

Off-Chip Interconnect

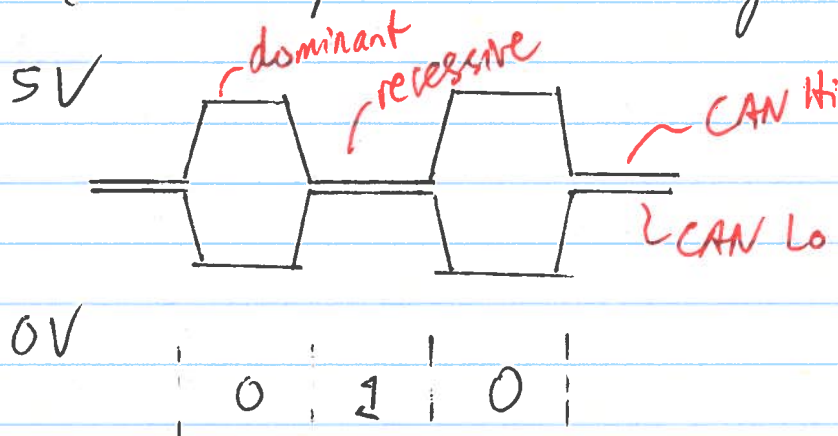
①

Distributed Embedded Applications
e.g. aerospace, automobiles, defence

- comprised of distributed nodes (ECU - Electronic Control Units)
- need off-chip network
- puts computing power near the event
 - shorter delays for sensing/actuation
 - communicate processed data, not raw data
- mixed criticality
e.g. aircraft
 - control network: safety critical, dedicated h/w protocols
 - management network: mission critical (e.g. navigation), ethernet protocol - isolated from low-criticality traffic
 - passage network: internet connected, open protocol

CAN bus - Controller Area Network

- Bosch, 1985, 1 Mbps
- mandated for on-board auto. diagnostics in North America and Europe
- serial - twisted-pair differential signalling (broadcast)



(2)

- there are no addresses, only message identifiers
- a msgID has exactly 1 sender, and 1+ receivers
- the msgID defines the message priority via wired-and
- arbitration:
 - wait for idle bus
 - start sending its msgID and will drop out if it senses a dominant(0) while transmitting a recessive(1)

msgID A = 11001000111 idle SOF 0 1 0 0 1 0 0 0 1 1 1 ...

msgID B = 11011100011 idle SOF 1 1 0 1 drops out

received by A+B idle SOF 1 1 0 0 1 0 0 0 1 1 1 ...

- lower message IDs have higher priority
- in practice, msbits can be used for priority and lsbits to identify a recipient

- 4 frame types

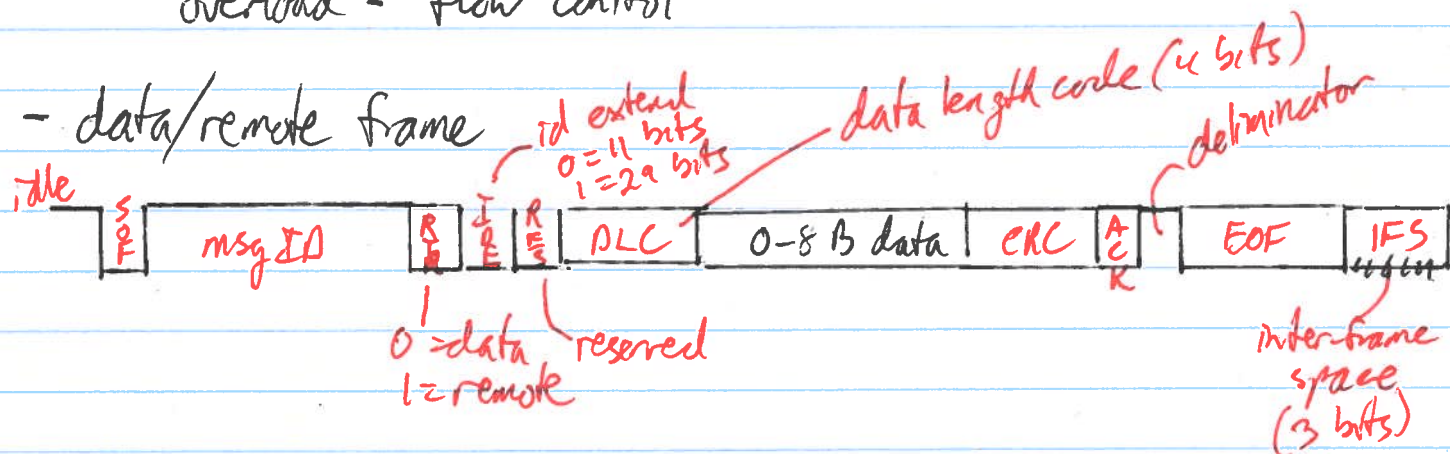
data - ECU output data

remote - request for ECU data

error

overload - flow control

- data/remote frame



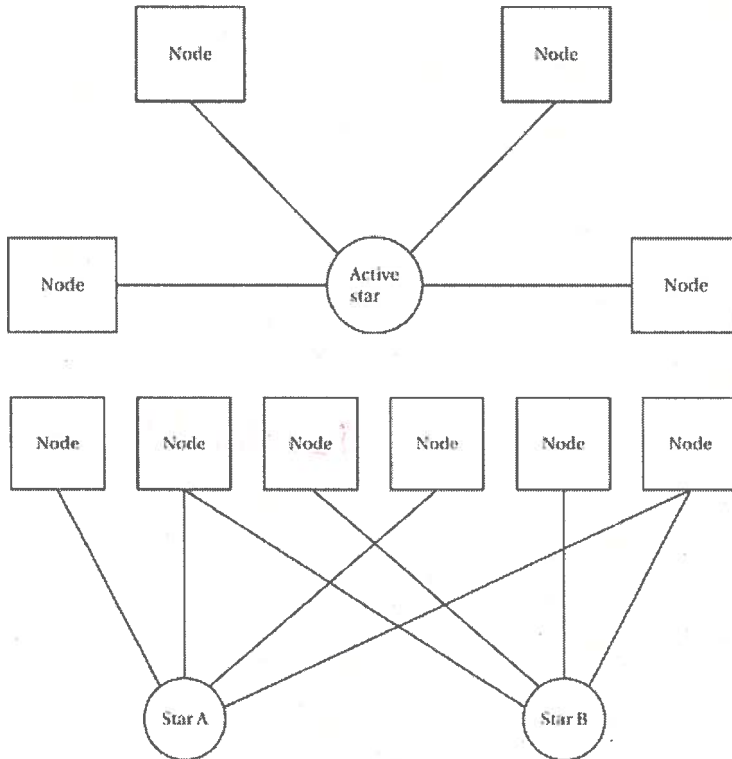
- nodes sync their clocks to SOF (start of frame)
- uses bit stuffing to maintain synchronization during frame transmission: after 5 bits of like polarity, a bit of opposing polarity is inserted
- CAN FD has up to 64 B data frames

FlexRay

- faster than CAN (up to 10 Mbps)
- single or dual twisted pair
 - ↳ redundancy or added bandwidth
- Handouts > offchip connect: topologies, cycle
- each node has its own clock
- smallest network time is the ~~micro~~ macro tick (often 1 μ s)
- static segment (time-triggered)
 - divided into time-triggered frames/slots
 - ECUs are assigned slots that only they can use
 - good for deterministic delivery of periodic data
 - "guardian" hardware in nodes and switches ensures that a node doesn't transmit outside its slot

FlexRay Topologies

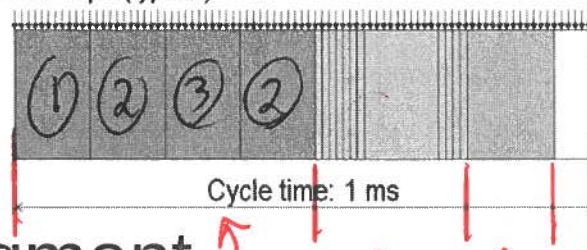
(4)



- bus or star
- switch can *"guardian"* block invalid transmissions
- multiple stars for redundancy

FlexRay Cycle

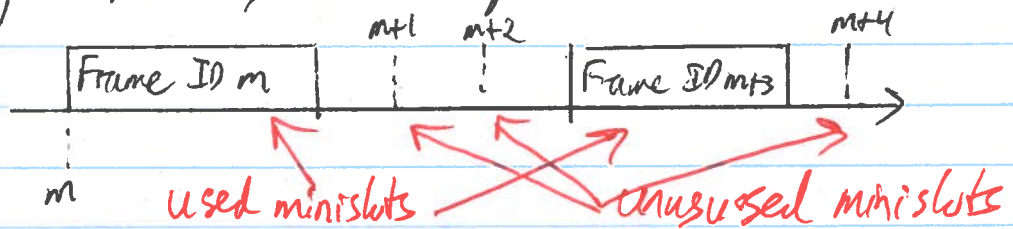
Macro-tick: 1 μ s (typical)



- Static segment
- Dynamic segment
- Symbol window
- Network Idle Time

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- dynamic slot
 - divided into minislots (typically a macrotick)
 - segment has fixed length
 - each data frame is assigned a minislot
 - higher priority frames get earlier minislots

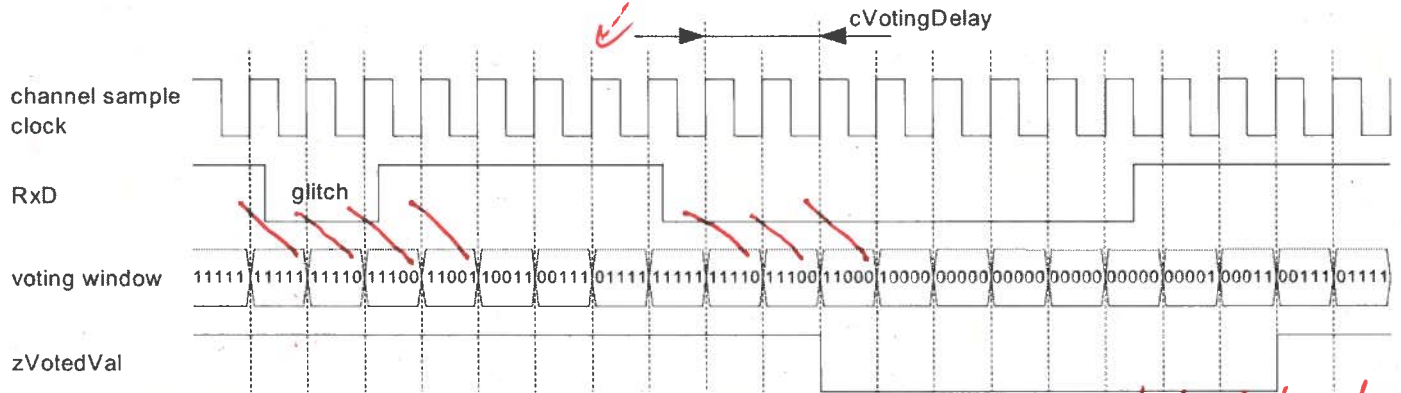


- lower priority frames might have to wait for the next cycle
- good for sporadic data

Handouts > offchip Connect: bitstream sampling & strobing

FlexRay Bitstream Sampling

sender holds a bit for 8 cycles

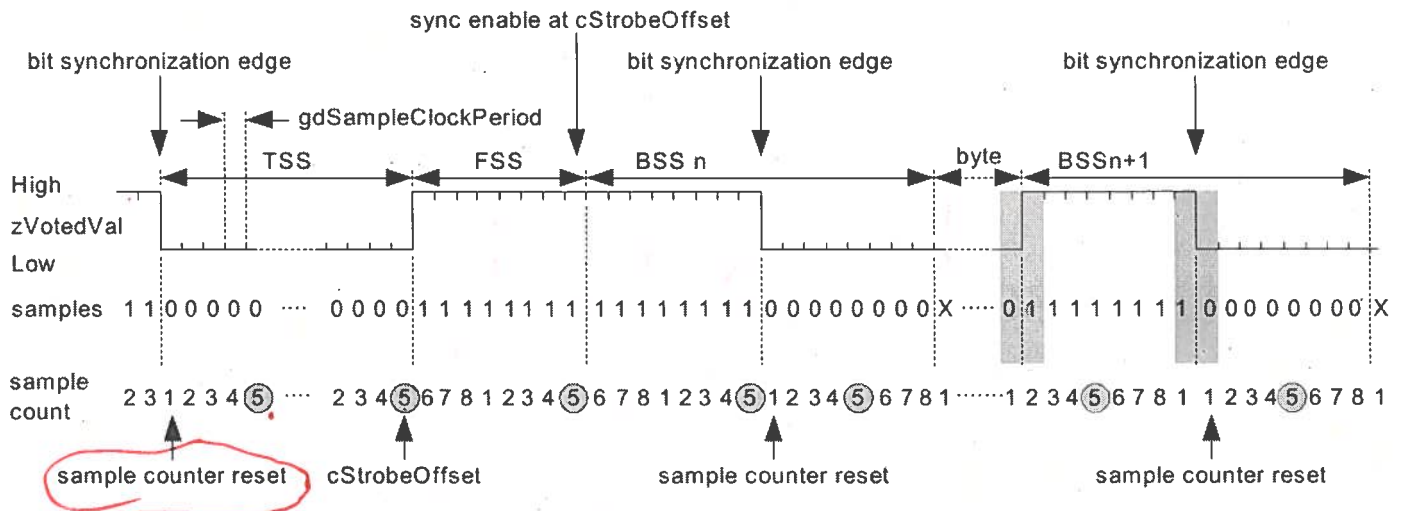


- node stores 5 most recent samples (voting window) and performs majority vote (zVotedVal)

stroke bit value

FlexRay Communications System Protocol Specification Version 2.0

FlexRay Bit Strobing



- each bit is held for 8 cycles
- sample counter resets on 1->0 transition
- the bit value is strobed when the sample counter reaches 5

FlexRay Communications System Protocol Specification Version 2.0

Time-Triggered Ethernet

- similar idea to FlexRay but implemented on Ethernet (100 Mbps - 1 Gbps)
- used by NASA, ESA; proposed for automotive

Traffic Classes

(1) time-triggered (TT)

- each node has a transmit schedule
- TTE switches have receive and forward schedules
- constant latency and small, bounded jitter
- good for hard real-time periodic data

(2) rate-constrained (RC)

- each node has reserved bandwidth
- bounded latency and jitter

(3) best-effort (BE)

- no timing guarantees
- compatible with 802.3 traffic

TTE Frames

- ~~compatible~~
- operates at OSI layer 2 (datalink)
- higher level protocols such as IP and UDP/TCP can be sent over TTE