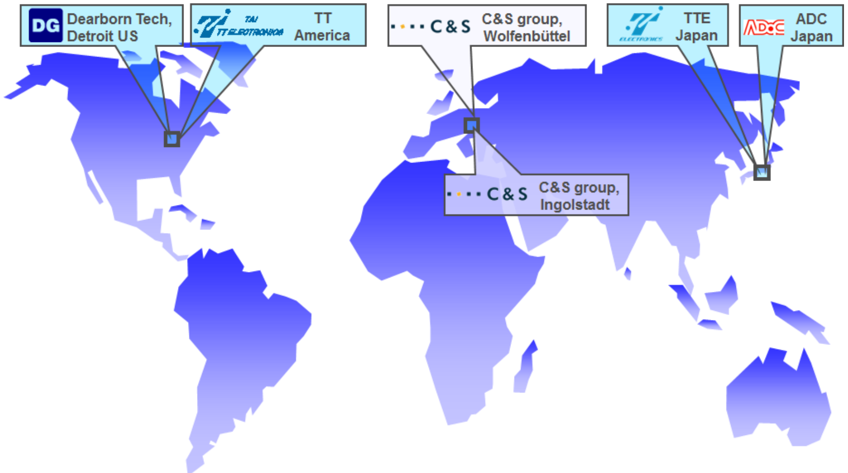
Validation of CAN-FD IVN topologies

CiA CAN-FD Tech Day – Munich (DE), 19.03.2015

Contents

Testing Competence for more than 20 Years

worldwide partnerships



longtime experience

C&S group GmbH

- Started in 1995 as part of University of Applied Sciences
- In November 2008 spin off into a private company
- High quality standard ISO/IEC 17025 accredited test laboratory
- Advanced high quality test & measurement equipment
- Worldwide accepted as test experts for networked systems
- Worldwide partnerships
- Customers: Leading automotive silicon vendors; Tier-1s and OEMs worldwide

DAkkS Deutsche Akkreditierungsstelle D-PL-18596-01-01

sustainable growth

1995
CAN DL (ISO 16845)
CAN PI
CAN Robustness

1999
Chairman ICT/GIFT
CAN PL Low-speed CT
CAN PL High-speed CT

2002
WG Active Member
LIN DL/PL CT
1.3, 2.0, 2.1, 2.2

2003
SAE J-2602-2
Authorized
CT Testhouse

2004
WG Active Development Member
FlexRay PL CT for BD/AS
2.1A/B and 3.0.1

2004
WG Active Development Member
Pilot CTA
Autosar CT (modules, stacks, clusters)

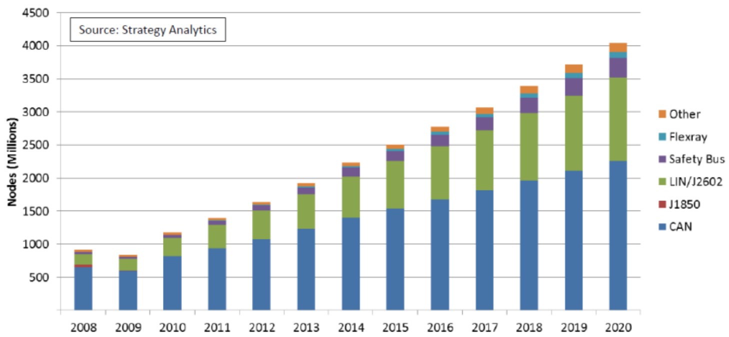
2010
Chairman SWITCH group
CT Specification ISO16845-2
OEM HW Requirements Spec

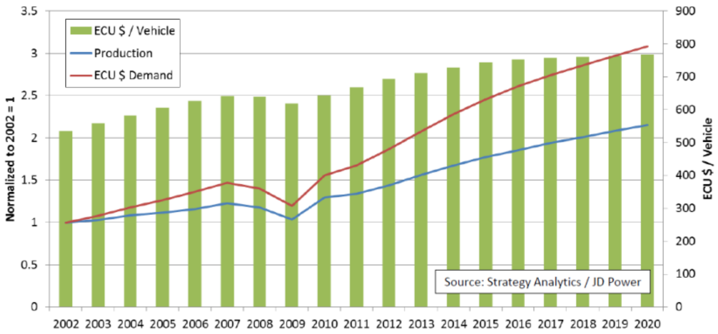
2010
Autosar Integration Tests
Autosar Acceptance Tests

2012
Adopter Member
TC1 Contribution
Compliance & Interoperability Tests

2012
CAN FD Interest & Marketing Groups
Use Case Analysis
CT Testplan development

Worldwide trend of increasing electronics complexity



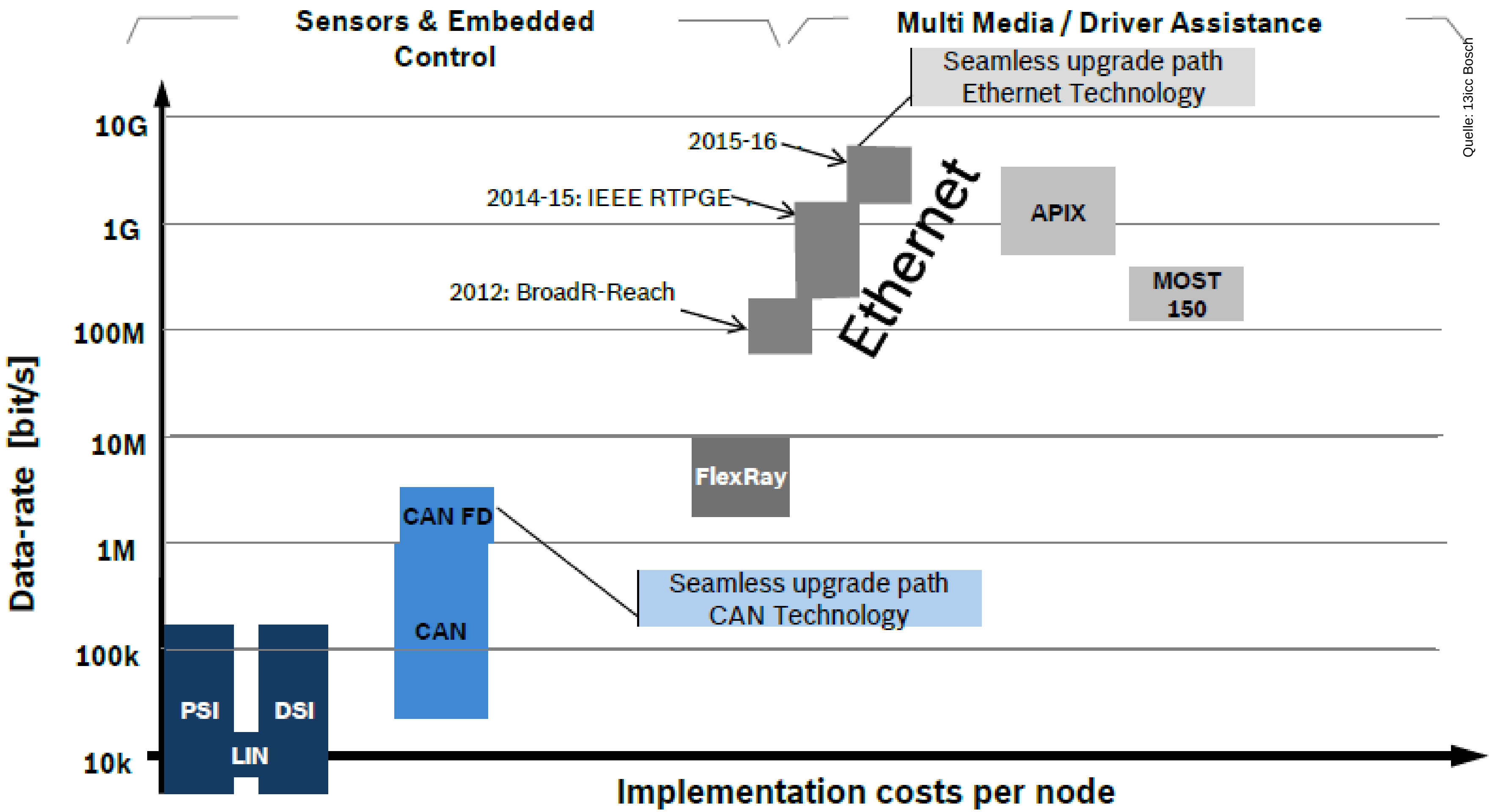


- Customer requirements in the areas of safety, increased comfort and easier handling are still intensifying the trend
- Many mechanically based functions will be replaced by software-based mechatronic functions

→ **The significance of electronics is increasing rapidly**

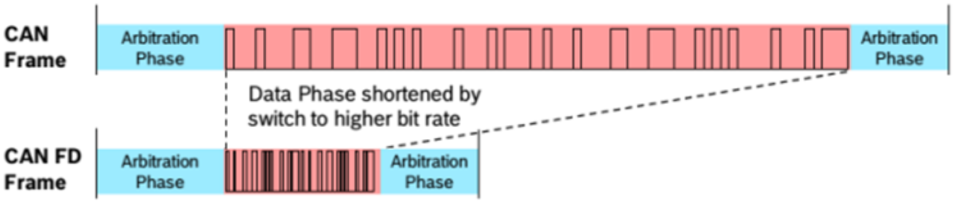
→ **But the components shall still work with each other!**

Automotive communication landscape



What is important to consider for CAN-FD IVN topology design?

The most significant technological challenges for the IVN topology designer as a result of the evolutionary step from classical CAN to CAN-FD.

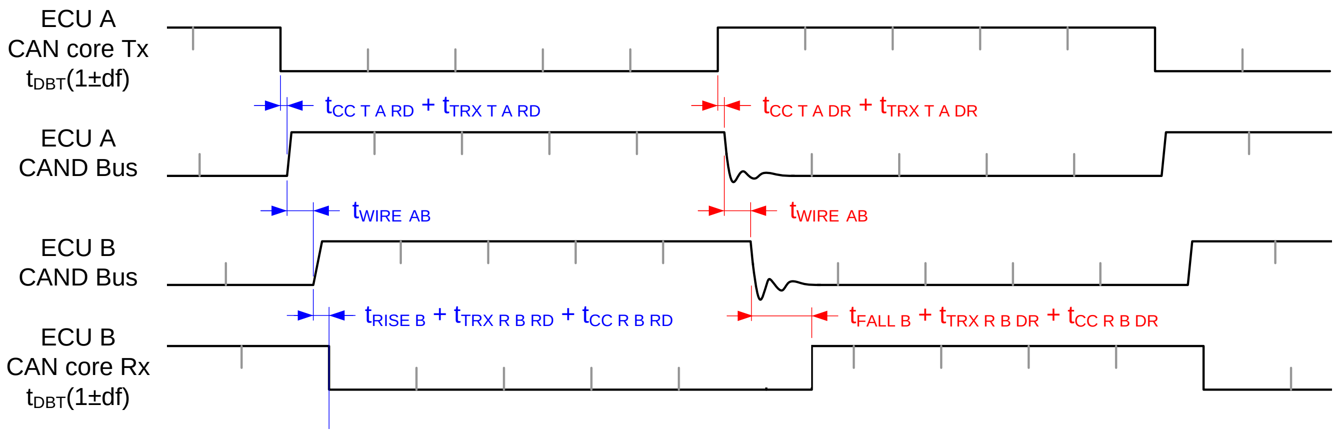


Quelle: 14icc_VIII-3_mutter.pdf

- Still valid are rules for the **arbitration phase**
  - **Oscillator frequency tolerance** considering the bit timing settings within the arbitration phase
  - Arbitration scenarios with focus on the **propagation delay**
- Additional rules for the **fast data phase**
  - **Oscillator frequency tolerance** considering the bit timing settings within the data phase
  - Data phase scenarios with focus on the **asymmetric delay**
  - Analogue **settle time** signal of differential signal at the receiving node

New validation criteria to be taken into account for CAN-FD IVN topology design and transceiver selection:

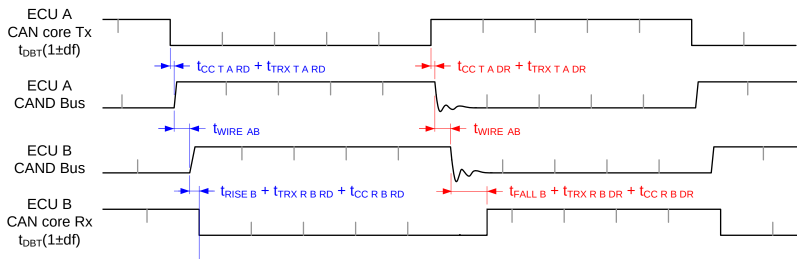
Asymmetric delay (t_{ASYM}) between recessive to dominant and dominant to recessive edges



$$t_{ASYM} = t_{PROP\ AB\ DR} - t_{PROP\ AB\ RD}$$

$t_{PROP\ AB\ DR} > t_{PROP\ AB\ RD} \rightarrow t_{ASYM} > 0$ // $t_{PROP\ AB\ DR} < t_{PROP\ AB\ RD} \rightarrow t_{ASYM} < 0$

Impacts on propagation delay symmetry



Propagation delays of systems are not symmetric ($t_{ASYM} \neq 0ns$)

- <u>T</u>ransmitter and <u>R</u>eceiver propagation delays are different
- Slope delays RD and DR are different
- Influence of different suppliers, temperature, supply voltage, etc.

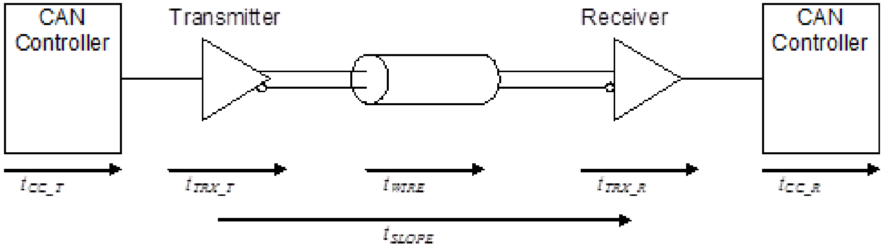
  - Communication controller: $t_{CC\ \underline{T}\ A\ RD} \neq t_{CC\ \underline{T}\ A\ DR} \neq t_{CC\ \underline{R}\ B\ RD} \neq t_{CC\ \underline{R}\ B\ DR}$
  - Transceiver: $t_{TRX\ \underline{T}\ A\ RD} \neq t_{TRX\ \underline{T}\ A\ DR} \neq t_{TRX\ \underline{R}\ B\ RD} \neq t_{TRX\ \underline{R}\ BA\ DR}$
  - Edges (rising and falling): $t_{RISE\ B} \neq t_{FALL\ B}$

What are the validation criteria for CAN-FD IVN topologies?

Rules recommended for the validation of CAN-FD systems:

- Bit timing settings according to ISO/CD 11898-1

- Propagation delay limits for CAN-FD



  - Propagation delay limits for the arbitration phase *(= classical CAN)*
  - Propagation delay limits for the data phase
  - Transmitter loop delay limits for the data phase

- Settle time of differential signal at the receiver

Bit timing settings according to ISO/CD 11898-1

To ensure correct communication, bit timing configurations and clock tolerance shall be taken into account for CAN-FD IVN topology design

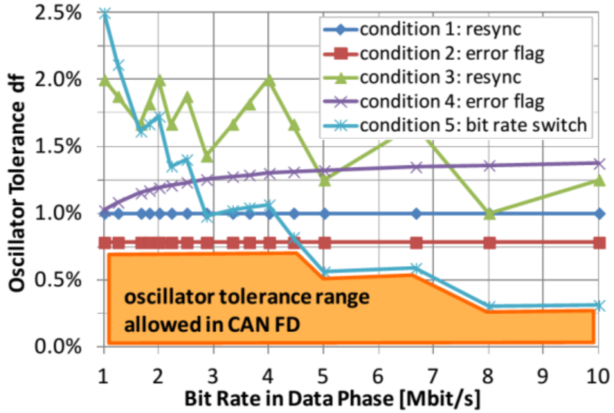
- Arbitration phase *(= classical CAN)*

1) Resynchronization

$$df \leq \frac{\mathrm{SJW\ N}}{2 \cdot 10 \cdot \mathrm{NBT}}$$

2) Sampling of Bit Succeeding own error Flag

$$df \leq \frac{\min\{\mathrm{PHASE\ SEG\ 1\ N},\ \mathrm{PHASE\ SEG\ 2\ N}\}}{2 \cdot (13 \cdot \mathrm{NBT} - \mathrm{PHASE\ SEG\ 2\ N})}$$



- Data phase

3) Resynchronization

$$df \leq \frac{\mathrm{SJW\ D}}{2 \cdot 10 \cdot \mathrm{DBT}}$$

4) Sampling of Bit Succeeding own Error Flag

$$df \leq \frac{\min\{\mathrm{PHASE\ SEG\ 1\ N}, \mathrm{PHASE\ SEG\ 2\ N}\}}{2 \cdot \left[(6 \cdot \mathrm{DBT} - \mathrm{PHASE\ SEG\ 2\ D}) \cdot \frac{m_D}{m_N} + 7 \cdot \mathrm{NBT}\right]}$$

5) Bit Rate Switching low → high bit rate

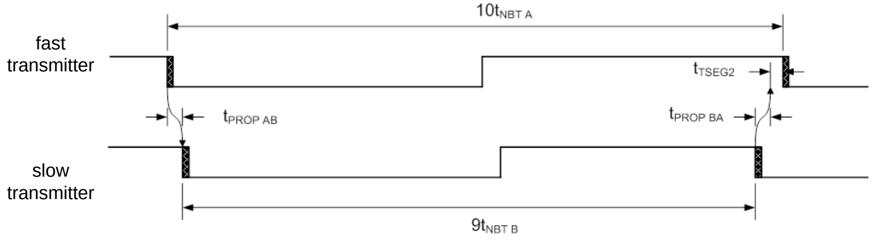
$$df \leq \frac{\mathrm{SJW\ D} - \max\left\{0,\ \frac{m_N}{m_D} - 1\right\}}{2 \cdot \left[(2 \cdot \mathrm{NBT} - \mathrm{PHASE\ SEG\ 2\ N}) \cdot \frac{m_N}{m_D} + \mathrm{PHASE\ SEG\ 2\ D} + 4 \cdot \mathrm{DBT}\right]}$$

Quelle: 14icc_VIII-3_mutter.pdf

Propagation delay limits for the arbitration phase

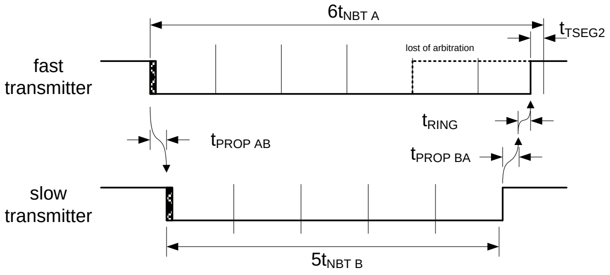
Propagation delay in the arbitration phase *(= classical CAN)*

- recessive to dominant



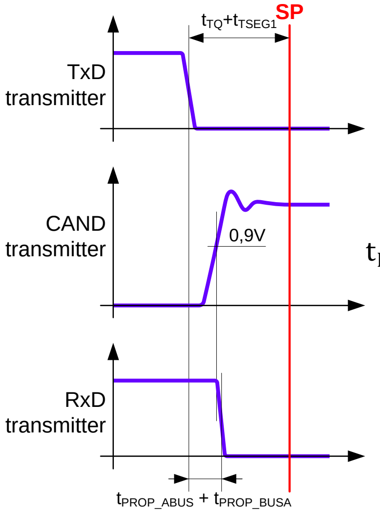
$$t_{PROP\ AB\ RD} + t_{PROP\ BA\ RD} \leq t_{NBT} - t_{TSEG2} - (19t_{NBT} - t_{TSEG2})df$$

- dominant to recessive

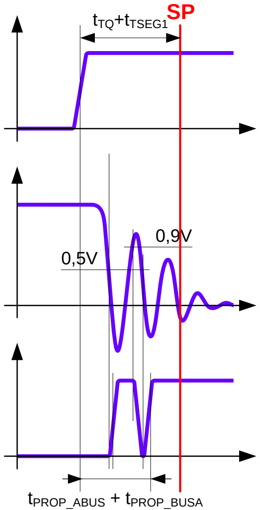


$$t_{PROP\ AB\ RD} + t_{PROP\ BA\ DR} \leq t_{NBT} - t_{TSEG2} - (11t_{NBT} - t_{TSEG2})df$$

Propagation delay at transmitter node *(= classical CAN)*

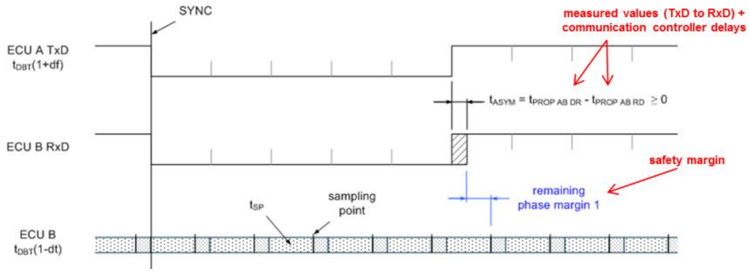


$$t_{PROP\ ABUS} + t_{PROP\ BUSA} \leq (t_{TQ} + t_{TSEG1})(1 - df)$$



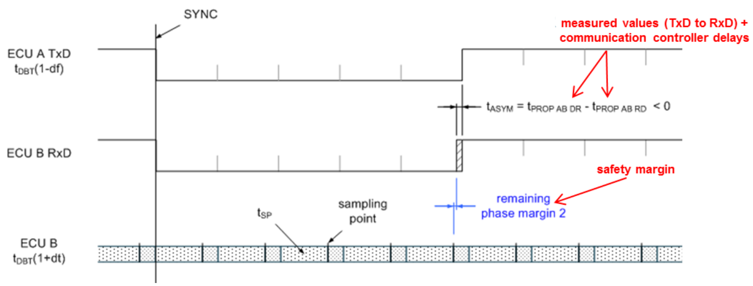
Propagation delay limits for the data phase

Propagation DR > Propagation RD



$$\frac{t_{ASYM}}{t_{DBT}} < \left(5 + \frac{t_{SP\,B}}{t_{DBT}} - \frac{t_{TQ\,B}}{t_{DBT}}\right)(1 - dt_B) - 5(1 + dt_A) - \frac{t_{RPM1}}{t_{DBT}}$$

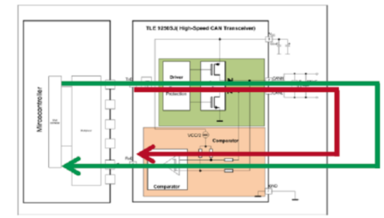
Propagation DR < Propagation RD



$$\frac{t_{ASYM}}{t_{DBT}} > \left(4 + \frac{t_{SP\,B}}{t_{DBT}}\right)(1 + dt_B) + \frac{t_{RPM2}}{t_{DBT}} - 5(1 - dt_A)$$

Transmitter loop delay limits for the data phase

with TDC



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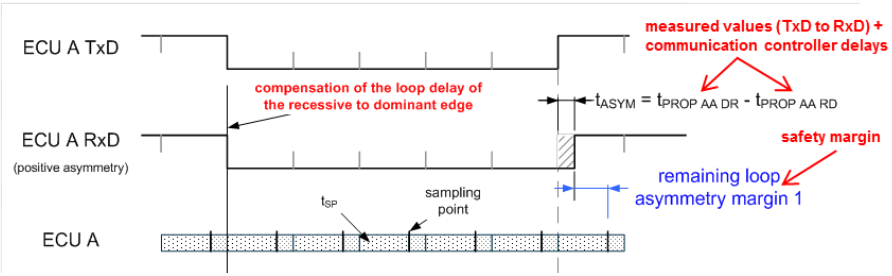
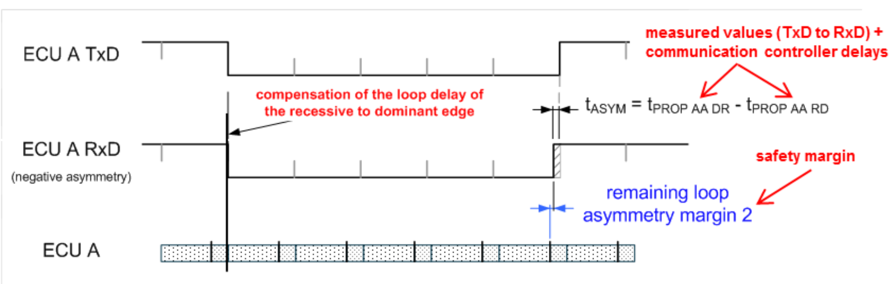
Propagation DR > Propagation RD



$$\frac{t_{ASYM}}{t_{DBT}} < \frac{t_{SP\ A}}{t_{DBT}}(1 - dt_A) - \frac{t_{RLM1}}{t_{DBT}}$$

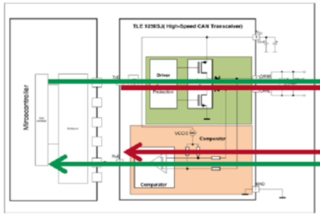
Propagation DR < Propagation RD



$$\frac{t_{ASYM}}{t_{DBT}} > \left(\frac{t_{SP\ A}}{t_{DBT}} - 1\right)(1 + dt_A) + \frac{t_{RLM2}}{t_{DBT}}$$

Transmitter loop delay limits for the data phase

without TDC



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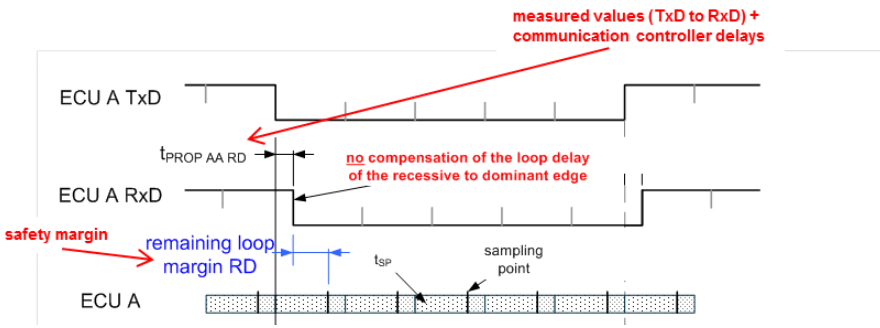
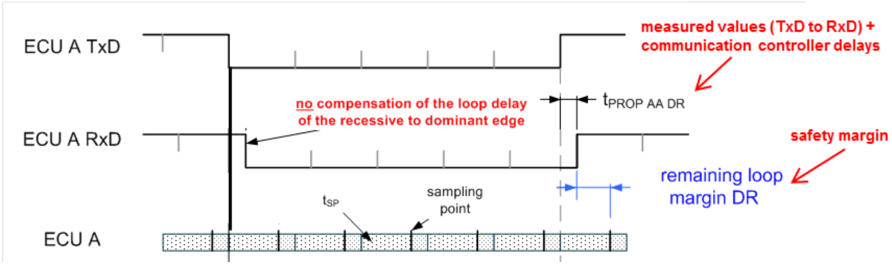
Propagation RD



$$\frac{t_{\mathrm{PROP\ AA\ RD}}}{t_{\mathrm{DBT}}} < \frac{t_{\mathrm{SP\ A}}}{t_{\mathrm{DBT}}}(1 - dt_A) - \frac{t_{\mathrm{RLM\ RD}}}{t_{\mathrm{DBT}}}$$

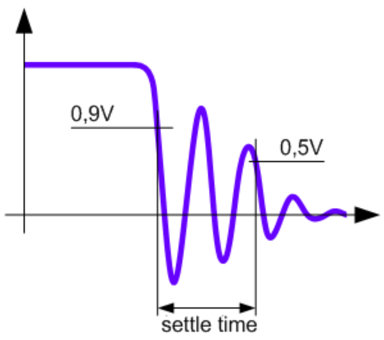
Propagation DR



$$\frac{t_{\mathrm{PROP\ AA\ DR}}}{t_{\mathrm{DBT}}} < \frac{t_{\mathrm{SP\ A}}}{t_{\mathrm{DBT}}}(1 - dt_A) - \frac{t_{\mathrm{RLM\ DR}}}{t_{\mathrm{DBT}}}$$

Settle time of differential signal at the receiver

Differential CAN signal at the bus pins of the transceiver



The settle time test does not consider any delays or baud rate drifts.

Recommendation

$$\frac{t_{\text{settle time}}}{t_{\text{DBT}}} \leq 30\% \quad \rightarrow \text{OK}$$

$$30\% < \frac{t_{\text{settle time}}}{t_{\text{DBT}}} \leq 50\% \quad \rightarrow \text{WARNING}$$

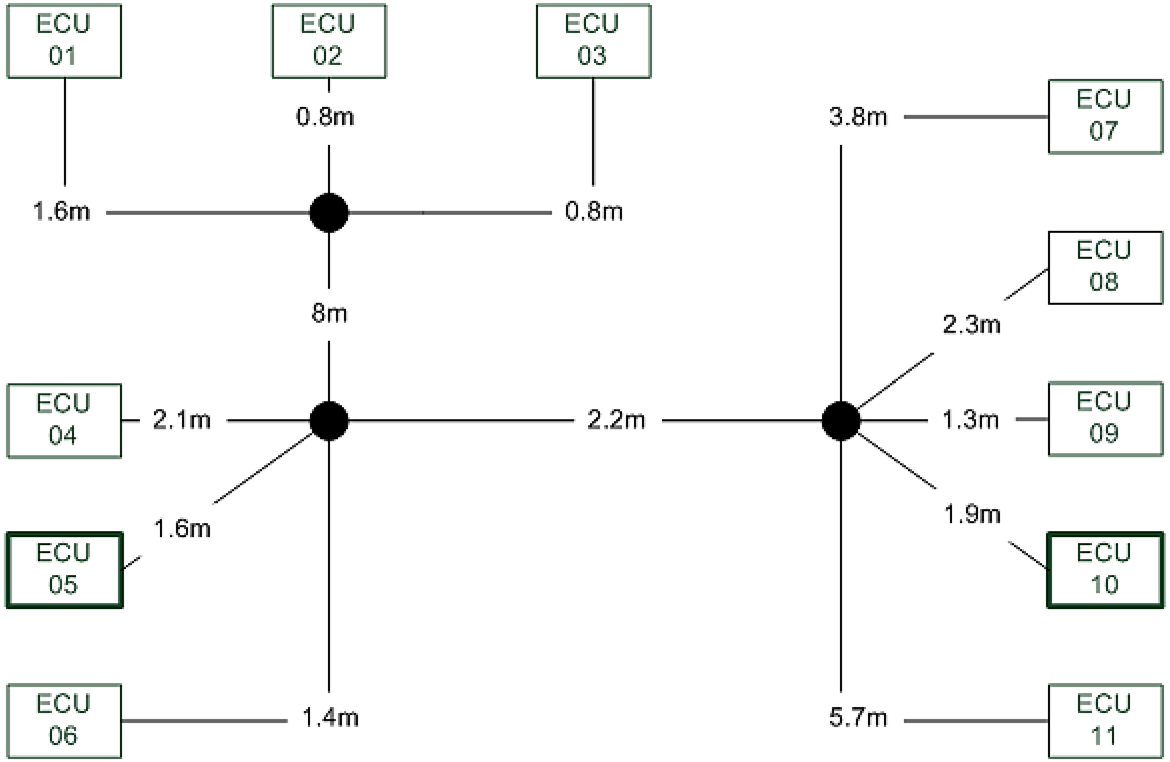
$$50\% < \frac{t_{\text{settle time}}}{t_{\text{DBT}}} \quad \rightarrow \text{SEVERE WARNING}$$

Baudrate[Mbps]	Bit time [ns]	30% of DBT [ns]	50% of DBT [ns]
0.5	2000	600	1000
1	1000	300	500
2	500	150	250
3	333	100	167
4	250	75	125
5	200	60	100

Example : Topology overview

CAN-FD plug fest topology as example

- Number of participants: 11 nodes with 3 splice points
- Total cable length: 33.5 meter
- Decentralized termination with 2x120Ω resistors (ECU 5 &10)



Example : Validation using simulation

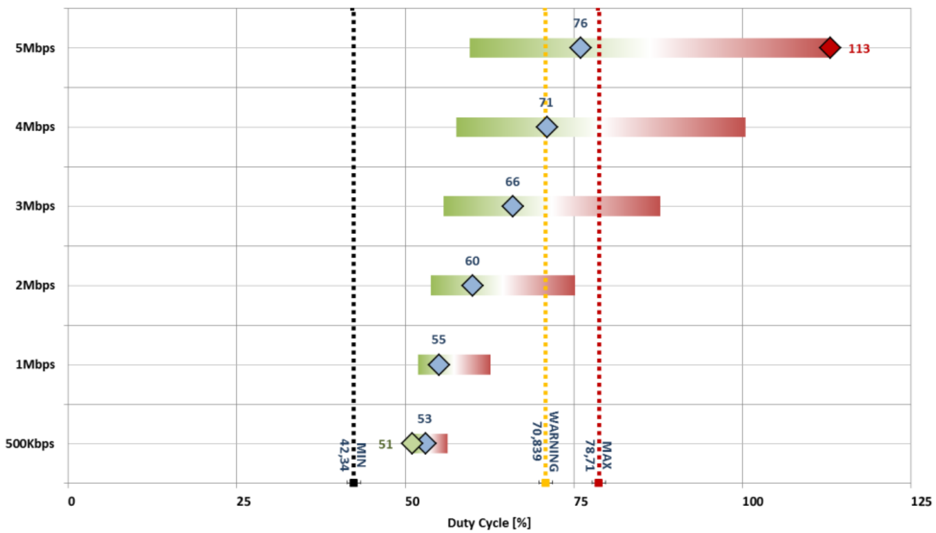
Simulation with established validation criteria

- Correct communication during baud rates up to 2 Mbps
- Without using TDC, several nodes switch in Bus-OFF state, correct communication will be granted only <u>with</u> TDC enabled

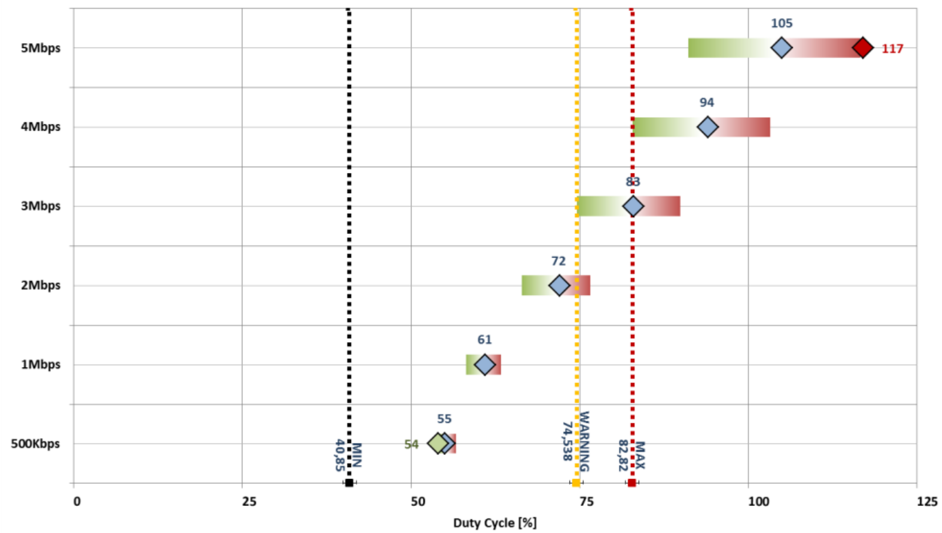
Simulation results

NOTE: A safety margin of 10% is set to compensate missing details in the datasheet, such as the worst case characteristics of the transceiver and propagation delays of the communication controller.

Propagation delay



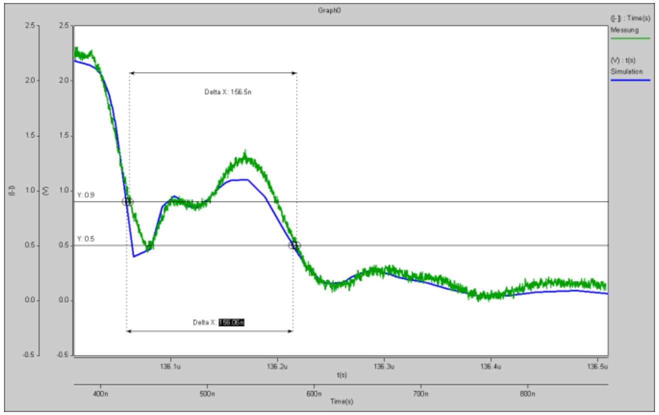
Transmitter loop delay



Example : Verification using CAN-FD Test Modules

Measurement with CAN-FD Test modules

- using an exact replica of topology and settings to verify simulation results
- validation criteria of measurement
  - adoption of an error counter on Tx/Rx
  - Bus-OFF state of one or more nodes



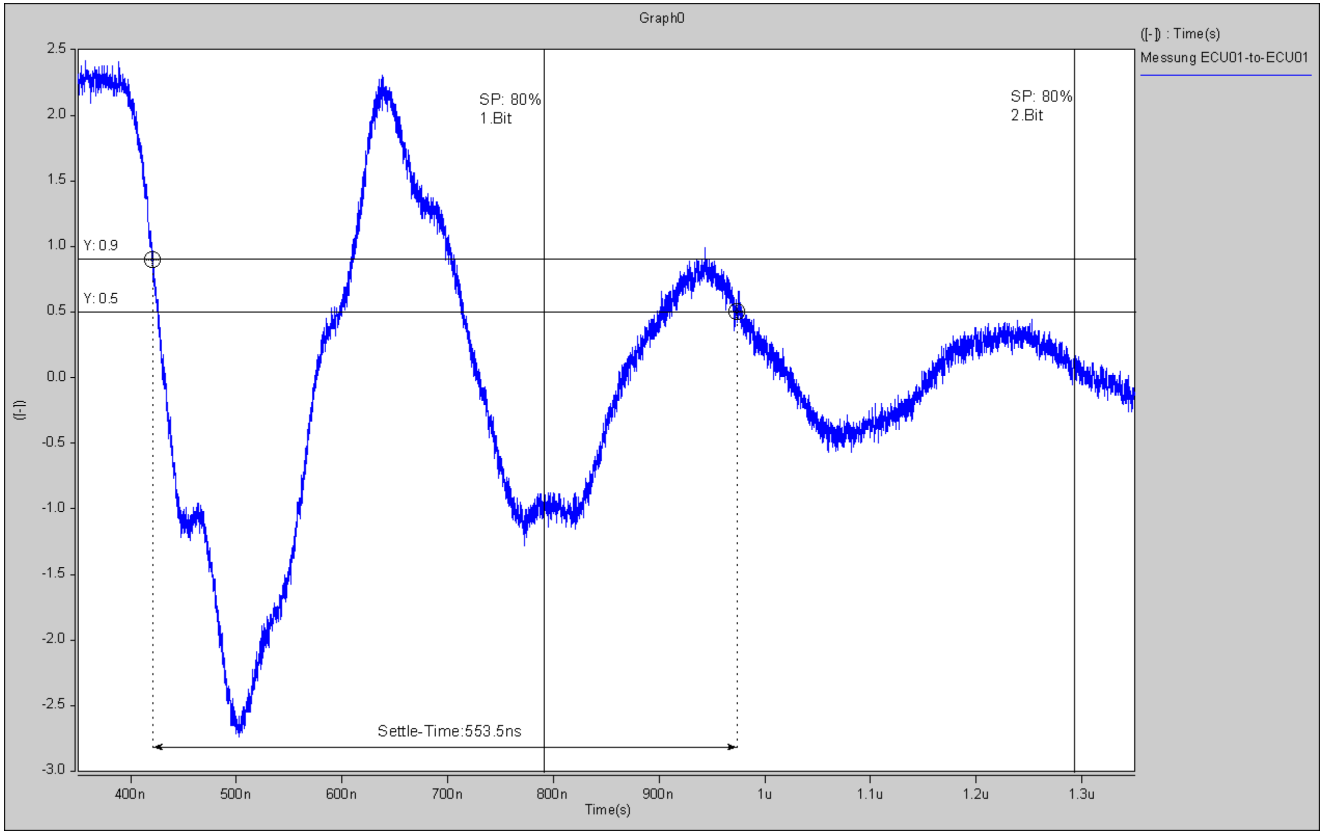
Measuring results

- The correct communication as well as the verification of the simulation results conform to the expected estimation

baud rate [Mbps]	simulation	measurement
0.5	PASS	PASS
1	PASS	PASS
2	PASS*	PASS*
3	FAIL	FAIL
4	FAIL	FAIL
5	FAIL	FAIL

*only with the optional use of the transmitter delay compensation

Example : Results at Settle Time



- Ringing duration larger than a bit time *(baud rate of 2 Mbps)*
- For safety communication topology has to be optimised

NOTE: Behaviour only occurs on communication between ECU01, ECU02 and ECU03 because of the missing termination node on the upper splice point – communication between these ECUs and other nodes is O.K.

Analysis of validation efforts in given example

Validation of a CAN-FD IVN topology 11 ECUs require at least:

- Creation of
  - 11 ECUs and their distinct assembly configuration
  - 13 cable elements and their distinct configuration
  - Stimulus components to generate bit patterns for 11 ECUs
- Setting up of
  - 3 different temperature case variations
    (simulation only, laboratory measurement imply just room temperature → less informative value)
- Execute, monitor and document
  - 726 propagation delay measurements *(11^2 [ECU] * 2 [edges/signal path] * 3 [temp.])*
  - 121 settle time measurements
- Calculate and apply to the measurements 8 limits for
  (using just one fixed bit timing setting for all ECUs)
  - 3 arbitration phase criteria
  - 5 data phase criteria

→ Simulation is not effective without <u>automation</u>!

Summary

- CAN-FD is a further building block, helping to close the gap between the growing needs regarding exchange of information between electronic units and the currently available technologies.
- CAN-FD indeed bases on the well-known CAN 2.0 technology but additional criteria need to be considered for the topology validation.
- Maximum baud rate depends on the target topology (example topology → 2Mbps), i.e. each topology needs to be validated.
- Automation supports the CAN-FD IVN topology designer by the handling of the high effort for the topology validation.

Thanks for your attention!
Please visit our booth!

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