Table of Contents

Description.....279

EGED 310-1 Diagnostic Form.....279
- **Electronic Control System Diagnostics**.....279

Sensor and Actuator Locations.....281
- **Engine Mounted Components**.....281
- **Vehicle Mounted Components**.....282

Diagnostic Procedures for Sensors and Actuators.....283
- **Pin Grip Inspection**.....283
- **V_{REF} Tests using MasterDiagnostics®**.....283
- **Temperature Sensor Tests using MasterDiagnostics®**.....284

Pin-Point Diagnostics.....285
- **Voltage Checks - Connectors**.....285
- **Voltage Checks - Connector to Ground**.....285
- **Harness Resistance Checks**.....286
- **Operational Voltage Checks**.....286

Circuit Diagnostics.....287
- **AMS (Air Management System)**.....287
  - **AMS Operation**.....288
- **APS/IVS (Accelerator Pedal Position Sensor and Idle Validation Switch)**.....291
  - **APS/IVS Circuit Operation**.....293
  - **APS/IVS Operational Diagnostics**.....296
  - **APS/IVS Pin-Point Diagnostics (CF)**.....298
  - **APS/IVS Pin-Point Diagnostics (Stripped Chassis)**.....302
- **ATA (American Trucking Association) Datalink**.....306
  - **ATA Circuit Operation**.....307
  - **ATA Pin-Point Diagnostics**.....309
- **BAP (Barometric Absolute Pressure) Sensor**.....311
  - **BAP Circuit Operation**.....312
  - **BAP Pin-Point Diagnostics**.....313
- **BCS (Boost Control Solenoid) Assembly**.....316
  - **BCS Circuit Operation**.....317
  - **BCS Assembly Pin-Point Diagnostics**.....318
- **Brake Switch Circuits**.....321
  - **Brake Switch Circuit Operation**.....322
  - **Brake Switch Circuits Pin-Point Diagnostics**.....323
- **CAN (Controller Area Network) Communications**.....325
  - **CAN Pin-Point Diagnostics**.....327
- **CKP (Crankshaft Position) Sensor**.....329
  - **CKP Circuit Operation**.....330
  - **CKP Pin-Point Diagnostics**.....331
- **CMP (Camshaft Position) Sensor**.....333

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CMP Circuit Operation....334
CMP Pin-Point Diagnostics....335
ECI (Engine Crank Inhibit) System....337
ECI Circuit Diagnostics....339
ECL Sensor (Engine Coolant Level)....341
ECL Circuit Operation....342
ECL Pin-Point Diagnostics....343
ECM (Electronic Control Module) Self-Diagnostics....345
ECM Self Diagnostic Trouble Codes (DTCs)....345
ECM/IDM (Electronic Control Module and Injector Driver Module) Communications....348
ECM/IDM Circuit Operation....349
ECM/IDM Pin-Point Diagnostics....351
ECM PWR (Electronic Control Module Power)....355
ECM PWR Circuit Operation....356
ECM PWR Pin-Point Diagnostics....358
ECT (Engine Coolant Temperature) Sensor....361
ECT Circuit Operation....363
ECT Operational Diagnostics....364
ECT Pin-Point Diagnostics....366
EFAN Control (Engine Fan Control)....368
Fan Clutch Circuit Operation....368
Fan Clutch Pin-Point Diagnostics....370
EGR (Exhaust Gas Recirculation) Control....374
EGR Circuit Operation....376
EGR Pin-Point Diagnostics....379
EOP (Engine Oil Pressure) Switch....396
EOP Circuit Operation....397
EOP Operational Diagnostics - DTC 225....398
EOP Operational Diagnostics - DTC 313....399
EOP Pin-Point Diagnostics....401
EOT (Engine Oil Temperature) Sensor....403
EOT Circuit Operation.... 405
EOT Operational Diagnostics....406
EOT Pin-Point Diagnostics....408
EWPS (Engine Warning and Protection System)....410
EWPS Operational Descriptions....411
EWPS Operational Diagnostics....412
GPC (Glow Plug Control) Circuit....415
GPC Circuit Operation....416
GPC Pin-Point Diagnostics....418
HFCM (Horizontal Fuel Conditioning Module) Fuel Pump 421
Fuel Pump Circuit Operation....422
Fuel Pump Pin-Point Diagnostics....424
IAH (Inlet Air Heater) Circuit....431
IAH Circuit Operation....432
IAH Pin-Point Diagnostics....434
IAT (Intake Air Temperature) Sensor....438
IAT Circuit Operation....439
IAT Operational Diagnostics....441
IAT Pin-Point Diagnostics....444
ICP (Injection Control Pressure) Sensor....447

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ICP Circuit Operation....448
ICP Operational Diagnostics....450
ICP Pin-Point Diagnostics....453
ICP (Injection Control Pressure) System....457
ICP System Operation....458
IDM PWR (Injector Drive Module) Power....466
IDM PWR Circuit Operation....467
IDM PWR Pin-Point Diagnostics....469
12-Pin Breakout Harness....470
INJ (Injector Drive) Circuits....475
INJ Circuit Operation....475
INJ Pin-Point Diagnostics....476
IPR (Injection Pressure Regulator)....483
IPR Circuit Operation....484
IPR Pin-Point Diagnostics....486
IST (Idle Shutdown Timer) System....488
IST Operation....488
MAF (Mass Air Flow) Sensor....490
MAF Circuit Operation....492
MAF Pin-Point Diagnostics....494
MAP (Manifold Absolute Pressure) Sensor....497
MAP Circuit Operation....498
MAP Operational Diagnostics....499
MAP Pin-Point Diagnostics....501
MAT (Manifold Air Temperature) Sensor....505
MAT Circuit Operation....506
MAT Operational Diagnostics....507
MAT Pin-Point Diagnostics....509
SCCS (Speed Control Command Switches)....511
SCCS Circuit Operation....511
SCCS Pin-Point Diagnostics....513
Tachometer Output Circuit....518
Tachometer Pin-Point Diagnostics....519
V_{REF} (Reference Voltage)....521
V_{REF} Circuit Operation....522
V_{REF} Pin-Point Diagnostics....523
WIF (Water In Fuel) Sensor....526
WIF Circuit Operation....527
WIF Operational Diagnostics....527
WIF Pin-Point Diagnostics....528

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Description

This section includes the following diagnostic information:

Electronic Control System Diagnostic form EGED 310-1

Sensor and actuator locations

Sensor and actuator tests

Diagnostic procedures for sensors and actuators

Pin-point diagnostics

Circuit diagnostics - Circuit diagnostics pertain to a specific ECM circuit and has the following structure:

Function diagram and text

Circuit diagram and diagnostic tests to diagnose Diagnostic Trouble Codes (DTCs) and verify circuit functions

EGED 310-1 Diagnostic Form

Electronic Control System Diagnostics

Engine diagnostic forms assist technicians in troubleshooting International® VT 275 diesel engines. Diagnostic schematics and signal values help technicians find problems systematically and quickly to avoid unnecessary repairs.

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Figure 310 Electronic Control System Diagnostics form EGED 310-1 (front)

The front side of the Electronic Control System Diagnostics form EGED 310-1 consists of a circuit diagram for electrical components mounted on the engine and related vehicle circuits. For detailed description of vehicle circuits see Electrical Circuit Diagram manual for circuit numbers, connector and fuse locations. The back side of the form consists of signal values for the engine circuits.

NOTE: All recorded signal values are with the Breakout Box installed on the Electronic Control Module (ECM) and harness.

Electronic Control System Diagnostic Form EGED 310-1 is available in 50 sheet pads and can be ordered from:

International Truck and Engine Corporation
Order Desk

Printing and Distribution Services

C/O Moore Wallace North America

1750 Wallace Avenue

St. Charles, IL 60174

Phone (630) 313-7507

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Sensor and Actuator Locations

Engine Mounted Components

Figure 311 Top

Figure 312 Front

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Figure 313 MAF/IAT location

Vehicle Mounted Components

Figure 314 APS/IVS sensor (CF)

The APS/IVS sensor is located above the accelerator pedal.

Figure 315 APS/IVS sensors (stripped chassis)

The BAP sensor is located in the Driver Control Module (DCM) near the steering column.

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Diagnostic Procedures for Sensors and Actuators

Pin Grip Inspection

Figure 316 Male pin grip test

Figure 317 Female pin grip test

1. Disconnect the harness connector from the switch, sensor, or actuator.
2. Inspect for corrosion, bent pins, spread terminals, or conditions that could cause a loose or intermittent connection.
3. Inspect the harness connector sealing surfaces to insure a tight, water proof seal.
4. Check the pin grip in both the female and male terminals by inserting the correct tool from Terminal Test Adapter Kit.

V_{REF} Tests using MasterDiagnostics®

1. Plug the Electronic Service Tool (EST) tool into the American Trucking Association (ATA) datalink connector and start MasterDiagnostics®.
2. Disconnect sensor to be tested.
3. Install correct breakout harness to engine harness only.
4. Turn ignition switch to ON (do not crank the engine).
5. Monitor signal voltage with the EST using continuous monitor session and initiating KOEO Continuous Monitor Test. Voltage should be near 0, unless the signal circuit is shorted or incorrectly wired to V_{REF}, B+, or other voltage sources. See diagnostic table in this section for the sensor being tested.

Figure 318 V_{ref} check

6. Use a Digital Multimeter (DMM) to verify V_{REF} at BLUE (V_{REF}) pin in breakout harness (should be 5 ± 0.5 volts).

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V_{ref} check with breakout harness

Greater than 5.5 volts	5 ± 0.5 V	Check V_{REF} for short to B+
Less than 4.5 volts	5 ± 0.5 V	Check V_{REF} for open or short to ground

7. Install 500 ohm resistor harness between GREEN (signal circuit), and BLUE (V_{REF}) pin of breakout harness. Monitor signal voltage with EST.

V_{ref} check with 500 ohm harness

Less than 4.5 volts	5 ± 0.5 V	Check signal circuit for open or short to ground

Figure 319 Ground resistance check

8. Use a DMM to check resistance from BLACK pin (signal ground) of breakout harness to chassis ground.

Ground resistance check

Resistance is greater than 5 ohm	Check for open or high resistance between ECM and sensor connector

9. Connect engine or chassis harness to sensor. Correctly connect the harness to the sensor to insure a complete water tight connection.
10. Use the EST to clear DTCs.
    - If an active DTC remains after checking test conditions, replace sensor.

Temperature Sensor Tests using MasterDiagnostics®

1. Plug the EST tool into the ATA connector and start MasterDiagnostics®.
2. Disconnect sensor to be tested.
3. Install correct breakout harness to engine harness only.
4. Turn ignition switch to ON (do not crank the engine).
5. Monitor signal voltage with the EST using continuous monitor session and initiating KOEO Continuous Monitor test (should be 5 ± 0.5 volts). See diagnostic table in this section for the sensor being tested.

KOEO Continuous Monitor Test

Less than 4.6 volts	5 ± 0.5 V	Check signal circuit for short to ground
Greater than 5.5 volts	5 ± 0.5 V	Check signal circuit for short to B+

6. Install 3-Banana plug harness between GREEN (signal circuit), and BLACK (signal ground) pin of breakout harness.

KOEO Continuous Monitor Test with 3-Banana plug harness

More than 0.127 volts	Check ground circuit for open or high resistance

7. Remove 3-Banana plug harness.
8. Connect engine or chassis harness to sensor. Correctly connect the harness to the sensor to insure a complete water tight connection.
9. Use the EST to clear DTCs.
    - If an active DTC remains after checking test conditions, replace sensor.

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Pin-Point Diagnostics

Voltage Checks - Connectors

CAUTION: The ECM harness connectors must be properly seated and the connector latched to avoid possible driveability or no-start conditions. Installing ECM connectors on an angle may cause an improper connection, misdiagnosis, and damaged components. Install the connector until the lever pivots and seats. Apply light pressure to position the connector on the ECM and then fully seat connector.

1. Turn ignition switch to ON (do not crank the engine).
2. Plug correct breakout harness into the harness connector.
3. Measure voltage at each pin with a DMM.
4. Compare sensor or actuator voltage readings with the expected voltages listed in the diagnostic table in this section for circuits being tested, this test will verify circuit integrity.

   If a breakout harness is not available, use the correct tool from Terminal Test Adapter Kit. Do not directly probe the connector terminals with the DMM leads.
5. Turn ignition switch to OFF.

For circuits without an expected voltage, this test will determine if that circuit is shorted or miss-wired to V_{REF}, B+ or other voltage sources.

Voltage Checks - Connector to Ground

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

1. Disconnect negative battery cable.
2. Use breakout harness to measure resistance from the lead of the harness to the negative battery cable.

Voltage Checks - Connector to Ground

Sensor signal ground circuits	Should measure less than 5 ohms (5 Ω)
V_{REF} and signal circuits	Should measure more than 1 kilo-ohm (1 kΩ)
The control side of an actuator will measure more than 1 kilo-ohm	The expected voltage for the other side of the actuator circuit will measure the voltage that the control side was switching, either power or ground
If the ECM is switching the ground circuit	The other side of the actuator circuit should measure more than 1 kilo-ohms from the connector terminal to battery ground
If the ECM is switching the power circuit	The other side of the actuator circuit should measure less than 5 ohms from the connector terminal to battery ground

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Harness Resistance Checks

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector or relay for the ECM and IDM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

1. Check harness resistance if a high resistance or open circuit is suspected.
2. Connect Breakout Box to the ECM end of the harness only.
3. Measure resistance from breakout harness pin to the Breakout Box pin. Circuit wires should have a resistance of less than 5 ohms.

Operational Voltage Checks

Operational voltages checks determine in-range faults or intermittent connections.

To determine in-range faults and intermittent connections, monitor a suspected circuit and recreate conditions likely to cause the problem.

- Monitor signal voltage with the EST using continuous monitor session and initiating KOEO Continuous Monitor Test. See diagnostic table in this section for the sensor being tested.
- Use a DMM and correct breakout harness or a DMM and Breakout Box. See diagnostic table in this section for circuits being tested.

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Circuit Diagnostics

AMS (Air Management System)

Figure 320 Air induction/exhaust system diagram

1. Dual turbocharger assembly
2. Exhaust outlet (to atmosphere)
3. Exhaust tubing
4. MAF/IAT sensor, air inlet (from air filter assembly)
5. EGR cooler
6. Intake manifold
7. Exhaust manifold (left)
8. Cylinder head (left)
9. Cylinder head (right)
10. Exhaust manifold (right)
11. EGR valve assembly
12. Air inlet duct
13. Charge Air Cooler

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The Air Management System includes the following:
Air filter assembly
Dual stage turbocharger with pneumatic actuator
Charge Air Cooler (CAC)
MAF/IAT sensor
MAP sensor
Intake manifold
Intake valves
Exhaust Gas Recirculation (EGR) system
Exhaust valves
Exhaust manifolds
Exhaust tube assembly
Catalytic converter - if equipped
Catalyzed Diesel Particulate Filter (CDPF) - if equipped

AMS Operation

Function

Dual stage turbocharger

The dual stage turbocharger responds directly to engine loads. Different engine loads affect exhaust energy that determines turbocharger speed. Turbocharger speed controls boost pressure for various engine loads. The dual stages of the turbocharger contribute to the lowering of exhaust emissions.

At engine low idle, engine load and boost are low. As engine rpm increases, more fuel and air enter the cylinders. Exhaust temperature and pressure increase; higher exhaust energy increases turbine and compressor speed that raises the pressure and temperature of inlet boost air .

As engine rpm and load decrease, less fuel and air enter the cylinders. Exhaust temperature and pressure decrease; lower exhaust energy decreases turbine and compressor speed that lowers the pressure and temperature of boost air.

The Exhaust Gas Recirculation (EGR) system controls the amount of exhaust gas being introduced to the intake manifold. When the EGR is commanded, the EGR valve opens allowing cooled exhaust gases to enter the intake manifold to be mixed with filtered intake air. The mixed air is then is recycled through combustion process. The EGR actuator is located at the front of the engine on the intake manifold.

The EGR drive module controls the actuator motor and is chassis mounted near the IDM and ECM modules.

The ECM calculates the appropriate desired EGR valve position in response to the changing engine speed, fuel desired, operator demand, engine operating temperatures, boost pressure and altitude.

The ECM uses sensor input from the following:
Accelerator Position Sensor (APS)
EGR actuator with position sensors
EGR drive module
Mass Air Flow (MAF) sensor
Manifold Absolute Temperature (MAT) sensor
Barometric Absolute Pressure (BAP) sensor
Engine Coolant Temperature (ECT) sensor
Engine Coolant Level (ECL) sensor
Engine Oil Temperature (EOT) sensor
Manifold Absolute Pressure (MAP) sensor

The EGR drive module provides feedback to the ECM on the valve position. The EGR drive module interprets the ECM command and sends the command using three pulse width modulated signals to the valve actuator.

The system is closed loop control using the EGR position signals. The EGR drive module provides a 9 volt supply and ground to the Integrated Circuit (IC) in the motor of the valve. When the EGR drive module directs the valve to move, the IC with three Hall effect sensors provides the EGR drive module with the valve position signals. The EGR drive module interprets the three signals to determine valve position and sends the information back to the ECM.

Fault Detection/Management

The ECM continuously monitors the Air Management System (AMS). When the ECM detects a fault in any of the interdependent systems. The ECM will set a DTC and illuminate the amber caution lamp.

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The Exhaust Gas Recirculation (EGR) actuator is continuously monitored by the EGR drive module. When an EGR control error is detected, the EGR drive module sends a message to the ECM, a DTC is set, and the amber caution lamp is illuminated. For additional function and operational information, see “EGR (Exhaust Gas Recirculation) Control (page 375)” in this section.

AMS DTCs

DTCs are read using the EST or by counting the flashes from the amber caution and red warning lamps.

NOTE: Before proceeding, make sure all sensor, injector, and actuator electrical DTCs have been repaired. Follow the procedures outlined in the “Performance Diagnostics (page 211)” section of this manual or Performance Diagnostics Form.

DTC 343

Excessive exhaust back pressure

This is an estimated value expressing excessive cylinder pressures based off of boost pressure.

MAP is continuously monitored through out the engine operation. DTC 343 is set when MAP is greater than expected.

Possible Causes	Comments
Turbocharger boost control (TCBC) system failure	Do “Performance Diagnostics Step 12 Boost Control(page 211).”
Biased high MAP sensor	See “MAP Operational Diagnostics (page 497)” in this section.

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DTC 346

Faults detected during EGR portion of the AMS Test	
DTC 346 is set by the ECM during AMS test when the ECM measures MAF and does not see the expected response in MAF.	
Possible Causes	**Comments**
EGR valve stuck or sticking	Do “Performance Diagnostics (page 211).”
MAF sensor bias	Check sensor signal frequency. See “MAF circuit diagnostics (page 491).”
Obstruction in air inlet to MAF sensor	Do “Performance Diagnostics (page 211).”
EGR control circuit	Check sensor signal frequency. See “EGR circuit diagnostics (page 376).”
Plugged air filter	Do “Performance Diagnostics (page 211).”
Loose clamps for induction system (MAF sensor to turbocharger)	Do “Performance Diagnostics (page 211).”
Exhaust leaks (engine to turbocharger)	Do “Performance Diagnostics (page 211).”
Plugged Exhaust system	Do “Performance Diagnostics (page 211).”

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APS/IVS (Accelerator Pedal Position Sensor and Idle Validation Switch)

Figure 321 Function diagram for APS/IVS

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The Function Diagram for the APS/IVS includes the following:

Accelerator Pedal Position Sensor and Idle Validation Switch (APS/IVS)
Injection Control Pressure Regulator (IPR)
Boost Control Solenoid (BCS)
Injection Driver Module (IDM)
Fuel injector
Amber lamp (Warn Engine Lamp (WEL) for CF)
Electronic Control Module (ECM)

Function

The APS/IVS sensor is a cab mounted potentiometer sensor. When the APS receives a 5 volt reference signal and a ground from the ECM, a linear analog voltage signal from the sensor will indicate the operator's demand for power. The IVS provides 0 or 12 volts to the ECM as redundant signal to verify the pedal idle position.

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APS/IVS Circuit Operation

Figure 322 APS/IVS circuit diagram (CF)

The APS/IVS are integrated into one component and mounted on the accelerator pedal assembly. The APS/IVS sensor can be replaced without replacing the complete assembly.

The ECM determines the accelerator pedal position by processing input signals from the APS and the IVS.

The accelerator pedal position is one of the controlling variables in the calculation of desired injection control pressure.

APS

The ECM supplies a regulated 5 volt signal from ECM chassis connector Pin X4-4 to APS connector Pin C. The APS returns a variable voltage signal (depending on pedal position) from the APS connector Pin A to ECM Pin X4-18. The APS is grounded at Pin B from the ECM Pin X4-24.

APS Auto-Calibration

The ECM learns the lowest and highest pedal positions by reading and storing the minimum and maximum voltage levels from the APS. In this manner the ECM auto-calibrates the system to allow maximum pedal sensitivity. The ECM auto-calibrates as ignition switch is on, but when ignition switch is turned OFF, these values are lost. When ignition switch is turned on again, this process starts over. When the pedal is disconnected (or a new one is installed), the pedal does not need to be calibrated. It simply auto-calibrates the new pedal assembly whenever ignition switch is turned on again.

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IVS

The ECM expects to receive one of two signals through the ECM chassis connector Pin X4-12 from APS/IVS connector Pin D:

- 0 volts when the pedal is at the idle position.
- B+ when the pedal is depressed

The IVS receives a 12 volt ignition voltage at Pin F from the ignition fuse in the power distribution box. When the pedal is not in the idle position (throttle applied), the IVS supplies a 12 volt signal to the ECM.

The ECM compares APS/IVS inputs to verify when the pedal is in the idle position. If the APS signal at Pin X4-18 indicates throttle is being applied, the ECM expects to see 12 volts at the IVS. If the APS signal indicates throttle is not applied, the ECM expects to see 0 volts at the IVS. The timing process is critical between the APS and IVS sensors. For this reason, it is very difficult to determine if the APS/IVS assembly is working correctly when using a DMM.

Fault Detection/Management

When ignition switch is on, the ECM continuously monitors the APS/IVS circuits for expected voltages. It also compares the APS and IVS signals for conflict. If the signals are not what the ECM expects to see, DTCs will be set.

Any detected malfunction of the APS/IVS sensor circuit will illuminate the amber WEL. If the ECM detects an APS signal Out of Range HIGH or LOW, the engine will ignore the APS signal and operate at low idle. If a disagreement in the state of IVS and APS is detected by the ECM and the ECM determines that it is an IVS fault, the ECM will only allow a maximum of 50% APS to be commanded. If the ECM cannot discern if it is an APS or IVS fault, the engine will be allowed to operate at low idle only.

APS/IVS DTCs

DTCs are read using the Electronic Service Tool (EST) or by counting the flashes from the amber and red lamps.

NOTE: If multiple APS/IVS DTCs are present, verify the APS/IVS part number is correct for the specific vehicle model.

NOTE: If elevated low idle rpm is experienced after replacing the pedal assembly or APS/IVS sensor, and there are no DTCs present, check pedal assembly or APS/IVS sensor part numbers for correctness.

DTC 131

APS Out of Range Low (ORL)
DTC 131 is set if the ECM detects less than 0.147 volts. Possible causes include a short to ground or an open in the APS signal circuit. DTC 131 can be set due to a short to ground or an open V_{REF} or signal circuits. If the condition causing DTC 131 is intermittent and the condition is no longer present, the code will become inactive and normal engine operation will resume. When DTC 131 is active the amber lamp (WEL for CF) is illuminated.

DTC 132

APS Out of Range High (ORH)
DTC 132 is set if the ECM detects greater than 4.55 volts then the ECM restricts engine speed to idle. DTC 132 can be set due to a short to V_{REF} or B+ in the APS signal circuit. When DTC 132 is active the amber lamp will be illuminated.

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DTC 133, 134 and 135

APS in-range faults

The ECM checks the voltage output of the APS by comparing the APS signal with the IVS signal. APS and IVS signals can disagree in two cases:

- The APS signal indicates the pedal is pressed down to accelerate, but the IVS signal indicates idle position.
- The APS signal indicates the pedal has been released to allow the engine to return to idle, but the IVS signal indicates off-idle position of the pedal.

If the ECM detects either of the above conditions, the ECM attempts to isolate the source of conflict and set the appropriate DTC.

DTC 133

APS signal in-range DTC

If the IVS signal is changing and the APS signal is constant, the ECM assumes the APS is the conflict source and sets DTC 133. The engine rpm is restricted to idle.

When DTC 133 is active the amber lamp (WEL for CF) is illuminated.

DTC 134

APS signal and IVS disagree

If neither the APS or IVS is changing, or both are changing, or the ECM cannot determine the DTC in specified time, DTC 134 is set and engine rpm is restricted to idle.

When DTC 134 is active the amber lamp (WEL for CF) is illuminated.

DTC 135

IVS circuit fault

If the APS is changing but IVS is constant, the ECM assumes the IVS is the conflict source and sets DTC 135. In this case the ECM limits the APS signal to a lower value that provides less than full rpm, but does not limit engine rpm to idle.

When DTC 135 is active the amber lamp (WEL for CF) is illuminated.

NOTE: DTC 133, 134, and 135 are caused by intermittent conditions. These DTCs remain active until the vehicle has been shutdown and restarted. They do not recover without cycling ignition switch. Later calibration versions may allow DTC recovery without cycling ignition switch.

Tools

EST with MasterDiagnostics® software

EZ-Tech Interface Cable

Digital Multimeter (DMM)

3-Banana plug harness

500-Ohm resistor harness

Breakout Box

APS/IVS breakout harness

Terminal Test Adapter Kit

The APS/IVS circuit requires the use of vehicle circuit diagrams. See applicable truck *Circuit Diagram Manual* for circuit numbers, connector and fuse locations.

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APS/IVS Operational Diagnostics

Figure 323 APS/IVS circuit diagram (CF)

WARNING: To prevent personal injury or death, be careful to avoid rotating parts (belts and fan) and hot engine surfaces.

Figure 324 Continuous Monitor session

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WARNING: To prevent personal injury, use care to prevent contact with the door edge when the cab is up and the door is open.

1. Select D_ContinuousMonitor.ssn from the Open Session File window, select Open to open the session.

Figure 325 Continuous Monitor test

2. Select Diagnostics from the menu bar.
3. Select Key-On Engine-Off Tests from the drop down menu.
4. From the KOEO Diagnostics menu, select Continuous Monitor and select Run to start the test.

WARNING: To prevent personal injury or death, be careful around rotating parts (belts and fan) and hot engine surfaces.

5. Monitor APS signal voltage. Verify an active DTC for the APS/IVS circuit.
6. If code is active, do step 8 and 9. Refer to Circuit Checks - APS sensor table.
7. If code is inactive, wiggle connectors and wires at all suspected problem locations. If circuit continuity is interrupted, the EST will display DTCs related to the condition.
8. Disconnect chassis harness from APS sensor.

NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

9. Connect APS sensor breakout harness to chassis harness only.

Figure 326 Close session

10. When finished with this test, select Session from menu bar, then Close.
11. Connect chassis harness to sensor. Use the EST to clear DTCs. If an active code remains after checking test conditions, inspect pedal assembly for excessive wear. If pedal assembly is intact, replace the APS/IVS sensor.

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Figure 327 APS/IVS circuit diagram (CF)

APS/IVS Pin-Point Diagnostics (CF)

Circuit Checks - APS Sensor (CF)

Use EST, DMM, breakout harness, and 500-ohm resistor harness.

Test Condition	Spec	Checks
Sensor disconnected	0 V	If voltage greater than 0.147 volts, check signal circuit for short to V_{REF} or B+.
Measure voltage from Pin C (BLUE) to ground with DMM	5 ± 0.5 V	If voltage greater than 5.5 volts, check V_{REF} for short to B+. If voltage is less than 4.5 volts, check V_{REF} for open or short to ground.
500 Ohm resistor harness installed between Pin A (GREEN) and Pin C (BLUE) of breakout harness.	5 V	If voltage greater than 4.55 volts, check signal circuit for open or short to ground. Remove negative battery cable. Measure resistance from Pin C to ground (spec > 1 kΩ) to check for short to ground. Use a Breakout Box to measure from Pin A to Pin X4-18 (spec < 5 Ω) to check for open in the harness.
Resistance from Pin B (BLACK) of breakout harness to chassis ground using DMM.	< 5 Ω	If resistance is greater than 5 Ω, check for open or high resistance between ECM and sensor connector. Use a Breakout Box and measure resistance from between Pin B and Pin X4-24 (spec < 5 Ω)

Read all safety instructions in the "Safety Information" section of this manual before doing any procedures.
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Voltage Checks - Connector (CF)

Turn ignition switch to OFF. Disconnect harness from sensor. Inspect for bent pins or corrosion. Connect breakout harness to chassis harness only. Turn ignition switch to ON.

Test Point	Spec	Comments
A to gnd	0 to 0.25 V	Voltage greater than 0.25 volts, signal is shorted to V_{REF} or B+
B to gnd	0 V	Ground circuit, no voltage expected
C to gnd	5 ± 0.5 V	Voltage greater than specification, circuit shorted to B+; Voltage less than specification, circuit open or shorted to ground
D to gnd	0 to 0.25 V	Voltage greater than 0.25 volts, IVS signal circuit shorted to V_{REF} or B+
F to gnd	B+	Voltage less than 10.5 volts check circuit for open or high resistance, blown fuse

NOTE: See applicable truck *Circuit Diagram Manual* for fuse location.

Resistance Checks - Connector to Chassis Ground (CF)

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Disconnect negative battery cable. Disconnect harness from sensor. Use disconnected negative battery cable for ground test point.

Test Point	Spec	Comments
A to gnd	> 1 kΩ	If less than 1 kΩ, check for short to ground
B to gnd	< 5 Ω	If greater than 5 Ω, check for open signal ground
C to gnd	> 500 Ω	If less than 500 Ω, check for short to ground
D to gnd	> 1 kΩ	If less than 1 kΩ, check for short to ground
F to gnd	> 1 kΩ	If less than 1 kΩ with fuse removed, check for short to ground

NOTE: See applicable truck *Circuit Diagram Manual* for fuse location.

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Figure 328 APS/IVS circuit diagram (CF)

Harness Resistance Checks (CF)

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Connect breakout box X4 only to chassis harness only. Connect breakout harness to chassis harness only.

Test Point	Spec	Comments
X4-18 to A	< 5 Ω	If greater than 5 Ω, check for APS signal circuit open
X4-24 to B	< 5 Ω	If greater than 5 Ω, check for open signal ground
X4-4 to C	< 5 Ω	If greater than 5 Ω, check for open V_{REF} circuit
X4-12 to D	< 5 Ω	If greater than 5 Ω, check for open IVS signal circuit
Fuse to F	< 5 Ω	If greater than 5 Ω, check for open IVS power circuit

NOTE: See applicable truck *Circuit Diagram Manual* for fuse location.

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Operational Voltage Checks - APS/IVS Sensor with Breakout Harness (CF)

Turn ignition switch to OFF. Check with breakout harness connected to sensor and engine harness. Turn ignition switch to ON.

a. APS test points: (+) X4-18 to (-) X4-24 or (+) green and (-) black

b. IVS test points: (+) X4-12 to (-) X4-24 or (+) green and (-) black

Position	Voltage	% APS	IVS Voltage	Comments
Low idle	0.15 to 0.66 V	0%	0 V	IVS toggles just off idle
High idle	3.84 to 4.4 V	98 to 102%	B+	

Operational Voltage Checks - APS/IVS Sensor with Breakout Box (CF)

Turn ignition switch to OFF. Check with breakout box connected X-4 only to ECM and engine harness. Turn ignition switch to ON.

a. APS test points: (+) X4-18 to (-) X4-24 or (+) green and (-) black

b. IVS test points: (+) X4-12 to (-) X4-24 or (+) green and (-) black

Position	Voltage	% APS	IVS Voltage	Comments
Low idle	0.15 to 0.66 V	0%	0 V	IVS toggles just off idle
High idle	3.84 to 4.4 V	98 to 102%	B+	

APS/IVS Diagnostic Trouble Code

DTC 131 = APS signal voltage was less than 0.147 volts for more than 0.35 seconds.

DTC 132 = APS signal voltage was greater than 4.55 volts for more than 0.35 seconds.

DTC 133 = APS signal in-range fault

DTC 134 = APS and IVS disagree

DTC 135 = Idle validation switch circuit fault - 50% APS only

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APS/IVS Pin-Point Diagnostics (Stripped Chassis)

Figure 329 APS/IVS circuit diagram (Stripped Chassis)

Circuit Checks - APS Sensor (Stripped Chassis)

Use EST, DMM, breakout harness, and 500-ohm resistor harness.

Test Condition	Spec	Checks
Sensor disconnected	0 V	If voltage greater than 0.147 volts, check signal circuit for short to V_{REF} or B+.
Measure voltage from Pin D (BLUE) to ground with DMM	5 ± 0.5 V	If voltage greater than 5.5 volts, check V_{REF} for short to B+. If voltage is less than 4.5 volts, check V_{REF} for open or short to ground.
500 Ohm resistor harness installed between Pin E (GREEN) and Pin D (BLUE) of breakout harness.	5 V	If voltage greater than 4.55 volts, check signal circuit for open or short to ground. Remove negative battery cable. Measure resistance from Pin C to ground (spec > 1 kΩ) to check for short to ground. Use a Breakout Box to measure from Pin E to Pin X4-18 (spec < 5 Ω) to check for open in the harness.
Resistance from Pin K (BLACK) of breakout harness to chassis ground using DMM.	< 5 Ω	If resistance is greater than 5 Ω, check for open or high resistance between ECM and sensor connector. Use a Breakout Box and measure resistance from between Pin B and Pin X4-24 (spec < 5 Ω)

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Voltage Checks - Connector (Stripped Chassis)

Turn ignition switch to OFF. Disconnect harness from sensor. Inspect for bent pins or corrosion. Connect breakout harness to chassis harness only. Turn ignition switch to ON.

Test Point	Spec	Comments
E to gnd	0 to 0.25 V	Voltage greater than 0.25 volts, signal is shorted to V_{REF} or B+
K to gnd	0 V	Ground circuit, no voltage expected
D to gnd	5 ± 0.5 V	Voltage greater than specification, circuit shorted to B+; Voltage less than specification, circuit open or shorted to ground
G to gnd	0 to 0.25 V	Voltage greater than 0.25 volts, IVS signal circuit shorted to V_{REF} or B+
J to gnd	B+	Voltage less than 10.5 volts check circuit for open or high resistance, blown fuse

NOTE: See applicable truck *Circuit Diagram Manual* for fuse location.

Resistance Checks - Connector to Chassis Ground (Stripped Chassis)

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Disconnect negative battery cable. Disconnect harness from sensor. Use disconnected negative battery cable for ground test point.

Test Point	Spec	Comments
E to gnd	> 1 kΩ	If less than 1 kΩ, check for short to ground
K to gnd	< 5 Ω	If greater than 5 Ω, check for open signal ground
D to gnd	> 500 Ω	If less than 500 Ω, check for short to ground
G to gnd	> 1 kΩ	If less than 1 kΩ, check for short to ground
J to gnd	> 1 kΩ	If less than 1 kΩ with fuse removed, check for short to ground

NOTE: See applicable truck *Circuit Diagram Manual* for fuse location.

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Figure 330 APS/IVS circuit diagram (Stripped Chassis)

Harness Resistance Checks (Stripped Chassis)

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Connect breakout box X4 only to chassis harness only. Connect breakout harness to chassis harness only.

Test Point	Spec	Comments
X4-18 to E	< 5 Ω	If greater than 5 Ω, check for APS signal circuit open
X4-24 to K	< 5 Ω	If greater than 5 Ω, check for open signal ground
X4-4 to D	< 5 Ω	If greater than 5 Ω, check for open V_{REF} circuit
X4-12 to G	< 5 Ω	If greater than 5 Ω, check for open IVS signal circuit
Fuse to J	< 5 Ω	If greater than 5 Ω, check for open IVS power circuit

NOTE: See applicable truck *Circuit Diagram Manual* for fuse location.

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Operational Voltage Checks - APS/IVS Sensor with Breakout Harness (Stripped Chassis)

Turn ignition switch to OFF. Check with breakout harness connected to sensor and engine harness. Turn ignition switch to ON.

a. APS test points: (+) X4-18 to (-) X4-24 or (+) green and (-) black

b. IVS test points: (+) X4-12 to (-) X4-24 or (+) green and (-) black

Position	Voltage	% APS	IVS Voltage	Comments
Low idle	0.15 to 0.4 V	0%	0 V	IVS toggles just off idle
High idle	3.55 to 4.4 V	98 to 102%	B+	

Operational Voltage Checks - APS/IVS Sensor with Breakout Box (Stripped Chassis)

Turn ignition switch to OFF. Check with breakout box connected X-4 only to ECM and engine harness. Turn ignition switch to ON.

a. APS test points: (+) X4-18 to (-) X4-24 or (+) green and (-) black

b. IVS test points: (+) X4-12 to (-) X4-24 or (+) green and (-) black

Position	Voltage	% APS	IVS Voltage	Comments
Low idle	0.15 to 0.4 V	0%	0 V	IVS toggles just off idle
High idle	3.55 to 4.4 V	98 to 102%	B+	

APS/IVS Diagnostic Trouble Code

DTC 131 = APS signal voltage was less than 0.147 volts for more than 0.35 seconds.

DTC 132 = APS signal voltage was greater than 4.55 volts for more than 0.35 seconds.

DTC 133 = APS signal in-range fault

DTC 134 = APS and IVS disagree

DTC 135 = Idle validation switch circuit fault - 50% APS only

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ATA (American Trucking Association) Datalink

Figure 331 Function diagram for the ATA datalink

The function diagram for the ATA datalink includes the following:
EST with MasterDiagnostics® software
Electronic Control Module (ECM)
Injection Driver Module (IDM)

Function

The Data Communication Link signal is a 0 to 5 volts variable width square wave form signal that enables communication between the MasterDiagnostics® software and the ECM. The data communication link also allows for programming the IDM.

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ATA Circuit Operation

Figure 332 ATA circuit diagram

The ECM communicates with the EST and MasterDiagnostics® software through the EST connector. The EST communicates with the ECM through the ATA datalink using Standard Corporate Protocol (SCP).

The IDM uses ATA only for programming.

The ATA circuit uses a twisted wire pair. All repairs must maintain one complete twist per inch along the entire length of the circuit. This circuit is polarized (one positive and one negative) and reversing the polarity of this circuit will disrupt communications.

ATA Datalink Connector

Vehicles are equipped with the ATA datalink connector for communication between the Electronic Control Module (ECM) and the EST.

The ATA datalink supports the following functions:

Transmission of engine parameter data
Transmission and clearing of DTCs
Diagnostics and trouble shooting
Programming performance parameter values
Programming engine and vehicle features
Programming calibrations and strategies in the ECM and IDM

Fault Detection/Management

The ECM continuously monitors the ATA datalink for an open, short or intermittent connection. If an active DTC occurs on the ATA datalink, the MasterDiagnostics® software will not display correct data.

The IDM uses ATA for programming only. DTCs are not transmitted from the IDM through the ATA datalink.

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ATA DTCs

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

Figure 333 ATA circuit diagram

DTC 231
ATA data communication link error
DTC 231 is set when the ECM can not access the ATA datalink. When this occurs, ATA data can not be retrieved using the EST. DTCs can only be retrieved using the cruise control feature. DTC 231 can be set when the any of the following conditions occur: a. Failed ATA device (transmission controller or anti-lock brake controller) is connected to ATA bus and pulls signal to ground. b. ATA+ or ATA- open or shorted c. Number of ATA devices exceeds limit d. Failed ECM When DTC 231 is active the amber lamp (WEL for CF) is not illuminated.

Tools
EST with MasterDiagnostics® software
EZ-Tech® interface cable
Digital Multimeter (DMM)
Breakout Box
Breakout harness

ATA circuit diagnosis requires the use of vehicle circuit diagrams. See the applicable truck *Circuit Diagram Manual* for circuit numbers, connector and fuse locations.

Read all safety instructions in the "Safety Information" section of this manual before doing any procedures.
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ATA Pin-Point Diagnostics

Voltage Checks - Connector at EST

Turn ignition switch to ON (the engine should not be started).

Test Point	Spec	Signal	Comments
B to A	B+	Voltage	Voltage should be at B+ at all times. If no voltage is present, check ground and power circuits.

Voltage Checks - EST to Ground

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF and disconnect negative battery cable.

Test Point	Spec	Signal	Comments
F to gnd	> 1 kΩ	ATA +	If less than 1 kΩ, check for short to ground through harness or internal within the ECM and IDM. Disconnect ECM and IDM and measure ground again. If short is still present, disconnect other devices connected to data communication link and retest. If short is still present, repair harness.
G to gnd	> 1 kΩ	ATA -	
B to gnd	> 1 kΩ	Power	With fuse removed, if less than 1 kΩ, check for short to ground.
A to gnd	< 5 Ω	gnd	If greater than 5 Ω, check for an open circuit. The EST tool will not communicate.

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Figure 334 ATA circuit diagram

Harness Resistance Checks - EST and Dash

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF, disconnect negative battery cable, and install Breakout Box.

Test Point	Spec	Signal	Comments
F to ECM X4-20	< 5 Ω	ATA +	Resistance from ECM chassis connector to EST connector.
G to ECM X4-21	< 5 Ω	ATA -	Resistance from ECM chassis connector to EST connector.
F to IDM X3-28	< 5 Ω	ATA +	Resistance from IDM connector to EST connector.
G to IDM X3-29	< 5 Ω	ATA -	Resistance from IDM connector to EST connector.
B to fuse	< 5 Ω	Power	Resistance from EST connector to power fuse. See the applicable truck *Circuit Diagram Manual* for circuit numbers, connector and fuse locations.
A to gnd	< 5 Ω	gnd	If greater than 5 Ω, check for an open circuit. Open circuit will prevent EST power up.

Diagnostic Trouble Code Description
231 ATA data communication link error - ATA wiring or connector

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BAP (Barometric Absolute Pressure) Sensor

Figure 335 Function diagram for the BAP sensor

The function diagram for the BAP sensor includes the following:

Barometric Absolute Pressure (BAP) sensor
Electronic Control Module (ECM)
Injection Driver Module (IDM)
Boost Control Solenoid (BCS) assembly
Fuel injector
Amber Lamp (Warn Engine Lamp (WEL) for CF)
Exhaust Gas Recirculation (EGR)

Function

The BAP sensor is a cab mounted variable capacitance sensor. The ECM supplies a 5 volt reference signal which the BAP sensor uses to produce a linear analog voltage signal that indicates pressure.

The primary function of the BAP sensor is to provide a feedback signal to the ECM to adjust fuel timing and quantity. The ECM monitors the BAP signal to determine altitude, adjust fuel timing and quantity, glow plug operation, and air heater operation.

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BAP Circuit Operation

Figure 336 BAP circuit diagram

The BAP sensor is supplied with a 5 volt reference at Pin 2 from ECM Pin X4-4 . The BAP sensor is grounded at Pin 1 from ECM Pin X4-24. The BAP sensor returns a variable voltage signal from Pin 3 to ECM at Pin X3-24.

Fault Detection/Management

When the ECM detects the BAP voltage signal out of range high or low, the ECM will ignore the BAP signal and use the Manifold Absolute Pressure (MAP) signal generated at low idle as an indication of barometric pressure. When a MAP fault is detected, the BAP signal will default to barometric pressure at sea level, 100.24 kPa (29.6 in Hg).

BAP DTCs

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

DTC 151
BAP signal out of range high
DTC 151 is set when the BAP signal is greater than 4.95 volts for more than 0.5 second.
DTC 151 can be set when the signal circuit is shorted to V_{REF} or B+ or a failed BAP sensor.
When DTC 151 is active the amber lamp (WEL for CF) is illuminated.

DTC 152
BAP signal out of range low
DTC 152 is set when the BAP signal is less than 1.0 volt for more than 0.5 seconds.
DTC 152 can be set when the signal circuit is shorted to ground or open. If the V_{REF} is shorted to ground, DTC 152 can be set. A failed BAP sensor can set DTC 152.
When DTC 152 is active the amber lamp (WEL for CF) is illuminated.

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Tools

EST with MasterDiagnostics® software
EZ-Tech® interface cable
Digital Multimeter (DMM)
Breakout Box

BAP Pin-Point Diagnostics

See applicable truck *Circuit Diagram Manual* for circuit numbers, connector and fuse locations.

Voltage Checks - Connector

Turn ignition switch to OFF. Disconnect harness from sensor. Inspect for bent pins or corrosion. Turn ignition switch to ON.

Test Point	Spec	Comments
1 to gnd	0 to 0.25 V	If greater than 0.25 volts, check ground circuit for open or high resistance. Check signal ground for short to V_{REF} or B+.
2 to gnd	5 ± 0.5 V	If voltage is not to specification, V_{REF} circuit is shorted to ground, shorted to B+, or open.
3 to gnd	0 to 0.25 V	If voltage greater than 0.25 volts, signal circuit is shorted to V_{REF} or B+.

Resistance Checks - Connector to Chassis Ground

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Disconnect negative battery cable. Disconnect harness from sensor. Use disconnected negative battery cable for ground test point.

Test Point	Spec	Comments
1 to gnd	> 500 Ω	If less than 500 Ω , check for short to ground.
2 to gnd	>1 kΩ	If less than 1 kΩ, check for V_{REF} short to ground.
3 to gnd	>1 kΩ	If less than 1 kΩ, check for signal short to ground.

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Harness Resistance Checks

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Connect Breakout Box to chassis harness X3 and X4 only.

Test Point	Spec	Comments
X4-24 to 1	<5 Ω	If greater than 5 Ω, check for open signal ground
X4-4 to 2	<5 Ω	If greater than 5 Ω, check for open V_{REF}
X3-24 to 3	<5 Ω	If greater than 5 Ω, check for open signal circuit

Figure 337 BAP circuit diagram

Read all safety instructions in the "Safety Information" section of this manual before doing any procedures.
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Operational Voltage Checks - BAP Sensor

Check with breakout box connected X3 and X4 only to ECM and chassis harness.

Test Point	Voltage	kPa (in Hg)	Comments
X3-24 to X4-24	4.89 V	105 kPa (31.09 in Hg)	High atmospheric pressure.
X3-24 to X4-24	4.60 V	100 kPa (29.61 in Hg)	Normal atmospheric pressure at sea level.
X3-24 to X4-24	2.60 V	60 kPa (17.766 in Hg)	Normal atmospheric pressure at 10,000 feet.

BAP Diagnostic Trouble Codes

DTC 151 = Signal voltage was greater than 4.95 volts for more than 0.5 second

DTC 152 = Signal voltage was less than 1.0 volts for more than 0.5 seconds

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BCS (Boost Control Solenoid) Assembly

Figure 338 Functional diagram for the BCS assembly

The Functional Diagram for the BCS assembly includes the following:

- Boost Control Solenoid (BCS) assembly
- Electronic Control Module (ECM)
- Injection Pressure Regulator (IPR)
- Accelerator Pedal Position sensor and Idle Validation Switch (APS/IVS)
- Barometric Absolute Pressure (BAP) sensor
- Camshaft Position (CMP) sensor
- Crankshaft Position (CKP) sensor
- Exhaust Gas Recirculation (EGR) valve
- Engine Oil Temperature (EOT) sensor
- Manifold Absolute Pressure (MAP) sensor
- Mass Air Flow/Intake Air Temperature (MAF/IAT) sensor

Function

The BCS assembly is a two position valve that controls boost pressure going to the pneumatic actuator. During engine operation, the ECM will energize the BCS (100% duty cycle) dumping boost pressure from the pneumatic actuator into the air inlet, keeping the turbocharger bypass valve closed. When boost pressure is higher then desired, the ECM will de-energize the BCS allowing boost pressure to the pneumatic actuator and opening the turbocharger bypass valve.

Actuator control is achieved by setting duty cycle to 100% or to 0% in response to engine speed, desired fuel quantity, and altitude.

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BCS Circuit Operation

Figure 339 BCS circuit diagram

The BCS assembly receives ground at Pin 1 from Pin 4 of the 12-pin connector. The ECM controls the BCS by sending a 100% duty cycle signal from Pin X2-18 to Pin 2 on the BCS.

NOTE: Although BCS is duty cycle controlled, 0% and 100% cannot be monitored with DMM. Voltage, not duty cycle, needs to be monitored.

Fault Detection/Management

There are no specific Diagnostic Trouble Codes (DTCs) relating to the wiring or Output Circuit Check (OCC) for the BCS. When diagnosing the air management system, BCS wiring can be tested with the following checks.

Tools
EST with MasterDiagnostics® software
EZ-Tech® interface cable
Digital Multimeter (DMM)
Breakout Box
Terminal Test Adapter Kit
12-pin breakout harness

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BCS Assembly Pin-Point Diagnostics

Voltage Checks - BCS

Disconnect the BCS connector, using DMM measure voltage. Negative lead Pin 1, positive lead to B+ at alternator.

Test Point	Spec	Comments
1 to B+ at alternator	B+	If voltage is below specifications, check for an open in the BCS ground circuit.

Voltage Checks - ECM (Output State Test)

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging relays or the ECM module. Failure to turn ignition switch to OFF could cause a voltage spike and damage the electrical components.

Install Breakout Box X2 and X3 to ECM and harness. Connect 500 Ω resistor between X2-18 and X3-6. Turn ignition switch to ON (do not crank the engine). Run Output State Tests, see “Diagnostic Tests” in the “Diagnostic Software Operation” section of this manual for the procedure to do the Output State Tests.

Test Point	Spec	Comments
Output State Test - Low		
X2-18 to X3-6	0 to 0.25 V	If greater than 0.25 volts disconnect engine harness from Breakout Box and retest. a. If less than 0.25 volts, diagnose engine wiring harness. Do Harness Resistance Check - ECM to BCS. b. If greater than 0.25 volts, with Breakout Box only connected to ECM, replace ECM.
Output State Test - High		
X2-18 to X3-6	B+ ± 0.5 V	If value is not in specification, disconnect engine harness from Breakout Box and retest. a. If equal to B+, diagnose engine wiring harness. Do Harness Resistance Check - ECM to BCS. b. If less than B+ with Breakout Box only connected to ECM, replace ECM.

Read all safety instructions in the "Safety Information" section of this manual before doing any procedures.
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Figure 340 BCS circuit diagram

Harness Resistance Checks - Chassis Ground

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging relays or the ECM module. Failure to turn ignition switch to OFF could cause a voltage spike and damage the electrical components.

Turn ignition switch OFF. Disconnect harness from BCS. Disconnect the negative battery cable.

Test Point	Spec	Comments
1 to gnd	< 5 Ω	If greater than 5 Ω, check for an open in ground.
2 to gnd	> 1 kΩ	If less than 1 kΩ, check for short to ground.

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Harness Resistance Checks - 12-Pin Connector to Chassis Ground

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging relays or the ECM module. Failure to turn ignition switch to OFF could cause a voltage spike and damage the electrical components.

Turn ignition switch to OFF. Disconnect 12-pin connector, connect 12-pin breakout harness. Disconnect negative battery cable, use negative battery cable as ground test point.

Test Point	Spec	Comments
4 (12-pin) to gnd	< 5 Ω	If greater than 5 Ω, check for open in ground.

Harness Resistance Checks - ECM to BCS

Turn ignition switch to OFF. Disconnect BCS connector. Connect Breakout Box X2 to engine harness only.

Test Point	Spec	Comments
X2-18 to 2	< 5 Ω	If greater than 5 Ω, check for open in BCS circuit.

Harness Resistance Checks - 12-pin Connector to BCS

Turn ignition switch to OFF. Disconnect BCS connector and 12-pin connector. Connect 12-pin breakout harness to engine harness only.

Test Point	Spec	Comments
4 (12-pin) to 1	< 5 Ω	If greater than 5 Ω, check for open in ground.

Actuator Resistance Check - Across BCS Terminals

Turn ignition switch to OFF. Disconnect the BCS connector. Check resistance through the BCS only.

Test Point	Spec	Comments
Across BCS terminals	40 to 44 Ω	If resistance is not within specifications, replace the BCS assembly.

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Brake Switch Circuits

Figure 341 Function diagram for brake switch circuits

The functional diagram for the brake switch circuits includes the following:

- Electronic Control Module (ECM)
- Brake Pressure Switch (BPS)
- Brake ON/OFF (BOO) switch
- Output - cancels cruise control
- Output - cancels Power Takeoff (PTO) control
- Output - cancels Cold Ambient Protection (CAP)
- Output - cancels Idle Shutdown Timer (IST)

Function

The brake switch circuit signals the ECM when the brakes are applied. The information is used to disengage the cruise control and PTO functions. The brake signal will interrupt the CAP feature and will reset the time interval for the IST feature.

NOTE: CF chassis has a switching delay between the BOO and BPS signals.

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Brake Switch Circuit Operation

Figure 342 Brake switch circuit diagram

Fault Detection/Management

The ECM continuously monitors the BOO circuit at Pin X1-15 and BPS at Pin X1-16. If the ECM receives a mismatch signal such as an open BPS and an open BOO a DTC will be set.

Brake Switch Circuits DTCs

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

DTC 222
Brake switch circuit Fault
DTC 222 is set by the ECM when BPS and BOO are mismatched. DTC 222 can be set for an open or shorted BOO switch circuit, an open BPS switch circuit, an open V_{IGN} circuit, or a failed BOO or BPS switch.

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Brake Switch Circuits Pin-Point Diagnostics

Figure 343 Brake switch circuit diagram

Voltage Checks - Brake Switch Circuits at ECM

Turn ignition switch to OFF. Connect Breakout Box X1 and X3 to ECM and harness. Turn ignition switch to ON.

Test Point	Spec	Comments
X1-15 to X3-7	Normal state = 0 V Pedal depressed = B+	If not within specification, check for blown fuse, open circuit, short to ground, short to power, or failed switch.
X1-16 to X3-7	Normal state = B+ Pedal depressed = 0 V	If not within specification, check for blown fuse, open circuit, short to ground, short to power, or failed switch.

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Harness Resistance Checks - Brake Switch Circuits to Chassis Ground

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging relays or the ECM module. Failure to turn ignition switch to OFF could cause a voltage spike and damage the electrical components.

Turn ignition switch to OFF. Connect Breakout Box X1 to wiring harness only. Disconnect negative battery cable, use negative battery cable as ground test point.

Test Point	Spec	Comments
X1-15 to gnd	> 1 kΩ	If less than 1 kΩ, check for short to ground.
X1-16 to gnd	> 1 kΩ	If less than 1 kΩ, check for short to ground.

Harness Resistance Checks - ECM to Switch

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging relays or the ECM module. Failure to turn ignition switch to OFF could cause a voltage spike and damage the electrical components.

Turn ignition switch to OFF. Connect Breakout Box X1 to wiring harness only. Disconnect negative battery cable, use negative battery cable as ground test point.

Test Point	Spec	Comments
X1-15 to switch	< 5 Ω	If greater than 5 Ω, check for open circuit.
X1-16 to switch	< 5 Ω	If greater than 5 Ω, check for open circuit.

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CAN (Controller Area Network) Communications

Figure 344 Function diagram for CAN

The function diagram for the CAN includes the following:

- Electronic Control Module (ECM)
- Drivetrain Datalink (CAN1)
- Terminating resistors - 120-ohm
- Instrument Panel (Lamps)
- Other nodes

Function

The Drivetrain Datalink is a Society of Automotive Engineers (SAE) term referring to datalinks common to trucks. The Drivetrain Datalink is the communication link for the Electronic Control Module (ECM), cab and chassis, instrument panel, and is also used for power train communication and control.

The ECM transmits component information across the Drivetrain Datalink to the instrument panel.

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The following instrument panel components are in constant communication with the Drivetrain Datalink:

Tachometer
Speedometer
Odometer
Coolant temperature gauge
Red Lamp (Oil/Water Lamp (OWL) for CF)
Amber Lamp (Warn Engine Lamp (WEL) for CF)
Change oil lamp
WAIT TO START lamp
Water In Fuel (WIF) lamp
Anti-lock Breaking System (ABS)

Fault Detection/Management

There are no engine DTCs for CAN1 communications.

NOTE: See the applicable truck *Circuit Diagram Manual* and *Service Manual*.

Tools

EST with MasterDiagnostics® software
EZ-Tech® interface cable
DMM

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CAN Pin-Point Diagnostics

Figure 345 CAN communication circuit diagram

Voltage Checks

Check at EST connector with key-on engine-off.

Test Point	Spec	Signal	Comments
B to A	B+	Power	Should be B+ power at B all times. If no power, check ground and power circuits. See the applicable truck *Circuit Diagram Manual*.
C to A	1 to 4 V	Digital signal	The sum of C to A and D to A equals 4 to 5 volts.
D to A	1 to 4 V	Digital signal	The sum of C to A and D to A equals 4 to 5 volts.

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Resistance Checks

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Check at EST connector with negative battery cable disconnected.

Test Point	Spec	Signal	Comments
C to A	>1 MΩ	CAN+	If less than 1 MΩ, a short between CAN+ and ground exists. Disconnect ECM X3 and check again. If short is no longer present, replace ECM. If short exists, harness or other node component failure.
D to A	>1 MΩ	CAN-	If less than 1 MΩ, a short between CAN- and ground exists. Disconnect ECM X3 and check again. If short is no longer present, replace ECM. If short still exists, harness or other node component failure.
C to D	60 Ω	CAN	The datalink has two terminating resistors in parallel of 120 Ω each. If greater than 70 Ω, check for missing terminating resister or open in the CAN+ or CAN- wires. If less than 50 Ω, check for extra terminating resistor. If less than 5 Ω, check for short between CAN+ and CAN-.

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CKP (Crankshaft Position) Sensor

Figure 346 Function diagram for CKP sensor

The function diagram for the CKP sensor includes the following:

Crankshaft Position (CKP) sensor
Electronic Control Module (ECM)
Injector Driver Module (IDM)
Fuel injector
Amber Lamp (Warn Engine Lamp (WEL) for CF)

Function

The CKP sensor provides the ECM with a signal that indicates crankshaft speed and position. As the crankshaft turns the CKP sensor detects a 60 tooth timing disk on the crankshaft. Teeth 59 and 60 are missing. By comparing the CKP signal with the CMP signal, the ECM calculates engine rpm and timing requirements. The CKP is installed in the front right side of the lower crankcase.

The sensor produces pulses for each tooth edge that passes it. Crankshaft speed is derived from the frequency of the CKP sensor signal. The crankshaft position is determined by synchronizing the SYNC tooth with the SYNC gap signals from the target disk. From the CKP signal frequency, the ECM can calculate engine rpm and timing requirements. Diagnostic information on the CKP input signal is obtained by performing accuracy checks on frequency, and duty cycle with software strategies.

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CKP Circuit Operation

Figure 347 CKP circuit diagram

The ECM uses the CKP and CMP signal to calculate engine speed and position. The CKP sensor provides the ECM with a signal that indicates crankshaft speed and position. The CKP contains a permanent magnet that creates a magnetic field. The signal is created when the timing disk rotates and breaks the magnetic field created by the sensor. The ECM terminals for the CKP sensor are CKP negative X1-2 and CKP positive X1-1.

NOTE: Engine will not operate without CKP signal.

Fault/Detection Management

An inactive CKP signal during cranking is detectable by the ECM. During engine cranking the ECM monitors the CMP signal and Injection Control Pressure (ICP) to verify the crankshaft is rotating. If the CKP signal is inactive during this time a DTC will be set. Electrical noise can also be detected by the ECM, if the level is sufficient to effect engine operation a corresponding DTC will be set. An inactive CKP signal will cause a no start condition.

CKP DTCs

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

DTC 146

CKP signal inactive
DTC 146 is set by the ECM when CKP signal is not detected while the CMP signal is active or ICP has increased. DTC 146 can be set due to an open, short to ground or voltage source in the CKP circuit. A failed CKP sensor can also set DTC 146.

DTC 147

Incorrect CKP signal signature
DTC 147 is set by the ECM when the CKP signal has too few or many transitions per engine rotation. DTC 147 can be set due to an electrical noise in the CKP circuit or a failed CKP sensor.

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Tools

EST with MasterDiagnostics® software
EZ-Tech® interface cable
Digital Multimeter (DMM)
Breakout Box

CKP Pin-Point Diagnostics

Figure 348 CKP circuit diagram

Resistance Checks - Sensor and Circuit

Turn ignition switch to OFF. Check with Breakout Box connected (X1 only) to engine harness only and CKP sensor connected.

Test Point	Spec	Comments
X1-2 to X1-1	300 to 400 Ω	Resistance through sensor and complete circuit. If not within specification, do Resistance Checks - Sensor. If in specification, check for short to ground or open within wiring.

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Resistance Checks - Sensor

Turn ignition switch to OFF. Disconnect harness from sensor.

NOTE: Test point to sensor only.

Test Point	Spec	Comments
1 to 2	300 to 400 Ω	If within specification, check for short to ground or open within wiring. If not within specification, replace sensor.

Resistance Checks - Connector to Chassis Ground

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Disconnect negative battery cable. Disconnect harness from sensor. Use disconnected negative battery cable for ground test point.

Test Point	Spec	Comments
X1-1 to gnd cable	> 1 kΩ	If less than 1 kΩ, check for short to ground.
X1-2 to gnd cable	> 500 Ω	If less than 500 Ω, check for short to ground.

Harness Resistance Checks

Check with breakout box connected to engine harness only. Check from ECM to sensor harness connector.

Test Point	Spec	Comments
X1-2 to 2	<5 Ω	If greater than 5 Ω, check for open circuit.
X1-1 to 1	<5 Ω	If greater than 5 Ω, check for open circuit.

Operation Checks - CKP Sensor

Check with Breakout Box installed to ECM and engine harness.

Test Point	Engine Cranking	Low Idle	High Idle	Comments
CKP X1-1 to gnd X1-6	130-225 Hz @ 130-225 rpm	650-700 Hz @ 700 rpm	3.3 KHz @ 3400 rpm	Set DMM to DCmV-Hz

CKP Diagnostic Trouble Codes

DTC 146 = CKP signal inactive (CMP signal active and ICP increased)

DTC 147 = Incorrect CKP signal signature

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CMP (Camshaft Position) Sensor

Figure 349 Function diagram for CMP sensor

The function diagram for the CMP sensor includes the following:

Camshaft Position (CMP) sensor
Electronic Control Module (ECM)
Injector Drive Module (IDM)
Fuel Injector
Amber Lamp (Warn Engine Lamp (WEL) for CF)

The CMP sensor provides the ECM with a signal that indicates camshaft position. As the cam rotates, the sensor identifies the position of the cam by locating a peg on the cam. The CMP is installed in the front left side of the lower crankcase.

Camshaft speed is calculated from the frequency of the CMP sensor signal. Diagnostic information on the CMP input signal is obtained by performing accuracy checks on signal levels, frequency, and duty cycle with software strategies.

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CMP Circuit Operation

Figure 350 CMP circuit diagram

The ECM needs the CKP and CMP signal to calculate engine speed and position. The CMP contains a permanent magnet which creates a magnetic field. The signal is created when the camshaft peg rotates past the sensor breaking the magnetic field. The ECM terminals for the CMP sensor are CMP positive X1-9 and CMP negative X1-10.

NOTE: Engine will not operate without CMP signal.

Fault Detection/Management

An inactive CMP signal during cranking is detectable by the ECM. During engine cranking the ECM monitors the CKP signal and Injection Control Pressure (ICP) to verify the engine is rotating. If the CMP signal is inactive during this time a DTC will be set. Electrical noise can also be detected by the ECM. When the level is sufficient to effect engine operation a corresponding DTC will be set. An inactive CMP signal will cause a no start condition.

CMP DTCs

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

DTC 143
Incorrect CMP signal signature
DTC 143 is set by the ECM when the CMP transition occurs at the wrong CKP location. DTC 143 can be set due to a mistimed camshaft to crankshaft, electrical noise in the CMP circuit, or a failed CMP sensor.

DTC 145
CMP signal inactive
DTC 145 is set by the ECM when the CMP signal is inactive, the CKP signal is active, and the ICP has increased. DTC 145 can be set due to an open short to ground or open voltage source in the CMP circuit. A failed sensor can cause DTC 145 to be set.

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Tools

EST with MasterDiagnostics® software
EZ-Tech® interface cable
Digital Multimeter (DMM)
Breakout Box

CMP Pin-Point Diagnostics

Figure 351 CMP circuit diagram

Resistance Checks - Sensor and Circuit

Check with breakout box connected [X1 only] to engine harness only and CKP sensor connected. Inspect for bent pins or corrosion.

NOTE: Set DMM to 4 kΩ range.

Test Point	Spec	Comments
X1-9 to X1-10	800 to 1 kΩ	Resistance through sensor and complete circuit. If not within specification, do “Resistance Checks - Sensor (page 336).” If in specification, check for short to ground or open within wiring.

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Resistance Checks - Sensor

Disconnect harness from sensor.

NOTE: Test point to sensor only.

Test Point	Spec	Comments
1 to 2	800 Ω to 1 kΩ	If within specification, check for short to ground or open within wiring. If not within specification, replace sensor.

Resistance Checks - Connector to Chassis Ground

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Disconnect negative battery cable. Disconnect harness from sensor. Use disconnected negative battery cable for ground test point.

Test Point	Spec	Comments
X1-9 to gnd cable	> 1 kΩ	If less than 1 kΩ, check for short to ground.
X1-10 to gnd cable	> 500 Ω	If less than 500 Ω, check for short to ground.

Harness Resistance Checks

Check with breakout box connected to engine harness only. Check from ECM to sensor harness connector.

Test Point	Spec	Comments
X1-9 to 1	<5 Ω	If greater than 5 Ω, check for open circuit.
X1-10 to 2	<5 Ω	If greater than 5 Ω, check for open circuit.

Operational Checks - CMP Sensor

Check with Breakout Box installed to ECM and engine harness.

Test Point	Engine Cranking	Low Idle	High Idle	Comments
X1-9 to X1-6	130-225 rpm[2]@ 130-225 rpm	700 rpm[2]@ 700 rpm	3400 rpm[2] @ 3400 rpm	Set DMM to DCmV-rpm[2]

Diagnostic Trouble Code Description

DTC 143 = Incorrect CMP signal signature

DTC 145 = CMP signal inactive

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ECI (Engine Crank Inhibit) System

Figure 352 Function diagram for ECI system

The function diagram for the ECI system consists of the following:

Electronic Control Module (ECM)
Transmission Control Module (TCM)
Transmission position switch / Park interlock solenoid
Ignition switch
Starter relay
Starter solenoid

Function

The Engine Crank Inhibit (ECI) is a function of the ECM to control the operation of the starter motor. The ECM prevents engagement of the starter motor when the engine is running. This prevents damage to the starter pinion and ring gear. The transmission position switch/Park interlock solenoid prevents engagement of the starter motor when the transmission is in gear.

The starter relay controls battery voltage to the starter solenoid.

Operation

The ECM controls the starting system. The TCM provides input to the ECM.

Starter Relay

The starter relay controls voltage to the starter motor. Turning ignition switch to ON position supplies current to energize the relay at Pin 85. If the engine is not

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running and the driveline is not engaged, the ECM Pin X3-23 will enable the relay by suppling a ground circuit to Pin 86 of the relay. When the relay is latched, current passes through the relay to the terminals on the starter solenoid.

Before troubleshooting, inspect circuit connectors for loose or damaged terminals or wires. Wires and connections must be free of damage or corrosion. When connectors corrode, a white residue will be present and must be removed. Make sure the batteries are fully charged. To ensure accurate readings, check battery cables and grounds for clean and tight connections.

Transmission Position Switch / Park Interlock Solenoid

Supplies power to the TCM, which signals the ECM that the driveline is disengaged. When the transmission is in gear, ground is not supplied to the starter relay.

Electronic Control Module (ECM)

When the ECM recognizes that the engine is not running and the driveline is not engaged, the ECM will ground Pin X3-23. This provides a current path for the starter relay to latch when ignition switch is in crank position.

When the ECM recognizes that the engine is running or the driveline is engaged, the ECM will open Pin X3-23. This prevents the starter relay from latching and the starter motor from engaging.

Fault Detection/Management

There are no specific Diagnostic Trouble Codes (DTCs) relating to the wiring for the ECI.

Tools

EST with MasterDiagnostics® software
EZ-Tech® interface cable
Digital Multimeter (DMM)
Breakout Box
Relay breakout harness

The ECI circuit requires the use of vehicle circuit diagrams. See the applicable truck *Circuit Diagram Manual* for circuit numbers, connector and fuse locations.

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ECI Circuit Diagnostics

Figure 353 ECI circuit diagram

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Voltage Checks - ECM

Turn ignition switch to OFF. Connect Breakout Box to X3 and X4 to ECM and harness. Turn ignition switch to ON.

Test Point	Spec	Comments
X3-8 to X3-7 (gnd)	Transmission in Park or Neutral = B+	
	Transmission in gear = 0 V	
X3-23 to X3-7 (gnd)	Transmission in Park or Neutral, Engine not running - Ignition OFF or ON = 0 V	
	Transmission in Park or Neutral, Engine not running - Ignition cranking = 0 V	
	Transmission in Park or Neutral, Engine running - Ignition OFF or ON = 0 V	
	Transmission in Park or Neutral, Engine running - Ignition cranking = B+	

Harness Resistance Checks - ECM to Ground

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Disconnect negative battery cable. Connect Breakout Box to X3 harness only. Use negative battery cable as ground test point.

Test Point	Spec	Comments
X3-8 to gnd	> 1 kΩ	If less than 1 kΩ check for short to ground
X3-23 to gnd	> 1 kΩ	If less than 1 kΩ check for short to ground

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ECL Sensor (Engine Coolant Level)

Figure 354 Function diagram for ECL system

The ECM monitors engine coolant level and alerts the operator when coolant is low. The ECM can be programmed to shut the engine off when coolant is low.

The ECL system includes the Electronic Control Module (ECM), engine coolant tank with coolant level sensor, and red lamp. A ECL switch is used in plastic deaeration tanks.

Coolant level monitoring is a customer programmable feature that can be programmed by the EST. The coolant level feature is operational if programmed for 3-way warning or 3-way protection. The feature can not be enabled if the ECM was not factory programmed for 3-way protection.

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ECL Circuit Operation

Figure 355 ECL circuit diagram

The coolant level sensor uses a floating ball and a magnetic switch. When the coolant level is full, the float will rise and the magnet will pull the level switch open. This allows a 5 volt signal at ECM Pin X3-4. When the level is low, the switch will close and ECM Pin X3-4 will be 0 volts.

Fault Detection/Management

The ECM continuously monitors the ECL circuit for in-range faults. The ECM does not detect open or short circuits in the ECL system. When the ECM detects an in-range fault, DTC 236 will be set.

ECL Diagnostic Trouble Codes (DTCs)

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

DTC 236
ECL switch circuit fault (not connected for CF)
DTC 236 is set when the ECM detects an in-range fault voltage and the voltage is between 3.4 and 4.3 volts at ECM Pin X3-4 for more than 2.0 seconds.
DTC 236 is set when a high resistance connection or intermittent short to ground in the circuit exists.
DTC 236 will not illuminate the red lamp (OWL is not connected for CF. If the condition is intermittent, the DTC will be logged as inactive.

Tools
EST with MasterDiagnostics® software
EZ-Tech® interface cable
Digital Multimeter (DMM)
Breakout Box

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ECL Pin-Point Diagnostics

Figure 356 ECL circuit diagram

The ECL circuit may require the use of vehicle circuit diagrams. See the applicable truck *Circuit Diagram Manual* for circuit numbers, connector and fuse locations.

Coolant Level Sensor Connector

Disconnect sensor from harness, turn ignition switch to ON. Test with coolant level full.

NOTE: After removing connector, inspect for damaged pins, corrosion, or loose pins. Repair as required.

Test Point	Spec	Comment
A to gnd	5 ± 0.5 V	If voltage less than 5 volts, check for open signal circuit, short to ground or failed ECM.
B to gnd	0 V	If voltage greater than 0 volts, check for signal circuit shorted to another circuit

Resistance Checks - Coolant Level Sensor

Disconnect sensor connector and measure across sensor.

Test Point	Spec	Comment
A to B	> 1 kΩ	If less than 1 kΩ, check for low coolant or failed sensor.

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Harness Resistance Checks - Coolant Level Sensor

Turn ignition switch to OFF. Connect breakout box to chassis harness only. Disconnect sensor.

Test Point	Spec	Comment
B to gnd	< 5 Ω	If greater than 5 Ω, check for open ground wire
X3-4 to A	< 5 Ω	If greater than 5 Ω, check for open signal wire (breakout box connected)

Operational Voltage Checks - Coolant Level Sensor

Check with breakout box connected and sensor connected. Turn ignition switch to ON.

Test Point	Spec	Comment
X3-4 to X3-7	5 V	Voltage greater than 4.3 volts with tank full.
		Voltage less than 3.4 volts with tank empty

ECL Diagnostic Trouble Code

DTC 236 = Signal voltage between 3.4 and 4.3 volts for more than 2.0 seconds.

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ECM (Electronic Control Module) Self-Diagnostics

Figure 357 Function diagram for the ECM

The ECM monitors and controls the engine operation and performance.

The ECM also performs the following functions:
Enables cruise control
Communicates engine and vehicle information to instrument cluster
Enables electronically controlled transmission
Enables diagnostic programming tools

Fault Detection/Management

The ECM automatically performs diagnostic self-checks. The ECM self-test includes memory, programming, and internal power supply checks. The ECM will detect internal Diagnostic Trouble Codes (DTCs), depending on the severity of the problem, and provide DTC management strategies to permit limited engine and vehicle operation.

When DTCs 613, 614, 621, 622, or 623 are set by the ECM, the amber lamp (WEL for CF) will be illuminated.

ECM Self Diagnostic Trouble Codes (DTCs)

DTC 111

No errors detected - flash code only	
Condition:	No DTC conditions detected

NOTE: Can only determine if ECM has detected continuous DTCs detected during an Output Circuit Check. DTCs generated during an On-Demand Test such as KOER Standard Test can only be accessed by an EST.

DTC 613

ECM/IDM software not compatible	
Condition	ECM/IDM software is incompatible
Symptoms	Possible no start - low power
Possible Causes	Field replacement ECM or IDM mismatch
Actions	Program ECM or IDM. May require ECM or IDM replacement.

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DTC 614

EFRC/ECM configuration mismatch	
Condition	EFRC/ECM configuration mismatch
Symptoms	Possible hard start and no start or low power condition
Possible Causes	Wrong Engine Family Rating Code (EFRC) selected for the ECM strategy programmed in the module.
Actions	Check EFRC and verify that it matches the ECM strategy level. Reprogram the ECM or change the EFRC as required.

DTC 621

Engine using manufacture default rating	
Condition	Manufacturing defaults selected.
Symptoms	Very low power (25 hp).
Possible Causes	Programmable parameters for the ECM were never programmed in module. (Usually occurs in new vehicle or new module).
Actions	Program ECM.

DTC 622

Engine using field default rating	
Condition	Engine using field default rating.
Symptoms	Low power (lowest rating in engine class) and vehicle features not working.
Possible Causes	Programmable parameters for the ECM incorrectly programmed in module.
Actions	Program ECM.

DTC 623

Invalid engine EFRC	
Condition	Invalid EFRC
Symptoms	Possible hard start and no start or low power condition.
Possible Causes	Wrong EFRC selected for the ECM strategy programmed in the module.
Actions	Check the EFRC and verify that it matches the ECM strategy level. Reprogram the ECM or change the EFRC as necessary.

DTC 624

Field default active	
Condition	Field defaults active.
Symptoms	Low power (lowest rating in engine class) and vehicle features not functioning.
Possible Causes	Programmable parameters for the ECM incorrectly programmed in module.
Actions	Program ECM

DTC 631

Read Only Memory (ROM) self-test fault	
Condition	ROM self-test fault
Symptoms	No start.
Possible Causes	Internal ECM problem.
Actions	Replace the ECM.

DTC 632

Random Access Memory (RAM) - CPU self-test fault	
Condition	RAM Memory - CPU self-test fault
Symptoms	No start
Possible Causes	Internal ECM problem
Actions	Replace the ECM

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DTC 655

Programmable parameter list level incompatible	
Condition	Programmable parameter list level incompatible
Symptoms	No start or run in field defaults
Possible Cause	Programming problem or internal ECM problem
Actions	Program ECM. May require ECM replacement

DTC 661

RAM programmable parameter list corrupt	
Condition	RAM programmable parameter list corrupt
Symptoms	No start or run in field defaults
Possible Causes	Internal ECM problem
Actions	Program ECM. May require ECM replacement

DTC 664

Calibration level incompatible	
Condition	Calibration level incompatible
Symptoms	No start or run in field defaults
Possible Causes	Programmable problem or internal ECM problem
Actions	Program ECM

DTC 665

Programmable parameter memory content corrupt	
Condition	Programmable parameter memory content corrupt
Symptoms	No start or run in field defaults
Possible Causes	Internal ECM problem
Actions	Replace the ECM

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ECM/IDM (Electronic Control Module and Injector Driver Module) Communications

Figure 358 Function diagram for the ECM/IDM communication system

The function diagram for the ECM/IDM communication system includes the following:

- Electronic Control Module (ECM)
- Injector Drive Module (IDM)
- Exhaust Gas Recirculation (EGR) drive module
- Crankshaft Position Output (CKPO) signal
- Camshaft Position Output (CMPO) signal
- Controller Area Network (CAN2) link
- Amber Lamp (Warn Engine Lamp (WEL) for CF)

Function

The ECM provides two output channels to aid the IDM with engine speed and position signals. The CKPO and CMPO channels are in phase with the CKP and CMP signals received by the ECM.

The ECM and IDM are in continuous communication. The CKPO and CMPO signals are generated when the ECM switches these circuits to ground. The IDM uses these signals for engine speed and timing.

The CAN2 datalink is a bidirectional communication line between the ECM, IDM, and EGR drive module. The three modules use the datalink to send operating strategies, sensor information, diagnostic demands, and DTCs.

NOTE: The engine will not operate without the CAN2, CKPO, or CMPO signal.

Read all safety instructions in the "Safety Information" section of this manual before doing any procedures.
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ECM/IDM Circuit Operation

Figure 359 ECM/IDM circuit diagram

The ECM/IDM communication link consists of a series of interdependent signals that include the CKPO, CMPO, and the CAN2 datalink.

The CKPO signal is a 0 to 12 volt signal that communicates (from the ECM to IDM) the position of the crankshaft. The signal is used by the IDM to synchronize the injector firing sequence and is calculated from the signal generated from the CKP sensor. The ECM generates the CKPO signal by pulling down (switching to ground) a 12 volt communication circuit in the IDM.

The CMPO signal is a 0 to 12 volt signal that communicates (from the ECM to IDM) the position of the camshaft. The signal is used by the IDM to synchronize the injector firing sequence and is calculated from the signal generated from the CMP sensor. The ECM generates the CMPO signal by pulling down (switching to ground) a 12 volt communication circuit in the IDM.

CAN2 datalink is a J1939 high speed private communication datalink between the ECM and IDM. The ECM receives messages that include injector coil status, IDM calibration level, CMPO and CKPO DTCs, injector DTCs, IDM DTCs, and injector test results from the IDM. The IDM receives injector diagnostic commands, operation strategies, modes and conditions from the ECM.

NOTE: CAN2 datalink is used only as communication between the ECM, EGR drive module, and IDM. There is no relation to the CAN1 link that is used for communication with various processors on a vehicle.

Fault Detection/Management

The ECM continuously monitors the IDM. When the ECM fails to receive required continuous communication from the IDM, the ECM will set a DTC.

ECM/IDM DTCs

DTCs are read using the Electronic Service Tool (EST) or by counting the flashes from the amber and red lamps.

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DTC 543

ECM/IDM communications fault

DTC 543 is set by the ECM when the ECM is not communicating with the IDM.

DTC 543 can be set when CAN2 datalink J1939 between ECM and IDM is shorted to ground, V_{REF}, or battery or the current is open. If IDM power is low, DTC 543 can be set.

When DTC 543 is active the amber lamp (WEL for CF) is illuminated.

NOTE: If a no start condition exists with DTC 543 and DTC 368 active, check the CAN2 datalink wiring (EGR to ECM and IDM). See “EGR (Exhaust Gas Recirculation) Control (page 375)” in this section. One of the CAN2 datalink wires (CAN2 positive or negative) is open, shorted, or a short to power exists.

DTC 551

IDM/CMPO signal inactive

DTC 551 is set by the ECM when no CMPO signal is present while the CKPO is active. DTC 551 can also be set when no CMPO/CKPO is present while the ECM reports it is in the run mode.

DTC 551 can be set when the CMPO is open, or shorted to ground or shorted to a voltage source. DTC 551 can also be set, if logic power is low.

DTC 552

IDM incorrect CMPO signal signature

DTC 552 is set when the CMPO transition occurs at the wrong CKPO tooth.

DTC 552 can be set due to electrical noise creating a miscount on CMP location.

DTC 553

IDM/CKPO signal inactive

DTC 553 is set by the ECM when no CKPO signal is present while the CMPO is active. DTC 552 can also be set when no CMPO/CKPO is present while the ECM reports it is in the run mode.

DTC 553 can be set when CKPO is open, shorted to ground, or shorted to a voltage source. DTC 553 can also be set if logic power is low.

DTC 554

IDM incorrect CKPO signal signature

DTC 554 is set by the ECM when CKPO signal has too few or too many transitions per engine rotation.

DTC 554 can be set due to electrical noise creating a miscount on CKP location.

Tools

EST with MasterDiagnostics® software

EZ-Tech® interface cable

Digital Multimeter (DMM)

Breakout Box

Terminal Test Adapter Kit

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ECM/IDM Pin-Point Diagnostics

Figure 360 ECM/IDM circuit diagram

Voltage Checks - ECM Connector to Chassis Ground

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector or relay for the ECM and IDM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Check with Breakout Box connected (X1 and X2) to engine harness only. Inspect for bent pins or corrosion. Turn ignition switch to ON.

NOTE: ECM is not connected, IDM output is checked through the wiring harness.

Test Point	Spec	Comments
X2-6 to gnd	1 to 4 V	Digital signal. If no voltage check for open or short to ground and do resistance checks to chassis ground, harness resistance checks, and resistance checks - IDM CAN2 checks.
X2-13 to gnd	1 to 4 V	Digital signal. If no voltage check for open or short to ground and do resistance checks to chassis ground, harness resistance checks, and resistance checks - IDM CAN2 checks.
X1-19 to gnd	11 to 12 V	If less than specification, check for open or short to ground. Check IDM power relay.
X1-24 to gnd	11 to 12 V	If less than specification, check for open or short to ground. Check IDM power relay.
X2-12 to gnd	0 V	Ground, no voltage expected

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Resistance Checks - to Chassis Ground

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Check with Breakout Box connected (X1 and X2) to engine harness only. Disconnect negative battery cable. Use disconnected battery cable for ground test point.

Test Point	Spec	Comments
X1-19 to gnd cable	>1 kΩ	If less than 1 kΩ, check for short to ground or internal IDM problem. Test with IDM connector X3 disconnected. If problem remains, repair or replace harness. If disconnect of X3 corrected problem, replace IDM.
X1-24 to gnd cable	>1 kΩ	If less than 1 kΩ, check for short to ground or internal IDM problem. Test with IDM connector X3 disconnected. If problem remains, repair or replace harness. If disconnect of X3 corrected problem, replace IDM.
X2-6 to gnd cable	>1 kΩ	If less than 1 kΩ, check for short to ground or internal IDM problem. Test with IDM connector X3 disconnected. If problem remains, repair or replace harness. If disconnect of X3 corrected problem, replace IDM.
X2-13 to gnd cable	>1 kΩ	If less than 1 kΩ, check for short to ground or internal IDM problem. Test with IDM connector X3 disconnected. If problem remains, repair or replace harness. If disconnect of X3 corrected problem, replace IDM.
X2-12 to gnd cable	>1 kΩ	If less than 1 kΩ, check for short to ground or internal IDM problem. Test with IDM connector X3 disconnected. If problem remains, repair or replace harness. If disconnect of X3 corrected problem, replace IDM.

Harness Resistance Checks

Turn ignition switch to OFF. Check with Breakout Box connected to (X1 and X2) to engine harness only. IDM checked at harness connector X3 using terminal test pins. IDM pins are numbered on the mating end of the connector.

NOTE: Test points are from ECM to IDM.

Test Point	Spec	Comments
ECM X1-19 to IDM X3-5	<5 Ω	If greater than 5 Ω, check for open in harness
ECM X1-24 to IDM X3-10	<5 Ω	If greater than 5 Ω, check for open in harness
ECM X2-6 to IDM X3-30	<5 Ω	If greater than 5 Ω, check for open in harness
ECM X2-13 to IDM X3-31	<5 Ω	If greater than 5 Ω, check for open in harness
ECM X2-12 to IDM X3-32	<5 Ω	If greater than 5 Ω, check for open in harness

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Figure 361 ECM/IDM circuit diagram

Resistance Checks - CAN2 Datalink

Connect Breakout Box to ECM and chassis harness.

Test Point	Spec	Comments
ECM X2-6 to gnd	3 ± 0.1 MΩ	If greater than spec, check for short to ground or another circuit. Check ECM and IDM separately. If less than spec, check for open circuit on CAN2+. Check ECM and IDM separately.
ECM X2-13 to gnd	3 ± 0.1 MΩ	If greater than spec, check for short to ground or another circuit. Check ECM and IDM separately. If less than spec, check for open circuit on CAN2+. Check ECM and IDM separately.
ECM X2-6 to X2-13	60 Ω	If greater than spec, check for open circuit on CAN2+ and CAN2-. Check ECM and IDM separately. Do Resistance Checks - ECM CAN2 Circuit and Resistance Checks - IDM CAN2 Circuit.

Resistance Checks - ECM CAN2 Circuit

Remove ECM following procedure in the *Engine Service Manual*. Measure directly to ECM pins only

NOTE: Use ECM ground pins (X3-7 or X3-6) only for this test.

Test Point	Spec	Comments
ECM X2-6 to gnd	3.9 ± 0.2 MΩ	If greater than spec, replace the ECM.
ECM X2-13 to gnd	3.9 ± 0.2 MΩ	If greater than spec, replace the ECM.
ECM X2-6 to X2-13	120 Ω	If greater than spec, replace the ECM.

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Resistance Checks - IDM CAN2 Circuit

Remove ECM following procedure in the *Engine Service Manual*. Measure directly to ECM pins only.

NOTE: Use IDM ground pins (X3-1, X3-2, X3-3, X3-22, or X3-26) only for this test.

Test Point	Spec	Comments
IDM X3-30 to gnd	1.85 ± 0.2 MΩ	If greater than spec, replace the IDM.
IDM X3-31 to gnd	1.85 ± 0.2 MΩ	If greater than spec, replace the IDM.
IDM X3-30 to X3-32	120 Ω	If greater than spec, replace the IDM.
IDM X3-32 to gnd	< 5 Ω	If greater than spec, replace the IDM.
IDM housing to gnd	< 5 Ω	If greater than spec, replace the IDM.

Operational Checks for CMPO and CKPO

Check with Breakout Box connected to ECM and engine harness.

Test Point	Engine Cranking	Low Idle	High Idle	Comment
X1-24 to X1-6	130-225 rpm[2] @ 130-225 rpm	700 rpm[2] @ 700 rpm	3400 rpm [2] @ 3400 rpm	Set DMM to DC-rpm[2]
X1-19 to X1-6	130-225 Hz @ 130-225 rpm	700 Hz @ 700 rpm	3.3 Hz @ 3400 rpm	Set DMM to DC-Hz

Diagnostic Trouble Codes

DTC 543 = ECM/IDM communication fault

DTC 551 = IDM CMPO signal inactive

DTC 552 = IDM incorrect CMPO signal signature

DTC 553 = IDM CKPO signal inactive

DTC 554 = IDM incorrect CKPO signal signature

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ECM PWR (Electronic Control Module Power)

Figure 362 Function diagram for the ECM PWR

The function diagram for ECM PWR includes the following:

- Electronic Control Module (ECM)
- Battery
- ECM power relay
- Ignition switch or Power relay
- Fuses

Function

The Electronic Control Module (ECM) requires a 12 volt power source to function correctly. Operating power is received from the vehicle batteries through the ECM main power relay each time the ignition switch is turned ON.

When the ignition switch is turned ON, the ECM provides an internal ground to the coil side of the ECM power relay. This closes the relay contacts and provides the ECM with power.

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ECM PWR Circuit Operation

Figure 363 ECM PWR circuit diagram

The ECM is grounded to the battery negative terminal at ECM terminals X3-6 and X3-7.

When the ignition switch is turned on the ECM receives V_{IGN} power at Pin X3-3. The power signals the ECM to provide a ground path to switch the ECM power relay from Pin X3-5 to relay Pin 2(85). Switching the ECM relay provides power directly from the battery positive terminal through two fuses and relay contacts 3(30) and 5(87) to Pins X4-1 and X4-2. See the applicable truck *Circuit Diagram Manual* for circuit numbers, connector and fuse locations.

Fault Detection/Management

The ECM internally monitors battery voltage. When the ECM continuously receives less than 7 volts or more than 23 volts, a Diagnostic Trouble Code (DTC) will be set.

ECM PWR DTCs

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

DTC 112

Electrical system voltage B+ out-of-range high
DTC 112 is set when the ECM detects an alternator output greater than 23 volts at PIN X3-3 for more than 0.5 seconds. DTC 112 can be set when jump starting the engine and additional voltage is introduced. Incorrect external battery connections can cause the voltage increase. If the condition causing DTC 112 is intermittent, the code will change from active to inactive status. DTC 112 will not cause the amber lamp (WEL for CF) to turn on.

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DTC 113

Electrical system voltage B+ out-of-range low

DTC 113 is set when the ECM detects less than 7 volts at PIN X3-3 for more than 0.5 seconds.

DTC 113 can be set by a failed alternator or ECM power relay, discharged batteries, or increased resistance in the battery feed circuits.

If the condition causing DTC 113 is intermittent, the code will change from active to inactive status. DTC 113 will not cause the amber lamp (WEL for CF) to turn on.

When DTC 112 or 113 is active, see the applicable truck *Circuit Diagram Manual* for circuit numbers, connector and fuse locations.

DTC 626

Unexpected reset fault

DTC 626 is set when power is interrupted to the ECM. Loose or dirty connections at battery or ground cables can cause the ECM to power down.

After circuit becomes intact, the ECM will reboot. Erratic engine performance can occur. Turning engine ignition switch to OFF and then to ON will cause the code to change from active to inactive status.

When DTC 626 is active, monitor the voltage at ECM PIN X4-1 and X4-2. Examine for intermittent connections in the power feed wiring. The EST can be used to indicate DTCs and display the V_{IGN} voltage measured by the ECM to PIN X3-3.

DTC 626 will not turn the amber lamp (WEL for CF) on.

Tools

EST with MasterDiagnostics® software

EZ-Tech® interface cable

Digital Multimeter (DMM)

Relay breakout harness

Breakout Box

Terminal Test Adapter Kit

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ECM PWR Pin-Point Diagnostics

Figure 364 ECM PWR circuit diagram

Voltage Checks - ECM Power Relay Socket (KOEO)

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector or relay for the ECM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Follow tests in order. Check with ECM relay and breakout harness installed, ignition switch to ON and the engine is off. Inspect for bent pins or corrosion.

The ECM PWR circuit requires the use of vehicle circuit diagrams.

Test Point	Spec	Comments
1(86) to gnd	B+	Continuous voltage. If no voltage, check power circuits from batteries through fuse. If fuse is blown, check for short to ground. If fuse is good, check for open between PIN 3(30) and B+.
3(30) to gnd	B+	Continuous voltage. If no voltage, check fuses. If fuse is blown, check for short to ground. If fuse is good, check for open between PIN 3(30) and B+.
2(85) to gnd	0.06 to 2 V	If greater than 2 volts is present, check for open circuit between PIN X3-5 to PIN 2(85) on relay or V_{IGN} circuit.
5(87) to gnd	B+	Continuous voltage. If no voltage, replace relay.

NOTE: See the applicable truck *Circuit Diagram Manual* for circuit numbers, connectors, relay, and fuse locations.

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Voltage Checks - ECM (KOEO)

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector or relay for the ECM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Follow tests in order. Check with Breakout Box installed between chassis harness and ECM. Inspect for bent pins and corrosion.

Test Point	Spec	Comments
X3-3 to gnd	B+	Power from ignition switch to ECM. If no voltage. Check for blown fuse or open circuit.
X3-6 to gnd	0 V	Ground - voltage reading indicates poor ground to battery. If voltage is present check for open or high resistance between battery (-) and ECM pins.
X3-7 to gnd	0 V	Ground - voltage reading indicates poor ground to battery. If voltage is present check for open or high resistance between battery (-) and ECM pins.
X3-5 to gnd	0.06 to 2 V	ECM grounds relay through internal transistor. If greater than 2 volts is present, replace ECM.
X4-1 to gnd	B+	Power from relay to ECM. If no voltage, check for open between X4-1 and 5(87) on ECM relay.
X4-2 to gnd	B+	Power from relay to ECM. If no voltage, check for open between X4-2 and 5(87) on ECM relay.

NOTE: See the applicable truck *Circuit Diagram Manual* for circuit numbers, connector, relay, and fuse locations.

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Harness Resistance Checks

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

CAUTION: To avoid engine damage, turn ignition switch to OFF before unplugging the connector or relay for the ECM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Check with ignition switch to OFF. Disconnect negative battery cable. Inspect for bent pins or corrosion. Install relay breakout harness and Breakout Box to X3 and X4 chassis harness only.

Test Point	Spec	Comments
X3-5 to 2(85) (ECM relay)	<5 Ω	If greater than 5 Ω, check connections for open between ECM and relay.
X4-1 to 5(87) (ECM relay)	<5 Ω	If greater than 5 Ω, check connections for open between ECM and relay.
X4-2 to 5(87) (ECM relay)	<5 Ω	If greater than 5 Ω, check connections for open between ECM and relay.
3(30) (ECM relay) to B+ cable	<5 Ω	If greater than 5 Ω, check connections for open between relay and positive battery cable. Check fuses.
1(86) (ECM relay) to B+ cable	<5 Ω	If greater than 5 Ω, check connections for open between relay and positive battery cable. Check fuse.
X3-6 to neg bat cable	<5 Ω	If greater than 5 Ω, check connections to battery ground.
X3-7 to neg bat cable	<5 Ω	If greater than 5 Ω, check connections to battery ground.
X3-3 to V_{IGN} (power relay)	<5 Ω	If greater than 5 Ω, check connections or open between ECM and V_{IGN} power relay.

NOTE: See the applicable truck *Circuit Diagram Manual* for circuit numbers, connector, relay, and fuse locations.

ECM PWR Diagnostic Trouble Codes

DTC 112 = Internal voltage power out of range high greater than 23 volts

DTC 113 = Internal voltage power out of range low less than 7 volts

DTC 626 = Unexpected reset fault

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ECT (Engine Coolant Temperature) Sensor

Figure 365 Function diagram for the ECT sensor

The function diagram for the ECT sensor includes the following:

Engine Coolant Temperature (ECT) sensor
Electronic Control Module (ECM)
Injector Drive Module (IDM)
Fuel injector
Exhaust Gas Recirculation (EGR) valve
Amber Lamp (Warn Engine Lamp (WEL) for CF)
Red Lamp (Oil/Water Lamp (OWL) for CF)

Function

The ECT sensor is a thermistor sensor located on the left side of the front cover. The ECM supplies a 5 volt reference signal which the ECT sensor uses to produce an analog voltage that indicates temperature.

The ECT sensor changes resistance when exposed to different temperatures. As the coolant temperature decreases, the resistance of the thermistor increases. This causes the signal voltage to increase. As the coolant temperature increases, the resistance of the thermistor decreases. This causes the signal voltage to decrease.

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The ECT sensor provides a feedback signal to the ECM indicating engine coolant temperature.

The ECM monitors the ECT signal to control the following features:

Engine Warning and Protection System (EWPS)
Cold Ambient Protection (CAP)
Idle Shutdown Timer (IST)
Fast Idle
Coolant compensation

During engine operation, if the ECM recognizes that the ECT signal is lower or higher than the expected value it will set a DTC.

Coolant Temperature Compensation

Coolant temperature compensation reduces fuel delivery if ECT is above cooling system specification.

The reduction in fuel delivery begins when ECT reaches approximately 111 °C (232 °F). A relatively rapid reduction of 15% will be achieved as the ECT reaches approximately 113 °C (235 °F).

Fuel reduction is calibrated to a maximum of 30% before standard engine warning or optional warning/protection is engaged. If warning or shutdown occurs, a DTC is stored in the ECM memory.

NOTE: Coolant temperature compensation may be disabled in emergency vehicles that require 100% power on demand.

Fast Idle

Fast idle increases engine cold idle speed up to 875 rpm (normally 700 rpm) for faster warm-up to operating temperature. This is accomplished by the ECM monitoring the ECT sensor input and adjusting the fuel injector operation accordingly.

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

Engine Warning and Protection (EWPS)

The EWPS is an optional feature that can be enabled or disabled. When enabled, the EWPS will warn the operator of an overheat condition and can be programmed to shut down the engine. The ECM will illuminate the red lamp.

The red lamp (OWL for CF) will come on and an audible alarm will sound when ECT reaches approximately 113 °C (235 °F). A coolant temperature event logging function will occur when ECT reaches approximately 116 °C (240 °F) and will record the event in engine hours and odometer readings. The engine will shut down when the ECT reaches approximately 116 °C (240 °F), if 3-way protection is enabled.

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ECT Circuit Operation

Figure 366 ECT circuit diagram

The ECT sensor is supplied with a 5 volt reference voltage at Pin 2 from ECM Pin X1-8. The sensor is grounded at Pin 1 through the signal ground terminal at the ECM Pin X1-6 as the coolant temperature increases or decreases, the sensor changes resistance and provides the coolant temperature signal voltage at the ECM. The signal voltage is monitored by the ECM to determine the temperature of the coolant.

Fault Detection/Management

The ECM continuously monitors the signal of the ECT sensor to determine if the signal is within an expected range. If the ECM detects an out of range high or low, the ECM will ignore the ECT signal and assume an engine coolant temperature of -20 °C (-4 °F) for starting and 82 °C (180 °F) for engine running conditions. When this occurs, the EWPS, CAP, IST, cold idle advance, and coolant temperature compensation features are disabled.

ECT DTCs

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

DTC 114

ECT signal out of range low
DTC 114 set by the ECM when the ECT signal is less than 0.127 volts for more than 0.35 seconds. DTC 114 can be set due to a short to ground in the signal circuit or a failed ECT sensor. When DTC 114 is active the amber lamp (WEL for CF) is illuminated.

DTC 115

ECT signal out of range high
DTC 115 set by the ECM when the ECT signal is greater than 4.6 volts for more than 0.35 seconds. DTC 115 can be set due to an open signal or ground circuit, a short to a voltage source, or a failed ECT sensor. When DTC 115 is active the amber lamp (WEL for CF) is illuminated.

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Tools
EST with MasterDiagnostics® software
EZ-Tech® interface cable
Digital Multimeter (DMM)
3-Banana plug harness
500 Ohm resistor harness
Breakout Box and harness
Terminal Test Adapter Kit

ECT Operational Diagnostics

Figure 367 Continuous Monitor session

WARNING: To prevent personal injury, use care to prevent contact with the door edge when the cab is up and the door is open.

1. Use EST, select D_ContinuousMonitor.ssn from the Open Session File window, select Open to open the session.

Figure 368 Continuous Monitor test

2. Select Diagnostics from the menu bar.
3. Select Key-On Engine-Off Tests from the drop down menu.
4. From the KOEO Diagnostics menu, select Continuous Monitor and select Run to start the test.
5. Monitor ECT signal voltage. Verify an active DTC for the ECT circuit.
6. If code is active, do step 8 and 9 to check circuit for the ECT sensor using the following table.

WARNING: To prevent personal injury or death, be careful around rotating parts (belts and fan) and hot engine surfaces.

7. Wiggle connectors and wires at all suspected problem locations. If circuit continuity is interrupted, the EST will display DTCs related to the condition.

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8. Disconnect engine harness from temperature sensor.

NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

9. Connect Temperature Sensor Breakout Harness to engine harness only.

Figure 369 Close session

10. When finished with this test, select Session from menu bar, then Close.

NOTE: After removing connector, inspect for damaged pins, corrosion, or loose terminals. Repair as required.

Circuit Checks - ECT Sensor

Use EST, breakout harness, 3-Banana Plug Harness, and 500 ohm resistor harness.		
Test Condition	**Spec**	**Checks**
Sensor disconnected	> 4.6 V	If voltage less than 4.6 volts, check signal circuit for short to ground.
3-Banana Plug Harness connected between Pin 2 (Green) and Pin 1 (Black) of breakout harness	0 V	If voltage is greater than 0.127 volts, check ground and signal circuit for open or high resistance. Use a breakout box and measure resistance from Pin 1 to Pin X1-6 and from Pin 2 to X1-8 (spec < 5 Ω).
500 Ohm resistor harness connected between Pin 2 (Green) and Pin 1 (Black) of breakout harness	< 1.0 V	If voltage is greater than 1.0 volts, check signal circuit for short to V_{REF}, B+, or another sensor's signal voltage.
Connect engine harness to sensor. Use the EST to clear DTCs. If an active code remains after checking test conditions, replace the ECT sensor.		

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ECT Pin-Point Diagnostics

Figure 370 ECT circuit diagram

Voltage Checks - Sensor Connector

Turn ignition switch to OFF. Disconnect harness from sensor. Inspect for bent pins or corrosion. Connect breakout harness to engine harness only. Turn ignition switch to ON.

Test Point	Spec	Comments
2 to gnd	4.6 to 5.0 V	Pull up voltage, if no voltage or low, circuit is open, has high resistance, or short to ground
1 to gnd	0 to 0.25 V	Voltage greater than 0.25 volts, wire shorted to V_{REF} or B+.

Resistance Checks - Connector to Chassis Ground

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Disconnect harness from sensor. Connect ECT breakout harness to engine harness only. Disconnect negative battery cable.

Test Point	Spec	Comments
1 to gnd	< 5 Ω	If greater than 5 Ω, check for open ground circuit
2 to gnd	> 1 kΩ	If less than 1 kΩ, check for shorted signal to ground

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Harness Resistance Checks

Connect Breakout Box to engine harness only. Connect breakout harness to engine harness only.

Test Point	Spec	Comments
X1-6 to 1	< 5 Ω	If greater than 5 Ω, check for open ground wire
X1-8 to 2	< 5 Ω	If greater than 5 Ω, check for open signal wire

Operational Voltage Checks - ECT Sensor (with Breakout Box)

Use EST and DMM. Check with Breakout Box connected X-1 only to ECM and engine harness.

Test Point	Coolant Temp	Resistance	Voltage
X1-8 to X1-6 (gnd)	-17 °C (0 °F)	249.1 kΩ	4.32 V
X1-8 to X1-6 (gnd)	0 °C (32 °F)	94.6 kΩ	3.88 V
X1-8 to X1-6 (gnd)	20 °C (68 °F)	37.4 kΩ	3.11 V
X1-8 to X1-6 (gnd)	37 °C (100 °F)	18.3 kΩ	2.31 V
X1-8 to X1-6 (gnd)	100 °C (212 °F)	2.3 kΩ	0.52 V

Operational Voltage Checks - ECT Sensor (with Breakout Harness)

Use EST and DMM. Check with breakout harness connected to sensor and engine harness.

Test Point	Coolant Temp	Resistance	Voltage
2 (Green) to 1 (Black)	108 °C (228 °F)	1.605 kΩ	0.37 V
2 (Green) to 1 (Black)	87.7 °C (190 °F)	3 kΩ	0.65 V
2 (Green) to 1 (Black)	0 °C (32 °F)	91.1 kΩ	3.86 V
2 (Green) to 1 (Black)	–17.8 °C (0 °F)	208 kΩ	4.25 V

ECT Diagnostic Trouble Codes

DTC 114 = Signal voltage was less than 0.127 volts for more than 0.35 seconds.

DTC 115 = Signal voltage was greater than 4.6 volts for more than 0.35 seconds.

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EFAN Control (Engine Fan Control)

Figure 371 Function diagram for EFAN

The function diagram for EFAN includes the following:

Electronic Control Module (ECM)
Engine Coolant Temperature (ECT) sensor
Intake Air Temperature (IAT) sensor
Electronic System Controller (ESC)
Engine fan relay

Function

The EFAN control provides ON/OFF control of the engine cooling system fan. The ECM can be programmed to set and monitor limits for engine coolant temperature, intake air temperature, engine mode selection (operating or diagnostic).

EFAN is accessible with the EST. Fan on and off temperature can be programmed by technician, but the mode of operation must be done by Technical Services.

The purpose of the engine fan control is to provide the correct logic to determine when the fan should be turned on or off by energizing/de-energizing the fan drive relay. The purpose of the engine fan is to allow a higher air flow for heat exchange between the radiator and the ambient air when needed.

Engine Fan Control – This parameter indicates to the on-board electronics whether or not the truck has the electronic engine fan control feature.
AC Fan Activation – This feature will allow fan activation through the ECM when requested from the ESC during AC operation.
Disable – Feature is turned off at all times.
Fan On Temperature – This parameter indicates the coolant temperature that the fan will be electronically activated.
Fan Off Temperature – This parameter indicates the coolant temperature that the fan will be electronically deactivated.

Fan Clutch Circuit Operation

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Figure 372 Fan clutch circuit diagram

Electric current locks the fan clutch and allows fan activation and cooling.

When the fan needs to be activated, the ground is removed from ECM Pin X4-14. The coil side of the fan relay is de-energized causing the switch side to close, this sends 12 volts from Pin 87A to the fan clutch. The fan clutch locks the fan in place when power is present at Pin 87A.

When the fan needs to be deactivated, Pin X4-14 is grounded through the ECM. The coil side of the fan relay is energized, causing the switch side to open, and removes power from Pin 87A to the fan clutch. The fan clutch unlocks the fan when the power is removed from Pin 87A.

NOTE: With Stripped Chassis, a 15 second delay in fan engagement will occur after the fan clutch receives power from the fan relay. A 75 second fan disengagement delay will occur when power from the fan relay is turned off. Verify fan engagement and disengagement at 2000 rpm.

Fault Detection/Management

An open or short to ground in the EFAN can be detected by the ECM during an on-demand engine standard test. The IAT and ECT are monitored continuously. If a DTC is detected in the IAT or ECT, the EFAN control is disabled and the engine fan is on all the time.

NOTE: Before diagnosing, check that the ECM is programmed correctly. Verify vehicle/application has an electronic fan.

EFAN Diagnostic Trouble Codes (DTCs)

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

DTC 246
Engine Fan - OCC self-test fault
DTC 246 is set by the ECM only during KOEO Standard Test. During this test the ECM performs an output circuit test that momentarily enables the EFAN solenoid and measures the voltage drop across the relay

Tools
EST with MasterDiagnostics® software
EZ-Tech® interface cable
Digital Multimeter (DMM)
Relay Breakout Harness

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Fan Clutch Pin-Point Diagnostics

Figure 373 Fan clutch circuit diagram

Voltage Checks - Fan Connector

Disconnect fan connector. Turn ignition switch to ON. Test done during KOEO Standard Test.

Test Point	Spec	Comment
A to gnd	B+ ± 0.5 V	If less than B+, check relay. Also check for an open circuit, short to ground, or short to voltage source. Do Output State Test - Voltage Check at Fan Connector.
B to gnd	0 to 0.25 V	If greater than 0.25 volts, check for an open ground circuit or a short to voltage source. Do Harness Resistance Checks.

Output State Test - Voltage Checks - Fan Connector

Disconnect fan connector. Turn ignition switch to ON. Run Output State Tests. For help, see “Diagnostic Tests (page 73)” in the “Diagnostic Software Operation (page 70)” section in this manual for the procedure to run Low and High Output State Tests.

Test State/Point	Spec	Comment
Output State Test - Low		
A to gnd	0 to 0.25 V	If greater than 0.25 volts, check relay. Also check for short to voltage source.
Output State Test - High		
A to gnd	B+ ± 0.5 V	If less than B+, check relay. Also check for an open circuit, short to ground, or a short to voltage source. Do “Output State Test - Voltage Checks at Fan Relay (page 371).”

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Output State Test - Voltage Checks - Fan Relay

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector or relay for the ECM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Check with relay breakout harness connected with relay. Turn ignition switch to ON. Run the Output State Tests. For help, see “Diagnostic Tests (page 73)” in the “Diagnostic Software Operation (page 70)” section of this manual for the procedure to run Low and High Output State Tests.

Test State/Point	Spec	Comment
Output State Test - Low		
30 to gnd	B+ ± 0.5 V	If less than B+, do Harness Resistance Checks.
85 to gnd	B+ ± 0.5 V	If less than B+, do Harness Resistance Checks.
86 to gnd	0 to 0.25 V	If greater than 0.25 volts, check for open circuit, short to voltage source, ECM programming, or failed ECM. Do Harness Resistance Checks.
87 to gnd	B+ ± 0.5 V	If less than B+, and previous checks (30, 86, 85 to gnd) are within specification, replace relay.
87A to gnd	0 to 0.25 V	If greater than 0.25 volts, and previous checks (30, 86, 85 to gnd) are within specification, but 87 to gnd is not within specification, replace relay.
Output State Test - High		
30 to gnd	B+ ± 0.5 V	If less than B+, do Harness Resistance Checks.
85 to gnd	B+ ± 0.5 V	If less than B+, do Harness Resistance Checks.
86 to gnd	B+ ± 0.5 V	If less than B+, check for open circuit, ECM programming, or failed ECM. Do Harness Resistance Checks.
87 to gnd	0 to 0.25 V	If greater than 0.25 volts, and previous checks (30, 86, 85 to gnd) are within specification, replace relay.
87A to gnd	B+ ± 0.5 V	If less than B+, and previous checks (30, 86, 85 to gnd) are within specification, but 87 to gnd is not within specification, replace relay.

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Figure 374 Fan clutch circuit diagram

Output State Test - Voltage Checks - ECM

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector or relay for the ECM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Disconnect X3 and X4 from ECM. Connect breakout box X3 and X4 to ECM and wiring harness. Disconnect relay. Turn ignition switch to ON. Run the Output State Tests. For help, see “Diagnostic Tests (page 73)” in the “Diagnostic Software Operation (page 70)” section of this manual for the procedure to run the Low and High Output State Tests.

Test State/Point	Spec	Comment
Output State Test - Low		
X3-3 to X4-14	B+ ± 0.5 V	If less than B+, verify that ECM is programmed correctly. If ECM is programmed correctly, replace ECM.
Output State Test - High		
X3-3 to X4-14	0 to 0.25 V	If greater than 0.25 volts, verify that ECM is programmed correctly. If ECM is programmed correctly, replace ECM.

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Harness Resistance Checks

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector or relay for the ECM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Turn ignition switch to OFF. Disconnect fan. Remove relay and connect relay breakout harness. Connect breakout box X4 to chassis wiring harness only.

Test State/Point	Spec	Comment
X4-14 to 86	< 5 Ω	If greater than 5 Ω, check for harness open between ECM and relay terminal.
87A to A (fan)	< 5 Ω	If greater than 5 Ω, check for harness open between relay terminal and A (fan).
30 to Fuse	< 5 Ω	If greater than 5 Ω, check for harness open between fuse and relay terminal. See the applicable truck *Circuit Diagram Manual* for fuse information.
85 to Fuse	< 5 Ω	If greater than 5 Ω, check for harness open between fuse and relay terminal. See the applicable truck *Circuit Diagram Manual* for fuse information.

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EGR (Exhaust Gas Recirculation) Control

Figure 375 Function diagram for EGR control

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The function diagram for EGR control includes the following:

Electronic Control Module (ECM)
Exhaust Gas Recirculation (EGR) valve assembly
Boost Control Solenoid (BCS) assembly
EGR drive module
Manifold Absolute Temperature (MAT) sensor
Barometric Absolute Pressure (BAP) sensor
Engine Coolant Temperature (ECT) sensor
Engine Oil Temperature (EOT) sensor
Manifold Absolute Pressure (MAP) sensor
APS/IVS
Amber lamp (Warn Engine Lamp (WEL) for CF)

Function

The EGR valve assembly consists of three major components, a valve, an actuator motor, and an Integrated Circuit (IC). The IC has three Hall effect position sensors to monitor valve movement. The EGR valve assembly is located at the front of the engine on the intake manifold.

An EGR Drive Module is used to control the EGR valve assembly. It is mounted under the coolant deaeration tank on the left side of the mounting stand.

The EGR valve is a variable position valve that controls the amount of exhaust that enters the intake system. The ECM uses sensor input from the BAP, MAT, MAP, APS, EOT, ECT, and BCS control to calculate the desired position of the EGR valve. The EGR drive module receives the desired EGR valve position from the ECM across the CAN2 datalink to activate the valve for exhaust gas recirculation. The EGR drive module provides feedback to the ECM of the valve position. The EGR drive module interprets the ECM command and sends the command using three pulse width modulated signals to the valve actuator.

The system is closed loop control using the EGR position signals. The EGR drive module provides a 9 volt supply and ground to the IC in the motor of the valve. When the EGR drive module drives the valve to move using the three pulse width modulated signals the IC containing three Hall effect sensors provides the EGR drive module with the valve position signals. The EGR drive module interprets the three signals to determine valve position and sends the information back to the ECM.

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EGR Circuit Operation

Figure 376 EGR circuit diagram

The EGR drive module is supplied 12 volts to Pin 1 from the ECM main power relay through Pin 10 of the 12-pin connector. Ground is supplied to Pin 2 from battery ground through Pin 4 of the 12-pin connector.

The ECM sends the desired position to the EGR drive module across the CAN2 datalink. CAN2 positive is ECM Pin X2-6 to EGR drive module Pin 3. CAN2 negative is ECM Pin X2-13 to EGR drive module Pin 4.

The EGR drive module provides a 9 volt supply from Pin 12 to EGR valve assembly Pin 1. The EGR drive module provides ground from Pin 16 to Pin 5 of the EGR valve assembly.

The EGR valve assembly produces the following valve position signals:

Position U - EGR valve Pin 4 to EGR drive module Pin 13

Position V - EGR valve Pin 3 to EGR drive module Pin 14

Position W - EGR valve Pin 2 to EGR drive module Pin 15

Depending on desired valve position from the ECM signal and position feedback signal from the IC.

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EGR drive module drives the three-phase DC motor to move the valve to the proper position using the following pulse width modulated signals:

Motor U - EGR drive module Pin 6 to EGR valve Pin 8
Motor V - EGR drive module Pin 7 to EGR valve Pin 7
Motor W - EGR drive module Pin 8 to EGR valve Pin 6

The EGR drive module provides two shields to suppress electrical noise. One shield is for the CAN2 datalink (EGR drive module Pin 5). The other shield is for the valve position sensor signals used by the EGR drive module to monitor position (EGR drive module Pin 9).

Fault Detection/Management

The EGR drive module constantly monitors the EGR valve. When an EGR control error is detected, the EGR drive module sends a message to the ECM, a DTC is set, and the amber lamp (WEL for CF) is illuminated.

EGR DTCs

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

DTC 163

EGR valve position signal out of range low
DTC 163 is set by the ECM when the EGR drive module detects a position signal failure. DTC 163 can be set due to an open or short to ground on the position sensor signal power supply circuit, an open ground circuit, an open or short to ground on any of the position signal circuits, or a failed IC. When DTC 163 is active the amber lamp (WEL for CF) is illuminated.

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DTC 365

EGR valve position above/below desired level

DTC 365 is set when the actual EGR valve position does not match desired.

Possible Causes	Comments
EGR valve stuck or sticking	Do “Performance Diagnostics (page 211).”
EGR valve position sensor bias	Check sensor signal voltage. See “EGR circuit diagnostics (page 376).”
EGR control circuit	Do “KOEO Standard Test (page 73)” and “EGR circuit diagnostics (page 376).”

DTC 368

EGR drive module/ECM2 communication fault

DTC 368 is set by the ECM when CAN2 datalink communications are not received from EGR drive module.

DTC 368 can be set for the EGR drive module due to the following conditions:	If engine starts and runs, the DTC is specific to the EGR drive module and ECM communications. The following are possible causes:	An open or short to ground on the power circuit exists An open or short to power on the ground circuit exists CAN2 positive and CAN2 negative are both open or high resistance exists

When CAN communication is not present from the EGR drive module, the ECM sends 100 percent EGR position to the EST.

If a no start condition exists with DTC 368 and 543 active, check the CAN2 wiring (EGR to ECM and IDM to ECM). See “ECM/IDM (Electronic Control Module and Injector Driver Module) Communications (page 348).” One of the CAN2 datalink wires (CAN2 positive or negative) is open, short to ground, or short to power exists.

When DTC 368 is active the amber lamp (WEL for CF) is illuminated.

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Tools

EST with MasterDiagnostics® software
EZ-Tech® interface cable
Digital Multimeter (DMM)
12-Pin Breakout Harness
EGR Valve Breakout Harness
Breakout Box
Terminal Test Adapter Kit

EGR Pin-Point Diagnostics

Figure 377 EGR circuit diagram

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EGR Pin Diagram

EGR Valve Connector Pins

NOTE: Harness connectors shown with mating end view.

EGR Drive Module Connector Pins

Pin		Pin		Pin	
1	Position sensor power	1	Power	9	Ground shield
2	Position sensor W	2	Ground	10	Not used
3	Position sensor V	3	CAN high	11	Not used
4	Position sensor U	4	CAN low	12	Position sensor power
5	Position sensor ground	5	Not used	13	Position sensor U
6	Motor W	6	Motor U	14	Position sensor V
7	Motor V	7	Motor V	15	Position sensor W
8	Motor U	8	Motor W	16	Position sensor ground

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Voltage Checks - EGR Valve Harness Connector

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

To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

CAUTION: To prevent engine damage, *use utmost care* when disconnecting harness from the EGR valve or EGR drive module, inserting Terminal Test Adapter probe into connector to test for specifications, and connecting harness to EGR valve or EGR drive module. Failure to use care when disconnecting, testing, or connecting components may result in damaged or bent connector pins.

Disconnect harness from valve. Connect EGR Valve Breakout Harness. Turn ignition switch to ON.

Test Point	Spec	Comment
1 to gnd	8 to 11 V	If not in spec, check for an open, short to ground or short to voltage source.
2 to gnd	5 ± 0.5 V	If not in spec, check for an open, short to ground or short to voltage source.
3 to gnd	5 ± 0.5 V	If not in spec, check for an open, short to ground or short to voltage source.
4 to gnd	5 ± 0.5 V	If not in spec, check for an open, short to ground or short to voltage source.
5 to gnd	0 V	If not in spec, check for a short to voltage source.
6 to gnd	0 V	If not in spec, check for a short to voltage source.
7 to gnd	0 V	If not in spec, check for a short to voltage source.
8 to gnd	0 V	If not in spec, check for a short to voltage source.

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Figure 378 EGR circuit diagram

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Resistance Checks - EGR Valve Only

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

To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

CAUTION: To prevent engine damage, *use utmost care* when disconnecting harness from EGR valve or EGR drive module, inserting Terminal Test Adapter probe into connector to test for specifications, and connecting harness to EGR valve or EGR drive module. Failure to use care when disconnecting, testing, or connecting components may result in damaged or bent connector pins.

Turn ignition switch to OFF. Disconnect harness from valve. Connect EGR Valve Breakout Harness to valve only.

NOTE: Ensure DMM and leads are zeroed.

Test Point	Spec	Comment
1 to 2	> 1 kΩ	If less than 1 kΩ, short to sensor power exists.
1 to 3	> 1 kΩ	If less than 1 kΩ, short to sensor power exists.
1 to 4	> 1 kΩ	If less than 1 kΩ, short to sensor power exists.
1 to 5	> 1 kΩ	If less than 1 kΩ, short to sensor power exists.
5 to 2	> 1 kΩ	If less than 1 kΩ, short to sensor power exists.
5 to 3	> 1 kΩ	If less than 1 kΩ, short to sensor power exists.
5 to 4	> 1 kΩ	If less than 1 kΩ, short to sensor power exists.
6 to 7	2.1 ± 0.5 Ω	If not in spec, replace actuator.
6 to 8	2.1 ± 0.5 Ω	If not in spec, replace actuator.
7 to 8	2.1 ± 0.5 Ω	If not in spec, replace actuator.

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Figure 379 EGR circuit diagram

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Harness Resistance Checks - EGR Valve Connector to Chassis Ground

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

To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

CAUTION: To prevent engine damage, *use utmost care* when disconnecting harness from EGR valve or EGR drive module, inserting Terminal Test Adapter probe into connector to test for specifications, and connecting harness to EGR valve or EGR drive module. Failure to use care when disconnecting, testing, or connecting components may result in damaged or bent connector pins.

Turn ignition switch to OFF. Disconnect harness from valve. Connect EGR Valve Breakout Harness to engine harness only. Disconnect negative battery cable and harness from sensor. Use disconnected battery cable for ground test point.

See the applicable truck *Circuit Diagram Manual* for complete chassis side ECM and IDM ground circuit information.

Test Point	Spec	Comment
1 to gnd	> 1 kΩ	If less than 1 kΩ, short to ground exists.
2 to gnd	> 1 kΩ	If less than 1 kΩ, short to ground exists.
3 to gnd	> 1 kΩ	If less than 1 kΩ, short to ground exists.
4 to gnd	> 1 kΩ	If less than 1 kΩ, short to ground exists.
5 to gnd	< 5 Ω	If greater than 5 Ω, an open circuit exists or high resistance.
6 to gnd	> 1 kΩ	If less than 1 kΩ, short to ground exists.
7 to gnd	> 1 kΩ	If less than 1 kΩ, short to ground exists.
8 to gnd	> 1 kΩ	If less than 1 kΩ, short to ground exists.

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Figure 380 EGR circuit diagram

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Voltage Checks - EGR Drive Module Connector

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

To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

CAUTION: To prevent engine damage, *use utmost care* when disconnecting harness from EGR valve or EGR drive module, inserting Terminal Test Adapter probe into connector to test for specifications, and connecting harness to EGR valve or EGR drive module. Failure to use care when disconnecting, testing, or connecting components may result in damaged or bent connector pins.

Disconnect harness from the EGR drive module. Turn ignition switch to ON.

Test Point	Spec	Comment
1 to gnd	9 to 16 V	If not in spec, check for an open, short to ground, or short to voltage source.
2 to gnd	0 V	If not in spec, check for a short to voltage source.
3 to gnd	1 to 4 V	Digital signal. See “ECM/IDM Communications (page 345)” in this section.
4 to gnd	1 to 4 V	Digital signal. See “ECM/IDM Communications”(page 345)” in this section.
5 to gnd	0 V	If not in spec, check for a short to voltage source.
6 to gnd	0 V	If not in spec, check for a short to voltage source.
7 to gnd	0 V	If not in spec, check for a short to voltage source.
8 to gnd	0 V	If not in spec, check for a short to voltage source.
9 to gnd	0 V	If not in spec, check for a short to voltage source.
12 to gnd	0 V	If not in spec, check for a short to voltage source.
13 to gnd	0 V	If not in spec, check for a short to voltage source.
14 to gnd	0 V	If not in spec, check for a short to voltage source.
15 to gnd	0 V	If not in spec, check for a short to voltage source.
16 to gnd	0 V	If not in spec, check for a short to voltage source.

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Figure 381 EGR circuit diagram

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Resistance Checks - EGR Drive Module Only

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

To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

CAUTION: To prevent engine damage, *use utmost care* when disconnecting harness from EGR valve or EGR drive module, inserting Terminal Test Adapter probe into connector to test for specifications, and connecting harness to EGR valve or EGR drive module. Failure to use care when disconnecting, testing, or connecting components may result in damaged or bent connector pins.

Turn ignition switch to OFF. Disconnect harness from EGR drive module. Measure at EGR drive module pins.

Test Point	Spec	Comment
1 to 2	> 50 Ω	If less than 50 Ω, short to ground exists.
2 to 3	> 1 kΩ	If less than 1 kΩ, short to ground exists.
2 to 4	> 1 kΩ	If less than 1 kΩ, short to ground exists.
2 to 5	> 1 kΩ	If less than 1 kΩ, short to ground exists.
2 to 6	> 1 kΩ	If less than 1 kΩ, short to ground exists.
2 to 7	> 1 kΩ	If less than 1 kΩ, short to ground exists.
2 to 8	> 1 kΩ	If less than 1 kΩ, short to ground exists.
2 to 9	< 5 Ω	If greater than 5 Ω, an open circuit or high resistance exists.
2 to 12	> 1 kΩ	If less than 1 kΩ, short to ground exists.
2 to 13	> 1 kΩ	If less than 1 kΩ, short to ground exists.
2 to 14	> 1 kΩ	If less than 1 kΩ, short to ground exists.
2 to 15	> 1 kΩ	If less than 1 kΩ, short to ground exists.
2 to 16	< 5 Ω	If greater than 5 Ω, an open circuit or high resistance exists.
9 to 16	< 5 Ω	If greater than 5 Ω, an open circuit or high resistance exists.
12 to 16	> 1 kΩ	If less than 1 kΩ, short to ground exists.
13 to 16	> 1 kΩ	If less than 1 kΩ, short to ground exists.
14 to 16	> 1 kΩ	If less than 1 kΩ, short to ground exists.
15 to 16	> 1 kΩ	If less than 1 kΩ, short to ground exists.

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Figure 382 EGR circuit diagram

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Harness Resistance Checks - EGR Drive Module Connector to Chassis Ground

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

To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

CAUTION: To prevent engine damage, *use utmost care* when disconnecting harness from EGR valve or EGR drive module, inserting Terminal Test Adapter probe into connector to test for specifications, and connecting harness to EGR valve or EGR drive module. Failure to use care when disconnecting, testing, or connecting components may result in damaged or bent connector pins.

Turn ignition switch to OFF. Disconnect harness from EGR drive module. Disconnect negative battery cable and harness from sensor. Use disconnected battery cable for ground test point.

See the applicable truck *Circuit Diagram Manual* for complete chassis side ECM and IDM ground circuit information.

Test Point	Spec	Comment
1 to gnd	> 1 kΩ	If less than 1 kΩ, short to ground exists.
2 to gnd	< 5 Ω	If greater than 5 Ω, an open circuit or high resistance exists.
3 to gnd	> 1 kΩ	If less than 1 kΩ, short to ground exists.
4 to gnd	> 1 kΩ	If less than 1 kΩ, short to ground exists.
6 to gnd	> 1 kΩ	If less than 1 kΩ, short to ground exists.
7 to gnd	> 1 kΩ	If less than 1 kΩ, short to ground exists.
8 to gnd	> 1 kΩ	If less than 1 kΩ, short to ground exists.
9 to gnd	> 1 kΩ	If less than 1 kΩ, short to ground exists.
12 to gnd	> 1 kΩ	If less than 1 kΩ, short to ground exists.
13 to gnd	> 1 kΩ	If less than 1 kΩ, short to ground exists.
14 to gnd	> 1 kΩ	If less than 1 kΩ, short to ground exists.
15 to gnd	> 1 kΩ	If less than 1 kΩ, short to ground exists.
16 to gnd	> 1 kΩ	If less than 1 kΩ, short to ground exists.

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Figure 383 EGR circuit diagram

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Harness Resistance Checks - EGR Drive Module to EGR Actuator

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

To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

CAUTION: To prevent engine damage, *use utmost care* when disconnecting harness from EGR valve or EGR drive module, inserting Terminal Test Adapter probe into connector to test for specifications, and connecting harness to EGR valve or EGR drive module. Failure to use care when disconnecting, testing, or connecting components may result in damaged or bent connector pins.

Turn ignition switch to OFF. Disconnect harness from EGR drive module and EGR actuator.

NOTE: Test points are EGR drive module to EGR actuator.

Test Point	Spec	Comment
Pin 6 to Pin 8	< 5 Ω	If greater than 5 Ω, open circuit or high resistance to MTR U.
Pin 7 to Pin 7	< 5 Ω	If greater than 5 Ω, open circuit or high resistance to MTR V.
Pin 8 to Pin 6	< 5 Ω	If greater than 5 Ω, open circuit or high resistance to MTR W.
Pin 12 to Pin 1	< 5 Ω	If greater than 5 Ω, open circuit or high resistance to position sensor power.
Pin 13 to Pin 4	< 5 Ω	If greater than 5 Ω, open circuit or high resistance to position sensor U.
Pin 14 to Pin 3	< 5 Ω	If greater than 5 Ω, open circuit or high resistance to position sensor V.
Pin 15 to Pin 2	< 5 Ω	If greater than 5 Ω, open circuit or high resistance to position sensor W.
Pin 16 to Pin 5	< 5 Ω	If greater than 5 Ω, open circuit or high resistance to position sensor ground.

Read all safety instructions in the "Safety Information" section of this manual before doing any procedures.
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Figure 384 EGR circuit diagram

Harness Resistance Checks - EGR Drive Module to 12-Pin Connector

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

Turn ignition switch to OFF. Disconnect harness at EGR drive module and 12-pin connector.

Test Point	Spec	Comment
Pin 1 to Pin 10	< 5 Ω	If greater than 5 Ω, open circuit or high resistance to actuator power.
Pin 2 to Pin 4	< 5 Ω	If greater than 5 Ω, open circuit or high resistance to actuator ground.

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Harness Resistance Checks - EGR Drive Module to ECM

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

Turn ignition switch to OFF. Disconnect harness at EGR drive module and ECM connector X2. Connect Breakout Box X2 to engine harness only.

Test Point	Spec	Comment
Pin 3 to Pin X2-6	< 5 Ω	If greater than 5 Ω, open circuit or high resistance to CAN2 positive.
Pin 4 to Pin X2-13	< 5 Ω	If greater than 5 Ω, open circuit or high resistance to CAN2 negative.

EGR Actuator Diagnostic Trouble Codes
DTC 163 = EGR drive module detects position signal fault
DTC 365 = EGR valve position above/below desired level
DTC 368 = EGR drive module/ECM2 communication fault

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EOP (Engine Oil Pressure) Switch

Figure 385 Function diagram for the EOP switch

The function diagram for the EOP switch includes the following:

- Engine Oil Pressure (EOP) switch
- Electronic Control Module (ECM)
- Amber Lamp (Warn Engine Lamp (WEL) for CF)
- Red Lamp (Oil/Water Lamp (OWL) for CF)

Function

The EOP switch is located in the oil filter base assembly. The ECM supplies a 5 volt signal to the EOP switch. When engine oil pressure is present the 5 volt signal is switched to ground (the switch is grounded).

The Engine Warning and Protection System (EWPS), is enabled to warn the engine operator when a low engine oil pressure condition occurs.

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EOP Circuit Operation

Figure 386 EOP circuit diagram

The EOP switch is supplied with a 5 volt signal at Pin 1 from ECM Pin X1-13. The EOP switch housing is grounded to the engine block. The ECM monitors Pin X1-13.

When engine oil pressure is present, the 5 volt signal is switched to ground and Pin X1-13 is 0 volts. When oil pressure is not present, X1-13 is 5 volts.

Fault Detection/Management

The ECM continuously monitors the signal of the EOP switch to determine if the signal is within an expected range. If there is an open circuit it is interpreted as no oil pressure. If there is a short to ground, it is interpreted as oil pressure with KOEO.

EOP DTCs

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

DTC 225

EOP sensor signal in range fault
DTC 225 is set by the ECM when the EOP signal voltage is less than expected with ignition switch to ON and the engine off. DTC 225 can be set due to a short to ground or failed EOP switch. When DTC 225 is active, the amber lamp (WEL for CF) is illuminated.

DTC 313

EWPS - Engine Oil Pressure below warning level
DTC 313 is set by the ECM, when engine oil pressure is lower than expected while the engine is running. DTC 313 can be set by an open circuit, short to voltage source in the EOP circuit, a loose or failed EOP switch, or low oil pressure. When DTC 313 is active, the red lamp (OWL for CF) is illuminated.

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Tools
EST with MasterDiagnostics® software
EZ-Tech® interface cable
Digital Multimeter (DMM)
500 Ohm resistor harness
Breakout Box
Breakout harness
Terminal Test Adapter Kit

EOP Operational Diagnostics - DTC 225

WARNING: To prevent personal injury or death, be careful to avoid rotating parts (belts and fan) and hot engine surfaces.

Figure 387 Continuous Monitor session

1. Using EST, select D_ContinuousMonitor.ssn from the Open Session File window, select Open to open the session.

Figure 388 Continuous Monitor Test

2. To monitor signal voltage, run KOEO Continuous Monitor Test. For help, see “Continuous Monitor Test (page 76)” in the “Diagnostic Software Operation (page 211)” section of this manual.
3. Monitor EOP signal voltage. Verify an active DTC for the EOP circuit.
4. If code is active, do step 6 to check circuit for the EOP switch using the following table.
5. If code is inactive, wiggle connectors and wires at all suspected problem locations. If circuit continuity is interrupted, the EST will display DTCs related to the condition.
6. Disconnect engine harness from pressure switch.

NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

Figure 389 Close session

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7. When finished with this test, select Session from menu bar, then Close.

Circuit Checks - EOP Switch

Use EST, DMM, and 500 ohm wire harness		
Test Point	**Spec**	**Comment**
Switch disconnected	5 V	If voltage is less than 5 volts, check signal circuit for open or short to ground.
500 Ohm resistor harness connected between wire and ground	0 V	If 5 volts, check for open circuit to ECM or possible ECM failure.
Connect engine harness to switch. Use the EST to clear DTCs. If an active code remains after checking test conditions, replace the EOP switch.		

EOP Operational Diagnostics - DTC 313

WARNING: To prevent personal injury or death, be careful to avoid rotating parts (belts and fan) and hot engine surfaces.

Figure 390 Continuous Monitor session

WARNING: To prevent personal injury, use care to prevent contact with the door edge when the cab is up and the door is open.

1. Using EST, select D_ContinuousMonitor.ssn from the Open Session File window, select Open to open the session.
2. Start the Engine.

Figure 391 Continuous Monitor test

3. Select Diagnostics from the menu bar.
4. Select Key-On Engine-Running tests from the drop down menu.
5. Monitor EOP signal voltage. Verify an active DTC for the EOP circuit.

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6. If code is active, do step 8 and 9 to check circuit for the EOP sensor using the following table.

WARNING: To prevent personal injury or death, be careful around rotating parts (belts and fan) and hot engine surfaces.

7. If code is inactive, wiggle connectors and wires at all suspected problem locations. If circuit continuity is interrupted, the EST will display DTCs related to the condition. Check for loose switch.
8. Disconnect engine harness from pressure sensor.

NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

9. Connect Pressure Sensor Breakout Harness to engine harness only.

Figure 392 Close session

10. When finished with this test, select Session from menu bar, then Close.

Circuit Checks - EOP Switch

Disconnect engine harness from pressure switch. Use EST, DMM, and 500 ohm wire harness		
Test Point	**Spec**	**Comment**
Switch disconnected	5 V	If voltage is less than 5 volts, check signal circuit for open or short to ground.
500 Ohm resistor harness connected between the wire and ground	0 V	If 5 volts, check for open wire to ECM or possible ECM failure.
Connect engine harness to switch. Use the EST to clear DTCs. If an active code remains after checking test conditions, replace the EOP switch.		

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EOP Pin-Point Diagnostics

Figure 393 EOP circuit diagram

Voltage Checks - Connector

Disconnect harness from sensor and turn ignition switch to ON.

Test Point	Spec	Comments
1 to gnd	5 ± 0.5 V	If voltage is not to spec, EOP circuit is open or shorted to ground.

Resistance Checks - Connector to Chassis Ground

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Disconnect negative battery cable and switch connector.

Test Point	Spec	Comments
1 to gnd	> 1 kΩ	If less than 1 kΩ, check for short to ground

Harness Resistance Checks - ECM to EOP Switch

Connect Breakout Box on engine harness only.

Test Point	Spec	Comments
X1-13 to 1	< 5 Ω	If greater than 5 Ω, check for open signal wire.

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Operational Voltage Checks - EOP Switch (KOEO)

Use EST to monitor engine oil pressure PID. Turn ignition switch to ON, do not crank engine.

Test Point	Spec	Comments
EOP connected	0 psi	If 40 psi, check for short to ground. If 0 psi, do next check “EOP disconnected”.
EOP disconnected	0 psi	If 0 psi, do “Operational Voltage Checks - EOP Switch (Engine Idle) (page 402)” in the next table. If 40 psi, check for short to ground.

Operational Voltage Checks - EOP Switch (Engine Idle)

Use EST to monitor engine oil pressure PID. Engine idling.

Test Point	Spec	Comments
EOP connected	40 psi	If 0 psi and EOP circuit resistance checks are good, check oil pressure with gauge, do “Test 8. Engine Oil (page 154)” in the “Hard Start and No Start Diagnostics (page 131)” section of this manual. If oil pressure is within specification, replace EOP switch.

EOP Diagnostic Trouble Codes
DTC 225 = EOP signal was 0 volts with Key-On Engine Off.
DTC 313 = EOP signal was 5 volts with engine running.

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EOT (Engine Oil Temperature) Sensor

Figure 394 Function diagram for the EOT sensor

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The function diagram for the EOT sensor includes the following:

Engine Oil Temperature (EOT) sensor
Electronic Control Module (ECM)
Injection Driver Module (IDM)
Fuel injector
Exhaust Gas Recirculation (EGR) valve
Injection Pressure Regulator (IPR)
Boost Control Solenoid (BCS) assembly
Amber Lamp (Warn Engine Lamp (WEL) for CF)

Function

The EOT sensor is a thermistor sensor installed in the oil filter base. The ECM supplies a 5 volt reference signal which the EOT sensor uses to produce an analog voltage that indicates temperature.

The EOT changes resistance when exposed to different temperatures. When oil temperature decreases, the resistance of the thermistor increases. This causes the signal voltage to increase. When oil temperature increases, the resistance of the thermistor decreases. This causes the signal voltage to decrease.

The EOT sensor provides a feedback signal to the ECM indicating engine oil temperature. The ECM monitors the EOT signal to control fuel quantity and timing throughout the operating range of the engine. The EOT signal allows the ECM to compensate for oil viscosity variations due to temperature changes in the operating environment, ensuring that adequate power and torque are available for all operating conditions. During engine operation, if the ECM recognizes that the EOT signal is lower or higher than the expected value it will set a DTC.

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EOT Circuit Operation

Figure 395 EOT circuit diagram

The EOT sensor is supplied with a 5 volt reference voltage at Pin 2 from ECM Pin X2-1. The sensor is grounded at Pin 1 through the signal ground terminal at ECM Pin X1-6. As the oil temperature increases or decreases, the sensor changes resistance and provides the oil temperature signal voltage at the ECM. The signal voltage is monitored by the ECM to determine the temperature of the oil.

Fault Detection/Management

The ECM continuously monitors the signal of the EOT sensor to determine if the signal is within an expected range. If the ECM detects an out of range high or low, the ECM will ignore the EOT signal and assume an engine oil temperature of -20 °C (-4 °F) for starting and 100 °C (212 °F) for engine running conditions.

EOT DTCs

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

DTC 311
EOT signal out of range low
DTC 311 is set by the ECM when the EOT signal is less than 0.2 volts for more than 0.35 seconds.
DTC 311 can be set due to a sensor signal wire short to ground or an failed EOT sensor.
When DTC 311 is active the amber lamp (WEL for CF) is illuminated.

DTC 312
EOT signal out of range high
DTC 312 is set by the ECM when the EOT signal is greater than 4.8 volts for more than 0.35 seconds.
DTC 312 can be set due to a signal or ground circuit open, a short to a voltage source, or an failed EOT sensor.
When DTC 312 is active the amber lamp (WEL for CF) is illuminated.

Tools
EST with MasterDiagnostics® software
EZ-Tech® interface cable
Digital Multimeter (DMM)
3-Banana plug harness
500 Ohm resistor harness
Breakout Box
Breakout harness
Terminal Test Adapter Kit

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EOT Operational Diagnostics

WARNING: To prevent personal injury or death, be careful around rotating parts (belts and fan) and hot engine surfaces.

Figure 396 Continuous Monitor session

WARNING: To prevent personal injury, use care to prevent contact with the door edge when the cab is up and the door is open.

1. Select D_ContinuousMonitor.ssn from the Open Session File window, select Open to open the session.

Figure 397 Continuous Monitor test

2. Select Diagnostics from the menu bar.
3. Select Key-On Engine-Off Tests from the drop down menu.
4. From the KOEO Diagnostics menu, select Continuous Monitor and select Run to start the test.

WARNING: To prevent personal injury or death, be careful around rotating parts (belts and fan) and hot engine surfaces.

5. Monitor EOT signal voltage. Verify an active DTC for the EOT circuit.
6. If code is active, do step 8 and 9 to check circuit for the EOT sensor using the “Circuit Checks - EOT Sensor (page 407)” table.

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7. Wiggle connectors and wires at all suspected problem locations. If circuit continuity is interrupted, the EST will display DTCs related to the condition.
8. Disconnect engine harness from temperature sensor.

NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

9. Connect Temperature Sensor Breakout Harness to engine harness only.

Figure 398 Close session

10. When finished with this test, select Session from menu bar, then Close.

Circuit Checks - EOT Sensor

Use EST, breakout harness, 3-Banana Plug Harness, and 500 ohm resistor harness.		
Test Condition	**Spec**	**Checks**
Sensor disconnected	> 4.78 V	If voltage less than 4.78 volts, check signal circuit for short to ground.
3-Banana plug harness installed between Pin 2 (GREEN) and Pin 1 (BLACK) of breakout harness.	0 V	If voltage is greater than 0.2 volts, check ground and signal circuit for open or high resistance. Use a Breakout Box and measure resistance from PIN 1 to X1-6 and from PIN 2 to X2-1 (specification is < 5 Ω).
500 Ohm resistor harness installed between Pin 2 (GREEN) and Pin 1 (BLACK) of breakout harness.	< 1.0 V	If voltage greater than 1.0 volts, check signal circuit for short to V_{REF}, B+, or another sensor's signal voltage.
Connect engine harness to sensor. Use the EST to clear DTCs. If an active code remains after checking test conditions, replace the EOT sensor.		

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EOT Pin-Point Diagnostics

Figure 399 EOT circuit diagram

Voltage Checks - Connector to Ground

Turn ignition switch to OFF. Disconnect harness from sensor. Inspect for bent pins or corrosion. Connect breakout harness to engine harness only. Turn ignition switch to ON.

Test Point	Spec	Comments
2 to gnd	4.8 to 5.0 V	Pull up voltage, if low or no voltage, circuit has open, high resistance, or short to ground.
1 to gnd	0 to 0.25 V	If greater than 0.25 volts, signal ground wire is shorted to V_{REF} or B+.

Resistance Checks - Connector to Chassis Ground

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Disconnect harness from sensor. Connect breakout harness to engine harness only. Disconnect negative battery cable and sensor connector.

Test Point	Spec	Comments
1 to gnd	< 5 Ω	If greater than 5 Ω, check for open ground circuit
2 to gnd	> 1 kΩ	If less than 1 kΩ, check for signal short to ground

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Harness Resistance Checks

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Connect Breakout Box to engine harness only. Connect breakout harness to engine harness only.

Test Point	Spec	Comments
X1-6 to 1	<5 Ω	If greater than 5 Ω, check for open ground wire
X2-1 to 2	<5 Ω	If greater than 5 Ω, check for open signal wire

Operational Voltage Checks - EOT Sensor

Turn ignition switch to OFF. Use EST and DMM. Connect Breakout Box to ECM and engine harness with the EOT connected. Turn ignition switch to ON, do not crank the engine.

Test Point	Temp	Resistance	Voltage
X2-1 to X1-6 (gnd)	-29 °C (-20 °F)	0.482 MΩ	4.73 V
X2-1 to X1-6 (gnd)	0 °C (32 °F)	99.3 kΩ	4.40 V
X2-1 to X1-6 (gnd)	20 °C (68 °F)	38.08 kΩ	3.85 V
X2-1 to X1-6 (gnd)	37 °C (100 °F)	17.84 kΩ	3.14 V
X2-1 to X1-6 (gnd)	100 °C (212 °F)	2.2 k Ω	0.90 V

EOT Diagnostic Trouble Code

DTC 311 = Signal voltage was less than 0.2 volts for more than 0.35 seconds.

DTC 312 = Signal voltage was greater than 4.78 volts for more than 0.35 seconds.

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EWPS (Engine Warning and Protection System)

Figure 400 Function diagram for the EWPS

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The function diagram for the EWPS includes the following:

Electronic Control Module (ECM)
Crankshaft Position (CKP) sensor
Camshaft Position (CMP) sensor
Engine Oil Pressure (EOP) switch
Engine Coolant Temperature (ECT)
Engine Coolant Level (ECL) sensor
Red Lamp (Oil/Water Lamp (OWL) for CF)
Amber Lamp (Warn Engine Lamp (WEL) for CF)

Function

EWPS safeguards the engine from undesirable operating conditions to prevent engine damage and to prolong engine life. When a warning condition is detected, the on-board electronics will illuminate a red lamp (OWL for CF) and sound an audible alarm.

When a critical engine condition is detected, the on-board electronics will shut the engine down if the protection feature has been enabled. The critical engine condition will be recorded by a logging feature that records the event in engine hours and odometer readings. After the engine has shutdown, the engine may be restarted for a thirty second run time.

When EWPS is enabled and a critical engine condition occurs, the on-board electronics will send a warning to the instrument panel.

There are five options of EWPS:

Standard warning
2-way warning
3-way warning
3-way protection
4-way warning

NOTE: EWPS modes available will vary, depending on application.

EWPS Operational Descriptions

NOTE: All EWPS modes will set the amber lamp if engine speed increases over 3900 rpm (non-programmable).

The EWPS includes the following features:

EWPS mode – This parameter indicates to the on-board electronics the desired mode of operation for the engine warning and protection feature.

Standard warning (rpm, ECT) – Engine over speed and overheat are provided as the default operating mode. No engine shutdown is available.

2-way warning (rpm, ECT, EOP) – Engine over speed, overheat, and low oil pressure are monitored in the engine warning operating mode. No engine shutdown is available.

3-way warning (rpm, ECT, EOP, ECL) – Engine over speed, overheat, low oil pressure, and low coolant level are monitored in the engine warning operating mode. No engine shutdown is available.

3-way Protection (rpm, ECT, EOP, ECL) – Engine over speed, overheat, low oil pressure, and low coolant level are monitored in the engine protection operating mode. Engine shutdown can be made available when a critical engine condition is detected. Critical engine conditions include overheat, low oil pressure and low coolant level.

4-way warning (rpm, ECT, EOP, ECL, genset fault) – Engine over speed, overheat, low oil pressure, low coolant level and genset faults are monitored in the engine warning operating mode. No engine shutdown is available.

ECT Warning Temperature – This parameter indicates when an engine overheat condition warrants, red lamp is illuminated and a warning buzzer is activated.

ECT Critical Temperature – This parameter indicates when an engine overheat condition warrants an engine shutdown. The engine shutdown can be programmed to operate if desired. The event logging feature will log when this event has occurred in both engine hours and odometer readings.

EOP RPM Boundary 1 – This parameter indicates the rpm range that engine oil pressure level 1 is used for the loss of engine oil pressure detection.

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EOP RPM Boundary 2 – This parameter indicates the rpm range that engine oil pressure level 2 is used for the loss of engine oil pressure detection.

EOP RPM Boundary 3 – This parameter indicates the rpm range that engine oil pressure level 3 is used for the loss of engine oil pressure detection.

EOP Warning Level 1 – This parameter indicates when a loss of engine oil pressure warrants the red lamp to be illuminated and the warning buzzer to be activated.

EOP Warning Level 2 – This parameter indicates when a loss of engine oil pressure condition warrants, red lamp is illuminated and a warning buzzer is activated.

EOP Warning Level 3 – This parameter indicates when a loss of engine oil pressure condition warrants, red lamp is illuminated and a warning buzzer is activated.

EOP Critical Level 1 – This parameter indicates when a loss of engine oil pressure condition warrants an engine shutdown. The engine shutdown can be programmed to operate if desired. The event logging feature will log when this event has occurred in both engine hours and odometer readings.

EOP Critical Level 2 – This parameter indicates when a loss of engine oil pressure condition warrants an engine shutdown. The engine shutdown can be programmed to operate if desired. The event logging feature will log when this event has occurred in both engine hours and odometer readings.

EOP Critical Level 3 – This parameter indicates when a loss of engine oil pressure condition warrants an engine shutdown. The engine shutdown can be programmed to operate if desired. The event logging feature will log when this event has occurred in both engine hours and odometer readings.

EWPS Operational Diagnostics

EWPS DTCs

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

DTC 313

EWPS - Engine Oil Pressure below warning level	
DTC 313 is set by the ECM, when engine oil pressure is lower than expected while the engine is running. The specifications for the warning are:	34 kPa (5 psi) @ 700 rpm 69 kPa (10 psi) @ 1400 rpm 138 kPa (20 psi) @ 2000 rpm
For diagnostics, see “Low Oil Pressure Diagnostics (page 119)” in the “Engine Symptoms Diagnostics (page 99)” section of this manual.	
DTC 313 can be set by an open, circuit short to voltage source in the EOP circuit, a loose or failed EOP switch, or low oil pressure.	
When DTC 313 is active, the red lamp (OWL for CF) is illuminated.	

DTC 314

EWPS - Engine Oil Pressure below critical level	
DTC 314 is set by the ECM, when the engine oil pressure drops below the critical level while the engine is running. The specifications are:	14 kPa (2 psi) @ 700 rpm 83 kPa (12 psi) @ 1400 rpm 152 kPa (22 psi) @ 2000 rpm
For diagnostics, see “Low Oil Pressure Diagnostics (page 119)” in the “Engine Symptoms Diagnostics (page 99)” section of this manual.	
DTC 314 can be set by an open, circuit short to voltage source in the EOP circuit, a loose or failed EOP switch, or low oil pressure.	
When DTC 314 is active, the red lamp (OWL for CF) flashes and sounds an audible signal.	

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DTC 315

Engine speed above warning level	
DTC 315 is set by the ECM when the engine rpm has exceeded 3900 rpm.	
DTC 315 can be set due to any of the following conditions:	Excessive engine speed in an unintended downshift. Steep acceleration downhill without correct brake application. External fuel source being ingested into air intake system.
When DTC 315 is active the amber lamp (WEL for CF) is illuminated. The engine hours and miles of the last two over speed occurrences will be recorded in the engine event log.	

DTC 316

ECT unable to reach commanded set point	
NOTE: DTC 316 only indicates the engine has not been able to reach operating temperature. It does not indicate an electronic failure.	
DTC 316 is set if the engine does not reach operating temperature. DTC 316 will only be set with engines that have Cold Ambient Protection (CAP) strategy enabled. DTC 316 is set after the engine has run for more than 120 minutes and has not exceeded the following specifications for engine coolant temperature. DTC 316 can be cleared with the EST.	Automatic transmission 60 °C (140 °F)
DTC 316 can be set due to any of the following conditions:	Extended idle time Cold ambient temperatures (may require use of winter front) Thermostat stuck in open position Incorrectly plumbed cooling system (thermostat bypassed) Fan clutch locked on

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DTC 321

ECT above warning level

DTC 321 is set by the ECM when the engine coolant temperature is above 113 °C (228 °F). The ECM illuminates the red lamp (OWL for CF). When the temperature drops below 113 °C (228 °F) the DTC will become inactive. For diagnostics, see ”Coolant Over-Temperature (page 109)” in the “Engine Symptoms Diagnostics” (page 99) section of this manual.

For high altitude applications (103 kPa [15 psi] radiator cap), DTC 321 is set by the ECM when the engine coolant temperature is above 116 °C (240 °F). When the temperature drops below 116 °C (240 °F) the DTC will become inactive.

DTC 322

ECT above critical level

DTC 322 is set by the ECM when the engine coolant temperature is above 116 °C (240 °F). The ECM illuminates the red lamp (OWL for CF). When the temperature drops below 116 °C (240 °F) the DTC will become inactive. For diagnostics, see ”Coolant Over-Temperature (page 109)” in the “Engine Symptoms Diagnostics (page 99)” section of this manual.

For high altitude applications (103 kPa [15 psi] radiator cap), DTC 321 is set by the ECM when the engine coolant temperature is above 119 °C (246 °F). When the temperature drops below 119 °C (246 °F) the DTC will become inactive.

DTC 323

ECL below warning/critical level

DTC 323 is set by the ECM when coolant is low. When the EWPS mode is 3-way protection and DTC 323 is active, the engine will shutdown. The ECM will log the engine hours and odometer reading at the time of occurrence. After the shutdown, the engine can be restarted for thirty seconds. When the coolant has returned to correct levels, DTC 323 will become inactive.

NOTE: If coolant level is correct, see “ECL Sensor (page 341)” in this section. An ECL signal shorted to ground can cause DTC 323.

DTC 325

Power reduced, matched to cooling system performance

DTC 325 is set by the ECM when the cooling system temperature exceeds 111 °C (232 °F). At this temperature the ECM will reduce the fuel delivered to the engine. When the temperature drops below 111 °C (232 °F) the DTC will become inactive and the engine will return to normal operation. No lamp will be illuminated.

For each Celsius degree of temperature the fuel will be reduced 6%. This reduces the heat produced by the engine and reduces the burden on the cooling system. The vehicle speed will also be reduced and allow the operator to downshift and increase the efficiency of the cooling system. As the temperature is reduced the compensation level is reduced until the temperature drops below 111 °C (232 °F) and normal operation is resumed.

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GPC (Glow Plug Control) Circuit

Figure 401 Function diagram for the Glow Plug Control (GPC)

The function diagram for the Glow Plug Control system includes the following:

- Glow plugs
- Glow plug relay
- Electronic Control Module (ECM)
- Engine Coolant Temperature sensor (ECT)
- Barometric Absolute Pressure sensor (BAP)
- Battery
- WAIT TO START lamp

Function

The glow plug control system warms the engine cylinders to aid cold engine starting and reduce exhaust emissions during warm-up.

The ECM is programmed to energize the glow plugs (through the glow plug relay) while monitoring certain programmed conditions for engine coolant temperature and atmospheric pressure.

The ECM monitors battery voltage, Barometric Absolute Pressure (BAP) sensor and Engine Coolant Temperature (ECT) sensor to determine the amount of time that the WAIT TO START lamp and glow plugs are on.

NOTE: The WAIT TO START lamp on time is independent from the glow plug relay on time.

The WAIT TO START lamp indicates when the glow plugs have been on long enough to start the engine. The on time normally varies between 2 to 10 seconds.

The engine is ready to start when the WAIT TO START lamp is turned off by the ECM. The glow plugs can remain on up to 120 seconds while the engine is running to reduce exhaust emissions during engine warm-up.

The glow plugs are self limiting and do not require cycling on and off. The glow plug relay will only cycle on and off repeatedly if system voltage is greater than 14.0 volts.

Glow plugs are activated for a longer time, if the engine is cold or the barometric pressure is low (high altitude).

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GPC Circuit Operation

Figure 402 GPC Circuit Diagram

The glow plug control system operation on time is dependent upon the ECT, BAP, and battery voltage. The glow plug relay is activated by power supplied by the ECM through Pin X1-17 to the Glow Plug Control (GPC) circuit. The coil of the glow plug relay is grounded through the actuator power ground circuit, Pin 4 of the 12-pin connector to the battery negative terminal. Power is supplied to the switch side of the glow plug relay from the starter motor. When the relay coil is energized, power is supplied to the glow plugs that are grounded through the cylinder head.

The ECM monitors the output of the relay, from the relay to Pin X1-21.

The WAIT TO START lamp time is transmitted over the CAN1 datalink. See the applicable truck *Service Manual*.

Fault Detection/Management

The ECM continuously monitors the output of the Glow Plug relay, when voltage is not as expected a DTC will be set.

An open or short to ground in the glow plug relay control circuit can be detected by an on demand Output Circuit Check (OCC) performed during the KOEO Standard test. When a circuit fault is detected, a DTC will be set. Glow plug and glow plug harness problems can not be detected by the ECM.

Glow Plug Control DTCs

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

DTC 251

Glow Plug Control OCC self-test failed
DTC 251 is set by the ECM when the OCC test has failed after the KOEO Standard test has been run. DTC 251 can be set for an open or shorted GPC signal circuit, an open actuator power ground, or an open glow plug relay coil.

DTC 375

Glow Plug Relay Circuit Fault
DTC 375 is set by the ECM when the relay output voltage does not meet expected voltage. DTC 375 can be set by an open in the B+ supply circuit to the glow plug relay, open or shorted GPD circuit, or failed glow plug relay. DTC 375 can be set if there is a failed control circuit, repair DTC 251 first.

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Tools
EST with MasterDiagnostics® software
EZ-Tech® interface cable
Digital Multimeter (DMM)
Breakout Box
12-pin Breakout Harness

NOTE: The GPC relay ground circuit diagnosis requires the use of vehicle circuit diagrams. See the applicable truck *Circuit Diagram Manual* for circuit numbers, connector and fuse locations.

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GPC Pin-Point Diagnostics

Figure 403 GPC Circuit Diagram

Voltage Checks - Relay (KOEO)

Turn ignition switch to ON. Measure voltage (on-time is temperature dependent).

NOTE: If on-time is not long enough, do the Voltage Checks at Relay - Output State Test.

Test Point	Spec	Comments
Glow plug battery supply terminal to gnd	B+	Relay switch power, B+ should be present at all times. Check connection at starter or fusible links if no voltage is present.
Glow plug relay output terminal to gnd	ON = B+ OFF = 0 V	Glow plug control, ECM commands relay ON = B+, OFF = 0 volts. When ignition switch is turned on the glow plug relay output voltage should remain on for 20 to 120 seconds (Temperature dependent).
GPC to gnd	ON = B+ OFF = 0 V	Glow plug control, ECM commands relay ON = B+, OFF = 0 volts. When ignition switch is turned on the glow plug relay output voltage should remain on for 20 to 120 seconds (Temperature dependent).
Actuator Pwr Gnd to gnd	0 V	Glow plug relay has constant ground through 12-pin connection from batteries. If voltage is present, check for open circuit.

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Voltage Checks - Relay (Output State Test)

Turn ignition switch to ON. Run “Glow Plug/Inlet Air Heater Output State test (page 80)” see the “Diagnostic Software Operation (page 70)” section of this manual for the procedure.

Test Point	Spec	Comments
Glow plug relay output terminal to gnd	B+	Glow plug relay output terminal voltage with GP/IAH Output State Test activated, voltage should be present for 120 seconds.
GPC to gnd	B+	Glow plug relay output terminal voltage with GP/IAH Output State Test activated, voltage should be present for 120 seconds.

Voltage Checks - ECM (Output State Test)

NOTE: Do this check only if active DTC 375 and all other voltage checks are in specifications.

Turn ignition switch to OFF, connect the Breakout Box X1 and X3 only to the ECM and the harness. Turn ignition switch to ON. Run “Glow Plug/Inlet Air Heater Output State test (page 80)” see the “Diagnostic Software Operation (page 70)” section of this manual for the procedure.

Test Point	Spec	Comments
X1-21 to X3-7 (gnd)	ON = B+ OFF = 0 V	Glow plug relay output terminal voltage with GP/IAH Output State Test activated, voltage should be present for 120 seconds. If all other voltages are in specification and active DTC 375, check for open circuit and short to power source.

Harness Resistance Checks - Relay to Chassis Ground

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Disconnect the negative battery cable. Disconnect the control wiring from the relay. Use the disconnected negative battery cable as the ground test point.

Test Point	Spec	Comments
Actuator Pwr Gnd to gnd	<5 Ω	If greater than 5 Ω, check for open circuit between relay and gnd. Do “Harness Resistance Checks - 12-Pin connector (page 420).”
GPC to gnd	>1 kΩ	If less than 1 kΩ, check for short to ground from relay to X1-17 Do Harness Resistance Checks.

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Figure 404 GPC Circuit Diagram

Harness Resistance Checks - 12-Pin connector

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Disconnect the 12-Pin connector, connect 12-pin breakout harness. Disconnect negative battery cable, use negative battery cable as ground test point.

Test Point	Spec	Comments
Actuator Pwr Gnd relay to Pin 4 on 12-pin breakout harness	<5 Ω	If greater than 5 Ω, check for open from relay to 12-pin connector.
Pin 4 on 12-pin breakout harness to chassis gnd	<5 Ω	If greater than 5 Ω, check for open from 12-pin connector to chassis ground.

Harness Resistance Check - Relay to ECM

Turn ignition switch to OFF. Check with the ECM Breakout Box connected to the X1 harness only.

Test Point	Spec	Comments
GPC at relay to X1-17	<5 Ω	If greater than 5 Ω, check for open between relay and the ECM.
GPD at relay to X1–21	<5 Ω	If greater than 5 Ω, check for open between relay and the ECM.

For glow plug and harness diagnostics, see “Test 14. Glow Plug System (page 192)” in the “Hard Start and No Start Diagnostics (page 131)” section of this manual.

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HFCM (Horizontal Fuel Conditioning Module)
Fuel Pump

Figure 405 Functional diagram for the fuel pump

The functional diagram for the fuel pump includes the following:

Fuel pump
Electronic Control Module (ECM)
Fuel pump relay
Battery
Ignition switch

Function

The fuel pump is located inside the Horizontal Fuel Conditioning Module (HFCM) and is serviceable separately. The ECM controls a fuel pump relay that powers the fuel pump. When the ignition switch is turned to ON, the fuel pump relay is energized for 60 seconds. If the ECM does not detect engine running at the end of the 60 seconds it will de-energize the fuel pump relay and the fuel pump. The ECM monitors the voltage with the output of the fuel pump relay on the Fuel Pump Monitor (FPM) circuit.

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Fuel Pump Circuit Operation

Figure 406 Fuel pump circuit diagram

The fuel pump relay is supplied power at Pin 1(86) from V_{IGN}. The fuel pump relay is energized by ground supplies by the ECM through Pin X3-9 to Pin 2(85). Power is supplied to Pin 3(30) from the battery. When the relay coil is energized power is supplied to the fuel pump from Pin 5(87). The ECM monitors the output of the relay from the relay to X4-15.

Fault Detection/Management

The ECM continuously monitors the output of the fuel pump relay; when voltage is out of expected range a DTC will be set.

An open or short to ground in the fuel pump relay control circuit can be detected by an on-demand Output Circuit Check (OCC) performed during the KOEO Standard test. When a circuit fault is detected, a DTC will be set. Fuel pump and fuel pump harness problems can not be detected by the ECM.

Fuel Pump DTCs

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

DTC 237

Fuel Pump Control OCC self-test failed
DTC 237 is set by the ECM when the OCC test has failed after the KOEO Standard test has been run. DTC 237 can be set for an open or short to ground on FPC circuit, an open or short to ground on V_{IGN} circuit to the fuel pump relay, or an open fuel pump relay coil.

DTC 374

Fuel pump relay circuit fault
DTC 374 is set by the ECM when the relay output voltage does not meet expected voltage. DTC 374 can be set for an open in the B+ supply circuit to fuel pump relay, open or shorted FPM circuit, or a failed fuel pump relay. DTC 374 can be set if there is a failed control circuit, repair DTC 237 first.

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Tools
EST with MasterDiagnostics® software
EZ-Tech® interface cable
Relay breakout harness
Breakout Box
Digital Multimeter (DMM)

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Fuel Pump Pin-Point Diagnostics

The fuel pump circuit requires the use of vehicle circuit diagrams. See the applicable truck *Circuit Diagram Manual* for circuit numbers, connector and fuse locations.

Figure 407 Fuel pump circuit diagram

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Voltage Checks - Relay (KOEO)

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector or relay for the ECM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Turn ignition switch to ON. Connect relay breakout harness to relay and socket. Measure voltage (on-time is 60 seconds).

NOTE: If on-time is not long enough, do the “Voltage Checks - Relay (Output State Test.) (page 426)”

Test Point	Spec	Comments
3(30) to gnd	B+	Continuous voltage from V_{IGN}; if no voltage, check power fuse or battery. If fuse is blown, check for short to ground. If fuse is good, check for open between Pin 3(30) and V_{IGN}.
1(86) to gnd	B+	Continuous voltage from battery; if no voltage, check power fuse or battery. If fuse is blown, check for open between Pin 1(86) and Pin 10 of the 12-pin connector.
2(85) to gnd	ON = 0 to 0.25 V OFF = B+	Switched ground from ECM, 60-second on-time. If greater than 0.25 volts , check for open or shorted to power between Pin 2(85) and Pin X3-9.
5(87) to gnd	ON = B+ OFF = 0 V	Switched power from fuel pump relay, 60-second on-time. If no voltage, replace the fuel pump relay.

Figure 408 Fuel pump circuit diagram

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Voltage Checks - Relay (Output State Test)

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector or relay for the ECM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Turn ignition switch to ON. Connect relay breakout harness to relay and socket. Run “Output State Test Low (page 77)” see the “Diagnostic Software Operation (page 70)” section in this manual for the procedure.

Test Point	Spec	Comments
5(87) to gnd	B+	Fuel pump relay output voltage with “Output State Test Low (page 77)” activated, voltage should be present until test is cancelled.
2(85) to gnd	0 to 0.25 V	Fuel pump control with “Output State Test Low (page 77)” activated, ground should be present until test is cancelled.

Voltage Checks - ECM (Output State Test)

NOTE: Do this check only if active DTC 374 and all other voltage checks are in specifications.

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector or relay for the ECM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Turn ignition switch to OFF, connect the Breakout Box X4 and X3 only to the ECM and the harness. Turn ignition switch to ON. Run “Output State Test Low (page 77)” see the “Diagnostic Software Operation (page 70)” section in this manual for the procedure.

Test Point	Spec	Comments
X4-15 to X3-7 (gnd)	ON = B+ OFF = 0 V	Fuel pump relay output voltage with “Output State Test Low (page 77)” activated, voltage should be present until test is cancelled. If all other voltages are in specification and active DTC 374, check for open circuit or short to power source on fuel pump monitor circuit.

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Harness Resistance Checks - Relay to Ground

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging relay or ECM. Failure to turn ignition switch to OFF could cause a voltage spike and damage to the electrical components.

Turn ignition switch to OFF. Remove fuel pump relay, connect relay breakout harness to the relay socket only. Disconnect the negative battery cable. Use disconnected negative battery cable for ground test point.

Test Point	Spec	Comments
3(30) to gnd	> 1 kΩ	If less than 1 kΩ, check for short to ground and blown fuse
5(87) to gnd	> 1 kΩ	If less than 1 kΩ, check for short to ground and blown fuse
2(85) to gnd	> 1 kΩ	If less than 1 kΩ, check for short to ground
1(86) to gnd	> 1 kΩ	If less than 1 kΩ, check for short to ground and blown fuse
		NOTE: If ignition switch is grounded when turned off this will be less than 5 Ω.

Figure 409 Fuel pump circuit diagram

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Harness Resistance Checks - Relay to Battery

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging relay or ECM. Failure to turn ignition switch to OFF could cause a voltage spike and damage to the electrical components.

Turn ignition switch to OFF. Remove relay, connect relay breakout harness to socket only. Disconnect negative battery cable. Use disconnected negative battery cable for ground test point.

Test Point	Spec	Comments
3(30) to B+	< 5 Ω	If greater than 5 Ω, check for open or high resistance. Check fuse and battery connections.

Harness Resistance Checks - Relay to V_{IGN}

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging relay or ECM. Failure to turn ignition switch to OFF could cause a voltage spike and damage to the electrical components.

Turn ignition switch to OFF. Remove fuel pump relay, connect relay breakout harness to socket only. Disconnect negative battery cable. Remove V_{IGN} fuse. Use disconnected negative battery cable for ground test point.

Test Point	Spec	Comments
1(86) to V_{IGN}	<5 Ω	If greater than 5 Ω, check for open in ignition circuit. Check V_{IGN} relay and fuses.

Harness Resistance Checks - Relay to Pump

Turn ignition switch to OFF. Disconnect fuel pump connector, remove relay, connect relay breakout harness to socket only.

Test Point	Spec	Comments
5(87) (relay) to 1 (pump)	< 5 Ω	If greater than 5 Ω, check for open between fuel pump relay and fuel pump connector

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Figure 410 Fuel pump circuit diagram

Harness Resistance Checks - Relay to ECM

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging relay or ECM. Failure to turn ignition switch to OFF could cause a voltage spike and damage to the electrical components.

Turn ignition switch to OFF. Remove relay, connect relay breakout harness to socket only. Connect Breakout Box X4 only to harness only.

Test Point	Spec	Comments
5(87) to X4-15	<5 Ω	If greater than 5 Ω, check for open between Pin X4-15 and fuel pump relay

Harness Resistance Checks - Fuel Pump Connector to Ground

Turn ignition switch to OFF. Disconnect fuel pump connection. Inspect for bent pins or corrosion.

Test Point	Spec	Comments
1 to gnd	> 1 kΩ	If less than 1 kΩ, check for short to ground
2 to gnd	< 5 Ω	If greater than 5 Ω, check for open in ground circuit to fuel pump connector

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Harness Resistance Checks - Fuel Pump Connector to ECM

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging relay or ECM. Failure to turn ignition switch to OFF could cause a voltage spike and damage to the electrical components.

Turn ignition switch to OFF. Disconnect fuel pump connection. Inspect for bent pins or corrosion. Connect Breakout Box X4 to harness only.

Test Point	Spec	Comments
1 (pump) to X4-15	< 5 Ω	If greater than 5 Ω, check for open in fuel pump power and monitor circuit

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IAH (Inlet Air Heater) Circuit

Figure 411 Function diagram for Inlet Air Heater

The function diagram for the IAH system includes the following:

Inlet Air Heater (IAH)
Inlet Air Heater relay
Electronic Control Module (ECM)
Engine Oil Temperature (EOT) sensor
Barometric Absolute Pressure (BAP) sensor
Mass Air Flow/Inlet Air Heater (MAF/IAT) sensor
WAIT TO START lamp
Battery

Function

The inlet air heater control system warms the air entering the intake manifold to aid cold engine starting and reduce exhaust emissions during warm-up.

The ECM is programmed to energize the inlet air heater (through the inlet air heater relay) while monitoring programmed conditions for engine oil temperature, inlet air temperature, and atmospheric pressure.

The ECM monitors battery voltage and uses information from the Barometric Absolute Pressure (BAP) sensor, the Inlet Air Temperature (IAT), and the Engine Oil Temperature (EOT) sensor to determine the amount of time that the WAIT TO START lamp is ON and the activation time of the inlet air heater. The ECM controls the WAIT TO START lamp and the activation of the inlet air heater separately.

Inlet air heater is activated if the engine is cold or the barometric pressure is low (high altitude).

The engine is ready to start when the WAIT TO START lamp is turned off by the ECM.

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IAH Circuit Operation

Figure 412 IAH circuit diagram

The inlet air heater control system operation on time depends on IAT, EOT, BAP, and battery voltage. The inlet air heater relay is activated by power supplied by the ECM through Pin X1-18 to the IAHC circuit. The coil of the inlet air heater relay is grounded through the actuator power ground circuit, Pin 4 of the 12-pin connector to the battery negative terminal. Power is supplied to the switch side of the inlet air heater relay from the starter motor. When the relay coil is energized, power is supplied to the inlet air heater that is grounded through the intake manifold.

The ECM monitors the output of the relay, from the relay to Pin X2-11.

The WAIT TO START lamp time is transmitted over the CAN1 datalink. See the applicable truck *Circuit Diagram Manual*.

Fault Detection/Management

The ECM continuously monitors the output of the IAH relay, when voltage is not as expected a DTC will be set.

An open or short to ground in the inlet air heater relay control circuit can be detected by an on demand Output Circuit Check (OCC) performed during the KOEO Standard test. When a circuit fault is detected, a DTC will be set. Inlet air heater and inlet air heater wiring problems can not be detected by the ECM.

IAH DTCs

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

DTC 238
Inlet Air Heater Control OCC self-test failed
DTC 238 is set by the ECM when the OCC test has failed after the KOEO Standard test has been run. DTC 238 can be set for an open or shorted IAHC circuit, an open actuator power ground, or an open IAH relay coil.

DTC 373
Inlet Air Heater relay circuit fault
DTC 373 is set by the ECM when the relay output voltage does not meet the expected voltage. DTC 373 can be set for an open in the B+ supply circuit to the IAH relay, open or shorted IAHD circuit, or a failed IAH relay. DTC 373 can be set if there is a failed control circuit, repair DTC 238 first.

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Tools
EST with MasterDiagnostics® software
EZ-Tech® interface cable
Digital Multimeter (DMM)
Breakout Box
12-pin Breakout Harness

NOTE: The IAH relay ground circuit requires the use of vehicle circuit diagrams. See the applicable truck *Circuit Diagram Manual* for circuit numbers and locations for fuses and connectors.

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IAH Pin-Point Diagnostics

Figure 413 IAH circuit diagram

Voltage Checks - Relay (KOEO)

Turn ignition switch to ON. Measure voltage (on-time is temperature dependent).

NOTE: If on-time is not long enough do the “Voltage Checks - Relay (Output State Test) (page 435).”

Test Point	Spec	Comments
IAH battery supply terminal to gnd	B+	Relay switch power, B+ should be present at all times. Check connection at starter or fusible links if no voltage is present.
IAH relay output terminal to gnd	ON = B+ OFF = 0 V	IAH Control, ECM commands relay ON = B+, OFF = 0 volts. When ignition switch is turned on the IAH relay output voltage should remain on for 9 to 120 seconds (Temperature dependent).
IAHC to gnd	ON = B+ OFF = 0 V	IAH Control, ECM commands relay ON = B+, OFF = 0 volts. When ignition switch is turned on the IAH relay output voltage should remain on for 9 to 120 seconds (Temperature dependent).
Actuator Pwr Gnd to gnd	0 V	IAHC relay has constant ground through 12-Pin connector from batteries. If voltage is present, check for open circuit.

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Figure 414 IAH circuit diagram

Voltage Checks - Relay (Output State Test)

Turn ignition switch to ON. Run “Glow Plug/Inlet Air Heater Output State test (page 80)” see the “Diagnostic Software Operation (page 70)” section in this manual for the procedure.

Test Point	Spec	Comments
IAH relay output terminal to gnd	B+	IAH relay output terminal voltage with “GP/IAH Output State Test (page 80)” activated, voltage should be present for 30 seconds after a 3 second pause.
IAHC to gnd	B+	IAH relay output terminal voltage with “GP/IAH Output State Test (page 80)” activated, voltage should be present for 30 seconds after a 3 second pause.

Voltage Checks - At ECM (Output State Test)

NOTE: Do this check only if active DTC 373 and all other voltage checks are in specifications.

Turn ignition switch to OFF, connect the Breakout Box X2 and X3 to the ECM and the harness. Turn ignition switch to ON. Run “Glow Plug/Inlet Air Heater Output State test (page 80)” see the “Diagnostic Software Operation (page 70)” section in this manual for the procedure.

Test Point	Spec	Comments
X2-11 to X3-7 (gnd)	ON = B+ OFF = 0 V	IAH relay output terminal voltage with “GP/IAH Output State test (page 80)” activated, the voltage should be present for 30 seconds after a 3 second pause.

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Harness Resistance Checks - Relay to Chassis Ground

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Disconnect the negative battery cable, disconnect the control wiring from the relay, use the disconnected negative battery cable as the ground test point.

Test Point	Spec	Comments
Actuator Pwr Gnd to gnd	<5 Ω	If greater than 5 Ω, check for open circuit between relay and gnd. Do “Harness Resistance Checks - 12-Pin connector (page 436).”
IAHC to gnd	>1 kΩ	If less than 1 kΩ, check for short to ground from relay to X1-18 Do “Harness Resistance Checks - Relay to ECM (page 437).”

Harness Resistance Checks - 12-Pin connector

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Disconnect the 12-Pin connector, connect 12-pin breakout harness. Disconnect negative battery cable, use negative battery cable as ground test point.

Test Point	Spec	Comments
Actuator Pwr Gnd relay to PIN 4 on 12-pin breakout harness	<5 Ω	If greater than 5 Ω, check for open from relay to 12-pin connector.
Pin 4 on 12-Pin breakout harness to chassis gnd	<5 Ω	If greater than 5 Ω, check for open from 12-pin connector to chassis ground.

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Figure 415 IAH circuit diagram

Harness Resistance Check - Relay to ECM

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging relay or ECM. Failure to turn ignition switch to OFF could cause a voltage spike and damage to the electrical components.

Turn ignition switch to OFF. Check with the ECM Breakout Box connected X1 and X2 engine harness only.

Test Point	Spec	Comments
IAHC at relay to X1-18	<5 Ω	If greater than 5 Ω, check for open between relay and the ECM.
IAHD at relay to X2–11	<5 Ω	If greater than 5 Ω, check for open between relay and the ECM.

For IAH and harness diagnostics, see “Test 15. Inlet Air Heater System” (page 199) in the “Hard Start and No Start Diagnostics (page 131)” section in this manual.

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IAT (Intake Air Temperature) Sensor

The Intake Air Temperature (IAT) sensor is part of the Mass Air Flow/Intake Air Temperature (MAF/IAT) sensor, they are in a common housing.

Figure 416 Functional diagram for IAT sensor

The functional diagram for the IAT sensor includes the following:

- MAF/IAT sensor
- Electronic Control Module (ECM)
- Injector Drive Module (IDM)
- Fuel injector
- Amber Lamp (Warn Engine Lamp (WEL) for CF)

Function

The MAF/IAT sensor is a dual sensor unit. The IAT portion is a thermistor sensor located in the air flow to the turbocharger. The ECM supplies a 5 volt reference signal which the IAT uses to produce an analog voltage that indicates the inlet air temperature. The IAT changes resistance when exposed to different temperatures. When air temperature decreases, the resistance of the thermistor increases. This causes

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the signal voltage to increase. When air temperature increases, the resistance of the thermistor decreases. This causes the signal voltage to decrease.

The IAT sensor provides a feedback signal to the ECM indicating inlet air temperature. The ECM monitors the IAT signal to control fuel timing and rate for cold starting. The continuous monitoring by the IAT sensor limits smoke emissions.

IAT Circuit Operation

Figure 417 IAT circuit diagram

The IAT sensor is supplied with a 5 volt reference signal at Pin A from ECM Pin X1-7. The sensor is grounded at Pin B through sensor ground at ECM Pin X1-6. As the air temperature increases or decreases, the sensor changes resistance and provides the air temperature signal voltage at the ECM. The signal voltage is monitored by the ECM to determine the inlet air temperature.

Fault Detection/Management

When the ECM detects an IAT signal out of range high or low, the ECM will ignore the IAT signal and assume an ambient temperature of 25 °C (77 °F).

IAT DTCs

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

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DTC 154

IAT signal out of range low

DTC 154 is set by the ECM if signal voltage is less than 0.127 volts for more than 0.35 seconds.

DTC 154 can be set due to a short to ground in the signal circuit or a failed IAT sensor.

When DTC 154 is active, the amber lamp (WEL for CF) is illuminated.

DTC 155

IAT signal out of range high

DTC 155 is set by the ECM if signal voltage is greater than 4.6 volts for more than 0.35 seconds.

DTC 155 can set due to an open signal or ground circuit, a short to a voltage source, or a failed IAT sensor.

When DTC 155 is active, the amber lamp (WEL for CF) is illuminated.

Tools

EST with MasterDiagnostics® software

EZ-Tech® interface cable

Digital Multimeter (DMM)

3-Banana plug harness

500 Ohm resistor harness

MAF/IAT breakout harness

12-Pin breakout harness

Breakout Box

Terminal Test Adapter Kit

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IAT Operational Diagnostics

Figure 418 IAT circuit diagram

WARNING: To avoid personal injury, death, including damage to the engine or vehicle, keep away from rotating parts (belts and fan) and hot engine surfaces.

Figure 419 Continuous Monitor session

WARNING: To prevent personal injury, use care to prevent contact with the door edge when the cab is up and the door is open.

1. Select D_ContinuousMonitor.ssn from the Open Session File window, select Open to open the session.

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Figure 420 Continuous Monitor test

2. Select Diagnostics from the menu bar.
3. Select Key-On Engine-Off Tests from the drop down menu.
4. From the KOEO Diagnostics menu, select Continuous Monitor and select Run to start the test.
5. Monitor IAT signal voltage. Verify an active DTC for the IAT circuit.
6. If code is active, do step 8 and 9 to check circuit for the IAT sensor using the following table.

WARNING: To prevent personal injury or death, be careful around rotating parts (belts and fan) and hot engine surfaces.

7. If code is inactive, wiggle connectors and wires at all suspected problem locations. If circuit continuity is interrupted, the EST will display DTCs related to the condition.
8. Disconnect chassis harness from temperature sensor.

NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

9. Connect MAF/IAT Breakout Harness to engine harness only.

Figure 421 Close session

10. When finished with this test, select Session from menu bar, then Close.

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Circuit Checks - IAT Sensor

Use EST, MAF/IAT breakout harness, 3-banana harness, and 500 ohm resistor harness.

Test Condition	Spec	Checks
Sensor disconnected	> 4.6 V	If voltage is less than 4.6 volts, check signal circuit for short to ground.
3-Banana harness installed between Pin A (GREEN) and Pin B (BLACK) on breakout harness.	0 V	If voltage is greater than 0.127 volts, check ground and signal circuit for open or high resistance. Use a Breakout Box and measure resistance from PIN B to PIN X1-6 and from PIN A to X1-7 (specification < 5 Ω).
500 Ohm resistor harness installed between Pin A (GREEN) and Pin B (BLACK) on breakout harness.	< 1.0 V	If voltage is less than 1.0 volts, check signal circuit for short to V_{REF}, B+, or another sensor's signal voltage.

NOTE: Connect engine harness to sensor. Use the EST to clear DTCs. If an active code remains after checking test conditions, replace the MAF/IAT sensor.

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IAT Pin-Point Diagnostics

Figure 422 IAT circuit diagram

Voltage Checks - Connector to Ground

Turn ignition switch to OFF. Disconnect harness from sensor. Inspect for bent pins or corrosion. Connect MAF/IAT breakout harness to harness only. Turn ignition switch to ON, do not crank the engine.

Test Point	Spec	Comments
A to gnd	4.6 to 5.0 V	Pull up voltage, if no voltage, circuit has open, high resistance, or short to ground.
B to gnd	0 to 0.25 V	Signal ground (No voltage expected). If greater than 0.25 volts, signal ground is shorted to V_{REF} or B+.

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Figure 423 IAT circuit diagram

Resistance Checks - Connector to Chassis Ground

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Disconnect harness from sensor. Disconnect negative battery cable.

Test Point	Spec	Comments
A to gnd	> 1 kΩ	If less than 1 kΩ, check for signal circuit short to ground.
B to gnd	< 5 Ω	If greater than 5 Ω, check for open ground circuit.

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Harness Resistance Checks - ECM to Sensor

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging relay or ECM. Failure to turn ignition switch to OFF could cause a voltage spike and damage to the electrical components.

Turn ignition switch to OFF. Disconnect harness from sensor. Connect Breakout Box to engine harness X1 only harness only.

Test Point	Spec	Comments
X1-7 to A	< 5 Ω	If greater than 5 Ω, check for open signal circuit open.
X1-6 to B	< 5 Ω	If greater than 5 Ω, check for open ground circuit.

Operational Voltage Checks - IAT Sensor (Breakout Harness)

Turn ignition switch to OFF. Connect MAF/IAT breakout harness to sensor and harness. Turn ignition switch to ON, do not crank the engine.

Test Point	Temp	Resistance	Voltage
A to B	-29 °C (-20 °F)	47.5 kΩ	3.34 V
A to B	0 °C (32 °F)	9.62 kΩ	1.59 V
A to B	20 °C (68 °F)	3.6 kΩ	0.76 V
A to B	37 °C (100 °F)	1.8 kΩ	0.41 V

Operational Voltage Checks - IAT Sensor (Breakout Box)

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging relay or ECM. Failure to turn ignition switch to OFF could cause a voltage spike and damage to the electrical components.

Turn ignition switch to OFF. Connect Breakout Box to the ECM and engine harness with the IAT connected. Turn ignition switch to ON, do not crank the engine.

Test Point	Temp	Resistance	Voltage
X1-7 to X1-6 (gnd)	-29 °C (-20 °F)	47.5 kΩ	3.34 V
X1-7 to X1-6 (gnd)	0 °C (32 °F)	9.62 kΩ	1.59 V
X1-7 to X1-6 (gnd)	20 °C (68 °F)	3.6 kΩ	0.76 V
X1-7 to X1-6 (gnd)	37 °C (100 °F)	1.8 kΩ	0.41 V

IAT Diagnostic Trouble Code

DTC 154 = Signal voltage was less than 0.127 volts for more than 0.35 seconds

DTC 155 = Signal voltage was greater than 4.6 volts for more than 0.35 seconds

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ICP (Injection Control Pressure) Sensor

Figure 424 Function diagram for ICP sensor

The function diagram for the ICP sensor includes the following:

- Injection Control Pressure (ICP) sensor
- Electronic Control Module (ECM)
- Injector Drive Module (IDM)
- Fuel injectors
- Injection Pressure Regulator (IPR)
- Amber Lamp (Warn Engine Lamp (WEL) for CF)

Function

The ICP sensor is a micro strain gauge (MSG) sensor. The ICP sensor is installed through the right side valve cover in the high-pressure oil rail. The ECM supplies a 5 volt reference signal which the ICP sensor uses to produce a linear analog voltage which indicates pressure.

The ICP sensor provides a feedback signal to the ECM indicating injection control pressure. The ECM monitors ICP as the engine is operating to modulate the IPR. This is a closed loop function which means the ECM continuously monitors and adjusts for ideal ICP, determined by conditions such as load, speed, and temperature.

During engine operation, if the ECM recognizes the ICP signal is lower or higher than the value the IPR is trying to achieve the ECM will set a DTC and illuminate the amber lamp (WEL for CF).

The ICP signal from the ECM is one of the signals the IDM uses to command the correct injector timing.

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ICP Circuit Operation

Figure 425 ICP circuit diagram

The ICP sensor is supplied with a 5 volt reference voltage at Pin 2 from ECM Pin X1-14. The ICP sensor is grounded at Pin 1 from ECM Pin X1-6. The ICP sensor returns a variable voltage signal from Pin 3 to ECM Pin X1-20.

Fault Detection/Management

The ECM continuously monitors the signal of the ICP sensor to determine if the signal is within an expected range. If the ECM detects a higher or lower voltage than expected, the ECM will set a DTC, illuminate the amber lamp (WEL for CF), ignore the ICP sensor signal, and use a preset value based on engine operating conditions.

ICP (DTCs)

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

DTC 124
ICP signal out of range low
DTC 124 is set by the ECM if signal voltage is less than 0.039 volts for more than 0.1 second.
DTC 124 can be set due to an open or short to ground on the signal circuit, a failed ICP sensor or an open V_{REF} circuit or V_{REF} short to ground.
When DTC 124 is active the amber lamp (WEL for CF) is illuminated.

DTC 125
ICP signal out of range high
DTC 125 is set by the ECM if the signal voltage is greater than 4.9 volts for more than 0.1 second.
DTC 125 can be set due to a signal circuit shorted to V_{REF} or B+, or a failed ICP sensor.
When DTC 125 is active the amber lamp (WEL for CF) is illuminated.

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DTC 332

ICP above specification with engine not running

DTC 332 is set by the ECM, if the voltage signal from the ICP sensor is higher than expected with ignition switch on and the engine off. If the ECM sets DTC 332, the ECM will ignore the ICP signal and operate the IPR with fixed values based on engine operating conditions.

DTC 332 can be caused by an open signal ground, V_{REF} shorted to voltage source greater than 5.5 volts, a biased circuit, a failed ICP sensor, or a momentary loss of either the CMP or CKP signal.

When DTC 332 is active the amber lamp (WEL for CF) is illuminated.

Tools

EST with MasterDiagnostics® software

EZ-Tech® interface cable

Digital Multimeter (DMM)

3-Banana Harness

500 Ohm resistor harness

Pressure sensor breakout harness

Breakout Box

Terminal Test Adapter Kit

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ICP Operational Diagnostics

Figure 426 ICP circuit diagram

WARNING: To prevent personal injury or death, be careful to avoid rotating parts (belts and fan) and hot engine surfaces.

Figure 427 Continuous Monitor session

WARNING: To prevent personal injury, use care to prevent contact with the door edge when the cab is up and the door is open.

1. Select D_ContinuousMonitor.ssn from the Open Session File window, select Open to open the session.

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Figure 428 Continuous Monitor test

2. Select Diagnostics from the menu bar.
3. Select Key-On Engine-Off Tests from the drop down menu.
4. From the KOEO Diagnostics menu, select Continuous Monitor and select Run to start the test.
5. If code is active, do step 7 and 8 to check circuit for the ICP sensor using the following table.

WARNING: To prevent personal injury or death, be careful around rotating parts (belts and fan) and hot engine surfaces.

6. If code is inactive, wiggle connectors and wires at all suspected problem locations. If circuit continuity is interrupted, the EST display DTCs related to the condition.
7. Disconnect engine harness.

NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

8. Connect pressure sensor breakout harness to engine harness only.

Figure 429 Close session

9. When finished with this test, select Session from menu bar, then Close.

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Circuit Checks - ICP Sensor

Use EST, DMM, pressure sensor breakout harness, and 500 ohm resistor harness.

NOTE: Connect engine harness to sensor. Use the EST to clear DTCs. If an active code remains after checking test conditions, replace the ICP sensor.

Test Condition	Spec	Checks
Sensor disconnected	0 V	If voltage is greater than 0.039 volts, check signal circuit for short to V_{REF} or B+.
Voltage from Pin 2 (BLUE) to ground using DMM	5 ± 0.5 V	If voltage is greater than 5.5 volts, check V_{REF} for short to B+. If voltage is less than 4.5 volts, check V_{REF} for open or short to ground.
500 Ohm resistor harness installed between Pin 3 (GREEN) and Pin 2 (BLUE) of breakout harness.	5 V	If voltage is less than 4.9 volts, check signal circuit for open or short to ground. Remove negative battery cable. Measure resistance from Pin 3 to ground (specification > 1 kΩ) to check for short to ground. Use a Breakout Box from Pin 3 to PIN X1-20 (specification < 5 Ω) to check for open in the harness.
Resistance from Pin 1 (BLACK) of breakout harness to chassis ground using DMM.	< 5 Ω	If resistance is greater than 5 Ω, check for open or high resistance between ECM and sensor connector. Use a Breakout Box and measure resistance from between Pin 1 and Pin X1-6 (specification < 5 Ω).

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ICP Pin-Point Diagnostics

Figure 430 ICP circuit diagram with breakout harness

Voltage Checks - Connector

Turn ignition switch to OFF. Disconnect harness from sensor. Inspect for bent pins or corrosion. Connect breakout harness to engine harness only. Turn ignition switch to ON.

Test Point	Spec	Comments
1 to gnd	0 to 0.25 V	Signal ground (no voltage expected). If greater than 0.25 volts, check ground circuit for open or high resistance and check signal ground for short to V_{REF} or B+.
2 to gnd	5 ± 0.5 V	If voltage is not to specification, V_{REF} circuit is shorted to ground, shorted to B+, or open.
3 to gnd	0 to 0.25 V	If greater than 0.25 volts, signal circuit is shorted to V_{REF} or B+.

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Resistance Checks - Connector to Chassis Ground

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Disconnect negative battery cable. Disconnect harness from sensor. Use disconnected negative battery cable for ground test point.

Test Point	Spec	Comments
1 to gnd	> 500 Ω	If less than 500 Ω, check for short to ground.
2 to gnd	> 500 Ω	If less than 500 Ω, check for short to ground.
3 to gnd	> 1 kΩ	If less than 1 kΩ, check for short to ground.

Harness Resistance Checks

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging relay or ECM. Failure to turn ignition switch to OFF could cause a voltage spike and damage to the electrical components.

Turn ignition switch to OFF. Connect breakout box to engine harness X1 and X2 only and breakout harness to engine harness only.

Test Point	Spec	Comments
X1-6 to 1	< 5 Ω	If greater than 5 Ω, check for open ground circuit.
X1-14 to 2	< 5 Ω	If greater than 5 Ω, check for open V_{REF} circuit.
X1-20 to 3	< 5 Ω	If greater than 5 Ω, check for open signal circuit.

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Figure 431 ICP circuit diagram with breakout harness

Operational Voltage Checks - ICP Sensor with Breakout Harness

Check with pressure sensor breakout harness connected to sensor and engine harness.

Test Point	EST voltage readings: Signal to ground	Spec	Checks
3 (Green) to 1 (Black)	0.92 V	0 kPa (psi)	Voltage with KOEO. Atmospheric pressure dependent on altitude and BAP pressure.
3 (Green) to 1 (Black)	1.73 V	55 kPa (8 psi)	
3 (Green) to 1 (Black)	2.72 V	129 kPa (18 psi)	
3 (Green) to 1 (Black)	3.71 V	193 kPa (28 psi)	
3 (Green) to 1 (Black)	See appropriate performance specification		Rated speed, full load

See “Appendix A: VT 275 Performance Specifications (page 571)”

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Operational Voltage Checks - ICP Sensor with Breakout Box

CAUTION: To avoid engine damage, turn ignition switch to OFF before unplugging relay or ECM. Failure to turn ignition switch to OFF could cause a voltage spike and damage to the electrical components.

Check with breakout box connected X1 and X2 only to the ECM and engine harness.

Test Point	EST voltage readings: Signal to ground	Spec	Checks
X2-3 to X1-6	0.92 V	0 kPa (psi)	Voltage with KOEO. Atmospheric pressure dependent on altitude and BAP pressure.
X2-3 to X1-6	1.73 V	55 kPa (8 psi)	
X2-3 to X1-6	2.72 V	129 kPa (18 psi)	
X2-3 to X1-6	3.71 V	193 kPa (28 psi)	
X2-3 to X1-6	See appropriate performance specification		Rated speed, full load

See “Appendix A: VT 275 Performance Specifications (page 571)”

ICP Diagnostic Trouble Codes

DTC 124 = Signal voltage was less than 0.039 volts for more than 0.1 seconds.

DTC 125 = Signal voltage was greater than 4.9 volts for more than 0.1 seconds.

DTC 332 = Signal voltage was greater than 1.625 volts, ignition switch on and the engine off 7.99 MPa (1160 psi).

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ICP (Injection Control Pressure) System

Figure 432 Function diagram for ICP system

1. Injection Control Pressure (ICP) sensor
2. High-pressure oil rail assembly
3. Case-to-head tube plug (2)
4. Case-to-head tube (2)
5. High-pressure oil inlet (injector)
6. Oil exhaust port (2)
7. Fuel inlet (4)
8. Branch tube assembly
9. Injection Pressure Regulator (IPR) valve
10. Crankcase
11. High-pressure pump assembly
12. Fuel injector (6)

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The ICP system consists of the following subsystems and components:

Electronic Control Module (ECM)
Injectors
Injection Pressure Regulator (IPR)
Injection Control Pressure (ICP) sensor
Engine lubrication system
High-pressure pump reservoir
Reservoir screen
Crankcase passage
High-pressure pump assembly
Case-to-head tube assembly
Branch tube assembly
High-pressure oil rail assemblies
Associated wiring

Function

The function of the ICP system is to develop, maintain, and control the high-pressure injection control pressure to provide the force to actuate the injectors and provide fuel to the engine.

ICP System Operation

Fault Detection/Management

Diagnostic Trouble Codes (DTCs) associated with this system may indicate an electrical or electronic control system failure, but will most likely indicate a mechanical or hydraulic problem with the ICP system.

The ECM continuously monitors the ICP in the system to assure the control system is providing the proper control pressure at all times. If the oil pressure feedback provided by the ICP sensor does not meet the ECM desired values, the ECM will set a DTC, illuminate the amber lamp (WEL for CF) and control the operation of the ICP system by calculating the correct oil pressure for all engine operating conditions until the system is diagnosed and repaired.

The ECM monitors the ICP developed while the engine is cranking. When pressure does not develop in an expected time frame, the ECM will set a DTC. The DTC will aid in identifying and diagnosing the hard start and no start condition.

The EST can be used to command the ECM to perform an engine running test on the ICP system. The ECM controls the IPR in a programmed sequence and evaluates system performance. When the test concludes, if a performance issue has been detected, the ECM will set a DTC for that system condition.

When an ICP fault is detected, the ECM will default to open loop of IPR control and the EST will display N/A for ICP data. ICP desired will indicate default pressure.

ICP System DTCs

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

NOTE: Repair all injector, sensor, and actuator DTCs before doing ICP diagnostic checks and tests.

Tools

EST with MasterDiagnostics® software
EZ-Tech® interface cable
Digital Multimeter (DMM)

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WARNING: To prevent personal injury or death, when performing ICP system checks and tests, comply with the following:

- **Read all safety instructions in the foreword of this manual. Follow all warnings, cautions, and notes.**
- **Before running the engine for diagnostic or service procedures, shift transmission to park or neutral, set parking brake, and block wheels.**
- **Be careful to avoid rotating parts (belts and fan) and hot engine surfaces.**

DTC 331

ICP above system working range

DTC 331 is set by the ECM when the injection control pressure is above 24.0 MPa (3554 psi) up to 27.5 MPa (3989 psi) depending on temperature for 1.5 seconds. DTC 331 can be an indicator of a problem in the mechanical injection control pressure system, wiring, or ICP sensor.

When DTC 331 is active, the ECM will ignore feedback from the ICP sensor and control the IPR valve from programmed default values. The amber lamp (WEL for CF) will be illuminated when DTC 331 is active.

Possible causes for DTC 331 include:
- Debris in engine
- Incorrect grade of oil
- Failed, stuck or plugged inlet on the IPR valve
- IPR control wire shorted to ground
- ICP sensor or circuit causing signal to be biased high

Checks and Tests	Comments
Check oil level and quality.	Check oil level and for contamination, debris, and correct API classification.
Check active and inactive DTCs.	Repair any ICP sensor codes. See “ICP (Injection Control Pressure) Sensor (page 447)” in this section.
Do ICP Operational Voltage Checks.	Check KOEO pressure sensor value and voltage. See “ICP Operational Diagnostics (page 448)” in this section.
Do IPR Pin-Point Diagnostics.	See “IPR Pin-Point Diagnostics (page 486)” in this section.
Do the KOEO Standard Test.	Test will verify IPR valve circuit continuity. See “KOEO Standard Test (page 218)” in the “Performance Diagnostics (page 211)” section of this manual.
Do KOER Standard Test and Injection Control Pressure Test.	See “KOER Standard Test (page 237)” in the “Performance Diagnostics (page 211)” section of this manual.

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DTC 333

ICP above/below desired level

DTC 333 indicates an injection control system response time fault and may be set during normal engine operation through the continuous monitor function or during the KOER Standard Test.

DTC 333 is set by the ECM when the measured pressure does not match the pressure expected by the ECM. DTC 333 will be set if the measured value is less than or greater than 2.5 MPa (362 psi) of desired injection control pressure for a period greater than 7 seconds.

When DTC 333 is active, the ECM will ignore feedback from the ICP sensor and control the IPR valve from programmed default values. The amber lamp (WEL for CF) will be illuminated when DTC 333 is active.

Possible causes for DTC 333 include:

- Low or high oil level in crankcase
- Contaminated or aerated engine oil
- Debris in engine oil
- Trapped air in the ICP system (particularly after an injector or high-pressure pump replacement)
- Intermittent IPR valve wiring connection. Inspect engine wiring harness connector and IPR valve terminal for corrosion. Inspect terminal for bent or pushed back pins.
- Failed or stuck injection pressure regulator
- Leaks in ICP system
- Problem with ICP sensor or sensor circuit, incorrect sensor, system biased high or low
- Failed high-pressure hydraulic pump

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Checks and Tests	Comments
Check repair history - Determine if trapped air caused by ICP system disassembly.	If ICP system was serviced, vehicle should be operated 32 km (20 mi) to validate system performance.
Check oil level and quality.	Check oil level, API classification. Inspect for debris. If contamination is suspected, check oil filter element.
Check active and inactive DTCs.	Repair any ICP sensor codes. See “ICP (Injection Control Pressure) Sensor (page 448)” in this section.
Do ICP Operational Voltage Checks.	Check KOEO pressure sensor value and voltage. See “ICP Operational Diagnostics (page 447)” in this section.
Do IPR Pin-Point Diagnostics.	See “IPR Pin-Point Diagnostics (page 486)” in this section.
Do KOEO Standard Test.	Test will verify IPR valve circuit continuity. See “KOEO Standard Test (page 218)” in the “Performance Diagnostics (page 211)” section of this manual.
Do KOER Standard Test.	Test will verify major ICP system failure. See “KOER Standard Test (page 218)” in the “Performance Diagnostics (page 211)” section of this manual.
Do KOER Continuous Monitor Test (intermittent DTC detected).	When running test, wiggle wires on ICP sensor and IPR valve connectors while engine is running.
Do Injection Control Pressure Test.	Verify if oil is aerated at high idle. See “Injection Control Pressure (page 239)” in the “Performance Diagnostics (page 211)” section of this manual.
Test ICP system for leaks.	See “Low ICP System Pressure (page 178)” in the “Hard Start and No Start Diagnostics (page 131)” section of this manual.

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DTC 334

ICP unable to achieve set point in time (poor performance)

DTC 334 indicates an injection control system response time fault and may be set during normal engine operation through the continuous monitor function or during the KOER Standard test.

DTC 334 compares measured ICP to desired ICP and looks for a large pressure difference of 9 MPa (1300 psi) for a period of 3 seconds.

When DTC 334 is active, the ECM ignores the ICP sensor and controls the IPR valve operation from programmed default values.

Possible causes for DTC 334 include:

- Low or high oil level in crankcase
- Contaminated or aerated engine oil
- Debris in engine oil
- Trapped air in the ICP system (particularly after an injector or high-pressure pump replacement)
- Intermittent IPR valve wiring connection. Inspect engine wiring harness connector and IPR valve terminal for corrosion. Inspect terminal for bent or pushed back pins.
- Failed or stuck injection pressure regulator
- Leaks in ICP system
- Problem with ICP sensor or sensor circuit, incorrect sensor, system biased high or low
- Failed high-pressure hydraulic pump

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Checks and Tests	Comments
Check repair history - Determine if trapped air caused by ICP system disassembly.	If ICP system was serviced, vehicle should be operated 32 km (20 mi) to validate system performance
Check oil level and quality.	Check oil level, API classification. Inspect for debris. If contamination is suspected, check oil filter element.
Check active and inactive DTCs.	Repair any ICP sensor codes. See “ICP (Injection Control Pressure) Sensor (page 448)” in this section.
Do ICP Operational Voltage Checks.	Check KOEO pressure sensor value and voltage. See “ICP Operational Diagnostics (page 447)” in this section.
Do IPR Pin-Point Diagnostics.	See “IPR Pin-Point Diagnostics (page 486)” in this section.
Do KOEO Standard Test.	Test will verify IPR valve circuit continuity. See “KOEO Standard Test (page 218)” in the “Performance Diagnostics (page 211)” section of this manual.
Do KOER Standard Test.	Test will verify major ICP system failure. See “KOER Standard Test (page 218)” in the “Performance Diagnostics (page 211)” section of this manual.
Do KOER Continuous Monitor Test (intermittent DTC detected).	When running test, wiggle wires on ICP sensor and IPR valve connectors while engine is running.
Do Injection Pressure Control Test.	Verify if oil is aerated at high idle. See “Injection Control Pressure (page 239)” in the “Performance Diagnostics (page 211)” section of this manual.
Test ICP system for leaks.	See “Low ICP System Pressure (page 178)” in the “Hard Start and No Start Diagnostics (page 131)” section of this manual.

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DTC 335

ICP unable to build pressure during cranking

DTC 335 is set when the ECM detects less than 4 MPa (580 psi) of ICP after cranking the engine for 9 to 15 seconds depending on temperature . Engine cranking speed must be greater than 130 rpm before diagnostic trouble code detection can begin.

Engine cranking time varies with engine temperature.

NOTE: If DTC becomes active during Relative Compression Test, ignore and close DTC.

Possible causes for DTC 335 include:

- Low oil level in crankcase
- No lube oil pressure or lube oil delivery (reservoir empty or not filling)
- Trapped air in the ICP system (particularly after an injector or high-pressure pump replacement)
- Leaks in ICP system
- Inoperative or stuck injection pressure regulator
- Intermittent IPR valve wiring connection. Inspect engine wiring harness connector and IPR valve terminal for corrosion. Inspect terminal for bent or pushed back pins.
- Loose high-pressure hydraulic pump gear
- Inoperative high-pressure hydraulic pump

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Checks and Tests	Comments
Visual inspection	Verify ICP sensor and IPR wiring is connected. Check for oil leaks. Verify if system has been recently serviced (air entrapment). If ICP system was serviced, vehicle should be operated 32 km (20 mi) to validate system performance.
Check oil level and pressure.	Inspect engine oil for debris. Verify lube oil pressure and delivery during engine cranking. Verify delivery by collecting oil from lube oil pressure tap. See “Engine Oil (page 154)” and “Electronic Service Tool (EST) Data List (page 146)” in the “Hard Start and No Start Diagnostics (page 131)” section of this manual.
Check active and inactive DTCs.	Repair any ICP, CKP, or CMP sensor codes first. See”ICP (Injection Control Pressure) Sensor (page 448),” “CKP (Crankshaft Position) Sensor (page 330),” and “CMP (Camshaft Position) Sensor (page 334)” in this section.
Do KOEO Standard Test.	Test will verify IPR valve circuit continuity. See “KOEO Standard Test (page 142)” in the “Hard Start and No Start Diagnostics (page 131)” section of this manual.
Do KOER Continuous Monitor Test.	When engine is running, enable test, wiggle wires on ICP sensor, IPR valve, and all pass through connectors. If DTC is set, or engine dies, check codes and inspect wires at connection point.
Do ICP pressure test.	Verify if oil is aerated at high idle. See “Injection Control Pressure (page 239)” in the “Performance Diagnostics (page 211)” section of this manual.
Test ICP system for leaks.	See “Low ICP System Pressure (page 178)” in the “Hard Start and No Start Diagnostics (page 131)” section of this manual.
Do IPR Pin-Point Diagnostics.	See “IPR Pin-Point Diagnostics (page 486)” in this section.

Read all safety instructions in the "Safety Information" section of this manual before doing any procedures.
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IDM PWR (Injector Drive Module) Power

Figure 433 Function diagram for IDM PWR supply

The function Diagram for the IDM PWR includes the following:

Injector Drive Module (IDM)
IDM main power relay
Battery
Ignition switch
Fuses

Function

The Injector Drive Module (IDM) requires a 12 volt power source. The operating power is received from the vehicle batteries through the IDM main power relay each time the ignition switch is turned ON.

When the ignition switch is turned ON, the IDM provides an internal ground to the coil side of the IDM main power relay. This closes the relay contacts and provides the IDM with power.

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IDM PWR Circuit Operation

Figure 434 IDM PWR circuit diagram

The IDM is grounded to the battery negative terminal at IDM Pins X3-1, X3-2, X3-3, X3-22 and X3-26.

The IDM receives V_{IGN} power at Pin X3-7. Key power signals the IDM to provide a ground path to switch the IDM power relay from Pin X3-27 to 86. Switching the IDM relay provides power directly from the battery positive terminal through a fuse and relay contacts 30 and 87 to terminals X3-4, X3-23, X3-24 and X3-25. Power is also supplied to Pin X3-8 for IDM logic and is protected with a fuse. See the applicable truck *Circuit Diagram Manual* for circuit numbers, connector and fuse locations.

Fault Detection/Management

The IDM internally monitors battery voltage. When the IDM continuously receives less than 7 volts or greater than 16 volts a Diagnostic Trouble Code (DTC) will be set.

IDM PWR DTCs

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

DTC 523

IDM V_{IGN} voltage low
DTC 523 is set by the ECM when the voltage from V_{IGN} is less than 7 volts. DTC 523 can be set due to poor connections between the IDM Pin X3-7 and the V_{IGN}. DTC 523 will not illuminate the amber lamp (WEL for CF).

DTC 525

IDM fault
DTC 525 is set by the ECM when there is an internal IDM failure. When DTC 525 is set, replace the IDM. When DTC 525 is active the amber lamp (WEL for CF) is illuminated.

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DTC 533

IDM relay voltage high

DTC 533 is set by the ECM when the voltage from the IDM power relay is greater than 16 volts.

DTC 533 can be set due to an alternator voltage output of 16 volts or more. DTC 533 can also be set when jump starting the engine or incorrect external battery connections exist.

DTC 523 will not illuminate the amber lamp (WEL for CF).

DTC 534

IDM relay voltage low

DTC 534 is set by the ECM when the voltage from the IDM power relay is less than 7 volts.

DTC 534 can be set due to a failed alternator, IDM power relay, discharged batteries or increased resistance in the battery feed circuits.

DTC 534 will not illuminate the amber lamp (WEL for CF).

Tools

EST with MasterDiagnostics® software

EZ-Tech® interface cable

Digital Multimeter (DMM)

12-pin breakout harness

Breakout Box

Terminal Test Adapter Kit

Relay breakout harness

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IDM PWR Pin-Point Diagnostics

Figure 435 IDM PWR circuit diagram

Voltage Checks - IDM Power Relay Socket (KOEO)

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector relay for the IDM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

The IDM PWR circuit requires the use of vehicle circuit diagrams. Follow tests in order. Check with IDM relay and breakout harness installed, with ignition switch on and the engine off. If all tests are in spec, proceed to 12-pin voltage checks.

Test Point	Spec	Comments
85 to gnd	B+	Continuous voltage. If no voltage, check power circuits from battery or fuse. If fuse is blown, check for short to ground. If fuse is good, check for open between PIN 85 and B+.
30 to gnd	B+	Continuous voltage. If no voltage, check power circuits from battery or fuse. If fuse is blown, check for short to ground. If fuse is good, check for open between PIN 30 and B+.
86 to gnd	0.06 to 2 V	If greater than 2 volts, check for open circuit between IDM PIN X3-27 to PIN 86 on relay or V_{IGN} circuit - continue with 12-pin voltage checks.
87 to gnd	B+	Continuous voltage. If no voltage, replace relay.

NOTE: See the applicable truck *Circuit Diagram Manual* for circuit numbers, connector and fuse locations.

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12-Pin Breakout Harness

Voltage Checks - 12-pin Connector (KOEO)

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector or relay for the IDM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Check with breakout harness installed at 12-pin connector, IDM relay installed, and KOEO. Follow tests in order. Inspect for bent pins or corrosion.

Test Point	Spec	Comments
9 to gnd	B+	Power from ignition switch to IDM. If no voltage. Check for blown fuse or open circuit.
8 to gnd	0.06 to 2 V	IDM MPR - 12-pin connector. If greater than 2 volts, check for open circuit between IDM PIN X3-27 to PIN 8.
12 to gnd	B+	IDM power from relay PIN 87. If no voltage, check from PIN 12 to PIN 87 on relay for open or short to ground.
6 to gnd	B+	IDM logic power from relay PIN 87 with fuse. If fuse is blown, check for short to ground. If fuse is good, check for open circuit between fuse to PIN 6.
1 to gnd	0 V	Ground - voltage reading indicates poor ground to battery. If voltage is present check for open or high resistance between battery (-) and IDM pins.

NOTE: See the applicable truck *Circuit Diagram Manual* for circuit numbers, connector and fuse locations.

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Voltage Checks - IDM (KOEO)

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector or relay for the IDM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Check with IDM power relay installed. Disconnect IDM X3 connector. Ground Pin X3-27 using Terminal Test Pin Adapter and harness to activate relay and check at harness connector. Inspect for bent pins or corrosion.

Test Point	Spec	Comments
IDM X3-7 to gnd	B+	Power from ignition switch to IDM. If no voltage.
IDM X3-1 to gnd	0 to 0.25 V	Ground - voltage reading indicates poor ground to battery.
IDM X3-2 to gnd	0 to 0.25 V	Ground - voltage reading indicates poor ground to battery.
IDM X3-3 to gnd	0 to 0.25 V	Ground - voltage reading indicates poor ground to battery.
IDM X3-22 to gnd	0 to 0.25 V	Ground - voltage reading indicates poor ground to battery.
IDM X3-26 to gnd	0 to 0.25 V	Ground - voltage reading indicates poor ground to battery.
IDM X3-27 to gnd	0 to 0.25 V	IDM grounds relay through internal transistor. Expect 0 volts with X3-27 grounded. If voltage is present, check Terminal Test Pin Adapter and jumper.
IDM X3-8 to gnd	B+	Power from relay to IDM. If no voltage, check fuses. If a fuse is blown, check for short to ground. If fuses are good, check for open circuit between 87 and X3-8.
IDM X3-4 to gnd	B+	Power from relay to IDM. If no voltage, check for open between PIN X3-4 and 87 on IDM relay.
IDM X3-23 to gnd	B+	Power from relay to IDM. If no voltage, check for open between PIN X3-23 and 87 on IDM relay.
IDM X3-24 to gnd	B+	Power from relay to IDM. If no voltage, check for open between PIN X3-24 and 87 on IDM relay.
IDM X3-25 to gnd	B+	Power from relay to IDM. If no voltage, check for open between PIN X3-25 and 87 on IDM relay.

NOTE: See the applicable truck *Circuit Diagram Manual* for circuit numbers, connector and fuse locations.

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Figure 436 IDM PWR circuit diagram

Harness Resistance Checks - Main Power Relay to Battery

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector relay for the IDM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Check with ignition switch OFF. Disconnect negative battery cable and IDM X3 harness. IDM harness connector end is numbered at mating end.

Test Point	Spec	Comments
30 (IDM relay) to B+ cable	< 5 Ω	If greater than 5 Ω, check connections for open between relay and positive battery cable. Check fuses.
86 (IDM relay) to B+ cable	< 5 Ω	If greater than 5 Ω, check connections for open between relay and positive battery cable. Check fuse.

NOTE: See the applicable truck *Circuit Diagram Manual* for circuit numbers, connector and fuse locations.

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Harness Resistance Checks - IDM to Main Power Relay

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector relay for the IDM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Turn ignition switch to OFF. Inspect for bent pins or corrosion. Connect relay breakout harness and use Terminal Test Adapter Kit to test. Disconnect IDM X3 (32-pin) connector.

NOTE: The mating end of the X3 connector is numbered 1 through 32.

Test Point	Spec	Comments
IDM X3-4 to 87	< 5 Ω	If greater than 5 Ω, check connection from IDM to relay.
IDM X3-23 to 87	< 5 Ω	If greater than 5 Ω, check connection from IDM to relay.
IDM X3-24 to 87	< 5 Ω	If greater than 5 Ω, check connection from IDM to relay.
IDM X3-25 to 87	< 5 Ω	If greater than 5 Ω, check connection from IDM to relay.
IDM X3-8 to 87	< 5 Ω	If greater than 5 Ω, check connection from IDM through fuse to relay.
IDM X3-27 to 85	< 5 Ω	If greater than 5 Ω, check connection from IDM to relay.

NOTE: See the applicable truck *Circuit Diagram Manual* for circuit numbers, connector and fuse locations.

Figure 437 IDM PWR circuit diagram

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Harness Resistance Checks - IDM to Chassis Ground

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Disconnect negative battery cable. Disconnect harness from IDM relay. Use disconnected negative battery cable for ground test point.

Test Point	Spec	Comments
IDM X3-1 to gnd cable	< 5 Ω	If greater than 5 Ω, check connection to battery ground.
IDM X3-2 to gnd cable	< 5 Ω	If greater than 5 Ω, check connection to battery ground.
IDM X3-3 to gnd cable	< 5 Ω	If greater than 5 Ω, check connection to battery ground.
IDM X3-22 to gnd cable	< 5 Ω	If greater than 5 Ω, check connection to battery ground.
IDM X3-26 to gnd cable	< 5 Ω	If greater than 5 Ω, check connection to battery ground.
IDM X3-4 to gnd cable	> 900 Ω	If less than 900 Ω, check for short to ground.
IDM X3-23 to gnd cable	> 900 Ω	If less than 900 Ω, check for short to ground.
IDM X3-24 to gnd cable	> 900 Ω	If less than 900 Ω, check for short to ground.
IDM X3-25 to gnd cable	> 900 Ω	If less than 900 Ω, check for short to ground.
IDM X3-8 to gnd cable	> 900 Ω	If less than 900 Ω, check for short to ground.
IDM X3-27 to gnd cable	> 900 Ω	If less than 900 Ω, check for short to ground.
IDM X3-7 to gnd cable	> 900 Ω	If less than 900 Ω, check for short to ground.

NOTE: See the applicable truck *Circuit Diagram Manual* for circuit numbers, connector and fuse locations.

IDM PWR Diagnostic Trouble Codes

DTC 523 = IDM V_{IGN} voltage low

DTC 525 = IDM fault

DTC 533 = IDM relay voltage high

DTC 534 = IDM relay voltage low

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INJ (Injector Drive) Circuits

Figure 438 Function diagram for INJ circuit

The function diagram for INJ circuit includes the following:

- fuel Injectors
- Electronic Control Module (ECM)
- Injector Driver Module (IDM)
- Controller Area Network (CAN2) link
- Camshaft Position Output (CMPO) signal
- Crankshaft Position Output (CKPO) signal
- Amber Warn Engine Lamp (WEL)

Function

The IDM is used to control the injectors. The IDM receives CMPO and CKPO signals and fueling information via CAN2 from the ECM. The IDM calculates injection timing and injector actuation time based on the fuel quantity requested for any engine operation condition.

INJ Circuit Operation

When a coil needs to be energized the IDM turns on both the high and low side driver.

High Side Drive Output

The IDM regulates the current at an average of 20 amps. When the current reaches 24 amps the IDM shuts off the high side driver. When the current drops to 16 amps the IDM turns on the high side driver.

Low Side Drive Return

The injector solenoids are grounded through the low side return circuits. The IDM monitors the low side return circuits. The IDM monitors the low side return signal for diagnostic purposes and utilizes the fly-back current from the injector solenoids to help charge the drive capacitors internal to the IDM.

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Fault Detection/Management

When the engine is running, the IDM can detect individual injector coil open and shorts to ground or battery. A KOEO Injector Test allows the operator to enable all injector coils when the engine is off to verify circuit operation. When the IDM detects a fault, DTCs are transmitted over the CAN2 line between the ECM and IDM.

The IDM transmits a high and low side drive output to the injectors. The high side output supplies the injectors with a power supply of 48 volts DC at 20 amps. The low side output supplies a return circuit to each injector coil.

The injectors are under the right and left valve covers. Each injector has a close and open coil. The IDM continuously monitors the amount of time (rising time) taken by each coil to draw 20 amps. The time is compared to calibrated values and the IDM determines if a circuit or injector fault exists. Each injector has six failure modes and three DTCs. A failure can occur on the open or close coil circuit.

When a short to ground condition is detected on an injector (low or high side), the IDM discontinues power to the shorted injector, enables the amber WEL, and operates the engine on the remaining cylinders.

INJ DTCs

DTCs are read using the EST or by counting the flashes from the amber and red lamps. The last digit in the injector DTC corresponds to the cylinder where a fault has been detected.

DTC 421-426
High side to low side open (cylinder number indicated)
DTC 421-426 is set by the ECM when the rising time is too long on open or close coil. DTC 421-426 usually indicates a harness or coil is open.

DTC 431-436
High side shorted to low side (cylinder number indicated)
DTC 431-436 is set by the ECM when the rising time to 20 amps is short, but not zero on the open or close coil. DTC 431-436 usually indicates an internally shorted coil.

DTC 451-456
High side short to ground or V_{BAT} (cylinder number indicated)
DTC 451-456 is set by the ECM when the rising time to 20 amps is zero on the open or close coil. DTC 451-458 usually indicates the harness or coil is shorted to ground.

Tools
EST with MasterDiagnostics® software
EZ-Tech® interface cable
Digital Multimeter (DMM)
Terminal Test Adapter Kit

INJ Pin-Point Diagnostics

WARNING: To prevent personal injury or death, do not perform voltage checks with the engine running. Injector solenoid operating voltage of 48 volts DC at 20 amps is present on injector circuits.

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector or relay for the IDM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Before doing injector diagnostic testing:

1. Turn ignition switch to OFF.
2. Disconnect IDM connectors (X1 and X2).

All tests are checked at the harness end. Terminal numbers are marked on all connector mating ends. After checking resistance through injector coils and resistance to chassis ground, if tests are within specification and DTC is active, replace the injector.

NOTE: Only diagnose injectors with active DTCs.

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Figure 439 Cylinder 1 circuit diagram

Injector Cylinder 1

Test Point	Spec	Comments
X1-5 to X1-20	0.7 to 1.5 Ω	If greater than 1.5 Ω, check for open or high resistance between IDM and injector, or open injector coil
X1-5 to gnd, X1-20 to gnd	>1 kΩ	If less than 1 kΩ, check for short to ground in harness or injector coil. Disconnect injector and retest. If greater than 1 kΩ, the short is in the injector.
X1-2 to X1-19	0.7 to 1.5 Ω	If greater than 1.5 Ω, check for open or high resistance between IDM and injector, or close injector coil.
X1-2 to gnd, X1-19 to gnd	>1 kΩ	If less than 1 kΩ, check for short to ground in harness or injector coil. Disconnect injector and retest. If greater then 1 kΩ, the short is in the injector.

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Figure 440 Cylinder 3 circuit diagram

Injector Cylinder 3

Test Point	Spec	Comments
X1-1 to X1-23	0.7 to 1.5 Ω	If greater than 1.5 Ω, check for open or high resistance between IDM and injector, or open injector coil
X1-1 to gnd, X1-23 to gnd	>1 kΩ	If less than 1 kΩ, check for short to ground in harness or injector coil. Disconnect injector and retest. If greater than 1 kΩ, the short is in the injector.
X1-6 to X1-24	0.7 to 1.5 Ω	If greater than 1.5 Ω, check for open or high resistance between IDM and injector, or close injector coil.
X1-6 to gnd, X1-24 to gnd	>1 kΩ	If less than 1 kΩ, check for short to ground in harness or injector coil. Disconnect injector and retest. If greater than 1 kΩ, the short is in the injector.

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Figure 441 Cylinder 5 circuit diagram

Injector Cylinder 5

Test Point	Spec	Comments
X1-3 to X1-17	0.7 to 1.5 Ω	If greater than 1.5 Ω, check for open or high resistance between IDM and injector, or open injector coil
X1-3 to gnd, X1-17 to gnd	>1 kΩ	If less than 1 kΩ, check for short to ground in harness or injector coil. Disconnect injector and retest. If greater than 1 kΩ, the short is in the injector.
X1-8 to X1-18	0.7 to 1.5 Ω	If greater than 1.5 Ω, check for open or high resistance between IDM and injector, or close injector coil
X1-8 to gnd, X1-18 to gnd	>1 kΩ	If less than 1 kΩ, check for short to ground in harness or injector coil. Disconnect injector and retest. If greater than 1 kΩ, the short is in the injector.

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Figure 442 Cylinder 6 circuit diagram

Injector Cylinder 6

Test Point	Spec	Comments
X2-4 to X2-19	0.7 to 1.5 Ω	If greater than 1.5 Ω, check for open or high resistance between IDM and injector, or open injector coil
X2-4 to gnd, X2-19 to gnd	>1 kΩ	If less than 1 kΩ, check for short to ground in harness or injector coil. Disconnect injector and retest. If greater than 1 kΩ, the short is in the injector.
X2-8 to X2-20	0.7 to 1.5 Ω	If greater than 1.5 Ω, check for open or high resistance between IDM and injector, or close injector coil
X2-8 to gnd, X2-20 to gnd	>1 kΩ	If less than 1 kΩ, check for short to ground in harness or injector coil. Disconnect injector and retest. If greater than 1 kΩ, the short is in the injector.

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Figure 443 Cylinder 2 circuit diagram

Injector Cylinder 2

Test Point	Spec	Comments
X2-2 to X2-17	0.7 to 1.5 Ω	If greater than 1.5 Ω, check for open or high resistance between IDM and injector, or open injector coil
X2-2 to gnd, X2-17 to gnd	>1 kΩ	If less than 1 kΩ, check for short to ground in harness or injector coil. Disconnect injector and retest. If greater than 1 kΩ, the short is in the injector.
X2-6 to X2-18	0.7 to 1.5 Ω	If greater than 1.5 Ω, check for open or high resistance between IDM and injector, or close injector coil
X2-6 to gnd, X2-18 to gnd	>1 kΩ	If less than 1 kΩ, check for short to ground in harness or injector coil. Disconnect injector and retest. If greater than 1 kΩ, the short is in the injector.

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Figure 444 Cylinder 4 circuit diagram

Injector Cylinder 4

Test Point	Spec	Comments
X2-1 to X2-21	0.7 to 1.5 Ω	If greater than 1.5 Ω, check for open or high resistance between IDM and injector, or open injector coil
X2-1 to gnd, X2-21 to gnd	>1 kΩ	If less than 1 kΩ, check for short to ground in harness or injector coil. Disconnect injector and retest. If greater than 1 kΩ, the short is in the injector.
X2-5 to X2-22	0.7 to 1.5 Ω	If greater than 1.5 Ω, check for open or high resistance between IDM and injector, or close injector coil
X2-5 to gnd, X2-22 to gnd	>1 kΩ	If less than 1 kΩ, check for short to ground in harness or injector coil. Disconnect injector and retest. If greater than 1 kΩ, the short is in the injector.

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IPR (Injection Pressure Regulator)

Figure 445 Function diagram for IPR

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The function diagram for the IPR includes the following:

Injection Pressure Regulator (IPR)
Engine Oil Temperature (EOT) sensor
Injection Control Pressure (ICP) sensor
Manifold Absolute Pressure (MAP) sensor
Barometric Absolute Pressure (BAP) sensor
Camshaft Position (CMP) sensor
Crankshaft Position (CKP) sensor
Accelerator Position/Idle Validation (APS/IVS) sensor
Electronic Control Module (ECM)
Amber Lamp (Warn Engine Lamp (WEL) for CF)

Function

The IPR valve controls oil pressure in the high-pressure injection control system that actuates the injectors. The IPR valve consists of a solenoid, poppet, and a spool valve assembly. The IPR is mounted in the body of the high-pressure pump. The ECM regulates ICP by controlling the ON/OFF time of the IPR solenoid. An increase or decrease in the ON/OFF time positions the poppet and spool valve inside the IPR and maintains pressure in the ICP system or vents pressure to the oil sump via the rear cover.

NOTE: The engine may not operate with an IPR fault, depending on the mode of failure.

IPR Circuit Operation

Figure 446 IPR circuit diagram

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The IPR valve is supplied with voltage at Pin A of the IPR connector through 12-pin connector (Pin 9) from V_{IGN}. The control of the injection control system is gained by the ECM grounding Pin B of the IPR valve through Pin X1-12 of the ECM. Precise control is gained by varying the percentage of ON/OFF time of the IPR solenoid. A high duty cycle indicates a high amount of injection control pressure is being commanded. A low duty cycle indicates less pressure being commanded.

Fault Detection/Management

An open or short to ground in the ICP control circuit can be detected by an on demand output circuit check during KOEO Standard Test. If there is a circuit fault detected a Diagnostic Trouble Code (DTC) will be set. When the engine is running, the ECM can detect if the injection control pressure is equal to the desired pressure. When the measured injection control pressure does not compare to the desired pressure, the ECM will ignore the measured ICP signal and controls the engine with the desired value.

IPR Diagnostic Trouble Codes (DTCs)

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

DTC 241
IPR OCC self-test failed
DTC 241 is set by the ECM when the Output Circuit Check (OCC) test has failed after the “KOEO Standard Test (page 73)” in the “Diagnostic Software Operation (page 70)” section has been run.
DTC 241 can be set when a poor connection to the IPR solenoid or inoperative IPR coil exists.
When DTC 241 is active the engine will not run and the amber lamp (WEL for CF) will not be illuminated

Tools
EST with MasterDiagnostics® software
EZ-Tech® interface cable
Digital Multimeter (DMM)
Breakout Box
Actuator Breakout harness
Terminal Test Adapter Kit

Read all safety instructions in the "Safety Information" section of this manual before doing any procedures.
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IPR Pin-Point Diagnostics

Figure 447 IPR circuit diagram

Voltage Checks - IPR

Disconnect IPR connector. Connect breakout harness to engine harness only. Turn ignition switch to ON.

The IPR circuit requires the use of vehicle circuit diagrams. See the applicable truck *Circuit Diagram Manual* for circuit numbers, connector and fuse locations.

Test Point	Spec	Comments
A to gnd	B+	IPR power from V_{IGN}, If no voltage, check from fuse to IPR connector.
B to gnd	0 to 0.25 V	If greater than 0.25 volts, control wire is shorted to V_{REF} or B+.

Resistance Checks - Connector to Chassis Ground

Turn ignition switch to OFF. Connect breakout harness to engine harness only.

Test Point	Spec	Comments
A to gnd	>1 kΩ	Resistance to chassis ground. If less than 1 kΩ, check for short to ground in circuit (check with fuse removed)
B to gnd	>1 kΩ	If less than 1 kΩ, check for short to ground

Harness Resistance Checks - ECM to IPR Connector

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector or relay for the ECM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Turn ignition switch to OFF. Connect breakout box X1 and X2 only to engine harness. Connect actuator breakout harness to engine harness only. Check with fuse removed.

Test Point	Spec	Comments
X2-24 to A	< 5 Ω	If greater than 5 Ω check for open circuit.
X1-12 to B	< 5 Ω	If greater than 5 Ω check for open circuit.

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Harness Resistance Checks - 12-pin Connector to IPR Connector

Turn ignition switch to OFF. Connect 12- pin breakout harness to engine harness only. Connect actuator breakout harness to engine harness only. Check with fuse removed.

Test Point	Spec	Comments
Pin 9 to A	< 5 Ω	If greater than 5 Ω check for open circuit.

Harness Resistance Checks - IPR Circuit Including Regulator

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector or relay for the ECM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Turn ignition switch to OFF. Connect Breakout Box X1 to engine harness only. Connect engine harness to IPR. Check with fuse remove.

Test Point	Spec	Comments
X1-12 to fuse	5 to 20 Ω	Resistance through entire IPR circuit including regulator. If not within specification do “Actuator Resistance Checks (page 487).”

Actuator Resistance Checks

Turn ignition switch to OFF. Disconnect the connector from the IPR, connect breakout harness to IPR only. Check resistance through the IPR only.

Test Point	Spec	Comments
A to B	5 to 20 Ω	Resistance through IPR coil only. If not within specification replace IPR.

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IST (Idle Shutdown Timer) System

Figure 448 Function diagram for IST system

IST Operation

The IST is an optional feature that allows the ECM to shutdown the engine when an extended idle condition occurs. The idle timer can be programmed for the customer to automatically shut the engine down for idle times that range from 2 to 120 minutes.

Before engine shutdown, the red lamp (OWL for CF) will illuminate. The lamp will flash for 30 seconds to warn the operator the engine is approaching shutdown. Idle time is measured from last brake pedal transition. The engine must be out of gear for the IST to work.

The IST feature can be programmed to operate at specific ambient air temperatures, allowing engine operation in cold or hot weather.

The resets for the IST include:

- Engine speed is not at idle speed (700 rpm)
- Vehicle movement is detected
- Engine coolant operating temperature is below 60 °C (140 °F) or above 150 °C (302 °F) .
- Ambient air temperature is below 16 °C (60 °F) or above 35 °C (95 °F).
- Brake pedal movement or a brake switch fault is detected.
- Shift selector is moved from neutral or park.

The IST feature provides several advantages when enabled. Reduced emissions, fuel consumption, and engine wear are all direct results from the IST strategy.

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Four states of IST electronic operation

Idle shutdown timer	Indicates to the on-board electronics that the vehicle has the following features: OFF - turned off at all times. No engine load - allows prolonged engine idle shutdown when engine is in low idle/no load condition. Tamper proof - prohibits operator override.
Idle shutdown time	Indicates the programmed value of engine idle time before engine will shutdown.
Maximum ambient intake air temperature	Indicates maximum value of ambient intake air temperature programmed to shutdown engine. This feature prevents engine shutdown due to air conditioner usage.
Minimum ambient intake air temperature	Indicates minimum value of ambient intake air temperature programmed to shutdown engine. This feature prevents engine shutdown due to cold ambient temperature.

Fault Detection/Management

The IST feature is internal to the ECM. The subsystems that contribute to the IST strategy have their own fault codes. The fault code for the IST is not a system diagnostic trouble code. The IST fault code is only set to indicate that the IST has been activated and the engine has shutdown.

IST DTCs

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

DTC 324

IST enabled engine shutdown

DTC 324 is set by the ECM when the engine has been shutdown due to exceeding the programmed idle time criteria. The IST feature must be enabled for DTC 324 to be displayed.

NOTE: DTC 324 does not indicate any system or circuit DTCs. Diagnostic checks are not required for DTC 324.

Tools

EST with MasterDiagnostics® software

EZ-Tech® interface cable

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MAF (Mass Air Flow) Sensor

The Mass Air Flow (MAF) sensor is part of the Mass Air Flow/Intake Air Temperature (MAF/IAT) sensor, they are in a common housing.

Figure 449 Functional diagram for the MAF/IAT sensor

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The functional diagram for the MAF/IAT sensor includes the following:

- MAF/IAT sensor
- Exhaust Gas Recirculation (EGR) valve assembly
- Electronic Control Module (ECM)
- Injector Drive Module (IDM)
- Fuel injectors
- Amber Lamp (Warn Engine Lamp (WEL) for CF)

Function

The MAF/IAT sensor is a dual sensor unit. The MAF sensor portion is a flow meter located in the air flow to the turbocharger.

The MAF sensor is supplied power and ground which it uses to produce a digital signal (frequency) that is interpreted as mass air flow.

The ECM monitors MAF and Manifold Absolute Pressure (MAP) signals to optimize control of fuel rate and injection timing for all engine operating conditions.

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MAF Circuit Operation

Figure 450 MAF circuit diagram

The MAF sensor is supplied a 12 volt signal at Pin D from Pin 9 of the 12-pin connector. Ground is supplied at Pin C from Pin 4 of the 12-pin connector. The MAF sensor returns a signal from Pin E to ECM X2-2. The signal is monitored by the ECM to determine mass air flow.

Fault Detection/Management

When the ECM detects a MAF signal out of range high or low, the ECM will ignore the MAF signal. The engine will continue to operate based on estimated values.

MAF DTCs

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

DTC 148
MAF signal frequency out of range low
DTC 148 is set by the ECM, if MAF frequency is less than 200 Hz for 5 seconds. Default MAF will disable the EGR.
DTC 148 can be set due to an open or short to ground in the MAF signal circuit, an open in V_{IGN} circuit, an open ground circuit, or a failed MAF sensor.
When DTC 148 is active, the amber lamp (WEL for CF) is illuminated.

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DTC 149

MAF signal frequency out of range high

DTC 149 is set by the ECM, if MAF frequency is more than 11,500 Hz for 5 seconds. Default MAF will disable the EGR.

DTC 149 can be set due to a short to voltage in the MAF signal circuit, or a failed MAF sensor.

When DTC 149 is active, the amber lamp (WEL for CF) is illuminated.

DTC 166

Mass air flow sensor in-range fault

DTC 166 is set by the ECM when MAF reading is above 20 gps at key-on-engine-off.

DTC 166 will be set if MAF is not reading 15 +/- 5 gps at low idle in Park or neutral or 25 +/- 5 gps at low idle in Drive.

DTC 166 can be set due to a biased MAF/IAT sensor, plugged or leaking air intake, air filter, or plugged exhaust system.

When DTC 166 is active the amber lamp will be illuminated.

DTC 167

Excessive mass air flow

DTC 167 is set by the ECM when MAF reads above a calibrated set point based on engine rpm. Signal will default to 300 gps when this code is set.

DTC 167 can be set due to a biased or disconnected MAF/IAT sensor or a short to voltage in the MAF signal circuit.

When DTC 167 is active the amber lamp will be illuminated.

Tools

EST with MasterDiagnostics® software

EZ-Tech® interface cable

Digital Multimeter (DMM)

3-Banana plug harness

500 Ohm resistor harness

MAF/IAT breakout harness

12-Pin breakout harness

Breakout Box

Terminal Test Adapter Kit

Read all safety instructions in the "Safety Information" section of this manual before doing any procedures.
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MAF Pin-Point Diagnostics

Figure 451 MAF circuit diagram

Voltage Checks - at MAF/IAT Connector

Turn ignition switch to OFF. Disconnect harness from sensor. Inspect for bent pins or corrosion. Connect MAF/IAT breakout harness. Turn ignition switch to ON, do not crank the engine.

Test Point	Spec	Comments
C to B+	B+	Actuator power ground. If less than B+, open or high resistance in circuit.
D to gnd	B+	V_{IGN} (B+ expected). If less than B+, circuit is open, blown fuse, or shorted to ground.

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Resistance Checks - Connector to Chassis Ground

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Disconnect negative battery cable. Disconnect harness from sensor. Inspect for bent pins or corrosion. Connect MAF/IAT breakout harness to the harness only.

Test Point	Spec	Comments
C to gnd	< 5 Ω	If greater than 5 Ω, check for open in ground circuit.
D to gnd	> 1 kΩ	If less than 1 kΩ, check for short to ground in V_{IGN} circuit.
E to gnd	> 1 kΩ	If less than 1 kΩ, check for short to ground in MAF circuit.

Harness Resistance Checks - 12- Pin Connector to Sensor

Turn ignition switch to OFF. Connect 12-pin breakout harness to engine harness only.

Test Point	Spec	Comments
Pin 4 to C	< 5 Ω	If greater than 5 Ω, check for open in actuator power ground circuit.
Pin 9 to D	< 5 Ω	If greater than 5 Ω, check for open in V_{IGN} circuit.

Harness Resistance Checks - ECM to Sensor

Turn ignition switch to OFF. Disconnect the harness from sensor. Connect MAF/IAT breakout harness to the harness only. Connect Breakout Box X2 only to engine harness.

Test Point	Spec	Comments
X2-2 to E	< 5 Ω	If greater than 5 Ω, check for open in MAF signal circuit.

Operational Frequency Checks - MAF Sensor (Breakout Harness)

Turn ignition switch to OFF. Connect MAF/IAT breakout harness to MAF/IAT sensor and harness. Turn ignition switch to ON.

Test Point	Engine State	Frequency Range	Comments
E to C	KOEO	350 ± 125 Hz	
E to C	Low idle	See appropriate performance specification	
E to C	High idle	See appropriate performance specification	

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Figure 452 IAT circuit diagram

Operational Frequency Checks - MAF Sensor (Breakout Box)

Turn ignition switch to OFF. Connect Breakout Box to the ECM and engine harness with the MAF/IAT sensor connected. Turn ignition switch to ON.

Test Point	Engine State	Frequency Range	Comments
X2-2 to X3-7 (gnd)	KOEO	350 ± 125 Hz	
X2-2 to X3-7 (gnd)	Low idle	See appropriate performance specification	
X2-2 to X3-7 (gnd)	High idle	See appropriate performance specification	

MAF Diagnostic Trouble Codes

DTC 148 = MAF signal frequency is less than 200 Hz for more than 5 seconds.

DTC 149 = MAF signal frequency is greater than 11.5 kHz for more than 5 seconds

DTC 166 = MAF signal frequency at KOEO or low idle is above or below desired for more then 3 seconds.

DTC 167 = MAF signal frequency is above desired range for more then 3 seconds.

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MAP (Manifold Absolute Pressure) Sensor

Figure 453 Functional diagram for the MAP sensor

The functional diagram for the MAP sensor includes the following:

- Manifold Absolute Pressure (MAP) sensor
- Electronic Control Module (ECM)
- Injector Drive Module (IDM)
- Boost Control Solenoid (BCS)
- Fuel injectors
- Amber Lamp (Warn Engine Lamp (WEL) for CF)
- Exhaust Gas Recirculation (EGR) valve

Function

The MAP sensor is a variable capacitance sensor which measures pressure. It is installed to the right of the intake air elbow in the intake manifold. The ECM supplies a 5 volt reference signal which the MAP sensor uses to produce a linear analog voltage that indicates pressure. The ECM monitors the MAP signal to determine intake manifold (boost) pressure. This information is used to control the Boost Control Solenoid (BCS).

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MAP Circuit Operation

Figure 454 MAP circuit diagram

The MAP sensor is supplied with a 5 volt reference voltage at Pin 2 from ECM Pin X1-14. The MAP sensor is grounded at Pin 1 from ECM Pin X1-6. The MAP sensor returns a variable voltage signal from Pin 3 of the sensor to ECM Pin X2-3.

Fault Detection/Management

The ECM will ignore the MAP signal when the signal is detected to be out of range or an incorrect value is monitored. The engine will continue to operate based on estimated values.

MAP DTCs

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

DTC 121

Intake MAP signal out of range high
DTC 121 is set by the ECM when the MAP signal is greater than 4.9 volts for more than 0.4 seconds.
DTC 121 can be set due to a sensor signal circuit short to V_{REF} or B+ or a failed MAP sensor
When DTC 121 is active the amber lamp (WEL for CF) is illuminated.

DTC 122

Intake MAP signal out of range low
DTC 122 is set by ECM when the MAP signal is less than 0.039 volts for more than 0.4 seconds.
DTC 122 can be set due to an open or short to ground on the signal circuit, a failed MAP sensor or an open V_{REF} circuit or V_{REF} short to ground. DTC 122 can also be set due to an extremely restricted CAC/intake system.
When DTC 122 is active the amber lamp (WEL for CF) is illuminated.

DTC 123

Intake MAP signal in range fault
DTC 123 is set by ECM when the MAP signal is greater than 120 kPa (2 psi) absolute at low idle.
DTC 123 can be set due to a restricted or plugged sensor inlet, open signal ground, V_{REF} shorted to voltage source above 5.5 volts, biased circuit, or a failed MAP sensor.
When DTC 123 is active the amber lamp (WEL for CF) is illuminated.

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Tools
EST with MasterDiagnostics® software
EZ-Tech® interface cable
Digital Multimeter (DMM)
3-Banana plug harness
500 Ohm resistor harness
Breakout Box
Pressure sensor breakout harness
Terminal Test Adapter Kit

MAP Operational Diagnostics

WARNING: To prevent personal injury or death, be careful to avoid rotating parts (belts and fan) and hot engine surfaces.

Figure 455 Continuous Monitor session

WARNING: To prevent personal injury, use care to prevent contact with the door edge when the cab is up and the door is open.

1. Select D_ContinuousMonitor.ssn from the Open Session File window, select Open to open the session.

Figure 456 Continuous Monitor test

2. Select Diagnostics from the menu bar.
3. Select Key-On Engine-Off Tests from the drop down menu.
4. From the KOEO Diagnostics menu, select Continuous Monitor and select Run to start the test.

WARNING: To prevent personal injury or death, be careful around rotating parts (belts and fan) and hot engine surfaces.

5. Monitor MAP signal voltage. Verify an active DTC for the MAP circuit.
6. If code is active, do step 8 and 9 to check circuit for the MAP sensor using the following table.
7. If code is inactive, wiggle connectors and wires at all suspected problem locations. If circuit continuity is interrupted, the EST will display DTCs related to the condition.

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8. Disconnect engine harness from pressure sensor.

NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

9. Connect Pressure Sensor Breakout Harness to engine harness only.

Figure 457 Close session

10. When finished with this test, select Session from menu bar, then Close.

Circuit Checks - MAP Sensor

Use EST, DMM, pressure sensor breakout harness, and 500 ohm resistor harness.

Test Condition	Spec	Checks
Sensor disconnected	0 V	If voltage greater than 0.039 volts, check signal circuit for short to V_{REF} or B+.
Voltage from Pin 2 (BLUE) to ground using DMM	5 ± 0.5 V	If voltage greater than 5.5 volts, check V_{REF} for short to B+. If voltage is less than 4.5 volts, check V_{REF} for open or short to ground.
500 Ohm resistor harness connected between Pin 3 (GREEN) and Pin 2 (BLUE) of breakout harness.	5 V	If voltage less than 4.9 volts, check signal circuit for open or short to ground. Remove negative battery cable. Measure resistance from Pin 3 to ground (specification > 1 kΩ) to check for short to ground. Use a Breakout Box from PIN 3 to Pin X2-3 (specification < 5 Ω) to check for open in the harness.
Resistance from Pin 1 (BLACK) of breakout harness to chassis ground using DMM.	< 5 Ω	If resistance is greater than 5 Ω, check for open or high resistance between ECM and sensor connector. Use a Breakout Box and measure resistance from between Pin 1 and PIN X1-6 (specification < 5 Ω).

NOTE: Connect engine harness to sensor. Use the EST to clear DTCs. If an active code remains after checking test conditions, replace the MAP sensor.

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MAP Pin-Point Diagnostics

Figure 458 MAP circuit diagram

Voltage Checks - MAP Connector

Turn ignition switch to OFF. Disconnect harness from sensor. Inspect for bent pins or corrosion. Connect breakout harness to engine harness only. Turn ignition switch to ON, do not crank engine.

Test Point	Spec	Comments
1 to gnd	0 to 0.25 V	Signal ground (no voltage expected). If greater than 0.25 volts, check ground circuit for open or high resistance and check signal ground for short to V_{REF} or B+.
2 to gnd	5 ± 0.5 V	If voltage is not to specification, V_{REF} circuit is shorted to ground, shorted to B+, or open.
3 to gnd	0 to 0.25 V	If greater than 0.25 volts, MAP signal circuit is shorted to V_{REF} or B+.

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Resistance Checks - MAP Connector to Chassis Ground

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector or relay for the ECM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Turn ignition switch to OFF. Disconnect harness from sensor. Connect breakout harness to engine harness only. Disconnect negative battery cable. Use disconnected negative battery cable for ground test point.

Test Point	Spec	Comments
1 to gnd	< 5 Ω	If greater than 5 Ω, check for open circuit
2 to gnd	> 500 Ω	If less than 500 Ω, check for short to ground
3 to gnd	> 1 kΩ	If less than 1 kΩ, check for short to ground

Harness Resistance Checks

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector or relay for the ECM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Turn ignition switch to OFF. Connect Breakout Box to engine X1 harness only. Connect breakout harness to engine harness only.

Test Point	Spec	Comments
X1-6 to 1	< 5 Ω	If greater than 5 Ω, check for open ground circuit
X1-14 to 2	< 5 Ω	If greater than 5 Ω, check for open V_{REF} wire
X2-3 to 3	< 5 Ω	If greater than 5 Ω, check for open signal circuit

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Figure 459 MAP circuit diagram

Operational Voltage Checks - MAP Sensor with Breakout Harness

Check with breakout harness connected to sensor and engine harness.

Test Point	EST voltage readings: Signal to ground	Spec	Checks
3 (Green) to 1 (Black)	0.92 V	0 kPa (0 psi)	Voltage with KOEO. Atmospheric pressure dependent on altitude and BAP pressure.
3 (Green) to 1 (Black)	1.73 V	55 kPa (8 psi)	
3 (Green) to 1 (Black)	2.72 V	129 kPa (18 psi)	
3 (Green) to 1 (Black)	3.71 V	193 kPa (28 psi)	
3 (Green) to 1 (Black)	See appropriate performance specification		Rated speed, full load

“Appendix A: VT 275 Performance Specifications (page 571)”

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Operational Voltage Checks - MAP Sensor with Breakout Box

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector or relay for the ECM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Check with breakout box connected X1 and X2 only to the ECM and engine harness.

Test Point	EST voltage readings: Signal to ground	Spec	Checks
X2-3 to X1-6	0.92 V	0 kPa (psi)	Voltage with KOEO. Atmospheric pressure dependent on altitude and BAP pressure.
X2-3 to X1-6	1.73 V	55 kPa (8 psi)	
X2-3 to X1-6	2.72 V	129 kPa (18 psi)	
X2-3 to X1-6	3.71 V	193 kPa (28 psi)	
X2-3 to X1-6	See appropriate performance specification		Rated speed, full load

“Appendix A: VT 275 Performance Specifications (page 571)”

MAP Diagnostic Trouble Code

DTC 121 = Signal voltage was greater than 4.9 volts for more than 0.4 seconds.

DTC 122 = Signal voltage was less than 0.039 volts for more than 0.4 seconds.

DTC 123 = Detected boost signal voltage was greater than 14 kPa (2.0 psi) at low idle.

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MAT (Manifold Air Temperature) Sensor

Figure 460 Functional diagram for the MAT sensor

The functional diagram for the MAT sensor includes the following:

Manifold Air Temperature (MAT) sensor
Exhaust Gas Recirculation (EGR) valve assembly
Electronic Control Module (ECM)
Amber Lamp (Warn Engine Lamp (WEL) for CF)

Function

The MAT sensor is installed in the left side of the intake manifold. The ECM supplies a 5 volt reference signal that the MAT sensor uses to produce an analog voltage that indicates temperature. The MAT changes resistance when exposed to different temperatures. As air temperature decreases, the resistance of the thermistor increases. This causes the signal voltage to increase. As air temperature increases, the resistance of the thermistor decreases. This causes the signal voltage to decrease.

The MAT sensor provides a feedback signal to the ECM indicating manifold air temperature. During engine operation, if the ECM recognizes that the MAT signal is lower or higher than the expected value it will set a Diagnostic Trouble Code (DTC).

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MAT Circuit Operation

Figure 461 MAT circuit diagram

The MAT sensor is supplied with a 5 volt reference voltage at Pin 2 from ECM Pin X2-14. The sensor is grounded at Pin 1 through the signal ground at ECM Pin X1-6. As the air temperature increases or decreases, the sensor changes resistance and provides the air temperature signal voltage at the ECM. The signal voltage is monitored by the ECM to determine the temperature of the air.

Fault Detection/Management

The ECM continuously monitors the signal of the MAT sensor to determine if the signal is within an expected range. If the ECM detects the signal voltage is higher or lower than expected, the ECM will set a DTC.

MAT DTCs

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

DTC 161
MAT signal out of range low
DTC 161 is set by the ECM when the signal voltage is less than 0.098 volts for more than 0.35 seconds.
DTC 161 can be set due to a short to ground in the signal circuit or a failed MAT sensor.
When DTC 161 is active the amber lamp (WEL for CF) is illuminated.

DTC 162
MAT signal out of range high
DTC 162 is set by ECM when the signal voltage is greater than 4.58 volts for more than 0.35 seconds.
DTC 162 can be set due to an open signal or ground circuit , short to a voltage source, or a failed MAT sensor.
When DTC 162 is active the amber lamp (WEL for CF) is illuminated.

Tools
EST with MasterDiagnostics® software
EZ-Tech® interface cable
Digital Multimeter (DMM)
3-Banana plug harness
500 Ohm resistor harness
Breakout Box
Breakout harness
Terminal Test Adapter Kit

Read all safety instructions in the "Safety Information" section of this manual before doing any procedures.
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MAT Operational Diagnostics

Figure 462 Continuous Monitor session

WARNING: To prevent personal injury, use care to prevent contact with the door edge when the cab is up and the door is open.

1. Select D_ContinuousMonitor.ssn from the Open Session File window, select Open to open the session.

Figure 463 Continuous Monitor test

2. Select Diagnostics from the menu bar.
3. Select Key-On Engine-Off Tests from the drop down menu.
4. From the KOEO Diagnostics menu, select Continuous Monitor and select Run to start the test.

WARNING: To prevent personal injury or death, be careful around rotating parts (belts and fan) and hot engine surfaces.

5. Monitor MAT signal voltage. Verify an active DTC for the MAT circuit.
6. If code is active, do step 8 and 9 to check circuit for the MAT sensor using the following table.

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7. If code is inactive, wiggle connectors and wires at all suspected problem locations. If circuit continuity is interrupted, the EST will display DTCs related to the condition.
8. Disconnect engine harness from temperature sensor.

NOTE: Inspect connectors for damaged pins, corrosion, or loose pins. Repair if necessary.

9. Connect Temperature Sensor Breakout Harness to engine harness only.

Figure 464 Close session

10. When finished with this test, select Session from menu bar, then Close.

Circuit Checks - MAT Sensor

Use EST, breakout harness, and wire harnesses - 3-Banana plug and 500 ohm.

Test Condition	Spec	Checks
Sensor disconnected	> 4.58 V	If voltage less than 4.58 volts, check signal circuit for short to ground.
3-Banana plug harness installed between Pin 2 (GREEN) and Pin 1 (BLACK) pin of breakout harness.	0 V	If voltage is greater than 0.098 volts, check ground and signal circuit for open or high resistance. Use a Breakout Box and measure resistance from PIN 1 to PIN X1-6 and from PIN 2 to X2-14 (specification < 5 Ω).
500 Ohm resistor harness installed between Pin 2 (GREEN) and Pin 1 (BLACK) pin of breakout harness.	< 1.0 V	If voltage greater than 1.0 volts, check signal circuit for short to V_{REF}, B+, or another sensor's signal voltage.

NOTE: Connect engine harness to sensor. Use the EST to clear DTCs. If an active code remains after checking test conditions, replace the MAT sensor.

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MAT Pin-Point Diagnostics

Figure 465 MAT circuit diagram

Voltage Checks - Connector

Turn ignition switch to OFF. Disconnect harness from sensor. Inspect for bent pins or corrosion. Connect breakout harness to engine harness only. Turn ignition switch to ON.

Test Point	Spec	Comments
1 to gnd	0 to 0.25 V	If greater than 0.25 volts, signal wire is shorted to V_{REF} or battery
2 to gnd	4.6 to 5 V	Pull up voltage, if no voltage, circuit has open or high resistance or short to ground

Resistance Checks - Connector to Chassis Ground

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Disconnect negative battery cable. Disconnect harness from sensor. Connect breakout harness to engine harness only. Use disconnected negative battery cable for ground test point.

Test Point	Spec	Comments
1 to gnd	<5 Ω	If greater than 5 Ω, check for open circuit
2 to gnd	>1 kΩ	If less than 1 kΩ, check for shorted signal to ground

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Harness Resistance Checks

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector or relay for the ECM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Turn ignition switch to OFF. Connect breakout box X1 and X2 only to engine harness.

Test Point	Spec	Comments
X1-6 to 1	< 5 Ω	If greater than 5 Ω, check for open ground wire.
X2-14 to 2	< 5 Ω	If greater than 5 Ω, check for open signal wire.

Operational Voltage Checks - MAT Sensor

Turn ignition switch to OFF. Use EST and DMM. Connect Breakout Box ECM and engine harness with MAT sensor connected. Turn ignition switch to ON, do not crank the engine.

Test Point	Temp	Resistance	Voltage
X2-14 to X1-6 (gnd)	-17 °C (0 °F)	230.3 kΩ	4.63 V
X2-14 to X1-6 (gnd)	0 °C (32 °F)	98.2 kΩ	4.39 V
X2-14 to X1-6 (gnd)	20 °C (68 °F)	35.77 kΩ	3.8 V
X2-14 to X1-6 (gnd)	37 °C (100 °F)	17.74 kΩ	3.13 V
X2-14 to X1-6 (gnd)	100 °C (212 °F)	2.2 kΩ	0.9 V

MAT Diagnostic Trouble Code

DTC 161 = Signal voltage was less than 0.098 volts for more than 1.0 seconds

DTC 162 = Signal voltage was greater than 4.58 volts for more than 1.0 seconds

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SCCS (Speed Control Command Switches)

Figure 466 Functional diagram for SCCS

The functional diagram for the SCCS includes the following:

Electronic Control Module (ECM)
Cruise control switches

Cruise Control

The ECM will control engine speed to maintain a constant road speed with cruise control. Activating the CRUISE RPM (Cruise ON OFF) switch when the vehicle is at the desired speed activates the cruise control. Speed is increased or decreased by activating the RESUME (R/A) or SET switches. The cruise control is deactivated by pressing or sliding the CRUISE RPM (Cruise ON OFF) switch, applying the brake pedal, or by placing the transmission in neutral.

Power Takeoff (PTO) Control

Engine speed can be controlled by the SCCS switches if the PTO option has been programmed into the ECM and the vehicle is stationary. Variable as well as preset speeds are available depending on ECM programming. The PTO function is turned on by pressing the CRUISE RPM (Cruise ON OFF) switch. Activating the RESUME (R/A) or SET switches will increase or decrease engine speed depending on PTO programming.

SCCS Circuit Operation

Cruise control allows the ECM to control the engines power delivery to maintain a constant vehicle speed. The speed set point is determined by the operator and the cruise high and low set points are programmed in the ECM. The minimum engine speed that the cruise control can be engaged is programmed in the ECM.

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Figure 467 SCCS circuit diagram (CF)

Figure 468 SCCS circuit diagram (Stripped Chassis)

SCCS circuit operation (CF)

Voltage is supplied to both switches (CRUISE RPM and RESUME+/SET-) from V_{IGN}. When CRUISE RPM (COO) switch is latched B+ is present at X4-6, and the lamp at the top switch is illuminated. When CRUISE RPM switch is not latched 0 volts is present at X4-6.

When RESUME+ (RAS) portion of the RESUME+/SET- switch is depressed, B+ is present at X3-14. When the RESUME+ portion of the RESUME+/SET- switch is not depressed 0 volts is present at X3-14.

When the SET- (SCS) portion of the RESUME+/SET- switch is depressed, B+ is present at X3-21. When the SET- portion of the RESUME+/SET- switch is not depressed 0 volts is present at X3-21.

SCCS circuit operation (Stripped Chassis)

Voltage is supplied to the Cruise ON OFF switch from V_{IGN}. When the Cruise ON OFF (COO) switch is latched B+ is present at X4-6. When Cruise ON OFF switch is not latched 0 volts is present at X4-6.

When R/A (RAS) switch is activated, B+ is present at X3-14 and when the R/A switch is not activated 0 volts is present at X3-14.

When the SET (SCS) switch is depressed, B+ is present at X3-21 and when the SET switch is not depressed 0 volts is present at X3-21.

Tools

EST with MasterDiagnostics® software

EZ-Tech® interface cable

The SCCS circuit requires the use of vehicle circuit diagrams. See the applicable truck *Circuit Diagram Manual* for circuit numbers, connector and fuse locations.

Fault Detection/Management

The ECM monitors the SCCS system for proper voltages and sets DTC 221. If ignition switch is turned off, the fault will be recorded as an inactive fault.

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SCCS DTCs

DTCs are read using the EST or by counting the flashes from the amber and red lamps.

DTC 221

Cruise-PTO control switch circuit fault
DTC 221 is set by the ECM when the signal voltage is less than 0.098 volts for more than 0.35 seconds.
DTC 221 can be set due to a short to ground in the signal circuit or a failed SCCS sensor.
When DTC 221 is active the amber lamp (WEL for CF) is illuminated.

SCCS Pin-Point Diagnostics

Voltage Checks - Breakout Box at ECM

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector or relay for the ECM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Turn ignition switch to OFF. Connect Breakout Box to X3 and X4 to ECM and harness. Turn ignition switch to ON.

Test Point	Spec	Comments
X4-6 to X3-7 (gnd)	Latched = B+ Not latched = 0 V	Latching switch. If less than B+ when latched, check for open or short to ground.
X3-14 to X3-7 (gnd)	Depressed = B+ Not depressed = 0 V	Momentary switch. If less than B+ when depressed, check for open or short to ground.
X3-21 to X3-7 (gnd)	Depressed = B+ Not depressed = 0 V	Momentary switch. If less than B+ when depressed, check for open or short to ground.

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Figure 469 SCCS circuit diagram (CF)

Voltage Checks - CRUISE RPM Switch (CF)

Turn ignition switch to ON.

Test Point	Spec	Comments
4 to gnd	B+	Constant voltage from V_{IGN}. If less than B+, check for open circuits or blown fuse.
3 to gnd	Latched = B+ Not latched = 0 V	Latching switch. If less than B+ when latched and 4 to ground is in specification, check for open, short to ground or failed switch.
2 to gnd	0 to 0.25 V	Constant ground. If less than 0.25 volts, check for open or short to power source.

Voltage Checks - RESUME/SET Switch (CF)

Turn ignition switch to ON.

Test Point	Spec	Comments
D to gnd	B+	Constant voltage from V_{IGN}. If less than B+, check for open circuits or blown fuse.
B to gnd	Depressed = B+ Not depressed = 0 V	Momentary switch. If less than B+ when depressed and D to ground is in specification, check for open, short to ground, or failed switch.
H to gnd	Depressed = B+ Not depressed = 0 V	Momentary switch. If less than B+ when depressed and D to ground is in specification, check for open, short to ground, or failed switch.

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Figure 470 SCCS circuit diagram (Stripped Chassis)

Voltage Checks - CRUISE ON OFF Switch (Stripped Chassis)

Turn ignition switch to ON.

Test Point	Spec	Comments
A to gnd	B+	Constant voltage from V_{IGN}. If less than B+, check for open circuits or blown fuse.
B to gnd	Latched = B+ Not latched = 0 V	Latching switch. If less than B+ when latched and A to ground is in specification, check for open, short to ground or failed switch.

Voltage Checks - R/A and Set Switches (Stripped Chassis)

Turn ignition switch to ON. Turn Cruise ON OFF switch ON.

Test Point	Spec	Comments
B to gnd	B+	Constant voltage from V_{IGN}. If less than B+, check for high resistance or open circuit, open Cruise ON OFF switch, or blown fuse.
D to gnd	Depressed = B+ Not depressed = 0 V	Momentary switch. If less than B+ when depressed and B to ground is in specification, check for open, short to ground, or failed switch.
C to gnd	Depressed = B+ Not depressed = 0 V	Momentary switch. If less than B+ when depressed and B to ground is in specification, check for open, short to ground, or failed switch.

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Resistance Checks - Chassis Ground

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector or relay for the ECM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Turn ignition switch to OFF. Connect Breakout Box X3 and X4 to harness only. CRUISE RPM (Cruise ON OFF) switch is not latched.

Test Point	Spec	Comments
X4-6 to gnd	> 1 kΩ	If less than 1 kΩ, check for short to ground
X3-14 to gnd	> 1 kΩ	If less than 1 kΩ, check for short to ground
X3-21 to gnd	> 1 kΩ	If less than 1 kΩ, check for short to ground

Harness Resistance Checks - ECM to CRUISE RPM (Cruise ON OFF) Switch

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector or relay for the ECM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Turn ignition switch to OFF. Connect breakout box X4 to harness only.

Test Point	Spec	Comments
X4-6 to: 3 (CF) or B (Stripped Chassis)	< 5 Ω	If greater than 5 Ω, check for open circuit.

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Harness Resistance Checks - ECM to RESUME/SET Switch or R/A and Set Switches

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector or relay for the ECM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Turn ignition switch to OFF. Connect breakout box X4 to harness only.

Test Point	Spec	Comments
X3-14 to: H (CF) or C (Stripped Chassis)	< 5 Ω	If greater than 5 Ω, check for open circuit.
X3-21 to: B (CF) or D (Stripped Chassis)	< 5 Ω	If greater than 5 Ω, check for open circuit.

Harness Resistance Checks - V_{IGN} to Switches

Turn ignition switch to OFF. Pull fuses.

Test Point	Spec	Comments
Fuse to: 4 (CF) or A (Stripped Chassis)	< 5 Ω	If greater than 5 Ω, check for open circuit.
Fuse to D (CF)	< 5 Ω	If greater than 5 Ω, check for open circuit.

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Tachometer Output Circuit

Figure 471 Functional diagram for the tachometer output circuit

The functional diagram for the tachometer output circuit consists of the following:

Remote tachometer
Electronic Control Module (ECM)
Camshaft Position (CMP) sensor
Crankshaft Position (CKP) sensor

The ECM provides output for a remote tachometer with a 0 to 12 volt digital signal that indicates engine speed. The frequency sent by the ECM is 1/5th of the actual engine rpm (12 pulses per engine revolution).

Tachometer Input Signal

The ECM receives a signal from the CMP sensor and calculates engine speed (rpm). The ECM sends the calculated engine speed as a digital buffered TACH signal from the ECM connector to the owner installed tachometer.

Tachometer DTCs

DTCs are not available for communication between the ECM and the remote tachometer.

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Tachometer Pin-Point Diagnostics

Figure 472 Tachometer circuit diagram

Voltage Checks - ECM (KOEO)

Turn ignition switch to OFF. Connect Breakout Box. Turn ignition switch to ON, do not crank the engine.

Test Point	Spec	Signal	Comments
X3-11 to X3-7	12 ± 1.5 V	TACH	The signal is pulled up by the ECM with ignition switch on and the engine off.

Voltage Checks - ECM Connector to Ground (KOEO)

Turn ignition switch to OFF. Connect Breakout Box. Turn ignition switch to ON, do not crank the engine.

Test Point	Spec	Signal	Comments
X3-11 to X3-7	> 1 kΩ	TACH	If less than 1 kΩ, check for short to ground either through the harness or internal ECM. Disconnect the ECM from the Breakout Box and measure to ground again. If short is still present, repair harness.

Harness Resistance Checks (KOEO)

Turn ignition switch to OFF. Connect Breakout Box. Turn ignition switch to ON, do not crank the engine.

Test Point	Spec	Signal	Comments
X3-11 to tach	<5 Ω	TACH	Resistance from ECM connector to TACH input - Optional owner/operator tachometer.

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Signal Checks - Tach (Engine Running)

Turn ignition switch to OFF. Connect Breakout Box. Turn ignition switch to ON, start engine.			
Test Point	**Spec**	**Signal**	**Comments**
X3-11 to X3-7	140-700 Hz		Tach signal from the ECM is a frequency that is engine rpm ÷ 5.

NOTE: The instrument cluster tachometer does not use these outputs. See the applicable truck *Service Manual*.

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V_{REF} (Reference Voltage)

Figure 473 Functional diagram for the V_{REF}

The functional diagram for the V_{REF} includes the following:
Manifold Absolute Pressure (MAP) sensor
Injection Control Pressure (ICP) sensor
Barometric Absolute Pressure (BAP) sensor
Accelerator Position Sensor and Idle Validation Switch (APS/IVS)
Electronic Control Module (ECM)

Function

The ECM contains a regulated 5 volt DC reference source to power engine and vehicle sensors. The signals are compared to the V_{REF} to determine actual output signal values. These values are processed by the ECM for engine operation.

The system has two V_{REF} circuits:

- V_{REF}A for engine sensors
- V_{REF}B for chassis sensors

NOTE: See the applicable truck *Circuit Diagram Manual* for APS, and BAP sensor circuit diagrams.

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V_{REF} Circuit Operation

Figure 474 V_{REF} circuit diagram

The ECM supplies V_{REF} when ignition switch is on at Pins X1-14 (engine connector) and X4-4 (chassis connector).

Fault Detection/Management

There are no DTCs for V_{REF}circuit. If a V_{REF} circuit fault such as an open, a short to ground, or a short to power (above 5 volts) occurs, multiple DTCs are set for each sensor not getting the correct V_{REF} value. If a circuit fault such as an open or a short to power on signal ground occurs, multiple DTCs are set for each sensor not getting the correct ground. One sensor having an internal short (V_{REF} shorted to signal ground could cause this condition). The sensors affected is dependent upon where the open or short is located.

When the ECM sets multiple sensor DTCs, the V_{REF} circuit is open or shorted, or the signal ground circuit is open. To determine if the V_{REF} circuits are the cause, complete the pin-point diagnostics check.

Tools
EST with MasterDiagnostics® software
EZ-Tech® interface cable
Digital Multimeter (DMM)
Breakout harnesses
Breakout Box
Terminal Test Adapter Kit

NOTE: After removing connector, inspect for damaged pins, corrosion, or loose terminals. Repair as required.

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V_{REF} Pin-Point Diagnostics

Figure 475 V_{REF} circuit diagram

Voltage Checks - Connector

If multiple DTCs are set, remove harness connections. Connect breakout harness. Turn ignition switch to ON, do not crank the engine. Measure V_{REF} at suspected sensor circuits.

Sensor	Test Point	Spec	Comments
MAP	2 to gnd	5 ± 0.5 V	Check V_{REF} at each sensor. To isolate area of short or open circuit, identify sensors without V_{REF} and sensors that share a common V_{REF}. If disconnecting a sensor causes V_{REF} to be present in the circuit that had no previous V_{REF}, it is likely that the disconnected sensor had shorted V_{REF} to ground.
ICP	2 to gnd	5 ± 0.5 V	
APS/IVS	(C for CF or D for stripped chassis) to gnd	5 ± 0.5 V	
BAP	2 to gnd	5 ± 0.5 V	

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Resistance Checks - Connector to Chassis Ground

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Disconnect harness from sensors using V_{REF}. Disconnect negative battery cable.

Sensor	Test Point	Spec	Comments
MAP	2 to gnd	> 500 Ω	If resistance is less than specification, check for short to ground. If a short to ground condition exists, remove all sensor connectors that are connected to V_{REF} and ECM. Inspect to determine if short is in sensor, ECM, or wiring harness. Specification is > 1 kΩ with all common sensors disconnected from harness.
ICP	2 to gnd	> 500 Ω	
APS/IVS	(C for CF or D for stripped chassis) to gnd	> 1 kΩ	
BAP	2 to gnd	> 1 kΩ	

Harness Resistance Checks - V_{REF} to ECM

Turn ignition switch and all accessories to OFF. Disconnect harness from sensors using V_{REF}. Connect breakout harness to harness only. Connect Breakout Box to harness only.

Sensor	Test Point	Spec	Comments
MAP	2 to X1-14	< 5 Ω	Measure resistance with DMM from sensor connector to ECM 24-pin connectors. If resistance is greater than 5 Ω, check for high resistance or an open in the V_{REF} supply circuit.
ICP	2 to X1-14	< 5 Ω	
APS/IVS	(C for CF or D for stripped chassis) to X4-4	< 5 Ω	
BAP	2 to X4-4	< 5 Ω	

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Figure 476 V_{REF} circuit diagram

Harness Resistance Checks - Signal Ground to ECM

CAUTION: To prevent engine damage, turn ignition switch to OFF before unplugging the connector or relay for the ECM. Failure to turn ignition switch to OFF will cause a voltage spike and damage to electrical components.

Turn ignition switch and all accessories to OFF. Disconnect harness from sensors using V_{REF}. Connect breakout harness to harness only. Connect Breakout Box to engine harness only.

Sensor	Test Point	Spec	Comments
MAP	1 to X1-6	< 5 Ω	Measure resistance with DMM from sensor connector to ECM 24-pin connectors. If resistance is greater than 5 Ω, check for loose connection or open in signal ground circuit.
ICP	1 to X1-6	< 5 Ω	
APS/IVS	(B for CF or K for stripped chassis) to X4-24	< 5 Ω	
BAP	1 to X4-24	< 5 Ω	

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WIF (Water In Fuel) Sensor

Figure 477 Functional diagram for the WIF

The functional diagram for the WIF includes the following:
Water In Fuel (WIF) sensor
Electronic Control Module (ECM)
Amber lamp (Water In Fuel (WIF) for CF)
CAN1

Function

The WIF sensor is used to detect water in the fuel system and is located in the Horizontal Fuel Conditioning Module (HFCM). The WIF sensor is monitored by the ECM. If the ECM detects water for more than 5 seconds, the ECM will send a CAN1 message to the instrument panel turning on the WIF indicator lamp. To drain the HFCM water separator See “Drain Water from HFCM (page 116)” in the “Engine Symptoms Diagnostics (page 99)” section of this manual.

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WIF Circuit Operation

Figure 478 WIF circuit diagram

V_{IGN} is supplied to Pin 2. If water is present in fuel, the water completes the circuit between the two probes on the sensor. This provides voltage to Pin 1 which the ECM monitors at Pin X3-1.

Fault Detection/Management

There are no specific Diagnostic Trouble Codes (DTCs) related to the wiring or Output Circuit Check (OCC) for the WIF.

WIF DTCs

None active

The WIF circuit requires the use of vehicle circuit diagrams. See the applicable truck *Circuit Diagram Manual* for circuit numbers, connector and fuse locations.

Tools

EST with MasterDiagnostics® software
EZ-Tech® interface cable

WIF Operational Diagnostics

Figure 479 Road performance session

1. Select D_RoadPerformance_V6.ssn from the Open Session File window, select Open to monitor engine operation.

WARNING: To prevent personal injury, keep away from the door edge when cab is up and the door is open.

2. Monitor WIF Parameter Identifier (PID) (YES/NO).

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NOTE: The WIF PID will read YES if there is water in the fuel filter housing (HFCM) or if the WIF signal circuit is shorted high.

3. If PID is reading YES and there is no water in the fuel filter housing (HFCM), complete with next step and do circuit check for the WIF sensor in the following tables.
4. If the WIF lamp comes on intermittently, wiggle connectors and wires at all suspected problem locations while looking at PID.

NOTE: After removing connector, inspect for damaged pins, corrosion, or loose terminals. Repair as required.

Voltage Checks - WIF

Follow test is order. Check with WIF sensor disconnected, ignition switch to ON, and the engine off.

Test Point	Spec	Comments
1 to gnd	< 0.5 V	If voltage is present, check WIF circuits for short to power.
2 to gnd	B+	If voltage is below specification, check for an open in the V_{IGN} circuit.

WIF Pin-Point Diagnostics

Harness Resistance Checks - Sensor to Ground

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Disconnect harness from sensor. Disconnect negative battery cable.

Test Point	Spec	Comments
1 to gnd	> 1 kΩ	If less than 1 kΩ, check for short to ground
2 to gnd	> 1 kΩ	If less than 1 kΩ, check for short to ground

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Harness Resistance Checks

WARNING: To prevent personal injury or death, always disconnect main negative battery cable first. Always connect the main negative battery cable last.

Turn ignition switch to OFF. Disconnect negative battery cable and sensor. Connect Breakout Box X3 to chassis harness only.

Test Point	Spec	Comments
X3-1 to 1	< 5 Ω	If greater than 5 Ω, check for open circuit.
X3-1 to gnd	> 1 kΩ	If less than 1 kΩ, check for short to ground.

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Table of Contents

Tools and Accessories....533
EZ-Tech® Electronic Service Tool (EST)....533
EZ-Tech® Interface Kit....533
MasterDiagnostics® Software....533
Digital Multimeter (Fluke 88™)....534
Amp Clamp....534
96-Pin Breakout Box - DLC II....535
Breakout Harness Kit....535
3-Banana Plug Harness....536
12-Pin Breakout Harness....536
500-Ohm Resistor Harness....536
Actuator Breakout Harness....536
APS/IVS Sensor Breakout Harness....537
Pressure Sensor Breakout Harness....537
Relay Breakout Harness....537
Relay Breakout Harness....537
Temperature Sensor Breakout Harness....538
MAF/IAT Sensor Breakout Harness....538
EGR Valve Breakout harness....538
Terminal Test Adapter Kit....539
Gauge Bar Tool....539
Fuel Pressure Gauge....540
Slack Tube Manometer....540
Fuel/Oil Pressure Test Coupler....541
Fuel Pressure Test Fitting....541
ICP System Test Adapter....541
ICP Adapter/Plug Kit....542
Case-To-Head Tube Removal Tool....542
Intake Manifold Pressure Test Plug (EGR Valve)....542
EGR Cooler Test Plates....542
Fuel Inlet Restriction Adapter....543
Fuel Line Test Adapter....543
Fuel Pressure Test Adapter....543
In-line Shutoff Valve....543
Vacuum Pump and Gauge....544
Crankcase Pressure Test Adapter....544
Oil Fill Extension....545
Cylinder Compression Gauge....545
Compression Test Adapter....545

Electronic Circuit Testing....546
Electrical Theory....546
Voltage....546
Ohm's Law....546
Using the Digital MultiMeter....547
Test Meters....547

Read all safety instructions in the "Safety Information" section of this manual before doing any procedures.
Follow all warnings, cautions, and notes.
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Jumper Wires.....548
Voltmeter.....548
Ammeter.....550
Ohmmeter.....551
Troubleshooting.....553

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Tools and Accessories

EZ-Tech® Electronic Service Tool (EST)

Figure 480 J-45067

The Electronic Service Tool (EST) is used to run MasterDiagnostics® software for diagnosing and troubleshooting engine and vehicle problems.

EZ-Tech® Interface Kit

Figure 481 ZTSE4632

These interface cables, included with the EZ-Tech®, connect the Electronic Service Tool (EST) to Electronic Control Module (ECM).

MasterDiagnostics® Software

MasterDiagnostics® software, loaded to an EST or laptop computer, is used to check performance of engine systems, diagnose engine problems, and store troubleshooting history for an engine.

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Digital Multimeter (Fluke 88™)

Figure 482 ZTSE4357

The Fluke 88™ Digital Multimeter (DMM) is used to troubleshoot electrical components, sensors, injector solenoids, relays, and wiring harnesses. The DMM has a high input impedance that allows testing of sensors while the engine is running, without loading the circuit being tested. This ensures that the signal voltage measurement will not be affected by the voltmeter.

Amp Clamp

Figure 483 ZTSE4575

The Amp Clamp is to measure amperage draw for the glow plug and inlet air heater systems.

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96-Pin Breakout Box - DLC II

Figure 484 ZTSE4582A

The Breakout Box allows testing of the electronic control system components without disturbing connections or piercing wire insulation to access various signal voltages in the electronic control system.

CAUTION: The Breakout Box is used for measurement only, not to activate or control circuits. High current passing through the breakout box will burn out the internal circuitry.

Breakout Harness Kit

Figure 485 ZTSE4505D

The Breakout Harness Kit contains the following breakout harnesses and test leads:

3-Banana Plug Harness
12-Pin Breakout Harness
500 Ohm Resistor Harness
Actuator Breakout Harness
APS/IVS Breakout Harness
Pressure Sensor Breakout Harness
Relay Breakout Harness - IDM
Relay Breakout Harness - ECM
Temperature Sensor Breakout Harness
MAF/IAT Sensor Breakout Harness
EGR Valve Breakout Harness

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3-Banana Plug Harness

Figure 486 ZTSE4498

The 3-Banana Plug Harness is used for operational diagnostics of sensor circuits.

12-Pin Breakout Harness

Figure 487 ZTSE4665

The 12-Pin Breakout Harness is used for circuit diagnostics for the Injector Drive Module (IDM) powers and ground, actuator power and ground in addition to sensor and ATA data link circuits.

500-Ohm Resistor Harness

Figure 488 ZTSE4497

The 500-Ohm Resistor Harness is used for operational diagnostics of sensor circuits and Output State Tests for actuator control circuits.

Actuator Breakout Harness

Figure 489 ZTSE4484

The Actuator Breakout Harness is used to measure the voltage supplied to the Injection Pressure Regulator (IPR).

For electrical circuit diagnostics, install the breakout harness between the electrical harness and the valve. For Injection Control Pressure (ICP) system diagnostics, plug the Actuator Breakout Harness into the IPR valve only.

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APS/IVS Sensor Breakout Harness

Figure 490 ZTSE4485 (CF)

The Accelerator Pedal Position Sensor (APS) / Idle Validation Switch (IVS) harness is used to measure V_{REF}, APS signal, signal ground, IVS signal, and IVS power at the APS/IVS sensor.

NOTE: At the time of publication APS/IVS harness (stripped chassis) is under development.

Pressure Sensor Breakout Harness

Figure 491 ZTSE4347

The Pressure Sensor Breakout Harness is used to access V_{REF}, signal ground, and signal voltage circuits for the following sensors:

- Manifold Absolute Pressure (MAP)
- Injection Control Pressure (ICP)

Relay Breakout Harness

Figure 492 ZTSE4596 (CF)

The Relay Breakout Harness is used to measure power from the IDM main power relay to check the operation of the relay in the circuit.

NOTE: At the time of publication Relay breakout harness (stripped chassis) is under development.

Relay Breakout Harness

Figure 493 ZTSE4693

The Relay Breakout Harness is used to measure power from the ECM main power relay to check the operation of the relay in the circuit. Also, the fuel pump control relay and A/C clutch relay.

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Temperature Sensor Breakout Harness

Figure 494 ZTSE4602

The Temperature Sensor Breakout Harness enables the technician to quickly connect a voltmeter and read voltage signals for the following sensors:

- Engine Coolant Temperature (ECT)
- Engine Oil Temperature (EOT)
- Manifold Absolute Temperature (MAT)

MAF/IAT Sensor Breakout Harness

Figure 495 ZTSE4695

The MAF/IAT Sensor Breakout Harness is used to access power, ground and signal circuits for the MAF sensor. The MAF/IAT Sensor Breakout Harness is also used to access voltage signals for the IAT Sensor.

EGR Valve Breakout harness

Figure 496 ZTSE4664

The EGR Valve Breakout Harness is primarily used to pin out the harness to look for opens and shorts. The EGR Breakout Harness is also used to access supply voltage and ground to the EGR valve, as well as to monitor drive signals and position sensor signals.

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Terminal Test Adapter Kit

Figure 497 ZTSE4435B

The Terminal Test Adapter Kit is used to access circuits in the connector harness and allows for the use of a DMM without damaging the harness connectors. The probes may also be used as a guide to determine if the harness connector is retaining correct tension on the mating terminal.

Gauge Bar Tool

Figure 498 ZTSE4409

The Gauge Bar Tool is used to measure intake manifold (boost) pressure, fuel system inlet restriction, fuel pressure, oil pressure, air cleaner intake restriction, and crankcase pressure.

0-200 kPa (0-30 psi) measures intake manifold pressure. The pump and gauge are used to pressurize the pneumatic actuator for the turbocharger bypass valve.

60-1100 kPa (0-160 psi) gauge may be used to check the fuel pressure and oil pressure.

0-30 in Hg vacuum /0-200 kPa (0-30 psi) compound gauge measures fuel system inlet restriction and intake manifold pressure.

0-30 in H_2O 0-7.5 kPa (0-1 psi maximum pressure magnehelic gauge measures crankcase pressure and air inlet restriction.

0-200 kPa (0-30 psi) gauge with a built in regulator may be used to check the movement of pneumatic actuator for turbocharger bypass valve.

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Fuel Pressure Gauge

Figure 499 ZTSE4681

1. Test fitting connection (Adapt to the ICP system test adapter.)
2. Pressure test line
3. Pressure Gauge (can adapt gauge bar tool)
4. In-line shut off valve
5. Clear sample line

The Fuel Pressure Gauge is used to measure fuel pressure, take a fuel sample, and check for aerated fuel.

If a second gauge was purchased, it should be dedicated to measure oil pressure, take an oil sample or check for oil aeration.

Slack Tube Manometer

Figure 500 ZTSE 2217A

The Slack Tube Manometer is a U-shaped tube with a scale mounted between the legs of the tube. When the portability of the gauge bar tool is not required, this manometer is used to measure low vacuum for intake restriction or low pressure for crankcase or exhaust back pressure.

Filling

Fill the manometer with water before checking pressure. Use only drinking water without additives. Add some colored water vegetable dye so the scale can be read more easily. With both legs of the manometer open to the atmosphere, fill the tube until the top of the fluid column is near the zero mark on the scale. Shake the tube to eliminate any air bubbles.

Installing, Reading, and Cleaning

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1. Support the manometer vertically. Make sure the fluid level is in line with the zero indicator on the graduated scale.
2. Connect one leg of the manometer to the source of the pressure or vacuum. Leave the other leg open to atmospheric pressure.
3. Start the engine and allow it to reach normal operating temperature. Then run the engine to high idle. The manometer can be read after 10 seconds.
4. Record the average position of the fluid level when it is above and below the zero indicator. Add the two figures together. The sum of the two is the total column of fluid (distance A). This represents the crankcase pressure in inches of water (in H_2O).

   At times, both columns of the manometer will not travel the same distance. This is no concern if the leg not connected to the pressure or vacuum source is open to the atmosphere.
5. Compare the manometer reading with engine specifications.
6. When test is done, clean the tube thoroughly using pure soap and water. Avoid liquid soaps and solvents.

Fuel/Oil Pressure Test Coupler

Figure 501 ZTSE4526

The Fuel/Oil Pressure Test Coupler is used with the test line from the Gauge Bar Tool for an easy connection to the Fuel Pressure Test Fitting to check oil pressure.

The Fuel/Oil Pressure Test Coupler was sent with VT 365 essential tools.

Fuel Pressure Test Fitting

Figure 502 ZTSE4542

The Fuel Pressure Test Fitting (installed in the EOP switch port) is used to measure oil pressure.

The Fuel Pressure Test Fitting was sent with VT 365 essential tools.

ICP System Test Adapter

Figure 503 ZTSE4594

The ICP System Test Adapter is used to pressurize the ICP system to test ICP system integrity with the

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influence of the IPR valve. This adapter is also used to measure fuel pressure at the fuel pressure test port in the secondary fuel filter housing.

The ICP System Test Adapter was sent with VT 365 essential tools.

ICP Adapter/Plug Kit

Figure 504 ZTSE4690

1. ICP Sensor Adapter (Threaded hex head)
2. ICP Leak Test Plug (Solid hex head)

This ICP Adapter/Plug Kit is used to check for ICP system leaks.

Case-To-Head Tube Removal Tool

Figure 505 ZTSE4694

The Case-To-Head Plug Removal Tool is used to remove Case-To-Head tubes from the engine.

Intake Manifold Pressure Test Plug (EGR Valve)

Figure 506 ZTSE4544

The Intake Manifold Pressure Test Plug (EGR Valve) is used to isolate the EGR valve during EGR cooler testing.

EGR Cooler Test Plates

Figure 507 ZTSE4545

The EGR cooler test plates supply air pressure to the EGR cooler for testing

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Fuel Inlet Restriction Adapter

Figure 508 ZTSE4698

The Fuel Inlet Restriction Adapter is used to measure fuel inlet restriction. Install in place of the fuel drain plug on the Horizontal Fuel Conditioning Module (HFCM). This must be used with in-line shutoff valve (221406) that is included in the ZTSE4409 Pressure Test Kit (gauge bar).

Fuel Line Test Adapter

Figure 509 ZTSE4607

The fuel line test adapter is used to pressurize the fuel supply to the cylinder head to check for leaks.

Fuel Pressure Test Adapter

Figure 510 ZTSE4696

The Fuel Pressure Test Adapter is used to check the fuel output from the HFCM secondary fuel filter.

In-line Shutoff Valve

Figure 511 Part No. 221406

The In-line Shutoff Valve is used to make a test hose assembly that connects to the lube oil system or fuel supply system to check for oil or fuel.

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Vacuum Pump and Gauge

Figure 512 ZTSE2499

The Vacuum Pump and Gauge is used to test the integrity of the control lines. Adapters in this kit are used to pressurize the pneumatic actuator with the gauge bar.

Crankcase Pressure Test Adapter

Figure 513 ZTSE4510

The Crankcase Pressure Test Adapter is used for two tests.

- To measure combustion gas flow from the engine breather

  The Crankcase Pressure Test Adapter is used with the magnehelic gauge or slack tube manometer for pressure readings.

  Pressure readings taken using the Crankcase Pressure Test Adapter, must be used as the main source of engine condition indication. If the pressure readings are over the specified limits, oil consumption trend data must also be used to establish a specific problem. Using just the changes in oil consumption trends or crankcase diagnostic pressure trends cannot establish a specific problem. Each of these changes only indicate a problem.

- To check for ICP leaks

  The Crankcase Pressure Test Adapter is used to magnify the sound of air flowing through the crankcase.

The Crankcase Pressure Test Adapter was sent with VT 365 essential tools.

NOTE: The Crankcase Pressure Test Adapter is designed to create a seal with an Oil Fill Extension. If the engine does not have an Oil Fill Extension, one will have to be acquired. The valve cover does not have enough thread engagement. The Oil Fill Extension is not supplied as part of a tool kit.

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Oil Fill Extension

Figure 514 Part No. 1830971C91

The Oil Fill Extension is used with the Crankcase Pressure Test Adapter to measure combustion gas flow from the engine breather or check for ICP leaks.

NOTE: The mechanic is expected to keep the Oil Fill Extension for future diagnostics. Expense the Oil Fill Extension as an essential tool and keep it with the other diagnostic tools. Warranty will not cover the cost of the Oil Fill Extension. If replacing the O-ring, order replacement O-ring for ZTSE4510 from SPX. It is Viton and will not swell.

Cylinder Compression Gauge

Figure 515 ZTSE2482A

The Cylinder Compression Gauge is used measure cylinder pressure (compression)

Compression Test Adapter

Figure 516 ZTSE4506

The Compression Test Adapter is used with a compression gauge to measure the cylinder pressure (compression). Install it in place of the glow plug.

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Electronic Circuit Testing

Electrical Theory

Voltage

Voltage is electrical pressure or force that pushes current through a circuit. The pressure is measured in volts. The symbol V (for example, 12V) is used in circuit diagrams to denote voltage. The letter E (Electromotive force) is also used for voltage. Voltage can be compared to the pressure necessary to push water through a metering valve.

Low voltage to a lamp will cause the lamp to glow dimly. This can be caused by low source voltage (discharged battery or low alternator output) or by high circuit resistance resulting from a poor connection. Resistance from a poor connection or poor ground is an additional load in the circuit. The additional load reduces voltage available to push current through the load device. Before making any meter measurements, review Ohm's Law.

Ohm's Law

Ohm's Law describes the relationship between current, voltage, and resistance in an electrical circuit. Ohm's Law also provides the basic formula for calculations.

Figure 517 Ohm's Law

Memorize the formula in the circle. Cover the letter with a finger for the desired formula. For example, I is covered, the formula is I = E ÷ R.

If two values are known for a given circuit, the missing one can be found by substituting the values in amperes, volts, or ohms.

The three basic formulas for Ohm's Law are as follows:
I = Current (amperes)
E = Voltage (volts)
R = Resistance (ohms)

- I = E ÷ R

  This formula states that the current flow (I) in the circuit equals the voltage (E) applied to the circuit divided by the total resistance (R) in the circuit. This shows that an increase in voltage or a decrease in resistance increases the current flow.

- E = I × R

  This formula states that the voltage (E) applied to the circuit equals the current flow (I) in the circuit multiplied by the total resistance (R) in the circuit. The voltage drop is caused by resistance across a particular load device in a series of load devices.

- R = E ÷ I

  This formula states that the total resistance (R) in the circuit equals the voltage (E) applied to the circuit divided by the current flow (I) in the circuit. Resistance can be calculated for a specific current flow when a specific voltage is applied.

Figure 518 Simple Electrical Circuit

In a typical circuit, battery voltage is applied to a bulb through a 10 amp fuse and a switch. Closing the switch turns on the bulb.

To find the current flow, use the formula I = E ÷ R:

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Fill in the numbers for the formula:

I = 12V ÷ 2 ohms

I = 6 amps

The bulb in this circuit operates at 6 amps and is rated at 6 amps. With 12 volts applied, the bulb will glow at the rated output level (candlepower rating). However,

- If the voltage applied is low (low battery), the value of E is lower, current flow will be less, and the bulb will glow less brightly.
- If connections are loose or the switch is corroded, the circuit resistance will be greater (value of R will be larger), the current flow will be reduced, and the bulb will glow less brightly.

Voltage drops are important for the following reasons:

- High voltage drops indicate excessive resistance. For example, if a blower motor runs too slowly or a light glows too dimly, the circuit may have excessive resistance. Voltage drop readings can isolate problems in parts of a circuit (corroded or loose terminals, for example).
- Too low of a voltage drop indicates low resistance. For example, if a blower motor runs too fast, the problem could be low resistance in a resistor pack.
- Maximum allowable voltage drop under load is critical, especially for more than one high resistance problem. All voltage drops in a circuit are cumulative. Corroded terminals, loose connections, damaged wires or other similar conditions create undesirable voltage drops that decrease the voltage available across the key components in the circuit. Increased resistance will decrease current flow in the circuit, preventing other components from operating at peak efficiency. A small drop across wires (conductors), connectors, switches, etc., is normal because all conductors have some resistance, but the total should be less than 10% of the total voltage drop in the circuit.

Using the Digital MultiMeter

The following electrical test equipment should be available for testing electronic circuits:

Voltmeter

Ohmmeter

Ammeter

Jumper wires

Test lights

Test Meters

Figure 519 Typical Test Meters

All test meters come in a variety of models. Any working model will be adequate for simple tests. However, accurate readings are important. Make sure the test meter is of high quality. The Fluke 88™ Digital Multimeter is recommended because it has very little current and a high impedance (resistance) of 10 megaohms (10 MΩ).

CAUTION: Only use a high impedance digital multimeter when troubleshooting electronic circuits. Do not use a battery powered test light which can cause a current spike and damage electronic circuits.

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NOTE: Some devices in an electronic control system are not capable of carrying an appreciable amount of current. Therefore, test equipment must be designed to not damage any part the electronic control system. Do not use analog meters unless specified. Analog meters use too much current to test an electronic control system.

Jumper Wires

Figure 520 Jumper Wires

Jumper wires allow a circuit to by-pass a suspected opening or break in a circuit. Use a jumper wire to check for open relay contacts, wire breaks and poor ground connections. Several jumper wires with different tips should be available.

Figure 521 Troubleshooting with Jumper Wires

If the circuit works correctly with the jumper wire in place, but does not work when the jumper wire is removed, the circuit is open.

A circuit with no openings or breaks has continuity (uninterrupted current flow) and needs no further testing.

An opening in the ground circuit exists for the following:

- A switch is closed but the light does not illuminate.
- Jumping the switch does not illuminate the light.
- Jumping the light to the ground causes the light to illuminate.

Voltmeter

Use a voltmeter to answer the following questions:

- Does the circuit have voltage?
- What is the voltage reading?
- What is the voltage drop across a load device?

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Figure 522 Checking Power to a Load Device

Figure 523 Checking Power to a Connector

To check for voltage to a load device, connect the positive meter lead to the input connection of the device (positive side) and connect the negative meter lead to a good vehicle ground.

Voltage to a device can also be measured by disconnecting the harness connector and using the correct tool in the Terminal Test Adapter Kit.

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Figure 524 Checking Voltage Drop

To check the voltage drop across a load device, connect the positive lead of the voltmeter to the positive side of the device and the negative meter lead to the negative side of the device.

With the device operating, this will measure the voltage drop across the device. With only one device, all of the voltage should be dropped at the device. In any circuit, the voltage applied will equal the voltage dropped in the circuit. If this circuit only dropped 9V across the load, it indicates the wires and connections dropped 3V, indicating excessive circuit resistance.

Ammeter

An ammeter measures current flow (amperage) in a circuit. Amperes (or amps) are units of electron flow that indicate how many electrons are passing through the circuit. An amp is the unit of measurement for the current flow in the circuit.

Ohm's Law states that the current flow is equal to the circuit voltage divided by the total circuit resistance (I = E ÷ R). Therefore, increasing the voltage also increases the current flow. Any decrease in resistance will also increase the current flow.

At normal operating voltage, most circuits have a characteristic amount of current flow (current draw). Current draw can be measured with an ammeter. Valuable diagnostic information can be provided by referring to a specified current draw rating for a component (electrical device), measuring the current flow in the circuit, and then comparing the two measurements (rating vs. actual measurement).

Figure 525 Installing the Ammeter

An ammeter is connected in series with the load, switches, resistors, etc., so that all of the current flows through the meter. The ammeter measures

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current flow only when the circuit is powered up and operating. The DMM is fused to measure up to 10 amps using the 10A connection point.

Before measuring current flow, determine approximately how many amps are in the circuit to correctly connect the ammeter. The estimate of current flow can easily be calculated. The resistance of the light bulb is 2 ohms. Applying Ohm's law, current flow will be 6 amps (6 amps = 12V ÷ 2 ohms). If the fuse is removed and an ammeter is installed with the switch closed, 6 amps of current will be measured flowing in the circuit. Notice that the ammeter is installed in series so that all the current in the circuit flows through it.

WARNING: To prevent personal injury or death, always make sure the power is off before cutting, soldering, removing circuit components or before inserting the digital multimeter for current measurements. Small amounts of current can be dangerous.

Excessive current draw means that more current is flowing in a circuit than the fuse and circuit were designed to handle. Excessive current draw will open fuses and circuit breakers, and will also quickly discharge batteries. An ammeter can diagnose these conditions.

Reduced current draw will cause a device (an electric window motor, for example) to operate poorly. Increased circuit resistance will cause lower current flow (often due to loose or corroded connections).

Ohmmeter

CAUTION: To prevent damage to the test meter, only use the ohmmeter on circuits when the power is OFF. Power from 12-volt systems may damage the meter.

The ohmmeter measures resistance (ohms) in a circuit. Ohmmeters use a small battery to supply voltage and current flow through the circuit being tested. Based on Ohm's Law, the ohmmeter calculates resistance in the circuit by measuring the voltage of the meter battery and the amount of current flow in the circuit. With the DMM, range selection and meter adjustment are not necessary.

Figure 526 Measuring Resistance

Resistance measurements are used to determine the resistance of a load or conductors, the value of resistors and the operation of variable resistors.

To measure the resistance of a component or a circuit, remove power from the circuit. Isolate the component or circuit from other components and circuits so that the meter current (from probe to probe) only flows through the selected component or circuit. When measuring the resistance of the load, most of the current flow from the meter will go through the indicator lamp because it has less resistance.

Remove one connector to the load. It is not always apparent when a component must be isolated, so it is a good practice to isolate a component or circuit by disconnecting one circuit. Place the ohmmeter leads across the component or circuit to display the resistance in ohms. When checking a sensor or variable resistor such as the fuel level gauge, heating the element or moving the arm should move the meter through a range of resistance that can be compared to a specification.

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Figure 527 Checking for Open Circuits

Figure 528 Checking for Short Circuits

Open electrical circuits can be diagnosed using an ohmmeter. Disconnect the power supply to the circuit and isolate the circuit from all other circuits. The circuit between the light and the ground is disconnected to prevent reading a circuit that may be shorted to ground ahead of the load device as a continuous circuit. Connect the ohmmeter to the open ends of the circuit. A high reading (infinity) indicates an open circuit. A reading near zero indicates a continuous circuit. With the Fluke 88™ Digital Multimeter, an open circuit will read OL (over limit).

Checks for short circuits are similar to checks for open circuits. Isolate the circuit from the power source and the ground point. Connect the ohmmeter between an isolated circuit and a good ground point to check the circuit for a short to ground. A short to ground will be indicated by a reading near zero. A circuit that is not shorted to ground will cause a high meter reading.

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Troubleshooting

1. Verify the problem.

   Operate the complete system and list all symptoms as follows:

   - Check the accuracy and completeness of the complaint.
   - Learn more that might give a clue to the nature and location of the problem.
   - Analyze what parts of the system are working.

2. See “Electronic Control Systems Diagnostics” in this manual or the correct chassis manual

   Read the electrical operation for the problem circuit and review the circuit diagram. Understanding electrical operation and the circuit diagram can narrow the cause of the problem to one component or certain parts of the circuit.

3. Check the circuit diagram.

   Check the circuit diagram for possible clues to the problem. Location of specific components in the circuit will help identify the source of the problem.

   Circuit diagrams are designed to make it easy to identify common points in circuits. This helps to narrow the problem to a specific area. For example, if several circuits fail at the same time, check for a common power source or common ground connection.

   If part of a circuit fails, check the connections between the part that works and the part that does not work. For example, if the low-beam headlights work, but both high-beam headlights and the high-beam indicator do not work, the power and ground paths must be good. Since the dimmer switch is the component that switches the power to the high-beam headlights, it is probably the cause of failure.

4. Determine the cause of the problem and follow diagnostic procedures in Section 7.

5. Make the repair.

   Repair the problem circuit as directed in the diagnostic tables

6. Verify that the repair is complete.

   Operate the system. Check that the repair has removed all symptoms and that the repair has not caused new symptoms.

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Table of Contents

Abbreviations and Acronyms.....557

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Abbreviations and Acronyms

AAT – Ambient Air Temperature
ABDC – After Bottom Dead Center
ABS – Antilock Brake System
AC – Alternating Current
ACC – Air Conditioner Control
ACCEL – Accelerate
AF – Air to Fuel ratio
AIT – Air Intake Temperature
Amb – Ambient
amp – Ampere
AMS – Air Management System
API – American Petroleum Institute
APS – Accelerator Position Sensor
ASTM – American Society for Testing and Materials
ATA – American Trucking Association
ATDC – After Top Dead Center
AWG – American Wire Gauge
AWHP – Available Wheel Horsepower

BAP – Barometric Absolute Pressure
Bar – Barometric
BBDC – Before Bottom Dead Center
BCS – Boost Control Solenoid
BDC – Bottom Dead Center
bhp – Brake Horsepower
BK – Black (electrical wire color)
BNO – Brake Normally Open
BTDC – Before Top Dead Center
BTU – British Thermal Unit
BPP – Brake Pedal Position Switch

C – Celsius
CAC – Charge Air Cooler
CAN – Controller Area Network
CAN 1 – Controller Area Network (public)
CAN 2 – Controller Area Network (private)
CAP – Cold Ambient Protection
CARB – California Air Resources Board
cc – Cubic centimeter
CCA – Cold Cranking Ampere
CDPF – Catalyzed Diesel Particulate Filter
CG – Center of Gravity
CID – Cubic Inch Displacement
cfm – Cubic feet per minute
cfs – Cubic feet per second
CKP – Crankshaft Position
CLS – Coolant Level Switch
cm – Centimeter
CMP – Camshaft Position
CO – Carbon Monoxide
CTC – Coolant Temperature Compensation
DB – Decibel
DCA – Diesel Coolant Additive
DDI – Digital Direct Fuel Injection
DDS – Driveline Disengagement Switch
DLC – Data Link Connector
DME – Dimethyl Ether
DMM – Digital Multimeter
DTC – Diagnostic Trouble Code
DTRM – Diesel Thermo Recirculation Module

EBP – Exhaust Back Pressure
EBPD – Exhaust Back Pressure Desired
ECI – Engine Crank Inhibit
ECM – Electronic Control Module
ECM PWR – Electronic Control Module Power
ECT – Engine Coolant Temperature
EFRC – Engine Family Rating Code
EG – Ethylene Glycol
EGR – Exhaust Gas Recirculating
EGRP – Exhaust Gas Recirculating Position
EMI – Electromagnetic Interference
EOP – Engine Oil Pressure
EOT – Engine Oil Temperature
EPA – Environmental Protection Agency
EPACT – Energy Policy ACT
EPR – Engine Pressure Regulator
ESC – Electronic System Controller
ESN – Engine Serial Number
EST – Electronic Service Tool
EVRT® – Electronic Variable Response Turbocharger International® version of VGT (see VGT)
EWPS – Engine Warning Protection System

F – Fahrenheit
FEL – Family Emissions Limit
fhp – Friction horsepower
FMI – Failure Mode Indicator
FPC – Fuel Pump control
fpm – Feet per minute
fps – Feet per second
ft – Feet

G – Ground (electrical) or Acceleration of Gravity
gal – Gallon
gal/h – Gallons per hour
gal/min – Gallons per minute
GCW – Gross Combined Weight
GCWR – Gross Combined Weight Rating
GPC – Glow Plug Control
gph – Gallons per hour
gpm – Gallons per minute
GY – Gray (electrical wire color)
GVW – Gross Vehicle Weight

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H_2O – Water
HC – Hydrocarbons
HFCM – Horizontal Fuel Conditioning Module
Hg – Mercury
hp – Horsepower
hr – Hour
Hyd – Hydraulic

IAT – Intake Air Temperature
IAHC – Inlet Air Heater Control
IC – Integrated Circuit
ICP – Injector Control Pressure
ID – Inside Diameter
IDM – Injector Drive Module
IGN – Ignition
Imep – Indicated mean effective pressure
in – Inch
inHg – Inch of mercury
inH_2O – Inch of water
INJ – Injector drive
IPR – Injection Pressure Regulator
ISIS – International® Service Information System
IST – Idle Shutdown Timer
IVS – Idle Validation Switch

JCT – junction (electrical)

kg – Kilogram
km – Kilometer
km/h – Kilometers per hour
km/l – Kilometers per liter
KOEO – Key-On Engine-Off
KOER – Key-On Engine-Running
kPa – Kilopascal
kW – Kilowatt

L – Liter
L/h – Liters per hour
L/m – Liters per minute
L/s – Liters per second
lb – Pound
lbf – Pounds of force
lb/s – Pounds per second
lbf•ft – Pounds of force per foot
lbf•in – Pounds of force per inch
lbm – Pounds of mass
IVS – Idle Validation Switch

m – Meter
m/s – Meters per second
MAF – Mass Air Flow
MAG – Magnetic
MAP – Manifold Absolute Pressure
MAT – Manifold Absolute Temperature
MD – Master Diagnostics
mep – Mean effective pressure
mi – Mile
mm – Millimeter
mpg – Miles per gallon
mph – Miles per hour
MSDS – Material Safety Data Sheet

N – Newton
NC – Normally closed (electrical)
NETS – Navistar Electronics Technical Support
N•m – Newton meter
NO – Normally Open (electrical)
NO – Nitrogen Oxide
NO_x – Nitrogen Oxides

OAT – Organic Acid Technology
OCC – Output Circuit Check
OCP – Overcrank Protection
OD – Outside Diameter
OL – Over Limit
ORH – Out of Range High
ORL – Out of Range Low
OSHA – Occupational Safety and Health Administration
OWL – Oil/Water Lamp

PG – Propylene Glycol
PID – Parameter Identifier
PK – Pink (electrical wire color)
PM – Particulate matter
P/N – Part Number
ppm – Parts per million
PROM – Programmable Read Only Memory
psi – Pounds per square inch
psia – Pounds per square inch absolute
psig – Pounds per square inch gauge
pt – Pint
PTO – Power Take Off
PWR – Power

qt – Quart

RAM – Random Access Memory
REPTO – Rear Engine Power TakeOff
RFI – Radio Frequency Interference
rev – Revolution
rpm – Revolutions per minute
RTV – Room Temperature Vulcanized

SAE – Society of Automotive Engineers
SCA – Supplemental Cooling Additive
SCCS – Speed Control Command Switches
SID – Subsystem Identifier

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SIG GRD – Signal Ground
S/N – Serial Number
SW – Switch (electrical)
SYNC – Synchronization

TACH – Tachometer output signal
TBD – To Be Determined
TCAPE – Truck Computer Analysis of Performance and Economy
TDC – Top Dead Center
TCM – Transmission Control Module
TTS – Transmission Tailshaft Speed

UK – United Kingdom
UVC – Under Valve Cover

V – Volt
V_{BAT} – Battery Voltage
V_{IGN} – Ignition Voltage
V_{REF} – Reference Voltage
V_{REF} A – Reference Voltage (engine)
V_{REF} B – Reference Voltage (chassis)
VEPS – Vehicle Electronics Programming System
VGT – Variable Geometry Turbocharger
VIN – Vehicle Identification Number
VOP – Valve Opening Pressure
VRE – Vehicle Retarder Enable
VSS – Vehicle Speed sensor
VT – Violet (electrical wire color)

WEL – Warn Engine Lamp
WIF – Water In Fuel
WTEC – World Transmission Electronically Controlled automatic transmissions (Allison)

XMNS – Transmission

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Table of Contents

Terminology.....**563**

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Terminology

Accessory work – The work per cycle required to drive engine accessories (normally, only those essential to engine operation).

Actuator – A device that performs work in response to an input signal.

Aeration – The entrainment of air or combustion gas in coolant, lubricant, or fuel.

Aftercooler (Charge Air Cooler) – A heat exchanger mounted in the charge air path between the turbocharger and engine intake manifold. The aftercooler reduces the charge air temperature by transferring heat from the charge air to a cooling medium (usually air).

Ambient temperature – The environmental air temperature in which a unit is operating. In general, the temperature is measured in the shade (no solar radiation) and represents the air temperature for other engine cooling performance measurement purposes. Air entering the radiator may or may not be the same ambient due to possible heating from other sources or recirculation. (SAE J1004 SEP81)

Ampere (amp) – The standard unit for measuring the strength of an electrical current. The flow rate of a charge in a conductor or conducting medium of one coulomb per second. (SAE J1213 NOV82)

Analog – A continuously variable voltage.

Analog to digital converter (A/D) – A circuit in the ECM processing section that converts an analog signal (DC or AC) to a usable digital signal for the microprocessor.

American Trucking Association (ATA) Datalink – A serial datalink specified by the American Trucking Association and the SAE.

Boost pressure – 1. The pressure of the charge air leaving the turbocharger.

2. Inlet manifold pressure that is greater than atmospheric pressure. Obtained by turbocharging.

Bottom Dead Center (BDC) – The lowest position of the piston during the stroke.

Brake Horsepower (bhp) – The power output from an engine, not the indicated horsepower. The power output of an engine, sometimes-called flywheel horsepower is less than the indicated horsepower by the amount of friction horsepower consumed in the engine.

Brake Horsepower (bhp) net – Net brake horsepower is measured with all engine components. The power of an engine when configured as a fully equipped engine. (SAE J1349 JUN90)

Calibration – The data values used by the strategy to solve equations and make decisions. Calibration values are stored in ROM and put into the processor during programming to allow the engine to operate within certain parameters.

Catalyst – A substance that produces a chemical reaction without undergoing a chemical change itself.

Catalytic converter – An antipollution device in the exhaust system that contains a catalyst for chemically converting some pollutants in the exhaust gases (carbon monoxide, unburned hydrocarbons, and oxides of nitrogen) into harmless compounds.

Cavitation – A dynamic condition in a fluid system that forms gas-filled bubbles (cavities) in the fluid.

Cetane number – 1. The self-ignition quality of diesel fuel.

2. A rating applied to diesel fuel similar to octane rating for gasoline.

3. A measure of how readily diesel fuel starts to burn (self-ignites) at high compression temperature.

Diesel fuel with a high cetane number self-ignites shortly after injection into the combustion chamber. Therefore, it has a short ignition delay time. Diesel fuel with a low cetane number resists self-ignition. Therefore, it has a longer ignition delay time.

Charge air – Dense, pressurized, heated air discharged from the turbocharger.

Charge Air Cooler (CAC) – See **Aftercooler**.

Closed crankcase – A crankcase ventilation that recycles crankcase gases through a breather, then back to the clean air intake.

Closed loop operation – A system that uses a sensor to provide feedback to the ECM. The ECM uses the sensor to continuously monitor variables and adjust to match engine requirements.

Cloud point – The point when wax crystals occur in fuel, making fuel cloudy or hazy. Usually below -12 °C (10 °F).

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Cold cranking ampere rating (battery rating) – The sustained constant current (in amperes) needed to produce a minimum terminal voltage under a load of 7.2 volts per battery after 30 seconds.

Continuous Monitor Test – An ECM function that continuously monitors the inputs and outputs to ensure that readings are within set limits.

Coolant – A fluid used to transport heat from one point to another.

Coolant level switch – A switch sensor used to indicate low coolant level.

Crankcase – The housing that encloses the crankshaft, connecting rods, and allied parts.

Crankcase breather – A vent for the crankcase to release excess interior air pressure.

Crankcase pressure – The force of air inside the crankcase against the crankcase housing.

Current – The flow of electrons passing through a conductor. Measured in amperes.

Damper – A device that reduces the amplitude of torsional vibration. (SAE J1479 JAN85)

Deaeration – The removal or purging of gases (air or combustion gas) entrained in coolant or lubricating oil.

Deaeration tank – A separate tank in the cooling system used for one or more of the following functions:

- Deaeration
- Coolant reservoir (fluid expansion and afterboil)
- Coolant retention
- Filling
- Fluid level indication (visible)

Diagnostic Trouble Code (DTC) – Formerly called a Fault Code or Flash Code. A DTC is a three digit numeric code used for troubleshooting.

Digital Multimeter (DMM) – An electronic meter that uses a digital display to indicate a measured value. Preferred for use on microprocessor systems because it has a very high internal impedance and will not load down the circuit being measured.

Disable – A computer decision that deactivates a system and prevents operation of the system.

Displacement – The stroke of the piston multiplied by the area of the cylinder bore multiplied by the number of cylinders in the engine.

Driver (high side) – A transistor within an electronic module that controls the power to an actuator circuit.

Driver (low side) – A transistor within an electronic module that controls the ground to an actuator circuit.

Duty cycle – A control signal that has a controlled on/off time measurement from 0 to 100%. Normally used to control solenoids.

Engine lamp – An instrument panel lamp that comes on when DTCs are set. DTCs can be read as flash codes (red and amber instrument panel lamps).

Engine OFF tests – Tests that are done with the ignition switch ON and the engine OFF.

Engine rating – Engine rating includes **Rated hp** and **Rated rpm**.

Engine RUNNING tests – Tests done with the engine running.

Exhaust brake – A brake device using engine exhaust back pressure as a retarding medium.

Exhaust manifold – Exhaust gases flow through the exhaust manifold to the turbocharger exhaust inlet and are directed to the EGR cooler.

Fault detection/management – An alternate control strategy that reduces adverse effects that can be caused by a system failure. If a sensor fails, the ECM substitutes a good sensor signal or assumed sensor value in its place. A lit amber instrument panel lamp signals that the vehicle needs service.

Filter restriction – A blockage, usually from contaminants, that prevents the flow of fluid through a filter.

Flash code – See **Diagnostic Trouble Code (DTC)**.

Fuel inlet restriction – A blockage, usually from contaminants, that prevents the flow of fluid through the fuel inlet line.

Fuel pressure – The force that the fuel exerts on the fuel system as it is pumped through the fuel system.

Fuel strainer – A pre-filter in the fuel system that keeps larger contaminants from entering the fuel system.

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Fully equipped engine – A fully equipped engine is an engine equipped with only those accessories necessary to perform its intended service. A fully equipped engine does not include components that are used to power auxiliary systems. If these components are integral with the engine or for any reason are included on the test engine, the power absorbed may be determined and added to the net brake power. (SAE J1995 JUN90)

Fusible link (fuse link) – A fusible link is a special section of low tension cable designed to open the circuit when subjected to an extreme current overload. (SAE J1156 APR86)

Gradeability – The maximum percent grade which the vehicle can transverse for a specified time at a specified speed. The gradeability limit is the grade upon which the vehicle can just move forward. (SAE J227a)

Gross Combined Weight Rating (GCWR) – Maximum combined weight of towing vehicle (including passengers and cargo) and the trailer. The GCWR indicates the maximum loaded weight that the vehicle is allowed to tow.

Gross brake horsepower – The power of a complete basic engine, with air cleaner, without fan, and alternator and air compressor not charging.

Hall effect – The development of a transverse electric potential gradient in a current-carrying conductor or semiconductor when a magnetic field is applied.

Hall effect sensor – Generates a digital on/off signal that indicates speed and timing.

High speed digital inputs – Inputs to the ECM from a sensor that generates varying frequencies (engine speed and vehicle speed sensors).

Horsepower (hp) – Horsepower is the unit of work done in a given period of time, equal to 33,000 pounds multiplied by one foot per minute. **1hp = 33,000 lb x 1 ft /1 min**.

Hydrocarbons – Unburned or partially burned fuel molecules.

Idle speed –

- Low idle is minimum rpm at no load.
- High idle is maximum rpm at no load.

Intake manifold – A collection of tubes through which the fuel-air mixture flows from the fuel injector to the intake valves of the cylinders.

International NGV Tool Utilized for Next Generation Electronics (INTUNE) – The diagnostics software for chassis related components and systems.

Low speed digital inputs – Switched sensor inputs that generate an on/off (high/low) signal to the ECM. The input to the ECM from the sensor could be from a high input source switch (usually 5 or 12 volts) or from a grounding switch that grounds the signal from a current limiting resistor in the ECM that creates a low signal (0 volts).

Lubricity – Lubricity is the ability of a substance to reduce friction between solid surfaces in relative motion under loaded conditions.

Lug (engine) – A condition when the engine is operating at or below maximum torque speed.

Manometer – A double-leg liquid-column gauge, or a single inclined gauge, used to measure the difference between two fluid pressures. Typically, a manometer records in inches of water.

MasterDiagnostics® (MD)™ – The diagnostics software for engine related components and systems.

Microprocessor – An integrated circuit in a microcomputer that controls information flow.

Nitrogen Oxides (NO_x) – Nitrogen oxides form by a reaction between nitrogen and oxygen at high temperatures and pressures in the combustion chamber.

Normally closed – Refers to a switch that remains closed when no control force is acting on it.

Normally open – Refers to a switch that remains open when no control force is acting on it.

Ohm (Ω) – The unit of resistance. One ohm is the value of resistance through which a potential of one volt will maintain a current of one ampere. (SAE J1213 NOV82)

On demand test – A self test that the technician initiates using the EST and associated software.

Output Circuit Check (OCC) – An On demand test done during an Engine OFF self test to check the continuity of selected actuators.

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Output State Test (OST) – An On demand test that forces the processor to activate actuators (High or Low) for additional diagnostics.

pH – A measure of the acidity or alkalinity of a solution.

Particulate matter – Particulate matter includes mostly burned particles of fuel and engine oil.

Piezometer – An instrument for measuring fluid pressure.

Positive On Shaft Excluder (POSE) – A Positive On Shaft Excluder is a separate piece from the rest of the front or rear seal used to keep out dust / debris.

Power – Power is a measure of the rate at which work is done. Compare with **Torque**.

Power TakeOff (PTO) – Accessory output, usually from the transmission, used to power a hydraulic pump for a special auxiliary feature (garbage packing, lift equipment, etc).

Pulse Width Modulation (PWM) – The time that an actuator, such as an injector, remains energized.

Random Access Memory (RAM) – Computer memory that stores information. Information can be written to and read from RAM. Input information (current engine speed or temperature) can be stored in RAM to be compared to values stored in Read Only Memory (ROM). All memory in RAM is lost when the ignition switch is turned off.

Rated gross horsepower – Engine gross horsepower at rated speed as declared by the manufacturer. (SAE J1995 JUN90)

Rated horsepower – Maximum brake horsepower output of an engine as certified by the engine manufacturer. The power of an engine when configured as a basic engine. (SAE J1995 JUN90)

Rated net horsepower – Engine net horsepower at rated speed as declared by the manufacturer. (SAE J1349 JUN90)

Rated speed – The speed, as determined by the manufacturer, at which the engine is rated. (SAE J1995 JUN90)

Rated torque – Maximum torque produced by an engine as certified by the manufacturer.

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

Read Only Memory (ROM) – Computer memory that stores permanent information for calibration tables and operating strategies. Permanently stored information in ROM cannot be changed or lost by turning the engine off or when ECM power is interrupted.

Reference voltage (V_{REF}) – A 5 volt reference supplied by the ECM to operate the engine sensors.

Reserve capacity – Time in minutes that a fully charged battery can be discharged to 10.5 volts at 25 amperes.

Signal ground – The common ground wire to the ECM for the sensors.

Speed Control Command Switches (SCCS) – A set of switches used for cruise control, Power TakeOff (PTO), and remote hand throttle system.

Steady-state condition – An engine operating at a constant speed and load and at stabilized temperatures and pressures. (SAE J215 JAN80)

Strategy – A plan or set of operating instructions that the microprocessor follows for a desired goal. Strategy is the computer program itself, including all equations and decision making logic. Strategy is always stored in ROM and cannot be changed during calibration.

Stroke – Stroke is the movement of the piston from Top Dead Center (TDC) to Bottom Dead Center (BDC).

Substrate – Material that supports the washcoating or catalytic materials.

Sulfur dioxide (SO_2) – Sulfur dioxide is caused by oxidation of sulfur contained in fuel.

System restriction (air) – The static pressure differential that occurs at a given air flow from air entrance through air exit in a system. Usually measured in inches (millimeters) of water. (SAE J1004 SEP81)

Tachometer output signal – Engine speed signal for remote tachometers.

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Thermistor – A semiconductor device. A sensing element that changes resistance as the temperature changes.

Thrust load – A thrust load pushes or reacts through a bearing in a direction parallel to the shaft.

Top Dead Center (TDC) – The uppermost position of the piston during the stroke.

Torque – A force having a twisting or turning effect. For a single force, the cross product of a vector from some reference point to the point of application of the force within the force itself. Also known as moment of force or rotation moment. Torque is a measure of the ability of an engine to do work.

Truck Computer Analysis of Performance and Economy (TCAPE) – Truck Computer Analysis of Performance and Economy is a computer program that simulates the performance and fuel economy of trucks.

Turbocharger – A turbine driven compressor mounted to the exhaust manifold. The turbocharger increases the pressure, temperature and density of intake air to charge air.

Variable capacitance sensor – A variable capacitance sensor measures pressure. The pressure forces a ceramic material closer to a thin metal disc in the sensor, changing the capacitance of the sensor.

Vehicle Electronic System Programming System – The computer system used to program electronically controlled vehicles.

Vehicle Retarder Enable/Engage – Output from the ECM to a vehicle retarder.

Vehicle Speed Sensor (VSS) – Normally a magnetic pickup sensor mounted in the tailshaft housing of the transmission, used to indicate ground speed.

Viscosity – The internal resistance to the flow of any fluid.

Viscous fan – A fan drive that is activated when a thermostat, sensing high air temperature, forces fluid through a special coupling. The fluid activates the fan.

Volt (v) – A unit of electromotive force that will move a current of one ampere through a resistance of one Ohm.

Voltage – Electrical potential expressed in volts.

Voltage drop – Reduction in applied voltage from the current flowing through a circuit or portion of the circuit current multiplied by resistance.

Voltage ignition – Voltage supplied by the ignition switch when the key is ON.

Washcoat – A layer of alumina applied to the substrate in a monolith-type converter.

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Table of Contents

International® VT 275 Diesel Engine (General information)……571

International® VT 275 Diesel Engine (CF)……573

International® VT 275 Diesel Engine (Stripped Chassis)……576

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International® VT 275 Diesel Engine (General information)

Temperature, Fuel, and Lubrication

International® VT 275 diesel engine specifications	
Measure water temperature differential across the radiator with engine on a chassis dynamometer, at full load and ambient temperature of 26.7 °C (80 °F) or above.	2 to 5 °C (6 to 12 °F)
Water temperature - maximum out of the radiator with ambient air temperature of 37.7°C (100°F)	113 °C (235 °F)
Thermostat	
Type	Balanced pressure, wax pellet
Minimum recommended coolant operating temperature	71 °C (160 °F)
Start-to-open temperature, 0.38 mm (0.015 in) stroke	87 to 91 °C (188 to 196 °F)
Full-open temperature, 8 mm (0.315 in) stroke	104 °C (219 °F)
Diesel fuel (maximum sulfur content of 0.05%)	
Minimum fuel requirements	42 cetane
Expected temperature	**Preferred fuel grade**
Above -1 °C (30 °F)	Grade No. 2-D
Below -17 °C (0 °F)	Grade No. 1-D
NOTE: If grade No. 1-D is not available, use a winterized or climatized Grade No. 2-D fuel. This is made by blending Grade No. 1-D with No. 2-D fuel to match the temperature conditions in your area.	
Between -1 and -17 °C (30 and 0 °F)	1-D / 2-D Blended
Lubrication	
Oil quality	API category CI-4, CI-4 PLUS
Oil viscosity recommendations	15W-40 preferred above -6 °C (20 °F)
	10W-30 preferred between -6 and -17 °C (20 and 0 °F)
	5W-40 synthetic or 0W-30 synthetic below -17 °C (0 °F)
Cold Start Component Guidelines	

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Temperature, Fuel, and Lubrication (cont.)	
Battery Requirements	1300 CCA minimum above -12 °C (10 °F)
	1950 CCA minimum below -12 °C (10 °F)
Starting Aid Recommendations	Below -12 °C (10 °F) use block heater
	Below -17 °C (0 °F) use fuel heater
	Below -17 °C (0 °F) use oil pan heater

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International® VT 275 Diesel Engine (CF)

200 hp @ 2700 rpm (12NRN)

International® VT 275/200 hp @ 2700 rpm (440 ft·lbf torque @ 1800 rpm)	
50 state 2006 Model Year (MY)	
Engine unit code	12NRN
International® VT 275 diesel engine specifications	
Engine model	International® VT 275/200
Engine rating	200 bhp @ 2700 rpm
Engine Family Rating Code (EFRC)	3111
Injector part number, original equipment	1846692C1
Turbocharger part number	1854407C94
Injection timing	Nonadjustable
High idle speed - automatic transmission	3600 rpm
Low idle speed	700 rpm
Component Specification	
Air pressure - bypass valve starts to open (approximately 5 mm (0.2 inches) of travel)	130 ± 7 kPa (18.8 ± 1.0 psi)
Air pressure - start of actuator travel	110 ± 7 kPa (16.0 ± 1.0 psi)
Key On Engine Off	
Fuel pump discharge pressure	517 to 690 kPa (75 to 100 psi)
Fuel inlet restriction, maximum	152 mm Hg (6 in Hg)
Engine cranking	
Minimum battery voltage	9.0 V
Minimum cranking rpm	100 rpm
Minimum ICP, pressure / voltage	6 MPa (870 psi) / 1.15 V
Minimum oil pressure, test gauge	34.5 kPa (5 psi)
EGRP	0%
Minimum fuel pressure	276 kPa (40 psi)

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200 hp @ 2700 rpm (12NRN) (cont.)

Data taken at low idle, no load, stabilized operating temperature	
Injection Control Pressure, pressure / voltage	4.0 ± 0.5 MPa (580 ± 70 psi) / 0.80 ± 0.07 V
Minimum fuel pressure	276 kPa (40 psi)
Mass Air Flow (MAF), flow / Hz	15 ± 5 gms/sec (2.0 ± 0.7 lb/min) / 3600 ± 500 Hz
Minimum oil pressure, test gauge	69 kPa (10 psi)
Data taken at high idle, no load, stabilized operating temperature	
Air cleaner restriction, maximum	3.1 kPa (12.5 in H_2O)
Injection Control Pressure, pressure / voltage	17 ± 2 MPa (2465 ± 300 psi) / 2.77 ± 0.31 V
Fuel pressure, minimum	276 kPa (40 psi)
Mass Air Flow (MAF), flow / Hz	210 ± 10 gms/sec (28.3 ± 1.3 lb/min) 9200 ± 150 Hz
Minimum oil pressure, test gauge	276 kPa (40 psi)
Crankcase pressure using restrictor tool ZTSE4510, maximum	1.99 kPa (8.0 in H_2O)
Data taken at full load, rated speed on chassis dynamometer or highway, stabilized operating temperature	
Air cleaner restriction, maximum.	6.2 kPa (25 in H_2O)
Injection Control Pressure, pressure / voltage	27 ± 1 MPa (3916 ± 145 psi) / 4.3 ± 0.12 V
Minimum fuel pressure	276 kPa (40 psi)
Minimum oil pressure, test gauge	276 kPa (40 psi)
Intake manifold pressure (full load, rated speed), pressure / voltage	195 ± 14 kPa (28 ± 2 psi) / 2.28 ± 0.2 V @ 2700 rpm
Mass air flow (full load, rated speed), flow / Hz	230 ± 10 gms/sec (30.5 ± 1.3 lb/min) / 9500 ± 150 Hz @ 2700 rpm
Intake manifold pressure (full load, peak torque), pressure / voltage	210 ± 14 kPa (30.5 ± 2 psi) / 2.5 ± 0.2 V @ 1800 rpm
Mass air flow (full load, peak torque), flow / Hz	180 ± 10 gms/sec (24.3 ± 1.3 lb/min) / 8700 ± 150 Hz @ 1800 rpm

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200 hp @ 2700 rpm (12NRN) (cont.)

Data taken after engine reaches stabilized operating temperature	
Torque converter stall (rpm/time) @ sea level	2000 rpm or greater / 8 sec or less / Oil Temp stable at 82 °C (180 °F)
NOTE: Deterioration will occur with colder temperature and higher altitude.	
Lube oil temperature (oil gallery), maximum	121 °C (250 °F)

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International® VT 275 Diesel Engine (Stripped Chassis)

200 hp @ 2700 rpm (12NRN)

International® VT 275/200 hp @ 2700 rpm (440 ft·lbf torque @ 1800 rpm)	
50 state 2006 Model Year (MY)	
Engine unit code	12NRN
International® VT 275 diesel engine specifications	
Engine model	International® VT 275/200
Engine rating	200 bhp @ 2700 rpm
Engine Family Rating Code (EFRC)	3112
Injector part number, original equipment	1846692C1
Turbocharger part number	1854407C94
Injection timing	Nonadjustable
High idle speed - automatic transmission	3300 rpm
Low idle speed	700 rpm
Component Specification	
Air pressure - bypass valve starts to open (approximately 5 mm (0.2 inches) of travel)	130 ± 7 kPa (18.8 ± 1.0 psi)
Air pressure - start of actuator travel	110 ± 7 kPa (16.0 ± 1.0 psi)
Key On Engine Off	
Fuel pump discharge pressure	517 to 690 kPa (75 to 100 psi)
Fuel inlet restriction, maximum	152 mm Hg (6 in Hg)
Engine cranking	
Minimum battery voltage	9.0 V
Minimum cranking rpm	100 rpm
Minimum ICP, pressure / voltage	6 MPa (870 psi) / 1.15 V
Minimum oil pressure, test gauge	34.5 kPa (5 psi)
EGRP	0%
Minimum fuel pressure	276 kPa (40 psi)

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200 hp @ 2700 rpm (12NRN) (cont.)

Data taken at low idle, no load, stabilized operating temperature	
Injection Control Pressure, pressure / voltage	4.0 ± 0.5 MPa (580 ± 70 psi) / 0.80 ± 0.07 V
Minimum fuel pressure	276 kPa (40 psi)
Mass Air Flow (MAF), flow / Hz	15 ± 5 gms/sec (2.0 ± 0.7 lb/min) / 3900 ± 500 Hz
Minimum oil pressure, test gauge	69 kPa (10 psi)
Data taken at high idle, no load, stabilized operating temperature	
Air cleaner restriction, maximum	3.1 kPa (12.5 in H_2O)
Injection Control Pressure, pressure / voltage	17 ± 2 MPa (2465 ± 300 psi) / 2.77 ± 0.31 V
Fuel pressure, minimum	276 kPa (40 psi)
Mass Air Flow (MAF), flow / Hz	210 ± 10 gms/sec (28.3 ± 1.3 lb/min) 8900 ± 150 Hz
Minimum oil pressure, test gauge	276 kPa (40 psi)
Crankcase pressure using restrictor tool ZTSE4510, maximum	1.99 kPa (8.0 in H_2O)
Data taken at full load, rated speed on chassis dynamometer or highway, stabilized operating temperature	
Air cleaner restriction, maximum.	6.2 kPa (25 in H_2O)
Injection Control Pressure, pressure / voltage	27 ± 1 MPa (3916 ± 145 psi) / 4.3 ± 0.12 V
Minimum fuel pressure	276 kPa (40 psi)
Minimum oil pressure, test gauge	276 kPa (40 psi)
Intake manifold pressure (full load, rated speed), pressure / voltage	195 ± 14 kPa (28 ± 2 psi) / 2.28 ± 0.2 V @ 2700 rpm
Mass air flow (full load, rated speed), flow / Hz	230 ± 10 gms/sec (30.5 ± 1.3 lb/min) / 10000 ± 150 Hz @ 2700 rpm
Intake manifold pressure (full load, peak torque), pressure / voltage	210 ± 14 kPa (30.5 ± 2 psi) / 2.5 ± 0.2 V @ 1800 rpm
Mass air flow (full load, peak torque), flow / Hz	180 ± 10 gms/sec (24.3 ± 1.3 lb/min) / 8550 ± 150 Hz @ 1800 rpm

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200 hp @ 2700 rpm (12NRN) (cont.)

Data taken after engine reaches stabilized operating temperature	
Torque converter stall (rpm/time) @ sea level	2000 rpm or greater / 8 sec or less
NOTE: Deterioration will occur with colder temperature and higher altitude.	
Lube oil temperature (oil gallery), maximum	121 °C (250 °F)

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Table of Contents

Diagnostic Trouble Code Index.....581

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Diagnostic Trouble Code Index

DTC	PID	SID	FMI	SEC. 7 PAGE NO.	CIRCUIT	CONDITION DESCRIPTION
*Indicates amber ENGINE lamp on when a Diagnostic Trouble Code (DTC) is set.						
** Indicates red ENGINE lamp on if the Engine Warning Protection System (EWPS) is enabled and a DTC is set.						
✓ See *Circuit Diagram Manual* and *Engine Diagnostics Manual* for more information						
111				(page 345)	ECM	No errors detected – flash code only
112✓	168	0	3	(page 356)	ECM PWR	Electrical system voltage B+ out of range high
113✓	168	0	4	(page 357)	ECM PWR	Electrical system voltage B+ out of range low
114*	110	0	4	(page 363)	ECT	Engine Coolant Temperature signal out of range low
115*	110	0	3	(page 363)	ECT	Engine Coolant Temperature signal out of range high
121*	102	0	3	(page 498)	MAP	Intake Manifold Absolute Pressure signal out of range high
122*	102	0	4	(page 498)	MAP	Intake Manifold Absolute Pressure signal out of range low
123*	102	0	2	(page 498)	MAP	Intake Manifold Absolute Pressure signal in range fault
124*	164	0	4	(page 448)	ICP	Injection Control Pressure signal out of range low
125*	164	0	3	(page 448)	ICP	Injection Control Pressure signal out of range high
131*✓	91	0	4	(page 294)	APS/IVS	APS signal out of range low
132*✓	91	0	3	(page 294)	APS/IVS	APS signal out of range high
133*✓	91	0	2	(page 295)	APS/IVS	APS signal in range DTC
134*✓	91	0	7	(page 295)	APS/IVS	APS signal and IVS disagree
135*✓	0	230	11	(page 295)	APS/IVS	Idle Validation Switch circuit fault
143	0	21	2	(page 334)	CMP	Incorrect CMP signal signature
145	0	21	12	(page 334)	CMP	CMP signal inactive

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146	0	64	12	(page 330)	CKP	CKP signal inactive
147	0	64	2	(page 330)	CKP	Incorrect CKP signal signature
148*	149	0	5	(page 492)	MAF	Mass Air Flow signal frequency out of range low
149*	149	0	8	(page 493)	MAF	Mass Air Flow signal frequency out of range high
151*✓	108	0	4	(page 312)	BAP	Barometric Absolute Pressure signal out of range high
152*✓	108	0	4	(page 312)	BAP	Barometric Absolute Pressure signal out of range low
154*	171	0	4	(page 440)	IAT	Air inlet temperature signal out of range low
155*	171	0	3	(page 440)	IAT	Air inlet temperature signal out of range high
161*	105	0	4	(page 506)	MAT	Manifold Air Temperature Signal out of range low
162*	105	0	3	(page 506)	MAT	Manifold Air Temperature Signal out of range high
163*	27	0	4	(page 377)	EGR	Exhaust Gas Recirculation Valve Position Signal out of range low
221✓	0	244	2	(page 513)	SCCS	Cruise-PTO control switch circuit fault
222✓	0	247	2	(page 322)	BRAKE	Brake switch circuit fault
225	100	0	0	(page 397)	EOP	EOP sensor signal in range fault
231✓	0	250	2	(page 308)	ATA	ATA data communication link error
237✓	0	78	11	(page 422)	FPC	Fuel Pump Control OCC self test failed
238✓	45	0	11	(page 432)	IAH	Inlet Air Heater Control (V6) OCC self test failed
239✓	143	0	11		BCS	BCS OCC self test failed
241✓	0	42	11	(page 485)	IPR	Injection Pressure Regulator OCC self test failed
251✓	0	38	11	(page 416)	GPC	Glow Plug Control OCC self test failed
252✓	0	36	11		GPC	Glow Plug Lamp OCC self test failed
311*	175	0	4	(page 405)	EOT	Engine Oil Temperature signal out of range low

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312*	175	0	3	(page 405)	EOT	Engine Oil Temperature signal out of range high
313	100	0	1	(page 397)	EOP**	Engine Oil Pressure below warning level
314	190	0	0	(page 412)	EWPS**	Engine Oil Pressure below critical level
315*	190	0	0	(page 413)	EWPS	Engine speed above warning level
316	110	0	1	(page 413)	EWPS	Engine Coolant Temperature unable to reach commanded set point
321	110	0	0	(page 414)	EWPS**	Engine Coolant Temperature above warning level
322	110	0	7	(page 414)	EWPS**	Engine Coolant Temperature above critical level
323	111	0	13	(page 414)	EWPS**	Engine Coolant Level below warning/critical level
324	71	0	14	(page 489)	IST**	Idle Shutdown Timer enabled engine shutdown
325	110	0	14	(page 414)	EWPS	Power reduced, matched to cooling system performance
331*	164	0	0		ICP sys	Injection Control Pressure above system working range
332*	164	0	13	(page 449)	ICP	Injection Control Pressure above spec. with engine not running
333*	164	0	10	(page 460)	ICP sys	Injection Control Pressure above/below desired level
334	164	0	7	(page 462)	ICP sys	ICP unable to achieve setpoint in time (poor performance)
335	164	0	1	(page 464)	ICP sys	ICP unable to build pressure during cranking
343*	0	34	0	(page 289)	AMS	Excessive exhaust back pressure
346	27	0	2	(page 290)	AMS	Faults detected during EGR portion of the AMS Test
365*	27	0	10	(page 378)	EGR	EGR Valve Position above/below desired level
368*	0	146	7	(page 378)	EGR	EGR drive module/ECM2 communication fault
373✓	45	0	12	(page 432)	IAH	Inlet Air Heater relay circuit fault
374✓	0	78	12	(page 422)	FPC	Fuel pump relay circuit fault

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375✓	0	38	12	(page 416)	GPC	Glow plug relay circuit fault
421-426	0	1-6	5	(page 476)	INJ	High side to low side open (cylinder number indicated)
431-436	0	1-6	4	(page 476)	INJ	High side shorted to low side (cylinder number indicated)
451-456	0	1-6	6	(page 476)	INJ	High side short to ground or V_{BAT} (cylinder number indicated)
523✓	0	233	4	(page 467)	IDM	IDM V_{IGN} voltage low
525*	0	254	6	(page 467)	IDM	IDM fault
533✓	0	221	3	(page 468)	IDM	IDM relay voltage high
534✓	0	221	4	(page 468)	IDM	IDM relay voltage low
543*	0	155	7	(page 350)	ECM/IDM	ECM/IDM communications fault
551	0	22	12	(page 350)	ECM/IDM	IDM/CMPO signal inactive
552	0	22	2	(page 350)	ECM/IDM	IDM incorrect CMPO signal signature
553	0	22	11	(page 350)	ECM/IDM	IDM CKPO signal inactive
554	0	22	8	(page 350)	ECM/IDM	IDM incorrect CKPO signal signature
613*	0	252	1	(page 345)	ECM	ECM/IDM software not compatible
614*	0	252	13	(page 346)	ECM	EFRC/ECM configuration mismatch
621*	0	253	1	(page 346)	ECM	Engine using mfg. default rating
622*	0	253	0	(page 346)	ECM	Engine using field default rating
623*	0	253	13	(page 346)	ECM	Invalid Engine Family Rating Code (EFRC)
624	0	240	14	(page 346)	ECM	Field default active
626✓	0	254	8	(page 357)	ECM PWR	Unexpected reset fault
631	0	240	2	(page 346)	ECM	Read Only Memory (ROM) self test fault

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632	0	254	12	(page 346)	ECM	Random Access Memory (RAM) - CPU self test fault
655	0	240	13	(page 347)	ECM	Programmable parameter list level incompatible
661	0	240	11	(page 347)	ECM	RAM programmable parameter list corrupt
664	0	253	14	(page 347)	ECM	Calibration level incompatible
665	0	252	14	(page 347)	ECM	Programmable parameter memory content corrupt

Read all safety instructions in the "Safety Information" section of this manual before doing any procedures.
Follow all warnings, cautions, and notes.
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Table of Contents

Description.....589

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Description

Technical Service Information (TSI) letters are periodically published to inform service technicians of product enhancements and field service issues. File TSIs in this section for supplemental reference.

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