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Abstract This application note presents an overview of the fundamental concepts of J1939 in order to give a first impression.

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1.0 Overview

SAE J1939 is used in the commercial vehicle area for communication in the commercial vehicle. In this application note, the properties of SAE J1939 should be described in brief.

SAE J1939 uses CAN (Controller Area Network, ISO11998) as physical layer. It is a recommended practice that defines which and how the data is communicated between the Electronic Control Units (ECU) within a vehicle network. Typical controllers are the Engine, Brake, Transmission, etc.

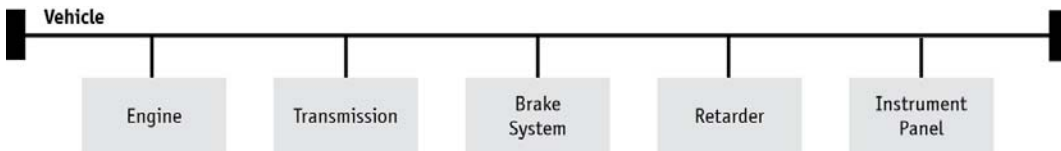


Figure 1: Typical J1939 vehicle network

The particular characteristics of J1939 are:

- Extended CAN identifier (29 bit)
- Bit rate 250 kbit/s
- Peer-to-peer and broadcast communication
- Transport protocols for up to 1785 data bytes
- Network management
- Definition of parameter groups for commercial vehicles and others
- Manufacturer specific parameter groups are supported
- Diagnostics features

There exist several standards which are derived from SAE J1939. These standards use the basic features of SAE J1939 with a different set of parameter groups and modified physical layers. These standards are:

ISO11783 – Tractors and machinery for agriculture and forestry – Serial control and communication

Defines the communication between tractor and implements on an implement bus. It specifies some services on application layer, like Virtual Terminal, Tractor ECU, Task Controller and File Server. It adds an Extended Transport Protocol and Working Set Management.

NMEA2000® – Serial-data networking of marine electronic devices

It defines parameter groups for the communication between marine devices. It specifies the additional Fast Packet transport protocol.

ISO11992 – Interchange of digital information between towing and towed vehicle

Specifies the interchange of information between road vehicle and towed vehicle. It uses same parameter group format as J1939 on a different physical layer with 125 kbit/s.

FMS – Fleet Management System

The FMS standard defines a gateway between the J1939 vehicle network and a fleet management system.

2.0 Parameter Groups

A parameter group is a set of parameters belonging to the same topic and sharing the same transmission rate. The definition of the application relevant parameter groups and parameters can be found in application layer document [9].

The length of a parameter group is not limited to the length of a CAN frame. Usually a parameter group has a minimum length of 8 bytes up to 1785 bytes. Parameter groups with more than 8 bytes require a transport protocol for transmission.

2.1 Interpretation of the CAN Identifier

The CAN identifier of a J1939 message contains Parameter Group Number (PGN), source address, priority, data page bit, extended data page bit and a target address (only for a peer-to-peer PG).

The identifier is composed as follows:

Priority	Extended Data Page	Data Page	PDU Format	PDU Specific	Source Address
3 bit	1 bit	1 bit	8 bit	8 bit	8 bit

- With PDU format < 240 (peer-to-peer), PDU specific contains the target address. Global (255) can also be used as target address. Then the parameter group is aimed at all devices. In this case, the PGN is formed only from PDU format.
- With PDU format \geq 240 (broadcast), PDU format together with the Group Extension in the PDU specific field forms the PGN of the transmitted parameter group.

2.2 Parameter Group Number

Each parameter group is addressed via a unique number – the PGN. For the PGN a 24 bit value is used that is composed of the 6 bits set to 0, PDU Format (8 bits), PDU Specific (8 bits), Data Page (1 bit) and Extended Data Page (1 bit).

There are two types of Parameter Group Numbers:

- Global PGNs identify parameter groups that are sent to all (broadcast). Here the PDU Format, PDU Specific, Data Page and Extended Data Page are used for identification of the corresponding Parameter Group. On global PGNs the PDU Format is 240 or greater and the PDU Specific field is a Group Extension.

$$\text{PGN} = 00\text{FE}01_{16}$$

$\geq \text{F0}_{16}$ ← [PDU Format] [PDU Specific] → Group Extension

- Specific PGNs are for parameter groups that are sent to particular devices (peer-to-peer). Here the PDU Format, Data Page and Extended Data Page are used for identification of the corresponding Parameter Group. The PDU Format is 239 or less and the PDU Specific field is set to 0.

$$\text{PGN} = 00\text{ED}00_{16}$$

$\leq \text{F0}_{16}$ ← [PDU Format] [PDU Specific] → always 0

With this breakdown of the PGN, $240 + (16 * 256) = 4336$ different parameter groups within each data page are possible. With the transmission of a parameter group, the PGN is coded in the CAN identifier.

With the Data Page bit and Extended Data Page bit 4 different data pages can be selected, see following table.

Extended Data Page Bit	Data Page Bit	Description
0	0	SAE J1939 Page 0 Parameter Groups
0	1	SAE J1939 Page 1 Parameter Groups (NMEA2000®)
1	0	SAE J1939 reserved
1	1	ISO 15765-3 defined

Table 1: Data Pages

Sample of a parameter group definition:

Name: Engine temperature 1 – ET1
 Transmission rate: 1s
 Data length: 8 bytes
 Extended Data Page: 0
 Data page: 0
 PDU format: 254
 PDU specific: 238
 Default priority: 6
 PG Number: 65,262 (00FEEE₁₆)

Description of data:

Byte: 1 Engine Coolant Temperature
 2 Engine Fuel Temperature 1
 3,4 Engine Oil Temperature 1
 5,6 Engine Turbocharger Oil Temperature
 7 Engine Intercooler Temperature
 8 Engine Intercooler Thermostat Opening

2.3 Suspect Parameter Number (SPN)

A suspect parameter number is assigned to each parameter of a parameter group or component. It is used for diagnostic purpose to report and identify abnormal operation of a Controller Application (CA).

The SPN is a 19 bit number and has a range from 0 to 524287. For proprietary parameters a range from 520192 to 524287 is reserved.

2.4 Special Parameter Groups

SAE J1939-21 defines some parameter groups on the data link layer:

Request parameter group

The request parameter group (RQST, PGN 00EA00₁₆) can be sent to all or a specific CA to request a specified parameter group. The RQST contains the PGN of the request parameter group. If the receiver of a specific request cannot respond, it must send a negative acknowledgment. The RQST has a data length code of 3 bytes and is the only parameter group with a data length code less than 8 bytes.

Acknowledgement parameter group

The acknowledgement parameter group (ACKM, PGN 00E800₁₆) can be used to send a negative or positive acknowledgment, i.e. in response to a request.

Address claiming parameter group

The address claiming parameter group (ACL, PGN 00EE00₁₆) is used for network management, see chapter 3.0.

Commanded address parameter group

The commanded address parameter group (CA, PGN 00FED8₁₆) can be used to change the address of a CA.

Transport protocol parameter group

The transport protocol parameter groups (TPCM, PGN 00EC00₁₆ and TPDT, PGN 00EB00₁₆) are used to transfer parameter groups with more than 8 data bytes, see chapter 4.0.

3.0 Network Management

The software of an Electronic Control Unit (ECU) is the Controller Application (CA). An ECU may contain one or more CAs. Each CA has a unique address and an associated device name.

Each message that is sent by a CA contains this source address. There are 255 possible addresses:

- 0..253 – Valid source addresses for CAs
- 0..127 and 248..253 – Used for CAs with Preferred Addresses and defined functions
- 128..247 – Available for all CAs
- 254 – Null
- 255 – Global

Most CAs like Engine, Gearbox, etc. have a preferred address (see [2]). Before a CA may use an address, it must register itself on the bus. This procedure is called "address claiming." Thereby the device sends an "Address Claim" parameter group (ACL, PGN 00EE00₁₆) with the desired source address. This PG contains a 64-bit device name. If an address is already used by another CA, then the CA whose device name has the higher priority has claimed the address.

The device name contains some information about the CA and describes its main function. A manufacturer code must be requested by the SAE. The values of the fields are defined in SAE J1939-81 [11].

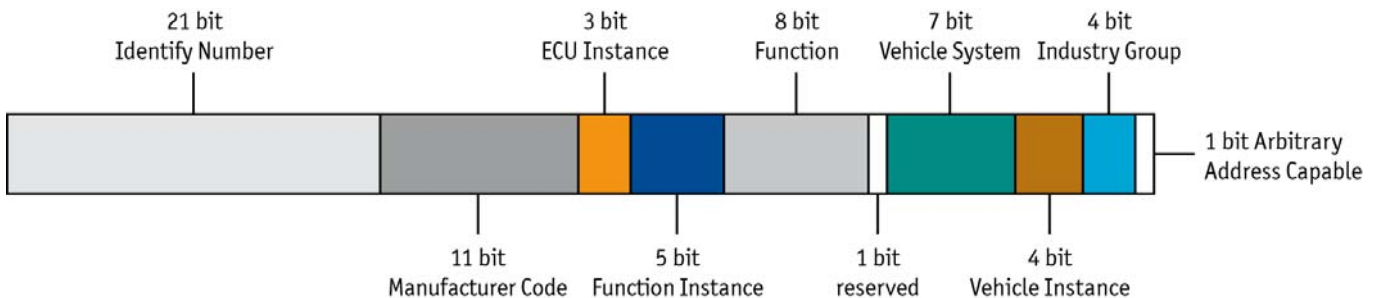


Figure 2: Device name data of the address claim parameter group

3.1 Address Claiming Procedure

In a common situation the controller application sends an Address Claim parameter group at start up and waits a defined amount of time. If it does not detect an address conflict it can start with its normal communication.



Figure 3: Address claiming procedure

In a situation where another CA already uses the address an address conflict occurs. The CA with the higher priority of the device name will obtain the address. The other CA must send a “Cannot Claim Address” parameter group, with source address Null (254).

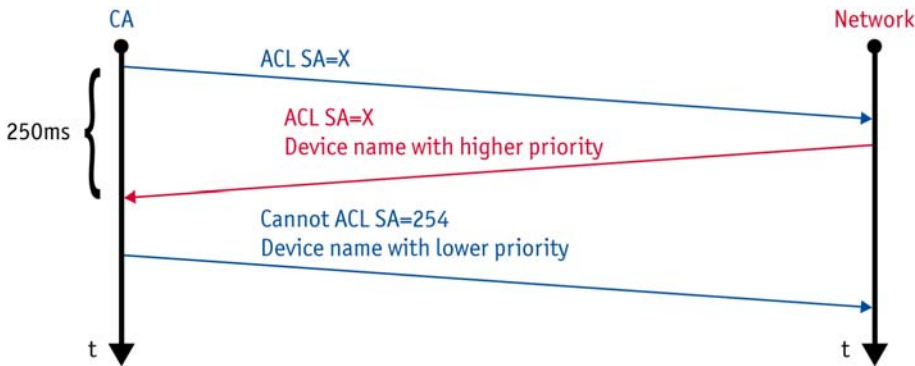


Figure 4: Address claiming procedure with address conflict

It depends on the address capability of a CA how to proceed, if an address cannot be obtained.

3.2 Request for Address Claim

A CA can detect other CAs in the network by requesting the ACL parameter group. It is allowed to use the Null-Address (254) as source address before a CA has performed the address claiming procedure. If the request is addressed to the Global address (255) all CAs in the network must respond with the ACL parameter group (including own CA if an address has been claimed already).

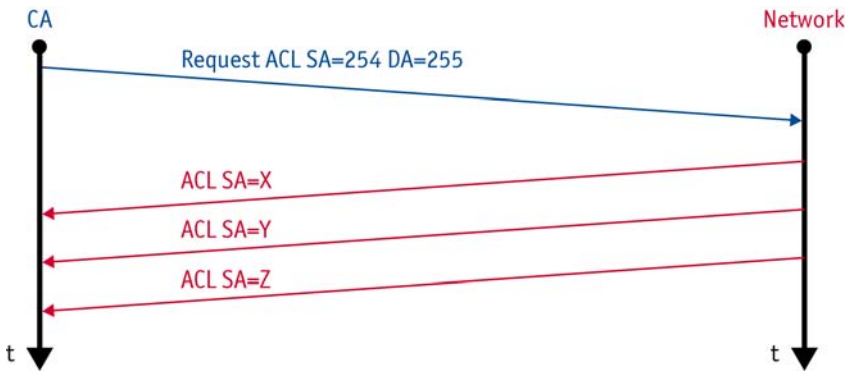


Figure 5: Request address claim

3.3 Address Capability

SAE J1939-81 defines the following types of capability to obtain an address:

Arbitrary address capable CA

The CA selects its source address by internal algorithm. It is able to select a new address on an address conflict. The Arbitrary Address Capable field in the device name indicates this capability.

Single address capable CA

A CA of this type can use only one address. On address conflicts it is not able to select another address. It can support the commanded address parameter group or proprietary mechanisms to change the address. The Arbitrary Address Capable field is not set for these CAs.

4.0 Transport Protocols

Parameter groups that contain more than 8 data bytes are transmitted by means of a transport protocol.

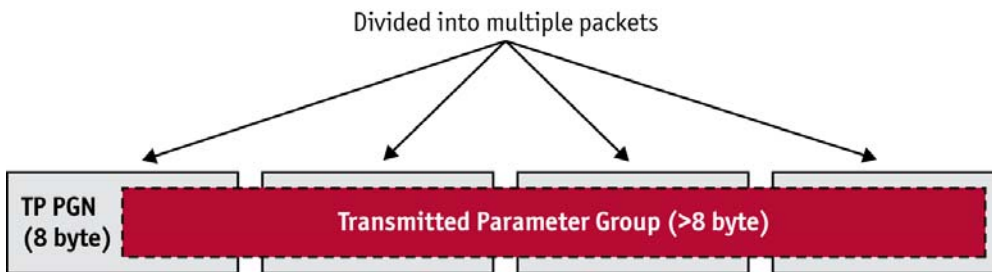


Figure 6: Transport Protocol

For peer-to-peer and broadcast transmission, there are two different protocols. The transport protocols utilize two special parameter groups which are used for the connection management (TP.CM) and the transmission of the data (TP.DT).

For broadcast transmission, the BAM (Broadcast Announce Message) protocol is used. Here, after a BAM-PG, the transmitter sends all data PGs at a minimum interval of 50ms.



Figure 7: BAM transmission

With the peer-to-peer transmission, the transmitter initiates the connection with a "request to send" message. The receiver then controls the transport protocol with "clear to send" and finally acknowledge it with "end of message acknowledge."

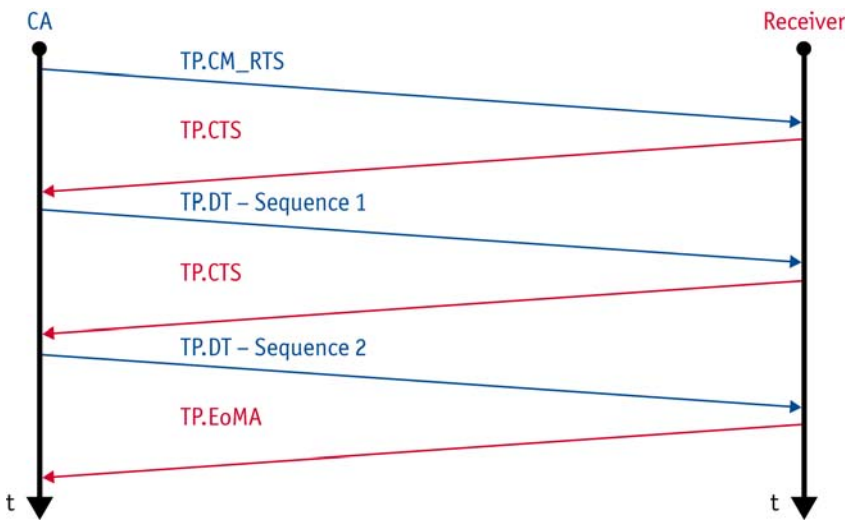


Figure 8: RTS/CTS transmission

5.0 Diagnostics

The diagnostic features of SAE J1939 supports following services:

- Reporting and identification of abnormal operation
- Memory access
- Monitored tests

An important parameter group is the Diagnostics Message 1 (DM1, PGN FECA₁₆). If supported, it shall be sent cyclic by each CA to report its state. The parameter group contains the state for different lamps:

- Malfunction Indicator Lamp
- Red Stop Lamp
- Amber Warning Lamp
- Protect Lamp

An instrument cluster can use this information to report the state of the system to the driver.

Additionally the parameter group contains a list of Diagnostic Trouble Codes (DTC). Together with the address of a sender the parameter of misbehaving components can be identified.

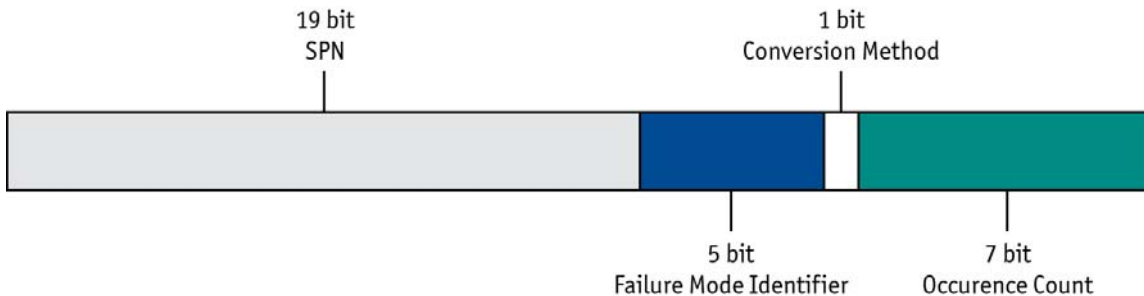


Figure 9: Diagnostic Trouble Code

A DTC contains 4 bytes, which contain the SPN, the Failure Mode Identifier (FMI) and an Occurrence Count. If the DM1 contains more than one DTC a transport protocol must be used.

6.0 Summary

With the specification of the parameter groups, CAN identifier scheme, and the network management, a manufacturer-spanning cooperation of control units will be ensured.

J1939 describes, in addition to the mechanisms presented here, the physical properties and use of bus sub segments.

7.0 Additional Sources

SAE Documents

- [1] SAE J1939 Recommended Practice for a Serial Control and Communications Vehicle Network
- [2] SAE J1939-01 Recommended Practice for Control and Communications Network for On-Highway Equipment
- [3] SAE J1939-02 Agricultural and Forestry Off-Road Machinery Control and Communication Network
- [4] SAE J1939-03 On Board Diagnostics Implementation Guide
- [5] SAE J1939-05 Marine Stern Drive and Inboard Spark-Ignition Engine On-Board Diagnostics Implementation Guide
- [6] SAE J1939-11 Physical Layer - 250k bits/s, Twisted Shielded Pair
- [7] SAE J1939-13 Off-Board Diagnostic Connector
- [8] SAE J1939-14 Physical Layer, 500k bits/s
- [9] SAE J1939-15 Reduced Physical Layer, 250K bits/sec, Un-Shielded Twisted Pair (UTP)
- [10] SAE J1939-21 Data Link Layer
- [11] SAE J1939-31 Network Layer
- [12] SAE J1939-71 Vehicle Application Layer
- [13] SAE J1939-73 Application Layer - Diagnostics
- [14] SAE J1939-74 Application - Configurable Messaging
- [15] SAE J1939-75 Application Layer - Generator Sets and Industrial
- [16] SAE J1939-81 Network Management
- [17] SAE J1939-82 Compliance - Truck and Bus
- [18] SAE J1939-84 OBD Communications Compliance Test Cases for Heavy Duty Components and Vehicles

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