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Electronic Tools and Accessories

180-pin Breakout Box

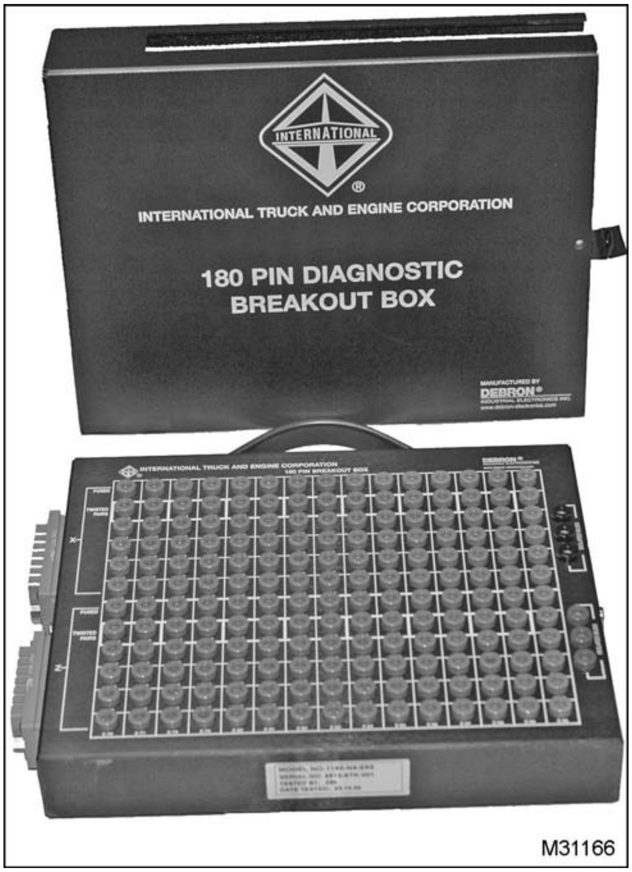

Figure 258 1180–N4–0X0

The 180 Pin Breakout Box allows testing of electronic control system components without disturbing connections or piercing wire insulation to access various signal voltages in the electronic control system.

This breakout box is universal and can adapt to any control system by means of a unique jumper harness. Each jumper harness is a separate part, complete with a breakout box overlay (pin identifier) sheet.

The standard box layout is as follows:

- Two 90-pin connectors which feed 90 banana plug probing points.
- Each 90-pin section of the box is basically a stand alone box.
- The top row is all fuse protected circuits, the second row is all twisted pair circuits.

NOTE: Use Breakout Box for measurement only, not to activate or control circuits. High current will burn out internal circuitry.

16-pin Breakout Harness

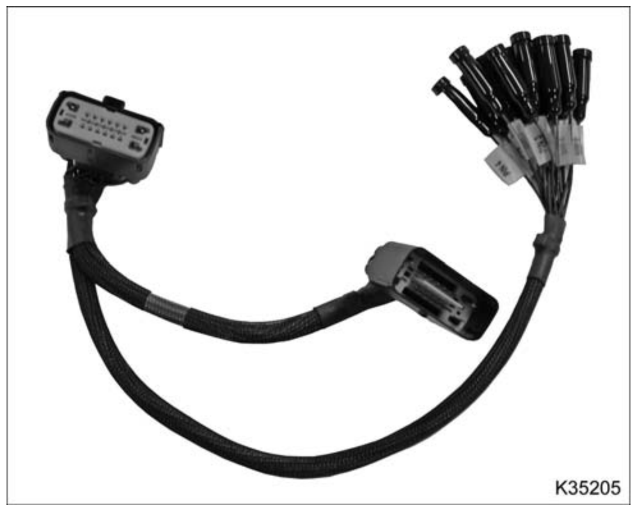

Figure 259 ZTSE4762

The 16-pin Breakout Harness is used to check multiple circuits between engine and chassis harnesses to include, but not limited to: fuel heater, AC clutch, turbocharger, EGR, and starter.

3-banana Plug Harness

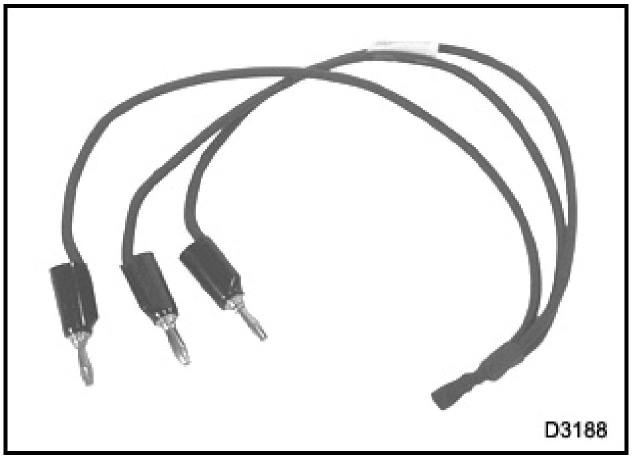

Figure 260 ZTSE4498

The 3-banana Plug Harness is used for sensor end diagnostics of sensor circuits. The harness can be found in Breakout Harnesses Kit (ZTSE4505D).

36-pin Injector Driver Cable

Figure 261 3036 Injector Harness

The 36-pin Injector Driver Cable with breakout box overlay (pin identifier) sheet is used with the 180 Pin Breakout Box to test the injector circuits to the ECM with no ECM connection.

42-pin Engine to Chassis Interface Cable

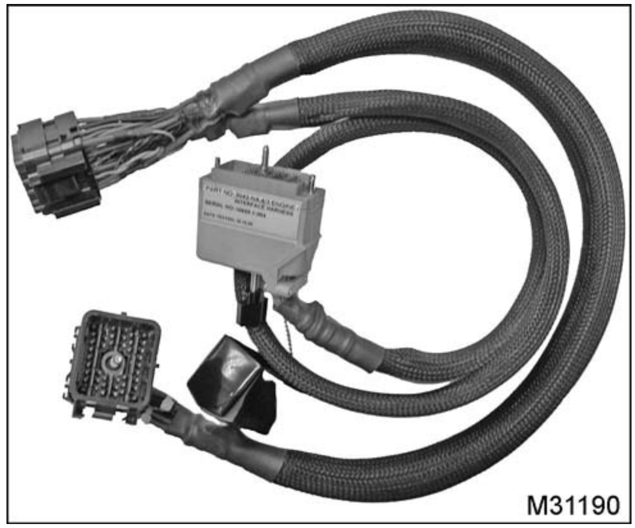

Figure 262 3042–N4

The 42-pin Engine to Chassis Interface Cables with breakout box overlay (pin identifier) sheet is used with the 180 Pin Breakout Box to test the 42-pin connector circuits.

76-pin Engine and Chassis Cables

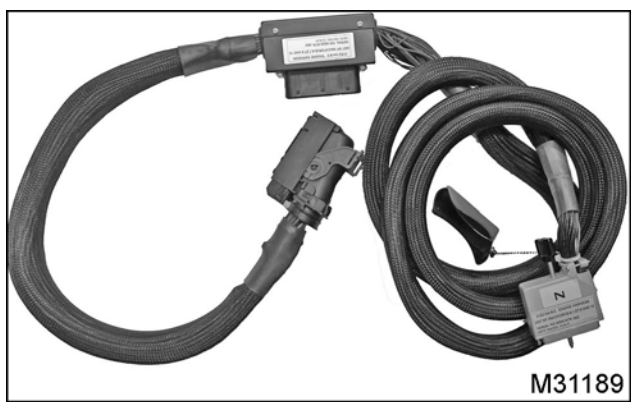

Figure 263 3152–N4

The 76-pin Engine and Chassis Cables (2 cables) with breakout box overlay (pin identifier) sheet are used with the 180 Pin Breakout Box. These jumpers are used to test the circuits going to the engine and chassis 76-pin connectors on the ECM.

500 Ohm Resistor Harness

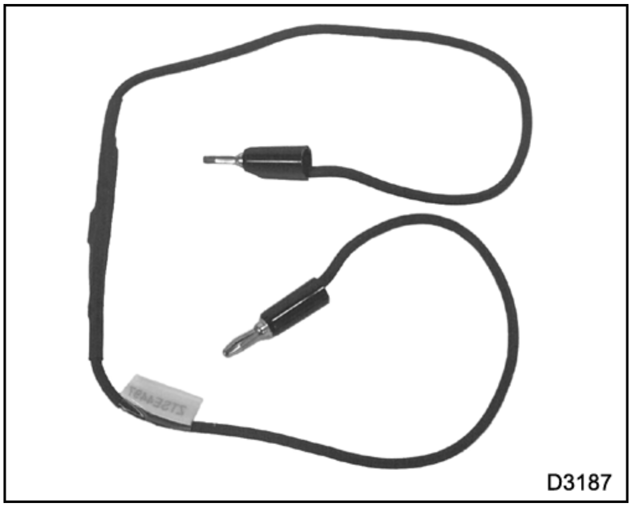

Figure 264 ZTSE4497

The 500 Ohm Resistor Harness is used for sensor end diagnostics of sensor circuits. The harness can be found in Breakout Harnesses Kit (ZTSE4505D).

Actuator Breakout Harness

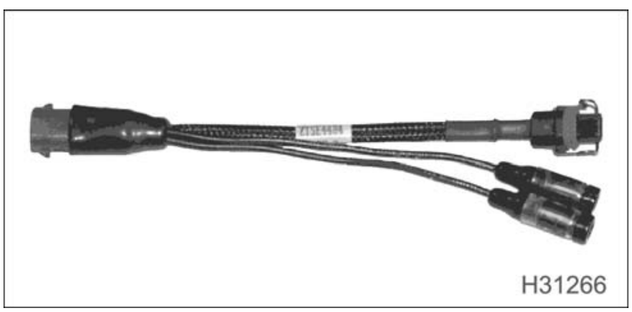

Figure 265 ZTSE4484

The Actuator Breakout Harness is used to measure 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.

Amp Clamp

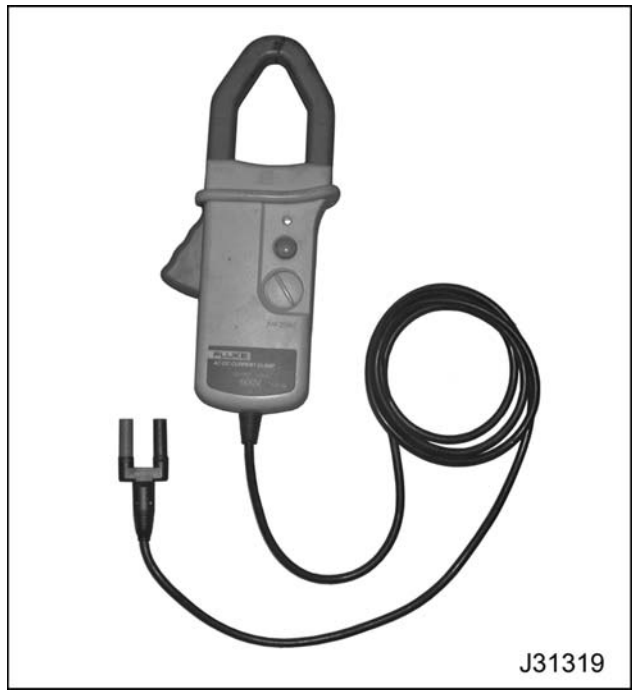

Figure 266 ZTSE4575

The Amp Clamp is used to measure amperage draw for the glow plug and Intake Air Heater systems.

APS/IVS Breakout Harness

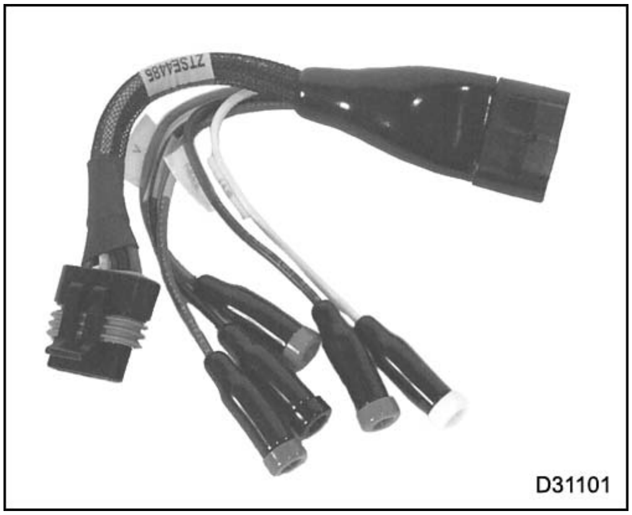

Figure 267 ZTSE4485

The APS/IVS Breakout Harness is used to measure voltage and resistance on circuits that go to the APS/IVS sensor. This harness can be found in Breakout Harnesses Kit (ZTSE4505D).

Breakout Harnesses Kit

Figure 268 ZTSE4505E

The Breakout Harnesses Kit contains the following breakout harnesses and test leads needed for International® MaxxForce™ 5 engines:

- EGR Valve Breakout Harness (ZTSE4735)
- Exhaust Temperature Breakout Harness (ZTSE4760)
- DDP Breakout Harness (ZTSE4761)
- 16-pin Breakout Harness (ZTSE4762)
- Intake Throttle Valve Breakout Harness (ZTSE4765)
- Glow Plug Sensor Harness (ZTSE4808)

Digital Multimeter (DMM)

Figure 269 ZTSE4357 or Purchase Locally

The DMM is used to troubleshoot electrical components, sensors, injector solenoids, relays, and wiring harnesses. The DMM has a high input impedance that allows testing of sensors while the engine is running, without loading the circuit being tested. This ensures the signal voltage measurement will not be affected by the voltmeter.

EGR Valve Breakout Harness

Figure 270 ZTSE4758

EGR Valve Breakout Harness is used to measure voltage and resistance on circuits that go to the Exhaust Gas Recirculation (EGR) valve.

NOTE: Initial shipments of EGR Valve Breakout Harness were labeled incorrectly.

The following graphic shows the breakout harness labeled correctly.

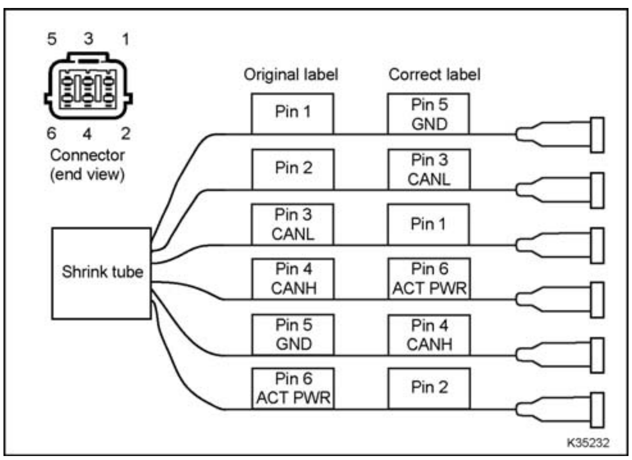

Figure 271 ZTSE4758A

EZ-Tech® Electronic Service Tool (EST)

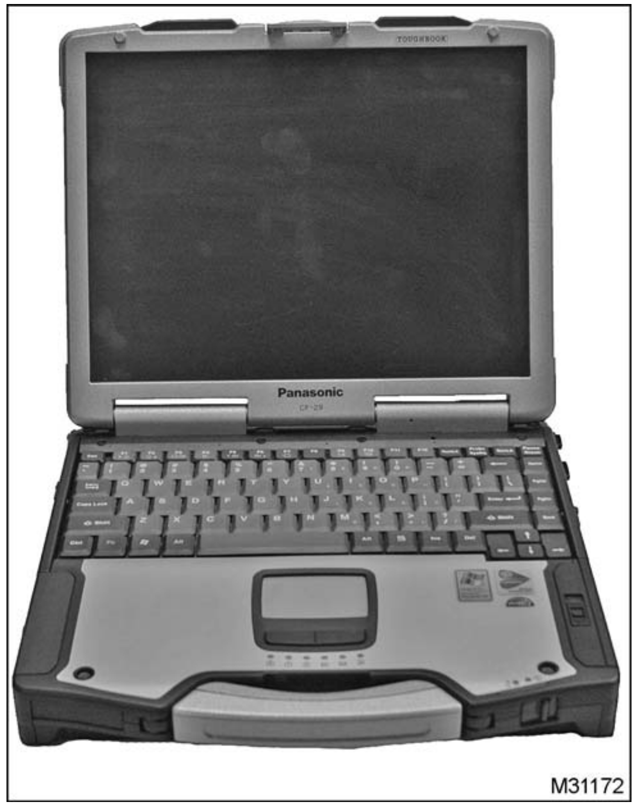

Figure 272 J-45067

The EST is used to run MasterDiagnostics® software for diagnosing and troubleshooting engine and vehicle problems.

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 of an engine.

IC4–USB Interface Cable

Figure 273 ZTSE4632–USB

The IC4–USB Interface Cable, included with the EZ-Tech®, is used to connect the Electronic Service Tool (EST) to the vehicle electronic control system.

DDP Breakout Harness

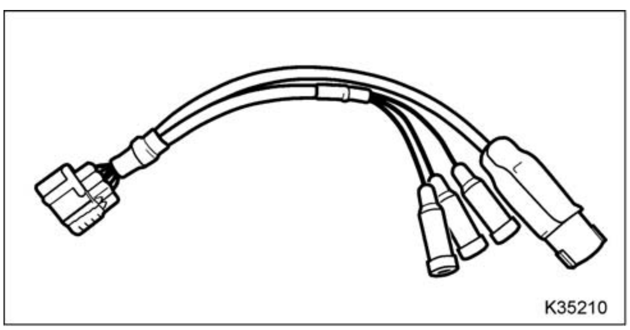

Figure 274 ZTSE4761

The DDP breakout harness is used to measure voltage and resistance on circuits that go to the Exhaust Gas Differential Pressure (EGDP) sensor.

Exhaust Temperature Breakout Harness

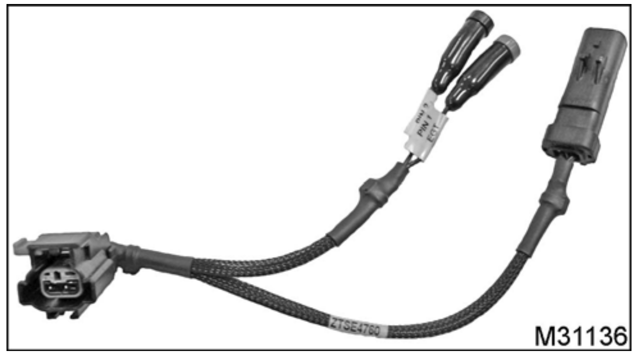

Figure 275 ZTSE4760

The Exhaust Temperature Breakout Harness is used to measure voltage and resistance of circuits that go to the Exhaust Gas Temperature (EGT) sensors.

Glow Plug Sensor Harness

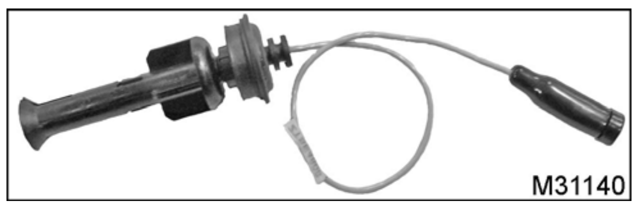

Figure 276 ZTSE4808

The Glow Plug Sensor Harness is used to measure resistances through each glow plug.

Intake Throttle Valve Breakout Harness

Figure 277 ZTSE4765

The Intake Throttle Valve Breakout Harness is used to measure voltage and resistance on circuits that go to the ITV actuator.

Pressure Sensor Breakout Harness

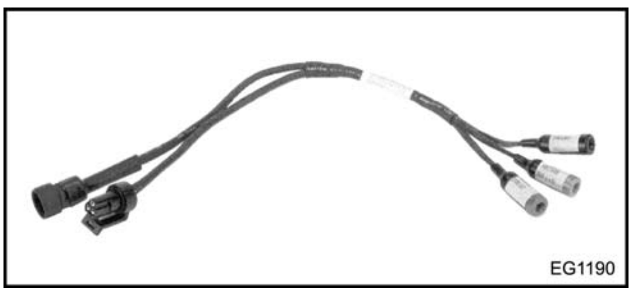

Figure 278 ZTSE4347

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)
- Exhaust Back Pressure (EBP)

Relay Breakout Harness

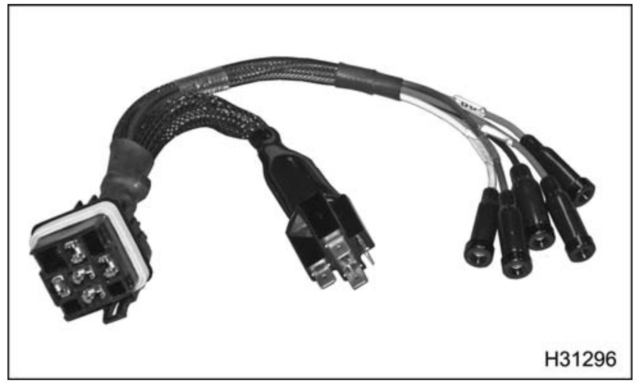

Figure 279 ZTSE4596

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.

NOTE: At the time of publication Relay Breakout Harness (stripped chassis) is under development.

Main Power Relay Breakout Harness

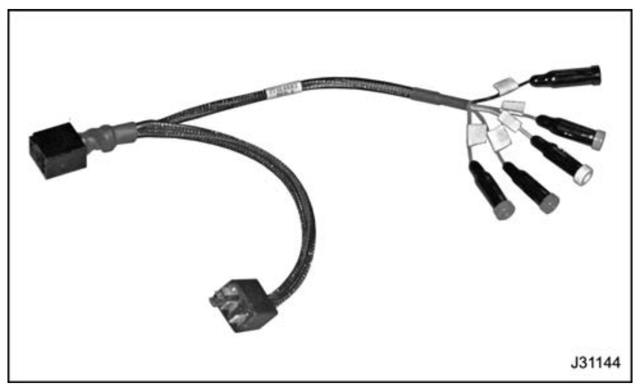

Figure 280 ZTSE4693

The Main Power 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.

Temperature Sensor Breakout Harness

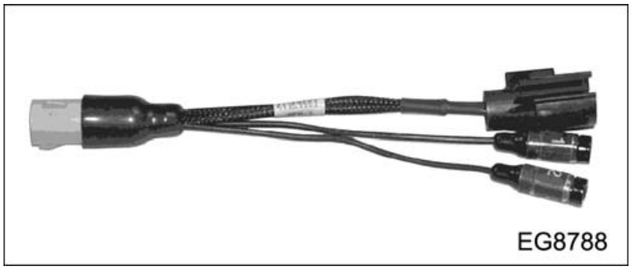

Figure 281 ZTSE4483

Temperature Sensor Breakout Harness ZTSE4483 is used to measure voltage and resistance on circuits that go to the IAT sensor.

Temperature Sensor Breakout Harness

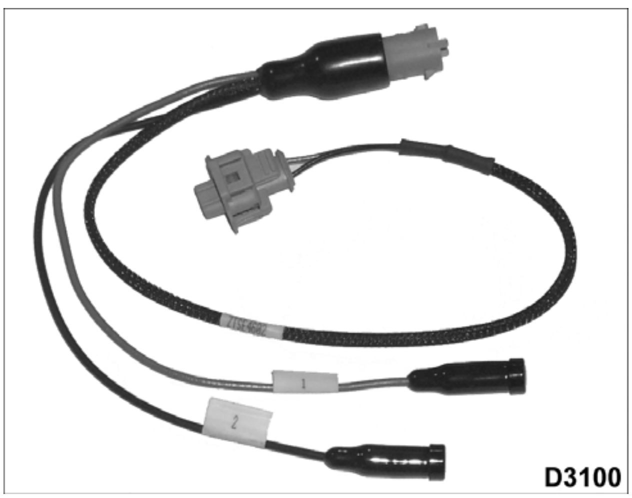

Figure 282 ZTSE4602

Temperature Sensor Breakout Harness ZTSE4602 is used to measure voltage and resistance on circuits that go to the ECT, EFT, EOT, and MAT sensors.

Terminal Test Adapter Kit

Figure 283 ZTSE4435C

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 whether the harness connector is retaining correct tension on the mating terminal.

Mechanical Tools

CAC Test Kit

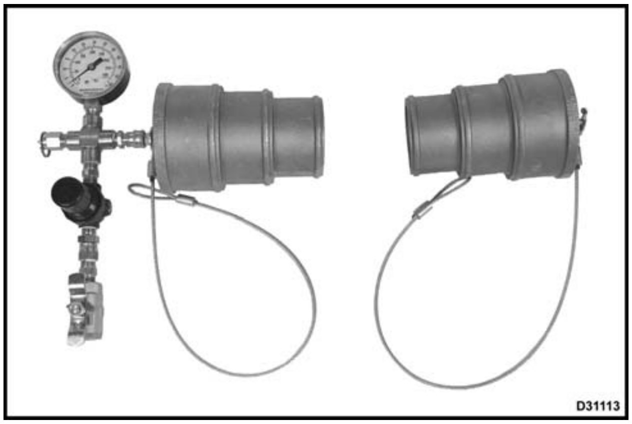

Figure 284 ZTSE4341

The CACTest Kit is used to pressurize the charge air cooler and piping to check for leaks.

Gauge Bar Tool

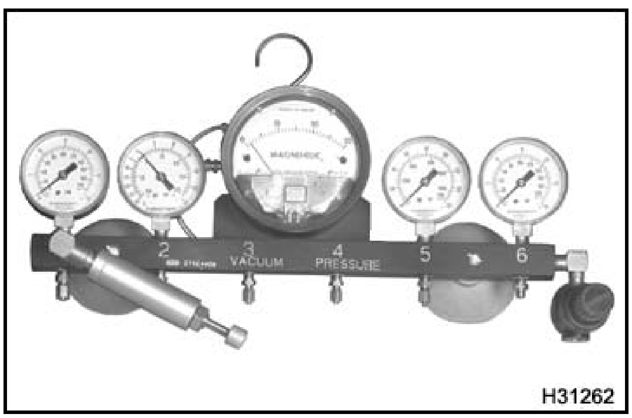

Figure 285 ZTSE4409

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 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.

Fuel Pressure Gauge

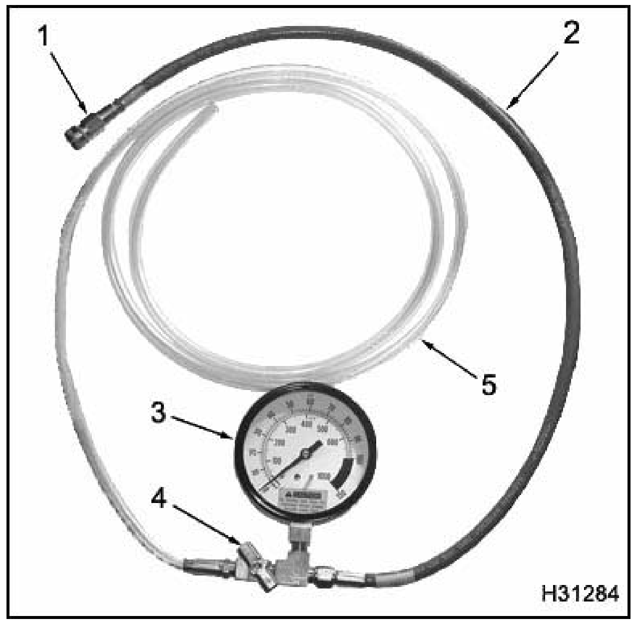

Figure 286 ZTSE4681

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.

Water Manometer – Kit

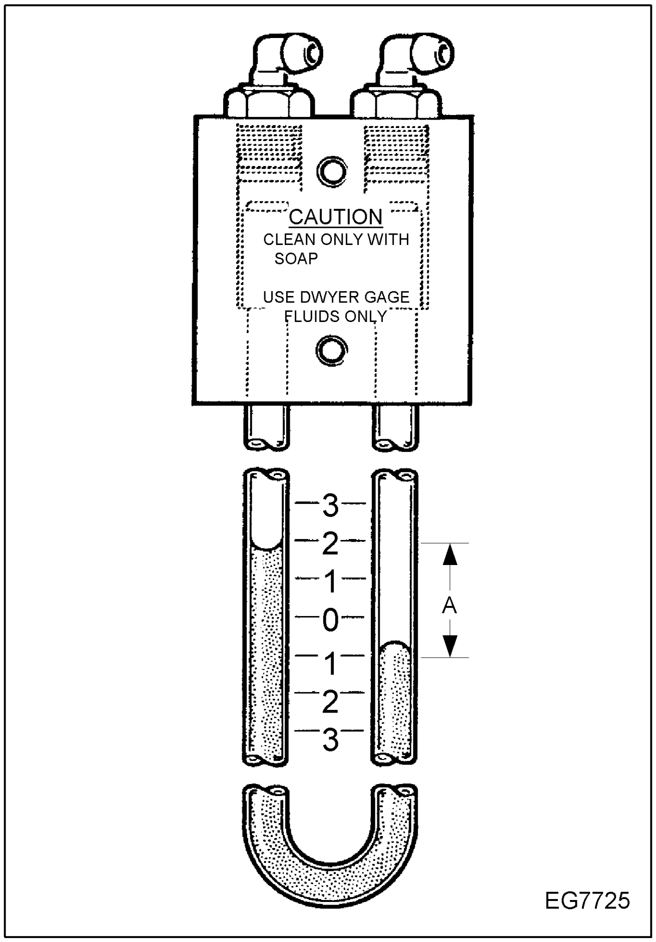

Figure 287 ZTSE2217A

The Water 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

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.

Fuel/Oil Pressure Test Coupler

Figure 288 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 289 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

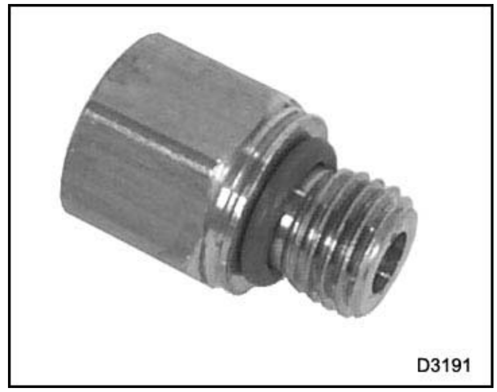

Figure 290 ZTSE4594

The ICP System Test Adapter is used to pressurize the ICP system to test ICP system integrity with the 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

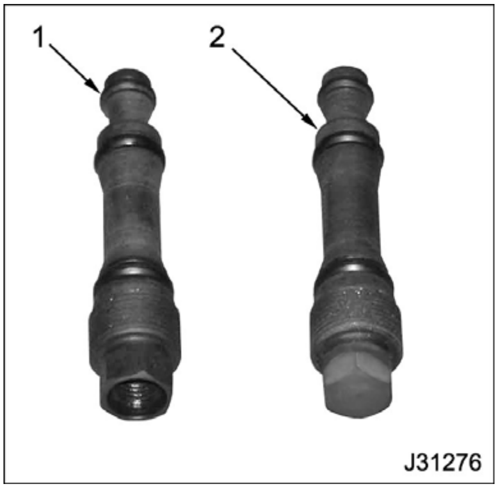

Figure 291 ZTSE4690

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 292 ZTSE4694–A

The Case-to-head Tube Removal Tool is used to remove Case-to-head tubes from the engine.

EGR Valve Block OFF Plug

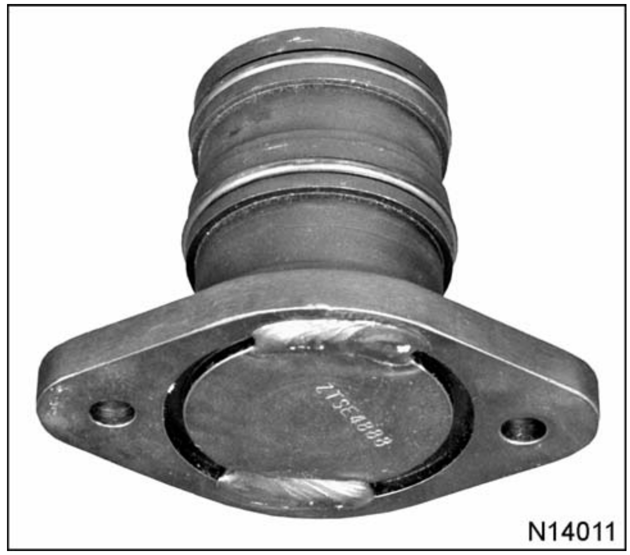

Figure 293 ZTSE4888

The EGR Valve Block OFF Plug is used to seal the EGR valve opening during intake manifold pressure testing.

EGR Cooler Pressure Test Plates

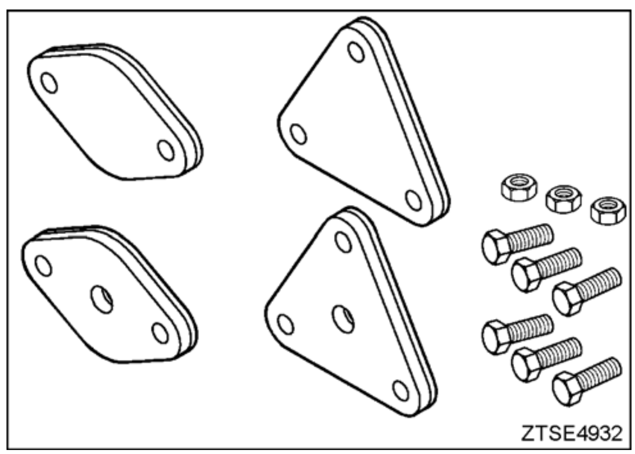

Figure 294 ZTSE4932

The EGR cooler test plates are a set of four plates with fasteners used for pressure testing the EGR cooler to check for leaks.

Fuel Inlet Restriction Adapter

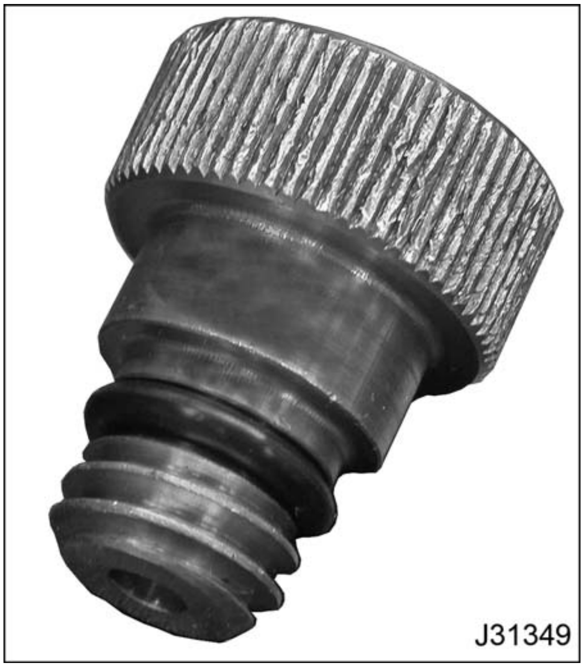

Figure 295 ZTSE4698

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 296 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 297 ZTSE4696

The Fuel Pressure Test Adapter is used to check fuel output from the HFCM to the secondary fuel filter.

In-line Shutoff Valve (part of ZTSE4409 Pressure Test Kit)

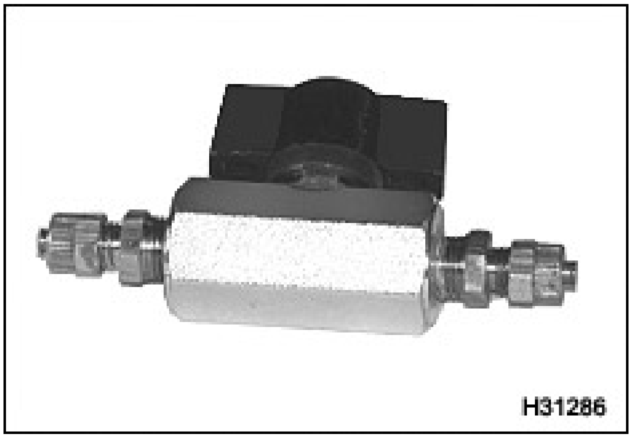

Figure 298 Part No. 221406

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.

Vacuum Pump and Gauge

Figure 299 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

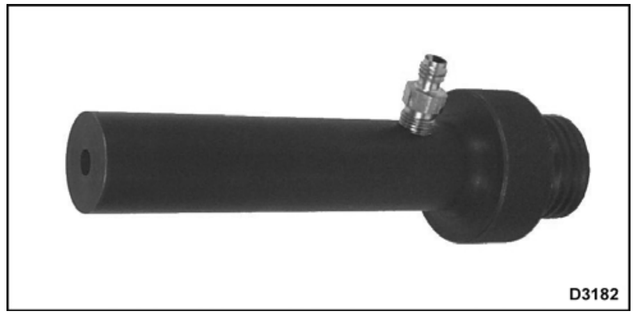

Figure 300 ZTSE4510

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 water 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.

Oil Fill Extension

Figure 301 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

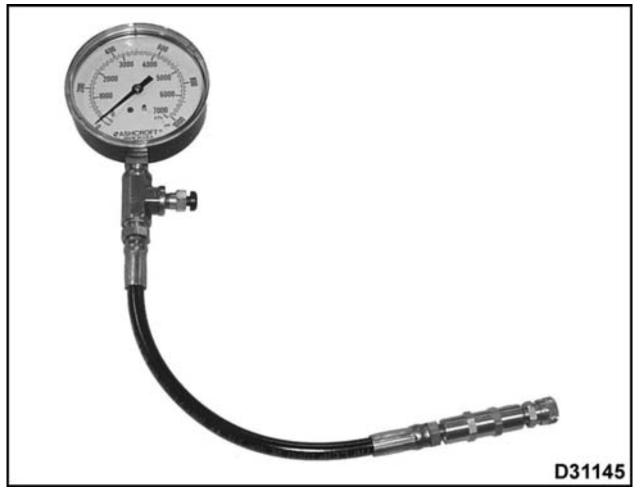

Figure 302 ZTSE2482A

The Cylinder Compression Gauge is used measure cylinder pressure (compression)

Compression Test Adapter

Figure 303 ZTSE4506

The Compression Test Adapter is used with a compression gauge to measure cylinder pressure (compression). Install it in place of a glow plug.

Oil Cooler Pressure Test Plate

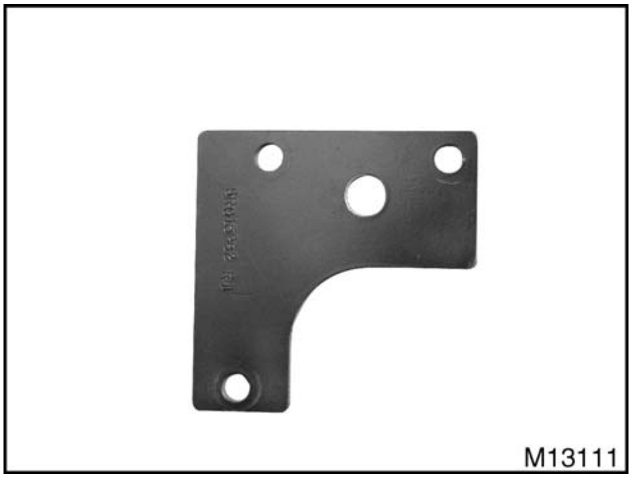

Figure 304 ZTSE4730

The Oil Cooler Pressure Test Plate is used to pressure test the oil cooler bundle for leaks.

Turbocharger Oil Supply Block Off Plug Kit

Figure 305 ZTSE4785

The Turbocharger Oil Supply Block Off Plug Kit is used to block off the turbocharger feed line and drain port so the engine can be operated to verify fuel system repairs.

Fuel Test Fitting

Figure 306 ZTSE4692

The Fuel Test Fitting is used to measure fuel inlet restriction or fuel pressure.

When measuring fuel inlet restriction, the fitting is installed at the diagnostic port (inlet-side) of the fuel filter housing.

When measuring fuel pressure, the fitting can be installed on the fuel rail instead of the Shrader valve.

The Fuel/Oil Pressure Test Coupler can then be connected to the Fuel Test Fitting to measure fuel pressure or fuel inlet restriction.

Electronic Circuit Testing

Electrical Theory

Voltage

Voltage is electrical potential or electromotive force that pushes current through a circuit. The pressure is measured in volts. The symbol V (for example, 12 V) is used 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.

Ohm's Law

Ohm's Law describes the relationship between current, voltage, and resistance in an electrical circuit.

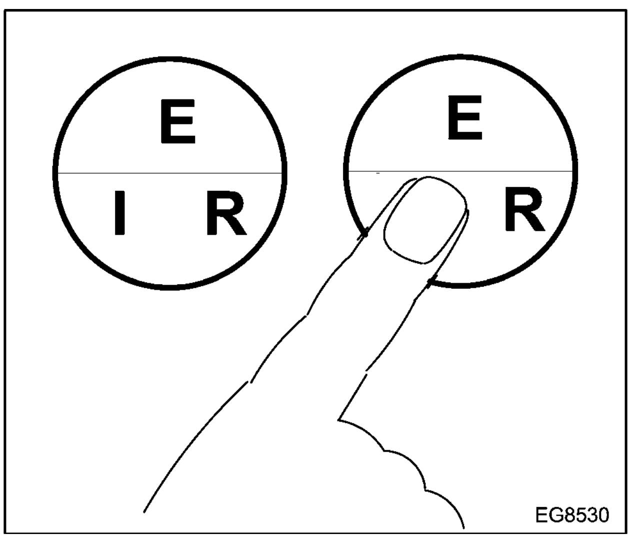

Figure 307 Ohm's Law

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

  Current flow (I) in the circuit equals the voltage (E) applied divided by the total resistance (R). This shows that an increase in voltage or a decrease in resistance increases current flow.

- E = I × R

  Voltage (E) applied to the circuit equals the current flow (I) multiplied by the total circuit resistance (R). Voltage drops are caused by resistance across the circuit and load devices in the circuit.

- R = E ÷ I

  Resistance (R) in the circuit equals the voltage (E) divided by the current flow (I). Resistance can be calculated for a specific current flow when a specific voltage is applied.

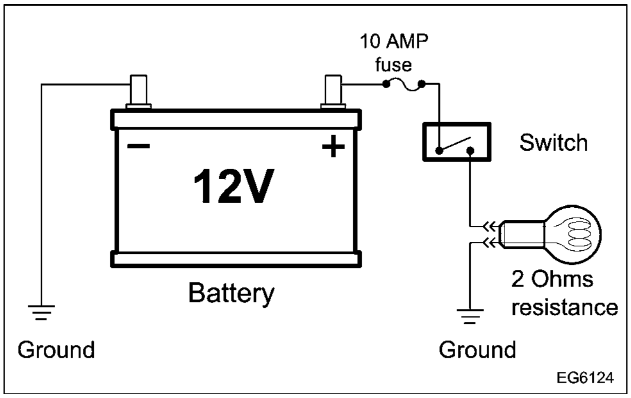

Figure 308 Simple electrical circuit

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:

Fill in the numbers for the formula:

I = 12 V ÷ 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 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

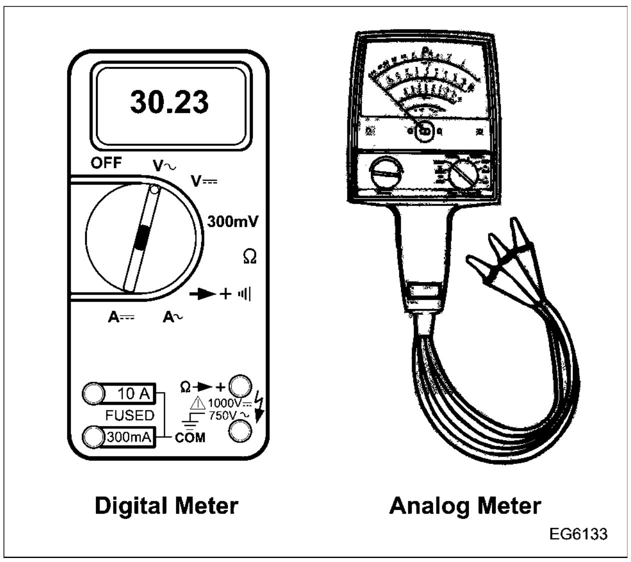

Figure 309 Typical Test Meters

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 (DMM) 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 an electronic circuit. Do not use any kind of battery powered test light. Battery test lights can damage an electronic control circuit.

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.

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?

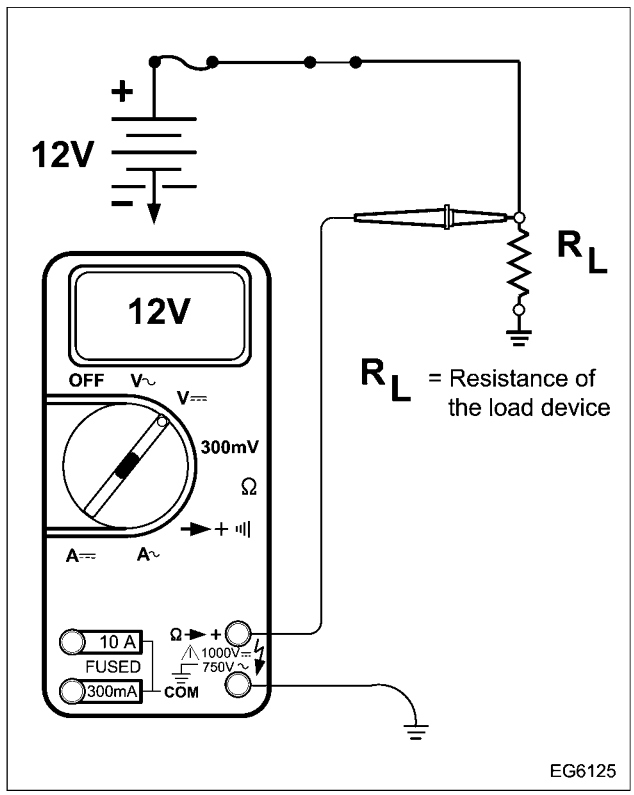

Figure 310 Checking power to a load device

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.

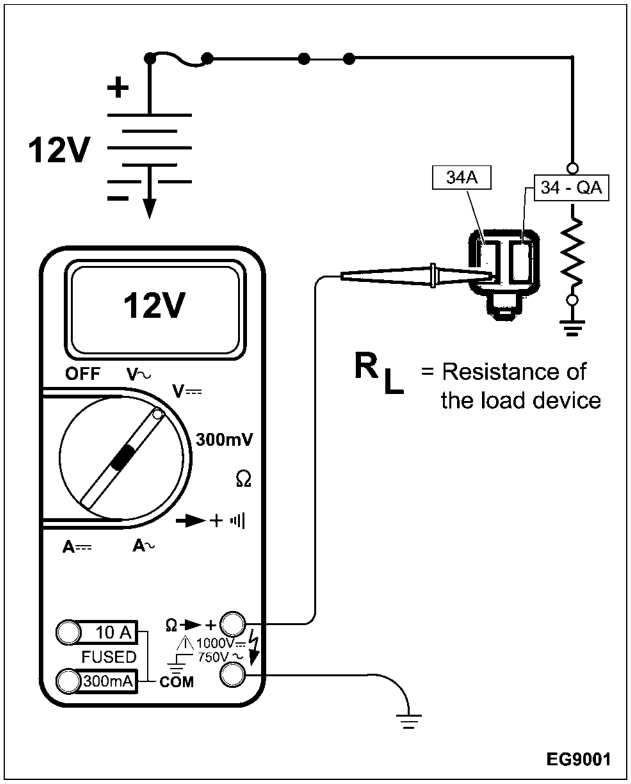

Figure 311 Checking power to a connector

Voltage to a device can also be measured by disconnecting the harness connector and using the correct tool in the Terminal Test Adapter Kit.

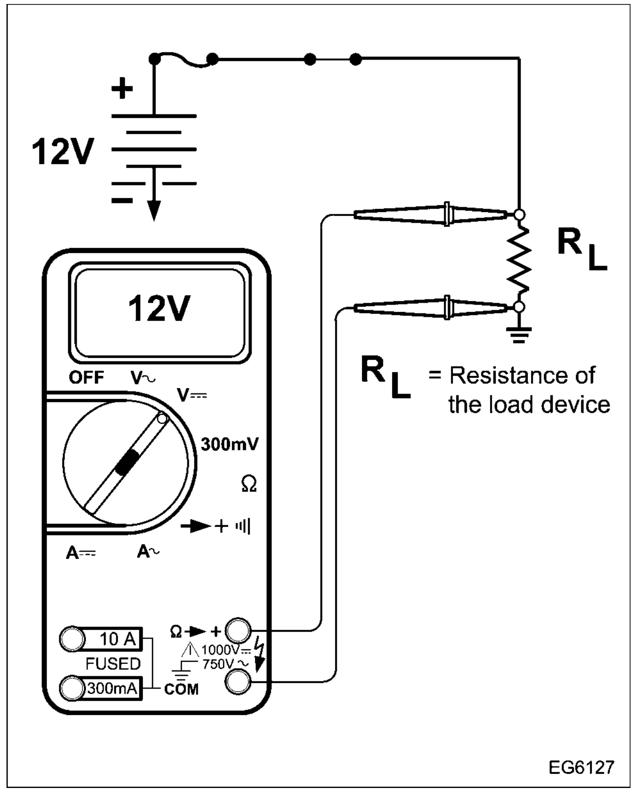

Figure 312 Checking voltage drop

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 9 V across the load, it indicates the wires and connections dropped 3 V, indicating excessive circuit resistance.

Ammeter

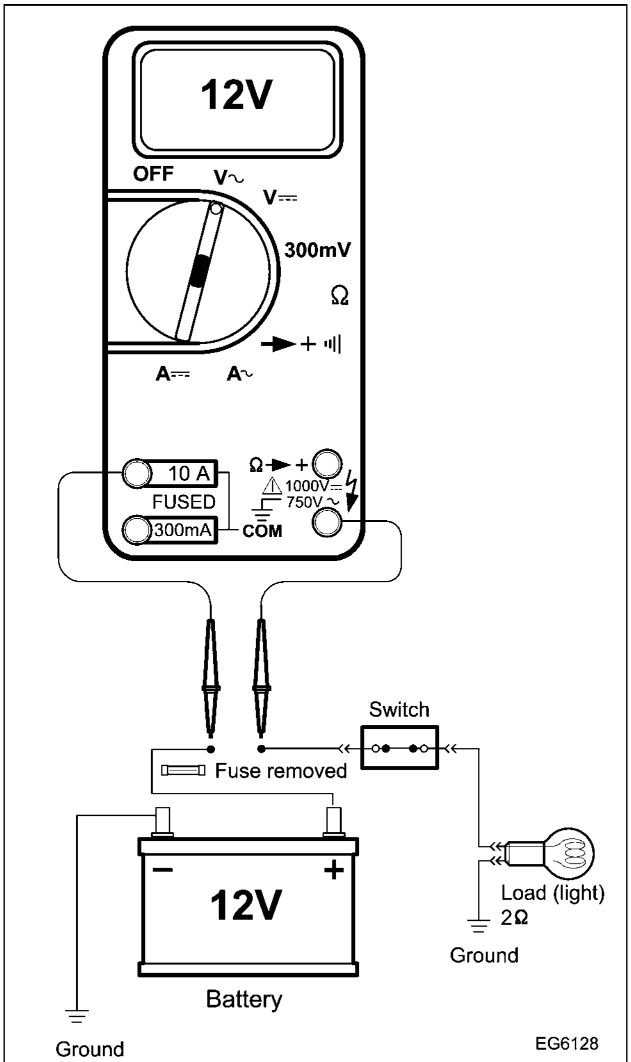

Figure 313 Installing the ammeter

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 (the specified current draw versus the actual measurement).

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 current flow only when the circuit is powered up and operating. The DMM is fused to measure up to 10 amps using the 10 A 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 = 12 V ÷ 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, turn power off before cutting, soldering, removing circuit components, or before inserting the digital multimeter for current measurements.

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 V 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. Range selection and meter adjustment are not necessary with the DMM.

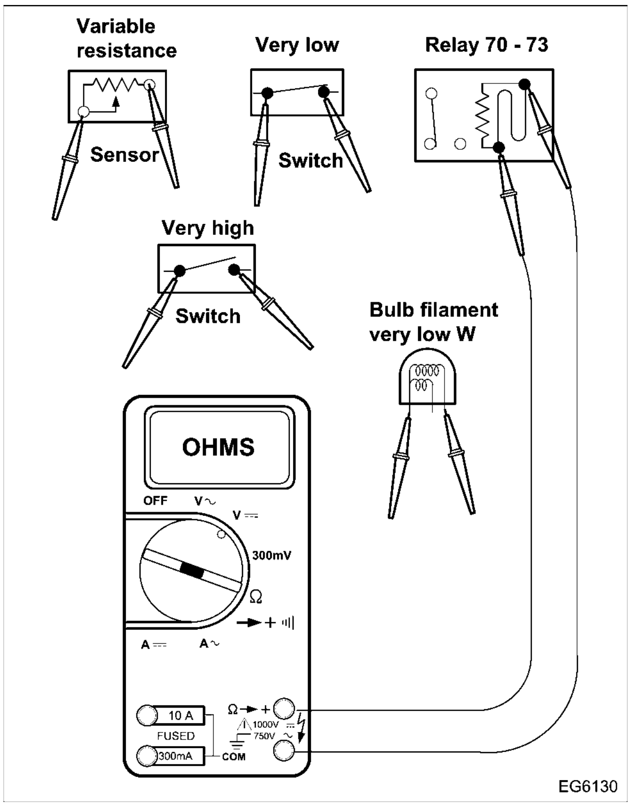

Figure 314 Measuring resistance

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.

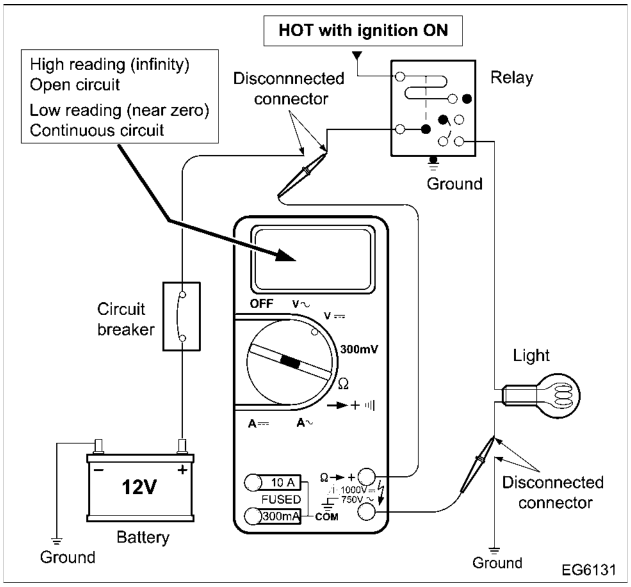

Figure 315 Checking for OPEN circuits

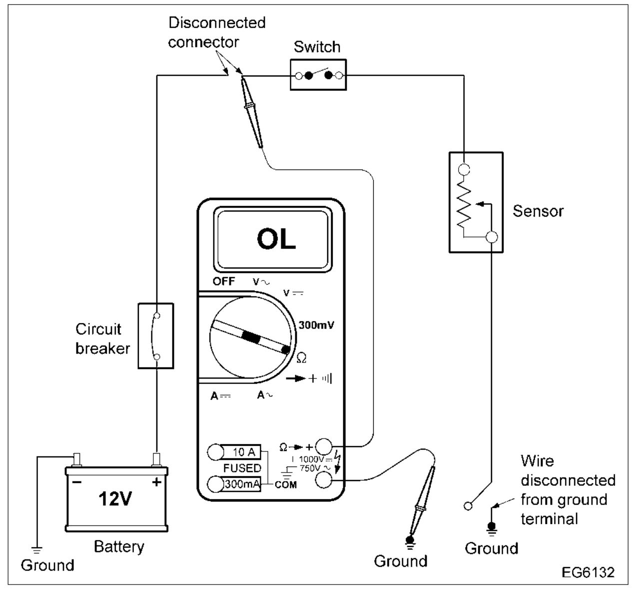

Figure 316 Checking for short circuits

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 (DMM), 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.

Measuring Duty Cycle with FLUKE 88 DMM

When measuring duty cycle, ensure that the large dial on the meter is pointing to volts DC, the DUTY button is set to the Duty Cycle function, and the trigger has a positive slope.

Use the following procedure to check duty cycle:

H31325

Figure 317 FLUKE 88 in volts dc mode

1. Turn the large dial on the meter to volts DC, indicated by V RPM.

H31324

Figure 318 FLUKE 88 with negative trigger slope in duty cycle mode

2. Press the % DUTY button to select duty cycle mode. The screen on the meter will show TRIG (with a _ under the TRIG) in the lower left hand corner of the screen. A percent sign will appear on the upper right hand corner of the screen.

Figure 319 FLUKE 88 in duty cycle mode with positive trigger slope

3. In duty cycle mode, press the ALERT button to change from negative to positive trigger slope. The slope is indicated by a plus or minus sign below TRIG in the lower left hand corner of the screen. A percent sign will appear on the upper right hand corner of the screen.
4. After the meter has been set to the correct settings, connect meter as indicated in Pin-point Diagnostics.

Jumper Wires

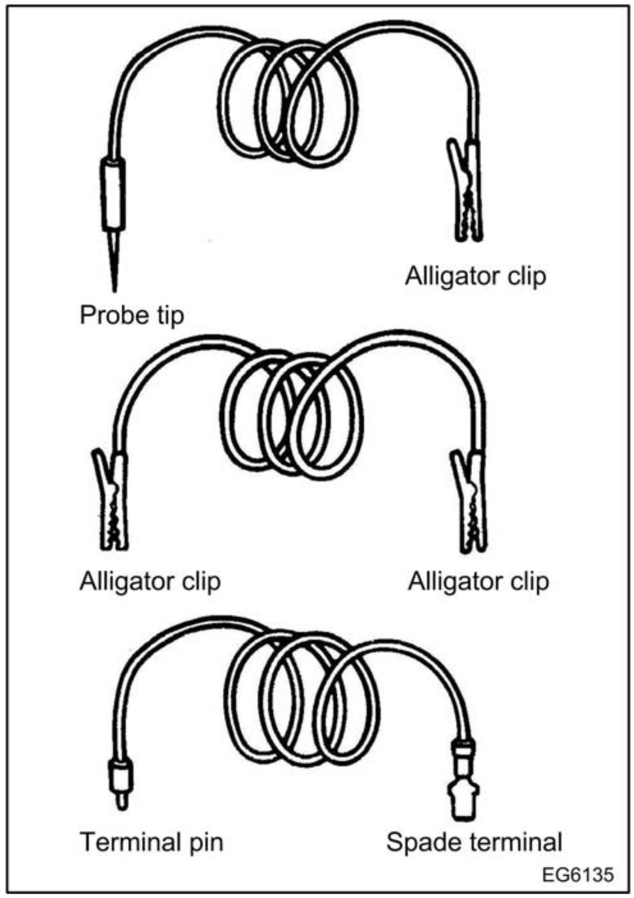

Figure 320 Jumper wires

Jumper wires allow a circuit to by-pass a suspected OPEN 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.

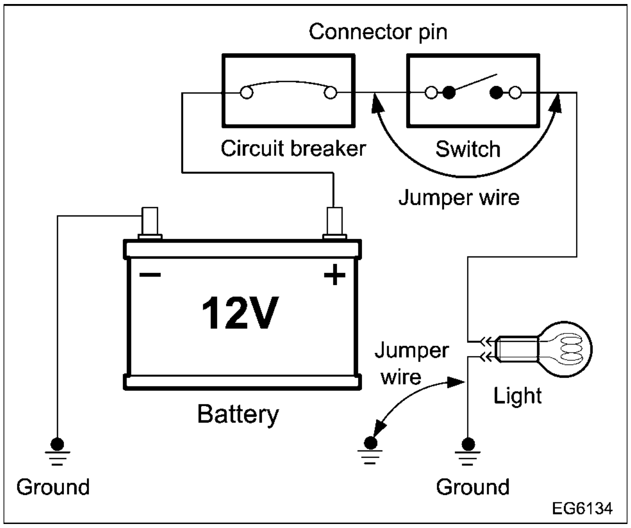

Figure 321 Troubleshooting with jumper wires

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 OPENs or breaks has continuity (uninterrupted current flow) and needs no further testing.

An OPEN 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.

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 (i.e., V_{REF}, signal ground, actuator power, actuator ground).

   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 “Electronic Control Systems Diagnostics”.

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.

Table of Contents

Abbreviations and Acronyms

Abbreviations and Acronyms

A or amp – Ampere
ABDC – After Bottom Dead Center
ABS – Antilock Brake System
AC – Alternating Current
A/C – Air Conditioner
ACC – Air Conditioner Control
ACCEL – Accelerate
ACD – Air Conditioner Demand
ACT PWR GND – Actuator Power Ground
AF – Air to Fuel ratio
AFT – Aftertreatment
AIT – Air Intake Temperature
Amb – Ambient
amp or A – Ampere
AMS – Air Management System
API – American Petroleum Institute
APS – Accelerator Position Sensor
APS/IVS – Accelerator Position Sensor / Idle Validation Switch
ASTM – American Society for Testing and Materials
ATA – American Trucking Association
ATDC – After Top Dead Center
AWG – American Wire Gauge

B+ or VBAT – Battery Voltage
BARO – Barometric Absolute Pressure
BBDC – Before Bottom Dead Center
BCP – Brake Control Pressure
BCS – Boost Control Solenoid
BDC – Bottom Dead Center
bhp – Brake Horsepower
BNO – Brake Normally Open
BOO – Brake On / Off
BPS – Brake Pressure Switch
BSV – Brake Shut-off Valve
BTDC – Before Top Dead Center
BTU – British Thermal Unit

C – Celsius
CAC – Charge Air Cooler
CAN – Controller Area Network
CAP – Cold Ambient Protection
CARB – California Air Resources Board
cc – Cubic centimeter
CCA – Cold Cranking Ampere
CID – Cubic Inch Displacement
cfm – Cubic feet per minute
cfs – Cubic feet per second
CKP – Crankshaft Position
CKPO – Crankshaft Position Out
cm – Centimeter
CMP – Camshaft Position
CMPO – Camshaft Position Out
CO – Carbon Monoxide
COO – Cruise On / Off switch
CPU – Central Processing Unit
CTC – Coolant Temperature Compensation
Cyl – Cylinder

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
DOC – Diesel Oxidation Catalyst
DPF – Diesel Particulate Filter
DT – Diesel Turbocharged
DTC – Diagnostic Trouble Code
DTRM – Diesel Thermo Recirculation Module

EBP – Exhaust Back Pressure
EBPD – Exhaust Back Pressure Desired
ECI – Engine Crank inhibit
ECL – Engine Coolant Level
ECM – Electronic Control Module
ECM PWR – Electronic Control Module Power
ECT – Engine Coolant Temperature
EFAN – Engine Fan
EFP – Engine Fuel Pressure
EFRC – Engine Family Rating Code
EFT – Engine Fuel Temperature
EG – Ethylene Glycol
EGC – Electronic Gauge Cluster
EGDP – Exhaust Gas Differential Pressure
EGR – Exhaust Gas Recirculating
EGRH – Exhaust Gas Recirculation High control
EGRL – Exhaust Gas Recirculation Low control
EGRP – Exhaust Gas Recirculating Position
EGT1 – Exhaust Gas Temperature 1
EGT2 – Exhaust Gas Temperature 2
EGT3 – Exhaust Gas Temperature 3
EMI – Electromagnetic Interference
EOP – Engine Oil Pressure
EOT – Engine Oil Temperature
EPA – Environmental Protection Agency
EPR – Engine Pressure Regulator
ESC – Electronic System Controller
ESN – Engine Serial Number
EST – Electronic Service Tool

EWPS – Engine Warning Protection System

F – Fahrenheit
FCV – Fuel Coolant Valve
FEL – Family Emissions Limit
fhp – Friction horsepower
FMI – Failure Mode Indicator
FPC – Fuel Pump Control
FPCV – Fuel Pressure Control Valve
fpm – Feet per minute
fps – Feet per second
FRP – Fuel Rail Pressure
ft – Feet
FVCV – Fuel Volume Control Valve

GND – Ground (electrical)
gal – Gallon
gal/h – U.S. Gallons per hour
gal/min – U. S. Gallons per minute
GCW – Gross Combined Weight
GCWR – Gross Combined Weight Rating
GPC – Glow Plug Control
GPD – Glow Plug Diagnostic
GPR – Glow Plug Relay
GVW – Gross Vehicle Weight

H_2O – Water
HC – Hydrocarbons
HEST – High Exhaust System Temperature
HFCM – Horizontal Fuel Conditioning Module
Hg – Mercury
hp – Horsepower
HPCR – High-Pressure Common Rail
HPFP – High-Pressure Fuel Pump
hr – Hour
Hyd – Hydraulic

IAT – Intake Air Temperature
IAHC – Inlet Air Heater Control
IAHD – Inlet Air Heater Diagnostic
IAHR – Inlet Air heater Relay
IC – Integrated Circuit
ICP – Injector Control Pressure
ID – Inside Diameter
IDM – Injector Drive Module
IGN – Ignition
ILO – Injector Leak Off
in – Inch
inHg – Inch of mercury
inH_2O – Inch of water
INJ – Injector
IPR – Injection Pressure Regulator
ISIS – International® Service Information System
IST – Idle Shutdown Timer
ITP – Internal Transfer Pump
ITV – Intake Throttle Valve
ITVH – Intake Throttle Valve High control
ITVL – Intake Throttle Valve Low control
ITVP – Intake Throttle Valve Position
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

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
LSD – Low Sulfur Diesel

m – Meter
m/s – Meters per second
MAF – Mass Air Flow
MAG – Magnetic
MAP – Manifold Absolute Pressure
MAT – Manifold Air Temperature
mep – Mean effective pressure
mi – Mile
mm – Millimeter
mpg – Miles per gallon
mph – Miles per hour
MPR – Main Power Relay
MSDS – Material Safety Data Sheet
MSG – Micro Strain Gauge
MSM – Multiplex System Module
MY – Model Year

NC – Normally closed (electrical)
NETS – Navistar Electronics Technical Support
Nm – Newton meter
NO – Normally Open (electrical)
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

PID – Parameter Identifier
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 Takeoff
PWM – Pulse Width Modulate
PWR – Power (voltage)

qt – Quart

RAM – Random Access Memory
RAS – Resume / Accelerate Switch (speed control)
REPTO – Rear Engine Power Takeoff
RFI – Radio Frequency Interference
rev – Revolution
rpm – Revolutions per minute
RPRE – Remote Preset
RSE – Radiator Shutter Enable
RVAR – Remote Variable

SAE – Society of Automotive Engineers®
SCA – Supplemental Cooling Additive
SCCS – Speed Control Command Switches
SCS – Speed Control Switch
SHD – Shield (electrical)
SID – Subsystem Identifier
SIG GRD – Signal Ground
S/N – Serial Number
SPN – Suspect Parameter 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

ULSD – Ultra Low Sulfur Diesel
UVC – Under Valve Cover

V – Volt
VBAT or B+ – Battery Voltage
VC – Volume Control
VEPS – Vehicle Electronics Programming System
VGT – Variable Geometry Turbocharger
VIGN – Ignition Voltage
VIN – Vehicle Identification Number
VOP – Valve Opening Pressure
VRE – Vehicle Retarder Enable
VREF – Reference Voltage
VSO – Vehicle Speed Output
VSS – Vehicle Speed Sensor

WEL – Warn Engine Lamp
WIF – Water In Fuel
WTEC – World Transmission Electronically Controlled automatic transmissions (Allison)

XMSN – Transmission

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Terminology

Terms

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 temperature 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 auto-ignition quality of diesel fuel.

2. A rating applied to diesel fuel similar to octane rating for gasoline.

3. A measure of how readily diesel fuel starts to burn (self-ignites) at high compression temperature.

Diesel fuel with a high cetane number self-ignites shortly after injection into the combustion chamber. Therefore, it has a short ignition delay time. Diesel fuel with a low cetane number resists self-ignition. Therefore, it has a longer ignition delay time.

Charge air – Dense, pressurized, heated air discharged from the turbocharger.

Charge Air Cooler (CAC) – See **Aftercooler**.

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).

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.

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 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 is run from a program in the processor.

Output Circuit Check (OCC) – An On demand test done during an Engine OFF self test to check the continuity of selected actuators.

pH – A measure of the acidity or alkalinity of a solution.

Particulate matter – Particulate matter includes mostly burned particles of fuel and engine oil.

Piezometer – An instrument for measuring fluid pressure.

Power – Power is a measure of the rate at which work 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 Modulate (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.

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.

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.

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 is 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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200 hp @ 2700 rpm

Engine model	International® MaxxForce™ 5
50 state 2008 Model Year (MY)	
Displacement	4.5 Liters
Engine rating	200 hp @ 2700 rpm (440 ft•lb @ 1800 rpm)
Engine unit code	12NTM (CityStar), 12NTT (Stripped Chassis)
Engine Family Rating Code (EFRC)	3111 (CityStar), 3112 (Stripped Chassis)
ECM part number	1883034C91
Injector part number, original equipment	1877748C1
Turbocharger part number	1877652C91
Injection timing	Nonadjustable
High idle speed - automatic transmission	3200 rpm
Low idle speed	700 rpm

Key On Engine Off

Barometric pressure @ 620 ft above sea level	99.62 kPa (14.44 psi) (absolute) / 4.00 V
Engine Oil Pressure	0 kPa (0 psi)
Exhaust Back Pressure	0 kPa (0 psi) / 0.72 V
Exhaust Gas Differential Pressure	0 kPa (0 psi) / 0.69 V
Injection Control Pressure	0 MPa (0 psi) / 0.29 V
Manifold boost pressure	0 kPa (0 psi) / 0.72 V
Accelerator Position Sensor (at idle)	0.67 V / 0 %
Accelerator Position Sensor (to the floor)	3.86 V / 100 %
Exhaust Gas Recirculation Valve Position	0 %
Intake Throttle Valve Position	1.1 V / 5 %
Fuel pump will run for 60 seconds at key ON.	
Engine fuel pressure (min)	310 kPa (45 psi)
Engine fuel pressure (max)	448 kPa (65 psi)
Fuel pump inlet restriction (max)	6 in Hg (20 kPa)

Engine Cranking

20 seconds maximum crank time per attempt. Wait 2 to 3 minutes before repeating.	
Cranking rpm (min)	130 rpm
Battery voltage (min)	9 V
Engine oil pressure	34.5 kPa (5 psi)
Injection Control Pressure (min to start engine)	3.5 MPa (507 psi) / 0.71 V
Exhaust Gas Recirculation Valve Position	always 0 %
Engine fuel pressure (min)	310 kPa (45 psi)

Low idle, stabilized engine operating temperature

Readings taken at 16 °C (60 °F) ambient temperature.	
Engine oil temperature should not go 6 °C (10 °F) above engine coolant temperature	
Engine Coolant Temperature (at thermostat opening)	89 °C (192 °F) / 1.13 V
Engine Coolant Temperature (max before DTC is set)	117 °C (242 °F) / 0.58 V
Manifold Air Temperature	72 °C (161 °F) / 1.6 V
Exhaust Back Pressure	4.4 kPa (0.64 psi) / 0.74 V
Injection Control Pressure	4.6 MPa (681 psi) / 0.98 V
Manifold boost pressure	0 kPa (0.0 psi) / 0.74 V
Engine fuel pressure (min)	310 kPa (45 psi)
Engine fuel pressure (max)	448 kPa (65 psi)
Fuel pump inlet restriction (max)	20 kPa (6 in Hg)
Engine Oil Pressure (min with gauge)	82.7 kPa (12 psi)

High idle, stabilized engine operating temperature

Air cleaner restriction (max)	6.2 kPa (25 in H_2O)
Exhaust Back Pressure	159 kPa (23 psi) / 1.96 V
Injection Control Pressure	12 MPa (1761 psi) / 2.15 V
Engine fuel pressure (min)	310 kPa (45 psi)
Engine fuel pressure (max)	448 kPa (65 psi)
Fuel pump inlet restriction (max with gauge)	20 kPa (6 in Hg)
Water temperature differential across radiator (top to bottom)	3 to 7 °C (6 to 12 °F)
Manifold boost pressure	69 kPa (10 psi) / 1.29 V
Crankcase pressure (max) using Crankcase Pressure Test Adapter ZTSE-4510	1.99 kPa (8 in H_2O)

Full load, rated speed on chassis dynamometer or highway, stabilized engine operating temperature

Air cleaner restriction (max)	6.2 kPa (25 in H_2O)
Exhaust Back Pressure (actual at rated speed)	269 kPa (39 psi) / 2.86 V
Injection Control Pressure	26.7 MPa (3879 psi) / 4.33 V
Engine fuel pressure (min)	310 kPa (45 psi)
Engine fuel pressure (max)	448 kPa (65 psi)
Fuel pump inlet restriction (max with gauge)	20 kPa (6 in Hg)
Manifold boost pressure (actual at rated speed)	193 kPa (28 psi) / 2.27 V

Component Specifications

Temperature Sensors (ECT, EOT, MAT)	
Temperature at -18 °C (0 °F)	4.65 V / 99.3 kΩ
Temperature at 0 °C (32 °F)	4.39 V / 93 kΩ
Temperature at 21 °C (70 °F)	3.78 V / 35.3 kΩ
Temperature at 66 °C (150 °F)	1.88 V / 6.26 kΩ
Temperature at 93 °C (200 °F)	1.02 V / 2.45 kΩ
Temperature Sensors (IAT)	
Temperature at -18 °C (0 °F)	4.25 V / 197 Ω
Temperature at 0 °C (32 °F)	3.86 V / 85.6 kΩ
Temperature at 21 °C (70 °F)	3.02 V / 34.5 kΩ
Temperature at 66 °C (150 °F)	1.16 V / 6.17 kΩ
Temperature Sensors (EGT1, EGT2, EGT3)	
Temperature at 21 °C (68°F)	0.88 V / 111.8 Ω
Temperature at 64 °C (148 °F)	1 V / 146.6 Ω
Temperature at 92 °C (198 °F)	1.05 V / 266.1 Ω
Temperature at 205 °C (401 °F)	1.29 V / 347.1 Ω
Temperature at 482 °C (899 °F)	1.76 V / 536 Ω

Other Components	
Camshaft position (CMP) sensor	616 to 1275 Ω
Crankshaft position (CKP) sensor	280 to 560 Ω
Injection Pressure Regulator (IPR) valve	5.6 Ω
Injector coil	1.0 Ω ± 0.5 Ω
Boost Control Solenoid (BCS)	40 to 44 Ω

Automatic Transmission

Torque converter stall	2200 rpm or greater @ 5 seconds or less

Actuator Output State Test

Injection Pressure Regulator (IPR) valve	Output state low – 0 % Output state high – 98 %
Exhaust Gas Recirculation (EGR) valve	Output state low – 0 % Output state high – 90 %

Use a pressure pump and ruler on the pneumatic actuator to measure the specs below.

Turbocharger pneumatic actuator – start of actuator travel.	103 kPa (15 psi)
Turbocharger pneumatic actuator travel – normal state to full travel	14.3 mm (9/16 in)

Inlet Air Heater

Amperage draw (at element)	45 to 70 amps within 2 seconds

Glow Plugs

Amperage draw (right side)	30 to 42 amps after 9 seconds
Amperage draw (left side)	30 to 42 amps after 9 seconds

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International® MaxxForce™ 5 Diagnostic Trouble Codes

DTC	SPN	FMI	Lamp	Circuit	Condition Description
1112	168	3	WEL	ECM PWR (page 252)	B+ out-of-range HIGH
1113	168	4	WEL	ECM PWR (page 252)	B+ out-of-range LOW
1114	110	4	WEL	ECT (page 262)	ECT signal out-of-range LOW
1115	110	3	WEL	ECT (page 262)	ECT signal out-of-range HIGH
1121	102	3	WEL	MAP (page 362)	MAP signal out-of-range HIGH
1122	102	4	WEL	MAP (page 362)	MAP signal out-of-range LOW
1124	164	4	MIL	ICP (page 325)	ICP signal out-of-range LOW
1125	164	3	MIL	ICP (page 325)	ICP signal out-of-range HIGH
1131	91	4	WEL	APS/IVS (page 210)	APS signal out-of-range LOW
1132	91	3	WEL	APS/IVS (page 210)	APS signal out-of-range HIGH
1133	91	2	WEL	APS/IVS (page 210)	APS in-range fault
1134	91	7	WEL	APS/IVS (page 210)	APS and IVS disagree
1135	558	11	WEL	APS/IVS (page 210)	IVS signal fault
1143	8021	2	WEL	CMP (page 235)	CMP signal incorrect for CKP sync
1144	8021	8	WEL	CKP (page 232)	CKP signal noise detected
1146	8064	12	WEL	CKP (page 232)	CKP signal inactive
1147	8064	2	WEL	CKP (page 232)	CKP incorrect signal signature
1151	108	3	WEL	ECM SELF (page 257)	BAP signal out-of-range HIGH
1152	108	4	WEL	ECM SELF (page 257)	BAP signal out-of-range LOW
1154	171	4	none	IAT (page 321)	IAT signal out-of-range LOW
1155	171	3	none	IAT (page 321)	IAT signal out-of-range HIGH
1156	102	0	MIL*	MAP (page 362)	MAP signal in-range HIGH MAP above BARO at start
1157	102	1	MIL*	MAP (page 362)	MAP signal in-range LOW MAP below BARO at start
1161	105	4	WEL	MAT (page 366)	MAT signal out-of-range LOW
1162	105	3	WEL	MAT (page 366)	MAT signal out-of-range HIGH
1221	536	2	none	CCS (page 229)	SCCS switch circuit fault
1222	597	2	none	BOO/BPS (page 222)	Brake switch circuit fault
1253	97	3	none	WIF (page 379)	WIF signal out-of-range LOW
1254	97	4	none	WIF (page 379)	WIF signal out-of-range HIGH

WEL – Warn Engine Lamp MIL – Malfunction Indicator Lamp OWL – Oil and Water Lamp

* Lamp is illuminated after second or third notification

DTC	SPN	FMI	Lamp	Circuit	Condition Description
1255	97	5	none	WIF (page 379)	WIF signal open circuit fault
1276	8366	6	WEL	IPR (page 350)	IPR short to B+, over temperature
1277	8366	5	WEL	IPR (page 350)	IPR short circuit
1287	3464	1	WEL*	ITV (page 357)	ITVL OCC self-test failed / ITV position control deviation below MIN threshold
1288	3464	0	WEL*	ITV (page 357)	ITVH OCC self-test failed / ITV position control deviation above MAX threshold
1293	7318	3	MIL	ITV (page 357)	ITVP signal out-of-range HIGH
1294	7318	4	MIL	ITV (page 357)	ITVP signal out-of-range LOW
1295	51	4	MIL	ITV (page 357)	ITV H-Bridge Electrical Check
1296	51	5	MIL	ITV (page 357)	ITV H-Bridge Electrical Check
1297	51	3	MIL	ITV (page 357)	ITV H-Bridge Electrical Check
1298	51	2	MIL	ITV (page 357)	ITV operation fault – under V, over amp, over temp / ITV H-bridge electrical check
1299	175	10	WEL*	EOT (page 298)	EOT in-range fault
1311	175	4	WEL	EOT (page 298)	EOT signal out-of-range LOW
1312	175	3	WEL	EOT (page 298)	EOT signal out-of-range HIGH
1328	164	2	MIL	ICP Sensor (page 325)	ICP signal constant
1362	412	0	WEL*	EGR (page 279)	EGR valve internal high circuit failure
1363	412	1	WEL*	EGR (page 279)	EGR valve internal low circuit failure
1374	7279	11	none	IAH (page 316)	IAH relay circuit fault
1375	7264	11	none	GPC (page 311)	Glow Plug Relay circuit fault
1396	7137	12	none	EGR (page 279)	EGRV initialization fault
1397	7137	4	none	EGR (page 279)	EGR position in-range fault
1398	8327	7	none	EGR (page 279)	EGR unable to achieve desired position
1729	3251	4	MIL	EGDP (page 274)	EGDP signal out-of-range LOW
1731	3251	3	MIL	EGDP (page 274)	EGDP signal out-of-range HIGH
1737	3241	4	MIL	EGT1 (page 283)	EGT1 signal out-of-range LOW
1738	3241	3	MIL	EGT1 (page 283)	EGT1 signal out-of-range HIGH
1741	3242	4	MIL	EGT2 (page 287)	EGT2 signal out-of-range LOW
1742	3242	3	MIL	EGT2 (page 287)	EGT2 signal out-of-range HIGH
1744	3245	4	MIL	EGT3 (page 291)	EGT3 signal out-of-range LOW
1745	3245	3	MIL	EGT3 (page 291)	EGT3 signal out-of-range HIGH

WEL – Warn Engine Lamp MIL – Malfunction Indicator Lamp OWL – Oil and Water Lamp

* Lamp is illuminated after second or third notification

DTC	SPN	FMI	Lamp	Circuit	Condition Description
2179	97	2	none	WIF (page 379)	Water in fuel detected
2313	100	1	OWL	EWPS (page 302)	EOP below Warning level
2314	100	7	OWL	EWPS (page 302)	EOP below Critical level
2315	190	0	none	EWPS (page 302)	Engine speed above Warning level
2319	518	2	none	EWPS (page 302)	Torque limited to control engine overheat
2321	110	0	OWL	EWPS (page 302)	ECT above Warning level
2322	110	7	OWL	EWPS (page 302)	ECT above Critical level
2323	111	1	OWL	EWPS (page 302) and ECL (page 249)	ECL below Warning / Critical level
2324	593	14	OWL	IST (page 354)	Engine stopped by IST
2327	164	10	none	ICP SYS (page 330)	ICP abnormal rate of change
2332	164	13	MIL*	ICP Sensor (page 325)	ICP above KOEO spec
2335	8392	1	none	ICP SYS (page 330)	ICP unable to build during engine cranking
2338	1639	1	WEL	EFAN (page 267)	Engine fan speed too low.
2351	7129	1	MIL*	AMS (page 207)	EBP below desired level
2352	7129	0	MIL*	AMS (page 207)	EBP above desired level
2368	8146	7	WEL	EGR (page 279)	EGR valve communication fault
2369	1378	2	none		Engine oil service required
2372	94	1	WEL	EFP (page 271)	Fuel pressure below normal
2388	2659	0	MIL*	AMS (page 207)	EGR flow excessive - possible leak to atmosphere
2389	2659	1	MIL*	AMS (page 207)	EGR flow insufficient - possible plugged system
2391	2791	11	MIL	EGR (page 279)	EGR valve internal circuit failure
2392	7138	6	MIL	EGR (page 279)	EGR duty cycle above limit
2393	7137	2	MIL	EGR (page 279)	EGR position sensor fault
2394	8146	2	MIL	EGR (page 279)	EGR valve not receiving ECM CAN messages
2395	7317	3	WEL*	EGR (page 279)	EGRH OCC self-test failed
2396	7317	4	WEL*	EGR (page 279)	EGRL OCC self-test failed
2543	1136	2	none	CAN public (page 225)	CAN error present, missing message from TCM
2544	8329	7	none	CAN public (page 225)	ECM unable to send CAN messages
2614	7277	10	WEL	FPC (page 306)	Fuel Pump Relay circuit fault
2673	3242	2	MIL	EGT2 (page 287)	EGT2 not warming along with engine
2674	3242	2	MIL	EGT2	EGT2 reading off compared to EGT1 and EGT3

WEL – Warn Engine Lamp MIL – Malfunction Indicator Lamp OWL – Oil and Water Lamp

* Lamp is illuminated after second or third notification

DTC	SPN	FMI	Lamp	Circuit	Condition Description
2675	3241	2	MIL	EGT1 (page 283)	EGT1 temp not increasing with engine temp
2676	3241	1	MIL	EGT1 (page 283)	EGT1 reading off compared to EGT2 and EGT3
2677	3245	2	MIL	EGT3 (page 291)	EGT3 not warming along with engine
2678	3245	1	MIL	EGT3 (page 291)	EGT3 reading off compared to EGT1 and EGT2
2681	3242	1	WEL*	EGT2 (page 287)	EGT2 reading off compared to EGT1 and EGT3
2688	8302	0	MIL	AFT SYS (page 200)	DPF over temperature - possible filter damage
2699	3251	1	MIL	EGDP (page 274)	EGDP below desired level
2732	3251	2	MIL*	EGDP (page 274)	EGDP stuck in-range fault
2733	3251	10	MIL*	EGDP (page 274)	EGDP mismatch between key-on/off
2782	8317	13	WEL*	AFT SYS (page 200)	DPF servicing required
2783	8318	13	none	AFT SYS (page 200)	DPF load: above Warning level
2784	8319	13	WEL	AFT SYS (page 200)	DPF load: above Critical level 1 - engine de-rate
2785	8320	13	WEL	AFT SYS (page 200)	DPF load: above Critical level 2 - further engine de-rate
3333	8492	0	MIL*	ICP SYS (page 330)	ICP above desired level
3334	8492	1	MIL*	ICP SYS (page 330)	ICP below desired level
3341	1209	4	MIL	EBP (page 240)	EBP signal out-of-range LOW
3342	1209	3	MIL	EBP (page 240)	EBP signal out-of-range HIGH
3373	164	15	WEL	ICP SYS (page 330)	ICP too high during test
3374	164	17	none	ICP SYS (page 330)	ICP unable to build during test
4411	8001	6	WEL	INJ (page 335)	Cyl 1 close coil: open circuit
4412	8002	6	WEL	INJ (page 335)	Cyl 2 close coil: open circuit
4413	8003	6	WEL	INJ (page 335)	Cyl 3 close coil: open circuit
4414	8004	6	WEL	INJ (page 335)	Cyl 4 close coil: open circuit
4415	8005	6	WEL	INJ (page 335)	Cyl 5 close coil: open circuit
4416	8006	6	WEL	INJ (page 335)	Cyl 6 close coil: open circuit
4421	8001	5	WEL	INJ (page 335)	Cyl 1 open coil: open circuit
4422	8002	5	WEL	INJ (page 335)	Cyl 2 open coil: open circuit
4423	8003	5	WEL	INJ (page 335)	Cyl 3 open coil: open circuit
4424	8004	5	WEL	INJ (page 335)	Cyl 4 open coil: open circuit
4425	8005	5	WEL	INJ (page 335)	Cyl 5 open coil: open circuit
4426	8006	5	WEL	INJ (page 335)	Cyl 6 open coil: open circuit
4431	8001	4	WEL	INJ (page 335)	Cyl 1 open coil: short circuit

WEL – Warn Engine Lamp MIL – Malfunction Indicator Lamp OWL – Oil and Water Lamp

* Lamp is illuminated after second or third notification

DTC	SPN	FMI	Lamp	Circuit	Condition Description
4432	8002	4	WEL	INJ (page 335)	Cyl 2 open coil: short circuit
4433	8003	4	WEL	INJ (page 335)	Cyl 3 open coil: short circuit
4434	8004	4	WEL	INJ (page 335)	Cyl 4 open coil: short circuit
4435	8005	4	WEL	INJ (page 335)	Cyl 5 open coil: short circuit
4436	8006	4	WEL	INJ (page 335)	Cyl 6 open coil: short circuit
4441	8001	3	WEL	INJ (page 335)	Cyl 1 close coil: short circuit
4442	8002	3	WEL	INJ (page 335)	Cyl 2 close coil: short circuit
4443	8003	3	WEL	INJ (page 335)	Cyl 3 close coil: short circuit
4444	8004	3	WEL	INJ (page 335)	Cyl 4 close coil: short circuit
4445	8005	3	WEL	INJ (page 335)	Cyl 5 close coil: short circuit
4446	8006	3	WEL	INJ (page 335)	Cyl 6 close coil: short circuit
4515	8151	5	WEL	INJ (page 335)	Bank A injector open coil short
4516	8151	6	WEL	INJ (page 335)	Bank A injector close coil short
4521	8152	5	WEL	INJ (page 335)	Bank B injector open coil short
4522	8152	6	WEL	INJ (page 335)	Bank B injector close coil short
4551	8021	12	WEL	CMP (page 235)	CMP signal inactive
4552	8022	2	WEL	CMP (page 235)	CMP loss of sync
4553	8022	12	WEL	CKP (page 232)	CKP signal inactive
4554	8022	7	WEL	CKP (page 232)	CKP loss of sync
4555	8064	8	WEL	CKP (page 232)	CKP signal noise detected
4556	8022	8	WEL	CKP (page 232)	CKP period too short
4611	8021	13	WEL	CKP (page 232)	CKP signature one tooth off
4612	8021	7	WEL	CMP (page 235) and CKP (page 232)	CMP to CKP incorrect reference
5382	1136	0	WEL	ECM SELF (page 257)	ECM error – over temperature
5618	8334	2	none	ECM SELF (page 257)	ECM error – SPI-BUS error 1
5619	8334	12	none	ECM SELF (page 257)	ECM error – SPI-BUS error 2
5627	8333	12	none	ECM SELF (page 257)	ECM error – Checksum program
5628	8333	2	none	ECM SELF (page 257)	ECM error – Checksum dataset
5632	8254	12	none	ECM SELF (page 257)	ECM error – RAM/CPU self-test fault
5633	8254	0	none	ECM SELF (page 257)	ECM error – CPU load above maximum
5634	8336	12	none	ECM SELF (page 257)	ECM error – MQPS daisy chain failure
5635	8337	12	none	ECM SELF (page 257)	ECM error – OCT daisy chain failure

WEL – Warn Engine Lamp MIL – Malfunction Indicator Lamp OWL – Oil and Water Lamp

* Lamp is illuminated after second or third notification

DTC	SPN	FMI	Lamp	Circuit	Condition Description
5636	8338	12	none	ECM SELF (page 257)	ECM error – QPS daisy chain failure
5644	190	2	WEL	ECM SELF (page 257)	ECM error – Engine speed limitation
5645	7253	7	none	ECM SELF (page 257)	ECM error – EEPROM failure
5646	190	14	WEL	ECM SELF (page 257)	ECM error – Engine Speed: monitoring
5649	1136	14	WEL	ECM SELF (page 257)	ECM error – A/D conversion monitoring
5652	8240	14	none	ECM SELF (page 257)	ECM error – NVMY channel
5653	8300	14	WEL	ECM SELF (page 257)	ECM error – PPS monitoring
5656	8335	14	WEL	ECM SELF (page 257)	ECM error – Processor monitoring
5666	8339	4	WEL	VREF (page 372)	VREF engine voltage below min
5667	8339	3	WEL	VREF (page 372)	VREF engine voltage above max
5668	8340	4	WEL	VREF (page 372)	VREF chassis voltage below min
5669	8340	3	WEL	VREF (page 372)	VREF chassis voltage above max
5671	8341	4	WEL	VREF (page 372)	VREF body voltage below min
5672	8341	3	WEL	VREF (page 372)	VREF body voltage above max

WEL – Warn Engine Lamp MIL – Malfunction Indicator Lamp OWL – Oil and Water Lamp

* Lamp is illuminated after second or third notification

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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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