

# Lecture 2

# Camera Interface

Multimedia Systems  
Spring 2020

# Camera types

- ▶ DSLR



- ▶ Vision camera (산업용)



- ▶ Mobile camera

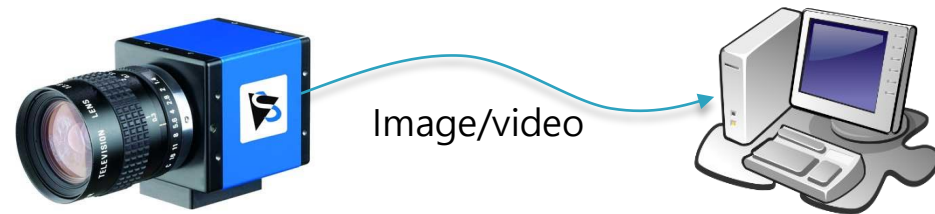


# Camera interface

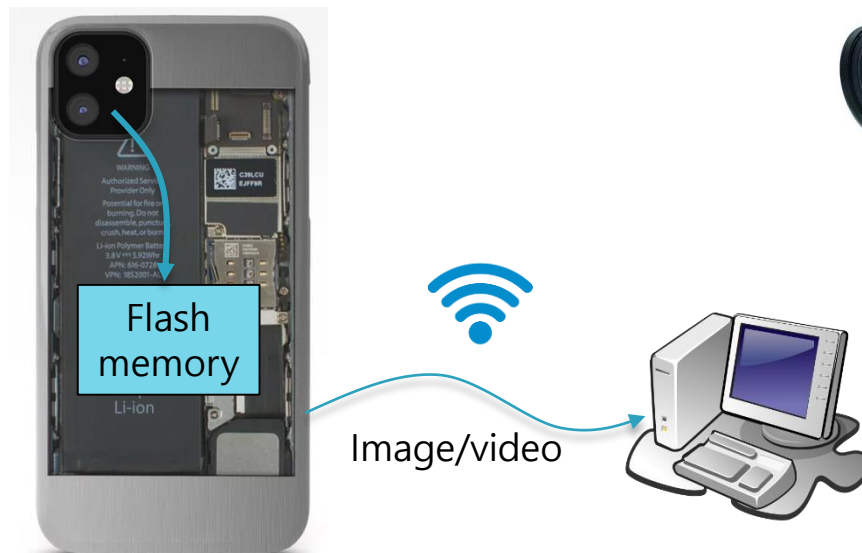
- DSLR camera interface



- Industrial vision camera interface

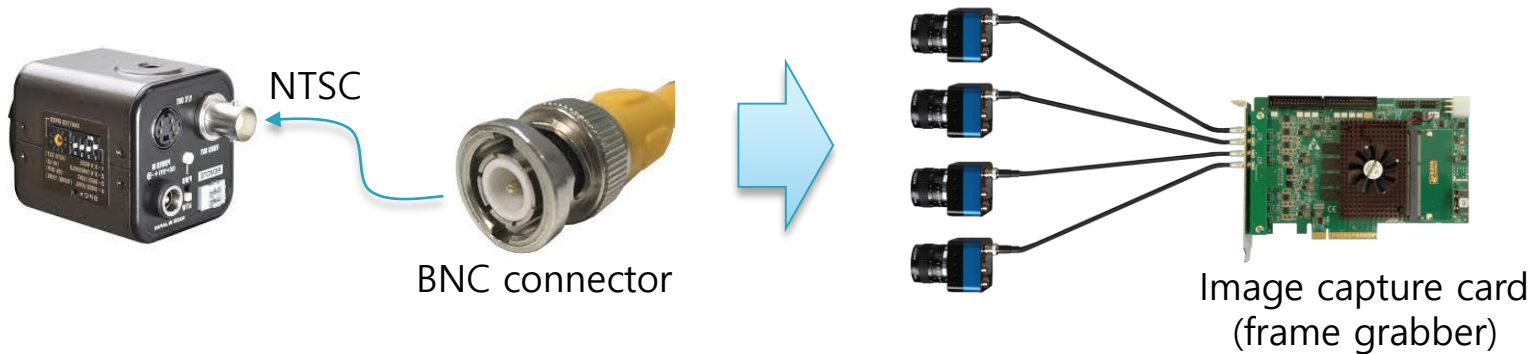


- Mobile camera interface

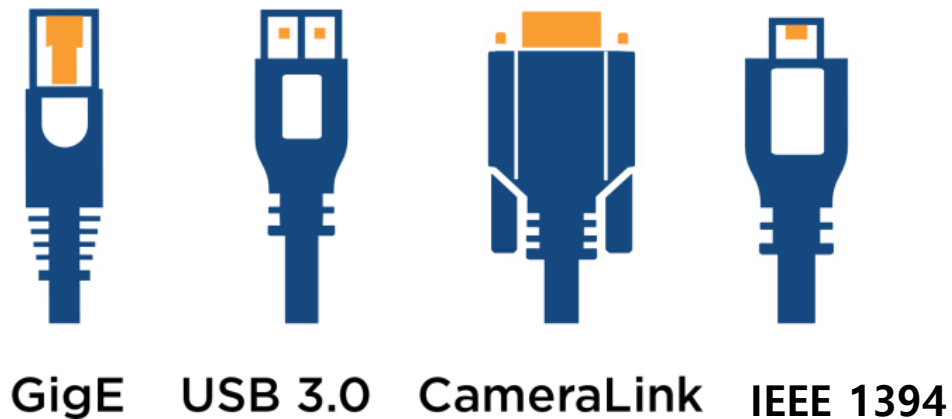


# Camera Interface (industrial camera)

- ▶ Industrial camera
  - Analog interface



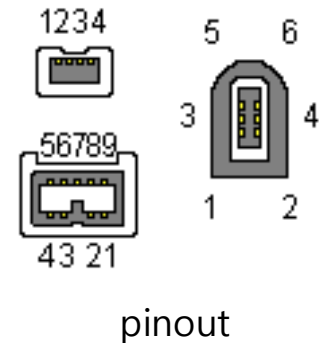
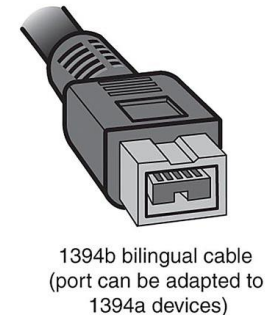
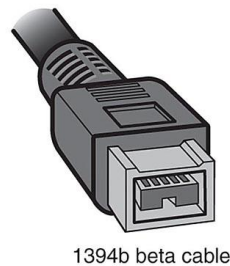
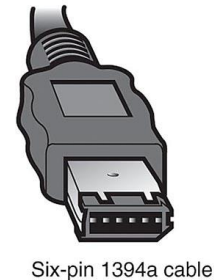
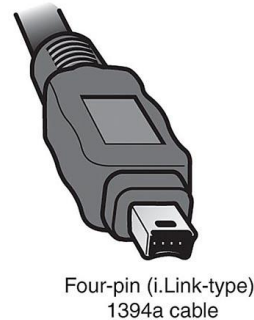
- Digital interface



# Camera Interface (industrial camera)

## ▶ IEEE1394

- IEEE 1394, also known as **FireWire**, is an interface based on a technology developed by Apple Inc.
- There are two types: IEEE 1394a and IEEE 1394b



# Camera Interface (industrial camera)

## ▶ IEEE1394

### ◦ Speed

- IEEE 1394a: 400 Mbits/s with 6 pin connector.
- IEEE 1394b: 800 Mbits/s (일반적) 3.2 Gbits/s (최대)

### ◦ Receiver Device

- PC (direct or capture card)

### ◦ Cable

- IEEE 1394a,b uses shielded twisted pair (STP) cable
- IEEE 1394b, sometimes uses an optical fiber cable (HPCF, GOF, POF) or UTP cable can be used.

### ◦ Connectors

- Latch type for IEEE 1394a
- Screw type for IEEE 1394b.

For example:

- 24-bit, 1080i @ 60 fps:  $24 \times 1920 \times 540^{[b]} \times 60 = 1.49 \text{ Gbit/s}$
- 24-bit, 1080p @ 60 fps:  $24 \times 1920 \times 1080 \times 60 = 2.98 \text{ Gbit/s}$ .

# Camera Interface (industrial camera)

## ► USB 3.0

### Single Camera



Camera connected by single cable to PC/laptop USB 3.0 ports providing power and up to 400 Mbytes/s data rate.  
No frame grabber required.

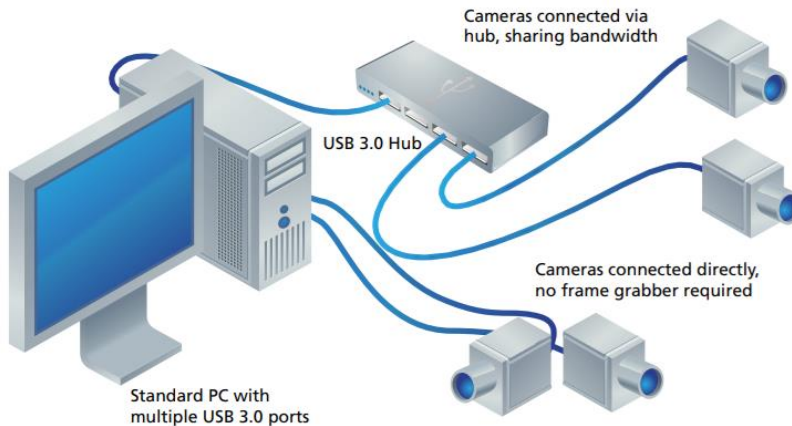
*Host side  
(standard A  
locking)*



*Device side  
(micro-B locking)*



### Multiple Cameras





# Camera Interface (industrial camera)

---

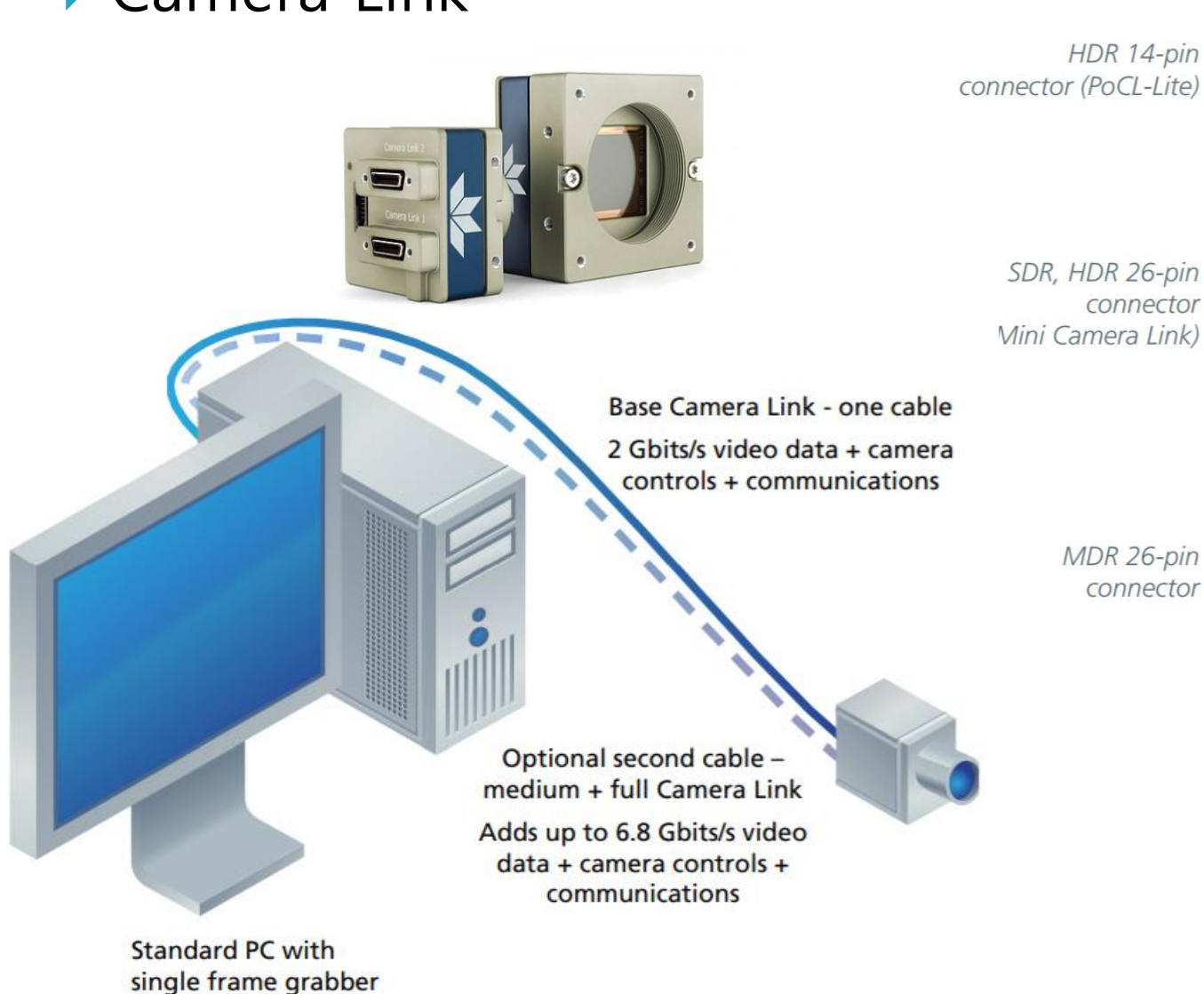
## ▶ USB 3.0 and USB 3.1

- Speed
  - 400 Mbytes/s. (max 5 Gbps, 실제로는 약 4 Gbps)
  - USB 3.1 standard max 10 Gbps (실제로는 약 9.7 Gbps)
- Receiver
  - Device PC (direct). With USB interfaces
- Cable
  - Standard passive copper cable 3-5m
  - Active copper cable 8+m (with power input)
  - Multi-mode fiber optic cable 100m.
- Connectors
  - USB3 Vision type connectors: host side (standard A locking) and device side (micro-B locking).
- Camera Power Supply
  - 4.5W (5V, 950 mA) maximum



# Camera interface (industrial camera)

## ► Camera Link



*HDR 14-pin connector (PoCL-Lite)*



*SDR, HDR 26-pin connector (Mini Camera Link)*



*MDR 26-pin connector*



# Camera interface (industrial camera)

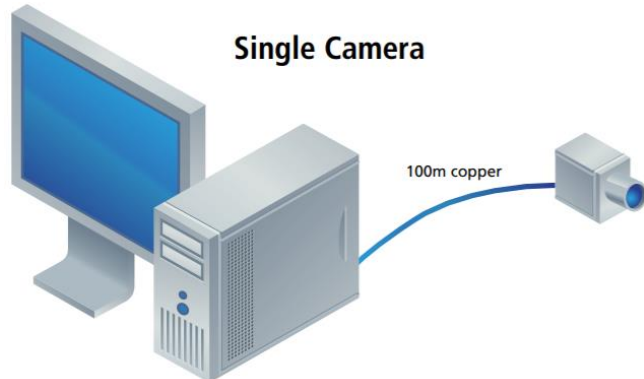
---

## ▶ Camera Link

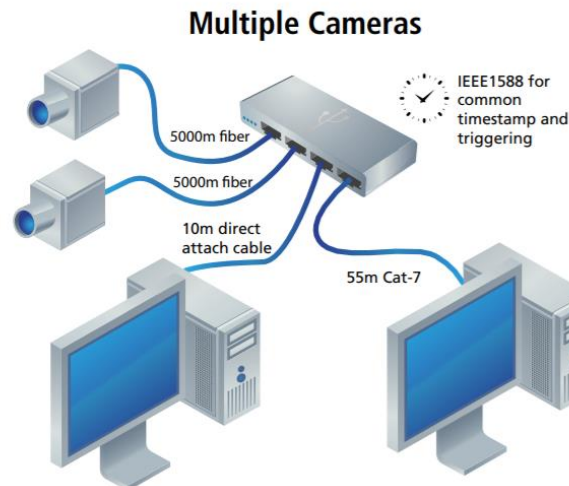
- Speed
  - The high bandwidth of 255 Mbytes/s for one cable and up to 850 Mbytes/s for two cables
- Receiver Device
  - Frame grabber.
- Cable
  - Camera Link defines its own dedicated cable.
  - Maximum cable length is in the range of 7 to 15 meters
- Connectors
  - MDR 26-pin connector;
  - SDR, HDR 26-pin connector (Mini Camera Link)
  - HDR 14-pin connector (PoCL-Lite).
- Camera Power Supply
  - By frame grabber through the Camera Link cable

# Camera interface (industrial camera)

## ► GigE Vision



Line scan or area scan camera powered through Ethernet cable or externally.  
Data rate up to 10 Gbits/s.  
No frame grabber required.



Cameras powered through Ethernet cable or externally.  
Total data rate up to 10 Gbits/s (for a 10 Gbits/s link to the PCs).

## Ethernet (IEEE 802.3)

*Copper Ethernet cable*



*Copper Ethernet with vision locking screws*



*10 Gigabit Ethernet direct attach cable*



*Ethernet fiber optic cable*



# Camera interface (industrial camera)

---

- ▶ GigE
  - Speed
    - Currently 1 and 2 Gbits/s (max 10 Gbits/s)
  - Receiver
    - Device PC (direct)
  - Cable
    - Lengths up to 100m (copper) and 5,000m (fiber optic)
  - Connectors
    - Copper Ethernet;
    - Copper Ethernet with vision locking screws;
    - 10 Gigabit Ethernet direct attach cable;
    - Ethernet fiber optic cable.
  - Camera Power Supply
    - Through Ethernet cable (POE) or externally.

# Smartphone and Automotive cameras

---

Source: LG Innotek



Single camera



Dual camera



Triple camera



Automotive camera



3D camera

# MIPI Alliance Interface

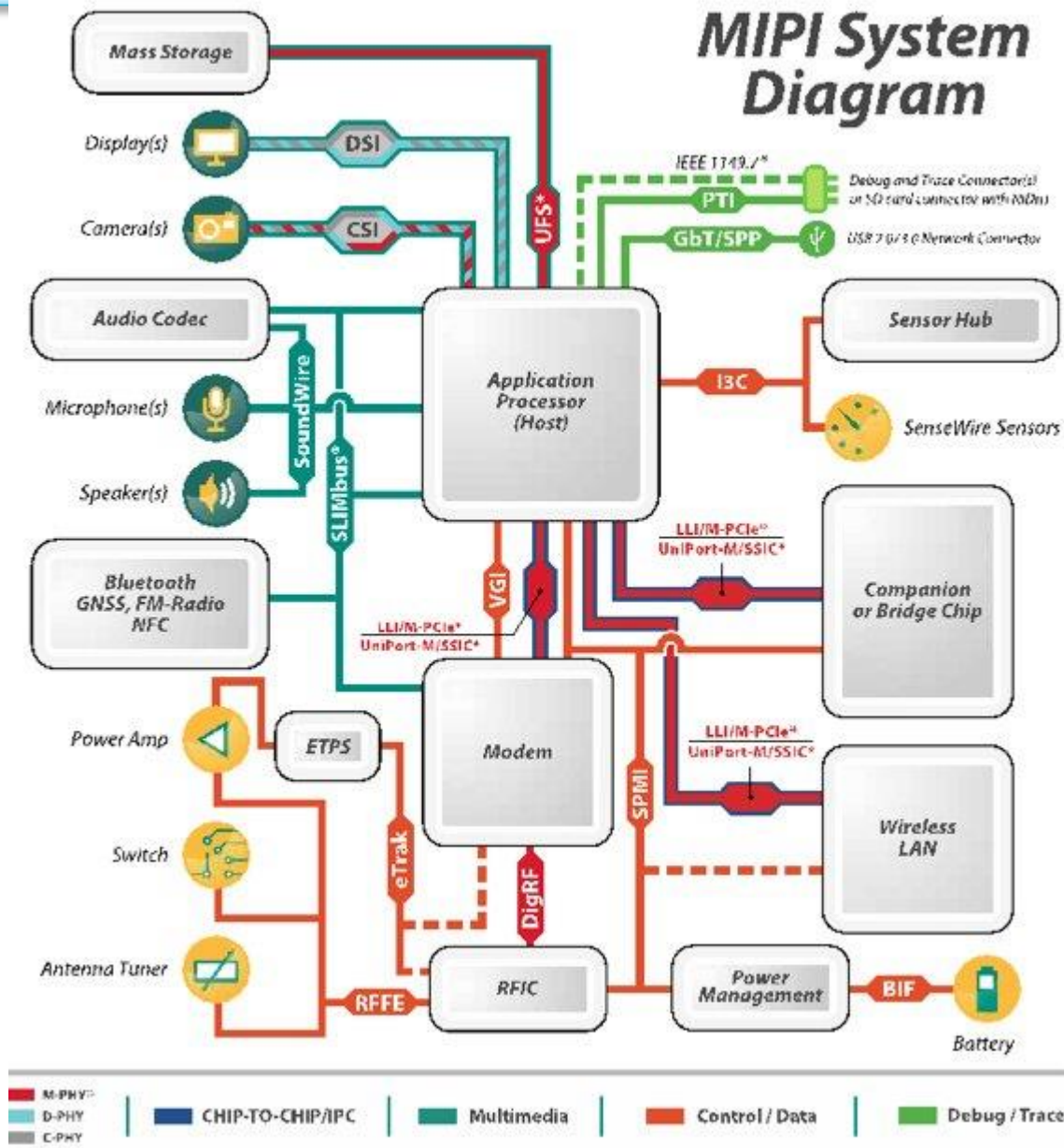
---

- ▶ 2003년에 ARM, 인텔, 노키아, 삼성, STMicroelectronics 와 텍사스 인스트루먼트가 모여서 MIPI(Mobile Industry Processor Interface) 얼라이언스를 설립
- ▶ MIPI는 모바일 및 사물인터넷 기기에서 재사용 및 호환성을 강화하기 위해 AP(Application Processor)를 비롯한 프로세서와 주변 기기들에 대한 인터페이스 사양을 개발하고 정의함
- ▶ MIPI에서 만든 대표적인 인터페이스
  - DSI(Display Serial Interface)는 AP와 LCD와 같은 디스플레이를 연결하는 인터페이스에 관한 표준
  - CSI(Camera Serial interface)는 AP와 카메라를 연결하는 인터페이스에 관한 표준
- ▶ 한편, MIPI는 세 종류의 고속 물리계층 (PHY)를 정의함: M-PHY, D-PHY, C-PHY.
  - M-PHY: The MIPI "Performance" Interface (DSI-2/CSI-3) (2011년)
  - D-PHY: DSI/CSI-2 Protocol에 대한 물리계층 표준 (2009년)
  - C-PHY: D-PHY의 개선 버전 (2014년)



# MIPI Alliance Interface

Source: MIPI Alliance

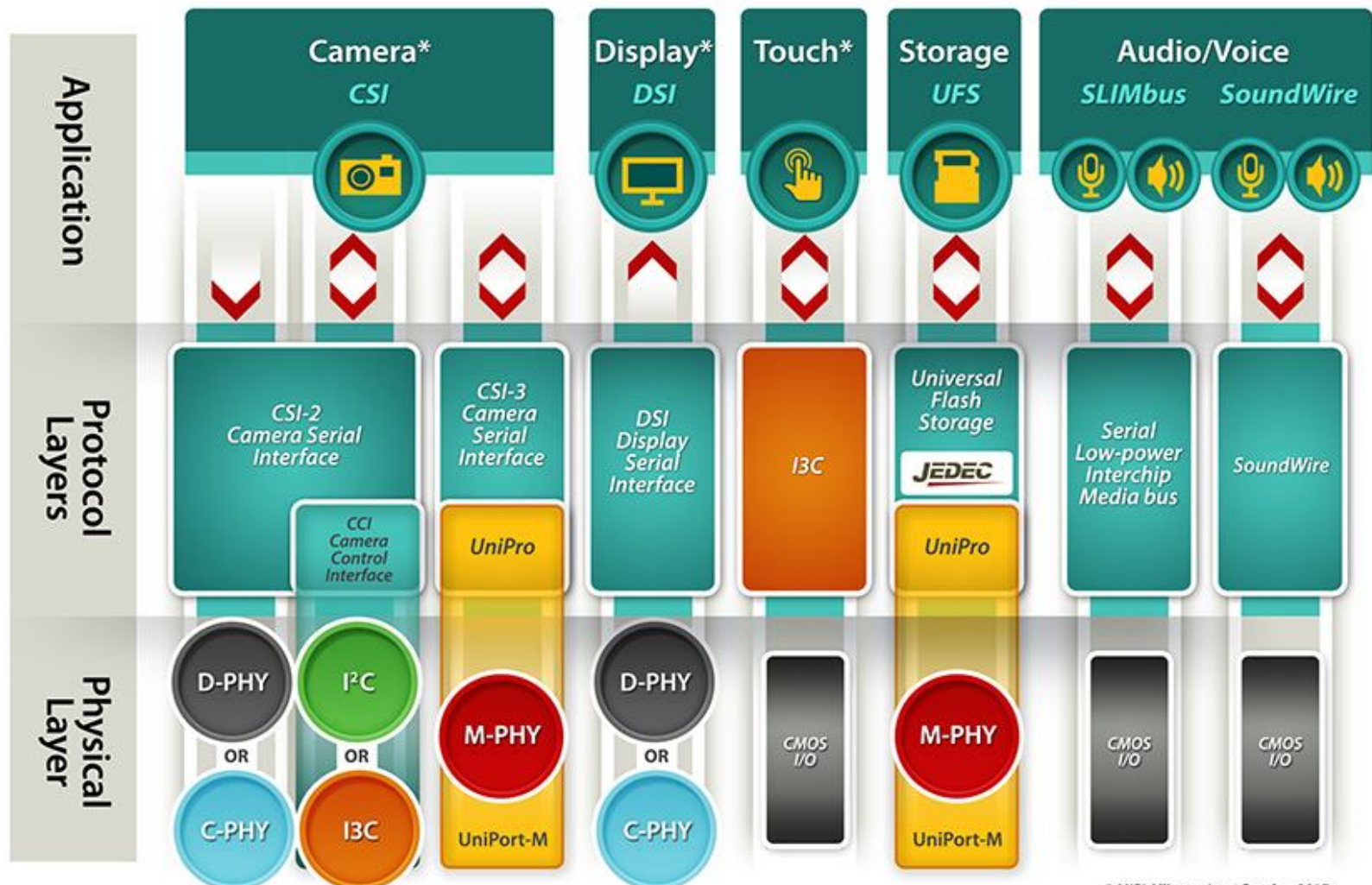




# MIPI Alliance Interface

Source: MIPI Alliance

## MIPI Multimedia Specifications



© MIPI Alliance, Inc. | October 2017

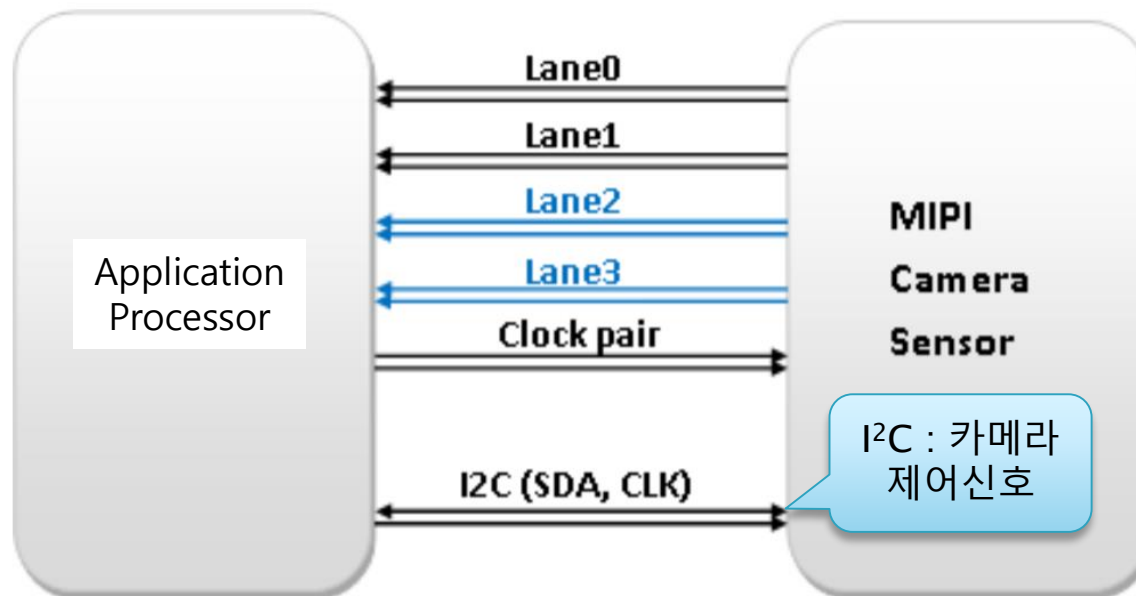
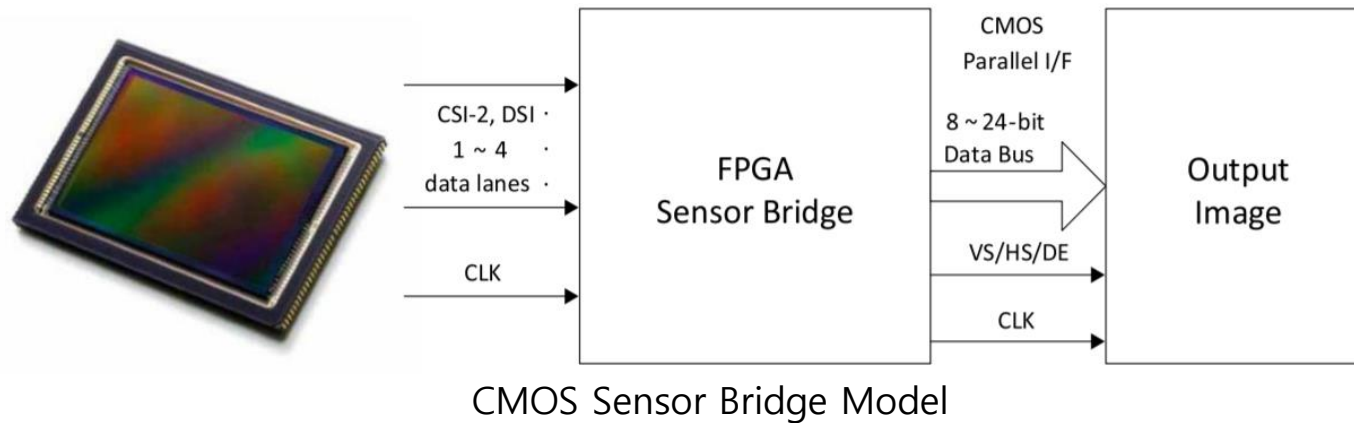
# CSI : Camera Serial interface

---

- ▶ MIPI camera interface
  - Today almost every mobile phone contains cameras.
  - These camera modules can be directly connected to a baseband or multimedia processor (AP).
  - **CSI (camera serial interface):** a main fast serial interface connection protocol.
  - Two interface protocols:
    - **CSI-2 uses the MIPI D-PHY (or C-PHY) specification** for the data transport. Version : CSI-2 v3.0 (2019년)
    - **CSI-3, MIPI's next-generation interface**, is a preferred option for designers who are working with new, **higher-performance camera technologies (2014년 v1.1)**



# CSI : Camera Serial interface



CSI-2 and D-PHY interface diagram

# CSI : Camera Serial interface

- ▶ Example of camera sensor block diagram

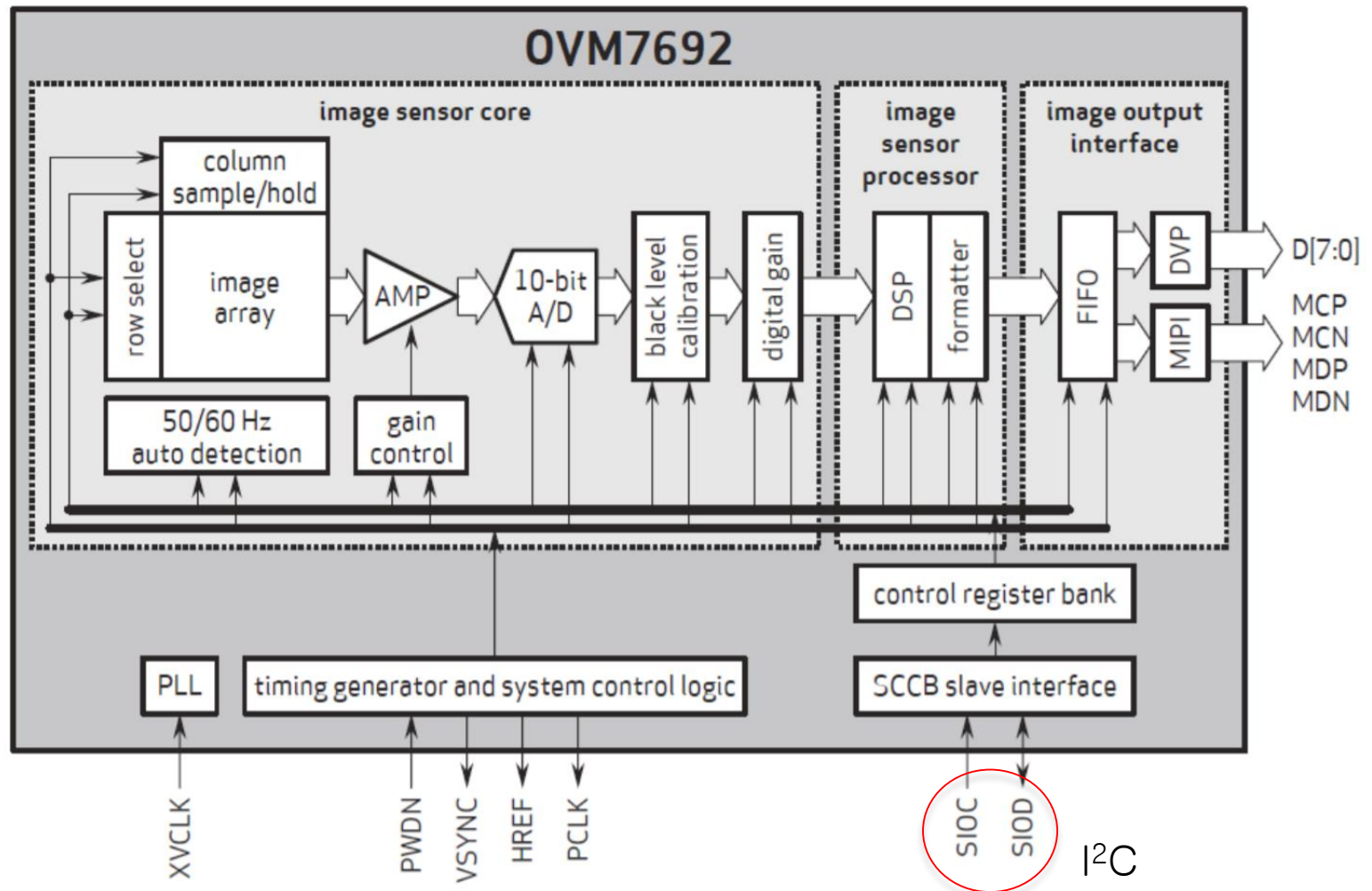
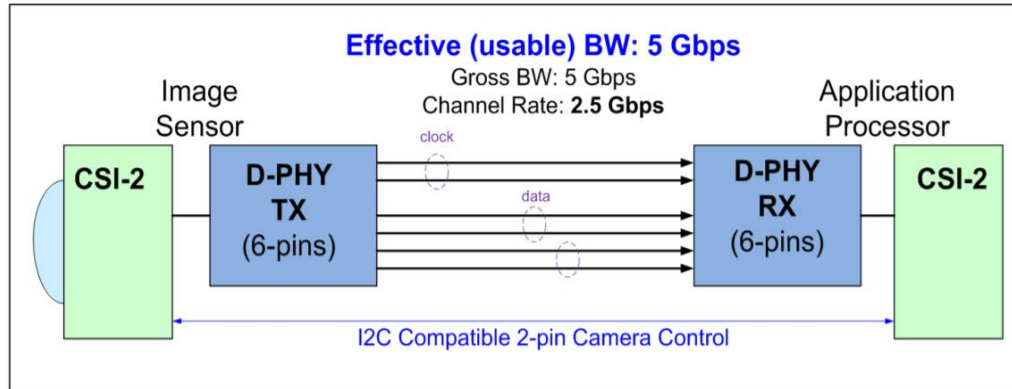


Image from OmniVision OVM7692 Product Brief

# CSI : Camera Serial interface

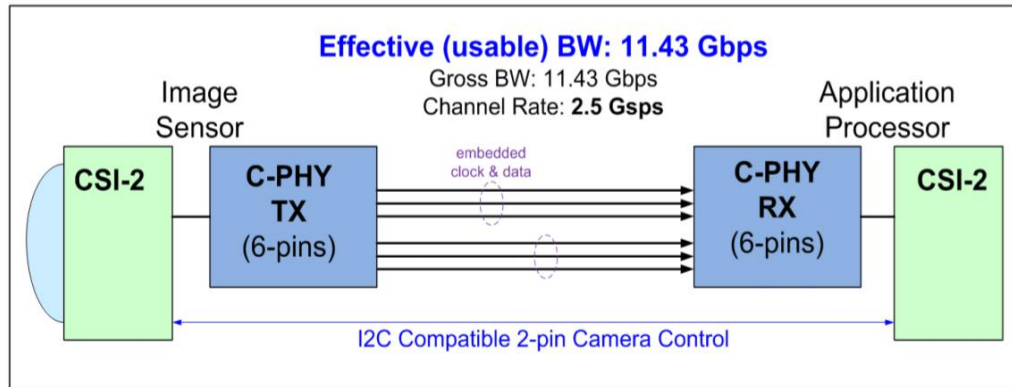
CSI-2  
D-PHY



- CSI-2 D-PHY 1.2 extension Pix BW scales linearly
  - 2.5 Gbps Channel delivers 10 Gbps over 4 data lanes and a clock lane (10 D-PHY pins).

Pin compatible coexistence supports  
CSI-2 over combo C/D-PHY solutions

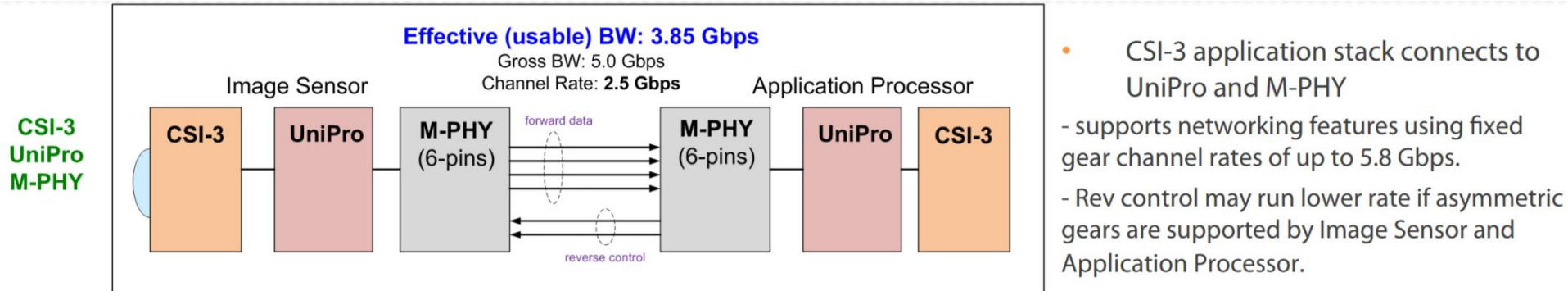
CSI-2  
C-PHY



- CSI-2 C-PHY 1.0 extension Pix BW benefit from  $\log_2 5$  mapping gain
  - 2.5 Gbps Channel delivers 17.1 Gbps over 3 lanes (9 C-PHY pins), or 22.7 Gbps over 4 lanes (12 C-PHY pins)



# CSI : Camera Serial interface



CSI-3 camera host interface

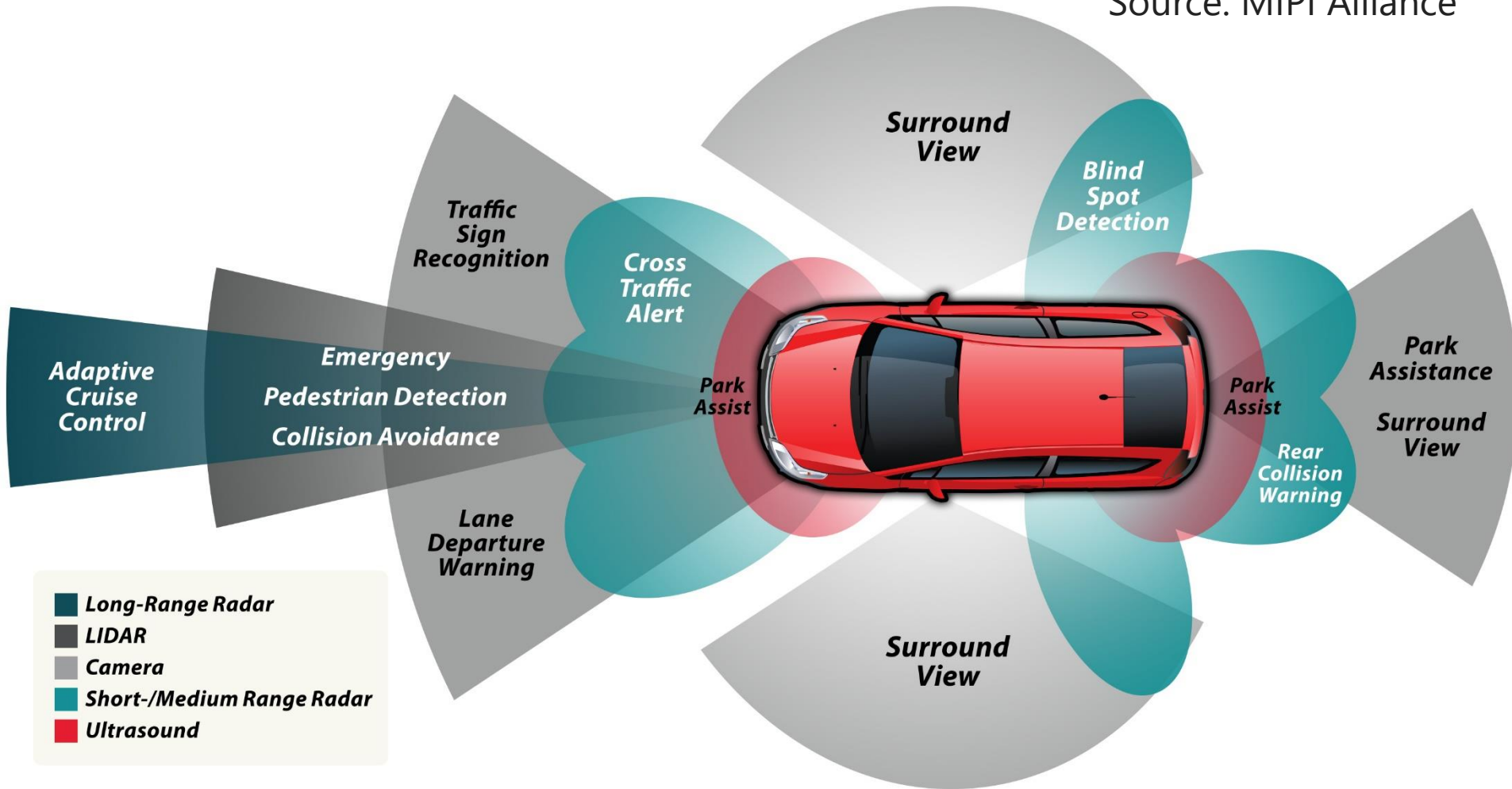
# CSI : Camera Serial interface

| Characteristic                       | M-PHY  | D-PHY  | C-PHY  |
|--------------------------------------|--|--|--|
| Primary use case                     | Performance driven, bidirectional packet/ network oriented interface                               | Efficient unidirectional, streaming interface, with low speed in-band, reverse channel | Efficient unidirectional, streaming interface, with low speed in-band, reverse channel |
| HS clocking method                   | Embedded Clock   | DDR Source-Sync Clock  | Embedded Clock   |
| Channel compensation                 | Equalization   | Data skew control, relative to clock   | Encoding to reduce data, toggle rate   |
| Minimum configuration and pins       | 1 lane per direction, dual-simplex, 2 pins each (4 total)  | 1 lane plus clock, simplex, 4 pins   | 1 lane (trio), simplex, 3 pins   |
| Maximum transmitter swing amplitude  | SA: 250mV (peak), LA: 500mV (peak)   | LP: 1300mV   | (peak), HS: 360mV (peak)   |
| Data rate per lane (HS)              | HS-G1: 1.25, 1.45 Gb/s, HS-G2: 2.5, 2.9 Gb/s, HS-G3: 5.0, 5.8 Gb/s; (Line rates are 8b10b encoded) | 80 Mbps to ~2.5 Gbps (aggregate)   | 80 Msym/s to 2.5 Gsym/s times 2.28 bits/sym, or max 5.7 Gbps (aggregate)               |
| Data rate per lane (LS)              | 10kbps – 600 Mbps  | < 10 Mbps  | < 10 Mbps  |
| Bandwidth per Port (3 or 4 lanes)    | ~ 4.0 – 18.6 Gb/s (aggregate BW)   | Max ~10 Gbps per 4-lane port (aggregate)   | Max ~ 17.1 Gbps per 3-lane port (aggregate)  |
| Typical pins per Port (3 or 4 lanes) | 10 (4 lanes TX, 1 lane RX)   | 10 (4 lanes, 1 lane clock)<br>9 (3 lanes)  |  |
| Version                              | v4.1 (March 2017)  | v2.1 (March 2017)  | v1.2 (March 2017)  |

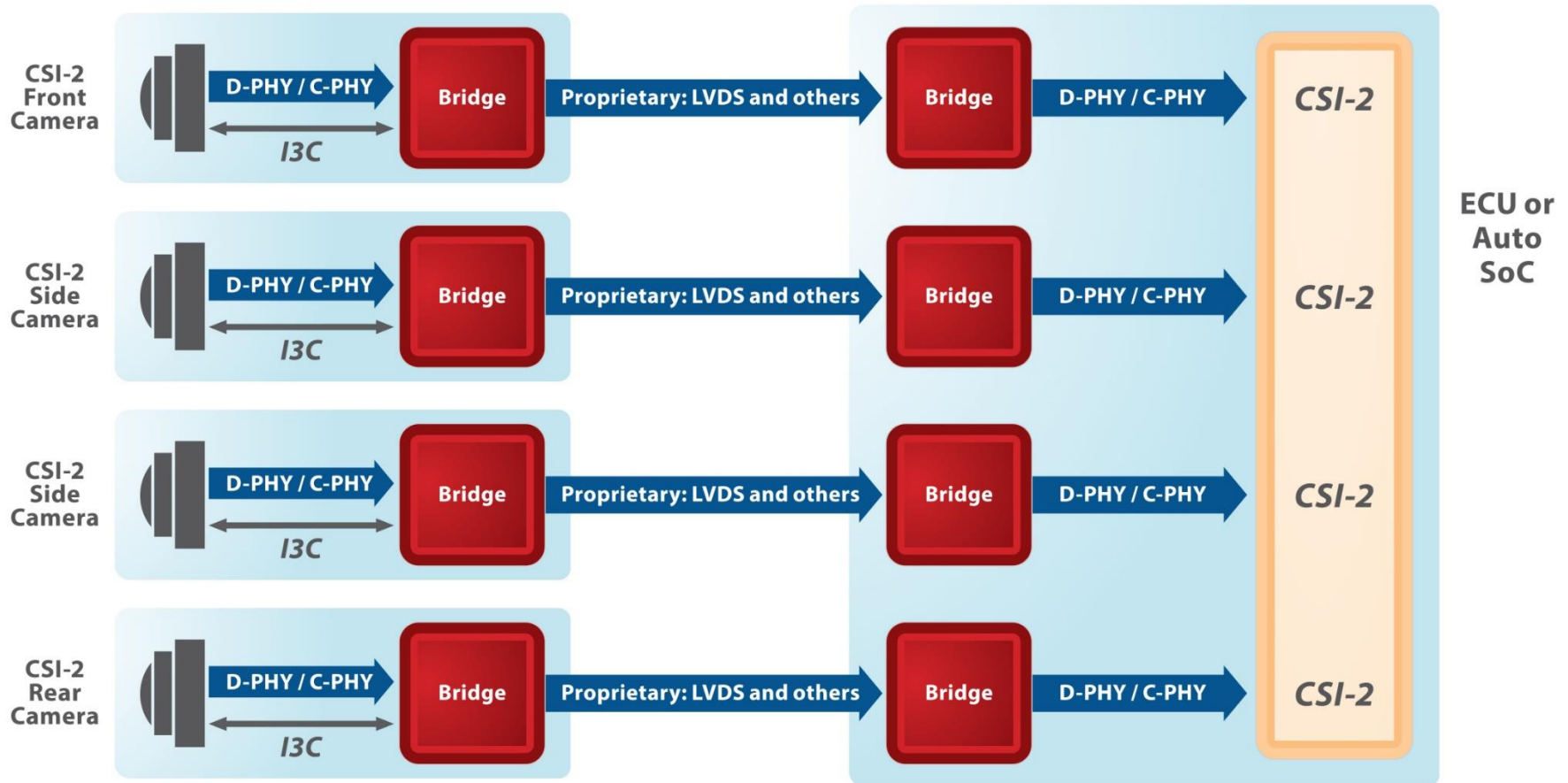


# Multimedia for Automotive

Source: MIPI Alliance



# Multimedia for Automotive



Multiple camera interface using bridged D-/C-PHY

# MIPI interface specifications for Automotive

| <i><b>MIPI Specification</b></i> | <i><b>Description</b></i>                     | <i><b>Automotive Use</b></i>  | <i><b>Features</b></i>   |
|----------------------------------|---|---|--|
| <b>CSI-2</b>                     | Camera Serial Interface protocol              | Protocol for cameras, lidar, radar sensors                            | <ul style="list-style-type: none"><li>• High pixel count</li><li>• High frame rate</li><li>• Functional safety</li><li>• Transportable over A-PHY</li></ul>                        |
| <b>DSI-2</b>                     | Display Serial Interface protocol             | Protocol for dashboard and rear displays and HUDs                     | <ul style="list-style-type: none"><li>• HD and beyond</li><li>• High frame rate</li><li>• Content protection</li><li>• Transportable over A-PHY</li></ul>                          |
| <b>C-PHY</b>                     | 3-phase physical layer for CSI-2 & DSI-2      | Short-reach physical layer for cameras and displays                   | <ul style="list-style-type: none"><li>• High performance (Gbps), low power</li><li>• Embedded clock</li><li>• Symbol rate encoding</li></ul>                                       |
| <b>D-PHY</b>                     | Differential physical layer for CSI-2 & DSI-2 | Short-reach physical layer for cameras and displays                   | <ul style="list-style-type: none"><li>• High performance (Gbps), low power</li><li>• Simple clock-forwarding</li><li>• Differential signaling</li></ul>                            |
| <b>I3C</b>                       | Control and data bus protocol and interface   | Sensor and general purpose data and control interface within a module | <ul style="list-style-type: none"><li>• High performance (10s Mbps) and low power relative to legacy interfaces</li><li>• Multi-point</li><li>• Transportable over A-PHY</li></ul> |

# MIPI interface specifications for Automotive

| <i><b>MIPI Specification</b></i> | <i><b>Description</b></i>   | <i><b>Automotive Use</b></i>                                      | <i><b>Features</b></i>   |
|----------------------------------|---|---|--|
| <i><b>RFFE</b></i>               | RF control protocol   | Front end control within a wireless module                        | <ul style="list-style-type: none"><li>• High performance (10s Mbps), low power</li><li>• Multi-point</li><li>• Low latency</li></ul> |
| <i><b>SoundWire</b></i>          | Digital audio and control interface                                     | Audio interface within a module                                   | <ul style="list-style-type: none"><li>• Simple, low cost</li><li>• Multi-point</li><li>• Flexible topologies</li></ul>               |
| <i><b>UniPro</b></i>             | Data transport protocol for UFS over M-PHY                              | Transport protocol for UFS storage                                | <ul style="list-style-type: none"><li>• High reliability and QOS via bit-rate monitoring</li></ul>                                   |
| <i><b>M-PHY</b></i>              | Differential physical layer for UFS storage                             | Short-reach physical transport for UFS storage                    | <ul style="list-style-type: none"><li>• High performance and low power</li><li>• Full duplex (dual simplex)</li></ul>                |
| <i><b>A-PHY</b></i>              | Long reach physical layer for MIPI protocols, including CSI-2 and DSI-2 | Long reach interface to cameras, lidar, radar, sensors & displays | <ul style="list-style-type: none"><li>• High performance</li><li>• High noise immunity</li><li>• Functional safety</li></ul>         |