Autonomous Driving with the MIPI Camera and Sensor Interfaces
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Abstract

- Advanced Driver Assistance Systems (ADAS) SoCs for self-driving cars incorporate numerous interfaces for functions such as camera, radar, lidar and sensors. It is vital for such interfaces to meet the new stringent automotive standards, and offer the low power and high performance requirements that designers are looking for. The MIPI interfaces for camera (CSI-2) and sensors (I3C) are playing an essential role in enabling ADAS SoCs for autonomous driving. This presentation describes how these MIPI specifications are implemented in automotive SoCs and why.
Agenda

Implementation of MIPI interfaces in applications beyond mobile
MIPI camera and sensor specifications for automotive applications
Meeting automotive reliability requirements
Summary
MIPI Specifications in New Applications
Automotive, IoT / Wearables, Virtual / Augmented Reality
Safety-Critical ADAS Applications
Require ISO 26262 Functional Safety Compliance and ASIL Certification

Electronics Failures Can Have Hazardous Impact
Advanced Driver Assistance Systems (ADAS)
A Rapidly Evolving Technology: Car Mirrors, Multiview Systems

• Passive Driver Assistance Systems
  – Back-up, surround view camera
  – Distance alert system

• Active Driver Assistance Systems
  – Back-up camera with identification & braking
  – Collision avoidance
Example: Automotive Surround View

Using MIPI CSI-2 Image Sensors & DSI Display

- Power Supply
- MPU
- Proprietary, LVDS or Ethernet Switch
- DRAM
- Flash Memory
- CAN Interface
- LVDS or Ethernet Link
- MIPI CSI-2 Image Sensors
- Front Camera Module
- Left Camera Module
- Right Camera Module
- Rear Camera Module
- Other Camera Module

- Display
- MIPI DSI Display
- V_{bat}

- Front Camera
- Left Camera
- Right Camera
- Rear Camera
- Other Camera

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Automotive Applications Require Different SoC Architectures

**High-End ADAS**
- LPDDR4, Ethernet AVB, MIPI, HDMI, PCIe, SATA, ADC
- Embedded Vision
- Security
- Sensor Fusion
- Requires Functional Safety

**Infotainment**
- USB, LPDDR4, Ethernet AVB, MIPI, HDMI, PCIe, SATA, ADC, UFS, eMMC
- Real-time Multimedia
- Security
- Sensor Fusion

**MCU**
- IP: Ethernet 10/100/1000, ADC, I/F peripherals
- Medium Density NVM
MIPI CSI-2 and D-PHY Specifications
MIPI CSI-2 Over D-PHY

Overview
MIPI CSI-2 Packets

**Short packets used for frame synchronization**

**Image data**

**Short packets used for frame synchronization**

Frame Start Packet

First Packet of Data

Last Packet of Data

Frame End Packet

KEY:
- SoT – Start of Transmission
- EoT – End of Transmission
- LPS – Low Power State
- PH – Packet Header
- PF – Packet Footer + Filler (if applicable)
- FS – Frame Start
- FE – Frame End
- LS – Line Start
- LE – Line End

Low power states between image lines
MIPI CSI-2 v2.0 Feature Enhancements for Automotive Applications

• RAW-16 and RAW-20 color depth
  – improves intra-scene High Dynamic Range (HDR) and Signal to Noise Ratio (SNR) to bring “advanced vision” capabilities to autonomous vehicles and systems

• Latency Reduction and Transport Efficiency (LRTE) feature
  – supports increased image sensor aggregation without adding to system cost; facilitate real-time perception, processing and decision-making; and optimized transport to reduce the number of wires, toggle rate and power consumption

• Differential Pulse Code Modulation (DPCM) 12-10-12 compression
  – reduces bandwidth while delivering superior SNR images devoid of compression artifacts for mission-critical vision applications

• Scrambling to reduce Power Spectral Density (PSD) emissions
  – minimize radio interference and allow further reach for longer channels

• Expanded number of virtual channels from 4 to 32
  – accommodate the proliferation of image sensors with multiple data types and support multi-exposure and multi-range sensor fusion for Advanced Driver Assistance Systems (ADAS) applications such as enhanced collision avoidance

Image courtesy of the MIPI Alliance
Virtual Channels
D-PHY Architecture

The Popular Physical Layer Used for CSI-2 and DSI Specifications

- Synchronous forwarded DDR clock link architecture
- One clock and multiple data lanes configuration
- Static/dynamic de-skew supported through calibration
- No encoding overhead
- Low-power and high-speed modes
- Primarily targeting camera and display
- Spread spectrum clocking supported for EMI/EMC considerations
- Large ecosystem, proven in millions of phones and cars
MIPI I3C Specification

Standardizing Sensor Interface
Why I3C?

*The Challenge of Integrating Multiple Sensors with Different Requirements*

- Today Smartphones typically have 10-15+ sensors
  - Which require 12-18+ pins
- Different Sensors have different requirements
  - Fingerprint vs Compass
- Typical approach is to connect sensors using a mix of I2C and SPI
  - I2C for lower data rates and SPI for higher data rates
- Multiple side band signals
  - For interrupts, chip selects, power management
- No Standard driver for these fragmented interfaces

This will increase the package size and add complexity which translates into additional costs.

Image courtesy of the MIPI Alliance
Why I3C?
You Can do Everything with Two IOs!

+ It takes the goodness of I2C
  – Two-wire, Simple
+ It takes the goodness of SPI
  – Low Power and Speed
+ Adds features such as
  – In-band interrupt/command support
  – Dynamic addressing
  – Advanced power management
  – High data rates
+ While maintaining support for legacy I2C sensors
  – Evolutionary, not revolutionary

Image courtesy of the MIPI Alliance
I3C Enables Efficient System Architectures

Example: Sensor Hub

Power Reduction, More Efficient System, Faster Data Transfer
MIPI CSI-2, D-PHY & MIPI I3C

• Supports advancements in imaging for new applications: Health, Convenience, Security, Lifestyle, Efficiency

• Camera Controller Interface (CCI) and Always-ON advancement considerations using I2C and future MIPI I3C
Summary
MIPI Specs for Multimedia, Storage, Sensor & Wireless Connectivity in Automotive Applications

Infotainment
- Navigation
- Audio/video
- Entertainment

Driver Information
- Instrument clusters
- Voice recognition
- Hi-def displays
- Surround view

Vehicle Networks & V2X
- Real time video & data network
- Gateways
- Telematics
- V2V
- V2I
- Security

Driver Assistance
- Parking assist
- Lane departure warning & Lane keep aid
- Pedestrian detection & correction
- Automatic emergency braking

Image courtesy of the MIPI Alliance
Key Requirements of Automotive-Grade IP
Reduce Risk and Accelerate Qualification for Automotive SoCs

- **Functional Safety**: Accelerate ISO 26262 functional safety assessments to help ensure designers reach target ASIL levels
- **Reliability**: Reduce risk & development time for AEC-Q100 qualification of SoCs
- **Quality**: Meet quality levels required for automotive applications
ASIL Ready ISO 26262 Certified MIPI IP

Single-Vendor Solution, Production-Proven, Interoperable

Synopsys Provides Complete Camera, Display & Sensor Interface IP Solutions

- MIPI CSI-2, D-PHY and I3C protocols
  - Leveraged for mobile and beyond – IoT, automotive, AR/VR

- Enables new set of applications in automotive, AR/VR, IoT markets
  - Lowers integration risk for application processors, bridge ICs and multimedia co-processors

- Future proof IP supporting variety of speeds, proven in silicon
  - Reduces cost and power for multiple instantiations
  - Testability features enable low cost manufacturing