MIPI Automotive SerDes Solutions (MASS):
A Standardized Framework for Creating Functionally Safe and Secure Automotive Sensor Systems

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Agenda

• About MIPI Alliance
• Overview of MIPI A-PHY
• MIPI Automotive SerDes Solutions (MASS) Overview
• MASS End-to-End Protection
• MASS Security
• Summary
• Q&A
About MIPI Alliance

TODAY’S MIPI MEMBER ECOSYSTEM

- Automotive Processors Developers
- Device OEMs
- Consumer Electronics (Cameras, Tablets, PCs, Laptops, Peripherals, Wearables)
- Software Providers
- Test Equipment Companies
- Test Labs
- IP and VIP Providers
- Semiconductor Companies

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385+ members
Number of countries 29
Percentage of members active in automotive sector 45%
MIPI Alliance Members in Automotive

*Partial listing – not all companies represented
MIPI and the Mobile Gs... Including Automotive

First camera phone
MIPI Alliance forms
MIPI establishes Automotive WG

CSI/DSI protocols evolve.
New PHYs emerge for different requirements

Approximate wireless speeds in bps

1G (analog) 2G (digital & data) 3G (mobile broadband) 4G (all-IP & more bands) 5G eMBB, mMTC & URLLC

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MIPI in Automotive

Cameras, displays, audio, sensors, storage, RFFE for 5G, Wi-Fi, Bluetooth, NFC

Re-use & extend well-proven protocols == reduced NRE/cost
Intra-box usage has been limited due to lack of native long-reach PHY

SPECIFICATIONS IN AUTOMOTIVE TODAY

Most MIPI interfaces are implemented as "short reach" (~15 to ~30cm+)

- **CSI-2**
  Camera Serial Interface protocol
  Protocol for cameras, lidar, radar sensors

- **DSI-2**
  Display Serial Interface protocol
  Protocol for smartphone, IoT and automotive displays

- **C-PHY SerDes**
  3-phase physical layer for CSI-2 & DSI-2
  Short-reach physical layer for cameras and displays

- **D-PHY SerDes**
  Differential physical layer for CSI-2 & DSI-2
  Short-reach physical layer for cameras and displays

- **I3C**
  Control and data bus protocol and interface
  Sensor and general-purpose data and control interface within a module

- **RFFE**
  RF control protocol
  Front-end control within a wireless module

- **UniPro for JEDEC UFS**
  Data transport protocol for UFS over M-PHY
  Transport protocol for UFS storage

- **M-PHY SerDes for JEDEC UFS**
  Differential physical layer for UFS storage
  Short-reach physical transport for UFS storage

- **A-PHY SerDes**
  Long-reach (up to 15m) asymmetrical physical layer (released Sep 2020)
About MIPI A-PHY
MIPI A-PHY Overview

**Today: Proprietary Interface Bridge Solutions**
- CSI-2 Front Camera
- CSI-2 Side Camera
- CSI-2 Rear Camera

**Tomorrow: A-PHY Standard Interface Bridge Solutions**
- D-PHY/C-PHY/PC/TC
- Bridge
- Standard A-PHY SerDes
- Bridge
- D-PHY/C-PHY/PC/TC

**Future: Integrated A-PHY**
- Standard A-PHY SerDes

- CSI-2 Front Camera
- CSI-2 Side Camera
- CSI-2 Rear Camera

Lower cost through standardization and economies of scale
Lower cost/eBOM through integration

ECU: Electronic Control Unit
SoC: System On Chip
MIPI A-PHY – Automotive Long-Reach PHY

The first industry-standard long-reach asymmetric SerDes physical layer specification targeted for ADAS/ADS surround sensor applications and infotainment display applications.

**NEW** A-PHY v1.1 Enhancements:
- Increased support for lower cost legacy cables
- Double uplink data rate
- Star quad cable support, enabling dual downlink operation

A-PHY v1.0 offers:
- Direct coupling to native CSI-2/DSI-2/DP-eDP protocols
- High performance of up to 16 Gbps over 10-15m
- High noise immunity, ultra low PER ($< 10^{-19}$)
- Supports bridge-based and endpoint integration
- Support for automotive coax and STP channels
- Power over cable
MIPI A-PHY Activity

MIPI A-PHY
ADOPTED AS
IEEE STANDARD

Milestone expands access to automotive SerDes specification

A-PHY v1.0 adopted as IEEE 2977-2021 (June 2021)

WHAT'S NEXT:
A-PHY v1.1 development complete and will also be submitted to IEEE adoption process
MIPI Automotive SerDes Solutions (MASS)
Overview
MIPI Automotive SerDes Solutions (MASS) in the Car

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

A collection of MIPI specifications advancing camera and display solutions for automotive:

- **A-PHY**
  - Long reach PHY (15m)
  - v1.0: 2-16 Gbps (Coax, SDP)
  - v1.1: up to 32Gbps (STQ)

- **PAL: Protocol Adaptation Layers**
  - MIPI CSI-2, DSI-2 and I3C
  - VESA eDP/DP
  - Ethernet, I2C, GPIO

- **Service Extensions for End-to-End FuSa and Security**
  - CSE: Camera Service Extensions
  - DSE: Display Service Extensions
  - MIPI Security Specification

- **High noise immunity PHY, informed by extensive EMI/EMC measurement/test campaign**
- **Leverage and extend well-proven CSI-2/DSI-2 protocols used in billions of devices**
- **End-to-end solution including Functional Safety and Security**

- **PHY-level:**
  - Retransmission (RTS)
  - Advanced modulation (PAM-4,8,16)

- **Economies of scale**
- **Reduced NRE/cost**
- **Backward Compatibility**

- **Camera/sensor to ECU**
- **ECU to display**
- **Bridged and Integrated**
MASS – Solution Elements
Comprising PHY, Protocols and Extent for a flexible system solution

**Robust Long-Reach PHY (PER 10^{-19})**
- MTBF of 1 error over the full vehicle life-time
- Asymmetric high-speed link with fixed low latency ~6μs @G5
- High speed downlink and aggregation to support **multiple** 4K cameras and displays

**Application-level End-to-End Functional Safety**
- End to end protection covering various topologies
- Flexible coverage: per frame, per ROI, per message, compression ON/OFF
- CRC for error detection
- Frame loss detection
- Time-out Monitoring
- BIST
- Faults injection

**Application-level End-to-End Security**
- Authentication
- Data integrity
- Encryption
- HDCP for display

**Deep system level consideration for native interfaces and the legacy ecosystem**
- Heterogeneous display protocols:
  - DSI-2, eDP/DP
  - Different source/sink configs
  - C-PHY, D-PHY, # Lanes, I2C, I3C
  - Integrated A-PHY or bridged A-PHY

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**Abbreviations**
- **BIST**: Built In Self Test
- **MTBF**: Mean-Time Between Failure
- **PER**: Packet Error Rate
- **ROI**: Region Of Interest
- **HDCP**: High Definition Multimedia Interface Protection

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MASS – Examples for Supported Topologies

Cameras and Sensors Aggregation

- **MIPI CSI-2 Sensors**
- **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**

**DID**
- Driver Instrument Display

**CID**
- Central Information Display

**CDD**
- Co-Driver Display

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MASS Stack – Current Status

Applications
- MIPI Protocol Layers
  - MIPI Functional Safety and Security
  - Protocol Adaptation Layer (PAL)
  - Link Layer
  - Physical Layer

Camera / Lidar / Radar
- MIPI CSI-2
- MIPI PAL/CSI-2
- MIPI A-PHY Data Link Layer

MIPI Display
- MIPI DCS
- MIPI DSI-2
- MIPI A-PHY SerDes Physical Layer

VESDA Display
- MIPI I3C
- I2C
- SPI
- Future Protocols

Supporting Interfaces
- Ethernet
- GPIO
- MIPI I3C
- I2C
- SPI
- Other MIPI PALs

- Specification published
- Completed – in adoption process
- Work in progress
MASS – End to End Protection

Functional Safety and Security
MASS 1-5 Model & MIPI Protocols
End-to-End Functional Safety and Security Protection

#1 Controller (SoC)
- (Application) Data Plane Messages (in-band)
- (Application) Control Plane Messages (in-band or sideband)
- A-PHY Control Plane Messages (sideband)

#2 C.Bridge (Opt)
- (C/D/DP-PHY)

#3 A-PHY
- Forwarding Element (Opt)

#4 T.Bridge (Opt)
- (C/D/DP-PHY)

#5 Target (Peripheral)
- (SNS or Display TCON/DDIC)

Bridge to Bridge Protection

End to End Protection
MASS 1-5 Model & MIPI Protocols
End-to-End Functional Safety and Security Protection

Controller (SoC)
(Application) Data Plane Messages (in-band)
(Application) Control Plane Messages (in-band or sideband)
A-PHY Control Plane Messages (sideband)

(C/D/DP-PHY) Display

In-band protection with SEP
(CSI-2, DSI-2, DP, eDP)

Side-band protection with ESS-CCI
(CCI, A-PHY Control)

End to End Protection

Bridge to Bridge Protection

Target (Peripheral) (SNS or Display TCON/ DDIC)
Service Extension Packets (SEP) for End-to-End Protection

Source Pixels

Target (Sensor)

Sink Pixels

Controller (ECU)

A-PHY Network

Application Data Source

Service Extensions

(SEP)

Protocol Layer

Protocol Adaptation

Layer

A-PHY

Application Data Sink

Service Extensions

(SEP)

Protocol Layer

Protocol Adaptation

Layer

A-PHY

Source Pixels

End to End Protection

Security Controls

FuSa Controls

Protocol Payload Data (pixels)

 CSI-2 Header

 CSI-2 Footer

 Protocol Payload Data (pixels)

 SEP Header

 SEP Footer

 A-PHYS

 A-PHY Header

 A-PHY Footer

 Payload Data (#1)

 A-PHY Header

 A-PHY Footer

 Payload Data (#N)

 A-PHY Header

 A-PHY Footer

 Payload Data (last)

 A-PHY Header

 A-PHY Footer

 Last A-Packet

 Message Sequence Counter

 Header CRC

 Error flags

 CRC

 Link Protection (Bridge to Bridge)

 E2E: End-to-End; B2B: Bridge to Bridge

 MAC: Message Authentication Code

 CRC: Cyclic Redundancy Check
Annex D – Communication bus safety mechanisms:

- One-bit hardware redundancy
- Multi-bit hardware redundancy
- Read back of sent message
- Complete hardware redundancy
- Inspection using test patterns
- Transmission redundancy
- Information redundancy
- Frame counter
- Timeout monitoring
- Combination of information redundancy, frame counter and timeout monitoring
Functional Safety – A-PHY

- **A-Packets provide**
  - CRC-32 for each packet providing a Hamming Distance > 3 – detecting communication failure (bad payload)
  - Message Sequence Counter – detecting packet loss / duplication
  - Timeout Monitoring – detecting potential loss of communication
  - Header CRC – header protection
  - BIST
Functional Safety – Service Extensions (CSE/DSE)

- **Flexible End-to-End Functional Safety and Security framework with SEP**
  - Packet based: per SEP
  - Frame based: per Video Frame
  - Regions of Interest: per ROI
  - With compression enabled/disabled

- **Example of FuSa Elements used**
  - CRCs with Hamming distance > 3
    - SEP Header CRC + SEP Footer CRC
    - ROIs, Compression Slices / Columns etc.
  - Message Sequence Counter
  - Timeout monitoring
  - Test pattern generators (solid colors, color bar, tiles etc.)
  - Faults injection – checking error detection mechanisms

Example for ROI usage in Driver Information Display
Control Plane End-to-End protection

**ESS-CCI: Enhanced Safety and Security – Camera Control Interface**

**Display: MIPI DSI-2**
- In-band Control Plane is protected with **SEP**
- Defined in MIPI DSE Specification

**Camara: MIPI CSI-2**
- In-band Data Plane is protected with **SEP**
  - Defined in MIPI CSE Specification
- **ESS-CCI** for Camera Control Interface
  - I2C-based register access
  - Defined in MIPI CSE Specification

**A-PHY Network: MIPI A-PHY**
- **ACMP** for A-PHY Control
  - I2C-based register access
  - Re-use of ESS-CCI Protocol
  - Defined in MIPI A-PHY Specification

**Notes:**
- **ACMP**: A-PHY Control and Management Protocol
- **CCI**: Camera Control Interface
ESS-CCI

- ESS-CCI provides services to support E2E FuSa and Security
  - CSE v1.0: Functional Safety Services
  - CSE v2.0: Provides FuSa + Security Services
- CCI Read and Write Messages are extended with ESS-CCI Tags
  - Message Counters and CRCs
  - Separate Tags for Read and Write messages
  - Tags are used for verification of the CCI messages
- ESS-CCI Mode 1
  - ESS-CCI Tags are transmitted along with the CCI Messages
  - Each message can be verified and processed as soon as it is received by the Target or by the Controller
- ESS-CCI Mode 2
  - ESS-CCI Tags are accumulated over multiple messages (e.g. per Frame)
  - The accumulated Tags are sent as CSI-2 Embedded Data from the Target to the Controller
  - The Controller verifies the ESS-CCI Tags
  - No bandwidth overhead on I2C
MASS – Security
What are the Data Security Services Protecting?

**Image Data**
- Integrity of Sensor images
- Confidentiality of Sensor images
- Integrity of Display images

**Security Considerations**
- Manipulating ADAS
- Privacy: location-revealing images
- Incorrect dashboard display

**Control Data**
- Integrity of Sensors Capabilities/config
- Integrity of Display Capabilities/config
- Integrity of A-PHY Capabilities/config
- Confidentiality of all config

**Security Considerations**
- Disable/操纵 sensor
- Disable/操纵 display
- Disrupt A-PHY network
- Proprietary/sensitive/privacy
MIPI Security Flow

Applies to all Data Security Services (DSS)

1. Authenticate & establish secure session
   For protecting Steps 1 & 2.

2. Read Capabilities
   Read/Identify DSS supported security algorithms per component

3. Build multiple DSS configurations
   Combo of DSS security algorithms, keys. Built based on supported DSS security algorithms and desired DSS operation

4. Provision multiple DSS configurations

5. Build Real-time Operating Control
   Per-message DSS controls, selecting
   • A DSS config
   • payload encryption on/off
   • payload integrity on/off)

6. Communicate & execute per-message DSS controls

System Security Management (SSM) Suite
Component Configuration over secure connection established by Controller

SSM Suite Establishes Data Security Services

Data Security Service (DSS)

Out of scope
Implementation details depending on policy of Integrator.
### MIPI Security Framework

**System Security Provisioning (SSP)**

- Between SSMC (#1) and SSMTs (#2, #3, #4, #5)
  - Authenticate and establishes secure sessions using DMTF's SPDM
    - DSP0274: Symmetric / Asymmetric mutual authentication
    - DSP0277: Secured Messages to protect MIPI SCAP (encryption and integrity protection)
  - Service Association Configuration Protocol (SACP)
    - Read Security Capability Registers for DSS
    - Write Security SA Registers for DSS
  - MIPI Security Specification

**Applying Data Security Services (DSS)**

- Flexible DSS
  - Encryption
  - Integrity Protection via Message Authentication Codes (MAC)
  - Per Message / per Frame / per ROI → Trade-offs
- SEP Security for MIPI CSI-2, MIPI DSI-2 and VESA eDP/DP
  - To be specified in next versions of MIPI CSE, MIPI DSE
- Side band control channel security
  - ESS-CCI Security for Camera Control
  - Extending ESS-CCI to include DSS in next CSE version
  - ACMP Security for A-PHY Control (re-use of ESS-CCI)

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**Notes:**

- SSP: System Security Provisioning
- SSMC: System Security Management Controller
- SSMT: System Security Management Target
- DMTF: Distributed Management Task Force
- SPDM: Security Protocol and Data Model

Framework can be applied directly from Controller #1 to Target #5 over any MIPI PHYs.
Summary

• MASS provides a standardized framework enabling end-to-end FuSa and Security
  – Addresses both the data and control planes including side-band control
  – Flexible framework to allow tailoring the FuSA and security services for a wide range of use cases and OEM preferences

• MASS reuses widely adopted MIPI and VESA protocols to address automotive requirements

• MIPI has completed the first suite of MASS specifications
  – A-PHY v1.0 / v1.1, Protocol Adaptation Layers for CSI-2, DSI-2, VESA eDP/DP, I2C, GPIO, Ethernet
  – MIPI DSE and MIPI CSE providing service extensions for FuSa

• MASS Security Specification is expected in 2022
Q&A
MIPI Automotive Resources

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** implementation, system modelling and test.

https://www.mipi.org/events/2021-automotive-workshop

Information on A-PHY can be found at:

• **MIPI A-PHY Specification Homepage**
• **MIPI White Paper: Introduction to MASS**
Thank you