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”
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
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

- $V_{sup}$ 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)

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
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
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

Nominal Bus Levels

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

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.
FlexRay – Details

Frame Format

Clock Synchronization

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)
    - …
## Bus - Comparison

<table>
<thead>
<tr>
<th>Bus</th>
<th>LIN</th>
<th>CAN</th>
<th>FlexRay</th>
<th>MOST</th>
</tr>
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<tbody>
<tr>
<td>Cost/Node [$]</td>
<td>1.50</td>
<td>3.00</td>
<td>6.00</td>
<td>4.00</td>
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<tr>
<td>(ABIreport: Y08)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Used in</td>
<td>Subnets</td>
<td>Soft real-time</td>
<td>Hard real-time</td>
<td>Multimedia</td>
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<tr>
<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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<tr>
<td>Message identification</td>
<td>Identifier</td>
<td>Identifier</td>
<td>Time slot</td>
<td></td>
</tr>
<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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<tr>
<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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<tr>
<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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<tr>
<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>
<thead>
<tr>
<th>WPN</th>
<th>OPN (T&amp;R)</th>
<th>Description</th>
<th>Standard</th>
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<tbody>
<tr>
<td>AMIS-30600</td>
<td>AMIS30600LINI1RG</td>
<td>LIN Transceiver</td>
<td>LINv1.3</td>
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<tr>
<td>NCV7321</td>
<td>NCV7321D10R2G</td>
<td>Stand-alone LIN Transceiver</td>
<td>LINv2.1</td>
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<td>NCV7321D11R2G</td>
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<td>J2602</td>
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<td>NCV7420</td>
<td>NCV7420D23R2G</td>
<td>LIN Transceiver with 3.3V VReg.</td>
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<td>NCV7420D24R2G</td>
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<td>NCV7420D25R2G</td>
<td>LIN Transceiver with 5V VReg.</td>
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<td>NCV7420D26R2G</td>
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<tr>
<td>NCV7425</td>
<td>NCV7425DW0R2G</td>
<td>LIN Transceiver with 3.3V Vreg (150mA)</td>
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<td>NCV7425DW5R2G</td>
<td>LIN Transceiver with 5V Vreg (150mA)</td>
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### Released CAN Products from ON Semiconductor

<table>
<thead>
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<th>WPN</th>
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<th>Standard</th>
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<tr>
<td>AMIS-30660</td>
<td>AMIS30660CANH2RG</td>
<td>CAN HS Transceiver (5V)</td>
<td>ISO11898-2</td>
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<td>AMIS-30663</td>
<td>AMIS30663CANG2RG</td>
<td>CAN HS Transceiver (3.3V)</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>
<td>AMIS42665TJAA1RG</td>
<td>HS LP CAN Transceiver (Level WU - Matte Sn)</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>
<td>NCV7340D12R2G</td>
<td>HS LP CAN Transceiver (Level WU)</td>
<td>ISO11898-5</td>
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<td>NCV7340D13R2G</td>
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<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;6KV)</td>
<td>ISO11898-3</td>
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<td>AMIS-41682</td>
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<td>CAN LS Transceiver (5V)</td>
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<td>AMIS-41683</td>
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<tr>
<td>NCV7356</td>
<td>See datasheet (6 versions)</td>
<td>Single Wire CAN</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