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C7 & C9 Truck Engines EPA 2004

Electrical and Electronic Application and Installation Guide

Serial Number Prefixes

FMM

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ELECTRICAL & ELECTRONIC APPLICATION AND INSTALLATION GUIDE

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INTRODUCTION AND PURPOSE

This document is intended to provide necessary information for correct electrical & electronic application and installation of a C7 or C9 truck engine into an on-highway truck, bus, motor coach or vocational chassis. Caterpillar expects there will be some additions and modifications to this document as the engine program development continues, and as OEM requests for information not currently addressed are added. The information contained in this version of the document reflects the Caterpillar design for production C7 and C9 engines built with March 2004 software.

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General Electronic Engine Operation

1.0 Engine Functions

1.1 Electronic Governing

Two engine speed range electronic governors are available for use. These electronic governors are selectable through a programmable parameter.

1.2 Fuel/Air Ratio Control

The control system has full authority over engine fuel delivery. The mechanical fuel/air ratio control is eliminated. Electronic control of the fuel/air ratio provides optimum performance with reduced emissions.

1.3 Injection Timing Control

Injection timing is varied as a function of engine operating conditions to optimize engine performance for emissions, noise, fuel consumption, and drivability.

1.4 Torque Rise Shaping

Electronic controls provide increased flexibility to tailor the torque curve over a wide speed range.

1.5 Cold Mode Operation

When the engine is started with cold coolant, the engine will operate in "Cold Mode". The engine will operate with reduced performance until the coolant temperature has warmed. The Caterpillar electronic service tool software will indicate when the engine is operating in Cold Mode. The C7 engine will operate in Cold Mode below 64 Deg C and the C9 engine will operate in Cold Mode below 40 Deg C.

2.0 Engine Component Overview

2.1 Engine Control Module (ECM)

The ECM is located on the left rear side of the engine. The ECM has two connectors, one for the Caterpillar Engine Harness, the other for the Vehicle OEM Harness.

2.2 Boost Pressure Sensor

The Boost Pressure Sensor is an absolute pressure sensor measuring inlet manifold pressure. Boost pressure displayed by service tools and communicated over the data link is referenced to the Atmospheric Pressure Sensor reading. The Boost Pressure Sensor measures gauge pressure from 0 psi (0 kPa) to 49 psi (340 kPa). The ECM supplies the sensor with a regulated 5 Volts DC.

2.3 Atmospheric Pressure Sensor

The Atmospheric Pressure Sensor is an absolute pressure sensor. The Atmospheric Pressure Sensor measures pressure to 16.8 psiA (116 kPaA). The ECM supplies the sensor with a regulated 5 Volts DC.

2.4 Oil Pressure Sensor

An optional Oil Pressure Sensor is available for use in applications where an actual oil pressure indication is desired. Typical applications include vehicles with a vehicle data link capable Instrument Cluster that can display engine information. C7 or C9 engines do not require Engine Lube Oil Pressure monitoring because the HEUI (Hydraulically actuated Electronically controlled Unit Injector) fuel system requires oil pressure for the engine to operate. Without sufficient oil pressure, the fuel system cannot supply fuel to the engine.

The Oil Pressure Sensor measures gauge pressure from 0 psi (0 kPa) to 165 psi (1135 kPa). Oil Pressure as displayed by service tools and communicated over the data link is referenced to the Atmospheric Pressure Sensor reading. The ECM supplies this sensor with the necessary voltage.

2.5 Coolant Temperature Sensor

The thermistor based Coolant Temperature Sensor is used to monitor engine coolant temperature. Output from this sensor is used for several engine functions including Inlet Air Heater Operation, Cold Mode Operation, Cold Elevated Idle and the Engine Monitoring System.

2.6 Inlet Manifold Air Temperature Sensor

The Inlet Manifold Air Temperature Sensor is used to measure the inlet air temperature and is thermistor based like the Coolant Temperature Sensor. This sensor output is used in controlling the Inlet Air Heater, Cold Elevated Idle, Cooling Fan Output, and for Engine Monitoring.

2.7 Engine Speed/Timing Sensors

The engine speed/timing sensors are used to determine both engine speed and fuel injection timing. The sensors detect this information from a wheel on the camshaft.

2.8 Coolant Level Sensor

The coolant level sensor is an option device used to monitor the engine's coolant level. This sensor is usually mounted in the cooling system's surge tank. There are three types of sensors that may be used.

2.9 Injection Actuation Pressure (IAP) Sensor

The Injection Actuation Pressure Sensor measures the pressure in the high-pressure oil manifold. This oil is used to feed the hydraulically actuated electronically controlled unit injectors. The ECM supplies the sensor with the necessary voltage.

2.10 Injection Actuation Pressure Control Valve (IAPCV)

This valve controls the output injection actuation pressure of the high-pressure oil pump. The ECM uses the output of the Injection Actuation Pressure Sensor to determine the required output to this valve.

2.11 Inlet Air Heater and Relay

The Inlet Air Heater is an engine mounted, Caterpillar supplied and installed heater grid used for warming the inlet air to aid in starting during cold ambient temperatures. Operation is based on elevation (above sea level) and the sum of the Coolant and Inlet Manifold Air temperatures. The ECM controls the normally open relay to provide battery power to the grid.

2.12 Fuel Pressure Sensor

A Fuel Pressure sensor is included in the engine pressure sensor package. This sensor monitors the fuel supply pressure to the engine.

2.13 Oil Level Switch (GMT560 Trucks Only)

An Oil Level Switch is available only on General Motors engines. This switch is mounted in the oil pan and wired to the Engine Connector (J2) of the ECM. This switch monitors the oil level in the oil pan and is checked at initial engine power up. Proper Oil level in the engine will keep a normally open switch closed. Oil level that is too low will allow the switch to open. If the ECM senses an open switch upon three sequential engine starts, low oil level is indicated.

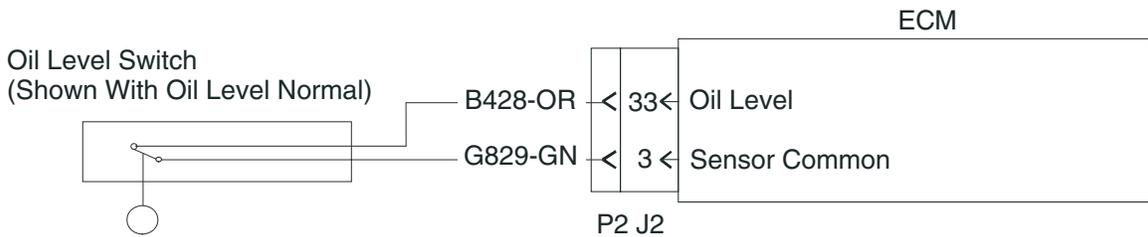


Figure 1

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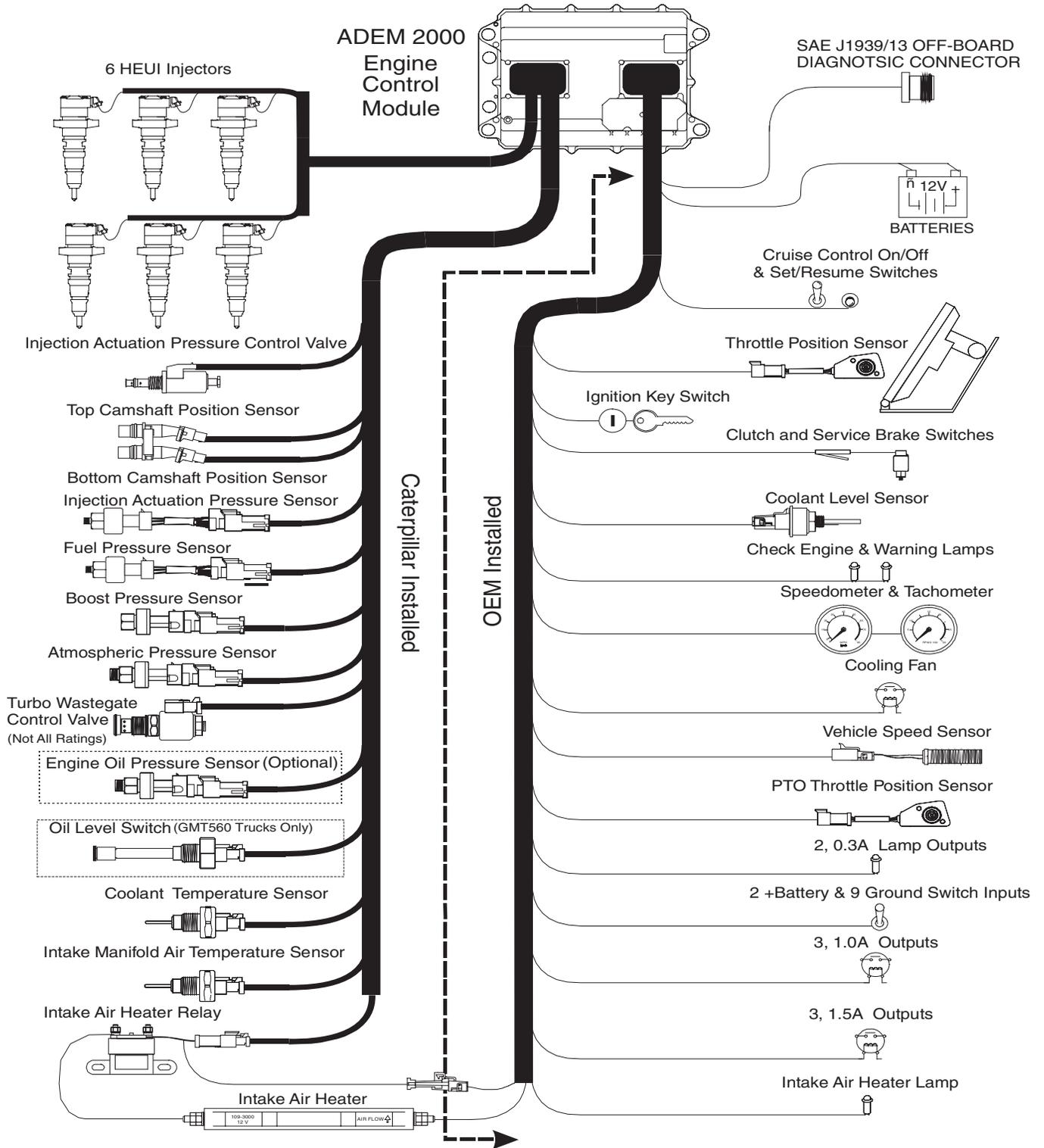


Figure 2

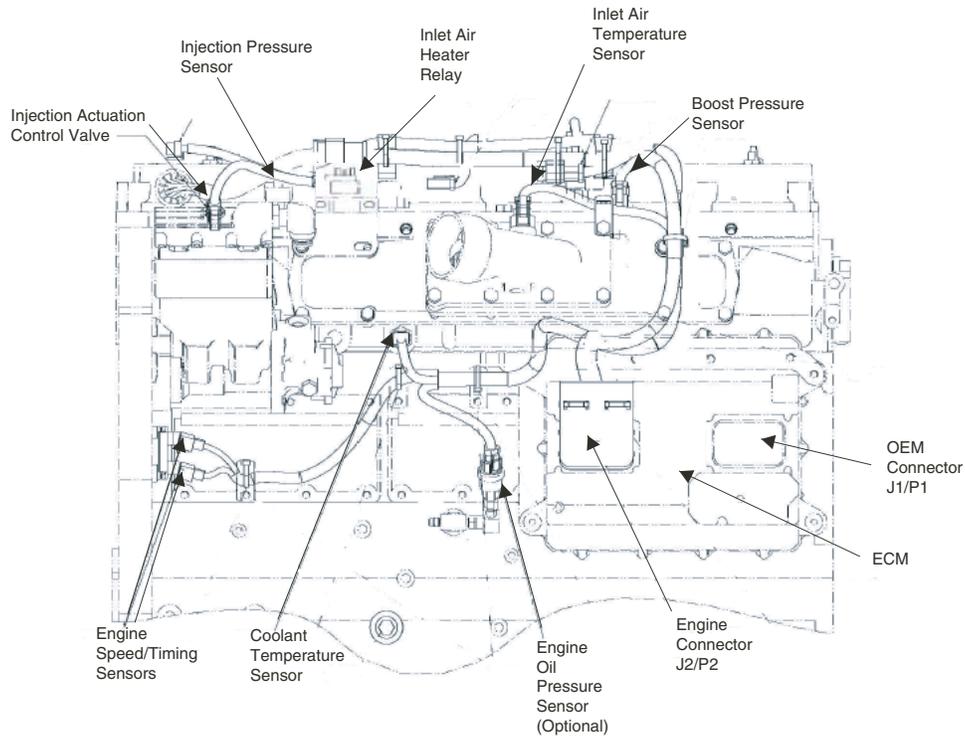


Figure 3 - C7 Sensor Locations

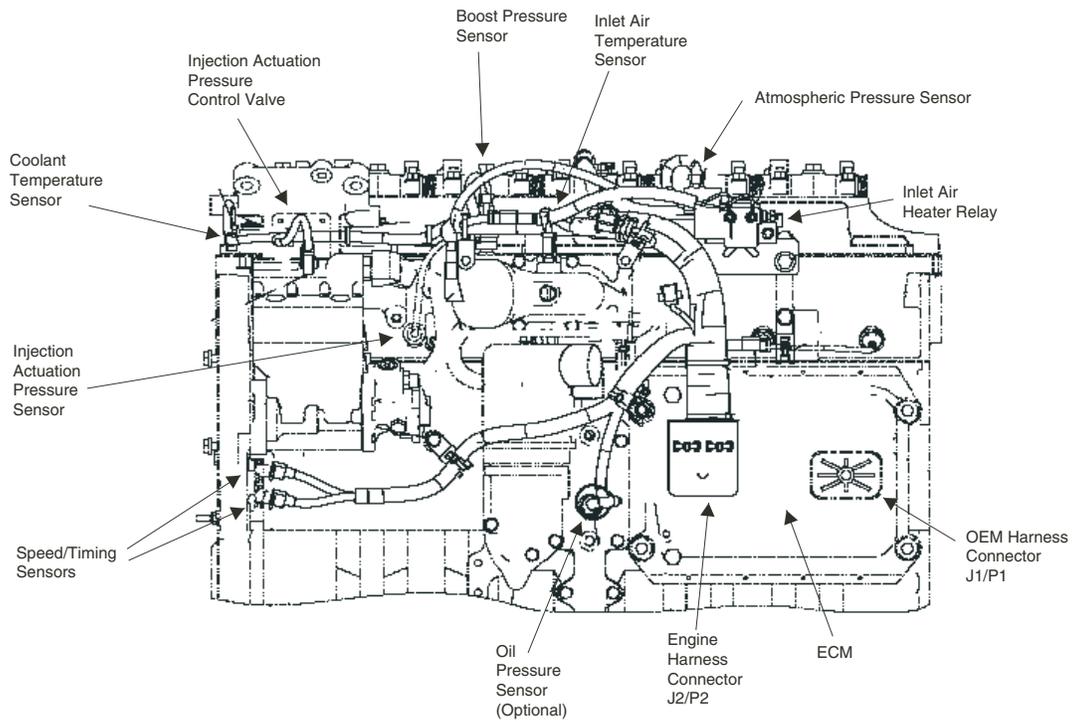


Figure 4 - C9 Sensor Locations

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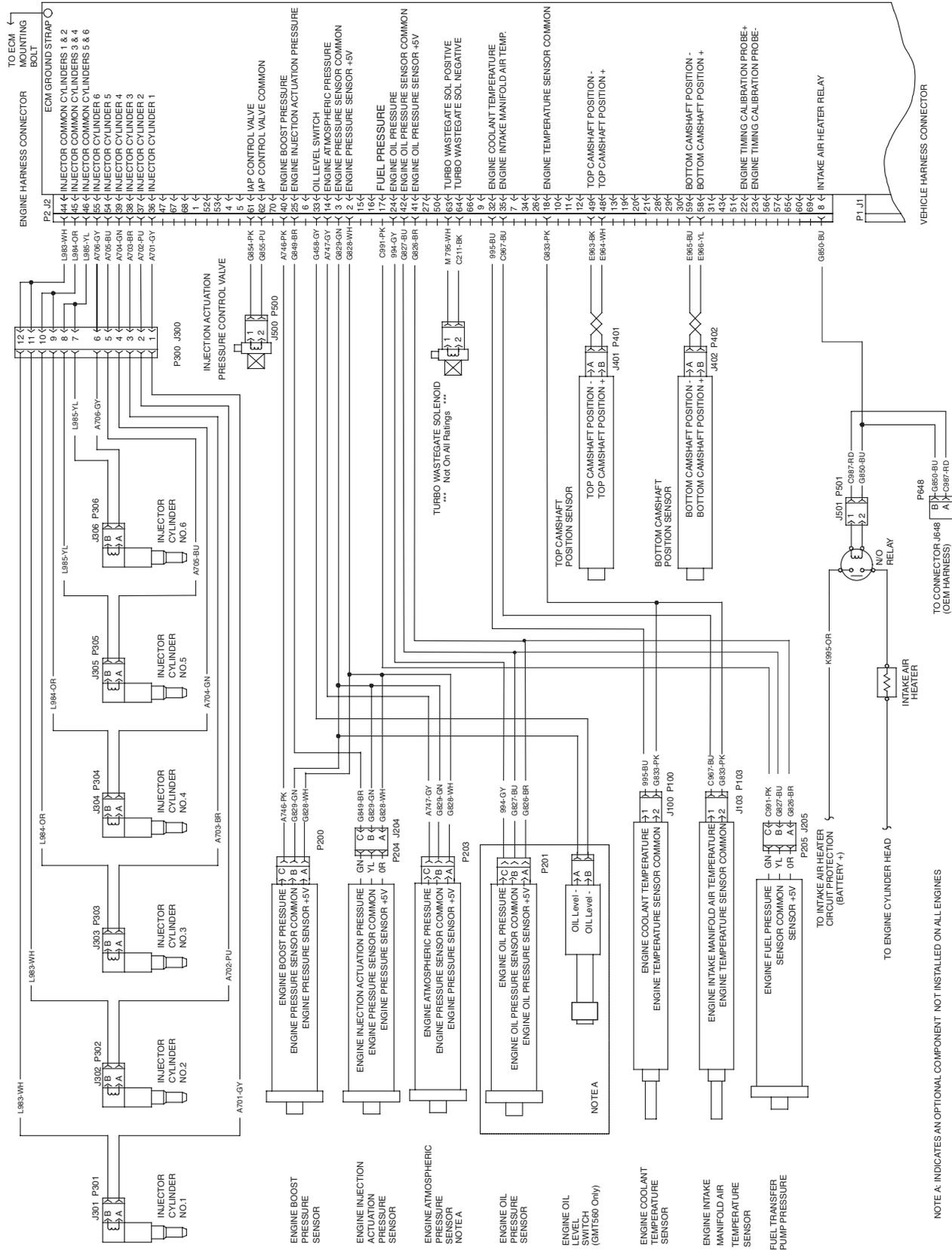


Figure 5 - C7 Engine Wiring Diagram

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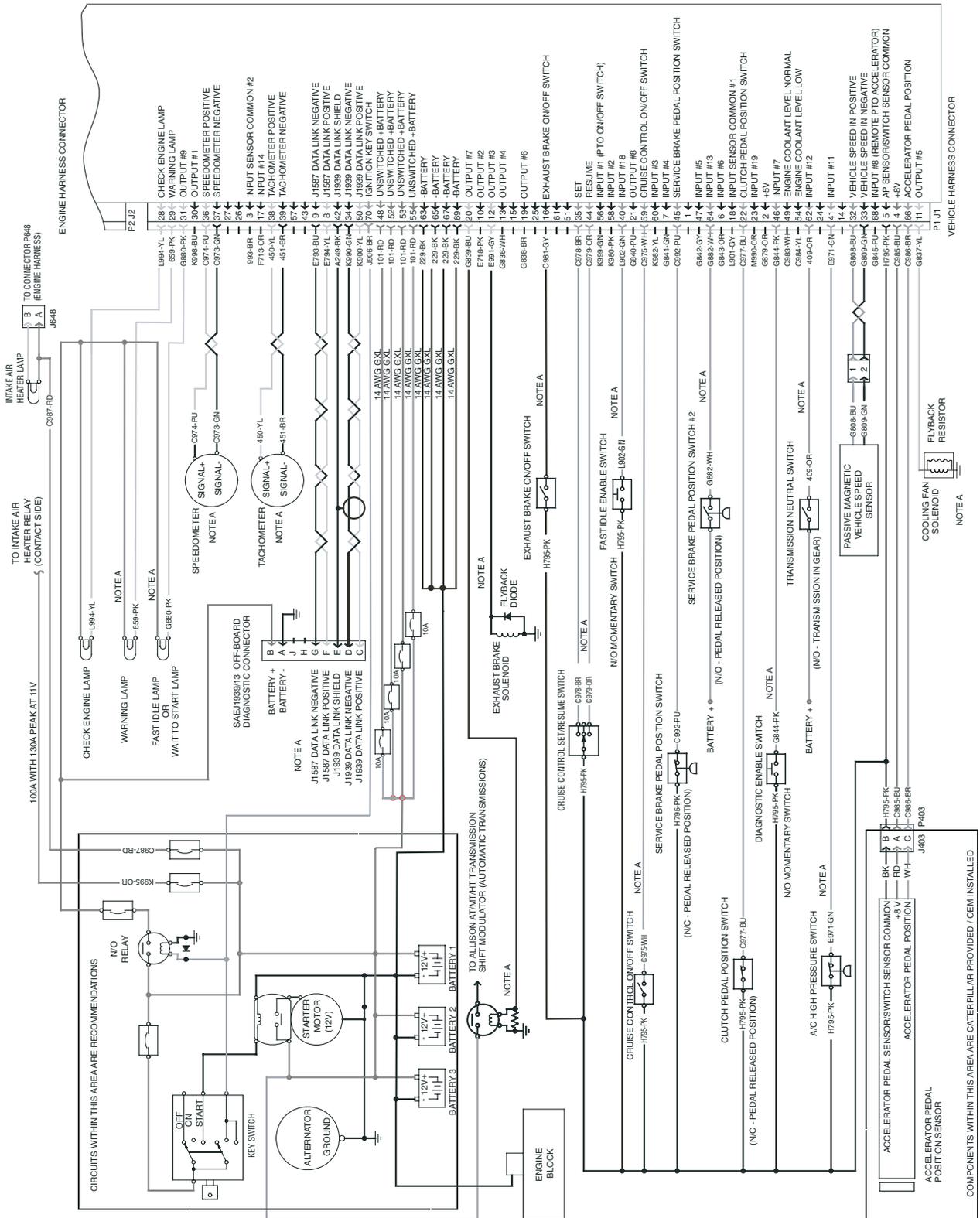


Figure 7 - C7 & C9 OEM Diagram

3.0 Engine Monitoring

The Engine Monitoring system monitors engine coolant temperature, engine oil pressure (optional), coolant level (optional) and Inlet manifold air temperature. C7 and C9 engines are shipped with the Caterpillar coolant temperature sensor and Inlet manifold air temperature sensor. Optional sensors include an engine oil pressure sensor and an OEM supplied coolant level sensor. If a monitored engine parameter exceeds normal conditions, one or more lamps will be turned on and one or more diagnostic codes will be logged. There are three Customer Programmable Levels for the Engine Monitoring Mode parameter.

- 1) Warning.
- 2) Derate.
- 3) Shutdown.

3.1. Engine Monitoring Lamp Options

The Check Engine Lamp is a requirement but a Programmable Customer Parameter, Engine Monitoring Lamps, is available to determine what additional lamps are to be turned On if normal engine operating conditions are exceeded. The default option for Engine Monitoring Lamps is Warning Lamp. This default option provides for one lamp output designated as the Warning Lamp and is used for all monitored engine condition warnings. When the Engine Warning Lamps parameter is programmed to Option 1, the lamp outputs are re-designated as follows:

J1/P1: 29 (normally used as the Warning Lamp) is used as a Low Oil Pressure Lamp.

J1/P1: 30 (normally used as a PTO Enabled Lamp) is used as a Low Coolant Lamp.

J1/P1: 31 is used as a High Coolant Temperature lamp.

The Check Engine Lamp (J1/P1: 28) is unaffected.

NOTE: The Engine Monitoring Lamps parameter is not available for GM trucks.

3.2. Engine Monitoring and OEM Requirements

The OEM is responsible for providing and installing lamps and the optional Coolant Level Sensor. The coolant level sensor is programmed through the Customer Programmable Parameter, Coolant Level Sensor. This parameter has a default factory setting of NO.

OEM provided and installed components required:

- 1) Lamp connected to J1/P1: 28 (Check Engine Lamp).
- 2) Lamp connected to J1/P1: 29 (Warning Lamp or Low Oil Pressure – Warning Lamp programmed to Option 1).
- 3) Lamp connected to J1/P1: 30 (Low Coolant Level – Warning Lamp programmed to Option 1).
- 4) Lamp connected to J1/P1: 31 (High Coolant Temp – Warning Lamp programmed to Option 1).
- 5) Coolant Level sensor – 4 Pin, 2 Wire Float Sensor or 2 Pin Switch (GM only).

Customer Parameter programming required:

- 1) Coolant Level Sensor programmed to “4-pin” or “2 Wire Float Sensor”.
- 2) Engine Monitoring programmed to “Warning”, “Derate”, or “Shutdown”.
- 3) Warning Lamps programmed to “Warning” or “Option 1”.

3.3. Engine Monitoring – Engine Sensors

The Engine Monitoring System Engine uses the engine's sensors to monitor the engine's operating condition. Limits have been established for each of the engine conditions monitored by these sensors.

3.3.1. Engine Monitoring – Intake Air Temperature Sensor

Intake Manifold Air Temperature is monitored to warn the operator of excessive intake manifold air temperature. Excessive intake manifold air temperatures will not cause the ECM to derate or shutdown the engine when Engine Monitoring is programmed to Derate or Shutdown.

Intake Manifold Air Temperature must exceed the triggering temperatures for 30 seconds after engine start up before a Diagnostic Code is generated and logged. A High Intake Manifold Air Temperature Warning diagnostic code is triggered at 194°F (90°C), and a Very High Intake Manifold Air Temperature at 230°F (110°C).

In addition to the Check Engine Lamp, the Warning Lamp is also turned ON if Engine Monitoring is programmed to Warning, Derate, or Shutdown.

3.3.2. Engine Monitoring – Oil Pressure Sensor

The Engine Oil Pressure Sensor is an optional sensor and can be used to automatically protect the engine from operating without sufficient oil pressure.

With Engine Monitoring programmed to Warning, the Check Engine Lamp will turn On at the Low Oil Pressure trip point. At the Very Low Oil Pressure trip point the Warning Lamp will be turned On in addition to the Check Engine Lamp.

When programmed to Derate the Check Engine Lamp will turn On at the Low Oil Pressure trip point. At the Very Low Oil Pressure trip point the Warning Lamp will flash and the engine will be derated.

When programmed to Shut Down the Check Engine Lamp will turn On at the Low Oil Pressure trip point. At the Very Low Oil Pressure trip point the Warning Lamp will flash during engine derate and then the engine will shut down after 30 seconds.

The ECM will indicate a Very Low Oil Pressure fault when the Engine Oil Pressure falls below 4 psi (29 kPa) at 750 RPM or below 6 psi (43 kPa) at 800 RPM and higher.

3.3.3. Engine Monitoring – Coolant Temperature Sensor

C7 and C9 engines include a Coolant Temperature Sensor as standard equipment. Engine coolant temperature trip points have been established for High and Very High Coolant Temperatures. These trip points are illustrated in the charts on the following pages and are used for logging fault codes.

With the Engine Monitoring System programmed to Warning the Check Engine Lamp will turn On at the High Coolant Temperature trip point (110-00). At the Very High Coolant Temperature trip point (110-11) the Warning Lamp will turn On in addition to the Check Engine Lamp.

When programmed to Derate, the Check Engine Lamp will turn On at the High Coolant Temperature trip point. The Warning Lamp will flash at the Very High Coolant temperature trip point and the engine will be derated.

When programmed to Shutdown, the Check Engine Lamp will turn On at the High Coolant Temperature trip point. The Warning Lamp will flash at the Very High Coolant temperature trip point and the engine will be derated. After 20 seconds the engine will be shut down.

The ECM derates available power and limits vehicle speed in steps as temperature increases. Each step represents a reduction in available power and limits vehicle speed as follows:

HP REDUCTION = 25% X (rated HP – 120 hp [90 kW])

VSL REDUCTION = 25% X (VSL – 45 mph [72.5 km/h])

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The actual rate of change of HP or VSL reduction is limited to 10% per second maximum.

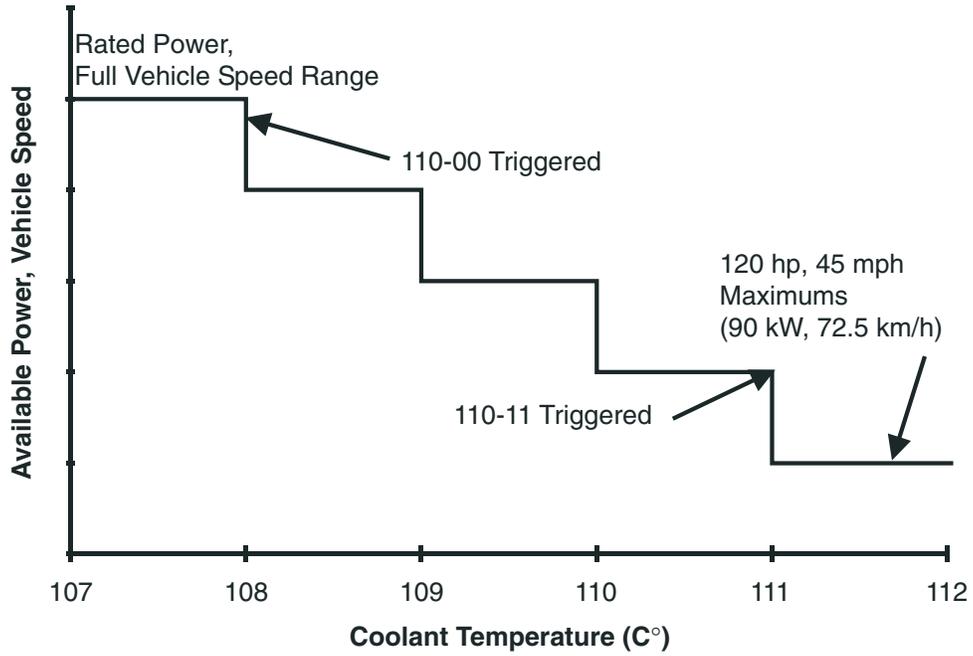


Figure 8 - C7 Truck Trip Points

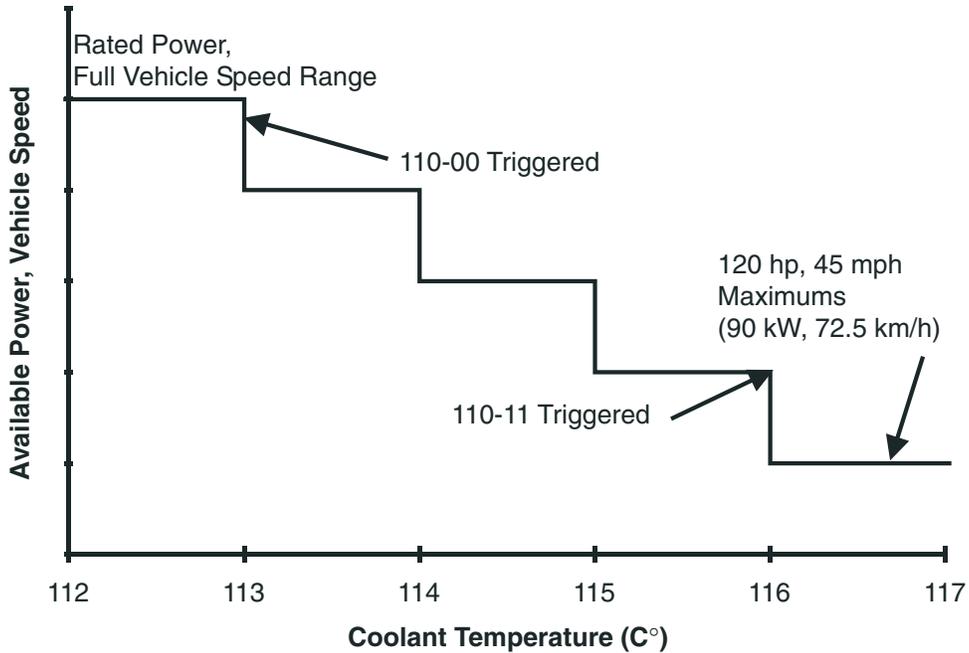


Figure 9 - C7 Emergency and C9 Truck Trip Points

Coolant Temperature Engine Monitoring Operation – Emergency Vehicle Applications

For C9 emergency vehicle ratings with automatic transmissions, the High and Very High Coolant Temperature trip points are adjusted as indicated below.

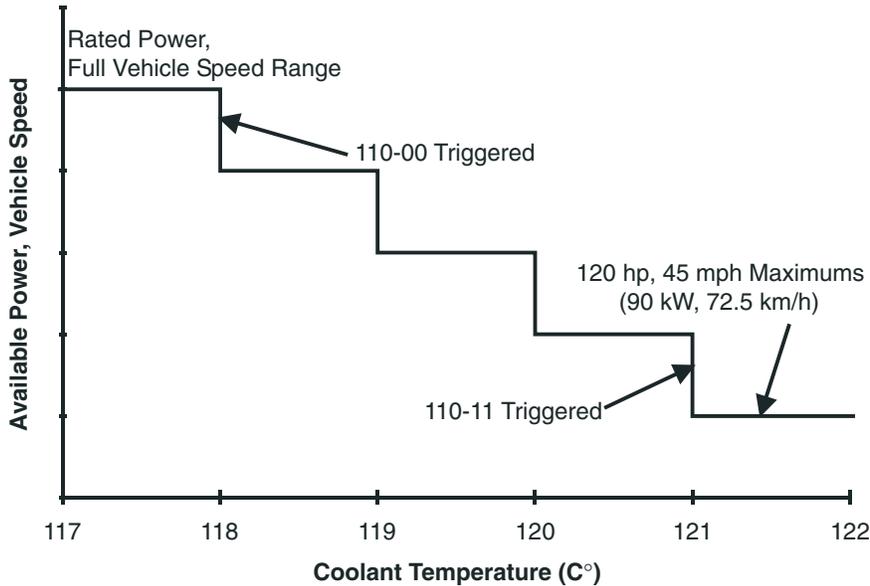


Figure 10 - C9 Emergency Trip Points

C9 Coolant Temperature Graph for Emergency Vehicles with automatic transmissions

3.3.4. Engine Monitoring – Coolant Level Sensor

The coolant level will be monitored if an optional Coolant Level Sensor is installed and the Customer Parameter, Coolant Level Sensor, is programmed to one of the available options. The OEM is responsible for providing, installing, and programming the ECM to monitor the optional coolant level sensor. Trip points, times or values, have been established for Low and Very Low coolant levels.

When programmed to Warning, the Check Engine Lamp will be turned on at the Low Coolant Level trip point and the Warning Lamp will be turned on at the Very Low Coolant Level trip point.

When programmed to Derate, the Check Engine Lamp will be turned on at the Low Coolant Level trip point. At the Very Low Coolant level trip point the Warning Lamp will flash and the engine will be derated.

When programmed to Shutdown, the Check Engine Lamp will be turned on at the Low Coolant Level trip point. At the Very Low Coolant Level trip point the Warning Lamp will flash and the engine will be derated. After 30 seconds the engine will shut down.

3.3.5. Low Coolant Level During an Engine’s First 6 Hours of Operation

If a low coolant level condition is detected during the first six hours of engine operation, an OEM clearable fault (111-14) will be recorded. This delay in logging of low coolant level events will allow OEMs to purge air trapped in the engine’s cooling system during the assembly process. After the engine has logged 6 hours of engine running time, the diagnostic faults and events for Low (111-01) and Very Low Coolant Levels (111-11) will be logged into the ECM’s nonvolatile memory. Service technicians are required to contact Caterpillar for permissions to clear Low (111-01) and Very Low (111-11) Coolant Level events from the ECM’s nonvolatile memory.

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3.4. Engine Monitoring Programmed to “Warning”

Warning is the default setting of the Engine Monitoring System. The ECM monitors Coolant Temperature, Inlet Manifold Air Temperature and the optional Coolant Level or Engine Oil Pressure (if installed). The following table indicates the diagnostic codes available. There is no effect on engine performance when active. The Check Engine Lamp will flash and the Warning Lamp will come ON as indicated in the table when the diagnostic code is active.

| PID-FMI | Code Description | Trip Point Emergency Vehicle Ratings | Trip Point | Warning Lamp | Derate |
|---------|--|--|--|-----------------|--------|
| 100-11 | Very Low Oil Pressure 750 RPM 800 RPM and up | 4 psi (29 kPa) 6psi (43 kPa) | 4 psi (29 kPa) 6psi (43 kPa) | SOLID | NONE |
| 105-00 | High Inlet Manifold Air Temp. Warning | 90°C (194°F) | 90°C (194°F) | SOLID | NONE |
| 105-11 | Very High Inlet Manifold Air Temp. | 110°C (230°F) | 110°C (230°F) | SOLID | NONE |
| 110-00 | High Coolant Temp. Warning | C9 – 113°C (235°F) C7 – 108°C (226°F) | C9 – 118°C (244°F) C7 – 113°C (235°F) | SOLID | NONE |
| 110-11 | Very High Coolant Temperature | C9 – 116°C (241°F) C7 – 111°C (232°F) | C9 – 121°C (250°F) C7 – 116°C (241°F) | SOLID | NONE |
| 111-01 | Low Coolant Level Warning | | | SOLID | NONE |
| 111-11 | Very Low Coolant Level | | | SOLID | NONE |
| 111-14 | Low Coolant Level Warning (less than 6 Hours) | | | SOLID | NONE |

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3.5. Engine Monitoring Programmed to Derate

When the Engine Monitoring System is programmed to Derate, the ECM will alter engine performance when operating parameters are exceeded. Whenever the engine is derated, the Check Engine Lamp (due to active diagnostic) and the Engine Warning Lamp will flash. For the DERATE column in the following table, mph indicates vehicle speed is limited (maximum speed is 45 mph [72.5 km/h]), “pwr” indicates engine power is limited (maximum derate is 120 hp [90 kW]), and rpm indicates engine speed is limited (maximum derate is 1350 rpm). For operating conditions causing these codes see the appropriate section for the sensor under consideration.

| PID-FMI | Code Description | Trip Point | Trip Point Emergency Vehicle Ratings | Warning Lamp | Derate |
|---------|--|--|--|-----------------|--------|
| 100-11 | Very Low Oil Pressure 750 RPM 800 RPM and up | 4 psi (29 kPa) 6psi (43 kPa) | 4 psi (29 kPa) 6psi (43 kPa) | FLASH | NONE |
| 105-00 | High Inlet Manifold Air Temp. Warning | 90°C (194°F) | 90°C (194°F) | SOLID | NONE |
| 105-11 | Very High Inlet Manifold Air Temp. | 110°C (230°F) | 110°C (230°F) | SOLID | NONE |
| 110-00 | High Coolant Temp. Warning | C9 – 113°C (235°F) C7 – 108°C (226°F) | C9 – 118°C (244°F) C7 – 113°C (235°F) | FLASH | NONE |
| 110-11 | Very High Coolant Temperature | C9 – 116°C (241°F) C7 – 111°C (232°F) | C9 – 121°C (250°F) C7 – 116°C (241°F) | FLASH | NONE |
| 111-01 | Low Coolant Level Warning | | | SOLID | NONE |
| 111-11 | Very Low Coolant Level | | | FLASH | NONE |
| 111-14 | Low Coolant Level Warning (less than 6 Hours) | | | FLASH | NONE |

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3.6. Engine Monitoring Programmed to Shutdown

The following table indicates the active diagnostic codes capable of shutting down the engine when the ECM is programmed to Shutdown. The "Time to Shutdown, Engine running > 30 Sec" column indicates the minimum time before the engine will shutdown if the engine has already been running for at least 30 seconds. The "Time to Shutdown, Fault Code at Start/Restart" column is running time if the code is active when the engine starts, or following an Engine Monitoring caused shutdown. "NO" indicates the code will not shutdown the engine.

Note: These times assume the condition causing the code exists continuously and is not intermittent.

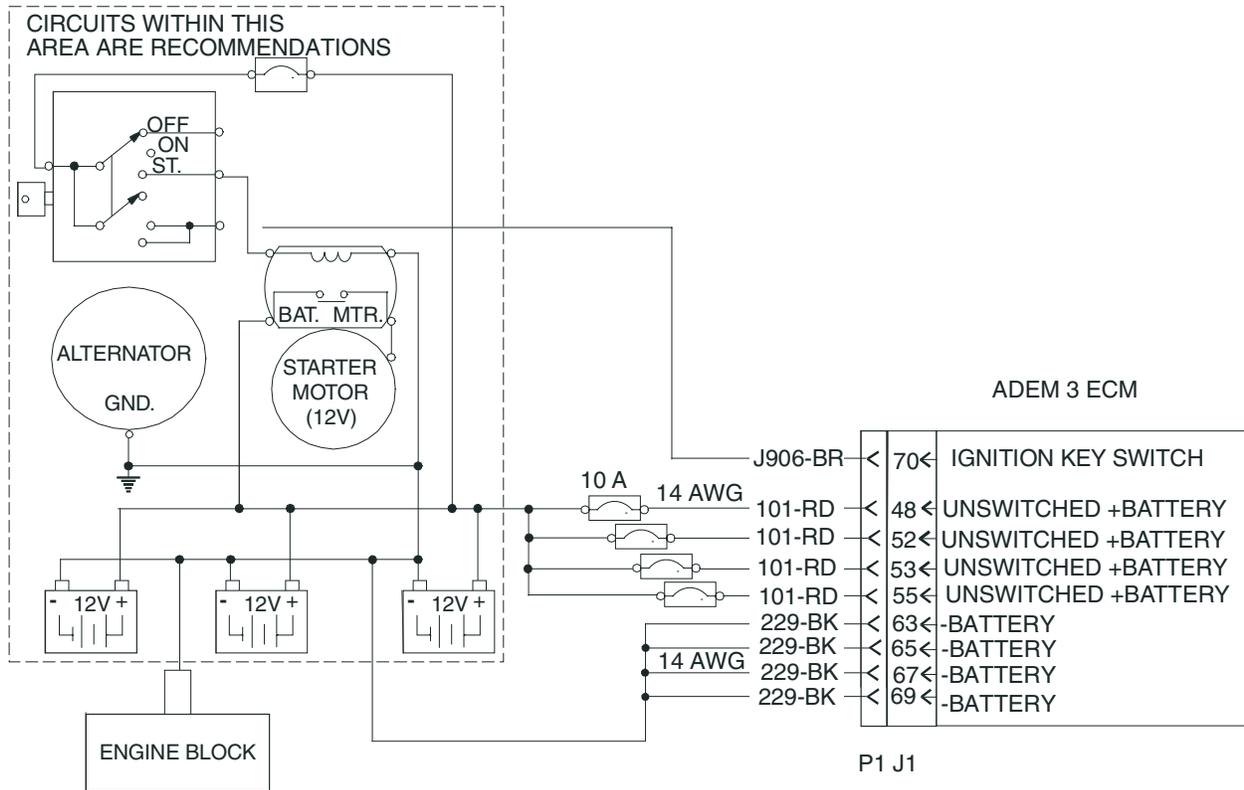
| PID-FMI | Code Description | Time To Shutdown Engine running > 30 Sec | Time to Shutdown Fault Code at Start/Restart |
|---------|--|---|--|
| 100-11 | Very Low Oil Pressure 750 RPM 800 RPM and up | 30 Sec | 18 SEC |
| 105-00 | High Inlet Manifold Air Temp. Warning | NO | NO |
| 105-11 | Very High Inlet Manifold Air Temp. | NO | NO |
| 110-00 | High Coolant Temp. Warning | NO | NO |
| 110-11 | Very High Coolant Temperature | 30 Sec | 60 Sec |
| 111-01 | Low Coolant Level Warning | NO | NO |
| 111-11 | Very Low Coolant Level | 30 Sec | 60 Sec |
| 111-14 | Low Coolant Level Warning (less than 6 Hours) | 30 Sec | 60 Sec |

OEM INSTALLED COMPONENT REQUIREMENTS and FEATURES

All of the functions described in the following text are available or enhanced if the vehicle OEM provides and installs the appropriate components. The components required for each feature are listed with the particular feature description. It is assumed the associated wire harness necessary for component connection is part of the component.

4.0 Power and Grounding Requirements and Considerations

The ECM requires unswitched power and ground connections. An Ignition Key Switch input is used to turn the ECM ON, allowing the engine to start and run.



Wiring Diagram 1 - Preferred Wiring Medium Duty ACERT Engine Battery Wiring For C7 & C9

4.1 Grounding

Proper grounding for vehicle and engine electrical systems is necessary for proper performance and reliability. Improper grounding results in unreliable electrical circuit paths. Stray electrical currents can damage main bearings, crankshaft journal surfaces, and aluminum components. They can also cause electrical noise degrading control system, vehicle, speedometer, and radio performance. These problems are often very difficult to diagnose and repair.

All ground paths must be capable of carrying any conceivable fault currents. An AWG # 4 or larger cable is recommended between the engine ground stud and the frame or starter negative post to handle alternator currents. A maximum of three ring terminals are to be connected to the engine ground stud to insure ground connection integrity. More than three terminals can cause the stud to loosen too easily. Caterpillar recommends splicing like size wires together as a method of reducing ring terminal congestion at the ground stud.

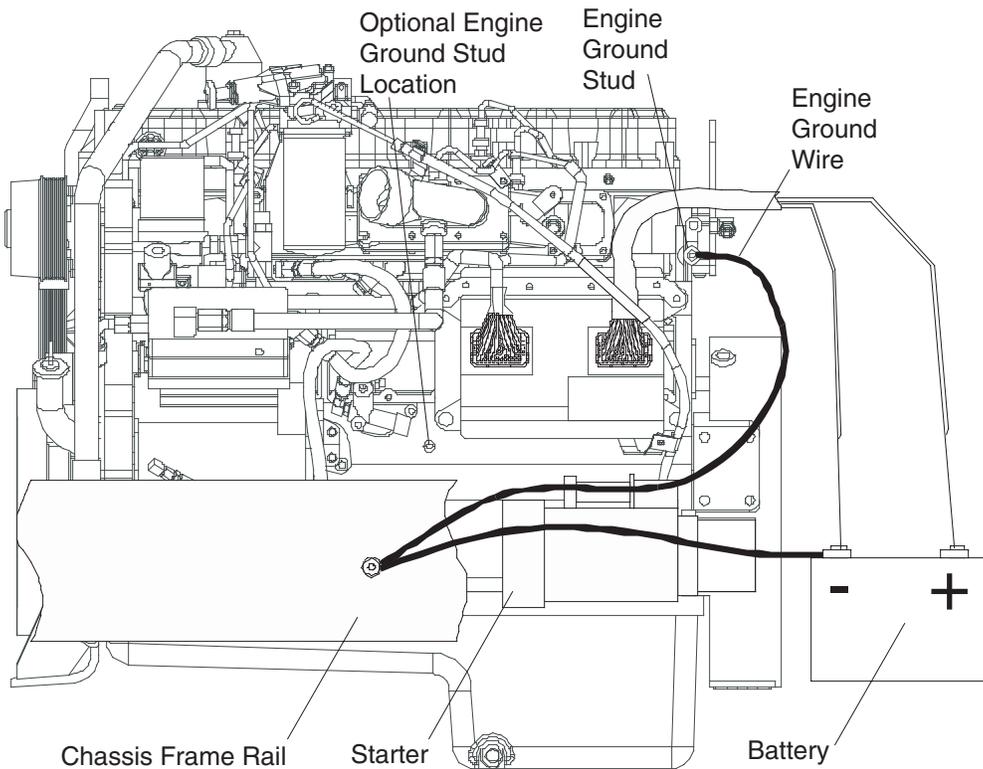


Figure 11 - Ground Stud to Frame Rail

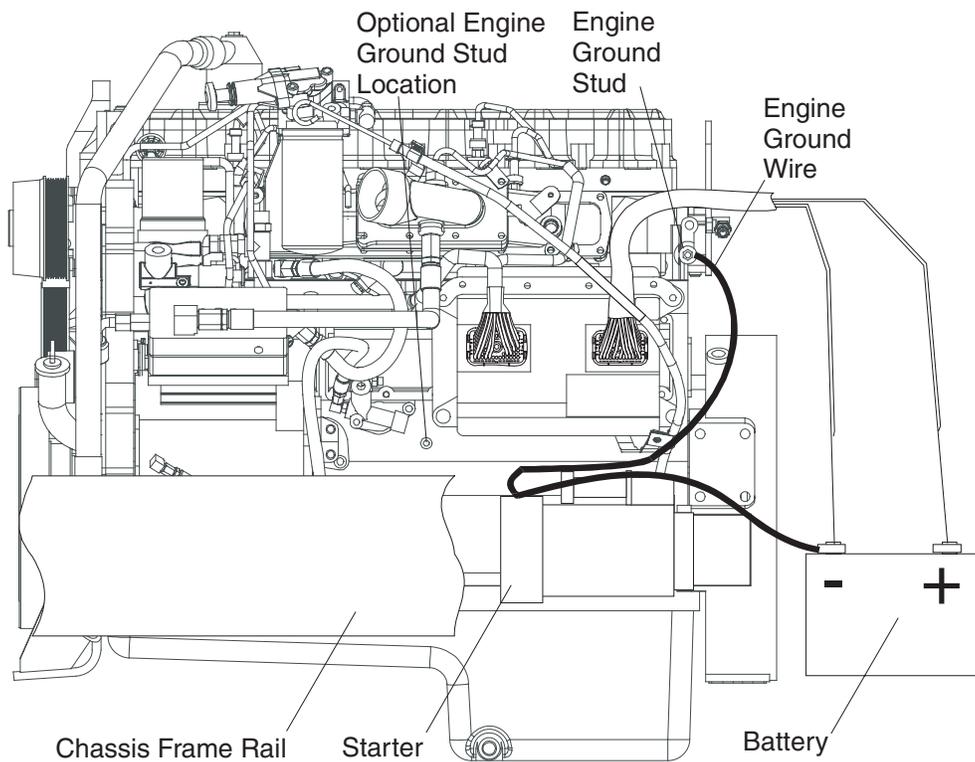


Figure 12 - Ground Stud to Starter

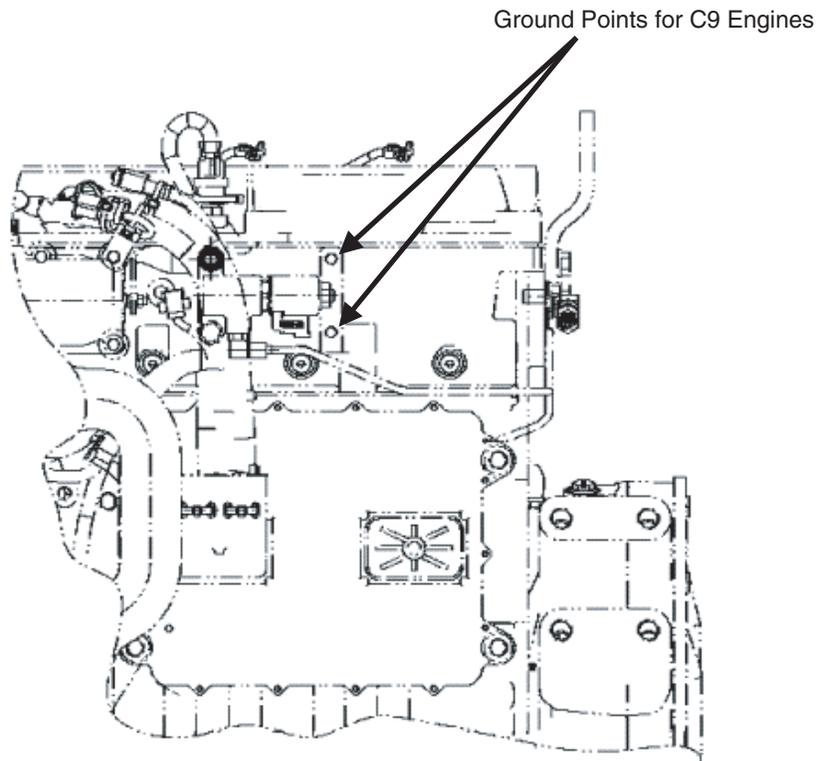


Figure 13

Note: C9 Ground Points are different from C7.

4.2 Engine Connection To Vehicle Battery Ground

To insure proper functioning of the vehicle and engine electrical systems, there must be a direct wire path from the engine ground stud to the battery negative post. Caterpillar prefers this connection route through the starter negative post. In Figure 13 and Figure 14 an additional ground stud location is identified, either location can be used.

A connection routed to a main frame ground, can also be made if the following guidelines are followed:

- 1) Connections to the frame must not be made with star washers. Star washers should not be counted on to remove paint from painted surfaces. Use flat washers for this connection, with the paint completely removed in this area.
- 2) Any paint must be completely removed from the frame rail at the point where the connection is made. Failure to do so reduces the effectiveness of the connection.
- 3) The ground path is not made through frame cross members. Bolted connections of frame cross members may not always provide required continuity for this critical connection.
- 4) Conductive grease or other methods used to reduce/eliminate the affect of corrosion on the frame rail connection.
- 5) Caterpillar does not recommend a connection from the engine ground stud to the main frame rail at a connection point different than where the battery ground connection is made. A two-point frame rail connection method depends on frame rail connections. Manufacturing process control of frame rail connections is difficult to control. This multiple frame rail connection scheme is also more difficult to troubleshoot.

4.3 ECM Negative Battery Connections

Caterpillar requires the OEM to install the ECM “-Battery” wires into their harness connector. These connections should be #14 AWG GXL wire.

4.3.1 Engine Ground Stud

C7 and C9 engines use a M8 X 1.25 Thread stud with a 20 mm stud length located on the cylinder head. The stud has two washers and properly sized nut supplied for attaching all OEM supplied ground terminals.

4.4 Electric Starting Motors

The truck engine starting system must be able to crank the engine at sufficient speed for fuel combustion to begin normal firing and keep the engine running. This requires adequate battery capacity, a starting motor, and cables to connect the battery to the starter. The following must be observed in order to obtain a satisfactory installation:

Electric starting motors must be 12 or 24 volt DC and use a positive engagement pinion drive which engages with the flywheel ring gear before the motor begins to turn. Air or hydraulic starters may also be used.

4.5 Sensor Common Connections

Only those components interfacing directly to the ECM should be connected to the ECM Sensor Common connections. ECM Connector P1 terminal-5 should be used to connect the ground side of the following engine control connected items: cruise control switches, clutch pedal position switch, fast idle enable switch, 1 service brake pedal position switch #1, A/C High Pressure switch, and the accelerator pedal position sensor. These components must not be connected to any vehicle ground.

Additional Sensor Common connections are also available. ECM terminal-18 (Input Sensor Common #1) and terminal-3 (Input Sensor Common #2) can be used if required by the harness design, for example, to splice all cab components together at terminal-5, and engine compartment components at terminal-18 or terminal-3.

Caterpillar recommends that Input Sensor Common #2 remain open for Aftermarket/Body Builder connections. If additional Sensor Common connections are required, please contact Caterpillar.

All switches connected to the control system must be externally grounded, two-wire design. Internally grounded or case grounded switches must not be used.

OEM installed components used as inputs to the ECM must not be connected to the vehicle or cab ground, and must not be case grounded. OEM installed switches must be grounded to an ECM Sensor Common via a dedicated return line to the ECM.

| Terminal Description | ECM Terminal Assignment |
|--------------------------------|-------------------------|
| AP Sensor/Switch Sensor Common | J1/P1: 5 |
| Input Sensor Common #1 | J1/P1: 18 |
| Input Sensor Common #2 | J1/P1: 3 |

4.6 Suppression Of Voltage Transients and Electrical Noise

Caterpillar recommends transient suppression be installed at the source of the transient in addition to the suppression in the ECM. Caterpillar controls are designed to comply with SAE J1455.

The use of inductive devices such as relays and solenoids can result in the generation of voltage transients on the battery lines. Unsuppressed voltage transients can exceed SAE J1455 specifications and degrade control system performance. Some specific devices that should use transient suppression are fan clutch solenoids, A/C clutch solenoids, and all relays. This is not an all-inclusive list. The OEM should specify relays and solenoids with built-in voltage transient suppression on the vehicle where possible.

The following illustration provides several possible suppression techniques to minimize the generation of voltage transients from relays and solenoids without built-in voltage transient suppression. These include, but are not limited to, installing a properly sized diode or resistor in parallel with solenoid and relay coils.

Inductive devices should be located to maximize the distance from control system components. OEM installed wiring harnesses should be routed to maximize the distance from the control system wiring harness to avoid inductive coupling of noise transients.

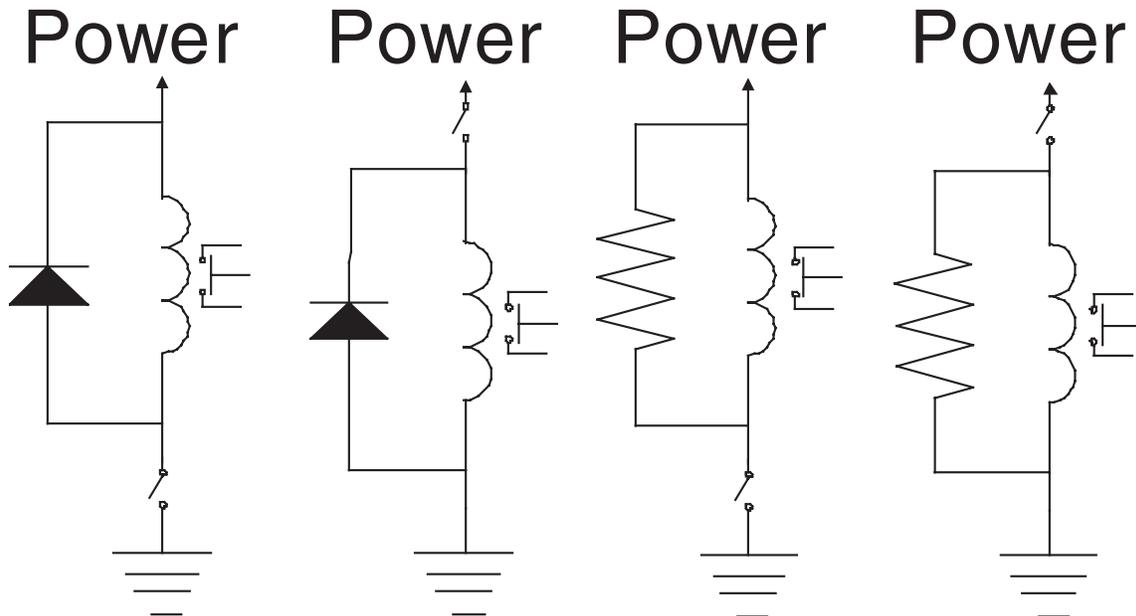


Figure 14 - Examples of Voltage Transient Suppression

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4.6.1 EMI/RFI Testing

Caterpillar EMI/RFI testing on C7 and C9 engines is performed at both the component and system level.

Component level testing is performed in a TEM cell and screen room. This radiated susceptibility testing is performed using the substitution method. In-vehicle radiated susceptibility testing is also performed.

4.7 ECM Positive Battery Connections

The positive battery connection to the C7 or C9 ECM must be made through a dedicated and unswitched circuit of 4 individual #14 AWG wires capable of a continuous duty load of 30 Amperes at 9 volts DC. Recommended fusing is 10 Amperes for each wire for a total of 40 amperes. The four required unswitched positive battery connections are terminals 48, 52, 53 and 55.

Caterpillar prefers the circuit protection be located in the cab if possible. On vehicle documentation for the circuit protection should be provided for none cab locations.

In the event of a charging system failure, the engine will operate with a supplied voltage of 9 Volts DC. At this voltage level the engine will draw up to 30 amperes. Fusing the unswitched battery wiring with less than the stated fusing recommendation of 40 Amperes can result in blown fuses and an unexpected engine shutdown due to a failed vehicle charging system.

In addition to suppressing inductive loads, powering the ECM on a dedicated fused circuit will reduce the possibility of degraded control system performance due to voltage transients. No additional loads should be connected between the ECM and ECM circuit protection.

The ECM monitors the battery supply voltage and will trigger a diagnostic code if this voltage drops below and then returns above 6 Volts DC.

4.8 Voltage Requirements and Considerations

The control system has been designed to operate on 12 Volt or 24 Volt electrical systems. The control system is protected against jump start conditions and short circuits to positive battery and negative battery.

Minimum voltage requirements and maximum current draw for the C7 and C9 control system are as follows:

| Condition | Minimum Voltage | Maximum Current Draw |
|------------------------------------|-----------------|----------------------|
| Normal Operation | 11.0 VDC | 22.0 Amperes |
| Engine Cranking | 6.0 VDC | 16 Amperes |
| Ignition Key On, Engine Off ** | 9.0 VDC | 20 Amperes |
| Electrical Charging System Failure | 9.0 VDC | 30 Amperes |

**This condition includes the Inlet Air Heater Relay and HEUI injector solenoid cycling during cold weather conditions.

Minimum voltages are specified at the OEM connector (P1 – terminals 48, 52, 53, 55 referenced to P1 – terminals 63, 65, 67, 69).

4.9 ECM Current Draw with Ignition Key Off

The ECM draws less than 20 mA while the Ignition Key Switch is in the OFF position.

4.10 Welding on a Vehicle Equipped with a C7 or C9 Engine

Before welding on a vehicle equipped with an electronic engine, the following precautions should be observed.

1. Turn the engine OFF. Place the ignition key switch in the OFF position.
2. Disconnect the negative battery cable from the battery. If the vehicle is equipped with a battery disconnect switch, open the switch.

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3. Clamp the ground cable of the welder to the component that will be welded. Place the clamp as close as possible to the weld.
4. Protect any wiring harnesses from welding debris and spatter. Use proper welding procedures in order to weld the materials.

NOTICE

DO NOT use electrical components in order to ground the welder. Do not use the ECM or sensors or any other electronic component in order to ground the welder. Clamp the ground cable for the welder to the component that will be welded.

Place that clamp as close as possible to the weld. This will reduce the possibility of damage to the bearings of the drive train, hydraulic components, ground straps, and other components of the vehicle.

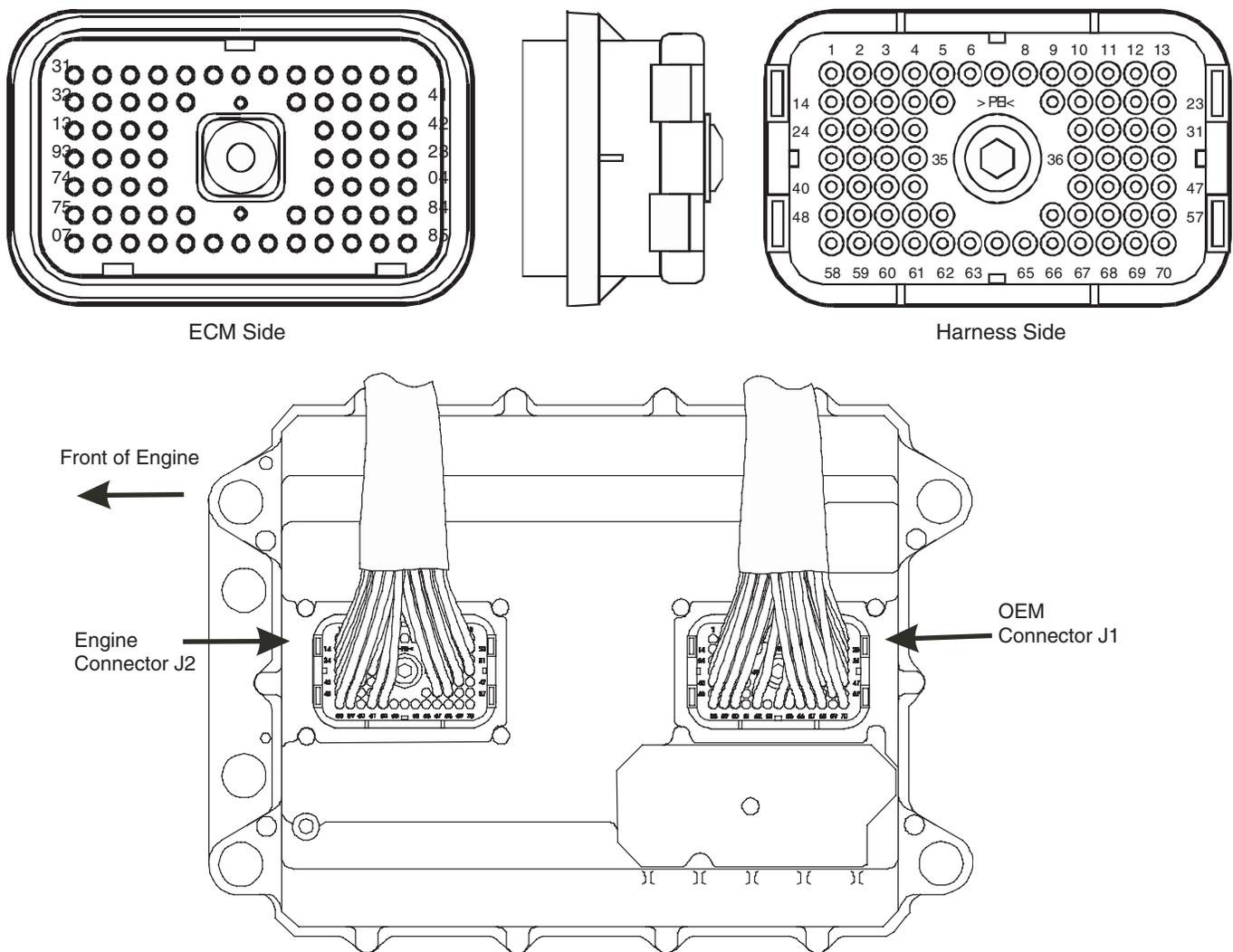


Figure 15 - ADEM 2000TM ECM and Wiring Harness Connectors

5.0 Connectors and Wiring Harness Requirements

5.1 ECM Connector

Caterpillar does not recommend the use of “non-conductive grease” with the ECM connector.

5.1.1 70 Terminal ECM Connector Part Numbers

The ECM uses an integral rectangular 70 Terminal AMP connector to interface to the OEM vehicle wiring harness (AMP part number 776241-1, Caterpillar part number 160-7689). The ECM also uses a 70 Terminal AMP connector to interface to the engine electronics (AMP part number 776241-2, Caterpillar part number 160-7690).

5.1.2 ECM 70 Terminal Connector Allen Screw Torque

ECM Connector Screw torque should be 6 N•m ±1 N•m (4.4 lb.- ft. ± 0.7 lb.- ft., 53 lb. - in. ± 8.9 lb. - in.).

5.2 ECM Connector Wire Gauge Size

The battery positive and negative connections must be made with #14 AWG SAE J1128 type GXL wire for the AMP 776093-1 stamped and formed terminal or the Deutsch 0462-209-1631 solid terminal. All other connections may be #16 SAE J1128 type SXL or GXL or #18 AWG SAE J1128 type SXL (or equivalent wire).

5.2.1 ECM 70 Terminal Connector Wire Insulation and Size Range

Insulation material is cross – linked polyethylene. Outside diameter insulation range is 2.26 to 3.33 mm (0.089 to 0.131 in.). The following table provides insulation diameter range for each gauge and wire type.

ECM Connector Wire Insulation and Gauge Size

| Wire Type | Wire Gauge | Insulation Diameter |
|-----------|------------|---------------------|
| GXL | 14 | 0.114 - 0.125 |
| | 16 | 0.098 - 0.112 |
| | 18 | 0.089 - 0.098 |
| SXL | 16 | 0.116 - 0.131 |
| | 18 | 0.103 - 0.118 |

5.3 ECM Connector Terminals and Sealing Plugs

The OEM connector socket terminals must be compatible with the wire size used. All unused connector socket slots must be filled with plugs to insure connector sealing.

Note: Do not use “non-conductive” grease to seal unused terminal cavities.

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5.3.1 ECM 70 Terminal Connector Terminals

The following table provides terminal and plug part numbers. All terminals used in the ECM connectors must be gold or selective gold flash terminals.

Required ECM 70 Terminal Connector Parts

| Description | Usage | Vendor – Part Numbers | Caterpillar Part Numbers |
|--|---|----------------------------|--------------------------|
| 70 Terminal Plug, Keyed | OEM Vehicle Harness | AMP – 776241-1 | 160-7689 |
| AMP Gold Socket Contact (stamped & formed) | #16 & #18 AWG SXL and #14, #16 & #18 AWG GXL wire | AMP – 638090-1 | 126-1766 |
| Deutsch Gold Socket Contact (machined-for field service) | #14 AWG SXL and #14 AWG GXL wire | Deutsch – 0462-209-1631 | 126-1768 |
| Deutsch Gold Socket Contact (machined-for field service) | #16 & #18 AWG SXL and #16 & #18 AWG GXL wire | Deutsch – 0462-201-1631 | 9X-3402 |
| Sealing Plug #14 – 18 AWG | Unused Connector Cavities | PEI Genesis – 225-0093-000 | 9G-3695 |
| Sealing Plug #14 – 18 AWG | Unused Connector Cavities | Deutsch – 114017 | 8T-8737 |

5.3.2 ECM Connector Terminal Installation Guidelines

Two options are available for AMP terminals. It is critical the harness supplier use the correct crimp tools and tool calibration/setup procedures, when selecting AMP and Deutsch connector terminals. The following tables indicate proper crimp tooling, go-no-go criteria, and crimp dimensions for each contact- wire combination.

*AMP 776093-1 Stamped & Formed Socket with #16 and #18 AWG SXL Wire or with #14, #16 or #18 AWG GXL Wire (Caterpillar P/N 126-1766)

| Wire Type | Wire Gauge | Crimp Height (+/- 0.002 In) | Crimp Width (in) |
|-----------|------------|-----------------------------|------------------|
| GXL | 14 | 0.064 | 0.100 |
| | 16 | 0.059 | 0.100 |
| | 18 | 0.054 | 0.100 |
| SXL | 16 | 0.054 | 0.100 |
| | 18 | 0.059 | 0.100 |

*Insulation barrel crimp height for AMP 776093-1 stamped and formed sockets must be set according to the insulation diameter. Crimp width for all insulations is 0.145 inches maximum.

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Deutsch 0462-209-1631 Solid Socket with #14 AWG Wire (Caterpillar P/N 126-1768)

| Crimp Tool Options | DIE | Locator | GO | No – GO |
|-----------------------------|---------|------------|-------|---------|
| Deutsch Hand Tool HDT-48-00 | N/A | N/A | 0.045 | 0.057 |
| Pico Model 400 | 4301-16 | 414DA- 16N | 0.043 | 0.50 |

Deutsch 0462-209-1631 Solid Socket with #16 and #18 AWG Wire (Caterpillar P/N 9X3402)

| Crimp Tool Options | DIE | Locator | GO | No – GO |
|-----------------------------|------------|---------|-------|---------|
| Deutsch Hand Tool HDT-48-00 | N/A | N/A | 0.045 | 0.050 |
| Pico Model 400 | 414DA- 16N | 4301-16 | 0.043 | 0.50 |

5.3.3 ECM 70 Terminal Connector Sealing Plugs

Two options are available for plugging unused connector cavities. Either the Deutsch 114017 (Caterpillar part number 8T-8737) or PEI Genesis 225-0093-000 (Caterpillar part number 9G-3695) sealing plugs can be used. Correct installation of either of these cavity plugs is critical to maintain connector socket seal integrity. The plug cap is designed to rest against the seal, not inserted in the hole in the seal.

Note: Do not use “non-conductive” grease to seal unused cavities.

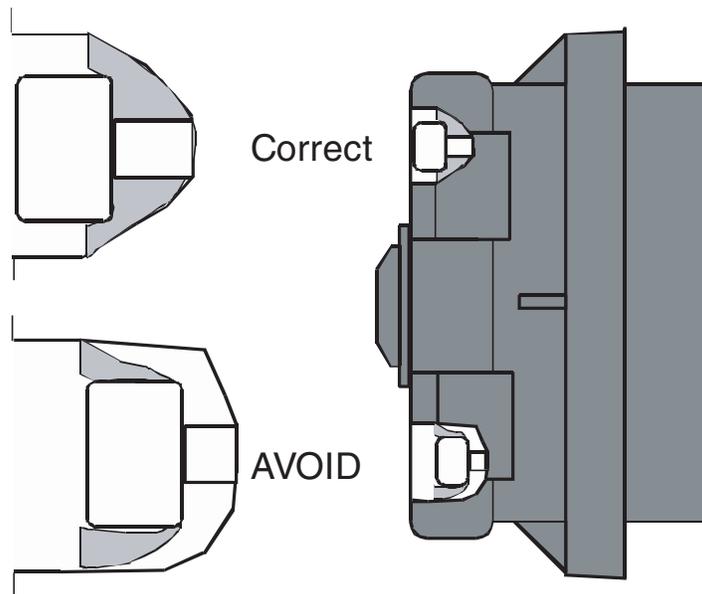


Figure 16

5.3.4 Connector Interface Seal

The ECM Connector Interface seal is serviceable using Caterpillar part number 159-9322.

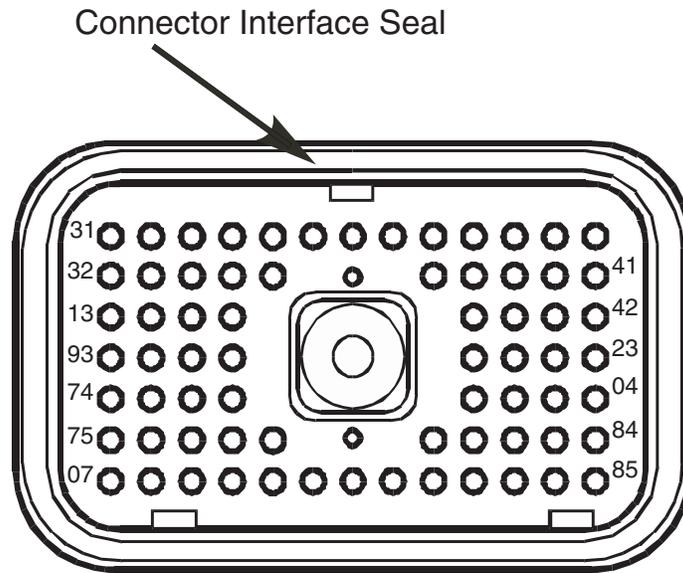


Figure 17 - ECM 70 Terminal Interface Seal

5.4 Sealing Splices and Ring Terminals

Caterpillar requires all ring terminals and splices connected to the Engine ECM be sealed using Raychem ES2000 or equivalent. This reduces moisture invasion under wire insulation.

5.5 OEM Harness Routing

Routing of the harness should insure connector seals are not stressed because the harness curvature is too close to the connector. This applies to routing of OEM lines on or near the engine harness as well as the OEM ECM Connector.

The following graphic illustrates the problem if the harness curvature is too close to the connector. When this occurs the connector seal is stretched away from the wire, providing an opening for moisture entry. The wire should exit perpendicular to the connector before curving as necessary for routing. The harness bundle should have a bend radius greater than twice the harness diameter. This routing practice will also ensure the harness is not pulled too tightly resulting in intermittent connections or broken harness wires.

Caterpillar recommends the OEM harness supplier perform the harness to provide the correct bend radius, assuring connector sealing and preventing harness abrasion.

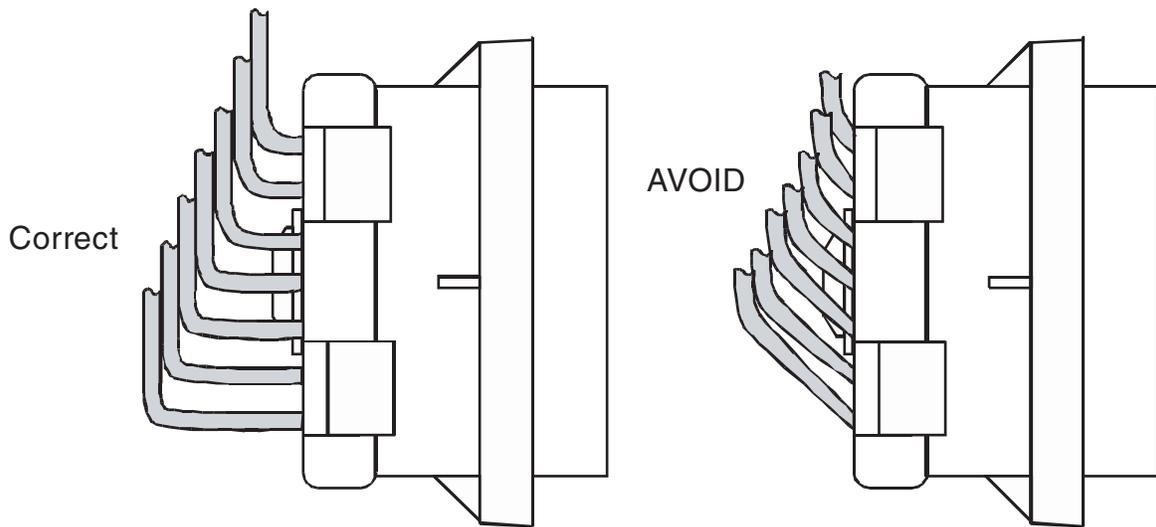


Figure 18

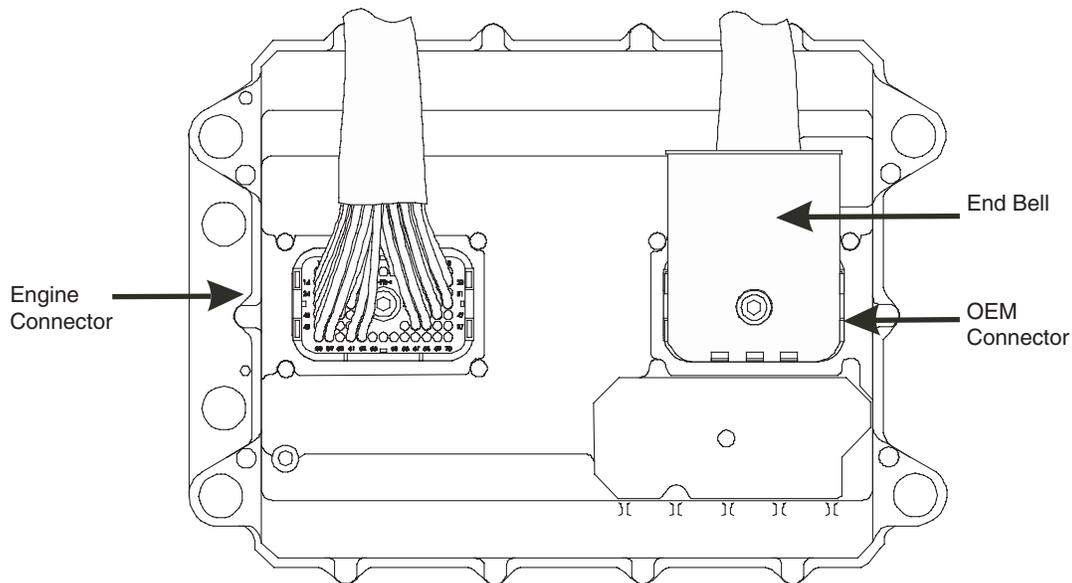


Figure 19 - 70 Terminal ECM Connector with Endbell