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System and Latency Requirements

Contribution to 802.3dm Task Force

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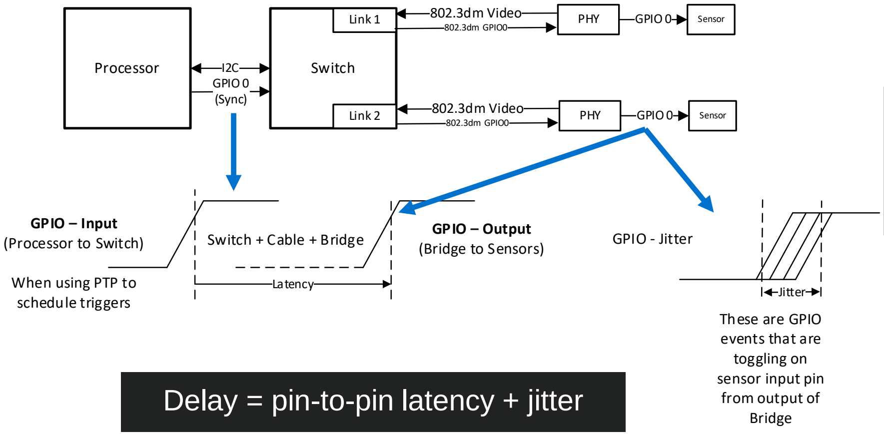
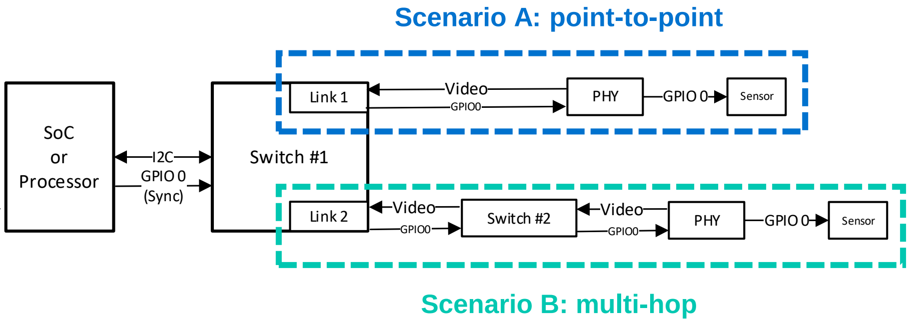
Topics

- Delay, latency and jitter
- Differences in point-to-point and multi-hop 802.3dm links
- Can PTP (IEEE 1588) handle all scenarios
- GPIO forwarding requirements
- I2C latency importance
- Link start-up delay
- Task force proposals: latency limits

Delay in point-to-point and multi-hop scenarios

- Delay = latency measured from pin to pin + jitter
  - Customers care about the worst-case time of arrival at the pin of the sensor
- Scenario A: refers to a point-to-point use case (link 1)
- Scenario B: refers to multi-hop(s) or a “daisy-chain” or reaggregation application (link 2)





Delay = pin-to-pin latency + jitter

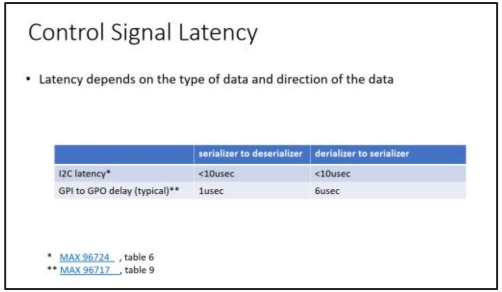
This presentation will focus on point-to-point delay (scenario A)

Referenced: https://www.ieee802.org/3/dm/public/0724/houck_fuller_3dm_01_0724.pdf

Reminder: latency requirements

- Latency and jitter are important for current production systems
  - These systems use low latency to avoid long sensor initializations
  - Systems can require unique frame synchronization with other ADAS sensors
- For automotive sensor applications, Ethernet latency should not exceed **10us**
  - Hard limit related for system designs (from SoC to camera)
    - This includes trigger (GPIO) events or a single I2C command without ACK/NACK response
    - This measurement is from Pin of Bridge to Pin of Switch as shown in the previous diagram

GMSL Latency



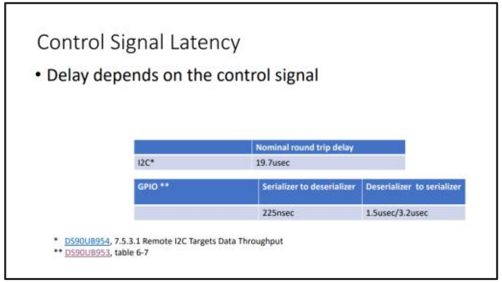
Control Signal Latency

- Latency depends on the type of data and direction of the data

	serializer to deserializer	derializer to serializer
I2C latency*	<10usec	<10usec
GPI to GPO delay (typical)**	1usec	6usec

* MAX 96724 , table 6
** MAX 96717 , table 9

FPD-Link Latency



Control Signal Latency

- Delay depends on the control signal

	Nominal round trip delay
I2C*	19.7usec

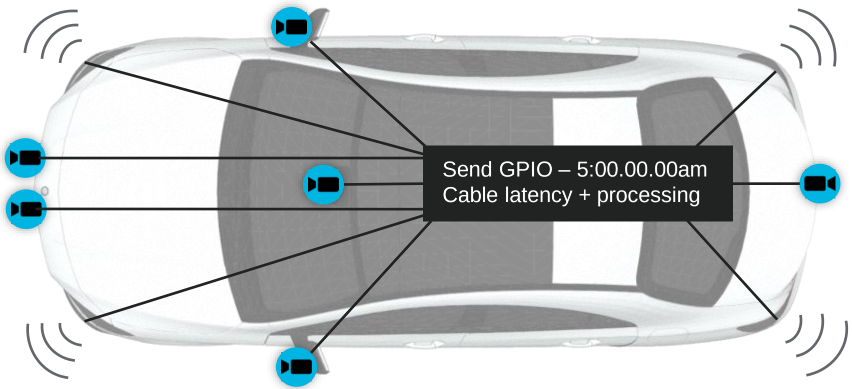
GPIO **	Serializer to deserializer	Deserializer to serializer
	225nsec	1.5usec/3.2usec

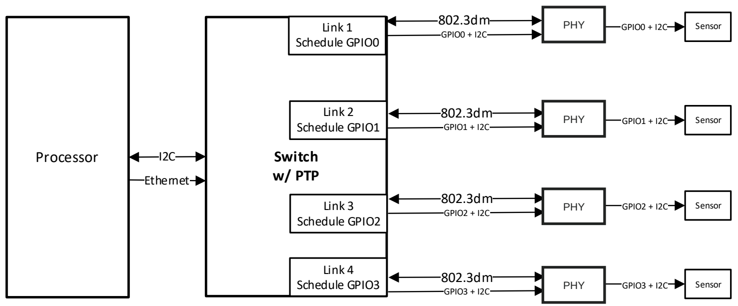
* DS90UB954, 7.5.3.1 Remote I2C Targets Data Throughput
** DS90UB953, table 6-7

Referenced: https://www.ieee802.org/3/dm/public/adhoc/090524/razavi_dm_09042024.pdf
Referenced: https://www.ieee802.org/3/dm/public/adhoc/082224/razavi_dm_08222024_v2.pdf

Can PTP handle every scenario?

- Why not use PTP to synchronize all the sensors?
  - PTP can be effective for general synchronization
  - Software overhead and proper alignment is difficult for all scenarios

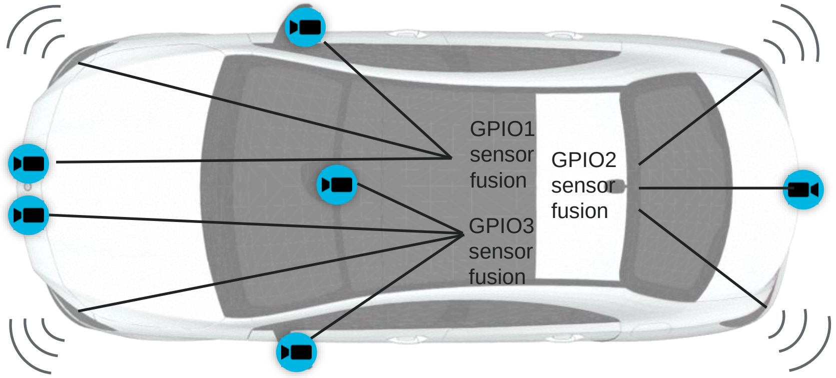


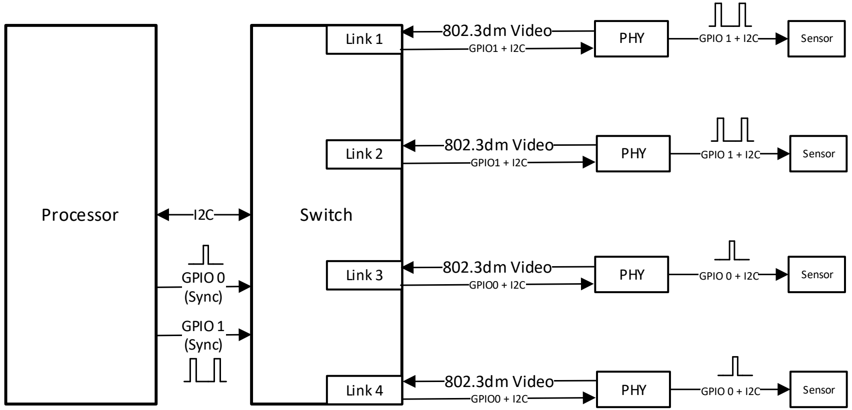


When scenarios are changing, controlling latency is paramount.
GPIO can provide precision delay control.

GPIO addresses system delay requirements

- GPIO forwarding provides the ability to rapidly respond to changing scenarios
  - GPIO allows for easy implementation with no software overhead
- Example application: camera and sensor fusion applications
  - LIDAR and radar have varying FPS and need to avoid interference

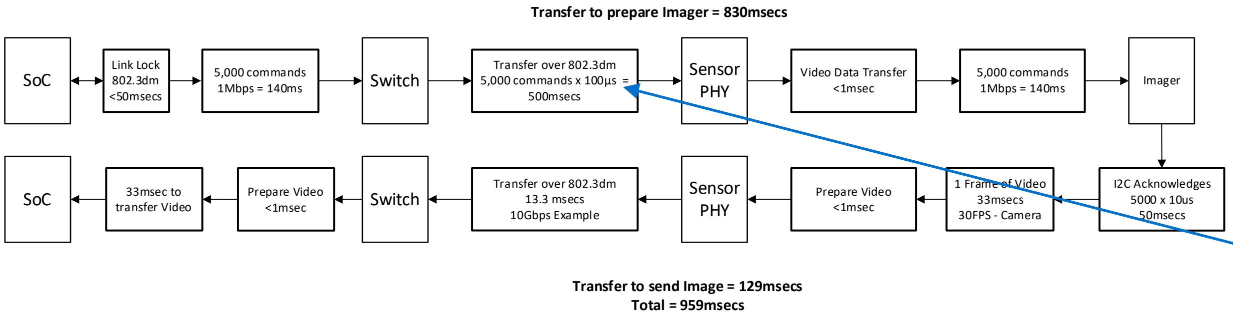


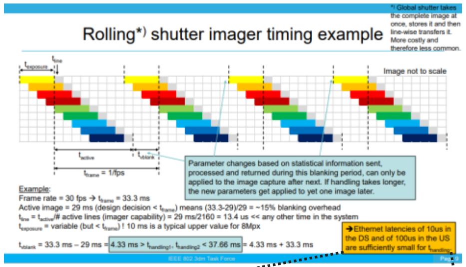


GPIO: for all sensors to sync properly, a delay <12-15us is required to properly align radar, LIDAR and camera data

Link initialization imposes strict requirements

- Additional latency will accumulate quickly for I2C commands
- Customers expect 1st frame in <300ms for rear-facing cameras due to FMVSS No.111
  - The regulations mandate that rearview camera systems must be operational within 2 seconds of the vehicle being placed in reverse
  - As more sensors are added customer expects quicker initialization
- Example total link budget impact is ~1 second





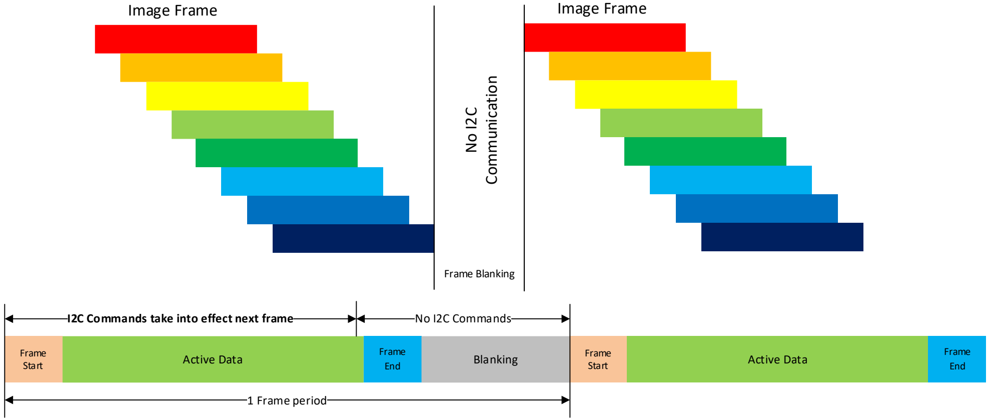
→Ethernet latencies of 10us in the DS and of 100us in the US are sufficiently small for $t_{handling}$.

Increasing link budget time impacts overall processing cycle timing budget. This example leaves only 1.04 seconds

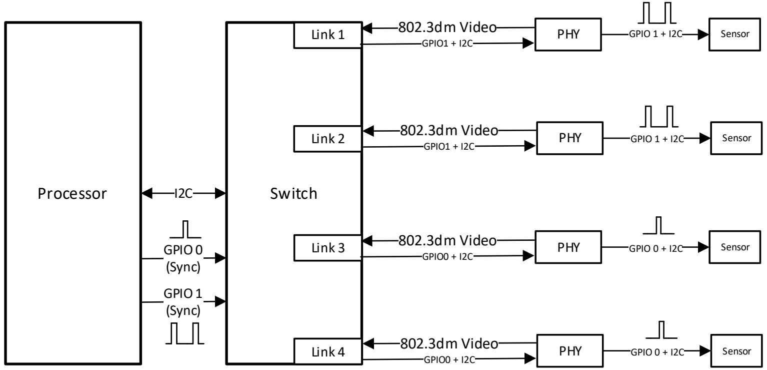
Referenced: https://www.ieee802.org/3/dm/public/0724/houck_fuller_3dm_01_0724.pdf
Image from: https://www.ieee802.org/3/dm/public/0724/matheus_dm_02b_latency_07152024.pdf

I2C real-time operating requirements

- Imagers have a fixed window to communicate
  - Making use of the given allocation time is critical to get the next image frame updated before the “window” of communication closes



- Sensors can take <10 to 30 I2C commands to update frame information
- 100us = 3msecs | 10us = 300usecs
- Next-generation sensors: Interior 90-120FPS | Exterior – 60FPS
- This means sensors will only have 11-15msecs/frame
- SoCs will want to process as much as the frame as possible before issuing commands



- When 4 sensors use the same I2C bus additional latency will be experienced
- When all 4 sensors are needing the bus at the same time the communication is now 1/4th of the allotted time of a single sensor

802.3dm links will now be

3msecs x 4 = 12msecs

300usecs x 4 = 1.2msecs

This would take 1 frame to complete all the transactions for the last sensor, NOT INCLUDING PTP SCHEDULING COMMANDS

Summary

1 It is essential to limit both **delay** and **start-up time** for automotive Ethernet links to meet customer and application requirements

2 It is proposed to **limit delay to <12µs** from Processor (SoC) to Sensor for I2C commands and GPIO trigger events

3 It is proposed to **restrict link lock time to <50ms** on initial / cold power up

4 Minimize Change on Existing SERDES (GMSL/FPD-Link)

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