SAE J1939

Serial Control and Communications Vehicle Network

COPPERHILL technologies

SAE J1939

Serial Control and Communications Vehicle Network

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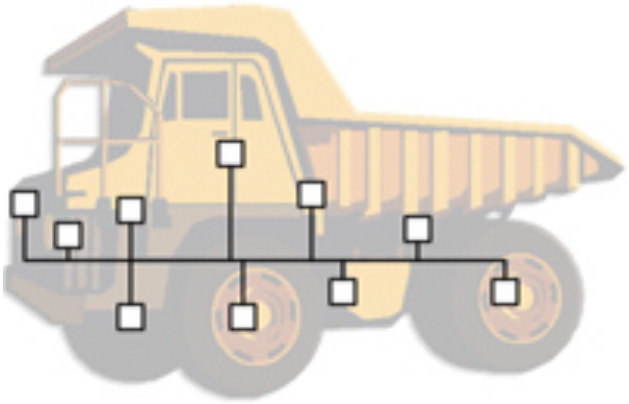
https://copperhilltech.com

Literature

Literature on
Controller Area Network,
CANopen and SAE J1939

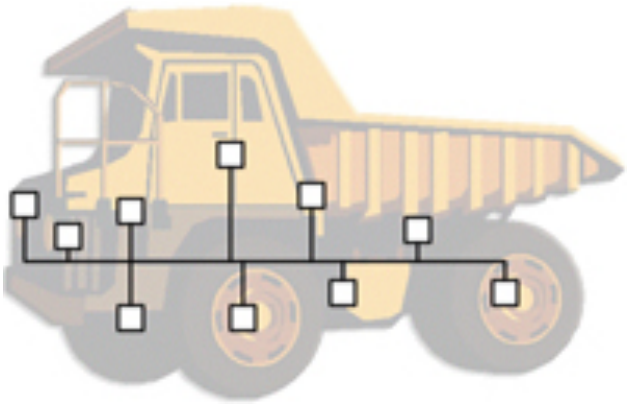
https://copperhilltech.com/technical-literature/

What is SAE J1939 – General Aspects



- Higher-layer protocol based on Controller Area Network (CAN)
- Provides serial data communications between Electronic Control Units (ECU) in any kind of heavy duty vehicles.
- Protocol features based on J1708 (RS485) + J1587
- Ingenious protocol design with very little protocol overhead
- Driven by data, not myriad of functions as other HLPs
- Takes full advantage of all CAN features
- Detailed documentation only available through SAE

SAE J1939 Applications

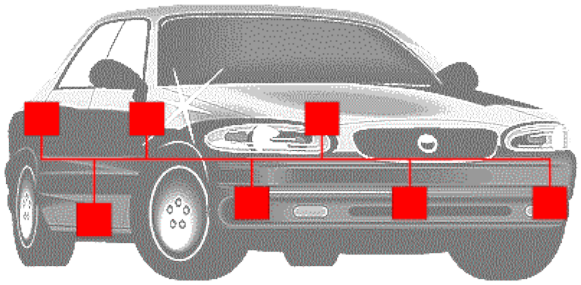


J1939-based protocols are used in:

- Diesel power-train applications
- In-Vehicle networks for trucks and buses
- Agriculture and forestry machinery (ISO 11783)
- Truck-Trailer connections
- Military vehicles (MiLCAN)
- Fleet management systems
- Recreational vehicles
- Marine navigation systems (NMEA2000)

What is CAN – General Aspects

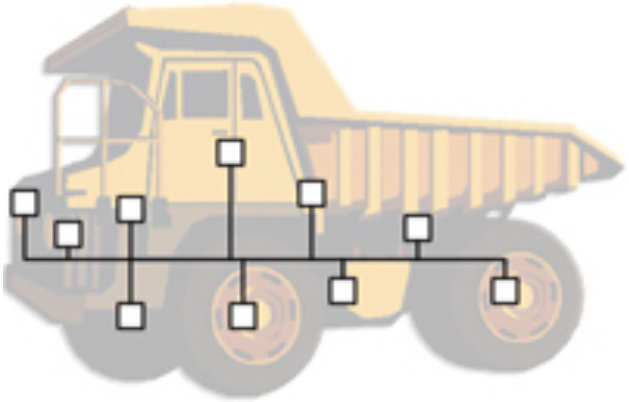
- Serial Network Technology for Embedded Solutions



- Originally designed by Bosch for automotive industry
- Became very popular in industrial automation

- Network technology established among micro-controllers
- Well suited for high speed/real-time applications
- Replaces expensive Dual-Port RAM technology
- Excellent error detection and fault confinement
- Extremely reliable
- Max. baud rate of 1 MBit/sec – SAE J1939 uses 250/500 kBit/sec

SAE J1939 – Quick Reference



J1939 takes advantage of CAN features such as:

- Maximum reliability
- Excellent error detection & fault confinement
- Collision-free bus arbitration

J1939 Specifics:

- Shielded twisted pair wire
- Max. network length of 40 meters (~120 ft.)
- Standard baud rate of 250/500 kBit/sec
- Uses 29-Bit Message ID
- Max. 30 nodes (ECUs) in a network

SAE J1939 – Quick Reference

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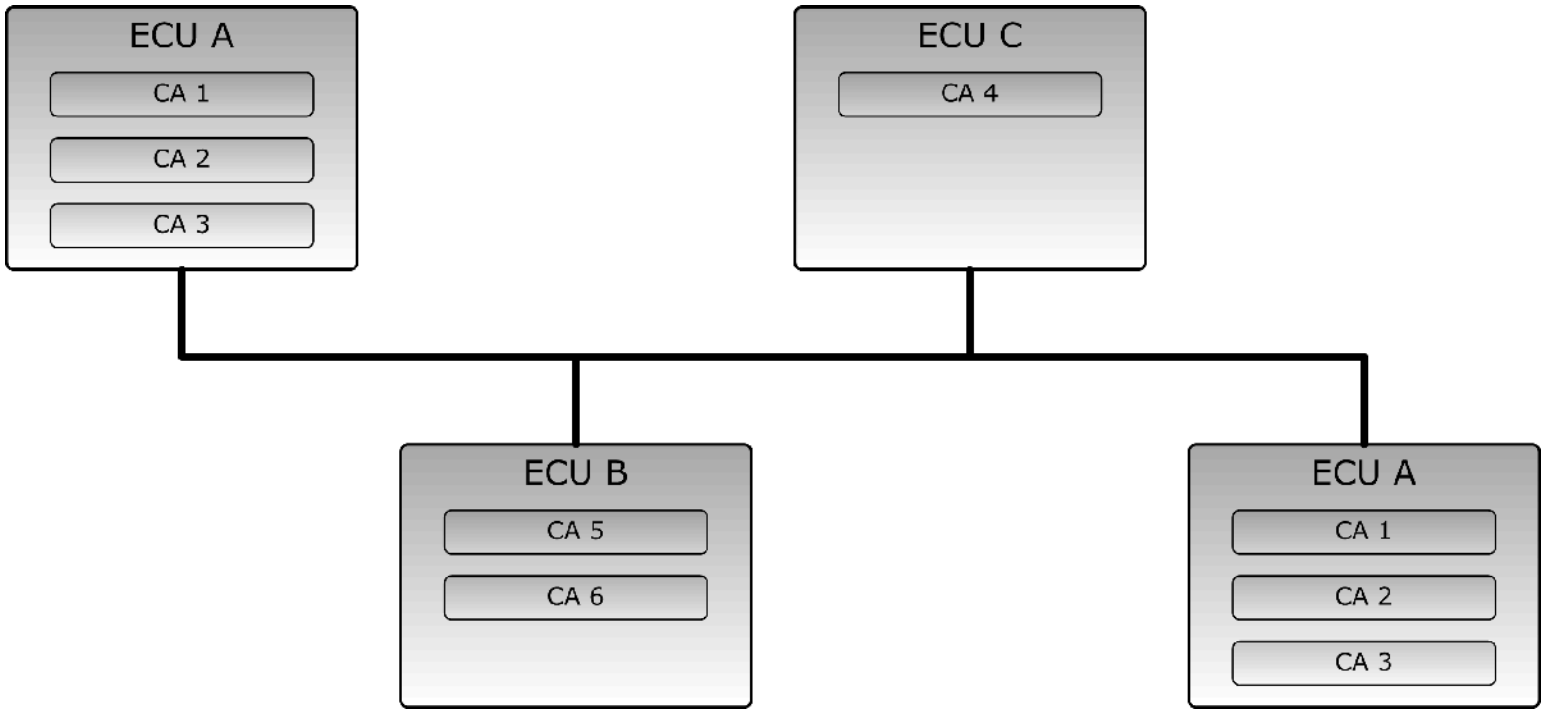
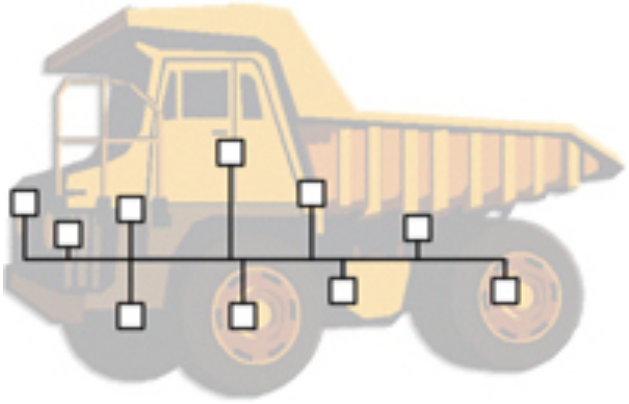


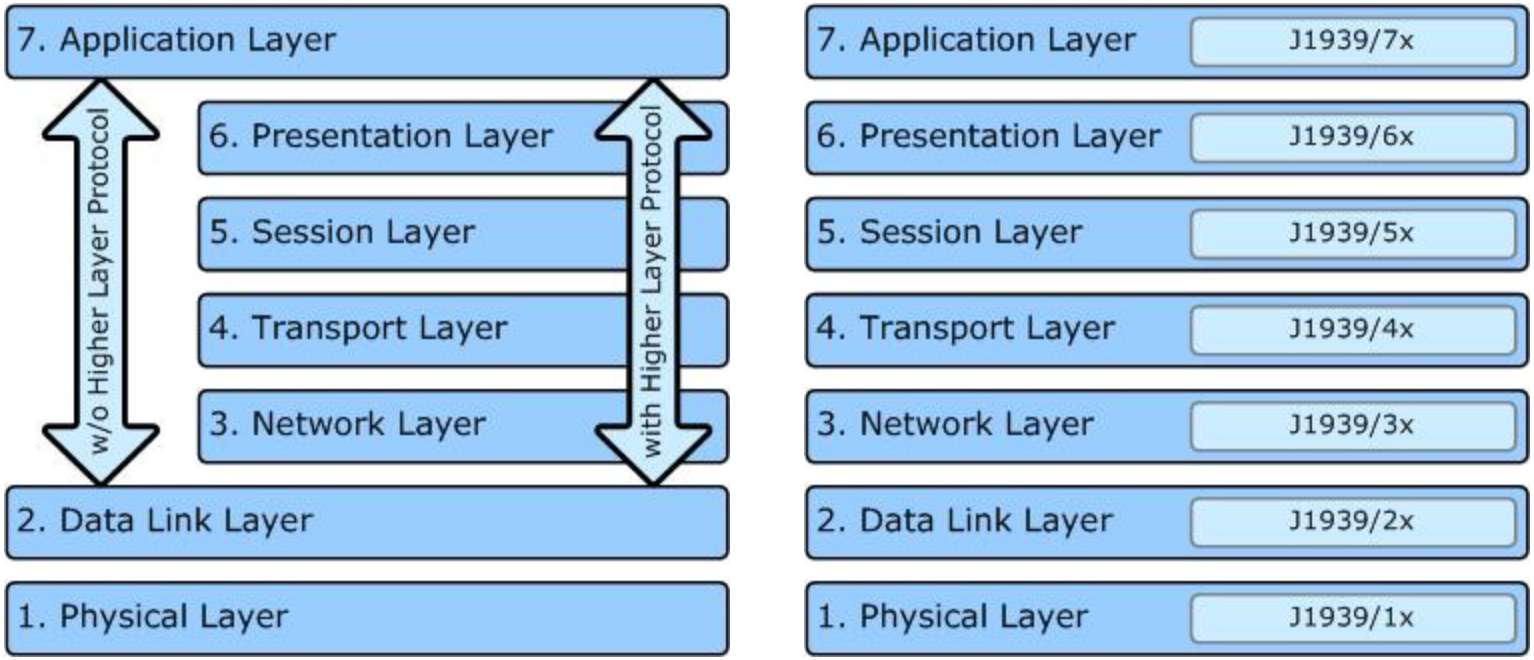
SAE J1939 – Quick Reference



J1939 Specifics:

- Does **not** support Master/Slave or Client/Server configuration
- Does **not** support node monitoring
- Features Address Claiming immediately after network start-up
- Allows “Plug&Play” feature
- Allows segmentation of messages larger than 8 bytes

SAE J1939 – Standards Collection



SAE J1939 Standards Collection scheme is based on the ISO/OSI 7-Layer Model

SAE J1939 – Standards Collection

J1939
Recommended Practice for a Serial Control and Communications Vehicle Network

J1939-01
Recommended Practice for Control And Communications Network for On-Highway Equipment

J1939-02
Agricultural and Forestry Off-Road Machinery Control and Communication Network

J1939-11
Physical Layer - 250k bits/s, Twisted Shielded PairJ1939-13Off-Board Diagnostics Connector

J1939-15
Reduced Physical Layer, 250k bits/sec, Un-Shielded Twisted Pair (UTP)

J1939-21
Data Link Layer

J1939-31
Network Layer

J1939-71
Vehicle Application Layer

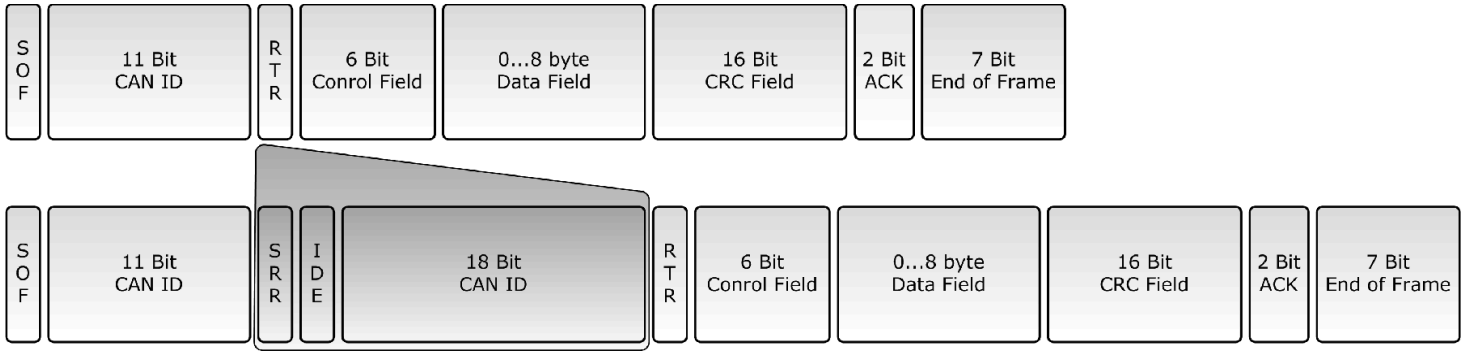
J1939-73
Application Layer – Diagnostics

J1939-74
Application - Configurable Messaging

J1939-75
Application Layer - Generator Sets and Industrial

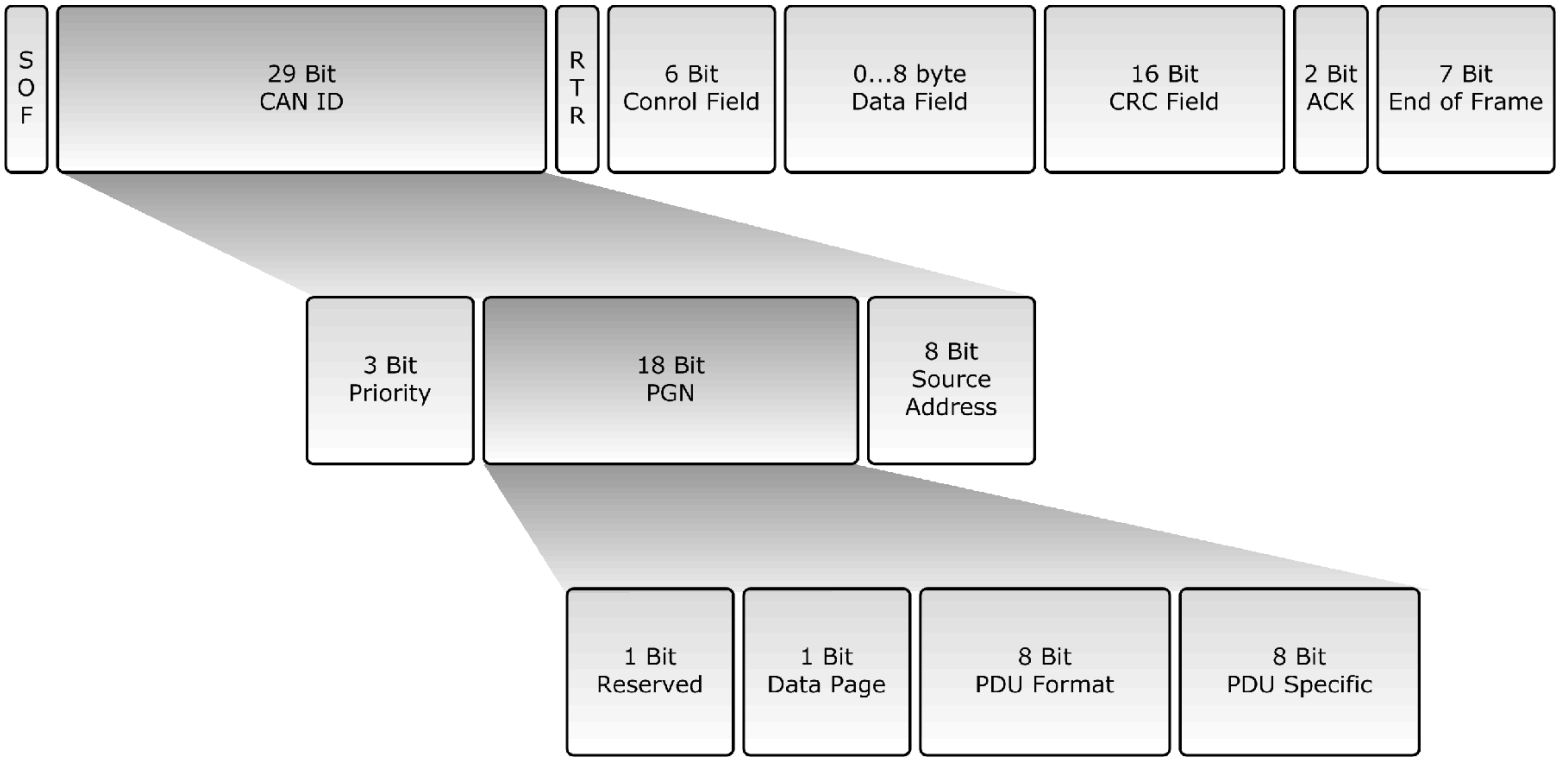
J1939-81
Network Management

SAE J1939 – Message Format (J1939/21)



- CAN Standard 2.0A was extended to 2.0B to allow a 29-Bit Identifier according to J1708 and J1587.
- IDE Bit indicates 11-Bit or 29-Bit Message Identifier
- Both formats can co-exist on the same CAN bus
- MilCAN uses J1939 29-Bit Message ID and CANopen 11-Bit Message ID
- J1939/21 also defines the segmentation of messages larger than 8 bytes.

SAE J1939 – Message Format



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SAE J1939 – Parameter Group Number

- Parameters embedded in the 29-Bit message identifier are divided into three sections:
  - Priority
  - PGN (Parameter Group Number)
  - 8 Bit Source Address
- PGN identifies the Parameter Group (PG)
- PGs point to information of parameter assignments within 8 byte CAN data field, repetition rate and priority
- 8672 different Parameter Groups per page – 2 pages are available

SAE J1939 – Parameter Group Number

Priority

- First three bits represent priority during arbitration process
- Provides eight priority levels
- A value of 0 (000) = highest priority;
  a value of 8 (111) = lowest priority
- High priority messages assigned to time critical data such as torque control data from transmission to engine
- Lower level priorities suitable for non-time-critical data such as engine configuration data

R

- Reserved for future purposes
- Should always be set to 0 when transmitting messages

SAE J1939 – Parameter Group Number

DP – Data Page

- Page selector for PDU (Protocol Data Unit) Format (PF) field
- Currently at 0, pointing to Page 0
- Page 1 for future purposes

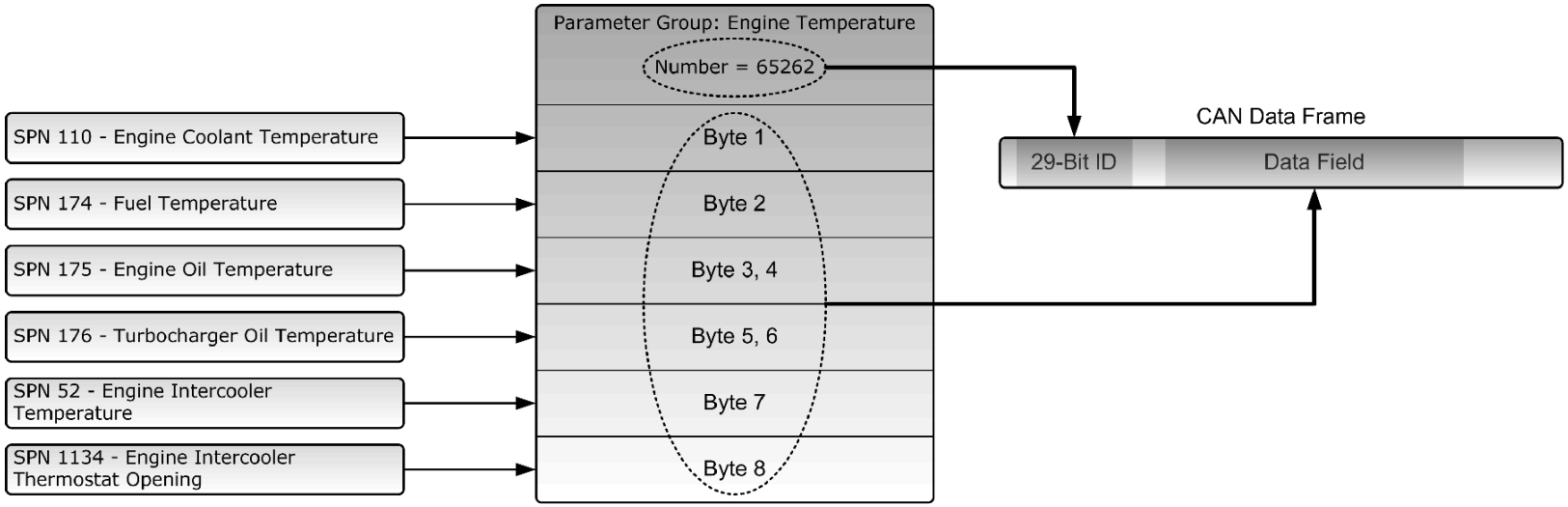
PDU Format (PF)

- PF = 0 - 239 (PDU1) indicates a destination address in PS
- PF = 240 - 255 (PDU2) indicates extension to PDU Format (PF)

PDU Specific (PS)

- Content interpreted according to information in PDU Format (PF)

SAE J1939 – PGNs and SPNs



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SAE J1939 – PGNs and SPNs

PGN 65262	**Engine Temperature**
Transmission Rate	1 sec
Data Length	8 bytes
Data Page	0
PDU Format (PF)	254
PDU Specific (PS)	238
Default Priority	6
PG Number	65262 ($FEEE_{hex}$)

Description of Data			**SPN**
Byte	1	Engine Coolant Temperature	110
	2	Fuel Temperature	174
	3, 4	Engine Oil Temperature	175
	5, 6	Turbocharger Oil Temperature	176
	7	Engine Intercooler Temperature	52
	8	Engine Intercooler Thermostat Opening	1134

SAE J1939 – PGNs and SPNs

SPN 110 **Engine Coolant Temperature**

Temperature of liquid engine cooling system

Data Length	1 Byte
Resolution	1 deg C / Bit
Offset	-40 deg C
Data Range	-40 to 210 deg C
Type	Measured
Reference	PGN 65262

SAE J1939 – PGN Range

DP	PGN Range (hex)	Number of PGNs	SAE or Manufacturer Assigned	Communication
0	000000 – 00EE00	239	SAE	PDU1 = Peer-to-Peer
0	00EF00	1	MF	PDU1 = Peer-to-Peer
0	00F000 – 00FEFF	3840	SAE	PDU2 = Broadcast
0	00FF00 – 00FFFF	256	MF	PDU2 = Broadcast
1	010000 – 01EE00	239	SAE	PDU1 = Peer-to-Peer
1	01EF00	1	MF	PDU1 = Peer-to-Peer
1	01F000 – 01FEFF	3840	SAE	PDU2 = Broadcast
1	01FF00 – 01FFFF	256	MF	PDU2 = Broadcast

SAE = Assigned by SAE

MF = Manufacturer Specific – Proprietary Messages

SAE J1939 – Proprietary Parameter Groups

Proprietary Parameter Groups and their numbers are designed using the exact same structure as Parameter Group and their numbers defined by the SAE.

Parameter Group Name	**Proprietary A**
Parameter Group Number	61184 ($00EF00_{hex}$)
Definition	Proprietary PG using the PDU1 Format for Peer-to-Peer communication.
Transmission Rate	Manufacturer Specific
Data Length	0 – 1785 bytes (multi-packet supported)
Extended Data Page (R)	0
Data Page	0
PDU Format	239
PDU Specific	8 bit Destination Address – Manufacturer Assigned
Default Priority	6
Data Description	Manufacturer Specific

SAE J1939 – Communication Methods

Destination Specific Communications:

- Use PDU1 (PF values 0 to 239)
- Destination address required

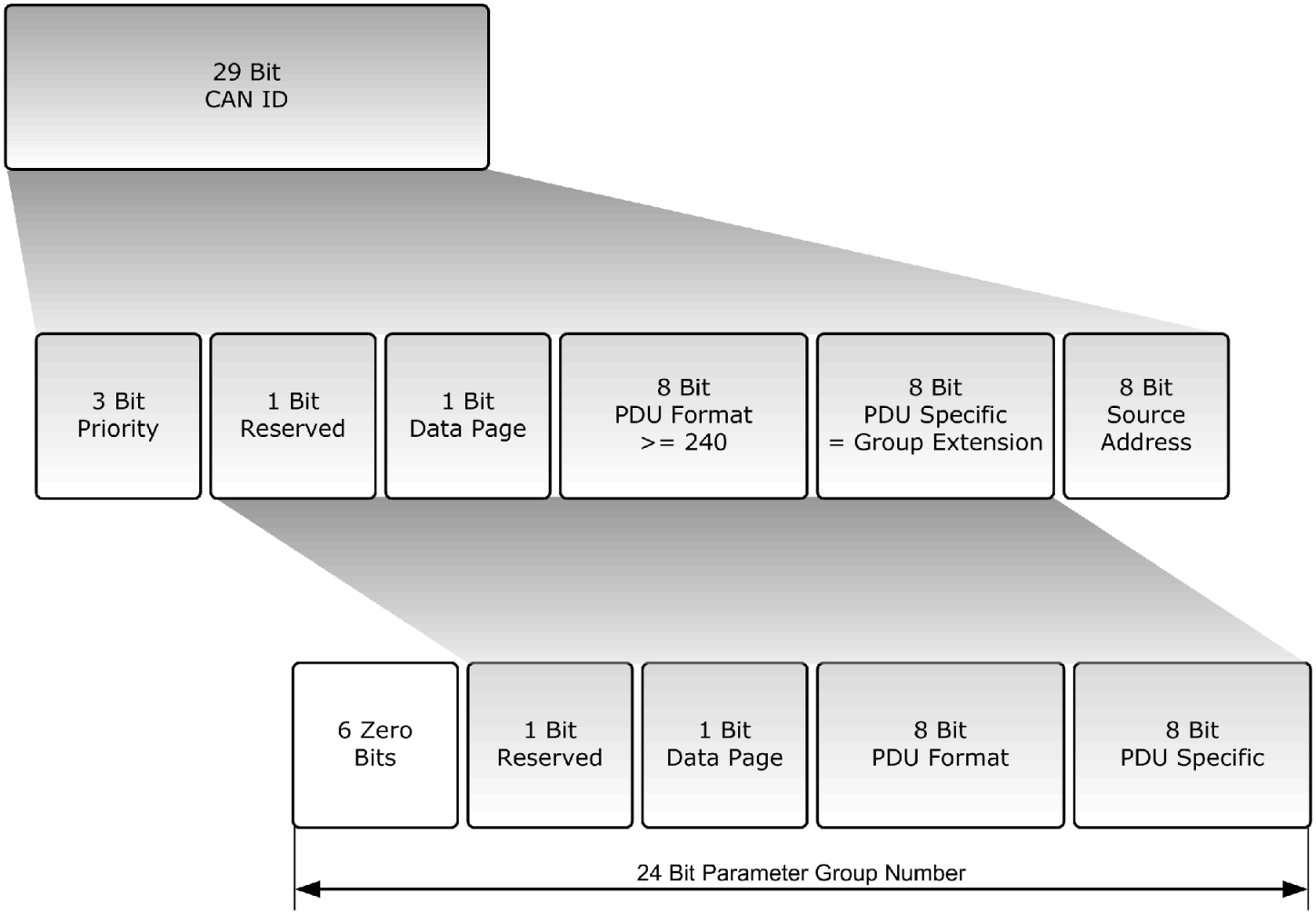
Broadcast Communications:

- Use PDU2 (PF values 240 to 255)
- Sending a message from single or multiple sources to single destination.
- Sending a message from single or multiple sources to multiple destinations.

Proprietary Communications:

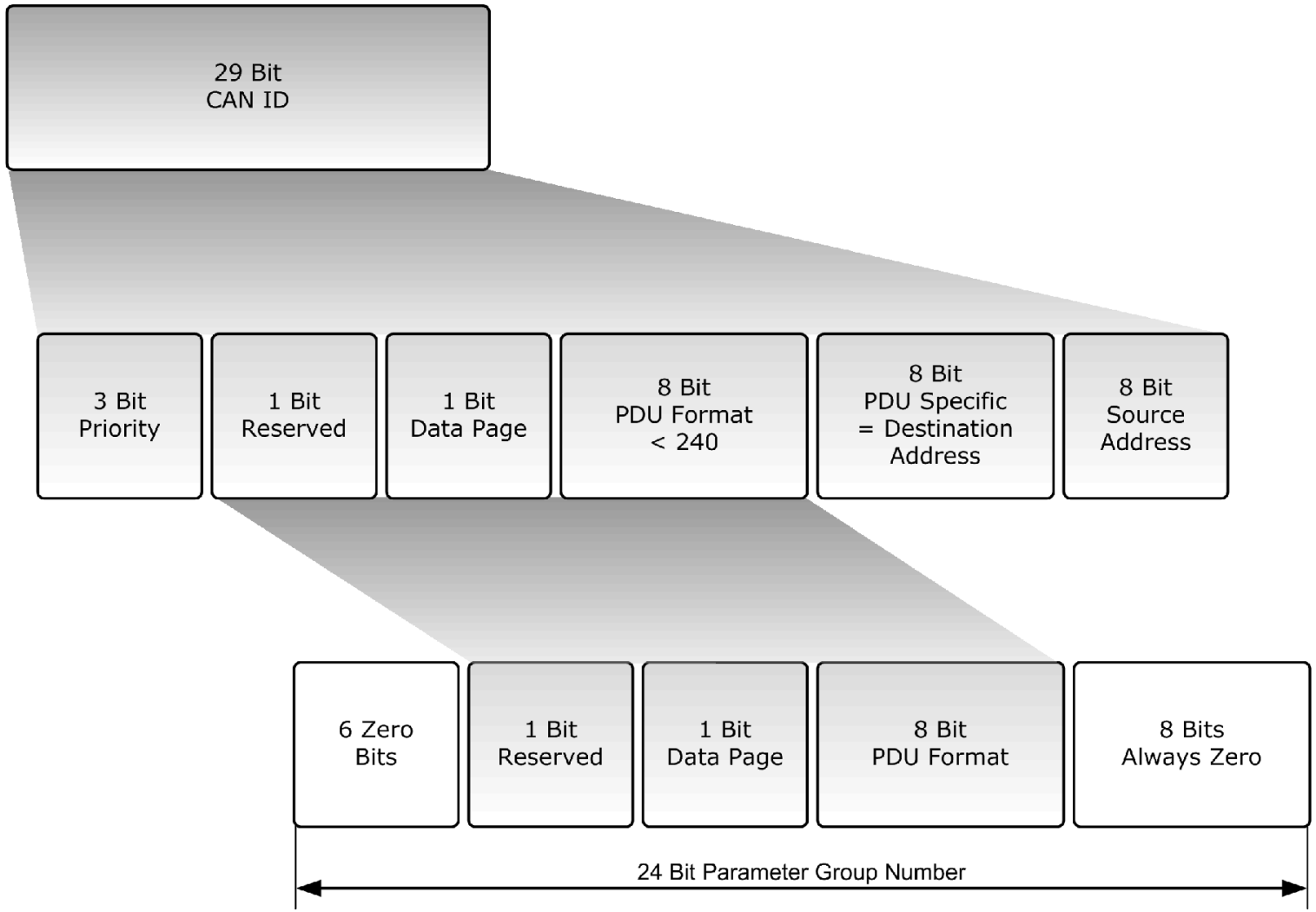
- Use either PDU1 or PDU2
- CAN be either Destination Specific or Broadcast
- Use proprietary PGNs

SAE J1939 – Parameter Group Number



Broadcast Communication

SAE J1939 – Parameter Group Number



Destination Specific Communication

SAE J1939 – Source Address

- Source Address = Last 8 bits of 29-Bit message identifier
- Source address = Adress of transmitting ECU (node)
- A total of 254 addresses available
- Every address must be unique within the network
- ECUs cannot share addresses
- PGNs are independent of source address
- Every ECU is allowed to transmit any message

Note: The CAN standard in itself does not support node (ECU) addresses, only message IDs.

SAE J1939 – Message Types

1. Command

Ordinary PGN – Supports both, PDU1 and PDU2

2. Request

Specifically Assigned PGN (00EA00hex)

PDU1 Only (Peer-to-Peer)

Destination Address 255 = Global Destination Address

3. Broadcast/Response

Ordinary PGN – Supports both, PDU1 and PDU2

4. Acknowledgement

Specifically Assigned PGN (00E800hex)
PDU1 Only (Peer-to-Peer)
Destination Address 255 = Global Destination Address

5. Group Functions

Specifically Assigned PGNs
Used for proprietary functions, network management and multi-packet functions.

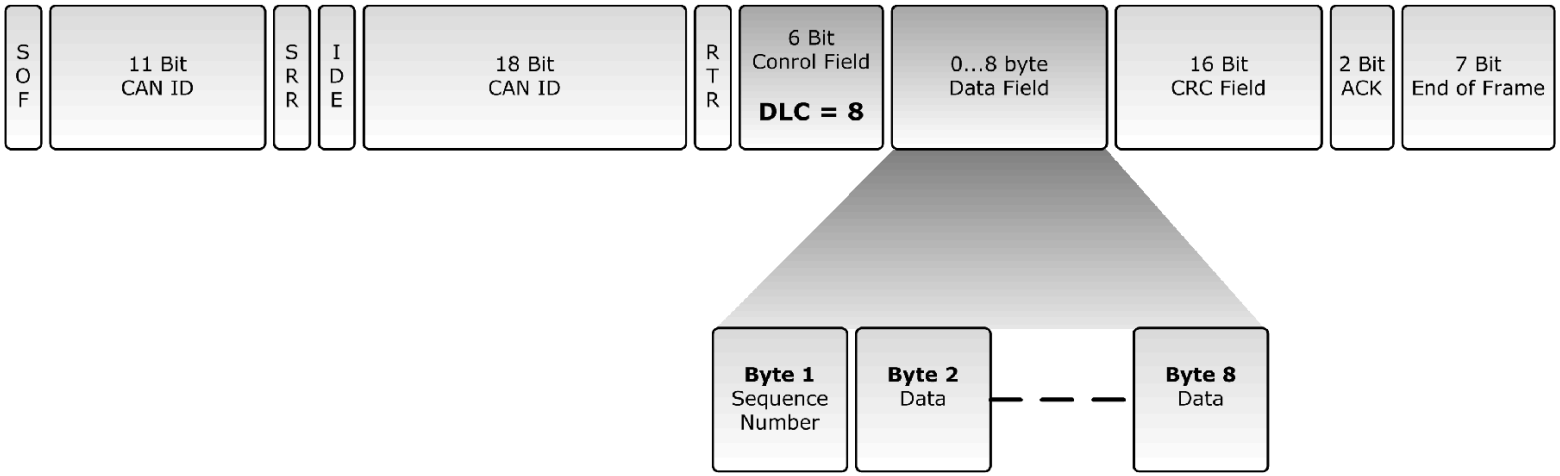
SAE J1939 – Request Message

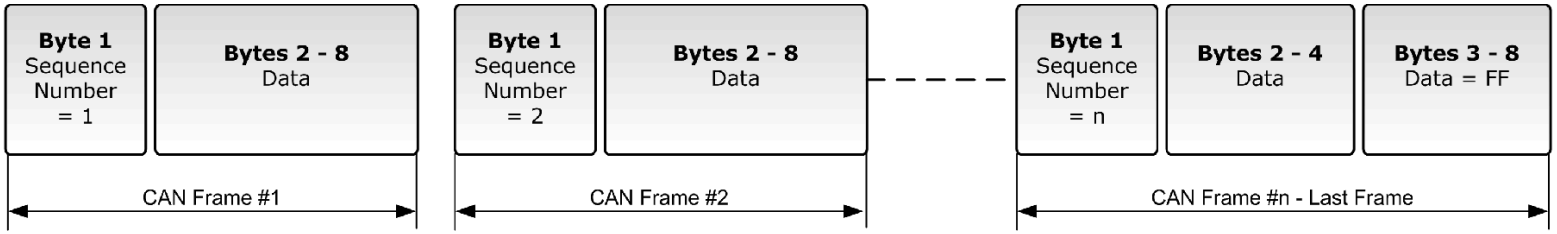
Parameter Group Name	Request
Parameter Group Number	59904 ($00EA00_{hex}$)
Definition	Requests a Parameter Group from a single device or all devices in the network.
Transmission Rate	User defined (no more than 2 to 3 times a second is recommended)
Data Length	3 bytes (CAN DLC = 3)
Extended Data Page (R)	0
Data Page	0
PDU Format	234
PDU Specific	Destination Address (Global or Specific)
Default Priority	6
Data Description	Byte 1, 2, 3 = Requested Parameter Group Number

SAE J1939 – Acknowledgement Message

Parameter Group Name	Acknowledgement
Parameter Group Number	59392 ($00E800_{hex}$)
Definition	Provides handshake between transmitting and responding nodes.
Transmission Rate	Upon reception of a command or request.
Data Length	8 bytes (as described in the following)
Extended Data Page (R)	0
Data Page	0
PDU Format	232
PDU Specific	Destination Address (Global = 255)
Default Priority	6
Data Description	Bytes 1…8 = Positive Acknowledgement, Negative Acknowledgement, Access Denied or Cannot Respond

SAE J1939 – Multi-Packet Transport





Supports Peer-to-Peer and Broadcast

SAE J1939 – Broadcast Announce Message

BAM!

In order to broadcast a multi-packet message a node must first send a *Broadcast Announce Message* (BAM). A BAM message contains the following components:

- Parameter Group Number of the multi-packet message
- Size of the multi-packet message
- Number of packages

The *Broadcast Announce Message* (BAM) is embedded in the Transport Protocol – Connection Management (TP.CM) PGN 60416 and the actual data transfer is handled by using the Data Transfer PGN 60160.

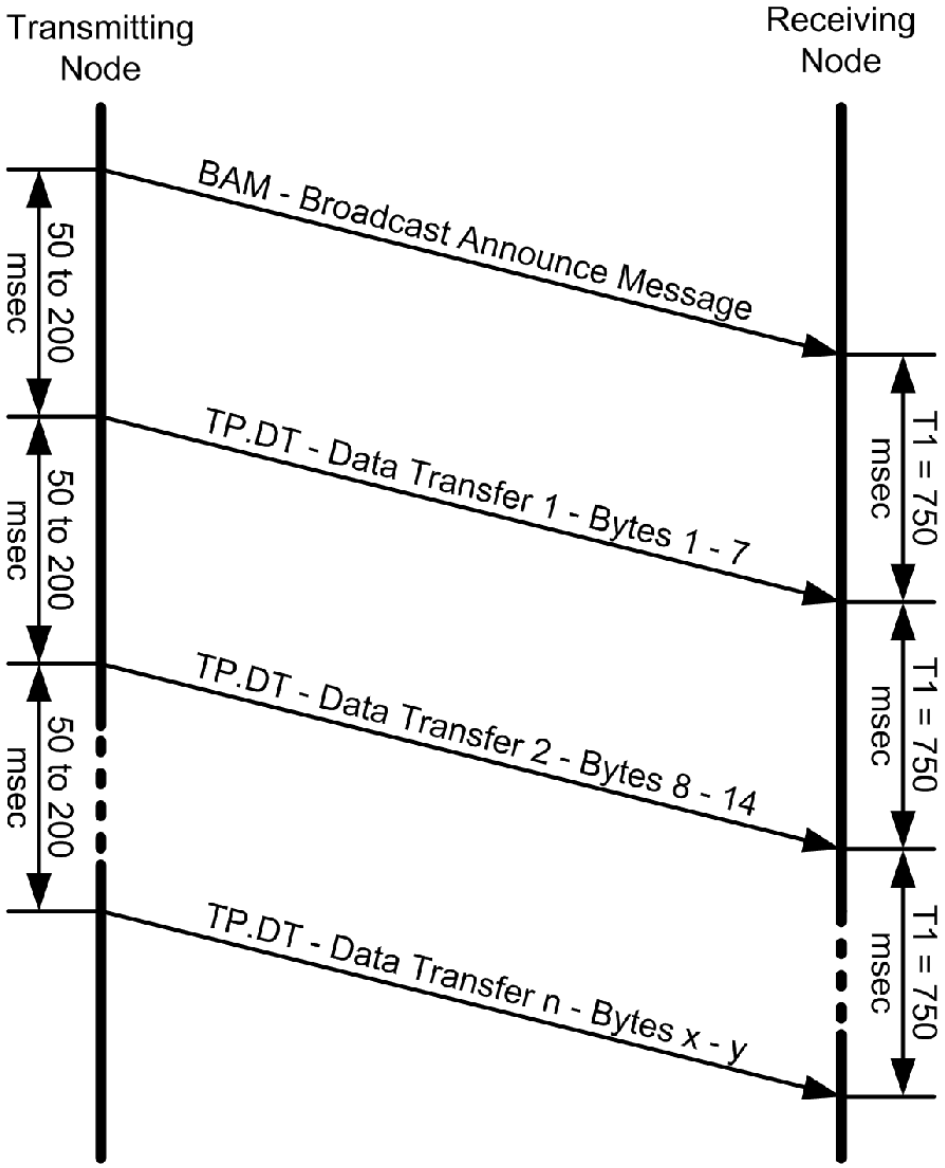
SAE J1939 – Transport Protocol

Parameter Group Name	**Transport Protocol – Connection Management (TP.CM)**
Parameter Group Number	60416 ($00EC00_{hex}$)
Definition	Used for Communication Management flow-control (e.g. Broadcast Announce Message).
Transmission Rate	According to the Parameter Group Number to be transferred
Data Length	8 bytes
Extended Data Page (R)	0
Data Page	0
PDU Format	236
PDU Specific	Destination Address (= 255 for broadcast)
Default Priority	7
Data Description	(For Broadcast Announce Message only)
Byte	1 - Control Byte = 32
	2,3 – Message Size (Number of bytes)
	4 – Total number of packages
	5 – Reserved (should be filled with FF_{hex})
	6-8 – Parameter Group Number of the multi-packet message (6=LSB, 8=MSB)

SAE J1939 – Transport Protocol

Parameter Group Name	**Transport Protocol – Data Transfer (TP.DT)**
Parameter Group Number	60160 ($00EB00_{hex}$)
Definition	Data Transfer of Multi-Packet Messages
Transmission Rate	According to the Parameter Group Number to be transferred
Data Length	8 bytes
Extended Data Page (R)	0
Data Page	0
PDU Format	235
PDU Specific	Destination Address
Default Priority	7
Data Description	
Byte	1 – Sequence Number (1 to 255)
	2-8 - Data

SAE J1939 – Broadcast Data Transfer



SAE J1939 – Flow Control

Transport Protocol

Connection Management (TP.CM) – PGN 00EC00hex

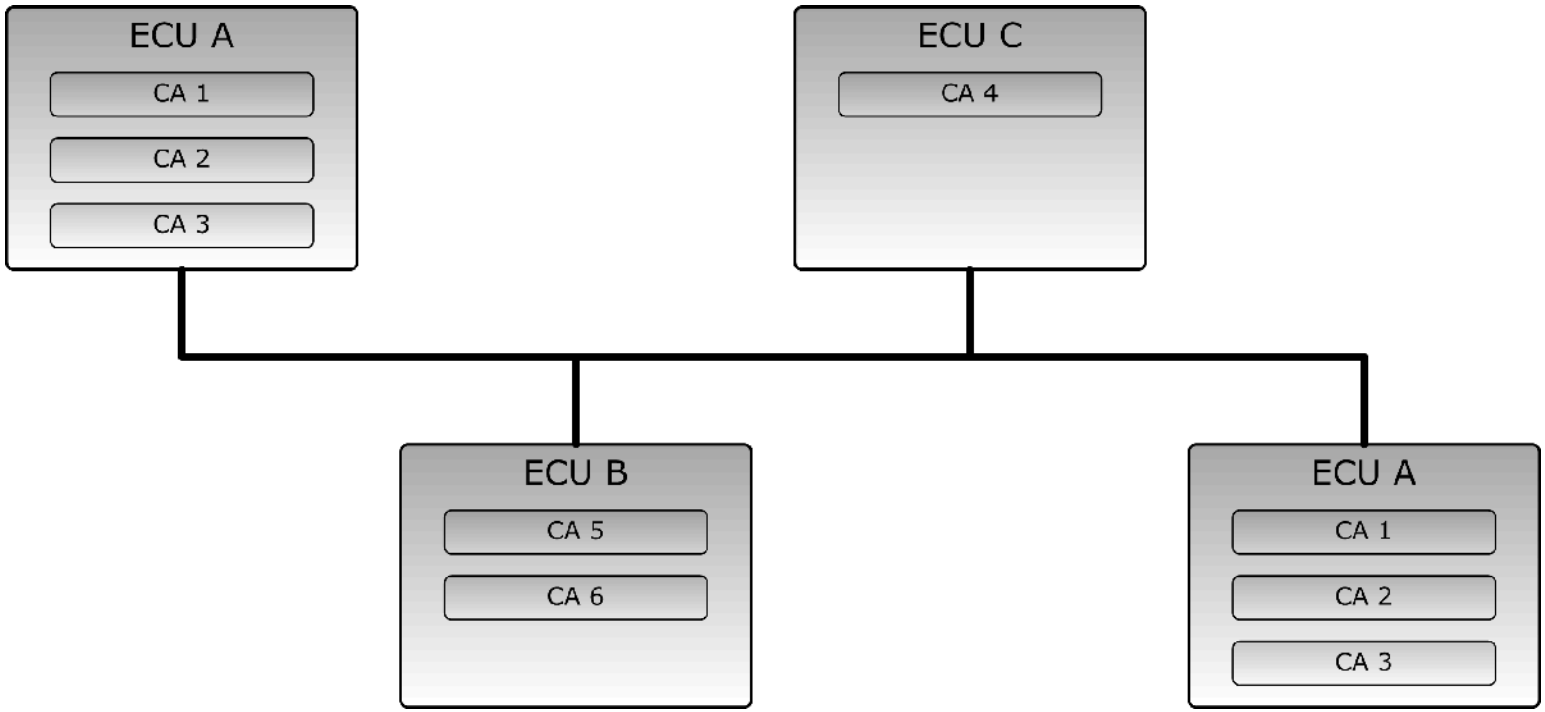
The TP.CM Data can be:

- Connection Mode Request to Send – TP.CM_RTS
- Connection Mode Clear To Send – TP.CM_CTS
- End of Message Acknowledgement – TP.CM_EndOfMsgACK
- Connection Abort – TP.Conn_Abort

SAE J1939 – Network Management

- Network Management defined in SAE J1939/81
- Handles automatic allocation of node addresses (Plug & Play) per Address Claiming procedure
- Address Claiming not supported per default in any other HLP
- J1939 Network Management allows to identify ECUs and their primary function.
- Node monitoring is not defined in J1939 – must be application specific
- J1939 does not support Master/Slave or Client/Master - must be application specific

SAE J1939 – ECUs and CAs



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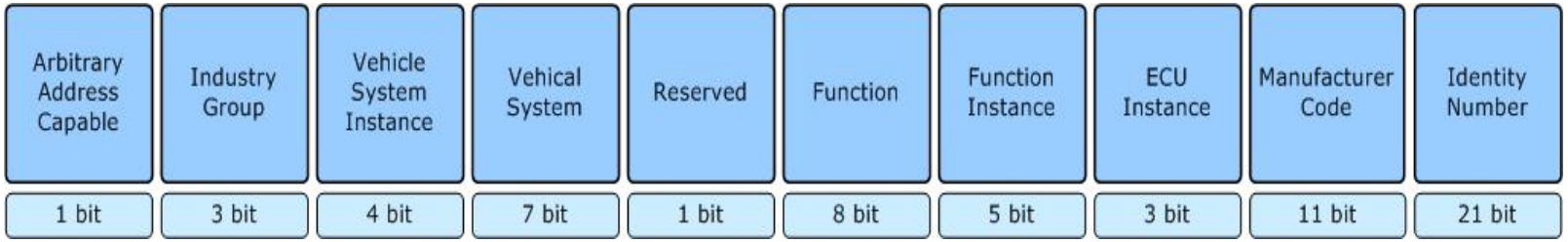
SAE J1939 – Address and NAME



- SAE J1939 defines 64 bit NAME to uniquely identify each ECU
- Each ECU must hold at least one name and one address for identification purposes
- ECU address defines the source or destination for messages
- ECU name indicates ECU main function performed at ECU address
- Function instance indicator used when multiple ECUs with same main function share the same network

SAE J1939 – Address Claiming

- 64 bit NAME to uniquely identify nodes (ECUs)
- Necessitates unreasonable resources to maintain standard communications
- Each ECU utilizes an 8 bit address to identify the source of a message or to access (destination address) another ECU in the network
- Address Claim Procedure:
    - Designed to assign addresses to ECUs right after the network startup
    - Assuring that assigned address is unique to ECU
- SAE J1939 Standard defines Preferred Addresses to commonly used devices in order to minimize the rate of multiple devices demanding the same address

SAE J1939 – Preferred Addresses

Industry Group	Preferred Address Range
Global (Applies to all industry groups)	0 – 84 Assigned 85 – 127 Reserved 248, 252 - 255 Reserved
Industry Group #1 – On-Highway Equipment	128 – 160 Dynamic 161 – 247 Assigned
Industry Group #2 – Agricultural and Forestry Equipment	128 – 207 Dynamic 208 – 247 Reserved
Industry Group #3 – Construction Equipment	128 - 207 Dynamic 208 – 247 Reserved
Industry Group #4 – Marine Equipment	128 – 207 Dynamic 208 – 247 Reserved
Industry Group #5 – Industrial, Process Control, Stationary Equipment	128 – 207 Dynamic 208 – 247 Reserved

SAE J1939 – Address Claiming

Two possible scenarios:

Sending an Address Claimed message (Standard)

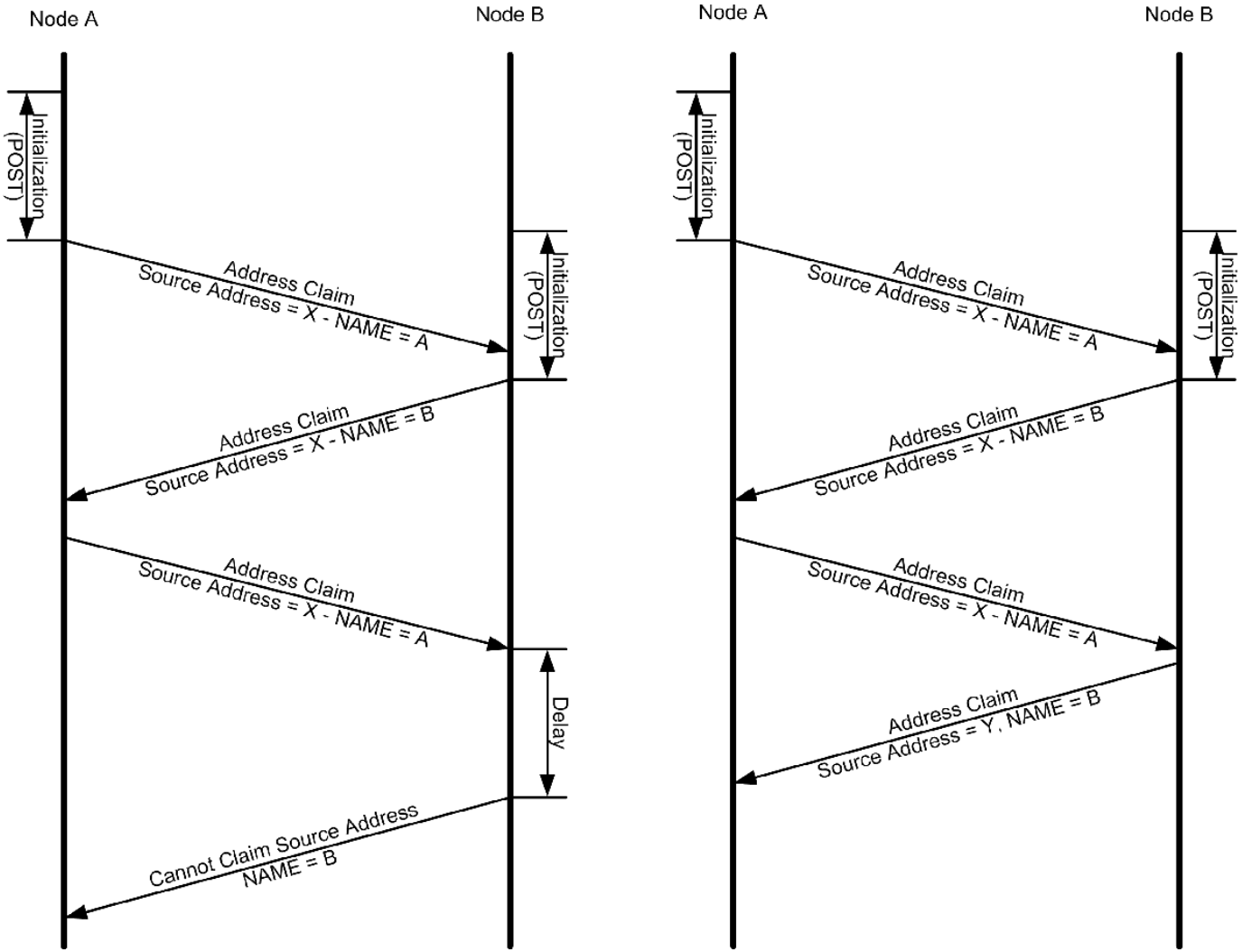
- ECU sends Address Claimed message into the CAN bus
- ECUs receiving address claim will record & verify claimed address with internal address table
- In case of address conflict ECU with lowest NAME value will succeed
- Remaining ECUs must claim different address or stop transmitting to network

Request for Address Claimed message

- Necessary procedure for ECUs powering up late (e.g. trailers, diagnostics tools, etc.)
- Used to determine and claim available address or to find out which ECUs are currently on the network

SAE J1939 – Address Claiming

Two possible address claim scenarios:



SAE J1939 – Address Claiming

• Node A starts initialization and Power-On Self Test (POST) some time ahead of node B.

• While node B is going through initialization and POST, node A sends out it address claim message.

• Node B, after having finished initialization and POST, attempts to claim the same source address as node A

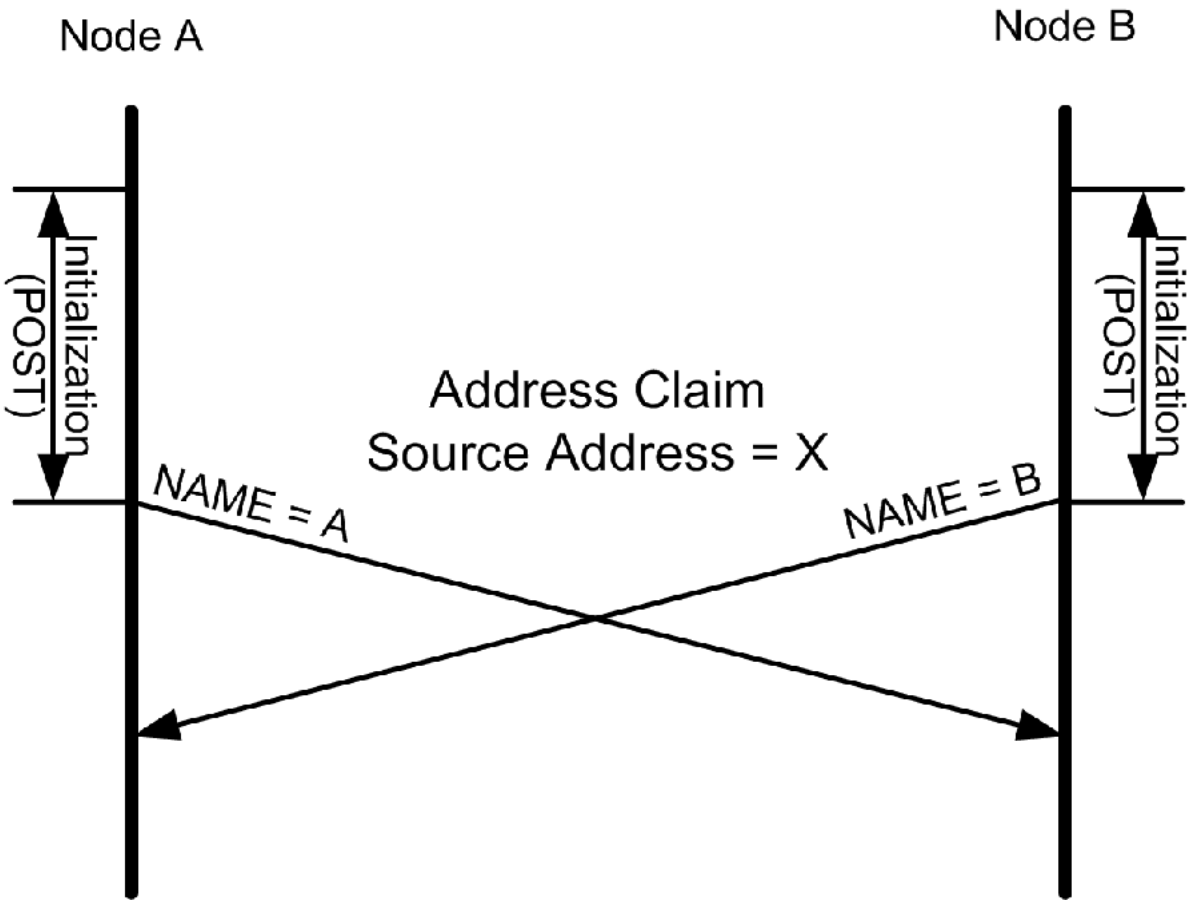
• In response node A, having determined that its NAME has higher priority, resends the address claim message.

• Node B receives the address claim message, determines that node A's name has higher priority.

• In the left scenario, node B sends a *Cannot Claim* message. In the right scenario it claims another address by sending another *Address Claim* message.

SAE J1939 – Address Claiming

CAN Message Collision is possible!



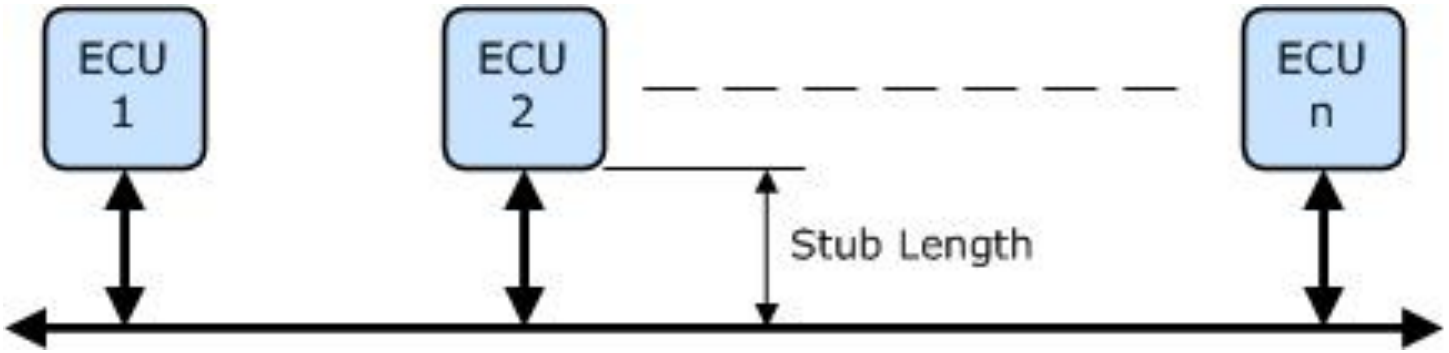
SAE J1939 – Address Management Messages

Message	PGN	PF	PS	SA	Data Length	Data
Request for Address Claimed	59904	234	DA	SA[1)]	3 bytes	PGN 60928
Address Claimed	60928	238	255	SA	8 bytes	NAME
Cannot Claim Source Address	60928	238	255	254	8 bytes	NAME
Commanded Address	65240	254	216	SA	9[2)]	NAME, new SA

1) In case no address has been claimed as of yet the source address could be set to 254.

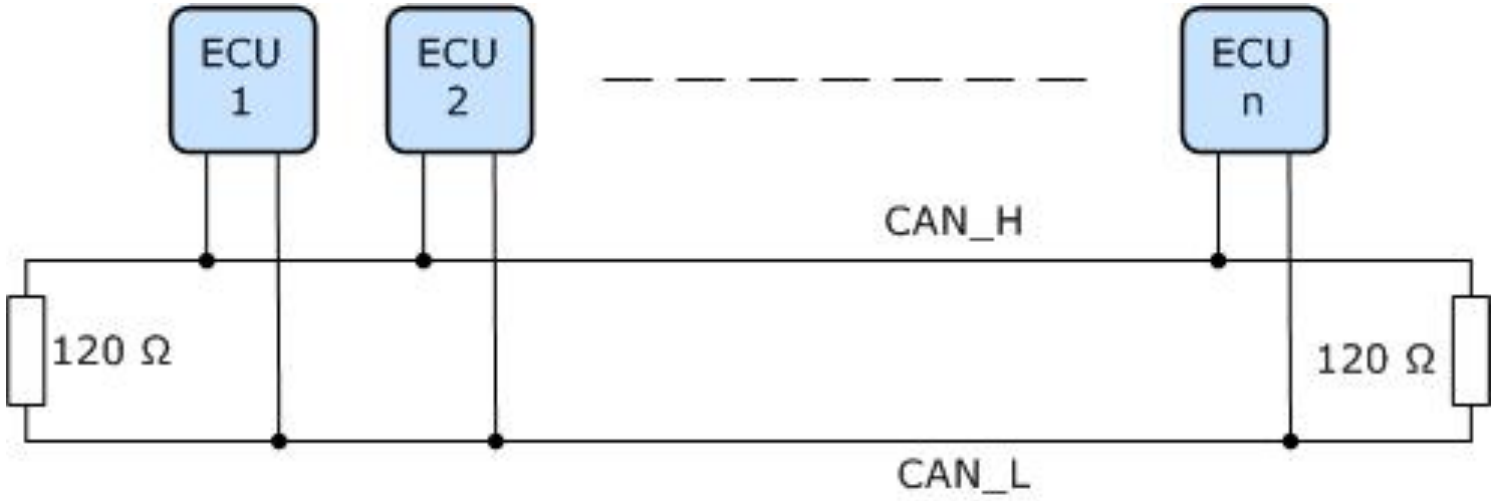
2) The commanded address, since it is longer than 8 bytes, is sent using the Transport Protocol as described in chapter *Transport Protocol*.

SAE J1939 – Network Topology



- ECUs in a J1939 network segment are connected by a single, linear, shielded twisted pair of wires
- Wiring topology of the network should be as straight as possible to minimize electrical reflections:
  - Short stub lengths
  - Avoiding complex network structures

SAE J1939 – Network Topology



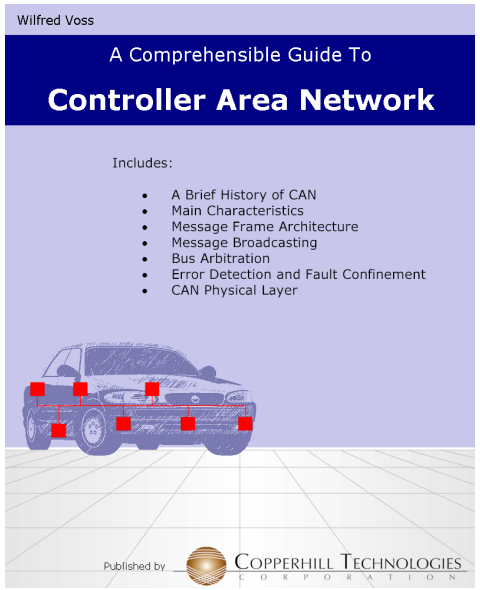
- Each bus segment should be terminated by resistors, typically 120 Ω
- Termination resistors should always be on both ends of the bus
- Dividing network into sub-networks may be necessary (e.g. for truck and trailer)
- Segmentation requires bridges

J1939/13 Off-Board Diagnostic Connector

J1939/13 defines a standard connector for diagnostic purpose.

The connector is a Deutsch HD10 - 9 – 1939 (9 pins, round connector).

Literature



Literature on
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