MIPI Automotive Workshop

15 November 2022

Live Virtual Event
MIPI Automotive SerDes Solutions:
What Is New in the MASS℠ Connectivity Framework

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Agenda

• MASS Overview
• MASS Common End-to-End Model for Sensors and Display
• Camera Service Extensions
• Command and Control Interface Service Extensions
• Display Service Extensions
• Summary
MIPI Automotive SerDes Solutions (MASS)
A framework for integrating sensors and displays with End-to-End 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 solution using A-PHY bridges
MASS solution using integrated 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, 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 lifespan
- Long-reach PHY (15m)
- Coax, SDP and STQ cables
- Data rates: 2 Gbps – 32 Gbps

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

Cameras and Sensors Aggregation

Daisy Chaining of Heterogeneous Displays

MIPI DSI-2 + VESA eDP over A-PHY

End-to-End Protection

Multi-port A-PHY RX SerDes with CSI-2 Aggregator

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 Layered Architecture
  - MIPI Protocol Layers
  - MIPI Functional Safety and Security
  - MIPI Functional Safety and Security

- Camera/Lidar/Radar
  - MIPI CCS
  - MIPI CSE

- MIPI Display
  - MIPI DCS
  - MIPI DSE

- VESA Display
  - VESA 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<sup>SM</sup> 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/I3C 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<sup>SM</sup> 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>
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<tbody>
<tr>
<td>• End to End Functional Safety Services</td>
<td>• End to End Security Services: Encryption, Authentication</td>
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<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>
<td></td>
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<tr>
<td>• ESS-CCI Protocol for End to End Control Plane protection</td>
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### CCISE v1.0

- Separate specification
- End to End protection of the Control Plane
- Backward compatible to ESS-CCI in CSE v1.0
- Adding Security Services

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
## Display Service Extensions (DSE)

<table>
<thead>
<tr>
<th><strong>DSE v1.0</strong></th>
<th><strong>DSE v1.1</strong></th>
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</table>
| • End to End Functional Safety Services | • Advanced FuSa features:  
• Message-based Functional Safety protection |  
• FuSa protection for ROIs, Compressed Frames |
| • SEP support for DSI-2 and VESA eDP/DP | • FSED Protocol  
• Frame-based protection  
• SEP protection per Frame |
| • Message Counter and CRC are added per SEP | • Audio Forwarding Service |
| • DSI-2 content protection with HDCP IIA |  

**SEP**: Service Extensions Packet  
**FSED**: Frame Service Extensions Data  
**CRC**: Cyclical Redundancy Check  
**HDCP IIA**: HDCP Interface Independent Adaptation (by DCP LLC)  

<table>
<thead>
<tr>
<th><strong>DSE v2.0</strong></th>
</tr>
</thead>
</table>
| • End to End Security Services: Encryption, Authentication  
• Side band control (TBD)  
• End to End protection of the Control Plane |
MASS End-to-End Protection
Common Model for Sensors and Displays
ISO26262-5 Annex D – Communications Bus

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
1-5 Model: Reference Topology
End-to-End Functional Safety and Security Protection

- Up to 5 functional components
- Controller connections to all components that include Bridges and Forwarding Elements
- Any combination of Bridges

Topology options
- End-to-End (No bridges)
  - May use A-PHY or native interfaces (C/D-PHY & I2C/3C)
- Bridge-to-Bridge (Dual Bridges)
- T.Bridge only
- C.Bridge only

CCI: Camera Control Interface
3 Data Service Protocols (DSP): SEP, FSED, CCISE

End-to-End Functional Safety and Security Protection

**Data Service Protocols (DSP)**

**SEP: Service Extensions Packet**
- **Granularity**: Message-based
- **Reach**: Sensor to Controller, End-to-End (1-5)
  - Bridge to Bridge (2-4), also (1-4) and (2-5)

**FSED: Frame-Based Service Extensions Data**
- **Granularity**: Frame-based
- **Reach**: Sensor to Controller, End-to-End (1-5)

**CCISE: CCI Service Extensions**
- **Granularity**: I²C Transaction (Start to Stop)
- **Reach**: Controller to all Targets, End-to-End (1-5)
  - End-to-End (1-2), (1-3), (1-4)
SEP and FSED for Sensors

Camera Service Extensions (CSE)
MIPI Camera Service Extensions (CSE) Layering

- Data Service Protocols (DSP) provide Security and Functional Safety Services for protecting CSI-2 and CCI traffic in the following order:
  - TX Security first
  - TX FuSa last
- The receiver performs the operations in reverse order
- This layering applies to all 3 DSPs: FSED, SEP and CCISE
- Failure management policy is defined by the system
Service Extension Packet (SEP) over A-PHY

- CSI-2 Packets are extended with SEP
- SEP is protected end-to-end on application protocol level with
  - FuSa Message Counter in SEP Header
  - Security Message Counter in SEP Header
  - MAC in SEP Footer
  - CRC-32 with Hamming Distance ≥ 3 in SEP Footer
- SEP Header contains extended CSI-2 PH information
  - eVC: extended Virtual Channel
  - eDT: extended Data Type
  - Source ID: identifying the sensor
  - Other fields (timestamp, Row ID, Column ID etc.)
- SEP are chunked to multiple A-Packets when transported over A-PHY. Each A-Packet is protected with a Message Counter and CRC-32
CSE SEP Tag Modes

- Two Tag Modes for FuSa
  - Per Message
  - Per Frame
- Three Tag Modes for Security
  - Per Message
  - Per Data Type
  - Per Frame
- Provides a trade-off between Tag overhead and error detection latency
- Optional TOP Tag for early error detection in TOP Embedded Data when using a single Tag per Frame
- CSE v1.0 supports only Per Message CRC
- CSE v2.0 introduces Per DT and Per Frame Tag Modes
Frame-Based Service Extensions Data (FSED) in CSE

- FSED protects End-to-End CSI-2 Frames at application protocol level
- PHY agnostic using “legacy” CSI-2 packets
- Adds FSED Messages to “regular” CSI-2 Frames
  - FSED CTRL_SYNC provides Frame information and security configuration
  - Optional FSED TOP_TAG protecting the Top Block
  - FSED FRAME_TAG protecting the full CSI-2 Frame
- FSED Messages transported as CSI-2 Embedded Data
### Built-In Self Tests (BIST) and Diagnostics

- **Example of Test Pattern in portion of image Frame**
  - **FP-1:**
    - ePH
    - FS
    - ePF
    - Top Block Embedded Data
    - ePF
  - **FP-2:**
    - ePH
    - Middle Block Image Data
    - ePF
    - Top Block Embedded Data
    - ePF
  - **FP-3:**
    - ePH
    - Middle Block Image Data
    - ePF
    - Top Block Embedded Data
    - ePF
  - **FP-4:**
    - ePH
    - Top Block Embedded Data
    - ePF
    - Middle Block Test Data
    - ePF
  - **FP-5:**
    - ePH
    - Bottom Block Embedded Data
    - ePF
    - Top Block Embedded Data
    - ePF

- **Example of a Test Pattern Frame**
  - **FP-1:**
    - ePH
    - FS
    - ePF
    - Top Block Embedded Data
    - ePF
    - Top Block Embedded Data
    - ePF
    - Top Block Embedded Data
    - ePF
  - **FP-2:**
    - ePH
    - Middle Block Image Data
    - ePF
    - Top Block Embedded Data
    - ePF
    - Top Block Embedded Data
    - ePF
    - Top Block Embedded Data
    - ePF
  - **FP-3:**
    - ePH
    - Middle Block Image Data
    - ePF
    - Top Block Embedded Data
    - ePF
    - Top Block Embedded Data
    - ePF
    - Top Block Embedded Data
    - ePF
  - **FP-4:**
    - ePH
    - Middle Block Test Data
    - ePF
    - Bottom Block of Embedded Data
    - ePF
    - Middle Block Test Data
    - ePF
  - **FP-5:**
    - ePH
    - Middle Block Test Data
    - ePF
    - Bottom Block of Embedded Data
    - ePF
    - Middle Block Test Data
    - ePF

**KEY:**
- ePH: SEP Header
- ePF: SEP Footer
- FS: Frame Start
- FE: Frame End
- FP-n: Frame Partition n

- **Increasing diagnostic level with**
  - Test pattern generation
  - Faults injection

- **Tests can be applied**
  - During initialization
  - Runtime
  - Every N frames

- **CSE specifies 5 standards patterns. Sensor vendors can add own specific patterns**

- **Further diagnostics with A-PHY BIST**
  - BIST A-Packets generation
  - BIST A-Packets monitoring
Command and Control Interface Service Extensions (CCISE)
Control Plane Protection with CCISE

- Command and Control Interface Service Extensions (CCISE) add Functional Safety and Security services to CCI (I2C)
- CCISE supports control of
  - Camera Control Interface CCI (I2C)
  - A-PHY bridges and forwarding elements
  - Any other device controlled via I2C (or virtual I2C with PAL/I2C)
- CCI (I2C) Messages are extended with Tags
  - Functional Safety 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.
CCISE Mode 1
Tags are added as Footer to CCI (I2C) Read/Write Transactions

WRITE Transaction

READ Transaction

CCI (I2C) Write Messages

Security Write Tags

FuSa Write Tags

CCI (I2C) Read Messages

Security Read Tags

FuSa Read Tags

Register address of Write Message Counter
Write Message Counter
Write CRC

Register address of Read Message Counter
Read Message Counter
Read CRC

Note: the dashed boxes above are optional
Clear tests from Controller to Target
Write CRC
Unlock data from Target to Controller
Clear tests from Target to Controller
P = STOP condition
A = Acknowledge
N = Negative Acknowledge
CCISE Mode 2

WRITE TO RANDOM ADDRESS (16-BIT INDEX)

Byte 1 Byte 2 Byte 3 Byte 4 Byte L+3 (L ≥ 1)

TARGET ADDRESS [8:0] A
SUB ADDRESS [15:8] A
DATA[0] [7:0] A
DATA[-1] [7:0] A

READ FROM RANDOM ADDRESS (16-BIT INDEX)

Byte 1 Byte 2 Byte 3 Byte 4 Byte 5 Byte L+4 (L ≥ 1)

TARGET ADDRESS [8:0] A
SUB ADDRESS [15:8] A
SUB ADDRESS [7:0] A
TARGET ADDRESS [8:0] A
DATA[0] [7:0] A
DATA[-1] [7:0] A

Exactly same transactions on the line as in CCI (I2C)
• No Tags on the wire
• No overhead

Controller verifies Tags
Accumulated Tags are sent from the Sensor to the Controller at the end of the CSI-2 Frame
• As CSI-2 Embedded Data or
• Controller reads Tags registers

Both Controller and Target calculate independently the Functional Safety Tags accumulated over the CSI-2 Frame
• Write Message Counter (FWMC), Write CRC (WCRC)
• Read Message Counter (FRMC), Read CRC (RCRC)
Display Service Extensions (DSE)

Features for v1.1
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
FuSa Support for Compression in DSE

- 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, CRCs 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
Summary

• MASS leverages and extends well-proven protocols (e.g., CSI-2, DSI-2, eDP)

• MASS provides a standardized framework enabling end-to-end functional safety and security protection at the application protocol level
  – Data plane with SEP and FSED
  – Control plane with CCISE

• Flexibility with message-based and frame-based protections to enable system integrator trade-offs

• Advanced self-testing and error injection features for a higher functional safety diagnosis level

• A-PHY and MASS are architected for seamless integration into sensors, providing an optimal robust and resilient solution for automotive safety applications
THANK YOU

Check back at http://www.mipi.org/2022-automotive-workshop to view recordings of any sessions you missed