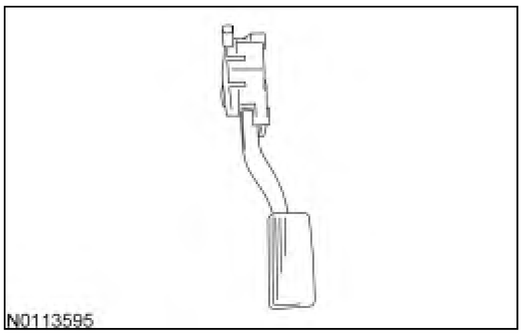
Engine Control Components

Accelerator Pedal Position (APP) Sensor

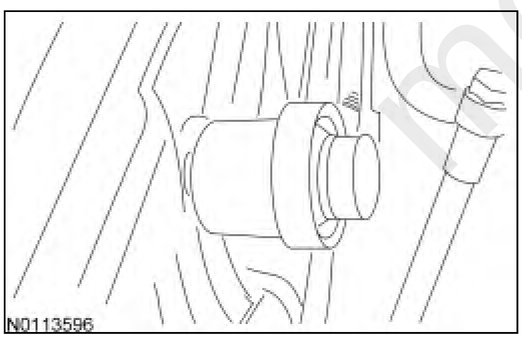
The APP sensor is a 2 track potentiometer that is used to calculate driver demand for power based on the rotation angle of the accelerator pedal. The sensor receives a reference voltage from the PCM and provides a variable voltage signal directly proportional to the accelerator pedal position. The PCM uses the 2 APP sensor inputs to calculate the desired fuel quantity, injection timing, and the correct fuel pressure. A concern with the APP sensor illuminates the powertrain malfunction indicator (wrench). Normal engine operation is permitted if the PCM detects a concern on one of the 2 sensor signals. If the PCM detects a concern on both of the sensor signals, the PCM only allows the engine to operate at idle.



Typical APP Sensor

Air Filter Restriction Gauge

An air filter restriction gauge is located in the air cleaner housing. When the airflow in the intake air system reaches the maximum allowable restriction limit, the air filter restriction gauge indicator moves from the yellow bar to the red bar at the base of the gauge. Correct the source of the restriction and manually reset the gauge by pressing the red button at the top of the gauge.



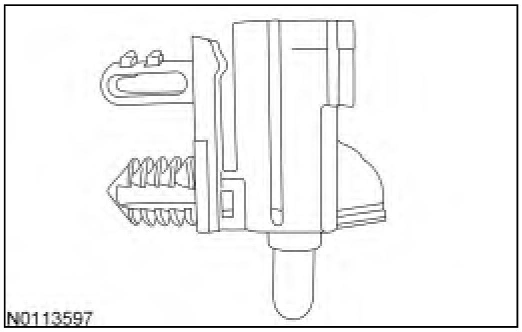
Typical Air Filter Restriction Gauge

Ambient Air Temperature (AAT) Sensor

The AAT sensor is a thermistor device in which resistance changes with temperature. The electrical resistance of a thermistor decreases as the temperature increases, and the resistance increases as the temperature decreases. The varying resistance affects the voltage drop across the sensor terminals and provides electrical voltage signals to the PCM corresponding to temperature.

Thermistor-type sensors are considered passive sensors. A passive sensor is connected to a voltage divider network so that varying the resistance of the passive sensor causes a variation in total current flow. Voltage that is dropped across a fixed resistor in a series with the sensor resistor determines the voltage signal at the PCM. This voltage signal is equal to the reference voltage minus the voltage drop across the fixed resistor.

The AAT sensor provides ambient air temperature information to the PCM which is used for the temperature sensor correlation tests and controls the reductant heaters. The PCM also communicates the AAT information to all other modules on the controller area network (CAN).



Typical AAT Sensor

Barometric Pressure (BARO) Sensor

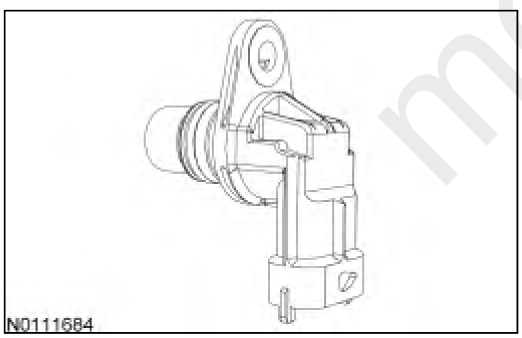
The BARO sensor is a variable capacitor sensor that is supplied a 5-volt reference signal by the PCM and returns a voltage signal to the PCM relative to the intake manifold pressure. The sensor voltage increases as the pressure increases. The BARO sensor is integral to the PCM.

Boost Pressure Gauge

The boost pressure gauge is controlled by the instrument panel cluster. The PCM sends a message through the controller area network (CAN) to the instrument panel cluster indicating engine boost pressure.

Camshaft Position (CMP) Sensor

The CMP sensor is a Hall effect sensor that detects the position of the camshaft. The CMP sensor identifies when piston number 1 is on its compression stroke. The PCM calculates the CMP signal and the crankshaft position (CKP) sensor signal to determine the camshaft to crankshaft position for correct fuel injection timing during the compression stroke. The CMP sensor is located on the left side rear of the cylinder head (Transit). The CMP sensor is mounted at the front of the engine block, above the crankshaft pulley (All others).

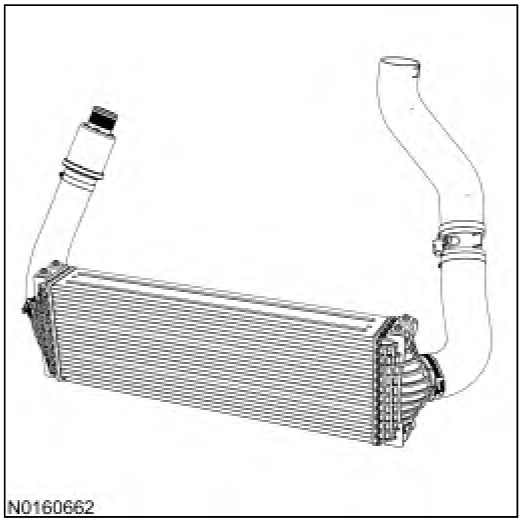


Typical CMP Sensor

Charge Air Cooler (CAC)

Charge Air Cooler (CAC) — Air to Air Cooled

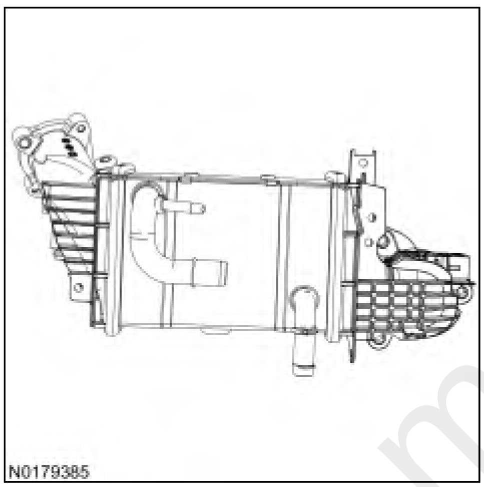
The CAC is composed of a heat exchanger and the tubing used to connect the output of the turbocharger to the intake of the engine. The CAC is designed to cool the induction air which has been heated by the turbocharger. As the heated air flows through the CAC, heat is transferred from the intake air entering the intake manifold to the air flowing over the outside of the CAC.



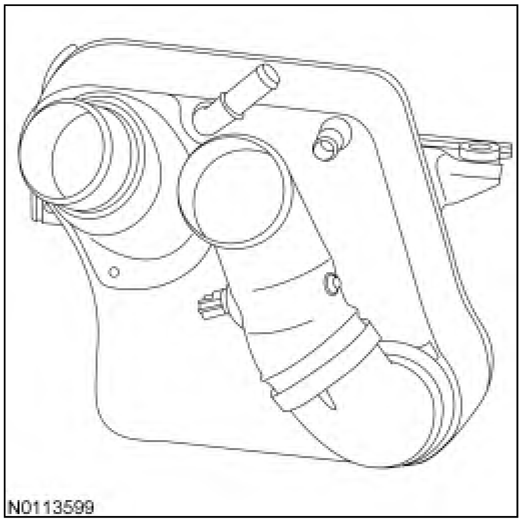
CAC (Air to Air Cooled)

Charge Air Cooler (CAC) — Air To Liquid Cooled

The CAC is composed of an air to liquid heat exchanger mounted next to the engine on the driver side of the vehicle and the tubing used to connect the output of the turbocharger to the intake of the engine. The CAC is designed to cool the induction air which has been heated by the turbocharger. As the heated air flows through the CAC, heat is transferred to the coolant reducing the temperature of the intake air.



CAC Transit Connect (Air To Liquid Cooled)

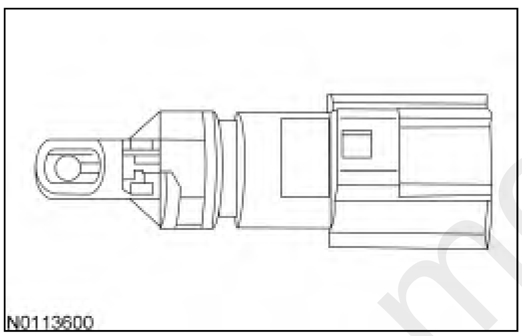


Typical CAC (Air To Liquid Cooled)

Charge Air Cooler Temperature (CACT) Sensor

The CACT sensor is a thermistor device in which resistance changes with temperature. The electrical resistance of a thermistor decreases as the temperature increases, and resistance increases as the temperature decreases. The varying resistance affects the voltage drop across the sensor terminals and provides electrical voltage signals to the PCM corresponding to temperature.

The CACT sensor is located in the tube between the charge air cooler (CAC) and the intake throttle assembly. The sensor provides a charge air cooler output temperature signal to the PCM. The PCM uses the CACT signal as an input to control the turbocharger, exhaust recirculation (EGR) valve, fuel system and the regeneration function.



Typical CACT Sensor

Cooling Fan

Cooling Fan — Transit

The primary cooling fan is a mechanical fan driven by the engine. The fan speed is relative to the engine RPM depending on the ambient air temperature.

The secondary cooling fan is electric and controlled by the PCM. The PCM monitors certain parameters (such as engine coolant temperature, vehicle speed, A/C ON/OFF status, A/C pressure) to determine engine cooling fan needs.

The PCM controls the secondary fan operation through the low fan control (LFC), high fan control (HFC) outputs.

The PCM output circuits are called low and high fan control, and the secondary cooling fan speed is controlled by a combination of these outputs.

Cooling Fan — All Others

The cooling fan and viscous drive actuator valve controls the fluid flow from the reservoir into the working chamber. Once viscous fluid is in the working chamber, shearing of the fluid results in fan rotation. The valve is activated by a pulse width modulation (PWM) output signal from the PCM. By opening and closing the fluid port valve, the PCM controls the fan speed. Fan speed is measured through a Hall effect sensor, and is monitored by the PCM during closed loop operation. The PCM optimizes the fan speed based on the engine coolant temperature, the engine oil temperature, the fuel rail temperature, the transmission fluid temperature, the intake air temperature, or air conditioning requirements. When an increased demand for fan speed is requested for vehicle cooling, the PCM monitors the fan speed through the Hall effect sensor. If a fan speed increase is required, the PCM outputs the PWM signal to the fluid port, providing the required fan speed increase. During the key on, engine running (KOER) self-test, the PCM commands a 100% duty cycle. A DTC sets if the PCM detects the voltage on the valve control circuit is not within the expected range or if the fan speed is less than a calibrated value.

Crankcase Ventilation

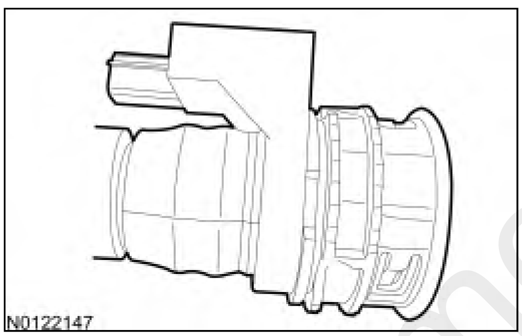
The crankcase ventilation provides a means of routing and separating the oil from the crankcase vapors. For additional information, refer to Crankcase Ventilation System in this section.

Crankcase Ventilation Heater

The crankcase ventilation heater is used to heat the crankcase ventilation system vapor to keep any oil that may be present from sludging in the charge air cooler, turbocharger and intake manifold. The crankcase ventilation heater is located on the crankcase ventilation hose. For additional information on the crankcase ventilation system, refer to Crankcase Ventilation System in this section.

Crankcase Ventilation Sensor

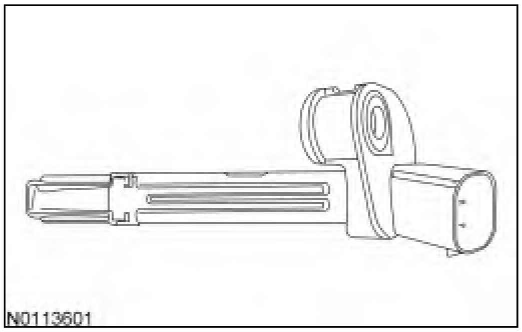
The crankcase ventilation sensor is a hall effect sensor mounted on the crankcase ventilation hose at the air inlet connection. The crankcase ventilation separator is mounted on the driver side rocker cover, with the crankcase ventilation hose connecting the separator to the crankcase ventilation sensor at the air inlet of the turbocharger. The crankcase ventilation hose on the separator side has a tamper proof connector. The crankcase ventilation sensor monitors the crankcase ventilation hose connection at the air inlet of the turbocharger. The crankcase ventilation sensor signal to the PCM indicates if the crankcase ventilation hose is connected or disconnected.



Typical Crankcase Ventilation Sensor

Crankshaft Position (CKP) Sensor

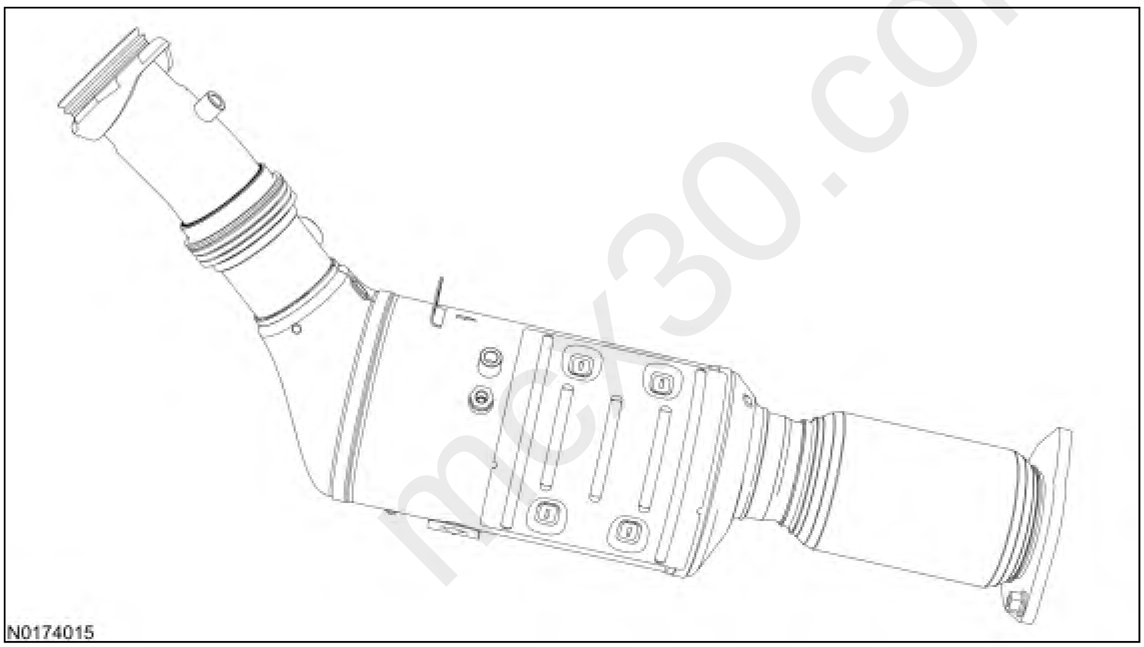
The CKP sensor is a hall effect sensor mounted at the rear of the engine block, adjacent to a trigger wheel located on the crankshaft. The trigger wheel is a 60 minus 2 steel disk with 58 evenly spaced magnetic indicators and a minus 2 indicator slot spaced for each 6 degrees of crank angle. As the crankshaft rotates, the CKP sensor produces a square wave for each magnetic indicator edge of the trigger wheel and it detects the missing 59th and 60th magnetic indicator. This configuration allows the CKP sensor to provide the PCM with the angular position of the crankshaft relative to a fixed reference for the CKP sensor. The PCM uses the CKP sensor input to calculate engine RPM, fuel timing, fuel quantity and duration of the fuel injection.



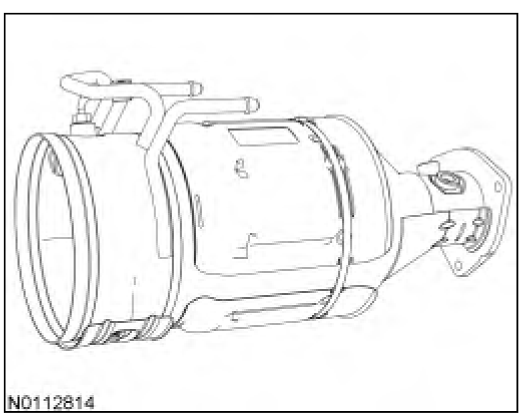
Typical CKP Sensor

Diesel Particulate Filter

The diesel particulate filter collects the soot and ash particles that are present in the exhaust gas of diesel engines. The diesel particulate filter assembly typically consists of active precious metals deposited on a substrate filter. The exhaust gas is forced to flow through the walls of the porous substrate and exit through the adjoining channels. The particulates that are larger than the pore size of the walls are trapped for regeneration. During regeneration the temperature in the diesel particulate filter increases to greater than 550°C (1,022°F). The precious metal washcoat promotes the regeneration of the trapped particulates through the heat-generating reaction and catalyzes the untreated exhaust gas. The substrate filter is held in the metal shell by a ceramic fiber support system. The support system makes up the size differences that occur due to thermal expansion and maintains a uniform holding force on the substrate filter.



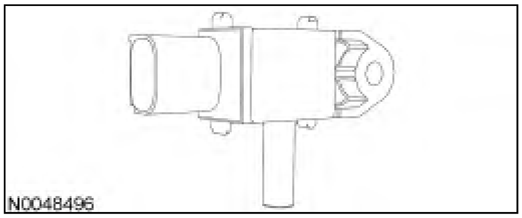
Diesel Particulate Filter (F-150)



Typical Diesel Particulate Filter (All Others)

Diesel Particulate Filter Pressure Sensor

The diesel particulate filter pressure sensor is an input to the PCM and measures the pressure before the diesel particulate filter. The sensor is a differential type sensor. The diesel particulate filter pressure sensor bank 1, sensor 1 (DPFP11) is referenced to atmospheric pressure and is located at the exhaust system upstream of the diesel particulate filter. At ignition ON, engine OFF the diesel particulate filter pressure sensor pressure value reads 0 kPa (0 psi). The range of the sensor is 0-80 kPa (0-11.6 psi). The PCM calculates soot load based on the diesel particulate filter pressure and initiates a regeneration when the soot load reaches a threshold.



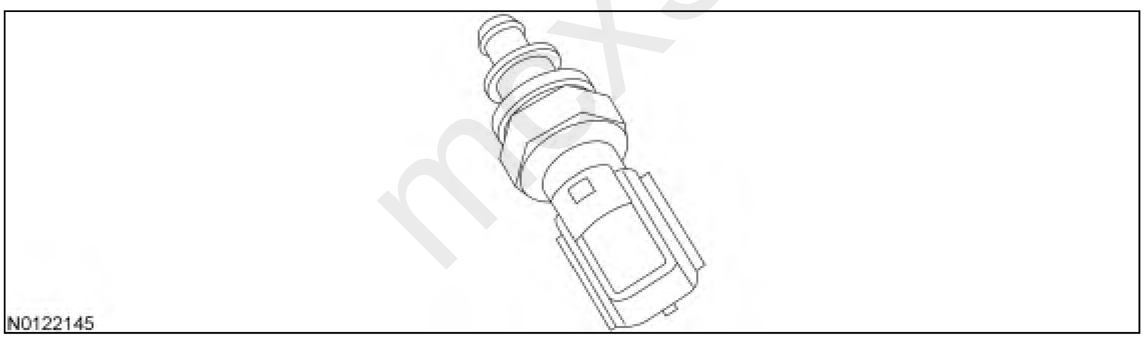
Typical Diesel Particulate Filter Pressure Sensor

Engine Coolant Temperature (ECT) Sensor

The ECT sensor is a thermistor device in which resistance changes with temperature. The electrical resistance of a thermistor decreases as the temperature increases, and resistance increases as the temperature decreases. The varying resistance affects the voltage drop across the sensor terminals and provides electrical signals to the PCM corresponding to temperature.

Engine Coolant Temperature (ECT) Sensor — Transit

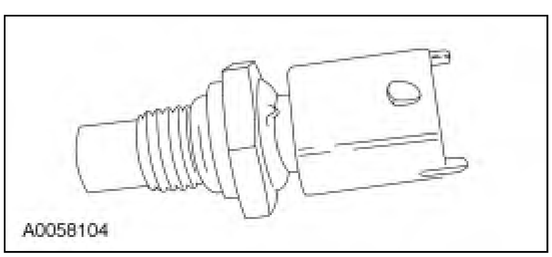
The ECT sensor is located on the upper coolant inlet housing. The ECT sensor measures the temperature of the engine coolant and provides a feedback signal to the PCM. The PCM uses the ECT sensor input for cooling fan control, EGR flow, fuel quantity, and injection timing calculations.



ECT Sensor (Transit)

Engine Coolant Temperature (ECT) Sensor — All Others

The ECT sensor is located on the upper coolant inlet housing. The ECT sensor measures the temperature of the engine coolant and provides a feedback signal to the PCM. The PCM uses the ECT sensor input fuel and cooling fan control.

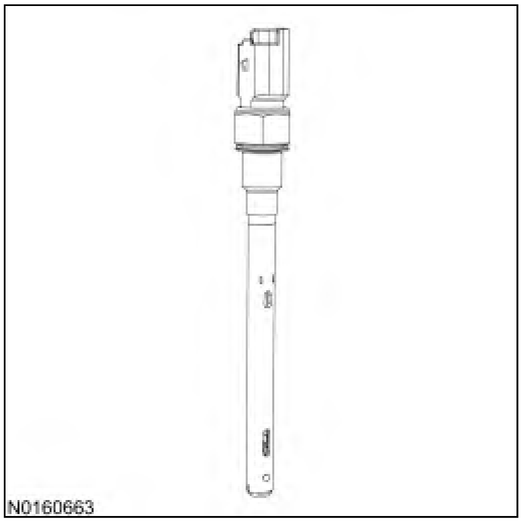


Typical ECT Sensor (All Others)

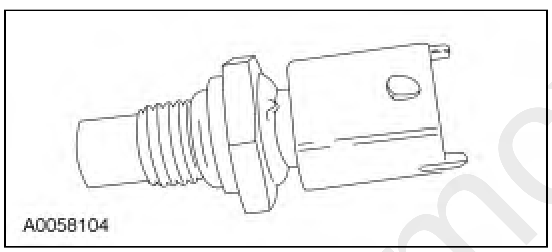
Engine Oil Temperature (EOT) Sensor

The EOT sensor is a thermistor device in which resistance changes with temperature. The electrical resistance of a thermistor decreases as the temperature increases, and resistance increases as the temperature decreases. The varying resistance affects the voltage drop across the sensor terminals and provides electrical signals to the PCM corresponding to temperature. The PCM uses the EOT sensor input to calculate fuel quantity and injection timing.

The F-150 does not have an EOT sensor. For Transit, the EOT sensor is located on the right hand side of the engine block near the rear of the engine. For all others except F-Series Super Duty, the EOT sensor is located at the rear of the engine on the oil filter adapter.



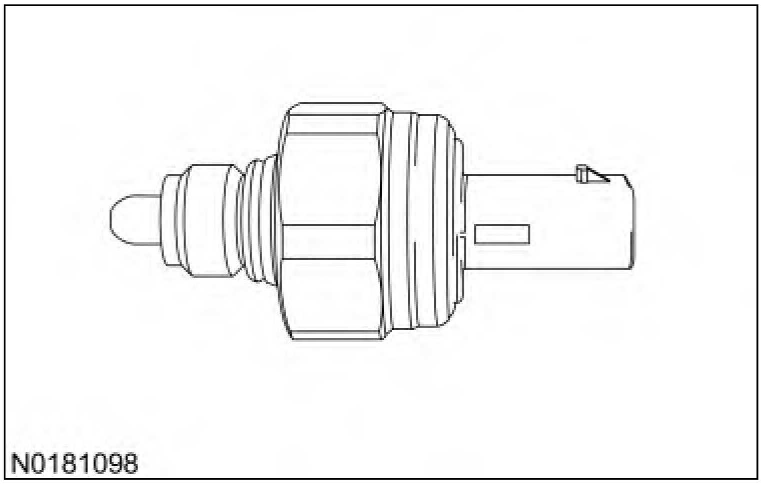
EOT Sensor (Transit)



Typical EOT Sensor (All Others)

Engine Oil Pressure and Temperature Sensor — F-Series Super Duty

F-Series Super Duty is equipped with a sensor that monitors oil pressure and oil temperature. The EOT sensor is located at the rear of the engine on the oil filter adapter.



Typical EOT Sensor (All Others)

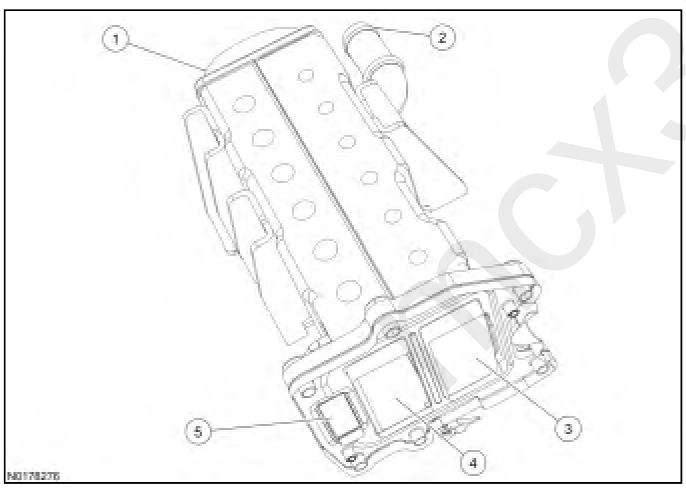
Exhaust Gas Recirculation (EGR) Cooler

The EGR cooler removes heat from the exhaust gases before the gases enter the intake manifold. When the exhaust gases are directed through the EGR cooler, coolant from the engine cooling system reduces the exhaust gas temperature. The exhaust gases are directed through the EGR cooler by a PCM controlled EGR cooler bypass valve.

Exhaust Gas Recirculation (EGR) Cooler — F-150

The EGR cooler is located on the driver side of the cylinder block.

EGR Cooler (F-150)

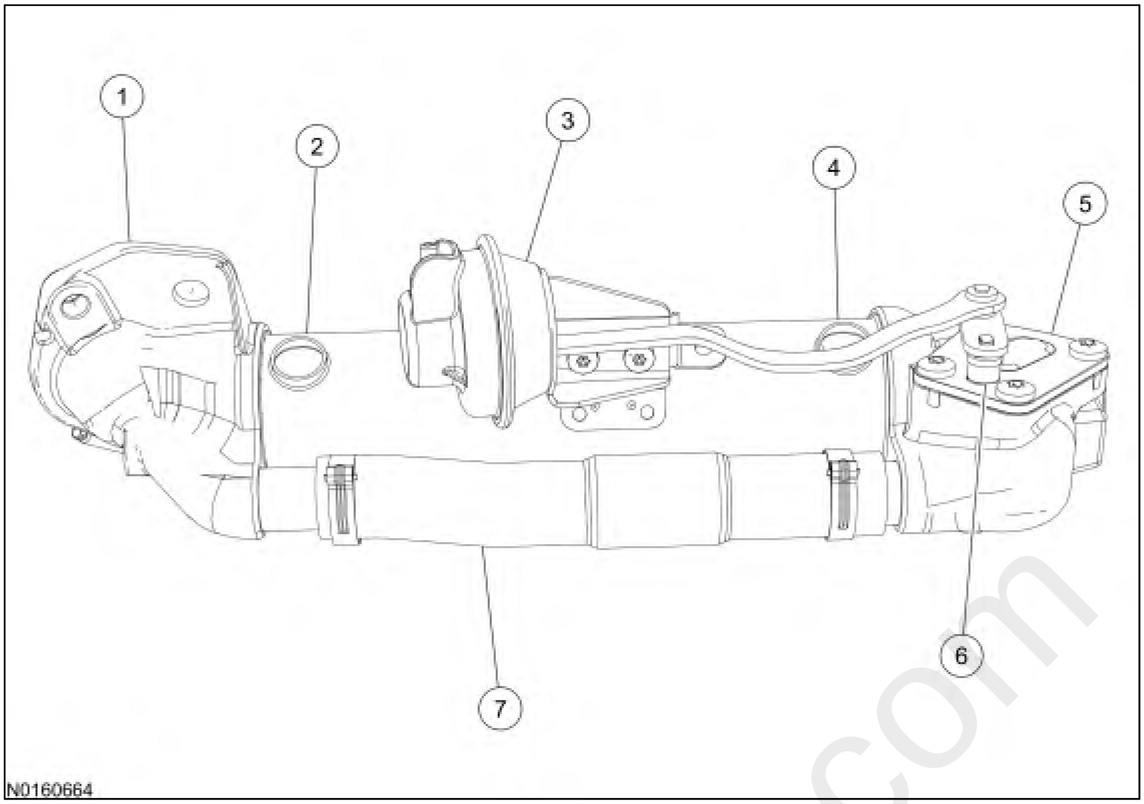


Item	Number	Description
1	—	EGR Cooler Assembly
2	—	Cooling System Coolant Return From The EGR Cooler
3	—	Exhaust Gas Outlet From The EGR Cooler To The EGR Valve
4	—	Exhaust Gas Inlet From The Exhaust Manifold To The EGR Cooler
5	—	Cooling System Coolant Supply To The EGR Cooler

Exhaust Gas Recirculation (EGR) Cooler — Transit

The EGR cooler is located at the rear of the cylinder block.

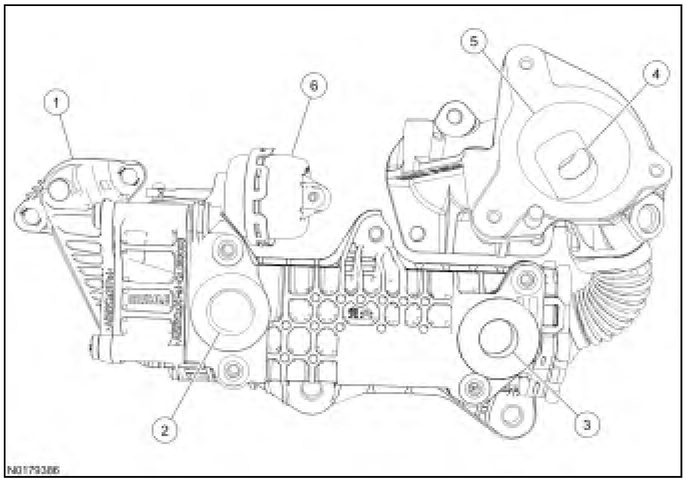
EGR Cooler (Transit)



Item	Number	Description
1	—	Exhaust Gas Outlet From The EGR Cooler To The EGR Valve
2	—	Cooling System Coolant Supply To The EGR Cooler
3	—	EGR Cooler Bypass Valve Actuator
4	—	Cooling System Coolant Return From The EGR Cooler
5	—	Exhaust Gas Inlet From The Exhaust Manifold To The EGR Cooler
6	—	EGR Cooler Bypass Valve
7	—	EGR Cooler Assembly

Exhaust Gas Recirculation (EGR) Cooler — Transit Connect

The EGR cooler is located in the rear of the cylinder block.

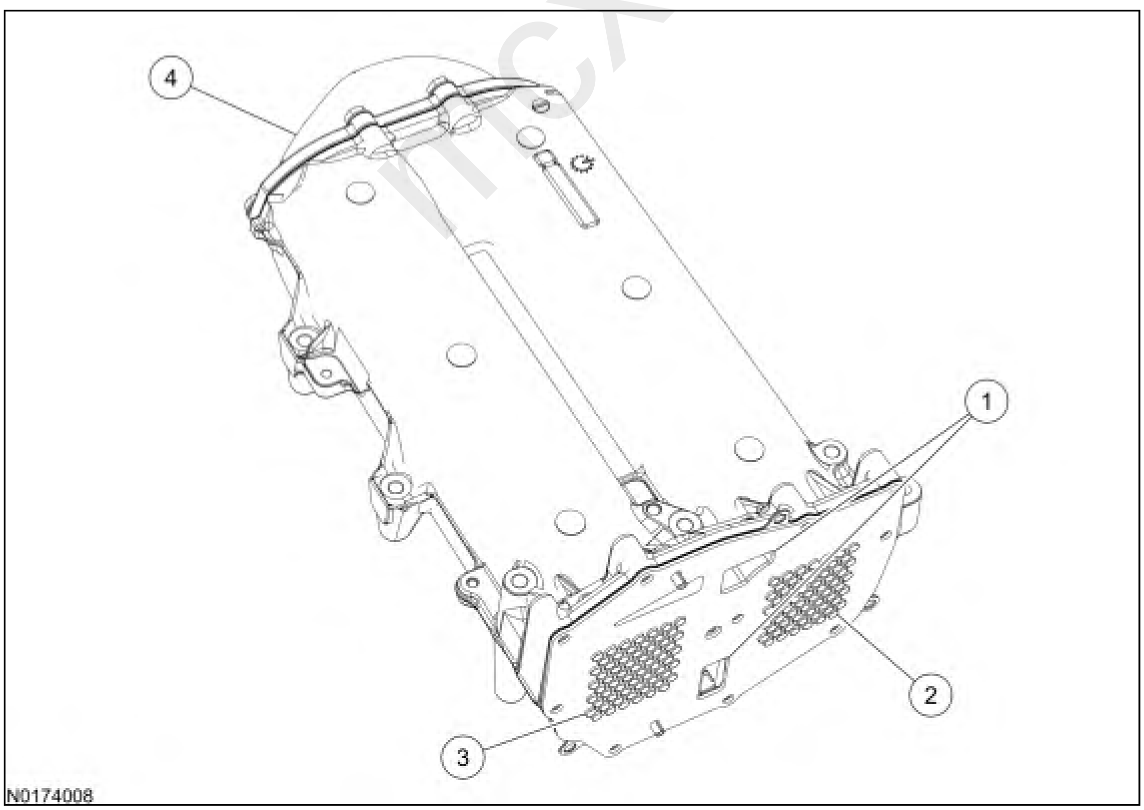


Item	Number	Description
1	—	Exhaust Gas Inlet From The Exhaust Manifold
2	—	Engine Coolant Return
3	—	Engine Coolant Supply
4	—	Exhaust Gas Outlet From The EGR Cooler
5	—	Air Inlet From Charge Air Cooler
6	—	EGR Cooler Bypass Valve Actuator

EGR Cooler — All Others

The EGR cooler is located above the right hand valve cover.

Typical EGR Cooler (All Others)



Item	Number	Description
1	—	Engine Coolant Supply To The EGR Valve From The RH Valve Cover
2	—	Exhaust Gas Outlet From The EGR Cooler To The Intake Manifold
3	—	Exhaust Gas Inlet From The EGR Valve To The EGR Cooler
4	—	EGR Cooler Assembly

Exhaust Gas Recirculation (EGR) Cooler Bypass Valve

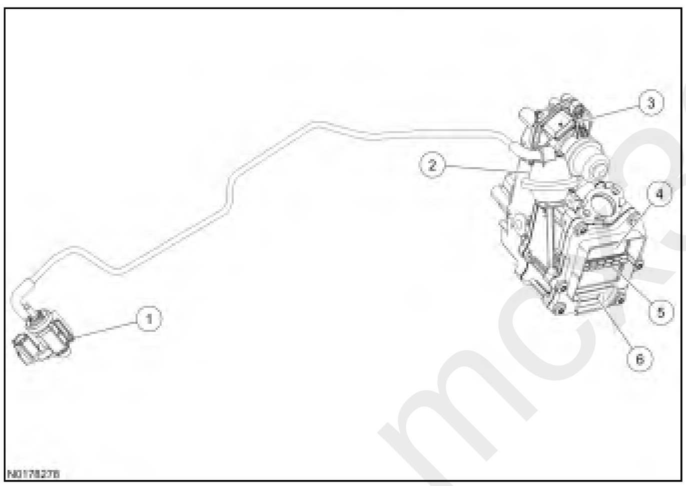
Exhaust Gas Recirculation (EGR) Cooler Bypass Valve — F-150

The exhaust gas is directed through the EGR cooler by the EGR cooler bypass valve to remove heat before entering the intake manifold. The EGR cooler bypass valve is internal to the EGR cooler.

When the EGR cooler bypass valve solenoid is commanded off by the PCM, the EGR cooler bypass valve is closed. When the EGR cooler bypass valve is closed, the exhaust gas passes through the EGR cooler to the intake manifold.

When the EGR cooler bypass valve solenoid is commanded on by the PCM, the EGR cooler bypass valve is opened. When the EGR cooler bypass valve is open, the exhaust gas passes directly to the intake manifold without passing through the EGR cooler.

Typical EGR Cooler Bypass Valve (F-150)



Item	Number	Description
1	—	EGR Cooler Bypass Valve Actuator Solenoid
2	—	EGR Cooler Bypass Valve Actuator
3	—	EGR Valve
4	—	Exhaust Gas Outlet From The EGR Cooler To The EGR Valve
5	—	Exhaust Gas Inlet From The Exhaust Manifold To The EGR Cooler
6	—	Cooling System Coolant Supply To The EGR Cooler

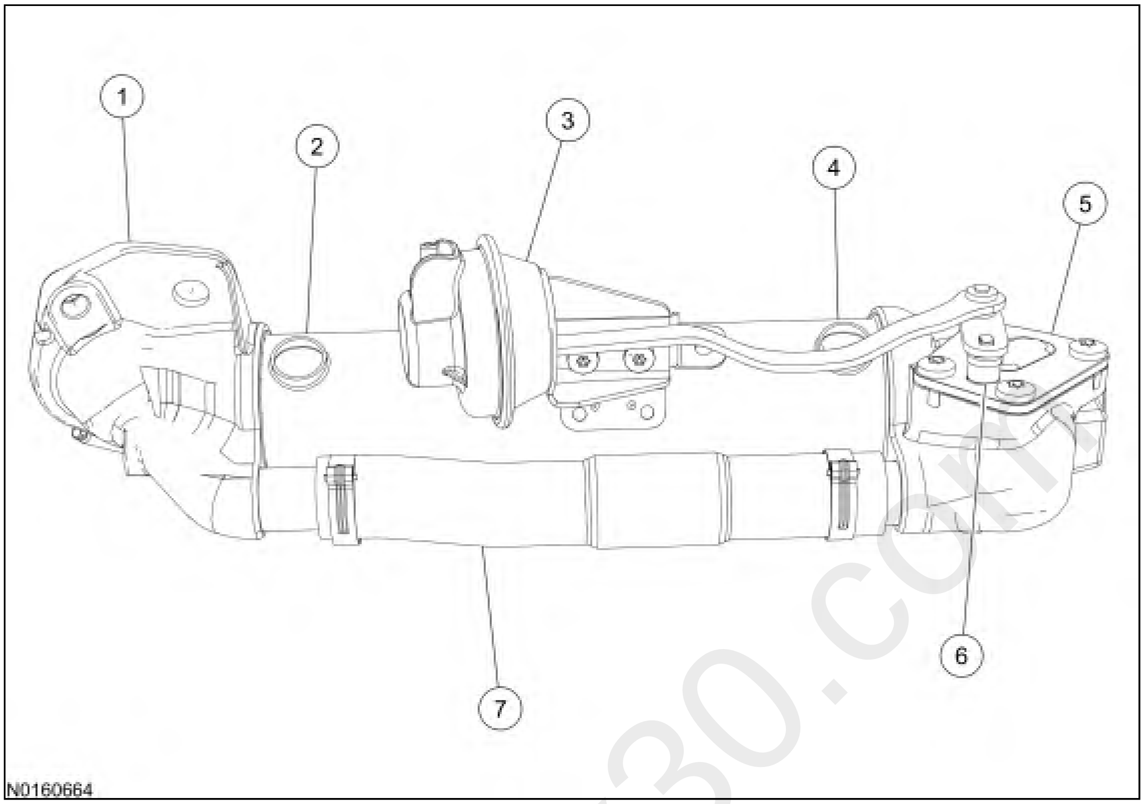
Exhaust Gas Recirculation (EGR) Cooler Bypass Valve — Transit

The exhaust gas is directed through the EGR cooler by the EGR cooler bypass valve to remove heat before entering the intake manifold. The EGR cooler bypass valve is internal to the EGR cooler.

When the EGR cooler bypass valve solenoid is commanded off by the PCM, the EGR cooler bypass valve is closed. When the EGR cooler bypass valve is closed, the exhaust gas passes through the EGR cooler to the intake manifold.

When the EGR cooler bypass valve solenoid is commanded on by the PCM, the EGR cooler bypass valve is opened. When the EGR cooler bypass valve is open, the exhaust gas passes directly to the intake manifold without passing through the EGR cooler.

Typical EGR Cooler Bypass Valve (Transit)



Item	Number	Description
1	—	Exhaust Gas Outlet From The EGR Cooler To The EGR Valve
2	—	Cooling System Coolant Supply To The EGR Cooler
3	—	EGR Cooler Bypass Valve Actuator
4	—	Cooling System Coolant Return From The EGR Cooler
5	—	Exhaust Gas Inlet From The Exhaust Manifold To The EGR Cooler
6	—	EGR Cooler Bypass Valve
7	—	EGR Cooler Assembly

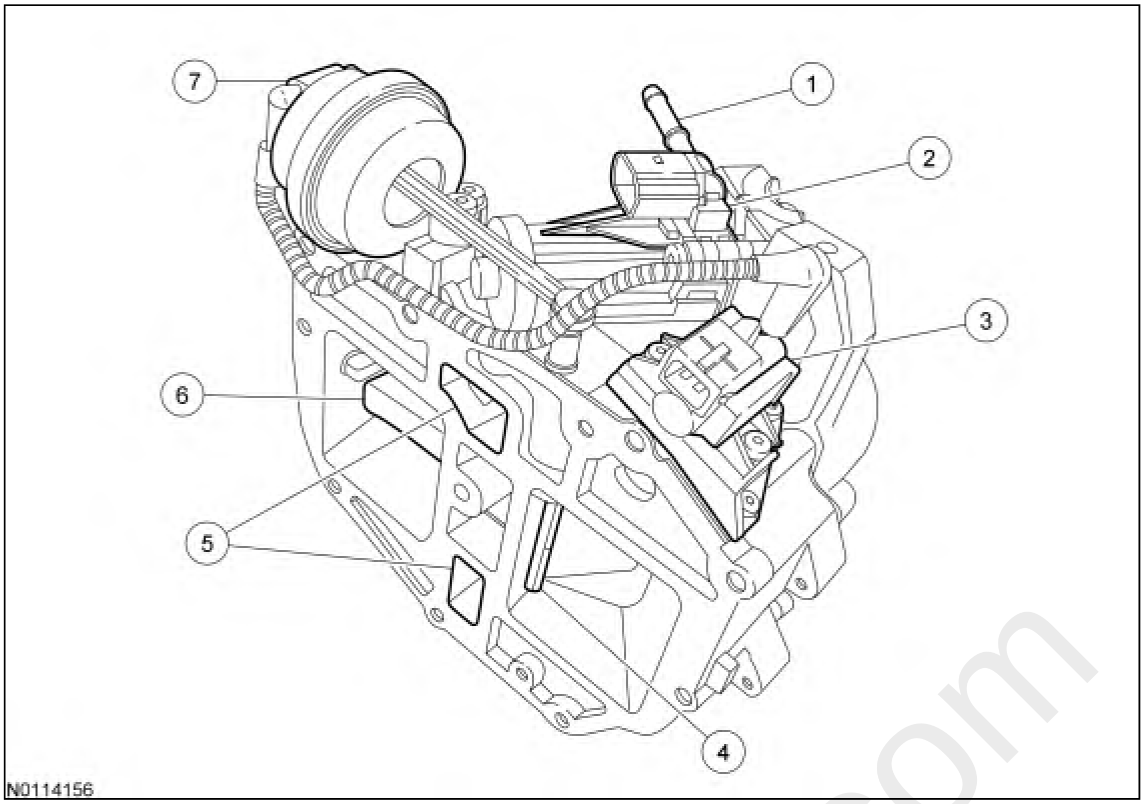
EGR Cooler Bypass Valve — All Others

The exhaust gases are directed through an EGR cooler by the EGR cooler bypass valve to remove heat before entering the intake manifold. The EGR cooler bypass valve is internal to the EGR cooler.

When the EGR cooler bypass valve solenoid is commanded to 0% duty cycle by the PCM, the EGR cooler bypass valve is closed. When the EGR cooler bypass valve is closed, the exhaust gases pass through the EGR cooler to the intake manifold.

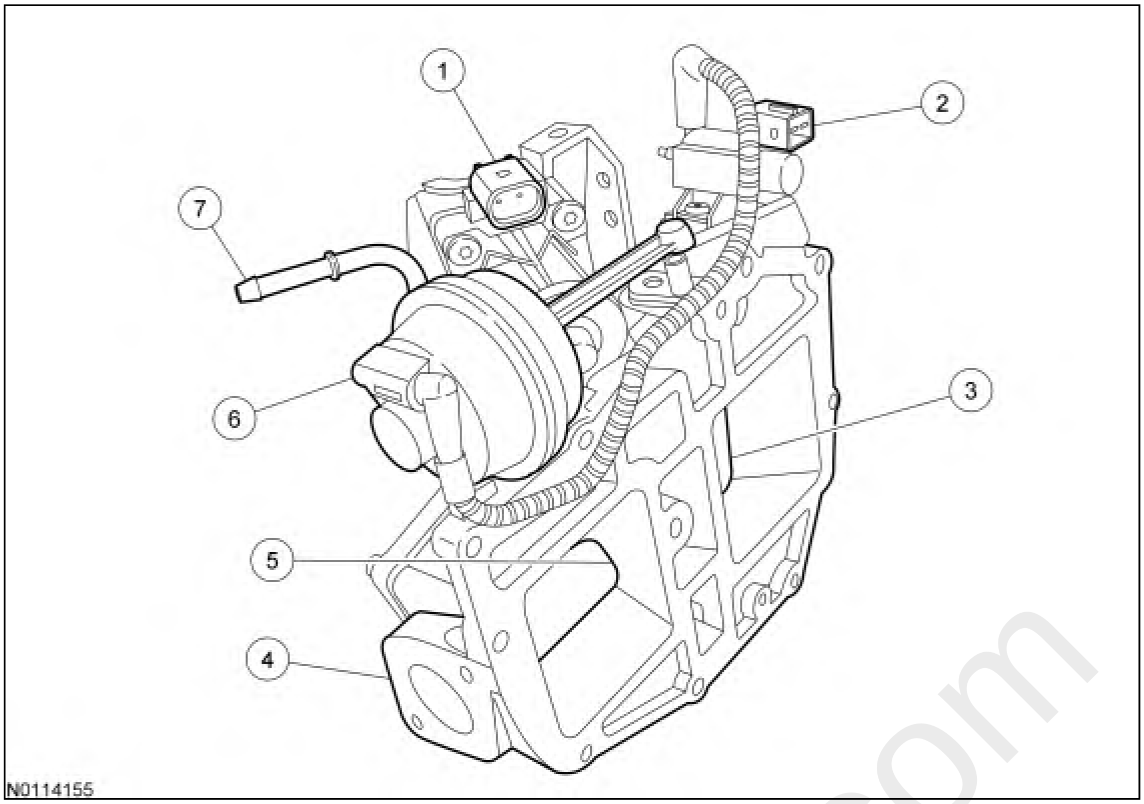
When the EGR cooler bypass valve solenoid is commanded to 100% duty cycle by the PCM, the EGR cooler bypass valve is opened. When the EGR cooler bypass valve is open, the exhaust gases pass directly to the intake manifold without passing through the EGR cooler.

Typical EGR Cooler Bypass Valve (All Others)



Item	Number	Description
1	—	Engine Coolant Return
2	—	EGR Valve And The EGR Valve Position Sensor
3	—	EGR Cooler Bypass Valve Solenoid
4	—	EGR Cooler Bypass Valve
5	—	Engine Coolant Supply To The EGR Valve From The RH Valve Cover
6	—	EGR Outlet To The Intake Manifold
7	—	EGR Cooler Bypass Valve Actuator

Typical EGR Cooler Bypass Valve (All Others)



Item	Number	Description
1	—	EGR Valve And The EGR Valve Position Sensor
2	—	EGR Cooler Bypass Valve Solenoid
3	—	EGR Outlet To The EGR Cooler
4	—	EGR Outlet To The Intake Manifold
5	—	EGR Outlet To The Intake Manifold During EGR Cooler Bypass
6	—	EGR Cooler Bypass Valve Actuator
7	—	Engine Coolant Return

Exhaust Gas Recirculation (EGR) Cooler Bypass Valve Solenoid

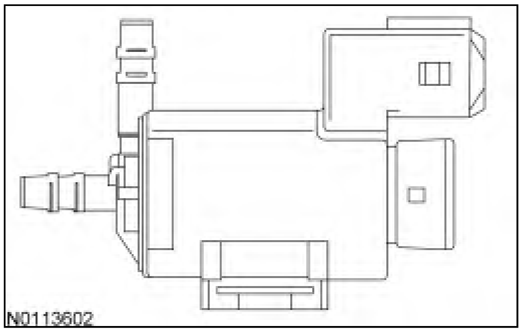
The EGR cooler bypass valve solenoid is a PCM controlled vacuum solenoid. The EGR cooler bypass valve solenoid controls the EGR cooler bypass valve position by applying vacuum from the vacuum pump to the EGR cooler bypass valve actuator. The EGR cooler bypass valve solenoid is located at the top front of the EGR cooler.

For Transit, when the EGR cooler bypass valve solenoid is commanded off by the PCM, no vacuum from the vacuum pump is applied to the EGR cooler bypass valve actuator and the EGR cooler bypass valve is closed. When the EGR cooler bypass valve is closed, the exhaust gas passes through the EGR cooler to the intake manifold.

When the EGR cooler bypass valve solenoid is commanded on by the PCM, vacuum from the vacuum pump is applied to the EGR cooler bypass valve actuator and the EGR cooler bypass valve is opened. When the EGR cooler bypass valve is open, the exhaust gas passes directly to the EGR valve and into the intake manifold without passing through the EGR cooler.

For all others, when the EGR cooler bypass valve solenoid is commanded to 0% duty cycle by the PCM, no vacuum from the vacuum pump is applied to the EGR cooler bypass valve actuator and the EGR cooler bypass valve is closed. When the EGR cooler bypass valve is closed, the exhaust gases pass through the EGR cooler to the intake manifold.

When the EGR cooler bypass valve solenoid is commanded to 100% duty cycle by the PCM, vacuum from the vacuum pump is applied to the EGR cooler bypass valve actuator and the EGR cooler bypass valve is opened. When the EGR cooler bypass valve is open, the exhaust gases pass directly to the intake manifold without passing through the EGR cooler.



Typical EGR Cooler Bypass Valve Solenoid

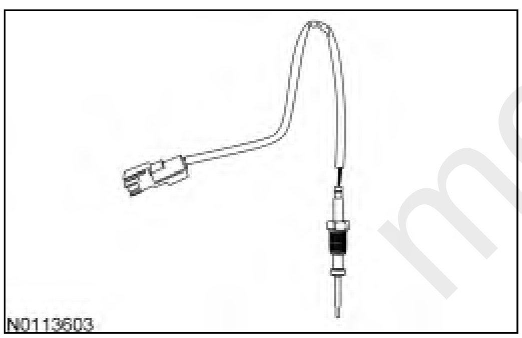
Exhaust Gas Recirculation Temperature (EGRT) Sensor

Exhaust Gas Recirculation Temperature (EGRT) Sensor — Transit

The EGRT bank 1, sensor 1 (EGRT11) is a is a resistance temperature detector (RTD) type sensor. The EGRT 11 sensor is an input to the PCM and measures the temperature of the exhaust gas in the exhaust manifold. The electrical resistance of the sensor increases as the temperature increases, and resistance decreases as the temperature decreases. The varying resistance changes the voltage drop across the sensor terminals and provides electrical signals to the PCM corresponding to temperature.

The EGRT bank 1, sensor 2 (EGRT12) is a thermistor device in which resistance changes with temperature. The EGRT 12 sensor is an input to the PCM. The electrical resistance of the sensor increases as the temperature decreases, and the resistance decreases as the temperature increases. The varying resistance changes the voltage drop across the sensor terminals and provides electrical signals to the PCM corresponding to temperature.

The EGRT sensors are used to determine if the EGR cooler is operating correctly. The EGRT bank 1, sensor 1 (EGRT11) monitors the exhaust gas temperature before the EGR cooler and the EGRT bank 1, sensor 2 (EGRT12) monitors the exhaust gas temperature after the EGR cooler.



Typical EGRT Sensor (Transit)

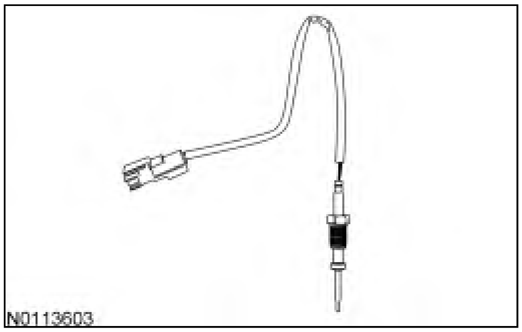
Exhaust Gas Recirculation Temperature (EGRT) Sensor — All Others

The EGRT sensor is a thermistor type sensor. The electrical resistance of the sensor increases as the temperature decreases, and the resistance decreases as the temperature increases. The varying resistance changes the voltage drop across the sensor terminals and provides electrical voltage to the PCM corresponding to temperature. The EGRT sensor is an input to the PCM.

The EGRT sensor is used to determine if the EGR cooler is operating correctly.

For F-Series Super Duty wide frame vehicles, the EGRT bank 1, sensor 1 (EGRT11) monitors the exhaust gas temperature before the EGR cooler and the EGRT bank 1, sensor 2 (EGRT12) monitors the exhaust gas temperature after the EGR cooler.

For all others, the EGRT12 sensor monitors the exhaust gas temperature after the EGR cooler.

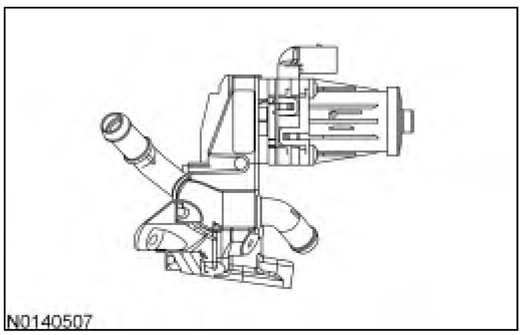


Typical EGRT Sensor (All Others)

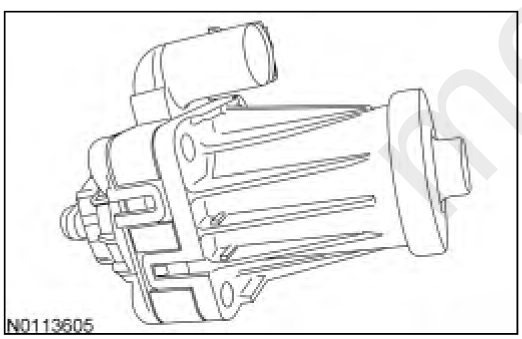
Exhaust Gas Recirculation (EGR) Valve

The EGR valve is a variable position valve that controls the amount of exhaust that enters the intake manifold. The PCM controls the EGR valve which operates between 0 and 100% duty cycles.

The EGR valve operation can be monitored by viewing the EGR valve position PID. The EGR valve position sensor is integral to the EGR valve.



Typical EGR Valve (Transit)



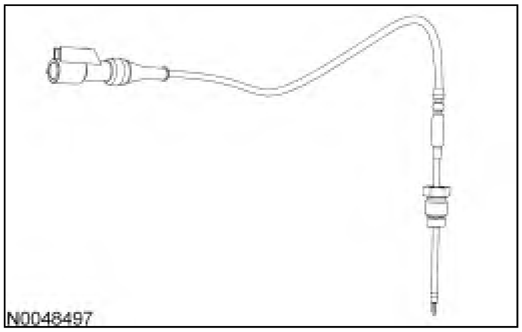
Typical EGR Valve (All Others)

Exhaust Gas Temperature (EGT) Sensor

The EGT sensor is a resistance temperature detector (RTD) type sensor. The EGT sensor is an input to the PCM and measures the temperature of the exhaust gas passing through the exhaust system. The electrical resistance of the sensor increases as the temperature increases, and resistance decreases as the temperature decreases. The varying resistance changes the voltage drop across the sensor terminals and provides electrical signals to the PCM corresponding to temperature.

For Transit, the PCM uses the input from 3 EGT sensors to monitor the exhaust gas temperature. The EGT bank 1, sensor 1 (EGT11) is located before the diesel particulate filter. The EGT bank 1, sensor 2 (EGT12) is located after the diesel particulate filter. The EGT bank 1, sensor 3 (EGT13) is located after the SCR catalyst.

For all others, the PCM uses the input from 4 EGT sensors to monitor the exhaust gas temperature. The EGT bank 1 sensor 1 (EGT11) is located before the OC. The EGT bank 1 sensor 2 (EGT12) is located after the OC. The EGT bank 1 sensor 3 (EGT13) is located after the SCR catalyst (F-Series Super Duty wide frame) or after the diesel particulate filter (F-650 / F-750, F-Series Super Duty narrow frame). The EGT bank 1 sensor 4 (EGT14) is located after the diesel particulate filter (F-Series Super Duty wide frame) or after the SCR catalyst (F-650 / F-750, F-Series Super Duty narrow frame).



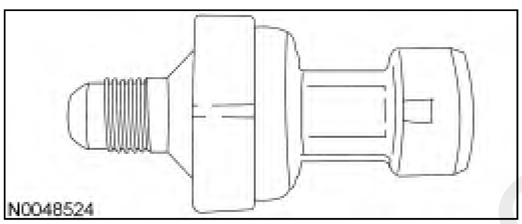
Typical EGT Sensor

Exhaust Pressure (EP) Sensor

The EP sensor is a 3-wire variable capacitance sensor that is supplied a 5.0 volt reference signal by the PCM and returns a linear analog voltage signal that indicates pressure. The sensor voltage input to the PCM increases as the pressure increases.

The EP sensor measures the pressure in the exhaust manifold. The EP sensor signal is used for pressure correlation with the manifold absolute pressure (MAP) sensor and input for exhaust gas recirculation (EGR) valve control.

The EP sensor is located at the left rear of the engine. It is attached to an extension tube from the right hand up pipe going to the turbocharger.



Typical EP Sensor

Fan Speed Sensor (FSS)

The FSS is a Hall effect sensor integral to the cooling fan clutch. The PCM monitors the sensor input and controls the cooling fan speed based upon the engine coolant temperature, the transmission fluid temperature, and the intake air temperature requirements. When an increase in cooling fan speed for vehicle cooling is requested, the PCM monitors the FSS signal and outputs the required pulse width modulation (PWM) signal to a fluid port valve within the cooling fan.

Fuel Conditioning Module

Fuel Conditioning Module — F-150

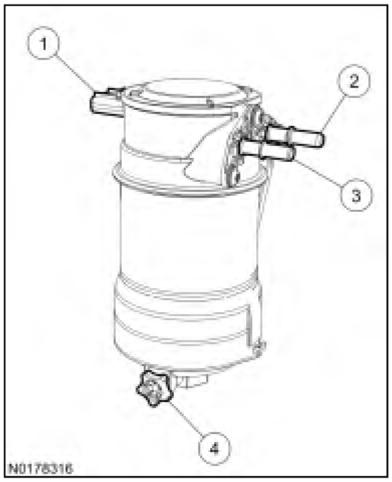
The internal components of the fuel conditioning module include the following:

- 10 micron fuel filter and water separator
- water in fuel (WIF) sensor

The fuel pump (FP) assembly supplies fuel from the fuel tank through the fuel supply line. When the fuel enters the fuel conditioning module, water is separated from the fuel before it flows through the 10 micron fuel filter which separates particles from the fuel. The separated water collects at the bottom of the fuel conditioning module. If enough water is collected, the WIF sensor detects it and the PCM illuminates the WIF indicator. The conditioned fuel is then delivered to the secondary fuel filter then to the high pressure fuel injection pump.

The vented fuel from the fuel pressure control valve returns from the high pressure fuel injection pump, combines with the fuel from the fuel injector return line and enters the unfiltered side of the secondary fuel filter.

Fuel Conditioning Module (F-150)



Item	Number	Description
1	—	Water In Fuel (WIF) Sensor
2	—	Fuel Supply Line To The High Pressure Fuel Injection Pump
3	—	Fuel Supply Line From The Fuel Tank
4	—	Fuel Drain Valve

Fuel Conditioning Module — F-650 / F-750

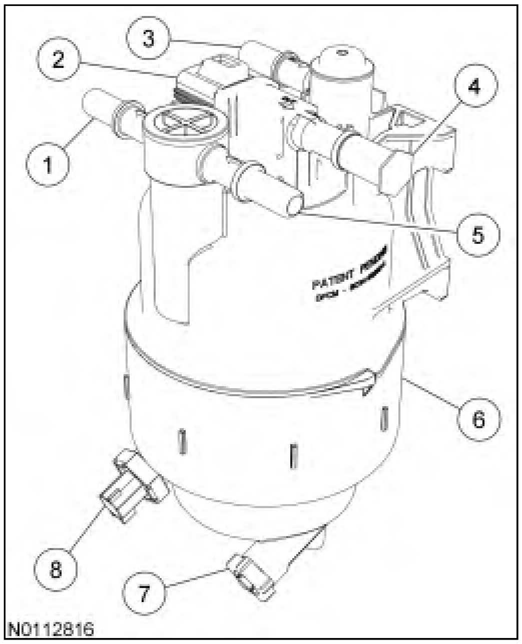
The internal components of the fuel conditioning module include the following:

- electric fuel pump
- 10 micron fuel filter and water separator
- water in fuel (WIF) sensor
- recirculation thermostat

The electric fuel pump draws fuel from the fuel tank through the fuel supply line. When the fuel enters the fuel conditioning module, water is separated from the fuel before it flows through the 10 micron fuel filter which separates particles from the fuel. The separated water collects at the bottom of the pump. If enough water is collected, the WIF sensor detects it and the PCM illuminates the WIF indicator. The conditioned fuel is then delivered to the secondary fuel filter.

The vented fuel from the fuel pressure control valve returns from the secondary fuel filter through the fuel return port and enters the unfiltered side of the fuel conditioning module. Depending on the fuel temperature returning from the secondary fuel filter, the recirculation thermostat directs the fuel to the fuel tank or through the fuel conditioning module back to the inlet of the primary filter.

Fuel Conditioning Module (F-650 / F-750)



Item	Number	Description
1	—	Fuel Return Line To The Fuel Tank
2	—	Electric Fuel Pump Electrical Connector
3	—	Fuel Supply Line From The Fuel Tank
4	—	Fuel Supply Line To The Secondary Fuel Filter
5	—	Fuel Return Line From The Secondary Fuel Filter
6	—	Fuel Filter Cover
7	—	Fuel Drain Valve
8	—	WIF Sensor Electrical Connector

Fuel Conditioning Module — Transit

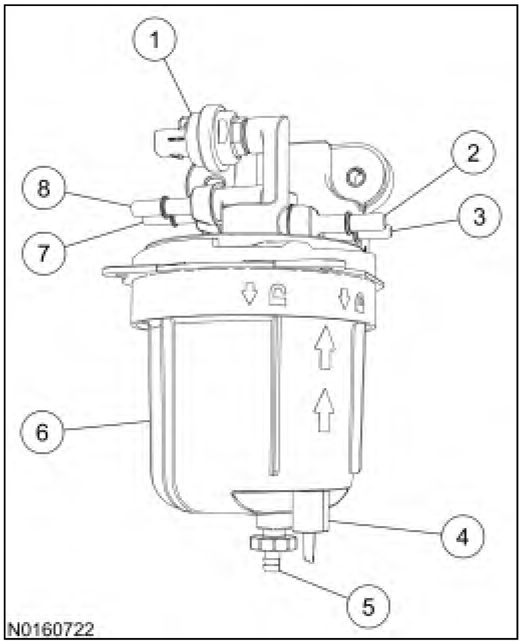
The internal components of the fuel conditioning module include the following:

- 10 micron fuel filter and water separator
- water in fuel (WIF) sensor
- recirculation thermostat

The fuel pump (FP) assembly supplies fuel from the fuel tank through the fuel supply line. When the fuel enters the fuel conditioning module, water is separated from the fuel before it flows through the 10 micron fuel filter which separates particles from the fuel. The separated water collects at the bottom of the pump. If enough water is collected, the WIF sensor detects it and the PCM illuminates the WIF indicator. The conditioned fuel is then delivered to the high pressure fuel injection pump.

The vented fuel from the fuel pressure control valve returns from the high pressure fuel injection pump, combines with the fuel from the fuel injector return line and enters the unfiltered side of the fuel conditioning module. Depending on the fuel temperature returning from the high pressure fuel injection pump, the recirculation thermostat directs the fuel through the fuel cooler back to the fuel tank or through the fuel conditioning module back to the high pressure fuel injection pump.

Fuel Conditioning Module (Transit)



Item	Number	Description
1	—	Fuel Delivery Pressure Switch
2	—	Fuel Supply Line To The High Pressure Fuel Injection Pump
3	—	Fuel Return Line From The High Pressure Fuel Injection Pump
4	—	Water In Fuel (WIF) Sensor
5	—	Fuel Drain Valve
6	—	Fuel Filter Cover
7	—	Fuel Return Line To The Fuel Cooler And Fuel Tank
8	—	Fuel Supply Line From The Fuel Tank

Fuel Conditioning Module —Transit Connect

The internal components of the fuel conditioning module include the following:

- 10 micron fuel filter and water separator
- water in fuel (WIF) sensor

The fuel pump (FP) assembly supplies fuel from the fuel tank through the fuel supply line. When the fuel enters the fuel conditioning module, water is separated from the fuel before it flows through the 10 micron fuel filter which separates particles from the fuel. The separated water collects at the bottom of the fuel conditioning module. If enough water is collected, the WIF sensor detects it and the PCM illuminates the WIF indicator. The conditioned fuel is then delivered to the secondary fuel filter then to the high pressure fuel injection pump.

The vented fuel from the fuel pressure control valve returns from the high pressure fuel injection pump, combines with the fuel from the fuel injector return line and enters the unfiltered side of the secondary fuel filter.

Fuel Conditioning Module — All Others

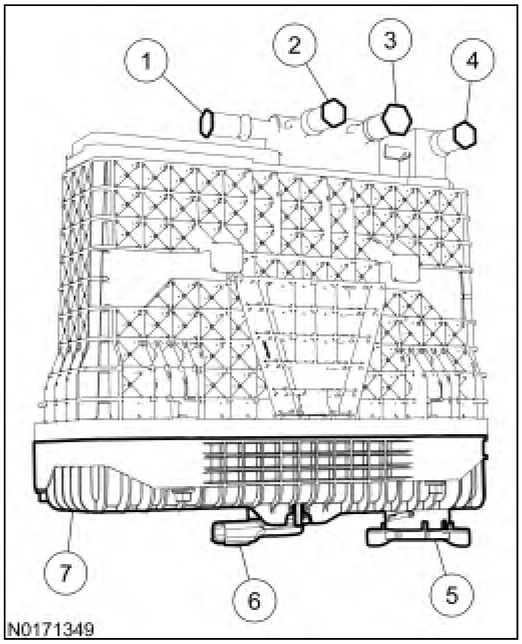
The internal components of the fuel conditioning module include the following:

- 10 micron fuel filter and water separator
- water in fuel (WIF) sensor
- recirculation thermostat

The fuel pump (FP) assembly draws fuel under vacuum through the fuel conditioning module through the fuel tank supply and return lines. When the fuel enters the fuel conditioning module, water is separated from the fuel before it flows through the 10 micron fuel filter which separates particles from the fuel. The separated water collects at the bottom of the filter housing. If enough water is collected, the WIF sensor detects it and the PCM illuminates the WIF indicator. The conditioned fuel returns to the FP assembly. The FP delivers the conditioned fuel to the secondary fuel filter assembly to supply the high pressure fuel injection pump.

The vented fuel from the fuel pressure control valve returns from the high pressure fuel injection pump, combines with the fuel from the fuel injector return line and enters the unfiltered side of the fuel conditioning module. Depending on the fuel temperature returning from the high pressure fuel injection pump, the recirculation thermostat directs the fuel back to the fuel tank or through the fuel conditioning module back to the high pressure fuel injection pump.

Typical Fuel Conditioning Module (All Others)

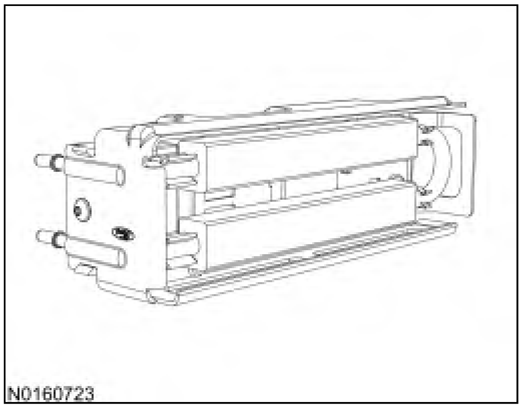


Item	Number	Description
1	—	Fuel Return Line From The Secondary Fuel Filter
2	—	Thermostat Bypass Fuel Return Line To The Fuel Tank
3	—	Unfiltered Fuel Supply Line From The Fuel Tank
4	—	Filtered Fuel Return Line To The FP Assembly
5	—	Fuel Drain Valve
6	—	Water In Fuel (WIF) Sensor
7	—	Fuel Filter Cover

Fuel Cooler

Fuel Cooler — Transit

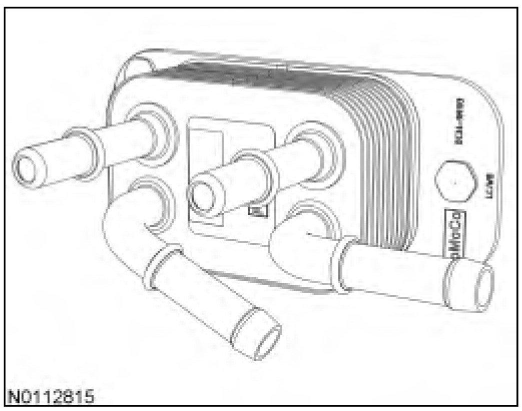
The fuel cooler is an air to liquid heat exchanger located adjacent to the fuel conditioning module. Fuel that bypasses the high pressure fuel injection pump and the fuel pressure control valve is subjected to high temperatures. The fuel cooler transfers this heat to the atmosphere before the fuel is returned to the fuel tank. Refer to Fuel System in this section for additional information.



Fuel Cooler (Transit)

Fuel Cooler — All Others

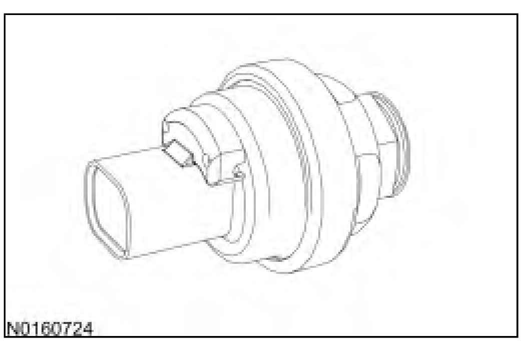
The fuel cooler is a liquid-to-liquid heat exchanger located on the inside of the left frame rail. Fuel that bypasses the high pressure fuel injection pump and the fuel pressure control valve is subjected to high temperatures. The fuel cooler transfers this heat to the coolant before the fuel is returned to the fuel conditioning module. Refer to Fuel System in this section for additional information.



Typical Fuel Cooler (All Others)

Fuel Delivery Pressure Switch

The fuel delivery pressure switch is a normally closed switch that monitors the fuel delivery system pressure prior to the high pressure fuel injection pump. The fuel delivery pressure switch opens when the fuel system pressure reaches 17.5 kPa (2.5 psi) or above. If the fuel delivery system pressure drops below 17.5 kPa (2.5 psi) the switch closes and the PCM notifies the driver by displaying a low fuel pressure warning in the message center, and an engine derate occurs. The fuel delivery pressure switch is located at the top of the fuel conditioning module.



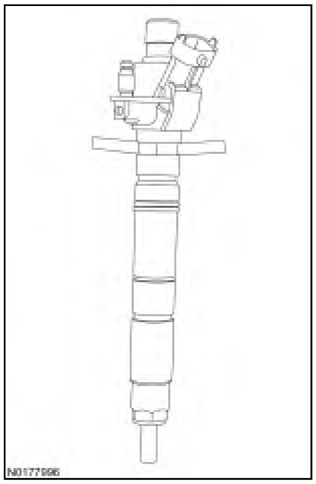
Typical Fuel Delivery Pressure Switch

Fuel Injectors

Fuel Injectors — F-150

The fuel injectors are connected to the high pressure fuel rail and deliver a calibrated amount of fuel directly into the combustion chamber. The piezo actuator is commanded on by the PCM during the main injection stage for approximately 0-1000 microseconds. The fuel injectors on and off time is controlled by the piezo actuator device which allows extreme precision during the injection cycle. For additional information on fuel injection operation, refer to Fuel System in this section.

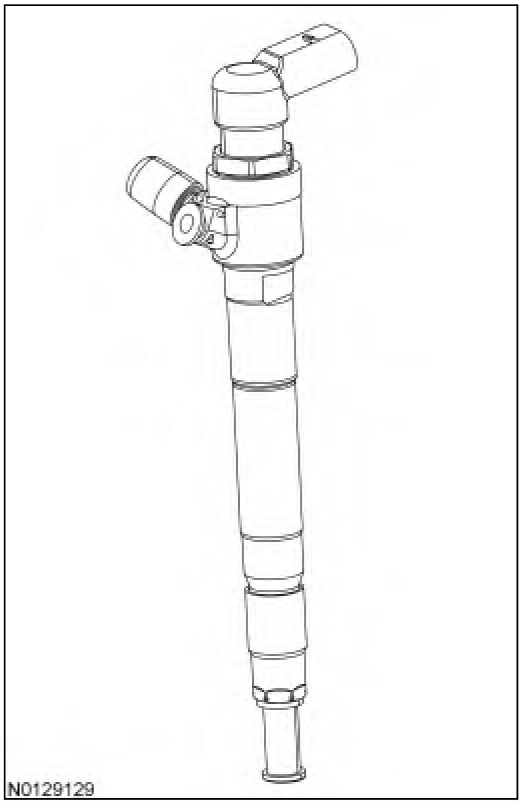
Fuel Injector (F-150)



Fuel Injectors — Transit

The fuel injectors are connected to the high pressure fuel rail and deliver a calibrated amount of fuel directly into the combustion chamber. The piezo actuator is commanded on by the PCM during the main injection stage for approximately 0-1000 microseconds. The fuel injectors on and off time is controlled by the piezo actuator device which allows extreme precision during the injection cycle. For additional information on fuel injection operation, refer to Fuel System in this section.

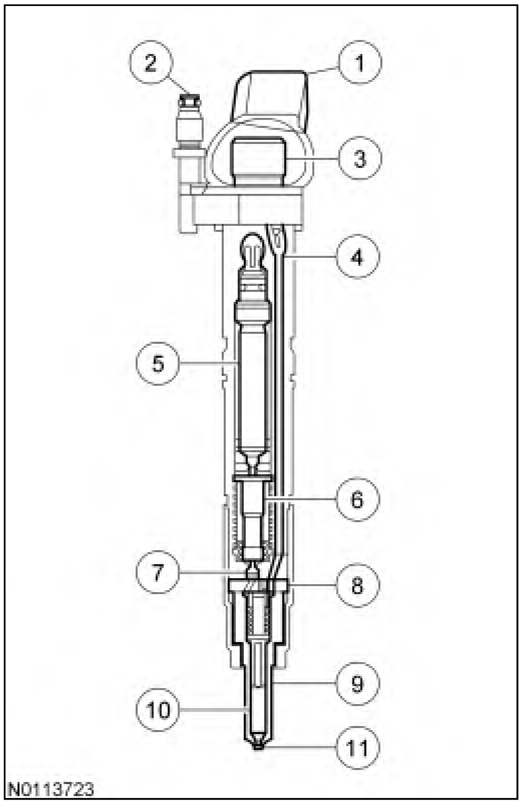
Fuel Injector (Transit)



Fuel Injectors — All Others

The fuel injectors are connected to the high pressure fuel rail and deliver a calibrated amount of fuel directly into the combustion chamber. The piezo actuator is commanded on by the PCM during the main injection stage for approximately 0-1000 microseconds. The fuel injectors on and off time is controlled by the piezo actuator device which allows extreme precision during the injection cycle. For additional information on fuel injection operation, refer to Fuel System in this section.

Typical Fuel Injector (All Others)



Item	Number	Description
1	—	Wiring Harness Electrical Connector
2	—	Fuel Return
3	—	High Pressure Delivery Connection
4	—	High Pressure Fuel Passage
5	—	Piezo Actuator
6	—	Hydraulic Coupler
7	—	Control Valve
8	—	Intermediate Plate
9	—	Nozzle
10	—	Nozzle Needle (Pintle)
11	—	Fuel Delivery Orifices (8 Each)

O-ring And Combustion Gasket

The fuel injector has 1 replaceable O-ring on the fuel return, 1 replaceable O-ring on the fuel injector body and 1 replaceable stepped copper combustion gasket on the tip of the fuel injector.

Piezo Actuator

The piezo actuator consists of a series of small disks. When the piezo actuator is electrically energized, it causes the disks to deform which results in an expansion. The expansion generates a longitudinal motion which pushes down against the valve piston. When the PCM supplied current is removed from the piezo crystals, they contract. When the crystals contract, they create voltage (current flow reverses). The PCM supplies current to the piezo stack and when the injector is deenergized the current is removed from the piezo stack and stored by the PCM to actuate the fuel injector in a companion cylinder. The piezo actuator returns to its non-energized state by fuel and spring pressure during engine operation, and by the spring pressure from the fuel injector valve return spring when the engine is shut down.

Hydraulic Coupler

The hydraulic coupler transfers the longitudinal movement from the piezo actuator to the fuel injector control valve. It also acts as a seal preventing fuel from entering the piezo actuator device.

Fuel Injector Control Valve

The fuel injector control valve is a hydraulic check valve that allows the high fuel pressure to bleed off into the fuel return chamber directly above it, when the piezo actuator is energized and the valve piston pushes down on it.

Fuel Injector Valve Return Spring

The fuel injector valve return spring holds the fuel injector valve in the sealed position to prevent any fuel from leaking into the fuel return chamber when the piezo actuator is not energized.

Control Piston

The control piston uses its large surface area on top as a downward force to overcome an upward force created by the smaller surface area in the high pressure chamber. The control piston also keeps the nozzle needle in the closed position when the piezo actuator is not energized.

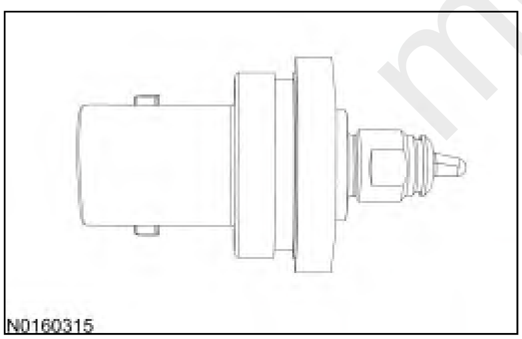
Nozzle Needle And Needle Control Spring

The high pressure chamber uses the high fuel pressure to lift the nozzle needle inwards whenever the piezo actuator is energized. When the nozzle needle is lifted the fuel at the high pressure nozzle is atomized and is injected directly into the combustion chamber through 8 spray holes. The needle control spring holds the nozzle needle in a closed position when the piezo actuator is not energized.

Fuel Pressure And Temperature Sensor

The fuel pressure and temperature sensor monitors both pressure and temperature of the low pressure fuel system. The temperature component of the sensor is a thermistor device in which resistance changes with temperature. The electrical resistance of a thermistor decreases as the temperature increases, and resistance increases as the temperature decreases. The varying resistance affects the voltage drop across the sensor terminals and provides electrical voltage signals to the PCM corresponding to temperature. The pressure component of the sensor provides a signal to the PCM indicating low pressure fuel system pressure. The PCM supplies a 5 volt reference (VREF) signal, as well as supplying 5 volts on the FLP circuit. As pressure increases, the sensor signal voltage decreases.

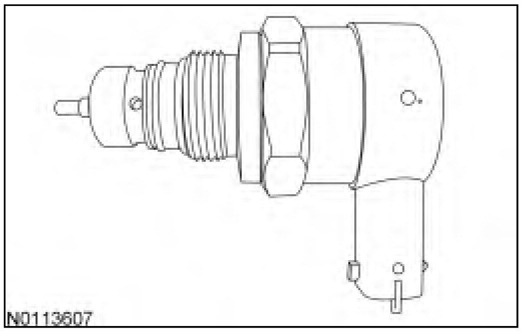
The sensor is located at the top left of the engine in the fuel injection pump supply tube, forward of the secondary fuel filter. The PCM uses the fuel pressure and temperature sensor inputs to command the correct fuel injector timing, the pulse width, and the correct injection control pressure for correct fuel delivery at all speed and load conditions.



Typical Fuel Pressure And Temperature Sensor

Fuel Pressure Control Valve

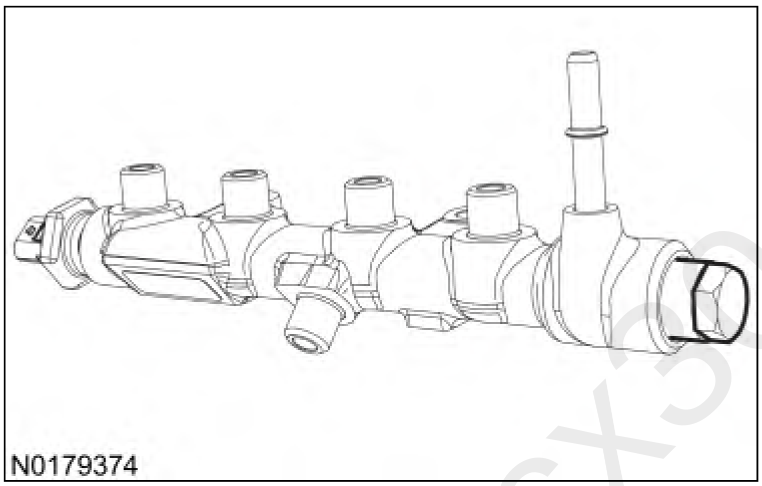
The PCM controls the fuel rail pressure by activating the fuel pressure control valve which regulates the fuel pressure in the fuel rails. For additional information, refer to Fuel System, Fuel Pump System in this section. The PCM regulates fuel rail pressure by controlling the duty cycle of the fuel pressure control valve solenoid. An increase or decrease in the duty cycle maintains pressure in the fuel system or vents pressure to the fuel cooler. A high duty cycle indicates a high fuel rail pressure is being commanded. A low duty cycle indicates less pressure is being commanded. The fuel pressure control valve is mounted on the fuel rail.



Typical Fuel Pressure Control Valve

Fuel Pressure Relief Valve

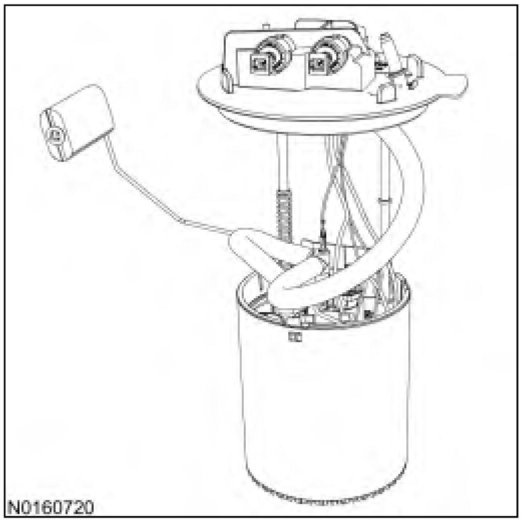
The fuel pressure relief valve is a mechanical spring activated valve. If the pressure exceeds the maximum expected pressure for the system the fuel pressure relief valve activates to relieve fuel pressure back to the fuel tank. The fuel pressure relief valve is not expected to activate during normal vehicle operation. The fuel pressure relief valve has a limited number of activations before the part is no longer reliable and may not fully close. The fuel pressure control valve is mounted at the opposite end of the fuel rail as the fuel rail pressure (FRP) sensor.



Typical Fuel Pressure Relief Valve

Fuel Pump (FP) Assembly

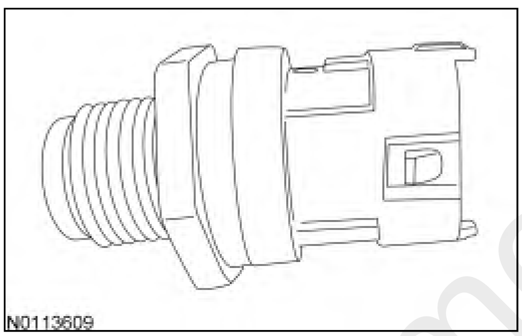
The FP assembly contains the fuel pump and sender assembly. The fuel pump is located inside the FP assembly reservoir and supplies fuel through the FP assembly manifold to the engine and FP assembly jet pump. The jet pump continuously refills the reservoir with fuel, and a check valve located in the manifold outlet maintains system pressure when the fuel pump is not energized. A flapper valve located in the bottom of the reservoir allows fuel to enter the reservoir and prime the fuel pump during the initial fill. The FP assembly is located inside the fuel tank.



Typical FP Assembly

Fuel Rail Pressure (FRP) Sensor

The fuel pressure sensor is a 3 wire variable capacitance sensor. The FRP sensor is located at the rear of the fuel rail (Transit) or at the front of the left hand side fuel rail (all others). The PCM supplies a 5 volt reference signal which the FRP sensor uses to produce a linear analog voltage that indicates high fuel pressure. The primary function of the FRP sensor is to provide a feedback signal to the PCM indicating the pressure of the fuel in the fuel rail. The PCM monitors fuel rail pressure as the engine is operating to control fuel pressure. This is a closed loop function which means the PCM continuously monitors and adjusts for ideal fuel rail pressure determined by conditions such as engine load, speed and temperature.

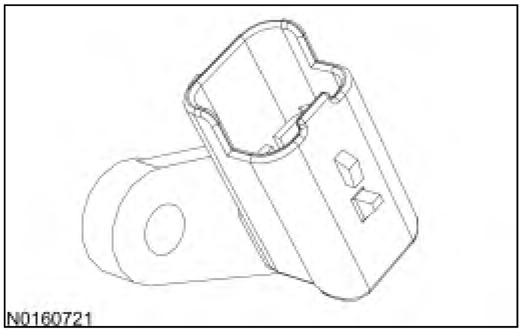


Typical FRP Sensor

Fuel Rail Temperature (FRT) Sensor

The FRT sensor is a thermistor device in which resistance changes with temperature. The electrical resistance of a thermistor decreases as the temperature increases, and resistance increases as the temperature decreases. The varying resistance affects the voltage drop across the sensor terminals and provides electrical voltage signals to the PCM corresponding to temperature.

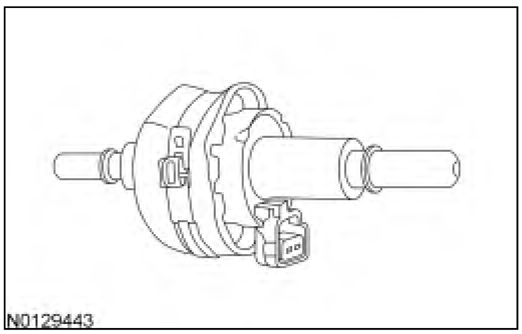
The sensor is mounted on the high pressure fuel injection pump. The FRT sensor measures the temperature of the fuel at the inlet of the high pressure fuel injection pump and provides a feedback signal to the PCM. The PCM uses the FRT sensor input to command the correct fuel injector timing, the pulse width, and the correct injection control pressure for correct fuel delivery at all speed and load conditions.



Typical FRT Sensor

Fuel Vaporizer System Fuel Pump

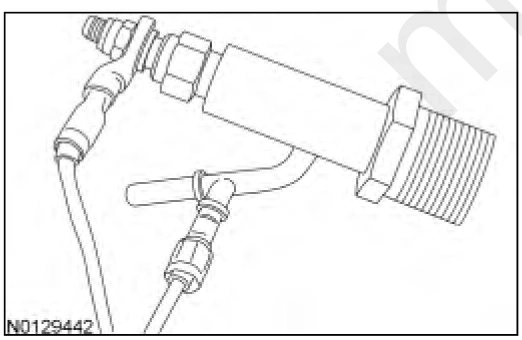
The fuel vaporizer system fuel pump delivers fuel to the fuel vaporizer system glow plug when the PCM commands a diesel particulate filter regeneration. The vaporizer pump is located inside the left frame rail forward of the fuel tank.



Typical Fuel Vaporizer System Fuel Pump

Fuel Vaporizer System Glow Plug

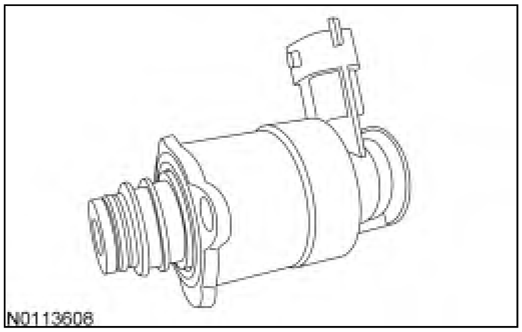
The fuel vaporizer system glow plug regenerates the diesel particulate filter by burning a controlled amount of fuel in the exhaust system upstream of the particulate filter. Fuel is delivered by the fuel vaporizer system pump and ignited by the fuel vaporizer system glow plug when the PCM commands a regeneration. The burning fuel increases the exhaust gas temperature to burn off particulates in the diesel particulate filter.



Typical Fuel Vaporizer System Glow Plug

Fuel Volume Control Valve

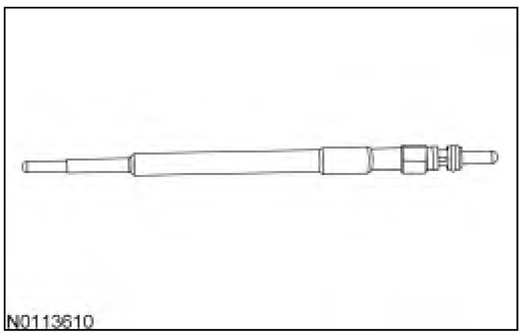
The PCM regulates fuel volume by controlling the duty cycle of the fuel volume control valve. For the Transit, the fuel volume control valve is a normally closed valve. For all others, the fuel volume control valve is a normally open valve. A high duty cycle indicates low fuel volume is being admitted to the high pressure fuel injection pump or low pressure. A low duty cycle indicates high volume is being admitted to the high pressure fuel injection pump or high pressure. The fuel volume control valve is mounted on the high pressure fuel injection pump.



Typical Fuel Volume Control Valve

Glow Plug

The glow plug provides a heat source for combustion to improve cold engine starting and operation. The glow plugs are made of a resistive material that heats up when electricity flows through it. The glow plugs are duty cycle controlled by the glow plug control module (GPCM) and activated when modulated voltage is supplied. The metallic instant start glow plugs can operate up to 8 minutes (Transit). The ceramic instant start glow plugs can operate up to 20 minutes (all others). The GPCM may activate the glow plugs during an extended idle at cold ambient temperatures. The GPCM provides battery voltage for approximately 2 seconds to heat the glow plugs, then modulates the voltage to 7 volts to maintain temperature. For additional information on glow plug system operation, refer to Powertrain Control Hardware Glow Plug Control Module (GPCM) in this section.



Typical Glow Plug

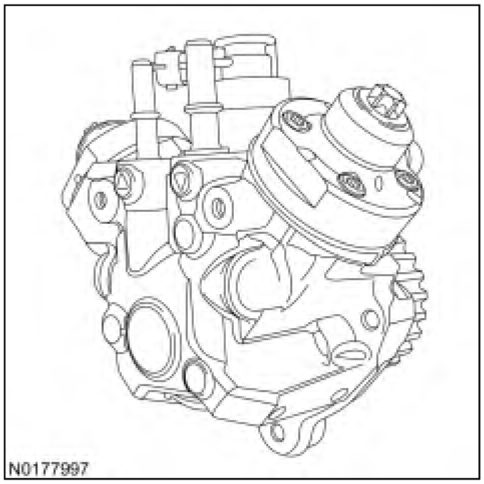
Glow Plug Indicator

The glow plug indicator is located in the instrument panel cluster (IPC) and informs the operator when the engine is ready to start. The indicator is controlled by the IPC based on an electronic command signal from the PCM through the CAN. The on time of the indicator is independent of the glow plug relay on time. For F-650 / F-750 and F-Series Super Duty, as a prove out, the indicator is commanded on at every ignition switch cycle even though the glow plug system may not be operating.

High Pressure Fuel Injection Pump

High Pressure Fuel Injection Pump — F-150

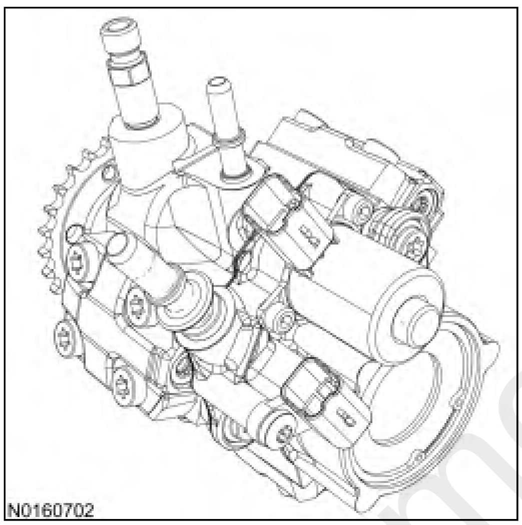
The high pressure fuel injection pump is belt driven with the camshafts and crankshaft and is located in the center at the rear of the engine. It increases the fuel pressure from approximately 414 kPa (70 psi) up to 200 MPa (29,007 psi) and delivers it to the fuel rails.



High Pressure Fuel Injection Pump (F-150)

High Pressure Fuel Injection Pump — Transit

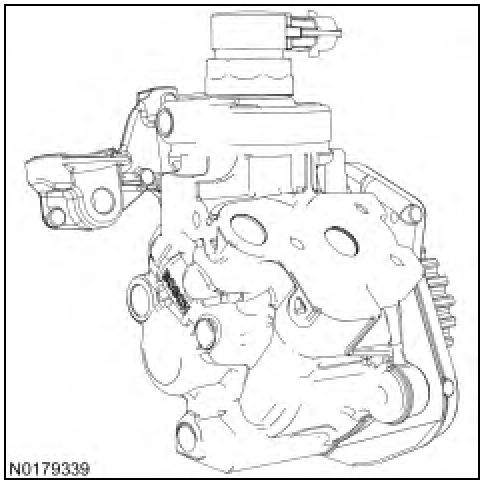
The high pressure fuel injection pump is chain driven with the camshafts and crankshaft and is located at the front left hand side of the engine near the cylinder head. It increases the fuel pressure from approximately 414 kPa (70 psi) up to 200 MPa (29,007 psi) and delivers it to the fuel rails.



High Pressure Fuel Injection Pump (Transit)

High Pressure Fuel Injection Pump — Transit Connect

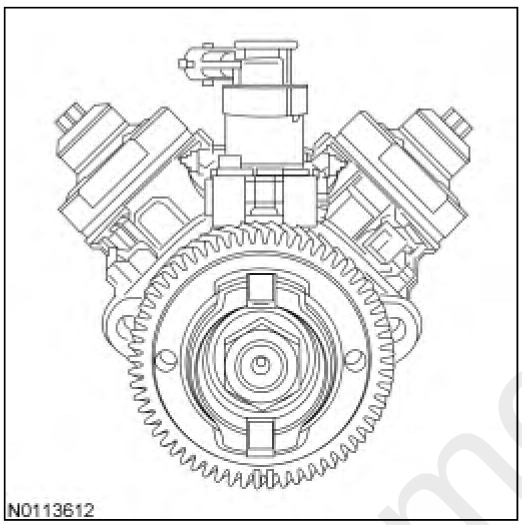
The high pressure fuel injection pump is belt driven and is located at the front right hand side of the engine near the cylinder head. It increases the fuel pressure from approximately 414 kPa (70 psi) up to 200 MPa (29,007 psi) and delivers it to the fuel rail.



High Pressure Fuel Injection Pump (Transit Connect)

High Pressure Fuel Injection Pump — All Others

The high pressure fuel injection pump is gear driven by the camshaft gear and is located at the front of the engine. It increases the fuel pressure from approximately 414 kPa (70 psi) up to 250 MPa (36,259 psi) (F-Series Super Duty) or 200 MPa (29,007 psi) (all others) and delivers it to the fuel rails.

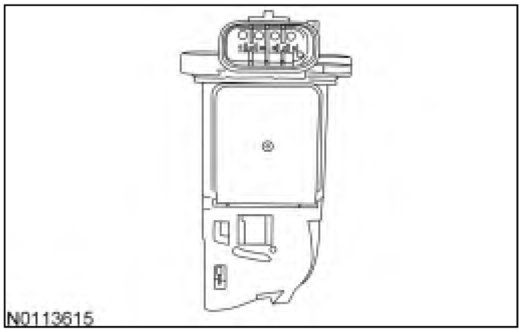


Typical High Pressure Fuel Injection Pump (All Others)

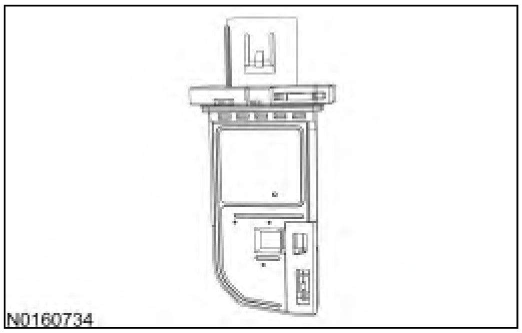
Intake Air Temperature (IAT) Sensor

The IAT sensor is a thermistor device in which resistance changes with temperature. The electrical resistance of a thermistor decreases as the temperature increases, and resistance increases as the temperature decreases. The varying resistance affects the voltage drop across the sensor terminals and provides electrical voltage signals to the PCM corresponding to temperature.

The IAT sensor is integrated with the mass airflow (MAF) sensor. The MAF/IAT sensor is located in the intake air tube between the air filter housing and the turbocharger intake. On some vehicles the turbocharger inlet pressure (TCIP) sensor is integrated with the MAF/IAT sensor.



Typical MAF/IAT Sensor

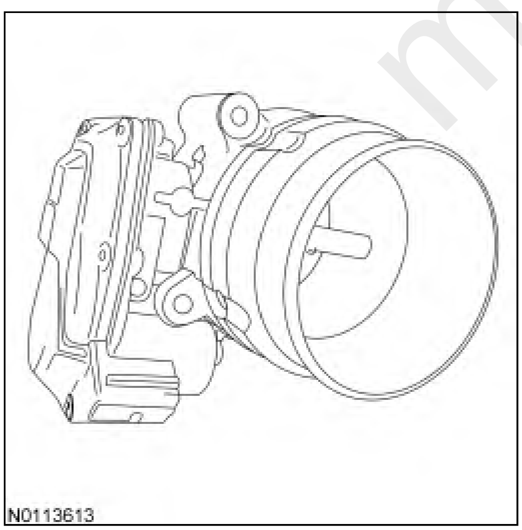


Typical MAF/IAT/TCIP/RHS Sensor

Intake Throttle

The intake throttle modulates the intake airflow from the charge air cooler (CAC) into the intake manifold system. The intake throttle uses an electric motor to open and close a throttle plate, based upon inputs from the PCM. The intake throttle actuator is controlled by a pulse width modulated (PWM) signal to attain the desired position using the TACM+ and TACM- circuits. The throttle position ranges between 0%, or fully open, and 100%, or fully closed.

The PCM senses the intake throttle plate position by monitoring the TP circuit. If the PCM detects an intake throttle plate position concern, a DTC sets indicating the throttle plate is either not at the desired position or the TP circuit is out of range.

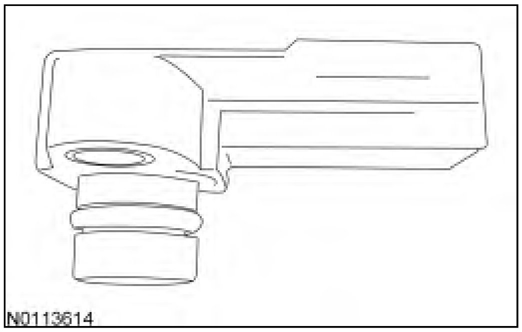


Typical Intake Throttle

Manifold Absolute Pressure (MAP) Sensor

The MAP sensor is a variable capacitor sensor that is supplied a 5 volt reference signal by the PCM and returns a voltage signal to the PCM relative to the intake manifold pressure. The sensor voltage increases as the pressure increases. The

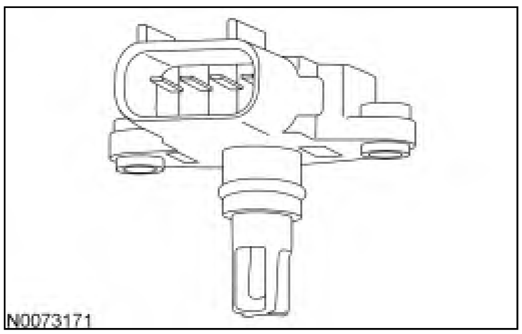
MAP sensor allows the PCM to determine the engine boost to calculate fuel quantity. In addition, the MAP sensor signal is used by the PCM for EGR system calculations and control.



Typical MAP Sensor

Manifold Absolute Pressure Temperature (MAPT) Sensor

The MAPT sensor is located on the intake manifold and may be integrated with an intake air temperature (IAT) sensor or a charge air cooler temperature (CACT) sensor.



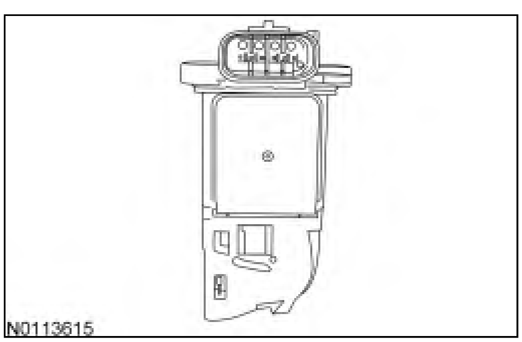
Typical MAPT Sensor

Mass Airflow (MAF) Sensor

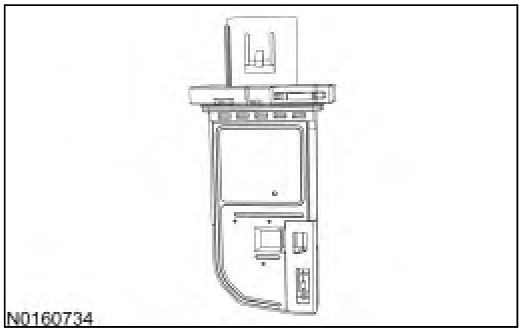
The MAF sensor provides a signal to the PCM proportional to the intake air mass. The MAF sensor uses a hot wire sensing element to measure the amount of air entering the engine. The hot wire is maintained at a constant temperature above ambient. Air passing over the hot wire cools the wire. The current required to maintain the temperature of the hot wire is proportional to the airflow.

The MAF sensor is a digital sensor that provides an output signal of varying frequency. The signals time period is proportional to the flow rate crossing the sensor. The greater the airflow the shorter the time period. The time period varies from 1480 microseconds at a low flow or idle condition, to 106 microseconds at a high flow rate condition.

The IAT sensor is integrated with the mass airflow (MAF) sensor. The MAF/IAT sensor is located in the intake air tube between the air filter housing and the turbochargeoipr intake. On some vehicles the turbocharger inlet pressure (TCIP) sensor and a relative humidity sensor is integrated with the MAF/IAT sensor.



Typical MAF/IAT Sensor



Typical MAF/IAT/TCIP/RHS Sensor

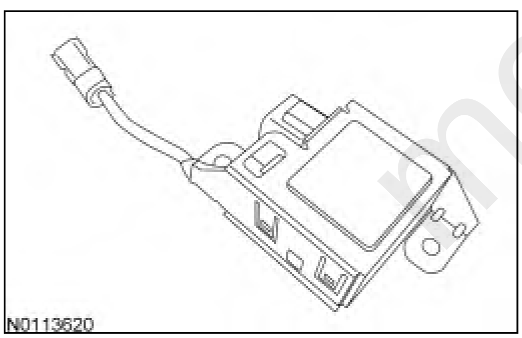
Nitrogen Oxides (NOx) Modules

There are 2 NOx modules for the exhaust system. The nitrogen oxides bank 1, sensor 1 (NOx11) module is located on the right hand frame rail upstream of the selective catalytic reduction (SCR) catalyst. The nitrogen oxides bank 1, sensor 2 (NOx12) module is located on the right hand frame rail downstream of the SCR catalyst.

The NOx modules monitor the NOx sensors and control the NOx sensors heater element. The NOx modules communicate with the PCM through the controller area network (CAN) to report NOx concentrations, oxygen (O_2) concentrations, and NOx sensor system concerns.

The NOx module consists of a microprocessor, RAM, ROM, EEPROM, heater driver, and temperature sensor. The EEPROM stores the module calibration. The heater driver supplies a pulse width modulated (PWM) voltage to the heater portion of the sensor to maintain operational temperature. The microprocessor processes all of the inputs from the sensor and communicates the information to the PCM. The temperature sensor in the module is used for compensating the temperature dependency of circuit components and for NOx module and NOx sensor rationality checks.

On some vehicles, the NOx module and the NOx sensor are an assembly.



Typical NOx Module

Nitrogen Oxides (NOx) Sensors

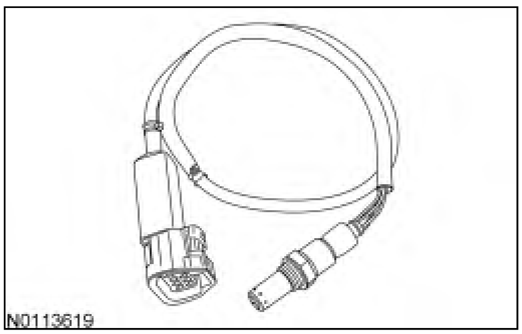
There are two NOx sensors located in the exhaust system. The nitrogen oxides bank 1, sensor 1 (NOx11) sensor is located upstream of the selective catalytic reduction (SCR) catalyst. The nitrogen oxides bank 1, sensor 2 (NOx12) sensor is located downstream of the SCR catalyst.

Each NOx sensor is equipped with a memory component which stores gain and offset characteristics of the sensor to compensate for part to part variation of the element during the manufacturing process.

The NOx11 sensor is only used to detect the presence of NOx concentrations in the exhaust system. The NOx11 sensor has two measurement chambers. The first measurement chamber is for oxygen (O_2) concentration and is not used. The NOx concentration measurement takes place in the second measurement chamber. The exhaust gas passes from the first measurement chamber through a second diffusion barrier into the second measurement chamber. The NOx present in the second measurement chamber is dissociated into nitrogen (N_2) and O_2. The excess O_2 is pumped out of the measurement chamber by the pumping current. The amount of current required to pump the oxygen ions out of the measurement chamber calculates the NOx content. The calculated NOx content is the output from the pumping current controller in the NOx11 module and not a signal directly from the NOx11 sensor.

The NOx12 sensor detects the presence of O_2 and NOx concentrations in the exhaust system. The NOx12 sensor uses two measurement chambers to determine O_2 and NOx concentrations. The O_2 concentration is measured in the first measurement chamber. The exhaust gas enters the first chamber through a diffusion barrier. The NOx12 sensor infers an air to fuel ratio relative to the stoichiometric air to fuel ratio by balancing the amount of oxygen pumped in or out of the measurement chamber. As the exhaust gases become richer or leaner, the amount of oxygen that must be pumped in or out to maintain a stoichiometric air to fuel ratio in the measurement chamber varies in proportion to the air to fuel ratio. The amount of current required to pump the oxygen in or out of the measurement chamber calculates the air to fuel ratio. The calculated air to fuel ratio is the output from the pumping current controller in the NOx12 module and not a signal directly from the NOx12 sensor. The NOx concentration measurement takes place in the second measurement chamber. The exhaust gas passes from the first measurement chamber through a second diffusion barrier into the second measurement chamber. The NOx present in the second measurement chamber is dissociated into nitrogen (N_2) and O_2. The excess O_2 is pumped out of the measurement chamber by the pumping current. The amount of current required to pump the oxygen ions out of the measurement chamber calculates the NOx content. The calculated NOx content is the output from the pumping current controller in the NOx12 module and not a signal directly from the NOx12 sensor.

On some vehicles, the NOx module and the NOx sensor are an assembly.



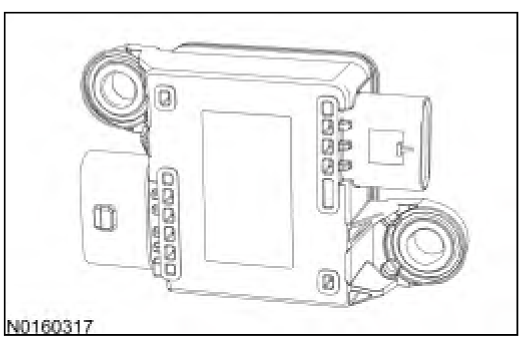
Typical NOx Sensor

Particulate Matter Bank 1, Sensor 1 (PM11) Module

The PM11 module monitors the PM11 sensor and controls the PM11 sensor heater element. The PM11 module communicates with the PCM through the controller area network (CAN) to report the presence of particulates in the exhaust gas, indicating a concern with the diesel particulate filter.

The PM11 module consists of a microprocessor, RAM, ROM, EEPROM, and heater driver. The EEPROM stores the module calibration. The heater driver supplies a pulse width modulated (PWM) voltage to the heater portion of the sensor to clean and regenerate the sensor element. The microprocessor processes all of the inputs from the sensor and communicates the information to the PCM.

The PM11 module is located on the right hand frame rail downstream of the diesel particulate filter.



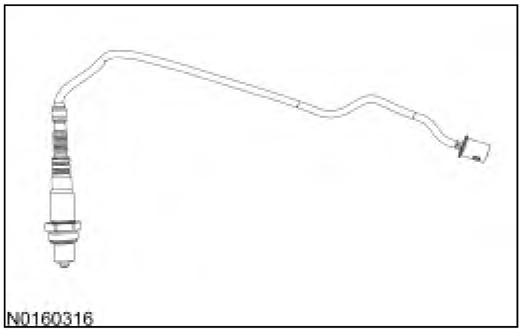
Typical PM11 Module

Particulate Matter Bank 1, Sensor 1 (PM11) Sensor

The PM11 sensor detects the presence of particulates in the filtered exhaust gas. The sensor element consists of comb electrodes of infinite resistance through which exhaust gases pass. Diesel particulates (soot) are primarily carbon and are a good conductor of electricity. When the particulates pass through the electrodes, they allow voltage to pass from one electrode to another, completing a circuit. This change in resistance is detected by the PM11 module and interpreted as soot leakage.

The PM11 sensor also contains a heater element to regenerate the sensor electrodes. The PM11 module activates the heater element, which heats the sensor to greater than 600°C (1112°F) to burn off soot deposits.

The PM11 sensor is located downstream of the diesel particulate filter.



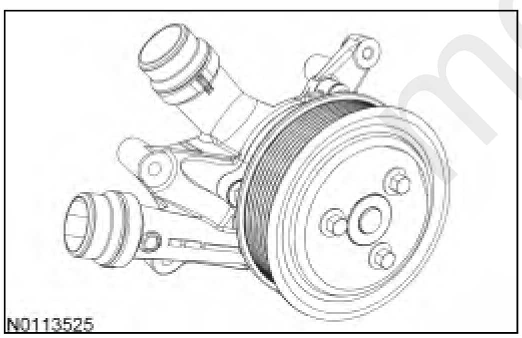
Typical PM11 Sensor

Power Take Off

The PTO system provides an input signal to the PCM indicating there is an additional load being applied to the engine. The PCM disables the on board diagnostic (OBD) monitors and increases the engine RPM based on the PTO system or auxiliary idle control input.

Powertrain Secondary Cooling System Coolant Pump

The belt driven powertrain secondary cooling system coolant pump is mounted to the front of the engine and circulates the coolant which cools the fuel in the fuel cooler system, in addition to cooling other powertrain components. Refer to Fuel System, Fuel Cooling in this section for additional information.



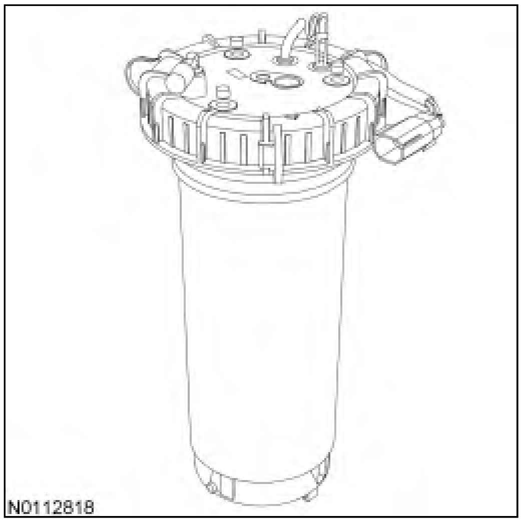
Typical Powertrain Secondary Cooling System Coolant Pump

Reductant Heater And Sender Assembly — Transit

The reductant heater and sender assembly contains the pickup tube for the reductant pump module, an electric heating element, a reductant temperature sensor, and an electrode-type level sensor.

The heating element is directly above the pickup tubes inlet filter. When the reductant temperature sensor detects the diesel exhaust fluid (DEF) temperature dropping to its freezing point of -11°C (12°F), the PCM commands the reductant dosage control module (RDCM) to provide voltage to the heating element. The heating element thaws and maintains a pool of liquid reductant within the reductant heater and sender assembly reservoir during cold ambient temperatures.

The reductant level sensor incorporates four stainless steel electrodes, with three electrodes arranged vertically to provide a high, middle, and low level signal. The fourth electrode runs the length of the level sensor and acts as a ground. The DEF is a good conductor of electricity. When the reductant tank is full, the DEF closes a circuit between all three level electrodes and the ground electrode, indicating the tank is full. As the DEF is consumed, the level drops and uncovers each electrode in sequence. The PCM calculates the DEF level based on these signals.



Typical Reductant Heater And Sender Assembly

Reductant Heaters

Reductant Heaters — Transit

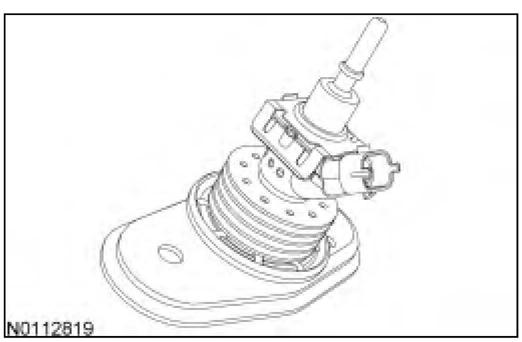
The reductant heaters maintain the diesel exhaust fluid (DEF) in a liquid state during cold ambient temperatures. There are three heating elements in the system, each receiving voltage from the reductant dosage control module. The reductant pressure line heater is integral to the reductant pressure line. The reductant tank heater is integral to the reductant heater and sender assembly. For additional information on the reductant tank heater, refer to the reductant heater and sender assembly description in this section. The reductant pump heater is integral to the reductant pump assembly. For additional information on the reductant pump heater, refer to the reductant pump assembly description in this section.

Reductant Heaters — All Others

The reductant heaters maintain the diesel exhaust fluid (DEF) in a liquid state during cold ambient temperatures. There are two heating elements in the system, each receiving voltage from the reductant dosage control module (Transit Connect) or the glow plug control module (GPCM) (all others). The reductant pressure line heater is integral to the reductant pressure line. The reductant tank heater is integral to the reductant pump assembly. For additional information on the reductant tank heater, refer to the reductant pump assembly description in this section.

Reductant Injector

The reductant injector is a pulse width modulated (PWM) solenoid controlled directly by the PCM. The injector receives diesel exhaust fluid (DEF) from the reductant pressure line and sprays it into the exhaust stream, where it is mixed into the exhaust gases before entering the selective catalytic reduction (SCR) catalyst.



Typical Reductant Injector

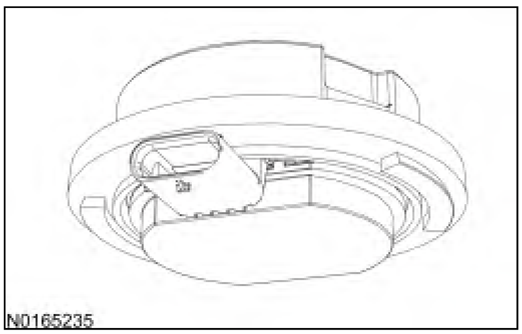
Reductant Quality Module

Reductant Quality Module— Transit

The reductant quality module provides the reductant concentration to the PCM. The reductant quality module incorporates an ultrasonic transducer and sensor assembly, located at the bottom of the reductant tank. The sensor monitors reductant concentration percentage by calculating the speed of sound travel through the diesel exhaust fluid (DEF) and comparing it to an expected value. If this value is not met, the reductant is diluted or contaminated. The reductant quality module is integral to the reductant tank assembly. For addition information on the reductant level sensor, refer to the reductant heater and sender assembly description in this section.

Reductant Quality Module— All Others

The reductant quality module provides the reductant tank level and reductant concentration to the PCM. The reductant quality module incorporates an ultrasonic transducer and sensor assembly, located at the bottom of the reductant tank. The transducer produces timed ultrasonic sound waves through the diesel exhaust fluid (DEF) and the sensor measures the return rate of the sound waves. As the DEF is consumed, the liquid level lowers and the return speed increases. Additionally, the sensor monitors reductant concentration percentage by calculating the speed of sound travel through the DEF and comparing it to an expected value. If this value is not met, the reductant is diluted or contaminated. The reductant quality module is integral to the reductant tank assembly.



Typical Reductant Quality Module (All Others)

Reductant Pressure Sensor

The reductant pressure sensor provides feedback to the RDCM (Transit) or PCM (all others), which regulates system pressure by controlling pump speed using pulse width modulation (PWM). The reductant pressure sensor is integral to the reductant pump assembly. For additional information on the reductant pressure sensor, refer to the reductant pump assembly description in this section.

Reductant Pump Assembly

Reductant Pump Assembly — Transit

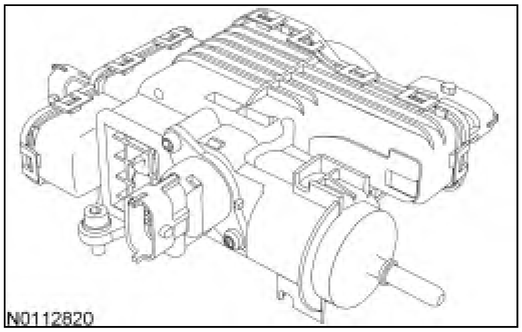
The reductant pump assembly contains a diaphragm pressure pump, a pressure sensor, a purge valve, an outlet filter, and an internal heating element.

The reductant pressure sensor provides feedback to the RDCM, which regulates system pressure by controlling pump speed using pulse width modulation (PWM).

When the RDCM requests reductant injection, the reductant injector opens and the pump operates, filling the reductant pressure line and injector and purging air from the system. When all air is purged, the injector closes and the pump builds pressure to 500 kPa (73 psi). The system is then primed and the injector provides diesel exhaust fluid (DEF) to the selective catalytic reduction (SCR) catalyst as commanded by the RDCM.

When the vehicle is shut down, the RDCM closes the injector and actuates the reductant purge valve, causing the pump to reverse flow and bleed down pressure on the reductant pressure line. The RDCM then opens the injector to allow gas to enter the reductant pressure line, which in turn allows the pump to purge all remaining DEF from the system and return it to the reductant tank. The RDCM closes the injector and returns the purge valve to the forward position.

The RDCM provides voltage to the reductant pump assembly internal heating element when the reductant temperature approaches -11°C (12°F).



Typical Reductant Pump Assembly (Transit)

Reductant Pump Assembly — All Others

The reductant pump assembly contains a rotary vane pump, a pressure sensor, a temperature sensor, and an internal heating element.

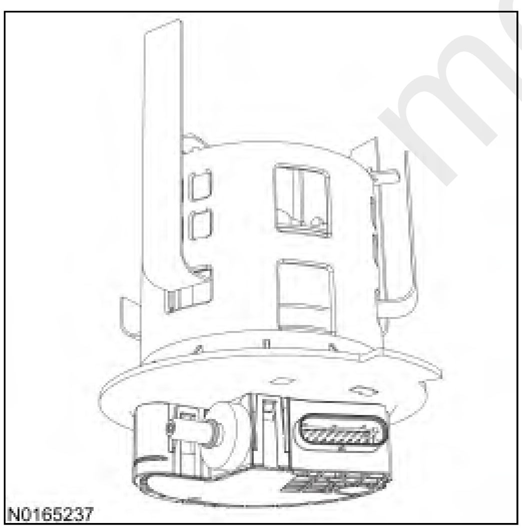
The reductant pressure sensor provides feedback to the PCM, which regulates system pressure by controlling pump speed using pulse width modulated (PWM) signals to the reductant pump control module.

The reductant temperature sensor is a thermistor device which provides feedback to the PCM, which controls the reductant heaters to keep the reductant in a liquid state during low ambient temperatures. The reductant temperature sensor is integral to the reductant pump assembly.

When the PCM requests reductant injection, the reductant injector opens and the pump operates, filling the reductant pressure line and injector and purging air from the system. When all air is purged, the injector closes and the pump builds pressure. The system is then primed and the injector provides diesel exhaust fluid (DEF) to the selective catalytic reduction (SCR) catalyst as commanded by the PCM.

When the vehicle is shut down, the PCM closes the injector and reverses the pump direction, causing the pump to reverse flow and bleed down pressure on the reductant pressure line. The PCM then opens the injector to allow gas to enter the reductant pressure line, which in turn allows the pump to purge all remaining DEF from the system and return it to the reductant tank. The PCM closes the injector and shuts down the reductant pump.

The PCM commands the glow plug control module (GPCM) to provide voltage to the reductant pump assembly internal heating element when the reductant temperature approaches -11°C (12°F).



Typical Reductant Pump Assembly (All Others)

Reductant Purge Valve

The reductant purge valve allows the reductant pump assembly to reverse flow and purge the system when commanded by the PCM. The reductant purge valve is integral to the reductant pump assembly. For additional information on the reductant purge valve, refer to the reductant pump assembly description in this section.

Reductant Temperature Sensor

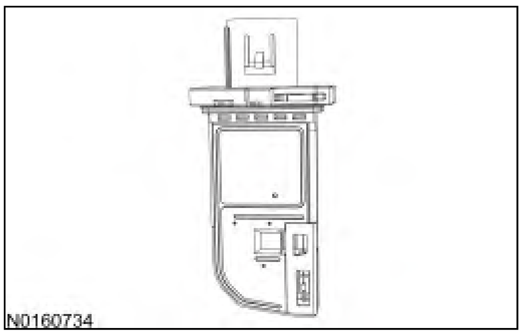
The reductant temperature sensor is a thermistor device in which resistance changes with temperature. The electrical resistance of a thermistor decreases as the temperature increases, and resistance increases as the temperature decreases. The varying resistance affects the voltage drop across the sensor terminals and provides electrical voltage signals to the PCM corresponding to temperature.

The reductant temperature sensor provides feedback to the PCM, which controls the reductant heaters to keep the reductant in a liquid state during low ambient temperatures. The reductant temperature sensor is integral to the reductant quality module (Transit Connect), the reductant heater and sender assembly (Transit) or the reductant pump assembly (all others). For additional information on the reductant temperature sensor, refer to the reductant quality module (Transit Connect), the reductant heater and sender assembly (Transit) or the reductant pump assembly (all others) description in this section.

Relative Humidity (RHS) Sensor

The relative humidity sensor measures the humidity of the intake air by using a membrane allowing air to enter the cell while protecting it from liquid contaminants and dust. Relative humidity is the ratio of water vapor present in the air compared to the maximum amount the air can hold at that temperature and pressure.

The intake air humidity measurement is a key parameter for engine management. The PCM uses the input from the relative humidity sensor to adjust EGR flow rates in high humidity environments.

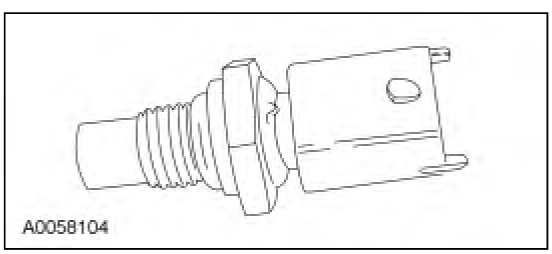


Typical MAF/IAT/TCIP/RHS Sensor

Secondary Cooling System Engine Coolant Temperature 2 (ECT2) Sensor

The secondary cooling system ECT2 sensor is a thermistor device in which resistance changes with temperature. The electrical resistance of a thermistor decreases as the temperature increases, and resistance increases as the temperature decreases. The varying resistance affects the voltage drop across the sensor terminals and provides electrical signals to the PCM corresponding to temperature.

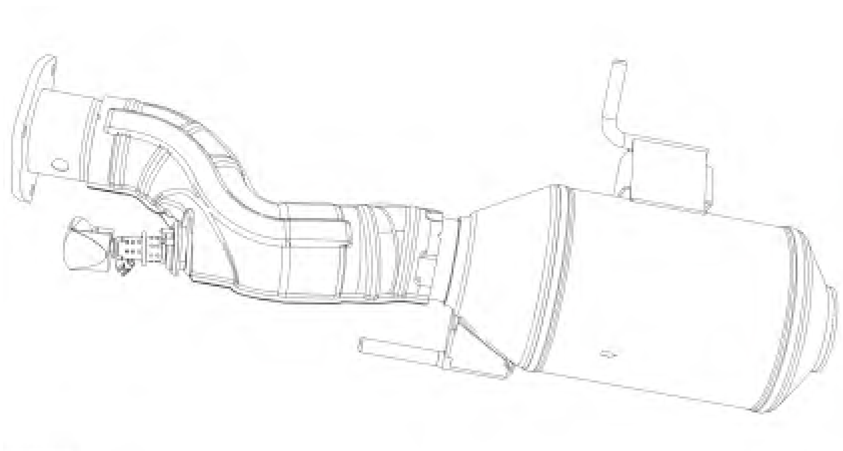
The secondary cooling system ECT2 sensor is located in the coolant hose on the right side of the core support. The secondary cooling system ECT2 sensor measures the temperature of the secondary cooling system and provides a feedback signal to the PCM.



Typical Secondary Cooling System ECT2 Sensor

Selective Catalytic Reduction (SCR) Catalyst

The SCR catalyst reduces nitrogen oxides (NOx) present in the exhaust stream to nitrogen (N_2) and water (H_2O). The SCR catalyst contains a copper catalyst washcoated on a zeolite substrate. At the inlet of the SCR catalyst is a port for the reductant injector, followed by a louvered diffuser and a twist mixer. The reductant diesel exhaust fluid (DEF) is a solution of urea in deionized water. The urea solution percentage for correct SCR system operation is 28 - 35%. When DEF is introduced into the system, it finely atomizes in the louvered diffuser and mixes evenly with exhaust gases in the twist mixer. During this time, the heat of the exhaust gases causes the urea to split into carbon dioxide (CO_2) and ammonia (NH_3). As the ammonia and NOx pass over the SCR catalyst, a reduction reaction takes place and the ammonia and NOx are converted to N_2 and H_2O. This reaction takes place at up to 95% efficiency and allows the engine to run leaner and more efficiently, since the high NOx levels that are produced under lean conditions are eliminated.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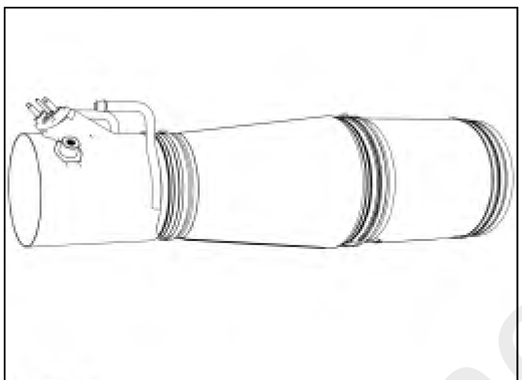
Typical SCR Catalyst (F-150)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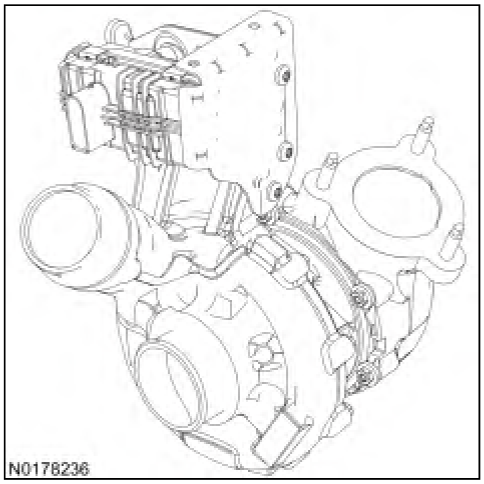
Typical SCR Catalyst (All Others)

Turbocharger

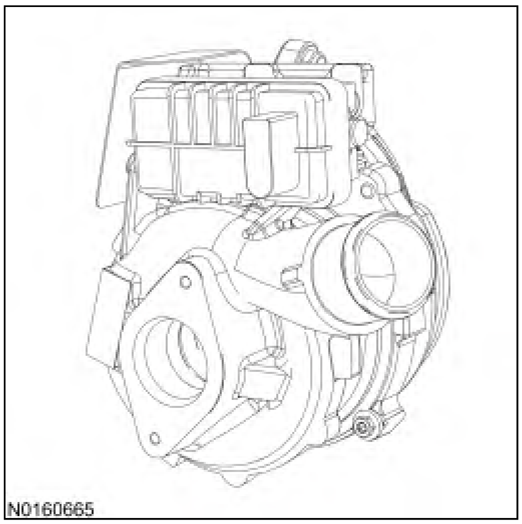
Turbocharger — F150 and Transit

The turbocharger uses variable vanes that surround the turbine wheel to dynamically adjust turbocharger speed using exhaust gas. During engine operation at low speeds and load, the vanes are closed to accelerate exhaust gas across the turbine wheel to help quickly increase turbo wheel speed. At high speeds the vanes open to prevent turbocharger overspeed conditions.

The turbocharger provides up to approximately 158.58 kPa (23 psi) boost at up to 175,000 RPM.



Turbocharger (F-150)



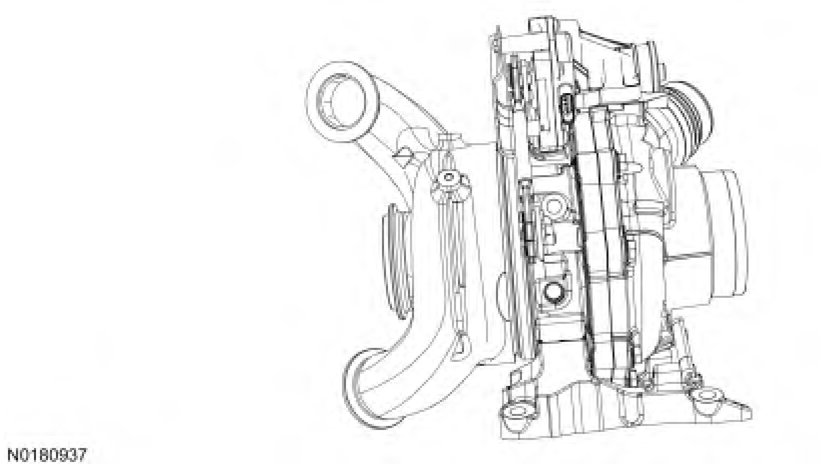
Turbocharger (Transit)

Turbocharger — F-Series Super Duty

The turbocharger uses variable vanes that surround the turbine wheel to dynamically adjust turbocharger speed using exhaust gases. During engine operation at low speeds and load, the vanes are closed to accelerate exhaust gases across the turbine wheel to help quickly increase turbo wheel speed. At high speeds the vanes open to prevent turbocharger overspeed conditions.

The turbocharger uses a ball bearing cartridge that surrounds the turbocharger shaft to help provide a decrease in spool up times. Separate oil and water feeds flow through the turbo mounting pedestal to lubricate and cool the turbocharger to eliminate as many external connections as possible.

The turbocharger provides up to approximately 206.84 kPa (30 psi) boost at up to 130,000 RPM.



Typical Turbocharger (F-Series Super Duty)

Turbocharger — All Others

The turbocharger uses variable vanes that surround the turbine wheel to dynamically adjust turbocharger speed using exhaust gases. During engine operation at low speeds and load, the vanes are closed to accelerate exhaust gases across the turbine wheel to help quickly increase turbo wheel speed. At high speeds the vanes open to prevent turbocharger overspeed conditions.

The turbocharger uses a ball bearing cartridge that surrounds the turbocharger shaft to help provide a decrease in spool up times. Separate oil and water feeds flow through the turbo mounting pedestal to lubricate and cool the turbocharger to eliminate as many external connections as possible.

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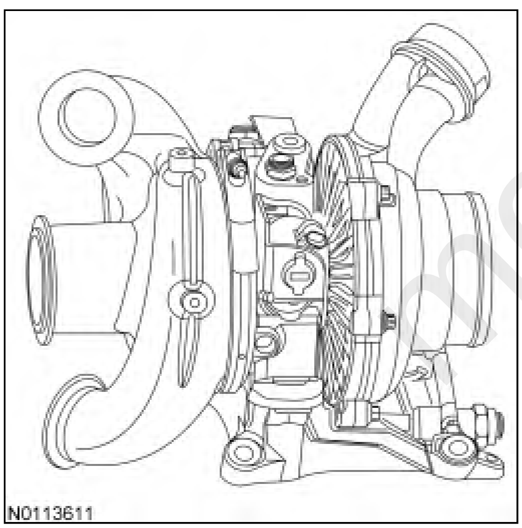
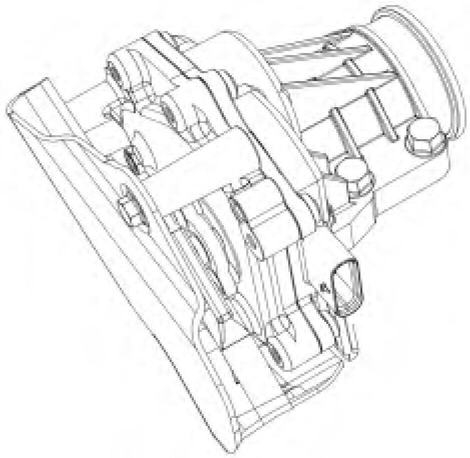


Typical Turbocharger (All Others)

Turbocharger Actuator

Turbocharger Actuator — F-Series Super Duty

The turbocharger actuator contains a stepper motor that moves the VGT vanes to the commanded position with a mechanical linkage. The turbocharger actuator also contains a position sensor for feedback to the PCM.


N0180938

Turbocharger Actuator (F-Series Super Duty)

Turbocharger Actuator — Transit

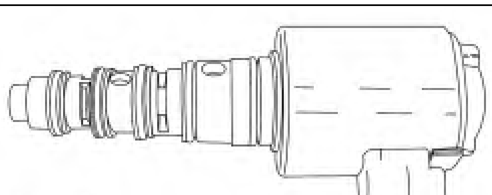
The turbocharger actuator contains a stepper motor that moves the VGT vanes to the commanded position with a mechanical linkage. The turbocharger actuator also contains a position sensor for feedback to the PCM.


N0160666

Turbocharger Actuator (Transit)

Turbocharger Actuator — All Others

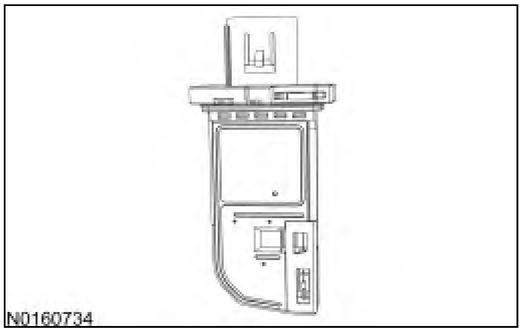
The turbocharger actuator is a 4-way proportional hydraulic flow control valve with a closed center position. The valve controls the linear actuator position of a closed loop hydraulic servo by charging and venting the flow on both sides of a piston. Linear displacement feedback from the actuator varies a feedback spring force to move the valve spool to the center closed position when the actuator reaches the desired position. The actuator position is dependent only on the control valve current and not on the hydraulic fluid temperature and viscosity.


A0058121

Typical Turbocharger Actuator (All Others)

Turbocharger Inlet Pressure (TCIP) Sensor

The TCIPT sensor is located in the intake air tube between the air filter assembly and the turbocharger. The TCIP sensor measures the turbocharger intake pressure. The PCM uses the information from the TCIP sensor to determine if the airflow to the turbocharger is being restricted by a clogged air filter or other debris. On some vehicles the TCIP sensor is integrated with the MAF/IAT sensor.



Typical MAF/IAT/TCIP/RHS Sensor