
TECHNICIAN
TRAINING
BY DORMAN PRODUCTS
DORMAN
Training Seminar Series
Presents
HD Vehicle Multiplexing
Part 2

1


DORMAN
Aftermarket Innovators

2

Your Instructor For This Class

Sulev "Swede" Oun

- **Owner, O&K Truck and Auto Repairs Ltd.**
- **ATTP Master Instructor, New York State**
- **Author, "Medium/Heavy Duty Truck Electricity and Electronics"**
- **Training provider for various Associations, industry and various NY State agencies**
- **Developed trainings that range from four hours to multiple days, specializing in brakes, electrical, regulations and many other subjects relating to our industry.**
- **Member of various organizations such as SAE, CVSA, TANY**

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What will be covered

- **Continuation of "Multiplexing"**
- **Controller Area Networking (CAN)**
- **Understanding Scan-tool interface and relationship to its relationship to a network.**
- **Diagnostic Tips.**

I will utilize J1939. Part 2 will continue also utilizing J1587/J1708.
Many systems share information on both J1587/J1708 and J1939.

Part 1 was the beginning of another journey.
Part 2 will continue the journey.

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Quick review from Multiplexing Part 1

- **Benefits of using Multiplexing:**
  - Reduced wiring
  - Multiple controllers can be utilized over a bus, simplifying communications.
  - Coupled with Controller Area Network (CAN) ,higher multiple speeds of communication is available.
  - In many cases relays and circuit breakers are replaced with electronic devices.
  - The multiplexed system continuously monitors inputs and sends messages over a shared-wire data bus to control outputs.
- **A "Multiplexed System" can interpret "different messages" transmitted on the same wire "data bus".**
  - The data bus handles multiple messages at the same time.
  - Multiple Control modules communicate with each other.
- **A typical data bus consists of a "twisted" pair of wires to carry messages.**

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- **Most vehicles adopted the "Controller Area Network" (CAN) as the preferred data bus system.**
- **CAN is a serial data transmission network used for:**
  - ECM networking
  - Mobil on-board and external communications
- **Major advantage is that should one of the modules fail, the remaining modules will still be able to communicate.**
- **CAN 2 is the basis for J1939. This is the high-speed network standard used by trucks and buses in North America.**
- **The J1939 bus is designed to function from 125K bits per second (kb/s) up to 1Mb/s.**
  - However, it also allows for speeds as low as 10Kb/s.
  - 500Kb/s is the typical maximum, making it a class C bus.

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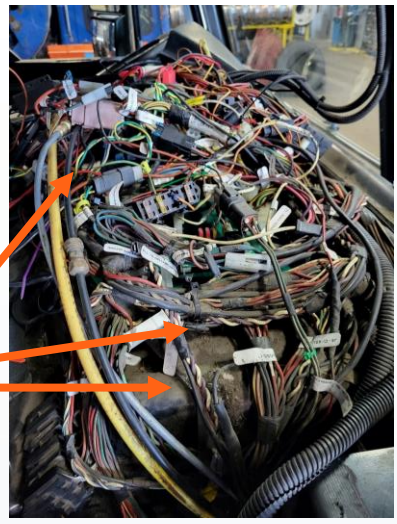
Peterbilt Packer
(Garbage Truck)

This is the "Real World"

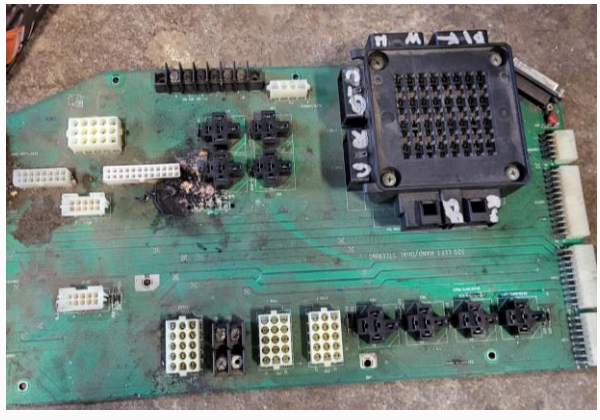
Welcome to our world.

Twisted wires indicating chances are good these are part of a multiplex System.



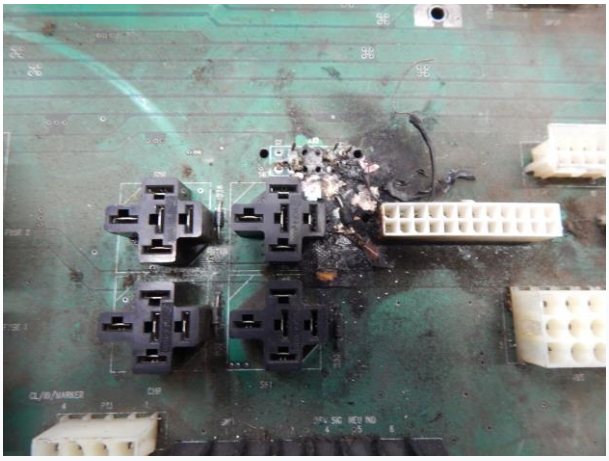
Center Dash

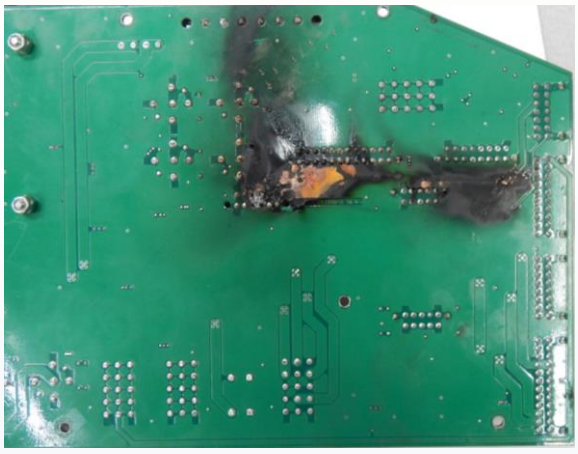
Can you pick out the "CAN J1939" wires?



Circuit board under all the harness/wiring in center dash

What Happened?





Washer dropped unto board and shorted/burnt circuit board.

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REVIEW

J1939. What is it?

- **From SAE " The SAE J1939 communications network is a high-speed ISO 11898-1 CAN-based communications network that supports real-time closed loop control functions, simple information exchanges, and diagnostic data exchanges between Electronic Units (ECUs), physically distributed throughout the vehicle".**
- **Think about a typical truck and the number of major manufactures and their components involved for the final end product.**
  - **Different truck manufacturers**
  - **Different engine manufacturers**
  - **Different transmission manufacturers**
  - **Different ABS manufacturers**
  - **Different other component manufacturers**

They all need to communicate to each other.

- **Your scan tool becomes another part of this communication network the minute you hook up to this system. This test tool will appear as another controller on the vehicles network. Basically, it has access to all the data that the other controllers can access.**

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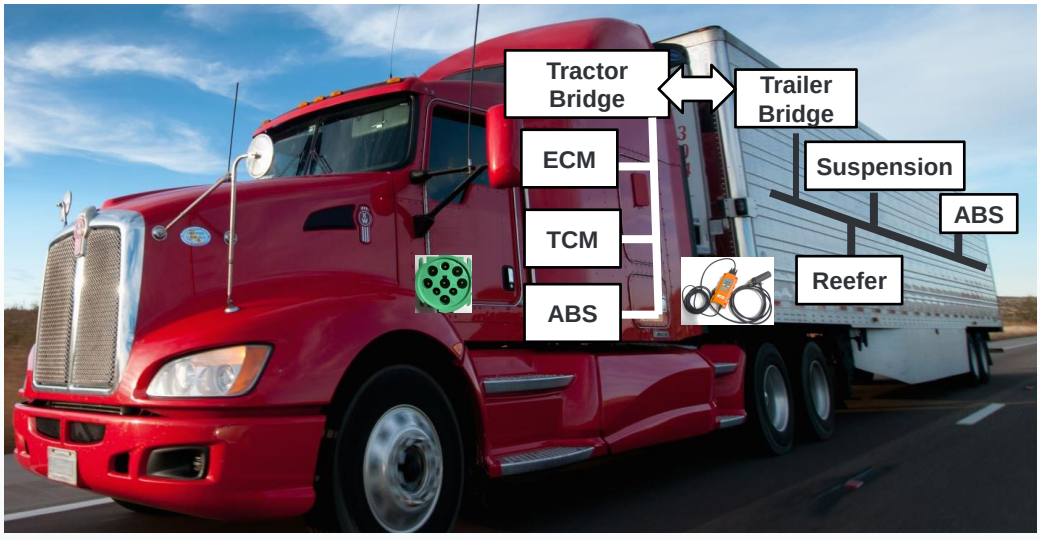

J1939 Implementation

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Electronic Service Tools (ESTs)

Before we continue our journey, let's look at different options of connecting to a vehicle's Electrical/Electronic system.

An electronic service tool (EST) is used to perform the following:

- View system identification data
- Access active codes and history codes
- Erase (clear) inactive (history) codes
- View data
- Perform bi-directional tasks (diagnostic tests) on various subcomponents
- Snapshot function
- Reprogram customer data parameters on engine and chassis systems
- Enable updates

Note: There are also "read-only" scan-tools. Usually, the smaller hand-held type with minimal command keys to display fault codes and system status. Usually used to service vehicles and not necessarily repair vehicles.

➢ **The test tool (scan tool) must locate the messages and convert them to useful data.**

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- A typical tester is connected to a device called a **"Vehicle Communication Interface" (VCI).**
- The VCI acts as a converter between the external interface of the tester and the diagnostic link connector (DLC).

Note: An example of the external interface of the tester is a USB connector. It could also be Bluetooth, Ethernet or WiFi.

USB

VCI

Trailer ABS VCI

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Non –VCI. Cables have OBD 16 pin to allow tablet internally convert/request to communicate.

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Wireless VCI

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- **The physical layer is based on CAN and the "Open System Interconnect" (OSI) higher layers are based on J1939 (9 pin).**

Note: J1587/J1708 . J11587 data bus was the original truck data backbone using a 6-pin connector for access. J1587 governs the communications protocols used for data transactions. J1708 governs all the hardware standards used on a J1587 data bus.

- **The typical HD connector (DLC) is a J1939 (9 pin) connector. However, because HD trucks need to also meet OBD requirements, some manufacturers will also use the J1962 (16 pin) connector.**
- **VCI's utilize an "Application Programming Interface" (API).**
  - The API contains the procedures and commands for "initializing" the connection.
  - Perform diagnostic communications in both directions and
  - Terminate the connection.

BENEFIT:

- VCI's from different suppliers can be connected to any tester tool that supports the same standardized API.

Simply put: A standardized API supports the connecting of different tester applications and different VCI's

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Connecting the service tool

- Initializing process permits the chassis electronic system to communicate with the EST (scan tool).
- The first information usually displayed will be the system software identification, which identifies the chassis system.

Once the application has finished loading, the typical tool allows options such as:

- Reading fault codes.
- Monitor various parameters.
- Diagnostic (bi-directional) tools.
- Customer programming.

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DATA Connectors, also referred to as a diagnostic link connector (DLC) are used to connect the electronic service tool (EST) to the vehicle's electronics (PCM).

J1708 Data Connector:

- Used to access a J1587 data bus.
- It's a 6-pin Duetsh Connector

Various communication protocols are used in transmitting data such as vehicle data and diagnostic information. This J1708 was a common protocol in the 1990s and early 2000s.

It's all about speed.

OBD legislation and other factors led the change requiring trucks to utilize the 500kbs 9-pin or 16-pin OBD port.

Note: Old speed were 250kbs.

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J1939 Data Connector
Three types are available

- J1939 black 9-pin
- J1939 green 9-pin for EPA MY 2013
- J1962 16-pin ALDL (Volvo-Mack in 2014

Reduced "F" cavity to prevent designed to block access to older black version connector.

The first generation J1939 DLC incorporates J1587/1708, which may or may not be used.
The second generation is green in color and has a reduced "F" cavity (see next slide) to block access by the older black version.
Volvo-Mack opted to make the 16 pin "automotive assembly line diagnostic link" (ALDL) J1962 connector their data connector from MY 2014 on.

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J1939 Data Connector
J1939 green 9-pin for EPA MY 2013

A. Battery negative
B. Battery positive
C. J1939 Can busline, dominant high (+)
D. J1939 Can busline, dominant low (–)
E. Can shield
F. J1587 busline, dominant high (+)
G. J1587 busline, dominant low (–)

Note: The post 2013 green colored 9-pin data connector is backwards compatible with pre-2013 receptacles. A smaller F-pin cavity on the green receptacle is designed to block access by a black pre-2013 plug.

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Putting CAN and Data Links Together

- **2017 saw the introduction of multiple CAN channels to compensate for the increase of sensors and ECUs. For example:**
  - One CAN channel for powertrain components
  - Another CAN channel for everything else such as radios, body controllers, etc.
- Can1 has been used typically for the powertrain. In 2016 Peterbilt, Kenworth, and Volvo moved the powertrain traffic to CAN3. That is why the normal 9-pin connectors would not work. One way to overcome this is to purchase a CAN3 to CAN1 cross over cable.

Reduced "F" cavity to prevent designed to block access to older black version connector.

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Which plug should I use?

- **Mack and Volvo use the 16-pin OBDII plug/port.**
  - But they also added the 9-pin port to allow repair facilities without the means to connect to the 16-pin configuration to connect to Macks and Volvos with Cummins engines and diagnose the truck with the 16-pin.
- **The problem is that the 500k 9-pin doesn't always read the entire vehicle and may only provide diagnostic information from the drivetrain.**
- Unfortunately, we are creatures of habit. Which plug do we go to first? Yes, the 9-pin.
- **You will get engine information for diagnostics but fail to find issues related to the truck.**
- Get in the habit of connecting to the 16-pin to identify all issues.

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Scan tool Quick take-aways.

What to call an Electronic Tester/Diagnostic Tester.? I'm comfortable calling it a scan tool.

- **When you hook up a scan-tool, it becomes part of the network.**
- **For communication to occur, the partners (scan-tool and control unit) adhere to the same communications rules (protocols).**
  - **Known as "Diagnostic Protocols".**
  - **The scan-tool sends a message (request) to a specific controller or to a group of controllers to receive an answer.**
- **So, we don't get confused, the following common terms might help:**
  - **On- Board Diagnostics – Vehicle and ECU self diagnostics, monitoring etc.**
  - **Off-Board Diagnostics – That's us troubleshooting.**
  - **On-Board Communication – ECU to ECU communication over the in-vehicle network.**
  - **Off-Board Communication – Scan-tool to ECU (request) and ECU to Scan-tool (response) communication following the diagnostic protocol.**

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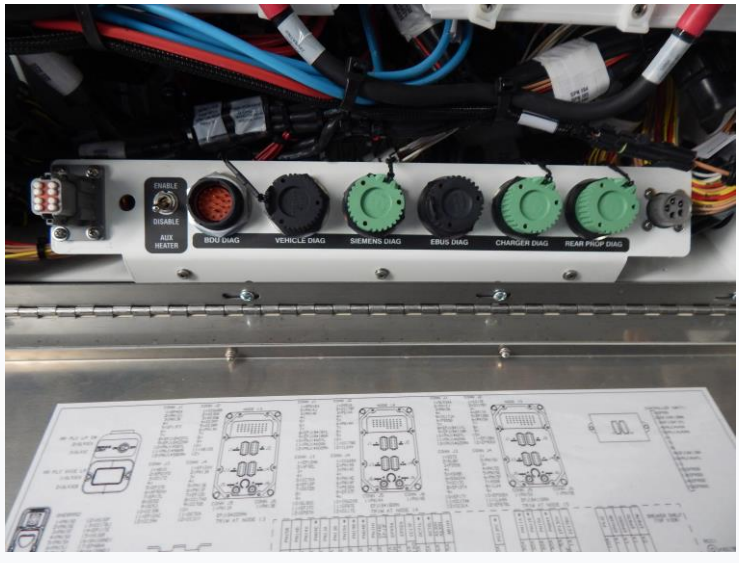

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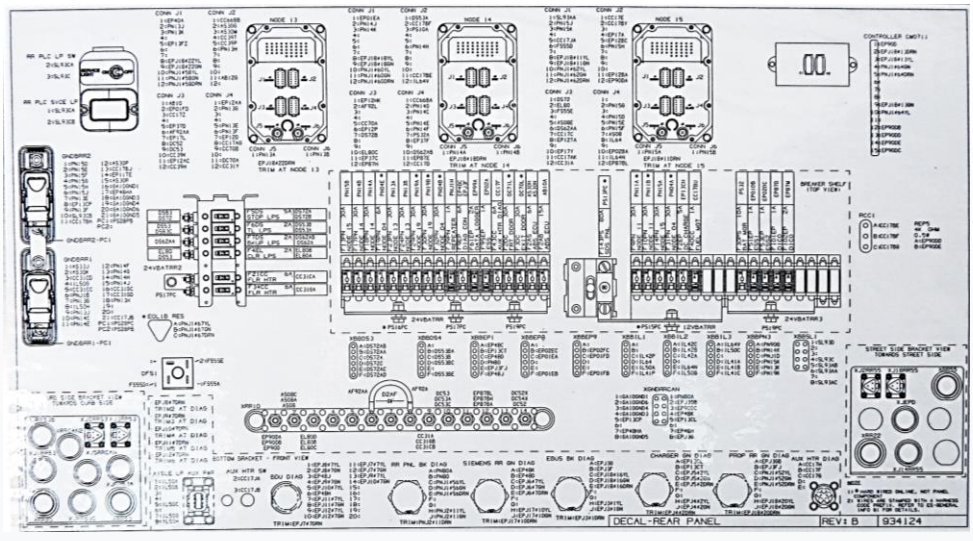

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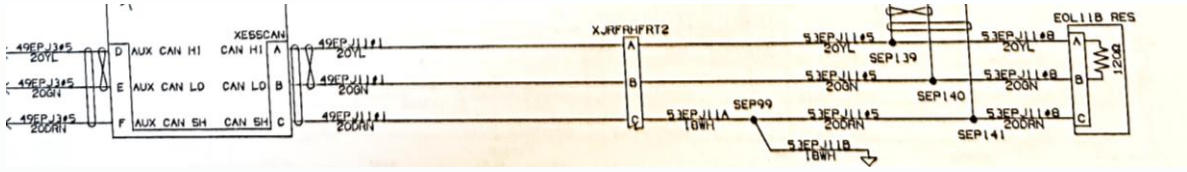

Pick out:

- End of Line Resistor (Terminating resistor)
- CAN HI
- CAN LO
- CAN Shield
- Wire colors
- Wire numbers

PIN C- J1939 + Can H
PIN D- J1939 – Can L
PIN E- J1939 Shield

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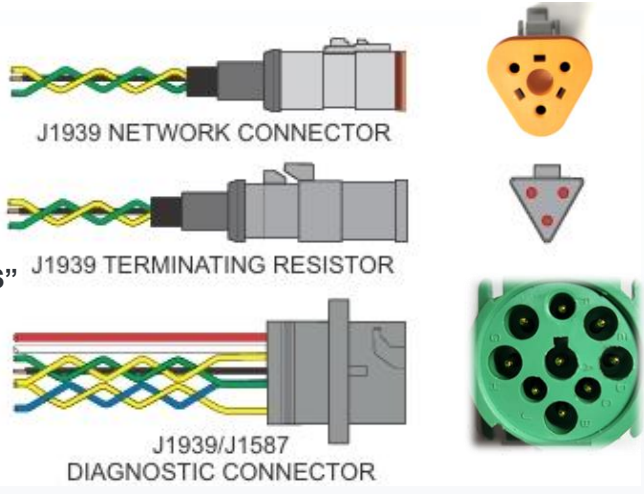
Typical Legend

Light Green- VMM Modules (CAN BUS)
Yellow- OEM Modules (CAN BUS)
Green- J1939 Primary CAN
(250 KBPS).
Yellow- J1939 Propulsion CAN
(500 KBPS).
Note: Other colors will be designated by OEM for systems on "CAN BUS"
Example:

- Red- J1939 Secondary CAN
(250 KBPS)



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Topology

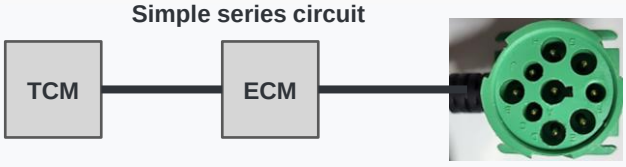
Why would you care?

- This type of information is crucial for reading wiring diagrams.

Note: You might run across a single wire network used where the slow data rate is not a critical issue, and faults are not a safety concern. Most "CAN" networks utilize dual wires. (See Part 1).

- Because of the numerous manufacturers and subsystems involved in a typical vehicle, you will run across versions of series and parallel wire strategies being used.
- **Examples:**
  - A series network can be found in a straight line or loop.
  - Parallel networks can be parallel legs of a central series circuit.

Simple series circuit



(Sometimes also referred to as a "Daisy Chain")

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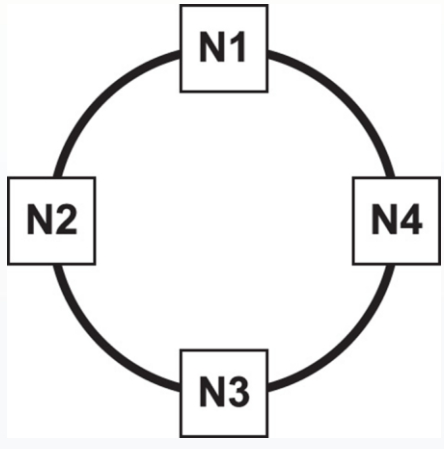
Series Loop

- The modules (nodes) are connected in a line like the series (straight line), but the ends are connected to form a ring (circle).
- In this configuration, a generated message is sent out in both directions.
- Each module (node) receives the generated messages from both directions at the same time.

Note: This type of network is often used in conjunction with other networks (parallel) (star).

- This type of network has no central point (location) for testing.
- For testing, each module must be disconnected to find a circuit or module fault.



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Star Network.
Also referred to as a Spliced Star Parallel.

- In this type the individual legs project out from the central junction (connection).
- In these type of system, you might want to isolate the legs from each other to find a short or open as an example.

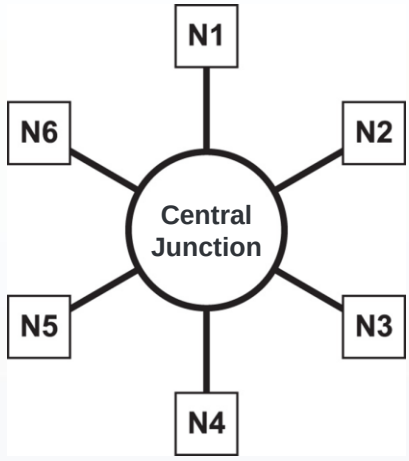

Fig. 1-81

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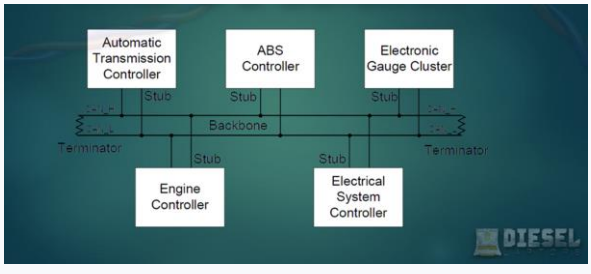
Parallel

- Each module (node) has its own leg (stub) from a central bus.

Note: You will find that most networks will have one or more of these parallel sections.

- This style of network is easier to isolate the modules for testing.



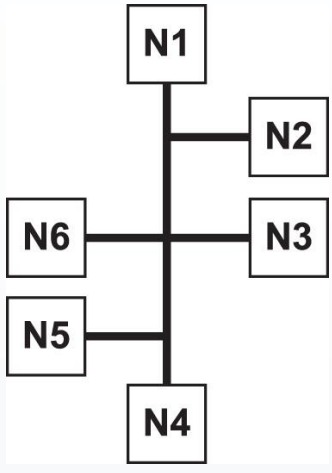


Fig. 1-83

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Junction Connector Star Parallel Style

- These type of networks are easiest to diagnose.
- A module can go offline and the others will stay online.
- Isolate and use jumper wires to connect the leg of the offline module to the DLC.
- This will eliminate the wires if you suspect an open, short or high resistance.
- Each leg can be directly tested to find the fault.

Note: Signal Acquisition Module (SAM):

- **SAMs are part of CAN and act similarly to a router in a communication network.**

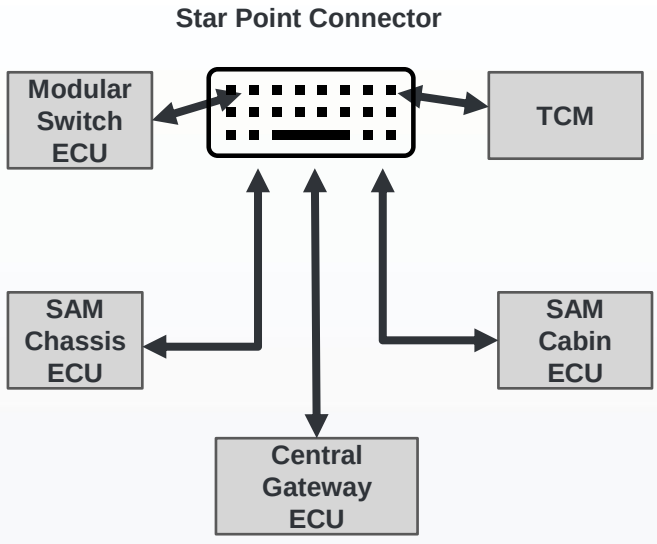

Fig. 1-82

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Topology Continued

- Chances are pretty good that most vehicles will have a combination of networks.
- **You will also run across different types of junction (connectors).**
  - A star point style or comb or cap style (popular with cars) to connect all circuits.
  - Circuit to circuit style using blade or similar connector to connect each leg to the bus.
- **Knowing the connection locations and what type (style) can simplify the testing of the modules and circuits involved.**
- Unfortunately, looking at a diagram doesn't always let you know the type of connection you are looking for.
- **What about optional (add-on) modules. It might show up on the wiring diagram, but it physically is not on that vehicle. Is it possible for the scan tool, to show that optional module as a no-communication issue?**
- What about an aftermarket module not on the diagram affecting modules on the bus?

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High Speed Can and Low Speed CAN

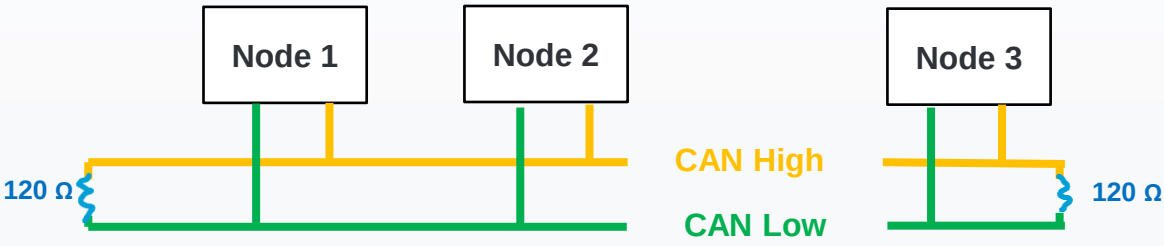
➢ **Vehicles typically implement more than one CAN network.**

Most common will be the High-Speed CAN (HSC) and Low-Speed CAN (LSC).

- HSC- Has a nominal data rate of maximum 1Mbit/s.
- LSC- Has a data rate of up to 125Kbit/s.

Reminder: Even though HSC is specified for a data rate of up to 1Mbits/s, in practice only 500Kbit/s is used.

Note: The main difference between HSC and LSC are the voltage levels and bus termination. **High Speed example below.**



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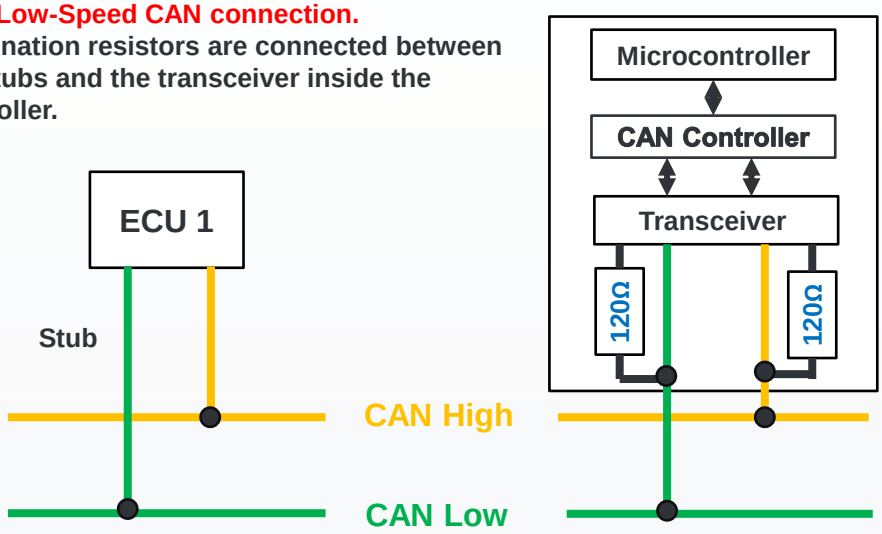
Example of Low-Speed CAN connection.

- Termination resistors are connected between the stubs and the transceiver inside the controller.



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Checking/Testing for Terminating Resistors

- A missing terminating resistor will result in a higher resistance
- What happens if an additional terminating resistor is added?
  - This can occur due to an installation of an aftermarket controller on the bus and that controller has an integral resistor.
- Easiest way to test for the above issues is using a multimeter in the "Ohms" setting/mode.

"Very Important": Make sure that the bus is powered down (ignition off) and both terminating resistors are in place.

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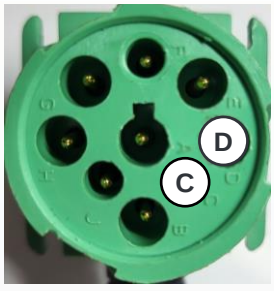
Practical Application

Testing for terminating resistors and bus test.



- 60 ohms: Good.
- 120 ohms: One terminating resistor missing.
- 0 ohms: Short between CAN high and CAN low.
- 40 ohms: An additional resister has been added.
- OL: Open circuit

PIN C- J1939 + Can H
PIN D- J1939 – Can L
PIN E- J1939 Shield

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Going a little deeper

"Bus Access and Arbitration"

- **Beginning transmission of a message, the first thing the controller checks to see if the bus is available (idle state), also referred to as "Carrier Sense"(CS).**
- **If more than one controller (node) starts sending a message, a collision will occur.**
- **"Arbitration" solves the collision.**

The following will help in understanding "Arbitration":

- **CAN differentiates between "dominant" and "recessive" bits.**
- **Logical 1 is equal to a recessive bit.**
- **Logical 0 is equal to dominant bit.**
- **CAN bus is in the recessive state (Logical 1) if all the connected transceivers send a recessive bit.**
- **If one transceiver send a dominant bit (Logical 0), it overwrites the recessive state of the bus.**

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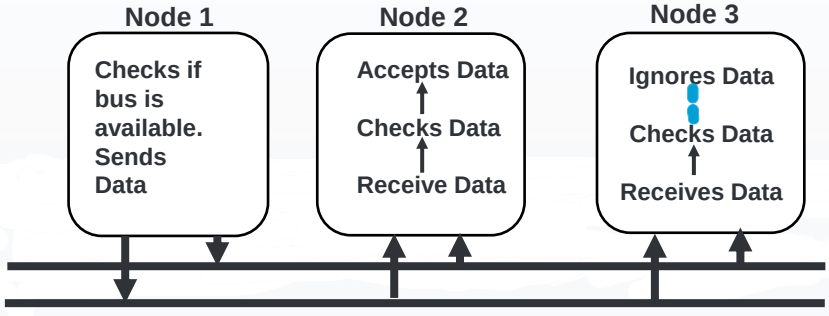
- **Every Can message starts with a start bit (Logical 0).**
  - **A dominant "0" overwrites a recessive "1".**
  - **Basically, the lowest value wins the "arbitration".**
  - **The control unit that loses the arbitration stops sending and continues reading.**
  - **When the bus is idle again, the loser retries to send its message.**

Wow! Talk about a potential traffic jam and accidents waiting to happen.

"Below is a simple graphic of a data sending sequence."



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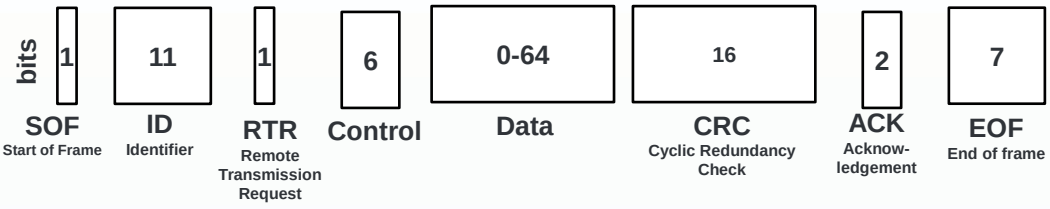
CAN frame simplified



The 8 CAN bus protocol message fields

- **SOF: Start of Frame is the "dominant 0" telling the other nodes on the bus that a CAN node intends to talk (send a message).**
- **ID: This is the frame identifier. Lower values have higher priority.**
- **RTR: The "Remote Transmission Request" indicates whether a node sends data or requests dedicated data from another node.**

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- **Control: The "Control "contains the Identifier Extension Bit (IDE). This Bit is a "dominant 0" for 11-bit. The "Control" also contains the 4 bit Data Length Code (DLC) specifying the length of the data bytes to be transmitted (0-8 bytes).**
- **Data: Contains the data bytes payload. This includes CAN signals that can be extracted and decoded for information.**
- **CRC: The "Cyclic Redundancy Check" is used to ensure data integrity.**
- **ACK: Indicates if the node has acknowledged and received the data correctly.**
- **EOF: Marks the end of the CAN frame.**

Note: Quite often the CAN-ID, control bits and data field is also referred to as the "payload".

The classical CAN data field carries between 0 and 64 bits (8 bytes of data).

Reminder: A "bit" is short for "binary digit" and the smallest unit of data that a computer stores and processes. A value of either 0 or 1. (Represented by lower case b).

A "byte" is a unit of information made up of "bits". 8 bits is 1 byte.

This previous information is useful in understanding "CAN Errors"

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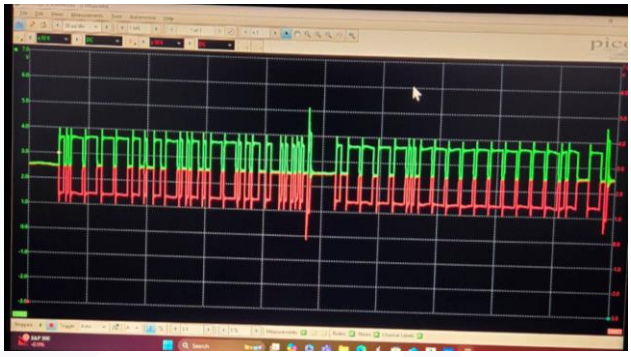
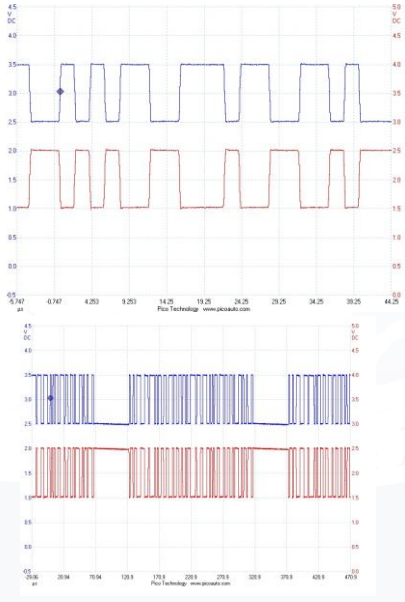




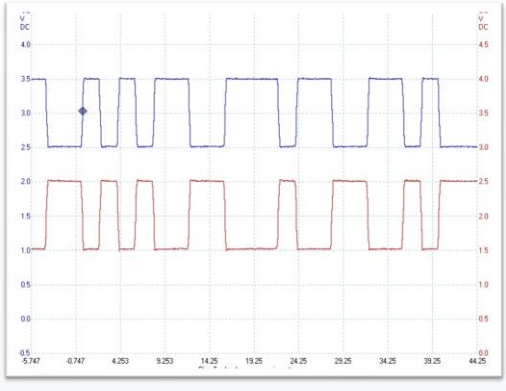
Screen shot using Pico lab scope from former student and friend Geno.
Graphics on side from Pico Technology.

"Looking at messages"

What to look for in CAN waveform:

- CAN-H and CAN-L waveforms mirror each other about 2.5 V. Each has 1 V peak-peak amplitude.
- CAN-L switches from 2.5 V down to 1.5 V.
- CAN-H switches from 2.5 V up to 3.5 V.
- When the signals are both at 2.5 V, they are in the recessive state and logic 1 is being sent.
- When the signals are apart, a logic 0 is being sent.
- CAN-L and CAN-H remain 2.5 V (recessive state) in the periods between messages.
- The low and high voltages need to be relatively uniform.
- No significant noise or distortions.

The above is a general characteristic of a Bus waveform.



Pico Technology

CAN Errors

As good as CAN is, errors do occur.

Some reasons for errors:

- **Faulty cables/wiring**
- **Incorrect termination**
- **Noise**
- **Controllers (Nodes) malfunctioning.**
- **Not to mention adding aftermarket nodes**

Error handling – What is it?

A means of identifying and rejecting erroneous messages by:

- **Enabling a sender to re-transmit the message.**
- **Disconnect a CAN node(s) that keep transmitting erroneous messages.**

Note: Error handling is part of the CAN standard and built into every CAN controller.

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Simplified step by step example:

- **CAN node 1 transmits a message onto the CAN bus.. It also reads every "bit: it sends. (The read part is important).**
- **Because it read every bit that was sent, it discovers that one bit that was sent dominant (0) was read recessive (1). (previous slides).**
- **This is known as "Bit Error" and Node 1 raises the "Active Error Flag" to let the other nodes know.**

Note: Node 1 does this by sending a sequence of 6 dominant bits on the bus (000000).

- **The other nodes see the 6 dominant bits as a "Bit Stuffing Error".**
- **Using 3 nodes on a bus as an example; Nodes 2 and 3 simultaneously raise an "Active Error Flag" in response.**
- **This sequence of raised error flags will compromise part of the "CAN error frame".**
- **CAN node 1 (transmitter) increases its "Transmit Error Counter" (TEC) by 8.**

Note: Bit Stuffing is a technique that inserts extra bits into a data stream to help ensure proper data transmission.

It also helps to keep the receiver synchronized by breaking up long sequences of 1s or 0s.

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- CAN nodes 2 and 3 increase their "Receiver Error Counter" (REC) by 1.
- CAN node 1 will automatically re-transmit the message and now succeeds.
- Because of this, Node 1 reduces its TEC by 1 and nodes 2 and 3 reduce their REC by 1.

The above was just an example to get anyone that wants to get into "Data Logging" to identify errors.

- Built-in CAN error handling is used to help reduce (eliminate) erroneous messages and allow CAN nodes to retry the transmission of erroneous messages.
- **The benefits are that short disturbances (noises) will not result in lost/invalid data. By being able to re-send the message and winning the arbitration (also no error), the message would be successfully sent.**
- But what happens if the errors are due to systematic malfunctions in a transmitting node?
  An endless loop of the sending and destroying of the same message can trigger a jamming of the CAN bus.

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- CAN controllers have a **"Status"** and **"Error Counters".**
- **CAN controllers (nodes) keep track on a:**
  - "Transmit Error Counter" TEC) and
  - "Receiver Error Counter" (REC).

As an example:

- A CAN node enters the "BUS OFF" state if the TEC exceeds 255.
- A CAN "Error Passive" state occurs if REC or TEC exceeds 127.

Three possible states:

1. Error Active- Default state of CAN nodes. The node can transmit and raise "Active Error Flags" when an error is detected.
2. Error Passive- The CAN node can still transmit data, but it now raises **"Passive Error Flags"** when an error is detected.
3. Bus Off- The CAN node disconnects itself from the CAN bus and can no longer transmit data or raise error flags.

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Codes

In the practical world we don't necessarily get this deep unless you are data logging. However, some scan tools will log a lot of communication faults that might mislead you in the diagnostic process.

A good example is wiper communication faults ????.

Yet the wipers work, and the driver never complained.

I personally ignore those type of communication faults unless they are relevant to a hard (active) fault.

- **You will notice a lot of U-Codes (Communication codes) when there is a battery/charging system. Why?**
  - **Each module has its fault criteria relating to voltage.**
  - **For that reason, some modules will go off-line.**
  - **Remaining modules might set codes due to missing messages from the off-line ones.**
- **That could be the reason for codes with no symptoms. Try clearing them and see if they come back. (Record, capture, write down the codes before clearing).**

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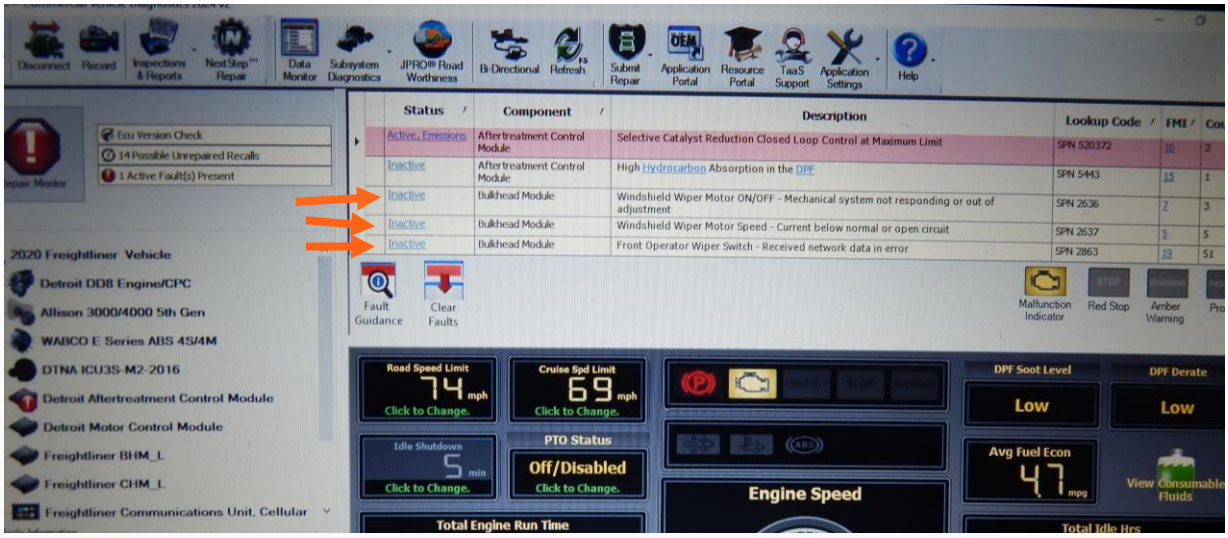

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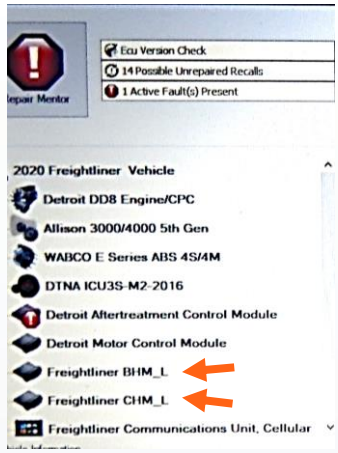
Codes cont.

Picture on right shows a **Bulkhead Head Module (BHM)** and a **Chassis Module (CHM).** They tend to control less critical systems. **These modules and quite often the sensors and actuators for these systems tend to be less robust than modules like the PCM, TCM, ABS and safety critical controllers.**

Consequently, minor variations can cause codes to set. Not to mention they are more prone to error cause codes.

That's why we went through the previous slides. (Re-visit).

- These codes can sit in memory for a long time.
- That's why the counts (occurrences) tend to be high.
- Newer trucks with OBD require the codes to self-clear (see OBD lunch and learns).
- There are no requirements for wiper, light issues etc. to self-clear.



Cropped section from previous picture.

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Resets

Whenever I have an issue with my computer (personal), phone etc. I instinctively **"re-boot"** these type of devices. It's as if these devices get confused with too much information happening at the same time.

Today's vehicles are no different. Think of all the module to modules communication, error strategies, adaptive capabilities and not to mention software versions(updates). This opens the door for total confusion.

Clearing codes today doesn't erase stored information.

Tip: If you run across improper communication or not operating properly, try a reset if the scan tool supports that function.

I have cleared up inoperative systems by resets on occasion, and, also restored module communications. It is a worthwhile first step.

Tip: Removing a module fuse (if available) kills power do that module, which causes the module to reset. Providing the modules don't have capacitors to retain any learned values. This might require a long time for resets.

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Resets cont.

Alternative reset.

Removing power from module and shorting only at that module.

- Remove the fuse to that module.
- Back probe the power circuit and ground at the module connector.
- Make sure there is no voltage (use your DVOM).
- Jumper the power and ground probes together.

Note: You might have to relearn that or any other module that share that fuse.

Important! Make sure you are on the right circuit to prevent any possible damage.

Another way is to disconnect the module and short the power terminal on the module side to ground and on the module side.

Important! Make sure of your terminal position to make assure you are working with the correct one(s).

Also keep in mind the terminals are fragile and disturbing them can cause another issue that wasn't there before.

Assess the situation first before diving in.

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We offer greater freedom to fix cars and trucks
by engineering exclusive, labor-saving
and cost-effective repair solutions.

Thank You !

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