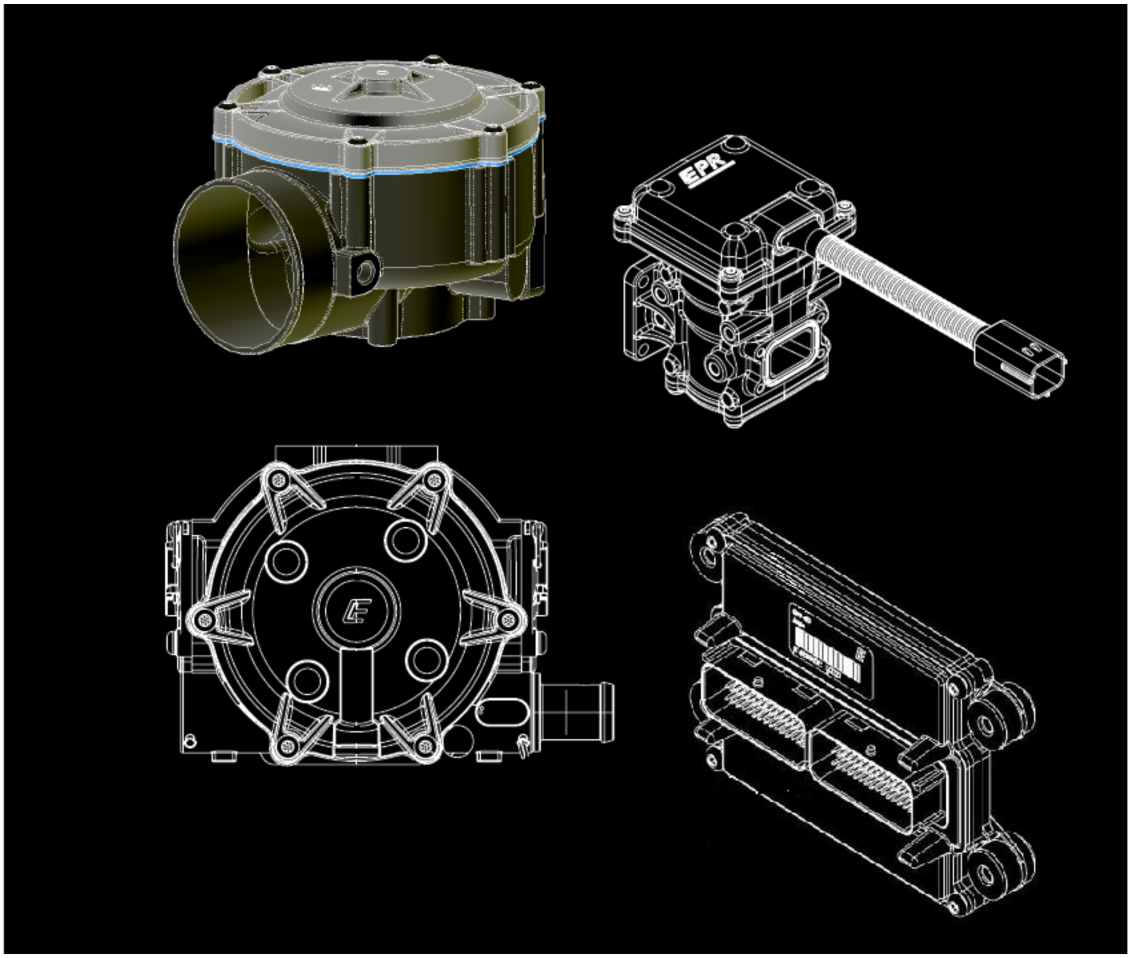
LIGHT DUTY FUEL SYSTEM SERVICE MANUAL SUPPLEMENT



ECONTROLS, LLC
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EMISSION CERTIFIED ENGINE SYSTEM SCHEMATICS (LIGHT DUTY LPG DEDICATED SYSTEM)

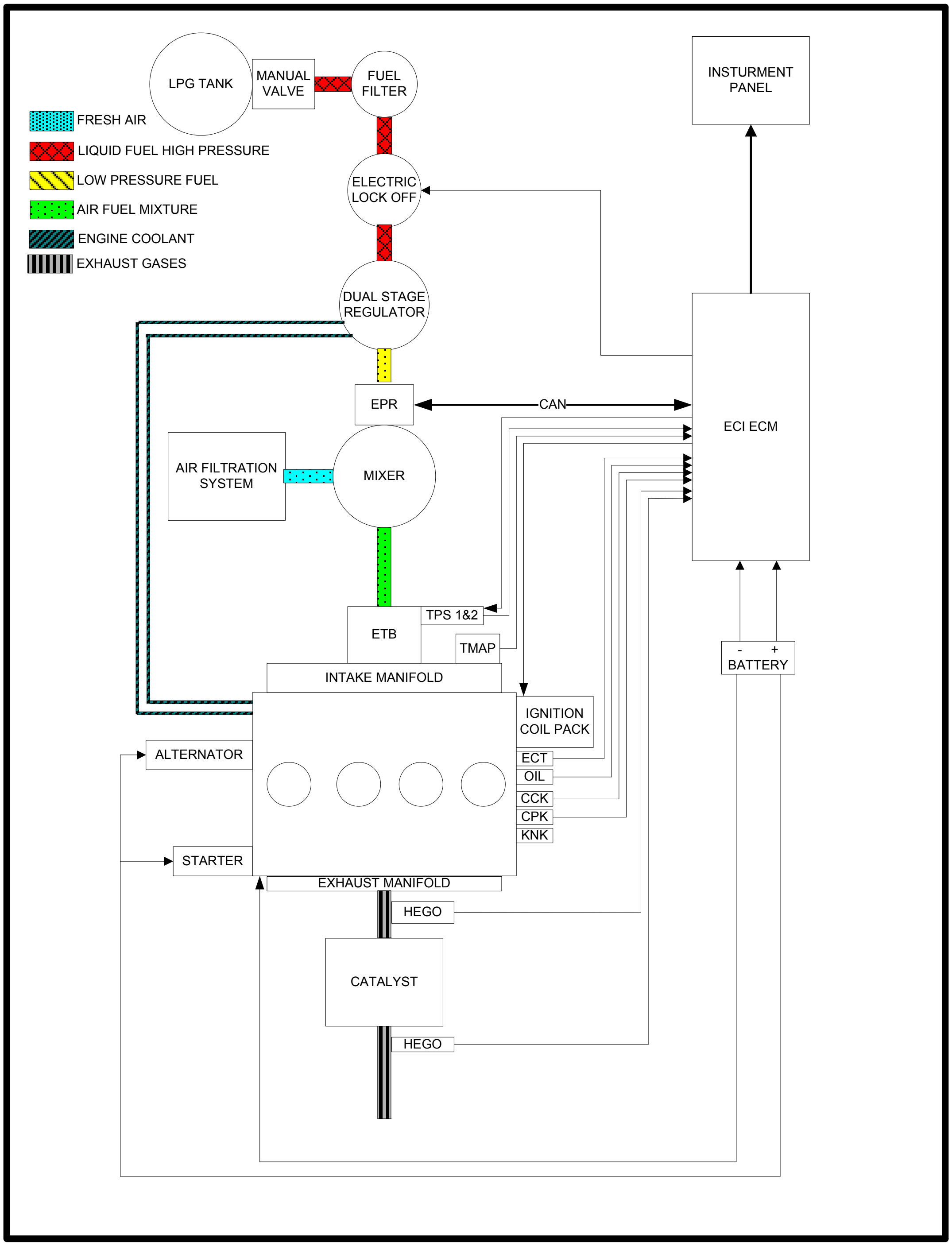


Figure 1 - *LPG Dedicated System*

EMISSION CERTIFIED ENGINE SYSTEM SCHEMATICS
(LIGHT DUTY GASOLINE DEDICATED SYSTEM)

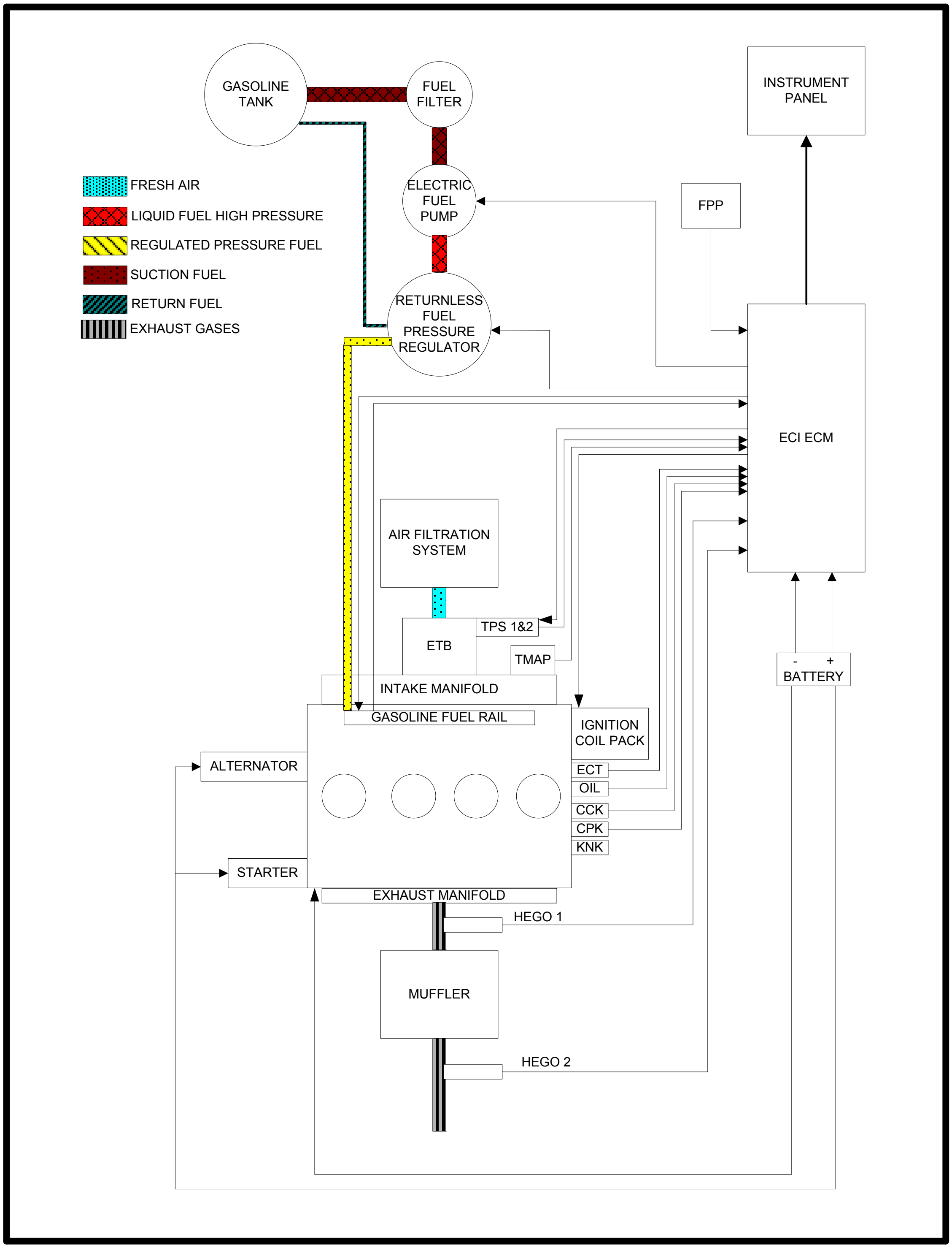


Figure 2 - *Gasoline Dedicated System*

EMISSION CERTIFIED ENGINE SYSTEM SCHEMATICS (LIGHT DUTY GASOLINE & LPG BI-FUEL SYSTEM)

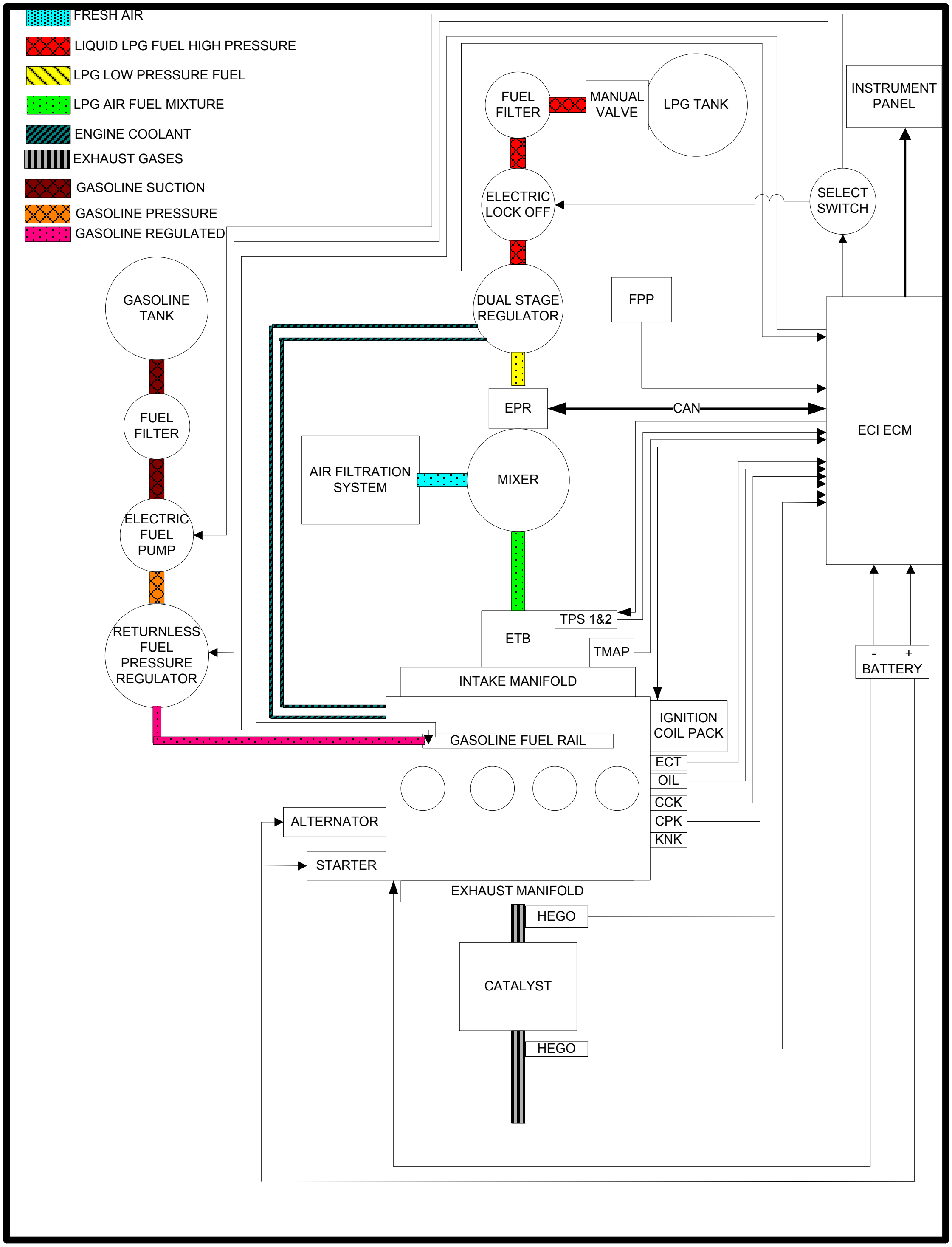


Figure 3 - *LPG and Gasoline Bi-Fuel System*

OPEN LOOP ENGINE SYSTEM SCHEMATICS
(LIGHT DUTY OPEN LOOP LPG SYSTEM)

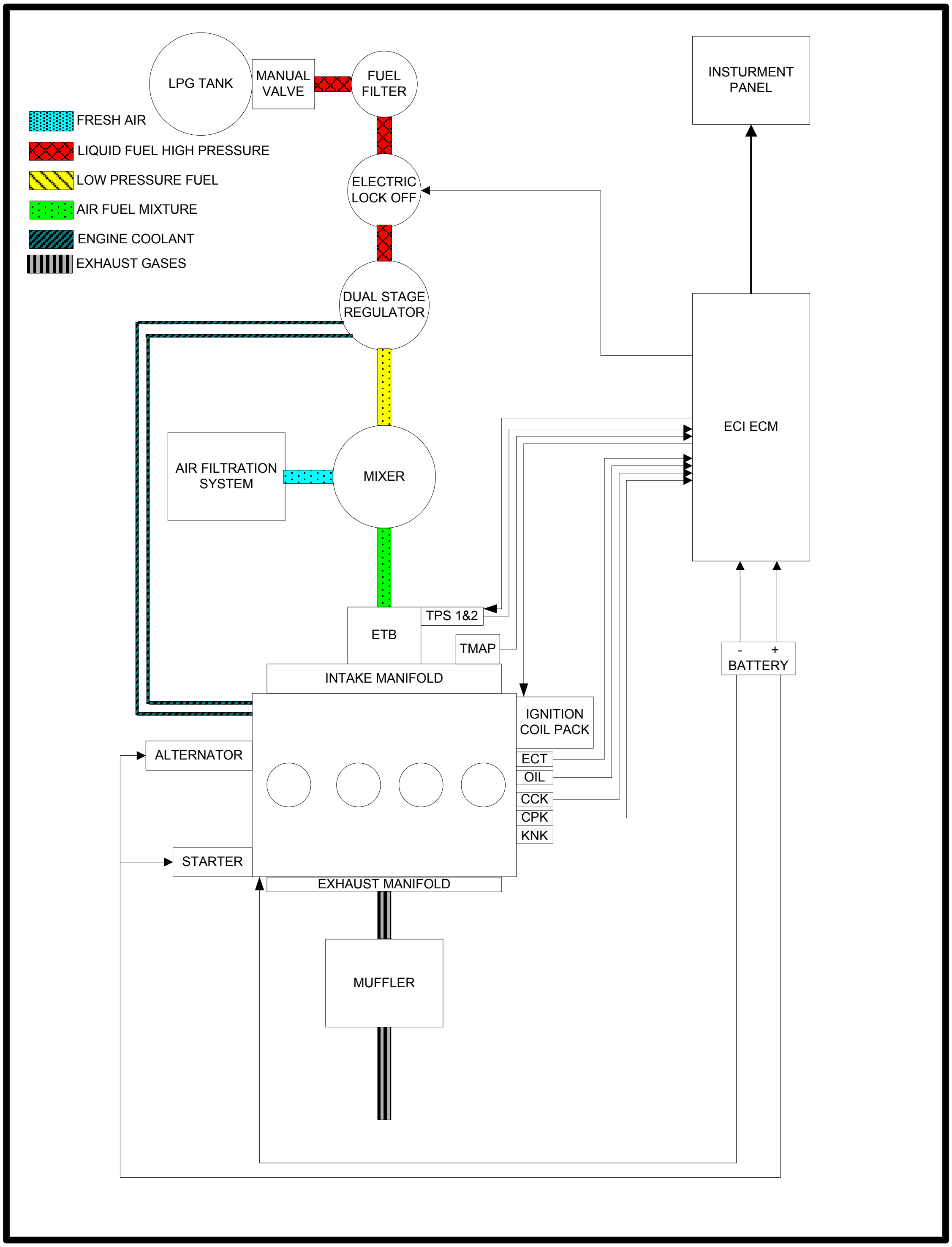


Figure 4 - *Open Loop LPG System*

CLOSED LOOP ENGINE SYSTEM SCHEMATICS
(LIGHT DUTY CLOSED LOOP GASOLINE SYSTEM)

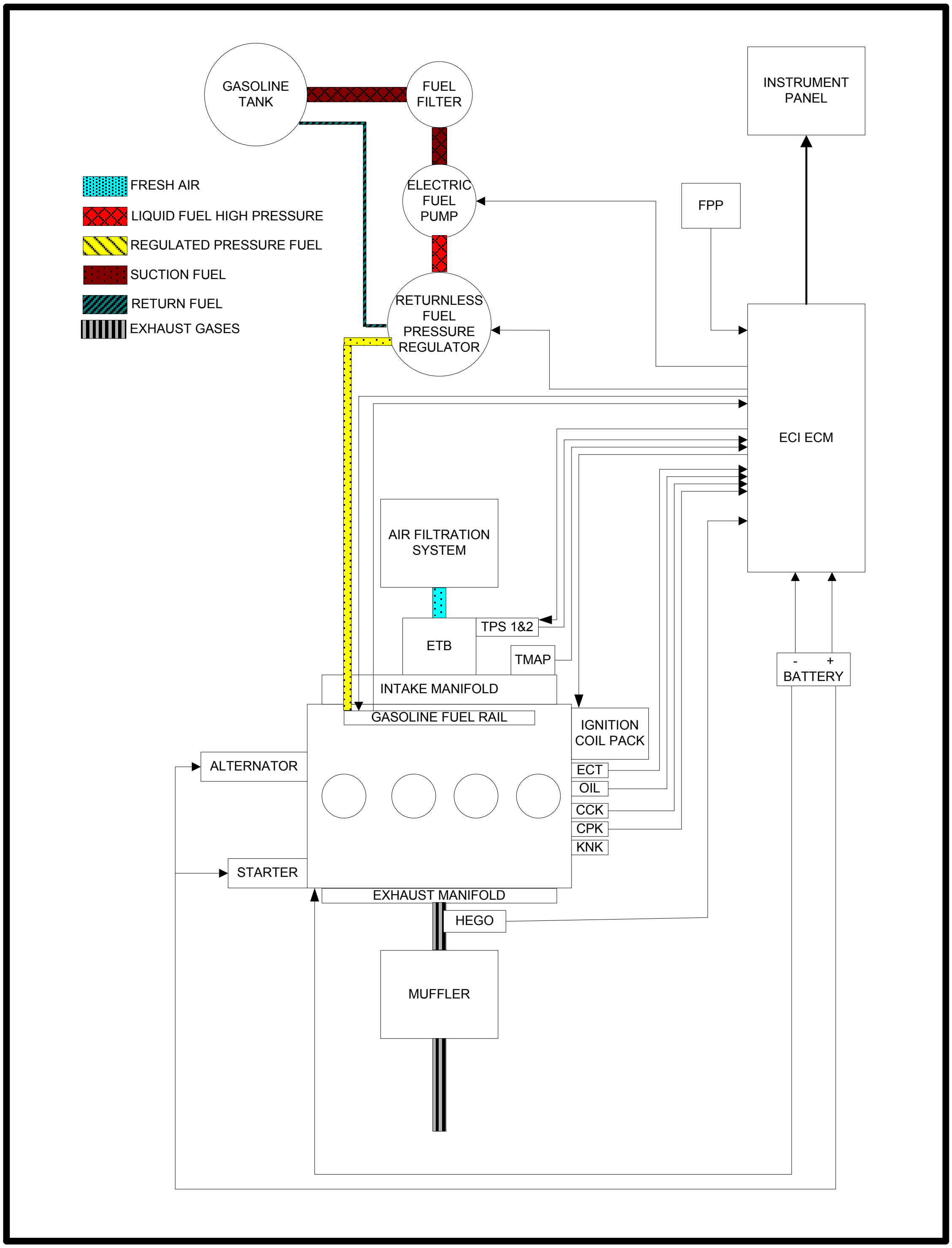


Figure 5 - *Closed Loop Gasoline System*

INTRODUCTION

This service manual supplement has been developed to provide a service technician with the basic understanding of the fuel systems provided by *EControls*. The construction and layout of the service manual supplement includes the different types of fuel systems, such as Dedicated LPG or Gasoline, or Bi-Fuel Gasoline and LPG.

The purpose of the general section of the manual is to advise the technician in the use of the manual, general definitions, and how to use the manual to diagnose and repair the EControls fuel system.

EControls provides specific fuel systems to its OEM customer, based on specifics, for each OEM. The criteria may vary based on regional requirements such as fuel supply, emissions requirements, and/or OEM customer specific requirements.

EControls develops all its fuel systems with the complete system in mind. Typically EControls supplies the Engine Control Module (ECM), and Gaseous fuel delivery components; such as mixers and regulating components. Components typically supplied by others include the fuel tank, fuel delivery lines, brackets, and base engine sensors. EControls components are identified by a bar code label with the EControls logo.

NOTE: When servicing and or replacing any part of an EControls designed fuel system, only replace with the originally designed parts, as substituting components may result in loss of design performance, introduce a safety risk, loss of emissions control and void OEM warranties.

Included in this section are block diagrams of each of the fuel system types, that will give the technician the ability to understand fuel system components, and an over view of each of the systems. More detailed description of the typical fuel system components can be found in this manual under the section labeled Description and Operation.

This manual should be used in conjunction with the OEM base vehicle manual, when diagnosing electrical, diagnostic error and fueling problems. This manual has been categorized into sections, which are similar to those sections found, in most OEM Service Manuals, for vehicles, and off road and stationary equipment.

FUEL SYSTEM CAUTIONS

CAUTION: Do not smoke, carry lighted tobacco or use a lighted flame of any type when working on, or near any fuel related component. Highly flammable air-fuel mixtures may be present, and can be ignited causing personal injury.

CAUTION: Do not allow LPG to contact the skin. LPG is stored in the fuel tank under high pressure. LPG can cause severe burns to the skin.

CAUTION: LPG is heavier then air and will drift downwards and can accumulate in pits, and near the floor. In both cases do not release the fuel without adequate ventilation.

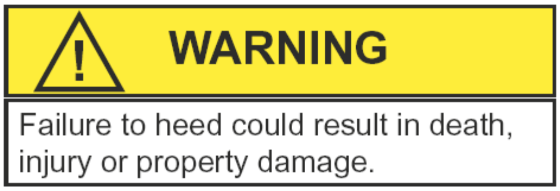
CAUTION: Do not make repairs to the LPG fuel system, if you are not familiar with, or trained to service LPG fuel systems. Contact the OEM dealer who sold you the vehicle or equipment, or the OEM, to locate a repair facility with trained technicians, to repair your fuel system.

WARNINGS, CAUTIONS and NOTES

This manual contains several different Warnings, Cautions, and Notes that must be observed, in order to prevent personal injury, and or damage to the vehicle, the fuel system or personal property. Each type of warning is relative to the level of risk, if the service procedure is performed improperly.

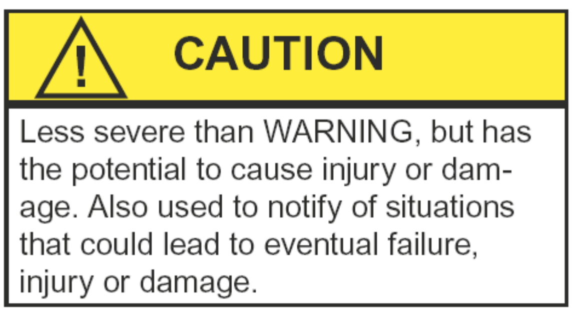
A "**WARNING** "statement is used when it has been determined that by performing a process or procedure, defined in the manual improperly, could result in serious bodily injury, and or death, or serious damage to the vehicle or property damage.

Typical Warning Label



A "**CAUTION**" label or statement is used when it has been determined that by performing a process or procedure defined in the manual improperly, a less severe result may occur. It could however, result in serious bodily injury, and or serious damage to the vehicle or property damage.

Typical Warning Label



This caution label may also appear in areas of this manual which apply to service and repair procedures, which could render the fuel and emissions control system non-compliant. In addition, it may also be used to indicate a failure to observe, which may influence the terms of the warranty.

An "**IMPORTANT**" statement generally denotes a situation, which requires strict adherence to the assembly, tightening, or service procedure. Failure to observe this procedure could result in an unsafe condition or improper performance of the vehicle or a component.

A "**NOTE**" statement applies to a specific item or procedure, which is to be followed during the servicing of the vehicle or its components.

PROPER USE OF THIS SERVICE MANUAL, TOOLS AND EQUIPMENT

To reduce the potential for injury to the technician or others, and to reduce damage to the vehicle or equipment during service repairs, the technician should observe the following steps:

- The service procedures defined in this manual, when followed, have been found to be a safe and efficient process, to repair the fuel system. In some cases, special tools may be required, to perform the necessary procedures, to safely remove and replace a failed component.

- When servicing the fuel and emissions control system, you should follow all the recommended service and repair procedures, to insure the fuel and emissions system, is operating as designed, and certified by the region the vehicle or equipment is being used, despite the location of the manufacturing. When applications are being used in the United States and are certified by the Environmental Protection Agency (EPA) and /or the California Air Resources Board (CARB), you can not knowingly or purposely defeat or disable any part of the fuel and emissions system which would leave the fuel and emissions control system in a non-compliant state.

IMPORTANT:

It is important to remember that there may be a combination of Metric and Imperial fasteners, used in the installation of the EControls, LPG or Gasoline fuel systems. Check to insure proper fit, when using a socket or wrench on any fastener, to prevent damage to the component being removed, or injury from "slipping off" the fastener.

IMPORTANT:

The LPG & Gasoline fuel systems may utilize fuel lines or hoses with swivel connections, and compression fittings, which attach to fixed mating connectors. You should always use a wrench of the proper size on both the swivel and fixed fitting, to prevent turning of the fixed fitting. Turning of the fixed fitting may cause a "twisting" or "kinking" of the hose and may result in a restriction of the fuel line or a leak.

WARNING

ALWAYS LEAK CHECK ANY FUEL SYSTEM CONNECTION AFTER SERVICING! USE AN ELECTRONIC LEAK DETECTOR OR A LIQUID LEAK DETECTION SOLUTION, OR BOTH. FAILURE TO LEAK CHECK COULD RESULT IN SERIOUS BODILY INJURY AND OR DEATH, OR SERIOUS PROPERTY DAMAGE.

WARNING

ECONTROLS GASOLINE FUEL SYSTEMS ARE DESIGNED FOR REGULAR GASOLINE FUELS. THESE SYSTEMS ARE NOT DESIGNED FOR GASOLINE BIO FUEL PRODUCTS. USE OF THE GASOLINE BIO FUELS MAY CAUSE DAMAGE TO THE INTERNAL PARTS OF THE GASOLINE FUEL SYSTEM AND MAY CREATE A DANGEROUS CONDITION.

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ABREVIATIONS

ACRONYM	DEFINITION
AC	Alternating Current
AF	Air Fuel Ratio
AL	Adaptive Learn
ATC	After Top Center
ATDC	After Top Dead Center
AVV	Air Valve Vacuum
BARO	Barometric Pressure
BAT	Battery
BHP	Brake Horse Power
BL	Block Learn
BP	Barometric Pressure
BTU	British Thermal Unit
°C	Celsius
CC	Cubic Centimeter
CAC	Charged Air Cooler
CAN	Controller Area Network
CARB	California Air Resources Board
CAT	Catalyst
CCP	CAN Calibration Protocol
CFM	Cubic Feet Per Minute
CHT	Cylinder Head Temperature
CID	Cubic Inch Displacement
CKP	Crankshaft Position Sensor
CL	Closed Loop
CMP	Camshaft Position Sensor
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO2	Carbon Dioxide
CPP	Clutch Pedal Position Sensor
CTP	Closed Throttle Position
DBW	Drive-By-Wire
DC	Direct Current
DFCO	Decel Fuel Cut Off
DFI	Direct Fuel Injection
DLC	Data Link Connector
DM	Diagnostic Message
DMM	Digital Multi-Meter (high imp.)
DST	Diagnostic Scan Tool
DTC	Diagnostic Trouble Code
DVOM	Digital Voltage and Ohm Meter (high imp.)
ECIPP	EControls Proprietary Protocol
ECM	Engine Control Module
ECT	Engine Coolant Temperature
EDIS	EControls Display and Interface Software
EGO	Exhaust Gas Oxygen Sensor
EGR	Exhaust Gas Recirculation
EI	Electronic Ignition
EMI	Electromagnetic Interference
EMWT	Exhaust Manifold Water Temperature
EOBD	Euro Onboard Diagnostic
EPR	Electronic Pressure Regulator
ERWT	Exhaust Manifold Riser Temperature
ETB	Electronic Throttle Body
ETC	Electronic Throttle Control
EVAP	Evaporative Emissions
°F	Fahrenheit
FC	Fan Control
FDR	Flight Data Recorder
FF	Flex Fuel
FMI	Failure Mode Indicator
FO	Firing Order
FP	Fuel Pressure
FPP	Foot Pedal Position
FRP	Fuel Rail Pressure
FRT	Fuel Rail Temperature
FSS	Fault Snapshot
FT	Fuel Temperature
FT	Fuel Trim
ft. lb.	Foot Pounds
FTP	Federal Test Procedure
GCP	Global Control Platform
GEN	Generator
GND	Ground
GPM	Grams Per Mile
HC	Hydrocarbon
HVS	High Voltage Switch
HDGCP	Heavy-Duty Global Control Platform (On-Road Heavy-Duty)

HEGO	Heated Exhaust Gas Oxygen Sensor (same as HO2S)
HO2S	Heated Oxygen Sensor
HO2S1	Upstream Heated Oxygen Sensor (Pre CAT)
HO2S2	Downstream or Downstream Heated Oxygen Sensor (Pre CAT)
HP	Horsepower
IAC	Idle Air Control
IAT	Intake Air Temperature
IC	Ignition Control Circuit
ICM	Ignition Control Module
ICAV	Instant Crank Angle Velocity
ID	Inside Diameter
IFI	Indirect Fuel Injection
IGN	Ignition
IP	Instrument Panel
IPC	Instrument Panel Cluster
IVS	Idle Validation Switch
kHz	Kilohertz
Km	Kilometers
kPA	Kilopascals
KPH	Kilometers Per Hour
KOEC	Key On Engine Cranking
KOEO	Key On Engine Off
KOER	Key On Engine Running
KS	Knock Sensor
KV	Kilovolt
L.	Liter
lb.ft.	Pound Feet
LDGCP	Light-Duty Global Control Platform (Industrial, Smart/Logic Coil)
LED	Light Emitting Diode
LPG	Liquefied Propane Gas
LTFT	Long Term Fuel Trim
MAF	Mass Airflow Sensor
MAP	Manifold Absolute Pressure
MDGCP	Medium-Duty Global Control Platform (Industrial, Dumb Coil)
MDP	Manifold Differential Pressure
mP	Microprocessor
Mfg	Manufacture
MIL	Malfunction Indicator Lamp
mm	Millimeters
ms	Millisecond
mV	Millivolt
MPG	Miles Per Gallon
MPH	Miles Per Hour
NG	Natural Gas
Nm	Newton Meters
O2	Oxygen Sensor
OBD	On-Board Diagnostics
OBD I	On-Board Diagnostics generation one
OBD II	On-Board Diagnostics generation two
OBD III	On-Board Diagnostics generation three
OBD IV	On-Board Diagnostics generation four
OC	Oxidation Catalyst
OD	Outside Diameter
OEM	Original Equipment Manufacture
OHC	Overhead Cam
OL	Open Loop
PC	Personal Computer
PCV	Positive Crankcase Ventilation
PFI	Port Fuel Injection
PGN	Parameter Group Number
PPM	Parts Per Million
PSA	Pressure Switch Assembly
PSI	Pounds Per Square Inch
PWM	Pulse Width Modulated
RAM	Random Access Memory
RFI	Radio Frequency Interference
RPM	Revolutions Per Minute
Rx	Receive
SA	Source Address
SFI	Sequential Fuel Injection
SHOC	Single Overhead Cam
SPFI	Sequential Port Fuel Injection
SPN	Suspect Parameter Number
SRI	Service Reminder Indicator
SRT	System Readiness Test
Tach	Tachometer
TBI	Throttle Body Injection
TDC	Top Dead Center
TIP	Throttle Inlet Pressure
TPS1	Throttle Position Sensor One
TPS2	Throttle Position Sensor Two

TSC	Torque/Speed Control
TWC	Threeway Catalyst
TWC+OC	Threeway Catalyst + Oxidation Catalytic Converter
Tx	Transmit
UEGO	Universal Exhaust Gas Oxygen Sensor (also called wide-range EGO)
VBAT	Battery Voltage
VDC	Voltage, Direct Current
VIN	Vehicle Identification Number
VR	Variable Reluctance
VSS	Vehicle Speed Sensor
Vsw	Switched, Ignition Voltage
WGP	Waste-Gate Pressure
WOT	Wide Open Throttle

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MAINTENANCE SECTION

MAINTENANCE OF THE ECONTROLS FUEL SYSTEMS

The maintenance of the engine fitted with EControls LPG and Gasoline fuel systems, and its related components, is critical to the life of the engine and optimum performance, during its useful life. All engines require a certain amount of maintenance. The suggested maintenance requirements are contained in this section. Industrial engines operate in various environmental conditions, and various temperature ranges.

NOTE: **This is a recommended guide line only; each user must assess the daily operational usage and environmental conditions, and determine an appropriate schedule**.

In addition, the owner may have installed additional equipment to the vehicle, which may also increase the requirements for service on certain components. Therefore, the owner and the service agent, should review the operating condition of the equipment, and determine if more frequent inspections, and maintenance cycles maybe required.

This section of the service manual supplement, covers the maintenance items of both the LPG and Gasoline fuel systems, which are designed and supplied by EControls, and general information on those items which are supplied by the OEM, and requires regularly scheduled maintenance. For maintenance of the base engine and or chassis, refer to the OEM manual which covers the maintenance of the equipment.

GENERAL LPG FUEL TANK MAINTENANCE

LPG TANKS

The typical LPG fuel storage cylinder should be inspected daily or at the beginning of each shift for any of the following

- o External leaks, external damage
- o Manual service valve is fully open
- o Securely mounted; inspect the securing straps for damage, and that the securing devices are closed and locked.
- o Insure that the fuel storage cylinder is properly positioned in the locating pin, in the tank collar, on all horizontally mounted tanks. This will insure that the tank pressure relief device will always be in the correct position, to function if required

When refueling or exchanging a cylinder, check the following:

- o Quick fill valve for thread damage
- o Insure that the o-ring seal is in place
- o Check the o-ring for cracks, separation or chunking;
- o Replace the o-ring if necessary before refueling
- o Check the service line quick coupler for any thread damage
- o Check the coupler o-ring for cracks, separation, or chunking
- o Replace the o-ring if necessary, before refueling.

IMPORTANT: When refueling the cylinder, clean both the fill hose and the tank connector with a clean cloth to remove any dust, dirt or debris to prevent contamination of the fuel system.

WARNING

NEVER CUT OR WELD ON EITHER THE LPG OR GASOLINE FUEL TANK. REPAIRS TO THE FUEL TANK SHOULD ONLY BE MADE BY A CERTIFIED TANK REPAIR FACILITY. FAILURE TO OBSERVE THIS WARNING COULD RESULT IN SERIOUS BODILY INJURY AND OR DEATH AND COULD RESULT IN SERIOUS PROPERTY DAMAGE

FUEL FILTER MAINTENANCE

All EControls fuel systems will be designed with a specification, which requires filtration of the system. With the EControls designed fuel system; the filter may be supplied by the OEM or have been equipped with additional filtration, (*Refer to OEM Base engine section*).

To determine the recommended maintenance intervals, refer to the EControls Recommended Maintenance Schedule at the end of this section. However, engines which operate in extremely dirty environment will require more frequent maintenance.

When inspecting the fuel filtration systems, check the following:

- o Check for any fuel leaks at the inlet and outlet fittings
- o Check to make sure the filter is securely mounted
- o Check for any external damage or distortion; if damaged replace the filter element

To replace the filters use the following steps:

1. Move the equipment to a well ventilated area and insure there are no external ignition sources
2. On LPG systems start the engine and close the manual valve on the cylinder, and run the engine until the engine runs out of fuel.
3. Remove and replace the fuel filter
4. Leak check the connections with a soapy solution, or electronic leak detector
5. On Gasoline fuel pumps with integrated fuel filters or screens located in the tank, follow the OEM recommended procedures for pump removal
6. On externally mounted filters, close the manual valve at the gasoline tank to prevent fuel from draining from the tank.
7. Drain any excess fuel into an approved container and replace the filter
8. After replacing the filter, start the engine and leak check all connections

⚠ WARNING

ALWAYS WEAR PROTECTIVE EYEWEAR AND GLOVES WHEN PERFORMING MAINTENANCE ON THE LPG OR GASOLINE FUEL SYSTEMS, TO PREVENT SERIOUS INJURY. ALWAYS PERFORM MAINTENANCE PROCEDURES IN A WELL VENTILATED AREA AND INSURE THAT THERE ARE NO EXTERNAL SOURCES OF IGNITION

FUEL SUPPLY AND RETURN LINE MAINTENANCE

Many of the EControls LPG and Gasoline fuel systems utilize fuel supply and return lines that are always supplied by the OEM. These lines are made of special rubber or metal material, which meet the design working pressures, regional requirements, and provide the proper protection from chemicals found in the fuels. It is recommended that all the fuel line connections be leak checked annually at a minimum, or anytime the lines have been removed. The routing of the lines should also be inspected annually, to insure that the lines have not come into contact with any rotating devices, hot surfaces, or are located in a position in which they may be impacted by debris.

LPG PRESSURE REGULATOR

LPG DUAL STAGE REGULATOR (DSR)

The EControls LPG DSR is a two stage mechanical regulator with an integral vaporizer which reduces the fuel inlet or tank pressure to a specific lower pressure and adds heat to the fuel for vaporization. You should check the following items at a minimum of once per year:

- o Check for any fuel leaks at the inlet and outlet fittings
- o Check for any fuel leaks at the connecting seams of the regulator body
- o Check the inlet and outlet coolant fittings at the regulator body
- o Check the inlet and outlet coolant lines for hardening, cracking, chaffing or splits. If

any of these conditions exist replace the coolant lines

- Check the inlet and outlet coolant line hose clamps at each connection, tighten if necessary
- Check the mounting bracket to insure the regulator is securely mounted, tighten if necessary
- Check any of the rubber isolators used for mounting for cracking, hardening or separation
- Check the regulator for a buildup of oil in the second stage chamber of the regulator. Drain the oil by opening the drain plug located at the bottom of the secondary chamber.

NOTE: Certain EControls LPG systems may be fitted with a Direct Electronic Pressure Regulator (DEPR) which is downstream of the DSR. Check these items when inspecting the DEPR:

- Check the harness connection on the electronic control section, to insure it is seated and locked
- Check to make sure the DEPR assembly is securely mounted

NOTE: All EControls LPG systems are fitted with an LPG Fuel Lock Off device which is typically mounted to the inlet of the DSR. These are the additional items when inspecting the regulator:

- Check for any fuel leaks at the inlet and outlet fittings
- Check the Lock Off electrical connector, to insure it is seated and locked
- Check to insure the solenoid retaining nut is tightened and fully seated

GASOLINE FUEL PRESSURE MANIFOLD

On Bi-fuel and dedicated gasoline engines, fuel is delivered to the gasoline injector rails via an electric fuel pump. The ECM controls fuel delivery pressure via a PWM low side drive circuit connected to the ground terminal of the pump. The ECM increases or decreases the fuel pump's voltage to achieve the desired pressure using pressure feedback information from the gasoline fuel pressure manifold assembly. This manifold assembly also measures the gasoline fuel temperature and provides this information to the ECM. This manifold, along with the electric fuel pump, will be located on the chassis. By closely maintaining the target fuel pressure using minimum pump current flow, a minimal amount of fuel is returned to the tank. The fuel pressure manifold and fuel pump do not require adjustment. The following items must be inspected once per year.

- Check the mounting bracket for the fuel pressure manifold and fuel pump, for cracks or breakage
- Check the securing method for the fuel pressure manifold and fuel pump to insure the devices are firmly attached
- Check the electrical connection at both the fuel pressure manifold and fuel pump

INJECTOR RAIL AND INJECTORS

The injector rail and injectors require no periodic adjustment. You should annually inspect the following items on the fuel rails and injectors.

- Check to make sure the rail bracket is securely attached to the engine
- Check to make sure the rail brackets have no cracking or breaking
- Check to make sure that each injector is securely attached to the rail bracket
- Check each injector electrical connection to insure the connector is securely attached
- Leak check all the connections on the manifold at each injector connector, and the inlet and outlet fitting at the rail, using an electronic leak detector or a soapy solution
- Check the injector delivery hose (if used) for any cracking, kinky, cuts, or deformation, and replace if necessary

ELECTRICAL SYSTEM CHECKS

The electrical system, sensors, wiring harness, and ECM do not require any periodic adjustments. You should annually inspect the following items.

BATTERY

- Check and clean the battery terminal connections and insure the connections are tight

- Check the battery for any cracks or damage to the case
- Check the Positive and Negative battery cables for any corrosion build up, rubbing or chaffing, and check ground connections on chassis, to insure they are tight

ECM CHECKS

- Check the mounting bracket for the EControls ECM, for cracks or breaking
- Check the controller mounting bracket, securing bolts to insure they are securely fastened
- Check the rubber isolators for cracks or deterioration
- Check the electrical connector and insure the connector is securely attached, locked and the secondary lock is in position. Check the connector for any corrosion in the connector, or on the pins. Clean if observed

WIRE HARNESS CHECKS

- Check the wire harness routing, under the hood, to insure the main harness and injector harness have not come into contact with any rotating devices, hot surfaces, or have come loose from their securing points, and are hanging in an unsafe location.
- Check all wire ties and / or clamps used to secure the harness for cracking, splitting, or breakage, replace if necessary
- Check the harness routing and insure the harness is securely attached to the frame and protected from any hot surfaces, rotating devices or road debris, repair any unsafe condition.

SENSORS

- While inspecting the wire harness connector for each sensor, check for any damage to the sensor
- If the sensor is retained by threads or by fasteners, insure the retaining device is fully secured

IGNITION SYSTEM

- Check ignition coil and spark plug cables for hardening, cracking, chaffing, separation, split boot covers and properly fitted
- Replace spark plugs at the proper intervals, as prescribed in the recommended maintenance
- Check to make sure all electrical components are fitted securely

MISCELLANEOUS ELECTRICAL

- Check the instrument panel to insure all warning lights are functioning, MIL, oil pressure and temperature gauges are registering
- Check the ignition switch and electrical connectors to insure the connections are fully seated and locked and the tumbler mechanism is working properly

RECOMMEDNED MAINTENANCE

The maintenance schedule represents manufacturers recommended maintenance intervals to maintain proper engine/equipment function. Specific state and federal regulations may require equipment operators to conduct comprehensive engine/equipment inspections at more periodic intervals than those specified above.

GASOLINE AND LPG ENGINE MAINTENANCE REQUIREMENTS											
	Install	Interval Hours									
	Date	Daily	500	1000	1500	2000	2500	3000	4000	5000
General Maintenance Section											
Visual check for leaks		X								
Check engine oil level		X								
Check coolant level		X								
Change engine oil and filter		**Every 250 hours or 180 days of operation**								
Check LPG/Gas system for leaks		**After any service or maintenance activity**								
Inspect accessory drive belts				X		X		X	X	X
Replace Drive Belt									X	
Inspect electrical system						X			X	
Inspect all vacuum lines and fitting						X			X	
Engine Coolant Section										
Clean debris from radiator core		**Every 100 hours or 60 days of operation**								
Change coolant		**Annually**								
Inspect coolant hoses for cracks, swelling or deterioration				X		X		X	X	X
Engine Ignition System										
Inspect Battery case for damage				X		X		X	X	X
Inspect battery cables				X		X		X	X	X
Check all electrical connectors				X		X		X	X	X
Check ignition coil boots							X			X
Change Spark Plugs							X			X
Fuel System Maintenance										
Replace fuel filter (Gas & LPG)				X		X		X	X	X
Inspect lock off for leaks & closing						X			X	
Check LPG/Gas regulator pressure						X			X	
Leak check LPG/Gas fuel lines						X			X	
Drain DSR for oil build up *1							X			X
Inspect DSR for coolant leaks		**Annually or every 2000 hours**								
Check air induction for leaks						X			X	
Check manifold for vacuum leaks						X			X	
Check injector & rails for leaks						X			X	
Inspect air cleaner		**Every 250 hours, or every 100 hours in dusty environments**								
Replace filter element		**Annually, or Bi-annually in dusty environments**								
Engine Exhaust System										
Inspect exhaust manifold for leaks						X			X	
Inspect exhaust piping for leaks						X			X	
Inspect catalyst inlet and outlet						X			X	
Check HEGO sensors connections						X			X	

IMPORTANT:

*1 If the fuel outlet of the DSR, or the hose routing between the DSR & the DEPR, is below the inlet of the EPR the oil must be drained every 250 hours

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DESCRIPTION AND OPERATIONS SECTION

DESCRIPTION AND OPERATION OF THE ECONTROLS FUEL SYSTEMS

ECONTROLS FUEL SYSTEMS

EControls supplies various fuel systems for its OEM customers, as explained in the General Operation section of this manual. In this section of the manual, each of the various types of EControls fuel systems will be explained further to provide the technician the ability to understand how each system operates and the general layout of each system. A typical installation schematic has been included to identify where in the system the components are located, and how the component communicates to other fuel system components, and the EControls ECM.

NOTE: Some of the components described in each section are not supplied by EControls, and may not necessarily represent the component on your chassis, or stationary equipment. However the function of these components, are likely to be similar and will aid in the diagnostic of a failure.

FUEL METERING SYSTEMS

In all cases where EControls has supplied the fuel metering system for an OEM, EControls has designed the system for peak engine performance, durability, precise fuel metering and control of the exhaust emission. Each design has been tested and developed in conjunction with the OEM. When servicing an EControls system, you should always follow the prescribed service instructions and procedures, to repair the engine fuel system. When replacing parts within the fuel metering system you should use only the OEM or EControls replacement parts. Failure to do so may result in improper performance, an unsafe conditions, and lack of emissions control.

ENGINE CONTROL MODULE

Each EControls system will utilize an EControls Engine Control Module (ECM), to control fueling and control emissions output, in the exhaust. In some cases the ECM provides signal output to the vehicle instrument panel. The ECM will utilize signal inputs, from the engine sensors, to control the fuel metering and speed control, while the engine is running. As well, the ECM will provide diagnostic control, over the fuel system.

The diagnostics within the ECM, continually monitor the fuel system performance, by measuring sensor voltage, and if the ECM determines that a sensor value has exceeded the high or low threshold value, the ECM will make changes in the fuel metering system operation, to protect the engine fuel system. These changes were developed during the EControls calibration activities, and during the design of the system. To assist the technician, in determining the fault condition, in the EControls fuel system, Diagnostic Trouble Codes (DTC), are used, to identify the fault conditions. These fault codes can be identified, by using the EControls Global Control Platform laptop diagnostic tool (GCP). To determine fault codes and corrective action to be taken, the technician will use the GCP and the Diagnostic Trouble Code section, of this manual, to determine the root cause of the failure, the effective changes in the EControls fuel system, as well as what repairs must be made, to correct the fault in the fuel system.

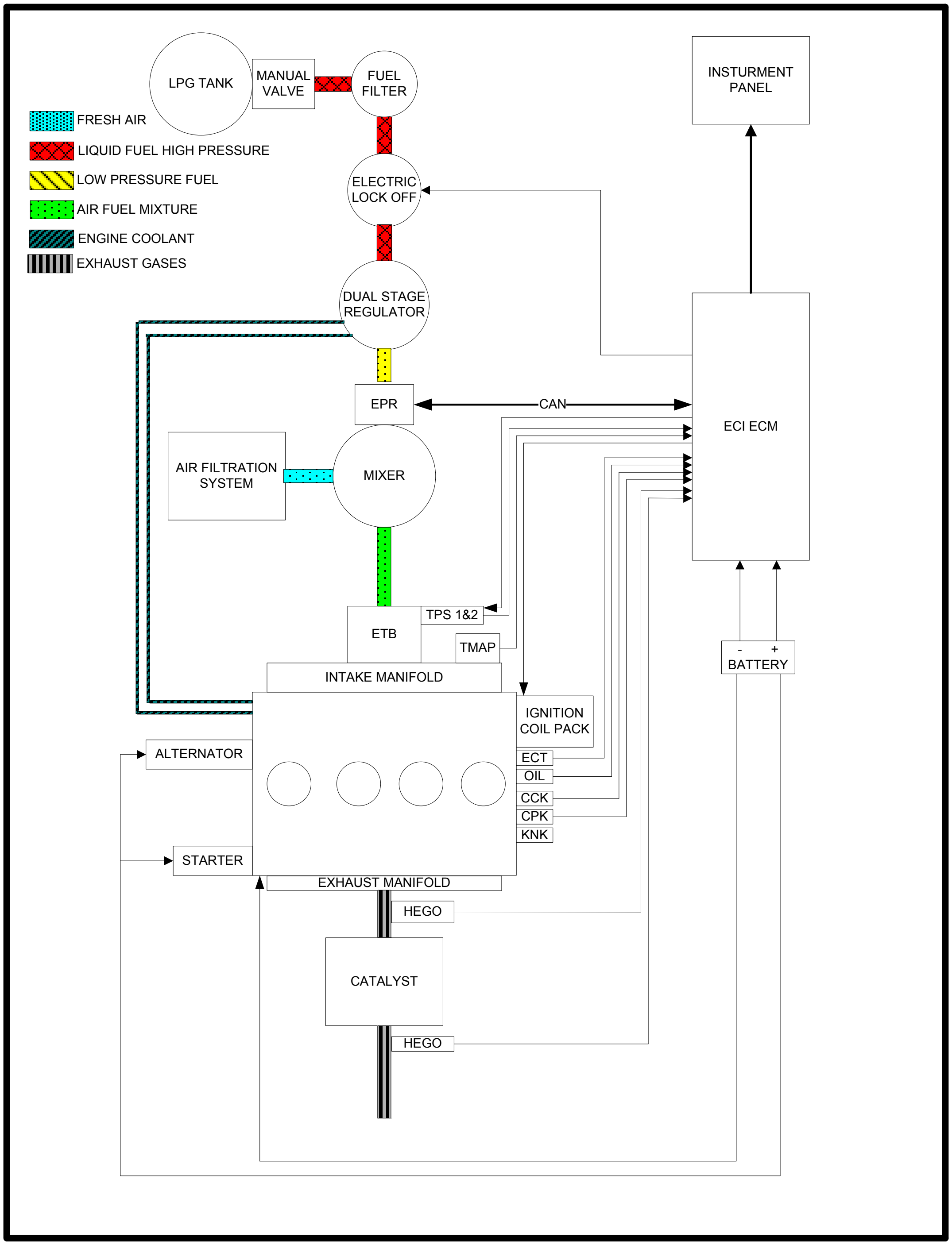

Figure 1 - *Typical Dedicated Light Duty Emissions Certified LPG Fuel System Schematic*

LIGHT DUTY EMISSION CERTIFIED DEDICATED LPG FUEL SYSTEMS

The primary components, of the propane fuel system are the fuel storage tank, pressure regulator, fuel mixer modules, electronic throttle control device, electric fuel lock-off solenoid, Engine Control Module (ECM), engine wire harness and a Three Way Catalytic (TWC) converter. The systems normally operate at pressures which range from 355.6 mm (14.0 inches) of water column, up to 21.5 BAR (312 psi).

LPG FUEL TANK

Propane is stored in the fuel tank as a liquid. The approximate pressure of the fuel in the tank is 16.5 bar (240 psi), when the tank is full at an ambient temperature of 27° C (80°F) and at atmospheric pressure. The boiling point, (temperature at which the liquid LPG fuel becomes vapor) is approximately -40° C (-40° F). When the fuel changes from liquid to vapor, the fuel expands and creates pressure inside the tank. When the tank service valve (Item 1) is opened, the pressure inside the tank forces the liquid fuel out though the pickup tube, located near the bottom of the fuel cylinder (Item 1). Because the Propane is stored under pressure, the tank is equipped with a safety valve, which is normally set at 25.8 bar (375 psi), to prevent tank rupture, due to over-pressurization of the cylinder (Item 3). The service valve (Item 1) mounted in the end of the cylinder, controls the flow of fuel from the tank. By turning the handle to its “open” position, fuel flows out of the tank, and into the service line. The service valve is also equipped with a safety feature called an “excess flow check valve”. This feature reduces the flow from the service valve, in the event of a rupture, of the fuel line, or any downstream component. Some tanks may be equipped with quick fill valves (Item 2), manual gauge assembly (Item 5), and an 80% fill valve, which signals the tank is at 80% full, and fueling should stop, as to not over fill the tank, and cause a dangerous condition. If the EControls LPG dedicated system is installed on a motor vehicle, the tank will be equipped with a automatic stop fill device, but the overall design and function, is the same as the industrial LPG tank.

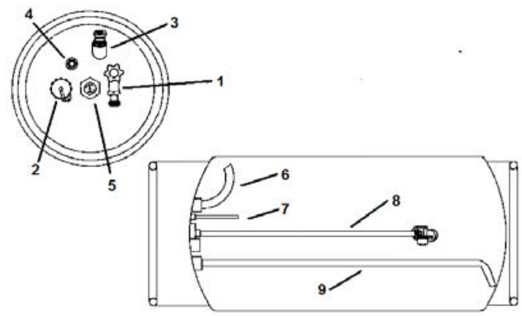

Figure 2 - *Typical Industrial Use LPG tank*

WARNING

NEVER CUT OR WELD ON EITHER THE LPG OR GASOLINE FUEL TANK. REPAIRS TO THE FUEL TANK SHOULD ONLY BE MADE BY A CERTIFIED TANK REPAIR FACILITY. FAILURE TO OBSERVE THIS WARNING COULD RESULT IN SERIOUS BODILY INJURY AND OR DEATH AND COULD RESULT IN SERIOUS PROPERTY DAMAGE.

WARNING

ALWAYS WEAR PROTECTIVE EYEWEAR AND GLOVES WHEN PERFORMING MAINTENANCE ON THE LPG OR GASOLINE FUEL SYSTEMS, TO PREVENT SERIOUS INJURY. ALWAYS PERFORM MAINTENANCE PROCEDURES IN A WELL VENTILATED AREA AND INSURE THAT THERE ARE NO EXTERNAL SOURCES OF IGNITION.

SERVICE LINE

Propane flows from the fuel tank to the electric lock, via the service line. The service line is most commonly connected to the tank, utilizing a quick coupler. The other end of the service line is connected to a "bulkhead connector," which is used to allow the service line, to pass through the metal enclosure, vehicle body panels, or hoods. This hose is made of special material, which protects the inner core of the hose, from chemicals contained within the LPG, which could result in a failure of the hose. The hose should never be kinked or allowed to come into contact with the chassis, or other engine components, and electrical connection or wiring. When replacing the fuel line, use care as there may be fuel retained in the line between the tank manual valve connection, and the electric lock off device.

FUEL FILTER

Propane fuel, like all other motor fuels, is subject to contamination from outside sources. Refueling of the equipment tank and removal of the tank from the equipment can inadvertently introduce dirt and other foreign matter, into the fuel system. It is therefore necessary to filter the fuel, prior to entering the fuel system components downstream, of the tank. EControls has advised the OEM during the design, to incorporate a filtering device between the tank and the fuel system. An inline or bulkhead filter has been installed by the OEM. These in-line filters are generally replaceable, as a unit only where as bulkhead filters generally are serviceable. Maintenance of the filter is critical to proper operation of the fuel system, and should be replaced as defined in the *Recommended Maintenance Schedule*. In severe operating conditions, or regions where fuel supply has been recognized to contain more contaminants, more frequent replacement may be required. Filters are always marked in some fashion, to indicate the direction flow of the fuel, through the filter.

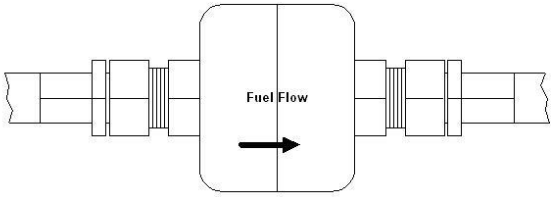

Figure 3 - *Typical In-line LPG filter*

LPG FUEL LOCK OFF

The LPG Fuel Lock Off device is an integrated assembly. The electric lock assembly is a 12 volt, normally closed valve. The solenoid is mounted to the valve body. When energized the solenoid opens the pilot valve, within the lock off, which uses the tank pressure, to assist in opening the valve. By using the pilot valve, to help open the valve, the service life of the valve, is extended, and requires less electrical energy, to open the valve. The valve opens, during cranking, and remains open, during the run cycles of the engine. The lock off supply voltage is controlled by the Engine Control Module (ECM), or may be energized by a relay, which supplies battery voltage, when energized.

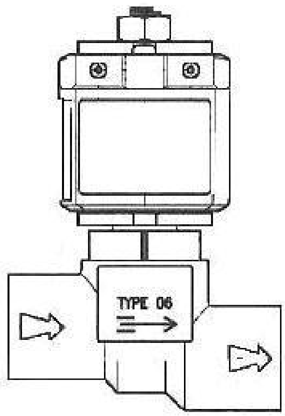

Figure 4 - *LPG Fuel Lock Off*

DUAL STAGE REGULATOR (DSR)

The DSR is a combination vaporizer, pressure regulating device. The DSR is a two stage regulator that is normally closed, when the engine is not running. When the engine is cranking or running, a partial vacuum is created in the fuel line, which connects the regulator to the Direct Electronic Pressure Regulators (DEPR), and mixer. This partial vacuum opens the second stage regulator, permitting fuel to flow to the DEPR, and mixer.

Propane fuel enters the primary port of the DSR, and passes through the primary jet, and into the primary/exchanger chamber. As the propane passes through the heat exchanger, the fuel expands, and creates pressure inside the chamber. The pressure rises as the fuel expands, when the pressure rises above 10.34 kpa (1.5 psi); sufficient pressure is exerted on the primary diaphragm, to cause the diaphragm plate to pivot, and press against the primary valve pin, thus closing off the flow of fuel. This action causes the flow of fuel, into the regulator to be regulated. When the engine is cranking, sufficient vacuum will be introduce into the secondary chamber, from the EPR/mixer, drawing the secondary diaphragm down onto the spring loaded lever, and opening the secondary valve, allowing vaporized fuel, to pass to the mixer. Increased vacuum, in the secondary chamber, increases the downward action on the secondary lever, causing it to open wider, allowing more fuel to flow to the mixer.

The DSR requires a connection to the engine coolant, to prevent freezing in the regulator, during the pressure reduction phase, within the regulator. Coolant connections on the DSR are fitted with “Push In” fittings. These fitting are designed with an o-ring seal, which allows the fitting to be pushed into the water connection on the DSR, and are then lock by spring locks, and retained by screws.

The DSR is connected to the DEPR, by a low pressure flexible hose. Like the other fuel hoses used in the fuel system, the low pressure hose is designed with a special inner core, and is usually wire reinforced, to prevent collapse of the hose, during high demand fueling operations. The low pressure hose should only be replaced, with the recommended OEM hose replacement.

The packaging of the regulator, into the engine and chassis, must be approved by EControls, to insure continued long term operation, of the fuel delivery and emission control system. You should never relocate the regulator, or any of the fuel system components, as doing so, may cause excess build up of oil in the regulator, improper coolant flow, or improper fuel delivery.

In certain regions, fuel supplies may be made up of much different chemicals and during the heating of the fuel, in the heat exchange section of the regulator, “heavy end” or petroleum oils, may accumulate over time. To drain the DSR, remove the fuel outlet hose and pour the oils out of the regulator. To determine the frequency, for draining the regulators, refer to the *Recommended Maintenance Schedule*.

The regulator utilized on USA emission certified engines, is a critical part of the certified emissions system, and does not require any periodic adjustment.

Figure 5 - *Dual Stage Regulator (DSR)*

DIRECT ELECTRONIC PRESSURE REGULATOR (DEPR)

The Direct Electronic Pressure Regulator (DEPR) is the primary fuel control device, used to maintain both performance and emissions control. The DEPR contains an internal computer, which communicates to the EControls Engine Control Module (ECM), via a Communications Area Network (CAN), high speed connection.

The DEPR precisely controls the fuel flow required to insure Stoichiometric (correct air/fuel mixture for complete burn) fuel delivery to the engine combustion chambers. The DEPR also contains internally mounted fuel pressure and temperature sensors, which provide input across the CAN link, to the ECM, for fuel calculation. The ECM will process this information and command changes back across the CAN link, to the DEPR, to adjust fueling.

The DEPR internal computer also maintains certain levels of diagnostics within the system, to ensure emissions control is always maintained. If the DEPR detects a fault within the regulator or fuel delivery system, the DEPR will send that fault information across the CAN link to the ECM. The ECM will then activate the Malfunction Indicator Light (MIL), in the operator control panel. Depending on the type of fault, and its effect on fuel control, or engine performance, the ECM may command the DEPR to change fueling, limit fuel delivery, or in some cases shut down the engine.

The DEPR is connected directly to the mixer on all certified engines. A special designed inlet fitting, is mounted to the DEPR, which allows for the connection, to the DSR. The outlet connection is bolted directly to the mixer.

The DEPR utilized on USA emission certified engines is a critical part of the certified emissions system, and do not require any periodic adjustment.

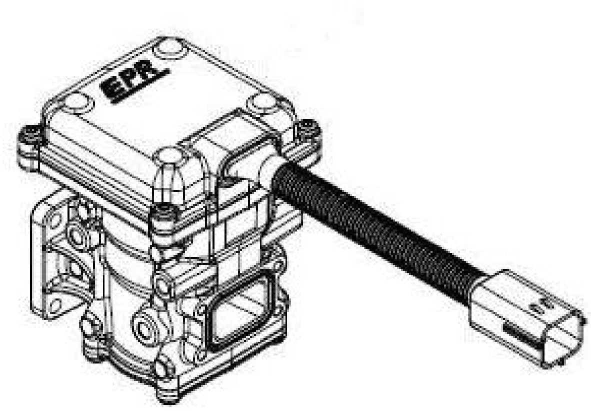

Figure 6 - *Direct Electronic Pressure Regulator (DEPR)*

MIXER ASSEMBLY

The air valve mixer is an air-fuel metering device, and is completely self-contained. The mixer is an air valve design, utilizing a relatively constant pressure drop, to draw fuel into the mixer from cranking, to full load. The mixer is mounted in the air stream, ahead of the throttle control device.

When the engine begins to crank, it draws in air, with the air valve covering the inlet, negative pressure begins to build. This negative pressure signal is communicated to the top of the air valve chamber, through 4 vacuum ports, in the air valve assembly. A pressure/force imbalance begins to build, across the air valve diaphragm, between the air valve vacuum chamber, and the atmospheric pressure, below the diaphragm. The air valve vacuum spring is calibrated, to generate from 101.6 mm (4.0 inches) of water column at start, to as high as 355.60 mm (14.0 inches) of water column, at full throttle. The vacuum being created is referred to as Air Valve Vacuum (AVV). As the air valve vacuum reaches 101.6mm (4.0 inches) of water column, the air valve begins to lift against the air valve spring. The amount of AVV generated is a direct result of the throttle position. At low engine speed, the air valve vacuum is low and the air valve position is low, thus creating a small venturi, for the fuel to flow. As the engine speed increases, the AVV increases, and the air valve is lifted higher, thus creating a much larger venturi. This air valve vacuum is communicated from the mixer venture, to the DSR secondary chamber, via DEPR and the low pressure fuel supply hose. As the AVV increases in the secondary chamber, the secondary diaphragm is drawn further down, forcing the secondary valve lever to open wider.

The DEPR maintains the precise fuel control to the mixer, despite the air valve position, and AVV being sent to the DSR secondary chamber. The mixer acts as the secondary fuel metering device, and delivery device, in the EControls emission control systems. The mixer is attached to the Electronic Throttle Body (ETB), via an adapter. The adapter is fitted with specific spacers and o-rings, to insure a seal tight fit, with the ETB.

The Mixer is designed such that the air valve diaphragm assembly can be replaced, should the diaphragm be damaged, during operation, from fuel contaminants. Refer to *Mixer Diaphragm Replacement* section in this manual. The Mixer utilized on USA emission certified engines are a critical part of the certified emissions system, and do not require any periodic adjustment. The mixer does not have any external nor internal adjustments.

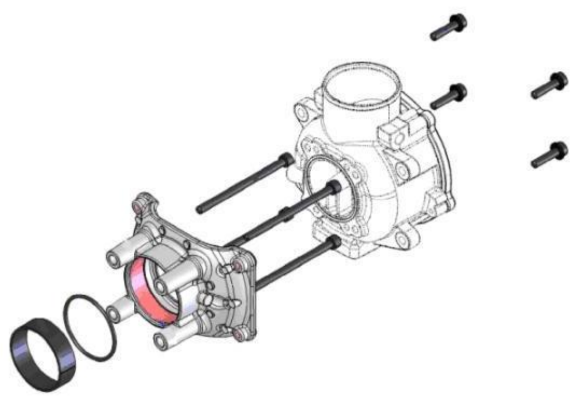

Figure 7 - *Mixer and ETB Adapter*

ELECTRONIC THROTTLE BODY (ETB)

The EControls fuel systems utilize Drive By Wire (DBW), to control engine speed, in this type of application. There is no direct connection between the operator pedal, and the throttle shaft. Speed and load control are determined by the ECM. Defaults programmed into the ECM software, and throttle position sensors, allow the ECM, to maintain safe operating control, over the engine.

In a drive by wire application, the Electronic Throttle Body (ETB) device, or “throttle body assembly,” is connected to the intake manifold of the engine. The electronic throttle control device, utilizes an electric motor, connected to the throttle shaft. In addition, a Foot Pedal Position sensor (FPP) is located in the operator’s compartment. When the engine is running, electrical signals are sent from the foot pedal position sensor, to the engine ECM, when the operator depresses or release the foot pedal. The ECM then sends an electrical signal to the motor, on the electronic throttle control, to increase or decrease the angle of the throttle blade, thus increasing or decreasing the air flow to the engine.

The electronic throttle control device also incorporates two internal Throttle Position Sensors (TPS), which provide output signals to the ECM, as to the location of the throttle shaft and blade. The TPS information is used by the ECM, to correct for speed and load control, as well as emission control, and engine protection.

The ETB utilized on USA emission certified engines does not require any periodic adjustment.

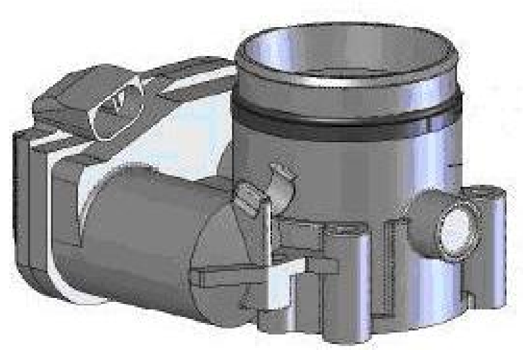

Figure 8 - *Electronic Throttle Body ETB*

THREE WAY CATALYST

The emission certified engine has been designed and calibrated, to meet the emission standards in effect for 2010. To help meet the emission requirements, the vehicle has been equipped with a Three Way Catalyst (TWC). The EControls has designed and supplied the catalyst, to the OEM for packaging, either in a separate unit, or integrated into the muffler. The catalyst function is the final treatment, of the exhaust gases, which are created from the combustion process. The three-way catalyst consists of a honeycomb, coated with a mixture of platinum, palladium, and rhodium. As the hot gases flow through the catalyst section, an oxidation and reduction reactions takes place. This chemical reaction reduces the amount of CO, HC and NOx, in the engines exhaust. The Exhaust gas then flows through the outlet.

HEATED EXHAUST GAS OXYGEN SENSOR (HEGO)

The Heated Exhaust Gas Oxygen Sensor (HEGO) is mounted in the exhaust system, downstream of the engine, but before the catalyst, referred to as the “Pre Catalyst” sensor. The ECM continuously monitors the HEGO sensor output if a rich or lean condition is present for an extended period of time, and if the ECM cannot correct the condition, the ECM will set a diagnostic code, and turn on the MIL light in the dash.

The HEGO is used to measure the amount of oxygen, present in the exhaust stream, and communicate that to the ECM, via an electrical signal. The amount of oxygen, present in the exhaust stream, indicates whether the fuel air ratio is too rich or too lean. If the HEGO sensor signal indicates that the exhaust stream is too rich, the ECM will decrease or lean the fuel mixture, during engine operation. If the mixture is too lean, the ECM will richen the mixture.

When the air/fuel mixture is rich, and there is little oxygen in the exhaust, the difference in oxygen levels, across the sensing element, generates a voltage through the sensor's electrodes: typically 0.8 to 0.9 volts. When the air/fuel mixture is lean and there is more oxygen in the exhaust, the sensor's voltage drops to 0.1 to 0.3 volts. When the air/fuel mixture is perfectly balanced and combustion is cleanest, the sensor's output voltage is around 0.45 volts.

The oxygen sensor's voltage signal is monitored by the EControls ECM, to regulate the fuel mixture. When the ECM sees a rich signal (high voltage), from the O2 sensor, it commands the fuel mixture to go lean. When the computer receives a lean signal (low voltage) from the O2 sensor, it commands the fuel mixture to go rich. The continued cycling, back and forth from rich to lean, averages out the overall air/fuel mixture, to minimize emissions, and to help the catalytic converter operate at peak efficiency, which is often referred to as the “duty cycle”.

The speed with which the oxygen sensor reacts to oxygen changes in the exhaust is very important for accurate fuel control, peak fuel economy, and low emissions. Aging of the sensor due to exposure to contaminants in the fuel, will occur over time, and may cause the sensor to slow down.

On all USA Emission certified engines, the exhaust system is equipped with a second HEGO, located after the catalyst, referred to as the “Post Catalyst” sensor. The function of the second HEGO is to monitor the efficiency of the catalyst and fuel control. The operation of the HEGO is the same as the Pre Catalyst sensor; it provides an output voltage to the ECM, to determine the level of oxygen, in the exhaust stream after the catalyst. This type of monitoring is referred to as the On Board Diagnostic, in which additional sensors are installed in the system, to monitor the fuel control systems.

The ECM continuously monitors the HEGO sensors output, if a rich or lean condition is present for an extended period of time and the ECM cannot correct the condition, the ECM will set a diagnostic code and turn on the MIL light in the dash.

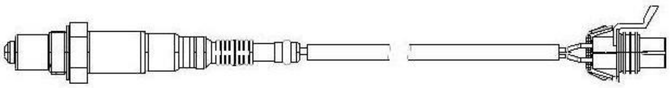

Figure 9 - *Heated Exhaust Gas Oxygen Sensor (HEGO)*

CAUTION

The Heated Exhaust Gas Oxygen Sensor is an emissions control component. If the HEGO fails to operate, replace only with an OEM replacement part. The HEGO sensor is sensitive to silicone and silicone based products and can become contaminated. Avoid using silicone sealers or hoses, treated with silicone lubricant, in the air stream or fuel supply lines.

ENGINE CONTROL MODULE (ECM)

In all EControls fuel systems the Engine Control Module (ECM) provides total control of the engine, fuel control, ignition spark control, and auxiliary features. The ECM depends on the wire harness to receive the required input data from sensor, and send the appropriate outputs. The harness is specifically designed, to provide the necessary electrical supply to the engine, through the life of the equipment. All electrical connectors utilize sealed connectors, to prevent damage from moisture intrusion, necessary shielding, when required, and protective covering, to protect the wiring.

To obtain maximum effect from the catalyst and accurate control of the air fuel ratio, the emission certified engine is equipped with an onboard computer, or Engine Control Module (ECM). The ECM is a 32 bit controller, which receives input data from sensors fitted to the engine and fuel system, and then outputs various signals, to control engine operation.

One specific function of the controller is to maintain “closed loop fuel control”. Closed loop fuel control is accomplished, when the exhaust gas oxygen sensor (HEGO) mounted in the exhaust system, sends a voltage signal to the controller. The controller, then calculates, any correction that may need to be made, to the air fuel ratio. The controller then outputs signals to the DEPR, to change the amount of fuel being delivered, from the regulator, or mixer, or to the engine.

The ECM also performs diagnostic functions on the fuel system, and notifies the operator of malfunctions, by turning on a Malfunction Indicator Light (MIL) mounted in the dash. Malfunctions in the system are identified by a Diagnostic Code number. In addition to notifying the operator of the malfunction in the system, the controller also stores the information about the malfunction, in its memory. A technician can than utilize a computerized diagnostic tool, to retrieve the stored diagnostic code, and by using the diagnostic charts in this manual, determine the cause of the malfunction. In the event a technician does not have the computerized diagnostic tool, the MIL light can be used to identify the diagnostic code. By following specific steps, the technician can activate the “blink” feature, and count the number of blinks, to determine the diagnostic code number, to locate the fault in the system.

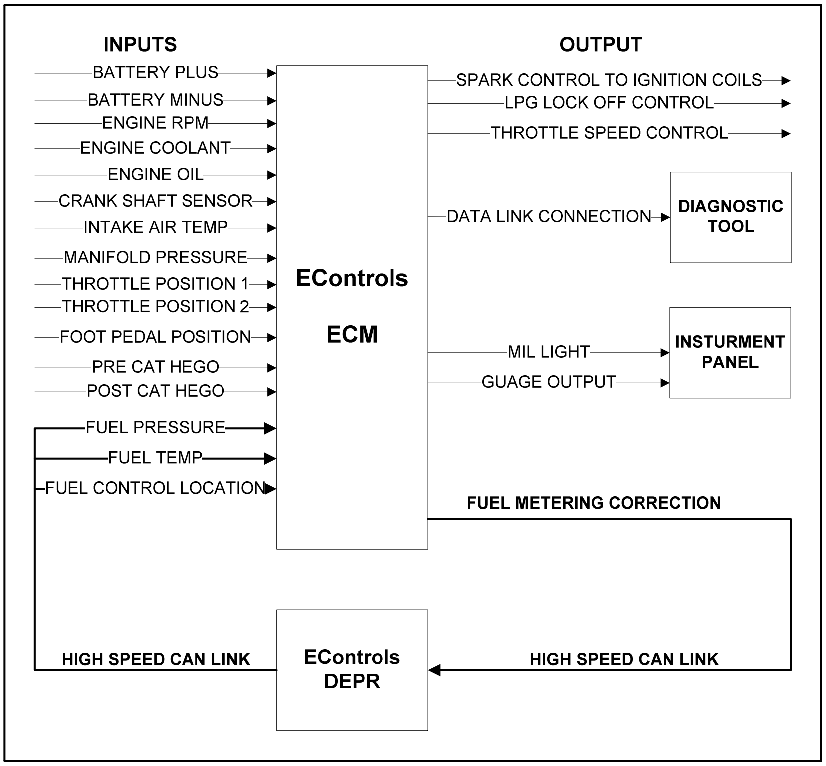

Figure 9 - *ECM Input and Outputs*

ENGINE SENSOR GROUP

To maintain fuel control and insure the system provides the optimum performance, the ECM depends on sensor installed in the engine, and fuel system, to provide input to the ECM for calculating fuel delivery, as well as fuel system diagnostics. This section will provide the technician with the understanding of the function of each sensor. Due to the variation of each OEM designed system, sensors may vary in both design and supplier; however the function of each will be the same.

TEMPERATURE MANIFOLD ABSOLUTE PRESSURE (TMAP)

The TMAP sensor is a combination sensor, and provides the ECM with the Intake Air Temperature (IAT), and the Manifold Absolute Pressure (MAP). The ECM uses the intake air temperature to correct fueling based on the density of the air.

The MAP portion of the TMAP sensor provides the ECM with a measurement of the pressure in the intake manifold. During the start up, the MAP provides the ECM with the barometric pressure, to allow the ECM to adjust fueling, based on barometric pressure. Once the engine has started, the ECM uses the MAP to measure the load on the engine, and make fuel and RPM corrections, to compensate for changing load conditions.

In most EControls fuel system designs, the TMAP is generally mounted to the intake manifold, however in some cases the TMAP may be two individual sensors, in this case these components perform the same function, but are identified as IAT and MAP sensors. The TMAP is a 5 volt reference signal sensor, which operates by the resistance change in the sensor, to output a reference voltage for the ECM to use. The sensor can be either a 0 to 5v or a 5v to 0 depending on the sensors, which are supplied by the OEM on the engine. During the development phase of the system, the minimum and maximum thresholds of operation are determined, and are part of the fuel calibration and diagnostics, programmed into the ECM. These thresholds are used to establish the point at which the ECM will set the MIL light, to indicate that a fault has been detected in the fuel system.

ENGINE COOLANT TEMPERATURE (ECT)

The ECM monitors the engine coolant temperature, through the ECT sensor mounted in the engine. The ECM uses this sensor input to make corrections in fueling, and to protect the engine from overheating during normal operation.

In most EControls fuel system designs, the ECT is generally mounted in the cylinder block, and is usually supplied by the OEM engine manufacturer. The ECT is a 5 volt reference signal sensor, which operates by the resistance change in the sensor, to output a reference voltage for the ECM to use. The sensor can be either a 0 to 5v or a 5v to 0, depending on the sensors which are supplied by the OEM on the engine. During the development phase of the system, the minimum and maximum threshold of engine temperature, during normal operation, are determined and are part of the fuel calibration and diagnostics, programmed into the ECM. These thresholds are used to establish the point at which the ECM will set the MIL light, to indicate that a fault has been detected in the fuel system. Should the temperature be exceeded, the ECM will first reduce the engine performance capabilities, often referred to as "limp home," which allows the operator to move the equipment to a facility for repair, or safely shut down the system. In the event the temperature continues to rise, the ECM will shut down the engine in a specified period of time, after the "limp home" strategy has been activated.

ENGINE OIL PRESSURE (EOP)

The ECM monitors the engine oil pressure, through the EOP sensor, mounted in the engine. The ECM uses this sensor input, to protect the engine from damage, from the lack of oil in the crank case.

In most EControls fuel system designs, the EOP is generally mounted in the cylinder block, and is usually supplied by the OEM engine manufacturer. The EOP is a 5 volt reference signal sensor, which operates by the resistance change in the sensor, to output a reference voltage for the ECM to use. The sensor can be either a 0 to 5v, or a 5v to 0, depending on the sensors, which are supplied by the OEM on the engine. During the development phase of the system, the minimum and maximum threshold of engine temperature, during normal operation are determined, and are part of the fuel calibration and diagnostics, programmed into the ECM. These thresholds are used to establish the point, at which the ECM will set the MIL light, to indicate that a fault has been detected in the engine. Should the pressure be exceeded or fall below the minimum pressure, the ECM will shut down the engine in a specified period of time.

THROTTLE POSITION SENSORS 1 & 2 (TPS 1&2)

EControls fuel systems use an Electronic Throttle Body (ETB) for speed and load control. Internal to the ETB, are two Throttle Position Sensors (TPS), which provide an "actual position" of the throttle plate. During the calibration development, the throttle blade variation, from actual to command, is defined. A maximum variation threshold is determined and included in the calibration, this threshold insures that the variation between actual and command do not vary above this threshold. In the event the variation exceeds the threshold, the ECM will command the ETB to idle, or shutdown the engine. The ECM will also set a diagnostic code, and turn on the MIL light

FOOT PEDAL POSITION SENSORS (FPP)

EControls fuel systems, utilize a "drive by wire" technique, to allow the operator to accelerate the engine. This type of technique does not use a physical connection, between the operator foot pedal and the throttle body. Therefore control of the engine is managed by electrical signals, using a Foot Pedal Position Sensor (FPP), to determine the location, or how much the pedal is being depressed or released, which is relative to the command, that the operator desires. The

FFP is a reference voltage sensor, therefore changing the voltage output level up or down, indicates a different desired position to the ECM. The ECM then changes the output signal, to the ETB, thus changing the throttle blade position, to correspond to the desired foot pedal command. The FPP is generally integrated, in the foot pedal mechanism, mounted in the operator's platform.

CRANKSHAFT POSITION SENSOR (CKP)

To determine the engine RPM and piston position of number one cylinder, the ECM receives this information from the Crankshaft Sensor. The CKP is generally located near the crankshaft pulley, on the front of the engine, or on the flywheel at the rear of the engine, and is supplied by the engine OEM. CKPs vary in design, depending on the signal that the sensor produces. Induction sensors produce a sine wave, or "s-shaped" signal, where as the Halleffect crank position sensor, which reads a notched metal "interrupter" ring, on the back of the harmonic balancer, creates a square wave pattern.

CAMSHAFT POSITION SENSOR (CKP)

The cam shaft sensor is used to determine which stroke of the engine cycle the engine is running on for control of the fuel and spark. The sensor is usually mounted at the front of the engine or the rear and reads a pick up wheel mounted internally within the engine. The pick up wheel can be of vary design and number of pulses. The sensor can be either an inductive pick up which will give a sine wave or a Hall effect sensor and reads a square wave from zero to either 12 or 5 volts.

KNOCK SENSOR (KCS)

To prevent engine "knock," which occurs when the fuel air mixture does not burn smoothly, during this condition timing is generally decreased, to assist with the fuel burn process. The EControls gasoline fuel system, utilizes a Knock Sensor, which is installed to the engine block, and supplied by the OEM engine supplier. The Knock Sensor is a 5 volt reference signal sensor, which operates by the resistance change in the sensor, to output a reference voltage for the ECM to use. The knock sensor sends a base or "no knock" signal to the EControls ECM, when knocking does occur the sensor detects the increased vibration, and increases the voltage output to the ECM. When the ECM receives the voltage change, the ECM will slightly retard the timing, until such time, the knocking no longer exists. To determine of your engine uses a knock sensor, consult the OEM section of the manual.

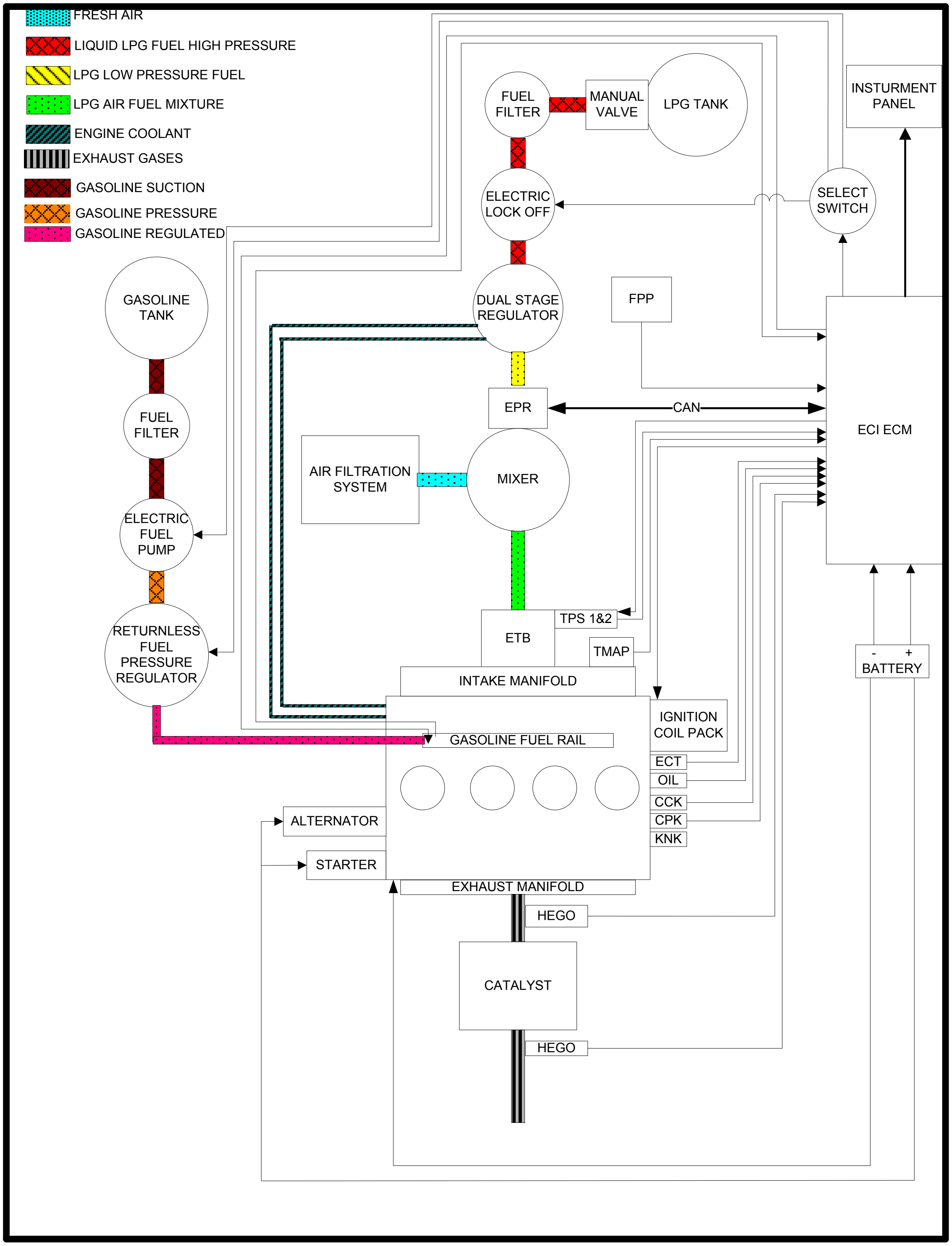

Figure 10 - *EControls Emissions Certified Bi-fuel LPG Gasoline Schematic*

LIGHT DUTY EMISSION CERTIFIED BI-FUEL LPG/GASOLINE FUEL SYSTEMS

The EControls Bi-Fuel LPG and Gasoline fuel system, incorporates two complete fuel systems, but are controlled by a single ECM. The EControls Bi-fuel system, will utilize all of the LPG fuel system components, identified in the Light Duty Dedicated Emission Certified LPG Fuel System section above, as well as the necessary components for the Gasoline fuel system along with a Bi-Fuel engine harness. This section will deal with the gasoline fuel system components and any special components, which are required for the bi-fuel system to function.

FUEL SYSTEM SELECT SWITCH

As explained earlier, there are two complete fuel systems, included in an EControls bi-fuel system. To adequately protect the engine from damage caused by introducing two fuels simultaneously, the OEM has designed a Fuel System Select switch which signals the ECM to change fuels. The switch is typically either a two position, or three positioned switch. When using a three position switch in the center position neither the gasoline fuel pump nor the electric lock off, can be energized. Rotating the switch in one direction or the other will activate the fuel system, the operator has chosen.

ELECTRIC GASOLINE FUEL PUMP

To supply gasoline to the fuel system, the EControls bi-fuel system will utilize an external electric gasoline fuel pump. The pump will be mounted in the chassis of the vehicle, or equipment near the fuel tank. Gasoline rated fuel hose and securing devices supplied by the OEM, will be used to transfer the pumped fuel to the Gasoline Fuel Pressure Manifold assembly. The OEM may have installed a fuel filtration device ahead of the electric pump, which may be located in the tank or an external filter. Most industrial equipment will be exposed to dusty and dirty environments, therefore use caution when opening the gasoline tank, to prevent dirt and debris from falling in the tank. For filter maintenance, refer to the *Recommended Maintenance Chart*.

The electric gasoline fuel pump, utilized on USA emission certified engines are a critical part of the certified emissions system, and do not require any periodic adjustment.

Figure 11 *Electric Gasoline Fuel Pump*

GASOLINE FUEL PRESSURE MANIFOLD

The EControls gasoline fuel system, utilizes a Fuel Pressure Manifold assembly, to control the delivery pressure to the gasoline injector rail. The manifold is mounted to the chassis, between the electric fuel pump and the gasoline injector rail. The manifold is equipped with a sensor, which provides the ECM with the gasoline fuel temperature, and pressure being regulated to the gasoline injector rail. The ECM uses the fuel temperature and pressure, to calculate the precise amount of gasoline, to be injected to the engine during operation. The manifold is designed into the system, to control pressure, as well as the amount of gasoline, to be returned to the fuel tank. In normal gasoline delivery systems, the electric fuel pump, delivers a constant pressure to the injector rails, and allows a significant amount of fuel to be recycled to the tank, thus causing the gas to heat and vaporize, and requiring the use of a vapor recovery system to control the excess vapor. The EControls system manages the fuel pressure at the manifold and minimizes the amount of returned fuel, thus reducing the vapor fuel in the tank.

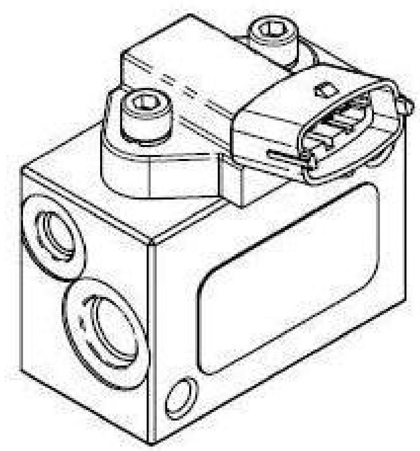

Figure 12 *Gasoline Fuel Pressure Manifold*

GASOLINE INJECTORS AND INJECTOR RAIL

The EControls gasoline fuel delivery system, utilizes a fuel rail mounted with injectors, for each cylinder. The fuel rail and injectors are supplied by the OEM, and may vary with each OEM application. During the design and calibration phase, the EControls ECM gasoline fuel delivery calibrations are developed. The ECM will utilize these calibrations, to pulse width modulate each injector, to deliver the correct amount of gasoline, for optimized performance and emission control. The injector pulsing or “firing” is accomplished by supplying a 12 volt supply, to the positive side of the injector coil, and switching the ground circuit side, using the injector drivers, internal to the ECM.

Because the EControls gasoline fuel system utilizes the Fuel Pressure Manifold, to control fuel delivery to the rail, the EControls fuel system does not use a separate return line, from the fuel rail assembly. Gasoline injectors are an emissions control device, and do not require periodic adjustment. When servicing or replacing injectors, use only OEM replacement injectors, to insure the fuel system operates as designed.

ENGINE CONTROL MODULE (ECM)

In all EControls fuel systems, the Engine Control Module (ECM) provides total control of the engine, fuel control, ignition spark control, and auxiliary features. The ECM depends on the EControls designed wire harness, to receive the required input data from sensors, and sends the appropriate outputs. The harness is specifically designed, to provide the necessary electrical supply to the engine, through the life of the equipment. All electrical connectors utilize sealed connectors, to prevent damage from moisture intrusion, necessary shielding when required, and protective covering, to protect the wiring.

To obtain maximum effect from the catalyst and accurate control of the air / fuel ratio, the emissions certified engine is equipped with an onboard computer known as the ECM. The ECM is a 32 bit controller, which receives input data from sensors, fitted to the engine and fuel system, and then outputs various signals, to control engine operation.

In the EControls Bi-fuel LPG and Gasoline systems, the ECM controls the engine, in both LPG and Gasoline fueling modes. All of the engine sensors, which are used for LPG fuel calculation and control, are also used for the gasoline. Those sensors which are unique to the specific fuel, such as fuel pressure and temperature, provide the necessary electrical inputs to the ECM, when operating in that specific fueling mode.

The EControls bi-fuel system, utilizes a single wire harness, to direct the input, and output electrical voltage signals, to and from the ECM. The circuits, which are unique in the harness for the gasoline system, and the LPG system, are separated, and those that are common, are shared circuits.

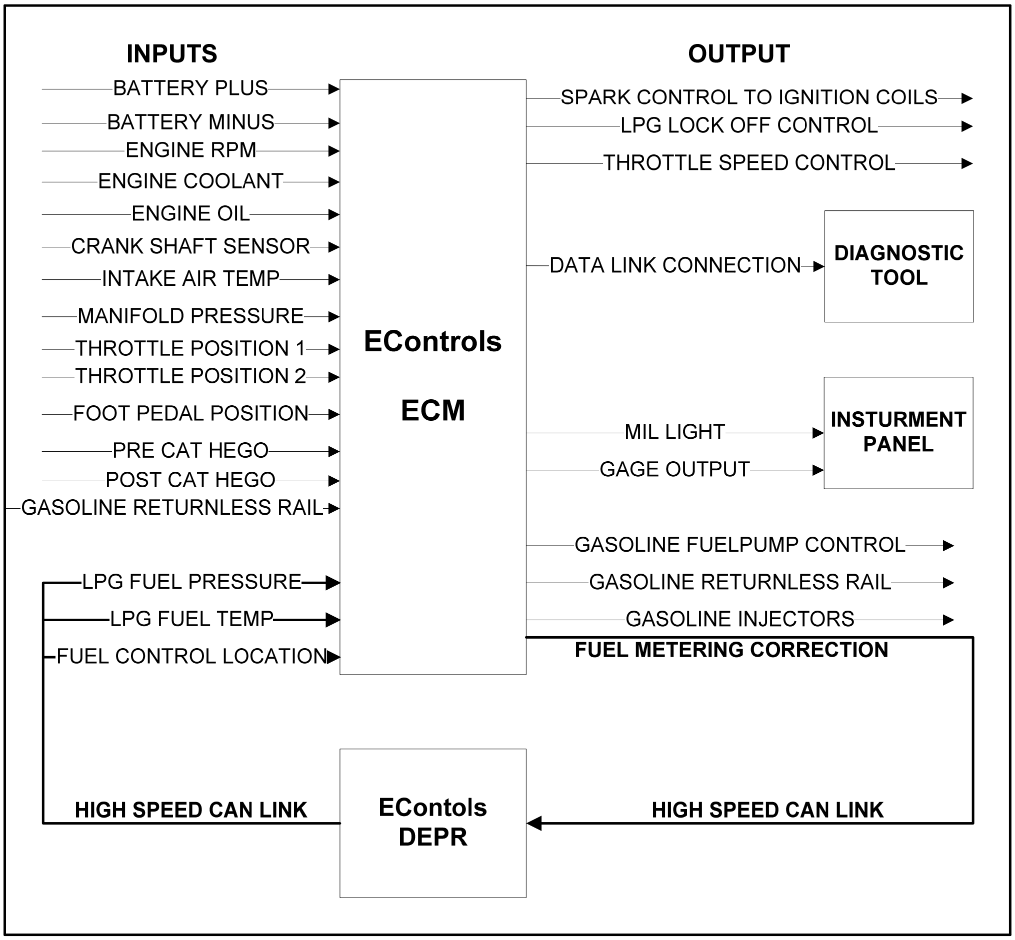

Figure 13 - *Bi-Fuel ECM Input and Outputs*

ENGINE SENSOR GROUP

The shared sensors in the bi-fuel system are those sensors identified in the *LIGHT DUTY EMISSION CERTIFIED DEDICATED LPG FUEL SYSTEMS,* which preceded this section. For information on each sensor refer to the sensor specific information.

GASOLINE PRESSURE SENSORS (GPS)

The Gasoline Pressure Sensor (GPS) provides a reference voltage signal to the ECM. The ECM reads the voltage signal and determines the pressure of the gasoline in the Fuel Pressure Manifold. The ECM uses this value to maintain the precise amount of gasoline pressure for injection, to maintain engine performance and emission control. Thresholds of operation are determined during the development of the calibrations; these thresholds are used to provide diagnostics, of the fuel delivery system. If the GPS output voltage is outside the threshold, either high or low, the ECM will detect the condition and either correct the fuel delivery, or set an engine code, and utilize a “limp home” strategy, or shut down the engine. The sensor is located in the Fuel Pressure Manifold, and is serviceable as a separate part.

GAS TEMPERATURE SENSORS (GTS)

The EControls ECM adjusts gasoline fuel delivery to the engine, by utilizing a Gasoline Temperature Sensor (GTS), which provides a reference voltage signal, to the ECM. The ECM reads the voltage signal, and determines the temperature of the gasoline, in the Fuel Pressure Manifold, and uses this value, to correct the precise amount of gasoline, required for injection, to maintain engine performance, and emissions control. Thresholds of operation are determined during the development of the calibrations; these thresholds are used to provide diagnostics, of the fuel delivery system. If the GTS output voltage is outside the threshold, either high or low, the ECM will detect the condition, and either correct the fuel delivery, or set an engine code, and utilize a “limp home” strategy, or shut down the engine. The sensor is located in the Fuel Pressure Manifold, and is serviceable as a separate part.

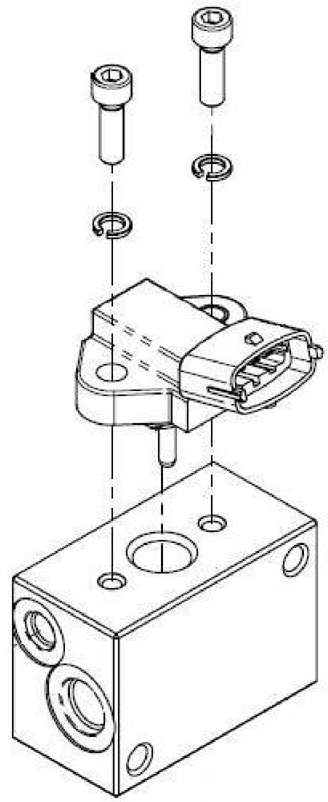

Figure 14 - *Gasoline Temperature and Pressure Sensor*

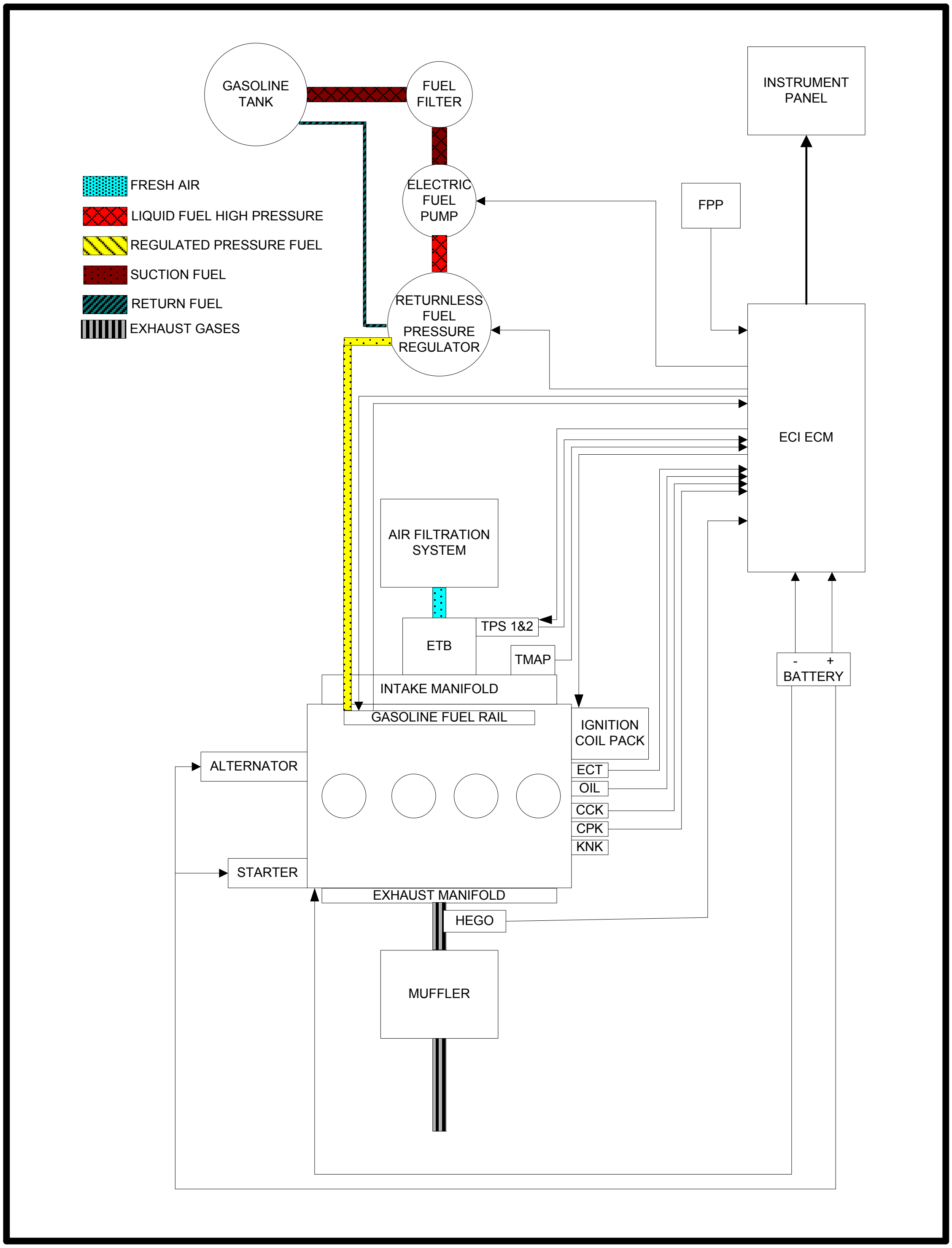

Figure 15 - *EControls Closed Loop Gasoline Schematic*

LIGHT DUTY CLOSED LOOP GASOLINE FUEL SYSTEMS

EControls supplies to OEMs a gasoline fuel system, which is an uncertified “closed loop” system, and is used in regions where there are no specific emissions regulatory requirements, for light duty industrial or stationary operation, exist.

NOTE: ENGINES FITTED WITH THIS TYPE OF FUEL CONTROL, CAN NOT BE USED IN THE USA

The EControls “closed loop” system utilizes specific components, to deliver the gasoline from the tank to the engine. The components used in the fuel system are defined in this section.

ELECTRIC GASOLINE FUEL PUMP

To supply gasoline to the fuel system, the EControls bi-fuel system will utilize an external electric gasoline fuel pump. The pump will be mounted in the chassis of the vehicle, or equipment near the fuel tank. Gasoline rated fuel hose and securing devices supplied by the OEM, will be used to transfer the pumped fuel to the Gasoline Fuel Pressure Manifold assembly. The OEM may have installed a fuel filtration device ahead of the electric pump, which may be located in the tank or an external filter. Most industrial equipment will be exposed to dusty and dirty environments, therefore use caution when opening the gasoline tank, to prevent dirt and debris from falling in the tank. For filter maintenance, refer to the *Recommended Maintenance Chart*.

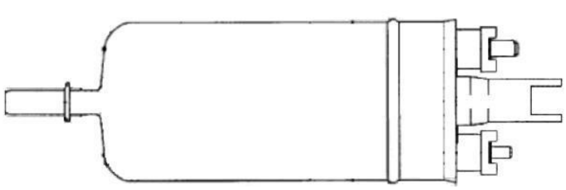

Figure 16 - *Electric Gasoline Fuel Pump*

GASOLINE FUEL PRESSURE MANIFOLD

The EControls gasoline fuel system, utilizes a Fuel Pressure Manifold assembly, to control the delivery pressure to the gasoline injector rail. The manifold is mounted to the chassis, between the electric fuel pump and the gasoline injector rail. The manifold is equipped with a sensor, which provides the ECM with the gasoline fuel temperature, and pressure being regulated to the gasoline injector rail. The ECM uses the fuel temperature and pressure, to calculate the precise amount of gasoline, to be injected to the engine during operation. The manifold is designed into the system, to control pressure, as well as the amount of gasoline, to be returned to the fuel tank. In normal gasoline delivery systems, the electric fuel pump, delivers a constant pressure to the injector rails, and allows a significant amount of fuel to be recycled to the tank, thus causing the gas to heat and vaporize, and requiring the use of a vapor recovery system to control the excess vapor. The EControls system manages the fuel pressure at the manifold and minimizes the amount of returned fuel, thus reducing the vapor fuel in the tank.

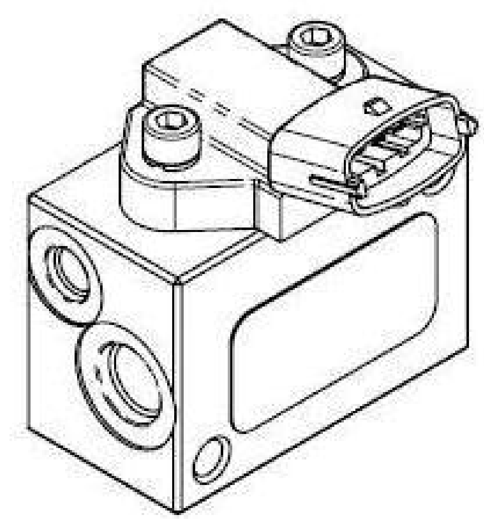

Figure 17 - *Gasoline Fuel Pressure Manifold*

GASOLINE INJECTORS AND INJECTOR RAIL

The EControls gasoline fuel delivery system, utilizes a fuel rail, mounted with injectors, for each cylinder. The fuel rail and injectors, are supplied by the OEM, and may vary with each OEM application. During the design and calibration phase, the ECM gasoline fuel delivery calibrations are developed. The EControls ECM will utilize these calibrations, to pulse width modulate each injector, to deliver the correct amount of gasoline, for optimized performance, and reduced tail pipe emissions. The injector pulsing or “firing,” is accomplished by supplying a 12 volt supply to the positive side of the injector coil, and switching the ground circuit side, using the injector drivers, internal to the ECM.

Because the EControls gasoline fuel system, utilizes the Fuel Pressure Manifold, to control fuel delivery to the rail, the EControls fuel system does not use a separate return line, from the fuel rail assembly. Gasoline injectors are an emissions control device, and do not require periodic adjustment. When serving or placing injectors, use only OEM replacement injectors, to insure the fuel system operates as designed.

ENGINE CONTROL MODULE (ECM)

In all EControls fuel systems, the Engine Control Module (ECM) provides total control, of the engine, fuel control, ignition spark control, and auxiliary features. The ECM depends on the EControls designed wire harness, to receive the required input data, from sensors, and sends the appropriate outputs. The harness is specifically designed to provide the necessary electrical supply, to the engine, through the life of the equipment. All electrical connectors utilize sealed connectors, to prevent damage from moisture intrusion, necessary shielding, when required, and protective covering, to protect the wiring.

To obtain maximum effect from the catalyst and accurate control of the air / fuel ratio, the emissions certified engine is equipped with an onboard computer known as the ECM. The ECM is a 32 bit controller, which receives input data from sensors, fitted to the engine and fuel system, and then outputs various signals, to control engine operation.

In the EControls closed loop Gasoline systems, the ECM controls the engine, in the Gasoline fueling mode. Engine sensors are used for fuel calculation and control, and are also used for the gasoline diagnostics. Those sensors are defined in the sensor group, in this section.

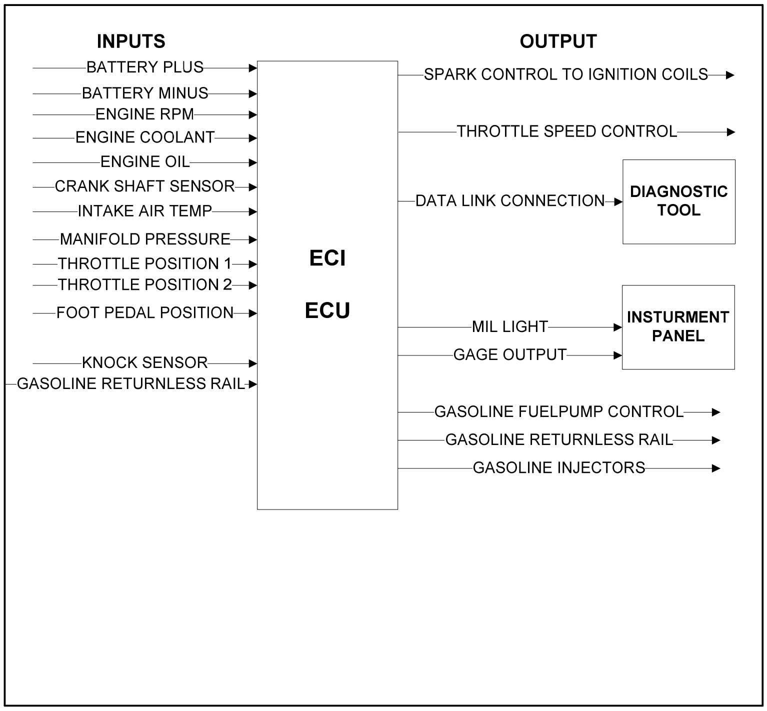

Figure 18 - *EControls Closed Loop Gasoline ECM Input and Outputs*

ENGINE SENSOR GROUP

To maintain fuel control, and insure the system provides the optimum performance, the ECM depends on sensors installed in the engine and fuel system, to provide input to the ECM, for calculating fuel delivery, as well as fuel system diagnostics. This section will provide the technician, with the understanding of the function of each sensor. Due to the variation of each OEM designed system, sensors may vary in both design, and supplier, however the function of each will be the same.

TEMPERATURE MANIFOLD ABSOLUTE PRESSURE (TMAP)

The TMAP sensor is a combination sensor, and provides the ECM with the Intake Air Temperature (IAT), and the Manifold Absolute Pressure (MAP). The ECM uses the intake air temperature to correct fueling based on the density of the air.

The MAP portion of the TMAP sensor provides the ECM with a measurement of the pressure in the intake manifold. During the start up, the MAP provides the ECM with the barometric pressure, to allow the ECM to adjust fueling, based on barometric pressure. Once the engine has started, the ECM uses the MAP to measure the load on the engine, and make fuel and RPM corrections, to compensate for changing load conditions.

In most EControls fuel system designs, the TMAP is generally mounted to the intake manifold, however in some cases the TMAP may be two individual sensors, in this case these components perform the same function, but are identified as IAT and MAP sensors. The TMAP is a 5 volt reference signal sensor, which operates by the resistance change in the sensor, to output a reference voltage for the ECM to use. The sensor can be either a 0 to 5v or a 5v to 0 depending on the sensors, which are supplied by the OEM on the engine. During the development phase of the system, the minimum and maximum thresholds of operation are determined, and are part of the fuel calibration and diagnostics, programmed into the ECM. These thresholds are used to establish the point at which the ECM will set the MIL light, to indicate that a fault has been detected in the fuel system.

ENGINE COOLANT TEMPERATURE (ECT)

The ECM monitors the engine coolant temperature, through the ECT sensor mounted in the engine. The ECM uses this sensor input to make corrections in fueling, and to protect the engine from overheating during normal operation.

In most EControls fuel system designs, the ECT is generally mounted in the cylinder block, and is usually supplied by the OEM engine manufacturer. The ECT is a 5 volt reference signal sensor, which operates by the resistance change in the sensor, to output a reference voltage for the ECM to use. The sensor can be either a 0 to 5v or a 5v to 0, depending on the sensors which are supplied by the OEM on the engine. During the development phase of the system, the minimum and maximum threshold of engine temperature, during normal operation, are determined and are part of the fuel calibration and diagnostics, programmed into the ECM. These thresholds are used to establish the point at which the ECM will set the MIL light, to indicate that a fault has been detected in the fuel system. Should the temperature be exceeded, the ECM will first reduce the engine performance capabilities, often referred to as “limp home,” which allows the operator to move the equipment to a facility for repair, or safely shut down the system. In the event the temperature continues to rise, the ECM will shut down the engine in a specified period of time, after the “limp home” strategy has been activated.

ENGINE OIL PRESSURE (EOP)

The ECM monitors the engine oil pressure, through the EOP sensor, mounted in the engine. The ECM uses this sensor input, to protect the engine from damage, from the lack of oil in the crank case.

In most EControls fuel system designs, the EOP is generally mounted in the cylinder block, and is usually supplied by the OEM engine manufacturer. The EOP is a 5 volt reference signal sensor, which operates by the resistance change in the sensor, to output a reference voltage for the ECM to use. The sensor can be either a 0 to 5v, or a 5v to 0, depending on the sensors, which are supplied by the OEM on the engine. During the development phase of the system, the minimum and maximum threshold of engine temperature, during normal operation are determined, and are part of the fuel calibration and diagnostics, programmed into the ECM. These thresholds are used to establish the point, at which the ECM will set the MIL light, to indicate that a fault has been detected in the engine. Should the pressure be exceeded or fall below the minimum pressure, the ECM will shut down the engine in a specified period of time.

THROTTLE POSITION SENSORS 1 & 2 (TPS 1&2)

EControls fuel systems use an Electronic Throttle Body (ETB) for speed and load control. Internal to the ETB, are two Throttle Position Sensors (TPS), which provide an “actual position” of the throttle plate. During the calibration development, the throttle blade variation, from actual to command, is defined. A maximum variation threshold is determined and included in the calibration, this threshold insures that the variation between actual and command do not vary above this threshold. In the event the variation exceeds the threshold, the ECM will command the ETB to idle, or shutdown the engine. The ECM will also set a diagnostic code, and turn on the MIL light

FOOT PEDAL POSITION SENSORS (FPP)

EControls fuel systems, utilize a “drive by wire” technique, to allow the operator to accelerate the engine. This type of technique does not use a physical connection, between the operator foot pedal and the throttle body. Therefore control of the engine is managed by electrical signals, using a Foot Pedal Position Sensor (FPP), to determine the location, or how much the pedal is being depressed or released, which is relative to the command, that the operator desires. The FFP is a reference voltage sensor, therefore changing the voltage output level up or down, indicates a different desired position to the ECM. The ECM then changes the output signal, to the ETB, thus changing the throttle blade position, to correspond to the desired foot pedal command.

The FPP is generally integrated, in the foot pedal mechanism, mounted in the operator's platform.

GASOLINE PRESSURE SENSORS (GPS)

The Gasoline Pressure Sensor (GPS) provides a reference voltage signal to the ECM. The ECM reads the voltage signal and determines the pressure of the gasoline in the Fuel Pressure Manifold. The ECM uses this value to maintain the precise amount of gasoline pressure for injection, to maintain engine performance and emission control. Thresholds of operation are determined during the development of the calibrations; these thresholds are used to provide diagnostics, of the fuel delivery system. If the GPS output voltage is outside the threshold, either high or low, the ECM will detect the condition and either correct the fuel delivery, or set an engine code, and utilize a "limp home" strategy, or shut down the engine. The sensor is located in the Fuel Pressure Manifold, and is serviceable as a separate part.

GAS TEMPERATURE SENSORS (GTS)

The EControls ECM adjusts gasoline fuel delivery to the engine, by utilizing a Gasoline Temperature Sensor (GTS), which provides a reference voltage signal, to the ECM. The ECM reads the voltage signal, and determines the temperature of the gasoline, in the Fuel Pressure Manifold, and uses this value, to correct the precise amount of gasoline, required for injection, to maintain engine performance, and emissions control. Thresholds of operation are determined during the development of the calibrations; these thresholds are used to provide diagnostics, of the fuel delivery system. If the GTS output voltage is outside the threshold, either high or low, the ECM will detect the condition, and either correct the fuel delivery, or set an engine code, and utilize a "limp home" strategy, or shut down the engine. The sensor is located in the Fuel Pressure Manifold, and is serviceable as a separate part.

CRANKSHAFT POSITION SENSOR (CKP)

To determine the engine RPM and piston position of number one cylinder, the ECM receives this information from the Crankshaft Sensor. The CKP is generally located near the crankshaft pulley, on the front of the engine, or on the flywheel at the rear of the engine, and is supplied by the engine OEM. CKPs vary in design, depending on the signal that the sensor produces. Induction sensors produce a sine wave, or "s-shaped" signal, where as the Halleffect crank position sensor, which reads a notched metal "interrupter" ring, on the back of the harmonic balancer, creates a square wave pattern.

CAMSHAFT POSITION SENSOR (CKP)

The cam shaft sensor is used to determine which stroke of the engine cycle the engine is running on for control of the fuel and spark. The sensor is usually mounted at the front of the engine or the rear and reads a pick up wheel mounted internally within the engine. The pick up wheel can be of vary design and number of pulses. The sensor can be either an inductive pick up which will give a sine wave or a Hall effect sensor and reads a square wave from zero to either 12 or 5 volts.

KNOCK SENSOR (KCS)

To prevent engine "knock," which occurs when the fuel air mixture does not burn smoothly, during this condition timing is generally decreased, to assist with the fuel burn process. The EControls gasoline fuel system, utilizes a Knock Sensor, which is installed to the engine block, and supplied by the OEM engine supplier. The Knock Sensor is a 5 volt reference signal sensor, which operates by the resistance change in the sensor, to output a reference voltage for the ECM to use. The knock sensor sends a base or "no knock" signal to the EControls ECM, when knocking does occur the sensor detects the increased vibration, and increases the voltage output to the ECM. When the ECM receives the voltage change, the ECM will slightly retard the timing, until such time, the knocking no longer exists. To determine of your engine uses a knock sensor, consult the OEM section of the manual.

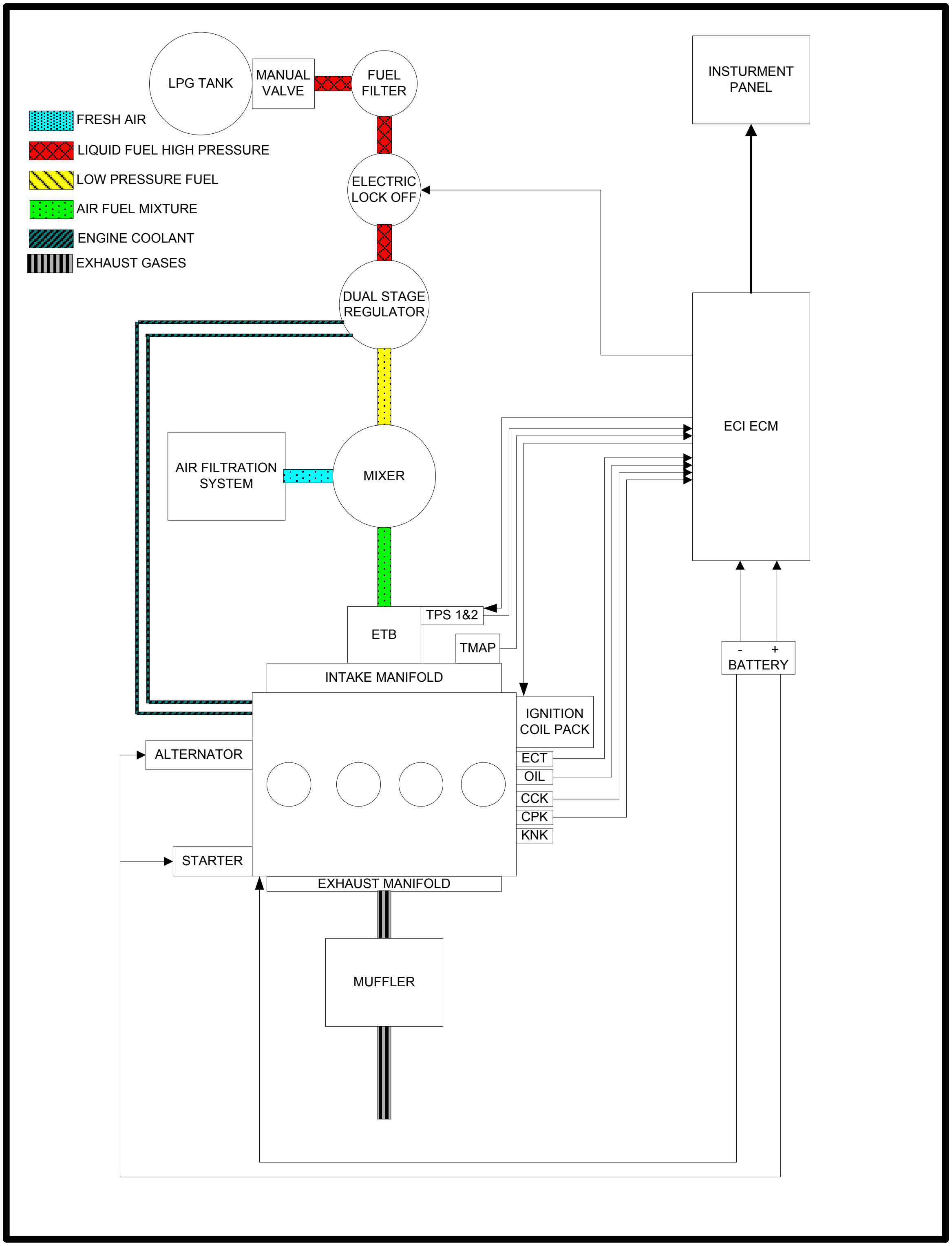

Figure 20 - *EControls Open Loop LPG Schematic*

LIGHT DUTY OPEN LOOP LPG FUEL SYSTEMS

EControls supplies to OEMs, LPG fuel systems, which are an "open loop" system, and are used in regions, where there are no specific emissions regulatory requirements, for light duty industrial or, stationary operation.

NOTE: ENGINES FITTED WITH THIS TYPE OF FUEL CONTROL, CAN NOT BE USED IN THE USA

The EControls "open loop" system, utilizes specific components, to deliver the LPG fuel, from the tank to the engine. The components used in the fuel system are defined in this section.

LPG FUEL TANK

Propane is stored in the fuel tank, as a liquid. The approximate pressure, of the fuel in the tank, is 16.5 bar (240 psi), when the tank is full at an ambient temperature of 27° C (80°F). The boiling point, (temperature at which the liquid LPG fuel becomes vapor) is approximately -40° C (-40° F). When the fuel changes from liquid to vapor, the fuel expands, and creates pressure inside the tank. When the tank service valve (Item 1) is opened, the pressure inside the tank forces the liquid fuel out though the pickup tube, located near the bottom of the fuel cylinder (Item 1). Because the Propane is stored under pressure, the tank is equipped with a safety valve, which is normally set at 25.8 bar (375 psi), to prevent tank rupture, due to over-pressurization of the cylinder (Item 3). The service valve (Item 1) mounted at the end of the cylinder, controls the flow of fuel from the tank. By turning the handle to its "open" position, fuel flows out of the tank, and into the service line. The service valve is also equipped with a safety feature, called an "excess flow check valve." This feature reduces the flow from the service valve, in the event of a rupture of the fuel line, or any downstream component. Some tanks may be equipped with quick fill valves (Item 2), manual gauge assembly (Item 5), and an 80% fill valve, which signals the tank is at 80% full and fueling should stop, as to not over fill the tank, and cause a dangerous condition. If the EControls LPG dedicated system is installed on a motor vehicle, the tank will be equipped with an automatic stop fill device, but the over design and function, is the same as the industrial LPG tank.

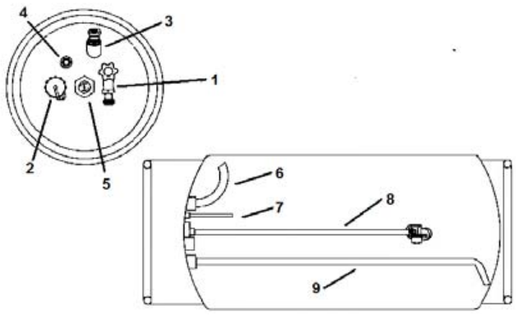

Figure 21 - *Typical Industrial Use LPG tank*

⚠ WARNING

NEVER CUT OR WELD ON EITHER THE LPG OR GASOLINE FUEL TANK. REPAIRS TO THE FUEL TANK SHOULD ONLY BE MADE BY A CERTIFIED TANK REPAIR FACILITY. FAILURE TO OBSERVE THIS WARNING COULD RESULT IN SERIOUS BODILY INJURY AND OR DEATH AND COULD RESULT IN SERIOUS PROPERTY DAMAGE.

⚠ WARNING

ALWAYS WEAR PROTECTIVE EYEWEAR AND GLOVES WHEN PERFORMING MAINTENANCE ON THE LPG OR GASOLINE FUEL SYSTEMS, TO PREVENT SERIOUS INJURY. ALWAYS PERFORM MAINTENANCE PROCEDURES IN A WELL VENTILATED AREA AND INSURE THAT THERE ARE NO EXTERNAL SOURCES OF IGNITION.

WR00003 Rev A

SERVICE LINE

Propane flows from the fuel tank, to the electric lock, via the service line. The service line is most commonly connected to the tank, utilizing a quick coupler. The other end of the service line is connected to a "bulkhead connector," which is used to allow the service line, to pass through the metal enclosure, or vehicle body panels, or hoods. This hose is made of special material, which protects the inner core of the hose, from chemicals contained within the LPG, which could result in a failure of the hose. The hose should never be kinked or allowed to come into contact with the chassis, or other engine components, and electrical connection, or wiring. When replacing the fuel line, use care, as there may be fuel retained in the line, between the tank manual valve connection, and the electric lock off device.

FUEL FILTER

Propane fuel, like all other motor fuels, is subject to contamination from outside sources. Refueling, of the equipments tank, and removal of the tank, from the equipment, can inadvertently introduce dirt, and other foreign matter into the fuel system. It is therefore necessary to filter the fuel, prior to entering the fuel system components, downstream of the tank. EControls has advised the OEM, during the design, to incorporate a filtering device, between the tank and the fuel system. An inline, or bulkhead filter, has been installed, by the OEM. These in-line filters are generally replaceable, as a unit only, whereas bulkhead filters, generally are serviceable. Maintenance of the filter is critical, to proper operation of the fuel system, and should be replaced, as defined in the *Recommended Maintenance Schedule*. In severe operating conditions, or regions where fuel supply has been recognized to contain more contaminants, more frequent replacement may be required. Filters are always marked in some fashion, to indicate the direction flow, of the fuel, through the filter.

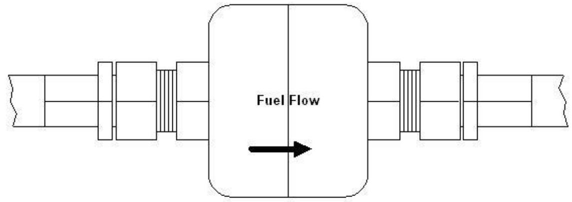

Figure 22 - *In-line LPG filter*

LPG FUEL LOCK OFF

The LPG Fuel Lock Off device is an integrated assembly. The electric lock off assembly is a 12 volt, normally closed valve. The solenoid is mounted to the valve body. When energized the solenoid opens the pilot valve, within the lock off, which uses the tank pressure, to assist in opening the valve. By using the pilot valve, to help open the valve, the service life of the valve is extended, and requires less electrical energy, to open the valve. The valve opens during cranking, and remains open, during the run cycles of the engine. The lock off supply voltage is controlled by the Engine Control Module (ECM), or may be energized by a relay, which supplies battery voltage, when energized.

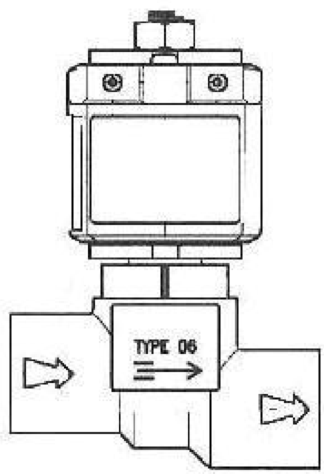

Figure 23 - *Typical In-line LPG Fuel Lock Off device*

DUAL STAGE REGULATOR (DSR)

The DSR is a combination vaporizer, pressure regulating device. The DSR is a two stage regulator that is normally closed, when the engine is not running. When the engine is cranking or running, a partial vacuum is created in the fuel line, which connects the regulator to the mixer. This partial vacuum opens the second stage regulator, permitting fuel to flow to the mixer.

Propane fuel enters the primary port of the DSR, and passes through the primary jet, and into the primary/exchanger chamber. As the propane passes through the heat exchanger, the fuel expands, and creates pressure inside the chamber. The pressure rises as the fuel expands, when the pressure rises above 10.34 kpa (1.5 psi); sufficient pressure is exerted on the primary diaphragm, to cause the diaphragm plate to pivot, and press against the primary valve pin, thus closing off the flow of fuel. This action causes the flow of fuel, into the regulator to be regulated. When the engine is cranking, sufficient vacuum will be introduce into the secondary chamber, from the EPR/mixer, drawing the secondary diaphragm down onto the spring loaded lever, and opening the secondary valve, allowing vaporized fuel, to pass to the mixer. Increased vacuum, in the secondary chamber, increases the downward action on the secondary lever, causing it to open wider, allowing more fuel to flow to the mixer.

The DSR requires a connection to the engine coolant, to prevent freezing in the regulator, during the pressure reduction phase, within the regulator. Coolant connections on the DSR are fitted with “Push In” fittings. These fitting are designed with an o-ring seal, which allows the fitting to be pushed into the water connection on the DSR, and are then lock by spring locks, and retained by screws.

The DSR is connected to the mixer, by a low pressure flexible hose. Like the other fuel hoses used in the fuel system, the low pressure hose is designed with a special inner core, and is usually wire reinforced, to prevent collapse of the hose, during high demand fueling operations. The low pressure hose should only be replaced, with the recommended OEM hose replacement.

The packaging of the regulator, into the engine and chassis, must be approved by EControls, to insure continued long term operation, of the fuel delivery and emission control system. You should never relocate the regulator, or any of the fuel system components, as doing so, may cause excess build up of oil in the regulator, improper coolant flow, or improper fuel delivery.

In certain regions, fuel supplies may be made up of much different chemicals and during the heating of the fuel, in the heat exchange section of the regulator, “heavy end” or petroleum oils, may accumulate over time. To drain the DSR, remove the fuel outlet hose and pour the oils out of the regulator. To determine the frequency, for draining the regulators, refer to the *Recommended Maintenance Schedule*.

Figure 24 - *Dual Stage Regulators (DSR)*

MIXER ASSEMBLY

The air valve mixer, is an air-fuel metering device, and is completely self-contained. The mixer is an air valve design, utilizing a relatively constant pressure drop, to draw fuel into the mixer, from cranking, to full load. The mixer is mounted in the air stream, ahead of the throttle control device.

When the engine begins to crank, it draws in air, and with the air valve covering the inlet, negative pressure begins to build. This negative pressure signal, is communicated to the top of the air valve chamber, through 4 vacuum ports, in the air valve assembly. A pressure/force imbalance begins to build, across the air valve diaphragm, between the air valve vacuum chamber, and the atmospheric pressure below the diaphragm. The air valve vacuum spring is calibrated, to generate from 101.6 mm (4.0 inches) of water column at start, to as high as 355.60 mm (14.0 inches) of water column, at full throttle. The vacuum being created is referred to as Air Valve Vacuum (AVV). As the air valve vacuum reaches 101.6mm (4.0 inches) of water column, the air valve begins to lift against the air valve spring. The amount of AVV generated, is a direct result of the throttle position. At low engine speed, the air valve vacuum is low, and the air valve position is low, thus creating a small venturi for the fuel to flow. As the engine speed increases the AVV increases and the air valve is lifted higher, thus creating a much larger venturi. This air valve vacuum is communicated from the mixer venture, to the DSR secondary chamber, and the low pressure fuel supply hose. As the AVV increases in the secondary chamber, the secondary diaphragm is drawn further down, forcing the secondary valve lever to open wider.

The mixer is attached to the Electronic Throttle Body (ETB), via an adapter. The adapter is fitted with specific spacers, and o-rings, to insure a seal tight fit with the ETB.

The Mixer is designed such that, the diaphragm can be replaced, should the diaphragm be damaged during operation, from fuel contaminants, refer to *Mixer Diaphragm Replacement* section in this manual. The Mixer, utilized on open loop LPG systems, is fitted with a power adjustment valve, to make periodic adjustments to the mixer. To make adjustment to the mixer, refer to *Open Loop Mixer Adjustment* section in this manual.

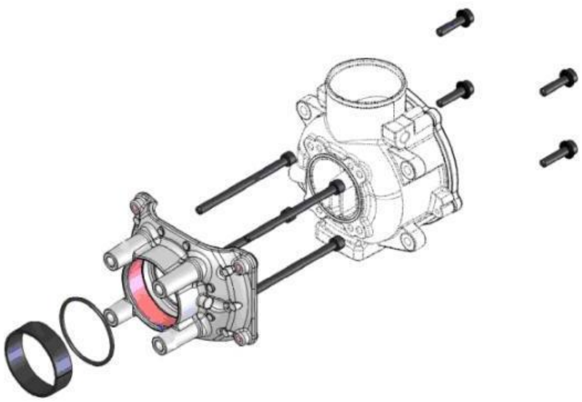

Figure 25 - *Open Loop Mixer and ETB Adapter*

ELECTRONIC THROTTLE BODY (ETB)

The EControls fuel systems, utilize Drive By Wire (DBW) Electronic Throttle Body (ETB). In this type of application, there is no direct connection between the operator pedal, and the throttle shaft. Speed and load control, are determined by the ECM. Defaults programmed into the ECM software and throttle position sensors, allow the ECM to maintain safe operating control, over the engine.

In a drive by wire application, the Electronic Throttle Body (ETB) device, or “throttle body assembly,” is connected to the intake manifold of the engine. The electronic throttle control device, utilizes an electric motor, connected to the throttle shaft. In addition, a Foot Pedal Position sensor (FPP) is located in the operator’s compartment. When the engine is running, electrical signals are sent from the foot pedal position sensor, to the engine ECM, when the operator depresses or releases the foot pedal. The ECM then sends an electrical signal to the motor, on the electronic throttle control, to increase or decrease the angle of the throttle blade, thus increasing or decreasing the air flow, to the engine.

The electronic throttle control device also incorporates two internal Throttle Position Sensors (TPS), which provide output signals to the ECM, as to the location of the throttle shaft, and blade. The TPS information is used by the ECM, to correct for speed and load control, as well as emission control, and engine protection.

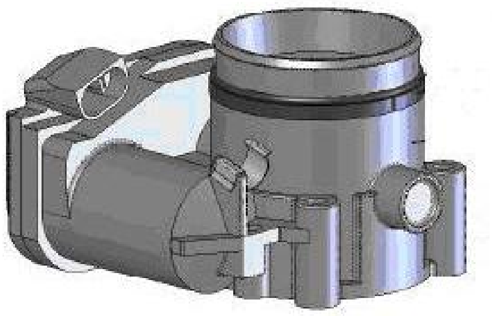

Figure 26 - *Electronic Throttle Body (ETB)*

ENGINE CONTROL MODULE (ECM)

In all EControls fuel systems, the Engine Control Module (ECM) provides total control of the engine, fuel control, ignition spark control, and auxiliary features. The ECM depends on the EControls supplied wire harness, to receive the required input data from sensors, and send the appropriate outputs. The harness is specifically designed to provide the necessary electrical supply to the engine, through the life of the equipment. All electrical connectors utilize sealed connector, to prevent damage from moisture intrusion, necessary shielding when required, and protective covering, to protect the wiring.

One primary function of the controller is to maintain "open loop fuel control". Open loop fuel control is accomplished by mapping and developing a specific calibration, which provides optimum performance, and minimizes excessive tail pipe emissions. The controller calculates any correction that may need to be made, to the air fuel ratio, based on sensor input, and the predetermined calibration, contained within the ECM.

The ECM also performs diagnostic functions, on the fuel system, and notifies the operator of malfunctions, by turning on a Malfunction Indicator Light (MIL), mounted in the dash. Malfunctions, in the system, are identified by a Diagnostic Code number. In addition to notifying the operator, of the malfunction in the system, the controller also stores the information about the malfunction in its memory. A technician can than utilize a computerized diagnostic tool, to retrieve the stored diagnostic code, and by using the diagnostic charts, in this manual, to determine the cause of the malfunction. In the event a technician does not have the computerized diagnostic tool, the MIL light can be used to identify the diagnostic code. By following specific steps, the technician can activate the "blink" feature, and count the number of blinks, to determine the diagnostic code number, to locate the fault in the system.

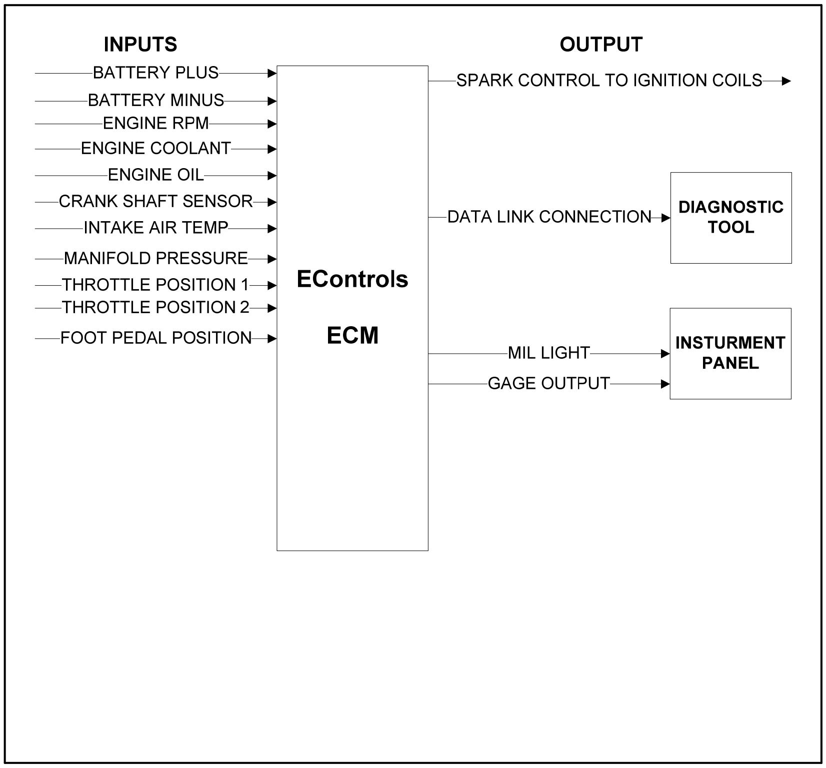

Figure 27 - *EControls Open Loop LPG ECM Input and Outputs*

ENGINE SENSOR GROUP

To maintain fuel control, and insure the system provides the optimum performance, the ECM depends on sensors installed in the engine and fuel system, to provide input to the ECM for calculating fuel delivery, as well as fuel system diagnostics, and engine protection. This section will provide the technician with the understanding, of the function of each sensor. Due to the variation of each OEM designed system, sensors may vary in both design and supplier, however the function of each, will be the same.

TEMPERATURE MANIFOLD ABSOLUTE PRESSURE (TMAP)

The TMAP sensor is a combination sensor, and provides the ECM with the Intake Air Temperature (IAT), and the Manifold Absolute Pressure (MAP). The ECM uses the intake air temperature to correct fueling based on the density of the air.

The MAP portion of the TMAP sensor provides the ECM with a measurement of the pressure in the intake manifold. During the start up, the MAP provides the ECM with the barometric pressure, to allow the ECM to adjust fueling, based on barometric pressure. Once the engine has started, the ECM uses the MAP to measure the load on the engine, and make fuel and RPM corrections, to compensate for changing load conditions.

In most EControls fuel system designs, the TMAP is generally mounted to the intake manifold, however in some cases the TMAP may be two individual sensors, in this case these components perform the same function, but are identified as IAT and MAP sensors. The TMAP is a 5 volt reference signal sensor, which operates by the resistance change in the sensor, to output a reference voltage for the ECM to use. The sensor can be either a 0 to 5v or a 5v to 0 depending on the sensors, which are supplied by the OEM on the engine. During the development phase of the system, the minimum and maximum thresholds of operation are determined, and are part of the fuel calibration and diagnostics, programmed into the

ECM. These thresholds are used to establish the point at which the ECM will set the MIL light, to indicate that a fault has been detected in the fuel system.

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The ECM monitors the engine coolant temperature, through the ECT sensor mounted in the engine. The ECM uses this sensor input to make corrections in fueling, and to protect the engine from overheating during normal operation.

In most EControls fuel system designs, the ECT is generally mounted in the cylinder block, and is usually supplied by the OEM engine manufacturer. The ECT is a 5 volt reference signal sensor, which operates by the resistance change in the sensor, to output a reference voltage for the ECM to use. The sensor can be either a 0 to 5v or a 5v to 0, depending on the sensors which are supplied by the OEM on the engine. During the development phase of the system, the minimum and maximum threshold of engine temperature, during normal operation, are determined and are part of the fuel calibration and diagnostics, programmed into the ECM. These thresholds are used to establish the point at which the ECM will set the MIL light, to indicate that a fault has been detected in the fuel system. Should the temperature be exceeded, the ECM will first reduce the engine performance capabilities, often referred to as “limp home,” which allows the operator to move the equipment to a facility for repair, or safely shut down the system. In the event the temperature continues to rise, the ECM will shut down the engine in a specified period of time, after the “limp home” strategy has been activated.

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SYMPTOM DIAGNOSTIC SECTION

LPG SYMPTOM CHARTS

Important Preliminary Checks	
Checks	**Action**
Before Using This Section	Before using this section, you should have performed On Board Diagnostic Check and determined that: • The Control Module and MIL (Malfunction Indicator Lamp) are operating correctly. • There are no Diagnostic Trouble Codes (DTCs) stored, or a DTC exists, but without a MIL. Several of the following symptom procedures call for a careful visual and physical check. The visual and physical checks are very important. The checks can lead to correcting a problem, without further checks, that may save valuable time. Most importantly talk to the operator about the failure this may provide important information about the fault.
Important Question to Ask the Operator	• When and how did the operator first notice the fault condition • What engine speed and load condition did the fault occur at • Did the fault occur just after or before refueling • Did the fault occur at start up or shut down • Did the fault occur at a particular time of day or during the shift • Did the fault occur in a particular location • Has there been any recent repair to the engine or vehicle • Has the fault ever occurred before • Has there been any new external customer installed devices added to the vehicle and or engine
LPG Fuel System Check	• Verify the customer complaint. • Locate the correct symptom table. • Check the items indicated, under that symptom. • Operate the vehicle, under the condition the symptoms occurs. Verify HEGO is switching between lean and rich. **IMPORTANT!** • **Normal HEGO switching, indicates the LPG fuel system is in closed loop, and operating correctly at that time.** • If a scan tool is available, **take a snapshot,** under the condition that the symptom occurs. Go to *Engine Scan Tool Data* List, to verify normal sensor values and parameters.

Visual and Physical Checks	• Check all ECM system fuses and/or circuit breakers. • Check the ECM ground for being clean, tight, and in its proper location. • Check the vacuum hoses for splits, kinks, and proper connections. • Check thoroughly for any type of leak or restriction. • Check for air leaks, at all the mounting areas, of the intake manifold sealing surfaces.
	• Check for proper installation of the mixer module assembly. • Check for air leaks, at the mixer assembly. • Check the ignition wires, for the following conditions: o Cracking o Hardness o Proper routing o Carbon tracking • Check the wiring, for the following items: o Proper connections, pinches, or cuts. • Check the fuel level and fuel delivery system for leaks • Check the battery condition • The following symptom tables contain groups of possible causes, for each symptom. The order of these procedures is not important. If the scan tool readings do not indicate the problems, then proceed in a logical order, easiest to check, or most likely to occur first.

Intermittent	
Checks	**Action**
DEFINITION: The problem may or may not turn ON the Malfunction Indicator Lamp (MIL), or store a Diagnostic Trouble Code (DTC).	
Preliminary Checks	• Refer to *Important Preliminary Checks.* • Do not use the DTC tables, if a fault is an intermittent, the use of the DTC tables may result in the replacement of good parts.

Faulty Electrical Connections, or Wiring	• Faulty electrical connections, or wiring, can cause most intermittent problems.
	• Check the suspected circuit for the following conditions:
	  • Faulty fuse, or circuit breaker
	  • Connectors poorly mated
	  • Corrosion or loose pins in the connectors
	  • Terminals not fully seated, in the connector (backed out)
	  • Terminals not properly formed, or damaged
	  • Terminal to wire joints poorly connected
	  • Terminal tension, insufficient
	  • Wire strain from improper wire routing
	  • Burned or damaged wires from contacting hot surfaces or rotating devices
	  • Improper splicing method used when optional equipment is installed to the vehicle
	• Carefully remove all the connector terminals in the problem circuit, in order to ensure the proper contact tension. If necessary, replace all the connector terminals in the problem circuit, in order to ensure the proper contact tension.
	• Checking for poor terminal, to wire connections, requires removing the terminal from the connector body.

Operational Test	If a visual and physical check does not locate the cause of the problem, drive the vehicle with a scan tool. When the problem occurs, an abnormal voltage or scan reading indicates the problem may be in that circuit.
Intermittent Malfunction Indicator Lamp (MIL)	The following components can cause intermittent MIL, and no DTC(s): • A defective relay Control Module driven solenoid, or a switch that can cause electrical system interference. Normally, the problem will occur when the faulty component is operating. • The improper installation of electrical devices, such as lights, 2-way radios, electric motors, etc. • The ignition, secondary voltage, is shorted to a ground. • The Malfunction Indicator Lamp (MIL) circuit, or the Diagnostic Test Terminal, is intermittently shorted to ground. • The Control Module grounds

Loss of DTC Memory	To check for the loss of the DTC Memory: 1. Disconnect the TMAP sensor. 2. Idle the engine, until the Malfunction Indicator Lamp illuminates.
	The ECM should store a TMAP DTC. The TMAP DTC should remain in the memory, when the ignition is turned OFF. If the TMAP DTC does not store and remains, the ECM is faulty.

No Start	
Checks	**Action**
DEFINITION: The engine cranks OK, but does not start.	
Preliminary Checks	• Refer to *Important Preliminary Checks*.
Battery and Voltage Check	• Check the battery charge condition • Check the battery cranking voltage, voltage less the 9.0 VDC are outside the parameters of operation • Check Battery positive and negative cable ends for corrosion build up
Control Module Checks	• Check the inline fuse in the ECM battery power circuit. Refer to *Engine Controls Schematics.* • Check battery power, ignition power, and ground circuits, to the ECM. Refer to *Engine Control Schematics.* Verify voltage and/or continuity, for each circuit.
Sensor Checks	• Crank sensor • Cam sensor .
Fuel System Checks	**Important**: A closed LPG manual fuel shut off valve, will create a no start condition. Check the fuel supply line connection to ensure the Excess flow check valve has not set • Check for air intake system leakage, between the mixer and the throttle body. • Verify proper operation, of the low pressure lock-off solenoids. • Fuel filter plugging. • Check the fuel system pressures. Refer to the *LPG Fuel System Diagnosis*. • Check the low pressure fuel supply hose for restrictions and or blockage • Check for restrictions in the air intake system • Check for large vacuum leaks in the intake system • Check for proper mixer air valve operation. • Check for exhaust pipe or catalyst restrictions

Ignition System Checks	Note: LPG, being a gaseous fuel, requires higher secondary ignition system voltages, for the equivalent gasoline operating conditions. • Check for the proper ignition voltage output. • Verify that the spark plugs are correct, for use with LPG. • Check the spark plugs, for the following conditions: Wet plugs Cracks Wear
	Improper gap Burned electrodes Heavy deposits • Check for bare or shorted ignition wires. • Check for loose ignition, coil connections, at the coil.
Engine Mechanical Checks	**Important:** The LPG Fuel system works on a fumigation principle, of fuel introduction, and is more sensitive, to intake manifold leakage, than the gasoline fuel supply system. • Check for the following: • Vacuum leaks • Improper valve timing • Low compression • Bent pushrods • Worn rocker arms • Broken, or weak valve springs • Worn camshaft lobes.
Exhaust System Checks	• Check the exhaust system, for a possible restriction: • Inspect the exhaust system, for damaged or collapsed pipes. • Inspect the muffler, for signs of heat distress, or for possible internal failure. • Check for, possible, plugged catalytic converter. Refer to *Restricted Exhaust System Diagnosis*

Hard Start	
Checks	**Action**
DEFINITION: The engine cranks OK, but does not start for a long time. The engine does eventually run, or may start, but immediately dies.	
Preliminary Checks	• Refer to *Important Preliminary Checks*. • Make sure the vehicle's operator is using the correct starting procedure. • Be sure that there is fuel in the fuel tank • Check to make sure the manual tank valve is fully open
Sensor Checks	• Check the Crankshaft Position (CKP) sensor. • Check the Camshaft sensor.
Fuel System Checks	**Important**: A closed LPG manual fuel shut off valve will create an extended crank, OR no start condition. • Verify the excess flow valve, in the LPG manual shut-off valve, is not tripped. • Check mixer module assembly, for proper installation and leakage. • Verify proper operation, of the low pressure lock-off solenoids. • Check for air intake system leakage, between the mixer and the throttle body. • Check the fuel system pressures. Refer to the *Fuel System Diagnosis*.

Ignition System Checks	Note: LPG, being a gaseous fuel, requires higher, secondary ignition system voltages, for the equivalent gasoline operating conditions.
	• Check for the proper ignition voltage output
	• Verify that the spark plugs are correct, for use with LPG.
	• Check the spark plugs, for the following conditions:
	    • Wet plugs
	    • Cracks
	    • Wear
	    • Improper gap
	    • Burned electrodes
	    • Heavy deposits
	• Check for bare or shorted ignition wires.
	• Check for moisture, in the distributor cap, if applicable.
	• Check for loose ignition coil connections.
	Important:
	1. If the engine starts, but then immediately stalls, check Crankshaft Position (CKP).
	2. Check for improper gap, debris, or faulty connections.

Engine Mechanical Checks	**Important:** The LPG Fuel system, works on a fumigation principle of fuel introduction, and is more sensitive to intake manifold leakage, than the gasoline fuel supply system.
	• Check for the following:
	  • Vacuum leaks
	  • Improper valve timing
	  • Low compression
	  • Bent pushrods
	  • Worn rocker arms
	  • Broken or weak valve springs
	  • Worn camshaft lobes. Ref
	• Check the intake and exhaust manifolds, for casting flash.

Exhaust System Checks	• Check the exhaust system for a possible restriction: • Inspect the exhaust system, for damaged or collapsed pipes. • Inspect the muffler, for signs of heat distress, or for possible internal failure. • Check for possible, plugged, catalytic converter. Refer to *Restricted Exhaust System Diagnosis*

Cuts Out, Misses	
Checks	**Action**
DEFINITION: A surging or jerking, that follows engine speed, usually more pronounced as the engine load increases, which is not normally felt, above 1500 RPM. The exhaust has a steady spitting sound at idle, low speed, or hard acceleration, for the fuel starvation, that can cause the engine to cut-out.	
Preliminary Checks	• Refer to *Important Preliminary Checks*. • Check the battery condition • Check the positive and negative cable connections • Check the ECM and system grounds for corrosion at the connectors • Check the coil electrical connections • Check the air filter for restriction

Ignition System Checks	• Start the engine.
	• Wet down the secondary ignition system, with water from a spray bottle, and look/listen for arcing, or misfiring as you apply water.
	• Check for proper ignition output voltage, with spark tester
	• Check for a cylinder misfire.
	• Verify that the spark plugs are correct for use, with LPG.
	• Remove the spark plugs and check for the following conditions:
	  • Insulation cracks
	  • Wear
	  • Improper gap
	  • Burned electrodes
	  • Heavy deposits
	  • Visually/Physically inspect the secondary ignition, for the following:
	  • Ignition wires for arcing, cross-firing, and proper routing.
	  • Ignition coils, for cracks or carbon tracking

Engine Mechanical Checks	• Perform a cylinder compression check.
	• Check the engine for the following:
	  • Improper valve timing
	  • Bent pushrods
	  • Worn rocker arms
	  • Worn camshaft lobes.
	  • Broken or weak valve springs.
	• Check the intake and exhaust manifold passages, for casting flash.

Fuel System Checks	• Check the fuel system - plugged fuel filter, low fuel pressure, etc. Refer to *LPG Fuel System Diagnosis*. • Check the condition of the wiring, to the low pressure lock-off solenoid • Check the DEPR wire harness connection at the DEPR
	• Check the VSW electrical connection to make sure it is fully seated and locked.
Additional Check	Check for Electromagnetic Interference (EMI). • EMI on the reference circuit can cause a missing condition. • Monitoring the engine RPM, with a scan tool, can detect an EMI. • A sudden increase, in the RPM, with little change in the actual engine RPM, indicates EMI is present. • If the problem exists, check the routing of the secondary wires, and the ground circuit. • Check for secondary electrical equipment improperly spliced into the engine electrical system

Hesitation, Sag, Stumble	
Checks	**Action**
DEFINITION: The vehicle has a momentary lack of response when depressing the accelerator. The condition can occur at any vehicle speed. The condition may cause the engine to stall if it's severe enough.	
Preliminary Checks	• Refer to *Important Preliminary Checks*. • Check the battery condition • Check the positive and negative cable connections • Check the ECM and system grounds for corrosion at the connectors • Check the coil electrical connections Check the air filter for restriction
Fuel System Checks	• Check the fuel pressure. Refer to *LPG Fuel System Diagnosis*. • Check for low fuel pressure, during a moderate, or full throttle acceleration. If the fuel pressure drops below specification, there is a possibility of a faulty low pressure regulator, or a restriction, in the fuel system. • Check the Manifold Absolute Pressure (MAP) sensor response and accuracy. • Check Lock off electrical connection. • Check the mixer air valve for sticking or binding. • Check the mixer module assembly, for proper installation and leakage.
Ignition System Checks	Note: LPG, being a gaseous fuel, requires higher secondary ignition system voltages, for the equivalent gasoline operating conditions. If a problem is reported on LPG, and not gasoline, do not discount the possibility of a LPG only, ignition system failure, and test the system accordingly. • Check for proper ignition output voltage, with spark tester • Verify that the spark plugs are correct, for use with LPG. • Check for faulty spark plug wires. • Check for fouled spark plugs.
Additional Check	• Check for manifold vacuum, or air induction, system leaks. • Check the generator, output voltage.

<table>
<tr><th colspan="2">Backfire</th></tr>
<tr><th>Checks</th><th>Action</th></tr>
<tr><td colspan="2">DEFINITION: The fuel ignites in the intake manifold, or in the exhaust system, making a loud popping noise.</td></tr>
<tr><td>Preliminary Check</td><td>• Refer to Important Preliminary Checks.</td></tr>
<tr><td>Ignition System Checks</td><td>Important!
LPG, being a gaseous fuel, requires higher secondary ignition system voltages, for the equivalent gasoline operating conditions. The ignition system must be maintained in peak condition, to prevent backfire.
• Check for the proper ignition coil output voltage, using the spark tester.
• Check the spark plug wires, by connecting an ohmmeter, to the ends of each wire in question. If the meter reads over 30,000 ohms, replace the wires.
• Check the connection, at each ignition coil.
• Check, for deteriorated spark plug wire insulation.
• Check the spark plugs.
• Remove the plugs, and inspect them, for the following conditions:
• Wet plugs
• Cracks
• Wear
• Improper gap
• Burned electrodes
• Heavy deposits</td></tr>
<tr><td>Engine Mechanical Check</td><td>Important!
The LPG, Fuel system, works on a fumigation principle, of fuel introduction, and is more sensitive to intake manifold leakage, than a gasoline fuel supply system.
• Check the engine for the following:
• Improper valve timing
• Engine compression
• Manifold vacuum leaks
• Intake manifold gaskets
• Sticking or leaking valves
• Exhaust system leakage
• Check the intake and exhaust system, for casting flash or other restrictions.</td></tr>
<tr><td>Fuel System Checks</td><td>• Perform a fuel system diagnosis. Refer to LPG Fuel System Diagnosis.</td></tr>
</table>

<table>
<tr><th colspan="2">Lack of Power, Sluggishness, or Sponginess</th></tr>
<tr><th>Checks</th><th>Action</th></tr>
<tr><td colspan="2">DEFINITION: The engine delivers less than expected power. There is little or no increase in speed, when partially applying the accelerator pedal.</td></tr>
<tr><td>Preliminary Checks</td><td>• Refer to Important Preliminary Checks.
• Refer to the LPG Fuel system, OBD System Check
• Compare the customer's vehicle, with a similar unit. Make sure the customer has an actual problem. Do not compare the power output, of the vehicle operating on LPG, to a vehicle operating on gasoline, as the fuels do have different drive feel characteristics
• Remove the air filter, and check for dirt or restriction.
• Check the vehicle transmission. Refer to the OEM transmission diagnostics
• Verify the fuel tank has fuel</td></tr>
<tr><td>Fuel System Checks</td><td>• Check for a restricted fuel filter, contaminated fuel, or improper fuel pressure. Refer to LPG Fuel System Diagnosis.
• Check for the proper ignition output voltage, with the spark tester
• Check for proper installation, of the mixer module assembly.
• Check all air inlet ducts, for condition and proper installation.
• Check for fuel leaks, between the DSR, and the mixer.
• Verify that the LPG tank manual shut-off valve is fully open.
• Verify that liquid fuel (not vapor) is being delivered to the DSR.</td></tr>
<tr><td>Sensor Checks</td><td>• Check the Heated Exhaust Gas Oxygen Sensor (HEGO), for contamination and performance.
• Check for proper operation of the MAP sensor.
• Check for proper operation of the TPS sensor.</td></tr>
<tr><td>Exhaust System Checks</td><td>• Check the exhaust system, for a possible restriction:
• Inspect the exhaust system, for damaged or collapsed pipes.
• Inspect the muffler, for signs of heat distress, or for possible internal failure.
• Check for possible plugged catalytic converter.</td></tr>
<tr><td>Engine Mechanical Check</td><td>Check the engine for the following:
• Engine compression
• Valve timing
• Improper or worn camshaft. Refer to Engine Mechanical, in the Service Manual.</td></tr>
</table>

Additional Checks	• Check the ECM grounds, for being clean, tight, and in their proper locations. • Check the generator output voltage.
	• Visually and physically, inspect all electrical connections, within the suspected circuit and/or systems. • Check the scan tool data.

Poor Fuel Economy	
Checks	**Action**
DEFINITION: Fuel economy, as measured by refueling records, is noticeably lower than expected. Also, the economy is noticeably lower, than it was on this vehicle at one time, as previously shown by refueling records.	

Preliminary Checks	• Refer to *Important Preliminary Checks*.
	• Check the air cleaner element (filter), for dirt or being plugged.
	• Visually (Physically) check the vacuum hoses, for splits, kinks, and proper connections.
	• Check the operators driving habits, for the following items:
	  • Is there excessive idling, or stop and go driving?
	  • Are the tires at the correct air pressure?
	  • Are excessively heavy loads being carried?
	  • Is their often rapid acceleration?
	• Suggest to the owner, to fill the fuel tank, and to recheck the fuel economy.
	• Suggest that a different operator, use the equipment and record the results.

Fuel System Checks	• Check the DSR fuel pressure. Refer to *LPG Fuel System Diagnosis*. • Check the fuel system for leakage.
Sensor Checks	• Check the Temperature Manifold Absolute Pressure (TMAP) sensor.
Ignition System Checks	• Verify that the spark plugs are correct, for use with LPG. Check the spark plugs. Remove the plugs, and inspect them, for the following conditions: Wet plugs Cracks Wear Improper gap Burned electrodes • Heavy deposits • Check the ignition wires for the following items: • Cracking • Hardness – Proper connections
Cooling System Checks	• Check the engine thermostat, for always being open, or for the wrong heat range

Engine Mechanical Check	Check the engine for the following: • Engine compression • Valve timing • Improper or worn camshaft. Refer to *Engine Mechanical,* in the Service Manual.
Additional Check	• Check the transmission shift pattern. Refer to the OEM Transmission Controls section of the Service Manual. • Check for dragging brakes.

Rough, Unstable, or Incorrect Idle, Stalling	
DEFINITION: The engine runs unevenly at idle. If severe enough, the engine or vehicle may shake. The engine idle speed may vary, in RPM. Either condition may be severe enough, to stall the engine.	
Preliminary Check	• Refer to *Important Preliminary Checks*.
Sensor Checks	• Check for silicon contamination, from fuel or improperly used sealant. The sensor will have a white powdery coating. The sensor will result in a high but false signal voltage (rich exhaust indication). The ECM will reduce the amount of fuel delivered to the engine, causing a severe driveability problem. • Check the Heated Exhaust Gas Oxygen Sensor (HEGO) performance: • Check the Temperature Manifold Absolute Pressure (TMAP) sensor, response and accuracy.
Fuel System Checks	• Check for rich or lean symptom, that causes the condition. Drive the vehicle, at the speed of the complaint. Monitoring the oxygen sensors, will help identify the problem. • Check for a sticking mixer air valve. • Perform a cylinder compression test. Refer to *Engine Mechanical* in the Service Manual. • Check the DSR fuel pressure. Refer to the *LPG Fuel System Diagnosis*. • Check mixer module assembly, for proper installation and connection.
Ignition System Checks	• Check for the proper ignition output voltage, using the spark tester. • Verify that the spark plugs are correct, for use with LPG. • Check the spark plugs. Remove the plugs and inspect them for the following conditions: • Wet plugs • Cracks • Wear • Improper gap • Burned electrodes • Blistered insulators • Heavy deposits • Check the spark plug wires, by connecting an ohmmeter to the ends of each wire in question. If the meter reads over 30,000 ohms, replace the wires.

Additional Checks	**Important:** The LPG Fuel system works on a fumigation principle, of fuel introduction, and is more sensitive to intake manifold leakage, than the gasoline fuel supply system. • Check for vacuum leaks. Vacuum leaks can cause a higher than normal idle, and low throttle angle control command. • Check the ECM grounds, for being clean, tight, and in their proper locations.
	• Check the battery cables, and ground straps. They should be clean and secure. Erratic voltage may cause all sensor readings to be skewed, resulting in poor idle quality.
Engine Mechanical Check	• Check the engine for the following: • Broken motor mounts • Improper valve timing • Low compression • Bent pushrods • Worn rocker arms • Broken or weak valve springs • Worn camshaft lobes

Surges/Chuggles	
Checks	**Action**
DEFINITION: The engine has a power variation, under a steady throttle or cruise. The vehicle feels as if it speeds up and slows down, with no change in the accelerator pedal.	
Preliminary Checks	• Refer to *Important Preliminary Checks*. • Be sure the driver understands the Torque Converter Clutch operation.
Sensor Checks	Check the Heated Exhaust Gas Oxygen Sensor (HEGO) performance.
Fuel System Checks	• Check for Rich or Lean symptom that causes the condition. Drive the vehicle at the speed of the complaint. Monitoring the oxygen sensors will help identify the problem. • Check the fuel pressure, while the condition exists. Refer to *LPG Fuel System Diagnosis.* • Verify proper fuel control solenoid operation. • Verify that the LPG manual shut-off valve is fully open. • Check the in-line fuel filter for restrictions.
Ignition System Checks	• Check for the proper ignition output voltage, using a spark tester. • Verify that the spark plugs are correct, for use with LPG • Check the spark plugs. Remove the plugs, and inspect them for the following conditions: Wet plugs Cracks Wear Improper gap Burned electrodes • Heavy deposits • Check the Crankshaft Position (CKP) sensor.
Additional Check	• Check the ECM grounds, for being clean, tight, and in their proper locations. • Check the generator output voltage. • Check the vacuum hoses, for kinks or leaks. • Check Transmission.

GASOLINE SYMPTOM CHARTS

Important Preliminary Checks	
Checks	**Action**
Before Using This Section	Before using this section you should have performed On Board Diagnostic Checks and determined that: • The Control Module and MIL (Malfunction Indicator Lamp) are operating correctly. • There are no Diagnostic Trouble Codes (DTCs) stored or a DTC exists but without a MIL. Several of the following symptom procedures call for a careful visual and physical check. The visual and physical checks are very important. The checks can lead to correcting a problem, without further checks, that may save valuable time. Most importantly talk to the operator about the failure this may provide important information about the fault.
Important Question to Ask the Operator	• When and how did the operator first notice the fault condition • What engine speed and load condition did the fault occur at • Did the fault occur just after or before refueling • Did the fault occur at start up or shut down • Did the fault occur at a particular time of day or during the shift • Did the fault occur in a particular location • Has there been any recent repair to the engine or vehicle • Has the fault ever occurred before • Has there been any new external customer installed devices added to the vehicle and or engine
Gasoline Fuel System Check	Verify the customer complaint. Locate the correct symptoms table. • Check the items indicated under that symptom. • Operate the vehicle under the conditions the symptom occurs. Verify HEGO switching between lean and rich. • **IMPORTANT!** • **Normal HEGO switching indicates the Gasoline fuel system is in closed loop and operating correctly at that time.** • If a scan tool is available **take a snapshot** under the condition that the symptom occurs. Go to *Engine Scan Tool Data.* List to verify normal sensor values and parameters.

Visual and Physical Checks	• Check all ECM system fuses and circuit breakers. • Check the ECM ground for being clean, tight and in its proper location. • Check the vacuum hoses for splits, kinks and proper connections. • Check thoroughly for any type of fuel leak or restriction.
	• Check for air leaks at all the mounting areas of the intake manifold sealing surfaces. • Check for proper installation of the Throttle Body assembly.
	• Check for fuel leaks at the fuel rail and injectors. • Check the ignition wires for the following conditions: – Cracking – Hardness – Proper routing – Carbon tracking • Check the wiring for the following items: – Proper connections, pinches or cuts. • The following symptoms table contains groups of possible causes for each symptom. The order of these procedures is not important. If the scan tool readings do not indicate the problems, then proceed in a logical order easiest to check or most likely to cause first.

Intermittent	
Checks	**Action**
DEFINITION: The problem may or may not turn ON the Malfunction Indicator Lamp (MIL), or store a Diagnostic Trouble Code (DTC).	
Preliminary Checks	• Refer to *Important Preliminary Checks.* • Do not use the DTC tables. If a fault is an intermittent, the use of the DTC tables may result in the replacement of good parts.
Faulty Electrical Connections or Wiring	• Faulty electrical connections or wiring can cause most intermittent problems. • Check the suspected circuit for the following conditions: • Check for faulty fuses or circuit breakers • Check for poorly mated electrical connectors • Check for connector pin and terminals not fully seated • Check for terminal pin damaged or deformation • Check poor soldering in the joints and connectors • Check for excessive wire strain on the harness • Check for burned or damaged wiring • Check for recently added customer installed electrical options which may be improperly spliced into the harness assembly • Carefully remove all the connector terminals in the problem circuit in order to ensure the proper contact tension. If necessary, replace all the connector terminals in the problem circuit in order to ensure the proper contact tension. • Checking for poor terminal to wire connections requires removing the terminal from the connector body.
Operational Test	If a visual and physical check does not locate the cause of the problem, drive the vehicle with a scan tool. When the problem occurs, an abnormal voltage or scan reading indicates the problem may be in that circuit.
Intermittent Malfunction Indicator Lamp (MIL)	The following components can cause intermittent MIL and no DTC(s): • A defective relay Control Module driven solenoid, or a switch that can cause electrical system interference. Normally, the problem will occur when the faulty component is operating. • The improper installation of electrical devices, such as lights, 2-way radios, electric motors, etc. • The ignition secondary voltage, shorted to a ground. • The Malfunction Indicator Lamp (MIL) circuit or the Diagnostic Test Terminal intermittently shorted to ground. • The Control Module grounds.

Loss of DTC Memory	To check for the loss of the DTC Memory: 1. Disconnect the TMAP sensor.
	2. Idle the engine until the Malfunction Indicator Lamp illuminates. The ECM should store a TMAP DTC. The TMAP DTC should remain in the memory, when the ignition is turned OFF. If the TMAP DTC does not store and remain, the ECM is faulty.

No Start	
Checks	**Action**
DEFINITION: The engine cranks OK but does not start.	
Preliminary Checks	• Refer to *Important Preliminary Checks*.
Control Module Checks	· Check the battery cranking voltage, voltage should not be less then 9.0 VDC • Check the inline fuse in the ECM battery power circuit. Refer to *Engine Controls Schematics.* • Check battery power, ignition power and ground circuits to the ECM. Refer to *Engine Control Schematics.* Verify voltage and/or continuity for each circuit.
Sensor Checks	• Check the TMAP sensor. • Check the Camshaft position (CMP) and Crankshaft (CKP) position sensors. • Check the Gasoline pressure sensor. .
Fuel System Checks	• Check for fuel pump electrical circuit. • Verify proper fuel pump pressure. • Verify proper Fuel rail pressure. • Refer to the *Gasoline Fuel System Diagnosis*. • Check Electrical connections at the injectors.
Ignition System Checks	• Check for the proper ignition voltage output. • Verify that the spark plugs are correct. • Check the spark plugs for the following conditions: – Wet plugs – Cracks – Wear – Improper gap – Burned electrodes – Heavy deposits • Check for bare or shorted ignition wires. • Check for loose ignition coil connections at the coil.

Engine Mechanical Checks	• Check for the following: – Vacuum leaks – Improper valve timing – Low compression – Bent pushrods – Worn rocker arms – Broken or weak valve springs – Worn camshaft lobes.
Exhaust System Checks	• Check the exhaust system for a possible restriction: – Inspect the exhaust system for damaged or collapsed pipes. – Inspect the muffler for signs of heat distress, or for possible internal failure. • Check for possible plugged catalytic converter. Refer to *Restricted Exhaust System Diagnosis.*

<table>
<tr><th colspan="2">Hard Start</th></tr>
<tr><th>Checks</th><th>Action</th></tr>
<tr><td colspan="2">DEFINITION: The engine cranks OK, but does not start for a long time. The engine does eventually run, or may start but immediately dies.</td></tr>
<tr><td>Preliminary Checks</td><td>• Refer to Important Preliminary Checks.
• Make sure the vehicle's operator is using the correct starting procedure.</td></tr>
<tr><td>Sensor Checks</td><td rowspan="2">• Check the Throttle position (TPS) sensor
• Check the Camshaft position (CMP) and Crankshaft (CKP) position sensors.
• Check for fuel pump electrical circuit.
• Verify proper fuel pump pressure.
• Verify proper fuel rail pressure.
• Refer to the Gasoline Fuel System Diagnosis.
Check Electrical connections at the injectors.</td></tr>
<tr><td>Fuel System Checks</td></tr>
<tr><td>Ignition System Checks</td><td>• Check for the proper ignition voltage output.
• Verify that the spark plugs are correct.
• Check the spark plugs for the following conditions:
– Wet plugs
– Cracks
– Wear
– Improper gap
– Burned electrodes
– Heavy deposits
• Check for bare or shorted ignition wires.
• Check for moisture in the distributor cap if applicable.
• Check for loose ignition, coil connections.
Important:
1. If the engine starts but then immediately stalls. Check the Crankshaft Position (CKP) sensor.
2. Check for improper gap, debris or faulty connections.</td></tr>
</table>

Engine Mechanical Checks	• Check for the following: – Vacuum leaks – Improper valve timing – Low compression – Bent pushrods – Worn rocker arms – Broken or weak valve springs
	• Check the intake and exhaust manifolds, for casting flash.
Exhaust System Checks	• Check the exhaust system for a possible restriction: – Inspect the exhaust system for damaged or collapsed pipes. – Inspect the muffler for signs of heat distress, or for possible internal failure. • Check for possible plugged catalytic converter. Refer to *Restricted Exhaust System Diagnosis*

Cuts Out, Misses	
Checks	**Action**
DEFINITION: A surging or jerking that follows engine speed, usually more pronounced as the engine load increases, which is not normally felt above 1500 RPM. The exhaust has a steady spitting sound at idle, low speed, or hard acceleration for the fuel starvation that can cause the engine to cut-out.	
Preliminary Checks	• Refer to *Important Preliminary Checks*.

Ignition System Checks	• Start the engine.
	• Wet down the secondary ignition system with water from a spray bottle and look/listen for arcing or misfiring as you apply water.
	• Check for proper ignition output voltage with spark tester.
	• Check for a cylinder misfire.
	• Verify that the spark plugs are correct.
	• Remove the spark plugs in these cylinders and check for the following conditions:
	  • Insulation cracks
	  • Wear
	  • Improper gap
	  • Burned electrodes
	  • Heavy deposits
	  • Visually/Physically inspect the secondary ignition for the following:
	  • Ignition wires for arcing, cross-firing and proper routing.
	  • Ignition coil for cracks or carbon tracking.

Engine Mechanical Checks	• Perform a cylinder compression check.
	• Check the engine for the following:
	  – Improper valve timing
	  – Bent pushrods
	  – Worn rocker arms
	  – Worn camshaft lobes.
	  – Broken or weak valve springs.
	• Check the intake and exhaust manifold passages, for casting flash.

Fuel System Checks	• Check the fuel system - plugged fuel filter, low fuel pressure, etc. Refer to *Gasoline Fuel System Diagnosis*. • Check the condition of the wiring to the fuel pump and injectors.

Additional Check	Check for Electromagnetic Interference (EMI). • EMI on the reference circuit can cause a missing condition. • Monitoring the engine RPM with a scan tool, can detect an EMI. • A sudden increase in the RPM with little change in the actual engine RPM, indicates EMI is present. • If the problem exists, check the routing of the secondary wires and the ground circuit.

Hesitation, Sag, Stumble	
Checks	**Action**
DEFINITION: The vehicle has a momentary lack of response, when depressing the accelerator. The condition can occur at any vehicle speed. The condition may cause the engine to stall, if it's severe enough.	
Preliminary Checks	Refer to *Important Preliminary Checks*.
Fuel System Checks	• Check the fuel pump electrical circuit. • Verify proper fuel pump pressure. • Verify proper fuel rail pressure. • Refer to the *Gasoline Fuel System Diagnosis*. • Check Electrical connections at the injectors.
Ignition System Checks	• Check for the proper ignition voltage output. • Verify that the spark plugs are correct. • Check for faulty spark plug wires. • Check for fouled spark plugs. •
Additional Check	• Check for manifold vacuum or air induction system leaks. • Check the generator output voltage.

Backfire	
Checks	**Action**
DEFINITION: The fuel ignites in the intake manifold, or in the exhaust system, making a loud popping noise. A backfire which is heard in the intake manifold and air stream indicates that the fuel is being ignited in the intake manifold and is a result of a spark igniting the fuel air mixture. A backfire heard in the exhaust system indicates that there is an over fueling condition or a late spark event which ignites unburned fuel in the exhaust.	
Preliminary Check	• Refer to *Important Preliminary Checks*.
Ignition System Checks	• Check for the proper ignition coil output voltage using a spark tester. • Check the spark plug wires by connecting an ohmmeter to the ends of each wire in question. If the meter reads over 30,000 ohms replace the wires. • Check the connection at each ignition coil. • Check for deteriorated, spark plug wire insulation. • Check the spark plugs. • Remove the plugs and inspect them for the following conditions: – Wet plugs – Cracks – Wear – Improper gap – Burned electrodes – Heavy deposits
Engine Mechanical Check	• Check the engine for the following: – Improper valve timing – Engine compression – Manifold vacuum leaks – Intake manifold gaskets – Sticking or leaking valves – Exhaust system leakage • Check the intake and exhaust system for casting flash or other restrictions.
Fuel System Checks	• Perform a fuel system diagnosis. Refer to Gasoline *Fuel System Diagnosis*.

Lack of Power, Sluggishness, or Sponginess	
Checks	**Action**
DEFINITION: The engine delivers less than expected power. There is little or no increase in speed when partially applying the accelerator pedal.	
Preliminary Checks	• Refer to *Important Preliminary Checks.* • Refer to the *Gasoline Fuel system OBD System Check* • Compare the customer's vehicle with a similar unit. Make sure the customer has an actual problem. • Remove the air filter and check for dirt or restriction. • Check the vehicle transmission. Refer to the OEM transmission diagnostics.
Fuel System Checks	• Check for a restricted fuel filter, contaminated fuel, or improper fuel pressure. Refer to *Gasoline Fuel System Diagnosis*. • Check for the proper ignition output voltage, with the spark tester. • Check the fuel pump electrical circuit. • Verify proper fuel pump pressure. • Verify proper fuel rail pressure. • Refer to the *Gasoline Fuel System Diagnosis*. Check electrical connections at the injectors.
Sensor Checks	• Check the Heated Exhaust Gas Oxygen Sensor (HEGO) for contamination and performance. Check for proper operation of the MAP sensor. • Check for proper operation of the TPS sensor.
Exhaust System Checks	• Check the exhaust system for a possible restriction: – Inspect the exhaust system for damaged or collapsed pipes. – Inspect the muffler for signs of heat distress or for possible internal failure. – Check for possible plugged catalytic converter.
Engine Mechanical Check	Check the engine for the following: • Engine compression • Valve timing • Improper or worn camshaft. Refer to *Engine Mechanical*
Additional Check	• Check the ECM grounds for being clean, tight, and in their proper locations. • Check the generator output voltage. • If all procedures have been completed, and no malfunction has been found, review and inspect the following items: • Visually and physically inspect all electrical connections within the suspected circuit and/or systems. • Check the brake system for sticking or dragging brakes

Poor Fuel Economy	
Checks	**Action**
DEFINITION: Fuel economy, as measured by refueling records is noticeably lower than expected. Also, the economy is noticeably lower, than it was on this vehicle at one time as previously shown by refueling records.	
Preliminary Checks	• Refer to *Important Preliminary Checks*. • Check the air cleaner element (filter) for dirt or being plugged. • Visually (Physically) check the vacuum hoses for splits, kinks and proper connections. • Check the operators driving habits for the following items: – Is there excessive idling or stop and go driving? – Are the tires at the correct air pressure? – Are excessively heavy loads being carried? – Is there often rapid acceleration? • Suggest to the owner to fill the fuel tank and to recheck the fuel economy. • Suggest that a different operator use the equipment and record the results.
Fuel System Checks	• Check the fuel Rail pressure. Refer to Gasoline *Fuel System Diagnosis*. • Check the fuel system for leakage.
Sensor Checks	• Check the Temperature Manifold Absolute Pressure (TMAP) sensor.
Ignition System Checks	• Verify that the spark plugs are correct. • Check the spark plugs. Remove the plugs and inspect them for the following conditions: – Wet plugs – Cracks – Wear – Improper gap – Burned electrodes – Heavy deposits • Check the ignition wires for the following items: – Cracking – Hardness – Proper connections
Cooling System Checks	• Check the engine thermostat for always being open or for the wrong heat range.

Engine Mechanical Check	Check the engine for the following: • Engine compression • Valve timing • Improper or worn camshaft. Refer to *Engine Mechanical,* in the Service Manual.
Additional Check	• Check the transmission shift pattern. Refer to the OEM Transmission Controls section in their Service Manual. • Check for dragging brakes.

Rough, Unstable or Incorrect Idle or Stalling	
Checks	**Action**
DEFINITION: The engine runs unevenly at idle. If severe enough, the engine or vehicle may shake. The engine idle speed may vary in RPMs. Either condition may be severe enough to stall the engine.	
Preliminary Check	• Refer to *Important Preliminary Checks*.
Sensor Checks	• Check for silicon contamination from fuel or improperly used sealant. The sensor will have a white powdery coating. The sensor will result in a high but false, signal voltage (rich exhaust indication). The ECM will reduce the amount of fuel delivered to the engine causing a severe drivability problem. • Check the Heated Exhaust Gas Oxygen Sensor (HEGO) performance: • Check the Temperature Manifold Absolute Pressure (TMAP) sensor response and accuracy.
Fuel System Checks	• Check for rich or lean symptoms that causes the condition. Drive the vehicle at the speed of the complaint. Monitoring the oxygen sensors will help identify the problem. • Verify proper operation of the injectors. • Perform a cylinder compression test. Refer to *Engine Mechanical* in the Service Manual. • Check the fuel Rail pressure. Refer to the Gasoline *Fuel System Diagnosis*. • Check injector electrical connections.
Ignition System Checks	• Check for the proper ignition output voltage using the spark tester. • Verify that the spark plugs are correct. • Check the spark plugs. Remove the plugs and inspect them for the following conditions: – Wet plugs – Cracks – Wear – Improper gap – Burned electrodes – Blistered insulators – Heavy deposits • Check the spark plug wires by connecting an ohmmeter to the ends of each wire in question. If the meter reads over 30,000 ohms, replace the wires.
Additional Checks	• Check the ECM grounds for being clean, tight and in their proper locations. • Check the battery cables and ground straps. They should be clean and secure. Erratic voltage may cause all sensor readings to be skewed, resulting in poor idle quality.

Engine Mechanical Check	• Check the engine for the following: – Broken motor mounts – Improper valve timing – Low compression – Bent pushrods – Worn rocker arms – Broken or weak valve springs – Worn camshaft lobes

Surges/Chuggles	
Checks	**Action**
DEFINITION: The engine has a power variation under a steady throttle or cruise. The vehicle feels as if it speeds up and slows down with no change in the accelerator pedal.	
Preliminary Checks	• Refer to *Important Preliminary Checks*. • Be sure the driver understands "the Torque Converter Clutch operation."
Sensor Checks	Check the Heated Exhaust Gas Oxygen Sensor (HEGO), performance.
Fuel System Checks	• Check for Rich or Lean symptom that causes the condition. Drive the vehicle at the speed of the complaint. Monitoring the oxygen sensors will help identify the problem. • Check the fuel rail pressure while the condition exists. Refer to *Gasoline Fuel System Diagnosis.* • Verify check injector electrical connections. • Check the in-line fuel filter for restrictions.
Ignition System Checks	• Check for the proper ignition output voltage using the spark tester. • Verify that the spark plugs are correct. • Check the spark plugs. Remove the plugs and inspect them for the following conditions: – Wet plugs – Cracks – Wear – Improper gap – Burned electrodes – Heavy deposits – Check the Crankshaft Position (CKP) sensor.
Additional Check	• Check the ECM grounds for being clean, tight and in their proper locations. • Check the generator output voltage. • Check the vacuum hoses for kinks or leaks. • Check Transmission

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FUEL SYSTEM REMOVE REPLACE AND REPAIR SECTION

REMOVE, REPLACE AND REPAIR

This section of the manual has been prepared, to provide the technician with the ability to remove and repair, and if allowed, to replace, specific components, of the EControls fuel system. Certain components of any EControls fuel system, may be supplied by the OEM engine manufacturer, and would therefore require the technician to use the OEM service repair manual in conjunction with the EControls service manual, to complete all the necessary repairs.

PROPANE FUEL SYSTEM PRESSURE RELIEF

CAUTION: The propane fuel system operates at pressures up to 21.5 BAR (312 psi). To minimize the risk of fire and personal injury, relieve the propane fuel system pressure (where applicable) before servicing the propane fuel system components.

To relieve propane fuel system pressure:

1. Close the manual shut-off valve (MSV) on the propane fuel tank.
2. Start and run the vehicle until the engine stalls. Repeat until the engine will not start.
3. Turn the ignition switch OFF.

If the engine is unable to start, to release the pressure in the LPG fuel system supply, use the following procedure.

1. Close the manual shut-off valve (MSV) on the propane fuel tank.
2. Using the appropriate wrench, slowly loosen the fitting at either the tank connection, or the inlet to the LPL, and release the pressure.

Important

- Residual vapor pressure will be present, in the fuel system. Ensure the work area is well ventilated, before disconnecting any fuel line.

PROPANE FUEL SYSTEM LEAK TEST

CAUTION: Never use an open flame of any type, to check for propane fuel system leaks.

Always inspect the propane fuel system for leaks after performing service. Check for leaks at the fittings of the service, or replaced component, and at all fuel line connections in the system. Use a commercially available liquid leak detector or an electronic leak detector. When using both methods, use the electronic leak detector first, to avoid contamination by the liquid, leak detector.

⚠ WARNING

ALWAYS WEAR PROTECTIVE EYEWEAR AND GLOVES WHEN PERFORMING MAINTENANCE ON THE LPG OR GASOLINE FUEL SYSTEMS. TO PREVENT SERIOUS INJURY, ALWAYS PERFORM MAINTENANCE PROCEDURES IN A WELL VENTILATED AREA AND INSURE THAT THERE ARE NO EXTERNAL SOURCES OF IGNITION.

⚠ WARNING

ALWAYS LEAK CHECK ANY FUEL SYSTEM CONNECTION AFTER SERVICING! USE AN ELECTRONIC LEAK DETECTOR, OR A LIQUID LEAK DETECTION SOLUTION, OR BOTH. FAILURE TO LEAK CHECK COULD RESULT IN SERIOUS BODILY INJURY AND OR DEATH, OR SERIOUS PROPERTY DAMAGE.

FUEL FILTER REPLACEMENT

In-Line Type Fuel Filter Replacement (FIGURE 1)

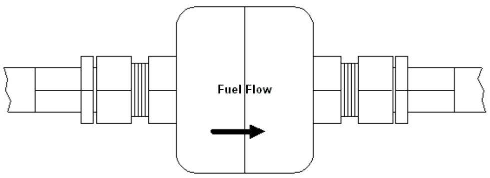

Figure 1 - *Typical In-line Filter*

Removal Procedure

1. Relieve the propane fuel system pressure. Refer to *Propane Fuel System Pressure Relief.*
2. Disconnect the negative battery cable.
3. Using the appropriate wrench size for the fitting connection, slowly loosen the fuel inlet fitting to the filter, and remove the line.
4. Using the appropriate wrench size for the fitting connection, remove the outlet fitting from the filter.
5. Remove the filter from the retaining bracket and discard.

Installation Procedure

Important:

- Be sure to install the filter in the correct direction of the flow marked with an arrow.
- **Do Not** use Teflon tape on the pipe fittings. **Use only a non fibrous paste or liquid pipe sealant.**

6. Install the filter to the retaining device and secure.
7. Install the outlet fuel line and tighten to specification.
8. Install the inlet fuel line and tighten to specification.
   Tighten
   Until fully seated
9. Reconnect the negative battery cable.
10. Open manual shut-off valve.
11. Start the vehicle and leak check the propane fuel system at each serviced fitting. Refer to *Propane Fuel System Leak Test*.

Integrated LPG Fuel Lock off with Filter Replacement (FIGURE 2)

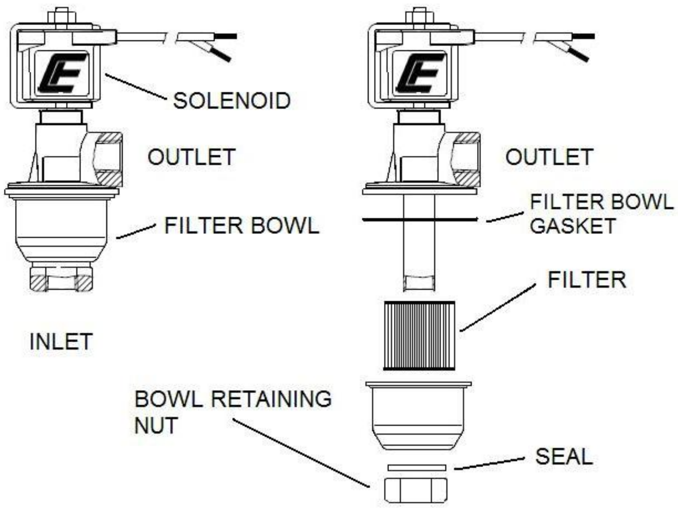

Figure 2 - *Integrated LPG Fuel Lock Off Filter replacement*

Removal Procedure

1. Relieve the propane fuel system pressure. Refer to *Propane Fuel System Pressure Relief.*
2. Disconnect the negative battery cable.

NOTE: If the lock off filter is mounted in such a manner to allow service on the equipment, skip to Item 3.

3. Disconnect the lock off electrical connector.
4. Using the appropriate wrench size for the inlet and outlet fuel supply hoses or pipes, remove the hose or fuel lines from both the inlet and outlet of the LPG Fuel Lock Off.
5. Using a 22 mm wrench, remove the filter bowl retaining nut and ring seal and retain.
6. Using caution, pull down on the filter housing to expose the filter and bowl sealing gasket.
7. Pull the filter off the bowl mounting stem and the bowl gasket, and discard both.

8. Clean the housing and lock off mounting base to remove any debris, which has accumulated on the filter housing.

Important:

- **Do not** use Teflon tape on the pipe fittings. Use only a non fibrous paste, or liquid pipe sealant.

9. Place the new bowl gasket, into the filter bowl.
10. Place the new filter element onto the bowl mounting stem and push UP, until it is fully sealed to the housing.
11. Place the bowl onto the mounting stem, and secure using the one (1) previously removed retaining nut.
12. Check to make sure the bowl sealing gasket is in the proper location.
13. Tighten the housing bolt until it is fully seated.
14. Reinstall the lock off.
15. Open the manual tank valve.
16. Turn the key to the “ON” position. Start the vehicle and leak check the propane fuel system, at each serviced fitting. Refer to *Propane Fuel System Leak Test*.

LPG FUEL LOCK OFF REPLACEMENT AND REPAIR

LPG Fuel Lock Off Replacement (FIGURE 3)

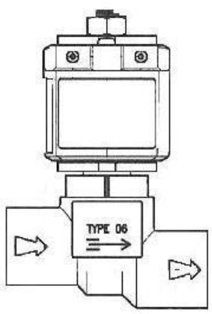

Figure 3 - *Inline 12v Lock Off*

Removal Procedure

1. Relieve the propane fuel system pressure. Refer to *Propane Fuel System Pressure Relief.*
2. Disconnect the negative battery cable.
3. Disconnect the Lock Off electrical connector.
4. Using the appropriate wrenches, disconnect the LPG fuel inlet line from the Lock Off inlet fitting.
5. Using the appropriate wrenches, unscrew the Lock Off from the DSR inlet fitting.

Installation Procedure

Important

- **Do not** use Teflon tape on the pipe fittings. Use only a non fibrous paste or liquid pipe sealant.
- .The EControls Lock Off has been stamped with an “Arrow” to indicate the flow of fuel. Be sure to mount the LPL in the proper direction.

1. Apply pipe thread sealant, to the DSR inlet fitting if direct mounted to the DSR.
2. Install the Lock Off to the DSR. Tighten until snug, plus 1 to 2 turns and place the Lock Off in the correct position.
3. Install the fuel inlet line.
4. Tighten the fuel line fitting to the Lock Off.
   Tighten
   27 Nm (20 ft lbs)
5. Connect the Lock Off electrical connector.
6. Connect the negative battery cable.
7. Open the tank manual shut off valve.
8. Start the vehicle and leak check the propane fuel system, at each serviced fitting.

LPG Fuel Lock Off Solenoid replacement (FIGURE 4)

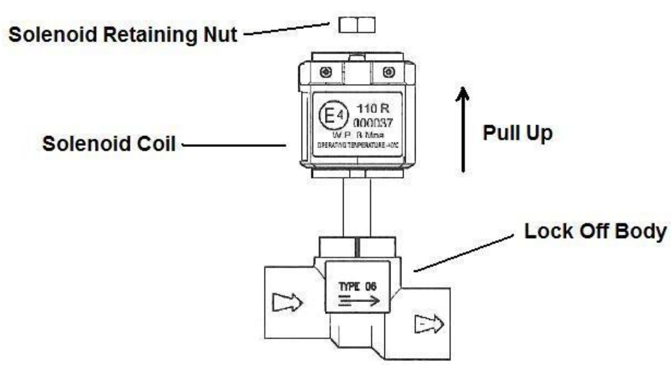

Figure 4 - *Inline 12v Lock Off*

1. Disconnect the Lock Off electrical connector.
2. Using a 10 mm wrench, remove the solenoid retaining nut.
3. Remove the solenoid from the valve stem and discard.

Installation Procedure

1. Install the new solenoid onto the valve mounting stem.
2. Secure the solenoid with the previously removed nut, and tighten to specification.
   Tighten
   9 N•m (80 lb-in)
3. Connect the Lock Off electrical connector.

DUAL STAGE REGULATOR (DSR) (FIGURE 5)

Figure 5 - *DSR Closed Loop*

Dual Stage Pressure Regulator (DSR) Open and Closed Loop Replacement

Removal Procedure

1. Relieve the propane fuel system pressure. Refer to *Propane Fuel System Pressure Relief.*
2. Disconnect the negative battery cable.
3. Block the coolant supply to the regulator by using a hose locking clamp pliers, or drain the radiator.
4. Remove the Lock Off. Refer to *LPG Fuel Lock Off Replacement*
5. Disconnect the supply, and return coolant lines from the DSR.
6. Loosen the hose clamps on the water/coolant inlet and outlet hoses.
7. Remove the water/coolant inlet and outlet hoses, and retain the clamps.
8. Remove the two (2) DSR mounting bolts, and retain
9. Loosen the fuel vapor hose clamp, at the DSR fuel outlet fitting.
10. Disconnect the fuel vapor hose, from the DSR outlet fitting, and remove the DSR.
11. Remove the DSR.

Installation Procedure

Important

- Do not use Teflon tape on any fuel fitting. Use a paste or liquid non-fibrous pipe thread sealant, when installing threaded fittings.
- Lubricate the o-rings on each of the fittings, with light weight oil.

1. Install the inlet water fitting and secure with retaining pin.
2. Install the outlet water fitting and secure with retaining pin.
3. Insert the vapor hose to the fuel outlet fitting. Place clamp and tighten until fully seated.
4. Secure the DSR to the mounting bracket, using the two (2) retaining bolts, and tighten to specification.
   Tighten
   14 Nm (10 ft lbs)
5. Install the water inlet and outlet lines to the fittings, place clamp and tighten until fully seated.
6. Install Lock Off. Refer to *LPG Fuel Lock-off Replacement.*
7. Tighten fuel line fitting.
   Tighten
   27 Nm (20 ft lbs)
8. Replace the drained coolant.
9. Start the vehicle and leak check the propane fuel system, at each serviced fitting.
10. With the engine running, check the coolant level after the engine is fully warmed and add coolant if necessary.

Refer to OEM section for instructions on how to purge and refill the coolant system.

Rebuild Procedure

1. Relieve the propane fuel system pressure. Refer to *Propane Fuel System Pressure Relief.*
2. Disconnect the negative battery cable.
3. Block the coolant supply to the regulator by using a hose locking clamp pliers, or drain the radiator.
4. Remove the Lock Off. Refer **to** *Light Duty LPG Fuel Lock Off Replacement.*
5. Remove the DSR. Refer to *Dual Stage Pressure Regulator Replacement*
6. Clean excess debris from the regulator, prior to disassembly.
7. Place the regulator on a clean flat surface, with the primary side facing down.
8. Remove the six (6) secondary cover screws, using a TS-20H Torx tool and discard.
9. The cover will likely pop up, due to the spring force of the secondary diaphragm spring.
10. Remove cover, and set aside for cleaning.
11. Remove the secondary spring, and set aside for cleaning.
12. Remove the secondary diaphragm, and discard.
13. Using a TS-20H Torx tool, partially remove the one short lever retaining screw enough to remove the lever, do not fully remove.
14. Remove the secondary lever and pull the secondary seat off the lever, and discard the seat.
15. Using a Torx tool remove the two screws in each of the coolant fitting housings, and discard.
16. Remove the coolant fitting housings using a small screwdriver. Only use the screw driver on the separation tabs on the castings, be careful not to scratch the sealing surfaces. Next, remove the rubber seals, and discard. Set the housings aside for cleaning.
17. Turn the regulator over, and place the regulator face down on the secondary side.
18. Using a TS-20H Torx tool, remove the eight (8) long screws from the primary cover, and discard.
19. Remove the primary cover using a small screwdriver. Only use the screw driver on the separation tabs on the castings, be careful not to scratch the sealing surfaces.
20. Remove the primary diaphragm from the cover, and discard. Set the cover aside for cleaning.
21. Remove the heat exchanger cover plate using a small screwdriver. Only use the screwdriver on the separation tabs on the castings, be careful not to scratch the sealing surfaces.
22. Using a small screw driver, remove the e-clip from the primary pin by **USING CAUTION WHEN REMOVING TO PREVENT THE CLIP FROM RAPIDLY SEPARATING.** Discard the clip.
23. Remove the primary pin from the plate, and discard the pin. Set aside the spring and plate for cleaning.
24. Remove the heat exchanger seal and discard. Set aside the plate for cleaning.

Important

- Do not use abrasive tools, metal brushes, grinding wheel, or abrasive or flammable cleaning material, on the parts to be cleaned. As personal injury, or damage to mating surfaces can occur.
- Clean parts in a solvent based material, either by bathing and soaking the parts, or aerosol spray cleaners, compatible with Aluminum parts.
- After cleaning, use air pressure, to remove the heavy residue from the parts, and allow drying prior to assembly.
- Do not use any lubricants, on the new seals and seats, during the assembly process.

Dual Stage Regulator (DSR) Closed Loop Repair
(FIGURE 6)

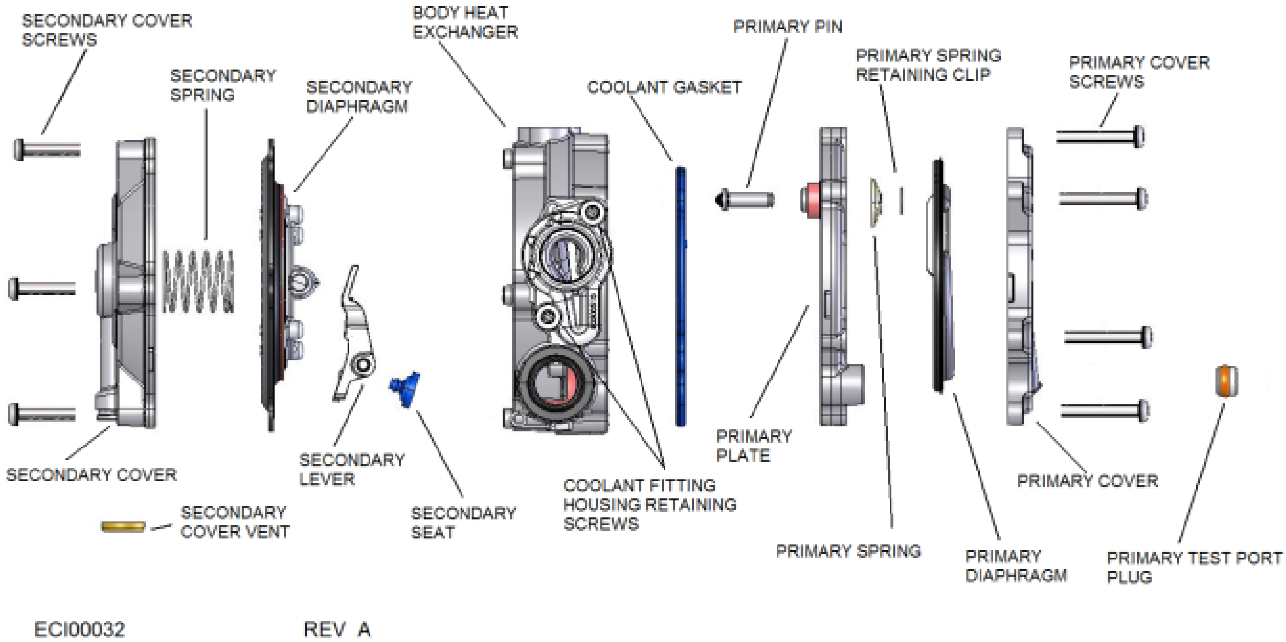

Figure 6 - *Exploded View DSR Closed Loop*

25. Place the cleaned DSR exchanger section on a clean dry surface, with the secondary chamber facing down.
26. Install the primary pin into the intermediate plate, and push until seated at the primary pin bore edge.
27. Turn the plate over and place on a clean surface. Protect the rubber tip of the primary pin. Place the primary spring over the pin.
28. Using a suitable tool, depress the spring down, and using your other hand and finger, insert the e-clip into the mating lock area of the primary pin, and push until fully seated and locked.
29. Install the heat exchanger blue seal onto the intermediate plate, and position the two (2) small nipples into the mating holes in the plate and pull on each nipple to fully seat the seal.
30. Check to make sure the primary test port hole is clean and visible, with the seal in place.
31. Align and place the plate onto the heat exchanger section, and position with the mounting holes, ensuring the seal is still fully seated.
32. Place the new primary diaphragm into the cover, so that the triangular metal plate with the folded lips is facing down.
33. Place the primary cover onto the intermediate plate. Position to align with the mounting holes.

    NOTE: ALL SCREWS USED IN THE DSR WERE INSTALLED NEW AS "SELF TAPPING SCREWS," USE CARE WHEN STARTING EACH SCREW INTO THE BODY. MAKE SURE THE THREADS ALIGN IN THEIR ORIGINAL FORMED THREAD. FAILURE TO HAND START THE SCREWS MAY RESULT IN STRIPPING THE ORIGINAL THREADS, AND RESULT IN A LEAK IN THE REGULATOR.

34. Pre-start the eight (8) screws by hand and using a "crossing" pattern tighten to specification.
    Tighten
    4.5-5.0 N•m (40-45 lb-in)
35. Place the regulator on a clean surface with the primary plate facing down.
36. Install and fully seat the new rubber seals into each of the inlet and outlet fitting housings.
37. Install each coolant housing using the two (2) previously removed screws. Hand start each screw, then tighten in a crossing pattern to specification.
    Tighten
    2.9 – 3.8 N•m (26-34 lb-in)
    NOTE: ALL SCREWS USED IN THE DSR WERE INSTALLED NEW AS "SELF TAPPING SCREWS," USE CARE WHEN STARTING EACH SCREW INTO THE BODY. MAKE SURE THE THREADS ALIGN IN THEIR ORIGINAL FORMED THREAD. FAILURE TO START THE SCREWS MAY RESULT IN STRIPPING THE ORIGINAL THREADS, AND RESULT IN A LEAK IN THE REGULATOR.
38. Ensure the screws are fully seated, and the covers are properly sealed to the housing.
39. Install the secondary seat into the secondary lever, by pressing the small nipple into the opening on the secondary lever, and then gently pulling the nipple until the seat is fully installed in the lever.
40. Place the lever pin into the lever.
41. Place the Lever and fulcrum pin into the secondary chamber.
42. Using the One (1) previously loosened (short screw) tighten to specification.
    Tighten
    2.9 – 3.8 N•m (26-34 lb-in)
43. Place the new secondary diaphragm onto the secondary lever and position the diaphragm holes with the body.
44. Place the secondary diaphragm spring, on to the top of the diaphragm, and then place the secondary onto the spring, and press down on the cover.
45. Hand start the six (6) medium length screws into the cover, using a "crossing" tightening pattern, and tighten to specification.
    Tighten
    4.5-5.0 N•m (40-45 lb-in)
46. Reinstall the regulator.

Dual Stage Regulator (DSR) Open Loop Repair
(FIGURE 7)

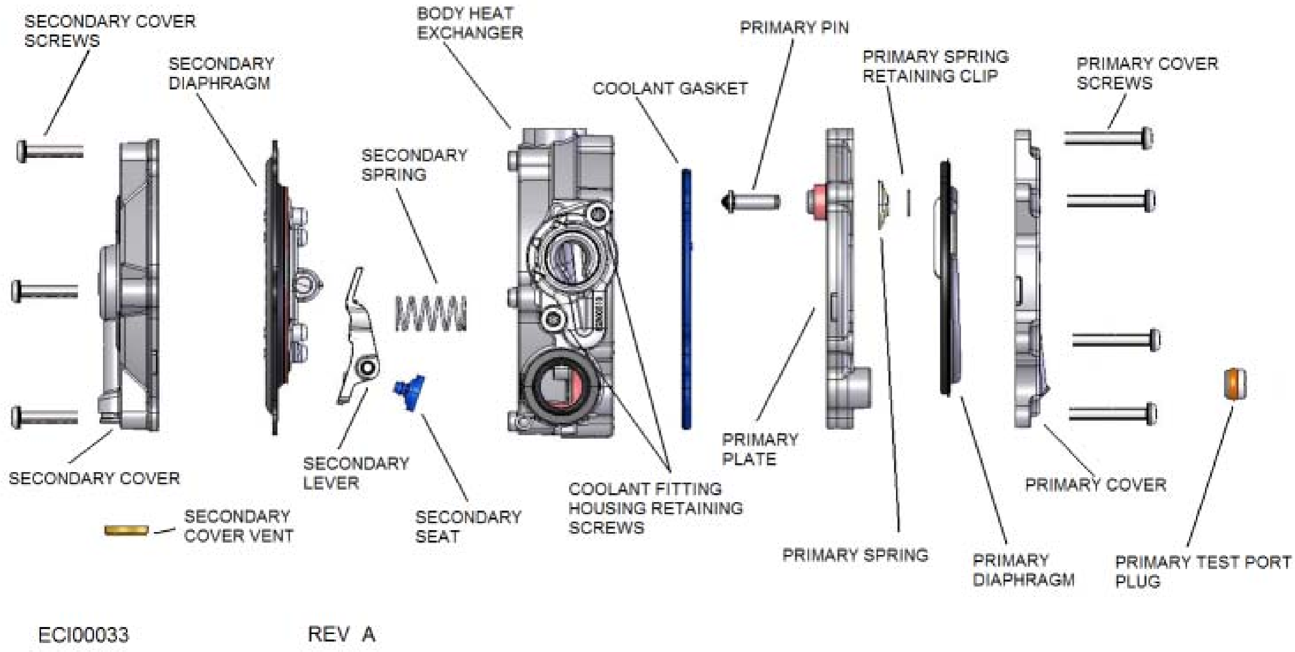

Figure 7 - *Exploded View DSR Open Loop*

Rebuild Procedure

1. Relieve the propane fuel system pressure. Refer to *Propane Fuel System Pressure Relief.*
2. Disconnect the negative battery cable.
3. Remove the six (6) secondary cover screws, using a TS-20H Torx tool and discard.
4. Remove cover, and set aside for cleaning.
5. Remove the secondary spring, and set aside for cleaning.
6. Remove the secondary diaphragm, and discard.
7. Using a TS-20H Torx tool, partially remove the one short lever retaining screw enough to remove the lever, do not fully remove.
8. Remove the secondary lever and pull the secondary seat off the lever, and discard the seat.
9. Using a Torx tool remove the two screws in each of the inlet and outlet water/coolant fitting housings, and discard.
10. Remove the water inlet and outlet housing using a small screwdriver. Only use the screw driver on the separation tabs on the castings, be careful not to scratch the sealing surfaces. Next, remove the rubber seals, and discard. Set the housings aside for cleaning.
11. Turn the regulator over, and place the regulator face down on the secondary side.
12. Using a TS-20H Torx tool, remove the eight (8) long screws from the primary cover, and discard.
13. Remove the primary cover using a small screwdriver. Only use the screw driver on the separation tabs on the castings, be careful not to scratch the sealing surfaces.

14. Remove the primary diaphragm from the cover, and discard. Set the cover aside for cleaning.
15. Remove the heat exchanger cover plate using a small screwdriver. Only use the screwdriver on the separation tabs on the castings, be careful not to scratch the sealing surfaces.
16. Using a small screw driver, remove the e-clip from the primary pin by **USING CAUTION WHEN REMOVING TO PREVENT THE CLIP FROM RAPIDLY SEPARATING.** Discard the clip.
17. Remove the primary pin from the plate, and discard the pin. Set aside the spring and plate for cleaning.
18. Remove the heat exchanger seal and discard. Set aside the plate for cleaning.

Important

- Do not use abrasive tools, metal brushes, grinding wheel, or abrasive or flammable cleaning material, on the parts to be cleaned. As damage to mating surfaces can occur, or personal injury.
- Clean parts in a solvent based material, either by bathing and soaking the parts, or aerosol spray cleaners, compatible with Aluminum parts.
- After cleaning, use air pressure, to remove the heavy residue from the parts, and allow drying prior to assembly.
- Do not use any lubricants, on the new seals and seats, during the assembly process.

Installation Procedure

26. Place the cleaned DSR exchanger section on a clean dry surface, with the secondary chamber facing down.
29. Install the primary pin into the intermediate plate, and push until seated at the primary pin bore edge.
30. Turn the plate over and place on a clean surface. Protect the rubber tip of the primary pin. Place the primary spring over the pin.
31. Using a suitable tool, depress the spring down, and using your other hand and finger, insert the e-clip into the mating lock area of the primary pin, and push until fully seated and locked.
19. Install the heat exchanger blue seal onto the intermediate plate, and position the two (2) small nipples into the mating holes in the plate and pull on each nipple to fully seat the seal.
20. Check to make sure the primary test port hole is clean and visible, with the seal in place.
21. Align and place the plate onto the heat exchanger section, and position with the mounting holes, ensuring the seal is still fully seated.
22. Place the new primary diaphragm into the cover, so that the triangular metal plate with the folded lips is facing down.
23. Place the primary cover onto the intermediate plates. Position to align with the mounting holes.
    NOTE: ALL SCREWS USED IN THE DSR WERE INSTALLED NEW AS "SELF TAPPING SCREWS," USE CARE WHEN STARTING EACH SCREW INTO THE BODY. MAKE SURE THE THREADS ALIGN IN THEIR ORIGINAL FORMED THREAD. FAILURE TO START THE SCREWS MAY RESULT IN STRIPPING THE ORIGINAL THREADS, AND RESULT IN A LEAK IN THE REGULATOR.
24. Pre-start the eight (8) screws by hand and using a "crossing" pattern tighten to specification.
    Tighten
    4.5-5.0 N•m (40-45 lb-in)
25. Place the regulator on a clean surface with the primary plate facing down.
26. Install and fully seat the new seals into each of the inlet and outlet coolant fitting housings.
27. Install each fitting using the two (2) previously removed screws. Hand start each screw, then tighten in a crossing pattern to specification.
    Tighten
    2.9 – 3.8 N•m (26-34 lb-in)

NOTE: ALL SCREWS USED IN THE DSR WERE INSTALLED NEW AS "SELF TAPPING SCREWS," USE CARE WHEN STARTING EACH SCREW INTO THE BODY. MAKE SURE THE THREADS ALIGN IN THEIR ORIGINAL FORMED THREAD.

FAILURE TO START THE SCREWS MAY RESULT IN STRIPPING THE ORIGINAL THREADS, AND RESULT IN A LEAK IN THE REGULATOR.

28. Ensure the screws are fully seated, and the covers are properly sealed to the housing.
29. Install the secondary seat into the secondary lever, by pressing the small nipple into the opening on the secondary lever, and then gently pulling the nipple until the seat is fully installed in the lever.
30. Place the lever pin into the lever.
31. Place the Lever and fulcrum pin into the secondary chamber.
32. Using the One (1) previously loosened (short screw) tighten to specification.
    Tighten
    2.9 – 3.8 N•m (26-34 lb-in)
33. Place the new secondary diaphragm onto the secondary lever and position the diaphragm holes with the body.
34. Place the secondary diaphragm spring, on to the top of the diaphragm, and then place the secondary onto the spring, and press down on the cover.
35. Hand start the six (6) medium length screws into the cover, using a “crossing” tightening pattern, and tighten to specification.
    Tighten
    4.5-5.0 N•m (40-45 lb-in)
36. Reinstall the regulator.

ELECTRONIC THROTTLE BODY (ETB) ASSEMBLY (FIGURE 8)

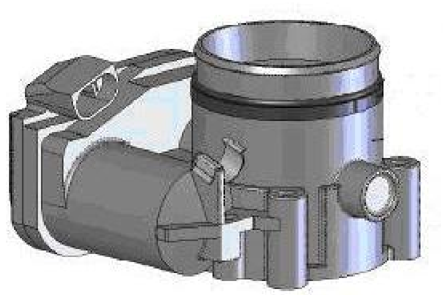

Figure 8 - *Electronic Throttle Body*

ELECTRONIC THROTTLE BODY (ETB) REPLACEMENT OPEN AND CLOSED LOOP (FIGURE 8)

Removal Procedure

1. Disconnect the negative battery cable.
2. Remove the air intake duct.
3. Disconnect the electronic throttle control device electrical connector.
4. Release mixer fuel inlet hose clamp, and remove hose from mixer inlet.
5. Remove the four (4), mixer to adapter retaining bolts and retain bolts.
6. Separate the mixer assembly from the adapter, and set mixer aside.
7. Remove the four (4), adapter to ETB retaining bolts, and retain the bolts.
8. Pull the adapter off the ETB, retain the adapter and discard the ETB.
9. Remove and retain the adapter, and discard o-ring, and the mixer assembly sealing o-ring.

Installation Procedure

Important

- Lightly lubricate both the o-rings, of the ETB adapter and mixer sealing ring.
- Cover intake manifold opening, to prevent debris from entering engine until reassembly.

10. Install adapter, to the top of the electronic throttle control assembly.
11. Install the o-ring to the manifold adapter.
12. Insert electronic throttle control assembly, into the bottom of the adapter.
13. Install the electronic throttle control to the manifold adapter and secure, using the four previously removed bolts.
14. Tighten the four screws to specification.
    Tighten
    12 N•m (106 lb-in)
15. Install the mixer to the adapter and secure using the four (4) previously removed bolts and tighten to specification.
    Tighten
    12 N•m (106 lb-in)
16. Connect the electronic throttle control electrical connector.
17. Connect the air inlet duct.

18. Start engine.
19. Install the diagnostic tool and check for DTC codes and no MIL light.

MIXER REPLACEMENT AND REPAIR (FIGURE 9)

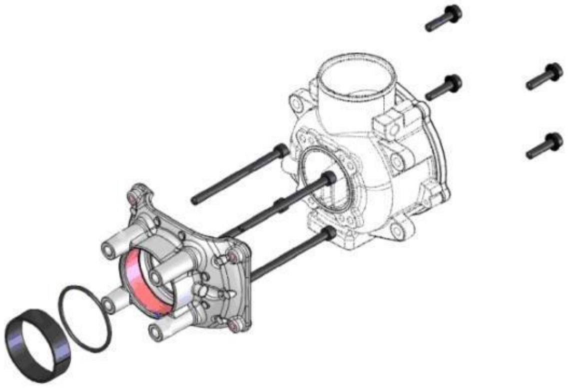

Figure 9 - *Light Duty Mixer and ETB Adapter*

Closed Loop Mixer Replacement E100 Series

Removal Procedure

1. Disconnect the negative battery cable.
2. Remove the air intake duct.
3. Disconnect the electronic throttle control device electrical connector.
4. Release mixer fuel inlet hose clamp, and remove hose from the DEPR inlet.
5. Remove the four (4) DEPR to mixer mounting bolts and retain.
6. Remove the DEPR and set aside.
7. Remove the four (4), mixer to adapter retaining bolts and retain bolts.
8. Separate the mixer assembly from the adapter, and set mixer aside.

Installation Procedure

Important

- Cover the DEPR, to protect from debris entering the DEPR.
- Lightly lubricate the o-rings, of the mixer sealing ring.
- Cover intake manifold opening, to prevent debris from entering engine until reassembly.

9. Install the mixer to the adapter and secure using the four (4) previously removed bolts. Tighten to specification.
   Tighten
   12 N•m (106 lb-in)
10. Insert the DEPR to mixer o-rings, into the DEPR, and place the EPR onto the mixer, and secure the mixer using the four (4), previously removed screw, and tighten until fully seated.
11. Connect the vapor fuel line to the DEPR inlet and secure using the previously removed hose clamp.
12. Connect the air inlet duct.
13. Start engine.
14. Leak check, the fuel system.
15. Install the diagnostic tool and check for DTC codes and no MIL light.

OPEN LOOP MIXER REPLACEMENT E100 SERIES (Figure 10)

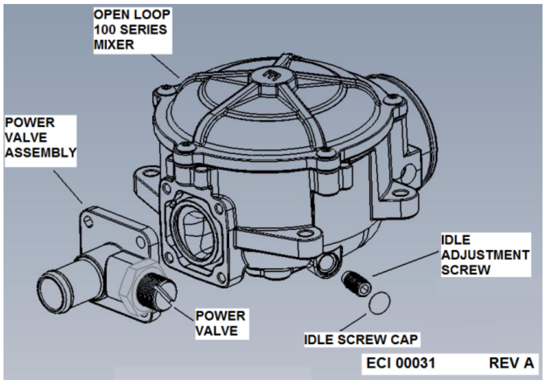

Figure 10 - *Light Duty Mixer Open Loop*

LIGHT DUTY OPEN LOOP MIXER REPLACEMENT 100 SERIES (Figure 10)

Removal Procedure

1. Disconnect the negative battery cable.
2. Remove the air intake duct.
3. Release mixer fuel inlet hose clamp, and remove hose from mixer inlet.
4. Remove the four (4), mixer to adapter retaining bolts, and retain bolts.
5. Separate the mixer assembly from the adapter, and set mixer aside.

Installation Procedure

Important

- Lightly lubricate the o-rings of the mixer sealing ring.
- Cover intake manifold opening, to prevent debris from entering engine until reassembly.

6. Install the mixer to the adapter and secure using the four (4), previously removed bolts, and tighten to specification.
   Tighten
   12 N•m (106 lb-in)
7. Connect the air inlet duct.
8. Connect the fuel inlet hose and secure with hose clamp,
9. Start engine,
10. Warm engine and adjust idle. (Refer to Open Loop Mixer Adjustment.)
11. Adjust Power valve. (Refer to Open Loop Mixer Adjustment.)
12. Check Idle.
13. Replace cap on Idle screw.

MIXER REPAIR CLOSED LOOP E100 SERIES (Figure 11 & 12)

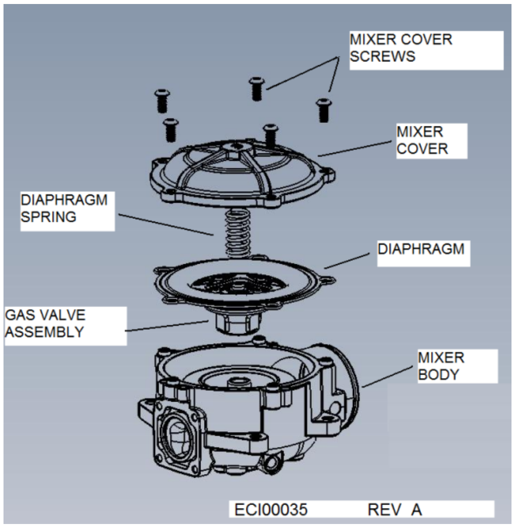

Figure 11 - *Closed Loop Mixer*

Removal Procedure

1. Using a torx tool, remove the five (5) mixer cover screws and retain.
2. Lift the mixer cover off the mixer, and retain.
3. Carefully remove the spring and retain.
4. Lift the air valve assembly out of the mixer body.
5. Place the air valve on a clean surface.

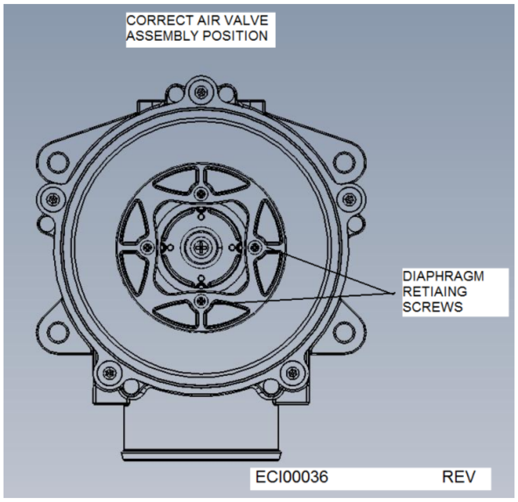

Figure 12 - *Closed Loop Mixer Air Valve Position*

6. Using a Torx tool, remove the four (4) diaphragm retaining screws, from the air valve.
7. Lift the diaphragm, from the air valve and discard.

Installation Procedure

Important

- Do not use abrasive tools, metal brushes, grinding wheel, or abrasive or flammable cleaning material on the parts to be cleaned, as damage to mating surfaces can occur, or personal injury.
- Clean parts in a solvent based material, either by bathing and soaking the parts, or aerosol spray cleaners, compatible with Aluminum parts.
- After cleaning, use air pressure to remove the heavy residue from the parts. Allow to dry, prior to assembly.

8. Place the new diaphragm, onto the air gas valve assembly. Align the holes in the diaphragm with the air valve.

9. Secure the diaphragm to the air valve, using the four (4), previously removed screws.
10. Tighten the screws to specification.
    Tighten
    0.6 N•m (5.4 lb-in)
11. Place the air valve assembly into the mixer body and align as shown, (Figure 12).
12. Place the previously removed air valve spring onto the top of the diaphragm.
13. Place the cover onto the spring and press down firmly.
14. Hand start the five (5), previously removed cover screws.
15. Tighten to specification.
    Tighten
    4.5-5.0 N•m (40-45 lb-in)
16. Reinstall the mixer and secure.
17 Install the EControls GCP laptop tool and start and run engine, to verify closed loop operation.

MIXER REPAIR OPEN LOOP E100 SERIES (Figure 13 &14)

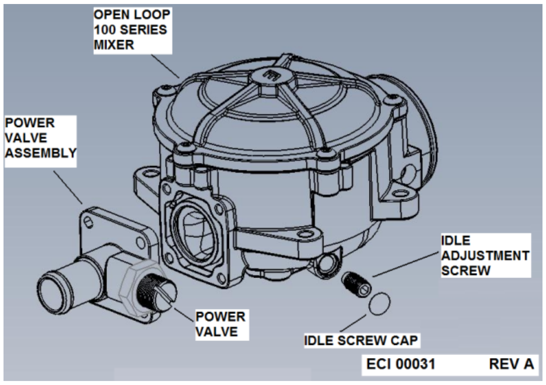

Figure 13 - *Light Duty Open Loop Mixer*

Removal Procedure

1. Using a Torx tool, remove the five (5) mixer cover screws and retain.
2. Lift the mixer cover off the mixer and retain.
3. Carefully remove the spring and retain.
4. Lift the air valve assembly, out of the mixer body.
5. Place the air valve on a clean surface.

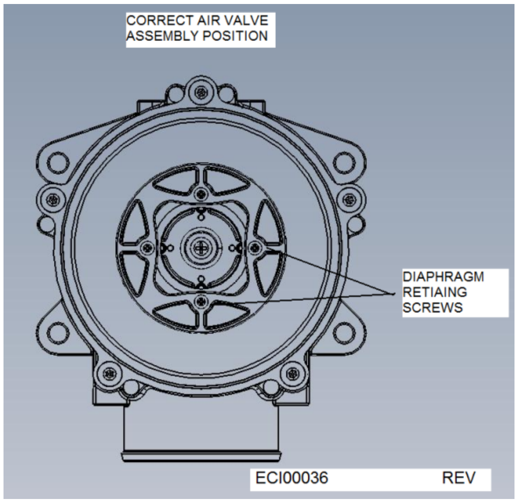

Figure 14 - *Open Loop Mixer Air Valve Position*

6. Using a Torx tool, remove the four (4) diaphragm retaining screws, from the air valve.
7. Lift the diaphragm from the air valve and discard.

Installation Procedure

Important

- Do not use abrasive tools, metal brushes, grinding wheel, or abrasive or flammable cleaning material on the parts to be cleaned, as damage to mating surfaces can occur, or personal injury.
- Clean parts in a solvent based material, either by bathing and soaking the parts, or aerosol spray cleaners, compatible with Aluminum parts.
- After cleaning, use air pressure to remove the heavy residue from the parts. Allow to dry prior to assembly.

8. Place the new diaphragm, onto the air gas valve assembly. Align the holes in the diaphragm, with the air valve, as shown in *Figure 14*.
9. Secure the diaphragm to the air valve, using the four (4), previously removed screws.
10. Tighten the screws to specification.
    Tighten
    0.6 N•m (5.4 lb-in)

11. Place the air valve assembly into the mixer body, and align as shown (Figure 12).
12. Place the previously removed air valve spring, onto the top of the diaphragm.
13. Place the cover onto the spring, and press down firmly.
14. Hand start the five (5), previously removed, cover screws.
15. Tighten to specification.

    Tighten

    4.5-5.0 N•m (40-45 lb-in)
16. Start engine and warm to operating temperature.
17. Adjust the mixer. Refer to *Light Duty Open Loop Mixer Adjustment 100 series.*

OPEN LOOP MIXER ADJUSTMENT E100 SERIES (FIGURE 15)

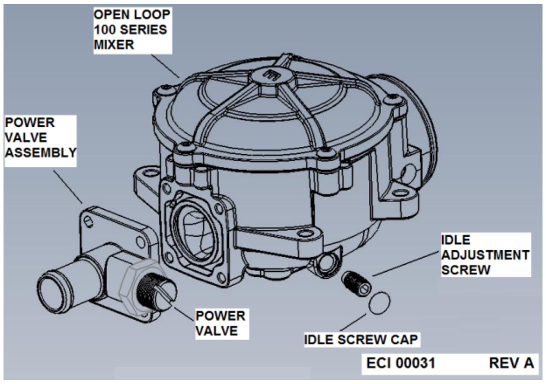

Figure 15 - *Open Loop Mixer*

NOTE: Before adjusting the mixer, make sure there is fuel in the LPG tank, and that the engine is fully warmed up, and at operating temperature.

Procedure when adjusting using a gas analyzer

1. With the engine at idle, remove the idle screw cap.
2. Using an Allen wrench, turn the idle screw "IN" until the engine begins to stumble.
3. Back the screw "OUT" slowly, until the desired reading is achieved on the gas analyzer.
4. Loosen the jam nut on the power valve, to allow for adjustment.
5. Accelerate the engine to full throttle and the highest possible load can be achieved.
6. With the engine at load, turn the power valve "IN" until the RPMs begin to decrease.
7. Slowly turn the power valve out until the desired reading is achieved on the gas analyzer.
8. Allow the engine to return to idle. Check for desired reading on the analyzer. If required, readjust the idle screw.
9. Accelerate the engine several times, to check for acceleration stumbles. A slight leaner or richer adjustment on the power valve and idle, may be required to allow for smooth transitions from idle to full throttle.

Procedure when adjusting without a gas analyzer

NOTE: When you do not have an analyzer available, you will need to use the engine tachometer or/and external tachometer to adjust the engine power.

1. With the engine at idle, remove the idle screw cap.
2. Using an Allen wrench, turn the idle screw "IN" until the engine begins to stumble.
3. Back the screw "OUT" slowly, until the highest possible RPM is achieved.
4. Loosen the jam nut on the power valve to allow for adjustment.
5. Accelerate the engine to full throttle and the highest possible load can be achieved.
6. With the engine at load, turn the power valve "IN" until the RPM begins to decrease.
7. Slowly turn the power valve out until the desired highest possible RPM is achieved.
8. Allow the engine to return to idle. Check the idle stability. If required, readjust the idle screw.
9. Accelerate the engine several times to check for acceleration stumbles. A slight leaner or richer adjustment on the power valve and idle may be required to allow for smooth transitions from idle to full throttle.

DIRECT ELECTRONIC PRESSURE REGULATOR (DEPR) REPLACEMENT

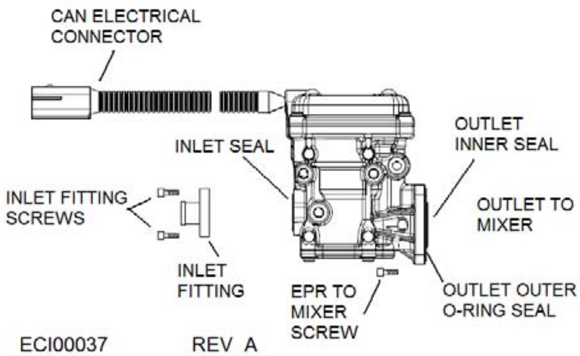

Figure 19 - *DEPR*

Removal Procedure

1. Disconnect the DEPR wire harness connection (CAN).
2. Release the vapor hose clamp to the DEPR inlet fitting and remove the vapor hose, retaining the clamp.
3. Using an Allen wrench, remove the four (4) screws, retaining the inlet fitting to the DEPR and retain.
4. Remove the inlet fitting, and set aside.
5. Using an Allen wrench, remove the four (4), DEPR to mixer retaining screws and retain.
6. Remove the DEPR.

Important

- Do not use abrasive tools, metal brushes, grinding wheel, or abrasive or flammable cleaning material, on the parts to be cleaned, as damage to mating surfaces can occur or personal injury.
- Clean the DEPR inlet fitting and the mixer inlet mounting area, of all debris.

7. Insert the inner and outer outlet seals, into the respective ring slots on the DEPR.
8. Secure the DEPR to the mixer, using the four previously removed screws and tighten until fully seated.
9. Insert the inlet seal into the ring slot on the inlet of the DEPR.
10. Position the inlet fitting onto the DEPR and secure, using the four (4) previously removed screws and tighten until fully seated.
11. Install the vapor hose to the inlet fitting and secure, using the one (1) previously remove clamp.
12. Connect the EControls GCP display tool.
13. Start and warm the engine and check to insure the fuel system is in closed loop.

COOLANT HOSE REPLACEMENT

Removal Procedure

1. Drain coolant.
2. Using a hose clamp pliers, disconnect both hose clamps on each hose.
3. Remove the coolant inlet hose from each fitting.
4. Remove the coolant outlet hose.

Installation Procedure

- Coolant hoses are specifically designed. **DO NOT** use hose material or length, other than the OEM specified parts.
- DO NOT mix the inlet or outlet hoses, when reinstalling.

5. Install hose clamps, and set back on each hose.
6. Reinstall **the coolant inlet hose, to each fitting.**
7. Reinstall **the coolant outlet hose, to each fitting.**
8. Reset clamps.
9. Refill with coolant.
10. Start engine and check for coolant leaks.

VAPOR HOSE REPLACEMENT

Removal Procedure

1. Using a hose clamp pliers, disconnect both hose clamps.
2. Remove the vapor hose from each fitting.

Installation Procedure

Vapor supply hose is specifically designed. **DO NOT** use hose material, or length, other than the OEM specified parts.

3. Install hose clamps, and set back on each hose.

4. Reinstall **the vapor hose to each fitting.**
5. Reset clamps.
6. Start engine and check for leaks.

ENGINE CONTROL MODULE (ECM) REPLACEMENT (FIGURE 20)

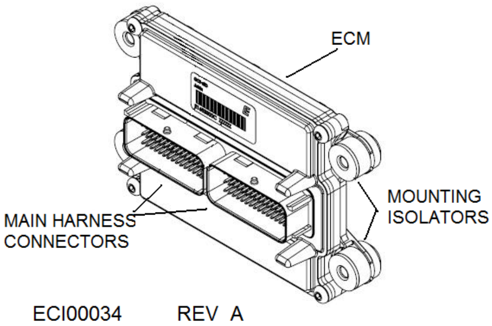

Figure 20 - *ECM*

Removal Procedure

1. Disconnect Negative battery cable.
2. Remove controller from mounting bracket.
3. Push connector lock back to unlock connector.
4. Unplug ECM and remove.

Installation Procedure

- The ECM is calibrated for each engine. Verify you have the correct ECM part number.
- **NOTE**: Wire harness connector and ECM male connectors are "keyed," to prevent incorrect installation of the connector to the ECM.

5. Plug connector into controller.
6. Push lock into place.
7. Mount controller into mounting bracket.
8. Reconnect the battery cable.
9. Install Diagnostic service tool.
10. Start engine.
11. Check for any DTC codes and clear.
12. Verify engine is in closed loop and no MIL lights are present.

HEATED EXHAUST GAS OXYGEN SENSOR REPLACEMENT

Removal Procedure

1. Disconnect Negative battery cable.
2. Disconnect the O-2 sensor electrical connector.
3. Using an O-2 Sensor socket, remove the O-2 Sensor and discard.

Installation Procedure

Important
- Before installing the O-2 sensor, lubricate threads with anti-seize compound, GM P/N 5613695 or equivalent. Avoid getting compound on the sensor tip.

4. Install O-2 sensor.
   Tighten
   41 N•m (30 lb-ft)
5. Start engine.
6. Check for any DTC codes and clear.
7. Verify engine is in closed loop and no MIL lights are present.

THREE WAY CATALYTIC CONVERTER MUFFLER REPLACEMENTS

Removal Procedure

1. Remove the TWC muffler, using the OEM vehicle manufactures process.

Installation Procedure

Important
- The Three Way Catalytic converter is specifically designed to meet the emissions control, of the certified engine. Use only the OEM specified parts.

2. Install **the TWC muffler using the OEM** vehicle manufactures process.
3. Start engine.
4. Check for any DTC codes, and clear.
5. Verify engine is in closed loop and no MIL lights are present.

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FUEL SYSTEM DIAGNOSTIC SECTION

LPG Fuel System Diagnosis (Open & Closed Loop Systems)

Figure 1

DUAL STAGE REGULATOR (DSR)

This section of the manual has been prepared to allow the technician to check the mechanical functions, of the regulator and fuel delivery devices, of the EControls "closed loop" fuel control delivery system. The design of the EControls closed loop system is such that, Diagnostic Trouble Codes (DTC) are employed to monitor the fuel delivery system. To properly diagnose fuel delivery system faults, you should first install the EControls GCP diagnostic laptop tool to check for any DTC present in the ECM first, and refer to the proper DTC chart, prior to utilizing this diagnostic section.

The DSR is a combination vaporizer, pressure regulating device. The DSR is a two stage regulator that is a positive pressure regulator that is normally open in the secondary chamber, when the engine is not running. When the engine is cranking or running, pressure from the secondary chamber passes from the regulator to Direct Electronic Pressure Regulators (DEPR), and mixer. .

Propane fuel enters the primary port of the DSR, and passes through the primary jet, and into the primary/exchanger chamber. As the propane passes through the heat exchanger, the fuel expands and creates pressure inside the chamber. The pressure rises as the fuel expands. When the pressure rises above 10.34 kpa (1.5 psi), sufficient pressure is exerted on the primary diaphragm, to cause the diaphragm plate, to pivot and press against the primary valve pin, thus closing off the flow of fuel. This action causes the flow of fuel into the regulator, to be regulated. The secondary diaphragm is spring loaded on top of the secondary diaphragm, causing the secondary lever to be pressed down, which opens the secondary seat. When the pressure in the primary chamber enters the secondary chamber, the diaphragm is forced in an upward motion, thus closing the secondary lever against the valve seat. When commanded by the ECM, the DEPR will open, which causes a pressure drop in the secondary seat, and allows the secondary seat to open, and allow fuel to flow to the DEPR. The DEPR regulates the fuel delivery to the mixer, based on the calibration required, for the specific engine load and speed, determined during engine fuel system development.

The DSR requires a connection to the engine coolant, to prevent freezing in the regulator, during the pressure reduction phase, within the regulator. Coolant connections on the DSR are fitted with "Push In" fittings. These fitting are designed with an o-ring seal, which allows the fitting to be pushed into the water connection on the DSR, and are then locked by spring locks, and retained by screws.

The DSR is connected to the DEPR, by a low pressure flexible hose. Like the other fuel hoses used in the fuel system, the low pressure hose is designed with a special inner core and may also be wire reinforced, to prevent collapse of the hose, during high demand fueling operations. The low pressure hose should only be replaced with the recommended OEM hose replacement.

The packaging of the regulator, into the engine and chassis, has been approved by EControls, to insure continued long term operation, of the fuel delivery and emissions control system.

NOTE: You should never relocate the regulator or any of the fuel system components, as doing so may cause excess build up of oil in the regulator, improper coolant flow, or improper fuel delivery.

In certain regions, fuel supplies may contain different chemicals and may employ different manufacturing processes to make the LPG, which during the heating of the fuel in the heat exchange section of the regulator, may cause "heavy ends," to accumulate over time. The DSR is equipped with a drain plug, to allow the technician to drain excess oil and other contaminants from the regulator. To determine the frequency for draining the regulators, refer to the *Recommended Maintenance Schedule*.

The regulator utilized on USA emissions certified engines, are a critical part of the certified emissions system, and do not require any periodic adjustment.

Tools Required:

- 7/16 Open end wrench (for test port plugs)
- Straight Blade screw driver
- DVOM

Diagnostic Scan Tool

- GCP Display Software (laptop)

Pressure Gauges

- 0-10 PSI Gauge

Test Description

The numbers below refer to step numbers, on the diagnostic table which identify faulty components.

4. This step will determine if the DSR primary fuel pressure regulation is correct.
6. This step determines if the LPG Fuel Lock Off is functioning properly
8. This step checks for Plugged filters if equipped
9. This step determines if fuel is available, from the fuel tank & supply system.

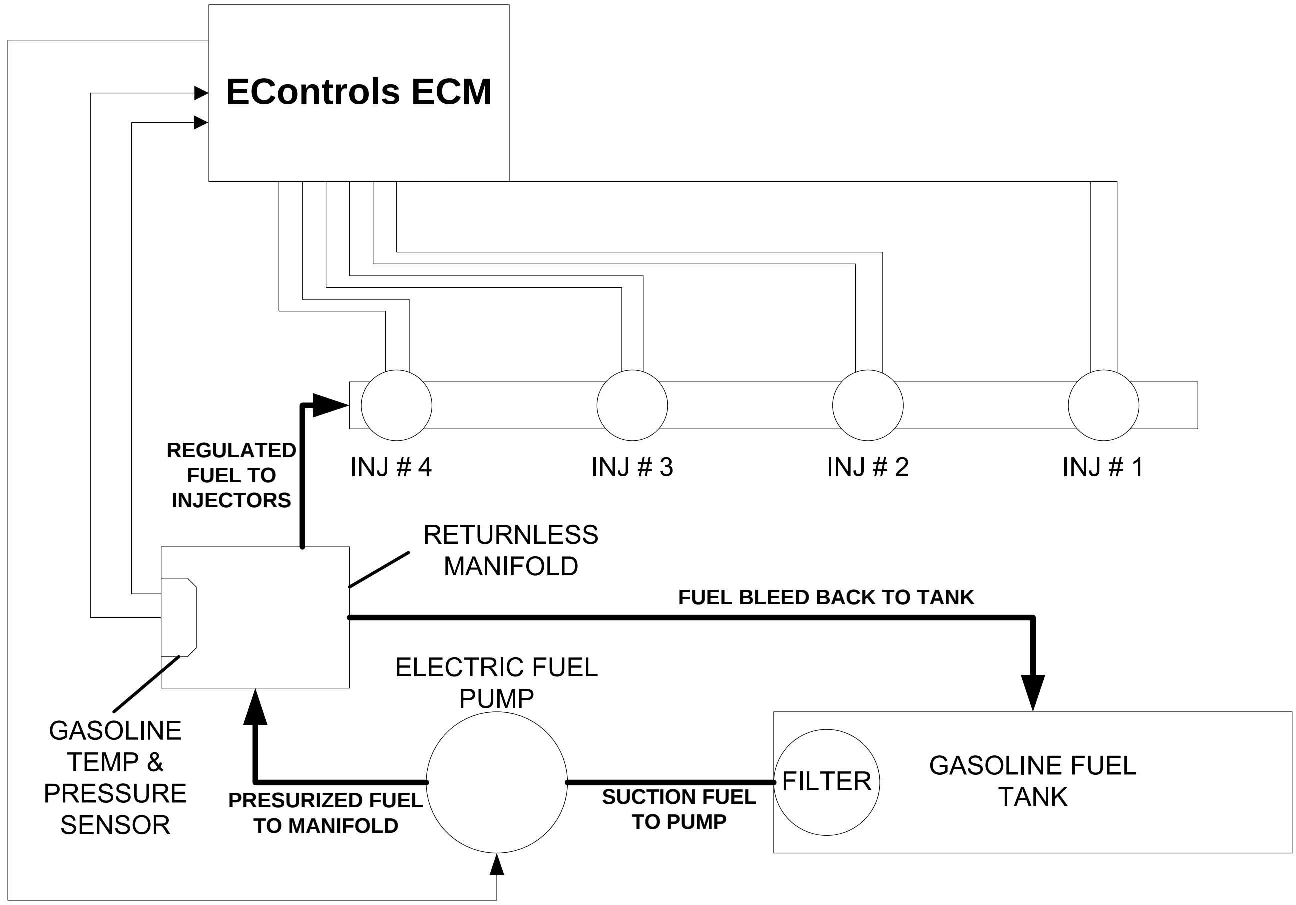
LPG Fuel System Diagnosis

Step	Action	Value(s)	Yes	No
1	Were you referred to this procedure by a DTC diagnostic chart?	—	Go to Step 3	Go to Step 2
2	Connect the EControls GCP display SW (EDIS). Key On Engine Off System Mode Stopped Are any DTCs present in the ECM?	—	Go to the applicable DTC Table	Go to Step 3
3	Verify that the LPG fuel tank has a minimum 1/4 tank of fuel, and that the manual valve is open. Is the tank valve open and fuel in the tank?	—	Go to Step 4	Refuel tank and Open Valve
4	Connect a 0-10 psi gauge to the primary test port of the dual stage regulator (DSR). Key On Engine Running System Running Mode Observe the pressure reading, for the DSR primary pressure. Is the fuel pressure **ABOVE** the specified value?	2.0 – 3.5 psi	Go to Step 13	Go to Step 5
5	Turn OFF the ignition. Disconnect the LPG Fuel lock Off electrical connector. Install a test light between the 12 volt supply pin of the LPG Fuel lock-off connector and battery ground, or connect a DVOM between the two pins. Crank the engine. The test light should illuminate or 12v should be present. Does the test light illuminate?	12VDC	Go to Step 6	Go to Step 12
6	Using a DVOM, check the resistance of the LPG fuel lock-off. Is the resistance within the specified range?	12 -24 Ω	Go to Step 7	Go to Step 14

Step	Action	Value(s)	Yes	No
7	Turn the ignition OFF. Close the manual shut-off valve on the LPG tank. **CAUTION: When disconnecting LPG fuel lines, liquid LPG may be present. Perform this step in a well ventilated area.** Slowly loosen the fuel inlet hose fitting, at the inlet of the Lock off. Was fuel present, when the fitting was loosened?	—	Go to Step 8B	Go to Step 8A
8A	Engines fitted with a LPG in-line fuel filter: Slowly loosen the inlet to the fuel filter Was fuel present, when the fitting was loosened?	—	Go to Step 11	Go to Step 9
8B	Engines fitted with a integrated filter to the Lock off. Remove the filter from the Lock off. Empty the contents, of the inlet side of the LPG fuel filter, onto a clean surface. Inspect the contents of the LPG fuel filter, for an excessive amount of foreign material or water. If necessary, locate and repair the source of contamination. Verify if the LPG fuel filter is not restricted or plugged. Was a problem found?	—	Go to Step 11	Go to Step 9
9	With the fuel line loose at the fuel filter inlet (in-line filter) or at the Lock off inlet Slowly open and close the manual valve Did fuel begin to flow when the manual valve was opened?		Go To Step 14	Go To Step 10
10	Check the fuel supply system, the hoses are plugged or restricted or the tank valve is not opening. Locate and repair the problem. Is the action complete?	—	Go to Step 16	—
11	Replace the fuel filter. Refer to *Fuel Filter Replacement.* Is the action complete?	—	Go to Step 16	—
12	Repair the open or short, in the lock-off circuit. Is the action complete?	—	Go to Step 16	—

Step	Action	Value(s)	Yes	No
13	Replace the dual stage regulator (DSR). Refer to *Dual Stage Regulator Replacement*. Is the action complete?	—	Go to Step 16	—
14	Replace the lock-off. Refer to *Low Pressure Lock-off (LPL) Replacement*. Is the action complete?	—	Go to Step 16	—
15	The fuel supply system is operating normally. Install the test plug, in the DSR secondary chamber. If you were sent to this routine by another diagnostic chart, return to the previous diagnostic procedure. Is the action complete?	—	System OK	—
16	Disconnect all test equipment. Install the primary and secondary test port plugs, if removed. Start the engine. Using SNOOP® or equivalent, leak check the test port plugs, if removed. Is the action complete?	—	System OK	—

Gasoline Fuel System Diagnosis



Fuel System Description

Engines which use the EControls gasoline fuel injection system will utilize a gasoline fuel tank which is either part of the chassis or a standalone vessel for the storage of the gasoline. On EControls USA emissions certified engines fuel tanks will not have a vented gasoline tank as the design of the system does not require the use of any vapor recovery from the fuel tank.

When the engine is operating the fuel is being drawn from the tank by the suction created from the fuel pump. A inline fuel filter will be installed either in-line or in the tank to filter out the small contaminants which may be in the fuel prior to reaching the fuel pump.
The EControls ECM controls the fuel pump by varying the supplied voltage to control the outlet pressure. The pump subsequently 'pulses,' sending pressurized fuel to the Fuel Pressure Manifold. A fuel temperature and pressure sensor mounted in the manifold measures the gasoline temperature and pressure for feedback to the ECM. By controlling the fuel pump outlet pressure, excess fuel is not being sent to the injector rail and therefore the rail does not have a return line back to the tank. Any excess pressure is allowed to "bleed back" to the tank from the Fuel Pressure Manifold. This method of fuel delivery prevents large amounts of hot fuel from being returned to the tank from the injector rail which would normally cause a vapor build up in the fuel tank and subsequently requiring the need for a vapor recovery system on the engine.

The fuel pressure is controlled by the ECM and therefore to properly measure the pressure, the EControls GCP Display SW is required. On engines where a test port in the fuel rail has been installed, a gauge method can be used to measure pressure.

Diagnostic Aids

This procedure is intended to diagnose a vehicle operating on Gasoline. If the vehicle will not continue to run on Gasoline, refer to *Hard Start* for preliminary checks. Before proceeding with this procedure, verify that the vehicle has a sufficient quantity of fuel.

Tools Required:

Diagnostic Scan Tool

- EControls GCP Display SW tool.

CAUTION: To reduce the risk of fire or personal injury that may result form fuel spray on the engine, make sure fuel rails is positioned over injector port and injector retaining clips are intact.

Gasoline Fuel System Diagnosis

Step	Action	Value(s)	Yes	No
1	Were you referred to this procedure by a DTC diagnostic chart?	—	Go to Step 3	Go to Step 2
2	Connect the EControls GCP Display SW tool Perform the On Board Diagnostic (OBD) System Check Key On Engine Off System Stopped Mode Check for DTC 87, 88, 91,92, 627,628,629 Are any fuel pump DTCs present in the ECM? If codes are present follow those procedures first	—	Go to the applicable DTC Table	Go to Step 3
3	Verify that the Gasoline fuel tank has a minimum of 1/4 tank of fuel, Does the vehicle have fuel?	—	Go to Step 4	—
4	Check the fuel supply line from the tank to the fuel pump for leakage, crimping, kinks or restriction Was there a problem found?	—	Go to Step 2	Go to Step 5
5	Check the electrical connections at the fuel pump and insure they are secured and tightened Was there a problem found?	—	Go to Step 2	Go to Step 6
6	Check the Fuel Temperature and Pressure electrical connectors at the Fuel Pressure Manifold Was there a problem found?	—	Go to Step 2	Go to Step 7
7	Check the fuel delivery lines, to and from, the Fuel Pressure Manifold for kinks, crimps or blockage of fuel flow Was there a problem found?	—	Go to Step 2	Go to Step 8
8	Key Off Engine Off Remove the fuel inlet hose to the injector rail Place the hose end into a container Key On Engine Off Did fuel flow from the hose during the prime sequence?	—	Go to Step 2	Go To Step 9

Step	Action	Value(s)	Yes	No
9	Key Off Engine Off Using a volt meter place one probe on the VBAT connector to the fuel pump and ground Key On Engine Off Was the voltage > 80% of VBAT?	> 80% of VBAT	Go to Step 16	Go To Step 10
10	Check the 10 Amp fuel pump fuse Was there a problem found?	—	Go to Step 2	Go to Step 11
11	Check the fuel pump relay power supply Key off Engine Off Using a DVOM place the positive probe on Pin 5 at the fuel pump relay and battery ground Key On Engine Off Was the voltage > 80% of VBAT?	> 80% of VBAT	Go to Step 16	Go to Step 12
12	Check the supply voltage to the relay Using a DVOM place the positive lead on Pin 3 at the relay and battery ground Was the voltage > 80% of VBAT?	> 80% of VBAT	Go To Step 13	Repair Supply voltage wiring
13	Check the fuel pump signal circuit at the ECM Using DVOM place the Positive probe at the relay and ground Key On Engine Off Was the voltage present?	—	Go to Step 14	Go to Step 15
14	Replace fuel pump relay Is this action Complete?	—	Go to *Step 2*	—
15	Replace the ECM Is this action Complete?	—	Go to *Step 2*	—
16	Check for restricted fuel pump strainer Check for plugged fuel filter 129 Was a problem found?	—	Go to *Step 2*	—
17	Replace fuel pump Is this action Complete?	—	Go to *Step 2*	—

Restricted Exhaust System Diagnosis

Exhaust System Description

The emission certified engine has been designed and calibrated to meet the emission standards in effect for 2010. To help meet the emission requirements the vehicle has been equipped with a Three Way Catalytic (TWC) muffler. The catalyst muffler is a three way catalyst, sound damping and spark arresting unit. Besides controlling the noise created from the combustion process, and preventing sparks from escaping from the exhaust system the most important function is treating the exhaust gases which are created from the combustion process. The three-way catalyst consists of a honeycomb core coated with a mixture of precious metals. The hot gases flow through the catalyst honeycomb core where an oxidation and reduction reactions take place. These chemical reactions reduce the amount of CO, HC and NOX in the engines exhaust. The Exhaust gas then flows through the tailpipe outlet.

During normal operation the exhaust system could become damaged. Damage which reduces the flow of the exhaust gas will create increased back pressure in the engine. Reduction in exhaust flow can result from crushed muffler outlets or melted catalyst brick inside the converter.

It may be necessary to measure the back pressure in the exhaust system. To determine if the back pressure in the engine is correct use the following procedure.

Diagnostic Aids

Tools Required:

- Back pressure gage (0-10 PSI)

Diagnostic Scan Tool

- EControls GCP Display SW Tool

Check at Heated Exhaust Gas Oxygen Sensor (HEGO)

1. Carefully remove the HEGO
2. Install exhaust backpressure gage in place of the HEGO Refer to Figure 1.
3. With the engine idling at normal operating temperature, observe the exhaust system back pressure reading on the gage. Reading should not exceed 8.6 kPa (1.25 psi)
4. Increase engine speed to 2000 RPM and observe gage. Reading should not exceed 20.7 kPa (3 psi)
5. If the back pressure at either speed exceeds specification, a restricted exhaust system is indicated.
6. Inspect the entire exhaust system for a collapsed pipe, heat distress or possible internal muffler failure.
7. If there are no obvious reasons for the excessive back pressure, the catalytic converter is suspected to be restricted and should be replaced using the recommended procedures

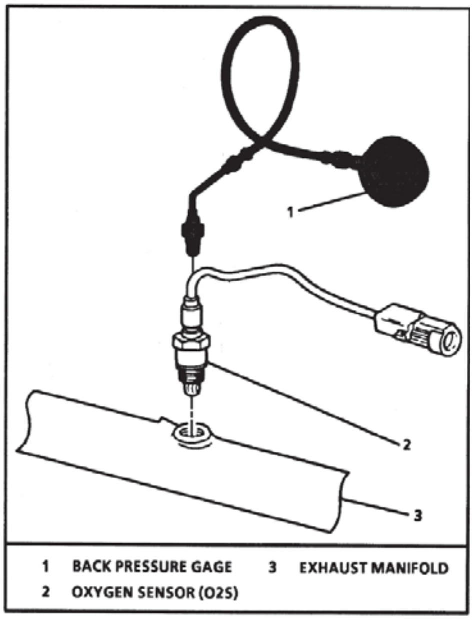


Figure 1

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ELECTRICAL SYSTEM DIAGNOSTIC SECTION

USING THE ELECTRICAL SECTION

INTRODUCTION

This section of the EControls manual has been designed to allow the technician to be able to select the section of the electrical system which is applicable to the fuel system being used. EControls systems are designed such that variation in fuel, engine size and auxiliary control feature are controlled by only several variations of Engine Control Modules (ECM). During the design of each of the OEM fuel systems the OEM defines the components that will interface with the EControls ECM and what options and auxiliary system are to be controlled by the ECM. Each OEM fuel system wire harness varies slightly not only in circuits but in length and connector end. However each of the EControls ECM has identical 90 pin connectors. Variations in each ECM will dictate what the individual pin function is however there are many of the pins which have the same function regardless of fuel system or engine size. Some pins may not be used in certain OEM fuel system and are blanked in the connector.

WIRE HARNESS SCHEMATICS

To enable EControls to develop a standard service manual supplement for the EControls fuel system without violating any OEM proprietary information the schematic has been reduced to specific circuit diagrams. To obtain the specific wire harness schematic you can contact EControls Service department.

CONNECTOR VIEWS

For those circuits which are not likely to vary, the individual circuits are documented in the harness section of this manual. Also included are the standard connector mating views which define the pin location in each connection. The view display is from mating connector perspective. Each connector in the overall wire harness has a connector number which begins with the prefix **CO-** followed by a three (3) digit number.

CIRCUIT IDENTIFICATION

Circuit numbers are not identified and wire colors may vary slightly as the OEM may request specific wire colors for certain circuits. Standard circuit descriptions are used to identify each circuit, (*example: Injector #1 +)*

WIRE DESCRIPTION

Each of the individual circuit diagrams contains the wiring information necessary for the technician to make repairs to that circuit without causing future damage to any electrical component or the wiring harness itself. All components use a crimped connector unless otherwise defined.

WIRE HARNESS REPAIR

EControls recognizes that through normal wear or improper handling of the main wire harness damage can occur over time. Wires, connector ends, and pins may become damaged and require replacement or repair. EControls has provided in this manual a section which described the proper repair procedures when making repairs to any wire harness. Use this section and the proper tools when making splices or repairs to the harness.

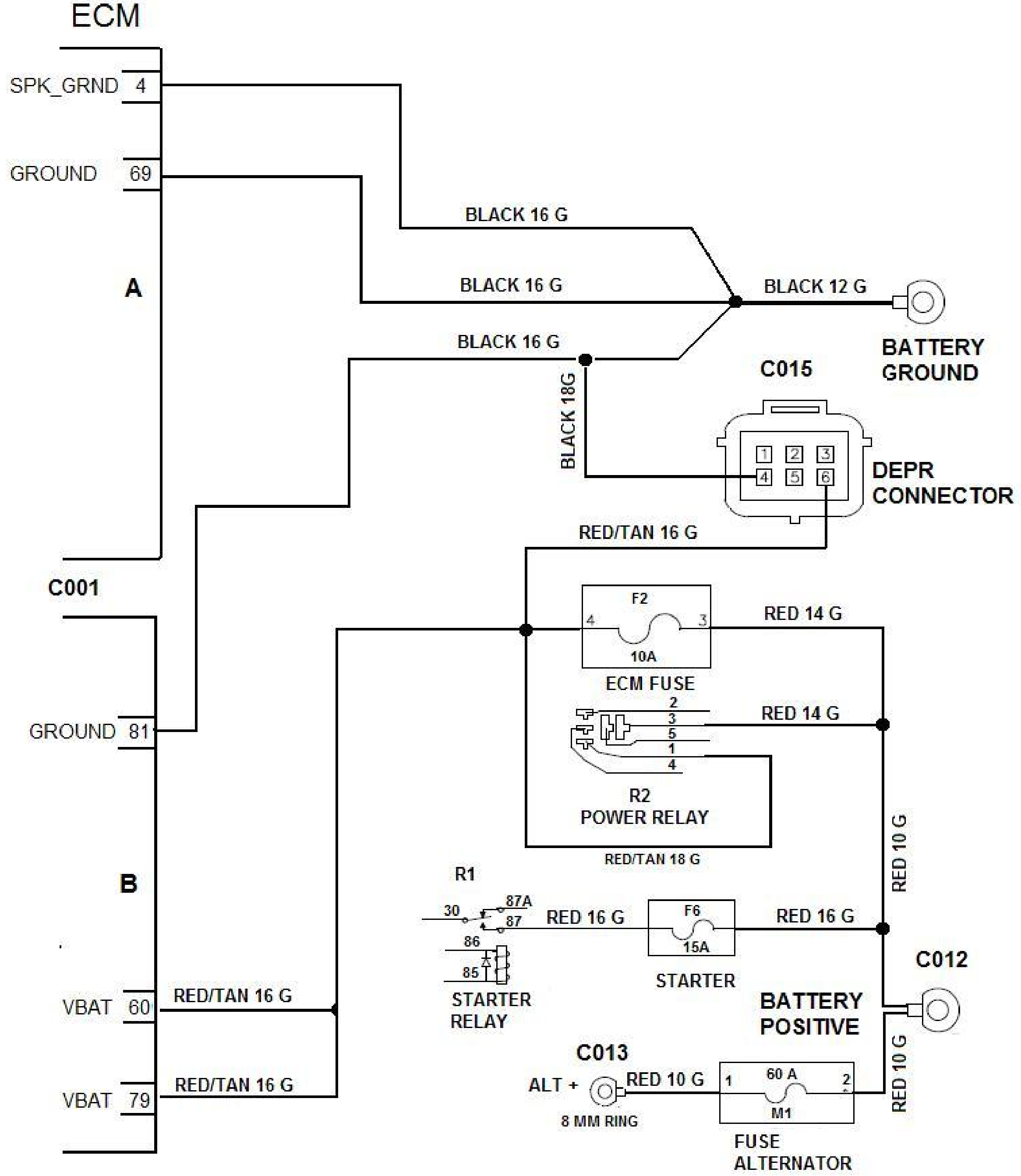
NOTE: BEFORE DIAGNOSING ANY ELECTRICAL PROBLEM CHECK THE MAIN ECM CONNECTOR TO IDENTIFY WHAT PINS ARE BLANKED.

BEFORE MAKING HARNESS REPAIRS BE SURE TO USE THE CORRECT WIRE HARNESS REPAIR TOOLS SUCH AS CRIMPING TOOLS, WIRE STRIPPING TOOLS, AND ELECTRICAL DIAGNOSTIC TOOLS

BEFORE ADDING ANY OPTIONAL ELECTRICAL EQUIPMENT TO THE VEHICLE FITTED WITH AN ECONTROLS SYSTEM CONSULT WITH THE OEM MANUFACTURER OF THE EQUIPMENT TO VERIFY THAT THE ELECTRICAL SYSTEM CAN SUSTAIN THE NEW ELECTRICAL LOADS AND WHERE TO CONNECT THE ADDITIONAL LOAD.

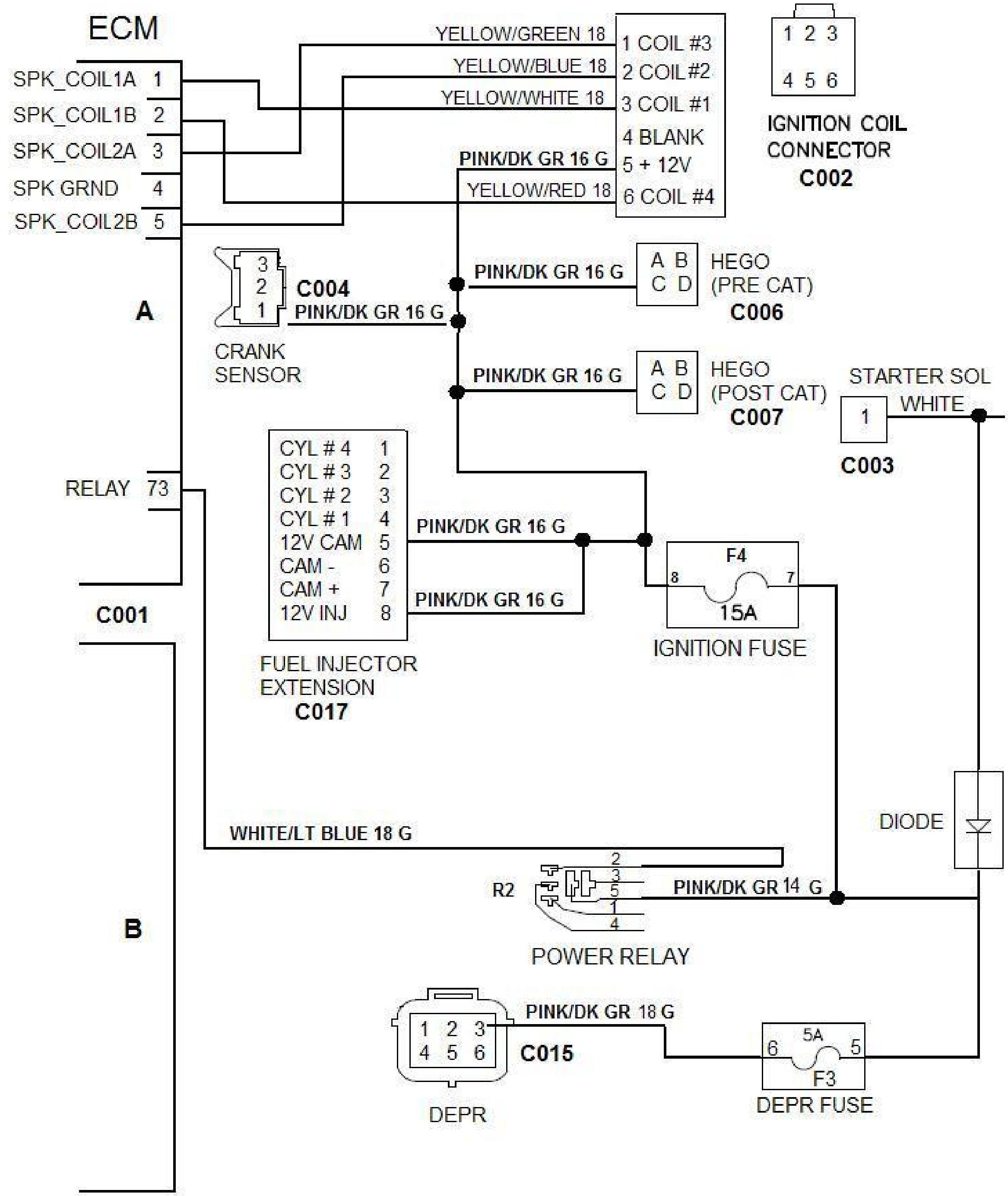
WHEN ADDING OPTIONAL ELECTRICAL EQUIPMENT BE SURE TO USE A IN-LINE FUSE OF THE PROPER ELECTRICAL LOAD TO PROTECT THE VEHICLE ELECTRICAL SYSTEM

Engine Harness Schematics



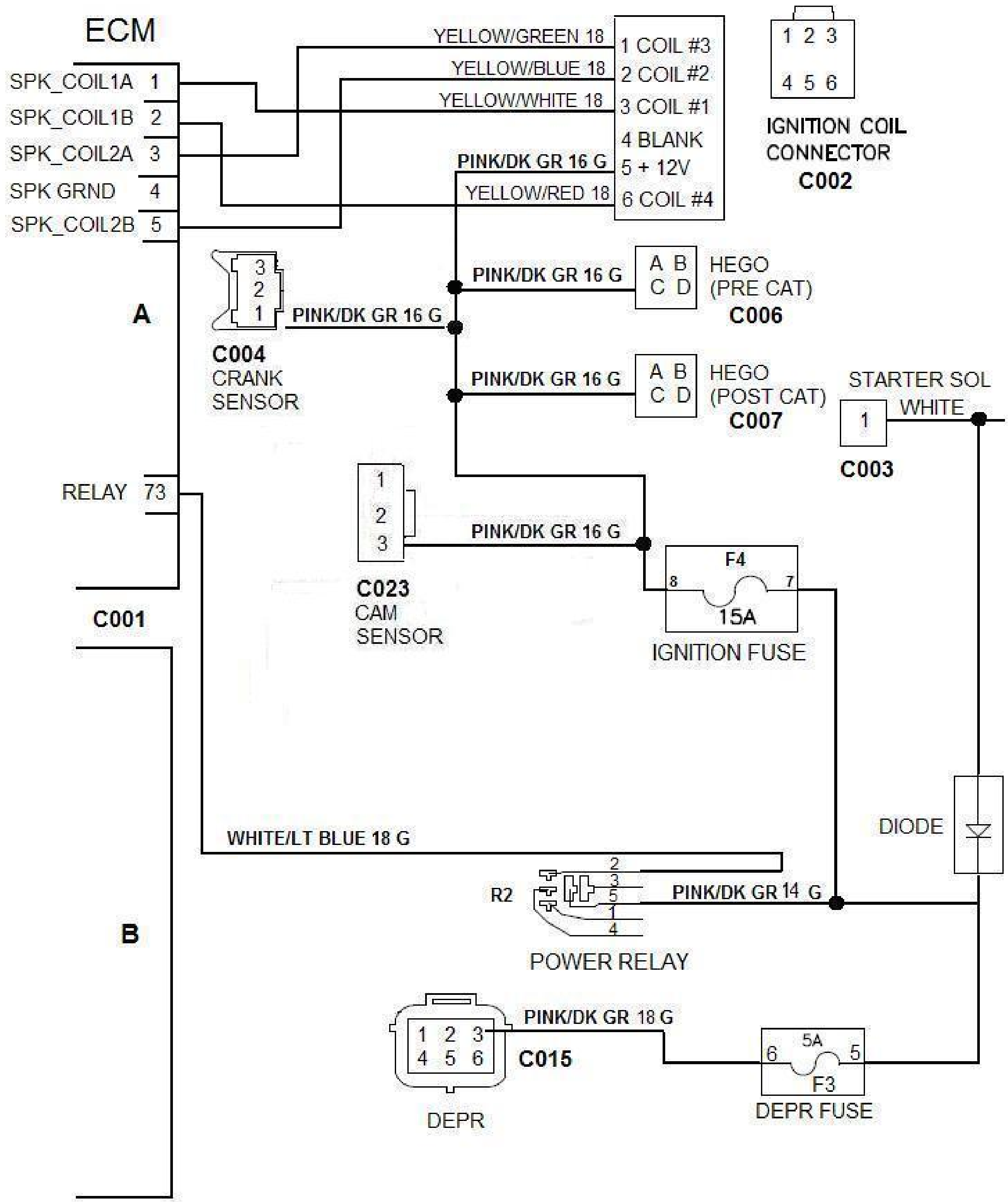
Note: All connector views are the mating connector view. Please refer to the harness schematic for a complete circuit defintiion.

Figure 1 - Power and Ground Circuits



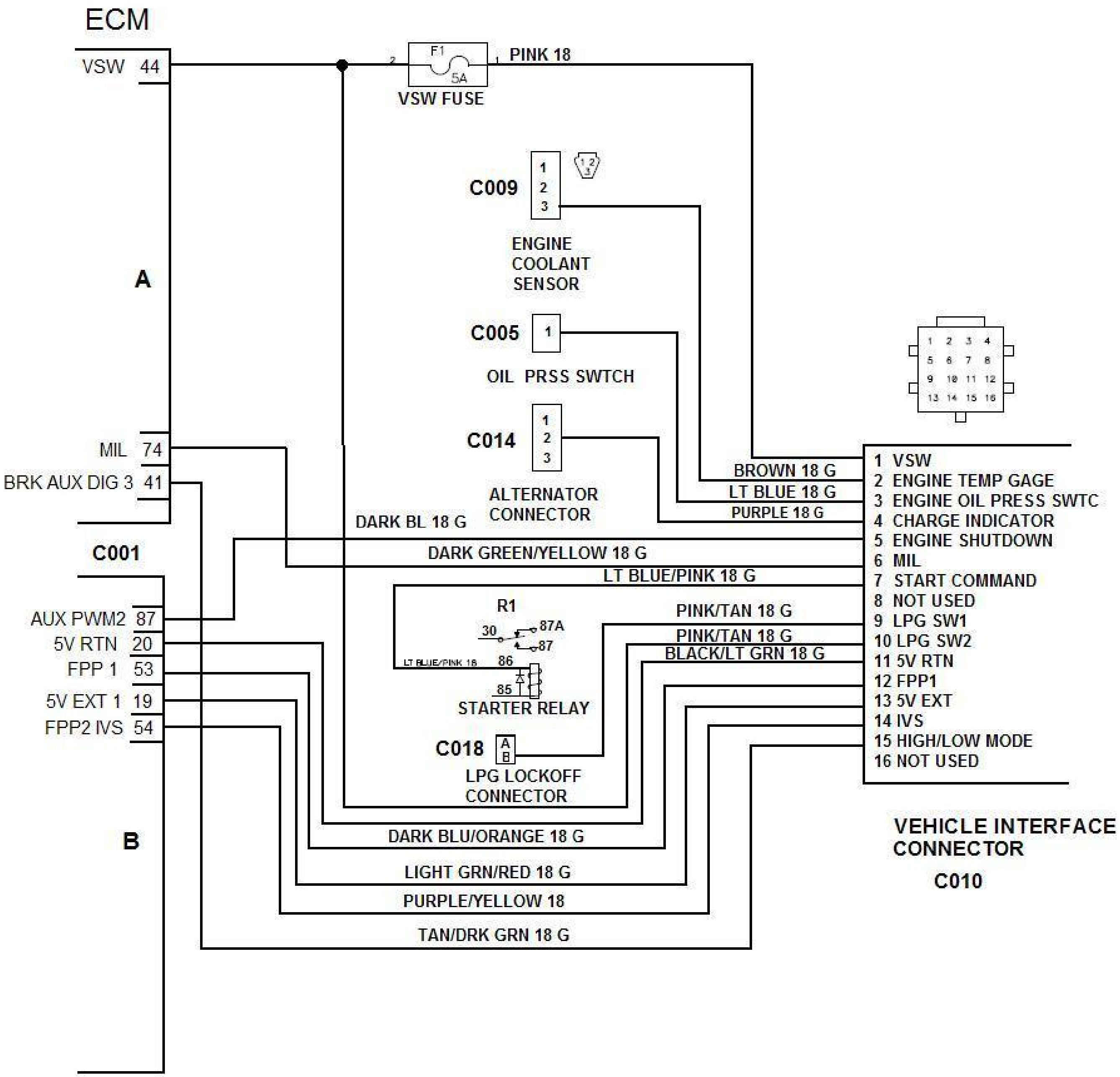
Note: All connector views are the mating connector view. Please refer to the harness schematic for a complete circuit defintiion.

Figure 2A - Ignition Circuits for Bifuel and Gasoline applications



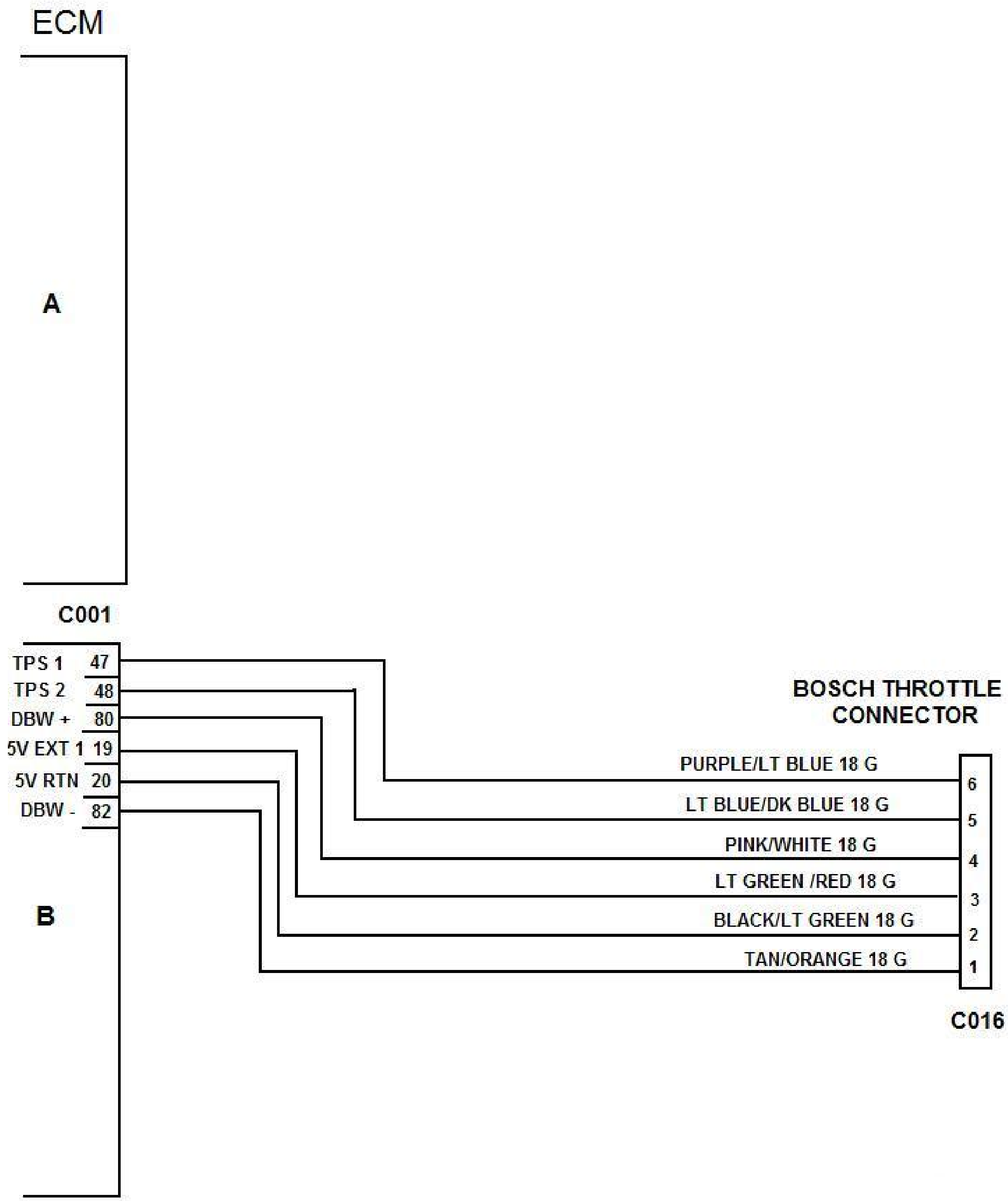
Note: All connector views are the mating connector view. Please refer to the harness schematic for a complete circuit defintiion.

Figure 2B - Ignition Circuits for LPG applications



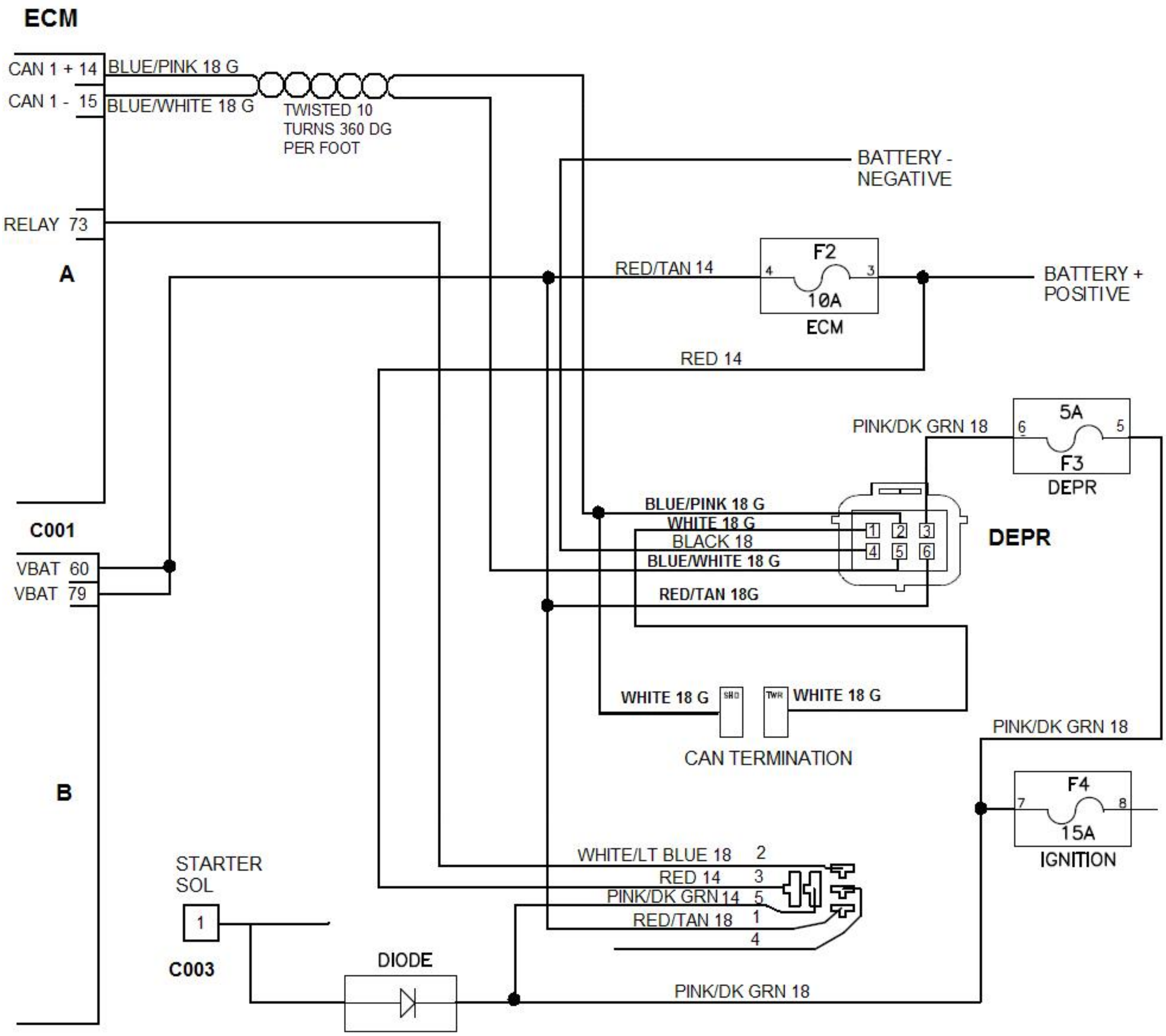
Note: All connector views are the mating connector view. Please refer to the harness schematic for a complete circuit defintiion.

Figure 3 - Vehicle Interface Connector Circuits



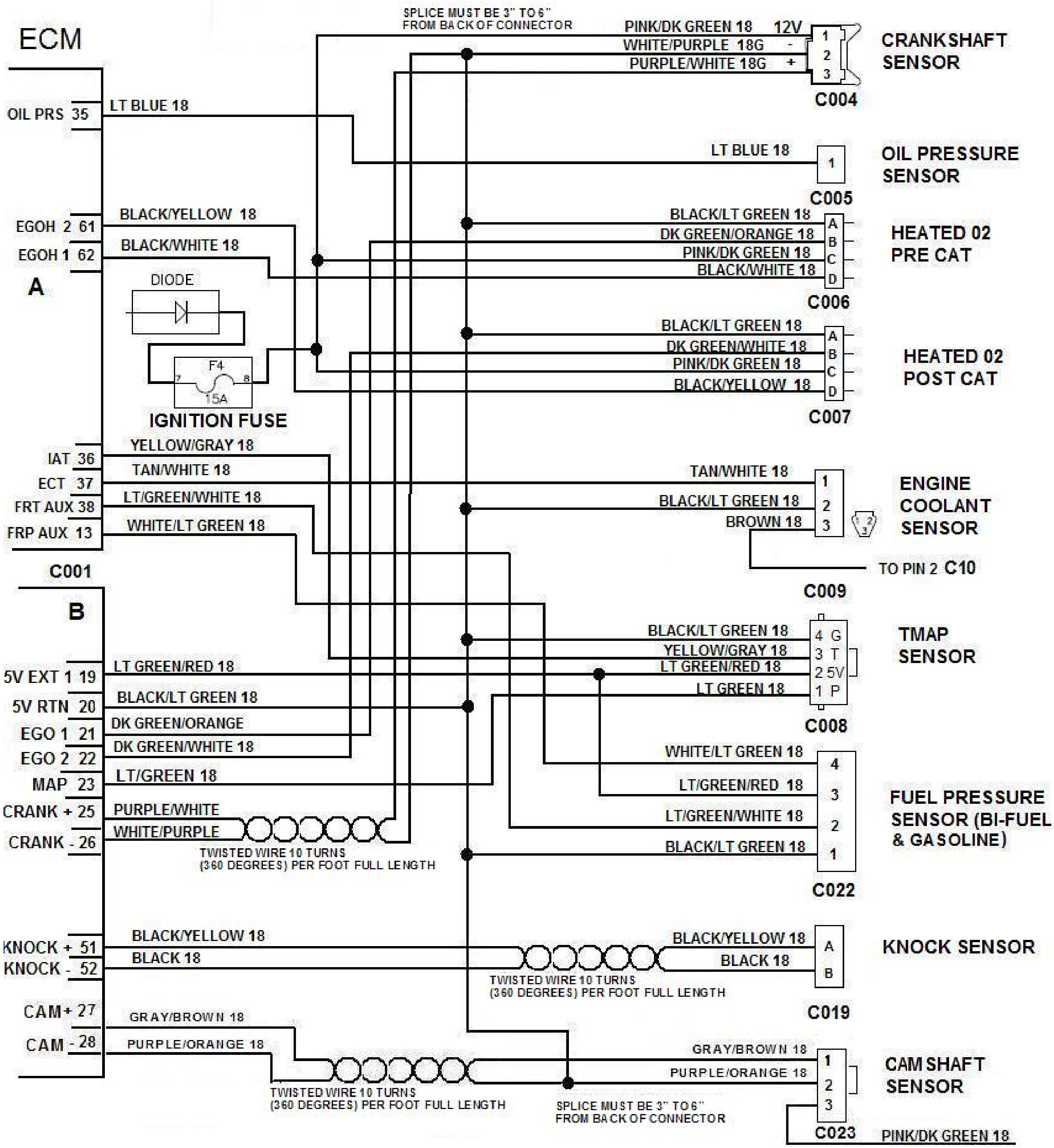
Note: All connector views are the mating connector view. Please refer to the harness schematic for a complete circuit defintiion.

Figure 4 - Electronic Throttle Body Circuits



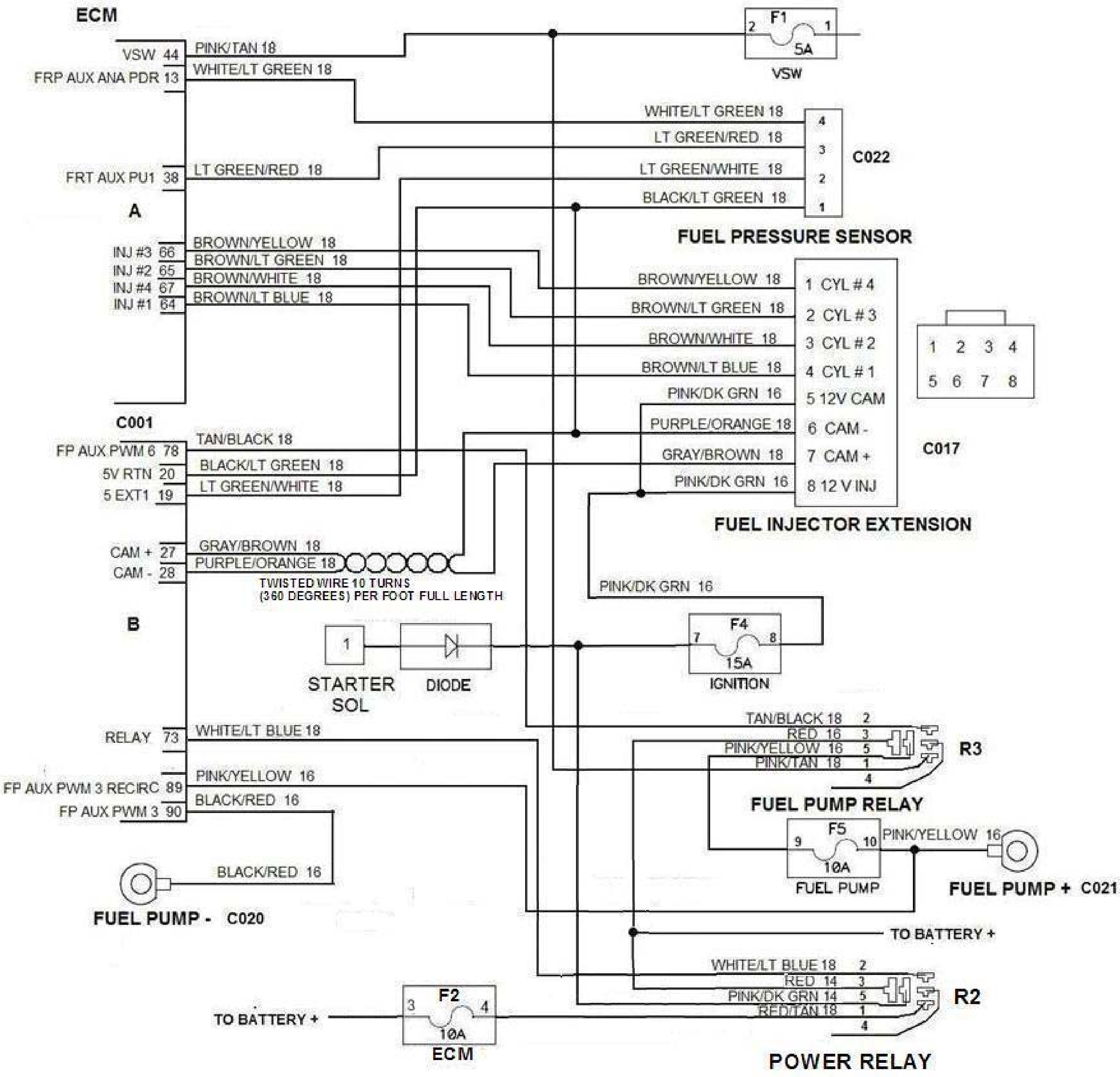
Note: All connector views are the mating connector view. Please refer to the harness schematic for a complete circuit defintiion.

Figure 5 - DEPR Circuits



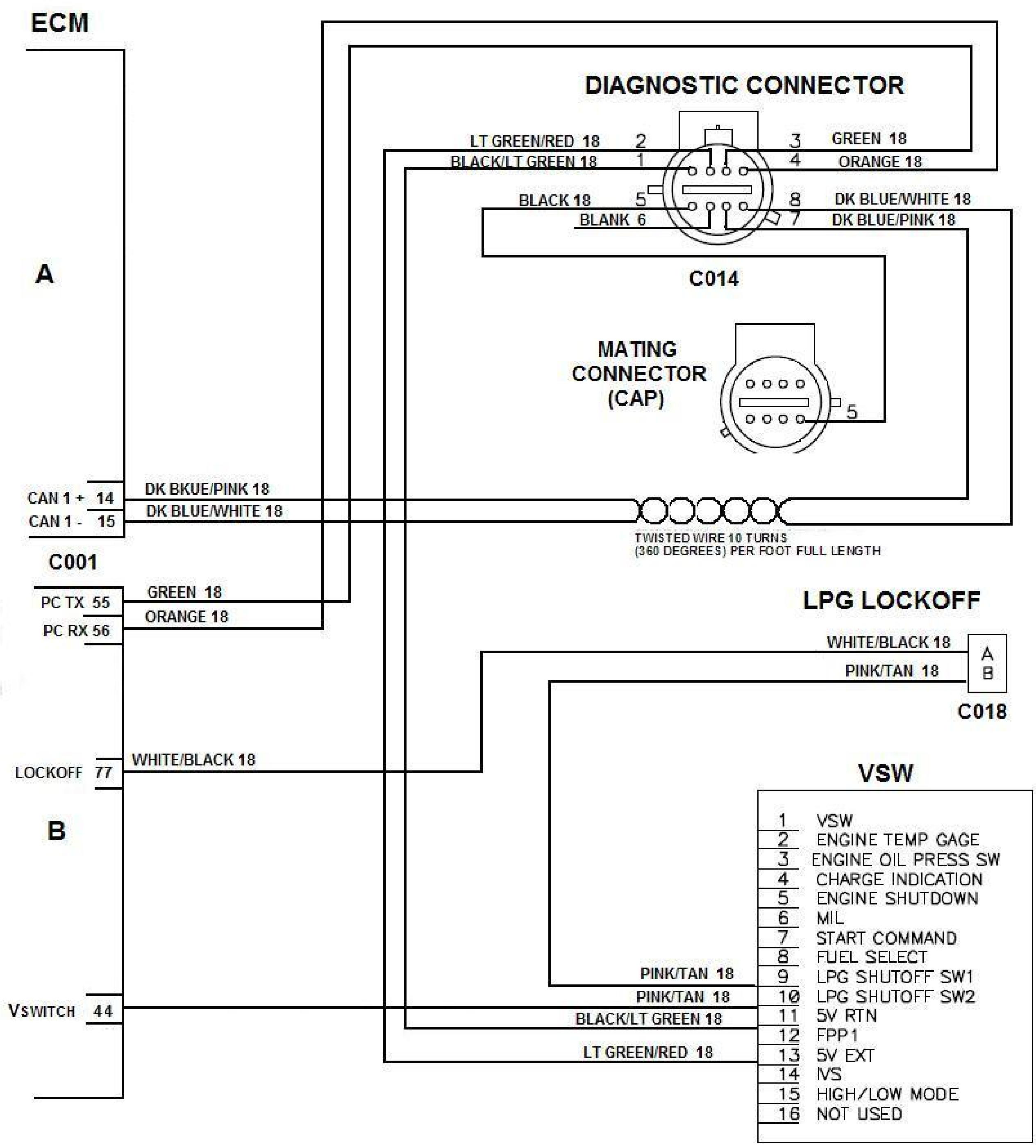
Note: All connector views are the mating connector view. Please refer to the harness schematic for a complete circuit defintiion.

Figure 6 - Sensor Circuits



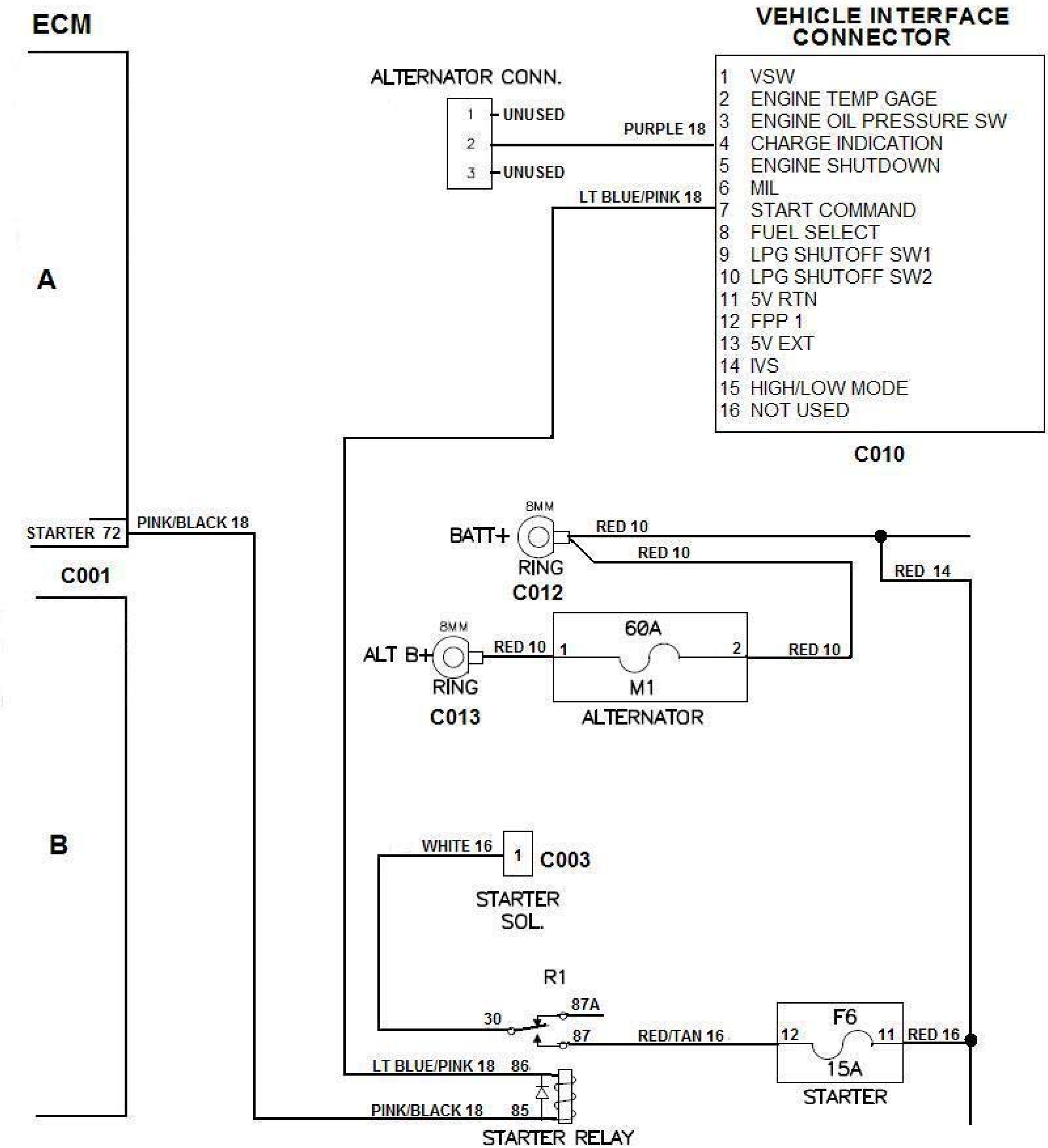
Note: All connector views are the mating connector view. Please refer to the harness schematic for a complete circuit defintiion.

Figure 7 - Gasoline Injection Circuits



Note: All connector views are the mating connector view. Please refer to the harness schematic for a complete circuit defintiion.

Figure 8 - Lock Off and Diagnostic Connector Circuits



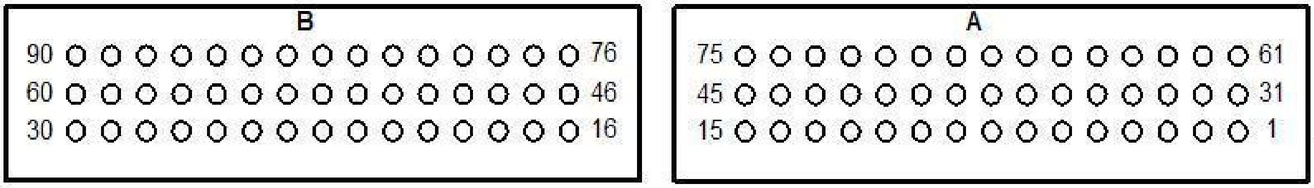
Note: All connector views are the mating connector view. Please refer to the harness schematic for a complete circuit defintiion.

Figure 9 - Starter and Alternator Circuits

MATING CONNECTOR VIEW ECM PIN LOCATIONS

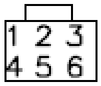
Connector Number: C001 **Name: ECM CONNECTOR**

ECM PIN LOCATIONS



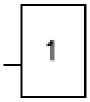
PIN	DESCRIPTION	PIN	DESCRIPTION	PIN	DESCRIPTION
1	SPK_COIL1A (Yellow/White 18)	31	5V EXT 2 (BLANK)	61	EGOH 2 (Black/Yellow 18)
2	SPK_COIL1B (Yellow/Red 18)	32	5V RTN 2 (BLANK)	62	EGOH 1 (Black/White 18)
3	SPK_COIL2A (Yellow/Green 18)	33	PULSE IN (BLANK)	63	INJ HS (BLANK)
4	SPK_GRND (Black 16)	34	GOV 1 (BLANK)	64	INJ1 LS (Brown/Lt Blue 18)
5	SPK_COIL1A (Yellow/Blue 18)	35	OIL PRESSURE (Lt Blue 18)	65	INJ2 LS (Brown/Lt Green 18)
6	SPK_COIL3A (BLANK)	36	IAT (Yellow/Gray 18)	66	INJ3 LS (Brown/Yellow 18)
7	SPK_COIL3B (BLANK)	37	ECT (Tan/White 18)	67	INJ4 LS (Brown/White 18)
8	UEGOS (BLANK)	38	(FRT) AUX ANA PU1 (Lt Green/White18	68	INJ5 LS (BLANK)
9	UEGOC (BLANK)	39	(LPTEMP) AUX ANA PU2 (BLANK)	69	GROUND (Black 16)
10	UEGOP (BLANK)	40	(IVS) AUX ANA PU3 (BLANK)	70	INJ6 LS (BLANK)
11	UEGPR (BLANK)	41	BRAKE AUX DIG 3 (Tan/Dk Green 18)	71	AUX PWM8 (BLANK)
12	AUX ANA PD1 (BLANK)	42	(GOV2)AUX DIG 4 (BLANK)	72	STARTER (Pink/Black 18)
13	(FRP) AUX ANA PDI (White/Lt Green 18)	43	TACH (BLANK)	73	RELAY (White/Lt Blue 18)
14	CAN 1 + (Dk Blue/Pink 18)	44	VSW (Pink/Tan 18)	74	MIL (Dk Green/Yellow 18)
15	CAN 1 - (Dk Blue/White 18)	45	AUX ANA PUD 2 (BLANK)	75	UEGO H (BLANK)
16	CAN 2 - (BLANK)	46	AUX ANA PUD 2 (BLANK)	76	AUX PWM7 (BLANK)
17	CAN 2 + (BLANK)	47	TPS 1 (Purple/Lt Blue 18)	77	LOCK OFF (White/Black 18)
18	AUX ANA PUD3 (BLANK)	48	TPS 2 (Lt Blue/Dk Blue 18)	78	FUEL PUMP AUX PWMT (Tan/Blk 18)
19	5V EXT 1 (Lt Green/Red 18)	49	FUEL SELECT AUX DIG 1(Tan/Brown18	79	VBAT (Red/Tan 16)
20	5V RTN (Black/Lt Green 18)	50	AUX DIG 2 (BLANK)	80	DBW+ (Pink/White 18)
21	EGO 1 (Dk Green/Orange 18)	51	KNOCK + (Black/Yellow 18)	81	GROUND (Black 16)
22	EGO 2 (Dk Green/White 18)	52	KNOCK - (Black 18)	82	DBW- (Tan/Orange 18)
23	MAP (Lt Green 18)	53	FPP1 (Dk Blue/Orange 18)	83	AUX PWM5 REC (BLANK)
24	AUX ANA PUD3 (BLANK)	54	(FPP2) FPP2 IVS (Purple/Yellow 18)	84	AUX PWM5 (BLANK)
25	CRANK + (Purple/White 18)	55	PC TX (Green 18)	85	AUX PWM1 (BLANK)
26	CRANK - (White/Purple 18)	56	PC RX (Orange18)	86	AUX PWM4 (BLANK)
27	CAM + (Gray/Brown 18)	57	KNOCK 2+ (BLANK)	87	AUX PWM2 (Dk/Blue 18)
28	CAM - (Purple/Orange 18)	58	KNOCK 2- (BLANK)	88	AUX PWM4 REC (BLANK)
29	SPEED + (BLANK)	59	VBAT PROT (BLANK)	89	FP REC AUX PWMS REC (Pink/Ylw 16)
30	SPEED - (BLANK)	60	VBAT (Red/Tan 16)	90	FUEL PUMP AUX PWM (Black/Red 16)

Connector Number: C002*1 **Name: Ignition Coil Connector**



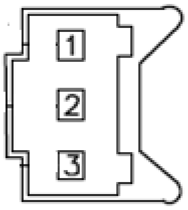
Pin Number	Description	Wire Color
1	Coil # 3	Yellow/Green
2	Coil # 2	Yellow/Blue
3	Coil # 1	Yellow/White
4	Blank	
5	+ 12 Volt	Pink/Dk Green
6	Coil # 4	Yellow/Red

Connector Number: C003*1 **Name: Starter Solenoid**



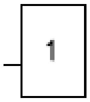
Pin Number	Description	Wire Color
1	Starter Solenoid	White

Connector Number: C004*1 **Name: Crankshaft Sensor**



Pin Number	Description	Wire Color
1	12 Volt	Pink/DK Green
2	Crank +	White/Purple
3	Crank -	Purple/White

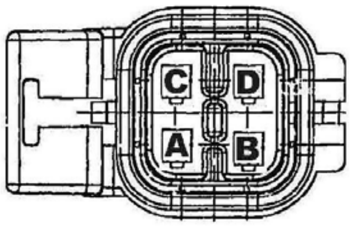
Connector Number: C005 *1 **Name: Oil Pressure Switch**



Pin Number	Description	Wire Color
1	Oil Pressure	Lt Blue

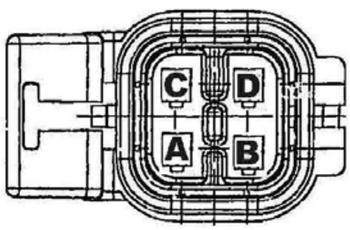
***1 Note: All connector views are the mating connector view.**

Connector Number: C006 [*1] **Name: Heated O2 Sensor (Pre-Cat)**



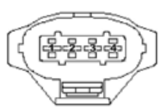
Pin Number	Description	Wire Color
A	5V RTN	Black/Lt Green
B	EGO 1 Signal	Dk Green/Orange
C	12V	Pink/Dk Green
D	EGO 2 Heater Ground	Black/White

Connector Number: C007 [*1] **Name: Heated O2 Sensor (Post-Cat)**



Pin Number	Description	Wire Color
A	5V RTN	Black/Lt Green
B	EGO 2 Signal	Dk Green/White
C	12V	Pink/Dk Green
D	EGO 2 Heater Ground	Black/Yellow

Connector Number: C008 [*1] **Name: TMAP**



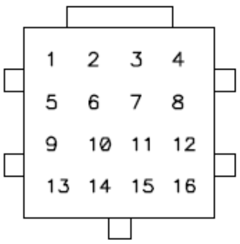
Pin Number	Description	Wire Color
4	Analog Return	Black/Lt Green
3	IAT	Yellow/Gray
2	5V Reference	Lt Green/Red
1	Map	MAP

***1 Note: All connector views are the mating connector view.**

Connector Number: C009 *1 **Name: Engine Coolant Temperature**

Pin Number	Description	Wire Color
1	ECT Signal	Tan/White
2	Analog Return	Black/Lt Green
3	Engine Gauge	Brown

Connector Number: C010 *1 **Name: Vehicle Interface Connector**



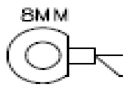
Pin Number	Description	Wire Color
1	VSW	Pink
2	Temperature Gauge	Brown
3	Engine Oil Pressure	Lt Blue
4	Charge Indicator	Purple
5	Engine Shutdown	Dark Blue
6	MIL	Dk Green/Yellow
7	Start Command	Lt Blue/Pink
8	Fuel Select	Tan/Brown
9	LPG Lock Off 12V Out	Pink/Tan
10	LPG Lock Off 12V In	Pink/Tan
11	Analog Return	Black/Lt Green
12	FPP1	Dk Blue/Orange
13	5V Reference	Lt Green/Red
14	IVS	Purple/Yellow
15	High / Low Mode	Tan/Dk Green
16	Not Used	

Connector Number: C011 **Name: System Ground Connection**

Pin Number	Description	Wire Color
1	Sys Ground	BLACK

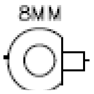
***1 Note: All connector views are the mating connector view.**

Connector Number: C012 **Name: 12 Volt Battery + Connection**



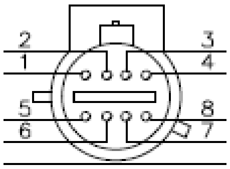
Pin Number	Description	Wire Color
1	Battery 12V +	Red

Connector Number: C013 **Name: Alternator Battery +**



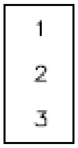
Pin Number	Description	Wire Color
1	Alternator 12V +	Red

Connector Number: C014 *1 **Name: Diagnostic Tool Connector**



Pin Number	Description	Wire Color
1	Analog Return	Black/Lt Green
2	5V Reference	Lt Green/Red
3	PC TX	Green
4	PC RX	Orange
5	Connector Cap Connection	Black
6	Not Used	
7	CAN +	Dk Blue/Pink
8	CAN -	Dk Blue/White

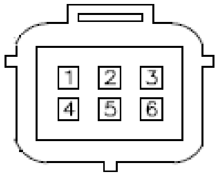
Connector Number: C014 *1 **Name: Alternator Connector**



Pin Number	Description	Wire Color
1	Not Used	
2	Charge Indicator	Purple
3	Not Used	

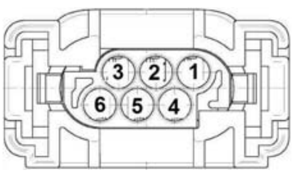
***1 Note: All connector views are the mating connector view.**

Connector Number: C015 *1 **Name: DEPR Connector**



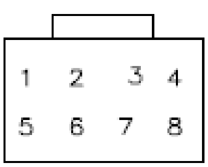
Pin Number	Description	Wire Color
1	CAN Termination	White
2	CAN 1 +	Dk Blue/Pink
3	12 V +	Pink/Dk Green
4	Ground	Black
5	CAN -	Dk Blue/White
6	VBAT	Red/Tan

Connector Number: C016 *1 **Name: Bosch Throttle Connector**



Pin Number	Description	Wire Color
1	DBW -	Tan/Orange
2	Analog Return	Black/Lt Green
3	5V Reference	Lt Green/Red
4	DBW +	Pink/White
5	TPS 2	Lt Blue/Dk Blue
6	TPS 1	Purple/Lt Blue

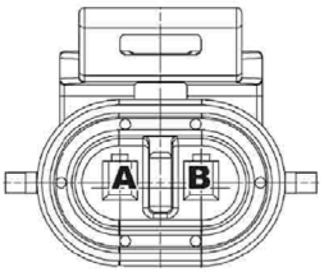
Connector Number: C017 *1 **Name: Gasoline Injector Extension Connector**



Pin Number	Description	Wire Color
1	Cyl. 4 Inj.	Brown/Yellow
2	Cyl. 3 Inj.	Brown/Lt Green
3	Cyl. 2 Inj.	Brown/White
4	Cyl. 1 Inj.	Brown/Lt Blue
5	12V Cam	Pink/DK Green
6	Cam -	Purple/Orange
7	Cam +	Gray/Brown
8	12 V Injector	Pink/Dk Green

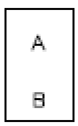
***1 Note: All connector views are the mating connector view.**

Connector Number: C018 [*1] **Name: LPG Fuel Lock Off Connector**



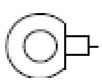
Pin Number	Description	Wire Color
A	Lock Off -	White/Black
B	Lock Off +	Pink/Tan

Connector Number: C019 [*1] **Name: Knock Sensor Connector**



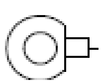
Pin Number	Description	Wire Color
A	Knock +	Black/Yellow
B	Knock -	Black

Connector Number: C020 **Name: Gasoline Fuel Pump Ground Ring**



Pin Number	Description	Wire Color
1	Fuel Pump Ground	Black/Red

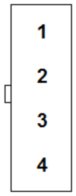
Connector Number: C021 **Name: Gasoline Fuel Pump Positive Ring**



Pin Number	Description	Wire Color
1	Fuel Pump 12V	Pink/Yellow

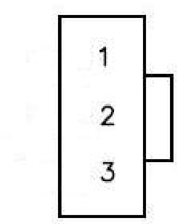
***1 Note: All connector views are the mating connector view.**

Connector Number C022 [*1] **Name: Fuel Pressure Manifold Gasoline Sensor Connector**



Pin Number	Description	Wire Color
1	5v Rtn	Black/Lt Green
2	FRT Aux	Lt Green/White
3	5v Ext	Lt Green/Red
4	FRP Aux	White/Lt Green

Connector Number C023 [*1] **Name: Camshaft Position Sensor Connector**



Pin Number	Description	Wire Color
1	Cam +	Gray/Brown
2	Cam -	Purple/Orange
3	12 Volt	Pink/DK Green

***1 Note: All connector views are the mating connector view.**

WIRE HARNESS REPAIR

INTRODUCTION

The EControls ECM for both certified and non-certified fuel system relies on precise voltage input and outputs to maintain precise fuel control during normal operation. The ECM utilizes reference voltage signals to calculate fuel control, command throttle and engine speed and provide data to the operator through the instrument cluster.

When diagnosing faults in the system often the technician is required to disconnect the electrical connectors in the wire harness. Technicians should always use care when working on the wire harness. Special care should be given to the following items:

- When disconnecting connectors always grasp the connector at its base **DO NOT PULL ON THE WIRES** this make cause extreme stress on the crimped or solder joints
- Always depress or unlatch the connector **DO NOT USE A SCREW DRIVER TO PRY THE CONNECTOR APART** as damage to the connector or mating electrical device can occur
- When disconnecting a electrical connector always check the connector for corrosion in the connector pins, moisture in the connector, missing or damage water seals.
- **DO NOT PUSH THE ELECTRICAL PROBES INTO THE PINS WHEN TESTING CIRCUITS** as this will cause the pin to become enlarged and result in intermittent electrical problems
- When reconnecting an electrical connector "PUSH" the connector together until you here the "CLICK" then "PULL" on the connector base to make sure it is seated and locked
- Make sure to route the harness in the original fashion and secure the harness using straps, wire ties or clips to prevent the harness from contact with hot surfaces, rotating devices or damage for external elements

Because the critical sensor control circuits operate at low voltage it is always best to use solder to make joints and replace connector pins. Ref to Figure 1. If a connector is the "Molded" type and requires repair the complete connector must be replaced using a "pig tail" replacement.

CONNECTORS AND TERMINALS

As stated earlier always use care when probing a connector or replacing terminals in a connector housing. Improper repair of a connector can resulting in shorts at the connector and can damage critical electrical components. Always use a jumper wire between the terminal when checking circuits. NEVER USE A SHARP POINTED OBJECT TO PROBE THROUGH THE WEATHER TIGHT SEALS, doing so will allow water to intrude into the circuit and will result in future electrical faults in the system or may deter system performance.

Using the proper tools when working on the wire harness is essential to making proper and durable repairs. Use of an improper tool may result in damaging other electrical components and will result in needless repair costs. When working with the use proper wire stripping and cutting tools, use a fuse removal tool when replacing or check fuses, use a small screw driver to unlock connector latches, use electrical probes when testing wires, it is often best to find mating connectors to the EControls wire harness connectors for testing circuits as this will ensure a positive connection when reading ohms or voltage. Use the proper "Pin Removal Tool" when removing a connector terminal from its housing.

When diagnosing intermittent shorts in the electrical system is often easy to find the fault by wiggling the wires in a connector while the engine is operating as this may cause the misalignment, or corrosion to negatively affect the connection. Corrosion is a primary cause of electrical faults within the system, always look for visible signs of corrosion when diagnosing an electrical fault.

WIRE HARNESS REPAIR

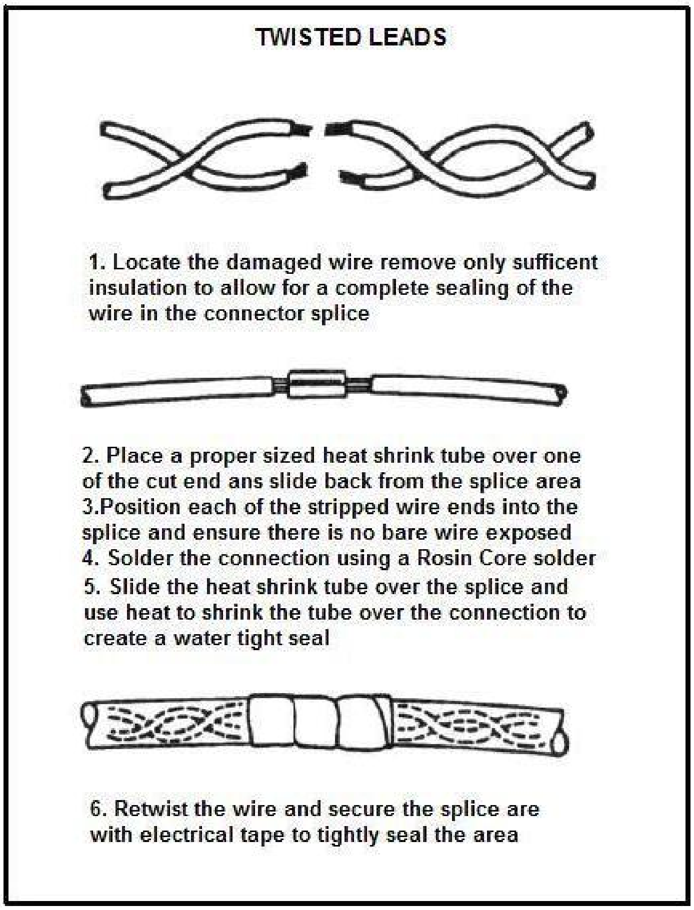


Figure 1 - *Wire Harness Repair*

CONNECTOR END REPAIR OR REPLACEMENT

Before making a connector repair, be certain of the type of connector for example Weather-Pack connectors and Compact Three connectors look very similar but are service differently.

MICRO-PACK CONNECTOR

Refer to Figure 2 for the repair procedure for the repair of a MICRO-PACK connector

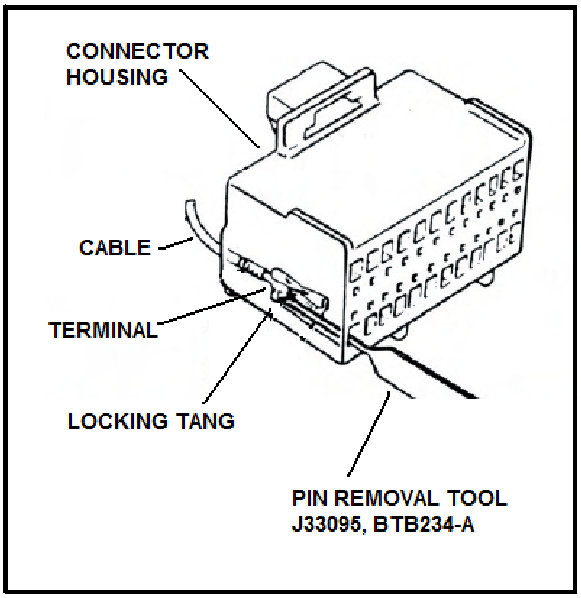


Figure 2 - *MICRO PACK CONNECTOR REPAIR*

METRI-PACK CONNECTORS

Some electrical connectors on the harness may utilize a METRI-PACK connector. Refer to *Figure 3* for removal and repair of the terminal.

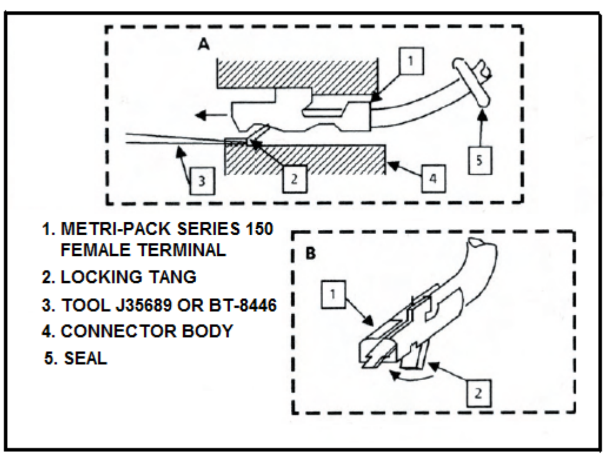


Figure 3 - *METRI-PACK Terminal Repair*

WEATHER PACK CONNECTOR

A Weather-Pack connector can be identified by a rubber seal installed to the wire at the rear of the connector. This type of connector is use in the engine compartment to protect against moisture intrusion into the connector. Refer to Figure 4 for terminal removal and repair

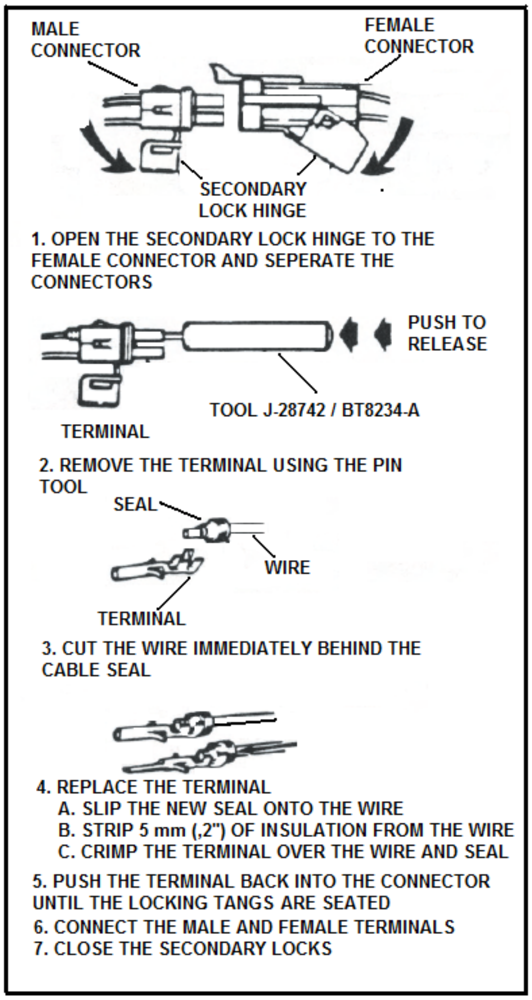


Figure 4 - *Weather-Pack Terminal Repair*

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ONBOARD DIAGNOSTIC SECTION

OVERVIEW

This manual is intended to be used as an aid for original equipment manufacturers (OEMs) and/or EControls' customers to author technical and training publications. Certain portions of this manual are only intended for use by the OEM to understand the fault detection system. This section of the manual defines the diagnostics and recommended troubleshooting procedures associated with an EControls Global Control Platform (GCP) engine control module (ECM) for use on industrial, heavy-duty gas, and marine engines.

USING THE GCP DIAGNOSTIC DISPLAY TOOL

Fault Code Broadcast

All diagnostic trouble codes are broadcast through EDIS for display on a PC. EDIS can acquire the data from the ECM through either of two protocols; CAN or RS-232 both using the EControls Inc. Proprietary Protocol (ECIPP). Faults may also be acquired over the CAN1 network through CAN J1939-based scan tools or multi-function display units.

Diagnostic Trouble Codes

The numeric diagnostic trouble codes assigned to the faults in this manual are cross-referenced to SAE's "Recommended Practice for Diagnostic Trouble Code Definitions" (SAE J2012). While these codes are recommended, customers may define their own codes by assigning a new number to the flash code in the diagnostic calibration. This will assign both the DTC as displayed in EDIS as well as the flash code output on the MIL output pin. EDIS may be used to connect to the GCP using either RS232 (serial) or Controller Area Network (CAN) communication protocols.

Serial Network

Fault code information can only be acquired through a PC tool compatible with ECIPP.

CAN

The GCP supports SAE J1939 CAN based diagnostic support. This includes:

- DM1: Active Diagnostic Trouble Codes
- DM2: Previously Active Diagnostic Trouble Codes
- DM3: Diagnostic Data Clear/Reset of Previously Active DTCs
- DM4: Freeze Frame Parameters
- DM5: Diagnostic Readiness (bytes 1, 2, and 3 are supported)
- DM11: Diagnostic Data Clear/Reset For Active DTCs
- DM12: Emissions-Related Active Diagnostic Trouble Codes
- DM19: Calibration Information

All diagnostic trouble codes broadcast over CAN1 will be according to SAE J1939 DM1 and DM2. MY08 MGCP ECUs are compliant with J1939 OBD-M, supporting the Diagnostic Messages above as well as user indicators and CAN data defined in the OBD-M protocol. Faults available for broadcast and their respective SPN/FMI numbers are dependent on the application and engine calibration. There are 4 CAN SPN/FMI lists available in the GCP software set, contact EControls for a list of CAN SPN/FMIs.

The data capture at the occurrence of a fault, known in the ECM as fault snapshot (FSS), is available upon DM4 request. The following bytes are supported for DM4 if configured in the ECM software:

- Byte 1: Freeze Frame Length
- Byte 2-6: SPN, FMI, SPN Conversion Method, and Occurrence
- Byte 7: Manifold Absolute Pressure
- Byte 8-9: Engine Speed
- Byte 10: Engine Load (MAP based estimate)
- Byte 11: Engine Coolant Temperature
- Byte 14: # of starts since fault was last active

- Byte 15: Index into FSS_storage table for Fault Snap Shot retrieval

Resetting active and previously active DTCs is handled through DM11 and DM3, respectively. DM1 and DM2 lamp indicators are assigned to each fault based on the fault's diagnostic action as defined in the calibration. The lamps are assigned based on the configuration outlined in Table 1.

Table 1: J1939 Diagnostic Lamp Configuration

ECM Diagnostic Action	J1939 Lamp
MIL	MIL
Soft Warning	Amber
Hard Warning, Low Rev Limit, Shutdown	Red Stop
Power Derate 1 & 2	Protect
Forced Idle	None (use in combination with other action)

Flash Codes and MIL Output

The MIL output is used to convey fault information to the equipment operator. The MIL is always on (grounded) when the system is in a key-on (Vsw), engine-off state. This provides assurance that the output is functional. If a DTC is logged as previously-active (historic) the MIL will send a single flash for the "Blink on-time" every "Blink off-time" + "Extra time between codes."

A feature of EControls ECMs is that diagnostic trouble codes can be displayed to a technician to indicate what historic faults are present without requiring the use of a personal computer. The DTCs can be flashed over the MIL output while the RS232 serial receive input (PC RX) is grounded. This input may be grounded at the diagnostic connector or at any connector in the wire harness where the PC RX input circuit is terminated.

Once the ECM recognizes that the user is requesting flash codes, it will flash or blink a standard code for a standard number of times in a row. Generally, the standard code is set to 1654 and the standard number of times a code is flash is generally set to 3, however, both may be altered in the calibration. If a code other than 1654 will be used as the standard code, please consult with EControls to determine whether or not the code will interfere with diagnostic DTCs.

After the standard code has been flashed for the standard amount of times, the first flash code in the historic faults category will be flashed at the same rate. DTCs are flashed over the MIL based on their order in the ECU memory map, which is fixed; DTCs are not flashed based on the order in which they set or became active. DTCs will continue to flash depending on the number of historic faults retained in memory. If there are no historic faults, the standard flash code will be repeated. Figure 1 provides an example of the MIL output during a flash code sequence based on the calibration defined in Table 2.

Table 2: Example Calibration of MIL

MIL Blink Code Timings		
Delay before start of code blinking	1000	ms
Blink on-time	500	ms
Blink off-time	500	ms
Time between digits in a code	1000	ms
Extra time between code repeats	2000	ms
Extra time between codes	4000	ms
Extra time before starting codes over	2000	ms
Number of times to repeat a code	2	
Default first code (always output)	123	
Key-on engine-off stored fault MIL on-time	4500	ms
Key-on engine-off stored fault MIL off-time	500	ms
Power derate mode MIL fast-blink on-time	250	ms
Power derate mode MIL fast-blink off-time	250	ms

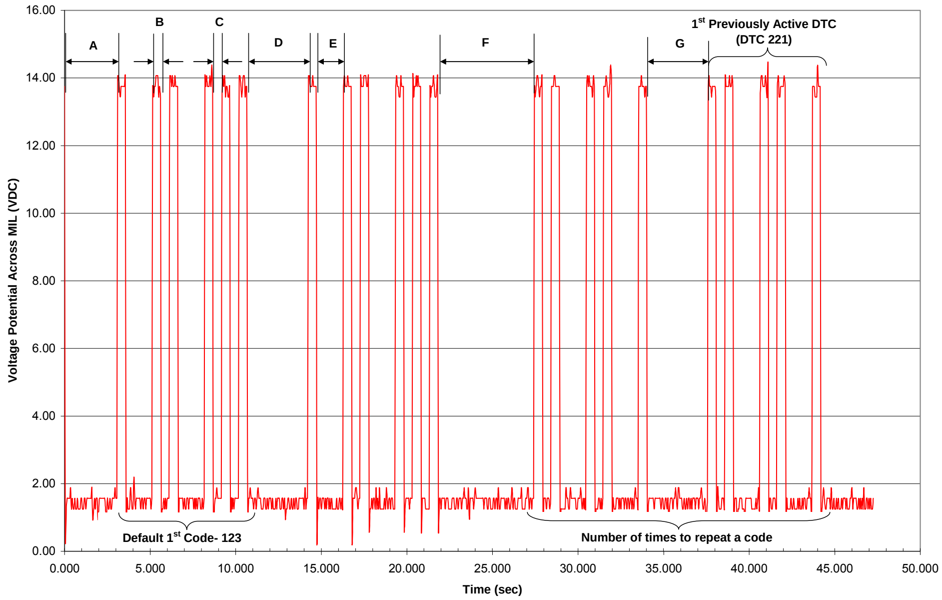


Figure 1: - *Electrical Pattern of MIL Output During a Flash Code Sequence*

A= Delay before start of code blinking + Extra time before starting codes over
Ex. 1000 ms + 2000 ms= 3000 ms

B= Blink on-time
Ex. 500 ms

C= Blink off-time
Ex. 500 ms

D= Blink off-time + Time between digits in a code + Extra time between code repeats
Ex. 500 ms + 1000 ms + 2000 ms= 3500 ms

E= Blink off-time + Time between digits in a code
Ex. 500 ms + 1000 ms= 1500 ms

F= Blink off-time + Time between digits in a code + Extra time between codes
Ex. 500 ms + 1000 ms + 4000 ms= 5500 ms

G= Blink off-time + Extra time between code repeats + Time between digits in a code
Ex. 500 ms + 2000 ms + 1000 ms= 3500 ms

Diagnostic Calibration Configuration and Corrective Actions

Each fault within the GCP is capable of being uniquely configured in the engine's diagnostic calibration to cause one or more corrective actions while a given fault is active. Table 3 identifies the configuration options and corrective actions available for configuration of each fault. The desired action is set by the OEM calibration engineers.

Table 3: Diagnostic Corrective Actions

Corrective Action	Description
Enable	Enables the fault for fault detection
Shutdown	Cause an engine shutdown when fault becomes active
Never Forget	Retain fault as historic/previously active until cleared by a technician and does not allow historic fault to be "auto-cleared"
Turn on MIL	Turn on MIL output when fault becomes active
CL Disable	Disable closed-loop while the fault is active
CL Disable Key- Cyc	Disable closed-loop while the fault is active and for the remainder of the key cycle
AL Disable	Disable adaptive learn while the fault is active
AL Disable Key-Cyc	Disable adaptive learn while the fault is active and for the remainder of the key cycle
Power Derate 1	Limit TPS to the Power Derate 1 percent set in the diagnostic calibration while the fault is active. The Power Derate 1 TPS percent should be set higher than Power Derate 2 as Power Derate 2 adds a higher level of protection.
Power Derate 2	Limit TPS to the Power Derate 2 percent set in the diagnostic calibration while the fault is active. If the calibration is set to "Latched for Key-Cycle" Power Derate 2 remains active until engine speed and FPP conditions are satisfied. The Power Derate 2 TPS percent should be set lower than Power Derate 1 as Power Derate 2 adds a higher level of protection.
Low Rev Limit	Limit RPM to the Low Rev Limit speed set in the diagnostic calibration while the fault is active. If the calibration is set to "Latched for Key-Cycle" Low Rev Limit remains active until engine speed and FPP conditions are satisfied.
Forced Idle	Limit RPM to the Forced Idle speed set in the diagnostic calibration while the fault is active and for the remainder of the key cycle
Soft Warning	Turn on the soft warning output when the fault becomes active
Hard Warning	Turn on the hard warning output when the fault becomes active
Stopped Check	Run fault detection/checking while the engine is in a key-on, engine-off condition. NOTE: It is recommended that this feature only be used for general sensor faults (high/low voltage) and some output drivers

Fault/Diagnostic Trouble Code Interaction

All fault and diagnostic information is managed through the Faults page. Interaction includes viewing fault messages, downloading fault data (fault snapshot and flight data recorder), erasing faults from memory, and defining variables for fault data logging.

Faults are separated into two categories, Active and Historic. Active faults are active in real-time and historic faults have been generated at some instance in time that may or may not be active in real-time. Once a fault has become active, it is immediately logged as historic and a snapshot and flight data log is saved.

Figure **2** shows an example of the fault page when an active fault has been generated. Notice that the fault is present in both the active and historic lists and the malfunction indicator lamp (MIL) has been illuminated.
Figure **3** shows an example of the fault page with a historic fault stored in memory.

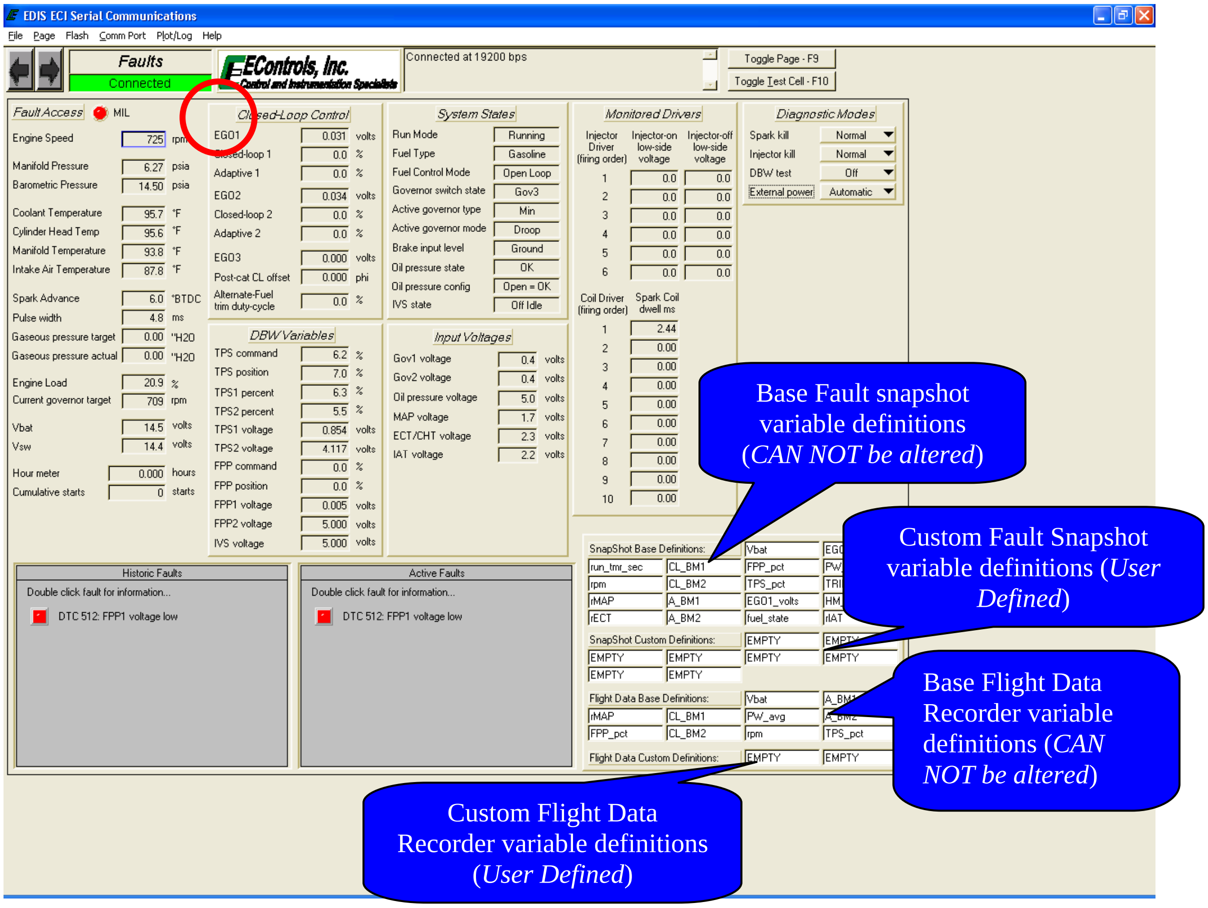


Figure 2: - *Faults Page with Active Fault Message*

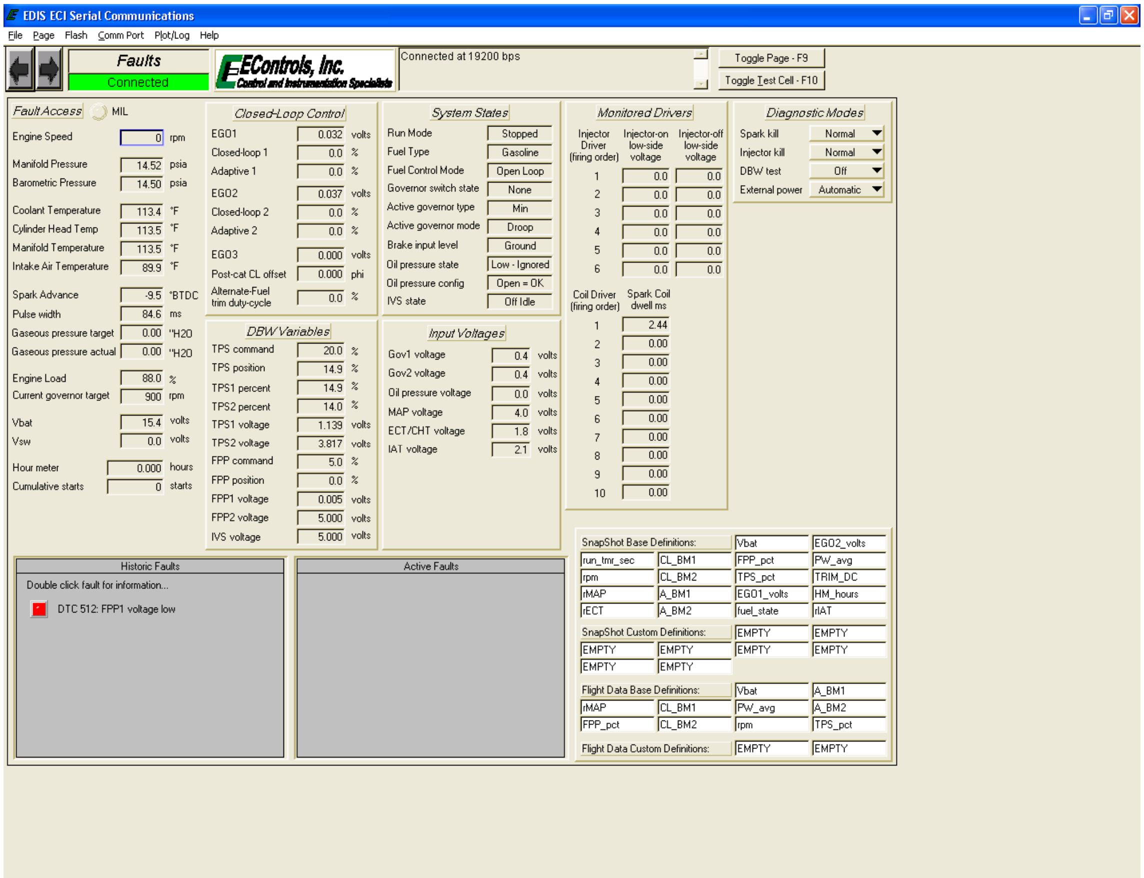


Figure 3: - *Faults Page with Historic Fault Message*

Once an active fault has occurred two sets of data are recorded, fault snapshot and flight data recorder. The fault snapshot (FSS) is a sample of data taken at the instance the fault triggered. Variables included in the FSS are defined in the Snapshot Base and Snapshot Custom Definition fields found on the Faults Page. A FSS is saved with each of the first eight (8) faults for the first time the fault becomes active. Conversely, the flight data recorder (FDR) is a ten-second stream of data that includes eight-seconds prior and two-seconds after triggering the fault. An FDR is saved for each of the first two (2) faults for the first time the fault becomes active. Variables included in the FDR are defined in the Flight Data Base and Flight Data Custom Definition fields found on the Faults Page. The memory location of the FDR is RAM, therefore this data is only available if the ECM has not lost battery power. In addition, if there is a “Dirty Flash Page” in the ECM, the FDR data will not be available. The memory location of the FSS data is EEPROM and is retained when the ECM loses battery power.

Both sets of data are accessed from the Historic Fault Information interface and can be saved to the PC upon retrieval. Base variables for FSS and FDR are generally defined by the OEM to include variables most often referenced during fault diagnosis. The base definitions are not fault dependent. Additional variables may be selected for capture during a fault occurrence through a single, left-click of the custom table and selecting the desired variables from a list. An example of custom fault variable definitions is shown in Figure **4**.

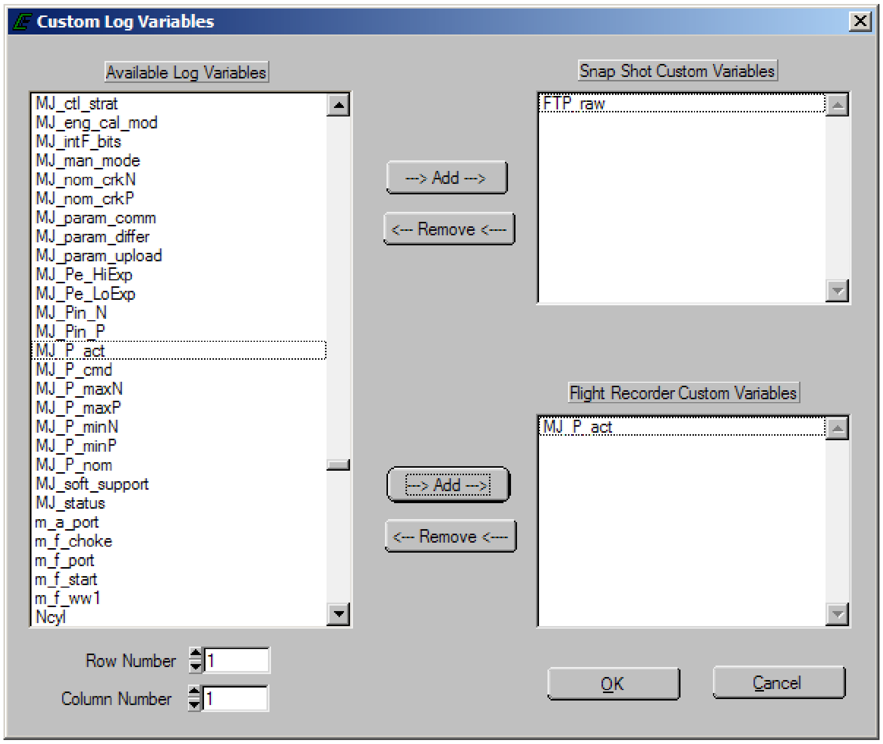


Figure 4: - *Custom Fault Variable Interface*

Accessing fault information is accomplished through a double left-click of the fault LED in the historic fault list. This produces the Historic Fault Information interface shown in Figure **5**. From this interface the user can interpret a diagnostic trouble code (DTC) message, identify whether or not the fault occurred during the current key cycle, identify if the fault caused the engine to shutdown, determine how many key cycles have occurred since the fault was last active, clear selected or all historic faults, and view snapshot and flight data. Table 4 outlines the options displayed in the Historic Fault Information screen. Historic faults are not overwritten if the same fault becomes active, storing data from the original active fault.

Figure **6** is an example of a fault snapshot after View Fault Snapshot is selected. Data is presented in two columns, base and custom variables. Once retrieved, the FSS data may be saved to the PC in text format with an *.fss* extension. A FSS saved to a PC may be reviewed in any ASCII based software program.

Figure **7** shows the Flight Data Recorder interface after View Flight Data Recorder is selected. The FDR captures a ten second (eight seconds prior and two seconds after generating the fault) strip of data for base and custom variables. FDR data is presented in an interface similar to the Plot interface for a quick graphical presentation. From this interface, the FDR data may be saved to the PC in text, tab-delimited format with an *.fdr* file extension. Once saved to PC, FDR data may be reviewed using any graphical post-processing software capable of handling tab-delimited formatting.
Fault information may be manually erased using the “Clear” button functions. Once a “Clear” function has been selected, the dialog prompt shown in Figure **8** will be displayed. Choosing YES deletes all fault information from the ECM.

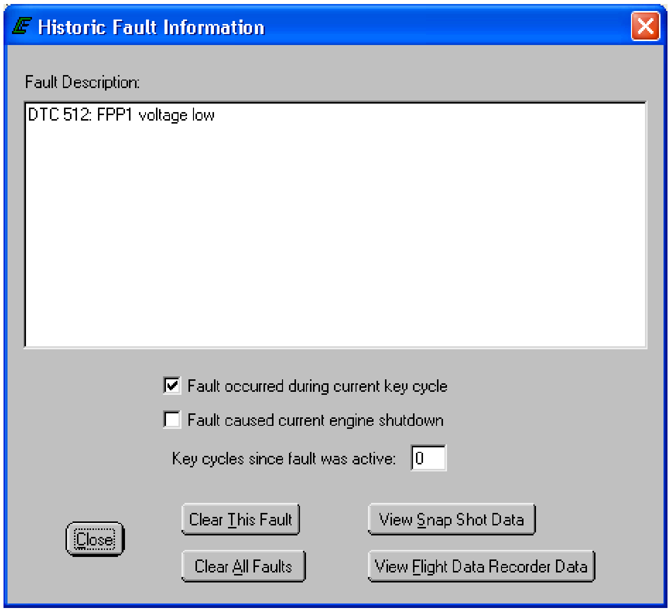


Figure 5: - *Historic Fault Information Interface*

Table 4: Historic Fault Information Interface Functions

Fault Description Message Box	Customized text that references the DTC flash code and describes the fault.
Fault During Key Cycle Checkbox	Informs that the fault occurred during the current key-on event.
Fault Caused Engine Shutdown Checkbox	Informs that the fault caused the engine to shutdown.
Key Cycles Since Fault Active Indicator	Displays the amount of key-on events since the fault was last active.
Clear This Fault Button*	Erases the selected historic fault from the ECM.
Clear All Faults Button*	Erases all historic faults from the ECM.
View Snap Shot Data Button	Retrieves a data “snap shot” from the ECM for variables defined in the base and custom snapshot variable definition lists. An example of a fault snap shot is shown in Figure **6**.
View Flight Data Recorder Data Button	Retrieves a 10-second data strip chart (8 seconds prior, 2 seconds after fault trigger) from the ECM for variables defined in the base and custom flight data recorder definition lists. An example of a fault snap shot is shown in Figure **7**.
Close Button	Exits the Historic Fault Information interface. DOES NOT cancel or clear any faults.
* Snapshot and flight data recorder data for historic faults is erased after the prompt shown in Figure **8** is satisfied	

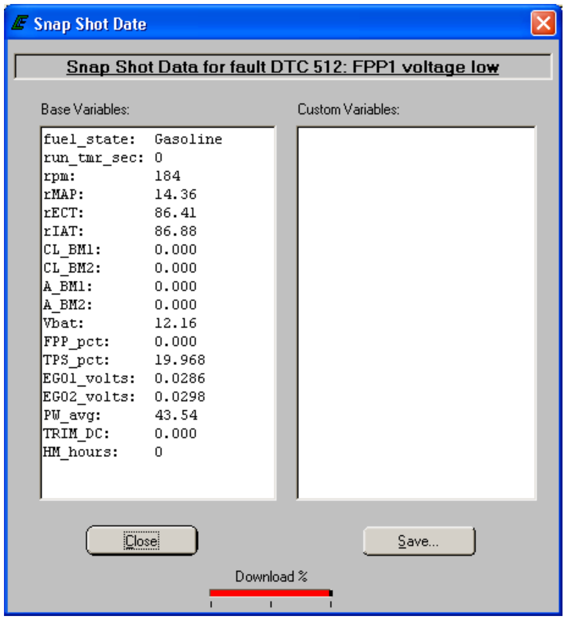


Figure 6: - *Snapshot Data Interface*

Figure 7: - *Flight Data Recorder Interface*

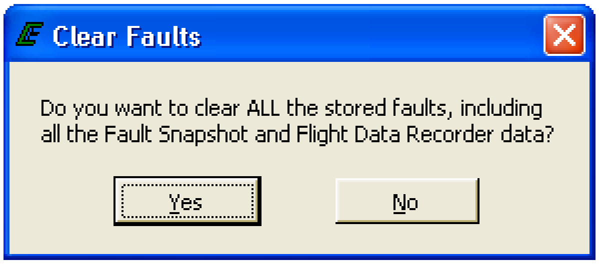


Figure 8: - *Clear Faults Prompt*

DIAGNOSTIC TESTS

The GCP engine control module for spark-ignited engine applications incorporates a set of twelve (12) diagnostic tests that perform specific functions used as an aid for verifying proper engine control. This section describes the tests supported, test states, and operating criteria for each test.

Diagnostic tests are software selectable via RS-232 communication through the EDIS and EControls supplied gcp_dll.dll using the ECIPP protocol or can be initiated via CAN using CCP.

Spark Kill Test

"Coil X" disables individual cylinders at any operating condition for the duration defined in calibration or until released through software. 'Spark Kill' may be used in conjunction with 'Injector Kill' to disable two cylinders at any given time. Upon a state change from one cylinder to another, the test sequence will automatically re-enable the first coil prior to disabling the selected coil. This test reverts to normal operation if "Normal" state is selected, ignition voltage is cycled from high to low, or the calibrated timeout expires.

⚠ ***NOTE: This test should not be initiated prior to the "Injector Kill" test when the engine is equipped with a catalyst. If performed while the injector for the selected cylinder is firing, raw-unburned fuel and air will be present in the exhaust and will react in the catalyst resulting in extremely high catalyst substrate temperatures which can cause wash coat or substrate damage and failure.***

States

1) Normal: State of normal operation
2) Coil 1: Disables coil or spark for cylinder 1 in firing order
3) Coil 2: Disables coil or spark for cylinder 2 in firing order
4) Coil 3: Disables coil or spark for cylinder 3 in firing order
5) Coil 4: Disables coil or spark for cylinder 4 in firing order
6) Coil 5: Disables coil or spark for cylinder 5 in firing order
7) Coil 6: Disables coil or spark for cylinder 6 in firing order
8) Coil 7: Disables coil or spark for cylinder 7 in firing order
9) Coil 8: Disables coil or spark for cylinder 8 in firing order

Monitored Status

1) Test not started
2) Test is running
3) Test finished (timeout achieved)
4) ~~Error: Pre-condition 1 not fulfilled~~
5) ~~Error: Pre-condition 2 not fulfilled~~
6) ~~Error: Pre-condition 3 not fulfilled~~
7) ~~Error: Pre-condition 4 not fulfilled~~
8) Cannot start test

Injector Kill Test

"Inj X" disables individual cylinders at any operating condition for the duration defined in calibration or until released through software. 'Injector Kill' may be used in conjunction with 'Spark Kill' to disable two cylinders at any given time. Upon a state change from one cylinder to another, the test sequence will automatically re-enable the first injector prior to disabling the selected injector. Reverts to normal operation if "Normal" state is selected, ignition voltage is cycled from high to low, or the calibrated timeout expires.

States

1) Normal: State of normal operation
2) Inj 1: Disables injector 1 in firing order
3) Inj 2: Disables injector 2 in firing order
4) Inj 3: Disables injector 3 in firing order
5) Inj 4: Disables injector 4 in firing order
6) Inj 5: Disables injector 5 in firing order
7) Inj 6: Disables injector 6 in firing order
8) Inj 7: Disables injector 7 in firing order
9) Inj 8: Disables injector 8 in firing order

Monitored Status

1) Test not started
2) Test is running
3) Test finished (timeout achieved)
4) ~~Error: Pre-condition 1 not fulfilled~~
5) ~~Error: Pre-condition 2 not fulfilled~~
6) ~~Error: Pre-condition 3 not fulfilled~~
7) ~~Error: Pre-condition 4 not fulfilled~~
8) Cannot start test

NOTE: This test should not be initiated at high loads or for more than five (5) seconds if the engine is equipped with a catalyst. If done so, a large quantity of oxygen will fuel undesirable reactions in the catalyst resulting in extremely high catalyst substrate temperatures which can cause wash coat or substrate damage and failure.

Injector Fire Test

"Inj X" activates a selected injector for a finite duration with the engine in the "Stopped" state only. Upon initiation of the test, the fuel pump relay will remain disabled and the injector will fire. The injector on-time will be calibrated in software to allow a noticeable pressure drop at the fuel rail. The test reverts to normal operation if the "Normal" state is selected, ignition voltage is cycled from high to low, engine speed is sensed, or the calibrated timeout expires. Once an injector on test has been run, subsequent injectors may only be activated/tested after the engine has achieved *X* cranking revolutions (as defined in calibration) and the engine has stopped. This test may not be run in conjunction with a Spark Fire or Compression test.

States

1) Disabled: State of normal operation
2) Inj 1: Activates injector 1 in firing order
3) Inj 2: Activates injector 2 in firing order
4) Inj 3: Activates injector 3 in firing order
5) Inj 4: Activates injector 4 in firing order
6) Inj 5: Activates injector 5 in firing order
7) Inj 6: Activates injector 6 in firing order
8) Inj 7: Activates injector 7 in firing order
9) Inj 8: Activates injector 8 in firing order

Monitored Status

1) Test not started
2) Test is running
3) Test finished (timeout is reached)
4) ~~Error: Pre-condition 1 not fulfilled~~
5) ~~Error: Pre-condition 2 not fulfilled~~
6) ~~Error: Pre-condition 3 not fulfilled~~
7) ~~Error: Pre-condition 4 not fulfilled~~
8) Cannot start test (engine speed is sensed or engine needs to crank)

Spark Fire Test

"Coil X" activates a selected coil for X seconds (defined in calibration) with the engine in the "Stopped" state only. The coil will be fired at a rate equivalent to 1600 RPM/14.5 psi. The test reverts to normal operation if the "Normal" state is selected, ignition voltage is cycled from high to low, engine speed is sensed, or the calibrated timeout expires. This test will not run in conjunction with a Compression test or following an Injector Fire test.

States

1) Disabled: State of normal operation
2) Coil 1: Activates Coil 1 in firing order
3) Coil 2: Activates Coil 2 in firing order
4) Coil 3: Activates Coil 3 in firing order
5) Coil 4: Activates Coil 4 in firing order
6) Coil 5: Activates Coil 5 in firing order
7) Coil 6: Activates Coil 6 in firing order
8) Coil 7: Activates Coil 7 in firing order
9) Coil 8: Activates Coil 8 in firing order

Monitored Status

1) Test not started
2) Test is running
3) Test finished (timeout is reached)
4) ~~Error: Pre-condition 1 not fulfilled~~
5) ~~Error: Pre-condition 2 not fulfilled~~
6) ~~Error: Pre-condition 3 not fulfilled~~
7) ~~Error: Pre-condition 4 not fulfilled~~
8) Cannot start test (speed is sensed)

NOTE: This test should not be initiated on gaseous fueled engines in which gaseous fuel may be present in the combustion chamber, intake, or exhaust. If using this test is desirable on gaseous fueled engines, remove the spark plug wires from all spark plugs, install a spark plug tester in the desired spark plug wire and initiate the test.

DBW Test

Permits full-authority operation of an electronic throttle via the throttle command input while the engine is in the "Stopped" state only. Reverts to normal operation if "Off" state is selected, ignition voltage is lost, or engine speed is sensed.

NOTE: Ensure that the foot pedal position sensor/electronic throttle control input is at 0% or idle prior to starting/operating the engine. While this test mode will revert to disabled when engine speed is sensed, the throttle command will follow the FPP % commanded by the sensor causing the engine to accelerate.

States

1) Off: State of normal operation
2) Enabled: Enables full authority control of an electronic throttle

Monitored Status

1) Test not started
2) Test is running
3) Test finished
4) ~~Error: Pre-condition 1 not fulfilled~~
5) ~~Error: Pre-condition 2 not fulfilled~~
6) ~~Error: Pre-condition 3 not fulfilled~~
7) ~~Error: Pre-condition 4 not fulfilled~~
8) Cannot start test (speed is sensed)

External Power Test

Manually activates relays (relay power, fuel pump, and drive-by wire power) controlled by the ECM while the engine is in the "Stopped" or "Running" states. Reverts to normal operation if "Automatic" state is selected or ignition voltage is cycled from high to low.

States

1) Automatic: State of normal operation
2) Relay On: Activates relay power (injector and coil high-side power)
3) All On: Activates fuel pump and relay power

Monitored Status

1) Test not started
2) Test is running
3) Test finished
4) ~~Error: Pre-condition 1 not fulfilled~~
5) ~~Error: Pre-condition 2 not fulfilled~~
6) ~~Error: Pre-condition 3 not fulfilled~~
7) ~~Error: Pre-condition 4 not fulfilled~~
8) Cannot start test (no ignition voltage)

IAC Test

Commands the idle air control (IAC) motor to perform a “home” sequence and reset. The reset procedure may be selected such that it will cause the IAC to travel to the full-closed stop (“Stopped” or “Running”) or the full-open stop (“Stopped” only) and back to the ECM commanded position. The test reverts to “Normal” operation upon completion of the procedure or if the abort command is requested (Normal).

NOTE: In some instances, the engine may stall if the test is performed while “Running.”

States

1) Disabled: State of normal operation
2) Closed-Home Sequence: Resets IAC with full-closed homing sequence
3) Full-Open Sequence: Resets IAC with full-open homing sequence (“Stopped” engine ONLY)

Monitored Status

1) Test not started
2) Test is running
3) Test finished
4) ~~Error: Pre-condition 1 not fulfilled~~
5) ~~Error: Pre-condition 2 not fulfilled~~
6) ~~Error: Pre-condition 3 not fulfilled~~
7) ~~Error: Pre-condition 4 not fulfilled~~
8) Cannot start test (State 2: Engine speed is sensed)

Compression Test

Disables all coils and injectors permitting cylinder compression testing. To prevent against firing coils and injectors in the event of a microprocessor reboot during low voltage cranking, the test state will be burned into EEPROM. In addition, EControls Inc. requires that the relay power fuse be removed. This test may only be activated while the engine is in the "Stopped" state. Test reverts to normal operation only when the "Normal" state is selected. This test may be initiated by selecting "Enabled" in the software or through use of a switched hardware input. This test may not be run in conjunction with Spark Fire or Injector Fire tests.

NOTE: Due to the liability of initiating a compression test in software, EControls Inc. burns this test state into EEPROM. As a result, this test must manually be disabled by the operator through software. EControls Inc. recommends that this test only be performed while the vehicle is in an appropriate location in the event that the diagnostic PC has a low-battery condition that may not permit re-enabling normal operation.

States

1) Disabled: State of normal operation
2) Active: Enables compression test mode

Monitored Status

1) Test not started
2) Test is running
3) Test finished
4) ~~Error: Pre-condition 1 not fulfilled~~
5) ~~Error: Pre-condition 2 not fulfilled~~
6) ~~Error: Pre-condition 3 not fulfilled~~
7) ~~Error: Pre-condition 4 not fulfilled~~
8) Cannot start test (engine run speed is sensed > than crank speed)

NOTE: Due to the personal and property liability exposure with such a test, EControls requires that the diagnostic/service manual specifically identifies that removal of the coil and injector high-side relay and/or fuse(s) is required during a compression test. If procedures are not written that require removal of the relay power relay or fuse(s) and the test will only be enable through software, EControls Inc. will require a written release-of-liability against human liability and property damage.

Spark Advance Test

Commands a calibrated base spark advance if engine speed and manifold pressure are below a calibrated limit. If engine is operated above the calibrated operating limit, base spark advance as set in the normal calibration will be used until the engine set point falls below the calibrated limit. This test may be initiated by selecting "Enabled" in the software or through use of a switched hardware input. The test reverts to normal operation when "Normal" state is selected or when ignition voltage is cycled from high to low.

States

1) Disabled: State of normal operation
2) Active: Sets spark timing to a calibrated default spark advance

Monitored Status

1) Test not started
2) Test is running
3) Test finished
4) ~~Error: Pre-condition 1 not fulfilled ("RPM/MAP too high)~~
5) ~~Error: Pre-condition 2 not fulfilled~~
6) ~~Error: Pre-condition 3 not fulfilled~~
7) ~~Error: Pre-condition 4 not fulfilled~~
8) Cannot start test

Idle Speed Command

Commands a temporary idle speed, up to X RPM as defined in calibration through modulation of an IAC motor or an electronic throttle. Reverts to normal operation when "Normal" state is selected, a throttle command input (for electronic throttle engines) above X% (defined in calibration) is detected, a throttle position (for IAC engines) above X% (defined in calibration) is detected, or ignition voltage is cycled from high to low.

States

1) Disabled: State of Normal operation
2) Active: Enables manual entry of engine speed into a speed entry field
3)

Monitored Status

1) Test not started
2) Test is running
3) Test finished (TPS or TCP % above limit is detected during test)
4) ~~Error: Pre-condition 1 not fulfilled~~
5) ~~Error: Pre-condition 2 not fulfilled~~
6) ~~Error: Pre-condition 3 not fulfilled~~
7) ~~Error: Pre-condition 4 not fulfilled~~
8) Cannot start test (TPS or TCP % above limit is detected)

⚠ ***NOTE:* EControls will not permit programmed idle speeds above 800 RPM without a written release-of-liability if the engine is not equipped with a transmission position sensor.**

Fuel/Spark Inhibit Input

Disables triggering of spark and injection of fuel when the input (analog or digital) selected meets the calibrated state. This is often linked to the fuel select switch as a neutral mode.

States

1) Disabled
2) Aux PU1 = Gnd
3) Aux PU2 = Gnd
4) Aux PU3 = Gnd
5) Aux DIG1 = Gnd
6) Aux DIG1 = V+
7) Aux DIG2 = Gnd
8) Aux DIG2 = V+
9) Aux DIG3 = Gnd
10) Aux DIG3 = V+
11) Aux DIG4 = Gnd
12) Aux DIG4 = V+
13) Aux DIG1 = Open
14) Aux DIG2 = Open
15) Aux DIG3 = Open
16) Aux DIG4 = Open

Monitored Status

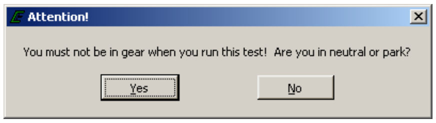
1) Inactive/Normal: Test is inactive, state of normal operation
2) Active/Shutdown: Test is active and system will not inject fuel or trigger spark

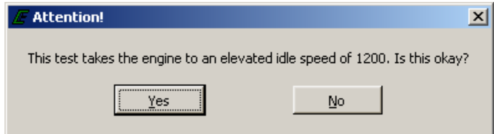
Closed-Loop Test

Tests the closed-loop fueling feedback system to verify that exhaust gas oxygen sensors are properly functioning and are providing reliable information. The test runs in the order defined below and aborts if at any time an error/fault is identified, the throttle input is elevated, or the operator requests the test to STOP. Aborting the test due to identification of an error/fault requires that the service technician addresses the identified error and then repeats the test to fully validate the system.

1. Enable Strategy and HEGO Sensors (*CL Test State*= Pre-cat init test)

a. The test mode is entered by selecting START from EDIS. Once initiated, the user must acknowledge two prompts prior to the test running. These prompts require that the vehicle be in neutral or park and notify the user that the engine speed will increase to run the test. Answering YES to both of these prompts will initiate the test.





NOTE: EControls requires that 3rd party diagnostic scan tools also use similar prompts to notify the operator to ensure idle or park is selected and to notify that an elevated speed will be commanded during the test.

a. Govern engine to X RPM as defined in the calibration. NOTE: Test disables if FPP% exceeds the % used in Idle Speed Command Test (Tidlspd_FPP_max)

b. Turn all configured EGO heaters on according to 'EGOZ Heater-Control Target Impedance / Voltage Limit Schedule'.

NOTE: EGO heater control during this phase uses the run time and heater impedance target schedule, including the heater voltage limits, until the heaters are operating at the final impedance target.

c. *CL pre-cat test status* will indicate "Test Running" through steps 2-3.

2. Pre-Catalyst EGO Heater Diagnosis (*CL Test State*= Pre-cat heater & pre-cat power test)

- *The purpose of this portion of the test is:*

1. To validate that the pre-catalyst EGO heater element(s) are capable of heating the sense element(s) to a useable state.

2. To validate that the pre-catalyst sense element(s) are operating at the desired temperature.

a. Monitor EGO impedance feedback and verify impedance ≤ 'EGO impedance active threshold'; this stage runs up to the maximum run time in the 'EGOZ Heater-Control Target Impedance / Voltage Limit Schedule' + 'EGO Heater Additional Wait Time'. If this check fails for any of the pre-catalyst sensors the *CL pre-cat test status* will indicate "Pre or Post-cat EGO Lazy" and the appropriate EGO Lazy fault for the sensor(s) is set.

b. In addition, the system monitors EGO impedance feedback and verifies that impedance is equal to the fully warm 'EGOZ Impedance Target' + 'EGO Heater Impedance Max Error'. If any EGO impedance fails to reach the final target plus the impedance error tolerance the heater power is deemed low , the *CL pre-cat test status* "Pre-cat EGO Power Low" is generated, and the appropriate EGO Lazy fault for the sensor(s) is set. Once all pre-catalyst EGOs have reached the active threshold ('Pre-cat EGO impedance active threshold) the closed-loop system is activated and fueling perturbation begins at the nominal fueling target defined in the test setup parameters.

3. Pre-Catalyst EGO Sensor Check (*CL Test State*= Pre-cat voltage test & Pre-cat BM test)

- *The purpose of this portion of the test is:*

1. To validate that the pre-catalyst EGO sensor feedback is perturbating and providing feedback that correlates to commanded fueling excursions.

2. *Attempt to identify leaks within the pre-catalyst sensor assembly and/or the exhaust system and/or identify significant fuel delivery problems.*

a. Once all pre-catalyst EGOs have reached the active threshold ('Pre-cat EGO impedance active threshold') closed-loop is activated and fueling perturbation begins at the nominal fueling target defined in the test setup parameters. During this time, adaptive learn is disabled and the fueling error is monitored (CL_BM). Once the closed-loop system validates a certain number of EGO switches, the total fueling correction (CL_BM+A_BM) is compared to allowable fueling correction limit for the test ('CL + adapt multiplier max value').

b. If the fueling correction is within the limits defined in the calibration, the *CL pre-cat test status* will indicate "Test Finished: Passed."

c. This portion of the test will fail if the EGO fails to generate the required number of switching cycles or if the fueling correction is outside of the acceptable limits. The *CL pre-cat test status* will indicate "Pre-cat EGO non-responsive" or "Pre-cat EGO fueling error" status, respectively. In addition, the appropriate "Closed-Loop High/Low" fault will be generated if this check fails.

4. Post-Catalyst EGO Heater Diagnosis (*CL Test State*= Post-cat heater test & post-cat power test)

- *The purpose of this portion of the test is:*

1. *To validate that the post-catalyst EGO heater element(s) are capable of heating the sense element(s) to a useable state.*
2. *To validate that the post-catalyst sense element(s) are operating at the desired temperature.*

a. Upon successful completion of the pre-catalyst EGO test checks, the system begins to monitor the post-catalyst sensor(s). The first check is to monitor EGO impedance feedback and verify impedance ≤ 'EGO impedance active threshold'; this stage runs up to the maximum run time in the 'EGOZ Heater-Control Target Impedance / Voltage Limit Schedule' + 'EGO Heater Additional Wait Time'. If this check fails for any of the post-catalyst sensors the *CL post-cat test status* will indicate "Post-cat EGO Lazy" and the appropriate EGO Lazy fault for the sensor(s) is set.

b. In addition, the system monitors EGO impedance feedback and verifies that impedance is equal to the fully warm 'EGOZ Impedance Target' + 'EGO Heater Impedance Max Error'. If any EGO impedance fails to reach the final target plus the impedance error tolerance the heater power is deemed low , the *CL post-cat test status* "Post-cat EGO Power Low" is generated, and the appropriate EGO Lazy fault for the sensor(s) is set. Once all post-catalyst EGOs have reached the active threshold ('Post-cat EGO impedance active threshold) the rich/lean test is run on the post-catalyst sensors.

5. Post-Catalyst EGO Sensor Check (*CL Test State*= Post-cat rich test & Post-cat lean test)

- *The purpose of this portion of the test is:*

1. *To validate that the post-catalyst EGO sensor feedback is changing as a result of significant changes in pre-catalyst fueling.*

a. Command nominal fueling while applying the fueling multiplier(s) generated during the 'CL pre-cat voltage test' mode (step 3a).

b. Command a rich open-loop fueling command as defined in the calibration and monitor the post-catalyst EGO voltage feedback to verify that the sensor's rich feedback is within tolerance.

c. Command a lean open-loop fueling command as defined in the calibration and monitor the post-catalyst EGO voltage feedback to verify that the sensor's lean feedback is within tolerance.

d. If the post-catalyst EGO voltage feedback is within the limits defined in the calibration, the *CL post-cat test status* will indicate "Test Finished: Passed" and the *CL Test State* will indicate "Finished." If post-cat voltage(s) fall outside of the rich/lean limits, *CL post-cat test status* will indicate "Post-cat EGO Rich Failure" or "Post-cat EGO Lean Failure" and the EGO Lazy fault will be set for the appropriate sensor, respectively.

The engine will return to idle upon completion or abortion of the of the closed-loop diagnostic test.

NOTE: Be sure to check CL Test State, CL pre-cat test status, and CL post-cat test status to determine if the test was successful. If the test failed for ANY reason, faults will be displayed and configured system alarm(s) (soft warning, hard warning, or MIL) will be generated. Technicians should clear faults after running the Closed-Loop Test.

States (CL Test State)

1) Inactive
2) Pre-cat init test
3) Pre-cat heater test
4) Pre-cat power test
5) Pre-cat voltage test
6) Pre-cat BM test
7) Post-cat heater test
8) Post-cat power test
9) Post-cat rich test
10) Post-cat lean test
11) Finished
12) Invalid

Pre-Catalyst Monitored Status (CL Pre-Cat Test Status)

1) Test Not Started
2) Test Running
3) Test Finished: Passed
4) Pre-cat EGO Lazy (generates appropriate EGO Lazy fault)
5) Pre-cat EGO Power Low
6) Pre-cat EGO non-responsive
7) Pre-cat EGO fueling error
8) Cannot start test (FPP or TCP % above limit is detected)

Post-Catalyst Monitored Status (CL Post-Cat Test Status)

1) Test Not Started
2) Test Running
3) Test Finished: Passed
4) Post-cat EGO Lazy (generates appropriate EGO Lazy fault)

5) Post-cat EGO Power Low
6) Post-cat EGO Rich Failure
7) Post-cat EGO Lean Failure
8) Cannot start test (FPP or TCP % above limit is detected)

Diagnostic Trouble Code Fault Descriptions

LDGCP and MGCP header pins are in standard font, HDGCP and MDGCP header pins are in italicized parentheses *(##)*.

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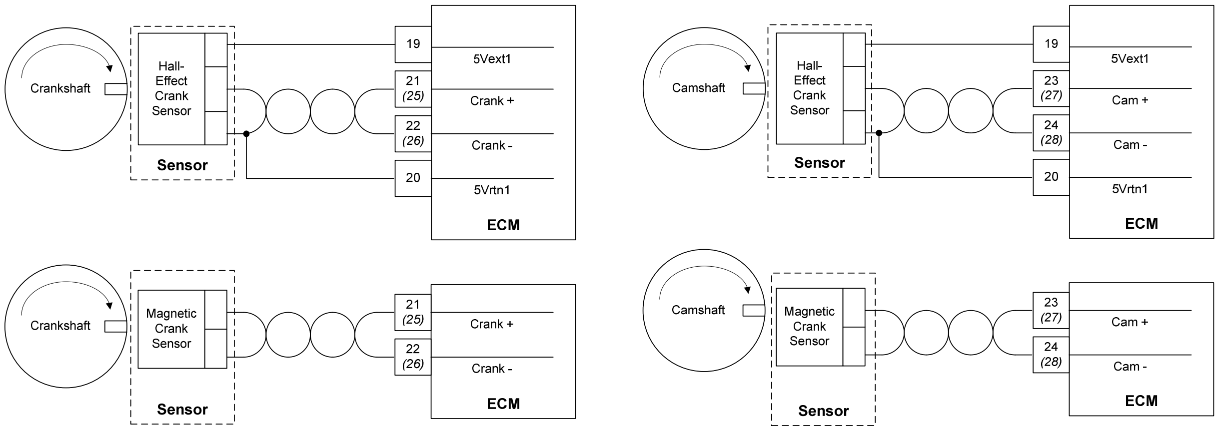
DIAGNOSTIC TROUBLE CODE SECTION

DTC 16- Crank and/or Cam Could Not Synchronize During Start



- Hardware: Crankshaft Position Sensor/Camshaft Position Sensor Input Circuits
- Enabling Conditions: Engine Cranking or Running
- Set Conditions: Engine cranking longer than 4 revolutions above 90 rpm without crank and/or cam synchronization
- Corrective Action(s): Illuminate MIL and/or sound audible warning or illuminate secondary warning lamp
- Emissions related fault
- Possible causes: Mechanical misalignment between cam and crank, CMP or CKP signal (+)/ground (-) wires misplaced in connectors, bad ECM

The crankshaft position sensor is a magnetic sensor (variable reluctant/magnetic pick-up or hall-effect) installed in the engine block adjacent to a “coded” trigger wheel located on the crankshaft. The sensor-trigger wheel combination is used to determine crankshaft position (with respect to TDC cylinder #1 compression) and the rotational engine speed. Determination of the crankshaft position and speed is necessary to properly activate the ignition, fuel injection, and throttle governing systems for precise engine control.

The camshaft position sensor is a magnetic sensor (variable reluctant/magnetic pick-up or hall-effect) installed in the engine block or valve train adjacent to a “coded” trigger wheel located on or off of the camshaft. The sensor-trigger wheel combination is used to determine cam position (with respect to TDC cylinder #1 compression). Determination of the camshaft position is necessary to identify the stroke (or cycle) of the engine to properly activate the fuel injection system and ignition (for coil-on-plug engines) for precise engine control.

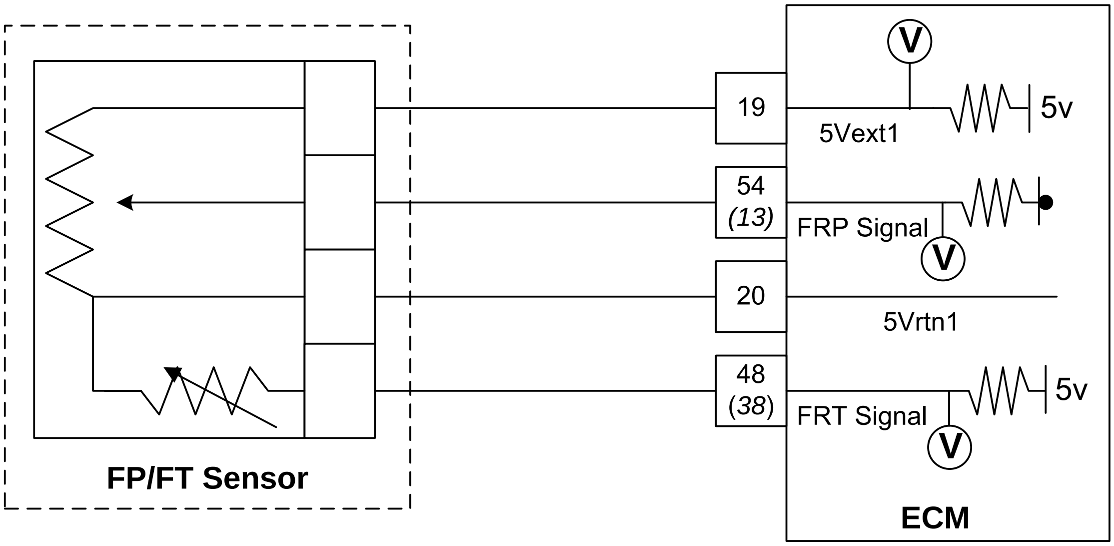
Typically, this fault will result in an engine that will not start or run.

DTC 16- Crank and/or Cam Could Not Synchronize During Start

Diagnostic Aids

- ☐ If there are any other CMP or CKP DTC's, diagnose them first
- ☐ Ensure that all 3 terminals are in the correct slot in the connector for both the CMP and the CKP sensors
- ☐ Ensure that the cam, crank and/or distributor are properly installed and timed
- ☐ Check that crankshaft and/or camshaft position sensor(s) is/are securely connected to harness
- ☐ Check that crankshaft and/or camshaft position sensor(s) is/are securely installed into engine block
- ☐ Check crankshaft and/or camshaft position sensor(s) circuit(s) wiring for open circuit
- ☐ Connect a 2 channel oscilloscope, scope CMP and CKP inputs and compare to known good waveforms

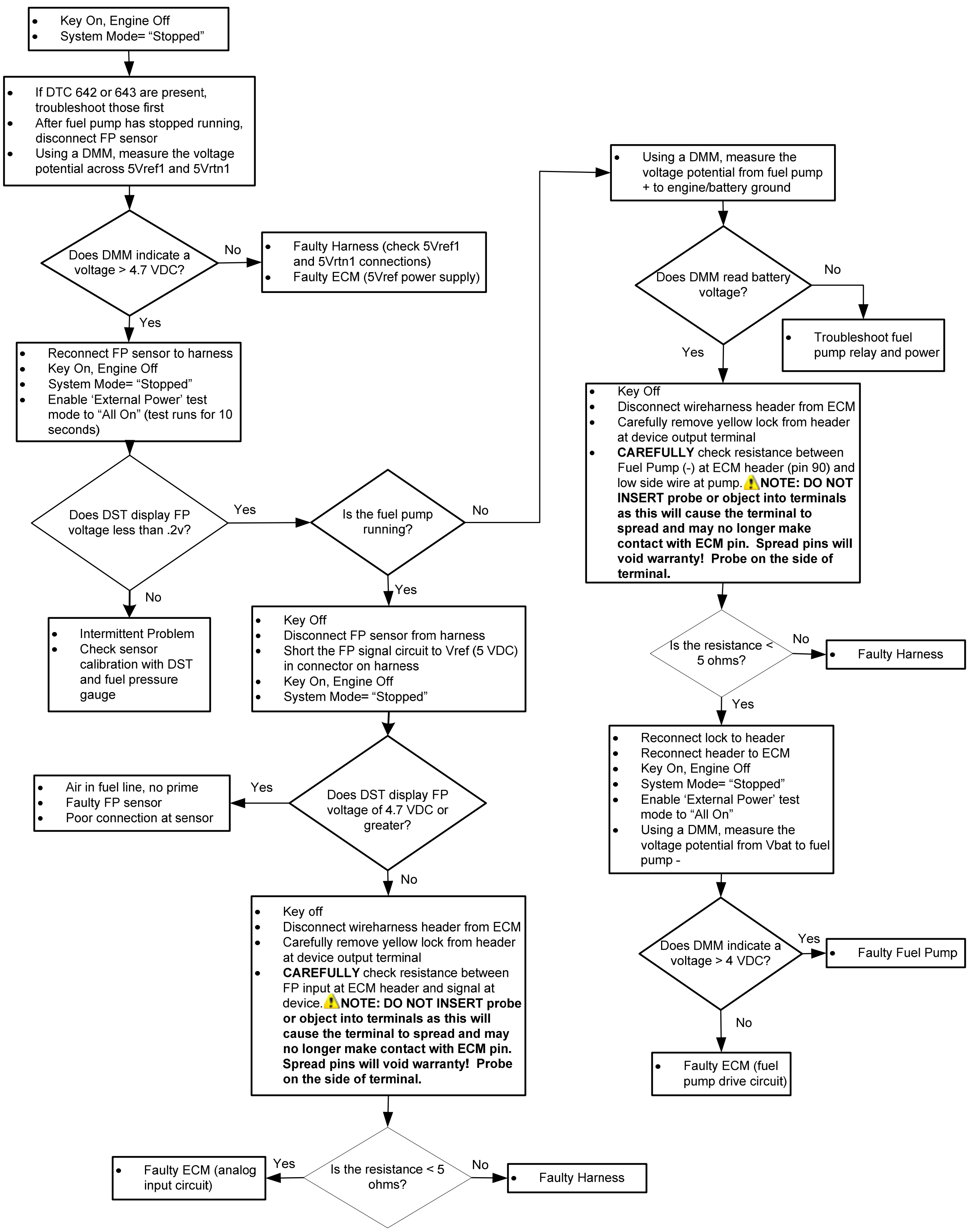
DTC 91- FP (Fuel Pressure Sensor) Low Voltage



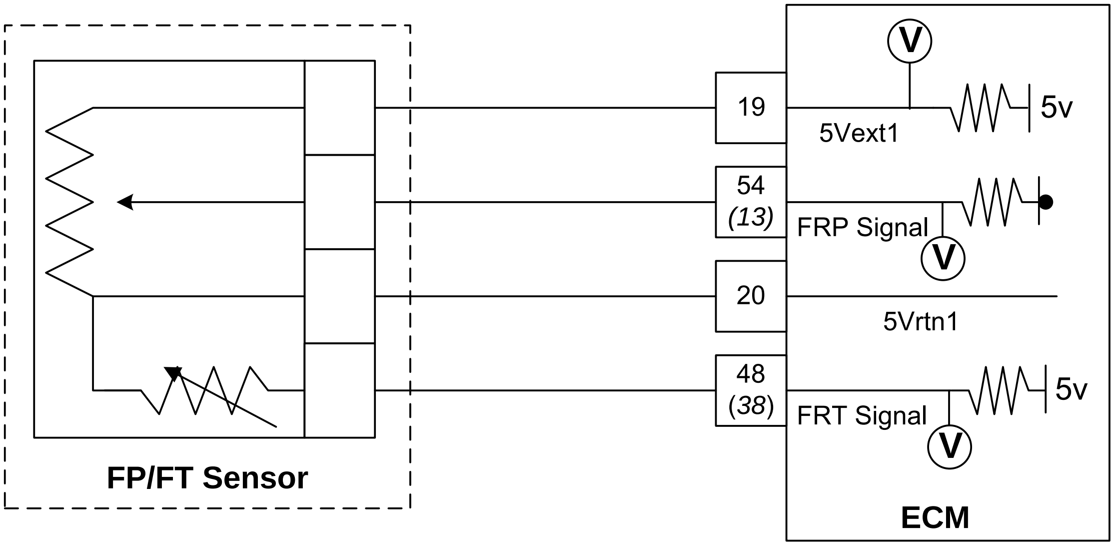
- Hardware: Liquid Fuel Pressure and Temperature Sensor
- Enabling Conditions: Engine Running
- Set Conditions: Fuel pressure feedback voltage lower than .2v for longer than 6 seconds
- Corrective Action(s): Illuminate the MIL and disable adaptive learn fueling correction for the rest of the key-cycle.
- Emissions related fault
- Possible Causes: FP sensor connector disconnected, an open-circuit or short-to-ground of the FP signal circuit in the wiring harness, a loss of sensor reference voltage, or a failure of the sensor.

The fuel pressure sensor is installed inline in the gasoline fuel supply line and is used to provide fuel pressure feedback to the ECM. The ECM sets a target rail pressure based on running conditions and then the fuel pump is PWM controlled through a low side driver in the ECM. The fuel pressure sensor feedback is used to determine when the actual rail pressure has reached the target rail pressure.

DTC 91- FP (Fuel Pressure) Low Voltage



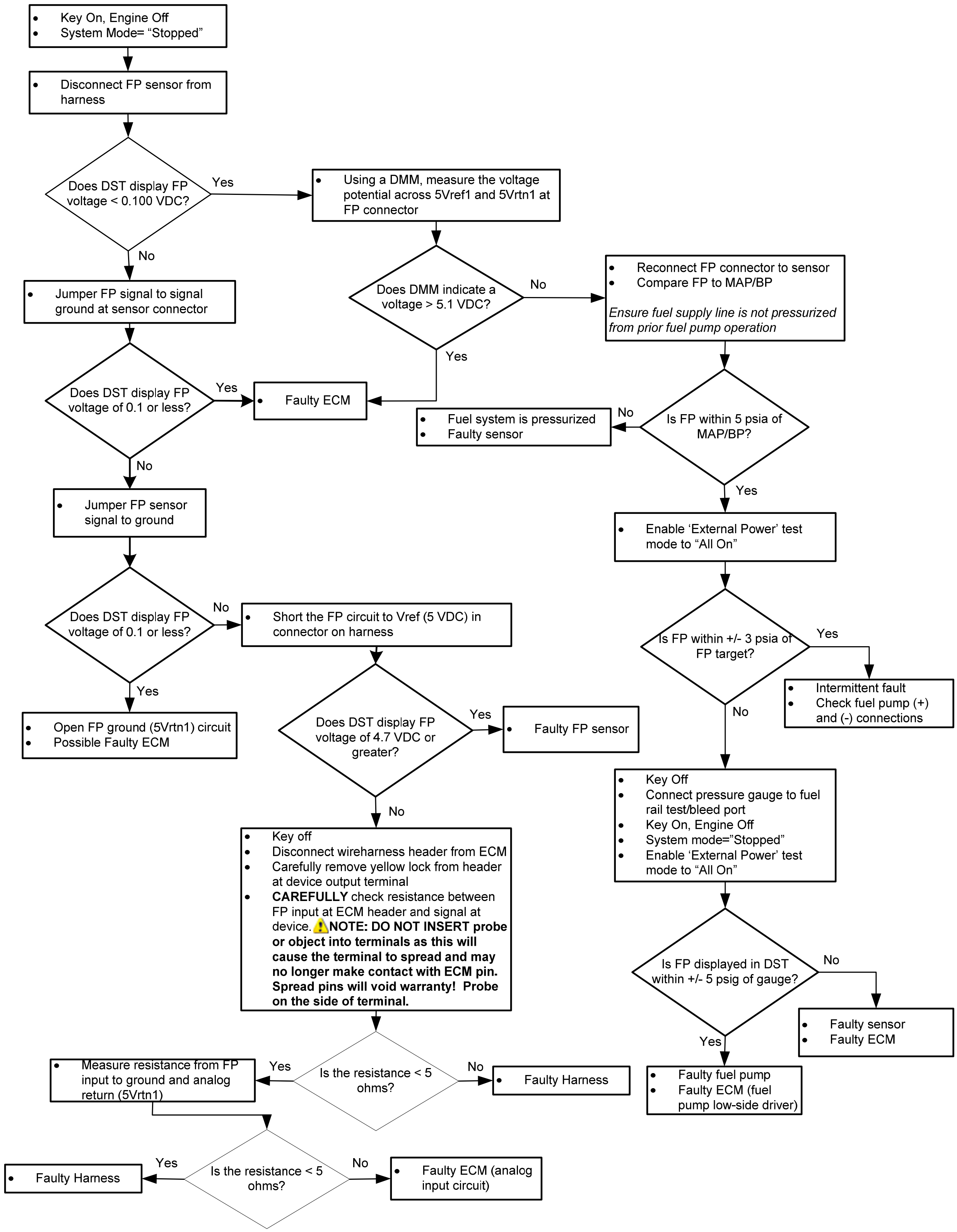
DTC 92- FP (Fuel Pressure Sensor) High Voltage



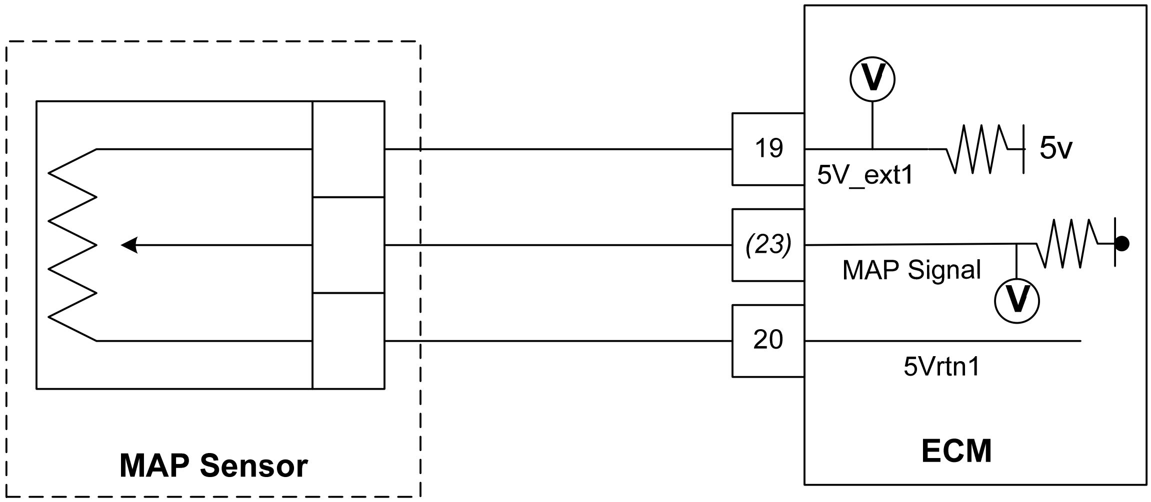
- Hardware: Liquid Fuel Pressure and Temperature Sensor
- Enabling Conditions: Engine Running
- Set Conditions: Fuel pressure feedback voltage higher than 4.8v for longer than 2 seconds.
- Corrective Action(s): Illuminate MIL and disable adaptive learn fueling correction for the rest of the key-cycle.
- Emissions related fault
- Possible Causes: FP signal circuit or 5v rtn1 open, open sensor or sensor signal shorted to voltage

The fuel pressure sensor is installed inline in the gasoline fuel supply line and is used to provide fuel pressure feedback to the ECM. The ECM sets a target rail pressure based on running conditions and then the fuel pump is PWM controlled through a low side driver in the ECM. The fuel pressure sensor feedback is used to determine when the actual rail pressure has reached the target rail pressure.

DTC 92- FP (Fuel Pressure Sensor) High Voltage



DTC 107- MAP Low Voltage

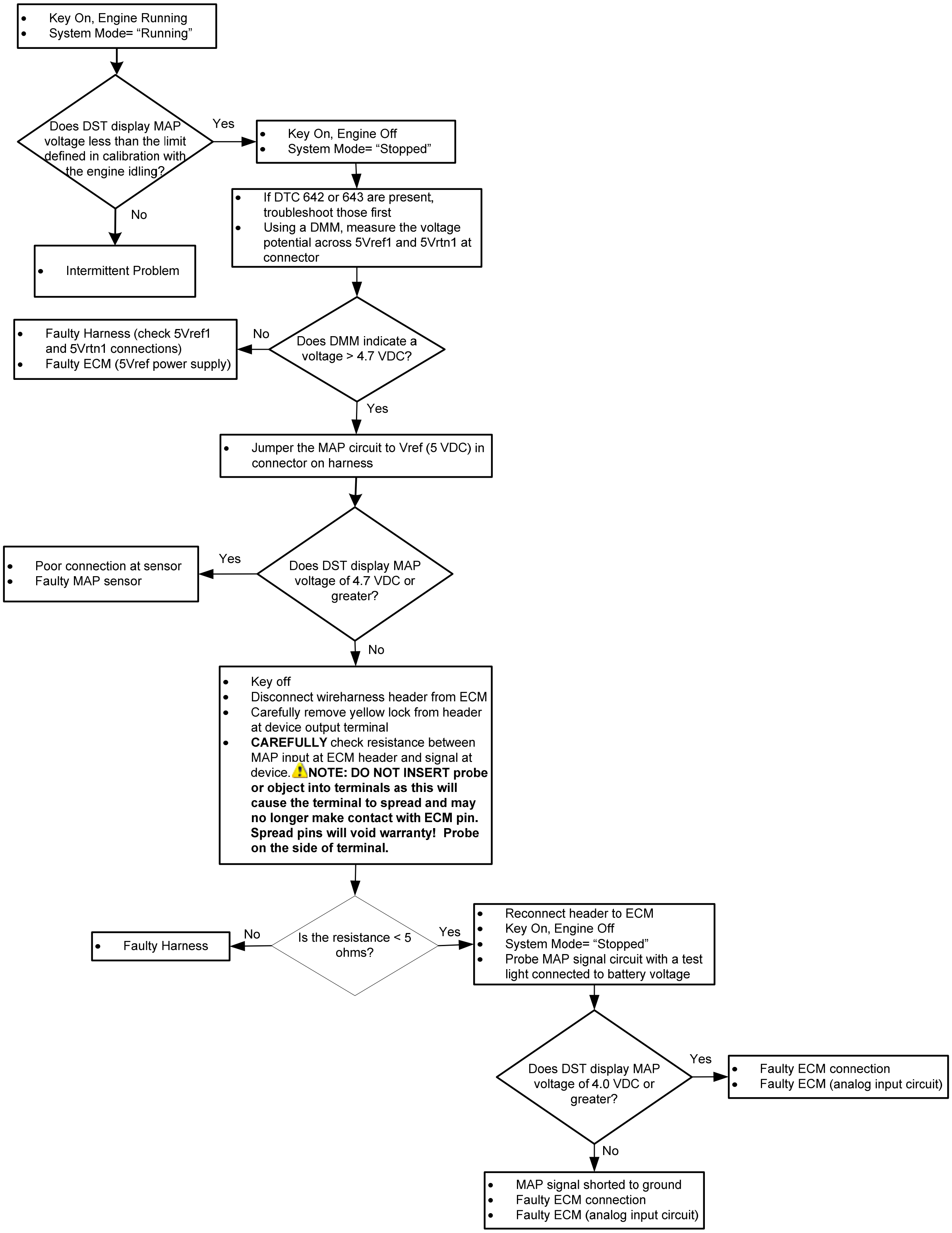


- Hardware: Manifold Absolute Pressure Sensor
- Enabling Conditions: Engine Cranking or Running
- Set Conditions: MAP sensor voltage feedback less than .05v when throttle position is greater than 5% and engine speed is less than 4000.
- Corrective Action(s): Illuminate MIL and disable adaptive learn fueling correction for the rest of the key-cycle.
- Emissions related fault
- Possible Causes: Loss of 5 volt reference feed to sensor, open or shorted to ground sensor signal wire, faulty sensor or faulty ECM.

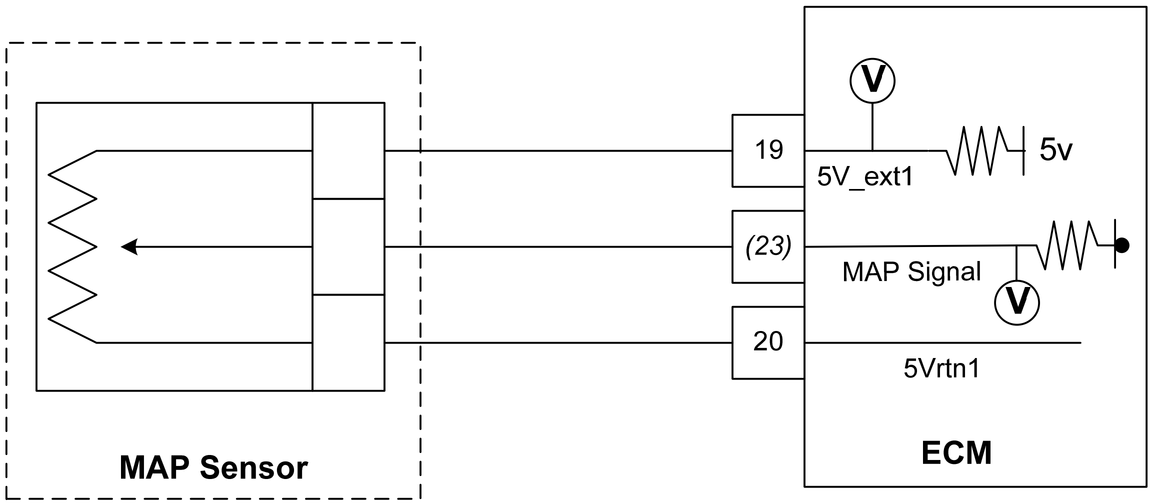
The Manifold Absolute Pressure sensor is a pressure transducer connected to the intake manifold. It is used to measure the pressure of air in the manifold prior to induction into the engine. The pressure reading is used in conjunction with other inputs to determine the rate of airflow to the engine. The rate of airflow into the engine is used to determine the required fuel flow rate.

When this fault is active, the ECM operates in a limp home mode in which an estimated MAP based on TPS feedback is used to fuel the engine.

DTC 107- MAP Low Voltage



DTC 108- MAP High Pressure

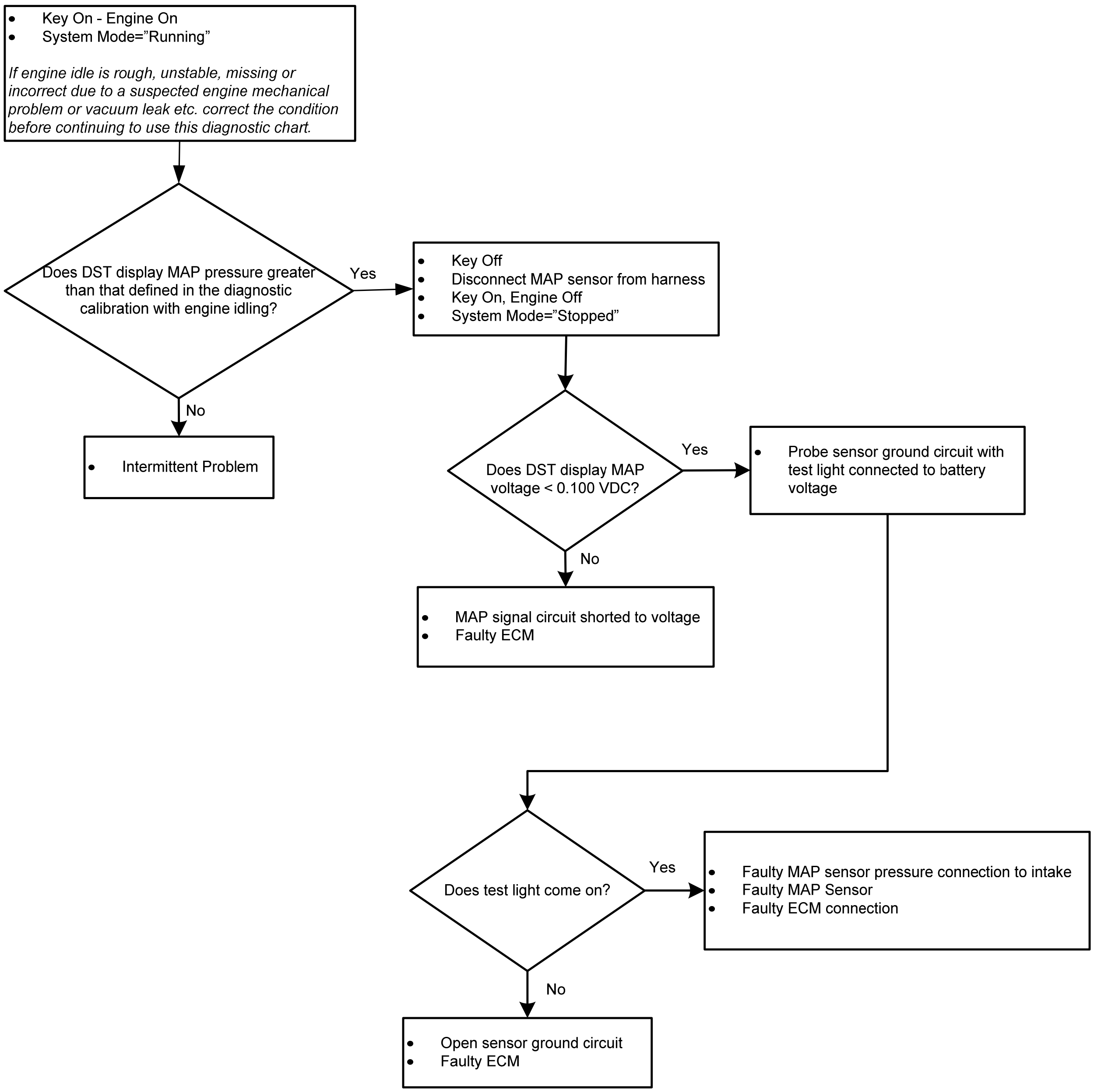


- Hardware: Manifold Absolute Pressure Sensor
- Enabling Conditions: Engine Cranking or Running
- Set Conditions: MAP is higher than 16 psi when throttle position is less than 3% and engine speed is greater than 1000 rpm.
- Corrective Action(s): Illuminate MIL and disable adaptive learn fueling correction for the rest of the key-cycle.
- Emissions related fault
- Possible Causes: 5v reference feed shorted to voltage, signal circuit shorted to voltage, open 5Vrtn1 (sensor ground), faulty sensor or faulty ECM.

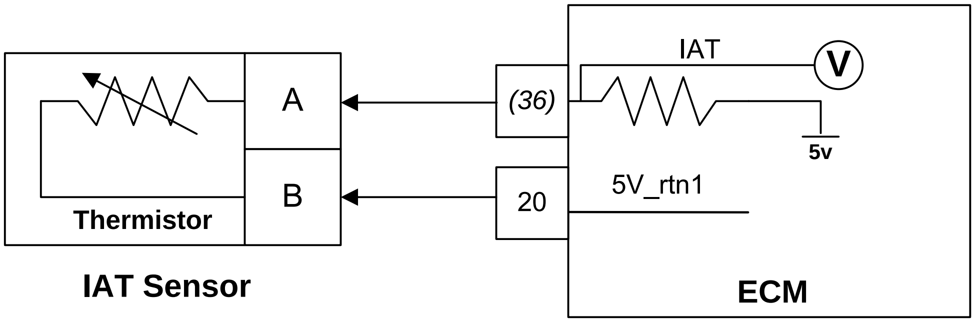
The Manifold Absolute Pressure sensor is a pressure transducer connected to the intake manifold. It is used to measure the pressure of air in the manifold prior to induction into the engine. The pressure reading is used in conjunction with other inputs to determine the rate of airflow to the engine. The rate of airflow into the engine is used to determine the required fuel flow rate.

When this fault is active, the ECM operates in a limp home mode in which an estimated MAP based on TPS feedback is used to fuel the engine.

DTC 108- MAP High Pressure



DTC 111- IAT Higher Than Expected Stage 1



- Hardware: Intake Air Temperature Sensor
- Enabling Conditions: Engine Running higher than 1000 rpm
- Set Conditions: Intake Air Temperature greater than stage 1 limit (200^{o} F) for longer than 60 seconds when rpm is above 1000 rpm.
- Corrective Action(s): Activate power derate 1 (max 50% throttle angle)
- Non-emissions related fault
- Possible Causes: Damaged inlet air system allowing hotter than normal air into engine intake system

The Intake Air Temperature sensor is a thermistor (temperature sensitive resistor) located in the intake manifold of the engine. It is used to monitor incoming air and the output, in conjunction with other sensors, is used to determine the airflow to the engine. The ECM provides a voltage divider circuit so that when the air is cool, the signal reads higher voltage, and lower when warm.

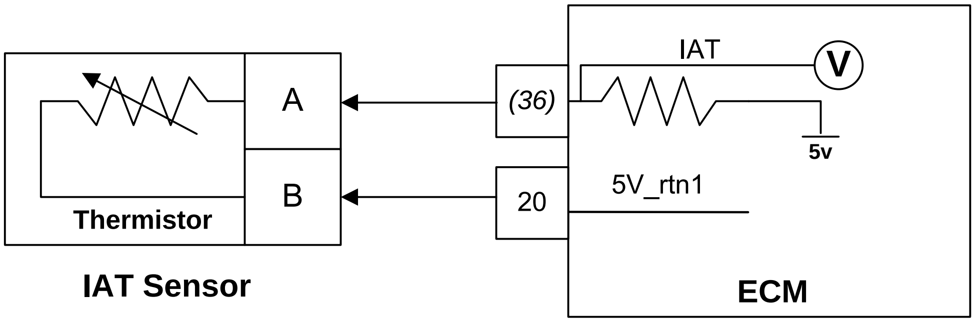
The Manifold Air Temperature is a calculated value based mainly on the IAT sensor at high airflow and influenced more by the ECT/CHT at low airflow. It is used to monitor incoming air and the output, in conjunction with other sensors, is used to determine the airflow to the engine, and ignition timing.

DTC 111- IAT Higher Than Expected 1

Diagnostic Aids

- ☐ This fault will set when inlet air is hotter than normal. The most common cause of high inlet air temperature is a result of a problem with routing of the inlet air. Ensure inlet plumbing sources are external, is cool, and is not too close to the exhaust at any point.
- ☐ Inspect the inlet air system for cracks or breaks that may allow unwanted underhood air to enter the engine.
- ☐ If no problem is found, replace the IAT sensor with a known good part and retest.

DTC 112- IAT Low Voltage

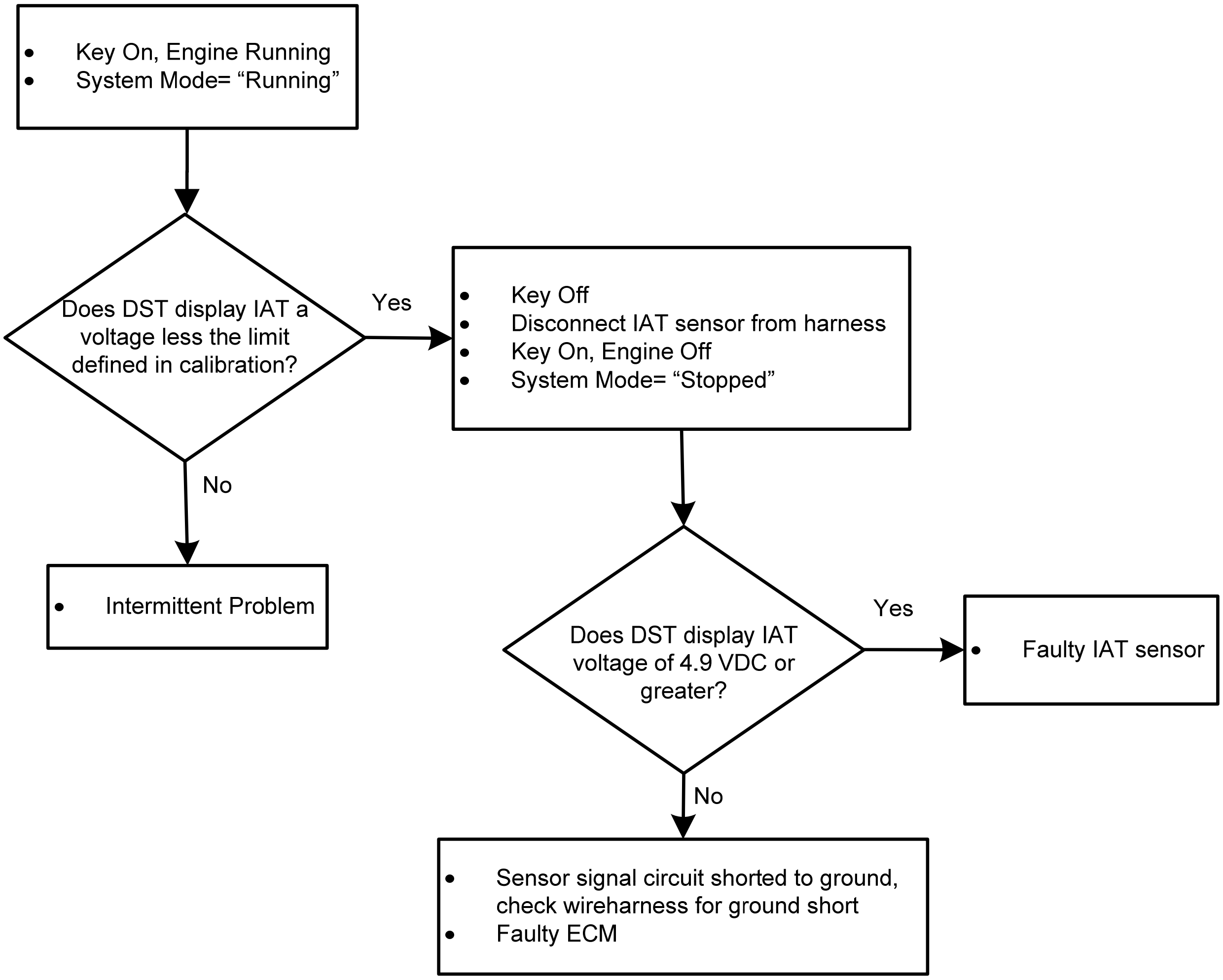


- Hardware: Intake Air Temperature Sensor
- Enabling Conditions: Engine Running
- Set Conditions: IAT sensor voltage less than .05v for longer than 1 second
- Corrective Action(s): Illuminate MIL, disable fuel adaptive learning while the code is active.
- Emissions related fault
- Possible Causes: Faulty ECM (no voltage on signal wire), signal wire shorted to ground or sensor internally shorted

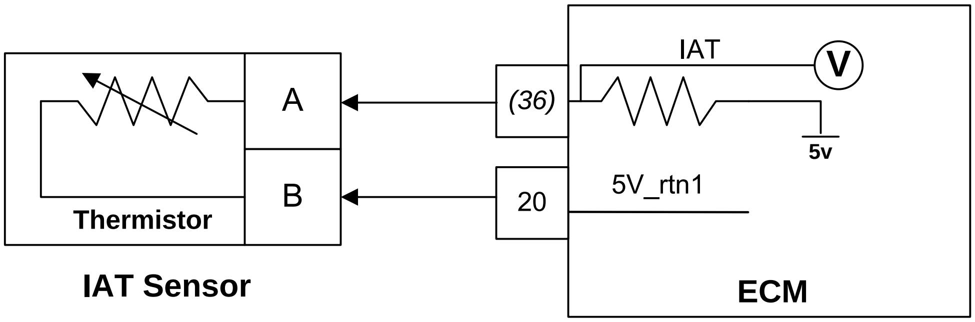
The Intake Air Temperature sensor is a thermistor (temperature sensitive resistor) located in the intake manifold of the engine. It is used to monitor incoming air and the output, in conjunction with other sensors, is used to determine the airflow to the engine. The ECM provides a voltage divider circuit so that when the air is cool, the signal reads higher voltage, and lower when warm.

The Manifold Air Temperature is a calculated value based mainly on the IAT sensor at high airflow and influenced more by the ECT/CHT at low airflow. It is used to monitor incoming air and the output, in conjunction with other sensors, is used to determine the airflow to the engine, and ignition timing.

DTC 112- IAT Low Voltage



DTC 113- IAT High Voltage

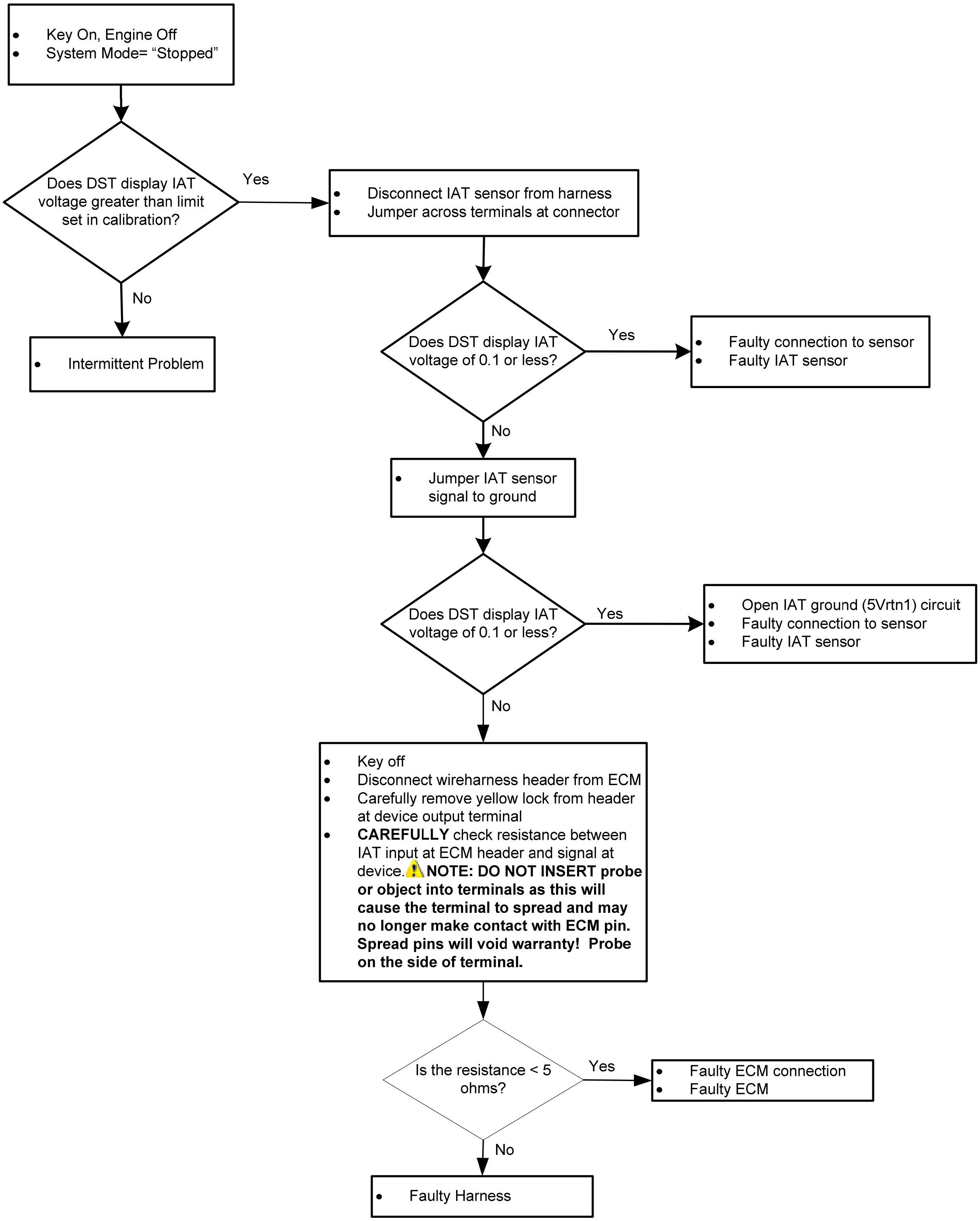


- Hardware: Intake Air Temperature Sensor
- Enabling Conditions: Engine Running
- Set Conditions: IAT sensor voltage greater than 4.95v for longer than 1 second
- Corrective Action(s)- Disable fuel adaptive learn while code is active
- Emissions related fault
- Possible Causes: Signal wire shorted to 12v, signal wire open, sensor open internally or open 5Vrtn1 (sensor ground)

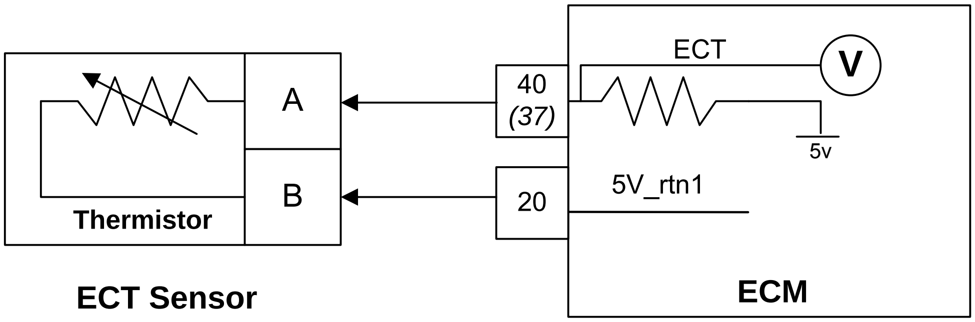
The Intake Air Temperature sensor is a thermistor (temperature sensitive resistor) located in the intake manifold of the engine. It is used to monitor incoming air and the output, in conjunction with other sensors, is used to determine the airflow to the engine. The ECM provides a voltage divider circuit so that when the air is cool, the signal reads higher voltage, and lower when warm.

The Manifold Air Temperature is a calculated value based mainly on the IAT sensor at high airflow and influenced more by the ECT/CHT at low airflow. It is used to monitor incoming air and the output, in conjunction with other sensors, is used to determine the airflow to the engine, and ignition timing.

DTC 113- IAT High Voltage



DTC 116- ECT Higher Than Expected Stage 1



- Hardware: Engine Coolant Temperature Sensor
- Enabling Conditions: Engine Running above 500 rpm
- Set Conditions: Engine Coolant Temperature reading or estimate greater than the stage 1 limit (230^{o} F) for longer than 30 seconds
- Corrective Action(s): Illuminate MIL, active power derate 1
- Non-emissions related fault
- Possible Causes: Overheating engine, sensor out of calibration, signal wire partially shorted to ground or faulty ECM

The Engine Coolant Temperature sensor is a thermistor (temperature sensitive resistor) located in the engine coolant. The ECT is used for engine fuel calculation (cold engine), ignition timing control, to enable certain features, and for engine protection (overheats). The ECM provides a voltage divider circuit so when the sensor reading is cool the sensor reads higher voltage, and lower when warm.

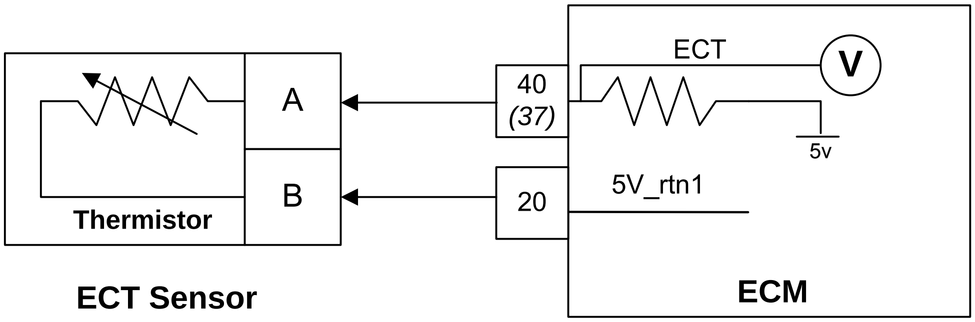
This fault will help protect the engine in the event of over temperature.

DTC 116- ECT Higher Than Expected Stage 1

Diagnostic Aids

- ☐ If the "ECT High Voltage" fault is also present, follow the troubleshooting procedures for that fault as it may have caused "ECT Higher Than Expected 1."
- ☐ If the cooling system utilizes an air-to-water heat exchanger (radiator) and fan:
  - o Check that the radiator has a proper amount of ethylene glycol/water and that the radiator is not leaking
  - o Ensure that there is no trapped air in the cooling path
  - o Inspect the cooling system (radiator and hoses) for cracks and ensure connections are leak free
  - o Check that the fan is operating properly
  - o Check that the thermostat is not stuck closed
- ☐ If the cooling system utilizes a water-to-water heat exchanger:
  - o Check that the heat exchanger has a proper amount of ethylene glycol/water and that the heat exchanger is not leaking
  - o Ensure that there is no trapped air in the cooling path
  - o Inspect the cooling system (radiator and hoses) for cracks and ensure connections are leak free
  - o Check that the raw water pickup is not blocked/restricted by debris and that the hose is tightly connected
  - o Check that the thermostat is not stuck closed
  - o Check that the raw water pump/impeller is tact and that it is not restricted

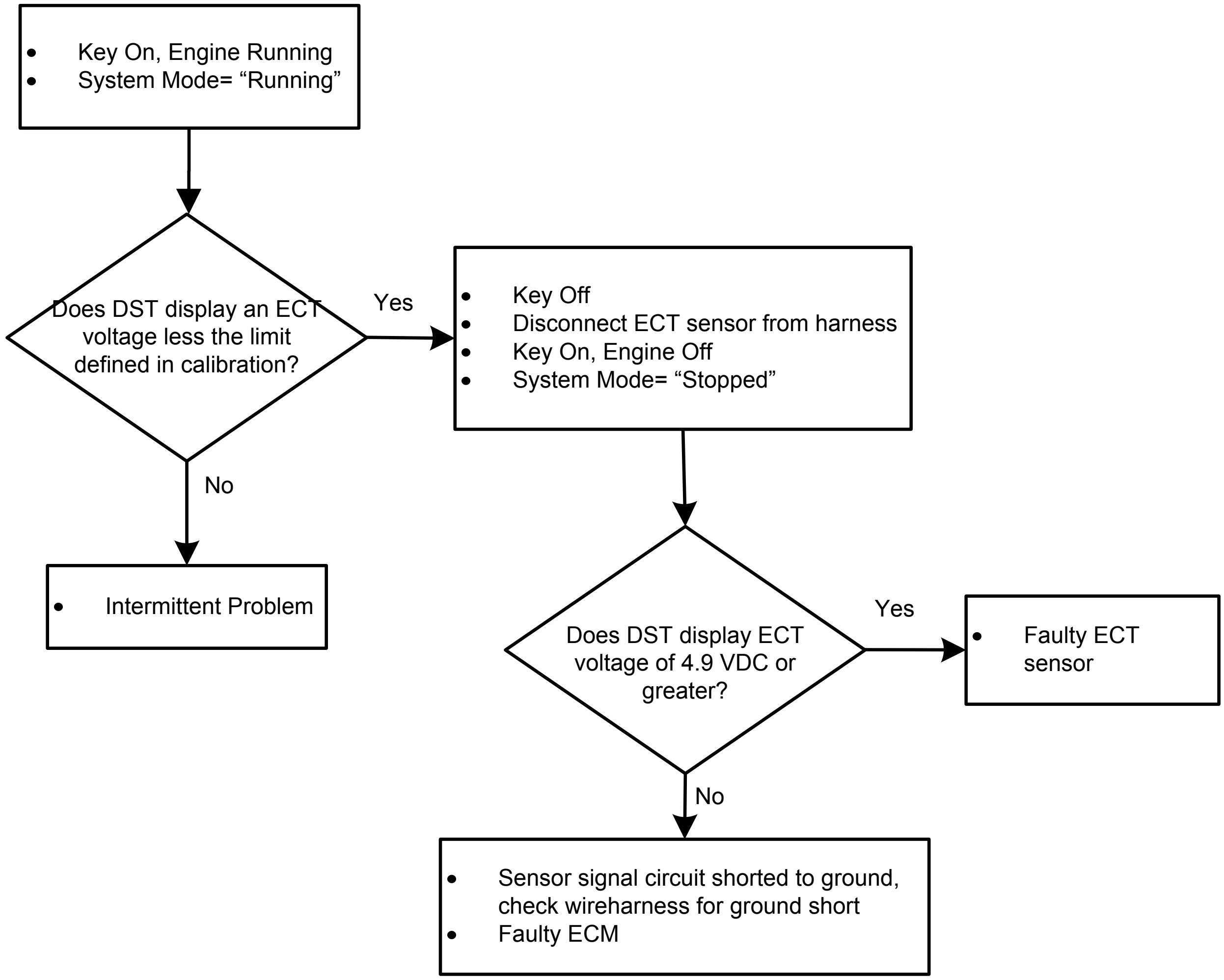
DTC 117- ECT Low Voltage



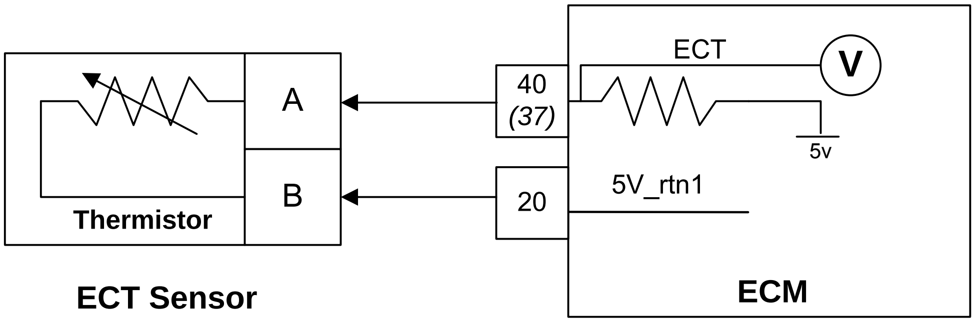
- Hardware: Engine Coolant Temperature Sensor
- Enabling Conditions: Engine Running
- Set Conditions: ECT sensor voltage less than .10v for longer than 1 second
- Corrective Action(s): Illuminate MIL, disable fuel adaptive learn while code is active
- Emissions related fault
- Possible Causes: Faulty ECM (no voltage on signal wire), signal wire shorted to ground or sensor internally shorted

The Engine Coolant Temperature sensor is a thermistor (temperature sensitive resistor) located in the engine coolant. The ECT is used for engine fuel calculation (cold engine), ignition timing control, to enable certain features, and for engine protection (overheats). The ECM provides a voltage divider circuit so when the sensor reading is cool the sensor reads higher voltage, and lower when warm. The ECM will use a default value for the ECT sensor in the event of this fault.

DTC 117- ECT Low Voltage



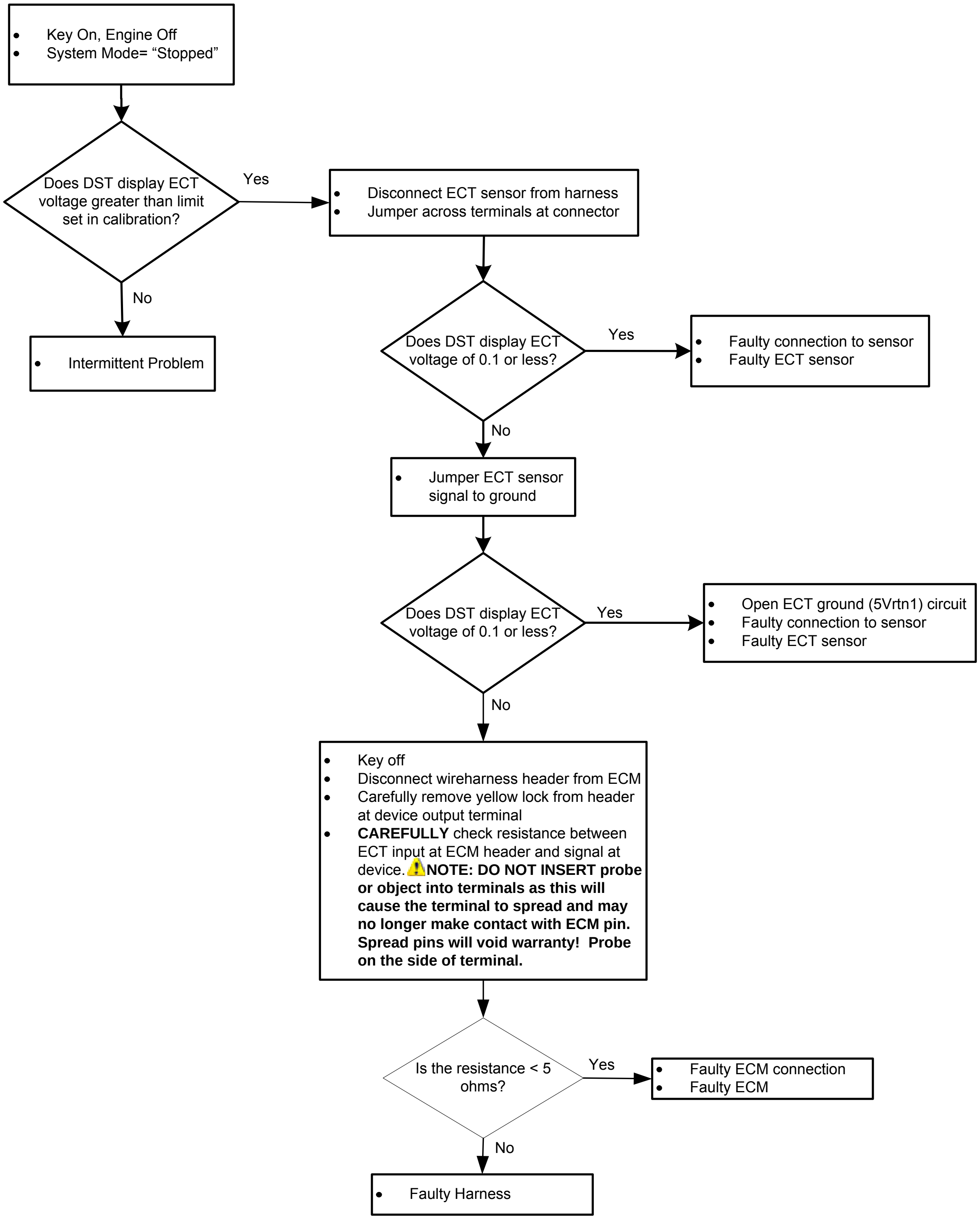
DTC 118- ECT High Voltage



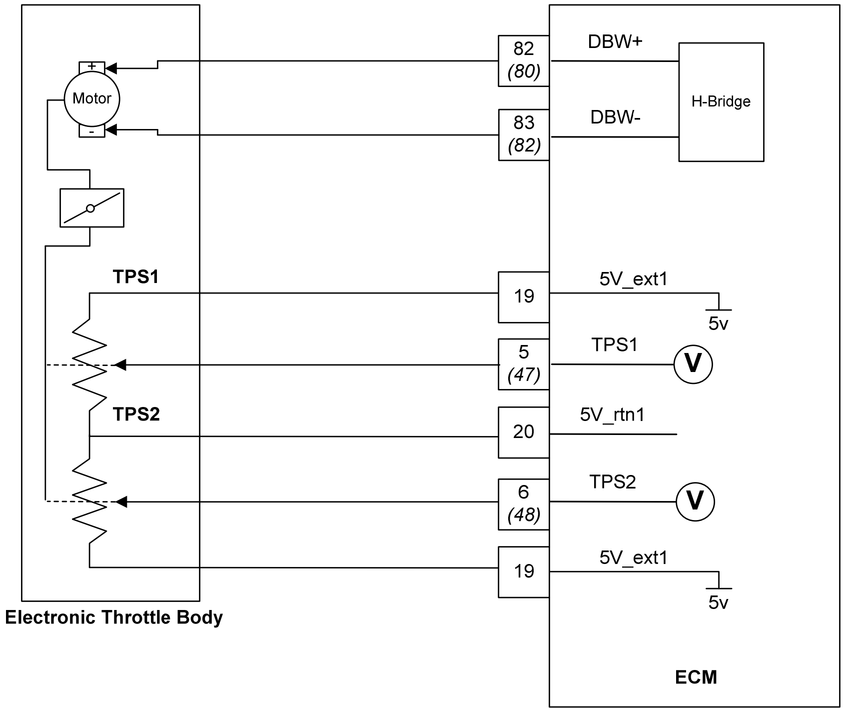
- Hardware: Engine Coolant Temperature Sensor
- Enabling Conditions: Engine Running
- Set Condition: ECT sensor voltage greater than 4.9v for longer than 1 second
- Corrective Action(s): Turn on MIL, disable fuel adaptive learn while code is active.
- Emissions related fault
- Possible Causes: : Signal wire shorted to 12v, signal wire open, sensor open internally or open 5Vrtn1 (sensor ground)

The Engine Coolant Temperature sensor is a thermistor (temperature sensitive resistor) located in the engine coolant. The ECT is used for engine fuel calculation (cold engine), ignition timing control, to enable certain features, and for engine protection (overheats). The ECM provides a voltage divider circuit so when the sensor reading is cool the sensor reads higher voltage, and lower when warm. The ECM will use a default value for the ECT sensor in the event of this fault.

DTC 118- ECT High Voltage



DTC 121- TPS1 % Lower Than TPS2 %

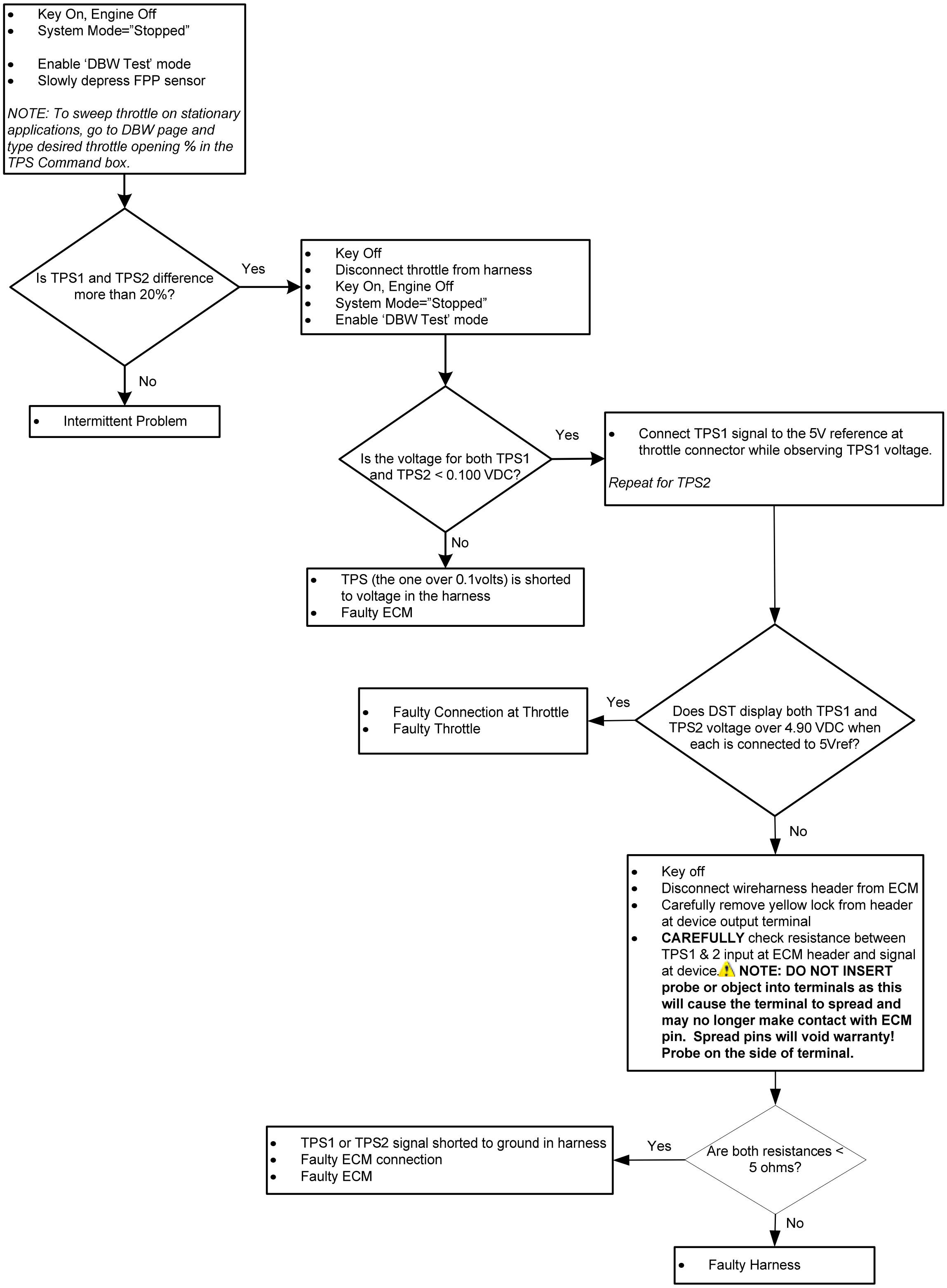


- Hardware: Throttle Body-Throttle Position Sensors 1 & 2 relationship
- Enabling Conditions: Key-On, Engine Cranking, or Running
- Set Conditions-TPS1% lower than TPS2% by more than 20% for longer than 1 second
- Corrective Action(s): Turn on MIL, **activate engine shutdown mode**
- Emissions related fault
- Possible Causes: TPS1 or TPS2 out of calibration in throttle body, unwanted resistance in either TPS1 or TPS2 signal circuits, unwanted resistance in either the shared reference feed (5V_ext1) or shared sensor ground (5Vrtn1), bad ECM

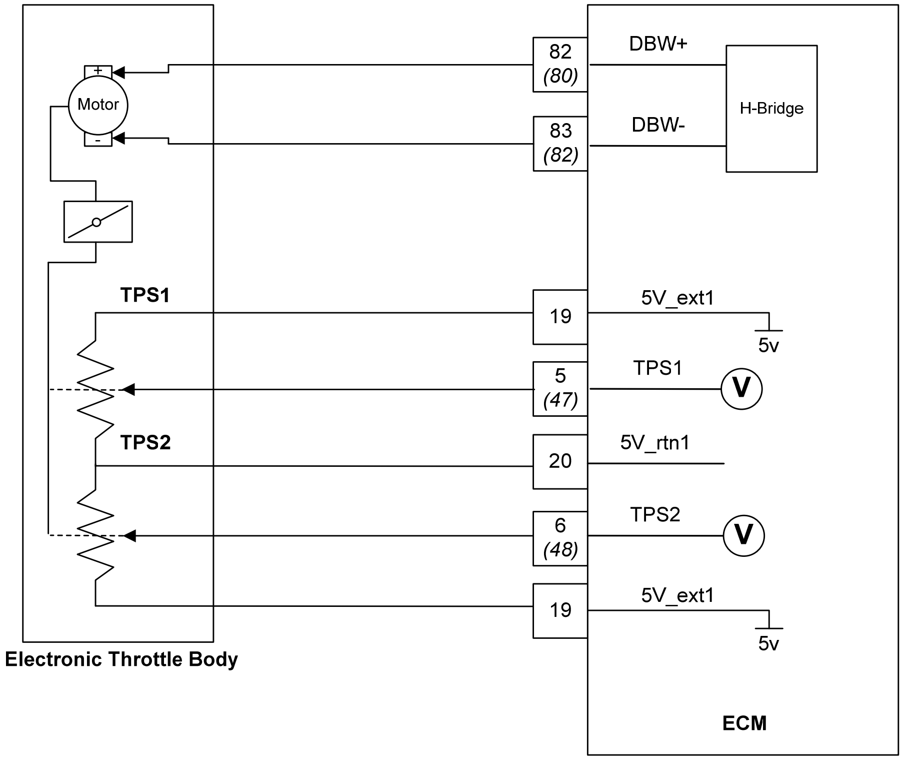
The throttle controls the airflow through the engine, directly affecting the power output of the engine. When the throttle is electronically controlled in an Electronic Throttle Body it can be used to control the idle stability and limit engine speed based on operating conditions.

Each Throttle Position Sensor uses either 1) a variable resistor and voltage divider circuit or 2) a non-contact hall-effect sensor to determine throttle plate position, and is located within the throttle body. The output of the TPS is linear with angular position. The TPS input(s) provide angular position feedback of the throttle plate. In an Electronic Throttle Body multiple position feedback sensors (usually two counteracting potentiometers/hall-effects) are used to perform speed governing with improved safety and redundancy.

DTC 121- TPS1 % Lower Than TPS2 %



DTC 122- TPS1 Signal Voltage Low

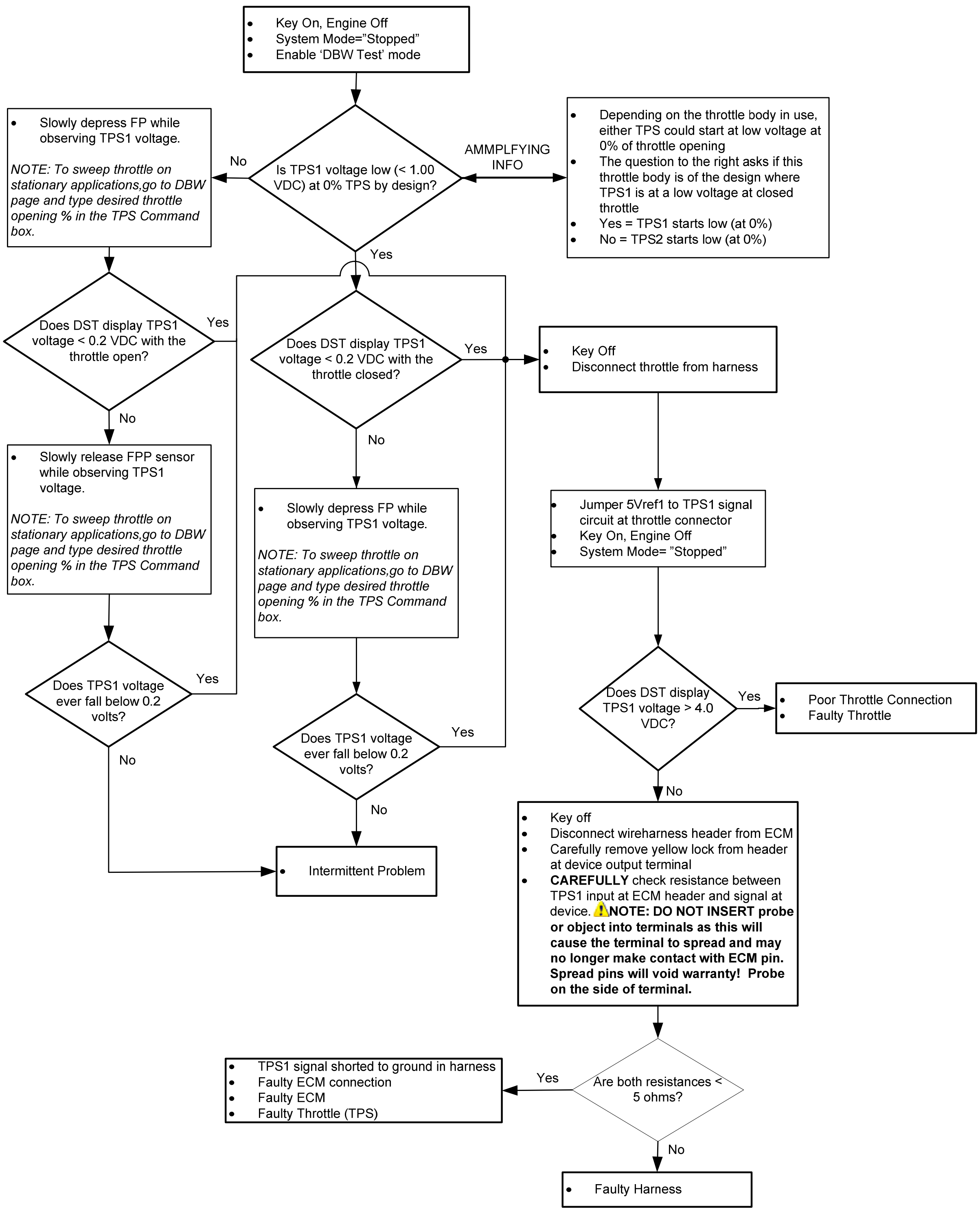


- Hardware: Throttle Body-Throttle Position Sensor 1
- Enabling Conditions: Engine running
- Set Conditions: TPS1 sensor voltage lower than 0.2v for longer than 0.5 seconds
- Corrective Action(s): Illuminate MIL, shutdown engine
- Emissions related fault
- Possible Causes: Loss of 5v reference feed, open or shorted to ground signal circuit, open or shorted to ground TPS in throttle body, bad ECM

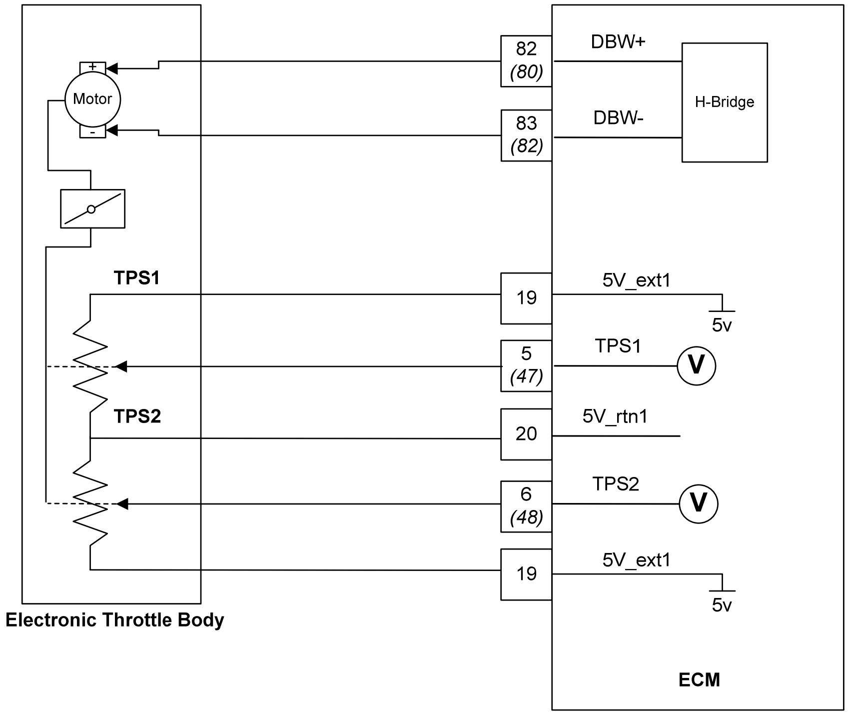
The throttle controls the airflow through the engine, directly affecting the power output of the engine. When the throttle is electronically controlled in an Electronic Throttle Body it can be used to control the idle stability and limit engine speed based on operating conditions.

Each Throttle Position Sensor uses either 1) a variable resistor and voltage divider circuit or 2) a non-contact hall-effect sensor to determine throttle plate position, and is located within the throttle body. The output of the TPS is linear with angular position. The TPS input(s) provide angular position feedback of the throttle plate. In an Electronic Throttle Body multiple position feedback sensors (usually two counteracting potentiometers/hall-effects) are used to perform speed governing with improved safety and redundancy.

DTC 122- TPS1 Signal Voltage Low



DTC 123- TPS1 Signal Voltage High

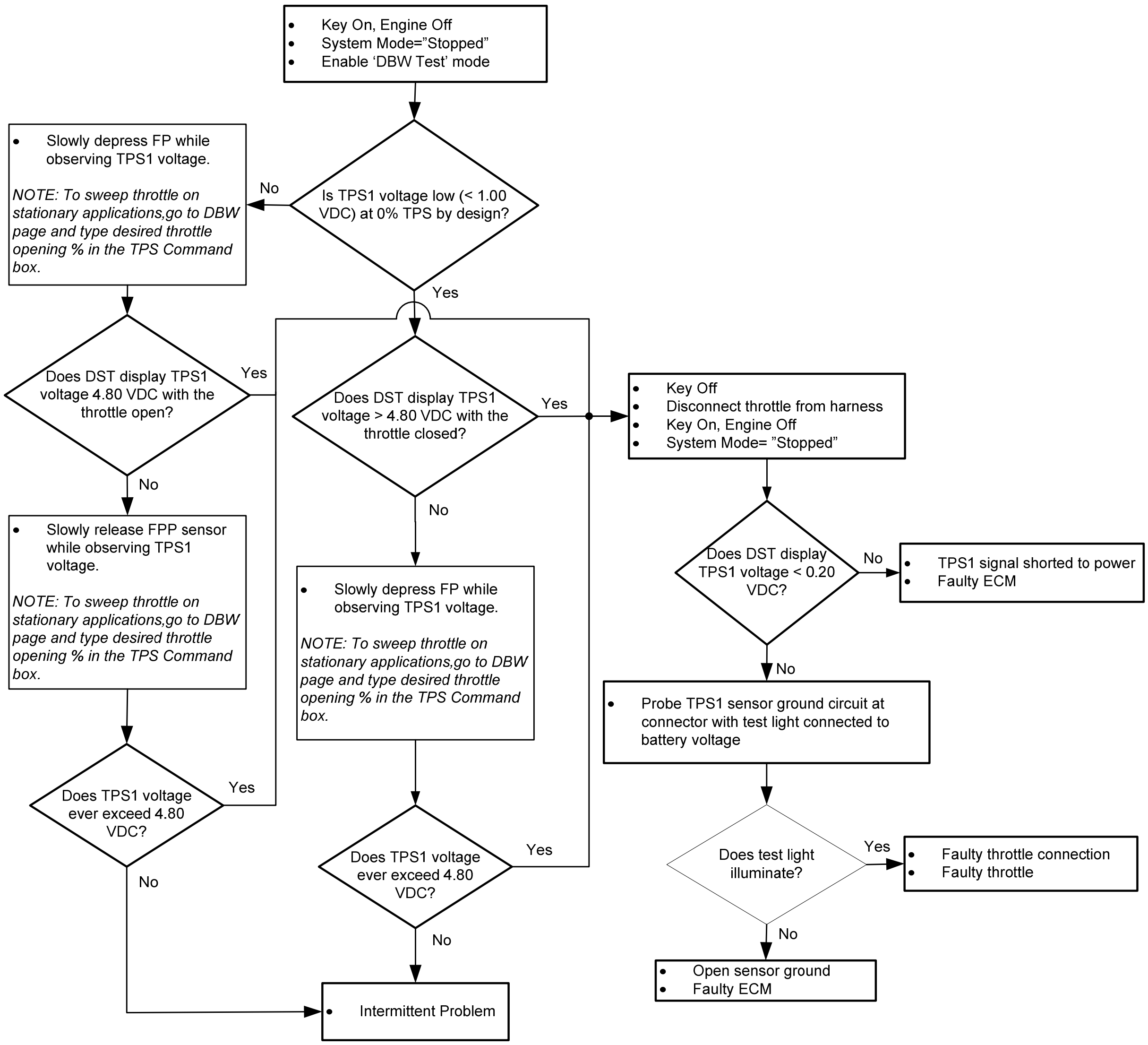


- Hardware: Throttle Body-Throttle Position Sensor 1
- Enabling Conditions: Engine running
- Set Conditions: TPS1 sensor voltage higher than 4.8v for longer than 0.5 seconds
- Corrective Action(s): Illuminate MIL, shutdown engine
- Emissions related fault
- Possible Causes: 5 volt reference feed (5V_ext1) shorted to voltage, Open sensor ground (5vrtn1) circuit, signal wire shorted to voltage or bad TPS in throttle body

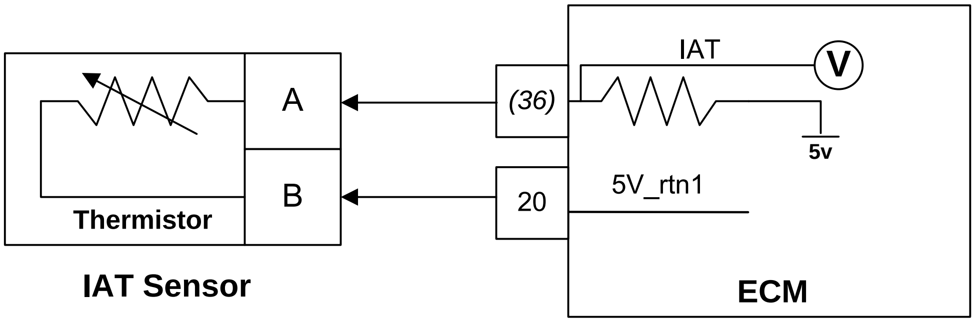
The throttle controls the airflow through the engine, directly affecting the power output of the engine. When the throttle is electronically controlled in an Electronic Throttle Body it can be used to control the idle stability and limit engine speed based on operating conditions.

Each Throttle Position Sensor uses either 1) a variable resistor and voltage divider circuit or 2) a non-contact hall-effect sensor to determine throttle plate position, and is located within the throttle body. The output of the TPS is linear with angular position. The TPS input(s) provide angular position feedback of the throttle plate. In an Electronic Throttle Body multiple position feedback sensors (usually two counteracting potentiometers/hall-effects) are used to perform speed governing with improved safety and redundancy.

DTC 123- TPS1 Signal Voltage High



DTC 127- IAT Higher Than Expected Stage 2



- Hardware: Intake Air Temperature
- Enabling Conditions: Engine Running higher than 1000 rpm
- Set Conditions: Intake Air Temperature greater than stage 2 limit (210^{o} F) for longer than 2 minutes
- Corrective Action(s)- Illuminate MIL, disable fuel adaptive learning while code is active
- Emissions related fault
- Possible Causes: : Damaged inlet air system allowing hotter than normal air into engine intake system

The Intake Air Temperature sensor is a thermistor (temperature sensitive resistor) located in the intake manifold of the engine. It is used to monitor incoming air and the output, in conjunction with other sensors, is used to determine the airflow to the engine. The ECM provides a voltage divider circuit so that when the air is cool, the signal reads higher voltage, and lower when warm.

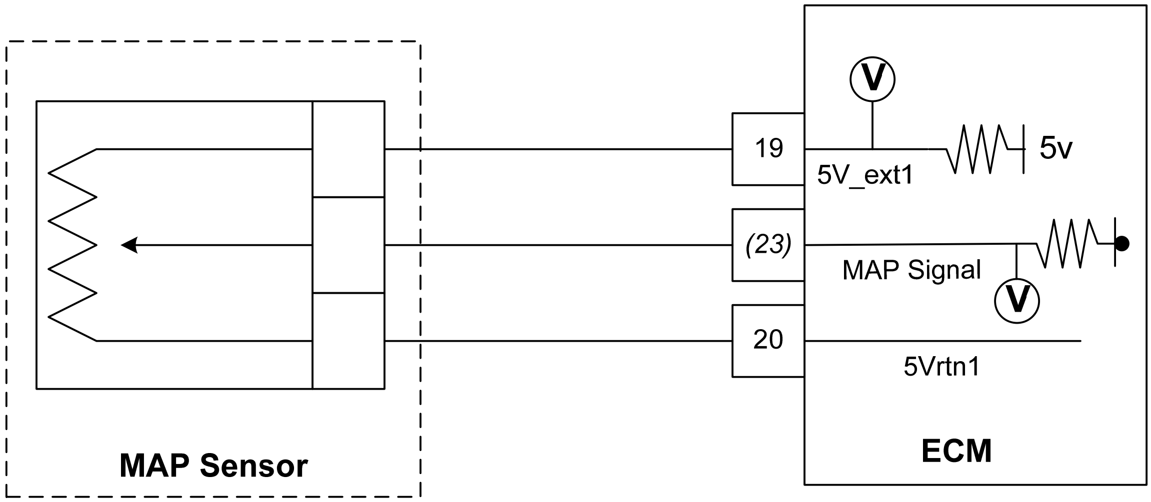
The Manifold Air Temperature is a calculated value based mainly on the IAT sensor at high airflow and influenced more by the ECT/CHT at low airflow. It is used to monitor incoming air and the output, in conjunction with other sensors, is used to determine the airflow to the engine, and ignition timing.

DTC 127- IAT Higher Than Expected Stage 2

Diagnostic Aids

- ☐ This fault will set when inlet air is hotter than normal. The most common cause of high inlet air temperature is a result of a problem with routing of the inlet air. Ensure inlet plumbing sources are external, is cool, and is not too close to the exhaust at any point.
- ☐ Inspect the inlet air system for cracks or breaks that may allow unwanted underhood air to enter the engine.
- ☐ If no problem is found, replace the IAT sensor with a known good part and retest.

DTC 129- BP Low Pressure

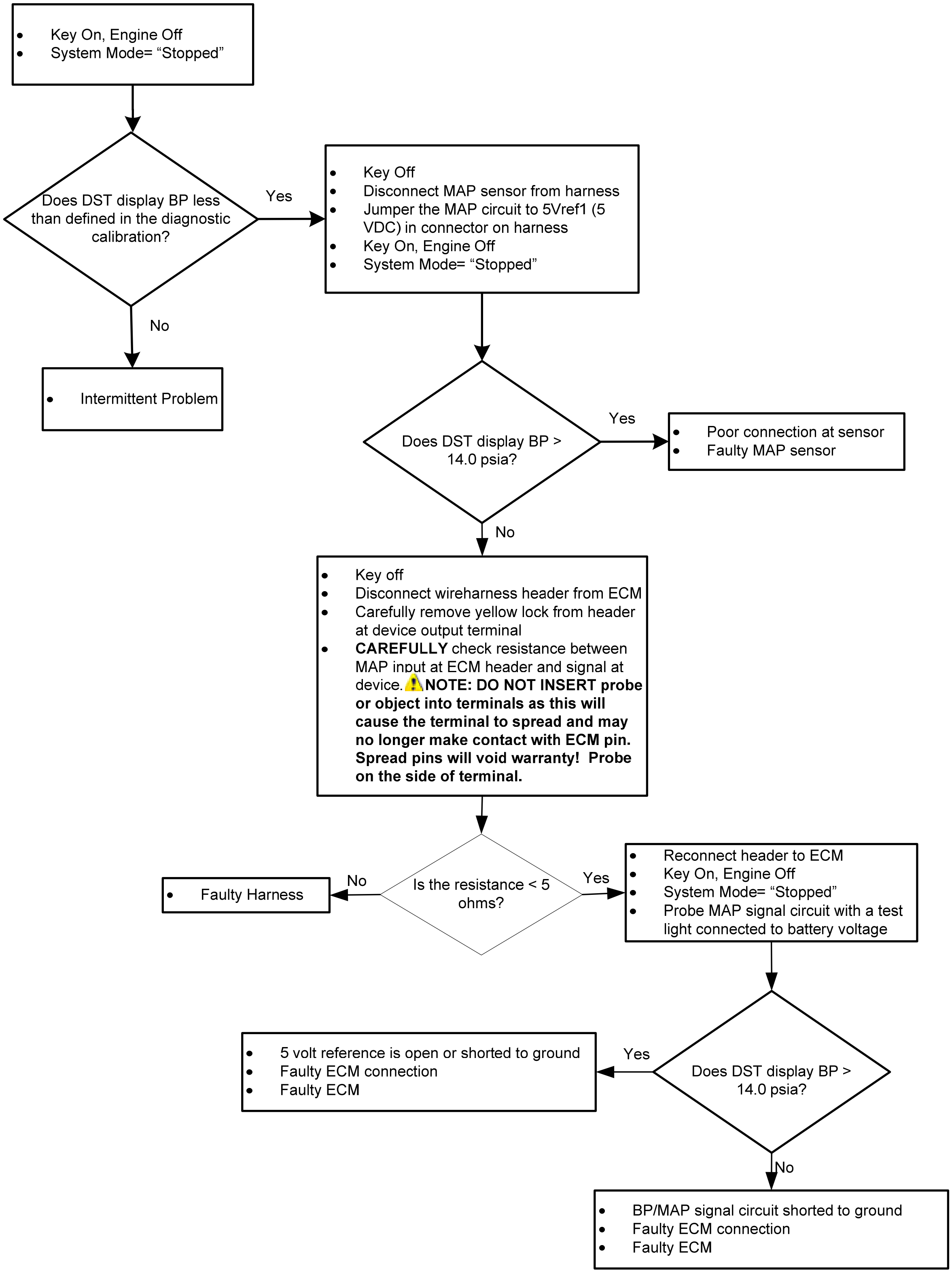


- Hardware: MAP sensor - Barometric Pressure
- Enabling Conditions: Engine running after BP estimate during start up or low-speed/high load operation
- Set Condition: Barometric Pressure is less than 8.3 psia for longer than 1 second
- Corrective Action(s): Illuminate MIL, disable fuel adaptive learn for the rest of the key cycle
- Emissions related fault
- Possible causes: Sensor out of calibration, loss for 5v reference feed (5V_ext1) to MAP, signal wire open or shorted to ground

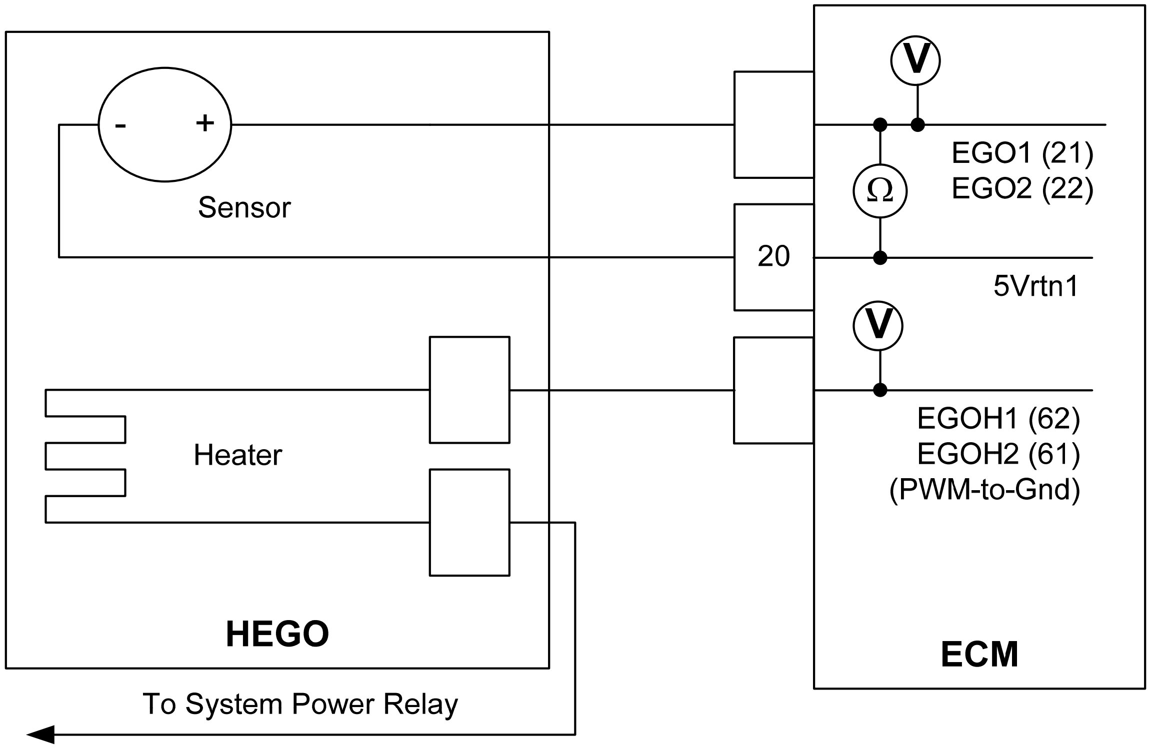
This code could set in conjunction with a MAP Voltage Low code

Barometric Pressure is estimated from the MAP sensor at key-on and in some calibrations during low speed/high load operation as defined in the engine's calibration; however fault will not set until engine is running. The barometric pressure value is used for fuel and airflow calculations and equivalence ratio targets based on altitude.

DTC 129- BP Low Pressure



DTC 134- EGO1 Open/Lazy (HO2S1)

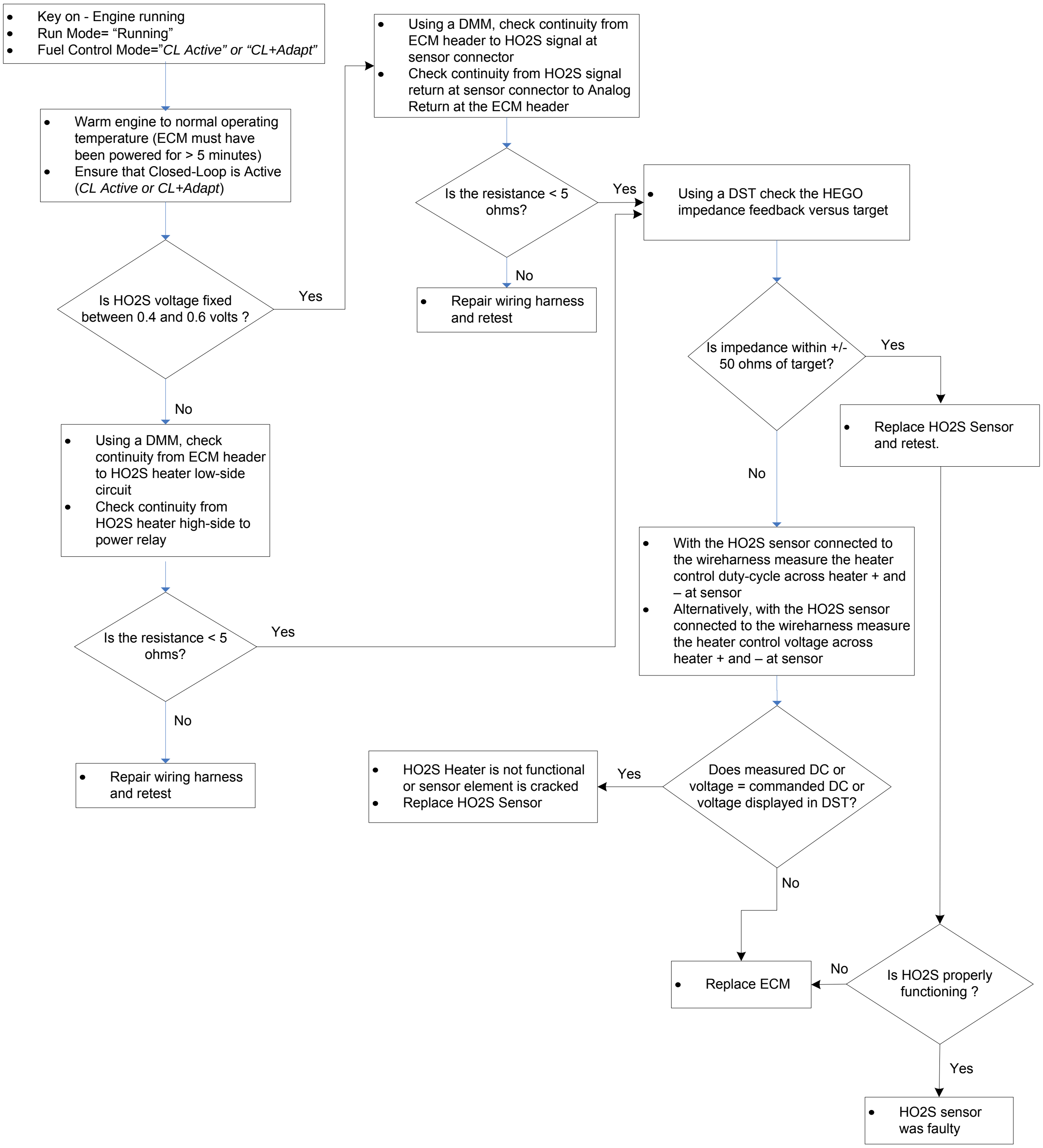


- o Hardware: Heated Exhaust Gas Oxygen Sensor (Pre-Catalyst)
- o Enabling Conditions: Engine Running
- o Set Conditions: HEGO/HO2S cold or non-responsive for longer than 120 seconds
- o Corrective Action(s): Illuminate MIL, disable closed loop operation and fuel adaptive learn correction (both) while the code is active.
- o Emissions related fault
- o Possible Causes: Open feed circuit to O_2 heater, Open heater ground circuit, Open or shorted to ground O_2 signal wire, open sensor ground (5Vrtn1), inoperative sensor

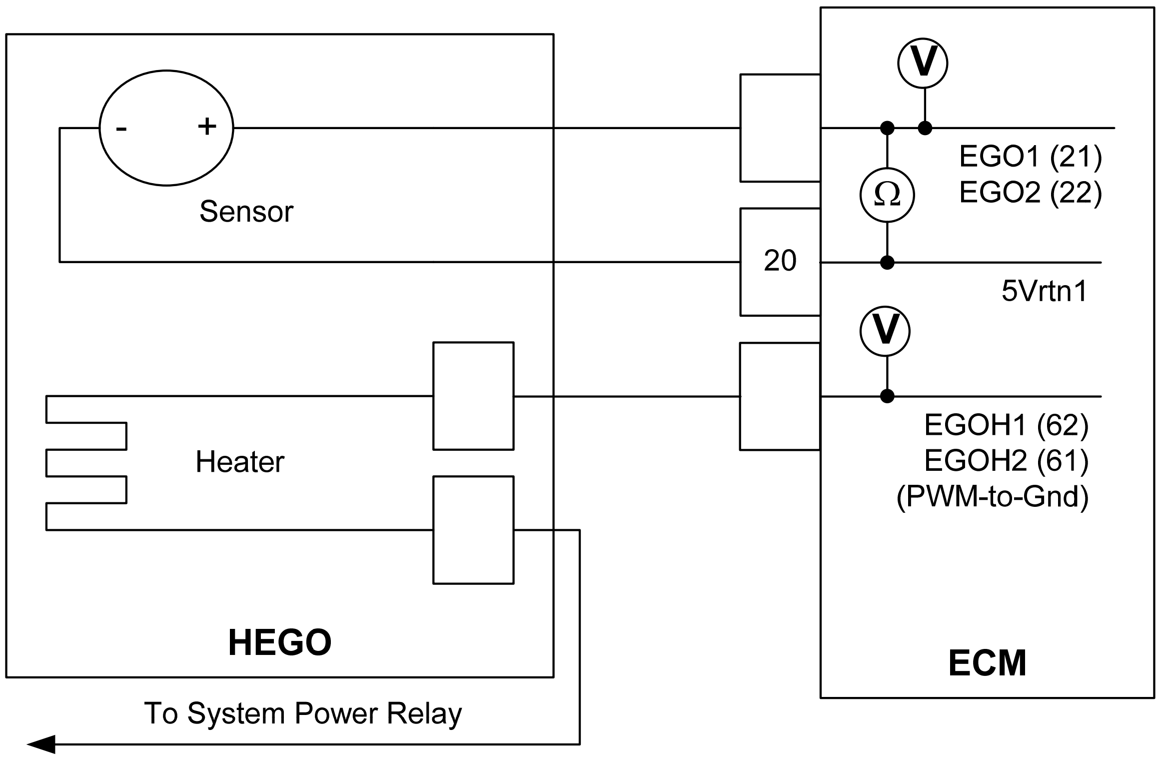
The HEGO/HO2S sensor is a switching-type sensor about stoichiometry that measures the oxygen content present in the exhaust to determine if the fuel flow to the engine is correct. If there is a deviation between the expected reading and the actual reading, fuel flow is precisely adjusted using the Closed Loop multiplier and then "learned" with the Adaptive multiplier. The multipliers only update when the system is in either *"CL Active"* or *"CL + Adapt"* control modes.

Cold or non-responsive is defined as the actual impedance of the sensor heater not reaching the target impedance

DTC 134- EGO1 Open/Lazy (HO2S1)



DTC 154- EGO2 Open/Lazy (HO2S2)

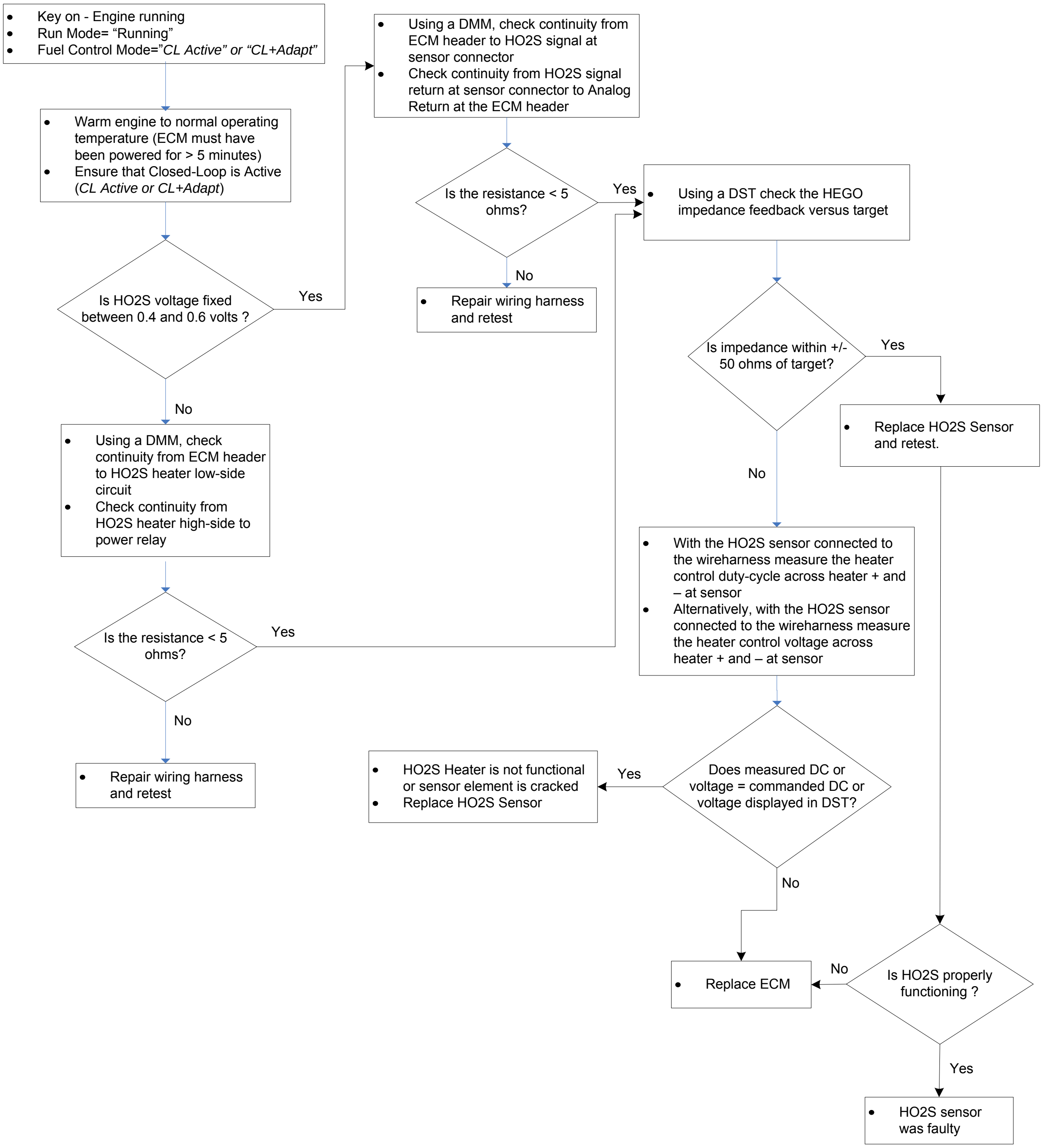


- o Hardware: Heated Exhaust Gas Oxygen Sensor (Post-Catalyst)
- o Enabling Conditions: Engine Running
- o Set Conditions: HEGO/HO2S cold or non-responsive longer than 120 seconds
- o Corrective Action(s): Illuminate MIL.
- o Emissions related fault
- o Possible Causes: Open feed circuit to O_2 heater, Open heater ground circuit, Open or shorted to ground O_2 signal wire, open sensor ground (5Vrtn1), inoperative sensor

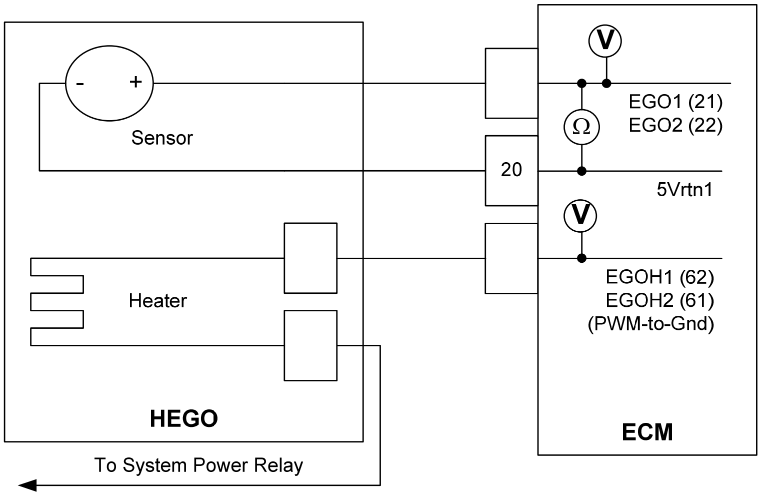
In a post-catalyst configuration the HEGO/HO2S sensor is a switching-type sensor around stoichiometry that measures the oxygen content downstream of the catalyst for two main functions: 1) to compare it to the oxygen content upstream of the catalyst to determine how efficiently the catalyst is using oxygen to determine its effectiveness and 2) trim the commanded equivalence ratio target to maximize the catalyst conversion efficiency. The post-catalyst strategy and diagnostic is only active when the system is in either *"CL Active"* or *"CL + Adapt"* control modes.

Cold or non-responsive is defined as the actual impedance of the sensor heater not reaching the target impedance

DTC 154- EGO2 Open/Lazy (HO2S2)



DTC 171- Adaptive Learn Bank 1 High (Gasoline)



- Hardware: HEGO Sensor (Pre-Catalyst) rich-lean switch rate
- Enabling Conditions: Engine Running in closed loop active mode updating adaptive learn multiplier (CL+Adap mode)
- Set Conditions: Bank 1 adaptive learn multiplier ≥ +30% for longer than 3 updates (see below)
- Corrective Action(s): Illuminate MIL
- Emissions related fault
- Possible Causes: See Diagnostic aids below and on next page

The purpose of the Adaptive Learn Multiplier is to adjust fuel flow due to variations in fuel composition, engine wear, engine-to-engine build variances, and component degradation. The Adaptive Learn multiplier values are held in a table and are remembered between key cycles. Adaptive memory tables are erased at battery disconnects and with the DST.

An “update” (from Set Conditions above) can be thought of as a “variable timer”, one that takes longer to set a fault at low engine speeds than at higher speeds.

This fault sets if the Adaptive multiplier exceeds the high limit of normal operation indicating that the engine is operating lean (excess oxygen) and requires more fuel than allowed by corrections. Often high positive fueling corrections are a function of one or more of the following conditions: 1) exhaust leaks upstream or near the HEGO sensor, 2) reduced fuel supply pressure to the fuel injection system, 3) a inoperative sensor, 3) an injector that is stuck closed or dirty, 4) weak spark or lack of spark to a cylinder and/or 5) a MAP sensor that indicates pressure that is lower than true pressure.

To test the O_2 sensor run the CL test. This test tests both pre-cat and post-cat O_2 sensor functionality.

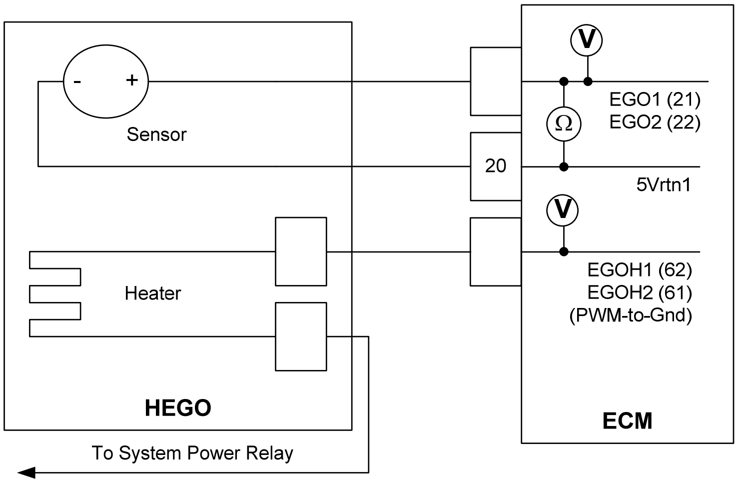
DTC 171- Adaptive Learn Bank 1 High (Gasoline)

Diagnostic Aids

NOTE: If any other DTCs are present, diagnose those first.

- ☐ Oxygen Sensor Wire - Sensor may be mispositioned contacting the exhaust. Check for short to ground between harness and sensor and on sensor harness
- ☐ Inoperative Oxygen Sensor - sensor may be damaged internally and unable to switch resulting in a system that over fuels or under fuels the engine.
- ☐ Weak Spark or Lack of Spark to a Cylinder – improper burning of the fuel/air mixture in a cylinder results in excess unburned oxygen exiting the cylinder causing the pre-cat O_2 sensor to see a lean condition
- ☐ Vacuum Leaks - Large vacuum leaks and crankcase leaks can cause a lean exhaust condition at light load.
- ☐ Injectors - System will be lean if an injector driver or driver circuit fails. The system will also be lean if an injector fails in a closed manner or is dirty.
- ☐ Fuel Pressure - System will be lean if fuel pressure is too low. Check fuel pressure in the fuel rail during key-on, engine off and during normal operating conditions.
- ☐ Air in Fuel - If the fuel return hose/line is too close to the fuel supply pickup in the fuel tank, air may become entrapped in the pump or supply line causing a lean condition and driveability problems.
- ☐ Exhaust Leaks - If there is an exhaust leak, outside air can be pulled into the exhaust and past the O2 sensor causing a false lean condition.
- ☐ Fuel Quality - A drastic variation in fuel quality may cause the system to be lean including oxygenated fuels.
- ☐ System Grounding - ECM and engine must be grounded to the battery with very little resistance allowing for proper current flow. Faulty grounds can cause current supply issues resulting in many undesired problems.
- ☐ If all tests are OK, replace the HO2S sensor with a known good part and retest.

DTC 172- Adaptive Learn Bank1 Low (Gasoline)



- Hardware: HEGO Sensor (Pre-Catalyst) rich-lean switch rate
- Enabling Conditions: Engine Running in closed loop active mode updating adaptive learn multiplier (CL+Adap mode)
- Set Condition: Bank 1 adaptive learn multiplier ≤ -30% for longer than 3 updates (see below)
- Corrective Action(s): Illuminate MIL
- Emissions related fault
- Possible Causes: See Diagnostic aids below and on next page

The purpose of the Adaptive Learn Multiplier is to adjust fuel flow due to variations in fuel composition, engine wear, engine-to-engine build variances, and component degradation. The Adaptive Learn multiplier values are held in a table and are remembered between key cycles. Adaptive memory tables are erased at battery disconnects and with the DST.

An “update” (from Set Conditions above) can be thought of as a “variable timer”, one that takes longer to set a fault at low engine speeds than at higher speeds.

This fault sets if the Adaptive multiplier exceeds the low limit of normal operation indicating that the engine is operating rich (low oxygen content) and requires less fuel than allowed by corrections. Often high negative fueling corrections are a function of one or more of the following conditions: 1) an inoperative O_2 sensor, 2) high fuel supply pressure or temperature, 3) internal mechanical engine damage, 3) an injector that is stuck open or leaking, and/or 4) improper airflow through the engine due to things such as valve timing problems, collapsed lifters/followers, worn cam lobes or bent pushrods.

To test the O_2 sensor run the CL test. This test tests both pre-cat and post-cat O_2 sensor functionality.

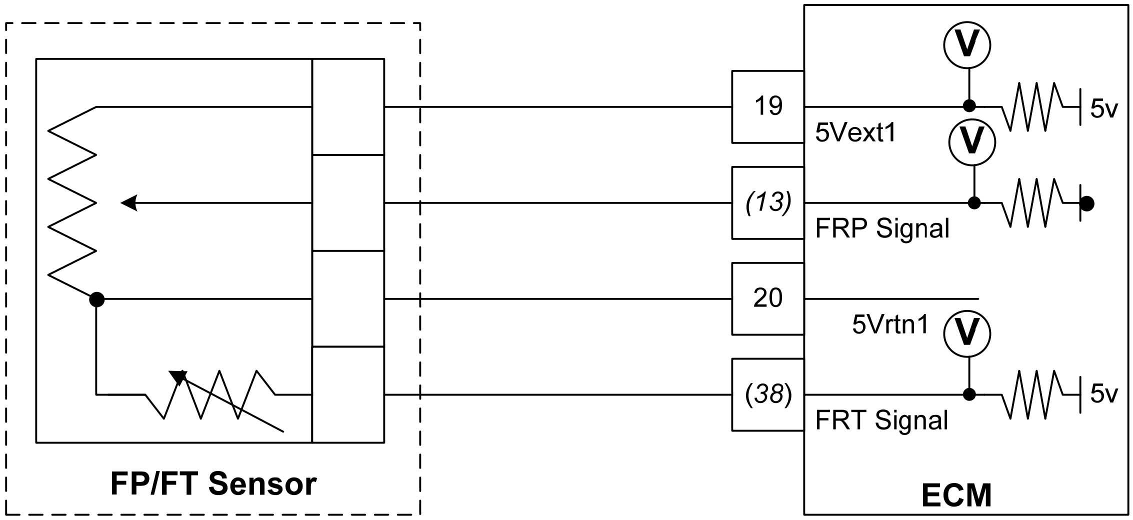
DTC 172- Adaptive Learn Bank1 Low (Gasoline)

Diagnostic Aids

NOTE: If any other DTCs are present, diagnose those first.

- ☐ Oxygen Sensor Wire - Sensor may be mispositioned contacting the exhaust. Check for short to ground between harness and sensor and on sensor harness
- ☐ Injectors - System will be rich if an injector driver or driver circuit fails shorted-to-ground. The system will also be rich if an injector fails in an open position or leaks.
- ☐ Fuel Pressure - System will be rich if fuel pressure is too high. Check fuel pressure in the fuel rail during key-on, engine off and during normal operating conditions.
- ☐ System Electrical Grounding - ECM and engine must be grounded to the battery with very little resistance allowing for proper current flow. Faulty grounds can cause current supply issues resulting in many undesired problems (causing sensors to provide bad information to the ECM).
- ☐ Internal mechanical engine damage causing lower than normal intake manifold vacuum
- ☐ MAP sensor that indicates pressure higher than true pressure
- ☐ Coolant Temperature Sensor – A sensor that indicates the engine is colder than actual engine temperature
- ☐ If all tests are OK, replace the HO2S sensor with a known good part and retest.

DTC 182- Fuel Temp (Gasoline) Low Voltage/Low Temp

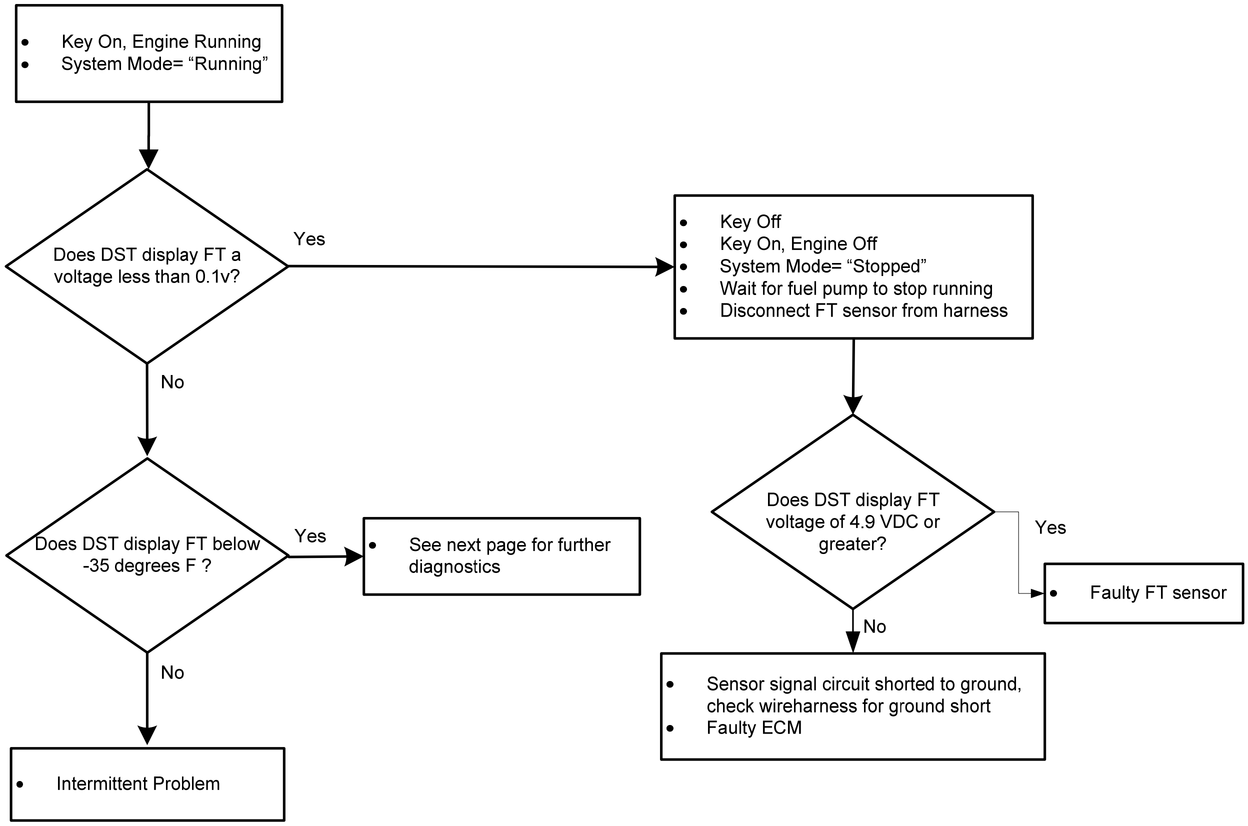


- o Hardware: Liquid Fuel Temperature Sensor
- o Enabling Conditions: Engine Running
- o Set Conditions: FT sensor voltage less than 0.05v **OR** indicated temperature below -35^{o}F for longer than 1 second
- o Corrective Action(s): Illuminate MIL and disable fuel adaptive learn for the rest of the key cycle
- o Emissions related fault (evaporative emissions)
- o Possible causes:
  - o Voltage Low: Sensor signal wire shorted to ground, sensor shorted internally, faulty ECM
  - o Temperature Low: Operating in a frigid atmosphere, Sensor out of calibration, partial short to ground in signal circuit causing circuit to indicate a very cold temp (below – 35^{o}F) but not high enough to set a high voltage fault

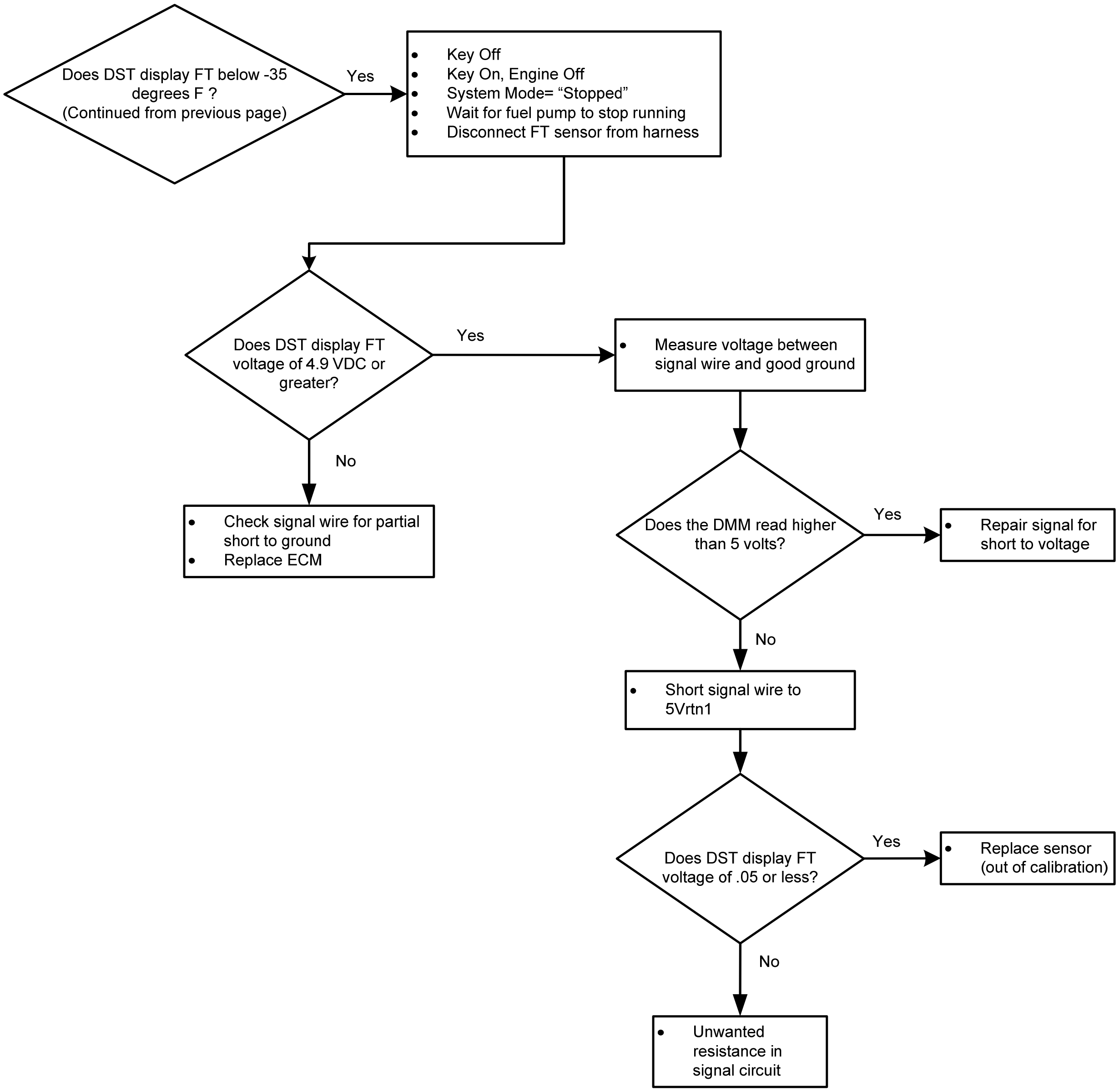
The Fuel Temperature sensor is a thermistor (temperature sensitive resistor) integrated into the fuel pressure TMAP located in the fuel supply line between the fuel pump and the fuel rail. It is used to monitor the fuel temperature exiting the fuel pump to set a fault if the fuel temperature is too high resulting in increased fuel vapor from the fuel tank causing excessive evaporative emissions (for emissions regulations compliance). The ECM provides a voltage divider circuit so that when the fuel is cool, the signal reads higher voltage, and lower when warm.

This fault will set if the signal voltage is less than 0.05v anytime that the engine is running **OR** the indicated temperature from the sensor is below -35^{o}F for longer than 1 second.

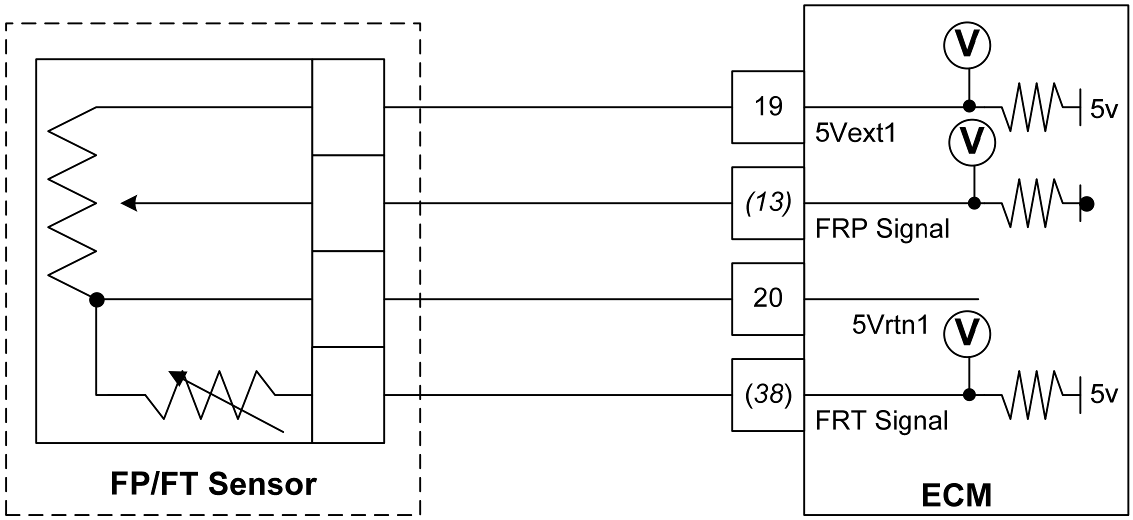
DTC 182- Fuel Temp (Gasoline) Low Voltage/Low Temp



DTC 182- Fuel Temp (Gasoline) Low Voltage/Temp



DTC 183- Fuel Temp (Gasoline) High Voltage/High Temp

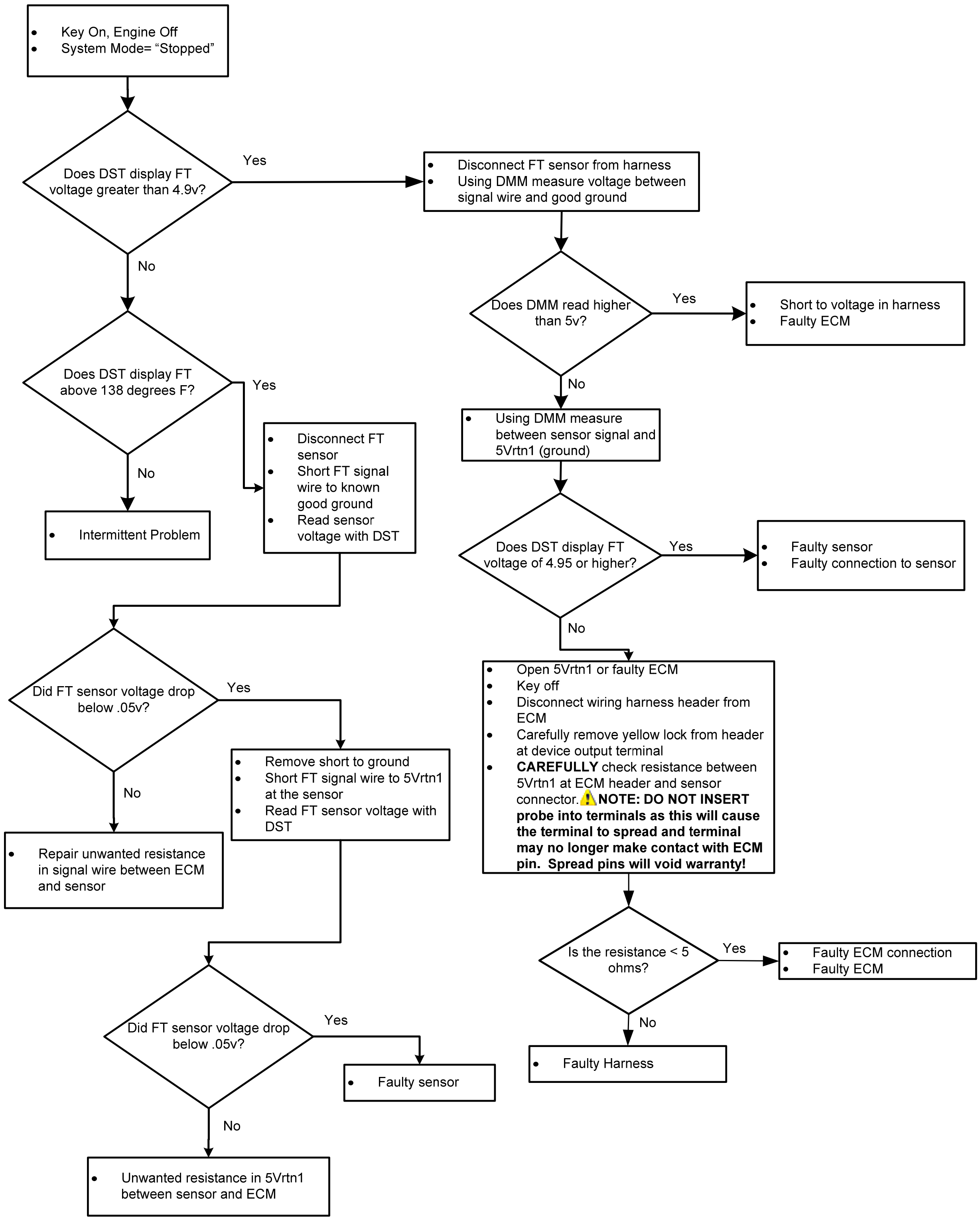


- Hardware: Liquid Fuel Temperature Sensor
- Enabling Conditions: Engine Running
- Set Conditions: FT sensor voltage higher than 4.9v **OR** indicated temperature above 138°F for longer than 2 minutes
- Corrective Action(s): Illuminate MIL and disable fuel adaptive learn for the rest of the key cycle
- Emissions related fault
- Possible Causes:
  - Voltage High: Sensor signal wire shorted to voltage, sensor open, signal circuit open or faulty ECM
  - Temperature High: Operating in a hot environment, Sensor out of calibration, unwanted resistance in signal circuit causing circuit to indicate a very hot temp (above 138°F) but voltage not low enough to set a low voltage fault

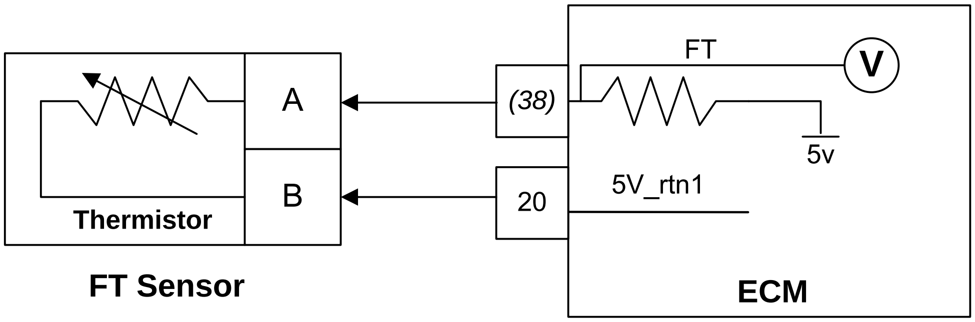
The Fuel Temperature sensor is a thermistor (temperature sensitive resistor) integrated into the fuel pressure TMAP located in the fuel supply line between the fuel pump and the fuel rail. It is used to monitor the fuel temperature exiting the fuel pump to set a fault if the fuel temperature is too high resulting in increased fuel vapor from the fuel tank causing excessive evaporative emissions. The ECM provides a voltage divider circuit so that when the fuel is cool, the signal reads higher voltage, and lower when warm.

This fault will set if the signal voltage is higher than 4.9v anytime that the engine is running **OR** the indicated temperature from the sensor is above 138°F for longer than 1 second.

DTC 183- Fuel Temp (Gasoline) High Voltage/High Temp



DTC 187- Gaseous Fuel Temperature Sensor Low Voltage

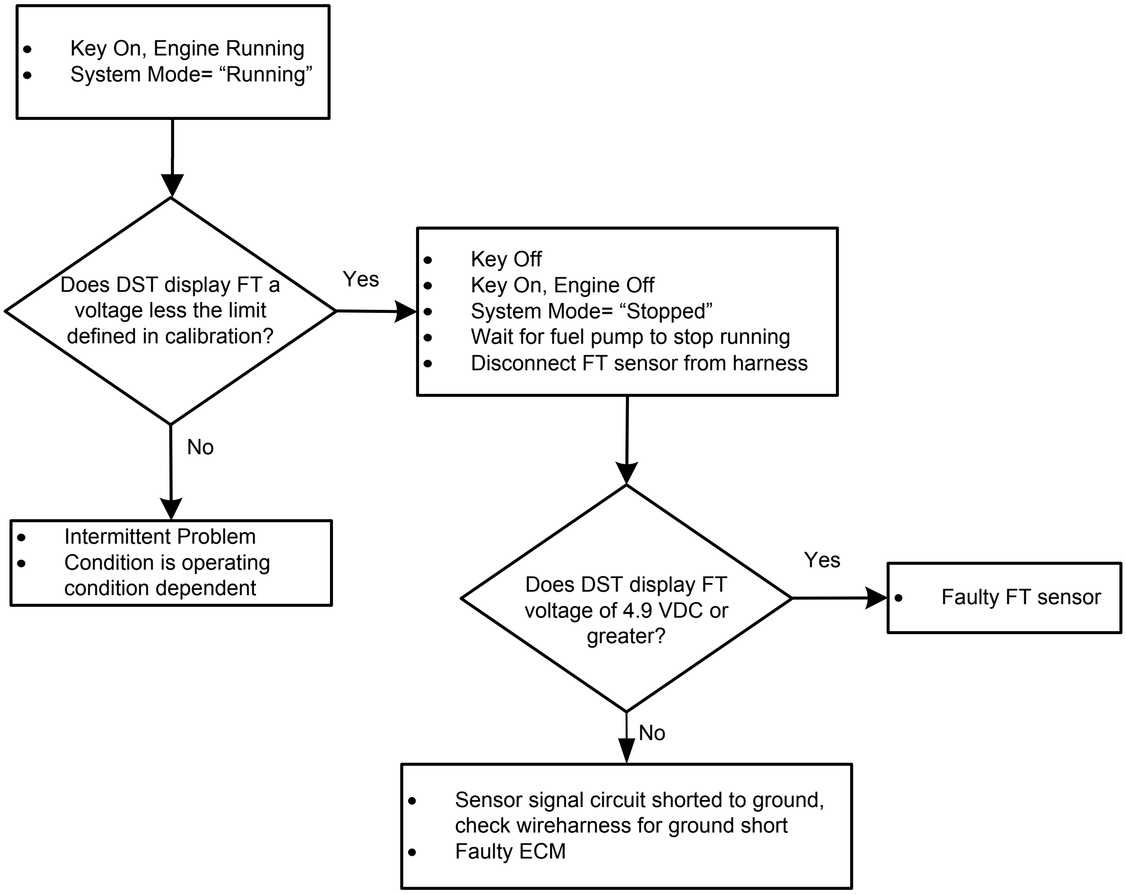


- o Hardware: Gaseous Fuel Temperature Sensor
- o Enabling Conditions: Engine Running
- o Set Conditions: FT sensor voltage less than defined in diagnostic calibration
- o Corrective Action(s): Illuminate MIL and/or sound audible warning or illuminate secondary warning lamp
- o Non-emissions related fault
- o Possible Causes:

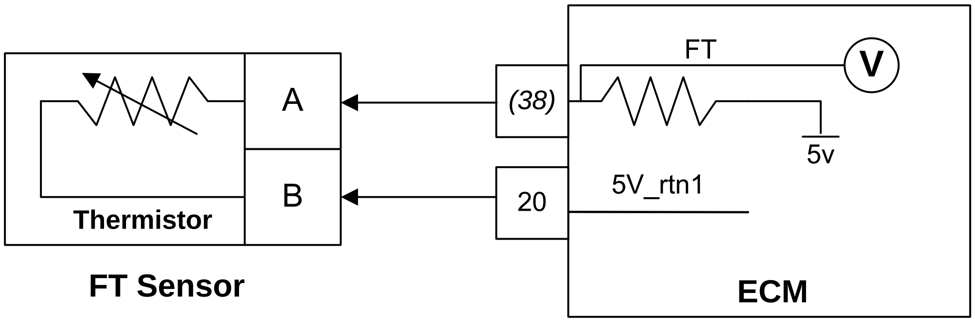
The Fuel Temperature sensor is a thermistor (temperature sensitive resistor) integrated into the EPR fuel outlet. It is used to monitor the gaseous fuel temperature exiting the EPR to be used as an input in a fuel temperature estimation of the temperature entering the gaseous mixer. This information is used to calculate a real-time fuel pressure correction in order to reduce fueling errors. The ECM provides a voltage divider circuit so that when the fuel is cool, the signal reads higher voltage, and lower when warm.

This fault will set if the signal voltage is less than the low voltage limit as defined in the diagnostic calibration anytime that the engine is running. The limit is generally set to 0.10 VDC. During this active fault the MIL and/or secondary warning device should be activated.

DTC 187- Gaseous Fuel Temperature Sensor Low Voltage



DTC 188- Gaseous Fuel Temperature Sensor High Voltage

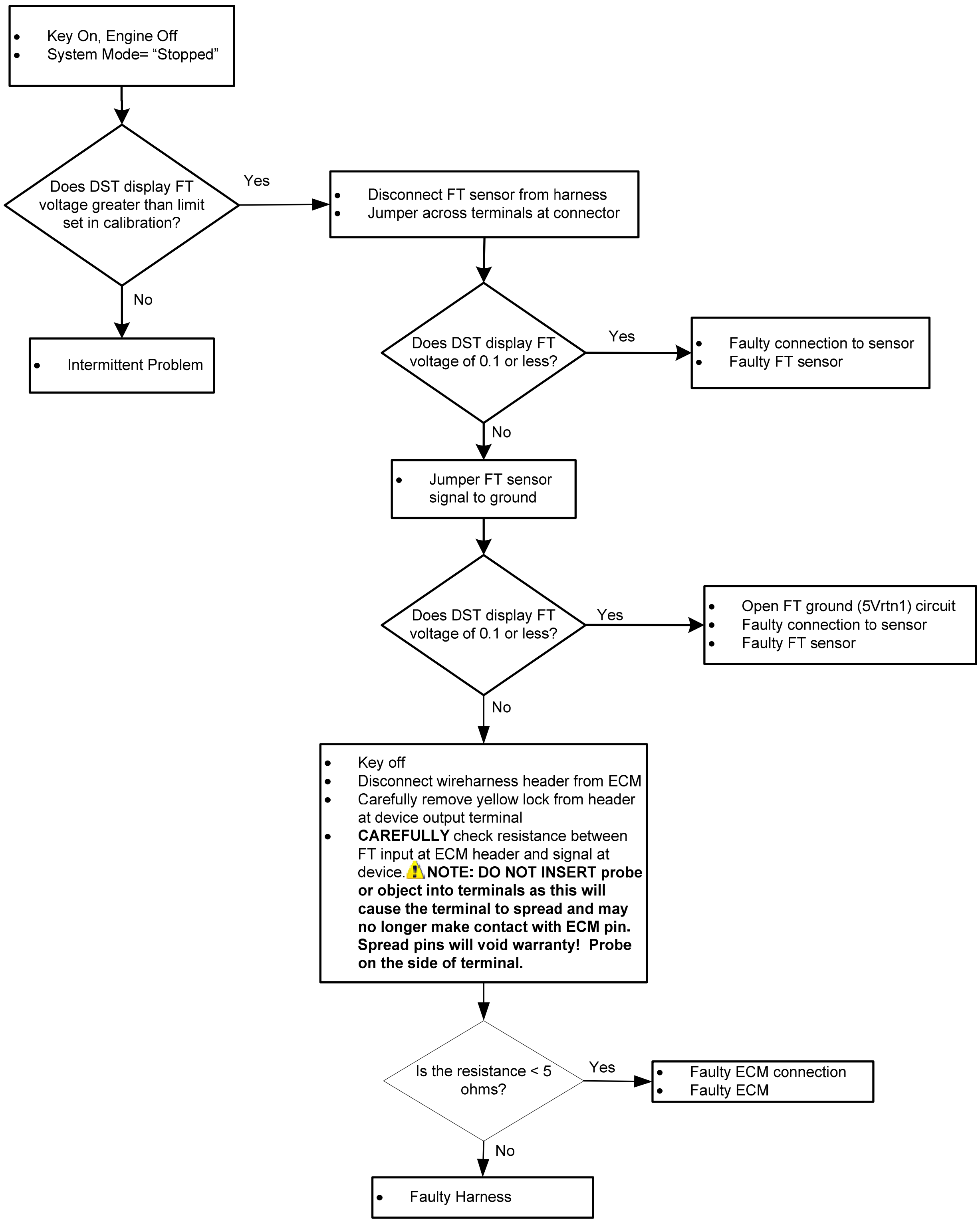


- Gaseous Fuel Temperature Sensor
- Check Condition- Engine Running
- Fault Condition- FT sensor voltage higher than defined in diagnostic calibration
- Corrective Action(s)- Illuminate MIL and/or sound audible warning or illuminate secondary warning lamp
- Non-emissions related fault

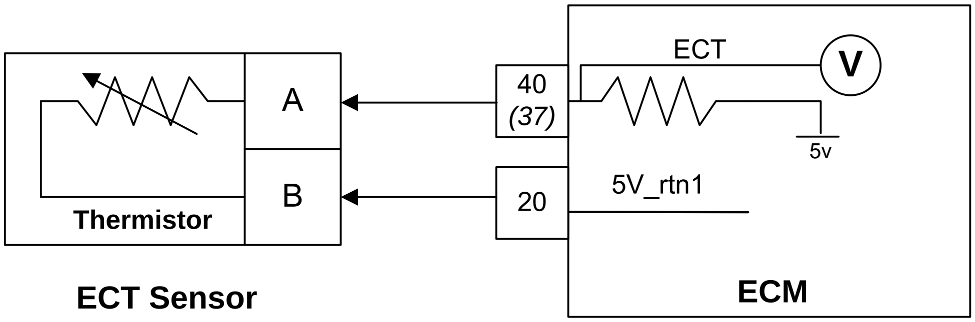
The Fuel Temperature sensor is a thermistor (temperature sensitive resistor) integrated into the EPR fuel outlet. It is used to monitor the gaseous fuel temperature exiting the EPR to be used as an input in a fuel temperature estimation of the temperature entering the gaseous mixer. This information is used to calculate a real-time fuel pressure correction in order to reduce fueling errors. The ECM provides a voltage divider circuit so that when the fuel is cool, the signal reads higher voltage, and lower when warm.

This fault will set if the signal voltage is greater than the high voltage limit as defined in the diagnostic calibration anytime that the engine is running. The limit is generally set to 4.90 VDC. During this active fault the MIL and/or secondary warning device should be activated.

DTC 188- Gaseous Fuel Temperature Sensor High Voltage



DTC 217- ECT Higher Than Expected 2



- Hardware: Engine Coolant Temperature Sensor
- Enabling Conditions: Engine Running above 500 rpm
- Set Conditions: Engine Coolant Temperature reading or estimate greater than the stage 1 limit (248^{o} F) for longer than 10 seconds
- Corrective Action(s): Illuminate MIL, active power derate 2
- Emissions related fault
- Possible Causes: Overheating engine, sensor out of calibration, signal wire partially shorted to ground or faulty ECM

The Engine Coolant Temperature sensor is a thermistor (temperature sensitive resistor) located in the engine coolant. The ECT is used for engine fuel calculation (cold engine), ignition timing control, to enable certain features, and for engine protection (overheats). The ECM provides a voltage divider circuit so when the sensor reading is cool the sensor reads higher voltage, and lower when warm.

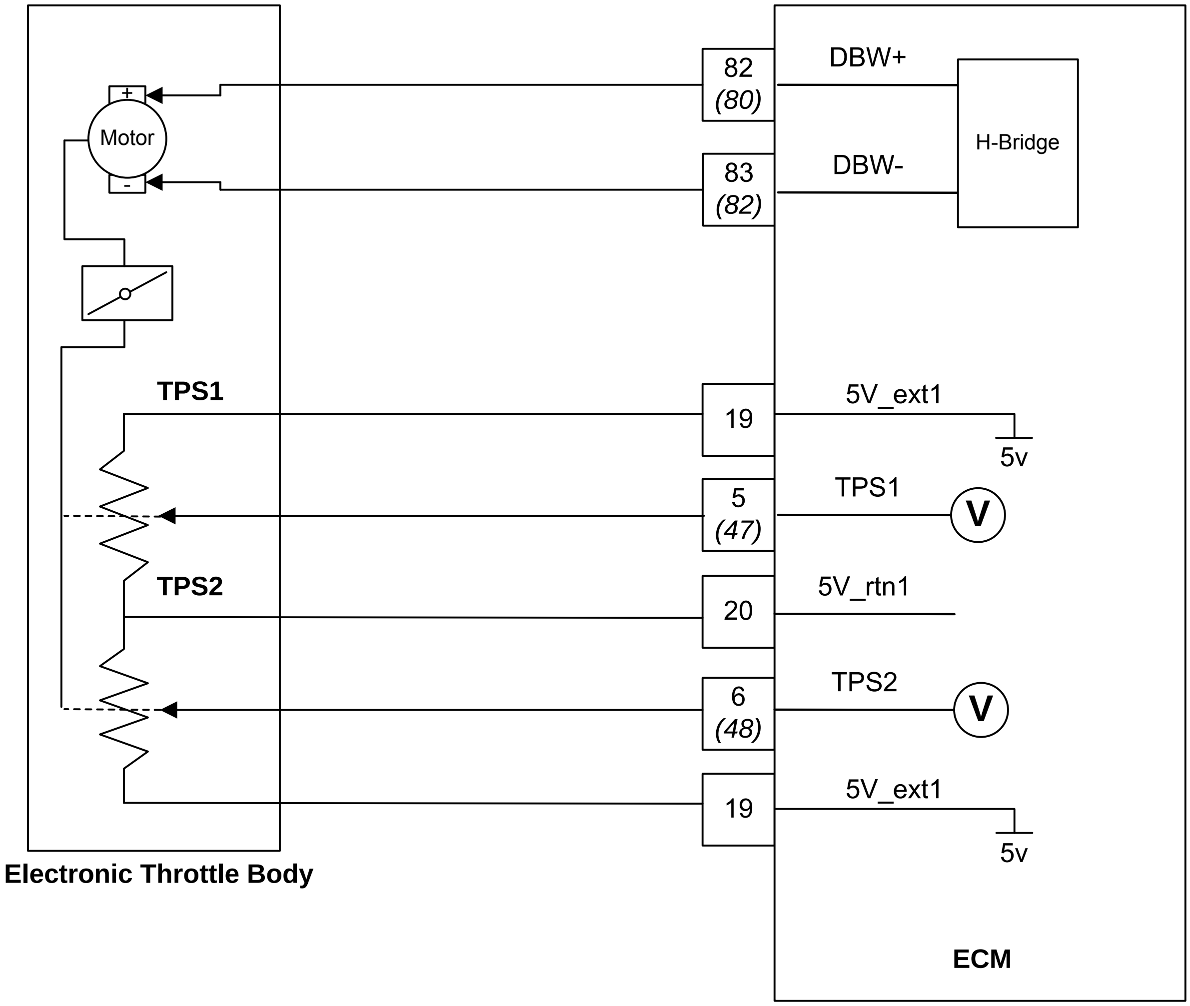
This fault will help protect the engine in the event of over temperature.

DTC 217- ECT Higher Than Expected 2

Diagnostic Aids

- ☐ If the "ECT High Voltage" fault is also present, follow the troubleshooting procedures for that fault as it may have caused "ECT Higher Than Expected 2."
- ☐ If the cooling system utilizes an air-to-water heat exchanger (radiator) and fan:
  - o Check that the radiator has a proper amount of ethylene glycol/water and that the radiator is not leaking
  - o Ensure that there is no trapped air in the cooling path
  - o Inspect the cooling system (radiator and hoses) for cracks and ensure connections are leak free
  - o Check that the fan is operating properly
  - o Check that the thermostat is not stuck closed
- ☐ If the cooling system utilizes a water-to-water heat exchanger:
  - o Check that the heat exchanger has a proper amount of ethylene glycol/water and that the heat exchanger is not leaking
  - o Ensure that there is no trapped air in the cooling path
  - o Inspect the cooling system (radiator and hoses) for cracks and ensure connections are leak free
  - o Check that the raw water pickup is not blocked/restricted by debris and that the hose is tightly connected
  - o Check that the thermostat is not stuck closed
  - o Check that the raw water pump/impeller is tact and that it is not

DTC 219- RPM Higher Than Max Allowed Governed Speed



- Hardware: Max Govern Speed Override- Crankshaft Position Sensor
- Enabling Conditions: Engine Running
- Fault Condition-Engine speed greater 3900 for longer than 1 second
- Corrective Action(s): Illuminate MIL
- Non-emissions related fault
- Possible Causes: Engine over speed condition, stuck throttle, large vacuum leak into intake manifold after throttle blade

This fault will set anytime the engine RPM exceeds 3900 for longer than 1 second.. This fault is designed to help prevent engine or equipment damage.

The throttle will be lowered in order to govern the engine to the speed set in the diagnostic calibration.

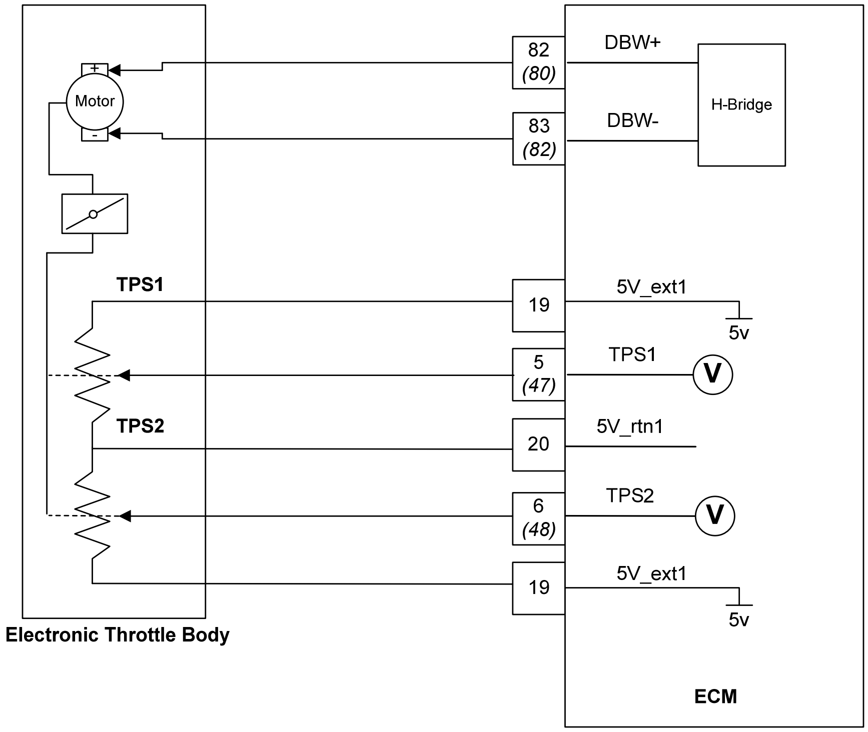
DTC 219- RPM Higher Than Max Allowed Governed Speed

Diagnostic Aids

NOTE: If any other DTCs are present, diagnose those first.

- ☐ Ensure that no programmed governor speeds exceed the limit set in the diagnostic calibration for Max Gov Override Speed
- ☐ Check mechanical operation of the throttle
- ☐ Check the engine intake for large air leaks downstream of the throttle body

DTC 221- TPS1 % Higher Than TPS2 %

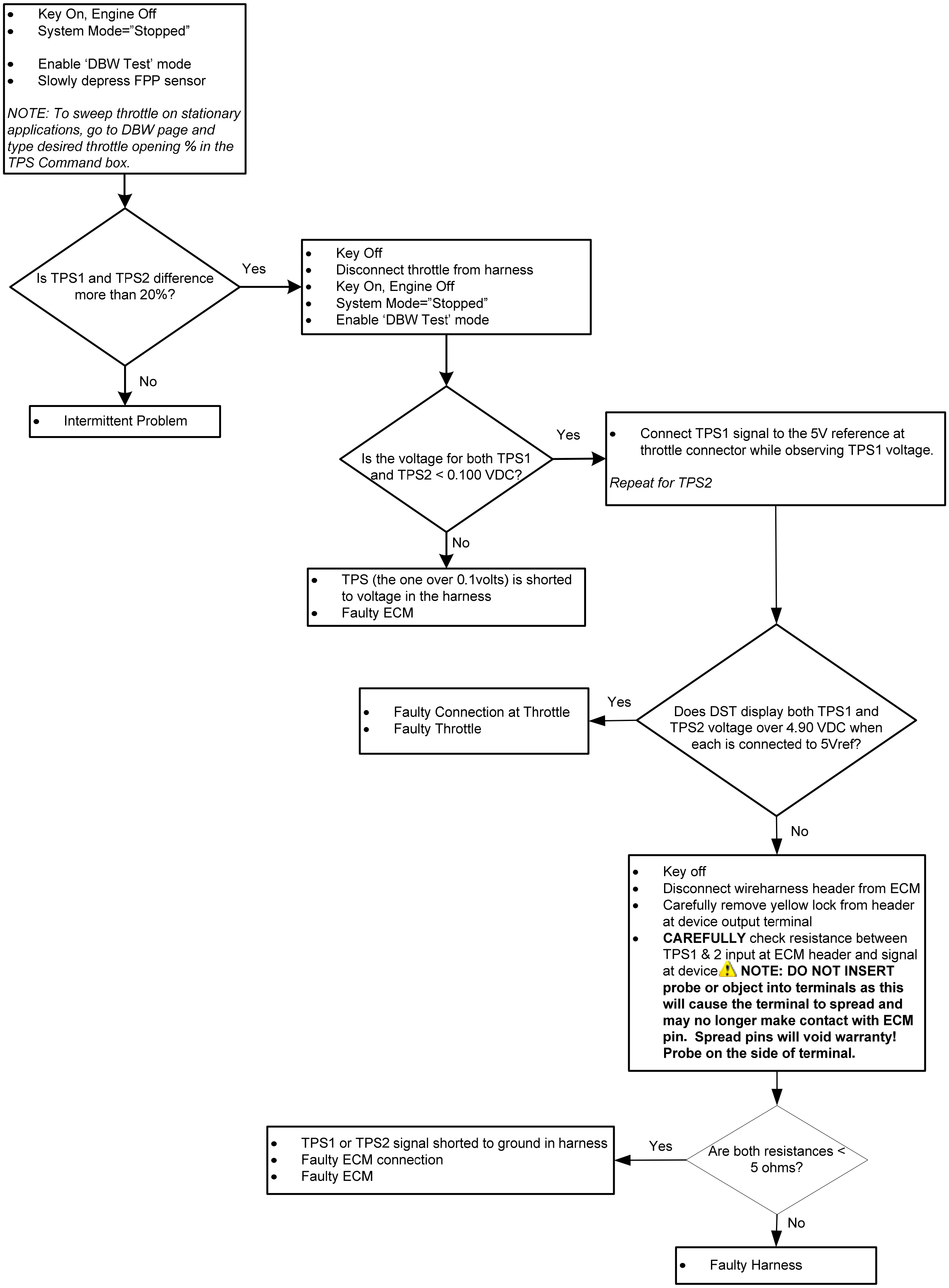


- Hardware: Throttle Body-Throttle Position Sensor 1 & 2 relationship
- Enabling Conditions: Key-On, Engine Cranking, or Running
- Set Conditions: TPS1% higher than TPS2% by more than 20% for longer than 1 second
- Corrective Action(s): Illuminate MIL, **activate engine shutdown**
- Non-emissions related fault
- Possible Causes: TPS1 or TPS2 out of calibration in throttle body, unwanted resistance in either TPS1 or TPS2 signal circuits, unwanted resistance in either the shared reference feed (5V_ext1) or shared sensor ground (5Vrtn1), bad ECM

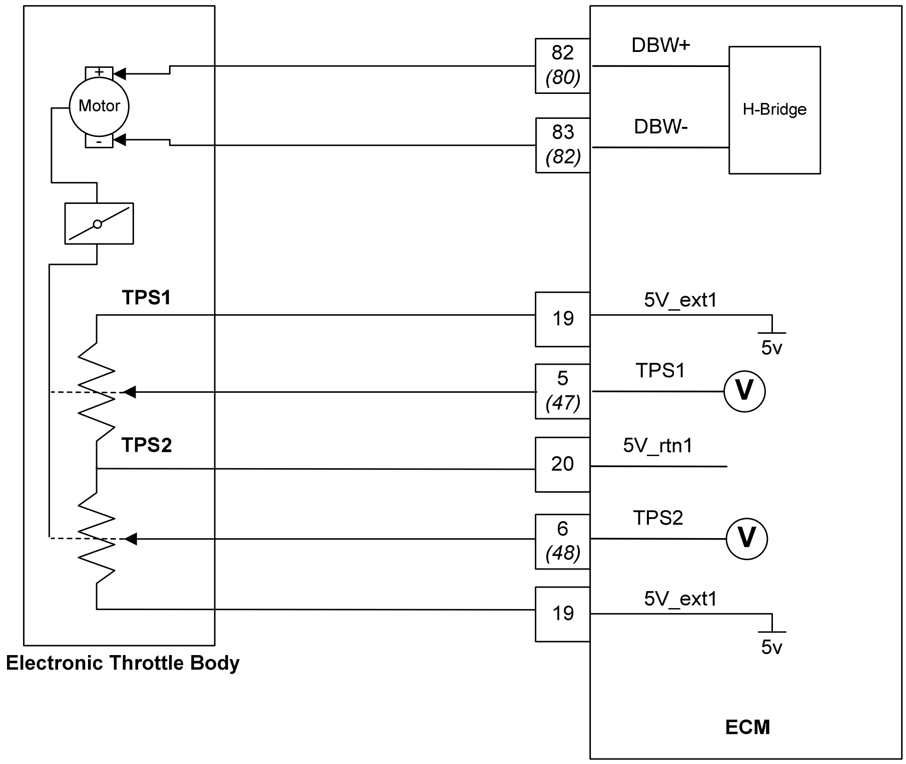
The throttle controls the airflow through the engine, directly affecting the power output of the engine. When the throttle is electronically controlled in an Electronic Throttle Body it can be used to control the idle stability and limit engine speed based on operating conditions.

Each Throttle Position Sensor uses either 1) a variable resistor and voltage divider circuit or 2) a non-contact hall-effect sensor to determine throttle plate position, and is located within the throttle body. The output of the TPS is linear with angular position. The TPS input(s) provide angular position feedback of the throttle plate. In an Electronic Throttle Body multiple position feedback sensors (usually two counteracting potentiometers/hall-effects) are used to perform speed governing with improved safety and redundancy.

DTC 221- TPS1 % Higher Than TPS2 %



DTC 222- TPS2 Signal Voltage Low

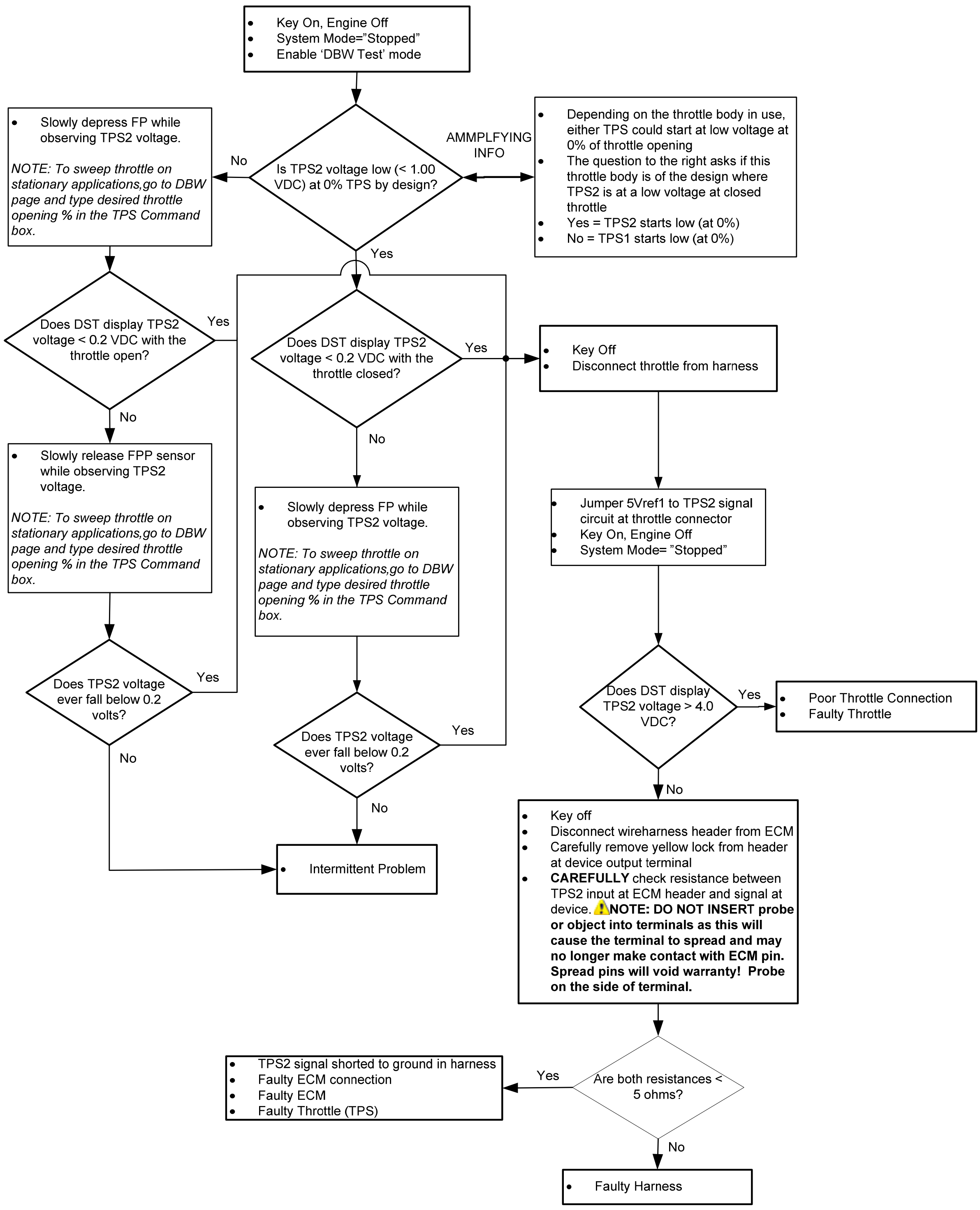


- o Hardware: Throttle Body-Throttle Position Sensor 2 (electronic throttle body only)
- o Enabling Condition: Key-On, Engine Off
- o Set Condition: TPS2 sensor voltage lower 0.2v for longer than 0.5 seconds
- o Corrective Action(s): Illuminate MIL, **activate engine shutdown**
- o Emissions related fault
- o Possible Causes: Loss of 5v reference feed, open or shorted to ground signal circuit, open or shorted to ground TPS in throttle body, bad ECM

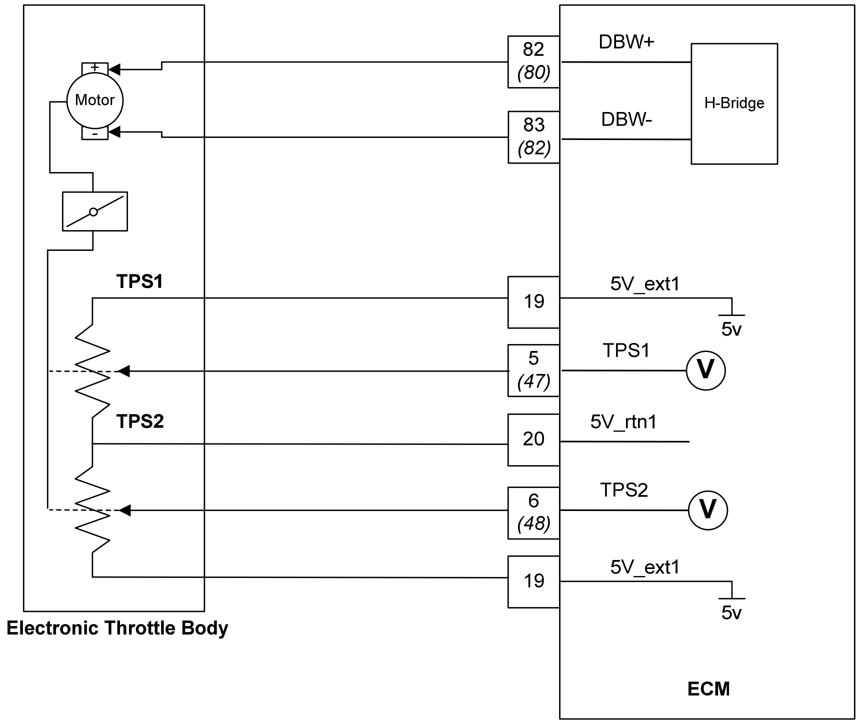
The throttle controls the airflow through the engine, directly affecting the power output of the engine. When the throttle is electronically controlled in an Electronic Throttle Body it can be used to control the idle stability and limit engine speed based on operating conditions.

The Throttle Position Sensor uses either 1) a variable resistor and voltage divider circuit or 2) a non-contact hall-effect sensor to determine throttle plate position, and is located within the throttle body. The output of the TPS is linear with angular position. The TPS input(s) provide angular position feedback of the throttle plate. In an Electronic Throttle Body multiple position feedback sensors (usually two counteracting potentiometers/hall-effects) are used to perform speed governing with improved safety and redundancy.

DTC 222- TPS2 Signal Voltage Low



DTC 223- TPS2 Signal Voltage High

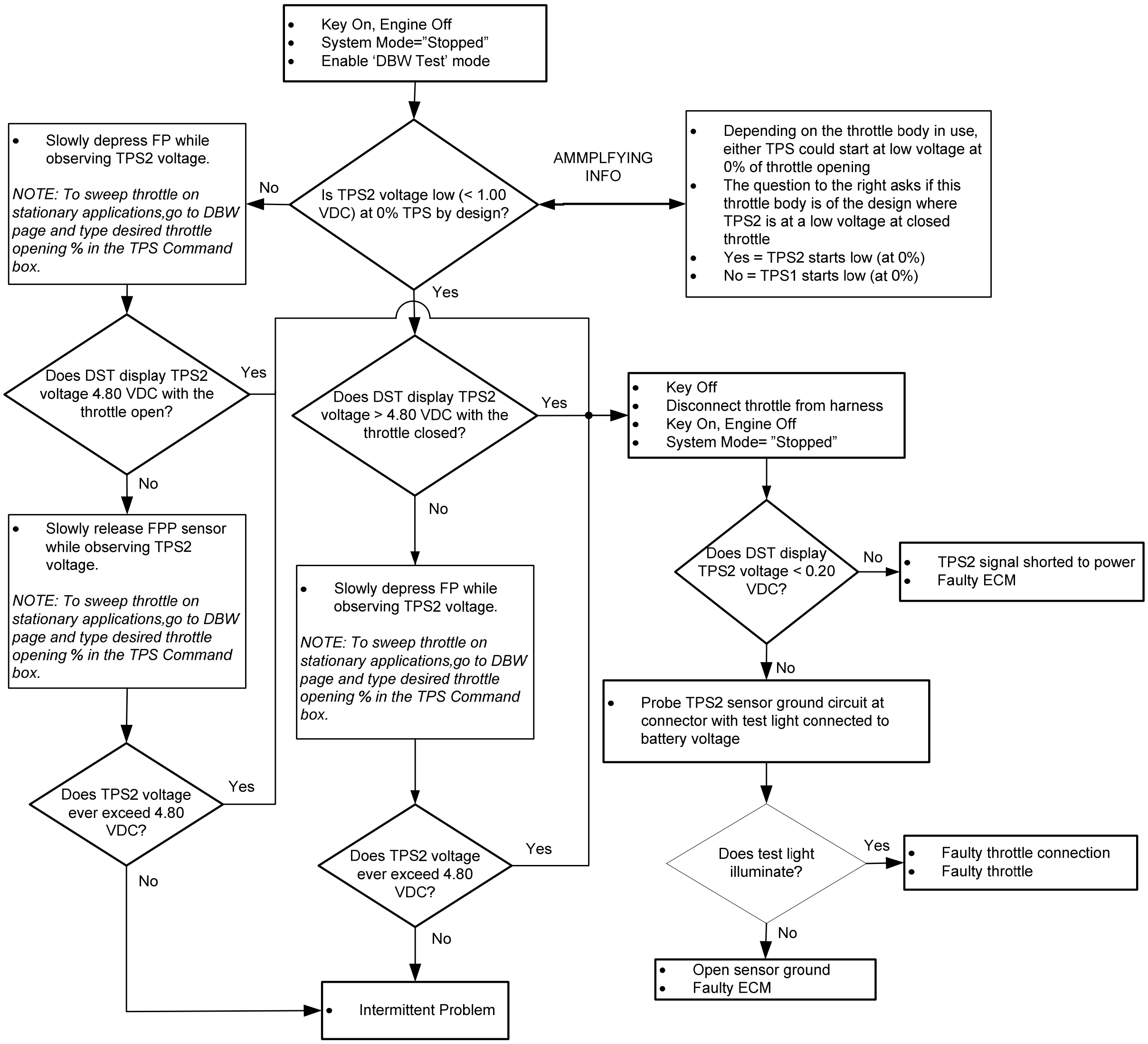


- Hardware: Throttle Body-Throttle Position Sensor 2 (electronic throttle body only)
- Enabling Conditions: Engine running
- Set Conditions: TPS2 sensor voltage higher than 4.8v for longer than 0.5 seconds
- Corrective Action(s): Illuminate MIL, **activate engine shutdown**
- Emissions related fault
- Possible Causes: 5 volt reference feed (5V_ext1) shorted to voltage, Open sensor ground (5vrtn1) circuit, signal wire shorted to voltage or bad TPS in throttle body

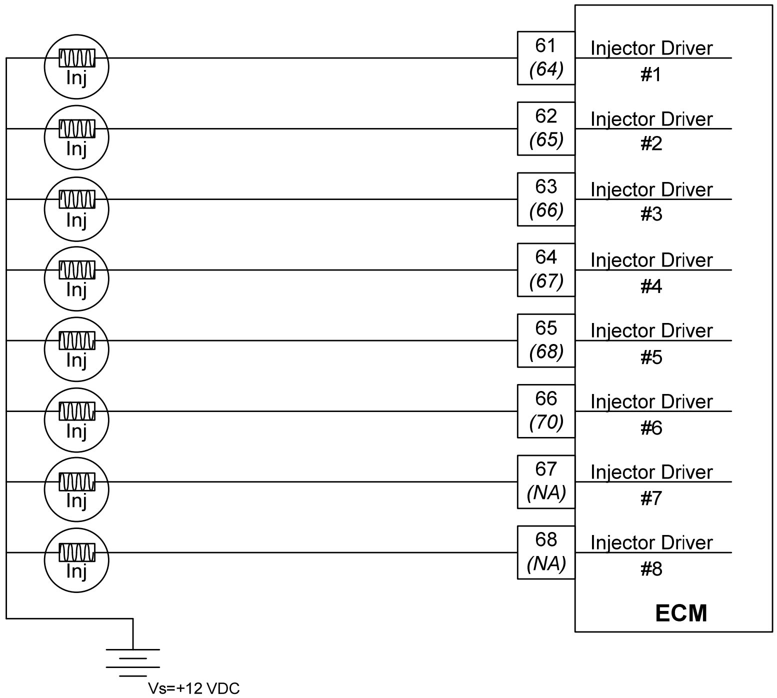
The throttle controls the airflow through the engine, directly affecting the power output of the engine. When the throttle is electronically controlled in an Electronic Throttle Body it can be used to control the idle stability and limit engine speed based on operating conditions.

Each Throttle Position Sensor uses either 1) a variable resistor and voltage divider circuit or 2) a non-contact hall-effect sensor to determine throttle plate position, and is located within the throttle body. The output of the TPS is linear with angular position. The TPS input(s) provide angular position feedback of the throttle plate. In an Electronic Throttle Body multiple position feedback sensors (usually two counteracting potentiometers/hall-effects) are used to perform speed governing with improved safety and redundancy.

DTC 223- TPS2 Signal Voltage High



DTC 261- Injector Driver #1 Open/Short-To-Ground

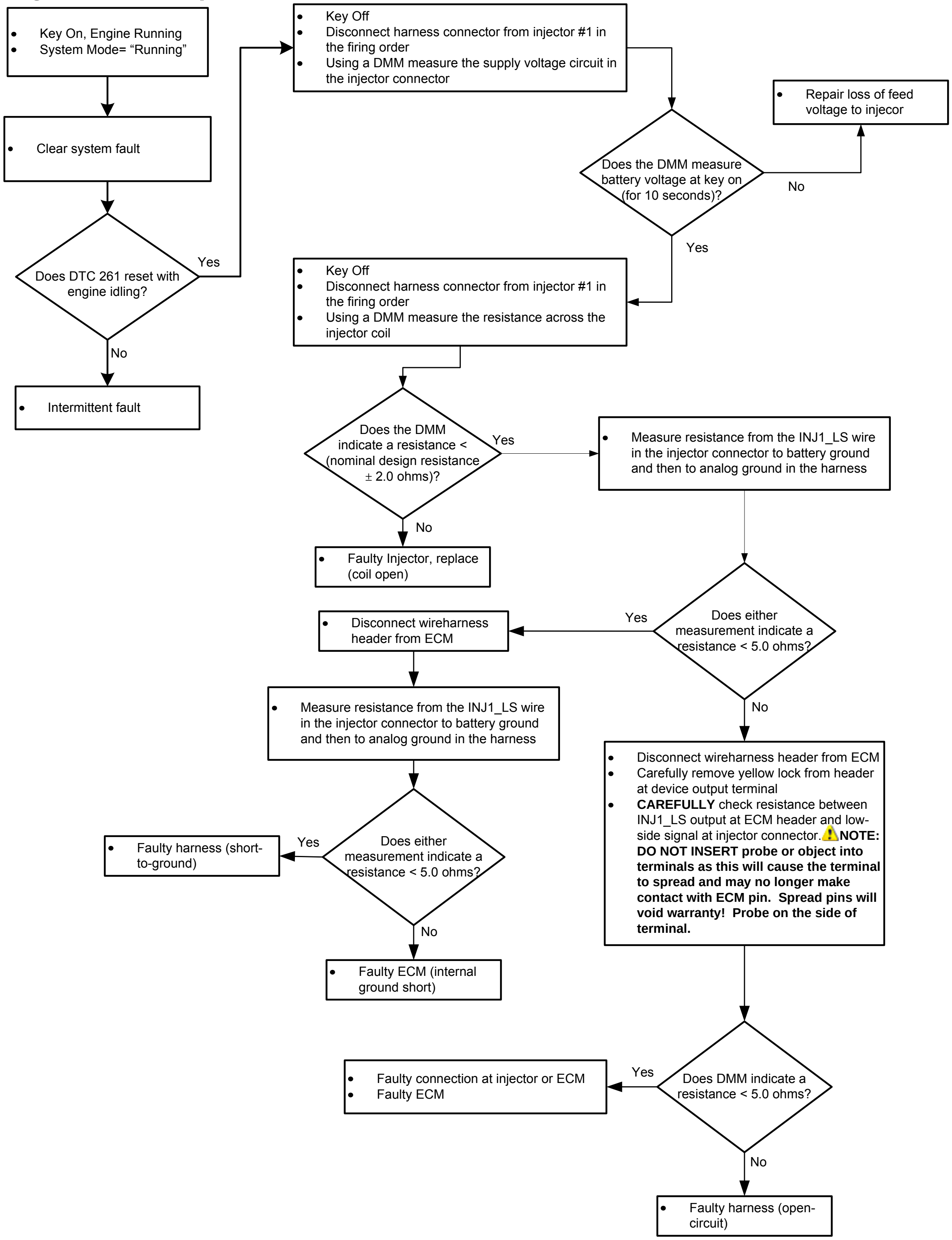


- Hardware: Injector Driver #1 (**first cylinder in the firing order**)
- Enabling Conditions: Key-On, Engine Running
- Set Conditions: Battery voltage at ECM greater than 9 volts and injector driver #1 off voltage less than 4 volts for 10 samples
- Corrective Action(s): Illuminate MIL, Disable Closed Loop operation while fault is active, disable fuel adaptive learn for the rest of the key cycle.
- Emissions-related fault
- Possible Causes: Loss of 12v feed to injector, open injector coil, open or shorted to ground injector driver circuit in engine harness, bad ECM

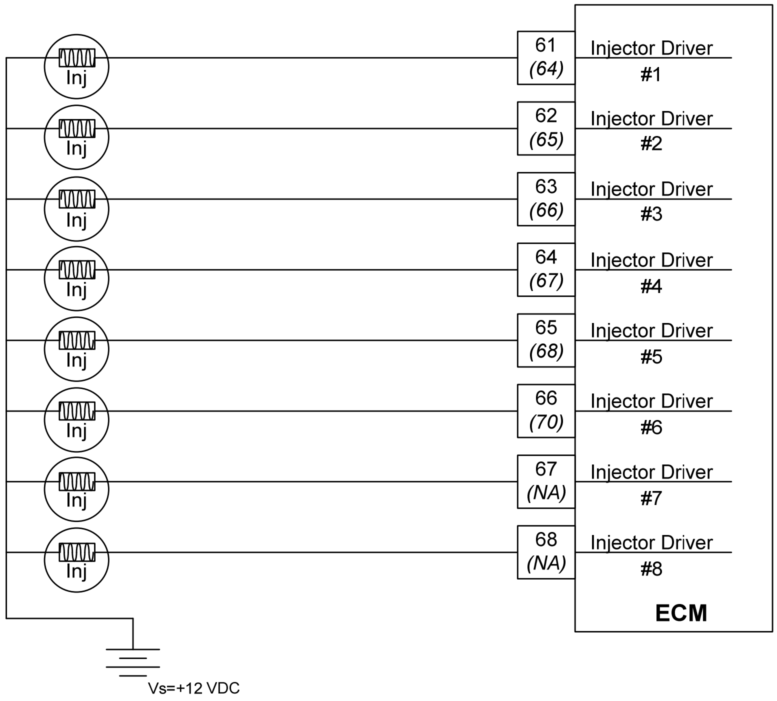
The fuel injector is an electronically controlled valve and nozzle that is controlled to deliver a precise quantity of fuel to a cylinder. Each fuel injector is supplied 12v from the power relay and is operated by the ECM through a low side driver (LSD) circuit that is monitored for the correct voltage for the current state of the injector (on or off).

DTC 261- Injector Driver #1 Open/Short-To-Ground

Firing Order Example



DTC 262- Injector Driver #1 Short-To-Power

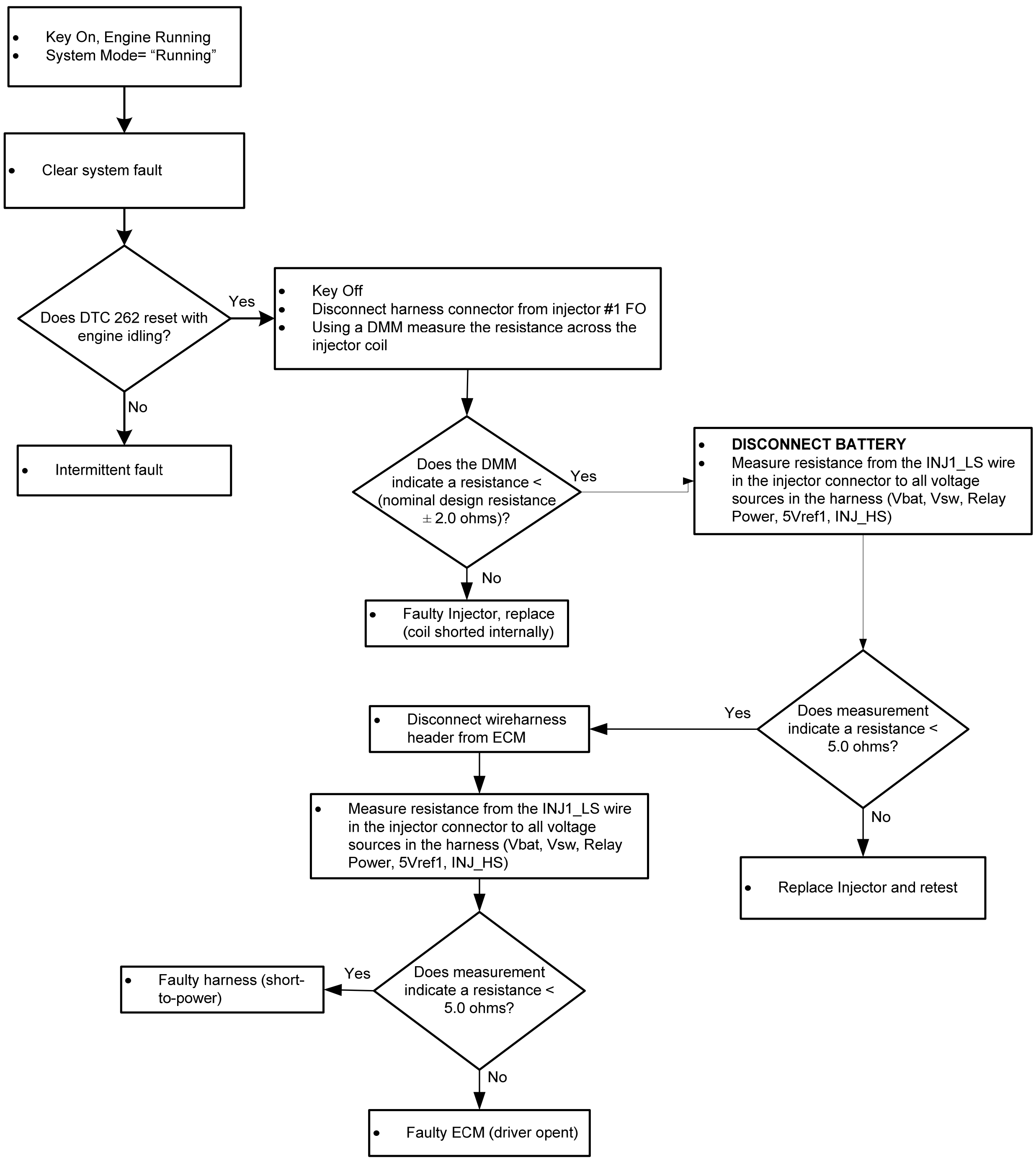


- Hardware: Injector Driver #1 (**first cylinder in the firing order**)
- Enabling Conditions: Key-On, Engine Running
- Set Conditions: Battery voltage at ECM less than 16 volts and injector driver #1 on voltage greater than 4 volts for 10 samples
- Corrective Action(s): Illuminate MIL, Disable Closed Loop operation while fault is active, disable fuel adaptive learn for the rest of the key cycle.
- Emissions-related fault
- Possible Causes: Injector coil shorted internally, injector driver circuit shorted to voltage between injector and ECM, bad ECM

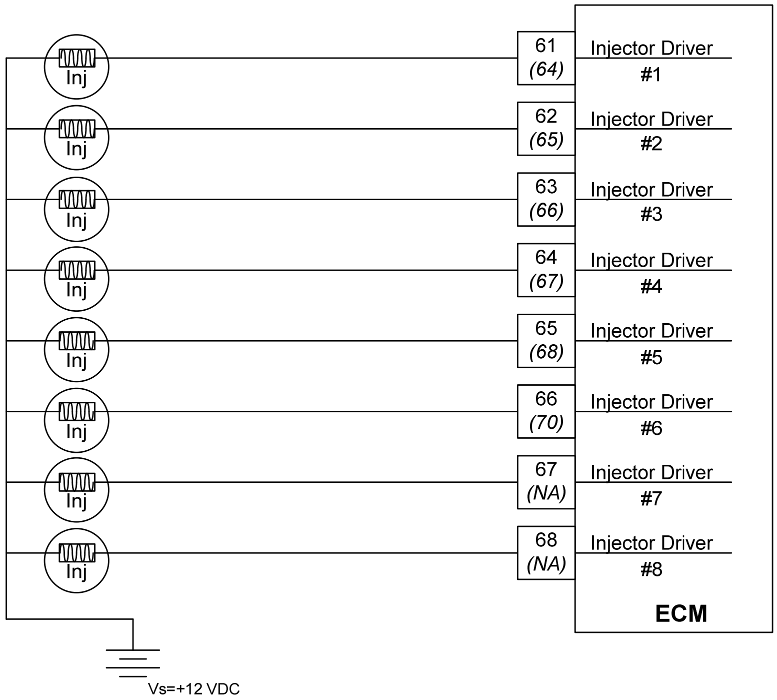
The fuel injector is an electronically controlled valve and nozzle that is controlled to deliver a precise quantity of fuel to a cylinder. Each fuel injector is supplied 12v from the power relay and is operated by the ECM through a low side driver (LSD) circuit that is monitored for the correct voltage for the current state of the injector (on or off).

DTC 262- Injector Driver #1 Short-To-Power

Firing Order Example



DTC 264- Injector Driver #2 Open/Short-To-Ground



- Hardware: Injector Driver #2 (**second cylinder in the firing order**)
- Enabling Conditions: Key-On, Engine Running
- Set Conditions: Battery voltage at ECM greater than 9 volts and injector driver #2 off voltage less than 4 volts for 10 samples
- Corrective Action(s): Illuminate MIL, Disable Closed Loop operation while fault is active, disable fuel adaptive learn for the rest of the key cycle.
- Emissions-related fault
- Possible Causes: Loss of 12v feed to injector, open injector coil, open or shorted to ground injector driver circuit in engine harness, bad ECM

The fuel injector is an electronically controlled valve and nozzle that is controlled to deliver a precise quantity of fuel to a cylinder. Each fuel injector is supplied 12v from the power relay and is operated by the ECM through a low side driver (LSD) circuit that is monitored for the correct voltage for the current state of the injector (on or off).

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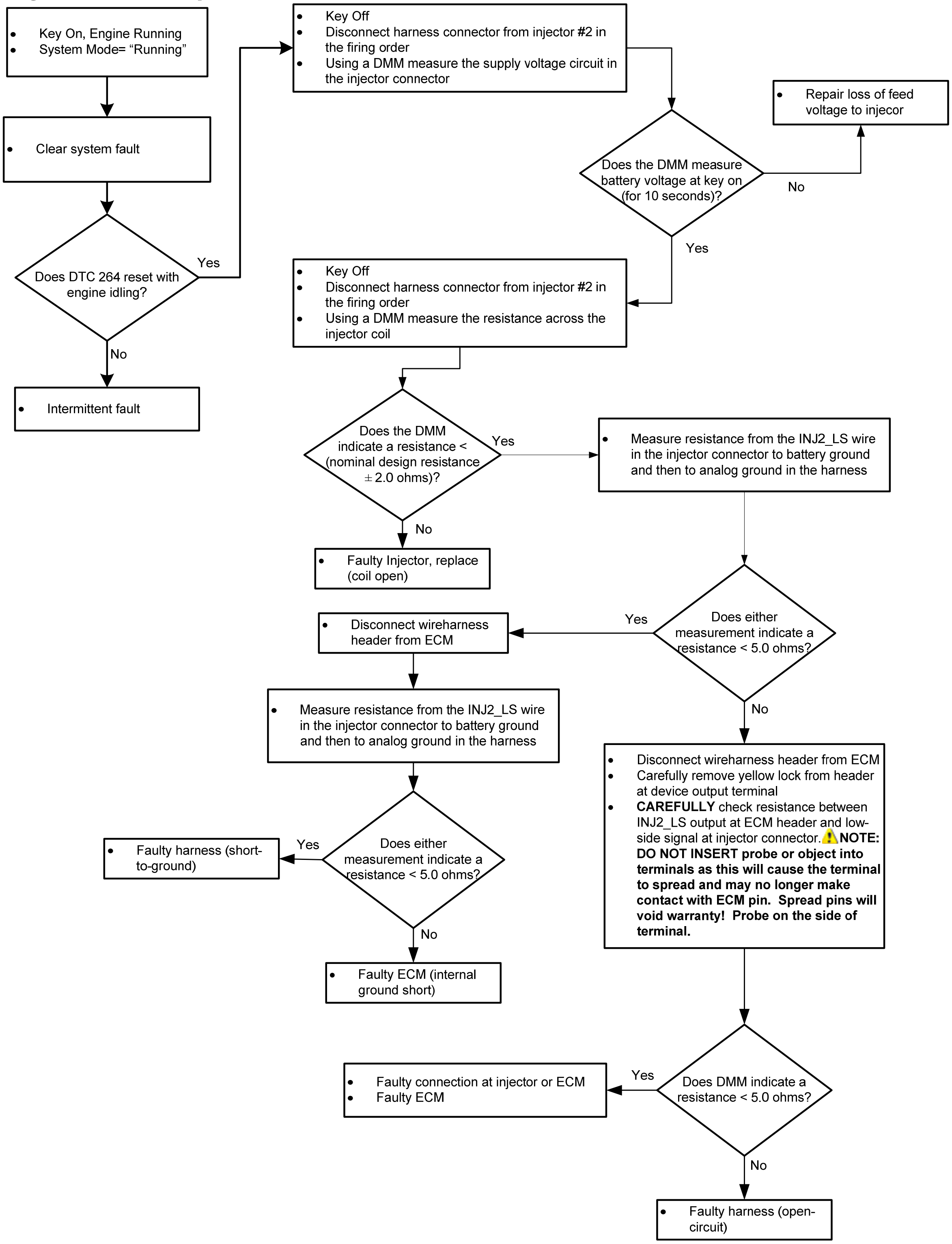
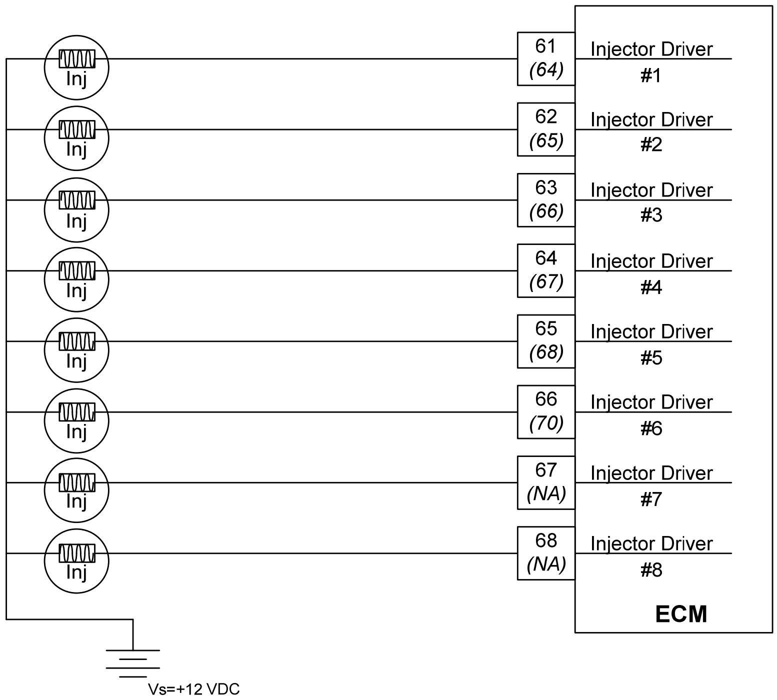
DTC 264- Injector Driver #2 Open/Short-To-Ground

Firing Order Example



DTC 265- Injector Driver #2 Short-To-Power

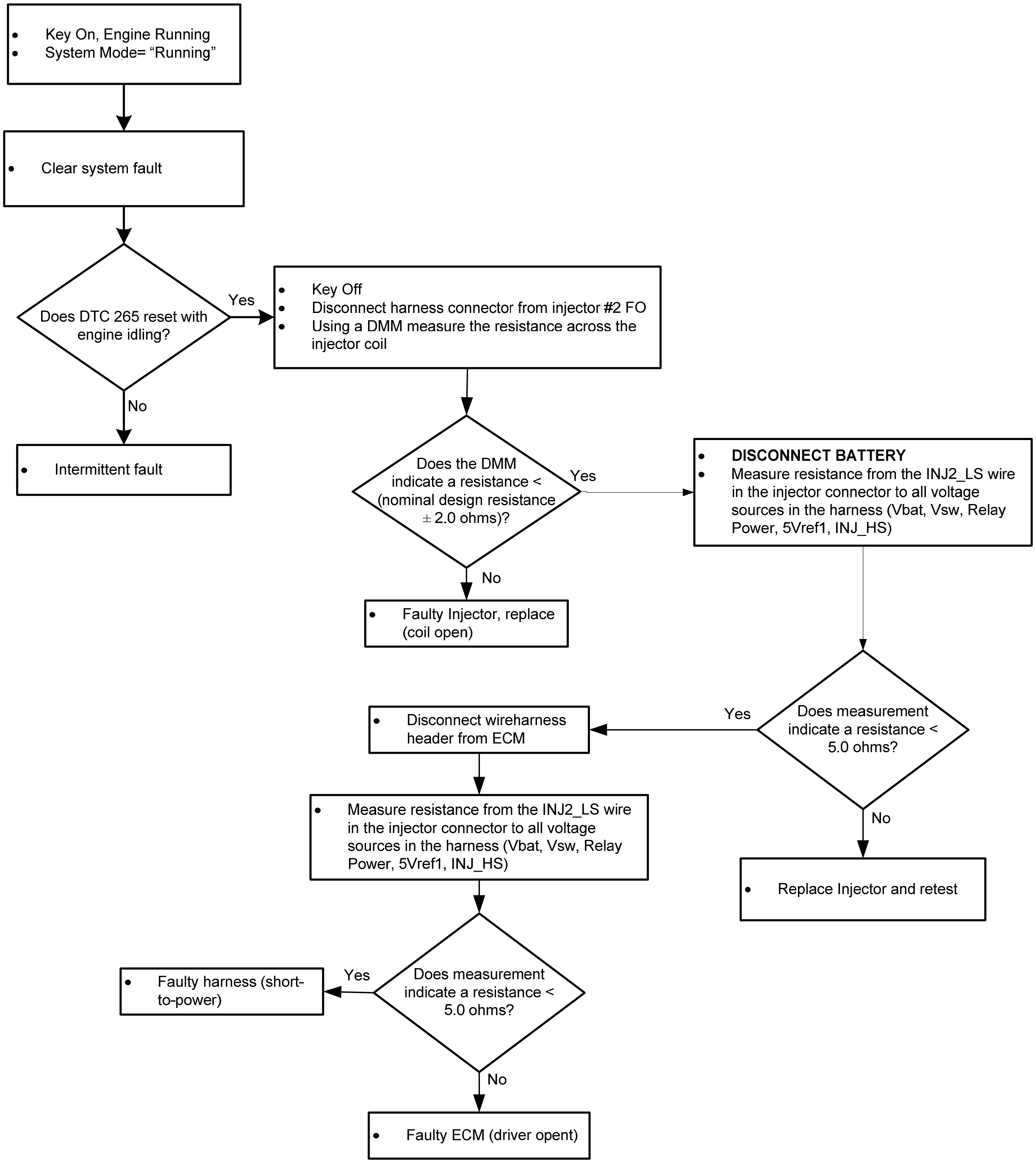


- Hardware: Injector Driver #2 (**second cylinder in the firing order**)
- Enabling Conditions: Key-On, Engine Running
- Set Conditions: Battery voltage at ECM less than 16 volts and injector driver #2 on voltage greater than 4 volts for 10 samples
- Corrective Action(s): Illuminate MIL, Disable Closed Loop operation while fault is active, disable fuel adaptive learn for the rest of the key cycle.
- Emissions-related fault
- Possible Causes: Injector coil shorted internally, injector driver circuit shorted to voltage between injector and ECM, bad ECM

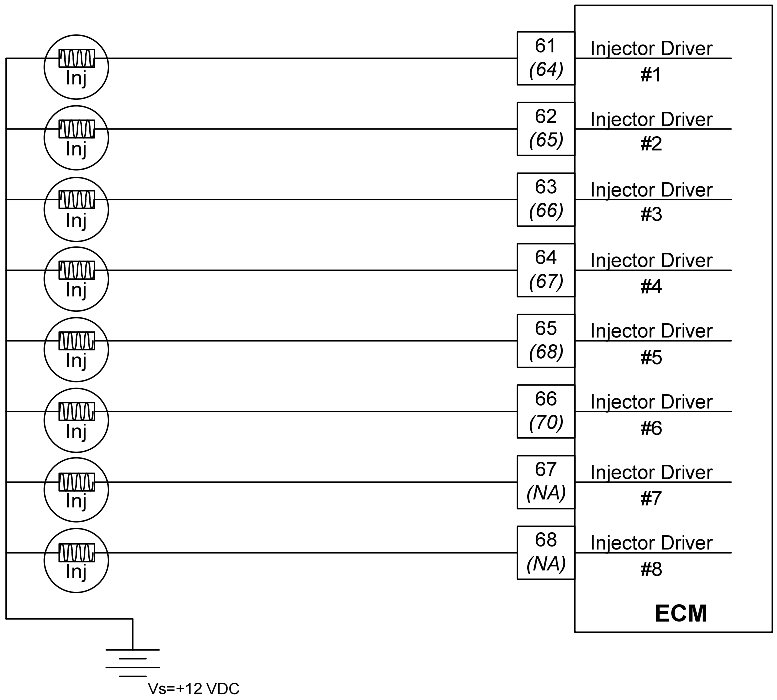
The fuel injector is an electronically controlled valve and nozzle that is controlled to deliver a precise quantity of fuel to a cylinder. Each fuel injector is supplied 12v from the power relay and is operated by the ECM through a low side driver (LSD) circuit that is monitored for the correct voltage for the current state of the injector (on or off).

DTC 265- Injector Driver #2 Short-To-Power

Firing Order Example



DTC 267- Injector Driver #3 Open/Short-To-Ground

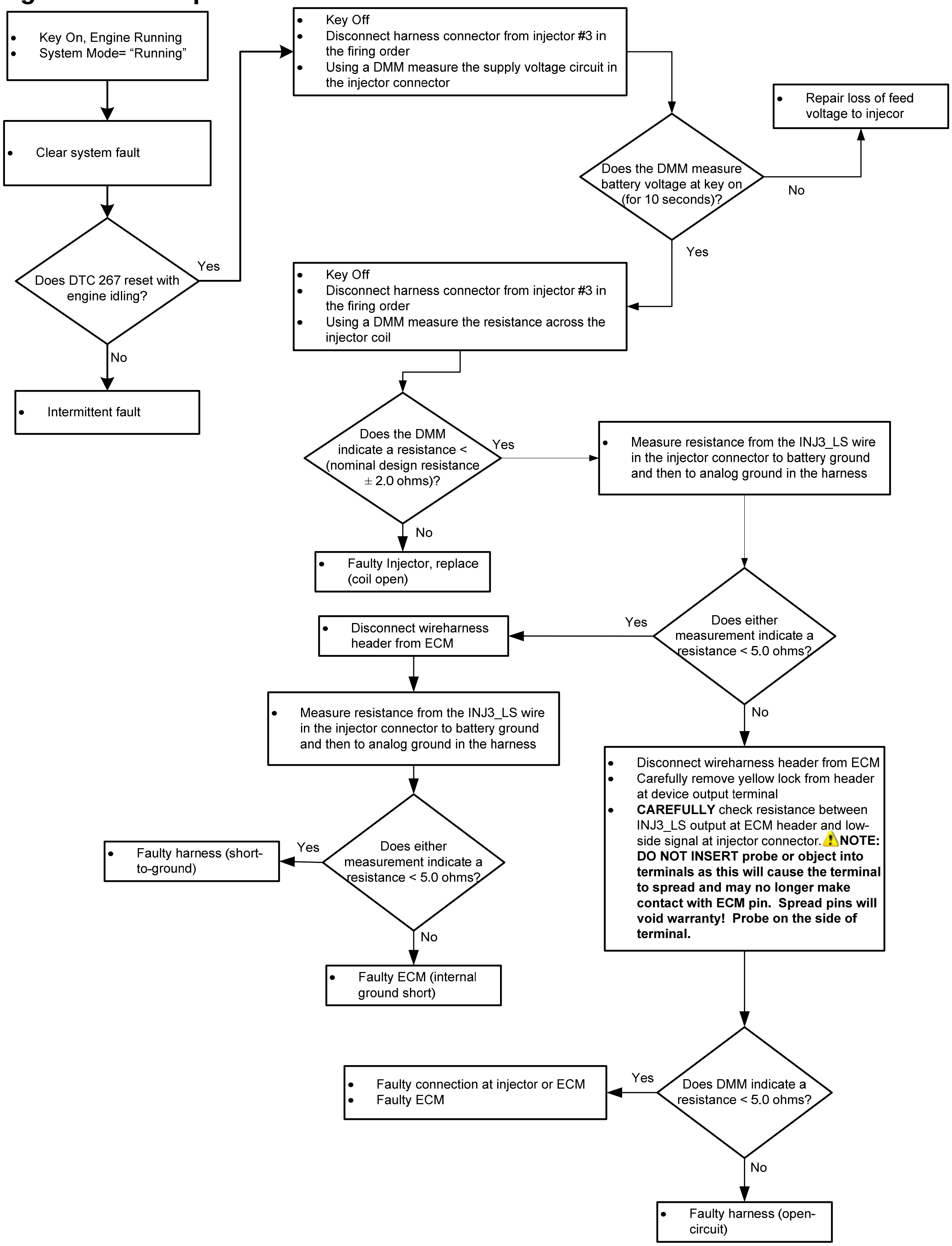


- Hardware: Injector Driver #3 (**third cylinder in the firing order**)
- Enabling Conditions: Key-On, Engine Running
- Set Conditions: Battery voltage at ECM greater than 9 volts and injector driver #3 off voltage less than 4 volts for 10 samples
- Corrective Action(s): Illuminate MIL, Disable Closed Loop operation while fault is active, disable fuel adaptive learn for the rest of the key cycle.
- Emissions-related fault
- Possible Causes: Loss of 12v feed to injector, open injector coil, open or shorted to ground injector driver circuit in engine harness, bad ECM

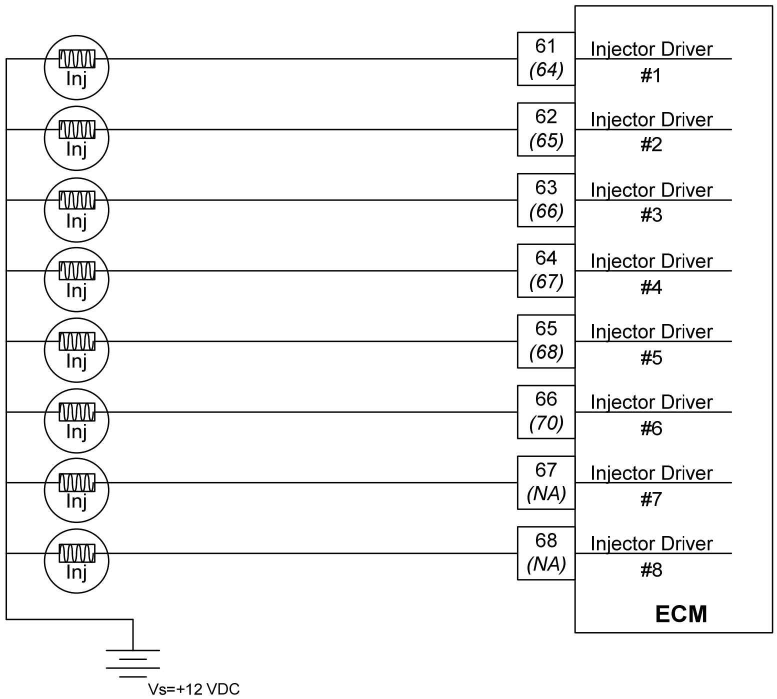
The fuel injector is an electronically controlled valve and nozzle that is controlled to deliver a precise quantity of fuel to a cylinder. Each fuel injector is supplied 12v from the power relay and is operated by the ECM through a low side driver (LSD) circuit that is monitored for the correct voltage for the current state of the injector (on or off).

DTC 267- Injector Driver #3 Open/Short-To-Ground

Firing Order Example



DTC 268- Injector Driver #3 Short-To-Power

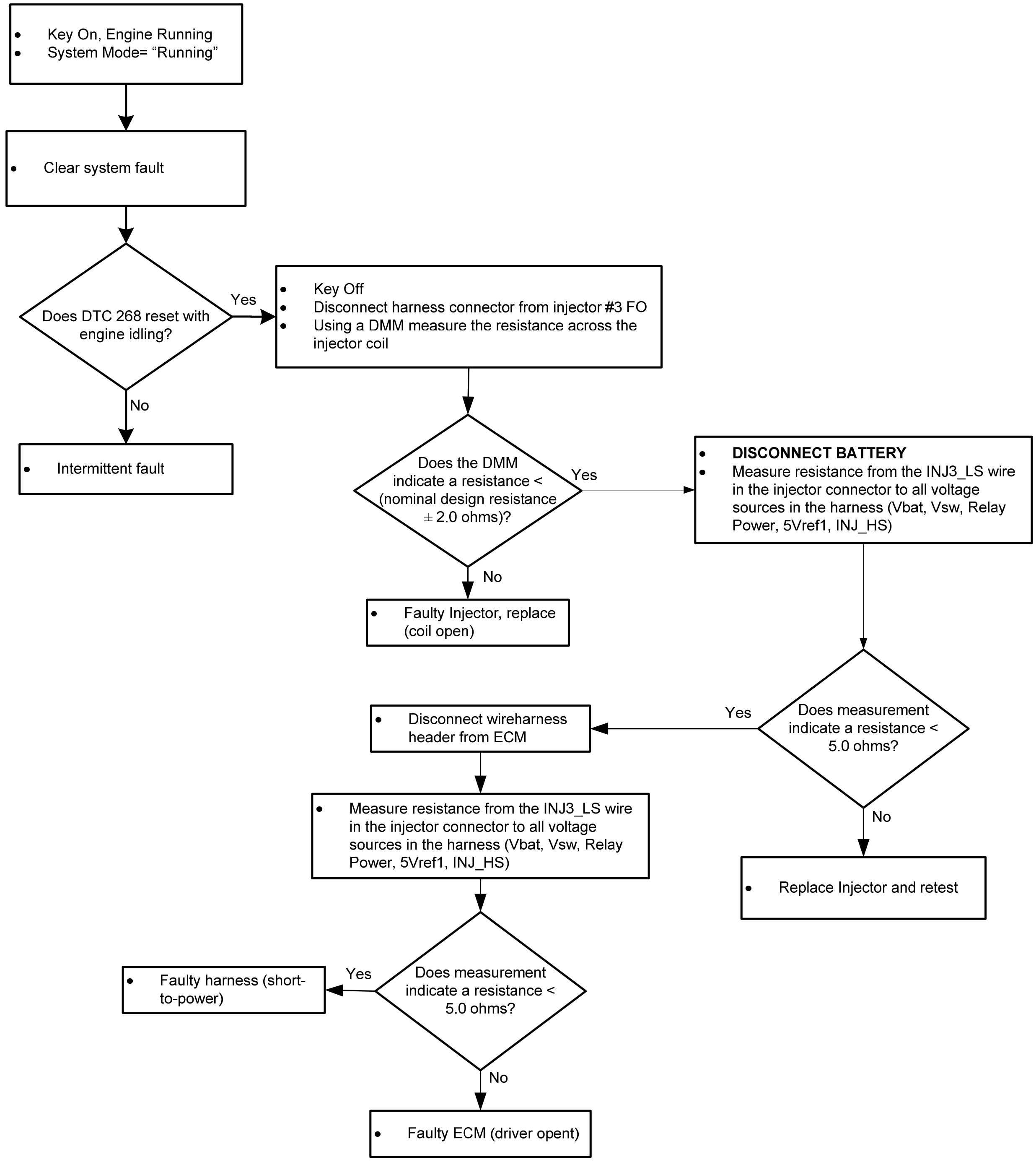


- Hardware: Injector Driver #3 (**third cylinder in the firing order**)
- Enabling Conditions: Key-On, Engine Running
- Set Condition: Battery voltage at ECM less than 16 volts and injector driver #3 on voltage greater than 4 volts for 10 samples
- Corrective Action(s): Illuminate MIL, Disable Closed Loop operation while fault is active, disable fuel adaptive learn for the rest of the key cycle.
- Emissions-related fault
- Possible Causes: Injector coil shorted internally, injector driver circuit shorted to voltage between injector and ECM, bad ECM

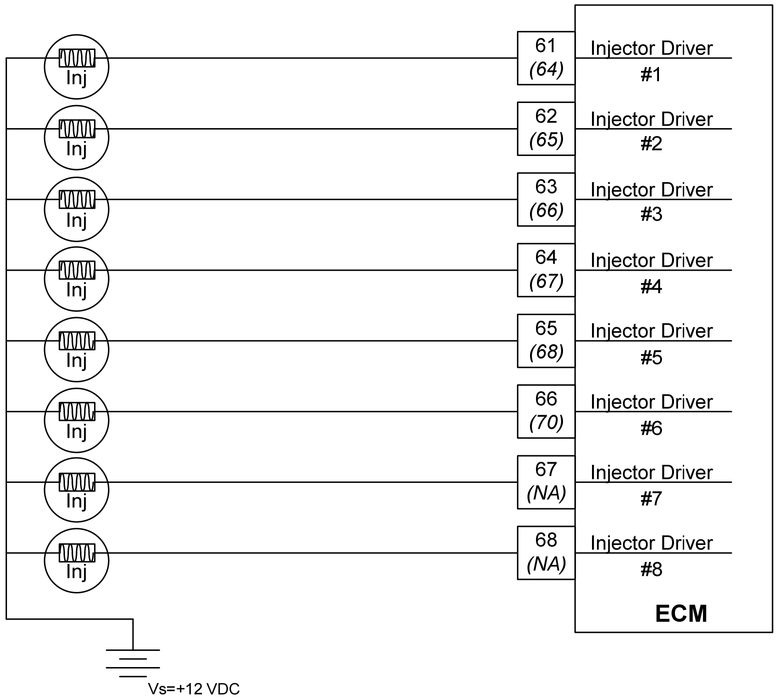
The fuel injector is an electronically controlled valve and nozzle that is controlled to deliver a precise quantity of fuel to a cylinder. Each fuel injector is supplied 12v from the power relay and is operated by the ECM through a low side driver (LSD) circuit that is monitored for the correct voltage for the current state of the injector (on or off).

DTC 268- Injector Driver #3 Short-To-Power

Firing Order Example



DTC 270- Injector Driver #4 Open/Short-To-Ground

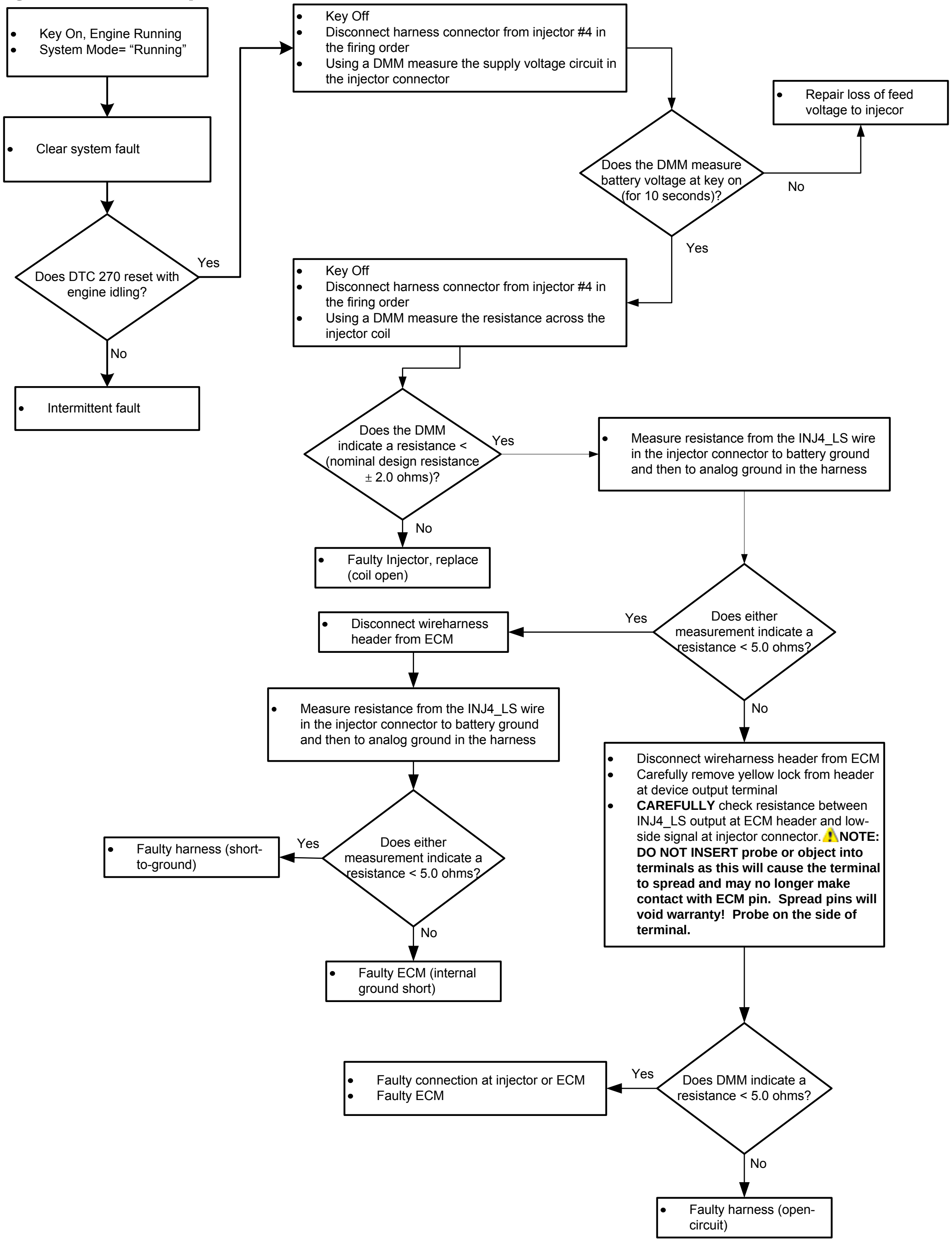


- Hardware: Injector Driver #4 (**fourth cylinder in the firing order**)
- Enabling Conditions: Key-On, Engine Running
- Set Conditions: Battery voltage at ECM greater than 9 volts and injector driver #4 off voltage less than 4 volts for 10 samples
- Corrective Action(s)- Illuminate MIL, Disable Closed Loop operation while fault is active, disable fuel adaptive learn for the rest of the key cycle.
- Emissions-related fault
- Possible Causes: Loss of 12v feed to injector, open injector coil, open or shorted to ground injector driver circuit in engine harness, bad ECM

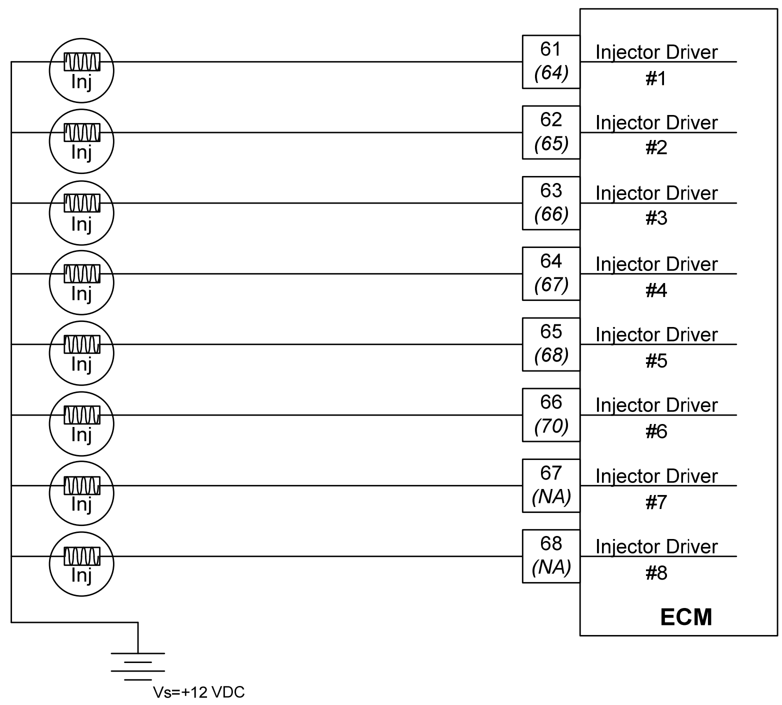
The fuel injector is an electronically controlled valve and nozzle that is controlled to deliver a precise quantity of fuel to a cylinder. Each fuel injector is supplied 12v from the power relay and is operated by the ECM through a low side driver (LSD) circuit that is monitored for the correct voltage for the current state of the injector (on or off).

DTC 270- Injector Driver #4 Open/Short-To-Ground

Firing Order Example



DTC 271- Injector Driver #4 Short-To-Power

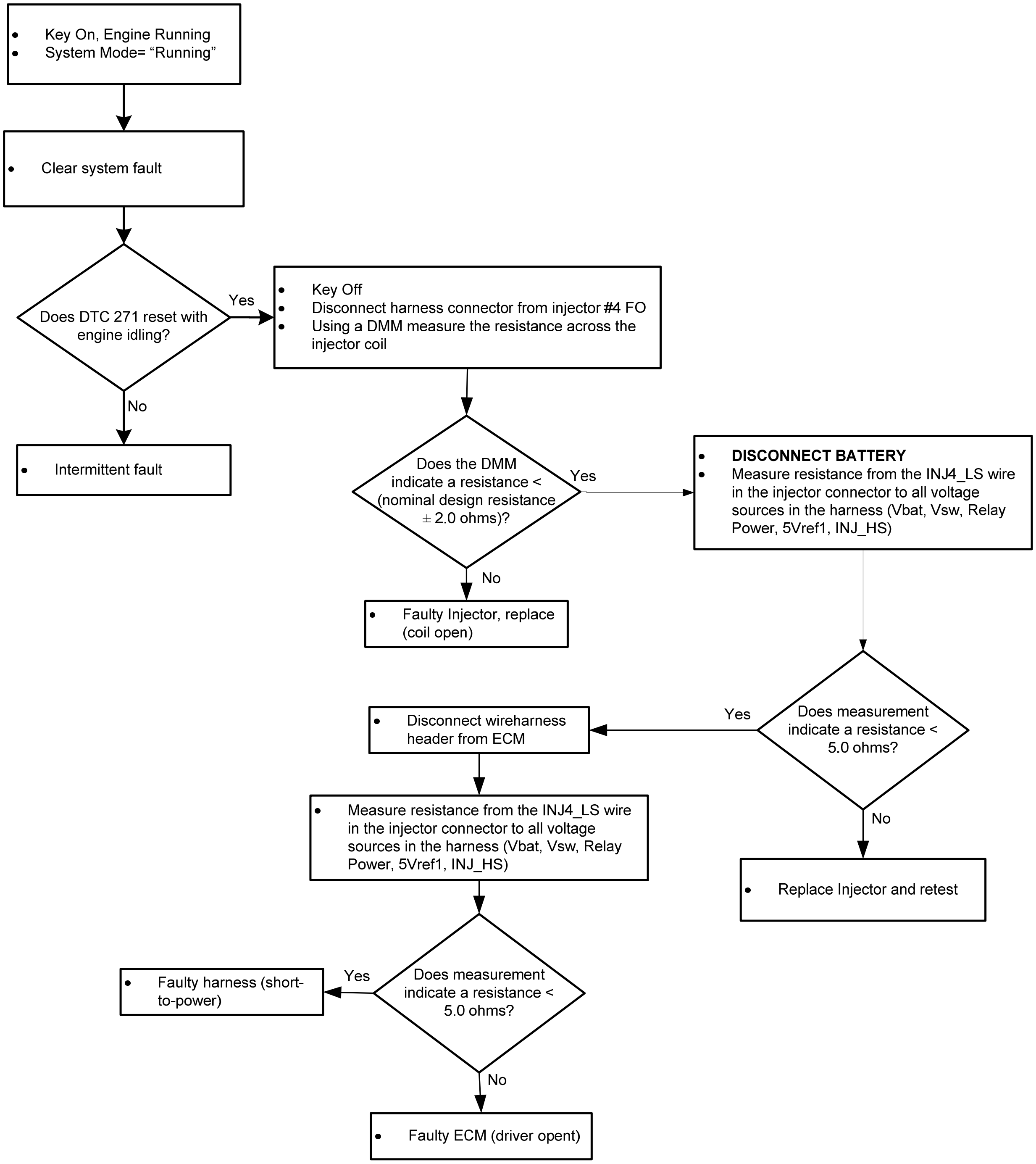


- Hardware: Injector Driver #4 (**fourth cylinder in the firing order**)
- Enabling Conditions: Key-On, Engine Running
- Set Conditions: Battery voltage at ECM less than 16 volts and injector driver #4 on voltage greater than 4 volts for 10 samples
- Corrective Action(s): Illuminate MIL, Disable Closed Loop operation while fault is active, disable fuel adaptive learn for the rest of the key cycle.
- Emissions-related fault
- Possible Causes: Injector coil shorted internally, injector driver circuit shorted to voltage between injector and ECM, bad ECM

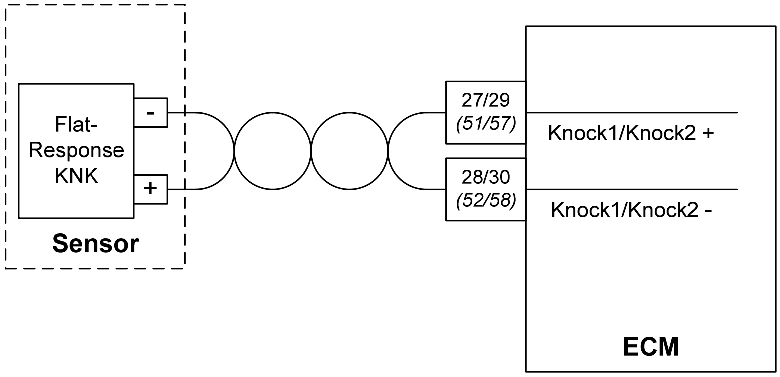
The fuel injector is an electronically controlled valve and nozzle that is controlled to deliver a precise quantity of fuel to a cylinder. Each fuel injector is supplied 12v from the power relay and is operated by the ECM through a low side driver (LSD) circuit that is monitored for the correct voltage for the current state of the injector (on or off).

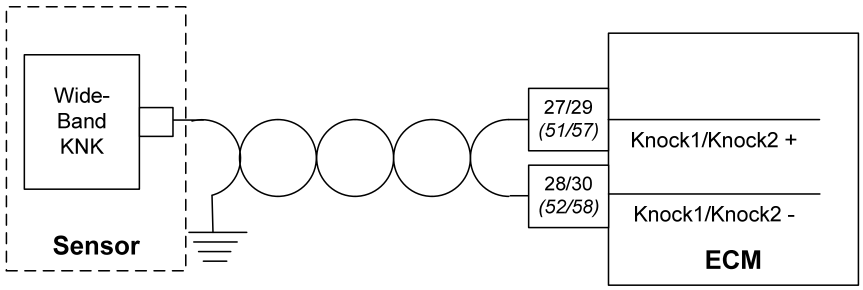
DTC 271- Injector Driver #4 Short-To-Power

Firing Order Example



DTC 326- Knock 1 Excessive or Erratic Signal



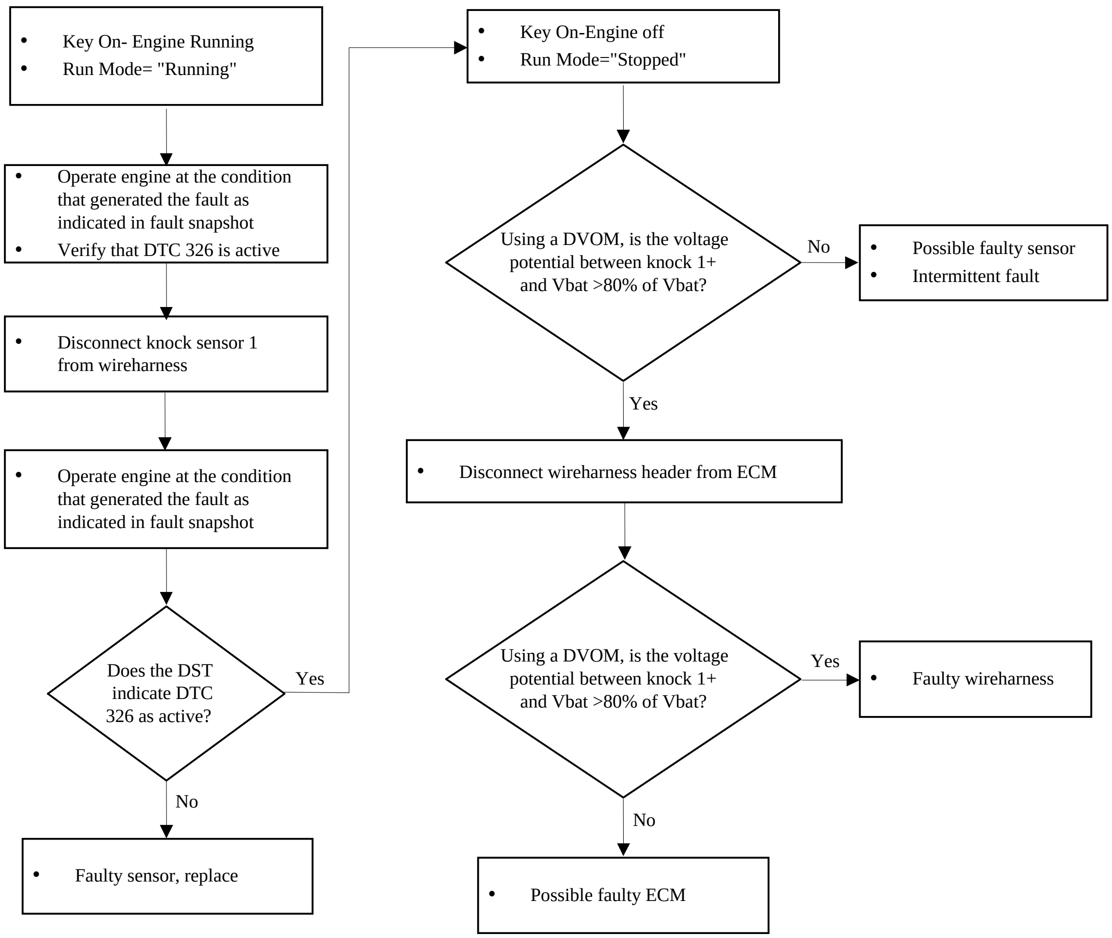


- Hardware: Knock sensor #1
- Enabling Conditions: Key On, Engine On
- Set Conditions: Knock sensor 1 voltage above 2v with MAP less than 9 psi <u>and</u> knock retard is a maximum retard value for longer than 3 seconds.
- Corrective Action(s): Illuminate MIL
- Emissions related fault
- Possible Causes: Internal engine damage causing audible noise, knock sensor signal wire routed too close to spark plug wire, bad sensor, bad ECM

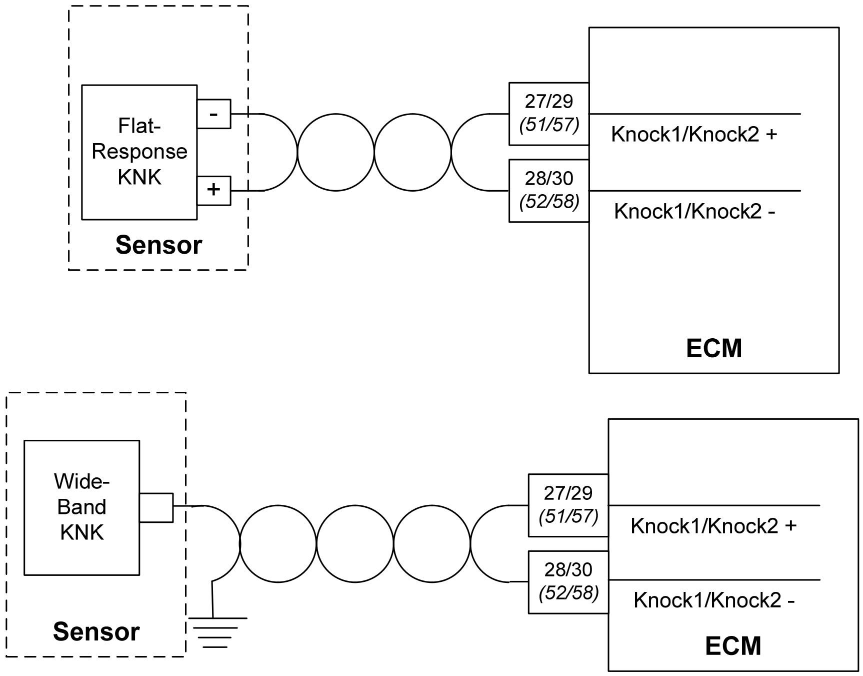
The knock sensor is used to detect detonation through mechanical vibration in the engine block and/or cylinder heads and provide feedback for the ignition system to retard spark to reduce knock intensity. The knock sensor is used to protect the engine from damage that can be caused from detonation or knock based on fixed spark advance.

This fault sets if the signal from knock sensor 1 is higher than expected for low load operation as defined in calibration. If this fault sets, spark is lowered by the amount defined in calibration for *Faulted KNK Retard*.

DTC 326- Knock 1 Excessive or Erratic Signal



DTC 327- Knock 1 Sensor Open or Not Present

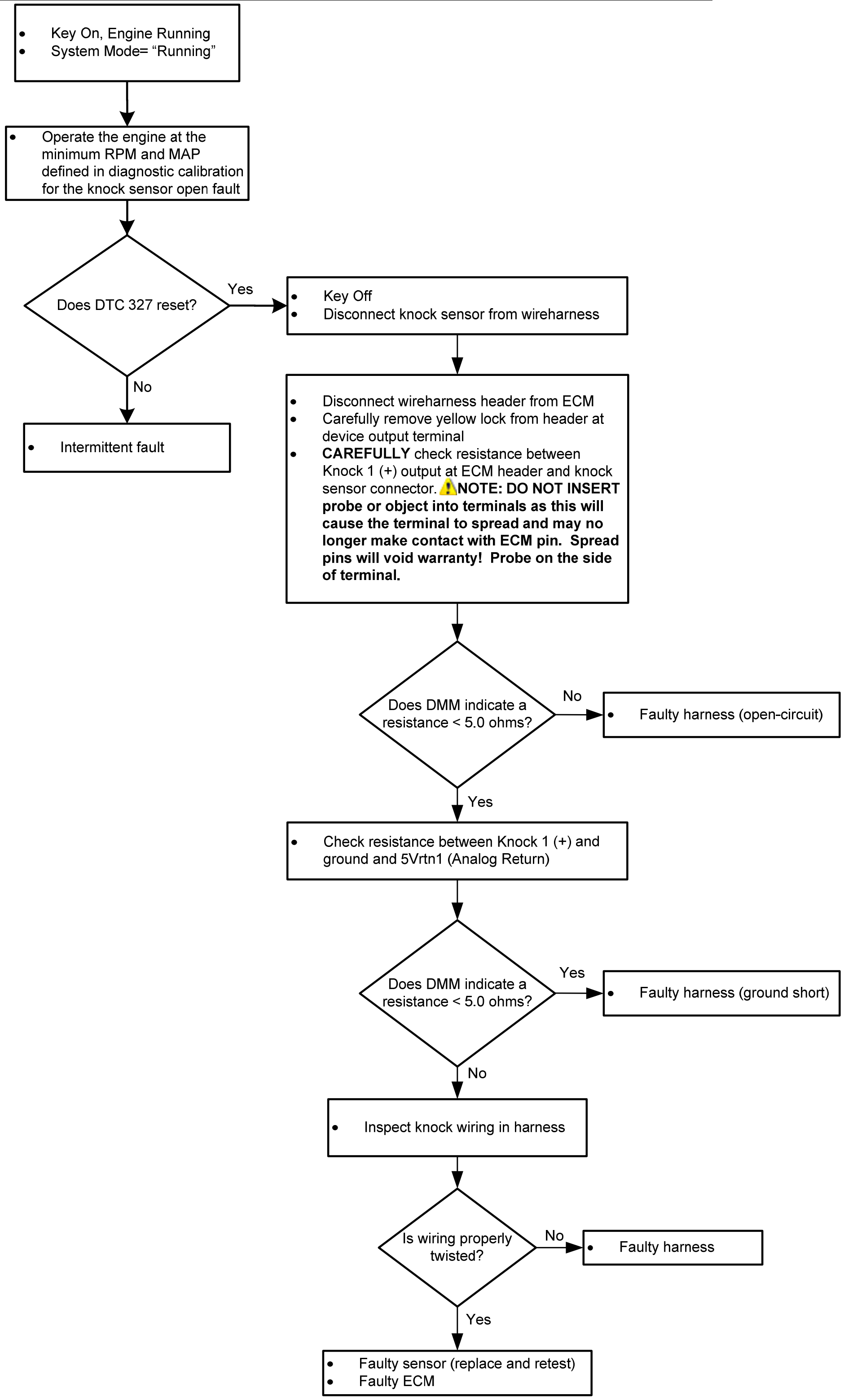


- Hardware: Knock sensor #1
- Enabling Conditions: Key On, Engine On
- Set Conditions: Knock sensor 1 signal below 0.005v, rpm above 2000 and MAP above 12 psi for longer than 3 seconds.
- Corrective Action(s): Illuminate MIL
- Emissions related fault
- Possible Causes: Knock sensor open internally, signal circuit open or shorted to ground or bad ECM

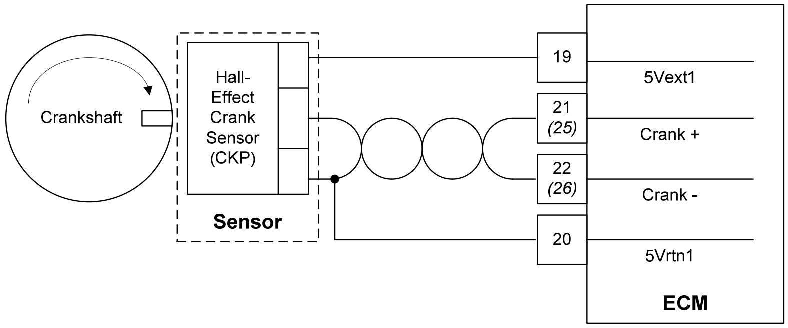
The knock sensor is used to detect detonation through mechanical vibration in the engine block and/or cylinder heads and provide feedback for the ignition system to retard spark to reduce knock intensity. In most applications the knock sensor is used to protect the engine from damage that can be caused from detonation or knock based on fixed spark advance. In other applications, the knock sensor is used to optimize spark advance and “learn” between spark tables based on fuel quality.

This fault sets if the signal from knock sensor 1 is lower than expected for higher speed and load operation as defined in calibration. If this fault sets, spark is lowered by the amount defined in calibration for *Faulted KNK Retard*.

DTC 327- Knock 1 Sensor Open or Not Present



DTC 336- Crank Input Signal Noise



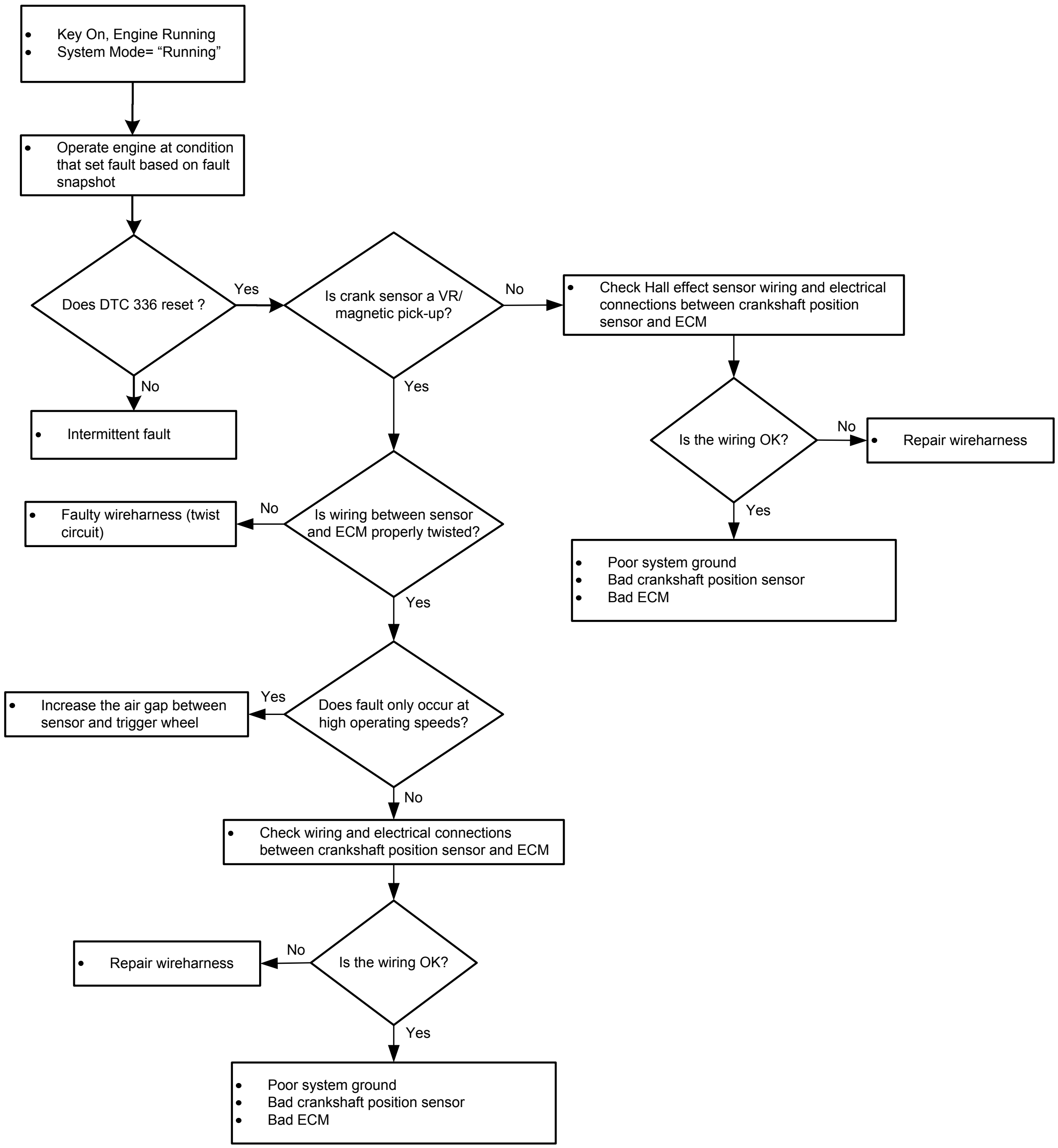
- Hardware: Crankshaft Position sensor
- Enabling Conditions: Key On, Engine On
- Set Conditions: Electrical noise or irregular crank pattern detected causing more than 1 crank re-synchronization events in less than 800 milliseconds
- Corrective Action(s): Illuminate MIL and disable fuel adaptive learn function for the rest of the key cycle.
- Emissions related fault
- Possible Causes: CKP+ or CKP- circuits in wrong connector terminal slot, improper CKP signal due to sensor air gap too large, excessive metal on sensor tip, improper wiring, intermittent connection in sensor circuitry, intermittent sensor internal problem

The crankshaft position sensor is a magnetic sensor (hall-effect) installed in the engine block adjacent to a “coded” trigger wheel located on the crankshaft. The sensor-trigger wheel combination is used to determine crankshaft position (with respect to TDC cylinder #1 compression) and the rotational engine speed. Determination of the crankshaft position and speed is necessary to properly activate the ignition, fuel injection, and throttle governing systems for precise engine control.

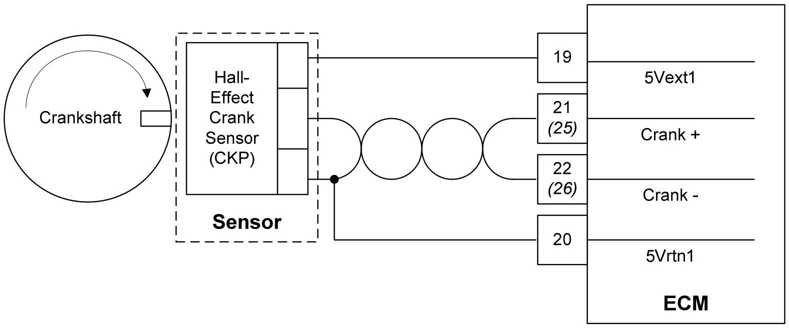
The ECM must see a valid crankshaft position signal while running. If no signal is present, the signal amplitude is too high (due to improper air gap with respect to trigger wheel), or an irregular crank pattern is detected causing the ECM to resynchronize x times for y ms or longer as defined in the diagnostic calibration (see set conditions above), this fault will set. Irregular crank patterns can be detected by the ECM due to electrical noise, poor machining of trigger wheel, or trigger wheel runout and/or gear lash.

Ensure crank circuit used with VR/magnetic pick-up sensors are properly twisted.

DTC 336- Crank Input Signal Noise



DTC 337- Loss of Crankshaft Input Signal



- Hardware: Crankshaft Position sensor
- Enabling Conditions: Key On, Engine On
- Set Conditions: Loss of crankshaft position signal (CKP) with more than 6 cam pulses from the camshaft position sensor (CMP).
- Corrective Action(s): Illuminate MIL
- Emissions related fault
- Possible Causes: Loss of sensor feed, open sensor ground (5Vrtn1 and CKP-), open or shorted to ground signal wire

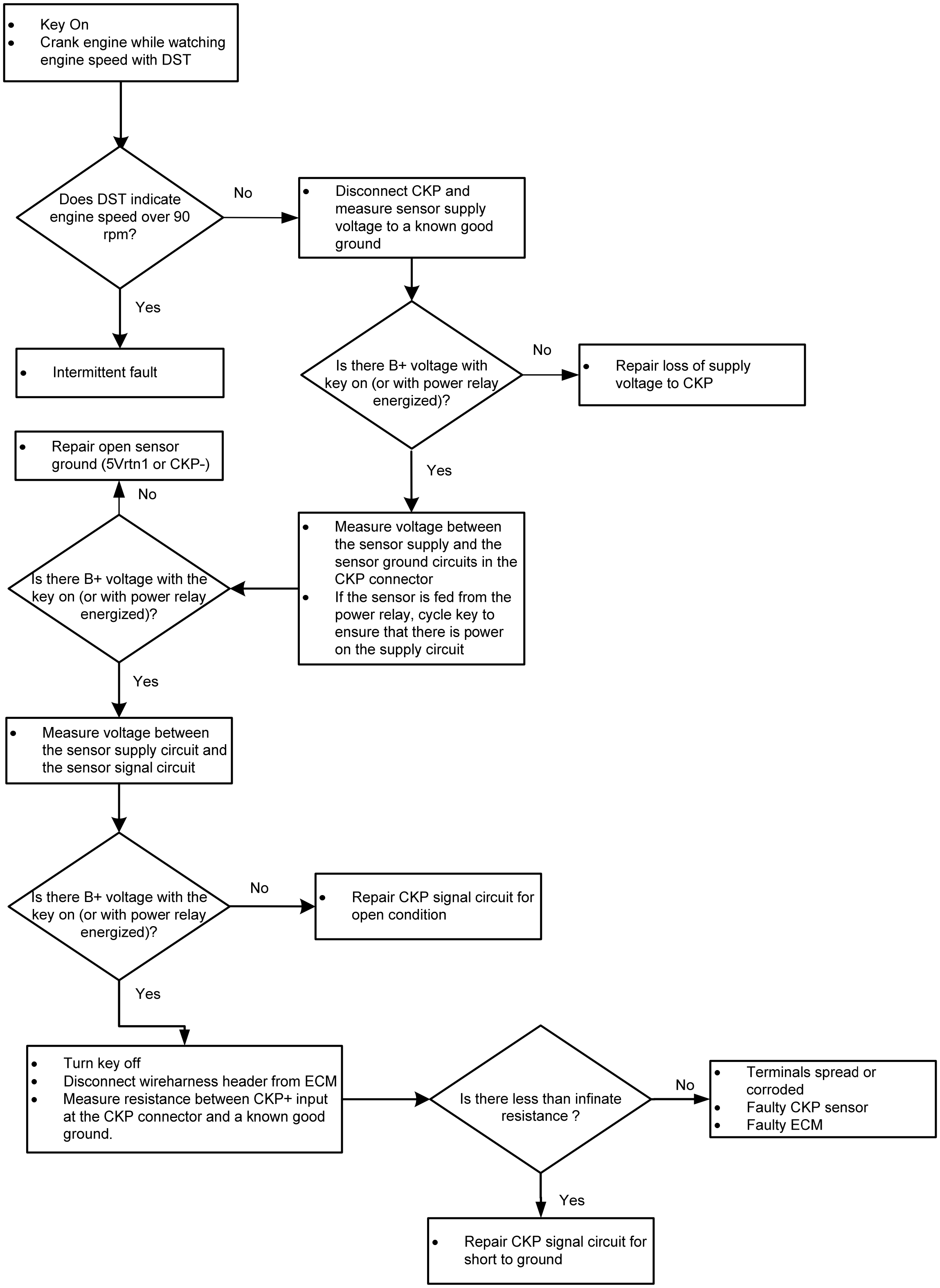
The crankshaft position sensor is a magnetic sensor (variable reluctant/magnetic pick-up or hall-effect) installed in the engine block adjacent to a "coded" trigger wheel located on the crankshaft. The sensor-trigger wheel combination is used to determine crankshaft position (with respect to TDC cylinder #1 compression) and the rotational engine speed. Determination of the crankshaft position and speed is necessary to properly activate the ignition, fuel injection, and throttle governing systems for precise engine control.

The ECM must see a valid crankshaft position signal while running. The engine typically stalls or dies as a result of this fault condition due to the lack of crankshaft speed input resulting in the inability to control ignition timing.

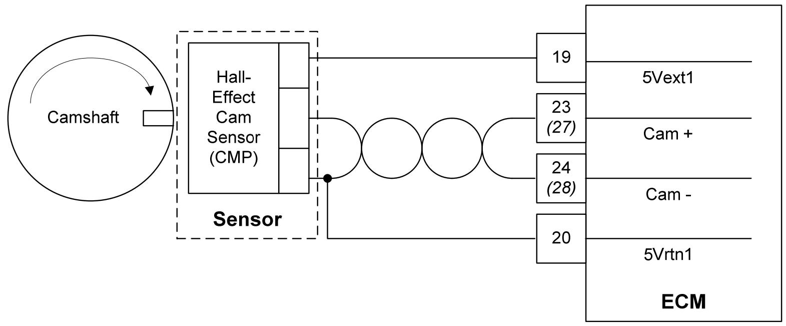
Diagnostic Aids

- ☐ Check that crankshaft position sensor is securely connected to harness
- ☐ Check that crankshaft position sensor is securely installed into engine block
- ☐ Check crankshaft position sensor circuit wiring for open circuit

DTC 337- Loss of Crankshaft Input Signal



DTC 341- Camshaft Input Signal Noise



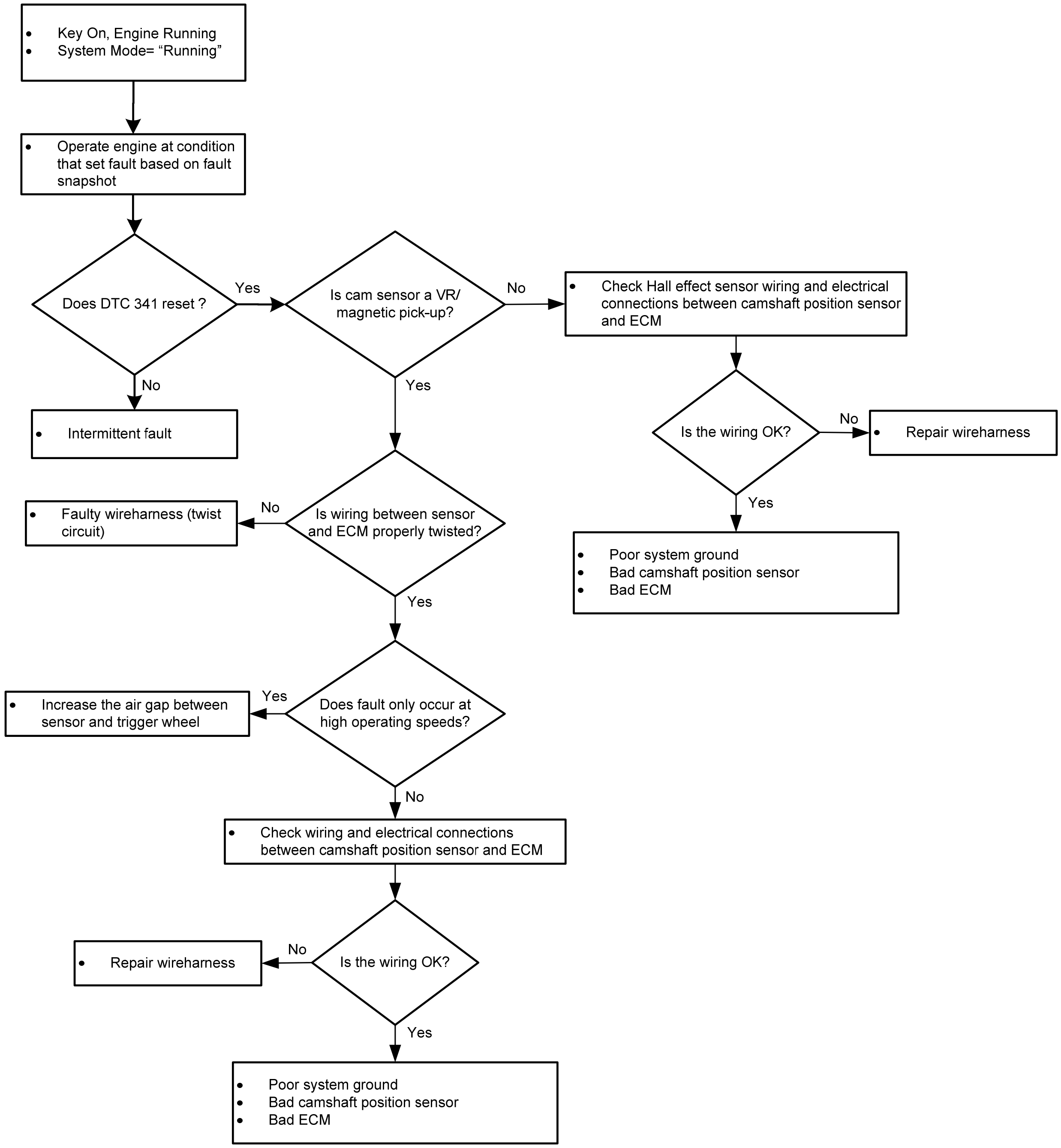
- Hardware: Camshaft Position sensor
- Enabling Conditions: Key On, Engine Running
- Set Conditions: Electrical noise or irregular cam pattern detected causing more than 1 cam re-synchronization events in less than 700 milliseconds.
- Corrective Action(s): Illuminate MIL and disable fuel adaptive learn for remainder of key-cycle.
- Emissions related fault
- Possible Causes: : CMP+ or CMP- circuits in wrong connector terminal slot, improper CMP signal due to sensor air gap too large, excessive metal on sensor tip, improper wiring, intermittent connection in sensor circuitry, intermittent sensor internal problem

The camshaft position sensor is a magnetic sensor (hall-effect) installed in the engine block or valve train adjacent to a “coded” trigger wheel located on or off of the camshaft. The sensor-trigger wheel combination is used to determine cam position so the ECM can determine which piston is coming up on TDC. Determination of the camshaft position is necessary to identify the stroke (or cycle) of the engine to properly activate the fuel injection system and ignition (for coil-on-plug engines) for precise engine control.

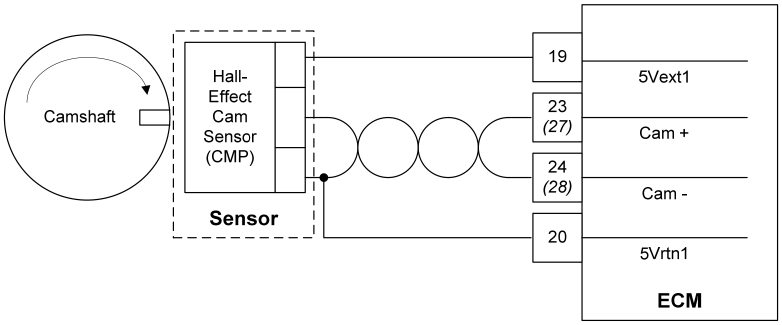
For a cam synchronized engine, the ECM must see a valid camshaft position signal while running. If no signal is present, the signal amplitude is too high (due to improper air gap with respect to trigger wheel), or an irregular cam pattern is detected causing the ECM to resynchronize this fault will set. Irregular cam patterns can be detected by the ECM and can be caused by: electrical noise, poor machining of trigger wheel, or trigger wheel runout and/or gear lash. Normally the engine will continue to run if equipped with a waste-spark or distributor ignition system. In some instances this fault can cause rough engine operation and can cause the engine to stall or die if equipped with coil-on-plug ignition engines.

Ensure cam circuit used with VR/magnetic pick-up sensors are properly twisted.

DTC 341- Camshaft Input Signal Noise



DTC 342- Loss of Camshaft Input Signal



- o Hardware: Camshaft Position sensor
- o Enabling Conditions: Key On, Engine Running above 1000 rpm
- o Set Conditions: Loss of camshaft position signal while valid crankshaft position signals continue for 2.5 engine cycles for longer than 1 second
- o Corrective Action(s): Illuminate MIL
- o Emissions related fault
- o Possible Causes: Loss of feed voltage to CMP sensor, loss of signal or ground circuits, faulty sensor, faulty ECM or damaged engine components

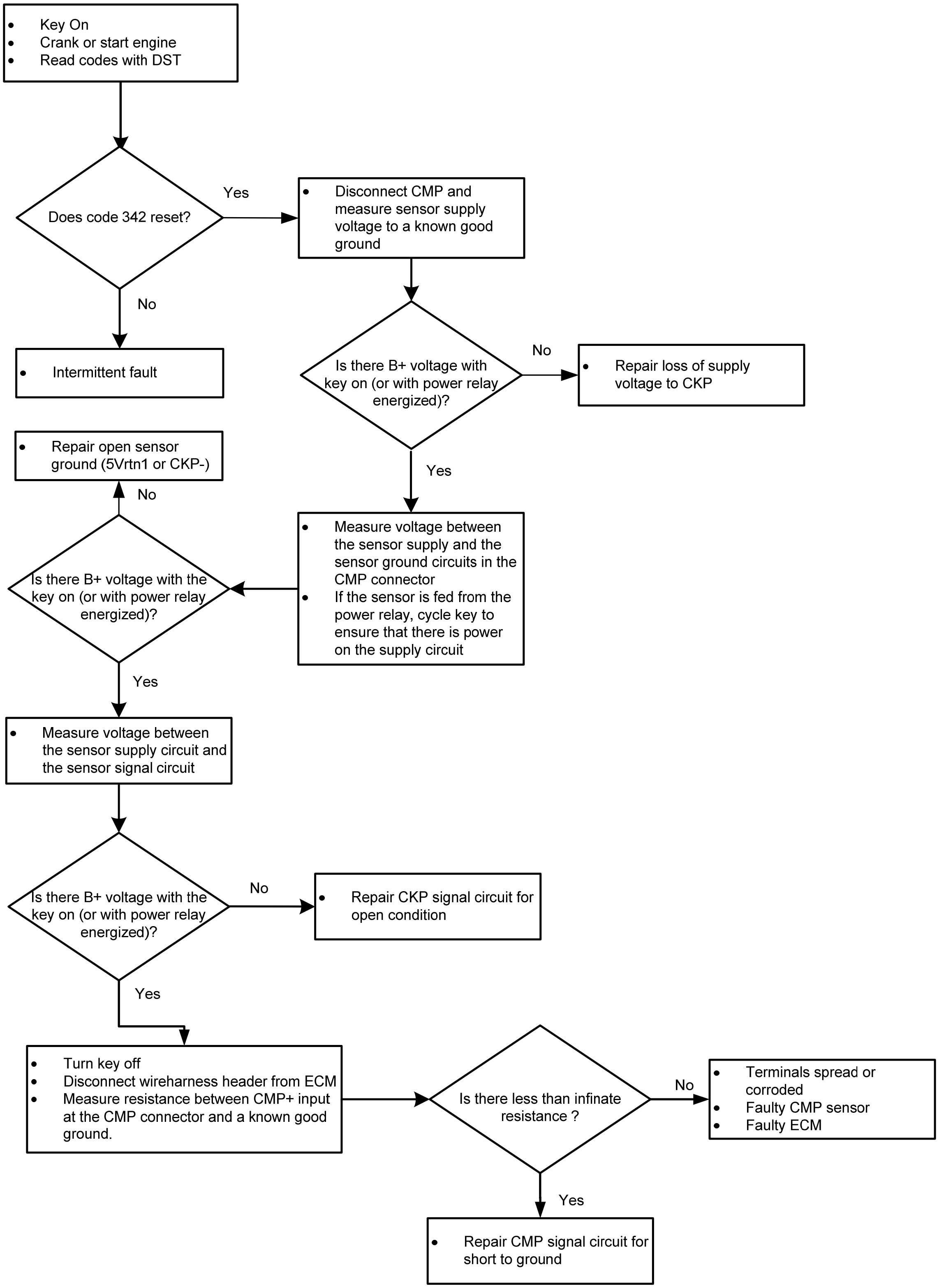
The camshaft position sensor is a magnetic sensor (hall-effect) installed in the engine block or valve train adjacent to a “coded” trigger wheel located on or off of the camshaft. The sensor-trigger wheel combination is used to determine cam position (with respect to TDC cylinder #1 compression). Determination of the camshaft position is necessary to identify the stroke (or cycle) of the engine to properly activate the fuel injection system and ignition (for coil-on-plug engines) for precise engine control.

For a cam synchronized engine, the ECM must see a valid camshaft position signal while running. Normally the engine will continue to run after this fault sets if the engine is equipped with a waste-spark or distributor ignition system. In some instances this fault can cause rough engine operation and can cause the engine to stall or die if equipped with coil-on-plug ignition engines.

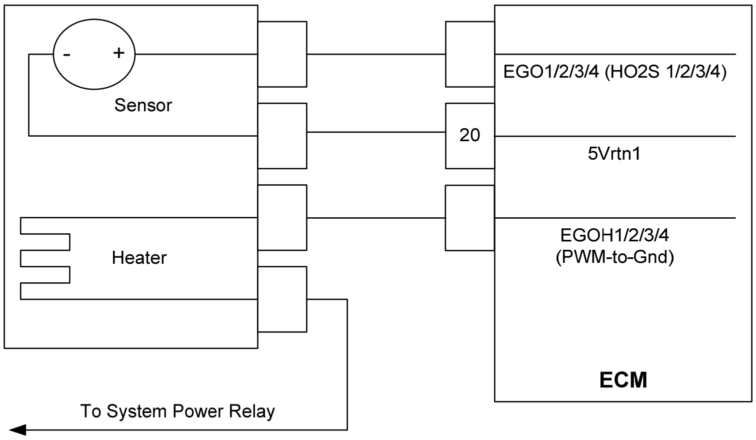
Diagnostic Aids

- ☐ Check that camshaft position sensor is securely connected to harness
- ☐ Check that camshaft position sensor is securely installed into engine block or distributor module
- ☐ Check camshaft position sensor circuit wiring for open circuit

DTC 342- Loss of Camshaft Input Signal



DTC 420- Catalyst Inactive on Gasoline (Bank1)



- o Hardware: Bank 1 Pre-Catalyst Exhaust Gas Oxygen Sensor and Bank 1 Post-Catalyst Exhaust Gas Oxygen Sensor
- o Enabling Conditions: Engine Running
- o Set Conditions: Bank 1 catalyst inactive on gasoline or LPG engine
- o Corrective Action(s): Illuminate MIL and/or sound audible warning or illuminate secondary warning lamp.
- o Emissions related fault
- o Possible Causes: Physically damaged catalyst element, contaminated catalyst element or post catalyst oxygen sensor signal circuit shorted to pre-catalyst oxygen sensor signal circuit

A catalyst or catalytic converter is a component in the exhaust subsystem used to accelerate/generate chemical reactions within the engine exhaust to convert undesirable gases/pollutants into less harmful gases. In many spark-ignited applications, a three-way catalyst is used to convert hydrocarbons, oxides of nitrogen, and carbon monoxide into nitrogen, water, and carbon dioxide. In addition, many low-emission applications require the use of OBD, which typically require a catalyst monitor to identify whether or not the catalyst is functioning properly. The catalyst monitor diagnostic is typically configured such that exhaust emissions are near compliance-failing levels based on the engines specific regulatory requirement(s). Catalyst monitor techniques typically utilize a HEGO sensor to monitor the amount of oxygen present downstream of the catalyst. This is generally a good indicator of how efficiently the catalyst is using the oxygen entering the catalyst. Some systems also use temperature measurements in the catalyst and compare it to data stored in the ECM for each operating condition to determine if the catalytic reaction is generating the proper amount of heat.

The GCP uses a HEGO/HO2S sensor for catalyst monitor. The HEGO/HO2S is a switching-type sensor around stoichiometry that measures the oxygen content downstream of the catalyst for two main functions: 1) to compare it to the oxygen content upstream of the catalyst to determine how efficiently the catalyst is using oxygen to determine its effectiveness and 2) trim the commanded equivalence ratio target to maximize the catalyst conversion efficiency. The post-catalyst strategy and diagnostic is only active when the system is in either *"CL Active"* or *"CL + Adapt"* control modes.

In theory if the catalyst is operated at a condition that could result in 100 percent conversion efficiency, the catalyst will use all available oxygen present in the exhaust gas to convert the emission pollutants (or reactants) to N_2, CO_2, and H_2O. However, since catalysts generally operate at efficiencies between 85-95% post-catalyst oxygen concentration can be a direct indicator of how efficient the catalyst is. **Figure 9** shows an example of a slightly rich biased feed gas or pre-catalyst equivalence ratio versus that of the post-catalyst for a functional catalyst. It can be noticed from this figure that the pre-catalyst equivalence ratio, as identified by '*EGO1_volts*', is varying due to the CL excursions (perturbation) and that the post-catalyst equivalence ratio, as identified by '*EGO2_volts*', is maintained relatively constant rich of stoichimetry. A similar waveform pattern should be expected on properly functioning catalysts.

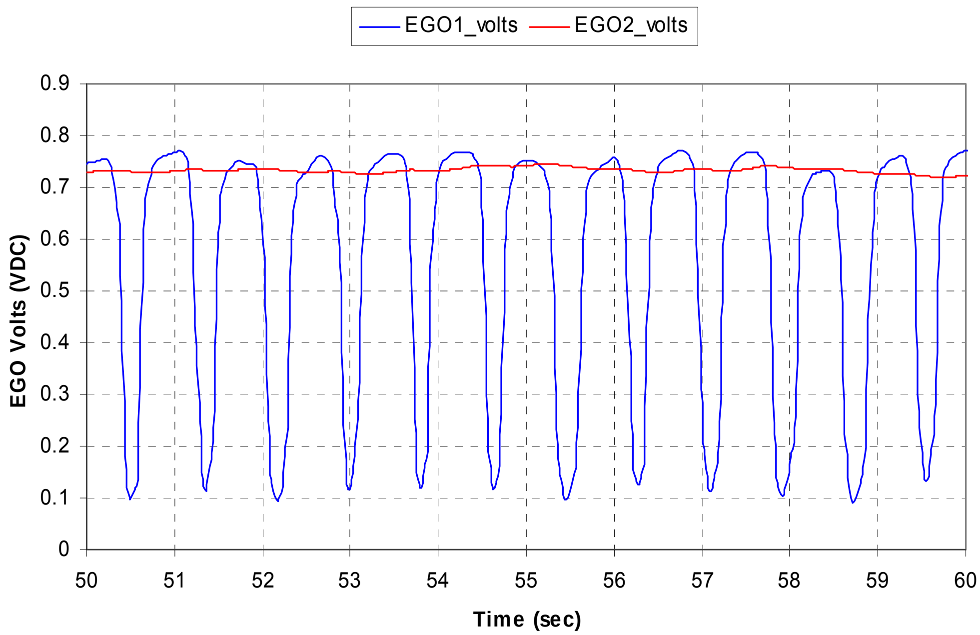


Figure 9: EGO Waveforms (Functional TWC)

Figure 10 shows an example of EGO waveforms for a catalyst with poor conversion efficiency. A significant difference between **Figure 9** and **Figure 10** is that the post-catalyst EGO feedback oscillates with the same frequency as the pre-catalyst EGO feedback and the amplitude is on the order of 60% of that of EGO1. This indicates that a certain amount of oxygen that is entering into the catalyst is passing through the catalyst unconsumed. Catalyst monitor diagnostics are configured such that if the post-catalyst EGO waveform has an amplitude that is directly proportional to the pre-catalyst EGO waveform and who's waveform similarly matches the closed-loop excursion (perturbation) a fault is generated.

Two metric comparisons that are used to identify the health of the catalyst are:

1) Post-catalyst EGO root-mean square (RMS) > Pre-catalyst EGO RMS x ??? %, where the ??? % is determined based on emissions compliance testing over the application's certified duty-cycle(s).
2) Post-catalyst EGO RMS > CL excursion RMS x ??? %, where the ??? % is determined based on emissions compliance testing over the application's certified duty-cycle(s).

There are a couple of ways in which the limits for diagnostics can be determined. In both cases, the system must be tested with an emissions measurement system to determine when the exhaust emissions are nearly failing emissions compliance.

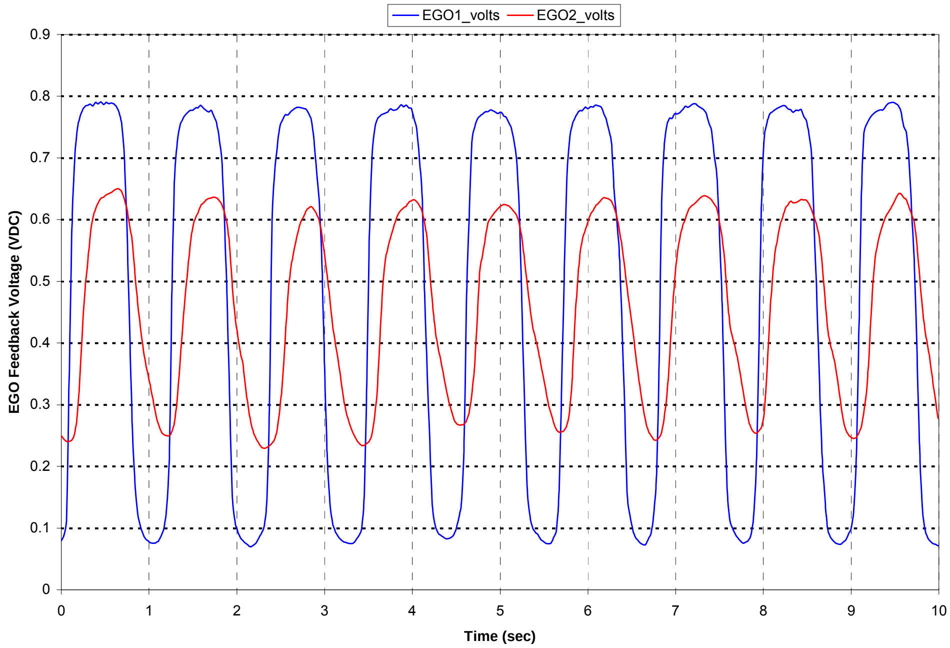


Figure 10: EGO Waveforms (Damaged TWC)

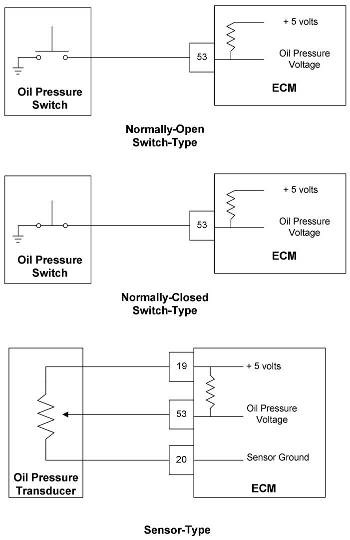
DTC 420- Catalyst Inactive on Gasoline (Bank1)

Diagnostic Aids

NOTE: If any other DTCs are present, diagnose those first.

- ☐ Exhaust Leak – Pressurize exhaust system with 1-2 psig of air and check for pressure leaks upstream and around catalyst and post-catalyst HEGO sensor. Replace gaskets and tighten fasteners if leaks are present.
- ☐ Perform manufacture recommended in-field emissions test.

DTC 524- Oil Pressure Low



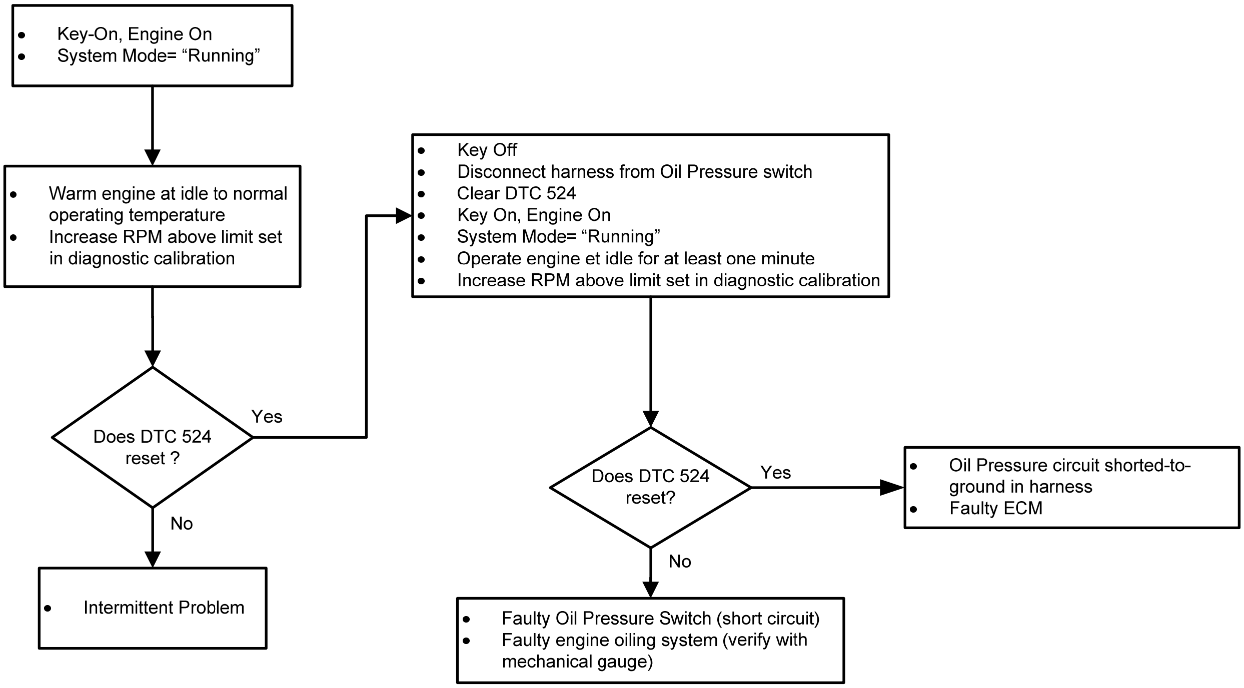
- Hardware: Engine Oil Pressure Sensor or Switch
- Enabling Conditions: Key on, Engine Running longer than 15 seconds and running higher than 1300 rpm
- Set Conditions: Engine oil pressure switch circuit < 2.5v for longer than 3 seconds
- Corrective Action(s): Illuminate MIL and initiate an engine shutdown
- Non-emissions related fault
- Possible Causes: Oil pressure problem with engine, oil pressure switch failure, oil pressure switch circuit shorted to ground, faulty ECM

The ECM can be configured to monitor oil pressure through a proportional transducer or through a switch. Oil pressure monitoring is important to prevent engine damage due to low oil pressure resulting in higher friction and lack of lubrication. In addition, high oil pressure can be undesirable because it can cause oil to leak past seals and rings, can be a result of a restriction in the oil flow path, or can be a sign of a malfunctioning oiling system.

For systems that use a transducer, this fault sets if the engine oil pressure is less than x psia and engine speed is greater than y RPM after the engine has been running for z seconds as defined in the diagnostic calibration. For systems that use a switch this fault can be configured two different ways. It may use a normally closed switch or a normally open switch. If the switch is normally open, the fault will set if the circuit becomes grounded. If the switch is normally closed, the fault will set if the circuit becomes open. Go to the Faults page in EDIS to determine how the input is configured. ("Open=OK" is normally open and "Ground=OK" is normally closed). The engine will should be configured to derate or force idle and/or shut down in the event of this fault to help prevent possible damage.

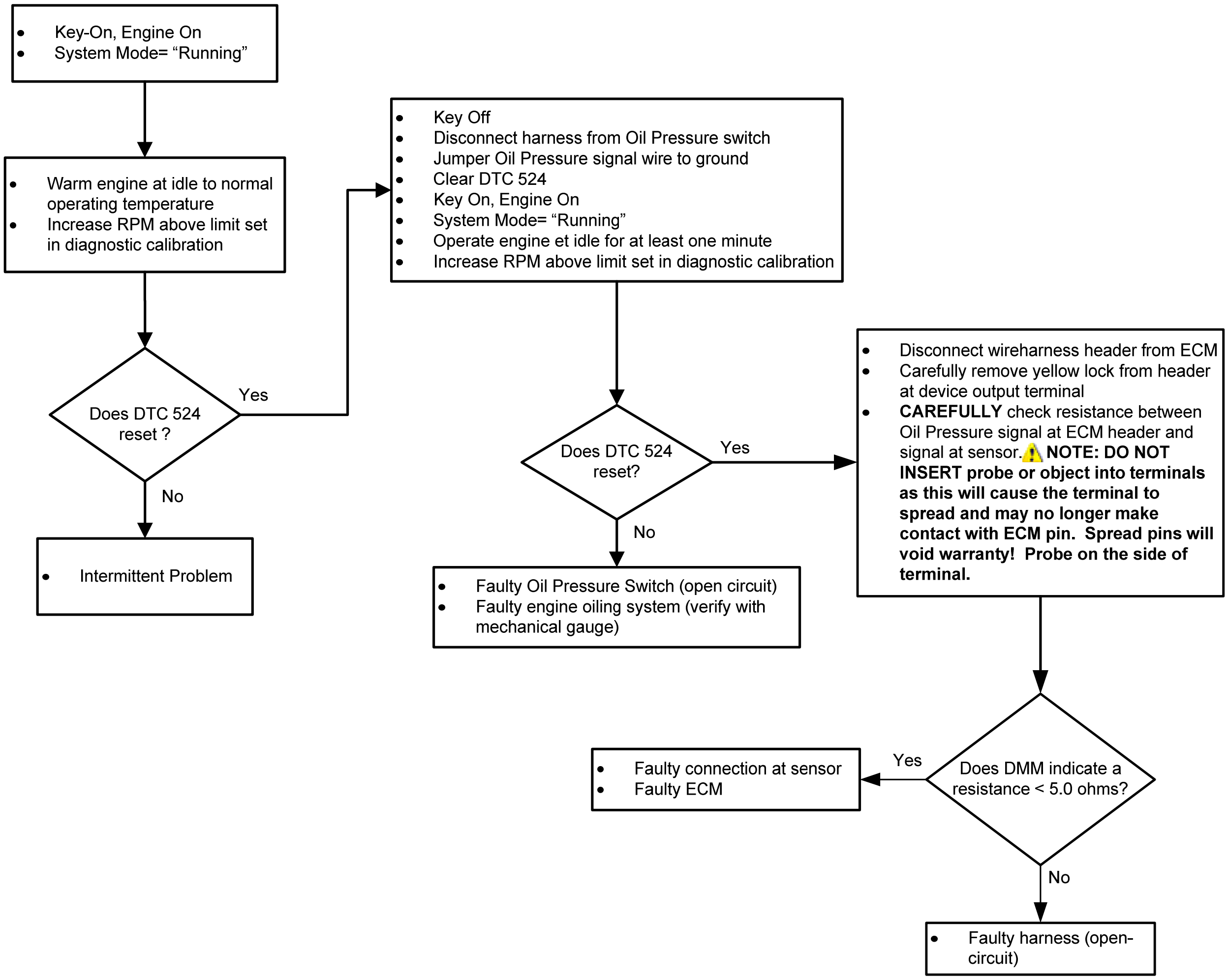
DTC 524-Oil Pressure Low

Normally-Open Switch



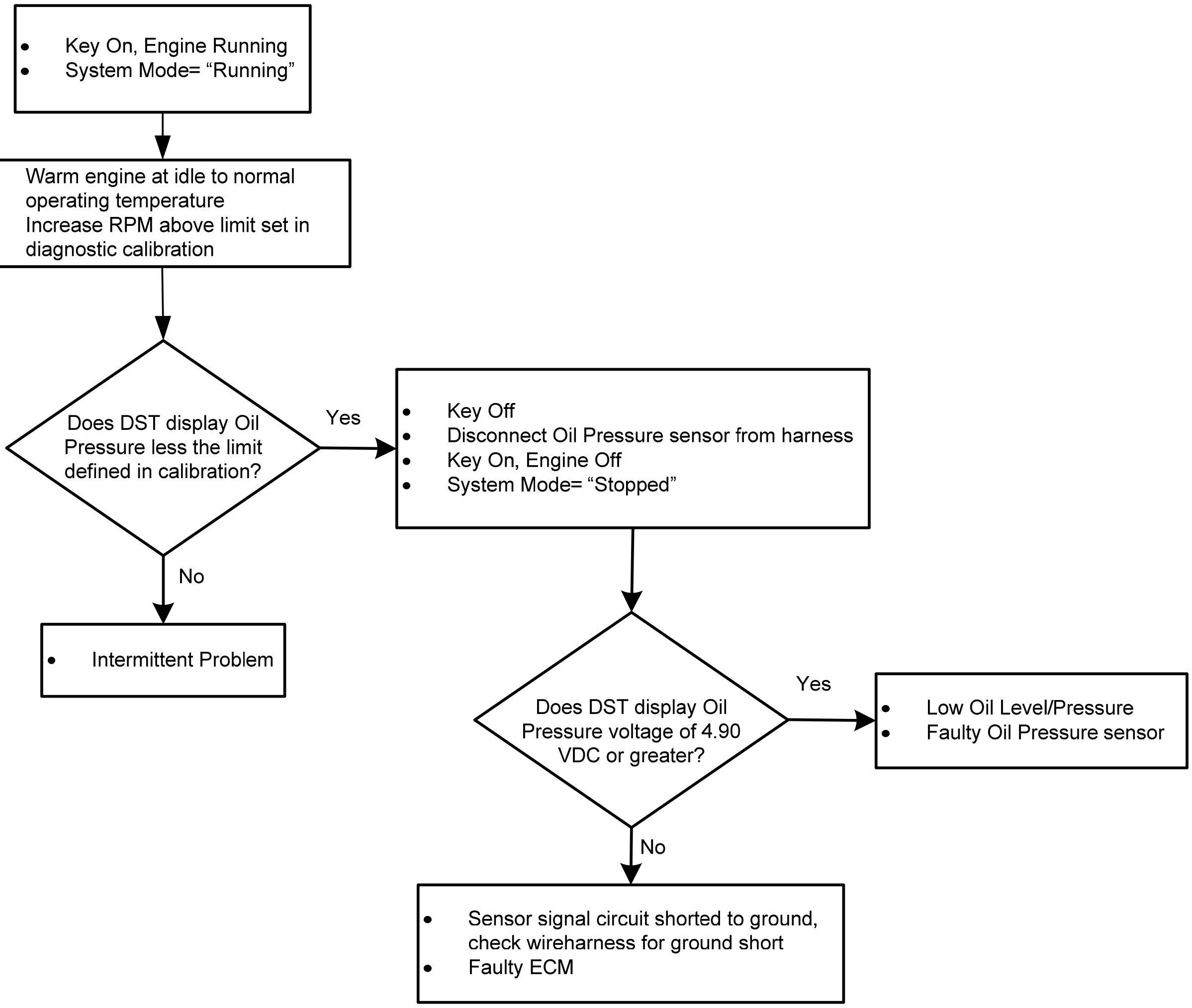
DTC 524-Oil Pressure Low

Normally-Closed Switch

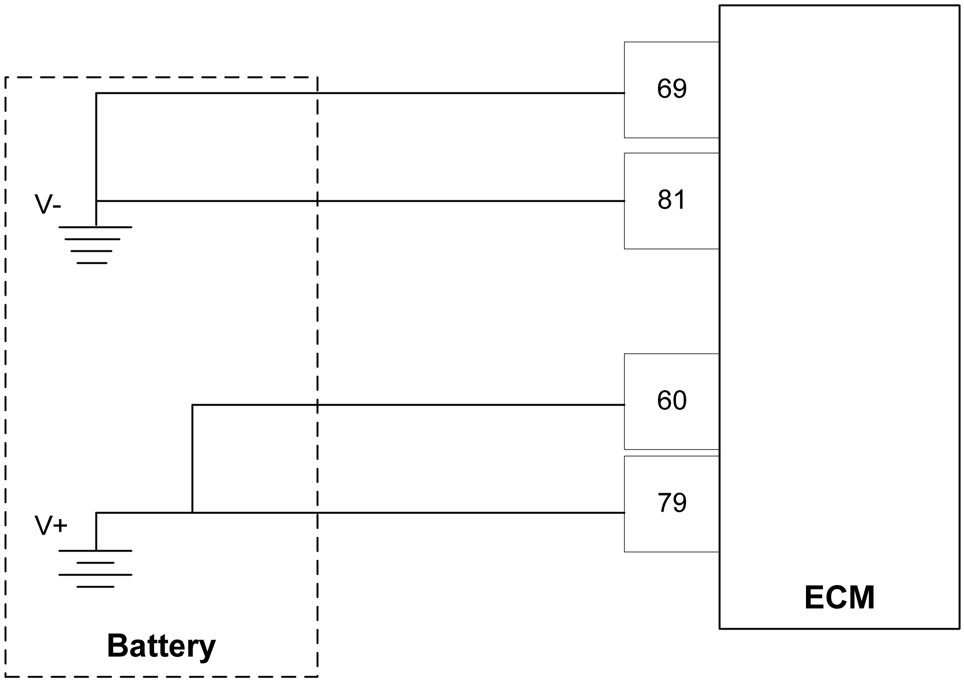


DTC 524-Oil Pressure Low

Sensor/Transducer Type



DTC 562- Battery Voltage (VBat) Low

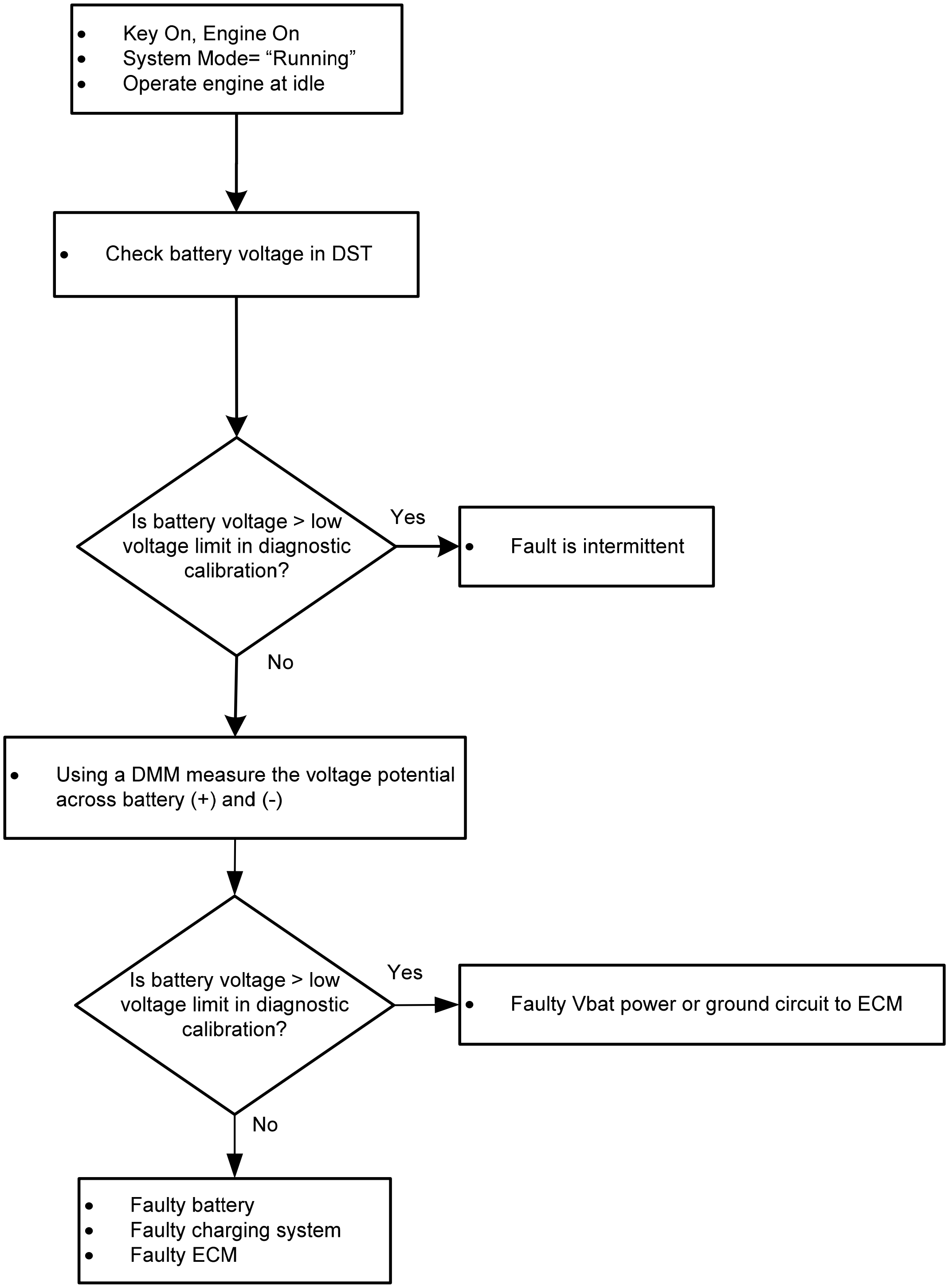


- o Hardware: System voltage to ECM
- o Enabling Conditions: Key on, Engine running above 1000 rpm
- o Set Conditions: Battery voltage to ECM less than 9 volts for longer than 5 seconds
- o Corrective Action(s): Illuminate MIL and disable fuel adaptive learn for the remainder of key cycle
- o Non-emissions related fault
- o Possible Causes: Low charging system output, low voltage input into ECM, faulty battery

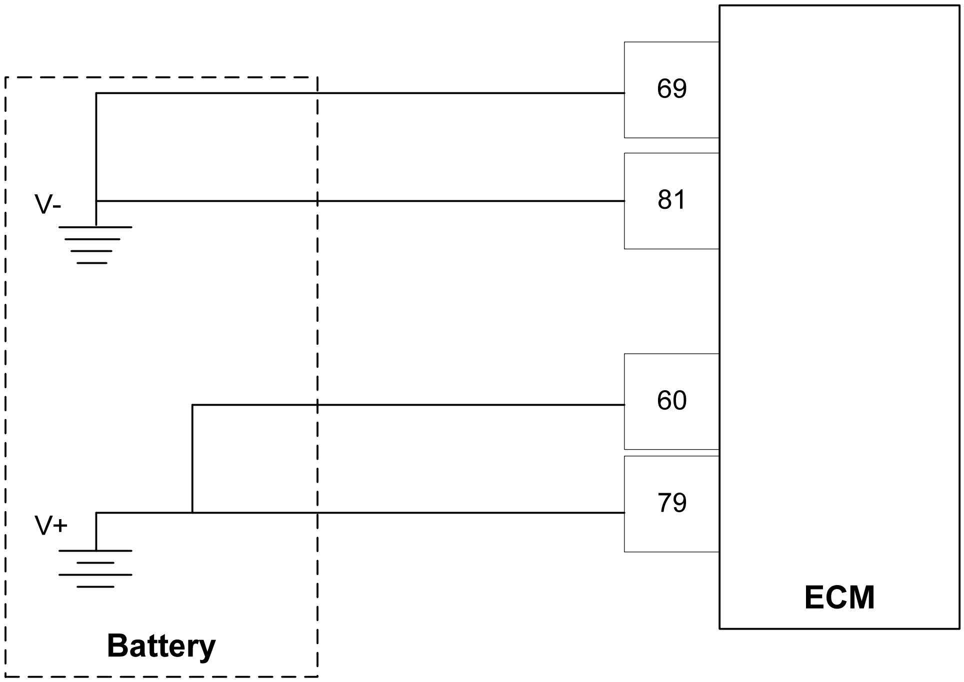
The battery voltage powers the ECM and must be within limits to correctly operate injector drivers, ignition coils, throttle, power supplies, and other powered devices that the ECM controls.

This fault will set if the ECM detects system voltage less than 9 volts while the engine is operating at above 1000 RPM as defined in the diagnostic calibration as the alternator should be charging the system. The adaptive learn is disabled to avoid improper adaptive learning due to the inability to correctly time injector firings.

DTC 562- Battery Voltage (VBat) Low



DTC 563- Battery Voltage (VBat) High

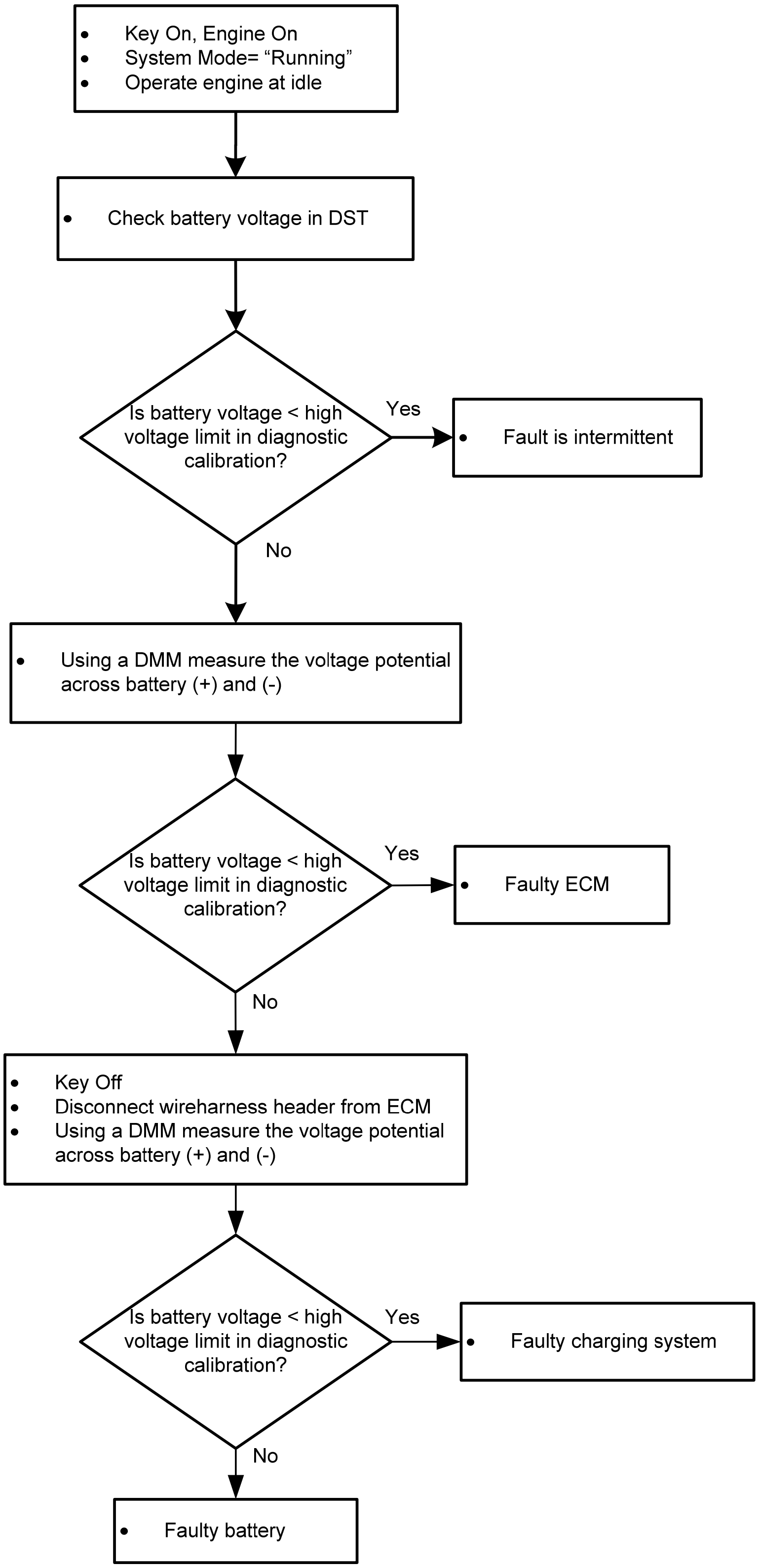


- Hardware: System voltage to ECM
- Enabling Conditions: Key on, Engine running
- Set Conditions: Battery voltage to ECM greater than 16 volts for longer than 3 seconds while the engine is running
- Corrective Action(s): Illuminate MIL and disable fuel adaptive learn for remainder of key cycle
- Non-emissions related fault
- Possible Causes: Charging system overcharging

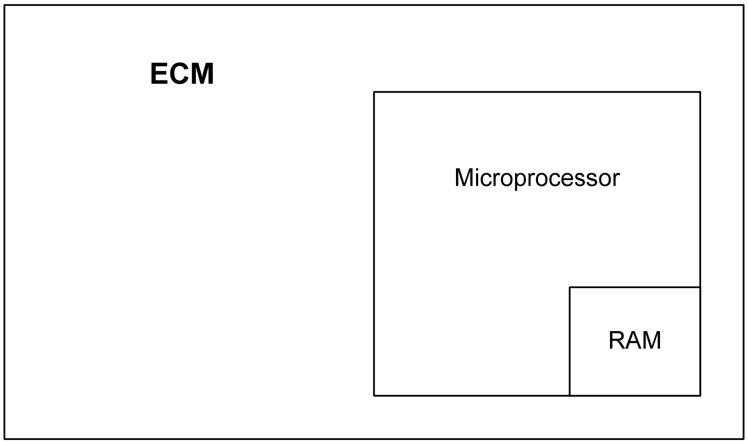
The battery voltage powers the ECM and must be within limits to correctly operate injector drivers, ignition coils, throttle, power supplies, and other powered devices that the ECM controls.

This fault will set if the ECM detects system voltage greater than 16 volts for longer than 3 seconds while the engine is running. The adaptive learn is disabled to avoid improper adaptive learning.

DTC 563- Battery Voltage (VBat) High



DTC 601- Microprocessor Failure - FLASH

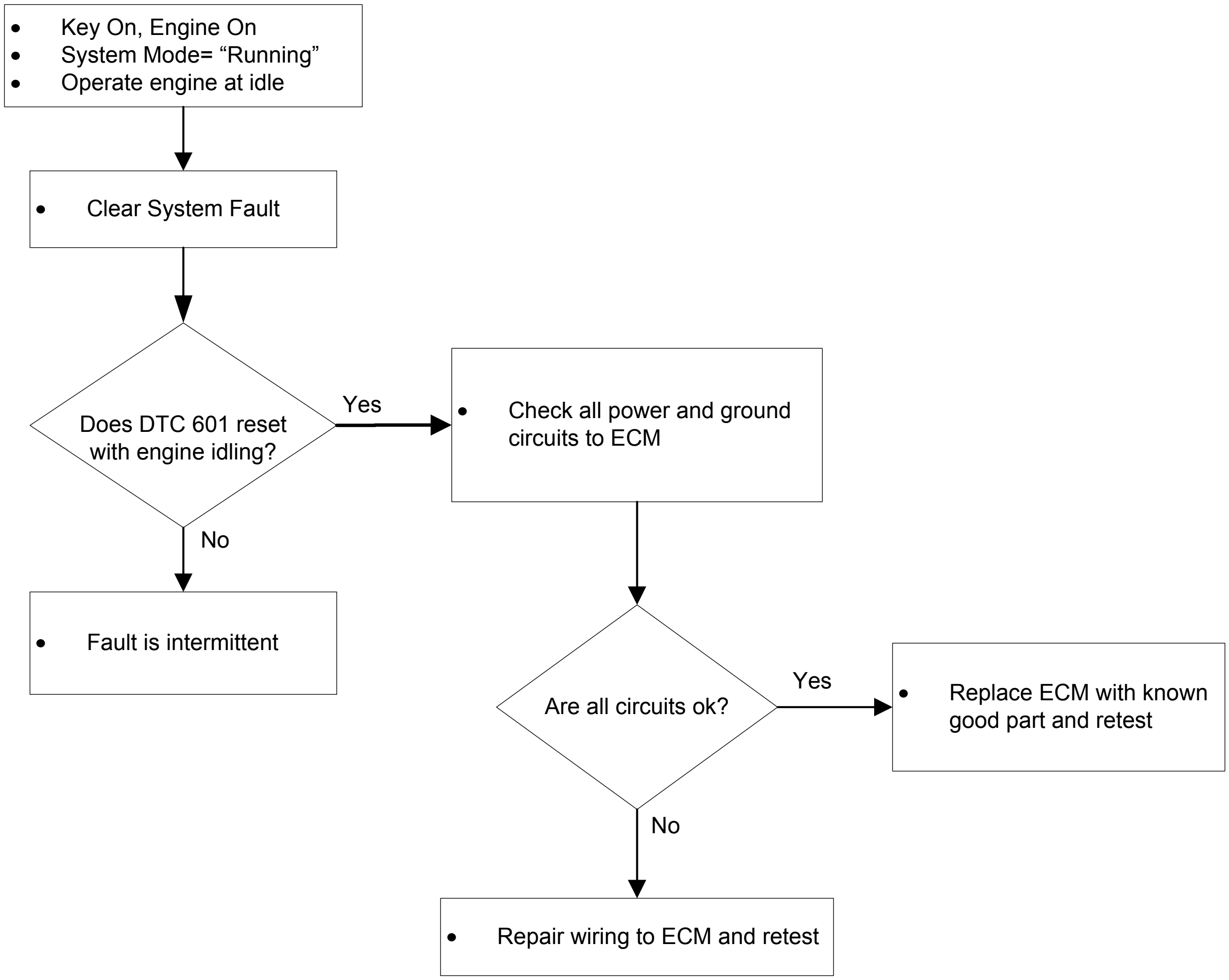


- Hardware: Engine Control Module- Flash Memory
- Enabling Conditions: Key on
- Set Conditions: Internal microprocessor error
- Corrective Action(s): Illuminate MIL, disable fuel adaptive learn for remainder of key cycle, activate power derate 2 and never forget code (code must be manually erased by technician with DST)
- Non-emissions related fault
- Possible Causes: Faulty ECM

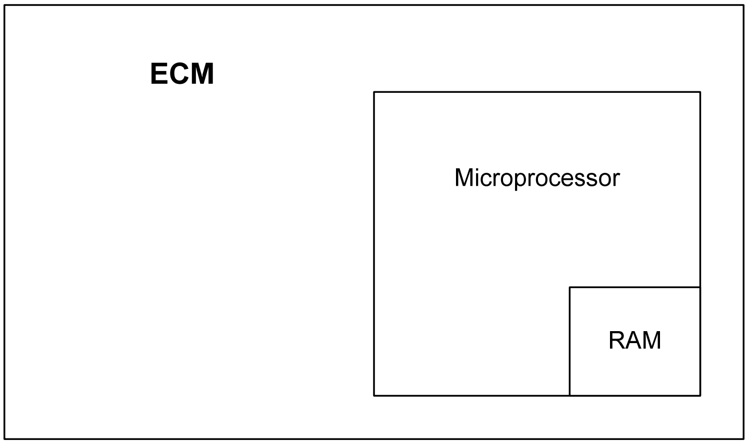
The ECM has checks that must be satisfied each time an instruction is executed. Several different things can happen within the microprocessor that will cause this fault.

If this fault sets, the ECM will reset itself and log the code. A fault of flash memory can occur for any calibration variable set and thus could cause undesirable operation.

DTC 601- Microprocessor Failure – FLASH



DTC 604- Microprocessor Failure - RAM

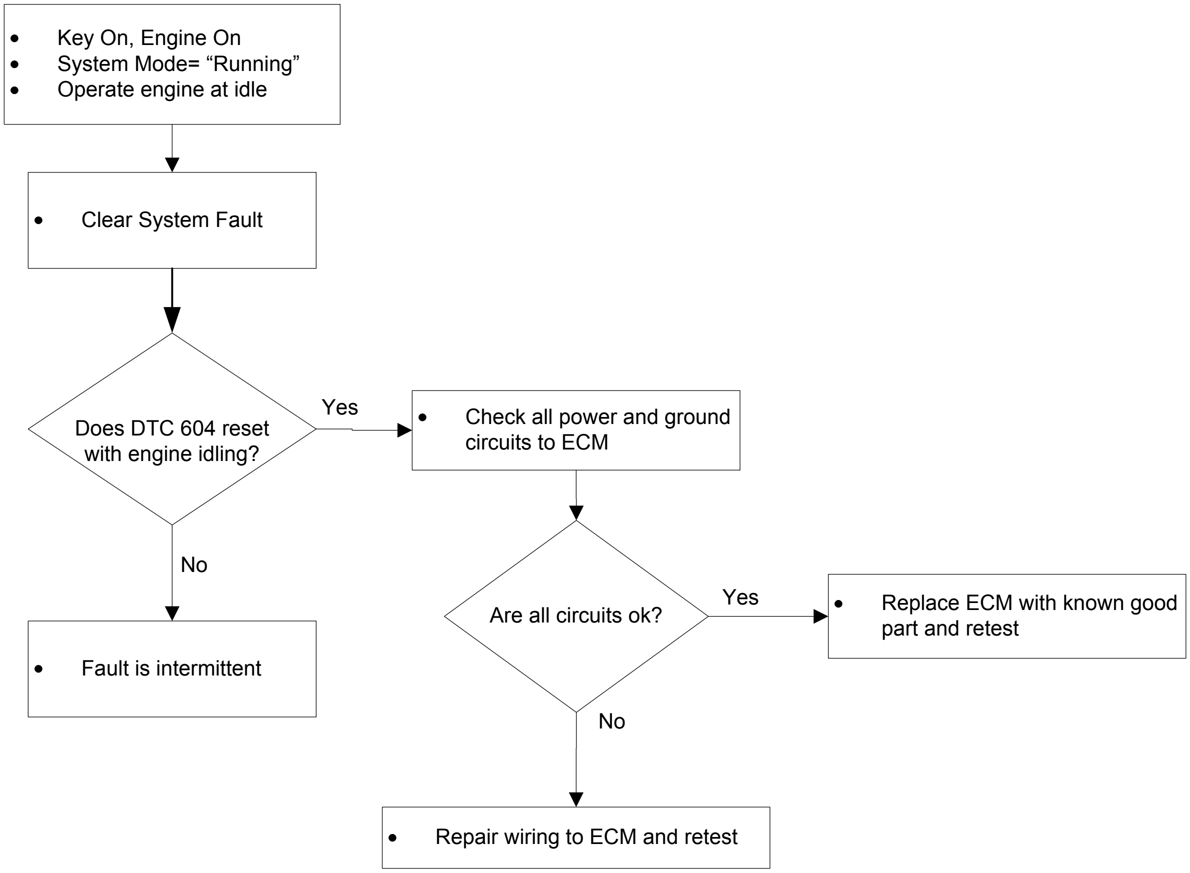


- Hardware: Engine Control Module- Random Access Memory
- Enabling Conditions: Key on
- Set Conditions: Internal ECM microprocessor memory access failure
- Corrective Action(s): Illuminate MIL, disable fuel adaptive learn for remainder of key cycle, activate power derate 2 and never forget code (code must be manually erased by technician with a DST)
- Non-emissions related fault
- Possible Causes: Faulty ECM

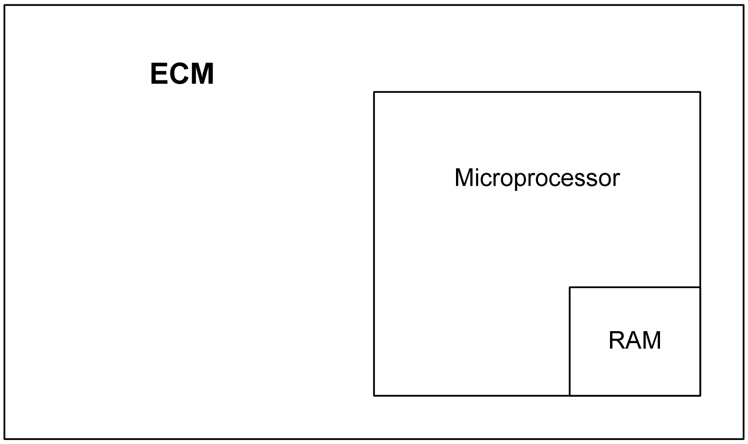
Random Access Memory is located within the microprocessor and can be read from or written to at any time. Data stored in RAM include DTCs (when fault configuration is set to "Battery Power Retained"), adaptive fuel learn tables, octane adaptation table, misfire adaption tables, and closed loop fuel multipliers. The ECM has checks that must be satisfied each time an instruction is executed.

This fault will set if the ECM detects a problem accessing or writing information to RAM. If this fault sets, the ECM will reset itself and log the code. This fault should be erased by a technician after diagnostics are performed.

DTC 604- Microprocessor Failure – RAM



DTC 606- Microprocessor Failure - COP

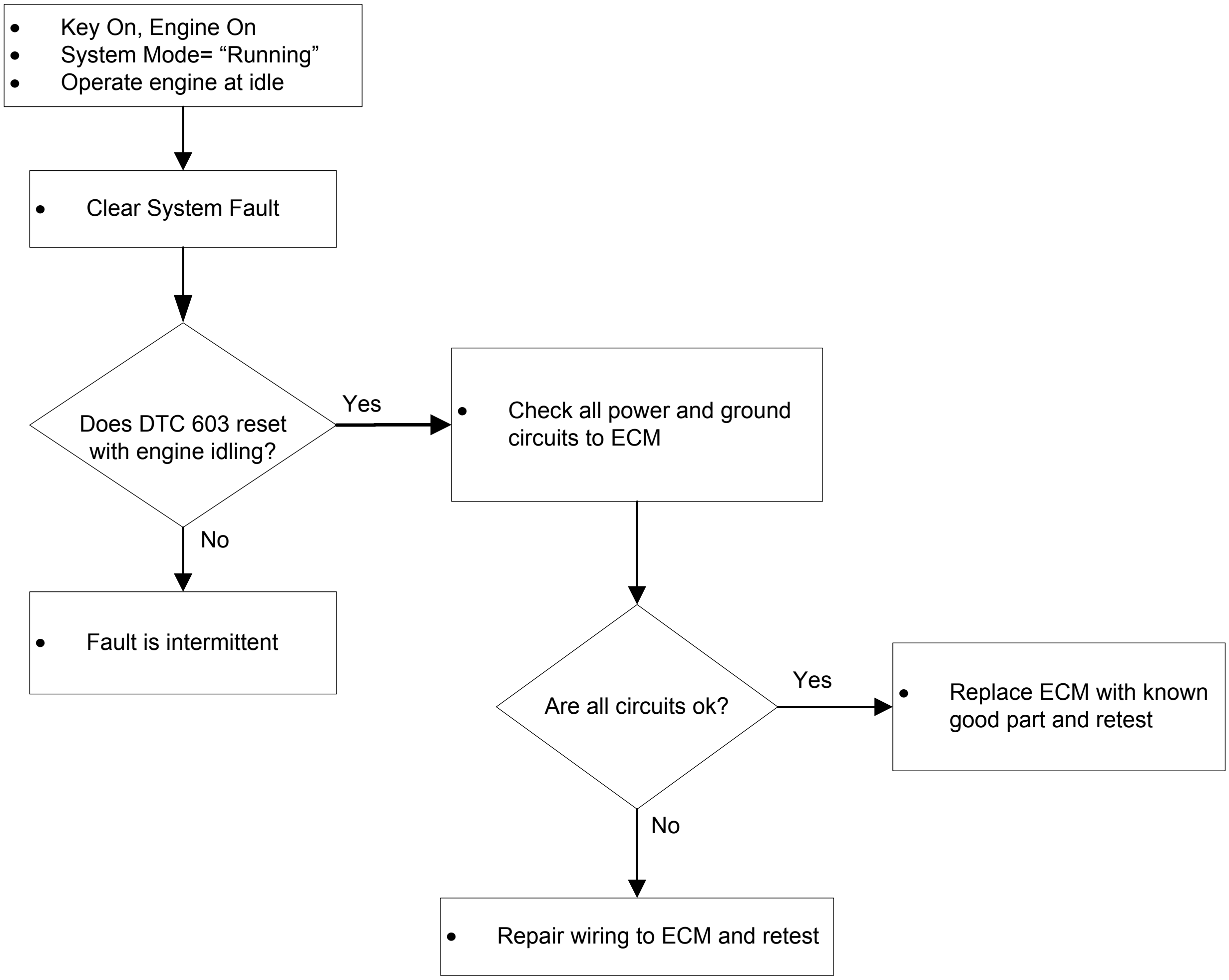


- Hardware: Engine Control Module
- Enabling Conditions: Key on
- Set Conditions: Internal microprocessor error
- Corrective Action(s): Illuminate MIL, disable fuel adaptive learn for remainder of key cycle, activate power derate 2 and never forget code (code must be manually erased by technician with a DST)
- Non-emissions related fault
- Possible Causes: Faulty ECM

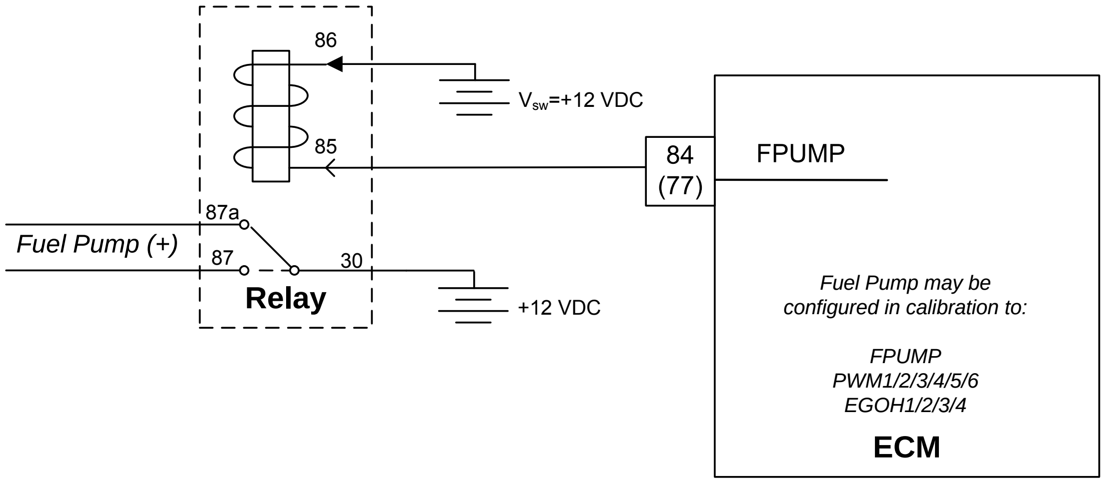
The ECM has checks that must be satisfied each time an instruction is executed. Several different things can happen within the microprocessor that will cause this fault.

If this fault sets, the ECM will reset itself and log the code.

DTC 606- Microprocessor Failure – COP



DTC 627- Fuel Pump Relay Coil Open

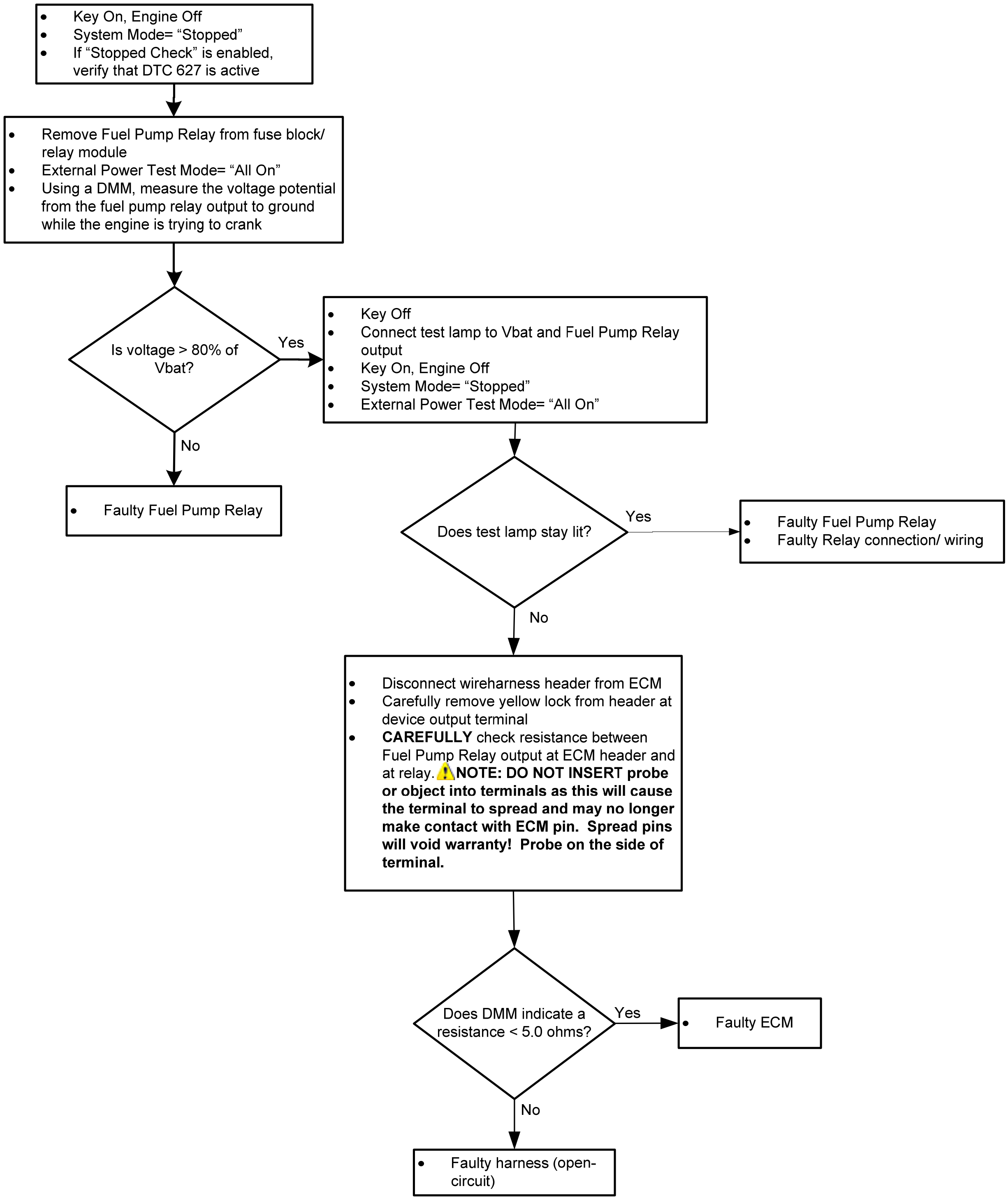


- Hardware: Fuel Pump Relay Pull in Coil
- Enabling Conditions: Key On
- Set Conditions: Fuel Pump relay coil output open circuit for more than 10 samples of the circuit
- Corrective Action(s): Illuminate MIL
- Non-emissions related fault
- Possible Causes: Open coil in relay, Open in relay driver circuit in engine harness or faulty ECM

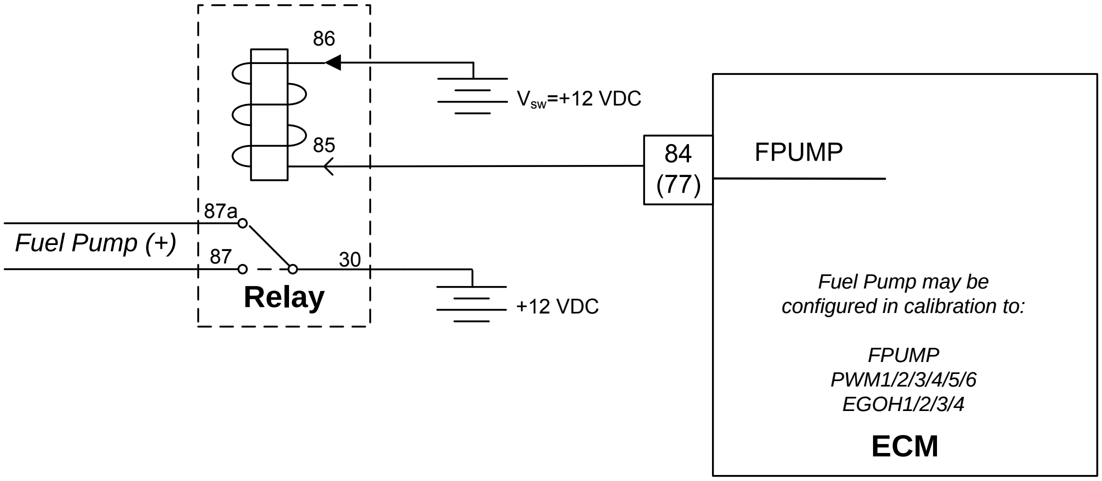
The ECM has auxiliary low-side drivers that can turn on warning devices or ground electromagnetic relay coils to control power to devices connected to the engine.

This fault sets if the output for the fuel pump relay is detected as an open circuit. If this fault is active the fuel pump will not receive power and the engine will not run on gasoline.

DTC 627- Fuel Pump Relay Coil Open



DTC 628- Fuel Pump Relay Ground Short

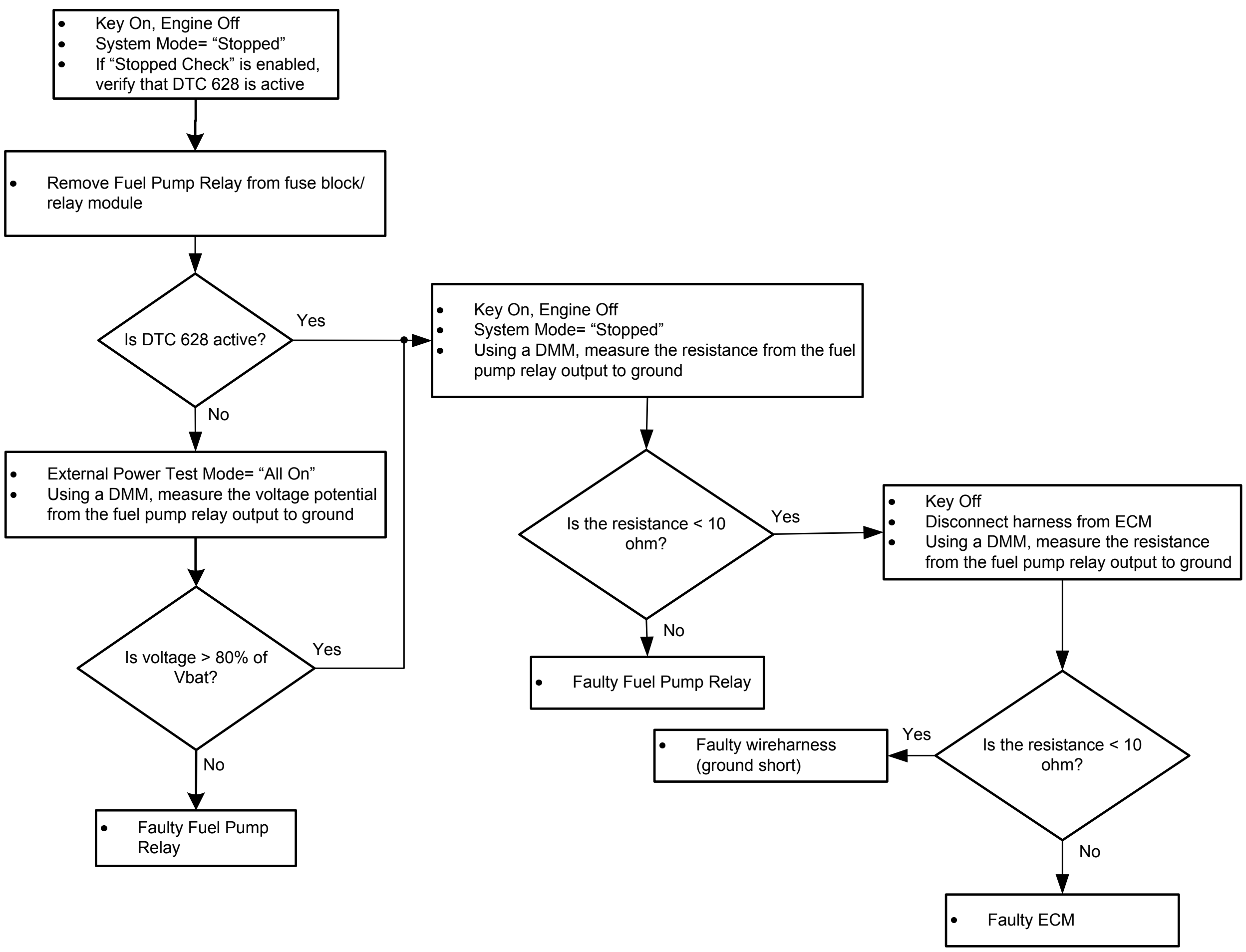


- Hardware: Fuel Pump Relay Pull in Coil
- Enabling Conditions: Key On, Engine Off
- Set Conditions: Fuel Pump relay coil output shorted to ground for more than 10 samples of the circuit
- Corrective Action(s): Illuminate MIL
- Non-emissions related fault
- Possible Causes: Relay pull in coil shorted internally, relay driver circuit shorted to ground in wire harness, faulty ECM

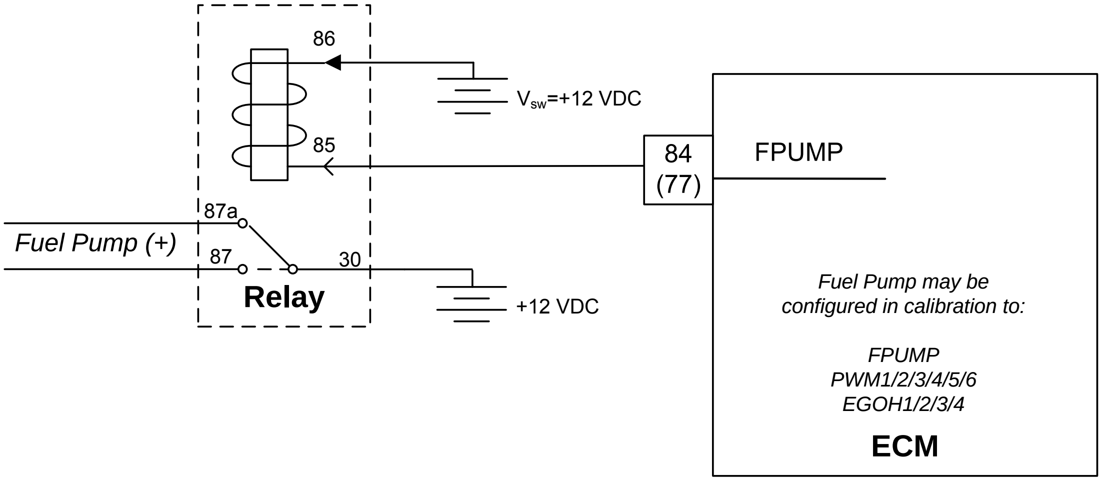
The ECM has auxiliary low-side drivers that can turn on warning devices or ground electromagnetic relay coils to control power to devices connected to the engine.

This fault sets if the output for the fuel pump relay is detected as being shorted to ground. If this fault is active and the high-side of the fuel pump relay is supplied, the fuel pump will run until the relay or high-side power is removed.

DTC 628- Fuel Pump Relay Ground Short



DTC 629- Fuel Pump Relay Coil Short-To-Power

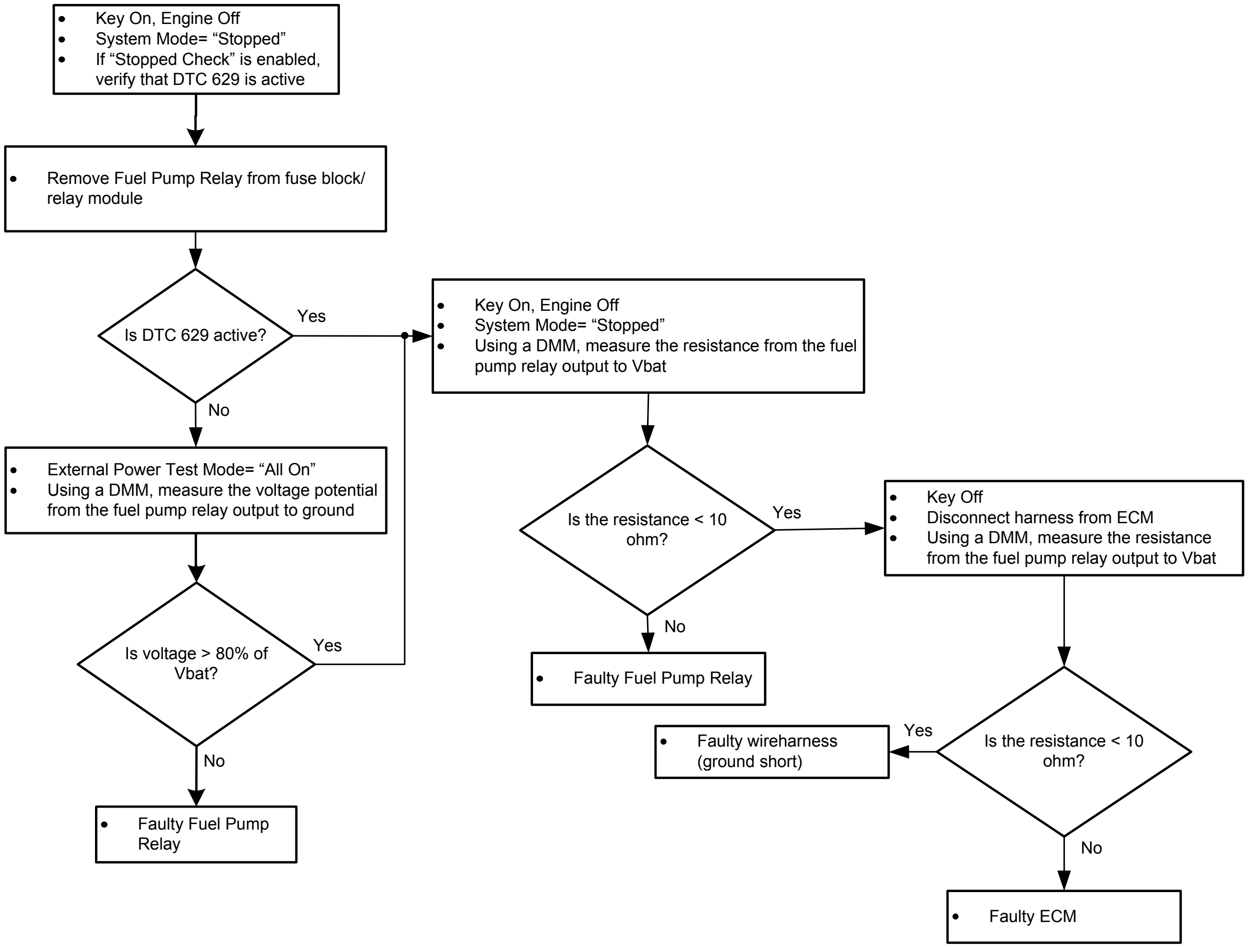


- Hardware: Fuel Pump Relay Pull in Coil
- Enabling Conditions: Key On, Engine Off
- Set Conditions: Fuel Pump relay coil output short to power/voltage
- Corrective Action(s): Illuminate MIL and/or sound audible warning or illuminate secondary warning lamp
- Non-emissions related fault
- Possible Causes: Shorted relay pull in coil, relay driver circuit shorted to voltage in wire harness

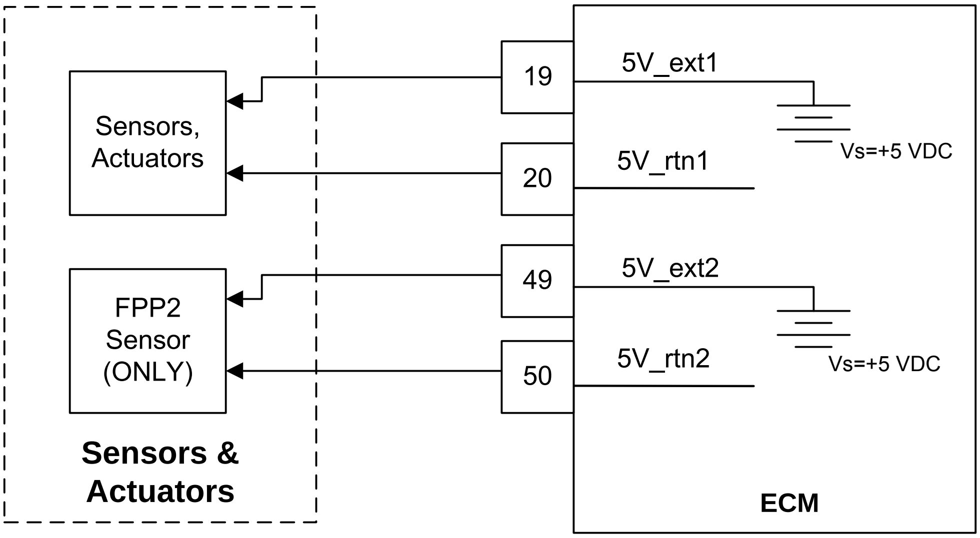
The ECM has auxiliary low-side drivers that can turn on warning devices or ground electromagnetic relay coils to control power to devices connected to the engine.

This fault sets if the output for the fuel pump relay is detected as shorted to power. If this fault is active the fuel pump will not receive power and will not run.

DTC 629- Fuel Pump Relay Coil Short-To-Power



DTC 642- Sensor Supply Voltage 1 Low (5Vext1)

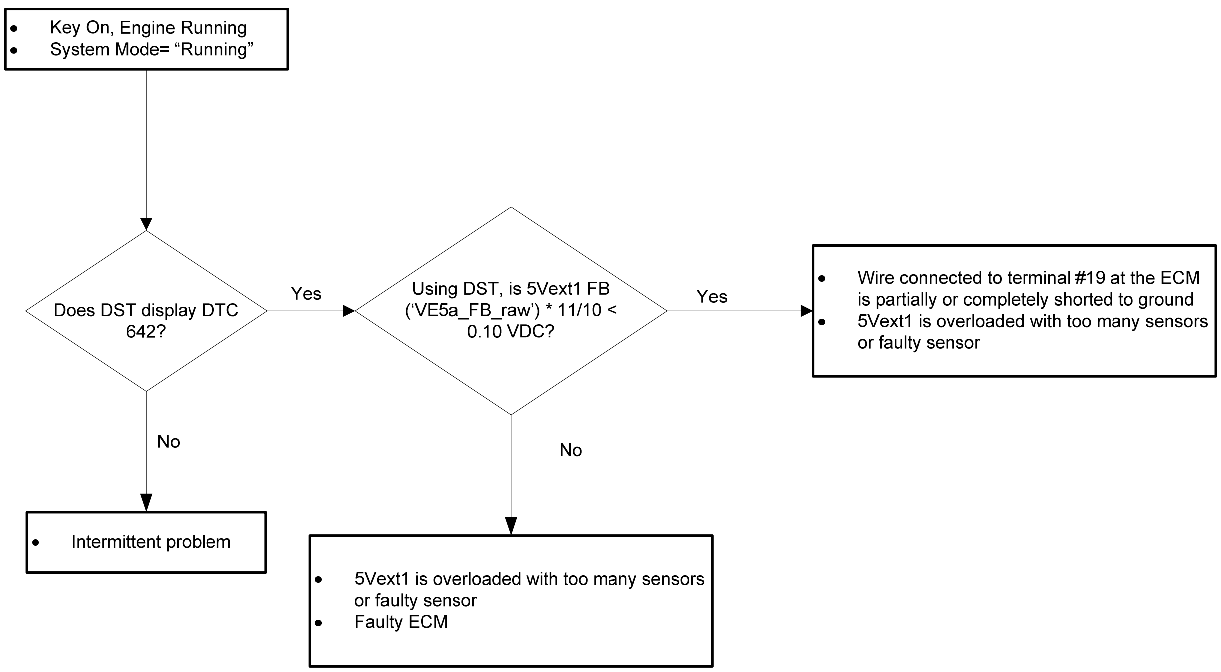


- Hardware: External Sensor Supply Voltage Regulator 1
- Enabling Conditions: Key On, Engine Off or Running
- Fault Condition- Voltage feedback on sensor supply circuit #1 below 4.6v for longer than 1 second
- Corrective Action(s)- Illuminate MIL and disable fuel adaptive learn while code is active
- Non-emissions related fault
- Possible Causes: Internal short to ground in any sensor fed by 5Vext1 supply, 5Vext1 shorted to ground in wire harness, faulty ECM (no 5v output on 5Vext1)

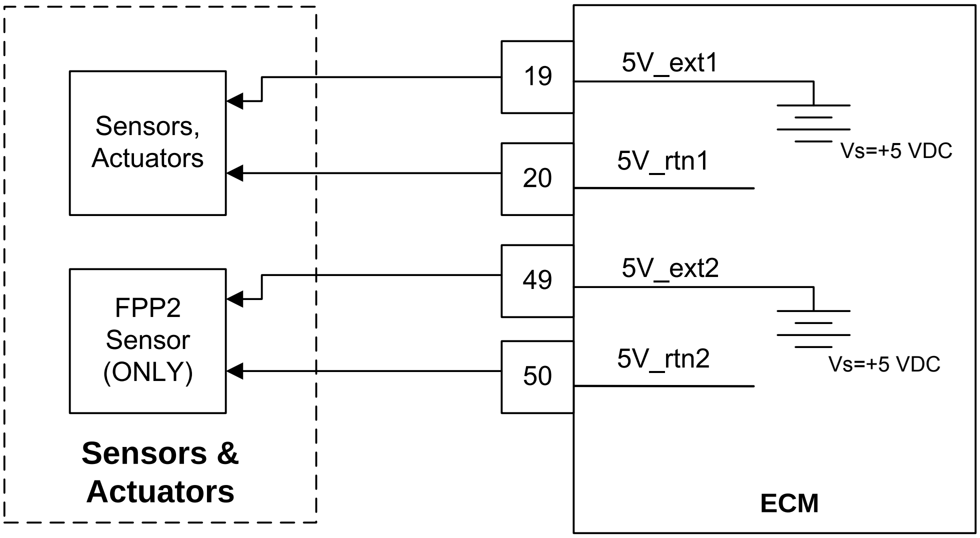
The external 5-volt supply powers sensors and other components in the engine control system. The accuracy of this supply is critical to the accuracy of the sensors' feedback, therefore, it is supplied from a precision regulator whose output is internally monitored by the ECM. The ECM monitors the 5-volt supply to ratio metrically correct sensor feedback and determine if the circuit is overloaded, shorted, or otherwise out of specification.

This fault will set if the internally measured voltage feedback of the regulator output is lower than the low voltage limit as defined in the diagnostic calibration anytime the engine is running or stopped at key-on (if applicable).

DTC 642- Sensor Supply Voltage 1 Low (5Vext1)



DTC 643- Sensor Supply Voltage 1 High (5Vext1)

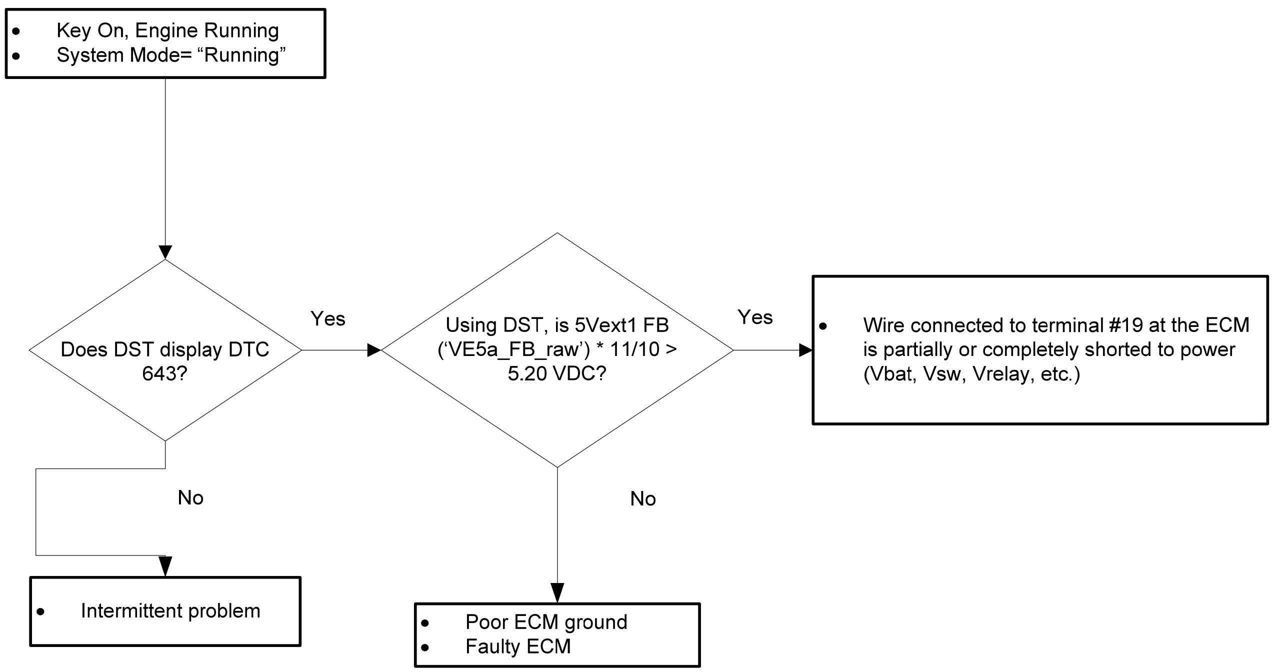


- Hardware: External Sensor Supply Voltage Regulator 1
- Enabling Conditions: Key On, Engine Off and Running
- Set Conditions: Voltage feedback on sensor supply circuit #1 is greater than 5.4v for longer than 1 second
- Corrective Action(s): Illuminate MIL and disable fuel adaptive learn while code is active
- Non-emissions related fault
- Possible Causes: 5Vext1 circuit shorted to 12v in wire harness

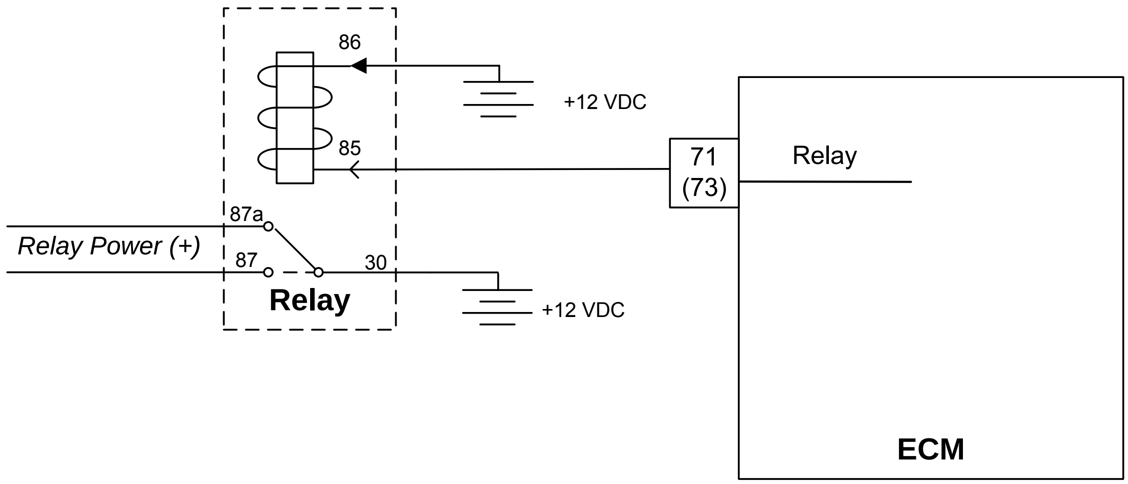
The external 5-volt supply powers sensors and other components in the engine control system. The accuracy of this supply is critical to the accuracy of the sensors' feedback, therefore, it is supplied from a precision regulator whose output is internally monitored by the ECM. The ECM monitors the 5-volt supply to ratio metrically correct sensor feedback and determine if the circuit is overloaded, shorted, or otherwise out of specification.

This fault will set if the internally measured voltage feedback of the regulator output is higher than the high voltage limit as defined in the diagnostic calibration anytime the engine is running or stopped at key-on (if applicable).

DTC 643- Sensor Supply Voltage 1 High (5Vext1)



DTC 685- Power Relay Coil Open

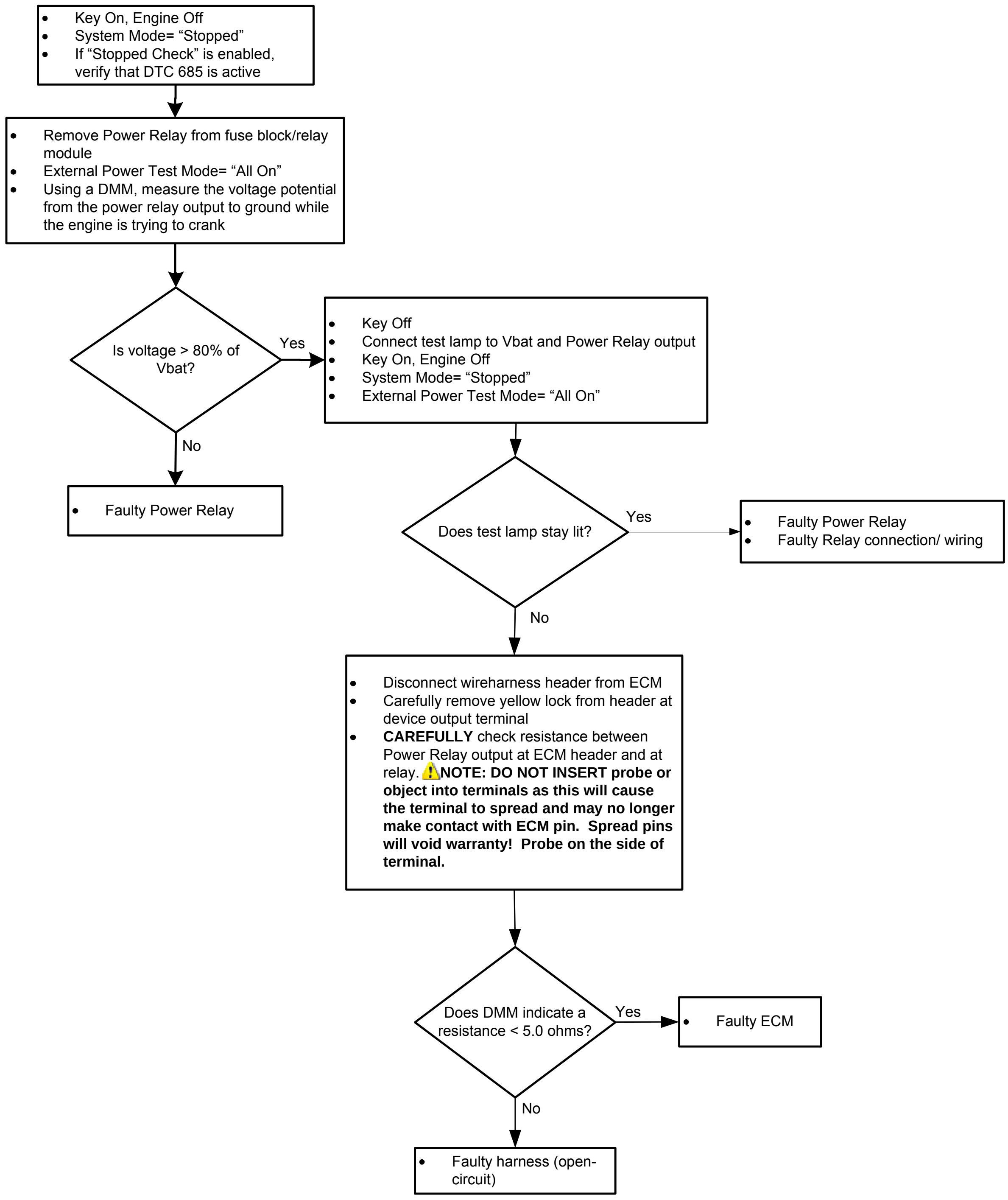


- Hardware: Power Relay Pull in Coil
- Enabling Conditions: Key On, Engine Off
- Set Conditions: Power relay coil output open circuit for more than 10 samples of circuit
- Corrective Action(s): Illuminate MIL
- Non-emissions related fault
- Possible Causes: Open in relay pull in coil, open in relay driver circuit in wire harness, faulty ECM

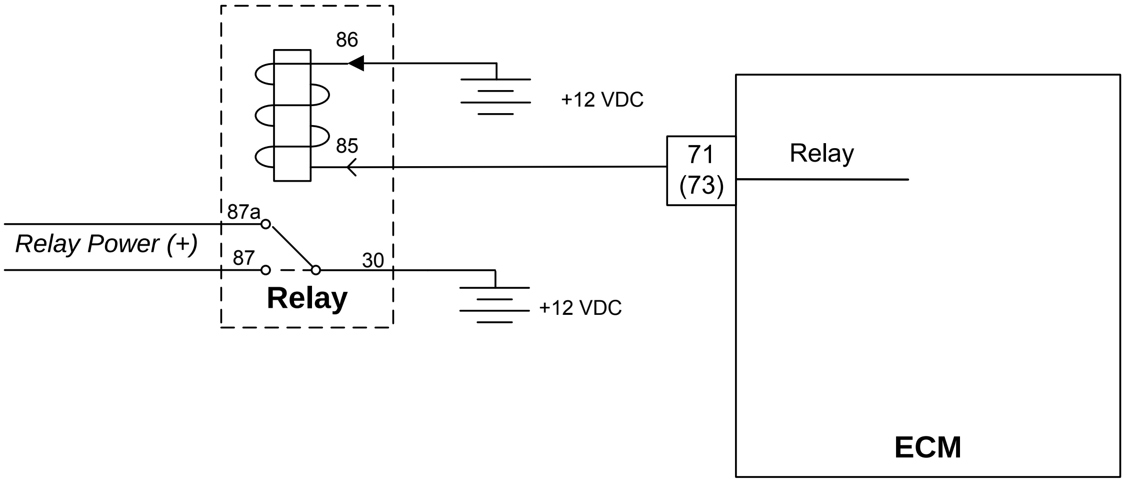
The ECM has auxiliary low-side drivers that can turn on warning devices or ground electromagnetic relay coils to control power to devices connected to the engine.

This fault sets if the output for the power relay is detected as an open circuit. If this fault is active the injector and ignition coil high-side will not receive power and the engine will not run.

DTC 685- Power Relay Coil Open



DTC 686- Power Relay Ground Short

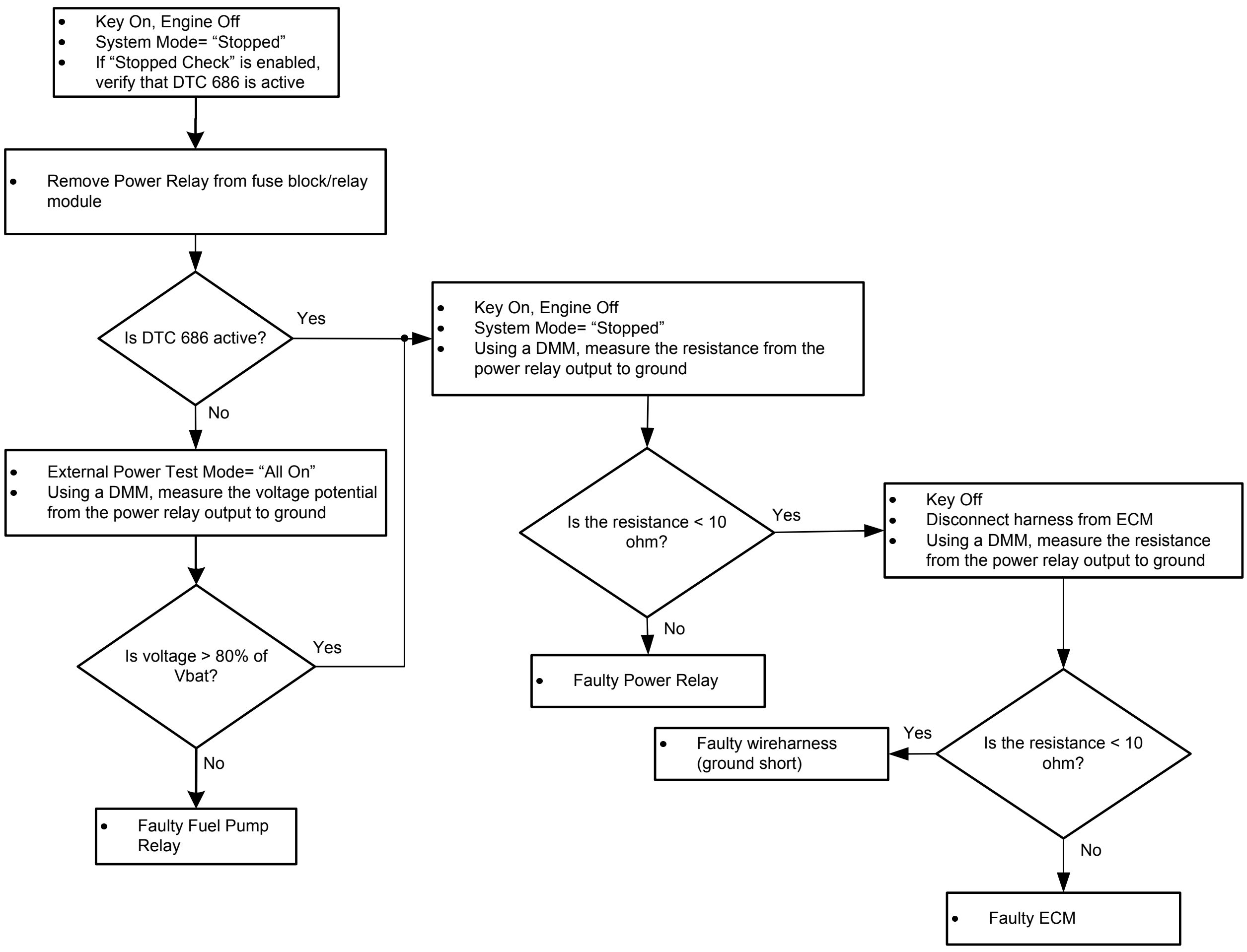


- o Hardware: Power Relay Pull in Coil
- o Enabling Conditions: Key On, Engine Off
- o Set Conditions: Power relay coil output shorted to ground for more than 10 samples of circuit
- o Corrective Action(s): Illuminate MIL
- o Non-emissions related fault
- o Possible Causes: Short to ground in relay pull in coil, short to ground in relay driver circuit in wire harness, faulty ECM

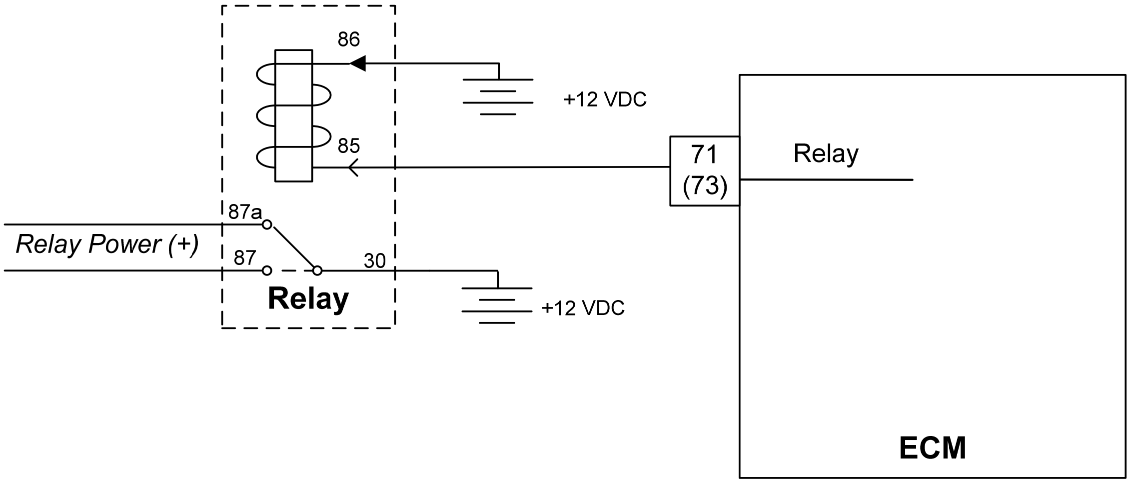
The ECM has auxiliary low-side drivers that can turn on warning devices or ground electromagnetic relay coils to control power to devices connected to the engine.

This fault sets if the output for the power relay is detected as being shorted to ground. If this fault is active and the high-side of the power relay is supplied, the following components will have power until the relay or high-side power is removed: CMP sensor, CKP sensor, both O2 sensors, the DEPR (if equipped) and all fuel injectors (gasoline engines).

DTC 686- Power Relay Ground Short



DTC 687- Power Relay Coil Short-To-Power

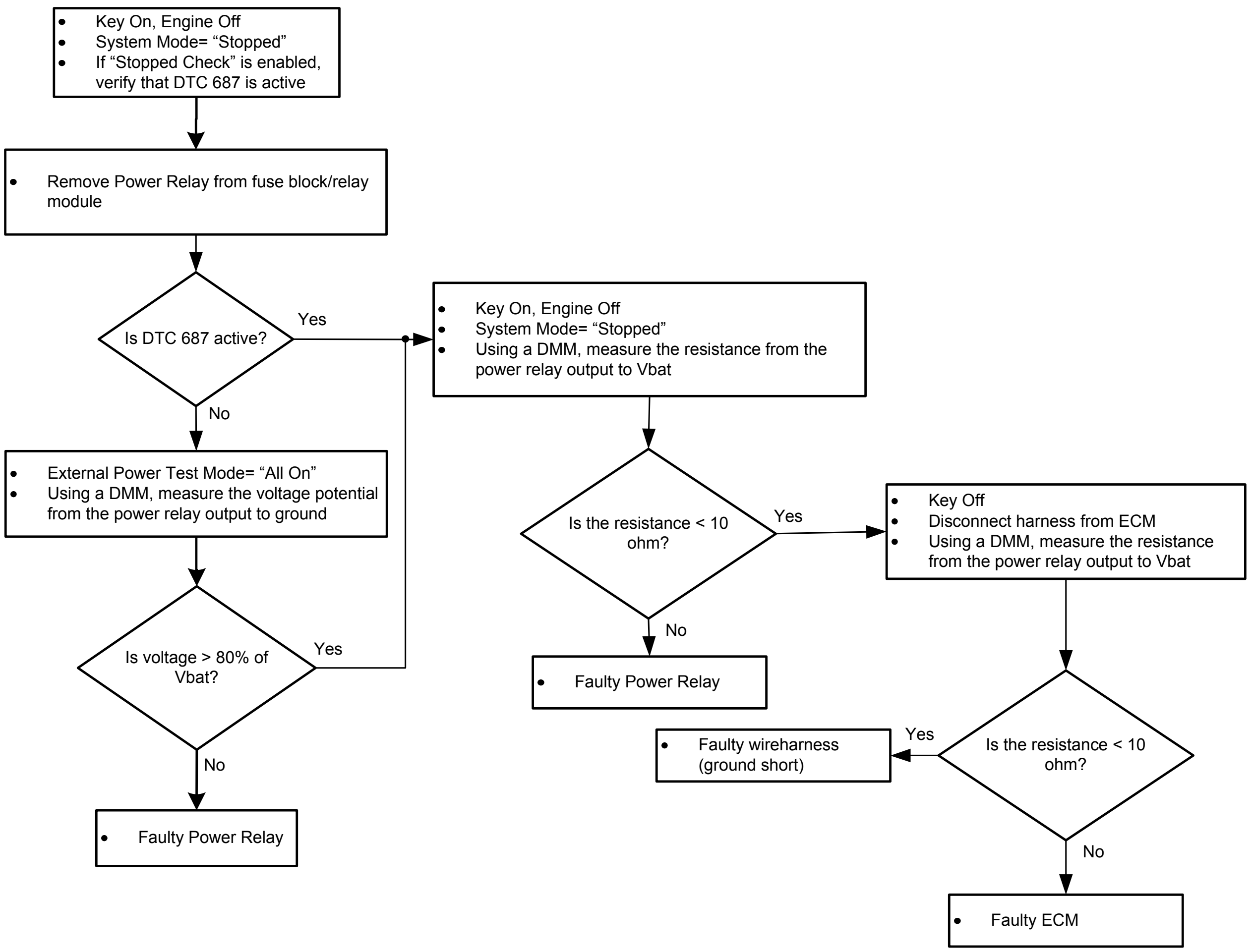


- Hardware: Power Relay Pull in Coil
- Enabling Conditions: Key On, Engine Off
- Set Conditions: Power relay coil output short to power/voltage
- Corrective Action(s): Illuminate MIL
- Non-emissions related fault
- Possible Causes: Shorted relay pull in coil, relay driver circuit shorted to voltage in wire harness

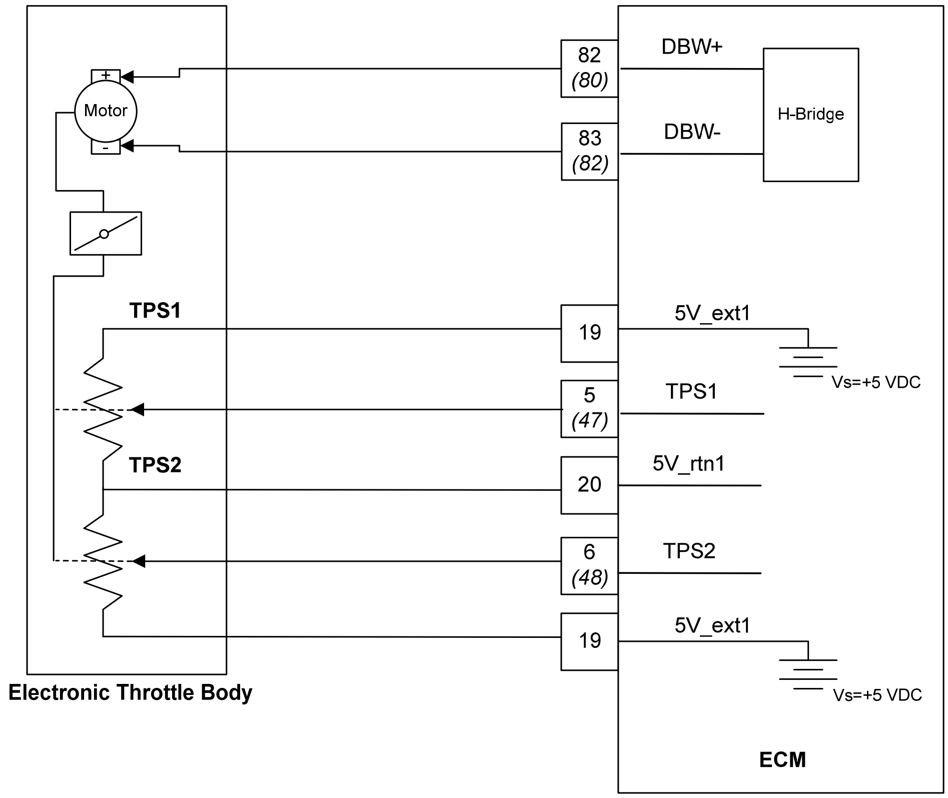
The ECM has auxiliary low-side drivers that can turn on warning devices or ground electromagnetic relay coils to control power to devices connected to the engine.

This fault sets if the output for the power relay is detected as shorted to power.

DTC 687- Power Relay Coil Short-To-Power



DTC 1111- RPM Above Fuel Rev Limit Level



- Hardware: Fuel Rev Limit- Crankshaft Position Sensor
- Enabling Conditions: Engine Running
- Set Conditions: Engine speed greater than the Fuel Rev Limit speed (4000 rpm) for longer than 0.5 seconds
- Corrective Action(s): Illuminate MIL
- Non-emissions related fault
- Possible Causes: Engine overspeed condition, faulty CKP sensor or input

This fault will set anytime the engine RPM exceeds the limit set in the diagnostic calibration for the latch time or more. This speed overrides any higher max governor speeds programmed by the user. This fault is designed to help prevent engine or equipment damage and will disable fuel injectors or gaseous fuel actuator to reduce engine speed. The throttle will also be lowered in order to govern the engine to the speed set in the diagnostic calibration for Max Gov Override.

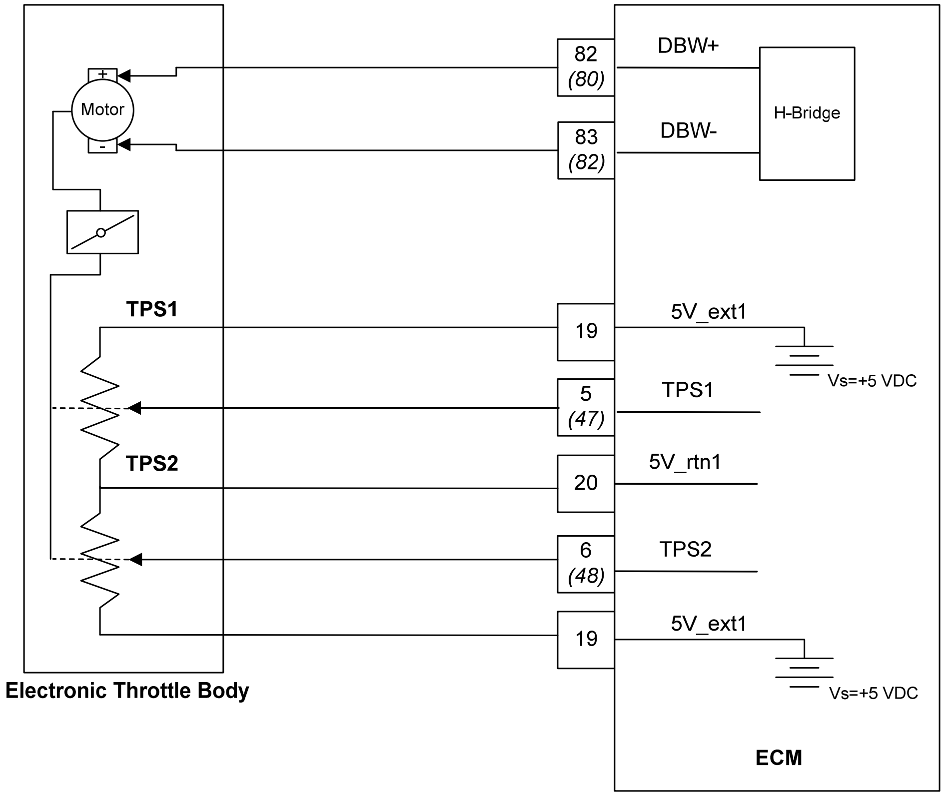
DTC 1111- RPM Above Fuel Rev Limit Level

Diagnostic Aids

NOTE: If any other DTCs are present, diagnose those first.

- ☐ Ensure that no programmed governor speeds exceed the limit set in the diagnostic calibration for Max Gov Override Speed
- ☐ Check mechanical operation of the throttle
- ☐ Check the engine intake for large air leaks downstream of the throttle body

DTC 1112- RPM Above Spark Rev Limit Level



- Hardware: Spark Rev Limit- Crankshaft Position Sensor
- Enabling Conditions: Engine Running
- Set Conditions: Engine speed greater than the Spark Rev Limit speed (4200 rpm) for longer than 0.5 seconds
- Corrective Action(s): Illuminate MIL
- Non-emissions related fault
- Possible Causes: Engine overspeed condition, faulty CKP sensor or input

This fault will set anytime the engine RPM exceeds the limit set in the diagnostic calibration for the latch time or more. This speed overrides any higher max governor speeds programmed by the user. This fault is designed to help prevent engine or equipment damage and will disable the ignition coils to reduce engine speed. In addition, the throttle will be lowered in order to govern the engine to the speed set in the diagnostic calibration for Max Gov Override and the fuel injectors or gaseous fuel control actuator will be disabled to reduce the engine speed below the speed set in the diagnostic calibration for Fuel Rev Limit.

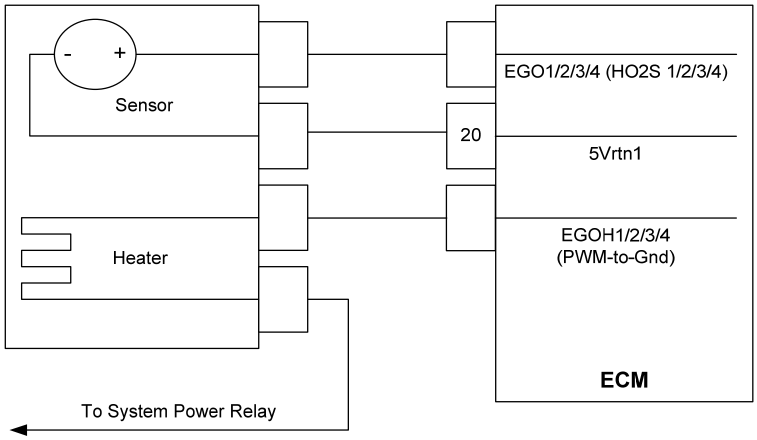
DTC 1112- RPM Above Spark Rev Limit Level

Diagnostic Aids

NOTE: If any other DTCs are present, diagnose those first.

- ☐ Ensure that no programmed governor speeds exceed the limit set in the diagnostic calibration for Max Gov Override Speed
- ☐ Check mechanical operation of the throttle
- ☐ Check the engine intake for large air leaks downstream of the throttle body

DTC 1151- Closed Loop High (LPG)



- Hardware: Heated or Universal Exhaust Gas Oxygen Sensor (Bank 1-Sensor 1/Bank 1-Before Catalyst)
- Enabling Conditions: Engine Running in closed loop
- Set Conditions: Closed Loop fuel multiplier higher than 35% for longer than 5 updates
- Corrective Action(s): Illuminate MIL
- Emissions related fault
- Possible Causes:

The HEGO/HO2S sensor is a switching-type sensor around stoichiometry that measures the oxygen content present in the exhaust to determine if the fuel flow to the engine is correct. A UEGO sensor measures the exhaust content across a wide-range of air-fuel ratios with a linear output proportional to lambda/equivalence ratio/air-fuel ratio. In either case, if there is a deviation between the expected reading and the actual reading, fuel flow is precisely adjusted for each bank using the Closed Loop multiplier and then “learned” with the Adaptive multiplier. The multipliers only update when the system is in either *“CL Active”* or *“CL + Adapt”* control modes. The purpose of the closed loop fuel multiplier is to quickly adjust fuel flow due to variations in fuel composition, engine wear, engine-to-engine build variances, and component degradation prior to adaptive learn fueling correction “learning” the fueling deviation.

This fault sets if the Closed Loop multiplier exceeds the high limit of normal operation indicating that the engine is operating lean (excess oxygen) and requires more fuel than allowed by corrections. Often high positive fueling corrections are a function of one or more of the following conditions: 1) exhaust leaks upstream or near the HEGO sensor, 2) reduced fuel supply pressure to the gaseous fuel control system, 3) a fuel supply or manifold leak, 4) a non-responsive HEGO/UEGO sensor, and/or 5) a defective gaseous fuel control component (actuator/valve and/or mixer). This fault should be configured to disable adaptive learn for the remainder of the key-cycle to avoid improperly learning the adaptive learn table and may be configured to disable closed loop.

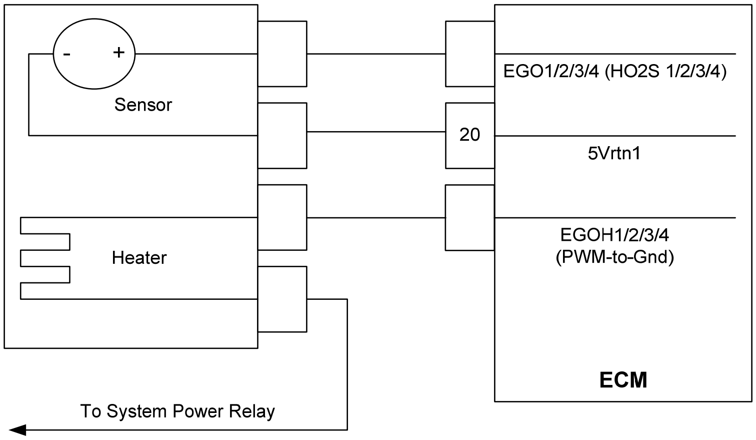
DTC 1151- Closed Loop High (LPG)

Diagnostic Aids

NOTE: If any other DTCs are present, diagnose those first.

- ☐ Oxygen Sensor Wire - Sensor may be mispositioned contacting the exhaust. Check for short to ground between harness and sensor sense signal.
- ☐ Vacuum Leaks - Large vacuum leaks and crankcase leaks can cause a lean exhaust condition at light load.
- ☐ Fuel Pressure - System will be lean if fuel pressure is too low. Ensure fuel tank pressure is not too low and that gaseous fuel control actuator/regulator has proper fuel pressure under all operating conditions.
- ☐ Exhaust Leaks - If there is an exhaust leak, outside air can be pulled into the exhaust and past the O2 sensor causing a false lean condition.
- ☐ Fuel Quality - A drastic variation in fuel quality may cause the system to be lean including fuels with high inert gas content.
- ☐ System Grounding - ECM and engine must be grounded to the battery with very little resistance allowing for proper current flow. Faulty grounds can cause current supply issues resulting in many undesired problems.
- ☐ If all tests are OK, replace the HO2S or UEGO sensor with a known good part and retest.

DTC 1152- Closed Loop Low (LPG)



- o Hardware: Heated or Universal Exhaust Gas Oxygen Sensor (Bank 1-Sensor 1/Bank 1-Before Catalyst)
- o Enabling Conditions: Engine Running in closed loop
- o Set Conditions: Closed Loop fuel multiplier lower than -35% for longer than 5 updates
- o Corrective Action(s): Illuminate MIL
- o Emissions related fault
- o Possible Causes:

The HEGO/HO2S sensor is a switching-type sensor around stoichiometry that measures the oxygen content present in the exhaust to determine if the fuel flow to the engine is correct. A UEGO sensor measures the exhaust content across a wide-range of air-fuel ratios with a linear output proportional to lambda/equivalence ratio/air-fuel ratio. In either case, if there is a deviation between the expected reading and the actual reading, fuel flow is precisely adjusted for each bank using the Closed Loop multiplier and then "learned" with the Adaptive multiplier. The multipliers only update when the system is in either *"CL Active"* or *"CL + Adapt"* control modes. The purpose of the closed loop fuel multiplier is to quickly adjust fuel flow due to variations in fuel composition, engine wear, engine-to-engine build variances, and component degradation prior to adaptive learn fueling correction "learning" the fueling deviation.

This fault sets if the Closed Loop multiplier exceeds the low limit of normal operation indicating that the engine is operating rich (excess fuel) and requires less fuel than allowed by corrections. Often high negative fueling corrections are a function of one or more of the following conditions: 1) high fuel supply pressure to the gaseous fuel control or faulty pressure regulator and/or 2) a non-responsive HEGO/UEGO sensor. This fault should be configured to disable adaptive learn for the remainder of the key-cycle to avoid improperly learning the adaptive learn table and may be configured to disable closed loop.

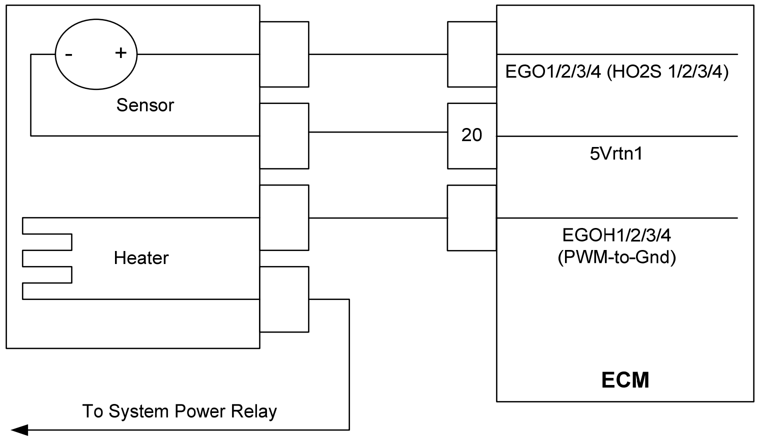
DTC 1152- Closed Loop Low (LPG)

Diagnostic Aids

NOTE: If any other DTCs are present, diagnose those first.

- ☐ Oxygen Sensor Wire - Sensor may be mispositioned contacting the exhaust. Check for short to ground between harness and sensor and on sensor harness
- ☐ Fuel Pressure - System will be rich if fuel delivery pressure is too high to gaseous control system. Check fuel pressure at the control actuator/valve under all operating conditions.
- ☐ System Grounding - ECM and engine must be grounded to the battery with very little resistance allowing for proper current flow. Faulty grounds can cause current supply issues resulting in many undesired problems.
- ☐ If all tests are OK, replace the HO2S or UEGO sensor with a known good part and retest.

DTC 1155- Closed Loop Bank 1 High (Gasoline)



- Hardware: Heated or Universal Exhaust Gas Oxygen Sensor (Bank 1-Sensor 1/Bank 1-Before Catalyst)
- Enabling Conditions: Engine Running in closed loop
- Set Conditions: Bank 1 closed loop fuel multiplier higher than 35% for longer than 5 updates
- Corrective Action(s): Illuminate MIL
- Emissions related fault
- Possible Causes:

The HEGO/HO2S sensor is a switching-type sensor around stoichiometry that measures the oxygen content present in the exhaust to determine if the fuel flow to the engine is correct. A UEGO sensor measures the exhaust content across a wide-range of air-fuel ratios with a linear output proportional to lambda/equivalence ratio/air-fuel ratio. In either case, if there is a deviation between the expected reading and the actual reading, fuel flow is precisely adjusted for each bank using the Closed Loop multiplier and then "learned" with the Adaptive multiplier. The multipliers only update when the system is in either *"CL Active"* or *"CL + Adapt"* control modes. The purpose of the closed loop fuel multiplier is to quickly adjust fuel flow due to variations in fuel composition, engine wear, engine-to-engine build variances, and component degradation prior to adaptive learn fueling correction "learning" the fueling deviation.

This fault sets if the closed loop multiplier exceeds the high limit of normal operation indicating that the engine is operating lean (excess oxygen) and requires more fuel than allowed by corrections. Often high positive fueling corrections are a function of one or more of the following conditions: 1) exhaust leaks upstream or near the HEGO sensor, 2) reduced fuel supply pressure to the fuel injection system, 3) a non-responsive HEGO/UEGO sensor, and/or 3) an injector that is stuck closed. This fault should be configured to disable adaptive learn for the remainder of the key-cycle to avoid improperly learning the adaptive learn table and may be configured to disable closed loop.

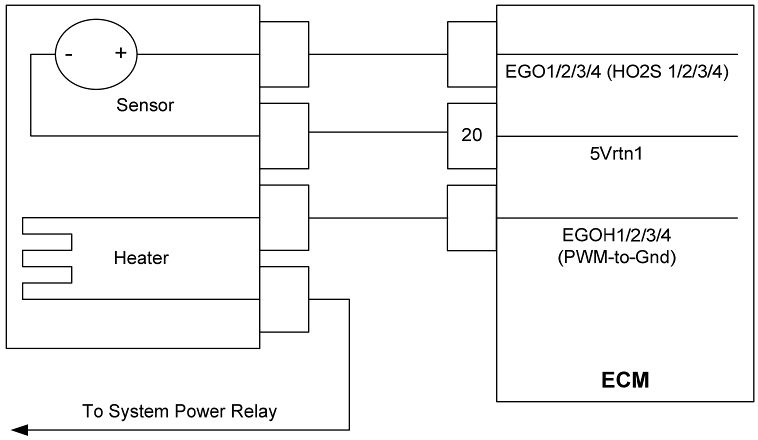
DTC 1155-Closed Loop Bank 1 High (Gasoline)

Diagnostic Aids

NOTE: If any other DTCs are present, diagnose those first.

- ☐ Oxygen Sensor Wire - Sensor may be mispositioned contacting the exhaust. Check for short to ground between harness and sensor and on sensor harness
- ☐ Vacuum Leaks - Large vacuum leaks and crankcase leaks can cause a lean exhaust condition at light load.
- ☐ Injectors - System will be lean if an injector driver or driver circuit fails. The system will also be lean if an injector fails in a closed manner or is dirty.
- ☐ Fuel Pressure - System will be lean if fuel pressure is too low. Check fuel pressure in the fuel rail during key-on, engine off and during normal operating conditions.
- ☐ Air in Fuel - If the fuel return hose/line is too close to the fuel supply pickup in the fuel tank, air may become entrapped in the pump or supply line causing a lean condition and driveability problems.
- ☐ Exhaust Leaks - If there is an exhaust leak, outside air can be pulled into the exhaust and past the O2 sensor causing a false lean condition.
- ☐ Fuel Quality - A drastic variation in fuel quality may cause the system to be lean including oxygenated fuels.
- ☐ System Grounding - ECM and engine must be grounded to the battery with very little resistance allowing for proper current flow. Faulty grounds can cause current supply issues resulting in many undesired problems.
- ☐ If all tests are OK, replace the HO2S sensor with a known good part and retest.

DTC 1156- Closed Loop Bank 1 Low (Gasoline)



- Hardware: Heated or Universal Exhaust Gas Oxygen Sensor (Bank 1-Sensor 1/Bank 1-Before Catalyst)
- Enabling Conditions: Engine Running in closed loop
- Set Conditions: Bank 1 closed loop fuel multiplier lower than -35% for longer than 5 updates
- Corrective Action(s): Illuminate MIL
- Emissions related fault
- Possible Causes:

The HEGO/HO2S sensor is a switching-type sensor around stoichiometry that measures the oxygen content present in the exhaust to determine if the fuel flow to the engine is correct. A UEGO sensor measures the exhaust content across a wide-range of air-fuel ratios with a linear output proportional to lambda/equivalence ratio/air-fuel ratio. In either case, if there is a deviation between the expected reading and the actual reading, fuel flow is precisely adjusted for each bank using the Closed Loop multiplier and then “learned” with the Adaptive multiplier. The multipliers only update when the system is in either *“CL Active”* or *“CL + Adapt”* control modes. The purpose of the closed loop fuel multiplier is to quickly adjust fuel flow due to variations in fuel composition, engine wear, engine-to-engine build variances, and component degradation prior to adaptive learn fueling correction “learning” the fueling deviation.

This fault sets if the closed loop multiplier exceeds the low limit of normal operation indicating that the engine is operating rich (excess fuel) and requires less fuel than allowed by corrections. Often high negative fueling corrections are a function of one or more of the following conditions: 1) high fuel supply pressure to the fuel injection system, 2) a non-responsive HEGO/UEGO sensor, and/or 3) an injector that is stuck open. This fault should be configured to disable adaptive learn for the remainder of the key-cycle to avoid improperly learning the adaptive learn table and may be configured to disable closed loop.

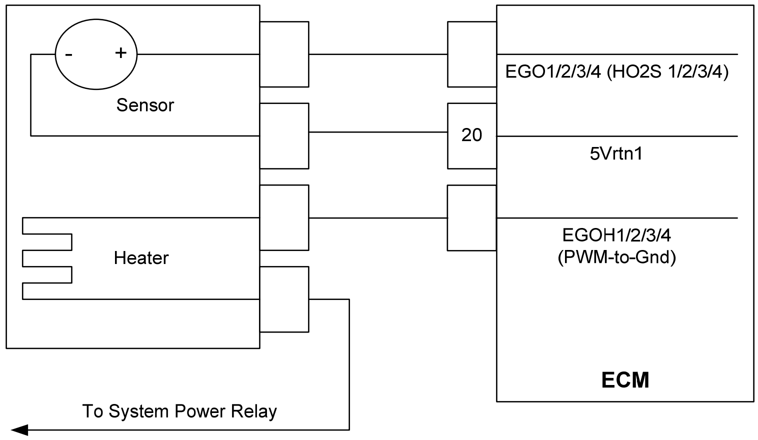
DTC 1156- Closed Loop Bank 1 Low (Gasoline)

Diagnostic Aids

NOTE: If any other DTCs are present, diagnose those first.

- ☐ Oxygen Sensor Wire - Sensor may be mispositioned contacting the exhaust. Check for short to ground between harness and sensor and on sensor harness
- ☐ Injectors - System will be rich if an injector driver or driver circuit fails shorted-to-ground. The system will also be rich if an injector fails in an open.
- ☐ Fuel Pressure - System will be rich if fuel pressure is too high. Check fuel pressure in the fuel rail during key-on, engine off and during normal operating conditions.
- ☐ System Grounding - ECM and engine must be grounded to the battery with very little resistance allowing for proper current flow. Faulty grounds can cause current supply issues resulting in many undesired problems.
- ☐ If all tests are OK, replace the HO2S sensor with a known good part and retest.

DTC 1161- Adaptive Learn High (LPG)



- Hardware: Heated or Universal Exhaust Gas Oxygen Sensor (Bank 1-Sensor 1/Bank 1-Before Catalyst)
- Enabling Conditions: Engine Running in closed loop and with fuel adaptive learn active
- Set Conditions: Adaptive fuel multiplier higher than 30% for longer than 3 updates
- Corrective Action(s): Illuminate MIL
- Emissions related fault
- Possible Causes:

The HEGO/HO2S sensor is a switching-type sensor around stoichiometry that measures the oxygen content present in the exhaust to determine if the fuel flow to the engine is correct. A UEGO sensor measures the exhaust content across a wide-range of air-fuel ratios with a linear output proportional to lambda/equivalence ratio/air-fuel ratio. In either case, if there is a deviation between the expected reading and the actual reading, fuel flow is precisely adjusted for each bank using the Closed Loop multiplier and then "learned" with the Adaptive multiplier. The multipliers only update when the system is in either *"CL Active"* or *"CL + Adapt"* control modes. The purpose of the Adaptive Learn fuel multiplier is to adjust fuel flow due to variations in fuel composition, engine wear, engine-to-engine build variances, and component degradation.

This fault sets if the Adaptive multiplier exceeds the high limit of normal operation indicating that the engine is operating lean (excess oxygen) and requires more fuel than allowed by corrections. Often high positive fueling corrections are a function of one or more of the following conditions: 1) exhaust leaks upstream or near the HEGO sensor, 2) reduced fuel supply pressure to the gaseous fuel control system, 3) a fuel supply or manifold leak, 4) a non-responsive HEGO/UEGO sensor, and/or 5) a defective gaseous fuel control component (actuator/valve and/or mixer). This fault should be configured to disable adaptive learn for the remainder of the key-cycle to avoid improperly learning the adaptive learn table and may be configured to disable closed loop.

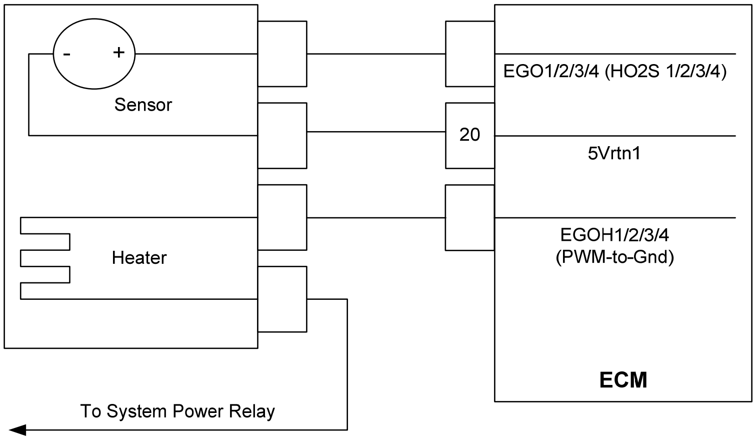
DTC 1161- Adaptive Learn High (LPG)

Diagnostic Aids

NOTE: If any other DTCs are present, diagnose those first.

- ☐ Oxygen Sensor Wire - Sensor may be mispositioned contacting the exhaust. Check for short to ground between harness and sensor sense signal.
- ☐ Vacuum Leaks - Large vacuum leaks and crankcase leaks can cause a lean exhaust condition at light load.
- ☐ Fuel Pressure - System will be lean if fuel pressure is too low. Ensure fuel tank pressure is not too low and that gaseous fuel control actuator/regulator has proper fuel pressure under all operating conditions.
- ☐ Exhaust Leaks - If there is an exhaust leak, outside air can be pulled into the exhaust and past the O2 sensor causing a false lean condition.
- ☐ Fuel Quality - A drastic variation in fuel quality may cause the system to be lean including fuels with high inert gas content.
- ☐ System Grounding - ECM and engine must be grounded to the battery with very little resistance allowing for proper current flow. Faulty grounds can cause current supply issues resulting in many undesired problems.
- ☐ If all tests are OK, replace the HO2S or UEGO sensor with a known good part and retest.

DTC 1162- Adaptive Learn Low (LPG)



- Hardware: Heated or Universal Exhaust Gas Oxygen Sensor (Bank 1-Sensor 1/Bank 1-Before Catalyst)
- Enabling Conditions: Engine Running in closed loop and with fuel adaptive learn active
- Set Conditions: Adaptive fuel multiplier lower than -30% for longer than 3 updates
- Corrective Action(s): Illuminate MIL
- Emissions related fault
- Possible Causes:

The HEGO/HO2S sensor is a switching-type sensor around stoichiometry that measures the oxygen content present in the exhaust to determine if the fuel flow to the engine is correct. A UEGO sensor measures the exhaust content across a wide-range of air-fuel ratios with a linear output proportional to lambda/equivalence ratio/air-fuel ratio. In either case, if there is a deviation between the expected reading and the actual reading, fuel flow is precisely adjusted for each bank using the Closed Loop multiplier and then “learned” with the Adaptive multiplier. The multipliers only update when the system is in either *“CL Active”* or *“CL + Adapt”* control modes. The purpose of the Adaptive Learn fuel multiplier is to adjust fuel flow due to variations in fuel composition, engine wear, engine-to-engine build variances, and component degradation.

This fault sets if the Adaptive multiplier exceeds the low limit of normal operation indicating that the engine is operating rich (excess fuel) and requires less fuel than allowed by corrections. Often high negative fueling corrections are a function of one or more of the following conditions: 1) high fuel supply pressure to the gaseous fuel control or faulty pressure regulator and/or 2) a non-responsive HEGO/UEGO sensor. This fault should be configured to disable adaptive learn for the remainder of the key-cycle to avoid improperly learning the adaptive learn table and may be configured to disable closed loop.

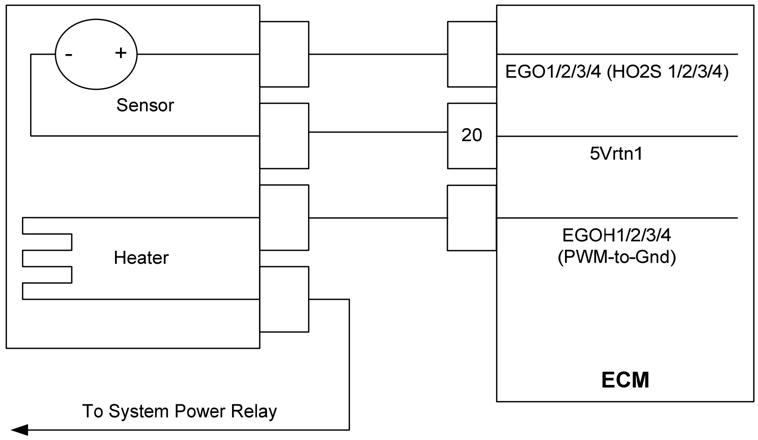
DTC 1162-Adaptive Learn Low (LPG)

Diagnostic Aids

NOTE: If any other DTCs are present, diagnose those first.

- ☐ Oxygen Sensor Wire - Sensor may be mispositioned contacting the exhaust. Check for short to ground between harness and sensor and on sensor harness
- ☐ Fuel Pressure - System will be rich if fuel delivery pressure is too high to gaseous control system. Check fuel pressure at the control actuator/valve under all operating conditions.
- ☐ System Grounding - ECM and engine must be grounded to the battery with very little resistance allowing for proper current flow. Faulty grounds can cause current supply issues resulting in many undesired problems.
- ☐ If all tests are OK, replace the HO2S or UEGO sensor with a known good part and retest.

DTC 1165- Catalyst Inactive on LPG



- Hardware: Bank 1 Catalyst, Heated or Universal Exhaust Gas Oxygen Sensor (Bank 1-Sensor 2-After Catalyst)
- Enabling Conditions: Engine Running
- Set Conditions: Catalyst inactive on LPG
- Corrective Action(s): Illuminate MIL, disable fuel adaptive learn and closed loop while fault is active
- Emissions related fault
- Possible Causes: Physically damaged catalyst element, contaminated catalyst element

A catalyst or catalytic converter is a component in the exhaust subsystem used to accelerate/generate chemical reactions within the engine exhaust to convert undesirable gases/pollutants into less harmful gases. In many spark-ignited applications, a three-way catalyst is used to convert hydrocarbons, oxides of nitrogen, and carbon monoxide into nitrogen, water, and carbon dioxide. In addition, many low-emission applications require the use of OBD, which typically require a catalyst monitor to identify whether or not the catalyst is functioning properly. The catalyst monitor diagnostic is typically configured such that exhaust emissions are near compliance-failing levels based on the engines specific regulatory requirement(s). Catalyst monitor techniques typically utilize a HEGO sensor to monitor the amount of oxygen present downstream of the catalyst. This is generally a good indicator of how efficiently the catalyst is using the oxygen entering the catalyst. Some systems also use temperature measurements in the catalyst and compare it to data stored in the ECM for each operating condition to determine if the catalytic reaction is generating the proper amount of heat.

The GCP uses a HEGO/HO2S sensor for catalyst monitor. The HEGO/HO2S is a switching-type sensor around stoichiometry that measures the oxygen content downstream of the catalyst for two main functions: 1) to compare it to the oxygen content upstream of the catalyst to determine how efficiently the catalyst is using oxygen to determine its effectiveness and 2) trim the commanded equivalence ratio target to maximize the catalyst conversion efficiency. The post-catalyst strategy and diagnostic is only active when the system is in either *"CL Active"* or *"CL + Adapt"* control modes.

In theory if the catalyst is operated at a condition that could result in 100 percent conversion efficiency, the catalyst will use all available oxygen present in the exhaust gas to convert the emission pollutants (or reactants) to N_2, CO_2, and H_2O. However, since catalysts generally operate at efficiencies between 85-95% post-catalyst oxygen concentration can be a direct indicator of how efficient the catalyst is. **Figure 11** shows an example of a slightly rich biased feed gas or pre-catalyst equivalence ratio versus that of the post-catalyst for a functional catalyst. It can be noticed from this figure that the pre-catalyst equivalence ratio, as identified by '*EGO1_volts*', is varying due to the CL excursions (perturbation) and that the post-catalyst equivalence ratio, as identified by '*EGO2_volts*', is maintained relatively constant rich of stoichimetry. A similar waveform pattern should be expected on properly functioning catalysts.

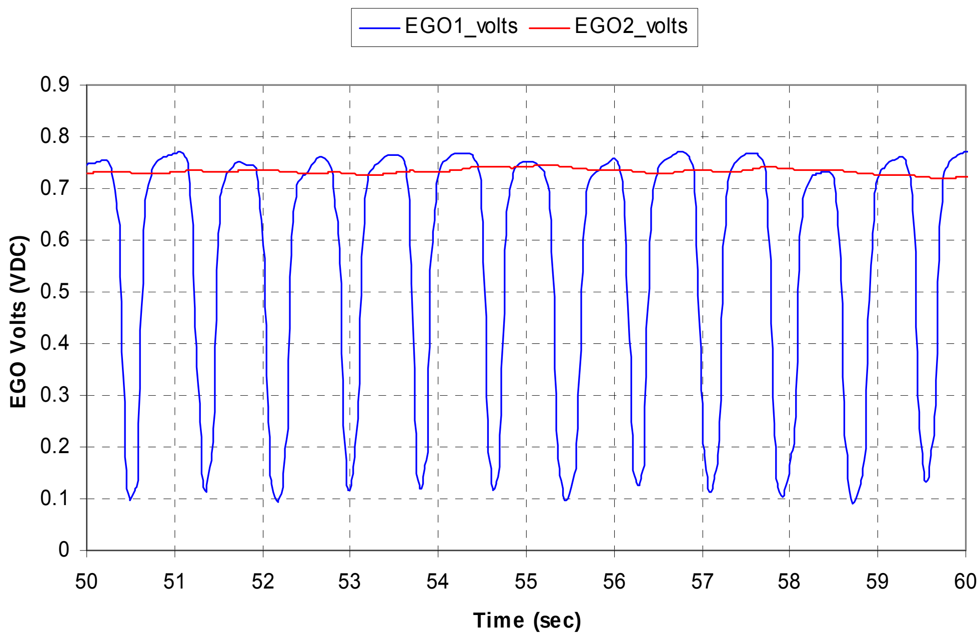


Figure 11: EGO Waveforms (Functional TWC)

Figure 12 shows an example of EGO waveforms for a catalyst with poor conversion efficiency. A significant difference between **Figure 11** and **Figure 12** is that the post-catalyst EGO feedback oscillates with the same frequency as the pre-catalyst EGO feedback and the amplitude is on the order of 60% of that of EGO1. This indicates that a certain amount of oxygen that is entering into the catalyst is passing through the catalyst unconsumed. Catalyst monitor diagnostics are configured such that if the post-catalyst EGO waveform has an amplitude that is directly proportional to the pre-catalyst EGO waveform and who's waveform similarly matches the closed-loop excursion (perturbation) a fault is generated.

Two metric comparisons that are used to identify the health of the catalyst are:

1) Post-catalyst EGO root-mean square (RMS) > Pre-catalyst EGO RMS x ??? %, where the ??? % is determined based on emissions compliance testing over the application's certified duty-cycle(s).
2) Post-catalyst EGO RMS > CL excursion RMS x ??? %, where the ??? % is determined based on emissions compliance testing over the application's certified duty-cycle(s).

There are a couple of ways in which the limits for diagnostics can be determined. In both cases, the system must be tested with an emissions measurement system to determine when the exhaust emissions are nearly failing emissions compliance.

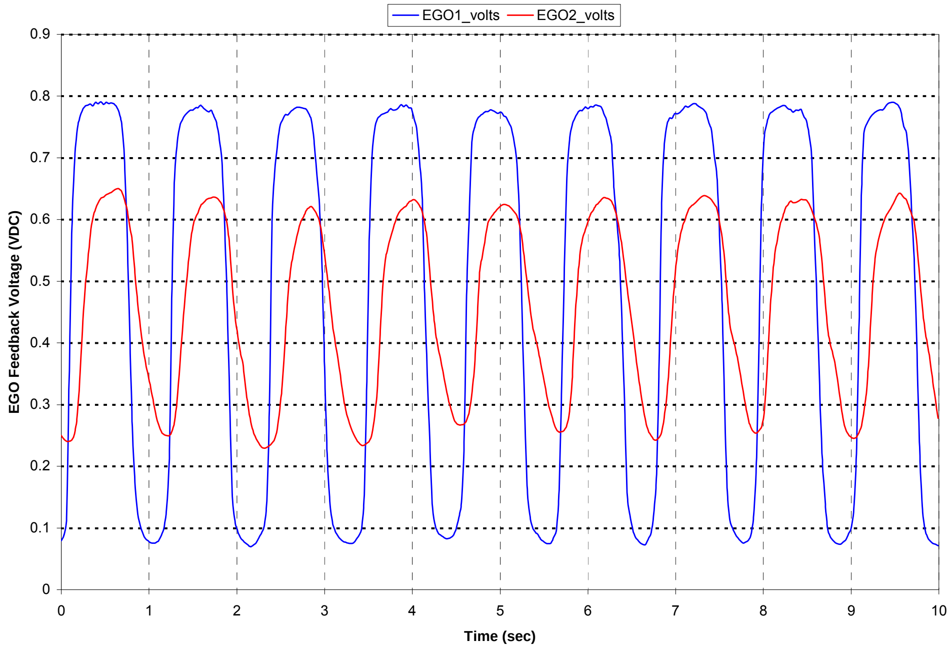


Figure 12: EGO Waveforms (Damaged TWC)

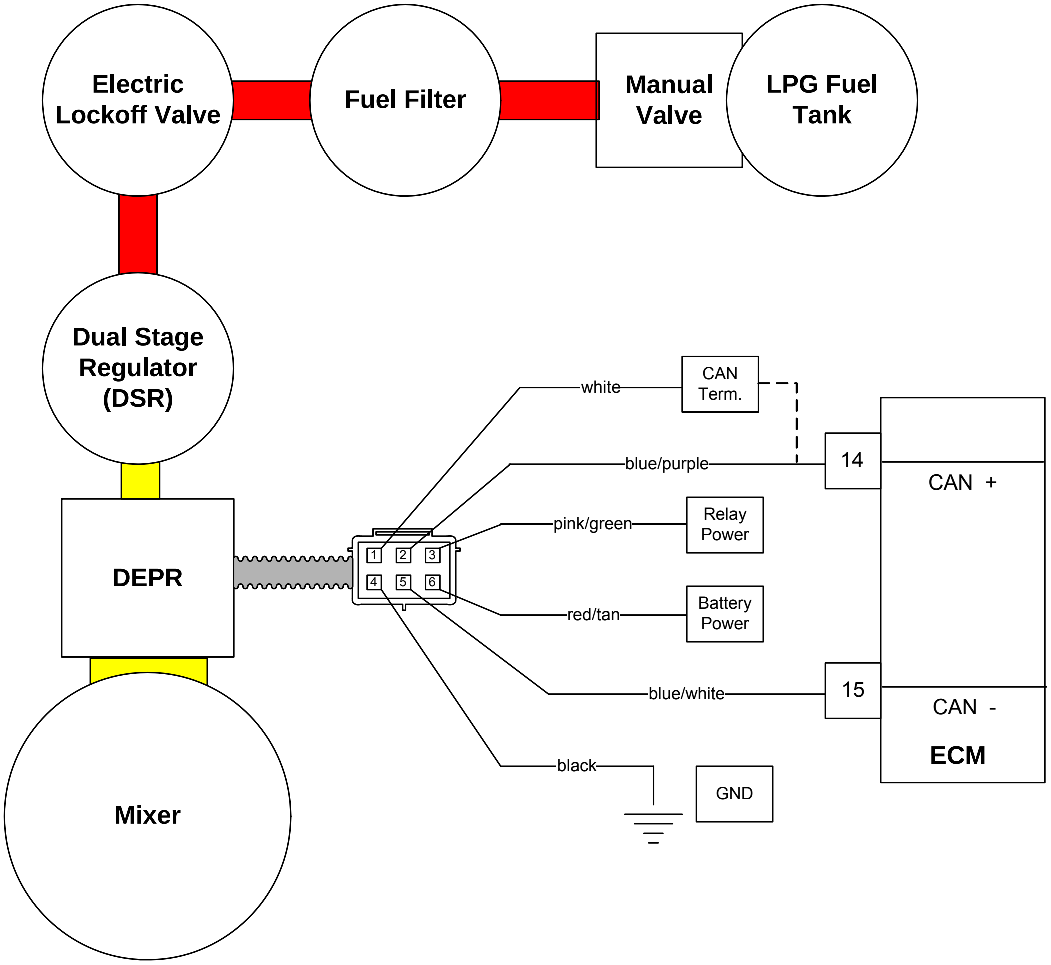
DTC 1165- Catalyst Inactive on LPG

Diagnostic Aids

NOTE: If any other DTCs are present, diagnose those first.

- ☐ Exhaust Leak – Pressurize exhaust system with 1-2 psig of air and check for pressure leaks upstream and around catalyst and post-catalyst HEGO sensor. Replace gaskets and tighten fasteners if leaks are present.
- ☐ Perform manufacture recommended in-field emissions test.

DTC 1171- DEPR Delivery Pressure Higher Than Expected



- Enabling Conditions: Engine running on LPG.
- Set Conditions: DEPR pressure command is lower than can be achieved and results in the actuator reaching its minimum authority limit.
- Corrective Action: Illuminate MIL and/or sound audible warning or illuminate secondary warning lamp, disable adaptive fueling correction for the remainder of the key-cycle
- Emissions related fault
- Possible Causes: Inlet pressure to DEPR is too high caused by malfunctioning Dual Stage Regulator.

DTC 1171- DEPR Delivery Pressure Higher Than Expected

The DEPR is the third generation of EControls' Electronic Pressure Regulators (EPR) found in many industrial and heavy-duty on-highway applications. The DEPR is a "smart" actuator designed to operate on low pressure feed gas as the final pressure regulation before providing fuel to the mixer. It is designed to be close coupled to the mixer and allows extremely fast and accurate gaseous fuel control to provide a combustible mixture to the engine in a small package.

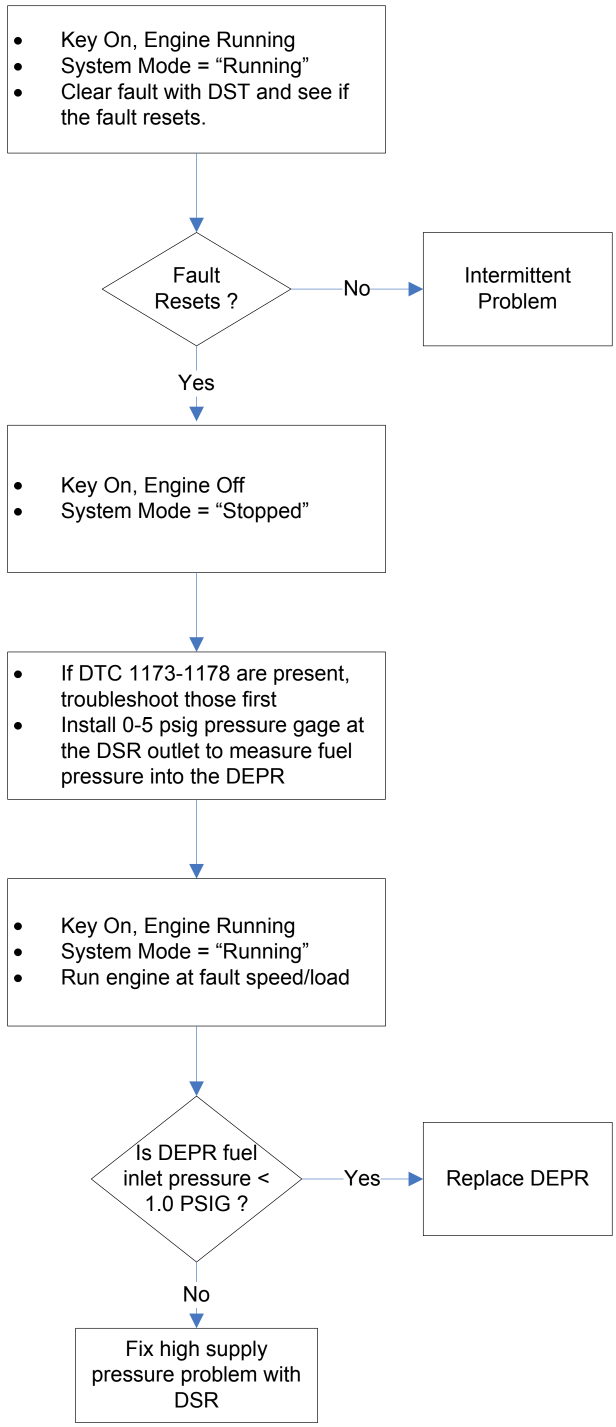
The DEPR receives fuel pressure commands from the ECM and quickly and precisely modulates fuel pressure to the gaseous fuel mixer.

The DEPR is designed to operate on an inlet fuel pressure of up to 0.75 psi above the pressure at the mixer air inlet.

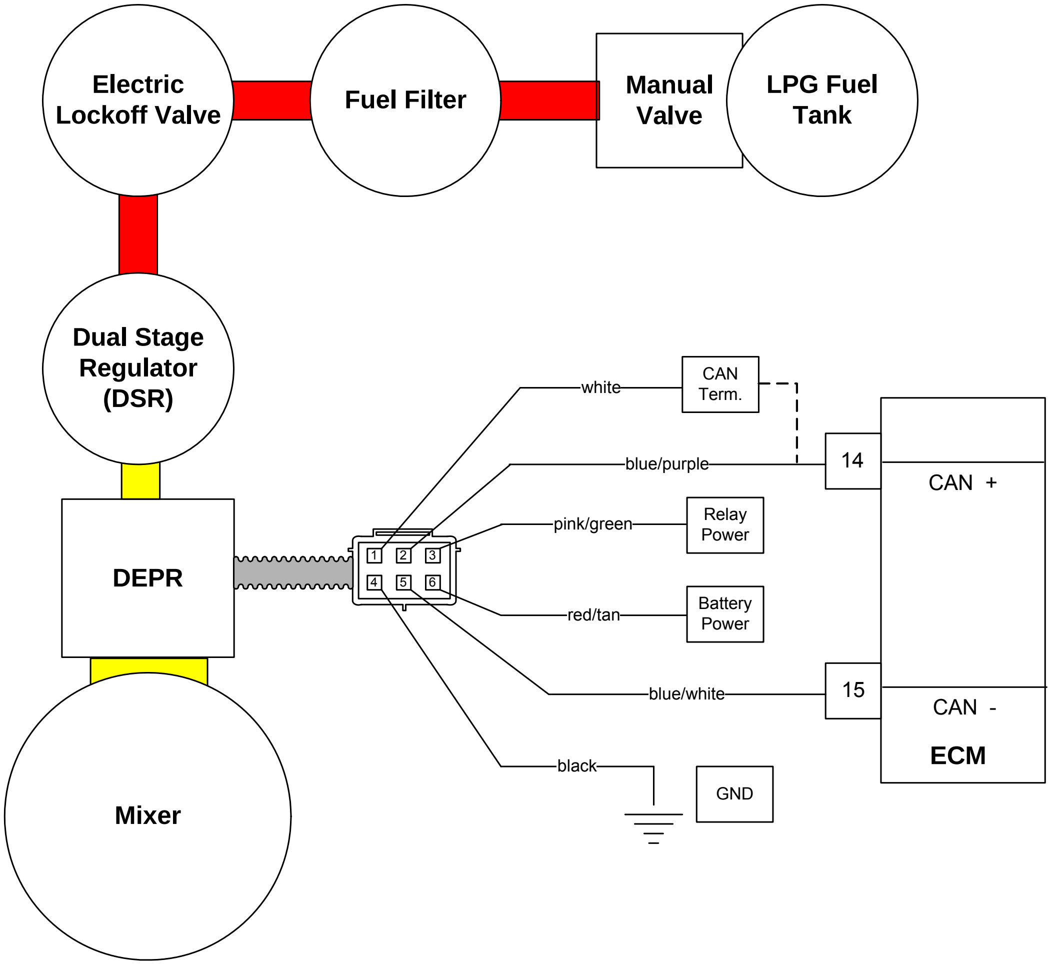
The DEPR Delivery Pressure Higher than Expected fault sets if the actual pressure sensed in the EPR is too high. This fault indicates that the actuator is at its minimum limit of authority and the pressure command can not be achieved, likely due to delivery/supply pressure being higher than expected. Adaptive fueling correction should be disabled for the key-cycle to avoid improper learning of the fuel correction table due to improper fuel supply pressure.

The most likely cause of this fault is a failure of the upstream pressure regulation device.

DTC 1171- DEPR Delivery Pressure Higher Than Expected



DTC 1172- DEPR Delivery Pressure Lower Than Expected



- Enabling Conditions: Engine running on LPG.
- Set Conditions: DEPR pressure command is higher than can be achieved and results in the actuator reaching its maximum authority limit.
- Corrective Action: Illuminate MIL and/or sound audible warning or illuminate secondary warning lamp, disable adaptive fueling correction for the remainder of the key-cycle
- Emissions related fault
- Possible Causes: Inlet pressure to DEPR is too low caused by malfunctioning Dual State Pressure Regulator, malfunctioning lockoff valve, plugged fuel filter, closed manual valve or fuel tank out of fuel.

DTC 1172- DEPR Delivery Pressure Lower Than Expected

The DEPR is the third generation of EControls Inc Electronic Pressure Regulators (EPR) found in many industrial and heavy-duty on-highway applications. The DEPR is a “smart” actuator designed to operate on low pressure feed gas as the final pressure regulation before providing fuel to the mixer. It is designed to be close coupled to the mixer and allows extremely fast and accurate gaseous fuel control to provide a combustible mixture to the engine in a small package.

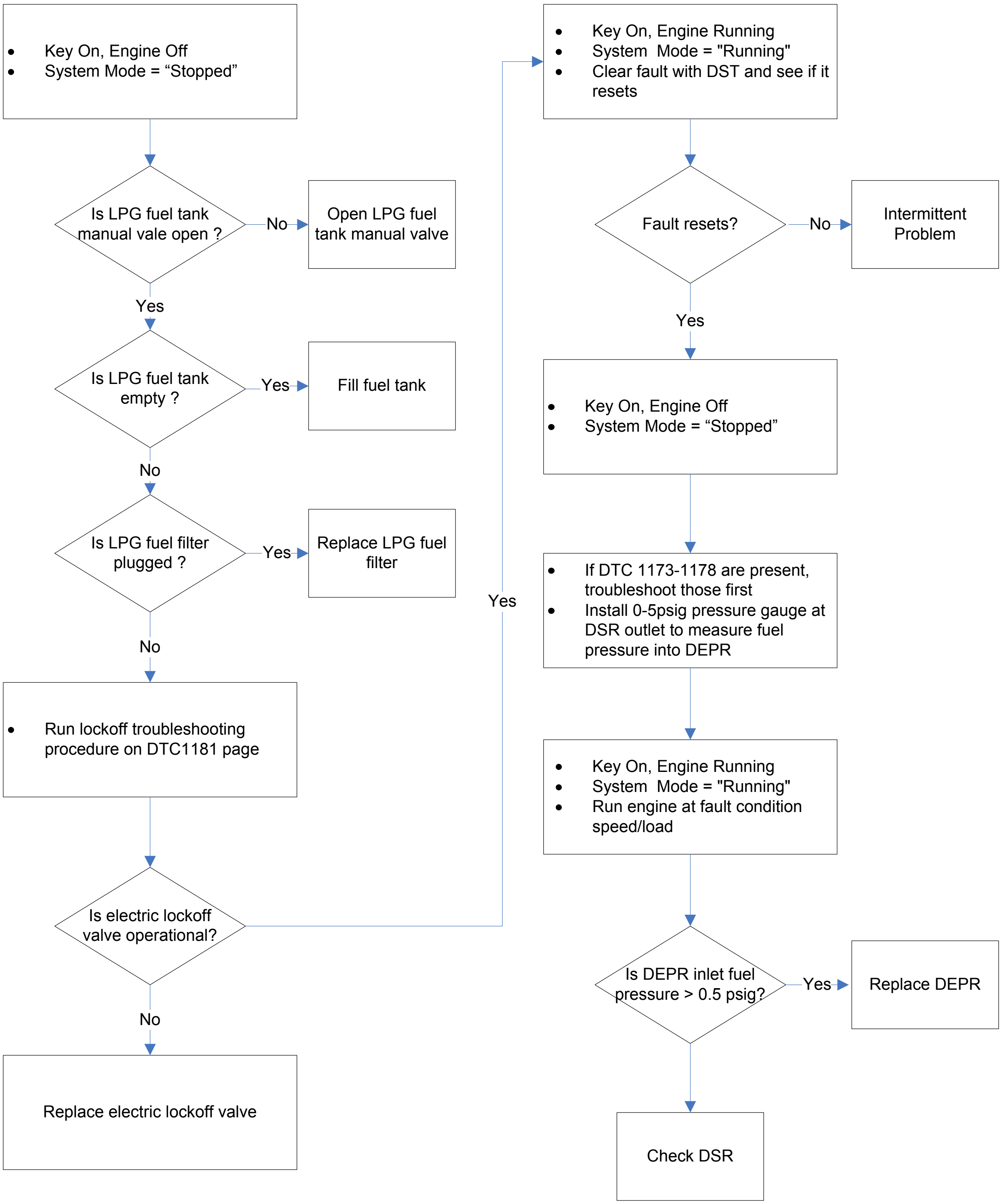
The DEPR receives fuel pressure commands from the ECM and quickly and precisely modulates fuel pressure to the gaseous fuel mixer.

The DEPR is designed to operate on an inlet fuel pressure of up to 0.75 psi above the pressure at the mixer air inlet.

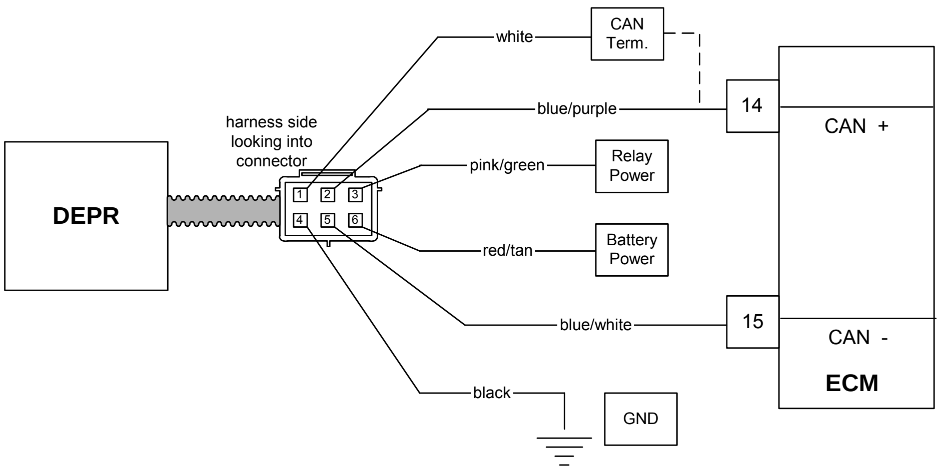
The DEPR Delivery Pressure Lower than Expected fault sets if the actual pressure sensed in the EPR is too low. This fault indicates that the actuator is at its maximum limit of authority and the pressure command can not be achieved, likely due to delivery/supply pressure being lower than expected. Adaptive fueling correction should be disabled for the key-cycle to avoid improper learning of the fuel correction table due to improper fuel supply pressure.

The most likely cause of this fault is the LPG fuel tank is out of fuel, the fuel tank manual valve is closed, the fuel filter is plugged, the electric lockoff valve has malfunctioned, or the DSR has malfunctioned, or when the fuel temperature is extremely cold (e.g. no vapor pressure).

DTC 1172- DEPR Delivery Pressure Lower Than Expected



DTC 1173- DEPR Comm Lost



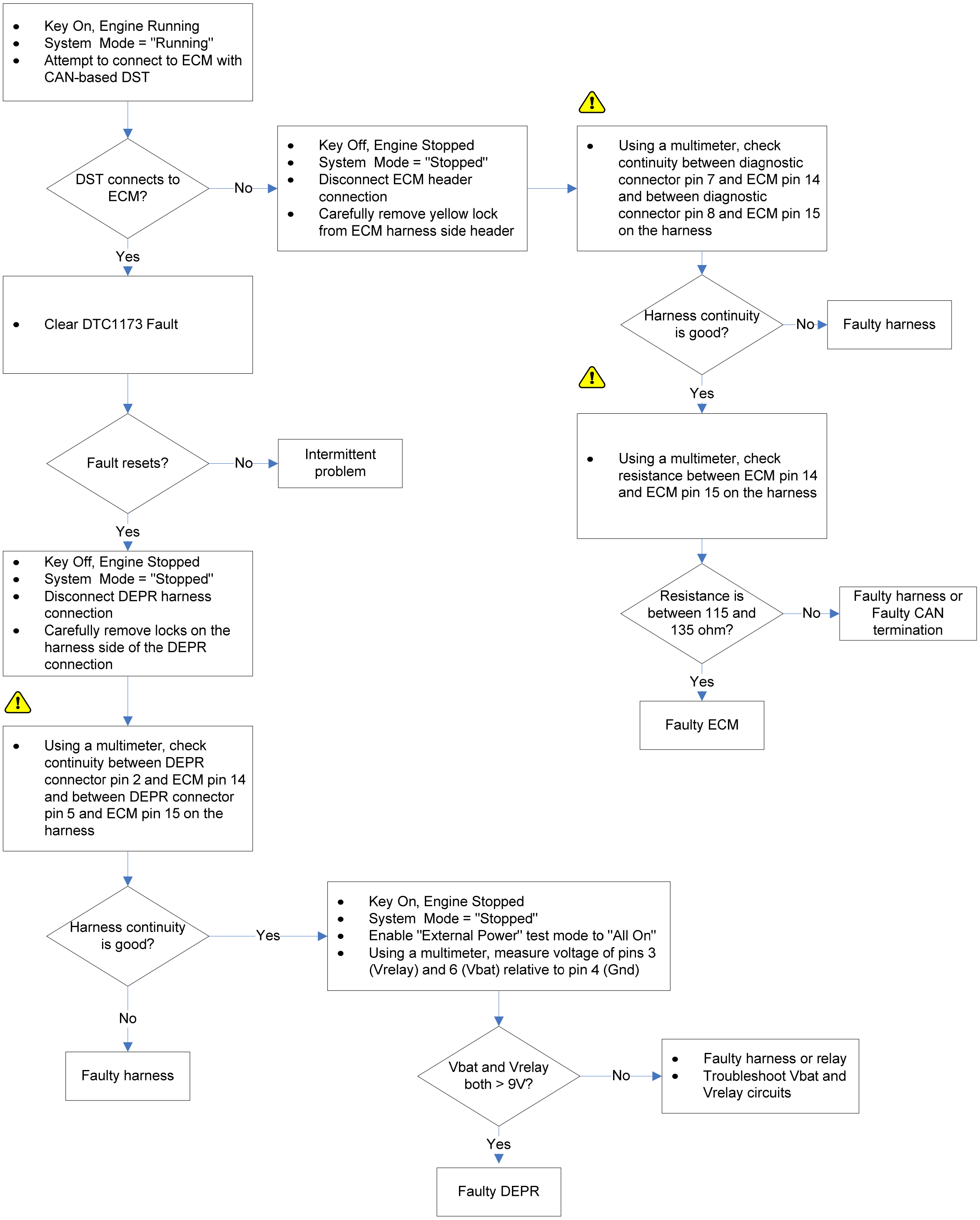
- Enabling Conditions: Engine running on LPG.
- Set Conditions: ECM is unable to communicate with the DEPR over the CAN communication bus.
- Corrective Action: Illuminate MIL and/or sound audible warning or illuminate secondary warning lamp, disable adaptive fueling correction for the remainder of the key-cycle
- Emissions related fault
- Possible Causes: Faulty CAN connection in wiring harness, CAN termination incorrect, loss of power to the DEPR, bad DEPR, bad ECM.

The DEPR is the third generation of EControls' Electronic Pressure Regulators (EPR) found in many industrial and heavy-duty on-highway applications. The DEPR is a "smart" actuator designed to operate on low pressure feed gas as the final pressure regulation before providing fuel to the mixer. It is designed to be close coupled to the mixer and allows extremely fast and accurate gaseous fuel control to provide a combustible mixture to the engine in a small package.

The DEPR receives fuel pressure commands from the ECM and quickly and precisely modulates fuel pressure to the gaseous fuel mixer.

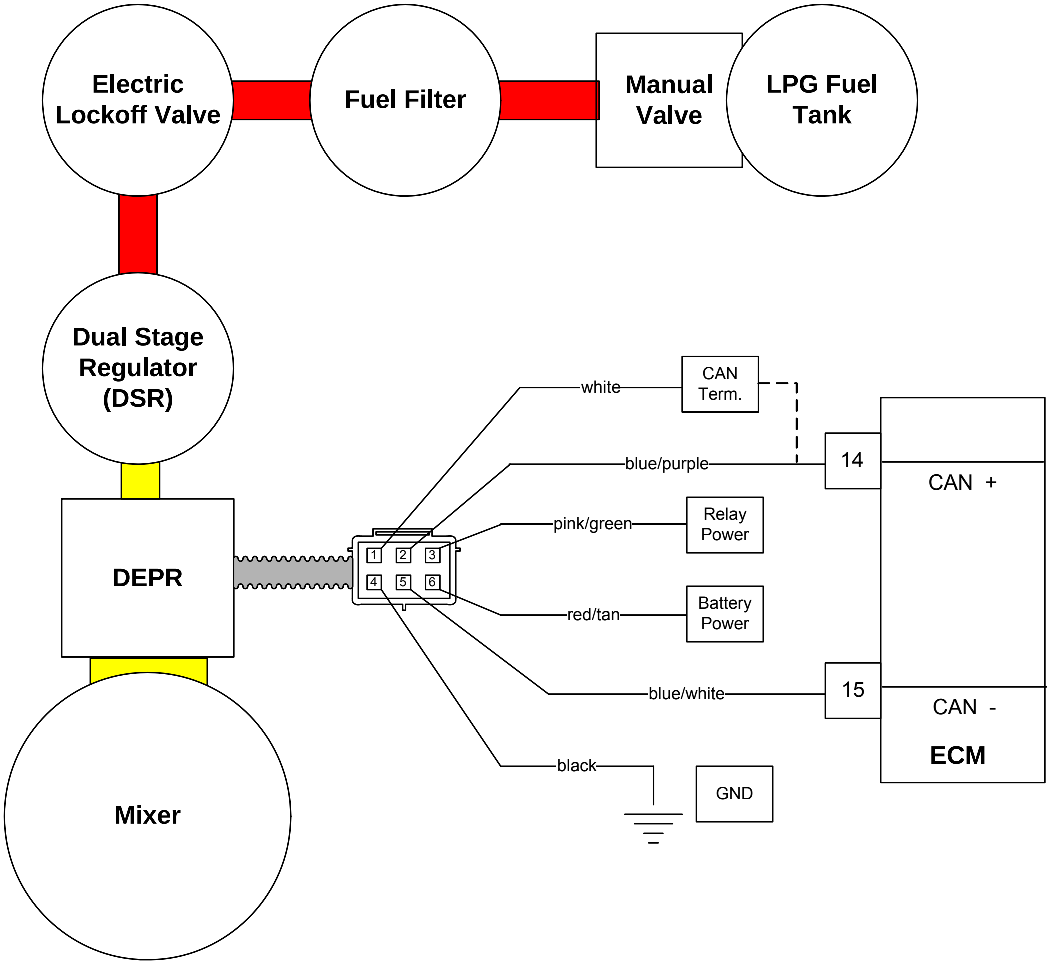
The DEPR Comm Lost fault sets if the ECM loses CAN communication with the EPR. This fault indicates that the ECM is no longer receiving CAN packets from the EPR. This is often a result of a power loss at the EPR or improper CAN termination or wiring. Adaptive fueling correction should be disabled for the key-cycle to avoid improper learning of the fuel correction table.

DTC 1173- DEPR Comm Lost



NOTE: Do not insert probe or object into terminalsas this will cause the terminal to spread and it may no longer make electrical contact with its mate. Spread pins will void warranty. Probe instead on side of terminal.

DTC 1176- DEPR Internal Actuator Fault Detection



- Enabling Conditions: Engine running on LPG.
- Set Conditions: the DEPR electronics detect a fault condition associated with its internal actuator.
- Corrective Action: Illuminate MIL and/or sound audible warning or illuminate secondary warning lamp, disable adaptive fueling correction for the remainder of the key-cycle
- Emissions related fault
- Possible Causes: Short or open circuit in actuator coil or associated wiring, overheating of actuator drive electronics.

DTC 1176- DEPR Internal Actuator Fault Detection

The DEPR is the third generation of EControls' Electronic Pressure Regulators (EPR) found in many industrial and heavy-duty on-highway applications. The DEPR is a "smart" actuator designed to operate on low pressure feed gas as the final pressure regulation before providing fuel to the mixer. It is designed to be close coupled to the mixer and allows extremely fast and accurate gaseous fuel control to provide a combustible mixture to the engine in a small package.

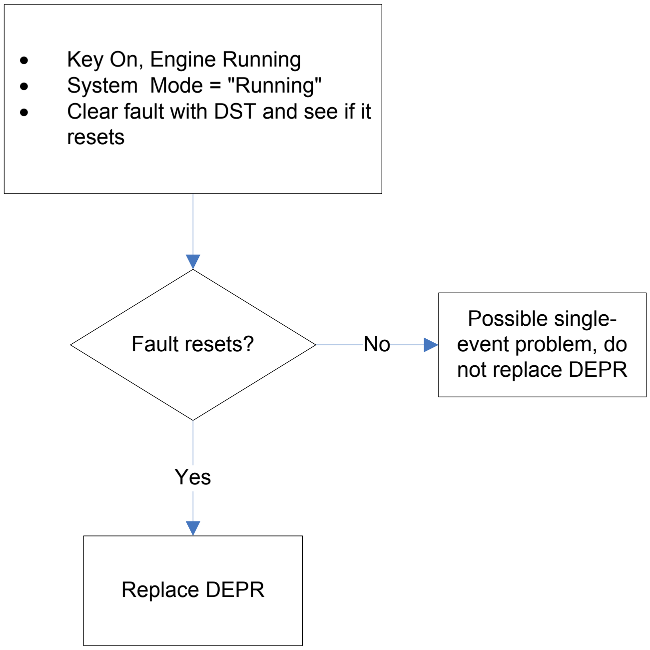
The DEPR receives fuel pressure commands from the ECM and quickly and precisely modulates fuel pressure to the gaseous fuel mixer.

The DEPR is designed to operate on an inlet fuel pressure of up to 0.75 psi above the pressure at the mixer air inlet.

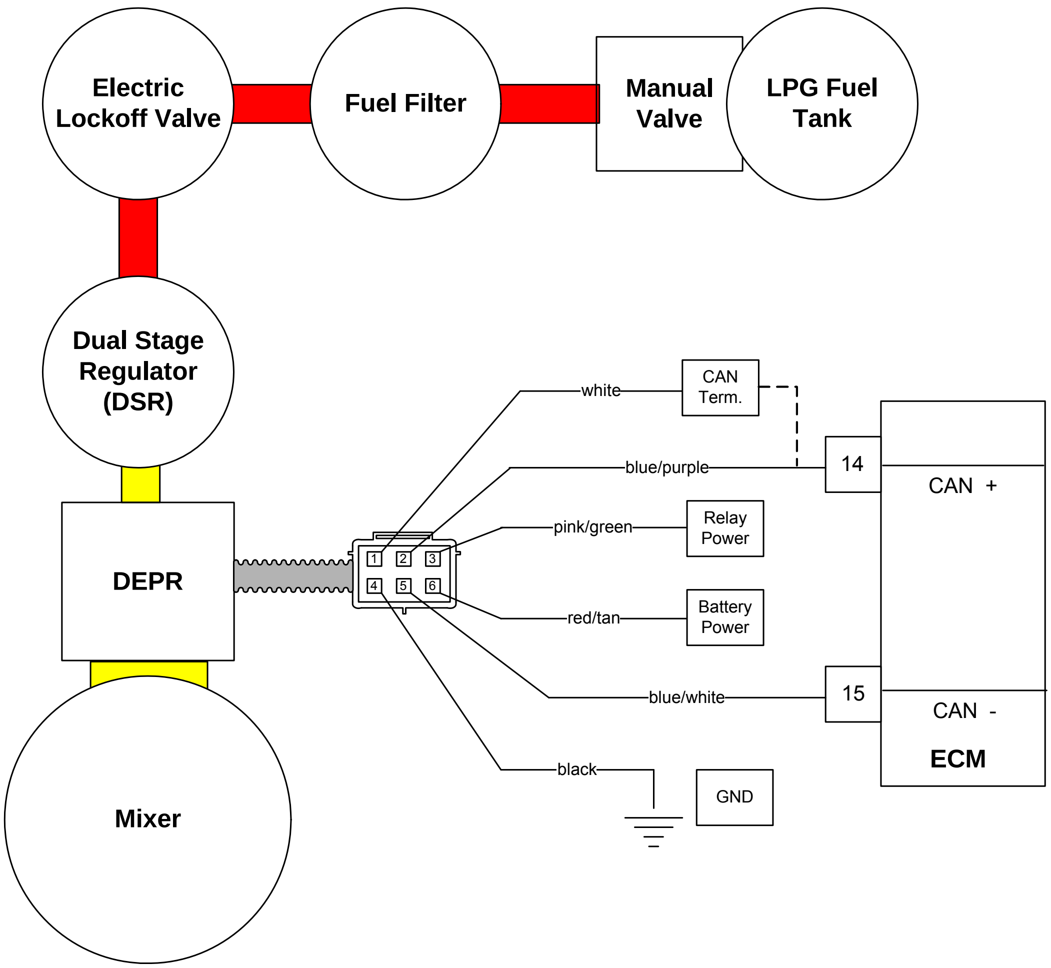
The DEPR Internal Actuator fault sets if the DEPR electronics detects a fault condition in its internal actuator circuit.

The most likely cause of this fault is a short or open circuit in the actuator coil or in the wiring between the electronics and the coil, or if the actuator drive electronics overheat and shut down. It can also be set if the internal pressure sensor is ruptured.

Since this fault can be set by an isolated operational event (overheating of the engine compartment), it is recommended that if the fault is cleared and does not reset, the unit should not be replaced as there may be no problem with it.



DTC 1177- DEPR Internal Circuitry Fault Detection



- Enabling Conditions: Engine running on LPG.
- Set Conditions: the DEPR electronics detect a fault condition associated with its internal circuitry.
- Corrective Action: Illuminate MIL and/or sound audible warning or illuminate secondary warning lamp, disable adaptive fueling correction for the remainder of the key-cycle
- Emissions related fault
- Possible Causes: DEPR internal microprocessor or memory failure, fuel temperature sensor failure.

DTC 1177- DEPR Internal Circuitry Fault

The DEPR is the third generation of EControls' Electronic Pressure Regulators (EPR) found in many industrial and heavy-duty on-highway applications. The DEPR is a "smart" actuator designed to operate on low pressure feed gas as the final pressure regulation before providing fuel to the mixer. It is designed to be close coupled to the mixer and allows extremely fast and accurate gaseous fuel control to provide a combustible mixture to the engine in a small package.

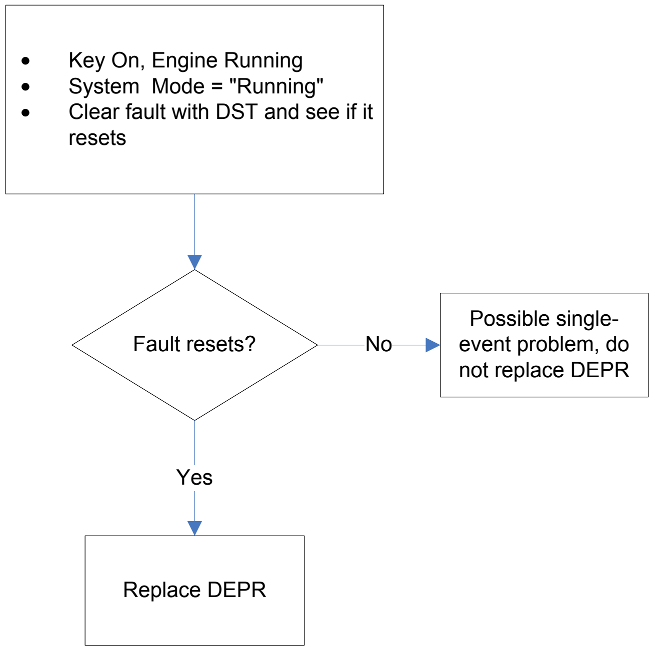
The DEPR receives fuel pressure commands from the ECM and quickly and precisely modulates fuel pressure to the gaseous fuel mixer.

The DEPR is designed to operate on an inlet fuel pressure of up to 0.75 psi above the pressure at the mixer air inlet.

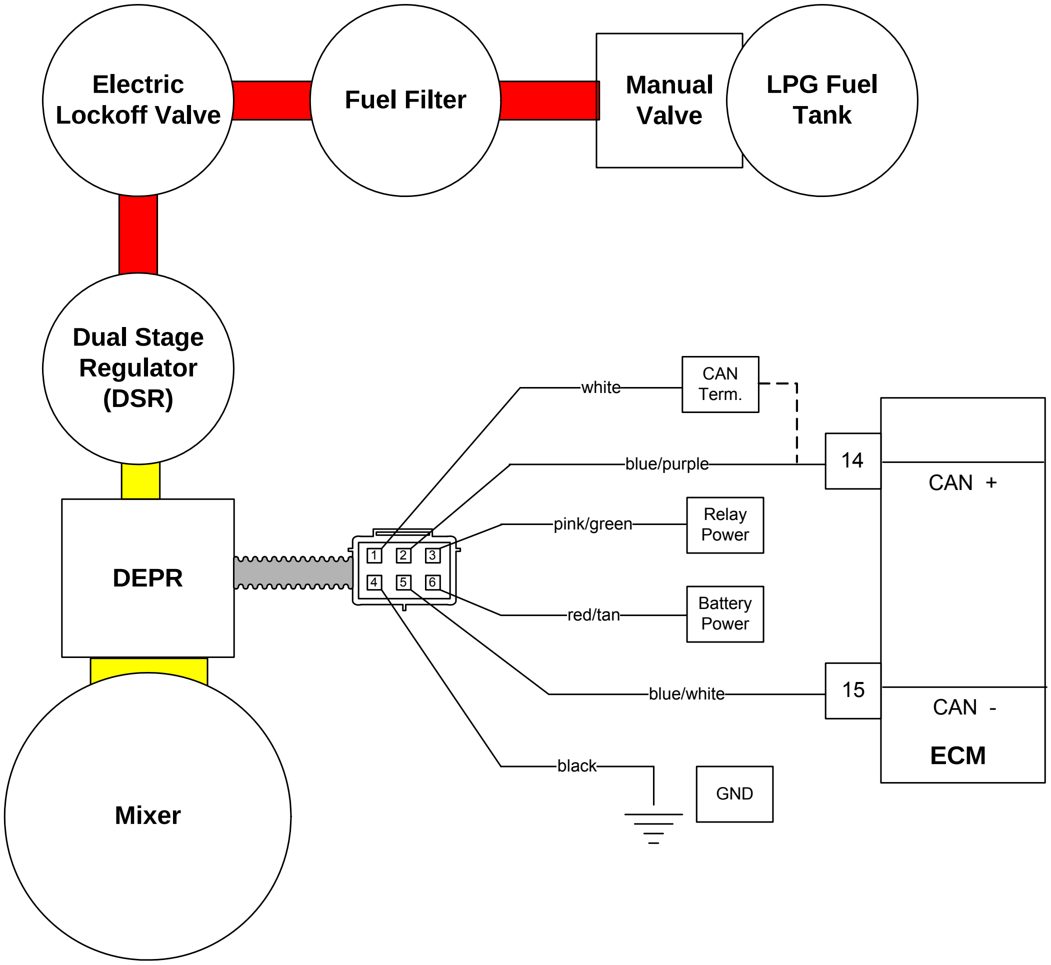
The DEPR Internal Circuitry fault sets if the DEPR electronics detects a fault condition in its internal circuitry.

The most likely cause of this fault is a problem in the DEPR microprocessor or memory circuitry. It can also be set if the internal fuel temperature sensor has an out of range voltage.

Since this fault can be set by an isolated operational event (overheating of the engine compartment), it is recommended that if the fault is cleared and does not reset, the unit should not be replaced as there may be no problem with it.



DTC 1181- Fuel Runout Longer Than Expected



- Enabling Conditions: Engine running on LPG.
- Set Conditions: on key-off, the electric lock off valve is closed but the engine does not die within a set time limit
- Corrective Action: Illuminate MIL and/or sound audible warning or illuminate secondary warning lamp, disable adaptive fueling correction for the remainder of the key-cycle
- Possible Causes: Electric lock off valve doesn't close or leaks.

DTC 1181- Fuel Runout Longer Than Expected

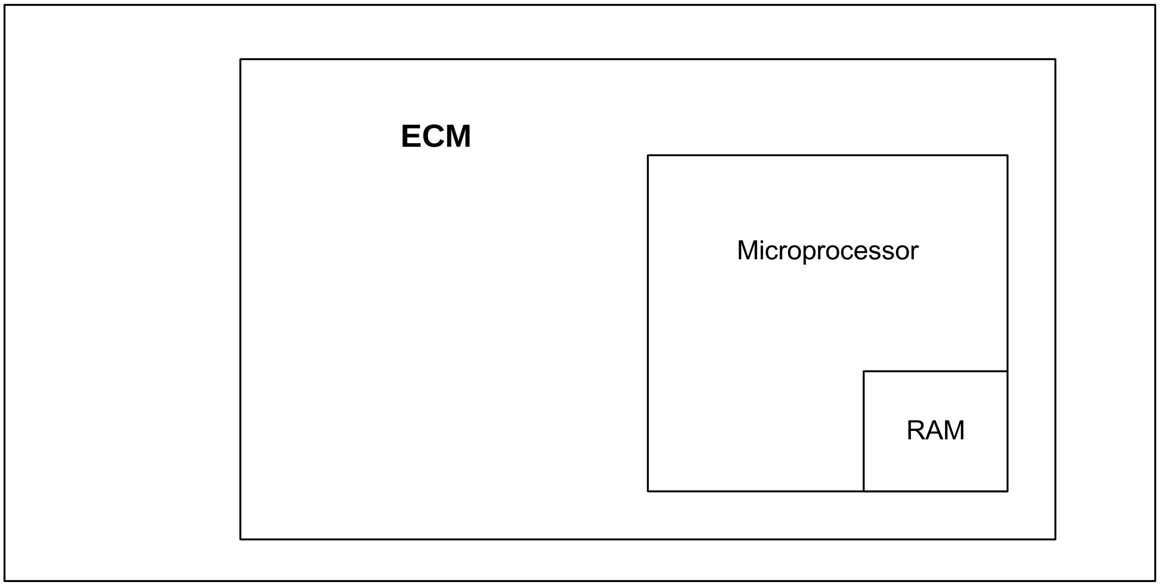
In order to provide a consistent start, the EControls ECM provides for a fuel runout capability. When this capability is enabled, and when running on LPG fuel, a key-off will not immediately kill power to the ignition system. Instead, the fuel lock off valve is closed, and the engine continues to run for a few seconds while the fuel trapped downstream of the lock off valve is drained through the engine. On the subsequent start, the startup fueling is then repeatable and consistent, providing for a consistent start and for consistent conditions in the catalytic converter, both of which yield low emissions operation.

If the engine doesn't die from lack of fuel within a short time after closing the electric lock off valve, the ECM will shutoff the ignition system to kill the engine. This situation sets the Fuel Runout Longer than Expected fault.

The most likely cause of this fault is an electric lock off valve that either doesn't shut or leaks when it is shut.

To troubleshoot this DTC, follow the steps starting at Step 5 of the *LPG Fuel System Diagnosis* section on page 120 of this manual.

DTC 1612- Microprocessor Failure - RTI 1

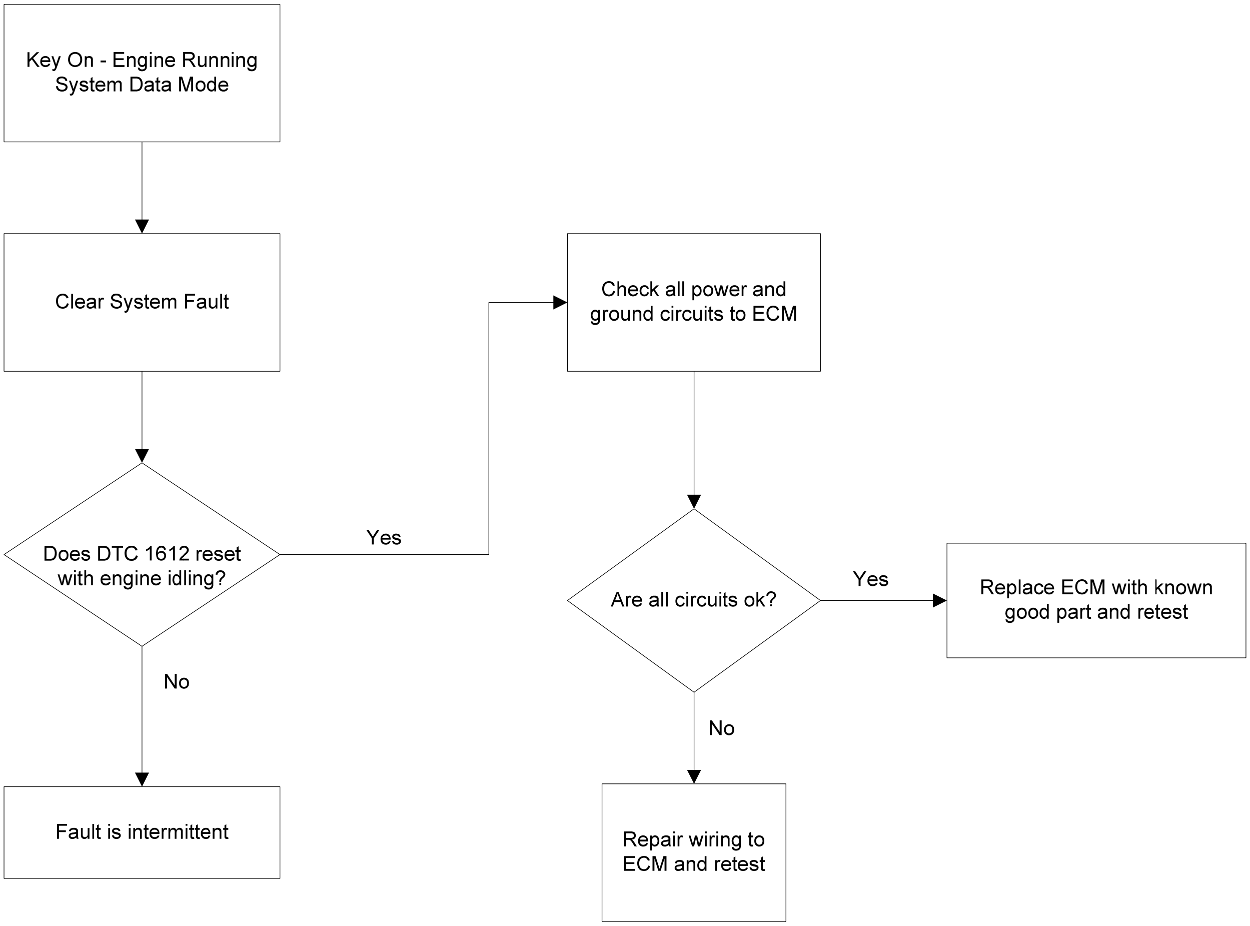


- Hardware: Engine Control Module
- Enabling Conditions: Key on
- Set Conditions: Internal microprocessor error
- Corrective Action(s): MIL- On, fuel adaptive learn disabled and power derate 2 while code is active fault remembered until fault is cleared manually with a scan tool
- Non-emissions related fault
- Possible Causes: Faulty ECM

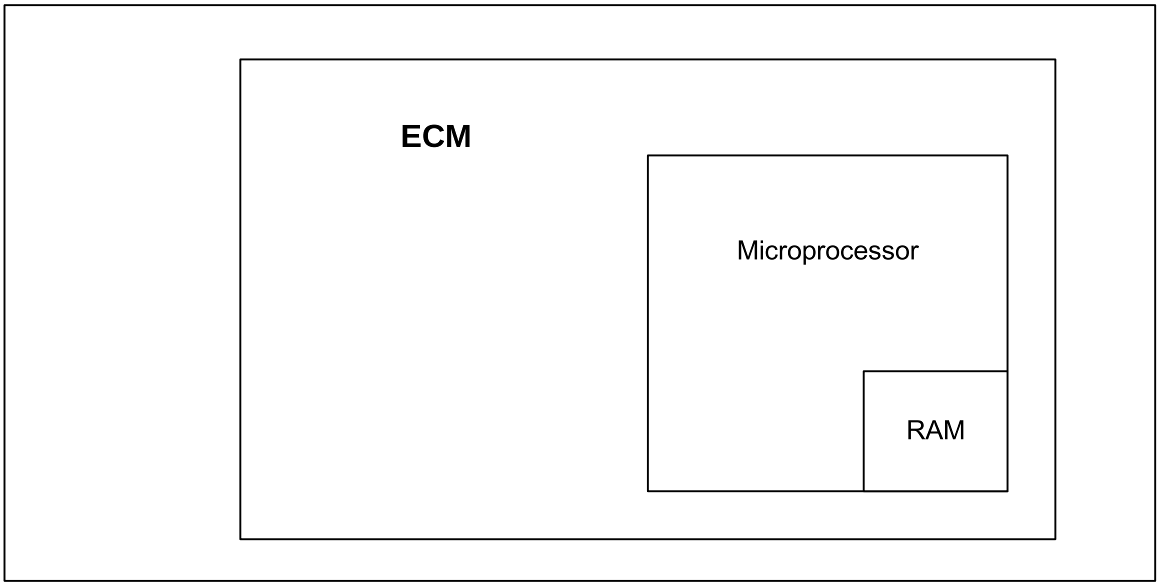
The ECM has checks that must be satisfied each time an instruction is executed. Several different things can happen within the microprocessor that will cause this fault. The ECM will reset itself in the event this fault is set, and the MIL will be on until the code is cleared. This fault should be erased after diagnosis using a scan tool. It will not self-erase.

During this active fault, Power Derate 2 will be enforced. When this is enforced, maximum throttle position will be 30%.

DTC 1612- Microprocessor Failure - RTI 1



DTC 1613- Microprocessor Failure - RTI 2

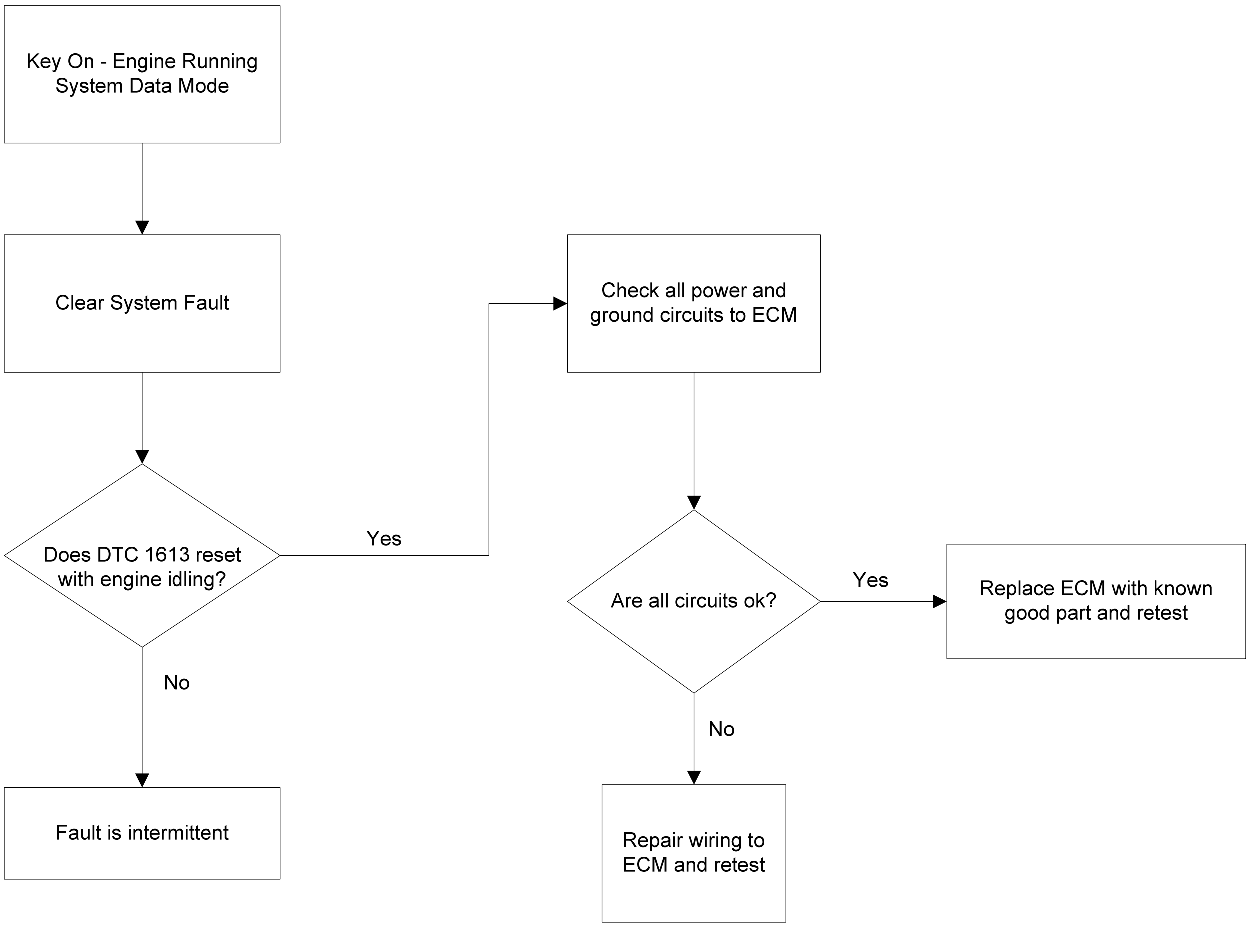


- Hardware: Engine Control Module
- Enabling Conditions: Key on
- Set Conditions: Internal microprocessor error
- Corrective Action(s): MIL- On, fuel adaptive learn disabled and power derate 2 while code is active fault remembered until fault is cleared manually with a scan tool
- Non-emissions related fault
- Possible Causes:

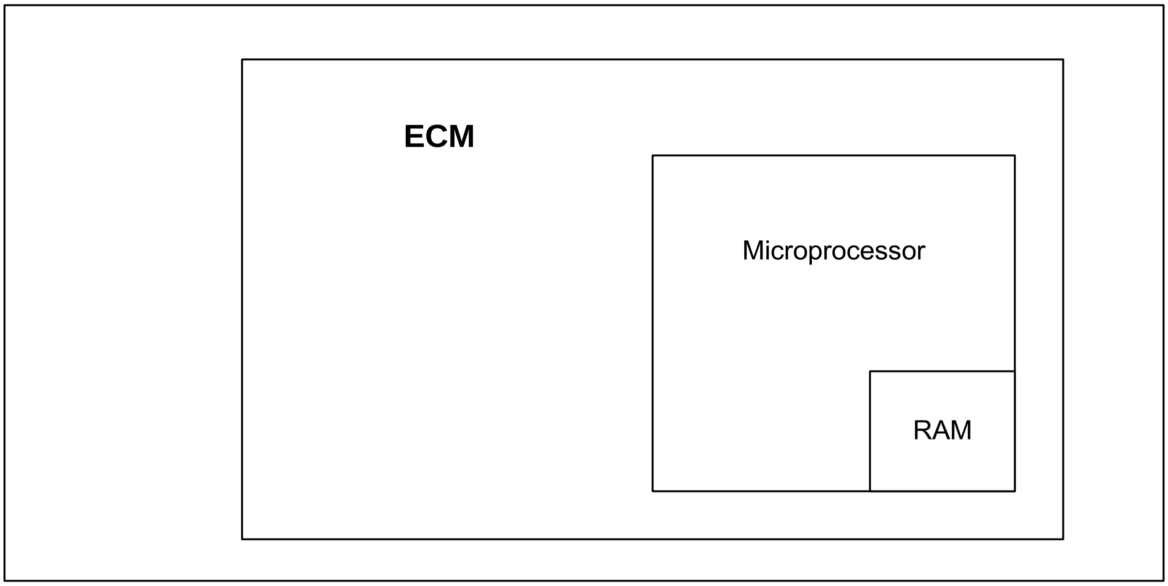
The ECM has checks that must be satisfied each time an instruction is executed. Several different things can happen within the microprocessor that will cause this fault. The ECM will reset itself in the event this fault is set, and the MIL will be on until the code is cleared. This fault should be erased after diagnosis using a scan tool. It will not self-erase.

During this active fault, Power Derate 2 will be enforced. When this is enforced, maximum throttle position will be 30%.

DTC 1613- Microprocessor Failure - RTI 2



DTC 1614- Microprocessor Failure - RTI 3

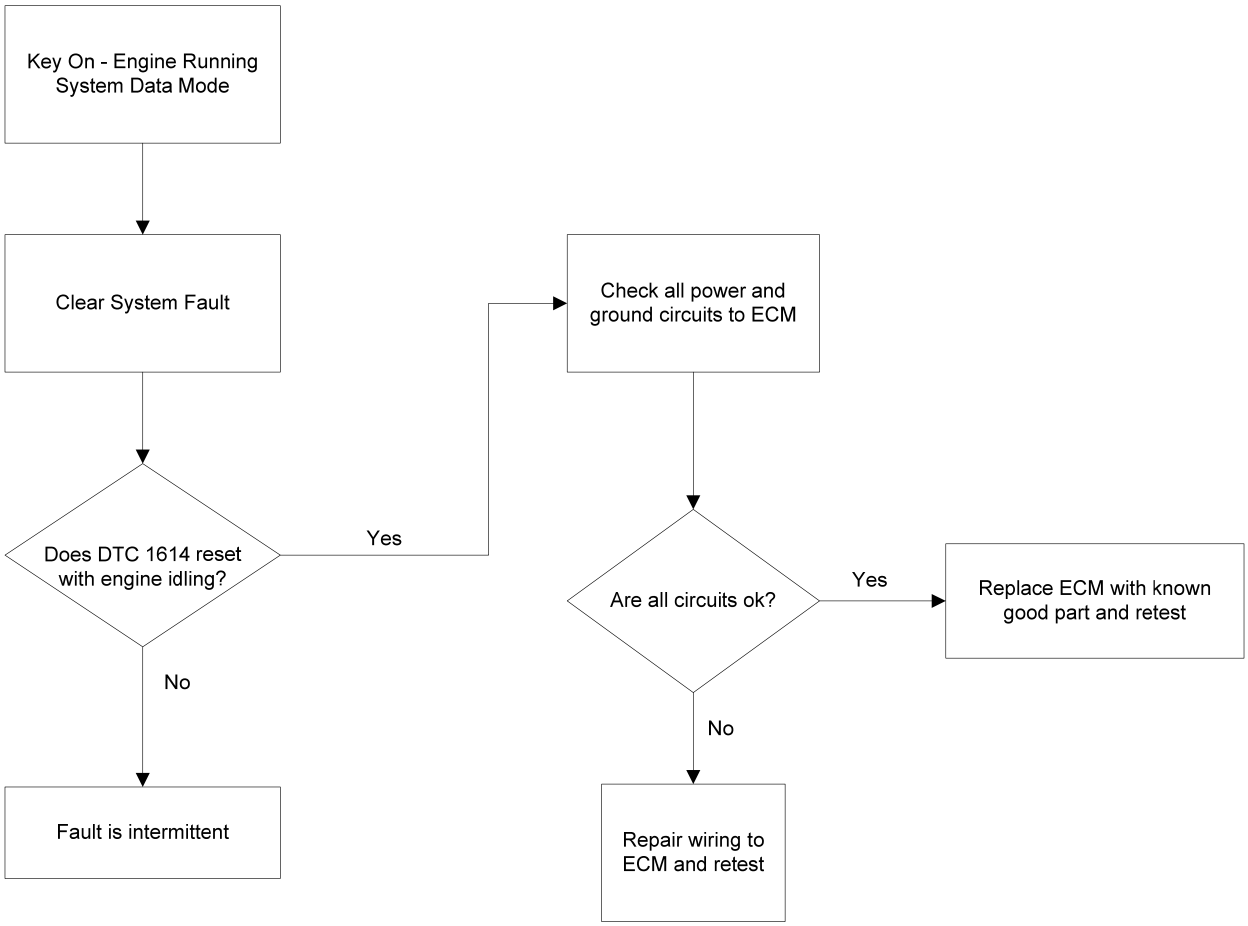


- Hardware: Engine Control Module
- Enabling Conditions: Key on
- Set Conditions: Internal microprocessor error
- Corrective Action(s): MIL- On, fuel adaptive learn disabled and power derate 2 while code is active fault remembered until fault is cleared manually with a scan tool
- Non-emissions related fault
- Possible Causes:

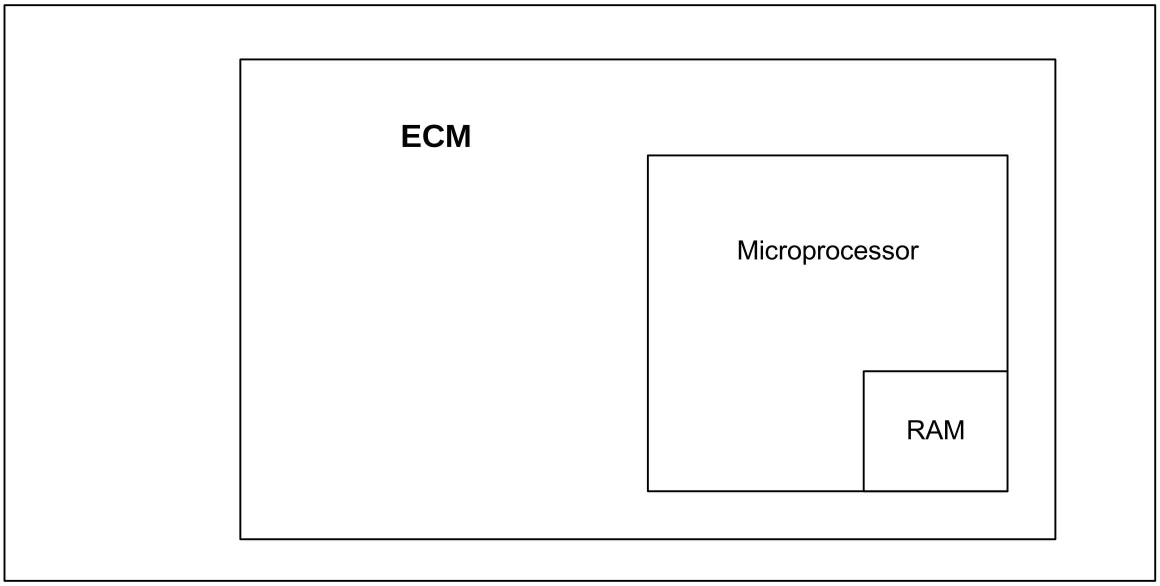
The ECM has checks that must be satisfied each time an instruction is executed. Several different things can happen within the microprocessor that will cause this fault. The ECM will reset itself in the event this fault is set, and the MIL will be on until the code is cleared. This fault should be erased after diagnosis using a scan tool. It will not self-erase.

During this active fault, Power Derate 2 will be enforced. When this is enforced, maximum throttle position will be 30%.

DTC 1614- Microprocessor Failure - RTI 3



DTC 1615- Microprocessor Failure - A/D

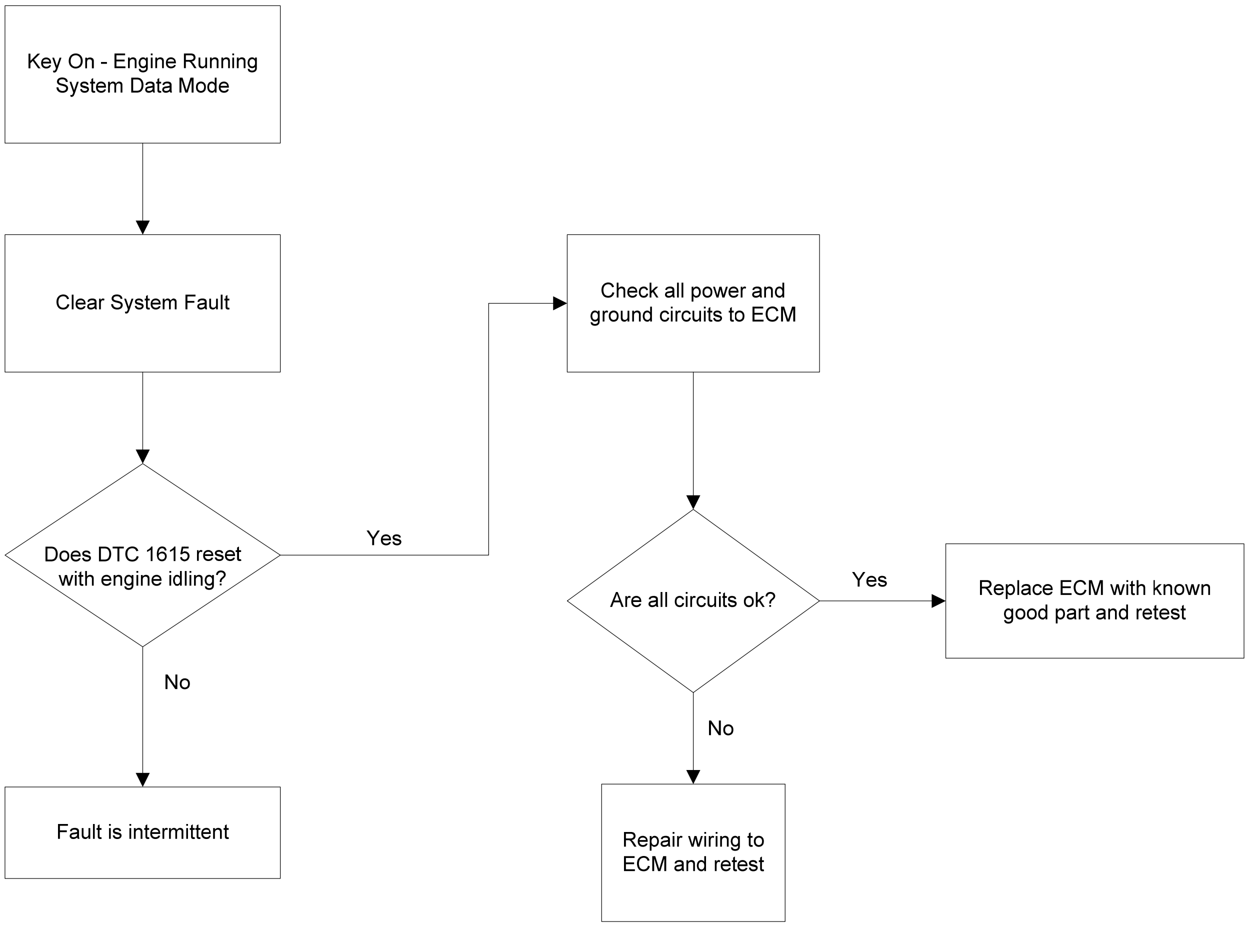


- Hardware: Engine Control Module
- Enabling Conditions: Key on
- Set Conditions: Internal microprocessor error
- Corrective Action(s): MIL- On, fuel adaptive learn disabled and power derate 2 while code is active fault remembered until fault is cleared manually with a scan tool
- Non-emissions related fault
- Possible Causes:

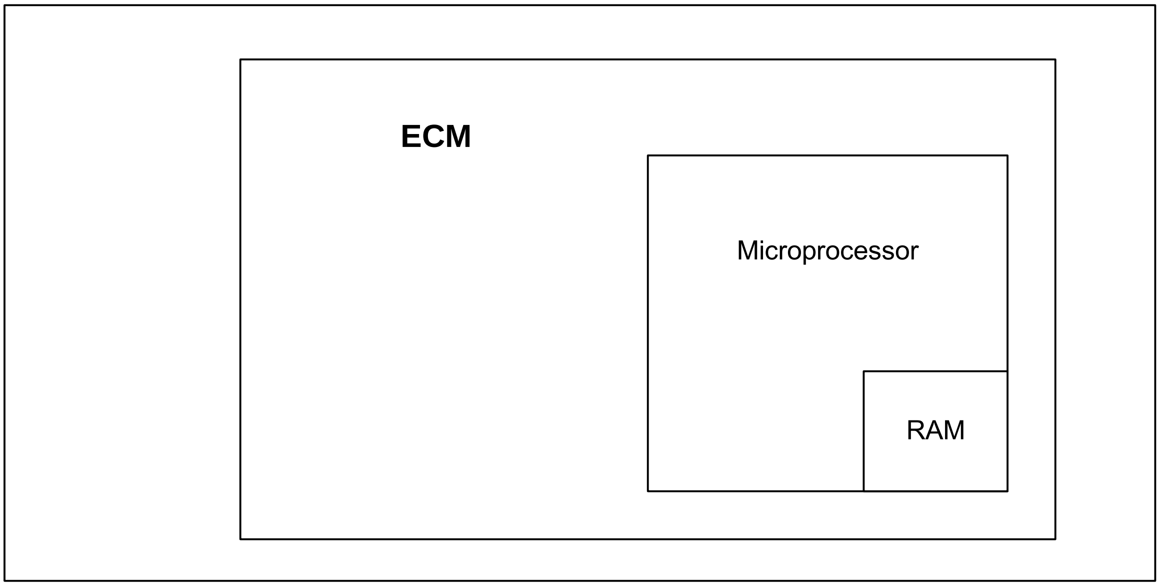
The ECM has checks that must be satisfied each time an instruction is executed. Several different things can happen within the microprocessor that will cause this fault. The ECM will reset itself in the event this fault is set, and the MIL will be on until the code is cleared. This fault should be erased after diagnosis using a scan tool. It will not self-erase.

During this active fault, Power Derate 2 will be enforced. When this is enforced, maximum throttle position will be 30%.

DTC 1615- Microprocessor Failure - A/D



DTC 1616- Microprocessor Failure - Interrupt

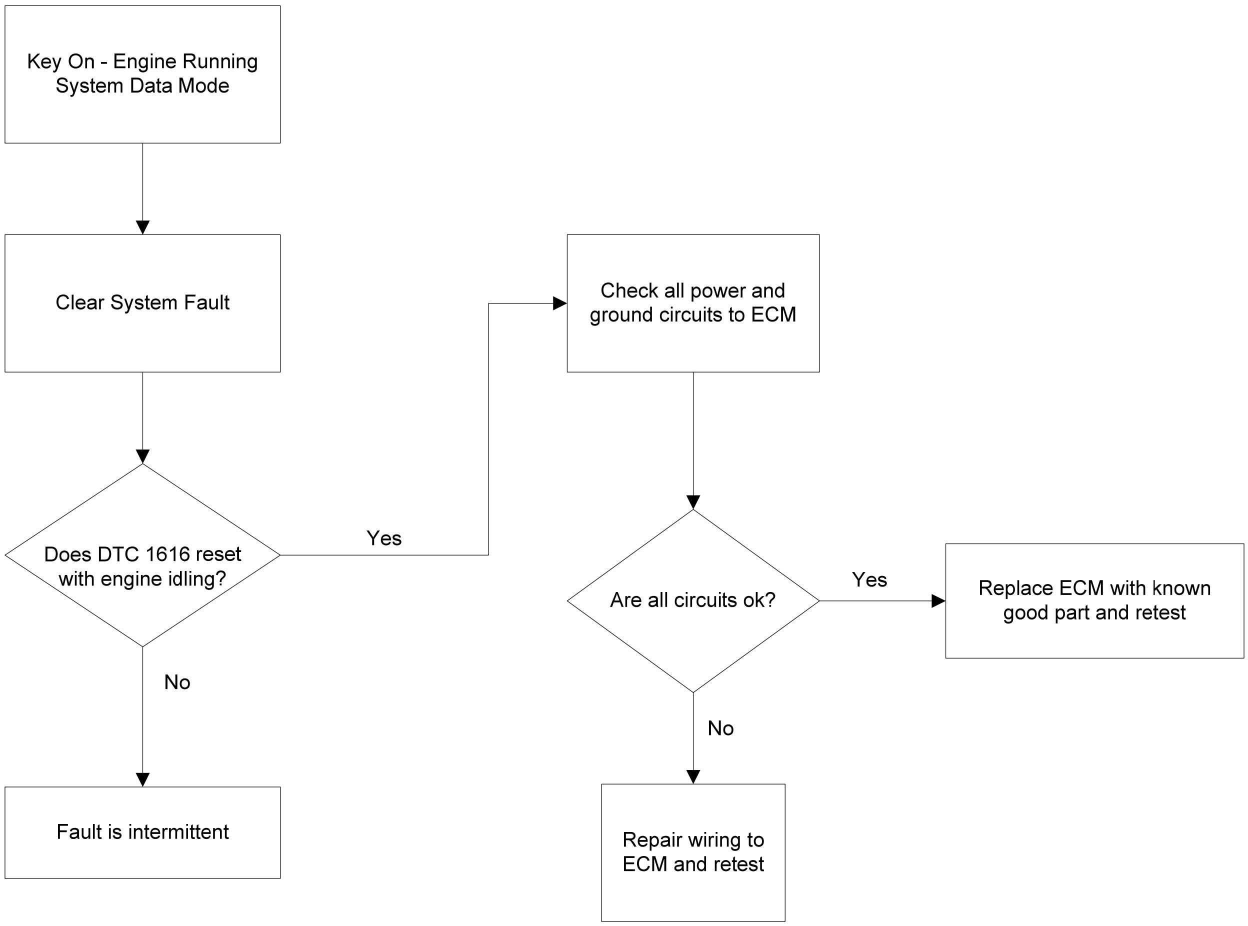


- Hardware: Engine Control Module
- Enabling Conditions: Key on
- Set Conditions: Internal microprocessor error
- Corrective Action(s): MIL- On, fuel adaptive learn disabled and power derate 2 while code is active fault remembered until fault is cleared manually with a scan tool
- Non-emissions related fault
- Possible Causes:

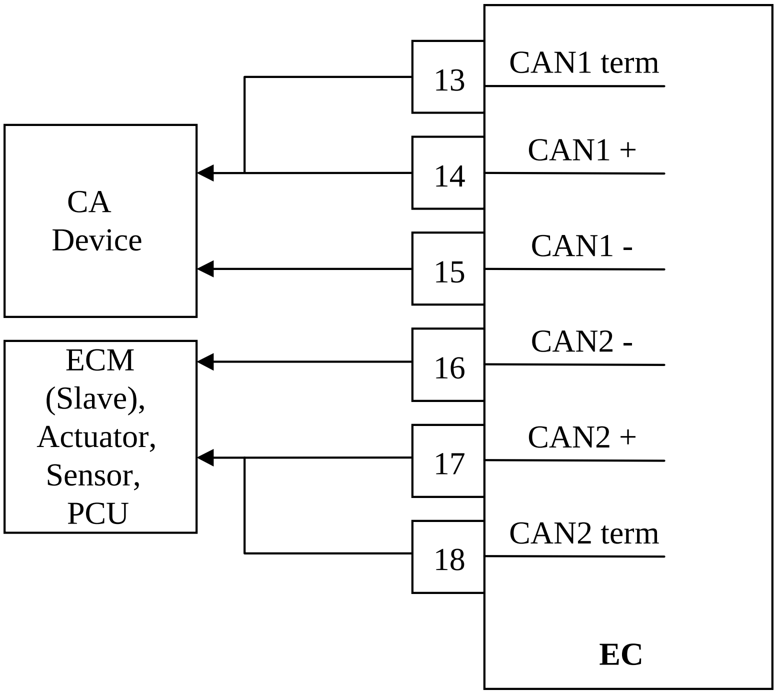
The ECM has checks that must be satisfied each time an instruction is executed. Several different things can happen within the microprocessor that will cause this fault. The ECM will reset itself in the event this fault is set, and the MIL will be on until the code is cleared. This fault should be erased after diagnosis using a scan tool. It will not self-erase.

During this active fault, Power Derate 2 will be enforced. When this is enforced, maximum throttle position will be 30%.

DTC 1616- Microprocessor Failure – Interrupt



DTC 1628- CAN Address Conflict Failure

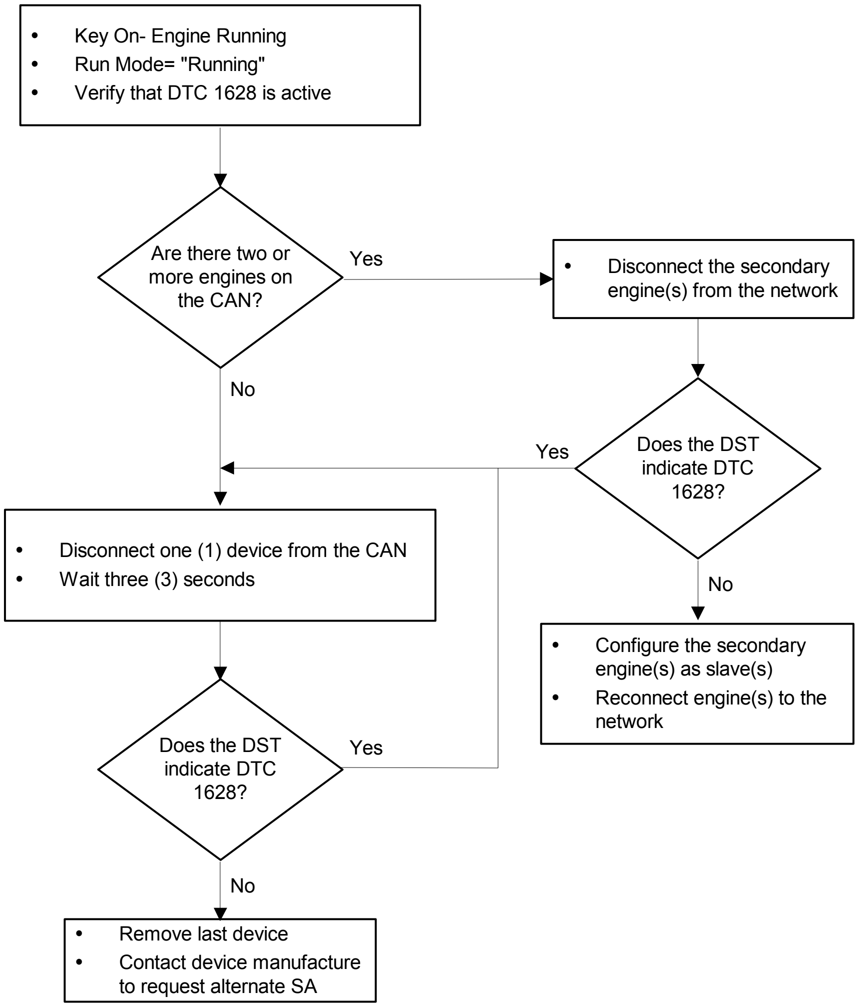


- Hardware: CAN device(s)
- Enabling Conditions: Key On, Engine on
- Set Conditions: two or more devices on the network that contain the same Source Address
- Corrective Action(s): Turn on MIL
- Non-emissions related fault
- Possible Causes: Software problem

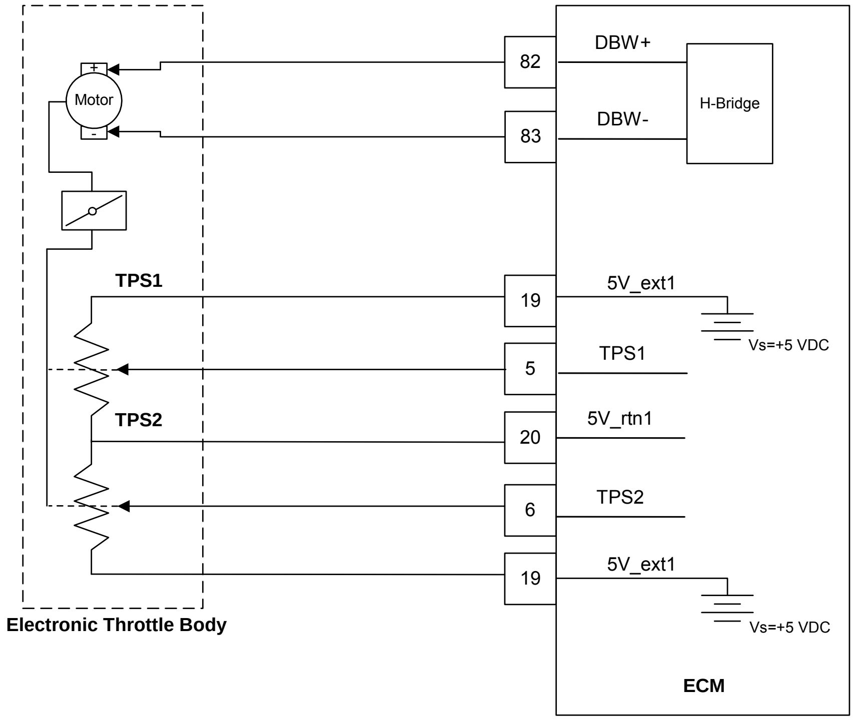
The controller area network serves as a communication portal between intelligent devices. These devices may be but are not limited to other engine ECMs (slave), diagnostic tools, "smart" gauges, "smart" sensors, powertrain control units, vehicle controllers, actuators, etc. The network permits several devices to communicate with each other receiving and broadcasting commands as programmed. This type of network allows devices to be added to an entire system through only two conductors and permits all other devices to broadcast and receive commands to and from the device when properly commanded. CAN1 is used for general network communication including gauge display, scan tool communication, and other general 3rd party traffic. CAN2 is reserved solely for engine control (engine synchronization, throttle control, vehicle controller commands, etc.) and is limited to EControls Inc. approved devices only.

This fault indicates that there are two (2) or more devices on the network that use the same source address.

DTC 1628- CAN Address Conflict Failure



DTC 2111: Unable to Reach Lower TPS



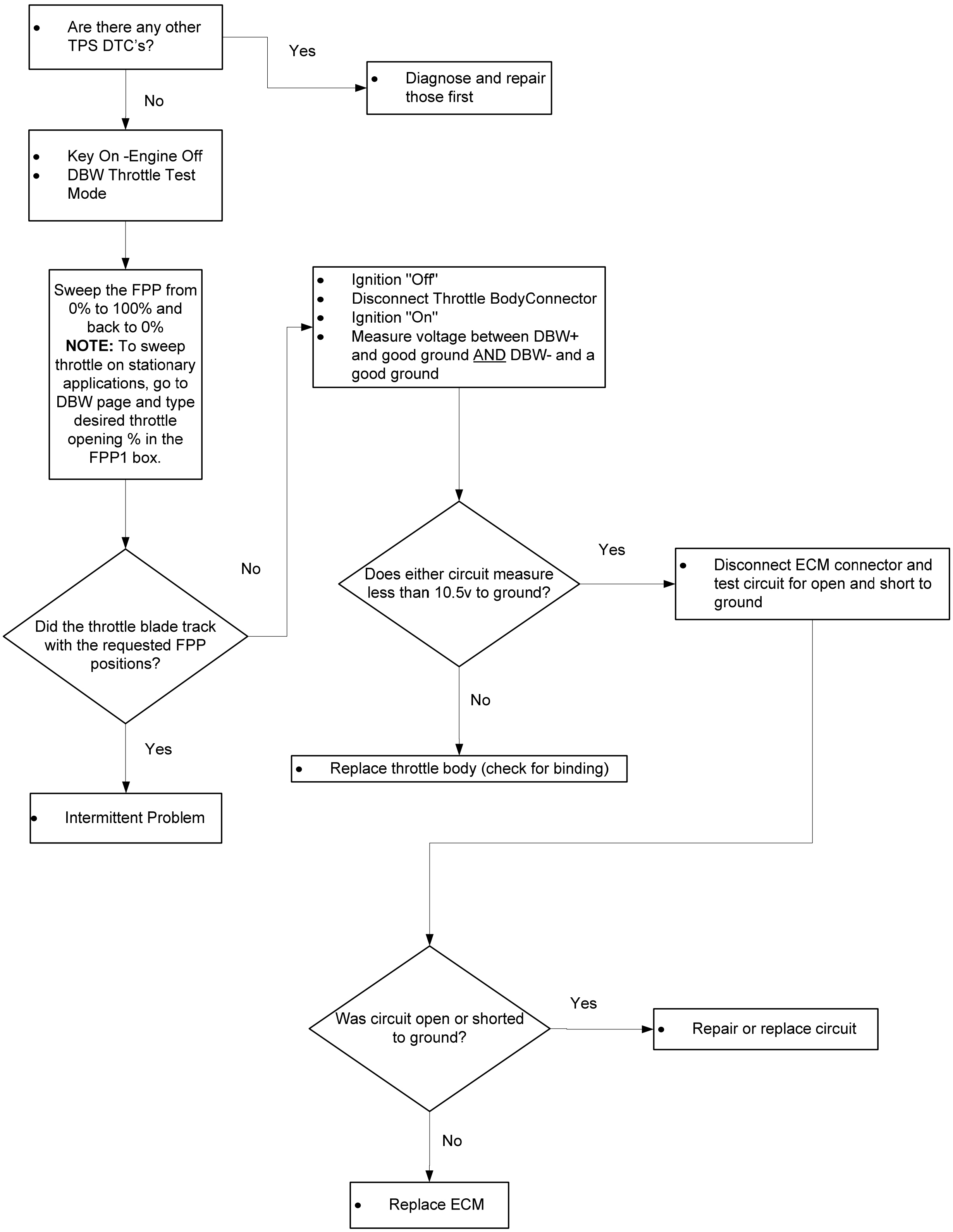
- o Hardware: Throttle Position Sensor
- o Enabling Conditions: Cranking or Running
- o Set Conditions: Throttle command is 20% less than throttle position for 200ms or longer
- o Corrective Action(s): Turn on MIL, activate engine shut down
- o Emissions related fault
- o Possible Causes:

There are 2 Throttle Position Sensors located within the throttle which use variable resistors to determine signal voltage based on throttle plate position. TPS1 will read low voltage when closed and TPS2 will read high voltage when closed. The TPS1 and TPS2 percentages are calculated from these voltages. Although the voltages are different, the calculated values for the throttle position percentages should be very close to the same. The TPS values are used by the ECM to determine if the throttle is opening as commanded.

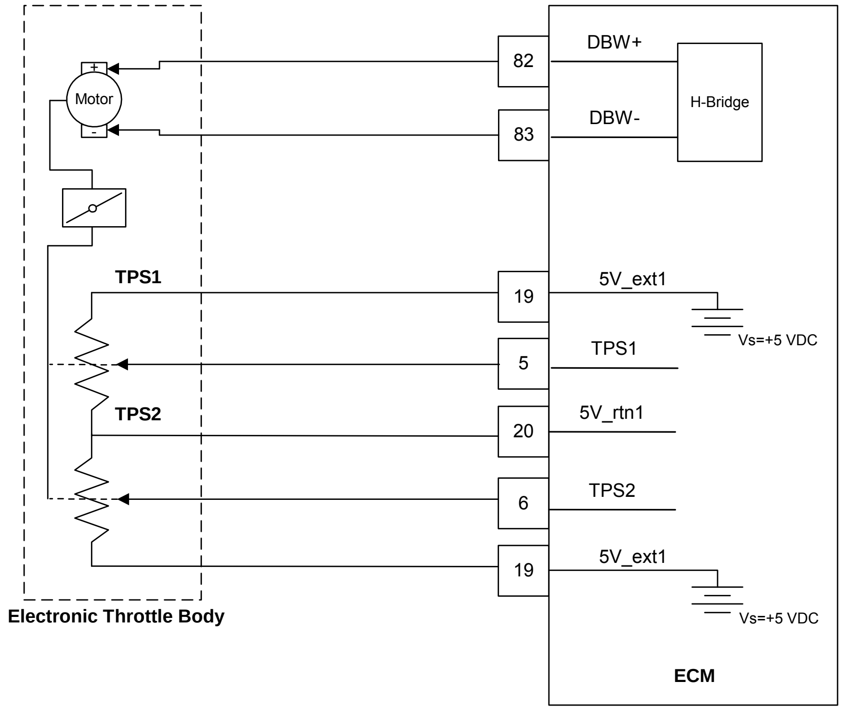
The DBW motor is a 2 wire DC motor that is PWM controlled by the ECM. Neither of these wires is watched by the ECM for electrical problems. DTCs 2111 and 2112 usually indicate that the ECM has lost control of the motor due to an electrical problem with the motor or a mechanical problem with the motor.

This fault will set if the throttle command is 20% lower or more than the actual throttle position. During this active fault the MIL light will be on and the engine will shut down.

DTC 2111: Unable to Reach Lower TPS



DTC 2112: Unable to Reach Higher TPS



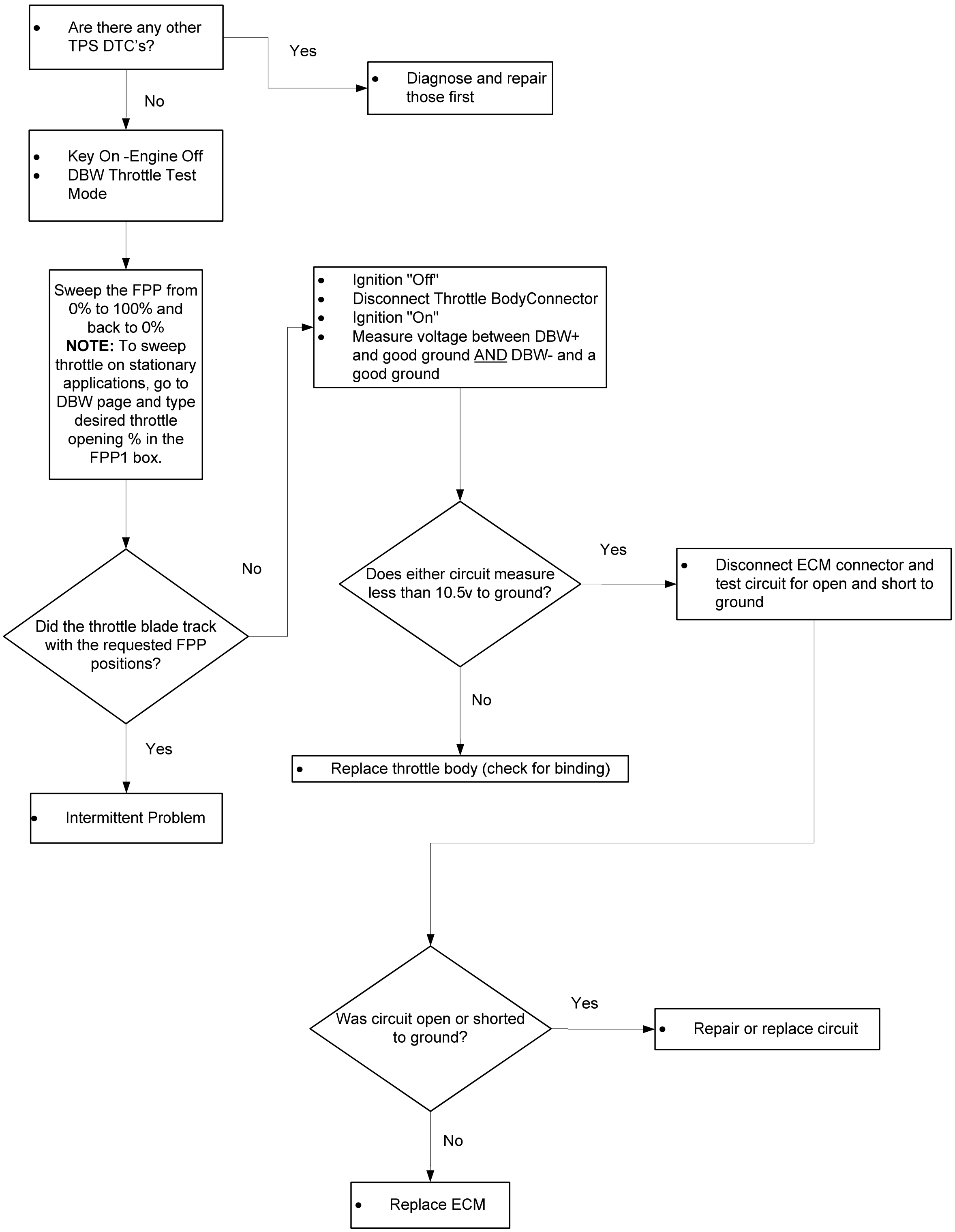
- o Hardware: Throttle Position Sensor
- o Enabling Conditions: Cranking or Running
- o Set Conditions: Throttle command is 20% more than actual throttle position
- o Corrective Action(s): MIL-On during active fault, Adaptive-Enabled, Closed Loop-Enabled, Engine Shut Down
- o Emissions related fault
- o Possible Causes:

There are 2 Throttle Position Sensors located within the throttle which use variable resistors to determine signal voltage based on throttle plate position. TPS1 will read low voltage when closed and TPS2 will read high voltage when closed. The TPS1 and TPS2 percentages are calculated from these voltages. Although the voltages are different, the calculated values for the throttle position percentages should be very close to the same. The TPS values are used by the ECM to determine if the throttle is opening as commanded.

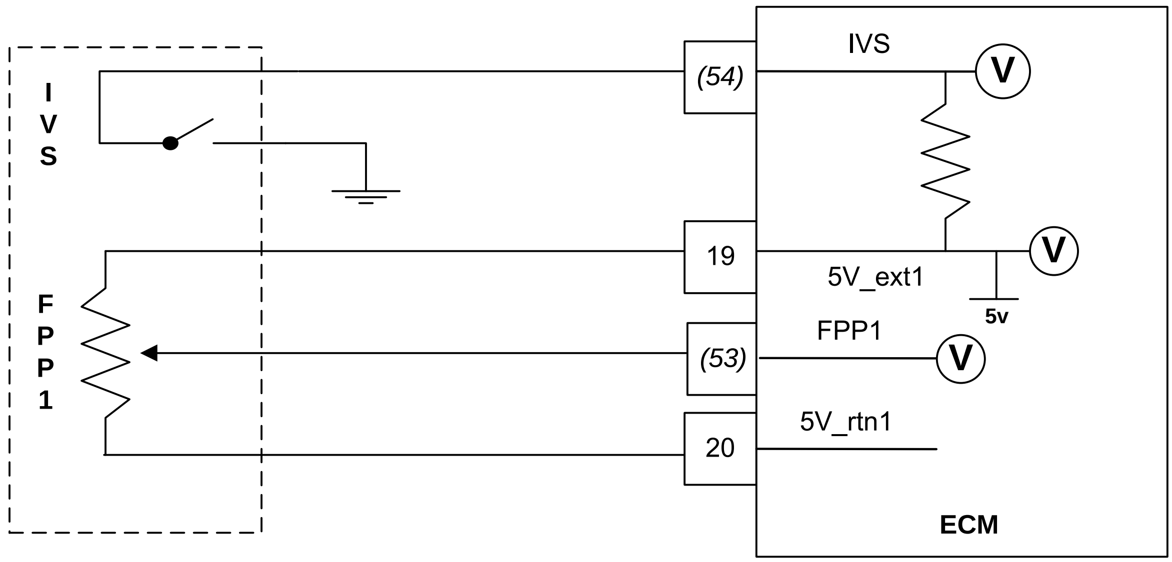
The DBW motor is a 2 wire DC motor that is PWM controlled by the ECM. Neither of these wires is watched by the ECM for electrical problems. DTCs 2111 and 2112 usually indicate that the ECM has lost control of the motor due to an electrical problem with the motor or a mechanical problem with the motor.

This fault will set if the throttle command is 20% higher or more than the actual throttle position. During this active fault the MIL light will be on and the engine will shut down.

DTC 2112: Unable to Reach Higher TPS



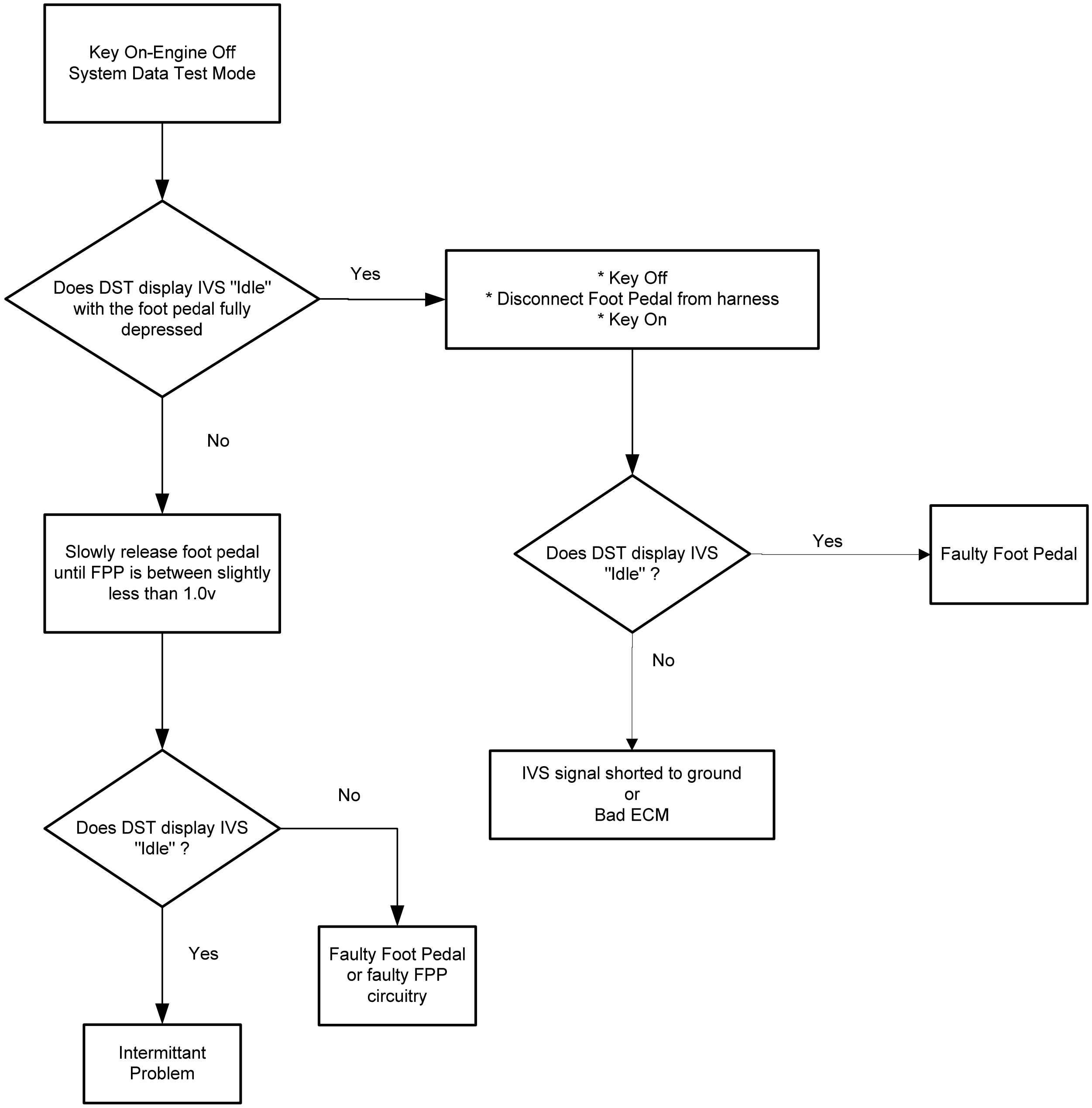
DTC 2115- FPP1 Higher Than IVS



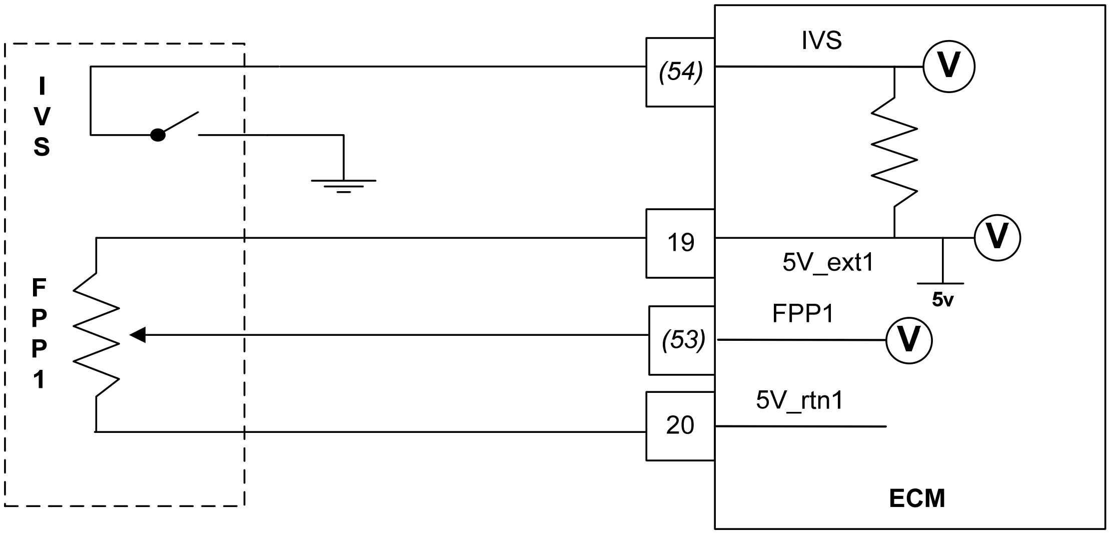
- o Hardware: Foot Pedal Position/Idle Validation Switch
- o Enabling Conditions: Engine Cranking or Running
- o Set Conditions: IVS at idle (open) and FPP voltage greater than 1.0 volts for longer than 1 second
- o Corrective Action(s): MIL-On during active fault and activate power derate 2 (max 30% throttle blade opening)
- o Non-emissions related fault
- o Possible Causes: IVS switch sticking, unwanted or incorrect resistance in FPP1 circuitry

The engine load command to the ECM is determined by operator depression of the electronic foot pedal. The ECM monitors the foot pedal position and controls the throttle to maintain the commanded power level. Because a problem with the foot pedal signal can result in a higher or lower power than intended by the operator, the pedal used with this control system incorporates a sensor with an idle validation switch. Checks and cross checks are constantly conducted by the ECM to determine the validity of the signals. The Idle Validation Switch (IVS) is a normally open switch (idle) that grounds the IVS circuit to the ECM when the pedal is depressed more than the idle position.

DTC 2115- FPP1 Higher Than IVS



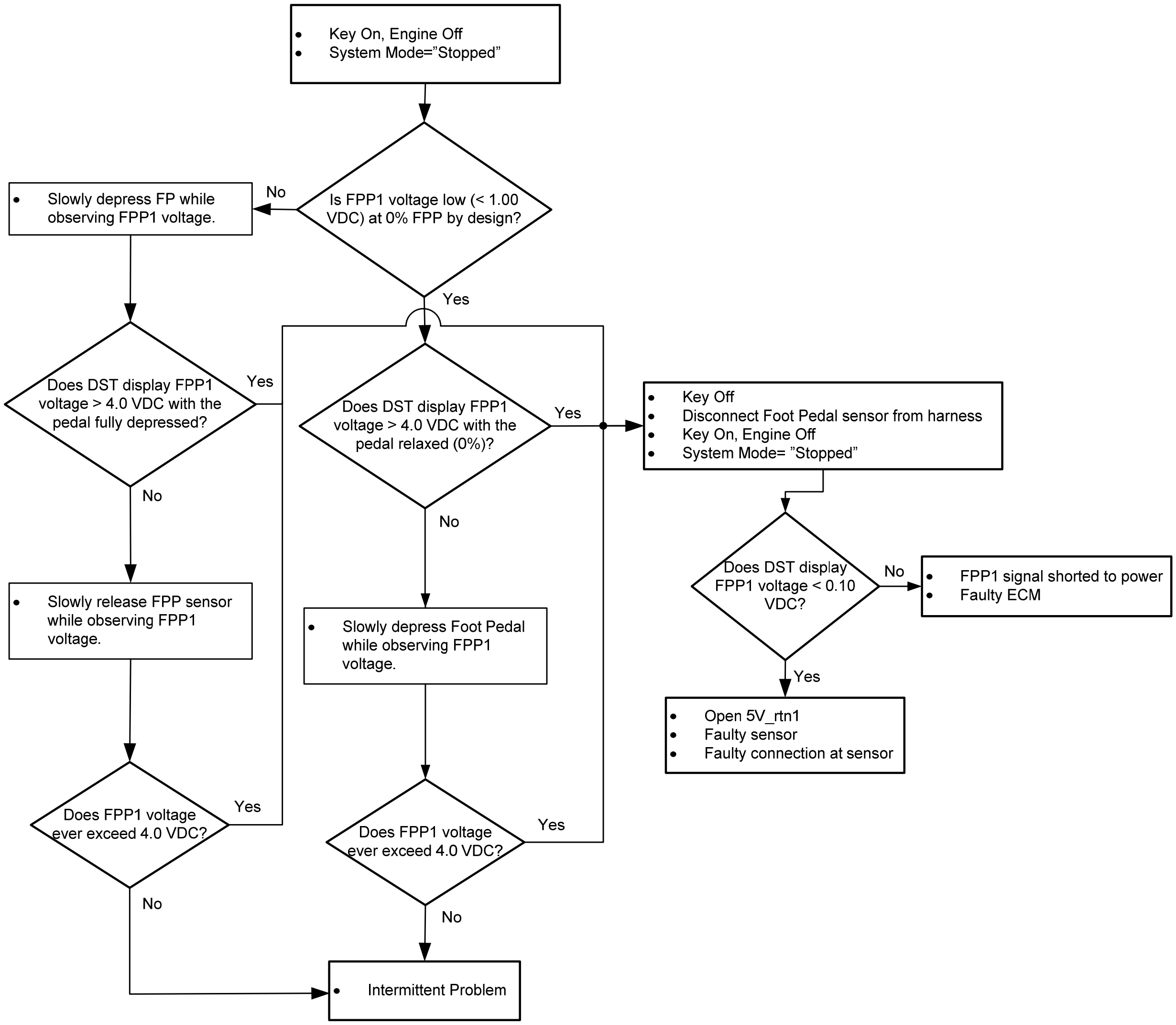
DTC 2122- FPP1 Voltage High



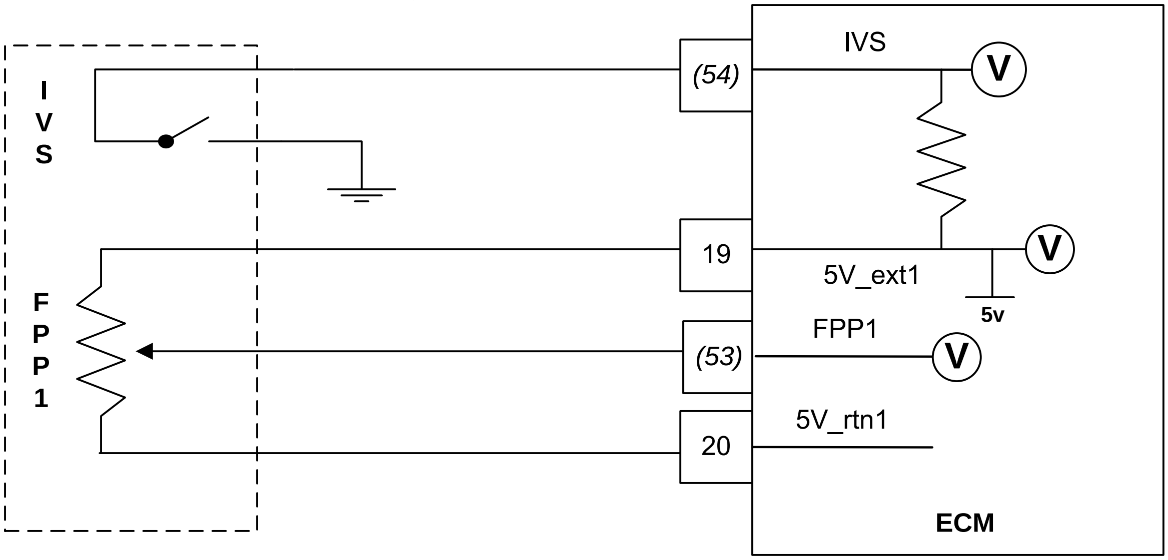
- Hardware: Electronic foot pedal/throttle control sensor
- Enabling Conditions: Key On, Engine Off
- Set Conditions: FPP1voltage > 4.0v for longer than 0.5 seconds
- Corrective Action(s): Illuminate MIL, activate low rev limit
- Non-emissions related fault
- Possible Causes: FPP signal shorted to voltage, 5v_rtn1 open to FPP, FPP open internally

The FPP sensor is an electronic device that is coupled to a mechanically driven input as commanded by the vehicle/engine operator. The FPP sensor output is proportional to the commanded input. The ECM uses the FPP sensor input to control the throttle and adjust the engine's load in order to achieve the requested power. Since the FPP sensor inputs directly affect the engine's power output, redundant sensors are generally used to ensure safe, reliable operation. In electronic throttle control systems the foot pedal position/throttle control position sensor is used by the engine/equipment operator or system to command either throttle position or a governor speed target proportional to the input in order to achieve desired system behavior.

DTC 2122- FPP1 Voltage High



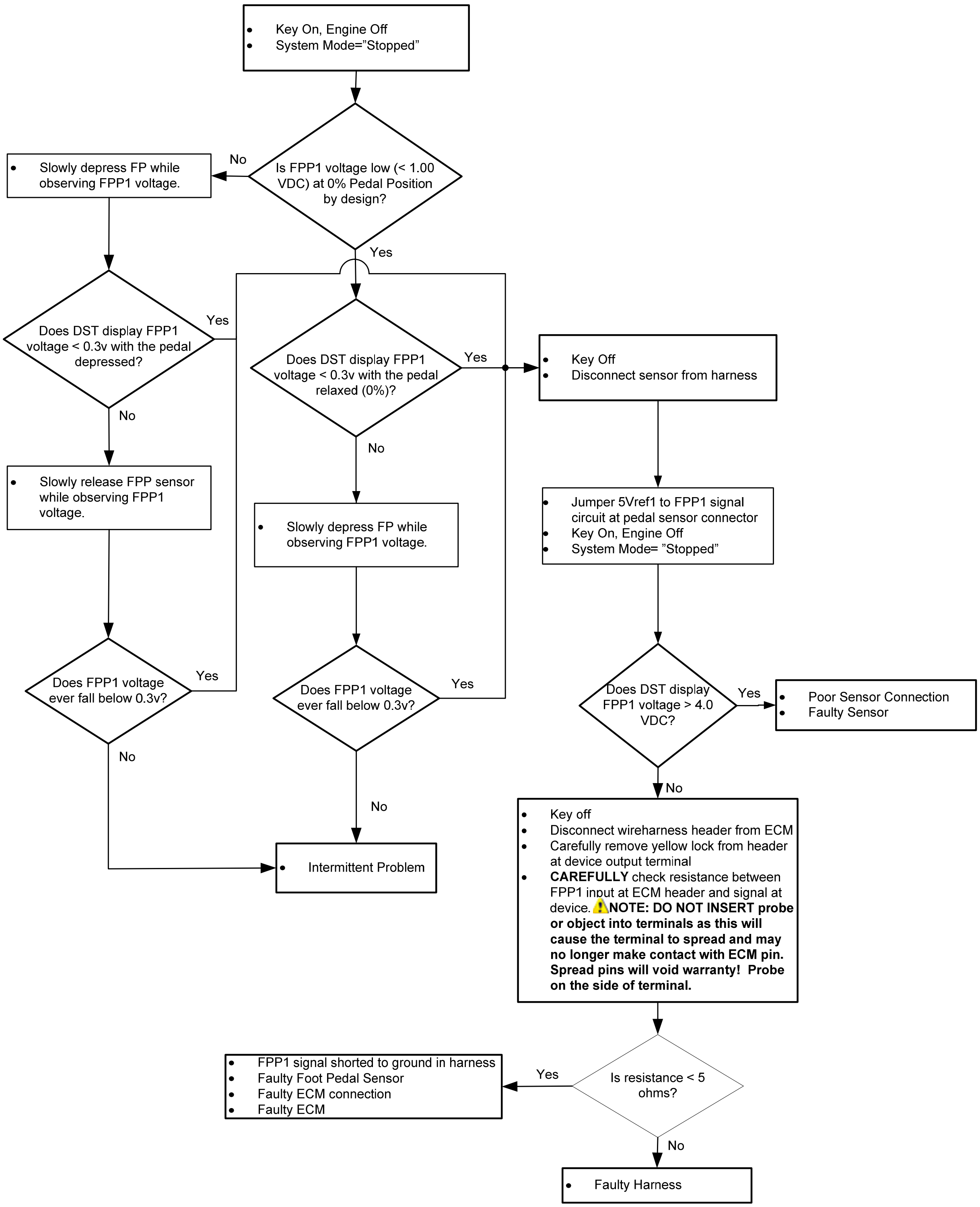
DTC 2123- FPP1 Voltage Low



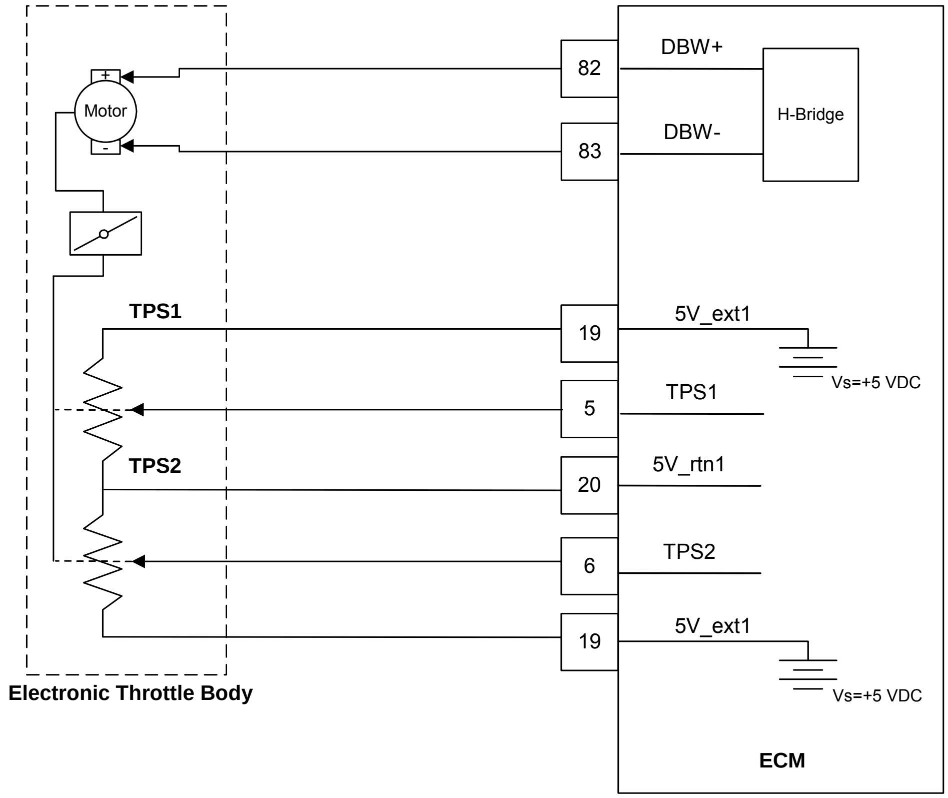
- o Hardware: Electronic foot pedal/throttle control sensor
- o Enabling Conditions: Key On, Engine Off
- o Set Conditions: FPP1voltage < 0.3v for longer than 0.5 seconds
- o Corrective Action(s): Illuminate MIL, activate low rev limit
- o Non-emissions related fault
- o Possible Causes: Loss of 5v supply, FPP 1 signal circuit open or shorted to ground, faulty FPP, faulty ECM

The FPP sensor is an electronic device that is coupled to a mechanically driven input as commanded by the vehicle/engine operator. The FPP sensor output is proportional to the commanded input. The ECM uses the FPP sensor input to control the throttle and adjust the engine's load in order to achieve the requested power. Since the FPP sensor inputs directly affect the engine's power output, redundant sensors are generally used to ensure safe, reliable operation. In electronic throttle control systems the foot pedal position/throttle control position sensor is used by the engine/equipment operator or system to command either throttle position or a governor speed target proportional to the input in order to achieve desired system behavior.

DTC 2123- FPP1 Voltage Low



DTC 2135- TPS1/2 Simultaneous Voltages Out-of-Range



- Hardware: Electronic throttle body
- Enabling Conditions: Key On, Engine Cranking or Running
- Set Condition: TPS1 and TPS2 voltages are both simultaneously out-of-range for longer than 0.5 seconds
- Corrective Action(s): Illuminate MIL and shutdown engine
- Non-emissions related fault
- Possible Causes: Loss of 5v feed to both sensors, loss of ground (5V_rtn1) to both sensors, problem with both TPSs at the same time

The throttle is an air valve used to control the amount of air available to the engine for combustion and thereby the engine's power output. An electronic throttle simply means that a motor is controlled electronically through an electronic control system to actuate the throttle valve. Electronic throttle control is advantageous because it tends to offer improved starting, improved idle governing, improved maximum speed governing, excellent load acceptance and steady-state speed governing, permits engine synchronization, and offers flexibility to protect the engine during certain fault conditions.

This fault is generated when both feedback sensors in the ETB (TPS1 and TPS2) simultaneously produce out-of-range faults. This fault indicates that there is no feedback of the throttle valve and as a result throttle control cannot take place.

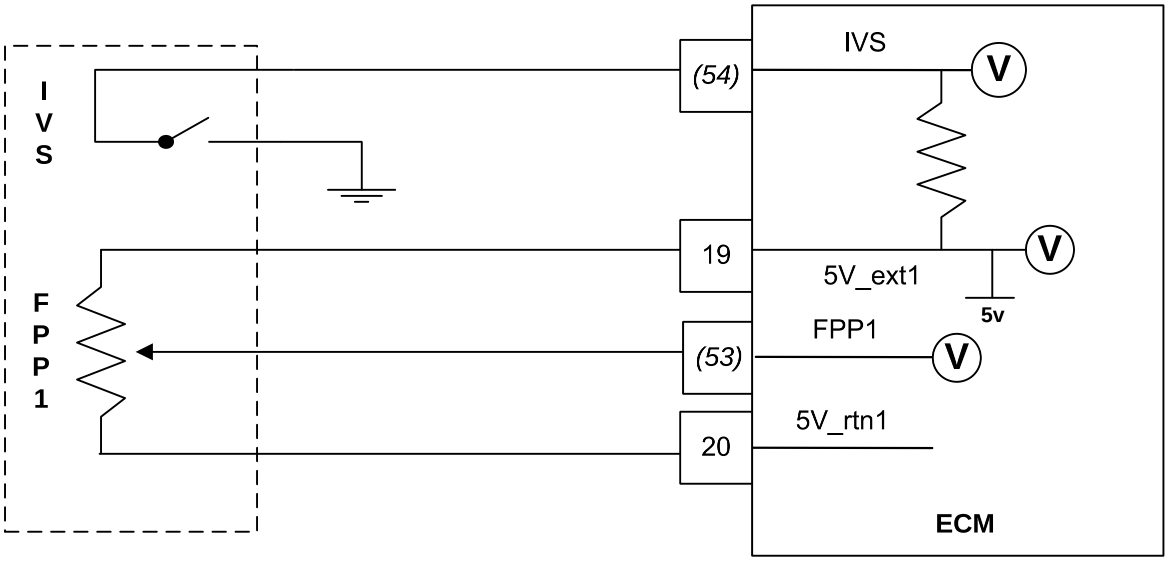
DTC 2135- TPS1/2 Simultaneous Voltages Out-of-Range

Diagnostic Aids

Troubleshoot according to *TPS1 voltage out-of-range* following DTC 122 and 123 procedures.

Troubleshoot according to *TPS2 voltage out-of-range* following DTC 222 and 223 procedures.

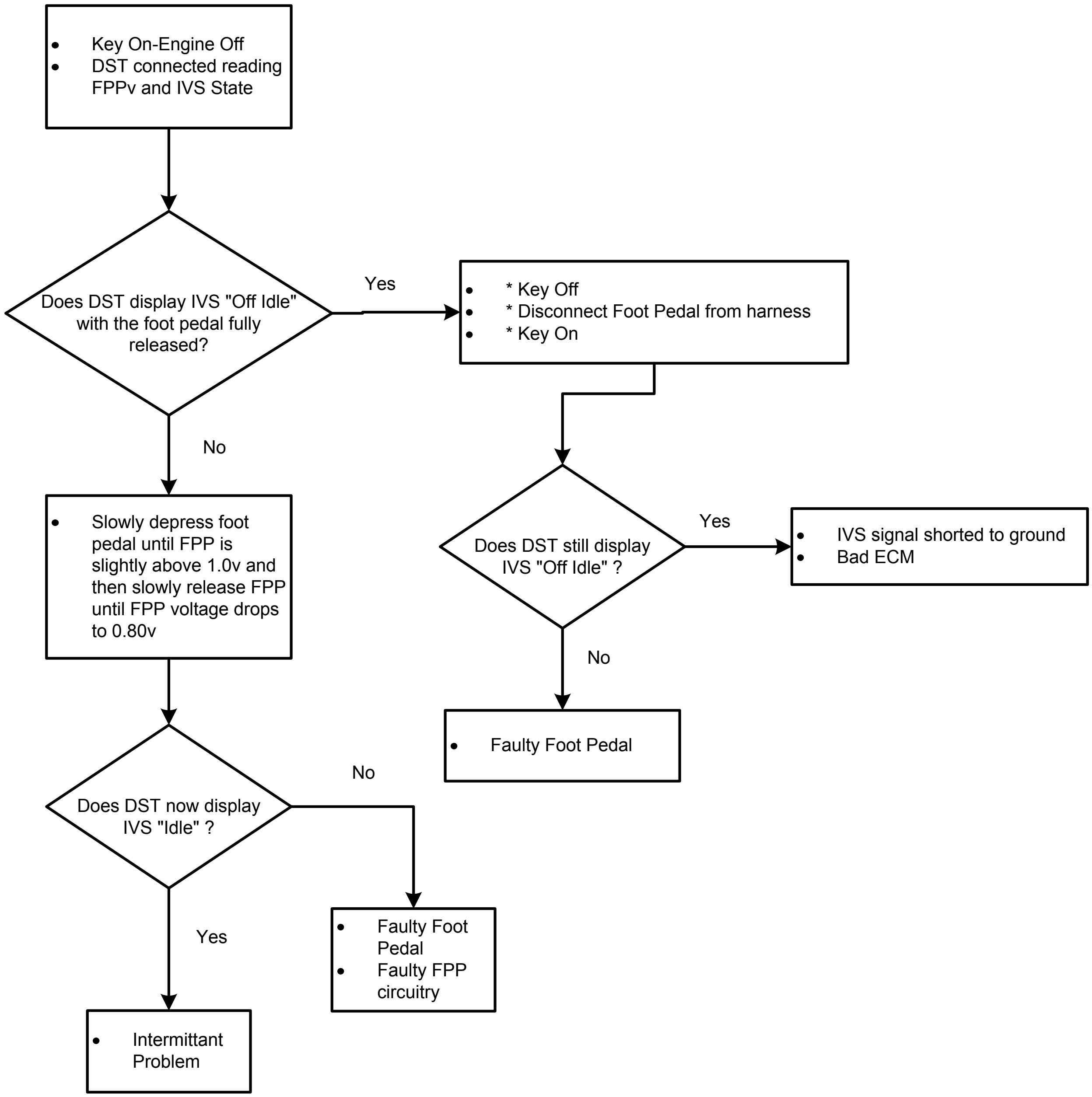
DTC 2139- FPP1 Lower Than IVS



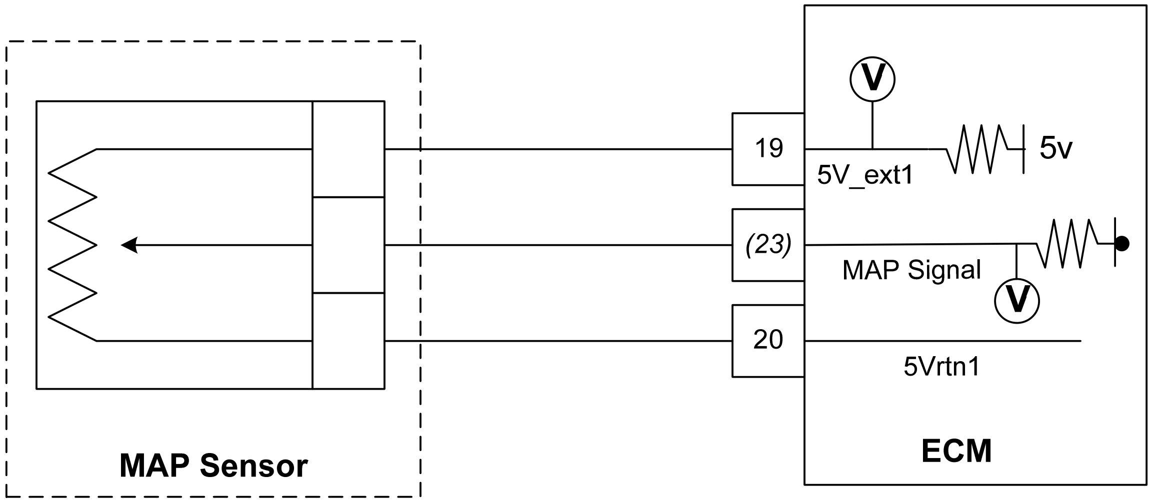
- o Hardware: Foot Pedal Position/Idle Validation Switch
- o Enabling Conditions: Engine Cranking or Running
- o Set Conditions: IVS off idle (closed) and FPP voltage less than 0.85 volts for longer than 1 second
- o Corrective Action(s): MIL-On during active fault and activate power derate 2 (max 30% throttle blade opening)
- o Non-emissions related fault
- o Possible Causes: IVS switch sticking, unwanted or incorrect resistance in FPP1 circuitry

The engine load command to the ECM is determined by operator depression of the electronic foot pedal. The ECM monitors the foot pedal position and controls the throttle to maintain the commanded power level. Because a problem with the foot pedal signal can result in a higher or lower power than intended by the operator, the pedal used with this control system incorporates a sensor with an idle validation switch. Checks and cross checks are constantly conducted by the ECM to determine the validity of the signals. The Idle Validation Switch (IVS) is a normally open switch (idle) that grounds the IVS circuit to the ECM when the pedal is depressed more than the idle position.

DTC 2139- FPP1 Lower Than IVS



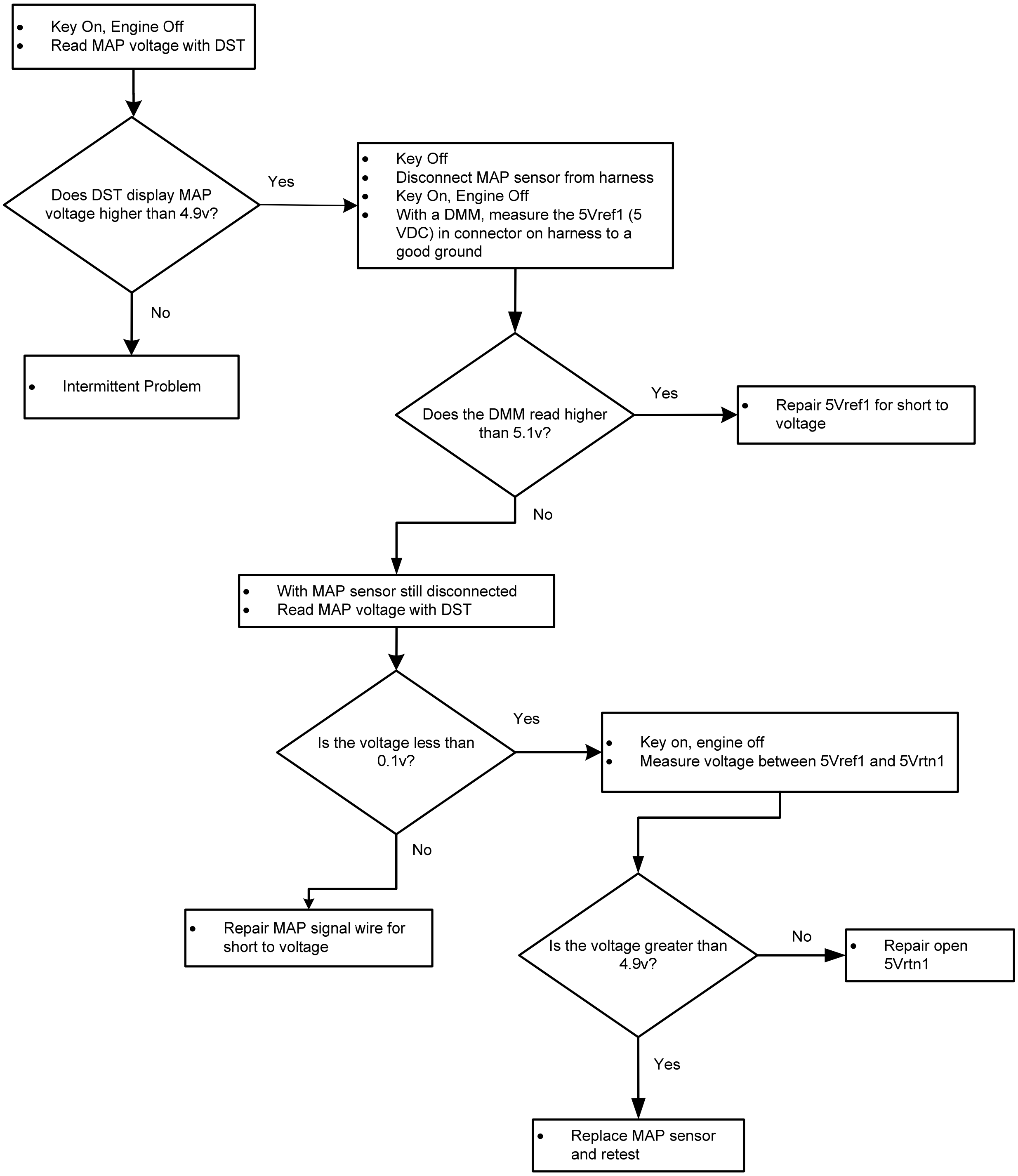
DTC 2229- BP High Pressure



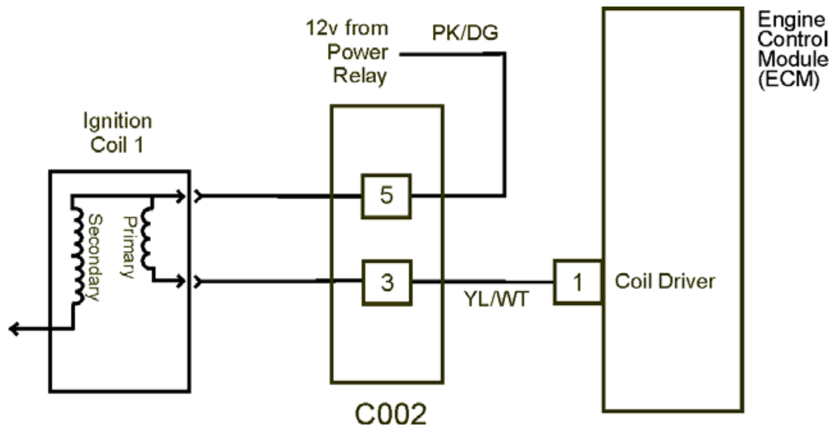
- Hardware: Barometric Pressure from MAP Sensor
- Enabling Conditions: Key On, Engine Off or after BP estimate during low-speed/high load operation
- Set Conditions: Barometric Pressure is greater than 17.3 psia for longer than 20 seconds
- Corrective Action(s): Illuminate MIL, disable fuel adaptive learn for the rest of the key-cycle
- Emissions related fault
- Possible Causes: MAP signal shorted to voltage, faulty MAP sensor, 5Vrtn1 open to MAP sensor or 5V_ext1 shorted to voltage

Barometric Pressure is estimated from the MAP sensor at key-on and in some calibrations during low speed/high load operation as defined in the engine's calibration. The barometric pressure value is used for fuel and airflow calculations.

DTC 2229- BP High Pressure



DTC 2300- Spark Coil #1 Primary Open/Short-to-Ground



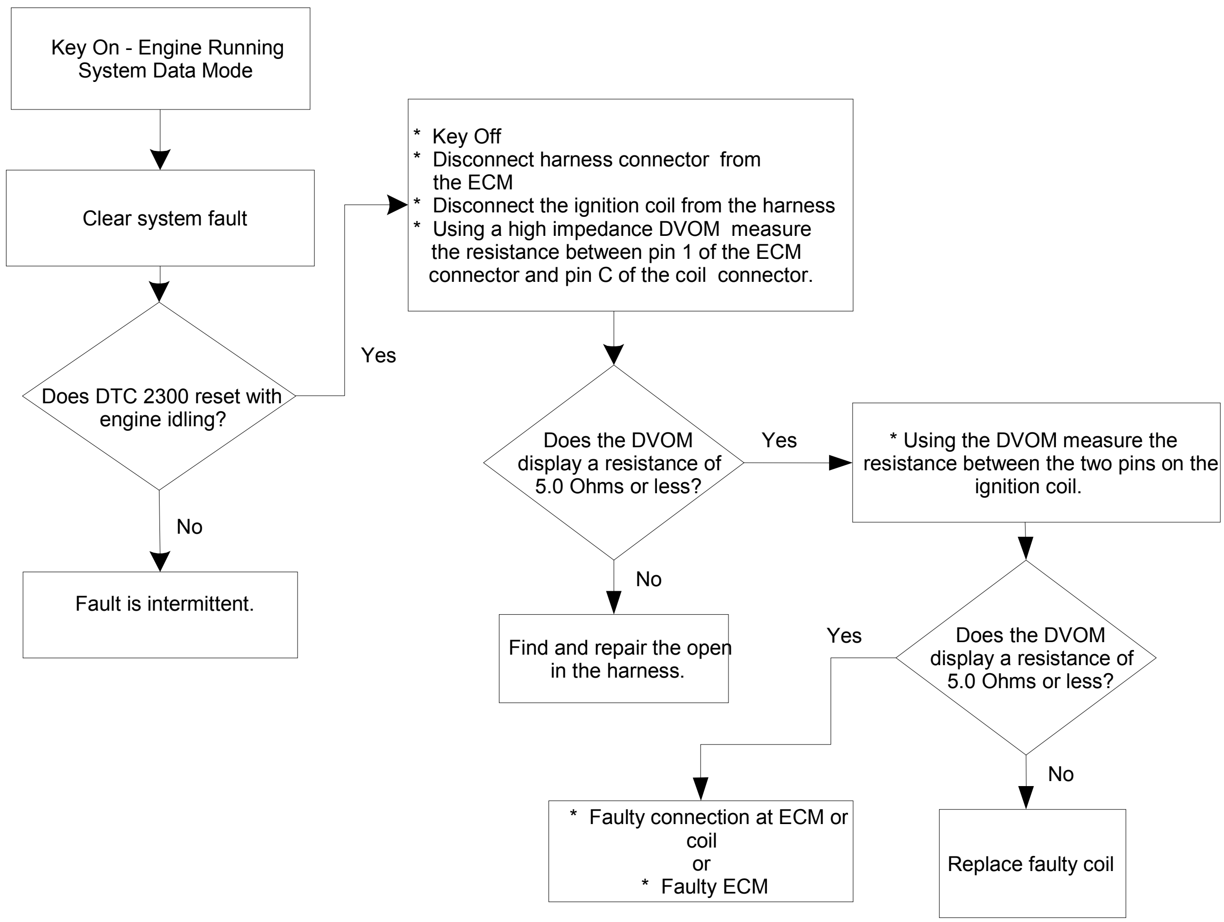
- Hardware: Ignition/Spark Coil (Dumb-coil ONLY)
- Enabling Conditions: Key On, Engine Running, Battery volts > 11.0
- Set Conditions: Primary circuitry of the ignition coil is an open circuit or shorted-to-ground
- Corrective Action(s): Illuminate MIL, disable closed-loop while code is active and disable fuel adaptive learn for the rest of the key cycle.
- Emissions related fault
- Possible Causes:

Coil driver #1 fires the 1st cylinder in the firing order.

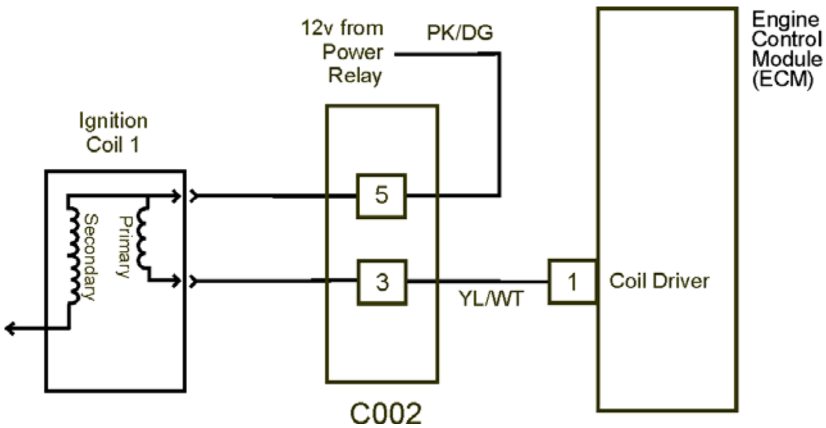
This fault will set if the ECM detects 10 coil firings in which the adaptive dwell adjustment is greater than 2 ms. or the total dwell is greater than 14 ms. and battery voltage is greater than 11.0 volts.

The purpose of this fault is to detect a short-to-ground or open circuit in the harness or an open internal to the primary coil.

DTC 2300- Spark Coil #1 Primary Open/Short-to-Ground



DTC 2301- Spark Coil #1 Primary Short-to-Power



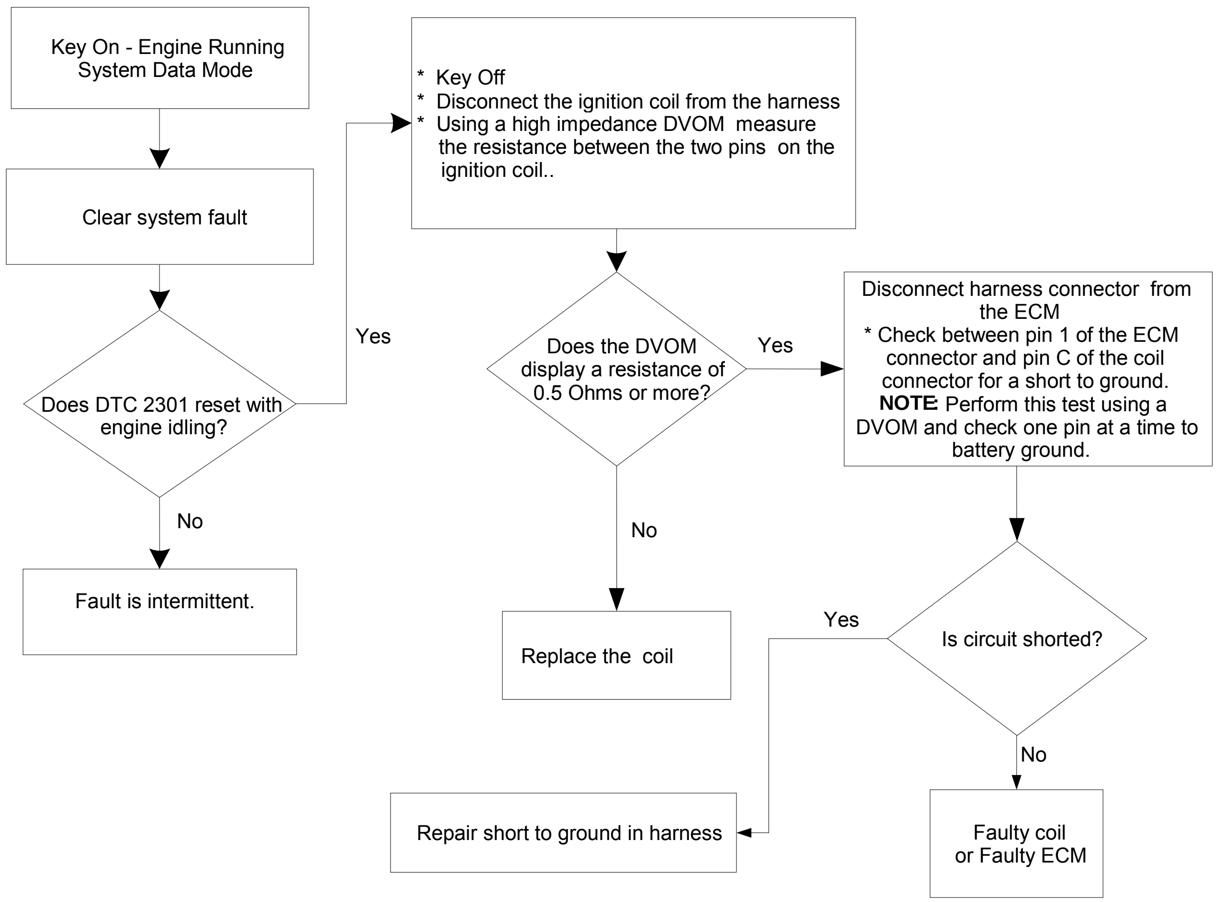
- Hardware: Ignition/Spark Coil (Dumb-coil ONLY)
- Enabling Conditions: Key On, Engine Running, Battery volts < 16.0
- Set Conditions: Primary circuitry of the ignition coil is shorted-to-power
- Corrective Action(s): Illuminate MIL, disable closed-loop while code is active and disable fuel adaptive learn for the rest of the key cycle.
- Emissions related fault
- Possible Causes:

Coil driver #1 fires the 1st cylinder in the firing order.

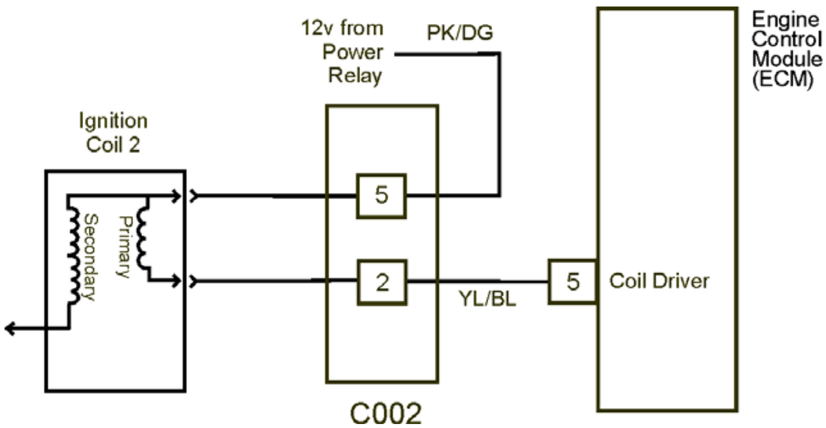
This fault will set if the ECM detects 10 coil firings in which the adaptive dwell adjustment is less than -2 ms. or the total dwell is less than 4.0 ms. and battery voltage is less than 16.0 volts.

The purpose of this fault is to detect a short-to-power in the harness or internal to the primary coil.

DTC 2301- Spark Coil #1 Primary Short-to-Power



DTC 2303- Spark Coil #2 Primary Open/Short-to-Ground



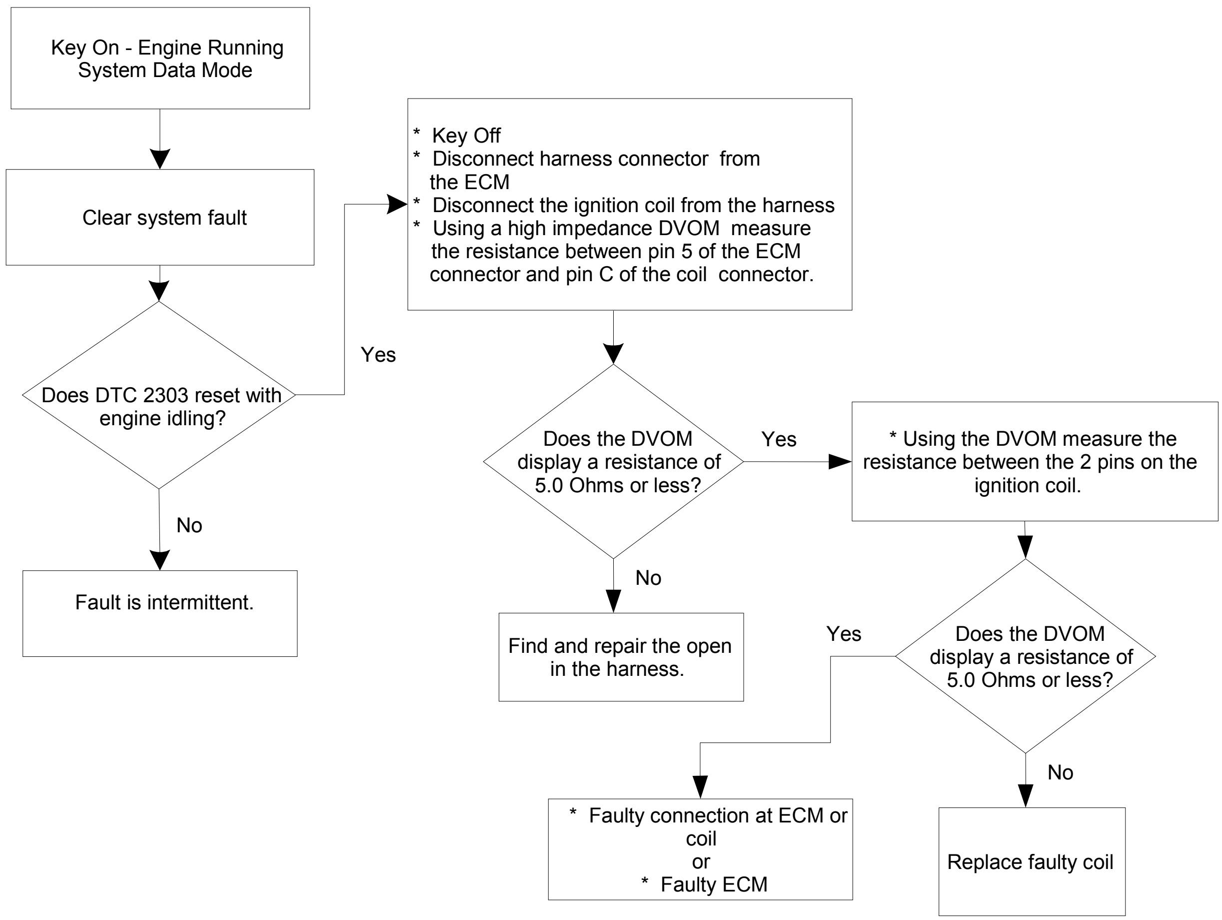
- Hardware: Ignition/Spark Coil (Dumb-coil ONLY)
- Enabling Conditions: Key On, Engine Running, Battery volts > 11.0
- Set Conditions: Primary circuitry of the ignition coil is an open circuit or shorted-to-ground
- Corrective Action(s): Illuminate MIL, disable closed-loop while code is active and disable fuel adaptive learn for the rest of the key cycle.
- Emissions related fault
- Possible Causes:

Coil driver #2 fires the 2nd cylinder in the firing order.

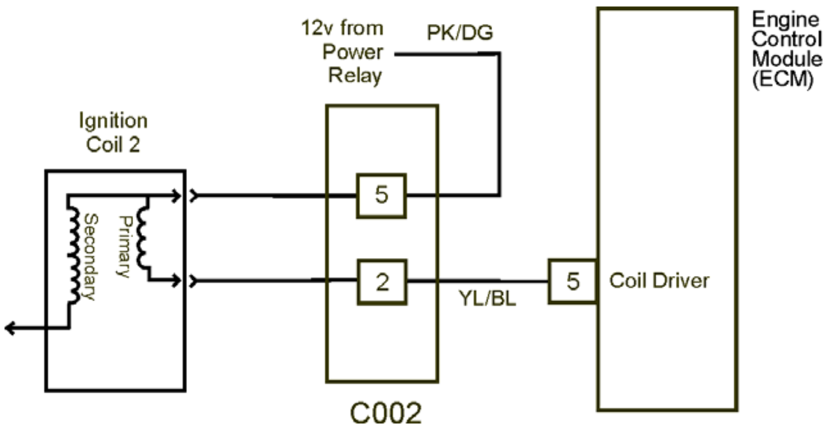
This fault will set if the ECM detects 10 coil firings in which the adaptive dwell adjustment is greater than 2 ms. or the total dwell is greater than 14 ms. and battery voltage is greater than 11.0 volts.

The purpose of this fault is to detect a short-to-ground or open circuit in the harness or an open internal to the primary coil.

DTC 2303- Spark Coil #2 Primary Open/Short-to-Ground



DTC 2304- Spark Coil #2 Primary Short-to-Power



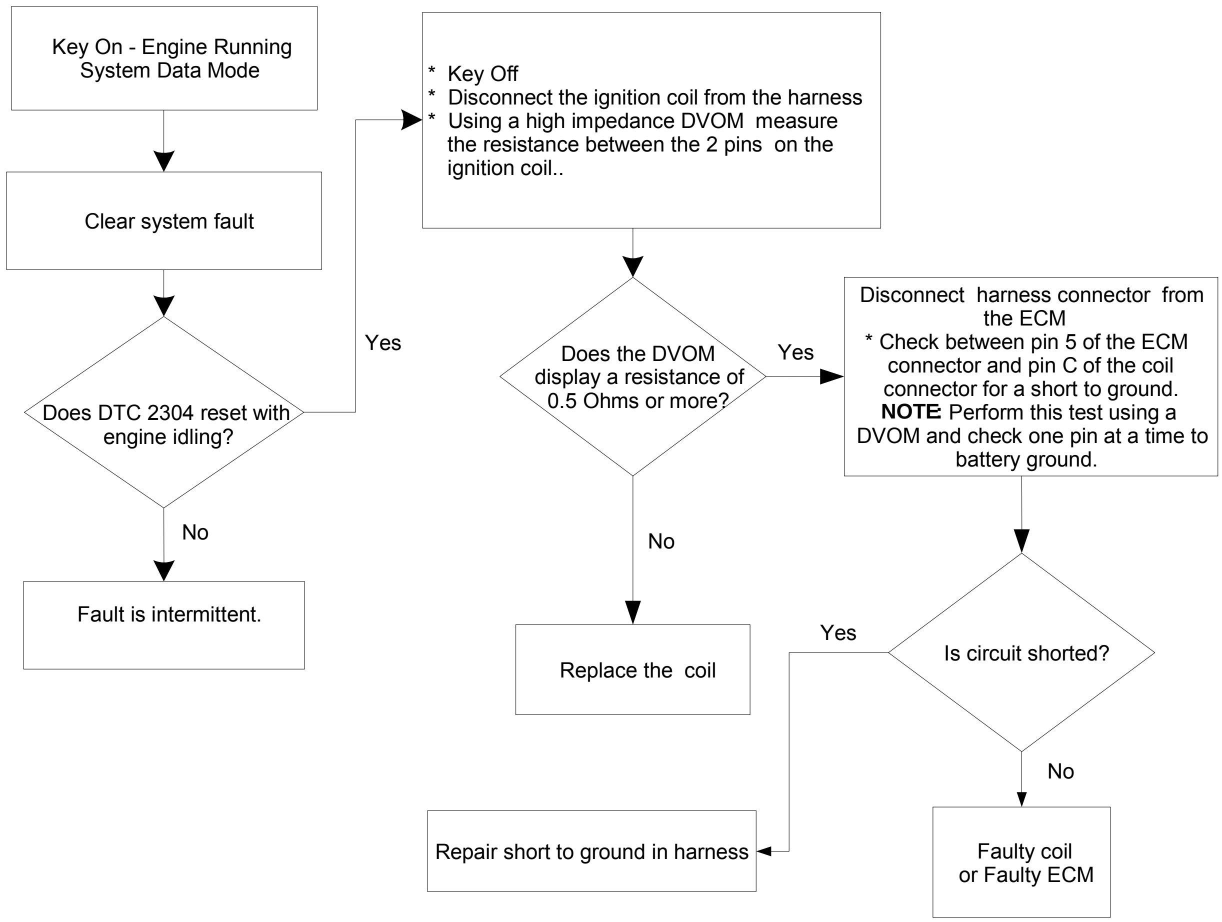
- Hardware: Ignition/Spark Coil (Dumb-coil ONLY)
- Enabling Conditions: Key On, Engine Running, Battery volts < 16.0
- Set Conditions: Primary circuitry of the ignition coil is shorted-to-power
- Corrective Action(s): Illuminate MIL, disable closed-loop while code is active and disable fuel adaptive learn for the rest of the key cycle.
- Emissions related fault
- Possible Causes:

Coil driver #2 fires the 2^{nd} cylinder in the firing order.

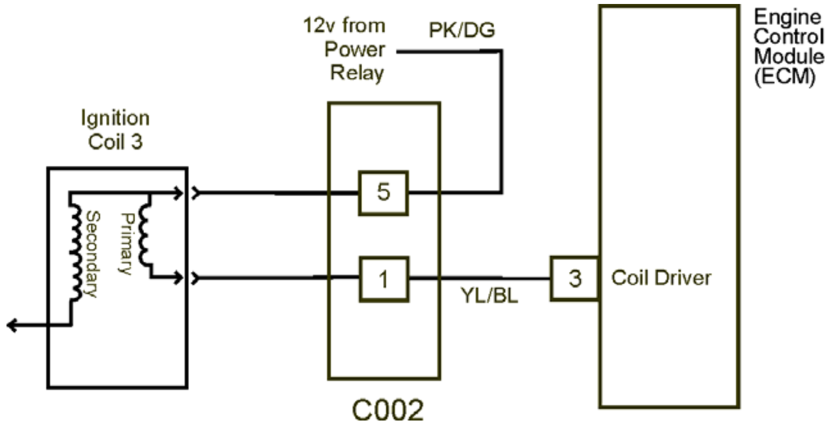
This fault will set if the ECM detects 10 coil firings in which the adaptive dwell adjustment is less than -2 ms. or the total dwell is less than 4.0 ms. and battery voltage is less than 16.0 volts.

The purpose of this fault is to detect a short-to-power in the harness or internal to the primary coil.

DTC 2304- Spark Coil #2 Primary Short-to-Power



DTC 2306- Spark Coil #3 Primary Open/Short-to-Ground



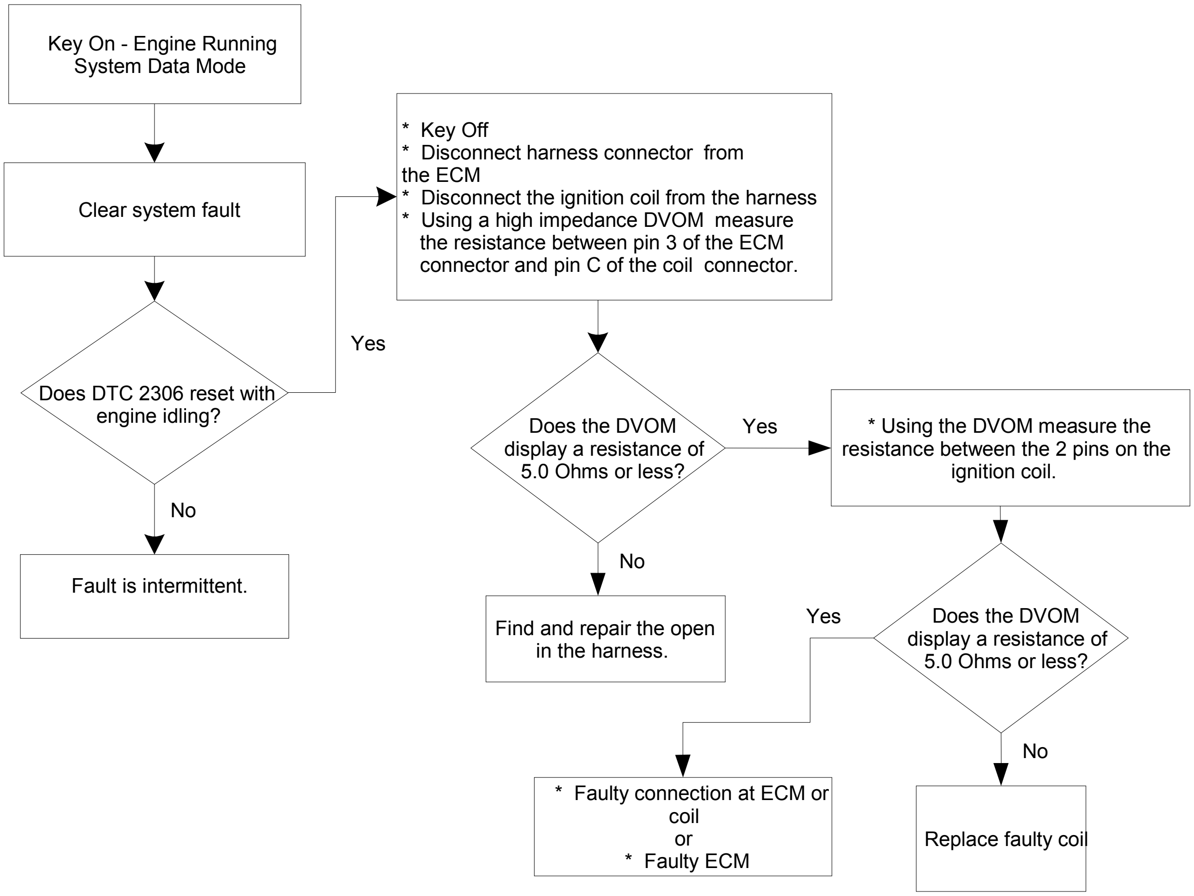
- Hardware: Ignition/Spark Coil (Dumb-coil ONLY)
- Enabling Conditions: Key On, Engine Running, Battery volts > 11.0
- Set Conditions: Primary circuitry of the ignition coil is an open circuit or shorted-to-ground
- Corrective Action(s): Illuminate MIL, disable closed-loop while code is active and disable fuel adaptive learn for the rest of the key cycle.
- Emissions related fault
- Possible Causes:

Coil driver #3 fires the 3rd cylinder in the firing order.

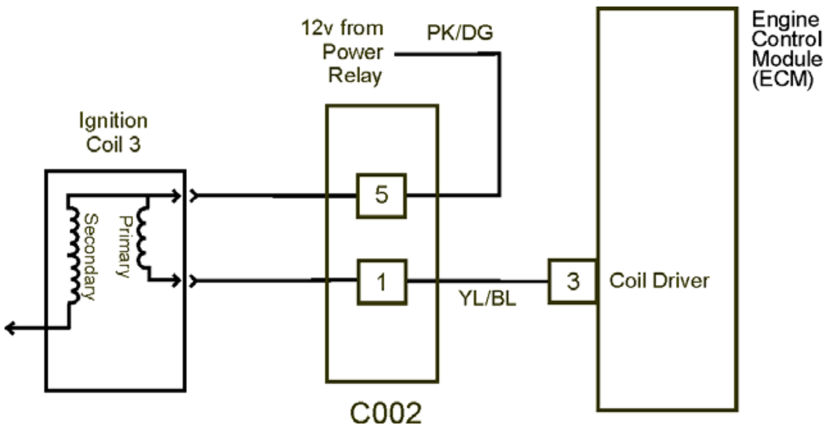
This fault will set if the ECM detects 10 coil firings in which the adaptive dwell adjustment is greater than 2 ms. or the total dwell is greater than 14 ms. and battery voltage is greater than 11.0 volts.

The purpose of this fault is to detect a short-to-ground or open circuit in the harness or an open internal to the primary coil.

DTC 2306- Spark Coil #3 Primary Open/Short-to-Ground



DTC 2307- Spark Coil #3 Primary Short-to-Power



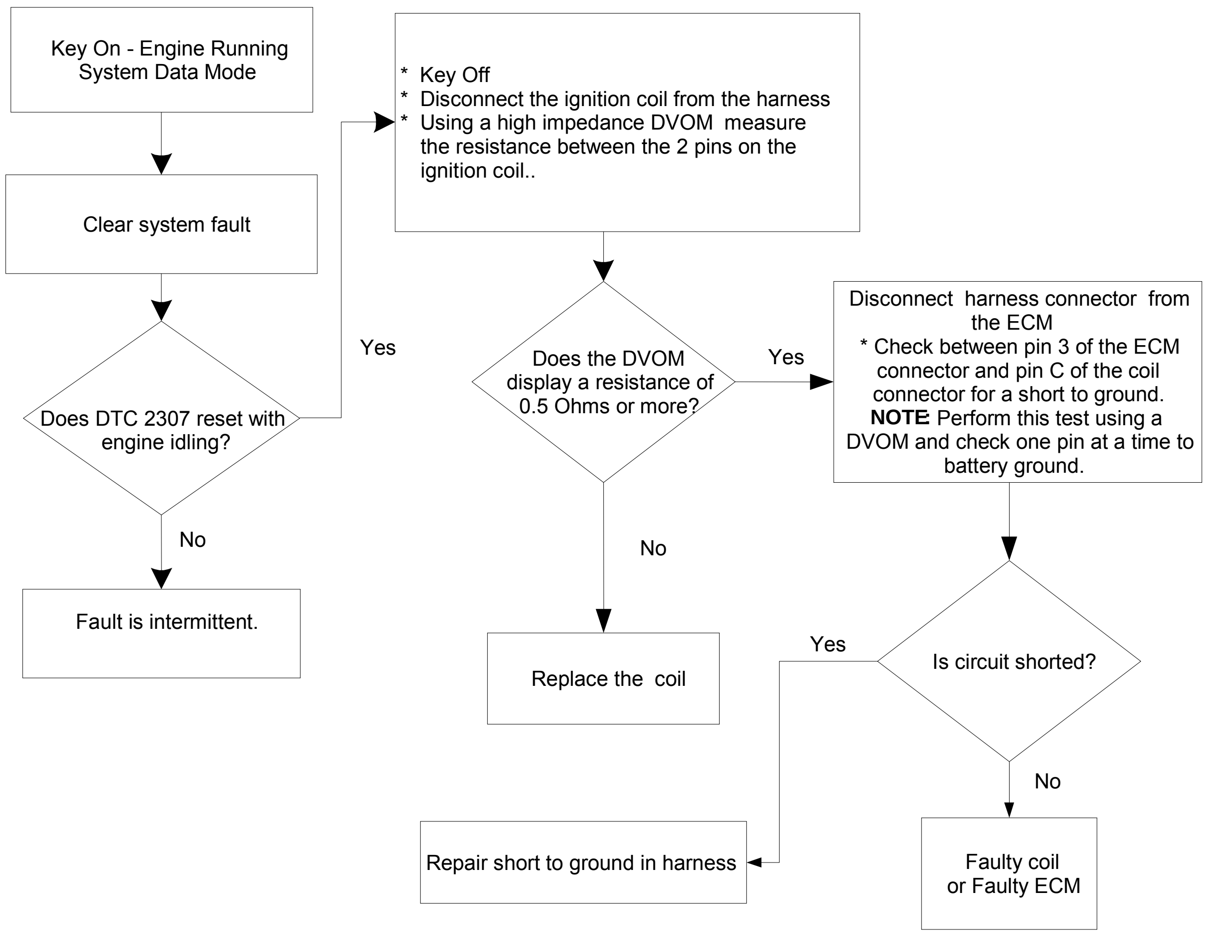
- o Hardware: Ignition/Spark Coil (Dumb-coil ONLY)
- o Enabling Conditions: Key On, Engine Running, Battery volts < 16.0
- o Set Conditions: Primary circuitry of the ignition coil is shorted-to-power
- o Corrective Action(s): Illuminate MIL, disable closed-loop while code is active and disable fuel adaptive learn for the rest of the key cycle.
- o Emissions related fault
- o Possible Causes:

Coil driver #3 fires the 3rd cylinder in the firing order.

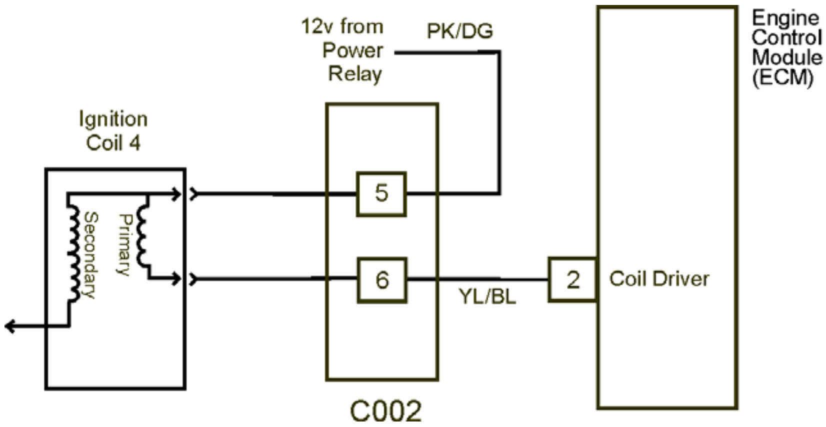
This fault will set if the ECM detects 10 coil firings in which the adaptive dwell adjustment is less than -2 ms. or the total dwell is less than 4.0 ms. and battery voltage is less than 16.0 volts.

The purpose of this fault is to detect a short-to-power in the harness or internal to the primary coil.

DTC 2307- Spark Coil #3 Primary Short-to-Power



DTC 2309- Spark Coil #4 Primary Open/Short-to-Ground



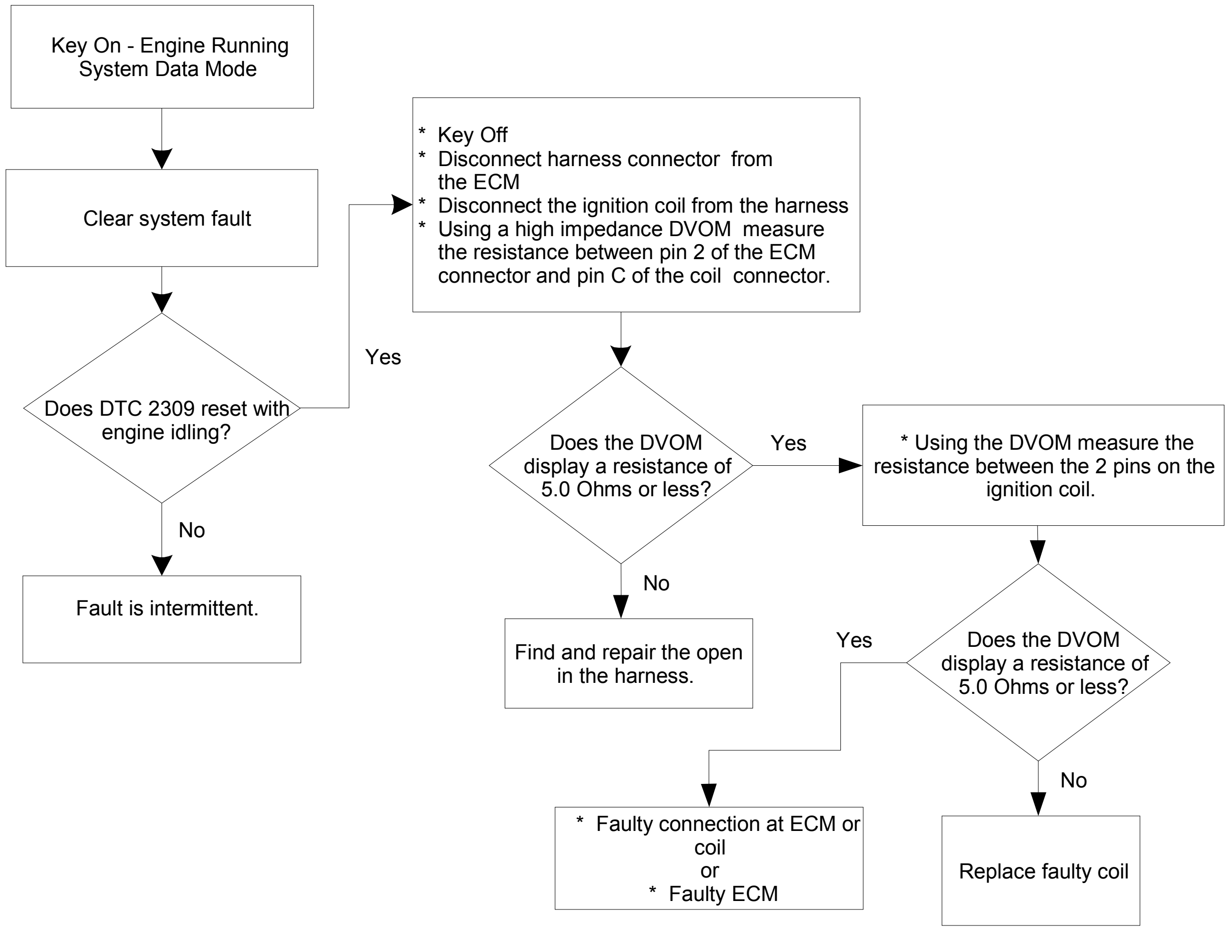
- o Hardware: Ignition/Spark Coil (Dumb-coil ONLY)
- o Enabling Conditions: Key On, Engine Running, Battery volts > 11.0
- o Set Conditions: Primary circuitry of the ignition coil is an open circuit or shorted-to-ground
- o Corrective Action(s): Illuminate MIL, disable closed-loop while code is active and disable fuel adaptive learn for the rest of the key cycle.
- o Emissions related fault
- o Possible Causes:

Coil driver #4 fires the 4th cylinder in the firing order.

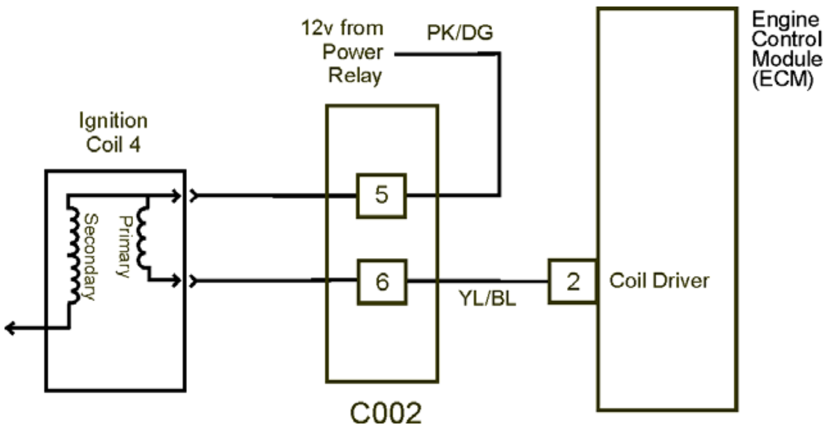
This fault will set if the ECM detects 10 coil firings in which the adaptive dwell adjustment is greater than 2 ms. or the total dwell is greater than 14 ms. and battery voltage is greater than 11.0 volts.

The purpose of this fault is to detect a short-to-ground or open circuit in the harness or an open internal to the primary coil.

DTC 2309- Spark Coil #4 Primary Open/Short-to-Ground



DTC 2310- Spark Coil #4 Primary Short-to-Power



- o Hardware: Ignition/Spark Coil (Dumb-coil ONLY)
- o Enabling Conditions: Key On, Engine Running, Battery volts < 16.0
- o Set Conditions: Primary circuitry of the ignition coil is shorted-to-power
- o Corrective Action(s): Illuminate MIL, disable closed-loop while code is active and disable fuel adaptive learn for the rest of the key cycle.
- o Emissions related fault
- o Possible Causes:

Coil driver #4 fires the 4th cylinder in the firing order.

This fault will set if the ECM detects 10 coil firings in which the adaptive dwell adjustment is less than -2 ms. or the total dwell is less than 4.0 ms. and battery voltage is less than 16.0 volts.

The purpose of this fault is to detect a short-to-power in the harness or internal to the primary coil.

DTC 2310- Spark Coil #4 Primary Short-to-Power