About MIPI Alliance

MIPI is a global, collaborative organization founded in 2003 that comprises 300+ member companies spanning the mobile and mobile-influenced ecosystems.

MIPI’s mission:
To provide the hardware and software interface specifications device vendors need to create state-of-the-art, innovative mobile-connected devices while accelerating time-to-market and reducing costs
MIPI for Mobile

To date, MIPI has developed more than 45 specifications. In fact, every smartphone on the market today has at least one MIPI specification.
Leveraging MIPI Beyond Mobile

Characteristics of MIPI specifications
MIPI specifications are suitable for use in a variety of other applications because they've been optimized for:

- High bandwidth
- Low power consumption
- Low electromagnetic interference
Momentum

MIPI CSI-2
LRTE | USL | IENC | SROI | RAW | CCS | CTS

Unified Imaging Conduit for AI Vision Spanning Multiple Platforms

A smart connected device is blessed with cognitive computing that uses AI and perception awareness to sense, learn, reason, and make decisions when interacting with individuals or surrounding situations.

- Complex problems cannot be solved by an individual company:
  - Autonomous vehicles
  - Paramedic drones
  - Device authentication
  - Machine awareness

- Need for global alliances
The Drive

Perception | Subjective Experience | Reality

- Fundamental Drivers: Fear | Desire
- Maximize Pleasure | Minimize Pain
- Rapid Technological Advancements

Credit: Daniel Siegel

https://books.google.com/books/about/The_Mindful_Therapist_A_Clinician_s_Guid.html?id=gFo_zhxys0AC&printsec=frontcover&source=kp_read_button#v=onepage&q&f=true
Two different CSI architectures

- Continuing to evolve and advance CSI-2 imaging conduit targeting multiple platforms
- CSI-3 is not a next-gen solution, nor superset, nor backwards compatible with CSI-2
The Bridge

**Ingredients**
Photon Collectors, Transistors, Optics, Emitters, Algorithms

**Applications**
Broad Spectrum of Imaging & Vision Use cases targeting multiple platforms

- **2018 Global Alliance Engagements:**
  1. MIPI Alliance (Camera & Imaging WG)
  2. Stanford Innovations in Psychiatry and Behavioral health (VR)
  3. Embedded Vision Alliance
  4. Image Sensor Auto

- Clear problem definitions
- Map features to use cases (~70% reject)
- Unified Imaging Software Driver
- End-to-end Conformance Test Suite
Platform Scope

Mobile
Target Platform: **Smart Phones**
Target Imaging Application: Pristine still photography I streaming video

IOT
Target Platform: **Content Creation** (AIO, Notebooks, Hub)
Target Imaging Application: Comprehensive E2E imaging conduit to enable machine awareness

Autonomous
Target Platform: **Automotive**
Target Imaging Application: Real time perception and decision making
CSI-2 over C/D-PHYs (2 Lanes)

**CSI-2 Imaging over D-PHY**
- Image Sensor
- D-PHY TX (6-pins)
- D-PHY RX (6-pins)
- Application Processor
- Periodic clock
- Data
- I2C Compatible 2-wire Camera Control
- Pin compatible
- 1x Effective Pixel BW

**CSI-2 Imaging over C-PHY**
- Image Sensor
- C-PHY TX (6-pins)
- C-PHY RX (6-pins)
- Application Processor
- Embedded clock & data
- I2C Compatible 2-wire Camera Control
- Pin compatible
- 2.3x Effective Pixel BW
CSI-2 over C-PHY 2.3x Effective BW

- 3 terminated conductors
- CSI-2 policy: symbol transition each state for trivial CDR
- Theoretical BW gain: \( \log_2^5 \)
- As implemented for CSI-2 = 16/7
Algorithm is King

- Unified Imaging Software Driver
- Enable Image Sensor Capabilities for Vision Compute
- Accelerate Bring up on Reference Platforms
CSI-2 CCS

- Vertical Flip | Horizontal Mirroring

- Sub-Sampled Readout | Binning | Digital Crop
Deep Neural Networks

Myriad X Hybrid Arch Deep Neural Network
8 Cameras using 16 MIPI Lanes - 700 MP/s
Drone Collision Avoidance (DJI SPARK)

LRTE

- Dramatically Improve Sensor Aggregation
- Optimal Transport Preserving Integrity
- Real-time Perception & Decision Making
- Phase out EOS &IL Impediments
- Asymmetric SP/LP Spacers
Detailed CSI-2 System Analysis & Benefits of Using LRTE PDQ

System 1: CSI-2 v2.0 over C-PHY v1.2 (3.5 Gbps/lane or 8Gbps/lane)
24 Gbps using 3 lanes (requires 9 wires)
CSI-2 v2.0 supports up to 32 Virtual Channels over C-PHY

Multi Sensor Aggregator with each sensor configured as
1920 x 1200 (2.3MP), 12 BPP, 60 FPS

Image Sensor Packet Transport
1920 pixels x 12Bps = 23040 bits per Horizontal Row Long Packet (LP)
23040 bits / 24Gbps = 0.960 us / LP (CSI-2 Payload; Ignoring PH/PF)
Packet Header + Packet Footer = 336+48 = 384 bits
23424 bits / 24Gbps = 0.976us / LP_PHF (CSI-2 Payload with PH and PF)

CSI-2 v2.0 with Legacy C-PHY Packet Delimiters:
LP Delimiter (SoT/ETo) = ~0.3 us
Total Time per LP_PHF = 1.276 us
Packet Delimiter Overhead = 23.5%

Stream 90 frames from single image sensor requires: 1.53ms x 60 = 91.87 ms
Maximum Supported Image Sensors on an Aggregator = 10
FLOOR[10/0.09187] = FLOOR[10.88]

CSI-2 v2.0 with LRTE PDQ:
Time per Image Frame = 0.976us x 1200 = 1.171 ms
Stream 60 frames from single image sensor requires: 1.172ms x 60 = 70.27 ms
Maximum Supported Image Sensors on an Aggregator = 14
FLOOR[14/0.07027] = FLOOR[14.25]

Benefits of CSI-2 v2.0 with LRTE PDQ:
Frame Transport Efficiency Improvement: 23.5%
Additional Supported Image Sensors on Aggregator: +4 (over the same channel)
Alternatively, reduce toggle rate / wires

**Considerations**

<table>
<thead>
<tr>
<th>Consideration</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legacy PD Hor Row Overhead</td>
<td>23.51%</td>
</tr>
<tr>
<td>Legacy PD Max Supported Sesnsors</td>
<td>10</td>
</tr>
<tr>
<td>LRTE PDQ Hor Row Overhead</td>
<td>0.20%</td>
</tr>
<tr>
<td>LRTE PDQ Frame Transport Efficiency Impact (reduce: power / wire / toggle)</td>
<td>23.35%</td>
</tr>
<tr>
<td>LRTE PDQ Max Sesnsors Supported</td>
<td>14</td>
</tr>
<tr>
<td>LRTE PDQ Additional Supported Sensors</td>
<td>40.00%</td>
</tr>
</tbody>
</table>
**System Considerations**

- Proliferation of Image Sensors Require CSI-2 Aggregators and VC Expansion
- System is limited to 16 or lower VCs:
  - Supported by CSI-2 over C/D-PHY
- System requires more than 16 VCs:
  - Supported by CSI-2 over C-PHY

**CSI-2 Virtual Channels** uniquely designate frames (RAW, JPG, IR) and Metadata captured by each image sensor

**CSI-2 Image Sensors**
- Ultrasonic
- Cameras (HDR & IR)
- Radars

**CSI-2 Vision**
CSI-2 Unified Serial Link

- Long Reach
- Wire Reduction
- Encapsulation
- Secure Channel
Interleaved Encryption

- Enterprise Security
- Pixel Authentication
- VC Mapped Interleaved Encryption
- Threat Model & Use Cases (GCM / AES)
Machine Awareness (ECV)

- Phase 1: LRTE & PSD (EOY 2016)
- Phase 2: USL & SROI (EOY 2018)
- Phase 3: AOSC (EOY 2020)
DPCM Objective Qualification

- Enable 10-bit compression of RAW-12 video image with better IQ than prior version 12-8-12
- Reduce maximum absolute error of single-bit change in pixel value by a factor of 4.43x
- Qualified 5 degree slanted edge input image with low, medium, and high illumination levels:
  - 12-10-12 virtually indistinguishable from original image
  - MTF frequency response analysis closely tracks the original (HI/MI/LI - LC/MC/HC)
- Benefits include Link BW reduction cost savings

<table>
<thead>
<tr>
<th>Use Case</th>
<th>Per-Lane 4-Lane Bit Rate (Gbps)</th>
<th>12-10-12 DPCM Enables Use of:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10 bpp</td>
<td>D-PHY</td>
</tr>
<tr>
<td>4Kp60 or 1080p240</td>
<td>1.485</td>
<td>v1.1</td>
</tr>
<tr>
<td>16M (4:3) @ 30 fps</td>
<td>1.45</td>
<td>v1.1</td>
</tr>
<tr>
<td>20M (16:9 crop) @ 30 fps</td>
<td>1.371</td>
<td>v1.1</td>
</tr>
<tr>
<td>32M (4:3) @ 24 fps</td>
<td>2.263</td>
<td>v1.2</td>
</tr>
</tbody>
</table>
CSI-2 over D-PHY PSD emission reduction with scrambling (data lanes)

CSI-2 over C-PHY PSD emission reduction with scrambling (embedded clock and data)
Smart Region of Interest

- Phase 1 EOY 2018 Single Frame
- Phase 2 EOY 2019 Multi Frame
- ARCH: Edge | Hybrid

Functional Safety

APPLICATION SPECIFIC PAYLOAD

32-bit PACKET HEADER (PH)

Data 0 Data 1 Data 2 Data 3 Data WC-11 Data WC-10 Data WC-9 Data WC-8

16-bit CRC Orig (Optional) (l.s. byte first) 16-bit Row ID (Optional) (l.s. byte first) 8-bit Source ID (Optional)

Message Counter (MC) Checksum CRC (CS)

32-bit PACKET FOOTER (PF)

Length = Word Count (WC) * Data Word Width (8-bits). There are NO restrictions on the values of the data words
Graceful Link Degradation

Image Sensor

Lane1
Lane2
Lane3

Imaging & Vision Processor

Lane1
Lane2
Lane3

Imaging & Vision Processor

Lane1
Lane2

Imaging & Vision Processor
Platform Architectures

**CSI-2 FEATURES**
- SROI
- IENC
- USL_GTA_BET
- FUNC_SAFETY
- F_NF_ERR
- LRTE_ALP_PDQ
- GLD
- H_F_DUPLEX
- T_S_SYNC

**SNS MODULE**
- HEALTH_MONITOR
- IRX
- VCM
- GYRO
- ACC
- EPROM
- LED
- LASER
  ...

**ARCH**
- CENTRAL
- EDGE / DISTRIBUTED
- HYBRID

**APP**
- ISP
- CVE
- GFX

**PHY**
- DISCRETE
- INTEGRATED
CSI-2 Aggregators may benefit from Virtual Channel Expansion and LRTE PDQ.

CSI-2 streaming data from aggregated image sensors for near real-time perception and decision making platform solutions.

CSI-2 Imaging Conduit:
- Mobile Devices
- Wearables
- IoT Appliances
- Enterprise
- Industrial
- Medical
- Automotive
- Submarines
- Exoplanet Rover
- ...

Learn more at https://www.mipi.org and join the MIPI Alliance at https://www.mipi.org/join.
Interconnect Support

- **Short-Range** (MIPI Short & Standard Channels)
  - C/D-PHYs

- **Mid-Range** (Support up to 4m)
  - CSI-2 LRTE + USL

- **Long-Range** (Support up to 15m)
  - A-PHY

**CSI-2 SCR, VCX (RES / ECC), LRTE (EPD, ALP), DPCM, RAW, CCI, USL, GLD, SROI, IENC, SYNC, FUNC_SAFETY, INTEROPS**

- Mid-Range solutions targeting EOY 2018 development
- Long-Range solution targeting EOY 2019 development
Summary

• Engage Imaging & Vision Global Alliances

• IOT Platform EOY 2018
  – USL
  – SROI (Single Frame)
  – RAW-24
  – EOTP
  – Interop Fixes

• Automotive Platform EOY 2019
  – Functional Safety
  – IENC | Pixel Integrity
  – SROI (Multi Frame)
  – Joint Imaging & Security BOF (January 2019)

• Balance Cleverness with Wisdom
  – Inclusive Vs Exclusive

• Machine Awareness EOY 2019
Questions

www.mipi.org