Trends in communication technology used in the automotive field

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Technology drivers for automotive systems

Safety
Legislation
Driving Excitement
Consumption
Comfort
Driver Assistance

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Introduction

- The number of communications solutions in the automotive market is increasing.
- Each year, vehicle manufacturers offer more sophisticated models equipped with electronic systems that deal with vehicle safety, telematics, and infotainment.
- There is an ever increasing number of high-tech equipment and digital systems in an automobile and their percentage of the vehicle’s cost increased over one third.
- The cars of the future will undoubtedly have higher performance, low emissions and increased safety than those manufactured today.

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Introduction

The next generation vehicles will be ‘intelligent’, incorporating computers and advanced communications for data exchange with on-road data devices, approaching vehicles and highway management systems.

They will be equipped with a large number of intelligent electronic devices and embedded microcontrollers.

As the number of microcontrollers, wireless sensors and high-rate communication systems used in cars continues to increase, the automobiles can be considered as “computers on wheels”.

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Historical milestones of microprocessors in automotive systems

- 1979: 8Bit µC
  - Start
  - Warmup
  - Acceleration
  - Deceleration Shut-off
  - Spark advance map
  - Revolution limiter

- 1990: 16Bit µC
  - Knock sensor control
  - Boost control
  - Sequential fuel injection
  - Self-diagnosis
  - Camshaft control
  - Canister purge control
  - Lambda control
  - Cruise control

- 2000: 32Bit µC
  - Drive-by-wire
  - Immobilizer
  - On-board-diagnosis
  - Heating of catalytic converter
  - Exhaust Gas Recirculation
  - Secondary air system
  - Automatic transmission control
  - Variable intake
  - Torque control
  - Automatic altitude correction
Introduction

- The automotive design cycle was shortened to 24 to 36 months, to cope with fast technological advances and changes.
- The vehicles of the future will benefit from vehicle-to-vehicle communications to ensure they keep a safe distance from each other to reduce and perhaps eliminate collisions.
- Telematics-driven infotainment services based on Bluetooth wireless and satellite radio drivers will provide drivers and passengers with instant safety, security and communications services.

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Introduction

- The software-defined infotainment systems implementations will ensure flexibility, ease of use and user friendliness.
- The performance of the modern automobiles was tremendously boosted by electronic systems and telecommunications using a combination of embedded hardware and software.
- This lead to improved reliability of cars, safer and more comfortable driving, and increased functionality.

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Introduction

- Several mechanical and hydraulic systems were replaced by mechatronic solutions that use Electronic Control Units (ECUs).
- Also new solutions and systems emerged.
- A few examples are:
  - fuel injection and electronic engine and gear box control
  - electronic driver assistant systems such as,
    - Electronic Stability Program (ESP)
    - Adaptive Cruise Control (ACC)
    - ABS
    - Electronic Brake Force Distribution (EBD)
    - Emergency Brake Assist (EBA)
    - automatic gearbox
    - park/reverse assistance
    - chassis and drivetrain control (e.g. Active Drive)
    - active suspension etc.
Processes managed by a Freescale dedicated microcontroller

Driver assistance applications that became a standard feature

- voice assisted driving directions (navigation systems)
- intelligent headlights
- vehicle failure detection
- dual-zone climate control
- remote keyless entry
- night vision camera
- passenger safety and airbag control including crash preparation systems
- voice recognition
- security alarm systems
- wiper/window control
- tire pressure monitoring
- telematics, etc.

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- A synergic operation is realized by networking between the ECUs supervised by communication protocols.
- The trends for networking materialized into the development of protocols and standards such as
  - Controlled Area Network (CAN)
  - FlexRay
  - Local Interconnect Network (LIN)
  - Time-Triggered Protocol (TTP)
  - MOST etc.

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Introduction

- The data flow between the entities engaged in communications, both inside and with the exterior will increase tremendously.
- This must be supported in a flexible manner in real-time.

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Introduction

- The state-of-art and the complexity of the electronic equipment that has to control an ever increasing number of processes in the car determine:
  - the future communication architecture will most probably be based on a hierarchy of networks exchanging data by backbone communications links.
  - the domains can use dedicated network protocols.

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Hierarchy of n networks

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Steps were undertaken to eliminate or limit the use of mechanical transmissions developing *X-by-Wire* systems

- *Steer-by-Wire*
- *Brake-by-Wire*
- *Throttle-by-Wire*.

For safety reasons, the implementations are not independent ones and should be complemented with traditional mechanical/hydraulic backups.

*Steer-by-Wire* eliminates the steering column, which proved to be very dangerous in the case of a road crash.
An extension from previous multiplex technologies, namely from the various existing CAN and LIN systems to FlexRay can be observed in Fujitsu microcontroller MB91F465XA.

This controller is a single-chip solution that supports the FlexRay protocol specification 2.1 and handles two channels at a maximum transmission rate of 10Mbit/s [9].
The data exchange between the ECUs, sensors and actuators in automobiles is nowadays mainly carried out via Controlled Area Networks (CAN).

CAN is based on a serial communications protocol oriented to real-time applications and in its most recent version achieves data transfer rates ~ 1 MB/s.

The protocol allows communication with automotive sensors and actuators using a single multiplexed communication bus.

Its main advantage resides in reducing the wiring costs of a classical multipoint control system.

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CAN does not use a physical address for the control system devices.

The message flow is managed using a priority identifier, which gives bus access to messages with higher priority.

The message identifier, offers four possibilities:
- data frame
- remote frame
- error frame
- overload frame.
The network nodes are in a ‘bus hearing state’ and examine the identifier to determine which one of them is the recipient of the message for processing.

The physical layer of CAN is defined by the standard ISO 11898.

A widely used IC for the interface between the CAN controller and the physical bus is the PCA82C250 by Philips.

**CAN-Conclusions**

- The introduction of the new *x-by-wire* systems results in increased requirements especially with regard to error tolerance and time-determinism of message transmission.
- The ever increasing numbers of microcontrollers and ECUs used in a modern vehicle made CAN overwhelmed and pushed for new higher speed buses.
LIN

- Local Interconnect Network (LIN)
- It represents a simple and low-cost technology used at car body level.
- LIN is based on a serial bus architecture.

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Format of a LIN frame

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The ratio of average signal power to average ICI power

- The introduction of the new *x-by-wire* systems results in increased requirements especially with regard to error tolerance and time-determinism of message transmission.

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Flex Ray

- Flex Ray is a deterministic and fault-tolerant serial bus system for use in very safety-critical use areas in the automobile on fiber optic channel that is twenty times faster than the conventional CAN bus system.
- It was proposed by a consortium founded by BMW, Robert Bosch, DaimlerChrysler and Philips in 2000.
- It was also promoted by General Motors, Hyundai Kia Motors, Motorola, Freescale, NXP Semiconductors, and Philips.

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Flex Ray

- a standard communications protocol intended for use in safety critical, fault-tolerant systems.
- developed to satisfy several requirements such as flexibility, composability, and security.
- use of a combined approach using:
  - a static segment (time-triggered approach) that provides message transmission in predefined time slots on the FlexRay bus
  - a dynamic segment (event-triggered approach) that gives flexibility for event triggered messages.

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Flex Ray Features

- high speed serial data transfer rates with an upper bound of 10 Mbps;
- time triggered bus;
- an optional event-triggered scheme;
- fault tolerant communication between participant electronic devices.
- To increase safety, redundancy is added by using a second Flex Ray communication channel as a back-up

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Flex Ray

- The time-triggered approach provides deterministic behavior with:
  - predefined latencies
  - avoidance of bus overloads
  - some fault tolerance by redundant message transmission on two channels
- These advantages and its baud rates of up to 10Mbits/s recommend it for advanced future automotive applications, such as Steer-by-Wire and Brake-by-Wire.

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Flex Ray

- FlexRay can use active and passive star bus topologies, as well as mixed topologies for data transmission.
- The topology of FlexRay is based on point-to-point connections with active stars that result in:
  - optimized EMC;
  - defined electrical behavior;
  - error limitations to affected branches only;
  - minimized reflections due to ideal bus terminations and flexible expandability.

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Active star connections and transfer functionality

PEGASUS Project

- Launched by TTTech Automotive in cooperation with Audi
  - to integrate several safety-relevant chassis applications in an Audi S4 Avant concept car
  - to demonstrate the benefits of FlexRay over CAN.
- aimed at interconnecting different data bus systems within the car and integration of existing ECUs and software within FlexRay technology.
- Flex Ray controls the optical bus system of the Adaptive Drive chassis control system
- Flex Ray drives the stabilisers and electromagnetic valves of the dampers, reducing the effect of body roll on the vehicle

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Driverless cars

- In the near future driverless cars with robotic chauffeurs will be made possible
  - thanks to the GPS system
  - based on a completely electronic car/driver interface
  - using high speed data communications, such as FlexRay

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Autonomous Robotic Cars

- **Shelley** is an autonomous robotic car that will participate to Colorado's Pikes Peak race in the second half of 2011.
- differential GPS determining the car's position on the Earth with an accuracy of about 2cm.
- wheel-speed and acceleration sensors gyroscopes, to control equilibrium and direction.

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Shelley – a robotic Audi TTS

FlexRay Nodes

- host - user software which controls the communication process;
- communication controller (CC) - an electronic component in a node that is responsible for implementing the protocol aspects of the FlexRay communications system;
- bus guardian (BG) - an electronic component which protects slots against faulty media access and is optional
- bus driver (BD) - a transmitter and a receiver that connects a communication controller to one communication channel.
The communication takes place in the periodic equal length cycles.

One communication cycle consists of four segments. Each communication cycle contains:
- static segment (ST)
- dynamic segment (DYN)
- symbol window (SW)
- network idle time (NIT).

A time division multiple access (TDMA) scheme is used for ST. ST is consisted of specific number of cycles (designated by global configuration parameter gdStaticSlot) of static equal-length.
FlexRay Timing Hierachy

- DYN is operated by a flexible time division multiple access (FTDMA) scheme and is optional element for non-periodic communication.
- DYN is consisted of specific number of minislots (designated by global configuration parameter gNumberOfMinislots).

- SW is used for run time tests
- NIT is a communication free period that concludes every communication cycle.

Message Handler (MHD)

- MHD module controls the handling of messages and functions such as:
  - acceptance filtering
  - transfer of messages between FlexRay channels
  - maintenance of the transmission schedule.
- The CPU accesses and controls the MHD and other units of the FlexRay controller, like the global time unit or interrupt control, through dedicated registers.

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FlexRay

- Max data field length = 12B
- Schedule determined at runtime;
- Event channel in parallel – two recurring intervals
  - synchronous for high priority
  - asynchronous for low priority
- Asynchronous messages controlled by Byteflight “minislotting” protocol.

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FR Frames

<table>
<thead>
<tr>
<th>ID</th>
<th>MUX</th>
<th>SYNC</th>
<th>LEN</th>
<th>DATA</th>
<th>CRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 bit</td>
<td>1 bit</td>
<td>1 bit</td>
<td>4 bit</td>
<td>0...12 byte</td>
<td>16 bit</td>
</tr>
</tbody>
</table>

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Nissan engineers said that the battery pack effort "was the largest-scale engineering focus we've ever had on a single technology, outside of engine design."

(Photo courtesy of Nissan)

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Unlike EVs that placed batteries in the back seat and trunk, the Nissan Leaf’s pack is made up of 48 stackable lithium-ion modules that reside under the floor. The resulting battery pack can take the car as much as 100 miles between charges, without clogging up valuable space in the back seat or trunk.
A dashboard energy monitor on the Prius plug-in hybrid will tell drivers how energy is being parceled between the pure electric mode and the hybrid mode. The device can be programmed to provide a breakdown of the energy percentages during any ride.

(Photo courtesy of Toyota)

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The Prius plug-in hybrid, due out in 2012, will use a 5.2kWh lithium-ion battery, which is relatively small by electric car standards.

To prevent overheating, Toyota engineers developed a complex cooling system that employs three fans and 42 temperature sensors.

(Figure courtesy of Toyota)

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Paul Braun, a professor of material science at the University of Illinois, says his structure could enable users to boost energy without sacrificing power. Braun’s three-dimensional open foam structure promotes efficient ion transfer, which translates to greater power and faster recharge times.

“Our system is particularly good at producing high peak power — anywhere from 10 to 100 times greater than the power of a conventional rechargeable battery,” he told. “For systems where you want a lot of power relative to the size of the battery, there’s a definite advantage.”

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**UWB Vehicular Radar**

**Road Conditions Sensing**

- UWB radar has the resolution to sense road conditions (i.e. potholes, dips, bumps, gravel vs. pavement).
- Information to dynamically adjust suspension, braking, and other drive systems.
Conclusions

- The number of calibration parameters in an engine management system is rising and so is the number of microcontrollers used in a modern car.
- This requires a fast data exchange between the ECUs, sensors and actuators.
- There is a definite migration from previous multiplex technologies, namely from the various existing CAN and LIN systems to FlexRay, in order to eliminate or limit the use of mechanical transmissions that are being replaced by X-by-Wire systems.

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Conclusions

- The number of calibration parameters for example in an engine management system has risen within the last 20 years from a few hundred to over 7000.
- Therefore, the engineering effort for software and their calibration has increased dramatically.
- The future challenge will be the re-use of software functions engineered by manufacturers and suppliers for different vehicles and systems.
- In the automotive industry this attempt is being undertaken by different companies under the name AUTOSAR.

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Inter- or intra-ECU communication services described by AUTOSAR

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Thank you!

Questions?

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