Understanding SAE J1939

by

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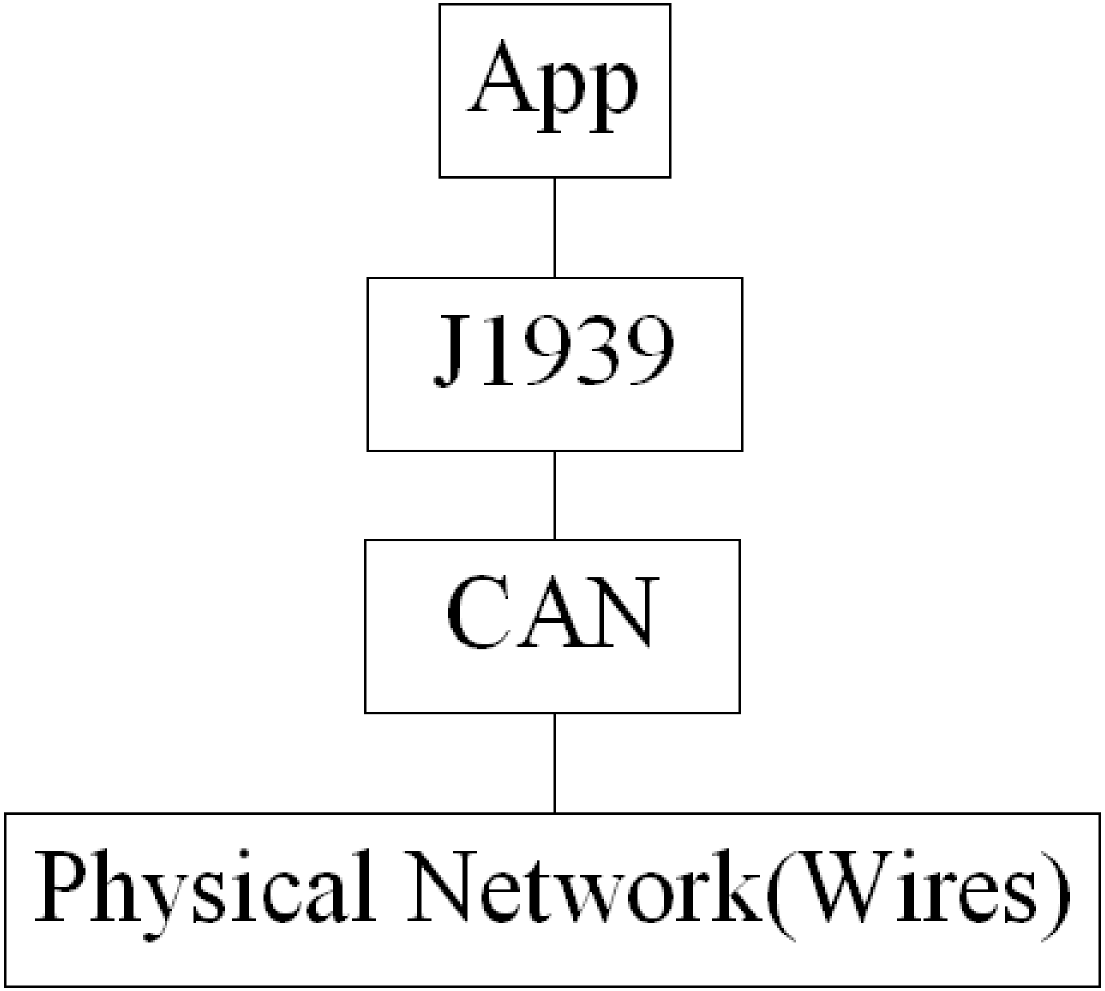
Starting Notes

- Ask questions anytime.
- This stuff is easy.
- Overview, not exhaustive. J1939 specification is 6.5MB, this PPT is 225KB.

What is J1939?

- It is a standard maintained by the Society of Automotive Engineers (SAE)
- The standard defines how information is transferred across a network to allow ECUs (i.e. computers) to communicate information. (e.g. vehicle speed)
- Think of J1939 as a software specification that rides on top of a CAN bus.
- In order to understand J1939, you must first understand CAN.



App

J1939

CAN

Physical Network(Wires)

What is CAN?

- CAN stands for Controller Area Network
- CAN is a form of serial communications (think sequential, 1 bit after another...)
- Multidrop bus meaning all ECUs are connected to the same set of wires.
- CAN transmits data with a binary model: 0 is called a dominant bit and a 1 is called a recessive bits.

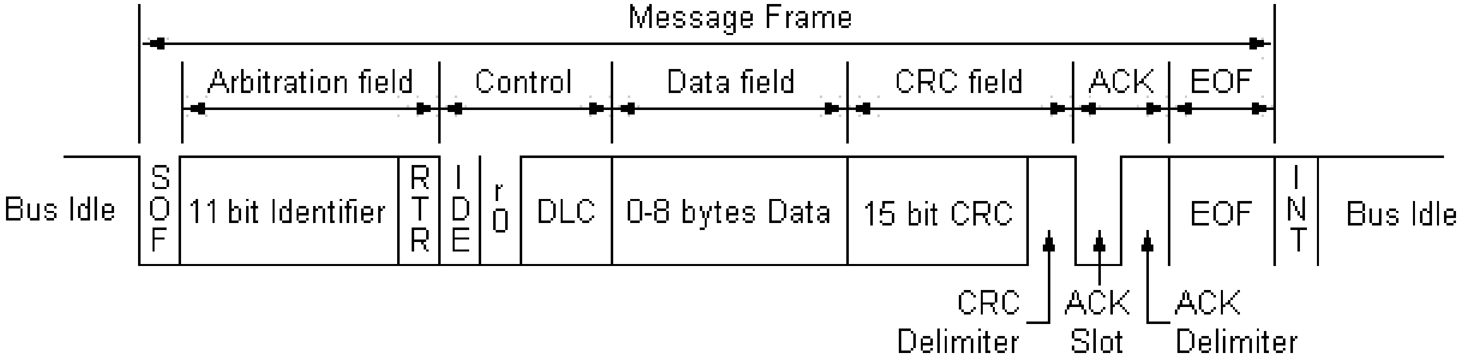
CAN Frames

- CAN uses four different types of frames for communicating information and the state of the bus.
  1) Data frame (used by CAN to send data)
  2) Request frame (used by CAN to request data)
  3) Error frame (used by CAN to indicate error)
  4) Overload frame (used by CAN to insert a delay)

CAN Data Frame

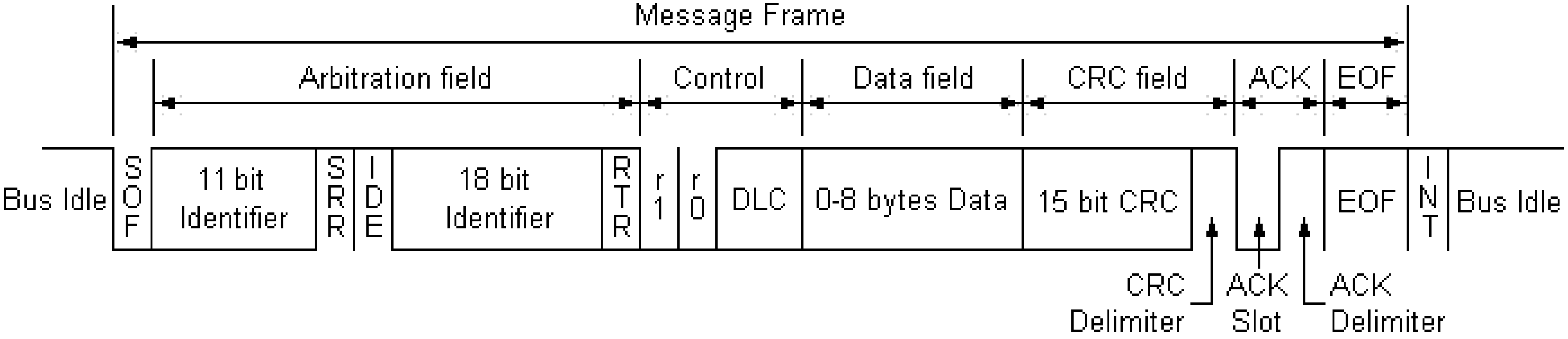
- A CAN data frame uses the standard communication architecture of a header followed by data.
- The header is known as the identifier. It is either 29 bits (CAN 2.0B) or 11 bits (CAN 2.0A)
- The data is sent as bytes and is somewhere from 0 to 8 bytes in length.
- Example: “984 1,2,3,4”

CAN 2.0A Format



SOF: Start of frame (start bit)
ID: Message identifier (indicates msg priority)
RTR: Remote transmission request
IDE: Identifier extension bit (2.0A or 2.0B)
r0: Reserved bit. Sent as dominant.
DLC: Data length code. Valid range 0 – 8.
CRC D: CRC delimiter. Marks end of CRC field.
ACK S: Used for receiver to ACK msg. Sent as recessive.
ACK D: Marks end of ACK field.
EOF: End of frame. (stop bit). Sent as 7 recessive bits.
INT: Intermission. Sent as 3 recessive bits.

CAN 2.0B Format



SRR: Substitute request bit. Sent as recessive. This is simply a placeholder bit to ensure compatibility between 2.0A and 2.0B because 2.0A has RTR.

Bit Stuffing

- 5 consecutive bits, 6th will be opposite.
- Allows for clock synchronization.
- Synchronization happens on recessive to dominant edges.

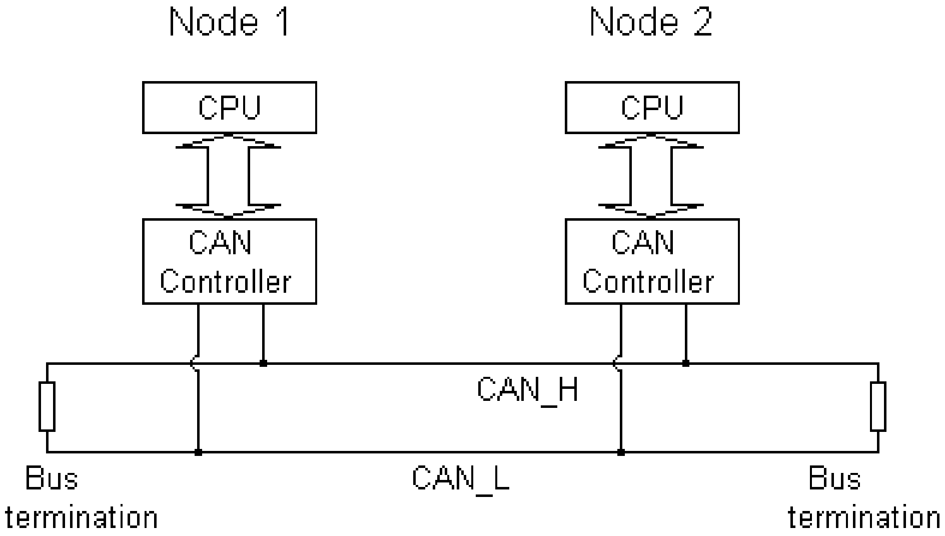
Questions???

- What are the names for the two types of bits?
- What is the DLC field for?
- What is bit stuffing?
- What questions do you have?

Physical Layer

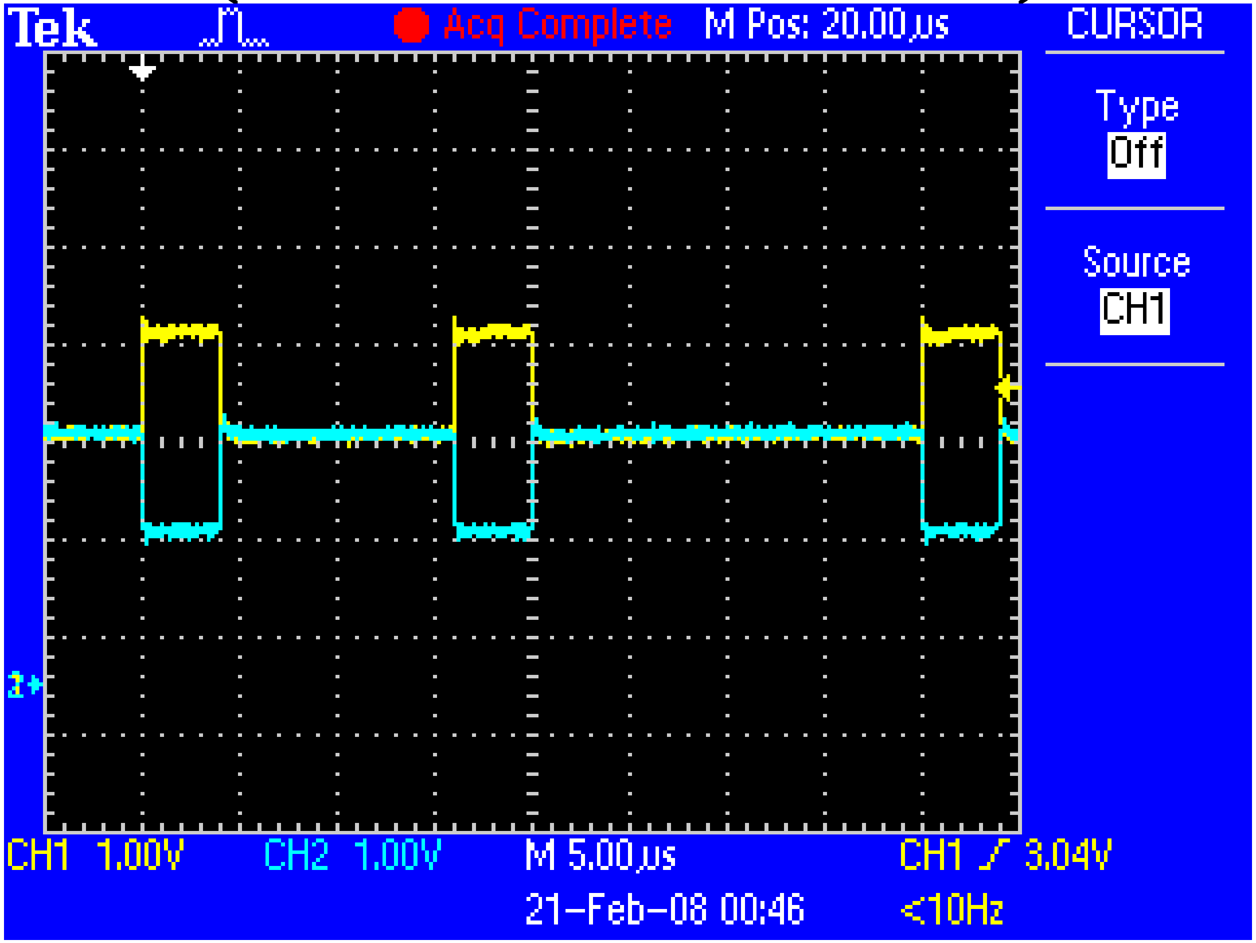
- Bus is made up of two wires: CAN_H and CAN_L. Terminate with 120 Ohm resistors.
- Bus is differential. Voltage drop from CAN_H to CAN_L determines 0 or 1.
- Dominant bit(0): CAN_H=3.5V, CAN_L=1.5V
- Recessive bit(1): CAN_H=2.5V, CAN_L=2.5V

CAN Bus Example



- J1939 defines physical layer parameters.
(e.g. max backbone length)

CAN ID = 0x1dffffff (1/1101/1111/1...)



Bus Arbitration

- It’s what happens when two or more ECUs start to transmit at the same time.
- Every transmitter must make sure what it sends is also what is on the bus.
- If there is a difference, then the CAN controller stops.
- The winner will always be the CAN messages with the lowest identifier.
- Non destructive.

Bus Arbitration Example

ECU #1	0	1	0	0	0	1
ECU #2	0	1	0	0	1	RX
ECU #3	0	1	1	RX	RX	RX
Bus	0	1	0	0	0	1

Questions

- What is bus arbitration used for?
- Who wins bus arbitration?
- Is CAN point to point or multidrop?
- What are the voltage levels for dominant and recessive bits?
- What questions do you have?

J1939 Overview

- Uses CAN 2.0B
- Replaces J1587 and J1708 (although both co-exist on some vehicles today)
- Used on commercial vehicles (i.e. tractor/trailers, cement mixers, military trucks)

J1939 Message Big Picture

- Just as CAN is centered around the ID, J1939 is centered around PGN. PGN is defined by the CAN ID.
- PGN: Parameter Group Number
- For example, PGN 65215 is “Wheel Speed Information”. Data comes in data field.
- Most PGNs are 8 bytes long. Multibyte variables are sent least significant byte first.
- Typically 0xFF means “data isn’t available”, 0xFE means “error”. Valid range is 0-250. Check MSB for multibyte variables.

CAN ID Mapping

28 26	25	24	16	8	0
P	EDP	DP	PF	PS	SA

P: Message priority. Must come first.

EDP: Extended data page. J1939 devices must set to 0.

DP: Data page. Used to create a second page of PGNs.

PF: PDU format:
< 240, PS is destination address. (PDU1 format)
>= 240, PS is group extension. (PDU2 format)

PS: PDU specific. Either destination address or group extension.

SA: Source address of controller application (CA).

J1939 PGN Mapping

- If PF < 240,

  then PGN = (DP << 9)+(PF<<8),

  else PGN = (DP << 9)+(PF<<8)+PS
- Max number of PGNs:

  (240 + (16 x 256)) x 2) = 8,672

Example J1939 PGN

J1939 Wheel Speed Information

PGN:	65215(0xFEBF)
Priority:	6 (default)
Length:	8
TX Rate:	100 ms

		SPN
Bytes 1-2:	Front axle speed	904
Byte 3:	Relative, front axle #1, left	905
Byte 4:	Relative, front axle #1, right	906
Byte 5:	Relative, rear axle #1, left	907
Byte 6:	Relative, rear axle #1, right	908
Byte 7:	Relative, rear axle #2, left	909
Byte 8:	Relative, rear axle #2, right	910

J1939 Request PGN

PGN:	59904 (0xEA00)
Priority:	6 (default)
Length:	3
Destination:	Global or specific
Bytes 1-3:	PGN which is being requested

J1939 Proprietary A PGN

PGN:	61184(0xFEBF)
Priority:	6 (default)
Length:	0 to 1785
Destination:	Specific
Bytes 0 - 1785:	Manufacture specific

- Usage should not exceed 2% of network utilization

J1939 Proprietary B PGN

PGN:	65280 to 65535 (0xFF00 to 0xFFFF))
Priority:	6 (default)
Length:	0 to 1785
Destination:	Global
Bytes 0 - 1785:	Manufacture specific

- Usage should not exceed 2% of network utilization

Questions

- Does J1939 use CAN 2.0B or 2.0A?
- CAN is centered around the ID, J1939 is centered around what?
- What does the PF field tell you?
- What questions do you have?

When 8 Bytes Isn’t Enough

- J1939 has a feature for PGNs up to 1,785 bytes. It’s called the transport protocol. Two ways:
  1) Send data to global dst (BAM).
  2) Send data to specific dst (CM).
- Both ways are similar when it comes to the data transfer part, but differ how they start and how fast data can be sent.
- Only two PGNs are used: Connection Management and Data Transfer

J1939 BAM Big Picture

- First: Transmit a message to the global address that says:
  1. I’m about to send the following PGN in multiple packets
  2. I’m sending X amount of data
  3. I’m sending Y number of packets.
- Second: Send data, wait 50ms, send data, wait 50ms, ect...

BAM Message

Transport Protocol – Connection Management

PGN:	60416(0xEC00)
Priority:	7 (default)
Length:	8
Destination:	Global

Byte 1:	Fixed at 32
Bytes 2-3:	Message size in bytes
Byte 4:	Number of packets
Byte 5:	Reserved. Filled with 0xFF
Byte 6-8:	PGN

Data Transfer PGN

Transport Protocol – Data Transfer

PGN:	60160(0xEB00)
Priority:	7 (default)
Length:	8
Destination:	Global

Byte 1:	Sequence number (1 to 255)
Bytes 2-8:	Data. Any unused locations in last packet should be filled with 0xFF

BAM Example

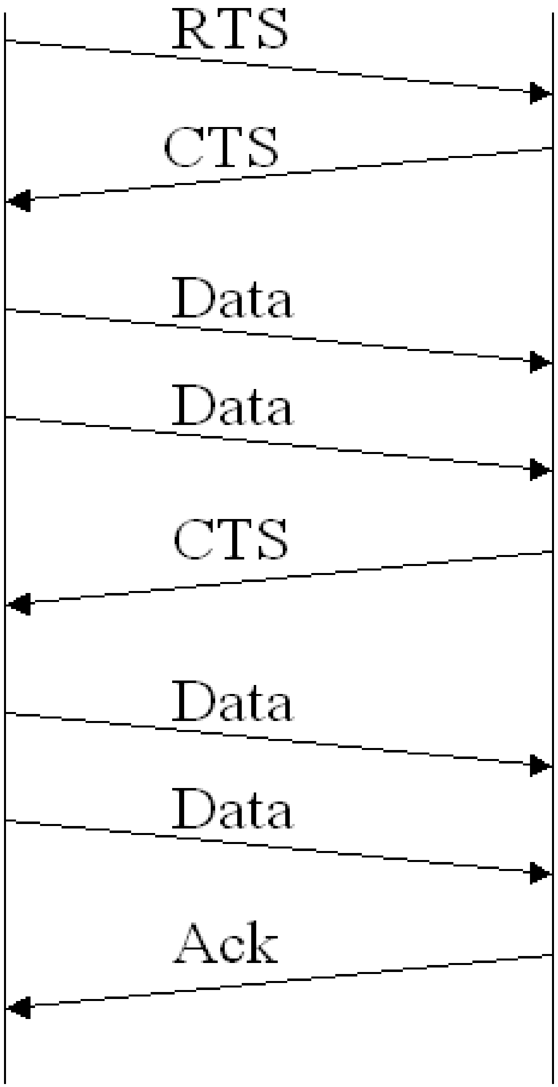
- Example transmission of VIN. PGN 65260(0xFEEC). Assumes VIN is 17 bytes long and is simply 1 through 17. VIN ends with an asterisk ‘*’.

Time (ms)	PGN	DST	0	1	2	3	4	5	6	7
0	60416	255	32	18	0	3	255	EC	FE	0
50	60160	255	1	1	2	3	4	5	6	7
100	60160	255	2	8	9	10	11	12	13	14
150	60160	255	3	15	16	17	‘*’	255	255	255

Destination Specific Big Picture

- First: Transmit a RTS message to the specific address that says:
    1. I’m about to send the following PGN in multiple packets.
    2. I’m sending X amount of data.
    3. I’m sending Y number of packets.
    4. I can send Z number of packets at once.
- Second: Wait for CTS: CTS says:
    1. I can receive M number of packets at once.
    2. Start sending with sequence number N.
- Third: Send data. Then repeat steps starting with #2. When all data sent, wait for ACK.

CM Example



RTS Message

Transport Protocol – Connection Management

PGN:	60416(0xEC00)
Priority:	7 (default)
Length:	8
Destination:	Specific

Byte 0:	Fixed at 16
Bytes 1-2:	Message size in bytes
Byte 3:	Number of packets
Byte 4:	Total number of packet sent in response to CTS.
Byte 5-7:	PGN

CTS Message

Transport Protocol – Connection Management

PGN:	60416(0xEC00)
Priority:	7 (default)
Length:	8
Destination:	Specific

Byte 0:	Fixed at 17
Byte 1:	Max number of packets that can be sent at once. (Not larger than byte 5 of RTS)
Byte 2:	Next sequence number to start with
Bytes 3-4:	Reserved. Filled with 0xFF
Bytes 5-7:	PGN

End of Msg ACK Message

Transport Protocol – Connection Management

PGN:	60416(0xEC00)
Priority:	7 (default)
Length:	8
Destination:	Specific

Byte 0:	Fixed at 19
Bytes 1-2:	Total message size in bytes.
Byte 3:	Total number of packets.
Byte 4:	Reserved. Filled with 0xFF
Bytes 5-7:	PGN

Connection Abort Message

Transport Protocol – Connection Management

PGN:	60416(0xEC00)
Priority:	7 (default)
Length:	8
Destination:	Specific

Byte 0:	Fixed at 255
Byte 1:	Connection abort reason.
Bytes 2-4:	Reserved. Filled with 0xFF.
Bytes 5-7:	PGN

J1939 Address Claim

- All ECUs must claim an address on the network.
- Claim an address by sending PGN 60928 with the source address set to the address you want to claim.
- If another ECU claims the same address, the ECU with the lower value NAME field wins. NAME field is 64 bits long and is placed in the data field of the address claimed message.
- If an ECU loses, it can attempt another source address.
- Two types: “Single Address” and “Arbitrary Address”

J1939 Address Claimed PGN

PGN:	60928(0xEE00)
Priority:	6 (default)
Length:	8
Source:	SA requested (254 for Cannot Claim)
Byte 1-8:	NAME field

J1939 NAME Field

- **Arbitrary Address Capable**: Specifies if the ECU can choose another source address if it loses the address claim procedure.
- **Industry Group**: Specifies the industry. (e.g. on-highway or Ag)
- **Vehicle System Instance Group**: Identifies a particular occurrence of vehicle system. (e.g. trailer #3)
- **Vehicle System**: Identifies vehicle system (e.g. trailer)
- **Function**: Identifies the function (e.g. ABS)
- **Function Instance**: Identifies the function instance (e.g. ABS #1)
- **ECU Instance**: Identifies the ECU instance inside of the function field. Used if you have two ECUs making up an ABS controller.
- **Manufacturer Code**: Assigned by the SAE to identify your company.
- **Identify Number**: Set by manufacturer. If all other fields are the same and two ECUs exist on the network, this field must be unique. (Last line of defense)

J1939/11 Physical Layer

- Max bus length: 40 meters
- Max stub length: 1 meters
- Max node count: 30
- Shielded twisted pair. Shield is connected directly to ground at center of backbone.
- Clock tolerance: +/- 0.05%
- Sample point as close to .875 but not past.

J1939/15 Physical Layer

- Max bus length: 40 meters
- Max stub length: 3 meters
- Max node count: 10
- Unshielded twisted pair.
- Clock tolerance: +/- 0.05%
- Sample point as close to .875 but not past.
- 200-500ns rise and fall time for CAN signal

Document Summary

- J1939: Parent. Includes things not listed elsewhere.
- J1939/11: Physical layer
- J1939/13: Off-board diagnostics connector
- J1939/15: Physical layer
- J1939/21: Data link layer
- J1939/31: Network layer
- J1939/71: Vehicle application layer
- J1939/73: Diagnostics
- J1939/81: Network management

References

- BOSCH CAN Specification
- SAE J1939/11 Physical Layer
- SAE J1939/15 Physical Layer
- SAE J1939/21 Data Link Layer
- SAE J1939/71 Application layer
- SAE J1939/81 Network Management

Post Class Questions

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