

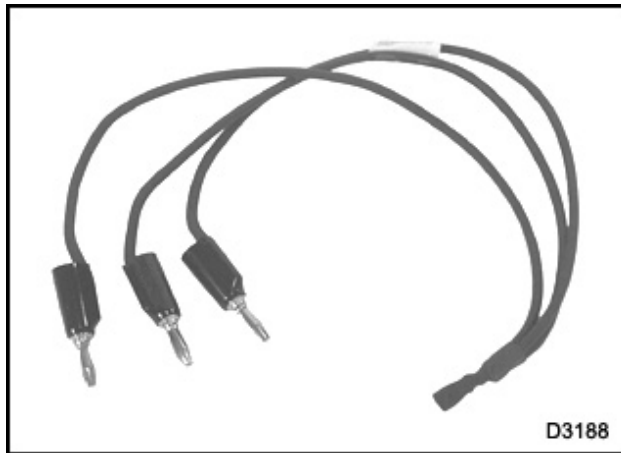
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## Electrical Tools

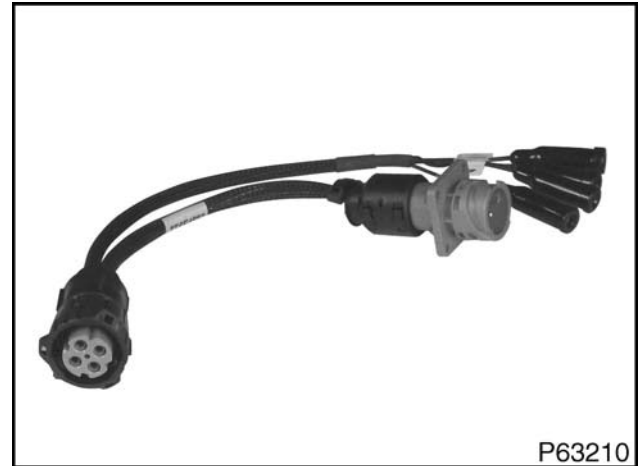
### 3-Banana Plug Harness



**Figure 288 ZTSE4498**

The 3-Banana Plug Harness is used for operational diagnostics of sensor circuits.

### 4-Pin Round Blue Breakout Harness



**Figure 290 ZTSE4883**

The 4-Pin Round Blue Breakout Harness is used to measure voltage and resistance on circuits connected to the Manifold Air Temperature (MAT) sensor.

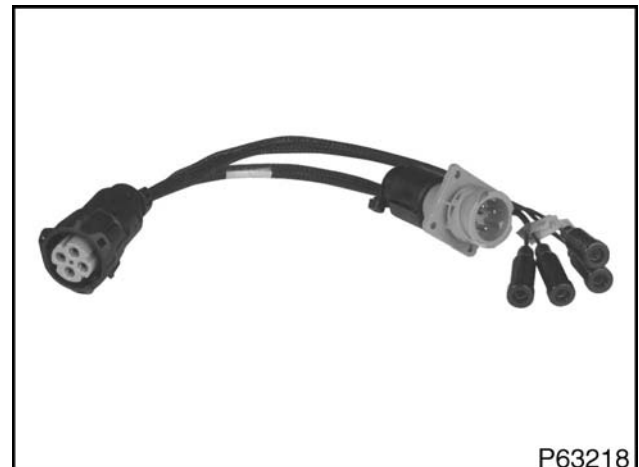
### 4-Pin Round Black Breakout Harness



**Figure 289 ZTSE4827**

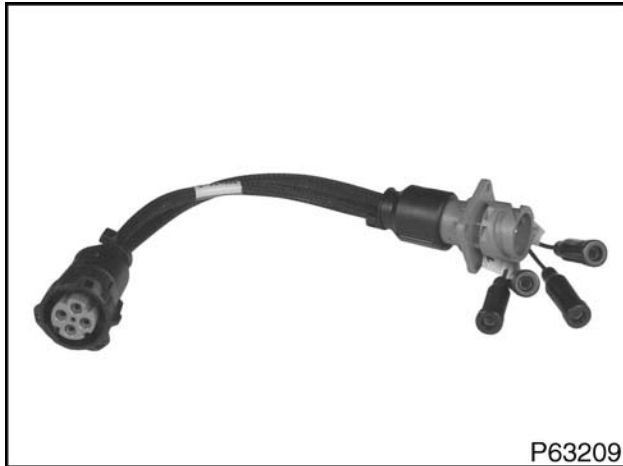
The 4-Pin Round Black Breakout Harness is used to measure voltage and resistance on circuits connected to the Exhaust Gas Recirculation (EGR) control valve, Engine Coolant Temperature (ECT) sensors, Engine Oil Temperature (EOT) sensor, and Cold Start Solenoid (CSS).

### 4-Pin Round Gray Breakout Harness



**Figure 291 ZTSE4881**

The 4-Pin Round Gray Breakout Harness is used to measure voltage and resistance on circuits connected to the Engine Fuel Pressure (EFP) sensor.

**4-Pin Round Green Breakout Harness**

P63209

**Figure 292 ZTSE4882**

The 4-Pin Round Green Breakout Harness is used to measure voltage and resistance on circuits connected to the Engine Oil Pressure (EOP) sensor.

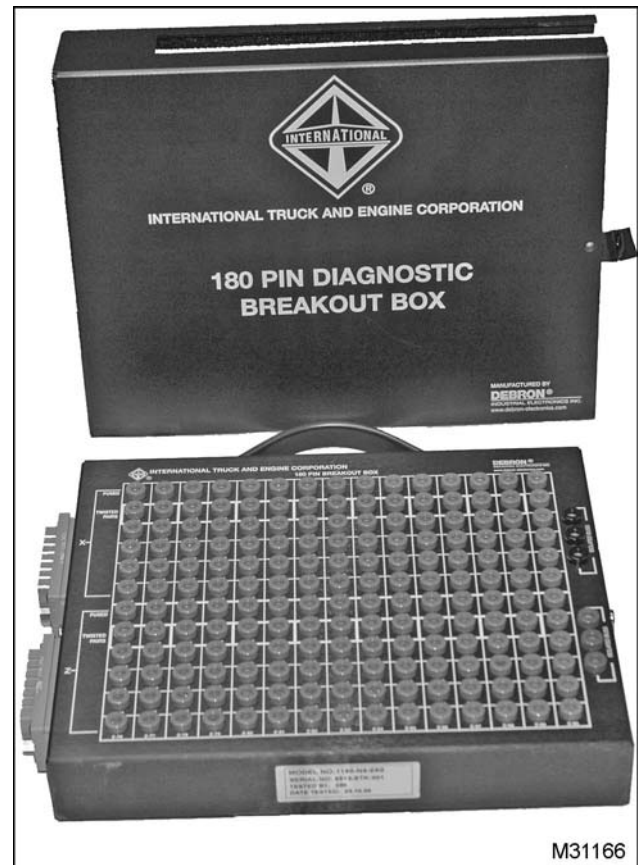
**96-Pin Breakout Box – DLC II**

H31274

**Figure 293 ZTSE4582**

The 96-Pin Breakout Box – DLC II allows testing of the Engine Interface Module (EIM) controlled components without disturbing connections or piercing wire insulation when accessing various signal voltages in the electronic control system.

**CAUTION:** To prevent damage to the breakout box, the breakout box is used for measurement only, not to activate or control circuits. High current levels passing through the breakout box will burn out the internal circuitry.

**180-Pin Breakout Box**

M31166

**Figure 294 1180-N4-0X0**

The 180-Pin Breakout Box allows testing of the Engine Control Module (ECM) and Aftertreatment Control Module (ACM) controlled components without disturbing connections or piercing wire insulation when accessing various signal voltages in the electronic control system.

**CAUTION:** To prevent damage to the breakout box, the breakout box is used for measurement only, not to activate or control circuits. High current levels passing through the breakout box will burn out the internal circuitry.

This box is a universal type box that 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.

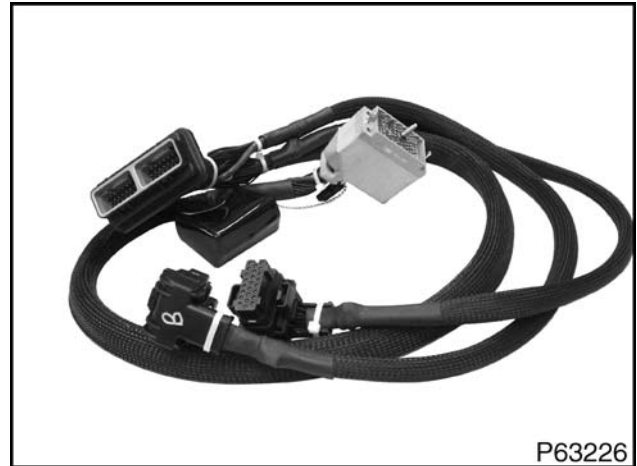
### 500 Ohm Resistor Harness



**Figure 295 ZTSE4497**

The 500 Ohm Resistor Harness is used for sensor end diagnostics of sensor circuits.

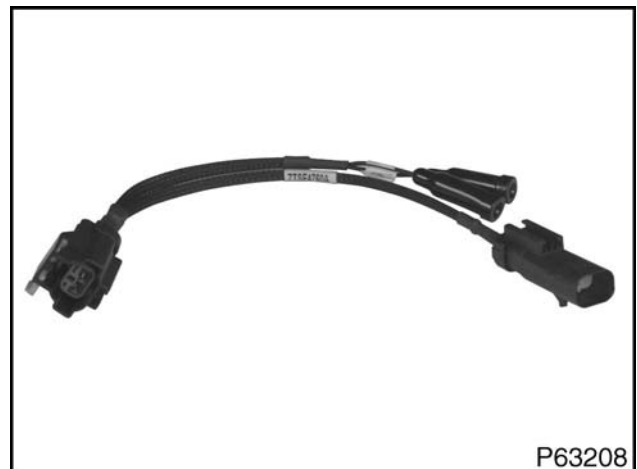
### Aftertreatment Harness



**Figure 296 00-01161-00**

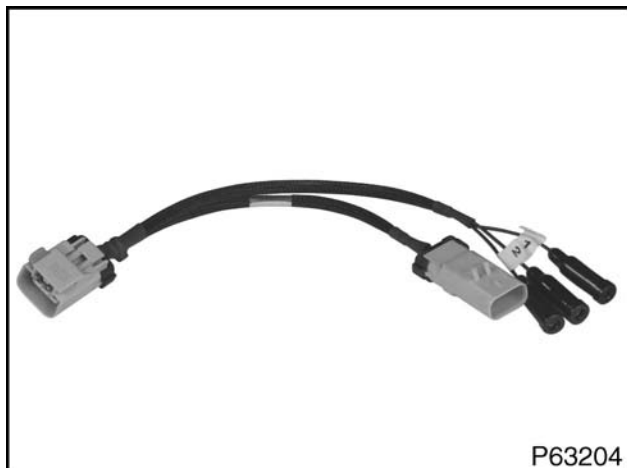
The Aftertreatment Harness with breakout box overlay (pin identifier) sheet is used with the 180-pin breakout box to test circuits connected to the ACM.

### Aftertreatment 2-Pin Breakout Harness



**Figure 297 ZTSE4760A**

The Aftertreatment 2-Pin Breakout Harness is used to measure voltage and resistance on circuits connected to the Exhaust Gas Temperature (EGT) sensors, Aftertreatment Fuel Supply (AFS) valve, Aftertreatment Fuel Injector (AFI), and Aftertreatment Fuel Drain (AFD) valve.

**Aftertreatment Fuel Pressure Breakout Harness****Figure 298 ZTSE4845**

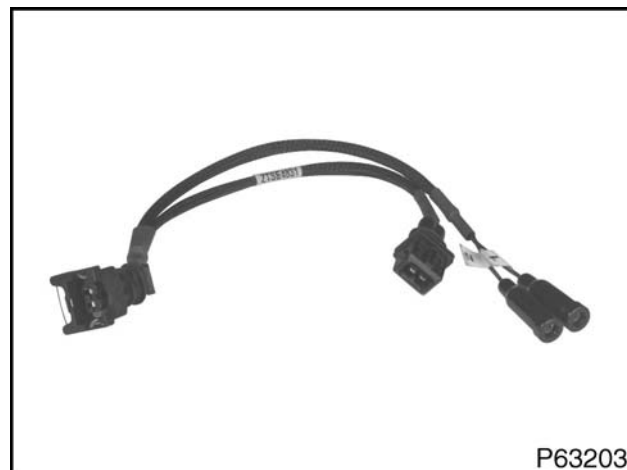
The Aftertreatment Fuel Pressure Breakout Harness is used to measure the voltage and resistance on circuits connected to the Aftertreatment Fuel Pressure (AFP) sensor.

**Amp Clamp****Figure 299 ZTSE4575**

The Amp Clamp is used to measure amperage draw for the cold start assist system glow plug.

**APS/IVS Sensor Breakout Harness****Figure 300 ZTSE4485A**

The APS/IVS Sensor Breakout Harness is used to measure voltage and resistance on circuits connected to the APS/IVS sensor.

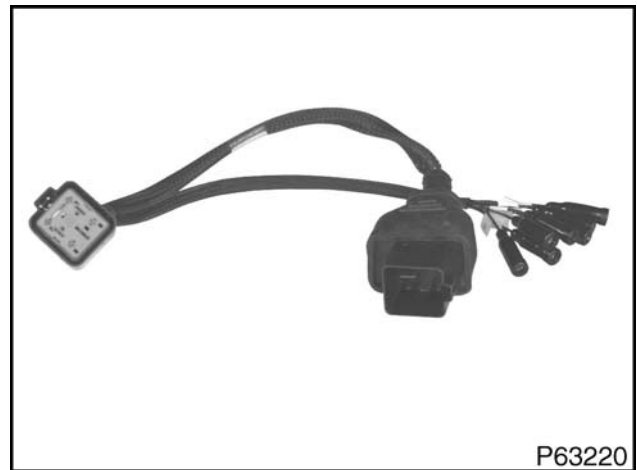
**Boost Control Solenoid Breakout Harness****Figure 301 ZTSE4831**

The Boost Control Solenoid Breakout Harness is used to measure voltage and resistance on circuits connected to the Boost Control Solenoid (BCS) valve.

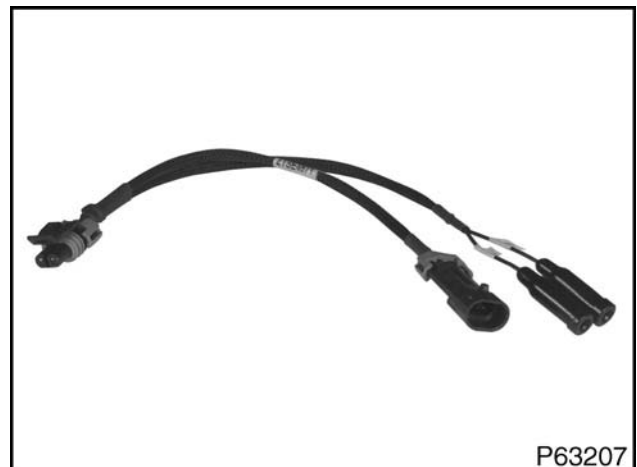
**Breakout Harnesses Kit****Figure 302 ZTSE4904**

The Breakout Harness Kit contains the following:

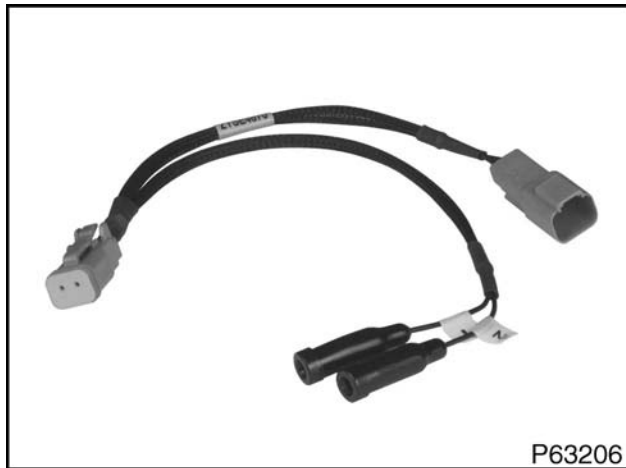
- 4-Pin Round Black Breakout Harness
- 4-Pin Round Blue Breakout Harness
- 4-Pin Round Gray Breakout Harness
- 4-Pin Round Green Breakout Harness
- Aftertreatment 2-Pin Breakout Harness
- Aftertreatment Fuel Pressure Breakout Harness
- APS/IVS Sensor Breakout Harness
- Boost Control Solenoid Breakout Harness
- CMP, CKP and FPCV Breakout Harness
- Coolant Flow Valve Breakout Harness
- Coolant Mixer Valve Breakout Harness
- Cold Start Relay Breakout Harness
- EGDP Breakout Harness
- EGR Position and ITV Breakout Harness
- EIM Power Relay Breakout Harness
- ELS and V8 EGR breakout Harness
- Engine Fan Control Breakout Harness
- FRP Breakout Harness
- MAP/IAT2 Breakout Harness
- Retarder Control Breakout Harness

**Cold Start Relay Breakout Harness****Figure 303 ZTSE4885**

The Cold Start Relay Breakout Harness is used to measure voltage and resistance on circuits connected to the Cold Start Relay (CSR).

**Coolant Flow Valve Breakout Harness****Figure 304 ZTSE4871**

The Coolant Flow Valve Breakout Harness is used to measure voltage and resistance on circuits connected to the Coolant Flow Valve (CFV).

**Coolant Mixer Valve Breakout Harness****Figure 305 ZTSE4870**

The Coolant Mixer Valve Breakout Harness is used to measure voltage and resistance on circuits connected to the Coolant Mixer Valve (CMV).

**CMP, CKP and FPCV Breakout Harness****Figure 306 ZTSE4828**

The CMP, CKP and FPCV Breakout Harness is used to measure voltage and resistance on circuits

connected to the Fuel Pressure Control Valve (FPCV), Crankshaft Position (CKP) sensor and Camshaft Position (CMP) sensor.

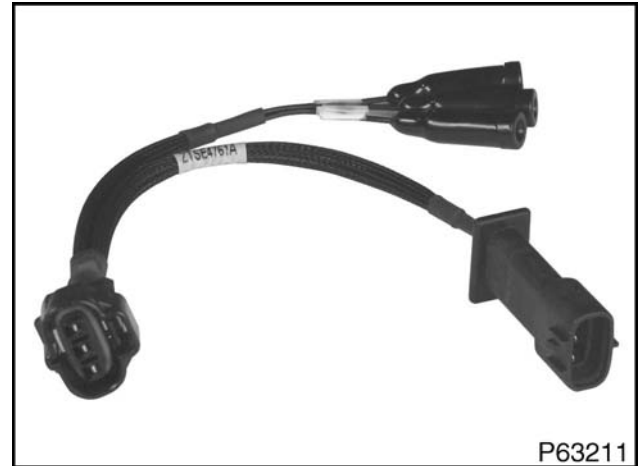
**Digital Multimeter (DMM) (Fluke 88V)****Figure 307 ZTSE4357**

The Digital Multimeter (DMM) (Fluke 88V) 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 is not affected by the voltmeter.



**E1-Engine Harness****Figure 308 00-01160-00**

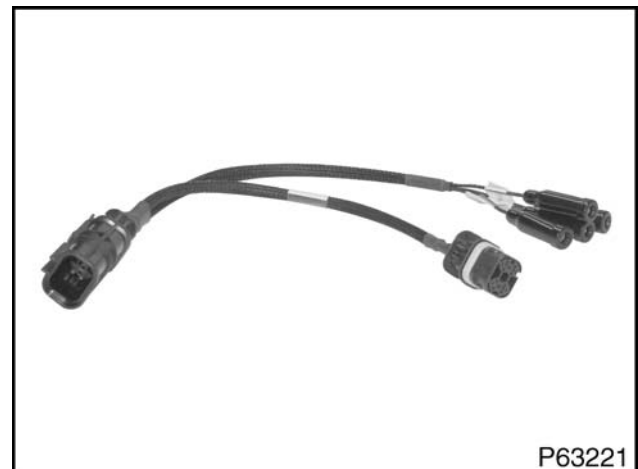
The E1-Engine Harness with breakout box overlay (pin identifier) sheet is used with the 180-pin breakout box to test circuits connected to the ECM E1 connector.

**EGDP Breakout Harness****Figure 310 ZTSE4761A**

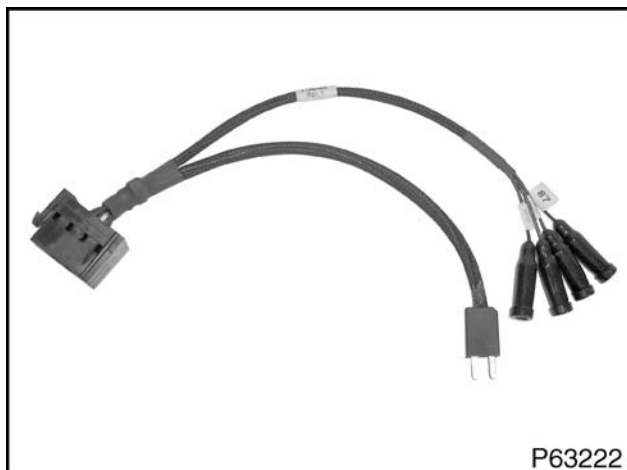
The EGDP Breakout Harness is used to measure voltage and resistance on circuits connected to the Exhaust Gas Differential Pressure (EGDP) sensor.

**E2-Engine, D-Injector, C-Chassis Harness****Figure 309 00-01162-00**

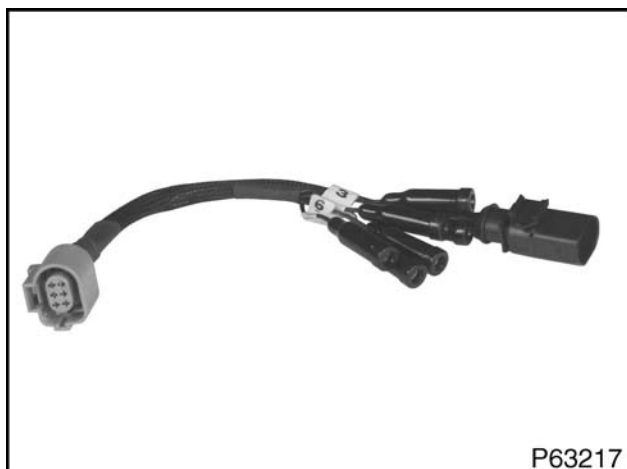
The E2-Engine, D-Injector, C-Chassis Harness with breakout box overlay (pin identifier) sheet is used with the 180-pin breakout box to test circuits connected to the ECM E2, D, and powertrain harness connectors.

**EGR Position and ITV Breakout Harness****Figure 311 ZTSE4833**

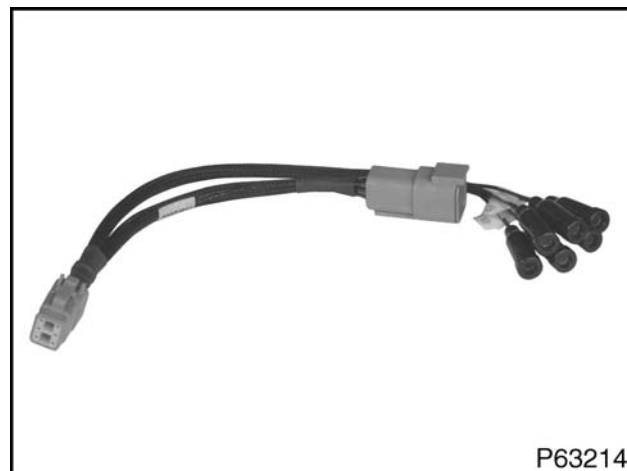
The EGR Position and ITV Breakout Harness is used to measure voltage and resistance on circuits connected to the Exhaust Gas Recirculation Position (EGRP) sensor and Intake Throttle Valve (ITV).

**EIM Power Relay Breakout Harness****Figure 312 ZTSE4908**

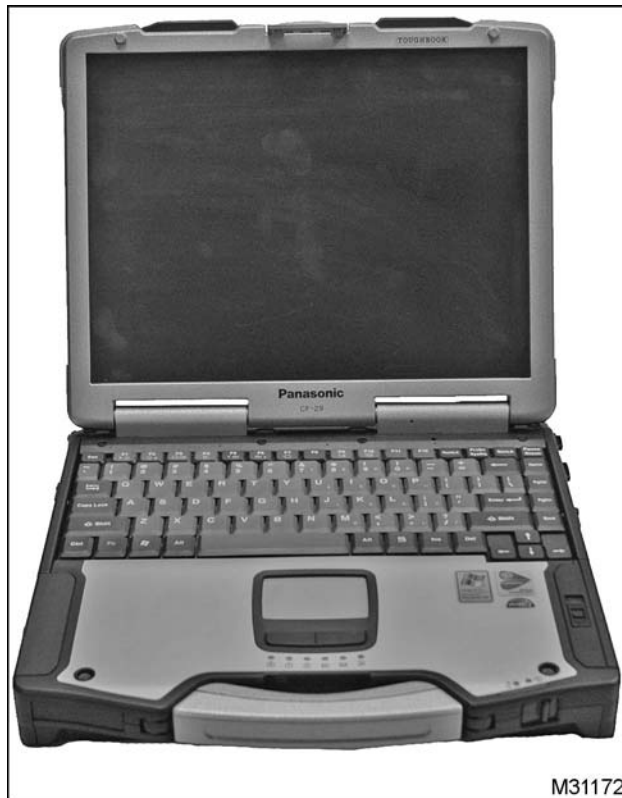
The EIM Power Relay Breakout Harness is used to measure voltage and resistance on circuits to the EIM relay.

**ELS and V8 EGR Breakout Harness****Figure 313 ZTSE4735A**

The ELS and V8 EGR Breakout Harness is used to measure voltage and resistance on circuits connected to the Exhaust Lambda Sensor (ELS).

**Engine Fan Control Breakout Harness****Figure 314 ZTSE4844**

The Engine Fan Control Breakout Harness is used to measure voltage and resistance on circuits connected to the variable electronic fan control.

**EZ-Tech® Electronic Service Tool (EST)****Figure 315 J-45067**

The EZ-Tech® Electronic Service Tool (EST) is used to run the MasterDiagnostics® software for diagnosing and troubleshooting engine and vehicle problems.

**MasterDiagnostics® Software**

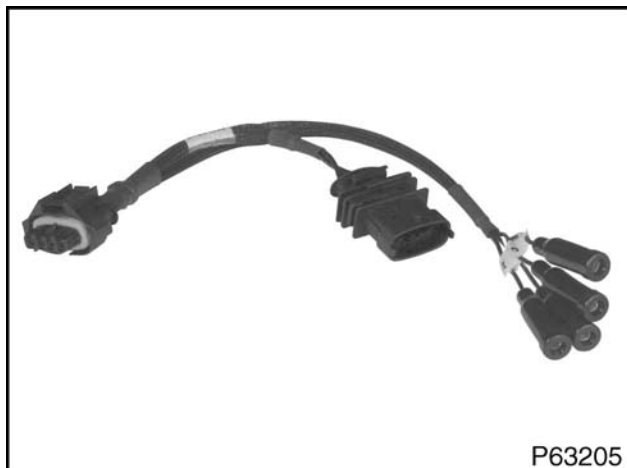
MasterDiagnostics® software, loaded to an EST or laptop computer, is used to check performance of engine systems, diagnose engine problems, and store troubleshooting history for an engine.

**FRP Breakout Harness****Figure 316 ZTSE4829**

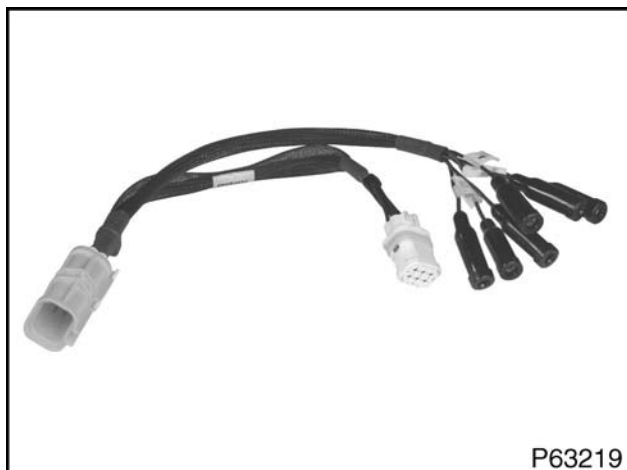
The FRP Breakout Harness is used to measure voltage and resistance on circuits connected to the Fuel Rail Pressure (FRP) sensor.

**IC4 USB Interface Cable****Figure 317 ZTSE4632-USB**

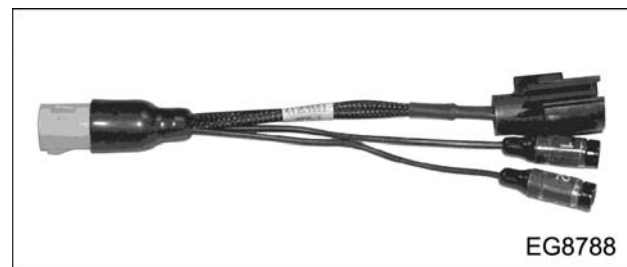
The IC4 USB Interface Cable connects the EST to the truck Controller Area Network (CAN) through the vehicle diagnostic connector.

**MAP/IAT2 Breakout Harness****Figure 318 ZTSE4830**

The MAP/IAT2 Breakout Harness is used to measure voltage and resistance on circuits connected to the Manifold Absolute Pressure/ Intake Air Temperature (MAP/IAT2) sensor.

**Retarder Control Breakout Harness****Figure 319 ZTSE4834**

The Retarder Control Breakout Harness is used to measure voltage and resistance on circuits connected to the retarder control.

**Temperature Sensor Breakout Harness****Figure 320 ZTSE4483**

The Temperature Sensor Breakout Harness is used to measure voltage and resistance on circuits connected to the Intake Air Temperature (IAT) sensor.

**Terminal Test Adapter Kit****Figure 321 ZTSE4435A**

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

### Air Intake Guard

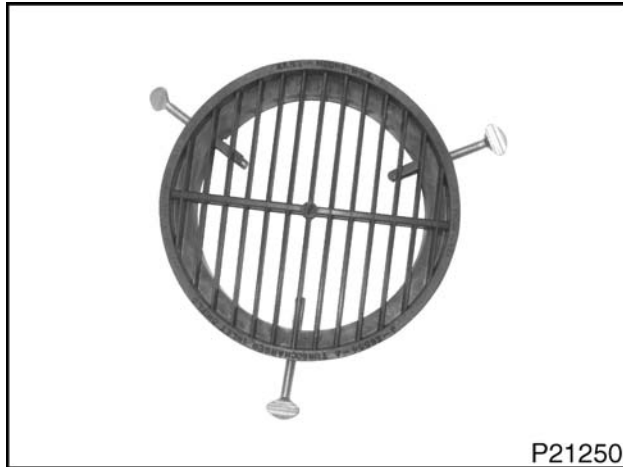


Figure 322 ZTSE4893

The Air Intake Guard is used to protect the turbochargers while performing diagnostics with the air cleaner disconnected.

### Crankcase Pressure Test Adapter

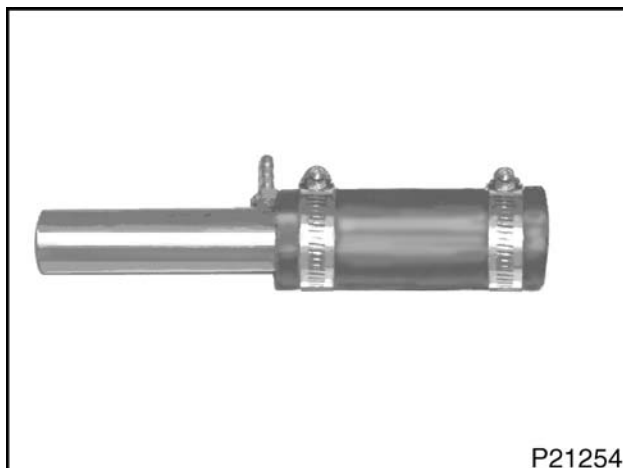


Figure 323 ZTSE4039 (0.406 in. diameter)

The Crankcase Pressure Test Adapter is used to measure combustion gas flow from the valve cover and may be used with the magnehelic gauge or slack tube manometer.

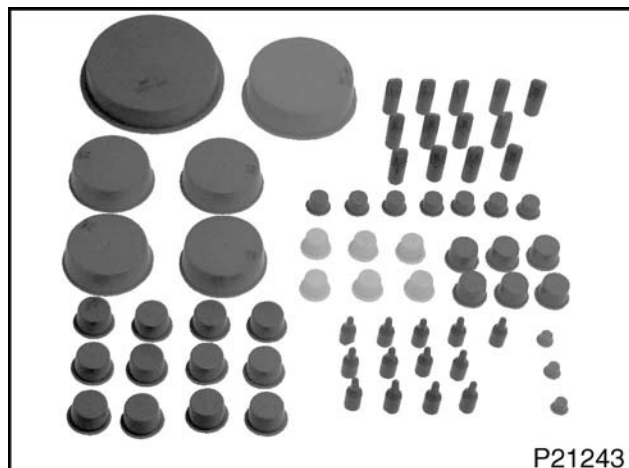
Use the pressure readings obtained with this adapter as the main source of engine condition. Use oil consumption trend data if the pressure readings are over the specified limits. Neither changes in oil consumption trends nor crankcase diagnostic pressure trends can establish a specific problem. These changes only indicate that a problem exists.

### Digital Manometer



Figure 324 Locally obtained

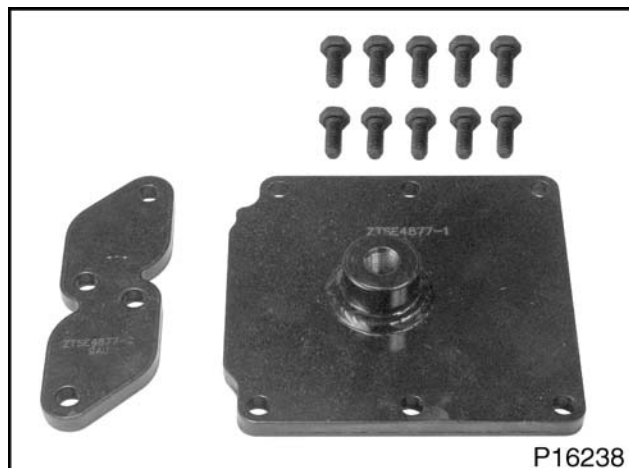
The digital manometer is used to measure low vacuum for intake restriction or low crankcase pressure. A variety of digital manometers are available for purchase locally.

**Disposable Air and Fuel Caps****Figure 325 ZTSE4891**

The Disposable Air and Fuel Caps are used to cap the fuel system lines and fittings when the fuel system is disconnected for diagnostics. The Disposable Air and Fuel Caps prevent dirt and foreign particles from entering and contaminating the fuel system.

**Fuel Block Off Tool****Figure 327 ZTSE4905**

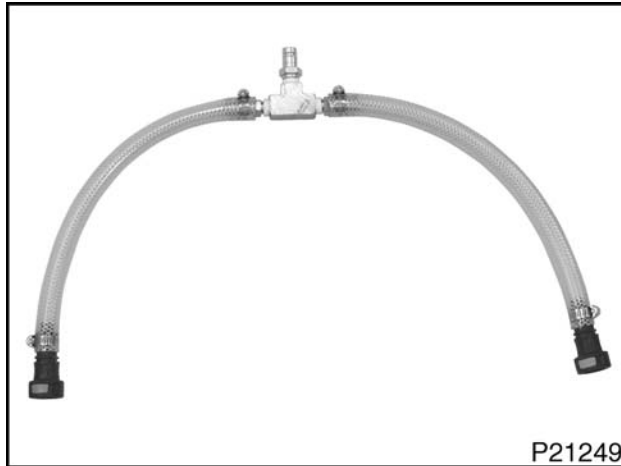
The Fuel Block Off Tool is used to block the T-connector fuel line at the high pressure pump in order to measure the low pressure pump output pressure.

**EGR Cooler Pressure Test Plates****Figure 326 ZTSE4877**

The EGR Cooler Pressure Test Plates are used to pressure test the EGR cooler.

**Fuel Fitting Adapter****Figure 328 ZTSE4906**

The Fuel Fitting Adapter is used in conjunction with the Fuel Inlet Restriction and Aeration Tool to measure the fuel pressure in the return line.

**Fuel Inlet Restriction and Aeration Tool****Figure 329 ZTSE4886**

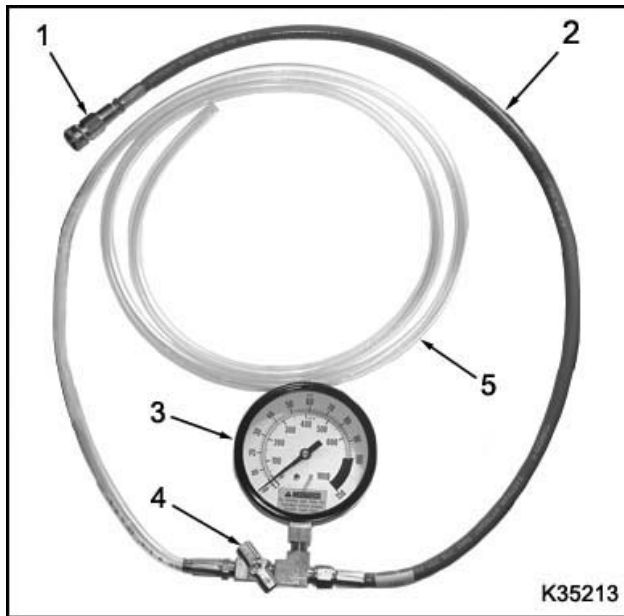
The Fuel Inlet Restriction and Aeration Tool is used to check for pressure and aerated fuel in the low fuel pressure system.

**Fuel Line Disconnect Tool 11.8 mm****Figure 330 ZTSE4773**

The Fuel Line Disconnect Tool 11.8 mm is used to release the locking mechanism on low pressure fuel line connectors.

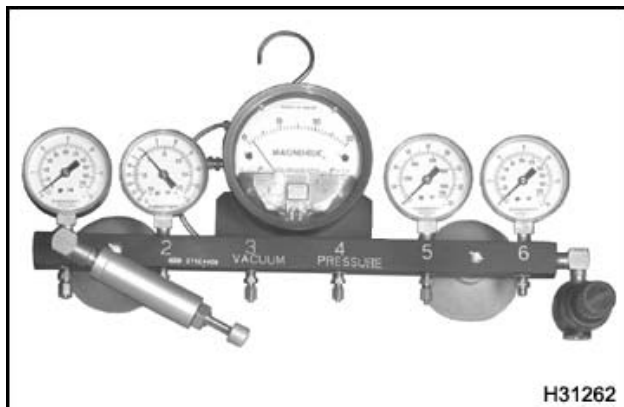
**Fuel Line Disconnect Tool 16 mm****Figure 331 ZTSE4772**

The Fuel Line Disconnect Tool 16 mm is used to release the locking mechanism on low pressure fuel line connectors.

**Fuel Pressure Gauge****Figure 332 ZTSE4681**

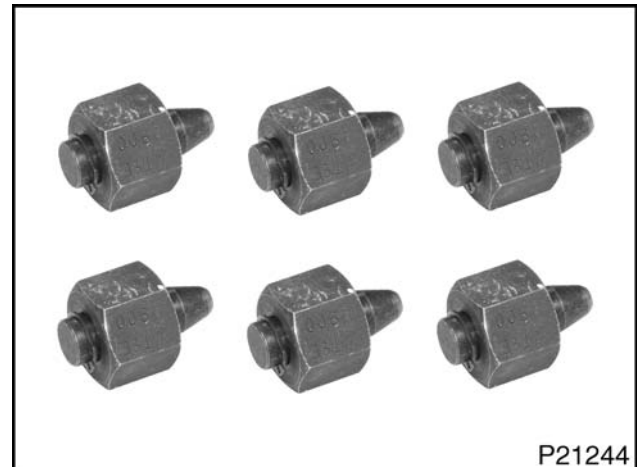
1. Quick disconnect check valve
2. Fuel test line
3. Fuel Pressure Gauge
4. Inline shut-off valve
5. Clear test line

The Fuel Pressure Gauge is used to check for fuel pressure and aerated fuel in the low fuel pressure system.

**Gauge Bar Tool****Figure 333 ZTSE4409**

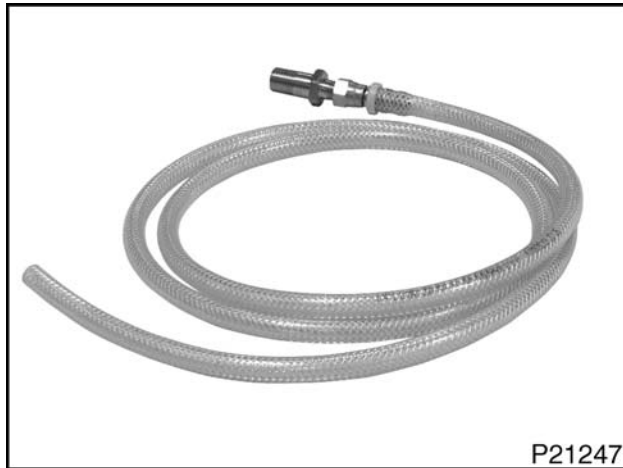
The Gauge Bar Tool is used to measure intake manifold (boost) pressure, fuel system inlet restriction, fuel pressure, oil pressure, air cleaner intake restriction, and crankcase pressure.

- 0 kPa to 200 kPa (0 psi to 30 psi) measures intake manifold pressure.
- 0-30 in-Hg vacuum / 0 kPa to 200 kPa (0 psi to 30 psi) compound gauge measures fuel system inlet restriction and intake manifold pressure.
- 0-30 in-H<sub>2</sub>O 0 kPa to 7.5 kPa (0 psi to 1 psi) maximum pressure magnehelic gauge measures crankcase pressure and air inlet restriction.
- 60 kPa to 1100 kPa (0 psi to 160 psi) gauge may be used to check the fuel pressure and oil pressure.

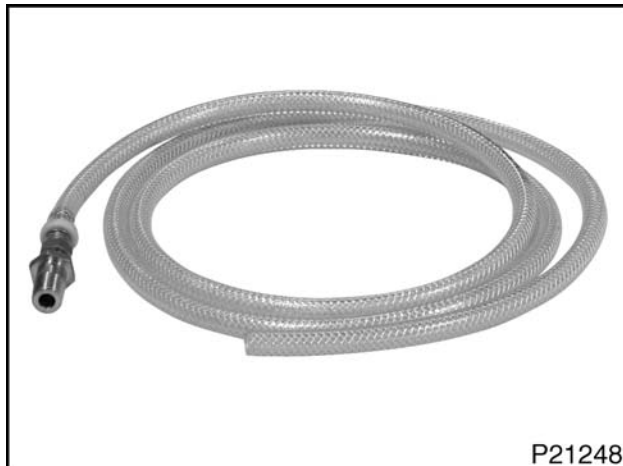
**High Pressure Rail Plugs****Figure 334 ZTSE4900**

The High Pressure Rail Plugs are used to isolate individual injectors by blocking the pressure pipe rail output.

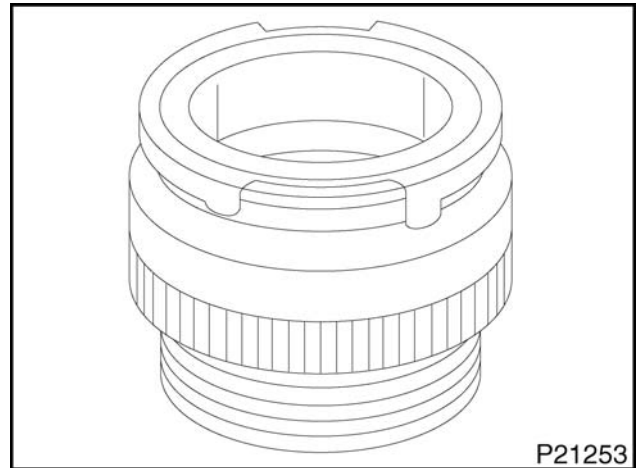


**High Pressure Return Line Tester****Figure 335 ZTSE4887-1 – 17 mm**

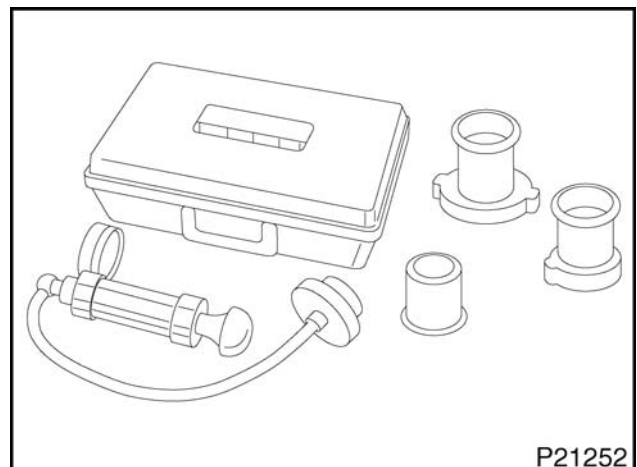
The 17 mm High Pressure Return Line Tester is used to check for fuel returning from the pressure pipe rail.

**Figure 336 ZTSE4887-2 – 19 mm**

The 19 mm High Pressure Return Line Tester is used to check for excessive fuel returning from the fuel injectors at the cylinder head fuel return port.

**Plastic Surge Tank Cap Adaptor****Figure 337 ZTSE23842**

The Plastic Surge Tank Cap Adaptor is used to block off the surge tank while performing a cooling system pressure test.

**Radiator Pressure Testing Kit****Figure 338 ZTSE2384**

The Radiator Pressure Test Kit is used to check pressure caps and cooling systems. The easy-to-read pressure gauge indicates if the cap is in good condition and whether the cooling system leaks.

### Slack Tube Manometer

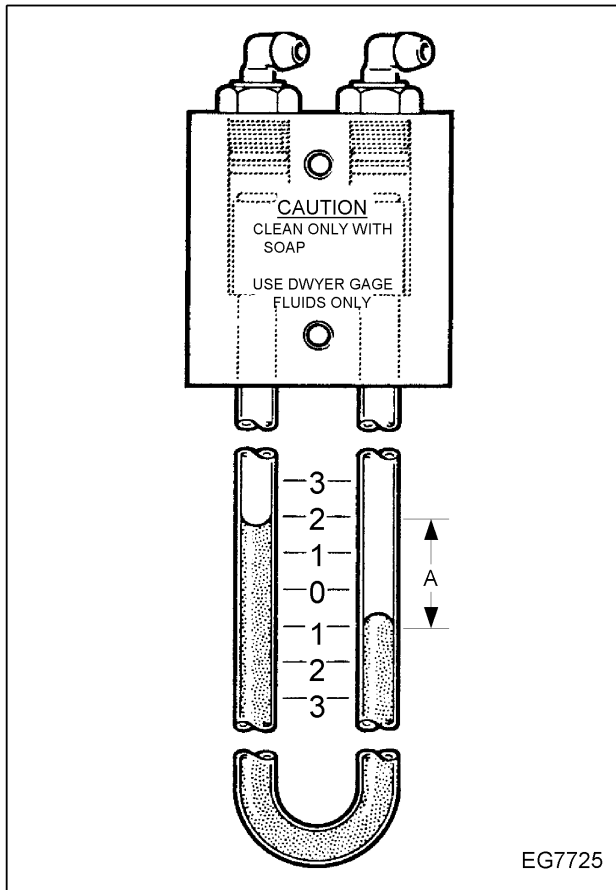


Figure 339 ZTSE2217A

The Slack Tube Manometer is a U-shaped tube with a scale mounted between the legs of the tube. When the portability of the gauge bar tool is not required, this manometer is used to measure low vacuum for intake restriction or low crankcase pressure.

#### Filling

Fill the manometer with water before checking pressure. Use only distilled water. Add some colored water vegetable dye so the scale can be read more easily. With both legs of the manometer open to the atmosphere, fill the tube until the top of the fluid column is near the zero mark on the scale. Shake the tube to eliminate any air bubbles.

#### Installing, Reading, and Cleaning

1. Support the manometer vertically. Make sure the fluid level is in line with the zero indicator on the graduated scale.
2. Connect one leg of the manometer to the source of the pressure or vacuum. Leave the other leg open to atmospheric pressure.
3. Start the engine and allow it to reach normal operating temperature. Then run the engine to high idle. The manometer can be read after 10 seconds.
4. Record the average position of the fluid level when it is above and below the zero indicator. Add the two figures together. The sum of the two is the total column of fluid (distance A). This represents the crankcase pressure in inches of water (in-H<sub>2</sub>O).

At times, both columns of the manometer will not travel the same distance. This is no concern if the leg not connected to the pressure or vacuum source is open to the atmosphere.

5. Compare the manometer reading with engine specifications.
6. When the test is done, clean the tube thoroughly using soap and water. Avoid liquid soaps and solvents.

### UV Leak Detection Kit



Figure 340 ZTSE4618

The UV Leak Detection Kit is used with fuel dye to quickly identify leaks. The fuel dye combines with

fuel and migrates out at the leak. The ultraviolet lamp illuminates the leaking fuel dye, which appears fluorescent yellow-green in color.

## Electronic Circuit Testing

### Electrical Theory

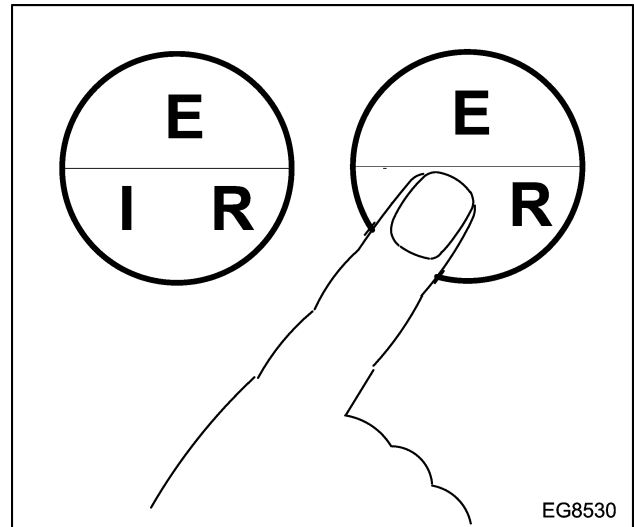
#### Voltage

Voltage is electrical pressure or force that pushes current through a circuit. The pressure is measured in volts. The symbol V (for example, 12 V) 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 causes 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 341 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  $I = E \div R$ .

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)

- $I = E \div R$

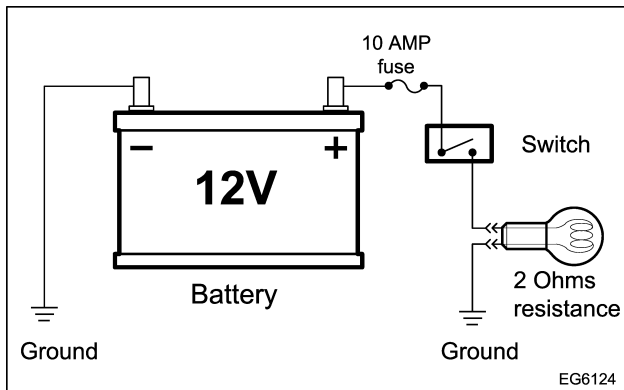
This formula states that the current flow (I) in the circuit equals the voltage (E) applied to the circuit divided by the total resistance (R) in the circuit. This shows that an increase in voltage or a decrease in resistance increases the current flow.

- $E = I \times R$

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.

- $R = E \div I$

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 342 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  $I = E \div R$ :

Fill in the numbers for the formula:

$$I = 12 \text{ V} \div 2 \text{ ohms}$$

$$I = 6 \text{ amps}$$

The bulb in this circuit operates at 6 amps and is rated at 6 amps. With 12 volts applied, the bulb glows at the rated output level (candlepower rating). However,

- if the voltage applied is low (low battery), the value of E is lower, current flow is less, and the bulb glows less brightly.
- if connections are loose or the switch is corroded, the circuit resistance are greater (value of R is larger), the current flow is reduced, and the bulb glows 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 (DMM)

The following electrical test equipment should be available for testing electronic circuits:

- Voltmeter
- Ohmmeter
- Ammeter
- Jumper wires
- Test lights

## Test Meters

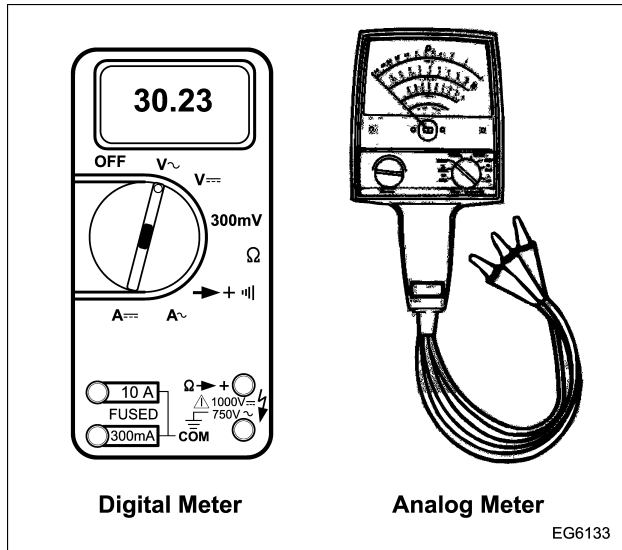


Figure 343 Typical Test Meters

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 megohms (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.

## Jumper Wires

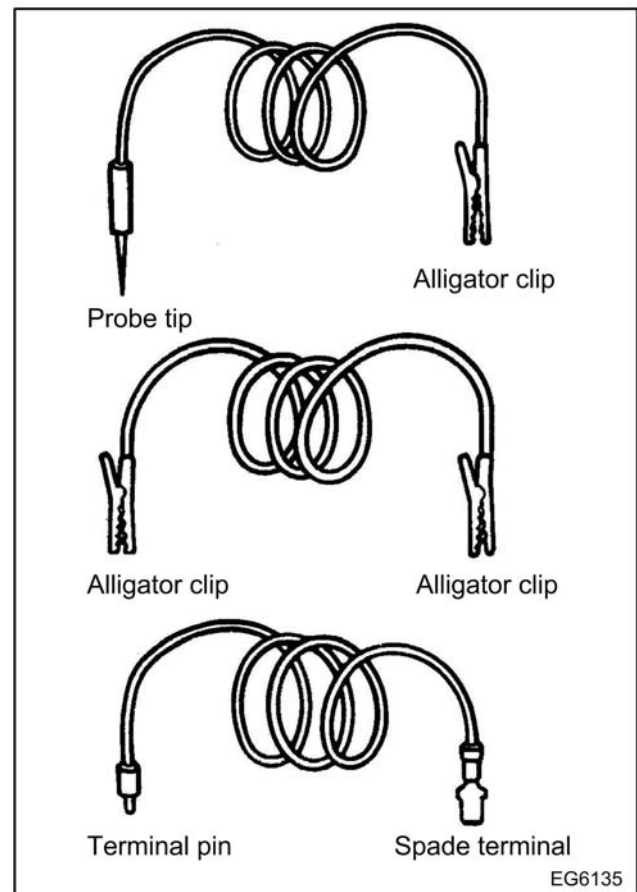
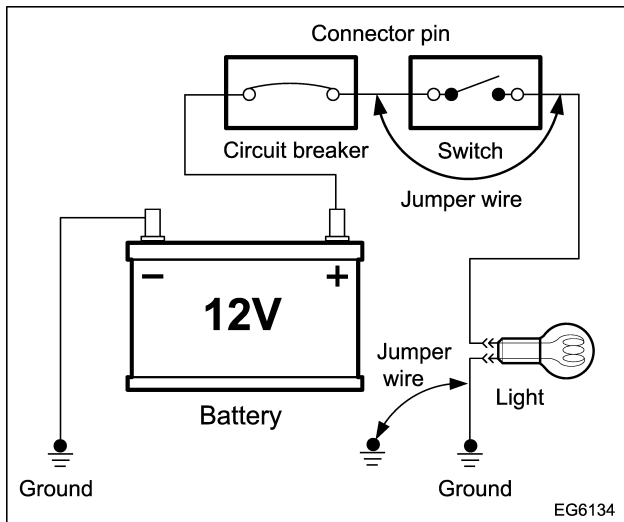


Figure 344 Jumper wires

Jumper wires allow a circuit to bypass 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 345 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:

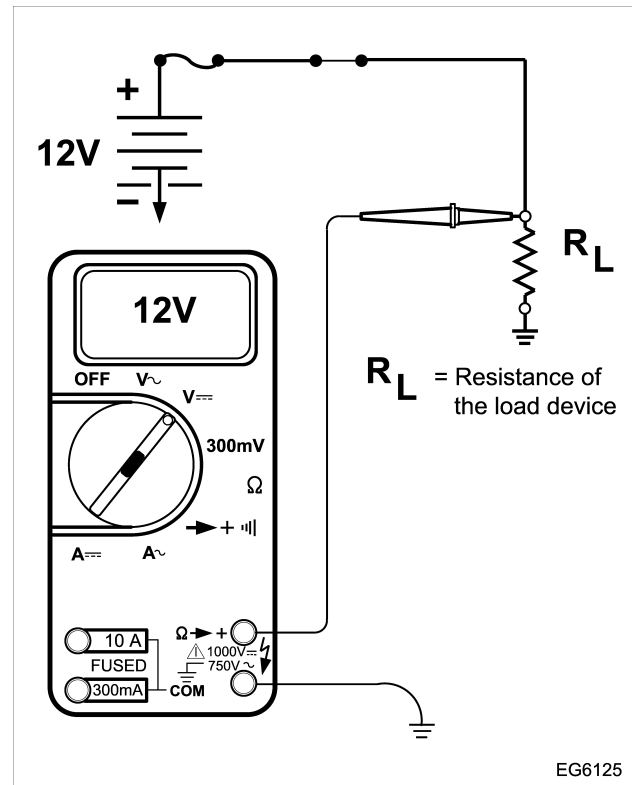
- A switch is closed but the light does not illuminate.
- Jumping the switch does not illuminate the light.
- Jumping the light to the ground causes the light to illuminate.

### 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?



**Figure 346 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.

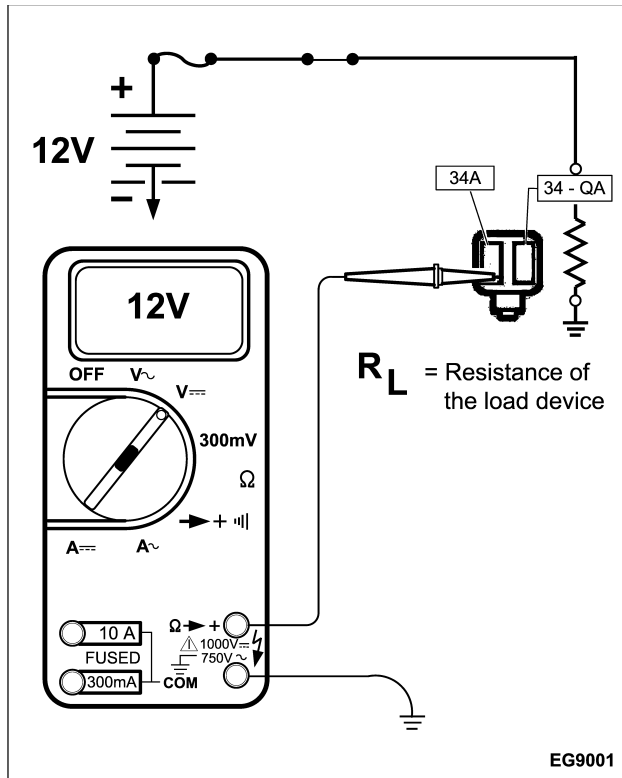


Figure 347 Checking power to a connector

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

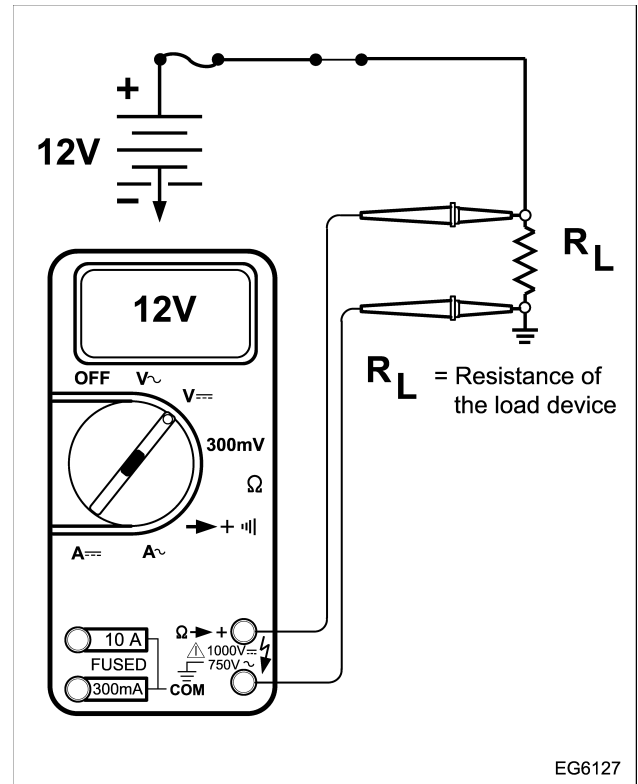


Figure 348 Checking voltage drop

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 measures 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 equals 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.

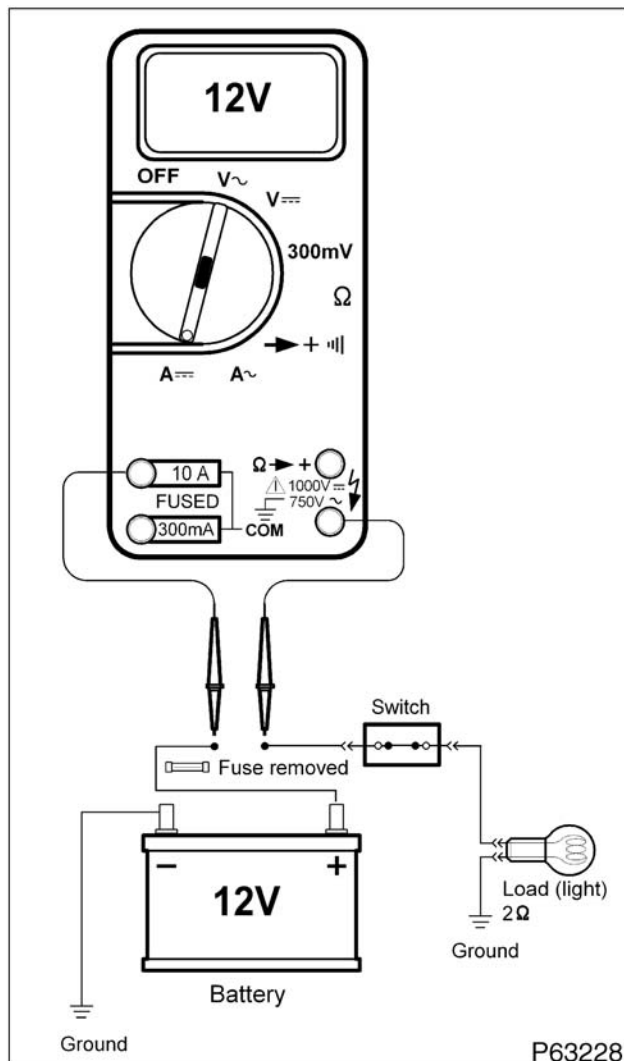
### Ammeter

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 ( $I = E \div R$ ). Therefore, increasing the voltage also

increases the current flow. Any decrease in resistance also increases 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).



**Figure 349** Installing the ammeter

An ammeter is connected in series with the load, 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 ( $6 \text{ amps} = 12 \text{ V} \div 2 \text{ ohms}$ ). If the fuse is removed and an ammeter is installed with the switch closed, 6 amps of current is 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 avoid serious personal injury or possible death, always make sure the power is off before cutting, soldering, removing circuit components, or before inserting the digital multimeter for current measurements. Even 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 opens fuses and circuit breakers, and also quickly discharges batteries. An ammeter can diagnose these conditions.

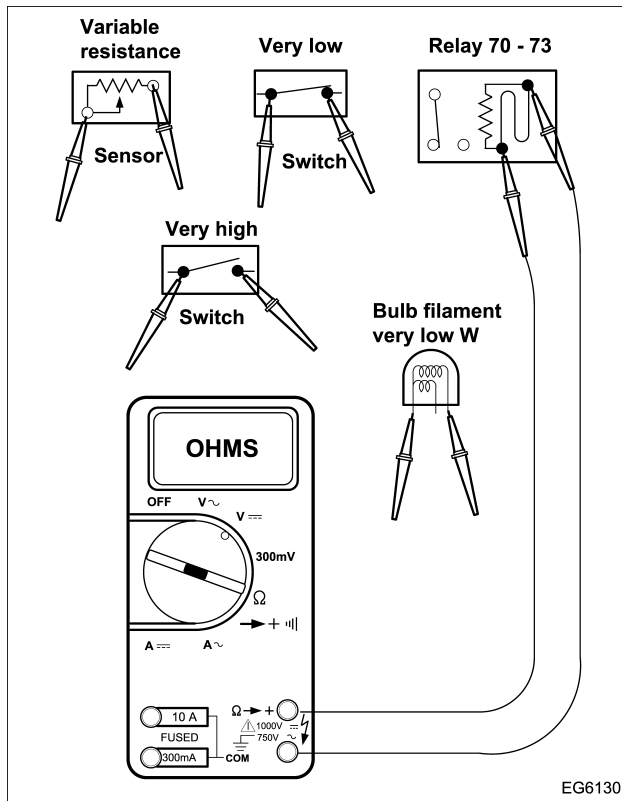
Reduced current draw causes a device (an electric window motor, for example) to operate poorly. Increased circuit resistance causes lower current flow (often due to loose or corroded connections).

### 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.





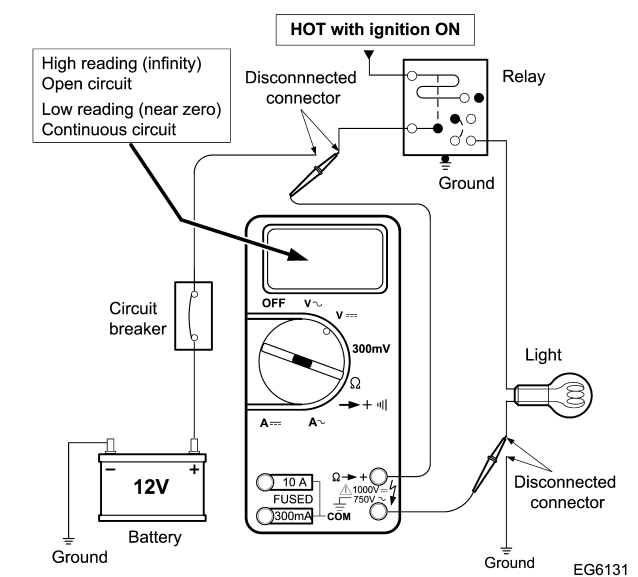
**Figure 350 Measuring resistance**

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 goes through the indicator lamp because it has less resistance.

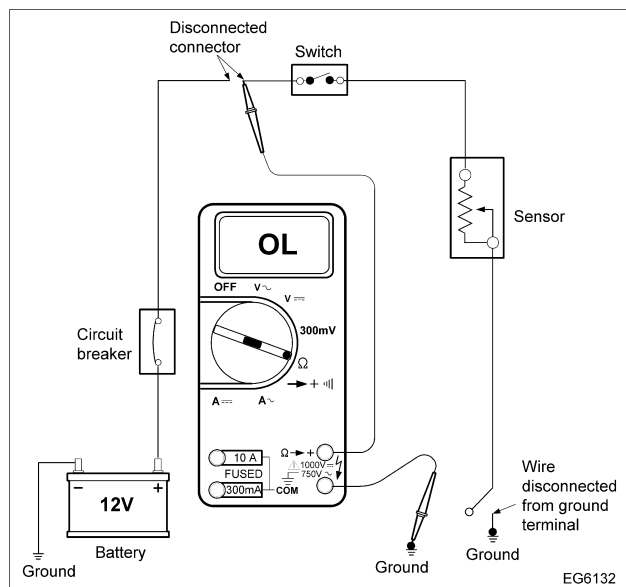
Remove one connector to the load. It is not always apparent when a component must be isolated, so it

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 351 Checking for open 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 reads OL (over limit).



**Figure 352** Checking for short circuits

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 is indicated by a reading near zero. A circuit that is not shorted to ground causes a high meter reading.

### Measuring Duty Cycle with Fluke 88

When measuring duty cycle, make sure 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:

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

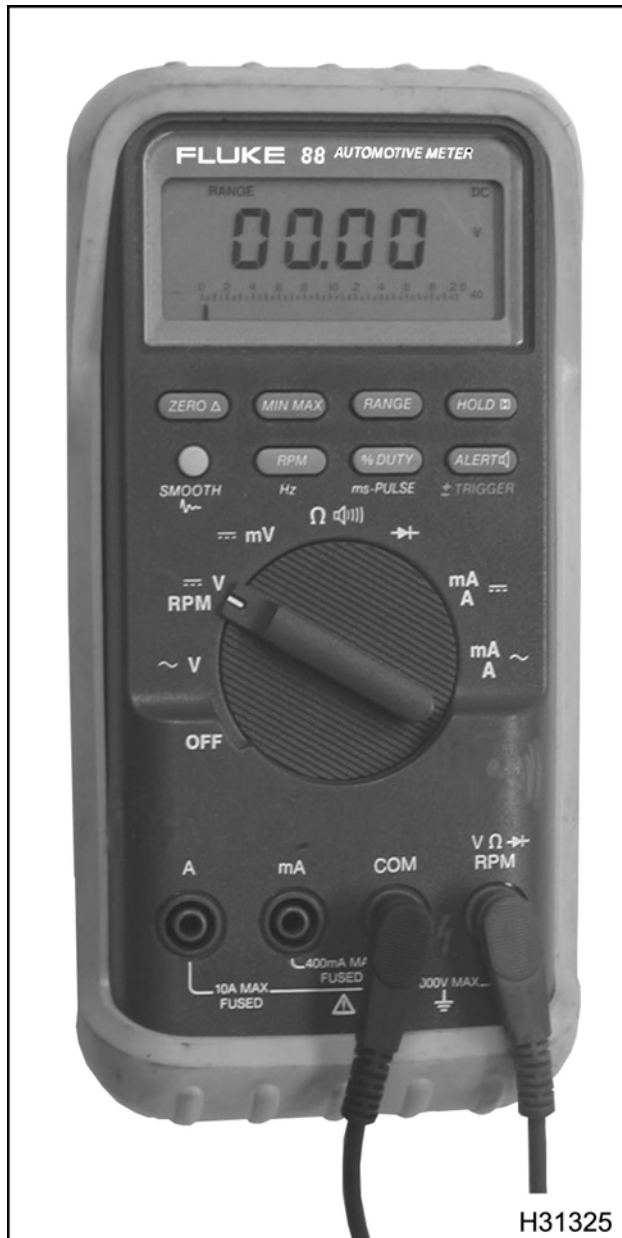


Figure 353 Fluke 88 in volts DC mode

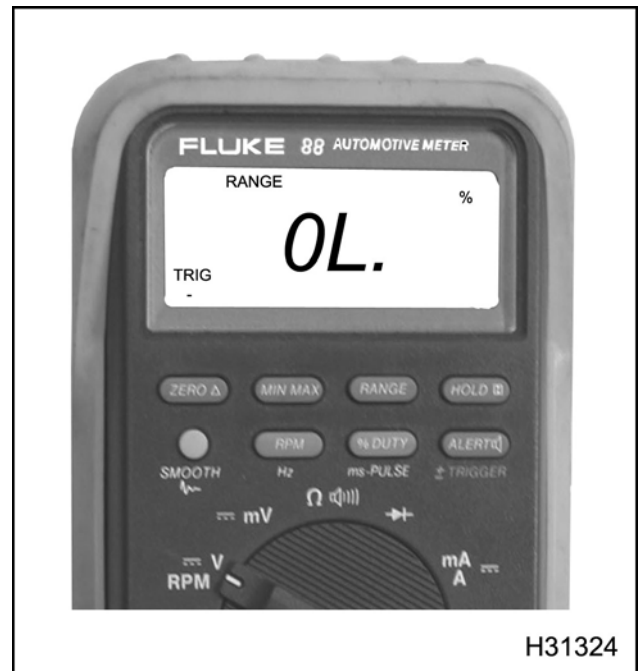


Figure 354 Fluke 88 with negative trigger slope in duty cycle mode

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



**Figure 355 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 appears 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 Pinpoint Diagnostics.

### 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 Section 7 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 helps 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 (such as  $V_{REF}$ , 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 Section 7.
5. Make the repair.

Repair the problem circuit as directed in the diagnostic tables.

6. Verify the repair is complete.

Operate the system. Make sure the repair has removed all symptoms and not caused any new symptoms.

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## Abbreviations and Acronyms

### Abbreviations and Acronyms

<b>A or amp</b> – Ampere	<b>cc</b> – Cubic centimeter
<b>ABDC</b> – After Bottom Dead Center	<b>CCA</b> – Cold Cranking Ampere
<b>ABS</b> – Antilock Brake System	<b>CCV</b> – Coolant Control Valve
<b>AC</b> – Alternating Current	<b>CDR</b> – Crankcase Depression Regulator
<b>A/C</b> – Air Conditioner	<b>CID</b> – Cubic Inch Displacement
<b>ACC</b> – Air Conditioner Control	<b>cfm</b> – Cubic feet per minute
<b>ACCEL</b> – Accelerator	<b>cfs</b> – Cubic feet per second
<b>ACD</b> – Air Conditioner Demand	<b>CFV</b> – Coolant Flow Valve
<b>ACM</b> – Aftertreatment Control Module	<b>CKP</b> – Crankshaft Position
<b>ACT PWR GND</b> – Actuator Power Ground	<b>CKPO</b> – Crankshaft Position Out
<b>A/F</b> – Air to Fuel ratio	<b>cm</b> – Centimeter
<b>AFD</b> – Aftertreatment Fuel Drain	<b>CMP</b> – Camshaft Position
<b>AFI</b> – Aftertreatment Fuel Injector	<b>CMPO</b> – Camshaft Position Out
<b>AFP</b> – Aftertreatment Fuel Pressure	<b>CMV</b> – Coolant Mixer Valve
<b>AFS</b> – Aftertreatment Fuel Supply	<b>CO</b> – Carbon Monoxide
<b>AFT</b> – Aftertreatment	<b>COO</b> – Cruise On / Off switch
<b>AIT</b> – Air Intake Temperature	<b>CPU</b> – Central Processing Unit
<b>Amb</b> – Ambient	<b>CSS</b> – Cold Start Solenoid
<b>amp or A</b> – Ampere	<b>CSR</b> – Cold Start Relay
<b>AMS</b> – Air Management System	<b>CTC</b> – Coolant Temperature Compensation
<b>API</b> – American Petroleum Institute	<b>Cyl</b> – Cylinder
<b>APS</b> – Accelerator Position Sensor	<b>DB</b> – Decibel
<b>APS/IVS</b> – Accelerator Position Sensor / Idle Validation Switch	<b>DCA</b> – Diesel Coolant Additive
<b>ASTM</b> – American Society for Testing and Materials	<b>DDI</b> – Digital Direct Fuel Injection
<b>ATA</b> – American Trucking Association	<b>DDS</b> – Driveline Disengagement Switch
<b>ATDC</b> – After Top Dead Center	<b>DLC</b> – Data Link Connector
<b>AWG</b> – American Wire Gauge	<b>DME</b> – Dimethyl Ether
<b>B+ or VBAT</b> – Battery Voltage	<b>DMM</b> – Digital Multimeter
<b>BAP or BARO</b> – Barometric Absolute Pressure	<b>DOC</b> – Diesel Oxidation Catalyst
<b>BARO or BAP</b> – Barometric Absolute Pressure	<b>DPF</b> – Diesel Particulate Filter
<b>BBDC</b> – Before Bottom Dead Center	<b>DT</b> – Diesel Turbocharged
<b>BCP</b> – Brake Control Pressure	<b>DTC</b> – Diagnostic Trouble Code
<b>BCS</b> – Boost Control Solenoid	<b>DTRM</b> – Diesel Thermo Recirculation Module
<b>BDC</b> – Bottom Dead Center	<b>EBC</b> – Exhaust Brake Controller
<b>bhp</b> – Brake Horsepower	<b>EBP</b> – Exhaust Back Pressure
<b>BNO</b> – Brake Normally Open	<b>EBPD</b> – Exhaust Back Pressure Desired
<b>BOO</b> – Brake On / Off	<b>ECI</b> – Engine Crank inhibit
<b>BPS</b> – Brake Pressure Switch	<b>ECL</b> – Engine Coolant Level
<b>BSV</b> – Brake Shut-off Valve	<b>ECM</b> – Engine Control Module
<b>BTDC</b> – Before Top Dead Center	<b>ECM PWR</b> – Engine Control Module Power
<b>BTU</b> – British Thermal Unit	<b>ECT</b> – Engine Coolant Temperature
<b>C</b> – Celsius	<b>ECT2</b> – Engine Coolant Temperature 2
<b>CAC</b> – Charge Air Cooler	<b>EFAN</b> – Electronic Engine Fan
<b>CAN</b> – Controller Area Network	<b>EFANS</b> – Electronic Engine Fan Speed
<b>CAP</b> – Cold Ambient Protection	<b>EFP</b> – Engine Fuel Pressure
<b>CARB</b> – California Air Resources Board	<b>EFRC</b> – Engine Family Rating Code
	<b>EFT</b> – Engine Fuel Temperature
	<b>EG</b> – Ethylene Glycol
	<b>EGC</b> – Electronic Gauge Cluster
	<b>EGDP</b> – Exhaust Gas Differential Pressure

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<b>EGR</b> – Exhaust Gas Recirculation	<b>IAT</b> – Intake Air Temperature
<b>EGRH</b> – Exhaust Gas Recirculation High control	<b>IAHC</b> – Inlet Air Heater Control
<b>EGRL</b> – Exhaust Gas Recirculation Low control	<b>IAHD</b> – Inlet Air Heater Diagnostic
<b>EGRP</b> – Exhaust Gas Recirculation Position	<b>IAHR</b> – Inlet Air heater Relay
<b>EGT1</b> – Exhaust Gas Temperature 1	<b>IC</b> – Integrated Circuit
<b>EGT2</b> – Exhaust Gas Temperature 2	<b>ICP</b> – Injector Control Pressure
<b>EGT3</b> – Exhaust Gas Temperature 3	<b>ID</b> – Inside Diameter
<b>EIM</b> – Engine Interface Module	<b>IDM</b> – Injector Drive Module
<b>ELS</b> – Exhaust Lambda Sensor	<b>IGN</b> – Ignition
<b>EMI</b> – Electromagnetic Interference	<b>ILO</b> – Injector Leak Off
<b>EOP</b> – Engine Oil Pressure	<b>in</b> – Inch
<b>EOT</b> – Engine Oil Temperature	<b>inHg</b> – Inch of mercury
<b>EPA</b> – Environmental Protection Agency	<b>inH<sub>2</sub>O</b> – Inch of water
<b>EPR</b> – Engine Pressure Regulator	<b>INJ</b> – Injector
<b>ESC</b> – Electronic System Controller	<b>IPR</b> – Injection Pressure Regulator
<b>ESN</b> – Engine Serial Number	<b>ISIS®</b> – International® Service Information System
<b>EST</b> – Electronic Service Tool	<b>IST</b> – Idle Shutdown Timer
<b>EVB</b> – Exhaust Valve Brake	<b>ITP</b> – Internal Transfer Pump
<b>EWPS</b> – Engine Warning Protection System	<b>ITV</b> – Intake Throttle Valve
<b>F</b> – Fahrenheit	<b>ITVH</b> – Intake Throttle Valve High control
<b>FCV</b> – Fuel Coolant Valve	<b>ITVL</b> – Intake Throttle Valve Low control
<b>FEL</b> – Family Emissions Limit	<b>ITVP</b> – Intake Throttle Valve Position
<b>fhp</b> – Friction horsepower	<b>IVS</b> – Idle Validation Switch
<b>FMI</b> – Failure Mode Indicator	<b>JCT</b> – Junction (electrical)
<b>FPC</b> – Fuel Pump Control	<b>kg</b> – Kilogram
<b>FPCV</b> – Fuel Pressure Control Valve	<b>km</b> – Kilometer
<b>fpm</b> – Feet per minute	<b>km/h</b> – Kilometers per hour
<b>fps</b> – Feet per second	<b>km/l</b> – Kilometers per liter
<b>FRP</b> – Fuel Rail Pressure	<b>KOEO</b> – Key-On Engine-Off
<b>ft</b> – Foot	<b>KOER</b> – Key-On Engine-Running
<b>FVCV</b> – Fuel Volume Control Valve	<b>kPa</b> – Kilopascal
<b>GND</b> – Ground (electrical)	<b>L</b> – Liter
<b>gal</b> – Gallon	<b>L/h</b> – Liters per hour
<b>gal/h</b> – U.S. Gallons per hour	<b>L/m</b> – Liters per minute
<b>gal/min</b> – U. S. Gallons per minute	<b>L/s</b> – Liters per second
<b>GCW</b> – Gross Combined Weight	<b>lb</b> – Pound
<b>GCWR</b> – Gross Combined Weight Rating	<b>lbf</b> – Pound-force
<b>GPC</b> – Glow Plug Control	<b>lb/s</b> – Pounds per second
<b>GPD</b> – Glow Plug Diagnostic	<b>lbf-ft</b> – Pound-force foot
<b>GPR</b> – Glow Plug Relay	<b>lbf-in</b> – Pound-force inch
<b>GVW</b> – Gross Vehicle Weight	<b>lbm</b> – Pounds of mass
<b>H<sub>2</sub>O</b> – Water	<b>LPCAC</b> – Low Pressure Charge Air Cooler
<b>HC</b> – Hydrocarbon	<b>LSD</b> – Low Sulfur Diesel
<b>HCI</b> – Hydrocarbon Injection	<b>m</b> – Meter
<b>HFCM</b> – Horizontal Fuel Conditioning Module	<b>m/s</b> – Meters per second
<b>Hg</b> – Mercury	<b>MAF</b> – Mass Air Flow
<b>hp</b> – Horsepower	<b>MAG</b> – Magnetic
<b>HPCAC</b> – High Pressure Charge Air Cooler	<b>MAP</b> – Manifold Absolute Pressure
<b>hr</b> – Hour	
<b>Hyd</b> – Hydraulic	

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<b>MAP/IAT</b> – Manifold Absolute Pressure/Intake Air Temperature Sensor	<b>rev</b> – Revolution
<b>MAT</b> – Manifold Air Temperature	<b>rpm</b> – Revolutions per minute
<b>mep</b> – Mean effective pressure	<b>RPRE</b> – Remote Preset
<b>mi</b> – Mile	<b>RSE</b> – Radiator Shutter Enable
<b>mm</b> – Millimeter	<b>RVAR</b> – Remote Variable
<b>mpg</b> – Miles per gallon	<b>SAE</b> – Society of Automotive Engineers®
<b>mph</b> – Miles per hour	<b>SCA</b> – Supplemental Coolant Additive
<b>MPR</b> – Main Power Relay	<b>SCCS</b> – Speed Control Command Switches
<b>MSDS</b> – Material Safety Data Sheet	<b>SCS</b> – Speed Control Switch
<b>MSG</b> – Micro Strain Gauge	<b>SHD</b> – Shield (electrical)
<b>MSM</b> – Multiplex System Module	<b>SID</b> – Subsystem Identifier
<b>MY</b> – Model Year	<b>SIG GRD</b> – Signal Ground
	<b>S/N</b> – Serial Number
<b>NC</b> – Normally closed (electrical)	<b>SW</b> – Switch (electrical)
<b>NETS</b> – Navistar Electronics Technical Support	<b>SYNC</b> – Synchronizer
<b>Nm</b> – Newton meter	<b>TACH</b> – Tachometer output signal
<b>NO</b> – Normally Open (electrical)	<b>TBD</b> – To Be Determined
<b>NO<sub>x</sub></b> – Nitrogen Oxides	<b>TCAPE</b> – Truck Computer Analysis of Performance and Economy
<b>OAT</b> – Organic Acid Technology	<b>TDC</b> – Top Dead Center
<b>OCC</b> – Output Circuit Check	<b>TCM</b> – Transmission Control Module
<b>OCP</b> – Overcrank Protection	<b>TTS</b> – Transmission Tailshaft Speed
<b>OD</b> – Outside Diameter	
<b>OL</b> – Over Limit	<b>ULSD</b> – Ultra Low Sulfur Diesel
<b>ORH</b> – Out-of-Range High	<b>UVC</b> – Under Valve Cover
<b>ORL</b> – Out-of-Range Low	
<b>OSHA</b> – Occupational Safety and Health Administration	<b>V</b> – Volt
<b>OWL</b> – Oil/Water Lamp	<b>VBAT or B+</b> – Battery Voltage
<b>PID</b> – Parameter Identifier	<b>VC</b> – Volume Control
<b>PN</b> – Part Number	<b>VEPS</b> – Vehicle Electronics Programming System
<b>ppm</b> – Parts per million	<b>VGT</b> – Variable Geometry Turbocharger
<b>PROM</b> – Programmable Read Only Memory	<b>VIGN</b> – Ignition Voltage
<b>psi</b> – Pounds per square inch	<b>VIN</b> – Vehicle Identification Number
<b>psia</b> – Pounds per square inch absolute	<b>VOP</b> – Valve Opening Pressure
<b>psig</b> – Pounds per square inch gauge	<b>VRE</b> – Vehicle Retarder Enable
<b>pt</b> – Pint	<b>VREF</b> – Reference Voltage
<b>PTO</b> – Power Take-off	<b>VSO or VSS_CAL</b> – Vehicle Speed Output
<b>PWM</b> – Pulse Width Modulate	<b>VSS</b> – Vehicle Speed Sensor
<b>PWR</b> – Power (voltage)	<b>VSS_CAL or VSO</b> – Vehicle Speed Output
<b>qt</b> – Quart	
<b>RAM</b> – Random Access Memory	<b>WEL</b> – Warn Engine Lamp
<b>RAS</b> – Resume / Accel Switch (speed control)	<b>WIF</b> – Water In Fuel
<b>REPTO</b> – Rear Engine Power Takeoff	<b>WTEC</b> – World Transmission Electronically Controlled automatic transmissions (Allison)
<b>RFI</b> – Radio Frequency Interference	<b>XMNS</b> – 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 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 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<sub>x</sub>)** – 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 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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## All Ratings

### Key-On Engine-Off

Barometric pressure (500 ft above sea level)	99.01 kPa (14.36 psi) / 3.91 V
Engine fuel pressure	0 kPa (0 psi) / 0.5 V
Engine oil pressure	0 kPa (0 psi) / 0.5 V
Exhaust gas differential pressure	0.83 kPa (0.12 psi) / 0.5 V
Fuel rail pressure	0 MPa (0 psi) / 0.5 V
Manifold boost pressure (gauge)	0 kPa (0 psi) / 1.06 V
Accelerator position sensor (at idle)	0.7 V / 0 %
Accelerator position sensor (depressed to floor)	3.75 V / 99.6 %
Exhaust gas recirculation (EGR) control valve position	0.47 V / 0 %
Intake throttle valve position	4.5 %

### Engine Cranking

Cranking rpm (min)	100 rpm
20 seconds minimum crank time per attempt. Wait 2 to 3 minutes before repeating.	
Battery voltage (min based on ECM drop out)	7.5 V
Fuel rail pressure (min before DTC is set)	+ or - 20 Mpa (2900 psi) from set point
Fuel rail pressure (min to start engine)	26 MPa (3771 psi) / 1 V
Exhaust gas recirculation (EGR) control valve	0 %
Engine fuel pressure (min)	48 kPa (7 psi) / 0.6 V

### Low Idle, no load, stabilized engine operating temperature

Engine coolant temperature (at thermostat opening)	83 °C (181 °F) / 1.41 V
Engine coolant temperature (max before DTC is set)	120 °C (248 °F) / 0.64 V
Engine coolant temperature 2 (at thermostat opening)	70 °C (157 °F) / 1.84 V
Engine coolant temperature 2 (max before DTC is set)	120 °C (248 °F) / 0.64 V
Engine oil temperature	89 °C (192 °F) / 1.26 V

**Low Idle, no load, stabilized engine operating temperature (cont.)**

Intake air temperature 2 (boost)	47 °C (117 °F) / 2.68 V
Intake air temperature 2 (boost) (max before DTC is set)	95 °C (203 °F) / 1.11 V
Manifold air temperature	61 °C (141 °F) / 2.14 V
Manifold air temperature (max before DTC is set)	135 °C (275 °F) / 0.47 V
Fuel rail pressure	49 kPa (7176 psi) / 1.49 V
Manifold boost pressure (gauge)	0 MPa (0 psi) / 1.06 V
Engine fuel pressure (min)	300 kPa (43.5 psi) / 1.3 V
Engine fuel pressure (max)	1000 kPa (145 psi) / 3.2 V
Fuel pump inlet restriction (max)	374 mm Hg (14.7 in Hg)
Engine oil pressure (min with gauge)	172 kPa (25 psi) / 0.93 V
Actuator supply pressure (min)	655 kPa (95 psi)
Boost control solenoid supply pressure (min)	358 kPa (52 psi)

**High Idle, no load, stabilized engine operating temperature**

Air cleaner restriction (max)	3.7 kPa (15 in H <sub>2</sub> O)
Fuel rail pressure	148 MPa (21425 psi) / 3.46 V
Engine fuel pressure (min)	300 kPa (43.5 psi) / 1.3 V
Engine fuel pressure (max)	1000 kPa (145 psi) / 3.2 V
Fuel pump inlet restriction (max with gauge)	374 mm Hg (14.7 in Hg)
Engine oil pressure (min with gauge)	172 kPa (25 psi) / 0.93 V
Exhaust gas differential pressure (max before DTC is set)	35 kPa (5 psi) / 1.9 V
Manifold boost pressure (min with gauge)	69 kPa (10 psi) / 1.85 V

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

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Air cleaner restriction (max)	6.2 kPa (25 in H <sub>2</sub> O)
Fuel rail pressure	180 MPa (26,000 psi) / 4.1 V
Engine fuel pressure (min)	450 kPa (65 psi) / 1.7 V
Engine fuel pressure (max)	1000 kPa (145 psi) / 0.31 V
Fuel pump inlet restriction (max with gauge)	374 mm Hg (14.7 in Hg)
Engine oil pressure (min with gauge)	372 kPa (54 psi) / 1.49 V
Engine oil temperature (max)	115 °C (240 °F) / 0.73 V
Exhaust gas differential pressure (max before DTC is set)	35 kPa (5 psi) / 1.9 V
Exhaust back pressure (max)	35 kPa (5 psi)
Water temperature differential across radiator (top and bottom)	9 °C (16 °F)

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**Component Specifications****Temperature Sensors (Engine Coolant Temperature [ECT], Engine Coolant Temperature 2 [ECT2], Engine Oil Temperature [EOT], Manifold Air Temperature [MAT])**

Temperature at -18 °C (0 °F)	4.6 V / 15410 Ω
Temperature at 0 °C (32 °F)	4.3 V / 5876 Ω
Temperature at 21 °C (70 °F)	3.7 V / 2492 Ω
Temperature at 65 °C (150 °F)	2.1 V / 5.6 Ω
Temperature at 93 °C (200 °F)	0.7 V / 212 Ω

**Temperature Sensors (Intake Air Temperature [IAT])**

Temperature at -18 °C (0 °F)	4.3 V / 276959 Ω
Temperature at 0 °C (32 °F)	3.85 V / 95851 Ω
Temperature at 21 °C (70 °F)	3.07 V / 37340 Ω
Temperature at 65 °C (150 °F)	1.34 V / 7548 Ω

**Temperature Sensors (Exhaust Gas Temperature 1 [EGT1], Exhaust Gas Temperature 2 [EGT2], Exhaust Gas Temperature 3 [EGT3])**

Temperature at 21 °C (70 °F)	5 V / 28100000 Ω
Temperature at 65 °C (150 °F)	4.6 V / 64493 Ω
Temperature at 93 °C (200 °F)	4.35 V / 37258 Ω
Temperature at 204 °C (400 °F)	2.7 V / 6612 Ω
Temperature at 482 °C (900 °F)	0.6 V / 761 Ω

**Other Components**

Camshaft Position (CMP) sensor	860 Ω ± 88 Ω
Crankshaft Position (CKP) sensor	860 Ω ± 86 Ω
Coolant Mixer Valve (CMV)	5.7 Ω ± 0.3 Ω
Coolant Flow Valve (CFV)	5.7 Ω ± 0.3 Ω
Cold Start Solenoid (CSS)	8 Ω ± 1 Ω
Boost Control Solenoid (BCS) valve	23 Ω ± 1.2 Ω
Exhaust Gas Recirculation (EGR) control valve	6 Ω + 0.6 Ω, -0.3 Ω
Injector coil	240 Ω ± 5% @ 20 °C



**Component Specifications (cont.)**

Cold start assist glow plug	0.17 $\Omega$ $\pm$ 0.015 $\Omega$
Retarder control	2.60 - 3.15 $\Omega$ @ 20 °C
	2.19 - 2.65 $\Omega$ @ -20 °C
Fuel Pressure Control Valve (FPCV)	2.80 - 3.34 $\Omega$ @ 40 °C
	3.29 - 3.99 $\Omega$ @ 90 °C

**Actuator Output State**

Exhaust Gas Recirculation (EGR) control valve	Output state low – 9.6 %
	Output state high – 83.6 %
Exhaust Gas Recirculation Position (EGRP)	Output state low – 0.75 V
	Output state high – 3.9 V
Coolant Mixer Valve (CMV)	Output state low – 11 %
	Output state high – 93.5 %
Coolant Flow Valve (CFV)	Output state low – 11 %
	Output state high – 93.5 %
Cold Start Solenoid (CSS)	Output state low – 0
	Output state high – 1
Intake Throttle Valve (ITV)	Output state low – 9.5 %
	Output state high – 83.5 %
Retarder control	Output state low – 9.5 %
	Output state high – 83.5 %
Boost Control Solenoid (BCS) valve	Output state low – 9.5 %
	Output state high – 83.5 %
Retarder actuator linkage (full travel)	36 mm
Boost control actuator (full travel)	10 mm at 60 psi supplied to valve

**Crankcase Pressure**

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High idle no load - crankcase blow by flow < 8 in H<sub>2</sub>O

High idle no load - crankcase pressure < 14 in H<sub>2</sub>O oil fill  
tube

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**Cold Start Assist Glow Plug (measurements taken with amp clamp)**

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Amperage draw

30 amps within 2 seconds

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**MaxxForce® 11 (10.5L)****330 hp @ 1700 rpm**

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International® MaxxForce® 11 330 hp @ 1700 rpm / 1250 ft·lb @ 1000 rpm

50 state 2008 Model Year (MY)

Engine model	GDT330
Engine Family Rating Code (EFRC)	2232 and 1132
Injector part number, original equipment	62.10100-6107
Turbocharger part number	62.09100-7793
Injection timing	Nonadjustable
High idle speed - manual transmission	2200 rpm
High idle speed - automatic transmission	2200 rpm
Low idle speed	600 rpm

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

Manifold boost pressure (gauge)	Peak torque – 203 kPa (30 psi) / 2.25 V
	Rated speed – 288 kPa (42 psi) / 3.22 V

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**370 hp @ 1700 rpm**

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International® MaxxForce® 11 370 hp @ 1700 rpm / 1350 ft•lb @ 1000 rpm

50 state 2008 Model Year (MY)

Engine model	GDT370
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Engine Family Rating Code (EFRC)	2222 and 1122
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Injector part number, original equipment	62.10100-6107
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Turbocharger part number	62.09100-7793
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Injection timing	Nonadjustable
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High idle speed - manual transmission	2200 rpm
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High idle speed - automatic transmission	2200 rpm
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Low idle speed	600 rpm
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**Full load on chassis dynamometer or highway, stabilized engine operating temperature**

Manifold boost pressure (gauge)	Peak torque – 227 kPa (33 psi) / 2.52 V
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	Rated speed – 288 kPa (42 psi) / 3.22 V
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**390 hp @ 1700 rpm**

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International® MaxxForce® 11 390 hp @ 1700 rpm / 1400 ft•lb @ 1000 rpm

50 state 2008 Model Year (MY)

Engine model	GDT390
Engine Family Rating Code (EFRC)	2212 and 1112
Injector part number, original equipment	62.10100-6107
Turbocharger part number	62.09100-7793
Injection timing	Nonadjustable
High idle speed - manual transmission	2200 rpm
High idle speed - automatic transmission	2200 rpm
Low idle speed	600 rpm

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

Manifold boost pressure (gauge)	Peak torque – 257 kPa (37 psi) / 2.87 V
	Rated speed – 295 kPa (43 psi) / 3.30 V

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**MaxxForce® 13 (12.4L)****410 hp @ 1700 rpm**

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International® MaxxForce® 13 410 hp @ 1700 rpm / 1450 ft•lb @ 1000 rpm

50 state 2008 Model Year (MY)

Engine model	GDT410
Engine Family Rating Code (EFRC)	2231 and 1131
Injector part number, original equipment	62.10100-6106
Turbocharger part number	62.09100-7791
Injection timing	Nonadjustable
High idle speed - manual transmission	2200 rpm
High idle speed - automatic transmission	2200 rpm
Low idle speed	600 rpm

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

Manifold boost pressure (gauge)	Peak torque – 196 kPa (29 psi) / 2.17 V
	Rated speed – 295 kPa (43 psi) / 3.30 V

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**430 hp @ 1700 rpm**

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International® MaxxForce® 13 430 hp @ 1700 rpm / 1550 ft•lb @ 1000 rpm

50 state 2008 Model Year (MY)

Engine model	GDT430
Engine Family Rating Code (EFRC)	2221 and 1121
Injector part number, original equipment	62.10100-6106
Turbocharger part number	62.09100-7791
Injection timing	Nonadjustable
High idle speed - manual transmission	2200 rpm
High idle speed - automatic transmission	2200 rpm
Low idle speed	600 rpm

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

Manifold boost pressure (gauge)	Peak torque – 213 kPa (31 psi) / 2.36 V
	Rated speed – 298 kPa (43 psi) / 3.33 V

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**475 hp @ 1700 rpm**

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International® MaxxForce® 13 475 hp @ 1700 rpm / 1700 ft•lb @ 1000 rpm

50 state 2008 Model Year (MY)

Engine model	GDT475
Engine Family Rating Code (EFRC)	2211 and 1111
Injector part number, original equipment	62.10100-6106
Turbocharger part number	62.09100-7791
Injection timing	Nonadjustable
High idle speed - manual transmission	2200 rpm
High idle speed - automatic transmission	2200 rpm
Low idle speed	600 rpm

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

Manifold boost pressure (gauge)	Peak torque – 254 kPa (36 psi) / 2.73 V
	Rated speed – 298 kPa (43 psi) / 3.33 V

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**Diagnostic Trouble Codes**

<b>DTC</b>	<b>SPN</b>	<b>FMI</b>	<b>Circuit</b>	<b>Condition Description</b>
1112	168	3	EIM PWR (page 350)	B+ to EIM out-of-range HIGH
1113	168	4	EIM PWR (page 350)	B+ to EIM out-of-range LOW
1114	110	4	ECT (page 308)	ECT signal out-of-range LOW
1115	110	3	ECT (page 308)	ECT signal out-of-range HIGH
1119	110	12	EWPS (page 371)	ECT temperature above maximum
1121	102	3	MAP (page 414)	MAP signal out-of-range HIGH
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1124	164	4	FRP (page 381)	FRP signal out-of-range LOW
1125	164	3	FRP (page 381)	FRP signal out-of-range HIGH
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1130	91	1	APS/IVS (page 241)	APS VREF out-of-range LOW
1131	91	4	APS/IVS (page 241)	APS signal out-of-range LOW
1132	91	3	APS/IVS (page 241)	APS signal out-of-range HIGH
1133	91	2	APS/IVS (page 241)	APS in-range fault
1134	91	7	APS/IVS (page 241)	APS and IVS disagree
1135	558	11	APS/IVS (page 241)	IVS signal fault
1136	94	4	EFP (page 316)	EFP signal out-of-range LOW
1137	94	3	EFP (page 316)	EFP signal out-of-range HIGH
1141	84	4	Truck	VSS signal out-of-range LOW
1142	84	3	Truck	VSS signal out-of-range HIGH
1148	84	8	Truck	VSS circuit frequency out-of-range HIGH
1149	84	2	Truck	VSS anti-tampering fault
1151	108	3	ECM Self (page 279)	BAP signal out-of-range HIGH
1152	108	4	ECM Self (page 279)	BAP signal out-of-range LOW
1153	108	10	ECM Self (page 279)	BAP signal abnormal rate of change
1154	171	4	IAT (page 392)	IAT signal out-of-range LOW
1155	171	3	IAT (page 392)	IAT signal out-of-range HIGH
1158	1131	0	IAT2 (page 414)	IAT2 Temp above maximum
1159	1131	3	IAT2 (page 414)	IAT2 signal out-of-range HIGH
1160	1131	4	IAT2 (page 414)	IAT2 signal out-of-range LOW
1161	105	4	MAT (page 419)	MAT signal out-of-range LOW
1162	105	3	MAT (page 419)	MAT signal out-of-range HIGH
1163	2791	4	EGRP (page 329)	EGRP signal out-of-range LOW

DTC	SPN	FMI	Circuit	Condition Description
1164	2791	3	EGRP (page 329)	EGRP signal out-of-range HIGH
1166	105	0	AMS (page 236)	MAT temperature above maximum
1211	100	4	EOP (page 363)	EOP signal out-of-range LOW
1212	100	3	EOP (page 363)	EOP signal out-of-range HIGH
1214	8029	3	Truck	Remote throttle signal out-of-range HIGH
1221	536	2	Truck	SCCS switch circuit fault
1222	597	2	Truck	Brake switch disagreement
1236	111	2	ECL (page 302)	ECL switch circuit fault
1245	7272	0	EFAN (variable speed) (page 431)	Fan speed above desired
1246	7272	11	EFAN (two speed) (page 428)	EFAN control circuit fault
1246	7272	11	EFAN (variable speed) (page 431)	EFAN control circuit fault
1256	7312	5	BCS (page 251)	Boost Control Solenoid open circuit
1257	7312	11	BCS (page 251)	Boost Control Solenoid short circuit
1258	7320	5	CMV (page 275)	Coolant Mixer Valve open circuit
1259	7320	11	CMV (page 275)	Coolant Mixer Valve short circuit
1260	7321	5	CFV (page 264)	Coolant Flow Valve open circuit
1261	7321	11	CFV (page 264)	Coolant Flow Valve short circuit
1286	51	7	ITV (page 408)	ITV unable to achieve commanded position
1289	51	0	ITV (page 408)	ITV overtemperature
1295	3464	5	ITV (page 408)	Intake Throttle Valve open circuit
1296	3464	11	ITV (page 408)	Intake Throttle Valve short circuit
1297	51	5	ITV (page 408)	ITV no input signal
1298	51	2	ITV (page 408)	ITV operation fault – under V, over amp, over temp
1311	175	4	EOT (page 367)	EOT signal out-of-range LOW
1312	175	3	EOT (page 367)	EOT signal out-of-range HIGH
1371	676	18	CSS (page 291)	Cold Start Solenoid fault
1372	676	17	CSR (page 285)	Cold Start Relay control fault
1373	7263	11	CSR (page 285)	Cold Start Relay fault
1375	7264	7	CSR (page 285)	Cold Start Relay circuit fault
1377	1136	3	ECM Self (page 279)	ECM Temp above maximum
1378	1136	4	ECM Self (page 279)	ECM Temp below minimum
1379	158	0	ECM Self (page 279)	B+ to ECM out-of-range HIGH

DTC	SPN	FMI	Circuit	Condition Description
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1381	158	3	ECM PWR (page 305)	B+ to ECM out-of-range spiked HIGH
1382	158	4	ECM PWR (page 305)	B+ to ECM out-of-range spiked LOW
1607	8021	5	CMP (page 271)	CMP - No signal
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1609	8021	8	CMP (page 271)	CMP sensor time based phase system disagreement
1610	8021	14	CMP (page 271)	CMP circuits reversed
1611	8021	3	CMP (page 271)	CMP signal out-of-range HIGH
1612	8021	4	CMP (page 271)	CMP signal out-of-range LOW
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1615	8064	4	CKP (page 268)	CKP signal out-of-range LOW
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1618	1119	0	ELS (page 356)	Lambda Sensor correction value above normal
1619	1119	1	ELS (page 356)	Lambda Sensor not plausible
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1622	1119	7	ELS (page 356)	Lambda Sensor circuit fault
1623	1119	11	ELS (page 356)	Lambda heater circuit fault
1624	7319	16	ELS (page 356)	Lambda Temp calculation above normal
1625	7319	17	ELS (page 356)	Lambda Temp calculation below normal
1626	7319	18	ELS (page 356)	Lambda Temp calibration calculation value above normal
1627	7319	19	ELS (page 356)	Lambda Temp calibration calculation value below normal
1628	1119	22	ELS (page 356)	Lambda Sensor Temp above maximum
1629	1119	12	ELS (page 356)	Lambda Sensor not detected in exhaust system
1630	1119	15	ELS (page 356)	Lambda Sensor SPI communication error status
1635	7311	4	ECT2 (page 312)	ECT2 signal out-of-range LOW
1636	7311	3	ECT2 (page 312)	ECT2 signal out-of-range HIGH
1729	3251	4	EGDP (page 320)	EGDP signal out-of-range LOW
1731	3251	3	EGDP (page 320)	EGDP signal out-of-range HIGH
1737	3241	4	EGT1 (page 336)	EGT1 signal out-of-range LOW
1738	3241	3	EGT1 (page 336)	EGT1 signal out-of-range HIGH

DTC	SPN	FMI	Circuit	Condition Description
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1742	3242	3	EGT2 (page 341)	EGT2 signal out-of-range HIGH
1744	3245	4	EGT3 (page 345)	EGT3 signal out-of-range LOW
1745	3245	3	EGT3 (page 345)	EGT3 signal out-of-range HIGH
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2235	8354	1	FRP SYS (page 385)	FRP unable to build during engine cranking
2243	8351	7	FRP SYS (page 385)	FRP above pressure relieve valve limitation
2244	8351	0	FRP SYS (page 385)	Fuel Rail Pressure Relief Valve opened (pressure was too high)
2245	8352	1	FRP SYS (page 385)	Fuel Pressure Controller output high at low idle
2246	8352	0	FRP SYS (page 385)	FRP above or below desired
2247	8353	7	FRP SYS (page 385)	HP fuel pump erratic fuel quantity balancing
2248	8354	0	FRP SYS (page 385)	Fuel Rail pressure above maximum
2310	100	10	EOP (page 363)	EOP abnormal rate of change
2311	100	0	EOP (page 363)	EOP above maximum
2312	100	11	EWPS (page 371)	EOP below minimum
2313	100	1	EWPS (page 371)	EOP below warning level
2314	100	7	EWPS (page 371)	EOP below critical level
2315	190	0	EWPS (page 371)	Engine speed above warning level
2316	190	16	EWPS (page 371)	Engine speed above maximum at ECM
2317	84	0	Truck	VSS value above programmable limit 1
2318	84	14	Truck	VSS value above programmable limit 2
2321	110	0	EWPS (page 371)	ECT above warning level
2322	110	7	EWPS (page 371)	ECT above critical level
2323	111	1	EWPS (page 371)	ECL below warning/critical level
2324	593	14	IST (California - Standard) (page 404)	Engine stopped by IST
2324	593	14	IST (Federal - Optional) (page 406)	Engine stopped by IST
2325	110	14	EWPS (page 371)	ECT value reached de-rate temperature
2351	7129	1	AMS (page 236)	EBP below desired level
2352	7129	0	AMS (page 236)	EBP above desired level
2357	7129	7	AMS (page 236)	Retarder control valve unable to achieve desired EBP
2369	1378	2	Service (page 427)	Engine oil service required
2370	94	17	Service (page 427)	Fuel filter change reminder

DTC	SPN	FMI	Circuit	Condition Description
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2372	94	1	EFP (page 316)	Fuel pressure below normal
2391	2791	11	EGR (page 325)	EGR valve internal circuit failure
2674	3242	2	EGT2 (page 341)	EGT2 signal in-range fault
2675	3241	2	EGT1 (page 336)	EGT1 signal in-range fault
2676	3245	2	EGT3 (page 345)	EGT3 signal in-range fault
2687	8302	1	AFT SYS (page 225)	DPF low flow resistance
2698	3251	0	AFT SYS (page 225)	DPF high restriction
2732	3251	2	EGDP (page 320)	EGDP stuck in-range fault
2773	8303	10	AFT SYS (page 225)	DOC unable to reach regen temp
2774	8303	1	AFT SYS (page 225)	DOC efficiency - AFI low flow
3333	164	0	FRP SYS (page 385)	Fuel Rail Pressure above maximum
3341	7129	4	EBP (page 298)	EBP signal out-of-range LOW
3342	7129	3	EBP (page 298)	EBP signal out-of-range HIGH
3787	8326	2	AFT SYS (page 225)	DPF cleanliness test - soot level too high
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4422	8002	5	INJ (page 396)	Cyl 2 open coil: open circuit
4423	8003	5	INJ (page 396)	Cyl 3 open coil: open circuit
4424	8004	5	INJ (page 396)	Cyl 4 open coil: open circuit
4425	8005	5	INJ (page 396)	Cyl 5 open coil: open circuit
4426	8006	5	INJ (page 396)	Cyl 6 open coil: open circuit
4511	8358	2	ECM Self (page 279)	Bank A Injector driver over voltage
4512	8358	3	ECM Self (page 279)	Bank A Injector driver under voltage
4513	8358	4	ECM Self (page 279)	Bank A Injector driver under current
4514	8358	5	ECM Self (page 279)	Bank A Injector driver over current
4515	8358	6	ECM Self (page 279)	Bank A Injector low driver over current
4516	8358	8	ECM Self (page 279)	Bank A Injector on phase time-out
4517	8358	10	ECM Self (page 279)	Bank A Injector time-out
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4522	8359	3	ECM Self (page 279)	Bank B Injector driver under voltage
4523	8359	4	ECM Self (page 279)	Bank B Injector driver under current
4524	8359	5	ECM Self (page 279)	Bank B Injector driver over current
4525	8359	6	ECM Self (page 279)	Bank B Injector low driver over current
4526	8359	8	ECM Self (page 279)	Bank B Injector on phase time-out

DTC	SPN	FMI	Circuit	Condition Description
4527	8359	10	ECM Self (page 279)	Bank B Injector time-out
4528	7253	14	ECM Self (page 279)	ECM Error - Injector control out of normal operating range
4553	8064	5	CKP (page 268)	CKP - No signal, open circuit
4554	8064	7	CKP (page 268)	CKP missing gap detection error
4555	8064	8	CKP (page 268)	CKP excessive pulses
4556	8064	14	CKP (page 268)	CKP circuits reversed
4571	8001	0	CYL BAL (page 295)	Cyl 1 cyl balance max limit exceeded
4572	8002	0	CYL BAL (page 295)	Cyl 2 cyl balance max limit exceeded
4573	8003	0	CYL BAL (page 295)	Cyl 3 cyl balance max limit exceeded
4574	8004	0	CYL BAL (page 295)	Cyl 4 cyl balance max limit exceeded
4575	8005	0	CYL BAL (page 295)	Cyl 5 cyl balance max limit exceeded
4576	8006	0	CYL BAL (page 295)	Cyl 6 cyl balance max limit exceeded
5536	8253	1	EIM Self (page 279)	EIM Error - Manufacturing defaults were selected
5541	8254	8	EIM Self (page 279)	EIM Error - Unexpected reset fault
5549	8240	11	EIM Self (page 279)	EIM Error - RAM programmable parameter list corrupted
5558	7314	4	AFP (page 216)	AFP VREF out-of-range
5559	7310	2	AFT (page 225)	AFP sensor failed ambient pressure test
5560	7310	4	AFP (page 216)	AFP signal out-of-range LOW
5561	7310	3	AFP (page 216)	AFP signal out-of-range HIGH
5565	7313	5	Retarder Control (page 423)	Retarder control valve open circuit
5566	7313	11	Retarder Control (page 423)	Retarder control valve short circuit
5632	8254	12	EIM Self (page 279)	EIM Error - RAM/CPU self-test fault
5637	3511	5	ECM Self (page 279)	ECM Error - Fuel Rail Pressure error
6233	3511	3	FRP (page 381)	FRP VREF out-of-range HIGH
6234	3511	4	FRP (page 381)	FRP VREF out-of-range LOW
6258	102	7	AMS (page 236)	Boost below desired
6259	2791	7	EGRP (page 329)	EGR control valve unable to achieve commanded position
6260	2791	0	EGRP (page 329)	EGRP unable to detect close position
6262	2791	5	EGR (page 325)	EGR control valve open circuit
6270	2791	14	EGRP (page 329)	EGRP valve stuck open
6271	2791	12	EGRP (page 329)	EGRP valve stuck closed



DTC	SPN	FMI	Circuit	Condition Description
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6315	8309	2	CAN Private (page 260)	ACM CAN message not received from ECM
6316	8311	2	CAN Private (page 260)	ACM CAN message not received from EIM
6317	8316	2	CAN Private (page 260)	EIM CAN message not received from ACM
6318	8342	14	CAN Private (page 260)	EIM CAN message not received from ECM
6319	8487	19	EIM Self (page 279)	EFRC information not received by ECM
6320	8484	19	EIM Self (page 279)	EFRC invalid value or time-out by ECM
6321	7311	0	EWPS (page 371)	ECT2 above warning level
6322	7311	7	EWPS (page 371)	ECT2 above critical level
6813	3241	0	EGT1(page 336) EGT2 (page 341)	EGT1 or EGT2 high temp without regen
6814	3242	7	AFT SYS (page 225)	EGT2 Temp above maximum severe
6817	3245	7	AFT SYS (page 225)	EGT3 Temp above maximum severe
6823	7311	14	EWPS (page 371)	ECT2 Temp above maximum
6835	8491	14	Truck	Auxiliary engine shutdown input circuit out-of-range
6840	51	12	ITV (page 408)	ITV broken spring or linkage
6841	51	8	ITV (page 408)	ITV feedback outside duty cycle range
6842	51	19	ITV (page 408)	ITV feedback signal not plausible
6900	8305	12	AFI (page 212)	AFI circuit fault
6901	8306	5	AFS (page 221)	AFS Valve circuit fault
6902	8307	5	AFD (page 208)	AFD Valve circuit fault
6905	8306	7	AFT SYS (page 225)	Aftertreatment fuel leak: fuel line, AFD, or AFI
6906	8306	14	AFS (page 221) AFD (page 208)	AFS valve and AFD valve connections reversed
6910	8307	12	AFT SYS (page 225)	AFD valve fail to open
6912	8308	7	AFT SYS (page 225)	AFP above normal with AFS closed
6913	7310	7	AFT SYS (page 225)	AFP above normal with AFD open
6914	7310	1	AFT SYS (page 225)	AFP below normal during DPF regen



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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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