

DIAGNOSTIC MANUAL

2010 MaxxForce® 7 Engine

Navistar, Inc.

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Foreword

Navistar, Inc. is committed to continuous research and development to improve products and introduce technological advances. Procedures, specifications, and parts defined in published technical service literature may be altered.

NOTE: Photo illustrations identify specific parts or assemblies that support text and procedures; other areas in a photo illustration may not be exact.

This manual includes necessary information and specifications for technicians to maintain Navistar® diesel engines. See vehicle manuals and Technical Service Information (TSI) bulletins for additional information.

Technical Service Literature

1172039R1	MaxxForce® 7 <i>Operation and Maintenance Manual</i>
EGES-480-1	MaxxForce® 7 <i>Engine Service Manual</i>
EGES-485-1	MaxxForce® 7 <i>Diagnostics Manual</i>
EGED-616	MaxxForce® 7 Hard Start and No Start Diagnostics Form
EGED-613	MaxxForce® 7 Performance Diagnostics Form
EGED-505-1	MaxxForce® 7 Electronic Control Systems Form

Technical Service Literature is revised periodically and mailed automatically to "Revision Service" subscribers. If a technical publication is ordered, the latest revision will be supplied.

NOTE: To order technical service literature, contact your International dealer.

Service Diagnosis

Service diagnosis is an investigative procedure that must be followed to find and correct an engine application problem or an engine problem.

If the problem is engine application, see specific vehicle manuals for further diagnostic information.

If the problem is the engine, see specific *Engine Diagnostic Manual* for further diagnostic information.

Prerequisites for Effective Diagnosis

- Availability of gauges and diagnostic test equipment
- Availability of current information for engine application and engine systems
- Knowledge of the principles of operation for engine application and engine systems
- Knowledge to understand and do procedures in diagnostic and service publications

Technical Service Literature required for Effective Diagnosis

- *Engine Service Manual*
 - *Engine Diagnostic Manual*
 - Diagnostics Forms
 - Electronic Control Systems Diagnostics Forms
 - Service Bulletins
-

Safety Information

This manual provides general and specific maintenance procedures essential for reliable engine operation and your safety. Since many variations in procedures, tools, and service parts are involved, advice for all possible safety conditions and hazards cannot be stated.

Read safety instructions before doing any service and test procedures for the engine or vehicle. See related application manuals for more information.

Disregard for Safety Instructions, Warnings, Cautions, and Notes in this manual can lead to injury, death or damage to the engine or vehicle.

Safety Terminology

Three terms are used to stress your safety and safe operation of the engine: Warning, Caution, and Note

Warning: A warning describes actions necessary to prevent or eliminate conditions, hazards, and unsafe practices that can cause personal injury or death.

Caution: A caution describes actions necessary to prevent or eliminate conditions that can cause damage to the engine or vehicle.

Note: A note describes actions necessary for correct, efficient engine operation.

Safety Instructions

Work Area

- Keep work area clean, dry, and organized.
- Keep tools and parts off the floor.
- Make sure the work area is ventilated and well lit.
- Make sure a First Aid Kit is available.

Safety Equipment

- Use correct lifting devices.
- Use safety blocks and stands.

Protective Measures

- Wear protective safety glasses and shoes.
- Wear correct hearing protection.
- Wear cotton work clothing.
- Wear sleeved heat protective gloves.
- Do not wear rings, watches or other jewelry.

- Restrain long hair.

Vehicle

- Make sure the vehicle is in neutral, the parking brake is set, and the wheels are blocked before servicing engine.
- Clear the area before starting the engine.

Engine

- The engine should be operated or serviced only by qualified individuals.
- Provide necessary ventilation when operating engine in a closed area.
- Keep combustible material away from engine exhaust system and exhaust manifolds.
- Install all shields, guards, and access covers before operating engine.
- Do not run engine with unprotected air inlets or exhaust openings. If unavoidable for service reasons, put protective screens over all openings before servicing engine.
- Shut engine off and relieve all pressure in the system before removing panels, housing covers, and caps.
- If an engine is not safe to operate, tag the engine and ignition key.

Fire Prevention

- Make sure charged fire extinguishers are in the work area.

NOTE: Check the classification of each fire extinguisher to ensure that the following fire types can be extinguished.

1. Type A — Wood, paper, textiles, and rubbish
2. Type B — Flammable liquids
3. Type C — Electrical equipment

Batteries

- Always disconnect the main negative battery cable first.
- Always connect the main negative battery cable last.
- Avoid leaning over batteries.
- Protect your eyes.

- Do not expose batteries to open flames or sparks.
- Do not smoke in workplace.

Compressed Air

- Use an OSHA approved blow gun rated at 207 kPa (30 psi).
- Limit shop air pressure to 207 kPa (30 psi).
- Wear safety glasses or goggles.
- Wear hearing protection.
- Use shielding to protect others in the work area.
- Do not direct compressed air at body or clothing.

Tools

- Make sure all tools are in good condition.
- Make sure all standard electrical tools are grounded.

- Check for frayed power cords before using power tools.

Fluids Under Pressure

- Use extreme caution when working on systems under pressure.
- Follow approved procedures only.

Fuel

- Do not over fill the fuel tank. Over fill creates a fire hazard.
- Do not smoke in the work area.
- Do not refuel the tank when the engine is running.

Removal of Tools, Parts, and Equipment

- Reinstall all safety guards, shields, and covers after servicing the engine.
 - Make sure all tools, parts, and service equipment are removed from the engine and vehicle after all work is done.
-

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Engine Identification

Engine Serial Number

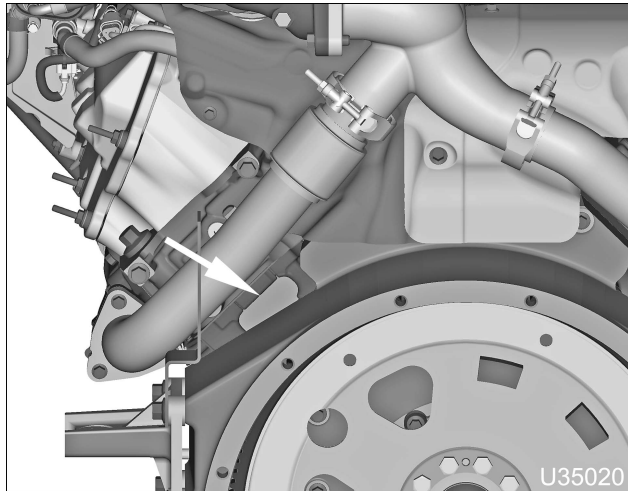


Figure 1 Engine serial number

The engine serial number is stamped on the crankcase pad, on the rear left side below the cylinder head.

Engine Serial Number Example

6.4HM2YXXXXXX

6.4 – Engine displacement (liters)

H – Diesel, turbocharged, air-intercooled and electronically controlled

M2 – Motor truck

Y – United States, Huntsville

7 digit suffix – Sequence number

Emission Label

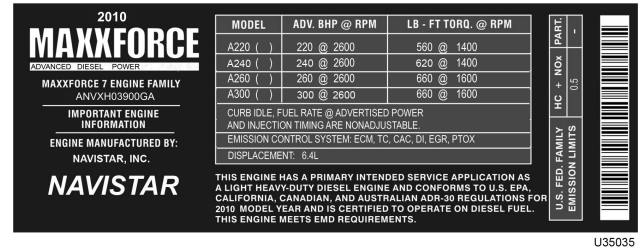


Figure 2 U.S. Environmental Protection Agency (EPA) exhaust emission label (example)

The U.S. Environmental Protection Agency (EPA) exhaust emission label is on top of the EGR manifold mixer on the front of the engine. The label includes the following:

- Advertised brake horsepower ratings
- Engine model code
- Service applications
- Emission family and control systems
- Year the engine was certified to meet EPA emission standards

Engine Accessories

The following engine accessories may have manufacturers' labels or identification plates:

- Air compressor
- Air conditioning compressor
- Alternator
- Cooling fan clutch
- Power steering pump
- Starter motor

Labels or identification plates include information and specifications helpful to vehicle operators and technicians.

Engine Description**MaxxForce® 7 Features and Specifications**

Engine configuration	4 stroke, V8 diesel
Displacement	6.4 liters (389 in ³)
Bore (sleeve diameter)	98.2 mm (3.87 in.)
Stroke	105 mm (4.134 in.)
Compression ratio	16.5:1
Aspiration	Dual Turbocharger and Charge Air Cooled (CAC)
Rated power @ rpm	See EPA exhaust emission label
Peak torque @ rpm	See EPA exhaust emission label
Engine rotation (facing flywheel)	Counterclockwise
Combustion system	Direct injection, turbocharged advanced EGR
Fuel system	Direct injection, common rail
Cooling system capacity (engine only)	10.23 liters (10.8 quarts US)
Lube system capacity (including filter)	18.9 liters (20 quarts US)
Lube system capacity (overhaul only, with filter)	19.9 liters (21 quarts US)
Firing order	1-2-7-3-4-5-6-8

Standard Features

The MaxxForce® 7 is a V8 engine with a displacement of 6.4 liters (389 cubic inches).

The electronic governor controls the engine rpm within a safe and stable operating range for ideal performance. A low-idle governor prevents the engine rpm from dropping below a stable speed to prevent stalling when various loads are demanded on the engine. A high-idle governor prevents the engine rpm from going above a safe speed that would cause internal damage to the engine.

The cylinder heads have four valves per cylinder. Each fuel injector is centrally located between the four valves and directs fuel over the piston bowl for improved performance and reduced emissions.

The camshaft is supported by five bushings pressed into the crankcase. The camshaft is crankshaft-driven and thrust is controlled by a plate mounted behind the rear bulkhead.

The overhead valve train includes hydraulic roller cam followers, push rods, rocker arms, and valve bridges to open the dual intake and exhaust valves.

The crankcase is composed of two major matching components. The upper crankcase houses the cylinders, main bearing saddles, and oil and coolant passages. Cast or machined. The lower crankcase consists of a structural plate with the main bearing caps machined into it for improved load retention and alignment.

The crankshaft is supported by five main bearings, with fore and aft thrust controlled at the upper half of the fourth main bearing. Two connecting rods are attached to each crankshaft rod journal and are offset to minimize vibration. Piston pins are free-floating, allowing the pins free, lateral movement within the connecting rod as well as the piston. Piston pins are held in place with retaining rings.

One-piece aluminum-alloy pistons are fitted with one keystone ring, one rectangular intermediate compression ring, and a two-piece oil control ring. The combustion bowl is located in the piston crown to reduce emissions. All pistons are mated to fractured cap joint connecting rods.

The Crankshaft Position (CKP) sensor and Camshaft Position (CMP) sensor are used by the Engine Control Module (ECM) to calculate rpm, fuel timing, fuel quantity, and duration of fuel injection.

The Exhaust Gas Recirculation (EGR) system includes an EGR valve, Intake Air Heater (IAH), and Engine Throttle Valve (ETV). The EGR valve assembly is mounted on the manifold mixer on the front top of the engine. The ETV is installed on the Intake Air Heater (IAH) mounted on the manifold mixer.

A gerotor lube oil pump, mounted on the front crankcase bulkhead, is driven by the crankshaft to supply pressurized oil to engine components. All MaxxForce® 7 engines use an engine oil cooler and spin-on oil filter. The oil filter is located at the lower driver-side corner of the engine where there is an integrated filter header to the cast-aluminum oil pan.

An open crankcase breather system draws crankcase vapors through a breather element. The breather element coalesces (separates) and oil migrates towards the low point in the housing which then gets returned back to crankcase. Clean blow-by gas (vapors) exit the breather cover and vents out to atmosphere.

The high-pressure fuel system includes a High-pressure Fuel Pump (HPFP), high-pressure common rails, and fuel injectors. The ECM electronically controls the injectors, which allows multiple injections and more precise fuel delivery to improve combustion, emissions, and cold-start performance.

The low-pressure fuel system uses an electric fuel lift pump to draw fuel from the fuel tank(s) to the engine. This eliminates the need for a hand primer. The pump is located in the primary and secondary fuel module mounted over the left valve cover. The primary fuel filter assembly includes a Water in Fuel (WIF) sensor and an optional fuel heater. Water and solids are separated from the fuel and the water is collected in the water separator bowl. The instrument panel WIF lamp illuminates and 'Water in Fuel' message is displayed when water needs to be drained. A manual drain valve is provided in the water separator bowl to drain water out. Fuel is discharged to the secondary fuel filter. The secondary fuel filter assembly is pressure-regulated and incorporates an air bleed orifice to automatically purge air introduced into the system.

A two-stage turbocharger provides boost air pressure to the engine for various speed and load conditions. An electronically controlled solenoid modulates boost air to a wastegate actuator.

The EGR system circulates cooled exhaust into the intake air stream in the intake manifold. This cools the combustion process and reduces the formation of NO_x engine emissions.

Diamond Logic® engine control is a single electronic control unit that monitors and controls the engine and chassis components.

A relay-controlled grid heater is used to aid cold, ambient starting

A coolant heater raises the temperature of the coolant surrounding the cylinders for improved performance during cold weather startups.

Optional Features

An air compressor is available for applications that require air brakes or air suspension.

An optional fuel heater is available and installed in the primary fuel filter assembly. It warms the supply fuel

to prevent waxing during cold conditions where the fuel filter module's internal fuel passages between the primary and secondary filter do not provide sufficient warming.

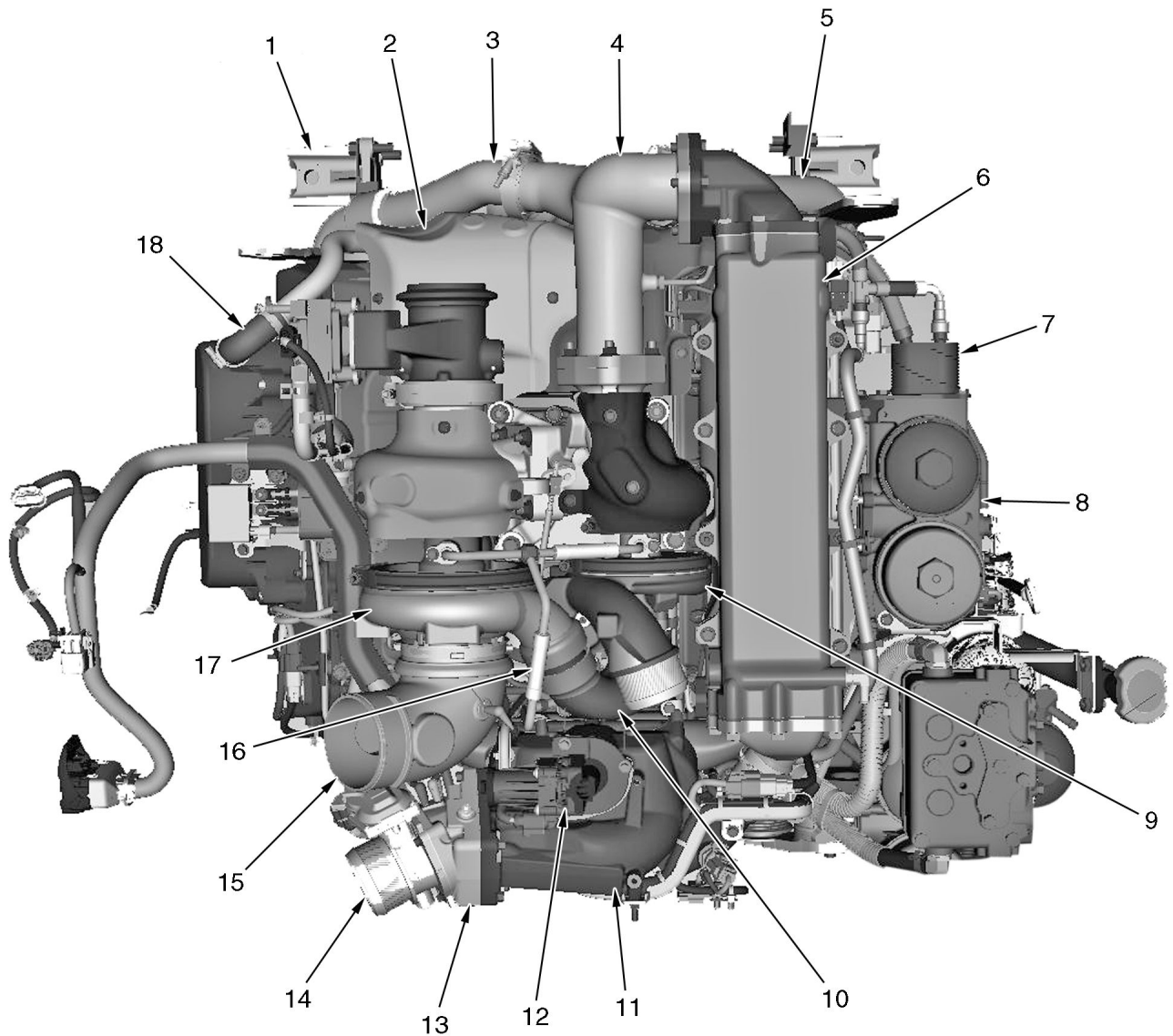
Chassis-mounted Features

A Charge Air Cooler (CAC) is an air-to-air heat exchanger which increases the density of the air charge.

The Aftertreatment System processes engine exhaust so that it meets emission requirements at the tailpipe.

- The oxidation catalyst removes oxygen and hydrocarbons in the exhaust stream.
 - The Diesel Particulate Filter (DPF) captures and removes particulates in the exhaust stream.
-

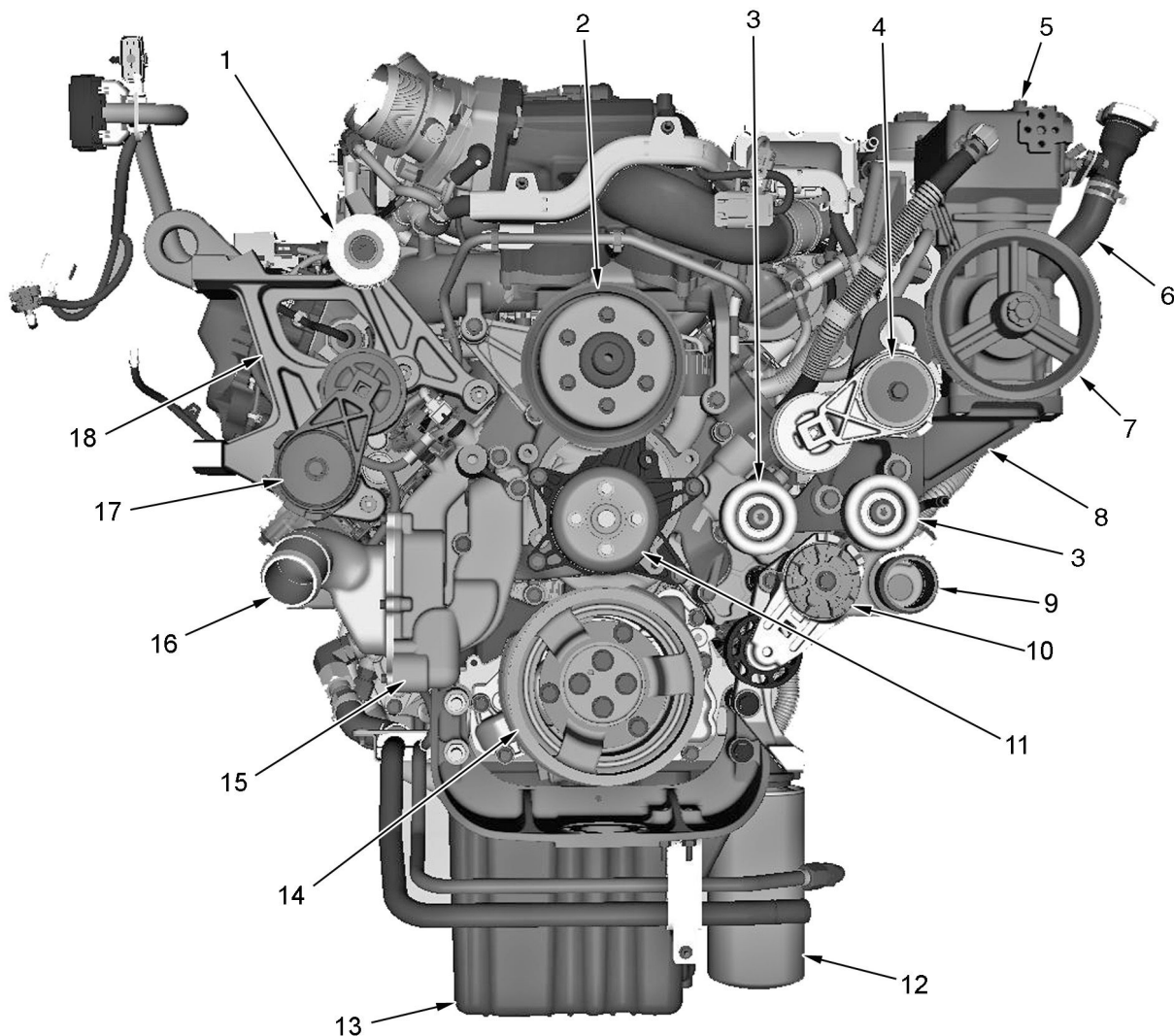
Engine Components



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Figure 3 Top

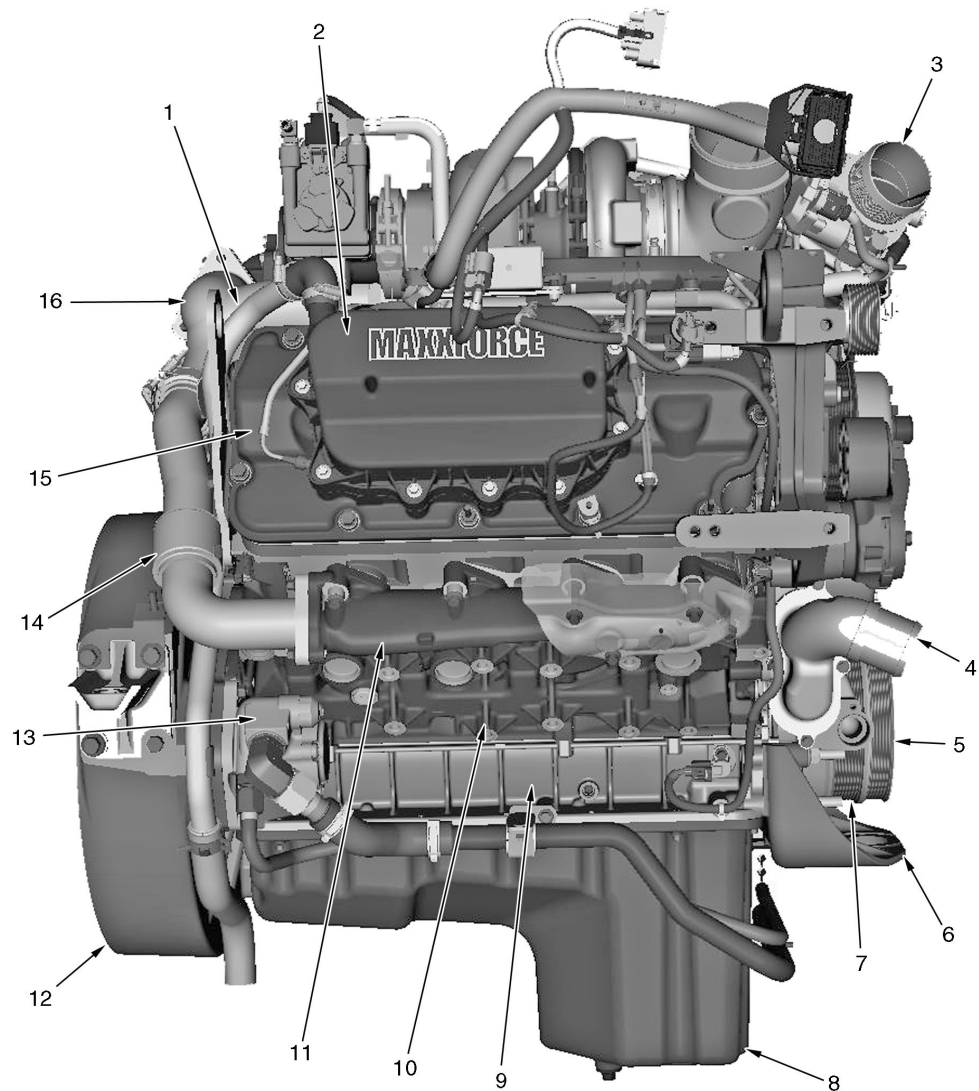
1. Rear engine mounting bracket (2)	7. Fuel cooler	14. Engine Throttle Valve (ETV)
2. Pump cover heat shield (right)	8. Fuel filter module housing	15. Turbocharger inlet duct assembly
3. Right exhaust tube assembly	9. High-pressure turbocharger assembly	16. Turbocharger oil supply tube
4. Exhaust turbocharger inlet manifold	10. Crossover tube	17. Low-pressure turbocharger assembly
5. Left exhaust tube assembly	11. Manifold mixer	18. Draft tube
6. EGR cooler	12. EGR valve	
	13. Inlet Air Heater (IAH)	



U35401

Figure 4 Front

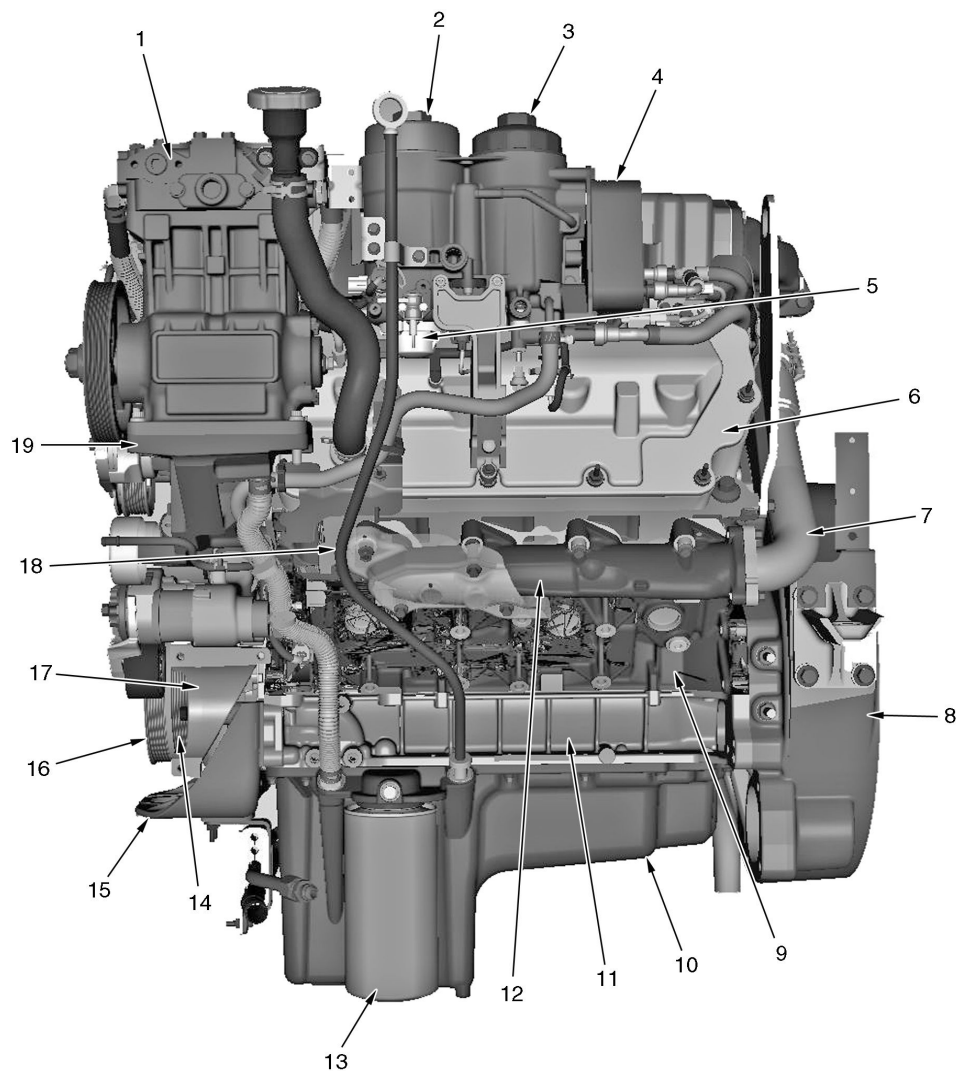
1. Grooved idler pulley	8. Air compressor bracket	13. Oil pan
2. Fan pulley	9. Coolant inlet	14. PTO air compressor front pulley
3. Flat idler pulley (2)	10. Belt tensioner (if equipped with secondary refrigerant compressor and without air compressor)	15. Front crankcase cover (heater return)
4. Belt tensioner (if equipped with air compressor)		16. Thermostat housing (coolant outlet)
5. Air compressor		17. Belt tensioner
6. Oil fill tube assembly	11. Water pump pulley	18. Alternator bracket
7. Air compressor pulley	12. Oil filter assembly	



U35402

Figure 5 Right

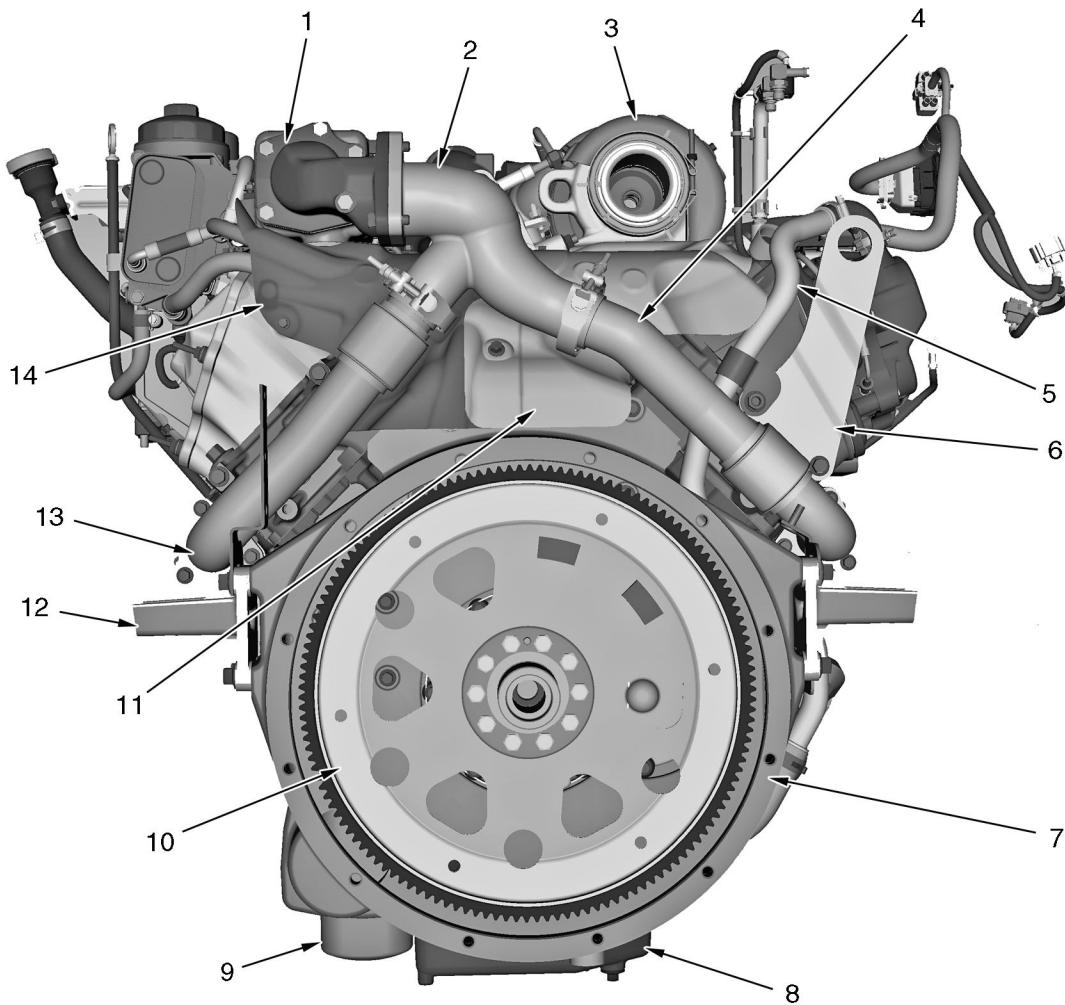
1. Draft tube	7. Vibration damper	13. Power steering pump
2. Breather cover	8. Oil pan	14. Right exhaust tube assembly
3. ETV	9. Lower crankcase	15. Right valve cover
4. Thermostat housing (coolant return)	10. Upper crankcase	16. Exhaust turbocharger inlet manifold
5. PTO air compressor front pulley	11. Right exhaust manifold	
6. Front engine mounting support	12. Rear crankcase cover assembly (flywheel housing)	



U35403

Figure 6 Left

1. Air compressor assembly	8. Crankcase rear cover (flywheel housing)	14. Vibration damper
2. Filter cap (primary)	9. Upper crankcase	15. Front engine mounting support
3. Filter cap (secondary)	10. Oil pan	16. PTO air compressor front pulley
4. Fuel cooler	11. Lower crankcase	17. Secondary freon compressor bracket
5. Fuel pump	12. Left exhaust manifold	18. Oil level gauge tube
6. Left valve cover	13. Oil filter	19. Air compressor bracket
7. Left exhaust tube assembly		



U35404

Figure 7 Rear

1. EGR cooler	5. Draft tube	10. Flexplate
2. Exhaust turbocharger inlet manifold	6. Lifting eye	11. Pump cover heat shield (right)
3. Low-pressure turbocharger assembly	7. Crankcase rear cover (flywheel housing)	12. Rear engine mounting bracket (2)
4. Right exhaust tube assembly	8. Oil pan	13. Left exhaust tube assembly
	9. Oil filter	14. Pump cover heat shield (left)

Air Flow

Air flows through the air filter assembly and enters the low-pressure turbocharger. The compressor in the low-pressure turbocharger increases pressure, temperature, and density of the intake air before it enters the air crossover tube. From the air crossover tube assembly, air enters the high-pressure turbocharger. The high-pressure turbocharger compressor further increases the pressure, temperature, and density of the intake air. The high-pressure Turbocharger 1 Wastegate Control (TC1WC) solenoid and the TC1WC actuator control the output of the high-pressure turbocharger by adjusting the wastegate valve inside the turbocharger. From the high-pressure turbocharger, air enters the Charge Air Cooler (CAC). Cooled compressed air flows from the CAC through the ETV and Exhaust Gas Recirculation (EGR) mixer into the intake manifold.

If the EGR valve is open, some exhaust gas mixes with compressed intake air inside the EGR mixer and flows into the cylinders. If the EGR valve is closed, only compressed intake air flows into the cylinders.

After combustion, exhaust gas is forced through the exhaust manifolds to the EGR cooler and turbochargers. Some exhaust gas is cooled in the EGR cooler and flows through the EGR valve to the intake air stream. When exhaust gas mixes with air and fuel, it reduces the formation of Nitrogen Oxides (NO_x) engine emissions. The rest of the exhaust gas

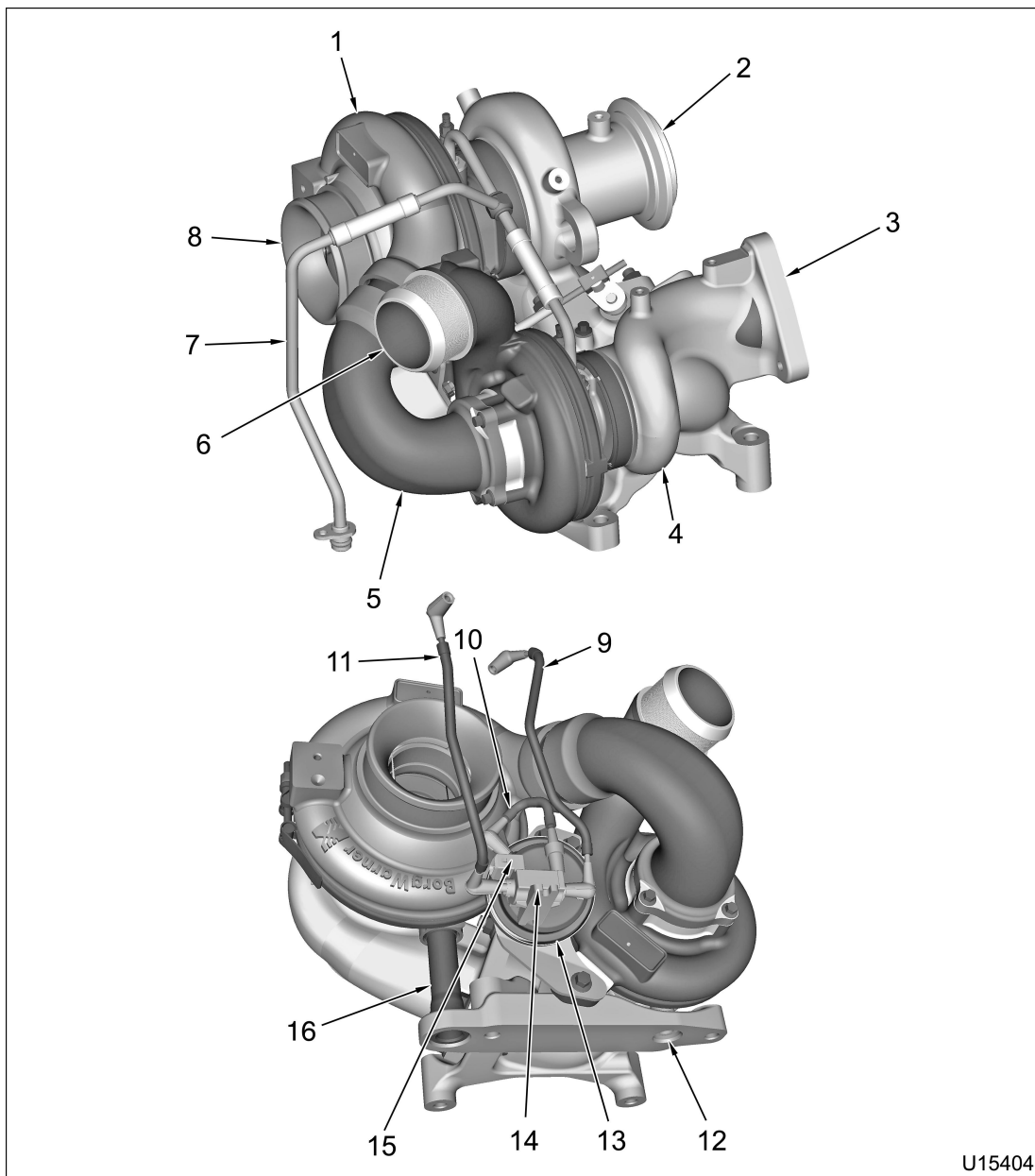
flows through the high-pressure turbocharger turbine and then through the low-pressure turbocharger turbine. The high-pressure turbine is on the same shaft as the high-pressure turbocharger compressor and compresses the mixture of filtered air. The low-pressure turbocharger turbine is on the same shaft as the low-pressure compressor.

The high-pressure TC1WC actuator is controlled by the Engine Control Module (ECM) and responds to engine loads. During heavy loads, increased exhaust flow turns the turbine wheel faster. This increased speed turns the compressor impeller faster and supplies greater boost pressure to the intake manifold. To prevent too much boost from building, the wastegate valve diverts exhaust away from the turbine wheel. Conversely, when engine load is light, the flow of exhaust decreases and less air is forced into the intake manifold. Therefore, the wastegate valve forces more exhaust towards the turbine wheel to compensate.

Charge Air Cooler (CAC)

Air from the dual stage turbocharger assembly passes through a network of heat exchanger tubes inside the CAC before entering the ETV. Outside air flows through the CAC and cools the charged air. Cooled intake air improves the fuel-to-air ratio during combustion. This results in improved emission control and power output.

Dual Turbocharger Assembly



U15404

Figure 9 Dual Turbocharger Assembly

1. Low-pressure turbocharger	7. Turbocharger oil supply tube	14. TC1WC solenoid
2. Low-pressure turbocharger turbine outlet	8. Air inlet	15. TC1WC solenoid electrical connector
3. Exhaust inlet	9. Relief-to-duct tube assembly	16. Low-pressure turbocharger drain tube
4. High-pressure turbocharger	10. Wastegate tube assembly	
5. Crossover tube	11. Boost solenoid tube assembly	
6. High-pressure turbocharger compressor outlet	12. High-pressure turbocharger drain port	
	13. TC1WC actuator	

MaxxForce® 7 engines are equipped with an electronically controlled dual turbocharging system. This system provides high levels of charge air pressure to improve engine performance and reduce emissions. The dual turbocharger assembly is connected to the turbocharger exhaust inlet manifold. Because of its ability to generate very high charge air pressure levels and to prevent Charge Air Cooler (CAC) overloading conditions, the system is fitted with a spring-loaded turbocharger wastegate valve.

The turbocharger wastegate valve is actuated by boost air pressure. Boost air pressure to the TC1WC actuator is controlled by an electronically controlled TC1WC solenoid, based on a Pulse Width Modulation (PWM) signal supplied by the Engine Control Module (ECM).

High-pressure Turbocharger

The high-pressure turbocharger assembly is equipped with a wastegate valve that regulates turbocharger boost by controlling the amount of exhaust gases that pass through the high-pressure turbine. When the boost demand is high, or when the boost demand reaches a predetermined value, the TC1WC actuator opens the wastegate valve. This allows part of the exhaust gas flow to bypass the high-pressure turbine. Compressed air from the low-pressure compressor housing enters the high-pressure turbine compressor through the air crossover tube. Where it is further compressed and sent to the charge air cooler.

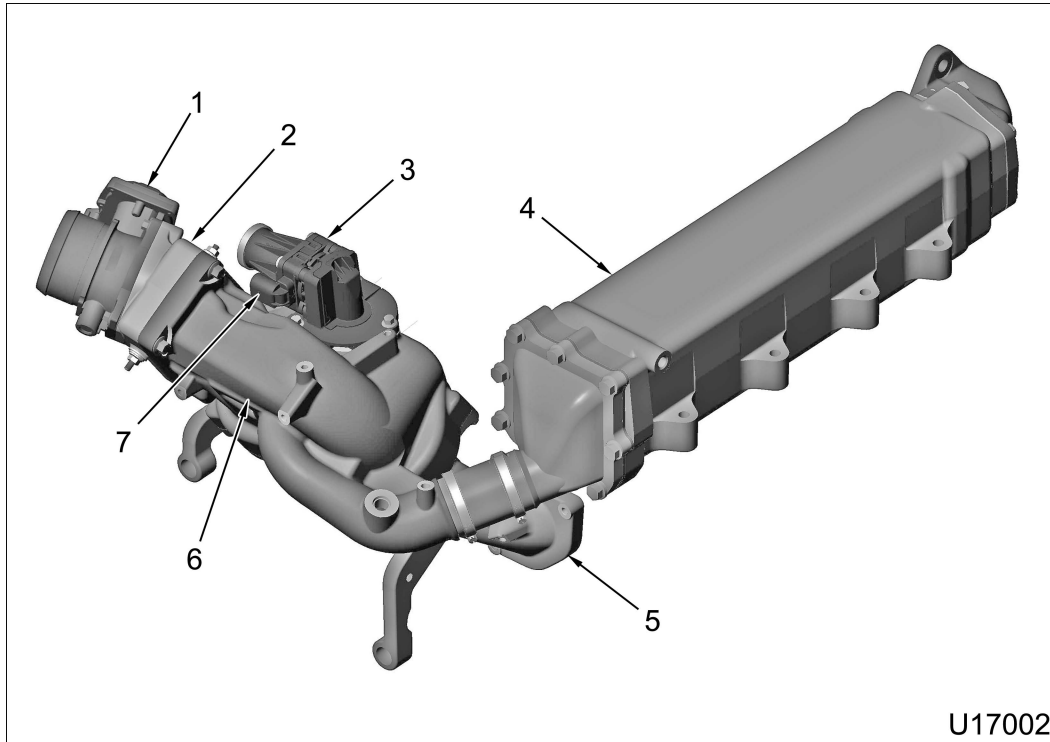
Low-pressure Turbocharger

The low-pressure turbine is attached directly to the output of the high-pressure turbine. The exhaust gases enter the low-pressure turbine housing and exit through the low-pressure turbine outlet. Fresh air from the air filter enters the low-pressure compressor where it is compressed and air from the low-pressure compressor is piped directly to the high-pressure compressor inlet.

Turbocharger 1 Wastegate Control (TC1WC) Solenoid

The TC1WC solenoid controls the TC1WC actuator by regulating the boost control air supply based on a Pulse Width Modulation (PWM) signal received from the ECM.

With no PWM signal, the TC1WC solenoid is open and control air is supplied to the TC1WC actuator maintaining it in the open position. When an increase in the charge air pressure is required, the ECM supplies PWM voltage to close the TC1WC solenoid. When the TC1WC solenoid closes, it interrupts the control air supply to the TC1WC actuator and at the same time relieves the air pressure from the TC1WC actuator by allowing it to vent to the turbocharger inlet duct. The TC1WC actuator then closes, resulting in increased charge air pressure.

Exhaust Gas Recirculation (EGR) System

U17002

Figure 10 EGR system

1. Engine Throttle Valve (ETV)	4. EGR cooler	7. EGR valve connector
2. Inlet Air Heater (IAH)	5. Distribution duct	
3. EGR valve	6. Manifold mixer	

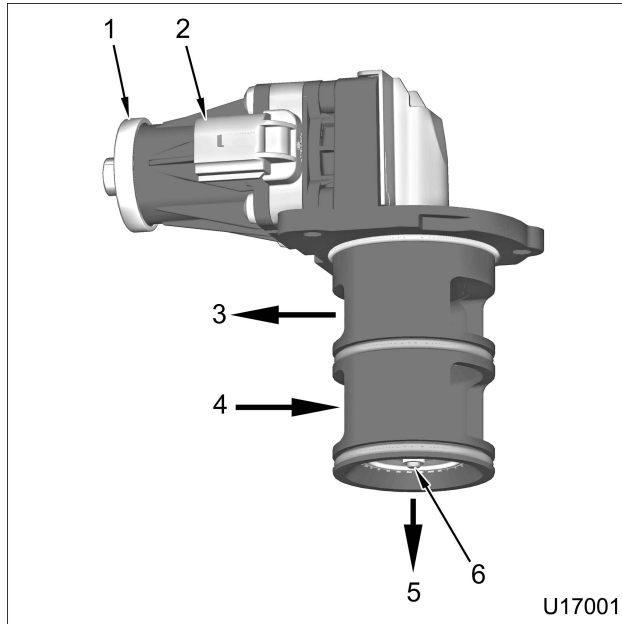
Exhaust Gas Recirculation (EGR) is an emission-control technology, which significantly reduces Nitrogen Oxide (NO_x) emissions. The EGR system is also used to adjust the fuel-to-air ratio for Diesel Particulate Filter (DPF) regeneration.

NO_x gas forms during a reaction between nitrogen and oxygen at the high temperatures of combustion. By mixing exhaust gases with the inlet air, peak combustion temperature is reduced thus reducing the formation of NO_x emissions.

EGR Flow

Some exhaust from the turbocharger inlet manifold flows into the EGR cooler. Exhaust from the EGR cooler flows into a manifold mixer, through the EGR valve, and then into the intake manifold.

When EGR is required, the EGR valve opens, allowing cooled exhaust gases to enter the intake manifold to be mixed with filtered intake air. The exhaust gases are then recycled through the combustion process.

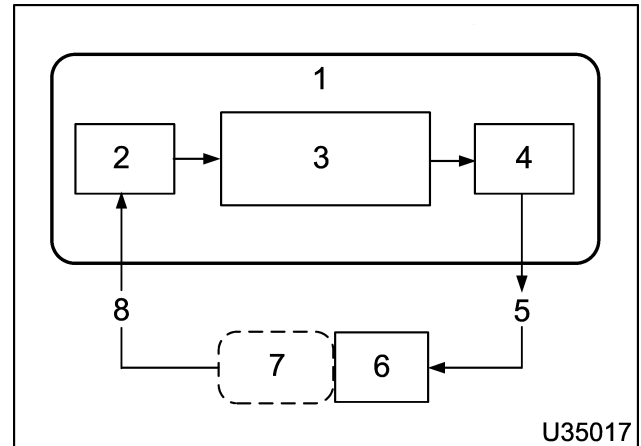
EGR Control Valve and Position Sensor**Figure 11 EGR valve**

1. Direct Current (DC) motor
2. Electrical connector
3. Exhaust outlet
4. Exhaust inlet
5. Exhaust outlet
6. Poppet valve assembly

The EGR valve uses a DC motor to control the position of the poppet valve assembly. The motor

drives the poppet valve assembly, while driving the position sensor. The poppet valve assembly has two valve heads (poppets) on a common shaft.

Exhaust flow enters the EGR valve elbow housing and enters the EGR valve. Exhaust flows through the two valve poppets into the manifold mixer, where it mixes with incoming air from the air inlet throttle valve. The mixed air goes into the intake manifold and cylinders.

**Figure 12 EGR closed loop operation**

1. ECM
2. Measured position
3. Compare with desired position
4. Adjust duty cycle
5. Duty cycle
6. EGR valve
7. Position sensor
8. Voltage

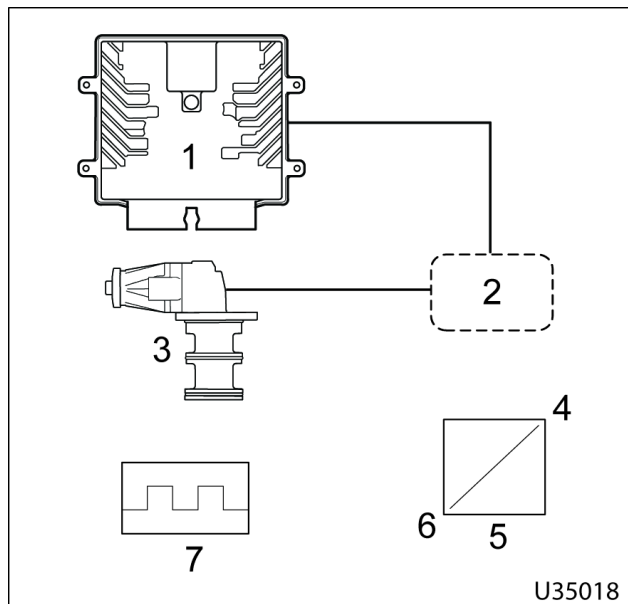


Figure 13 EGR control

1. ECM
2. Position sensor
3. EGR valve
4. 5 volts
5. Analog voltage
6. 0 volts
7. Output signal

The EGR valve consists of two major components: a valve body and an actuator motor. A Hall-effect position sensor monitors valve movement. The EGR valve assembly is mounted on the manifold mixer on the front top of the engine

The EGR motor receives the desired EGR position from the ECM to position the valve for exhaust gas recirculation. The EGR position sensor provides feedback to the ECM on the valve position.

Engine Throttle Valve (ETV) and Position Sensor

ETV regulates the amount of fresh air flow coming into the system. When the engine needs fresh air,

the default state of the ETV is opened. When air flow needs to be restricted, the ETV is commanded to close by the ECM.

The ECM monitors the Aftertreatment System. The ECM controls the ETV during AFT regeneration and purge. The ETV is controlled to restrict intake air, which increases the exhaust temperature to clean the Diesel Particulate Filter (DPF). The ETV is also used to help drive more EGR during normal operation.

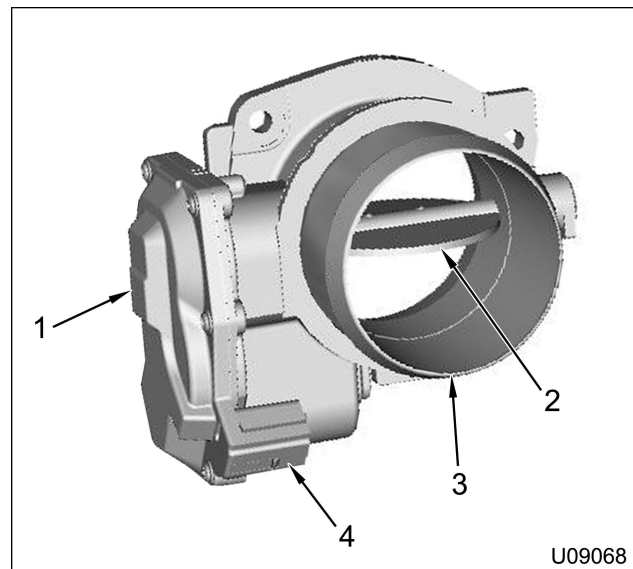


Figure 14 ETV

1. DC motor
2. Throttle blade
3. Inlet air intake
4. Electrical connector

The ETV uses a DC motor to control the position of the throttle blade. The motor drives the throttle blade, while at the same time the position sensor is being read. The ETV consists of two major components, the valve body and actuator motor. A Hall-effect position sensor monitors valve movement.

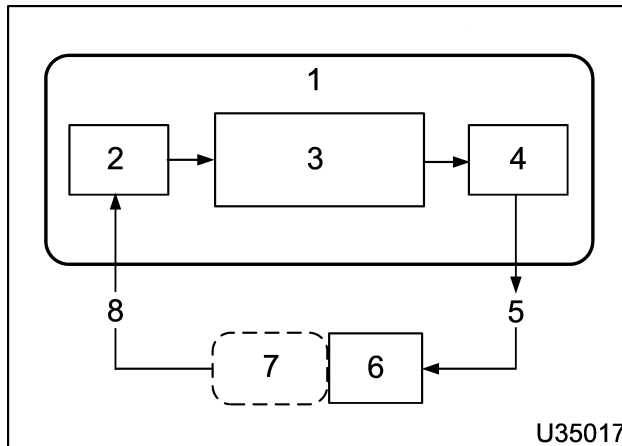


Figure 15 ETV closed loop operation

1. ECM
2. Measured position
3. Compare with desired position
4. Adjust duty cycle
5. Duty cycle
6. ETV
7. Position sensor
8. Voltage

The ETV motor receives the desired valve position from the ECM to position the valve for fresh air flow. The position sensor provides feedback to the ECM on valve position.

Aftertreatment (AFT) System

The AFT System, part of the larger exhaust system, processes engine exhaust to meet emissions requirements. The AFT system traps particulate matter (soot) and prevents it from leaving the tailpipe.

AFT Control System

The control system performs the following functions:

- Monitors exhaust gases and aftertreatment system, and controls engine operating parameters for emission processing and failure recognition
- Cancels regeneration in the event of catalyst or sensor failure
- Monitors the level of soot accumulation in the DPF and adapts engine operating characteristics to compensate for increased back pressure

- Controls engine operating parameters to make regeneration automatic
- Maintains vehicle and engine performance during regeneration

Sensors

Sensors produce a representative electronic signal based on temperature and pressure. It is used by the control system to regulate the aftertreatment function.

The sensors measure temperature and pressure in the exhaust flow.

Diesel Oxidation Catalyst (DOC)

The DOC does the following:

- Oxidizes hydrocarbons and carbon monoxide (CO) in exhaust stream
- Provides heat for exhaust system warm-up
- Aids in system temperature management for the DPF
- Oxidizes NO into NO₂ for passive DPF regeneration

Diesel Particulate Filter (DPF)

The DPF does the following:

- Captures and temporarily stores carbon-based particulates in a filter
- Allows for oxidation (regeneration) of stored particulates once loading gets to a particular level (pressure drop)
- Reduces exhaust back pressure for optimized engine performance by reducing the soot load through regeneration into ash
- Stores noncombustible ash

AFT Conditions and Responses

The operator is alerted audibly or with instrument panel indicators of system status. Automatic or manual regeneration is required when levels of soot exceed acceptable limits. For additional information see the applicable vehicle *Operator's Manual* and the vehicle visor placard.

Fuel System

Fuel System Components

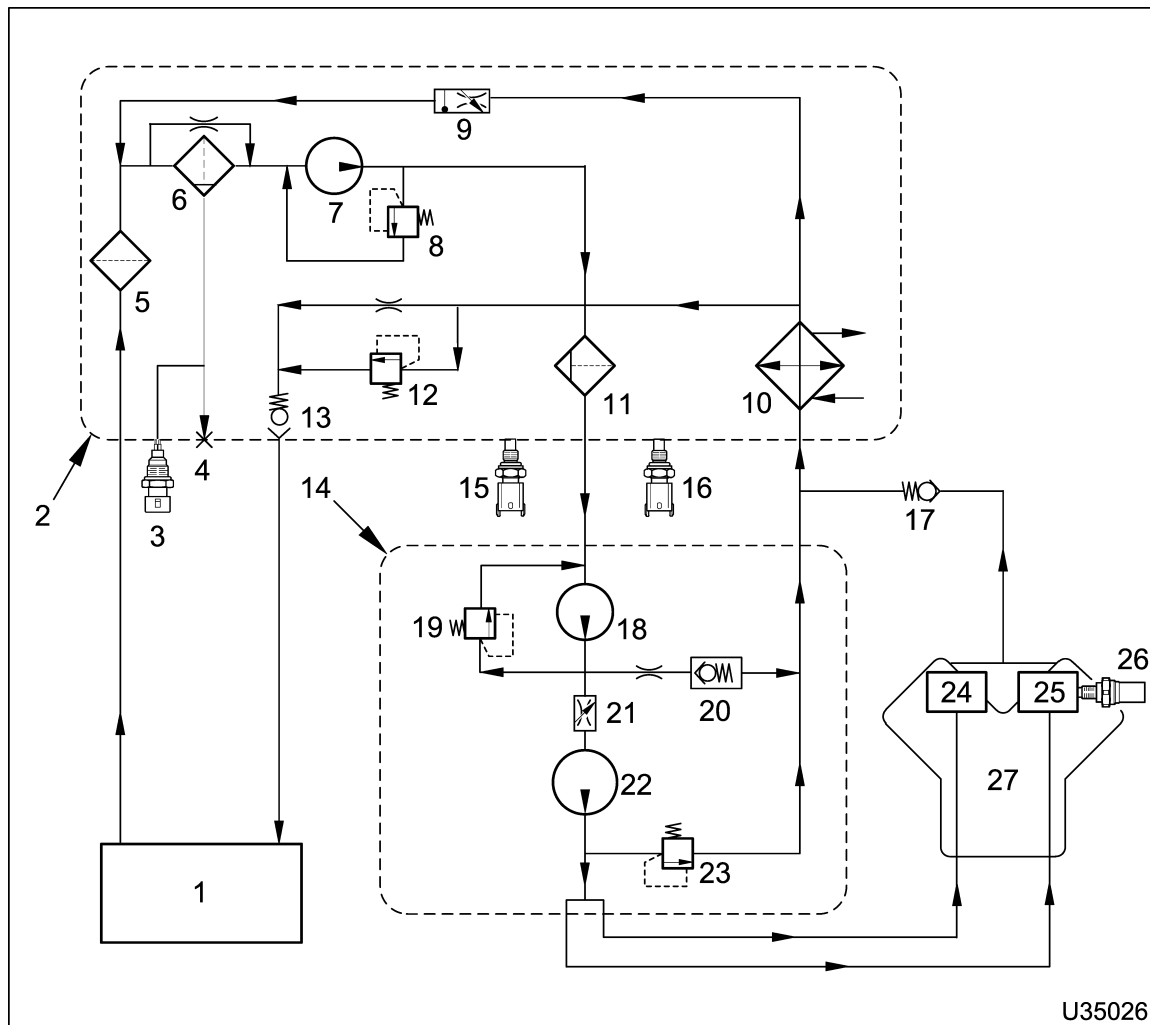


Figure 16 Fuel system schematic

1. Fuel tank	14. Engine High Pressure Fuel Pump (HPFP)	21. Fuel Volume Control Valve (FVCV)
2. Fuel filter module housing	15. Fuel Delivery Pressure (FDP) sensor (optional)	22. HPFP
3. Water In Fuel (WIF) sensor	16. Engine Fuel Temperature (EFT) sensor	23. Fuel Pressure Control Valve (FPCV)
4. Manual water drain	17. Injector Leak Off (ILO) check valve	24. High-pressure Common Rail (HPCR) (Left)
5. Fuel heater (Optional)	18. Internal Transfer Pump (ITP)	25. High-pressure Common Rail (HPCR) (Right)
6. Primary fuel filter	19. ITP regulator	26. Fuel Rail Pressure (FRP) sensor
7. Fuel Pump	20. HPFP cooling and lubrication flow valve	27. Engine
8. Pressure relief valve		
9. Thermal recirculation valve		
10. Liquid fuel cooler		
11. Secondary fuel filter		
12. Pressure regulator		
13. Shutoff valve		

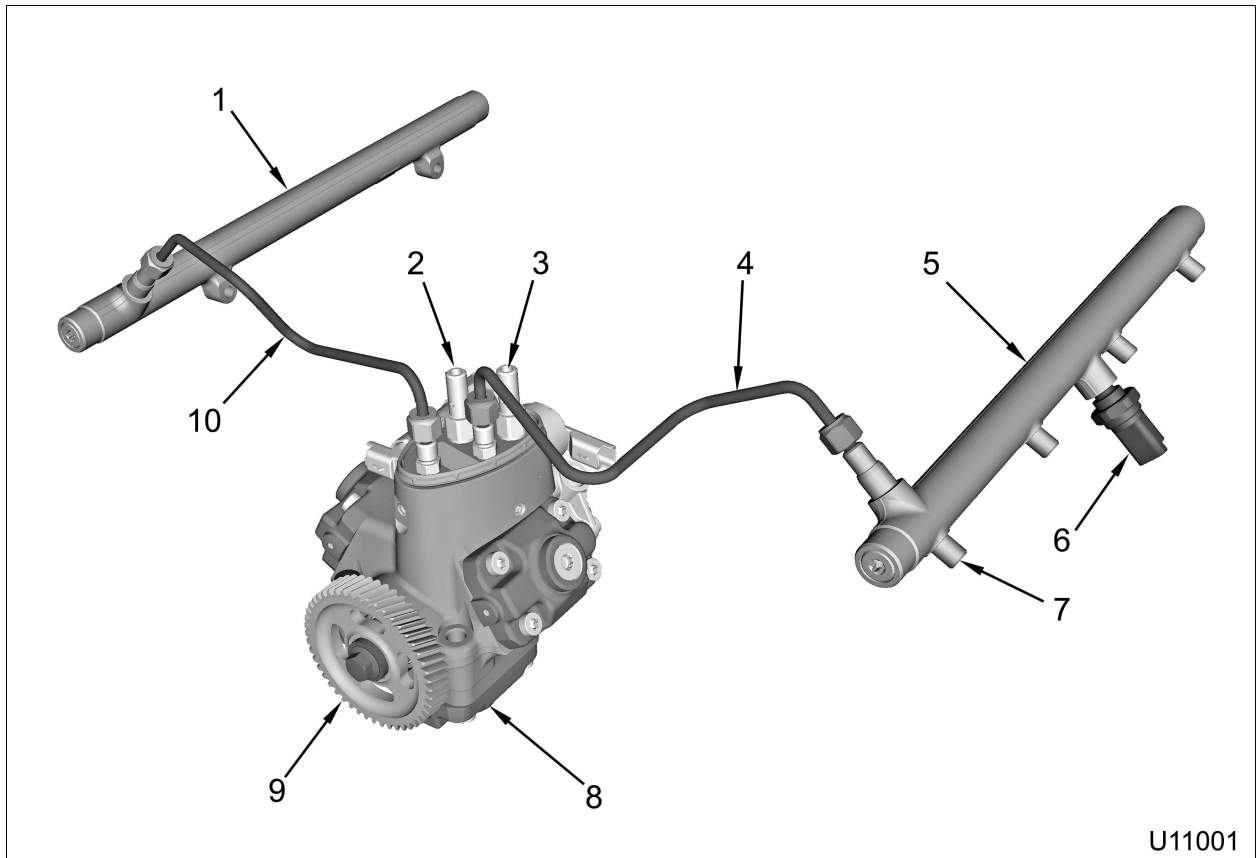


Figure 17 High-pressure fuel system

1. Left rail assembly	5. Right rail assembly	10. Pump left tube assembly (pump-to-rail)
2. Pump return hose connection (pump-to-cooler)	6. Fuel Rail Pressure (FRP) sensor	
3. Filter to pump hose connection (secondary fuel filter-to-pump)	7. Fuel rail-to-injector fuel tube port (4 for each rail)	
4. Pump right tube assembly (pump-to-rail)	8. HPFP	
	9. HPFP gear	

High-pressure Fuel System

High-pressure Fuel Pump (HPFP) Assembly

The HPFP is a three-piston volumetric pump that supplies fuel at high pressure to both fuel rails. The HPFP is mounted in the rear valley on top of the engine and is driven by the camshaft.

Internal Transfer Pump (ITP)

The ITP is part of the HPFP assembly and driven off the same shaft as the HPFP assembly. The ITP supplies fuel at a slightly higher pressure and flow

to the HPFP through the Fuel Volume Control Valve (FVCV). The ITP also provides fuel for cooling and lubrication of the HPFP. Fuel is rerouted as pump return flow through the HPFP cooling and lubrication valve. Pressure is maintained at the inlet of the HPFP piston pump by an ITP regulator.

Fuel Pressure Control Valve (FPCV)

The FPCV controls the fuel pressure to the fuel rails. The FPCV is located in the HPFP assembly and is controlled by the ECM. FPCV control depends on fuel pressure and fuel temperature.

Fuel Volume Control Valve (FVCV)

The FVCV regulates the volume of flow sent to the HPFP. The FVCV is located in the HPFP assembly and is controlled by fuel rail pressure, via the ECM. The FVCV allows just sufficient quantity of fuel to be delivered to the HPFP depending on engine load, speed, injector quantity, fuel temperature, and number of injections per cycle.

Fuel Rail Pressure (FRP) Sensor

The FRP sensor monitors fuel pressure in the fuel rails and sends a signal to the ECM. The FRP sensor is installed in the right fuel rail. The FRP sensor harness is routed through the right Under Valve Cover (UVC) harness along with the fuel injector connections.

High-pressure Piezo Common Rail (HPCR) System

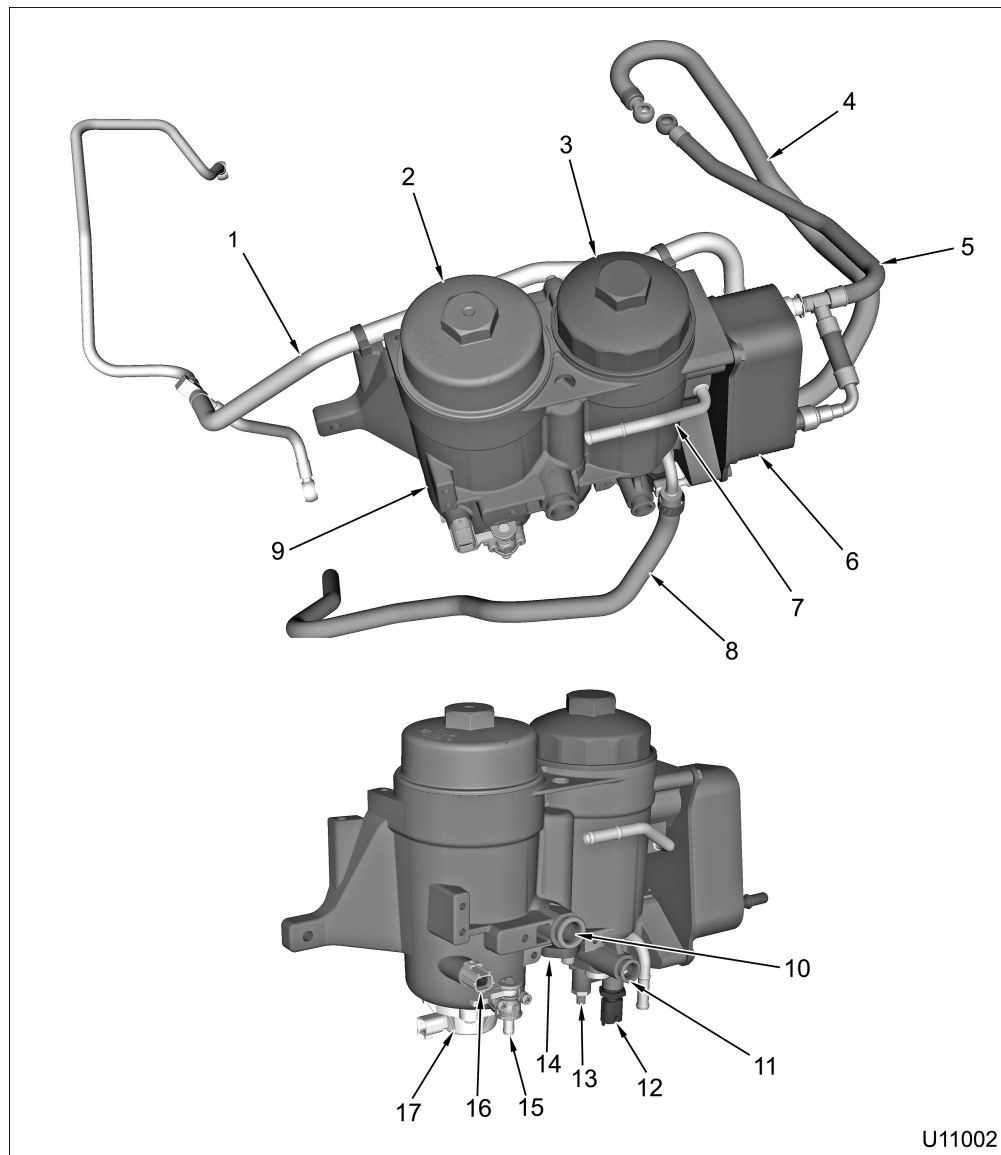
The HPFP pumps fuel through separate tubes to each fuel rail. Each fuel rail has four fuel tubes, one for each injector, that maintain constant pressure from the high-pressure pump to each injector.

The injectors are capable of five injections; two pre-injection, a main-injection, a post-injection, and a late post-injection. Pre-injection and post-injection reduce combustion noise, mechanical load, and exhaust emissions. The main-injection cycle injects and atomizes fuel in the combustion chambers for combustion. The late post-injection cycle adds fuel to the exhaust to regenerate the aftertreatment system.

Each injector has an actuator that opens or closes the injector nozzle holes. Charging the actuator opens the nozzle holes; discharging the actuator closes the nozzle holes. The ECM charges and discharges each actuator by energizing the appropriate high-side or low-side output. The low-side output supplies a return circuit for each actuator.

Return Fuel System

The return fuel system moves unused fuel from the fuel injectors to the fuel cooler. Excess fuel out of the FVCV and the FPCV mix with fuel from the fuel injectors on the way to the fuel cooler.



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Figure 18 Low-pressure fuel system

1. Injector return hose assembly	9. Fuel filter module housing	14. Fuel heater block-off plate or fuel heater (optional)
2. Filter cap (primary)	10. Fuel inlet from tank	15. Water drain valve
3. Filter cap (secondary)	11. Fuel return to tank	16. Water In Fuel (WIF) sensor
4. Filter-to-pump hose assembly	12. Engine Fuel Temperature (EFT) sensor	17. Fuel Pump
5. Pump-to-cooler hose assembly	13. Diagnostic valve (standard) or Fuel Delivery Pressure (FDP) sensor (optional)	
6. Fuel cooler		
7. Coolant supply hose		
8. Coolant return hose		

Low-pressure Fuel System**Fuel Pump**

A constant-flow electric pump draws fuel from the fuel tank(s) through the primary fuel filter and supplies fuel to the secondary fuel filter. The fuel pump is mounted at the bottom center of the primary fuel filter.

Primary Fuel Filter

A 10–micron primary filter removes water and filters fuel from the fuel tank(s). The primary filter is above the low-pressure fuel pump.

Secondary Fuel Filter

A 3–5 micron secondary fuel filter assembly also removes water and filters fuel from the low-pressure fuel pump. The filter has an internal drilled air bleed orifice to automatically remove air from the fuel. The filtered fuel from the primary fuel filter is mixed with the cooled fuel from the fuel cooler and is directed to a secondary fuel filter. System pressure is maintained by an internal pressure regulator.

Fuel from the pressure regulator and air bleed orifice returns to the fuel tank(s).

The fuel module has a temperature sensor mounted in the supply line to the HPFP. A fuel temperature sensitive recirculation fuel valve allows some warmer recirculated fuel from the fuel cooler to flow to the primary filter when tank fuel is colder. This helps prevent filter waxing. When fuel temperatures are warm to hot, the valve closes and all recirculated fuel goes into the secondary housing where it mixes with fuel from the primary filter, electric pump, and tank.

Fuel Cooler

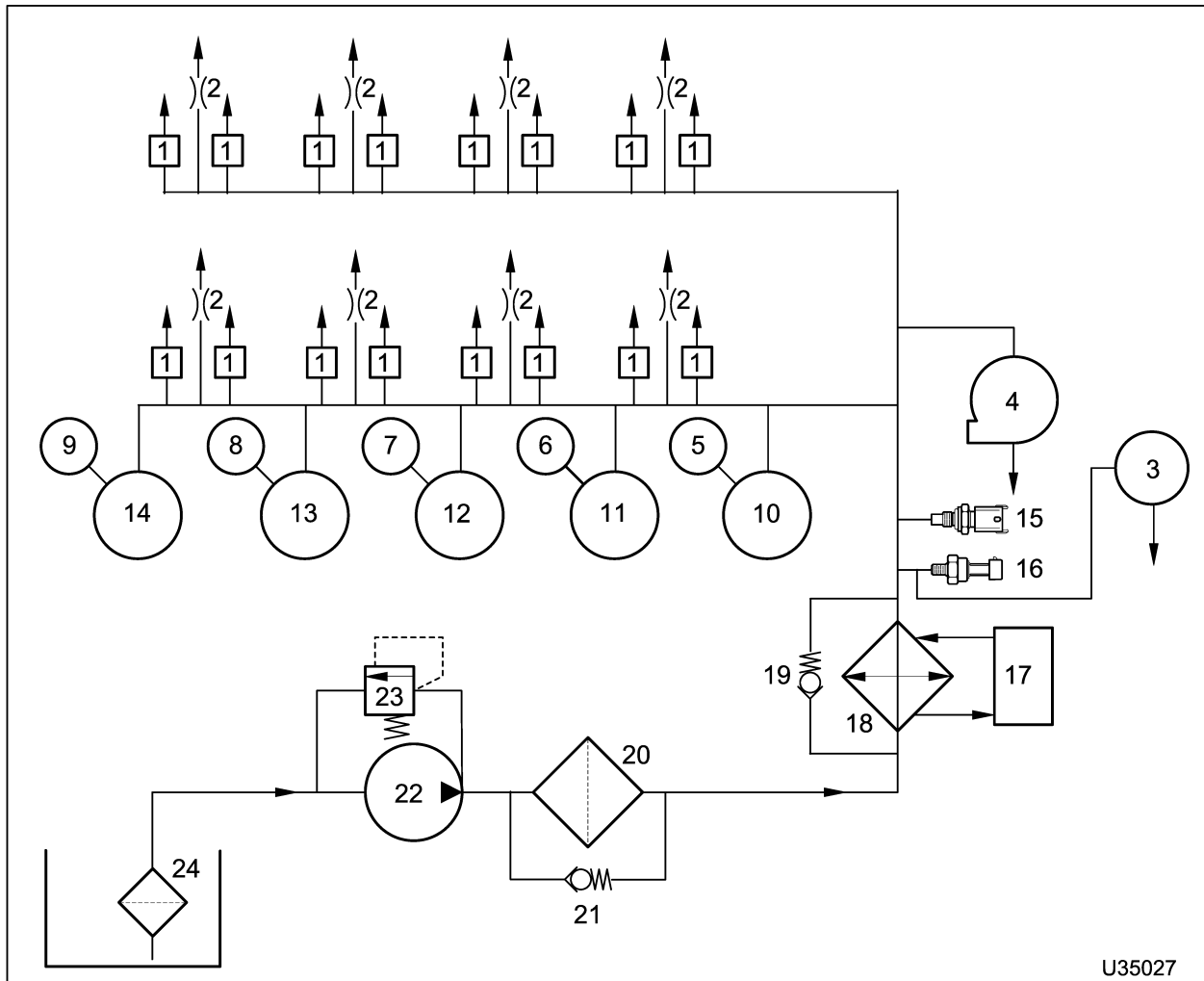
The combined fuel from the fuel injectors and the HPFP is cooled by the fuel cooler using engine coolant. Cooled fuel is then directed to the inlet of the secondary fuel filter.

Fault Detection/Management

The ECM can detect if the output is shorted to ground/battery, the output is open, or if an injector is shorted.

Engine Lubrication System

Lubrication System Components and Oil Flow



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Figure 19 Lubrication system

1. Camshaft follower	10. Main bearing 1 and crank pins	17. Engine coolant
2. Piston cooling tube	11. Main bearing 2 and crank pins	18. Oil cooler
3. Air compressor (optional)	12. Main bearing 3 and crank pins	19. Bypass valve
4. Dual turbocharger assembly	13. Main bearing 4 and crank pins	20. Oil filter
5. Cam bearing 1	14. Main bearing 5 and crank pins	21. Bypass valve
6. Cam bearing 2	15. Engine Oil Temperature (EOT) sensor	22. Oil Pump
7. Cam bearing 3	16. Engine Oil Pressure (EOP) sensor	23. Pressure regulator
8. Cam bearing 4		24. Oil pickup and screen
9. Cam bearing 5		

The lubrication system is pressure-regulated, full-flow cooled, and full-flow filtered.

A gerotor oil pump includes an oil pump housing, cover plate, gerotor assembly (inner and outer gears), and pressure-regulating valve assembly. The inner rotor gear of the gerotor pump is driven by the crankshaft.

The gerotor oil pump draws and pressurizes oil from the oil pan through an oil pickup tube and screen. Pressurized oil in the pump flows through passages in the oil pump housing, enters a passage in the lower crankcase dirty side, flows through a passage in the oil pan dirty side to the dirty side of the oil filter. Oil is filtered in the oil filter (outside to inside) and flows from the center of the oil filter into a passage in the clean side of the oil pan and lower crankcase before returning to the passage in the clean side of the oil pump.

If the oil cooler is restricted, a bypass valve in the oil cooler cover opens; oil bypasses the oil cooler and flows directly to the various systems in the engine. If the oil filter element is restricted, a bypass valve in the oil filter housing opens; oil bypasses the filter element

and flows through passages in the (clean side) of the oil pan-lower crankcase-upper crankcase, before going to the oil cooler.

Oil pressure is governed by the pressure-regulating valve assembly. The pressure-regulating valve in the discharge oil flow relieves excess oil pressure by allowing excess flow back to the suction side of the gerotor oil pump.

Oil flows from the oil pump into the upper crankcase, to a passage in the oil cooler cover, and through the oil cooler plates; cooled oil flows back to the cooler cover and is distributed to various systems in the engine.

Each bypass valve ensures full flow of oil to the engine, if the filter or cooler is restricted, including high oil viscosity cold start conditions.

The oil cooler passage directs cooled, filtered oil to the optional air compressor, oil supply tube to lubricate the turbocharger bearings, and oil to the main oil galleries. Lubrication oil from the turbocharger drains back to the oil pan through slotted passages in the cooler cover plate and upper crankcase. The cooler cover has ports for EOP and EOT sensors.

Cooling System

Cooling System Components and Flow

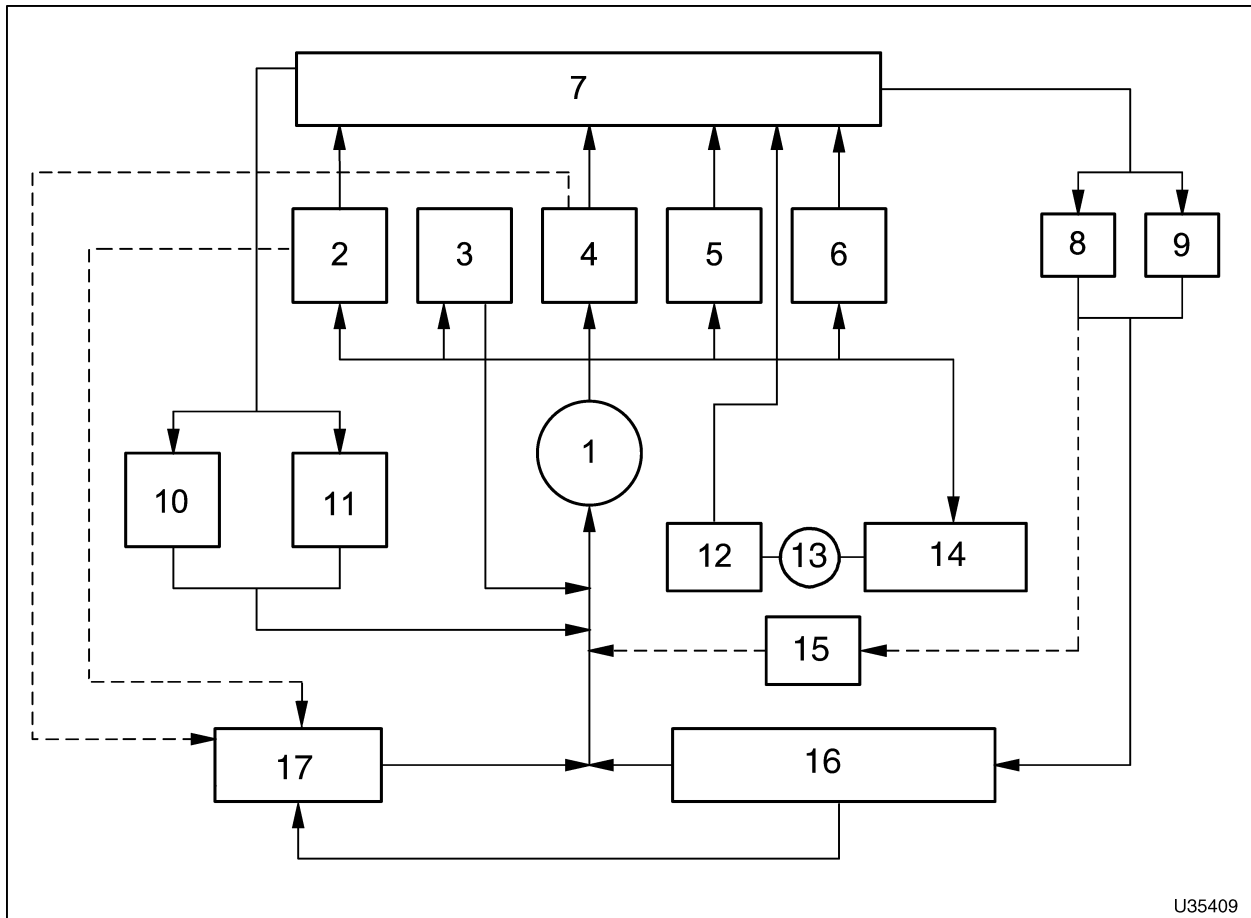


Figure 20 Cooling system schematic

1. Water pump	7. Cross-over	13. Fuel Coolant Valve (FCV)
2. EGR cooler	8. Thermostat 1	14. Secondary radiator
3. Oil cooler	9. Thermostat 2	15. Bypass
4. Air compressor (optional)	10. Heater core	16. Radiator
5. Left cylinder head/crankcase	11. Heater core (optional)	17. Deaeration tank
6. Right cylinder head/crankcase	12. Fuel cooler	

The cooling system keeps the engine within a designated temperature range.

Water Pump

The centrifugal water pump is mounted in the front crankcase cover. The water pump has a built-in reservoir to catch small amounts of coolant that may seep past the seal. Water pump rotation is

counterclockwise when viewed from the front of the engine.

If the dual thermostats are shut, coolant is circulated through an internal bypass in one of the thermostats.

The vehicle mounted deaeration tank keeps the system full with a line to the suction of the water pump.

Front Crankcase Cover Flow

Pressurized coolant from the water pump flows through the coolant supply housing in the front cover. Flow is directed through passages in the crankcase and ports in the front cover to support cooling system requirements.

- Two passages (left and right) direct coolant through the crankcase front to rear to cool the cylinder walls and then directed up to the cylinder head through ports in the top deck.
- A passage directs coolant from the front cover and through the crankcase to the oil cooler to cool the lubricating oil.
- A port in the front cover directs coolant through tubing to the EGR cooler to cool the exhaust gases.
- A port in the front cover directs coolant through tubing to the air compressor.
- A port in the front cover directs coolant through a secondary radiator to the fuel cooler, to cool unused fuel.

Hot coolant return flow is directed through passages in the crankcase and ports in the front cover to the coolant return cross-over housing.

- Two passages (left and right) through the crankcase return coolant from the cylinder heads.
- A port in the coolant return cross-over housing returns coolant through tubing from the air compressor.
- A port in the coolant return cross-over housing returns coolant through tubing from the EGR cooler.
- A port in the coolant return cross-over housing returns coolant through tubing from the fuel cooler.

The coolant return housing has one temperature sensor point.

The coolant return cross-over supplies coolant to the vehicle heater core for cab heating.

The coolant return cross-over housing directs coolant to the dual thermostat housing.

A passage through the crankcase returns coolant from the oil cooler directly to the water pump eye.

Thermostats

Two thermostats are located in the thermostat housing. If the coolant temperature is above the thermostat opening temperature, coolant flows to the vehicle mounted radiator to be cooled. If the coolant temperature is below the opening temperature for both thermostats, both thermostats are closed. Coolant returns back to the water pump through a bypass on one of the thermostats. As the coolant temperature increases, the first thermostat starts to open and allows flow through the radiator. As coolant temperature continues to increase, the first thermostat will fully open. The second thermostat will then start to open, increasing flow to the radiator until both thermostats are fully open.

Deaeration Tank

The radiator and the coolant system are kept full and pressurized by the deaeration tank. As coolant in the radiator heats up and expands, the level in the deaeration tank goes up and pressure increases. The deaeration tank also removes air from the cooling system.

Radiator Shutters (220 Horsepower only)

Closing the radiator shutters keeps the engine warm during cold weather operation. This provides faster warm-up of the passenger cab and faster windshield defrosting.

Fuel Coolant Valve (FCV)

The FCV is used to redirect coolant through the fuel cooler. The ECM uses the Engine Fuel Temperature (EFT) sensor to monitor fuel temperature and controls the FCV to maintain the desired fuel temperature. The valve opens automatically allowing coolant to pass through the cooler. The ECM controls this valve in cold weather to warm the fuel and also prevents the temperature from getting too hot.

Engine Speed Position System

The Engine Speed Position System provides a summary of camshaft and crankshaft synchronization status information to the system. It sets the operating modes of camshaft and crankshaft acquisition depending on synchronization status, availability, and detected failures. The signal source for engine position is selected on the activated operating mode.

Camshaft and crankshaft signal acquisition is set passive for a calibrated delay after key-off has been detected at low engine speed and for another calibrated delay after a loss of synchronization at low engine speed. This avoids wrong injection, ignition and diagnosis with backward rotation after rapid key-off/on or stalling.

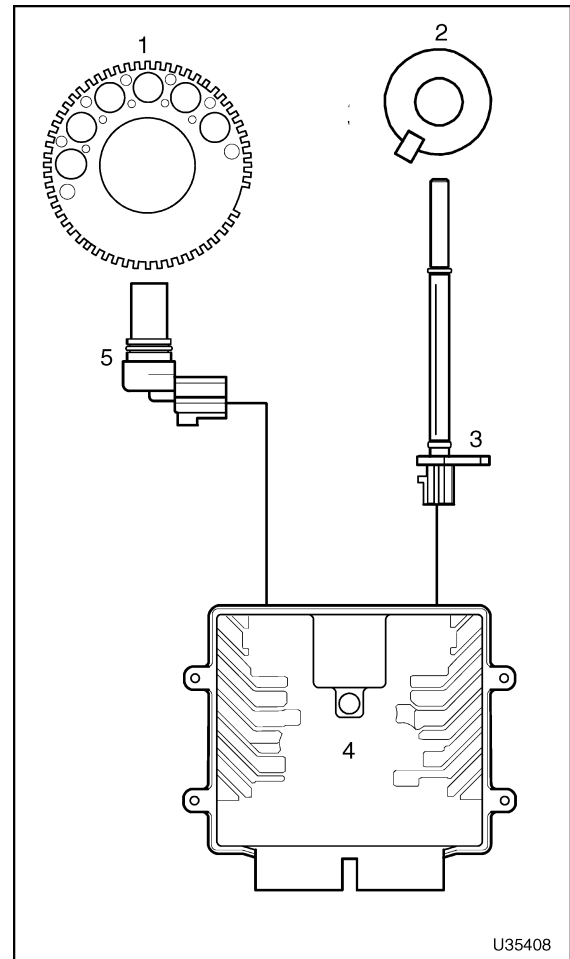


Figure 21 Engine Speed Position System

1. Crankshaft target wheel
2. Camshaft target wheel
3. Camshaft Position (CMP) sensor
4. ECM
5. Crankshaft Position (CKP) sensor

Electronic Control System

Electronic Control System Components

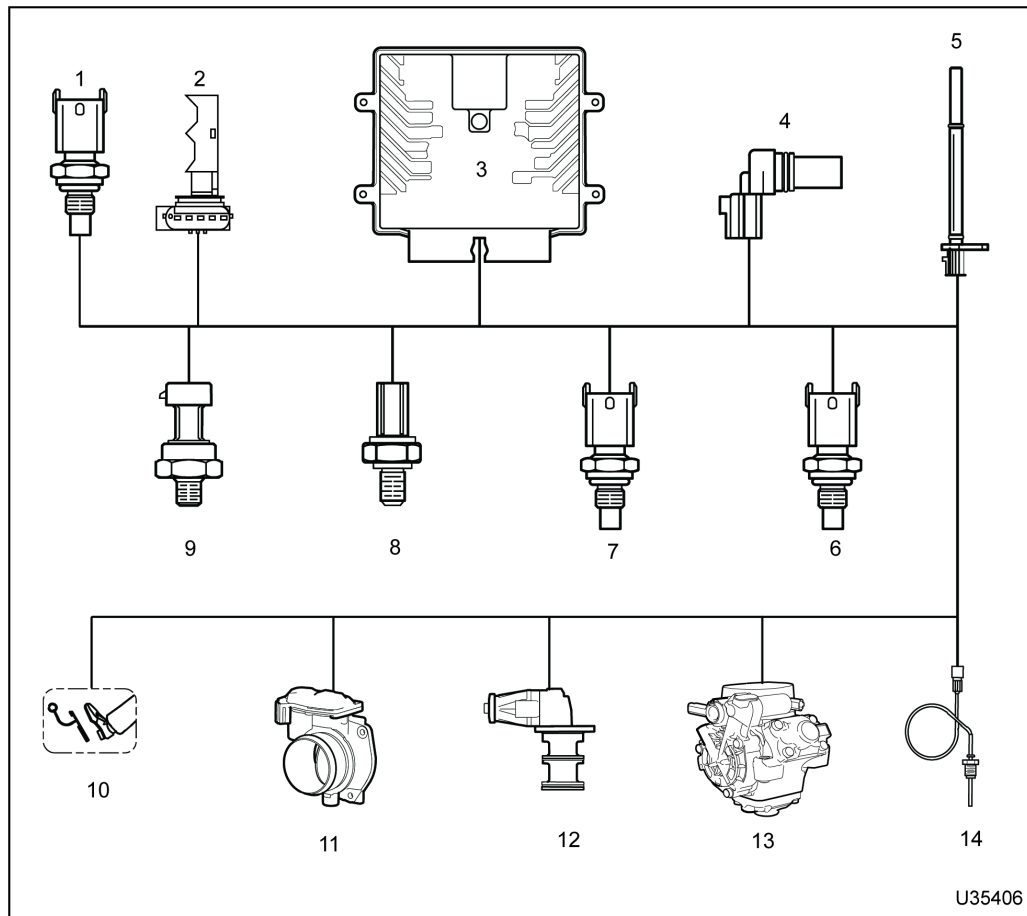


Figure 22 Electronic Control System

1. Engine Coolant Temperature (ECT) sensor	7. Engine Oil Temperature 1 (EOT) sensor	11. Engine Throttle Valve (ETV) and position sensor
2. Mass Air Flow/Air Inlet Temperature (MAF/AIT) sensor	8. Engine Oil Pressure (EOP) sensor	12. EGR Control Valve and position sensor
3. Engine Control Module (ECM)	9. Intake Manifold Pressure (IMP) sensor	13. High Pressure Fuel Pump (HPFP)
4. Crankshaft position (CKP) sensor	10. Accelerator Pedal Position (APP) sensor	14. Exhaust Gas Temperature (EGT) sensor
5. Camshaft position (CMP) sensor		
6. Engine Fuel Temperature sensor		

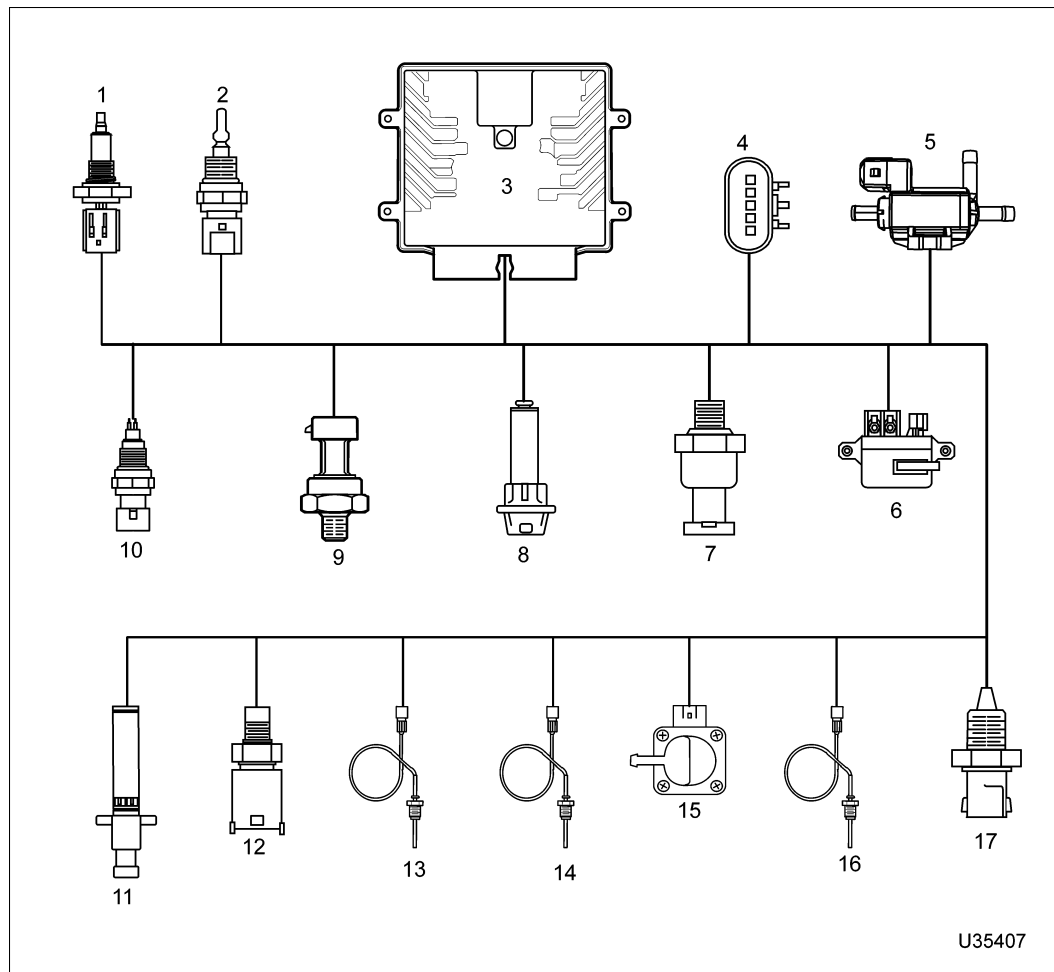


Figure 23 Electronic Control System

1. Exhaust Gas Recirculation Temperature (EGRT) sensor	7. Fuel Rail Pressure (FRP) sensor	14. DPF Inlet Temperature (DPFIT) sensor
2. Intake Manifold Temperature (IMT) sensor	8. Fuel Pump	15. DPF Differential Pressure (DPFDP) sensor
3. Engine Control Module (ECM)	9. Fuel Delivery Pressure (FDP) sensor (optional)	16. DPF Outlet Temperature (DPFOT) sensor
4. Engine Fan Control (EFC) (optional)	10. Water In Fuel (WIF) sensor	17. Engine Coolant Level (ECL) sensor
5. Turbocharger 1 Wastegate Control (TC1WC) solenoid	11. Fuel Heater (optional)	
6. Inlet Air Heater (IAH) relay	12. Transmission Outlet Temperature (manual)	
	13. DOC Inlet Temperature (DOCIT) sensor	

Operation and Function

The Engine Control Module (ECM) monitors and controls the engine to ensure maximum performance and adherence to emissions standards. The ECM has four primary functions:

- Provides reference voltage (VREF)
- Conditions input signals
- Processes and stores control strategies
- Controls actuators

Reference Voltage (VREF)

The ECM supplies a 5-volt VREF signal to input sensors in the electronic control system. By comparing the 5-volt VREF signal sent to the sensors with their respective returned signals, the ECM determines pressures, positions, and other variables important to engine and vehicle functions.

The ECM supplies three independent circuits for VREF:

- VREF supplies 5 volts to engine sensors
- VREF supplies 5 volts to vehicle aftertreatment
- VREF supplies 5 volts to fuel injector control

Signal Conditioner

The signal conditioner in the internal microprocessor converts analog signals to digital signals, squares up sine wave signals, or amplifies low-intensity signals to a level the ECM microprocessor can process.

Microprocessor

The ECM microprocessor stores operating instructions (control strategies) and value tables (calibration parameters). The ECM compares stored instructions and values with conditioned input values to determine the correct operating strategy for all engine operations.

Continuous calculations in the ECM occur at two different levels or speeds: Foreground and Background.

- Foreground calculations are faster than background calculations and are normally more critical for engine operation. Engine speed control is an example.

- Background calculations are normally variables that change at slower rates. Engine temperature is an example.

Suspect Parameter Numbers (SPN) and Fault Mode Indicators (FMI) are set by the microprocessor if inputs or conditions do not comply with expected values.

Diagnostic strategies are also programmed into the ECM. Some strategies monitor inputs continuously and command the necessary outputs for correct performance of the engine.

Microprocessor Memory

The ECM microprocessor includes Flash Memory and Random Access Memory (RAM).

Flash Memory

Flash memory is a nonvolatile form of memory that is electrically erasable and re-programmable. ROM (Read Only Memory) was used when the program (control strategy and calibration) was built into the physical silicon or was burnt in with a one time programming. In ROM, the program is fixed, and to change it you physically have to change the hardware. With Flash memory, you can keep reprogramming it. Flash memory is used to update vehicles in the field (over public CAN) with new calibrations, software bug fixes, or new features.

Flash memory includes the following:

- Vehicle configuration, modes of operation, and options
- Engine Family Rating Code (EFRC)
- Engine warning and protection modes

RAM

RAM stores temporary information for current engine conditions. Temporary information in RAM is lost when the ignition switch is turned to OFF or when ECM power is interrupted. RAM information includes the following:

- Engine temperature
 - Engine rpm
 - Accelerator pedal position
-

Engine Fan Control (EFC)

The purpose of the engine fan is to prevent engines in trucks with smaller cooling systems from overheating and to act as a vehicle retarding device.

The electrically controlled viscous fan drive consists of a fluid port that controls the amount of fluid flow which in turn leads to rotation of the fan. The opening and closing of the valve is activated with a pulse-width modulated output (PWM) from the ECM.

The valve is wired to Vehicle Power (VPWR) on one side and is connected to a switching low side driver in the ECM.

Inlet Air Heater (IAH)

The IAH is primarily used to assist the engine in starting under cold weather conditions. In addition, it helps to reduce white smoke emissions by heating the incoming air.

The ECM controls a relay through a 12V digital high side driver. When the relay coil is charged with 12 volts, the high current contacts inside are drawn together. This completes an electric circuit between the IAH and the vehicle's battery.

The ECM disables the relay by outputting zero volts. With no voltage across the relay coil, the contacts separate and the connection to the battery is broken, shutting down the IAH.

Actuator Control

The ECM controls the actuators by applying a low-level signal (low-side driver) or a high-level signal (high-side driver). When switched on, both drivers complete a ground or power circuit to an actuator.

Actuators are controlled in three ways, determined by the kind of actuator.

- A duty cycle (percent time on/off)
- A controlled pulse width
- Switched on or off

Actuators

The ECM controls engine operation with the following:

- EGR Valve and Position Sensor

- ETV and Position Sensor
- TC1WC Actuator
- Engine Fan Control (EFC)
- Exhaust Throttle
- Inlet Air Heater (IAH)
- Exhaust Back Pressure Valve (EBPV)

H-Bridge Circuit

The EGR valve and ETV actuator motors are operated by an H-Bridge (bipolar) circuit in each valve assembly.

An H-Bridge circuit operates like putting a power source on one side of a motor and connecting the other side of the motor to a ground. This turns the motor. By shifting the leads on the motor it will turn in the opposite direction.

To control the motor in both forward and reverse with a processor, you need an H-Bridge. Relays configured in this fashion make an H-Bridge. The high side drivers are the relays that control the positive voltage to the motor. This is called sourcing current. The low side drivers are the relays that control the negative voltage to sink current to the motor. Sinking current is the term for connecting the circuit to the negative side of the power supply, which is usually ground.

Exhaust Gas Recirculating (EGR) Valve and Control

The EGR valve controls the flow of exhaust gases to the intake manifold. The EGR valve is integrated with an EGR Position (EGRP) sensor.

The ECM controls the EGR valve with a Pulse Width Modulation (PWM) signal through H-Bridge circuitry.

The ECM controls motor speed using PWM. The EGR is closed by driving the EGR High (EGRH) circuit high. When driving the EGRH high, this causes EGR Low (EGRL) circuit to go low.

Variable voltage is needed to move the valve and minimal voltage is needed to maintain its position.

ETV and Engine Throttle Position Sensor

The ETV is used to control air/fuel mixture during a regeneration process of the aftertreatment system. The ETV is also used to ensure a smooth engine shut down by restricting air flow to the engine at shut down.

The ECM controls the ETV with a Pulse Width Modulation (PWM) signal through H-Bridge circuitry.

The ECM controls motor speed using PWM. The Engine Throttle Valve is close by driving the ETV circuit high. When driving the ETV high, this causes ETV circuit to go low.

Variable voltage is needed to move the valve and minimal voltage is needed to maintain its position.

Engine and Vehicle Sensors

Thermistor Sensors

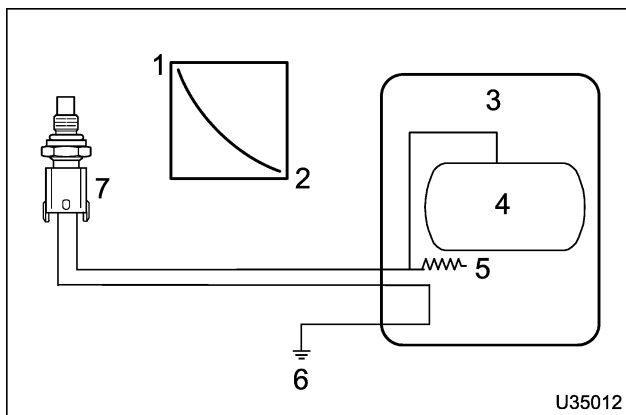


Figure 24 Thermistor sensors

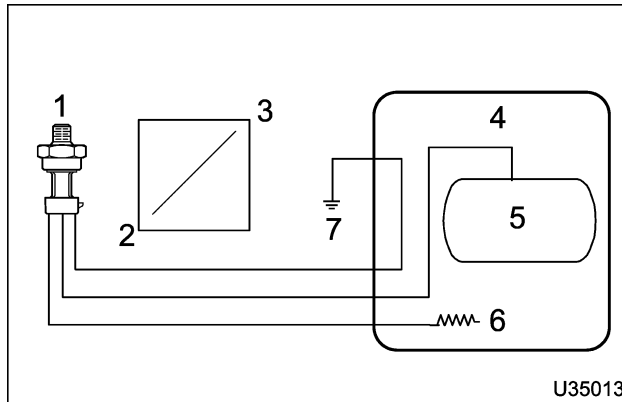
1. 5 Volts
2. 0 Volts
3. ECM
4. Microprocessor
5. VREF
6. Ground
7. Temperature sensor

A thermistor sensor changes electrical resistance with changes in temperature. Resistance in the thermistor decreases as temperature increases, and increases as temperature decreases. Thermistors work with a resistor that limits current in the ECM to form a voltage signal matched with a temperature value.

The top half of the voltage divider limits current inside the ECM. A thermistor sensor has two electrical connectors, signal return and ground. The output of a thermistor sensor is a nonlinear analog signal.

Thermistor type sensors include the following:

- Engine Coolant Temperature 1 (ECT) sensor
- Engine Oil Temperature (EOT) sensor
- Engine Fuel Temperature (EFT) sensor
- EGT sensor
- EGRT sensor
- DOC Inlet Temperature (DOCIT) sensor
- DPF Inlet Temperature (DPFIT) sensor
- DPF Outlet Temperature (DPFOT) sensor
- Transmission Outlet Temperature (manual) sensor
- Mass Air Flow/Air Inlet Temperature (MAF/AIT) sensor
- Intake Manifold Temperature (IMT) sensor

Variable Capacitance Sensors**Figure 25 Variable capacitance sensors**

1. Sensor
2. 0 Volts
3. 5 Volts
4. ECM
5. Microprocessor
6. VREF
7. Ground

Variable-capacitance sensors measure pressure. The pressure measured is applied to a ceramic material. The pressure forces the ceramic material closer to a thin metal disk. This action changes the capacitance of the sensor.

The sensor is connected to the ECM by three wires:

- VREF
- Signal
- Signal return (ground) (SIG GND)

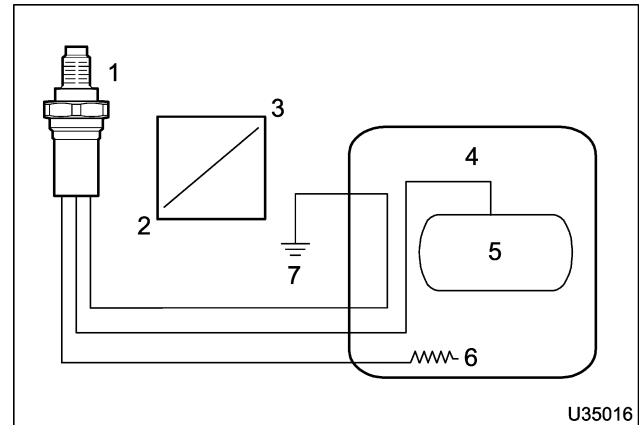
The sensor receives the VREF and returns an analog signal voltage to the ECM. The ECM compares the voltage with pre-programmed values to determine pressure.

The operational range of a variable capacitance sensor is linked to the thickness of the ceramic disk. The thicker the ceramic disk, the more pressure the sensor can measure.

Variable Capacitance type sensors include the following:

- Intake Manifold Pressure (IMP) sensor
- Engine Oil Pressure (EOP) sensor

- Fuel Delivery Pressure (FDP) sensor
- Fuel Rail Pressure (FRP) sensor

Micro Strain Gauge (MSG) Sensor**Figure 26 MSG sensor**

1. Pressure Sensor
2. 0 Volts
3. 5 Volts
4. ECM
5. Microprocessor
6. VREF
7. Ground

A Micro-Strain Gauge (MSG) sensor measures pressure. Pressure to be measured exerts force on a pressure vessel that stretches and compresses to change resistance of strain gauges bonded to the surface of the pressure vessel. Internal sensor electronics convert the changes in resistance to a ratiometric voltage output.

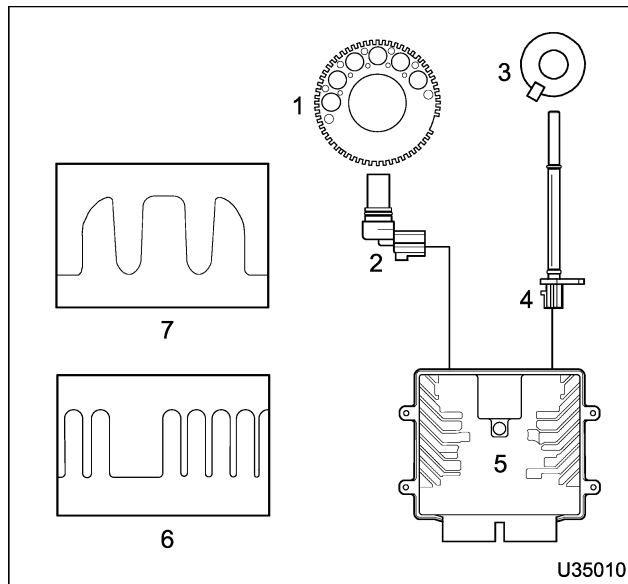
The sensor is connected to the ECM by three wires:

- VREF
- Signal
- Signal return (ground) (SIG GND)

The sensor is powered by VREF received from the ECM and is grounded through the ECM to a common sensor ground.

MSG Sensors

- Fuel Rail Pressure (FRP) sensor

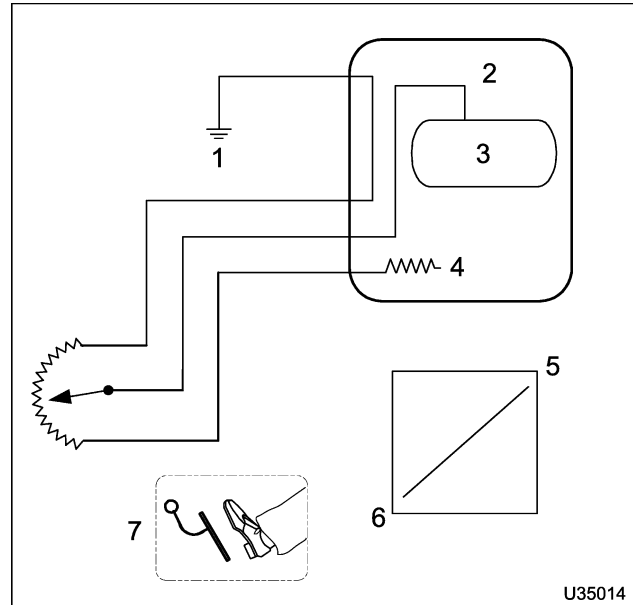
Magnetic Pickup Sensors**Figure 27 Magnetic pickup sensors (typical)**

1. Crankshaft Timing Disk
2. CKP Sensor
3. Camshaft with Peg
4. CMP Sensor
5. ECM
6. CKP signal
7. CMP signal

A magnetic pickup sensor generates an alternating frequency that indicates speed. Magnetic pickups have a two-wire connection for signal and ground. This sensor has a permanent magnetic core surrounded by a wire coil. The signal frequency is generated by the rotation of gear teeth that disturb the magnetic field.

Magnetic Pickup Sensors

- Crankshaft Position (CKP) sensor
- Camshaft Position (CMP) sensor

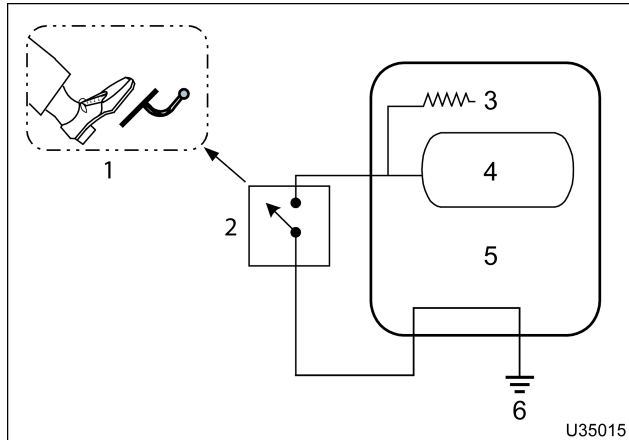
Potentiometer**Figure 28 Potentiometer**

1. Ground
2. ECM
3. Microprocessor
4. VREF
5. 5 Volts
6. 0 Volts
7. Accelerator pedal

A potentiometer is a variable-voltage divider that senses the position of a mechanical component. A reference voltage is applied to one end of the potentiometer. Mechanical, rotary, or linear motion moves the wiper along the resistance material, changing voltage at each point. Voltage is proportional to the amount of mechanical movement.

Potentiometer

- Accelerator Pedal Position (APP) sensor

Switches**Figure 29 Switch**

1. Accelerator pedal
2. Accelerator Pedal Position (APP)
3. VREF
4. Microprocessor
5. ECM
6. Ground

Switches indicate position or condition. They operate open or closed, regulating the flow of current. A switch can be a voltage input switch or a grounding switch. A voltage input switch supplies the ECM with a voltage when it is closed. A grounding switch grounds the circuit when closed, causing a zero voltage signal. Grounding switches are usually installed in series with a current limiting resistor.

Switches

- Engine Coolant Level (ECL) switch
- Water In Fuel (WIF) sensor

Inlet Air Heater (IAH) System

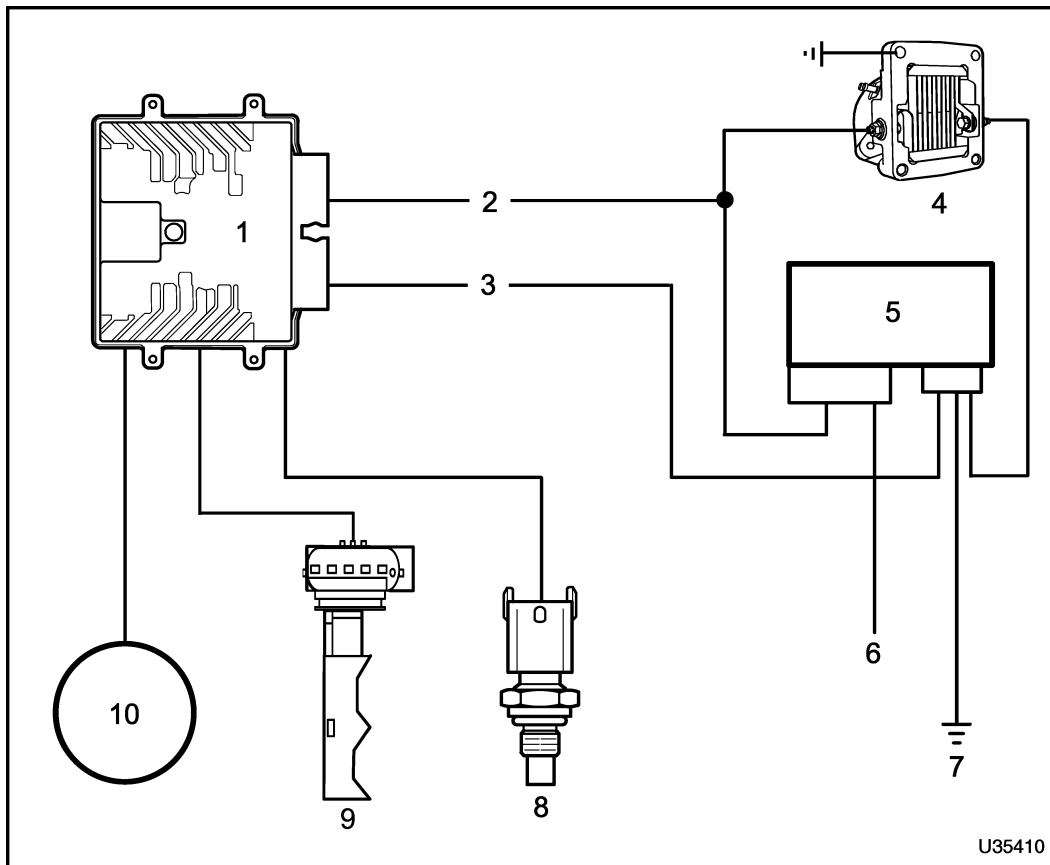


Figure 30 IAH system

1. ECM	4. Inlet Air Heater (IAH)	8. ECT sensor
2. IAHD – Inlet Air Heater Diagnostics	5. IAH relay	9. Mass Air Flow/Air Inlet Temperature (MAF/AIT) sensor
3. IAHC – Inlet Air Heater Control	6. B+ at alternator motor post	10. WAIT TO START lamp
	7. Ground	

The IAH system warms the incoming air to aid cold engine starting and reduce exhaust emissions during warm-up.

The ECM activates the IAH by energizing the IAH relay while monitoring programmed conditions for engine coolant temperature, air inlet temperature, and atmospheric pressure.

The ECM controls the WAIT TO START lamp and IAH relay separately.

The engine is ready to start when the WAIT TO START lamp is turned off by the ECM. The ECM turns the IAH on for a predetermined amount of time, based on ECT, AIT, and BAP. The IAH can remain on while the engine is running to reduce exhaust emissions and white smoke during engine warm-up.

If the ECT is above 50 °C (122 °F), the IAH will not reactivate when restarting the engine unless the AIT is 10 °C (50 °F) or colder.

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Standard Features

Electronic Governor Control

The governor controls engine rpm within a safe and stable operating range. The low idle governor prevents engine rpm from dropping below a stable speed to prevent stalling when various loads are demanded on the engine. The high idle governor prevents engine rpm from going above a safe speed that would cause engine damage.

SAE J1939 Data Link - also known as CAN (public)

The vehicle is equipped with an SAE standard J1939 CAN datalink:

- The J1939 datalink is used for diagnostics and calibration communications for the Engine Control Module (ECM).
- The J1939 datalink is used for communications between the ECM, Electric Gauge Cluster (EGC), and Body Controller (BC).

The J1939 datalink is accessed through the cab diagnostic connector. The datalink provides communication between the ECM and the Electronic Service Tool (EST).

The SAE J1939 data link supports:

- Transmission of engine parameter data
- Transmission and clearing of Diagnostic Trouble Codes (DTCs)
- Diagnostics and troubleshooting
- Programming performance parameter values
- Programming engine and vehicle features
- Programming calibrations and strategies in the ECM
- Inter-module communications between the:
 - Engine Control Module (ECM)
 - Body Controller (BC)
 - Electronic Gauge Cluster (EGC)
 - Automatic transmission controller
 - Electronic Service Tool (EST)

For additional information, see J1939 data link (page 181) in "Electronic Control Systems Diagnostics" section in this manual.

SAE J1587 Data Link - also known as the American Trucking Association (ATA) data link.

The SAE J1587 data link communicates limited information between the engine, the Electronic Gauge Cluster (EGC), Body Controller (BC), Transmission Control Module (TCM), Anti-lock Brake System (ABS) Module, and Telematics modules.

Service Diagnostics

NOTE: 2010 model year vehicles no longer utilize DTC identification by number. DTCs are now identified, using the Suspect Parameter Number (SPN) and Failure Mode Indicator (FMI) identifiers.

The EST provides diagnostic information, using the SAE J1939 data link. The recommended EST is the EZ-Tech® with ServiceMaxx™ diagnostic software provided by Navistar.

Faults from sensors, actuators, electronic components, and engine systems are detected by the ECM and sent to the EST as DTCs. Effective engine diagnostics require and rely on DTCs.

DTC identification is accomplished using two fault code identifiers. These two identifiers, known as the Suspect Parameter Number (SPN) and the Failure Mode Indicator (FMI) are displayed in the DTC window.

- **Suspect Parameter Number (SPN)** The SPN identifies the individual component causing the fault.
 - **Failure Mode Indicator (FMI)** The FMI identifies the fault or condition effecting the individual component.
-

Event Logging System

The event logging system records engine operation above maximum rpm (over speed), low engine coolant level, high engine coolant temperature, or low engine oil pressure. The readings for the odometer and hourmeter are stored in the ECM memory at the time of an event and can be retrieved, using the EST.

Electronic Speedometer and Tachometer

The engine control system calibrates vehicle speed from 0 to 157,157 pulses per mile. Any new speed calibration information must be programmed with an EST.

The tachometer signal is generated by the ECM by computing signals for the Camshaft position (CMP) sensor and Crankshaft Position (CKP) sensor. The calculated engine speed is then sent to the instrument cluster through the J1939 CAN Data link.

Aftertreatment (AFT) System

One of the most important reasons for aftertreatment is to catalyze carbon monoxide (CO), Oxides of Nitrogen (NOx), and Hydrocarbons (HC) (Normal operation). The engine and vehicle exhaust piping includes an Aftertreatment System to capture soot and other particulates before they exit the exhaust pipe. The soot is captured by the Diesel Particulate Filter (DPF) and is periodically converted to carbon dioxide (CO₂) by a Regeneration (Regen) process.

For additional information, see AFT System (page 151) in “Electronic Control Systems Diagnostics” section of this manual.

Fuel Delivery Pressure (FDP) Monitor

The FDP monitors the fuel pressure and indicates when the fuel filter needs to be serviced by displaying the Fuel Filter warning message on the instrument panel.

For additional information, see FDP Sensor in “Electronic Control Systems Diagnostics” section of this manual.

Inlet Air Heater (IAH)

The Inlet Air Heater (IAH) system warms the incoming air supply to aid cold engine starting and reduce white smoke during engine warmup. The ECM controls the intake air heater and monitors the engine temperature. When the engine is ready for cranking, the ECM sends a message to shut off the WAIT TO START lamp.

For additional information, see IAH System (page 299) in “Electronic Control Systems Diagnostics” section of this manual.

Fast Idle Advance

Fast idle advance increases engine idle speed up to 875 rpm for faster warmup to operating temperature. This occurs when the ECM monitors Engine Coolant Temperature (ECT) sensor input and adjusts fuel injector.

Low idle speed is increased proportionally when below 70 °C (158 °F) at 700 rpm to below -10 °C (14 °F) at 875 rpm maximum.

Cold Ambient Protection (CAP)

CAP safeguards the engine from damage caused by prolonged idle at no load during cold weather.

CAP maintains engine coolant temperature by increasing engine rpm to a programmed value. CAP also improves cab warmup.

CAP is standard on all trucks without an idle shutdown timer, with a clutch switch (manual transmissions) or a neutral safety switch (automatic transmission).

For additional information, see CAP in “Engine Operation” section of the *Engine Operation and Maintenance Manual*.

Coolant Temperature Compensation (CTC)

Coolant temperature compensation reduces fuel delivery if engine coolant temperature is above cooling system specifications.

Before standard engine warning or optional warning/protection systems engage, the ECM begins reducing fuel delivery when engine coolant temperature reaches approximately 107 °C (225 °F). A rapid reduction of 20 percent is commanded when engine coolant temperature reaches approximately 110 °C (230 °F).

NOTE: Coolant temperature compensation is disabled in emergency vehicles and school buses that require 100 percent power on demand.

Engine Crank Inhibit (ECI)

ECI will not allow the starting motor to crank when the engine is running or the automatic transmission is in gear.

For additional information, see SMC Circuit (page 340) in "Electronic Control Systems Diagnostics" section of this manual.

Optional Features**Change Oil Service Interval**

The change oil service interval feature is designed to provide a visual reminder to the operator that the oil change interval has expired and that routine maintenance procedures should be performed.

The term "interval" in this case is used to describe the distance, time, or fuel used between the last maintenance performed on the vehicle and the next maintenance which is due.

It is essential that operators are trained to know the maintenance schedules and instructions regarding the operation and reset functionality of the service interval for the feature to be effective.

The change engine oil interval message can be programmed with the EST for mileage, hours, or amount of fuel used. The change oil message timer can be reset using the CRUISE ON and RESUME/ACCEL switches or EST.

Road Speed Limiting (RSL)

Vehicle road speed can be limited to a maximum speed as programmed by the customer. An EST is required for programming.

RSL is a feature designed to regulate the maximum vehicle speed as controlled by the accelerator pedal.

Customer programmable parameters within the ECM provide vehicle speed governor-related options that can be adjusted to suit the customer's needs.

Additional programming flexibility is included to allow a trade-off to be made between performance and fuel economy.

Cruise Control

Cruise Control is a well known feature that offers driving comfort by providing a method for an operator to set and maintain a constant vehicle speed without using the accelerator pedal. It is especially useful when the operator is required to drive on highways at a constant speed for many miles. Customer programmable parameters within the engine control module (ECM) provide maximum and minimum allowable cruise control speeds.

To operate cruise control, see appropriate truck model Operator's Manual.

Traction Control

Traction control is a system that identifies when a wheel is going faster than the other wheels during acceleration.

When a traction control condition occurs, a data link message is sent to the ECM to limit fuel for the purpose of reducing engine torque.

Vehicles must have both a transmission and an Antilock Braking System (ABS) that supports traction control.

Exhaust Back Pressure Valve (EBPV)

The EBPV increases exhaust back-pressure to aid in the deceleration rate of the vehicle. This option is placed in the exhaust piping after the turbochargers.

Engine Warning Protection System (EWPS)

The EWPS safeguards the engine from undesirable operating conditions to prevent engine damage and to prolong engine life. The ECM will illuminate the red ENGINE lamp and sound the warning buzzer when the ECM detects:

- High engine oil temperature.
- Low engine oil pressure.
- High engine coolant temperature.
- Low engine coolant level (if equipped).

When the protection feature is enabled and a critical engine condition occurs, the on-board electronics will shut the engine down. An event logging feature will record the event in engine hours and odometer readings. After the engine has shutdown, and the critical condition remains, the engine can be started for a 30-second run time.

For complete EWPS description and additional information, see EWPS (page 269) in “Electronic Control Systems Diagnostics” section of this manual.

Idle Shutdown Timer (IST)



GOVERNMENT REGULATION: State and local regulations may limit engine idle time. The vehicle owner or operator is responsible for compliance with those regulations.

The IST allows the ECM to shut down the engine during extended engine idle times.

Thirty seconds before IST-defined engine shutdown, a vehicle instrument panel indicator activates. There are two types of indicators:

- Amber idle shutdown indicator for multiplex electrical systems.
- Red flashing indicator with audible alarm for non-multiplex electrical systems.

This continues until the engine shuts down or the low idle shutdown timer is reset.

IST for California ESS Compliant Engines

Beginning in 2008 MY, all International® MaxxForce® engines certified for sale in the state of California will conform to mandatory California Air Resources Board (CARB) Engine Shutdown System (ESS) regulations.

Engine idle duration is limited for California Engine Shutdown System (ESS) compliant engines as follows:

- When vehicle parking brake is set, the idle shutdown time is limited to the California Air Resources Board (CARB) requirement of 5 minutes.
- When vehicle parking brake is released, the idle shutdown time is limited to the CARB requirement of 15 minutes.

The duration of CARB mandated values can be reduced by programming the customer IST programmable parameter to a value lower than 15 minutes.

Engine Idle Shutdown Timer (IST for Federal–Optional)

Idle time can be programmed from 5 to 120 minutes. While the EST is installed, the IST function will be active with the programmed shutdown time in effect. Parking brake transitions reset the idle timer. If the IST is enabled, the Cold Ambient Protection (CAP) will not function.

For additional information, see IST System (page 324) in “Electronic Control Systems Diagnostics” section of this manual.

Electronic Fan (EFAN)

Engine electronics allow for the operation of an electronic fan or an air fan solenoid. The engine fan control commands higher airflow through the radiator when the Air Conditioner (A/C) is on or when the engine coolant or inlet air temperature goes above a set temperature. For additional information, see EFC (page 229) in “Electronic Control Systems Diagnostics” section of this manual.

Radiator Shutter Enable (RSE)

The RSE feature provides a signal to open or close the radiator shutters. Closing the shutters will keep the engine warm during cold weather operation. This provides faster warmup of the passenger cab and enables faster windshield defrosting.

For additional information, see RSE (page 337) in “Electronic Control Systems Diagnostics” section of this manual.

In Cab Power Take-Off (PTO) Control

The engine speed control feature, commonly referred to as Power Take-off (PTO), provides a method for an operator to set and maintain a constant engine speed without using the accelerator pedal. It is commonly used for powering auxiliary devices.

Customer programmable parameters within the ECM provide in-cab engine speed control related options that can be adjusted to suit the customer's needs. Choosing whether the operator is allowed to increase the engine speed using the accelerator pedal without disengaging the PTO is an example.

Remote Accelerator Pedal Position (RAPP)

This engine speed control feature, provides a method for an operator to set and maintain engine speed without using the accelerator pedal. It is commonly used for powering auxiliary devices.

When control over engine speed is required from outside the vehicle's cab, remote mounted switches must be used to turn on PTO engine speed control and select the desired engine speed. This functionality is referred to as Remote Engine Speed Control (RESC).

Engine speed can be ramped up and down with RESC similar to the way the in-cab PTO feature works; however, the RESC feature includes two additional switches (remote preset and remote variable), which allow the operator to choose the mode of engine speed control operation.

Customer programmable parameters within the ECM provide RESC related options that can be adjusted to suit the customer's needs. Choosing whether a remote throttle pedal is used for PTO operation is an example.

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Connecting EST with ServiceMaxx™ Software to Engine

To connect the Electronic Service Tool (EST) with ServiceMaxx™ software to the engine, the NAVCoM or NAVLink Interface cable must be connected between the EST and Diagnostic Connector. The Diagnostic Connector is located inside the vehicle cab, above the clutch pedal.

Viewing Diagnostic Trouble Codes

Diagnostic Trouble Codes (DTCs)

2010 model year vehicles no longer utilize DTC identification by number. DTCs are now identified using the Suspect Parameter Number (SPN) and Failure Mode Indicator (FMI) identifiers only. These two identifiers are displayed in the DTC Window.

Suspect Parameter Number (SPN)

The SPN identifies the individual component causing the fault.

Failure Mode Indicator (FMI)

The FMI identifies the fault or condition affecting the individual component.

Active and Previously Active DTCs

Active DTCs are codes that are currently present.

Previously active DTCs are historical codes that may be set by intermittent conditions, or by an operating condition, which is not currently present.

All active and previously active DTCs will be indicated in the DTC Type column.

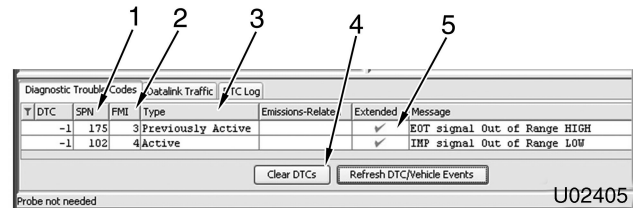


Figure 31 DTC window

1. SPN column
2. FMI column
3. DTC Type column
4. Clear DTCs button
5. Extended (Freeze Frame)

Service Bay Tests

Key On, Engine Off (KOEO) Tests

KOEO tests are available using the Tests menu option.

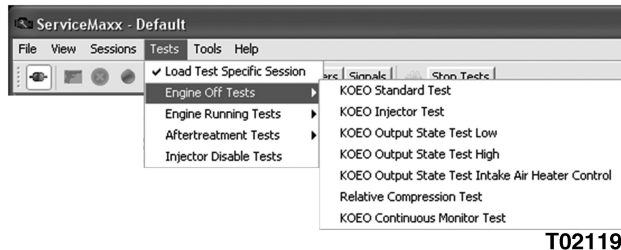


Figure 32 ServiceMaxx™ Test Menu – Engine Off Tests

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)

KOEO Standard Test

The KOEO Standard Test is done to ensure proper functioning of the Engine Control Module (ECM) memory areas. The KOEO Standard Test is used to conduct the CPU and RAM, SPI- Bus, Flash Memory,

and the ROM tests. It is also known as the ECM Self-Test.

NOTE: The ignition monitored by the ECM should be greater than 9V.

NOTE: Do not crank the engine.

To start the KOEO Standard Test, follow the steps below:

1. Using the NAVCoM or NAVLink Interface cable, connect the EST with ServiceMaxx™ software to the Diagnostic Connector.
2. Turn ignition key ON, engine OFF.
3. Start ServiceMaxx™ software.
4. Click on the Tests menu, select Engine Off Tests and request the KOEO Standard Test.

Once the KOEO Standard Test is started, ServiceMaxx™ software automatically loads the KOEO Standard Test Session for viewing during the test and does the ECM Self-Test.

The KOEO Standard Test runs for about 20 seconds. Once the test is complete, ServiceMaxx™ software exits the test and displays the Test Completed, Successful message.

NOTE: The output drivers are now smart chip sets, which have built in diagnostics, so any associated faults will be transmitted instantly in ServiceMaxx™ software. Therefore, the actuator part of the KOEO Standard test is no longer required.

KOEO Output State Low and High

The KOEO Output State Test is used to verify proper functionality of components, their related circuits, the harness, and the ECM.

The KOEO Output State Test is comprised of KOEO Output State Low and KOEO Output State High. During the KOEO Output State Low Test, the ECM commands the output circuits to their low voltage state (0V). The Exhaust Gas Recirculation (EGR) valve and Engine Throttle Valve (ETV) are DC motors that are commanded to 0% position during the test. The fuel pump is a two-pin actuator, where Fuel Pump Control-High (FPC-H) is commanded to low voltage (0V).

During the KOEO Output State High Test, the ECM commands the output circuits to their high voltage state (12V). EGR and ETV are commanded to 100% position during the test. FPC-H is commanded to high voltage (12V).

NOTE: The ignition monitored by the ECM should be greater than 9V.

NOTE: Do not crank the engine.

To start the KOEO Output State Low and High tests, follow the steps below:

1. Using the NAVCoM or NAVLink Interface cable, connect the EST with ServiceMaxx™ software to the Diagnostic Connector.
2. Turn ignition key ON, engine OFF.
3. Start ServiceMaxx™ software.
4. Complete the KOEO Standard Test before requesting the KOEO Output State Low and High tests.
5. Click on the Tests menu, select Engine Off Tests and request the KOEO Output State Low Test. Once the KOEO Output State Low Test is completed, follow the same procedure to request the Output State High Test.

⚠ WARNING: To prevent personal injury or death, when routing DMM leads, do not crimp leads, run leads too close to moving parts or let leads touch hot engine surfaces.

The Voltages are measured using a DMM. The following are the expected responses from the actuator pins during the Output State Tests:

Component	Output State Low	Output State High	Test Point
Fuel Pump	FPC-H ~0V	FPC-H ~12V	FPC-H to FPC-L
	FPC-L ~0V	FPC-L ~0V	FPC-H to FPC-L
Oil Water Lamp	~0V	~12V	OWL to GND
Warn Engine Lamp	~0V	~12V	WEL to GND
Turbocharger Wastegate Control	~0V	~12V	TC1WC to GND
Engine Fan Control	~0V	~12V	EFC to GND
Fuel Pressure Control Valve	~0V	~12V	FPCV to GND
Fuel Volume Control Valve	~0V	~12V	FVCV to GND
Starter Motor Control	~0V	~12V	ECI to GND
Radiator Shutter Enable	~0V	~12V	RSE to GND
Exhaust Gas Recirculation Position	~0% position	~100% position	EGRP to GND
Engine Throttle Valve	~0% position	~100% position	ETHP to GND

The KOEO Output State Low and High tests are designed to be aborted anytime by requesting Stop Tests in ServiceMaxx™ software. ServiceMaxx™

software will display the User Requested Cancellation message and abort the test. However, both tests automatically time out after about 30 minutes.

KOEO Intake Air Heater

The KOEO Output State Intake Air Heater test is used to check for proper functionality of the Intake Air Heater (IAH) relay circuit, harness, and ECM by energizing the IAH.

During the KOEO Output State Intake Air Heater test, the ECM commands the IAH to its High Voltage State (12V).

NOTE: The ignition monitored by the ECM should be greater than 9V.

NOTE: Do not crank the engine.

To start the KOEO Intake Air Heater test, follow the steps below:

1. Using the NAVCoM or NAVLink Interface cable, connect the EST with ServiceMaxx™ software to the Diagnostic Connector.
2. Turn ignition key ON, engine OFF.
3. Start ServiceMaxx™ software.
4. Complete the KOEO Standard Test before requesting the Output State Test.
5. Click on the Tests menu, select Engine Off Tests and request the KOEO Output State Test IAH.

 **WARNING:** To prevent personal injury or death, when routing DMM leads, do not crimp leads, run leads too close to moving parts or let leads touch hot engine surfaces.

The voltages are measured using a DMM. The following are the expected voltages at the IAH pins during the KOEO Intake Air Heater test:

Component	Output State IAH	Test Point
IAH Relay	~12V	Relay Output Side to GND IAHC to GND

The KOEO Intake Air Heater test will run for about 45 seconds. Once the test is complete, ServiceMaxx™ software automatically exits the test and displays the

Test Completed, Successful message. The KOEO Intake Air Heater test can be requested twice per key ON cycle.

KOEO Continuous Monitor Test

The KOEO Continuous Monitor test is used to detect intermittent circuit faults by disabling fault filtering.

During the test, signals are continuously monitored and faults are immediately logged. It provides a graphical view of all the signals, and allows the technician to easily detect intermittent spiking or momentary loss of signal. It is to be performed during manipulation of the connectors, wiring, and harnesses of the suspected faulty component.

NOTE: The ignition monitored by the Engine Control Module (ECM) should be greater than 9V.

NOTE: Do not crank the engine.

To start the KOEO Continuous Monitor Test, follow the steps below:

1. Using the NAVCoM or NAVLink Interface cable, connect the EST with ServiceMaxx™ software to the Diagnostic Connector.
2. Turn ignition key ON, engine OFF.
3. Start ServiceMaxx™ software.
4. Click on the Tests menu, select Engine Off Tests and request the KOEO Continuous Monitor Test.

Once the KOEO Continuous Monitor Test is requested, monitor the sensor voltage while wiggling the connectors, wiring, and harness of the component. If the circuit of the sensor is interrupted, the signal will spike.

The KOEO Continuous Monitor Test is designed to be aborted anytime by selecting Stop Tests in ServiceMaxx™ software. ServiceMaxx™ software will display the User Requested Cancellation message and abort the test. The test automatically times out after about 16 minutes.

Relative Compression Test

The Relative Compression Test is used to determine if any cylinder has abnormally low compression and is operating below peak efficiency.

The Relative Compression Test measures differences in crankshaft speed from the point of peak compression to the point of minimum compression for each cylinder. This test is only run during engine cranking and no fuel condition.

NOTE: The ignition monitored by the ECM should be greater than 9V.

NOTE: Do not crank the engine.

To start the Relative Compression Test, follow the steps below:

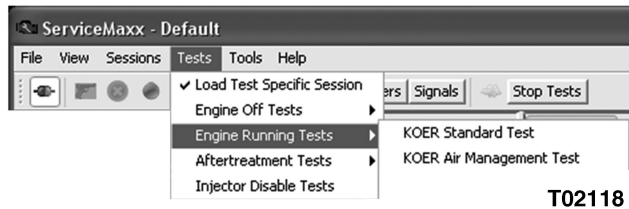
1. Using the NAVCoM or NAVLink Interface cable, connect the EST with ServiceMaxx™ software to the Diagnostic Connector.
2. Turn ignition key ON, engine OFF.
3. Start ServiceMaxx™ software.
4. Click on the Tests menu, select Engine Off Tests and request the Relative Compression Test.

Once the test is requested, engine speed at peak compression of each cylinder is captured while engine is cranked for about 15 seconds with no fuel. The results of the test are transmitted in ServiceMaxx™ software once the cranking is completed.

The duration of the test is about 20 seconds. Once the test is completed, ServiceMaxx™ software will display the Test Completed, Successful message and display the test results.

Key On, Engine Running (KOER) Tests

KOER tests are available using the Tests menu option.



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Figure 33 ServiceMaxx™ Tests Menu – Engine Running Tests

KOER Standard Test

The KOER Standard Test is used to perform a sequence of tests related to the fuel pressure and the exhaust back-pressure subsystems.

The KOER Standard Test elevates the engine speed and cycles the Fuel Rail Pressure (FRP) system pressure through its minimum and maximum value to ensure proper system functionality.

Ensure the following entry conditions are met before requesting the KOER Standard Test:

1. There are no active DTCs.
2. Vehicle is not moving.
3. Engine is running, Operating Mode Selection (OMS) mode is 2.
4. Engine speed is within idle range and should be less than 750 RPM.
5. Engine Coolant Temperature (ECT) should be within acceptable range. Warm ECT above 70 °C (158 °F). Temperature should not exceed 125 °C (257 °F).

6. Battery voltage monitored by the ECM should be greater than 9V.
7. Vehicle should be in park or neutral mode, with driveline disengaged and parking brake set.

! WARNING: To prevent personal injury or death, provide proper ventilation when operating an engine in a closed area. Inhalation of exhaust gas can be fatal.

To start the test, follow the steps below:

1. Ensure engine is running.
2. Start ServiceMaxx™ software.
3. Click on the Tests menu, select Engine Running Tests and request the KOER Standard Test.

The KOER Standard test starts by elevating the engine speed to 1200 RPM, disabling Diesel Particulate Filter (DPF) regeneration, and fixing set-points for the Exhaust Gas Recirculation (EGR) valve, Engine Throttle Valve (ETV), and Turbocharger 1 Wastegate Control (TC1WC) valve. Once these are maintained, the FRP system is commanded to its lowest operating pressure. If the pressure falls below the low threshold limit, the corresponding fault will be set as active in ServiceMaxx™ software. If the low pressure test passes, the system is commanded to its maximum pressure. If the pressure does not meet the minimum threshold for maximum pressure, the corresponding fault will be set as active in ServiceMaxx™ software. The duration of the KOER Standard Test is approximately 70 seconds. Once the test is complete, ServiceMaxx™ software displays the Test Completed, Successful message and aborts the test.

KOER Air Management Test

The KOER Air Management Test is used to perform a sequence of tests related to the Exhaust Gas Recirculation (EGR) System.

The KOER Air Management Test elevates the engine speed and cycles the EGR, Engine Throttle Valve (ETV), and Turbocharger 1 Wastegate Control (TC1WC) valves through their open and closed states. If there is a discrepancy between position desired and actual set-point, then a fault is set.

Ensure the following entry conditions are met before requesting the KOER Air Management Test:

1. KOER Standard Test is complete.
2. There are no active DTCs.
3. Vehicle is not moving.
4. Engine is running, OMS mode is 2.
5. Engine speed is within idle range and engine speed should be less than 750 RPM.
6. ECT should be within acceptable range. Warm ECT above 70°C (158°F). Temperature should not exceed 125°C (257°F).
7. Accelerator pedal is not depressed.
8. Battery voltage monitored by the ECM should be greater than 9V.
9. Vehicle should be in park or neutral mode, with driveline disengaged and parking brake set.



WARNING: To prevent personal injury or death, provide proper ventilation when operating an engine in a closed area. Inhalation of exhaust gas can be fatal.

To start the test, follow the steps below:

1. Ensure engine is running.
2. Start ServiceMaxx™ software.
3. Complete the KOER Standard Test before requesting the Air Management Test.
4. Click on the Tests menu, select Engine Running Tests, and request the KOER Air Management Test.

The KOER Air Management Test starts by elevating the engine speed to approximately 1200 RPM, disabling Diesel Particulate Filter (DPF) regeneration, and fixing set-points for the Fuel Pressure Control Valve (FPCV), Fuel Volume Control Valve (FVCV), ETV, and TC1WC. Once these are maintained, the EGR is cycled between open and closed by providing the desired Mass Air Flow (MAF) set-point to the EGR close-loop control. If the desired flow is not achieved, the subsystem is diagnosed. This is followed by cycling the ETV between open and close. The engine speed is then elevated to 2200 RPM to cycle the TC1WC by providing the desired boost set-point to the TC1WC close-loop control. If the desired boost is not achieved, the subsystem is diagnosed.

The duration of the KOER Air Management Test is approximately 105 seconds. Once the test is complete, ServiceMaxx™ software displays the Test Completed, Successful message.

KOER Cylinder Cutout Test

The KOER Cylinder Cutout Test disables injectors during any set idle engine speed to assist the technician in diagnosing injector failures.

The KOER Cylinder Cutout Test allows the technician to shut off/disable individual injectors for the duration of the test in order to identify an injector problem or to audibly diagnose an injector problem.

Ensure the following entry conditions are met before requesting the KOER Cylinder Cutout Test:

1. KOER Standard Test is complete.
2. There are no active DTCs.
3. Vehicle is not moving.
4. Engine is running, OMS mode is 2.
5. Engine speed is within idle range and engine speed should be less than 750 RPM.
6. ECT should be within acceptable range. Warm ECT above 70°C (158°F). Temperature should not exceed 125°C (257°F).
7. Accelerator pedal is not depressed.
8. Battery voltage monitored by the ECM should be greater than 9V.
9. Vehicle should be in park or neutral mode and driveline is disengaged.



WARNING: To prevent personal injury or death, provide proper ventilation when operating an engine in a closed area. Inhalation of exhaust gas can be fatal.

To start the test, follow the steps below:

1. Ensure engine is running.
2. Start ServiceMaxx™ software.
3. Complete the KOER Standard Test before requesting the Cylinder Cutout Test.
4. Click on the Tests menu, select Engine Running Tests, and request the KOER Cylinder Cutout Test.

Once the KOER Cylinder Cutout Test is initiated, each injector can be enabled or disabled individually in any order. The results of the disabling tests are displayed in ServiceMaxx™ software.

The test is designed to be aborted anytime by the user. Every time an injector is returned to its normal state after disabling, a Test Complete message associated with that injector is displayed in ServiceMaxx™ software.

ServiceMaxx™ Procedures

KOEO Fuel Pump Prime

The KOEO Fuel Pump Prime procedure is designed to allow air purge when the fuel system is in service.

Initial fuel pump priming (air purging) operation cycles the fuel pump command to prime and purge air out of the system.

NOTE: The ignition monitored by the ECM should be greater than 9V.

NOTE: Do not crank the engine.

To start the KOEO Fuel Pump Prime procedure, follow the steps below:

1. Using the NAVCoM or NAVLink Interface cable, connect the EST with ServiceMaxx™ software to the Diagnostic Connector.
2. Turn ignition key ON, engine OFF.
3. Start ServiceMaxx™ software.
4. Click on the Procedures menu, select Engine Off Procedures, and request KOEO Fuel Pump Prime.

The operation is active once per key-on event. This ensures that the electronic fuel pump module will be shut off whenever the engine transitions from running above low idle speed to Key ON engine OFF, which is the likely event of an accident. Furthermore, to ensure sufficient fuel pressure in the event of a hard start, the pump will continue to prime, unless the engine is above low idle speed for a calibrated period of time. The duration of the procedure is about 30 seconds. Once the procedure is complete, ServiceMaxx™ software displays the Procedure Completed, Successful message.

KOER MAF Sensor Calibrate Procedure

The KOER MAF Sensor Calibrate procedure is used to learn the Mass Air Flow (MAF) signal dynamically, based on the engine parameters, the MAF sensor signal itself, and by comparing it to appropriate MAF.

During the KOER MAF Sensor Calibrate procedure, the MAF signal is measured and its equivalent mass airflows are calculated at various engine speeds (6-16 set points) using the speed density equation.

Ensure the following entry conditions are met before requesting the KOER MAF Sensor Calibrate procedure:

1. KOER Standard Test is complete.
2. There are no active DTCs.
3. Vehicle is not moving.
4. Engine is running.
5. Engine speed is within idle range and less than 750 RPM.
6. ECT should be within acceptable range. Warm ECT above 70 °C (158 °F). Temperature should not exceed 125 °C (257 °F).
7. Accelerator pedal is not depressed.
8. Battery voltage monitored by the ECM should be greater than 9V.
9. Vehicle should be in park or neutral mode and driveline is disengaged.
10. MAF is within acceptable range, between 0 KPa and 600 kg/hr (1323 lbs/hr).
11. Intake Manifold Pressure (IMP) is within acceptable range and between 0 KPa and 305 KPa (44 psi).

12. Intake Manifold Temperature (IMT) is within acceptable range and between -30 °C (-22 °F) and 125 °C (257 °F).

 **WARNING:** To prevent personal injury or death, provide proper ventilation when operating an engine in a closed area. Inhalation of exhaust gas can be fatal.

To start the procedure, follow the steps below:

1. Ensure engine is running.
2. Start ServiceMaxx™ software.
3. Complete the KOER Standard Test before requesting KOER MAF Sensor Calibrate procedure.
4. Click on the Tests menu, select Engine Running Tests, and request KOER MAF Sensor Calibrate.

Once the KOER MAF Sensor Calibrate procedure is initiated, the engine speed is commanded to different set points, the Turbocharger 1 Wastegate Control (TC1WC) is adjusted accordingly, and the MAF signal values and the corresponding airflows are stored. These values are used to calculate the speed density coefficients, which help determine actual MAF readings.

The duration of the procedure is about two minutes and twenty seconds. Once the test is complete, ServiceMaxx™ software displays the result of the test and whether a MAF trim was successful. ServiceMaxx™ software displays the Test Completed, Successful message.

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Coolant System



GOVERNMENT REGULATION: Engine fluids (oil, fuel, and coolant) may be a hazard to human health and the environment. Handle all fluids and other contaminated materials (e.g. filters, rags) in accordance with applicable regulations. Recycle or dispose of engine fluids, filters, and other contaminated materials according to applicable regulations.

! WARNING: To prevent personal injury or death, do not let engine fluids stay on your skin. Clean skin and nails using hand cleaner and wash with soap and water. Wash or discard clothing and rags contaminated with engine fluids.

! WARNING: To prevent personal injury or death, shift transmission to park or neutral, set parking brake, and block wheels before doing diagnostic or service procedures.

! WARNING: To prevent personal injury or death, allow engine to cool before working with components.

Air Compressor Leak Test

Tools

ZTSE2384 – Radiator Pressure Test Kit

1. Drain coolant from the system as described in the *Engine Service Manual*.

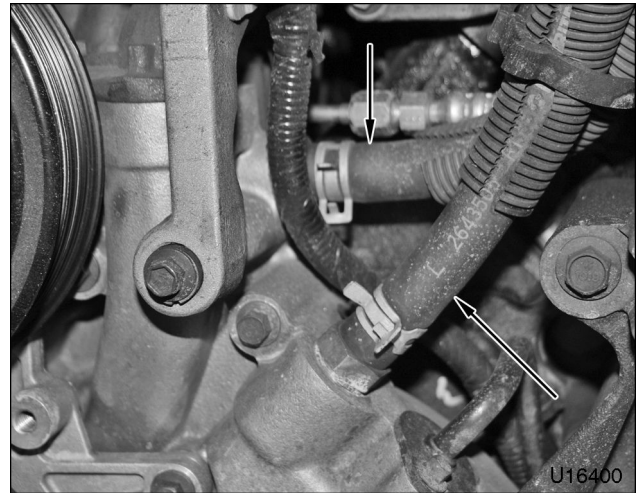


Figure 34 Air compressor coolant hoses

2. Remove two hose clamps and disconnect the coolant supply and return hoses for the air compressor from the crankcase.
3. Fill air compressor coolant passage and hoses with coolant.

! WARNING: To prevent personal injury or death, wear safety glasses with side shields.

4. Adapt air pressure fitting and regulator to one of the coolant hoses and block opposite hose.
5. Pressurize air compressor coolant hoses to 103 kPa (15 psi) using the Radiator Pressure Test Kit ZTSE2384 .
 - If a leak is noticed, repair or replace the air compressor.
 - If coolant is not leaking, see Front Cover Inspection (page 72) in this section.
6. Test the cooling system again after any repair to validate the repair.

Combustion Leaks to Coolant

 **WARNING:** To prevent personal injury or death, wear safety glasses with side shields.

Symptom

Combustion leaks can be identified by coolant overflowing from deaeration tank or air bubbles in the coolant.

Possible Causes

- Improper service
- Failed injector sleeve
- Failed air compressor (if equipped)
- Failed head gasket
- Failed Exhaust Gas Recirculation (EGR) cooler
- Porous cylinder wall

The likely cause of combustion gas leakage to the cooling system is an EGR cooler failure. However, this should not be considered unless there is evidence of engine overheating or high engine mileage without proper coolant conditioning.

Tools

- ZTSE2384 – Radiator Pressure Test Kit
- ZTSE4535 – Cylinder Head Test Plate
- Straight edge
- Feeler gauge

Combustion Leak Test

1. If the engine is equipped with an air compressor, verify that the excess coolant comes from a combustion leak and not the air compressor.
2. Plug in the cylinder block heater, if available, to warm coolant.
 - If the engine is equipped with an air compressor, go to the next step.
 - If the engine is not equipped with an air compressor, go to step 4.

3. Remove coolant discharge line from air compressor housing. Run the engine to test the coolant system for combustion leakage.

- If coolant continues overflowing from the deaeration tank, go to the next step.
- If coolant stops overflowing from deaeration tank, repair or replace the air compressor, see Air Compressor Leak Test (page 67) in this section.

 **WARNING:** To prevent personal injury or death, make sure the engine has cooled before removing components.

4. Remove exhaust tubes from the rear of the exhaust manifolds.

 **WARNING:** To prevent personal injury or death, do the following when removing the radiator cap or deaeration cap:

- Allow the engine to cool for 15 minutes.
 - Wrap a thick cloth around the radiator cap or deaeration cap.
 - Loosen cap slowly a quarter to half turn to vent pressure.
 - Pause for a moment to avoid being scalded by steam.
 - Continue to turn cap counterclockwise to remove.
5. Install Radiator Pressure Test Kit ZTSE2384 with appropriate adapter on the deaeration tank.
 6. Pressurize the cooling system to 103 kPa (15 psi).

 **WARNING:** To prevent personal injury or death, be aware that crankshaft may rotate suddenly when a cylinder is pressurized.

NOTE: Inspect for evidence of coolant in the exhaust manifold.

7. Bar engine over by hand and inspect for evidence of coolant in the exhaust manifold.
-

NOTE: This might have to be repeated several times.

- If leak is slight, pressure may have to be left on overnight and inspect cooling system for leakage in morning. If installed, leave cylinder block heater plugged in.
 - If leak is found, determine which cylinder head is leaking and go to the next step.
8. Remove leaking cylinder head from engine as described in the *Engine Service Manual*. Perform all inspections and pressure test cylinder head to verify leak path. Inspect cylinder head gasket for coolant leaks and verify crankcase and cylinder head surface flatness using a straight edge and feeler gauge.
- NOTE:** It is recommended to replace the injector sleeves for a cylinder that shows combustion leakage.
9. If the injector sleeves were replaced, retest the cylinder head with Cylinder Head Test Plate to verify repair.
 10. Reinstall cylinder head on the engine as described in the *Engine Service Manual*.
 11. Fill the deaeration tank, with coolant, to the FULL mark.

Coolant Leak to Exhaust/Intake

Symptoms

- Coolant residue at exhaust manifold flanges
- Engine overheating
- Coolant smell in exhaust
- Coolant leaking from exhaust
- Severe case - engine hydraulic lock

Possible Causes

- Failed EGR cooler
- Injector cup and gasket leak
- Porosity in cylinder head castings
- Blown or leaking cylinder head gasket

Tools

- ZTSE2384 – Radiator Pressure Test Kit

- KL 20040 NAV – EGR Cooler Leak Detection Kit

EGR Cooler Inspection

! WARNING: To prevent personal injury or death, make sure the engine has cooled before removing components.

! WARNING: To prevent personal injury or death, carefully remove turbocharger exhaust tubing. Coolant in tubing could splash out and create slippery conditions.

1. Remove the Exhaust Gas Recirculation Temperature (EGRT) sensor on the outlet side of the EGR cooler and inspect cavity for presence of coolant.
- If coolant is present, go directly to step 6.
- If no coolant is present, go to next step.
2. Remove the exhaust manifold turbo inlet crossover pipe between the EGR cooler exhaust inlet, exhaust tubes and turbocharger exhaust inlet following the procedures in the *Engine Service Manual*.
3. Remove both exhaust tubes.

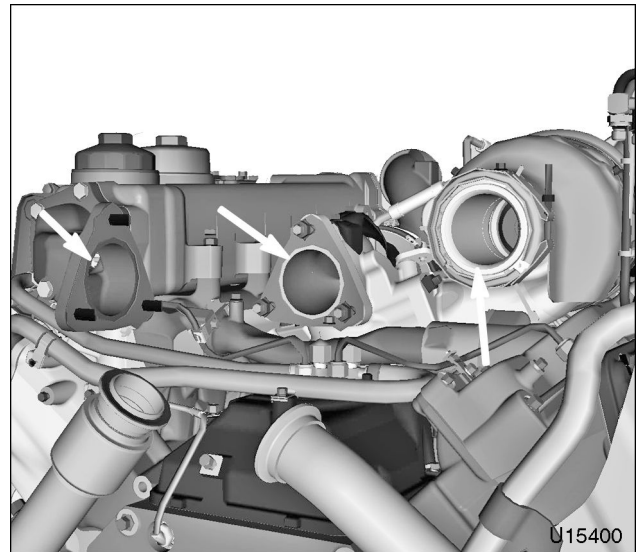


Figure 35 Exhaust ports

4. Check for presence of coolant in exhaust tubes, exhaust manifolds, and EGR cooler exhaust inlet.

5. Plug in the cylinder block heater, if available, to warm coolant.

 **WARNING:** To prevent personal injury or death, do the following when removing the radiator cap or deaeration cap:

- Allow the engine to cool for 15 minutes.
- Wrap a thick cloth around the radiator cap or deaeration cap.
- Loosen cap slowly a quarter to half turn to vent pressure.
- Pause for a moment to avoid being scalded by steam.
- Continue to turn cap counterclockwise to remove.

 **WARNING:** To prevent personal injury or death, wear safety glasses with side shields.

6. Install Radiator Pressure Test Kit ZTSE2384 with the appropriate adapter on the deaeration tank.
7. Pressurize cooling system to 103 kPa (15 psi).
8. Bar engine over by hand and check for evidence of coolant flowing out of the exhaust manifolds.
- If coolant is found, go to Cylinder Head Leak Test (page 72) in this section.
 - If no coolant is found, continue with the next step.
9. Check EGR cooler exhaust inlet for coolant.
- If coolant is present, replace EGR cooler following the procedures in the *Engine Service Manual*.
 - If no leak is found but pressure is dropping rapidly, go to Combustion Leak Test (page 68) in this section.
 - If no leak is found, continue with the next step.
10. Drain coolant from the system as described in the *Engine Service Manual*.

11. Remove and pressure test the EGR cooler following the procedure in the *Engine Service Manual*.

- If a leak is noticed, replace the EGR cooler.
- If a leak is not noticed, install the EGR cooler following the procedure in the *Engine Service Manual* and go to Cylinder Head Leak Test (page 72) in this section.

Coolant in Lube Oil

Symptom

Crankcase lube oil contaminated with coolant will generally cause the oil to thicken and turn gray. The crankcase may also be overfilled.

Possible Causes

- Accessory leak (water cooled air compressor)
- Injector sleeve leak
- Cylinder head cup plug failure
- Cylinder head gasket leak
- Oil cooler failure
- Front cover gasket damage
- Front cover, cylinder head, or crankcase porosity
- EGR cooler failure
- Cracked intake manifold coolant passage

Tools

- ZTSE2384 – Radiator Pressure Test Kit
 - ZTSE4409 – Pressure Test Kit
 - ZTSE6029 – Oil Cooler Block Off
 - Straight edge
 - Feeler gauge
-

Lube Oil Contamination

1. Check coolant level and oil level dipsticks to verify oil contamination complaint.
 - If the crankcase lube oil is contaminated with coolant, the oil will have a light gray sludgy appearance.
 - If coolant in the oil cannot be verified, an oil sample can be taken for analysis.
2. Plug in cylinder block heater, if available, to warm coolant.
3. If engine is equipped with an air compressor, isolate compressor from the engine and test for coolant leak. See Air Compressor Leak Test (page 67) in this section.
4. Drain engine oil and remove oil filter following procedures in the *Engine Service Manual*. Leave oil drain plug out of pan and oil filter off.

! WARNING: To prevent personal injury or death, do the following when removing the radiator cap or deaeration cap:

- Allow the engine to cool for 15 minutes.
- Wrap a thick cloth around the radiator cap or deaeration cap.
- Loosen cap slowly a quarter to half turn to vent pressure.
- Pause for a moment to avoid being scalded by steam.
- Continue to turn cap counterclockwise to remove.

! WARNING: To prevent personal injury or death, wear safety glasses with side shields.

5. Install Radiator Pressure Test Kit ZTSE2384 with appropriate adapter on the deaeration tank.
6. Pressurize cooling system to 103 kPa (15 psi).
7. Leave pressure on system for 15 minutes and verify 103 kPa (15 psi) pressure is maintained on Radiator Pressure Test Kit ZTSE2384.

8. Check for coolant leaking out of the oil pan drain hole.
 - If coolant system pressure is dropping and no coolant is leaking from oil pan drain hole, go to step 9.
 - If coolant is leaking into oil pan, remove valve covers following the procedure in the *Engine Service Manual* and inspect the following:

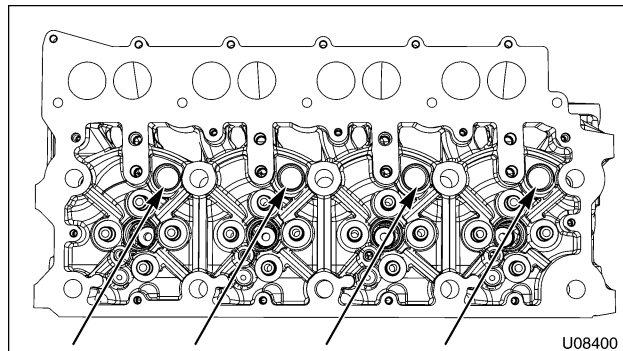


Figure 36 Cylinder head cup plugs

- Inspect entire cylinder head area for leaks at the cup plugs.
 - If no leaks are found in above areas, go to step 10, and inspect for crankcase leakage.
9. Remove the oil pan and filter following the procedures in the *Engine Service Manual*.

! WARNING: To prevent personal injury or death, be aware that crankshaft may rotate suddenly when a cylinder is pressurized.

! WARNING: To prevent personal injury or death, wear safety glasses with side shields.

10. Inspect for leakage in crankcase.
 - Verify 103 kPa (15 psi) pressure is maintained on Radiator Pressure Test Kit ZTSE2384.
 - If no leakage is found, do the next step.
 - If leak is found, verify leak path and make repair following the procedures in the *Engine Service Manual*.

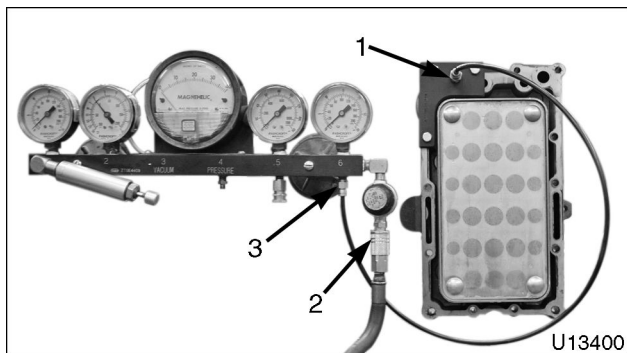


Figure 37 Oil cooler cover assembly pressure test

1. Oil Cooler Block Off
 2. Regulated air supply
 3. Pressure Test Kit
11. Remove and test the oil cooler following the procedures in the *Engine Service Manual*.
 - If a leak is found, replace oil cooler assembly.
 - If no leak is found, see Front Cover Inspection (page 72) in this section.

Front Cover Inspection

1. Remove front cover and inspect gaskets and sealing surfaces following the procedure in the *Engine Service Manual*.
2. Reinstall front cover following the procedure in the *Engine Service Manual*.
3. Pressure test the cooling system after any repair, to validate.

Cylinder Head Leak Test

1. Remove valve covers following the procedure in the *Engine Service Manual*.
2. Plug in block heater, if available, to warm coolant.

! WARNING: To prevent personal injury or death, do the following when removing the radiator cap or deaeration cap:

- Allow the engine to cool for 15 minutes.
- Wrap a thick cloth around the radiator cap or deaeration cap.
- Loosen cap slowly a quarter to half turn to vent pressure.
- Pause for a moment to avoid being scalded by steam.
- Continue to turn cap counterclockwise to remove.

! WARNING: To prevent personal injury or death, wear safety glasses with side shields.

3. Install Radiator Pressure Test Kit ZTSE2384 with appropriate adapter on the deaeration tank.
4. Pressurize cooling system to 103 kPa (15 psi).

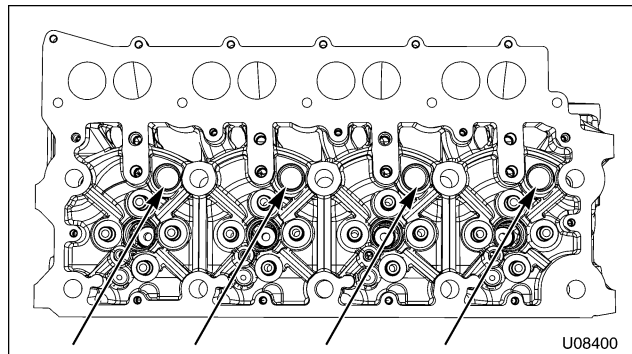


Figure 38 Cylinder head cup plugs

5. Inspect both cylinder heads for cracks or leaks at the cup plugs.
 - If leaking, repair or replace cracked or leaking component.
 - If no leak is found, do the next step.
6. Drain coolant from the system as described in the *Engine Service Manual*.
7. Remove one cylinder head from engine following the procedures in the *Engine Service Manual*.

8. Inspect and pressure test cylinder head following procedures in the *Engine Service Manual*.
 - Inspect cylinder head gasket for damage at sealing points. Verify crankcase and cylinder head surfaces flatness using a straight edge and feeler gauge. Replace cylinder head gasket and head bolts. Repair or replace cylinder head if necessary.
 - Inspect cylinder head for cracks in the coolant passages. Repair or replace.
9. Inspect crankcase coolant passages and cylinders for cracks following procedures in the *Engine Service Manual*.
10. If no leak is found, repeat steps 7 and 8 for the second cylinder head.
11. Pressure test cooling system to confirm repair.
12. Fill cooling system.

Coolant Over-Temperature

Symptom

When the coolant temperature is above 107 °C (224 °F), a Diagnostic Trouble Code (DTC) will set and the Engine Control Module (ECM) will command less fueling. A torque loss will occur.

When the coolant temperature is above 109 °C (228 °F), the red ENGINE lamp will be illuminated and a DTC will set.

When the coolant temperature is above 112 °C (234 °F), the red ENGINE lamp will flash, an audible alarm will sound, and a DTC will set. If the vehicle has the warning protection feature enabled, the engine will shut down after 30 seconds.

Possible Causes

- Low engine coolant level
- Coolant leaks
- Internal or external radiator blockage or wrong radiator
- Water pump failure
- One or both coolant thermostats missing or stuck (closed)
- Slipping cooling fan drive clutch
- Cooling fan blade assembly wrong or damaged
- Broken/worn accessory drive belt
- Accessory belt tensioner failure
- Instrument panel gauge error
- Engine Coolant Temperature 1 (ECT1) sensor biased
- Chassis effects, transmission, or aftermarket equipment

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Cable
- Digital Multimeter (DMM)
- ZTSE4799 – Digital Infrared Thermometer
- ZTSE2384 – Radiator Pressure Test Kit

Coolant Over-Temperature Diagnostics and Repair

1. Check coolant deaeration tank is filled to the FULL mark.

If coolant level is low, look for external leaks at radiator, engine, and all coolant tubes and hoses.

2. Inspect the condition of the following items: cooling fan, shroud, accessory drive belt, accessory drive belt tensioner, cooling fan drive clutch, and radiator.
 - If vehicle is new or recently repaired, verify the correct part number for any component related to the cooling system.
 - Verify that the cooling fan, cooling fan drive clutch, and radiator are clean of debris and dirt build-up. Clean areas as required.

CAUTION: To prevent radiator damage, when using high-pressure washer, be careful not to get the wand too close to radiator fins.

3. Connect EST and check for active and previously active DTCs related to engine coolant over-temp conditions. Compare Engine Coolant Temperature (ECT), Engine Oil Temperature (EOT), and Intake Manifold Temperature (IMT) with key ON, engine OFF. After a cold soak of at least eight hours, all temperature sensors should read within 2° C (3.6° F) of each other.
4. Run engine up to an operating temperature of at least 70° C (158° F). Monitor ECT using the EST.
5. Attempt to duplicate the operator's concern of coolant over-temperature.
 - If concern cannot be duplicated, clean radiator fins (if not done previously). Flush the radiator fins with water on the cooling fan side of the radiator. Do not continue further with diagnostics.
 - If coolant over-temperature is duplicated, continue with the next step.



WARNING: To prevent personal injury or death, do the following when removing the radiator cap or deaeration cap:

- Allow the engine to cool for 15 minutes.
 - Wrap a thick cloth around the radiator cap or deaeration cap.
 - Loosen cap slowly a quarter to half turn to vent pressure.
 - Pause for a moment to avoid being scalded by steam.
 - Continue to turn cap counterclockwise to remove.
6. Install the Radiator Pressure Test Kit ZTSE2384 with appropriate adapter on the deaeration tank and run engine at elevated idle. Monitor system pressure using the Radiator Pressure Test Kit ZTSE2384 gauge.
 - If pressure is higher than the pressure rating of the cooling system cap, continue with Combustion Leaks to Coolant (page 68) in this section.
 - If pressure gauge reading is below pressure rating of system, continue with step 7.
 7. Remove and inspect thermostats following the procedure in the *Engine Service Manual*. Check for correct opening temperature on both thermostats.
 - Replace as needed. Retest for condition after repair.
 - If both thermostats pass test, continue to next step.
 8. If over-temperature condition remains, remove radiator and have it flow tested and cleaned or replaced. Retest engine for over-temperature condition with repaired or new radiator.
-

Temperature Sensor Validation Test

1. Connect EST and check for active and previously active DTCs related to engine coolant over-temp conditions.
 - Repair problems relating to coolant over-temp DTCs before continuing.
 - If no DTCs exist, do next step.
2. Using the EST, compare ECT, EOT, and IMT with ignition key ON, engine OFF. After a cold soak of at least 8 hours, all temperature sensors should read within 2° C (3.6° F) of each other.
3. Use the Digital Infrared Thermometer ZTSE4799 at the EGR cooler inlet port, operate the engine, and use the EST to monitor ECT.
4. Run engine up to an operating temperature of at least 70 °C (158 °F). Monitor ECT using the EST, instrument panel coolant temperature gauge and the Digital Infrared Thermometer ZTSE4799. Attempt to duplicate the operator's concern of coolant over-temperature.
 - If instrument panel coolant temperature gauge reads a different temperature than the EST and thermometer, refer to the *Electrical System Troubleshooting Guide* for the appropriate model and year of vehicle.
 - If thermometer and EST read values with a difference greater than $\pm 3^{\circ}\text{C}$ ($\pm 5.4^{\circ}\text{F}$), see ECT1 Sensor (page 224) in the "Electronic Control Systems Diagnostics" section of this manual.
 - If the gauge is reading correctly and the engine is running over-temperature, go to Cooling System Operating Pressure Test (page 75) in this section.

Cooling System Operating Pressure Test

 **WARNING:** To prevent personal injury or death, wear safety glasses with side shields.

 **WARNING:** To prevent personal injury or death, do the following when removing the radiator cap or deaeration cap:

- Allow the engine to cool for 15 minutes.
 - Wrap a thick cloth around the radiator cap or deaeration cap.
 - Loosen cap slowly a quarter to half turn to vent pressure.
 - Pause for a moment to avoid being scalded by steam.
 - Continue to turn cap counterclockwise to remove.
1. Install the Radiator Pressure Test Kit ZTSE2384 on the deaeration tank and run engine at elevated idle.
 2. Monitor system pressure using the Radiator Pressure Test Kit ZTSE2384 gauge.
 - If pressure is higher than the pressure rating of the cooling system cap, go to Combustion Leaks to Coolant (page 68) in this section.
 - If pressure gauge reading is below pressure rating of system, replace the thermostats.

Engine Inspection

Symptom

Excessive low power on takeoff or intermittent low power from drive cycle to drive cycle

Possible Causes

Low Power

- Electrical power or ground issue
- Inoperative turbocharger assembly or failed turbocharger actuator
- Aerated fuel
- ECM or electronic control system faults
- Poor fuel quality
- Low supply pressure fuel pressure below specification
- High-pressure fuel pressure below specification
- Fuel injectors not working properly
- Inoperative Engine Throttle Valve (ETV)
- Power cylinders problem
- Valve train problems
- Failed Charge Air Cooler(s) (CAC)
- Aftertreatment (AFT) system issues
- Plugged Diesel Particulate Filter (DPF)
- Plugged Diesel Oxidation Catalyst (DOC)

Rough Idle

- Poor fuel quality
- Low supply fuel pressure below specification
- High-pressure fuel pressure below specification
- Aerated fuel
- Electronic control system faults
- Plugged DPF
- Plugged Diesel Oxidation Catalyst (DOC)
- Fuel injectors not working properly
- Exhaust Gas Recirculation (EGR) valve stuck open
- Power cylinder problems
- Valve train problems
- Engine or flywheel balance problems
- Exhaust system to cab/chassis contact
- Loose or worn engine mounts

Tools

- Digital Multimeter (DMM)
- EST with ServiceMaxx™ software

Low Power (Turbocharger Assembly and Actuator)

For low power issues, perform the tests in the "Performance Diagnostics" (page 113) section of this manual.

Rough Idle

1. Confirm conditions when rough idle complaint is present. When does rough idle occur?
 - Hot - operating temperature
 - Cold
 - After high speed operation
 - Over entire engine speed range
 - Combination of the above conditions
 - Is chassis vibration or any other condition or observation present when engine idles rough.
-

2. Inspect exhaust system for contact with frame or body of vehicle. Exhaust pipe contact with cab or frame may transmit engine vibrations and noise to cab.
3. Complete the following performance diagnostic tests in the “Performance Diagnostics” section of this manual.
 - Visual Inspections
 - Fuel. Verify quantity and quality. Check for aeration and correct pressure.
 - KOEO Standard Test
 - Check for DTCs
 - KOER Standard Test
 - KOER Air Management Test
 - Crankcase Pressure Test
 - Fuel Rail Pressure

Engine and Flexplate Balance Inspection

Inspect engine and drivetrain balance. Rough idle that gets worse with no-load acceleration may be caused by an out-of-balance engine, flexplate, or torque converter. Remove the accessory drive belt to isolate accessories during balance testing.

Inspect vibration damper for cracks and misalignment.

Inspect flexplate for cracks, damage and verify proper orientation. When removing or installing the flexplate, ensure the locating dowel is in the right place and the flexplate is located properly on the dowel.

Inspect the primary balancer shaft to ensure it is properly installed.

Isolate the engine from transmission by removing the transmission and torque converter. Start the engine and evaluate imbalance. If the engine runs smoothly, diagnose the torque converter and transmission. See applicable vehicle *Service Manual*.

Electrical System

ECM Reset (Intermittent Engine Stumble)

Symptom

An Engine Control Module (ECM) reset occurs when the ECM momentarily reboots or is turned OFF and ON while the engine is operating. Symptoms of this include the following:

- Wait to Start lamp cycles on while engine running
- Engine stumbles and may die
- Loss of accelerator pedal authority
- Miles driven are not logged if ECM reset occurs during current key cycle

If a reset occurs, the engine will momentarily stumble, and the ECM will go through a normal KEY ON cycle. This includes the following:

- Illuminate the Wait to Start lamp
- Validate the accelerator pedal position

If the pedal is not at idle position when the reset occurs, a DTC is set and engine speed goes to low idle. The ECM will not allow accelerator pedal authority until the Accelerator Pedal Sensor (APS) is released.

Possible Causes

Momentary loss of power to the ECM may be caused by:

- Poor (intermittent OPEN or high resistance) ground connection

- Poor battery power feed harness connection
- Poor fuse connection
- Intermittent open at connectors
- Poor power relay connection
- Poor module connection, corrosion, or water

Diagnostics for Engine Stumble

1. Go to Fuel System (page 79) in this section.

See ECM PWR Relay (page 216), and ECM Self Diagnostics (page 221) in the “Electronic Control Systems Diagnostics” section of this manual or the application specific truck *Circuit Diagram Manual* and *Service Manual* when performing the following steps.

2. Check all ECM related fuses.
 3. Check all Battery, VIGN and ground connections for the ECM.
 4. Monitor ECM powers and grounds with breakout box under operator complaint conditions.
 5. Monitor injector powers and grounds with breakout harness under operator complaint conditions.
 6. If root cause has not been identified in previous steps, continue diagnosis by doing the remaining tests in “Performance Diagnostics” section of this manual.
-

Fuel System

 **WARNING:** To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

 **WARNING:** To prevent personal injury or death, store diesel fuel properly in an approved container designed for and clearly marked **DIESEL FUEL**.

 **WARNING:** To prevent personal injury or death, wear safety glasses with side shields.

 **WARNING:** To prevent personal injury or death, do not let engine fluids stay on your skin. Clean skin and nails using hand cleaner and wash with soap and water. Wash or discard clothing and rags contaminated with engine fluids.

NOTE: If symptom is related to high pressure fuel supply, see “Hard Start and No Start Diagnostics” (page 89) section of this manual

Excessive Fuel Consumption

Symptom

Engine is using more fuel than previously required to perform the same task.

Possible Causes

Operator effects

- Inaccurate recordkeeping or tank filling

- Winter blend or No. 1 fuel
- Unrealistic expectations

Application effects

- Heavy loading Gross Vehicle Weight (GVW)
- Low rear axle ratio
- Large frontal area
- Accessory usage (Power Takeoff, etc.)
- Additional equipment drawing fuel from vehicle fuel tanks
- Extended idle applications
- Tire size, tire condition, or air pressure

Chassis effects

- Brake drag
- Cooling fan clutch locked ON
- Transmission slippage/shifting
- Fuel tank plumbing or venting
- Intake or exhaust restriction

Engine effects

- Oil aeration
- Incorrect or inoperative thermostat(s)
- Failed turbocharger control system
- Fuel system performance loss
- Fuel system leaks
- Base engine performance loss

Verifying Excessive Fuel Consumption Complaints

1. Review operator and fueling records.
2. Loss of fuel economy is normal if winter blend fuel, kerosene or No. 1 diesel fuel is being used.
3. Review vehicle specifications to determine if fuel consumption is normal for type of application and use of vehicle. Compare consumption with similar vehicles in the same application and Truck Computer Analysis of Performance and Economy (TCAPE) report.
4. Do all tests on Performance Diagnostic form or in "Performance Diagnostics" section of this manual.

These tests will verify the operating condition of the following engine and chassis systems:

- Intake system
- Exhaust system
- Fuel delivery and filtration
- High-pressure fuel system
- Injector operation
- Turbocharger operation
- Base engine condition
- Electronic control system condition

If all tests are passed, the engine is operating normally.

Fuel in Coolant

 **WARNING:** To prevent personal injury or death, wear safety glasses with side shields.

Symptom

Coolant contaminated with diesel fuel will have a diesel fuel odor.

Possible Causes

- Leaking or cracked injector sleeve with injector O-ring failure
- Cracked or porous cylinder head casting in fuel return area

- Broken fuel cooler

Tools

- ZTSE2384 – Radiator Pressure Test Kit
- Fitting attached to clear line to container (obtain locally)
- Diesel fuel container
- ZTSE4535 – Cylinder Head Test Plate
- ZTSE4607 – Fuel Line Test Adapter

Fuel in Coolant Leakage Test (Low-pressure)

1. Remove fuel line at the fuel cooler. Plug fuel line and place suitable diesel fuel container under the fuel cooler to catch draining fuel.

 **WARNING:** To prevent personal injury or death, store diesel fuel properly in an approved container designed for and clearly marked **DIESEL FUEL**.

 **WARNING:** To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

 **WARNING:** To prevent personal injury or death, do the following when removing the radiator cap or deaeration cap:

- Allow the engine to cool for 15 minutes.
 - Wrap a thick cloth around the radiator cap or deaeration cap.
 - Loosen cap slowly a quarter to half turn to vent pressure.
 - Pause for a moment to avoid being scalded by steam.
 - Continue to turn cap counterclockwise to remove.
2. Verify coolant contamination.
 - Check for diesel fuel odor in coolant.
 - Coolant may be discolored if diesel fuel is present.
 3. Fill deaeration tank with coolant to the FULL mark.
 4. Plug in the cylinder block heater, if available, to warm coolant.

! WARNING: To prevent personal injury or death, wear safety glasses with side shields.

5. Install Radiator Pressure Test Kit ZTSE2384 with appropriate adapter on the deaeration tank.
6. Pressurize cooling system to 103 kPa (15 psi).
7. Inspect the fuel cooler for any coolant coming from the fuel side. If the cooler is leaking, replace the cooler and retest.
8. If the fuel cooler is not leaking, remove fuel injector return line banjo fittings following the procedures in the *Engine Service Manual*.
9. Inspect the fuel injector return line bores at cylinder heads for coolant leaks.
 - If leak is found, remove valve cover and fuel injectors from the suspect cylinder head, following procedures in the *Engine Service Manual*. Observe injector sleeves for leakage. Repair cylinder head, as necessary. After repair, pressurize cooling system to confirm repair.
 - If no leak is found, remove each cylinder head one at a time following the procedures as described in the *Engine Service Manual*. Perform all inspections and pressure test cylinder head to check for leak paths.

Fuel in Coolant Leakage Test (High-pressure)

! WARNING: To prevent personal injury or death, do the following when removing the radiator cap or deaeration cap:

- Allow the engine to cool for 15 minutes.
- Wrap a thick cloth around the radiator cap or deaeration cap.
- Loosen cap slowly a quarter to half turn to vent pressure.
- Pause for a moment to avoid being scalded by steam.
- Continue to turn cap counterclockwise to remove.

1. Verify coolant contamination.
 - Check for diesel fuel odor in coolant.
 - Coolant may be discolored if diesel fuel is present.
2. Fill deaeration tank with coolant to the FULL mark.
3. Plug in the cylinder block heater, if available, to warm coolant.

! WARNING: To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

NOTE: When removing the cylinder head injector return line banjo bolts, fuel may leak out. Put in a suitable container to collect this leakage. Collect and dispose of this fuel according to local regulations.

! WARNING: To prevent personal injury or death, store diesel fuel properly in an approved container designed for and clearly marked DIESEL FUEL.

4. Remove the left and right cylinder head injector return line banjo bolts, following the procedures in the *Engine Service Manual*.

! WARNING: To prevent personal injury or death, wear safety glasses with side shields.

5. Individually pressurize both fuel injector return lines from the cylinder heads to 550 to 690 kPa (80 to 100 psi) using the Fuel Line Test Adapter ZTSE4607. Observe deaeration tank for air bubbles or loss of pressure at gauge.
 - If leak is found, do all inspections and test cylinder heads to verify leak path. Repair cylinder head, as necessary.
 - If no leak is found, continue with Fuel in Coolant Leakage Test (Low-pressure) (page 80) in this section.

Fuel In Lube Oil**Symptom**

Oil contaminated with diesel fuel will have diesel fuel odor and the oil level in engine will consistently increase.

Possible Causes**Leaking fuel under the valve cover**

- Fuel Rail Pressure (FRP) sensor
- Fuel rail to fuel injector supply lines
- Fuel injector(s)
- A leaking injector sleeve or injector tip could cause contaminated engine oil, but would most likely be identified as a performance problem.

Porous cylinder head

- Most likely on low mileage vehicles

Tools

- One gallon of clean diesel fuel
- ZTSE4618 – UV Leak Detection Kit (black light)

Verifying Fuel Dilution from Oil System

1. Verify oil contamination by performing a white paper test or oil analysis.
2. Place one drop of suspect oil on a clean sheet of printer or copier paper.
 - If the oil wicks away rapidly into the paper, there is fuel contamination. Check for related iKnow letters and service bulletins using Service Portal network.
 - If the oil maintains a uniform and slow expanding stain, there is no fuel contamination and no repair is required.

NOTE: The UV Leak Detection Kit ZTSE4618 (black light) requires warm-up time. Turn on the UV Leak Detection Kit ZTSE4618 (black light).

3. Verify there is no dye in the oil before starting the dye test.

NOTE: Only use indicator dye approved for use with diesel fuel.

4. Supply engine with an alternate supply of clean diesel fuel with dye mixed to manufacturers specification.
5. Perform a fuel leakage test.
 - a. Verify that there is no dye existing in the oil before starting the dye test.
 - b. Supply the engine with an alternate supply of clean diesel fuel with the manufacturers recommendations for the amount of dye per gallon to be added.
 - c. Remove both valve covers and check all internal fuel connections for leaks.
 - If no leaks are found under both valve covers, check for related iKnow letters and service bulletins using Service Portal network.

Fuel to Exhaust**Symptom**

Fuel leaking into the exhaust results in a wet exhaust system and possible damage to the Diesel Particulate Filter (DPF).

Possible Causes

- Fuel injector leaking
- Internal engine damage

Do High-pressure Fuel System Leak Test, (page 110) in the “Hard Start and No Start Diagnostics” section of this manual.

Air or Combustion Leaks to Fuel**Possible Causes**

- Compression leak past compression gasket to fuel return
 - Loose fuel injector hold down
 - Missing or damaged stainless steel injector gasket
-

- Combustion leaks to fuel will exhibit one or more of these characteristics:
 - Engine stall during operation
 - Rough running engine
 - Extended engine crank time (hard start)
 - Fuel Rail Pressure (FRP) slow to build while cranking
 - Excessive fuel pressure in the low-pressure fuel system while cranking
 - Pulsating fuel pressure (low-pressure fuel system) during crank or engine running at idle
 - No start

Air or Combustion Leak to Fuel Test

Inspect cylinder head for combustion leaks using a test adapter to validate cylinder head is leaking to the fuel system.

1. Verify operator complaint.

! WARNING: To prevent personal injury or death, do not smoke or park vehicle near open flames or sparks when draining fuel. Store diesel fuel properly in an approved container designed for and clearly marked DIESEL FUEL.

2. Place a suitable container under the secondary fuel filter housing to catch draining fuel.
3. Disconnect the injector return lines from each cylinder head following the procedure in the *Engine Service Manual*.
4. Install Fuel Line Test Adapter ZTSE4607 with clear plastic hose at the fuel return line fitting in the engine cylinder head.

! WARNING: To prevent personal injury or death, wear safety glasses with side shields.

CAUTION: To prevent engine damage, if engine fails to start within 20 seconds, release ignition switch and wait 2 to 3 minutes to allow starter motor to cool.

5. Submerge the test line in a container filled with water.
6. Turn ignition switch to ON and start or crank engine for 20 seconds. Inspect for air or

combustion leaks in the fuel. Inspect for the following.

- Combustion gasses or smoke coming from sample line or bubbles in water.
 - Audible sound of air/compression from sample line
7. If no leak is noticed testing one head, remove line and repeat steps 2 through 6 on the opposite head.
 8. If leak is noticed, continue to step 9.
 9. Remove one injector following the procedure in the *Engine Service Manual* and test for combustion leak.

NOTE: If failed cylinder is not diagnosed removing the first injector, reinstall injector following the procedure in the *Engine Service Manual* and continue one for the remaining injectors.

- If the leak stops, replace injector and cup plug.
 - If leakage continues, confirm an air or combustion leak to the fuel supply, identify the failed cylinder head and remove, following the procedure in the *Engine Service Manual*.
10. After air or combustion leaks to fuel have been repaired and retested, remove both return line banjo fittings, re-install the return line banjo fittings with new copper gasket, following the procedures in the *Engine Service Manual*.

Low Fuel Pressure and Aeration

Symptom

Fuel aeration will exhibit one or more of the following characteristics:

- Engine stall during operation
- Rough running engine
- Extended engine crank time (hard start)
- Fuel pressure slow to build while cranking
- Excessive fuel pressure while cranking
- Pulsating fuel pressure during crank or engine running at idle

- Difficulty priming fuel system

Possible Causes

- Leaks in fuel supply to fuel pump
- Loose fuel injector holddown
- Missing/damaged stainless steel injector gasket
- Suction side leak or cracked line

Water In Fuel (WIF) Check**Possible Causes**

- Water or ice in fuel supply system or damaged connection
- Corrosion on connector, sensor, or cover plate assembly
- Failed ECM
- Failed WIF sensor

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Clean flat drain pan, with a wide opening

Drain Water from Primary Fuel Filter

1. Connect Electronic Service Tool (EST) with ServiceMaxx™ software to vehicle's Diagnostic Connector.
2. Check for active and previously active DTCs.
3. Correct any sensor DTCs before proceeding. See WIF sensor (page 367) in the "Electronic Control Systems Diagnostics" section of this manual.
4. If the WIF DTC SPN 4192/FMI 31 is active or fuel system contamination is suspected, continue with next step.
5. Put a clean flat drain pan under the primary filter.

 **WARNING:** To prevent personal injury or death, do not smoke or park vehicle near open flames or sparks when draining fuel. Store diesel fuel properly in an approved container designed for and clearly marked DIESEL FUEL.

6. Drain the water separator following the procedures in the *Engine Service Manual*.
7. Check fuel in drain pan for contamination. Dispose of the contents in the drain pan properly, in accordance with local requirements.
 - Excessive water or contaminants may indicate that the tank and fuel system need to be flushed and cleaned.
 - The fuel should be clear, not cloudy. Cloudy fuel indicates that the fuel is not a suitable grade for cold temperatures.
 - The fuel should not be dyed red or blue, these colors indicate off-highway fuel.
 - Fuel should not be waxing or gelling. Waxing or gelling in cold weather can clog the fuel filters and the fuel pump and cause restrictions in the fuel or low fuel pressure.
8. Turn ignition switch to ON, determine if SPN 4192/FMI 31 is active.
 - If SPN 4192/FMI 31 is not active, the procedure is complete, do not continue.
 - If SPN 4192/FMI 31 is active, continue with the next step.

NOTE: If SPN 4192/FMI 31 is active after the water has been drained, the WIF sensor or the WIF sensor connector may be corroded, the condition should be corrected and retested.

9. Check the WIF sensor connector. See WIF sensor (page 367) in the "Electronic Control Systems Diagnostics" section of this manual.
10. Turn ignition switch to ON, determine if SPN 4192/FMI 31 is active.
 - If SPN 4192/FMI 31 is not active, the procedure is complete, do not continue.
 - If SPN 4192/FMI 31 is active, replace the primary fuel filter.
 - If SPN 4192/FMI 31 is active, check fuel lines and tank(s) water or other contaminants. Drain and clean fuel lines as needed.

Lubrication System

⚠ WARNING: To prevent personal injury or death, do not let engine fluids stay on your skin. Clean skin and nails using hand cleaner and wash with soap and water. Wash or discard clothing and rags contaminated with engine fluids.

⚠ WARNING: To prevent personal injury or death, when routing test line, do not crimp line, run line too close to moving parts, or let line touch hot engine. Secure the gauge and test line to not obstruct vehicle operation.

⚠ WARNING: To prevent personal injury or death, shift transmission to park or neutral, set parking brake, and block wheels before doing diagnostic or service procedures.

Low Oil Pressure

Possible Causes

- Low oil level: oil leak, oil consumption or incorrect servicing
- High oil level: incorrect servicing, fuel in oil, or coolant in oil
- Stuck oil pressure regulator
- Scored or damaged oil pump
- Engine Oil Pressure (EOP) sensor biased
- Missing oil gallery cup plugs (front or rear)
- Broken, missing, or loose piston cooling tube(s)
- Missing, damaged, or worn bearing inserts or camshaft bushings
- Lifter missing (will also have performance problems)
- Aeration (cracked pickup tube, missing O-ring)
- Debris in lifter(s)

Tools

ZTSE4409 – Pressure Test Kit

Low Oil Pressure Diagnostics

1. Verify oil level in engine using oil level gauge while vehicle is parked on level ground. Check to see if oil is contaminated with fuel or coolant.
 - Engine oil level will vary depending on temperature of engine.
 - If oil is contaminated, go to Fuel in Lube Oil (page 82) or Coolant in Lube Oil (page 70) in this section.
2. Connect Pressure Test Kit ZTSE4409 air gauge to diagnostic port on the oil pan, using adapter (obtain locally).
3. Start the engine and measure oil pressure at both low and high idle, under no load conditions. Engine must be at normal operating temperature.
 - If oil pressure reads within specification listed in “Appendix A: Performance Specifications” (page 425) and the instrument panel indicator indicated low pressure, perform EOP Sensor (page 253) in the “Electronic Control Systems Diagnostics” section of this manual. Repair or replace the oil pressure indicator as required.
 - If oil pressure does not read within the specification, continue with the next step.
4. Remove and inspect oil pressure regulator as described in the *Engine Service Manual*.
 - The oil pressure regulator piston should move freely in its bore in the front cover.
 - If oil pressure regulator is functional and passes visual inspection, reinstall regulator following the procedures in the *Engine Service Manual*. Redo this procedure starting with step 3. If oil pressure remains low, continue with the next step.
5. Remove and inspect the lube oil pump following the procedure in the *Engine Service Manual*.
 - Inspect the lube oil pump housing and cover for gouging or deep scratches.
 - Inspect the gerotor gears for excessive wear or damage.
 - If no excessive damage is found, continue with the next step.

6. Drain oil from engine using a clean drain pan. Inspect oil drain plug magnet, drained oil and oil filter for foreign debris.

An oil sample should be taken to determine level of engine wear metals and contaminants in the oil.

7. Remove oil pan following the procedure in the *Engine Service Manual*. Inspect for missing, loose, or damaged oil pickup tube, O-ring, piston cooling tubes, bearing inserts, and cam bushings.
8. To prevent damage to the engine, verify the oil filter is intact. Running the engine with a failed oil filter could cause rapid deterioration of the engine due to dirty oil.
9. Reinstall the oil pump and oil pump cover.

 **WARNING:** To prevent personal injury or death, wear safety glasses with side shields.

10. Connect regulated shop air line to the oil filter diagnostic coupling assembly.
11. Slowly apply air pressure in 34.5 kPa (5 psi) increments to 345 kPa (50 psi).
12. Inspect for gross leaks internally.
- If a major leak is observed from the front cover area, continue with the next step.

- If a major leak is observed from the rear cover area, continue with step 15.
- If a major leak is not observed, remove engine from vehicle. Disassemble engine and perform full inspection of all components following procedures in the *Engine Service Manual*.

13. Remove the front cover from the engine following procedures in the *Engine Service Manual* and complete inspection of the lube oil pump.

14. With front cover removed from the engine, verify that the front main oil gallery cup plugs are in position and not damaged.

 **WARNING:** To prevent personal injury or death, support engine (if in chassis) before removing rear cover or flywheel.

15. Remove the rear cover from the engine as described in the *Engine Service Manual*. Verify the rear main oil gallery cup plugs are in position and not damaged.
-

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Diagnostics Form

Required Test Procedures		
Do required test procedures in sequence. Doing a required test out of sequence can cause incorrect results.		
1. Initial Key On Check		
☐ Check Integral Digital Display for WATER IN FUEL indicator.		
Does WATER IN FUEL indicator stay on?	☐ Yes	☐ No
● If WATER IN FUEL stays on, go to Fuel Quality Check.		
2. Visual Inspection		
☐ Check all fluid levels.		
☐ Inspect electrical connectors.		
☐ Inspect air filter minder.		
Note: If filter minder indicates a restriction, go to Intake Restriction Test in Performance Diagnostics.		
☐ Inspect CAC.		
☐ Inspect for visible exhaust damage.		
Are all fluid levels within specifications?	☐ Yes	☐ No
Are power and ground connections okay?	☐ Yes	☐ No
Is air filter okay?	☐ Yes	☐ No
Is exhaust system okay?	☐ Yes	☐ No
Comments:		
● If intake system repair is made or intake system is disturbed, go to MAF Sensor Test in Performance Diagnostics.		
2.1 Fuel Level Check		
☐ Check instrument panel gauge and look into fuel tank to verify fuel level.		
Is there fuel in the fuel tank?	☐ Yes	☐ No
Comments:		
● If fuel gauge reads above empty, but tank is empty, diagnose gauge.		
● If fuel tank is empty, add fuel and turn ignition key ON. With ignition key ON and engine OFF, fuel system should self-prime within 30 seconds.		
2.2 Fuel Quality Check		
☐ Route clear hose from fuel drain valve on fuel filter housing to approved container. Open drain valve and fill approved container.		
☐ Check for water, waxing, icing, sediment, gasoline, or kerosene.		
Is fuel contaminated?	☐ Yes	☐ No
Comments:		

U02415

Figure 39 Diagnostics Form EGED-616 (Hard Start and No Start)

The Hard Start and No Start Diagnostics Form directs technicians to systematically troubleshoot a hard start or no start condition and avoid unnecessary repairs.

This Diagnostic Manual section shows detailed instructions of the tests on the form. The manual should be used along with the form and referenced for supplemental test information. Use the form as a worksheet to record test results.

Do Test Procedures in sequence. Doing a test out of sequence can cause incorrect results. If the customer complaint is found and corrected, it is not necessary to complete the remaining tests.

See appropriate section of this manual for Diagnostic Trouble Codes (DTCs) and engine specifications.

Diagnostics Form EGED-616 is available in 50-sheet pads. To order technical service literature, contact your International dealer.

Diagnostics Form Header Information

Note: This form must be completed before calling for technical assistance.		
Technician:	Date:	Unit Number:
ECM Calibration:	Miles:	Hours:
Engine Serial Number:	Horsepower Rating:	Torque:
Transmission (select one): ☐ Manual ☐ Automatic		
VIN:		
Complaint:		

U02413

Enter Diagnostics Form Header Information

1. Technician
2. Date
3. Unit No. (dealer's quick reference number)
4. Customer complaint (interview driver)
5. Connect Electronic Service Tool (EST) with ServiceMaxx™ software to Diagnostic Connector.
6. Using the EST with ServiceMaxx™ software, log all vehicle information needed on the form header.

ServiceMaxx - Default

File View Sessions Tests Procedures Tools Help

Sessions: Default Parameters Signals Stop Tests

Instructions

Default ☒ Lock

Vehicle Identification: Verify Information matches your vehicle. If your vehicle does not show up in this session, select it from the File / Select engine drop-down menu.

Vehicle Information

Engine Type: MaxForce DT/9/10 (2010 -)

Software Identification: WBL1WMRC

Engine Family Rating Code: 1151

Vehicle Identification Number: 1HTMMAAM36H334012

Engine Serial Number: 466HM2U3300202

Transmission Type: Allison MD

Rated Horsepower: 230.00 hp

Total Miles: 162.60 miles

Total Fuel Used: 17.88 gal

Total Engine Hours: 5.85 hr

Parameters

Undo All Changes... Program Engine... ☒ Only Show Watched

ID	Name	Value	Units	Undo	Wa...
74111	Engine Idle Shutdown CARB	CARB IST Disabled			☒
74001	Engine Idle Shutdown Timer Mode	PTO Option			☒
74010	Engine Idle Shutdown Time	15.00	min		☒
74021	Engine Idle Shutdown Maximum Inta...	302.00	F		☒
74031	Engine Idle Shutdown Minimum Inta...	30.55	F		☒

Position & Pressure **Voltage**

Name	Value	Units
Accel Pedal Position 1	0.00	%
Barometric Pressure	14.14	psi
Brake Ctrl Pressure	69.69	psi
DPF Differential Pre...	0.00	psi
DPF Status	Regen ...	
EGR Position	35.00	%
EGR Position		%
EWPS - Has Shutdown ...	No	
Engine Fuel Pressure	0.00	psi
Engine Oil Pressure	0.58	psi
Engine Speed	0.00	RPM
Exhaust Back Pressure	-0.03	psi
Injection Control Pr...	0.00	psi
Intake Manifold Pres...	Error	psi
Mass Air Flow	0.00	kg/hr

Temperature **Voltage**

Name	Value	U...
Air Inlet Temp	78.80	F
Ambient Air Temp	78.80	F
DIC Inlet Temp	79.76	F
DIC Outlet Temp	Not Ava...	F
DPF Outlet Temp		F
Engine Coolant Temp 1	71.60	F
Engine Fuel Temp	71.60	F
Engine Intercooler Temp	Not Ava...	F
Engine Oil Temp	71.60	F
Exhaust Gas Temp	775.63	F
Intake Manifold Temp	77.00	F
Turbo Oil Pressure	Not Ava...	F

Diagnostic Trouble Codes **Datalink Traffic** **DTC Log**

DTC	SPN	FMI	Type	Emissions-Related	Extended	Message	Module
-1	175	3	Previously Active		☒	EOT signal Out of Range HIGH	Engine
-1	102	4	Active		☒	IMP signal Out of Range LOW	Engine

Clear DTCs Refresh DTC/Vehicle Events

Probe not needed

Sniffer

Protocol	Module Name	Count
J1939	Engine	210631
J1939	Transmi...	87396
J1939	Brakes ...	31070
J1939	Vehicle...	680
J1939	Exhaust	7326

U02408

Figure 41 ServiceMaxx™ opening screen (example)

- Verify the following vehicle information matches the ServiceMaxx™ displayed information:
 - Vehicle Identification Number (VIN)
 - Electronic Control Module (ECM) calibration
 - Rated Horsepower (HP)
 - Engine Family Rating Code (EFRC)
 - Transmission
 - Engine Serial Number (SN)
- Enter the following information on the Diagnostics Form:
 - Odometer (miles)
 - Engine hours
 - Intake air temperature
 - Coolant temperature

NOTE: The engine serial number is located on the right side of the crankcase, below the cylinder head. It is also on the engine emission label on the valve cover.

Test Procedures

NOTE: If this is a cold start problem, do the Inlet Air Heater Test (page 99) first.



GOVERNMENT REGULATION: Engine fluids (oil, fuel, and coolant) may be a hazard to human health and the environment. Handle all fluids and other contaminated materials (e.g. filters, rags) in accordance with applicable regulations. Recycle or dispose of engine fluids, filters, and other contaminated materials according to applicable regulations.

! WARNING: To prevent personal injury or death, do not let engine fluids stay on your skin. Clean skin and nails using hand cleaner and wash with soap and water. Wash or discard clothing and rags contaminated with engine fluids.

! WARNING: To prevent personal injury or death, shift transmission to park or neutral, set parking brake, and block wheels before doing diagnostic or service procedures.

! WARNING: To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

! WARNING: To prevent personal injury or death, provide proper ventilation when operating an engine in a closed area. Inhalation of exhaust gas can be fatal.

! WARNING: To prevent personal injury or death, wear safety glasses with side shields.

1. Initial Key On Check

Purpose

Determine the following:

- Is the Engine Control Module (ECM) powered up?

- Is the WATER IN FUEL lamp on?

Tools

None

Procedure

1. Turn ignition switch to ON. Do not start engine. Check for the following:
 - WAIT TO START lamp is on
 - Warn Engine Lamp (WEL) is on
2. If the WEL stays on and a text message is displaying Water in Fuel, take a fuel sample and evaluate quality. If water is present, drain and flush fuel tank and replace both primary and secondary fuel filters.

Possible Causes

WAIT TO START lamp does not illuminate

- No key power (VIGN)
- Failed ECM ground circuit
- No power from main power relay to ECM
- ECM failure
- Amber WAIT TO START lamp is out (will not cause hard start or no start).
- CAN link to instrument panel not working (will not cause hard start or no start).

NOTE: Instrument panel WEL should cycle ON, then OFF, if there is no water in the system. Lamp will stay ON if water is detected.

WARN ENGINE lamp stays illuminated

- Water in fuel
- Electrical circuit failure

2. Visual Inspection

Purpose

Check all fluid levels and inspect engine systems for problems (leaks, open connections, harness chaffing, etc.).

Tools

None

Engine Oil

1. Park vehicle on level ground and check oil level.

NOTE: Turn ignition switch to OFF and shut down engine. Wait 15 minutes for oil level to stabilize.

2. Use oil level gauge (dipstick) to verify engine oil level.
3. Record results on Diagnostics Form.
 - If level is below specification, inspect for leaks, oil consumption, or improper servicing. If engine oil level is low, fill to specification.
 - If level is above specification, inspect for fuel dilution, coolant contamination, or improper servicing. If engine oil level is above specification, drain to specification.

CAUTION: If oil is contaminated, oil and filter must be replaced.

NOTE: If change engine oil indicator is illuminated, check maintenance history. See *Engine Operation and Maintenance Manual* for information on resetting service intervals.

Engine Coolant Level

1. Park vehicle on level ground.

NOTE: Turn ignition switch to OFF, shut down engine, and allow to cool. Ensure coolant temperature has stabilized to a safe temperature and pressure.

2. Check coolant level as indicated on deaeration tank level window.
3. Record results on Diagnostics Form.
 - If level is above or below deaeration tank fill level, inspect for leaks, coolant in the oil, or coolant in the intake or exhaust. See Coolant Over-Temperature Diagnostics and Repair (page 74), Fuel in Coolant (page 80), and Combustion Leaks to Coolant (page 68) in the “Engine Symptoms Diagnostics” section of this manual.
 - If level is at deaeration tank fill level, and no tank contamination is evident, no repair is required.

NOTE: If coolant is contaminated, replace coolant.

CAUTION: Coolant in the exhaust could damage the Diesel Particulate Filter (DPF) and Diesel Oxidation Catalyst (DOC). Inspect DPF and DOC for damage. See AFT System (page 151) in the “Electronic Control Systems Diagnostics” section of this manual for inspection of the DPF and DOC.

Electrical System

Inspect batteries and electrical system (engine and vehicle) for poor or loose connections, corroded terminals, or broken and damaged wires. Repair electrical system as required.

Exhaust System

Inspect exhaust system (engine and vehicle) for damaged or plugged tailpipe. Repair exhaust system as required.

Intake Air System and Charge Air Cooler (CAC)

1. Inspect CAC system, including intercooler and all intake piping and ducts, for leaks and damage.

Inspect the following parts for restriction, damage, or incorrect installation:

- Air inlet hoses and ducts
- Air filter housing, filter element, and gaskets
- CAC and piping
- Air filter inlet and duct - look inside duct and remove any restrictions.

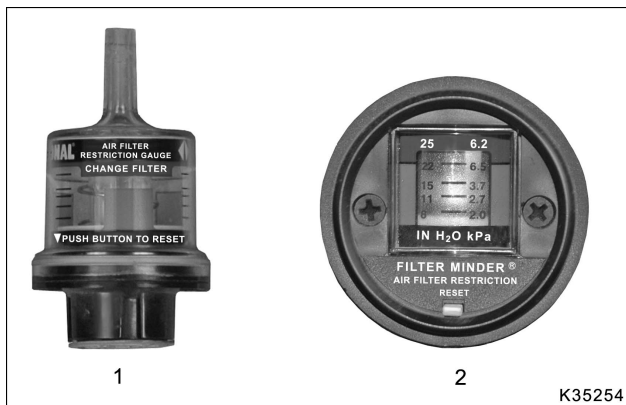


Figure 42 Air filter restriction gauge

2. Check the air filter restriction gauge.
3. Inspect all CAC and intake air connections and clamps.
4. If a CAC or intake air system problem is found, repair as required.

NOTE: If air intake system repair is made, or air intake system is disturbed, go to KOER MAF Sensor Calibrate Procedure in Diagnostic Software Operation (page 63) section in this manual for specific EST software procedures to perform this procedure.

2.1 Fuel Level Check

! WARNING: To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

1. Park vehicle on level ground.

2. Check instrument panel fuel gauge and look into fuel tank to verify fuel level.

- If fuel gauge reads above empty, but fuel tank is empty, diagnose fuel gauge, see *Electrical System Troubleshooting Guide* for the appropriate model and year of vehicle.
- If fuel tank is empty, add fuel and turn ignition switch to ON. With ignition key ON, engine OFF, fuel system should self-prime within 30 seconds.
- Always verify fuel level before diagnosing a fuel pressure problem.

2.2 Fuel Quality Check

Purpose

Check for poor fuel quality or contaminants.

Tools

- Clear diesel fuel container (approximately 1 liter or 1 quart)
- Clear plastic hose

Possible Causes

- Debris, waxing, water, or ice in the fuel system
- Oil, gasoline, or kerosene present in fuel tank
- Fuel grade incorrect for cold temperature

Procedure

! WARNING: To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

! WARNING: To prevent personal injury or death, store diesel fuel properly in an approved container designed for and clearly marked DIESEL FUEL.

1. Place approved diesel fuel container under fuel drain valve and open.
2. Turn ignition switch to ON, engine OFF.

NOTE: Instrument panel Warn Engine Lamp (WEL) should cycle on, then off, if there is no water in the system. Lamp will stay on if water is detected.

3. Turn ignition switch to OFF.

NOTE: To prevent aeration of the fuel, wait 30 to 60 seconds after turning ignition switch to OFF before opening fuel drain valve.

NOTE: If fuel sample does not flow, see Fuel Pump Check (page 101) in this section.



Figure 43 Fuel Sample

4. Drain enough fuel into container to effectively check for contamination.
5. Check for water, waxing, icing, sediment, gasoline, or kerosene by shaking fuel sample container and letting contents settle.
 - Sediments will fall to the bottom of the fuel sample container.
 - Gasoline and kerosene will separate from the diesel fuel.
 - Waxing or icing will prevent diesel fuel from flowing out of the fuel drain valve.
 - If the fuel quality is questionable, correct the problem. Take another sample to verify fuel quality is satisfactory.

- If the fuel quality is satisfactory, continue to next test.

3. EST Connection and Data Recording

NOTE: See the “Diagnostic Software Operation” (page 53) section in this manual for specific EST software procedures to do this test.

NOTE: Ideally, allow the engine to cold soak for at least 2 hours before recording results.

Purpose

Determine if engine sensor readings are within specification for engine starting.

Monitoring Engine Systems using an EST

Tools

- EST with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Cable

Procedure

! WARNING: To prevent personal injury or death, shift transmission to park or neutral, set parking brake, and block wheels before doing diagnostic or service procedures.

1. Turn ignition switch to ON, engine OFF.
2. Using the EST, start the ServiceMaxx™ software.

NOTE: See “Diagnostic Software Operation” (page 53) section in this manual for ECM and EST communication problems.

3. Record the following sensor readings on Diagnostics Form:
 - Barometric Pressure
 - Air Inlet Temperature
 - Engine Coolant Temperature
 - Engine Oil Temperature
 - Intake Manifold Temperature
 - Fuel Delivery Pressure
 - Fuel Rail Pressure
 - DPF Differential Pressure

4. If sensor is out of specification, go to suspect sensor diagnostic in “Electronic Control Systems Diagnostics” (page 135) section of this manual.
5. Use ServiceMaxx™ software to run KOEO Output State Test High and Low.
6. Record voltage signals for the following on the Diagnostics Form:
 - Exhaust Gas Recirculation Position (EGRP)
 - Engine Throttle Position (ETP)
7. If signal is out of specification, go to suspect actuator diagnostic in “Electronic Control Systems Diagnostics” (page 135) section of this manual.
8. Monitor DPF status signal value and record on Diagnostics Form.
 - If DPF status is Regen needed-critical level, disconnect exhaust system upstream of the Pre-Diesel Oxidation Catalyst (PDOC) and attempt to start engine.

4. Check for DTCs

NOTE: 2010 model year vehicles no longer utilize DTC identification by number. DTCs are now identified using the SPN and FMI identifiers only. These two identifiers, known as the Suspect Parameter Number (SPN) and the Failure Mode Indicator (FMI), are displayed in the DTC Window.

- Suspect Parameter Number (SPN) – The SPN identifies the individual component causing the DTC.
- Failure Mode Indicator (FMI) – The FMI identifies the fault or condition affecting the individual component.
- Active DTCs are codes that are active now.
- Previously active DTCs are historical faults that may be caused by intermittent signals or an operating condition that is not currently present.

Purpose

Identify DTCs.

Tools

- EST with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Cable

Procedure

1. Turn ignition switch to ON, engine OFF.
2. Start the ServiceMaxx™ software.

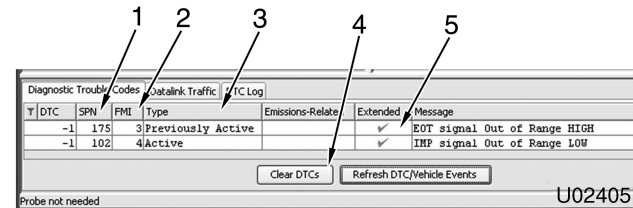


Figure 44 DTC window

1. Suspect Parameter Number (SPN) column
2. Failure Mode Indicator (FMI) column
3. DTC type column
4. Clear DTCs button
5. Extended (Freeze Frame)

NOTE: Click the extended button to receive a Freeze Frame data of when the code was set.

3. Record DTCs on the Diagnostics Form.
 - Correct any active DTCs. See the “Diagnostic Trouble Code Index” (page 373) in this manual.
 - Investigate any previously active DTCs for possible intermittent operating conditions during which the DTC was set.

5. Engine Cranking

NOTE: See the “Diagnostic Software Operation” (page 53) section in this manual for specific EST software procedures to do this test.

Purpose

Determine if engine systems meet operating specifications to start engine.

Monitoring Engine Systems using an EST

Tools

- EST with ServiceMaxx™ software

- NAVCoM or NAVLink Interface Cable
- Digital Multimeter (DMM)

Procedure

⚠ WARNING: To prevent personal injury or death, shift transmission to park or neutral, set parking brake, and block wheels before doing diagnostic or service procedures.

1. Turn ignition switch to ON, engine OFF.
2. Using the EST, start the ServiceMaxx™ software.

NOTE: See “Diagnostic Software Operation” (page 53) section in this manual for ECM and EST communication problems.

3. Click on Sessions from the menu bar and select the Hard Start – No Start session.

⚠ WARNING: To prevent personal injury or death, provide proper ventilation when operating an engine in a closed area. Inhalation of exhaust gas can be fatal.

4. Crank the engine for a maximum of 20 seconds while monitoring Key On, Engine Running (KOER) signals.
5. Monitor the following KOER signals:

NOTE: If engine is not equipped with a Fuel Delivery Pressure (FDP) sensor, use a mechanical gauge.

- Switched Battery volts (B+)
 - Engine Speed (RPM)
 - Fuel Delivery Pressure (FDP)
 - Fuel Rail Pressure (FRP)
6. Visually inspect Charge Air Cooler (CAC) between CAC and Engine Throttle Valve (ETV).
 - If CAC hose collapses while cranking engine, inspect for CAC plugging and if low-pressure turbocharger spins freely.

7. Record KOER signals on the Diagnostics Form.

- If Switched Battery voltage drops below specification, check cranking voltage at batteries using a DMM. If cranking voltage is below specification, check batteries and charging system, connect battery charger, and retest.
- If no Engine Speed signal is present, see CKP Sensor (page 188) and CMP Sensor (page 191) in Electronic Control Systems Diagnostics section of this manual.
- If cranking rpm is below specification, check batteries and starting system.
- If FDP is below specification, go to Low Pressure Fuel System (page 100) in this section and begin fuel system tests. If not equipped with FDP sensor, go to Fuel Pump Check (page 101) in this section and continue with the remainder of the fuel system check.
- If FRP does not increase, go to Low Pressure Fuel System (page 100) in this section.
- If AIT is below specification, see Inlet Air Heater Test (page 99) in this section.
-

Possible Causes

Low battery voltage

- Failed batteries
- High-resistance at battery cable connections or in wiring to the ECM
- Failed ECM main power relay

Low cranking rpm

- Electrical system malfunctions, low batteries, starter failure, or incorrect oil
- Mechanical engine damage

- No rpm indication on the EST while cranking the engine
 - Failed Crankshaft Position (CKP) sensor
 - Failed Camshaft Position (CMP) sensor
 - Failed circuit to ECM

Low Fuel Rail Pressure

- Failed FRP sensor
- Failed High Pressure Fuel Pump (HPFP)
- Low FDP
- Aerated fuel

Monitoring FRP using a Breakout Harness

NOTE: This is an alternate procedure to be used if an EST is not available.

Tools

- Digital Multimeter (DMM)
- Breakout Harness ZTSE6000 (UVC)

Procedure

! WARNING: To prevent personal injury or death, shift transmission to park or neutral, set parking brake, and block wheels before doing diagnostic or service procedures.

1. See “Appendix A: Performance Specifications” (page 425) in this manual for specifications and record on Diagnostics Form.



Figure 45 12-pin injector connector disconnected

2. Disconnect the engine harness from the right-side 12-pin injector connector.
3. Connect Breakout Harness ZTSE6000 to the 12-pin injector connector and engine harness.
4. Use DMM to measure FRP sensor voltage by connecting POS to Pin E-10 and NEG to Pin E-6.
5. Start or crank engine for no more than 20 seconds.
6. Measure signal voltage and cranking rpm. Compare measurements to specifications.
 - If in specification, continue to next test.
 - If not in specification, see LP.2 – Fuel Pressure Test (page 101) in this section.

Possible Causes

- Failed FRP sensor
- Failed high-pressure pump
- Low Fuel Delivery Pressure (FDP)
- High-pressure leaks
- Aerated fuel

Special Test Procedures

NOTE: Any special test procedure can be performed if directed from one of the previous required test procedures.

Inlet Air Heater (IAH) Test

Purpose

Inspect IAH system for malfunctions.

Tools

- EST with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Cable
- Digital Multimeter (DMM)
- EXP-1000 HD by Midtronics - Current Clamp

Possible Causes

- Failed wiring harness or connection
- Failed IAH relay
- Failed IAH element
- Failed ECM

Amperage Draw

Procedure

NOTE: Inspect for damaged, loose, or corroded terminals. Repair if necessary.

NOTE: KOEO Standard Test must be run before running other KOEO tests.

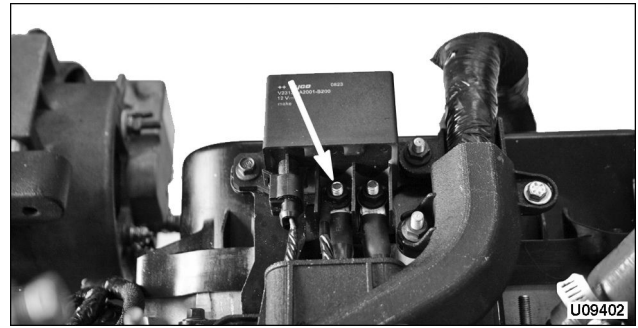
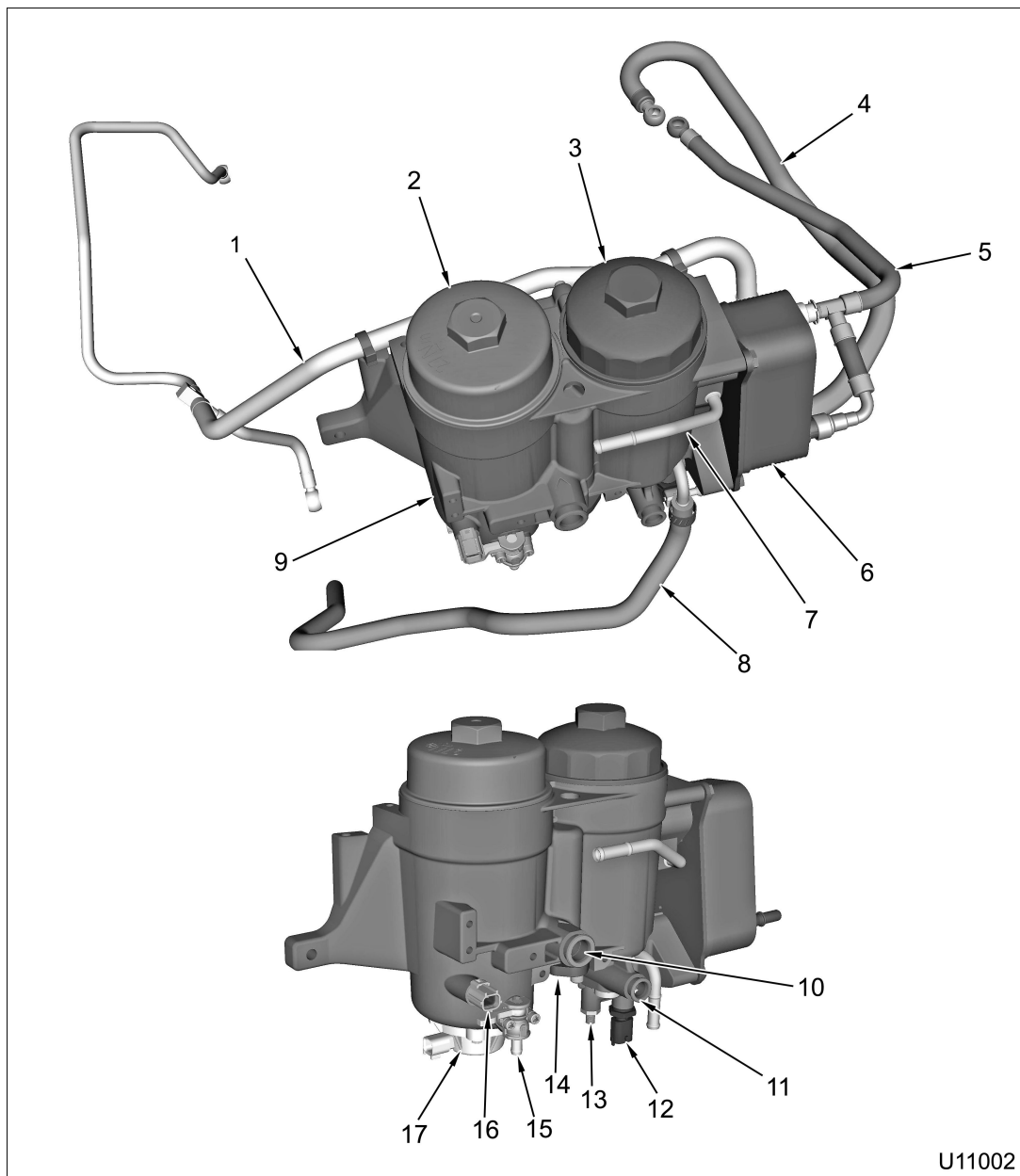


Figure 46 IAH Relay B+ feed circuit

1. See "Appendix A: Performance Specifications" (page 425) in this manual for specifications.
2. Install EXP-1000 HD by Midtronics with amp clamp around the IAH relay B+ feed circuit.
3. Turn ignition switch to ON, engine OFF.
4. Using the EST with ServiceMaxx™ software, run the KOEO Intake Air Heater test.
5. Use a DMM and EXP-1000 HD by Midtronics amp clamp to measure amperage draw going to the IAH element.
6. Record results on the Diagnostics Form.
 - If amperage draw does not meet specification, see IAH (page 299) in the Electronic Control Systems Diagnostics section of this manual.
 - If amperage draw meets specifications, the IAH system is working properly.

Low-pressure Fuel System



U11002

Figure 47 Low-pressure fuel system

1. Injector return hose assembly	9. Fuel filter module housing	14. Fuel heater block-off plate or fuel heater (optional)
2. Filter cap (primary)	10. Fuel inlet from tank	15. Water drain valve
3. Filter cap (secondary)	11. Fuel return to tank	16. Water In Fuel (WIF) sensor
4. Filter-to-pump hose assembly	12. Engine Fuel Temperature (EFT) sensor	17. Fuel Pump
5. Pump-to-cooler hose assembly	13. Diagnostic valve (standard) or Fuel Delivery Pressure (FDP) sensor (optional)	
6. Fuel cooler		
7. Coolant supply hose		
8. Coolant return hose		

 **WARNING:** To prevent personal injury or death, store diesel fuel properly in an approved container designed for and clearly marked **DIESEL FUEL**.

 **WARNING:** To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

 **WARNING:** To prevent personal injury or death, wear safety glasses with side shields.

LP.1 - Electrical Fuel Pump Check

Purpose

Check for fuel pump operation.

Tools

None

Procedure

NOTE: The ECM will command the fuel pump to run for 5 seconds after the ignition switch is turned to the OFF position.

1. Turn ignition switch to ON, engine OFF.
2. Listen for the fuel pump (shop noise can drown out the fuel pump sound).
 - The ECM will command the FPC to run for 5 seconds without the engine running. If FPC does not run for 5 seconds, see Fuel Pump (page 285) in the “Electronic Control Systems Diagnostics” section of this manual.
 - If fuel pump is not heard, verify ECM power by going to Fuel Pump (page 285) in the “Electronic Control Systems Diagnostics” section of this manual.
 - If fuel pump is heard and runs for 5 seconds with the engine off, continue to LP.2 - Fuel Pressure Test (page 101) in this section.

LP.2 - Fuel Pressure Test

Purpose

Check for low Fuel Delivery Pressure (FDP).

Tools

- Graduated cylinder (0 -700 mL)
- EST with ServiceMaxx™ software
- ZTSE4681 – Fuel Pressure Gauge with 30 psi gauge

Check Fuel Delivery Pressure Using the EST

NOTE: This procedure is only valid on engines equipped with an FDP sensor.

1. See Appendix A: Performance Specifications (page 425) in this manual for FDP specifications.
2. Turn ignition switch to ON, engine OFF.
3. Using the EST, start the ServiceMaxx™ software.
4. Monitor FDP and record results on Diagnostics Form.
 - If pressure is below specification, go to LP.3 - Fuel Aeration Check (page 102) in this section.
 - If within specification, go to LP.7 - Return Fuel Flow Test (page 105) in this section.
 - If fuel gauge pressure is above specification, go to LP.8 - Fuel Return Restriction Test (page 105) in this section.

Check Fuel Delivery Pressure Manually

NOTE: This procedure is only valid on engines equipped with a fuel filter module housing diagnostic valve.

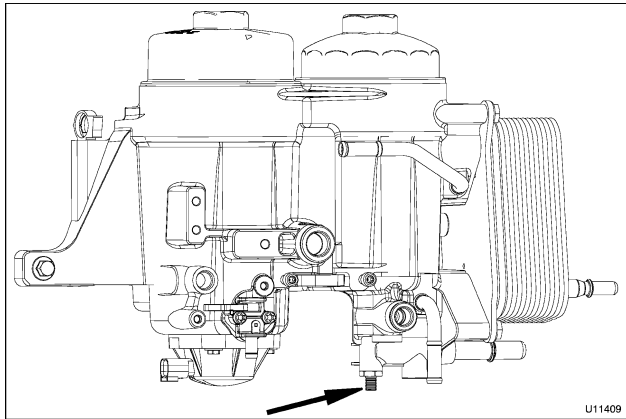


Figure 48 Fuel filter module housing diagnostic valve

1. Connect 30 psi Fuel Pressure Gauge ZTSE4681 with shutoff valve and clear drain hose to the diagnostic valve on the fuel filter assembly.
2. Route clear drain hose into an approved diesel fuel container.
3. Turn ignition switch to ON, engine OFF.
4. Close shutoff valve on Fuel Pressure Gauge ZTSE4681.
5. Measure fuel pressure at the fuel filter module housing diagnostic valve using the Fuel Pressure Gauge ZTSE4681.
 - If pressure is below specification, go to LP.3 - Fuel Aeration Check (page 102) in this section.
 - If within specification, go to LP.7 - Return Fuel Flow Test (page 105) in this section.
 - If fuel gauge pressure is above specification, go to LP.8 - Fuel Return Restriction Test (page 105) in this section.

LP.3 - Fuel Aeration Check

Purpose

Check for aerated fuel.

Tools

- Graduated cylinder (0 -700 mL)

- ZTSE4681 – Fuel Pressure Gauge with 30 psi gauge

Possible Causes

- Cracks or leaks in fuel supply line
- Leaks at the Fuel Filter assembly

Procedure

! WARNING: To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

! WARNING: To prevent personal injury or death, store diesel fuel properly in an approved container designed for and clearly marked **DIESEL FUEL**.

1. Retain fuel pressure gauge to fuel filter assembly diagnostic valve setup from LP.2 - Fuel Pressure Test (page 103).
2. Place approved diesel fuel container under fuel drain valve and open valve.
3. Turn ignition switch to ON, engine OFF and open fuel shutoff valve on Fuel Pressure Gauge ZTSE4681.

NOTE: Instrument panel Warn Engine Lamp (WEL) should cycle on, then off, if there is no water in the system. Lamp will stay on if water is detected.

4. Monitor fuel flow from clear line on Fuel Pressure Gauge ZTSE4681 and check for aeration (bubbles).

NOTE: To prevent aeration of the fuel, wait 30 to 60 seconds after turning ignition switch to OFF before opening fuel drain valve.

NOTE: If fuel sample does not flow, see Electrical Fuel Pump Check (page 101) in this section.



Figure 49 Fuel Sample

5. Drain enough fuel into container to effectively check for aeration. Mark results on Diagnostics Form.
 - If fuel does not flow from pressure gauge, go to LP.4 - Fuel Thermal Valve Check (page 104) in this section.
 - If fuel is aerated, repair fuel supply line between tank and fuel filter assembly.
 - If fuel is not aerated, go to LP.5 - Low-pressure Fuel Pump Dead Head Test (page 104) in this section.

LP.4 - Fuel Thermal Valve Check

Purpose

Check the fuel thermal valve.

Tools

- Diesel fuel container

! WARNING: To prevent personal injury or death, store diesel fuel properly in an approved container designed for and clearly marked **DIESEL FUEL**.

! WARNING: To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

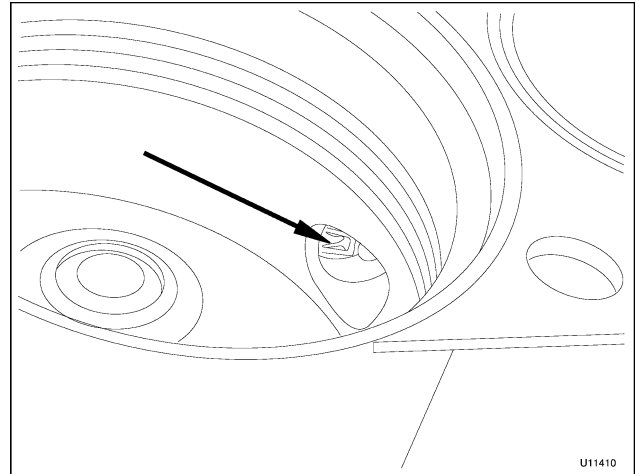


Figure 50 Fuel thermal valve (inside fuel filter assembly)

NOTE: Check for related recalls, iKnow letters, and service bulletins using Service Portal network regarding Fuel Thermal Bypass Valve.

1. Remove primary fuel filter cap.
2. Inspect and ensure fuel thermal bypass valve end cap, brass motor, and snap ring are in place and undamaged.
3. Record result on Diagnostics Form.
 - If thermal valve is damaged or is missing parts, replace fuel thermal valve.
 - If fuel thermal valve is not damaged, go to LP.5 - Fuel Pump Dead Head Test (page 104) in this section.

LP.5 - Fuel Pump Dead Head Test**Purpose**

Check for fuel supply system restriction and fuel pressure regulator valve function.

Tools

- Diesel fuel container
- ZTSE4681 – Fuel Pressure Gauge with 30 psi gauge

Procedure

1. Retain fuel pressure gauge to fuel filter assembly diagnostic valve setup from LP.2 - Fuel Pressure Test (page 103).

 **WARNING:** To prevent personal injury or death, store diesel fuel properly in an approved container designed for and clearly marked **DIESEL FUEL**.

 **WARNING:** To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

2. Disconnect fuel return line from fuel filter assembly and capture excess fuel into approved diesel fuel container.
3. Turn ignition switch to ON, engine OFF.
4. Close shutoff valve on Fuel Pressure Gauge ZTSE4681 and measure pressure.
5. Record results on the Diagnostics Form.
 - If fuel gauge pressure is below specification, go to LP.6 - Alternative Fuel Supply Test (page 104) in this section.
 - If fuel gauge pressure is within specification, replace fuel pressure regulator valve assembly.

LP.6 - Alternative Fuel Supply Test**Purpose**

Check for fuel supply system restriction and low-pressure fuel pump.

Possible Causes (High and Low Restriction)

- Dirt or jelled fuel in the fuel filter
- Kinked or bent fuel supply line or a blocked fuel pickup tube
- Loose fuel line on the suction side of the fuel system
- Failed fuel regulator valve (located in secondary fuel filter housing)
- Failed fuel pump

Tools

- Diesel fuel container
- 15-637-01 – Clean Fuel Source Tool
- ZTSE4681 – Fuel Pressure Gauge

Procedure

1. Retain fuel pressure gauge to fuel filter assembly diagnostic valve setup from LP.2 - Fuel Pressure Test (page 101).

 **WARNING:** To prevent personal injury or death, store diesel fuel properly in an approved container designed for and clearly marked **DIESEL FUEL**.

 **WARNING:** To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

2. Remove fuel supply line from fuel filter assembly and connect Clean Fuel Source Tool 15-637-01. Use diesel fuel container to collect fuel when line is disconnected.
 3. Turn ignition switch to ON, engine OFF.
 4. Close shutoff valve on Fuel Pressure Gauge ZTSE4681 and measure pressure.
-

5. Record results on the Diagnostics Form.

- If fuel gauge pressure is below specification, replace low-pressure fuel pump according to *Engine Service Manual*.
- If fuel gauge pressure is within specification, repair open or restriction in fuel supply line to fuel filter assembly.

LP.7 - Return Fuel Flow Test**Purpose**

Check for fuel pump or fuel filter housing damage.

Tools

- Fuel Return Test Line
- Graduated cylinder (0 - 700 mL)

Procedure

1. Connect Fuel Return Test Line to fuel filter assembly.

 **WARNING:** To prevent personal injury or death, store diesel fuel properly in an approved container designed for and clearly marked **DIESEL FUEL**.

 **WARNING:** To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

2. Route Fuel Return Test Line to an approved diesel fuel container with measuring marks.

NOTE: Fuel Pump will run for 5 seconds after ignition switch is turned to OFF. Accurately measuring fuel volume requires starting a timer as soon as ignition switch is turned to ON and turning ignition switch to OFF after 10 seconds.

3. Turn ignition switch to ON, engine OFF. Measure 15 seconds of fuel flow.
4. Record results on the Diagnostics Form.
 - If fuel flow volume is below specification, replace fuel filters and retest.
 - If fuel flow volume is within specification, go to LP.8 - Fuel Return Restriction Test (page 105) in this section.

LP.8 - Fuel Return Restriction Test**Purpose**

Check for fuel line, fuel pump, or fuel filter housing damage.

Tools

- Fuel Return Test Line
- Graduated cylinder (0 - 700 mL)

Procedure

1. Reconnect fuel return line to fuel filter assembly.

 **WARNING:** To prevent personal injury or death, store diesel fuel properly in an approved container designed for and clearly marked **DIESEL FUEL**.

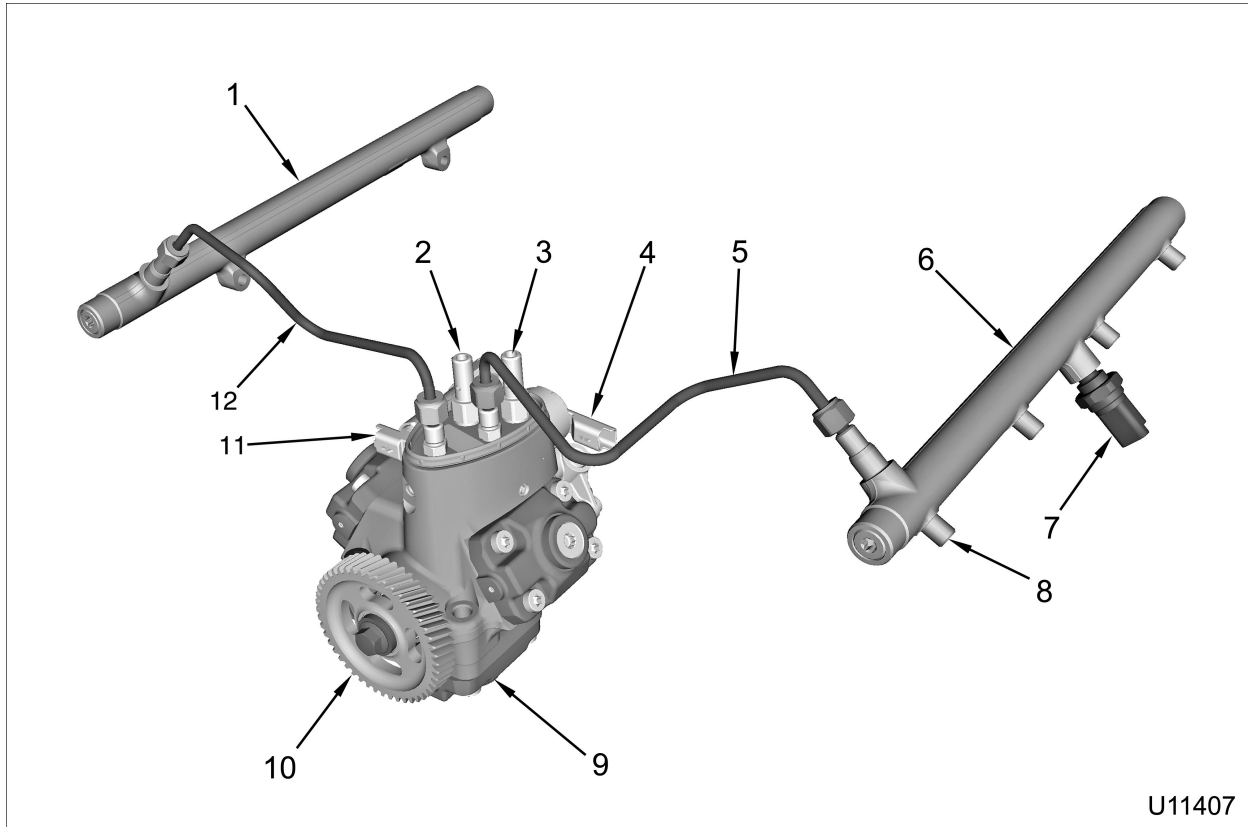
 **WARNING:** To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

2. Disconnect fuel return line from fuel tank.
3. Route fuel return line to an approved diesel fuel container with measuring marks.
4. Turn ignition switch to ON, engine OFF. Measure 15 seconds of fuel flow.

NOTE: Fuel Pump will run for 5 seconds after ignition switch is turned to OFF. Accurately measuring fuel volume requires starting a timer as soon as ignition switch is turned to ON and turning ignition switch to OFF after 10 seconds.

5. Measure 15 seconds of fuel flow.
6. Record results on the Diagnostics Form.
 - If fuel flow volume is below specification, repair restriction in fuel return line.
 - If fuel flow volume is within specification, go to HP.4 – High Pressure Fuel Pump Dead Head Test (page 109) in this section.

High-pressure Fuel System Tests



U11407

Figure 51 High-pressure fuel system

1. Left rail assembly	5. Pump right tube assembly (pump-to-rail)	10. HPFP gear
2. Pump return hose connection (pump-to-cooler)	6. Right rail assembly	11. Fuel Volume Control Valve (FVCV)
3. Filter to pump hose connection (secondary fuel filter-to-pump)	7. Fuel Rail Pressure (FRP) sensor	12. Pump left tube assembly (pump-to-rail)
4. Fuel Pressure Control Valve (FPCV)	8. Fuel rail-to-injector fuel tube port (4 for each rail)	
	9. HPFP	

⚠ WARNING: To prevent personal injury or death, store diesel fuel properly in an approved container designed for and clearly marked **DIESEL FUEL**.

⚠ WARNING: To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

⚠ WARNING: To prevent personal injury or death, wear safety glasses with side shields.

HP.1 - Fuel Pressure Control Valve (FPCV) and Fuel Volume Control Valve (FVCV) Check

Purpose

Check for FPCV and FVCV function.

Possible Causes

- Fuel Rail Pressure (FRP) sensor or circuit
- Missing Fuel Pressure Control Valve (FPCV)
- Fuel Volume Control Valve (FVCV) or circuit
- Engine Control Module (ECM)

- High-pressure fuel line leaks (internal or external fuel lines)
- Failed HPFP
- Fuel injectors
- Insufficient low-pressure fuel pressure
- Plugged fuel filter
- Aerated fuel
- Cracked or leaking fuel lines

Tools

- EST with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Cable
- Digital Multimeter (DMM)
- 00-01464-00 – 98-Pin Engine Cable
- 1180-N4-0X0 – 180-Pin Breakout Box
- ZTSE4674 – Breakout Harness

Procedure

NOTE: KOEO Standard Test must be run before any other ServiceMaxx™ tests are performed.

1. Connect 180-Pin Breakout Box 1180-N4-0X0 between ECM and engine harness using 98-Pin Engine Cable 00-01464-00.
2. Turn ignition switch to ON, engine OFF.
3. Start ServiceMaxx™ software.
4. Measure voltage from FPCV (E-18) to GND and record results on Diagnostics Form.
5. Measure voltage from FVCV (E-16) to GND and record results on Diagnostics Form.
6. Click on the Tests drop-down menu and select Engine Off Tests.
7. From the Engine Off Tests drop-down menu, select KOEO Output State Test High and Low.
8. Monitor the FPCV and FVCV voltage. Record results on Diagnostics Form.
 - If not in specification, see FPCV (page 282) or FVCV (page 296) in the Electronic Control Systems Diagnostics section of this manual.

- If in specification, continue to HP.2 - FPCV and FVCV Resistance Check (page 107) in this section.

HP.2 - FPCV and FVCV Resistance Check

Purpose

Check for FPCV and FVCV function.

Possible Causes

- Fuel Rail Pressure (FRP) sensor or circuit
- Fuel Volume Control Valve (FVCV) or circuit
- Engine Control Module (ECM)
- Fuel Volume Control Valve (FPCV) or circuit
- Failed HPFP
- Insufficient low-pressure fuel pressure
- Plugged fuel filter
- Aerated fuel
- Cracked or leaking fuel lines

Tools

- Digital Multimeter (DMM)
- 00-01464-00 – 98-Pin Engine Cable
- 1180-N4-0X0 – 180-Pin Breakout Box
- ZTSE4674 – Breakout Harness

Procedure

1. Turn ignition key OFF.
2. Connect 180-Pin Breakout Box 1180-N4-0X0 and 98-pin E-cable 00-01464-00 between ECM and Engine Harness, leave ECM disconnected.
3. Disconnect ECM relay and connect Breakout Harness ZTSE4674. Leave ECM relay disconnected.
4. Measure resistance between FVCV (E-18) and ECM relay pin 87.
5. Measure resistance between FVCV (E-16) and ECM relay pin 87.

6. Record results on Diagnostics Form.
 - If resistance is out of specification, go to “Electronic Control Systems Diagnostics” (page 135) for valve in question.
 - If resistance is within specification, go to HP.3 - Fuel Rail Leak Check.

HP.3 - Fuel Rail Leak Check

Purpose

Check for Fuel Rail leaks.

Possible Causes

- Fuel rail system leakage (fuel lines, etc.)
- Failed HPFP
- Failed injector
- Biased sensors
- Low or no low-side fuel pressure

Tools

- EST with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Cable
- ZTSE4861 - Fuel Rail Block Off Plug

⚠ WARNING: To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

⚠ WARNING: To prevent personal injury or death, wear safety glasses with side shields.

Procedure

CAUTION: To prevent engine damage, when high-pressure fuel line connections are broken, the fuel line must be replaced.

NOTE: When removing the pump tube assemblies, fuel may leak out. Put in a suitable catch or container to collect this leakage. Collect and dispose of this fuel according to local regulations.

1. Remove Breakout Harnesses from the previous test. Restore Electrical connections.

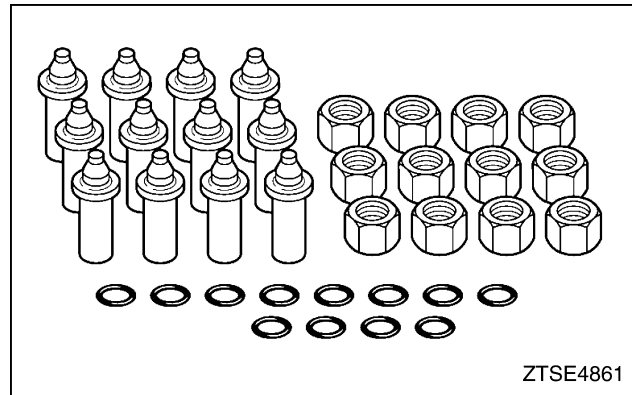


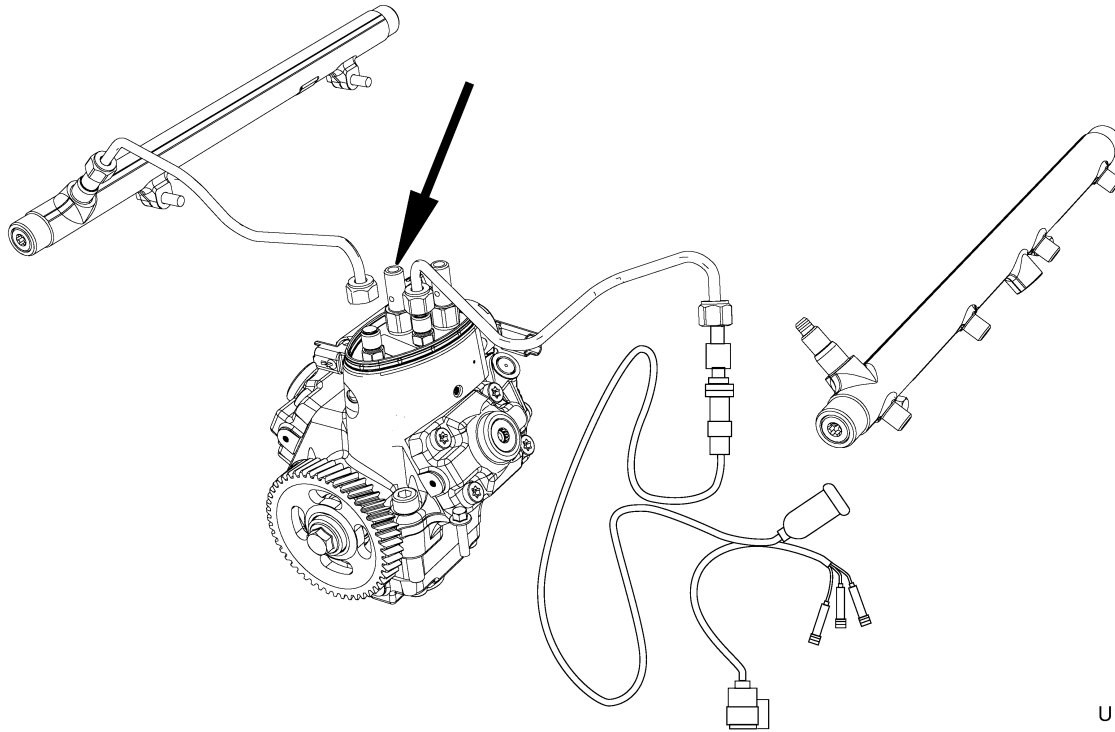
Figure 52 Fuel Rail Block Off Plugs

2. Disconnect the left head high-pressure fuel tube assembly and cap off the HPFP output port using the Fuel Rail Block Off Plug ZTSE4861.

NOTE: Replace any high-pressure fuel line that was disconnected during testing, after testing is completed.

3. Using the EST, start the ServiceMaxx™ software and monitor Fuel Rail Pressure (FRP).
4. Turn ignition switch to ON; crank the engine for 15 to 20 seconds, record the results on the Diagnostics Form.
 - If the FRP is not within specification, go to HP.4 High Pressure Pump (HPFP) Dead Head Test.
 - If the Fuel Rail Pressure is within specification, go to HP.5 Injector Leak Isolation Check (Left Bank) (page 110).

HP.4 - High-pressure Fuel Pump (HPFP) Dead Head Test



U11411

Figure 53 HPFP output port

Possible Causes

- Fuel Rail Pressure (FRP) sensor or circuit
- Missing Fuel Pressure Control Valve (FPCV)
- Fuel Volume Control Valve (FVCCV) or circuit
- Engine Control Module (ECM)
- High-pressure fuel line leaks (internal or external fuel lines)
- Failed HPFP
- Fuel injectors
- Insufficient low-pressure fuel pressure
- Plugged fuel filter
- Aerated fuel
- Cracked or leaking fuel lines

Tools

- EST with ServiceMaxx™ software

- NAVCoM or NAVLink Interface Cable
- Digital Multimeter (DMM)
- Spare FRP sensor (obtain locally)
- 1180-N4-0X0 – 180-Pin Breakout Box
- ZTSE4837 – High-Pressure Pump Test Fitting
- ZTSE4861 – Fuel Rail Block Off Plugs
- ZTSE6038 – Breakout Harness

Procedure

1. Retain test setup from previous test.
2. Disconnect right high-pressure tube assembly from cylinder head.
3. Use High-pressure Pump Test Fitting to connect Fuel Rail Pressure (FRP) sensor to right high-pressure tube assembly.

4. Connect Breakout Harness ZTSE6038 to right UVC harness. Leave disconnected from right head.
5. Connect other end of Breakout Harness ZTSE6038 to FRP sensor in right HPFP tube.
6. Use ServiceMaxx™ software to monitor FRP.
7. Crank engine for 15 to 20 seconds while monitoring FRP; record results on Diagnostics Form.
 - If FRP is within specification, go to HP.6 - Injector Leak Isolation Check (Right Bank) (page 110).
 - If FRP is not within specification, remove HPFP cover and verify gear is not loose or damaged. If gear is okay, replace HPFP.
5. Isolate leaking injector by removing one injector tube at a time; capping off HPFP rail feed using ZTSE4861 Fuel Rail Block-off Plugs.
6. Crank engine for 15 to 20 seconds while monitoring Fuel Rail Pressure; record results on Diagnostics Form.
 - Isolate the injector causing the problem; replace that injector and all the injector tubes that were removed during the test procedure.

HP.5 - Injector Leak Isolation Check (Left Bank)

Purpose

Check for and isolate leaking injector.

Possible Causes

- High-pressure fuel line leaks (internal or external fuel lines)
- Fuel injectors
- Cracked or leaking fuel lines

Tools

- ZTSE4861 – Fuel Rail Block-off Plugs
- ZTSE6038 – Breakout Harness

Procedure

1. Restore HPFP left tube assembly to cylinder head.
2. Disconnect HPFP right tube assembly; install FRP sensor and test fitting to HPFP right tube.
3. Connect ZTSE6038 breakout harness to right bank 12-pin injector engine harness; leave disconnected from right head.
4. Remove left cylinder head valve cover.

HP.6 - Injector Leak Isolation Check (Right Bank)

Purpose

Check for and isolate leaking injector.

Possible Causes

- High-pressure fuel line leaks (internal or external fuel lines)
- Fuel injectors
- Cracked or leaking fuel lines

Tools

- ZTSE4861 – Fuel Rail Block-off Plugs

Procedure

1. Restore 12-pin injector connection to right cylinder head.
 2. Restore HPFP right tube assembly to cylinder head.
 3. Remove right cylinder head valve cover.
 4. Isolate leaking injector by removing one injector tube at a time; capping off HPFP rail feed using Fuel Rail Block-off Plugs ZTSE4861.
 5. Crank engine for 15 to 20 seconds while monitoring Fuel Rail Pressure; record results on Diagnostics Form.
 - Isolate the injector causing the problem; replace that injector and all the injector tubes that were removed during the test procedure.
-

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Diagnostic Form

Required Test Procedures		
Do required test procedures in sequence. Doing a required test out of sequence can cause incorrect results.		
1. Initial Key On Check		
☐ Check Integral Digital Display for WATER IN FUEL indicator.		
Does WATER IN FUEL indicator stay on?	☐ Yes	☐ No
● If WATER IN FUEL stays on, go to Fuel Quality Check.		
2. Visual Inspection		
☐ Check all fluid levels.		
☐ Inspect electrical connectors.		
☐ Inspect for visible exhaust damage.		
☐ Inspect air filter minder.		
Note: If filter minder indicates a restriction, go to Intake Restriction Test in Performance Diagnostics.		
Are all fluid levels within specifications?	☐ Yes	☐ No
Are power and ground connections okay?	☐ Yes	☐ No
Is air filter okay?	☐ Yes	☐ No
Is exhaust system okay?	☐ Yes	☐ No
Comments:		
● If intake system repair is made or intake system is disturbed, go to MAF Sensor Test in Section 6 of the EGES-485.		
3 EST Connection and Data Recording		
☐ Use ServiceMaxx™ software to record KOEO pressure and temperature values.		
NOTE: Ideally, allow the engine to cold soak for at least 2 hours before recording results.		
Signals	Specification	Actual
Barometric pressure	-	
Air Inlet Temperature	-	
Engine Coolant Temperature	-	
Engine Oil Temperature	-	
Intake Manifold Temperature	-	
Fuel Delivery Pressure	5 psi	
Fuel Rail Pressure	0 psi	
DPF Differential Pressure	0 psi	
● If sensor is out of specification, go to suspect sensor in Electronic Control Systems Diagnostics.		

U02414

Figure 54 Diagnostics Form EGED-613 (Performance Diagnostics)

The Performance Diagnostics Form directs technicians to systematically troubleshoot a performance condition and avoid unnecessary repairs.

This Diagnostic Manual section shows detailed instructions of the tests on the form. The manual should be used along with the form and referenced for supplemental test information. Use the form as a worksheet to record test results.

Do Test Procedures in sequence. Doing a test out of sequence can cause incorrect results. If the customer complaint is found and corrected, it is not necessary to complete the remaining tests.

See appropriate section of this manual for Diagnostic Trouble Codes (DTCs) and engine specifications.

Diagnostics Form EGED-613 is available in 50-sheet pads. To order technical service literature, contact your International dealer.

Diagnostics Form Header Information

Note: This form must be completed before calling for technical assistance.		
Technician:	Date:	Unit Number:
ECM Calibration:	Miles:	Hours:
Engine Serial Number:	Horsepower Rating:	Torque:
Transmission (select one): ☐ Manual ☐ Automatic		
VIN:		
Complaint:		
U02413		

Enter Diagnostics Form Header Information

1. Technician
2. Date
3. Unit No. (dealer's quick reference number)
4. Customer complaint (interview driver)

5. Connect Electronic Service Tool (EST) with ServiceMaxx™ software to Diagnostic Connector.
6. Using the EST with ServiceMaxx™ software, log all vehicle information needed on the form header.

ServiceMaxx - Default

File View Sessions Tests Procedures Tools Help

Sessions: Default Parameters Signals Stop Tests

Instructions

Default ☒ Lock

Vehicle Identification: Verify Information matches your vehicle. If your vehicle does not show up in this session, select it from the File / Select engine drop-down menu.

Vehicle Information

Engine Type: MaxxForce DT/9/10 (2010 -)

Software Identification: WBL1WMRC

Engine Family Rating Code: 1151

Vehicle Identification Number: 1HTMMAAM36H334012

Engine Serial Number: 466HM2U3300202

Transmission Type: Allison MD

Rated Horsepower: 230.00 hp

Total Miles: 162.60 miles

Total Fuel Used: 17.88 gal

Total Engine Hours: 5.85 hr

Parameters

Undo All Changes... Program Engine... ☒ Only Show Watched

ID	Name	Value	Units	Undo	Wa...
74111	Engine Idle Shutdown CARB	CARB IST Disabled			☒
74001	Engine Idle Shutdown Timer Mode	PTO Option			☒
74010	Engine Idle Shutdown Time	15.00	min		☒
74021	Engine Idle Shutdown Maximum Inta...	302.00	F		☒
74031	Engine Idle Shutdown Minimum Inta...	30.55	F		☒

Position & Pressure **Voltage**

Name	Value	Units
Accel Pedal Position 1	0.00	%
Barometric Pressure	14.14	psi
Brake Ctrl Pressure	69.69	psi
DPF Differential Pre...	0.00	psi
DPF Status	Regen ...	
EGR Position	35.00	%
EGR Position		%
EWPS - Has Shutdown ...	No	
Engine Fuel Pressure	0.00	psi
Engine Oil Pressure	0.58	psi
Engine Speed	0.00	RPM
Exhaust Back Pressure	-0.03	psi
Injection Control Pr...	0.00	psi
Intake Manifold Pres...	Error	psi
Mass Air Flow	0.00	kg/hr

Temperature **Voltage**

Name	Value	U...
Air Inlet Temp	78.80	F
Ambient Air Temp	78.80	F
DOC Inlet Temp	79.76	F
DOC Outlet Temp	Not Ava...	F
DPF Outlet Temp		F
Engine Coolant Temp 1	71.60	F
Engine Fuel Temp	71.60	F
Engine Intercooler Temp	Not Ava...	F
Engine Oil Temp	71.60	F
Exhaust Gas Temp	775.63	F
Intake Manifold Temp	77.00	F
Turbo Oil Pressure	Not Ava...	F

Diagnostic Trouble Codes **Datalink Traffic** **DTC Log**

DTC	SPN	FMI	Type	Emissions-Related	Extended	Message	Module
-1	175	3	Previously Active		☒	EOT signal Out of Range HIGH	Engine
-1	102	4	Active		☒	IMP signal Out of Range LOW	Engine

Clear DTCs Refresh DTC/Vehicle Events

Probe not needed

Sniffer

Protocol	Module Name	Count
J1939	Engine	210631
J1939	Transmi...	87396
J1939	Brakes ...	31070
J1939	Vehicle...	680
J1939	Exhaust	7326

U02408

Figure 56 ServiceMaxx™ opening screen (example)

- Verify the following vehicle information matches the ServiceMaxx™ displayed information:
 - Vehicle Identification Number (VIN)
 - Electronic Control Module (ECM) calibration
 - Rated Horsepower (HP)
 - Engine Family Rating Code (EFRC)
 - Transmission
 - Engine Serial Number (SN)
- Enter the following information on the Diagnostics Form:
 - Odometer (miles)
 - Engine hours
 - Intake air temperature
 - Coolant temperature

Note: The engine serial number is located on the right side of the crankcase, below the cylinder head. It is also on the engine emission label on the valve cover.

Test Procedures

1. Initial Key On Check

Purpose

Determine the following:

- Is the Engine Control Module (ECM) powered up?
- Is the WATER IN FUEL lamp on?

Tools

None

Procedure

1. Turn ignition switch to ON. Do not start engine. Check for the following:
 - WAIT TO START lamp
 - Warn Engine Lamp (WEL)
2. If the WEL stays on and a text message is displaying Water in Fuel, go to Fuel Quality Check (page 120) .

Possible Causes

WAIT TO START lamp does not illuminate

- No key power (VIGN)
- Failed ECM ground circuit
- No power from main power relay to ECM
- ECM failure
- Amber WAIT TO START lamp is burned out (will not cause hard start or no start).
- CAN link to instrument panel not working (will not cause hard start or no start).

NOTE: Instrument panel WEL should cycle ON, then OFF, if there is no water in the system. Lamp will stay ON if water is detected.

WARN ENGINE lamp stays illuminated

- Water in fuel
- Electrical circuit failure

2. Visual Inspection



GOVERNMENT REGULATION: Engine fluids (oil, fuel, and coolant) may be a hazard to human health and the environment. Handle all fluids and other contaminated materials (e.g. filters, rags) in accordance with applicable regulations. Recycle or dispose of engine fluids, filters, and other contaminated materials according to applicable regulations.



WARNING: To prevent personal injury or death, do not let engine fluids stay on your skin. Clean skin and nails using hand cleaner and wash with soap and water. Wash or discard clothing and rags contaminated with engine fluids.



WARNING: To prevent personal injury or death, shift transmission to park or neutral, set parking brake, and block wheels before doing diagnostic or service procedures.



WARNING: To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.



WARNING: To prevent personal injury or death, provide proper ventilation when operating an engine in a closed area. Inhalation of exhaust gas can be fatal.



WARNING: To prevent personal injury or death, wear safety glasses with side shields.

Purpose

Check all fluid levels and inspect engine systems for problems (leaks, open connections, harness chaffing, etc).

Tools

None

Engine Oil

NOTE: Check engine oil level prior to starting performance diagnostics.

1. Park vehicle on level ground and check oil level.
NOTE: Turn ignition switch to OFF and shut down engine. Wait 15 minutes for oil level to stabilize.
2. Use oil level gauge (dipstick) to verify engine oil level.
3. Record results on Diagnostics Form.
 - If level is below specification, inspect for leaks, oil consumption, or improper servicing. If engine oil level is low, fill to specification.
 - If level is above specification, inspect for fuel dilution, coolant contamination, or improper servicing. If engine oil level is above specification, drain to specification.
 - If level is to specification, no oil level adjustment is required.

CAUTION: If oil is contaminated, oil and filter must be replaced.

NOTE: If change engine oil indicator is illuminated, check maintenance history. See *Engine Operation and Maintenance Manual* for information on resetting service intervals.

Fuel Level

 **WARNING:** To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

1. Park vehicle on level ground.
2. Check instrument panel gauge and look into fuel tank to verify fuel level.
 - If gauge reads above empty, but tank is empty, diagnose dash gauge. Verify sufficient fuel level before diagnosing a pressure problem.
 - If fuel tank is empty, add fuel, and prime fuel system following procedures in the *Engine Operation and Maintenance Manual*.
 - If no problems are found, no action is required.

Engine Coolant Level

1. Park vehicle on level ground.

NOTE: Turn ignition switch to OFF, shut down engine, and allow to cool. Ensure coolant temperature has stabilized to a safe temperature and pressure.

2. Check coolant level as indicated on deaeration tank level window.
3. Record results on Diagnostics Form.
 - If level is above or below deaeration tank fill level, inspect for leaks, coolant in the oil, or coolant in the intake or exhaust. See Coolant Over-Temperature Diagnostics and Repair (page 74), Fuel in Coolant (page 80), and Combustion Leaks to Coolant (page 68) in the “Engine Symptoms Diagnostics” section of this manual.
 - If level is at deaeration tank fill level, and no tank contamination is evident, no repair is required.

NOTE: If coolant is contaminated, replace coolant.

CAUTION: Coolant in the Exhaust could damage the Diesel Particulate Filter (DPF) and Diesel Oxidation Catalyst (DOC). Inspect DPF and DOC for damage. See AFT System (page 151) in the “Electronic Control Systems Diagnostics” section of this manual for inspection of the DPF and DOC.

Electrical System

Inspect batteries and electrical system (engine and vehicle) for poor or loose connections, corroded terminals, or broken and damaged wires.

- If electrical system problem is found, make repairs as required.
- If no problems are found, no repair is required.

Exhaust System

Inspect exhaust system (engine and vehicle) for damaged or plugged tailpipe.

- If exhaust system problem is found, make repairs as required.
- If no problems are found, no repair is required.

Intake Air System and Charge Air Cooler (CAC)

1. Inspect CAC system, including intercooler and all intake piping and ducts, for leaks, and damage.

Inspect the following parts for restriction, damage or incorrect installation:

- Air inlet hoses and ducts
- Air filter housing and filter element
- CAC and piping
- Air filter inlet and duct - look inside duct and remove any restrictions.

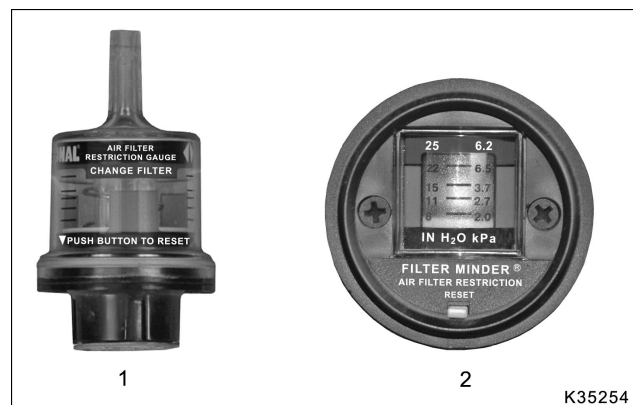


Figure 57 Air filter restriction gauge

2. Check the air filter restriction gauge.
3. Inspect all CAC and intake air connections and clamps.
4. If a CAC or intake air system problem is found, repair as required.

NOTE: If repair is made and intake system is disturbed, run the KOER MAF Sensor Calibrate Procedure (page 63).

3. EST Connection and Data Recording

NOTE: See the “Diagnostic Software Operation” (page 53) section in this manual for specific EST software procedures to do this test.

NOTE: Ideally, allow the engine to cold soak for at least 2 hours before recording results.

Purpose

Determine if engine sensor readings are within specification for engine starting.

Monitoring Engine Systems using an EST**Tools**

- EST with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Cable

Procedure

 **WARNING:** To prevent personal injury or death, shift transmission to park or neutral, set parking brake, and block wheels before doing diagnostic or service procedures.

1. Turn ignition switch to ON, engine OFF.
2. Using the EST, start the ServiceMaxx™ software.
NOTE: See “Diagnostic Software Operation” (page 53) section in this manual for ECM and EST communication problems.
3. Record the following sensor readings on Diagnostics Form:
 - Barometric Pressure
 - Air Inlet Temperature
 - Engine Coolant Temperature
 - Engine Oil Temperature
 - Intake Manifold Temperature
 - Fuel Delivery Pressure
 - Fuel Rail Pressure
 - DPF Differential Pressure
4. If sensor is out of specification, go to suspect sensor diagnostic in “Electronic Control Systems Diagnostics” (page 135) section of this manual.
5. Open Output State Test High and Low in the ServiceMaxx™ software.
6. Record voltage signals for the following on the Diagnostics Form:
 - Exhaust Gas Recirculation Position (EGRP)
 - Engine Throttle Position (ETP)

7. If signal is out of specification, go to suspect actuator diagnostic in “Electronic Control Systems Diagnostics” (page 135) section of this manual.
8. Monitor DPF status signal value and record on Diagnostics Form:
 - If DPF status is Regen needed-critical level, run Onboard Filter Cleanliness Test

4. Check for DTCs

NOTE: 2010 model year vehicles no longer utilize DTC identification by number. DTCs are now identified using the SPN and FMI identifiers only. These two identifiers, known as the Suspect Parameter Number (SPN) and the Failure Mode Indicator (FMI), are displayed in the DTC Window.

- Suspect Parameter Number (SPN) – The SPN identifies the individual component causing the DTC.
- Failure Mode Indicator (FMI) – The FMI identifies the fault or condition affecting the individual component.
- Active DTCs are codes that are active now.
- Previously active DTCs are historical faults that may be caused by intermittent signals or an operating condition that is not currently present.

Purpose

Identify DTCs.

Tools

- EST with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Cable

Procedure

1. Turn ignition switch to ON, engine OFF.
2. Start the ServiceMaxx™ software.

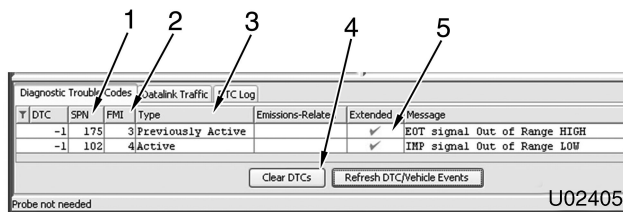


Figure 58 DTC window

1. Suspect Parameter Number (SPN) column
2. Failure Mode Indicator (FMI) column
3. DTC type column
4. Clear DTCs button
5. Extended (Freeze Frame)

NOTE: Click the extended button to receive a Freeze Frame data of when the code was set.

3. Record DTCs on the Diagnostics Form:

- Correct any active DTCs. See the “Diagnostic Trouble Code Index” (page 373) in this manual.
- Investigate any previously active DTCs for possible intermittent operating conditions during which the DTC was set.

5. Fuel Quality Check

Purpose

Check for poor fuel quality or contaminants.

Tools

- Clear diesel fuel container (approximately 1 liter or 1 quart)
- Clear plastic hose

Possible Causes

- Debris, water, or ice in the fuel system
- Oil, gasoline, or kerosene present in fuel tank
- Fuel grade incorrect for cold temperature

Procedure

! WARNING: To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

! WARNING: To prevent personal injury or death, store diesel fuel properly in an approved container designed for and clearly marked **DIESEL FUEL**.

1. Connect clear hose from fuel drain on filter housing to approved diesel fuel container.
2. Turn ignition switch to ON, engine OFF.

NOTE: Instrument panel Warn Engine Lamp (WEL) should cycle ON, then OFF, if there is no water in the system. Lamp will stay ON if water is detected.

3. Turn ignition switch to OFF.

NOTE: To prevent aeration of the fuel, wait 30 to 60 seconds after turning ignition switch OFF before opening fuel drain valve.



Figure 59 Fuel Sample

4. Drain enough fuel into container to effectively check for contamination.

5. Check for water, waxing, icing, sediment, gasoline, or kerosene by shaking fuel sample container and letting contents settle.
 - Sediments will fall to the bottom of the fuel sample container.
 - Gasoline and kerosene will separate from the diesel fuel.
 - Waxing or icing will prevent diesel fuel from flowing out of the fuel drain valve.
 - If the fuel quality is questionable, correct the problem. Take another sample to verify fuel quality is satisfactory.
 - If the fuel quality is satisfactory, continue to next test.

6. Fuel Pressure and Aeration Check

Purpose

Check for low Fuel Delivery Pressure (FDP) and aeration (bubbles in fuel).

Tools

- EST with ServiceMaxx™ software
- ZTSE4681 – Fuel Pressure Gauge
- Graduated cylinder (0 - 700 mL)

Check Fuel Delivery Pressure Using the EST

NOTE: This procedure is only valid on engines equipped with an FDP sensor and will not test for aeration.

1. See “Appendix A: Performance Specifications” (page 425) in this manual for FDP specifications.
2. Turn ignition switch to ON, engine OFF.
3. Using the EST, start the ServiceMaxx™ software.

4. Monitor FDP and record results on Diagnostics Form.

- If FDP is below specification, replace fuel filters, prime low-pressure fuel system and retest. See KOEO Fuel Pump Prime (page 62).
- If still below specification after fuel filter replacement and priming procedure, continue to the next test.
- If FDP is in specification, continue to next test.
- If FDP is above specification, see FDP Sensor (page 277) in “Electronic Control Systems Diagnostics” section of this manual.

Check Fuel Delivery Pressure Manually

NOTE: This procedure is only valid on engines equipped with a fuel filter housing diagnostic valve.

NOTE: Verify water drain lever is closed properly. If any leaks are noticed, see the *Engine Service Manual* for o-ring replacement procedure.

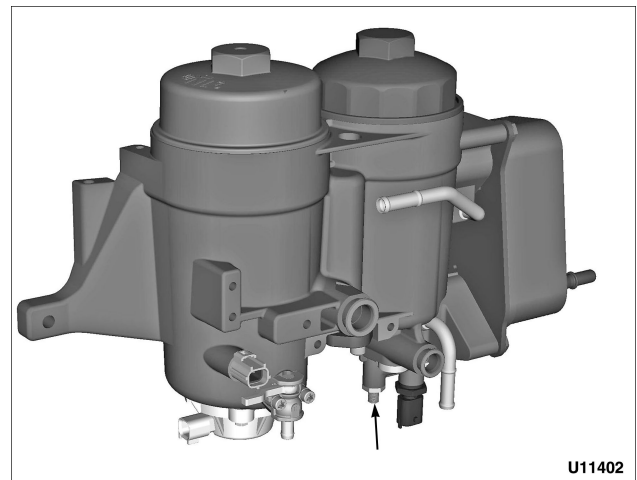


Figure 60 Fuel filter housing diagnostic valve

1. Connect Fuel Pressure Gauge ZTSE4681, with shutoff valve and clear drain hose, to the fuel test port located on the Fuel Filter module.
2. Route clear drain hose into an approved diesel fuel container.

3. Turn ignition switch to ON, engine OFF.
4. Open shutoff valve; check for aeration (bubbles flowing through clear line).
5. Close shut off valve and measure fuel pressure at the fuel filter housing diagnostic valve using the Fuel Pressure Gauge ZTSE4681.
6. Record results on Diagnostics Form.
 - If pressure is below specification, or aerated, go to Low-pressure Fuel System in Hard Start and No Start Diagnostics section (page 100).

NOTE: Analog or digital pressure gauge is required for measuring low-pressure side, if engine is not equipped with an FDP sensor.

7. Engine Low Idle to High Idle

NOTE: See “Diagnostic Software Operation” (page 53) section in this manual for specific EST software procedures to do this test.

Purpose

Determine APP function, CAC function, and Fuel Pressure performance.

Tools

- EST with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Cable
- ZTSE4681 – Fuel Pressure Gauge with 30 psi gauge

Procedure

1. Retain fuel pressure gauge setup from previous test.
2. Turn ignition switch to ON, engine OFF.
3. Start the ServiceMaxx™ software.
4. Open the Performance Session.
5. Monitor Accel Pedal signal and depress accelerator pedal to the floor.

6. Record results on Diagnostics Form.
 - If APP signal does not go from 0% to 99.6%, or response time is slow, see APP (page 167) in “Electronic Control Systems Diagnostics” section of this manual.
7. Start engine and press the record button.
8. Inspect CAC hose for collapsing while running test.
9. Allow engine to idle for 20 seconds.
10. Depress accelerator pedal to the floor and hold for 20 seconds.
11. Return to low idle and stop recording; record CAC observation on Diagnostics Form.
 - If CAC collapses during test, inspect CAC for plugging and check if the Low-pressure Turbocharger spins freely.
12. Play back logging and record results on Diagnostics Form.
 - If Fuel Pressure drops below specification, go to “Low-pressure Fuel System” in the Hard Start, No Start (page 89) section of this manual.
 - If Fuel Rail Pressure is below specification, verify Low-pressure Fuel System is working correctly, before diagnosing High-pressure Fuel System.
 - If engine does not accelerate smoothly or feels unbalanced, run the Relative Compression Test (page 129) and Cylinder Cutout Test (page 130).
 - If Intake Manifold Pressure is below specification, go to Turbocharger Checks (Under Boost) (page 125).
 - If all readings are within specification, go to Road Test.

8. Road Test (0–60 mph, Full Throttle)

NOTE: See “Diagnostic Software Operation” (page 53) section in this manual for specific EST software procedures to do this test.

Purpose

Check for unacceptable engine performance at 0–60 mph, full throttle by means of maximum boost and minimum fuel pressure.

Tools

- EST with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Cable

Unacceptable Boost Possible Causes

• Boost leaks	• Low fuel pressure
• Restricted intake or exhaust	• Failed EGR valve
• Control system faults	• Failed turbochargers
• Biased IMP sensor	• Failed fuel injectors
• Power cylinder condition	• Plugged DPF
• Exhaust leaks	• Plugged DOC
• Biased MAF sensor	

Unacceptable Fuel Rail Pressure Possible Causes

• FRP circuit fault	• Failed fuel injectors
• Failed electric fuel pump	• High-pressure fuel line leaks
• Failed high-pressure fuel pump	• Biased FRP sensor

Unacceptable Fuel Pressure Possible Causes

• Fuel filter blockage	• Fuel supply line leak, damage, or blockage
• Incorrect fuel grade for cold climate	• Air leak in suction side fuel line or filter assembly
• Debris, water, or ice in fuel system	• Failed fuel regulator valve (located in fuel filter housing)
• Oil, gasoline, or kerosene present in fuel system	• Failed fuel pump
• Excessive leak on high-pressure fuel side	• Failed fuel thermal valve

 **WARNING:** To prevent personal injury or death, read all safety instructions in the “Safety Information” section of this manual.

Procedure

1. Retain Fuel Gauge setup from previous test.
2. Turn ignition switch to ON, engine OFF.
3. Start the ServiceMaxx™ software and ensure full functionality.

NOTE: See “Diagnostic Software Operation” (page 53) in this manual for Engine Control Module (ECM) and EST communication problems.

4. Open the Performance session.
 5. Start engine and run until minimum engine coolant temperature of 158°F (70°C) is reached.
 6. Set the Performance snapshot to record at 0.2 second interval for the following Parameter Identifiers (PIDs):
 - Engine Speed (ERPM)
 - Engine load (EL %)
 - Fuel Rail Pressure (FRP)
 - Intake Manifold Pressure (IMP)
 - Vehicle speed
 7. Find an open stretch of road. Start snapshot recording. When driving conditions are safe, select a suitable gear and accelerate from 0 to 60 mph at uninterrupted full throttle.
 8. When road test is complete, stop snapshot recording.
 9. Save snapshot for review and future reference.
 10. Replay recording using the Open Engine File feature. Review results for EL %, ERPM, IMP, FRP, and vehicle speed.
 - Pay close attention to rated HP and peak TQ rpm.
 - EL % should be near 100 percent.
 11. Record results on Diagnostics Form.
 - If results are in specification, no repair is required.
 - If results are out of specification, correct problems. Test again to validate repairs.
 - If Fuel Pressure drops below specification, go to Special Test Procedures, Low Fuel Pressure in the Hard Start, No Start (page 89) section of this manual.
 - If Fuel Rail Pressure is below specification, verify Low-pressure Fuel System is working correctly, before trying to diagnose High-pressure System.
 - If engine does not accelerate smoothly or feels unbalanced, run the Relative Compression Test (page 129) and Cylinder Cutout Test (page 130).
 - If Intake Manifold Pressure is below specification, go to Turbocharger Checks (Under Boost) (page 125).
 - If Intake Manifold Pressure is above specification, go to Waste-gate checks (Over Boost) (page 125).
-

Special Test Procedures

Use any Special Test Procedure when directed from the above Required Procedures.

Turbocharger Checks (Under Boost)

Purpose

Check for Low-pressure Turbocharger malfunctions.

Possible Causes

- Failed turbocharger, wastegate actuator, or actuator solenoid

Procedure

1. Remove Turbocharger inlet tube on Low-pressure Turbo.
2. Visibly inspect turbo vanes for damage.
3. Verify vanes spin freely.
4. Record results on Diagnostics Form.
5. If Turbocharger vanes are damaged or do not spin freely, replace Turbocharger according to the *Engine Service Manual*.

Wastegate Checks (Over Boost)

Purpose

Check Turbocharger Wastegate operation.

Tools

- EST with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Cable
- ZTSE4409 – Pressure Test Kit

Procedure

! WARNING: To prevent personal injury or death, wear safety glasses with side shields.

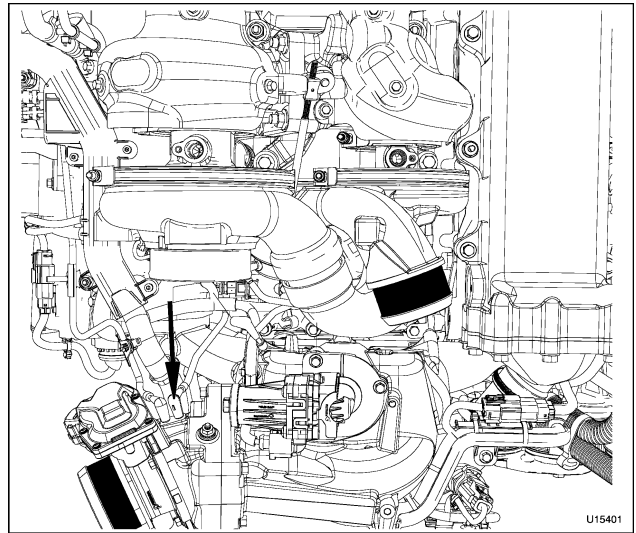


Figure 61 Location of Wastegate Hose Next to ETV

1. Use Pressure Test Kit ZTSE4409 with regulated compressed air.
2. Remove Wastegate hose next to Engine Throttle Valve.
3. Connect to regulated air.
4. Apply 186 kPa (27 psi) to supply hose.
5. Turn ignition switch to ON, engine OFF.
6. Using the EST, start ServiceMaxx™ software.
7. Run KOEO Output State Tests High and Low while visually monitoring wastegate movement.

NOTE: Vented air is directed to the turbo inlet elbow.

8. Record results on the Diagnostics Form.
 - If Wastegate actuator cycles open and closed during the Output State Tests High and Low, turbo control is working correctly.
 - If Wastegate does not open, continue to next step.
9. Remove Pressure Test Kit from wastegate hose and restore to pretest condition.
10. Connect regulated air directly to the pneumatic actuator.
11. Apply 186 kPa (27 psi) of regulated air to actuator.
12. Visually monitor Wastegate movement.

13. Record results on Diagnostics Form.

- If Wastegate actuator does not move, see TC1WC Solenoid (page 349) in “Electronic Control Systems Diagnostics” section of this manual.
- If Wastegate does not open, replace Turbocharger following procedures in the *Engine Service Manual*.

Charge Air Cooler (CAC) Checks**Purpose**

Inspect for clogged or leaking CAC.

Possible Causes

- Loose hose clamps
- Collapsing CAC hoses
- Engine oil in CAC

Procedure

1. Inspect CAC hoses for damage or leaks.
2. Verify all CAC hose clamps are tight.
3. Remove turbocharger-side CAC hose.
4. Inspect hose and CAC for engine oil.
5. Record results on Diagnostics Form.
 - If CAC or hose is filled with oil, drain oil from cooler, replace breather filter, and inspect breather supply hose for restriction or leaks.
 - If breather was replaced and supply hose is good, but oil is still entering the CAC, go to Blow-by Test and Crankcase Pressure Test (page 127).

Blow-by Test**Purpose**

Measure the condition of the power cylinders.

Tools

- Standard plug (obtain locally)

- ZTSE4146A – Orifice
- ZTSE4284 – Crankcase Pressure Test Adaptor
- ZTSE4409 – Pressure Test Kit

Possible Causes

- Dirt in air induction system
- Badly worn or broken rings
- Cylinder bores badly worn or scored
- Leaking valve seals or worn valve guides
- Failed turbocharger seals
- Damaged turbo boost feed lines

Procedure

 **WARNING:** To prevent personal injury or death, read all safety instructions in the “Safety Information” section of this manual.

 **WARNING:** To prevent personal injury or death, make sure the parking brake is set, the transmission is in neutral or park, and the wheels are blocked when running the engine in the service bay.

NOTE: Engine Coolant Temperature must be above 158°F (70°C) before testing.

1. Ensure the engine oil level is not above full mark and the oil level gauge is secured.
2. Inspect air induction for dirt ingestion.
 - If dirt has been ingested into air induction, go to Crankcase Pressure Test (page 127) in this section of the manual.
 - If no dirt has been ingested into air induction, continue to next step.

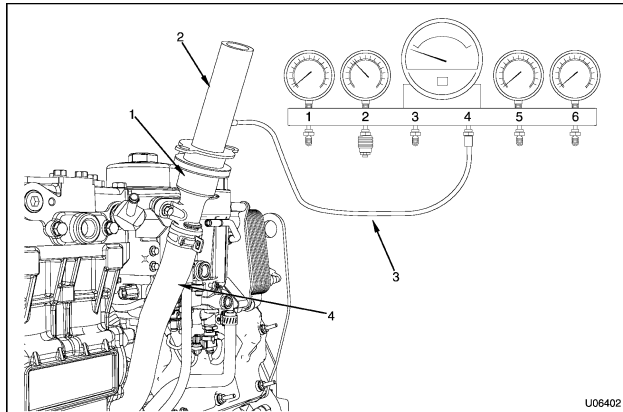


Figure 62 Blow-by Test Tool Setup

1. Crankcase Pressure Test Adaptor
2. Orifice
3. Line to Magnahelic Gauge
4. Oil Fill Tube

3. With engine OFF, remove oil fill cap.
4. Install Crankcase Pressure Test Adaptor ZTSE4284 to oil fill tube.
5. Connect Orifice ZTSE4146A to Crankcase Pressure Test Adaptor ZTSE4284.
6. Connect a line from the Orifice ZTSE4146A to the magnahelic gauge on the Pressure Test Kit ZTSE4409.
7. Using a standard plug, block off road draft tube, located on the bottom right side of the engine.
8. Start engine and run at low idle rpm. Monitor magnahelic gauge and record low idle blow-by pressure on Diagnostics Form.
9. Run engine at high idle (no load) rpm. Monitor magnahelic gauge and record high idle blow-by pressure on Diagnostics Form.

NOTE: Allow the magnahelic gauge reading to stabilize before recording pressure reading.

- If pressure is below specification, go to Crankcase Pressure Test (page 127).

- If pressure is above specification, go to Relative Compression Test (page 129).

Crankcase Pressure Test

Purpose

Measure the amount of pressure in the crankcase.

Tools

- Adaptor (locally obtained)
- ZTSE4409 – Pressure Test Kit

Possible Causes

- Dirt in air induction system
- Badly worn or broken rings
- Cylinder bores badly worn or scored
- Leaking valve seals or worn valve guides
- Failed turbocharger seals
- Breather system restriction

Procedure

! WARNING: To prevent personal injury or death, read all safety instructions in the “Safety Information” section of this manual.

! WARNING: To prevent personal injury or death, make sure the parking brake is set, the transmission is in neutral or park, and the wheels are blocked when running the engine in the service bay.

NOTE: Ensure engine is above operating temperature of 158°F (70°C) before starting test.

1. Ensure the engine oil level is not above full mark and the oil level gauge is secured.

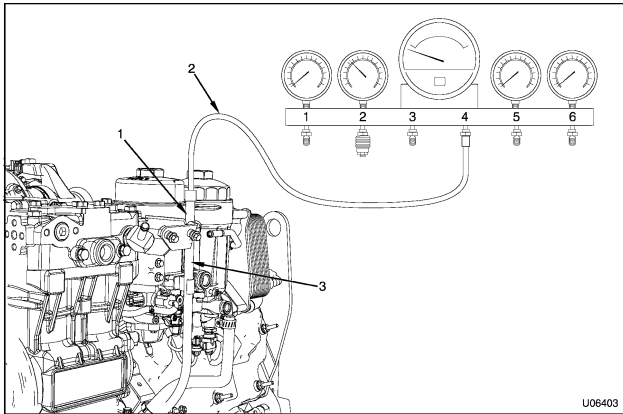


Figure 63 Crankcase Pressure Test Tool Setup

1. Adaptor (locally obtained)
 2. Line to Magnahelic Gauge
 3. Dipstick tube
2. Remove the dipstick from the dipstick tube. Attach 11/16-in hose with clamps and 1/4-in pipe adaptor to magnahelic gauge on Pressure Test Kit ZTSE4409.
 3. Start engine and run at high idle (no load) rpm. Allow reading to stabilize, before recording crankcase pressure reading.
 4. Record crankcase pressure on Diagnostics Form.
 - If pressure is within specification, no repair is needed.
 - If pressure is above specification, continue to next step.
 5. Turn engine OFF. Replace the breather filter and recheck crankcase pressure. See *Engine Operation and Maintenance Manual* for breather filter replacement procedure.
 - If pressure is within specification, no repair is needed.
 - If pressure is above specification, continue to the Relative Compression (page 129) test in this section.

Intake Air Restriction Test

Purpose

Check for restrictions causing performance problems.

Tools

- Engine or dash-mounted air restriction indicator

Possible Causes

- Restricted air filter inlet and ducts
- Restricted, dirty, or collapsed air filter element
- Leaking or damaged Charge Air Cooler (CAC) couplings
- Restricted or collapsed inlet piping or hoses
- Exhaust system damage
- Restricted or full Diesel Particulate Filter (DPF)

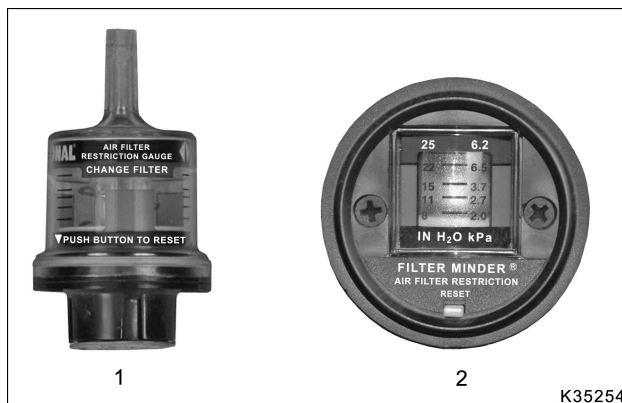


Figure 64 Air cleaner restriction indicators

1. Mounted on air cleaner
2. Mounted on instrument panel

Procedure

! WARNING: To prevent personal injury or death, shift transmission to park or neutral, set parking brake, and block wheels before doing diagnostic or service procedures.

NOTE: Intake Air Restriction should be less than 172-inH₂O at 100 percent engine load, 2600 rpm.

1. Locate air restriction indicator. Run engine at high idle, no load.

2. Record intake restriction on Diagnostics Form.

- If any restriction is detected, repair as required. If air filter is plugged, replace air filter. Reset restriction indicator and test again to validate repair.
- If restriction is not apparent, no repair is required.

Relative Compression Test

NOTE: See the “Diagnostic Software Operation” (page 53) section in this manual for specific EST software procedures to do this test.

Purpose

Check for low cylinder compression

NOTE: Use a battery charger when performing this test. It is important that cranking rpm remains consistent throughout test.

Tools

- EST with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Cable

Possible Causes

- Loose fuel injector
- Valve train damage
- Power cylinder damage

Procedure

1. Turn ignition switch to ON, engine OFF.
2. Start ServiceMaxx™ software.
3. Select Diagnostics from the menu bar and V8 Relative Compression Tests from the drop-down menu.
4. Follow the on-screen instructions.
5. Record results on Diagnostics Form.
 - If the rpm difference for one cylinder is significantly less than the other cylinders, that cylinder is suspect for compression loss.

Cylinder Cutout Test

NOTE: See the “Diagnostic Software Operation” (page 53) section in this manual for specific EST software procedures to do this test.

Purpose

Determine the cause of rough engine idle.

NOTE: Before running this test, you must first verify there are no problems with the fuel system, then run the Relative Compression Test to verify compression is evenly balanced.

Tools

- EST with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Cable

Possible Causes

- Open or shorted injector wiring
- Scuffed or failed injector
- Failed ECM
- Power cylinder problem

Procedure

1. Start the engine.
 2. Start ServiceMaxx™ software.
 3. Select Tests from menu bar.
 4. Select Cylinder Cutout Test from drop-down menu.
 5. Select cylinder number and select Run (injector selected will be disabled and engine noise should change).
 6. Record results on Diagnostics Form.
 7. Select Normal Operation. Injector will be enabled and engine noise should return to previous state of operation.
 8. Repeat steps 5 through 7 for the remaining cylinders.
 - Listen for tone changes from cylinder to cylinder.
 - If test identifies a suspect cylinder, replace that injector.
-

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Description

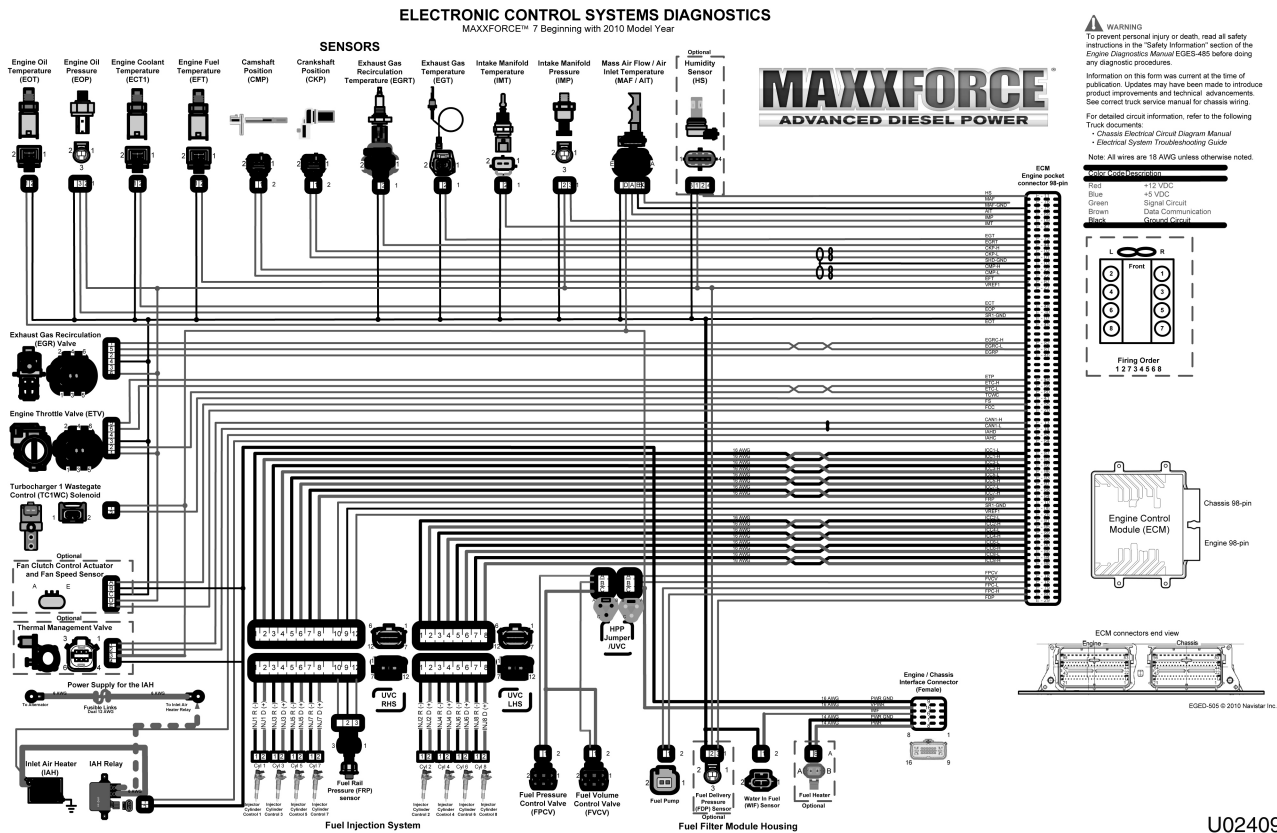
Section Information

All electrical faults in the engine control system can be diagnosed in this section. All components are divided into separate test procedures and contain the following information:

- Suspect Parameter Number (SPN) and Failure Mode Indicator (FMI) with possible cause
 - Circuit diagram
 - Component function
 - Circuit operation
 - Component location
 - Electronic Service Tool (EST) list
 - Sensor End Diagnostics (with ServiceMaxx™ software)
 - Pin-point Diagnostics (without ServiceMaxx™ software)
 - Harness resistance check
 - Operational voltage check (most components)
-

Electronic Control System Diagnostics Form

EGED-505 Diagnostic Form



U02409

Figure 65 EGED-505 (Front Side)

Engine diagnostic forms assist technicians in troubleshooting MaxxForce® diesel engines. Diagnostic schematics and signal values help technicians find problems to avoid unnecessary repairs.

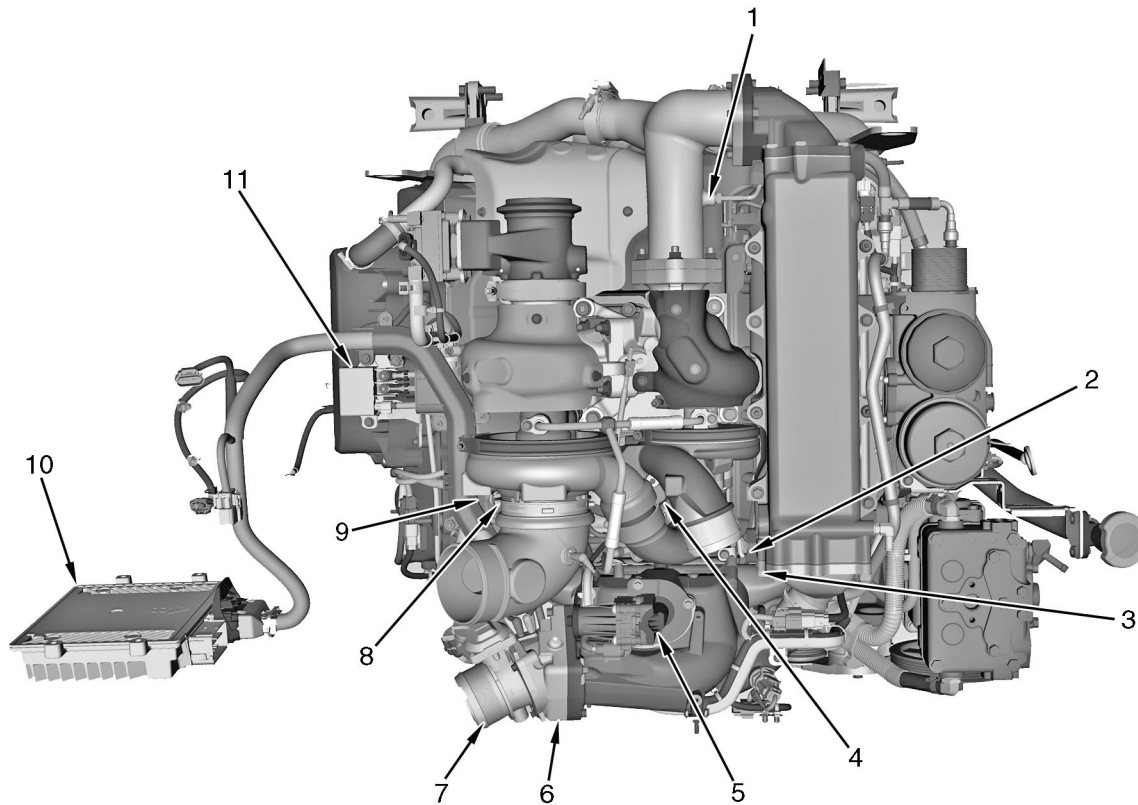
The Electronic Control System Diagnostics form consists of a circuit diagram for electrical components mounted on the engine and chassis side. For a detailed description of chassis circuits, circuit

numbers, or connector and fuse locations, see truck *Chassis Electrical Circuit Diagram Manual* and *Electrical System Troubleshooting Guide*. See "Appendix B: Signal Values" (page 431) for signal values.

Diagnostic Form EGED-505 is available in 50-sheet pads. To order technical service literature, contact your International dealer.

Sensor and Actuator Locations

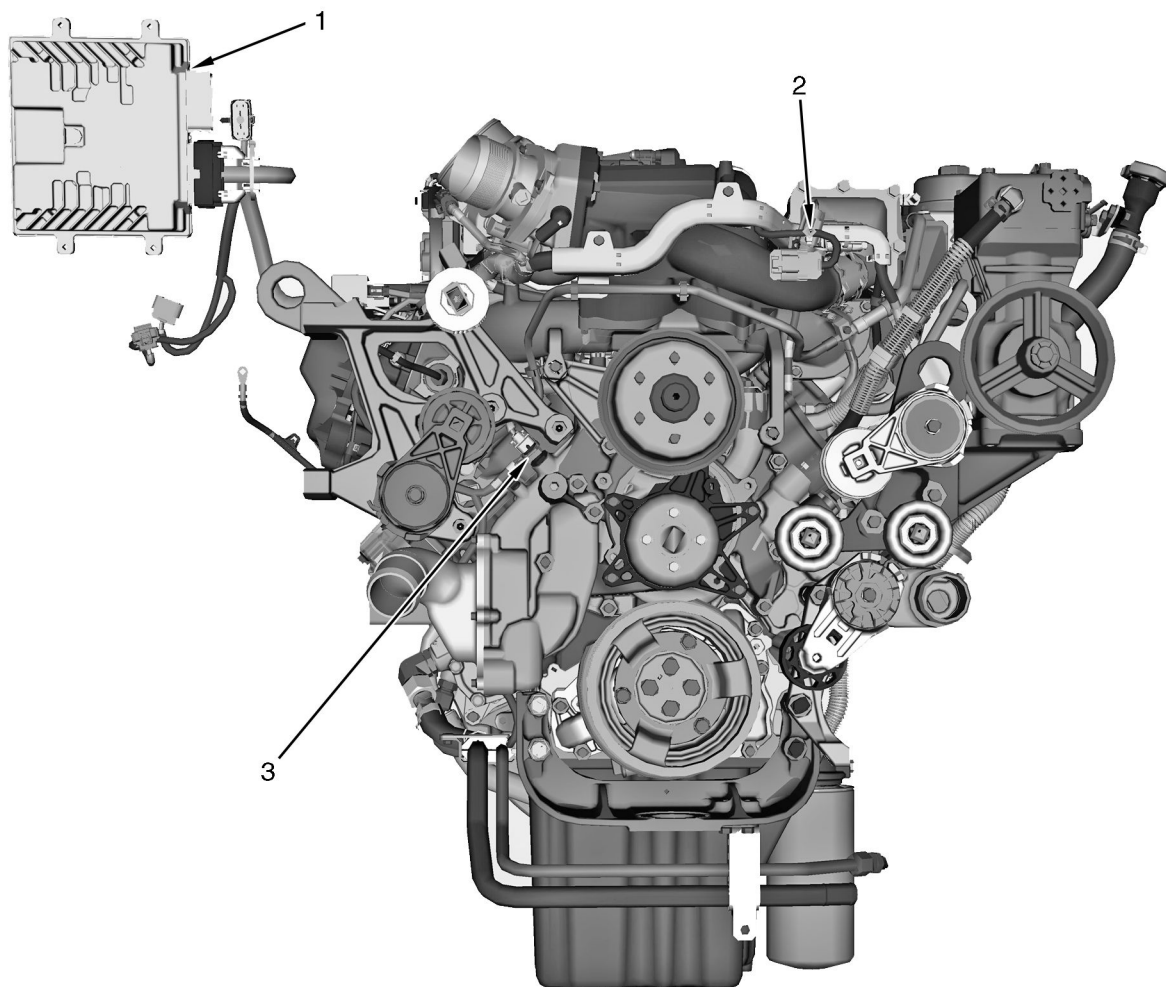
Engine Mounted Components



U09403

Figure 66 Engine View – Top

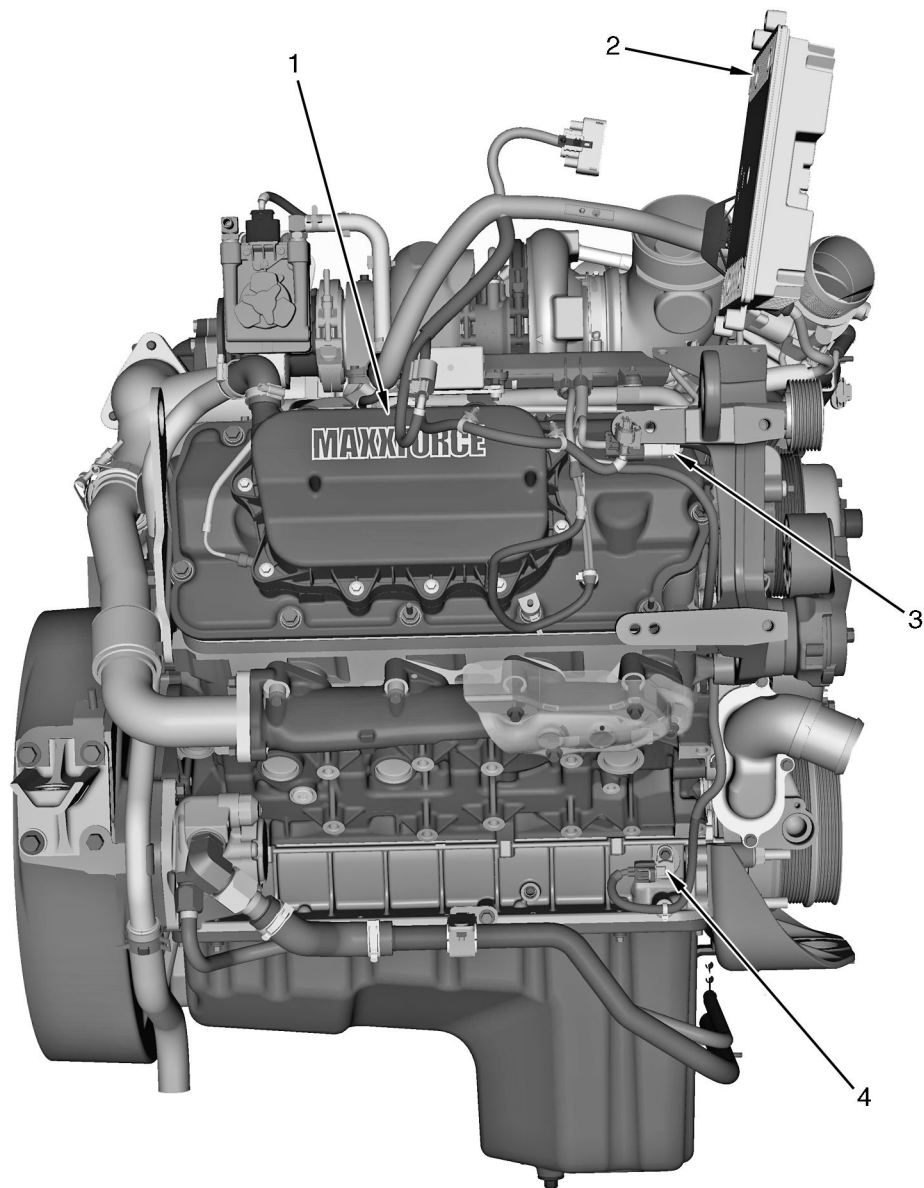
1. Exhaust Gas Temperature (EGT) sensor	4. Turbocharger 1 Wastegate Control (TC1WC) solenoid	8. Intake Manifold Pressure (IMP) sensor
2. Engine Oil Temperature (EOT) sensor	5. Exhaust Gas Recirculation (EGR) valve	9. Intake Manifold Temperature (IMT) sensor
3. Engine Oil Pressure (EOP) sensor	6. Inlet Air Heater (IAH)	10. Engine Control Module (ECM)
	7. Engine Throttle Valve (ETV)	11. Inlet Air Heater (IAH) relay



U09404

Figure 67 Engine View – Front

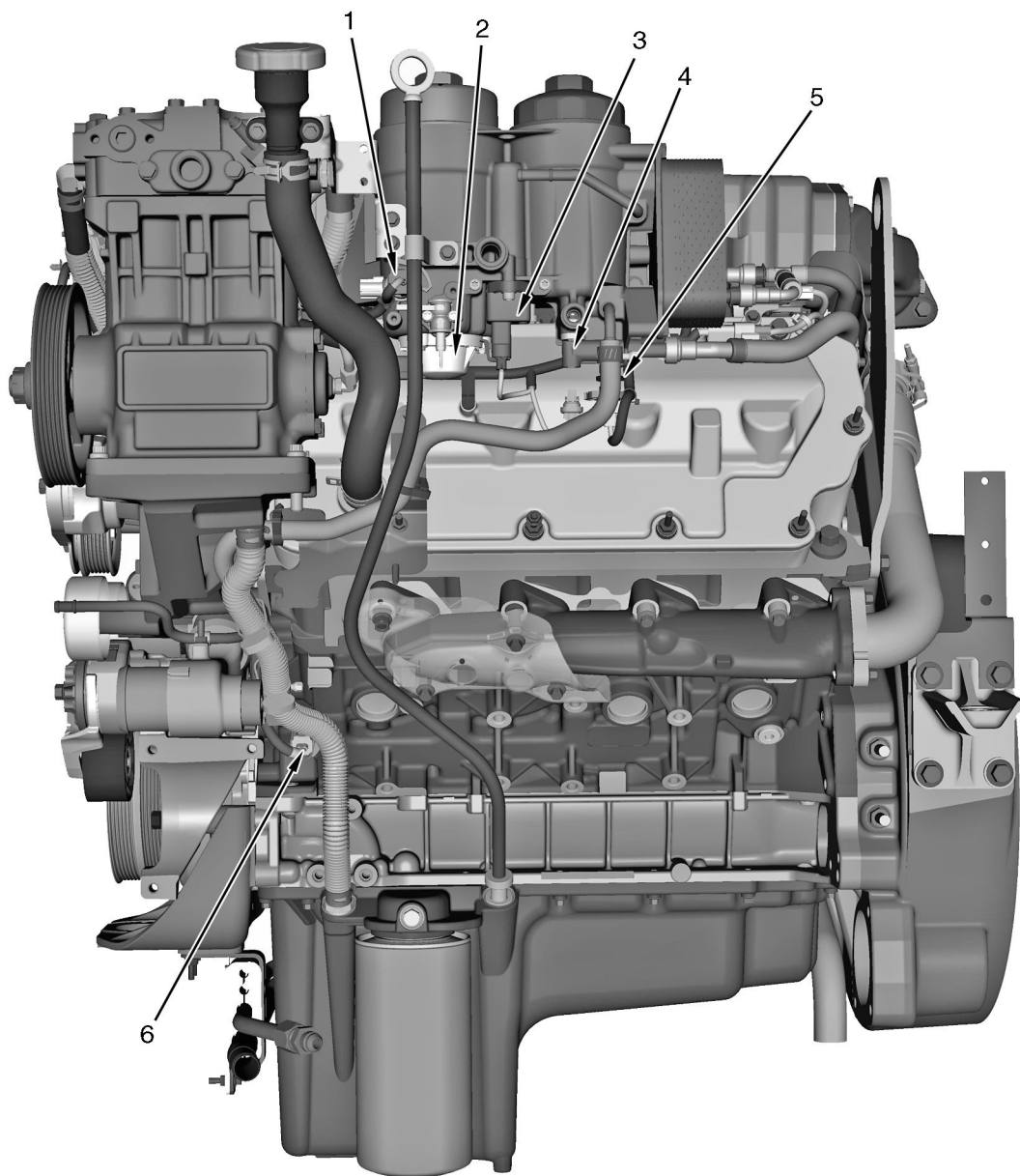
1. Engine Control Module (ECM)	2. Exhaust Gas Recirculation Temperature (EGRT) sensor	3. Engine Coolant Temperature 1 (ECT1) sensor



U09405

Figure 68 Engine View – Right

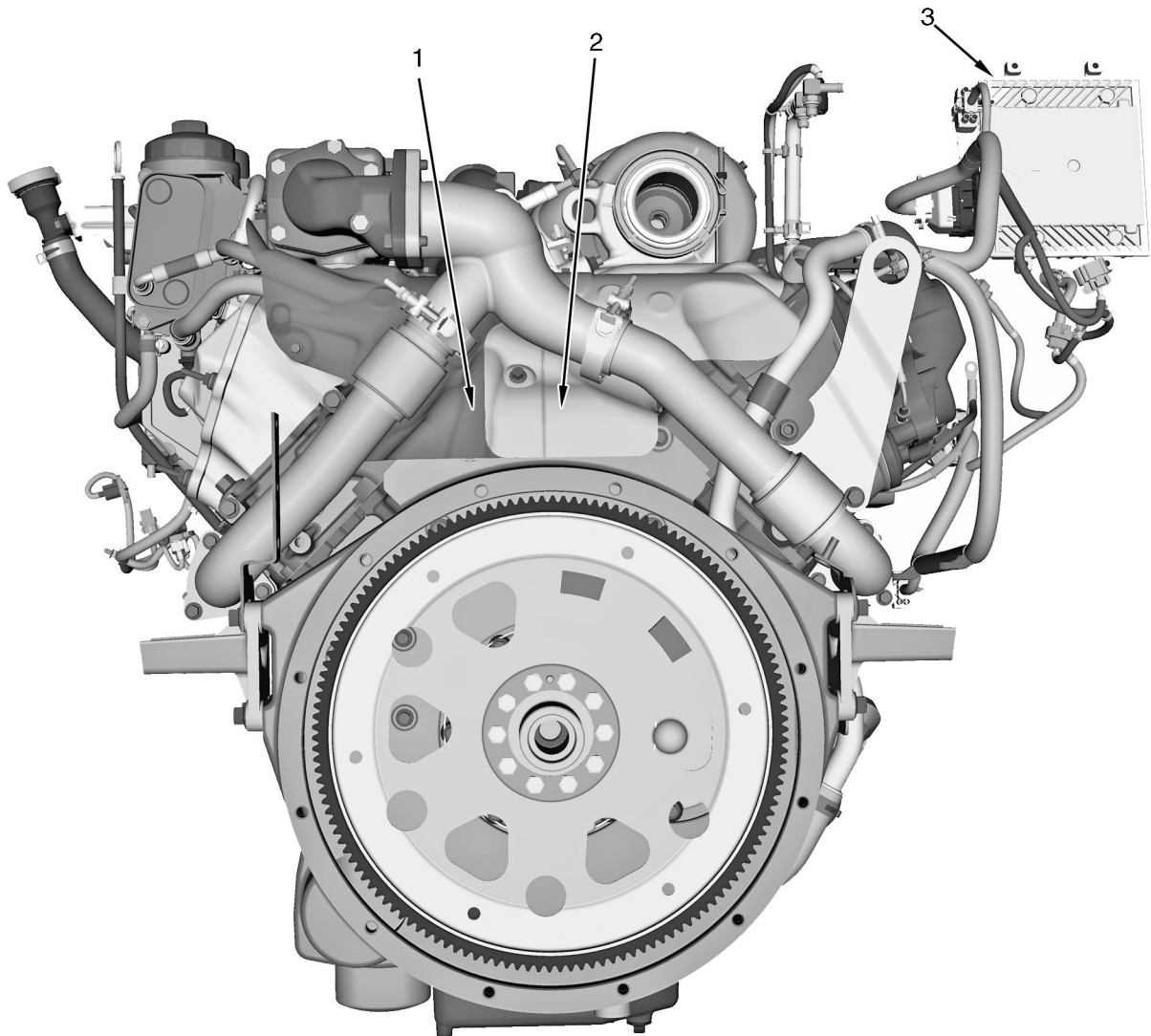
1. Fuel Rail Pressure (FRP) sensor (under valve cover)	2. Engine Control Module (ECM)	4. Crankshaft Position (CKP) sensor
	3. 12-Pin UVC connector	



U09406

Figure 69 Engine View – Left

1. Water In Fuel (WIF) sensor	4. Fuel Delivery Pressure (FDP) sensor (if equipped)	5. Engine Fuel Temperature (EFT) sensor
2. Fuel pump		6. Camshaft Position (CMP) sensor
3. Fuel Heater (if equipped)		



U09401

Figure 70 Engine View – Rear

1. Fuel Pressure Control Valve (FPCV) sensor (under heat shield)	2. Fuel Volume Control Valve (FVCV) sensor (under heat shield)	3. Engine Control Module (ECM)

Diagnostic Procedure Process

Description

The test procedures in this section are based on the assumption there is a DTC or problem with the component being tested.

Do checks in sequence unless directed otherwise. If a test point is out of specification, the comment area will direct the technician to the possible cause or to another test point. It is not necessary to complete all the test points, unless additional assistance is needed to pin-point the fault.

Pin-grip Inspection

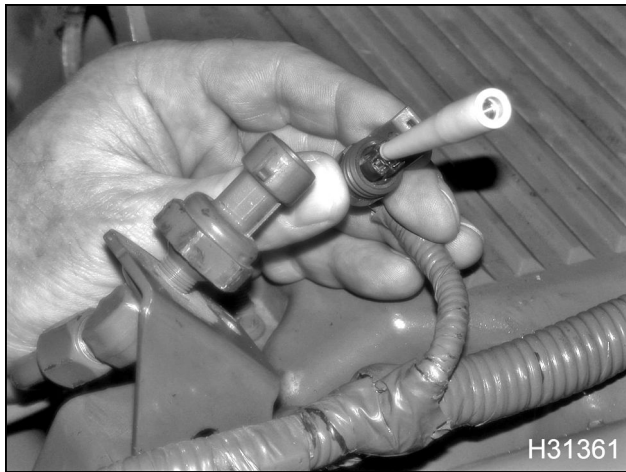


Figure 71 Pin grip check

1. Disconnect the harness connector from the sensor or actuator.
2. Inspect for corrosion, bent pins, spread pins, or conditions that could cause a loose or intermittent connection.
3. Check the pin grip in the female pin by inserting the correct tool from Terminal Test Kit.

Diagnostics with EST

Sensors can be diagnosed quickly using an Electronic Service Tool (EST) with ServiceMaxx™ software. The tool monitors sensor signals back to the Engine Control Module (ECM) while testing the sensor's harness connection. Start this procedure with Sensor End Diagnostics.

Actuators can be diagnosed using ServiceMaxx™ software to command Output State test (high or low) while measuring voltage at the actuator's harness connection.

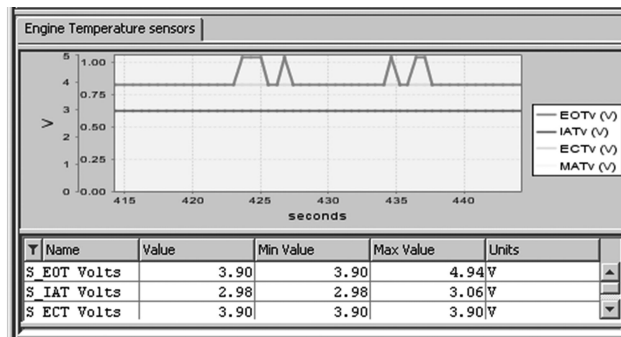
Diagnostics without EST

Sensors can also be diagnosed using only a Digital Multimeter (DMM). Start this test procedure with Pin-point Diagnostics.

Sensor End Diagnostics (with ServiceMaxx™ software)

Sensor End Diagnostics (2-Wire)

1. Connect the EST to the Diagnostic Connector.
2. Turn ignition switch to ON, engine OFF.
3. Start ServiceMaxx™ software.
4. Open the Continuous Monitor session. This session lists all engine sensors.



T02124

Figure 72 Sensor voltage

5. Monitor the sensor voltage and verify an active DTC is present.

NOTE: If sensor signal circuit is shorted or open, the signal value will read NA or Error.

- If the code is inactive, monitor the signal while wiggling the connector and all wires at suspected locations.

If the circuit is interrupted, the signal will spike. Isolate the fault and repair.

- If the code is active, continue to the next step.

6. Disconnect sensor. Inspect the connector for damaged pins. Repair as necessary.

Example

Connect breakout harness, leave sensor disconnected. Verify specified DTC goes active when fault is induced.

Test Point	Spec	Comment
EST – Check DTC	SPN 175 FMI 3	If SPN 175 FMI 4 is active, check EOT signal for short to GND. Do Harness Resistance Check.

- If specified DTC does not go active, repair short to Ground (GND) on the sensor signal circuit. Do Harness Resistance Check if additional assistance is needed in diagnosing fault.
 - If specified DTC goes active, continue to next test point.
7. Short 3-Banana Plug Harness ZTSE4498 across the sensor signal circuit and engine GND.
 8. The specified DTC should go active, unless the sensor signal circuit is open.

Example

Test Point	Spec	Comment
EST – Check DTC	SPN 175	If SPN 175 FMI 3 is active, check EOT signal circuit for OPEN. Do Harness Resistance Checks.
Short 3-Banana Plug Harness across 2 and GND	FMI 4	

- If specified DTC does not go active, repair open in sensor signal circuit. Do Harness Resistance Check if additional assistance is needed in diagnosing fault.
 - If specified DTC goes active, continue to next test point.
9. Short 3-Banana Plug Harness ZTSE4498 across the sensor signal circuit and Signal Ground (SIG GND) circuit.
 10. The specified DTC should go active, unless the SIG GND circuit is open.

Example

Test Point	Spec	Comment
EST – Check DTC	SPN 175	If DTC is not active, check SIG GND for OPEN. Do
Short 3-Banana Plug Harness	FMI 3	Harness Resistance Checks.
ZTSE4498 across 1 and 2		

- If corresponding DTC does not go active, repair open in SIG GND circuit. Do Harness Resistance Check if additional assistance is needed in diagnosing fault.
- If within specification, and both circuits tested acceptable, continue to the last step.

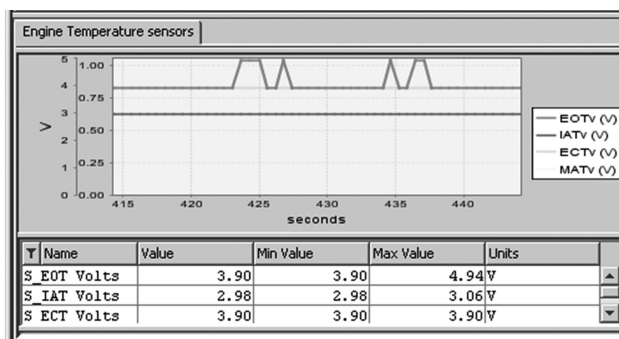
11. Connect the sensor and clear the DTC's, start the engine, and cycle the accelerator pedal a few times. If the active code remains, the sensor must be at fault. Replace the failed sensor.

Example

If checks are within specification, connect sensor and clear DTCs. If active code remains, replace sensor.

Sensor End Diagnostics (3-Wire)

1. Connect the EST to the Diagnostic Connector.
2. Turn ignition switch to ON, engine OFF.
3. Start ServiceMaxx™ software.
4. Run Continuous Monitor session. (This session lists all engine sensors.)



T02124

Figure 73 Sensor voltage

5. Monitor the sensor voltage and verify that an active DTC is present.

NOTE: If sensor signal circuit is shorted or open, the signal value will read NA or Error.

- If the code is inactive, monitor the signal while wiggling the connector and all wires at suspected locations.

If the circuit is interrupted, the signal will spike. Isolate the fault and repair.

- If the code is active, continue to the next step.
6. Disconnect the sensor. Inspect the connector for damaged pins. Repair as necessary.

Example

Test Point	Spec	Comment
EST – Check DTC	SPN 102 FMI 4	If SPN 102 FMI 3 is active, check IMP signal for short to Power (PWR)

- If specified DTC does not go active, repair short to voltage on sensor signal circuit.
 - If specified DTC goes active, continue to next test point.
7. Use a DMM to measure voltage on the Reference Voltage (VREF) circuit. Voltage should read 5 volts, unless VREF is open or shorted to GND, or a voltage is greater than VREF.

Example

Test Point	Spec	Comment
DMM – Measure volts	5 V	If > 5.5 V, check VREF for short to PWR.
2 to GND		If < 4.5 V, check VREF for OPEN or short to GND. Do Harness Resistance Checks.

- If not within specification, repair open or short in VREF circuit. Do Harness Resistance Check if additional assistance is needed in diagnosing fault.
 - If within specification, continue to the next test point.
8. Short 3-Banana Plug Harness ZTSE4498 across VREF and the sensor signal circuit.
9. The specified DTC should go active, unless the sensor signal circuit is open.

Example

Test Point	Spec	Comment
EST – Check DTC Short breakout harness across 2 and 3	SPN 102 FMI 3	If SPN 102 FMI 4 is active, check IMP signal for OPEN or short to GND. Do Harness Resistance Checks.

- If specified DTC does not go active, repair open in sensor signal circuit. Do Harness Resistance Check if additional assistance is needed in diagnosing fault.
- If specified DTC goes active, continue to the next test point.

10. Use a DMM to measure resistance on the SIG GND circuit to ground. Resistance should read less than 5 ohm, unless the SIG GND is open.

Example

Test Point	Spec	Comment
DMM – Measure resistance 1 to GND	< 5 Ω	If > 5 Ω , check SIG GND for OPEN. Do Harness Resistance Checks.

- If not within specification, repair open in the SIG GND circuit. Do Harness Resistance Check if additional assistance is needed in diagnosing fault.
- If within specification, and all three circuits tested acceptable, continue to the last step.

11. Connect the sensor and clear the DTC's. If the active code remains, the sensor must be at fault. Replace the failed sensor.

Example

If checks are within specification, connect sensor and clear DTC's. If active code remains, replace sensor.

Pin-point Diagnostics (without ServiceMaxx™ software)

1. Connect breakout harness to the engine harness. Leave sensor disconnected.
2. Turn ignition switch to ON, engine OFF.
3. Use a DMM to measure voltage on each circuit to engine ground.

Example

Test Point	Spec	Comment
C to GND	5 V	If > 5.5 V, check VREF for short to PWR. If < 4.5 V, check VREF for OPEN or short to GND. Do Harness Resistance Checks.

- If the circuit is not within specification, the comment area will list possible cause or direct the technician to the next test point. Do Harness Resistance Check if additional assistance is needed in diagnosing fault.
 - If the circuit is within specification, continue to the next test point.
2. Connect breakout harness between engine harness and actuator.
 3. Connect the EST to the Diagnostic Connector.
 4. Turn ignition switch to ON, engine OFF.
 5. Start ServiceMaxx™ software.
 6. Open the Output State session. This session allows the technician to monitor the state of all engine actuators.
 7. Run the Output State test (high or low) or Glow Plug / IAH test.
 8. Use a DMM to measure voltage on each circuit to engine ground.

Actuator Operational Voltage Check – Output State Test

This test will allow the technician to take voltage measurements on actuators commanded high or low.

1. Disconnect actuator. Inspect connector for damaged pins. Repair as necessary.

Example

Test Point	Test	Spec	Comment
A to GND	Key On-Engine Off (KOEO)	B+	If < B+, check for OPEN circuit
B to GND	KOEO	B+	If < B+, check actuator coil for OPEN.
B to GND	Output State HIGH	B+	If < B+, check actuator control circuit for short to GND.
B to GND	Output State LOW	7.5 V	If > 7.5 V, check actuator control circuit for OPEN or short to PWR or failed across coil.

- If any circuit is not within specification, the comment area will list possible cause or direct the technician to the next test point.
- If all circuits are within specification, the actuator may not be operating mechanically.

Harness Resistance Check

Complete Sensor End Diagnostics or Pin-point Diagnostics tests before using this procedure.

Resistance cannot be measured on a circuit if voltage is present. Isolate circuit from voltage before continuing.

1. Turn ignition switch to OFF or disconnect batteries.



WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

2. Connect breakout box and breakout harness to vehicle or engine harness. Leave ECM and sensor or actuator disconnected.
3. Use a DMM to measure resistance on each circuit from point to point, then to engine ground.

Example

Test Point	Spec	Comment
E-66 to 2	< 5 Ω	If > 5 Ω , check EOT control circuit for OPEN.
E-66 to GND	> 1 k Ω	If < 1 k Ω , check EOT control circuit for short to GND.

- If the circuit is not within specification, the comment area will list possible circuit faults.
- If the circuit is within specification, continue to the next test point.

Operational Voltage Check

This test shows what a normal sensor or actuator should read at certain operating conditions. This test is helpful in diagnosing in-range faults or intermittent problems.

1. Connect breakout box or breakout harness between Engine Control Module (ECM) and the component being tested.
2. Turn ignition switch to ON.
3. Open Continuous Monitor session or Output State test session (dependent upon what is being tested) using the ServiceMaxx™ software.
4. Run the Continuous Monitor test.
5. Verify actual sensor or actuator readings are within specification.

Example

Test Point	Condition	DMM	Signal Value
APP	Foot off pedal	0.64 V $\pm$ 0.5 V	0%
A to GND or C-48 to GND	Pedal to floor	3.85 V $\pm$ 0.5 V	102%
APP2	Foot off pedal	0 V	0 V
D to GND or C-33 to GND	Pedal to floor	B+	B+

Circuit Diagnostics

AFT System (Aftertreatment)

SPN	FMI	Condition
3251	0	DPFDP excessively HIGH (Plugged filter)
3251	21	DPFDP excessively LOW (sensor/circuit fault or DPF missing)
3719	0	DPF soot load – Highest (3/3)
3719	15	DPF soot load – Lowest (1/3)
3719	16	DPF soot load – Moderate (2/3)
3720	0	DPF Ash load at maximum limit (Remove DPF for cleaning)
3936	0	DPF soot load – Severe De-rate
3936	16	DPF Overtemp Monitor
5298	2	Reduced DOC Efficiency - De-rate
5319	31	DPF incomplete Regeneration

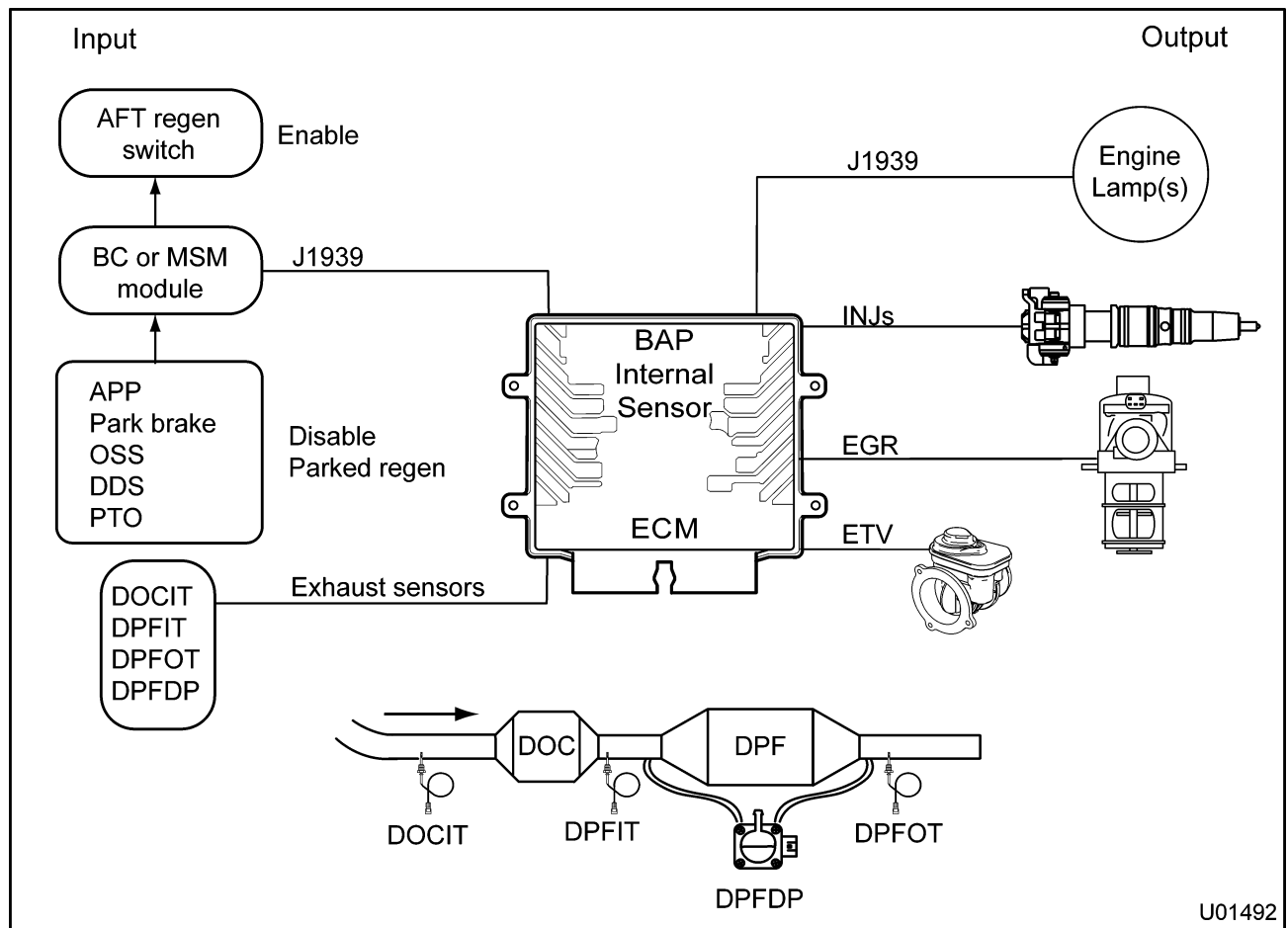


Figure 74 Function diagram for AFT system

The function diagram for the AFT system includes the following:

- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Diesel Oxidation Catalyst (DOC)
- Diesel Particulate Filter (DPF)
- DOC Inlet Temperature (DOCIT) sensor
- DPF Inlet Temperature (DPFIT) sensor
- DPF Outlet Temperature (DPFOT) sensor
- DPF Differential Pressure (DPFDP) sensor
- Fuel injectors (INJs)
- Exhaust Gas Recirculation (EGR) actuator
- Engine Throttle Valve (ETV)
- Engine Lamp(s)
- Inhibit regeneration switch (optional)
- Body Controller (BC) module

- Multiplex System Module (MSM) body module
- Accelerator Pedal Position (APP)
- Output Speed Sensor (OSS)
- Driveline Disconnect Switch (DDS)
- Power Takeoff (PTO)

Function

The AFT system is designed to decrease harmful exhaust emissions. The DPF captures particulate matter (soot) and ash from the exhaust. Soot builds up in the DPF and must occasionally be heated and turned into ash, this is the DPF regeneration process. Ash buildup is periodically removed from the DPF by a special cleaning machine.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
 - NAVCoM or NAVLink Interface Kit
-

AFT System Diagnostics

SPN	FMI	Condition	Possible Causes
3251	0	DPFDP excessively high (Plugged filter)	• Biased DPFDP sensor • DOC/DPF face plugged • High DPF soot load
3251	21	DPFDP excessively LOW (sensor/circuit fault or DPF missing)	• Biased DPFDP sensor • Leaks in DPFDP sensor hose • Reversed pressure lines on DPFDP sensor • Exhaust leak before DPF • Damaged DPF
3719	0	DPF Soot Load – Highest (Level 3/3)	DPF needs to regenerate.
3719	15	DPF Soot Load – Lowest (Level 1/3)	DPF needs to regenerate.
3719	16	DPF Soot Load – Moderate (Level 2/3)	DPF needs to regenerate.
3720	0	DPF Ash load at maximum limit (Remove DPF for cleaning)	Replace DPF and reset the DPF replacement counter
3936	0	DPF soot load – Severe De-rate (regen disabled)	Replace or clean out DPF beyond ability to regenerate.
3936	16	DPF Overtemp Monitor	• High hydro-carbon slip • Reduced DOC efficiency • Fuel injector leakage • High DPF soot load
5298	2	Reduced DOC efficiency - Engine De-rate	• Loss of washcoat • Cracked DOC • Removed/Tempered DOC • DOC face plugged • Aged DOC
5319	31	DPF incomplete Regeneration	• High DPFDP after DPF regen • High ash level in DPF • Biased DPFDP sensor or circuit

Alert Levels of DPF Soot Loading

! WARNING: To prevent personal injury or death, keep clear of exhaust system components while running the Diesel Oxidation Catalyst (DOC) Cleaning Procedure. The temperature of some of the exhaust system components may rise to 816 °C (1,500 °F) while running the procedure. You should take extreme caution while working on or around exhaust system components after testing has been completed.

There are four levels indicating the DPF is accumulating a level of soot and needs to be cleaned, each with an increasing urgency for action.

Levels	Conditions	Action
Regeneration lamp on solid	Exhaust regeneration required	Drive on highway at highway speeds so the system can autoregenerate. OR Start a parked regeneration to prevent loss of power.
Regeneration lamp flashing	DPF is full	Pull vehicle safely off roadway and start a parked regeneration to prevent loss of power.
Regeneration lamp flashing Audio alarm beeps five times every minute	DPF is full Engine performance is limited	Pull vehicle safely off roadway and start a parked regeneration to prevent engine stopping.
Engine STOP lamp on solid Audio alarm beeps continuously	DPF is overfull Engine may shutdown soon	Pull vehicle safely off roadway turn on flashers, place warning devices and stop engine, do not use parked regeneration. Call for service.

When the High Exhaust System Temperature lamp is illuminated, the exhaust is above 400 °C (752 °F) and a regeneration could be in process.

SPN 3251/FMI 0 – DPF high flow resistance

SPN 3251/FMI 0 sets if DPF is face plugged or soot loading is overfull. As a preventive measure, this fault disables regeneration until the next key on cycle.

Pin-point AFT System Fault

1. Inspect DPF for damage (tempered and leakage).
2. Inspect DPFDP, DPFIT, and DPDOT sensors for damage, loose connection, and sensor/harness rupture.
3. Check for active or previously active faults indicating high soot load in DPF. Any of SPN 3719 FMI 0,15,16 or SPN 3936 FMI 0 faults indicate high soot load in DPF.
4. Perform Onboard Filter Cleanliness test using EST. If test result confirms excessive soot load, service DPF.

SPN 3251/FMI 21 – DPF low flow resistance

SPN 3251/FMI 21 sets when the measured DPF differential pressure is less than a minimum value for a certain exhaust flow rate.

Pin-point AFT System Fault

1. Inspect exhaust and DPFDPS sensor for damage. Check for leaks in exhaust or DPFDPS sensor hose. Check that DPFDPS sensor hoses are not reversed.
 2. Check for active DPFDPS sensor DTC. See DPFDPS Sensor (page 201) in this section of the manual.
 3. Check for damaged DPF. Remove and inspect for cracks that could allow exhaust gas to bypass the filter.
-

SPN 3719/FMI 0 – DPF load: above critical level 1 - engine de-rate

SPN 3719/FMI 0 sets when Level 3 DPF soot loading is over 100% full and engine de-rate has been enabled. DPF regeneration is required.

Pin-point AFT System Fault

1. Check for active DTC that could prevent AFT System from regenerating.
 2. Do a Manual Parked Regeneration Procedure (page 158).
-

SPN 3719/FMI 15 – DPF servicing required

SPN 3719/FMI 15 sets when Level 1 DPF soot loading is above 80% full and a DPF regeneration is required.

Pin-point AFT System Fault

1. Check for active DTC that could prevent AFT system regeneration.
 2. Drive vehicle at highway speeds for 20 to 30 minutes until the regeneration lamp is not illuminated or do a Manual Parked Regeneration Procedure (page 158).
-

SPN 3719/FMI 16 – DPF load: above warning level

SPN 3719/FMI 16 sets when Level 2 DPF soot loading is 100% full and a DPF regeneration is required.

Pin-point AFT System Fault

1. Check for active DTC that could prevent AFT system regeneration.
 2. Do a Manual Parked Regeneration Procedure (page 158).
-

SPN 3720/FMI 0 – DPF Ash load at maximum limit (Remove DPF for cleaning)

SPN 3720 FMI 0 sets when the DPF is full of ash and must be removed and cleaned.

Pin-point AFT System Fault

1. Remove DPF filter and clean out the ash in a cleaning station.
 2. Load DPF Servicing session. Enter DPF serial number, cleaning, and installation date.
 3. Click the DPF has been serviced button.
-

SPN 3936/FMI 0 – DPF load: above critical level 2 - further engine de-rate

SPN 3936/FMI 0 sets when level 4 DPF soot loading is overfull and engine shutdown is enabled. DPF regeneration functionality has been disabled.

Pin-point AFT System Fault

1. Inspect DPFDSP sensor for damage or loose connection.
 2. Remove DPF and service the filter.
 3. Check for active DTC that could prevent the AFT system from regenerating.
 4. Do an Onboard Cleanliness Test to reset soot and ash monitors.
-

SPN 3936/FMI 16 – DPF Overtemp Monitor

SPN 3936/FMI 16 sets when if DPF inlet or outlet temperature increases beyond maximum threshold. As a preventive measure, this fault disables regeneration until the next key on cycle.

Pin-point AFT System Fault

1. Inspect DPFIT and DPFOT sensors for damage, loose connection, and sensor/harness rupture.
2. Check for active or previously active faults indicating high soot load in DPF. Any of SPN 3719 FMI 0,15,16, SPN 3936 FMI 0, or SPN 3251 FMI 0 faults indicate high soot load in DPF.
3. Check for active or previously active SPN 5298 FMI 2 referring to reduced DOC efficiency fault.
4. Perform Onboard Filter Cleanliness test using EST. If test result confirms reduced DOC efficiency, service or replace DOC.
5. Check for active or previously active fault codes referring to injector leakage.

SPN 5298/FMI 2 – Reduced DOC efficiency - engine de-rate

SPN 5298/FMI 2 sets when ability of DOC to convert hydrocarbon into heat reduces to a level that it cannot carry on normal regeneration process effectively. This also de-rates the engine.

Pin-point AFT System Fault

1. Inspect exhaust system for leaks or damage.
2. Inspect DPFDP, DPFIT, DPFOT, and DOCIT sensors for damage, loose connection, and sensor/harness rupture.
3. Check for active DTC that can prevent the AFT system from regenerating.
4. Perform Onboard Filter Cleanliness test using EST.
5. If DTC sets after Onboard Filter Cleanliness test. Remove the DOC and service it.

SPN 5319/FMI 31 – DPF Ash load at maximum limit (Remove DPF for cleaning)

DTC sets if AFT system monitors indicate that DPF still needs a Regen, after completing one.

Pin-point AFT System Fault

1. Turn ignition switch to ON, engine OFF. Check for Biased DPFDP sensor. See “Appendix A: Performance Specifications” (page 425).
 - If DPFDP sensor is not within specification, see DPFDP Sensor (page 201) in this section.
2. Remove DPF for ash cleaning.

AFT System Operation

When driving at high speeds or with heavy loads, the exhaust is hot enough to convert the soot to ash.

When driving at lower speeds or lighter loads, the exhaust is typically not hot enough to convert the soot to ash. In these situations, the engine control system

increases the exhaust temperature and the particulate matter can be converted to ash.

Automatic regeneration occurs when driving. The operator is not required to do anything to start regeneration.

An automatic regeneration is not possible during frequent stops or low operating speeds. If a regeneration is required in these conditions, do a manual parked regeneration.

Active Rolling Regeneration

When the ECM determines the DPF needs to be regenerated, the AFT lamp illuminates. The ECM controls the engine operation to increase exhaust temperature. This enables the DPF to convert accumulated particulate matter to ash.

The following entry conditions are required for active rolling regeneration:

- No disabling DTC (SPN 3936/FMI 0, SPN 3936/FMI 16, SPN 3251/FMI 0,)
 - Engine Coolant Temperature (ECT) above 55 °C (131 °F)
 - No engine warning, protection DTC active
-

Manual Parked Regeneration



WARNING: To prevent personal injury or death, keep clear of exhaust system components while running the Diesel Oxidation Catalyst (DOC) Cleaning Procedure. The temperature of some of the exhaust system components may rise to 816 °C (1,500 °F) while running the procedure. You should take extreme caution while working on or around exhaust system components after testing has been completed.

Manual parked regeneration occurs when the operator requests the control system to do a stationary regeneration. Exhaust temperature is increased and particulate matter is converted to ash.

The following entry conditions are required for manual parked regeneration:

- DPF lamp ON, signaling need to regenerate
 - No disabling DTC (SPN 3251/FMI 0, SPN 3936/FMI 0, SPN 3936/FMI 16)
 - ECT above 55 °C (131 °F)
 - Engine running
 - Vehicle speed below 1 mph
 - Parking brake must be set
 - Brake pedal not pressed
 - Accelerator pedal not pressed
 - PTO not active
 - Driveline disengaged or vehicle in park or neutral position
 - Turn inhibit regeneration switch to OFF and parked regeneration switch in ON position
 - Fuel temperature below 200 °C (392 °F)
-

Manual Parked Regeneration Procedure

 **WARNING:** To prevent personal injury or death, make certain the vehicle is safely off the roadway, away from people and flammable materials or structures. The regeneration process creates an elevated exhaust temperature.

It is necessary to do a manual parked regeneration when the exhaust filter indication (level 1) is on or the engine will lose power and shut down.

To start manual parked regeneration (cleaning) of exhaust DPF, do the following steps:

1. Park the vehicle safely off the road and away from flammable materials and vapors.
2. Before starting regeneration (using PARKED REGEN switch), the following conditions must be in place:
 - Parking brake must be set
 - Transmission must be in neutral or park
 - Coolant temperature must be minimum 55 °C (131 °F)
 - Accelerator, foot brake, or clutch pedal (if equipped) must not be pressed
 - Inhibit regeneration switch (if equipped), must be turned off
3. Press the ON position of the PARKED REGEN switch to initiate the regeneration cycle.

The engine speed automatically ramps up to a preset rpm. The switch indicator illuminates when the cycle has started. If the indicator is blinking, verify all conditions in step 2 are met. If the indicator cycle switch continues blinking, cycle the switch.

The regeneration cycle lasts approximately 30 minutes.

4. When the regeneration cycle is complete, the indicator switch turns off. The engine rpm returns to normal idle and all exhaust filter indicators turn off. The vehicle is now ready for normal driving operation.
-

Diesel Oxidation Catalyst (DOC)

The DOC converts fuel to heat for DPF regeneration.

Diesel Particulate Filter (DPF)

The DPF filters and stores particulate matter (soot) and ash (noncombustibles) from leaving the tailpipe.

Regeneration

Regeneration is the process of converting particulate matter trapped in the DPF to ash.

Passive Rolling Regeneration

Passive rolling regeneration occurs when the engine provides sufficient temperature through the exhaust gases to convert the particulate matter to ash.

Parked Regeneration Switch

The parked regeneration switch enables the operator to request a stationary regeneration for the DPF.

Inhibit Regeneration Switch (optional)

The inhibit regeneration switch enables the operator to cancel and prevent a DPF regeneration.

DPF Soot Loading Percentage

ECM calculation of the soot level in DPF.

DPF Ash Loading Percentage

ECM calculation of the ash level in DPF.

DPF Status Lamp

The DPF Status Lamp provides information on the need to regenerate the DPF. There are several DPF loading status levels. The lamp changes states from OFF, to solid ON, to flashing. The lamp is used in combination with the alarm sound.

High Exhaust System Temperature (HEST) Indicator

The HEST indicator alerts the operator when the exhaust temperature is elevated above 400 °C (752 °F). This may or may not be due to DPF regeneration.

Onboard Filter Cleanliness Test (ServiceMaxx™ software)

This test checks the status of the DPF if the soot level is within a Regen Needed limit. The test will automatically start a Parked Regen.

NOTE: The KOER Standard Test must be run before performing this test.

Engine speed is ramped up to increase exhaust flow through the DPF while the DPFDPS sensor monitors the pressure difference across the DPF. The test runs for about 30 minutes.

The following conditions are required for an Onboard Filter Cleanliness Test:

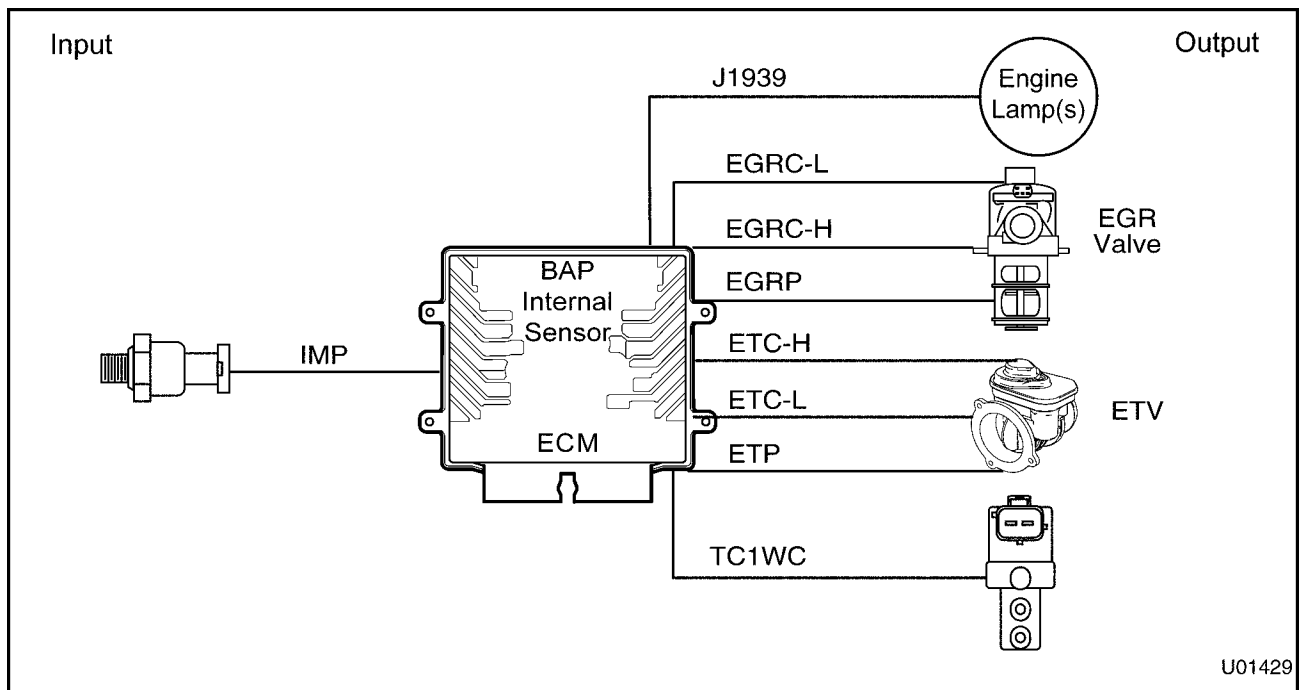
- Engine running for more than 11 seconds
- Engine Coolant Temperature above 65 °C (149 °F)
- Vehicle stationary
- Inhibit DTCs must not be active: Refer to Fault Code Inhibitors
- PTO not active (switch must be off)
- Regen inhibit switch not active (switch must be off)
- Parking brake must be applied
- Soot load under 120%
- Brake pedal not depressed
- Accelerator pedal not depressed
- Driveline disengaged

NOTE: Test abort flag will display if one of the above conditions is not met.

- If the soot level is within normal range and the test completes and displays "Test Completed Successful", no further action is required.
 - If the soot level is above the threshold, the engine will abort the test and ServiceMaxx™ software will display a "Soot Load out of Range" return code.
-

AMS (Air Management System)

SPN	FMI	Condition
1209	0	EBP above desired level
1692	0	Boost High/above desired level detected
1692	17	KOER STD - Boost unable to achieve desired set-point
1692	18	Boost unable to achieve desired set-point
2659	17	EGR Flow Rate unable to achieve desired set-point
2659	20	EGR High Flow Rate detected
2659	21	EGR Low Flow Rate detected

**Figure 75 Function diagram for AMS**

The Air Management System (AMS) includes the following:

- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Intake Manifold Pressure (IMP) sensor
- Turbocharger 1 Wastegate Control (TC1WC) actuator
- Exhaust Gas Recirculation (EGR) actuator
- Engine Throttle Valve (ETV)
- Engine Lamp(s)

Function

The Air Management System (AMS) controls the intake air flow and pressure. The EGR recirculates exhaust gases into the intake stream for cooler combustion which reduces the formation of NOx gases. The TC1WC is used to control the turbocharger waste gate, which increases boost pressures for increased performance or relieves

excessive exhaust backpressures. The dual stage turbocharger provides faster turbo response and quicker acceleration with less lag.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
 - NAVCoM or NAVLink Interface Kit
-

AMS Diagnostics

SPN	FMI	Condition	Possible Causes
1209	0	EBP above desired level	• CAC system leaks (hoses and cooler) • Restricted exhaust system • TC1WC not working • MAF sensor
1692	0	Boost High/above desired level detected	• Restricted exhaust system • TC1WC not working • MAF sensor
1692	17	KOER STD - Boost unable to achieve desired set-point	• CAC system leaks (hoses and cooler) • Exhaust or intake air system leaks • Restricted exhaust system • TC1WC not working
1692	18	Boost unable to achieve desired set-point	• CAC system leaks (hoses and cooler) • Exhaust or intake air system leaks • Restricted exhaust system • TC1WC not working
2659	17	EGR Flow Rate unable to achieve desired set-point	• Restricted air flow (intake or exhaust) CAC system leaks (Hoses and cooler) • Biased Engine Throttle Position (ETP) sensor, EGRP sensor, IMP sensor, or MAF sensor • EGR valve sticking or stuck
2659	20	EGR High Flow Rate detected	• Restricted air flow (intake or exhaust) • Charge Air Cooler (CAC) system leaks (hoses and cooler) • Biased ETP sensor, EGRP sensor, IMP sensor, or MAF sensor • EGR valve sticking or stuck
2659	21	EGR Low Flow Rate detected	• Restricted air flow (intake or exhaust) • Restricted EGR cooler • Biased ETP Sensor, EGRP Sensor, IMP Sensor, or MAF Sensor • EGR valve sticking or stuck

SPN 1209 and FMI 0 - EBP above desired level**Pin-point AMS Fault**

1. Check for other active or inactive IMP, EGRP, ETP, MAF, or EGR Control (EGRC) signal DTC. Repair any fault before continuing with this procedure.
 2. Check for biased sensors. Verify if the IMP, EGRP, ETP, and MAF are within the Key ON, Engine OFF (KOEO) specifications. See KOEO for the applicable engine horsepower in "Appendix A: Performance Specifications" (page 425).
 3. Check TC1WC operation. See KOEO for the applicable engine horsepower in "Appendix A: Performance Specifications" (page 425).
 4. Check for restricted exhaust. See Full Load Rated Speed for the applicable engine horsepower in "Appendix A: Performance Specifications" (page 425).
-

SPN 1692 and FMI 0 - Boost high/above desired level detected**Pin-point AMS Fault**

1. Check for other active or inactive IMP, EGRP, ETP, MAF, or EGRC signal DTC. Repair any fault before continuing with this procedure.
 2. Check for the biased sensors. Verify if the IMP, EGRP, ETP and MAF are within the KOEO specifications. See KOEO for the applicable engine horsepower in "Appendix A: Performance Specifications" (page 425).
 3. Check EGR Valve Operation. Monitor EGRC signal. Run KOEO Output State Low and High. See EGR Valve (page 238) in this section.
 4. Check TC1WC Operation. See KOEO for the applicable engine horsepower in "Appendix A: Performance Specifications" (page 425).
 5. Check for restricted exhaust. See Full Load Rated Speed for the applicable engine horsepower in "Appendix A: Performance Specifications" (page 425).
-

SPN 1692 and FMI 17 - KOER STD - Boost unable to achieve desired set-point Pin-Point AMS Fault**Pin-point AMS Fault**

1. Check for other active or inactive IMP, EGRP, ETP, MAF, or EGRC signal DTC. Repair any fault before continuing with this procedure.
 2. Check for biased sensors. Verify if the IMP, EGRP, ETP, and MAF are within the KOEO specifications. See KOEO for the applicable engine horsepower in "Appendix A: Performance Specifications" (page 425).
 3. Check TC1WC Operation. See KOEO for the applicable engine horsepower in "Appendix A: Performance Specifications" (page 425). Run KOEO Output State Low and High. See TC1WC Solenoid (page 349) in this section.
 4. Check for restricted exhaust. See Full Load Rated Speed for the applicable engine horsepower in "Appendix A: Performance Specifications" (page 425).
-

SPN 1692 and FMI 18 - Boost unable to achieve desired set-point**Pin-point AMS Fault**

1. Check for other active or inactive IMP, EGR, ETP, MAF, or EGRC signal DTC. Repair any fault before continuing with this procedure.
 2. Check for biased sensors. Verify if the IMP, EGRP, ETP, MAF are within the KOEO specifications. See KOEO for the applicable engine horsepower in "Appendix A: Performance Specifications" (page 425).
 3. Check TC1WC Operation. See KOEO for the applicable engine horsepower in "Appendix A: Performance Specifications" (page 425). Run KOEO Output State Low and High. See TC1WC Solenoid (page 349) in this section.
 4. Check for restricted exhaust. See Full Load Rated Speed for the applicable engine horsepower in "Appendix A: Performance Specifications" (page 425).
-

SPN 2659 and FMI 17 -EGR Flow Rate unable to achieve desired set-point**Pin-point AMS Fault**

1. Check for other active or inactive IMP, EGRP, ETP, MAF, or EGRC signal DTC. Repair any fault before continuing with this procedure.
 2. Check for the biased sensors. Verify if the IMP, EGRP, ETP, and MAF are within the KOEO specifications. See KOEO for the applicable engine horsepower in "Appendix A: Performance Specifications" (page 425).
 3. Check EGRC Operation. Monitor EGRC signal. Run KOEO Output State Low and High. See EGR Valve (page 238) in this section.
 4. Check intake and exhaust system for leaks.
-

SPN 2659 and FMI 20 - EGR high flow rate detected

Estimated EGR percent is greater than the maximum limit for the operating conditions.

Pin-point AMS Fault

1. Check for other active or inactive IMP, TC1WC, or EGR DTC. Repair any electrical fault before continuing with this procedure.
 2. Check for biased sensor. Verify BAP and IMP are within KOEO specification. See KOEO for the applicable engine horsepower in the "Appendix A: Performance Specifications" (page 425).
 3. Check EGR operation. Monitor EGRP signal and run KOEO Output State test HIGH and LOW. See EGR Valve (page 238) in this section.
-

SPN 2659 and FMI 21 - EGR low flow rate detected

Estimated EGR percent is less than the minimum limit for the operating conditions.

Pin-point AMS Fault

1. Check for other active or inactive IMP, TC1WC, or EGR DTC. Repair any electrical fault before continuing with this procedure.
 2. Check for biased sensor. Verify BAP and IMP are within KOEO Specification. See KOEO for the applicable engine horsepower in the "Appendix A: Performance Specifications" (page 425).
 3. Check for restricted EGR cooler. See EGR Cooler Inspection (page 69) in the "Engine Symptoms Diagnostics" section of this manual.
 4. Check EGR operation. Monitor EGRP signal and run KOEO Output State test HIGH and LOW. See EGR Valve (page 238) in this section.
 5. Check for restricted exhaust. See Full Load Rated Speed for the applicable engine horsepower in the "Appendix A: Performance Specifications" (page 425).
-

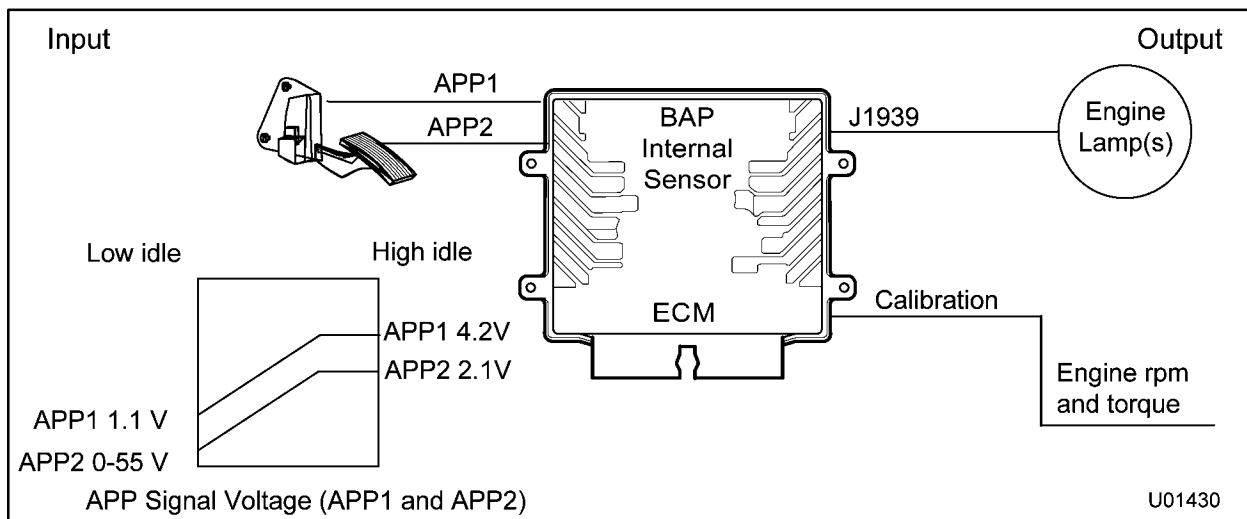
AMS Operation

The AMS test checks the operation of the EGR, ETV, and TC1WC by actuating each component OPEN and CLOSE while monitoring the effect it has on maintaining a stable engine operation.

The ECM monitors the BAP sensor as a baseline for zeroing the IMP signals.

APP Sensor (Accelerator Pedal Position)

SPN	FMI	Condition
91	2	APP1 and APP2 signal conflict
91	3	APP1 signal Out of Range HIGH
91	4	APP1 signal Out of Range LOW
91	7	APP1 and IVS signal conflict
2623	3	APP2 signal Out of Range HIGH
2623	4	APP2 signal Out of Range LOW

**Figure 76** Function diagram for the APP sensor

The APP sensor function diagram includes the following:

- Accelerator Pedal Position (APP) sensor
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Engine Lamp(s)

Function

The APP sensor is controlled by the operator. The ECM uses APP input to control engine acceleration based on the operator's demand for power.

Sensor Location

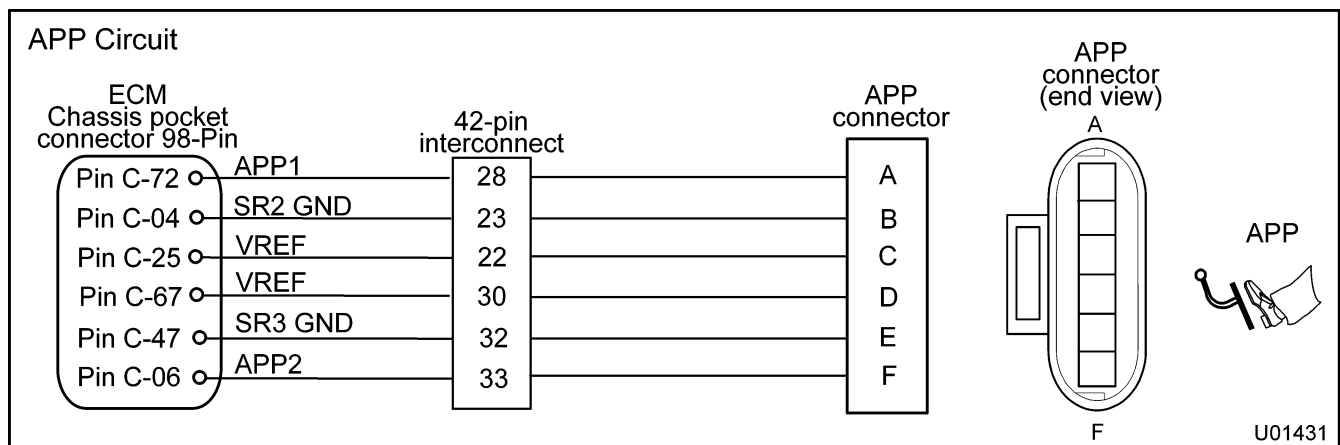
The APP sensor is installed in the vehicle cab on the accelerator pedal.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 1180–N4–0X0 – 180-Pin Breakout Box
- 3-Banana Plug Harness ZTSE4498
- Breakout Harness ZTSE4485A (APP)
- International® Electronic Engine Terminal Test Kit ZTSE4435C

APP Sensor End Diagnostics

SPN	FMI	Condition	Possible Causes
91	2	APP1 and APP2 signal conflict	- APP1 and APP2 mismatched - Biased sensor or circuit
91	3	APP1 signal Out of Range HIGH	- APP1 signal shorted to Power (PWR) - Signal Ground (SIG GND) circuit OPEN - Failed sensor
91	4	APP1 signal Out of Range LOW	- APP1 signal circuit OPEN or short to Ground (GND) - Reference Voltage (VREF) circuit OPEN or short to GND - Failed sensor
91	7	APP1 and IVS signal conflict	- APP1 and IVS mismatched - Biased sensor or circuit
2623	3	APP2 signal Out of Range HIGH	- APP2 signal circuit OPEN or short to PWR - SIG GND circuit OPEN - Failed sensor
2623	4	APP2 signal Out of Range LOW	- APP2 signal circuit OPEN or short to GND - VREF circuit OPEN or short to GND - Failed sensor

**Figure 77 APP sensor circuit diagram**

 **WARNING:** To prevent personal injury or death, stay clear of rotating parts (belts and fan) and hot engine surfaces.

1. Using Electronic Service Tool (EST) with ServiceMaxx™ software, open the Continuous Monitor session.
2. Verify sensor voltage is within KOEO specification. See “Appendix A: Performance Specifications” (page 425).
3. Monitor sensor voltage. Verify an active Diagnostic Trouble Code (DTC) for the sensor.
 - If DTC is inactive, monitor the signal while wiggling the connector and all wires at suspected location. If the circuit is interrupted, the signal will spike and the DTC will go active.
 - If DTC is active, proceed to the next step.
4. Disconnect engine harness from sensor.

NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.
5. Connect Breakout Harness ZTSE4485A to engine harness. Leave sensor disconnected.

Sensor Circuit Check

Connect Breakout Harness ZTSE4485A to engine harness. Leave sensor disconnected. Turn the ignition switch to ON. Use Electronic Service Tool (EST) with ServiceMaxx™ software to verify correct DTC goes active when corresponding fault is induced. Use DMM to measure circuits.

Test Point	Spec	Comments
EST - Check DTC Short breakout harness across A and C	SPN 91 FMI 3	If SPN 91/FMI 4 is active, check APP1 signal for OPEN. Do Harness Resistance Check (page 172).
EST - Check DTC Short breakout harness across F and C	SPN 2623 FMI 3	If SPN 2623/FMI 4 is active, check APP2 signal for OPEN. Do Harness Resistance Check (page 172).
EST - Check DTC	SPN 2623 FMI 3	If SPN 2623/FMI 3 is active, check APP2 signal for short to PWR.
EST - Check DTC	SPN 91 FMI 4	If SPN 91/FMI 3 is active, check APP1 signal for short to PWR.
DMM – Measure volts C to GND	5 V ± 0.5 V	If > 5.5 V, check VREF for short to PWR. If < 4.5 V, check VREF for OPEN or short to GND. Do Harness Resistance Check (page 172).
DMM – Measure resistance B to GND	< 5 Ω	If > 5 Ω, check SIG GND for OPEN. Do Harness Resistance Check (page 172).
DMM – Measure voltage D to GND	5 V ± 0.5 V	If > 5.5 V, check VREF for short to PWR. If < 4.5 V, check VREF for OPEN or short to GND. Do Harness Resistance Check (page 172).
DMM – Measure voltage E to GND	< 5 Ω	If > 5 Ω, check SIG GND for OPEN. Do Harness Resistance Check (page 172).
If checks are within specification, connect sensor, clear DTCs, and cycle the pedal a few times. If active DTC returns, replace sensor.		

APP Pin-point Diagnostics

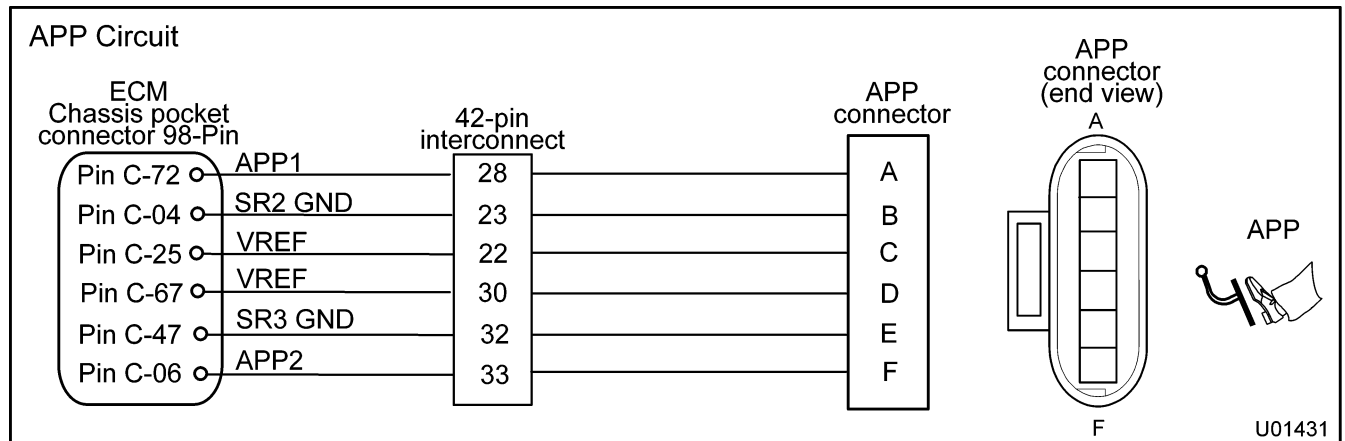


Figure 78 APP sensor circuit diagram

Connector Voltage Check

Connect Breakout Harness ZTSE4485A. Leave sensor disconnected. Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
A to GND	0 V	If > 0.25 V, check for short to PWR.
B to GND	0 V	If > 0.25 V, check for short to PWR.
C to GND	5 V $\pm$ 0.5 V	If > 5.5 V, check VREF for short to PWR. If < 4.5 V, check VREF for OPEN or short to GND. Do Harness Resistance Check (page 172).
D to GND	5 V $\pm$ 0.5 V	If > 5.5 V, check VREF for short to PWR. If < 4.5 V, check VREF for OPEN or short to GND. Do Harness Resistance Check (page 172).
E to GND	0 V	If > 0.25 V, check for short to PWR.
F to GND	0 V	If > 0.25 V, check for short to PWR.

Connector Resistance Check to GND

Turn ignition switch to OFF. Connect Breakout Harness ZTSE4485A. Leave sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
A to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
B to GND	< 5 Ω	If > 5 Ω , check for OPEN circuit.
C to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
D to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
E to GND	< 500 Ω to 600 Ω	If < 500 Ω , check for short to GND.
F to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.

 **WARNING:** To prevent personal injury or death, always disconnect main negative battery cable first. Always connect main negative battery cable last.

Harness Resistance Check

Turn ignition switch to OFF. Disconnect both battery GND cables. Connect 180-Pin Breakout Box and Breakout Harness ZTSE4485A. Leave ECM and sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
A to C-72	< 5 Ω	If > 5 Ω , check APP signal circuit for OPEN.
B to C-04	< 5 Ω	If > 5 Ω , check SIG GND circuit for OPEN.
C to C-25	< 5 Ω	If > 5 Ω , check VREF circuit for OPEN.
D to C-67	< 5 Ω	If > 5 Ω , check VREF circuit for OPEN.
E to C-47	< 5 Ω	If > 5 Ω , check SIG GND circuit for OPEN.
F to C-06	< 5 Ω	If > 5 Ω , check APP2 signal circuit for OPEN.

Operational Voltage Check

Connect 180-Pin Breakout Box and Breakout Harness ZTSE4485A between ECM and sensor. Turn ignition switch to ON. Use DMM to measure voltage and EST to read signal.

Test Point	Condition	DMM	EST Value
APP	Foot off pedal	1.14 V $\pm$ 0.25 V	0%
A to GND or C-72 to GND	Pedal to floor	4.32 V $\pm$ 0.25 V	100%
F to GND or C-06 to GND	Foot off pedal	0.56 V $\pm$ 0.25 V	0%
	Pedal to floor	2.16 V $\pm$ 0.25 V	100%

APP Circuit Operation

The APP sensor is a dual potentiometer sensor that provides dual independent linear output voltages. It operates from +5V power supplied by the ECM. The ECM converts analog voltages APP1 and APP2 into normalized pedal percentage Primary Track and Secondary Track. It also compares the APP1 and APP2 signals for conflict. If a conflict occurs, the ECM sets a DTC. Any malfunction of the APP sensor circuit illuminates the AWL.

Accelerator Pedal Position (APP) sensor

The APP sensor is a potentiometer sensor supplied with a 5-volt reference voltage at Pin C from ECM Pin C-25, and to Pin D from the ECM Pin C-67. The sensor is grounded at Pin B from ECM Pin C-04, and Pin E from ECM Pin C-47. The sensor returns a variable voltage signal from Pin A to ECM Pin C-72, and from Pin F to ECM Pin C-06.

Fault Detection/Management

Normally, Secondary Track APP2 voltage is half of Primary Track APP1 voltage. Pedal operation is based on Primary APP input with Secondary APP2 input. If ECM determines Out of Range fault in the Primary Track, the ECM defaults to Secondary Track with limitation of operation to 50%. Similarly, if the ECM detects Out of Range fault on Secondary Track, the ECM will limit the Primary Track with limitation of operation to 50%. If both tracks fail Out of Range or if the ECM detects an In-range fault (disagreement in the state of APP1 and APP2), the engine will be allowed to operate at low idle only.

NOTE: If multiple APP DTCs are present, verify the APP part number is correct for the specific vehicle model.

NOTE: If elevated low idle rpm is experienced after replacing the pedal assembly or APP sensor, and there are no DTCs present, check pedal assembly or APP sensor part numbers for correctness.

ATA Data Link (American Trucking Association) (SAE J1587)

SPN FMI Condition

None No communication to EGC

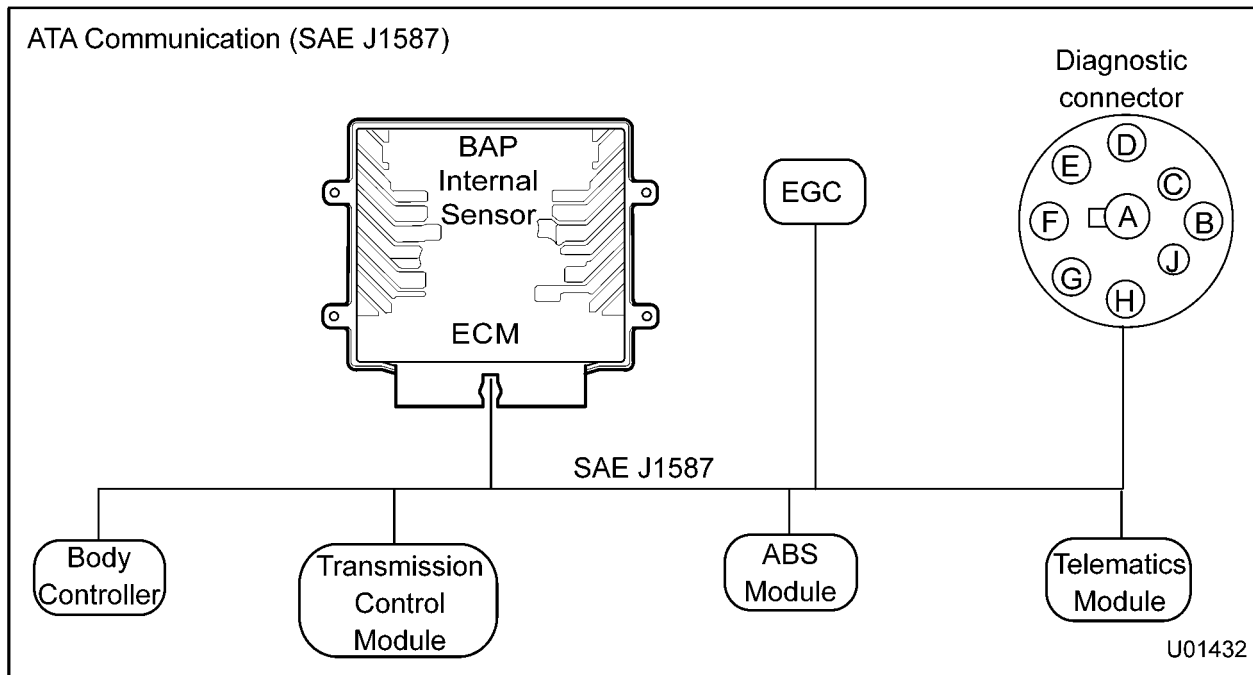


Figure 79 Function diagram for ATA (SAE J1587)

The function diagram for ATA (SAE J1587) includes the following:

- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Electronic Gauge Cluster (EGC)
- Diagnostic Connector
- Body Controller (BC)
- Transmission Control Module
- Antilock Brake System (ABS) Module
- Telematics Module

Function

The ATA (SAE J1587) data link provides communication between the ECM and an ATA (SAE

J1587) compatible EGC module. The Electronic Service Tool (EST) can access this data link at the Diagnostic Connector.

Location

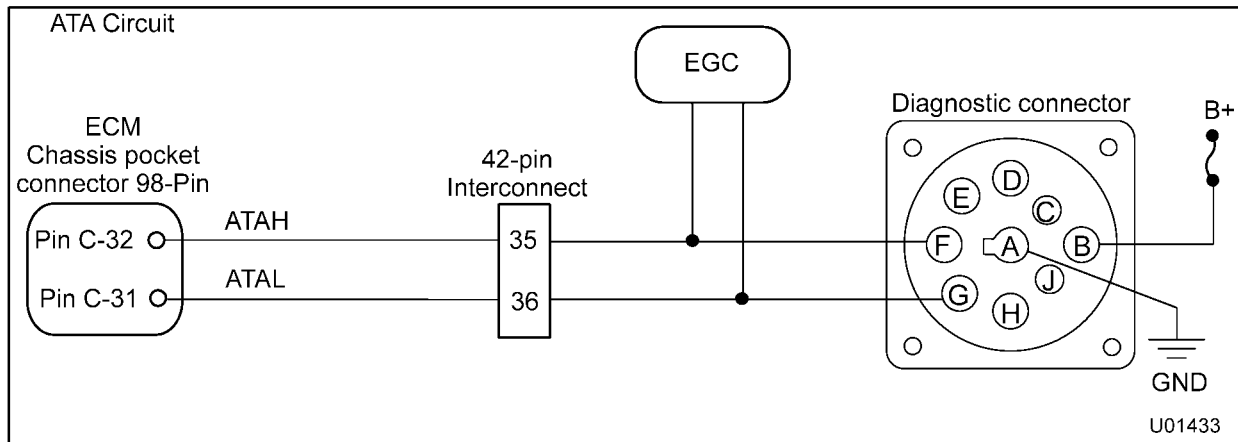
The ATA (SAE J1587) circuits are connected to the ECM, EGC and Diagnostic Connector. The Diagnostic Connector is located under the dash on the driver's side.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- International® Electronic Engine Terminal Test Kit ZTSE4435C

ATA (SAE J1587) Pin-point Diagnostics

SPN	FMI	Condition	Possible Causes
None	None	No communication with EST	- Battery Positive (B+) circuit OPEN or short to GND - GND circuit OPEN - ATA (SAE J1587) circuits OPEN or short to PWR or GND

**Figure 80 ATA (SAE J1587) circuit diagram****Connector Voltage Check - EST**

Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
B to GND	B+	If < B+, check B+ circuit to Diagnostic Connector for OPEN or short to GND or blown fuse.
B to A	B+	If < B+, check GND circuit to Diagnostic Connector for OPEN.
F to GND	1 V to 4 V	The sum of F to GND and G to GND should equal 4 V to 5 V.
G to GND	1 V to 4 V	The sum of G to GND and F to GND should equal 4 V to 5 V.

See *Chassis Electrical Circuit Diagram Manual* and *Electrical System Troubleshooting Guide* for EGC diagnostic information.

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box. Leave ECM disconnected.

Test Point	Spec	Comment
F to C-32	< 5 Ω	If > 5 Ω , check ATAH for OPEN in circuit.
F to GND	> 1 k Ω	If < 1 k Ω , check ATAH for short to GND.
G to C-31	< 5 Ω	If > 5 Ω , check ATAL for OPEN in circuit.
G to GND	> 1 k Ω	If < 1 k Ω , check ATAL for short to GND.
A to GND	< 5 Ω	If > 5 Ω , check GND for OPEN in circuit.

ATA (SAE J1587) Operation**Diagnostic Connector**

The fuse-protected B+ signal is supplied to the Diagnostic Connector through Pin B and ground is through Pin A. American Trucking Association High (ATAH) signal runs from ECM Pin C-32 and Diagnostic Connector Pin F. American Trucking Association Low (ATAL) signal runs from ECM Pin C-31 and Diagnostic Connector Pin G.

Electronic Gauge Cluster (EGC)

There are two types of EGC modules. One uses Controller Area Network CAN (J1939) communication and the other uses ATA (SAE J1587) communication. The following information is sent through data communication:

- Amber Warn Engine Lamp (AWL)
- Red Stop Lamp
- Software identification
- Total idle hours
- Idle fuel
- Vehicle Identification Number (VIN)
- Total miles

- Total fuel used
- Battery voltage
- Estimated fan speed
- Accelerator Pedal Position (APP) percent
- Speedometer
- Tachometer (TACH)
- Change oil message
- Oil pressure gauge
- Engine Coolant Temperature (ECT) gauge

Fault Detection/Management

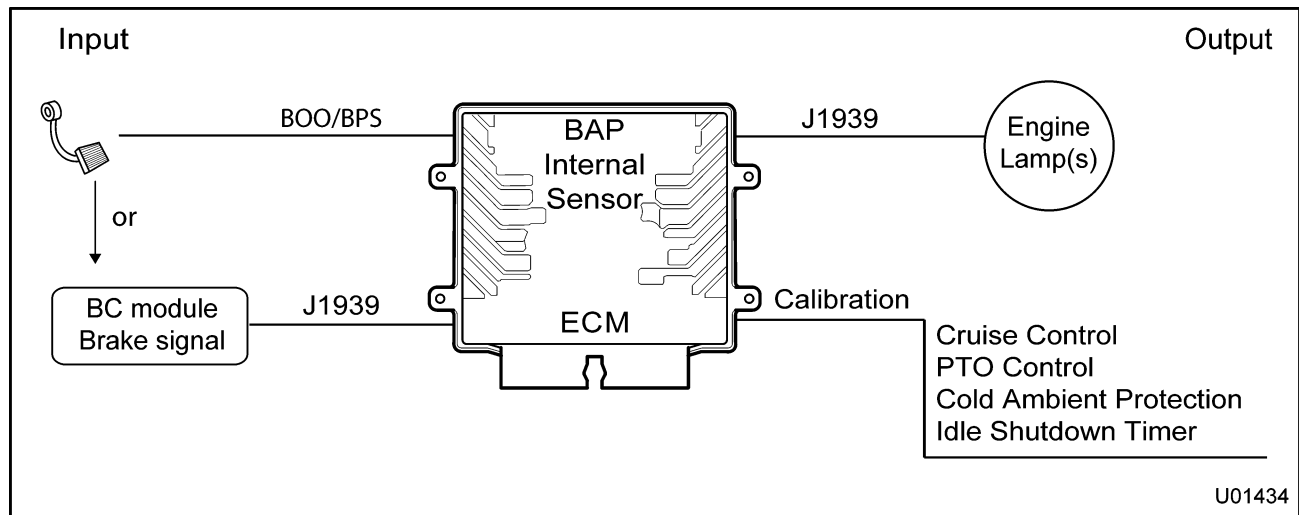
There are no engine DTCs for ATA (SAE J1587) communication faults. See *Chassis Electrical Circuit Diagram Manual* and *Electrical System Troubleshooting Guide*.

Repair Information

The ATA (SAE J1587) circuits use a twisted wire pair. All repairs must maintain one complete twist per inch along the entire length of the circuit. This circuit is polarized, one positive and one negative. Reversing the polarity of this circuit will disrupt communication.

Brake Switch Circuits

SPN	FMI	Condition
597	2	Brake switch circuit fault
597	19	Brake Switch not detected on J1939

**Figure 81 Function diagram for brake switch circuits**

The brake switch circuit function diagram includes the following:

- Brake On/Off (BOO) switch
- Brake Pressure Switch (BPS)
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Body Controller (BC)
- Output - cancels Cruise Control (CCS)
- Output - cancels Power Takeoff (PTO) control
- Output - cancels Cold Ambient Protection (CAP)
- Output - cancels Idle Shutdown Timer (IST)
- Engine Lamp(s)

Function

The brake switch circuit signals the ECM when the brakes are applied. The information is used to

disengage the cruise control and PTO functions. The brake signal interrupts the CAP feature and resets the time interval for the IST feature.

Location

The BOO switch is located on the brake pedal lever. The BPS is located on the brake pressure line.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 1180–N4–0X0 – 180-Pin Breakout Box
- International® Electronic Engine Terminal Test Kit ZTSE4435C
- Digital Multimeter (DMM)

Brake Switch Circuits Pin-point Diagnostics

SPN	FMI	Condition	Possible Causes
597	2	Brake Switch circuit fault	• OPEN in B+ circuit to the switches or blown fuse • BPS circuit OPEN or short to PWR or GND • Failed switch
597	19	Brake Switch not detected on J1939	• See Body Controller in <i>Electrical System Troubleshooting Guide</i>.

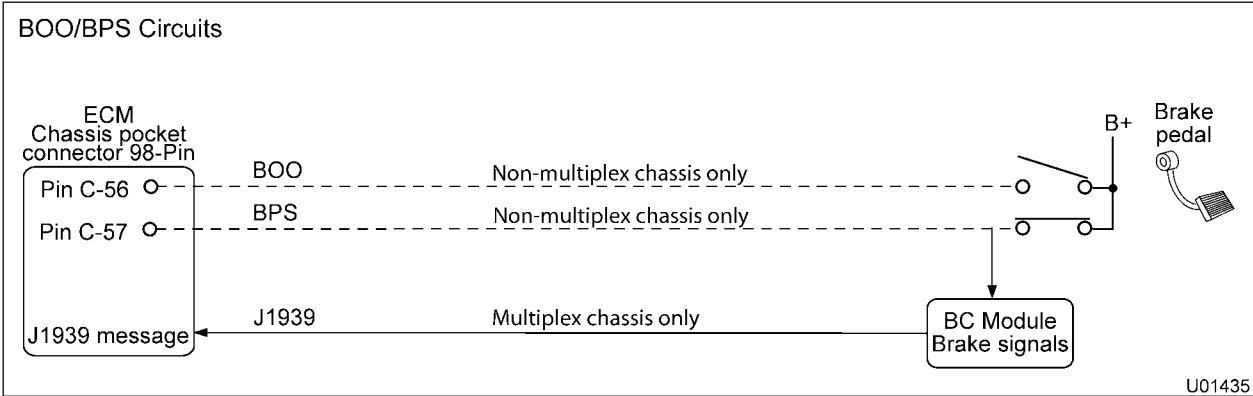


Figure 82 Brake switch circuit diagram

1. Connect EST to the Diagnostic Connector.
2. Turn ignition switch to ON.
 - If SPN 597 FMI 2 is displayed, continue to Brake Switch Circuits check.
 - If SPN 597 FMI 19 is displayed, see Body Controller in *Electrical System Troubleshooting Guide*.

Brake Switch Circuits

Turn the ignition switch to ON. Connect ServiceMaxx™ software. Open Switch session to monitor BOO (BOO only applies to nonmultiplex chassis) and BPS signal's.

Test Point	Spec	Comments
BOO	Normal state = Released	If not within specification, check for blown fuse, open circuit, short to GND, short to PWR, or failed switch.
	Pedal pressed = Applied	
BPS	Normal state = Released	If not within specification, check for blown fuse, open circuit, short to GND, short to PWR, or failed switch.
	Pedal pressed = Applied	
See <i>Chassis Electrical Circuit Diagram Manual</i> and <i>Electrical System Troubleshooting Guide</i> for circuit information. If the brake circuits are hard-wired to the ECM and do not go through the BC module, do Voltage Check (page 180).		

Voltage Check

Disconnect BOO (BOO only applies to nonmultiplex chassis) and BPS switches. Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comments
BOO		
B+ side	B+	If < B+, check for OPEN or short circuit, or blown fuse.
Signal side	0 V	If > 0.5 V, check for short to PWR.
BPS		
B+ side	B+	If < B+, check for OPEN or short circuit, or blown fuse.
Signal side	0 V	If > 0.5 V, check for short to PWR.

Harness Resistance Check

Turn ignition switch to OFF, connect 180-Pin Breakout Box, leave ECM, BOO (BOO only applies to nonmultiplex chassis) and BPS disconnected. Use DMM to measure resistance.

Test Point	Spec	Comments
BOO		
C-56 to switch	< 5 Ω	If > 5 Ω , check for OPEN circuit.
C-56 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
BPS		
C-57 to switch	< 5 Ω	If > 5 Ω , check for OPEN circuit.
C-57 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.

Brake Switch Circuit Operation**Fault Detection/Management**

The ECM continuously monitors the state of the brake switch or switches. If a fault is detected on the brake switch circuit, a Diagnostic Trouble Code (DTC) sets.

On multiplex vehicles, the BPS circuit is wired directly to the BC module, and the state of the switch is communicated to the ECM through the CAN (J1939) network.

CAN Communications (Controller Area Network) (J1939)

SPN	FMI	Condition
639	14	J1939 Data Link Error (ECM unable to transmit)

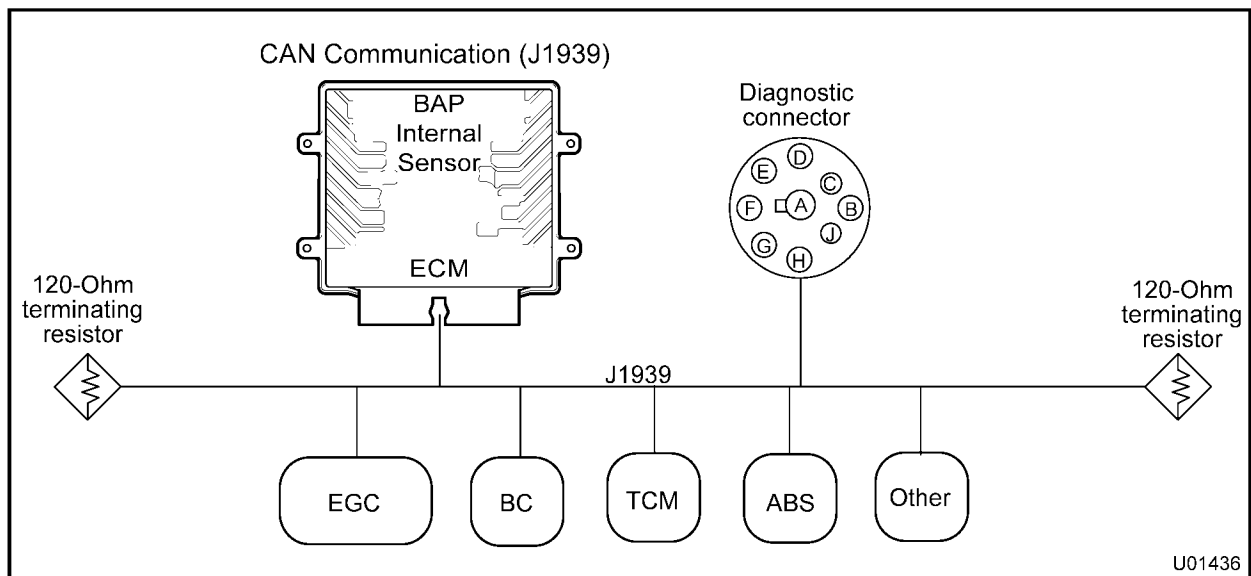


Figure 83 Function diagram for the CAN (J1939)

The CAN (J1939) function diagram includes the following:

- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Transmission Control Module (TCM)
- Body Controller (BC) module
- Antilock Brake System (ABS)
- Electronic Gauge Cluster (EGC)
- Diagnostic Connector
- 120-Ohm terminating resistors
- Other nodes (modules)

Function

The CAN (J1939) network provides a communication link between all connecting modules. The Diagnostic

Connector uses this network system to communicate with the ECM.

Location

The CAN (J1939) circuits run throughout the chassis harness. The Diagnostic Connector is located under the dash on the driver's side.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- International® Electronic Engine Terminal Test Kit ZTSE4435C

CAN (J1939) Pin-point Diagnostics

SPN	FMI	Condition	Possible Causes
None	None	No communication with Electronic Service Tool (EST)	• B+ circuit OPEN or short to GND • GND circuit OPEN • CAN (J1939) circuits OPEN to Diagnostic Connector
639	14	ECM unable to send CAN (J1939) messages	• CAN (J1939) circuit OPEN • CAN-H shorted to GND • CAN-L shorted to VBAT • CAN-H shorted to CAN-L • ECM not powering up or failed module • Failed resistor

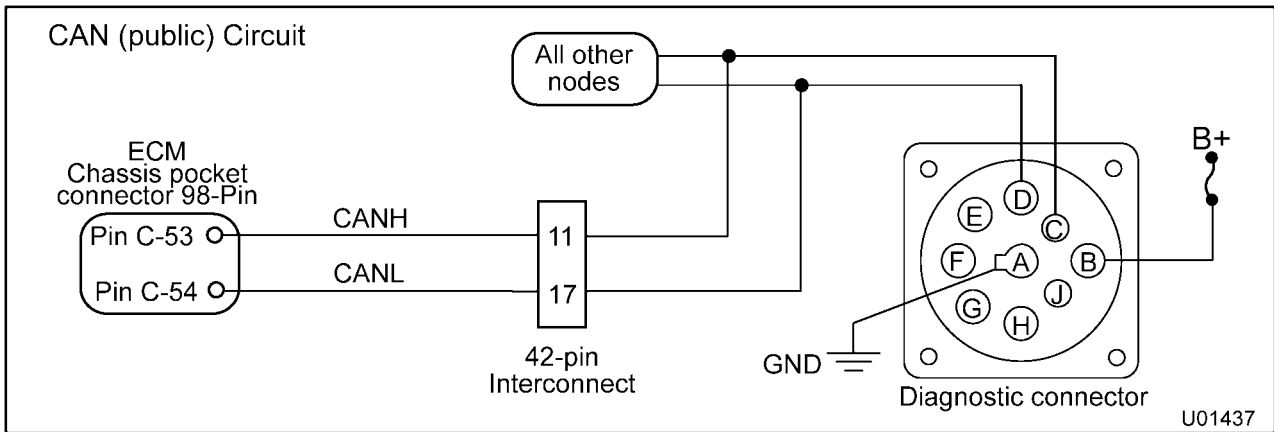


Figure 84 CAN (J1939) communication circuit diagram

Connector Voltage Check

Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
B to GND	B+	If < B+, check B+ circuit to Diagnostic Connector for OPEN or short to GND or blown fuse.
B to A	B+	If < B+, check GND circuit to Diagnostic Connector for OPEN.
C to GND	1 V to 4 V	The sum of C to GND and D to GND should equal 4 V to 5 V.
D to GND	1 V to 4 V	The sum of C to GND and D to GND should equal 4 V to 5 V.

EST Communication Check

Turn ignition switch to ON. Connect EST to Diagnostic Connector. If the EST is unable to communicate with the ECM, disconnect each module individually until communication can be established.

NOTE:

- If communication to ECM is established, check CAN (J1939) circuits to disconnected module for correct wiring. See *Chassis Electrical Circuit Diagram Manual* and *Electrical System Troubleshooting Guide*.
- If communication to ECM is not established, go to next test point.

Test Point	Comment
Disconnect TCM	See above note.
Disconnect ABS	See above note.
Disconnect BC	See above note.
Disconnect EGC	See above note.
Disconnect other nodes	See above note.

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box. Leave ECM disconnected.

Test Point	Spec	Comment
C to D	60 $\Omega \pm 5 \Omega$	If > 65 Ω , check CANH and CANL for faulty resistor or circuit.
C to C-53	< 5 Ω	If > 5 Ω , check CANH for OPEN in circuit.
C to GND	> 1 k Ω	If < 1 k Ω , check CANH for short to GND.
D to C-54	< 5 Ω	If > 5 Ω , check CANL for OPEN in circuit.
D to GND	> 1 k Ω	If < 1 k Ω , check CANL for short to GND.
A to GND	< 5 Ω	If > 5 Ω , check GND for OPEN in circuit.

CAN (J1939) Circuit Operation

Controller Area Network CAN (J1939) is a broadcast serial network standard. The CAN (J1939) network provides a communication link between all connecting modules, sending and receiving digital messages.

The Electronic Service Tool (EST) with ServiceMaxx™ software communicates with the ECM through the Diagnostic Connector. The EST, through the CAN (J1939) network, is able to retrieve Diagnostic Trouble Codes (DTCs), run diagnostic tests, and view signal's from all inputs and outputs of the ECM.

CAN (J1939) supports the following functions:

- Transmission of engine parameter data
- Transmission and clearing of DTCs

- Diagnostics and troubleshooting
- Programming performance parameter values
- Programming engine and vehicle features
- Programming calibrations and strategies in the ECM

CAN (J1939) versus ATA (SAE J1587)

The CAN (J1939) network is set up to communicate with many different modules. The network branches into many different locations with each path ending in a module connection or a 120-ohm terminating resistor. The termination resistors are used to reduce reflections.

The CAN (J1939) system is set up to only communicate between the ECM and specific engine controls.

Diagnostic Connector

The Diagnostic Connector provides an interface for the EST. The Electronic Service Tool (EST) with ServiceMaxx™ software communicates with the joining modules through the CAN (J1939) network for diagnostics and module programming. The Diagnostic Connector is supplied with fused B+ at Pin B and GND at Pin A. CANH runs between ECM Pin C-53 and Diagnostic Connector Pin C. CANL between C-54 and Diagnostic Connector Pin D.

Electronic Gauge Cluster (EGC)

There are two types of EGC modules, one uses CAN (J1939) communications and the other uses ATA (SAE J1587) communications. The following information is sent through data communication:

- Amber Warning Lamp (AWL)
- Coolant Level lamp
- Wait to Start lamp
- Red Stop Lamp (RSL)
- Speedometer
- Tachometer (TACH)
- Odometer/hourmeter
- Change oil message
- Oil pressure gauge
- Engine Oil Temperature (EOT) gauge

- Engine Coolant Temperature (ECT) gauge

Body Controller (BC) or Multiplex System Module (MSM)

Many EGC lamps and driver operated switches are wired to one of these modules, then communicated through CAN (J1939) to the ECM or EGC. Some of these control circuits include the following:

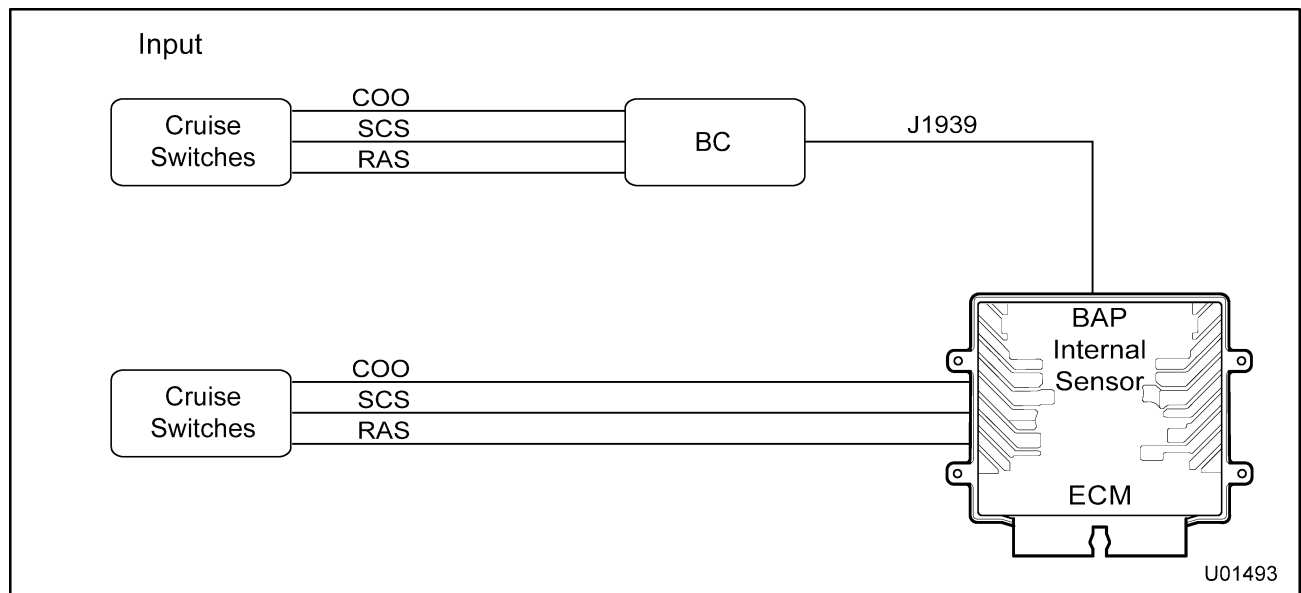
- Wait to Start lamp
- Fuel Pressure lamp
- OWL
- Soot Load lamp
- Cruise control
- Self-test input (cruise switches)
- Driveline Disengagement Switch (DDS)
- Brake pedal (BC only) hardwired to the ECM on vehicles using the MSM
- A/C Demand (ACD)
- Remote Accelerator Pedal
- In-Cab PTO/throttle switch
- AFT regeneration switch

Repair Information

The CAN (J1939) circuits use a twisted wire pair. All repairs must maintain one complete twist per inch along the entire length of the circuit. This circuit is polarized, one positive and one negative. Reversing the polarity of this circuit disrupts communications.

CCS (Cruise Control Switches)

SPN	FMI	Condition
596	2	SCCS switch circuit fault
596	19	Cruise Control Enable Switch not detected on J1939

**Figure 85 Function diagram for cruise control switches**

The Cruise Control System (CCS) function diagram includes the following:

- Cruise On/Off (COO)
- Cruise Set/Coast (SCS)
- Cruise Resume/Accel (RAS)
- Body Controller (BC)
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor

Function

Using the cruise control switches, the operator is able to set, resume, accelerate or coast to any desired vehicle speed within range of the system.

Location

The cruise control switches can be hard wired to the ECM or wired to the BC.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- 1180–N4–0X0 – 180-Pin Breakout Box
- Digital Multimeter (DMM)

Cruise Control Switches Pin-point Diagnostics

SPN	FMI	Condition	Possible Causes
596	2	SCCS switch circuit fault	• COO, SCS, or RAS switch short circuit • COO, SCS, or RAS switch OPEN circuit • COO, SCS, or RAS failed switch
596	19	Cruise Control Enable Switch not detected on J1939	• See Body Controller in <i>Electrical System Troubleshooting Guide</i>.
1. Turn ignition switch to ON. Connect the EST to the Diagnostic Connector. • If SPN 596 FMI 2 is displayed, continue to Switch Checks.			• If SPN 596 FMI 19 is displayed, see Body Controller in <i>Electrical System Troubleshooting Guide</i>.

Switch Checks

Connect the EST to the Diagnostic Connector. Turn ignition switch to ON. Monitor status of test point signals using signals session in ServiceMaxx™ software.

Test Point	Spec	Comments
COO switch	Unlatched = OFF Latched = ON	If not within specification, continue to Circuit End Voltage Check.
SCS switch	Normal state = Released Pressed = ON	If not within specification, continue to Circuit End Voltage Check.
RAS switch	Normal state = OFF Pressed = ON	If not within specification, continue to Circuit End Voltage Check.

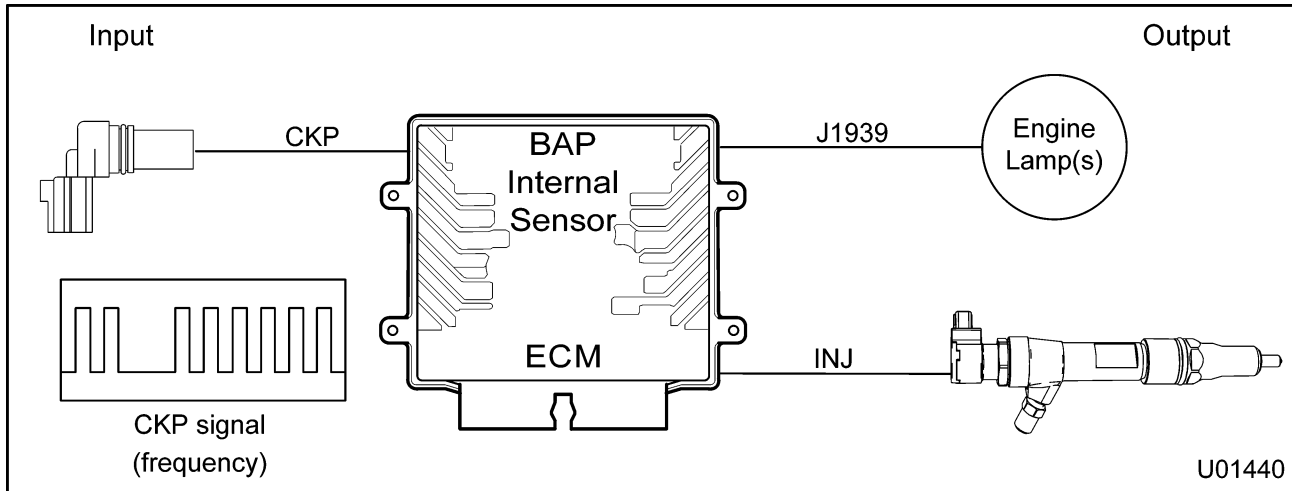
Circuit End Voltage Check

Connect the 180-Pin Breakout Box. Turn ignition switch to ON and COO switch ON. Use DMM to measure voltage.

Test Point	Spec	Comments
C-77 to GND	SCS Normal State = 0 V SCS Pressed = B+	If > 0 V, check for short to PWR circuit. If < B+, check for open or short to GND circuit.
C-75 to GND	RAS Normal State = 0 V RAS Pressed = B+	If > 0 V, check for short to PWR circuit. If < B+, check for open or short to GND circuit.
C-81 to GND	COO Unlatched = 0 V COO Latched = B+	If > 0 V, check for short to PWR circuit. If < B+, check for open or short to GND circuit.

CKP Sensor (Crankshaft Position)

SPN	FMI	Condition
637	8	CKP incorrect signal signature
637	10	CKP signal inactive

**Figure 86 Function diagram for the CKP sensor**

The CKP sensor function diagram includes the following:

- Crankshaft Position (CKP) sensor
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Fuel injectors (INJ)
- Engine Lamp(s)

Function

The CKP sensor provides the ECM with a crankshaft speed and position signals. The ECM uses this signal with the Camshaft Position (CMP) signal to calculate crankshaft speed and position.

Sensor Location

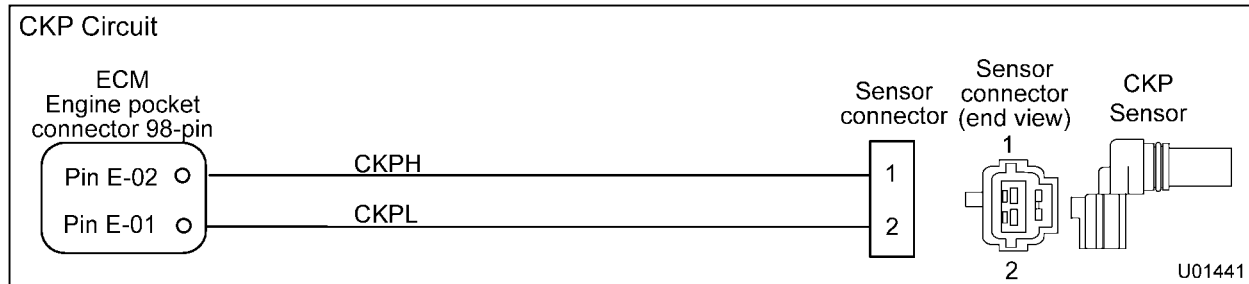
The CKP sensor is installed in the lower front right side of the crankcase.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 1180–N4–0X0 – 180-Pin Breakout Box
- International® Electronic Engine Terminal Test Kit ZTSE4435C

CKP Pin-point Diagnostics

SPN	FMI	Condition	Possible Causes
637	8	CKP incorrect signal signature	• Failed sensor
637	10	CKP signal inactive	• Electrical noise detected on CKP signal

**Figure 87 CKP circuit diagram****Sensor and Circuit Resistance Check**

Turn ignition switch to OFF. Connect 180-Pin Breakout Box. Leave ECM disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
E-02 to E-01	280 Ω to 560 Ω	If < 280 Ω , check for failed sensor. Do Harness Resistance check (page 189).
		If > 560 Ω , check for OPEN circuit or failed sensor. Do Harness Resistance check (page 189).

Harness Resistance Check

Turn ignition switch to OFF. Disconnect harness from sensor. Leave ECM disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
E-01 to 2	< 5 Ω	If > 5 Ω , check for OPEN circuit.
E-01 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
E-02 to 1	< 5 Ω	If > 5 Ω , check for OPEN circuit.
E-02 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.



WARNING: To prevent personal injury or death, stay clear of rotating parts (belts and fan) and hot engine surfaces.

Operational Check

Connect 180-Pin Breakout Box between ECM and sensor. Use DMM set to AC Volts-Hz.

Test Point	Condition	Spec
E-02 to E-01	Engine crank	100 Hz to 250 Hz (100 rpm to 250 rpm)
	Low idle	650 Hz to 750 Hz (650 rpm to 700 rpm)
	High idle	2900 Hz to 3000 Hz (2950 rpm)

CKP Circuit Operation

The CKP sensor contains a permanent magnet that creates a magnetic field. The signal is created when the timing disk rotates and breaks the magnetic field created by the sensor. The ECM Pins for the CKP sensor are CKPL E-01 and CKPH E-02.

As the crankshaft turns, the CKP sensor detects a 60-tooth timing disk on the crankshaft. Tooth 59 and tooth 60 are missing.

The sensor produces pulses for each tooth edge that passes it. Crankshaft speed is derived from the frequency of the CKP sensor signal. The crankshaft position is determined by synchronizing the CMP peg with the CKP gap signals from the respective target disk. From CKP signal frequency, the ECM calculates engine rpm.

Diagnostic information on the CKP input signal is obtained by performing rationality and accuracy checks on duty cycle with software strategies.

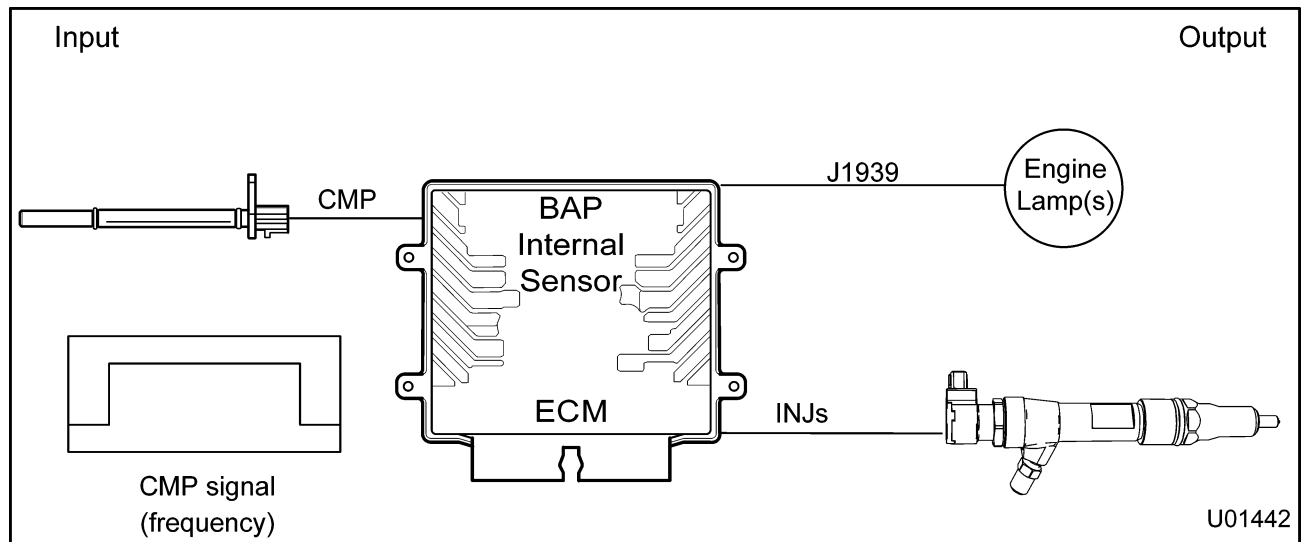
NOTE: The engine will not operate without a CKP signal.

Fault/Detection Management

While the engine is cranking or running, the ECM monitors the CMP signal to verify the engine is rotating. If a CKP fault is detected while engine is cranking, it causes a no start condition. If a fault is detected while the engine is running, it causes a stall condition.

CMP Sensor (Camshaft Position)

SPN	FMI	Condition
636	2	CMP and CKP Synchronization Error
636	7	CMP to CKP incorrect reference

**Figure 88 Function diagram for the CMP sensor**

The CMP sensor function diagram includes the following:

- Camshaft Position (CMP) sensor
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Fuel Injectors (INJ)
- Engine Lamp(s)

Function

The CMP sensor provides the ECM with a camshaft speed and position signal. The ECM uses this signal with the Crankshaft Position (CKP) signal to calculate crankshaft speed and position.

Sensor Location

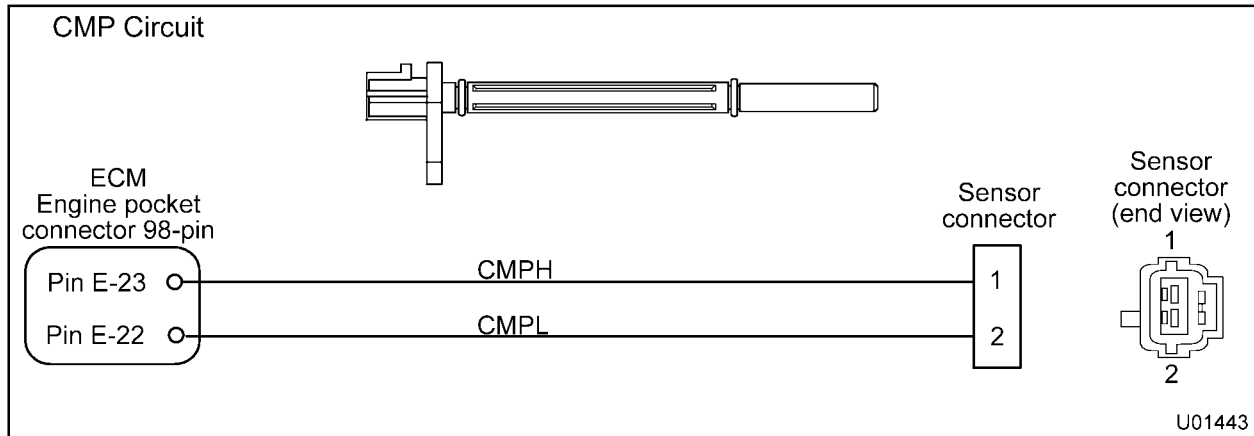
The CMP sensor is installed in the lower front left side of the engine crankcase.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 1180–N4–0X0 – 180-Pin Breakout Box
- International® Electronic Engine Terminal Test Kit ZTSE4435C

CMP Pin-point Diagnostics

SPN	FMI	Condition	Possible Causes
636	2	CMP and CKP Synchronization Error	• OPEN or shorted CMP circuits
636	7	CMP to CKP incorrect reference	• Failed harness

**Figure 89 CMP circuit diagram****Sensor and Circuit Resistance Check**

Turn the ignition switch to OFF. Connect 180-Pin Breakout Box. Leave ECM disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
C-22 to C-23	616 Ω to 1275 Ω	If < 616 Ω , check for failed sensor. Do Harness Resistance Check (page 192). If > 1275 Ω , check for OPEN circuit or failed sensor. Do Harness Resistance Check (page 192).

Harness Resistance Check

Turn ignition switch to OFF. Disconnect harness from sensor. Leave ECM disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
C-22 to 2	< 5 Ω	If > 5 Ω , check for OPEN circuit.
C-22 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
C-23 to 1	< 5 Ω	If > 5 Ω , check for OPEN circuit.
C-23 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.

Operational Check



WARNING: To prevent personal injury or death, stay clear of rotating parts (belts and fan) and hot engine surfaces.

Connect 180-Pin Breakout Box between ECM and sensor. Use DMM set to AC volts - RPM2.

Test Point	Condition	Spec
C-22 to C-23	Engine crank	100 rpm to 250 rpm
	Low idle	650 rpm to 700 rpm
	High idle	3000 rpm

CMP Circuit Operation

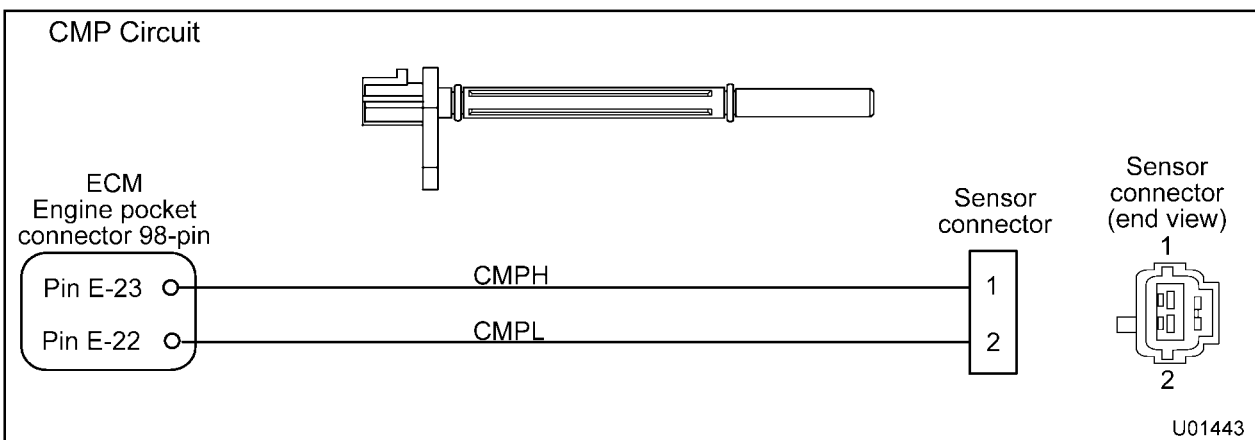


Figure 90 CMP circuit diagram

The CMP sensor provides the ECM with a signal that indicates camshaft speed and position.

The CMP sensor contains a permanent magnet that creates a magnetic field. The signal is created when a peg on the camshaft disk rotates and breaks the magnetic field. This identifies camshaft position. The ECM Pins for the CMP sensor are CMPL E-22 and CMPH E-23.

By comparing the CMP signal with the CKP signal, the ECM calculates engine rpm and timing. Diagnostic information on the CMP input signal is obtained by performing accuracy checks on frequency and duty cycle with software strategies.

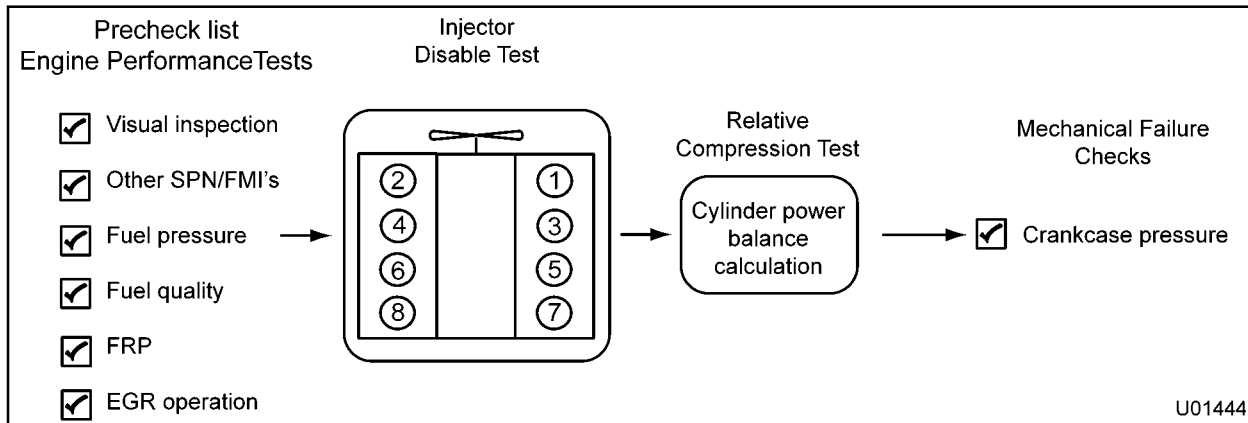
NOTE: The engine will not operate without a CMP signal.

Fault/Detection Management

During engine cranking, the ECM monitors the CMP signal to verify the camshaft is rotating. If the CMP signal is inactive during this time a DTC is set. Electrical noise can also be detected by the ECM. If the level is sufficient to affect engine operation, a corresponding DTC is set. An inactive CMP signal will cause a no-start condition.

Cylinder Balance

SPN	FMI	Condition
1323 – 1330	31	Misfire – Cylinder #
3387 – 3394	20	Cylinder Balance max limit exceeded
3387 – 3394	21	Cylinder Balance below min limit

**Figure 91 Function diagram for cylinder balance****Cylinder Balance Operation**

Power cylinder sealing, valve train condition, and fuel delivery influence torque contributions from each power cylinder. Variations in these factors can cause unevenness in torque and horsepower from one cylinder to the next. Power cylinder unevenness also causes increased engine noise and vibration, especially at low idle.

The ECM uses a Cylinder Balance control strategy to even the power contribution of the cylinders, particularly at low idle. This strategy incorporates information from the crankshaft position system. The ECM uses the instantaneous engine speed

near Top Dead Center (TDC) for each cylinder as an indication of that cylinder's power contribution. The ECM computes a nominal instantaneous engine speed value based on all cylinders. The nominal value would be the expected value from all cylinders if the engine is balanced. By knowing the error quantities, the ECM can add or subtract fuel from a particular cylinder. The control strategy attempts to correct cylinder unbalance by using fuel quantity compensation through adjustments of the pulse width values for each fuel injector. This method of compensation is repeated until all error quantities are close to zero, causing all cylinders to contribute the same amount.

Cylinder Balance Diagnostics

SPN	FMI	Condition	Possible Causes
1323 – 1330	31	Misfire – Cylinder #	• Electrical fault • Low fuel pressure • Fuel quality • Failed injector • Mechanical fault
3387 – 3394	20	Cylinder Balance max limit exceeded	• Electrical fault • Low fuel pressure
3387 – 3394	21	Cylinder Balance below min limit	• Fuel quality • EGR valve stuck open • Fuel system • Failed injector • Base engine compression imbalance • Mechanical fault

The ECM continuously calculates the balance of each cylinder during normal engine operation. If a cylinder is underperforming or overperforming, a cylinder balance Diagnostic Trouble Code (DTC) is set.

Pin-point Cylinder Balance Fault

1. Visually inspect engine for damaged or disconnected components.
 - Check all fluid levels.
 - Check engine and control system for electrical or mechanical damage.
2. Check for other active DTCs that could cause a cylinder imbalance.
 - If injector electrical faults are set, diagnose the electrical fault before diagnosing a cylinder imbalance.
3. Check fuel pressure, fuel aeration, and possible fuel contamination.

Note: These checks can be verified quickly by using the Fuel Pressure Test Gauge with shutoff valve. See Fuel Delivery and Pressure Test (page 103) in the “Hard Start and No Start Diagnostics” section of this manual.

4. Check Fuel Rail Pressure (FRP) and voltage.
 - Check FRP voltage at Key On, Engine Off (KOEO). Run KOEO Standard Test.
See “Appendix A: Performance Specifications” (page 425).
 - Check FRP system pressure during Key On, Engine-Running (KOER). Run KOER Standard Test.
See “Appendix A: Performance Specifications” (page 425).
 5. Inspect the EGR valve. Verify valve is not stuck open.
 - Run KOEO Standard Test
 - Run KOER Air Management Test.
-

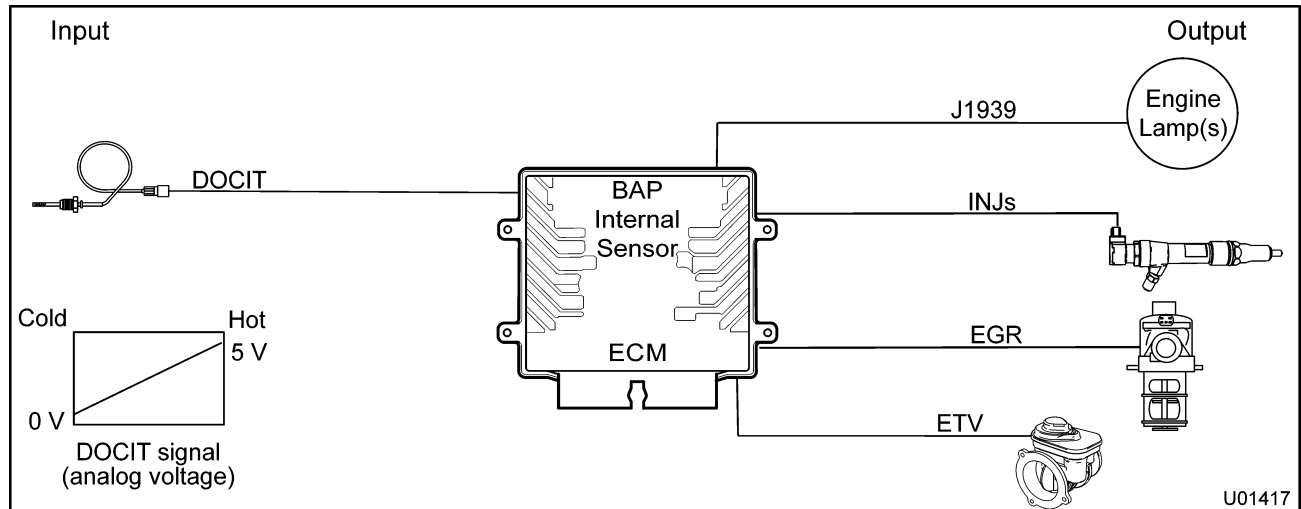
Repair any faults found in any of the preceding checks before continuing.

1. Run KOER Injector Disable Test to identify imbalanced cylinder. See “Performance Diagnostics” (page 113) section.
 2. Do Relative Compression Test to verify if cylinder imbalance is mechanical issue or injector issue. See “Performance Diagnostics” (page 113) section.

If the Relative Compression Test fails the same cylinder as indicated by Injector Disable Test, the fault is a mechanical failure.
 - Check crankcase pressure.
-

DOCIT Sensor (Diesel Oxidation Catalyst Inlet Temperature)

SPN	FMI	Condition
4765	3	DOCIT signal Out of Range HIGH
4765	4	DOCIT signal Out of Range LOW
4765	10	DOCIT signal abnormal rate of change

**Figure 92 Function diagram for the DOCIT sensor**

The DOCIT sensor function diagram includes the following:

- DOC Inlet Temperature (DOCIT) sensor
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Exhaust Gas Recirculation (EGR) valve
- Engine Throttle Valve (ETV)
- Fuel Injectors (INJ)
- Engine Lamp(s)

Function

The DOCIT sensor provides a feedback signal to the ECM indicating DOC inlet temperature. During catalyst regeneration, the ECM monitors this sensor along with DPFIT, DPFOT, DPFD, EGR, and ETV.

Sensor Location

The DOCIT sensor is the first exhaust temperature sensor installed downstream of the turbocharger and just before the DOC.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 3-Banana Plug Harness ZTSE4498
- 1180-N4-0X0 – 180-Pin Breakout Box
- Breakout Harness ZTSE4760A (DOCIT)
- International® Electronic Engine Terminal Test Kit ZTSE4435C

DOCIT Sensor End Diagnostics

SPN	FMI	Condition	Possible Causes
4765	3	DOCIT signal Out of Range HIGH	- DOCIT signal circuit OPEN or short to PWR - SIG GND circuit OPEN - Failed sensor
4765	4	DOCIT signal Out of Range LOW	- DOCIT signal circuit short to GND - Failed sensor
4765	10	DOCIT signal abnormal rate of change	- DOCIT biased sensor or circuit - DOCIT sensor outside of exhaust system

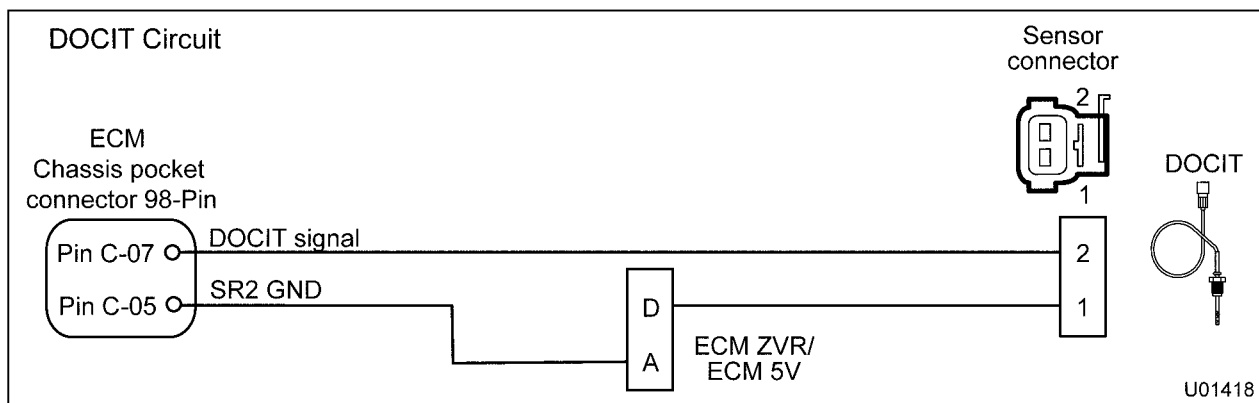


Figure 93 DOCIT circuit diagram

! WARNING: To prevent personal injury or death, be careful to avoid rotating parts (belts and fan) and hot engine surfaces.

- Using ServiceMaxx™ software, open the Aftertreatment session.
- Monitor sensor voltage. Verify an active DTC for the sensor.
 - If DTC is inactive, monitor the signal while wiggling the connector and all wires at suspected location. If the circuit is interrupted, the signal spikes and the DTC goes active.
 - If DTC is active, proceed to the next step.
- Disconnect engine harness from sensor.

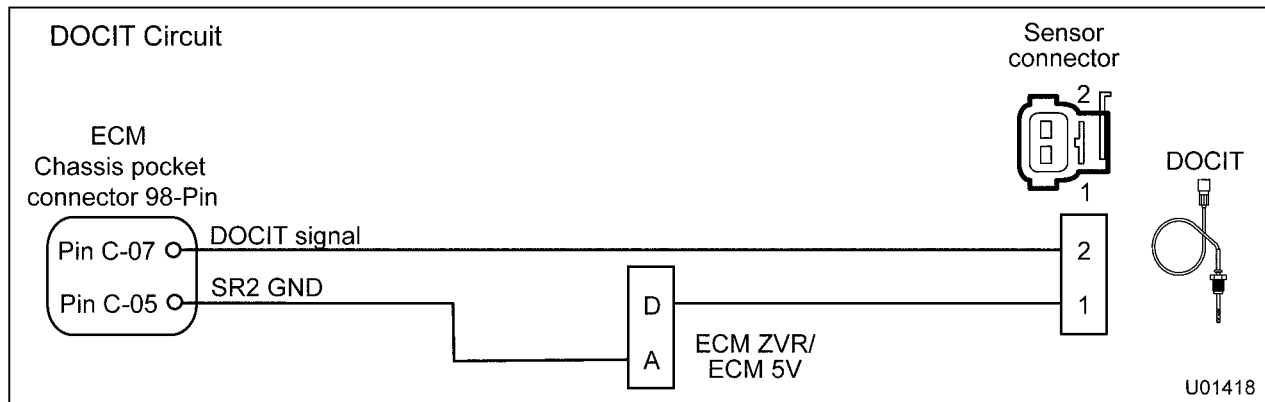
NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

- Connect Breakout Harness ZTSE4760A to engine harness. Leave sensor disconnected.

Sensor Circuit Check

Connect sensor Breakout Harness ZTSE4760A. Leave sensor disconnected. Turn the ignition switch to ON. Use ServiceMaxx™ to verify correct DTC goes active when corresponding fault is induced. Use DMM to measure circuits.

Test Point	Spec	Comments
EST - Check DTC	SPN 4765 FMI 3	If SPN 4765 and FMI 4 is active, check DOCIT signal for short to GND. Do Harness Resistance Check (page 200).
EST - Check DTC Short 3-Banana plug harness across 1 and GND	SPN 4765 FMI 4	If SPN 4765 and FMI 3 is active, check DOCIT signal for OPEN. Do Harness Resistance Check (page 200).
EST - Check DTC Short 3-Banana plug ZTSE4498 harness across 1 and 2	SPN 4765 FMI 4	If SPN 4765 and FMI 3 is active, check SIG GND for OPEN. Do Harness Resistance Check (page 200).
If checks are within specification, connect sensor and clear DTCs. If active DTC remains, replace sensor.		

DOCIT Pin-point Diagnostics**Figure 94 DOCIT circuit diagram****Connector Voltage Check**

Connect Breakout Harness ZTSE4760A. Leave sensor disconnected. Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
1 to GND	0 V	If > 0.25 V, check for short to PWR.
2 to GND	4.6 V to 5 V	If < 4.5 V, check for OPEN or short to GND. Do Harness Resistance Check (page 200).

Connector Resistance Check to GND

Turn ignition switch to OFF. Connect Breakout Harness ZTSE4760A. Leave sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to GND	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box and Breakout Harness ZTSE4760A. Leave ECM and sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to C-05	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to C-07	< 5 Ω	If > 5 Ω , check for OPEN circuit.

DOCIT Circuit Operation

DOCIT is a resistance temperature detector sensor supplied with a 5-volt reference voltage at Pin 2 from ECM Pin C-07. The sensor is grounded at Pin

1 from ECM Pin C-05. As temperature increases, resistance of the sensor increases. This causes the signal voltage to increase.

DPFDP Sensor (Diesel Particulate Filter Differential Pressure)

SPN FMI Condition

3251	3	DPFDP signal Out of Range HIGH
3251	4	DPFDP signal Out of Range LOW
3251	10	DPFDP signal abnormal rate of change

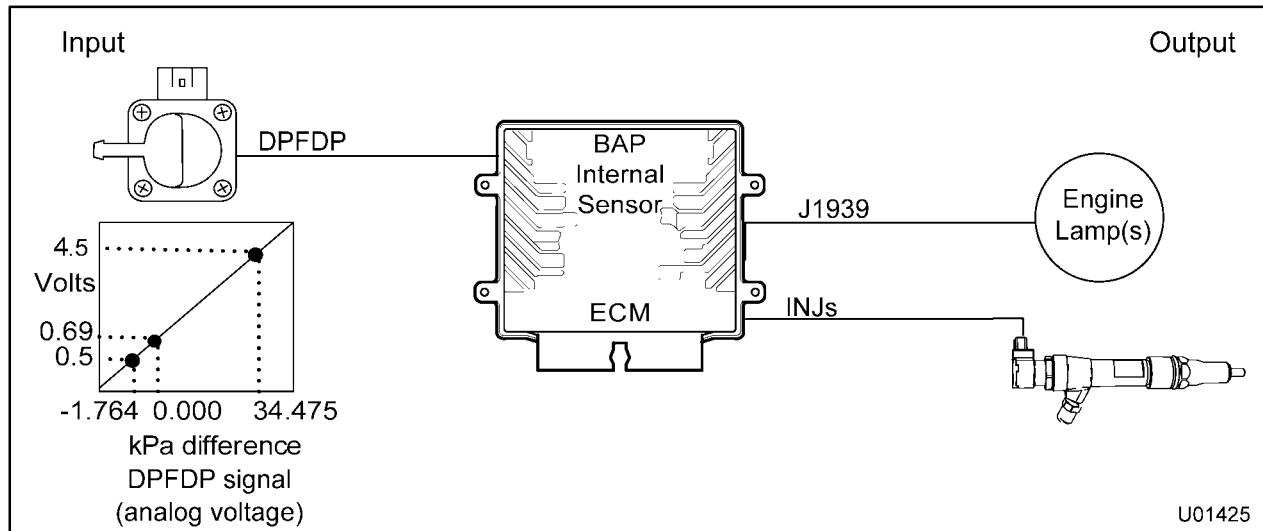


Figure 95 Function diagram for the DPFDP sensor

The DPFDP sensor function diagram includes the following:

- DPF Differential Pressure (DPFDP) sensor
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Fuel injectors (INJ)
- Engine Lamp(s)

Function

The DPFDP sensor provides a feedback signal to the ECM indicating pressure difference between the inlet and outlet of the DPF. Before and during a catalyst regeneration, the ECM monitors this sensor along with DOCIT, DPFIT, DPFOT, and MAF.

Sensor Location

The DPFDP sensor is a differential pressure sensor with two tap-offs installed above the DPF rail. A tap-off is located before and after the DPF.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 3-Banana Plug Harness ZTSE4498
- 1180–N4–0X0 – 180-Pin Breakout Box
- Breakout Harness ZTSE4761A (DPFDP)
- International® Electronic Engine Terminal Test Kit ZTSE4435C

DPFDP Sensor End Diagnostics

SPN	FMI	Condition	Possible Causes
3251	3	DPFDP signal Out of Range HIGH	- DPFDP signal short to power - SIG GND circuit OPEN - Failed sensor
3251	4	DPFDP signal Out of Range LOW	- DPFDP signal OPEN or short to GND - Failed sensor - Damaged or missing DPF
3251	10	DPFDP signal abnormal rate of change	- DPFDP sensor tubes restricted or open - Biased circuit or sensor

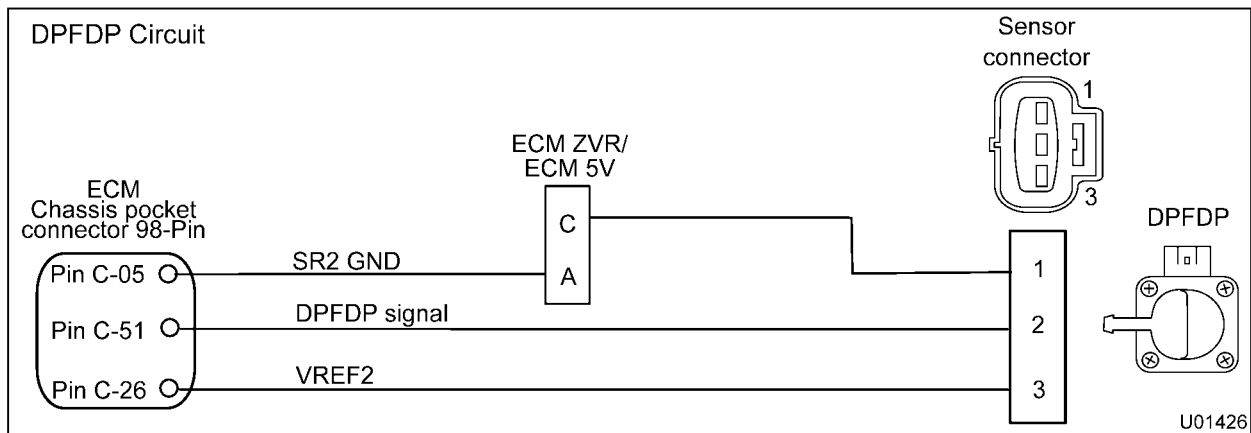


Figure 96 DPFDP circuit diagram

! WARNING: To prevent personal injury or death, be careful to avoid rotating parts (belts and fan) and hot engine surfaces.

1. Inspect DPFDP sensor and tubes for damage or incorrect assembly.
2. Using ServiceMaxx™, open the Aftertreatment session.
3. Verify sensor voltage is within KOEO specification. See "Appendix A: Performance Specifications" (page 425).

4. Monitor sensor voltage. Verify an active Diagnostic Trouble Code (DTC) for the sensor.

- If DTC is inactive, monitor the signal while wiggling the connector and all wires at suspected location. If the circuit is interrupted, the signal spikes and the DTC goes active.
- If DTC is active, proceed to the next step.

5. Disconnect engine harness from sensor.

NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

6. Connect Breakout Harness ZTSE4761A to engine harness. Leave sensor disconnected.

Sensor Circuit Check

Connect sensor Breakout Harness ZTSE4761A. Leave sensor disconnected. Turn the ignition switch to ON. Use EST with ServiceMaxx™ software to verify correct DTC goes active when corresponding fault is induced. Use DMM to measure circuits.

Test Point	Spec	Comments
EST - Check DTC	SPN 3251 FMI 3	If SPN 3251 and FMI 4 is active, check DPFDP signal for short to PWR.
DMM - Measure volts 3 to GND	5 V ± 0.5 V	If > 5.5 V, check VREF for short to PWR. If < 4.5 V, check VREF for OPEN or short to GND. Do Harness Resistance Check (page 204).
EST - Check DTC Short breakout harness across 2 and 3	SPN 3251 FMI 4	If SPN 3251 and FMI 3 is active, check DPFDP signal for OPEN. Do Harness Resistance Check (page 204).
DMM - Measure resistance 1 to GND	< 5 Ω	If > 5 Ω, check SIG GND for OPEN. Do Harness Resistance Check (page 204).
If checks are within specification, connect sensor and clear DTCs. If active DTC remains, replace sensor.		

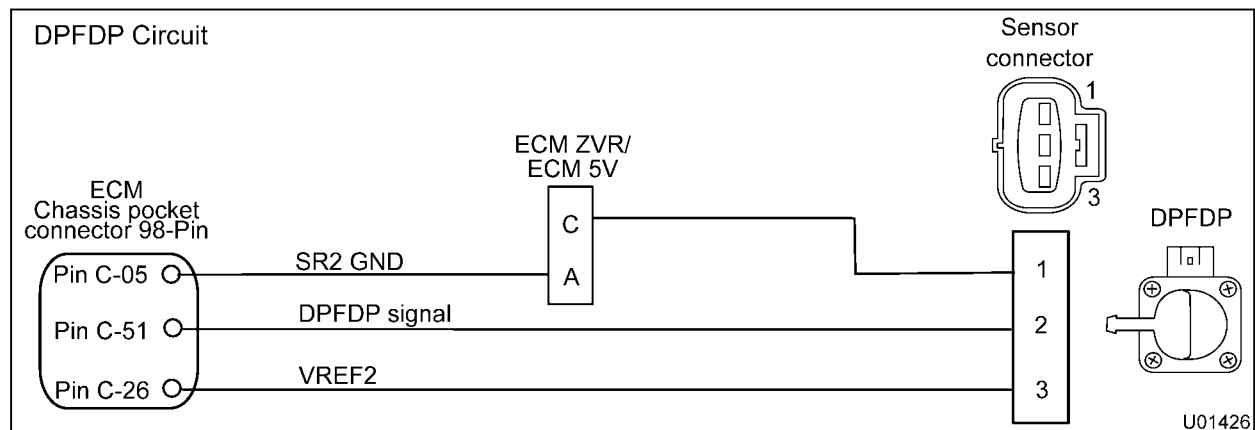
DPFDP Pin-point Diagnostics

Figure 97 DPFDP circuit diagram

Connector Voltage Check

Connect Breakout Harness ZTSE4761A. Leave sensor disconnected. Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
1 to GND	0 V	If > 0.25 V, check for short to PWR.
3 to GND	5 V +/- 0.5 V	If > 5.5 V, check VREF for short to PWR. If < 4.5 V, check VREF for OPEN or short to GND. Do Harness Resistance Check (page 204).
2 to GND	0 V	If > 0.25 V, check for short to PWR. Do Harness Resistance Check (page 204).

Connector Resistance Checks to GND

Turn ignition switch to OFF. Connect Breakout Harness ZTSE4761A. Leave sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to GND	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
3 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box and Breakout Harness ZTSE4761A. Leave ECM and sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to C-05	< 5 Ω	If > 5 Ω , check SIG GND circuit for OPEN.
2 to C-51	< 5 Ω	If > 5 Ω , check DPFDP signal circuit for OPEN.
3 to C-26	< 5 Ω	If > 5 Ω , check VREF circuit for OPEN.

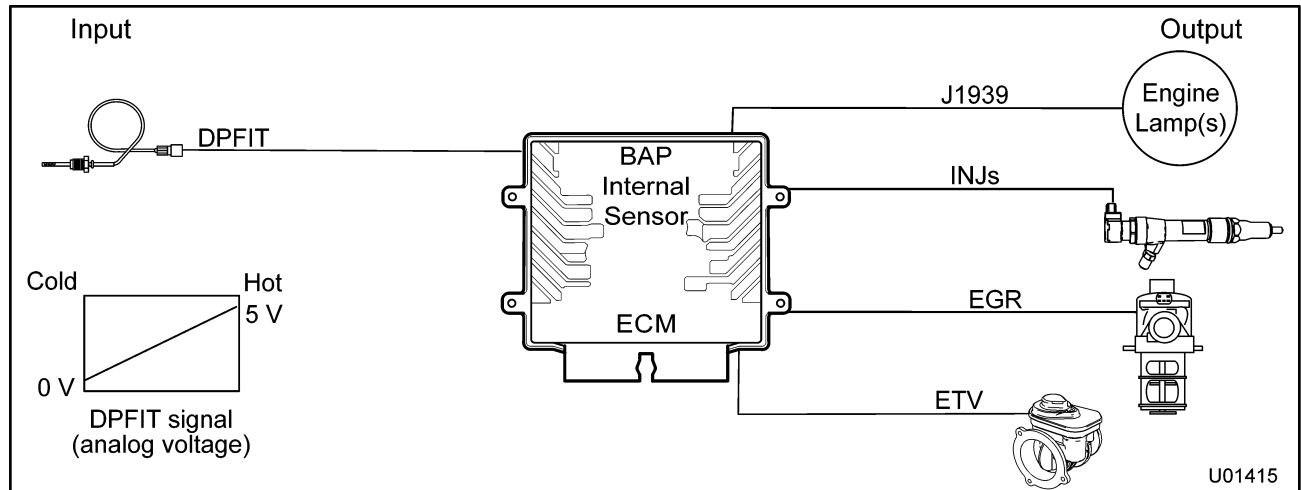
DPFDP Circuit Operation

The DPFDP is a differential pressure sensor supplied with a 5-V reference voltage at Pin 3 from ECM Pin

C-26. The sensor is grounded at Pin 1 from ECM Pin C-05. The sensor returns a variable voltage signal from Pin 2 to ECM Pin C-51.

DPFIT Sensor (Diesel Particulate Filter Inlet Temperature)

SPN	FMI	Condition
3242	3	DPFIT signal Out of Range HIGH
3242	4	DPFIT signal Out of Range LOW
3242	10	DPFIT abnormal rate of change

**Figure 98 Function diagram for the DPFIT sensor**

The DPFIT sensor function diagram includes the following:

- DPF Inlet Temperature (DPFIT) sensor
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Exhaust Gas Recirculation (EGR)
- Engine Throttle Valve (ETV)
- Fuel Injectors (INJ)
- Engine Lamp(s)

Function

The DPFIT sensor provides a feedback signal to the ECM indicating Diesel Particulate Filter (DPF) Inlet Temperature. During a catalyst regeneration, the ECM monitors this sensor along with DOCIT, DPFOT, DPFDP, EGRP, and ETV.

Sensor Location

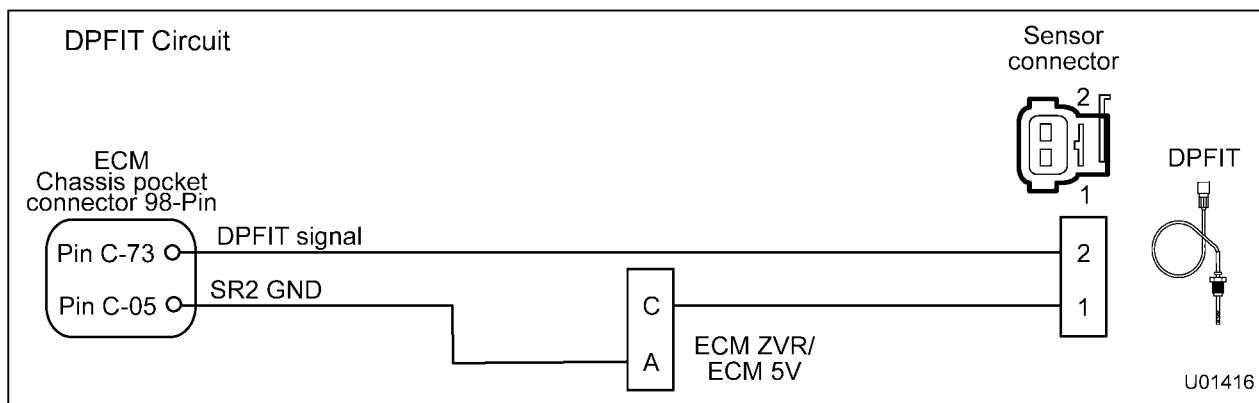
The DPFIT sensor is the second exhaust temperature sensor installed downstream of the turbocharger and is located between the Diesel Oxidation Catalyst (DOC) and the DPF.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 3-Banana Plug Harness ZTSE4498
- 1180–N4–0X0 – 180-Pin Breakout Box
- Breakout Harness ZTSE4760A (DPFIT)
- International® Electronic Engine Terminal Test Kit ZTSE4435C

DPFIT Sensor End Diagnostics

SPN	FMI	Condition	Possible Causes
3242	3	DPFIT signal Out of Range HIGH	• DPFIT signal OPEN or short to PWR • SIG GND circuit OPEN • Failed sensor
3242	4	DPFIT signal Out of Range LOW	• DPFIT signal circuit short to GND • Failed sensor
3242	10	DPFIT abnormal rate of change	• DPFIT biased circuit or sensor • DPFIT sensor outside of exhaust system

**Figure 99 DPFIT circuit diagram**

⚠ WARNING: To prevent personal injury or death, be careful to avoid rotating parts (belts and fan) and hot engine surfaces.

1. Using ServiceMaxx™, open the Aftertreatment session.
2. Monitor sensor voltage. Verify an active DTC for the sensor.
 - If DTC is inactive, monitor the signal while wiggling the connector and all wires at suspected location. If the circuit is interrupted, the signal spikes and the Diagnostic Trouble Code (DTC) goes active.
 - If DTC is active, proceed to the next step.
3. Disconnect engine harness from sensor.

NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

4. Connect Breakout Harness ZTSE4760A to engine harness. Leave sensor disconnected.

Sensor Circuit Check

Connect sensor Breakout Harness ZTSE4760A. Leave sensor disconnected. Turn ignition switch to ON. Use ServiceMaxx™ to verify correct DTC goes active when corresponding fault is induced. Use DMM to measure circuits.

Test Point	Spec	Comments
EST - Check DTC	SPN 3242 FMI 3	If SPN 3242 and FMI 4 is active, check DPFIT signal for short to GND. Do Harness Resistance Checks (page 208).
EST - Check DTC Short 3-Banana plug harness across 1 and GND	SPN 3242 FMI 4	If SPN 3242 and FMI 3 is active, check DPFIT signal for OPEN. Do Harness Resistance Check (page 208).
EST - Check DTC Short 3-Banana plug harness across 1 and 2	SPN 3242 FMI 4	If SPN 3242 and FMI 3 is active, check SIG GND for OPEN. Do Harness Resistance Check (page 208).
If checks are within specification, connect sensor and clear DTCs. If active DTC remains, replace sensor.		

DPFIT Pin-point Diagnostics

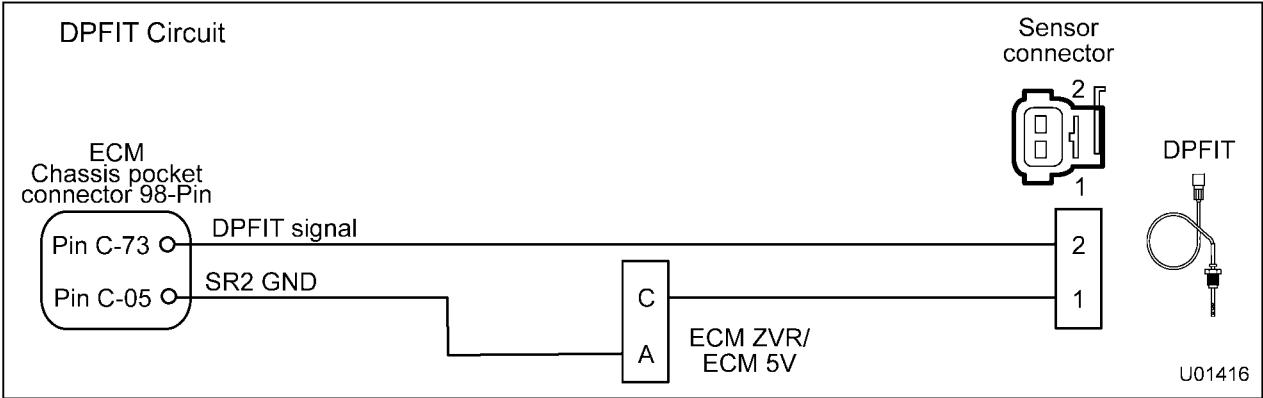


Figure 100 DPFIT circuit diagram

Connector Voltage Check

Connect Breakout Harness ZTSE4760A. Leave sensor disconnected. Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
1 to GND	0 V	If > 0.25 V, check for short to PWR.
2 to GND	4.6 V to 5 V	If < 4.5 V, check for OPEN or short to GND. Do Harness Resistance Check (page 208).

Connector Resistance Check to GND

Turn ignition switch to OFF. Connect Breakout Harness ZTSE4760A. Leave sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to GND	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box and Breakout Harness ZTSE4760A. Leave ECM and sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to C-05	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to C-73	< 5 Ω	If > 5 Ω , check for OPEN circuit.

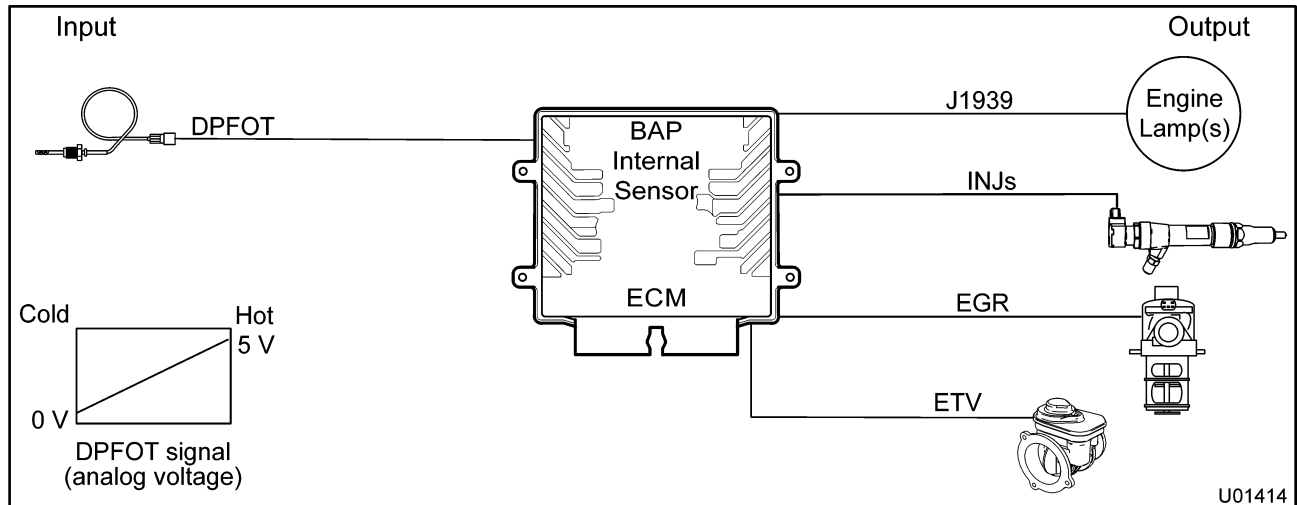
DPFIT Circuit Operation

DPFIT is a resistance temperature detector sensor supplied with a 5-volt reference voltage at Pin 2 from ECM Pin C-73. The sensor is grounded at Pin

1 from ECM Pin C-05. As temperature increases, resistance of the sensor increases. This causes the signal voltage to increase.

DPFOT Sensor (Diesel Particulate Filter Outlet Temperature)

SPN	FMI	Condition
3246	3	DPFOT signal Out of Range HIGH
3246	4	DPFOT signal Out of Range LOW
3246	10	DPFOT signal abnormal rate of change

**Figure 101 Function diagram for the DPFOT sensor**

The DPFOT sensor function diagram includes the following:

- DPF Outlet Temperature (DPFOT) sensor
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Exhaust Gas Recirculation (EGR)
- Engine Throttle Valve (ETV)
- Fuel Injectors (INJ)
- Engine Lamp(s)

Function

DPFOT sensor provides a feedback signal to the ECM indicating Diesel Particulate Filter (DPF) Outlet Temperature. During catalyst regeneration, the ECM monitors this sensor along with DOCIT, DPFIT, DPFDP, EGRP, and ETV.

Sensor Location

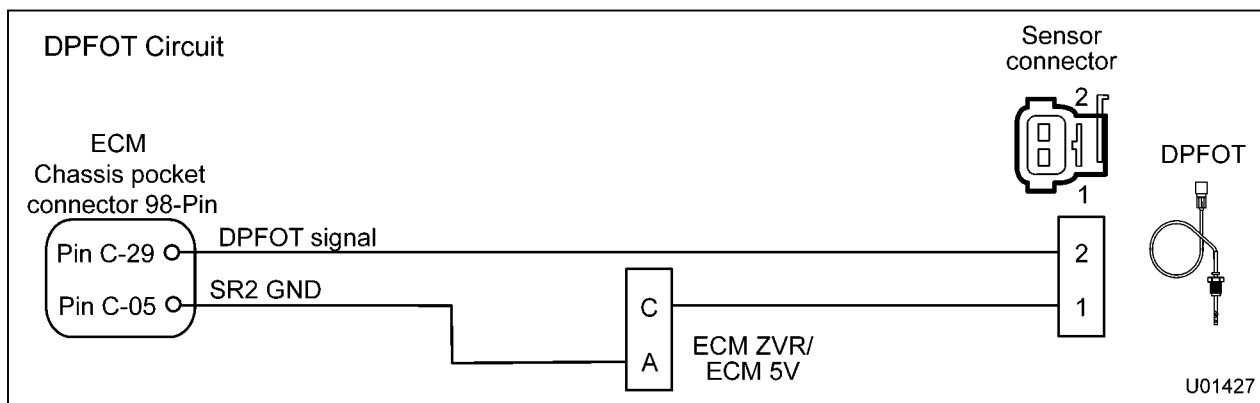
The DPFOT sensor is the third exhaust temperature sensor installed downstream of the turbocharger and is located just after the DPF.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 3-Banana Plug Harness ZTSE4498
- 1180–N4–0X0 – 180-Pin Breakout Box
- Breakout Harness ZTSE4760A (DPFOT)
- International® Electronic Engine Terminal Test Kit ZTSE4435C

DPFOT Sensor End Diagnostics

SPN	FMI	Condition	Possible Causes
3246	3	DPFOT signal Out of Range HIGH	• DPFOT signal OPEN or short to PWR • SIG GND circuit OPEN • Failed sensor
3246	4	DPFOT signal Out of Range LOW	• DPFOT signal circuit short to GND • Failed sensor
3246	10	DPFOT signal abnormal rate of change	• DPFOT biased circuit or sensor • DPFOT sensor outside of exhaust system

**Figure 102 DPFOT circuit diagram**

⚠ WARNING: To prevent personal injury or death, be careful to avoid rotating parts (belts and fan) and hot engine surfaces.

1. Using ServiceMaxx™, open the Aftertreatment session.
2. Monitor sensor voltage. Verify an active DTC for the sensor.
 - If DTC is inactive, monitor the signal while wiggling the connector and all wires at suspected location. If the circuit is interrupted, the signal spikes and the Diagnostic Trouble Code (DTC) goes active.
 - If DTC is active, proceed to the next step.
3. Disconnect engine harness from sensor.

NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

4. Connect to engine harness. Leave sensor disconnected.

Sensor Circuit Check

Connect sensor breakout harness. Leave sensor disconnected. Turn the ignition switch to ON. Use Electronic Service Tool (EST) with ServiceMaxx™ software to verify correct DTC goes active when corresponding fault is induced. Use DMM to measure circuits.

Test Point	Spec	Comments
EST - Check DTC	SPN 3246 FMI 3	If SPN 3246 and FMI 4 is active, check DPFOT signal for short to GND. Do Harness Resistance Check (page 212).
EST - Check DTC Short 3-Banana plug harness across 1 and GND	SPN 3246 FMI 4	If SPN 3246 and FMI 3 is active, check DPFOT signal for OPEN. Do Harness Resistance Check (page 212).
EST - Check DTC Short 3-Banana plug harness across 1 and 2	SPN 3246 FMI 4	If SPN 3246 and FMI 3 is active, check SIG GND for OPEN. Do Harness Resistance Check (page 212).
If checks are within specification, connect sensor and clear DTCs. If active DTC remains, replace sensor.		

DPFOT Pin-point Diagnostics

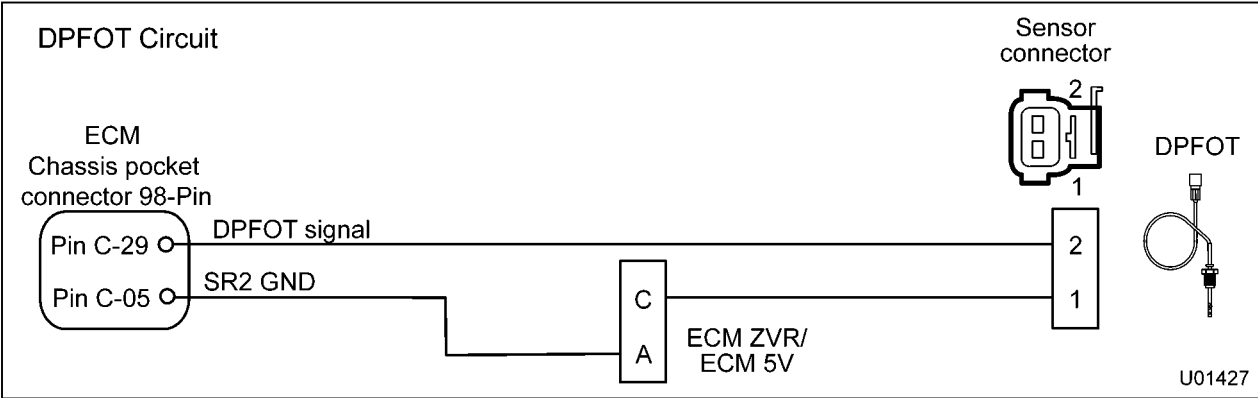


Figure 103 DPFOT circuit diagram

Connector Voltage Check

Connect Breakout Harness ZTSE4760A. Leave sensor disconnected. Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
1 to GND	0 V	If > 0.25 V, check for short to PWR.
2 to GND	4.6 V to 5 V	If < 4.5 V, check for OPEN or short to GND. Do Harness Resistance Check (page 212).

Connector Resistance Check to GND

Turn ignition switch to OFF. Connect Breakout Harness ZTSE4760A. Leave sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to GND	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box and Breakout Harness ZTSE4760A. Leave ECM and sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to C-05	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to C-29	< 5 Ω	If > 5 Ω , check for OPEN circuit.

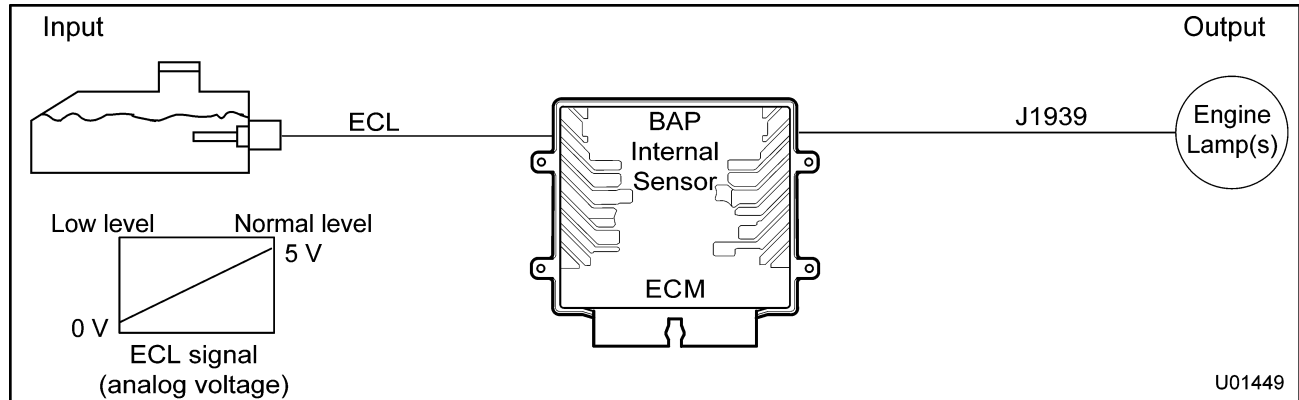
DPFOT Circuit Operation

The DPFOT is a resistance temperature detector sensor supplied with a 5-volt reference voltage at Pin 2 from ECM Pin C-29. The sensor is grounded at Pin

1 from ECM Pin C-05. As temperature increases, the resistance of the sensor increases. This causes the signal voltage to increase.

ECL Sensor (Engine Coolant Level)

SPN	FMI	Condition
111	1	Low Engine Coolant Level
111	2	ECL In-Range circuit fault
111	3	ECL signal Out of Range HIGH
111	4	ECL signal Out of Range LOW

**Figure 104 Function diagram for the ECL system**

The ECL system function diagram includes the following:

- Engine Coolant Level (ECL) sensor
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Engine Lamp(s)

Function

The ECM monitors Engine Coolant Level (ECL). The ECM will alert the operator when the ECL value is greater or equal to the closed switch value or less than or equal to the open switch value for a certain amount of time. The ECM can be programmed to shut the engine off when coolant is low.

Coolant level monitoring is a programmable feature that can be programmed using the Electronic Service

Tool (EST) with ServiceMaxx™ software. The coolant level feature is operational if programmed for 3-way warning or 3-way protection.

Location

The ECL sensor is installed in the plastic or metal deaeration tank.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 1180-N4-0X0 – 180-Pin Breakout Box

ECL Pin-point Diagnostics

SPN	FMI	Condition	Possible Causes
111	1	Low Engine Coolant Level	• Cooling system leak
111	2	ECL In-range circuit fault	• ECL circuit OPEN or short to GND or PWR • Failed sensor
111	3	ECL signal Out of Range HIGH	• ECL signal circuit OPEN or short to PWR • SR2 GND circuit OPEN • Failed sensor
111	4	ECL signal Out of Range LOW	• ECL signal circuit short to GND • Failed sensor

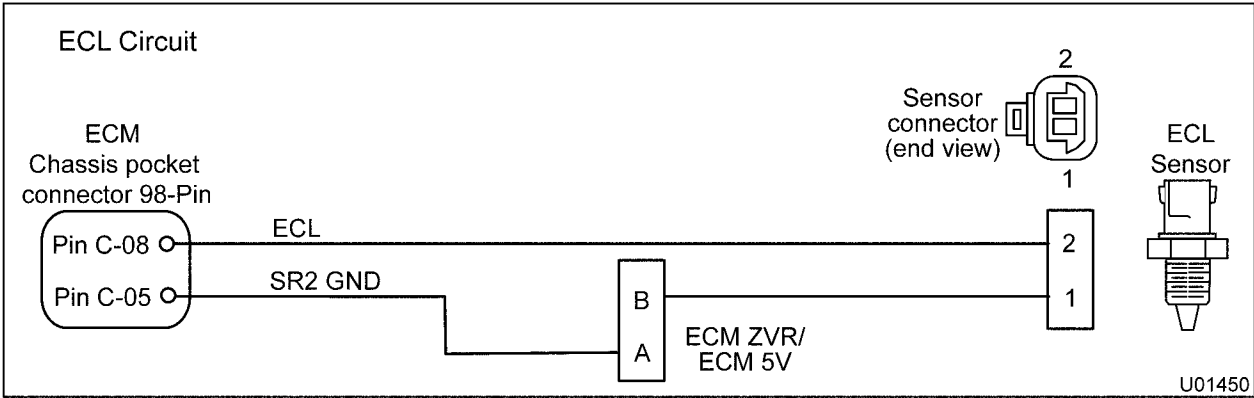


Figure 105 ECL circuit diagram

Connector Voltage Check

Disconnect ECL sensor. Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
1 to GND	0 V	If > 0.25 V, check for short to PWR.
2 to GND	4.6 V to 5 V	If < 4.5 V, check for OPEN or short to GND. Do Harness Resistance Check (page 215).

Connector Resistance Check to GND

Turn ignition switch to OFF. Connect breakout harness. Leave sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to GND	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.

Sensor Resistance Check

Disconnect ECL connector and measure across sensor.

Test Point	Spec	Comment
1 to 2	> 1 k Ω (full)	If < 1 k Ω , replace sensor.
1 to 2	< 5 Ω (empty)	If > 5 Ω , replace sensor.

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box and breakout harness. Leave ECM and sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to C-05	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to C-08	< 5 Ω	If > 5 Ω , check for OPEN circuit.

ECL Circuit Operation

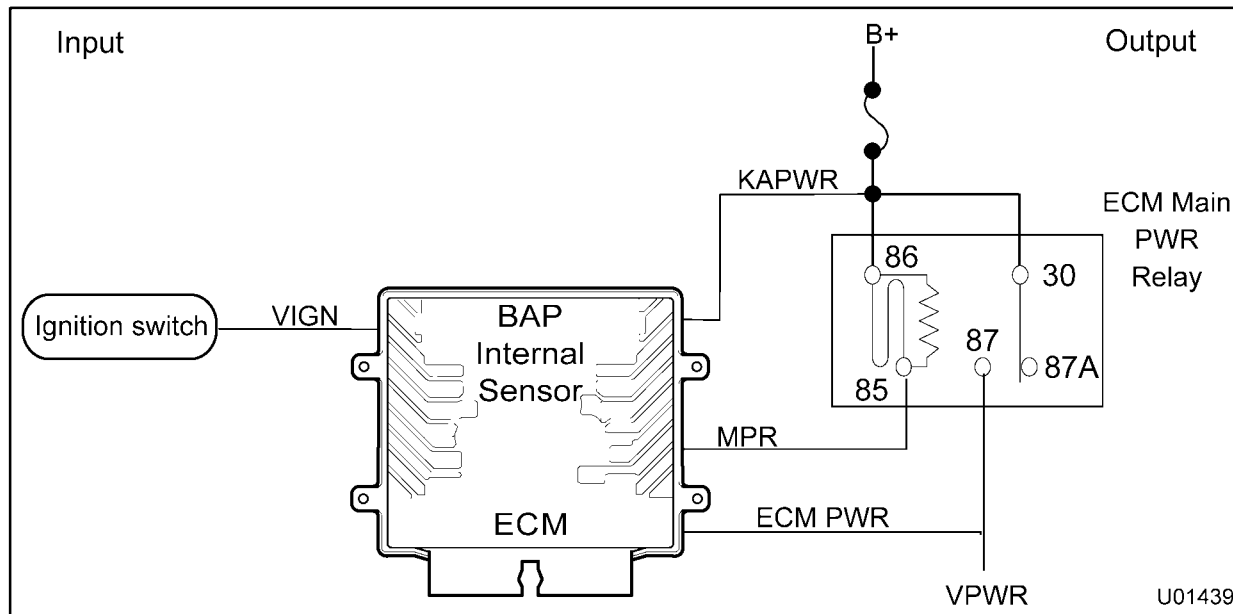
The ECL sensor uses a floating ball with a magnetic switch. When the coolant level is full, the float will rise and the magnet pulls the level switch open. This allows a 5-volt signal at ECM Pin C-08. When the level is low, the sensor closes and ECM Pin C-08 is 0 volts.

Fault Detection/Management

The ECM continuously monitors the ECL circuit for in-range faults. The ECM does not detect open or short circuits in the ECL system. When the ECM detects an in-range fault, a DTC is set.

ECM PWR Relay (Engine Control Module Power)

SPN	FMI	Condition
158	15	ECM Switched voltage too HIGH
158	17	ECM Switched voltage too LOW

**Figure 106 Function diagram for the ECM PWR**

The ECM PWR function diagram includes the following:

- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- ECM Main Power Relay (MPR)
- Ignition switch or power relay
- Battery
- Fuses

Function

The ECM requires battery power to operate the electronic control system and perform maintenance after turning the ignition switch to OFF. To do this, the ECM must control its own power supply. When the ECM receives the Vehicle Ignition (VIGN) signal from the ignition switch, the ECM enables the relay

to power-up. When turning the ignition switch to OFF, the ECM performs internal maintenance, then disables the ECM relay.

ECM Location

The ECM is installed on the right side of engine compartment on the air cleaner bracket.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 1180–N4–0X0 – 180-Pin Breakout Box
- Breakout Harness ZTSE4674 (ECM Relay)
- International® Electronic Engine Terminal Test Kit ZTSE4435C

ECM PWR Pin-point Diagnostics

SPN	FMI	Condition	Possible Causes
158	15	ECM Switched voltage too HIGH	- Jump starting using more than system voltage - Batteries wired incorrectly - Charging system fault
158	17	ECM Switched voltage too LOW	- Low discharged batteries - Inoperative alternator/charging system fault - High resistance in ECM powering circuits (ECM PWR, ECM GND, or VIGN)

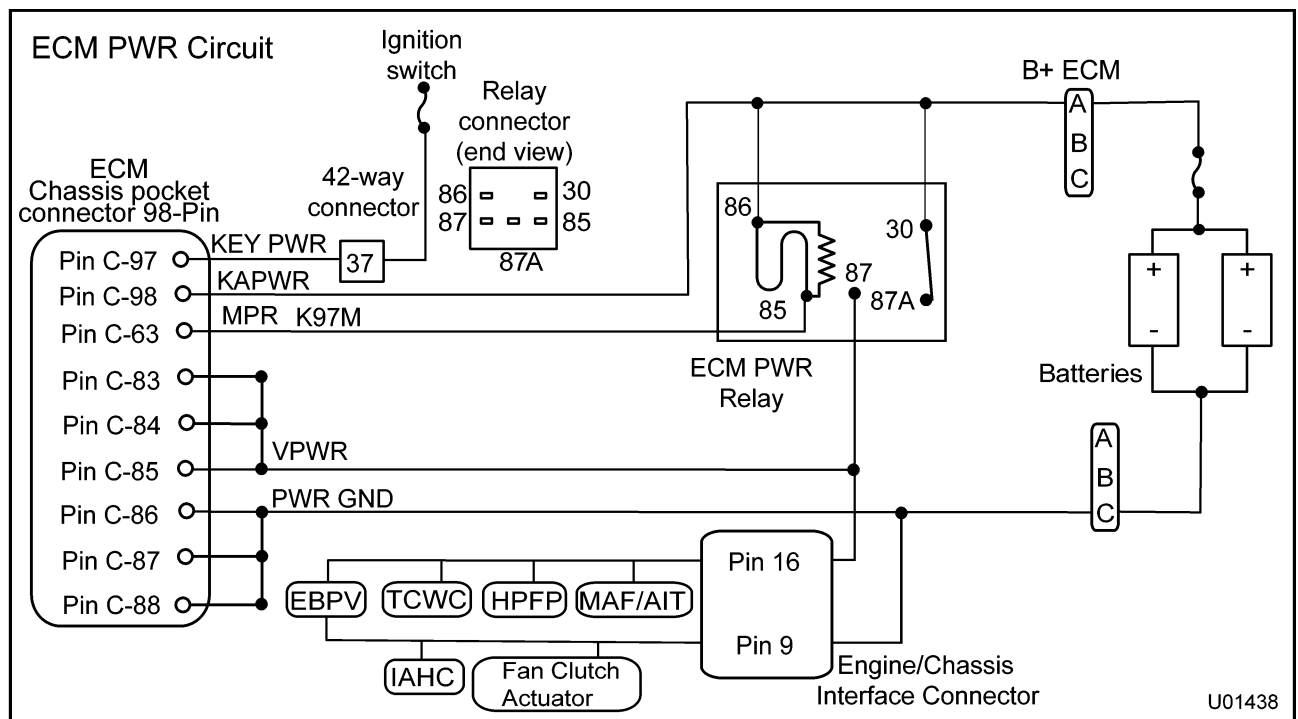


Figure 107 ECM PWR circuit diagram

NOTE: Reference the truck *Chassis Electrical Circuit Diagram Manual* and *Electrical System Troubleshooting Guide* for chassis side electrical system.

Voltage Check at Relay

Connect Breakout Harness ZTSE4674 between relay and relay socket. Turn the ignition switch to ON. Use DMM to measure voltage.

CAUTION: To avoid engine damage, turn the ignition switch to OFF before removing main power relay or any ECM connector supplying power to the ECM. Failure to turn the ignition switch to OFF will cause a voltage spike and damage to electrical components.

Test Point	Spec	Comment
86 to GND	B+	If 0 V, check power circuit to relay coil for OPEN or short to GND, or blown fuse. If < B+, check for failed circuitry between batteries and relay. Do Harness Resistance Check (page 219).
30 to GND	B+	If 0 V, check power circuit to relay switch for OPEN or short to GND, or blown fuse. If < B+, check for failed circuitry between batteries and relay. Do Harness Resistance Check (page 219).
85 to GND	0 V to 2 V	If > 2 V, check MPR control circuit for OPEN or short to PWR. Do Harness Resistance Check (page 219).
87 to GND	B+	If < B+ but > 0 V, replace relay. If B+, check ECM PWR and ECM GND circuits at the ECM. Do Voltage Check at ECM.

Voltage Check at ECM

Connect 180-Pin Breakout Box between ECM and chassis harness. Turn the ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
C-97 to GND	B+	If < B+, check VIGN circuit for OPEN or short to GND, or blown fuse.
C-86 to GND	0 V	If voltage is present, check for OPEN circuit. Do Harness Resistance Check (page 219).
C-87 to GND	0 V	
C-88 to GND	0 V	
C-63 to GND	0 V to 2 V	If > 2 V, check MPR control circuit for OPEN or short to PWR. Do Harness Resistance Check (page 219).
C-83 to GND	B+	If < B+, check for OPEN circuit, failed relay, or blown fuse. Do Harness Resistance Check (page 219).
C-84 to GND	B+	
C-85 to GND	B+	
C-63 to GND	0 V to 2 V	If > 2 V, check MPR control circuit for OPEN or short to PWR. Do Harness Resistance Check (page 219).
C-98 to GND	B+	If < B+, check for OPEN circuit.

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box and Breakout Harness ZTSE4674. Leave ECM, ECM and PWR relay, disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
C-63 to 85	< 5 Ω	If > 5 Ω , check MPR control circuit for OPEN.
C-63 to GND	> 1 k Ω	If < 1 k Ω , check MPR control circuit for short to GND.
C-83 to 87	< 5 Ω	If > 5 Ω , check ECM PWR circuit for OPEN.
C-83 to GND	> 1 k Ω	If < 1 k Ω , check ECM PWR circuit for short to GND.
C-84 to 87	< 5 Ω	If > 5 Ω , check ECM PWR circuit for OPEN.
C-84 to GND	> 1 k Ω	If < 1 k Ω , check ECM PWR circuit for short to GND.
C-85 to 87	< 5 Ω	If > 5 Ω , check ECM PWR circuit for OPEN.
C-85 to GND	> 1 k Ω	If < 1 k Ω , check ECM PWR circuit for short to GND.
C-86 to GND	< 5 Ω	If > 5 Ω , check ECM GND circuit for OPEN.
C-87 to GND	< 5 Ω	If > 5 Ω , check ECM GND circuit for OPEN.
C-88 to GND	< 5 Ω	If > 5 Ω , check ECM GND circuit for OPEN.
C-98 to 86	< 5 Ω	If > 5 Ω , check ECM KAPWR circuit for OPEN.

 **WARNING:** To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Harness Resistance Check on Relay Power Circuits

Turn ignition switch to OFF. Disconnect both battery GND cables and the inline connector on battery and cable. Use DMM to measure resistance.

Test Point	Spec	Comment
Relay (30) to battery positive post	< 5 Ω	If > 5 Ω , check for OPEN circuit or blown fuse.
Relay (30) to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
Relay (86) to battery positive post	< 5 Ω	If > 5 Ω , check for OPEN circuit or blown fuse.
Relay (86) to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.

ECM PWR Circuit Operation

The ECM receives VIGN power at Pin C-97. This signals the ECM to provide a ground path from Pin C-63 to C-85 to switch the ECM MPR. Switching the relay provides power from the battery positive terminal, through a fuse and relay contacts 30 and 87, to Pins C-83, C-84, and C-85.

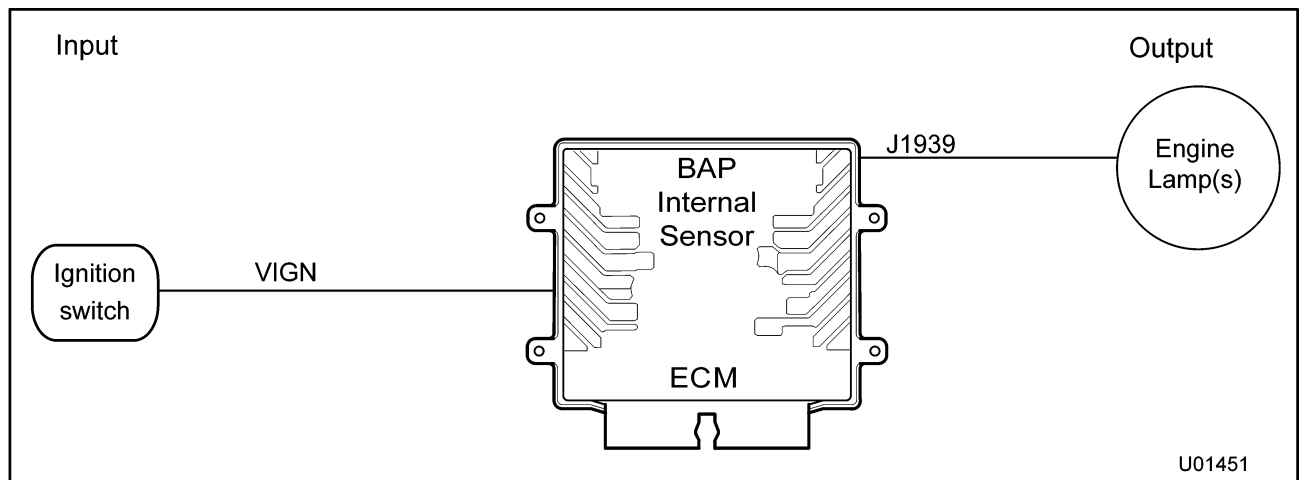
The ECM is grounded to the battery negative terminal at ECM Pin C-86, C-87, and C-88.

Fault Detection/Management

The ECM internally monitors battery voltage. When the ECM continuously receives less than 7 volts or more than 17.5 volts, a DTC is set.

ECM Self-Diagnostics (Engine Control Module)

SPN	FMI	Condition
108	3	BARO signal out of range HIGH
108	4	BARO signal out of range LOW
628	12	ECM Memory Error
628	14	ECM Programming- EFRC Error
629	2	ECM Error - Level 2 monitoring
629	10	ECM Error - Fuel Injector Circuit Performance Bank B
629	12	ECM Error - SPI
629	31	ECM Error - Level 3 monitoring
1136	0	ECM Error - over temperature
1136	1	ECM Error - under temperature

**Figure 108 Function diagram for the ECM**

The ECM does the following:

- Monitors and controls engine operation and performance
- Enables Power Takeoff (PTO) and Cruise Control (CCS)
- Communicates engine and vehicle information to the instrument cluster
- Enables electronically controlled transmission (if equipped)
- Enables diagnostic programming tools

Fault Detection/Management

The ECM automatically performs diagnostic self-checks. The ECM self-test includes memory, programming, and internal power supply checks. The ECM sets internal Diagnostic Trouble Codes (DTCs) depending on the severity of the problem. Additionally, the ECM provides DTC management strategies to permit limited engine and vehicle operation.

When SPN 108/FMI 3/4, SPN 1136/FMI 0/1, SPN 628/FMI 14, SPN 629/FMI 2, or SPN 629/FMI 31 are set by the ECM, the Amber Warning Lamp (AWL) is illuminated.

ECM Self-Diagnostic DTCs**SPN 108/FMI 3- BARO signal Out of Range HIGH**

Checks whether the signal from the BAP sensor is above the maximum threshold.

Pin-point ECM Self-Diagnostic Fault

1. Clear DTC, cycle ignition switch.
 2. If DTC is still active, replace ECM.
-

SPN 108/FMI 4 - BARO signal Out of Range LOW

Checks whether the signal from the BAP sensor is below the minimum threshold.

Pin-point ECM Self-Diagnostic Fault

1. Clear DTC, cycle ignition switch.
 2. If DTC is still active, replace ECM.
-

SPN 628/FMI 12 - ECM Memory Error

Pin-point ECM Self-Diagnostic Fault

1. Clear DTC, cycle ignition switch.
 2. If DTC is still active, replace ECM.
-

SPN 628/FMI 14 - ECM Programming - EFRC Error

Pin-point ECM Self-Diagnostic Fault

1. Clear DTC, cycle ignition switch.
 2. If DTC is still active, replace ECM.
-

SPN 629/FMI 2 - ECM Error - Level 2 Monitoring**Pin-point ECM Self-Diagnostic Fault**

1. Clear DTC, cycle ignition switch.
 2. If DTC is still active, replace ECM.
-

SPN 629/FMI 10 - ECM Error - Fuel Injector Circuit Performance Bank B**Pin-point ECM Self-Diagnostic Fault**

1. Clear DTC, cycle ignition switch.
 2. If DTC is still active, replace ECM.
-

SPN 629/FMI 12 - ECM Error - SPI**Pin-point ECM Self-Diagnostic Fault**

1. Clear DTC, cycle ignition switch.
 2. If DTC is still active, replace ECM.
-

SPN 629/FMI 31 - ECM Error - Level 3 Monitoring**Pin-point ECM Self-Diagnostic Fault**

1. Clear DTC, cycle ignition switch.
 2. If DTC is still active, replace ECM.
-

SPN 1136/FMI 0 - ECM Error - Over temperature

Checks whether the internal temperature is above the maximum threshold.

Pin-point ECM Self-Diagnostic Fault

1. Clear DTC, cycle ignition switch.
 2. If DTC is still active, replace ECM.
-

SPN 1136/FMI 1 - ECM Error - Under temperature

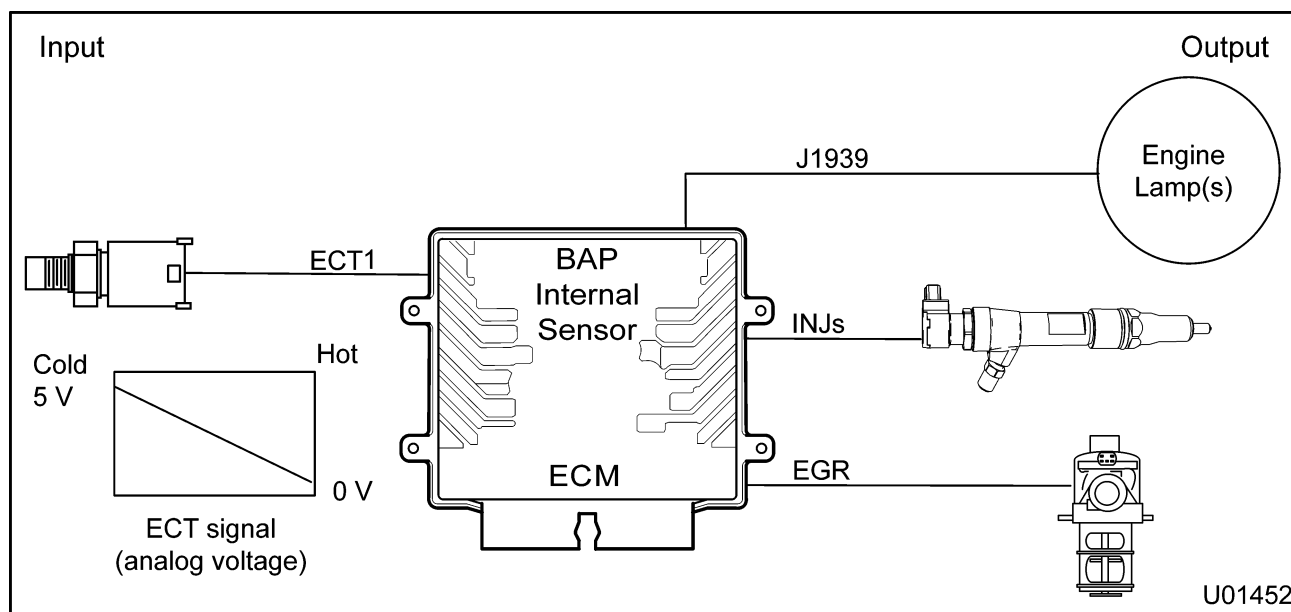
Checks whether the internal temperature is below the minimum threshold.

Pin-point ECM Self-Diagnostic Fault

1. Clear DTC, cycle ignition switch.
 2. If DTC is still active, replace ECM.
-

ECT1 Sensor (Engine Coolant Temperature 1)**SPN FMI Condition**

110	3	ECT1 signal Out of Range HIGH
110	4	ECT1 signal Out of Range LOW
110	10	ECT1 signal abnormal rate of change

**Figure 109 Function diagram for the ECT1 Sensor**

The ECT1 sensor function diagram includes the following:

- Engine Coolant Temperature 1 (ECT1) sensor
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Exhaust Gas Recirculation (EGR) valve
- Fuel injector (INJ)
- Engine Lamp(s)

Function

The ECT1 sensor provides a feedback signal to the ECM indicating ECT. During engine operation, the

ECM monitors the ECT signal to control the following features:

- Engine Warning Protection System (EWPS)
- Cold Ambient Protection (CAP)
- Idle Shutdown Timer (IST)
- Cold idle advance
- Coolant compensation
- Regeneration

Sensor Location

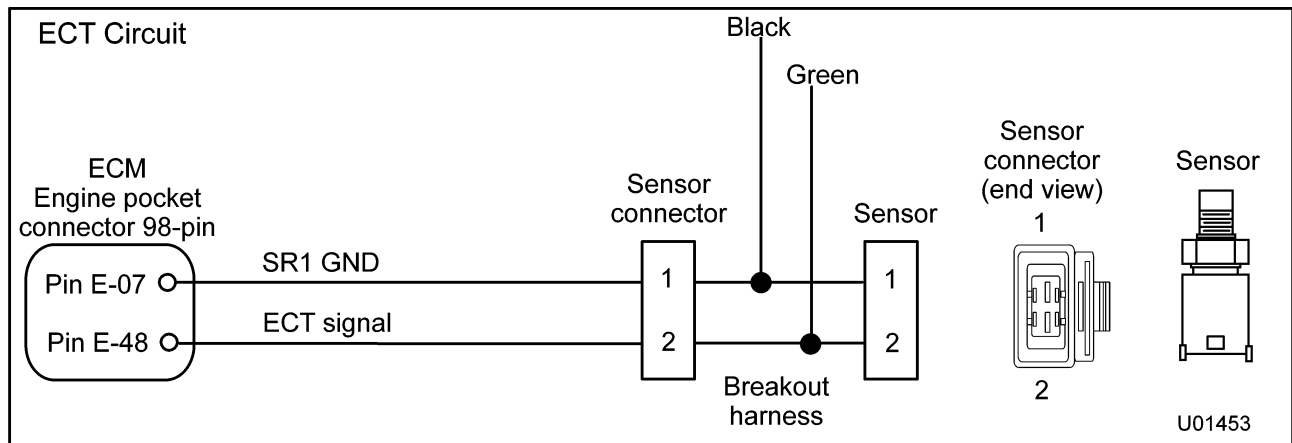
The ECT1 sensor is installed in the front cover, just to the left of the water pump pulley.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 3-Banana Plug Harness ZTSE4498
- 1180-N4-0X0 – 180-Pin Breakout Box
- Breakout Harness ZTSE4602 (ECT)
- International® Electronic Engine Terminal Test Kit ZTSE4435C

ECT1 Sensor End Diagnostics

SPN	FMI	Condition	Possible Causes
110	3	ECT1 signal Out of Range HIGH	• ECT signal OPEN or short to PWR • SIG GND circuit OPEN • Failed sensor
110	4	ECT1 signal Out of Range LOW	• ECT signal circuit short to GND • Failed sensor
110	10	ECT1 signal abnormal rate of change	• ECT1 biased sensor or circuit

**Figure 110 ECT1 circuit diagram**

⚠ WARNING: To prevent personal injury or death, stay clear of rotating parts (belts and fan) and hot engine surfaces.

1. Using Electronic Service Tool (EST) with ServiceMaxx™ software, open the Continuous Monitor session.
2. Monitor sensor voltage. Verify an active Diagnostic Trouble Code (DTC) for the sensor.
 - If code is inactive, monitor the signal while wiggling the connector and all wires at suspected location. If the circuit is interrupted, the signal spikes and the DTC will go active.
 - If DTC is active, proceed to the next step.
3. Disconnect engine harness from sensor.

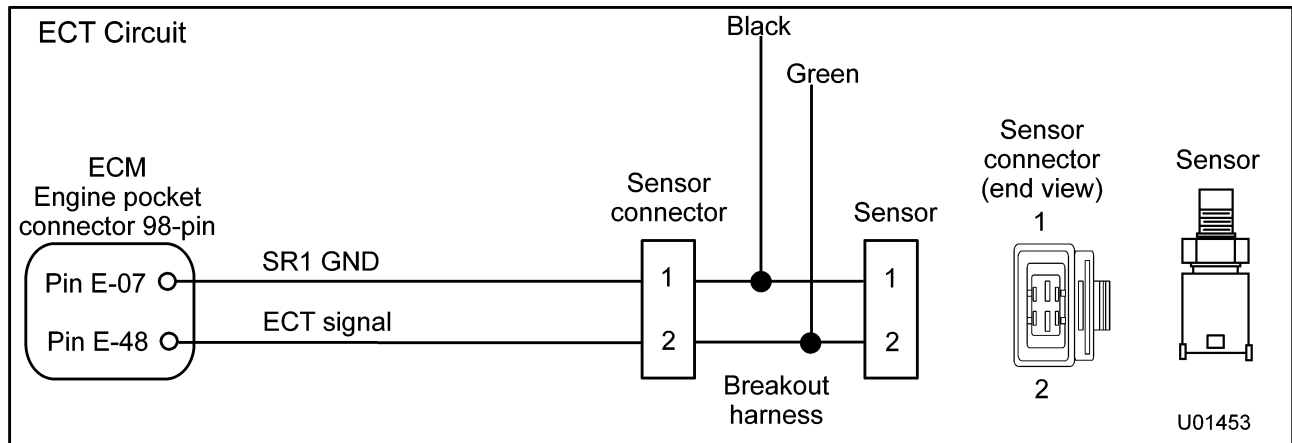
NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

4. Connect Breakout Harness ZTSE4602 to engine harness. Leave sensor disconnected.

Sensor Circuit Check

Connect Breakout Harness ZTSE4602. Leave sensor disconnected. Turn ignition switch to ON. Use Electronic Service Tool (EST) with ServiceMaxx™ software to verify correct DTC goes active when corresponding fault is induced. Use DMM to measure circuits.

Test Point	Spec	Comments
EST - Check DTC	SPN 110 FMI 3	If SPN 110/FMI 4 is active, check ECT signal for short to GND. Do Harness Resistance Check (page 227).
EST - Check DTC Short 3-banana plug harness across 2 and GND	SPN 110 FMI 4	If SPN 110/FMI 3 is active, check ECT signal for OPEN. Do Harness Resistance Check (page 227).
EST - Check DTC Short 3-banana plug harness across 1 and 2	SPN 110 FMI 4	If SPN 110/FMI 3 is active, check SIG GND for OPEN. Do Harness Resistance Check (page 227).
If checks are within specification, connect sensor and clear DTCs. If active code remains, replace sensor.		

ECT1 Pin-point Diagnostics**Figure 111 ECT1 circuit diagram****Connector Voltage Check**

Connect Breakout Harness ZTSE4602. Leave sensor disconnected. Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
1 to GND	0 V	If > 0.25 V, check for short to PWR.
2 to GND	4.6 V to 5 V	If < 4.5 V, check for OPEN or short to GND. Do Harness Resistance Check (page 227).

Connector Resistance Check to GND

Turn ignition switch to OFF. Connect Breakout Harness ZTSE4602. Leave sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to GND	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box and Breakout Harness ZTSE4602. Leave ECM and sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to E-07	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to E-48	< 5 Ω	If > 5 Ω , check for OPEN circuit.

ECT Circuit Operation

The ECT is a thermistor sensor supplied with a 5-volt reference voltage at Pin 2 from ECM Pin E-48. The

sensor is grounded at Pin 1 from ECM Pin E-07. As the coolant temperature increases, the resistance

of the thermistor decreases. This causes the signal voltage to decrease.

Coolant Temperature Compensation

Coolant temperature compensation reduces fuel delivery if ECT is above cooling system specifications.

The reduction in fuel delivery begins when ECT reaches approximately 107 °C (225 °F). A reduction of 20% is achieved as the ECT reaches approximately 110 °C (230 °F).

If a warning or shutdown occurs, a DTC is stored in ECM memory.

NOTE: Coolant temperature compensation may be disabled in emergency vehicles that require 100% power on demand.

Engine Warning Protection System (EWPS)

EWPS has standard and optional features. Optional features can be enabled or disabled. When enabled,

the EWPS warns the operator of an overheat condition and can be programmed to shut down the engine.

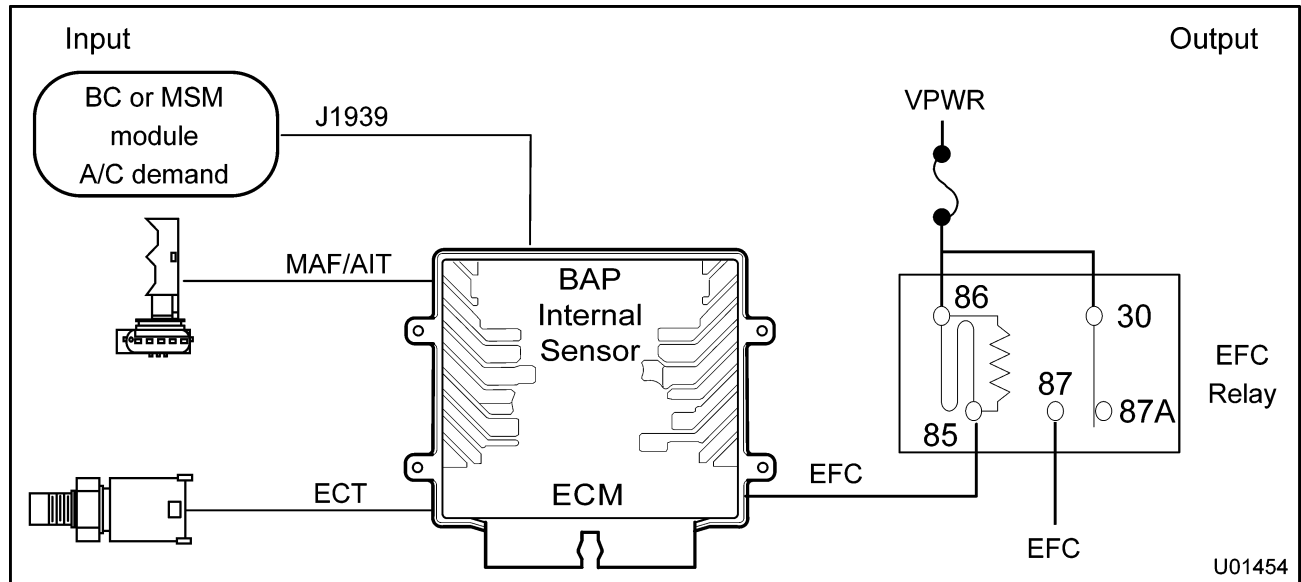
The Oil Warning Lamp (OWL) illuminates when ECT reaches approximately 109 °C (228 °F). A warning buzzer sounds when ECT reaches approximately 112 °C (234 °F). The engine will shut down when the ECT reaches approximately 112 °C (234 °F), if 3-way protection is enabled.

Fault Detection/Management

The ECM continuously monitors the control system. If the sensor signal is higher or lower than expected, the ECM disregards the signal and uses a calibrated default value. The ECM sets a DTC, turns on the Warn Engine Lamp (WEL), and runs the engine in a default range. When this occurs, the EWPS, CAP, IST, cold idle advance, and coolant temperature compensation features are disabled.

EFC (Engine Fan Control)

SPN	FMI	Condition
647	3	EFC short to PWR
647	4	EFC short to GND
647	5	EFC open load/circuit

**Figure 112 Function diagram for EFC**

The EFC function diagram includes the following:

- Engine Fan Control (EFC)
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Body Controller (BC)
- Multiplex System Module (MSM)
- Engine Coolant Temperature 1 (ECT1) sensor
- Air Inlet Temperature (AIT) signal from the Mass Air Flow (MAF) sensor
- Engine Fan (EFC) relay

Function

The engine fan allows increased air flow through the radiator when the A/C is on or when ECT or AIT goes above a set temperature.

Location

The EFC relay and switches are chassis mounted. For additional supporting information, see truck *Chassis Electrical Circuit Diagram Manual* and *Electrical System Troubleshooting Guide*.

Tools

- Digital Multimeter (DMM)
- 1180–N4–0X0 – 180-Pin Breakout Box
- Breakout Harness ZTSE4674 (EFC)
- International® Electronic Engine Terminal Test Kit ZTSE4435C

EFC Circuit Diagnostics

SPN	FMI	Condition	Possible Causes
647	3	EFC short to PWR	EFC relay control circuit shorted to PWR
647	4	EFC short to GND	EFC relay control circuit shorted to GND
647	5	EFC open load/circuit	- EFC relay control circuit OPEN - EFC relay coil PWR circuit OPEN - Blown fuse - Failed relay coil

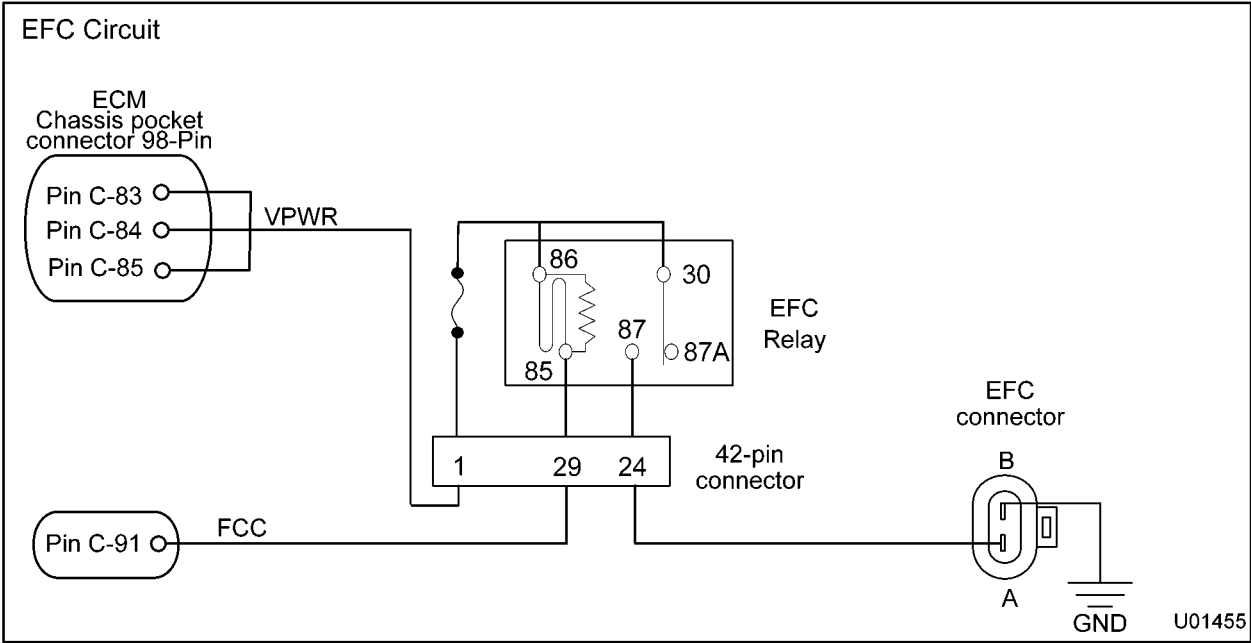


Figure 113 EFC circuit diagram

Voltage Check at EFC Connector Output State Test

Disconnect EFC 2-pin connector. Turn the ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
A to GND	0 V to 0.25 V	If > 0.25 V, check for short to PWR or EFC circuit for short to GND, or failed EFC relay.
B to GND	0 V to 0.25 V	If > 0.25 V, check for OPEN circuit.
Run Output State Test HIGH.		
A to GND	0 V to 0.25 V	If > 0.25 V, check for short to PWR, or EFC circuit for short to GND, or failed EFC relay.
Run Output State Test LOW.		
A to GND	B+	If < B+, check for OPEN circuit between relay and EFC, or EFC circuit for OPEN, or blown fuse, or failed relay. Do Harness Resistance Check (page 232).
A to B	B+	If < B+, check GND circuit for OPEN. Do Harness Resistance Check (page 232).

Voltage Check at Relay - Output State Test

Connect Breakout Harness ZTSE4674 between relay and relay socket. Connect EFC and turn the ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
30 to GND	B+	If < B+, check power circuit to relay switch for OPEN or short to GND, or blown fuse.
86 to GND	B+	If < B+, check power circuit to relay coil for OPEN or short to GND, or blown fuse.
Run Output State Test HIGH.		
85 to GND	B+	If < B+, check EFC circuit for short to GND. Do Harness Resistance Check (page 232).
Run Output State Test LOW.		
85 to GND	0.06 V to 2 V	If > 2 V, check EFC circuit for OPEN. Do Harness Resistance Check (page 232).
87 to GND	B+	If < B+, replace relay.

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box and relay harness. Leave ECM and relay disconnected.

Test Point	Spec	Comment
C-91 to 85	< 5 Ω	If > 5 Ω , check for OPEN circuit between ECM and relay terminal.
87 to A (fan)	< 5 Ω	If > 5 Ω , check for OPEN circuit between relay terminal and A (fan).
30 to C-1, 3 and 5	< 5 Ω	If > 5 Ω , check VPWR for OPEN in circuit.
30 to GND	> 1 k Ω	If < 1 k Ω , check VPWR for short to GND.
86 to C-1, 3 and 5	< 5 Ω	If > 5 Ω , check VPWR for OPEN in circuit.
86 to GND	> 1 k Ω	If < 1 k Ω , check VPWR for short to GND.

See truck *Chassis Electrical Circuit Diagram Manual* and *Electrical System Troubleshooting Guide* for fuse information.

EFC Circuit Operation

The default state of the EFC is ON. B+ is needed to turn the fan off.

ECM Pin C-91 controls the EFC to shut off by supplying a ground path to the EFC relay coil Pin 85. VPWR powers the other side of the relay coil, Pin 86. VPWR is sent through the relay switch, which deactivates the EFC.

EFC Programmable Parameters

By using an Electronic Service Tool (EST) with ServiceMaxx™ software, an authorized service technician can program the ECM to turn the EFC on for any desired temperature.

- Engine fan control - indicates to the onboard electronics whether the vehicle has the electronic engine fan control feature.

- A/C fan activation - allows fan activation through the ECM when requested from the BC during A/C operation.
- Disable - enables or disables the EFC feature.
- Fan on temperature - indicates at what coolant temperature the fan is electronically activated.
- Fan off temperature - indicates at what coolant temperature the fan is electronically deactivated.

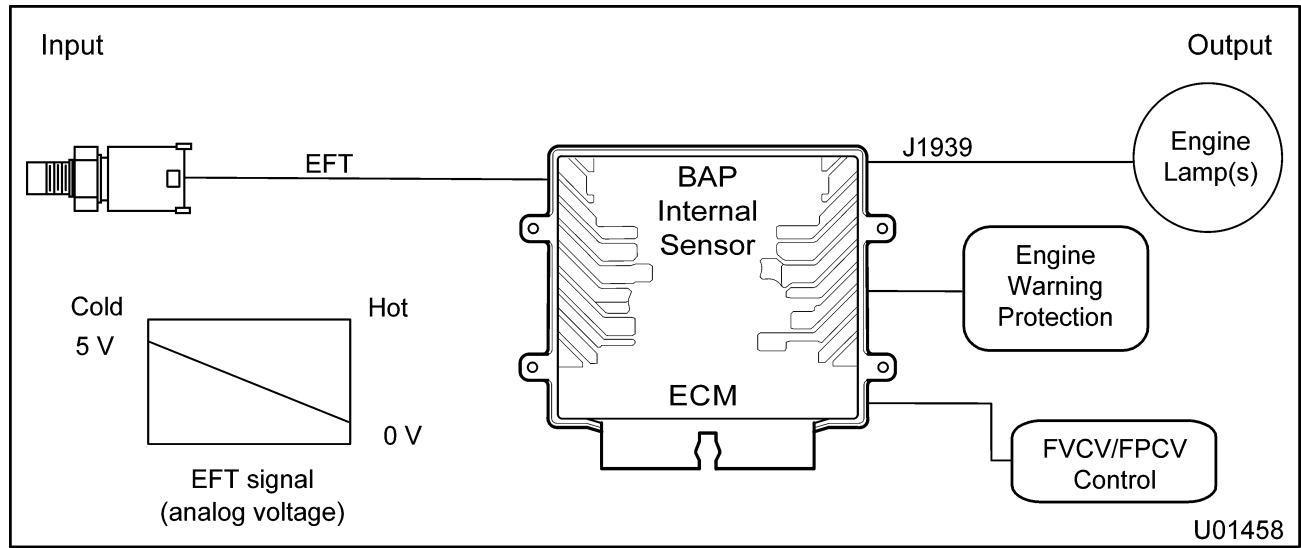
Fault Detection/Management

An open or short to ground in the EFC can be detected by the ECM during an on-demand engine standard test. The AIT and ECT are continuously monitored. If a fault is detected in the AIT or ECT circuit, the EFC control is disabled and the engine fan remains on.

NOTE: Before diagnosing, verify the vehicle has an electronic fan and the ECM is programmed correctly.

EFT Sensor (Engine Fuel Temperature)

SPN	FMI	Condition
174	3	EFT signal Out of Range HIGH
174	4	EFT signal Out of Range LOW
174	10	EFT signal abnormal rate of change

**Figure 114 Function diagram for the EFT sensor**

The EFT sensor function diagram includes the following:

- Engine Fuel Temperature (EFT) sensor
- Fuel Volume Control Valve (FVCV)/Fuel Pressure Control Valve (FPCV)
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Engine Lamp(s)
- Engine Warning Protection

Function

The EFT sensor provides a feedback signal to the ECM indicating fuel temperature out of the secondary fuel filter. The ECM monitors this sensor and controls the FVCV/FPCV to maintain desired fuel temperature.

Sensor Location

The EFT sensor is installed under the secondary fuel filter housing, next to the FDP sensor.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 3-Banana Plug Harness ZTSE4498
- 1180–N4–0X0 – 180-Pin Breakout Box
- Breakout Harness ZTSE4602 (EFT)
- International® Electronic Engine Terminal Test Kit ZTSE4435C

EFT Sensor End Diagnostics

SPN	FMI	Condition	Possible Causes
174	3	EFT signal Out of Range HIGH	- EFT signal OPEN or short to PWR - SIG GND circuit OPEN - Failed sensor
174	4	EFT signal Out of Range LOW	- EFT signal circuit short to GND - Failed sensor
174	10	EFT signal abnormal rate of change	- More than 10 °C (50 °F) change within 0.1 second - Low fuel level - Restricted fuel lines - EFT biased sensor or circuit fault - Failed sensor

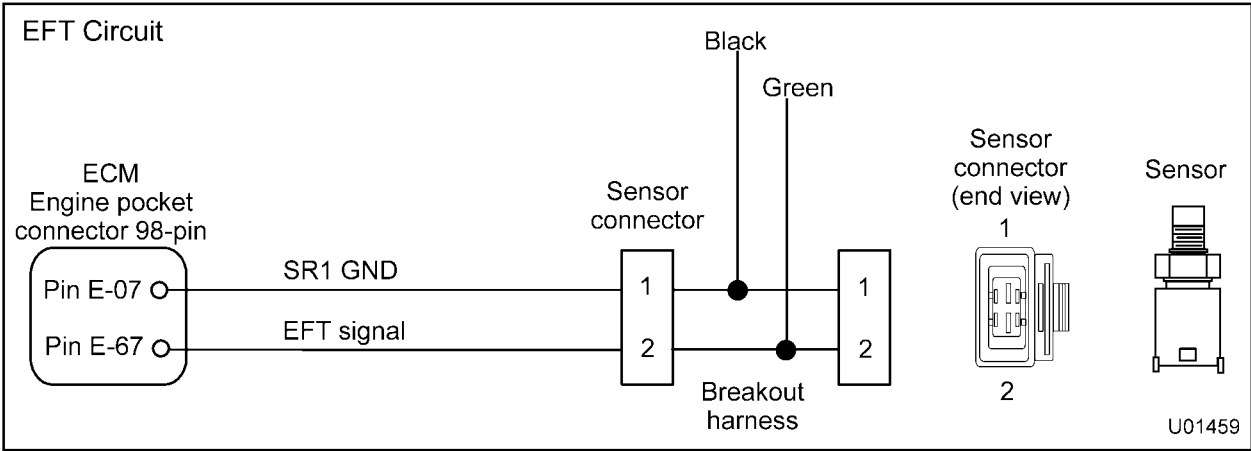


Figure 115 EFT circuit diagram

⚠ WARNING: To prevent personal injury or death, stay clear of rotating parts (belts and fan) and hot engine surfaces.

1. Using Electronic Service Tool (EST) with ServiceMaxx™ software, open the Continuous Monitor session.
2. Monitor sensor voltage. Verify an active Diagnostic Trouble Code (DTC) for the sensor.
 - If code is inactive, monitor the signal while wiggling the connector and all wires at suspected location. If the circuit is interrupted, the signal spikes and the fault goes active.
 - If DTC is active, proceed to the next step.
3. Disconnect engine harness from sensor.

NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

4. Connect breakout harness to engine harness. Leave sensor disconnected.

Sensor Circuit Check

Connect Breakout Harness ZTSE4602. Leave sensor disconnected. Turn ignition switch to ON. Use Electronic Service Tool (EST) with ServiceMaxx™ software to verify correct DTC goes active when corresponding fault is induced. Use DMM to measure circuits.

Test Point	Spec	Comments
EST - Check DTC	SPN 174 FMI 3	If SPN 174/FMI 4 is active, check EFT signal for short to GND. Do Harness Resistance Check (page 237).
EST - Check DTC Short 3-banana plug harness across 2 and GND	SPN 174 FMI 4	If SPN 174/FMI 3 is active, check EFT signal for OPEN. Do Harness Resistance Check (page 237).
EST - Check DTC Short 3-banana plug harness across 1 and 2	SPN 174 FMI 4	If SPN 174/FMI 3 is active, check SIG GND for OPEN. Do Harness Resistance Check (page 237).
If checks are within specification, connect sensor and clear DTCs. If active code remains, replace sensor.		

EFT Pin-point Diagnostics

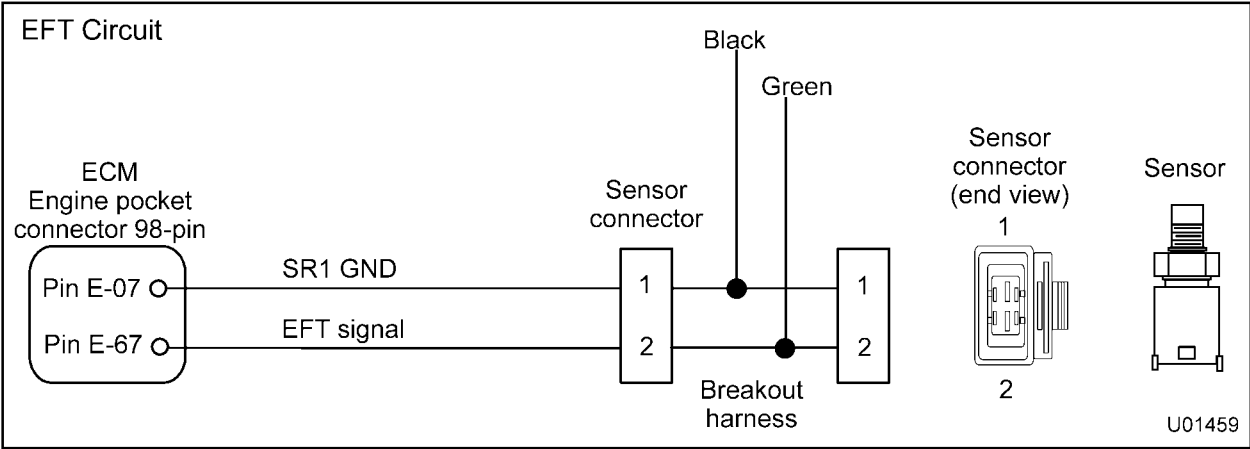


Figure 116 EFT circuit diagram

Connector Voltage Check

Connect Breakout Harness ZTSE4602. Leave sensor disconnected. Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
1 to GND	0 V	If > 0.25 V, check for short to PWR.
2 to GND	4.6 V to 5 V	If < 4.5 V, check for OPEN or short to GND. Do Harness Resistance Check (page 237).

Connector Resistance Check to GND

Turn ignition switch to OFF. Connect Breakout Harness ZTSE4602. Leave sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to GND	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box and Breakout Harness ZTSE4602. Leave ECM and sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to E-07	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to E-67	< 5 Ω	If > 5 Ω , check for OPEN circuit.

EFT Circuit Operation

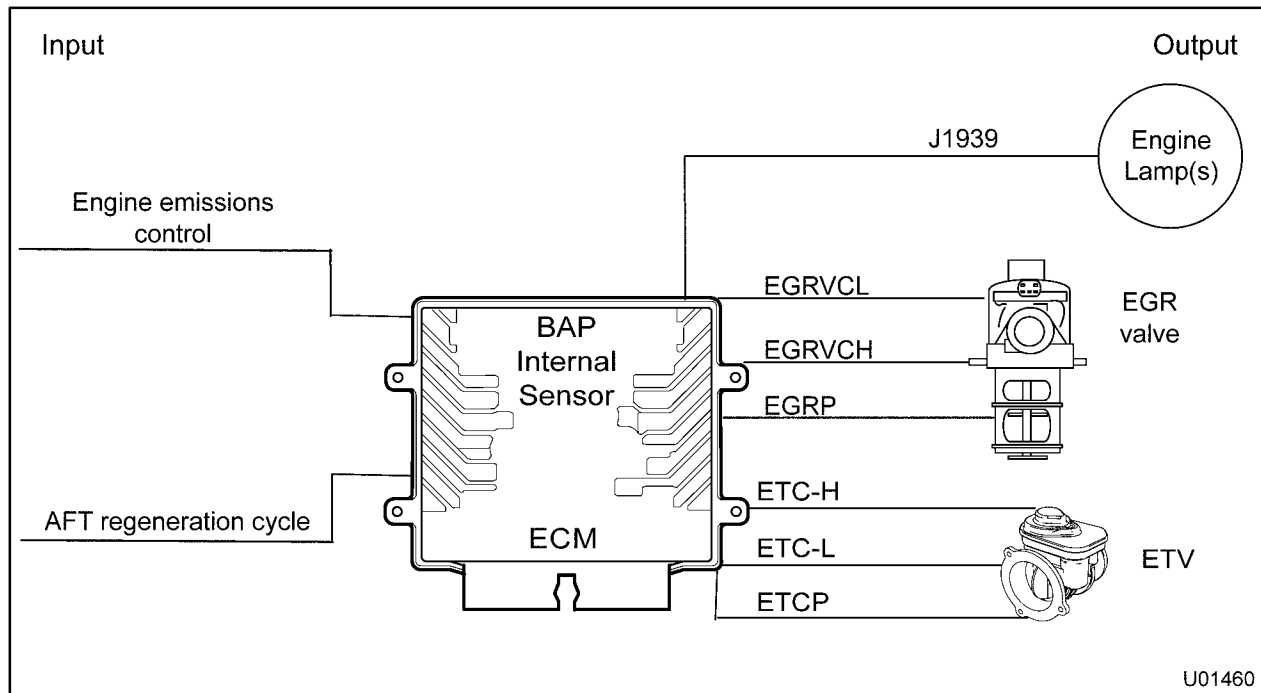
The EFT is a thermistor sensor supplied with a 5-volt reference voltage at Pin 2 from ECM Pin E-67. The sensor is grounded at Pin 1 from ECM Pin E-07. As temperature increases, the resistance of the thermistor decreases. This causes the signal voltage to decrease.

Fault Detection/Management

The ECM continuously monitors the control system. If the sensor signal is higher or lower than expected, the ECM disregards the signal and uses a calibrated default value. The ECM sets a DTC, turns on the Warn Engine Lamp (WEL), and runs the engine in a default range.

EGR Valve (Exhaust Gas Recirculation)

SPN	FMI	Condition
27	3	EGRP signal Out of Range HIGH
27	4	EGRP signal Out of Range LOW
27	10	EGRP signal abnormal rate of change
2791	3	EGRC short to PWR
2791	4	EGRC short to GND
2791	5	EGRC open load/circuit
2791	7	EGRC Unable to achieve desired set-point
2791	17	EGRC Unable to achieve desired set-point

**Figure 117 Function diagram for the EGR valve**

The EGR system function diagram includes the following:

- Exhaust Gas Recirculation (EGR) valve assembly with integrated EGR Position (EGRP) sensor
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Engine Throttle Valve (ETV)
- Engine Lamp(s)

Function

NO_x in the atmosphere contributes to the production of smog. NO_x is formed when temperature in the combustion chamber gets too hot.

The EGR system is used to reduce the amount of NO_x created by the engine. Exhaust gases that have already burned do not have oxygen. The EGR valve recirculates exhaust back into the intake stream. This cools the combustion process and reduces the formation of NO_x .

Component Location

The EGR valve is installed in the EGR valve elbow housing between the ETV and the intake manifold.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 3-Banana Plug Harness ZTSE4498
- 500-Ohm Resistor Harness
- 1180–N4–0X0 – 180-Pin Breakout Box
- Breakout Harness ZTSE4735A (EGR)
- International® Electronic Engine Terminal Test Kit ZTSE4435C

EGR Valve End Diagnostics

SPN	FMI	Condition	Possible Causes
27	3	EGRP signal Out of Range HIGH	• Failed H-Bridge circuit due to undervoltage, overcurrent, or overtemperature
27	4	EGRP signal Out of Range LOW	• EGRP signal circuit short to PWR • EGRP signal circuit OPEN or short to GND • VREF circuit OPEN or short to GND • Failed EGR assembly
27	10	EGRP signal abnormal rate of change	• EGRVCH control circuit fault • EGRVCL control circuit fault
2791	3	EGRC short to PWR	• Failed H-Bridge circuit due to undervoltage, overcurrent, or overtemperature.
2791	4	EGRC short to GND	• EGRP signal circuit OPEN or short to GND • Failed EGRP sensor • VREF circuit OPEN
2791	5	EGRC open load/circuit	• EGRP circuit fault • Failed ETC actuator
2791	7	EGRC Unable to achieve desired set-point	• EGRC-H Control Circuit Fault • EGRC-L Control Circuit Fault
2791	17	EGRC Unable to achieve desired set-point	• EGRC-H Control Circuit Fault • EGRC-L Control Circuit Fault

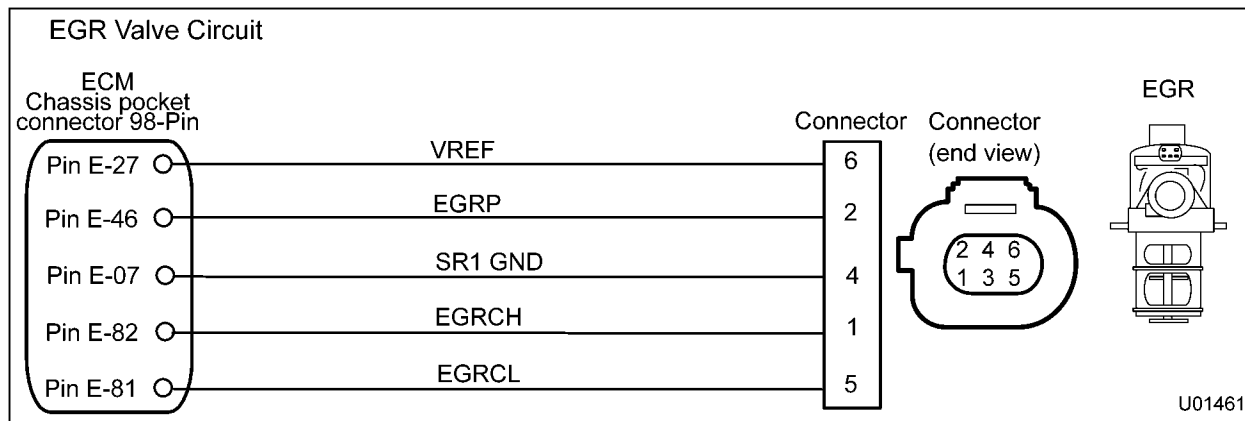


Figure 118 EGR valve circuit diagram

! WARNING: To prevent personal injury or death, stay clear of rotating parts (belts and fan) and hot engine surfaces.

1. Using Electronic Service Tool (EST) with ServiceMaxx™ software, open the Continuous Monitor session.
2. Verify sensor voltage is within Key On Engine Off (KOEO) specification. See "Appendix A: Performance Specifications" (page 425).
3. Monitor sensor voltage. Verify an active Diagnostic Trouble Code (DTC) for the sensor.
 - If DTC is inactive, monitor the signal while wiggling the connector and all wires at suspected location. If the circuit is interrupted, the signal spikes and the DTC goes active.
 - If DTC is active, proceed to the next step.
4. Disconnect engine harness from sensor.

NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

5. Connect breakout harness to engine harness. Leave sensor disconnected.

EGR Valve Circuit Check

Connect Breakout Harness ZTSE4735A. Leave EGR actuator disconnected. Turn the ignition switch to ON. Use Electronic Service Tool (EST) with ServiceMaxx™ software to monitor signal and DMM to measure voltage during Continuous Monitor test.

NOTE: Clear DTC after each test step and watch voltage value before it changes to error.

Test Point	Spec	Comments
EST - Monitor EGRP	0 V	If > .039 V, check EGRP signal for short to PWR.
DMM - Measure volts 1 to GND	5 V ± 0.5 V	If > 5.5 V, check VREF for short to PWR. If < 4.5 V, check VREF for OPEN or short to GND. Do Harness Resistance Check (page 243).
EST - Monitor EGRP Short 500-ohm Resistor Harness across 1 and 5	5 V	If < 4.5 V, check EGRP signal for OPEN or short to GND. Do Harness Resistance Check (page 243).
DMM - Measure resistance 3 to GND	< 5 Ω	If > 5 Ω, check SIG GND for OPEN. Do Harness Resistance Check (page 243).
If checks are within specification, do EGR Valve - Standard and Output State Test (page 241).		

EGR Valve - Standard and Output State Test

Connect Breakout Harness ZTSE4735A between ECM and EGR actuator. Run Key On Engine Off (KOEO). Use Electronic Service Tool (EST) with ServiceMaxx™ software to monitor EGRP volts.

Test	Spec	Comment
Output State HIGH	100%	If > 10%, check for OPEN or short in EGRC circuits. Do Harness Resistance Check (page 243).
Output State LOW	0%	If < 90%, check for OPEN or short in EGRC circuits. Do Harness Resistance Check (page 243).

EGR Valve Pin-point Diagnostics

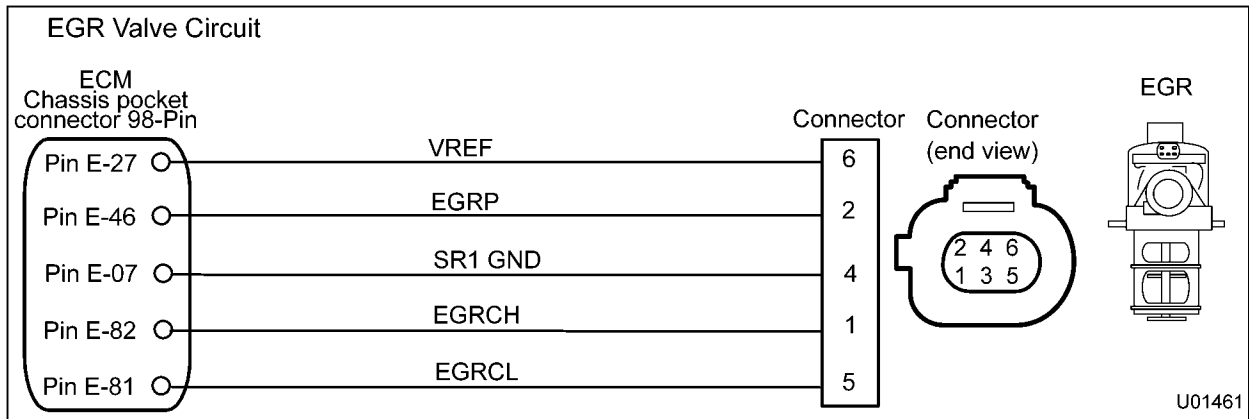


Figure 119 EGR valve circuit diagram

Connector Voltage Check

Connect Breakout Harness ZTSE4735A. Leave actuator disconnected. Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
4 to GND	0 V	If > 0.25 V, check SIG GND for short to PWR.
6 to GND	5 V ± 0.5 V	If > 5.5 V, check VREF for short to PWR. If < 4.5 V, check VREF for OPEN or short to GND. Do Harness Resistance Check (page 243).
5 to GND	B+	If < B+, check EGRVCL for OPEN or short to GND. Do Harness Resistance Check (page 243).
1 to GND	B+	If < B+, check EGRVCH for OPEN or short to GND. Do Harness Resistance Check (page 243).
2 to GND	0 V	If > 0.25 V, check EGRP for short to PWR. Do Harness Resistance Check (page 243).
If checks are within specification, do EGR Actuator - Output State Test (page 241).		

Connector Resistance Check to GND

Turn ignition switch to OFF. Connect Breakout Harness ZTSE4735A. Leave actuator disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
6 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
4 to GND	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
5 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
1 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.

Harness Resistance Check

Turn ignition switch to OFF. Disconnect battery GND and B+ ECM connector. Connect 180-Pin Breakout Box and Breakout Harness ZTSE4735A. Leave ECM and actuator disconnected. Use DMM to measure resistance.



WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect main negative battery cable last.

Test Point	Spec	Comment
6 to E-27	< 5 Ω	If > 5 Ω , check VREF circuit for OPEN.
4 to E-07	< 5 Ω	If > 5 Ω , check SIG GND circuit for OPEN.
2 to E-46	< 5 Ω	If > 5 Ω , check EGRP signal circuit for OPEN.
5 to E-81	< 5 Ω	If > 5 Ω , check EGRVCL circuit for OPEN.
1 to E-82	< 5 Ω	If > 5 Ω , check EGRVCH circuit for OPEN.

EGR Valve Circuit Operation**EGR Position (EGRP) sensor**

NOTE: The EGR valve is integrated with an EGRP sensor.

The EGRP is a potentiometer sensor supplied with a 5-volt reference voltage at Pin 6 from ECM Pin E-27. The sensor is grounded at Pin 4 from ECM Pin E-07. The sensor returns a variable voltage signal from Pin 2 to ECM Pin E-46.

EGR Actuator

The ECM controls the EGR valve with a Pulse Width Modulation (PWM) signal through H-bridge circuitry.

PWM voltage is supplied by a series of pulses. To control motor speed, it varies (modulates) the width of the pulses.

H-bridge is a bipolar circuit. The ECM controls the EGR valve to close by driving the EGRVCH circuit high and EGRVCL circuit low. The opposite occurs then the valve is commanded open.

Variable voltage is needed to move the valve. Minimal voltage is needed to maintain its position.

Fault Detection/Management

The ECM monitors the internal BAP sensor as a base line for zeroing the IMP signals.

The ECM continuously monitors the EGRP sensor. If the sensor signal is higher or lower than expected, the ECM sets a DTC and turns on the Amber Warning Lamp (AWL).

An open or short on the EGR controlling circuits can only be detected by an on-demand output circuit

check during KOEO. If there is a circuit fault detected, a DTC sets.

EGRT Sensor (Exhaust Gas Recirculation Temperature)

SPN FMI Condition

412	0	EGRT above Critical Temperature
412	3	EGRT signal Out of Range HIGH
412	4	EGRT signal Out of Range LOW
412	10	EGRT Abnormal Rate of Change

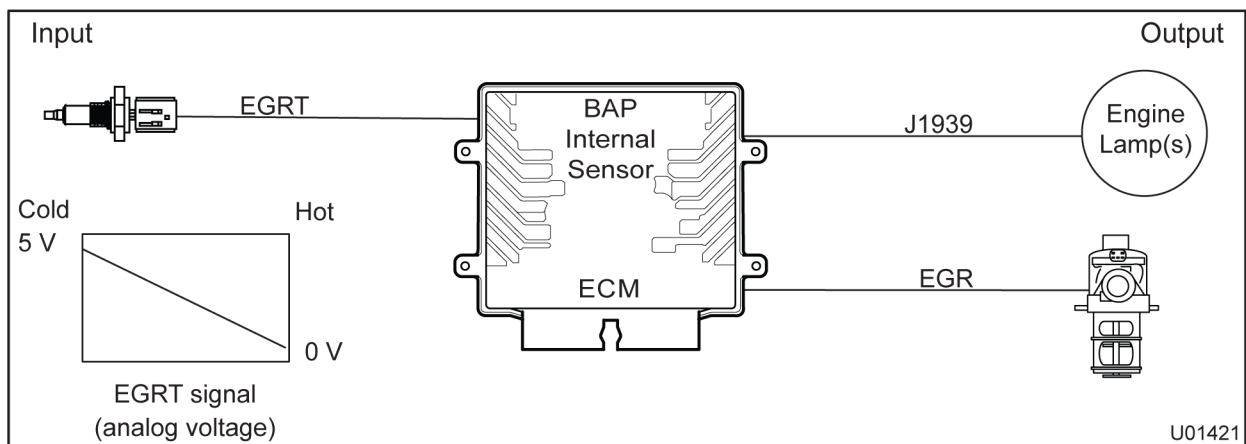


Figure 120 Function diagram for the EGRT sensor

The EGRT sensor function diagram includes the following:

- Exhaust Gas Recirculation Temperature (EGRT) sensor
- Exhaust Gas Recirculation (EGR) valve
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Engine Lamp(s)

Function

The EGRT sensor provides a feedback signal to the ECM indicating intake manifold air temperature. The ECM controls the EGR system by providing for the Advance EGR Combustion System additional engine protection.

Sensor Location

The EGRT sensor is installed after the EGR cooler, in front of the EGR valve.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 3-Banana Plug Harness ZTSE4498
- 1180-N4-0X0 – 180-Pin Breakout Box
- Breakout Harness ZTSE4760A (EGRT)
- International® Electronic Engine Terminal Test Kit ZTSE4435C

EGRT Sensor End Diagnostics

SPN	FMI	Condition	Possible Causes
412	0	EGRT above Critical Temperature	Plugged EGR cooler
412	3	EGRT signal Out of Range HIGH	- EGRT signal OPEN or short to PWR - SIG GND circuit OPEN - Failed sensor
412	4	EGRT signal Out of Range LOW	- EGRT signal circuit short to GND - Failed sensor
412	10	EGRT signal Abnormal Rate of Change	EGRT biased circuit or sensor

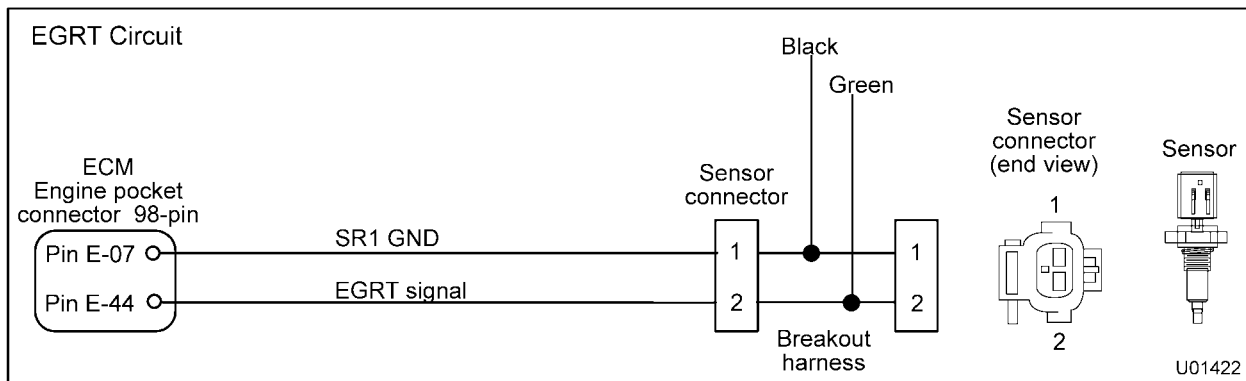


Figure 121 EGRT circuit diagram

! WARNING: To prevent personal injury or death, stay clear of rotating parts (belts and fan) and hot engine surfaces.

- Using Electronic Service Tool (EST) with ServiceMaxx™ software, open the Continuous Monitor session.
- Monitor sensor voltage. Verify an active Diagnostic Trouble Code (DTC) for the sensor.
 - If DTC is inactive, monitor the signal while wiggling the connector and all wires at suspected location. If the circuit is interrupted, the signal spikes and the DTC goes active.

- If DTC is active, proceed to the next step.

- Disconnect engine harness from sensor.

NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

- Connect breakout harness to engine harness. Leave sensor disconnected.

SPN 412 FMI 0 – EGRT above Critical Temperature**EGR Cooler Check**

1. Check for restricted EGR cooler. See EGR Cooler Inspection (page 69) in the “Engine Symptoms Diagnostics” section of this manual.

Sensor Circuit Check

Connect Breakout Harness ZTSE4760A. Leave sensor disconnected. Turn ignition switch to ON. Use Electronic Service Tool (EST) with ServiceMaxx™ software to verify correct DTC goes active when corresponding fault is induced. Use DMM to measure circuits.

Test Point	Spec	Comments
EST - Check DTC	SPN 412 FMI 3	If SPN 412 and FMI 4 is active, check EGRT signal for short to GND. Do Harness Resistance Check (page 248).
EST - Check DTC Short a 3-banana plug harness across 2 and GND	SPN 412 FMI 4	If SPN 412 and FMI 3 is active, check EGRT signal for OPEN. Do Harness Resistance Check (page 248).
EST - Check DTC Short a 3-banana plug harness across 1 and 2	SPN 412 FMI 4	If SPN 412 and FMI 3 is active, check SIG GND for OPEN. Do Harness Resistance Check (page 248).
If checks are within specification, connect sensor and clear DTCs. If active DTC remains, replace sensor.		

EGRT Pin-point Diagnostics**Connector Voltage Check**

Connect Breakout Harness ZTSE4760A. Leave sensor disconnected. Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
1 to GND	0 V	If > 0.25 V, check for short to PWR.
2 to GND	4.6 V to 5 V	If < 4.5 V, check for OPEN or short to GND. Do Harness Resistance Check (page 248).

Connector Resistance Check to GND

Turn ignition switch to OFF. Connect Breakout Harness ZTSE4760A. Leave sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to GND	< 5 Ω	If > 5 Ω, check for OPEN circuit.
2 to GND	> 1 kΩ	If < 1 kΩ, check for short to GND.

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box and Breakout Harness ZTSE4760A. Leave ECM and sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to E-07	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to E-44	< 5 Ω	If > 5 Ω , check for OPEN circuit.

EGRT Circuit Operation

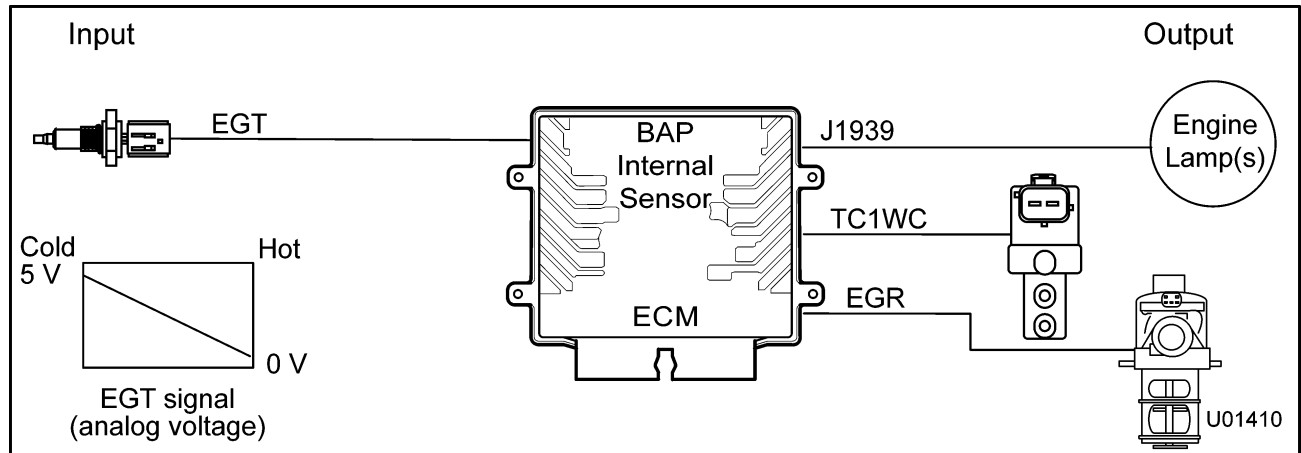
The EGRT is a thermistor sensor that is supplied with a 5-volt reference voltage at Pin 2 from ECM Pin E-44. The sensor is grounded at Pin 1 from ECM Pin E-07. As the temperature increases, the resistance of the thermistor decreases. This causes the signal voltage to decrease.

Fault Detection/Management

The ECM continuously monitors the control system. If the sensor signal is higher or lower than expected, the ECM disregards the sensor signal and uses a calibrated default value. The ECM sets a DTC, turns on the Amber Warning Lamp (AWL), and runs the engine in a default range.

EGT Sensor (Exhaust Gas Temperature)**SPN FMI Condition**

173	0	Exhaust Gas System above Critical Temperature
173	3	EGT signal Out of Range HIGH
173	4	EGT signal Out of Range LOW

**Figure 122 Function diagram for the EGT sensor**

The EGT sensor function diagram includes the following:

- Exhaust Gas Temperature (EGT) sensor
- Exhaust Gas Recirculation (EGR) valve
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Turbocharger 1 Wastegate Control (TC1WC)
- Engine Lamp(s)

Function

The EGT sensor provides a feedback signal to the ECM indicating exhaust gas temperature.

Sensor Location

The EGT sensor is installed before the EGR cooler and after the exhaust manifold.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 3-Banana Plug Harness ZTSE4498
- 1180–N4–0X0 – 180-Pin Breakout Box
- Breakout Harness ZTSE4946 (EGT)
- International® Electronic Engine Terminal Test Kit ZTSE4435C

EGT Sensor End Diagnostics

SPN	FMI	Condition	Possible Causes
173	3	Exhaust Gas System above Critical Temperature	• EGT signal OPEN or short to PWR • SIG GND circuit OPEN • Failed sensor
173	3	EGT signal Out of Range HIGH	• EGT signal OPEN or short to PWR • SIG GND circuit OPEN • Failed sensor
173	4	EGT signal Out of Range LOW	• EGT signal circuit short to GND • Failed sensor

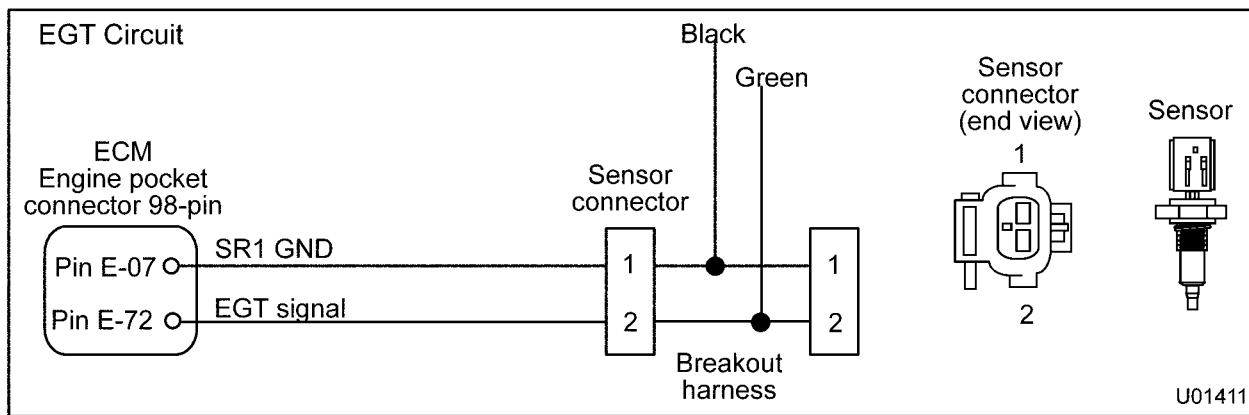


Figure 123 EGT circuit diagram

! WARNING: To prevent personal injury or death, stay clear of rotating parts (belts and fan) and hot engine surfaces.

1. Using Electronic Service Tool (EST) with ServiceMaxx™ software, open the Continuous Monitor session.
2. Monitor sensor voltage. Verify an active Diagnostic Trouble Code (DTC) for the sensor.
 - If DTC is inactive, monitor the signal while wiggling the connector and all wires at suspected location. If the circuit is interrupted, the signal spikes and the DTC goes active.

- If DTC is active, proceed to the next step.

3. Disconnect engine harness from sensor.

NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

4. Connect breakout harness to engine harness. Leave sensor disconnected.

Sensor Circuit Check

Connect sensor Breakout Harness ZTSE4946. Leave sensor disconnected. Turn ignition switch to ON. Use Electronic Service Tool (EST) with ServiceMaxx™ software to verify correct DTC goes active when corresponding fault is induced. Use DMM to measure circuits.

Test Point	Spec	Comments
EST - Check DTC	SPN 173 FMI 3	If SPN 173 and FMI 4 is active, check EGT signal for short to GND. Do Harness Resistance Check (page 252).
EST - Check DTC Short a 3-banana plug harness across 2 and GND	SPN 173 FMI 4	If SPN 173 and FMI 3 is active, check EGT signal for OPEN. Do Harness Resistance Check (page 252).
EST - Check DTC Short a 3-banana plug harness across 1 and 2	SPN 173 FMI 4	If SPN 173 and FMI 3 is active, check SIG GND for OPEN. Do Harness Resistance Check (page 252).
If checks are within specification, connect sensor and clear DTCs. If active DTC remains, replace sensor.		

EGT Pin-point Diagnostics**Connector Voltage Check**

Connect Breakout Harness ZTSE4946. Leave sensor disconnected. Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
1 to GND	0 V	If > 0.25 V, check for short to PWR.
2 to GND	4.6 V to 5 V	If < 4.5 V, check for OPEN or short to GND. Do Harness Resistance Check (page 252).

Connector Resistance Check to GND

Turn ignition switch to OFF. Connect Breakout Harness ZTSE4946. Leave sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to GND	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box and Breakout Harness ZTSE4946. Leave ECM and sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to E-07	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to E-72	< 5 Ω	If > 5 Ω , check for OPEN circuit.

EGT Circuit Operation

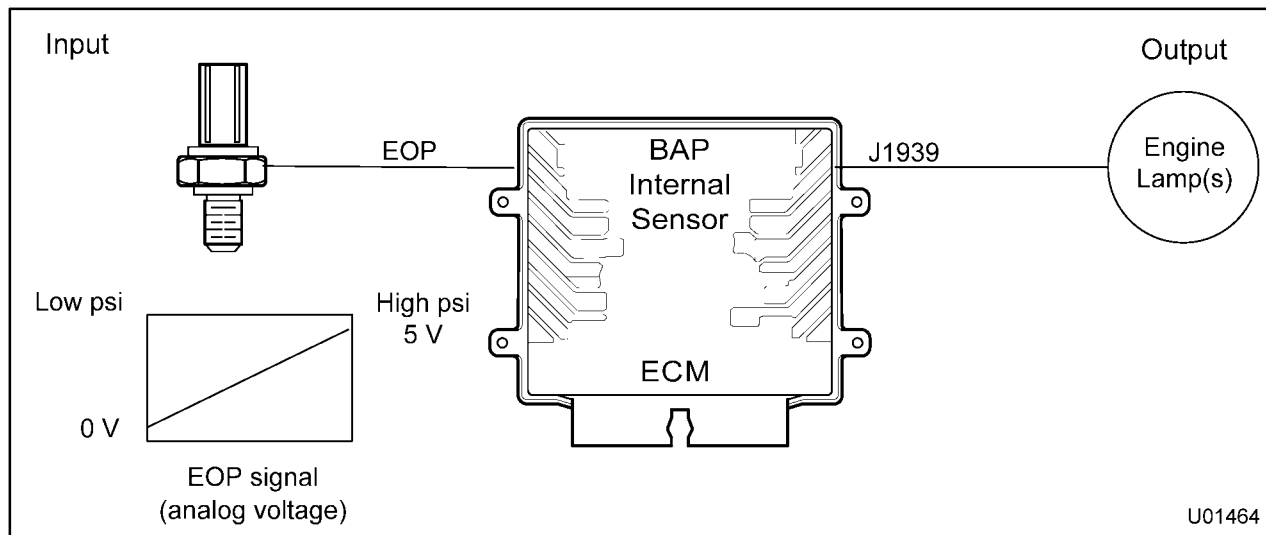
The EGT is a thermistor sensor that is supplied with a 5-volt reference voltage at Pin 2 from ECM Pin E-72. The sensor is grounded at Pin 1 from ECM Pin E-07. As the temperature increases, the resistance of the thermistor decreases. This causes the signal voltage to decrease.

Fault Detection/Management

The ECM continuously monitors the control system. If the sensor signal is higher or lower than expected, the ECM disregards the sensor signal and uses a calibrated default value. The ECM sets a DTC, turns on the Amber Warning Lamp (AWL), and runs the engine in a default range.

EOP Sensor (Engine Oil Pressure)

SPN	FMI	Condition
100	3	EOP signal Out of Range HIGH
100	4	EOP signal Out of Range LOW
100	10	EOP signal abnormal rate of change

**Figure 124 Function diagram for the EOP sensor**

The EOP sensor function diagram includes the following:

- Engine Oil Pressure (EOP) sensor
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Engine Lamp(s)

Function

The EOP sensor provides a feedback signal to the ECM indicating engine oil pressure. During engine operation, the ECM monitors the EOP signal to determine if oil pressure is satisfactory. If oil pressure is below required pressure, the ECM turns on the Amber Warning Lamp (AWL).

The Engine Warning Protection System (EWPS) can be enabled to warn the engine operator, derate the engine, and shut down the engine when a low engine oil pressure occurs.

Sensor Location

The EOP sensor is installed in the oil cooler assembly on the top of the engine.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 3-Banana Plug Harness ZTSE4498
- 1180–N4–0X0 – 180-Pin Breakout Box
- Breakout Harness ZTSE4850 (EOP)
- International® Electronic Engine Terminal Test Kit ZTSE4435C

EOP Sensor End Diagnostics

SPN	FMI	Condition	Possible Causes
100	3	EOP signal Out of Range HIGH	- EOP signal circuit short to PWR - Failed sensor
100	4	EOP signal Out of Range LOW	- EOP signal circuit OPEN or short to GND - VREF circuit OPEN - Failed sensor
100	10	EOP abnormal rate of change	- EOP biased circuit or sensor - Engine oil circuit restricted

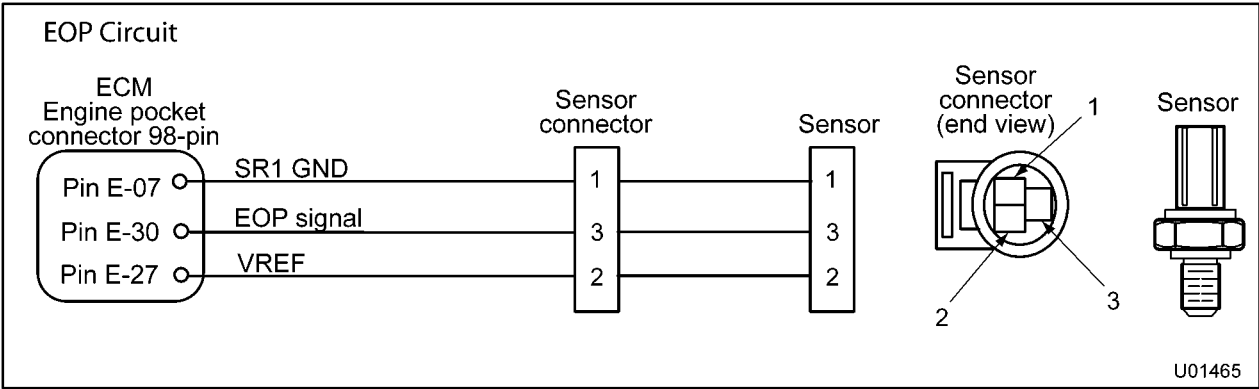


Figure 125 EOP circuit diagram

⚠ WARNING: To prevent personal injury or death, stay clear of rotating parts (belts and fan) and hot engine surfaces.

1. Using Electronic Service Tool (EST) with ServiceMaxx™ software, open the Continuous Monitor session.
2. Verify sensor voltage is within KOEO specification. See "Appendix A: Performance Specifications" (page 425).
3. Monitor sensor voltage. Verify an active Diagnostic Trouble Code (DTC) for the sensor.
 - If DTC is inactive, wiggle the connector and all wires at suspected location. If the circuit is interrupted, the DTC goes active.
 - If DTC is active, proceed to the next step.

4. Disconnect engine harness from sensor.

NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

5. Connect breakout harness to engine harness. Leave sensor disconnected.

Sensor Circuit Check

Connect sensor Breakout Harness ZTSE4850. Leave sensor disconnected. Turn ignition switch to ON. Use ServiceMaxx™ to verify correct DTC goes active when corresponding fault is induced. Use DMM to measure circuits.

Test Point	Spec	Comments
EST - Check DTC	SPN 100 FMI 3	If SPN 100/FMI 3 is active, check EOP signal for short to PWR.
DMM – Measure volts 2 to GND	5 V ± 0.5 V	If > 5.5 V, check VREF for short to PWR. If < 4.5 V, check VREF for OPEN or short to GND. Do Harness Resistance Check (page 257).
EST - Check DTC Short Breakout Harness ZTSE4850 across 2 and 3	SPN 100 FMI 4	If SPN 100/FMI 4 is active, check EOP signal for OPEN. Do Harness Resistance Check (page 257).
DMM – Measure resistance 1 to GND	< 5 Ω	If > 5 Ω, check SIG GND for OPEN. Do Harness Resistance Check (page 257).
If checks are within specification, connect sensor and clear DTC. If active code remains, replace sensor.		

EOP Pin-point Diagnostics

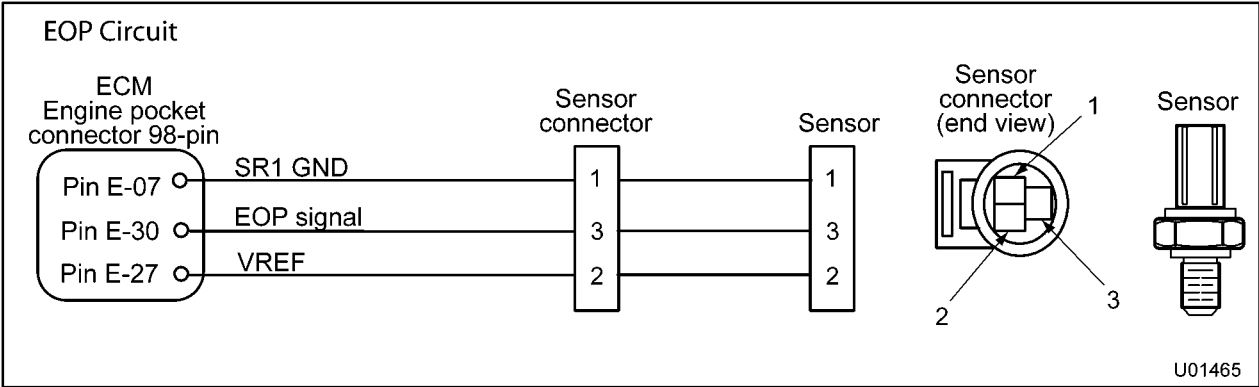


Figure 126 EOP circuit diagram

Connector Voltage Check

Connect Breakout Harness ZTSE4850. Leave sensor disconnected. Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
1 to GND	0 V	If > 0.25 V, check for short to PWR.
2 to GND	5 V $\pm$ 0.5 V	If > 5.5 V, check VREF for short to PWR. If < 4.5 V, check VREF for OPEN or short to GND. Do Harness Resistance Check (page 257).
3 to GND	0 V	If > 0.25 V, check for short to PWR. Do Harness Resistance Check (page 257).

Connector Resistance Check to GND

Turn ignition switch to OFF. Connect Breakout Harness ZTSE4850. Leave sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to GND	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
3 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box and Breakout Harness ZTSE4850. Leave ECM and sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to E-07	< 5 Ω	If > 5 Ω , check SIG GND circuit for OPEN.
2 to E-27	< 5 Ω	If > 5 Ω , check VREF circuit for OPEN.
3 to E-30	< 5 Ω	If > 5 Ω , check EOP signal circuit for OPEN.

EOP Circuit Operation

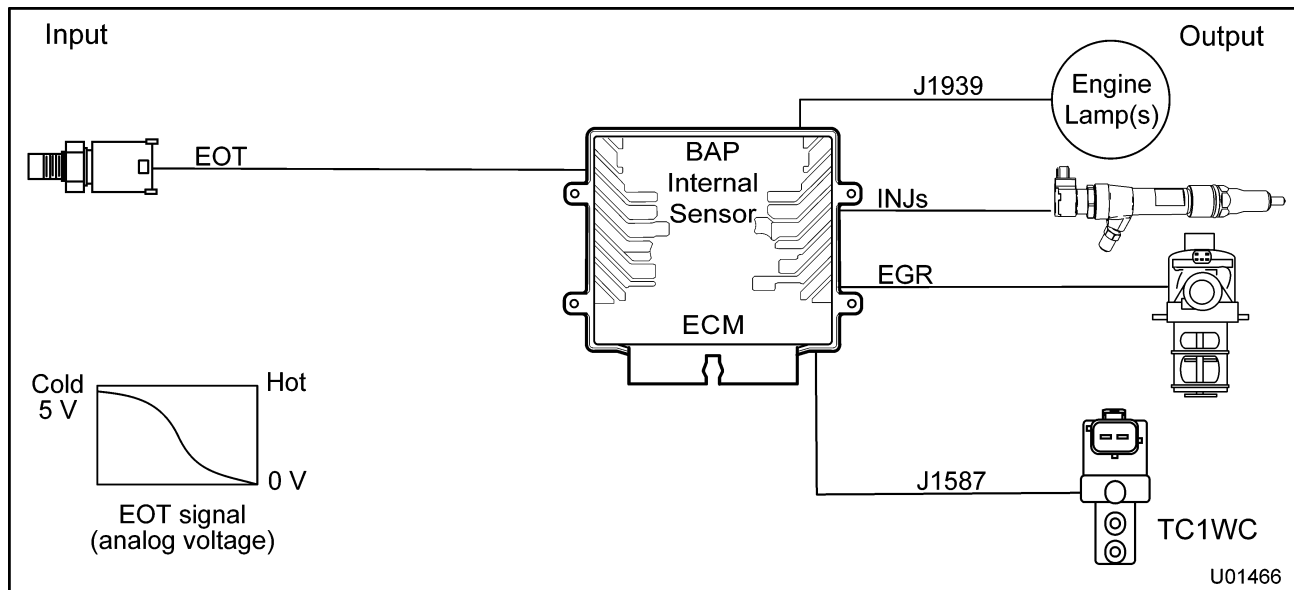
The EOP sensor is a variable capacitance sensor supplied with a 5-volt reference voltage at Pin 2 from ECM Pin E-27. The sensor is grounded at Pin 1 from ECM Pin E-07. The sensor returns a variable voltage signal from Pin 3 to ECM Pin E-30.

Fault Detection/Management

The ECM continuously monitors the control system. If the sensor signal is higher or lower than expected, the ECM will enable the EWPS, sets a DTC, and turns on the AWL.

EOT Sensor (Engine Oil Temperature)

SPN	FMI	Condition
175	3	EOT signal Out of Range HIGH
175	4	EOT signal Out of Range LOW
175	10	EOT abnormal rate of change

**Figure 127 Function diagram for the EOT sensor**

The EOT sensor function diagram includes the following:

- Engine Oil Temperature (EOT) sensor
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Fuel injectors (INJ)
- Exhaust Gas Recirculation (EGR) valve
- Turbocharger 1 Wastegate Control (TC1WC)
- Engine Lamp(s)

Function

The EOT sensor provides a feedback signal to the ECM indicating engine oil temperature. The ECM monitors the EOT signal to control fuel quantity and timing throughout the operating range of the engine. The EOT signal allows the ECM to compensate for oil

viscosity variations due to temperature changes in the operating environment, ensuring adequate power and torque are available for all operating conditions.

Fast Idle Advance

Fast idle advance increases engine cold idle speed up to 750 rpm (normally 700 rpm) for faster warmup to operating temperature. The ECM monitors the EOT sensor input and adjusts the fuel injector operation accordingly.

Low idle speed is increased proportionally with engine oil temperature between 15 °C (59 °F) at 700 rpm to below -10 °C (14 °F) at 750 rpm.

Sensor Location

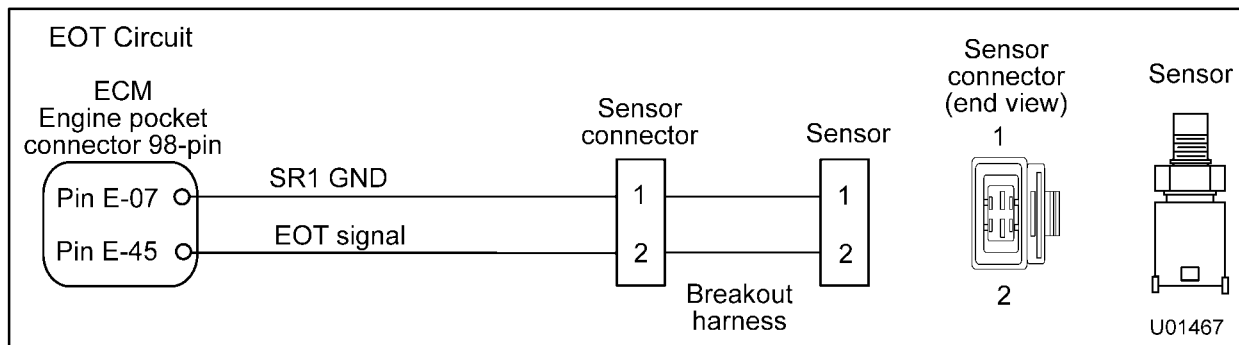
The EOT sensor is installed in the base of the oil cooler housing assembly, located on top of the engine, next to the EOP sensor.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 3-Banana Plug Harness ZTSE4498
- 1180–N4–0X0 – 180-Pin Breakout Box
- Breakout Harness ZTSE4602 (EOT)
- International® Electronic Engine Terminal Test Kit ZTSE4435C

EOT Sensor End Diagnostics

SPN	FMI	Condition	Possible Causes
175	3	EOT signal Out of Range HIGH	• EOT signal circuit short to GND • Failed sensor
175	4	EOT signal Out of Range LOW	• Biased EOT circuit or sensor
175	10	EOT abnormal rate of change	• EOT biased circuit or sensor • Engine oil circuit restricted

**Figure 128 EOT circuit diagram**

⚠ WARNING: To prevent personal injury or death, stay clear of rotating parts (belts and fan) and hot engine surfaces.

1. Using Electronic Service Tool (EST) with ServiceMaxx™ software, open the Continuous Monitor session.
2. Monitor sensor voltage. Verify an active Diagnostic Trouble Code (DTC) for the sensor.
 - If DTC is inactive, wiggle the connector and all wires at suspected location. If the circuit is interrupted, the DTC goes active.
 - If DTC is active, proceed to the next step.
3. Disconnect engine harness from sensor.

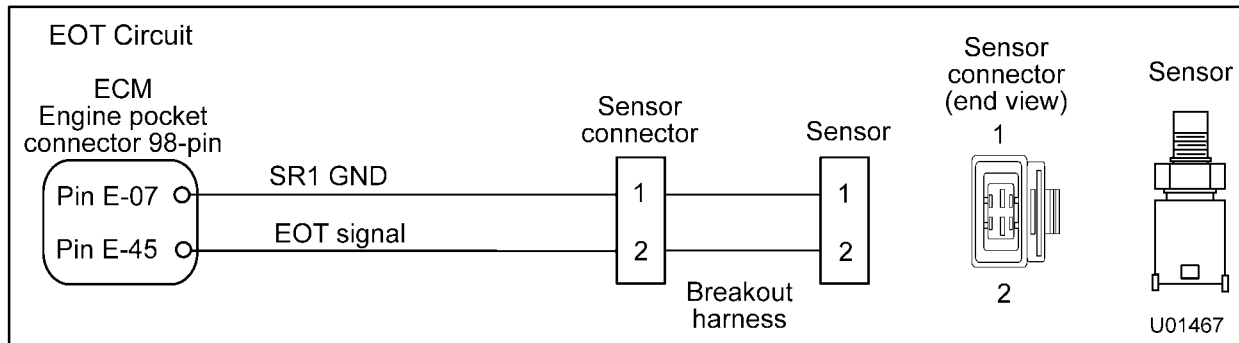
NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

4. Connect breakout harness to engine harness. Leave sensor disconnected.

Sensor Circuit Check

Connect sensor Breakout Harness ZTSE4602. Leave sensor disconnected. Turn ignition switch to ON. Use ServiceMaxx™ software to verify correct DTC goes active when corresponding fault is induced. Use DMM to measure circuits.

Test Point	Spec	Comments
EST- Check DTC	SPN 175 FMI 4	If SPN 175/FMI 4 is active, check EOT signal for short to GND. Do Harness Resistance Check (page 262).
EST - Check DTC Short 3-banana plug harness across 2 and GND	SPN 175 FMI 4	If SPN 175/FMI 4 is active, check EOT signal for OPEN. Do Harness Resistance Check (page 262).
EST - Check DTC Short 3-banana plug harness across 1 and 2	SPN 175 FMI 4	If SPN 175/FMI 4 is active, check SIG GND for OPEN. Do Harness Resistance Check (page 262).
If checks are within specification, connect sensor and clear DTCs. If active DTC remains, replace sensor.		

EOT Pin-point Diagnostics**Figure 129 EOT circuit diagram****Connector Voltage Check**

Connect Breakout Harness ZTSE4602. Leave sensor disconnected. Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
1 to GND	0 V	If > 0.25 V, check for short to PWR.
2 to GND	4.6 V to 5 V	If < 4.5 V, check for OPEN or short to GND. Do Harness Resistance Check (page 262).

Connector Resistance Check to GND

Turn ignition switch to OFF. Connect Breakout Harness ZTSE4602. Leave sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to GND	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box and Breakout Harness ZTSE4602. Leave ECM and sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to E-28	< 5 Ω	If > 5 Ω, check for OPEN circuit.
2 to E-66	< 5 Ω	If > 5 Ω, check for OPEN circuit.

EOT Circuit Operation

The EOT is a thermistor sensor supplied with a 5-volt reference voltage at Pin 2 from ECM Pin E-45. The sensor is grounded at Pin 1 from ECM Pin E-07. As temperature increases, resistance of the thermistor decreases. This causes signal voltage to decrease.

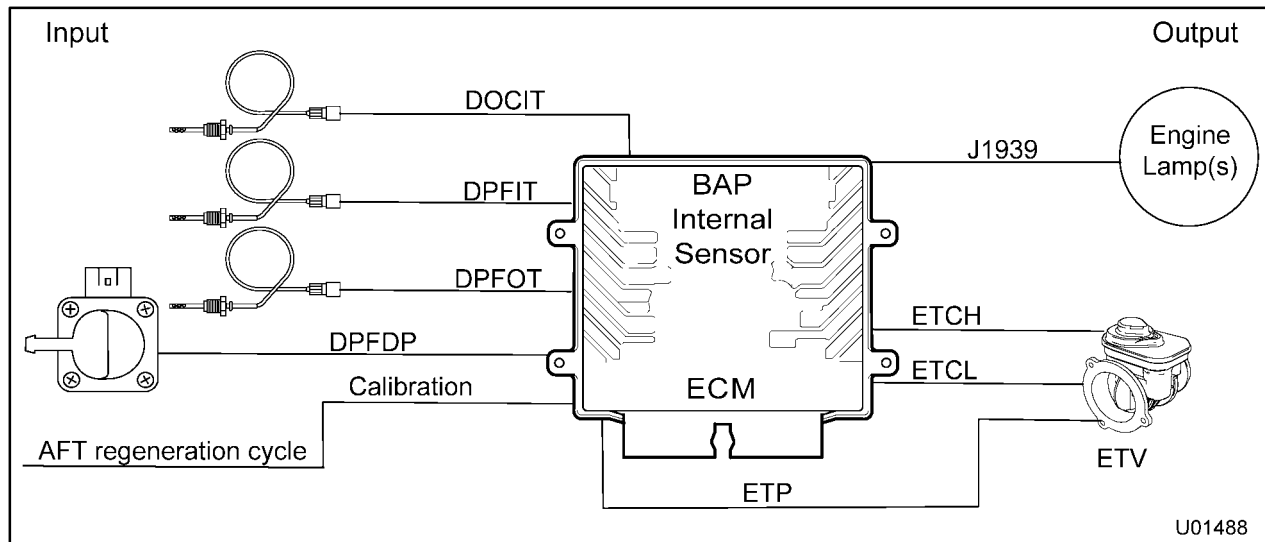
the ECM disregards the sensor signal and uses a calibrated default value. The ECM sets a DTC, turns on the Amber Warning Lamp (AWL), and runs the engine in a default range of -20 °C (-4 °F) for starting and 100 °C (212 °F) for engine running conditions.

Fault Detection/Management

The ECM continuously monitors the control system. If the sensor signal is higher or lower than expected,

ETV (Engine Throttle Valve)

SPN	FMI	Condition
51	3	ETP signal Out of Range HIGH
51	4	ETP signal Out of Range LOW
51	10	ETP signal abnormal rate of change
3464	3	ETC short to PWR
3464	4	ETC short to GND
3464	5	ETC open load/circuit

**Figure 130 Function diagram for the ETV**

The ETV function diagram includes the following:

- Engine Throttle Valve (ETV)
- Engine Throttle Control High (ETCH)
- Engine Throttle Control Low (ETCL)
- Engine Throttle Position (ETP) sensor
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Engine Lamp(s)
- DPF Differential Pressure (DPFDP) sensor
- DOC Inlet Temperature 1 (DOCIT) sensor

- DPF Inlet Temperature 2 (DPFIT) sensor
- DPF Outlet Temperature 3 (DPFOT) sensor

Function

The ETV is a variable-position actuator that restricts intake air flow to help heat the exhaust aftertreatment during regeneration.

Component Location

The ETV is mounted on the EGR valve elbow housing on the top front of the engine.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 3-Banana Plug Harness ZTSE4498
- 1180–N4–0X0 – 180-Pin Breakout Box
- Breakout Harness ZTSE4735A (ETC)
- International® Electronic Engine Terminal Test Kit ZTSE4435C

ETV End Diagnostics

SPN	FMI	Condition	Possible Causes
51	3	ETP signal Out of Range HIGH	• ETP signal circuit short to PWR • Failed ETP sensor
51	4	ETP signal Out of Range LOW	• ETP signal circuit OPEN or short to GND • Failed ETP sensor • VREF circuit OPEN
51	10	ETP signal abnormal rate of change	• ETP circuit fault • Failed ETP actuator
3464	3	ETC short to PWR	• ETCH control circuit fault • ETCL control circuit fault
3464	4	ETC short to GND	• ETCH control circuit fault • ETCL control circuit fault
3464	5	ETC open load/circuit	• ETCH control circuit fault • ETCL control circuit fault

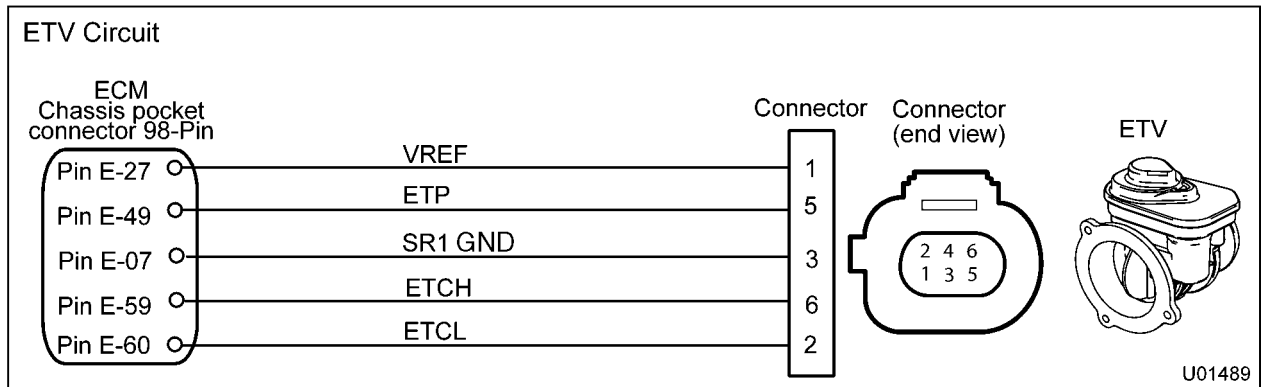


Figure 131 ETV circuit diagram

! WARNING: To prevent personal injury or death, stay clear of rotating parts (belts and fan) and hot engine surfaces.

1. Using Electronic Service Tool (EST) with ServiceMaxx™ software, open the Continuous Monitor session.
2. Verify sensor voltage is within KOEO specification. See "Appendix A: Performance Specifications" (page 425).

3. Monitor sensor voltage. Verify an active Diagnostic Trouble Code (DTC) for the sensor.

- If DTC is inactive, monitor the signal while wiggling the connector and all wires at suspected location. If the circuit is interrupted, the signal spikes and the DTC goes active.

- If DTC is active, proceed to the next step.

4. Disconnect engine harness from sensor.

NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

5. Connect breakout harness to engine harness. Leave sensor disconnected.

ETV Circuit Check

Connect Breakout Harness ZTSE4735A. Leave ETV connected. Turn the ignition switch to ON. Use Electronic Service Tool (EST) with ServiceMaxx™ software to monitor signal and DMM to measure voltage during Continuous Monitor test.

Test Point	Spec	Comments
EST- Check DTC	SPN 51 FMI 4	If SPN 51/FMI 3, check ETP signal for short to PWR
DMM - Measure volts VREF to GND	5 V ± 0.5 V	If > 5.5 V, check VREF for short to PWR. If < 4.5 V, check VREF for OPEN or short to GND. Do Harness Resistance Check (page 268).
EST - Check DTC Short breakout harness across EGRTP and VREF	SPN 51 FMI 3	If SPN 51/FMI 4, check ETCP signal for OPEN. Do Harness Resistance Check (page 268).
DMM - Measure resistance SR1 GND to GND	< 5 Ω	If > 5 Ω, check SIG GND for OPEN. Do Harness Resistance Check (page 268).
DMM - Measure voltage ETCL to GND	B+	If < B+, check ECTL for OPEN or short to GND. Do Harness Resistance Check (page 268).
DMM - Measure voltage ETCH to GND	B+	If < B+, check ECTH for OPEN or short to GND. Do Harness Resistance Check (page 268).

ETV - Standard Test and Output State Test

Connect Breakout Harness ZTSE4735A between ECM and ETV. Run KOEO test. Use Electronic Service Tool (EST) with ServiceMaxx™ software to monitor ETP volts.

Test	Spec	Comment
Output State HIGH	100%	If < 90%, check for OPEN or short in ETC control circuits. Do Harness Resistance Check (page 268).
Output State LOW	0%	If > 10%, check for OPEN or short in ETC control circuits. Do Harness Resistance Check (page 268).

ETV Pin-point Diagnostics

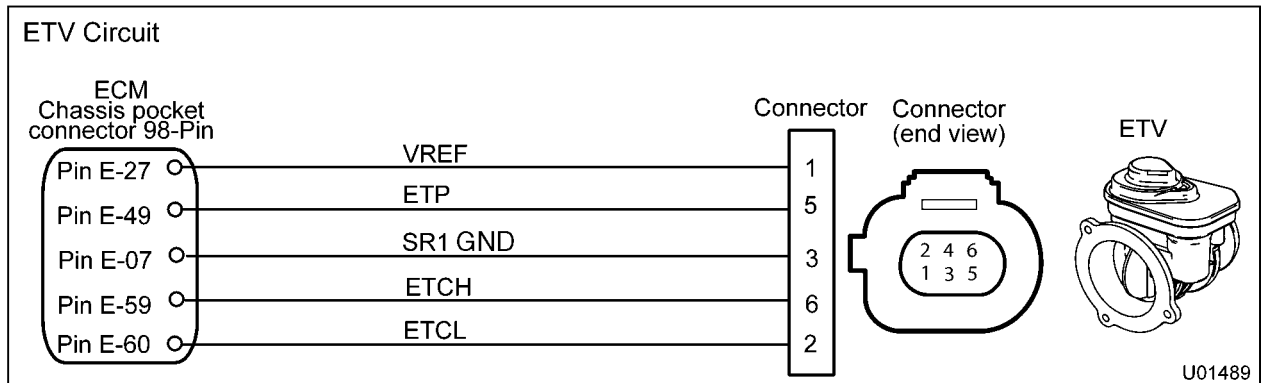


Figure 132 ETV circuit diagram

Connector Voltage Check

Connect Breakout Harness ZTSE4735A. Leave actuator disconnected. Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
3 to GND	0 V	If > 0.25 V, check SIG GND for short to PWR.
1 to GND	5 V ± 0.5 V	If > 5.5 V, check VREF for short to PWR. If < 4.5 V, check VREF for OPEN or short to GND. Do Harness Resistance Check (page 268).
5 to GND	0 V	If > 0.25 V, check ETP for short to PWR. Do Harness Resistance Check (page 268).
2 to GND	B+	If < B+, check ETCL for OPEN or short to GND. Do Harness Resistance Check (page 268).
6 to GND	B+	If < B+, check ETCH for OPEN or short to GND. Do Harness Resistance Check (page 268).
If checks are within specification, do ETV - Standard Test and Output State Test (page 266).		

Connector Resistance Check to GND

Turn ignition switch to OFF. Connect Breakout Harness ZTSE4735A. Leave actuator disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
5 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
3 to GND	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
6 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
1 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box and Breakout Harness ZTSE4735A. Leave ECM and actuator disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
5 to E-49	< 5 Ω	If > 5 Ω , check ETP signal circuit for OPEN.
3 to E-07	< 5 Ω	If > 5 Ω , check SIG GND circuit for OPEN.
2 to E-60	< 5 Ω	If > 5 Ω , check ETCL circuit for OPEN.
6 to E-59	< 5 Ω	If > 5 Ω , check ETCH circuit for OPEN.
1 to E-27	< 5 Ω	If > 5 Ω , check VREF circuit for OPEN.

ETV Circuit Operation

The ETV and ETP sensor are integrated into one component. ETC is the control valve actuator and ETP is the valve position sensor.

ETP (Engine Throttle Position) sensor

The ETP sensor is a potentiometer sensor supplied with a 5-volt reference voltage at Pin 1 from ECM Pin E-27. The sensor is grounded at Pin 3 from ECM Pin E-07. The sensor returns a variable voltage signal from Pin 5 to ECM Pin E-49.

ETV actuator

The ECM controls the ETV with a Pulse Width Modulation (PWM) signal through H-bridge circuitry.

PWM voltage is supplied by a series of pulses. To control motor speed, it varies (modulates) the width of the pulses.

H-bridge is a bipolar circuit. The ECM controls the ETV to close by driving the ETCH circuit high and the ETCL circuit low. The opposite occurs when the valve is commanded open.

Variable voltage is needed to move the valve. Minimal voltage is needed to maintain its position.

Fault Detection/Management

The ECM continuously monitors the ETP sensor. If the sensor signal is higher or lower than expected, the ECM sets a DTC and turns on the Amber Warning Lamp (AWL).

An open or short on the ETV controlling circuits can only be detected by on-demand output circuit check during KOEO test. If there is a circuit fault detected, a DTC is set.

EWPS (Engine Warning Protection System)

SPN	FMI	Condition
94	17	Fuel Delivery Pressure Below Warning
94	31	Fuel Filter Minder Service Interval Now
96	15	Fuel Below Warning Level
100	1	Engine Oil System below Critical Pressure
100	18	Engine Oil System below Warning Pressure
110	0	Engine Coolant System above Critical Temperature
110	15	Engine Coolant System above Warning Temperature
111	1	Low Engine Coolant Level
174	0	Engine Fuel System above Critical Temperature
174	15	Engine Fuel System above Warning Temperature
175	0	Engine Oil System above Critical Temperature
175	15	Engine Oil System above Warning Temperature
190	0	Engine Overspeed - Most Severe Level
2629	15	High Compressor Outlet Temperature

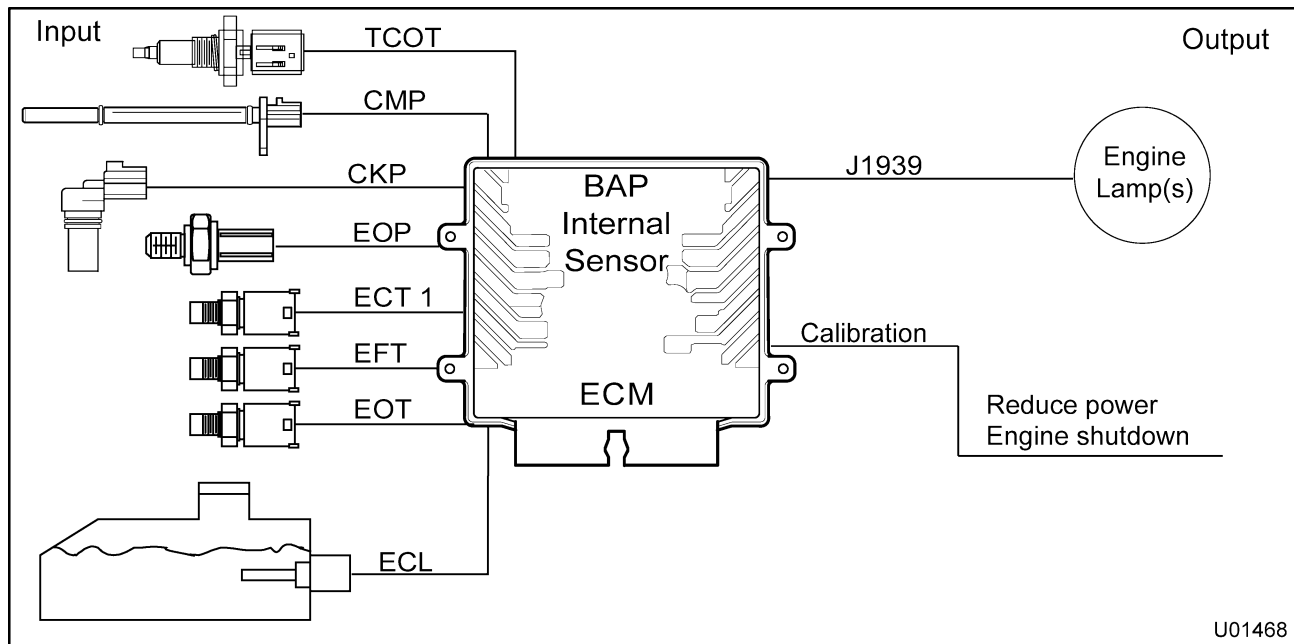


Figure 133 Function diagram for the EWPS

The EWPS function diagram includes the following:

- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Crankshaft Position (CKP) sensor
- Camshaft Position (CMP) sensor
- Engine Oil Pressure (EOP) sensor
- Engine Coolant Temperature 1 (ECT1) sensor
- Engine Coolant Level (ECL) sensor
- Engine Lamp(s)
- Engine Fuel Temperature (EFT) sensor
- Engine Oil Temperature (EOT)
- Turbocharger Compressor Outlet Temperature (TCOT) sensor

Function

The EWPS warns the operator of conditions that can damage the engine.

The Standard Warning System is the base system in which all engines are equipped. If one of these faults are detected, the ECM illuminates the Oil Warning

Lamp (OWL) and sets a corresponding Diagnostic Trouble Code (DTC).

Standard Warning – No engine shutdown available.

- RPM - Engine overspeed warning
- ECT - Engine overhear warning

The following optional features to this base system provide added warning or protection.

2-way Warning – No engine shutdown available.

- ECT - Engine overhear warning
- EOP - Low engine oil pressure warning

3-way Warning – No engine shutdown available.

- ECT - Engine overhear warning
- EOP - Low engine oil pressure warning
- ECL - Low engine coolant level warning

3-way Protection – Engine shutdown is available if critical condition is detected.

- ECT, EOP, ECL - Same as 3-way Warning
- ECT - Engine overhear critical protection
- EOP - Low engine oil pressure critical protection
- ECL - Low engine coolant level critical protection

Warning – Temperature above specific threshold will illuminate the OWL and set a fault.

Critical – Temperature above specific threshold shuts down the engine and sets a fault.

Event log – This feature logs occurrences of the event according to the engine hours and odometer readings.

EWPS Programmable Parameters

Engine Warning and Protection System Mode

- 0 = Standard Warning
- 1 = 3-way Warning
- 2 = 3-way Protection
- 3 = 2-way Warning

Engine Coolant Temperature (ECT) - WARNING

Specifies temperature threshold where the Oil Warning Lamp (OWL) and warning buzzer turns on.

Engine Coolant Temperature (ECT) - CRITICAL

Specifies temperature threshold where an engine shut-down is commanded.

Engine Oil Pressure Engine RPM Boundary 1

Specifies at what RPM a specified oil pressure (OIL-PRES-CRIT-SPD1) should be detected.

Engine Oil Pressure Engine RPM Boundary 2

Specifies at what RPM a specified oil pressure (OIL-PRES-CRIT-SPD2) should be detected.

Engine Oil Pressure Engine RPM Boundary 3

Specifies at what RPM a specified oil pressure (OIL-PRES-CRIT-SPD3) should be detected.

Engine Oil Warning Pressure for Region 1

Specifies the minimum oil pressure with engine speed greater than (PROT-ENG-SPD1). Failure to meet set-point turns on the OWL and warning buzzer.

Engine Oil Warning Pressure for Region 2

Specifies the minimum oil pressure with engine speed greater than (PROT-ENG-SPD1), but less than (PROT-ENG-SPD2). Failure to meet set-point turns on the OWL and warning buzzer.

Engine Oil Warning Pressure for Region 3

Specifies the minimum oil pressure with engine speed greater than (PROT-ENG-SPD2), but less than (PROT-ENG-SPD3). Failure to meet set-point turns on the OWL and warning buzzer.

Engine Oil Warning Pressure for Region 1

Specifies the minimum oil pressure with engine speed greater than (PROT-ENG-SPD1). Failure to meet set-point commands an engine shut down.

Engine Oil Warning Pressure for Region 2

Specifies the minimum oil pressure with engine speed greater than (PROT-ENG-SPD1), but less than (PROT-ENG-SPD2). Failure to meet set-point commands an engine shut down.

Engine Oil Warning Pressure for Region 3

Specifies the minimum oil pressure with engine speed greater than (PROT-ENG-SPD2), but less than (PROT-ENG-SPD3). Failure to meet set-point will command an engine shutdown.

SPN 94/FMI 17

Fuel Filter Minder Service Interval Soon

- Replace primary and secondary fuel filters following procedures in the *Engine Operation and Maintenance Manual*.

SPN 94/FMI 31

Fuel Filter Minder Service Interval Now

- Replace primary and secondary fuel filters immediately following procedures in the *Engine Operation and Maintenance Manual*.

SPN 100/FMI 1**Engine Oil System below Critical Pressure**

- SPN 100/FMI 1 is set by the ECM, when the engine oil pressure drops below the critical level while the engine is running. The specifications are:
 - 14 kPa (2 psi) @ 700 rpm
 - 83 kPa (12 psi) @ 1400 rpm
 - 152 kPa (22 psi) @ 2000 rpm
- For diagnostics, see Low Oil Pressure Diagnostics (page 85) in the “Engine Symptoms Diagnostics” section of this manual.
- SPN 100/FMI 1 can be set by an open, circuit short to voltage source in the EOP circuit, a loose or failed EOP sensor, or low oil pressure.
- When SPN 100/FMI 1 is active, the red stop lamp (also known as oil warning lamp) flashes and sounds an audible signal.

SPN 100/FMI 18**Engine Oil System below Warning Pressure**

- SPN 100/FMI 18 is set by the ECM when engine oil pressure is lower than expected, while the engine is running. The specifications for the warning are:
 - 34 kPa (5 psi) @ 700 rpm
 - 69 kPa (10 psi) @ 1400 rpm
 - 138 kPa (20 psi) @ 2000 rpm
- For diagnostics, see Low Oil Pressure (page 85) in the “Engine Symptoms Diagnostics” section of this manual.
- SPN 100/FMI 18 can be set by an open, circuit short to voltage source in the EOP circuit, a loose or failed EOP sensor, or low oil pressure.
- When SPN 100/FMI 18 is active, the amber warning lamp (also known as the warn engine lamp) is illuminated.

SPN 110/FMI 0**Engine Coolant System above Critical Temperature**

- SPN 110/FMI 0 is set by the ECM when engine coolant temperature is above 112 °C (234 °F). The ECM illuminates the red stop lamp (also known as oil warning lamp). When temperature drops below 112 °C (234 °F) the fault becomes inactive. For diagnostics, see Coolant Over-Temperature (page 73) in the “Engine Symptoms Diagnostics” section of this manual.

SPN 110/FMI 15**Engine Coolant System above Warning Temperature**

- SPN 110/FMI 15 is set by the ECM when engine coolant temperature is above 108 °C (226 °F). The ECM illuminates the amber warning lamp (also known as the warn engine lamp). When temperature drops below 108 °C (226 °F) the fault becomes inactive. For diagnostics, see Coolant Over-Temperature (page 73) in the “Engine Symptoms Diagnostics” section of this manual.

SPN 111/FMI 1**Low Engine Coolant Level**

- SPN 111/FMI 1 is set by the ECM when coolant is low. When the EWPS mode is 3-way protection and SPN 111/FMI 1 is active, the engine shuts down. The ECM logs engine hours and odometer reading at the time of occurrence. After the shutdown, the engine can be restarted for 30 seconds while the fault is active. When coolant has returned to correct levels, SPN 111/FMI 1 becomes inactive

NOTE: If the coolant level is correct, do ECL sensor Connector Voltage Check (page 214). An ECL signal short to ground can cause SPN 111/FMI 1.

SPN 174/FMI 0**Engine Fuel System above Critical Temperature**

- SPN 174/FMI 0 is set by the ECM when the engine fuel temperature is above 80 °C (176 °F). The ECM illuminates the red stop lamp (also known as oil warning lamp). When temperature drops below 80 °C (176 °F) the fault becomes inactive. For diagnosis, see Fuel Over-Temperature Diagnostics in the “Engine Symptoms Diagnostics” section of this manual.

SPN 174/FMI 15**Engine Fuel System above Warning Temperature**

- SPN 174/FMI 15 is set by the ECM when the engine fuel temperature is above 70 °C (158 °F). The ECM illuminates the amber warning lamp (also known as the warn engine lamp). When temperature drops below 70 °C (158 °F) the fault becomes inactive. For diagnosis, see Fuel Over-Temperature Diagnostics in the “Engine Symptoms Diagnostics” section of this manual.

SPN 175/FMI 0**Engine Oil System above Critical Temperature**

- SPN 175/FMI 0 is set by the ECM when the engine oil pressure raises above 140 °C (284 °F) while the engine is running. The ECM illuminates the red stop lamp (also known as oil warning lamp). When temperature drops below 140 °C (284 °F) the fault becomes inactive. For diagnosis, see Oil Over-Temperature Diagnostics in the “Engine Symptoms Diagnostics” section of this manual.

SPN 175/FMI 15**Engine Oil System above Warning Temperature**

- SPN 175/FMI 15 is set by the ECM when the engine oil temperature raises above 123 °C (254 °F) while the engine is running. The ECM illuminates the amber warning lamp (also known as the warn engine lamp). When temperature drops below 123 °C (254 °F), the fault becomes inactive. For diagnosis, see Oil Over-Temperature Diagnostics in the “Engine Symptoms Diagnostics” section of this manual.

SPN 190/FMI 0**Engine Overspeed - Most Severe Level**

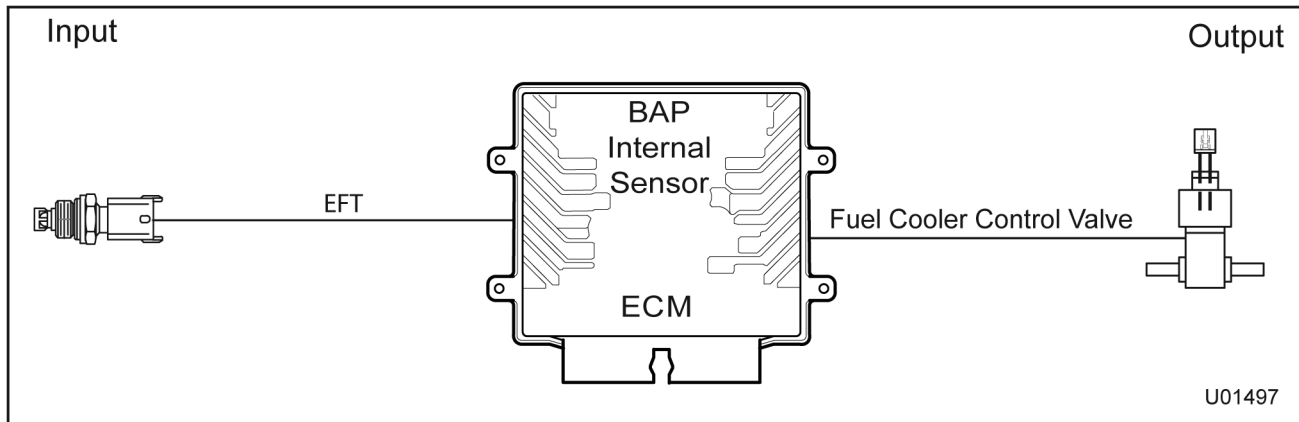
- SPN 190/FMI 0 is set by the ECM when the engine rpm has exceeded 3900 rpm.
- SPN 190/FMI 0 can be set due to any of the following conditions:
 - Excessive engine speed in an unintended downshift.
 - Steep acceleration downhill without correct brake application.
 - External fuel source being ingested into air intake system.
- When SPN 190/FMI 0 is active, the lamp is illuminated. The engine hours and miles of the last two over speed occurrences will be recorded in the engine event log.

SPN 2629/FMI 15**High Compressor Outlet Temperature**

- SPN 2629/FMI 15 is set by the ECM when turbocharger compressor outlet temperature is above 249 °C (480 °F) and the engine torque is being limited by the derate. When the temperature drops below 235 °C (455 °F) or the engine torque is no longer limited by the derate, the fault will go inactive.

Fuel Cooler Control Valve

SPN	FMI	Condition
522283	3	FCC short to PWR
522283	4	FCC short to GND
522283	5	FCC open load/circuit

**Figure 134** Function diagram for the Fuel Cooler Control Valve

The Fuel Cooler Control Valve function diagram includes the following:

- Fuel Cooler Control Valve
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Engine Fuel Temperature (EFT) sensor

Function

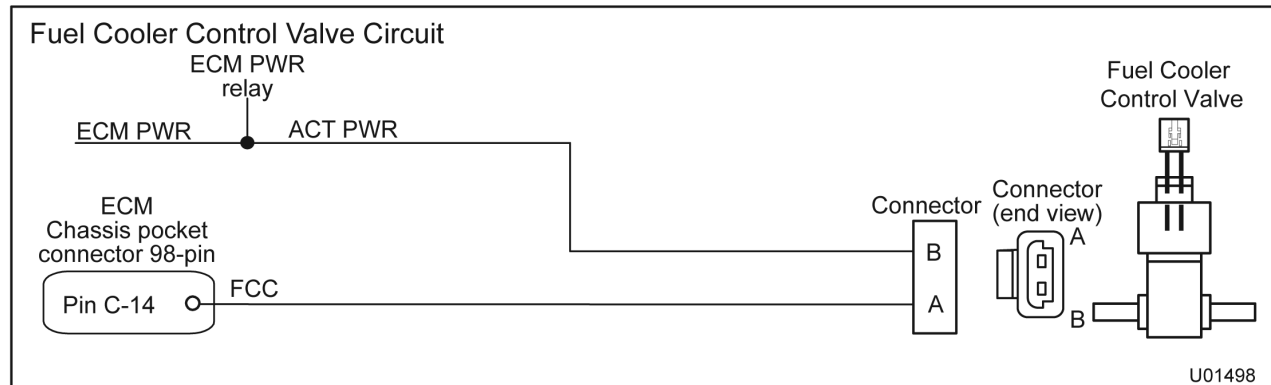
The Fuel Cooler Control Valve is used to redirect coolant through the fuel cooler. The ECM uses the EFT sensor to monitor fuel temperature and controls the Fuel Cooler Control Valve to maintain desired fuel temperature.

Sensor Location

The Fuel Cooler Control Valve is located on the left side radiator core support.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- International® Electronic Engine Terminal Test Kit ZTSE4435C

Fuel Cooler Control Valve Circuit Diagnostics**Figure 135 Fuel Cooler Control Valve circuit diagram****Voltage Check at Fuel Cooler Control Valve Connector – Output State Test**

Disconnect Fuel Cooler Control Valve solenoid 2-pin connector. Turn the ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comments
A to GND	0 V to 0.25 V	If > 0.25 V, check FCC circuit for short to PWR.
B to GND	B+	If < B+, check ACT PWR circuit for OPEN or blown fuse.
Run Output State Test HIGH.		
A to B+	0 V to 0.25 V	If > 0.25 V, check FCC circuit for short to GND.
Run Output State Test LOW.		
A to B+	B+	If < B+, check FCC circuit for OPEN or short to PWR. Do Harness Resistance Check.
B to A	B+	If < B+, check ACT PWR circuit for OPEN. Do Harness Resistance Check.

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box. Leave ECM and Fuel Cooler Control Valve disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
C-14 to A	< 5 Ω	If > 5 Ω , check FCC circuit for OPEN.
C-14 to GND	> 1k Ω	If < 1k Ω , check FCC circuit for short to GND.
B to C-83, 84, and 85	< 5 Ω	If > 5 Ω , check ACT PWR for OPEN in circuit.
B to GND	> 1k Ω	If < 1 k Ω , check ACT PWR for short to GND.

See truck *Chassis Electrical Circuit Diagram Manual* and *Electrical System Troubleshooting Guide* for fuse information.

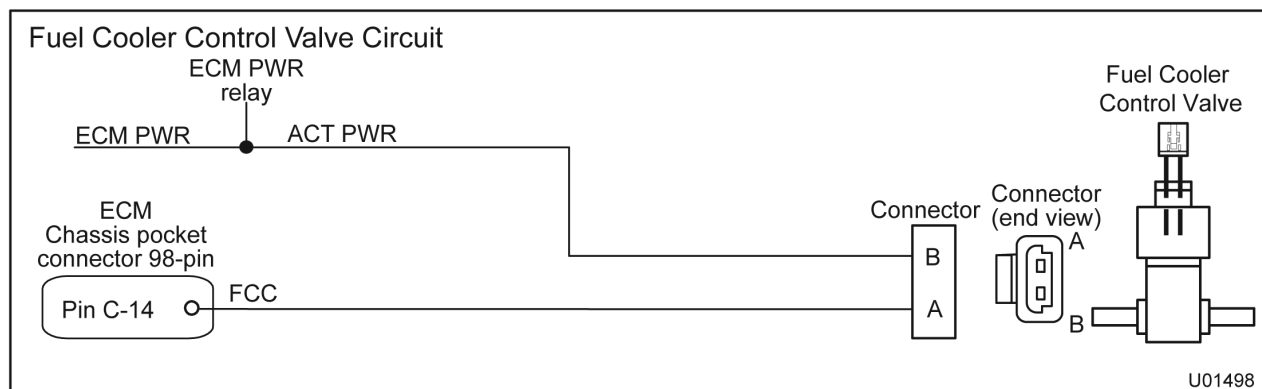


Figure 136 Fuel Cooler Control Valve circuit diagram

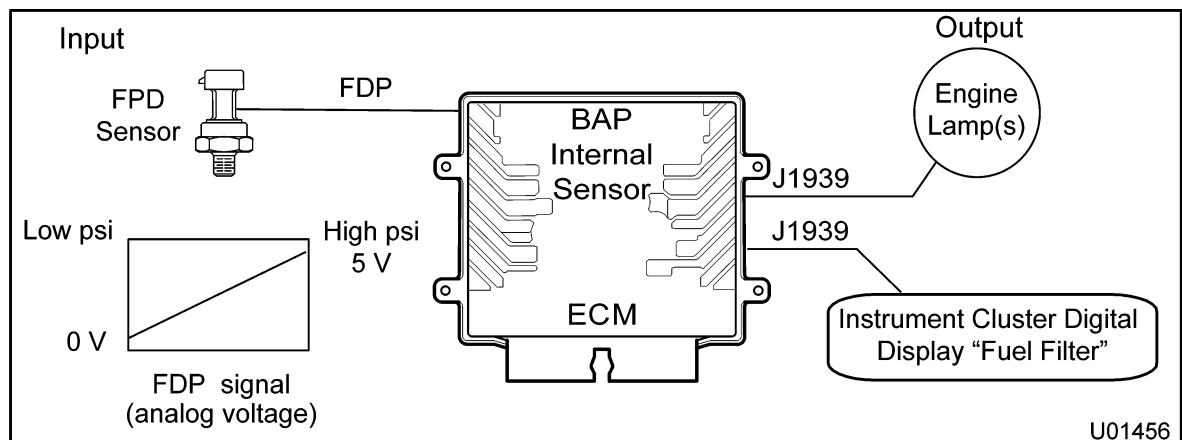
The Fuel Cooler Control Valve operates in a fail-safe manner. The valve opens automatically allowing coolant to pass through the fuel cooler. The ECM controls this valve in cold weather to warm the fuel and also controls the temperature from getting too hot.

Fuel Cooler Control Valve Circuit Operation

The Fuel Cooler Control Valve solenoid is supplied ACT PWR at Pin B. The ECM Pin C-14 controls the solenoid by grounding Pin A.

FDP Sensor (Fuel Delivery Pressure)

SPN	FMI	Condition
94	0	Fuel Filter Minder Above Maximum Pressure
94	3	FDP signal Out of Range HIGH
94	4	FDP signal Out of Range LOW
94	10	FDP signal abnormal rate of change

**Figure 137 Function diagram for the FDP sensor**

The FDP sensor function diagram includes the following:

- Fuel Delivery Pressure (FDP) Sensor
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Engine Lamp(s)
- Fuel filter display message

Function

The FDP sensor provides a feedback signal to the ECM indicating engine fuel supply pressure. During engine operation, if pressure is low, the ECM turns on the "Fuel Filter" display message to alert the operator when the fuel filter needs servicing.

Sensor Location

The FDP sensor is installed in the secondary fuel filter housing on the driver's side of the engine.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 3-Banana Plug Harness ZTSE4498
- 1180–N4–0X0 – 180-Pin Breakout Box
- Breakout Harness ZTSE6038 (FDP)
- International® Electronic Engine Terminal Test Kit ZTSE4435C

FDP Sensor End Diagnostics

SPN	FMI	Condition	Possible Causes
94	0	Fuel Filter Minder Above Maximum Pressure	- Failed or restricted fuel regulator valve - Restricted fuel return line - High suction pressure at low-pressure fuel pump inlet - Low-pressure fuel pump electrical problem
94	3	FDP signal Out of Range HIGH	- FDP signal circuit short to PWR - Failed sensor
94	4	FDP signal Out of Range LOW	- FDP signal circuit OPEN or short to GND - VREF circuit OPEN or short to GND - Failed sensor
94	10	FDP signal abnormal rate of change	Biased circuit or sensor

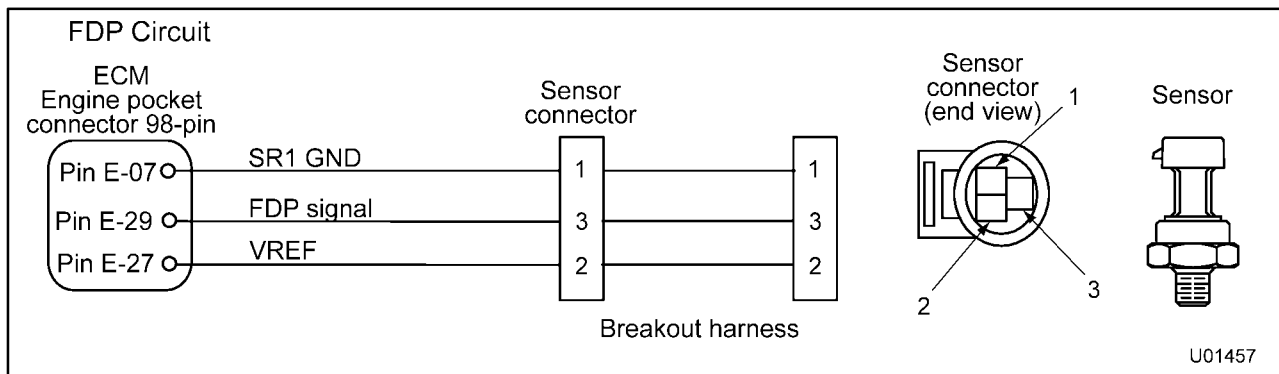


Figure 138 FDP circuit diagram

! WARNING: To prevent personal injury or death, stay clear of rotating parts (belts and fan) and hot engine surfaces.

- Using Electronic Service Tool (EST) with ServiceMaxx™ software, open the Continuous Monitor session
- Verify sensor voltage is within KOEO specification. See "Appendix A: Performance Specifications" (page 425).

- Monitor sensor voltage. Verify an active Diagnostic Trouble Code (DTC) for the sensor.

- If code is inactive, monitor the signal while wiggling the connector and all wires at suspected location. If the circuit is interrupted, the signal spikes and the DTC goes active.
- If DTC is active, proceed to the next step.

- Disconnect engine harness from sensor.

NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

- Connect breakout harness to engine harness. Leave sensor disconnected.

SPN 94 FMI 0 – Fuel Filter Minder Above Maximum Pressure**Fuel pressure, restriction, and pump voltage test**

1. Go to Fuel System in “PERFORMANCE DIAGNOSTICS” section of this manual to diagnose a restriction, failed regulator valve, and suction problem.
 - If no problems are found, continue to next step.
2. Check voltage/current to low-pressure fuel pump. High voltage will result in higher pressures. Go to Fuel Pump (page 285) in this section.

Sensor Circuit Check

Connect Breakout Harness ZTSE6038. Leave sensor disconnected. Turn the ignition switch to ON. Use Electronic Service Tool (EST) with ServiceMaxx™ software to verify correct DTC goes active when corresponding fault is induced. Use DMM to measure circuits.

Test Point	Spec	Comments
EST - Check DTC	SPN 94 FMI 4	If SPN 94/FMI 3 is active, check FDP signal for short to PWR.
DMM – Measure volts 2 to GND	5 V $\pm$ 0.5 V	If > 5.5 V, check VREF for short to PWR. If < 4.5 V, check VREF for OPEN or short to GND. Do Harness Resistance Check (page 275).
EST - Check DTC Short breakout harness across 2 and 3	SPN 94 FMI 3	If SPN 94/FMI 4 is active, check FDP signal for OPEN. Do Harness Resistance Check (page 275).
DMM – Measure resistance 1 to GND	< 5 Ω	If > 5 Ω , check SIG GND for OPEN. Do Harness Resistance Check (page 275).
If checks are within specification, connect sensor and clear DTCs. If active DTC remains, replace sensor.		

FDP Pin-point Diagnostics

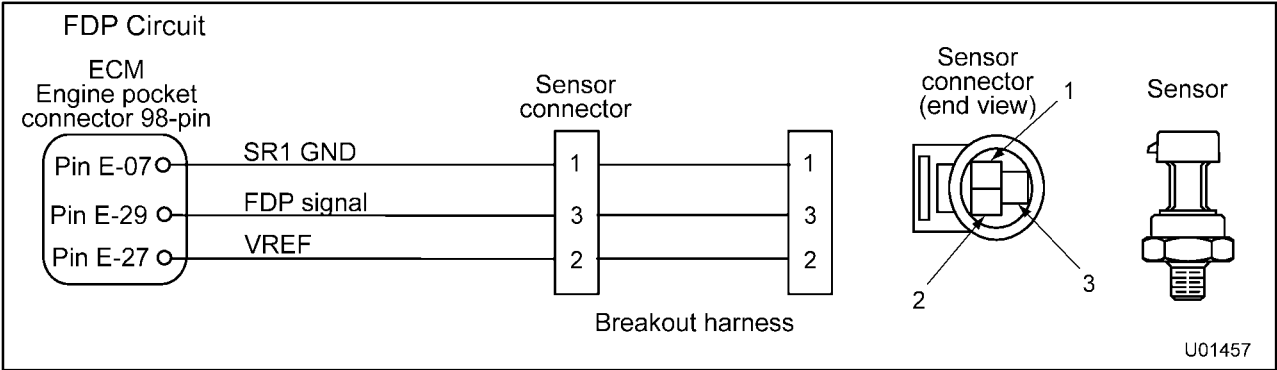


Figure 139 FDP circuit diagram

Connector Voltage Check

Connect Breakout Harness ZTSE6038. Leave sensor disconnected. Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
1 to GND	0 V	If > 0.25 V, check for short to PWR.
2 to GND	5 V ± 0.5 V	If > 5.5 V, check VREF for short to PWR. If < 4.5 V, check VREF for OPEN or short to GND. Do Harness Resistance Check (page 275).
3 to GND	0 V	If > 0.25 V, check for short to PWR. Do Harness Resistance Check (page 275).

Connector Resistance Check to GND

Turn ignition switch to OFF. Connect Breakout Harness ZTSE6038. Leave sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to GND	< 5 Ω	If > 5 Ω, check for OPEN circuit.
2 to GND	> 1 kΩ	If < 1 kΩ, check for short to GND.
3 to GND	> 1 kΩ	If < 1 kΩ, check for short to GND.

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box and Breakout Harness ZTSE6038. Leave ECM and sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to E-7	< 5 Ω	If > 5 Ω , check SIG GND circuit for OPEN.
2 to E-27	< 5 Ω	If > 5 Ω , check VREF circuit for OPEN.
3 to E-29	< 5 Ω	If > 5 Ω , check FDP signal circuit for OPEN.

FDP Circuit Operation

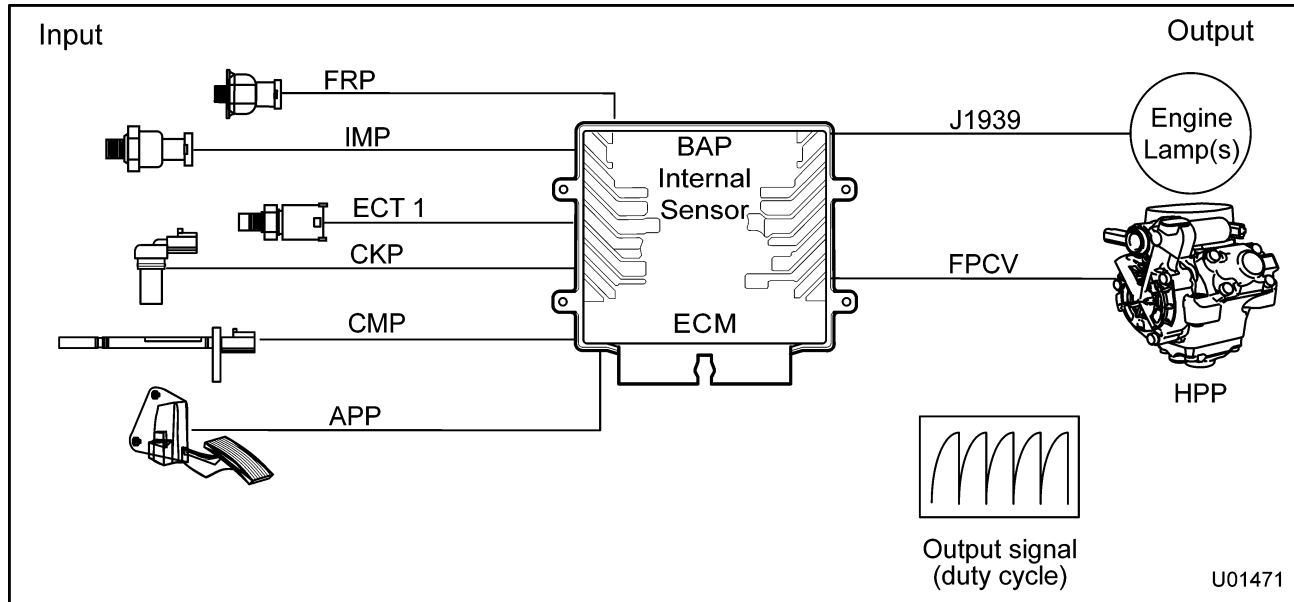
The FDP sensor is a variable capacitance sensor supplied with a 5-volt reference voltage at Pin 2 from ECM Pin E-27. The sensor is grounded at Pin 1 from ECM Pin E-7. The sensor returns a variable voltage signal from Pin 3 to ECM Pin E-29.

Fault Detection/Management

The ECM continuously monitors the control system. If the sensor signal is higher or lower than expected, the ECM disregards the signal and uses a calibrated default value. The ECM sets a DTC, turns on the WEL, and runs the engine in a default range.

FPCV (Fuel Pressure Control Valve)

SPN	FMI	Condition
633	3	FPCV short to PWR
633	4	FPCV short to GND
633	5	FPCV open load/circuit
633	6	FPCV Current max limit exceeded

**Figure 140 Function diagram for the FPCV**

The FPCV function diagram includes the following:

- High-Pressure Pump (HPP) with integrated Fuel Pressure Control Valve (FPCV)
- Engine Coolant Temperature 1 (ECT1) sensor
- Fuel Rail Pressure (FRP) sensor
- Intake Manifold Pressure (IMP) sensor
- Camshaft Position (CMP) sensor
- Crankshaft Position (CKP) sensor
- Accelerator Pedal Position (APP) sensor
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Engine Lamp(s)

Function

The FPCV regulates fuel pressure from the HPP that supplies the injectors. The ECM uses the FRP sensor to monitor system pressure and adjust the valve duty cycle to match engine requirements (starting, engine load, speed, and temperature).

NOTE: The engine may not operate with an FPCV fault, depending on the mode of failure.

FPCV Location

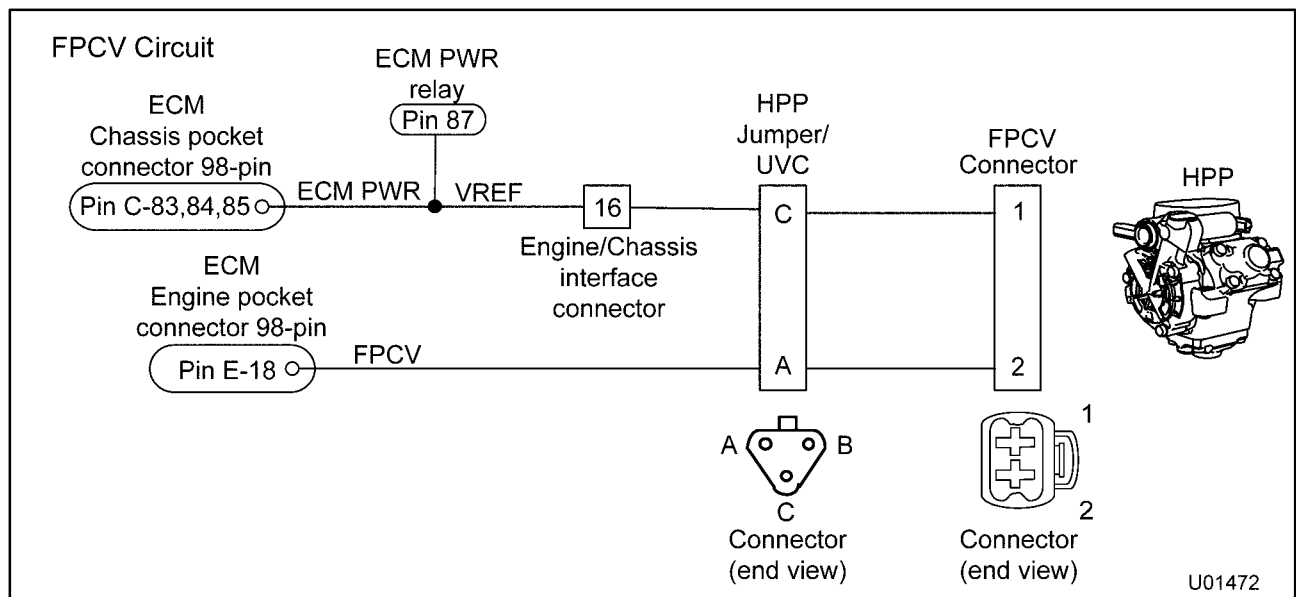
The FPCV is a nonserviceable part in the HPP. If the FPCV fails, replace the HPP.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 1180–N4–0X0 – 180-Pin Breakout Box
- International® Electronic Engine Terminal Test Kit ZTSE4435C

FPCV Pin-point Diagnostics

SPN	FMI	Condition	Possible Causes
633	3	FPCV short to PWR	• FPCV circuit short to PWR • Failed valve
633	4	FPCV short to GND	• FPCV circuit short to GND • Failed valve
633	5	FPCV open load/circuit	• FPCV circuit OPEN • Failed valve
633	6	FPCV current max limit exceeded	• Failed valve

**Figure 141 FPCV circuit diagram**

Actuator/Harness Resistance Check

Connect 180-Pin Breakout Box to Engine and Chassis harness. Leave ECM disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
E-18 to C-83	3.5 +/- 1.5 Ω	If not within specification, check for OPEN or short circuit or failed FPCV valve.
E-18 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND or failed FPCV valve.

Operational Voltage Check - Output Circuit Check

Connect 180-Pin Breakout Box between Engine and Chassis harness to ECM. Run KOEO test and Output Circuit Test HIGH and LOW. Use DMM to measure voltage. If unable to run KOEO test, see ECM PWR Relay (page 216) in this section.

Test Point	Test	Spec	Comment
E-18 to GND	Output State LOW	B+	If < B+, check FPCV circuit for short to GRD or internal shorted FPCV valve.
E-18 to GND	Output State HIGH	5.5 V	If < 2.5 V, check FPCV circuit for OPEN or internal OPEN FPCV valve.

FPCV Circuit Operation

The HPP is mechanically driven by the engine and electrically controlled by the ECM.

The HPP consists of a high-pressure pump and two electric control valves, the FPCV and Fuel Volume Control Valve (FVCV). This is a nonserviceable unit. If the HPP or either electric control valves fail, the HPP must be replaced as a unit.

The FVCV governs the amount of fuel supplied to the HPP. The FPCV regulates fuel pressure supplied to the injectors. The HPP delivers fuel to the rail at about 165 MPa (1650 Bar) (23,900 psi).

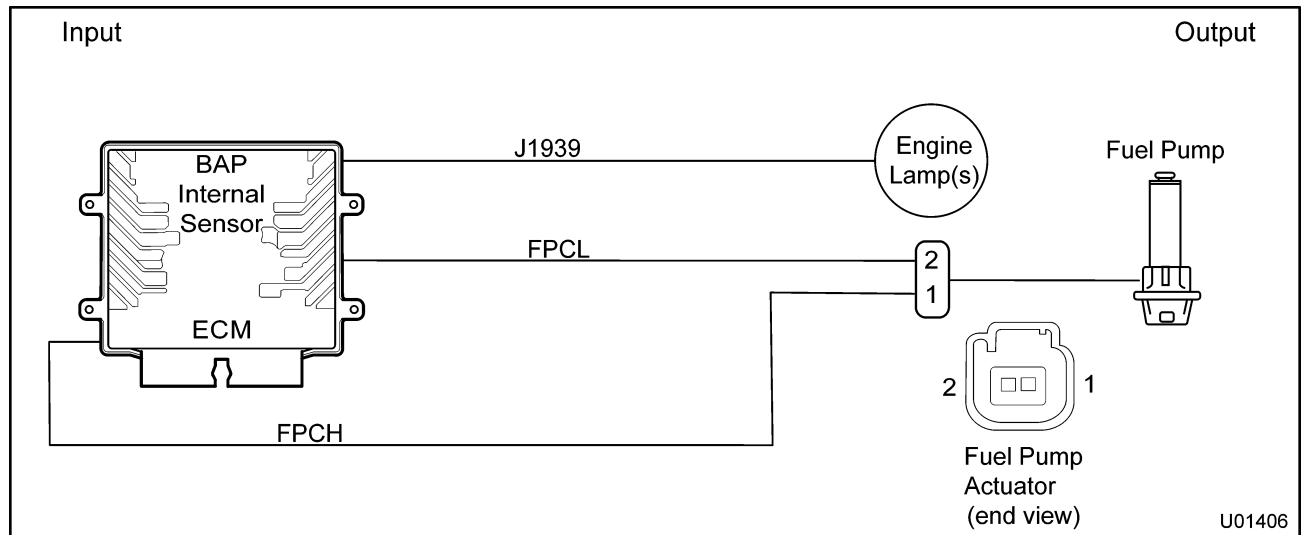
The FPCV is supplied with VPWR at Pin 1. ECM Pin E-18 controls the valve by duty cycling a ground path to FPCV Pin 2. High duty cycle indicates high pressure and low duty cycle indicates low pressure.

Fault Detection / Management

An open or short in the FPCV circuit can be detected by an on-demand output circuit check during KOEO Test. If there is a circuit fault detected, a DTC is set.

Fuel Pump

SPN	FMI	Condition
4082	2	FPC Relay Circuit Fault
4082	3	FPC short to PWR
4082	4	FPC short to GND
4082	5	FPC open load/circuit

**Figure 142 Function diagram for the Fuel Pump**

The Fuel Pump function diagram includes the following:

- Fuel pump
- Fuel Pump Control High (FPCH) circuit
- Fuel Pump Control Low (FPCL) circuit
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Engine Lamp(s)

Function

The fuel pump supplies fuel to the engine at approximately 60 psi. The ECM drives the fuel pump directly using H-Bridge driver.

FPC Location

The fuel pump is located in the fuel filter module.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 1180–N4–0X0 – 180-Pin Breakout Box
- Breakout Harness ZTSE6001 (FPC)

Fuel Pump Pin-point Diagnostics

SPN	FMI	Condition	Possible Causes
4082	2	FPC Relay Circuit Fault	- Failed relay - FPCH circuit OPEN - FPCL circuit OPEN
4082	3	FPC short to PWR	- FPCH circuit shorted to PWR - FPCL circuit shorted to PWR
4082	4	FPC short to GND	- FPCH circuit shorted to GND - FPCL circuit shorted to GND
4082	5	FPC open load/circuit	- FPCH circuit OPEN - FPCL circuit OPEN - Failed fuel pump

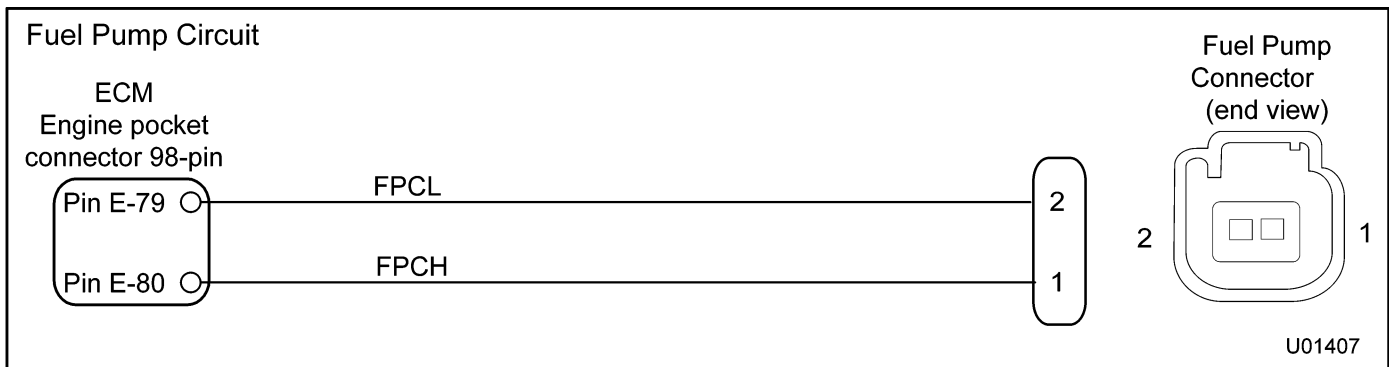


Figure 143 Fuel Pump circuit diagram

Connector Voltage Check

Connect Breakout Harness ZTSE6001. Leave actuator disconnected. Turn ignition switch to ON. Use DMM to measure voltage and Run Output State Test High and Low.

Run Output State Test – Low

Test Point	Spec	Comment
1 to GND	B+	If < B+, check FPCH for OPEN or short to GND. Do harness resistance check.
2 to GND	0 V	If > 0.25 V, check FPCL for short to B+. Do harness resistance check.

Run Output State Test – Low

1 to GND	0 V	If > 0.25V, check FPCH short to B+. Do harness resistance check.
2 to GND	0 V	If > 0.25 V, check FPCL for short to B+. Do harness resistance check.

Connector Resistance Check to GND

Turn ignition switch to OFF. Connect Breakout Harness ZTSE6001. Leave actuator disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
2 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box and Breakout Harness ZTSE6001. Leave ECM and actuator disconnected. Use DMM to measure resistance.

Test	Spec	Comment
1 to E-80	< 5 Ω	If > 5 Ω , check FPCH circuit for OPEN.
2 to E-79	< 5 Ω	If > 5 Ω , check FPCH circuit for OPEN.

Fuel Pump Actuator

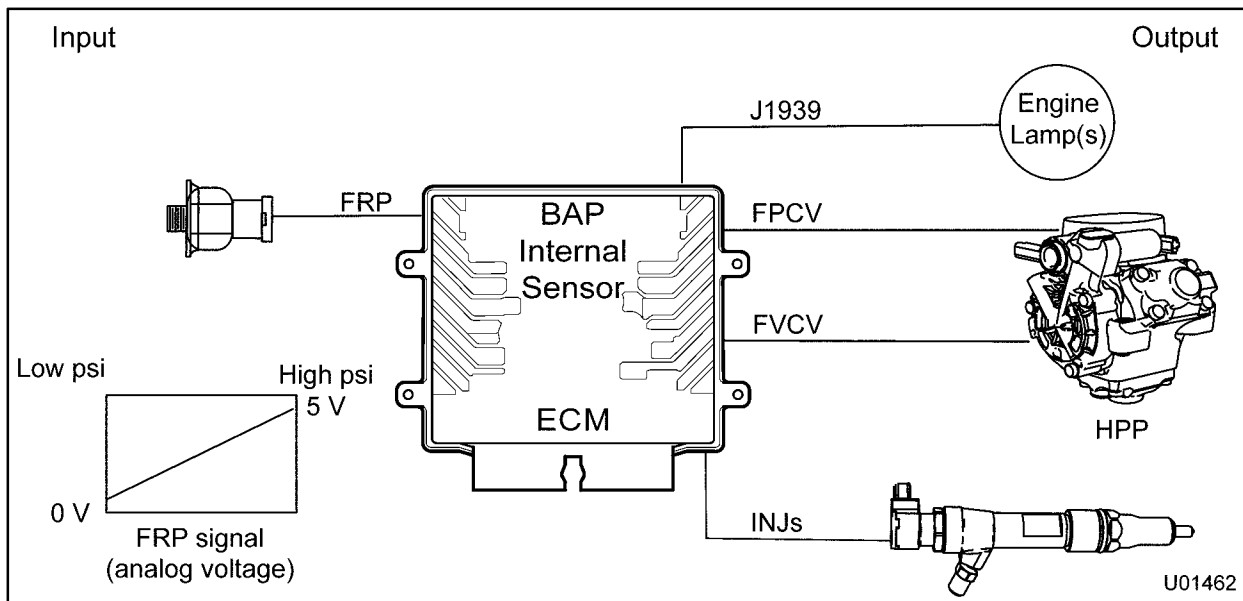
The ECM controls the fuel pump with a Pulse Width Modulation (PWM) signal through H-Bridge circuitry. PWM voltage is supplied by a series of pulses. To control motor speed, it varies (modulates) the width of the pulses. The ECM controls the fuel pump by driving the FPCH circuit high and low.

Fault Detection / Management

An OPEN or short FPCH or FPCL circuit will be detected while fuel pump command is ON or during the on-demand output circuit check during the KOEO standard test. If there is a circuit fault, a DTC is set.

FRP Sensor (Fuel Rail Pressure)

SPN	FMI	Condition
157	3	FRP signal Out of Range HIGH
157	4	FRP signal Out of Range LOW
157	10	FRP signal abnormal rate of change

**Figure 144 Function diagram for the FRP sensor**

The FRP sensor function diagram includes the following:

- Fuel Rail Pressure (FRP) sensor
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Fuel injectors (INJ)
- High-Pressure Pump (HPP) with integrated Fuel Pressure Control Valve (FPCV) and Fuel Volume Control Valve (FVCV)
- Engine Lamp(s)

Function

The FRP sensor provides a feedback signal to the ECM indicating fuel rail pressure. The ECM monitors FRP as the engine is operating to control the FPCV and FVCV. This is a closed loop function in which the ECM continuously monitors and adjusts for ideal FRP determined by conditions such as load, speed, and temperature.

Sensor Location

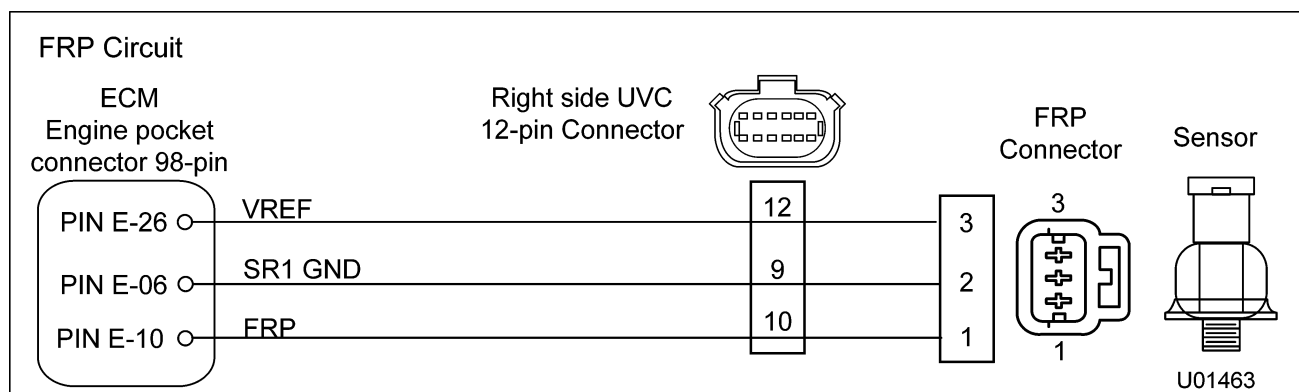
The FRP sensor is installed in the high-pressure fuel rail, under the right valve cover.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 3-Banana Plug Harness ZTSE4498
- Breakout Harness ZTSE6038 (FRP)
- 1180–N4–0X0 – 180-Pin Breakout Box
- International® Electronic Engine Terminal Test Kit ZTSE4435C

FRP Sensor End Diagnostics

SPN	FMI	Condition	Possible Causes
157	3	FRP signal Out of Range HIGH	• FRP signal circuit short to PWR • SIG GND circuit OPEN • Failed sensor
157	4	FRP signal Out of Range LOW	• FRP signal circuit short to GND • Failed sensor
157	10	FRP abnormal rate of change	• Set when FRP changes more then 40 MPa (5800 psi) within 0.1 second • FRP sensor • FRP intermittent circuit fault • SIG GND circuit OPEN • Biased circuit/sensor

**Figure 145 FRP circuit diagram**

⚠ WARNING: To prevent personal injury or death, stay clear of rotating parts (belts and fan) and hot engine surfaces.

1. Using Electronic Service Tool (EST) with ServiceMaxx™ software, open the Continuous Monitor session.
2. Verify sensor voltage is within KOEO specifications. See “Appendix A: Performance Specifications” (page 425).
3. Monitor sensor voltage. Verify active Diagnostic Trouble Code (DTC) for the sensor.
 - If DTC is inactive, monitor the signal while wiggling the connector and all wires at suspected location. If the circuit is interrupted, the signal spikes and the fault goes active.
 - If DTC is active, proceed to the next step.
4. Disconnect engine harness from sensor.

NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

5. Connect breakout harness to engine harness. Leave sensor disconnected.

Sensor Circuit Check

Disconnect 12-pin UVC connector from right cylinder head. Turn the ignition switch to ON. Use Electronic Service Tool (EST) with ServiceMaxx™ software to verify correct DTC goes active when corresponding fault is induced. Use DMM to measure circuits.

Test Point	Spec	Comments
EST - Check DTC	SPN 157	If SPN 157/FMI 4 is active, check FRP signal for short to GND.
Short breakout harness across 10 and 9	FMI 3	
DMM - Measure resistance 9 to GND	< 5 Ω	If > 5 Ω, check SIG GND for OPEN. Do Harness Resistance Check (page 292).
EST - Check DTC	SPN 157	If SPN 157/FMI 3 is active, check FRP signal for OPEN. Do Harness Resistance Check (page 292).
Short breakout harness across 10 and 9	FMI 4	
DMM - Measure volts 12 to GND	5 V ± 0.5 V	If > 5.5 V, check VREF for short to PWR. If < 4.5 V, check VREF for OPEN or short to GND. Do Harness Resistance Check (page 292).
If checks are within specification, connect 12-pin UVC connector and clear DTCs. If active DTC remains, check under valve cover harness for OPEN or shorts. If okay, replace sensor.		

FRP Pin-point Diagnostics

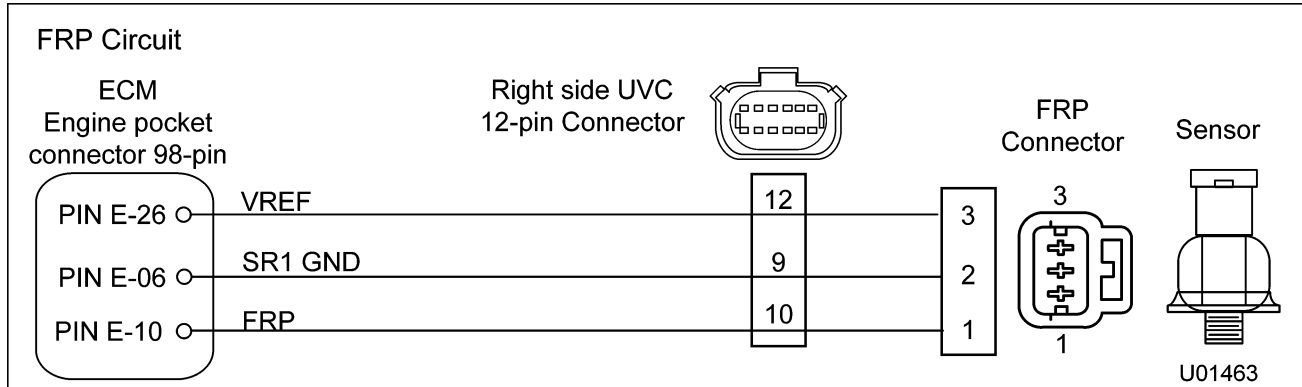


Figure 146 FRP circuit diagram

Connector Voltage Check

Connect Breakout Harness ZTSE6038 to 12-pin UVC connector from right cylinder head. Leave UVC harness disconnected. Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
9 to GND	0 V	If > 0.25 V, check for short to PWR.
10 to GND	5 V $\pm$ 0.5 V	If > 5.5 V, check FRP for short to PWR. If < 4.5 V, check FRP for OPEN or short to GND. Do Harness Resistance Check (page 292).
12 to GND	5 V $\pm$ 0.5 V	If > 5.5 V, check VREF for short to PWR. If < 4.5 V, check VREF for OPEN or short to GND. Do Harness Resistance Check (page 292).

Connector Resistance Check to GND

Turn ignition switch to OFF. Connect 12-pin UVC harness to right cylinder head. Leave UVC harness disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
9 to GND	< 5 Ω	If > 5 Ω , check for OPEN circuit.
10 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
12 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.

Under Valve Cover Resistance Check to Engine GND

Connect Breakout Harness ZTSE6038 to UVC 12-pin connector (right side). Leave engine harness disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
9 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
10 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
12 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.

Harness Resistance Check

Turn ignition switch to OFF. Remove right valve cover. Connect 180-Pin Breakout Box and Breakout Harness ZTSE6038 to engine. Leave ECM and FRP sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
E-06 to 2	< 5 Ω	If > 5 Ω , check SIG GND circuit for OPEN.
E-06 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
E-10 to 1	< 5 Ω	If > 5 Ω , check FRP signal circuit for OPEN.
E-10 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
E-26 to 3	< 5 Ω	If > 5 Ω , check VREF circuit for OPEN.
E-26 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.

FRP Circuit Operation

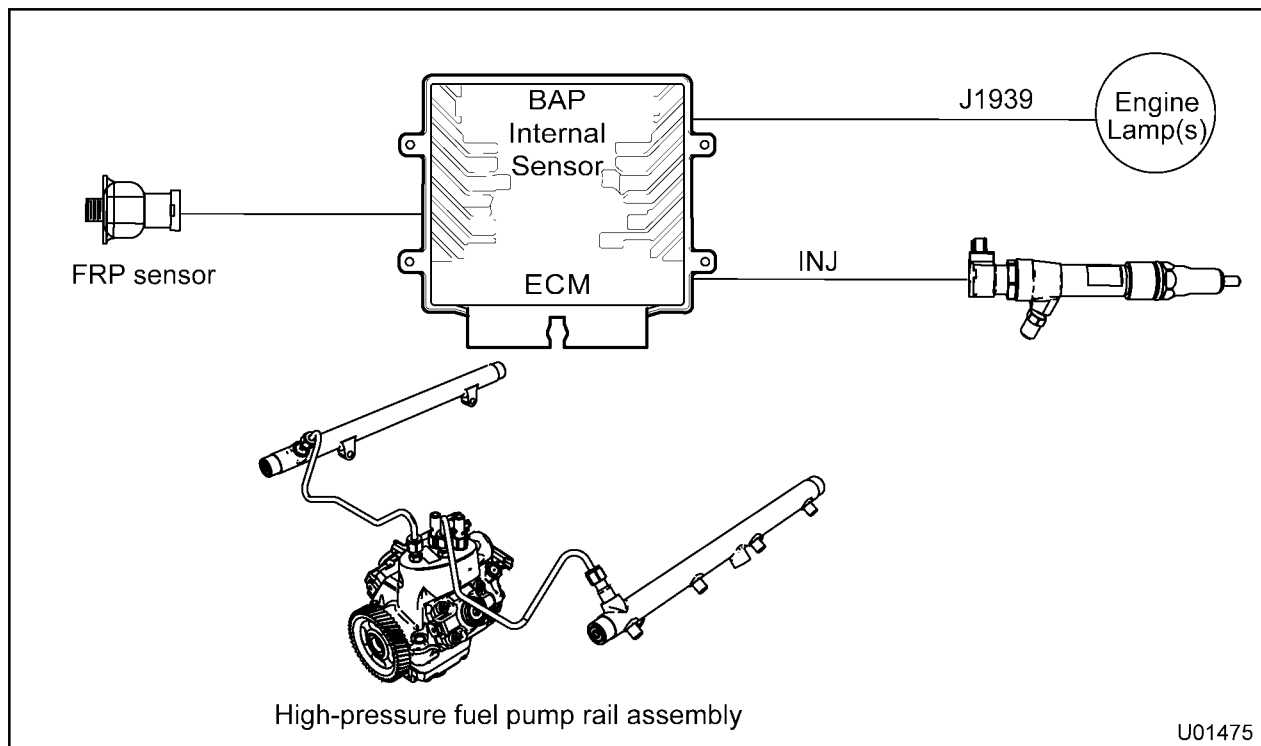
The FRP sensor is a micro strain gauge sensor supplied with a 5-volt reference voltage at Pin 3 from ECM Pin E-26. The sensor is grounded at Pin 2 from ECM Pin E-06. The sensor returns a variable voltage signal from Pin 1 to ECM Pin E-10.

Fault Detection/Management

The ECM continuously monitors the control system. If the sensor signal is higher or lower than expected, the ECM disregards the signal and uses a calibrated default value. The ECM sets a DTC, turns on the Amber Warning Lamp (AWL), and runs the engine in a default range.

FRP System

SPN	FMI	Condition
3055	0	FRP exceeded maximum
3055	1	Low Fuel Pressure at start
3055	13	Fuel Pressure offset check
3055	15	FRP below minimum with maximum command
3055	17	FRP above maximum with minimum command

**Figure 147** Function diagram for the FRP system

The FRP system includes the following:

- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Fuel Rail Pressure (FRP) sensor
- Fuel injectors (INJ)
- High-pressure fuel pump rail assembly
- Engine Lamp(s)

Function

Filtered fuel is supplied to the High-Pressure Pump (HPP) from the Fuel Pump and fuel filter. The HPP pressurizes fuel and routes it to separate fuel rails for each engine bank. The fuel rails then supply fuel to each injector through individual supply tubes. The FRP sensor, located in the right side fuel rail, provides a feedback signal to the ECM indicating FRP. The ECM continuously monitors and adjusts for ideal FRP based on load, speed, and temperature conditions.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit

FRP System Diagnostics

SPN	FMI	Condition	Possible Causes
3055	0	FRP exceeded maximum	• The FPCV/FVCV valve not responding appropriately • The FRP sensor not working properly
3055	1	Low Fuel Pressure at start	• Fuel line leakage • Fuel pump not able to prime up • Transfer case unable to draw fuel from one of the tanks when other tank is almost empty • Previous adaptive values inhibiting FUP control strategy
3055	13	Fuel pressure offset check	• The fuel line pressure is unable to fall to desired level after key OFF and before the next key ON • Fuel filter is choked • Ignition switch cycled too fast • Fuel pump does not shut off at key OFF and valves remain open • High hydraulic resistance in low pressure return line
3055	15	FRP below minimum with maximum command	• The FPCV/FVCV valve not responding appropriately • The PMW signal given to the valves are not adequate for commanded opening
3055	17	FRP above maximum with minimum command	• The FPCV/FVCV valve not responding appropriately • The PMW signal given to the valves are more than needed commanded opening

Pin-point FRP System Fault

1. At KOEO, verify FRP sensor is within specification. See “Appendix A: Performance Specifications” (page 425).
 2. Check for intermittent circuit faults. Open Continuous Monitor session and wiggle the engine harness while monitoring signals for spikes.
 3. Check fuel system for faults. See Fuel System (page 121) in the “Performance Diagnostics” section of this manual.
 4. Run KOEO Output State Test to verify FPCV and FVCV are working without an electrical fault. See FPCV (page 282) and FVCV (page 296) subsections in this section of the manual to test these valves.
 5. Check the FRP system for leaks. See “Hard Start and No Start Diagnostics” (page 89) section in this manual.
-

FRP System Operation

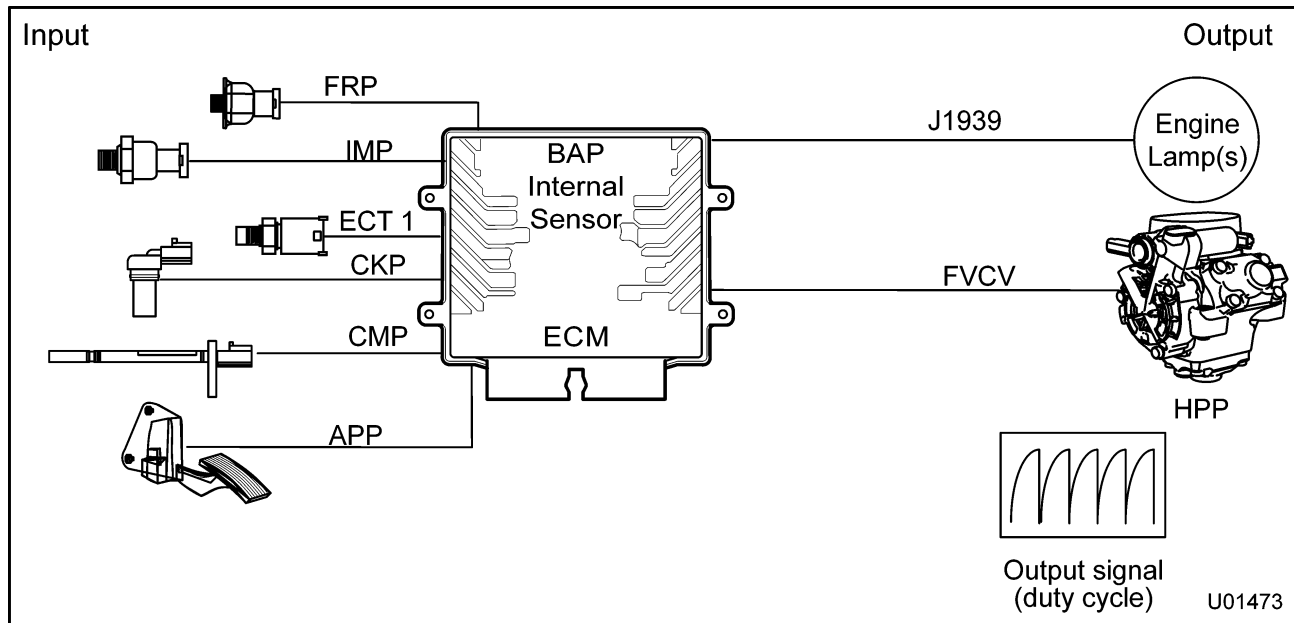
The ECM uses a strategy to control fuel supply to the injectors using the FPCV and FVCV. The strategy maintains fuel pressure and quantity by using the FRP sensor to measure fuel rail pressure.

Fault Detection/Management

The DTCs associated with this system may indicate an electrical or mechanical problem with the FRP system.

FVCV (Fuel Volume Control Valve)

SPN	FMI	Condition
1244	3	FVCV short to PWR
1244	4	FVCV short to GND
1244	5	FVCV open load/circuit
1244	6	FVCV Current max limit exceeded

**Figure 148 Function diagram for the FVCV**

The FVCV function diagram includes the following:

- High-Pressure Pump (HPP) with integrated Fuel Volume Control Valve (FVCV)
- Engine Coolant Temperature 1 (ECT1) sensor
- Fuel Rail Pressure (FRP) sensor
- Intake Manifold Pressure (IMP) sensor
- Camshaft Position (CMP) sensor
- Crankshaft Position (CKP) sensor
- Accelerator Pedal Position (APP)
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Engine Lamp(s)

Function

The FVCV regulates fuel volume through the HPP to supply the injectors. The ECM uses the FRP sensor to monitor system pressure and adjusts FVCV duty cycle to match engine requirements (starting, engine load, speed, and temperature).

NOTE: The engine may not operate with an FVCV fault, depending on the mode of failure.

FVCV Location

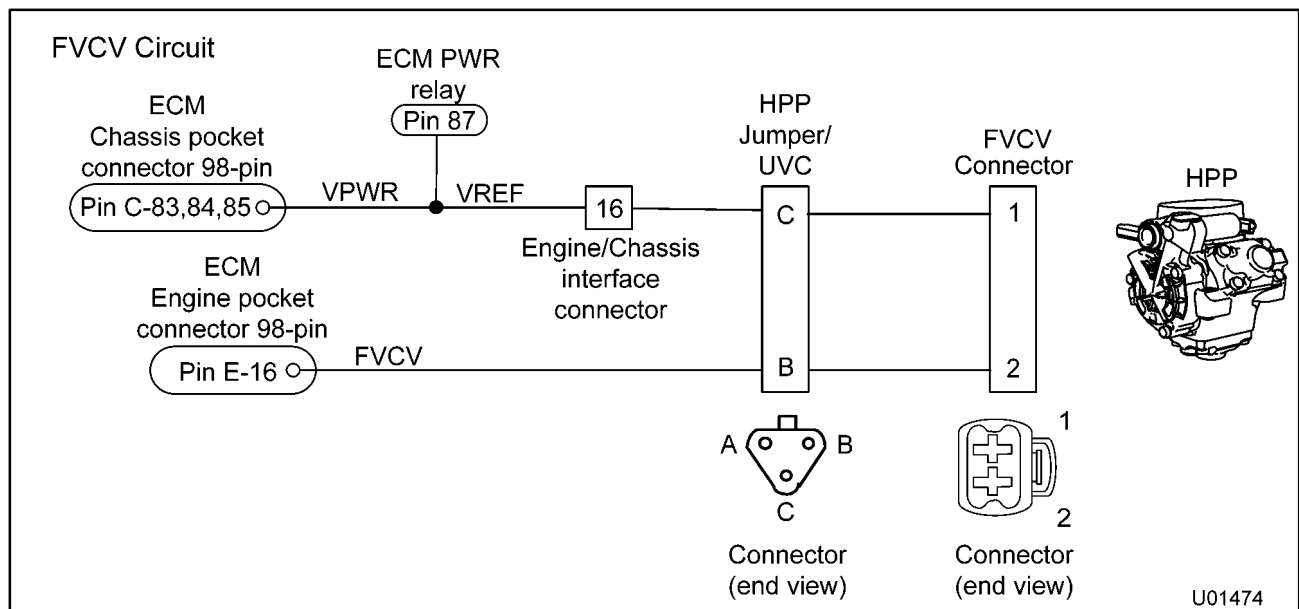
The FVCV is a nonserviceable part in the HPP. If the FVCV fails, replace the HPP.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 1180–N4–0X0 – 180-Pin Breakout Box
- International® Electronic Engine Terminal Test Kit ZTSE4435C

FVCV Pin-point Diagnostics

SPN	FMI	Condition	Possible Causes
1244	3	FVCV short to PWR	• FVCV circuit short to PWR • Failed valve
1244	4	FVCV short to GND	• FVCV circuit short to GND • Failed valve
1244	5	FVCV open load/circuit	• FVCV circuit OPEN • Failed valve
1244	6	FVCV Current max limit exceeded	• Failed valve

**Figure 149 FVCV circuit diagram**

Actuator/Harness Resistance Check

Connect 180-Pin Breakout Box to engine and chassis harness. Leave ECM disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
E-16 to C-83	3.5 +/- 1.5 Ω	If not within specification, check for OPEN or short circuit or failed FVCV valve.
E-16 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND or failed FVCV valve.

Operational Voltage Check - Output Circuit Check

Connect 180-Pin Breakout Box between engine and chassis harness to ECM. Run KOEO test and Output Circuit Test HIGH and LOW. Use DMM to measure voltage. If unable to run KOEO test, see ECM PWR Relay (page 216) in this section.

Test Point	Test	Spec	Comment
E-16 to GND	Output State LOW	B+	If < B+, check FVCV circuit for short to GRD or internal shorted FVCV valve.
E-16 to GND	Output State HIGH	5.5 V	If < 2.5 V, check FVCV circuit for OPEN or internal OPEN FVCV valve.

FVCV Circuit Operation

The HPP is mechanically driven by the engine and electrically controlled by the ECM.

The HPP consists of a high-pressure pump and two electric control valves, FPCV and FVCV. This is a nonserviceable unit. If the HPP or either of the two electric control valves fail, the HPP must be replaced as a unit.

The FVCV governs the amount of fuel supplied to the HPP. The FPCV regulates fuel pressure supplied to the injectors. The HPP delivers fuel to the rail at about 165 MPa. (24,000 psi)

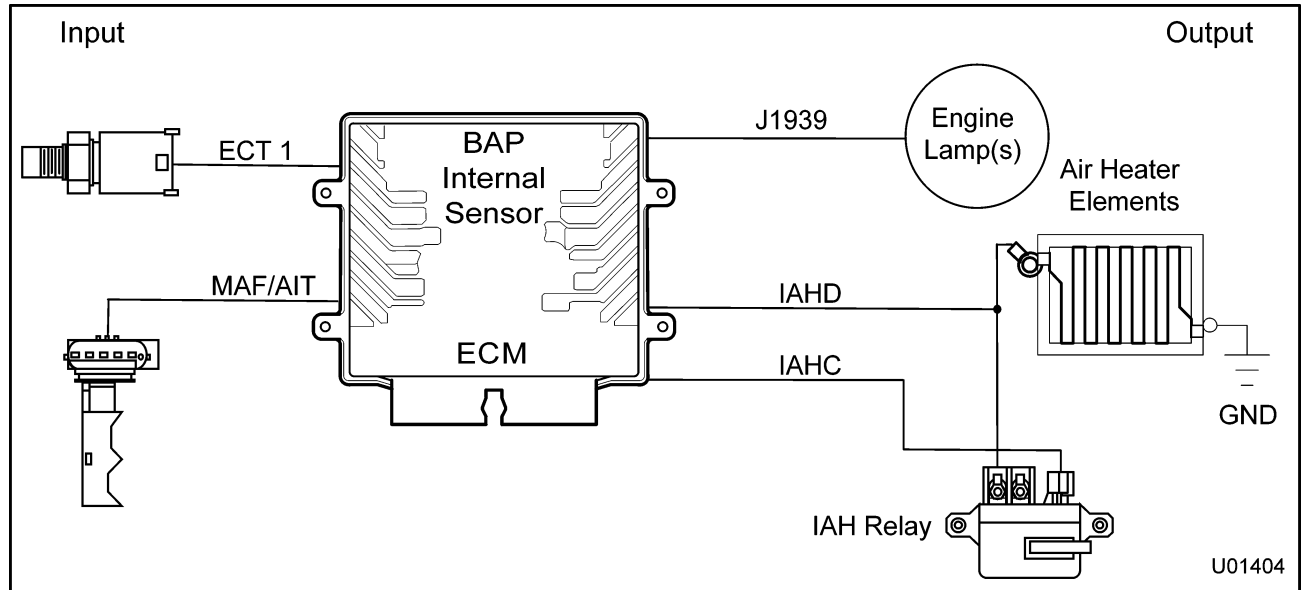
The FVCV is supplied with VPWR at Pin 1. The ECM Pin E-16 controls the valve by duty cycling a ground path to FVCV Pin 1. High duty cycle indicates high pressure and low duty cycle indicates low pressure.

Fault Detection/Management

An open or short in the FVCV circuit can be detected by an on-demand output circuit check during the KOEO Standard Test. If there is a circuit fault detected, a DTC is set.

IAH (Inlet Air Heater)**SPN FMI Condition**

729	2	IAHC Relay Circuit Fault
729	3	IAHC short to PWR
729	4	IAHC short to GND
729	5	IAHC open load/circuit

**Figure 150** Function diagram for the IAH system

The function diagram for the IAH system includes the following:

- IAH relay
- IAH element
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Engine Coolant Temperature 1 (ECT1) sensor
- Mass Air Flow (MAF)/Air Inlet Temperature (AIT) sensor
- Engine Lamp(s)

Function

The IAH system warms the incoming air supply prior to cranking to aid cold engine starting during warmup.

The IAH system also assists in reducing white smoke emissions during cold weather conditions.

Sensor Location

The IAH is installed on the manifold mixer. The IAH relay is installed on the right side of the engine on the valve cover.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- Breakout Harness ZTSE6025 (IAH)
- 1180–N4–0X0 – 180-Pin Breakout Box
- International® Electronic Engine Terminal Test Kit

IAH End Diagnostics

SPN	FMI	Condition	Possible Causes
729	2	IAHC Relay Circuit Fault	• IAH diagnostic circuit OPEN • IAH diagnostic circuit shorted to PWR • IAH diagnostic circuit shorted to GND • B+ supply circuit to relay switch OPEN • B+ supply circuit to relay switch shorted to GND • Blown fuse • IAH relay output side circuit OPEN • IAH relay output side circuit shorted to GND • IAH relay output side circuit shorted to PWR • IAH relay control circuit faults • IAH relay failed
729	3	IAHC short to PWR	• IAH relay control circuit shorted to PWR
729	4	IAHC short to GND	• IAH relay control circuit shorted to GND
729	5	IAHC open load/ circuit	• IAH relay control circuit OPEN • IAH relay coil GND circuit OPEN • Failed relay coil

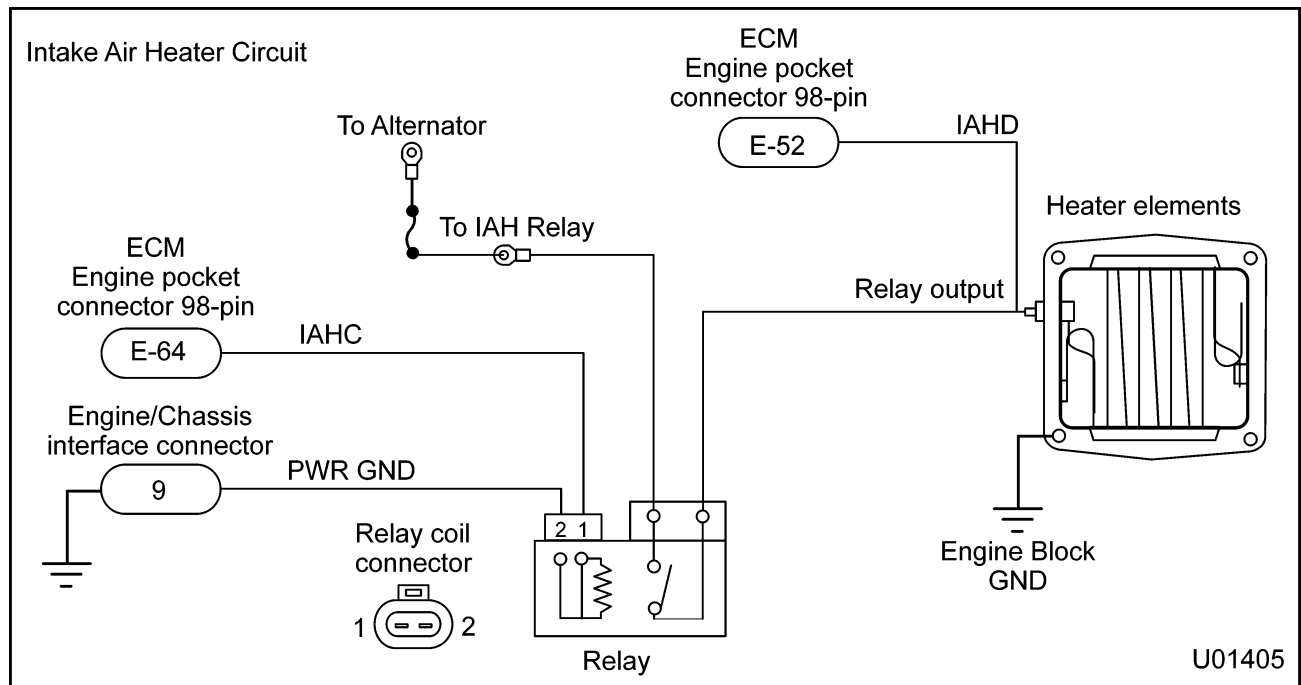


Figure 151 IAH circuit diagram

NOTE: For this procedure, run the KOEO Standard Test prior to KOEO Output State Test IAH.

The KOEO Output State Test IAH only enables the relay twice for 45 seconds each to prevent element overheating.

Voltage Check on Relay Switch – Output State Test IAH

Turn ignition switch to OFF. Use DMM to measure voltage on relay B+ side.

Test Point	Spec	Comments
Relay B+ side to GND	B+	If < B+, check large power circuit to relay for OPEN, corroded terminal, or blown fuse link.
Turn ignition switch to ON. KOEO Output State Test IAH. Use DMM to measure voltage when relay is commanded ON.		
Relay Output side to GND	B+	If 0 V, go to Voltage Check on Relay Coil – Output State Test.
Element to GND	B+	If < B+, check for corroded terminals on relay and element. Go to Amperage Check.

Voltage Check on Relay Coil – Output State Test

Disconnect relay connector. Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
IAH Relay	0 V	If > 0 V, check for OPEN or short to PWR.
Pin 1 to GND	2.74 V	If < 2 V, check for OPEN or short to GND. Go to Harness Resistance Check – Relay Coil.
Run KOEO Output State Test IAH. Use DMM to measure voltage when relay is commanded on.		
Pin 1 to GND	B+	If < B+, check IAH control circuit for OPEN. Go to Harness Resistance Check – Relay Coil.
Pin 1 to 2	B+	If < B+ check GND circuit for OPEN. Go to harness Resistance Check
If voltage checks at relay coil are okay, but voltage checks at relay switch failed, replace the relay.		

Amperage Draw Check

NOTE: Batteries must be fully charged before running this test.

Measure the amperage going to element. Run KOEO Output State Test IAH. Use a DMM with an amp probe. Set DMM to DCmV and zero amp clamp.

Test Point	Spec	Comment
Element	125 A $\pm$ 30 A (within 2 seconds)	If 0 A, go to Voltage Check on Relay Switch – Output State Test. If > 0 A, but below specification, check for corroded terminals on relay, element, and power source. Go to Element Resistance Check.
If > 0 A, but below specification, and element and wiring check out okay, replace the relay.		

Element Resistance Check

Turn ignition switch to OFF. Use a DMM to measure resistance from heater element to engine GND.

Test Point	Spec	Comment
Element to GND	< 0.5 Ω	If > 0.5 Ω , replace failed heater element.

Harness Resistance Check – Relay Coil Circuits

Turn ignition switch to OFF. Connect 180-Pin Breakout Box. Leave ECM and relay disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
IAH Relay	< 5 Ω	If > 5 Ω , check IAH control for OPEN circuit.
Pin 1 to E-64	< 5 Ω	If > 5 Ω , check VREF GND for OPEN circuit.
Pin 2 to GND	< 5 Ω	If > 5 Ω , check pin 2 for OPEN circuit.
E-64 to GND	> 38 $\Omega \pm 5 \Omega$	If < 33 Ω , check IAH control for short to GND. If > 43 Ω , check IAH control circuit for OPEN.

Harness Resistance Check – Relay Switch Circuits

Turn ignition switch to OFF. Use DMM to measure resistance.

Test Point	Spec	Comment
IAH Relay Output side to element	< 0.5 Ω	Disconnect both battery GND cables. Use DMM to measure resistance. If > 0.5 Ω , check for OPEN circuit or corroded terminals.



WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

IAH Relay B+ side to battery positive post	< 5 Ω	If > 5 Ω , check for OPEN circuit or corroded terminals.

If circuits and element are within specifications, but failed amperage test, replace the relay.

IAH Circuit Operation

The ECM controls the Amber Warning Lamp (AWL) and IAH element based on ECT, AIT, and BAP (inside ECM).

The ECM controls the AWL through the public J1939 Data Link to the Electronic Gauge Cluster (EGC).

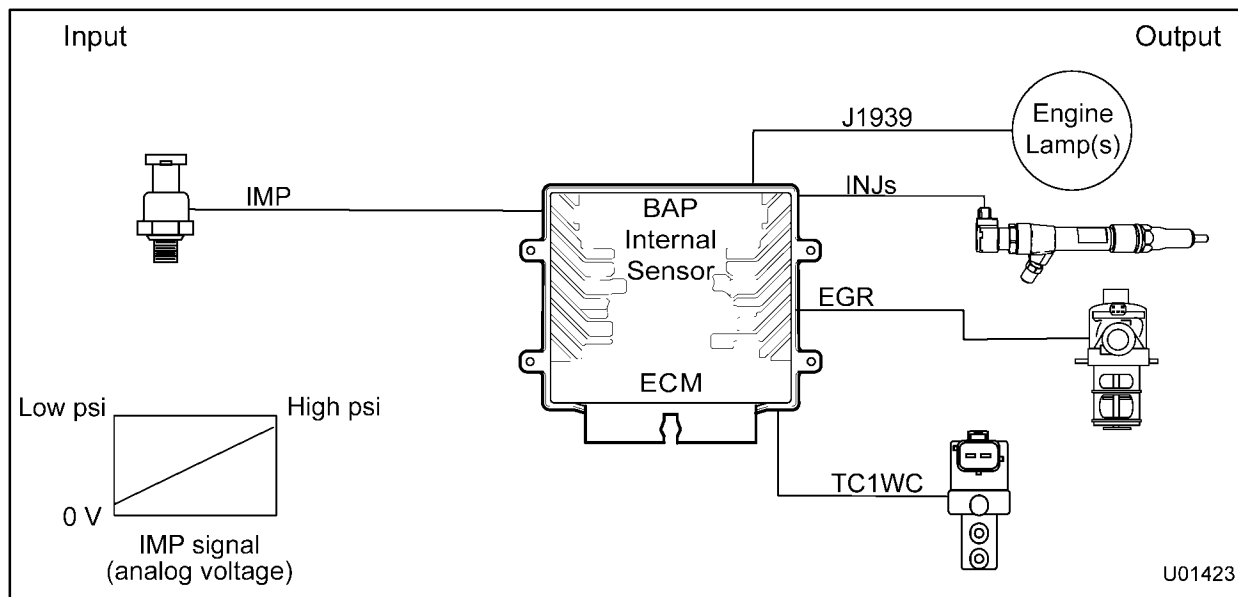
The ECM uses one relay to control the IAH element. The ECM will energize the relay by supplying power

from Pin E-64 to Pin 1 on the relay coil. The relay coil is grounded at Pin 2 through Pin 9 of the 16-pin connector from chassis harness ground. See vehicle electrical diagrams.

The power is supplied to the switch side of the relay from the alternator through a fusible link. When the relay is energized, power is supplied to the heating element, which is grounded to the intake manifold.

IMP Sensor (Intake Manifold Pressure)**SPN FMI Condition**

102	3	IMP signal Out of Range HIGH
102	4	IMP signal Out of Range LOW
102	10	IMP signal abnormal rate of change

**Figure 152 Function diagram for the IMP sensor**

The IMP sensor function diagram includes the following:

- Intake Manifold Pressure (IMP) sensor
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Exhaust Gas Recirculation (EGR) valve
- Turbocharger 1 Wastegate Control (TC1WC)
- Fuel injectors (INJ)
- Engine Lamp(s)

Function

The ECM uses the IMP sensor signal to assist in the calculation of the EGR and TCBC duty percentage. The ECM monitors the IMP signal to determine intake manifold (boost) pressure. From this information, the

ECM can optimize control of fuel rate and injection timing for all engine operating conditions.

Sensor Location

The EGR valve assembly is installed in the EGR valve elbow housing on the top front of the engine.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 3-Banana Plug Harness ZTSE4498
- 1180–N4–0X0 – 180-Pin Breakout Box
- Breakout Harness ZTSE4850 (IMP)
- International® Electronic Engine Terminal Test Kit ZTSE4435C

IMP Sensor End Diagnostics

SPN	FMI	Condition	Possible Causes
102	3	IMP signal Out of Range HIGH	- IMP signal circuit short to PWR - Failed sensor
102	4	IMP signal Out of Range LOW	- IMP signal circuit OPEN or short to GND - VREF circuit OPEN - Failed sensor
102	10	IMP signal abnormal rate of change	IMP biased circuit or sensor

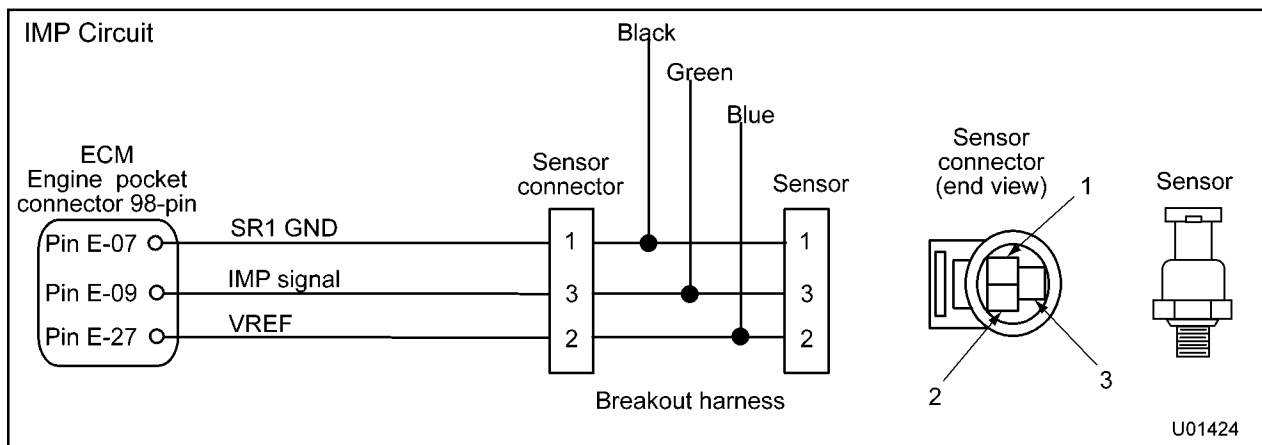


Figure 153 IMP circuit diagram

⚠ WARNING: To prevent personal injury or death, stay clear of rotating parts (belts and fan) and hot engine surfaces.

- Using Electronic Service Tool (EST) with ServiceMaxx™ software, open the Continuous Monitor session.
- Verify IMP and BAP are within specification. See "Appendix A: Performance Specifications" (page 425).
- Monitor sensor voltage. Verify an active Diagnostic Trouble Code (DTC) for the sensor.
 - If DTC is inactive, monitor the signal while wiggling the connector and all wires at suspected location. If the circuit is interrupted, the signal spikes and the DTC goes active.
 - If DTC is active, proceed to the next step.
- Disconnect engine harness from sensor.

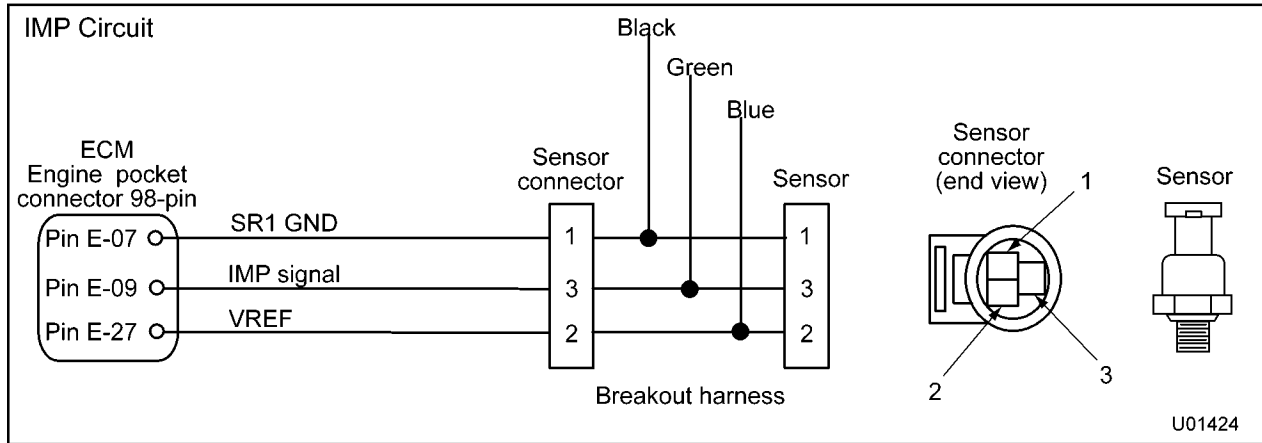
NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

- Connect breakout harness to engine harness. Leave sensor disconnected.

Sensor Circuit Check

Connect sensor Breakout Harness ZTSE4850. Leave sensor disconnected. Turn ignition switch to ON. Use Electronic Service Tool (EST) with ServiceMaxx™ software to verify correct DTC goes active when corresponding fault is induced. Use DMM to measure circuits.

Test Point	Spec	Comments
EST - Check DTC	SPN 102 FMI 4	If SPN 102/FMI 3 is active, check IMP signal for short to PWR.
DMM – Measure volts 2 to GND	5 V ± 0.5 V	If > 5.5 V, check VREF for short to PWR. If < 4.5 V, check VREF for OPEN or short to GND. Do Harness Resistance Check (page 308).
EST - Check DTC Short breakout harness across 2 and 3	SPN 102 FMI 3	If SPN 102/FMI 4 is active, check IMP signal for OPEN. Do Harness Resistance Check (page 308).
DMM – Measure resistance 1 to GND	< 5 Ω	If > 5 Ω, check SIG GND for OPEN. Do Harness Resistance Check (page 308).
If checks are within specification, connect sensor and clear DTCs. If active DTC remains, replace sensor.		

IMP Pin-point Diagnostics**Figure 154 IMP circuit diagram****Connector Voltage Check**

Connect Breakout Harness ZTSE4850. Leave sensor disconnected. Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
1 to GND	0 V	If > 0.25 V, check for short to PWR.
2 to GND	5 V $\pm$ 0.5 V	If > 5.5 V, check VREF for short to PWR. If < 4.5 V, check VREF for OPEN or short to GND. Do Harness Resistance Check (page 308).
3 to GND	0 V	If > 0.25 V, check for short to PWR. Do Harness Resistance Check (page 308).

Connector Resistance Check to GND

Turn ignition switch to OFF. Connect Breakout Harness ZTSE4850. Leave sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to GND	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
3 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box and Breakout Harness ZTSE4850. Leave ECM and sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to E-07	< 5 Ω	If > 5 Ω , check SIG GND circuit for OPEN.
2 to E-27	< 5 Ω	If > 5 Ω , check VREF circuit for OPEN.
3 to E-09	< 5 Ω	If > 5 Ω , check IMP signal circuit for OPEN.

IMP Circuit Operation

The IMP sensor is a variable capacitance sensor supplied with a 5-volt reference voltage at Pin 2 from ECM Pin E-27. The sensor is grounded at Pin 1 from ECM Pin E-07. The sensor returns a variable voltage signal from Pin 3 to ECM Pin E-09.

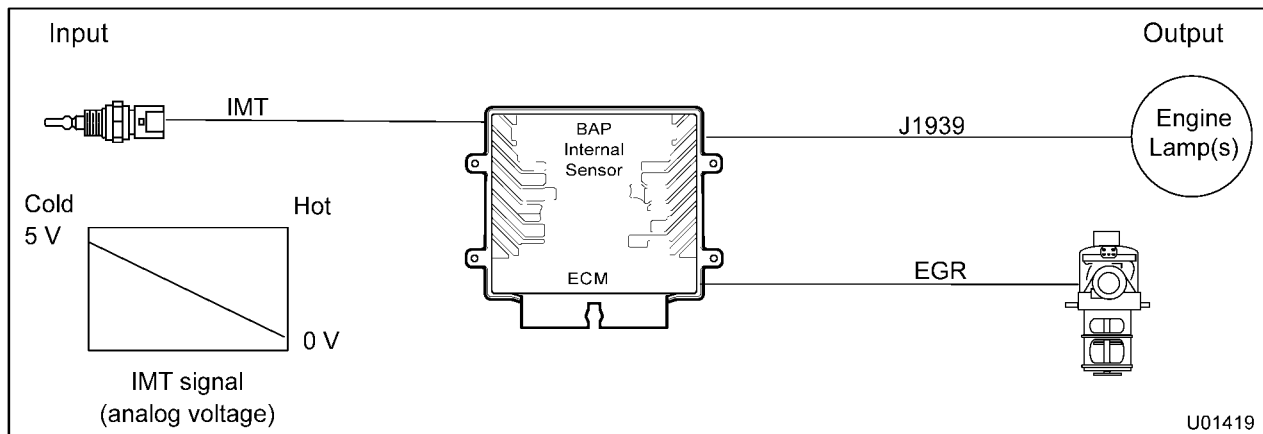
The ECM continuously monitors the control system. If the sensor signal is higher or lower than expected, the ECM disregards the signal and uses a calibrated default value. The ECM sets a DTC, turns on the Amber Warning Lamp (AWL), runs the engine in a default range, and disables the Engine Warning Protection System (EWPS).

Fault Detection/Management

The ECM monitors the internal BAP sensor as a baseline for zeroing the IMP.

IMT Sensor (Intake Manifold Temperature)**SPN FMI Condition**

105	3	IMT signal Out of Range HIGH
105	4	IMT signal Out of Range LOW
105	10	IMT signal abnormal rate of change

**Figure 155 Function diagram for the IMT sensor**

The IMT sensor function diagram includes the following:

- Intake Manifold Temperature (IMT) sensor
- Exhaust Gas Recirculation (EGR) valve
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Engine Lamp(s)

Function

The IMT sensor provides a feedback signal to the ECM indicating intake manifold air temperature. The ECM controls the EGR system based on the air temperature in the intake manifold. This aids in cold engine starting and warmups and also reduces exhaust emissions.

Sensor Location

The IMT sensor is installed in the left leg of the intake manifold, next to the IMP sensor, just behind the inlet to the turbocharger.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 3-Banana Plug Harness ZTSE4498
- 1180–N4–0X0 – 180-Pin Breakout Box
- Breakout Harness ZTSE4602 (IMT)
- International® Electronic Engine Terminal Test Kit ZTSE4435C

IMT Sensor End Diagnostics

SPN	FMI	Condition	Possible Causes
105	3	IMT signal Out of Range HIGH	• IMT signal OPEN or short to PWR • SIG GND circuit OPEN • Failed sensor
105	4	IMT signal Out of Range LOW	• IMT signal circuit short to GND • Failed sensor
105	10	IMT signal abnormal rate of change	• IMT biased circuit or sensor

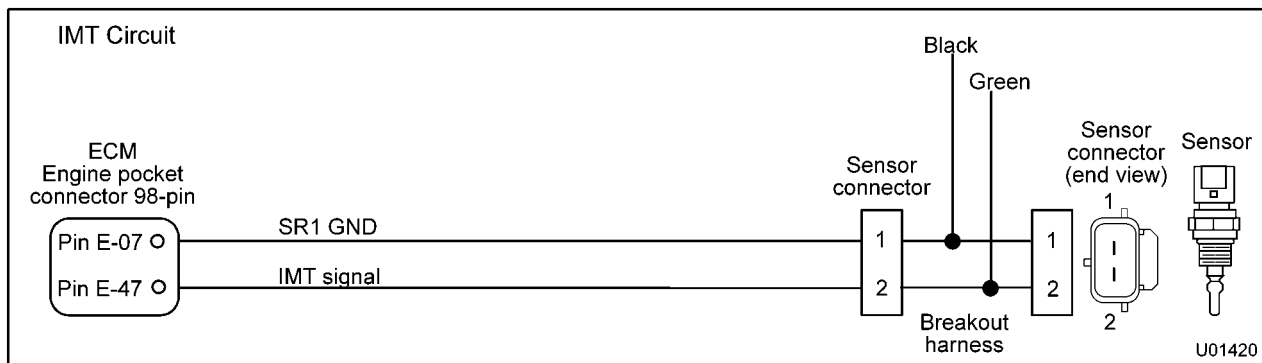


Figure 156 IMT circuit diagram

! WARNING: To prevent personal injury or death, stay clear of rotating parts (belts and fan) and hot engine surfaces.

1. Using Electronic Service Tool (EST) with ServiceMaxx™ software, open the Continuous Monitor session.
2. Monitor sensor voltage. Verify an active Diagnostic Trouble Code (DTC) for the sensor.
 - If DTC is inactive, monitor the signal while wiggling the connector and all wires at suspected location. If the circuit is interrupted, the signal spikes and the DTC goes active.

- If DTC is active, proceed to the next step.

3. Disconnect engine harness from sensor.

NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

4. Connect breakout harness to engine harness. Leave sensor disconnected.

Sensor Circuit Check

Connect Breakout Harness ZTSE4602. Leave sensor disconnected. Turn ignition switch to ON. Use Electronic Service Tool (EST) with ServiceMaxx™ software to verify correct DTC goes active when corresponding fault is induced. Use DMM to measure circuits.

Test Point	Spec	Comments
EST - Check DTC	SPN 105 FMI 3	If SPN 105 and FMI 4 is active, check IMT signal for short to GND. Do Harness Resistance Check (page 312).
EST - Check DTC Short a 3-banana plug harness across 2 and GND	SPN 105 FMI 4	If SPN 105 and FMI 3 is active, check IMT signal for OPEN. Do Harness Resistance Check (page 312).
EST - Check DTC Short 3-banana plug harness across 1 and 2	SPN 105 FMI 4	If SPN 105 and FMI 3 is active, check SIG GND for OPEN. Do Harness Resistance Check (page 312).
If checks are within specification, connect sensor and clear DTCs. If active DTC remains, replace sensor.		

IMT Pin-point Diagnostics**Connector Voltage Check**

Connect Breakout Harness ZTSE4602. Leave sensor disconnected. Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
1 to GND	0 V	If > 0.25 V, check for short to PWR.
2 to GND	4.6 V to 5 V	If < 4.5 V, check for OPEN or short to GND. Do Harness Resistance Check (page 312).

Connector Resistance Check to GND

Turn ignition switch to OFF. Connect Breakout Harness ZTSE4602. Leave sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to GND	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box and Breakout Harness ZTSE4602. Leave ECM and sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to E-07	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to E-47	< 5 Ω	If > 5 Ω , check for OPEN circuit.

IMT Circuit Operation

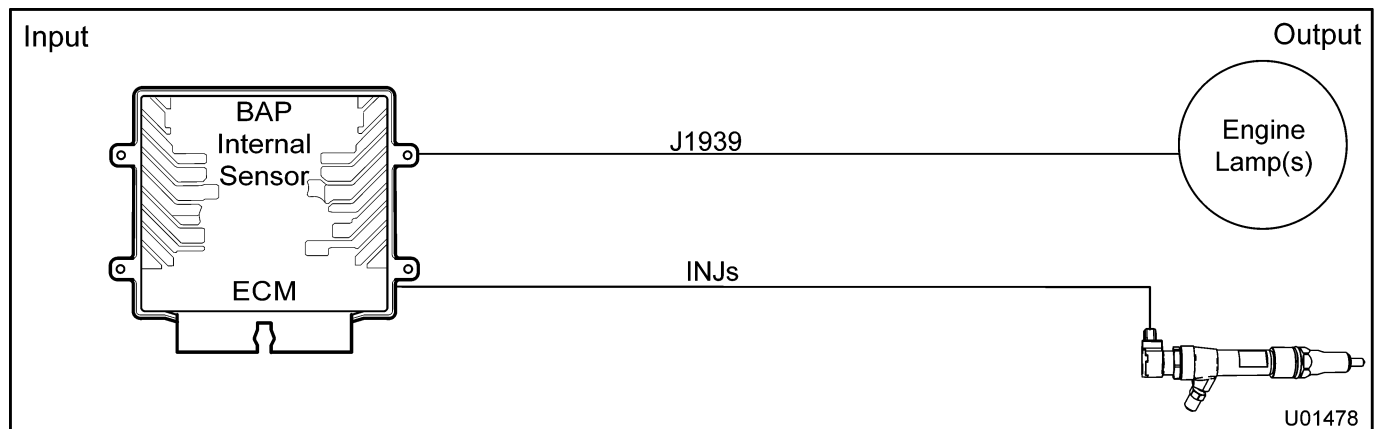
The IMT is a thermistor sensor that is supplied with a 5-volt reference voltage at Pin 2 from ECM Pin E-47. The sensor is grounded at Pin 1 from ECM Pin E-07. As the temperature increases, the resistance of the thermistor decreases. This causes the signal voltage to decrease.

Fault Detection/Management

The ECM continuously monitors the control system. If the sensor signal is higher or lower than expected, the ECM disregards the sensor signal and uses a calibrated default value. The ECM sets a DTC, turns on the Amber Warning Lamp (AWL), and runs the engine in a default range.

INJ (Injector Circuits)

SPN	FMI	Condition
651–658	4	Injector # short circuit
651–658	5	Injector # open circuit
2797	4	Initialization of fuel injector driver circuit failed group 1 (INJ 1, 3, 5, 7)
2797	11	Injector Control Group 1 short circuit (INJ 1, 3, 5, 7)
2798	4	Initialization of fuel injector driver circuit failed group 2 (INJ 2, 4, 6, 8)
2798	11	Injector Control Group 2 short circuit (INJ 2, 4, 6, 8)

**Figure 157 Function diagram for the INJ circuit**

The INJ circuit function diagram includes the following:

- Fuel injectors (INJ)
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Engine Lamp(s)

Function

The fuel injectors inject fuel into the cylinders. The ECM controls the timing and amount of fuel sprayed from each injector. The ECM also controls the high-pressure fuel system to regulate fuel pressure.

The injectors deliver several injections per ignition cycle including preinjection, main injection, and post injection. Preinjection reduces combustion noise, reduces mechanical load and exhaust emissions.

when needed, postinjection adds fuel to the exhaust to regenerate the aftertreatment system.

Component Location

The injectors are installed in the cylinder head, under the valve covers and under the high-pressure fuel rail.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- International® Electronic Engine Terminal Test Kit ZTSE4435C
- 1180–N4–0X0 – 180-Pin Breakout Box
- Breakout Harness ZTSE6000 (INJ)

Injector 1 Check

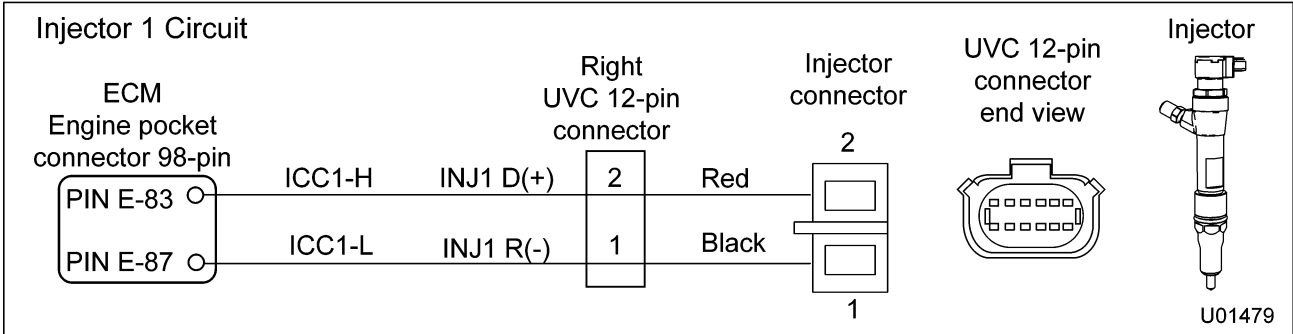


Figure 158 Injector 1 circuit diagram

Injector 1 - Resistance Checks Through Harness and Injector

! WARNING: To prevent personal injury or death, shut engine down before doing voltage checks for injectors. When the engine is running, injector circuits have high voltage and amperage.

CAUTION: To prevent engine damage, turn ignition switch to OFF before disconnecting the connectors. Failure to turn the ignition switch to OFF will cause a voltage spike and damage to electrical components.

Turn ignition switch to OFF. Connect 180-Pin Breakout Box to the ECM 98-pin connector. Leave ECM disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
E-83 to GND	> 1 kΩ	If < 1 kΩ, check circuit for short to GND or injector coil for internal short.
E-87 to GND	> 1 kΩ	
E-83 to E-87	195 kΩ to 205 kΩ	If not within specification, check for OPEN or short circuit or injector coil.

Injector 1 - Resistance UVC Checks

Turn ignition switch to OFF. Connect Breakout Harness ZTSE6000 to right UVC 12-pin harness. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to GND	> 1 kΩ	If < 1 kΩ, check circuit for short to GND or injector coil for internal short.
2 to GND	> 1 kΩ	
1 to 2	195 kΩ to 205 kΩ	If not within specification, check for OPEN or short circuit or injector coil.

Injector 1 - Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box to the ECM 98-pin connector. Leave ECM and UVC disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
E-83 to 2	< 5 Ω	If > 5 Ω , check for OPEN circuit.
E-83 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
E-87 to 1	< 5 Ω	If > 5 Ω , check for OPEN circuit.
E-87 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.

Injector 2 Check

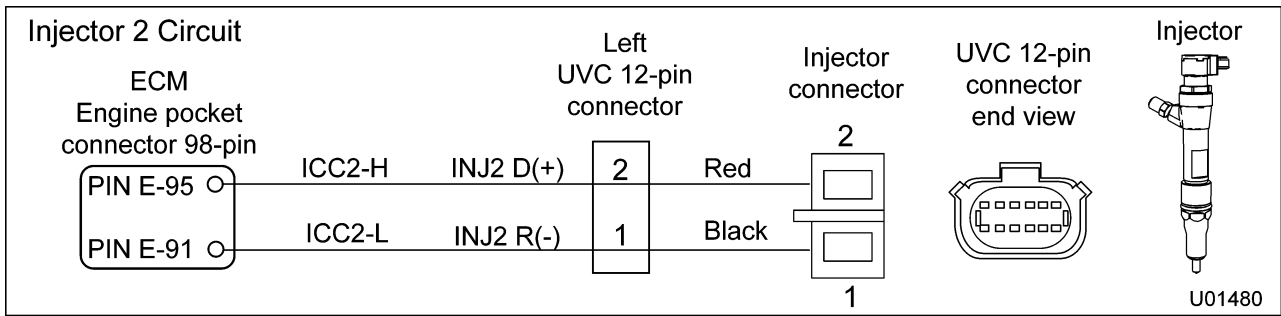


Figure 159 Injector 2 circuit diagram

Injector 2 - Resistance Through Valve Cover to Engine GND Check

! WARNING: To prevent personal injury or death, shut engine down before doing voltage checks for injectors. When the engine is running, injector circuits have high voltage and amperage.

CAUTION: To prevent engine damage, turn ignition switch to OFF before disconnecting connectors. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Turn ignition switch to OFF. Connect Breakout Harness ZTSE6000 to the left UVC 12-pin harness. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to GND	> 1 kΩ	If < 1 kΩ, check circuit for short to GND or injector coil for internal short.
2 to GND	> 1 kΩ	

Injector 2 - Coil Resistance Check

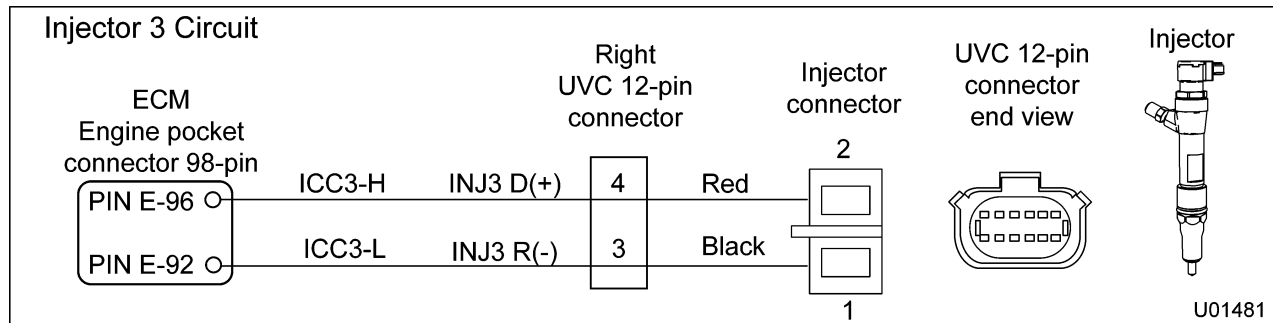
Turn ignition switch to OFF. Connect Breakout Harness ZTSE6000 to the left UVC 12-pin harness. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to 2	195 kΩ to 205 kΩ	If not within specification, check UVC harness for OPEN or short circuit. If harness is okay, replace injector.

Injector 2 - Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box to engine harness. Leave ECM and UVC disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
E-95 to 2	< 5 Ω	If > 5 Ω, check for OPEN circuit.
E-95 to GND	> 1 kΩ	If < 1 kΩ, check for short to GND.
E-91 to 1	< 5 Ω	If > 5 Ω, check for OPEN circuit.
E-91 to GND	> 1 kΩ	If < 1 kΩ, check for short to GND.

Injector 3 Check**Figure 160** Injector 3 circuit diagram**Injector 3 - Resistance Through Valve Cover to Engine GND Check**

! WARNING: To prevent personal injury or death, shut engine down before doing voltage checks for injectors. When the engine is running, injector circuits have high voltage and amperage.

CAUTION: To prevent engine damage, turn ignition switch to OFF before disconnecting connectors. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Turn ignition switch to OFF. Connect Breakout Harness ZTSE6000 to the right UVC 12-pin connector. Use DMM to measure resistance.

Test Point	Spec	Comment
3 to GND	> 1 kΩ	If < 1 kΩ, check circuit for short to GND or injector coil for internal short.
4 to GND	> 1 kΩ	

Injector 3 - Coil Resistance Check

Turn ignition switch to OFF. Connect Breakout Harness ZTSE6000 to the right UVC 12-pin connector. Use DMM to measure resistance.

Test Point	Spec	Comment
3 to 4	195 kΩ to 205 kΩ	If not within specification, check UVC harness for OPEN or short circuit. If harness is okay, replace injector.

Injector 3 - Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box to engine harness. Leave ECM and UVC disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
E-96 to 4	< 5 Ω	If > 5 Ω, check for OPEN circuit.
E-96 to GND	> 1 kΩ	If < 1 kΩ, check for short to GND.
E-92 to 3	< 5 Ω	If > 5 Ω, check for OPEN circuit.
E-92 to GND	> 1 kΩ	If < 1 kΩ, check for short to GND.

Injector 4 Check

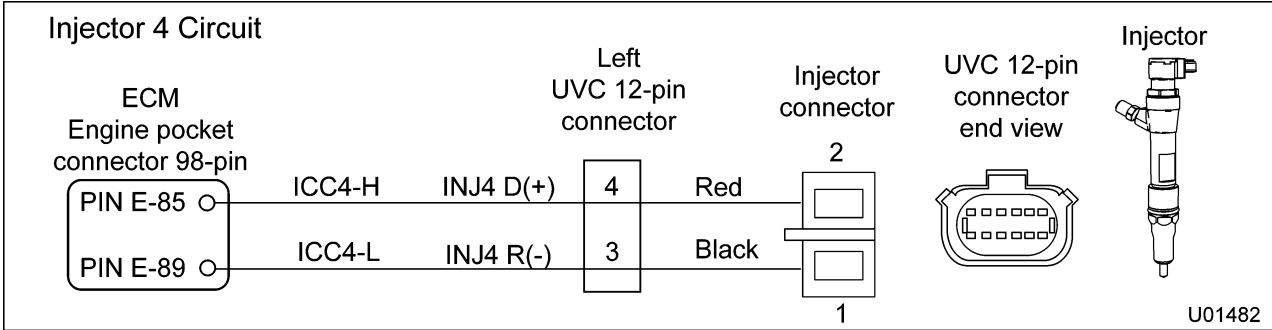


Figure 161 Injector 4 circuit diagram

injector 4 - Resistance Through Valve Cover to Engine GND Check

⚠ WARNING: To prevent personal injury or death, shut engine down before doing voltage checks for injectors. When the engine is running, injector circuits have high voltage and amperage.

CAUTION: To prevent engine damage, turn ignition switch to OFF before disconnecting connectors. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Turn ignition switch to OFF. Connect Breakout Harness ZTSE6000 to the left UVC 12-pin connector. Use DMM to measure resistance.

Test Point	Spec	Comment
3 to GND	> 1 kΩ	If < 1 kΩ, check circuit for short to GND or injector coil for internal short.
4 to GND	> 1 kΩ	

Injector 4 - Coil Resistance Check

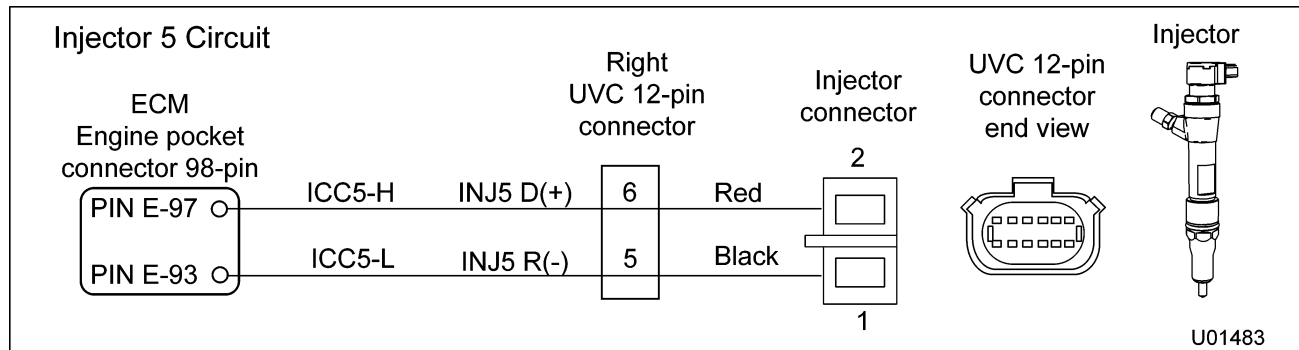
Turn ignition switch to OFF. Connect Breakout Harness ZTSE6000 to the left UVC 12-pin connector. Use DMM to measure resistance.

Test Point	Spec	Comment
3 to 4	195 kΩ to 205 kΩ	If not within specification, check UVC harness for OPEN or short circuit. If harness is okay, replace injector.

Injector 4 - Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box to engine harness. Leave ECM and UVC disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
E-85 to 4	< 5 Ω	If > 5 Ω, check for OPEN circuit.
E-85 to GND	> 1 kΩ	If < 1 kΩ, check for short to GND.
E-89 to 3	< 5 Ω	If > 5 Ω, check for OPEN circuit.
E-89 to GND	> 1 kΩ	If < 1 kΩ, check for short to GND.

Injector 5 Check**Figure 162** Injector 5 circuit diagram**Injector 5 - Resistance Through Valve Cover to Engine GND Check**

⚠ WARNING: To prevent personal injury or death, shut engine down before doing voltage checks for injectors. When the engine is running, injector circuits have high voltage and amperage.

CAUTION: To prevent engine damage, turn ignition switch to OFF before disconnecting connectors. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Turn ignition switch to OFF. Connect Breakout Harness ZTSE6000 to the right UVC 12-pin connector. Use DMM to measure resistance.

Test Point	Spec	Comment
5 to GND	> 1 kΩ	If < 1 kΩ, check circuit for short to GND or injector coil for internal short.
6 to GND	> 1 kΩ	

Injector 5 - Coil Resistance Check

Turn ignition switch to OFF. Connect Breakout Harness ZTSE6000 to the right UVC 12-pin connector. Use DMM to measure resistance.

Test Point	Spec	Comment
5 to 6	195 kΩ to 205 kΩ	If not within specification, check UVC harness for OPEN or short circuit. If harness is okay, replace injector.

Injector 5 - Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box to engine harness. Leave ECM and UVC disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
E-97 to 6	< 5 Ω	If > 5 Ω, check for OPEN circuit.
E-97 to GND	> 1 kΩ	If < 1 kΩ, check for short to GND.
E-93 to 5	< 5 Ω	If > 5 Ω, check for OPEN circuit.
E-93 to GND	> 1 kΩ	If < 1 kΩ, check for short to GND.

Injector 6 Check

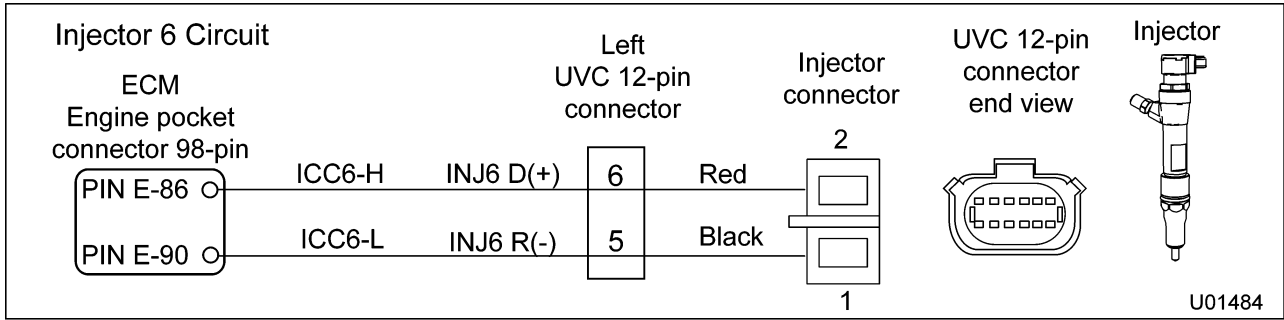


Figure 163 Injector 6 circuit diagram

Injector 6 - Resistance Through Valve Cover to Engine GND Check

⚠ WARNING: To prevent personal injury or death, shut engine down before doing voltage checks for injectors. When the engine is running, injector circuits have high voltage and amperage.

CAUTION: To prevent engine damage, turn ignition switch to OFF before disconnecting connectors. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Turn ignition switch to OFF. Connect Breakout Harness ZTSE6000 to the left UVC 12-pin connector. Use DMM to measure resistance.

Test Point	Spec	Comment
5 to GND	> 1 kΩ	If < 1 kΩ, check circuit for short to GND or injector coil for internal short.
6 to GND	> 1 kΩ	

Injector 6 - Coil Resistance Check

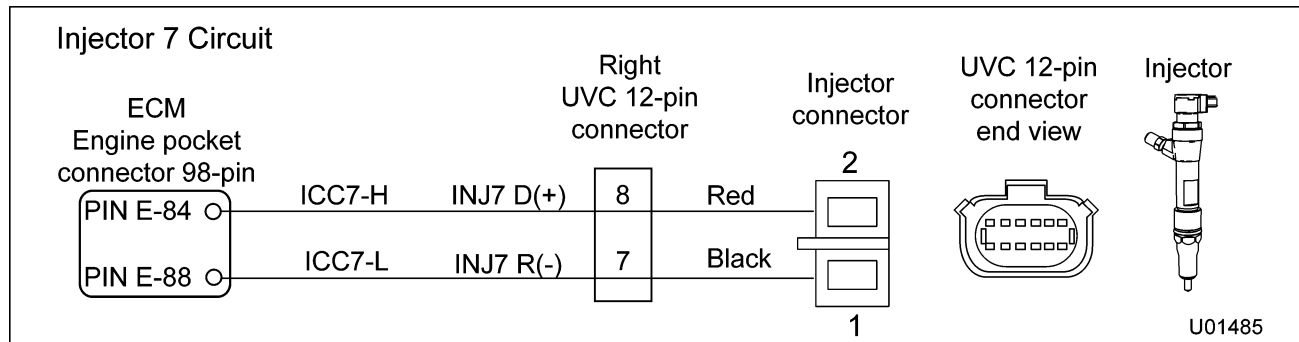
Turn ignition switch to OFF. Connect Breakout Harness ZTSE6000 to the left UVC 12-pin connector. Use DMM to measure resistance.

Test Point	Spec	Comment
5 to 6	195 kΩ to 205 kΩ	If not within specification, check UVC harness for OPEN or short circuit. If harness is okay, replace injector.

Injector 6 - Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box to engine harness. Leave ECM and UVC disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
E-86 to 6	< 5 Ω	If > 5 Ω, check for OPEN circuit.
E-86 to GND	> 1 kΩ	If < 1 kΩ, check for short to GND.
E-90 to 5	< 5 Ω	If > 5 Ω, check for OPEN circuit.
E-90 to GND	> 1 kΩ	If < 1 kΩ, check for short to GND.

Injector 7 Check**Figure 164** Injector 7 circuit diagram**Injector 7 - Resistance Through Valve Cover to Engine GND Check**

WARNING: To prevent personal injury or death, shut engine down before doing voltage checks for injectors. When the engine is running, injector circuits have high voltage and amperage.

CAUTION: To prevent engine damage, turn ignition switch to OFF before disconnecting connectors. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Turn ignition switch to OFF. Connect Breakout Harness ZTSE6000 to the right UVC 12-pin connector. Use DMM to measure resistance.

Test Point	Spec	Comment
7 to GND	> 1 kΩ	If < 1 kΩ, check circuit for short to GND or injector coil for internal short.
8 to GND	> 1 kΩ	

Injector 7 - Coil Resistance Check

Turn ignition switch to OFF. Connect Breakout Harness ZTSE6000 to the right UVC 12-pin connector. Use DMM to measure resistance.

Test Point	Spec	Comment
7 to 8	195 kΩ to 205 kΩ	If not within specification, check UVC harness for OPEN or short circuit. If harness is okay, replace injector.

Injector 7 - Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box to engine harness. Leave ECM and UVC disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
E-84 to 8	< 5 Ω	If > 5 Ω, check for OPEN circuit.
E-84 to GND	> 1 kΩ	If < 1 kΩ, check for short to GND.
E-88 to 7	< 5 Ω	If > 5 Ω, check for OPEN circuit.
E-88 to GND	> 1 kΩ	If < 1 kΩ, check for short to GND.

Injector 8 Check

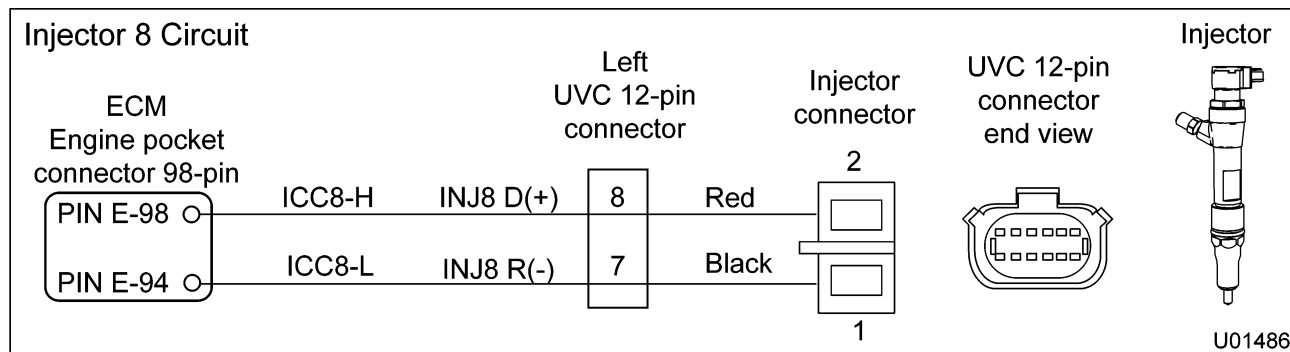


Figure 165 Injector 8 circuit diagram

Injector 8 - Resistance Through Valve Cover to Engine GND Check

⚠ WARNING: To prevent personal injury or death, shut engine down before doing voltage checks for injectors. When the engine is running, injector circuits have high voltage and amperage.

CAUTION: To prevent engine damage, turn ignition switch to OFF before disconnecting connectors. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Turn ignition switch to OFF. Connect Breakout Harness ZTSE6000 to the left UVC 12-pin connector. Use DMM to measure resistance.

Test Point	Spec	Comment
7 to GND	> 1 kΩ	If < 1 kΩ, check circuit for short to GND or injector coil for internal short.
8 to GND	> 1 kΩ	

Injector 8 - Coil Resistance Check

Turn ignition switch to OFF. Connect Breakout Harness ZTSE6000 to the left UVC 12-pin connector. Use DMM to measure resistance.

Test Point	Spec	Comment
7 to 8	195 kΩ to 205 kΩ	If not within specification, check UVC harness for OPEN or short circuit. If harness is okay, replace injector.

Injector 8 - Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box to engine harness. Leave ECM and UVC disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
E-98 to 8	< 5 Ω	If > 5 Ω, check for OPEN circuit.
E-98 to GND	> 1 kΩ	If < 1 kΩ, check for short to GND.
E-94 to 7	< 5 Ω	If > 5 Ω, check for OPEN circuit.
E-94 to GND	> 1 kΩ	If < 1 kΩ, check for short to GND.

Injector Circuit Operation

Each injector has an actuator that indirectly opens or closes the injector nozzle. Charging the actuator opens the nozzle and discharging the actuator closes the nozzle. The ECM charges and discharges the actuators by switching on either the high side or low side output. The high side output supplies the actuator with a power supply of 220 VDC at 2.5 A rms. The low side output supplies a return circuit for each injector actuator.

High Side Drive Output

There is one high side switch circuit per cylinder side. It is common to all injector circuits on that cylinder side.

High Direct Current (DC) voltage is present on these circuits.

Low Side Drive Return

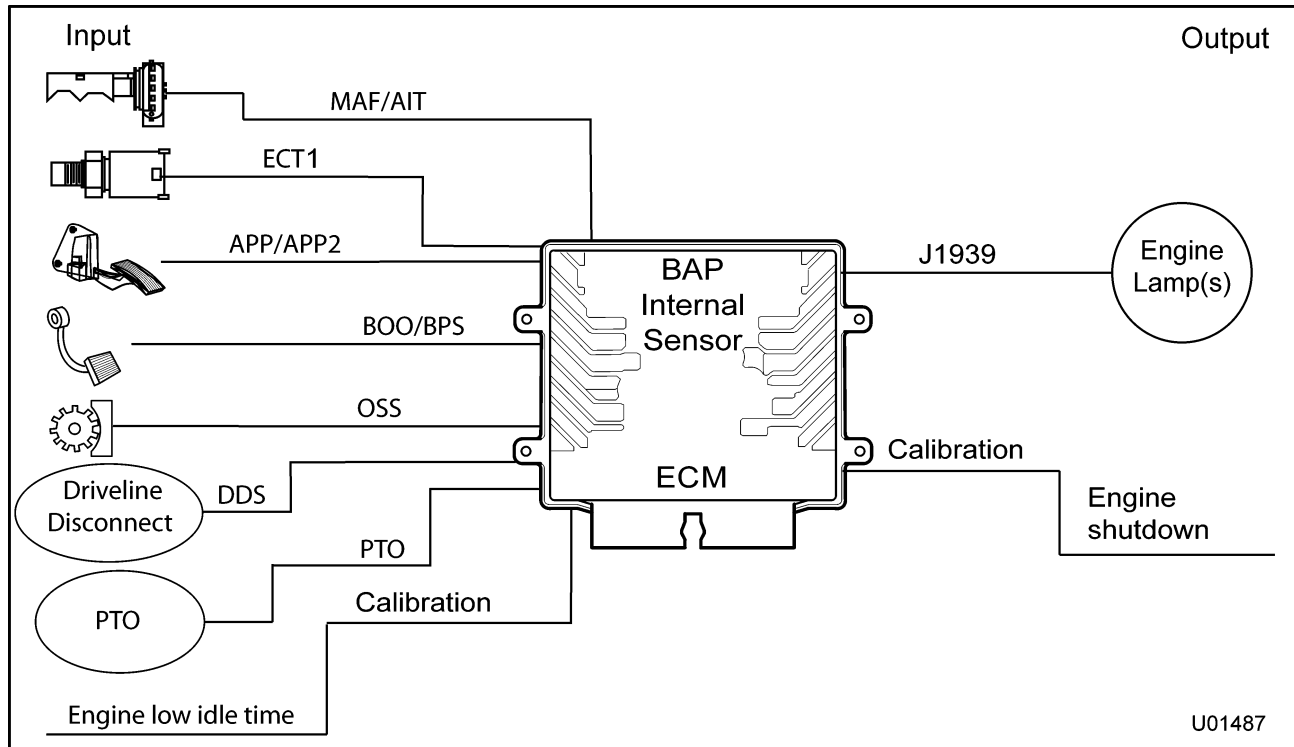
The injector actuators are grounded through the low side return switches, one per each injector.

Fault Detection/Management

The ECM can detect if the output is short to injector, short to ground/battery detection, or if output is open load.

IST System (Idle Shutdown Timer)

SPN	FMI	Condition
593	31	Engine stopped by IST

**Figure 166 Function diagram for IST system**

The IST system function diagram includes the following:

- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Mass Air Flow (MAF)/Air Inlet Temperature (AIT) sensor
- Engine Coolant Temperature 1 (ECT1) sensor
- Accelerator Pedal Position (APP) sensor
- Brake On/Off switch (BOO) and Brake Pressure Switch (BPS)
- Output Speed Sensor (OSS)
- Driveline Disengagement Switch (DDS)
- Power Takeoff (PTO)
- Engine lamp(s)

Function

The IST allows the ECM to shut down the engine during extended engine idle times.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit



GOVERNMENT REGULATION: State and local regulations may limit engine idle time. The vehicle owner or operator is responsible for compliance with those regulations.

IST Operation

Idle Shutdown Warning

Thirty seconds before IST-defined engine shutdown, a vehicle instrument panel indicator activates. There are two types of indicators:

- Amber idle shutdown indicator for multiplex electrical systems.
- Red flashing indicator with audible alarm for nonmultiplex electrical systems.

This continues until the engine shuts down or the low idle shutdown timer is reset.

Engine Idle Shutdown Timer for California ESS-Compliant Engines

Beginning in 2008 MY, International® MaxxForce® engines certified for sale in the state of California (CA) will conform to mandatory California Air Resources Board (CARB) Engine Shutdown System (ESS) regulations. The prior function of the IST is available on CA ESS exempt and federally certified engines (school buses, emergency, and military vehicles).

Engine idle duration is limited for ESS-compliant engines as follows:

- When vehicle parking brake sets, the idle shutdown time is limited to the CARB requirement of 5 minutes.
- When vehicle parking brake is released, the idle shutdown time is limited to the CARB requirement of 15 minutes.

The duration of CARB mandated values can be reduced by programming the customer IST programmable parameter to a value lower than 15 minutes. Adjusting this parameter reduces overall system shutdown time as follows:

- Adjusting parameter value between 5 and 15 minutes reduces idle shutdown time with the vehicle parking brake released. The default value of 5 minutes for the vehicle parking brake “set” condition remains unaffected.
- Adjusting parameter value between 2 and 5 minutes reduces idle time for both the vehicle parking brake “released” and “set” conditions.

While the EST is installed, idle shutdown time is factory defaulted to 60 minutes and cannot be

adjusted. If the IST is enabled, the Cold Ambient Protection (CAP) will not function.

NOTE: The CARB IST feature is factory programmed. Customers cannot turn IST off for ESS-compliant engines.

CARB IST Conditions

The following conditions must be true for the IST to activate in all modes. Any change of the “true” state of one or more of these conditions resets or disables the IST.

- Manual Diesel Particulate Filter (DPF) regeneration is inactive (not enabled).
- Steady driveline state (no transition detected). No change in the state of the clutch switch (manual transmission) or transmission shifter between the in-gear position and neutral or park (automatic transmission).
- Power Takeoff (PTO) Remote mode disabled.
- Engine coolant temperature greater than 15.6 °C (60 °F).
- Engine is operating in run mode or in active EST mode.
- Vehicle speed is less than 1.25 miles/hr.
- No active vehicle speed diagnostic faults.
- PTO control is in off or standby mode.
- Engine speed is less than 750 RPM.
- Steady accelerator pedal position (no transition detected from any preset position).
- Steady brake pedal state (no transition detected from any preset state).
- Steady parking brake state (CAN (J1939) message) (no transition detected from any preset state).

Engine Idle Shutdown Timer (Federal-Optional)

Idle time can be programmed from 5 to 120 minutes. While the EST is installed, the IST function is active with the programmed shutdown time in effect. Parking brake transitions reset the idle timer. If the IST is enabled, the Cold Ambient Protection (CAP) will not function.

Federal IST Conditions

The following conditions must be true for the IST to activate. Any change to the “true” state of one or more of these conditions resets or disables the IST.

Common Enable Conditions for All Federal IST Options

- Manual Diesel Particulate Filter (DPF) regeneration is inactive (not enabled).
- Steady driveline state (no transition detected). No change in the state of the clutch switch (manual transmission) or transmission shifter between the in-gear position and neutral or park (automatic transmission).
- PTO Remote mode disabled.
- Air inlet temperature greater than 15.6 °C (60 °F) (manufacturer's default, customer adjustable parameter).
- Air inlet temperature lower than 44 °C (111 °F) (manufacturer's default, customer adjustable parameter).
- Engine coolant temperature greater than 60° C (140 °F).
- Engine is operating in run mode or in active EST mode.
- Vehicle speed is less than 1.25 miles/hr.
- No active vehicle speed diagnostic faults.
- Steady parking brake state (CAN (J1939) message). No transition detected from any preset state.

Additional operation enable conditions depending on selected federal IST operation mode:

Federal IST Mode 1: PTO Operation Option Enable Conditions

- PTO control is in off or standby mode.

- Engine speed is less than 750 RPM.
- Accelerator pedal position is less than 2%.
- No active accelerator pedal diagnostic faults.
- Steady brake pedal state (no transition detected).
- No active brake system diagnostic faults.

Federal IST Mode 2: No Load / Light Load Limit Option Enable Conditions

- Accelerator pedal position is less than 2%.
- No active accelerator pedal diagnostic faults.
- Steady brake pedal state (no transition detected).
- No active brake system diagnostic faults.
- Engine reported fuel usage (load) is less than ECM specified limit (factory calibrated, not customer adjustable).

Federal IST Mode 3: Tamper Proof Option Enable Conditions

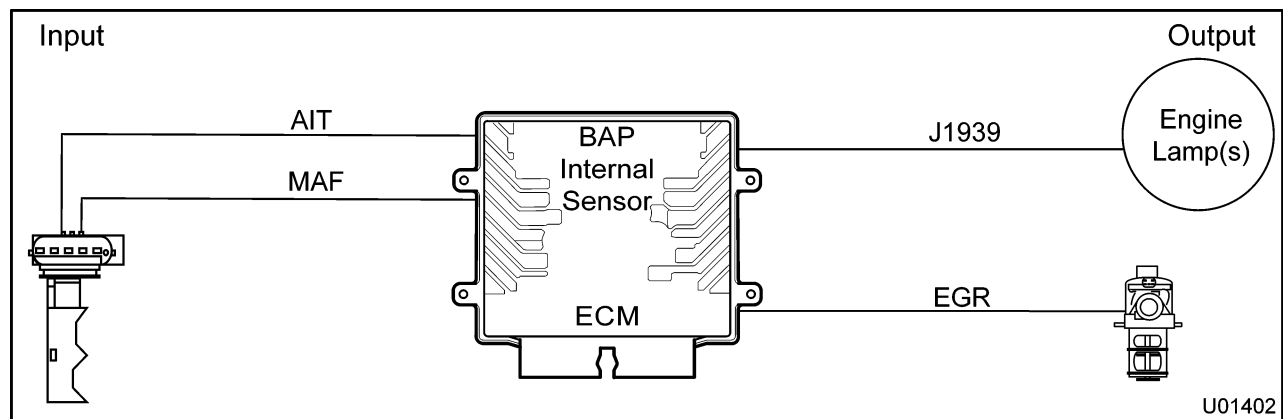
- Engine reported fuel usage (load) is less than ECM specified limit (factory calibrated, not customer adjustable).
- Steady accelerator pedal position (no transition detected from any preset position).
- Steady brake pedal state (no transition detected from any preset state).

Fault Detection/Management

The IST Diagnostic Trouble Code (DTC) does not indicate a system fault. SPN 595 FMI 31 sets by the ECM when the engine has been shut down due to exceeding the programmed idle time. The IST feature must be enabled for SPN 595 FMI 31 to be displayed.

MAF/AIT Sensor (Mass Air Flow/Air Inlet Temperature)

SPN	FMI	Condition
132	3	MAF signal Out of Range HIGH
132	4	MAF signal Out of Range LOW
132	10	MAF signal abnormal rate of change
132	11	MAF sensor Calibration – Insufficient number of data points
132	13	MAF sensor Calibration Needed
132	14	MAF sensor Calibration Failed
172	3	AIT signal Out of Range HIGH
172	4	AIT signal Out of Range LOW
172	10	AIT signal abnormal rate of change

**Figure 167 Function diagram for the MAF/AIT sensor**

The MAF/AIT sensor function diagram includes the following:

- Mass Air Flow (MAF)/Air Inlet Temperature (AIT) sensor
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Exhaust Gas Recirculation (EGR) valve
- Engine Lamp(s)

Function

The MAF/AIT sensor directly monitors the air entering the engine. The MAF also houses the AIT sensor, which is used with the MAF to calibrate the amount and density of the incoming air.

Sensor Location

The MAF/AIT sensor is installed in the intake duct between the engine and the air cleaner assembly.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 1180–N4–0X0 – 180-Pin Breakout Box
- Breakout Harness ZTSE4960 (MAF)
- International® Electronic Engine Terminal Test Kit ZTSE4435C

MAF/AIT Sensor End Diagnostics

SPN	FMI	Condition	Possible Causes
132	3	MAF signal Out of Range HIGH	• MAF signal circuit OPEN or short to PWR • Failed MAF/AIT sensor
132	4	MAF signal Out of Range LOW	• MAF signal circuit short to GND • Failed MAF/AIT sensor
132	10	MAF signal abnormal rate of change	• Biased MAF sensor or circuit
132	11	MAF sensor Calibration – Insufficient number of data points	• Engine condition not stable to accept MAF calibration • See MAF Calibration Pre-Checks
132	13	MAF Sensor Calibration Needed	• ECM was replaced • ECM was reprogrammed
132	14	MAF Sensor Calibration Failed	• Leak in intake air system • Leak in exhaust system • Failed MAF/AIT sensor
172	3	AIT signal Out of Range HIGH	• AIT signal circuit OPEN or short to PWR • SIG GND circuit OPEN • Failed MAF/AIT sensor
172	4	AIT signal Out of Range LOW	• AIT signal circuit short to GND • Failed MAF/AIT sensor
172	10	AIT signal abnormal rate of change	• Biased AIT signal or circuit • Failed MAF/AIT sensor

MAF Calibration Requirements

NOTE: Only run the MAF Calibration Procedure if one of the following conditions have occurred:

- SPN 132 FMI 13 is set
 - ECM replacement
 - Repair or replacement of MAF sensor or circuit
 - Repair or replacement of Intake Manifold Pressure (IMP) sensor or circuit
 - Repair or replacement of Intake Manifold Temperature (IMT) sensor or circuit
 - Repair or replacement of intake air system
 - Repair or replacement of CAC system
 - Repair or replacement of turbocharger
 - Repair or replacement of Engine Throttle Valve (ETV)
 - Repair or replacement of EGR valve
 - Repair base engine (cylinder head, pistons, camshaft)
 - Engine replacement or rebuild
-

Continue to MAF Calibration Pre-Checks

MAF Calibration Pre-Checks

NOTE: Verify the following before running the MAF Calibration Procedure:

- No active fault codes, other than SPN 132 FMI 13
 - Ambient Air Temperature (AAT) at or above 14 °C (58 °F)
 - KOER Standard Test run and successfully completed
 - Engine Coolant Temperature (ECT) at or above 70 °C (158 °F)
 - DPF Status = Regen Not Needed
 - No leaks in intake air system
 - No leaks in exhaust system
 - No shop exhaust hose attached
 - No engine performance issues
 - No engine misfire issues
 - Engine hood is closed
 - Transmission in Park or Neutral
 - Clutch disengaged
 - Engine Fan OFF
 - Parking brake ON
 - Power Takeoff (PTO) disabled
 - Air conditioning OFF
 - Accelerator pedal not depressed
 - MAF sensor within KOEO specification
 - IMP sensor within KOEO specification
 - IMT sensor within -30 °C (-22 °F) and 125 °C (257 °F)
-

Continue to MAF Calibration Procedure

MAF Calibration Procedure – Using ServiceMaxx™ Software

NOTE: Ensure MAF Calibration Requirements are met and MAF Calibration Pre-Checks are done, prior to doing this procedure.

1. Turn ignition switch to ON, engine OFF.
2. Start ServiceMaxx™ software.
3. Start engine. Ensure engine operating temperature is at or above 80 °C (176 °F).
4. Run KOER Standard Test.
5. Run KOER MAF Sensor Calibrate Procedure (page 63).
 - If calibration fails, verify all MAF Calibration Requirements (page 329) are met and MAF Calibration Pre-Checks (page 330) are done.
 - If calibration is successful, clear previously active DTC (SPN 132 FMI 13), if present. Turn ignition switch to OFF and wait for 3 seconds. Turn ignition switch ON and review results (programmable parameters 99391 and 99401) in the Parameters tab.

NOTE: If results do not update during the ignition switch cycle, cycle ignition switch again and manually select the engine from the File drop-down menu.

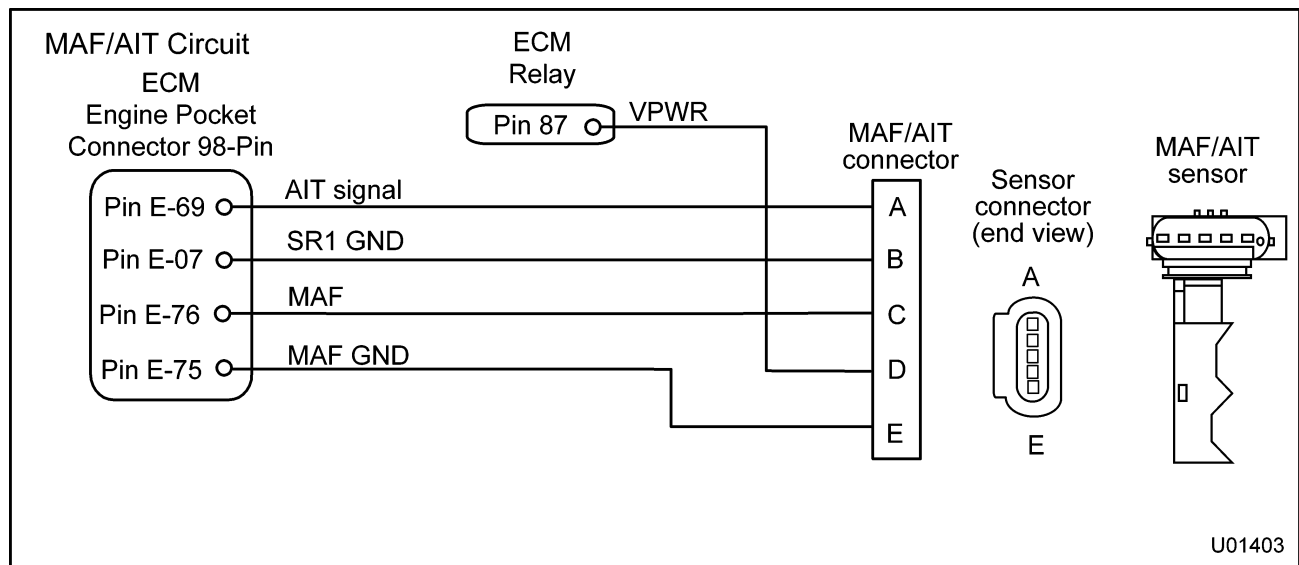
MAF/AIT Pin-point Diagnostics

Figure 168 MAF circuit diagram

Connector Voltage Check

Connect Breakout Harness ZTSE4960. Leave sensor disconnected. Turn ignition switch to ON, engine OFF. Use DMM to measure voltage. Use DMM to measure voltage.

Test Point	Spec	Comment
A to GND	4.6 V to 5 V	If < 4.5 V, check for OPEN AIT circuit or short to GND
B to B+	B+	If below B+ check for OPEN SR1 GND circuit.
C to GND	4.6 V to 5 V	If < 5 V, Check for OPEN MAF circuit or short to GND.
D to GND	B+	If < B+, Check for OPEN VPWR circuit.
E to B+	B+	If < B+, Check for OPEN MAF GND circuit.

If checks are within specifications, connect sensor and clear DTCs. If active DTCs remain, replace sensor.

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box and Breakout Harness ZTSE4960. Leave ECM and sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
A to E-69	< 5 Ω	If > 5 Ω , check for OPEN AIT circuit.
B to E-07	< 5 Ω	If > 5 Ω , check for OPEN SR1 GND circuit.
C to E-76	< 5 Ω	If > 5 Ω , check for OPEN MAF circuit.
E to E-75	< 5 Ω	If > 5 Ω , check for OPEN MAF GND circuit.

MAF/AIT Circuit Operation

The MAF sensor is used to measure the volume and density of air entering the engine at any given time. The ECM uses this information to calculate the correct amount of EGR during engine operation.

The MAF sensor assembly also contains the AIT sensor. The MAF and AIT sensors are integrated into this single component and mounted on the outlet of the air cleaner box.

The ECM determines the amount and density of the incoming air by processing input signals from the MAF sensor.

MAF Sensor

The MAF sensor directly monitors the amount of air entering the engine. The sensor is supplied with 12V from the ECM PWR Relay to Pin D. The sensor is supplied with ground from ECM Pin E-75 to Pin E. The MAF returns a digital signal from Pin C to ECM Pin E-76.

AIT Sensor

The AIT monitors the temperature of the air entering the intake system. The AIT is supplied with 12V from the ECM PWR Relay to Pin D and is supplied with ground from ECM Pin E-07 to in B. The AIT returns a variable voltage signal from Pin A to ECM Pin E-69.

Extended Diagnostic Information

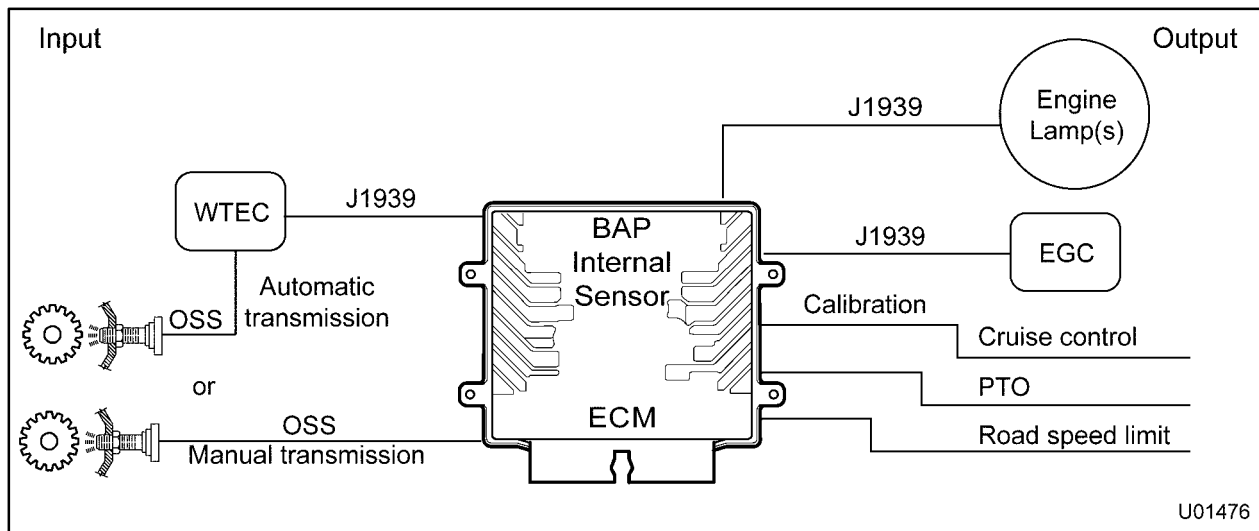
1. At KOEO, the MAF/AIT sensor produces a frequency of 750–10,000 Hz. Monitor the MAF Hz. Record your MAF/AIT sensor readings at KOEO and at idle and again at various RPM ranges. Compare the values against specifications.
2. Start from idle and increase the RPM while watching MAF/AIT reading. Increase should be steadily proportional to RPM change.
3. Perform the same checks while lightly tapping on the sensor or heating the sensor with a blow dryer. Any fluctuation or out-of-specification reading indicates a MAF/AIT sensor or related wiring concern. Repair and retest

Fault Detection / Management

The ECM continuously monitors the control system. If the sensor signal is higher or lower than expected, the ECM disregards the signal and uses a calibrated default value. The ECM sets a DTC, turns on the Amber Warning Lamp (AWL), and runs the engine in a default range.

OSS (Output Shaft Speed) Sensor**SPN FMI Condition**

191	3	TOSS signal Out of Range HIGH
191	4	TOSS signal Out of Range LOW
191	19	TOSS signal not detected on J1939

**Figure 169 Function diagram for the OSS**

The function diagram for the OSS includes the following:

- Output Shaft Speed (OSS) sensor
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- World Transmission Electronic Control (WTEC) ECM
- Cruise Control (CCS)
- Road Speed Limit (RSL)
- Power Takeoff (PTO)
- Electronic Gauge Cluster (EGC)
- Engine Lamp(s)

Function

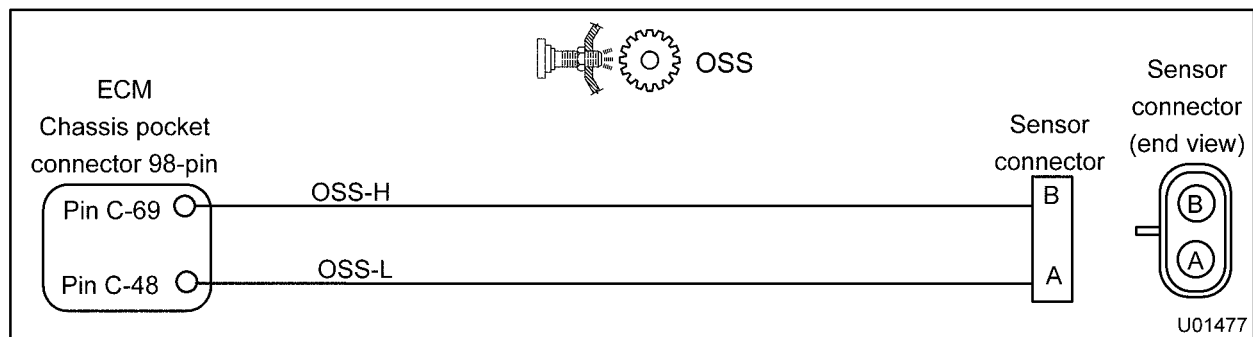
The OSS is used by the ECM to monitor the vehicle's speed. The ECM uses this signal to control PTO, road speed limiting, and cruise control. Automatic transmissions use this signal for shift scheduling.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- *Electrical System Troubleshooting Guide* (truck manual)
- *Chassis Electrical Circuit Diagram Manual* (truck manual)
- Digital Multimeter (DMM)

OSS Pin-point Diagnostics (Manual Transmissions)

SPN	FMI	Condition	Possible Causes
191	3	TOSS signal Out of Range HIGH	- OSS circuits OPEN or short to PWR - OSS frequency below 0.25 Hz - Failed OSS - Incorrect PP setting
191	4	TOSS signal Out of Range LOW	- OSS circuits short to GND - OSS frequency below 0.25 Hz - Incorrect PP setting
191	19	TOSS signal not detected on J1939	See <i>Electrical System Troubleshooting Guide</i>.

**Figure 170 OSS circuit diagram (manual transmissions)**

OSS circuit diagnostics require the use of vehicle circuit diagrams. See truck *Chassis Electrical Circuit Diagram Manual* and *Electrical System Troubleshooting Guide* for circuit numbers, connectors, and fuse locations.

1. Connect EST to Diagnostic Connector.

2. Turn ignition switch to ON.

- If SPN 191 FMI 19 is displayed, see *Electrical System Troubleshooting Guide*.
- If SPN 191 FMI 3 or 4 is displayed, continue to next check.

Connector Voltage Checks

Disconnect OSS. Turn ignition switch to ON. Use a DMM to measure voltage.

Test Point	Spec	Comment
B to GND	2.5 V $\pm$ 0.5 V	If < 2 V, check for OPEN or short to GND.
A to GND	2.5 V $\pm$ 0.5 V	If > 3 V, check for OPEN or short to PWR.

Sensor Resistance Check

Disconnect OSS. Use a DMM to measure resistance through sensor.

Test Point	Spec	Comment
A to B	700 Ω $\pm$ 100 Ω	If not within specification, replace OSS.

Harness Resistance Check

Connect breakout box. Leave OSS and ECM disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
C-48 to A	< 5 Ω	If > 5 Ω , check for OPEN circuit.
C-69 to B	< 5 Ω	If > 5 Ω , check for OPEN circuit.

OSS Circuit Operation (Manual and Allison Transmissions)

The OSS sensor produces a pulsating AC voltage. The voltage level and number of pulses increase with vehicle speed.

Allison WTEC MD, HD, and 2000 series transmissions use an internal OSS that sends a signal to the transmission module for Allison transmissions. The transmission module processes the signal and sends a frequency signal over J1939 to the engine ECM. For manual transmission, the engine ECM processes the signal, which comes directly from OSS sensor.

ECM transmits a voltage signal on the OSS circuit and determines if the return voltage is out of range high, low, or has a circuit fault. When a fault is detected, the ECM disables the cruise control and power takeoff. If the road speed limiting option is enabled, the ECM limits engine rpm for all gears.

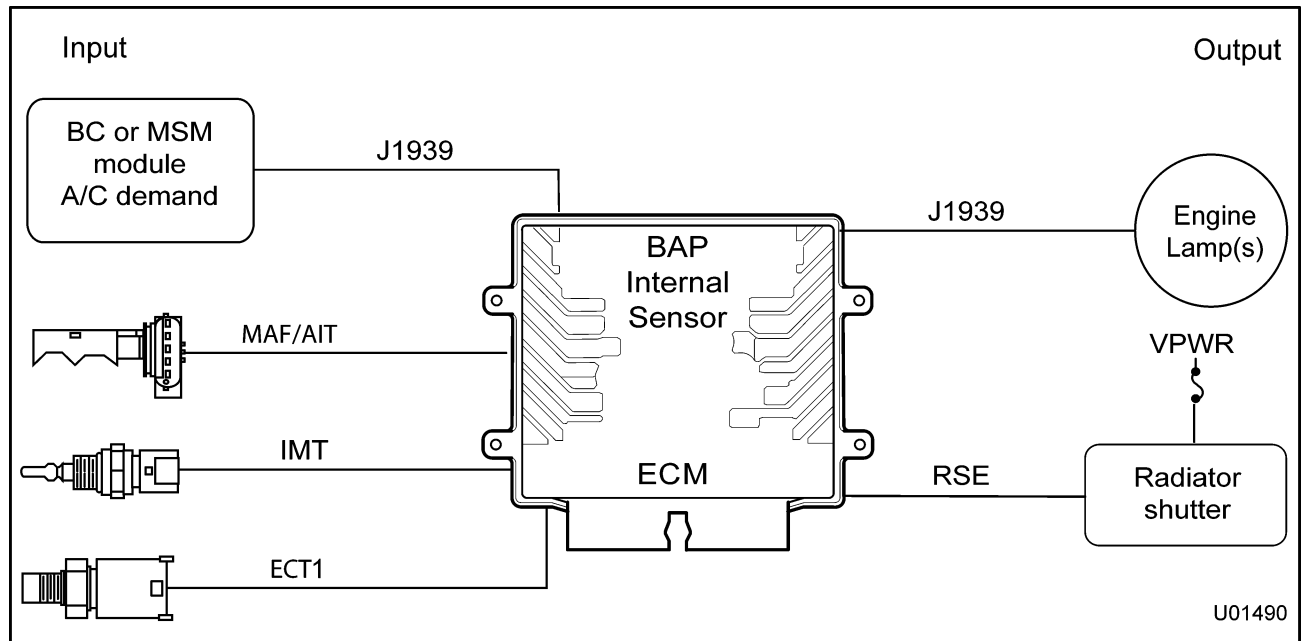
NOTE: See truck *Chassis Electrical Circuit Diagram Manual* and *Electrical System Troubleshooting Guide* for circuit numbers, connectors, and fuse locations. To diagnose Allison transmission OSS problems, use Allison maintenance and diagnostic manuals.

Fault Detection/Management

The ECM performs diagnostic checks on the OSS circuit when the vehicle is moving at 0 mph. The

RSE (Radiator Shutter Enable)

SPN	FMI	Condition
None	None	

**Figure 171 Function diagram for RSE**

The RSE function diagram includes the following:

- Radiator Shutter Enable (RSE)
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Air Inlet Temperature (AIT) signal from the Mass Air Flow (MAF) sensor
- Intake Manifold Temperature (IMT)
- Engine Coolant Temperature 1 (ECT1) sensor
- Engine Lamp(s)
- Body Controller (BC) or Multiplex System Module (MSM)

Function

RSE feature provides signals to open or close radiator shutters (energize or de-energize the solenoid).

Closing the shutters keeps the engine warm during cold weather operation. This provides faster warmup of the passenger cab and enables faster windshield defrosting.

Component Location

The radiator shutter solenoid is installed in the pressure line that feeds the shutters.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- International® Electronic Engine Terminal Test Kit ZTSE4435C

RSE Circuit Diagnostics

SPN	FMI	Condition	Possible Causes
None	None	Inactive radiator shutter	• RSE circuit OPEN or short to GND • VPWR circuit OPEN or short to GND, blown fuse • Failed relay • Failed RSE solenoid

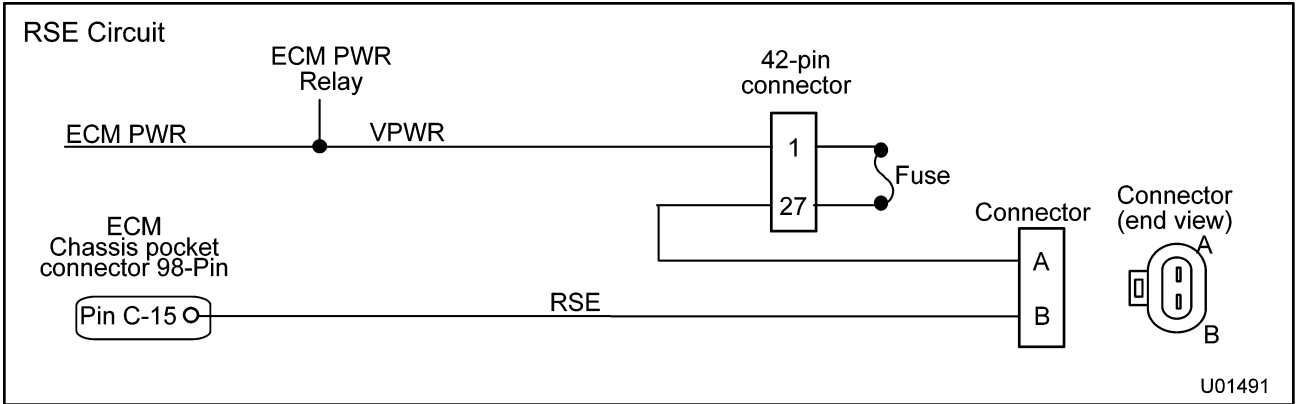


Figure 172 RSE circuit diagram

Voltage Check at RSE Connector - Output State Test

Disconnect radiator shutter solenoid 2-pin connector. Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
A to GND	B+	If < B+, check VPWR circuit for OPEN, blown fuse, or failed relay.
B to GND	0 V to 0.25 V	If > 0.25 V, check RSE circuit for short to PWR.
Run Output State Test HIGH.		
B to B+	0 V to 0.25 V	If > 0.25 V, check RSE circuit for short to GND.
Run Output State Test LOW.		
B to B+	B+	If < B+, check RSE circuit for OPEN or short to PWR. Do Harness Resistance Check (page 339).
A to B+	B+	If < B+, check VPWR circuit for OPEN. Do Harness Resistance Check (page 339).

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box. Leave ECM and radiator shutter solenoid disconnected.

Test Point	Spec	Comment
C-15 to B	< 5 Ω	If > 5 Ω , check RSE for OPEN circuit.
C-15 to GND	> 1 k Ω	If < 1 k Ω , check RSE circuit for short to GND.
A to C-83, C-84 and C-85	< 5 Ω	If > 5 Ω , check VPWR for OPEN in circuit.
A to GND	> 1 k Ω	If < 1 k Ω , check VPWR for short to GND.

See truck *Chassis Electrical Circuit Diagram Manual* and *Electrical System Troubleshooting Guide* for fuse information.

RSE Circuit Operation

The control cylinder responds to air or hydraulic pressure from the shutter control valve and actuates to hold the spring-loaded vanes closed. When pressure is relieved, the vanes open. The vanes open automatically when the vehicle is shut down.

The RSE solenoid is supplied VPWR at Pin A. The ECM Pin C-15 controls the solenoid by grounding Pin B.

The shutters close when all of the following conditions exist:

- IMT is less than 37 °C (99 °F)
- AIT is less than 7 °C (45 °F)
- ECT is less than 80 °C (176 °F)
- No transmission retarder request is present
- No engine fan request is present

The shutters will open when any of the following conditions exist:

- IMT is greater than 60 °C (140 °F)

- AIT is greater than 12 °C (54 °F)
- Transmission retarder request is present
- Engine fan request is present
- ECT is greater than 87° C (189 °F)

NOTE: ECT is customer programmable

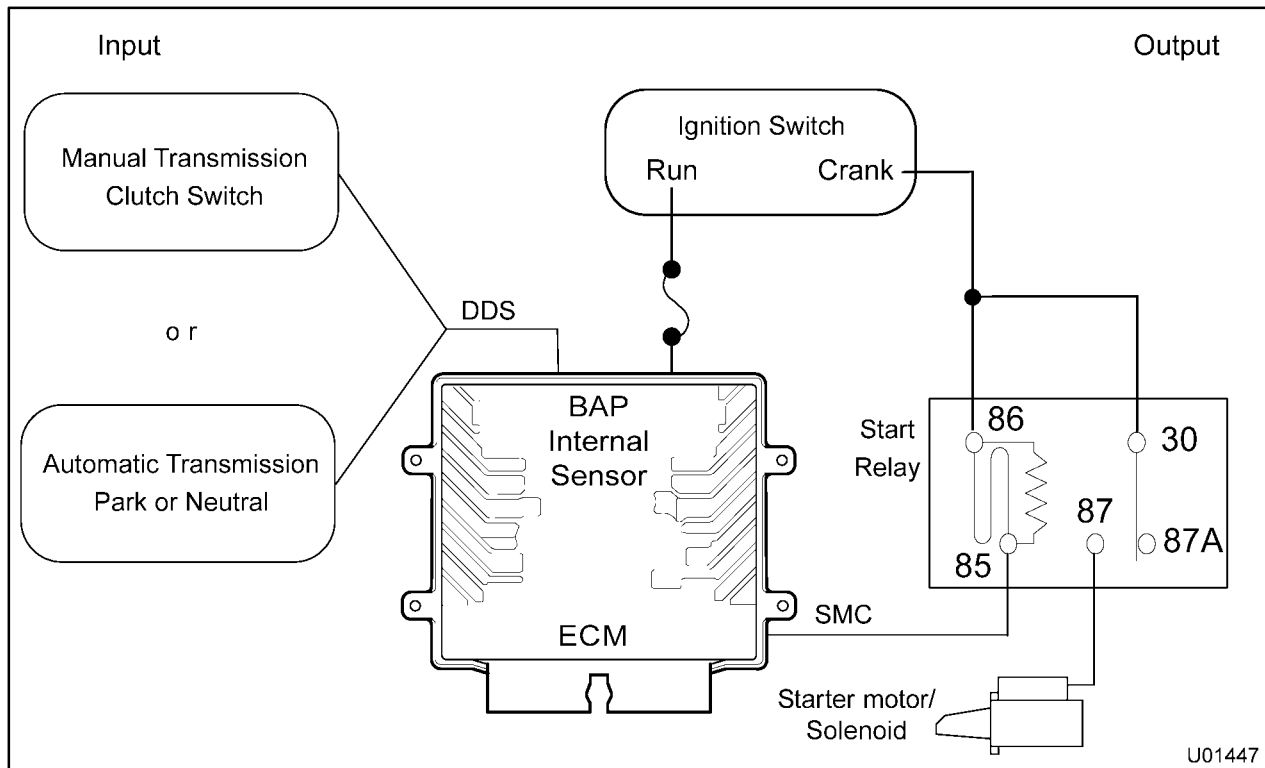
The shutters will not close again until all closed conditions exist.

Fault Detection/Management

An open or short to ground in the RSE can be detected by the ECM during an on-demand engine standard test. The AIT, IMT, and ECT are continuously monitored. If a fault is detected in the AIT, IMT, or ECT circuit, the RSE control is disabled and the radiator shutters remain open.

SMC Circuit (Starter Motor Control)**SPN FMI Condition**

None Engine starter motor will not engage

**Figure 173 Function diagram for SMC circuit diagram**

The SMC circuit function diagram includes the following:

- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Starter
- Start relay
- Starter Motor Control (SMC) circuit
- Driveline Disengagement Switch (DDS)

Function

SMC is a function of the ECM. It prevents starter engagement while the engine is running (above a set calibrated rpm), when the automatic transmission is

in gear, or when the manual transmission clutch pedal is not depressed. The start relay can also be disabled by an optional overcrank protection switch.

Location

The relay and switches are chassis mounted parts. For additional supporting information, see truck *Chassis Electrical Circuit Diagram Manual* and *Electrical System Troubleshooting Guide*.

Tools

- Digital Multimeter (DMM)
- 1180–N4–0X0 – 180-Pin Breakout Box
- Relay Breakout Harness ZTSE4908 (SMC)

SMC Circuit Diagnostics

SPN	FMI	Condition	Possible Causes
None	None	No engine crank	• Transmission in gear • Clutch pedal not pressed • No power to automatic transmission module • No power to ECM • Blown ignition switch fuse • Failed start relay • OPEN DDS circuit • OPEN SMC circuit • Failed ignition switch • Failed starter motor • Low battery state of charge. • High resistance or corroded cables to starter or battery. • Failed ECM • Failed Automatic Transmission Module • Failed Manual Transmission clutch switch • Open VIGN circuit • Open Relay Coil power circuit

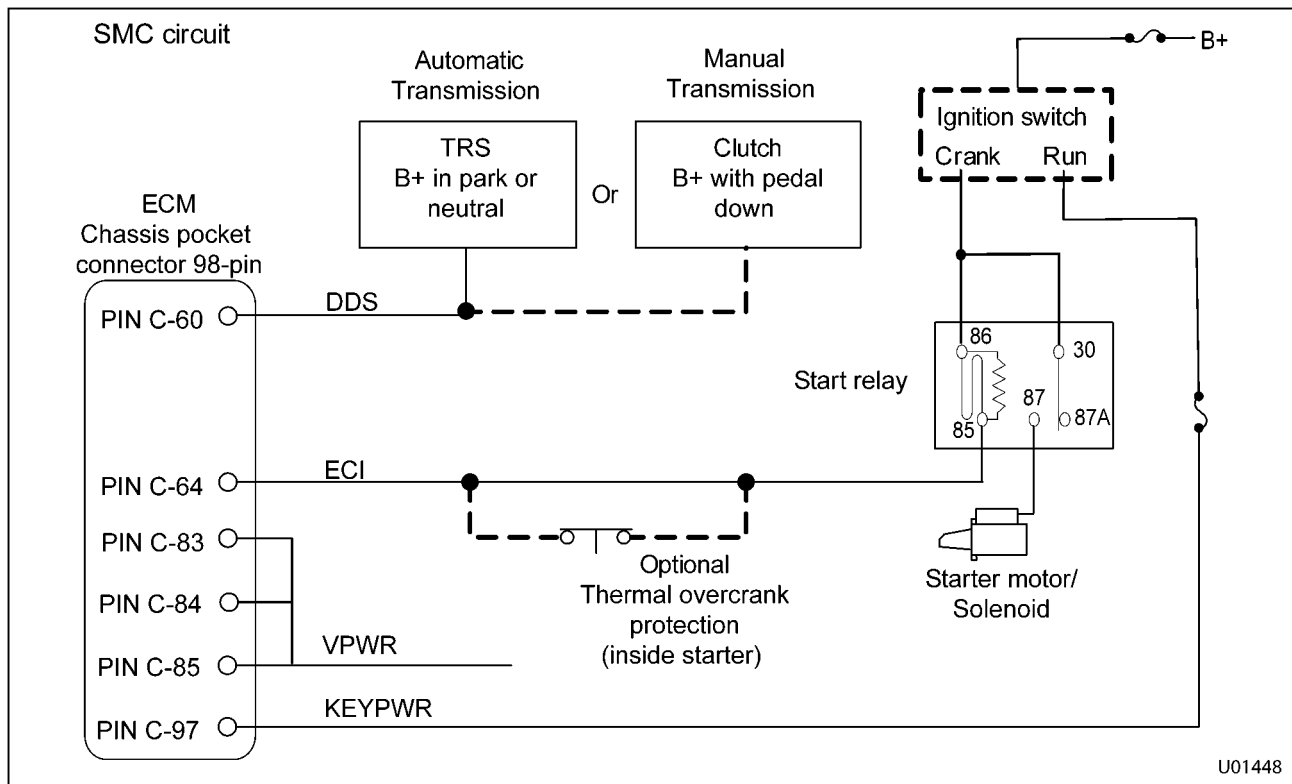


Figure 174 SMC circuit diagram

For additional circuit information, see truck *Chassis Electrical Circuit Diagram Manual* and *Electrical System Troubleshooting Guide*.

NOTE: Ensure battery is fully charged before starting the following procedures.

Voltage Check at Start Relay and Starter Solenoid

Connect Breakout Harness ZTSE4908 between relay and relay socket.

Test Point	Spec	Comment
Turn ignition switch to CRANK and hold. Use DMM to measure voltage.		
86 to GND	B+	If < B+, check power circuit to relay coil for OPEN or short to GND, blown fuse, or possible failed ignition switch.
85 to GND	< 2 V	If B+, check SMC control circuit for OPEN. If extended cranking attempt preceded the no crank condition, wait 15 minutes for Thermal Overcrank switch to reset.
87 to GND	B+	If < B+, replace relay. If B+, check voltage at starter solenoid's small control circuit wire terminal.
Solenoid Control to GND	B+	If < B+, check wiring between pin 87 of relay and solenoid control terminal for OPEN circuit.

Voltage Check at ECM

Connect 180-Pin Breakout Box between ECM and chassis harness. Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
C-97 to GND	B+	If < B+, check VIGN circuit for OPEN or short to GND, blown fuse, or possible failed ignition switch.
C-86 to GND C-87 to GND C-88 to GND	0 V	If voltage is present, check for OPEN ECM GND circuit. See ECM PWR Pin-point Diagnostics (page 217) in this section.
C-83 to GND C-84 to GND C-85 to GND	B+	If < B+, check for OPEN ECM PWR circuit. See ECM PWR Pin-point Diagnostics (page 217) in this section.
Place automatic transmission in park or neutral (manual transmission, press clutch). Use DMM to measure voltage.		
C-60 to GND	B+	If < B+, check DDS for OPEN circuit. - For automatic transmission, see transmission diagnostics. - For manual transmission, check PWR circuit to clutch pedal or blown fuse. A failed clutch pedal switch is possible.
C-64 to GND	< 2 V	If > 2 V, check ECM programming.

Harness Resistance Check - ECM to Relay

Turn ignition switch to OFF. Connect 180-Pin Breakout Box and Breakout Harness ZTSE4908. Leave ECM and relay disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
85 to C-64	< 5 Ω	If > 5 Ω , check SMC control circuit for OPEN or possible failed thermal overcrank protection switch.
85 to GND	> 1 k Ω	If < 1 k Ω , check SMC control for short to GND.
87 to starter	< 5 Ω	If > 5 Ω , check SMC control for OPEN or possible failed thermal over crank protection switch.
87 to GND	> 1 k Ω	If < 1 k Ω , check circuit for short to GND.

Harness Resistance Check - Relay to Battery

Disconnect both battery GND cables and the inline connector on battery ground cable. Disconnect start relay. Use DMM to measure resistance while holding ignition switch in CRANK position.



WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect main negative battery cable last.

86 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
30 to B+ battery post	< 5 Ω	If > 5 Ω , check circuit for OPEN or blown fuse.
30 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.
C-60 DDS circuit	See <i>Chassis Electrical Circuit Diagram Manual</i> . Check for OPEN or short to GND. Possible failed clutch switch or automatic transmission module circuit faults.	

Operational Voltage Check

Connect 180-Pin Breakout Box between ECM and chassis harness. Leave battery cables connected. Turn ignition switch to ON. Use DMM to measure voltage at the conditions specified.

Test Point	Spec	Condition
DDS C-60 to GND	B+	ECM Input - Clutch pedal not pressed or automatic transmission in gear. Cranking is disabled.
	0 V	ECM Input - Clutch pedal to the floor or automatic transmission in park or neutral. Cranking is enabled.
Turn the ignition switch to the CRANK position. Use DMM to measure voltage.		
SMC C-64 to PWR	0 V	ECM Control - SMC enabled. To enable SMC, fully depress clutch pedal or shift automatic transmission to park or neutral.
	B+	ECM Control - SMC disabled. To disable SMC, do not depress clutch pedal or place shifter of automatic transmission in gear.

SMC Circuit Operation

The ECM controls the starting system. The clutch switch or transmission neutral switch provides input to the ECM. Both switches prevent the starter from being engaged, unless the automatic transmission is in park or neutral or the manual transmission clutch is pressed.

Driveline Disengagement Switch (DDS) Circuit

The ECM monitors the DDS on Pin C-60. B+ indicates the drivetrain is disengaged and the engine is ready to start. Zero volts indicates the drivetrain is engaged and the engine is not ready to start. The source of this signal depends on the vehicle's hardware configuration. See appropriate electrical diagrams when diagnosing this circuit.

Ignition Switch

When the ignition switch is turned to CRANK, VIGN is supplied to the relay coil (Pin 86).

SMC Circuit

The ECM controls starter disable with the SMC circuit. Pin C-64 to relay coil Pin 85. Open or B+ will disable the relay. zero volts (GND) will enable the relay.

ECM

When the ECM recognizes the engine is not running and the driveline is not engaged, the ECM grounds Pin C-64. This provides a current path for the start relay to close when the start switch is engaged or the starter button is pressed.

When the ECM recognizes the engine is running or the driveline is engaged, it opens Pin C-64. This prevents the start relay from closing and the starter motor from engaging.

Start Relay

The engine start relay controls voltage to the starter solenoid. Turning the ignition switch to CRANK

supplies current to energize the relay at Pin 86. If the engine is not running and the driveline is not engaged, ECM Pin C-64 enables the relay by supplying a ground to Pin 85. When the relay is closed, current passes through the relay to the starter solenoid.

Clutch Switch

Manual transmissions use the clutch switch to supply a signal to the ECM indicating the driveline is disengaged. A 12-volt signal on the DDS circuit indicates the clutch is disengaged. A 0-volt signal indicates the clutch is engaged.

Neutral Switch

Allison LCT transmissions use the neutral position switch to supply power to the start relay and a signal to the ECM that the driveline is disengaged. Vehicles programmed for Allison AT/MT transmissions receive a 12-volt signal on the DDS circuit indicating the transmission is out of gear. A 0-volt signal indicates the transmission is in gear. When the transmission is in gear, no power is available to the start relay.

WTEC MD with Auto Neutral

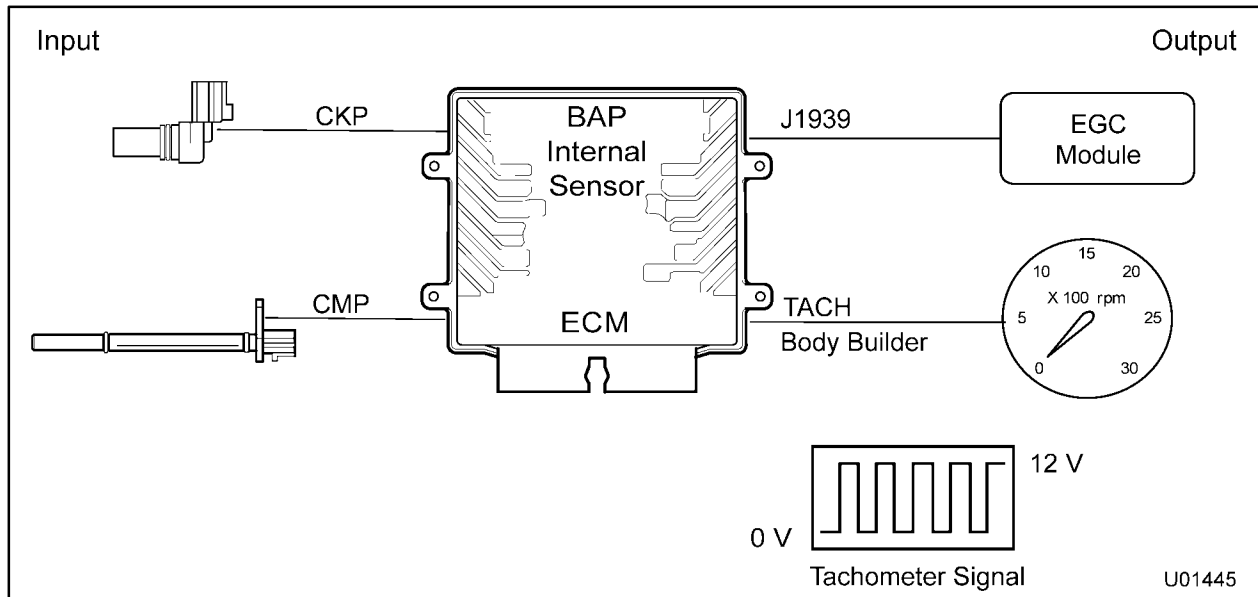
Allison MD World Transmission Electronically Controlled (WTEC) transmissions (with optional Auto Neutral) have a crank inhibit system with an additional relay. The relay inhibits cranking when the transmission is in auto neutral. Pin 6 of the transmission module controls 12 volts to Pin 86 of the start relay. Pin C-60 of the ECM receives 12 volts from the WTEC auto neutral relay when the transmission is shifted to neutral or auto neutral.

Fault Detection/Management

There are no DTCs associated with the SCM system.

TACH (Tachometer Output Circuit)**SPN FMI Condition**

190 14 Tachometer Drive Output Error

**Figure 175 Function diagram for the tachometer output circuit**

The tachometer output circuit function diagram includes the following:

- Remote tachometer
- Electronic Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Electronic Gauge Cluster (EGC) Module

- Crankshaft Position (CKP) sensor
- Camshaft Position (CMP) sensor

The tachometer signal is sent to the EGC through the public CAN network. The TACH signal is also supplied on one circuit to the body builder blunt cut-off circuits.

Tachometer Pin-point Diagnostics

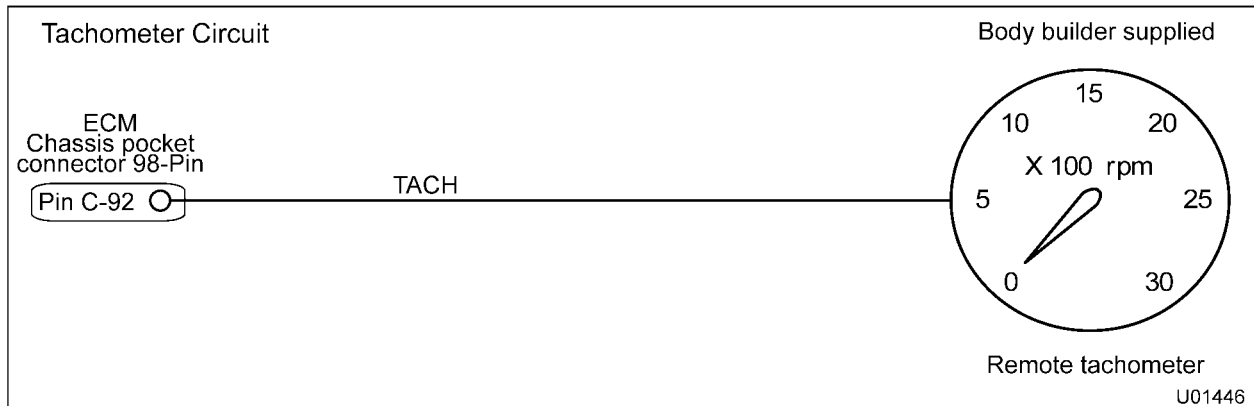


Figure 176 Tachometer circuit diagram

Circuit End Voltage Check

NOTE: If the tachometer is not working on the EGC, see truck *Chassis Electrical Circuit Diagram Manual* and *Electrical System Troubleshooting Guide*.

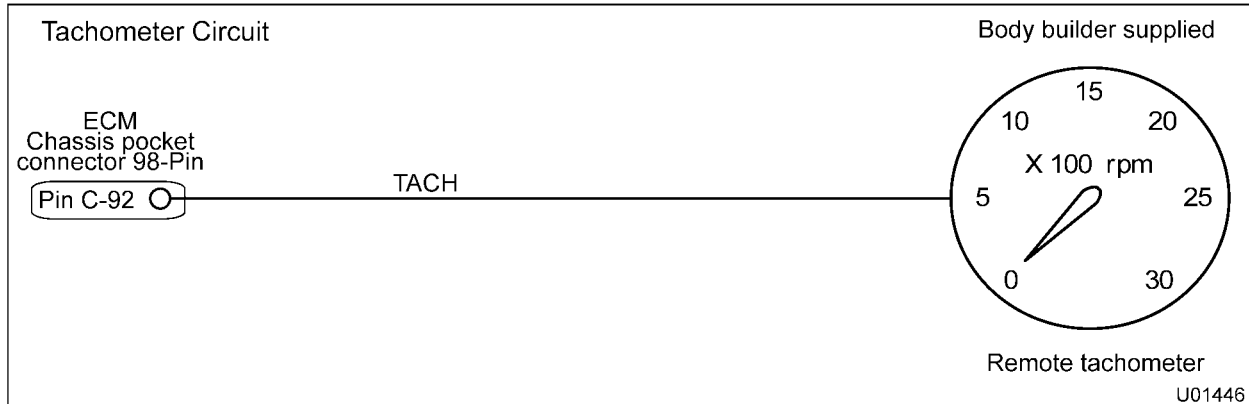
Disconnect component from the body builder blunt cut off circuit. Turn the ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
TACH to GND	12 V $\pm$ 1.0 V	If < 11.0 V, check for OPEN circuit
Start engine. Set DMM to ACV - RPM 2 to measure engine speed signal.		
TACH to GND	Low idle = 140 Hz at 700 RPM High idle = 590 Hz at 2950 RPM	If no signal, do Harness Resistance Check (page 347).

Harness Resistance Check

Connect breakout box, leave ECM and TACH component disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
C-71 to TACH	< 5 Ω	If > 5 Ω , check for OPEN circuit
C-71 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND

Tachometer Circuit Operation**Figure 177 Tachometer circuit diagram**

The ECM receives a signal from the CKP sensor and calculates engine speed (rpm). The ECM provides an output for a remote tachometer with a 0 to 12 volts digital signal that indicates engine speed. The frequency sent by the ECM is 1/5th of the actual engine rpm (12 pulses per engine revolution).

Diagnostic Trouble Codes (DTCs)

DTCs are not available for communication between the ECM and the remote tachometer.

TC1WC Solenoid (Turbocharger 1 Wastegate Control)

SPN FMI Condition

1188	3	TC1WC short to PWR
1188	4	TC1WC short to GND
1188	5	TC1WC open load/circuit

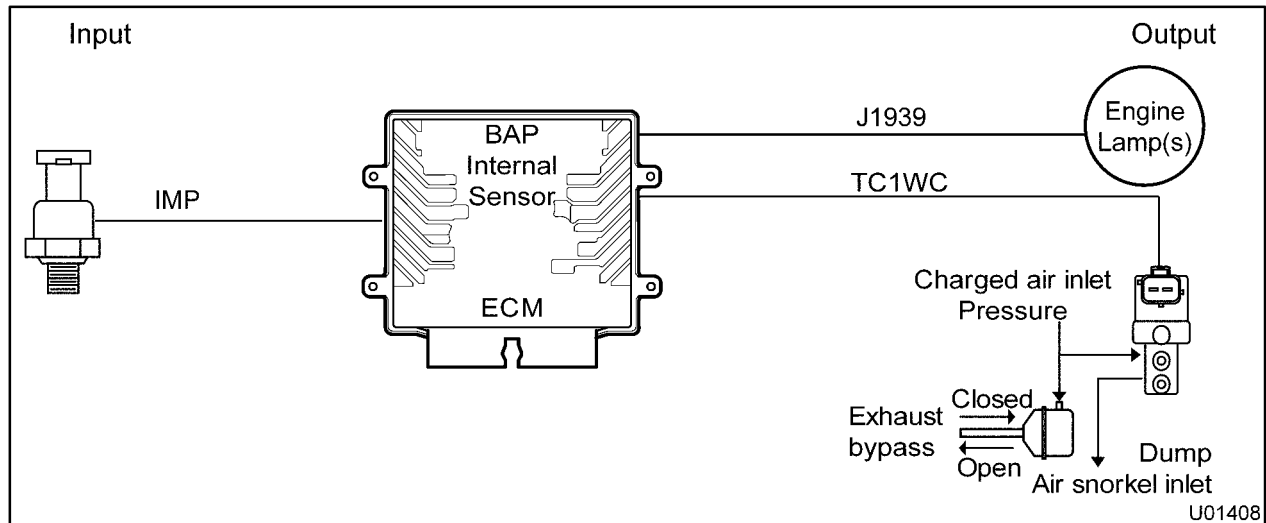


Figure 178 Function diagram for the TC1WC

The TC1WC function diagram includes the following:

- Turbocharger 1 Wastegate Control (TC1WC)
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Intake Manifold Pressure (IMP) sensor
- Engine Lamp(s)

Function

The ECM commands the TC1WC to control the turbocharger pneumatic actuator.

Sensor Location

The TC1WC is located towards the front of the engine, close to the turbo oil supply line.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 1180-N4-0X0 – 180-Pin Breakout Box
- International® Electronic Engine Terminal Test Kit ZTSE4435C
- Breakout Harness ZTSE4831 (TCWC)

TC1WC Circuit Diagnostics

SPN	FMI	Condition	Possible Causes
1188	3	TC1WC short to PWR	Signal circuit short to PWR/control circuit fault
1188	4	TC1WC short to GND	Signal circuit short to GND/control circuit fault
1188	5	TC1WC open load/circuit	Signal circuit OPEN/control circuit fault

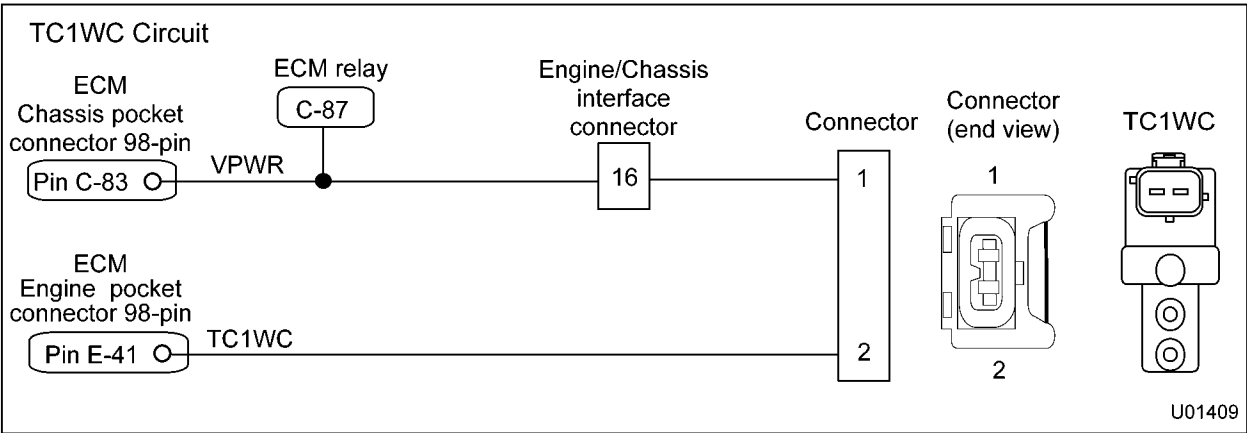


Figure 179 TC1WC circuit diagram

Voltage Check at TC1WC Connector - Output State Test

Disconnect TC1WC 2-pin connector. Turn the ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
1 to GND	B+	If < B+, check for OPEN circuit.
2 to GND	0 V to 0.25 V	If >0.25 V, check TC1WC circuit for short to PWR.
Run Output State Test HIGH.		
2 to B+	B+	If <B+, check TC1WC circuit for OPEN or short to PWR. Harness Resistance Checks (page 351).
1 to 2	B+	If <B+, check VREF circuit for OPEN. Do Harness Resistance Checks (page 351).

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box. Leave ECM and TC1WC disconnected.

Test Point	Spec	Comment
E-41 to 2	< 5 Ω	If > 5 Ω , check TC1WC for OPEN circuit.
E-41 to GND	> 1 k Ω	If < 1 k Ω , check TC1WC for short to GND.
1 to C-1, 3 and 5	< 5 Ω	If < 5 Ω , check VREF for OPEN in circuit.
1 to GND	> 1 k Ω	If < 1 k Ω , check VREF for short to GND.

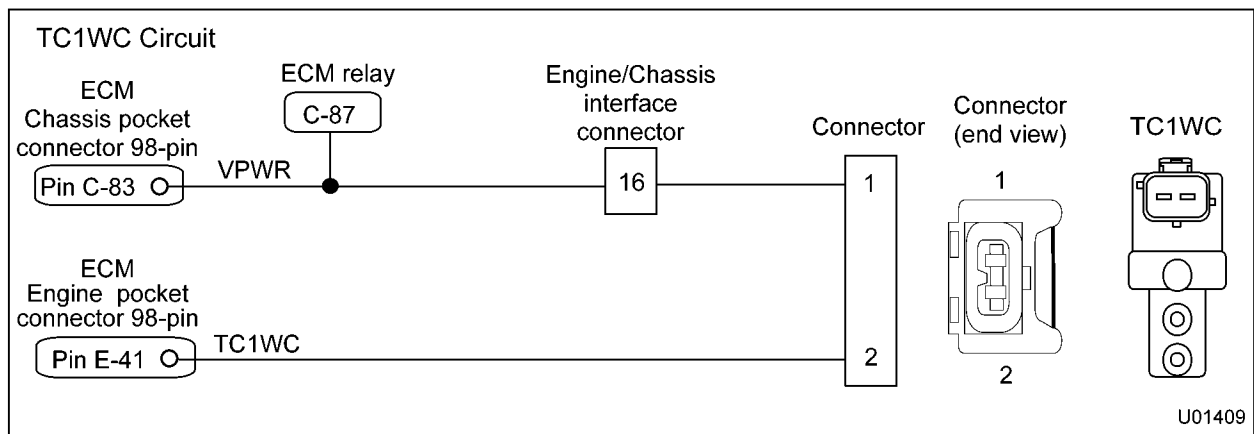
TC1WC Circuit Operation

Figure 180 TC1WC circuit diagram

The TC1WC is supplied VREF at Pin 1. The ECM grounds Pin E-41 to control the TC1WC at Pin 2.

An OPEN or short to ground in the TC1WC can be detected by the ECM during an on-demand engine standard test.

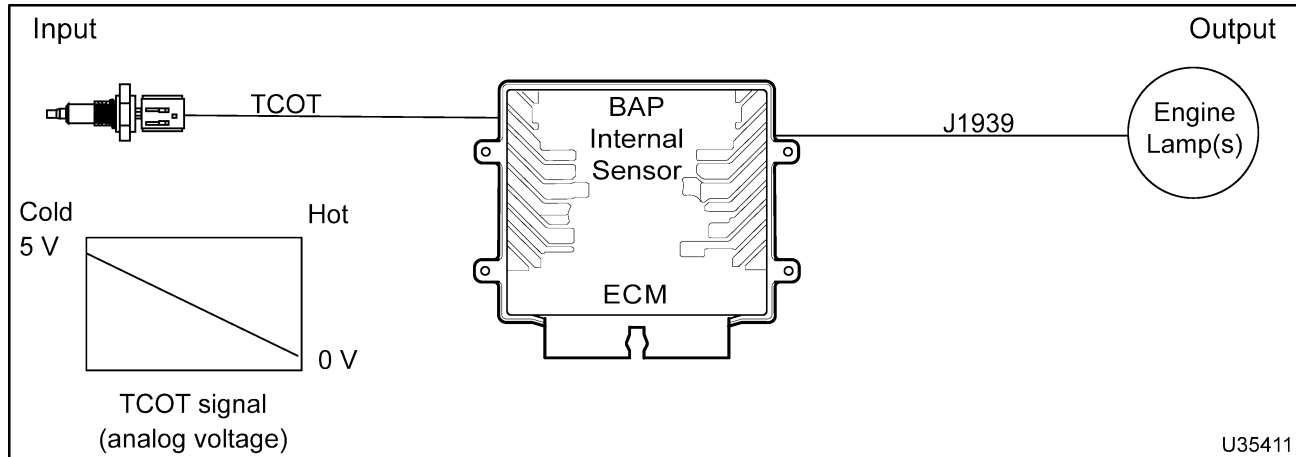
Fault Detection/Management

The ECM monitors the internal BAP sensor as a base line for zeroing the IMP.

TCOT Sensor (Turbocharger Outlet Temperature)**SPN FMI Condition**

2629 3 TCOT signal Out of Range HIGH

2629 4 TCOT signal Out of Range LOW

**Figure 181 Function diagram for the TCOT sensor**

The TCOT sensor function diagram includes the following:

- Turbocharger Compressor Outlet Temperature (TCOT) sensor
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Engine Lamp(s)

Function

The TCOT sensor provides a feedback signal to the ECM indicating turbocharger compressor outlet air temperature for use in engine protection.

Sensor Location

If equipped, the TCOT sensor is installed after the turbocharger compressor and in front of the intercooler.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 3-Banana Plug Harness ZTSE4498
- 1180–N4–0X0 – 180-Pin Breakout Box
- Breakout Harness ZTSE4760A (TCOT)
- International® Electronic Engine Terminal Test Kit ZTSE4435C

TCOT Sensor End Diagnostics

SPN	FMI	Condition	Possible Causes
2629	3	TCOT signal Out of Range HIGH	• TCOT signal OPEN or short to PWR • SIG GND circuit OPEN • Failed sensor
2629	4	TCOT signal Out of Range LOW	• TCOT signal circuit short to GND • Failed sensor

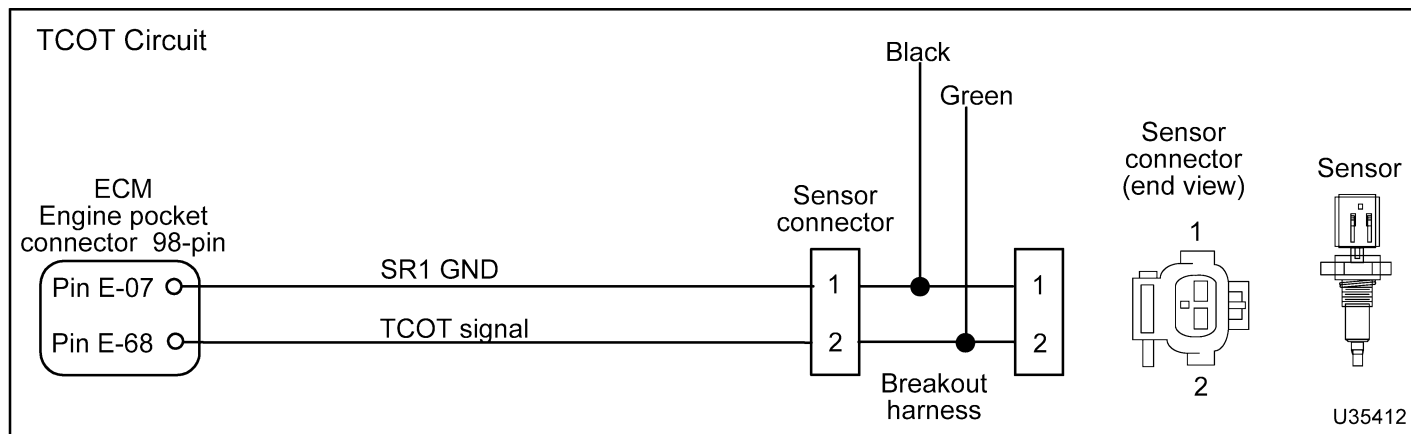


Figure 182 TCOT circuit diagram

! WARNING: To prevent personal injury or death, stay clear of rotating parts (belts and fan) and hot engine surfaces.

1. Using Electronic Service Tool (EST) with ServiceMaxx™ software, open the Continuous Monitor session.
2. Monitor sensor voltage. Verify an active Diagnostic Trouble Code (DTC) for the sensor.
 - If DTC is inactive, monitor the signal while wiggling the connector and all wires at suspected location. If the circuit is interrupted, the signal spikes and the DTC goes active.

- If DTC is active, proceed to the next step.

3. Disconnect engine harness from sensor.

NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

4. Connect breakout harness to engine harness. Leave sensor disconnected.

Sensor Circuit Check

Connect Breakout Harness ZTSE4760A. Leave sensor disconnected. Turn ignition switch to ON. Use Electronic Service Tool (EST) with ServiceMaxx™ software to verify correct DTC goes active when corresponding fault is induced. Use DMM to measure circuits.

Test Point	Spec	Comments
EST - Check DTC	SPN 2629 FMI 3	If SPN 2629 and FMI 4 is active, check TCOT signal for short to GND. Do Harness Resistance Check (page 355).
EST - Check DTC Short a 3-banana plug harness across 2 and GND	SPN 2629 FMI 4	If SPN 2629 and FMI 3 is active, check TCOT signal for OPEN. Do Harness Resistance Check (page 355).
EST - Check DTC Short a 3-banana plug harness across 1 and 2	SPN 2629 FMI 4	If SPN 2629 and FMI 3 is active, check SIG GND for OPEN. Do Harness Resistance Check (page 355).
If checks are within specification, connect sensor and clear DTCs. If active DTC remains, replace sensor.		

TCOT Pin-point Diagnostics**Connector Voltage Check**

Connect Breakout Harness ZTSE4760A. Leave sensor disconnected. Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
1 to GND	0 V	If > 0.25 V, check for short to PWR.
2 to GND	4.6 V to 5 V	If < 4.5 V, check for OPEN or short to GND. Do Harness Resistance Check (page 355).

Connector Resistance Check to GND

Turn ignition switch to OFF. Connect Breakout Harness ZTSE4760A. Leave sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to GND	< 5 Ω	If > 5 Ω, check for OPEN circuit.
2 to GND	> 1 kΩ	If < 1 kΩ, check for short to GND.

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box and Breakout Harness ZTSE4760A. Leave ECM and sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
1 to E-07	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to E-68	< 5 Ω	If > 5 Ω , check for OPEN circuit.

TCOT Circuit Operation

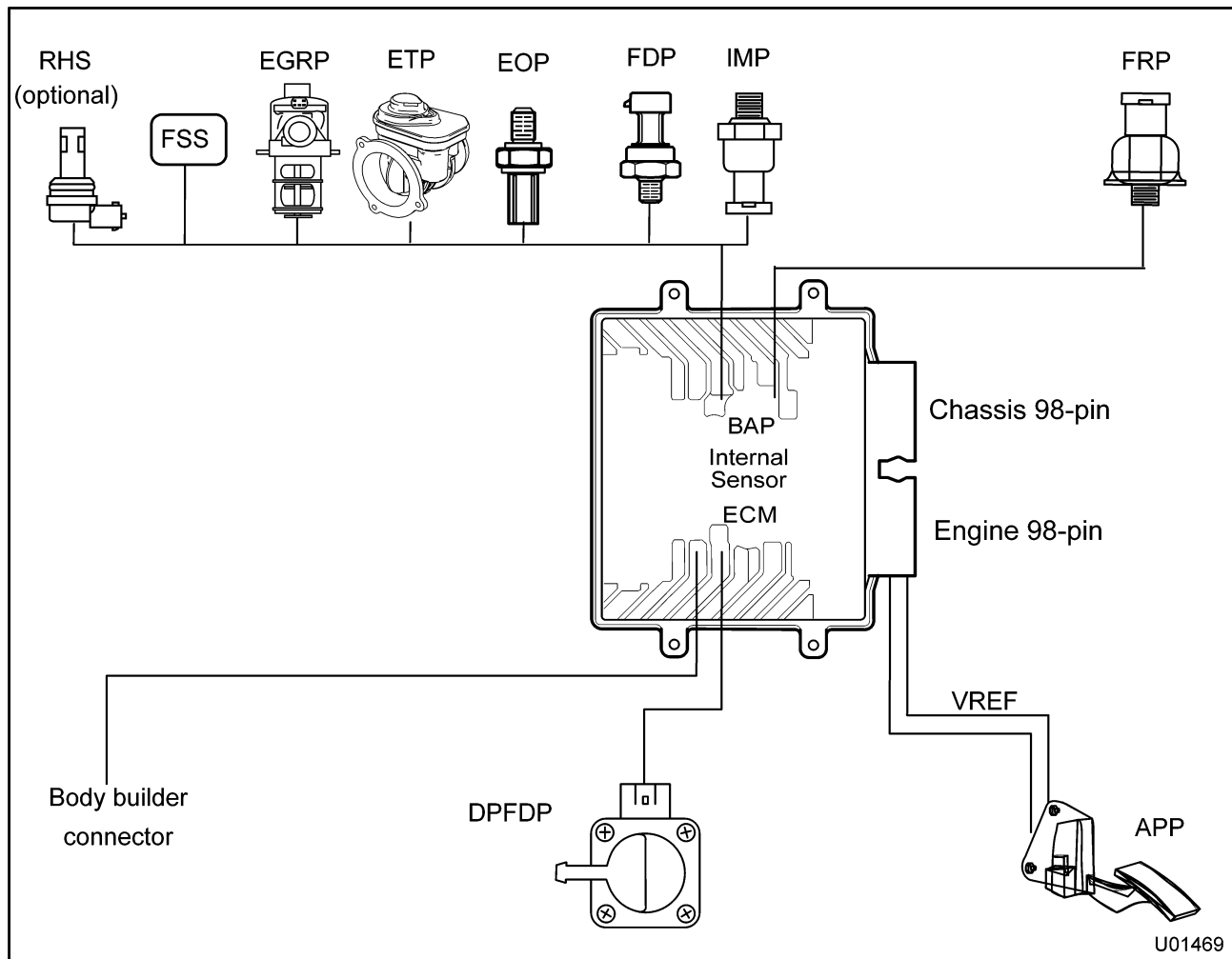
The TCOT is a thermistor sensor that is supplied with a 5-volt reference voltage at Pin 2 from ECM Pin E-68. The sensor is grounded at Pin 1 from ECM Pin E-07. As the temperature increases, the resistance of the thermistor decreases. This causes the signal voltage to decrease.

Fault Detection/Management

The ECM continuously monitors the control system. If the sensor signal is higher or lower than expected, the ECM disregards the sensor signal and uses a calibrated default value. The ECM sets a DTC, turns on the Amber Warning Lamp (AWL), and runs the engine in a default range.

VREF (Reference Voltage)

SPN	FMI	Condition
3509	3	VREF Engine voltage above max
3509	4	VREF Engine voltage below min
3510	3	VREF Chassis voltage above max
3510	4	VREF Chassis voltage below min
3511	3	VREF Body voltage above max
3511	4	VREF Body voltage below min

**Figure 183 Function diagram for the VREF**

The VREF function diagram includes the following:

- Accelerator Pedal Position (APP) sensor
- Body builder connector
- DPF Differential Pressure (DPFDP) sensor
- Engine Control Module (ECM)
with integrated Barometric Absolute Pressure (BAP) sensor
- Engine Oil Pressure (EOP) sensor
- Engine Throttle Position (ETP) sensor
- Exhaust Gas Recirculation Position (EGRP) sensor
- Fan Speed Sensor (FSS)
- Fuel Delivery Pressure (FDP) sensor
- Fuel Rail Pressure (FRP) sensor
- Intake Manifold Pressure (IMP) sensor
- Relative Humidity Sensor (RHS) [optional]

Function

The VREF circuit is a 5-volt reference supplied by the ECM and provides power to all 3-wire sensors.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit
- Digital Multimeter (DMM)
- 1180–N4–0X0 – 180-Pin Breakout Box
- International® Electronic Engine Terminal Test Kit ZTSE4435C

VREF Pin-point Diagnostics

SPN	FMI	Condition	Possible Causes
3509	3	VREF Engine voltage above max	• VREF on engine connector short to VBAT
3509	4	VREF Engine voltage below min	• VREF on engine connector short to GND
3510	3	VREF Chassis voltage above max	• VREF on chassis connector short to VBAT
3510	4	VREF Chassis voltage below min	• VREF on chassis connector short to GND
3511	3	VREF Body voltage above max	• VREF on body connector short to VBAT
3511	4	VREF Body voltage below min	• VREF on body connector short to GND

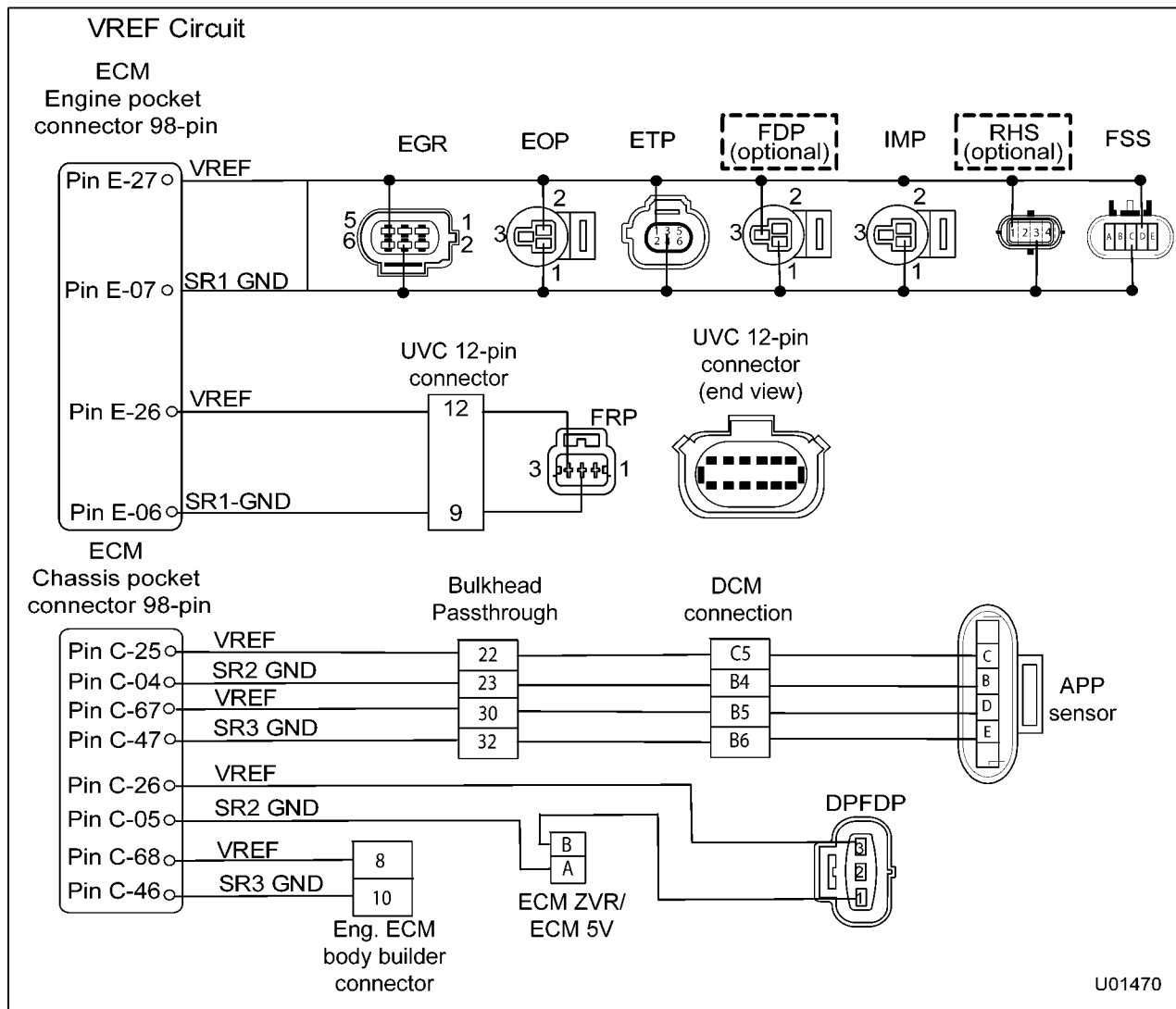


Figure 184 VREF circuit diagram

VREF Voltage Check

If multiple sensor SPNs and FMIs are set, turn ignition switch to ON. Disconnect each sensor one at a time. Use DMM to measure voltage at harness connector of each sensor.

NOTE:

- If VREF = B+ after all sensors in this section are disconnected, check for short circuit between the VREF wire and VPWR wire, key PWR wire, or KAPWR wire. (See ECM PWR Relay (page 216).
- If VREF is not present, but returns after disconnecting a sensor, inspect that sensor for internal short to GND.
- If VREF is not present after all sensors in this section are disconnected, check for an OPEN circuit between the ECM and sensors.

Test Point	Spec	Comment
APP C to GND	5 V $\pm$ 0.5 V	See above note.
APP D to GND	5 V $\pm$ 0.5 V	See above note.
Body builder connector 8 to GND	5 V $\pm$ 0.5 V	See above note.
DPFDP 3 to GND	5 V $\pm$ 0.5 V	See above note.
EGRP 6 to GND	5 V $\pm$ 0.5 V	See above note.
EOP 2 to GND	5 V $\pm$ 0.5 V	See above note.
ETP 1 to GND	5 V $\pm$ 0.5 V	See above note.
FDP 2 to GND	5 V $\pm$ 0.5 V	See above note.
FRP 12-pin 12 to GND	5 V $\pm$ 0.5 V	If this sensor caused VREF to go below specification, see above note. Check under valve cover harness for a short to GND or an internal shorted sensor.
FSS D to GND	5 V $\pm$ 0.5 V	See above note.
IMP 2 to GND	5 V $\pm$ 0.5 V	See above note.
RHS (optional) 1 to GND	5 V $\pm$ 0.5 V	See above note.

Connector Resistance Check to GND

Turn ignition switch to OFF. Disconnect each sensor one at a time. Use DMM to measure resistance at harness connector of each device.

NOTE:

- If resistance is below 1 k Ω , but goes above 1 k Ω after disconnecting a sensor, inspect that sensor for internal short to GND.
- If resistance is below 1 k Ω after all devices in this section are disconnected, check for short to GND of VREF wire between ECM and sensors.

Test Point	Spec	Comment
APP C to GND	> 1 k Ω	See above note.
APP D to GND	> 1 k Ω	See above note.
Body builder connector 8 to GND	> 1 k Ω	See above note.
DPFDP 3 to GND	> 1 k Ω	See above note.
EGRP 6 to GND	> 1 k Ω	See above note.
EOP 2 to GND	> 1 k Ω	See above note.
ETP 1 to GND	> 1 k Ω	See above note.
FDP 2 to GND	> 1 k Ω	See above note.
FRP (UVC 12-pin) 12 to GND	> 1 k Ω	If this sensor caused VREF to go below specification, see above note. Check under valve cover harness for a short to GND or an internal shorted sensor.
FSS D to GND	> 1 k Ω	See above note.
IMP 2 to GND	> 1 k Ω	See above note.
RHS (optional) 1 to GND	> 1 k Ω	See above note.

Harness Resistance Check

Turn ignition switch to OFF. Connect 180-Pin Breakout Box and breakout harness. Disconnect ECM and all sensors in this section. Use DMM to measure resistance between 180-Pin Breakout Box and ECM connector.

Sensor	Test Point	Spec	Comment
APP			
VREF	C to C-25	< 5 Ω	If > 5 Ω , check for OPEN circuit.
VREF	D to C-67		
SR2 GND	B to C-04		
SR3 GND	E to C-47		
Body builder connector			
VREF	8 to C-68	< 5 Ω	If > 5 Ω , check for OPEN circuit.
SR3 GND	10 to C-46		
DPFDP			
VREF	3 to C-26	< 5 Ω	If > 5 Ω , check for OPEN circuit.
SR2 GND	1 to C-05		
EGRP			
VREF	6 to E-27	< 5 Ω	If > 5 Ω , check for OPEN circuit.
SR1 GND	4 to E-07		
EOP			
VREF	2 to E-27	< 5 Ω	If > 5 Ω , check for OPEN circuit.
SR1 GND	1 to E-07		
ETP			
VREF	1 to E-27	< 5 Ω	If > 5 Ω , check for OPEN circuit.
SR1 GND	3 to E-07		
FDP			
VREF	2 to E-27	< 5 Ω	If > 5 Ω , check for OPEN circuit.
SR1 GND	1 to E-07		

Harness Resistance Check (cont.)

Turn ignition switch to OFF. Connect 180-Pin Breakout Box and breakout harness. Disconnect ECM and all sensors in this section. Use DMM to measure resistance between 180-Pin Breakout Box and ECM connector.

Sensor	Test Point	Spec	Comment
FRP (12-Pin UVC connector)			
VREF	12 to E-26	< 5 Ω	If > 5 Ω , check for OPEN circuit.
SR1 GND	2 to E-06		
FSS			
VREF	D to E-27	< 5 Ω	If > 5 Ω , check for OPEN circuit.
SR1 GND	C to E-07		
IMP			
VREF	2 to E-27	< 5 Ω	If > 5 Ω , check for OPEN circuit.
SR1 GND	1 to E-07		
RHS (optional)			
VREF	1 to E-27	< 5 Ω	If > 5 Ω , check for OPEN circuit.
SR1 GND	3 to E-07		

VREF Circuit Operation

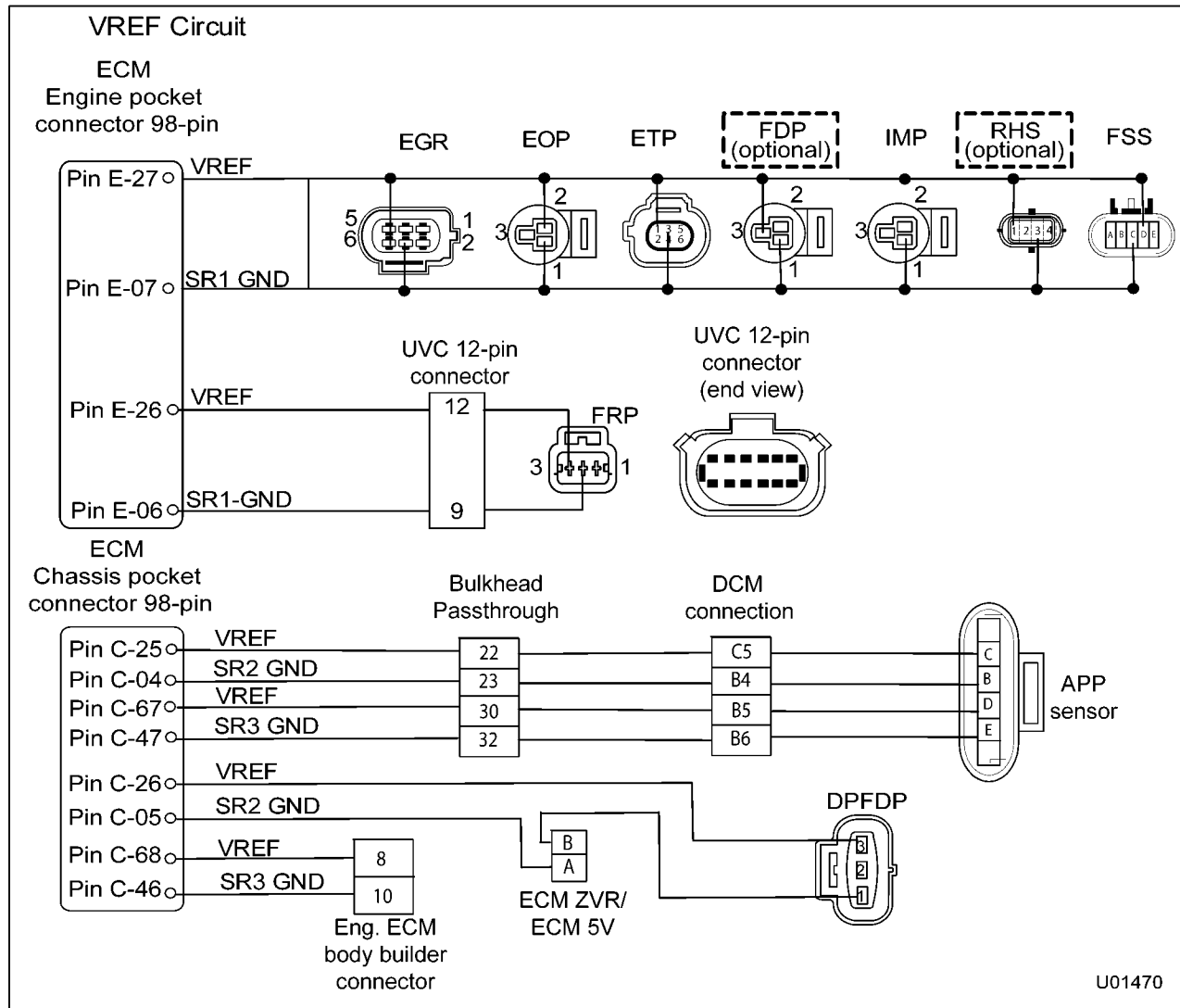


Figure 185 VREF circuit diagram

NOTE: See APP Sensor (page 167) and DPFDP Sensor (page 201) in this section of this manual for sensor circuit diagrams.

The ECM supplies VREF at Pins E-26 and E-27 (engine connector) and pins C-25, C-26, C-67, and C-68 (chassis connector) when the ignition switch is on.

VREF provides power to all 3-wire sensors on the engine and the chassis-mounted APP. The ECM also provides these sensors with a ground through the SRX GND circuit. Sensor signal voltage is between

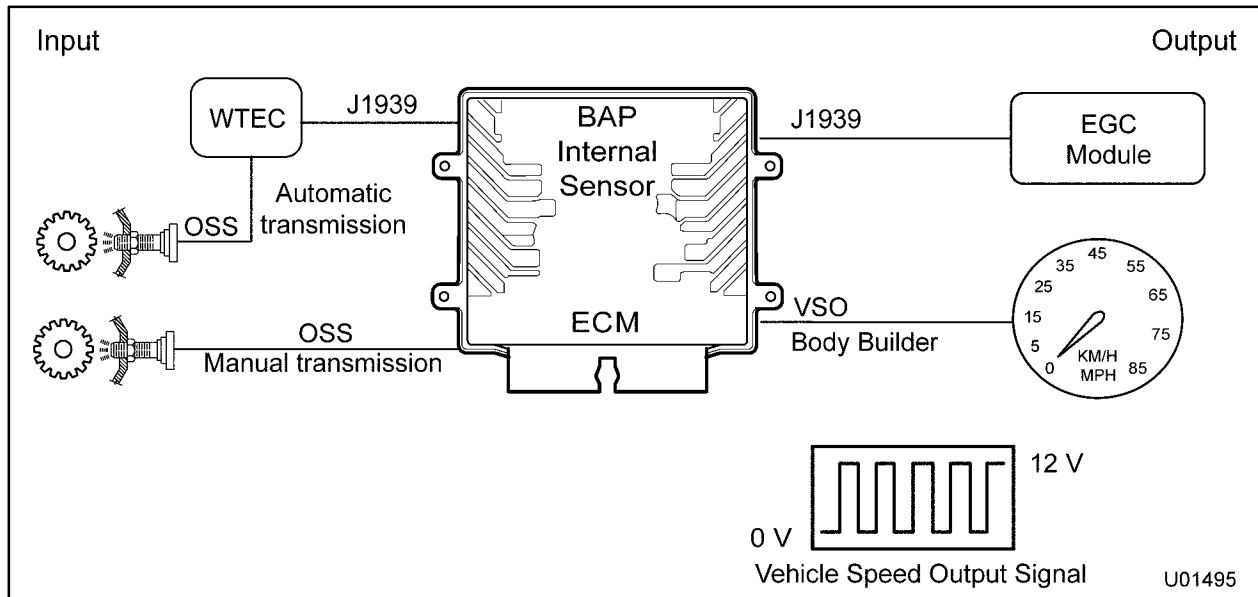
these two reference points based on the pressure or position the sensor is designed to measure.

Fault Detection/Management

When the ECM sets multiple sensor high or low DTCs, the VREF circuit could be open or shorted or the SIG GND circuit could be open. When a VREF signal is shorted to ground, the engine may stumble. To determine if the VREF circuits are the cause, complete the Pin-point diagnostics check.

VSO (Vehicle Speed Output)**SPN FMI Condition**

837 14 Speedometer Drive Output Error

**Figure 186 Function diagram for the tachometer output circuit**

The vehicle speed output circuit function diagram includes the following:

- Remote speedometer
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Electronic Gauge Cluster (EGC) module

- Output Shaft Speed (OSS) sensor
- World Transmission Electronic Control (WTEC) ECM

The vehicle speed signal is sent to the EGC through the J1939 network. The VSO signal is also supplied on one circuit to the body builder blunt cutoff circuits.

Vehicle Speed Output Pin-point Diagnostics

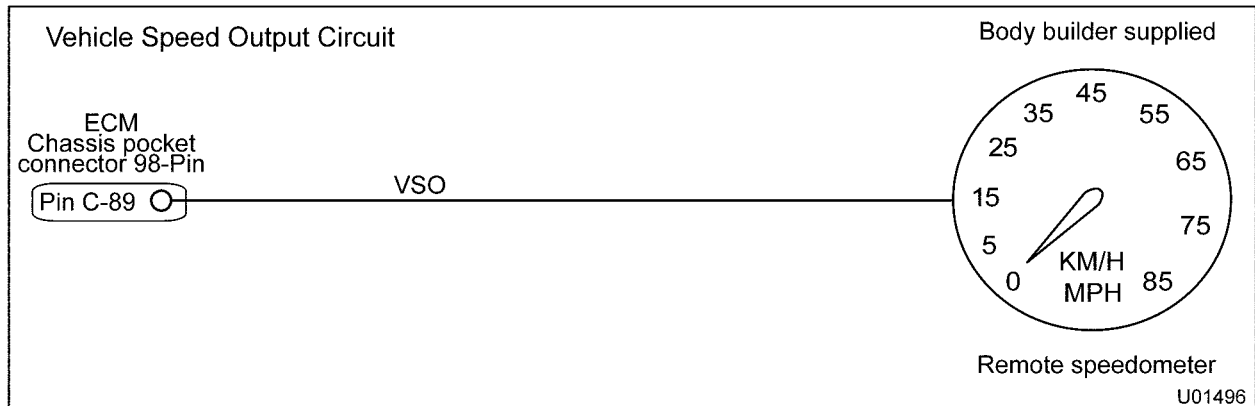


Figure 187 Vehicle Speed Output circuit diagram

Circuit End Voltage Check

NOTE: If speedometer is not working on the EGC, see truck *Chassis Electrical Circuit Diagram Manual* and *Electrical System Troubleshooting Guide*.

Disconnect component from the body builder blunt cutoff circuit. Turn the ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comment
VSO to GND	12 V $\pm$ 1.0 V	If < 11.0 V, check for OPEN circuit.

Harness Resistance Check

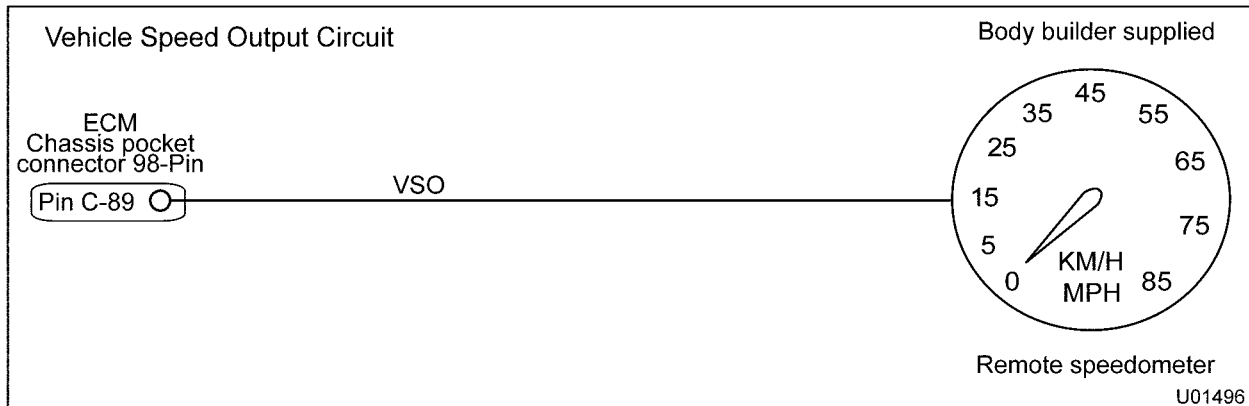
Connect breakout box, leave ECM and remote speedometer component disconnected. Use DMM to measure resistance.

Test Point	Spec	Comment
C-89 to Speedometer	< 5 Ω	If > 5 Ω , check for OPEN circuit.
C-89 to GND	> 1 k Ω	If < 1 k Ω , check for short to GND.

Operational Check

Connect terminal probes between the C-89 Vehicle Speed Output (VSO) circuit and GND. Use DMM to measure Hz

Test Point	Spec	Comment
Vehicle moving at 15 mph	125 Hz	If not within specification, check for circuit fault or failed sensor.
Vehicle moving at 30 mph	250 Hz	

Vehicle Speed Output Circuit Operation**Figure 188 Vehicle Speed Output circuit diagram**

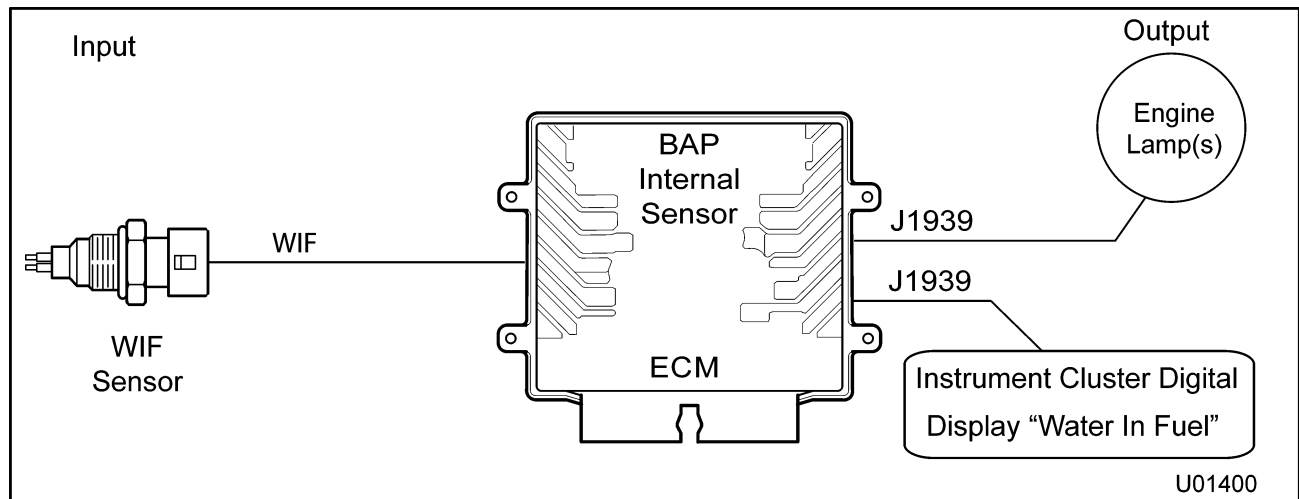
The ECM receives a signal from the OSS sensor and calculates vehicle speed (mph). The ECM provides an output for a remote speedometer with a 0- to 12-volt digital signal that indicates vehicle speed. The frequency sent by the ECM is 8.33 of the actual engine rpm (30,000 pulses per mile).

Diagnostic Trouble Codes (DTCs)

DTCs are not available for communication between the ECM and the remote tachometer.

WIF Sensor (Water In Fuel)

SPN	FMI	Condition
4192	3	WIF signal Out of Range HIGH
4192	4	WIF signal Out of Range LOW
4192	31	Water in Fuel Detected

**Figure 189 Function diagram for the WIF**

The WIF function diagram includes the following:

- Water In Fuel (WIF) sensor
- Engine Control Module (ECM) with integrated Barometric Absolute Pressure (BAP) sensor
- Engine Lamp(s)
- Water In Fuel display message

Function

The WIF sensor provides a feedback signal to the ECM when water is detected in the fuel supply. If

water is detected, the ECM turns on the "Water In Fuel" display message to alert the operator to drain water from the Primary Fuel Filter.

Sensor Location

The WIF sensor is installed in the primary fuel filter housing.

Tools

- Electronic Service Tool (EST) with ServiceMaxx™ software
- NAVCoM or NAVLink Interface Kit

WIF Pin-point Diagnostics

SPN	FMI	Condition	Possible Causes
4192	3	WIF signal Out of Range HIGH	- WIF signal circuit short to PWR - Failed sensor
4192	4	WIF signal Out of Range LOW	- WIF signal circuit short to GND - Failed sensor
4192	31	Water in Fuel Detected	Water detected in primary fuel filter housing

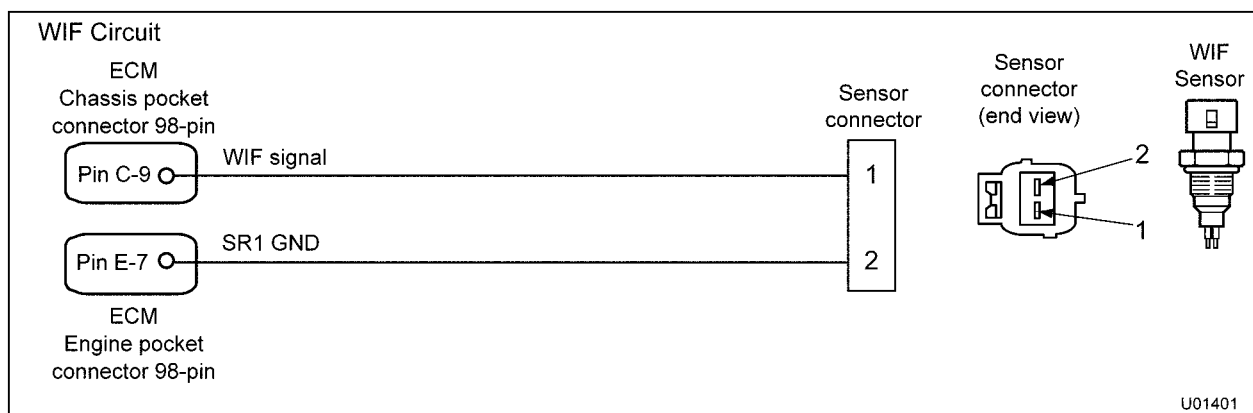


Figure 190 WIF circuit diagram

1. Drain a fuel sample from the water drain valve on the primary fuel filter housing. See Fuel Quality (page 94) in the "Hard Start and No Start Diagnostics" section of this manual.

- If water is present, drain all water out of the system.
- If no water is present in the fuel sample, continue to next step.

2. Use EST with ServiceMaxx™ Software.

NOTE: The WIF signal will read YES if there is water in the fuel filter housing or if the WIF signal circuit is shorted high.

- If Diagnostic Trouble Code (DTC) is inactive, monitor the signal while wiggling the connector and all wires at suspected location. If the circuit is interrupted, the signal will change from No to Yes and the DTC goes active.

- If DTC is active, proceed to the next step.

3. Disconnect engine harness from sensor.

NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

4. Connect breakout harness to engine harness. Leave sensor disconnected.

Voltage Check

Disconnect WIF sensor connector. Turn ignition switch to ON. Use DMM to measure voltage.

Test Point	Spec	Comments
1 to GND	4.6 V	If > 4.6 V, check WIF circuit for short to PWR. If < 4.6 V, check WIF circuit for short to GND.
2 to B+	B+	If < B+, check SIG GND circuit for OPEN.

Connector Resistance Checks to GND

Turn ignition switch to OFF, disconnect harness from WIF sensor, use DMM to measure resistance.

Test Point	Spec	Comment
1 to GND	> 1 k Ω	If < 1 k Ω , check WIF circuit for short to GND.
2 to GND	< 5 Ω	If > 5 Ω , check SIG GND for OPEN circuit.

Harness Resistance Check

Turn ignition switch to OFF. Connect breakout box and leave ECM and WIF sensor disconnected. Use DMM to measure resistance.

Test Point	Spec	Comments
1 to C-9	< 5 Ω	If > 5 Ω , check for OPEN circuit.
2 to E-7	< 5 Ω	If > 5 Ω , check for OPEN circuit.

WIF Circuit Operation

The WIF sensor is supplied with a 5-volt reference voltage at Pin 1 from the ECM Pin C-9. The sensor is grounded at Pin 2 from ECM Pin E-7. The WIF signal is 4.6 volts at normal state and below 3.6 volts when water is detected.

Fault Detection/Management

The ECM continuously monitors the WIF sensor. If voltage drops below 3.6 V, DTC sets and the "Water In Fuel" message is displayed. Two other DTCs can be set if there is a fault with the circuit or sensor.

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Diagnostic Trouble Codes.....	373

Diagnostic Trouble Codes

SPN	FMI	Circuit	Condition Description
27	3	EGR (page 238)	EGRP signal Out of Range HIGH
27	4	EGR (page 238)	EGRP signal Out of Range LOW
27	10	EGR (page 238)	EGRP signal abnormal rate of change
51	3	ETV (page 263)	ETP signal Out of Range HIGH
51	4	ETV (page 263)	ETP signal Out of Range LOW
51	10	ETV (page 263)	ETP signal abnormal rate of change
69	19	Truck	Two Speed Axle Switch not detected on J1939 See applicable vehicle <i>Electrical System Troubleshooting Guide</i> .
91	2	APP (page 167)	APP1 and APP2 signal conflict
91	3	APP (page 167)	APP1 signal Out of Range HIGH
91	4	APP (page 167)	APP1 signal Out of Range LOW
91	7	APP (page 167)	APP1 and IVS signal conflict
94	0	FDP (page 277)	Fuel Filter Minder Above Maximum Pressure
94	3	FDP (page 277)	FDP signal Out of Range HIGH
94	4	FDP (page 277)	FDP signal Out of Range LOW
94	10	FDP (page 277)	FDP signal abnormal rate of change
94	17	EWPS (page 269)	Fuel Delivery Pressure Below warning
94	31	EWPS (page 269)	Fuel Filter Minder Service Interval Now
100	1	EWPS (page 269)	Engine Oil System below Critical Pressure
100	3	EOP (page 253)	EOP signal Out of Range HIGH
100	4	EOP (page 253)	EOP signal Out of Range LOW
100	10	EOP (page 253)	EOP signal abnormal rate of change
100	18	EWPS (page 269)	Engine Oil System below Warning Pressure
102	3	IMP (page 304)	IMP signal Out of Range HIGH
102	4	IMP (page 304)	IMP signal Out of Range LOW
102	10	IMP (page 304)	IMP signal abnormal rate of change
105	3	IMT (page 309)	IMT signal Out of Range HIGH
105	4	IMT (page 309)	IMT signal Out of Range LOW
105	10	IMT (page 309)	IMT signal abnormal rate of change
108	3	ECM Self (page 221)	BARO signal Out of Range HIGH
108	4	ECM Self (page 221)	BARO signal Out of Range LOW
110	0	EWPS (page 269)	Engine Coolant System above Critical Temperature

SPN	FMI	Circuit	Condition Description
110	3	ECT1 (page 224)	ECT1 signal Out of Range HIGH
110	4	ECT1 (page 224)	ECT1 signal Out of Range LOW
110	10	ECT1 (page 224)	ECT1 signal abnormal rate of change
110	15	EWPS (page 269)	Engine Coolant System above Warning Temperature
111	1	EWPS (page 269)	Low Engine Coolant Level
		ECL (page 213)	
111	2	ECL (page 213)	ECL In-Range circuit Fault
111	3	ECL (page 213)	ECL signal Out of Range HIGH
111	4	ECL (page 213)	ECL signal Out of Range LOW
127	3	Truck	TOP signal Out of Range HIGH See applicable vehicle <i>Electrical System Troubleshooting Guide</i> .
127	4	Truck	TOP signal Out of Range LOW See applicable vehicle <i>Electrical System Troubleshooting Guide</i> .
132	3	MAF (page 327)	MAF signal Out of Range HIGH
132	4	MAF (page 327)	MAF signal Out of Range LOW
132	10	MAF (page 327)	MAF signal abnormal rate of change
132	11	MAF (page 327)	MAF sensor Calibration – insufficient number of data points
132	13	MAF (page 327)	MAF sensor Calibration Needed
132	14	MAF (page 327)	MAF sensor Calibration Failed
157	3	FRP (page 288)	FRP signal Out of Range HIGH
157	4	FRP (page 288)	FRP signal Out of Range LOW
157	10	FRP (page 288)	FRP signal abnormal rate of change
158	15	ECM PWR Relay (page 216)	ECM Switched voltage too HIGH
158	17	ECM PWR Relay (page 216)	ECM Switched voltage too LOW
172	3	AIT (page 327)	AIT signal Out of Range HIGH
172	4	AIT (page 327)	AIT signal Out of Range LOW
172	10	AIT (page 327)	AIT signal abnormal rate of change
173	0	EGT (page 249)	Exhaust Gas System above Critical Temperature
173	3	EGT (page 249)	EGT signal Out of Range HIGH
173	4	EGT (page 249)	EGT signal Out of Range LOW
174	0	EWPS (page 269)	Engine Fuel System above Critical Temperature

SPN	FMI	Circuit	Condition Description
174	3	EFT (page 233)	EFT signal Out of Range HIGH
174	4	EFT (page 233)	EFT signal Out of Range LOW
174	10	EFT (page 233)	EFT signal abnormal rate of change
174	15	EWPS (page 269)	Engine Fuel System above Warning Temperature
175	0	EWPS (page 269)	Engine Oil System above Critical Temperature
175	3	EOT (page 258)	EOT signal Out of Range HIGH
175	4	EOT (page 258)	EOT signal Out of Range LOW
175	10	EOT (page 258)	EOT signal abnormal rate of change
175	15	EWPS (page 269)	Engine Oil System above Warning Temperature
177	3	Truck	TOT signal Out of Range HIGH See applicable vehicle <i>Electrical System Troubleshooting Guide</i> .
177	4	Truck	TOT signal Out of Range LOW See applicable vehicle <i>Electrical System Troubleshooting Guide</i> .
177	4	Truck	TOT above warning temperature See applicable vehicle <i>Electrical System Troubleshooting Guide</i> .
190	0	EWPS (page 269)	Engine Overspeed - Most Severe Level
190	14	TACH (page 346)	Tachometer Drive Output Error
191	3	OSS (page 334)	TOSS signal Out of Range HIGH
191	4	OSS (page 334)	TOSS signal Out of Range LOW
191	19	OSS (page 334)	TOSS not detected on J1939
412	0	EGRT (page 245)	EGRT above Critical Temperature
412	3	EGRT (page 245)	EGRT signal Out of Range HIGH
412	4	EGRT (page 245)	EGRT signal Out of Range LOW
412	10	EGRT (page 245)	EGRT signal Abnormal Rate of Change
593	31	IST (page 324)	Engine stopped by IST
596	2	CCS (page 185)	SCCS switch circuit fault
596	19	CCS (page 185)	Cruise Control Enable Switch not detected on J1939
597	2	Brake Switch(page 177)	Brake Switch circuit fault
597	19	Brake Switch(page 177)	Brake Switch not detected on J1939

SPN	FMI	Circuit	Condition Description
598	0	Truck	Clutch switch circuit fault See applicable vehicle <i>Electrical System Troubleshooting Guide</i> .
628	12	ECM Self (page 221)	ECM Memory Error
628	14	ECM Self (page 221)	ECM Programming – EFRC Error
629	2	ECM Self (page 221)	ECM Error - Level 2 monitoring
629	10	ECM Self (page 221)	ECM Error – Fuel Injector Performance Bank B
629	12	ECM Self (page 221)	ECM Error – SPI
629	31	ECM Self (page 221)	ECM Error - Level 3 monitoring
633	3	FPCV (page 282)	FPCV short to PWR
633	4	FPCV (page 282)	FPCV short to GND
633	5	FPCV (page 282)	FPCV open load/circuit
633	6	FPCV (page 282)	FPCV Current max limit exceeded
636	2	CMP (page 191)	CMP and CKP Synchronization Error
636	7	CMP (page 191)	CMP to CKP incorrect reference
637	8	CKP (page 188)	CKP incorrect signal signature
637	10	CKP (page 188)	CKP signal inactive
639	14	CAN (page 181)	J1939 Data Link Error (ECM Unable to transmit)
647	3	EFC (page 229)	EFC short to PWR
647	4	EFC (page 229)	EFC short to GND
647	5	EFC (page 229)	EFC open load/circuit
651	4	INJ (page 313)	Injector 1 short circuit
651	5	INJ (page 313)	Injector 1 open circuit
652	4	INJ (page 313)	Injector 2 short circuit
652	5	INJ (page 313)	Injector 2 open circuit
653	4	INJ (page 313)	Injector 3 short circuit
653	5	INJ (page 313)	Injector 3 open circuit
654	4	INJ (page 313)	Injector 4 short circuit
654	5	INJ (page 313)	Injector 4 open circuit
655	4	INJ (page 313)	Injector 5 short circuit
655	5	INJ (page 313)	Injector 5 open circuit
656	4	INJ (page 313)	Injector 6 short circuit
656	5	INJ (page 313)	Injector 6 open circuit
657	4	INJ (page 313)	Injector 7 short circuit
657	5	INJ (page 313)	Injector 7 open circuit

SPN	FMI	Circuit	Condition Description
658	4	INJ (page 313)	Injector 8 short circuit
658	5	INJ (page 313)	Injector 8 open circuit
729	2	IAH (page 299)	IAHC Relay Circuit Fault
729	3	IAH (page 299)	IAHC short to PWR
729	4	IAH (page 299)	IAHC short to GND
729	5	IAH (page 299)	IAHC open load/circuit
837	14	VSO (page 364)	Speedometer Drive Output Error
974	3	Truck	Remote APP signal Out of Range HIGH See applicable vehicle <i>Electrical System Troubleshooting Guide</i> .
974	4	Truck	Remote APP signal Out of Range LOW See applicable vehicle <i>Electrical System Troubleshooting Guide</i> .
1136	0	ECM Self (page 221)	ECM Error – over temperature
1136	1	ECM Self (page 221)	ECM Error – under temperature
1188	3	TC1WC (page 349)	TC1WC short to PWR
1188	4	TC1WC (page 349)	TC1WC short to GND
1188	5	TC1WC (page 349)	TC1WC open load/circuit
1209	0	AMS (page 161)	EBP above desired level
1244	3	FVCV (page 296)	FVCV short to PWR
1244	4	FVCV (page 296)	FVCV short to GND
1244	5	FVCV (page 296)	FVCV open load/circuit
1244	6	FVCV (page 296)	FVCV Current max limit exceeded
1323	31	Cyl Bal (page 194)	Misfire - Cylinder 1
1324	31	Cyl Bal (page 194)	Misfire - Cylinder 2
1325	31	Cyl Bal (page 194)	Misfire - Cylinder 3
1326	31	Cyl Bal (page 194)	Misfire - Cylinder 4
1327	31	Cyl Bal (page 194)	Misfire - Cylinder 5
1328	31	Cyl Bal (page 194)	Misfire - Cylinder 6
1329	31	Cyl Bal (page 194)	Misfire - Cylinder 7
1330	31	Cyl Bal (page 194)	Misfire - Cylinder 8
1378	17	Truck	Change Engine Oil Service Interval Soon See <i>Engine Operation and Maintenance Manual</i> .
1378	31	Truck	Change Engine Oil Service Interval See <i>Engine Operation and Maintenance Manual</i> .

SPN	FMI	Circuit	Condition Description
1482	19	Truck	Transmission Control Module not detected on J1939 See applicable vehicle <i>Electrical System Troubleshooting Guide</i> .
1639	3	Truck	EFS unrealistically HIGH See applicable vehicle <i>Electrical System Troubleshooting Guide</i> .
1639	4	Truck	EFS unrealistically LOW See applicable vehicle <i>Electrical System Troubleshooting Guide</i> .
1692	0	AMS (page 161)	Boost High/above desired level detected
1692	17	AMS (page 161)	KOER STD – Boost unable to achieve desired set-point
1692	18	AMS (page 161)	Boost unable to achieve desired set-point
2623	3	APP (page 167)	APP2 signal Out of Range HIGH
2623	4	APP (page 167)	APP2 signal Out of Range LOW
2629	3	TCOT (page 352)	TC1COT signal Out of Range HIGH
2629	4	TCOT (page 352)	TC1COT signal Out of Range LOW
2629	15	EWPS (page 269)	High Compressor Outlet Temperature
2659	17	AMS (page 161)	EGR Flow Rate unable to achieve desired set-point
2659	20	AMS (page 161)	EGR High Flow Rate detected
2659	21	AMS (page 161)	EGR Low Flow Rate detected
2791	3	EGR (page 238)	EGRC short to PWR
2791	4	EGR (page 238)	EGRC short to GND
2791	5	EGR (page 238)	EGRC open load/circuit
2791	7	EGR (page 238)	EGRC Unable to achieve desired set-point
2791	17	EGR (page 238)	EGRC Unable to achieve desired set-point
2797	4	INJ (page 313)	Initialization of fuel injector driver circuit failed group 1 (INJ 1, 3, 5, 7)
2797	11	INJ (page 313)	Injector Control Group 1 short circuit (INJ 1, 3, 5, 7)
2798	4	INJ (page 313)	Initialization of fuel injector driver circuit failed group 2 (INJ 2, 4, 6, 8)
2798	11	INJ (page 313)	Injector Control Group 2 short circuit (INJ 2, 4, 6, 8)
3055	0	FRP System (page 293)	FRP exceeded maximum
3055	1	FRP System (page 293)	Low Fuel Pressure at start
3055	13	FRP System (page 293)	Fuel Pressure offset check

SPN	FMI	Circuit	Condition Description
3055	15	FRP System (page 293)	FRP below minimum with maximum command
3055	17	FRP System (page 293)	FRP above maximum with minimum command
3242	3	DPFIT (page 205)	DPFIT signal Out of Range HIGH
3242	4	DPFIT (page 205)	DPFIT signal Out of Range LOW
3242	10	DPFIT (page 205)	DPFIT abnormal rate of change
3246	3	DPFOT (page 209)	DPFOT signal Out of Range HIGH
3246	4	DPFOT (page 209)	DPFOT signal Out of Range LOW
3246	10	DPFOT (page 209)	DPFOT abnormal rate of change
3251	0	AFT System (page 151)	DPFDP excessively HIGH (Plugged filter)
3251	3	DPFDP (page 201)	DPFDP signal Out of Range HIGH
3251	4	DPFDP (page 201)	DPFDP signal Out of Range LOW
3251	10	DPFDP (page 201)	DPFDP signal abnormal rate of change
3251	21	AFT System (page 151)	DPFDP excessively LOW (Sensor/circuit fault or missing DPF)
3387	20	Cyl Bal (page 194)	Cyl 1 Balance max limit exceeded
3387	21	Cyl Bal (page 194)	Cyl 1 Balance below min limit
3388	20	Cyl Bal (page 194)	Cyl 2 Balance max limit exceeded
3388	21	Cyl Bal (page 194)	Cyl 2 Balance below min limit
3389	20	Cyl Bal (page 194)	Cyl 3 Balance max limit exceeded
3389	21	Cyl Bal (page 194)	Cyl 3 Balance below min limit
3390	20	Cyl Bal (page 194)	Cyl 4 Balance max limit exceeded
3390	21	Cyl Bal (page 194)	Cyl 4 Balance below min limit
3391	20	Cyl Bal (page 194)	Cyl 5 Balance max limit exceeded
3391	21	Cyl Bal (page 194)	Cyl 5 Balance below min limit
3392	20	Cyl Bal (page 194)	Cyl 6 Balance max limit exceeded
3392	21	Cyl Bal (page 194)	Cyl 6 Balance below min limit
3393	20	Cyl Bal (page 194)	Cyl 7 Balance max limit exceeded
3393	21	Cyl Bal (page 194)	Cyl 7 Balance below min limit
3394	20	Cyl Bal (page 194)	Cyl 8 Balance max limit exceeded
3394	21	Cyl Bal (page 194)	Cyl 8 Balance below min limit
3464	3	ETV (page 263)	ETC short to PWR
3464	4	ETV (page 263)	ETC short to GND
3464	5	ETV (page 263)	ETC open load/circuit

SPN	FMI	Circuit	Condition Description
3509	3	VREF (page 356)	VREF Engine voltage above max
3509	4	VREF (page 356)	VREF Engine voltage below min
3510	3	VREF (page 356)	VREF Chassis voltage above max
3510	4	VREF (page 356)	VREF Chassis voltage below min
3511	3	VREF (page 356)	VREF Body voltage above max
3511	4	VREF (page 356)	VREF Body voltage below min
3645	19	Truck	Transfer Case Status not detected on J1939 See applicable vehicle <i>Electrical System Troubleshooting Guide</i> .
3719	0	AFT System (page 151)	DPF Soot Load – Highest (level 3/3)
3719	15	AFT System (page 151)	DPF Soot Load – Lowest (level 1/3)
3719	16	AFT System (page 151)	DPF Soot Load – Moderate (level 2/3)
3720	0	AFT System (page 151)	DPF Ash load at maximum limit (Remove DPF for cleaning)
3936	0	AFT System (page 151)	DPF Soot Load – Severe De-Rate
3936	16	AFT System (page 151)	DPF Overtemp Monitor
4082	2	Fuel Pump (page 285)	FPC Relay Circuit Fault
4082	3	Fuel Pump (page 285)	FPC short to PWR
4082	4	Fuel Pump (page 285)	FPC short to GND
4082	5	Fuel Pump (page 285)	FPC open load/circuit
4192	3	WIF (page 367)	WIF signal Out of Range HIGH
4192	4	WIF (page 367)	WIF signal Out of Range LOW
4192	31	WIF (page 367)	Water in Fuel Detected
4227	14	Truck	Change Breather Service Interval Reset ahead of schedule See <i>Engine Operation and Maintenance Manual</i> .
4227	17	Truck	Change Breather Service Interval Soon See <i>Engine Operation and Maintenance Manual</i> .
4227	31	Truck	Change Breather Service Interval NOW See <i>Engine Operation and Maintenance Manual</i> .
4765	3	DOCIT (page 197)	DOCIT signal Out of Range HIGH
4765	4	DOCIT (page 197)	DOCIT signal Out of Range LOW

SPN	FMI	Circuit	Condition Description
4765	10	DOCIT (page 197)	DOCIT signal abnormal rate of change
5298	2	AFT System (page 151)	Reduced DOC Efficiency - de-rate
5319	31	AFT System (page 151)	DPF incomplete Regeneration
5543	4	EBPV	EBPC valve electrical fault
5543	7	EBPV	EBPC Actuator Fault
5543	12	EBPV	EBPC Actuator Fault
5543	16	EBPV	EBPC valve over temperature fault
5543	19	EBPV	EBPC valve other faults (set point or CAN bus fault)
522283	3	Fuel Cooler Control Valve (page 274)	FCC short to PWR
522283	4	Fuel Cooler Control Valve (page 274)	FCC short to GND
522283	5	Fuel Cooler Control Valve (page 274)	FCC open load/circuit

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Electrical Tools

42-Pin Engine to Chassis Interface Cable

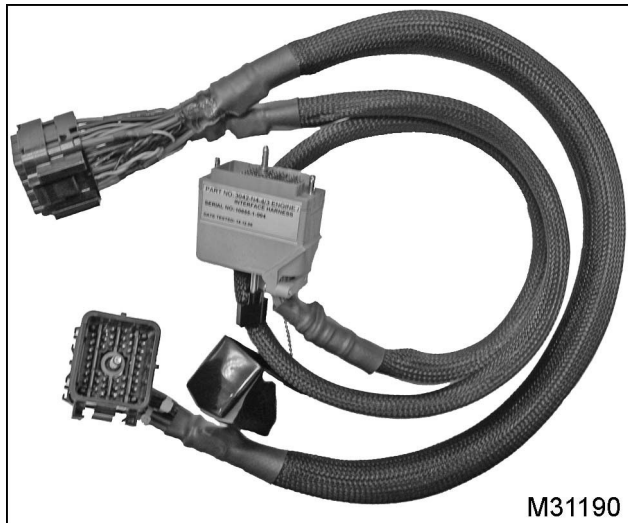


Figure 191 3042-N4

The 42-pin Engine to Chassis Interface Cable with breakout box overlay (pin identifier) sheet is used with the 180-pin Breakout Box to test the 42-pin connector circuits.

98-Pin Engine and Chassis Cables

The 98-pin Engine and Chassis Cables (2 cables) with breakout box overlay (pin identifier) sheet are used with the 180-pin Breakout Box. These cables are used to test the circuits going to the engine and chassis 98-pin connectors on the Engine Control Module (ECM).

180-Pin Breakout Box

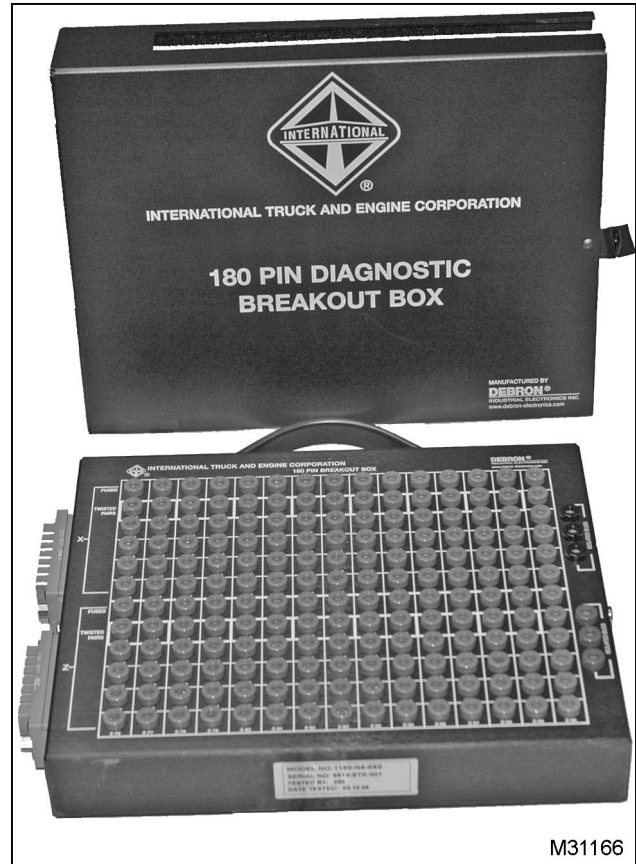


Figure 192 1180-N4-0X0

The 180-Pin Breakout Box allows testing of electronic control system components without disturbing connections or piercing wire insulation to access various signal voltages in the electronic control system.

CAUTION: To prevent damage to the breakout box, the breakout box is used for measurement only, not to activate or control circuits. High current levels passing through the breakout box will burn out the internal circuitry.

This box is universal and can adapt to any control system by means of a unique jumper harness. Each jumper harness is a separate part, complete with a breakout box overlay (pin identifier) sheet.

The standard box layout is as follows:

- Two 90-pin connectors, which feed 90 banana plug probing points.

- Each 90-pin section of the box is basically a stand-alone box.
- The top row is all fuse protected circuits, the second row is all twisted pair circuits.

Digital IR Thermometer

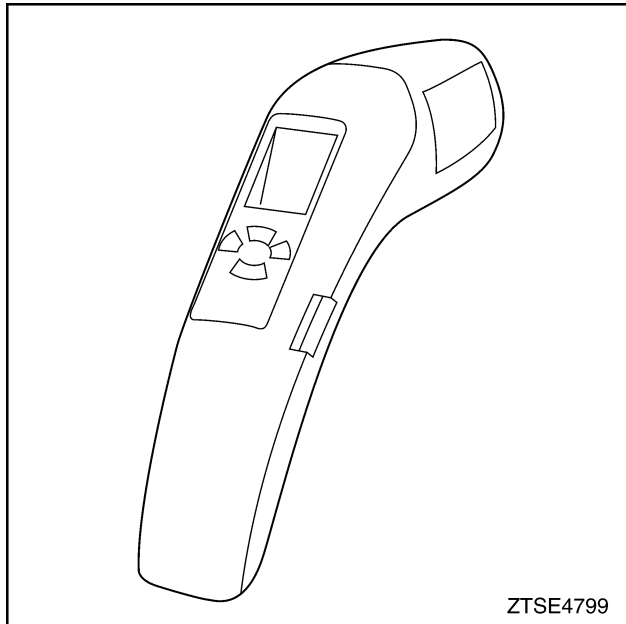


Figure 193 ZTSE4799

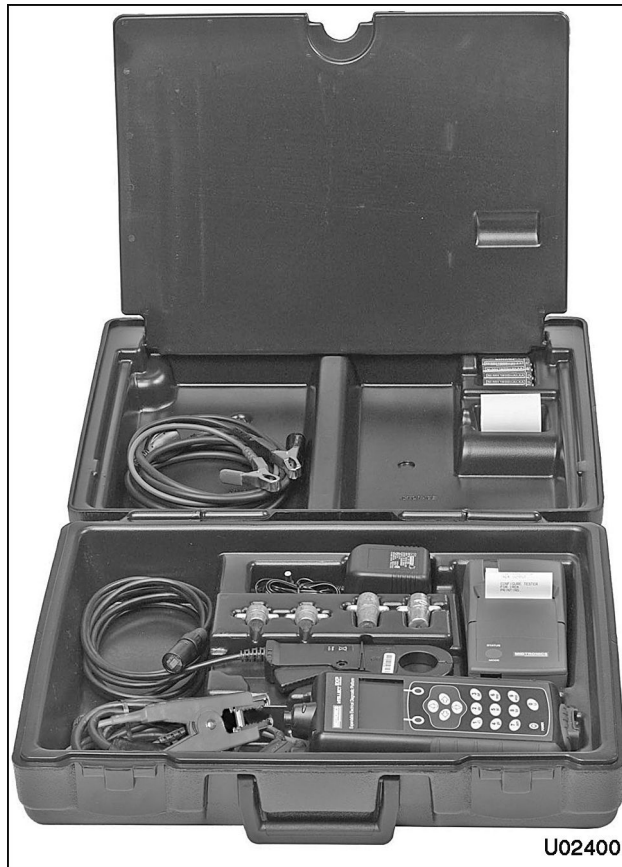
The Digital Infrared (IR) Thermometer is used to take temperature readings when Electronic Service Tool (EST) and dash gauge readings need to be verified.

Digital Multimeter (DMM)

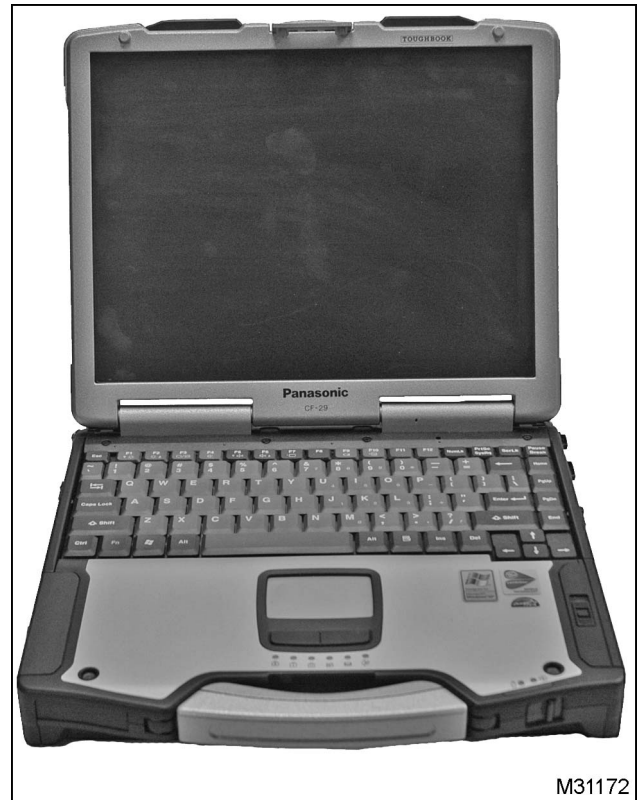


Figure 194 ZTSE4357

The DMM is used to troubleshoot electrical components, sensors, injector solenoids, relays, and wiring harnesses. The DMM has a high input impedance that allows testing of sensors while the engine is running, without loading the circuit being tested. This ensures the signal voltage measurement will not be affected by the voltmeter.

EXP-1000 HD by Midtronics**Figure 195 EXP-1000 HD INTL**

The EXP-1000 HD by Midtronics is used to measure amperage draw for the inlet air heater.

EZ-Tech® Electronic Service Tool (EST)**Figure 196 J-45067**

The EST is used to run ServiceMaxx™ software for diagnosing and troubleshooting engine and vehicle problems.

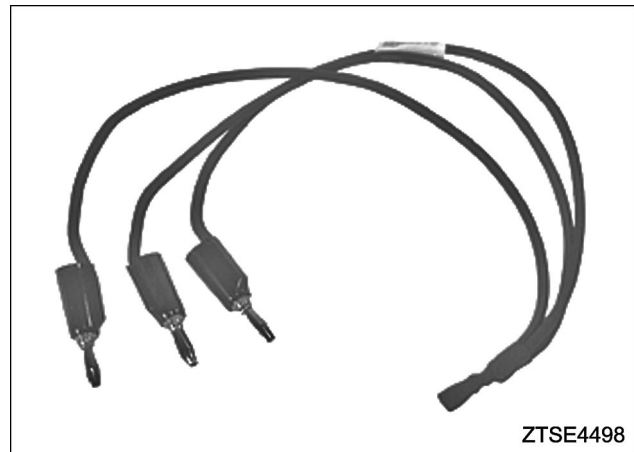
The EZ-Tech® Interface Kit cables are included with the EST.

International® Electronic Engine Terminal Test Kit**Figure 197 ZTSE4435C**

The International® Electronic Engine Terminal Test Kit is used to access circuits in the connector harness and allows for the use of a DMM without damaging the harness connectors. The probes may also be used as a guide to determine whether the harness connector is retaining correct tension on the mating terminal.

NAVCoM Interface Kit**Figure 198 NAVCoM Interface Kit**

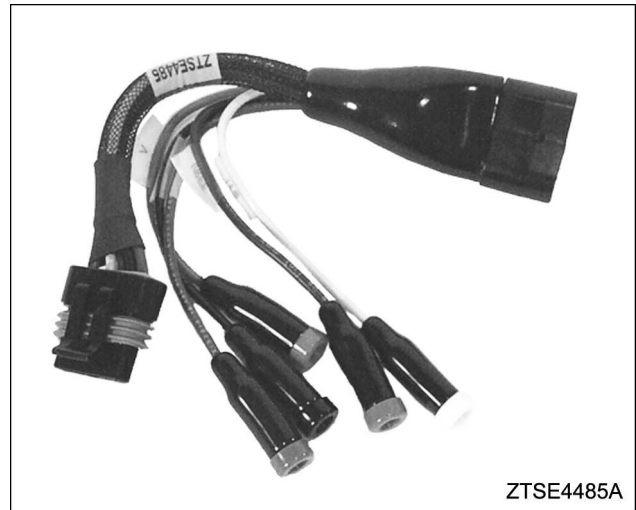
The NAVCoM Interface Kit is used to connect the EST to ECM. The NAVLink Interface Kit is an alternative to the NAVCoM Interface Kit.

3-Banana Plug Harness**Figure 199 ZTSE4498**

The 3-Banana Plug Harness is used for sensor end diagnostics of sensor circuits.

16-Way Breakout Harness**Figure 200 ZTSE4762**

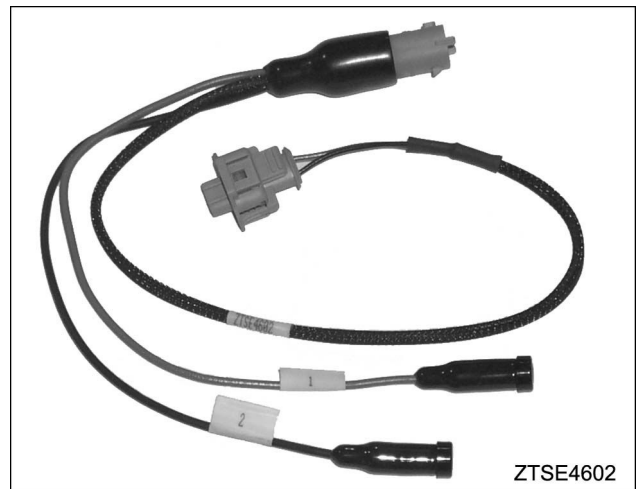
The 16-Way Breakout Harness is used for circuit diagnostics for actuator power and ground. Additional applications include the A/C clutch, alternator, and fuel heater.

Breakout Harness 4485A (APP)**Figure 202 ZTSE4485A**

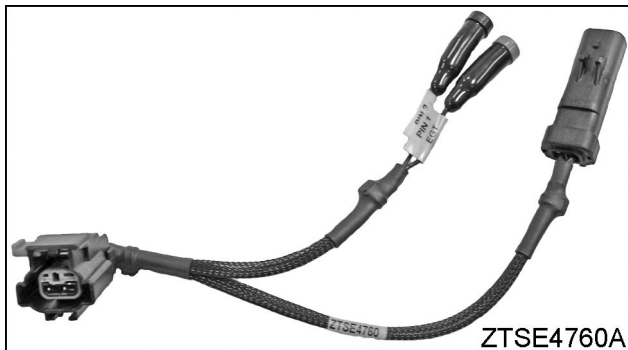
Breakout Harness 4485A is used to measure voltage and resistance on circuits that go to the Accelerator Pedal Position (APP) sensor.

500-Ohm Resistor Harness**Figure 201 ZTSE4497**

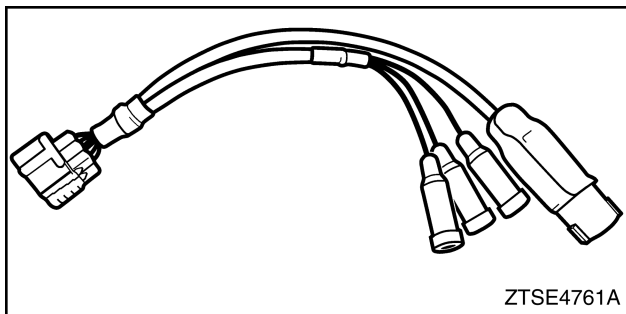
The 500-Ohm Resistor Harness is used for sensor end diagnostics of sensor circuits.

Breakout Harness 4602 (ECT, EFT, EOT, and IMT)**Figure 203 ZTSE4602**

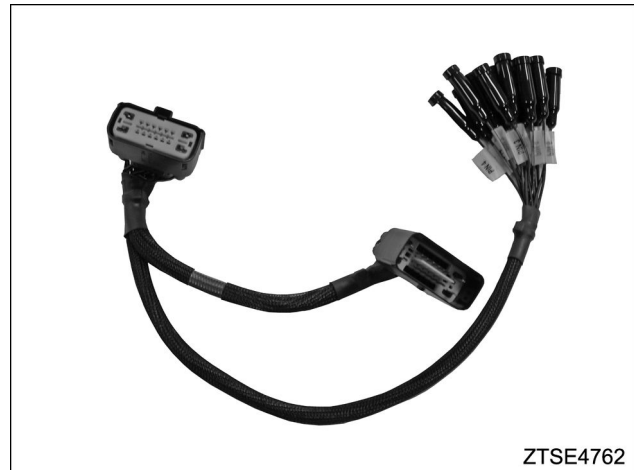
Breakout Harness 4602 is used to measure voltage and resistance on circuits that go to the Engine Coolant Temperature (ECT), Engine Fuel Temperature (EFT), Engine Oil Temperature (EOT), and Intake Manifold Temperature (IMT) sensors.

Breakout Harness 4760A (DOCIT, DPFIT, and DPFOT)**Figure 204 ZTSE4760A**

Breakout Harness 4760A is used to measure voltage and resistance on circuits that go to the Diesel Oxidation Catalyst Inlet Temperature (DOCIT), Diesel Particulate Filter Inlet Temperature (DPFIT), and Diesel Particulate Filter Outlet Temperature (DPFOT) sensors.

Breakout Harness 4761A (DPFDP)**Figure 205 ZTSE4761A**

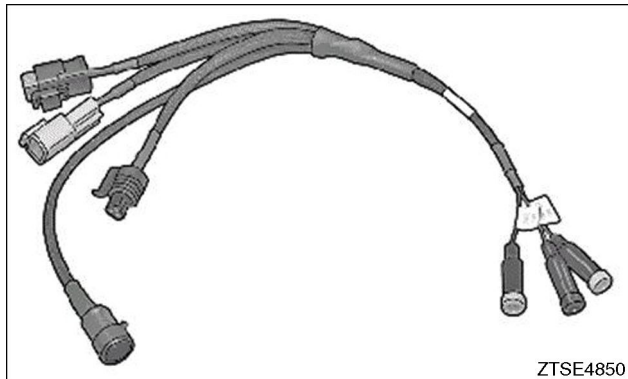
Breakout Harness 4761A is used to measure voltage and resistance on circuits that go to the Diesel Particulate Filter Differential Pressure (DPFDP) sensor.

Breakout Harness 4762 (IPR, EGR, and VGT)**Figure 206 ZTSE4762**

Breakout Harness 4762 is used for circuit diagnostics for actuator power and ground that go to Injection Pressure Regulator (IPR) and Exhaust Gas Recirculation (EGR) valve. Additional applications include the A/C clutch, alternator, and fuel heater.

Breakout Harness 4831 (TC1WC)**Figure 207 ZTSE4831**

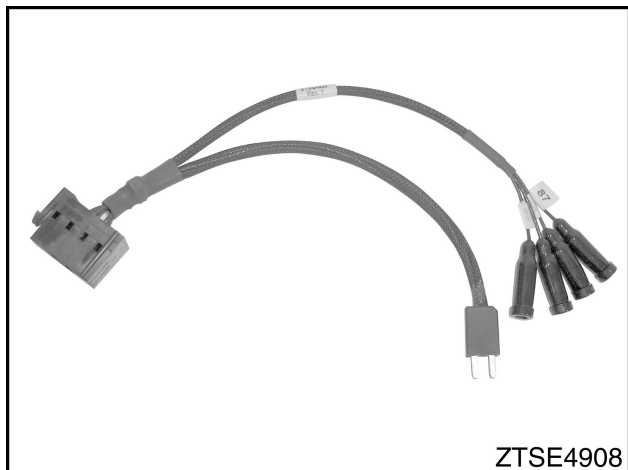
Breakout Harness 4831 is used to measure voltage and resistance on circuits connected to the Turbocharger 1 Wastegate Control (TC1WC) actuator.

Breakout Harness 4850 (IMP)**Figure 208 ZTSE4850**

Breakout Harness 4850 is used to measure voltage and resistance on circuits connected to the Intake Manifold Pressure (IMP) sensor.

Breakout Harness 4946 (EGT)**Figure 210 ZTSE4946**

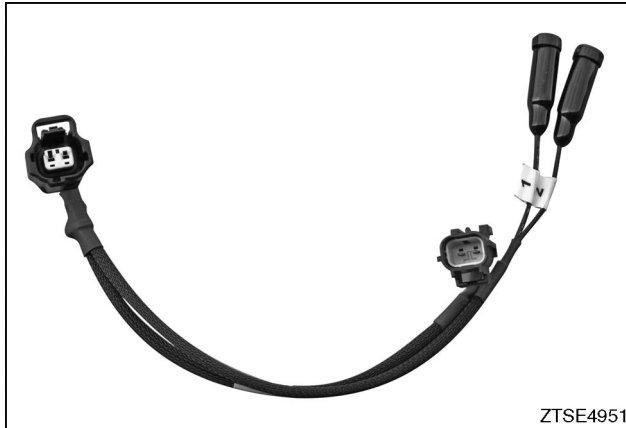
Breakout Harness 4946 enables the technician to quickly connect a voltmeter and read voltage signals for the Exhaust Gas Temperature (EGT) sensor.

Breakout Harness 4908 (ECM Relay)**Figure 209 ZTSE4908**

Breakout Harness 4908 is used to measure voltage and resistance on circuits to the Starter Motor Control (SMC) relay.

Breakout Harness 4950 (CMP)**Figure 211 ZTSE4950**

Breakout Harness 4950 is used to measure voltage and resistance on circuits connected to the Camshaft Position (CMP) sensor.

Breakout Harness 4951 (CKP)**Figure 212 ZTSE4951**

Breakout Harness 4951 is used to measure voltage and resistance on circuits connected to the Crankshaft Position (CKP) sensor.

Breakout Harness 4958 (FPCV and FVCV)**Figure 213 ZTSE4958**

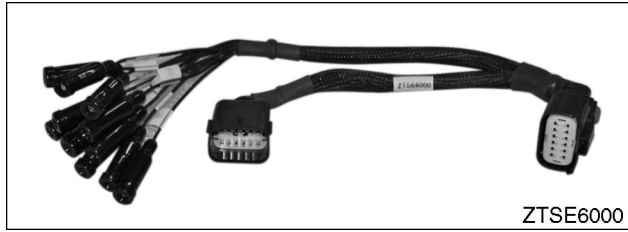
Breakout Harness 4958 is used to measure voltage and resistance on circuits connected to the Fuel Pressure Control Valve (FPCV) and Fuel Volume Control Valve (FVCV).

Breakout Harness 4960 (MAF)**Figure 214 ZTSE4960**

Breakout Harness 4960 is used to measure voltage and resistance on circuits that go to the Mass Air Flow (MAF) sensor.

Breakout Harness 4993 (IMT)**Figure 215 ZTSE4993**

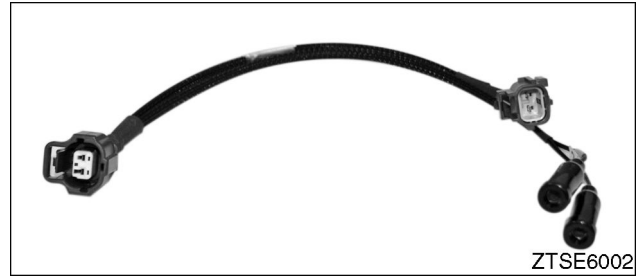
Breakout Harness 4993 is used to measure voltage and resistance on circuits that go to the Intake Manifold Temperature (IMT) sensor.

Breakout Harness 6000 (UVC)**Figure 216 ZTSE6000**

Breakout Harness 6000 is used to measure continuity of the Under Valve Cover (UVC) wiring and injector coils.

Breakout Harness 6001 (Fuel Pump)**Figure 217 ZTSE6001**

Breakout Harness ZTSE6001 is used to measure voltage and resistance on circuits that go to the Fuel Pump.

Breakout Harness 6002 (WIF)**Figure 218 ZTSE6002**

Breakout Harness 6002 is used to measure voltage and resistance on circuits that go to the Water In Fuel (WIF) sensor.

Breakout Harness 6005 (EBPV)**Figure 219 ZTSE6005**

Breakout Harness 6005 is used to measure voltage and resistance on circuits that go to the Exhaust Back Pressure Valve (EBPV).

Breakout Harness 6025 (IAH)**Figure 220 ZTSE6025**

Breakout Harness 6025 is used to measure voltage and resistance on circuits that go to the Inlet Air Heater (IAH) relay.

Breakout Harness 6038 (FRP)**Figure 221 ZTSE6038**

Breakout Harness 6038 is used to measure voltage and resistance on circuits that go to the Rail Fuel Pressure (FRP) sensor.

Mechanical Tools

Charge Air Cooler Test Kit

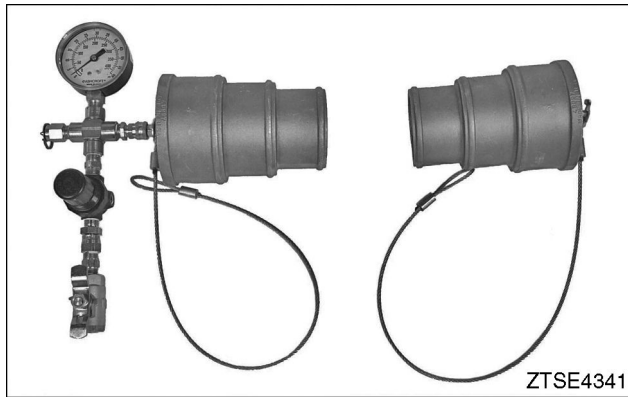


Figure 222 ZTSE4341

The Charge Air Cooler Test Kit is used to pressurize the charge air cooler and piping to check for leaks.

Clean Fuel Source Tool

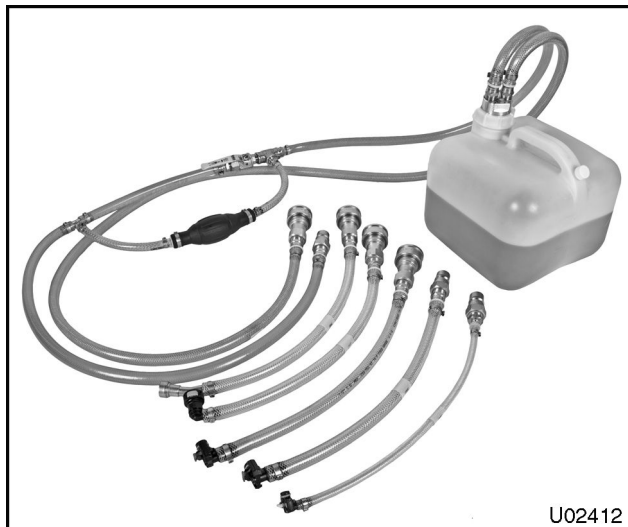


Figure 223 15-637-01

The Clean Fuel Source Tool is used to provide a clean, alternative fuel source to aid in the diagnosis of the fuel system.

Crankcase Pressure Test Adaptor

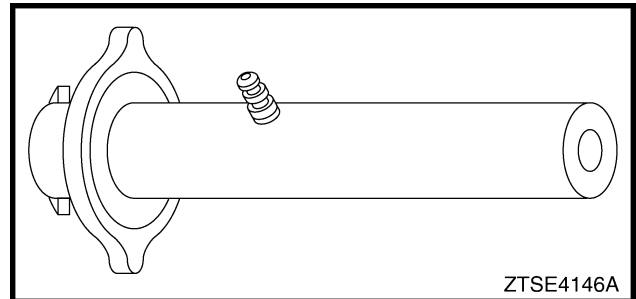
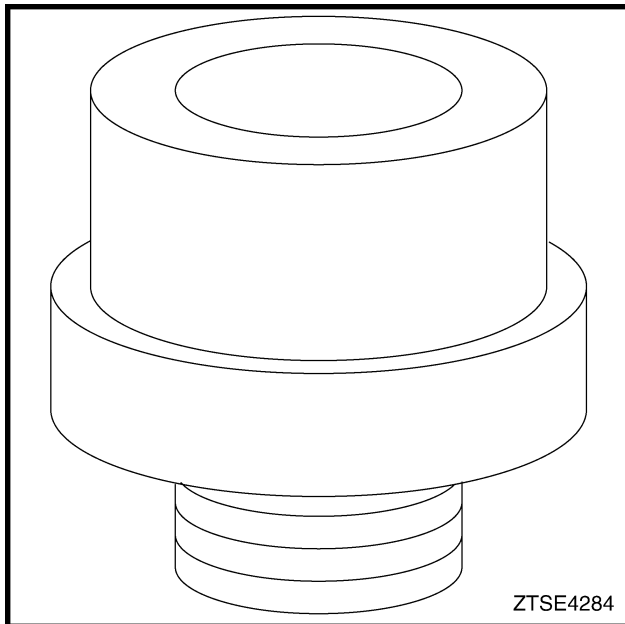


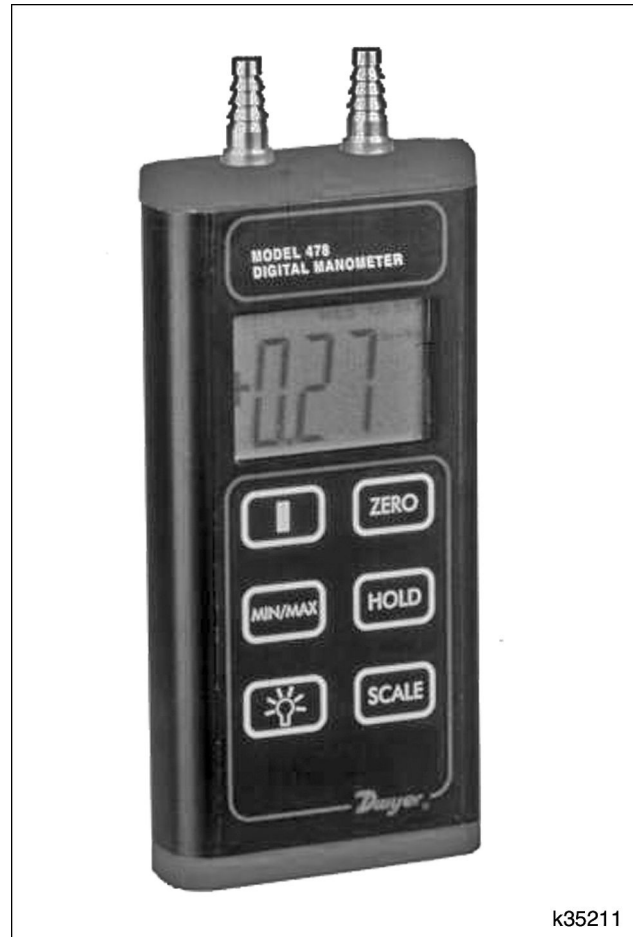
Figure 224 ZTSE4146A

The Crankcase Pressure Test Adaptor is used to measure combustion gas flow from the engine breather and may be used with the magnehelic gauge or manometer. Pressure readings obtained with this adaptor are used as the main indication of engine condition.

Oil consumption trend data must also be used if the pressure readings are over the specified limits. Neither changes in oil consumption trends nor crankcase diagnostic pressure trends can establish a specific problem. These changes only indicate a problem exists.

Crankcase Pressure Test Adaptor**Figure 225 ZTSE4284**

The Crankcase Pressure Test Adaptor is used to connect the Orifice Restrictor Tool to the oil fill tube.

Digital Manometer**Figure 226 Obtain locally**

The Digital Manometer is used to measure low vacuum due to intake restriction or low crankcase pressure. A variety of digital manometers are available for purchase locally. The Water Manometer kit (ZTSE2217A) is an alternative to the Digital Manometer

EGR Cooler Leak Detection Kit**Figure 227 KL 20040 NAV**

1. KL 20040 NAV (2010 MaxxForce® 7)
2. KL 20020 NAV (2007 MaxxForce® DT, 9, and 10)
3. KL 20030 NAV (2010 MaxxForce® DT, 9, and 10)

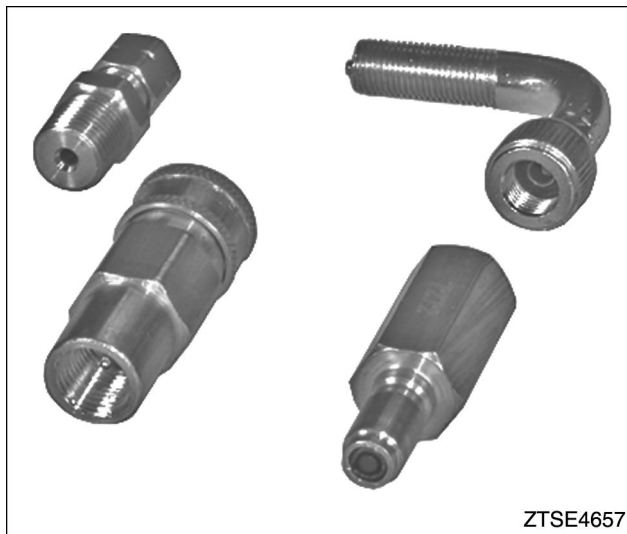
The EGR Cooler Leak Detection Test Kit is used to pressure test the Exhaust Gas Recirculation (EGR) cooler for leaks. KL 20020 NAV contains the plastic case with the EGR Cooler Leak Detection Test Kit for the 2007 MaxxForce® DT, 9, and 10. KL 20040 NAV is an add-on kit that contains the EGR Cooler Leak Detection Test Kit for the 2010 MaxxForce® 7. KL 20030 NAV is an add-on kit that contains the EGR Cooler Leak Detection Test Kit the 2010 MaxxForce® DT, 9, and 10. The three test kits can be purchased separately.

Fuel Inlet Restriction and Aeration Tool**Figure 228 ZTSE6009**

The Fuel Inlet Restriction and Aeration Tool is used to check for pressure and aerated fuel in the low fuel pressure system.

Fuel/Oil Pressure Test Coupler**Figure 229 ZTSE4526**

The Fuel/Oil Pressure Test Coupler is used with the fuel pressure test fitting for an easy connection to measure fuel pressure.

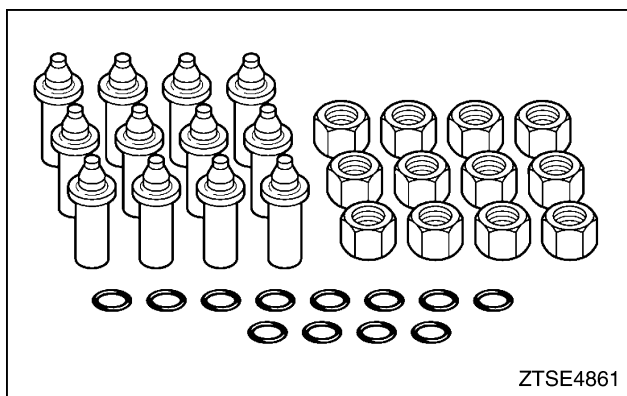
Fuel Pressure Test Kit

ZTSE4657

Figure 230 ZTSE4657

1. Compression fitting 1/8 NPT
2. 90° elbow
3. Quick disconnect check valve
4. Fuel pressure test adapter

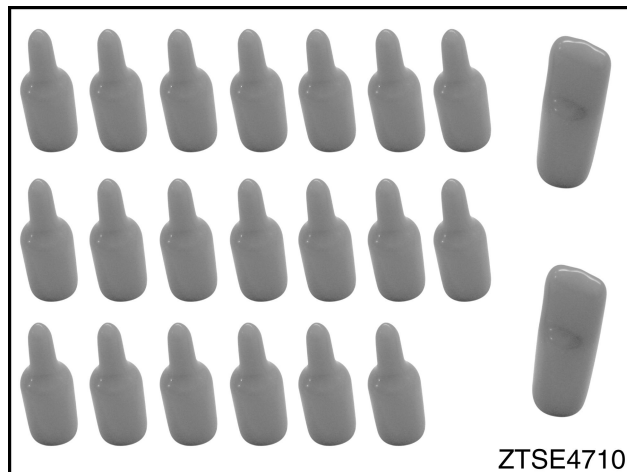
The Fuel Pressure Test Kit includes a quick disconnect check valve and fittings that can be used to make a test line to check fuel pressure at the high-pressure fuel rail.

Fuel Rail Block Off Plugs

ZTSE4861

Figure 231 ZTSE4861

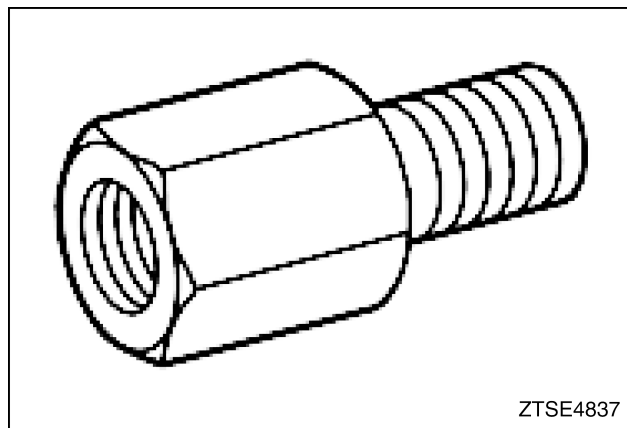
The Fuel Rail Block Off Plugs are used to test the high-pressure fuel system.

Fuel System Caps

ZTSE4710

Figure 232 ZTSE4710

The Fuel System Caps provide the required sizes needed to cap the fuel system fittings and injectors when the system has been disassembled for service. The caps prevent dirt and particles from entering the fuel system.

High-pressure Pump Test Fitting

ZTSE4837

Figure 233 ZTSE4837

The High-pressure Pump Test Fitting is used to test high-pressure system for leaks.

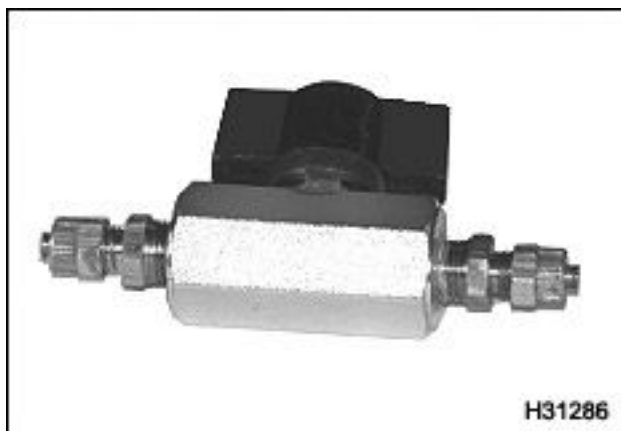
Fuel Injector Cups**Figure 234 ZTSE4709**

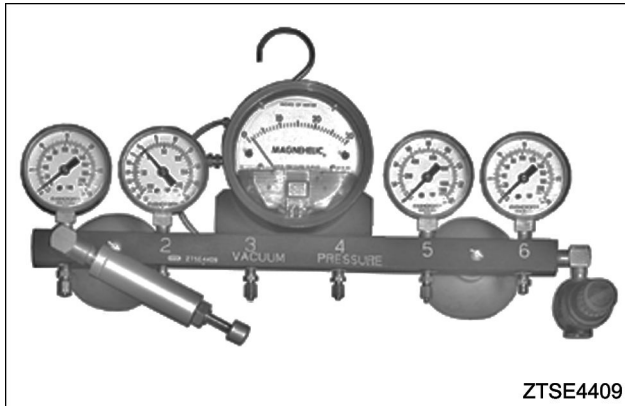
Injector Cups are plastic liners that fit in rack (ZTSE4299). The injectors fit tightly in the cups to prevent dirt from damaging the injectors.

The Inline Shut-off Valve is used to make a test line to check for aerated oil, specifically at the Engine Oil Temperature (EOT) sensor port. The Shut-Off valve can also be used to make a test line assembly to check for aerated fuel.

Oil Cooler Block Off**Figure 236 ZTSE6029**

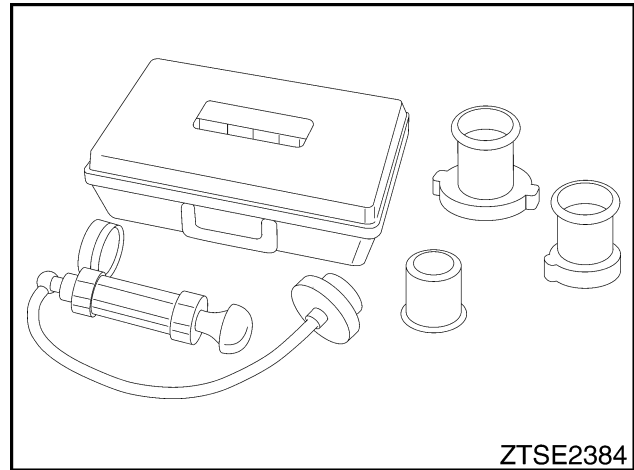
The Oil Cooler Block Off is used to pressure test the oil cooler for leaks.

Inline Shut-off Valve**Figure 235 Part No. 221406**

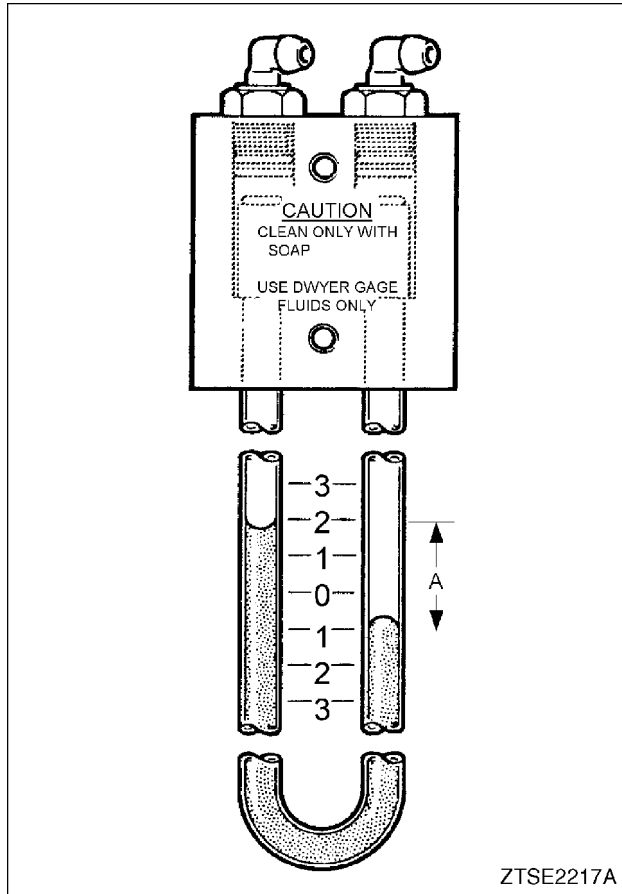
Pressure Test Kit**Figure 237 ZTSE4409**

The Pressure Test Kit is used to measure intake manifold (boost) pressure, fuel system inlet restriction, fuel pressure, oil pressure, air cleaner intake restriction, and crankcase pressure.

- 0 to 200 kPa (0 to 30 psi) measures intake manifold pressure.
- 0-30 in Hg vacuum / 0 to 200 kPa (0 to 30 psi) compound gauge measures fuel system inlet restriction and intake manifold pressure.
0-30 in H₂O 0 to 7.5 kPa (0 to 1 psi) maximum pressure magnehelic gauge measures crankcase pressure and air inlet restriction.
- 60 to 1100 kPa (0 to 160 psi) gauge may be used to check the fuel pressure and oil pressure.

Radiator Pressure Test Kit**Figure 238 ZTSE2384**

The Radiator Pressure Test Kit is used to check pressure caps and cooling systems. The pressure gauge indicates if the pressure cap holds the correct pressure and whether the cooling system has leaks or holds pressure.

Slack Tube® Manometer**Figure 239 ZTSE2217A**

The Slack Tube® Manometer is a U-shaped tube with a scale mounted between the legs of the tube. When the portability of the Pressure Test Kit is not required, this manometer is used to measure low vacuum for intake restriction, low pressure for crankcase, or exhaust back pressure.

Filling

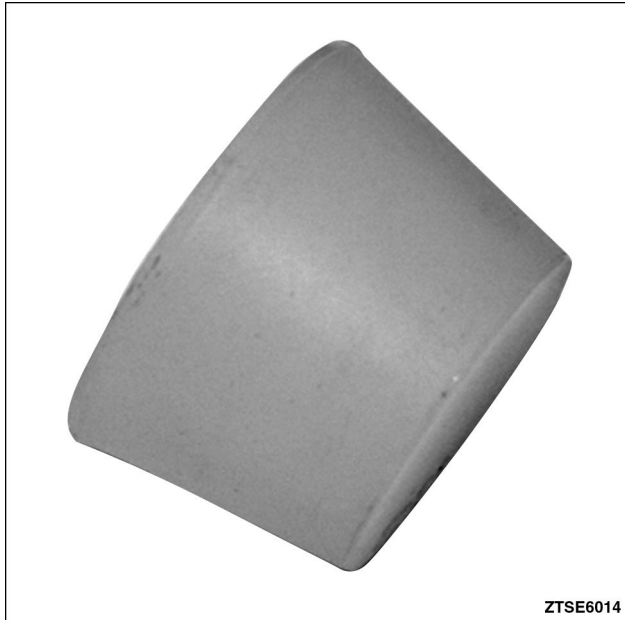
Fill the manometer with water before checking pressure. Use only distilled water. Add some colored water vegetable dye so the scale can be read more easily. With both legs of the manometer open to the atmosphere, fill the tube until the top of the fluid column is near the zero mark on the scale. Shake the tube to eliminate any air bubbles.

Installing, Reading, and Cleaning

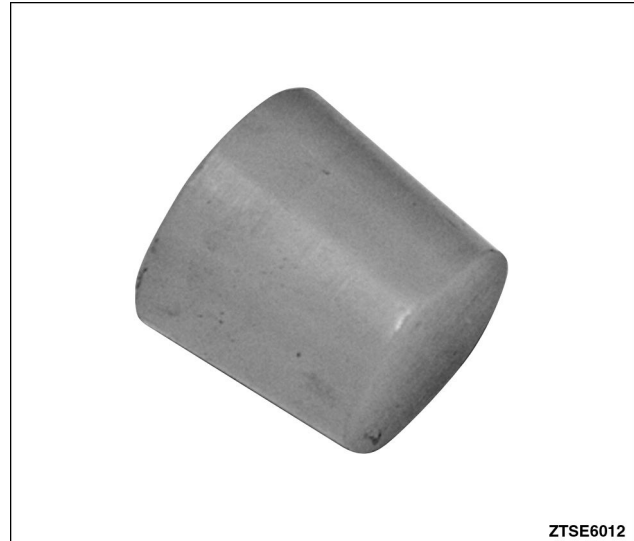
1. Support the manometer vertically. Make sure the fluid level is in line with the zero indicator on the graduated scale.
2. Connect one leg of the manometer to the source of the pressure or vacuum. Leave the other leg open to atmospheric pressure.
3. Start the engine and allow it to reach normal operating temperature. Then run the engine to high idle. The manometer can be read after 10 seconds.
4. Record the average position of the fluid level when it is above and below the zero indicator. Add the two figures together. The sum of the two is the total column of fluid (distance A). This represents the crankcase pressure in inches of water (in H₂O).

At times, both columns of the manometer will not travel the same distance. This is no concern if the leg not connected to the pressure or vacuum source is open to the atmosphere.

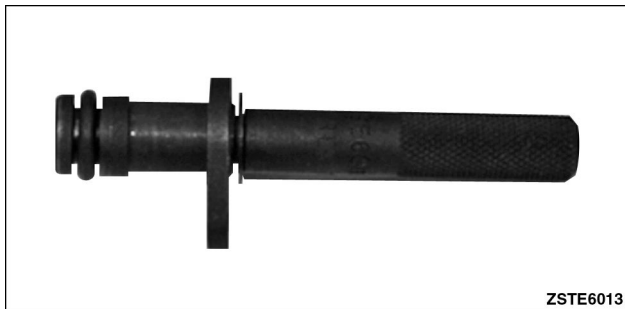
5. Compare the manometer reading with engine specifications.
6. When the test is done, clean the tube thoroughly using soap and water. Avoid liquid soaps and solvents.

Turbocharger Drain Block Off Plug**Figure 240 ZTSE6014**

The Turbocharger Drain Block Off Plug is used to block off the turbocharger oil drain line.

Turbocharger Supply Block Off Plug**Figure 242 ZTSE6012**

The Turbocharger Oil Supply Block Off Plug is used to block off the turbocharger lines.

Turbocharger Oil Supply Block Off**Figure 241 ZTSE6013**

The Turbocharger Oil Supply Block Off is used to block off the turbocharger oil supply ports and feed line so the engine can be operated to verify repairs.

UV Leak Detection Kit**Figure 243 ZTSE4618**

The UV Leak Detection Kit is used with fuel dye to quickly identify leaks. The fuel dye combines with fuel and migrates out at the leak. The ultraviolet lamp illuminates the leaking fuel dye, which appears fluorescent yellow-green in color.

Vacuum Analyzer and Fuel Pump Tester**Figure 244 ZTSE2499**

The Vacuum Analyzer and Fuel Pump Tester is used to test the operation of the fuel pump.

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Abbreviations and Acronyms.....407

Abbreviations and Acronyms

Abbreviations and Acronyms

A or amp – Ampere	BPS – Brake Pressure Switch
AAT – Ambient Air Temperature	BTDC – Before Top Dead Center
ABDC – After Bottom Dead Center	BTU – British Thermal Unit
ABS – Antilock Brake System	C – Celsius
AC – Alternating Current	CAC – Charge Air Cooler
A/C – Air Conditioner	CACOT – Charge Air Cooler Outlet Temperature
ACC – Air Conditioner Control	CAN – Controller Area Network
ACCEL – Accelerate	CAP – Cold Ambient Protection
ACD – Air Conditioner Demand	CARB – California Air Resources Board
ACM – Aftertreatment Control Module	cc – Cubic centimeter
ACT PWR GND – Actuator Power Ground	CCA – Cold Cranking Ampere
ACV – Air Control Valve	CCOSS – Crankcase Oil Separator Speed
AF – Air to Fuel ratio	CCS – Cruise Control Switches
AFT – Aftertreatment	cfm – Cubic feet per minute
AFTFD – Aftertreatment Fuel Doser	cfs – Cubic feet per second
AFTFDH – Aftertreatment Fuel Doser High	CFV – Coolant Flow Valve
AFTFDL – Aftertreatment Fuel Doser Low	CID – Cubic Inch Displacement
AFTFIT – Aftertreatment Fuel Inlet Temperature	CKP – Crankshaft Position
AFTFIS – Aftertreatment Fuel Inlet Sensor	CKPH – Crankshaft Position High
AFTFP – Aftertreatment Fuel Pressure	CKPL – Crankshaft Position Low
AFTFP1 – Aftertreatment Fuel Pressure 1	CKPO – Crankshaft Position Out
AFTFP2 – Aftertreatment Fuel Pressure 2	cm – Centimeter
AFTFSH – Aftertreatment Fuel Shutoff High	CMP – Camshaft Position
AFTFSL – Aftertreatment Fuel Shutoff Low	CMPH – Camshaft Position High
AFTFSV – Aftertreatment Fuel Shutoff Valve	CMPL – Camshaft Position Low
AIT – Air Inlet Temperature	CMPO – Camshaft Position Out
Amb – Ambient	CMV – Coolant Mixer Valve
amp or A – Ampere	CO – Carbon Monoxide
AMS – Air Management System	COO – Cruise On / Off switch
API – American Petroleum Institute	CPU – Central Processing Unit
APP – Accelerator Pedal Position	CSFI – Cold Start Fuel Igniter
APP1 – Accelerator Pedal Position 1	CSFS – Cold Start Fuel Solenoid
APP2 – Accelerator Pedal Position 2	CSR – Cold Start Relay
ASTM – American Society for Testing and Materials	CTC – Coolant Temperature Compensation
ATA – American Trucking Association	Cyl – Cylinder
ATAH – American Trucking Association Link High	DB – Decibel
ATAL – American Trucking Association Link Low	DC – Direct Current
ATDC – After Top Dead Center	DCA – Diesel Coolant Additive
AWG – American Wire Gauge	DDI – Digital Direct Fuel Injection
AWL – Amber Warning Lamp	DDS – Driveline Disengagement Switch
B+ or VBAT – Battery Voltage	DLC – Data Link Connector
BARO – Barometric Absolute Pressure	DME – Dimethyl Ether
BBDC – Before Bottom Dead Center	DMM – Digital Multi-meter
BC – Body Controller	DOC – Diesel Oxidation Catalyst
BDC – Bottom Dead Center	DOCIT – Diesel Oxidation Catalyst Inlet Temperature
bhp – Brake Horsepower	DOCOT – Diesel Oxidation Catalyst Outlet Temperature
BOO – Brake On / Off	DPF – Diesel Particulate Filter
BPP – Brake Pedal Position	DPFDP – Diesel Particulate Filter Differential Pressure
	DPFIT – Diesel Particulate Filter Inlet Temperature

DPFOT – Diesel Particulate Filter Outlet Temperature	ESC – Electronic System Controller
DSI – Down Stream Injection	ESN – Engine Serial Number
DT – Diesel Turbocharged	EST – Electronic Service Tool
DTC – Diagnostic Trouble Code	ETC – Engine Throttle Control
DTRM – Diesel Thermo Recirculation Module	ETCH – Engine Throttle Control High
EBP – Exhaust Back Pressure	ETCL – Engine Throttle Control Low
EBPD – Exhaust Back Pressure Desired	ETP – Engine Throttle Position
EBPV – Exhaust Back Pressure Valve	ETV – Engine Throttle Valve
ECB – Engine Compression Brake	EWPS – Engine Warning Protection System
ECB1 – Engine Compression Brake 1	F – Fahrenheit
ECB2 – Engine Compression Brake 2	FCV – Fuel Coolant Valve
ECBP – Engine Compression Brake Pressure	FDP – Fuel Delivery Pressure
ECI – Engine Crank Inhibit	FEL – Family Emissions Limit
ECL – Engine Coolant Level	fhp – Friction horsepower
ECM – Engine Control Module	FMI – Failure Mode Indicator
ECM GND – Engine Control Module Ground	FPC – Fuel Pump Control
ECM PWR – Engine Control Module Power	FPCV – Fuel Pressure Control Valve
ECS – Engine Coolant System	fpm – Feet per minute
ECSR – Engine Controlled Shutdown Request	FPM – Fuel Pump Monitor
ECT – Engine Coolant Temperature	fps – Feet per second
ECT1 – Engine Coolant Temperature 1	FRP – Fuel Rail Pressure
ECT2 – Engine Coolant Temperature 2	ft – Feet
EFAN – Engine Fan	FVCV – Fuel Volume Control Valve
EFC – Engine Fan Control	GND – Ground (electrical)
EFRC – Engine Family Rating Code	gal – Gallon
EFS – Engine Fan Speed	gal/h – U.S. Gallons per hour
EFT – Engine Fuel Temperature	gal/min – U.S. Gallons per minute
EG – Ethylene Glycol	GCW – Gross Combined Weight
EGC – Electronic Gauge Cluster	GCWR – Gross Combined Weight Rating
EGBP – Exhaust Gas Back Pressure	GPC – Glow Plug Control
EGDP – Exhaust Gas Differential Pressure	GPD – Glow Plug Diagnostic
EGR – Exhaust Gas Recirculation	GPR – Glow Plug Relay
EGRC – Exhaust Gas Recirculation Control	GVW – Gross Vehicle Weight
EGRH – Exhaust Gas Recirculation High control	H₂O – Water
EGRL – Exhaust Gas Recirculation Low control	HC – Hydrocarbons
EGROT – Exhaust Gas Recirculation Outlet Temperature	HEST – High Exhaust System Temperature
EGRP – Exhaust Gas Recirculation Position	HFCM – Horizontal Fuel Conditioning Module
EGRT – Exhaust Gas Recirculation Temperature	Hg – Mercury
EGT – Exhaust Gas Temperature	hp – Horsepower
EGT1 – Exhaust Gas Temperature 1	HPCAC – High-Pressure Charge Air Cooler
EGT2 – Exhaust Gas Temperature 2	HPCR – High-Pressure Common Rail
EGT3 – Exhaust Gas Temperature 3	HPFP – High-Pressure Fuel Pump
EMI – Electromagnetic Interference	hr – Hour
EMP – Exhaust Manifold Pressure	HS – Humidity Sensor
EMT – Exhaust Manifold Temperature	Hyd – Hydraulic
EOL – Engine Oil Level	IAH – Inlet Air Heater
EOP – Engine Oil Pressure	IAHC – Inlet Air Heater Control
EOT – Engine Oil Temperature	IAHD – Inlet Air Heater Diagnostic
EPA – Environmental Protection Agency	IAHR – Inlet Air heater Relay
EPR – Engine Pressure Regulator	IC – Integrated Circuit
	ICP – Injection Control Pressure

ICPR – Injection Control Pressure Regulator	mph – Miles per hour
ICG1 – Injector Control Group 1	MPR – Main Power Relay
ICG2 – Injector Control Group 2	MSDS – Material Safety Data Sheet
ID – Inside Diameter	MSG – Micro Strain Gauge
IGN – Ignition	MSM – Multiplex System Module
ILO – Injector Leak Off	MY – Model Year
IMP – Intake Manifold Pressure	NC – Normally closed (electrical)
IMT – Intake Manifold Temperature	NETS – Navistar Electronics Technical Support
in – Inch	Nm – Newton meter
inHg – Inch of mercury	NO – Normally Open (electrical)
inH₂O – Inch of water	NO_x – Nitrogen Oxides
INJs – Injectors	O2S – Oxygen Sensor
IPR – Injection Pressure Regulator	O2SH – Oxygen Sensor Heater
IPR PWR – Injection Pressure Regulator Power	OAT – Organic Acid Technology
ISC – Interstage Cooler	OCC – Output Circuit Check
ISIS – International Service Information System	OCF – Overcrank Protection
IST – Idle Shutdown Timer	OD – Outside Diameter
ITP – Internal Transfer Pump	OL – Over Limit
J1939H – J1939 Data Link High	ORH – Out-of-Range High
J1939L – J1939 Data Link Low	ORL – Out-of-Range Low
JCT – Junction (electrical)	OSHA – Occupational Safety and Health Administration
kg – Kilogram	OWL – Oil/Water Lamp
km – Kilometer	PID – Parameter Identifier
km/h – Kilometers per hour	P/N – Part Number
km/l – Kilometers per liter	PDOC – Pre-Diesel Oxidation Catalyst
KOEO – Key On Engine-Off	ppm – Parts per million
KOER – Key On Engine-Running	PROM – Programmable Read Only Memory
kPa – Kilopascal	psi – Pounds per square inch
L – Liter	psia – Pounds per square inch absolute
L/h – Liters per hour	psig – Pounds per square inch gauge
L/m – Liters per minute	pt – Pint
L/s – Liters per second	PTO – Power Takeoff
lb – Pound	PWM – Pulse Width Modulate
lbf – Pounds of force	PWR – Power (voltage)
lb/s – Pounds per second	qt – Quart
lbf ft – Pounds of force per foot	RAM – Random Access Memory
lbf in – Pounds of force per inch	RAPP – Remote Accelerator Pedal Position
lbm – Pounds of mass	RAS – Resume / Accelerate Switch (speed control)
LSD – Low Sulfur Diesel	REPTO – Rear Engine Power Takeoff
m – Meter	RFI – Radio Frequency Interference
m/s – Meters per second	rev – Revolution
MAF – Mass Air Flow	rpm – Revolutions per minute
MAF GND – Mass Air Flow Ground	RPRE – Remote Preset Power Take Off
MAG – Magnetic	RSE – Radiator Shutter Enable
MAP – Manifold Absolute Pressure	RVAR – Remote Variable
MAT – Manifold Air Temperature	SAE – Society of Automotive Engineers®
mep – Mean effective pressure	SCA – Supplemental Cooling Additive
mi – Mile	SCCS – Speed Control Command Switches
MIL – Malfunction Indicator Lamp	SCS – Speed Control Switch
mm – Millimeter	SHD – Shield (electrical)
mpg – Miles per gallon	

SID – Subsystem Identifier	ULSD – Ultra Low Sulfur Diesel
SIG GND – Signal Ground	UVC – Under Valve Cover
SIG GNDB – Signal Ground Body	V – Volt
SIG GNDC – Signal Ground Chassis	VBAT or B+ – Battery Voltage
SIG GNDE – Signal Ground Engine	VC – Volume Control
S/N – Serial Number	VEPS – Vehicle Electronics Programming System
SPEEDO – Speedometer	VIGN – Ignition Voltage
SPN – Suspect Parameter Number	VIN – Vehicle Identification Number
SW – Switch (electrical)	VOP – Valve Opening Pressure
SWBAT – Switch Battery	VRE – Vehicle Retarder Enable
SYNC – Synchronization	VREF – Reference Voltage
TACH – Tachometer output signal	VREFB – Reference Voltage Body
TBD – To Be Determined	VREFC – Reference Voltage Chassis
TC2CIS – Turbocharger 2 Compressor Inlet Sensor	VREFE – Reference Voltage Engine
TC1TOP – Turbocharger 1 Turbine Outlet Pressure	VSO – Vehicle Speed Output
TC2TOP – Turbocharger 2 Turbine Outlet Pressure	VSS – Vehicle Speed Sensor
TC1WC – Turbocharger 1 Wastegate Control	VSSH – Vehicle Speed Sensor High
TC2WC – Turbocharger 2 Wastegate Control	VSSL – Vehicle Speed Sensor Low
TCAPE – Truck Computer Analysis of Performance and Economy	WTSL – Wait to Start Lamp
TCM – Transmission Control Module	WEL – Warn Engine Lamp
TDC – Top Dead Center	WIF – Water In Fuel
TDE – Transmission Driving Engaged	WIFL – Water In Fuel Lamp
TOP – Transmission Oil Pressure	WTEC – World Transmission Electronically Controlled automatic transmissions (Allison)
TOSS – Transmission Output Shaft Speed	XCS – Transference
TOT – Transmission Oil Temperature	XMSN – Transmission
TTS – Transmission Tailshaft Speed	

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Terminology

Terms

Accelerator Pedal Position (APP) sensor – A potentiometer sensor that indicates the position of the throttle pedal.

Accessory work – The work per cycle required to drive engine accessories (normally, only those essential to engine operation).

Actuator – A device that performs work in response to an input signal.

Actuator Control – The ECM controls the actuators by applying a low-level signal (low-side driver) or a high-level signal (high side driver). When switched on, both drivers complete a ground or power circuit to an actuator.

Aeration – The entrainment of air or combustion gas in coolant, lubricant, or fuel.

Aftercooler (Charge Air Cooler) – A heat exchanger mounted in the charge air path between the turbocharger and engine intake manifold. The aftercooler reduces the charge air temperature by transferring heat from the charge air to a cooling medium (usually air).

Aftertreatment Fuel Doser (AFTFD) – A part of the Downstream Injection (DSI) unit that sends pressurized fuel to the Aftertreatment Fuel Injector (AFI) to inject fuel into the exhaust pipe.

Aftertreatment (AFT) system – A part of the exhaust system that processes engine exhaust to meet emission requirements and traps particulate matter (soot) to prevent it from leaving the tailpipe.

Air Control Valve (ACV) – Contains the LP turbocharger wastegate control port, HP turbocharger wastegate control port, the EBPV control port, and the TC1TOP port. Although these components are integral to the ACV, each circuit is controlled by the ECM. The ACV controls compressed air for each control valve.

Air Inlet Temperature (AIT) sensor – A thermistor sensor that monitors intake air temperature.

Ambient temperature – The environmental air temperature in which a unit is operating. In general, the temperature is measured in the shade (no solar radiation) and represents the air temperature for other engine cooling performance measurement purposes.

Air entering the radiator may or may not be the same ambient due to possible heating from other sources or recirculation. (SAE J1004 SEP81)

Ampere (amp) – The standard unit for measuring the strength of an electrical current. The flow rate of a charge in a conductor or conducting medium of one coulomb per second. (SAE J1213 NOV82)

Analog – A continuously variable voltage.

Analog to digital converter (A/D) – A device in the ECM that converts an analog signal to a digital signal.

American Trucking Association (ATA) Datalink – A serial datalink specified by the American Trucking Association and the SAE.

Boost pressure – 1. The pressure of the charge air leaving the turbocharger.

2. Inlet manifold pressure that is greater than atmospheric pressure. Obtained by turbocharging.

Bottom Dead Center (BDC) – The lowest position of the piston during the stroke.

Brake Horsepower (bhp) – The power output from an engine, not the indicated horsepower. The power output of an engine, sometimes-called flywheel horsepower, is less than the indicated horsepower by the amount of friction horsepower consumed in the engine.

Brake Horsepower (bhp) net – Net brake horsepower is measured with all engine components. The power of an engine when configured as a fully equipped engine. (SAE J1349 JUN90)

Calibration – ECM programming strategy to solve engine performance equations and make decisions. Calibration values are stored in ROM and put into the processor during programming to allow the engine to operate within certain parameters.

Camshaft Position (CMP) sensor – A magnetic pickup sensor that provides the ECM with a camshaft speed and position signal.

Carbon Monoxide (CO) – A colorless, odorless, highly poisonous gas that is formed by the incomplete combustion of carbon burning diesel engine. It is present in the exhaust gases of diesel engines.

Catalyst – A substance that produces a chemical reaction without undergoing a chemical change itself.

Catalytic converter – An antipollution device in the exhaust system that contains a catalyst for chemically converting some pollutants in the exhaust gases (carbon monoxide, unburned hydrocarbons, and oxides of nitrogen) into harmless compounds.

Cavitation – A dynamic condition in a fluid system that forms gas-filled bubbles (cavities) in the fluid.

Cetane number – 1. The auto-ignition quality of diesel fuel.

2. A rating applied to diesel fuel similar to octane rating for gasoline.

3. A measure of how readily diesel fuel starts to burn (self-ignites) at high compression temperature.

Diesel fuel with a high cetane number self-ignites shortly after injection into the combustion chamber. Therefore, it has a short ignition delay time. Diesel fuel with a low cetane number resists self-ignition. Therefore, it has a longer ignition delay time.

Charge air – Dense, pressurized, heated air discharged from the turbocharger.

Charge Air Cooler (CAC) – See **Aftercooler**.

Charge Air Outlet Temperature (CACOT) sensor – A thermistor sensor that monitors the temperature of charge air entering the intake air duct.

Closed crankcase – A crankcase ventilation that recycles crankcase gases through a breather, then back to the clean air intake.

Closed loop operation – A system that uses sensors to provide feedback to the ECM. The ECM uses the sensor input to continuously monitor variables and adjust actuators to match engine requirements.

Cloud point – The point when wax crystals occur in fuel, making fuel cloudy or hazy. Usually below -12 °C (10 °F).

Cold cranking ampere rating (battery rating) – The sustained constant current (in amperes) needed to produce a minimum terminal voltage under a load of 7.2 volts per battery after 30 seconds.

Cold Start Fuel Ignitor (CSFI) – The CSFI heats the intake air by vaporizing and igniting fuel in the air inlet duct.

Cold Start Fuel Solenoid (CSFS) – As the engine is cranked, the ECM energizes the CSFS valve, introducing fuel into the CSFI, which ignites and warms the air being drawn into the engine.

Cold Start Relay (CSR) – The CSR provides voltage to the CSFI, and is controlled by the ECM.

Controller Area Network (CAN) – A J1939 high speed communication link.

Coolant – A fluid used to transport heat from one point to another.

Coolant level switch – A switch sensor used to monitor coolant level.

Coolant Flow Valve (CFV) – The CFV is ECM controlled and redirects coolant through the fuel cooler, based on EFT, when directed.

Coolant Mixer Valve (CMV) – Controls coolant flow through the low-temperature radiator.

Continuous Monitor Test – An ECM function that continuously monitors the inputs and outputs to ensure that readings are within set limits.

Crankcase – The housing that encloses the crankshaft, connecting rods, and allied parts.

Crankcase breather – A vent for the crankcase to release excess interior air pressure.

Crankcase Oil Separator Speed (CCOSS) sensor – The CCOSS sensor sends the ECM information about the speed of the crankcase oil separator internal components.

Crankcase pressure – The force of air inside the crankcase against the crankcase housing.

Crankshaft Position (CKP) sensor – A magnetic pickup sensor that determines crankshaft position and speed.

Current – The flow of electrons passing through a conductor. Measured in amperes.

Damper – A device that reduces the amplitude of torsional vibration. (SAE J1479 JAN85)

Deaeration – The removal or purging of gases (air or combustion gas) entrained in coolant or lubricating oil.

Deaeration tank – A separate tank in the cooling system used for one or more of the following functions:

- Deaeration
- Coolant reservoir (fluid expansion and afterboil)
- Coolant retention
- Filling
- Fluid level indication (visible)

Diagnostic Trouble Code (DTC) – 2010 model year vehicles no longer utilize DTC identification by number. DTCs are now identified using the Suspect Parameter Number (SPN) and Failure Mode Indicator (FMI) identifiers only.

Diesel Particulate Filter (DPF) – A diesel particulate filter, sometimes called a DPF, is a device designed to remove diesel particulate matter or soot from the exhaust gas of a diesel engine.

Diesel Oxidation Catalyst (DOC) – A DOC is part of the diesel exhaust Aftertreatment system. DOCs are devices that use a chemical process to break down pollutants in the exhaust stream into less harmful components. More specifically, DOCs utilize rare metals such as palladium and platinum to reduce hydrocarbon based Soluble Organic Fraction (SOF) and carbon monoxide content of diesel exhaust by simple oxidation. The DOC can be used during an active regeneration to create higher exhaust temperatures, thereby reducing soot in the DPF.

Digital Multimeter (DMM) – An electronic meter that uses a digital display to indicate a measured value. Preferred for use on microprocessor systems because it has a very high internal impedance and will not load down the circuit being measured.

Disable – A computer decision that deactivates a system and prevents operation of the system.

Displacement – The stroke of the piston multiplied by the area of the cylinder bore multiplied by the number of cylinders in the engine.

Down Stream Injection (DSI) – The DSI system injects fuel into the exhaust system to increase temperature of the exhaust gases, and is necessary for DPF regeneration.

Driver (high side) – A transistor within an electronic module that controls the power to an actuator circuit.

Driver (low side) – A transistor within an electronic module that controls the ground to an actuator circuit.

Dual Stage Turbocharger – An assembly of two turbochargers (low-pressure and high-pressure) in series to provide a wide range of charge air pressures efficiently.

Duty cycle – A control signal that has a controlled on/off time measurement from 0 to 100%. Normally used to control solenoids.

EGR Cooler – A cooler that allows heat to dissipate from the exhaust gasses before they enter the intake manifold.

Engine Control Module (ECM) – An electronic processor that monitors and controls the engine.

Engine Back Pressure Valve (EBPV) – The ECM commands the EBPV to control the Exhaust Brake.

Engine Compression Brake (ECB) valve – The ECB valve controls pressure entering the brake oil gallery from the high-pressure oil rail gallery. This activates the brake actuator pistons and opens the exhaust valves.

Engine Compression Brake 1 (ECB1) solenoid – The ECB1 solenoid controls pressure entering the brake oil gallery from the high-pressure oil rail gallery.

Engine Compression Brake 2 (ECB2) solenoid – The ECB2 solenoid controls pressure entering the brake oil gallery from the high-pressure oil rail gallery.

Engine Compression Brake Pressure (ECBP) sensor – A high-pressure sensor that provides a feedback signal to the ECM indicating brake control pressure.

Engine Coolant Level (ECL) sensor – A switch sensor that monitors coolant level.

Engine Coolant Temperature 1 (ECT1) sensor – A thermistor sensor that detects engine coolant temperature.

Engine Coolant Temperature 2 (ECT2) sensor – A thermistor sensor that detects engine coolant temperature.

Engine Fuel Temperature (EFT) sensor – A thermistor sensor that measures fuel temperature.

Engine lamp – An instrument panel lamp that comes on when DTCs are set. DTCs can be read as flash codes (red and amber instrument panel lamps).

Engine OFF tests – Tests that are done with the ignition switch ON and the engine OFF.

Engine Oil Pressure (EOP) sensor – A variable capacitance sensor that measures oil pressure.

Engine Oil Temperature (EOT) sensor – A thermistor sensor that measures oil temperature.

Engine rating – Engine rating includes **Rated hp** and **Rated rpm**.

Engine RUNNING tests – Tests done with the engine running.

Engine Throttle Valve (ETV) and Engine Throttle Position Sensor – The ETV valve is used to control airflow during a regeneration process of the aftertreatment system. The ETV valve is also used to ensure a smooth engine shut down by restricting airflow to the engine at shut down.

Engine Warning Protection System (EWPS) – Safeguards the engine from undesirable operating conditions to prevent engine damage and to prolong engine life.

Exhaust Back Pressure (EBP) – The pressure present in the exhaust system during the exhaust period.

Exhaust Back Pressure Valve (EBPV) – A valve that regulates the amount of air pressure applied to the EBPV pneumatic actuator.

Exhaust brake – A brake device using engine exhaust back pressure as a retarding medium.

Exhaust Gas Recirculation (EGR) – A system used to recirculate a portion of the exhaust gases into the power cylinder in order to reduce oxides of nitrogen.

Exhaust Gas Temperature (EGT) – The temperature of exhaust gases.

Exhaust Gas Recirculation Temperature (EGRT) sensor – A thermistor sensor that detects the exhaust gas temperature entering the EGR cooler.

Exhaust Gas Recirculation (EGR) valve – The EGRV controls the flow of exhaust gases to the intake manifold. The EGRV is integrated with an EGR Position (EGRP) sensor.

Exhaust manifold – Exhaust gases flow through the exhaust manifold to the turbocharger exhaust inlet and are directed to the EGR cooler.

Exhaust Manifold Pressure (EMP) sensor – A variable capacitance sensor used to indicate air pressure in the exhaust manifold.

Exhaust Manifold Temperature (EMT) sensor – A thermistor style sensor used to indicate air temperature in the exhaust manifold.

Fault detection/management – An alternate control strategy that reduces adverse effects that can be caused by a system failure. If a sensor fails, the ECM substitutes a good sensor signal or assumed sensor value in its place. A lit amber instrument panel lamp signals that the vehicle needs service.

Failure Mode Indicator (FMI) – Identifies the fault or condition effecting the individual component.

Filter restriction – A blockage, usually from contaminants, that prevents the flow of fluid through a filter.

Flash code – See **Diagnostic Trouble Code (DTC)**.

Fuel Delivery Pressure (FDP) sensor – A variable capacitance sensor that monitors fuel pressure coming from the fuel tank and sends a signal to the ECM.

Fuel inlet restriction – A blockage, usually from contaminants, that prevents the flow of fluid through the fuel inlet line.

Fuel pressure – The force fuel exerts on the fuel system as it is pumped through the fuel system.

Fuel Pressure Control Valve (FPCV) – The FPCV controls the fuel pressure to the fuel rails and is controlled by the ECM. FPCV control depends on fuel pressure and fuel temperature.

Fuel Rail Pressure (FRP) – The amount of pressure in the fuel rail.

Fuel Rail Pressure (FRP) sensor – A variable capacitance sensor that monitors fuel pressure in the fuel rail and sends a signal to the ECM.

Fuel strainer – A pre-filter in the fuel system that keeps larger contaminants from entering the fuel system.

Fuel Volume Control Valve (FVCV) – The FVCV regulates the volume of flow sent to the HPFP. The FVCV allows a sufficient quantity of fuel to be delivered to the HPFP depending on engine load, speed, injector quantity, fuel temperature, and number of injections per cycle.

Fully equipped engine – A fully equipped engine is an engine equipped with only those accessories necessary to perform its intended service. A fully equipped engine does not include components that are used to power auxiliary systems. If these components are integral with the engine or, for any reason are included on the test engine, the power absorbed may be determined and added to the net brake power. (SAE J1995 JUN90)

Fusible link (fuse link) – A fusible link is a special section of low tension cable designed to open the circuit when subjected to an extreme current overload. (SAE J1156 APR86)

Gradeability – The maximum percent grade, which the vehicle can transverse for a specified time at a specified speed. The gradeability limit is the grade upon which the vehicle can just move forward. (SAE J227a)

Gross Combined Weight Rating (GCWR) – Maximum combined weight of towing vehicle (including passengers and cargo) and the trailer. The GCWR indicates the maximum loaded weight that the vehicle is allowed to tow.

Gross brake horsepower – The power of a complete basic engine, with air cleaner, without fan, and alternator, and air compressor not charging.

H-Bridge Circuit – An H-Bridge (bipolar) circuit operates like putting a power source on one side of a motor and connecting the other side of the motor to a ground. This turns the motor. By shifting the leads on the motor, it will turn in the opposite direction.

Hall effect – The development of a transverse electric potential gradient in a current-carrying conductor or semiconductor when a magnetic field is applied.

Hall effect sensor – Transducer that varies its output voltage in response to changes in a magnetic field. Commonly used to time the speed of wheels and shafts.

High Pressure Fuel Pump (HPFP) assembly – The HPFP is a volumetric pump that supplies fuel at high pressure. The HPFP is mounted in the rear valley on the top of the engine and is driven by the camshaft.

High-pressure Piezo Common Rail (HPCR) – The HPFP pumps fuel through separate tubes to each fuel rail. Each fuel rail has four fuel tubes, one for each injector, that maintain constant pressure from the high-pressure pump to each injector.

High speed digital inputs – Inputs to the ECM from a sensor that generates varying frequencies (engine speed and vehicle speed sensors).

Horsepower (hp) – Horsepower is the unit of work done in a given period of time, equal to 33,000 pounds multiplied by one foot per minute. $1\text{ hp} = 33,000\text{ lb} \times 1\text{ ft} / 1\text{ min}$.

Humidity Sensor (HS) – A sensor that measures the moisture content of filtered air entering the intake system.

Hydrocarbons – Organic compounds consisting of hydrogen and carbon (fuel and oil).

Hydrocarbon Injector – Injects fuel into the exhaust system to increase temperature of the exhaust gases.

Injection Pressure Regulator (IPR) valve – A valve that is used to maintain desired injection control pressure.

Injection Control Pressure (ICP) sensor – Provides a feedback signal to the ECM indicating injection control pressure.

Inlet Air Heater (IAH) – The IAH is primarily used to assist in starting the engine during cold weather. In addition, it helps to reduce white smoke emissions by heating the incoming air.

Intake manifold – Engine component that evenly supplies air to each intake port in the cylinder head(s).

Intake Manifold Pressure (IMP) sensor – A variable capacitance sensor used to indicate air pressure in the intake manifold.

Intake Manifold Temperature (IMT) sensor – A thermistor sensor used to indicate air temperature in the intake manifold.

Internal Transfer Pump (ITP) – The ITP is part of the HPFP assembly and driven off the same shaft as the HPFP assembly. The ITP supplies fuel at a slightly higher pressure and flow to the HPFP through the Fuel Volume Control Valve (FVCV). The ITP also provides fuel for cooling and lubrication of the HPFP. Fuel is rerouted as pump return flow through the HPFP cooling and lubrication valve. Pressure is maintained at the inlet of the HPFP piston pump by an ITP regulator.

International NGV Tool Utilized for Next Generation Electronics (INTUNE) – The diagnostics software for chassis related components and systems.

Interstage Cooler (ISC) – Uses cooled coolant to lower the charged air temperature that exits from the turbocharger low-pressure compressor and enters the turbocharger high-pressure compressor.

Low speed digital inputs – Switched sensor inputs that generate an on/off (high/low) signal to the ECM. The input to the ECM from the sensor could be from a high input source switch (usually 5 or 12 volts) or from a grounding switch that grounds the signal from a current limiting resistor in the ECM that creates a low signal (0 volts).

Low temperature radiator thermostat – Coolant flow to the low temperature radiator is regulated by the low temperature radiator thermostat.

Lubricity – Lubricity is the ability of a substance to reduce friction between solid surfaces in relative motion under loaded conditions.

Lug (engine) – A condition when the engine is run at an overly low RPM for the load being applied.

Manifold Absolute Pressure (MAP) – Boost pressure in the manifold that is a result of the turbocharger.

Manifold Absolute Pressure (MAP) sensor – A variable capacitance sensor that measures boost pressure.

Manometer – A double-leg liquid-column gauge, or a single inclined gauge, used to measure the difference between two fluid pressures. Typically, a manometer records in inches of water.

Mass Airflow – The intake airflow in an engine.

Mass Airflow (MAF) sensor – The MAF sensor is used for closed loop control of the EGR valve and ITV.

The ECM monitors the MAF signal so that the ECM can control the EGR and intake throttle systems.

MasterDiagnostics® (MD) – Diagnostics software for engine related components and systems.

Magnehelic Gauge – A gauge that measures pressure in inches of water.

Magnetic Pickup Sensor – A magnetic pickup sensor generates an alternating frequency that indicates speed. Magnetic pickups have a two-wire connection for signal and ground. This sensor has a permanent magnetic core surrounded by a wire coil. The signal frequency is generated by the rotation of the gear teeth that disturb the magnetic field.

Metering unit valve assembly – The Metering unit valve assembly provides a metered amount of fuel to the Aftertreatment Fuel Injector (AFI).

Microprocessor – An integrated circuit in a microcomputer that controls information flow.

Micro Strain Gauge (MSG) Sensor – A MSG sensor measures pressure. Pressure exerts force on a pressure vessel that stretches and compresses to change resistance of strain gauges bonded to the surface of the pressure vessel. Internal sensor electronics convert the changes in resistance to a ratiometric voltage output.

Nitrogen Oxides (NO_x) – Nitrogen oxides form by a reaction between nitrogen and oxygen at high temperatures and pressures in the combustion chamber.

Normally closed – Refers to a switch that remains closed when no control force is acting on it.

Normally open – Refers to a switch that remains open when no control force is acting on it.

Ohm (Ω) – The unit of electrical resistance. One ohm is the value of resistance through which a potential of one volt will maintain a current of one ampere. (SAE J1213 NOV82)

On demand test – A self-test the technician initiates using the EST that is run from a program in the software.

Output Circuit Check (OCC) – An on-demand test done during an Engine OFF self-test to check the continuity of selected actuators.

Oxides of Nitrogen (NO_x) – Nitrogen oxides formed by a reaction between nitrogen and oxygen at high temperatures.

Oxygen Sensor (O₂S) – A sensor that monitors oxygen levels in the exhaust.

pH – A measure of the acidity or alkalinity of a solution.

Particulate matter – Particulate matter includes mostly burned particles of fuel and engine oil.

Piezometer – An instrument for measuring fluid pressure.

Power – Power is a measure of the rate at which work (force x distance) is done during a specific time. Compare with Torque.

Power TakeOff (PTO) – Accessory output, usually from the transmission, used to power a hydraulic pump for a special auxiliary feature (garbage packing, lift equipment, etc).

Pulse Width Modulation (PWM) – Succession of digital electrical pulses, rather than an analog signal. Efficient method of providing power between fully on and fully off.

Random Access Memory (RAM) – Computer memory that stores information. Information can be written to and read from RAM. Input information (current engine speed or temperature) can be stored in RAM to be compared to values stored in Read Only Memory (ROM). All memory in RAM is lost when the ignition switch is turned off.

Rated gross horsepower – Engine gross horsepower at rated speed as declared by the manufacturer. (SAE J1995 JUN90)

Rated horsepower – Maximum brake horsepower output of an engine as certified by the engine manufacturer. The power of an engine when configured as a basic engine. (SAE J1995 JUN90)

Rated net horsepower – Engine net horsepower at rated speed as declared by the manufacturer. (SAE J1349 JUN90)

Rated speed – The speed, as determined by the manufacturer, at which the engine is rated. (SAE J1995 JUN90)

Rated torque – Maximum torque produced by an engine as certified by the manufacturer.

Regeneration – Oxidation of accumulated soot (carbon-based particulates) in the Diesel Particulate Filter (DPF). The soot is reduced to ash and stored in the DPF.

Ratiometric Voltage – In a Micro Strain Gauge (MSG) sensor, pressure to be measured exerts force on a pressure vessel that stretches and compresses to change resistance of strain gauges bonded to the surface of the pressure vessel. Internal sensor electronics convert the changes in resistance to a ratiometric voltage output.

Reference voltage (V_{REF}) – A 5 volt reference supplied by the ECM to operate the engine sensors.

Reserve capacity – Time in minutes that a fully charged battery can be discharged to 10.5 volts at 25 amperes.

Return Fuel System – The return fuel system moves unused fuel from the fuel injectors to the fuel cooler. Excess fuel out of the FVCV and the FPCV mix with fuel from the fuel injectors on the way to the fuel cooler.

ServiceMaxx™ software – Diagnostics software for engine related components and systems.

Signal Conditioner – The signal conditioner in the internal microprocessor converts analog signals to digital signals, squares up sine wave signals, or amplifies low-intensity signals to a level that the ECM microprocessor can process.

Signal ground – The common ground wire to the ECM for the sensors.

Speed Control Command Switches (SCCS) – A set of switches used for cruise control, Power TakeOff (PTO), and remote hand throttle system.

Steady state condition – An engine operating at a constant speed and load and at stabilized temperatures and pressures. (SAE J215 JAN80)

Strategy – A plan or set of operating instructions that the microprocessor follows for a desired goal. Strategy is the computer program itself, including all equations and decision making logic. Strategy is always stored in ROM and cannot be changed during calibration.

Stroke – The movement of the piston from Top Dead Center (TDC) to Bottom Dead Center (BDC).

Substrate – Material that supports the wash coating or catalytic materials.

Suspect Parameter Number (SPN) – A 19-bit number used to identify the item for which diagnostics are being reported. The SPN is used for multiple purposes, some that are specific to diagnostics are as follows;

- Identify the least repairable subsystem that has failed.
- Identify subsystems or assemblies that may not have hard failures but may be exhibiting abnormal operating performance.
- Identify a particular event or condition that will be reported.
- Report a component and non-standard failure mode.

System restriction (air) – The static pressure differential that occurs at a given airflow from air entrance through air exit in a system. Usually measured in inches (millimeters) of water. (SAE J1004 SEP81)

Tachometer output signal – Engine speed signal for remote tachometers.

Thermistor – A semiconductor device. A sensing element that changes resistance as the temperature changes.

Thermistor Sensor – Changes electrical resistance with changes in temperature. Resistance in the thermistor decreases as temperature increases, and increases as temperature decreases. Thermistors work with a resistor that limits current to form a voltage signal matched with a temperature value.

Thrust load – A thrust load pushes or reacts through a bearing in a direction parallel to the shaft.

Top Dead Center (TDC) – The uppermost position of the piston during the stroke.

Torque – A force having a twisting or turning effect. For a single force, the cross product of a vector from some reference point to the point of application of the force within the force itself. Also known as moment of force or rotation moment. Torque is a measure of the ability of an engine to do work.

Truck Computer Analysis of Performance and Economy (TCAPE) – A computer program that simulates the performance and fuel economy of trucks.

Turbocharger – A turbine driven compressor mounted on the exhaust manifold. The turbocharger increases the pressure, temperature and density of intake air to charge air.

Turbocharger 1 Turbine Outlet Pressure (TC1TOP) sensor – A variable capacitance sensor that monitors exhaust back-pressure.

Turbocharger 2 Compressor Inlet (TC2CIS) sensor – The TC2CIS sensor includes a thermistor sensor that monitors the temperature of charge air entering the HP turbocharger. This sensor also monitors boost pressure for the LP turbocharger.

Turbocharger Wastegate Control (TCWC) solenoid – Controls the TCWC actuator by regulating the amount of charge air pressure supplied to the TCWC actuator. The TCWC solenoid is controlled by signals from the ECM in response to engine speed, required fuel quantity, boost, exhaust back-pressure, and altitude.

Turbocharger 1 Wastegate Control (TC1WC) solenoid – Controls the TC1WC actuator by regulating the amount of charge air pressure supplied to the TC1WC actuator. The TC1WC solenoid is controlled by signals from the ECM in response to engine speed, required fuel quantity, boost, exhaust back-pressure, and altitude. The TC1WC actuator is part of the turbocharger assembly.

Turbocharger 2 Wastegate Control (TC2WC) solenoid – Controls the TC2WC actuator by regulating the amount of charge air pressure supplied to the wastegate actuator. The TC2WC solenoid is controlled by signals from the ECM in response to engine speed, required fuel quantity, boost, exhaust back-pressure, and altitude. The TC2WC actuator is part of the turbocharger assembly.

Variable capacitance sensor – A variable capacitance sensor measures pressure. The pressure forces a ceramic material closer to a thin metal disc in the sensor, changing the capacitance of the sensor.

Vehicle Electronic System Programming System – The computer system used to program electronically controlled vehicles.

Vehicle Retarder Enable/Engage – Output from the ECM to a vehicle retarder.

Vehicle Speed Sensor (VSS) – Normally a magnetic pickup sensor mounted in the tailshaft housing of the transmission, used to indicate ground speed.

Viscosity – The internal resistance to the flow of any fluid.

Viscous fan – A fan drive that is activated when a thermostat, sensing high air temperature, forces fluid through a special coupling. The fluid activates the fan.

Volt (v) – A unit of electromotive force that will move a current of one ampere through a resistance of one Ohm.

Voltage – Electrical potential expressed in volts.

Voltage drop – Reduction in applied voltage from the current flowing through a circuit or portion of the circuit current multiplied by resistance.

Voltage ignition – Voltage supplied by the ignition switch when the key is ON.

Washcoat – A layer of alumina applied to the substrate in a monolith-type converter.

Water In Fuel (WIF) sensor – A switch sensor that measures the amount of water in the fuel.

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MaxxForce® 7 (6.4L) All Ratings @ 2600 rpm (12NSH)

MaxxForce® 7/220, 240, 260, 300 hp @ 2600 rpm/660 (560 ft•lb for 220 hp) ft•lb @ 1400 rpm

50-State 2010 Model Year (MY)

Engine Unit Code 12NSH

MaxxForce® 7 diesel engine specifications

Engine model	MaxxForce® 7
Engine rating	220, 240, 260, 300 hp @ 2600 rpm
Engine Family Rating Code (EFRC)	1122, 1132, 1142, 1152
Injection timing	Nonadjustable
High idle speed - manual transmission	2950 rpm
High idle speed - automatic transmission	2950 rpm
Low idle speed	700 rpm

KOEO (Key ON, Engine OFF)

Barometric pressure at 620 ft above sea level	97 kPa (14 psi)
Engine oil pressure	0 kPa (0 psi)
Diesel particulate filter differential pressure	0 kPa (0 psi)
Fuel rail pressure	1724 kPa (250 psi) – 2758 kPa (400 psi)
Manifold boost pressure	97 kPa (14 psia)
Accelerator position sensor (at idle)	1.12 V / 0%
Accelerator position sensor (depressed to floor)	4.18 V / 100%
Exhaust gas recirculation valve position	0%
Engine throttle valve position	0%

Engine cranking

Minimum recommended battery voltage	10 V
Minimum cranking rpm	90 rpm
30 seconds maximum crank time per attempt. Wait 2 to 3 minutes before repeating.	
Minimum fuel rail pressure	14 MPa (2031 psi)
Inlet air heater amperage draw	125 A
Inlet air heater on-time and ambient temperature when initiated	0 seconds @ 16 °C (60 °F) or more 30 seconds @ -18 °C (0 °F) or less
EGRP starting	0 %
Minimum fuel pressure	34 kPa (5 psi)

Low Idle, no load, stabilized engine operating temperature

Engine coolant temperature (at thermostat opening)	92 °C (198 °F) @ thermostat opening
Engine oil temperature should not go 5 °C (10 °F) above engine coolant temperature.	
Engine fuel temperature	38 °C (100 °F) ± 4 °C (7 °F)
Minimum fuel pressure	34 kPa (5 psi)
Manifold boost pressure	97 kPa (14 psia) ± 7 kPa (1 psia)
Minimum oil pressure	69 kPa (10 psi) - engine hot

High Idle, no load, stabilized engine operating temperature

Manifold boost pressure	145 kPa (21 psia) ± 21 kPa (3 psia)
Maximum air cleaner restriction	3.1 kPa (12.5 in H ₂ O)
Turbocharger wastegate control actuator	100%
Maximum crankcase pressure using dipstick tube attachment to digital manometer	5.98 kPa (24 in H ₂ O)
Minimum fuel pressure	34 kPa (5 psi)
Blow-by pressure using ZTSE4146A while blocking off the breather down tube	2.24 kPa (9 in. H ₂ O)
Minimum oil pressure	276 kPa (40 psi)

Full load, rated speed on highway, stabilized engine operating temperature

Water temperature differential across radiator (top and bottom)	6.7 - 8.3 °C (12 - 15 °F) minimum
Maximum air cleaner restriction	6.2 kPa (25 in. H ₂ O)
Minimum fuel rail pressure	190 mPa (27557 psi) ± 10 mPa (1450 psi)
Minimum fuel pressure	34 kPa (5 psi)
Maximum fuel inlet restriction	5 - 6.2 kPa (20 - 25 in. H ₂ O)
Minimum oil pressure	276 kPa (40 psi)
Intake manifold pressure	228 kPa (33 psia) ± 21 kPa (3 psi)
Maximum exhaust restriction (after turbocharger)	356 mm Hg (14 in. Hg) @ 2600 rpm

Stabilized engine operating temperature

Torque converter stall (rpm/time)	2200 rpm or greater @ 5 seconds or less
Maximum lube oil temperature (oil gallery)	118 °C (245 °F)
Engine oil temperature should not go 17 °C (30 °F) above engine coolant temperature.	

Miscellaneous sensors and components

Fuel pressure control valve	10.14% @ KOEO
	10.61% @ engine cranking
	15.20% @ KOER
	81.32% @ 2875 rpm
	85.34% @ acceleration
Fuel volume control valve	20.40% @ KOEO
	20.42% @ engine cranking
	19.37% @ KOER
	21.86% @ 2875 rpm
	25.92% @ acceleration
Engine fuel pump volume	400 - 450 mL @ 18-20 seconds (pump stays on additional 8-10 seconds after key off)

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Signal Values

NOTE: Key On, Engine Off (KOEO) measurements were taken at approximately 21 °C (70 °F)

Key On, Engine Running (KOER) measurements were taken at approximately 86 °C (186 °F)

ECM Chassis Pocket Connector 98-pin			
ECM Pin	Abbreviation	Circuit Name	KOEO
C-04	SR2-GND	Signal Return Ground 2	1.1 Ω
C-05	SR2 GND	Signal Return Ground 2	1.1 Ω
C-06	APP2	Accelerator Pedal Position 2	0.05 V - 2.09 V 0% -100%
C-07	DOCIT	DOC Inlet Temperature	0.78 V 100 °C (212 °F)
C-08	ECL	Engine Coolant Level	4.76 V
C-09	WIF	Water in Fuel	4.62 V
C-13	RVAR	Remote Variable PTO	0 V
C-25	VREF2	Voltage Reference 2	4.98 V
C-26	VREF2	Voltage Reference 2	4.98 V
C-29	DPFOT	DPF Outlet Temperature	0.76 V 69 °C (156 °F)
C-31	ATA-L	ATA Data Link Low	0 V
C-32	ATA-H	ATA Data Link High	0 V
C-34	XCS	Transercase	0 V
C-35	OWL/RSL	Oil Warning Lamp / Red Stop Lamp	2.47 V
C-41	WEL/AWL	Warn Engine Lamp / Amber Warning Lamp	2.48 V
C-46	SR3-GND	Signal Return Ground 3	0.7 Ω
C-47	SR3-GND	Signal Return Ground 3	0.7 Ω
C-48	OSS-L	Output Shaft Speed Low	3.61 V @ 0 mph
C-51	DPFDP	DPF Differential Pressure	0.69 V 0.09 psi
C-53	CAN1-H	Controller Area Network 1 Communication Data Link High	2.72 V
C-54	CAN1-L	Controller Area Network 1 Communication Data Link Low	2.24 V
C-58	FCM	Fan Clutch Motor	0 V
C-60	DDS	Driveline Disconnect Switch	12.41 V
C-63	MPR	Main Power	0.88 V

ECM Chassis Pocket Connector 98-pin			
ECM Pin	Abbreviation	Circuit Name	KOEO
C-64	ECI	Engine Crank Inhibit	0.84 V
C-67	VREF3	Voltage Reference 3	4.98 V
C-68	VREF	Voltage Reference	4.98 V
C-69	OSS-H	Output Shaft Speed High	11.94 V @ 0 mph
C-72	APP1	Accelerator Pedal Position 1	1.10 V - 4.18 V 0% - 100%
C-73	DPFIT	Diesel Particulate Filter Inlet Temperature	0.83 V 82 °C (180 °F)
C-74	RPS	Remote Pedal Sensor	0 V
C-75	RAS	Resume Acceleration Switch	0 V
C-77	SCS	Speed Control Switch	0 V
C-79	RPRE	Remote Preset PTO	0 V
C-83, 84, 85	VPWR	Vehicle Power	12.41 V
C-86, 87, 88	PWR GND	Powered Ground	0.03 V
C-89	VSO	Vehicle Speed Output	11.80 V
C-91	EFC	Engine Fan Control	2.48 V
C-92	TACH	Tachometer	11.85 V
C-97	KEYPWR	Key Power	12.38 V
C-98	KAPWR	Keep Alive Power	12.37 V

NOTE: Key On, Engine Off (KOEO) measurements were taken at approximately 21 °C (70 °F)

Key On, Engine Running (KOER) measurements were taken at approximately 86 °C (186 °F)

ECM Engine Pocket Connector 98-pin				
ECM Pin	Abbreviation	Circuit Name	KOEO	KOER
E-01	CKP-L	Crankshaft Position Low	1.72V	1.71 V
E-02	CKP-H	Crankshaft Position High	1.67 V	1.71 V
E-03	SHD GND	Shield Ground	0.3 Ω	77k Ω
E-06	SR1 GND	Signal Return Ground 1	0.5 Ω	0.8 V
E-07	SR1 GND	Signal Return Ground 1	2 Ω	0.8 V
E-09	IMP	Intake Manifold Pressure	0.74 V	0.8 V
E-10	FRP	Fuel Rail Pressure	0.50 V	1.26 V 5,435 psi @ 700 rpm
E-11	HS	Humidity Sensor	0 V	0.07 V
E-13	CAN1-H	Controller Area Network 1 Communication Data Link High	2.71 V	2.71 V
E-14	CAN1-L	Controller Area Network 1 Communication Data Link Low	2.24 V	2.21 V
E-16	FVCV	Fuel Volume Control Valve	12.37 V Duty Cycle 18.9%	11.96 V Duty Cycle 82%
E-18	FPCV	Fuel Pressure Control Valve	12.37 V Duty Cycle 9.3%	12.55 V Duty Cycle 86.5%
E-20	FCC	Fan Clutch Control	2.49 V	N/A
E-22	CMP-L	Camshaft Position Low	2.46 V	2.54 V
E-23	CMP-H	Camshaft Position High	2.46 V	2.21 V
E-26	VREF1	Voltage Reference 1	4.97 V	5.06 V
E-27	VREF1	Voltage Reference 1	4.97 V	5.05 V
E-29	FDP	Fuel Delivery Pressure	0.57 V 1.16 psi	0.91 V 5.8 psi
E-30	EOP	Engine Oil Pressure	0.58 V 1.6 psi	1.95 V 25.69 psi
E-41	TC1WC	Turbocharger 1 Wastegate Control	0.3 V 100%	0.43 V 100%
E-44	EGRT	Exhaust Gas Recirculation Temperature	4.5 V 70 °C (158 °F)	4.19 V 85 °C (185 °F)
E-45	EOT	Engine Oil Temperature	3.28 V 33 °C (91 °F)	1.81 V 79 °C (175 °F)
E-46	EGRP	Exhaust Gas Recirculation Position	0.82 V 0%	2.54 V 90%

ECM Engine Pocket Connector 98-pin				
ECM Pin	Abbreviation	Circuit Name	KOEO	KOER
E-47	IMT	Intake Manifold Temperature	3.17 V 35 °C (95 °F)	2.50 V 58 °C (136 °F)
E-48	ECT1	Engine Coolant Temperature 1	3.28 V 33 °C (91 °F)	1.62 V 86 °C (187 °F)
E-49	ETP	Engine Throttle Position	1.13 V 0%	4.12 V 84.2%
E-52	IAHD	Inlet Air Heater Driver	-0.08 V	0.15 V
E-55	FS	Fan Speed	4.97 V	5 V
E-59	ETC-H	Engine Throttle Control High	11.72 V	10.61 V
E-60	ETC-L	Engine Throttle Control Low	11.72 V	13.62 V
E-64	IAHC	Inlet Air Heater Control	-0.06 V	0.09 V
E-67	EFT	Engine Fuel Temperature	3.25 V 60 °C (140 °F)	3.35 V 32 °C (90 °F)
E-69	AIT	Air Inlet Temperature	2.36 V 34 °C (93 °F)	2.51 V 31 °C (88 °F)
E-72	EGT	Exhaust Gas Temperature	4.63 V 72 °C (161 °F)	4.66 V 160 °C (320 °F)
E-75	MAF-GND	Mass Air Flow Ground	0 V 8.2 Ω	0.09 V
E-76	MAF	Mass Air Flow	2.68 V	2.66 V 40-45 kg/hr
E-79	FPC-L	Fuel Pump Control Low	0.29 V	0.45 V
E-80	FPC-H	Fuel Pump Control High	11.69 V	13.43 V
E-81	EGRC-L	Exhaust Gas Recirculation Control Low	12.14 V	0.13 V
E-82	EGRC-H	Exhaust Gas Recirculation Control High	11.04 V	0.56 V

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Technical Service Information (TSI) letters are periodically published to inform service technicians of

product enhancements and field service issues. File TSIs in this section for supplemental reference.

