS, FN)
  - PH (VC0, DT1)
  - Middle Block Image Data
  - FP (VC0, DT1)
  - PF (VC0, DT1)

- 4TH Packet (FP-4)
  - SP (VC0, FS, FN)
  - PH (VC0, DT1)
  - Middle Block Image Data
  - FP (VC0, DT1)
  - PF (VC0, DT1)

- 5TH Packet (FP-5)
  - SP (VC0, FS, FN)
  - PH (VC0, DT1)
  - Middle Block Image Data
  - FP (VC0, DT1)
  - PF (VC0, DT1)

CSI-2 with SEP Protection

- SEP Header
- Top Block Embedded Data
- SEP Footer

- SEP Header
- Top Block Embedded Data
- SEP Footer

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- Top Block Embedded Data
- SEP Footer

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- SEP Footer

- SEP Header
- Top Block Embedded Data
- SEP Footer

CSI-2 with FSED Protection

- FSED FRAME TAG
- ePH0: ePH1: eVC, eDT, MC, SID, + ...
- ePH0 : MAC

“Legacy” CSI-2 without FuSa/Security Protection

MAC: Message Authentication Code
CRC: Cyclic Redundancy Check

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FSED in Display Service Extensions (DSE)

- One FSED Message per DSI-2 Video Frame
- Contains FuSa & Security extension data
  - Frame number
  - CRCs
  - MACs
- FRAME CRC/MAC for Active Video Area
- TRANSPORT CRC/MAC for “meta data” (display commands and control)
- Region of Interest (ROI)
  - Up to 16 ROIs – ROIs can overlap
  - 1 CRC per ROI
- Note: Security support from DSE v2.0 only

FSED Message containing all CRC/MACs

TRANSPEC_CRC → FSED_CRC → FRAME_MAC
FSED_CRC → FSED_MAC → FRAME_CRC
FuSa support for Compression

- Visually lossless compression with VESA DSC and VDC-M
- CRCs are calculated over the “reconstructed" pixels
  - Matching between TX and RX
  - Compression engine is covered by the CRC
- Compression engine runs over slices. To ease the implementation DSE defines Slice Columns
- Each Slice Column has its own CRC
- For ROI, CRC are calculated over the Slice Columns
- All CRCs are sent in the FSED Message at the end of the DSI-2 Video Frame
- DSE aligning with VESA on CRC calculations
Control Plane Protection with CCISE

CCISE Functional Safety Protection Flow

- Command and Control Interface **Service Extensions** (CCISE) add Security and FuSa services to CCI (I2C)
- CCISE Supports control of
  - A-PHY bridges and forwarding elements
  - Any other device controlled via I2C (or virtual I2C with PAL/I2C).
- CCI (I2C) Transactions are extended with Tags
  - FuSa Tags: Message Counter, CRC
  - Security Tags: Message Counter, MAC
  - Separate Tags for Read and Write Messages
- Two CCISE verification modes
  - **Mode 1: Per-Transaction.** Tags are transmitted with the Messages and can be **verified immediately** by the Target or the Controller
  - **Mode 2: Per-Frame.** Tags are not transmitted with the Messages. Tags are calculated over an entire CSI-2 Frame, both at the Controller and at the Target. Tags are sent from the Target to the Controller
    - Within CSI-2 Embedded Data or
    - Controller read access to the Tags
  *Tags are verified by the Controller.* Mode 2 is motivated by the speed limit of I2C interface.
A-PHY Overview
MIPI A-PHY: SerDes System Foundation

First industry-standard asymmetric SerDes physical layer specification targeted for ADAS/ADS and infotainment applications

About A-PHY
(v1.0 released in Sep 2020)

• Direct coupling to native CSI-2/DSI-2/DP-eDP protocols
• High noise immunity, ultra low PER (< $10^{-19}$)
• Supports bridge-based and endpoint integration
• Support for automotive coax and SDP channels
• Upto 15m long reach with 4 inline connectors
• Power over cable
• Built-in functional safety according to ISO 26262
• Adopted by IEEE as IEEE 2977-2021

A-PHY v1.1 Enhancements
(released Dec 2021)

• Increased support for lower cost legacy cables
• Double uplink data rate
• Star quad cable support, enabling lower cost dual lane operation, for up to 32 Gbps data rate

PER: Packet Error Rate  SDP: Shielded Differential Pair
What Makes MIPI A-PHY So Robust and Efficient?

High throughput automotive links are EMI-limited — not AWGN limited

**RTS + NBIC**

- **Time bounded local PHY-level retransmission**
  - Only within pre-defined “Overall Delay” (~6μs@G5)
  - Local: Transparent to the upper layers
  - Local: Happens within a single A-PHY hop

- **Dynamic modulation for retransmitted packets with better error resistance**

- **Highly resilient**
  - Overcomes large thousands symbols-long error bursts
  - Multiple 10s mV, instantly attacking NBI peaks

- **High reliability \( \rightarrow \) PER < 10^{-19}**

- **Low overhead \( \rightarrow \) 90% net data rate**

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NBI: Narrow Band Interferences
NBIC: Narrow Band Interferences Canceller
PCS: Physical Coding Sub-Layer
PMD: Physical Media Dependent
RTS: Re-Transmission Sub-Layer
AWGN: Additive White Gaussian Noise
To Speed Up/Ensure JITC Convergence, JITC Re-training Is Used

Example: 4GBaud PAM4, 40mVpeak 3 Tone NBI, instant attack, without re-training
A-PHY Channel models

• Application note providing technical details on system modeling both for Profile 1 and Profile 2 is available to MIPI members.

• Along with this application note, we provided the complete system model in ADS and Matlab at the MIPI member site.

• Information Location (for registered members) -
  – Application note – https://members.mipi.org/wg/All-Members/document/download/84933
Next Generation A-PHY
What's Next for A-PHY?

A-PHY v2.0

GOALS

- Support emerging architecture and use cases:
- Zonal architecture and SDV (software-defined vehicle)
- Modern automotive cockpits
- Maintain backward compatibility
- Be forward compatible
- No changes in the upper layers for easy migration with minimal impact
- Maintain high EMC resilience and low packet error rate

PROPOSED FEATURES

- Double downlink throughput up to 32Gbps (28.8Gbps net data rate) per single lane
- Uplink throughput increase up to 1.6Gbps (1.166Gbps net data rate)
- Enhance interface support
- Add 1Gb Ethernet support (based on the new uplink BW)
- Other interfaces may be added based on market demand
- Enable support of a secure A-PHY network

A-PHY v1.1.1

- Inclusive Terminology
- Errata

TEST PROGRAM

- Reference Compliance Test Suite nearly complete
- Pilot Compliance program under development

IEEE ADOPTION

- v1.1.1 to be submitted to IEEE for adoption

NEW RESOURCES

- Retraining and Retransmission App Note
- Power Over A-PHY App Note
- Power Over A-PHY specification
- Link Layer and Link Layer Services App Note
# A-PHY v2.0 – Initial Downlink Gear Table (per LANE)

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<td>32</td>
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*Note:
Green – New speeds @ 8GBaud
Orange – Under discussion*
## A-PHY v2.0 – Initial Uplink Gear Table

<table>
<thead>
<tr>
<th>Uplink Gear</th>
<th>Modulation</th>
<th>Modulation Bandwidth [MHz]</th>
<th>Data Rate [Mbps]</th>
<th>Max Net App Data Rate [Mbps]</th>
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<td>U2</td>
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<td>U3</td>
<td>PAM4-8B/10B</td>
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<td>1600</td>
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</table>
Zonal Architecture

- Zonal architecture is adopted by many OEMs, many times in conjunction with SDV.
  - Aggregation of sensors and actuators in spatial proximity by zone ECUs
  - Unlike domain architecture that integrates functions by specific domains (e.g., ADAS)
- The aggregation of the local devices is relatively low bandwidth (i.e., < 1Gbps) except for cameras and other emerging new sensors as radar and lidar
- These new sensors are asymmetric, driving high-speed data toward the zone ECU and main ECU, and require only low bandwidth control data, with low latency
- A-PHY as a highly asymmetric PHY is well-situated to support use cases of zonal architecture that require high-speed data aggregation to the main computing unit
• Focus on front end of vehicle to reduce clutter
• Each zone ECU aggregates multiple sensors and actuators
• Very high-speed data in direction of central computing unit
  • Camera (could be more than one)
  • Radar
  • Lidar
• Bidirectional information up to 1Gbps is supported for the aggregation of low-speed sensors and actuators
A-PHY-Based Zonal Architecture

• Simplification of zonal ECU
  – Low computing overhead
  – Lower protocol overhead – Maintain native protocols for MIPI CSI-2 (e.g., camera) or Ethernet (e.g., lidar)
  – Designed for ultra-low PER at high noise environment for the entire lifespan of the vehicle

• Future-looking design and easy migration path
  – Scalable downlink speed from 2Gbps to 64Gbps over a single cable
  – Flexible and rich protocol support
  – Layered security scheme supporting variety of use cases
  – Embedded functional safety

• Guaranteed interoperability and backward/forward compatibility
Power over A-PHY – PoA

- A-PHY v1.0/1.1 include a section on PoA
- Separate specification is developed to provide better flexibility and enhanced capabilities without impacting the A-PHY specification
  - This specification will be backward compatible with current definitions.
- A-PHY v2.0 will be aligned with the new PoA specification
- The new PoA specification introduces new power types A-PHY link can support to enable power over cable to multiple types of devices and use cases.

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PoA System Type

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Type 1</th>
<th>Type 2</th>
<th>Type 3</th>
<th>Type 4</th>
<th>Type 5</th>
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Additional Information

1. See Section 7.2.2
2. See Section 7.2.4
3. See Section 7.2.5
4. See Section 8.3.3
5. See Section 8.3.1

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2. See Section 7.2.4
3. See Section 7.2.5
4. See Section 8.3.3
5. See Section 8.3.1
A-PHY & MASS Summary and Takeaways

• A-PHY provides a resilient and robust automotive SerDes standardized solution for camera, sensor and display applications.
• MASS provides End-to-End functional safety and security protections enabling flexible in-vehicle network topologies.
• Native support for standard protocols CSI-2, DSI-2, VESA eDP and DP along with related interfaces.
• CSE v1.0 and DSE v1.0 are already including End-to-End FuSa services.
• Next versions of CSE and DSE will include security and additional Frame-based FuSa services.
• Future versions of A-PHY and MASS continue to scale and increase design flexibility.
For automotive developers, system architects and engineering managers who are focused on the design, development, integration and test of next-generation automotive E/E architectures. Will cover:

- MIPI Automotive SerDes Solutions (MASS)
- Display and sensor (camera/lidar/radar) stacks
- Functional safety, security and data protection
- MIPI A-PHY v2.0, Power over A-PHY, system modelling and test.

https://resources.mipi.org/knowledge-library/webinars/events/2022-automotive-workshop

Information on A-PHY can be found at:

- MIPI A-PHY Specification Homepage
- MIPI White Paper: Introduction to MASS