ADAS High Bandwidth Imaging Implementation Strategies

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Automotive Imaging Applications

- SV/Park Assist
- Radar/Lidar
- Front Cam
- Smart Rear Cam
- DMS
- Fusion
- CMS

Compiled with Google Search Images
Challenges

- **High Bandwidth Requirements**
  - Faster frame rate
  - Higher sensor resolution
  - High dynamic range (multiple exposures per pixel)

- **Multi-Camera Systems**
  - Numerous image/video formats
  - Single processor to process video inputs from all cameras
  - Need to distinguish amongst video streams
  - Multi-modal fusion

- **SoC Design Constraints**
  - Package: Minimal pin count
  - Routing: Signal integrity
  - Lower cable usage

- **Automotive Quality & Safety**
  - Need to maintain signal integrity for interface distance > 20 ft
Example Solutions

- **FPD Link Deserializer**
  - Quad hub chip
  - Each camera connected through FPD-Link cable
  - VC tag for individual camera streams
  - Mux 4 cameras into a single CSI-2℠ stream

- **Vision Processor**
  - Rx module fully compliant with MIPI CSI-2℠ spec 1.0
    - Future: 32 Virtual Channels
    - Up to 6.0 Gbps throughput
    - HW support to parse CSI-2℠ streams
    - High speed, multi channel image processor
    - Vision accelerators: HW IPs + Programmable Core

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Why MIPI CSI-2℠ in Automotive

- Low power
- High speed transfers
- Low pin count
  - Flexibility in choosing 1/2/3/4 lane(s)
- Standardized vs Proprietary protocols
  - Easy to interface a wide range of transmitters and receivers
- Virtual channels
  - Allows connections of multiple devices to the same bus

- Error detection and recovery
  - Sync codes
  - ECC codes
  - 16-bits CRC Checksum

- Safety
  - Safety related meta-data along with pixel data
MIPI CSI-2℠ Lane Scalability

In high bandwidth scenarios, CSI-2℠ can be configured to split byte stream into 1/2/3/4 data lanes.

On Tx side the stream is distributed across multiple lanes. On Rx side incoming packets are merged into a single stream.

Each lane operates independently, including SoT frame, Start Packet code and End Packet code.

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Virtual Channels and Data Types

- Each CSI-2℠ packet has a “Data Identifier” field, which specifies the payload Data Type (DT) and Virtual Channel (VC) number it carries.

- Different data types from different sources can be merged into a single stream.

- CSI-2℠ Rx uses DT and VC fields to distinguish amongst different packets and process them accordingly.

- Examples:
  - Pixel data vs embedded data
  - Data from different cameras multiplexed into a single CSI-2℠ stream
  - Multi-exposure WDR where L/M/S pixels are coming in a single stream.
Example – Surround View

- 4x Full HD Cameras – Throughput requirement > 3 Gbps
- Each camera sends a high resolution RAW stream at a high frame rate
- Surround View Application (SRV)
  - 4:1 Deserializer Hub (DS90UB96x)
    - Synchronizes video inputs across multiple cameras
    - Aggregates camera streams from four sides of the vehicle
    - Tags each camera stream with unique VC and meta data
    - Multiplexes into a single stream
    - Sends over CSI-2℠ interface to the host processor

Host Processor (TDAx)
- Receives the incoming stream
- Parses each packet, identifies the camera stream based on VC
- Obtains 4 independent video stream in separate buffer queues
- Applies complex SRV image processing algorithms

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Example – Surround View

What is Surround View?

**Description:**
- 360 degree Bird’s Eye View using multiple cameras

**Key Care Abouts for Surround View:**
- **Safety**  
  - Gives more visibility around the vehicle
- **Convenience**  
  - Enables features such as park assist
- **Autonomy**  
  - Enables autonomous functions like self parking

What are the options for Surround View?

**Surround View Configurations:**
- **4 Cameras**
  - 2D
  - 3D

**ADAS Features**
- Park Assist
- Self Parking
- Obstacle Detection

**Variations:**
- Additional Cameras
  - Hitch
  - Truck Bed

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Surround View Configuration

LVDS

SoC care-about:
- ISP – Image Processing on SoC
- Graphics
- Analytics

CMOS Sensor
ISP – optional (not needed for TI)
FPD Link Tx

RAW or YUV video
Transmit over LVDS (FPD Link)

Send to display or Compress and send to ECU

Display

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Surround View Solution

Challenges
- High Data Rate – Up to 3 Gbps
- High Pin Count – To support multiple cameras
- Long Channel Length – Cameras located far away from the processor
- Sync – All cameras must be synchronized to eliminate motion artifacts

MIPI CSI-2℠ to the rescue
- 4-lane interface for High Speed Data Transfer
- Support for Virtual Channels and Data Types
  - Allows multiple camera streams to be muxed into a single CSI-2℠ stream
  - Processor can identify a CSI-2℠ packet using VC and DT info
- CSI-2℠ enabled SerDes chips allow long channel length over FPD Link
  - Act as 4-camera hub
  - Implements sync across all cameras

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Example – Multi-Modal Fusion

- **Passive Sensor**
  Camera
- **Active Sensor**
  Radar, Lidar, Ultrasound
- **Infrastructure**
  High-precision Map
  V2X Communication

- **Mid and Long Range**
  Adaptive Cruise Control,
  Emergency braking, Fully/Highly Autonomous Driving

- **Short Range and Ultra Short Range**
  Blind Spot, Collision Avoidance, Lane Change Assist, Pedestrian Detection, Park Assist

- **Proximity Sensors**
  Occupant Detection, Gesture Recognition, Driver Monitoring

- Lighting
- Rain
- Night
- Snow
- Fog/Smog
- Dirt

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Challenges

- High Data Rate – 1 Gbps/Camera + 2.4Gbps/Radar
- High PIN Count – To support large number of devices
- Imaging Format Variations – Need a standard protocol for imaging and non imaging devices

MIPI CSI-2℠ to the rescue

- 4-Lane interface for High Speed Data Transfer.
- Ability to MUX Camera/Radar/LIDAR
- Processor can identify the source using VC and DT
- CSI-2 specification easily extends to non imaging devices like Radar.
  - No design change needed at the processor Rx interface
  - Serializer and Deserializer chips for FPD link transmission can process Radar stream exactly like camera.

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Fusion – SLAM (Simultaneous Localization and Mapping)

- 6x-10x Cameras
- 6x-10x Radar
- 1x-4x LIDARs
- 8x-12x Ultrasonic
- Thermal/IR

Sensor Processing → Perception

IMU GPS Maps

FUSION
- Sensor Fusion
- Localization
- Mapping

PLANNING AND CONTROL
- Path planning
- Motion planning
- Vehicle controls
  - Acceleration
  - Brake
  - Steering

FEEDBACK TO DRIVER
- Visualization/Display
- Warnings

Driver monitoring

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Summary

MIPI CSI-2℠ is gaining popularity in Automotive industry because of the following benefits

• **High Bandwidth**: Total 6.0 Gbps. Allows 4x 1080p cameras on a single Processor
• **Low pin count**: Scalable from 6 - 12
• **Multi Camera/Multi Modal Architecture**: Efficient use of Virtual Channel and Data Types
• **Quality**: SerDes solutions converts image signal from digital to analog form. FPD link cable transports analog signal over long distance without degradation
• **Safety**: TDAxx processors has advanced capability for error detection, recovery, and embed safety data along with pixel data
• **Future**: 32 virtual channels

With more Image sensors, Radar and other devices adopting CSI-2℠, the trend is expected to continue and gain momentum in the years to come.

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