MIPI CSI-2 Image Sensor Interface Standard Features Enable Efficient Embedded Vision Systems

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Topics

- MIPI CSI-2 Frame Format & Complementary Specification
- Unified Serial Link Encapsulated Transport
- Always On Sentinel Conduit (AOSC) for Low Power Inferencing
- Integrated and External Smart Region of Interest
- Multi Pixel Compression building on Differential Pulse Code Modulation
- Summary with Present Developments & Explorations

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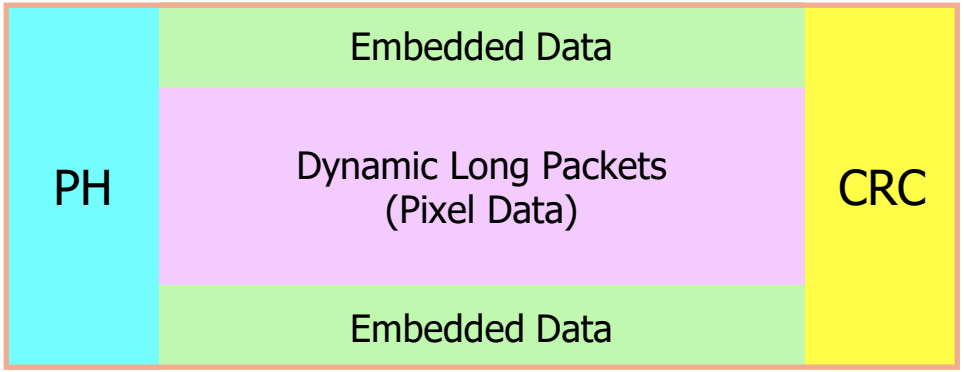
Recap CSI-2 Frame Format & Complementary Specifications

Packet Header (PH) contains Frame Data Type, Virtual Channel protected by Error Checking and Correction or replication.

The Dynamic Long Packet is structured as a best effort carrier with a Cyclic Redundancy Checker (CRC).

Multiple complementary specifications supporting CSI-2 include: physical layer transport (A/C/D-PHY & I3C), Functional Safety and Security (CSE), Unified Imaging SW Drivers (CCS & DisCo), and Conformance Test Suite (CTS).



SNS & APP Covenant

Low Energy Transport

Applications Driven Provisions

D-PHY | C-PHY | A-PHY | I3C | CTS | CSE (FS) | CSE (SEC) | CCS | DisCo

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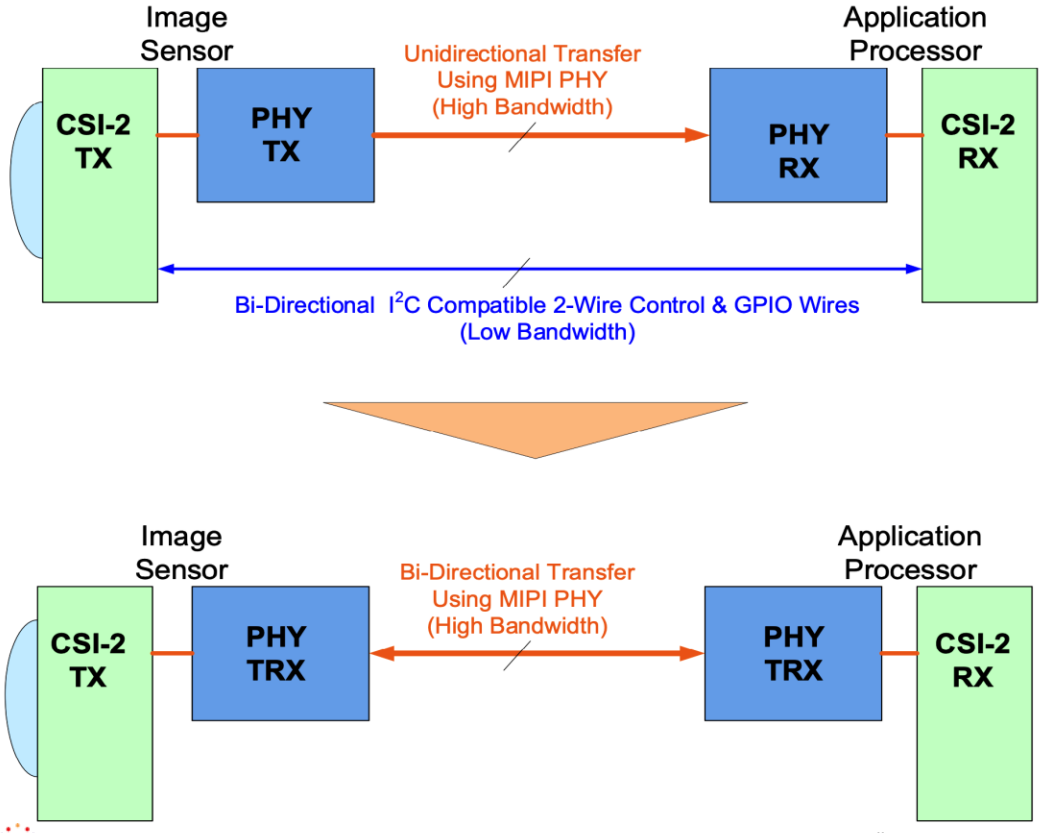
SNS = Sensor | APP = Application Processor | FS = Functional Safety | SEC = Security

Unified Serial Link (USL) Encapsulated Transport



- Wire Reduction
- Replay Protection
- Encapsulation
- Inheritance

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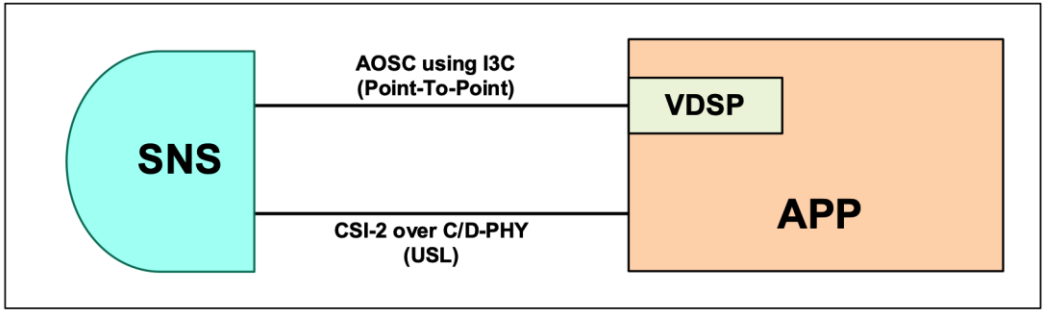
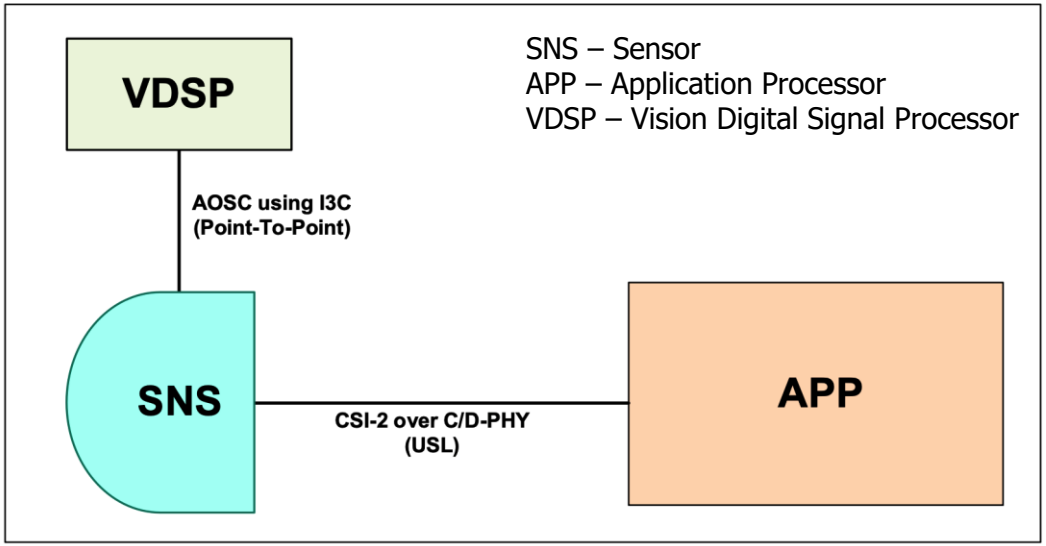
Always On Sentinel Conduit Developed for Ultra Low Power Inferencing

- Targeting single digit mW system power
- Low-cost two-wire GPIO pins
- Imaging System Options:
  - AOSC over I3C
  - AOSC over I3C & CSI-2 over C/D-PHY
  - Switch between AOSC and CSI-2
- Example System Configurations:
  - QVGA at 10 FPS using RAW10 (8.5 Mbps) = 1 Lane Standard Data Rate (11 Mbps effective BW)
  - 720p at 10 FPS using RAW8 (81 Mbps) = 4 Lane High Data Rate Bulk Transport (95 Mbps effective BW)





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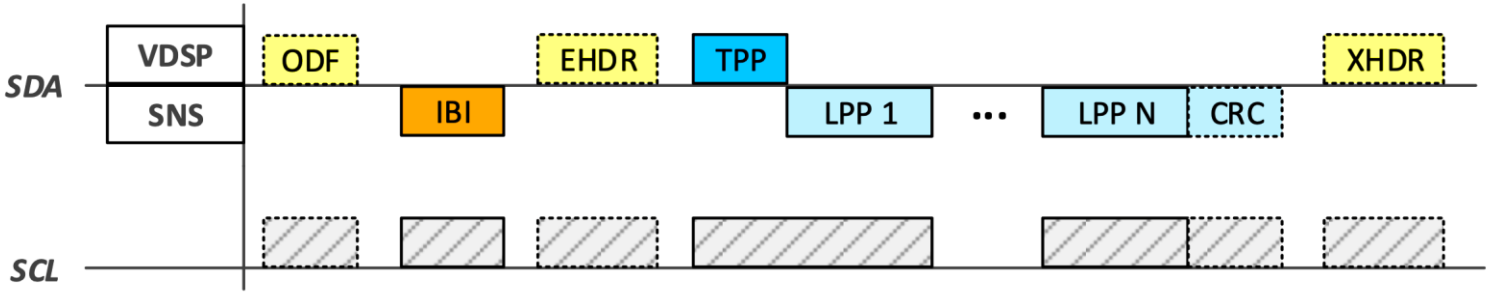
AOSC Optimal Transport Mode Operation

- AOSC OTM operations upon configuring the camera sensor
- ODF: On-Demand Frame command to initiate frame exposure
- IBI: In-Band Interrupt generated by the SNS at the beginning of an image frame
- EHDR: The VDSP may optionally Enter into an I3C HDR Mode that supports a higher data rate
- TPP: The VDSP generates a Transmit Packet Payload command to the SNS
- LPP 1 through LPP N: The VDSP reads all Long Packets (1 to N) encompassing an image frame from the SNS
  - Interconnect Synchronizing Padding Bytes (ISPB) may be appended to select Long Packets
- CRC: The VDSP reads the 16-bit CRC from the SNS if the OTM_CRC_GEN was enabled
- XHDR: The VDSP shall exit I3C HDR Mode (see EHDR step above)



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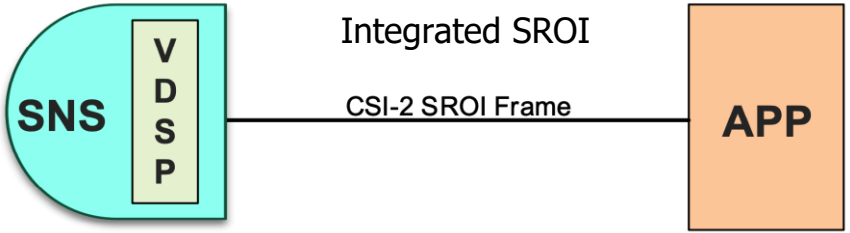
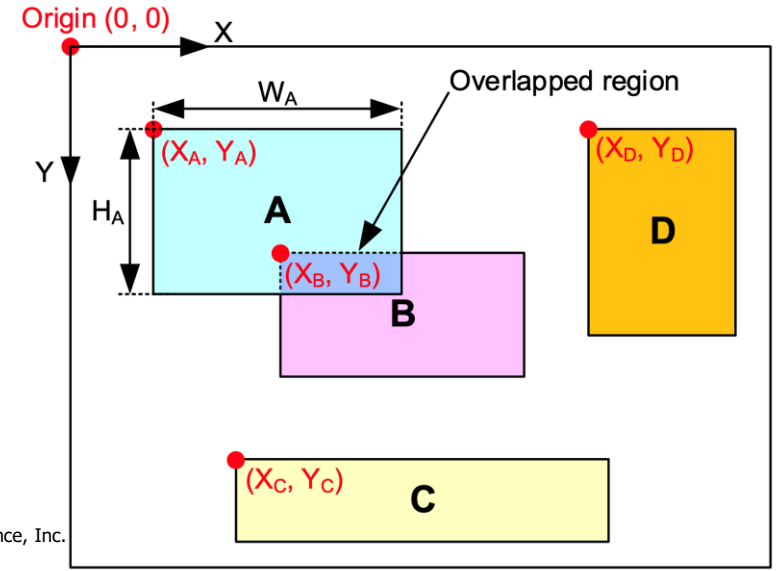
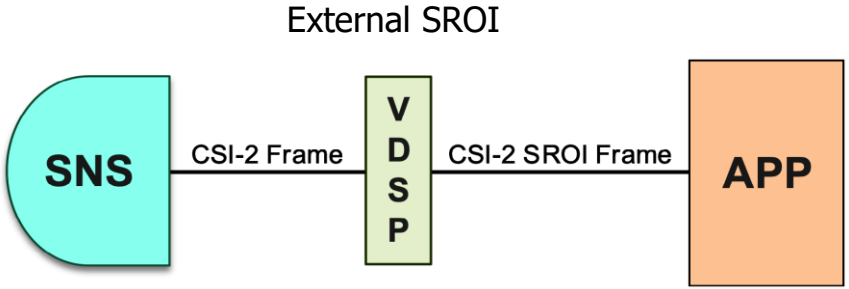
Integrated and External Smart Region of Interest

- The Smart Region of Interest (SROI) feature supports the adaptive transfer of rectangular Regions of Interest (ROI).
- SROI can be used to reduce data bandwidth by selectively transmitting one or more smaller ROIs carved out from the original frame, such as a human face or a license plate.
- CSI-2 over D-PHY with original ECC: 4 Virtual Channels
- CSI-2 over D-PHY with enhanced ECC: 16 Virtual Channels
- CSI-2 over C-PHY: 32 Virtual Channels (+Res = 1024)







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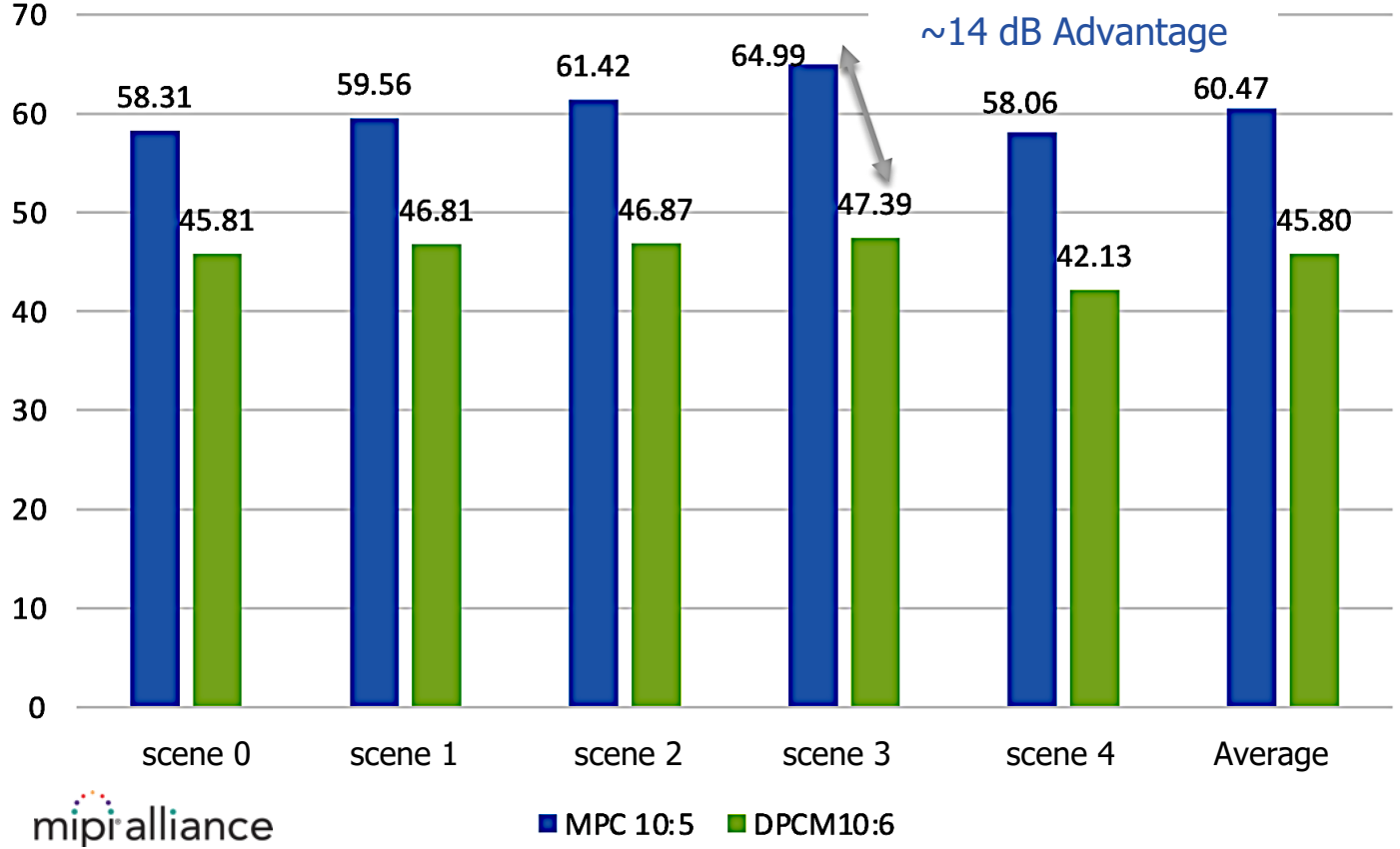
Multi Pixel Compression (MPC)



- Statistical probability of similar neighboring pixels
- Multi-pixel sensor architectures (Tetra-cell or Nona-cell)
- Superior image quality - ~14 dB Peak Signal to Noise Ratio (PSNR) improvement
- Better compression efficiency - MPC is 2:1, whereas the DPCM uses 1.67:1 yielding 20% improvement

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Summary

- MIPI CSI-2 protocol had the first mover advantage with smart phones, and continues to advance for beyond mobile product platforms.

- Key features and provisions developed for computer vision applications include:
  - Low Energy Transport
  - Smart Region of Interest to help improve system power
  - Always On Sentinel Conduit for inferencing applications
  - Unified Serial Link to help wire reduction with replay protection
  - Dual Compression Solutions including DPCM & MPC

- Welcome inputs on any additional MIPI CSI-2 protocol provisions that may be helpful for beyond camera sensors mapped to emerging vision applications (i.e. LiDAR, radar, sonar, and FLIR).

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Resources

https://www.mipi.org/specifications/csi-2

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Thank you

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