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”
LIN Overview

- 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.
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.
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)
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)

Message frame

0 = “dominant” state
1 = “recessive” state
Not used = recessive
LIN Reference Information

- www.lin-subbus.org

- LIN Specification Package Revision 2.2
  - Contact: Technical-Contact@lin-subbus.org
CAN Overview

- 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

Message frame for standard format (CAN Specification 2.0A)

Physical CAN Connection according to ISO 11898
CAN - details
Physical Layer(*)

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

(*) 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

![Diagram showing bus arbitration]

Node 3 wins arbitration and transmits his data.
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
- CAN 2.0 Part A (pdf) describing the CAN base frame format
- CAN 2.0 Part B (pdf) describing both base and extended frame formats
FlexRay Overview

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

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

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.
See chapter 8 of FlexRay Protocol Specification
FlexRay Reference Information

- www.flexray.com

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
    - ...

- ESD & EMC testing
  - According to OEM requirements
  - Executed by:
    - IBEE-Zwickau
    - Underwriters Laboratories(UL)
    - ...
<table>
<thead>
<tr>
<th>Bus</th>
<th>LIN</th>
<th>CAN</th>
<th>FlexRay</th>
<th>MOST</th>
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<tr>
<td>Cost/Node [$]</td>
<td>1.50</td>
<td>3.00</td>
<td>6.00</td>
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<td>(ABIreport: Y08)</td>
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<td>Used in</td>
<td>Subnets</td>
<td>Soft real-time</td>
<td>Hard real-time</td>
<td>Multimedia</td>
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<td>Application domains</td>
<td>Body</td>
<td>Powertrain, Chassis ...</td>
<td>Chassis, Powertrain</td>
<td>Multimedia, Telematics</td>
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<tr>
<td>Message transmission</td>
<td>Synchronous</td>
<td>Asynchronous</td>
<td>Synchronous &amp; Asynchronous</td>
<td>Synchronous &amp; Asynchronous</td>
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<td>Message identification</td>
<td>Identifier</td>
<td>Identifier</td>
<td>Time slot</td>
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<tr>
<td>Architecture</td>
<td>Single Master typ. 2…10 slaves</td>
<td>Multi-Master typ. 10…30 nodes</td>
<td>Multi-Master up to 64 nodes</td>
<td>Multi-Master up to 64 nodes</td>
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<td>Access control</td>
<td>Polling</td>
<td>CSMA/CA</td>
<td>TDMA</td>
<td>TDM CSMA/CA</td>
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<tr>
<td>Data Rate</td>
<td>20 kbps</td>
<td>1 Mbps</td>
<td>10 Mbps</td>
<td>24 Mbps</td>
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<td>Physical Layer</td>
<td>Single Wire</td>
<td>Dual-Wire</td>
<td>Dual-Wire (Optical Fiber)</td>
<td>Optical Fiber (Dual-wire)</td>
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<td>Latency Jitter</td>
<td>Constant</td>
<td>Load dependent</td>
<td>Constant</td>
<td>Data stream</td>
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<tr>
<td>Babbling idiot</td>
<td>n/a</td>
<td>Not provided</td>
<td>Provided</td>
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<tr>
<td>Extensibility</td>
<td>High</td>
<td>High</td>
<td>Low</td>
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# Released LIN Products from ON Semiconductor

<table>
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<tr>
<th>WPN</th>
<th>OPN (T&amp;R)</th>
<th>Description</th>
<th>Standard</th>
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<tr>
<td>AMIS-30600</td>
<td>AMIS30600LINI1RG</td>
<td>LIN Transceiver</td>
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<td>NCV7321</td>
<td>NCV7321D10R2G</td>
<td>Stand-alone LIN Transceiver</td>
<td>LINv1.3 LINv2.1 J2602</td>
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<td>NCV7321D11R2G</td>
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<td>NCV7420</td>
<td>NCV7420D23R2G</td>
<td>LIN Transceiver with 3.3 V VReg.</td>
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<td>NCV7420D24R2G</td>
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<td>NCV7420D25R2G</td>
<td>LIN Transceiver with 5 V VReg.</td>
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<tr>
<td>NCV7425</td>
<td>NCV7425DW0R2G</td>
<td>LIN Transceiver with 3.3 V Vreg (150 mA)</td>
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<td>NCV7425DW5R2G</td>
<td>LIN Transceiver with 5 V Vreg (150 mA)</td>
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# Released CAN Products from ON Semiconductor

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<tr>
<th>WPN</th>
<th>OPN (T&amp;R)</th>
<th>Description</th>
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<td>AMIS-30660</td>
<td>AMIS30660CANH2RG</td>
<td>CAN HS Transceiver (5 V)</td>
<td>ISO11898-2</td>
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<td>AMIS-42700</td>
<td>AMIS42700WCGA4RH</td>
<td>Dual CAN HS Transceiver</td>
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<td>AMIS-42665</td>
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<td>HS LP CAN Transceiver (Level WU - Matte Sn)</td>
<td>ISO11898-5</td>
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<td>AMIS42665TJAA3RL</td>
<td>HS LP CAN Transceiver (Level WU - NiPdAu)</td>
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<td>AMIS42665TJAA6RG</td>
<td>HS LP CAN Transceiver (Edge WU – GM spec.)</td>
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<td>NCV7340</td>
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<td>NCV7340D13R2G</td>
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<td>NCV7340D14R2G</td>
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<td>NCV7441</td>
<td>NCV7441D20R2G</td>
<td>Dual HS LP CAN Transceiver</td>
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<td>NCV7341</td>
<td>NCV7341D20R2G</td>
<td>Improved HS LP CAN Transceiver with Error Detection (&gt;6 KV)</td>
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<td>AMIS-41682</td>
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<tr>
<td>NCV7356</td>
<td>See datasheet (6 versions)</td>
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Released Protection Devices
from ON Semiconductor

NUP1105L

NUP2105L
IVN Products & Solutions
from ON Semiconductor

• For more information on IVN products & solutions from ON Semiconductor, visit:
  • Automotive Applications
  • ESD Protection Diodes
  • Data Transmitters & Receivers