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

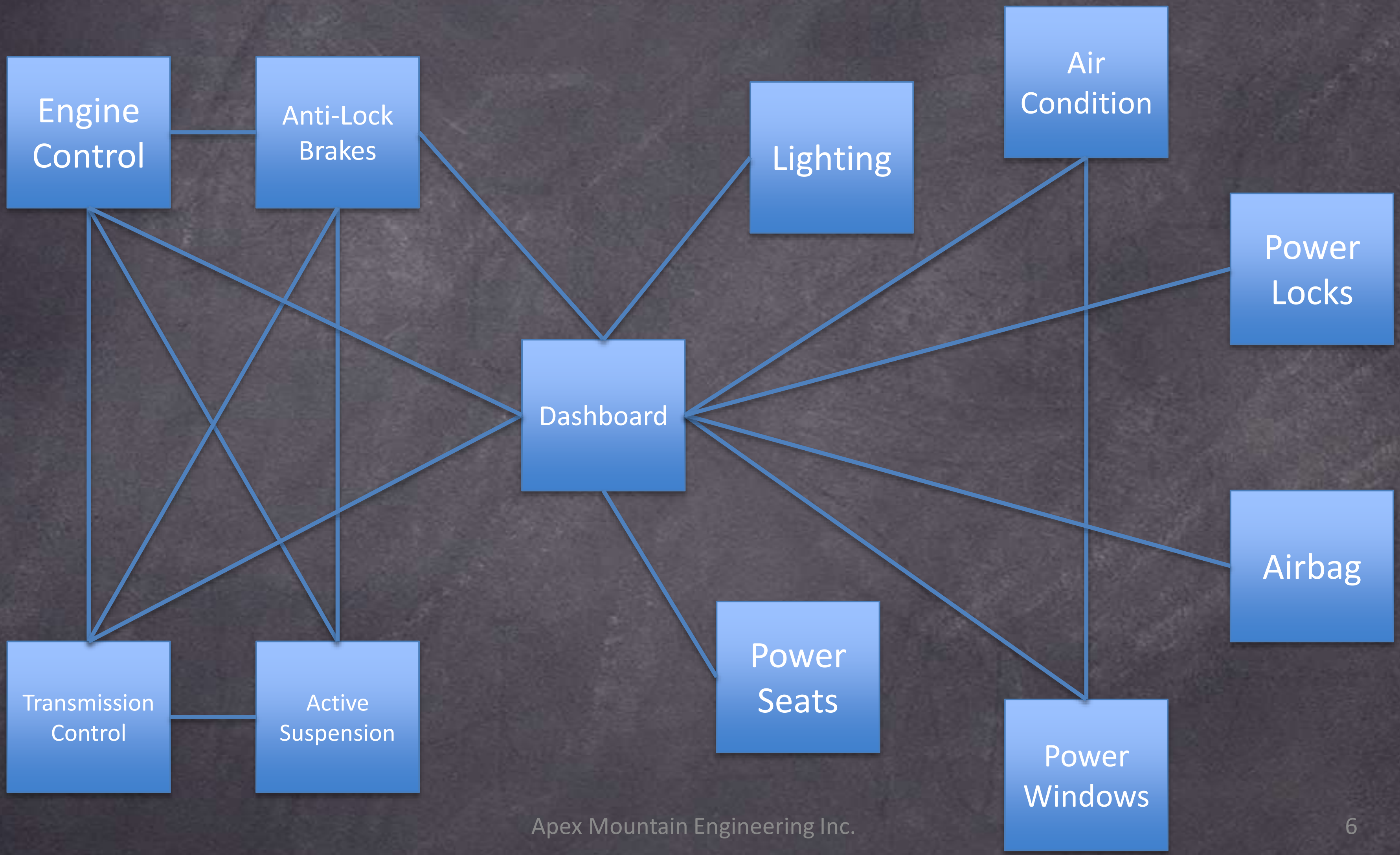
- The growth of automotive electronics is a result of:
  - Customers wish for better comfort and better safety.
  - Government requirements for improved emission control
  - Reduced fuel consumption

- Control systems com
  - Engine timing
  - Gearbox and carburetor throttle control
  - Anti-block systems (ABS)
  - Acceleration skid control (ASC)

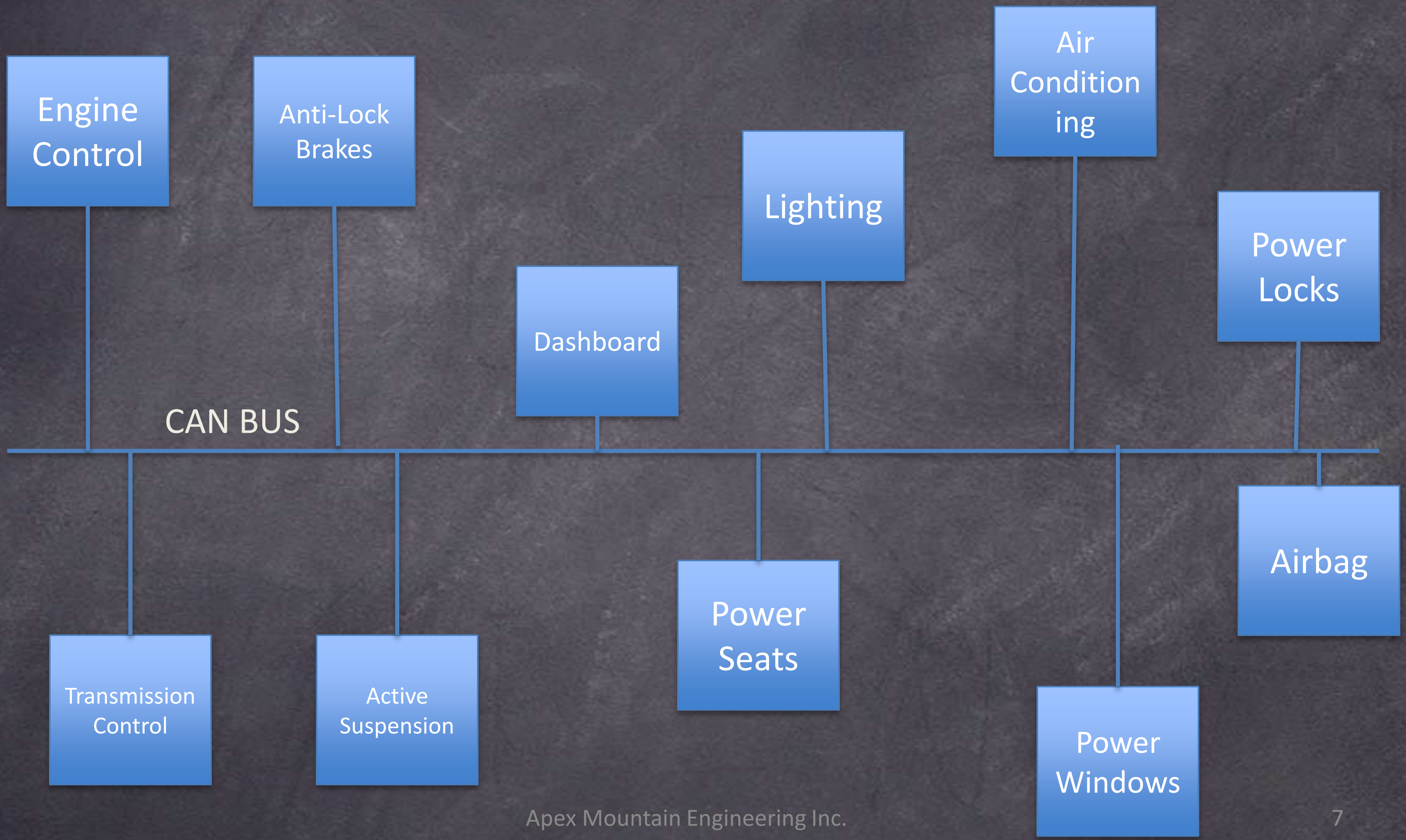
How it all began…

- Engine Control
- Anti-Lock Brakes
- Lighting
- Air Conditioning
- Power Locks
- Dashboard
- Airbag
- Transmission Control
- Active Suspension
- Power Seats
- Power Windows

How it all began…



How it all began… (cont.)



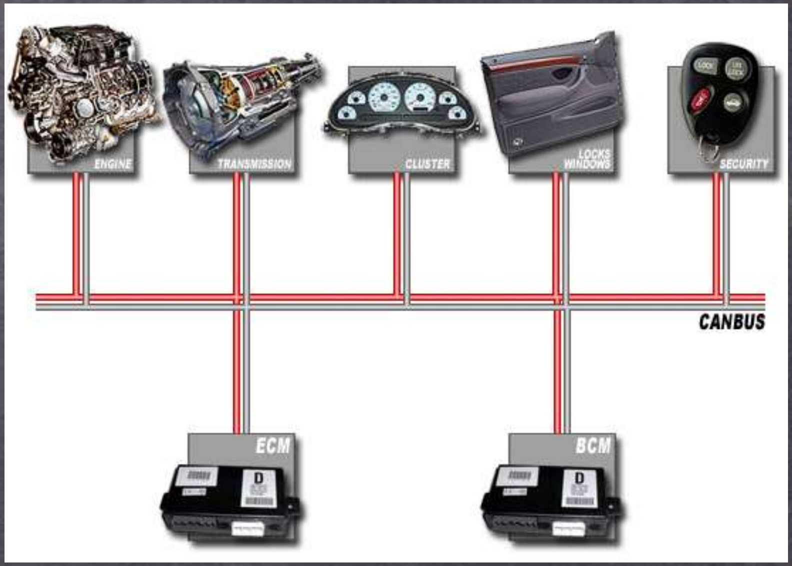
CAN Features

- 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



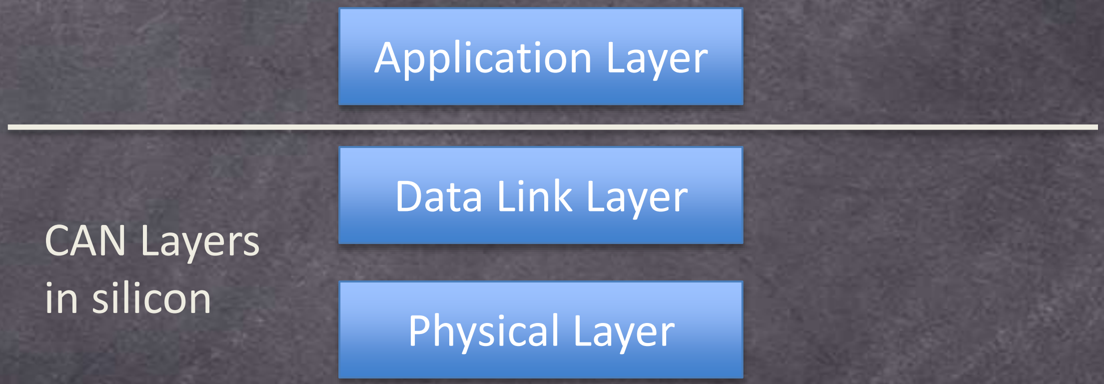
http://canbuskit.com/what.php

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 [edit]

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

OSI Model				
Layer		Data unit	Function[3]	Examples
Host layers	7. Application	Data	High-level APIs, including resource sharing, remote file access, directory services and virtual terminals	HTTP, FTP, SMTP
	6. Presentation		Translation of data between a networking service and an application; including character encoding, data compression and encryption/decryption	ASCII, EBCDIC, JPEG
	5. Session		Managing communication sessions, i.e. continuous exchange of information in the form of multiple back-and-forth transmissions between two nodes	RPC, PAP
	4. Transport	Segments	Reliable transmission of data segments between points on a network, including segmentation, acknowledgement and multiplexing	TCP, UDP
Media layers	3. Network	Packet/Datagram	Structuring and managing a multi-node network, including addressing, routing and traffic control	IPv4, IPv6, IPsec, AppleTalk
	2. Data link	Bit/Frame	Reliable transmission of data frames between two nodes connected by a physical layer	PPP, IEEE 802.2, L2TP
	1. Physical	Bit	Transmission and reception of raw bit streams over a physical medium	DSL, USB

From: http://en.wikipedia.org/wiki/OSI_model

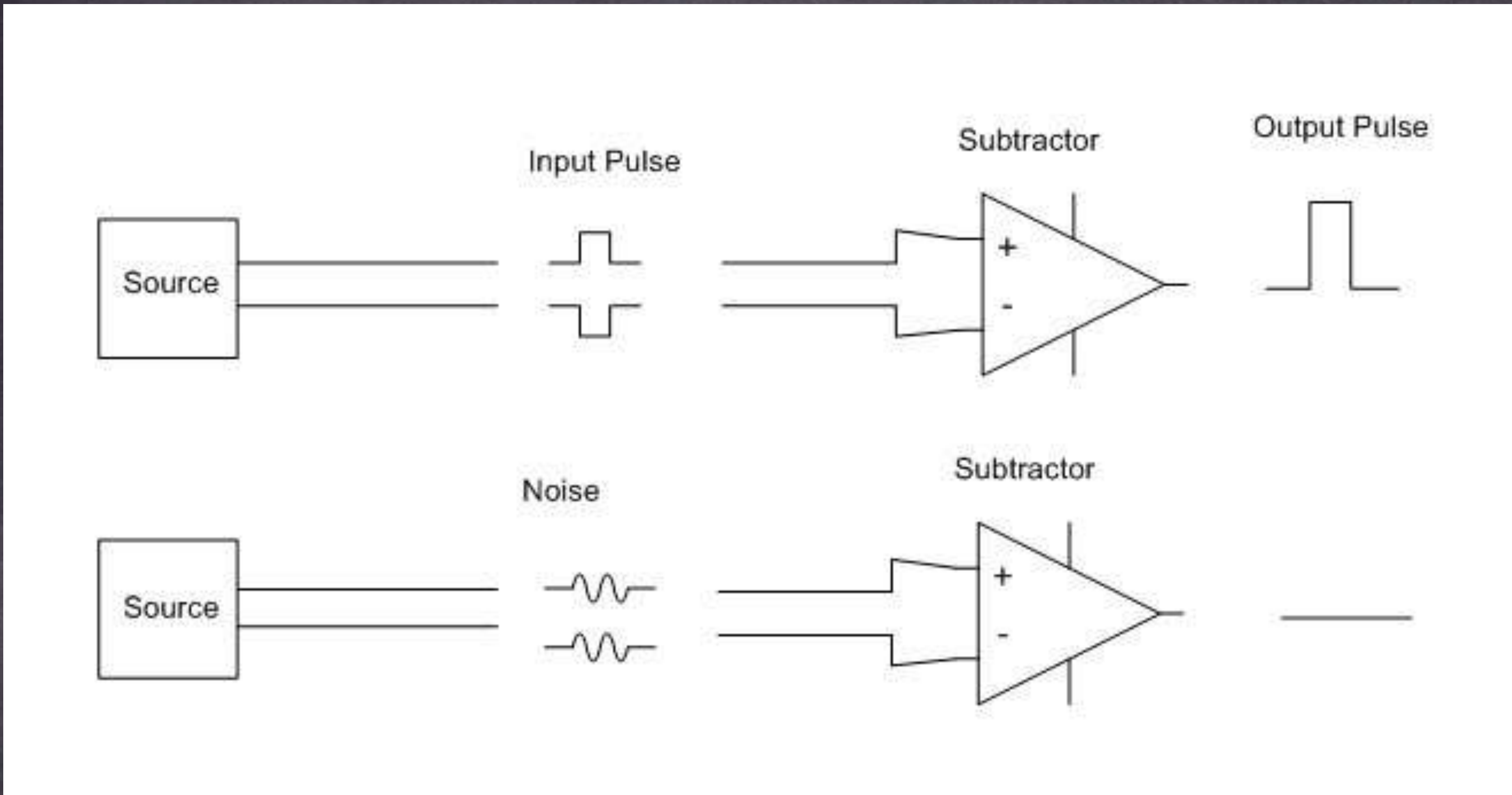
Basic Concepts

- Multi-master bus
- No node addressing
  - Message identifier specifies content & priority
- Easy connection/disconnection of nodes
- Multicasting and Broadcasting capability

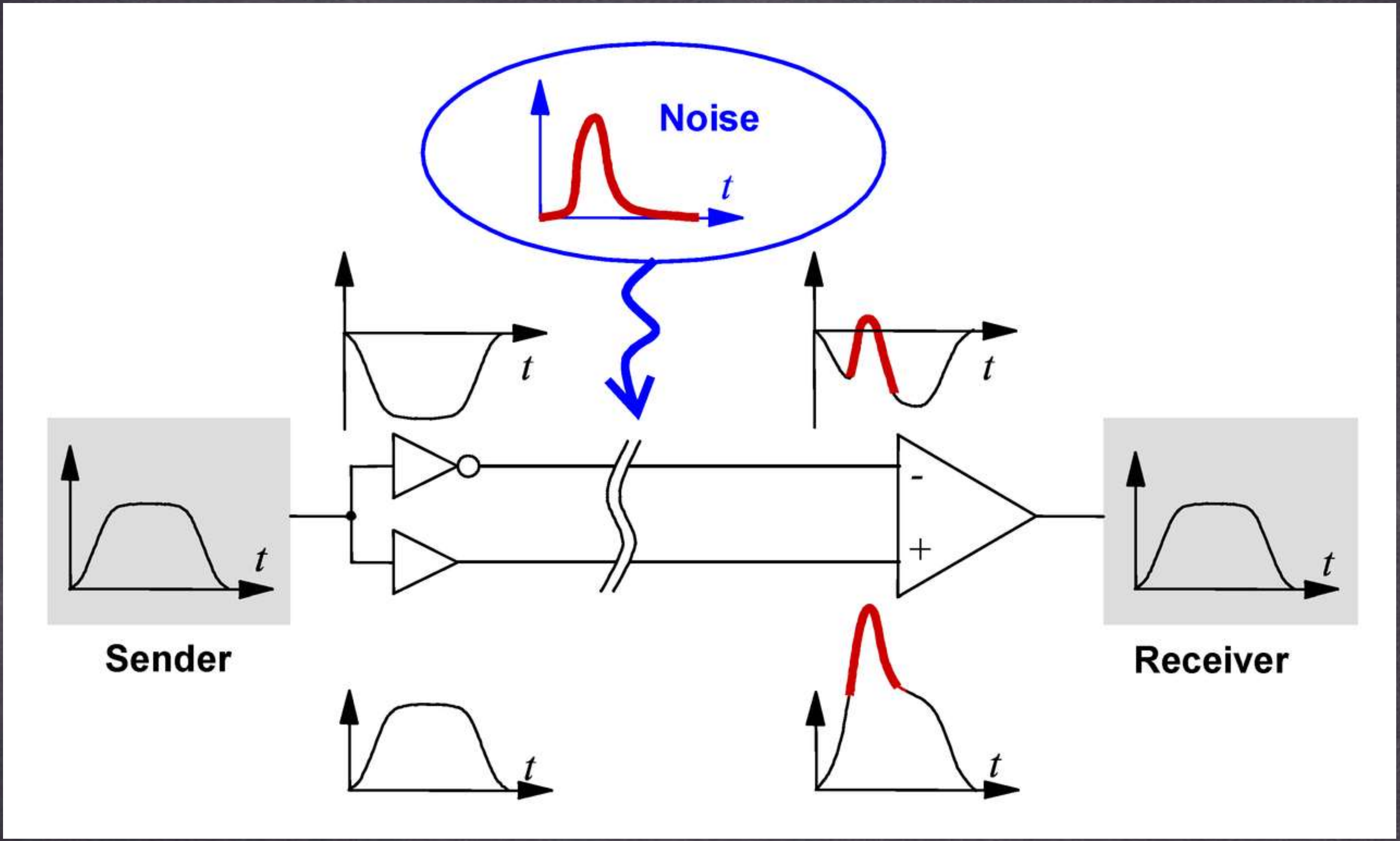
Basic Concepts (cont.)

- 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)

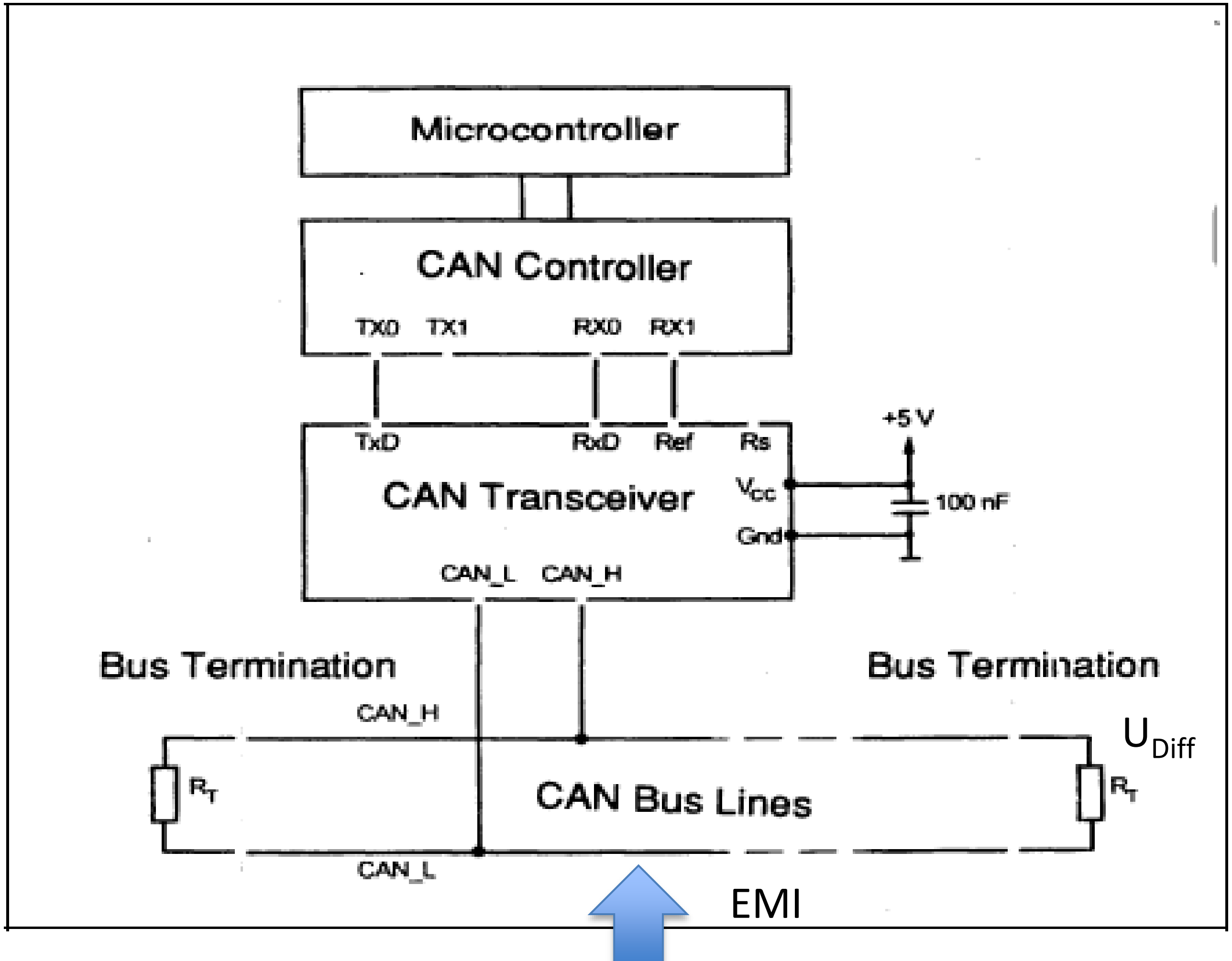
Differential Signals



Differential Signals



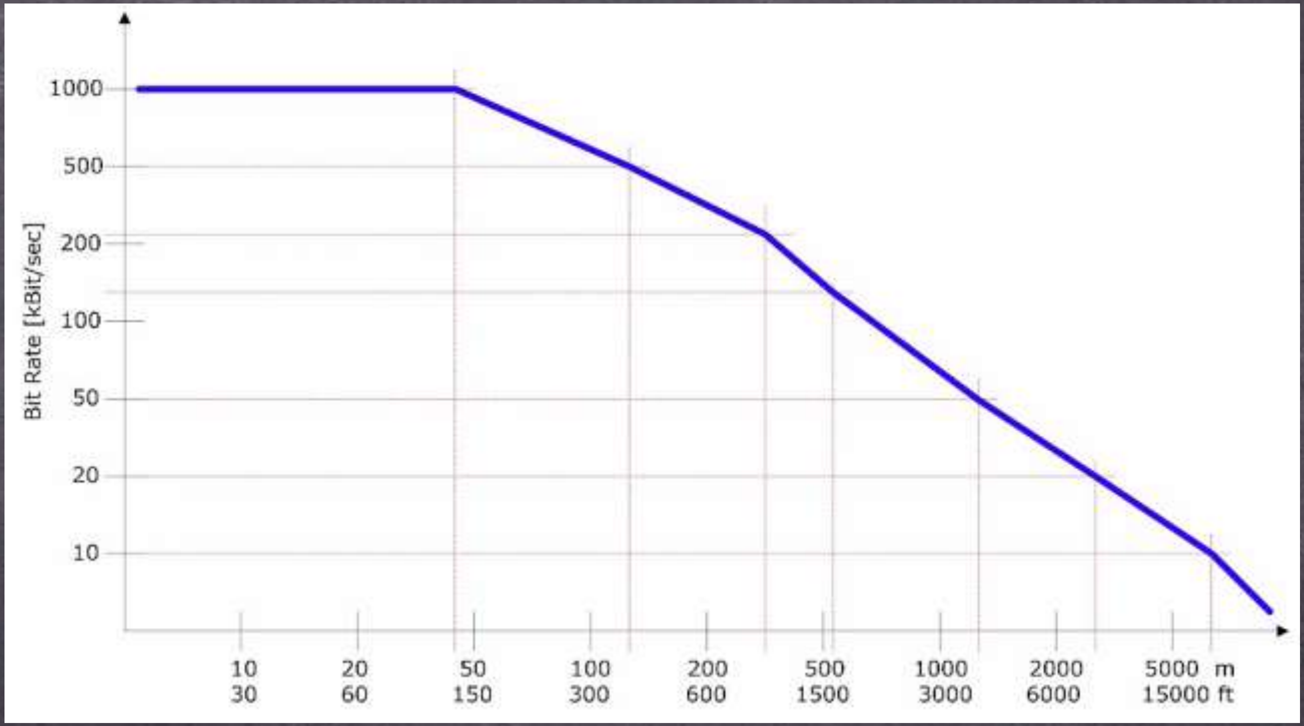
Physical CAN connection



Physical CAN Connection according to ISO 11898

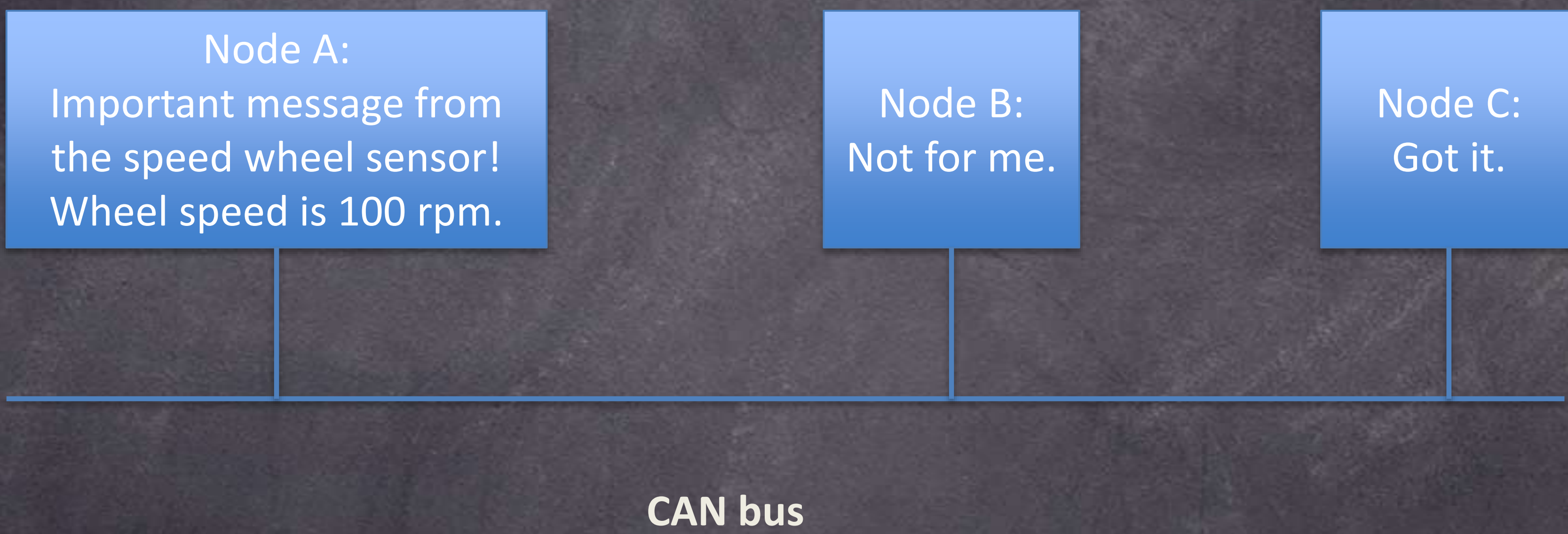
Transmission Characteristics

- 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



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

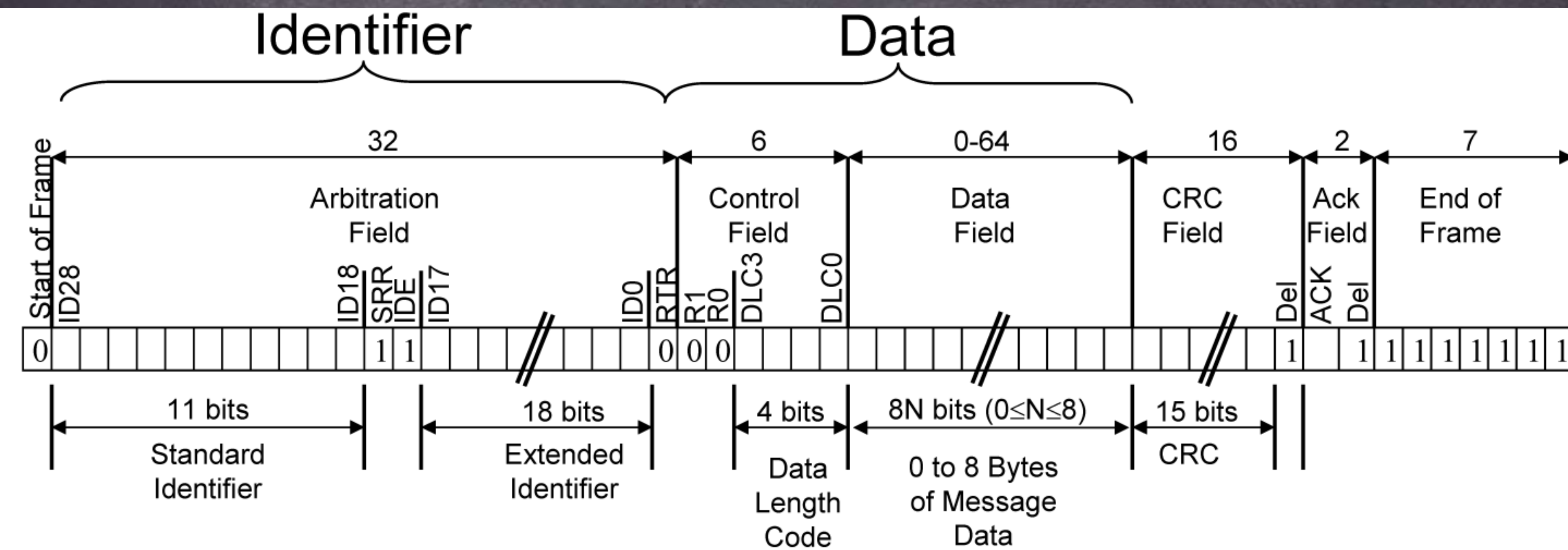
“0” dominant

Frame Formats

- Data Frame
- Remote Frame
- Error Frame
- Overload Frame
- Inter-frame Space

Message Format

- Each message has an ID, Data and overhead.
- Data – 8 bytes max
- Overhead – start, end, CRC, ACK



21

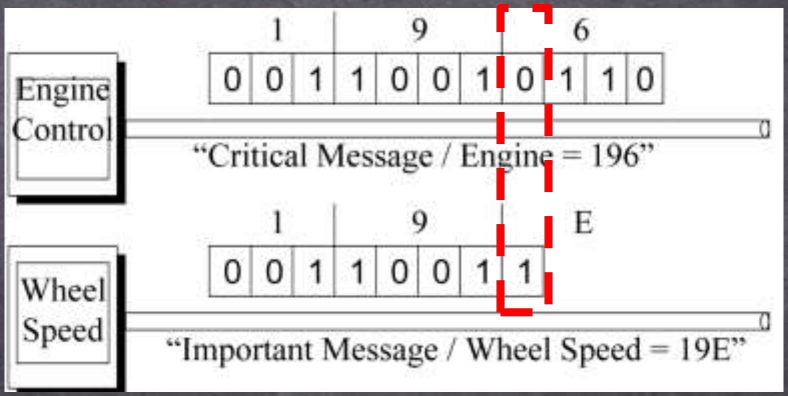
Example of Message Transaction

	ID	Data
▪ Instrument panel ECU says "can anyone tell me what the block temperature is?	400	
▪ Block ECU sees this message and issues a message "block temperature is 76 Celsius"	400	076
▪ Instrument panel ECU sees block temperature message and displays it on console		

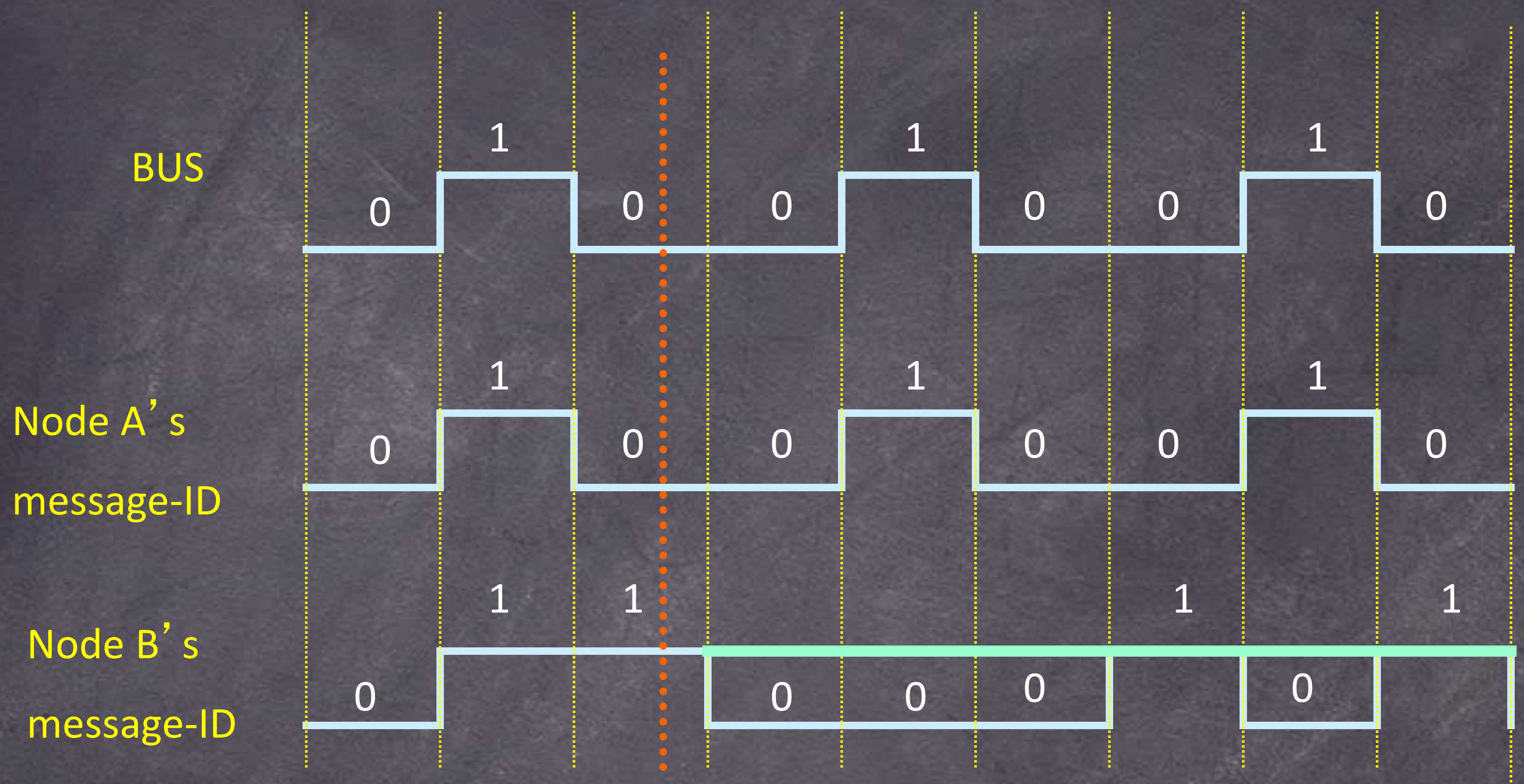
Bus Arbitration

- 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.



Implicit collision handling in the CAN bus: example



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
- Each segment is an integer number of time quanta (TQ)
  - Synchronization Segment – an edge must lie in this segment
  - Propagation Segment – compensate for physical delays
  - Phase Segments – compensate for edge phase errors

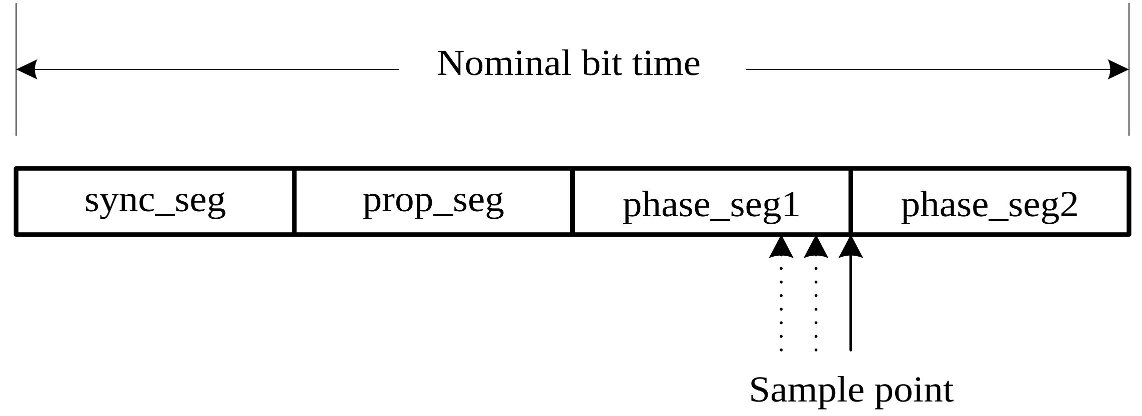


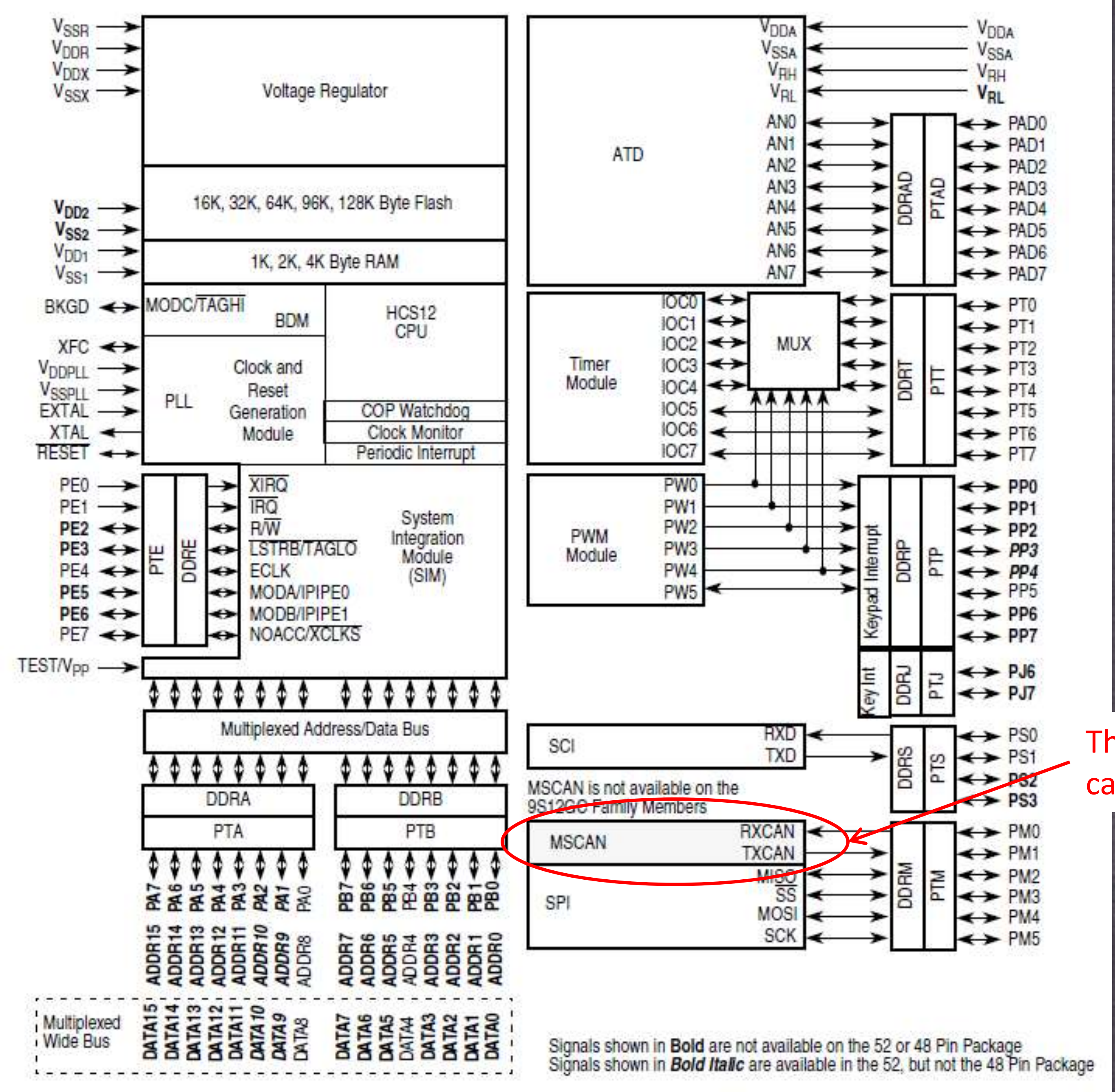
Figure 13.12 Nominal bit time

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 – **C**ontroller **A**rea **N**etwork 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)