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2023 Ford E-350 Super Duty Service and Repair Manual

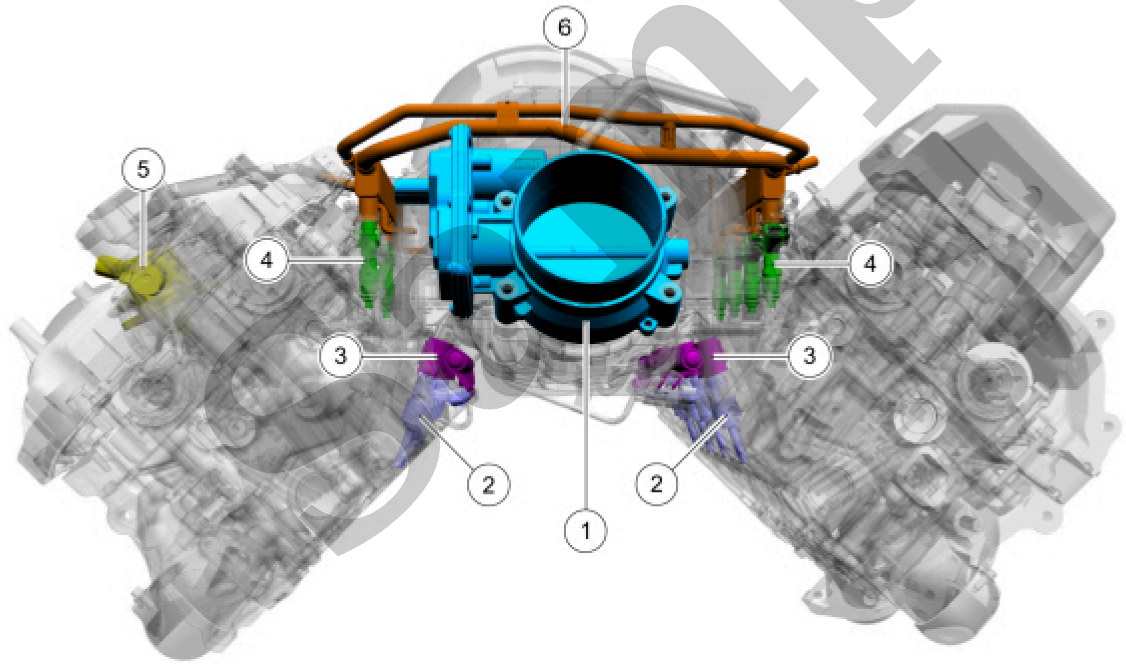
Go to manual page

Fuel Charging and Controls - Component Location

303-04E Fuel Charging and Controls - 5.0L 32V Ti-VCT	***2022 F-150***
Description and Operation	***Procedure revision date: 09/16/2020***

Fuel Charging and Controls - Component Location

5.0L 32V Ti-VCT



Item	Description
1	Throttle body
2	Direct injection fuel injector

Fuel Charging and Controls - System Operation and Component Description

303-04E Fuel Charging and Controls - 5.0L 32V Ti-VCT	***2022 F-150***
Description and Operation	***Procedure revision date: 10/13/2021***

Fuel Charging and Controls - System Operation and Component Description

System Operation

Air Fuel Ratio Imbalance Monitor

The air fuel ratio imbalance monitor is an on board diagnostic strategy designed to monitor the air fuel ratio.

Air Fuel Ratio Imbalance Monitor — Heated Oxygen Sensor (HO2S) Monitor

The air fuel ratio imbalance monitor estimates the cylinder to cylinder air fuel ratio difference using the universal HO2S (heated oxygen sensor) high frequency signal. The high frequency signal is updated at least once per engine combustion event to determine the amount the universal HO2S (heated oxygen sensor) signal is affected by individual cylinders. The result is a measurement of individual cylinder effect on the universal HO2S (heated oxygen sensor) . If the measurement exceeds a calibrated threshold, it is added to a differential signal accumulation window. An accumulation window is at least 50 engine revolutions. The differential signal accumulation is then compared to a calibrated signal threshold. A counter is incremented if the threshold is exceeded. This process is repeated for a calibrated number of total windows. After completing the calibrated number of windows the air fuel ratio imbalance index is calculated. The air fuel ratio imbalance index is a ratio of failed RPM (revolutions per minute) windows over total RPM (revolutions per minute) windows required to complete the monitor. If the air fuel ratio imbalance index exceeds the threshold value the test fails.

The MIL (malfunction indicator lamp) is activated after a concern is detected on 2 consecutive drive cycles.

Air Fuel Ratio Imbalance Monitor — Torque Monitor

The air fuel ratio imbalance torque monitor is supplemented by the air fuel ratio imbalance monitor HO2S (heated oxygen sensor) monitor. The air fuel ratio imbalance monitor torque monitor is used to detect small

- A cold start with alcohol blended fuel may be more difficult than with gasoline, due to the lower volatility of alcohol blended fuel.
- Ethanol requires more fuel flow than gasoline, and flex fuel vehicles require a higher flow injector.
- Vehicles with flex fuel capability have the fuel type identified on the fuel filler pipe.

Fuel Injection Systems

There are 2 types of fuel injection systems, direct fuel injection and port fuel injection. The direct fuel injection system delivers fuel directly into the engine cylinder. The port fuel injection system delivers fuel into the intake manifold ports where the fuel is mixed with air and enters the engine cylinder through the intake valve.

On engines with dual fuel injection systems, both the direct fuel injection system and the port fuel injection system are used to deliver fuel to the engine. During heavy acceleration, or higher engine loads, the direct fuel injection system is used to deliver fuel to the engine. During idle, or low engine load conditions, the port fuel injection system is used to deliver fuel to the engine. Both fuel injection systems may not be active at the same time. The PCM (powertrain control module) will ignore any related fuel system sensor inputs, if either fuel injection system is inactive. Related fuel injector DTCs can only be set while the direct fuel injection system or the port fuel injection system is active. A scan tool may be used to activate either system to assist in isolating the fuel injector concerns.

Fuel System Monitor

The fuel system monitor is an on board strategy designed to monitor the fuel control system. The fuel control system uses fuel trim tables stored in the PCM (powertrain control module) KAM (keep alive memory) to compensate for the variability that occurs in fuel system components due to normal wear and aging. Fuel trim tables are based on air mass. During closed loop fuel control, the fuel trim strategy learns the corrections needed to correct a biased rich or lean fuel system. The correction is stored in the fuel trim tables. The fuel trim has 2 means of adapting: long term fuel trim and a short term fuel trim. Long term fuel trim relies on the fuel trim tables and short term fuel trim refers to the desired air to fuel ratio parameter called LAMBSE. LAMBSE is calculated by the PCM (powertrain control module) from the universal HO2S (heated oxygen sensor) inputs and helps maintain a 14.7 to 1 (9 to 1 E100) air to fuel ratio during closed loop operation. Short term fuel trim and long term fuel trim work together. If the universal HO2S (heated oxygen sensor) indicates the engine is running rich, the PCM (powertrain control module) corrects the rich condition by moving the short term fuel trim into the negative range, less fuel to correct for a rich combustion. If after a certain amount of time the short term fuel trim is still compensating for a rich condition, the PCM (powertrain control module) learns this and moves the long term fuel trim into the negative range to compensate and allow the short term fuel trim to return to a value near 0%. Inputs from the CHT (cylinder head temperature) sensor or the ECT (engine coolant temperature) sensor, the IAT (intake air temperature) sensor and the MAF (mass air flow) sensor (if equipped) are required to activate the fuel trim system, which in turn activates the fuel system monitor. Once activated, the fuel system monitor looks for the fuel trim tables to reach the adaptive clip fuel trim (SHRTFT1 and SHRTFT2) where stoichiometric is represented by 0%. Richer (more fuel) is represented by a positive number and leaner (less fuel) is represented by a negative number. Normal operating range for short term fuel trim is between -25% and 25%. Some calibrations have time between switches and short term fuel trim excursions that are not equal. These unequal excursions run the system slightly lean or rich of stoichiometric. This practice is referred to as using bias. For example, the fuel system can be biased slightly rich during closed loop fuel to help reduce nitrogen oxides (NO_x).

Values for SHRTFT1 and SHRTFT2 may change significantly on a scan tool as the engine is operated at different RPM (revolutions per minute) and load points. This is because SHRTFT1 and SHRTFT2 react to fuel delivery variability that changes as a function of engine RPM (revolutions per minute) and load. Short term fuel trim values are not retained after the engine is turned OFF.

Long Term Fuel Trim

While the engine is operating in closed loop fuel control, the short term fuel trim corrections are learned by the PCM (powertrain control module) as long term fuel trim (LONGFT1 and LONGFT2) corrections. These corrections are stored in the KAM (keep alive memory) fuel trim tables. Fuel trim tables are based on engine speed and load and by bank for engines with 2 HO2S (heated oxygen sensor) forward of the catalyst. Learning the corrections in KAM (keep alive memory) improves both open loop and closed loop air fuel ratio control. Advantages include:

- Short term fuel trim does not have to generate new corrections each time the engine goes into closed loop.
- Long term fuel trim corrections can be used while in open loop and closed loop modes.

Long term fuel trim is represented as a percentage, similar to the short term fuel trim, however it is not a single parameter. A separate long term fuel trim value is used for each RPM (revolutions per minute) and load point of engine operation. Long term fuel trim corrections may change depending on the operating conditions of the engine (RPM (revolutions per minute) and load), ambient air temperature, and fuel quality (% alcohol, oxygenates). When viewing the LONGFT1 and LONGFT2 PIDs, the values may change a great deal as the engine is operated at different RPM (revolutions per minute) and load points. The LONGFT1 and LONGFT2 PID display the long term fuel trim correction currently being used at that RPM (revolutions per minute) and load point.

High Pressure Fuel System

The high pressure fuel system receives low pressure fuel from the fuel pump assembly and delivers fuel at high pressure to the direct injection fuel injectors.

The high pressure fuel system consists of the fuel injection pump, the fuel volume regulator, the FRP (fuel rail pressure) sensor, the fuel supply line, the fuel rail, and the fuel injectors.

The fuel injection pump receives fuel from the fuel pump assembly, increases the fuel pressure from approximately 448 kPa (65 psi) to a PCM (powertrain control module) determined pressure up to as high as 15 MPa (2175 psi), and delivers it to the fuel rails.

A functional test of the rear HO2S (heated oxygen sensor) is done during normal vehicle operation. The peak rich and lean voltages are continuously monitored. Voltages that exceed the calibrated rich and lean thresholds indicate a functional sensor. If the voltages have not exceeded the thresholds after a long period of vehicle operation, the air to fuel ratio may be forced rich or lean in an attempt to get the rear sensor to switch. This situation normally occurs only with a green, less than 804.7 km (500 miles), catalyst. If the sensor does not exceed the rich and lean peak thresholds, a concern is indicated. Also, a deceleration fuel shut off (DFSO) rear HO2S (heated oxygen sensor) response test is done during a deceleration fuel shut off (DFSO) event. Carrying out the HO2S (heated oxygen sensor) response test during a DFSO event helps to isolate a sensor concern from a catalyst concern. The response test monitors how quickly the sensor switches from a rich to lean voltage. It also monitors if there is a delay in the response to the rich or lean condition. If the sensor responds very slowly to the rich to lean voltage switch or is never greater than a rich voltage threshold or less than a lean voltage threshold, a concern is indicated.

The MIL (malfunction indicator lamp) is activated after a concern is detected on 2 consecutive drive cycles.

Idle Air Trim

Idle air trim is designed to adjust the idle air control calibration to correct for wear and aging of components. When the engine conditions meet the learning requirement, the strategy monitors the engine and determines the values required for ideal idle calibration. The idle air trim values are stored in a table for reference. This table is used by the PCM (powertrain control module) as a correction factor when controlling the idle speed. The table is stored in the KAM (keep alive memory) and retains the learned values even after the engine is shut OFF. A DTC (diagnostic trouble code) is set if the idle air trim has reached its learning limits.

Whenever an idle air control component is replaced, or a repair affecting idle is carried out, it is recommended the KAM (keep alive memory) be reset. This is necessary so the idle strategy does not use the previously learned idle air trim values. It is important to note that erasing DTCs with a scan tool does not reset the idle air trim table.

Once the KAM (keep alive memory) has been reset, the engine must idle for 15 minutes (actual time varies between strategies) to learn new idle air trim values. Idle quality improves as the strategy adapts. Adaptation occurs in 4 separate modes as shown in the following table.

Idle Air Trim Learning Modes

NEUTRAL	A/C ON
NEUTRAL	A/C OFF
DRIVE	A/C ON
DRIVE	A/C OFF

Sensor Response With Brake Override	plate response to the APP (accelerator pedal position) sensor input is delayed as the accelerator pedal is applied. The engine returns to idle RPM (revolutions per minute) whenever the brake pedal is applied. The powertrain malfunction indicator (wrench) illuminates, but the MIL (malfunction indicator lamp) does not illuminate in this mode. An APP (accelerator pedal position) sensor related DTC (diagnostic trouble code) sets.
Time Based Driver Demand With Brake Override	This mode is caused by the loss of one BPP (brake pedal position) and one APP (accelerator pedal position) sensor input or both APP (accelerator pedal position) sensor inputs due to sensor, wiring, or PCM (powertrain control module) concerns. The system is unable to determine driver demand. There is no response when the accelerator pedal is applied. The engine returns to idle RPM (revolutions per minute) whenever the brake pedal is applied. When the brake pedal is released, the PCM (powertrain control module) slowly increases the APP (accelerator pedal position) signal to a fixed value. The powertrain malfunction indicator (wrench) illuminates, but the MIL (malfunction indicator lamp) does not illuminate in this mode. An APP (accelerator pedal position) or BPP (brake pedal position) sensor related DTC (diagnostic trouble code) sets.
RPM (revolutions per minute) Guard With Pedal Follower	In this mode, torque control is disabled due to the loss of a critical sensor or PCM (powertrain control module) concern. The throttle is controlled in pedal follower mode as a function of the APP (accelerator pedal position) sensor input only. A maximum allowed RPM (revolutions per minute) is determined based on the position of the accelerator pedal (RPM (revolutions per minute) Guard). If the actual RPM (revolutions per minute) exceeds this limit, spark and fuel are used to bring the RPM (revolutions per minute) below the limit. The powertrain malfunction indicator (wrench) and the MIL (malfunction indicator lamp) illuminate in this mode and a DTC (diagnostic trouble code) for an ETC related component sets. The EGR (exhaust gas recirculation) and VCT (variable camshaft timing) outputs are set to default values and cruise control is disabled.
RPM (revolutions per minute) Guard With Default Throttle	In this mode, the throttle plate control is disabled due to the loss of both TP (throttle position) sensor inputs, loss of throttle plate control, stuck throttle plate, significant processor concerns, or other major electronic throttle body concern. The spring returns the throttle plate to the default (limp home) position. A maximum allowed RPM (revolutions per minute) is determined based on the position of the accelerator pedal (RPM (revolutions per minute) Guard). If the actual RPM (revolutions per minute) exceeds this limit, spark and fuel are used to bring the RPM (revolutions per minute) below the limit. The powertrain malfunction indicator (wrench) and the MIL (malfunction indicator lamp) illuminate in this mode and a DTC (diagnostic trouble code) for an ETC

Do not apply battery positive (B+) voltage directly to the fuel injector electrical connector pins. Internal damage to the solenoid may occur in a matter of seconds.

The fuel injector is a solenoid operated valve that meters fuel flow to the engine. The fuel injector opens and closes a constant number of times per crankshaft revolution. The amount of fuel is controlled by the length of time the fuel injector is held open.

The fuel injector is normally closed and is operated by a 12 volt source. The ground signal is controlled by the PCM (powertrain control module) .

The fuel injector is a deposit resistant injector (DRI) type and does not have to be cleaned. Install a new fuel injector if the flow is checked and found to be out of specification.

Fuel Injectors — Direct Injection

The gasoline direct fuel injection fuel injector delivers fuel directly into the cylinder under high pressure. Each injector is controlled by 2 circuits from the PCM (powertrain control module) .

A boosted voltage supply, up to 65 volts, is generated in the PCM (powertrain control module) and used to initially open the injector. The injector driver controls three transistor switches that apply the boost voltage to open the injector and then modulates the current to hold the injector open. If boost voltage is unavailable, the correct injector opening current may not be generated in the time required.

The PCM (powertrain control module) contains a smart driver that monitors and compares high side and low side injector currents to diagnose numerous concerns. Each fuel injector high side circuit is paired inside the PCM (powertrain control module) with another fuel injector high side circuit. All injector concerns are reported with a single DTC per injector.

Fuel Rail Pressure (FRP) Sensor

The FRP (fuel rail pressure) sensor sensor is a diaphragm strain gauge device. The FRP (fuel rail pressure) sensor sensor measures the pressure difference between the fuel rail and atmospheric pressure. The FRP (fuel rail pressure) sensor sensor nominal output varies between 0.5 and 4.5 volts, with 0.5 volts corresponding to 0 MPa (0 psi) gauge and 4.5 volts corresponding to 26 MPa (3771 psi) gauge. The FRP (fuel rail pressure) sensor can read vacuum and may lower the output voltage to slightly below 0.5 volts. This condition is normal and is usually the case after several hours of cold soak.

The FRP (fuel rail pressure) sensor sensor is located on the fuel rail and provides a feedback signal to indicate the fuel rail pressure to the PCM (powertrain control module) . The PCM (powertrain control module) uses the fuel rail pressure (FRP) signal to command the correct injector timing and pulse width for correct fuel delivery at all speed and load conditions. The FRP (fuel rail pressure) sensor, along with the fuel volume regulator (part of the fuel injection pump), form a closed loop fuel pressure control system. An electrically faulted FRP (fuel rail pressure) sensor sensor results in the deactivation of the fuel injection pump. Fuel pressure to injectors is then provided only by the fuel pump (FP) assembly. When the fuel injection pump is de-energized and the injectors are active, the fuel rail pressure is approximately 70 kPa (10 psi) lower than fuel pump (FP)

The universal HO2S (heated oxygen sensor) , sometimes referred to as a wideband oxygen sensor, uses the typical HO2S (heated oxygen sensor) combined with a current controller in the PCM (powertrain control module) to infer an air to fuel ratio relative to the stoichiometric air to fuel ratio. This is accomplished by balancing the amount of oxygen ions pumped in or out of a measurement chamber within the sensor. The typical HO2S (heated oxygen sensor) within the universal HO2S (heated oxygen sensor) detects the oxygen content of the exhaust gas in the measurement chamber. The oxygen content inside the measurement chamber is maintained at the stoichiometric air to fuel ratio by pumping oxygen ions in and out of the measurement chamber. As the exhaust gasses get 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 ions in or out of the measurement chamber is used to measure the air to fuel ratio. The measured air to fuel ratio is actually the output from the current controller in the PCM (powertrain control module) and not a signal that comes directly from the sensor.

The universal HO2S (heated oxygen sensor) also uses a self contained reference chamber to make sure an oxygen differential is always present. The oxygen for the reference chamber is supplied by pumping small amounts of oxygen ions from the measurement chamber into the reference chamber.

Part to part variance is compensated for by placing a resistor in the connector. This resistor trims the current measured by the current controller in the PCM (powertrain control module) .

The universal HO2S (heated oxygen sensor) heater is embedded with the sensing element allowing the engine to enter closed loop operation sooner. The heating element heats the sensor to a temperature of 780°C to 830°C (1,436°F to 1,526°F). The VPWR circuit supplies voltage to the heater. The PCM (powertrain control module) controls the heater ON and OFF by providing the ground to maintain the sensor at the correct temperature for maximum accuracy.

PCM (powertrain control module)	P0040:00	Oxygen Sensor Signals Swapped Bank 1 Sensor 1/Bank 2 Sensor 1: No Sub Type Information	GO to Pinpoint Test DZ
PCM (powertrain control module)	P0041:00	Oxygen Sensor Signals Swapped Bank 1 Sensor 2/Bank 2 Sensor 2: No Sub Type Information	GO to Pinpoint Test DW
PCM (powertrain control module)	P0050:00	HO2S Heater Control Circuit (Bank 2 Sensor 1): No Sub Type Information	GO to Pinpoint Test DZ
PCM (powertrain control module)	P0053:00	HO2S Heater Resistance (Bank 1 Sensor 1): No Sub Type Information	GO to Pinpoint Test DZ
PCM (powertrain control module)	P0054:00	HO2S Heater Resistance (Bank 1 Sensor 2): No Sub Type Information	GO to Pinpoint Test DW
PCM (powertrain control module)	P0056:00	HO2S Heater Control Circuit (Bank 2 Sensor 2): No Sub Type Information	GO to Pinpoint Test DW
PCM (powertrain control module)	P0059:00	HO2S Heater Resistance (Bank 2 Sensor 1): No Sub Type Information	GO to Pinpoint Test DZ
PCM (powertrain control module)	P0060:00	HO2S Heater Resistance (Bank 2 Sensor 2): No Sub Type Information	GO to Pinpoint Test DW
PCM (powertrain control module)	P00D2:00	HO2S Heater Control Circuit Range/Performance (Bank 1 Sensor 2): No Sub Type Information	GO to Pinpoint Test DW
PCM (powertrain control module)	P0130:00	O2 Sensor Circuit (Bank 1 Sensor 1): No Sub Type Information	GO to Pinpoint Test DZ
PCM (powertrain control module)	P0131:00	O2 Sensor Circuit Low Voltage (Bank 1 Sensor 1): No Sub Type Information	GO to Pinpoint Test DZ