Controller Area Network (CAN)
Presentation Goals

• CAN Introduction
  – Overview
  – History

• CAN Characteristics
  – OSI Model
  – Physical Layer
  – Transmission Characteristics

• Message Format
  – Bus Arbitration
  – Error Handling

• Miscellaneous
Overview

• It is an advanced serial bus system that efficiently supports distributed control systems.
• CAN Specification
  – Specified by Robert Bosch GmbH, Germany
  – Late 1980
• Internationally standardized
  – ISO and Society of Automotive Engineers (SAE)
  – ISO 11898
Intra-vehicular Communication

• A typical vehicle has a large number of electronic control systems

• The growth of automotive electronics is a result of:
  – Customers wish for better comfort and better safety.
  – Government requirements for improved emission control
  – Reduced fuel consumption

• Control systems com
  – Engine timing
  – Gearbox and carburetor throttle control
  – Anti-block systems (ABS)
  – Acceleration skid control (ASC)
How it all began...

- Engine Control
- Anti-Lock Brakes
- Lighting
- Dashboard
- Active Suspension
- Power Seats
- Transmission Control
- Power Locks
- Air Conditioning
- Airbag
- Power Windows
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How it all began... (cont.)
CAN Features

- Physical medium – two wires terminated at both ends by resistors.
- Differential signal - better noise immunity.
- Benefits:
  - Reduced weight, Reduced cost
  - Fewer wires = Increased reliability

Conventional multi-wire looms vs. CAN bus network

History

• 1983 : First CAN project at Bosch
• 1986 : CAN protocol introduced
• 1987 : First CAN controller chips sold
• 1991 : CAN 2.0A specification published
• 1992 : Mercedes-Benz used CAN network
• 1993 : ISO 11898 standard
• 1995 : ISO 11898 amendment
• Present : The majority of vehicles use CAN bus.
OSI Model

• Protocol uses Data Link Layer and Physical Layer
### Description of OSI layers

The recommendation X.200 describes seven layers, labeled 1 to 7. Layer 1 is the lowest layer in this model.

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Basic Concepts

• Multi-master bus
• No node addressing
  – Message identifier specifies content & priority
• Easy connection/disconnection of nodes
• Multicasting and Broadcasting capability
Basic Concepts (cont.)

• Sophisticated Error Detection/Handling
• NRZ Code + Bit Stuffing for Synchronization
• High data transfer rate of 1.0 Mbps
  – 40 m using twisted wire pair.
• Message length (Max. 8 bytes payload)
• Advanced Serial Communication
  – Bus access via Carrier Sense Multiple Access/Collision Detection with Non-Destructive Arbitration (CSMA/CD w/AMP (Arbitration on Message Priority)
Differential Signals
Differential Signals

![Diagram of differential signals](image)

Sender

Receiver

Noise

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Physical CAN connection

Physical CAN Connection according to ISO 11898

EMI

U_{Diff}
Transmission Characteristics

• Up to 1 Mbit/sec.
• Common baud rates: 1 MHz, 500 KHz and 125 KHz
• All nodes – same baud rate
• Max length: 120’ to 15000’ (rate dependent)
Message Oriented Transmission Protocol

- Each node – receiver & transmitter
- A sender of information transmits to all devices on the bus
- All nodes read message, then decide if it is relevant to them
- All nodes verify reception was error-free
- All nodes acknowledge reception

Node A: Important message from the speed wheel sensor! Wheel speed is 100 rpm.

Node B: Not for me.

Node C: Got it.

CAN bus
Basic Concepts - Signals

CAN Bus Characteristics – Wired-AND

• Two bus states
  – Dominant “0”
  – Recessive “1”

• Bus Logic
  – Wired-AND mechanism
  – Dominant bits overwrite recessive bits

“1” recessive
“0” dominant

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Frame Formats

• Data Frame
• Remote Frame
• Error Frame
• Overload Frame
• Inter-frame Space
Each message has an ID, Data and overhead.

- Data – 8 bytes max
- Overhead – start, end, CRC, ACK
Example of Message Transaction

- Instrument panel ECU says “can anyone tell me what the block temperature is?”
  ID: 400
  Data: 0

- Block ECU sees this message and issues a message “block temperature is 76 Celsius”
  ID: 400
  Data: 076

- Instrument panel ECU sees block temperature message and displays it on console
Bus Arbitration

• Message importance is encoded in message ID.
  Lower value = More important
• As a node transmits each bit, it verifies that it sees the same bit value on the bus that it transmitted.
• A “0” on the bus wins over a “1” on the bus.
• Losing node stops transmitting, winner continues.
MAC protocols which suffers from bandwidth degradation when a collision occurs. CAN does not. There is no wastage of bandwidth.

Hence, CAN achieves 100% bandwidth utilization.
Error Detection

• **CRC – Cyclic Redundancy Check**
  – Checksum is calculated by both transmitter and receiver. Checksum must match.

• **Acknowledge**
  – A frame must be acknowledged by at least one other node.

• **Frame Check – Form Error**
  – No dominant bits allowed in CRC Delimiter, ACK Delimiter, End-of-Frame and Intermission

• **Bit Monitoring**
  – A transmitted bit must be correctly read back from the CAN bus.
  – Dominant bits may overwrite recessive bits only in the Arbitration Field and in the Acknowledge Slot.

• **Bit Stuffing Check**
  – 6 consecutive bits with same polarity are not allowed between Start of Frame and CRC Delimiter.
Error Handling

- Detected errors are made public to all other nodes via Error Frames
- The transmission of the erroneous message is aborted and the frame is repeated as soon as possible.

Reliability - Undetected Errors
- Example: Vehicle with CAN running 2000 hours/year at 500 kbps with 25% bus load.
- Results in 1 undetected error every 1000 years.
CAN Protocol Versions

• Two CAN protocol versions
  – V2.0A (Standard) – 11 bit Message IDs – 2048 IDs available.
  – V2.0B (Extended) – 29 bit Message IDs – more than 536 Million IDs available.
Bit Construction

- One bit time is composed of four segments
  - Synchronization Segment – an edge must lie in this segment
  - Propagation Segment – compensate for physical delays
  - Phase Segments – compensate for edge phase errors

```
    sync_seg  |  prop_seg   |  phase_seg1 |  phase_seg2
```

Sample point

Figure 13.12 Nominal bit time
CAN Bus Connectors

• Mainly implemented on DSUB 9 connector (DB9).
• CAN_L on pin 2.
• CAN_H on pin 7
CAN Transceivers

• Microchip MCP2551
• NXP (Philips) TJA1050
• Texas Instruments
• Linear Technology
The CAN module is called “MSCAN” from MC9S12C Family Reference Manual.
Summary

• CAN bus – Controller Area Network bus
• Primarily used for building ECU networks in automotive applications.
• Two wires
• OSI - Physical and Data link layers
• Differential signal - noise immunity
• 1Mbit/s, 120’
• Messages contain up to 8 bytes of data
• CAN is being replaced by FlexRay for high speed critical applications (engine & transmission control)