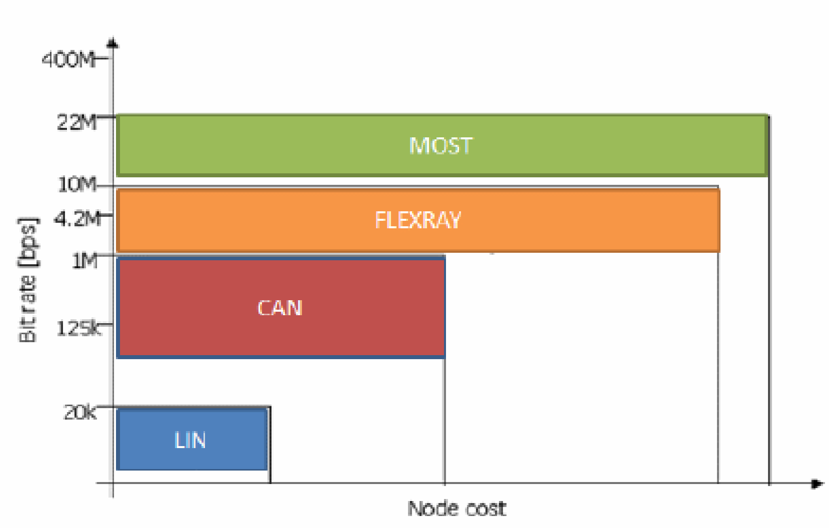
ON Semiconductor®

Basics of In-Vehicle Networking (IVN) Protocols

Available IVN Protocols

There are many Bus Systems used in a car but... "It is becoming clear that regardless of carmaker, new vehicles will be made using [LIN] for the lowest data-rate functions, [CAN] for medium speed, [MOST] for the high-speed data rates and [FlexRay], for safety-critical applications such as steer- and brake-by-wire." …

"Automotive Industries, 2005"



LOCAL INTERCONNECT NETWORK

GIFT/ICT

FlexRay™

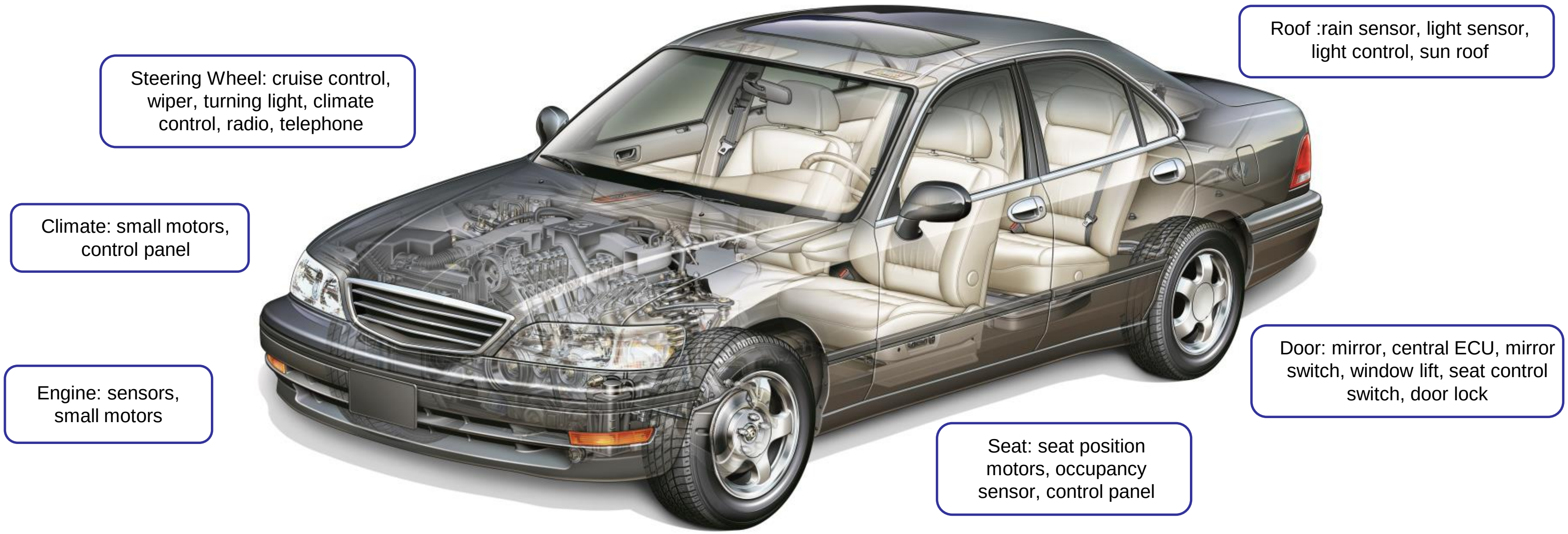
LIN Overview

Like in a classroom situation, the LIN 'master' initiates the response of the other participants

- LIN = 12 V, single-wire serial communications protocol based on the common SCI (UART) byte-word interface
- Maximum speed = 20 kb/s (EMC/clock synchronisation)
- Master controls the medium access: no arbitration or collision management, guaranteed latency times
- Clock synchronization mechanism by slave nodes (no need for quartz or ceramics resonator)
- Nodes added without HW/SW changes in other slave nodes
- Typically < 12 nodes, (64 identifiers & relatively low transmission speed)

LIN Applications

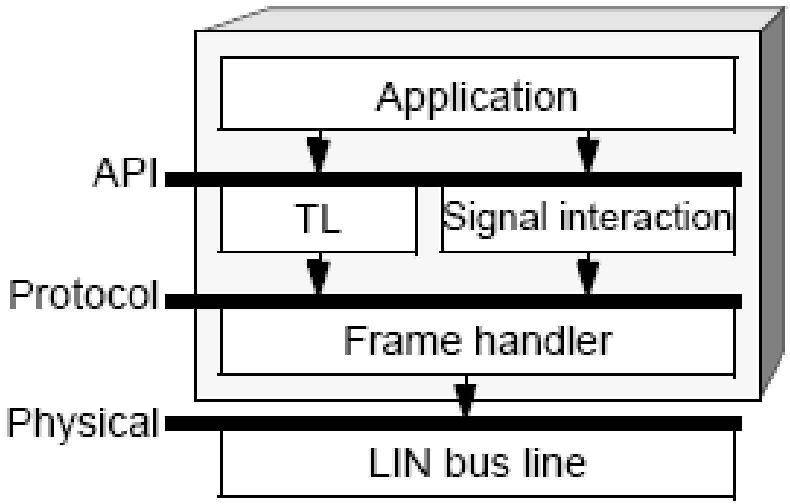
- Mirrors, window lift, doors switches, door lock, HVAC motors, control panel, engine sensors, engine cooling fan, seat positioning motors, seat switches, wiper control, light switches, interface switches to radio/navigation/phone, rain sensor, light control, sun roof, RF receivers, body computer/smart junction box, interior lighting, and more



LIN details

Protocol stack

A node in a cluster interfaces to the physical bus wire using a frame transceiver. The frames are not accessed directly by the application; a signal based interaction layer is added in between. As a complement, a transport layer interface exists between the application and the frame handler.



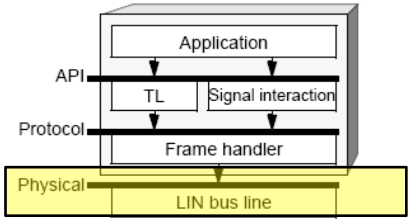
Application program Interface (API) Specification

Protocol Specification

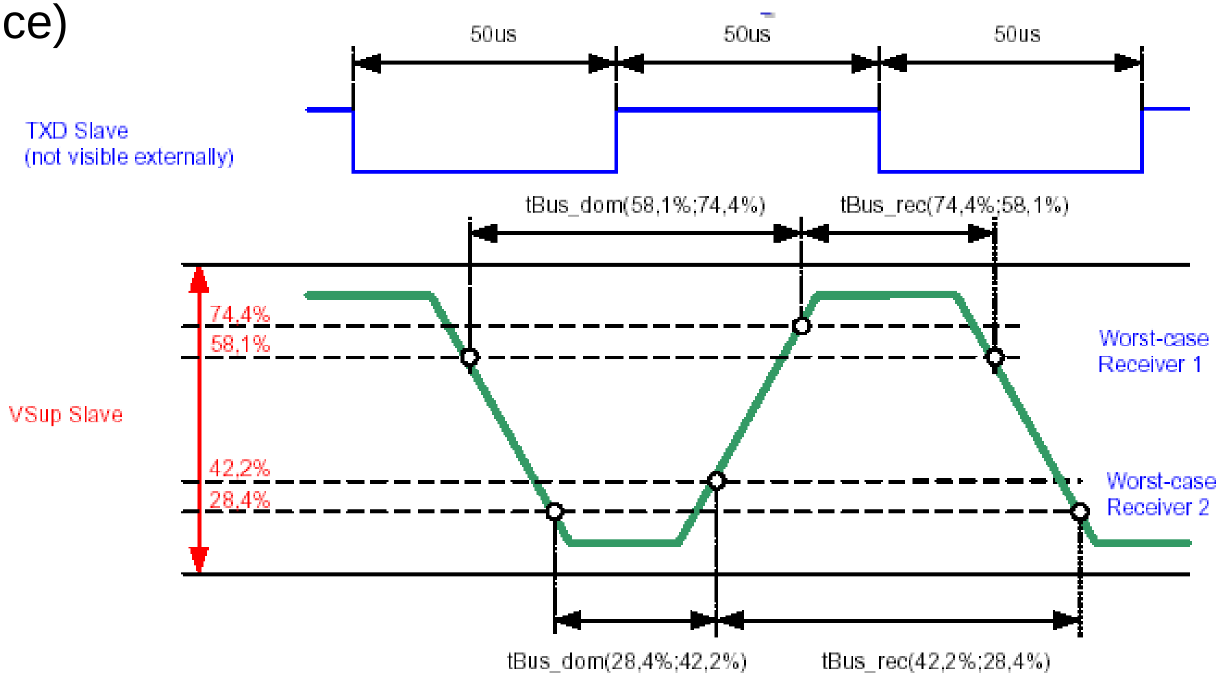
Physical Layer Specification

LIN details

Physical Layer



- Vsup between 7 V and 18 V
- Strict requirements for slope and symmetry
- Duty-cycle: Min = 39.6 %, Max = 58.1% (Bus-load: time-constant between 1 µs and 5 µs: 1k/1 nF 660/6.8 nF 500/10 nF) (not-synchronized oscillator <14% tolerance)

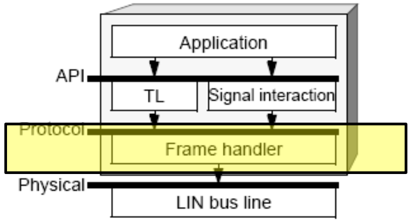


10.1.9	V_{BUSdom}			0.4	V_{SUP}	receiver dominant state
10.1.10	V_{BUSrec}	0.6			V_{SUP}	receiver recessive state
10.1.11	V_{BUS_CNT}	0.475	0.5	0.525	V_{SUP}	$V_{BUS\_CNT} = (V_{th\_dom} + V_{th\_rec})/2$
10.1.12	V_{HYS}			0.175	V_{SUP}	$V_{HYS} = V_{th\_rec} - V_{th\_dom}$

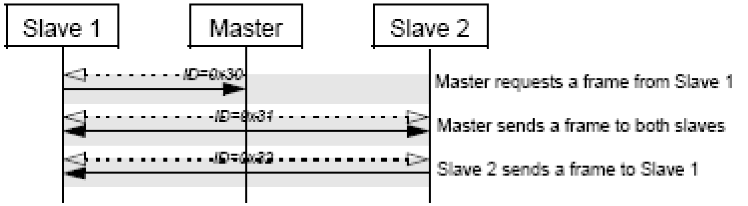
LOCAL INTERCONNECT NETWORK

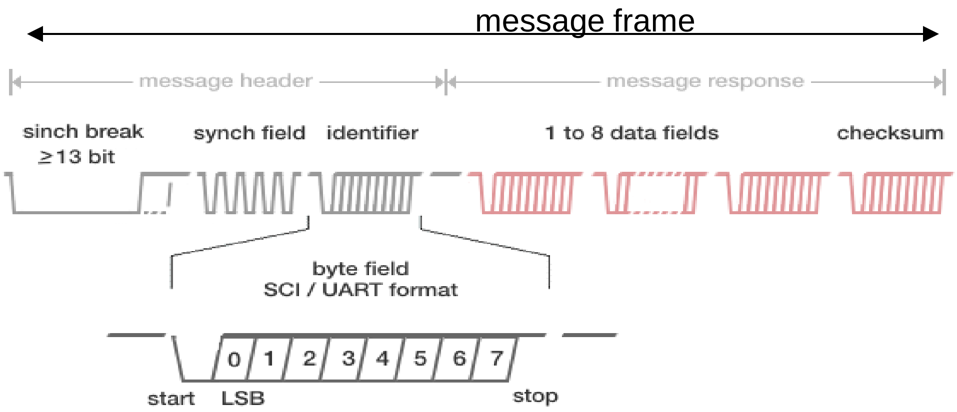
LIN details

Communication concept

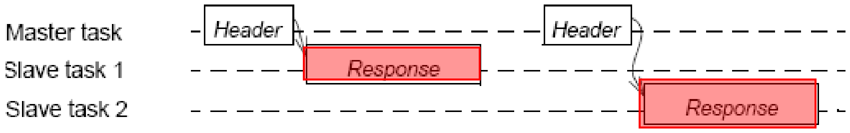


- Communication initiated by the master task (message header)
- Slave task activated upon recognition of identifier - starts the message response (1-8 data bytes + 1 checksum byte).
- Data correctness: parity, checksum
- Identifier = content, not the destination!
  - exchange of data in various ways:
    - M → S(s)
    - S → M
    - S → S(s)





0 = “dominant” state
1 = “recessive” state
Not used = recessive



CAN Overview

In CAN communication, all partners are equal and are able to communicate at any time. In case of conflicts (two speaking at the same time), arbitration is used to ensure messages are understood.

- Controller Area Network is a fast serial bus designed to provide an efficient, reliable and very economical link between sensors and actuators

- CAN connects the vehicle's electronic equipment

- These connections facilitate the sharing of information and resources among the distributed applications

- All nodes can send a message at any time, when two nodes are accessing the bus together, arbitration decides who will continue

CAN Applications

- CAN was developed in early 1980's for automotive and is widely used in all car parts (Powertrain, Chassis, Body); every car developed in Europe, USA, and Japan has at least a few CAN nodes; CAN is being adopted in Asia as well

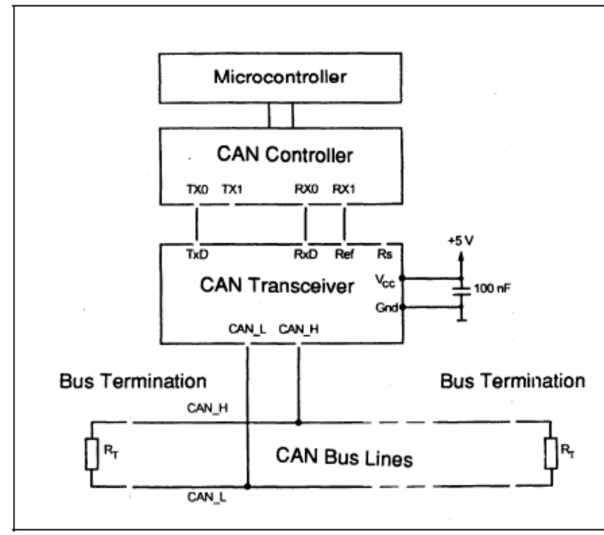
- An increasing number of products have a CAN transceiver implemented together with other functionality (e.g. in system basis chips, stepper motors, park assist, …)

- CAN also found its way into Industrial Applications

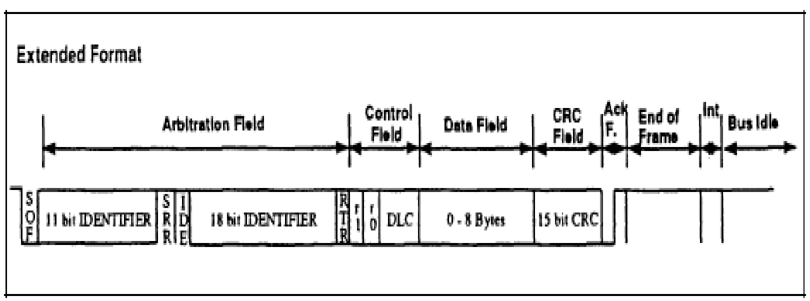
  See http://www.can-cia.de/

CAN - details
Characteristics

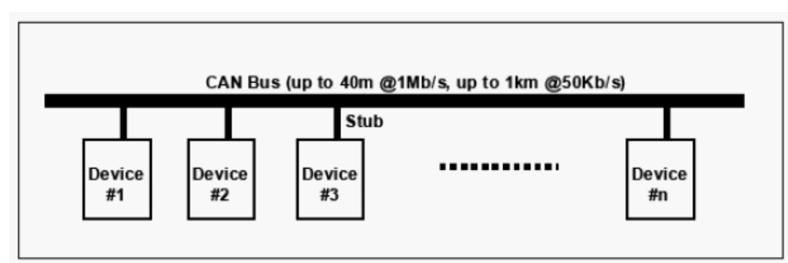
- Asynchronous communication (Event Triggered)
- Any node can access the bus when the bus is quiet
- Non-destructive arbitration, 100% use of the bandwidth without loss of data, large latency for low priority messages, low latency for high priority messages
- Variable message priority based on 11-bit (or extended 29 bit) packet identifier
- Automatic error detection, signaling and retries
- CAN uses a twisted pair cable to communicate at speeds up to 1 Mb/s with up to 40 devices



Physical CAN Connection according to ISO 11898



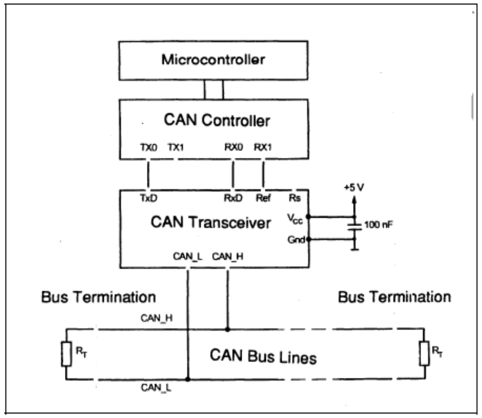
Message frame for standard format (CAN Specification 2.0A)



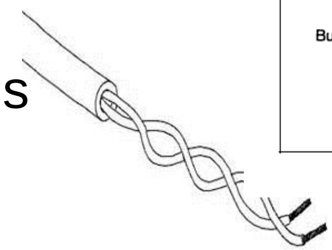
CAN - details

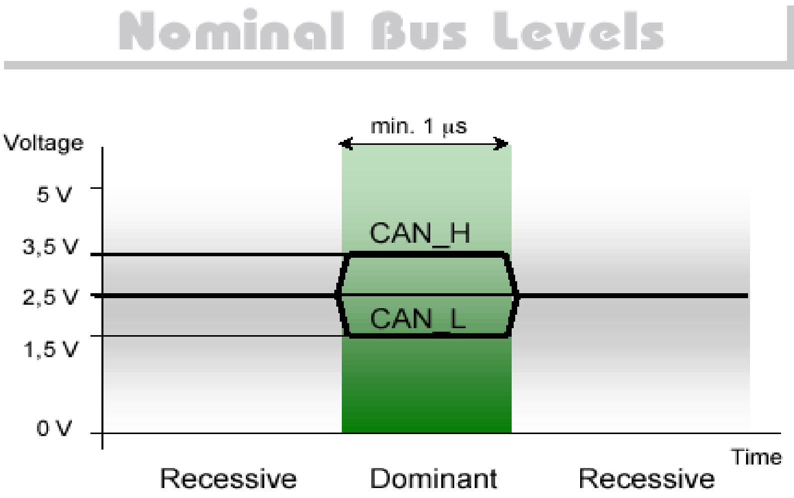
Physical Layer(*)

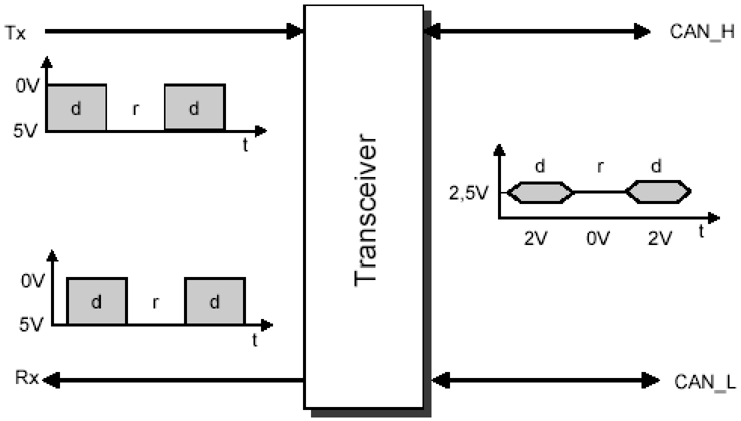
- CAN bus requires line termination
- ISO 11898 standard define the impedance of the cable as 120 ± 12 Ω
- Twisted pair, shielded or unshielded is requested



Physical CAN Connection according to ISO 11898



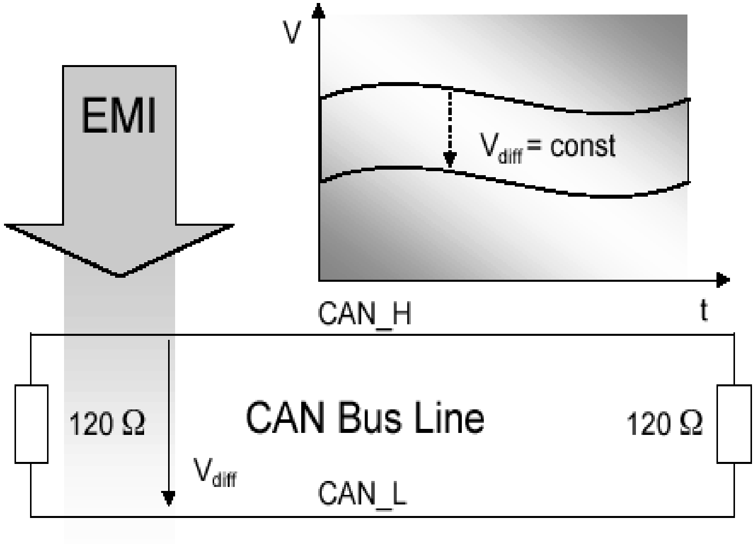


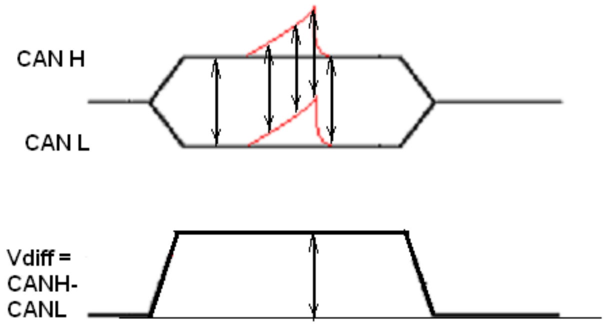


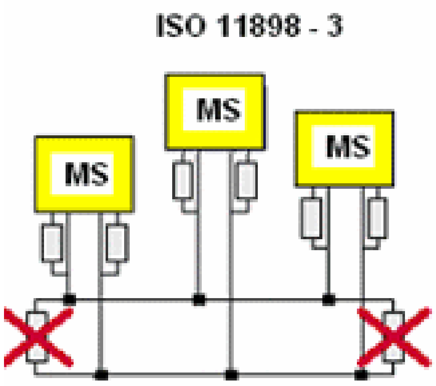
(*) Single wire CAN (SEA2411, 33,3 kbit/s) and low speed CAN (ISO11898-3, 125Kbit/s) are not covered by above description

CAN - details
Physical Layer

- What is the advantage of the two wire CAN communication?
- EMC applied on two terminated floating wires is not changing differential voltage
- When twisted pair is used it has advantage for electromagnetic emissions (EME)





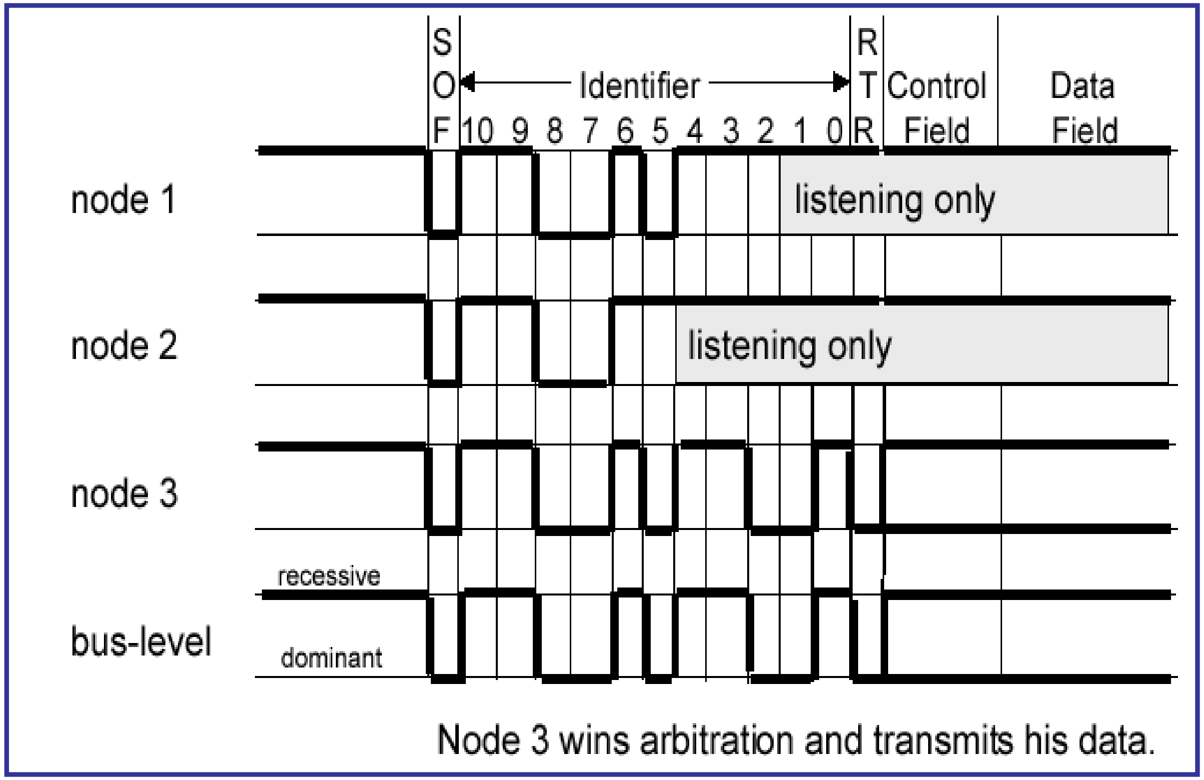


Note: Low speed CAN (ISO11898-3, 125Kbit/s) bus is not a terminated bus and 2 wires are used here for fault tolerance reasons. One wire shorted, disconnected or short in between the two wires causes communication switching to single ended communication.

CAN – details

Bus arbitration in more details

- If two messages are simultaneously sent over the CAN bus, the bus takes the “logical AND” of the signal
- Hence, the messages identifiers with the lowest binary number gets the highest priority
- Every device listens on the channel and backs off as and when it notices a mismatch between the bus’s bit and its identifier’s bit



CAN Reference Information

- (ISO11898-1) CAN Data Link Layer and Physical Signaling
- (ISO11898-2) High speed CAN Medium Access Unit
- (ISO11898-3) CAN Low-Speed, Fault-Tolerant
- (ISO11898-4) CAN Time-Triggered Communication
- (ISO11898-5) CAN High-Speed with Low-Power Mode
- (SEA2411) Single wire

FlexRay Overview

As in a train-schedule, all FlexRay traffic on the bus is nicely scheduled using time-slots.

- High data rates (up to 10 Mb/s)
- Time- and event-triggered behavior
- Redundancy
- Fault-tolerance
- Deterministic (use of “time-slots”)

FlexRay Applications

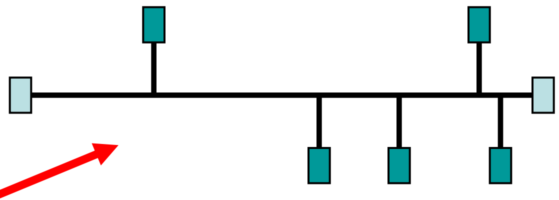
- FlexRay delivers the error tolerance, speed and time-determinism performance requirements for x-by-wire applications (i.e. drive-by-wire, steer-by-wire, brake-by-wire, etc.)

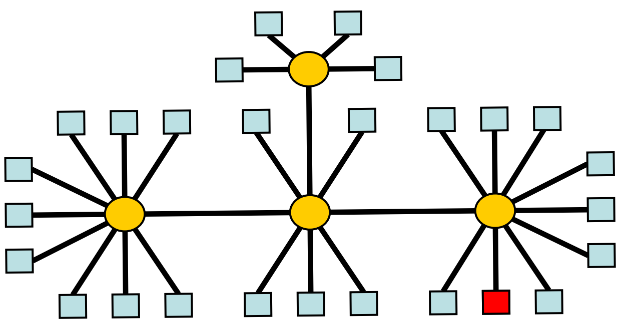
- The first series production vehicle with FlexRay was at the end of 2006 in the BMW X5, enabling a new and fast adaptive damping system

FlexRay - Details

Basic requirements

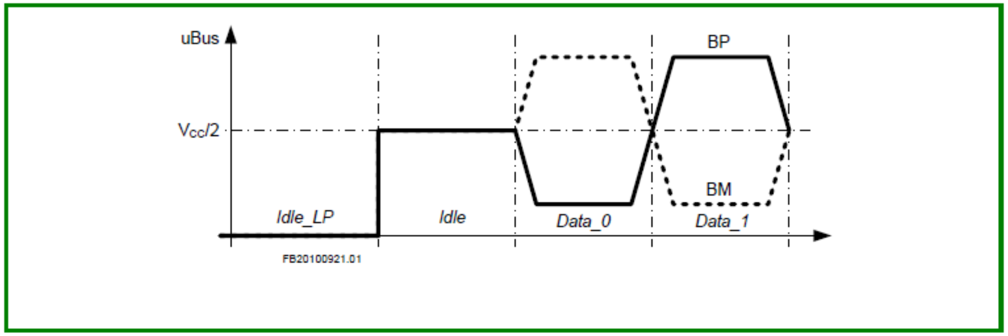
- Bit-rates up to 10 Mb/s over UTP or STP
  - Line termination (Line impedance 80 to 110 Ω)
  - Push-pull driver (2 dominant states + 1 idle state (recessive))
  - Maximum wire-length (strong attenuation at 10 Mb/s)
  - Slope-control + symmetry of slopes and delays ➔ Jitter
  - EMC
- For TT-protocols:
  - Time-skew versus delay
  - Oscillator stability: Jitter, accuracy
- Reliable and fault-tolerant ➔ Bus-Guardian:
  - To avoid babbling idiot
  - Control media access based on time-slots
- Bus Topologies:
  - Bus-architecture (passive bus)
    - More difficult for line-termination
  - Star-configuration (active star)
    - Point to point communication



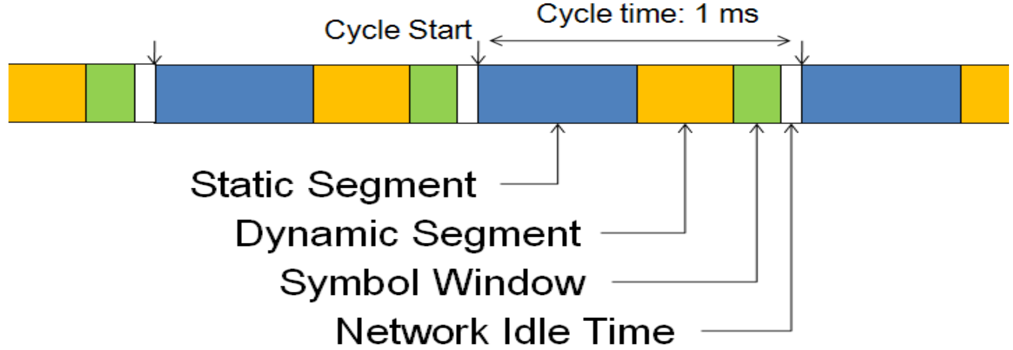


FlexRay – Details

Physical Layer



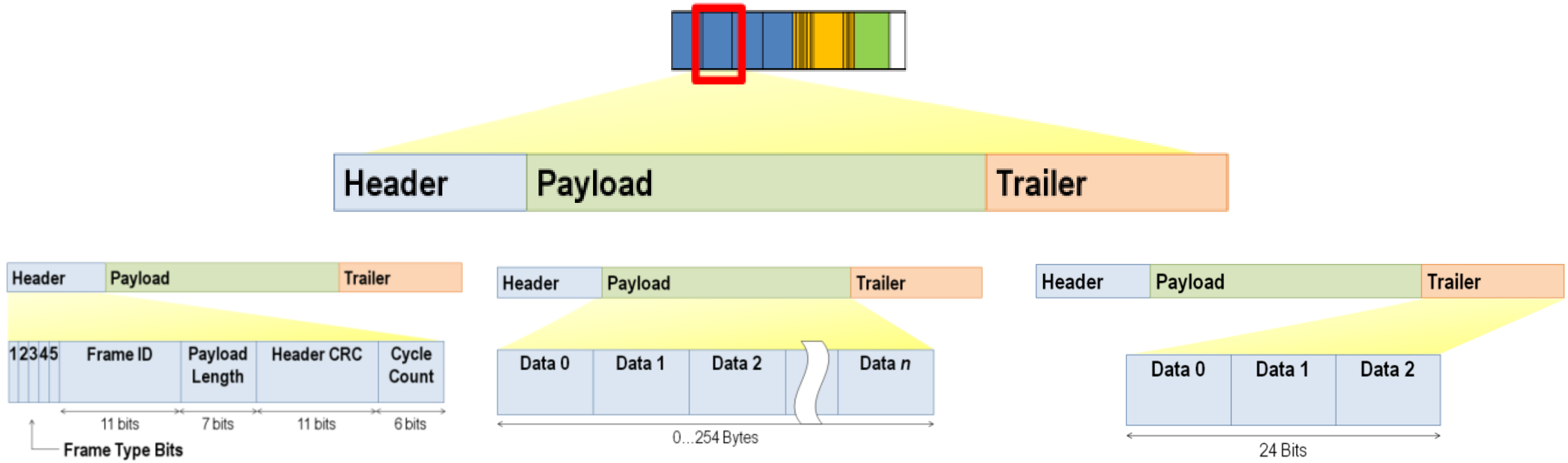
Communication cycle



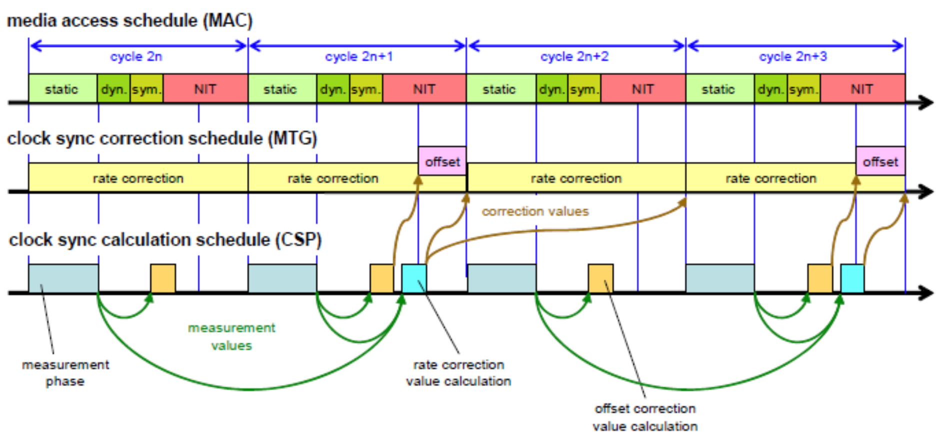
Static Segment:	Reserved slots for deterministic data that arrives at a fixed period.
Dynamic Segment:	Is used for a wider variety of event-based data that does not require determinism (cfr.CAN)
Symbol Window:	Typically used for network maintenance and signaling for starting the network.
Network Idle Time:	A known "quiet" time used to maintain synchronization between node clocks.

FlexRay – Details

Frame Format



Clock Synchronization



See chapter 8 of FlexRay Protocol Specification

FlexRay Reference Information

- Current standard (v3.0.1) has the following documents:
  - FlexRay™ Specifications Version 3.0.1
  - FlexRay™ Protocol Specification Version 3.0.1
  - FlexRay™ Protocol Conformance Test Specification Version 3.0.1
  - FlexRay™ Electrical Physical Layer Specification Version 3.0.1
  - FlexRay™ Electrical Physical Layer Conformance Test Specification Version 3.0.1
  - FlexRay™ Electrical Physical Layer Application Notes Version 3.0.1

- The FlexRay™ specifications v3.0.1 were submitted to ISO in order to be published as a standard for road vehicles

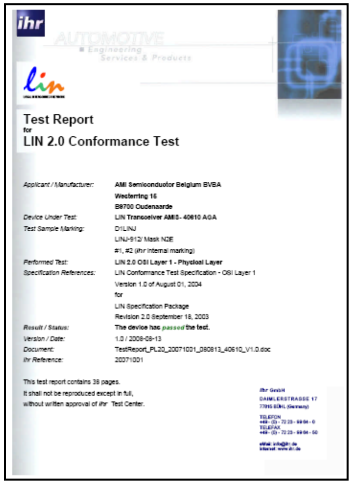
IVN Testing & Conformance

- Conformance testing
  - Compliance with the standard
  - Executed by:
    - C&S Group
    - Ihr
    - …

AMI 30600 0448LRL
J2602-2 Conformance Tests
Final – Report

Conformance Test Results

Wolfenbüttel, 2006-Jun-15



Test Report
for
LIN 2.0 Conformance Test

Applicant / Manufacturer: AMI Semiconductor Belgium BVBA

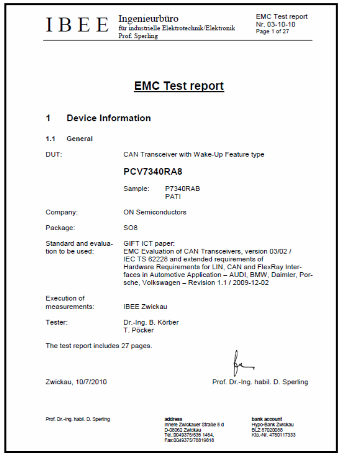
Device Under Test: LIN Transceiver AMIS-40610 AGA

Performed Test: LIN 2.0 OSI Layer 1 - Physical Layer

Result / Status: The device has passed the test.

This test report contains 38 pages.

- ESD & EMC testing
  - According to OEM requirements
  - Executed by:
    - IBEE-Zwickau
    - Underwriters Laboratories(UL)
    - …



IBEE Ingenieurbüro

EMC Test report

1 Device Information

1.1 General

DUT: CAN Transceiver with Wake-Up Feature type

PCV7340RA8

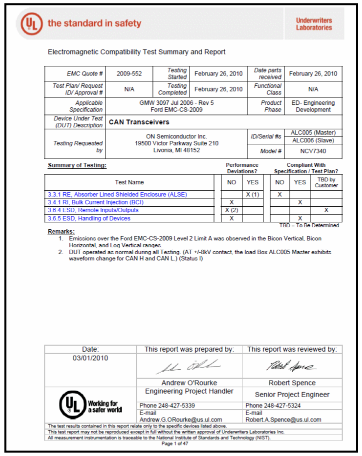
Company: ON Semiconductors

Package: SO8

Execution of measurements: IBEE Zwickau

The test report includes 27 pages.

Zwickau, 10/7/2010



the standard in safety

Electromagnetic Compatibility Test Summary and Report

CAN Transceivers

Summary of Testing:

Remarks:

Bus - Comparison

Bus	LIN	CAN	FlexRay	MOST
Cost/Node [$] (ABIreport: Y08)	1.50	3.00	6.00	4.00
Used in	Subnets	Soft real-time	Hard real-time	Multimedia
Application domains	Body	Powertrain, Chassis …	Chassis, Powertrain	Multimedia, Telematics
Message transmission	Synchronous	Asynchronous	Synchronous & Asynchronous	Synchronous & Asynchronous
Message identification	Identifier	Identifier	Time slot	
Architecture	Single Master typ. 2…10 slaves	Multi-Master typ. 10…30 nodes	Multi-Master up to 64 nodes	Multi-Master up to 64 nodes
Access control	Polling	CSMA/CA	TDMA	TDM CSMA/CA
Data Rate	20 kbps	1 Mbps	10 Mbps	24 Mbps
Physical Layer	Single Wire	Dual-Wire	Dual-Wire (Optical Fiber)	Optical Fiber (Dual-wire)
Latency Jitter	Constant	Load dependent	Constant	Data stream
Babbling idiot	n/a	Not provided	Provided	
Extensibility	High	High	Low	High

Released LIN Products
from ON Semiconductor

WPN	OPN (T&R)	Description	Standard
AMIS-30600	AMIS30600LINI1RG	LIN Transceiver	LINv1.3 LINv2.1 J2602
NCV7321	NCV7321D10R2G	Stand-alone LIN Transceiver	
	NCV7321D11R2G		
NCV7420	NCV7420D23R2G NCV7420D24R2G	LIN Transceiver with 3.3 V VReg.	
	NCV7420D25R2G NCV7420D26R2G	LIN Transceiver with 5 V VReg.	
NCV7425	NCV7425DW0R2G	LIN Transceiver with 3.3 V Vreg (150 mA)	
	NCV7425DW5R2G	LIN Transceiver with 5 V Vreg (150 mA)	

Released CAN Products

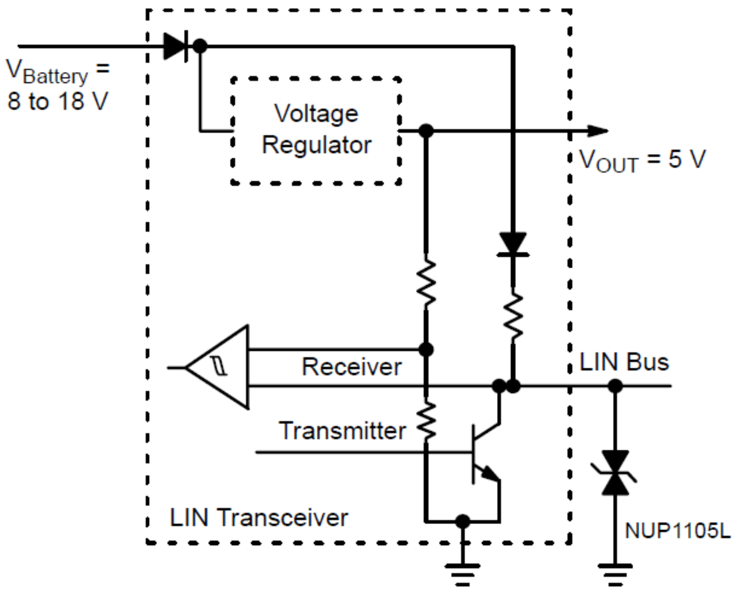
from ON Semiconductor

WPN	OPN (T&R)	Description	Standard
AMIS-30660	AMIS30660CANH2RG	CAN HS Transceiver (5 V)	ISO11898-2
AMIS-30663	AMIS30663CANG2RG	CAN HS Transceiver (3.3 V)	
AMIS-42700	AMIS42700WCGA4RH	Dual CAN HS Transceiver	
AMIS-42665	AMIS42665TJAA1RG	HS LP CAN Transceiver (Level WU - Matte Sn)	ISO11898-5
	AMIS42665TJAA3RL	HS LP CAN Transceiver (Level WU - NiPdAu)	
	AMIS42665TJAA6RG	HS LP CAN Transceiver (Edge WU – GM spec.)	
NCV7340	NCV7340D12R2G	HS LP CAN Transceiver (Level WU)	
	NCV7340D13R2G		
	NCV7340D14R2G	HS LP CAN Transceiver (Edge WU – GM spec.)	
NCV7441	NCV7441D20R2G	Dual HS LP CAN Transceiver	
NCV7341	NCV7341D20R2G	Improved HS LP CAN Transceiver with Error Detection (>6 KV)	
	NCV7341D21R2G	HS LP CAN Transceiver with Error Detection	
AMIS-41682	AMIS41682CANM1RG	CAN LS Transceiver (5 V)	ISO11898-3
AMIS-41683	AMIS41683CANN1RG	CAN LS Transceiver (3.3 V)	
NCV7356	See datasheet (6 versions)	Single Wire CAN	

GIFT/ICT

Released Protection Devices
from ON Semiconductor

NUP1105L



NUP2105L