



# Introduction to the MIPI CSI-2 Image Sensor Interface Standard

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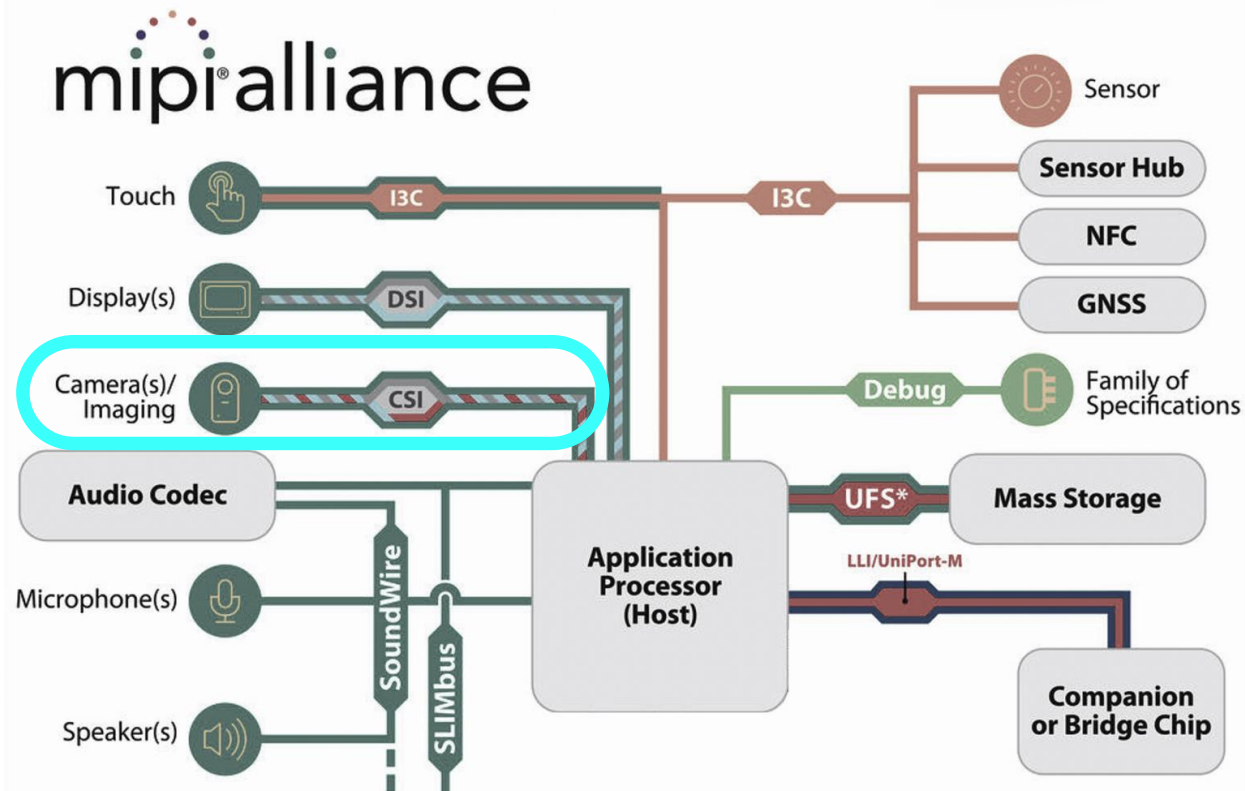
MIPI Alliance



- MIPI Alliance & Standardization of CSI-2 Frame Format
- Scope of Applications Spanning Mobile and Beyond Mobile Platforms
- Low Energy Pixel Transport Solutions & Imaging System Considerations
- Native Support for Long Reach & Provisions to Help Alleviate Emissions
- Summary with Technical Insights Track Coverage

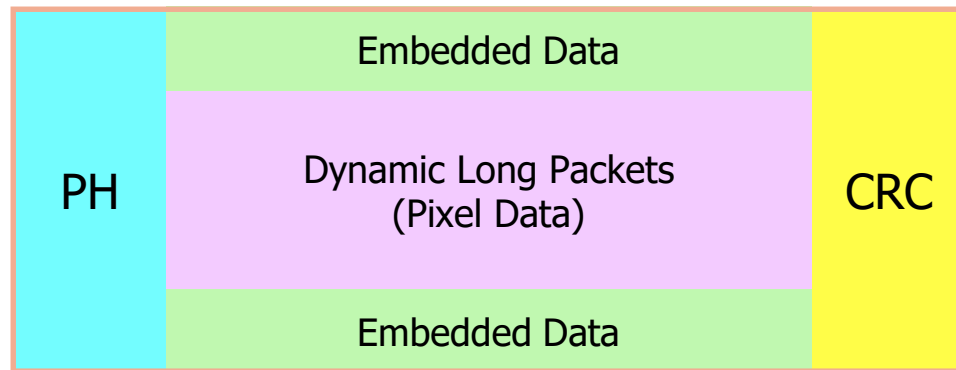
# MIPI Alliance and Camera Serial Interface (CSI-2) Standardization

- MIPI is a global, collaborative organization founded in 2003 that comprises 400+ member companies spanning the mobile and mobile-influenced ecosystems.
- MIPI's mission is to provide the hardware and software interface specifications device vendors need to create state-of-the-art, innovative devices while accelerating time-to-market and reducing costs.



# 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).
- 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)

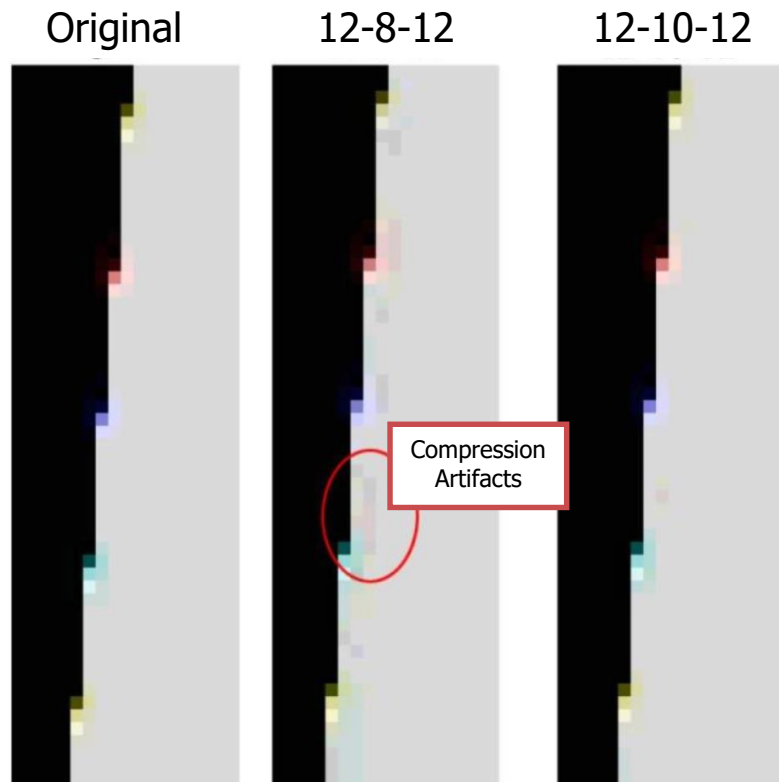
CCS

DisCo

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

# Beyond Mobile Transition: Differential Pulse Code Modulation for Street Sign Detection

- Pivotal timeframe in the evolution of CSI-2 development
- Qualified 5 degree slanted edge input image with low, medium, and high illumination levels
- MTF frequency response analysis closely track the original (HI/MI/LI X LC/MC/HC)
- Reduce maximum absolute error of single-bit change in pixel value by a factor of 4.43x
- Transport SerDes network bandwidth reduction & system cost reduction



# Scope of Applications Spanning Mobile and Beyond Mobile Platforms

## CONSUMER

Mobile Smart Phones  
Client Products (AIO | 2:1 | Laptops | Tablets)  
Smart Homes (Lights | Appliances | Irrigation)  
Home Security ( Doorbell | Property Surveillance)  
Emotional Metadata  
Tunable Avatars

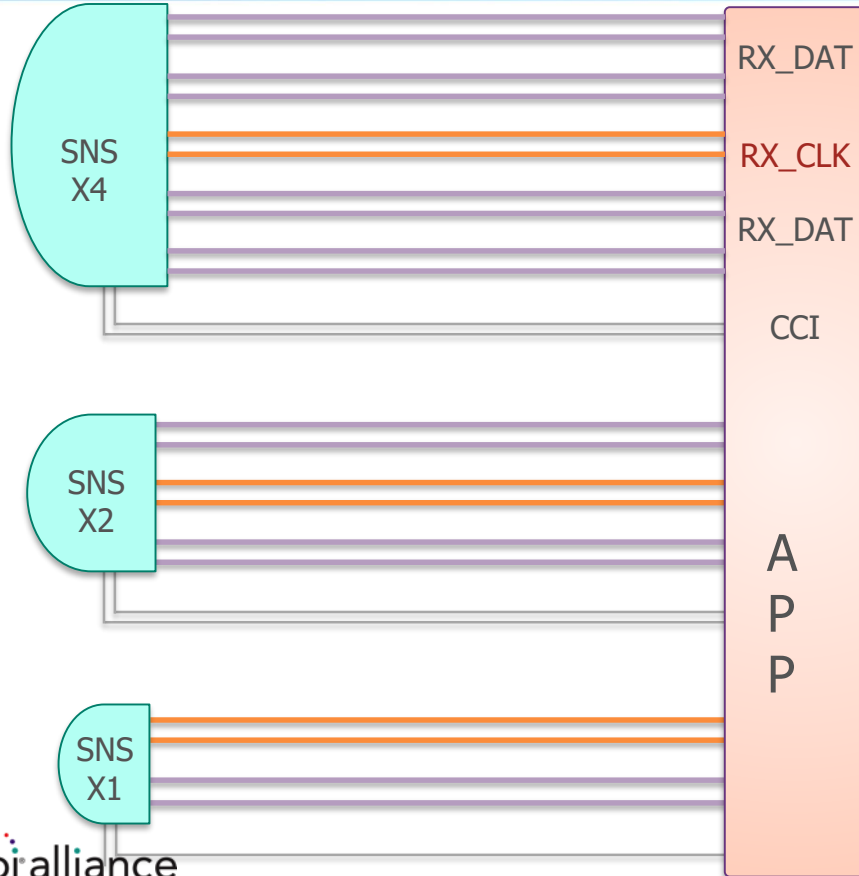
## COMMERCIAL

Smart Retail (Autonomous Checkout)  
Commercial Surveillance (Abnormal Behavior)  
Airport Retinal Scan  
Biometric Access Control | Payments  
Fire Detection | Parking Monitors  
Autonomous Transportation (Land | Water | Air)  
Medical & Industrial Client Products  
Commercial Drones & Robotics

## INFRASTRUCTURE

Robotics (Perception & Decision Making)  
Smart Municipal City (Abnormal Behaviors)  
Highway Traffic Monitoring (Accidents)  
Public Transportation (Abnormal Behavior)  
Long Range Perimeter Surveillance (Security)  
Environmental Monitoring (Fires | Earthquake)  
Space Exploration (Rover)

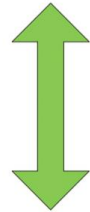
# CSI-2 Over D-PHY Low Energy Pixel Transport



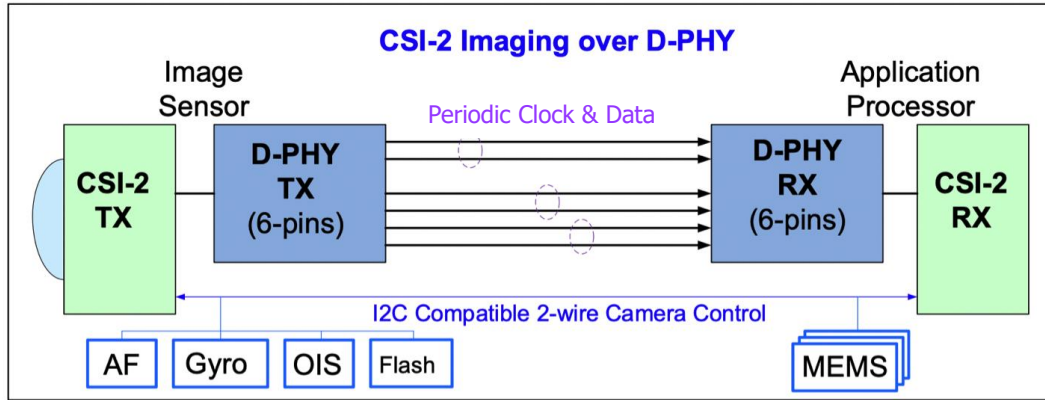
- Point-to-point unidirectional connection
- Forwarded differential half-rate periodic clock
- Differential pixel data sampling
- SoC physical imaging ports are frozen at pin level
- Variable link rate matched to SNS pixel clock
- Popular Camera Sensor (SNS) configurations:
  - X4 (4 Data Lanes comprising 10 pins)
  - X2 (2 Data Lanes comprising 6 pins)
  - X1 (1 Data Lane comprising 4 pins)

# CSI-2 Over C-PHY Low Energy Transport

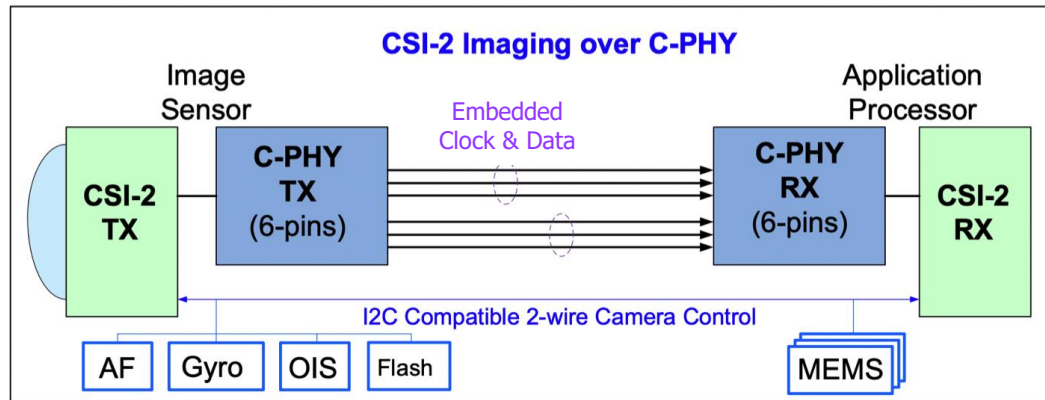
CSI-2  
D-PHY



CSI-2  
C-PHY



Pin compatible

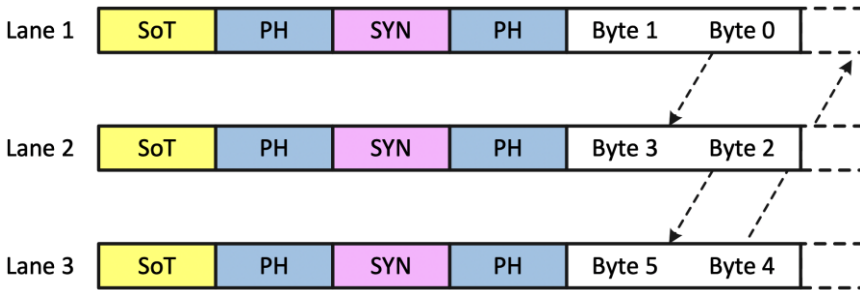


- Deployment of multiple classes of CSI-2 camera sensors using C/D-PHY transport.
- The CSI-2 over C-PHY supports variable link rate where the clock is recovered from the ternary symbol transitions over 3 wires.
- The CSI-2 over C-PHY offers an effective bandwidth coding gain of 2.28 by transporting 16 bits over 7 symbols.
- Select camera sensors may support CSI-2 over Combo C/D-PHY signaling since the pins are electrically compatible.
- Illustration depicts a 6-pin CSI-2 over D-PHY X2 (2 Lane) Port, and a CSI-2 over C-PHY T2 (2 Lane) Port.

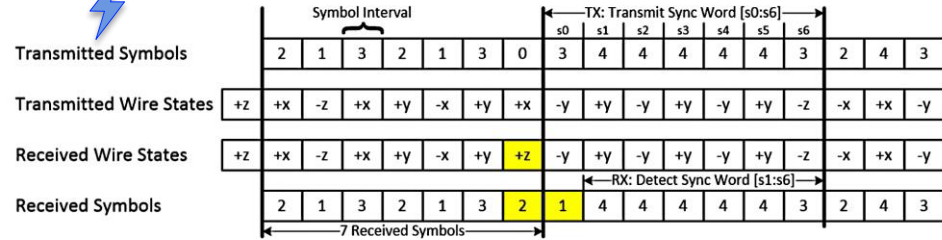


# Camera Link Error Mitigation

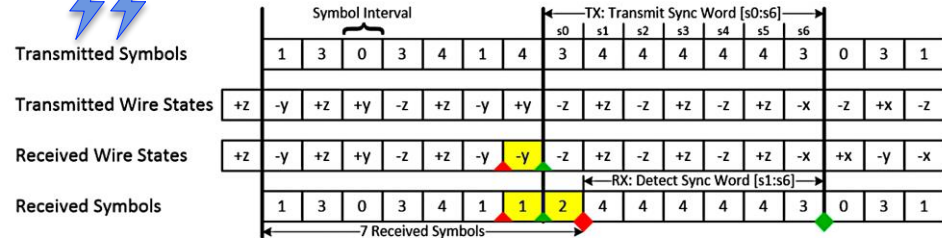
- Impact of gaussian errors on ternary signaling transport
- Provisions to facilitate run-time recovery:
  - CSI-2 Packet Header Replication
  - Camera Sensor TX: 3\_44444\_3
  - Application Processor RX Detection: X\_44444\_3



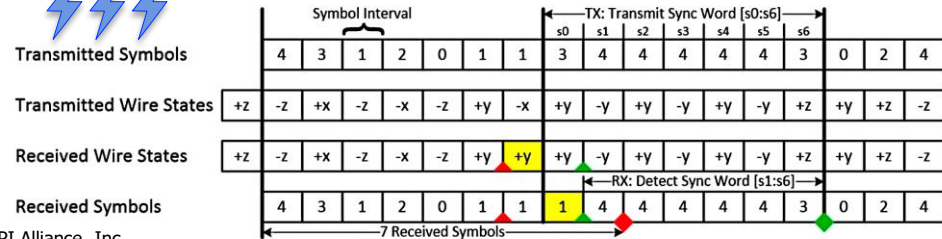
Link Error Example (a): Loss of No Symbol Clocks



Link Error Example (b): Loss of One Symbol Clock

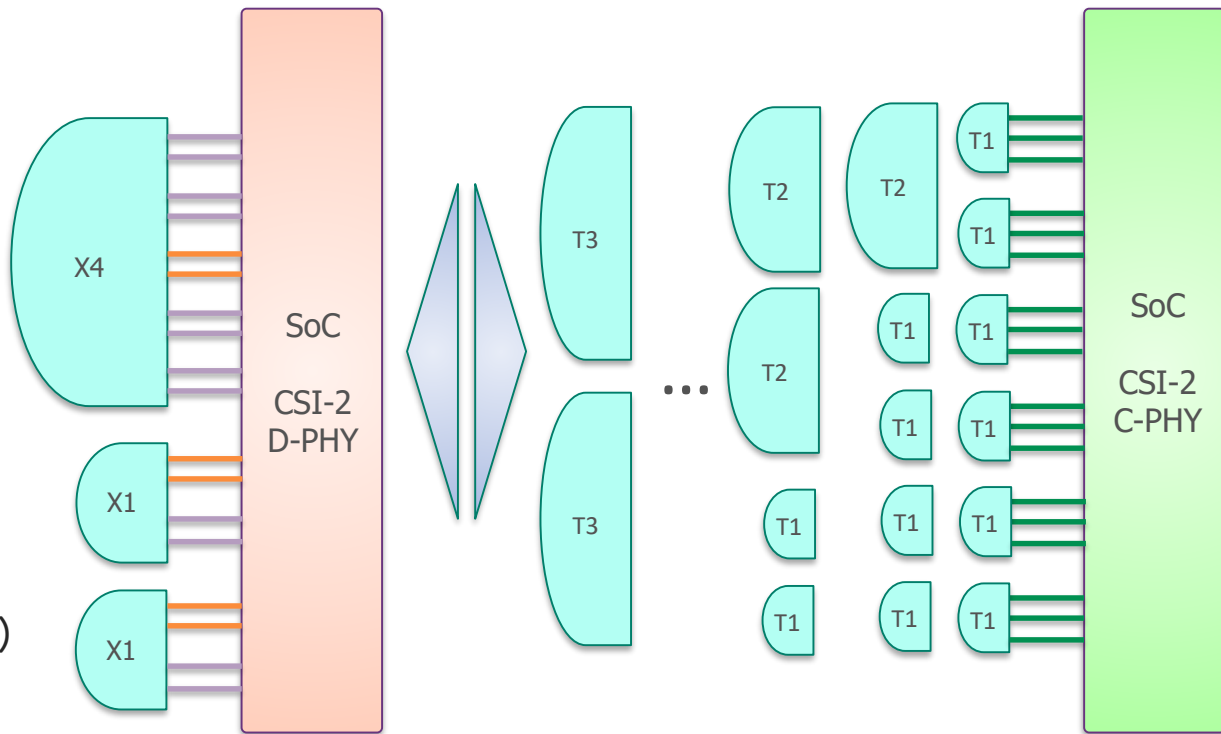


Link Error Example (c): Loss of Two Symbol Clocks



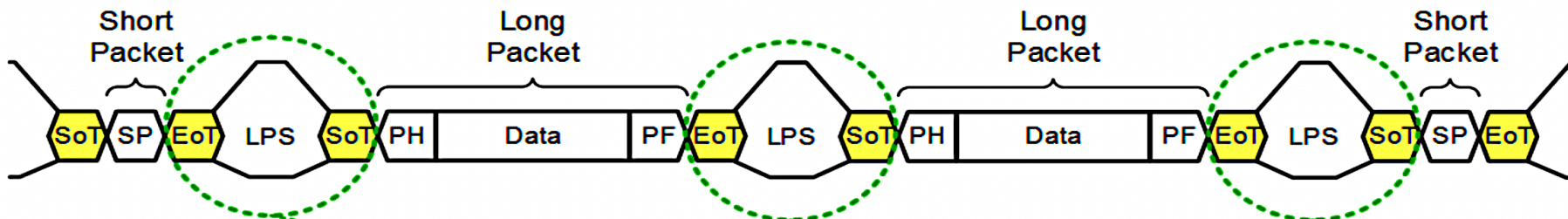
# Imaging System Architecture Considerations

- Imaging system with an 18-pin SoC
- Dynamic link rate
- Frozen vs logical ports
- Reduction of switching rate
- Virtual channels (4 / 16 / 32+)
- CSI-2 over D-PHY lane channel rates:
  - Standard: 9 Gbps
  - Short: 11 Gbps
- CSI-2 over C-PHY lane channel rates:
  - Standard: 6 GSps (13.7 Gbps)
  - Short: 8 GSps (18.3 Gbps)



# Latency Reduction and Transport Efficiency (LRTE) Benefits

Legacy Packet Transfers using End of Transmission (EoT), Low Power Signaling (LPS), and Start of Transmission (SoT) delimiters

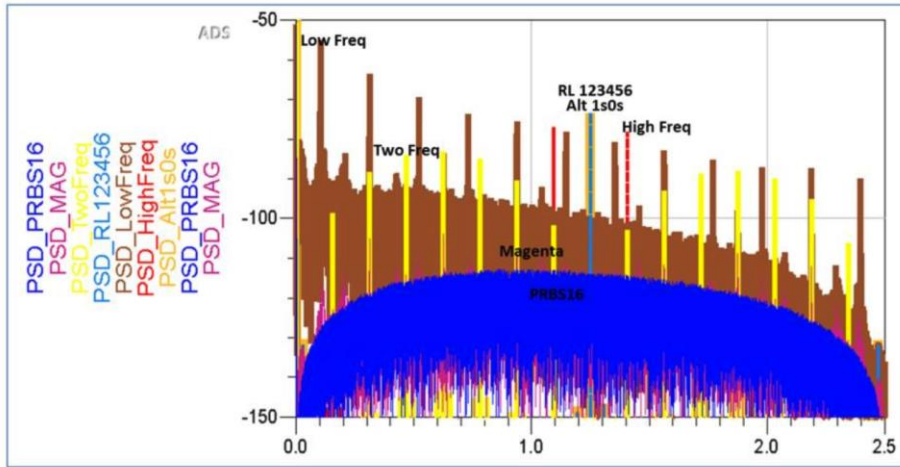


LRTE replaces legacy EoT, LPS, SoT with an Efficient Packet Delimiter (EPD)

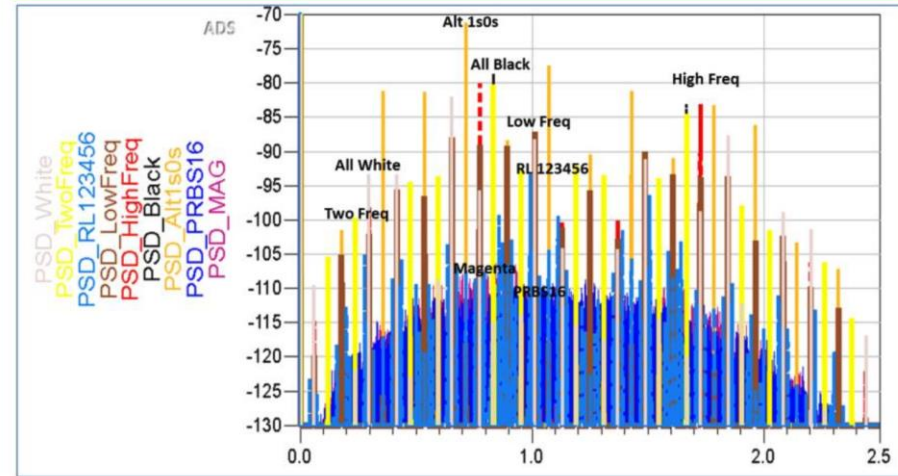
Imaging system benefits: Improve sensor aggregation, alleviate dual voltage signaling, support long reach

# Power Spectral Density Reduction Measurements

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)



Imaging system benefits: Pseudo random binary sequence to help reduce shielding costs

# Summary

- MIPI CSI-2 protocol had the first mover advantage with smart phones, and continues to advance for beyond mobile product platforms.
- Leveraging the established infrastructure, CSI-2 is universally used by camera sensors.
- Capabilities and features developed for computer vision applications will be covered in the Technical Insights Track:
  - Always On Sentinel Conduit for Inferencing
  - Integrated & External Smart Region Of Interest
  - Unified Serial Link with Encapsulation Support
  - Multi Pixel Compression (evolved Differential Pulse Code Modulation)
- 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).

# Resources

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

# Thank you

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