Requirements from Various Applications

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Introduction

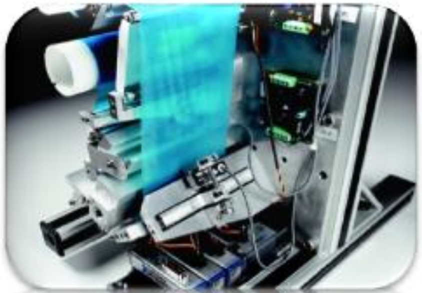
- Searched known time-sensitive applications
  - Find numbers to help guide AVB Gen 2 requirements
  - Future use of AVB is not assumed… just the numbers
- Applications discussed
  - Hardware-in-the-Loop (HIL) testing
  - SAE-2813 draft standard on FlexRay
  - Large telescope
  - Big Physics application

Hardware-in-the-Loop (HIL) testing

What is HIL?

- Testing methodology for large embedded systems

Medical Devices



Industrial Machines

Power Generation Systems

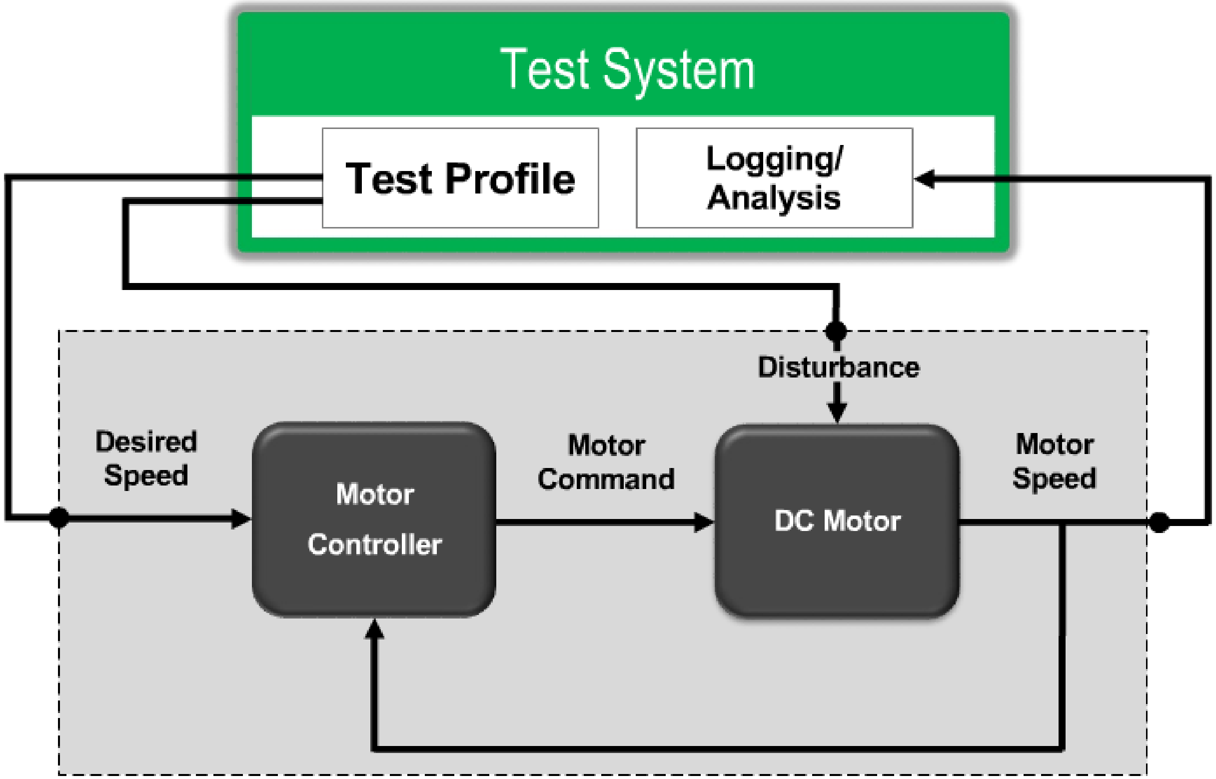
White Goods

Aerospace

Automotive

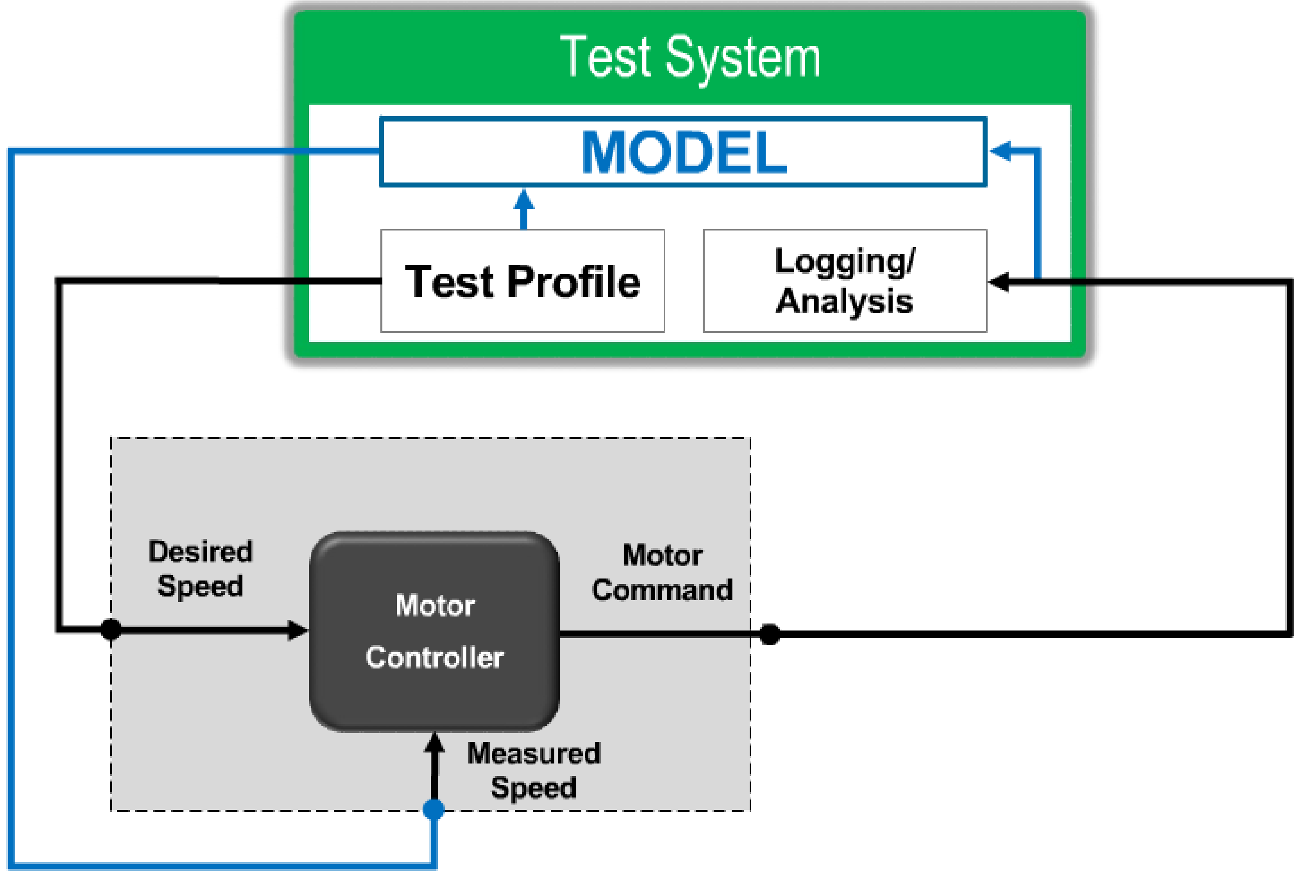
Simple Example: Motor Controller Test

- Test new controller within actual system (e.g. vehicle)?
  - Not always viable: availability, cost, safety, …



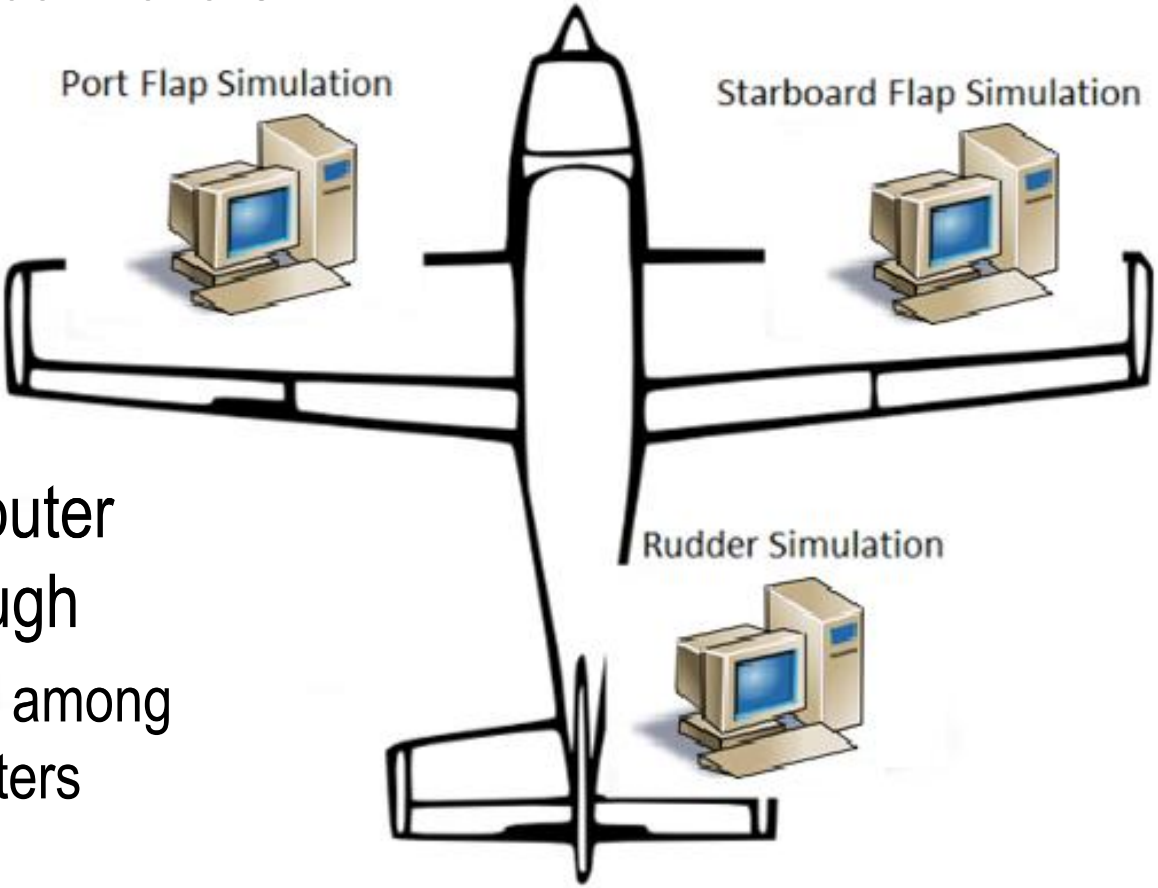
HIL Testing: Simulate Rest of System

- Model runs at same loop rate as controller (e.g. 1ms)



HIL Model has a lot to Simulate

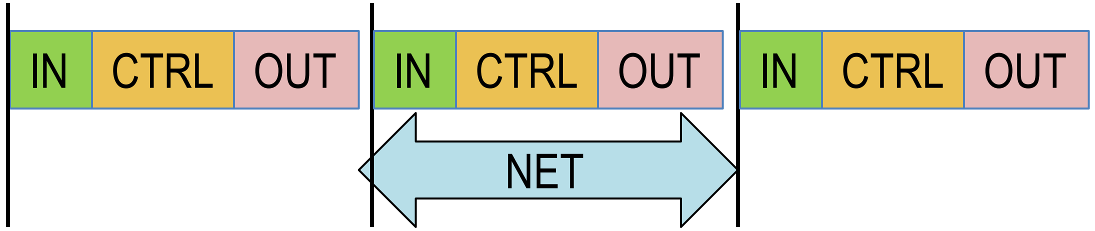
- Up to 100 other controllers
- Driver / pilot
- Environment



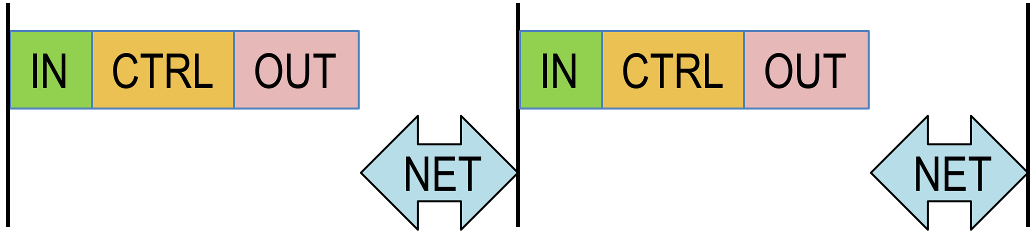
- Single test computer may not be enough
  - Split HIL model among multiple computers

Two Techniques that Drive Latency

- One (Loop/Sample/Tick) Delay
  - Model designed for distributed loops
  - Latency: fixed (one loop time)



- Zero Delay
  - Model is not designed to be split
  - Latency: minimal (lower is better)



Mapping to AVB Gen 2

- One Delay (from HIL test of airplane)
  - 18 end-stations, each is both talker and listener
  - GE; two bridges (not daisy chained)
  - 26666 bytes every 10.0ms (per talker), bandwidth 384Mbps
  - Latency: 10.0ms
  - Bottom line: AVB Gen 1 can meet this HIL use case
- Zero Delay
  - Latency: lower is better
    - Example: for 1ms loop, 50µs is 5% of my time spent waiting
  - Bottom line: No firm HIL requirement as yet
    - Future research / inquiry
  - Zero Delay comes up again in next 3 applications

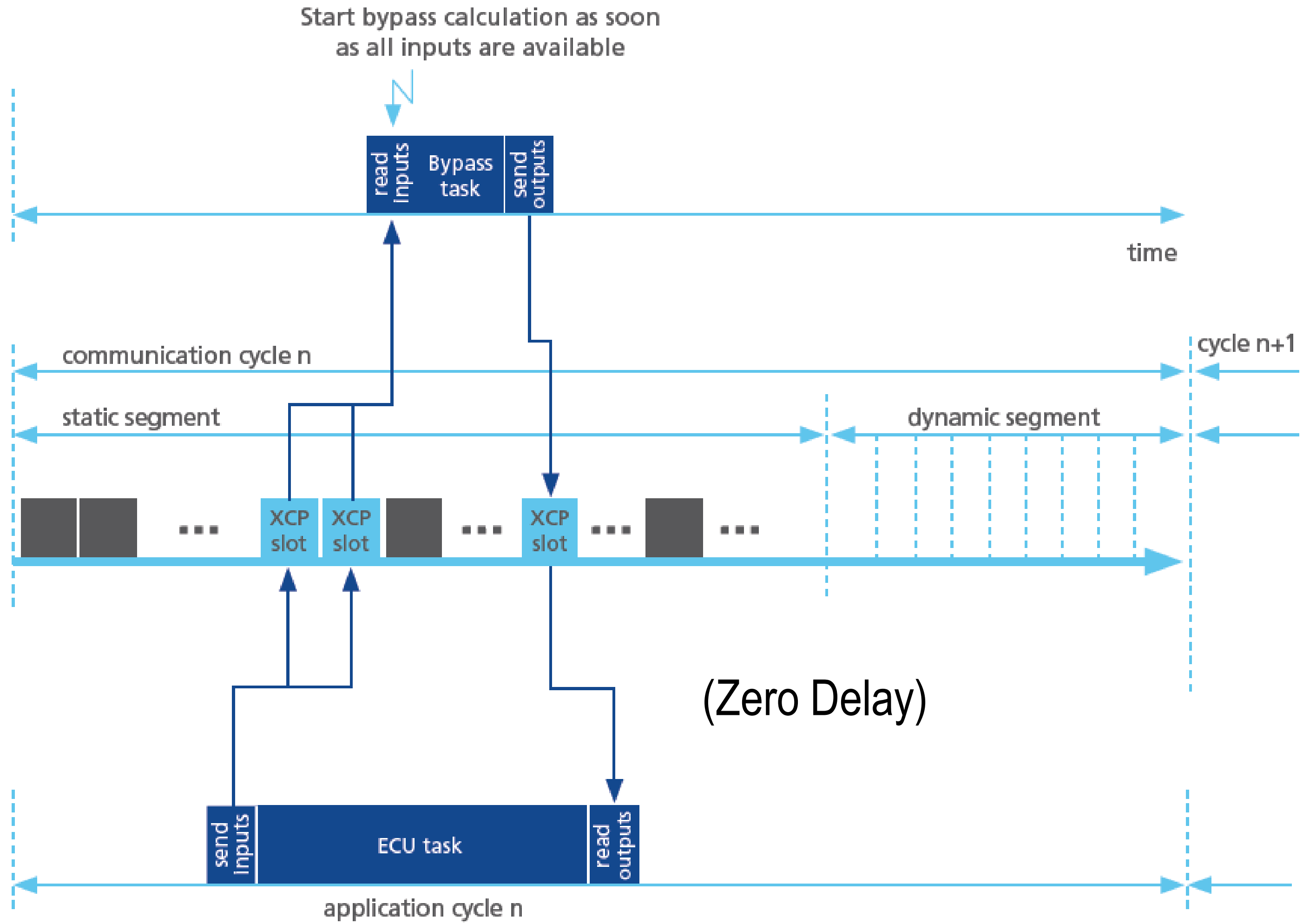
SAE-2813 draft standard on FlexRay

SAE-2813

- SAE International
  - Historically U.S. automotive (Society of Automotive Engineers)
  - Now global vehicle standards (including aerospace, truck, ag)
- FlexRay
  - Recent automotive network (10Mbps, TDMA)
- SAE-2813: FlexRay for Vehicle Applications
  - Requirements and configurations for specific use cases
  - Ford, GM, Chrysler, and their suppliers
  - Started March 2008; no ballots as yet

Synchronous Application

"By properly designing the scheduler, synchronous applications experience small delay and jitter from the time a signal is produced at the source node until it consumed at the destination node even when it is sent across the network."



(Zero Delay)

SAE-2813 Use Cases

1. High Speed Control
   - Synchronous applications
2. High Speed Backbone
   - See new-avb-KimNakamura-automotive-network-requirements-0311.pdf for an example using Ethernet
3. High Bandwidth Software Download
   - Ability to quickly update flash in a controller
4. Safety Critical Fault Tolerance with Redundancy
   - Dual cabling with immediate failover

SAE-2813 Requirements

- "Guaranteed Communication System Latency ≤ 0.5ms"
  - Send (at known time) to Read
  - Both Control and Backbone use case
- "Guaranteed Communication System Jitter ≤ 0.2ms"
  - Time variance as seen by Read
  - Both Control and Backbone use case
- Software Download: "≥80% bandwidth"
  - Since FlexRay is 10 Mbps, this is 8 Mbps
- FlexRay supports up to 22 nodes (linear passive bus)
  - 8 can be assumed for Control & Backbone

Mapping to AVB Gen 2

- Software download: Gen 1 is fine (25% of 100M > 8M)
- Redundancy: similar to industrial Gen 2 proposal
- Assume both Control and Backbone use cases
- Time sync: Gen 1 is fine (FlexRay is ~1µs)
- Assume 8 end-stations daisy-chained with FE
- Each end-station is talker, other 7 listen
  - 280 bytes every 2.5 ms (per talker)
- Gen 2 with time-based shaper: 500µs latency
  - Higher layer protocol handles 200µs jitter requirement

Large telescope

Application

- Primary mirror
  - > 40m diameter
- Composed of 984 hexagonal segment mirrors
- Adaptive optics
  - Correct for distortion caused by atmospheric turbulence

Requirements

- Control runs at 1ms
- Segment mirror contains sensors & actuators
  - Each connects to controller(s) via network
- Segment mirrors organized as 6 groups of 164
  - 300µs latency requirement per loop (Zero Delay)
  - Group transfers 5600 bytes

Mapping to AVB Gen 2

- Assumptions
  - Each of the 6 groups is LAN of GE AVB Gen 2
  - Each LAN uses 6-port bridge
    - 1 port to controller
    - 5 ports to daisy-chain of 33 segment mirrors (164 / 5 rounded up)
  - 34 talkers per LAN, each 5600/34=165 bytes every 1ms
  - Sensor → Control in same 300µs as Control → Actuator
- Gen 2: 300µs latency over 34 hops @GE
  - Mixed topology
  - Time sync: 1µs

Big Physics application

Application

- Sensors, Actuators, Controllers in distinct end-stations
  - 100 total
- Control loop runs at 2kHz (0.5ms period)
  - Zero Delay: Sensor → Control → Actuator
- Multicast communication required
- Use of Ethernet desired
  - Max 1000m distance
  - 10GE optical OK
- Control network can use dedicated LAN
  - No interfering traffic

Requirements

- Total bandwidth: 25 Mbytes/s
  - Most end-stations are talker
  - Small packets, always 0.5ms
- Latency: 50µs
  - 2 communications takes ≤ 20% of loop
- Topology assumes multi-port switches
  - Max 8 hops (i.e. sensor to actuator)
  - Only 3 hops apply to latency requirement
    - Sensor to controller

Mapping to AVB Gen 2

- Assumption: Want to mix
  - Sensor/Actuator/Controller traffic
  - Time sync (802.1AS)
  - Other best-effort traffic (interfering)
- Gen 2: 50µs latency over 3 hops @10GE
  - Multi-port topology

Summary

Summary

- HIL can use Gen 1
- Gen 2 Automotive latency requirement from March
  - 100μs latency over 3 hops @FE
    - Meets SAE-2813 requirements (500μs over 8 hops @FE)
    - Requires both preemption and time-based shaper
- Gen 2 Industrial latency requirements
  - 100μs latency over 7 hops @GE, any topology
    - Meets Big Physics application (50μs over 3 hops @10GE)
  - Proposed: 250μs latency over 32 hops @GE, daisy-chain
    - Meets Large Telescope application (300μs over 34 hops @GE)