Application & Installation Guide Electrical & Electronic

Cat® C3.6 U.S. EPA Tier 4 Final/EU Stage V, China NR4 and EU Stage IIIA Equivalent Engines

LEBH0061-12

Contents

The information contained in this manual is confidential and proprietary to Caterpillar. It is intended for circulation only to Caterpillar employees, or to employees of OEMs intending to purchase and install Tier 4 Final /EU Stage V and China NR4 Caterpillar engines in their equipment. Distribution of this material must be limited to personnel whose duties require knowledge of such material and is intended exclusively for their information and training. Distribution of this material for other purposes is strictly prohibited.

1.0 Introduction and Purpose

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1.1 A & I Manual Introduction

This manual has been compiled to explain mandatory requirements, provide information for designers, and provide information on the application and installation of the C3.6 engine into industrial equipment, to meet U.S. Environmental Protection Agency (EPA) Tier 4 Final / European Union (EU) Stage V emission standards. Note that the C3.6 Stage IIIA engine without aftertreatment is designed to meet EU Stage IIIA equivalent emissions tiers.

The following media publications should be used in conjunction with this manual for further technical information:

- C2.8 and C3.6 Mechanical Application & Installation Manual - LEBH0075
- Exhaust Fluid System Supplement.
- Customer Assembly Requirements (CAR)
- C3.6 Operator and Maintenance Manual (OMM).
- System Operation Test and Adjust (SOTA).
- Specifications (Specs)
- Disassembly and Assembly (D&A).
- Engine Sales Manual (ESM).

Always follow correct practices, procedures and safety precautions.

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Caterpillar is not responsible for failures resulting from attachments, systems, accessory items, and parts not sold or approved by Caterpillar. Consult the applicable warranties for complete details of the Caterpillar warranty coverage.

The OEM and customer are reminded that it is their responsibility to ensure compliance with the requirements of any applicable employee health and safety laws and regulations, both nationally and internationally, in relation to the engine installation applicable to the equipment concerned. In giving notice of approval in respect to the installation, Caterpillar does not assume such responsibilities on behalf of the OEM or customer and while engine installation approval and advice is an opinion given in good faith, the equipment manufacturer and customer remain responsible as detailed above and must act and insure accordingly.

1.1.1 Regulation

To ensure the Engine is compliant to the regulation, it’s important to note that the ECU and the Engine are correctly paired. To ease the matching process, both Engine and ECU have serial number labels attached.

It is the responsibility of the OEM to ensure the ECU and Engine are paired as per their serial number labels.

<u>Warning:</u>

Not respecting the pairing of the engine and ECU will result in emission non-compliance and a potential negative performance impact.

1.1.2 Safety

Most accidents that involve product operation, maintenance and repair are caused by failure to observe basic safety rules or precautions. An accident can often be avoided by recognizing potentially hazardous

situations before an accident occurs. A person must be alert to potential hazards. This person should also have the necessary training, skills and tools in order to perform these functions properly.
The information in this publication was based upon current information at the time of publication. Check for the most current information before you start any job. Caterpillar Dealer will have the most current information.
Improper operation, maintenance or repair of this product may be dangerous. Improper operation, maintenance or repair of this product may result in injury or death.
Do not operate or perform any maintenance or repair on this product until you have read and understood the operation, maintenance and repair information.
Caterpillar cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this publication and on the product are not all inclusive. If a tool, a procedure, a work method or an operating technique that is not specifically recommended by Caterpillar is used, you must be sure that it is safe for you and for other people. You must also be sure that the product will not be damaged and / or made unsafe by the procedures that are used.

1.1.3 Warning – Welding

Welding can cause damage to the on engine and aftertreatment electrical and electronics components. The following precautions should be taken before and during welding:

- Turn the engine OFF.
- Place the ignition key switch in the OFF position.
- Disconnect the negative battery cable from the battery. If the machine is fitted with a battery disconnect switch then open the switch.
- Clamp the ground cable of the welder to the component that will be welded. Place the clamp as close as possible to the weld.
- Protect any wiring harnesses from welding debris and splatter.

Important Note:

- **<u>Do not</u>** use electrical components in order to ground the welder.
- **<u>Do not</u>** use the ECU, sensors and / or any other electrical components in order to ground the welder.

1.1.4 Warning - Electrostatic Paint Spraying

The high voltages used in electrostatic paint spraying can cause damage to on engine electronics. The damage can manifest itself through immediate failure of components, or by weakening electronic components causing them to fail at a later date.
Electrostatic painting is not recommended. In circumstances where the engine must be painted using electrostatic processes, it is necessary to provide technical details of the applied voltage, estimated current and maximum process exposure time. Electrostatic painting is not permitted without prior consent.
As a minimum where the electrostatic process characteristics are acceptable it is necessary to use a common ground for all circuits on the engine electrical components and aftertreatment electrical components. All pins must be connected to a common ground. The engine ECU **<u>must not</u>** be painted using any processes.

1.1.5 Washing and Painting Processes (Excluding Electrostatic)

The engine and aftertreatment electrical components must not be painted without prior consent. The ECU must not be painted. Additionally the engine ECU pressure valve and connectors need to be protected against fluid / paint ingress. The ECU can only be washed if both of the ECU connectors are attached. During Jet washing the ECU must not be powered and the following limits must be adhered to:

Min Distance from ECU Case (mm)	300
Max Water Flow Rate (L/min)	14
Max Water Pressure (kPa)	8000
Max Water Temperature (^{0}C)	80
Max Exposure Time (sec)	30

Table 1.1

1.1.6 Warning – Jump Starting

Jump-starting an engine can cause higher than normal voltages to appear across the battery terminals. Care must be taken that this does not exceed the recommended maximum voltage for all electrical components on the engine and aftertreatment components.

1.2 Functional Safety

EU legislation for machinery safety necessitates compliance with harmonised functional safety standards at the point at which a machine product is placed on the market.

In anticipation that certain machine installations may place particular requirements on the functional safety performance level to be achieved by some functions within the engine control system, a number of developments have been made.

To understand whether the following information is relevant to a particular installation, a machine level PHA (Preliminary Hazard Analysis) or MCSSA (Machine Control System Safety Assessment) must be carried out to the functional safety standard relevant to your product (eg. ISO 13849 or ISO 19014).

Based upon a risk analysis (PHA) performed at the engine level, software developments have been made to allow two engine control functions (engine speed control and ether control) to achieve a Performance Level of C (PL-c) according to ISO 13849, if required by the PHA or MCSSA for a particular machine installation, AND if configured correctly.

It is the customer's responsibility to ensure that the engine is configured correctly with the service tool, as described below, AND that the throttles selected meet the defined reliability criteria AND that the resulting system is configured and validated correctly. Caterpillar cannot accept any responsibility for inappropriate configuration of the parameters associated with functional safety.

1.2.1 Engine Speed Control

In order to support PL-c for Engine Speed Control there are a number of configuration rules that must be followed to provide adequate Diagnostic Coverage (DC.)

The ECM will mitigate the following hazards if the configuration explained below is adhered to:

- Unintended Acceleration
- Unintended Elevated Idle
- Absence of Commanded Deceleration

1.2.1.1 Functional Safety Monitoring Configuration

To enable the engine software monitoring for the application features discussed below the following configuration must be made with the Service Tool to set Desired Engine Speed Monitor Enable Status Configuration to **Enabled**.

Configuration field names	Configuration Options	Default Configuration
Desired Engine Speed Monitor Enable Status Configuration	Enabled / Disabled	Disabled

Table 1.2

This configuration is protected by the Feature Protection System (FPS) so Factory Passwords must be obtained to change this.

1.2.1.2 Diagnostics and Fault Reaction

If the monitoring for Desired Engine Speed is triggered the following diagnostic error will be triggered

- 515-2 Engines Desired Operating Speed: Erratic, Intermittent or Incorrect

When the above code triggers the Limp Home feature is triggered which means the maximum engine speed will be limited to the Limp Home speed. This can be configured in the Service Tool as follows:

Configuration field names	Configuration Options	Default Configuration
Limp Home Desired Engine Speed	Low Idle to 1800rpm	1200rpm

Table 1.3

1.2.1.3 Throttles

Any throttle that is chosen must have a minimum Mean Time To Dangerous Failure (MTTFd) in excess of 150 years. Note that this is assuming no more than 2 throttles are used on the application e.g. 2 PWMs, 1 PWM and 1 TSC1.

The following methods are the only speed control options that support PLc:

- TSC1 Speed Control
- PWM (Pulse Width Modulation) throttle
    - If two PWM throttles are required then Speed Arbitration must be set to 'Largest Wins'

If TSC1 is to be used for Speed control then the new SPNs for Message Counter and Message Checksum must be used to provide better diagnostic coverage. Refer to the later section in the manual on TSC1 Operation for full details. A J1939 message overview is provided below:

NAME		PGN	Default Priority	Tx/Rx/On Req	SPN	Start Byte	Length	Units	Resolution	Min Value	Max Value
TORQUE SPEED CONTROL 1	0	0	3	Rx							
Override Control Mode					695	1.1	3 bits	States	4 states/2 bit	0	3
Requested Speed Control Conditions					696	1.3	2 bits	States	4 states/2 bit	0	3
Override Control Mode Priority					897	1.5	2 bits	States	4 states/2 bit	0	3
Requested Speed / Speed Limit					898	2-3	16 bits	rpm	0.125 rpm per bit, Offset = 0 rpm	0	8,031.875
Requested Torque / Torque Limit					518	4	8 bits	%	1 %/bit, Offset = -125 %	-125	125
TSC1 Transmission Rate					3349	5.1	3 bits	States	8 states/3 bit, Offset = 0	0	7
TSC1 Control Purpose					3350	5.4	5 bits	States	32 states/5 bit, Offset = 0	0	31
Message Counter					4206	8.1	4 bits	Count	1 count/bit, Offset = 0 count	0	15
Message Checksum					4207	8.5	4 bits	Count	1 count/bit, Offset = 0 count	0	15

Table 1.4

1.2.1.4 Ok to Elevate Idle

Permission to Elevate the Idle Speed to support Elevate Idle functionality must be done by J1939 using the following message:

The engine speed control function cannot support PL-c if hardwired switches are used to provide OK to Elevate Idle speed functionality

NAME		PGN	Default Priority	Tx/Rx/On Req	SPN	Start Byte	Length	Units	Resolution	Min Value	Max Value
CAB MESSAGE 2 (CM2)	8500	34048	6	RX							
Elevated Engine Speed Allowed Switch					7579	4.5	2 bits	states	4 states/2 bits	0	3

Table 1.5

This is a functional safety critical message.

States description:
00 Not Allowed
01 Allowed
10 Error
11 Not Available

This J1939 message must be sent to the ECM continuously every **1 second** to ensure the Machine controller stays in communication with the Engine controller. If the message is lost for 9 cycles (9 seconds) a diagnostic message will be triggered (639-9.) In this state the ECM will revert to 'working' state which does **not** allow the idle speed to be elevated. If this message is lost whilst speed is elevated the speed will drop back to the configured Low Idle speed.

To improve the level of Diagnostic Coverage for this feature it must now be configured with the Service Tool in the configuration menu:

Configuration field names	Configuration Options	Default Configuration
Elevated Engine Speed Allowed Input Configuration	J1939 Hardwired	J1939

Table 1.6

The ECM supports the following J1939 message to announce the speed that idle speed could be elevated to if Ok To Elevate Idle is allowed. Depending on the Machine definition of 'safe state' the following message should be monitored to decide whether or not it is safe to elevate the idle i.e. when SPN7579 should be set to '01' and sent to the ECM.

NAME		PGN	Default Priority	Tx/Rx/On Req	SPN	Start Byte	Length	Units	Resolution	Min Value	Max Value
CONTINUOUS TORQUE & SPEED LIMIT REQUEST (CTL)	CF00	52992	6	Rx							
Engine Speed Limit Request - Minimum Continuous					1784	1	8 bits	rpm	32 rpm per bit Offset = 0 rpm	0	8000

Table 1.7

1.2.1.5 Mode Selection Feature

If the Mode Selection feature is to be used then it must be controlled with J1939 and not the Hardwired switch method. The J1939 message for switching between modes is as follows:

NAME		PGN	Default Priority	Tx/Rx/On Req	SPN	Start Byte	Length	Units	Resolution	Min Value	Max Value
OFF HIGHWAY ENGINE CONTROL SELECTION (OHECS)	FDCB	64971	6	Rx							
Engine Operating Mode Command					8608	5.5	4 bits	States	16 states/4 bit	0	4

Table 1.8

The use of Min/Max governing is also not permitted if PL-c for Engine Speed control is required.

1.2.1.6 Alternative Low Idle

The Alternative Low Idle feature cannot be used if PL-c is required for Engine Speed control.
If this feature is required for the installation it must be controlled by the Machine controller. Alternative Low Idle speed can be easily managed with TSC1 if this is the Speed Control Method used.

1.2.2 Ether Injection

To provide PL-c for Ether Injection the OEM must use the Ether Injector Kit referenced in this manual, see Section on Cold Weather Engine Operation & Starting Aids

The ether control function will mitigate the following hazards:

- Unintended Automated Ether Injection leading to HC light off or explosion in aftertreatment
- Unintended Acceleration caused by Ether Injection

..
AND achieve PL-c provided the correct hardware is used and installed as specified in the Cold Weather Engine Operation & Starting Aids section of this manual.

2.0 Engine & Aftertreatment Component Overview

2.1 Main Engine Sensor and Actuator Detail

2.1.1 Electronic Control Module (ECU)

The A6E11 ECU is an electronic control device that governs engine speed, torque output and manages the engines performance and emissions via a number of sensors and actuators. The engine ECU should be mounted off the engine following the guidelines in this document. The device has two connection sockets J2 and J1. Engine and application wiring is distributed across both connectors. The ECU is air and surface cooled and is limited to a maximum ambient temperature and surface mounting temperature. Details of these limits are shown in the Mechanical A&I Guide.

2.1.2 Fuel System

The engine fuel system comprises of an electronic lift and / or prime pump, high pressure fuel pump, electronically controlled unit injectors and a High pressure fuel rail to feed the injectors. The electrical lift pump is used to provide a constant flow of fuel to the engine fuel pump. This pump also provides the user with an electrical priming feature. The fuel pump provides high pressure fuel to the fuel rail. The engine ECU via the fuel pump solenoid controls this fuel pump delivery and the resulting rail pressure. The engine ECU controls the fuel pump solenoid control based upon the inputs received from the fuel temperature sensor (which enables the control to be tailored to the specific fuel characteristics) and the fuel rail pressure sensor (which measures the actual pressure within the fuel rail).

Note: for more information regarding the electrical fuel lift pump and priming feature please see the Mechanical A&I Guide and section 6.6 of this document for electrical installation requirements.

High pressure fuel is delivered to each of the electronically controlled unit injectors which when activated by the engine ECU deliver a controlled measure of fuel for combustion. Voltages applied by the ECU to activate the injectors are high around 80V and the OEM must ensure that any systems sensitive to electromagnetic radiation are not close proximity to the harness components that lead to the injectors.

The engine fuel system is also fitted with a water in fuel switch mounted within the primary filter bowl. This switch is mandatory for all C3.6 engines to indicate to the operator that the filter water trap is full and needs emptying. This switch is supplied with the engine from the factory but it is the customer's responsibility to connect this component to the ECU J2 connector via the machine wiring harness.

It should be noted that in many cases a fault on any of these sensors, solenoids or switches will cause the engine to derate, or enter a limp home state due to their emissions critical nature.

2.1.3 Engine Speed

The engine is fitted with two Hall Effect speed sensors. The first is mounted on the engine to measure the crank speed and position and the other is used to measure the cam shaft speed, position and engine cycle. The engine uses the crank speed signal during normal engine operation as this signal is more accurate at higher speeds. If the crank shaft speed signal is lost during engine running then the engine will enter a derate condition, however if the engine is cranking the engine will start but be limited to a programmed derate. The cam shaft speed sensor is used to calculate the engine cycle during engine starting and for limp home operation. For this reason if the camshaft speed timing sensor signal is lost the engine will not start, but if the engine is running a fault code will be raised and the engine will continue to run normally.

During normal operation, the secondary speed/timing sensor is used to determine the cycle that the engine is on. When the timing has been established, the primary speed/timing sensor is then used to determine the engine speed and the angular position.

The loss of signal to the primary sensor and/or the secondary sensor will result in one of the following faults:

- The engine will continue to run when only one sensor signal is present from either the primary sensor or the secondary sensor.
- Loss of signal from the primary sensor and the secondary sensor during operation of the engine will cause fuel injection to be terminated and the engine will stop.

2.1.4 NOx Reduction System (NRS)

The NOx Reduction System recycles a portion of the exhaust gases back into the inlet air. The recirculation reduces the oxides of nitrogen (NOx) in the exhaust gases. The recycled exhaust gas passes through a cooler before being introduced into the inlet air.

The NOx reduction system is made up of the following components;

- NRS Combined Differential and Absolute Pressure Sensor*
- NRS Pre-Cooler Temperature Sensor*
- NRS Post-Cooler Temperature Sensor*
- NRS Metering Valve

*The C3.6 Stage IIIA engine uses only one NRS Temperature sensor and no Pressure sensor because it does not have an NRS Cooler.

Both the temperature and pressure sensor measurements are required by the engine control system to control NRS metering valve on the Stage V/Tier 4 Final engine. The metering valve controls the mass air flow through the NOx reduction system cooler by means of a DC motor and a position sensor.

This part of the engine control system is emissions critical and for this reason the engine may apply a derate if any of these components enter a fault condition.

2.1.5 Core Engine System

There are a number of core engine operation sensors that are used to determine how the engine control system should respond to various conditions. These components include the coolant temperature sensor and the oil pressure switch.

The barometric sensor is integral to the engine ECU. The sensor is used to determine atmospheric (barometric) pressure. The atmospheric pressure is used to determine the atmospheric related fuel limits (if any) e.g. at high altitude fuel may be limited during cranking to prevent turbo overspeed.

The coolant temperature sensor measurement is used as an input to the cold-start strategy. The sensor reading is also used to determine fuel limits and injection timing at various temperatures to control engine emissions.

The oil pressure switch detects engine oil pressure. The oil pressure switch is used for engine protection, e.g., if insufficient oil pressure is detected during engine operation, a low oil pressure diagnostic would be raised. The engine oil pressure switch is operated when a pressure of between 0.6 and 0.9 bar is detected.

2.1.6 Air System

The engine air system contains the following electronic components.

- **Air Inlet Temperature Sensor** - The air inlet temperature sensor is a passive sensor used to measure the Air temperature after the air cleaner. This temperature is used to regulate the engine NRS system during a number of scenarios.
- **Intake Throttle Valve** - The air intake throttle valve is used to adjust the air flow at intake manifold inlet to allow the engine to help control temperature in the aftertreatment system and control air flow into the NRS system.
  - **Note** that the C3.6 Stage IIIA engine does not use an Intake Throttle Valve
- **Combined Intake Manifold pressure / temperature sensor** - The intake manifold pressure sensor measures the air pressure inside the intake manifold. The intake manifold temperature sensor measures the temperature of the mixed air inside the inlet manifold. The temperature / pressure sensor is used in a number of engine management control strategies contained within the engine ECU.
- **Turbocharger Wastegate Regulator** - The regulator valve controls the pressure in the intake manifold to a value that is determined by the ECU. The waste gate regulator provides the interface between the ECU and the mechanical system that regulates intake manifold pressure to the desired value that is determined by the engine software.
- **Air To Air Charge Cooler (ATACC) Out Sensor** – The C3.6 Stage IIIA engine requires this sensor for combustion control. For the Stage V/Tier 4 Final engine this sensor is an optional fit as part of the Demand Fan Control system.

2.2 Aftertreatment System Components, Sensors & Actuator Overview

Not applicable to the C3.6 Stage IIIA engine.

2.2.1 Diesel Oxidation Catalyst (DOC)

The Diesel Oxidation Catalyst is also known as the (DOC). The DOC is a device in the exhaust system that oxidizes certain elements in the exhaust gases. These elements can include carbon monoxide (CO), hydrocarbons and the soluble organic fractions (SOF) of particulate matter.

2.2.2 Diesel Particulate filter (DPF)

The Tier 4 Final/Stage V product range use both in cylinder PM (Particulate Matter) reduction methods and additional PM capture (DPF) exhaust system components to meet the Tier 4 Final/Stage V PM reduction targets.

2.2.3 Selective Catalytic Reduction (SCR) – For >56kW Only

SCR is a process for reducing the oxides of nitrogen (NOx) in the exhaust gases. Ammonia is introduced into the exhaust and reacts with the exhaust gases in the SCR catalyst to convert the NOx into nitrogen and water vapour.

2.2.4 Ammonia Oxidizing (AMOX) catalyst – For >56kW Only

The AMOX catalyst removes any residual ammonia from the exhaust gas stream after completion of the Selective Catalytic Reduction (SCR) process.

2.2.5 DEF Injector Unit – For >56kW Only

The DEF injector controls the flow of DEF into the exhaust stream between the DOC, and SCR components The DEF injector is controlled by the engine ECU.

2.2.6 DEF Dosing Supply Module – For >56kW Only

The DEF Dosing Supply Module is used to control supply of the DEF fluid to the DEF injector, controls the purge of the DEF fluid and provides DEF Fluid system information to the engine ECU.

2.2.7 Engine Coolant diverter valve – For >56kW Only

The coolant diverter valve controls the flow of coolant to the Diesel Exhaust Fluid (DEF) tank, DEF dosing supply module and DEF injector. When required, the valve is opened to allow hot coolant to circulate through to the DEF tank, DEF dosing supply module and DEF injector. This flow allows the coolant to heat the DEF to a useable temperature.

2.2.8 DEF Heater lines – For >56kW Only

The DEF system Heated lines are required to prevent DEF fluid from freezing within the fluid supply and return lines.

2.2.9 DOC Inlet, DPF Inlet and SCR Inlet Outlet Temperature Sensors

The exhaust system will either have a single probe, dual probe or triple probe dependent on aftertreatment type or configuration.

- DOC, DPF, SCR Aftertreatment will have three temperature sensors.
- DOC, DPF Aftertreatment will have two temperature sensors.

All temperature sensors are required for accurate control /monitoring of the engine aftertreatment system.

2.2.10 NOx sensors – For >56kW Only

The exhaust system has two NOx sensors that measure O2 and NOx concentrations in the exhaust system. Sensor #1 is located before the DEF Injector and Sensor #2 is located in the exhaust tail pipe after the SCR catalyst and monitors the NOx and O2 exiting the exhaust system.

2.2.11 DEF Tank and Header Unit – For >56kW Only

The DEF tank header unit is used to provide a means of thawing the DEF fluid within the tank via engine coolant connections. In addition the header unit houses a DEF level switch which is used to communicate the level of DEF fluid within the tank and as a feed into emissions control strategies.

2.3 System Component Diagrams and Electrical Schematic

2.3.1 C3.6 Tier 4 Final/Stage V/China NR4 On Engine Harness layout

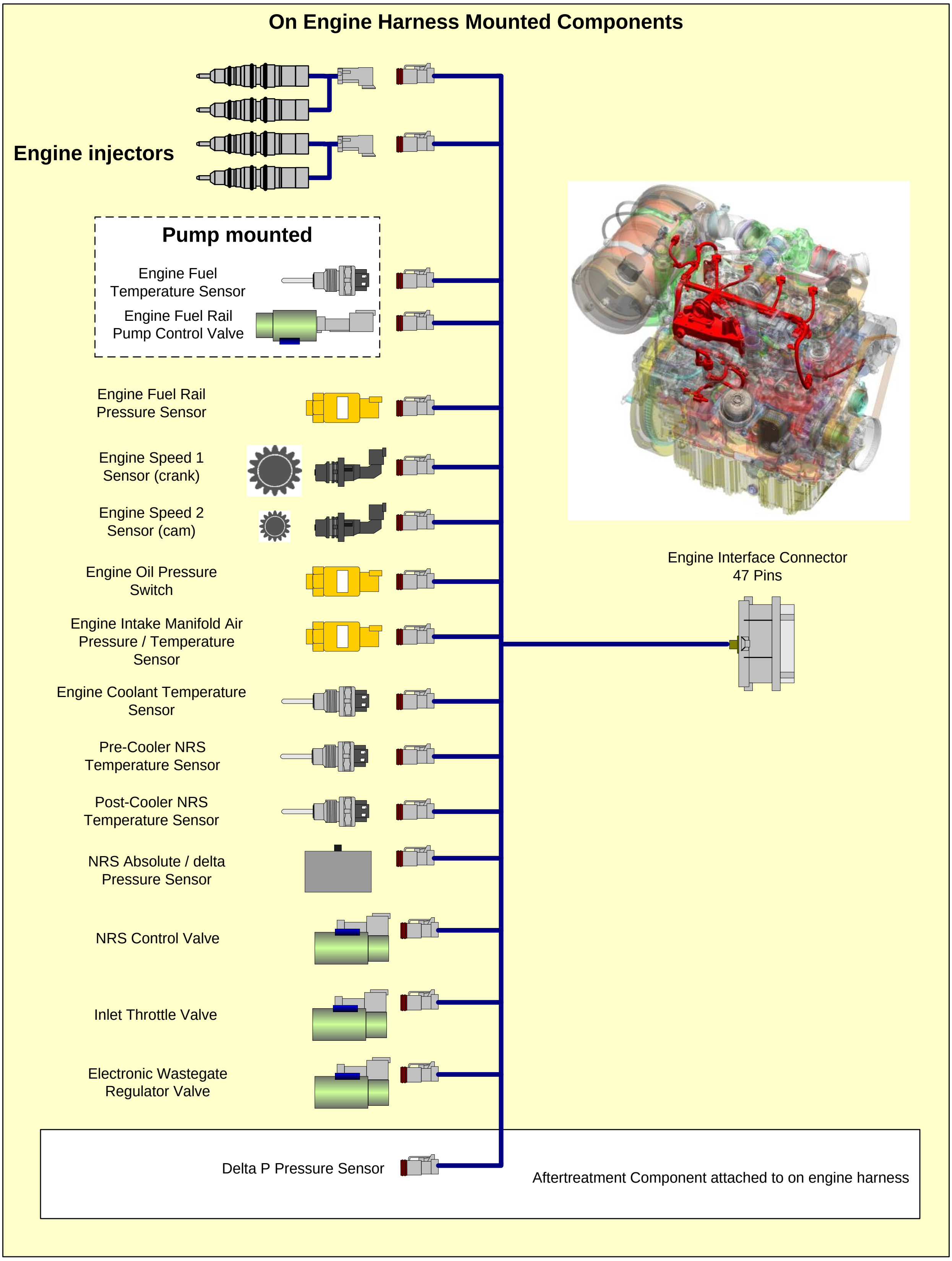


Figure 2.1

2.3.2 C3.6 Stage IIIA On Engine Harness layout

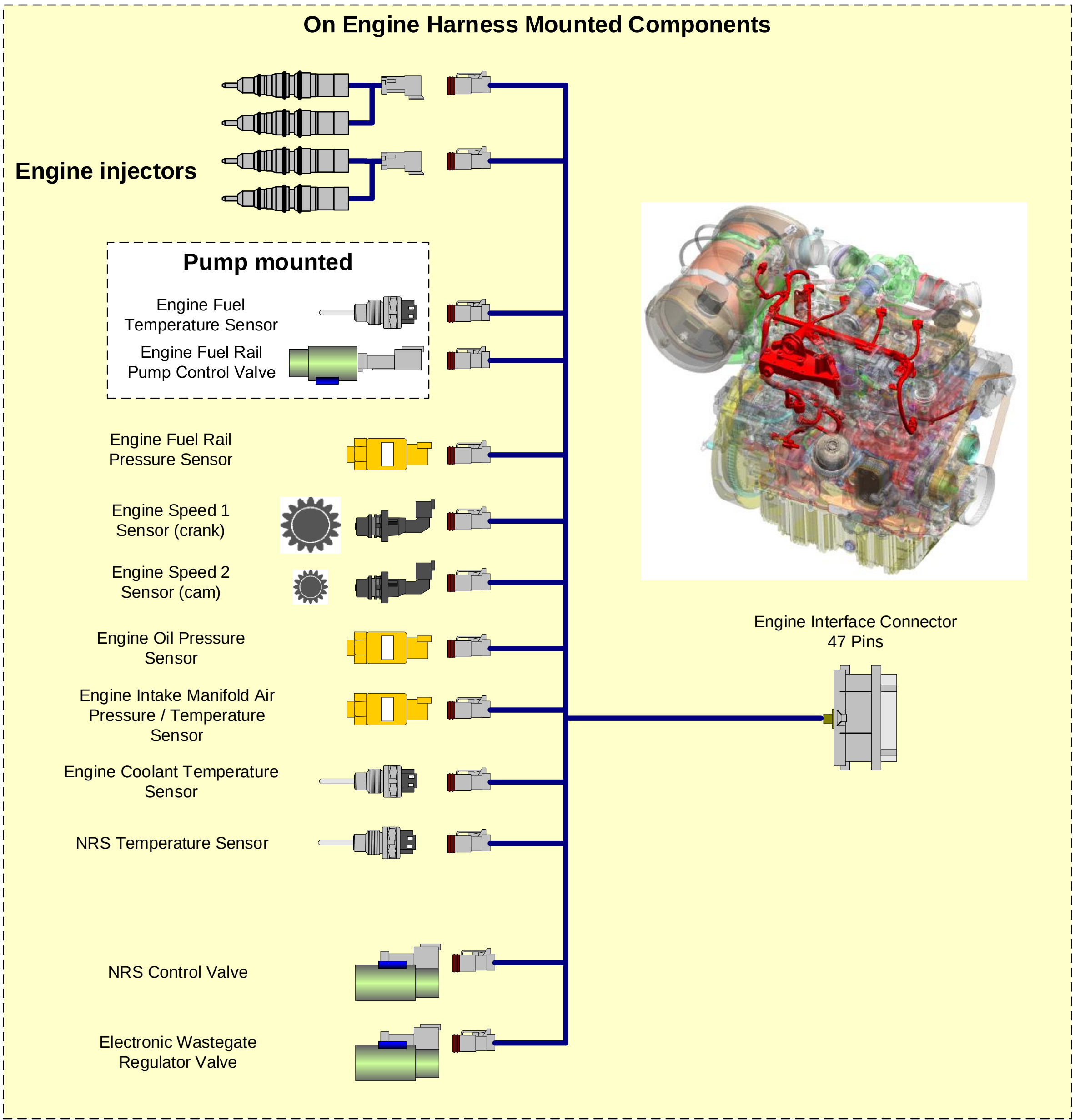


Figure 2.2

2.3.3 C3.6 > 56kW DOC, DPF and SCR aftertreatment component and sensor Layout

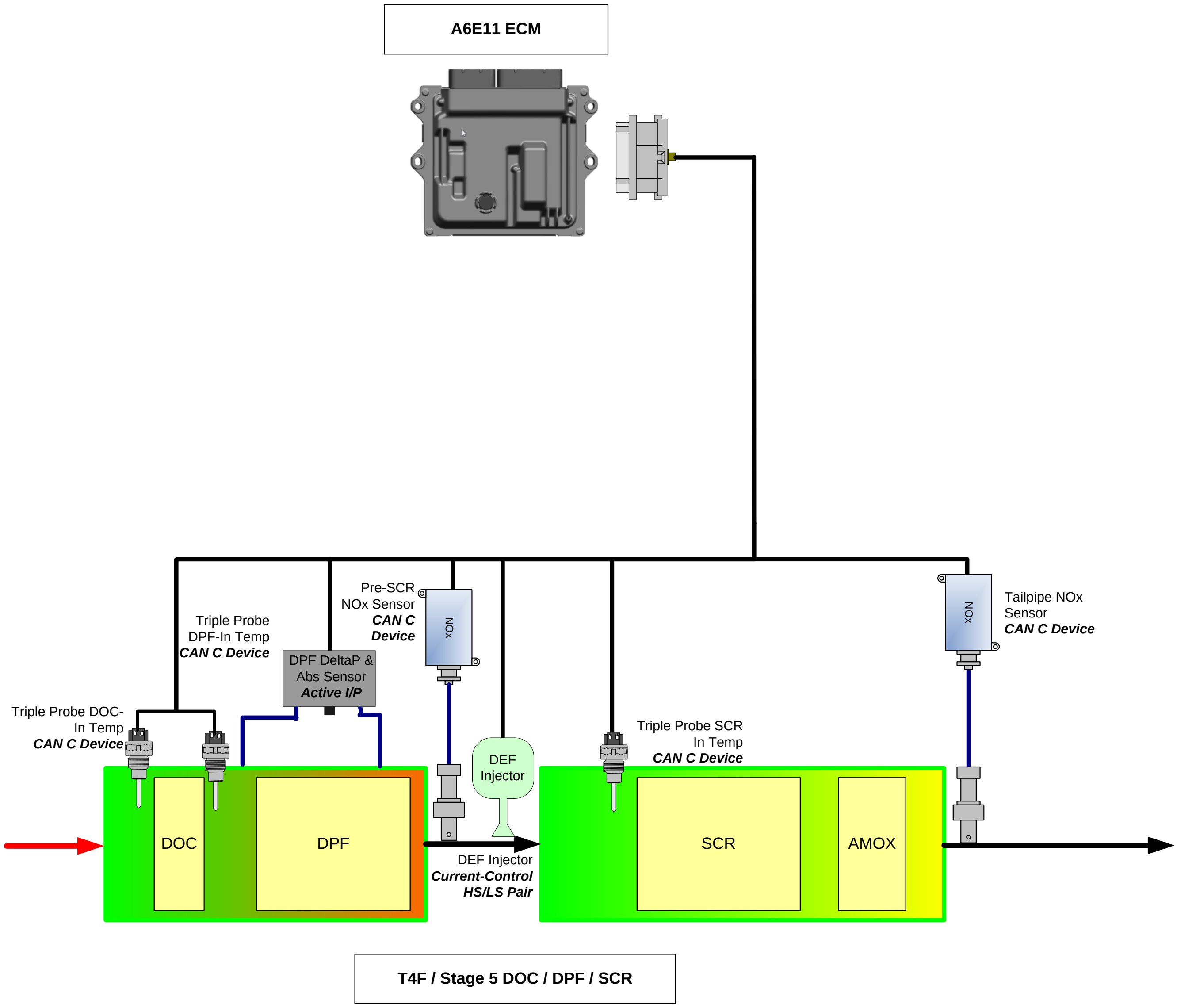


Figure 2.3

2.3.4 C3.6 < 56kW, C3.6EA DOC, DPF aftertreatment component and sensor Layout

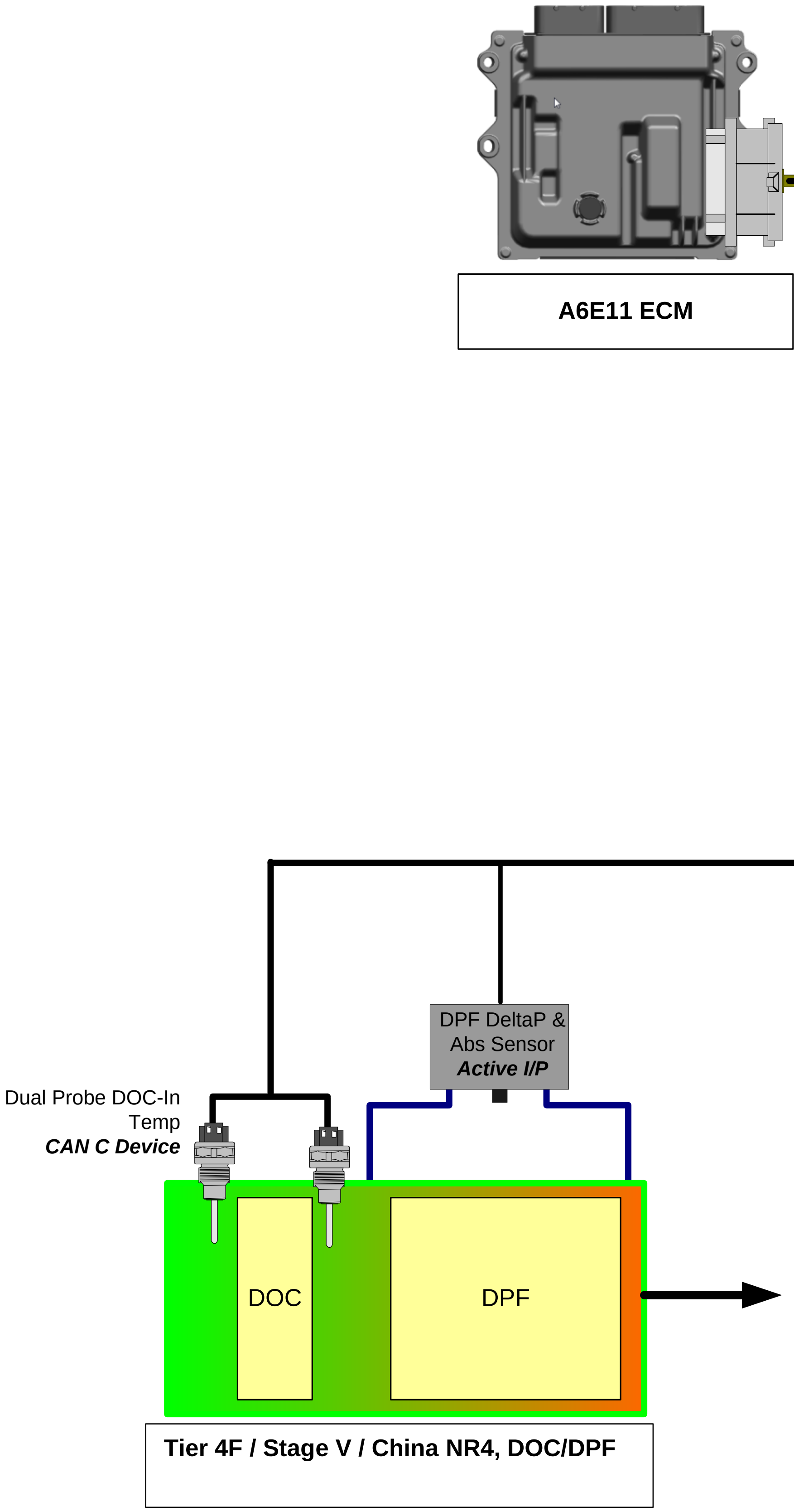


Figure 2.4

2.3.5 C3.6 Electrical Wiring Schematics

C3.6 > 56kW TIER 4 FINAL/STAGE V Electrical Schematic without link harness
LEBH0055-02
C3.6 > 56kW TIER 4 FINAL/STAGE V Electrical Schematic with factory supplied link harness
LEBH0056-02
C3.6 < 56kW TIER 4 FINAL/STAGE V/China NR4 Electrical Schematic without link harness
LEBH0057-02
C3.6 < 56kW TIER 4 FINAL/STAGE V/China NR4 Electrical Schematic with factory supplied link harness
LEBH0058-02
C3.6 STAGE IIIA Electrical Schematic without link harness
LEBH0060-02
C3.6 STAGE IIIA Electrical Schematic with factory supplied link harness
LEBH0059-02

3.0 Customer System Overview Key Elements

The following section provides details on both the mandatory and optional system connections that need to be made as part of the customer's machine wiring harness.

3.1 Aftertreatment Configurations

For an engine developing between 56kW and 560kW to be certified as TIER 4F compliant, it must demonstrate a particulate matter output of less than 0.025g/Kwh and a NOx output of less than 0.4g/Kwh.
For an engine developing between 56kW and 560kW to be certified as EU Stage V the NOx output must be less than 0.4g/kWh, Particulate Mass must be less than 0.015g/kWh and the total particulate number must be less than $1x10^{12}$.
For an engine developing between 37kW and 56kW to be certified as EU Stage V the Particulate Mass must be less than 0.015g/kWh and the total particulate number must be less than $1x10^{12}$.
To achieve this the engine exhaust must be treated before entering the atmosphere. The connection of the various sensing devices and actuators, which control and monitor the operation of the aftertreatment system now become a critical part of the total system installation.
The C3.6L Tier 4 Final and Stage V engine ranges use two different aftertreatment systems depending on the engine power and aspiration but both comprise of the same key elements: DOC, DPF and SCR. More details on the customer wiring requirements are given in section 7.0 of this document. For more information on the mechanical installation of the aftertreatment system please refer to the relevant Mechanical A&I Manual & DEF system supplements.
The C3.6 Stage IIIA engine has no aftertreatment unit.

Engine Model	DOC, DPF, SCR	DOC, DPF
C3.6 Tier 4 Final and Stage V >56kW	✓	
C3.6 Tier 4 Final and Stage V <56kW / 74.4 – 82kW		✓
C3.6 Stage IIIA	**N/A**	

Table 3.1 Aftertreatment Systems Applicability

3.2 Tier 4F / Stage V Mandatory Install Components

Mandatory or Required Components	A&I Guide Reference section C3.6L >56kW DOC, DPF, SCR	C3.6L <56kW DOC, DPF / 74.4 – 82kW	C3.6L Stage IIIA	Section #
Circuit Protection	✓	✓	✓	4.13
Key Switch	✓	✓	✓	4.14
Main Power relay	✓	✓	✓	4.5
ECU Case Grounding	✓	✓	✓	4.1
Engine Warning Indicator	✓	✓	✓	11.4.5
Engine Shutdown Indicator	✓	✓	✓	11.4.4
Engine Wait to Start Indicator	✓	✓	✓	11.4.6
Engine Wait to Disconnect Indicator	✓	Optional	Optional	11.4.10
Emissions System Malfunction Indicator (MIL Lamp)	✓	✓	N/A	11.4.8
DPF Lamp	✓	✓	N/A	11.4.11
Low DEF Level Indicator	✓	N/A	N/A	11.4.9
DEF Level Gauge	✓	N/A	N/A	13.7.1
72 Way ECU J1	✓	✓	✓	5.2
114 Way ECU J2	✓	✓	✓	5.3

Mandatory or Required Components	A&I Guide Reference section C3.6L >56kW DOC, DPF, SCR	C3.6L <56kW DOC, DPF / 74.4 – 82kW	C3.6L Stage IIIA	Section #
47 Way Engine Harness Connector (EIC)	✓	✓	✓	5.6
Glow Plug Relay	✓	✓	✓	10.1
Diagnostic Connector	✓	✓	✓	6.4
Air Inlet Temperature Sensor	✓	✓	✓	6.3
Water In Fuel Switch	✓	✓	✓	6.2
NOx Sensor	✓	N/A	N/A	7.2
Aftertreatment Temperature Sensors	✓	✓	N/A	7.3
Delta P Pressure Sensor	✓	✓	N/A	7.4
DEF Injector	✓	N/A	N/A	7.5
Engine Coolant Diverter Valve	✓	N/A	N/A	7.9
DEF Supply Module	✓	N/A	N/A	7.6
DEF Tank Sensors	✓	N/A	N/A	7.8
DEF Heated Lines (1-3)	✓	N/A	N/A	7.7
Machine Idle Safe State	✓	✓	✓	13.1.6
DEF System Purge	✓	N/A	N/A	13.4
Charge Air Temperature Sensor	Only required for Hydraulic Demand Fan	Only required for Hydraulic Demand Fan	**Mandatory**	15.5

Table 3.2

3.3 Optional Customer Installed Components

Optional Components	A&I Guide Section C3.6L >56kW DOC, DPF, SCR	C3.6L <56kW / 74.4 – 82kW DOC, DPF	C3.6L Stage IIIA	Section #
Low Oil Pressure Lamp	✓	✓	✓	11.4.7
Engine Running Output Lamp	✓	✓	✓	11.4.14
Service Maintenance Lamp	✓	✓	✓	15.10
Inhibit Switch and Regen Inhibit Lamp	Optional	Optional	N/A	13.3
Regen Active Lamp	Optional	Optional	N/A	11.4.12
User Defined Shutdown Switch	✓	✓	✓	8.2.3
Air Filter Restriction (Inlet Depression) Switch / Sensor	✓	✓	✓	6.5
Analogue Throttle Position Sensor with Idle Validation Switch (1) & (2)	✓	✓	✓	9.1
PWM Throttle (1) & (2)	✓	✓	✓	9.2
Throttle Arbitration Switch	✓	✓	✓	9.6
Multi-Position Switch	✓	✓	✓	9.4
PTO Mode	✓	✓	✓	9.3
Torques Speed Control (TSC1)	✓	✓	✓	16.3.2
Engine Operating Mode	✓	✓	✓	14.5
Limp Home Speed	✓	✓	✓	9.8
Coolant Level Switch	✓	✓	✓	15.2

Optional Components	A&I Guide Section C3.6L >56kW DOC, DPF, SCR	C3.6L <56kW / 74.4 – 82kW DOC, DPF	C3.6L Stage IIIA	Section #
Alternative Low Idle Speed	✓	✓	✓	15.1
Engine Immobiliser	✓	✓	✓	15.11
Battery Voltage Monitoring	✓	✓	✓	15.8
Hydraulic Demand Fan Control	✓	✓	✓	15.6
Engine No Load Fuel Map Offset	✓	✓	✓	15.7
Ether Control	✓	✓	✓	10.2
Low Idle Shutdown Switch	✓	✓	✓	8.2.6
Starter Control Mode	✓	✓	✓	8.1.1
Air Con Compressor	✓	✓	✓	15.12

Table 3.3

4.0 Power & Grounding Considerations

4.1 System Grounding

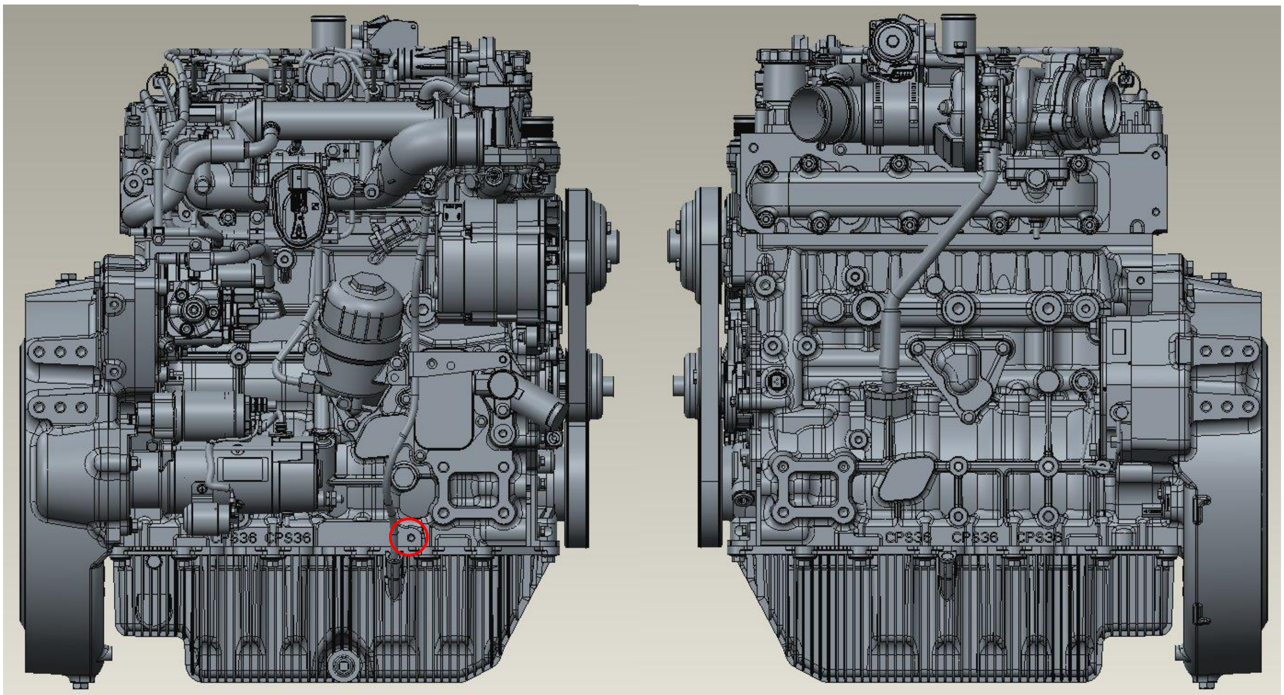
Although the engine electronics are all directly grounded via the ECU connector, it is also necessary to ensure that the engine block is properly grounded, to provide a good return path for components such as the starter motor, alternator and cold start aids.
Improper grounding results in unreliable electrical circuit paths. Stray electrical currents can damage mechanical components and make electronic systems prone to interference. These problems are often very difficult to diagnose and repair.

4.1.1 Ground Stud on Starter Motor

If the Starter motor has a grounding stud then this should be used. The ground connection should be made directly back to the battery negative terminal.
The starter motor ground path must not include any flanges or joints. Painted surfaces and flexible mounts in particular must be avoided. Star washers must not be relied upon to make contact though paint.
The ground cable should be of sufficient cross sectional area to ensure that the total starter motor supply circuit resistance does not exceed 1.7mOhms for a 12V system and 3.4mOhm for a 24V system.
Please refer to the Starting and Charging Systems Manual for further information on starter motor, alternator, battery and complete system installation guidelines.

4.1.2 Engine Block Ground Connection

An engine cylinder block ground point is required on all machines in addition to the engine starter motor ground, which also requires a separate ground connection. The choice of connection point will be dependent on option but the hole detailed below should be considered. It is important to avoid system ground potential differences. The maximum potential difference between ECU switch to ground references and the cylinder block is 1V.



The Engine Block Ground thread is M8x1.25 x 15mm.

4.1.3 ECU Body Grounding

To ensure EMC compliance the ECU Body must be grounded through a grounding strap attached to the mounting feet and to ECU pin J1-62. The strap length should be kept to a maximum length of 700 mm to the chassis.

4.2 Engine Electrical System Power and Grounding

The power and grounding of the electrical system must follow best practise as shown below to avoid an unreliable electrical system.

Voltage drop seen during situations where battery demand is high or when battery charge is low may risk components falling below minimum operating voltage thresholds. As an example engine cranking exerts a high battery demand, potentially reducing the overall system voltage. The effects can be worse in cold conditions where starter motor load may increase and battery performance decreases.

To reduce the effects of voltage drop, circuit design must minimize circuit resistance; the diagram below provides good practice wiring.

- Components in the circuit must be properly assessed for their resistive properties.
- Consider the number of connections in the circuit; minimizing this number will improve overall system performance.
- Over-sizing conductors or reducing their length should be considered as a method of reducing total circuit resistance.
- Junction blocks, situated close to the battery serve as a reliable supply and ground return point for components susceptible to voltage drop, this practice avoids sharing terminals with components that add to effects of voltage drop, such as starter motor circuits during cranking.
- Ground paths must be assessed and conductive paths need to be known, if there is any doubt or design requirements can't be met, a direct copper connection must be used.
- It is recommended that the battery disconnect switch have only one connection either side of the switch, preventing the switch being bypassed if incorrectly wired.
- Circuit design must consider specific component design requirements; components may have a maximum circuit resistance or minimum operating voltage.
- After system design, circuit resistance should be tested to ensure the results fall within the specification provided.

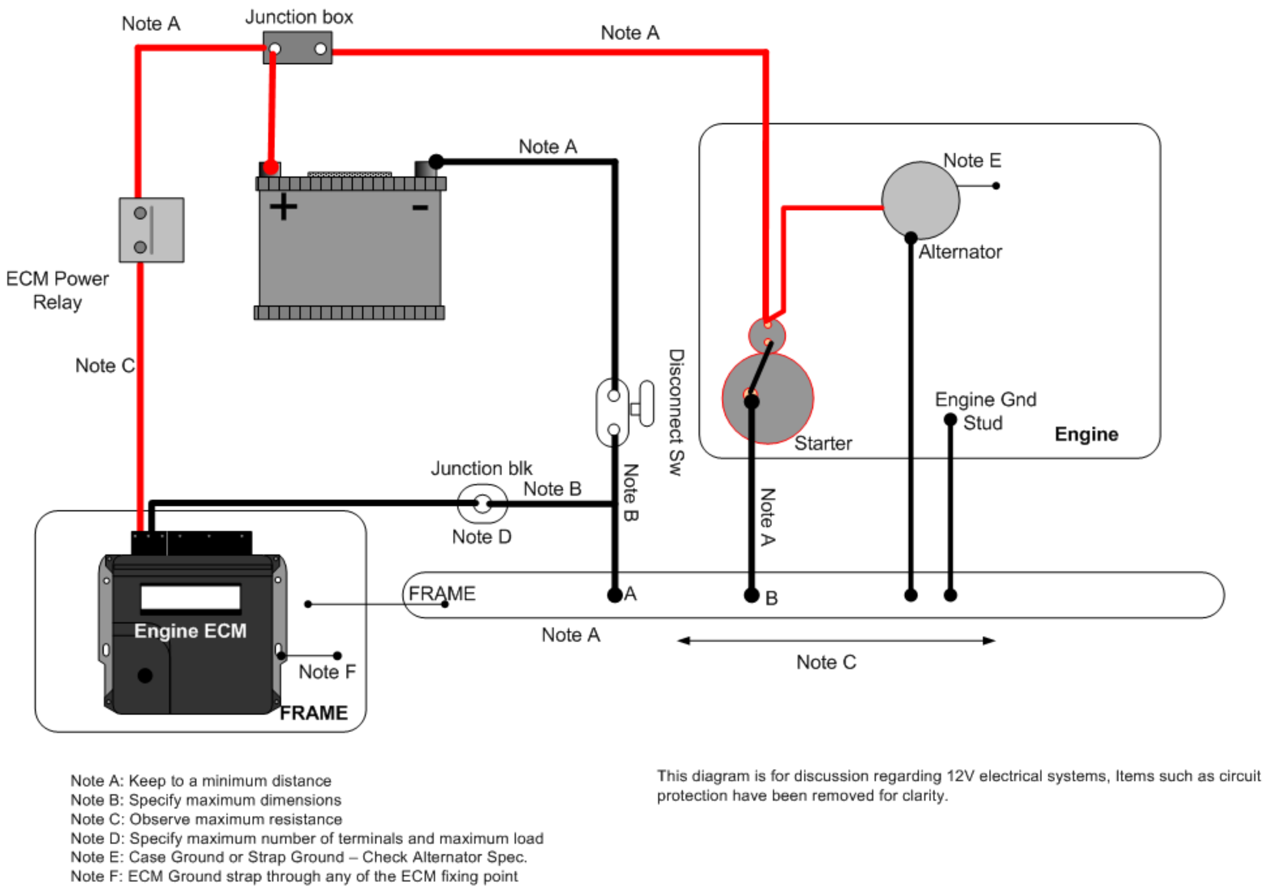


Figure 4.1 Engine Power and Grounding requirements

4.3 System Voltage & Current Requirements

Each C3.6L engine comes supplied with the following loose components. Each component has its own specific electrical requirements which need to be met for correct system operation. These electrical characteristics are shown in the following sections.

DESCRIPTION	Tier 4F/StageV >56kW	Tier 4F/StageV <56kW / 74.4 – 82kW	Stage IIIA
Engine ECU controller	✓	✓	✓
Electric Lift / Prime Pump (Optional fit)	✓	✓	✓
Aftertreatment temperature sensors	✓	✓	✕
NOx Sensors	✓	✕	✕
DEF Injector Unit	✓	✕	✕
DEF Pump Supply Module	✓	✕	✕
DEF Heated Lines	✓	✕	✕
DEF Tank and Header Unit	✓	✕	✕
Engine Coolant Diverter Valve	✓	✕	✕
DEF Heated Hose Lines	✓	✕	✕

Table 4.1

4.3.1 Engine ECU Controller

The engine ECU power supply requirements must be carefully considered when designing the engine power supply circuit. There are specific limitations that must be considered in the design to ensure a reliable consistent power supply to the engine electronic components. The table provides the electrical characteristics and limitations for the A6E11 engine ECU.

DESCRIPTION	12V	24V
Max Inrush Current* *(750µs)*	120A	120A
Peak Current Cranking	22A	17.5A
Max RMS Current	37A	36A
Suggested fuse rating**	40A	40A
Sleep Current	0.5mA	0.5mA
Min Running Voltage	10V	16V
Max Running Voltage	16V	32V
Minimum Voltage during Cranking***	6V	6V

Table 4.2

* All Current measurements have been taken for engine alternator sizing and are estimations only. RMS current will vary with engine speed (assuming constant voltage) no Lamp Drivers or application side components were fitted during measurement and will therefore need to be considered.
** Suggested fuse rating are based on automotive blade type fuses and are for guidance only.
*** Please refer to the Starting and Charging System A&I Manual for more information regarding the engine starting system installation requirements.

4.3.2 Glow Plug System

DESCRIPTION	12V	24V
Current - Initial	60A	40A
Current after 5 sec	43A	24A
Current after 10 sec	34A	20A

Table 4.3

4.3.3 SCR Inlet NOx Sensor

DESCRIPTION	12/24V
Typical supply current	3A
Max Peak Current at switch ON	22A
In rush current for loading of input caps	43A
Minimum Operating Voltage	10.8V
Maximum supply voltage (sensor heater)	32V
Max load dump protection	48V

Table 4.4

4.3.4 SCR Outlet NOx Sensor

DESCRIPTION	12/24V
Typical supply current	3A
Max Peak Current at switch ON	22A
In rush current for loading of input caps	43A
Minimum Operating Voltage	10.8V
Maximum supply voltage (sensor heater)	32V
Max load dump protection	48V

Table 4.5

4.3.5 DEF Injector Unit (Dual Voltage)

DESCRIPTION	12V	24V
Nominal Current Supply	1.2A	1.2A
Minimum Operating Voltage	10V	19V
Nominal Operating Voltage	14.2V	28.5V
Maximum Operating Voltage	16V	32V

Table 4.6

4.3.6 DEF Pump Supply Module

DESCRIPTION	12V	24V
Pump motor Nominal Current Supply	4A	2A
Pump Motor Inrush Current (20us)	40A	26A
Internal Pressure Sensor Current	10mA	10mA
Purging Pump Current	3A	3A
Minimum Operating Voltage	9V	18V
Nominal Operating Voltage	13.5V	28.5V
Maximum Operating Voltage	16V	32V

Table 4.7

4.3.7 DEF Heated Lines

Note: Current measurements taken @13.8 volts & -40°C.

Description	12V	24V
Normal Operating Voltage	12V	24V
Suction Line 1m	2.47A	1.28A
Suction Line 1.5m	2.98A	1.49A
Suction Line 2m	3.37A	1.69A
Return Line 1m	2.47A	1.28A
Return Line 1.5m	2.98A	1.49A
Return Line 2m	3.37A	1.69A
Pressure Line 1.5m	2.98A	1.49A
Pressure Line 2m	3.37A	1.69A
Pressure Line 2.5m	3.25A	1.63A
Pressure Line 3m	3.63A	1.82A

Table 4.8

4.3.8 DEF Tank and Header Unit (Dual Voltage)

DESCRIPTION	
Operating Voltage Range	9 – 32 Volts
Maximum Continuous Current	100 mA
Maximum Peak Current	600 mA

Table 4.9

4.3.9 Engine Coolant Diverter Valve

DESCRIPTION	12V	24V
Nominal Current Supply	1.5A	0.8A
Minimum Operating Voltage	11V	22V
Nominal Operating Voltage	12V	24V
Maximum Operating Voltage	15V	30V

Table 4.10

4.3.10 Aftertreatment Temperature Sensors (Dual Voltage)

DESCRIPTION	Triple Probe Sensor	Dual Probe Sensor	Single Probe Sensor
Nominal Current Supply	20mA	20mA	20mA
Minimum Operating Voltage	4.75V	4.75V	4.75V
Maximum Operating Voltage	5.25V	5.25V	5.25V

Table 4.11

4.3.11 Electric Lift / Prime Pump

DESCRIPTION	12V	24V
Nominal Current Supply	2 to 3.3A	0.6 to 1.8A
Nominal Operating Voltage	13.5V	27.6V

Table 4.12

4.3.12 System Effect on Alternator Specification

The overall system electrical current requirement for the engine and machine must be taken into account when sizing the alternator. The table below provides an indication to the total engine system current requirements.

	C3.6L >56kW DOC, DPF, SCR		C3.6L <56kW / 74.4 – 82kW DOC, DPF		C3.6L Stage IIIA	
DESCRIPTION	**12 Volts**	**24 Volts**	**12 Volts**	**24 Volts**	**12 Volts**	**24 Volts**
Engine Electrical Components	~22A	~21A	~22A	~21A	~22A	~21A
Aftertreatment Components	~16A	~16A	~1A	~1A	N/A	N/A
Total Electrical Current	**~38A**	**~37A**	**~23A**	**~22A**	**~22A**	**~21A**

Table 4.13

4.4 Engine ECU Location – Wiring Constraints

The circuit resistance of the Injector supply cables and the engine ECU power supply cable limits the distance of the engine ECU from the engine interface connector. The resistance of both circuits must be considered to ensure correct operation of the Injectors and ECU.

4.5 ECU Power Supply Conductors

There are six 2.0mm^2 conductors allocated for the engine ECU power supply circuit, three conductors for the battery positive supply and three conductors for the battery negative supply.
All six ECU pins allocated for the power supply must be wired to the ECU. The positive supply cables must be connected to a relay controlled by the engine ECU and must be circuit protected. To prevent voltage drop, avoid sharing and feeding the engine ECU supply circuit with or via other machine component circuits. The minimum recommended conductor cross-section for each individual power supply conductor is 2.0mm^2.
The maximum recommended end of life resistance for the total circuit, including positive and negative conductors is 50mOhms. When calculating the resistance of a circuit it is important to consider the resistance of the cable and connection points of the entire circuit.

4.6 ECU Body Grounding

To ensure EMC compliance the ECU Body must be grounded through a grounding pin J1-62, cable with a maximum length of 700 mm to the chassis.

4.7 Injector Power Supply Circuit Resistance

To ensure precise and reliable fuel delivery the injector circuit must be designed to minimise circuit resistance. The position of the ECM should be carefully considered to minimise the distance between the Injectors and ECM. The maximum recommended end of life resistance for an Injector circuit pair (both positive and negative conductors) is **100mOhms**. This limit applies to the wiring between the ECM and the EIC i.e. the engine harness (injectors to EIC) is not included. Each Injector supply circuit pair is recommended to be twisted.
To ensure the injector circuit resistance remains below the limits stated above for the life of the engine, Caterpillar recommend a design target of **80mOhms.**

4.8 Fuel Pump Solenoid Circuit Resistance

The Fuel Pump Solenoid control requires a similar waveform to the Injector control and so the same circuit resistance limit applies; maximum end of life circuit resistance is **100mohms.** Similarly to the injector circuit to account for aging of the wiring Caterpillar recommend a design limit of **80mOhms**.
Given that the circuit routing for these wires is the same as the injector circuit (between ECM and EIC connectors, if the same cable gauge of 1.0mm^2 (or greater) is used then this circuit will have the same resistance as the Injector circuit as so does not require a specific resistance test during A&I testing.

4.9 ECU Power Supply Circuit Resistance

The recommended machine end of life total ECU power supply circuit resistance for a **12V** system is **50mOhms**. Caterpillar advises a target resistance of **40mOhms**.
For a **24V** system the recommended end of life resistance is **100mOhms** so Caterpillar advise a target of **80mOhms**.
Notes:

- Circuit resistance measured at ambient temperature 20°C.
- The minimum acceptable cranking battery voltage is 7.3V. This will ensure that when the battery voltage is 7.3V the Injector fuel delivery will be stable and so avoids poor engine starting and ECU reset conditions.

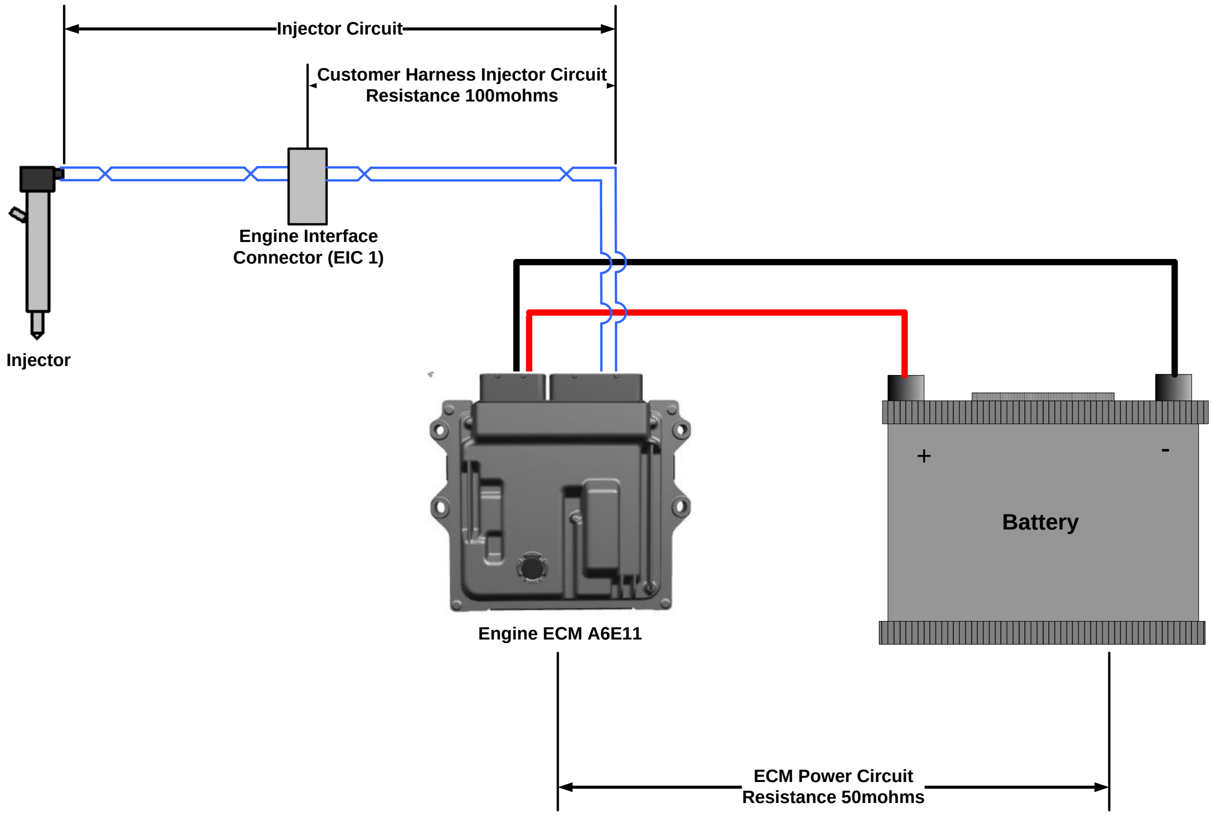


Figure 4.2

4.10 Injector Cables

The required cable cross section for Injector harness wiring is 1.0mm². The minimum dielectric strength of the cable insulation for Injectors is 125V.

The Injectors cables pair is recommended to be twisted with a maximum twist length of 25mm.

The Injectors cables should be separated from other signal circuits to avoid electrical disturbance, as the analogue signals are especially vulnerable to interference and must be clearly separated from the Injector circuit.

Separate analogue and speed signal circuits from Injector circuits. Bundle circuits supplying inductive loads separately to signals. If possible use separate conduit paths.

Please refer to the separate electrical schematics referenced in Section 2.3.5

4.11 Fuel Pump Solenoid Cable

The required cable cross section for fuel pump solenoid unit wiring is 1mm², recommended twisted pair. The minimum dielectric strength of the cable for the fuel metering valve is 48V. The fuel pump solenoid cables pair is recommended to be twisted with a maximum twist length of 25mm.
Please refer to the separate electrical schematics referenced in Section 2.3.5

4.12 Engine Solenoid and Actuators

Caterpillar recommends that Injector cables along with solenoid and actuators cables be separated from signal cables. As a minimum, the power related cables supplying the following components should be bundled separately to engine and Aftertreatment sensor cables, and where possible signal / sensor cables should use separate conduit channels for the machine harness.
The conductors for the following cables need to be bundled together.

- Injectors
- High Pressure Pump
- NRS
- TVA
- Boost Pressure Actuator
- Auxiliary PWM driver

4.13 Voltage Suppression Requirement

The engine ECU must be protected against high voltage spikes, also known as load dump. The factory fitted alternators are fitted with load dump protection as standard to protect the engine ECU. Load dump protection protects against high transient voltages sometimes seen when switching inductive components in the system circuit. The factory fitted alternators protect for voltages higher than 25V-30V depending on the alternator selected.
If an alternator is not used or a non-standard alternator is selected the engine electrical system must be designed to provide load dump protection for the engine ECU. The maximum permissible transient voltage measured at the ECU is 40Vdc. It is recommended that the electrical system be designed to protect against voltages higher than 35Vdc measured at the engine ECU.

4.14 ECU Key-Off

4.14.1 >56kW Products (DOC/DPF/SCR)

When the supply to the ECU key switch input (J1-5 and J1-6) is removed the ECU power relay will remain powered ON up to ~90 seconds**.** This is necessary to ensure the DEF system purges and all historical data is written to memory. Under no circumstances should the battery supply to engine ECU be removed or cut during normal engine operation. If the battery supply needs to be removed for maintenance using the battery disconnect switch the user should allow ~90 seconds after key-off before disconnecting.

4.14.2 <56kW / 74.4 – 82kW Products (DOC/DPF) China NR4 & Stage IIIA

When the supply to the ECU key switch input (J1-5 and J1-6) is removed the ECU power relay will remain powered ON up to ~20 seconds**.** This is necessary to ensure all historical data is written to memory. Under no circumstances should the battery supply to engine ECU be removed or cut during normal engine operation. If the battery supply needs to be removed for maintenance using the battery disconnect switch the user should allow ~20 seconds after key-off before disconnecting.

4.15 ECU Body to Chassis Maximum Potential Difference

The measured potential difference between the ECU ground pin and the battery ground should be kept to a minimum. Ideally there should be no difference and the maximum permissible difference is 1V.

4.16 ECM Output Driver Connection Warning

The OEM must ensure that none of the ECM Output drivers are ever directly connected to a power source e.g. battery positive feed when the ECM ignition is keyed-off. If this situation occurs there is a risk that the ECM will pull current back through the Output driver and damage the ECM circuit board, resulting in the output driver no longer functioning.

As shown in the Electrical Wiring schematic documents, any ECM pins requiring current supply should be wired up from the Main Power Relay or Keyswitch. In both instances this ensures that the ECM ignition is on before any of these circuits become live.

5.0 Engine Connectors & Wiring Harness Requirements

This section provides details on each of the engine ECU connectors and engine bay connectors that must be used to connect the mandatory engine and aftertreatment electrical components.

5.1 Engine ECU Connectors

The C3.6 engine ECU (A6E11) has two connection points. The J1 connector has 72 pins and the J2 connector has 114 pins. The ECU J1 and J2 connections are used by the customer / OEM as the main interface back to the engine control module for both the engine aftertreatment system and machine control systems.

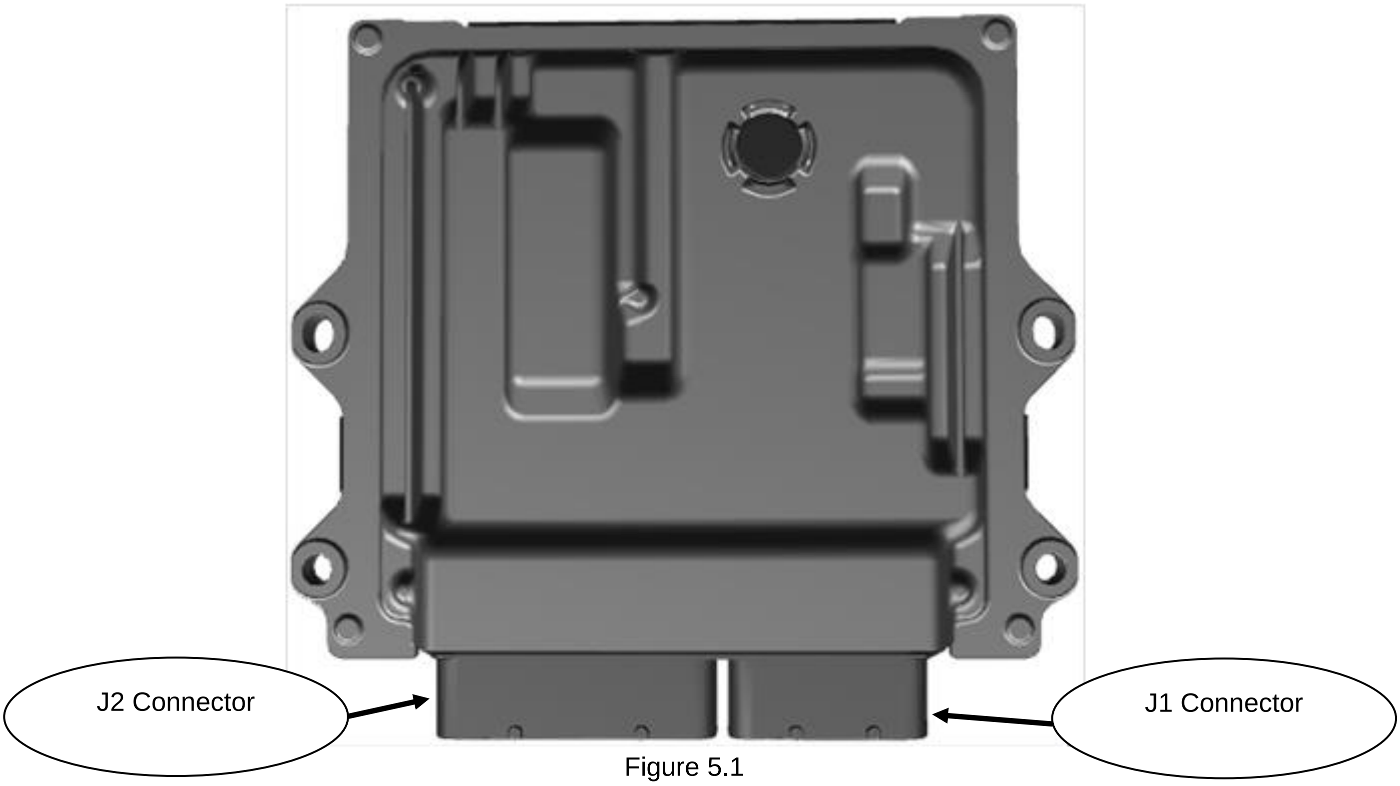


Figure 5.1

5.2 Engine ECU J1 Connector

5.2.1 Engine ECU J1 Connector Layout

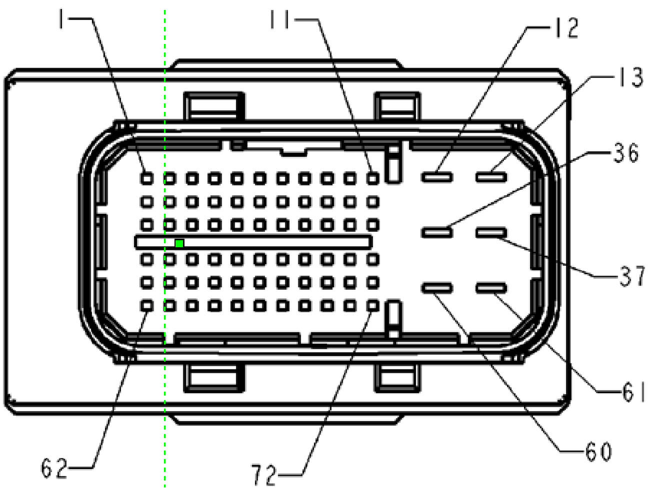


Figure 5.2

Please refer to the separate electrical schematics referenced in Section 2.3.5

5.3 Engine ECU J2 Connector

5.3.1 Engine ECU J2 Connector Layout

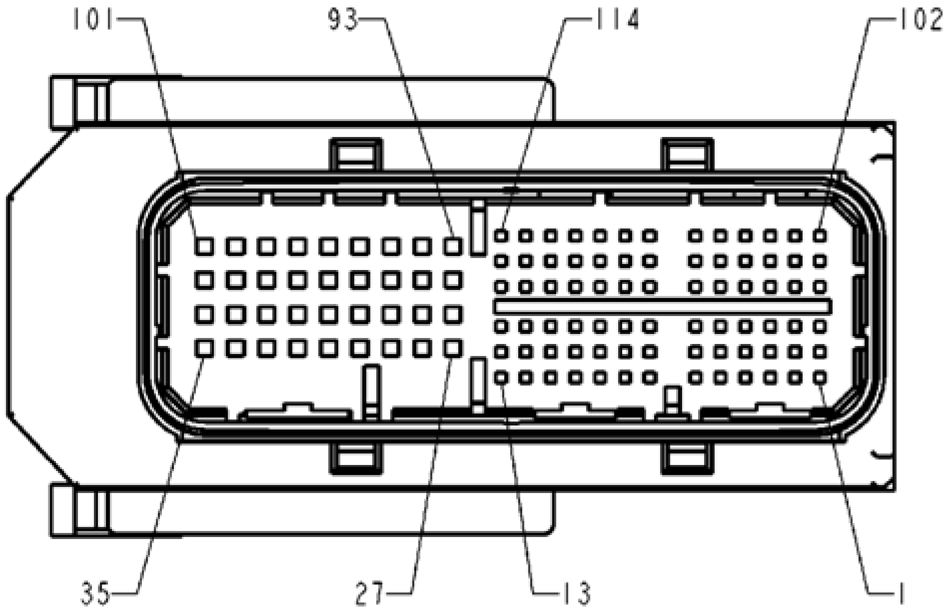


Figure 5.3

Please refer to the separate electrical schematics referenced in Section 2.3.5

5.4 ECU Connector Orientation

5.4.1 180deg-Exits Configuration

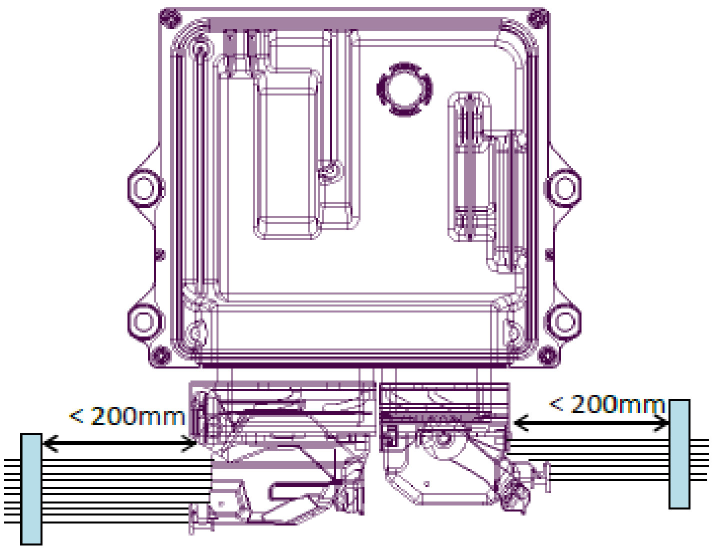


Figure 5.4

5.4.2 Right-Exit Configuration

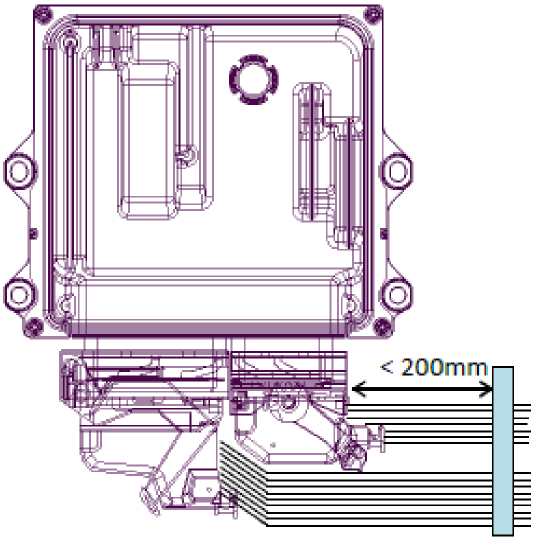


Figure 5.5

Note that Tyco call the above 'Right Exit' configuration 'Left-Left' as their naming convention is based around the ECU connector pointing upwards.

5.5 Engine ECU harness strain relief

Harness strain relief components must be positioned within 200mm of each ECU connector. The strain relief component must be mounted to the same surface as the ECU. The purpose of each strain relief is to prevent excessive movement between the connector, harness and engine ECU.

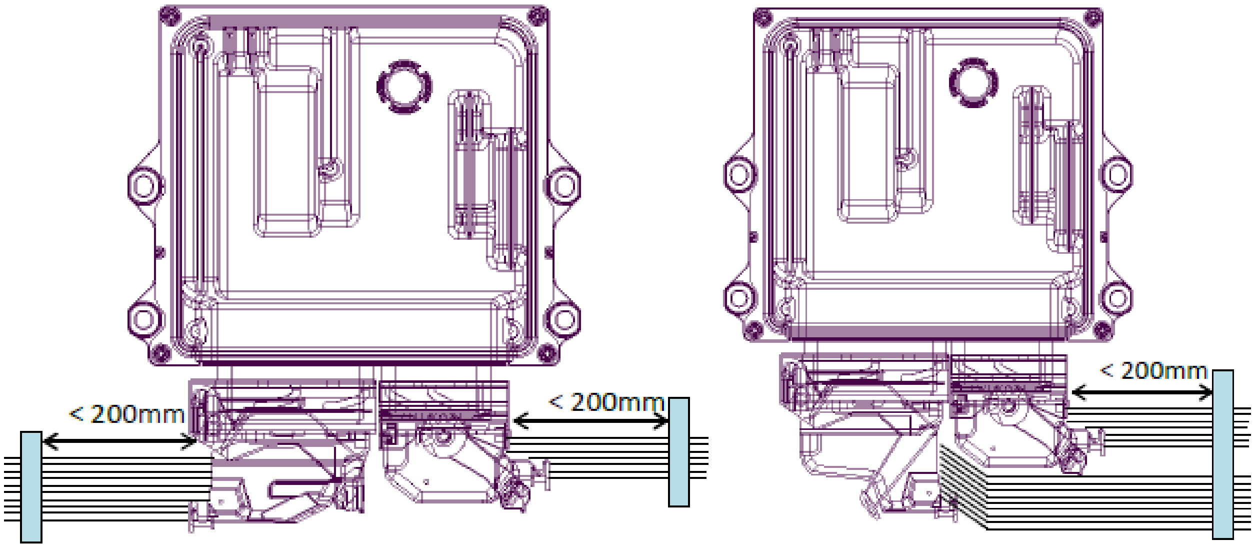


Figure 5.6

5.6 Engine Interface Connector 1 (EIC1) (47 pin)

5.6.1 EIC1 Connector Summary (47 Pin)

The wiring between Engine ECU and EIC connector is mandatory to ensure all the sensors are correctly linked to the Engine ECU. Specific resistance limit applies to the Injector circuit (section 4)

5.6.2 EIC1 Connector Layout

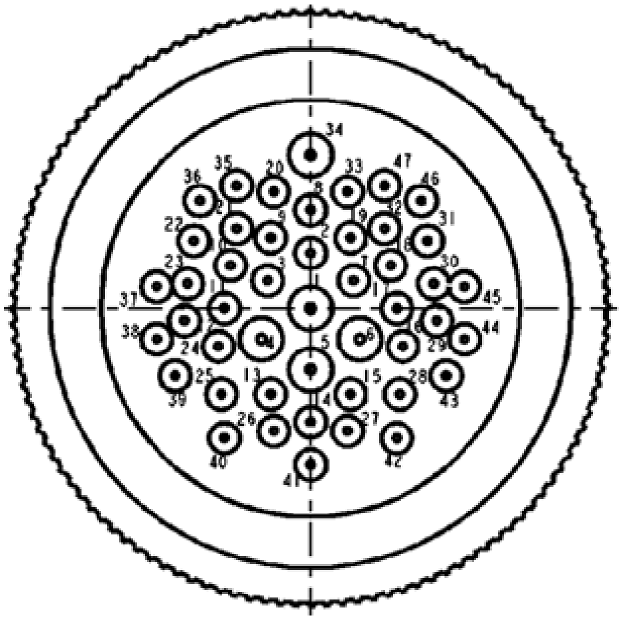


Figure 5.7

5.6.3 EIC1 Connector I/O

Please refer to the separate electrical schematics referenced in Section 2.3.5

5.7 All connector Sealing Plug Installation guidelines

All unused cavities must be filled with sealing plugs in order to ensure that the connector is sealed.
Note that while the sealing plugs will protect the cavities from dirt and dust ingress they will not protect against direct pressure washing, which may damage the ECU.

5.8 Wire Specification Requirements

The engine ECU connector system is designed to accept cables that comply with cable standard **ISO6722 Thin Wall Insulation**.
All connectors, seals and terminals shown throughout this document have been specified to comply with ISO6722 Thin Wall Insulation. If other wiring standards are to be used the following points must be considered.

- Cable Insulation Outside Diameter
- Cable Conductor Cross Sectional Area (CSA)
- Temperature Exposure
- Abrasion Risk.

To ensure all of the above points are taken into consideration, please consult the manufacturer's cable specification.
Only ISO6722 Thin wall wire may be used with the connector system used on this product. The following tables highlight the reasons why it is not possible to use wire that conforms to other international standards.

5.8.1 Wire Thickness Overview

The following sections provide some guidance on the differences in min/min cable thickness for some of the most popular wiring standards.

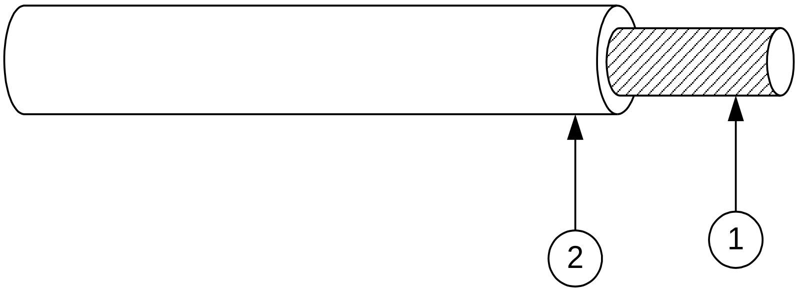


Figure 5.8

1 Wire Size – Cross Sectional Area (mm^2)
2 Cable – Insulation Diameter (mm).

5.8.2 SAE - GXL

GXL wire cannot be used with the connector system used on this product. The outside diameter of GXL wire exceeds the maximum possible for the ECU and engine connectors.

CSA mm2	Closest Wire Gauge Equivalent	Max Outside Dia. mm	Wall Thickness Nom. mm	Wall Thickness Min. mm
~~0.5~~	~~20~~	~~2.4~~	~~0.58~~	~~0.41~~
~~0.8~~	~~18~~	~~2.5~~	~~0.58~~	~~0.41~~
~~1~~	~~16~~	~~2.9~~	~~0.58~~	~~0.41~~
~~2~~	~~14~~	~~3.2~~	~~0.58~~	~~0.41~~
~~3~~	~~12~~	~~3.8~~	~~0.66~~	~~0.46~~

Table 5.1

5.8.3 SAE - TXL

SAE TXL wire cannot be used with this connector system. The TXL wire is not compatible with the connector terminals.

CSA mm2	Closest Wire Gauge Equivalent	Max Outside Dia. mm	Wall Thickness Nom. mm	Wall Thickness Min. mm
~~0.35~~	~~22~~	~~1.70~~	~~0.40~~	~~0.28~~
~~0.5~~	~~20~~	~~1.90~~	~~0.40~~	~~0.28~~
~~0.8~~	~~18~~	~~2.20~~	~~0.40~~	~~0.28~~
~~1~~	~~16~~	~~2.40~~	~~0.40~~	~~0.28~~
~~2~~	~~14~~	~~2.70~~	~~0.40~~	~~0.28~~
~~3~~	~~12~~	~~3.30~~	~~0.46~~	~~0.32~~

Table 5.2

5.8.4 ISO6722 – Thick Wall

Similar to SAE GXL, ISO thick wall exceeds the maximum outside diameter of the connectors system. Therefore is not compatible with this connector system.

CSA mm2	Closest Wire Gauge Closest Wire Gauge Equivalent	Max Outside Dia. mm	Wall Thickness Nom. mm	Wall Thickness Min. mm
~~0.5~~	~~20~~	~~2.3~~	~~0.6~~	~~0.48~~

~~0.75~~	~~18~~	~~2.5~~	~~0.6~~	~~0.48~~
~~1~~	~~16~~	~~2.7~~	~~0.6~~	~~0.48~~
~~1.5~~	~~*~~	~~3.00~~	~~0.6~~	~~0.48~~
~~2~~	~~14~~	~~3.3~~	~~0.6~~	~~0.48~~
~~2.5~~	~~*~~	~~3.6~~	~~0.70~~	~~0.56~~
~~3~~	~~12~~	~~4.1~~	~~0.70~~	~~0.56~~

Table 5.3

5.8.5 ISO6722 – Thin Wall

ISO6722 thin wall wire is the required wire standard for the engine connector system. Using this classification of wire ensures correct sealing and terminal compatibility.

CSA mm2	Closest Wire Gauge Equivalent	Dia.	Max Outside Dia. mm	Wall Thickness Nom. mm	Wall Thickness Min. mm
0.5	20	1.1	1.60	0.28	0.22
0.75	18	1.3	1.90	0.3	0.24
1.0	16	1.5	2.10	0.3	0.24
1.5	*	1.8	2.40	0.3	0.24
2.0	14	2.0	2.80	0.35	0.28
2.5	*	2.2	3.00	0.35	0.28
3.0	12	2.4	3.40	0.4	0.32

Table 5.4

5.8.6 Factory Supplied Link Harness

The C3.6L engine can be supplied with the addition of two link harnesses to aid the installation of the off engine ECU and provide interface connectors for machine specific wiring.
The link harness comes in two options from the factory:

- Engine Interface Connector & 1.5m Flying Lead with Diagnostic connector (Sales option code ZN401)
- Interface Connector & 2.5m Flying Lead with Diagnostic connector (Sales option code ZN403)

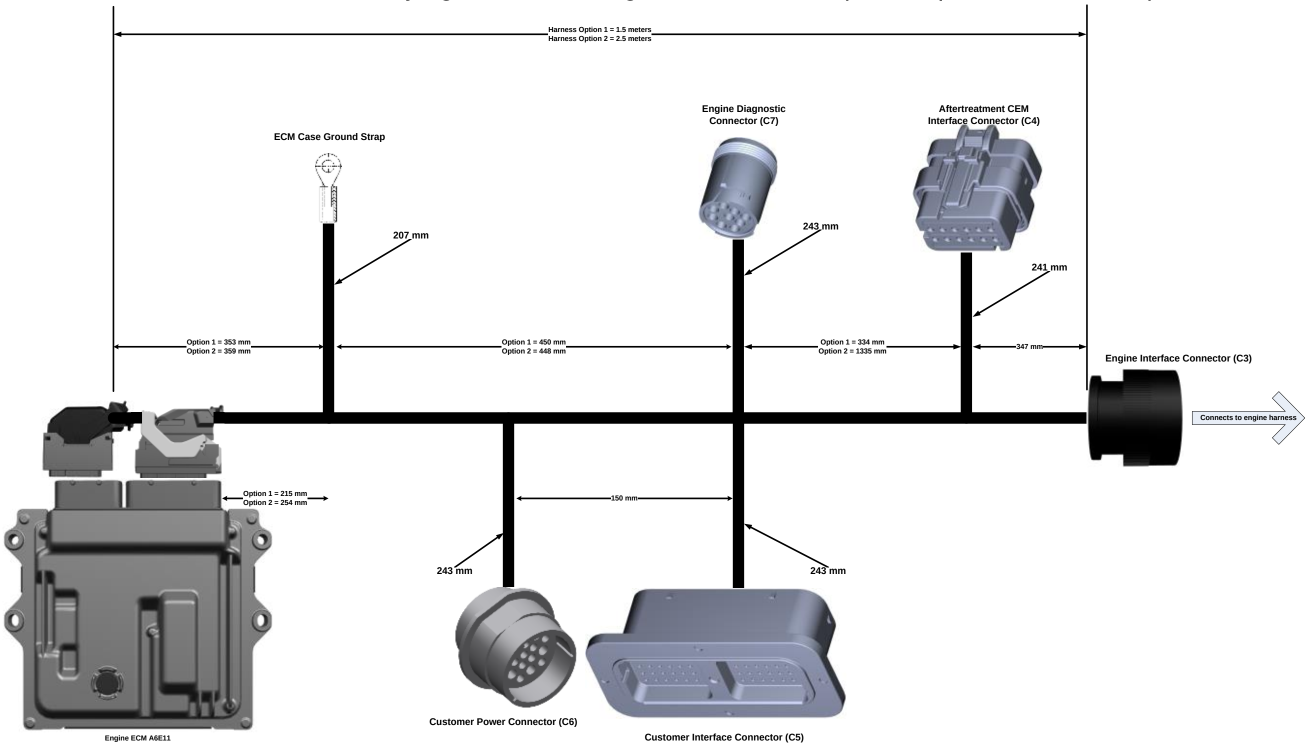


Figure 5.9 – Factory Supply Link harness

The benefit of this link harness is the engine ECU connectors are already assembled on the harness and the other supporting connectors on the harness can support either GXL or TXL wiring.

5.8.7 Harness wiring installation standard

The following are general “good practice” guidelines for wire harness design and installation. It is the responsibility of the machine designer to follow standards appropriate to the application type and to the geographical territory where the machine will be operated. These recommendations do not replace in any way any industrial standards or legal requirements. Please be aware however that any customer installed components, which are integral to the engine or aftertreatment system, are governed by mandatory requirements to ensure the correct operation of the complete system installation.
Do not connect or support other components to the engine wiring harness. Avoid risks of abrasion. The standard operating temperature of the engine wire harness assembly is **135DegC**.

5.8.8 Connector Installation Standard

Connectors should be horizontally mounted rather than vertically mounted to prevent ingress of water/chemicals or mounted to the requirement listed in this manual. Whenever possible, connectors should be mounted such that they are protected from direct exposure to extreme cold. Connectors can be damaged by frost if water does penetrate the seals.
Cables should not bend close to the connector seals, as the seal quality can be compromised.
The correct wire seal must be selected for the diameter of wire used.
Cables should be selected of an appropriate cross section for the current and voltage drop requirements.
Where large numbers of wires go to the same connector, it is essential that no single wire is significantly shorter than the others, such that it placed under exceptional strain.
Note: All electrical components and connectors are not designed to withstand direct exposure to high-pressure water.

5.8.9 Harness Bends near connectors

Harness bends within 25mm of the engine interface connector should be avoided. Bending a harness too close to the connector causes the connector seal to be stretched away from the wire, reducing its sealing capability to dirt and moisture. To avoid this the wires should exit perpendicular to the connector before curving as necessary for routing as shown in figure below.
Bends near to other sensor or actuator connectors should be no less than twice the wire harness diameter. Special consideration should be made to connectors with large wire counts. Stresses placed upon the retention system of the connector can cause retention failures and wire pull-out failures. To avoid these problems pre-form the harness to the required bend radius.

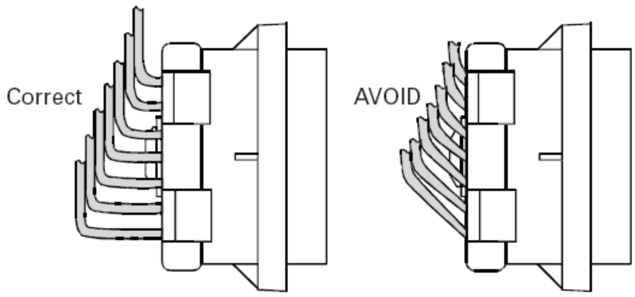


Figure 5.4.2: ECU J1 Harness Routing

5.8.10 Cable Routing

Cables should be routed such that bend radii are not too tight. A cable should not be either in compression or tension, nor should it be excessively long or loose, such that sections may become caught or trapped. Clips should be used at regular intervals to support cables. These clips should be of the correct diameter to grip the cable firmly without crushing it.
Ideally, to protect against damage and to ensure reliability throughout the life of the product the harness routing should provide protection from the following;

- Chafing / rubbing / vibrating against other parts
- Routed away from sharp edges
- Use as handholds or as support for personal equipment
- Damage by personnel moving within or servicing the vehicle
- Damage by impact
- Damage by battery acid fumes, engine and hydraulic oil, fuel and coolant
- Abrasion or damage when exposed to rocks, ice, mud etc
- Damage by moving parts
- Harsh environments such as nitrite mines, high temperatures, or areas susceptible to significant fluid or fume concentration

Conductors carrying high currents or voltages, particularly when these are alternating or switched, should be physically separated from conductors carrying small signal currents. In particular, high current and signal wires should not run parallel in the same harness bundle for any significant distance. Ideally, if high current wires must be in proximity to signal wires then they should cross at right angles.

The engine wire harness should not be used by the installer as a support for any components that are not supplied as part of the engine system. For example, external hoses and wires should not be tied to the engine harness.

Care should be taken during design to ensure that components are accessible for repair and possible replacement in the field. Poor maintenance access may lead to poor quality repairs in the field.

5.8.11 Twisted cable pairs

Mandatory Twisted pairs

- CAN Connection A
- CAN Connection C

Recommended Twisted pairs

- Injectors 1
- Injectors 2
- Injectors 3
- Injectors 4
- Fuel Rail Pressure Sensor
- Fuel Pump Control Valve
- Inlet Throttle Valve
- Crankshaft Speed Sensor
- Camshaft Speed Sensor
- NRS Valve
- Turbo Wastegate

5.8.12 Electromagnetic Compliance (EMC)

Special measures should be taken to shield cables if the application is to be used in extreme electromagnetic environments – e.g. aluminum smelting plants.

If screened cables are used, the screens should be connected to ground at one point only. That point should be central if possible. Please consult your applications engineering team for further information on EMC compatibility.

5.8.13 Insulation Selection and Thermal Protection

Care must be taken when routing the under hood electrical cabling to ensure that it is routed away from any hot objects such as the engine turbo and exhaust as well as the engine aftertreatment. In some cases this may not be possible in which case care must be taken to ensure that the cable insulation used is rated to the areas in which it is routed. In some cases specialist insulation maybe required such as Teflon etc.

It should also be noted that high temperature cables do in many cases have a reduced overall diameter when compared to ISO cable. If this is the case then an analysis of the connector sealing capabilities must be undertaken to ensure that each connector seal maintains its sealing capabilities.

6.0 Customer Connection of Engine Components

The C3.6 product range requires the customer to install some engine performance critical electrical sensors / components and some optional components. Details of these components are shown below.

Component	Mandatory	C3.6L >56kW DOC, DPF, SCR	C3.6L <56kW / 74.4 – 82kW DOC, DPF	C3.6L Stage IIIA
A6E11 Engine ECU	Yes	✓	✓	✓
EIC1 Wiring Connection	Yes	✓	✓	✓
Water In Fuel Switch	Yes	✓	✓	✓
Air Inlet Temperature Sensor	Yes	✓	✓	✓
Engine Diagnostic Connector	Yes	✓	✓	✓
Electric lift / Prime Pump	No	✓	✓	✓
Air Filter Restriction Switch	No	✓	✓	✓
Glow Plugs Relay	Yes	✓	✓	✓
Ether Solenoid	No	✓	✓	✓
ATACC Out Temperature Sensor	Yes	✕	✕	✓

Table 6.1

For the components above that are mandatory, the correct installation will be verified during the engine installation audit.

6.1 Engine ECU Installation Requirements

The engine ECU should be mounted off the engine following the guidelines in the Mechanical A&I document LEBH0075.

6.1.1 Engine ECU Power Supply

6.1.1.1 Engine ECU Keyswitch circuit

A low current key switch input activates the engine ECU. Upon activation the engine ECU will energise the Main power control relay to enable its power pins. The engine ECU must control the power control relay and direct power feed is not permitted. Reverse battery polarity protection is only provided when the main power control relay is used.

It is recommended that the key switch signal connected to pins J1-5 & J1-6 is not shared with other circuits to avoid interference or problems associated to voltage decay or stray system charge. Separating the circuit eliminates the risk of holding the key switch input high in a desired key off state. In some instances it may be necessary to add a blocking diode to separate the circuit.

The voltage thresholds to activate or de-activate the key switch input are given below. Pin J1-5 & J1-6 are protected against reverse polarity up to a maximum of –14Vdc (12-volt system) and -28Vdc (24-volt system). The ECU battery connections are polarity protected by the main power relay.

The keyswitch must not be powered without the main power relay being able to power the ECU through its main power pins.

Characteristic - Pin K54	Minimum	Maximum	Unit
V_In_High (Key On)	4.0		V
V_In_Low (Key Off)		2.1	V

Table 6.2

6.1.1.2 Engine ECU Switch Battery Positive circuit

When the Engine ECU receive the Keyswitch signal on the pin J1-5 and J1-6, it will then control the ECU Main Power relay to maintain the ECU powered during Engine operation and post-run activities.

The Engine ECU uses pins J1-26 and J1-27 to control the ECU Main Power Relay throug a Low Side Driver. The positive side of the relay needs to be powered through the Battery positive.

When the Main Power Relay is activated the Engine ECU will be powered through the pins J1-13, J1-37 and J1-61.

The selected relay must be capable of a continuous current of 40A and a pulse current of **150A** for **1ms**.

The ECM is capable of driving the control side of the relay with up to 1.2A

6.1.1.3 Engine ECU Battery Negative circuit

The Engine ECU is grounded through 3 pins, J1-12, J1-36 and J1-60. Those pins needs to be wired to the Battery negative.

The potential difference between Machine ground and ECU ground must not exceed 1V.

6.1.1.4 Engine ECU Case grounding

To improve EMC capability of the ECU, the ECU Case requires to be ground through a short grounding wire through pin J1-62.

The wire length must not exceed **700mm**.

6.1.1.5 Engine ECU powering schematic

Please refer to the separate electrical schematics referenced in Section 2.3.5

6.1.2 Engine ECU Mounting Orientation

The engine ECU must be positioned to minimize exposure to fluids and debris. The position of the ECU should be carefully considered to prevent foreign object damage and clogging of the air-cooling fins and connector mechanisms. The location design should incorporate measures to prevent fluids channelling towards the ECU through conduit or wiring. The ECU fasteners must not be used for secondary retention of pipe or wire clips. The ECU must not come into contact with other machine or engine components.

The ECU must not be submersed. The pressure compensation valve and integral barometric sensor will not operate correctly if submersed in fluids.

The mounting orientations shown in the diagram below should not be used if there's a risk of fluids standing on the ECU surfaces. If it is necessary to mount the ECU in positions shown in figure below measures must be taken to prevent standing water. Consider placing the ECU at an angle to allow fluid run-off.

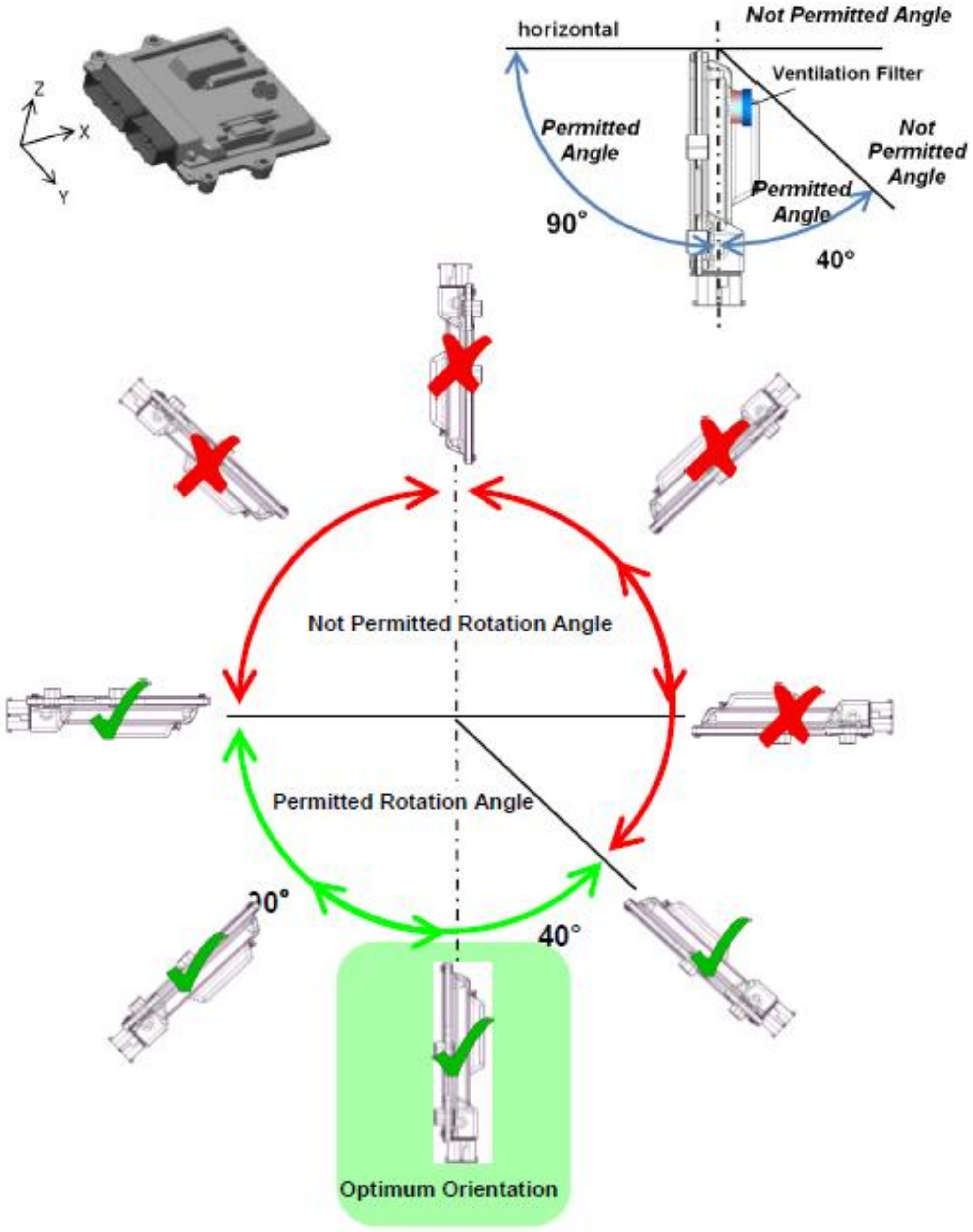


Figure 6.1

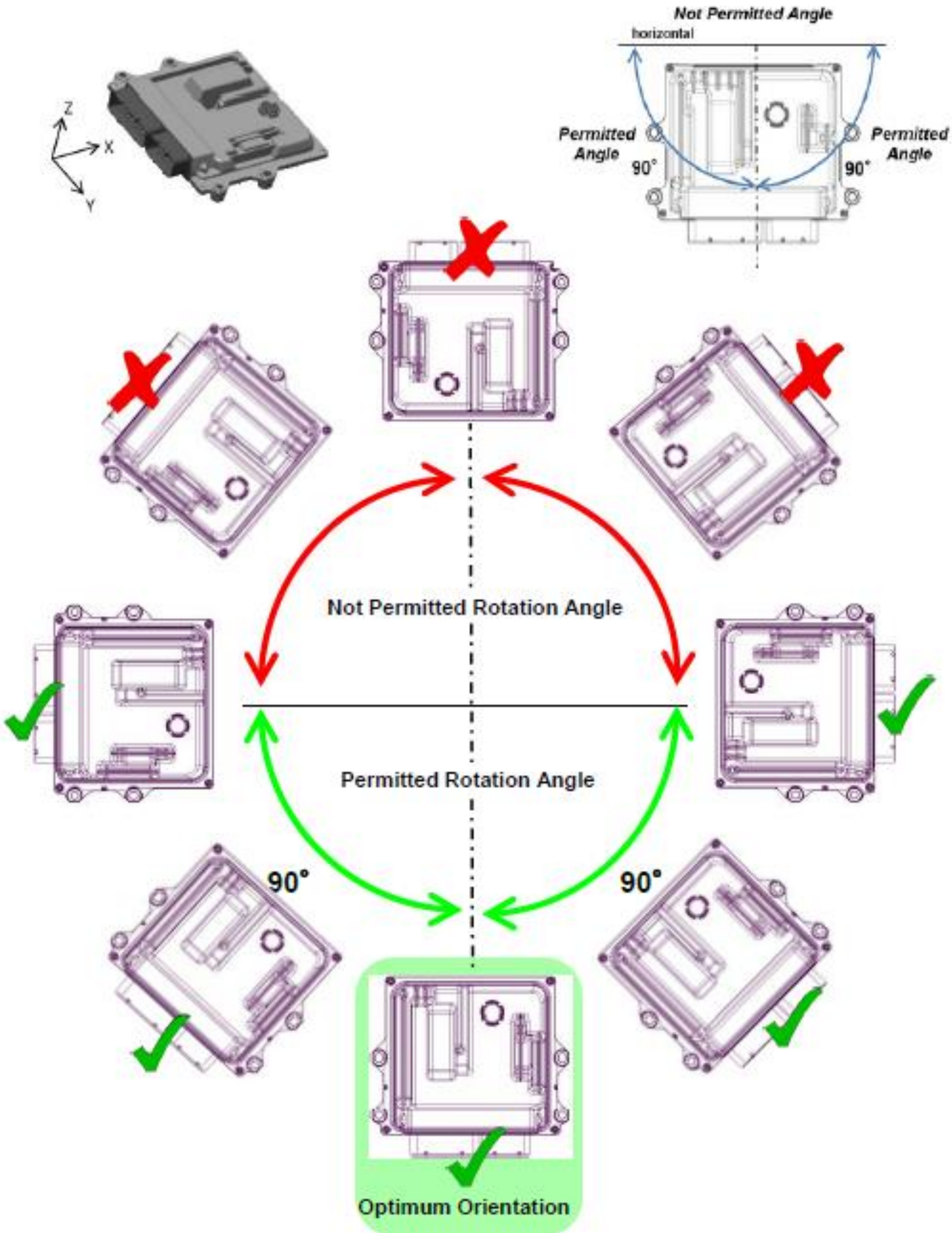


Figure 6.2
The wire harness should be directed downwards to prevent water from collecting at the ECU connector.

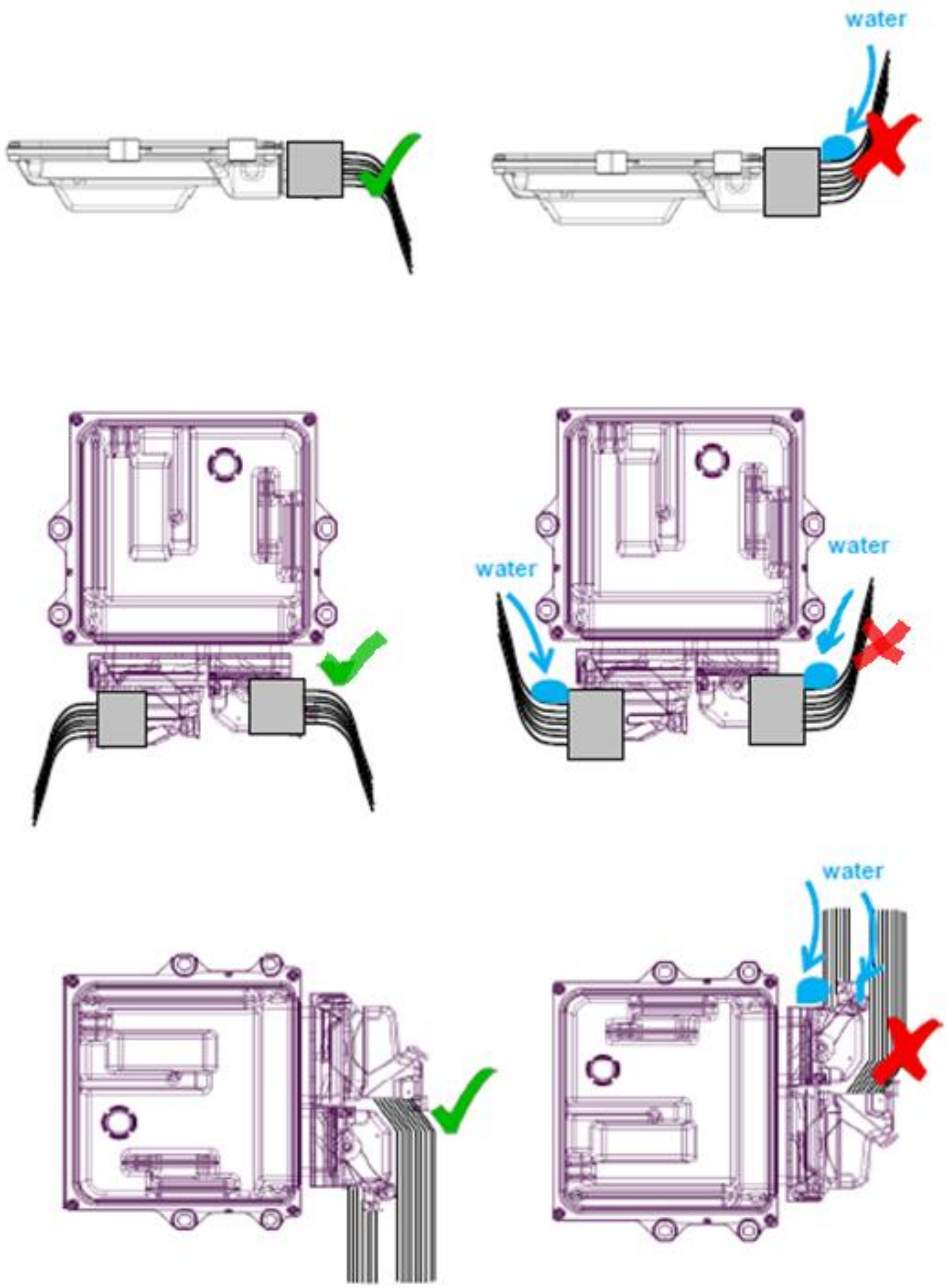


Figure 6.3

6.2 Water in Fuel Switch (WIF)

6.2.1 WIF Switch Operation

The water in fuel switch indicates that the fuel filter bowl is full. During normal engine operation the switch is immersed in diesel fuel. As water collects and reaches the maximum level the water enables a conductive path between electrodes (normally open switch), and triggers appropriate diagnostic codes when required. The WIF switch is supplied assembled to all engines and is a mandatory installation item. The electrical connection of the switch to the engine ECU is the responsibility of the customer and should form part of the machine wiring harness connection to the Engine ECU.

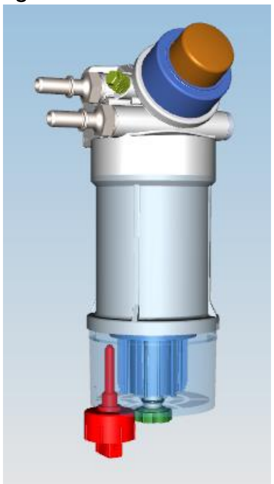


Figure 6.4 – WIF switch highlighted in red.

Service Tool Description	J1939 description	Status	SPN (J1939)	FMI (J1939)	Engine Action (If enabled)
Water in Fuel switch	Water In Fuel Indicator	Severity L1	97	15	Warning Lamp Only
		Severity L2	97	16	Warning and Derate
		Severity L3	N/A	N/A	N/A

Table 6.3 – WIF switch Monitoring

Note: For more detail on WIF switch diagnostic codes, refer to latest trouble shooting guide, which can be viewed from SIS web.

6.2.2 WIF Switch Configuration

The WIF switch is a mandatory item, which is always installed.
No configuration is required via Caterpillar Electronic Technician service tool (CAT ET).

6.2.3 WIF Switch Installation

The WIF switch is supplied connected to the bottom of the primary fuel filter. The switch is supplied with a flying lead connection, which provides the connection point for the customer to connect the switch to the ECU J1 and J2 connectors.

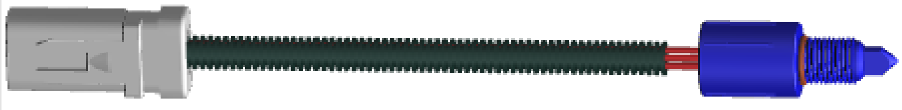


Figure 6.5

Please refer to the separate electrical schematics referenced in Section 2.3.5

Note: The switch is located in a vulnerable position, so every care should be taken to prevent accidental damage occurring to it or the flying lead attached to it.

It is the OEM’s responsibility to route the water in fuel switch flying lead harness and its connector plug and mount appropriately. To ensure that the wires entering the back of the switch are adequately protected against over stress and damage during filter and/or engine installation and machine operation, the switch can be supplied with a circular backshell to help control the orientation of the cabling and prevent direct side pull. This sleeve engages with the grooves at the end of the switch body and electrical wire conduit corrugations.

Figure 6.6

A backshell is recommended and is available in both 180° and 90° designs and is easily retrofitted by the clasp mechanism. It is not designed for frequent removal, as the latching tangs can become distorted and break, so once fitted it is intended to remain in place.

Figure 6.7

Backshell Type	Supplier	Supplier P/N	CAT Part #
90°	TE Connectivity	185793-1	596-1634
180°	TE Connectivity	185792-1	525-5220

Table 6.4

In all cases (with or without a backshell), the WIF installation should follow the guidance set out in the harness wiring installation standard in section 5.0

6.3 Air Inlet Temperature Sensor

6.3.1 Air Inlet Temperature Sensor Operation

The air inlet temperature sensor is a passive sensor used to measure the ambient air temperature. This temperature is used to regulate the engine NRS system during a number of scenarios. This sensor is a mandatory fit item, as the performance of the engine will be severely affected if it is not installed. The air inlet temperature sensor must not be exposed to temperatures in excess of 125ºC, as temperatures above the limit will exceed the temperature rating of the sensor connector.

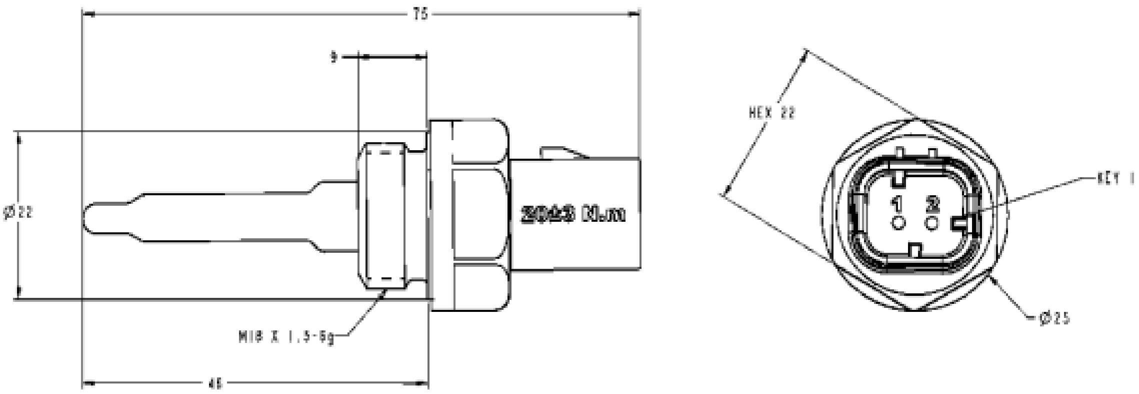


Figure 6.8

6.3.2 Air Inlet Temperature Sensor Configuration

The Air Inlet Temperature Sensor is a mandatory item, which is always installed.
No configuration is required via Caterpillar Electronic Technician service tool (CAT ET).
All engines are supplied programmed with a standard 5°C air inlet temperature sensor offset to calculate the local ambient air temperature being breathed by the engine. This offset value is fixed and requires no in application calibration. For further information on the installation requirements for the engine air intake system please refer to the Mechanical A&I manual.

6.3.3 Air Inlet Temperature Sensor Installation

The Air Inlet Temperature sensor should be installed after the air cleaner and tightened to a maximum permissible torque of 20 Nm +/-3 Nm. The sensor requires a M18 x 1.5 (metric) thread and sealing is an integral part of the sensor, therefore an o-ring is supplied with the sensor. The sensor should be positioned as close to centre of the inlet pipe as possible. It is recommended that the sensor is positioned in the upper half of the pipe to prevent any fluids pooling around the probe.
Please refer to the separate electrical schematics referenced in Section 2.3.5

6.4 Engine Diagnostic Connector

6.4.1 Engine Diagnostic Connector Operation

A 9-pin engine diagnostic connector must be fitted on all industrial installations. The diagnostic connector enables connection to the data link via Caterpillar ET service tool, and the J1939 data link that can be accessed by most third-party diagnostic tools.

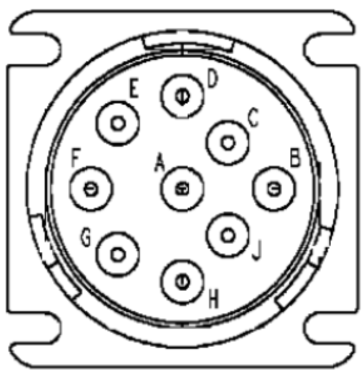


Figure 6.9

6.4.2 Engine Diagnostic Connector Configuration

The engine diagnostic connector is a mandatory item, which is always installed. No configuration is required via Caterpillar Electronic Technician service tool (CAT ET).

NOTE: For the C3.6EA the customer is required to provide an additional link harness, which converts the 9 pin diagnostic connector to the required SAE standard. This is required to support NR4 regulations. When you need to connect to the engine disconnect the link harness and plug directly onto the engine harness.

6.4.3 Engine Diagnostic Connector Installation

It is recommended that a diagnostic connector be wired in a location that can easily be accessed, free from possible water / dirt ingress and impact damage. A preferred location would be the machine cab on the basis of protection, convenience and safety. The engine wire harness must not be changed or modified. To wire a diagnostic connection use the data link pins available on the engine ECU J1 connector

It should be noted that the diagnostic connector is intended solely for diagnostic purposes and must not be used as means of connecting machine controllers or displays to the J1939 datalink. Dedicated I/O has been provided for this function via the engine ECU J1 connector.

All cables supplying the diagnostic connector are required to be no smaller than $0.5mm^2$ and should conform to the ISO67222 insulation specification. Larger cables for the diagnostic power supply are not required, as diagnostic hardware should draw no more than 1 amp total.

Please refer to the separate electrical schematics referenced in Section 2.3.5

6.5 Air Filter Restriction Switch

6.5.1 Air Filter Restriction Switch Operation

The air filter restriction switch indicates that the air intake circuit is restricted. The switch is installed or piped to the air filter housing or air induction pipe so that it is monitoring clean air (between the air filter and the engine). A normally closed Air filter restriction switch is available within the Caterpillar Parts system for order where required.

To enable the use of third party components this input in configurable from normally open to normally closed depending upon the type of switch selected.

During engine running the ECU shall continuously monitor the state of an air filter restriction switch via a hard wired SWB input on pin J2-43. When the filter restriction input has changed state, the software shall raise an event code and transmit this on the CAN link via the DM1 message frame and turn the amber warning lamp on. The software will also derate the engine after a calibrated time (in seconds) after the event code is raised, the amount of derate applied shall be determined by a calibration value.

Service Tool Description	J1939 description	Status	SPN (J1939)	FMI (J1939)	Engine Action (If enabled)
Air Filter Restriction Switch	Engine Air Filter 1 Differential Pressure	Severity L1	107	15	Warning lamp only
		Severity L2	107	16	Warning lamp will flash and engine is derated.
		Severity L3	N/A	N/A	N/A

Table 6.5 – Air Filter Restriction Monitoring

Note: For more detail on Air Filter Restriction Switch diagnostic codes, refer to latest trouble shooting guide.

6.5.2 Air Filter Restriction Switch Configuration

The Air Filter Restriction Switch is not a mandatory item and therefore not always activated.

To enable the operation of this switch, the configuration of the air filter restriction switch must be altered within Caterpillar ET, see table below.

Note: All air filter restriction switches supplied by Caterpillar are normally closed.

Configuration field Names	Configurable Options	Default Configuration
Air Filter Restriction Switch Installation Status	Installed Not Installed	Not Installed
Air Filter Restriction Switch Configuration	Normally Closed Normally Open	Normally Closed

Table 6.6

6.5.3 Air Filter Restriction Switch Installation

The air intake restriction switch is a two-wire switch which requires connection to switched battery. The switch is installed in the air induction pipe.
To validate the correct switch is chosen the application engineer will complete the Air Filter Restriction test procedure.
Although it is possible for the customer to source their own air filter restriction switch, Caterpillar recommends and supplies a range of he switches as shown in Table 6..

Caterpillar Part Number	Description	Trip Point
296-2735	Air Filter Restriction Switch	6.5 kPa
267-6197	Air Filter Restriction Switch	7.5 kPa

Table 6.7

Please refer to the separate electrical schematics referenced in Section 2.3.5

6.6 Engine Electric Fuel Prime / Lift Pump

6.6.1 Engine Electric Fuel Prime / Lift Pump Operation

The C3.6L engine has three options for the Low-pressure fuel system;

1. No low-pressure fuel pump
2. Single fuel filter with electric prime pump operation only
3. Heavy duty fuel filter with electric prime and lift pump operation.

Option 2 - The low-pressure fuel pump is used to prime fuel to ensure a continuous fuel flow is provided to the engine fuel pump, depending on the option requested by the customer. The low-pressure fuel pump hardware, engine ECU connections are the same for all operations. The low-pressure fuel pump is available in 12 and 24V options.
Option 3 - The electric prime pump operation is energized whenever the ignition key switch is turned ON. This enables the engine ECU to energise a low-pressure fuel pump relay. The pump will be used as an electric fuel priming pump when required (120 seconds is the maximum time allowed for fuel system priming using the electric lift pump). It should be noted that after ignition key 'ON' the pump will run for a maximum of 120 seconds without seeing the engine speed increase from 0rpm. If the engine speed does not exceed 0rpm within 120 seconds then the lift pump will turn off. When the engine speed is detected the low-pressure fuel prime pump will be turned on by the engine software.

6.6.2 Engine Electric Fuel Prime / Lift Pump Configuration

Depending on the option chosen by the customer the engine software will need to be configured to support that low-pressure fuel pump option. There are three options in the configuration screen of the service tool, see table below.

Configuration field names	Configuration Options	Default Configuration
Engine Fuel Supply Lift Pump Status	Not Installed *(M-base)* Installed *(E-base / Heavy Duty)*	Set from factory based on option selection

Periodic Fuel Priming Enable Status	Disabled *(M-base / Heavy Duty)* Enabled *(E-base)*	Set from factory based on option selection

Table 6.8

The service tool does also provide a means of overriding the engine ECU control of the pump relay to aid system diagnostics. This override parameter can be found in the following service tool menu location:
Diagnostics / Diagnostic Tests / Override parameters
It should be noted that the service tool override will be disabled when:

- The override will not operate if the engine speed is greater than 0rpm
- The test will abort if the engine speed exceeds 0rpm

6.6.3 Engine Electric Fuel Prime / Lift Pump Installation

The low-pressure fuel lift pump requires a fused battery positive and battery negative connection. The control of the lift pump is provided by the engine ECU via the ECU J1 connector and a fuel pump supply control relay which requires machine mounting by the customer.
Supply of the low-Pressure lift pump control relay is the responsibility of the OEM. An example relay specification is shown in the figure below. When mounting the relay, the following must be considered;

- Mounting location of the relay does not exceed the temperature and vibration limits of the chosen component.
- The relay must not be mounted under any circumstances to the engine.
- The relay should be positioned such that direct exposure to fluids and dirt/dust are minimized.

Parameter	Specification Requirements
Temperature Limit	-40°C To +85°C
Vibration Limit	10Grms
Coil Hold In current	< 300mA
Suppression	Diode

Table 6.9

In the event of a third-party relay being selected for low pressure fuel pump control care must be taken to ensure that the relay coil demands less than 300mA during activation and that the relay contacts are specified to meet the maximum current demand from the electric lift / prime pump as shown in the table below.

Component	Max Current Draw	Recommended Cable Size
12V Lift / Prime Pump	5A	14AWG
24V Lift / Prime Pump	3A	16AWG

Table 6.10

Please refer to the separate electrical schematics referenced in Section 2.3.5

7.0 Connecting Engine To Aftertreatment

The C3.6L Stage IIIA engine does not use an aftertreatment system so Section 7.0 can be ignored for this engine.

7.1 Aftertreatment system

The C3.6L TIER 4 Final / Stage V / China NR4 engine range can be supplied with two different aftertreatment system configurations.
The following section provides guidance on the electrical installation of these different aftertreatment systems;

1. >56kW DOC, DPF, SCR system.
2. <56kW / 74.4 – 82kW DOC, DPF system

7.1.1 Aftertreatment System Architecture Overview

The following table demonstrates the aftertreatment components fitted to each aftertreatment type.

Component Reference	Component Description	C3.6L >56kW DOC, DPF, SCR	C3.6L <56kW / 74.4 – 82kW DOC, DPF
1	NOx Sensors	✓	N/A
2	Triple temperature probe DOC/DPF/SCR	**Full EMAT or Full Remote**	N/A
3	Dual temperature probe DOC/DPF	**Partial EMAT & Full Remote**	**Full EMAT or Full Remote**
4	Single temperature probe SCR	**Partial EMAT & Full Remote**	N/A
5	Delta P Pressure Sensor	✓	✓
6	DEF Injector Unit	✓	N/A
7	DEF Pump Supply Module	✓	N/A
8	DEF Heater Lines	✓	N/A
9	SCR Main Relay	✓	N/A
10	DEF Tank and Header	✓	N/A
11	Engine Coolant Diverter Valve	✓	N/A

Table 7.1

This sections below provides the individual emissions system components installation requirements.

7.2 NOx Sensors

7.2.1 NOx Sensor Operation

There are two NOx sensors required for the Tier 4 Final/Stage V product range. These sensors are required to correctly operate and monitor the aftertreatment system. The sensing unit used in each operate in the same way however to prevent incorrect harness connection the mating connections have different keying.
The first NOx sensor is located within the pipe work post DPF, pre-DEF injector unit and the second sensor within the Tail pipe outlet from the Aftertreatment system. The sensing units communicate with the engine ECU on the dedicated aftertreatment CAN bus C.
There is one standard cable length between control module and sensor probe, length 908 mm.

Figure 7.1 – NOx Sensor standard length cable 908 mm.

The sensor requires Connection to the ECU J1 connector and is supply voltage dependent. Both 12 and 24V options are available. The sensor part numbers supplied below take into account both the supply voltage requirement and the Ampseal connector keying.
Both NOx sensors are available in 12 and 24V options as shown below.

- NOx Sensor 1 (Upstream):
  - 12V NOx Sensor with Ampseal connector Key 1 - 441-5129
  - 24V NOx sensor with Ampseal connector Key 1 - 441-5127
- NOx Sensor 2 (Downstream):
  - 12V NOx Sensor with Ampseal connector Key 2 - 441-5130
  - 24V NOx sensor with Ampseal connector Key 2 - 441-5128

7.2.2 NOx Sensor Configuration

No specific configuration is required to enable the correct operation of the NOx sensors via Caterpillar Electronic Technician service tool (CAT ET).

7.2.3 NOx Sensors Installation

It is the customers responsibility to mount the NOx sensors. The location of NOx sensor control unit must meet the criteria described below. Additional mechanical installation requirements can be found in the Mechanical A&I manual.

Installation Criteria	Specified Limits
Ambient Temperature Control Unit	Operating temp 110°C
Max Surface Temperature Control Unit	99°C (24V) 93°C (12V)
Vibration	8Grms
Torque (max allowable on mounting tabs)	12Nm +/- 3

Table 7.2

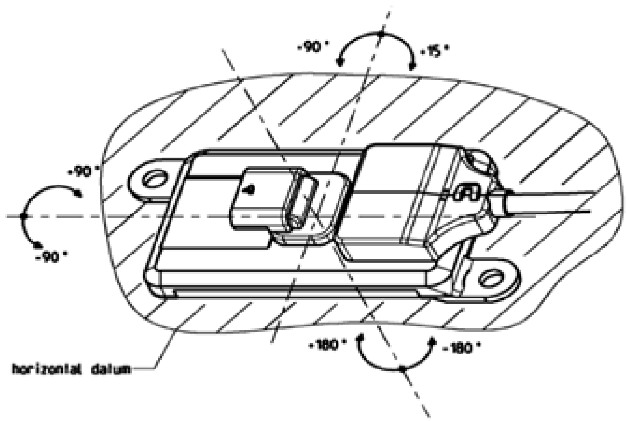


Figure 7.2 Acceptable NOx Sensor Orientation

The mounting orientation limitations of the sensor control unit are shown in the figure above. NOx sensor control units must be mounted sufficiently far away from one another to prevent cross installation of the sensor probes.

The **first NOx sensor (Upstream)** needs to be positioned in the exhaust gas pipe and you should avoid a dead zone position, for example shortly after bending or sharp edges. Also avoid positioning sensor close to other sensors in the exhaust gas pipe. For more detail please refer to the associated mechanical A & I manual.

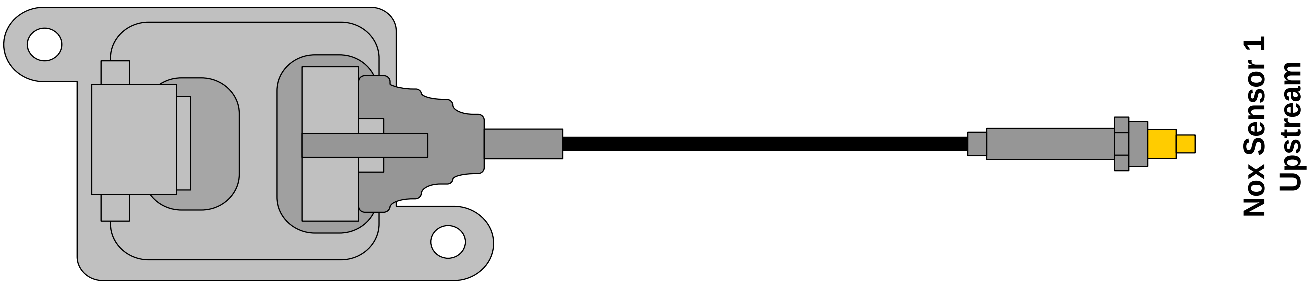


Figure 7.3 NOx Sensor 1 Upstream

The **second NOx sensor (Downstream)** needs to be positioned in the exhaust gas pipe after the SCR outlet pipe, and you should avoid a dead zone position, for example shortly after bending or sharp edges. Also avoid positioning sensor close to other sensors in the exhaust gas pipe. For more detail please refer to the associated mechanical A & I manual.

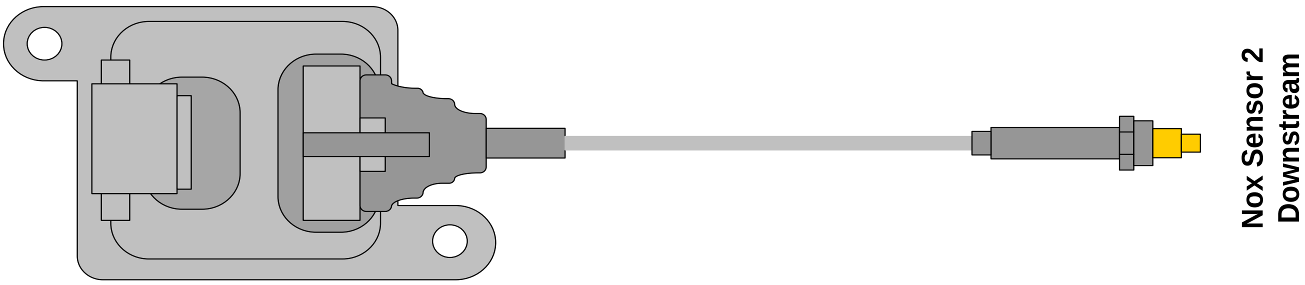


Figure 7.4 NOx Sensor 2 Downstream

7.2.3.1 NOx Sensor Cabling Routing & Support

The NOx sensor is fitted with a 908mm (12V option) and a 908mm (24V option) length of harness between the back of the sensor unit to the sensor control box. These limits are specified by the sensor supplier for EMC requirements.

To ensure that the wires entering the back of the sensing element are adequately protected against over stress and damage during engine installation and machine operation, the sensors are fitted with an attachment to control the orientation of the cabling as it exits the sensor.

The NOx sensor endbell attachment is available in bulk supply from Caterpillar but is also supplied with all engines as standard. It is strongly recommended the endbell is used to control the cable exit angle from the back of the sensor.

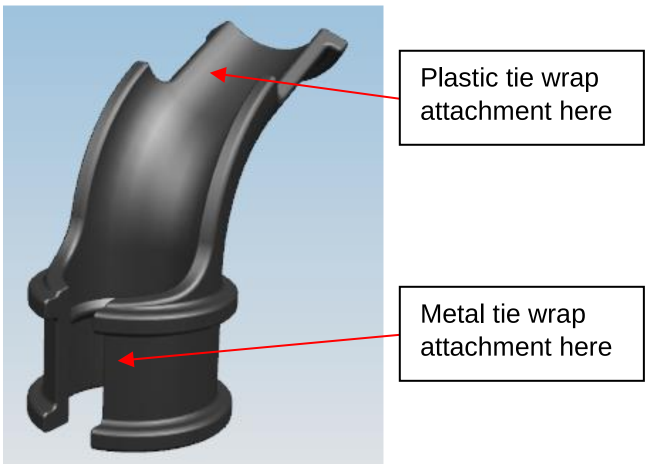


Figure 7.5 NOx Sensor Endbell attachment Diagram

Figure 7.6 NOx Sensor Diagram

- The Endbell attachment is clipped onto the end of the sensor body and should be secured in place with a metal tie wrap
- Once the orientation of the Endbell has been set to route the cable in the correct direction (towards first harness clipping point) the cable can be fixed to the curved end of the Endbell with a plastic tie wrap
- Harness must be secured every 6" or 150mm or less.
- Bend radius of the harness must be >=20mm.

For machines with relative motion between the first harness clipping point and the rear of the sensor, a security loop needs to be used as shown below. The loop needs to be implemented in such a way as to ensure that movement of the exhaust pipe during vehicle operation will not tighten and damage the harness. The length of the security loop should be adapted to suit the application to meet the amplitude of exhaust pipe movement.

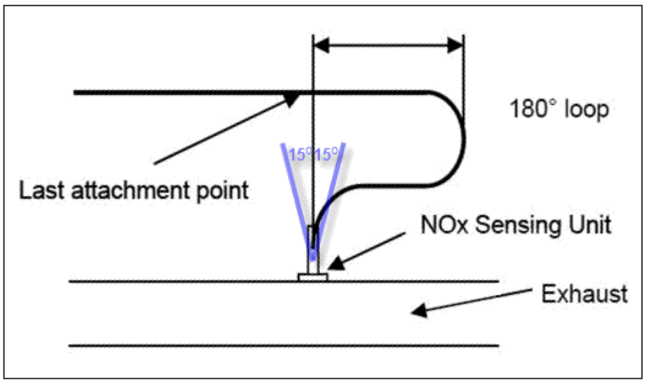


Figure 7.7 NOx Sensor Harness Clipping

Routing and clipping of the NOx sensor cable must not result in any of the temperature limits stated in the table below being exceeded.

Installation Criteria	Max Temp Limits
Sensor to Controller Electrical Cable	-40Deg to 200DegC
SEA Grommet (Rear of sensing element)	-40Deg to 200DegC
SEA hex fitting	-40Deg to 620DegC

Table 7.3 Sensing Unit Temperature Limits

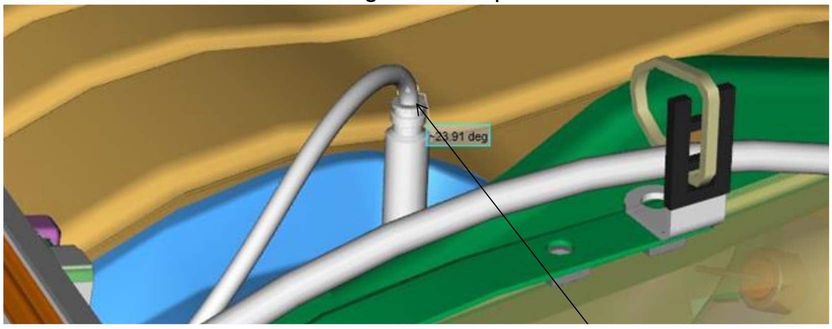


Figure 7.8 Bad cable support example exiting from rear of NOx sensor probe.

Under no circumstances should the NOx sensor cable be tie wrapped to the sensor probe body as shown in figure 7.8. The operation the sensing probe will heat to temperatures above 200DegC, which will cause damage to the sensor cable.

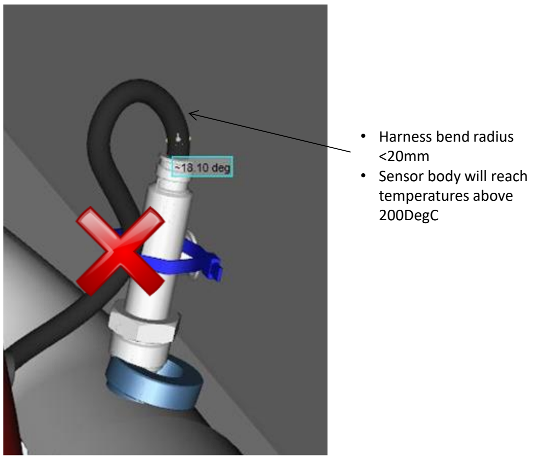


Figure 7.9 Incorrect NOx sensor cable clipping.

Please refer to the separate electrical schematics referenced in Section 2.3.5

7.3 Exhaust Gas Temperature Sensors

7.3.1 Exhaust Gas Temperature Sensor Operation

There are 3 exhaust gas temperature sensors and these sensors are required for accurate control / monitoring of the engine aftertreatment system.

The exhaust gas temperature sensors are supplied with engine fitted and loose depending on aftertreatment configuration;

1. Tripe Probe Exhaust Temperature Sensor

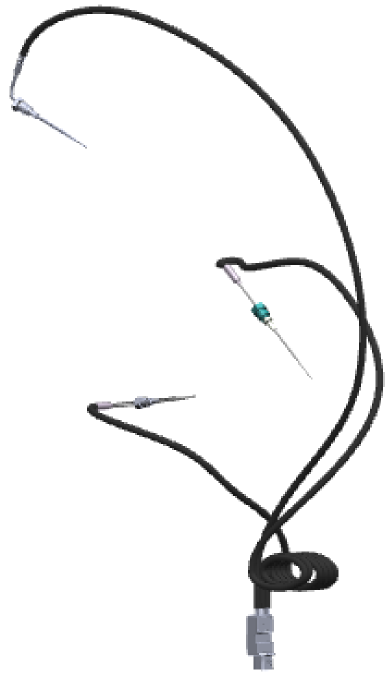


Figure 7.10

2. Dual Probe Exhaust Temperature Sensor

Figure 7.11

3. Single Probe Exhaust Temperature Sensor

Figure 7.12

The temperature sensors above consist of the following components;

1. Temperature Sensor Probe
2. Temperature Sensor Module
3. Electrical Connector

The aftertreatment system configuration can be supplied from the factory in the following configuration;

1. Full EMAT – Full Engine Mounted Aftertreatment
2. Partial EMAT – Partial Engine Mounted Aftertreatment
3. Full Remote – Full Remote Aftertreatment System

Depending on the configuration above the following exhaust temperature sensor will be utilized and customers must install all appropriate temperature sensors, see table below;

Aftertreatment Configuration	C3.6L >56kW DOC, DPF, SCR	C3.6L <56kW / 74.4 – 82kW DOC, DPF
Full EMAT	Triple Probe Sensor	Dual Probe Sensor
Partial EMAT	Dual Probe Sensor + Single Probe Sensor	N/A
Full Remote	Dual Probe Sensor + Single Probe Sensor **OR** Triple Probe Sensor	Dual Probe Sensor

Table 7.4

*Dual & Single or Triple Probe sensor selection will depend upon the installation of the aftertreatment cans in the machine. If the DOC/DPF and SCR are positioned close enough together, the triple probe sensor can be used. If they are not in close promitiy though, the Dual & Single Probe sensors will need to be used.
There is one standard cable length between senor probe and electrical control module, length 1270 mm.

7.3.2 Exhaust Gas Temperature Sensor Configuration

No configuration via Caterpillar Electronic Technician (CAT ET) service tool is required for these three exhaust gas temperature sensors.

7.3.3 Exhaust Gas Temperature Sensor Installation

The physical installation requirements to install exhaust temperature sensor probes can be understood by reviewing the associated Mechanical Application & Installation manual.
Care must be taken when connecting the exhaust gas temperature sensors to ensure that the associated electrical wiring is routed back to the correct engine ECU pin allocated on the J1 & J2 connector.
The exhaust gas temperature sensor must adhere to the following installation criteria;

- The cable for each sensor must not be bent <90°
- The bend radius of the cable must not be < 20 mm at the point where the cable exits the rear of the sensor,
- The bend radius of the flexible cable must not be < 10 mm
- The connector on the sensor must be placed is such a position, that water intrusion is kept to a minimum.
- First fixing point of sensor cable should be between 150 – 250 mm from the sensor nut
- Second fixing point of sensor cable should be between 150 – 250 mm before the sensor connector
- Prevent risk of friction and abrasion damage on cable at all times.

7.3.4 Exhaust Gas Temperature Sensor wiring schematic

Please refer to the separate electrical schematics referenced in Section 2.3.5

7.4 Delta P Pressure Sensor

7.4.1 Delta P Pressure Sensor Operation

The DPF Deferential Pressure Sensor is used to measure the difference in exhaust gas pressure between the DPF inlet (before the filter) and DPF outlet (after the filter). The maximum permissible operating ambient temperature is **130DegC**.

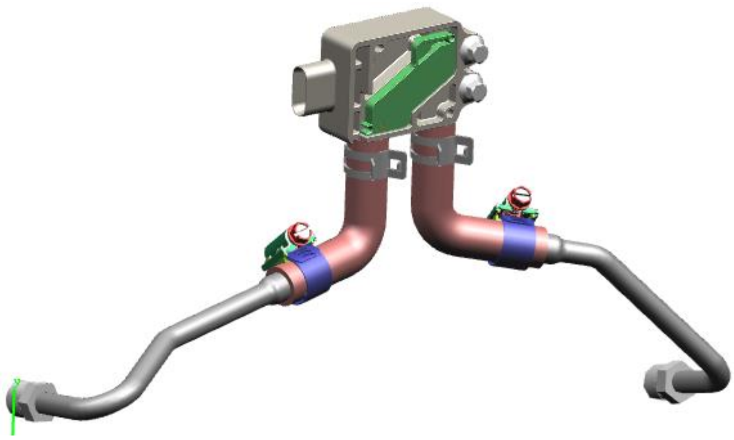


Figure 7.13

7.4.2 Delta P Pressure Sensor Configuration

No configuration via Caterpillar Electronic Technician (CAT ET) service tool is required for the Delta P Pressure Sensor.

7.4.3 Delta P Pressure Sensor Installation

The sensor is installed at the factory for full and partial aftertreatment configuration.
For full remote aftertreatment configuration the sensor should be located remotely from the engine and engine exhaust system and should avoid locations susceptible to freezing during engine operation. The sensor pipe ports should point downwards and must not exceed +/-15degrees from the vertical. Use an M5 screw with a 10mm washer to attach the sensor to the mounting surface. The first wiring harness clipping position must be within 200mm of the sensor socket. When a remote after treatment is selected, a link harness is required to connect the DPF Delta P sensor to the On-Engine connector.

7.4.4 Delta P Pressure Sensor Schematic

For Full EMAT and Partial Remote aftertreatment, the DPF Delta P sensor is connected through the 47 pin Engine interface connector, as shown in the schematic documents referenced in Section 2.3.5
For Full remote aftertreatment configuration, an additional link harness is required to connect the DPF Delta P sensor to the On-Engine connector. Please refer to the separate electrical schematics referenced in Section 2.3.5

7.5 DEF Injector Unit

7.5.1 DEF Injector Unit Operation

The DEF injector is used to control the dosing volume of DEF into the engine exhaust system. The activation of the DEF injector is controlled directly by the engine ECU and DEF is supplied to the DEF injector unit by the DEF pump supply module. The DEF Injector Unit is kept cool by the engine coolant during engine operation.

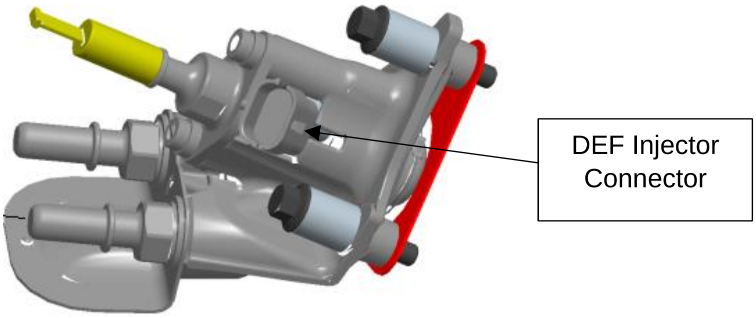


Figure 7.14 Def Injector

7.5.2 DEF Injector Unit Configuration

No configuration via Caterpillar Electronic Technician (CAT ET) service tool is required for this component.

7.5.3 DEF Injector Unit Installation

The DEF Injector unit is supplied from the factory installed in the aftertreatment mixer tube. It is the customer's responsibility to provide electrical connection to the 2-way electrical connector.
The DEF injector must adhere to the following installation criteria;

- First fixing point of customer harness should be between 150 – 250 mm from the harness connector.
- The bend radius of the customer harness must not be < 20 mm at the point where the cable exits the rear of the electrical connector.
- Prevent risk of friction and abrasion damage on cables at all times.
- Maximum ambient temperature limit at electrical connector 140°C.
- Painting of the DEF injector unit must be avoided.
- Minimum ambient temperature (in use) limits -30°C.
- Minimum ambient temperature (Not in Use) limits -40°C.
- DEF inlet temperature limit >-5°C to <110°C, over 80°C the system must be assessed by the Caterpillar application engineer.
- DEF Injector nozzle tip temperature limit >-5°C to <120°C.

It is recommended the use of a silicon capillary barrier in the customer electrical harness. Due to the low viscosity of DEF, the DEF could creep through the component electrical connector into the electrical wiring. This could cause a short circuit and malfunction in the aftertreatment system. To counter this issue it is recommended to use a silicon capillary barrier in the customer electrical harness.

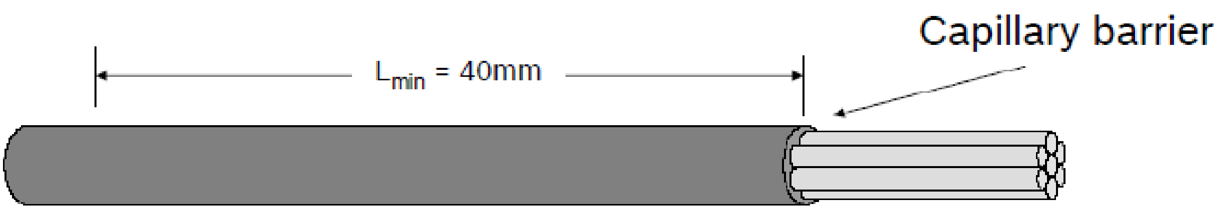


Figure 7.15 Capillary barrier recommendation

7.5.4 DEF Injector Unit Installation Wiring Schematic

Please refer to the separate electrical schematics referenced in Section 2.3.5

7.6 DEF Pump Supply Module

7.6.1 DEF Pump Supply Module Operation

The DEF pump supply module main function is to pump DEF from the DEF tanks, to the DEF injector unit, and return DEF Fluid back into the DEF tank.
The DEF pump supply module also has the following functions;

1. Provide stable DEF system pressure.
2. Provide filtration of the DEF before the DEF fluid injector unit.
3. Purges the DEF lines before the engine shuts down.

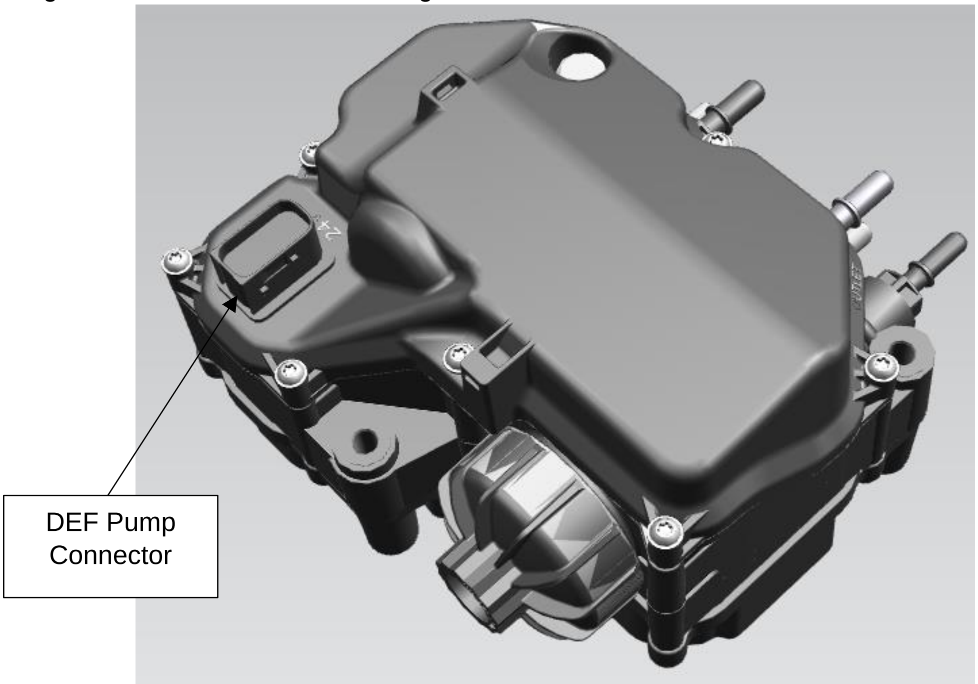


Figure 7.16 DEF Pump

Figure 7.17 DEF Pump 12-way Connector – note that pins 1 and 7 are not used and so not present

7.6.2 DEF Pump Supply Module Configuration

No configuration via Caterpillar Electronic Technician (CAT ET) service tool is required for this component.

7.6.3 DEF Pump Supply Module Installation

This component is shipped loose with this engine and it is the customer's responsibility to mount the DEF pump supply module to the aftertreatment system. The physical installation requirements for mounting a DEF pump supply module can be understood by reviewing the DEF system supplement manual.

- All electrical wiring must be fixed every 200 mm.
- The wiring harness must be strained relieved <150 mm from the electrical connector.

Installation Criteria	Specified Limits
Ambient Temperature Limit	-40°C – 70°C
Nominal Ambient Temperature Limit	25°C
Painting of DEF Pump Supply Module	Must be avoided

Table 7.5

7.6.4 DEF Pump Supply Module wiring schematic

Please refer to the separate electrical schematics referenced in Section 2.3.5
Please note that there are specific wiring gauge and length requirements for the DEF Pump Supply Module to ensure that there is no voltage drop for some components. This is important to ensure proper diagnostic capability for these components. Details regarding this can be found in the schematic document referenced above.

7.7 DEF Heated Lines

7.7.1 DEF Heated Lines Operation

The DEF heated lines are required to prevent DEF from freezing within the supply, return and pressure lines. The DEF heated lines layout consists of 3 electrically DEF heated lines;

1. One DEF heated line transferring pressurized DEF from the DEF Pump Supply Module to the DEF Injector Unit (Pressure Line).
2. Second DEF heated line from the DEF Pump Supply Module to the DEF Tank (Return Line).
3. Third DEF heated line coming from the DEF tank to the DEF Pump Supply Module (Suction Line)

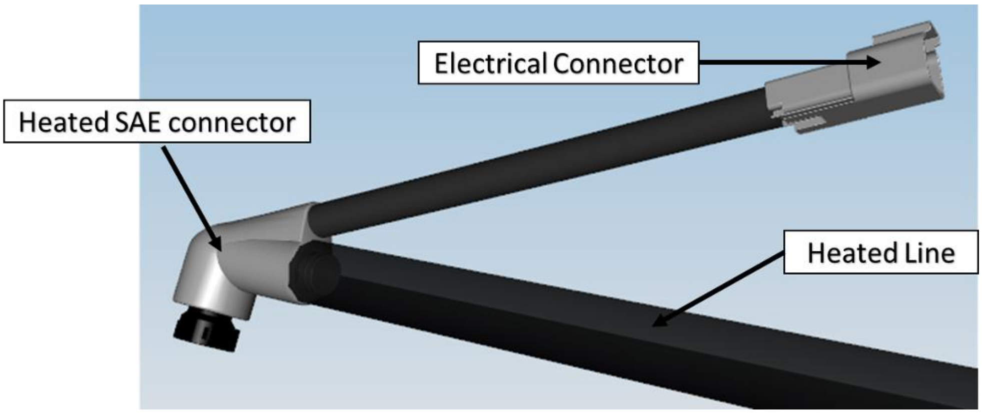


Table 7.6

7.7.2 DEF Heated Lines Configuration

No configuration via Caterpillar Electronic Technician (CAT ET) service tool is required for this component.

7.7.3 DEF Heated Lines Installation

All three DEF heated lines are shipped loose with the engine and it is the customer's responsibility to mount the DEF Heated Lines within their machine design. The physical installation requirements for mounting the DEF Heated Lines can be understood by reviewing the DEF system supplement manual.
Caterpillar has provided various lengths to accommodate the position of the DEF system equipment within customer machine designs. Listed in the table below are the available lengths.

Line Lengths (mm)	Type	Wedge Lock
1000	Suction Line	Key A
1500	Suction Line	Key A
2000	Suction Line	Key A
1000	Return Line	Key B
1500	Return Line	Key B
2000	Return Line	Key B
1500	Pressure Line	Key C
2000	Pressure Line	Key C
2500	Pressure Line	Key C
3000	Pressure Line	Key C

Table 7.7

The DEF Heated Lines specified in the table above have the following characteristics;

- Each DEF Heated line comes supplied with a two-way electrical socket connector pre-wired to the element around the DEF heated line.
- All electrical connectors on the DEF Heated Lines are keyed, refer to the table above.
- Electrical connector is attached to a 200-mm electrical harness length.

The cable and electrical connector are supplied cable tied to the DEF Heated Line. It is recommended that the cable and connector remain cable tied to the DEF Heated Line when installed into the machine as the cable tie acts as a strain relief. If removed, sufficient cable support and strain relief must be provided by the customer.

7.7.4 DEF Heater Lines wiring schematic

Please refer to the separate electrical schematics referenced in Section 2.3.5

7.8 DEF Tank and Header Unit

7.8.1 DEF Tank and Header Unit Operation

The DEF tank and header unit is used to provide a means of storing DEF on a machine, thawing the DEF within the DEF tank is done by diverting the engine coolant flow through the tank.
The DEF Tank Header Unit has the following components internal to the tank unit;

1. DEF Level Sensor
    - The DEF level sensor measures the volume of DEF in the DEF tank.
2. DEF Temperature Sensor
    - This sensor is used to control the flow of coolant from the engine via the engine coolant diverter valve.
3. DEF Quality Sensor
    - The quality sensor provides the engine ECU with confirmation that the correct concentration of DEF is present in the tank. If the tank is filled with a different fluid the engine ECU will raise a fault.

The Figure below shows some the available DEF tank option used by the C3.6L Stage V engine.

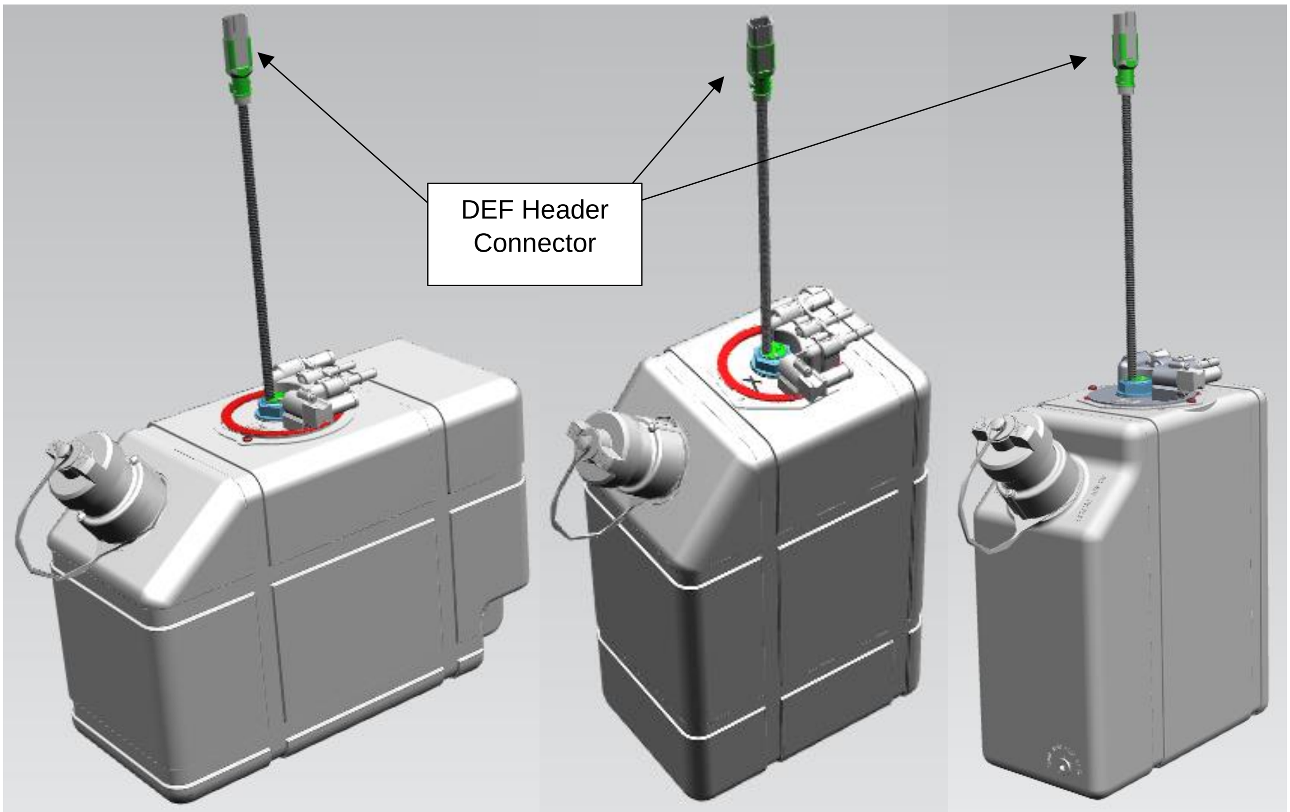


Figure 7.18 19L & 11.5L DEF Tanks

7.8.2 DEF Tank and Header Unit Configuration

Depending on the DEF tank option some configuration via Caterpillar Electronic Technician (CAT ET) service tool is required for this component.

Configuration field Name	Configurable Options	Default Configuration
Aftertreatment #1 DEF Tank Configuration	19 Liter Landscape 19 Liter Portrait 11.5 Liter Portrait	Set from factory based on option selection

Table 7.8

7.8.3 DEF Tank and Header Unit Installation

The DEF tank is shipped loose with the engine and it is the customer's responsibility to mount the DEF Tank Unit within their machine design. The physical installation requirements for mounting the DEF Tank can be understood by reviewing the DEF system supplement manual.
In addition to the requirement above the component above must adhere to the following installation criteria.

- The wiring harness must be strained relieved < 150 mm to the electrical connector.
- All electrical wiring harness must be fixed every 200 mm.

7.8.4 DEF Tank and Header Unit wiring schematic

Please refer to the separate electrical schematics referenced in Section 2.3.5

7.9 Engine Coolant Diverter Valve

7.9.1 Engine Coolant Diverter Valve Operation

The engine coolant diverter valve is provided by Caterpillar to enable the control of engine coolant out of the engine block to the thaw element within the DEF tank.
The coolant valve is a normally closed valve controlled by the engine ECU and connection is made using a 4-way electrical connector.

7.9.2 Engine Coolant Diverter Valve Configuration

No configuration via Caterpillar Electronic Technician (CAT ET) service tool is required for this component.

7.9.3 Engine Coolant Diverter Valve Installation

The engine coolant diverter valve is supplied as a loose part and it is the customer's responsibility to mount this component within their machine design. The physical installation requirements for mounting an engine coolant diverter valve can be understood by reviewing the DEF system supplement manual.
In addition, the engine coolant diverter valve must adhere to the following installation criteria.

- The wiring harness must be strained relieved < 150 mm to the electrical connector, and attached to the same surface as the engine coolant diverter valve.
- All electrical wiring harness must be fixed every 200 mm.
- Ambient operation temperature limits -40°C to 70°C.
- Coolant operation temperature limits -40°C to 120°C.

7.9.4 Engine Coolant Diverter Valve wiring schematic

Please refer to the separate electrical schematics referenced in Section 2.3.5

7.10 SCR Main Relay

7.10.1 SCR Main Relay Operation

The main fused battery supply connection to the DEF pump and engine coolant divider valve is controlled by the SCR main relay. The operation of the relay coil is controlled by the engine ECU.

7.10.2 SCR Main Relay wiring schematic

Please refer to the separate electrical schematics referenced in Section 2.3.5

7.10.3 SCR Main Relay Specification

The selected relay must be capable of a continuous current of 30A and a pulse current of 110A for 20us.
The ECM is capable of driving the coil side of the relay with up to 0.4A

7.11 DEF Reversing Valve Relay

7.11.1 DEF Reversing Valve Relay Operation

The DEF Reversing Valve relay is operated during the purge of the DEF System. The reverting valve come on during the power down sequence that happens when the engine is key off, to purge the DEF from the DEF lines, DEF Injector and pump to remove the failure mode of DEF freezing in these parts when the engine is shut down and therefore damaging the DEF parts.

7.11.2 DEF Reversing Valve Relay Specification

The selected relay must be capable of a continuous current of 10A.

Component	Max Current Draw
DEF Reversing Valve 12V	6A
DEF Reversing Valve 24V	3A

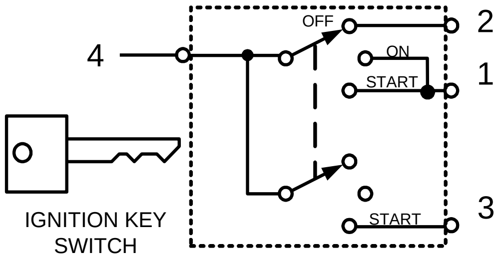
Table 7.9 - DEF Reversing Valve relay specification

The ECM is capable of driving the coil side of the relay with up to 3A

8.0 Starting and Stopping the Engine

8.1 Starting the Engine

Unlike mechanically controlled fuel systems no customer connection to the fuel pump solenoid is necessary. To activate the engine ECU switched battery voltage needs to be constantly supplied to pin J1-5 and J1-6. When the ECU is active the engine crankshaft needs to be rotated above a minimum cranking speed, a typical cranking speed is 180rpm (this will differ dependent on the application). Once the ECU has determined engine cranking speed and engine position, fuel pressure and delivery will be controlled. The engine must achieve at least 100rpm during cranking to enable fuel injection.
The most popular way to control engine starting is by a specifically designed 3 position key switch. The key switch controls battery voltage to the key switch input and the starter motor circuit.



POSITION	TERMINALS
POSITION 1 - OFF	2 & 4
POSITION 2 - RUN	1 & 4
POSITION 3 - START	1, 3 & 4

Figure 8.1

Automatic Starting – Some applications need to be started automatically. There is no automatic start feature available on this product. If an automatic start sequence is required the following points must be considered:

- Start Aid - Wait to Start Control
- Starter Cranking Duration
- Starter Abutment Detection
- Number of Start Attempts
- Starter Disengagement Speed
- Warm Up Period
- Cool Down Period
- DEF system purge cycle
- ECU power down sequence

The ECU software considers the engine running when the engine speed is 100rpm below the desired engine speed or has reached 1400rpm, at this point after a predetermined period of time the engine will switch from cranking fuel maps to running fuel maps. It is important to note that starter motors must be disengaged earlier to prevent the starter motor being driven by the engine. The engine is considered stalled when the engine has dropped below 300rpm.
For more information regarding the correct specification and installation of a starting and charging system please refer to the Starting and Charging System A&I Manual.

8.1.1 Starter Motor Control

8.1.1.1 ECU controlled Starter Motor Feature

This feature will be enable the configuration of the following starter motor conditions; activation input type, Crank terminate speed, maximum cranking time and maximum cranking cool down time.
The starter motor feature will help to prevent the following scenarios:

- **Starter Overrun**
  The starter relay will be turned off when the maximum crank speed is exceeded for a continuous period of >0.5 seconds.
  The maximum crank speed is configurable via the electronic service tool.
  The debounce time period will be hardcoded in the engine software.
- **Rapid re-engagement delay**
  The starter relay shall be turned Off, it shall remain off for a duration of 4 seconds (rest interval). After the rest interval of 4 second the starter relay can be turned On again.

The rest interval is configurable via the electronic service tool

- **Starter Overheat Protection**
  After 30 seconds of continuous cranking the operator shall be notified by a level 2 diagnostic code and the starter relay shall be disengaged to cool down.
  The minimum cool down interval between starts is set to 120 seconds
  To override the cool down period the customer can key cycle the engine ECU and continue to start the engine.
  To override the cool down period the customer can hold down the start request for 5 seconds and the start relay will be activated.
- **Click No crank (tooth abutment)**
  If no engine speed is measured within 2 seconds of a start command, The starter relay will disengage. After a rest interval of 2 seconds the starter relay can be turned On again.
- **Engage into a running engine**
  When measured engine speed is greater than zero the starter relay must not be transitioning from Off to ON. When engine speed is measured at < 0 rpm the starter relay may be engaged.

8.1.1.2 Starter Motor Control Operation

The engine ECU may be configured to control and interlock the engine starter motor operation. When configured in the engine software a relay may be connected to the engine ECU to interrupt the electrical supply to the engine starter motor solenoid (T50). The engine ECU will monitor specific inputs to determine when to engage or disengage the starter motor.

8.1.1.3 Starter Motor Control Configuration

If the engine ECM is to control any part of the starter motor relay, then the Starter Motor Control feature must be enabled within the engine ECM using Caterpillar Electronic Technician service tool (CAT ET). You can access this feature in the configuration screen of CAT ET. ECM control is set as default, shown as “Electrical”, if the machine control or wiring is to control the starter relay, then this setting must be changed.

Configuration Field Name	Configurable Options	Default Configuration
Starting System Type	Electrical Not Installed	Not Installed

Table 8.1

If the engine ECM is to control the starter motor then the ECM must be configured to be setup to the correct input type to the ECM for the cranking control, either hardwired switch input or J1939 message, sections **Error! Reference source not found.** and **Error! Reference source not found.** respectively. Table shows the input configuration set in the engine ECM accessed by CAT ET.

Configuration Field Name	Configurable Options	Default Configuration
Engine Starter Control Input Configuration	Hardwired Input CAN Input	Hardwired Input

Table 8.2

8.1.1.4 Starter Motor Hardwired Control Installation

When the engine ECU is switched On the software will monitor input J1-4. When battery voltage is detected on input J1-4 the relay connected to outputs J1-25 and J1-3 will be switched On. The relay will not be switched On if the engine speed is greater than 0 rpm or if there are engine stop/shutdown requests.
The engine ECU will switch Off the outputs controlling the relay once the engine speed reaches a specific threshold based on engine temperature. The maximum period that the relay will be switched On is 30 seconds. The relay will be switched Off immediately if a shutdown request is received, or if the battery voltage is removed from input J1-4.

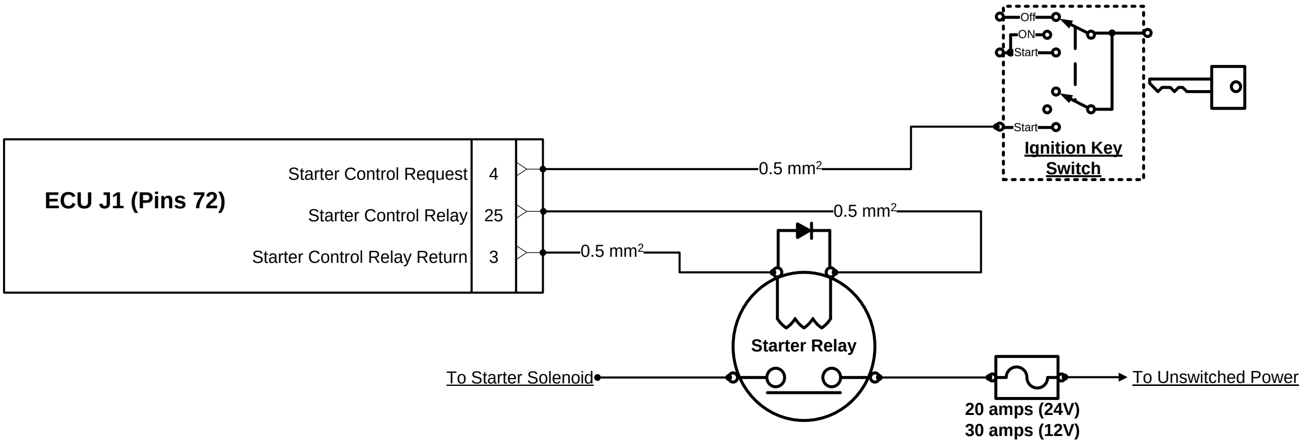


Figure 8.2 Hardwired Starter Motor Schematic

8.1.1.5 Starter Motor J1939 Control Installation

When the engine ECU is switched On the software will monitor the J1939 Network for the Start Request message (SPN7745). When the Start Request Message is detected on the J1939 Network, the ECU will wait for the Start Consent message (SPN7746). When the both messages are active the relay connected to outputs J1-25 and J1-3 will be switched On. The relay will not be switched On if the engine speed is greater than 0 rpm or if there are engine stop/shutdown requests (SPN 970).

The engine ECU will switch Off the outputs controlling the relay once the engine speed reaches a specific threshold based on engine temperature. The maximum period that the relay will be switched On is 30 seconds. The relay will be switched Off immediately if a shutdown request is received (Hardwired or J1939), or if a Start Abort Request message (SPN 7747) is received.

The Engine ECU will not switch Off the outputs controlling the relay after the Start Consent and the Start Request messages are received. This is to avoid the stop of cranking when the J1939 message is lost.

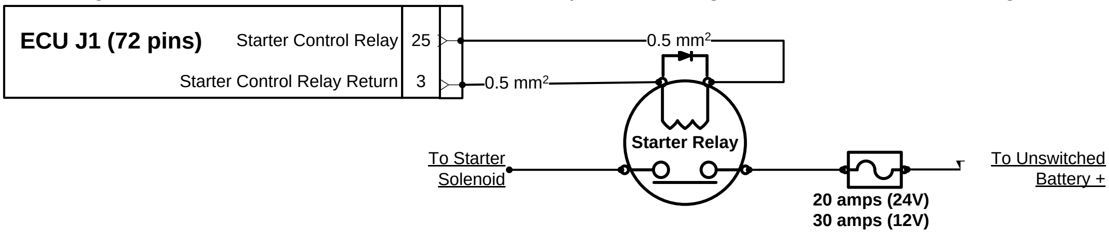


Figure 8.3 J1939 Starter Motor Schematic

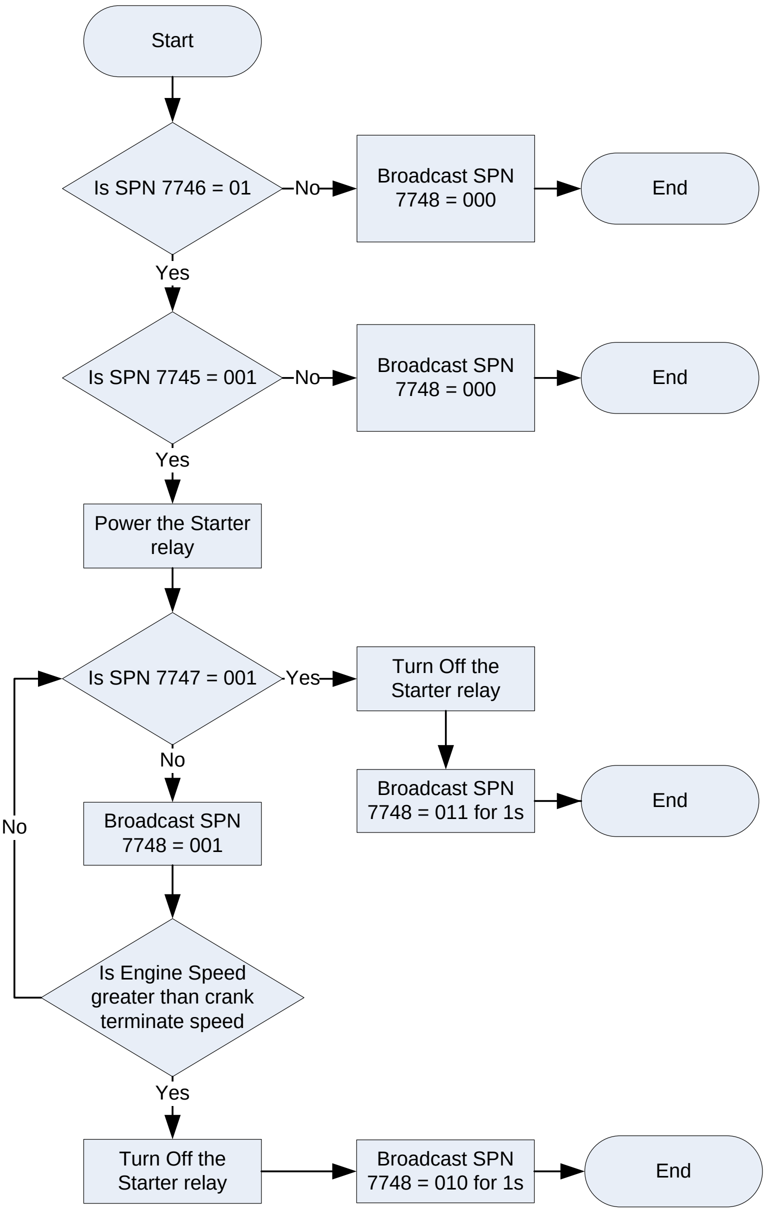


Figure 8.4 J1939 Start Logic

8.1.1.6 Starter Motor J1939 Messages

PGN #	PGN Description	SPN #	SPN Description
61677 F0ED	Engine Start Control (ENGSC)	7745	Engine Start Request
			Bit State 00 = Start not requested Bit State 01 = Start requested, operator type
		7746	Engine Start Consent
			Bit State 000 = No consent Bit State 001 = Consent to operator requested start only
		7747	Engine Start Abort Request
			Bit State 00 = Abort not requested Bit State 01 = Abort Requested
		7748	Engine Starter 1 Feedback
			Bit State 000 = Starter not commanded Bit State 001 = Starter command latched, starter active Bit State 010 = Starter command unlatched, start completed

			Bit State 011 = Starter command unlatched, start abort command Bit State 100 = Starter command unlatched, start aborted by starter controller

Table 8.3

8.2 Stopping the Engine (and Preventing Restart)

There is often some confusion about the different methods and devices used to either stop the engine or to prevent it from starting. These devices may be divided into the following categories:

- Ignition Key switch
- Battery disconnect Switch (also known as a battery Isolation Switch)
- Remote Stop Button
- Datalink stop (J1939)

Each of these devices is described below to assist the OEM in selecting the method that is most suitable for machine and market. It remains the responsibility of the OEM to ensure compliance of the machine with any specific legislation for the territories into which it is sold.

It is recommended that the OEM perform a risk assessment such as a Failure Mode Effects Analysis (FMEA) on the application to determine the most appropriate method of stopping the engine and/or preventing it from being restarted.

Note: Only the ignition key switch and the Datalink stop should be used as primary engine shutdown methods, to prevent damage under prolonged use of secondary shutdown devices.

It should be noted that under all conditions the engine ECU will remain active i.e. electrically active post ignition key power off. This is required for a number of engine calibration activities to take place. For this reason the main ECU supply power (unswitched battery) must not be removed during normal engine stopping. Removing the ECU unswitched battery supply will cause these calibrations to be interrupted and the values measured on the previous key cycle will be used. If the engine ECU is operated for long periods without performing these calibrations, engine performance may be affected and a diagnostic code will be raised. During this period the engine ECU will also require a certain level of current from the system batteries for a short period of time. For this reason care must be taken when working on the engine post ignition key off.

8.2.1 Ignition Key switch

It is a Caterpillar requirement that all machines have a simple intuitive and accessible method of stopping the engine. This will normally be a directly wired Ignition Key switch. When the key switch is turned to the off position or when the key is removed, power **must** be removed from the ignition key switch pin J1-5 and J1-6 of the ECU J1 connector.

Activation of the key switch must only affect the power supplied to pin J1-5 and J1-6 of the engine ECU J1 connector. All un-switched battery supply connections must remain connected via the engine ECU relay for a minimum of ~120 seconds.

8.2.2 Battery Disconnect Switches (also known Battery Isolation Switches)

Battery disconnect switches are usually fitted near the battery or the engine compartment of a machine. On some machines there may be a small number of low current devices which are not switched off by this device e.g. clocks or anti-theft tracking devices.

The function of a battery disconnect switch is as follows:

- Prevent battery discharge during vehicle shipping or storage
- Prevent service technician from danger caused by in advertent engine crank or start. To offer good protection of service personnel it is possible to provide a switch which can be locked in the open position (e.g. with a padlock) and the key removed and given to the service engineer who is working on the dangerous components.

The battery isolation switch is not a suitable method for stopping an engine, as it is not guaranteed to stop the engine as the ECU may continue to operate with power generated by the alternator.

It is also possible that opening the battery disconnect switch when the engine is running will cause an “alternator load dump”. This is a kind of electrical transient that can cause damage to electronic components on the engine and machine.

Caterpillar recommends the battery disconnect switch is fitted in the negative path, as close as possible to the battery.

8.2.3 User Defined Shutdown (Remote Shutdown)

8.2.3.1 User defined Shutdown Switch Operation

Remote stop is intended to provide a convenient method of stopping the engine. It is not designed to be fail safe and so should not be used to assure the protection of either personnel or equipment.
Remote stop buttons may be used on large machines, which can be operated from ground level and where the operator wants to stop the machine without climbing into the cab.
There are a number of variations on remote stop button circuits. The engine uses a single normally open contact, which must be closed to stop the engine.
The remote stop button will function as follows:

- When the switched is closed then the engine will stop. The ECU will remain ON, so it will continue to communicate over J1939 and with the service tool. Note however that it will continue to draw power from the battery so if it is left in this state it will eventually result in a flat battery.
- The engine may be restarted by opening the switch and activating the starter motor, no Key cycle is required.
- The red “mushroom” emergency stop buttons must not be used for remote stop functions as they may be mistaken for emergency stop buttons.

Please be aware that if this feature is installed with a Hardwired switch the engine may shut down if the switch malfunctions or if the ECM pin is accidently grounded through some other means.

8.2.3.2 User Defined Shutdown Switch Configuration

The user defined shutdown feature must be enabled within the engine ECU using Caterpillar Electronic Technician service tool (CAT ET).

Configuration field Name	Configurable Options	Default Configuration
User Defined Shutdown Enable Status	Disabled Enabled	Disabled

Table 8.4

8.2.3.3 User Defined Shutdown Switch Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5

8.2.3.4 Datalink stops

As with the remote shutdown stop button, the Datalink stop is not fail safe option and does not meet the requirements of emergency stop legislation, so should not be relied on to assure the safety of machine operators or other personnel.
Datalink stops may be used in the following circumstances;

- Immobilisers.
- Machine protection strategies.
- Automatic machine features (e.g. idle shutdown timer).
- Stopping machines by radio control or other telemetry devices.
- Geo-fencing is a particular application, where a machine will not operate outside defined map coordinates.

It is recommended that if such features are implemented, then they are clearly documented and communicated to the final users and owners of the machine. If this is not done then there may be complaints that the engine is stopping unexpectedly.

8.2.3.5 Datalink Stops Message

PGN #	PGN Description	SPN #	SPN Description
61441	Electronic Brake Controller 1 (EBC1)	970	Engine Auxiliary Shutdown Switch
			Bit State 00 = Off (Injection Enabled) Bit State 01 = ON (Injection Disabled)

Table 8.5

8.2.4 Engine Emergency Stops

It is the customer responsibility to complete a risk assessment on their product when considering the use and function of an emergency stop device. If residual risks remain on the product that the customer wants to mitigate by use of an emergency stop function, the following methods of emergency stopping the engine may be considered. The most appropriate method of emergency stop will depend on the application and appropriate regulations. Using a combination of the methods below may provide a more robust emergency stop solution. Using the emergency stop in situations other than an emergency could result in engine damage. In the event of an injector failure, cutting electrical power on electronic common rail engines may not stop the engine. For detailed information on how to implement the following methods of emergency stop, consult your application lead.

Cut electrical power to engine – Unswitched positive - Power should be isolated between the battery positive terminal and the battery positive pins on the engine ECU.

Cut electrical power to engine – Un-switched positive and negative - A double pole/double throw switch should be placed in a position on machine that will ensure main negative power and main positive power are disconnected upon switch activation isolating battery terminals from the ECU.

Cut air supply to engine - Slicer valve placed after the turbocharger compressor.

8.2.5 Common problems with the application of stop devices

It is possible, although extremely rare, that diesel engines continue to run even if all electrical power is removed. This can happen when high quantities of oil vapour or other inflammable gases are present in the air into the engine. The only way to prevent this is to provide an air inlet shut-off valve (slicer valve). It is not common practice to fit such devices to all engines, but they should be considered where there is a risk of flammable gases (e.g. in petroleum applications), or where the application demands high engine grade ability (slopes).

Some hazards are present when the engine is being cranked by the starter motor, as well as when it is running. For example, components will still rotate, hydraulic pressure will still be present, and fuel may still be pump to high pressures.

If an emergency stop button is pressed, to cut power to ECU and ignition, but is released while the engine is still turning, it is possible for the engine to continue to run.

8.2.6 Engine Idle Shutdown

8.2.6.1 Engine Idle Shutdown Operation

This feature allows the user to configure the engine to shutdown (disable Injection) after a set period of time. The engine speed and engine ECU input (J2-87) / SPN 7579 status will be monitored. The engine shutdown timer will start accumulating when the engine is at low idle and switch input J2-87 is closed / SPN 7579 is set to 01. If the engine shutdown timer exceeds the low idle delay time configured in the engine software, the engine will shut down.

- When the engine is about to be shut down the following event will be broadcasted by the engine software;
  - 594-31 – Engine idle shutdown driver alert mode.
- When the engine has shut down the following event will be broadcasted by the engine software;
  - 593-31 – Engine idle shutdown has shutdown engine.

The timer will reset if the switch input is opened or if the key switch is cycled. It is recommended that where possible this feature is used to prevent extended periods at low idle.

Note: The Thermal management strategy will always have the priority over the Low Idle Shutdown. The Low Idle Shutdown timer will be stopped during the Thermal Management strategy.

8.2.6.2 Engine Idle Shutdown Configuration

The engine idle shutdown feature must be enabled within the engine ECU using Caterpillar Electronic Technician service tool (CAT ET). You can access this feature in the configuration screen of Caterpillar ET.

Configuration field names	Configuration Options	Default Configuration
Engine Idle Shutdown Enable Status	Enabled Disabled	Disabled

Engine Idle Shutdown Delay Time	1 – 1440 minutes	5 minutes
Engine Idle Shutdown Ambient Temperature Override enable status	Enabled Disabled	Disabled
Engine Idle Shutdown Minimum Ambient Air Temperature	-40 – 99°C	0°C
Engine Idle Shutdown Maximum Ambient Air Temperature	-39°C – 100°C	100°C

Table 8.6

8.2.6.3 Engine Idle Shutdown Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5 to wire a physical switch.
It is also possible to allow the Low Idle Shutdown feature by sending a J1939 message to the ECM which gives permission for the ECM to shut the engine down, once the conditions in the table above have been met. This J1939 message is the same one as used for the Engine Elevated Idle feature described in Section 13.1.6.4

8.3 Telematics – C3.6EA Only

8.3.1 Description

To meet China NR4 regulations we need to support Telematics required data in datalink per the standard J1939 protocol. Refer to the below table for the list of J1939 telematics Parameters list support for telematics. As per the regulations we are required to support DM12 message for NCD/PCD Control diagnostic. This info will be parsed and packaged by the telematics device as needed by the China IV regulation and then send to back office.

- Diagnostic protocol
- Alarm light status
- Total number of fault codes
- Fault code information list

Also, there is a requirement for the machine to support telematics disconnection detection for China NR IV. The machine will need to communicate with the telematics device and transmit a fault when the connection is lost.

Up to 7 days of telematics data needs to be stored by the machine in the event that data cannot be transmitted to the back office. The equipment manufacturer is responsible to ensure telematics requirements are met. Diagnostics required to detect missing telematics module;

Function	PGN	SPN / Byte	Length	Range
Barometric Pressure	FEF5	108 / 1	1 byte	0-125kPa
Actual Engine - Percent Torque	F004	513 / 3	1 byte	-125-125%
Norminal Friction - Percent Torque	FEDF	514 / 1	1 byte	-125-125%
Engine Speed	F004	190 / 4-5	2 bytes	0-8031rpm
Engine Fuel Rate	FEF2	183 / 1-2	2 bytes	0-3212l/h
Engine Intake Air Mass Flow Rate	F00A	‘132 / 3-4	2 bytes	0-3212 kg/h
Aftertreatment 1 Diesel Particulate Filter Differential Pressure	FDB2	3251 / 5-6	3 bytes	0 - 6425.5 kPa
Engine Coolant Temperature	FEEE	110 / 1	1 byte	-40 – 210DegC
Engine Exhaust Gas Recirculation 1 Valve Position	FD94	27 / 1-2	2 bytes	0 – 160.637%
Engine Exhaust Gas Recirculation 1 Valve 1 Control	FDD5	2791 / 5-6	2 bytes	0 – 160.637%
Engine Reference Torque	FEE3	544/20-21	2 bytes	0 – 3212.75Nm

9.0 Engine Speed Demand

It is necessary to select a device that converts the speed requirements of the engine operator or controller to an electrical signal recognized by the engine ECU. There are eight types of speed demand inputs available on the C3.6 engine;

- Analogue Throttle speed control 1
- Analogue Throttle speed control 2
- PWM Throttle Speed control 1
- PWM Throttle Speed control 2
- PTO Mode
- Multi-Position Switch (MPTS)
- Torque Speed Control (TSC1) – Temporary Powertrain Control purpose
- Torque Speed Control (TSC1) – Accelerator Pedal Control purpose

The speed demand type must be carefully considered and appropriate for the application.
There are two dedicated software input channels that can be configured to accept specific types of speed demand inputs. The valid combinations and throttle logic are given in the following diagram. PTO mode can be used with Analogue combinations; it cannot be used with multi position switch. The J1939 TSC1 parameter will override any speed demand input when broadcast. Droop is applied to the requested desired engine speed only when All Speed governing is selected.

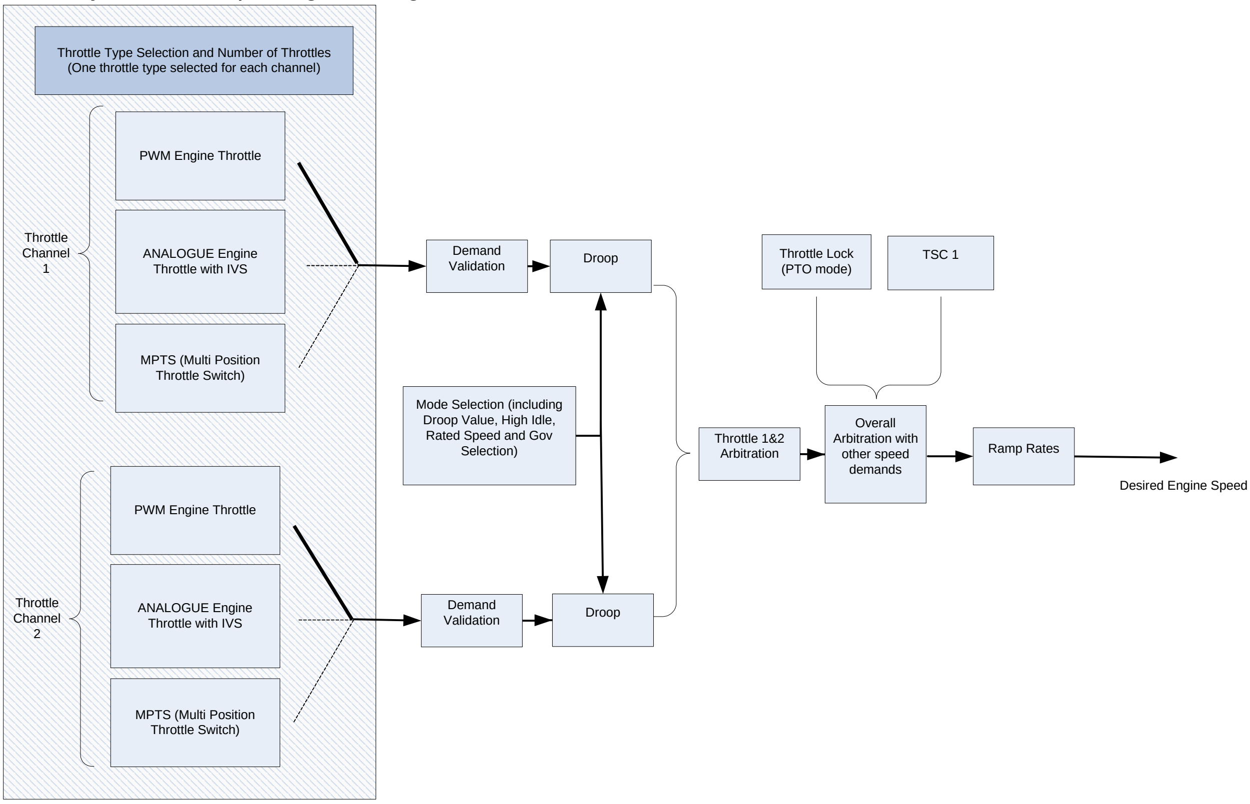
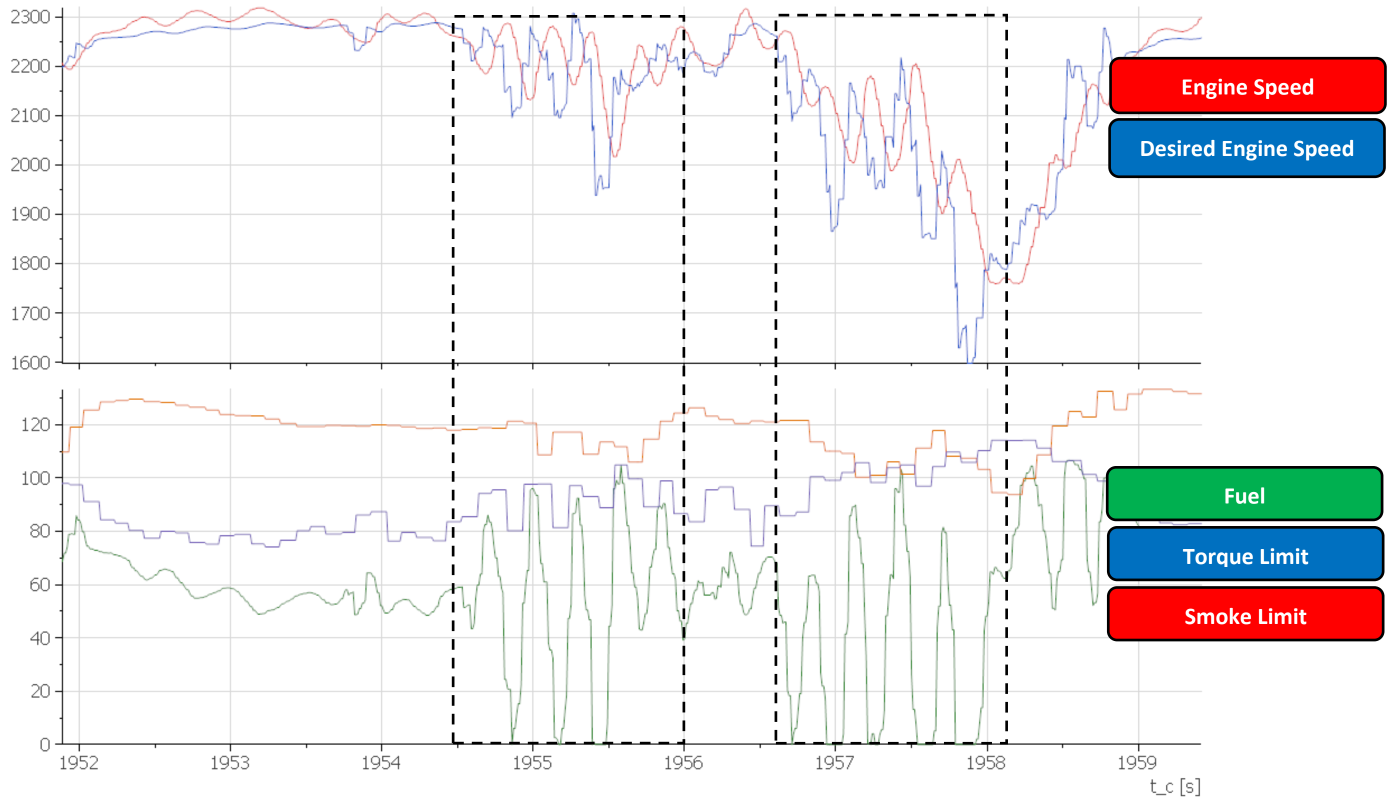


Figure 9.1

For machines with TSC1, Analogue or PWM throttle types, unstable machine throttle input / fast transient response for demanded speed can result in an erratic fuelling command, which can cause aftertreatment regen to abort by restricting the use of engine thermal management mode.
The graphs below show how abrupt changes to the desired engine speed may affect engine fuelling.



A way to address the 'noisy' desired engine speed signal is to apply a low pass filter to the machine desired speed demand. Depending on the throttle type this can be achieved either by filtering the desired speed in the machine controller or by damping the actual throttle. After filtering, some oscillations might still remain which can be further improved by tuning the fuel governor gains.

9.1 Analogue Throttle Sensor

9.1.1 Analogue Throttle Sensor Operation

Two inputs are available for Analogue throttle devices, which may be pedal, lever or cable operated. The Analogue sensor gives a DC Analog output in the range 0.6 to 4.0 volts, when connected to the engine ECU. The Analogue throttle sensor should use non-contact Hall Effect technology. Robust potentiometer contact sensors designed for use in vehicles may be considered, **and under no circumstances should ordinary carbon track or wire wound potentiometers be used, as they will not be reliable.**

For all mobile applications, and those where a rapid change in engine speed could cause a hazard, an idle validation switch is required. The idle validation switch closes to ground when the sensor is in the minimum position.

Off idle switches and kick down switches are not monitored by the engine ECU.

This Analogue input must only be used to control engine speed from a direct operator input and is not suitable as the mechanism for speed control by another electronic controller.
There is no special requirement for a relationship between angular movement of the pedal and output voltage.
This document does not measure component acceptability in terms of:

- Temperature
- Vibration
- Electromagnetic Compatibility
- Design Life
- Supply voltage requirements (min, max, stability)
- Legal Compliance

It the responsibility of the OEM and the throttle device manufacturer to ensure that the component is suitable for the application in which it is to be used.

9.1.2 Analogue Throttle Sensor Configuration

Before an analogue throttle can be used the configurable parameters must be programmed into the ECU via the service tool. These parameters are selectable in the main throttle configuration screen.

9.1.3 Evaluating Component Compatibility (Testing)

Before using an analogue throttle on the C3.6 it is the responsibility of the OEM to check the throttle is compatible. If the results of the voltage outputs from the sensor are not in the ranges specified in the table below, then the device will not be compatible with the default settings in the ECU. You can contact your Caterpillar Application Engineering Department to determine whether it will be possible to configure the input of the throttle to be compatible with the engine ECU.

Test	Parameter	Unit	Min	Nominal	Max
1	Output at min position	Volts	0.45	0.6	0.7
2	Output at min position: forced	Volts	0.4	0.6	-
3	Output at max position	Volts	3.8	4.0	-
4	Output at max position: forced	Volts	-	4.0	4.5
5	IVS switch closed voltage	Volts	-	-	1.2
6	IVS switch open voltage	Volts	4	10	24
7	IVS target switch point against analogue throttle input	Volts	1.08	1.15	1.22
8	Potentiometer Track Resistance	K Ohms	1	2.5	3

Table 9.1

9.1.4 Idle Validation Switch Compatibility Test

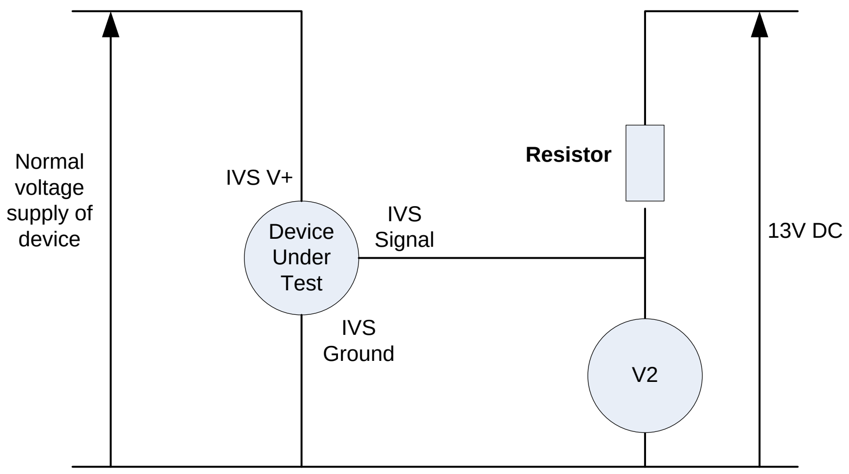


Figure 9.2

Resistor value should be **3k4** for the A6E11 IVS Input #1 pin and **3k6** for the A6E11 IVS Input #2 pin.

The above test circuit replicates the internal circuit of the ECU to allow the bench testing of the IVS on an analogue throttle.

9.1.5 Analogue Throttle Sensor Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5

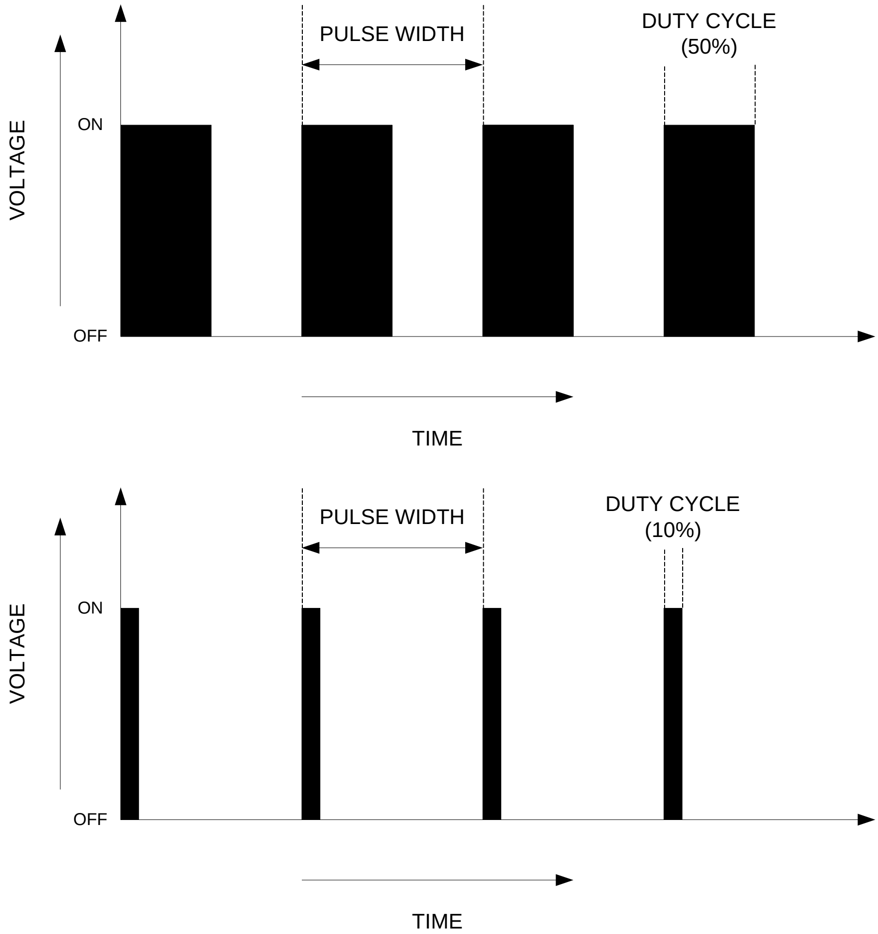
9.2 PWM Throttle Sensor

9.2.1 PWM Throttle Sensor Operation

Two inputs are available for PWM throttle devices, which may be pedal, lever or cable operated. The PWM sensor gives a Squared wave output with 5 volts amplitude and a duty cycle varying between 20% to 80%, when connected to the engine ECU. The engine ECU provides a regulated 5V 300mA power supply to support PWM Throttle sensor 1 and a second regulated 5V 100mA power supply for PWM Sensor 2.

A pulse width modulated signal is a signal whose voltage is either at a maximum or a minimum. The duration of the on time as opposed to the off time determines the strength of the outputted signal. This means that the outputted PWM signal takes the form of a square wave as shown in the figure below.

Figure 9.3 Pulse Width Modulation Waveform



The figure above shows that the square wave voltage is either fully on or fully off, the only parameter, which changes is the duration of the on time compared to the off time. The time between one pulses rising edge and the next is classed as the pulse width and the ratio within this pulse width of the ON time compared to the OFF time is defined as the duty cycle. In the case of the Caterpillar PWM drivers the larger the duty cycle the stronger the signal.

This PWM Throttle input must only be used to control engine speed from a direct operator input, and is not suitable as the mechanism for speed control by another electronic controller.

There is no special requirement for a relationship between angular movement of the pedal and output voltage.

This document does not measure component acceptability in terms of:

- Temperature
- Vibration
- Electromagnetic Compatibility
- Design Life
- Supply voltage requirements (min, max, stability)
- Legal Compliance

It is the responsibility of the OEM and the throttle device manufacturer to ensure that the component is suitable for the application in which it is to be used.

9.2.2 PWM Throttle Sensor Configuration

Before a PWM throttle can be used the configurable parameters must be programmed into the ECU via the service tool. These parameters are selectable in the main throttle configuration screen.

9.2.3 Evaluating Component Compatibility (Testing)

Before using a PWM throttle on the engine it is the responsibility of the OEM to check the throttle is compatible. If the results of the outputs from the sensor are not in the ranges specified in the table below, then the device will not be compatible with the default settings in the ECU. You can contact your Caterpillar Application Engineering Department to determine whether it will be possible to configure the input of the throttle to be compatible with the ECU.

Test	Parameter	Unit	Min	Nominal	Max
1	Output at min position	%	10	16	22
2	Output at max position: forced	%	75	82	90
3	Driver frequency	Hz	200	500	950
4	Driver Amplitude	Volts		5	

Table 9.2

Note: If a 5V powered PWM sensor cannot be sourced it is possible to use a 8-32V PWM sensor instead. Power for this sensor can be battery voltage supply from the Main Power Relay instead of the %v power supply from the ECM.

9.2.4 PWM Throttle Sensor Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5

9.3 Throttle Lock (PTO mode)

9.3.1 Throttle Lock (PTO Mode) Operation

Throttle Lock mode is also referred to as “PTO Mode”, “engine speed cruise control” or “set speed control”
Throttle Lock mode is a cost effective way to control engine speed as it only requires switched inputs.
Another benefit is that it can be used in an application where it is necessary to control the engine speed from several different points on the machine.
The disadvantage of controlling engine speed via Throttle Lock mode is that it takes some time to ramp up or down to the required speed.
To improve diagnostic detection and to make this feature safer, new logic has been introduced for C3.6 software. The following 3 pins mentioned below will be monitored and will not activate any functionality until they have seen a state change from OFF to ON.

- **PTO Mode ON/OFF**
- **PTO Set or Lower**
- **PTO Raise or Resume**

This means that if the ECU is keyed ON with one of the switches in the ON position (caused either by operator depressing the button or a Short circuit), the pin will not perform its function until the individual pin has been cycled OFF, then ON again. This effectively detects a short circuit at start-up.
The feature is operated by 5 switches / pushbutton and an optional second speed switch, which are shown in the table below.

Switch Description	ECU Pin Number	Throttle Lock Mode Configuration	
		Raise / Lower mode	Set / Resume mode
On / Off Switch	J2 - 110	Enables and disables the Throttle Lock mode function	Enables and disables the Throttle Lock mode function
Raise / Resume	J2 - 109	Raise only Function	Raises the desired engine speed and functions as a resume when set speeds are stored
Lower / Set	J1 - 67	Lower only Function	Lowers the desired engine speed and functions as a set or

			memorize current speed demand.
Disengage	J2 - 111	N/A	Disengages the current Throttle Lock mode.
Speed Toggle	J1 - 18	N/A	Allows the operator to select between two Throttle Lock mode set speeds if programmed. Switch closed is speed 1, Switch open is speed 2

Table 9.3 Throttle Lock Mode Configuration

The above table also shows that the Throttle Lock mode can be configured to operate in one of two ways and these are described below

- Ramp up / ramp down only mode. This mode uses three of the 5 available Throttle Lock functions, therefore providing a simpler Throttle Lock operation. In this mode with the On / off switch set to On the engine speed can be raised using the raised switched input. Applying a signal to this input will force the engine speed to accelerate at a rate defined by the Throttle Lock engine acceleration rate until it meets High idle. If the signal is removed at any point the engine will remain at the ACTUAL engine speed.
- Set / Resume mode. This mode provides the full Throttle Lock mode functionality and uses all 5 available functions. This is the standard Throttle Lock format.

The following sections describe the operation of each of the mode switches and configurable settings.

9.3.1.1 ON/OFF switch

When the switch input is open the PTO mode cannot be engaged, and none of the other buttons will have any effect. When the switch is turned off, any adjusted speeds will be lost.

Important note – To activate the PTO mode feature the customer must configure “Throttle Lock Feature Installation Status” to “Raise / Lower Switch”

9.3.1.2 Raise Switch

When the PTO mode is activated a momentary press of the raise switch will increment the engine speed by the configured increment value. If the button his held down the engine speed will ramp at the configured PTO ramp rate.

9.3.1.3 Lower Switch

When the PTO mode is activated a momentary press of the lower switch will decrement the engine speed by the configured decrement value. If the button his held down the engine speed will ramp down at the configured PTO ramp rate.

9.3.1.4 Resume Switch

When the PTO mode is activated pressing the resume button will set the PTO desired speed to the configured PTO engine speed setting.

9.3.1.5 Pre-set Speed (Throttle Lock Engine Set Speed #1)

The pre-set speed can be programmed via the Caterpillar Electronic Technician service tool (CAT ET). A speed may be selected such that if the resume button is pressed, then the engine speed will jump straight to this speed.

The speeds set with the Service Tool will act as the Set Speeds that the Speed Toggle switch will toggle between. The set speeds can be changed during operation though by using the Lower/Set button to memorise a new speed. The new memorised speed will replace one of the set speeds until the engine is keyed off again. In the following key cycle the pre-set Service Tool set speeds will be used again.

9.3.1.6 PTO Mode Speed Ramp Rate (Throttle Lock Increment / Decrement Speed Ramp Rate)

The ramp rate function provides the ability to configure independently the rate at which the engine speed increases (accelerate) when the raise function is selected and the speed decreases (decelerate) when the lower function is selected. These ramp rates are independent of the main throttle ramp rate configurations. The ramp rates can be programmed via Caterpillar Electronic Technician service tool (CAT ET). This function is operated when holding down the raise or lower buttons.

9.3.1.7 Disengage Switch

If the disengage switch input is opened the engine speed will not follow the memorised speed, but will return to the next highest engine speed demand i.e. another throttle. Therefore the Disengage switch should be closed if the Set/Resume functionality of the PTO Mode feature is required.

9.3.1.8 Example of PTO Mode Operation

It is recognized that the precise function of the PTO mode is difficult to understand from a written text document. The following table illustrates the operation of the PTO mode feature. In this example the pre-set speed has been set on the service tool to 1800rpm, the step size to 50 rpm and the ramp rate is set to 200 rpm/sec.

On/Off Switch	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0
Resume Switch	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0
Raise Switch	0	0	0	0	0	0	0	0	Quick Close	Hold Closed	0	0	0	0	Quick Close
Lower Switch	0	0	0	0	0	0	0	0	0	0	Quick Close	Hold Closed	0	0	Quick Close
Disengage Switch	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
Speed Select Switch	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1
Throttle Pedal Demand	1200	1200	1200	1200	1900	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
Memorised Speed	1800	1800	1800	1800	1800	1800	2200	2200	1800	1800	1800	1800	1800	1800	1800
Resulting engine speed	1200	1200	1800	1800	1900	1800	2200	1200	1850	2050	2000	1200	1800	1200	1200
Comments	PTO Mode in neutral state	PTO Mode ON	PTO jumps to memorised speed	Remuse Button released	Pedal overrides PTO (max wins)	Throttle pedal command reduced	Speed toggle switch opened	Disengage switch opened – throttle wins arbitration	Speed raised by 50 rpm	Speed ramps up	Lowered by 50rpm	Speed ramps down	Resumes to set speed	PTO Mode Off	No effect if both buttons are pressed at once

Table 9.4

PTO Mode				
Actual Engine Speed	0	rpm	0	0
Desired Engine Speed	850	rpm	850	850
Requested Desired Engine Speed	0	rpm	0	0
PTO Mode	Set/Resume			
Throttle Lock Engine Set Speed #1	800	rpm	800	800
Throttle Lock Engine Set Speed #2	800	rpm	800	800
Cruise Control On/Off Switch Status	Off			
Cruise Control Mode	Off			
Cruise Control Set/Decel Switch	Off			
Cruise Control Resume/Accel Switch	Off			
Cruise Control Disengage Switch Status	On			
Set Speed Control Speed Selector Switch Status	Open			

Figure 9.4 - PTO Mode Switch Status when viewed with the Service Tool

9.3.2 Throttle Lock (PTO Mode) Configuration

Five parameters must be configured using Caterpillar Electronic Technician service tool (CAT ET) prior to using the PTO mode feature. The parameters are listed in the main configuration of the service tool.

Throttle Lock and PTO Mode Parameters		
ET Description	**Range or Option**	**Description**
Throttle Lock Feature Installation Status	Not Installed/Installed	Used to install the Throttle Lock feature
PTO Mode	Ramp Up/Ramp Down Set/Resume	Used to change between the 2 different PTO Mode types
PTO Engine Set Speed 1	0 to 2500 rpm	Memorised speed used as the initial resume speed.
PTO Engine Set Speed 2	0 to 2500 rpm	Memorised speed used as the initial resume speed.
Throttle Lock Decrement Speed Ramp Rate	0 to 600 rpm/sec	Speed at which the engine will accelerate or decelerate when holding the raise or lower button down
Throttle Lock Increment Speed Ramp Rate	0 to 600 rpm/sec	Speed at which the engine will accelerate or decelerate when holding the raise or lower button down
Throttle Lock Engine Set Speed Decrement	0 to 200 rpm/sec	Speed at which the engine will increment or decrement when the raise or lower button is pressed quickly.
Throttle Lock Engine Set Speed Increment	0 to 200 rpm/sec	Speed at which the engine will increment or decrement when the raise or lower button is pressed quickly.

Table 9.5

9.3.3 Throttle Lock (PTO Mode) Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5

9.4 Multi Position Throttle Switch (MPTS)

9.4.1 MPTS Operation

The MPTS feature enables the user to select up to 16 pre-configured speed settings as defined by four throttle switch inputs. These switch inputs can be operated via individual or combined switching devices such as rotary switches. Care should be taken however when selecting switches to ensure that they are break before make.

This is a very powerful and flexible feature that may be used in a number of ways. For example:

- Principal speed control method for hydrostatic machines where engine speed is selected and then not required to be frequently changed by the operator. It is in this respect a good alternative to a hand throttle as the speeds selected on the switch can be designed to correspond to the optimum operating speeds of hydraulic pumps.
- Machine limp home speed feature. For example, if the normal throttle fails the operator could remove a fuse or a link and the engine would go to a speed that would allow the machine to be moved. In this application only one of the available 4 switch inputs would be used.
- Elevated idle. For example the OEM could increase the idle speed when work lights are switched on so that the alternator will provide sufficient current to recharge the battery. In this application only one of the available 4 switch inputs would be used.

If a switch combination is detected which has been configured as “Physical Position Enabled = No” then a fault code will be raised (91-2 or 774-2) and the ECU will ignore the MPTS for the rest of the key cycle as this switch combination has been configured as a fault status.
Due to the powerful nature of this feature for mobile applications it is strongly recommended that not all 16 settings are used. Instead mobile applications should be limited to paired switch positions, as shown in the table below. This will ensure that if one switch input state is changed in error the speed setting will not change, since two switches must change state if the paired configuration is followed.

9.4.2 MPTS Configuration

Some parameters must be configured using Caterpillar Electronic Technician service tool (CAT ET) prior to using the MPTS feature. The parameters are listed in the configuration screen of the service tool and are shown below. The configurable engine speeds 1 through 16 have to be greater than the configured low idle engine speed and less than the configured high idle speed.
The MPTS feature is activated by setting “Throttle Lock Feature Installation Status” to “Multi Position Throttle Switch” and setting “Multi State Input Switch Enable Status” to “Enabled”.
It is important that the engine be capable of running at both the low and high idle settings so the default position 0 should be set to the configured Low idle Speed. One of the other switch positions should be set to the configured High Idle speed e.g. position 15.

Physical Position	Switch 4	Switch 3	Switch 2	Switch 1	Physical Position Enabled	Suitable for Mobile applications?	Example Engine Speed
0	Open	Open	Open	Open	Yes / No	Yes	800
1	Open	Open	Open	Closed	Yes / No		800
2	Open	Open	Closed	Open	Yes / No		1800
3	Open	Open	Closed	Closed	Yes / No	Yes	1400
4	Open	Closed	Open	Open	Yes / No		2050
5	Open	Closed	Open	Closed	Yes / No	Yes	2000
6	Open	Closed	Closed	Open	Yes / No	Yes	1900
7	Open	Closed	Closed	Closed	Yes / No		1950
8	Closed	Open	Open	Open	Yes / No		800
9	Closed	Open	Open	Closed	Yes / No	Yes	800
10	Closed	Open	Closed	Open	Yes / No	Yes	800
11	Closed	Open	Closed	Closed	Yes / No		800
12	Closed	Closed	Open	Open	Yes / No	Yes	2100
13	Closed	Closed	Open	Closed	Yes / No		2200
14	Closed	Closed	Closed	Open	Yes / No		800
15	Closed	Closed	Closed	Closed	Yes / No	Yes	2350

Table 9.6

9.4.3 MPTS Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5

9.5 Torque Speed Control TSC1 (Speed Control Over CAN)

A special J1939 message called Torque/Speed Control #1 (TSC1) allows other electronic devices to control or to limit the engine speed. This message is explained in detail in section 16.3.2 of this application and installation guide.

9.6 Arbitration of Throttle speed demand

When two throttles are configured in the engine software different selection options may be configured to control and select a final speed demand. The engine software will monitor both speed demand inputs during engine operation, and there are four methods of arbitration;

1. **Manual Selection** - A switch is configured to select the required throttle
2. **Largest Wins** – The highest speed demand will be used (Default configuration in engine software).

3. **Lowest Wins** – The lowest speed demand will be used.

9.6.1 Throttle Arbitration Configuration

When two throttles are configured in the engine software different selection options may be configured to control and select a final speed demand. The engine software will monitor both speed demand inputs during engine operation, and there are four methods of arbitration;

Configuration field Names	Configurable Options	Default Configuration
Throttle Arbitration	Largest Wins Lowest Wins Manual	Largest Wins

Table 9.7

9.6.2 Manual Throttle Selection Switch

An engine ECU input is available that can be configured to allow manual selection between throttle 1 & throttle 2. The switch in its open state will select throttle 1, and when closed will select throttle 2. Switching throttles at any speed demand is possible as long as the speed demand from each throttle is within 50rpm of the other. Essentially the two throttle signals should be matched before the operator changes to the other throttle.

9.6.3 Manual Arbitration Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5

9.6.4 Largest Wins selection (Default)

When two throttles are connected and configured the engine ECU will monitor each input. The highest speed demand will be used to control engine speed.

9.6.5 Lowest Wins selection

When two throttles are connected and configured the engine ECU will monitor each input. The lowest speed demand will be used to control engine speed.

9.7 Throttle Calibration

The majority of throttle components have mechanical and electrical tolerances that affect the final output of a device, for example two components of the same design and part number may produce a different voltage output in the open position. Also after a period of time throttle components can mechanically wear, affecting/changing the output of a device. To accommodate these differences and changes the engine ECU may be configured to automatically calibrate to differing input values at the upper and lower positions. The diagrams below give an example pedal design where the open and closed position of the throttle pedal are set by adjusting the manufacturing adjustment screws. With this type of arrangement the mechanical accuracy is limited and therefore auto calibration may be used. The calibration control logic needs a number of parameters specific to the chosen device to allow auto calibration.

This feature is configurable for Analogue and PWM inputs. The algorithm treats either a PWM or analogue input as a 'raw signal' in the range 0 to 100% for example the analogue voltage range is 5V therefore 0.05V is treated as 1%.

Several parameters are used to:

- Define the boundaries for calibration in the open and closed positions
- Define the amount of 'deadzone /play' from the open and closed positions
- Define the upper and lower diagnostic boundaries

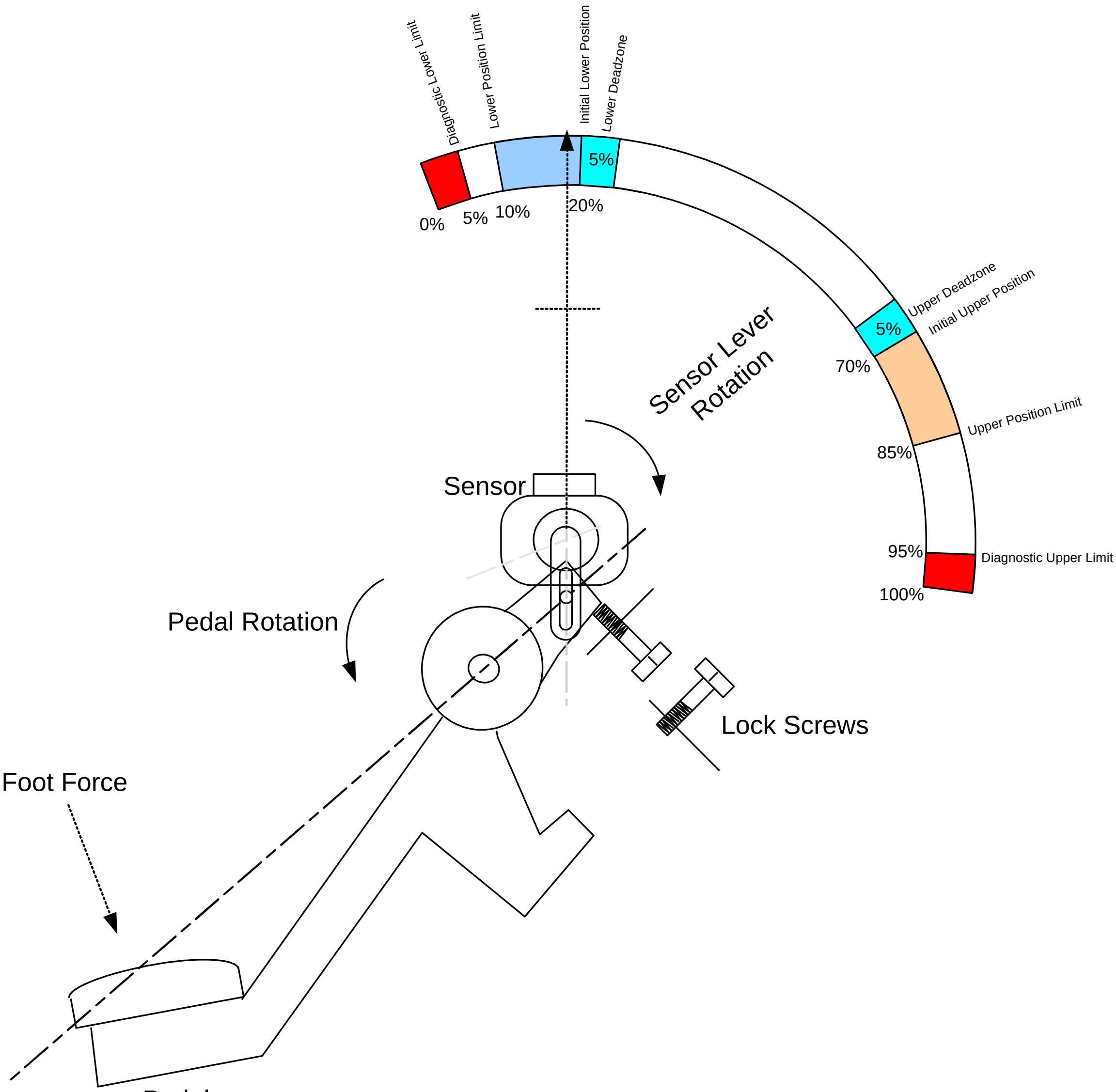


Figure 9.5 Analogue Throttle Setup Example

The diagram above is a simplified representation of a throttle pedal assembly; a small lever attaches the pedal to a throttle position sensor. Two lock screws limit the open and closed pedal movement, one for each position. The lever movement is directly proportional to the electrical output signal of the throttle sensor. The electrical raw signal is shown as a percentage of the total permissible input range.
Eight parameters are shown on the diagram scale, each parameter has a purpose; these parameters are required for correct calibration. The parameters are expressed as a percentage of raw signal, the parameters may be changed/configured to match the chosen device:

9.7.1 Throttle Parameter Description

Diagnostic Lower Limit
The lower diagnostic limit is the absolute minimum raw value accepted as a valid signal by the engine ECU. Any values below this point will flag appropriate diagnostics and invoke the limp-home strategy. Most analogue devices are classed as faulted with a voltage of 0.25V and below (5%) this is to prevent a possible open or short circuit being mistaken for a valid signal, for similar reasons a PWM duty cycle should not fall below 5% duty cycle.
Lower Position limit
This is the minimum point of the lower calibration boundary
Initial Lower Position limit

This is the maximum point of the lower calibration boundary. This value is also used as the initial lower position when no calibration has been applied.

Lower Deadzone

This position is given as a discrete raw signal percentage value. The lower dead zone effectively gives some play at the lower position. This dead band is expressed in terms of a raw signal percentage, such that the initial lower position plus the lower dead zone will give the 0% throttle position.

Initial Upper Position limit

This is the minimum point of the upper calibration boundary. This value is also used as the initial upper position when no calibration has been applied.

Upper Position Limit

This is the maximum point of the upper calibration boundary

Upper Deadzone

This position is given as a discrete raw signal percentage value. The upper dead zone effectively gives some play at the upper position. This dead band is expressed in terms of a raw signal percentage, such that the initial upper position minus the upper dead zone will give the 100% throttle position.

Diagnostic Upper Limit

The upper diagnostic limit is the absolute maximum raw value accepted as a valid signal by the engine ECU. Any values above this point will flag appropriate diagnostics and invoke the limp-home strategy. Most analogue devices are classed as faulted with a voltage of 4.75V and above, this is to prevent a possible open or short circuit being mistaken for a valid signal, for similar reasons a PWM duty cycle should not go above 95% duty cycle.

9.7.2 Throttle Calibration Function

When the engine ECU is active the raw throttle signal is continuously monitored. The following diagrams explain how the automatic calibration functions. The adjustment screws in the diagram have been purposely adjusted and differ from the previous throttle pedal diagram. When the engine ECU is active the raw throttle value is checked, if the value falls within the lower calibration region (defined by the ‘lower position limit’ & ‘Initial lower position limit’) calibration will take place. In the diagram below the lever position is at 11% and falls within the lower calibration area so auto calibration will be applied.

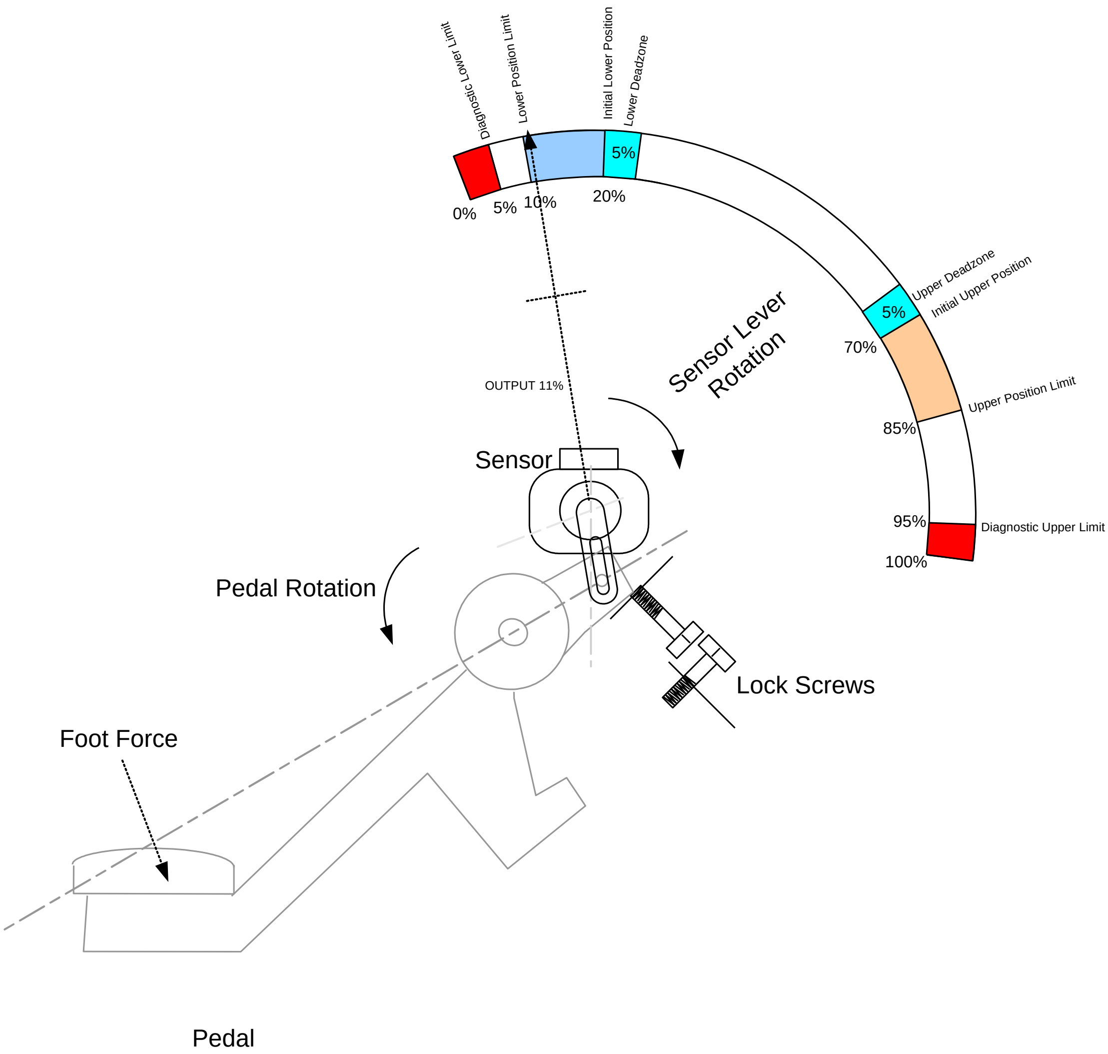


Figure 9.6 Analogue Throttle Lower Calibration Prior to Calibration

Before calibration, the sensor output falls within the lower calibration region, without auto calibration the 'initial lower position limit' is used by the engine ECU as the throttle start point. Once clear of the deadzone the desired engine speed will change. In this case the lever would have to move 14% of the raw signal (9% + 5% deadzone) before desired engine speed changes. This situation is undesirable.

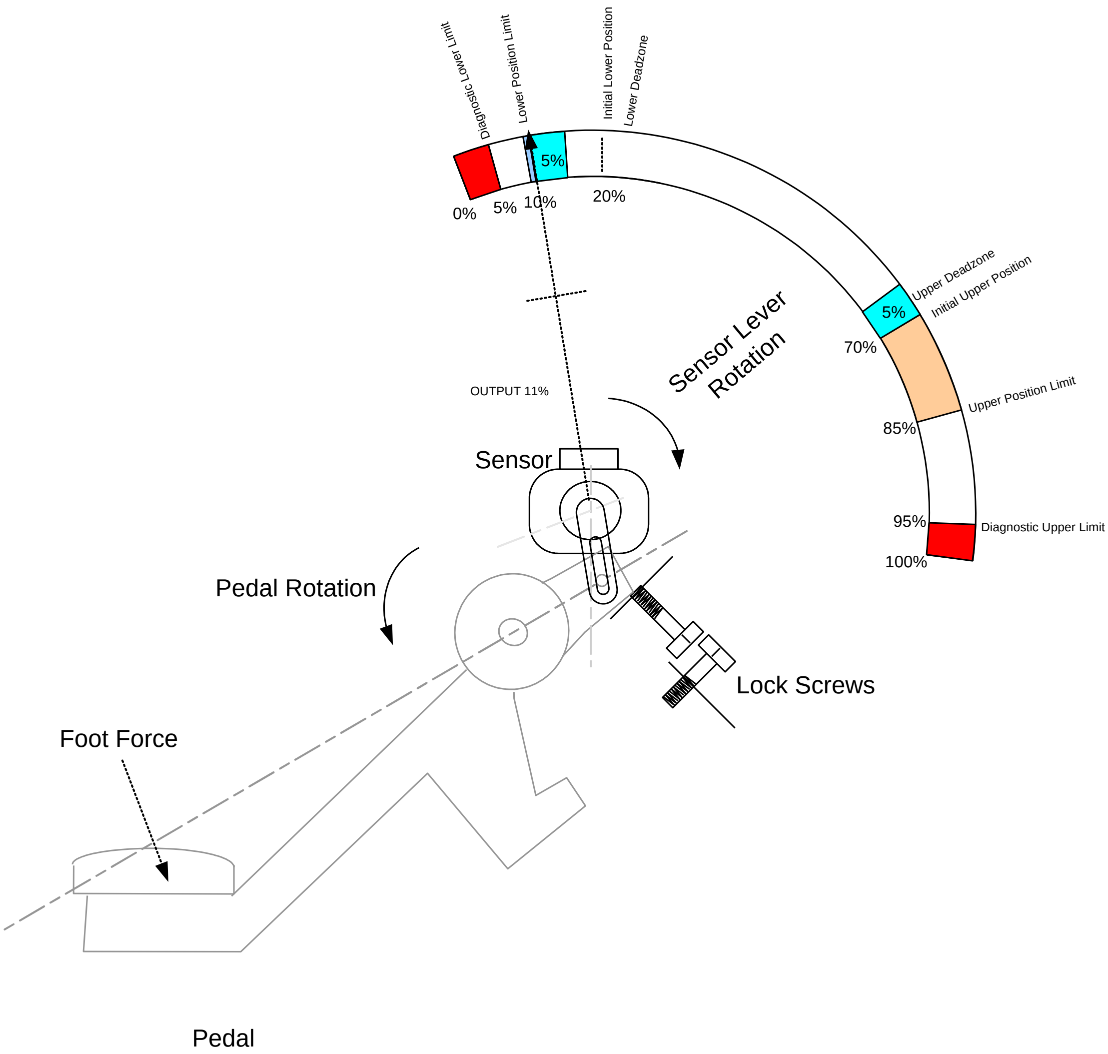


Figure 9.7 Analogue Throttle Lower Calibration Post Configuration

After calibration, the start position used by the engine ECU has changed; with this new initial lower position the lever needs to travel through the deadzone only. Once clear of the deadzone the desired engine speed will change.

The same principal applies for the upper calibration region as shown in the following diagram.

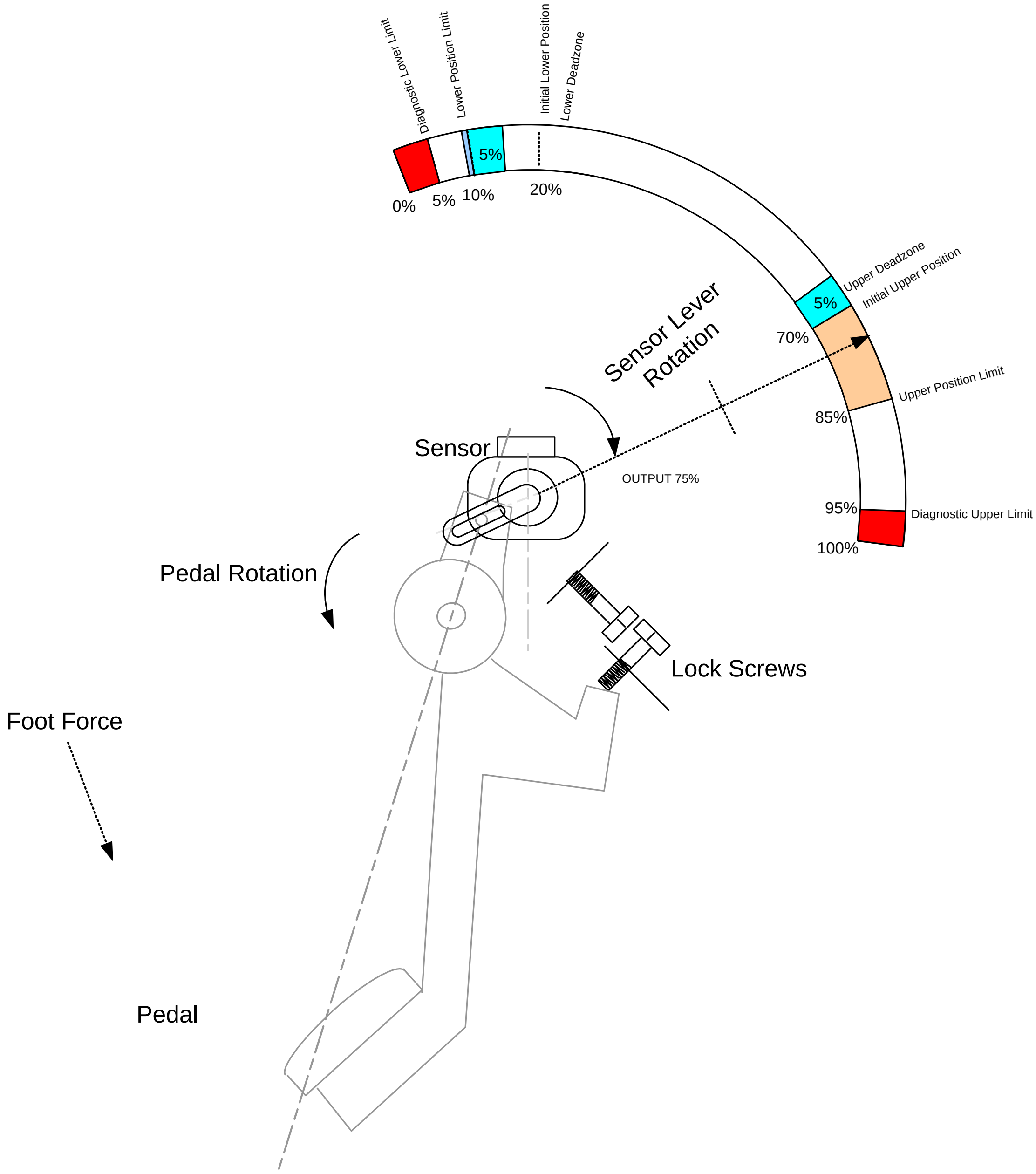


Figure 9.8 Analogue Throttle Upper Calibration Prior to Adjustment

Before calibration, the sensor output falls within the upper calibration region, without auto calibration the 'initial upper position limit' is used by the engine ECU as the throttle maximum point. Once clear of the dead zone the desired engine speed will change. In this case the lever would have to move 10% of the raw signal (5% + 5% dead zone) before desired engine speed changes. This is situation is undesirable.

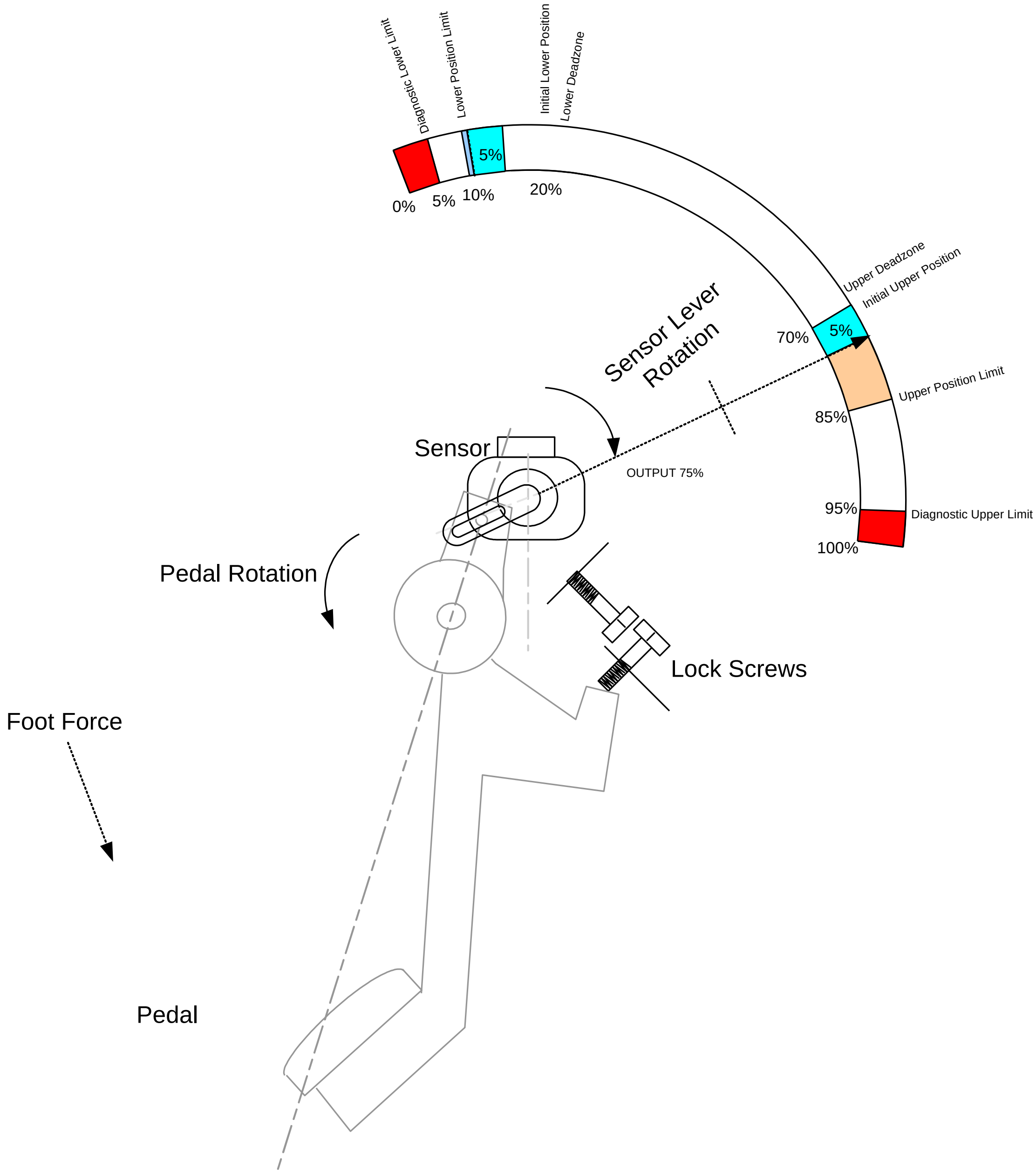


Figure 9.9 Analogue Throttle Upper Calibration Post Configuration

After calibration, the maximum position used by the engine ECU has changed; with this new initial upper position the lever needs to travel through the dead zone only. Once clear of the dead zone the desired engine speed will change.

The auto calibration feature is continuously active during engine operation if a lower minimum position or higher maximum position is seen auto calibration will take place on the new values. The initial positions (defined by the initial lower position limit and initial upper position limit) will be re-instated whenever the power to the ECU is recycled.

9.7.3 Idle Validation Switch

Analogue devices must use an idle validation switch. The idle validation switch is required to validate that a change in signal is indeed valid and not a potential electrical fault. Two parameters need to be defined for correct operation. When configured the engine ECU continually monitors the speed demand request and the Idle validation switch.

Idle validation maximum ON threshold (Closed)

The value is defined as percent raw signal. At low idle the Idle Validation switch should be 'ON' (the input should be switched to ground). When increasing engine speed the ECU will continually monitor the idle validation switch. The switch needs to have switched 'OFF between the two IVS thresholds. If the switch state does not change by the '*Idle validation maximum ON threshold'* the ECU will invoke the limp home strategy and the throttle will not respond.

Idle validation minimum OFF threshold (Open)

The value is defined as percent raw signal. At high idle the Idle Validation switch should be 'OFF' (the input should be switched to open). When decreasing engine speed the ECU will continually monitor the idle validation switch. The switch needs to have switched 'ON' between the two IVS thresholds. If the switch state does not change by the '*Idle validation minimum off threshold'* the ECU will invoke the limp home strategy and the throttle will not respond.

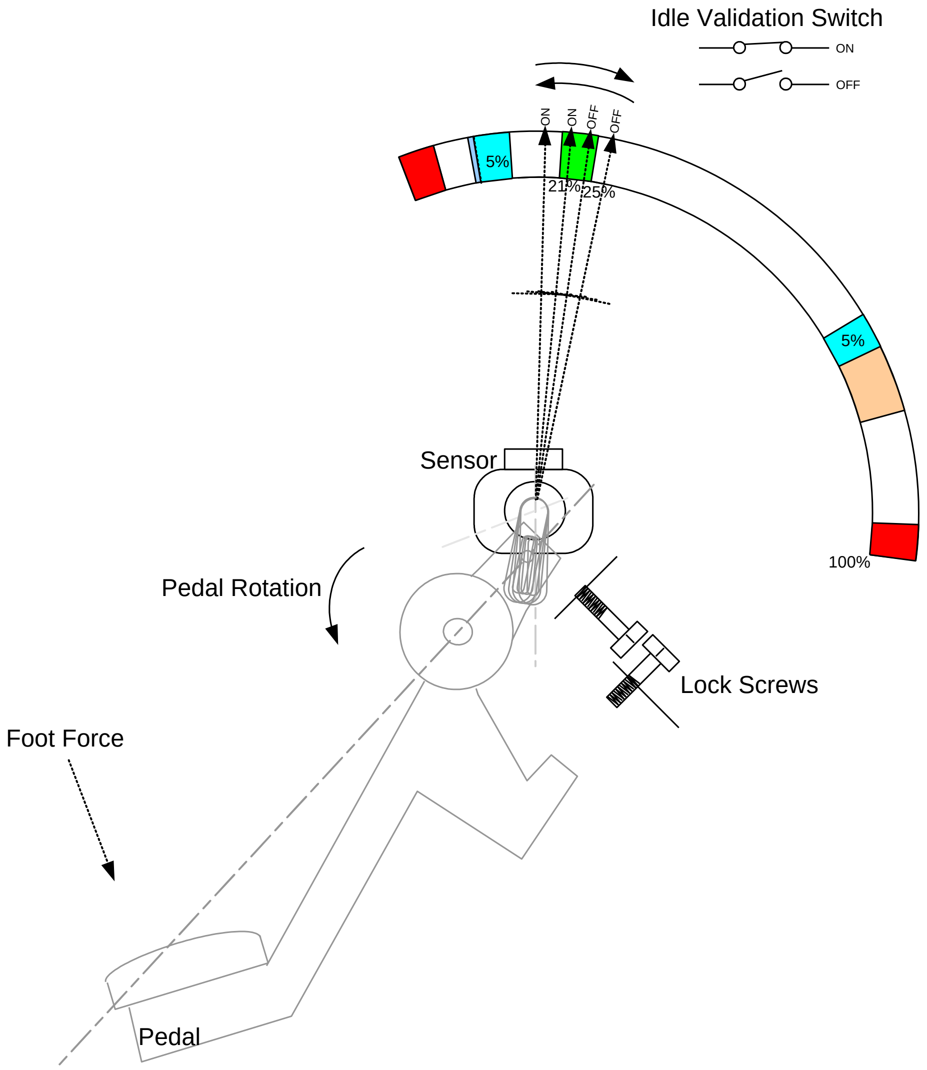


Figure 9.10 Idle validation switch transition

9.8 Engine Limp Home Speed

The engine limp home speed setting is a configurable default engine speed to which the engine controls in the event of a speed control input failure. This limp home speed is configurable using Caterpillar ET. It is

recommended that the limp home speed is set to a different value than the engine low idle. This ensures that in addition to an engine diagnostic code there is a clear indication to the operator that the speed control input has been lost. In addition the limp home speed is usually set to allow the machine to be placed into a safe condition / area for re-work to take place.
In the event of an engine speed control input failure (Single Speed Control installed only) the engine is designed to behave as follows;

1. If actual engine speed is above configured limp home speed when speed control input failure occurs the actual engine speed will default to the configured limp home speed (Default 1200 rpm).
2. If actual engine speed is below the configured limp home speed when speed control failure occurs the actual engine speed will default to the current speed.
3. If actual engine speed is at Low idle when speed control failure occurs the actual engine speed with remain at low idle speed.
4. The limp home strategy imposed by the engine software shall remain until problem has been resolved, self-healed or for the duration of that key cycle.
5. If the speed control fault is active on the next start, the engine speed will remain at low idle speed.

Configuration field Name	Configurable Options	Default Configuration
Limp Home Set Speed	800 – 1200 rpm	1200 rpm

Table 9.8

IMPORTANT NOTES

1. If more than one speed control is used, and a fault occurs on the primary speed signal, the engine software will revert to the secondary analogue speed signal and engine will have full speed capability.
2. PTO mode / MPTS features will trigger a different limp home strategy. If a speed fault occurs the engine will ramp down to low idle.

9.9 Definition of Engine Speed Points

There are a number of engine speed configuration points available for configuration by the customer. These points effect the engines operation when installed into a machine and should be configured to meet the specific needs of the Application. Each point is listed below and shown and in the following figure where there relationship with the torque curve can be seen.
Configurable by the customer;

- Engine Low Idle Speed (LI)
- Engine High Idle Speed (HI)
- Engine Rated Speed (RS)

Fixed Parameters which are non-configurable;

- Engine Low Idle Speed Lower Limit (LILL)
- Engine Low Idle Speed Upper Limit (LIUL)
- Engine High Idle Lower Limit (HILL)
- Engine High Idle Upper Limit (HIUL)
- Rated Speed Lower Limit (RSLL)
- Rated Speed Upper Limit (RSUL)

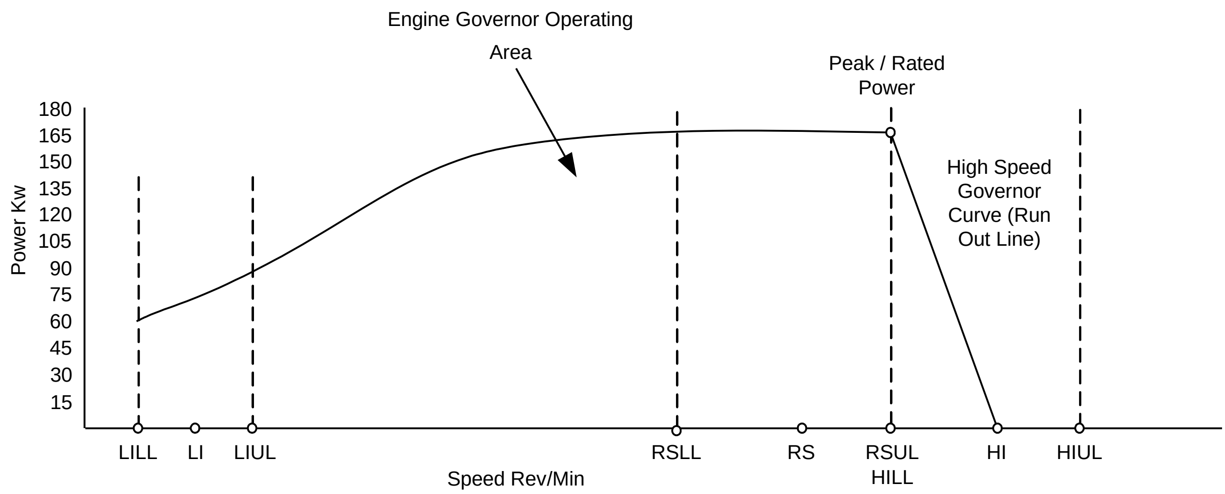


Figure 9.11 Example Power Curve with All Available Speed Settings

9.9.1 Engine Low Idle

9.9.1.1 Engine Low Idle Operation

The engine low idle speed determines the minimum allowable engine speed during normal engine operation i.e. if no throttle demand is supplied to the engine ECU (assuming the engine is running) and there is no load on the engine the engine will idle at the set low idle speed.

9.9.1.2 Engine Low Idle Configuration

The desired engine low idle speed can be set using Caterpillar ET (service tool) via the configuration screen.

Configuration field Names	Configurable Options	Default Configuration
Low Idle Speed	800 – 1200 rpm	Set from factory based on option selection

Table 9.9

9.9.2 Engine High Idle

9.9.2.1 Engine High Idle Operation

The engine high idle speed determines the engine full throttle desired engine speed value. As with the low idle setting this parameter is configurable by the customer and can be set to an engine speed limited by the fixed software limits High Idle Lower Limit (HILL) and High Idle Upper Limit (HIUL).
The high idle speed setting also works in conjunction with the Rated Speed Setting (RS) to determine the High Speed Governor (HSG) run out line. Varying the Rated speed and High Idle settings can alter the gradient of this line and the resulting governor response.
Note: Under some circumstances the engine may not be able to reach the desired HI setting under full throttle conditions due to machine torque requirement at this speed.

9.9.2.2 Engine High Idle Configuration

The desired engine High Idle Speed can be set using the service tool (ET) via the configuration screen. The engine High Idle speed defaults to rated speed + 5% and can be adjusted to a value between HILL and HIUL. As previously stated the relationship between High Idle and Rated Speed is not mutually exclusive for this reason HILL is set to RS and HIUL is RS + 10%. This means that the max HI setting available for any engine is RS + 10%.

Configuration field Name	Configurable Options	Default Configuration
High Idle Speed	RS +10%	RS +5%

Table 9.10

10.0 Cold Weather Engine Operation & Starting Aids

There are two types of start aid available for all Stage V engines, they are, glow plugs (fitted as standard to all engines) and ether (customer configurable option). Engines can be purchased with both start aids enabled however it should be noted that under no circumstances will the glow plugs and ether system be used in conjunction with one another for safety reasons. In general the following applies;

- Glow plugs are only used below +5°C
- Ether start activation is based on temperature and barometric pressure but in general will activate at temperatures below –25°

10.1 Control of Glow Plugs by the Engine ECU

10.1.1 Glow Plug System Operation

When the ignition key switch is on, the engine ECU will monitor the coolant temperature sensor and Air inlet temperature sensor and decide whether the glow plugs are required.
When the glow plug start aid is required the engine ECU will illuminate the ‘wait to start indicator’ and control the Glow Plug relay through pin J2-105.
The relay will be turned ON and the glow Plugs powered through it. To ensure reliable starting and glow plug protection it is mandatory to connect the glow plugs to the Glow Plug Relay. During engine operation the engine ECU monitors the wires to the Glow Plug Relay; if a fault is detected a diagnostic message will be communicate through the J1939 DM1 message during operation.

10.1.2 Glow Plug System Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5

Engine: Supply Voltage:	Four Glow Plugs 12 Volts	Four Glow Plugs 24 Volts
Current - Initial	60A	40A
Current after 5 sec	43A	24A
Current after 10 sec	34A	20A
Current after 30 sec	32A	16A
Recommended Fuse To SAEJ1888 (slow blow)	50A	30A
Recommended min cable gauge - mm^2 (SAE J6722 cable)	$6mm^2$	$6mm^2$

Table 10.1

Component	12 Volts	24 Volts
Glowplug Relay	241-8367	241-8368

Table 10.2 – Glowplug Relay Part Numbers

10.1.3 Glow Plug Connector

The Glow Plugs are connected together through a bus bar and the customer is required to connect to the Glow Plug Bus Stud. The Bus Bar provides two locations for the connection on each extremity, one is close to the Thermostat Housing and the other one is located behind the Engine Interface connector bracket.
The Bus Bar Connection is a M6 Stud, the tightening torque should not exceed 5.5Nm.

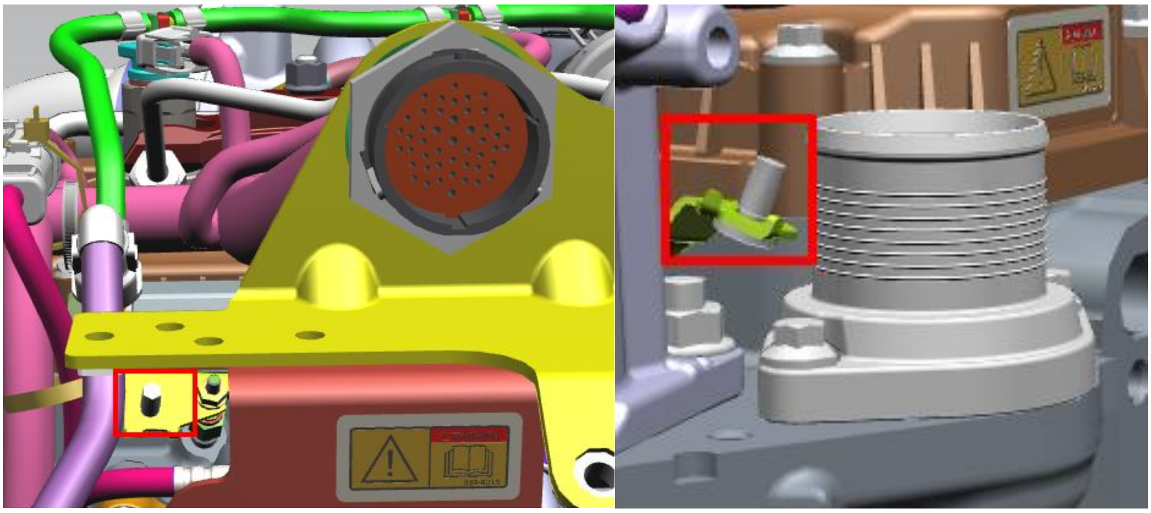


Figure 10.1 Glow Plug Stud Locations

Glow Plug Connection Component Description	Size	Tightning Torque
Glow Plug Stud	M6x1.0	Max 5.5 Nm

Table 10.3 Glow Plug Connection Stud

10.2 Ether Cold Start Systems

10.2.1 Ether start Operation

The ether solenoid control is available to drive a relay and/or solenoid to control ether delivery to the intake manifold. The ECU controls the ECU output when conditions dictate the use of an Ether starting aid. Caterpillar offers an optional ether start system matched to each engine's particular cold start strategy. Please refer to your Applications engineering department for more information.
The ether control strategy establishes ether injection durations based on maps configured for temperature and altitude. These values are fixed and are not configurable by the customer. As an example if the ambient temperature is below -25°C at sea level and an attempt is made to start the engine, the ether solenoid control will be enabled until the engine reaches 50rpm less than low idle. If the engine starts or a condition occurs that prevents fuel from being injected, the ether solenoid control will be disabled.
Ether will only be injected while the engine speed is greater than zero. Ether will not be injected prior to cranking the engine.

10.2.2 Ether start Configuration

To activate the ether start strategy within the engine ECU the option must be selected using the Service tool ET. This is achieved by double clicking the Ether start option displayed as part of the main configuration screen and selecting the 'Installed' option.

Configuration field Names	Configurable Options	Default Configuration
Ether	Installed / Not Installed	Not Installed

Table 10.4

10.2.3 Ether start Installation

The continuous flow ether system is available as an optional attachment. The component in the ether system that controls ether quantity and spray angle is the atomizer. The atomizer has a control orifice that is sized for a specific range of intake air flow. Be sure to order the correct ether system to match the engine.
NOTE: Ether atomizer location is critical to proper operation of each model's cold start strategy. For proper ether atomizer location, specific to each engine model, consult with your Applications Engineer.

The ECU is capable of directly controlling and activating the ether control valve solenoid as long as the parts used require no more than 2Amps. All Caterpillar parts are verified to ensure that they meet this requirement. An example of the Ether control solenoid is shown in the figure below.

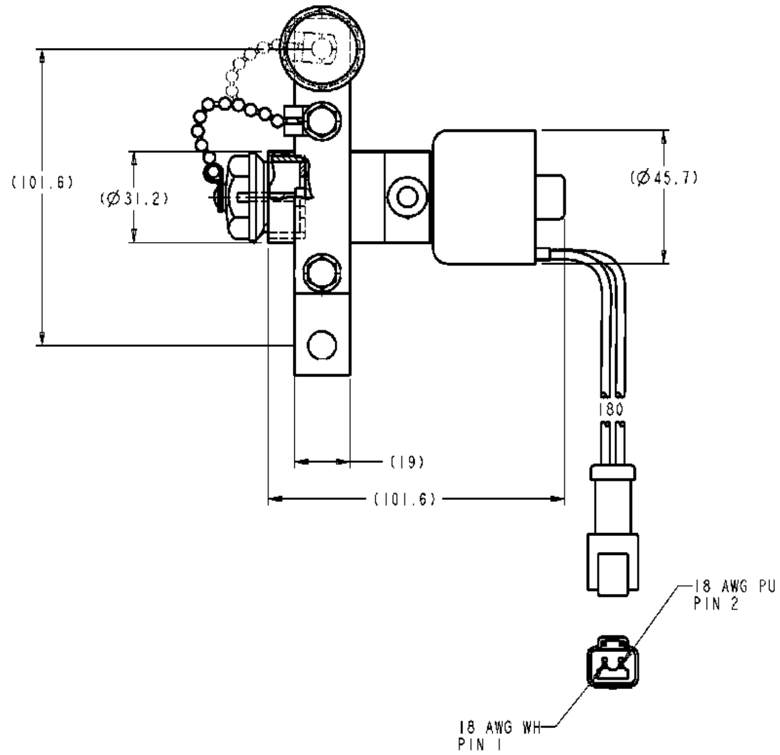


Figure 10.2 Example Ether Control Valve

Please refer to the separate electrical schematics referenced in Section 2.3.5

Component	Caterpillar Part Number
Ether Control Valve 12V	260-1844
Ether Control Valve 24V	239-1134

Table 10.5

10.3 Heated Breather

10.3.1 Heated Breather Operation

In low ambient conditions with low engine load there is a risk of ice formation at the interface between the breather gas hose and the induction pipe. The ice formation can occur at ambient temperatures below –18°C so a breather heater is mandatory for any installations that will experience ambient temperatures below -18°C. The electrical breather heater should be powered continually during engine operation. It is recommended that the electrical circuit be fused separately from other engine components.

System Parameters	Range
Voltage Range	6V to 30V
Current Range	-0.5 to 3A
Suggested Fuse Rating	5A

Table 10.6 Heated Breather Electrical Specification

10.3.2 Heated Breather Configuration

No configuration is required for this feature to function.

10.3.3 Heated Breather Installation

Caterpillar recommend that the breather heater is installed so that the electrical connector points horizontally from the pipe, to best avoid any water ingress. The ingress protection of the connector when fitted is IPX9k which is a high level but does not guarantee against ingress of fluid if the connector points vertically up from the breather pipe, so this should be avoided.
Please refer to the separate electrical schematics referenced in Section 2.3.5

10.4 Open/Closed Circuit Breather

10.4.1 Open/Closed Circuit Breather Operation

In software 1.37.2 (Released Sept. 2020), an additional configurable parameter was added for the breather. For all engines built with 1.37.2 this parameter will be set from the factory based on the breather option on the BOM.

10.4.2 Open/Closed Circuit Breather Configuration

Configuration field Name	Configurable Options	Default Configuration
Engine Crankcase Breather Configuration	Open Circuit / Closed Circuit	Set from factory based on option selection

Table 10.6

10.4.3 Open/Closed Circuit Breather Installation

No installation required. Installed from factory.

10.5 Engine Soft Start Protection

10.5.1 Engine Soft Start Protection Operation

After starting, a soft start strategy is employed which holds the engine speed at low idle or 850rpm depending on which is lowest for a duration between 1 and 25 seconds to allow engine systems to stabilise.
Under normal system conditions, the trigger to exit the soft start strategy is oil pressure. The time taken to build oil pressure depends on many factors, for example

- Ambient temperature
- Oil temperature
- Oil grade
- Oil filter position
- Time since engine last run
- Engine starting performance

Following the exit of the soft start strategy, the engine will ramp to the desired engine speed.
The soft start strategy includes a maximum allowed hold time, as backup in the event of a system failure, for example, oil pressure sensor failure. Soft start mode will be exited at the expiry of this maximum hold time, irrespective of whether oil pressure has been detected. In this case, normal engine diagnostics will apply. The maximum hold time is dependent on temperature, and is in the range 1 to 25 seconds.

10.5.2 Engine Soft Start Protection Configuration

There is no specific user configuration required for this feature.

10.5.3 Engine Soft Start Protection Installation

The engine ECU provides two methods for communicating the status of the soft start feature to the machine operator.
Option 1 Engine Wait to Start Lamp flash

The engine ECU will flash the Wait to start lamp output driver at a frequency of 2Hz for the duration of the soft start condition. Once conditions have been met for the exit of the soft start feature to occur the wait to start driver will turn off.

Option 2 J1939 Engine Oil Priming State (SPN 3551)
The engine ECU will communicate the status of the soft start feature via the J1939 datalink PGN FE6A (65130) SPN Engine Oil Priming State 3551. More details on the format of this message can be found in section 19.3.31 of this document.
The Engine Oil Priming State will operate as follows;

- During Soft start SPN 3551 will be transmitted with a 00 status (Not sufficiently Lubricated).
- Post Soft start SPN 3551 will be transmitted with 01 status (Sufficiently Lubricated).

11.0 Operator Indicators & Fault Displays

11.1 Engine & Aftertreatment Diagnostic Systems

Both the engine and aftertreatment systems are fitted with a number of sensors and actuators designed to provide tight control over engine performance and emissions management. Each of these devices enables the engine management system to closely monitor the health of the system and react as necessary when fault conditions occur.
In the event of an electronic component failure or an out of normal control boundaries condition being raised the engine management system will react by raising a specific indicator, fault code and in some cases take protective action such as derate or shutdown.
The conditions under which the engine signals a system error can be defined as fitting into one of three categories. The error category will dictate the specific engine response and the type of indication provided to the operator. The specific fault conditions are shown below.
Diagnostic Codes – These conditions are related to specific electrical hardware faults or failures such as open / short circuit conditions on sensors or wiring loom.
Event Codes – Events are raised when the engine control system recognises that the current system conditions are outside of some pre-defined boundaries. Examples are coolant temperature, oil pressure and DOC intake temperature etc.
Emissions System Inducements – These conditions are governed by specific emissions regulation, which requires the engine manufacturer to clearly identify specific emissions system failures to the operator outside of the normal engine fault condition strategies.
A complete list of the available lamps available on the C3.6 engine is shown below. Mandatory indicators are highlighted where applicable.

Mandatory Indicators to be installed in Application				
Indicator	C3.6L >56kW DOC, DPF, SCR	C3.6L <56kW / 74.4 – 82kW DOC, DPF	C3.6L Stage IIIa	Comments
Engine Warning Indicator	✓	✓	✓	Alert operator to a level 1 and 2 diagnostic issue.
Engine Shutdown Indicator	✓	✓	✓	Alert operator to a level 3 diagnostic issue.
Engine Wait To Start Indicator	✓	✓	✓	Inform the operator that the engine is ready to start when OFF.
Engine Oil Pressure Indicator	Optional	Optional	Optional	Alert operator that the engine oil pressure has dropped below a predefined threshold.
DEF Level Indicator	✓	N/A	N/A	Alert the operator that the DEF level is to low and needs to be replenished.

Mandatory Indicators to be installed in Application				
Indicator	C3.6L >56kW DOC, DPF, SCR	C3.6L <56kW / 74.4 – 82kW DOC, DPF	C3.6L Stage IIIa	Comments
Emissions System Failure Indicator (also known as MIL)	✓	✓	N/A	Alert the operator that an emission related component has failed, for example a fault with the EGR, DPF or SCR system.
DPF Lamp	✓	✓	N/A	Alerts the operator that a DPF Regeneration is required
Inhibit Regen Lamp	Mandatory with Inhibit Switch	Mandatory with Inhibit Switch	N/A	Alerts the operator that they have Inhibited Automatic Regeneration of the Aftertreatment
Regen Active Lamp	Optional but Mandatory with Inhibit Switch	Optional but Mandatory with Inhibit Switch	N/A	Alerts the operator that an Aftertreatment Regeneration is active and that the Exhaust system **may** be hotter than expected
Wait to Disconnect lamp	✓	Optional	Optional	Alert the operator that the system is purging DEF back to DEF Tank or that ECU housekeeping is in progress
Engine Running Output Lamp	Optional	Optional	Optional	Alerts the operator that the engine is running

Table 11.1

Note: It is mandatory to display all the mandatory indicators, this can be through a Hardwired method or J1939 driven. Whether using a hardwired or J1939 driven system all status indicators must use the Aftertreatment symbols documented in section 11.4.3.

11.2 Monitoring System Fault Status Levels

All engine and aftertreatment fault indicators are assigned a **W**arning **C**ategory **I**ndicator (WCI), which indicates the severity of the specific diagnostic, event or emissions critical failure. The high level operation of the indicator control strategy is shown in the figures below. It should be noted that the protect indicator status is only available via J1939 and not as a hardwired ECU output. If hardwired engine warning and shutdown lamps are used then engine events will be displayed in the same manner as engine diagnostic code, via a warning lamp and shutdown lamp only.

	Engine Diagnostic Codes / Event Codes						
	Warning Indicator	Protect Indicator	Stop Indicator	SPN Broadcasted	Engine Derate	Engine Shutdown	Comments
WCI 0	Off - SPN624	Off - SPN987	Off - SPN623	✓	✗	✗	Service Technician codes
WCI 1	Solid- SPN624	Off - SPN987	Off - SPN623	✓	✗	✗	Level 1 engine diagnostic.
WCI 2	Slow flash - SPN3040	Slow flash - SPN3041	Off - SPN623	✓	✓	✗	Level 2 engine diagnostic / event.
WCI 3	Fast Flash - SPN3040	Fast Flash - SPN3041	Solid - SPN623	✓	✓	✓	Level 3 engine diagnostic / event.

Table 11.2

11.3 Gauge Drivers

If a needle type analogue gauge is required to display an engine parameter such as engine speed or coolant temperature, it is recommended that the OEM use a gauge or display that can use the parameters broadcast by the ECU on the J1939 Datalink.
As an alternative, traditional single wire gauge 'senders' may be used if a suitable tapping is available. If this implementation is required, please contact the Caterpillar Application Department to discuss requirements.
A traditional tacho signal may be obtained from the 'W' terminal of the alternator, although this will not be as accurate as the value transmitted on the J1939 Datalink.

11.3.1 Datalink Driven Intelligent Displays

J1939 enabled operator display / gauge units can be connected to the engine J1939 Datalink. Caterpillar offers lamp information that conforms to the J1939 standard PGN and SPN messaging system.
Devices that are connected to the J1939 Datalink should meet the following standard if the OEM does not intend fitting the indicator lamps.

11.3.2 Minimum Functional Specification for J1939 display.

The following points describe the functional specification for the installation of an operator display.

- The display is always on when the engine is running.
- The display should be in the line-of-sight of the machine operator during machine operation.
- Display the whole J1939 fault code including Suspect Parameter Number (SPN), Failure Mode Indicator (FMI) and occurrence number.
- Clear indication of what action, if any the operator is required to take.
- Display of engine speed.
- Audible or bright lamp warning when a new fault code is detected.
- The scaling of any gauges (e.g. coolant temperature) should be such that the needle is not far to the right of vertical when the engine is in normal operation (this would give the impression that the engine was abnormally hot, when in fact it is running within its design limits).
- An initial Lamp check should be managed by the Display

Caterpillar will under no circumstances change the engine J1939 implementation in order to resolve compatibility issues with gauges or displays other than those displays supplied directly by Caterpillar.
Gauge manufacturers may contact the Caterpillar application department for information and assistance in ensuring that their products are compatible with the Caterpillar engine ECU.
To support new standards and requirements, Caterpillar may create additional fault code. Therefore, any active engine fault codes including those not recognized or referenced should be displayed.

11.4 Lamp Outputs & Operation

11.4.1 Hardwired Lamp Outputs

All mandatory engine and aftertreatment indicators are provided as standard as dedicated ECU outputs.
Please refer to the separate electrical schematics referenced in Section 2.3.5

11.4.2 J1939 Indicator Support

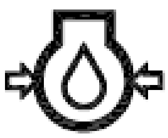
All hardwired status indicators are supported as J1939 messages to support those customers wishing to incorporate these signals into a machine display. PGN and SPN support for these parameters are shown below.

Indicator Description	PGN	SPN
Warning Indicator	FECA (65226)	624
Warning Indicator Flash	FECA (65226)	3040
Shutdown Indicator	FECA (65226)	623
Engine Protect Indicator	FECA (65226)	987
Engine Protect Indicator Flash	FECA (65226)	3041

Engine Wait To Start Indicator	FEE4 (65252)	1081
Oil Pressure Indicator	FD05 (64773)	5099
Emissions System Malfunction Indicator	FECA (65226)	1213
Emissions System Malfunction Indicator Flash	FECA (65226)	3038
Low DEF Level Indicator	FE56 (65110)	5245
Wait to Disconnect Indicator	F023 (61475)	4332
Engine Running Output Indicator	FD92 (64914)	3543
DPF Indicator	FD7C (64892)	3697
Aftertreatment Diesel Particulate Filter Active Regeneration Status	FD7C (64892)	3700
Aftertreatment Diesel Particulate Filter Status	FD7C (64892)	3701
Diesel Particulate Filter Active Regeneration Inhibited Due to Inhibit Switch	FD7C (64892)	3703

Table 11.3

11.4.3 Indicator ISO Reference Symbols

Symbol	Symbol Title (ISO)	Symbol Title	Description	ISO Ref
	Engine Failure Engine Malfunction	Engine Warning Indicator	Used to indicate engine and emissions system diagnostics	ISO 7000-1371
	Engine Stop	Shutdown Indicator	Indicates engine shutdown required for severe system faults / events	ISO 7000-1388
	Engine Electrical Preheat	Engine Wait To Start Indicator	Indicates pre-heat phase has been completed	ISO 7000-1704
	Engine Lubricating Oil Pressure	Oil Pressure Indicator	Indicates low oil pressure	ISO 7000-1374

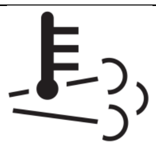
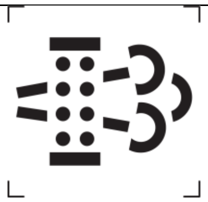
	Emissions System Malfunction Indicator	Emissions System Malfunction Indicator	Indicates a failure of an emissions critical component	ISO 7000-2596
	Low DEF Level Indicator	Low DEF Level Indicator	Used to indicate low DEF level	ISO 7000-2946
N/A	Wait To Disconnect Indicator	Wait To Disconnect	Used to indicate that the engine and DEF system are active.	N/A
	Engine Emissions System Temperature	DPF Regeneration Active	Indicates that the Exhaust System **may** be hot as a DPF Regeneration is Active	ISO-7000-2844A
	Engine Emission filter Active Regeneration Disabled	Regen Inhibit Lamp	Indicates that the Aftertreatment Regen has been Inhibited due to the Inhibit Switch	ISO 7000-2947
	Engine Emission Filter Active Regeneration Required	DPF Indicator	Indicates that Active Regeneration of the DPF is required	ISO-7000-2433

Table 11.4

11.4.4 Engine Shutdown Indicator

11.4.4.1 Engine Shutdown Indicator Operation

The engine shutdown indicator is operated upon the engine entering an operating / fault condition which requires the engine to shut down for control / safety reasons. If the engine monitoring system is configured to a level 3 (warning, de-rate and shutdown) then the engine may also automatically shut down. The engine shutdown indicator is also used in conjunction with the Emissions system malfunction indicator to signal emissions critical faults.

11.4.4.2 Engine Shutdown Indicator configuration

The engine shutdown indicator is a mandatory fit item. There is no configuration necessary for the Engine shutdown indicator. It can be either Hardwired or displayed through the J1939 Network.

11.4.4.3 Engine Shutdown Indicator Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5
The Engine shutdown Indicator is also available via J1939 as shown below.

Function	PGN	SPN	Byte	Start bit	Length	Applicable States
Shutdown Indicator status	FECA	623	1	5	2	00 (OFF)
						01 (ON)

Table 11.5

11.4.5 Engine Warning Indicator

11.4.5.1 Engine Warning Indicator Operation

The warning indicator is used to alert the operator of an engine / operating condition that has the potential to cause engine damage. The warning indicator will illuminate when an active diagnostic or event code is raised. The warning indicator will flash for any diagnostics that cause an engine derate or any event code with a severity level 2 or greater.

11.4.5.2 Engine Warning Indicator Configuration

The engine warning lamp is a mandatory fit item. There is no specific configuration necessary for the Engine warning Indicator. It can be either Hardwired or displayed through the J1939 Network.

11.4.5.3 Engine Warning Indicator Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5
The engine warning Indicator is also available via J1939 as shown below.

Function	PGN	SPN	Byte	Start bit	Length	Applicable States
Warning Indicator Status	FECA	624 987	1	3	2	00 (OFF)
						01 (ON)
Warning Indicator Flash	FECA	3040 3041	2	3	2	01 (Fast Flash)
						00 (Slow flash)

Table 11.6

11.4.6 Engine Wait to Start Indicator

11.4.6.1 Engine Wait to Start Indicator Operation

The Wait to Start Indicator is a mandatory component, which is used to indicate to the operator that the engine is ready to start. The Indicator is controlled by the engine cold start strategy and while illuminated indicates that the engine should not be started. For more information on the wait to start indicator operation please refer to Section 10.0.

11.4.6.2 Engine Wait to Start Indicator Configuration

The engine wait to start lamp is a mandatory fit item. There is no specific configuration necessary for the Engine warning Indicator. It can be either Hardwired or displayed through the J1939 Network.

11.4.6.3 Engine Wait to Start Indicator Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5
The engine wait to start Indicator is also available via J1939 as shown below.

Function	PGN	SPN	Byte	Start bit	Length	Applicable States

Wait To Start Indicator	FEE4	1081	4	1	2	00 (OFF) 01 (ON)

Table 11.7

11.4.7 Oil Pressure Indicator

11.4.7.1 Oil Pressure Indicator Operation

The low engine oil pressure indicator is used in conjunction with the engine monitoring system to indicate to the operator that the engine oil pressure has dropped below a predefined threshold. The engine control system constantly monitors the engine oil pressure switch and the switch is normally closed, the switch will open when a positive pressure between 60 to 90 kPa is detected. If the switch closes when the engine is running the oil pressure indicator will be activated and a diagnostic code will be raised.

11.4.7.2 Oil Pressure Indicator Configuration

The Threshold level for the lamp activation is set within the engine software and is non-configurable. There is no configuration required for the Oil Pressure Indicator to operate. It can be either Hardwired or displayed through the J1939 Network.

11.4.7.3 Oil Pressure Indicator Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5
The oil pressure indicator is also available via J1939 as shown below.

Function	PGN	SPN	Byte	Start bit	Length	Applicable States
Engine Oil Pressure Low Lamp Command	FD05	5099	2	5	2	00 (OFF) 01 (ON)

Table 11.8

11.4.8 Emissions System Malfunction Indicator (MIL Lamp)

11.4.8.1 Emissions System Malfunction Indicator Operation

The emissions system malfunction indicator is designed to highlight any faults with emissions system critical components. This indicator is used in conjunction with warning, and shutdown indicators to highlight system issues with the NRS system and SCR system. The indicator is mandatory and its use is governed by the EU, EPA and China NR4 emissions regulations. For more details regarding the use of the emissions system malfunction inducements please refer to section 12.3.1.

11.4.8.2 Emissions System Malfunction Indicator Configuration

The Emissions System Malfunction Indicator is a mandatory fit item. There is no specific configuration necessary for the emissions system malfunction indicator. It can be either Hardwired or displayed through the J1939 Network.

11.4.8.3 Emissions System Malfunction Indicator Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5
The emissions system malfunction indicator is also available via J1939 as shown below.

Function	PGN	SPN	Byte	Start bit	Length	Applicable States
Malfunction Indicator Lamp	FECA	1213	1	7	2	00 (OFF) 01 (ON)
Flash Malfunction Indicator		3038	2	7	2	00 (Slow flash) 01 (Fast Flash)

Table 11.9

11.4.9 Low DEF Level Indicator only for Engines >56kW

11.4.9.1 Low DEF Level Indicator Operation

The low DEF level indicator is designed to inform the operator that the DEF needs to be replenished. If the low DEF level indicator is continually ignored progressive inducements will be activated and the engine control system will force the engine to idle or if configured shutdown conditions will be invoked. For more details regarding the use of the DEF quality inducements please refer to section 12.3.1.

11.4.9.2 Low DEF level Indicator Configuration

The Low DEF Level lamp is a mandatory fit item. There is no specific configuration necessary for the Low DEF Indicator. It can be either Hardwired or displayed through the J1939 Network.

11.4.9.3 Low DEF Level Indicator Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5
The Low DEF Level indicator is also available via J1939 as shown below.

Function	PGN	SPN	Byte	Start bit	Length	Applicable States
Aftertreatment 1 Diesel Exhaust Fluid Tank 1 Low Level Indicator	FE56	5245	5	6	3	000 (OFF)
						001 (ON)
						100 (ON FAST BLINK)

Table 11.10

11.4.10 Wait To Disconnect Indicator

11.4.10.1 Wait To Disconnect Indicator Operation

The wait to disconnect indicator is a mandatory fit item used to alert the machine operator that the engine and DEF system are still active and the battery disconnect switch (battery isolation switch) should not be used. This is only mandatory for systems with DEF. Post ignition off, the DEF system must perform a DEF purge cycle that requires the use of the DEF pump motor. If system power is removed during the purge cycle, the fluid left within the pumps and the DEF Heater lines may cause component failures. Further information regarding the DEF purge operation is shown in Section 13.2.

11.4.10.2 Wait To Disconnect Indicator Configuration

No configuration is required to enable the wait to disconnect indicator as the indicator is activated by the ECU power relay. It can be either Hardwired or displayed through the J1939 Network.

11.4.10.3 Wait To Disconnect Indicator Installation

The location of the Wait To Disconnect indicator should be placed as close as possible to the battery disconnect switch (battery isolation switch).
Please refer to the separate electrical schematics referenced in Section 2.3.5
The Wait to Disconnect indicator is also available via J1939 as shown below.

Function	PGN	SPN	Byte	Start bit	Length	Applicable States
Wait to Disconnect Indicator	F023	4332	3	1	4	ON = any state other than 1011
						OFF = 1011 OK to power down

Table 11.11

11.4.11 DPF Indicator

11.4.11.1 DPF Indicator Operation

The DPF lamp is used to indicate that Active Regeneration is required to aid the removal of soot from the Aftertreatment canister. For more details on this Regeneration see Section 13.1.

11.4.11.2 DPF Indicator Configuration

The DPF lamp is an mandatory fit item. There is no specific configuration necessary for the DPF Indicator. It can be either Hardwired or displayed through the J1939 Network.

11.4.11.3 DPF Indicator Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5
The DPF Indicator is also available via J1939 as shown below.

Function	PGN	SPN	Byte	Start bit	Length	Applicable States
Diesel Particulate Filter Lamp Command	FD7C	3697	1	1	3	Off = 000
						On = 001
						Flash (1 Hz) = 100

						Fast Flash (2 Hz) = 101

Table 11.12

11.4.12 Regeneration Active Lamp

11.4.12.1 Regeneration Active Lamp Operation

The Regeneration Active Lamp can be used by OEMs that wish to display to the operator when the DPF Regeneration is active. This lamp indicates that the exhaust system **may** be hotter than normal, but this will depend heavily on the design of the machine tailpipe.

11.4.12.2 Regeneration Active Lamp Configuration

The Regeneration Active Lamp is an optional fit item, unless the Inhibit Switch is installed in which case it is mandatory. There is no specific configuration necessary for the Regeneration Active Lamp. It can be either Hardwired or displayed through the J1939 Network.

11.4.12.3 Regeneration Active Lamp Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5
The Regen Active Lamp is also available via J1939 as shown below.

Function	PGN	SPN	Byte	Start bit	Length	Applicable States
Aftertreatment Diesel Particulate Filter Active Regeneration Status	FD7C	3700	2	3	2	Not Active = 00
						Active = 01
						Regen Needed = 10

Table 11.13

11.4.13 Regeneration Inhibit Lamp

The ECU has the ability to display a lamp when the Regeneration of the Aftertreatment system is inhibited. This lamp is mandatory if the Regeneration Inhibit Switch is installed, otherwise it is not required. The Inhibit Switch is only required for certain applications, please **consult Section 13.3 for details**.

11.4.13.1 Regeneration Inhibit Lamp Configuration

There is no specific configuration necessary for the Regeneration Inhibit Lamp. It can be either Hardwired or displayed through the J1939 Network.

11.4.13.2 Inhibit Lamp Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5
The Regen Inhibited Lamp is also available via J1939 as shown below.

Function	PGN	SPN	Byte	Start bit	Length	Applicable States
Diesel Particulate Filter Active Regeneration Inhibited Due to Inhibit Switch	FD7C	3703	3	3	2	00 = Not Inhibited
						01 = Inhibited

Table 11.14

11.4.14 Engine Running Output Indicator

11.4.14.1 Engine Running Output Indicator Operation

The engine running feature shall switch an ECU output when the engine speed reaches a configurable speed threshold in the engine software. The purpose of this output is to indicate engine state for machine control systems.

11.4.14.2 Engine Running Output Indicator Configuration

The Engine Running Output lamp is an optional fit item. There is some specific configuration necessary for this indicator when it needs to be turned ON and at what engine speed. The configuration are expained in the chapter about the Running Output Feature.

11.4.14.3 Engine Running Output Indicator Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5
The Engine Running Output Indicator is also available via J1939 as shown below.

PGN #	PGN Description	SPN #	SPN Description
64914	Engine Operating Information (EOI)	3543	Engine Operating State
			Bit State 0000 = Engine Stopped Bit State 0100 = Running

Table 11.15

12.0 Engine & Aftertreatment Monitoring System

The engine control system is designed to monitor each engine and aftertreatment sensor / actuator and react to system critical or emissions critical failures. When a system error occurs such as high engine coolant temperature the engine monitoring system reacts by raising the appropriate engine diagnostic level and in some cases forces the engine into a derate condition or controlled shutdown.
It is recognized that for some applications a control system induced engine shutdown or derate could cause safety concerns or auxiliary equipment damage and for these reasons the engine response can be configured.
The engine monitoring system has been re-developed from the C4.4 Tier 4 Final platform to provide more configurability, as shown in the following Section.
Note: Due to emissions regulation some emissions critical diagnostics have fixed engine-response criteria, which is non-configurable. These conditions are shown in section 12.3.2.

12.1 Monitoring Levels

There are three configurable Engine Monitoring options available within the engine software. These options determine the engines response to the activation of a parameters severity level. The three available options are;

- Warning (Always active)
- Derate
- Shutdown

Engine warning is always active and cannot be disabled. The derate and shutdown parameters can however be enabled or disabled using the service tool as shown in the table below.

12.1.1 Monitoring Mode – ET Configurable Parameters

Warning (Level 1)

The Engine Monitoring warning is always active and cannot be disabled. Activation of this Engine monitoring option ensures that upon the engine measuring an engine parameter above the configurable threshold level a warning is triggered (Event Code), which is logged by the engine ECU and the appropriate lamp driver is activated.

De-rate (Level 2)

Each monitored parameter that uses the derate function has its own derate trigger threshold and map. If the derate threshold is equaled or exceeded by any parameter, a derate protection will be set active and the engine will derate. The ECU will log these events and turn on the appropriate lamp driver. The level of engine % derate will vary depending upon the parameter being monitored. A derate is only initialized when a severity level 2 is raised.

Shutdown (Level 3)

The engine shutdown indication lamp driver will be triggered when any parameter equals or exceeds its shutdown threshold for a time exceeding its shutdown indication guard time. Physical engine shutdown will occur only if enabled by the configurable parameter. The ECU will log these events and turn on the appropriate lamp driver. A Shutdown function will only operate once a severity level 3 is raised.

12.1.2 Parameter Severity Levels

The monitoring system provides up to three possible severity levels for each of the configurable system parameters. The level of severity is displayed upon activation of the parameter Event code for example. Engine coolant temperature severity level 1 is exceeded. Upon activation an Event code is generated in this case E361-1. The –1 part of the code signals that a severity level 1 threshold has been exceeded. If a level 2 is raised then the same event code is raised but with a –2.

The levels available for each parameter are set within software and cannot be changed. Whilst the number of levels are not configurable each available level is designed to offer an increased level of action by the engine once a threshold for the monitored parameter has been set. Some engine parameters enable the customer to directly configure the thresholds at which these conditions are activated and others are fixed.

12.1.3 Monitoring System Configurable Parameters

The table below details the Monitoring system parameters that are available for configuration by the customer.

	Level	State	Trip Point	Trip Point Range	Default Delay Time	Delay Time Range	Eng Speed Threshold	Default Startup Delay (s)	Startup Delay Range (s)
High Air Inlet Diff	1	Always ON	Switch	N/A	4	4	1400	0	0
	2	Always ON	Switch	N/A	30	30	1400	0	0
High Aux Press	1	Always ON	250kPa	0 - 3150	4	4 - 60	N/A	0	0
	2	ON / OFF	500kPa	0 - 3150	4	4 - 60	N/A	0	0
	3	ON / OFF	1000kPa	0 - 3150	4	4 - 60	N/A	0	0
High Aux Temp	1	Always ON	105	0 - 145	4	4 - 60	N/A	120	0 - 180
	2	ON / OFF	106	0 - 145	4	4 - 60	N/A	120	0 - 180
	3	ON / OFF	107	0 - 145	4	4 - 60	N/A	120	0 - 180
Low Coolant Level	1	Always ON	Switch	N/A	10	10	N/A	N/A	N/A
	2	Always ON	Switch	N/A	30	30	N/A	N/A	N/A
	3	ON / OFF	Switch	N/A	60	60	N/A	N/A	N/A
Low Oil Level	1	Always ON	Switch	N/A	2	2	N/A	N/A	N/A
	2	Always ON	Switch	N/A	3	3	N/A	N/A	N/A
	3	ON / OFF	Switch	N/A	12	12	N/A	N/A	N/A

Table 12.1 Available Engine Monitoring System Parameters

The following table shows an **example** of other monitoring system parameters that can be configured. Please note though that the values below are examples and will change depending on the Engine Hardware e.g. default settings for overspeed are depenant on the rated speed.

	Level	State	Trip Point	Trip Point Range	Default Delay Time	Delay Time Range	Eng Speed Threshold	Default Startup Delay (s)	Startup Delay Range (s)
Engine Overspeed	1	Always ON	3000	2600 - 3000	0	0	N/A	0	0
	3	ON / OFF	3000	2600 - 3000	0	0	N/A	0	0
High Coolant Temp	1	Always ON	109*	85 – 109*	5	1 – 60	N/A	N/A	N/A

	2	ON / OFF	111*	86 – 111*	5	1 – 60	N/A	N/A	N/A
	3	ON / OFF	114*	87 – 114*	5	1 - 60	N/A	N/A	N/A
High Intake Manifold Temp	1	Always ON	55	40 – 105	4	1 - 120	N/A	N/A	180
	2	ON / OFF	99	40 – 107	4	1 – 120	N/A	N/A	180
	3	ON / OFF	105	40 - 110	10	1 - 120	N/A	N/A	180

Table 12.2 Example Engine-dependent Monitoring System Parameters

*Coolant temp trip points above are for a 108degC top tank temperature. If a 112degC top tank temperature flash file is uesd, the trip points and max range values will all be 4deg higher.

12.2 Non Emissions Critical Component Monitoring & Protection

All of the monitoring parameters in the section below are driven by core engine sensors and some cannot be deactivated. Where Level 2 (moderate severity) limits are configured the associated torque derate is listed.

12.2.1 Coolant Temperature

12.2.1.1 Coolant Temperature Monitoring Mode Operation

The high engine coolant temperature monitoring mode is configured to indicate to the operator that the engine coolant temperature has exceed a pre-determined threshold. The configuration of these thresholds can be adjusted by the user to determine when a Severity Level 1, 2 and 3 is activated. The table below shows the default configuration for this mode assuming a 108°C Top Tank Temperature is chosen.

Parameter	Temp °C	Torque De-rate %
Severity L1	109	0
Severity L2	111	12.5
	112	25
	113	37.5
Severity L3	114	50
	115	50
	116	50

Table 12.3 Coolant Temperature Monitoring Mode Derate Operation

Once the engine ECU detects that the engine coolant temperature has exceeded one or more of the defined threshold limits a corresponding event code is raised as shown below.

Service Tool Description	J1939 Description	Status	SPN (J1939)	FMI (J1939)	Event Code	Engine Action (If Enabled)
High Engine Coolant Temperature	Engine Coolant Temperature	Severity L1	110	15	E361-1	Warning Lamp Only
		Severity L2	110	16	E361-2	Engine % Derate
		Severity L3	110	00	E361-3	Engine Shutdown

Table 12.4 Coolant Temperature Monitoring

12.2.1.2 Coolant Temperature Monitoring Mode Configuration

See Section 12.1.3.

12.2.1.3 Coolant Temperature Monitoring Mode Installation

No installation is required for the engine coolant temperature monitoring function.

12.2.2 Engine Oil Pressure

12.2.2.1 Engine Oil Pressure Monitoring Mode Operation

Engine oil pressure is automatically monitored by the engine ECU to protect the engine from operating without sufficient oil pressure, as low oil pressure could lead to catastrophic engine failure. If the Oil Pressure switch closes when the engine is running the engine will raise an appropriate event code and take appropriate action. The table below shows the oil pressure trigger levels for each monitoring mode configuration.

Parameter	Trigger Delay time (sec)	Engine derated by % torque	Heal Trigger debounce time (sec)
Severity L3	2	50	20

Table 12.5 Oil Pressure Monitoring Mode Derate Operation

Service Tool Description	J1939 Description	Status	SPN (J1939)	FMI (J1939)	Event Code	Engine Action (If enabled)
Low Engine Oil Pressure	Engine Oil Pressure	Severity L3	100	01	E360-3	Engine Shutdown

Table 12.6 Oil Pressure Monitoring

12.2.2.2 Engine Oil Pressure Monitoring Mode Configuration

The low engine oil pressure monitoring mode is a factory set monitoring mode, which has fixed thresholds that cannot be adjusted.

12.2.2.3 Engine Oil Pressure Monitoring Mode Installation

No installation is required for the engine oil pressure monitoring function.

12.2.3 Intake Manifold Temperature

12.2.3.1 Intake Manifold Temperature Monitoring Mode Operation

The engine intake manifold air temperature is monitored by the engine management system to ensure that the engine remains emissions compliant when high intake manifold temperatures are measured.

Parameter	Temp °C	Engine derated by % torque
Severity L1	55	0
Severity L2	99	0
	100	10
	101	15
	102	20
	103	25

Table 12.7 Example of Intake Manifold Temperature Monitoring Mode Derate Operation

Once the engine ECU detects that the engine intake manifold air temperature has exceeded one or more of the defined threshold limits a corresponding event code is raised as shown below.

Service Tool Description	J1939 Description	Status	SPN (J1939)	FMI (J1939)	Event Code	Engine Action (If Enabled)
High Intake Manifold Air Temperature	Intake Manifold Air Temperature	Severity L1	105	15	E539-1	Warning Lamp Only
		Severity L2	105	16	E539-2	Engine Derate
		Severity L3	105	0	E539-3	Engine Shutdown

Table 12.8 Intake Manifold Temperature Monitoring

12.2.3.2 Intake Manifold Temperature Monitoring Mode Configuration

See Section 12.1.3.

12.2.3.3 Intake Manifold Temperature Monitoring Mode Installation

No installation is required for the engine intake manifold temperature monitoring function.

12.3 Emissions Critical Components Monitoring & Protection

TIER 4 Final / Stage V / China NR4 emissions regulations for both EU and EPA engine sales, stipulate that the use of operator inducements are mandatory for all SCR equipped non-road engines. The term inducement covers any action intended to alert / prompt the operator of a machine to repair or perform maintenance on the emissions control system. Examples of inducements and use of engine warning indicators, engine torque / power derates and engine speed limiting etc. The China NR4 regulations have additional inducement requirements specifically for the DPF system known as Particulate Control Diagnostics (PCD.)

12.3.1 Inducement Strategy High Level Overview

The C3.6L Tier 4 Final/Stage V / China NR4 engine inducement strategy can be divided into four distinct escalation sections;

1. Warning indicators
2. Specific fault messages
3. Engine Power Derates, and Engine Speed Derate
4. Final engine inducement strategies including force engine idle down or shutdown.

The areas of the emissions system covered by the legislation and therefore form part of the specific inducement strategy are:

1. Low DEF Level – Only for Engines >56kW
2. Poor DEF Quality (Q) – Only for Engines >56kW
3. Dosing Interruption (D) – Only for Engines >56kW
4. System Tampering (T)
5. Impeded NRS (E)
6. PCD Related Faults (PCD)

Whilst the requirement for specific Inducement strategies relating to the engine emissions system are required by both the EU and EPA, the mandatory implementation requirements for each legislation do vary. For this reason Caterpillar has implemented a combined inducement strategy, which meets both emissions standards. For China NR4 Inducement strategy, please refer to **Section 12.3.8**

12.3.2 Combined EU / EPA Inducement Strategy Operation

The combined EU/EPA Inducement strategy can be segmented into specific responses for;

1. DEF Quality, Tampering and Dosing Interruption
2. Impeded NRS
3. Low DEF Level

In the event of one or more of these conditions becoming active the engine control system will raise an engine diagnostic or event code for the specific item or system causing the problem. In addition to this diagnostic code the engine will also raise further codes to indicate that the inducement strategy has been operated. The initial diagnostic / event code is designed to activate the engine warning indicator as with all engine related problems. The second set of codes are responsible for activation of the operator inducement strategy as described in sections below.

Inducement escalation codes applicable to sections 12.3.2.2 and 12.3.2.3.

- **5246-15** – Aftertreatment SCR Operator Inducement Severity High – Least Severe (Level 1)
- **5246-16** - Aftertreatment SCR Operator Inducement Severity High – Moderate Severity (Level 2)
- **5246-0** - Aftertreatment SCR Operator Inducement Severity High – Most Severe (Level 3)

Inducement escalation codes applicable to section 12.3.2.1

- **1761-17** – Catalyst Tank Level Low – Least Severe (Level 1)
- **1761-18** – Catalyst Tank Level Low – Moderate Severity (Level 2)
- **1761-1** - Catalyst Tank Level Low – Most Severe (Level 3)

12.3.2.1 Inducement - Low DEF Level – Only for Engines >56kW

	Low DEF Level										
	Warning Indicator	Protect Indicator	Stop Indicator	DEF Level indicator	Emission Systems Failure Indicator	DEF Level %	Escalation Time	Engine Power available	Engine speed available	Derate Ramp Time	Comments
WCI 0	Off	Off	Off	Solid	Off	< 20	0 minutes	100%	100%	-	Low DEF indication activated.
WCI 1	Solid	Off	Off	Solid	Solid	< 13.5	0 minutes	100%	100%	-	Low DEF Indication escalated with Level 1 Inducement
WCI 2	Slow flash	Slow flash	Off	Solid	Slow Flash	< 7.5 (RT) 0 (RP)	0 minutes	100% (RT) 75% (RP)	100%	N/A (RT) 10 minutes (RP)	Level 2 Inducement activated RT = Reduced Time (Mild) RP = Reduce Performance (Severe)
WCI 3	Fast Flash	Fast Flash	Solid	Solid	Fast Flash	< 3 (RT) 0 + DEF pressure low (RP)	0 minutes	50%	0%	-	Level 3 inducement activated Engine derate by 50% torque then 5 minutes cool down before Shutdown OR Idle

Table 12.9

12.3.2.2 Inducement - Technical SCR System Failure

	Technical SCR System Failure								
	Warning Indicator	Stop Indicator	Emission Systems Failure Indicator	Escalation Time 1st Occurence	Escalation Time Repeated Occurence	Engine Power available	Engine speed available	Derate Ramp Time	Comments
WCI 0	Off	Off	Off	0 minutes	0 minutes	100%	100%	-	Normal Operation
WCI 1	Solid	Off	Solid	150 minutes	5 minutes	100%	100%	-	level 1 inducement active.
WCI 2	Slow flash	Off	Slow Flash	220 minutes	10 minutes	100%	100%	- (Mild) 10 minutes (Severe)	Level 2 inducement active.
WCI 3	Fast Flash	Off	Fast Flash	Until Fault Heals	Until Fault Heals	50%	100%	5 minutes	Level 3 inducement actived 5 minutes cool down, Engine derate by 50% torque then Shutdown OR Idle

Table 12.10

Note: Safe Harbor will be activated for 20minutes by first key cycle after Inducement Level 3

12.3.2.3 Inducement – Impeded NRS Inducement strategy

	Impeded NRS								
	Warning Indicator	Stop Indicator	Emission Systems Failure Indicator	Escalation Time 1st Occurrence	Escalation Time Repeated Occurrence	Engine Power available	Engine speed available	Derate Ramp Time	Comments
WCI 0	Off	Off	Solid	0 minutes	0 minutes	100%	100%	-	Normal Operation
WCI 1	Slow flash	Off	Solid	35 hours	48 minutes	100%	100%	-	level 1 inducement active.
WCI 2	Fast Flash	Off	Slow Flash	36 hours	108 minutes	100%	100%	-	Level 2 inducement active.
WCI 3	Fast Flash	Solid	Fash Flash	Until Fault Heals	Until Fault Heals	50%	100%	5 minutes	Level 3 inducement actived 5 minutes cool down, Engine derate by 50% torque then Shutdown OR Idle

Table 12.11

Note: Safe Harbor will be activated for 20minutes by first key cycle after Inducement Level 3

12.3.3 Combined EU/EPA Inducement Strategy Configuration

There are two configurable options provided in order for the operation of the Inducement strategy to be tailored to a particular machine types needs. These options are listed below.

Note: only the reduced performance option is available on C3.6EA engine.

- Reduced Time or Reduced Performance (only applies to DEF Level Inducements)
- Level 3 Inducement Idle Down or Engine shutdown (applies to all Inducements)

Both items are made available for configuration via the Caterpillar Electronic Technician service tool.

12.3.3.1 Reduced Time or Performance

Selectable option applies to the DEF level inducements only. In this case selecting the Reduced Time Option will increase the DEF level (remaining useable DEF) at which a final Level 3 inducement occurs. This option

therefore leads to a level 3 Inducement event being raised in reduced time when compared to the second option Reduced Performance.
Selecting Reduced Performance will apply an engine Torque derate of 50% once the DEF level is below 1%. The level 3 Inducement will be triggered when the DEF level is less than 1% and a loss of DEF system pressure event is raised.
Options are configurable using ET from the main engine configuration screen as shown below.

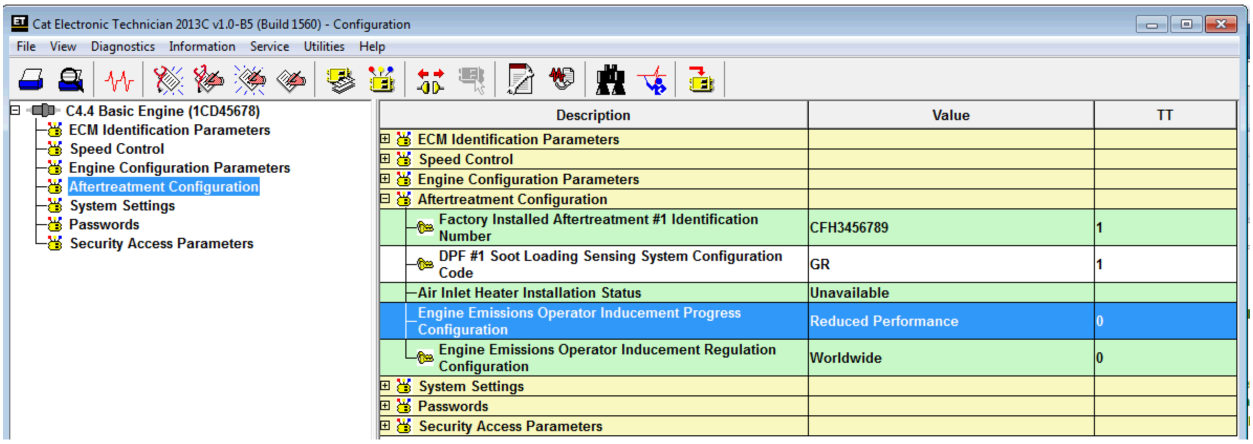


Figure 12.12

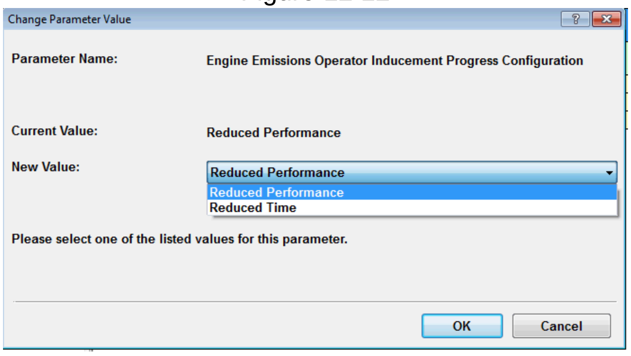


Figure 12.13 Inducement Reduced Time / Performance Configuration

12.3.3.2 Level 3 Engine Idle Down or Shutdown

The Engine Idle Down or Shutdown option provides configurability of the engine response once a L3 Inducement has been activated. This can be configured in the Service Tool under the Operator Final Inducement Action.

12.3.4 Repeat Occurrence and Final Inducement Handling

Both Tier 4 Final / Stage V and China NR4 emissions standards require specific system reactions to repeat occurrences and persistent failure of an emissions critical component or system. These requirements are covered within the Caterpillar World Wide inducement strategy as detailed in the following sections.

12.3.4.1 Final Inducement handling

In the event of an emissions system fault reaching a Level 3 severity the following actions will take place;

- Level 3 criteria must be active for 20sec before any Inducement is activated.
- After 20sec the engine will proceed to the selected level 3 inducement i.e. one of the following;
  - 5-min cool down at low idle / Available Torque reduced by 50% then shutdown,
  or
  - Idle only operation at no load.

12.3.4.2 Repeat Fault Occurrence Handling

For all emission critical failures covered by the inducement strategy other than DEF level, there is a requirement for repeat occurrences of faults to be monitored.
To meet the legislation requirements Caterpillar engines will monitor for a repeat occurrence of a fault for 40hrs after the fault condition is healed. If a system fault occurs in the same category within 40hrs the times for warning and inducements will be reduced (indicated by the Inducement Time Repeat Occurrence column)

12.3.5 Final Inducement Safe Harbor Mode

Safe Harbor mode is a mode of operation that allows for full engine torque capability post Inducement Level 3 activation for a limited time period. This strategy is designed to allow a machine that has been forced to low idle or shutdown due to a system failure causing a Level 3 inducement to be moved to an area where re work can take place.
Once the final inducement has been completed (section 12.3.4.1) the first ignition key switch cycle after this event will enable the safe Harbor strategy. Once active the following applies;

- Strategy is active for 20 minutes only and timer is **NOT** reset by cycling the ignition key switch.
- During the 20 minutes of safe Harbor mode the engine can be turned off and re started as many times as required
- During the 20 minutes of safe Harbor mode the engine will revert to a Level 2 inducement.
- After 20 minutes the engine will revert back to Level 3 inducement handling i.e. 5 min cooldown at Low idle with 50% Torque reduction then shutdown or idle.

Note: Safe Harbor mode does not apply to DEF Level Inducements.

12.3.6 Engine First Fit Inducement Activation

To ensure Inducement diagnostics are not false triggered during machine assembly the C3.6L product range is shipped with Inducements disabled. No ET configuration is required to enable the engine inducements once machine assembly has been completed. The automatic enablement of the Inducement strategy is based on either of the following criteria being met.

- Engine running exceeds 25hrs (initiated from first engine start and does not reset on key cycle)
- System has been detected (by Engine control system) as fault free for 2hrs of engine running time.

12.3.7 Emergency Inducement Override

12.3.8 Emergency Inducement Override Strategy

The US EPA and EU require the limiting of engine speed and/or power (derate) in certain conditions, to help ensure proper functioning of the engine’s emission control system. The limitation of the engine’s speed and/or power are described in the 1200J electronic A&I manual. The EU and EPA allows the temporary disabling of these limits (restoration of full engine speed and power capability) during a qualified emergency situation. A qualified emergency situation is defined as a significant direct or indirect risk to human life. Below are examples of direct verses indirect risks.

Direct - An emission controls condition that inhibits performance of an engine being used to rescue a person from life-threatening situation.

Indirect - An emission controls condition that inhibits performance of an engine being used to provide electrical power to a data centre that routes 911 emergency response communications.

The feature is only to be used on stationary off-highway applications. The emissions-related derates can be disabled for up to 120 hours of engine operation. The override must be paused by the operator if the emergency ends before the 120 hours of operation has expired. While paused, the equipment will be subject to derates.

When the 120 hours of operation with inducements overridden elapses, the feature will be disabled automatically. If emergency inducement overrides are still required, then the feature must be re-enabled to allow another 120 hours of override operation.

12.3.8.1 Emergency Inducement Override Enablement

- Use of the Emergency Inducement Override feature requires Applications Approval

To enable the feature Factory passwords will be required and so the feature can only be enabled in the field by an authorized Perkins Distributor. The feature can also be enabled at the factory prior to shipment for direct OEM engine sales.

The emissions regulatory bodies require that all instances of this feature being used are recorded by the engine manufacturer. Therefore, Perkins requires that any Perkins Distributor or OEM wishing to use this feature contact the local Applications Engineering team so that a PR/NORF can be raised to capture the details of the proposed application.

Once the PR/NORF has been reviewed by the Applications team and Emissions, Regulation and Compliance team the Distributor/OEM will be informed if the application has been approved to enable this feature.

Enabling the Override with the Perkins EST Tool:

1. Go to “Configuration Parameters”.
2. Select “Aftertreatment Configuration”.

Description	Value	TT
ECM Identification Parameters		
Speed Control		
Engine Configuration Parameters		
Aftertreatment Configuration		
Operator Inducement Progress Configuration	Reduced Performance	0
Operator Inducement Regulation Configuration	Worldwide	0
Operator Inducement Emergency Override Enable Status	Enabled	1
Operator Inducement Emergency Override Activation	Not Activated	2
Delayed Engine Shutdown Aftertreatment Gas Temperature Threshold	572.0 Deg F	0
System Settings		
Passwords		
Security Access Parameters		

Figure 12.14

3. Select “Operator Inducement Emergency Enable Status” and choose “Enabled.”

4. To complete this configuration Factory Passwords will be requested via a pop-up window. Input the passwords obtained from DSN following the approval of the NORF raised to allow use of the feature.

12.3.8.2 Emergency Inducement Override Activation

Once enabled, the feature can be activated through the Perkins EST tool.

The feature can also be activated through a switched to Battery ECM input, J1-78

Improper use of the override, failure to pause/deactivate the override when the emergency has ended, and failure to report use of the override is prohibited under federal regulations and subject to penalties imposed by the emission regulatory bodies.

Setting the Override with the Perkins EST Tool:

1. Go to “Configuration Parameters”.
2. Select “Aftertreatment Configuration”.

Description	Value	TT
ECM Identification Parameters		
Speed Control		
Engine Configuration Parameters		
Aftertreatment Configuration		
Operator Inducement Progress Configuration	Reduced Performance	0
Operator Inducement Regulation Configuration	Worldwide	0
Operator Inducement Emergency Override Enable Status	Enabled	1
Operator Inducement Emergency Override Activation	Not Activated	2
Delayed Engine Shutdown Aftertreatment Gas Temperature Threshold	572.0 Deg F	0
System Settings		
Passwords		
Security Access Parameters		

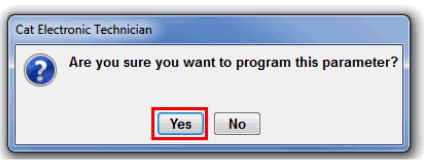
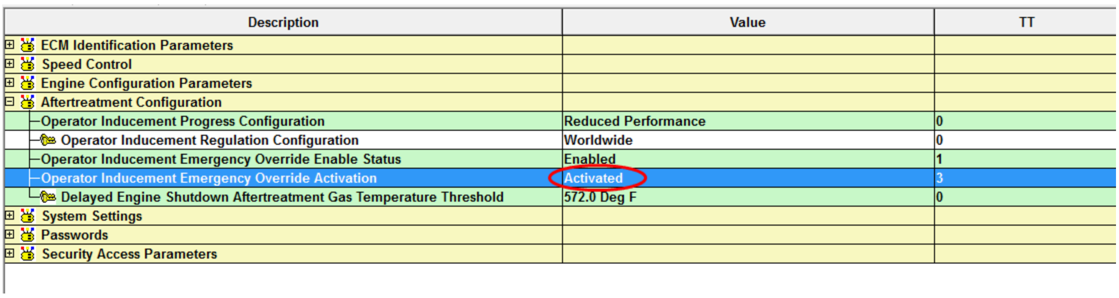


Figure 12.15

3. Select “Operator Inducement Emergency Override Activation” to activate the override.
4. The “Value” field should switch to “Activated”.
(To pause override, simply change the “Value” field back to “Not Activated”)



Description	Value	TT
⊞ ECM Identification Parameters		
⊞ Speed Control		
⊞ Engine Configuration Parameters		
⊟ Aftertreatment Configuration		
Operator Inducement Progress Configuration	Reduced Performance	0
Operator Inducement Regulation Configuration	Worldwide	0
Operator Inducement Emergency Override Enable Status	Enabled	1
Operator Inducement Emergency Override Activation	Activated	3
Delayed Engine Shutdown Aftertreatment Gas Temperature Threshold	572.0 Deg F	0
⊞ System Settings		
⊞ Passwords		
⊞ Security Access Parameters		

Figure 12.16

12.3.9 China NR4 Inducement Strategy Operation

The inducement strategy can be segmented into specific responses for;

- Impeded EGR
- PCD Related Faults (PCD is for China NR4 only)

In the event of one or more of these conditions becoming active the engine control system will raise an engine diagnostic or event code for the specific item or system causing the problem. In addition to this diagnostic code the engine will also raise further codes to indicate that the inducement strategy has been operated. The initial Diagnostic / event code is designed to activate the engine warning indicator as with all engine related problems. The second set of codes are responsible for activation of the operator inducement strategy as described in sections 12.3.8.1.

China NR4 Inducements escalation codes, applicable to **Section 12.3.8.1**

- 5826-15 – Emission Control System Operator Inducement Severity High – Least Severe (Level 1)
- 5826-16 – Emission Control System Operator Inducement Severity High – Moderate Severity (Level 2)

Specific PCD Inducements for China NR4 engines that will trigger the inducement escalation in **Section 12.3.8.1**

- High Soot Load – Most Severe (3)
- Aftertreatment Temperature sensors’ diagnostic fault
- DPF Abs & dP Pressure sensor faults
- High DPF Diferrential pressure
- Low DPF Differnetial pressure

12.3.8.1 China NR4 Reduce Performance Inducement - Impeded NRS & PCD Related Faults Inducement strategy

	Normal Operation	Level 1	Level 2	Safe Harbor
Inducement Time 1st Occurrence	Until Fault	36hrs	Mild: 64hrs Severe: Until Faults heals	30mins(x3) Initiated by first key cycle after Level 2 Severe
Inducement Time Repeat Occurrence	Until Fault	N/A	Mild: 5hrs Severe: Until Fault Heals	30mins(x3) Initiated by first key cycle after Level 2 Severe
Inducement	None	None	Mild: ≤ 75% Torque* Severe: ≤ 50% Torque** Greater of 47% speed, 1000rpm, or low idle	None
Notification	None	 Emissions System Failure Lamp On	 Emissions System Failure Lamp Slow Flash	 Emissions System Failure Lamp Slow Flash

12.3.8.2 Repeat Faults Occurrence Handling for China NR4
For all emission critical failures covered by the inducement strategy other than DEF level, there is a requirement for repeat occurrences of faults to be monitored.

To meet the legislation requirements Perkins engines will monitor for a repeat occurrence of a fault for 40hrs after the fault condition is healed. If all faults in a category self-heal or are cleared during Level 2 Severe, and any other fault in the same category occurs before the fault-free timer reaches 40 hours, it is treated as a repeat occurrence. In that case, the inducement timer resets, the fault-free timer resets, and the occurrence counter increments. The permitted inducement time for two-stage inducement system (reduced performance configuration) are reduced for repeat occurrences If a system fault occurs in the same category within 40hrs the times for warning and inducements as shown in section 12.3.8.1.

12.3.8.3 Final Inducement Safe Harbor Mode for China NR4
Safe harbor mode is a mode of operation that allows for full engine torque capability post Inducement Level 2 Severe in reduced performance activation for a limited time period. This strategy is designed to allow a machine that has been forced to low idle or shutdown due to a system failure causing a Level 2 Severe inducement to be moved to an area where rework can take place.

Once Level 2 Severe inducement was triggered, the first ignition key switch cycle after this event will enable the safe harbor strategy. Once active the following applies.

- Strategy is active for 30 minutes only and timer is **NOT** reset by cycling the ignition key switch.

- During the 30 minutes of safe harbor mode the engine can be turned off and re started as many times as required.
- After 30 minutes for 3 times, the engine will revert back to Level 2 severe, Level 2 severe inducement handling i.e.

12.3.8.4 Engine First Fit Inducement Activation for China NR4

To ensure Inducement diagnostics are not false triggered during machine assembly, the 904 3.6L product range is shipped with Inducements disabled. No EST configuration is required to enable the engine inducements once machine assembly has been completed. The automatic enablement of the Inducement strategy is based on either of the following criteria being met.

- Engine running exceeds 25hrs (initiated from first engine start and does not reset on key cycle)
- System has been detected (by Engine control system) as fault free for 2hrs of engine running time

13.0 Machine Integration Consideration

13.1 Aftertreatment System Operation

The Caterpillar C3.6 product range uses various combinations of aftertreatment technologies. In each case the chosen technologies have been selected as the optimal combination to meet the Tier 4 Final/Stage V emissions standards. The table below provides details of the C3.6L product configurations.

Aftertreatment Technology			
Engine	Power kW	Aftertreatment	Aftertreatment Management Type
C3.6L ETA / C3.6EA	<56kW / 74.4 – 82kW	DOC, DPF	Passive Plus
C3.6L ETA	70kW – 100kW	DOC, DPF, SCR	Passive Plus

Table 13.1 Tier 4F/Stage V Aftertreatment Technology

13.1.1 DOC Operation

The DOC consists of a ceramic substrate coated with an oxide mixture and a catalyzing metal. The engine DOC is required to perform the following functions;

- Remove CO and HC portions of the engine exhaust gas.
- Oxidize NO to NO2 to help reactions at both the DPF and SCR.

13.1.2 DPF Operation

The Diesel particulate filter is required to capture and then remove soot particles (via oxidation) from the engine exhaust via the passive plus strategy and HC Dosing.

13.1.3 SCR Operation

The SCR unit or Selective catalyst reduction unit is required to specifically target the removal or conversion of NOx particles into N2, H2O and CO2.

13.1.4 Passive Plus Operation

The products supplied by Caterpillar fitted with a DPF require DPF management using the passive plus strategy. DPF maintenance is performed continuously throughout the engine operation without the need of any operator interaction.
The passive plus control strategy uses a combination of the intake throttle valve and NRS valve when required to help elevate engine exhaust temperatures to allow the DPF maintenance and SCR maintenance to take place.

13.1.5 Active Regeneration

As part of the DPF maintenance strategy Active Regeneration will be required every 60 hours approximately. This will vary slightly depending on the load factor and ambient weather conditions as these factors affect the efficiency of the Passive Plus Regeneration mentioned above. This regeneration will happen automatically without operator interaction in most cases as the engine can generate enough heat in the DPF whilst the engine is working.
If Active Regeneration is not possible during normal work activities the Elevated Idle Strategy will be used to help regeneration, as detailed in Section 13.1.6 below.
Engine conditions required for Active Regeneration (HC Dosing) to start:

- Coolant Temperature above 65degC
- DOC In temperature above 250degC
- Engine speed above 1200rpm (unless soot load is high in which case HC dosing will start at lower speeds given above 2 conditions are met)

To help maintain Active Regeneration during normal work cycles:

- Engine Mounted Aftertreatment should be used

- Engine Speed should remain above 1200rpm
- Ambient Temperature above -5degC

If engine speed drops below 1200rpm HC dosing will continue until DOC In temperature drops below 250degC or Coolant temp drops below 65degC.
For installations using Remote aftertreatment or operating in very cold ambient conditions maintaining HC Dosing will be more difficult due to increased temperature loss and so operators should keep engine speed and load even higher than stated above, if possible.

13.1.6 Engine Elevated Idle (Mandatory Installation)

Elevated idle must be supported on all machines as the feature is required to support operation of the engine aftertreatment thermal management and Service test procedures using Caterpillar ET. Support for this feature is required for Service Test Procedures to run and is also used to help Active DPF Regeneration in applications that cannot regenerate during normal work cycles.
Minimum criteria for Service Tests to start (Idle status to be 'idle') are:

- Actual Engine speed = Configured Low Idle Speed (as per Service Tool configuration)
- Safe state message received
    - Grounding of J2-87 **or**
    - Transmission of J1939 PGN 8500 CAB Message 2 SPN 7579=01

Further criteria for Service Tests to start can be found in the Service Test screen.

13.1.6.1 Engine Elevated Idle Operation

DPF products require the customer to provision for an elevated idle operation as part of the machine design. The activation of the elevated idle strategy will be made automatically by the engine if the operator has declared the machine is in a safe state and is used in circumstances where exhaust temperatures are below those needed for Active Regeneration to occur.

First Level

The engine will increase the engine idle speed to 1800rpm (configurable in the Service Tool) and will attempt to perform an Active Regeneration. If Regeneration did not complete the ECU may illuminate the DPF Warning lamp (see Section 13.2 for full escalation logic) and the higher elevated idle speed setting will be requested (see below.)

Second Level

If Active Regeneration fails at 1800rpm because the DOC In temperature was too cold (either due to ambient conditions or because the regen was interrupted by the operator) the engine will illuminate the DPF lamp (PGN64892, SPN3697 = 001) which indicates that the next time Elevated Idle is allowed it will increase the engine idle speed to 2000rpm (configurable in the Service Tool.)
The engine provides two mechanisms for the machine to provide permission for an engine speed elevation to take place, these are;

- The grounding of J2-87.
- The transmission of J1939 PGN 8500 CAB Message 2 SPN 7579

The engine will only elevate engine speed if machine permission is given via one of the two methods listed above and an elevated idle speed is necessary e.g. regenetration support is required. Once activated the elevated idle request will be cancelled upon any of the conditions listed below being met.

- Regeneration is completed.
- Machine removes permission using J2-87 or J1939 PGN 8500 / SPN 7579.

At any time the machine can be placed back into work regardless of the elevated idle state. The elevated idle request will remain however until a full regeneration has been completed.
Note: It is the customers responsibility to ensure permission for elevated idle is only given when the machine is in a safe condition for idle to be increased to both configured speed thresholds (See First Level and Second Level above.)

13.1.6.2 Engine Elevated Idle Configuration

In software version v1.33 and later, the Elevated Idle Input method must be configured with the Service Tool.

Configuration field names	Configuration Range	Default Configuration
Elevated Engine Speed Allowed Input Configuration	J1939 Hardwired	J1939

Table 13.2

Note: The use of <u>both</u> hardwired and J1939 elevated idle permission is <u>not</u> possible.
It is possible to configure the Elevated Idle Speeds that the engine will use, as shown below:

Configuration field names	Configuration Range	Default Configuration
Aftertreatment Regeneration Assist Engine Minimum Speed Configuration	900rpm – 2600rpm*	1200rpm
Highest Level Aftertreatment Regeneration Assist Engine Minimum Speed Configuration	800rpm – 2600rpm	2000rpm

Table 13.3

*Aftertreatment Regeneration Assist Engine Minimum Speed Configuration cannot be set low than the Configured Low Idle speed.

Configuration of the Highest Level Aftertreatment Regeneration Assist Engine Minimum Speed Configuration (default setting 2000rpm) can be done by testing the Exhaust Temperature Drop. This test will assess the temperatures in the aftertreatment system in a given ambient temperature at different engine speeds and based upon the minimum ambeint operating temp requirement for the machine, an approriate speed can be chosen that will ensure regen can complete under all conditions.

13.1.6.3 Engine Elevated Idle Installation – Hardwired Input

Please refer to the separate electrical schematics referenced in Section 2.3.5 Engine Elevated Idle is labelled as ‘Low Idle Shutdown / Machine Safe State / Work Mode’.

The implementation of this input within a machine control system is a mandatory requirement to ensure that the Aftertreatment system can maintain operation under all conditions. The OEM may connect this input via a relay controlled by the machine MCU for example, to only ground when certain conditions are met such as machine in neutral etc.

13.1.6.4 Engine Elevated Idle Installation – J1939 Input

The Engine Elevated Idle permission can be provided using the J1939 CAN bus and PGN 8500 / SPN 7579. When SPN 7579 is set to 00 the ECU interprets this as an elevated idle NOT allowed input and when set to 01 elevated idle ALLOWED.

Important

The ECM expects to see the CM2 J1939 message for Ok to Elevate Idle speed at least once per second with either Allowed (01) or Not Allowed (00) state for SPN7579.

J1939 PGN	Parameter Number	SPN reference	State	Minimum Transmission Rate
8500 CAB Message 2 (CM2)	34048	Elevated Engine Speed Allowed Switch SPN 7579	00 Not Allowed 01 Allowed 10 Error 11 Not Available	1 sec

Table 13.4

13.1.7 Machine Integration Of Elevated Idle

The integration of elevated idle feature within a customer machine using either a hardwired input or the J1939 SPN 7579 is a mandatory requirement for all machines. It is important that the customer understands fully the risks of operating an elevated idle speed during operation and controls the permission given to the engine where needed.

For some machines it will be acceptable for permanent permission to be given to the engine for elevated idle conditions when required e.g. stationary machinery. Other machines will require conditions such as machine in neutral before the engine idle speed can be elevated.

J1939 PGN	Parameter Number	SPN reference	State
FC31 Aftertreatment System Information (ASI)	64561	Aftertreatment Engine Speed Increase Request SPN 7502	00 No Request 01 Speed Control Desired 10 Speed Control Urgently Desired 11 Not Available
CF00 CONTINUOUS TORQUE & SPEED LIMIT REQUEST (CTL)	52992	Engine Speed Limit Request - Minimum Continuous SPN 1784	Engine speed value 0 to 2000rpm*
FD7C Deisel Particulate Filter Control 1	64892	Aftertreatment DPF Active Regen Status SPN3700	00 Not Active 01 Regen Active 10 Regen Needed 11 Not Available
FD7C Deisel Particulate Filter Control 1	64892	DPF Lamp Command SPN 3697	000 Off 001 On 100 Blink 1Hz 101 Fast Blink 2Hz 111 Not Available

Table 13.5 Elevated Idle Machine Integration Parameter support

***Engine Speed value in SPN1784 will be set to the desired elevated engine speed to support regeneration before the ECU receives permission to Elevate the Idle speed. This will provide options in MCU software to control when to give permission to elevate idle speed, based on the situation. When elevated idle speed is not required this value will be either 0rpm or the configured low idle speed.**

Service tests and procedures that require the machine to be safe will need the Elevated Engine Speed Allowed Input to be set to safe, these service test and procedures will not send an aftertreatment engine speed increase request (SPN7502) and therefore the machine should send safe state whenever the machine is safe.

13.1.8 Parasitic Load Request (CAN Message)

In certain machines it may be possible to increase the parasitic load on the engine even if the machine is not working. If the thermal management system requires additional Parasitic Load at Low Idle, the Engine ECU will broadcast the SPN 7503 to 01 or 10 (depending on Escalation level.)
The machine can react to message SPN7503 to increase parasitic load when requested to help maintain Active Regeneration, as discussed in Section 13.1.5. Increasing parasitic load will help to increase the exhaust temperature and so help to maintain active regeneration during a transient work cycle.
It is still **mandatory** that the elevated idle function is installed though, to enable service tests to run and in case the additional parasitic load is still too low to complete the active regeneration.
At any time the machine can be placed back into work regardless of the parasitic load request state. The request will still remain however until an Active Regeneration has been completed.
Please contact your local Applications Engineer to help integrate additional parasitic load mechanisms to understand how much additional load your application requires and to validate the system.

13.2 DPF Regeneration Control System Overview

The control system is designed to constantly perform passive regeneration to maintain the DPF performance. Every 60 hours (approximately) the DPF will require an Active Regeneration, as explained above in Section 13.1.5.

To help the system regenerate with an Active Regen the control system may request that Elevated Idle permission is given so that more heat can be generated in the aftertreatment, which will support Active Regeneration with HC Dosing, see section 13.1.6 for more details.

If the requests for Elevated Idle are ignored (requests can be seen on the J1939 CAN BUS) but for machines without a J1939 Dashboard or MCU, there will be no visibility. Instead the Elevated Idle request should be accepted by giving permission on a regular basis i.e. whenever the machine is parked up/not working.

If the aftertreatment is not able to perform a regeneration because the Elevated Idle request is never answered, the system will eventually limit the use of the engine, to encourage the user to allow a regeneration to happen.

Ignoring the need for a regeneration could result in very high soot levels accumulating in the DPF which will eventually damage the DPF. The DPF would then need to be replaced.

Figure 13.1 and Table 13.6 explain the escalation levels that the control system will go through in the event that the system is not able to regenerate.

The escalation process has been designed so that even in applications where it is impossible to sustain active regeneration during normal work cycles e.g. light load and/or very transient operation, the control system is capable of performing the regen whilst the machine is parked up.

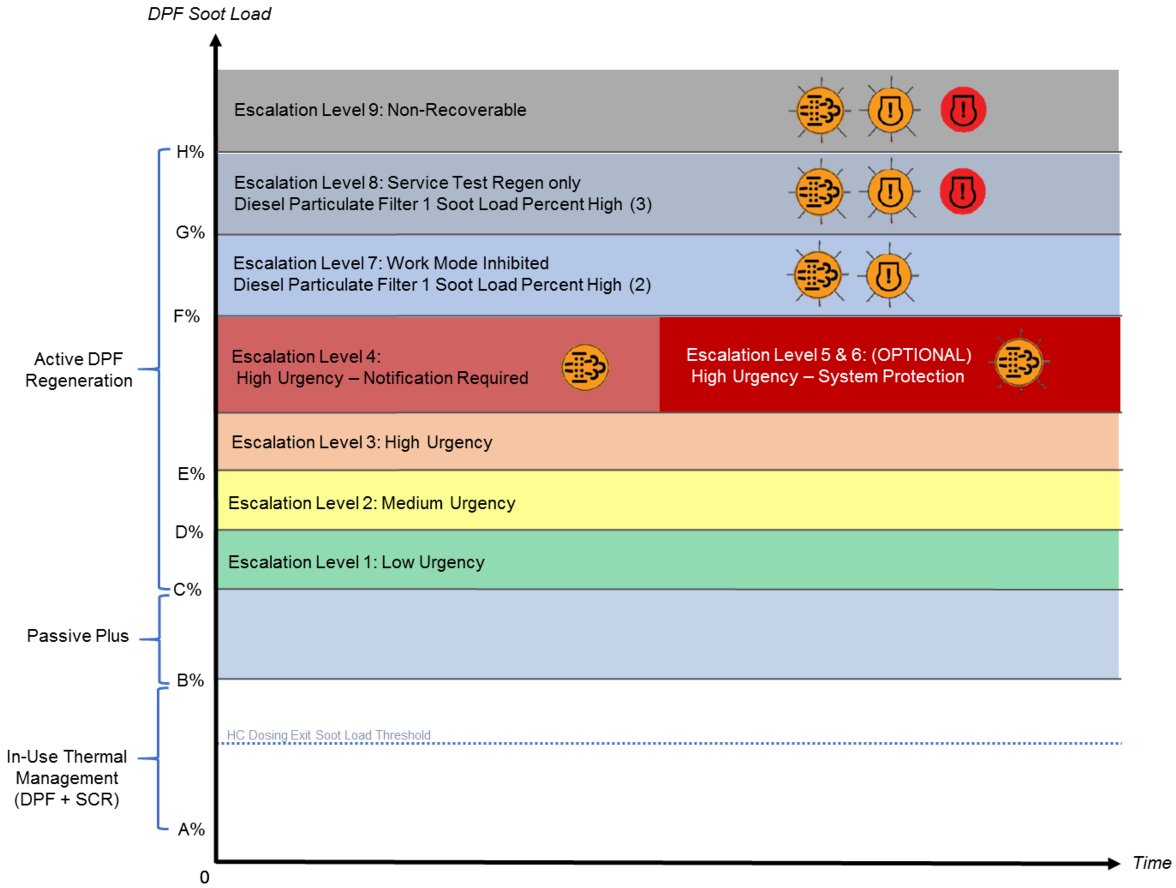
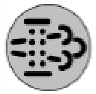
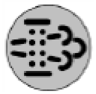
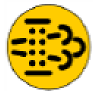
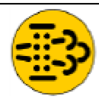
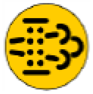
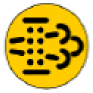
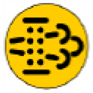


Figure 13.1 – DPF Regeneration Escalation Levels

Escalation Level	DPF Status (SPN3701)	Elevated Idle Speed Requested – SPN1784 (rpm)	Corrective Action Required	Trigger Criteria	Control System Behaviour	Lamps			Additional J1939 messages
						DPF	Warning	Shutdown	
0	000 - Regen Not Needed	N/A	N/A	Normal Operation with Passive Regen. Active Regen not required.	None	 Off SPN3697 = 000	 Off SPN624 = 00	 Off SPN623 = 00	
1	001 - Regen Needed – Lowest Level	Elevated Idle “1” Note that elevated idle will be requested only if regen has successfully started	Allow Elevated Idle / Work the machine harder	DPF Soot Load Increase OR ECU detects Active Regen has not completed in Time, T1	None	 Off SPN3697 = 000	 Off SPN624 = 00	 Off SPN623 = 00	
2	010 - Regen Needed – Moderate Level	Elevated Idle “1”	Allow Elevated Idle / Work the machine harder	DPF Soot Load Increase OR ECU detects Active Regen has not completed in Time, T2	None	 Off SPN3697 = 000	 Off SPN624 = 00	 Off SPN623 = 00	
3	011 - Regen Needed – Highest Level	Elevated Idle “1”	Allow Elevated Idle / Work the machine harder	DPF Soot Load Increase OR ECU detects Active Regen has not completed in Time, T3 *OR*	None	 Off SPN3697 = 000	 Off SPN624 = 00	 Off SPN623 = 00	

				Regen Inhibit command has been made					
4	011 - Regen Needed – Highest Level	Elevated Idle “2”	Allow Elevated Idle / Work the machine harder	DPF Soot Load Increase OR ECU detects Active Regen has not completed in Time, T4 *OR* *HCD started but failed to ignite* OR Regen Inhibit command has been made OR Engine has been shut down when Regen was urgently needed	None	 On SPN3697 = 001	 Off SPN624 = 00	 Off SPN623 = 00	
5	011 - Regen Needed – Highest Level	Elevated Idle “2”	Allow Elevated Idle / Work the machine harder	DPF Lamp has been on for 1 hour and Regen not completed	None	 1Hz Flash SPN3697 = 100	 Off SPN624 = 00	 Off SPN623 = 00	

6	011 - Regen Needed – Highest Level	Elevated Idle “2”	Allow Elevated Idle / Work the machine harder	DPF Lamp has been flashing for 1 hour and Regen not completed	Engine Speed will be locked to Low Idle Speed at key-on for 1 minute* If the machine **must** be moved in this 60s lockout then a quick key-cycle can be performed to restore speed control for a key-cycle After this 1 minute the idle speed will be elevated if permission is given. Still allowed to put the machine back into work	 2Hz Fast Flash when locked to low idle SPN3697 = 101 1Hz Flash when not locked SPN3697 = 100	 Off SPN624 = 00	 Of SPN623 = 00 f	SPN9677 = 01 when locked to low idle
7	011 - Regen Needed – Highest Level	Elevated Idle “2”	Allow Elevated Idle Machine cannot be worked any further until Regen has completed	Soot load is high	Engine Speed will be locked to Low Idle Speed at key-on* The idle speed will be elevated if permission is given to perform the regen Engine speed will ramp back to idle speed if elevated idle permission is removed. 25% torque derate active If the machine **must** be moved then a quick key-cycle can be performed to allow the machine to be used for a short time. Available torque will gradually be reduced from 75% to 0% in this mode though**	 2Hz Fast Flash when locked to low idle SPN3697 = 101 1Hz Flash when not locked SPN3697 = 100	 Flashing SPN3040 = 01	 Off SPN623 = 00	SPN9677 = 01 when locked to low idle 3719-16 high soot load moderate severity event active
8	011 - Regen Needed – Highest Level	N/A	Service Test required Elevated Idle will be	Soot load is very high	Engine Speed will be locked to Low Idle Speed at key-on until Service Test Regen has been performed.* Elevated Idle is no longer allowed.	 2Hz Fast Flash when	 Flashing SPN3040 = 01	 On SPN623 = 01	SPN9677 = 01 when locked to low idle

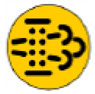
			required to support the service test		50% torque derate active If the machine **must** be moved then a quick key-cycle can be performed to allow the machine to be used for a short time. Available torque will gradually be reduced from 50% to 0% in this mode though**	locked to low idle SPN3697 = 101 1Hz Flash when not locked SPN3697 = 100			SPN3714 = 01 3719-0 high soot load most severe event active
9	011 - Regen Needed – Highest Level	N/A	Replace DPF	DPF is damaged due to high soot load and is not recoverable	Engine Speed will be permanently locked to Low Idle Speed Elevated Idle is no longer allowed. Service Test is no longer allowed If the machine **must** be moved then a quick key-cycle can be performed to allow the machine to be used for a short time. Available speed and torque will gradually be reduced to 0% in this mode though**	 2Hz Fast Flash SPN3697 = 101	 Flashing SPN3040 = 01	 On SPN623 = 01	SPN9677 = 01 when locked to low idle SPN3714 = 01 & SPN3715 = 01 3719-0 high soot load most severe event active

Table 13.6

*The introduction of a period of time locked at low idle is a new concept and is designed to alert the operator that something is wrong with the machine and the correct action should be taken. Please note that low idle speed will only ever be locked in this manner following key-on, it will not occur during machine operation.

**To account for emergency situations where the machine has been parked in an unsafe location and is locked at low idle it will be possible to override this idle lockout for a short period of time. To ensure that this strategy is not abused (used to simply avoid performing the regen) speed and torque capability will gradually be reduced until the machine is once again locked at low idle speed with no torque capability. If the engine stalls whilst it is being used after performing a quick key-cycle (due to the derate imposed) then a 7032-31 event code will be raised.

*** Elevated Idle “1” & Elevated Idle “2” are specified in 13.1.5.1. Default values are 1800RPM and 2000RPM respectively.

13.2.1 DPF Regen Escalation Configuration

It is possible to configure the ECU to avoid escalation stages 5 & 6 in the process above but this is not recommended, especially in applications that will typically have inexperienced/unfamiliar operators. Stages 5 and 6 are designed to provide the operator with a chance to complete regeneration of the aftertreatment during machine work cycles and avoid having to perform the regeneration in safe state when the machine is stationary.
It is also possible to choose the behaviour of the ECU in the scenario that the locked to low idle state has been bypassed by a quick key cycle. After a defined period of time, the ECU will either shut the engine down or lock the speed back to low idle again.

Configuration field names	Configuration Range	Default Configuration
High Soot Load Aftertreatment Protection Enable Status	Enabled Disabled	Enabled
High Soot Load Aftertreatment Protection Quick Restart Response	Shutdown Idle Down	Shutdown

Table 13.7.

13.3 Inhibit Switch and Inhibit Lamp

If the machine application has a specific requirement to work in environments where there is a risk of personnel burns (due to tailpipe design) or where flammable material is present in close proximity to the exhaust system then it is possible to fit a Regeneration Inhibit switch.
Note: This Inhibit switch **should not** be fitted to all applications as they are prone to misuse and the Regeneration system has been primarily designed to work automatically, with no operator input.

13.3.1 Inhibit Switch Operation

The inhibit switch must be a momentary switch, such that it cannot be depressed constantly. The inhibit function is designed to be a **temporary** function that is used when it would be unsafe for aftertreatment regeneration to occur.
The system is designed such that commanding an inhibit will inhibit the regeneration and in this state the Regen Inhibit lamp will be illuminated to alert the operator.
The logic in Section 13.2 will be in place whether or not the Inhibit function is also used An Inhibit command can only be made in Escalation Levels 0-5. If the Level increases from 5 or less to 6 or 7 in the same keycycle, then the inhibit request will be maintained. However if the engine is started in Level 6 or 7 an inhibit request cannot be made to stop a Regen from starting.
If Inhibit is desired but is unavailable and the engine is locked to low idle (escalation level 6) the machine should be moved to a safe location once speed control is reinstated so that a regen can be performed. The DPF lamp will have been on and then flashing for a total of 2 hours before the inhibit regen function is unavailable.
It will always be possible to cancel a regen that has started, even in the higher escalation levels, in case it is still not safe for a regen to occur, by removal of ‘Safe State’ using the ‘Safe State/Work Mode/OK to Elevate Idle’ switch.
It is possible to revoke an inhibit command by pressing the inhibit momentary switch again (or setting SPN3695 back to 00.) This will allow the DPF to regenerate again, if it is necessary and the conditions allow it to.

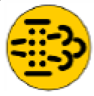
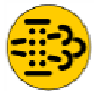
Regeneration Required?	Inhibit Status	Inhibit Active Timer	Lamps		
			Inhibit	DPF	Regen Active
Yes	Regen is Active Available	Not Applicable	 Off SPN3703 = 00	 Off SPN3697 = 000	 On SPN3700 = 01
No	Available	Until next key-cycle	 On SPN3703 = 01	 Off SPN3697 = 000	 Off SPN3700 = 10
Yes	Available	Until next key-cycle	 On SPN3703 = 01	 On SPN3697 = 001	 Off SPN3700 = 10
Yes – Urgently – Engine Speed will be locked to Low Idle for 60s at key-on	Not Available – Escalation level 6 and above	Not Allowed	 Off SPN3703 = 00	 Flash SPN3697 = 100	 Off SPN3700 = 10

Table 13.8

13.3.2 Regeneration Active Lamp Logic

If the inhibit switch function is required then a Regeneration Active lamp must also be fitted. This lamp will illuminate when an aftertreatment regeneration has started and is an **indication** of high exhaust temperatures. See the table above for the logic of this indicator combined with the use of the inhibit switch.
Installation instructions for this lamp are covered in Section 11.4.12.
Note this is not a 'HEST' lamp as it is not configured to illuminate when exhaust temperatures are above a certain threshold. Due to differences in customer machine designs the temperature of the exhaust gas at the tailpipe varies dramatically as different machines use different pipe lengths and designs e.g. use of a venturi section.
If the customer requires the lamp to illuminate at a certain temperature it is recommended that they fit a separate thermocouple switch in the exhaust system linked to a lamp which will illuminate when the specific temperature threshold is exceeded. This would then need to be linked to the dashboard for operator awareness.

13.3.3 Inhibit Switch Configuration

The Inhibit switch is not installed by default so it must be configured with the Service Tool by changing the follownig parameter in the Configuration Screen:

Configuration field names	Configuration Options	Default Configuration
Automatic Aftertreatment Regeneration Inhibit Interface Configuration	Not Installed Hardwired J1939	Not Installed

Table 13.9

13.3.4 Inhibit Switch and Lamp Installation

Using the Inhibit Switch makes the installation of the Regen Inhibit Lamp, DPF Indicator and Regeneration Active Lamp mandatory. Refer to Sections 11.4.11 and 11.4.12 for further lamp details.

13.3.4.1 Inhibit Switch

The Inhibit Regen switch should be a momentary operation switch (the switch should return to its normal state after it has been depressed) so that it is not held in the 'inhibt' state continuously.
The inhibit function can be controlled by a hardwired ECU input or by a J1939 command as follows:

Hardwired

Please refer to the separate electrical schematics referenced in Section 2.3.5

J1939

Function	PGN	SPN	Byte	Start bit	Length	Applicable States
Aftertreatment Regeneration Inhibit Switch	57344 (E000)	3695	6	1	2	00, Off = Not Inhibited 01, On = Inhibited

Table 13.10

13.3.4.2 Inhibit Lamp

Please refer to the separate electrical schematics referenced in Section 2.3.5
The Regen Inhibited Lamp is also available via J1939 as shown below.

Function	PGN	SPN	Byte	Start bit	Length	Applicable States
Diesel Particulate Filter Active Regeneration Inhibited Due to Inhibit Switch	FD7C	3703	3	3	2	00 = Not Inhibited 01 = Inhibited

Table 13.11

13.4 DPF Regen System J1939 Message Summary

Lamp Name/Purpose	ECU	J1939 Message	Available as Hardwired I/O?
Warning	Tx	SPN624 (Solid) SPN3040 (Flashing)	Yes
Shutdown	Tx	SPN623 (Solid) SPN3039 (Flashing)	Yes
DPF Loading	Tx	SPN3697	Yes
Regen Active	Tx	SPN3700	Yes
Regen Inhibited	Tx	SPN3703	Yes

Table 13.12

Information Message Name/Purpose	ECU	J1939 Message	Description	Available as Hardwired I/O?
Aftertreatment Elevated Idle Speed Required	Tx	SPN7502	Announces if the Engine needs the Idle Speed to be elevated for Regen	No
Requested Elevated Idle Speed	Tx	SPN1784	The idle speed that will be used if Safe State is declared	No
Elevated Engine Speed Allowed Switch	Rx	SPN7579	Message sent back to ECU to allow/not allow Elevated Idle - based upon machine conditions	Yes
Increased Parasitic Load Required	Tx	SPN7503	Announces if the Engine needs extra parasitic load to support Regen operation	No
Regeneration Required	Tx	SPN3701	Indicates the urgency of a regen request	No
Regen Inhibit Request	Rx	SPN3695	Request from the machine to inhibit a regeneration	Yes
Temporary Regen Lockout	Tx	SPN3714	Regen is only possible by Service Technician (Escalation Level 8)	No
Permanent Regen Lockout	Tx	SPN3715	DPF Regen can no longer be done, DPF must be replaced (Escalation Level 9)	No

Table 13.13

13.5 DEF System Purge

The DEF System must be purged of DEF on engine shutdown to protect the system components from damage due to DEF freezing. For this reason it is important that electrical power is maintained to the engine ECU and aftertreatment system after the ignition has been turned off. It is therefore important that the machine battery disconnect switch is not operated until the system purge has been completed.

13.5.1 DEF System Purge Operation

To ensure that all DEF is removed from the system prior to system shutdown (requested by the removal of the ignition signal to the ECU) a DEF purge sequence is activated. This purge procedure operates during every engine shutdown. The purge process ensures that any risks associated with the thermal expansion and contraction of freezing DEF is minimized.

The purge process is conducted by maintaining electrical power to the DEF pump post engine shutdown. To allow the purge sequence to complete, electrical power must be maintained to the DEF dosing system and to the un-switched battery connections at the engine ECU pins J1-13, J1-37 and J1-61. Engine ignition signal is not required as the purge process operates post the engine ignition OFF signal.

To prevent the purge cycle being disabled by the removal of power to the system by the use of a battery disconnect switch, it is mandatory to fit a “Wait to Disconnect” indicator locally to the battery disconnect switch. The “Wait to Disconnect” indicator operates as shown below and will remain illuminated whilst there is electrical power to the DEF system. Once the lamp turns OFF purge is complete and it is safe to use the battery disconnect switch.

The time duration for the DEF system to purge is approximately ~70 seconds, then the wait to disconnect indicator will turn OFF. The following diagram demonstrates an example for the DEF system purging and indicator turning OFF.

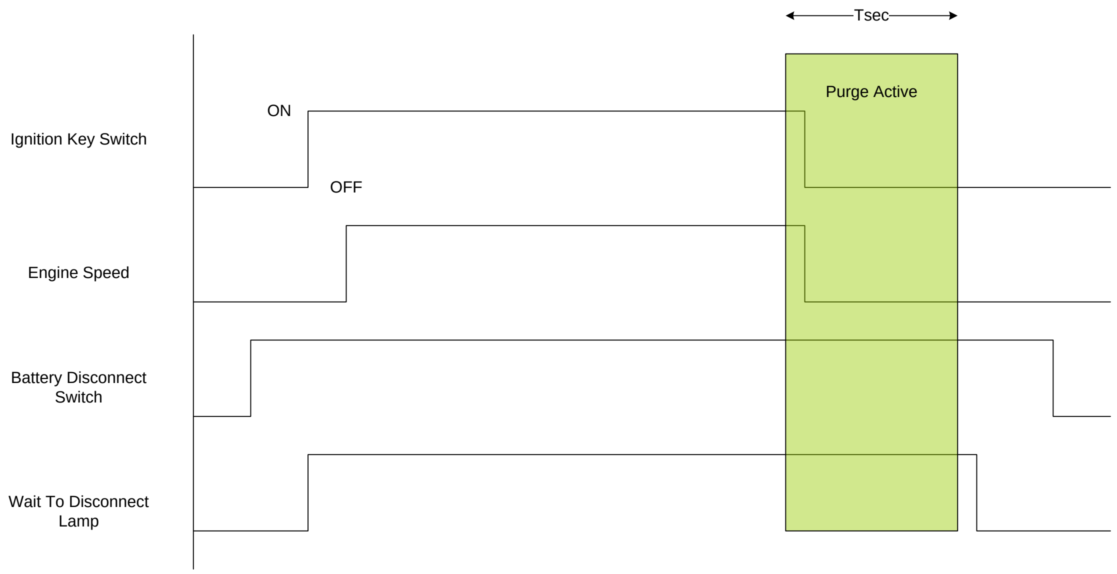


Figure 13.2

13.5.2 DEF System Purge Configuration

The DEF System purge is a mandatory feature enable in the engine software and requires no configuration via Caterpillar Electronic Technician (CAT ET).

13.5.3 DEF System Purge Installation

IThe completion of the DEF purge cycle is dependent upon main power to the engine and aftertreatment being maintained for the Max purge time of ~70 seconds.
To ensure that the operator is made aware that the system is still electrically live after the ignition key switch has been turned OFF, it is a mandatory requirement that a “Wait To Disconnect” indicator is fitted next to the machine battery disconnect switch (battery isolator switchf a wired indicator is to be used then please refer to the separate electrical schematics referenced in Section 2.3.5
In addition to the wiring shown in the figure above it is also recommended that a label is positioned next to the Wait To Disconnect indicator to ensure that the operator is informed of the lamps purpose. An example Wait To Disconnect label is shown below.

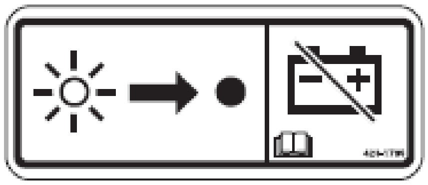


Figure 13.3 Example Label (433-9373)
For those machines using J1939 operator displays a SCR system state message transmitted by the engine ECU may be used to indicate to the operator that the system is electrically live while the system completes it purge cycle.

J1939 PGN	Parameter Number	SPN reference	State
Aftertreatment 1 SCR System State	61475	4332	0100 Purging 0111 Shutoff 1000 Diagnosis 1011 OK to Power down

Table 13.14 DEF system Purge State PGN / SPN
The method of machine implementation of SPN 4332 will depend on the position of the Wait to Disconnect Indicator (in the cab or next to the battery disconnect switch). For example an indicator within the machine cab may only want to illuminate when the ignition is OFF but the engine ECU and DEF system is still active (for

Purging). An indicator next to the machine battery however may need to be illuminated permanently while the engine ECU is live and not just during shutdown.
For this reason the C3.6 product offers the customer the ability to operate the Wait To Disconnect intwo different manner, based on the location of the Indicator.

J1939 Wait To Disconnect Indicator Control

Scenario 1 – Indicator active while ECU is LIVE. Most likely used for those customers fitting the indicator next to a battery disconnect switch.

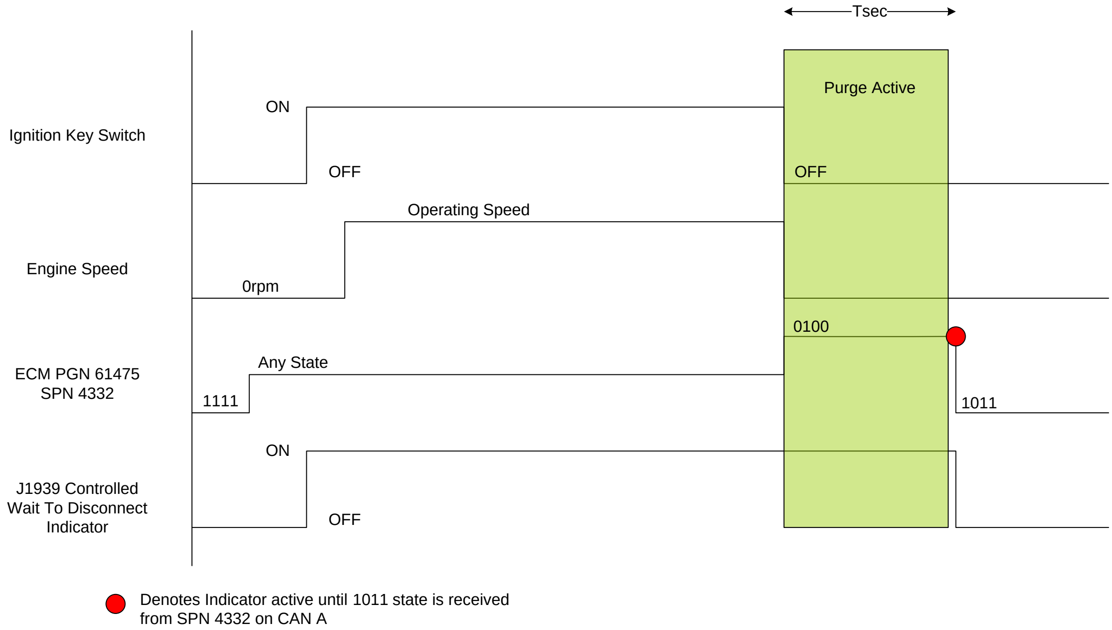


Figure 13.4 Wait To Disconnect Indicator Scenario 1

Scenario 2 – Indicator only active when ignition switch is OFF and DEF system is Purging. Most likely used for those customers fitting the Wait To Disconnect Indicator within the machine cab.

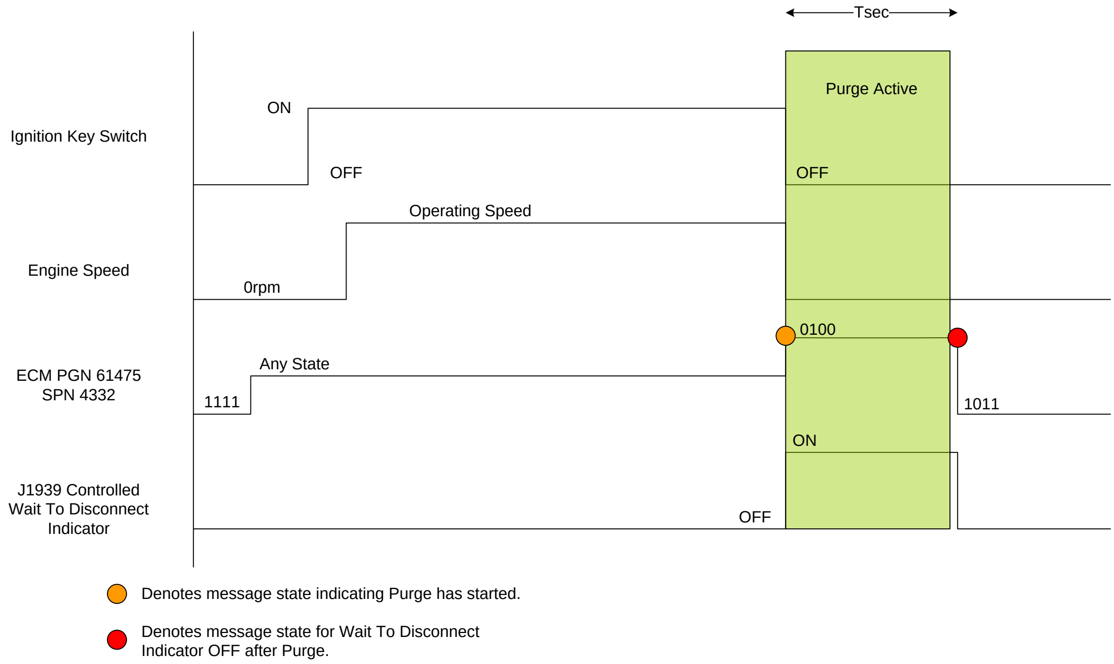


Figure 13.5 Wait To Disconnect Indicator Scenario 2

When implementing SPN 4332 any message state other than 1011 means DEF system is still electrically live. Once 1011 is received then the system is in shutdown mode. For more information on the format of PGN 61475 please refer to section 16.2 of this document.

13.6 DEF System Thaw – Only for Engines >56kW

13.6.1 DEF System Thaw Operation

DEF becomes a solid at temperatures of -11DegC and below. In order for engine out NOx levels to be controlled in cold ambient a DEF system heating or thaw strategy is used. The thaw strategy is an automatic strategy that uses main inputs from the following components;

- DEF Tank temperature
- Ambient Temperature
- DEF Pump Temperature

The DEF system thaw strategy is an engine running strategy only, using electrical heated DEF lines, and coolant heated by engine to thaw DEF tank.

13.6.2 DEF System Thaw Configuration

No configuration is required for the DEF thaw strategy to operate correctly via the Caterpillar Electronic Technician (CAT ET) service tool.

13.6.3 DEF System Thaw Installation

The DEF system requires an electrical current for the heating system to operate correctly. These Electrical currents may be required to thaw the system in cold ambient in addition to the current required to run the engine ECU and the machine system. For this reason it is important that an assessment of the engine low idle current demand is made to ensure that the chosen alternator specification can meet the total system demand. The highest electrical load on the engine is during the DEF heating stage where the DEF Heated Lines are still active (on an intermittent cycle) and the system is primed and dosing.

- Engine Coolant Diverter Valve Turns On at ~15°C and Turns Off at ~20°C.
- DEF Heated Lines Turn On at ~0°C, Turn Off at ~15°C.

13.7 Operator Indicators and displays

The table below provides a complete list of the available DEF system operator indicators including J1939 parameters where applicable.

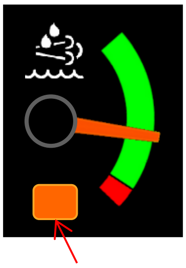
Indicator	ECU Output	J1939 PGN	J1939 SPN	Mandatory
Emissions System Malfunction Indicator	J2-59	65226	1213	Yes
Emissions System Malfunction Indicator Flash	J2-59	65226	3038	Yes
Low DEF Level	J1-63	65110	5245	Yes
DEF Level %	None	65110	1761	Yes
Wait To Disconnect Indicator	J2-93	61475	4332	Yes*

Table 13.15

***Wait to Disconnect Indicator is mandatory if OEM is installing a battery disconnect switch on their application.**

13.7.1 DEF Level Gauge Requirements

In addition to the specific DEF system indicators described in the table 13.5 the machine must also be fitted with a DEF level gauge. Whilst specific DEF level gauge requirements may differ between geographical machines and operating territories, Caterpillar requires a DEF level gauge to be constantly visible. The layout of the gauge is dependent upon the customers' requirements however as a minimum the 'RED' or low DEF section of the gauge must start at 20% remaining (point at which the low DEF level indicator is activated).



Low DEF Level Indicator
Optional Position

Figure 13.6

14.0 Engine Governor

14.1 Min / Max Governing

14.1.1 Min / Max Governing Operation

The min/max engine speed governor will provide an approximate amount of power for a given throttle position. Engine speed is allowed to vary between the low idle and high idle engine speed settings. This governor essentially only 'governs' engine speed when at the minimum or maximum allowed engine speed. In between these limits, the throttle position will cause the engine to produce power proportional to its value. The benefit of this type of governor is smoother shifting for engines with electronic automatic/automated transmissions. The Min/Max governor is also known as the 'limiting speed' or 'power throttle' governor.

The Min/Max engine speed governor control strategy uses the isochronous speed governor to control the engine speed when operating at the minimum (low idle) and maximum (high idle) speeds. This is the same control strategy used by the full range engine speed governor, but with a fixed desired engine speed input of low idle and high idle. The governor control strategy does not try to control fuel delivery and engine speed at the operating speeds between low idle and high idle.

The Min/Max engine speed governor will attempt to maintain a constant engine power output based on the throttle position. This design provides optimised shift quality with automatic transmissions and offers excellent power modulation, which allows the operator to adjust the engine power output to match typical vehicle operating conditions. The engine will accelerate or decelerate to 'find' a vehicle load level that matches the engine output command by the throttle. If the throttle is commanding more power than the vehicle load will offer, the engine will accelerate to the high idle speed.

Machines that are lightly loaded will achieve a desired acceleration at a lower throttle position than machines that are heavily loaded. Machines with very high power/weight ratios will accelerate at very low throttle positions.

The following figure illustrates the Min/Max engine speed governor operation across the engine operating speed range. The curve is bounded by the rating torque curve between LI and Rated engine speed (RS) once above rated speed the HSG limit curve takes over. For a fixed throttle position, the Min/Max governor will deliver a constant amount of power proportional to the throttle position, the engine power output will remain fairly constant, and engine speed will vary with engine load.

Min/Max governing above the configured Rated speed (RS) is limited by the HSG limit curve. This region of operation is often referred to as the overrun region (shown in the figure below as the High Speed Governor operating area). The HSG limit curve is always below the rated torque curve. This curve is linear and the slope of the line is determined by the configured Rated speed point (RS) and HI engine speeds (run out line).

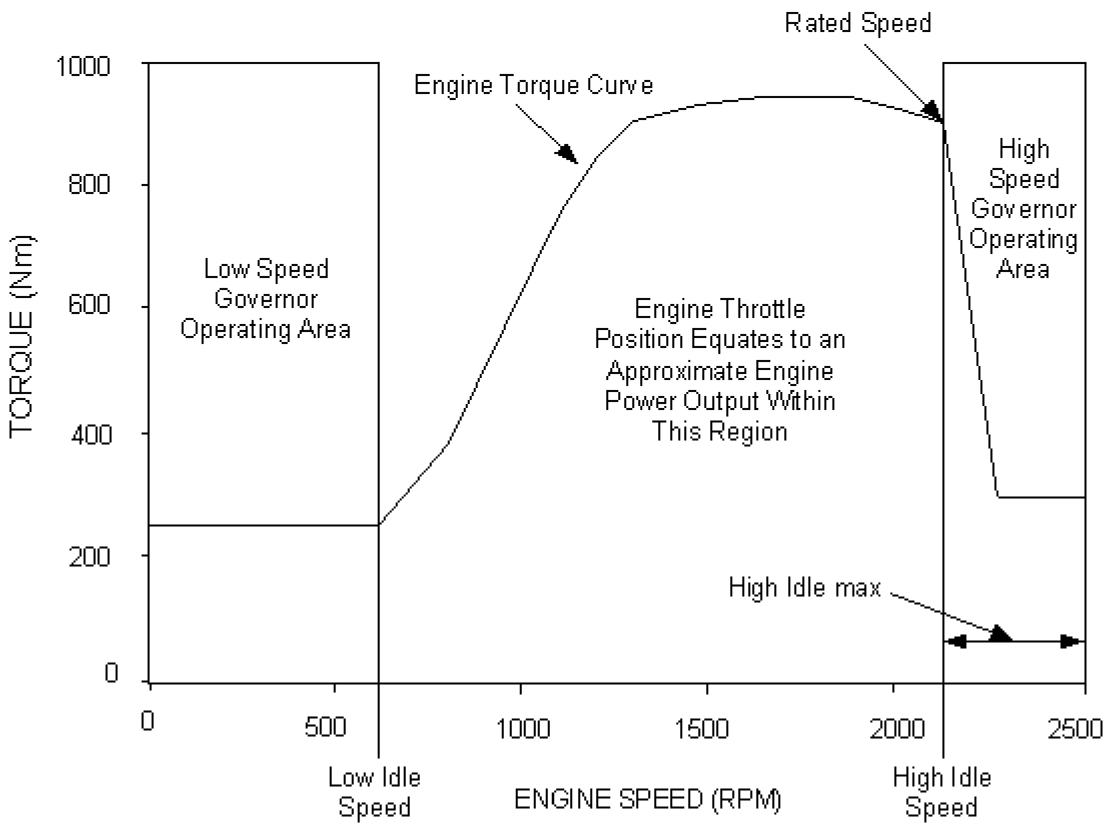


Figure 14.1 Min Max Governor Operating Regions

14.1.2 Min / Max Governing Configuration

The Min/Max governing option is available for all levels of engine software and is enabled by selecting min/max governing within the Mode selection section of the engine software.

14.1.3 Min / Max Governing Installation

The Min/Max governing feature requires no special installation other than a method of engine speed demand.

14.2 Engine All Speed Governing

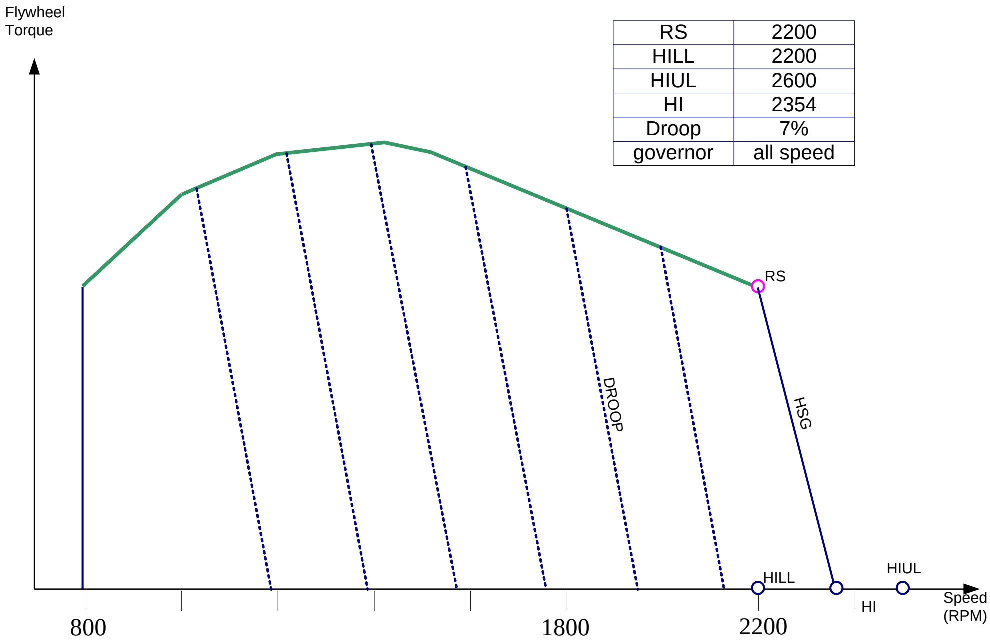
The default governor type is an All Speed Governor, also known as a variable Speed Governor.

14.2.1 Engine All Speed Governing Operation

The All Speed Engine Governor will attempt to hold a constant engine speed for a given throttle position. The governor senses engine speed and load and meters the fuel supply to the engine such that the engine speed remains constant or to vary with the load in a predetermined manner. This governor type is recommended for use on applications with a constant operating speed and applications with manual transmissions. The all speed governor is also known as 'variable speed' or 'full range engine speed governor'.

The governor strategy calculates the fuel quantity required to keep the actual engine speed equal to the desired engine speed. The desired engine speed is the output of the throttle arbitration strategy defined in the Engine speed demand section 9 of this document. All speed refers to the fact that the engine governor operates across the full engine speed operating range. The governor strategy has control parameters classed as governor gains, which determine the engine response and engine stability. These gains are 'tuned' to ensure that they are configured for optimum performance under both steady state and transient conditions. Under default conditions the engine is set to operate with isochronous governing across the engine speed range, during which the engine fuelling is bound by the engine torque curve. Note that the engine may not be capable of reaching the torque fuel limit curve in some circumstances. For example, if the turbocharger is not providing the required boost pressure, then the fuel will be limited so that the engine does not emit black smoke.

Engines can however be configured to operate with a level of engine droop, under the torque curve. Droop is the variation of engine speed as load is applied. For example, if an engine has 10% droop and is running at 1500RPM without load, then as load is applied the operator will feel and hear the engine speed gradually decreasing. This is represented by the diagonal dotted lines under the torque curve in the diagram below. When the load reaches the torque limit curve of the engine, the engine will lug back along the curve.
Note that droop values can be assigned to the multi-position throttle switch input, PWM accelerator pedal/lever input and the TSC1 speed demand over J1939. Droop does not apply, however to the PTO mode, which always operates isochronously (0% Droop)
The high speed governor (governor run-out) is governed by the relationship between the rated engine speed and the chosen high idle speed. High Idle is the maximum speed that the engine will reach. Note that this is on the bare engine and when installed in an application, it may not be possible to reach this speed due to the parasitic loads of the driven equipment. The range of possible high idle speeds is defined by the parameters, High Idle Lower limit (HILL) and High Idle Upper Limit. (HIUL). High Idle cannot be specified to be less than Rated Speed (RS) and cannot exceed RS+10%. This HIUL is specified to ensure governor stability is maintained throughout the engine operating range.
Example Governing1 - showing droop and HSG slopes approximately equal.



RS	2200
HILL	2200
HIUL	2600
HI	2354
Droop	7%
governor	all speed

Figure 14.2 Engine with Droop settings

Example Governing 2 – Showing isochronous droop but with a shallow HSG slope.

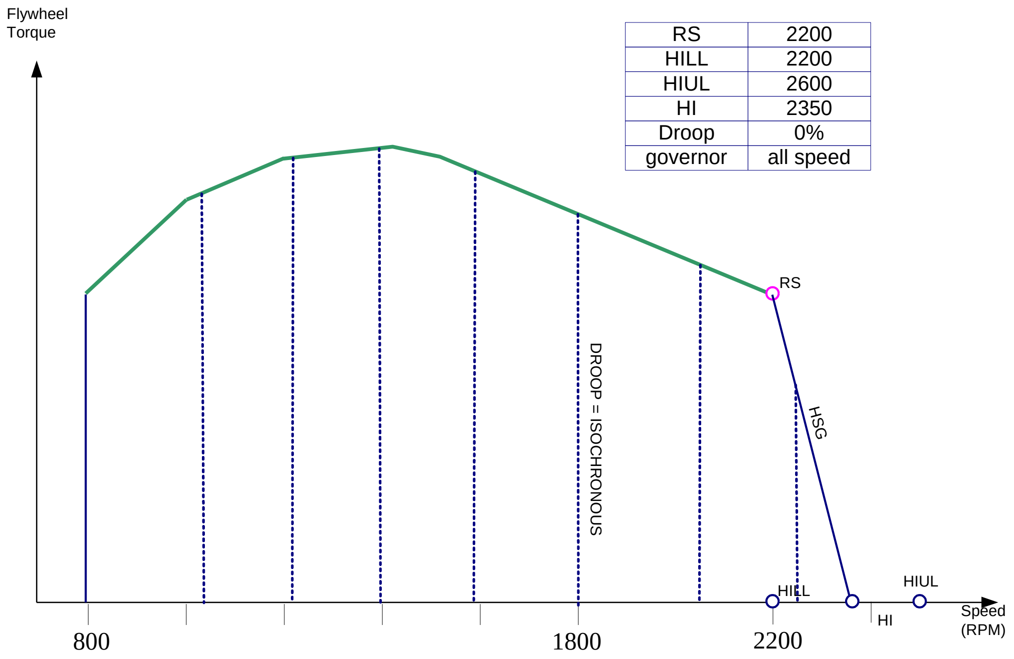


Figure 14.3 Isochronous Droop Settings

14.2.2 Engine All Speed Governing Configuration

The All Speed engine governing option is the default governor selected for all levels of engine software and can be de-selected / selected via the engine mode selection switches as with the Min/Max governor.

14.2.3 Engine All Speed Governing Installation

The All Speed engine governing feature requires no special installation other than a method of engine speed demand.

14.3 Rating Selection Using ET

Some engines will have the capability to run more than one power rating. If this is the case, the highest allowed rating may be changed via the engine operating mode screen within EST. Note however, that the engine may not be running the highest enabled rating due to the status of the mode switches or due to requests from another electronic module on the machine over the J1939 datalink.

14.4 Engine High Speed Governor (Governor Run-Out)

14.4.1 Engine High Speed Governor Operation

The C3.6 series engine range offers the ability to configure the run-out gradient of the High Speed Governor (HSG) via the configuration of the engine Rated Speed (RS) and the engine High Idle (HI).
Note: Not all engine ratings support the configuration of the engine RS. The HSG curve is a linear line. The slope of this line can be adjusted using the HI and RS speed settings. The line determines the response of the engine once the engine speed enters the HSG controlled area of the torque curve. The figure below shows a HSG run out line with the same rated speed and two different HI settings.

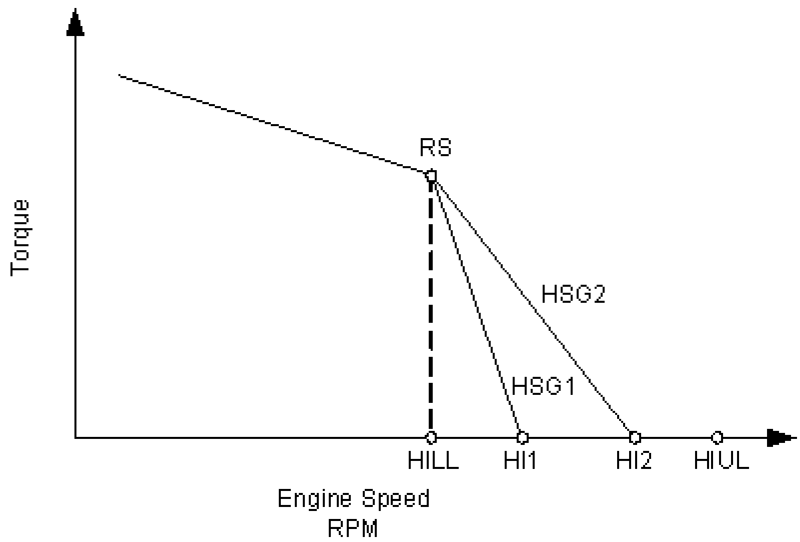


Figure 14.4 **HSG Run out Example**

14.4.2 Engine High Speed Governor Configuration

The high speed governor run out line gradient can be configured using the service tool and the mode selection feature. This is achieved by modifying RS or HI or both. It should be noted that HI cannot be configured to be less than RS and no higher than RS + 10%.

14.5 Mode Selection

14.5.1 Mode Selection Operation

A mode is a performance characteristic in terms of power / torque, droop, speed governing and rated speed. There are up to four modes configurable for the C3.6 product range. These modes are selectable during normal engine operation while the engine is running and on load apart from when a speed governing change is required.
Two ECU switched inputs, J2-65 and J2-66, are provided for this feature and each switch combination can be configured to provide a separate mode configuration. Examples of the selectable modes are shown below.

- Switch input combination
- Engine T Curve Rating (If multi ratings are enabled)
- Engine rated speed (Only if the rating supports multiple rated speeds)
- High Idle Speed (rpm)
- Engine % Droop, throttle 1, throttle 2 or TSC1 Throttle
- Engine speed governing mode (Min / Max or All Speed)
- Gain selection maps (1 – 4).

For all software files containing more than one rating the mode selection screen must be used to select the correct rating via the Rating Number field as shown in Table 14.1.

Mode Selection Switch Input 2	Mode Selection Switch Input 1	Enabled	Rating Number	Rated Speed (RPM)	High Idle Speed (RPM)	Throttle 1 Droop Percentage	Throttle 2 Droop Percentage	TSC1 Droop Percentage	Governor Selection	Gain Selection
*Open	*Open	Yes	1	2200	2420	0.00	0.00	0.00	All Speed	Gain Setting 1
*Open	Ground	No	1	2200	2420	5.00	5.00	5.00	All Speed	Gain Setting 1
Ground	*Open	No	1	2200	2420	5.00	5.00	5.00	All Speed	Gain Setting 1
Ground	Ground	No	1	2200	2420	5.00	5.00	5.00	All Speed	Gain Setting 1

Table 14.1 Engine Mode Selection

If an invalid switch position is selected a fault code will be raised (1743 -2) and the feature will revert to its last good state.
If a change of governing is required i.e. from all speed to min / max then unlike mode changes such as droop etc the engine speed must be seen to be at low idle or 0rpm before this change will take place regardless of the mode switch position.
IMPORTANT

The Mode Selection feature has the potential to change desired engine speed if a different High Idle Speed is set for modes 1-4. It is therefore recommended that the modes are configured such that the safest mode is when the switches are open as this is the likeliest unintended switch position. Similarly, if a multi-rating flash file is used and modes are set up to command different ratings that the lowest power rating is chosen for Mode 1 when both switches are open to avoid risk of a higher power rating being commanded unintentionally (through an open circuit wiring fault.)

14.5.2 Mode Selection Configuration

Configuration of the available engine modes is carried out by using the ET service tool under the following menu location, Service / Engine Operating Mode Configuration.

Mode Selection Switch Input 2	Mode Selection Switch Input 1	Enabled	Rating Number	Rated Speed (RPM)	High Idle Speed (RPM)	Throttle 1 Droop Percentage	Throttle 2 Droop Percentage	TSC1 Droop Percentage	Governor Selection	Gain Selection
*Open	*Open	Yes	1 ...	2200	2420	0.00	0.00	0.00	All Speed	Gain Setting 1
*Open	Ground	No	1 ...	2200	2420	5.00	5.00	5.00	All Speed	Gain Setting 1
Ground	*Open	No	1 ...	2200	2420	5.00	5.00	5.00	All Speed	Gain Setting 1
Ground	Ground	No	1 ...	2200	2420	5.00	5.00	5.00	All Speed	Gain Setting 1

Table 14.2

14.5.3 Mode Select Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5 J1 Connection

14.5.4 Mode Select changes requested via the J1939 datalink

For those applications wishing to use the J1939 CAN Bus system during machine integration, the engine operating mode can be adjusted using the Off Highway Engine Control Selection (OHECS) message PGN FDCB.

The mode selection via J1939 will be pointed towards the physical mode switch configuration shown in the "Mode Selection" section.

PGN #	PGN Description	SPN #	SPN Description
64971	Off Highway Engine Control Selection (OHECS)	8608	Engine Operating Mode Command
			Bit State 0000 = Not presently requesting a specific Engine Operating Mode be used Bit State 0001 = Engine Operating Mode 1 is requested Bit State 0010 = Engine Operating Mode 2 is requested Bit State 0011 = Engine Operating Mode 3 is requested Bit State 0100 = Engine Operating Mode 4 is requested Bit State 0101 = Engine Operating Mode 5 is requested Bit State 0110 = Engine Operating Mode 6 is requested Bit State 0111 = Engine Operating Mode 7 is requested Bit State 1000 = Engine Operating Mode 8 is requested Bit State 1001 = Engine Operating Mode 9 is requested Bit State 1010 = Engine Operating Mode 10 is requested Bit State 1011 = Engine Operating Mode 11 is requested Bit State 1100 = Engine Operating Mode 12 is requested Bit State 1101 = Engine Operating Mode 13 is requested Bit State 1110 = SAE Reserved Bit State 1111 = Not available / Take no action

Table 14.3

Arbitration between physical mode switches and J1939;

- J1939 SPNs above will always take priority over the physical mode switches.
- If engine software does not see the SPNs above the physical features will control the mode switch feature.

Change in mode switch input via J1939 can be applied during normal engine running and engine software will activate the appropriate mode switch settings.
If the customer send PGN 64971 with the bytes set to FF then the mode switch feature will be disabled for the remainder of that key cycle.
If the engine software does not receive the PGN 64971 correctly the following active diagnostic code will be broadcasted within the DM1 frame;

- 8608-9 – Engine Operating Mode Command: Abnormal Update Rate.

The ECM will send back SPN166 (PGN 65214) to confirm what power rating is running if a customer is using a multi-rating software and engine operating mode control.

15.0 Optional Engine Features

15.1 Alternative Low Idle

15.1.1 Alternative Low Idle Operation

The alternative low idle gives the possibility to change the Low Idle speed by the action of an ECU input or a J1939 message.
When the alternative Low Idle Input is activated, the Engine Low Idle speed will be changed after a debounce time of 5 seconds to the one configured in the Engine ECU and Engine speed will ramp to it at a 100rpm/s rate. The throttle will be remapped to obey to the new Low Idle.
This feature can be used as a Lower Low Idle for prolonged Idling period without Electrical Load or an elevated Idle for fast warmup.
When used as a Lower Low Idle, special attention is required about the Electrical Load to avoid the Machine battery discharge.
This feature is also supported through the J1939 Network and customer should use the following message to request the Alternative Low Idle:

PGN #	PGN Description	SPN #	SPN Description
64971	Off – Highway Engine Control Selection (OHECS)	2883	Engine Alternate Low Idle Switch
			Bit State 00 = Default low idle point is selected Bit State 01 = Alternate low idle point is selected

Table 15.1

15.1.2 Alternative Low Idle Configuration

This feature needs to be activated through the Service Tool as well as the Alternative Low Idle speed.

Configuration field names	Configuration Options	Default Configuration
Engine Alternative Low Idle Speed Status	Installed Not Installed	Not Installed
Engine Alternative Low Idle Speed	Range as per T-curve	Same as Configured LI

Table 15.2

15.1.3 Alternative Low Idle Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5

15.2 Coolant Level Switch

15.2.1 Coolant Level Switch Operation

The coolant level switch enables the ECU to monitor the coolant level within the radiator or expansion tank to protect the engine against operation with low or no coolant.

The coolant level switch should be mounted so that it is immersed during all normal operating conditions. If the switch is not fully immersed then the ECU will take action as configured within the engine monitoring system. The engine must have been running before a low coolant level condition can be triggered.
The coolant level switch should provide an analogue signal to the engine ECU. The engine ECU will support a 5 volt coolant level sensor which must be activated with the electronic service tool. The coolant level switch is a normally closed switch such that when fluid is present the switch will return 0V +/-0.25V back to the ECU on the signal channel.
Caterpillar supply a Coolant Level sensor which is recommended to be used, part number 430-9454.

Once this switch is activated the level 1, level 2 and Level 3 can be calibrated in the monitoring system screen to come on at different times. See the “Engine Monitoring Mode” chapter for more detail.
The Coolant Level Switch feature supports the following diagnostic codes:

- 111-17 – Engine Coolant Level : Low – Least severe (1)
- 111-18 – Engine Coolant Level : Low – Moderate severity (2)
- 111-1 – Engine Coolant Level : Low – Most severe (3)

A Low Coolant indicator is supported through J1939. The following message is used to communicate the status of this indicator:

PGN #	PGN Description	SPN #	SPN Description
64773	Direct Lamp Control Data 1 (DLCD1#0	5101	Engine Coolant Level Low Lamp Data
			Bit State 00 = Lamp Off Bit State 01 = Lamp On Bit State 10 = Error

Table 15.3

15.2.2 Coolant Level Switch Configuration

This feature needs to be installed and configured through the Service Tool:

Configuration field names	Configuration Options	Default Configuration
Coolant Level Sensor Installation Status	Installed Not Installed	Not Installed
Coolant level Sensor Switch Configuration	Normally Closed Normally Open	Normally Closed

Table 15.4

15.2.3 Coolant Level Switch Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5

15.2.3.1 Radiator Adaptor

The sensor has a ¼”-18 thread. If a CAT radiator is used, the radiator has a ½”-14NPSI thread, you need to use an adaptor such as 168-3334. The thread adaptor needs to be ½”-14NPSI male to ¼”-18 NPTF female.

15.3 Auxiliary Pressure Sensor

15.3.1 Auxiliary Pressure Sensor Operation

The Auxiliary Pressure sensor provides an input on the ECU that can be use as a Pressure sensor input. When this features is enabled, the Engine ECU will transform the sensor signal into a pressure in kPa and will make it available through the J1939 Network.
The J1939 message used to broadcast this information is the Auxiliary Analogue Information message (PGN FE8C SPN 1387). This message is only sent on request, so the Machine should have a mechanism to request it when needed. See below the message information:

PGN #	PGN Description	SPN #	SPN Description
FE8C	Auxiliary Analogue Information (AAI)	1387	Auxiliary Pressure #1
			16 kPa/bit, Offset = 0 kPa

Table 15.5

This feature supports three levels of diagnostic code, that can be configured through the Engine monitoring mode via the Service Tool.

- 1387-15 – Auxiliary Pressure 1 : High least severe (1)
- 1387-16 – Auxiliary Pressure 1 : High moderate severity (2)
- 1387-0 – Auxiliary Pressure 1 : High most severe (3)

This feature requires the usage of the correct Caterpillar Pressure sensor. The Caterpillar sensor is documented below:

	Supplier	Supplier Part Number	Quantity	Caterpillar Part Number
Pressure Sensor	N/A	N/A	1	161-9932

Table 15.6

15.3.2 Auxiliary Pressure Sensor Configuration

This feature needs to be installed through the Service Tool:

Configuration field names	Configuration Options	Default Configuration
Auxiliary Pressure Sensor Installation Status	Installed Not Installed	Not Installed

Table 15.7

15.3.3 Auxiliary Pressure Sensor Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5

15.4 Auxiliary Temperature Sensor

15.4.1 Auxiliary Temperature Sensor operation

The Auxiliary Temperature sensor provides an input on the ECU that can be use as a Temperature sensor input. When this features is enabled, the Engine ECU will transform the sensor signal into a temperature in ºC and will make it available through the J1939 Network.

The J1939 message used to broadcast this information is the Auxiliary Analogue Information message (PGN FE8C SPN 441). This message is only sent on request, so the Machine should have a mechanism to request it when needed. See below the message information:

PGN #	PGN Description	SPN #	SPN Description
FE8C	Auxiliary Analogue Information (AAI)	441	Auxiliary Temperature Sensor
			1 °C/bit, Offset = -40 °C

Table 15.8

This feature supports three level of diagnostic code, that can be configured through the Engine monitoring mode via the Service Tool. Below are the associated diagnostic codes:

- 441-15 – Auxiliary Temp 1 : High least severe (1)
- 441-16 – Auxiliary Temp 1 : High moderate severity (2)
- 441-0 – Auxiliary Temp 1 : High most severe (3)

This feature requires the usage of the correct Caterpillar Temperature sensor. The Caterpillar sensor is documented below:

	Supplier	Supplier Part Number	Quantity	CATERPILLAR Part Number
Temperature Sensor	N/A	N/A	1	145-7028

Table 15.9

15.4.2 Auxiliary Temperature ~Sensor Configuration

This feature needs to be installed through the Service Tool:

Configuration field names	Configuration Options	Default Configuration
Auxiliary Temperature Sensor Installation Status	Installed Not Installed	Not Installed

Table 15.10

15.4.3 Auxiliary Temperature Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5

15.5 Charge Air Temperature Sensor

15.5.1 Charge Air Temperature Sensor operation

The Charge Air Temperature sensor provides an input on the ECU that can be use as a Temperature sensor input. When this features is enabled, the Engine ECU will transform the sensor signal into a temperature in ºC and will make it available through the J1939 Network.
The J1939 message used to broadcast this information is the Engine Temperature 3 message (PGN FE69 SPN 2630). This message is broadcasted on the J1939 network at a 1s rate. See below the message information:

PGN #	PGN Description	SPN #	SPN Description
FE69	Engine Temperature 3 (ET3)	2630	Engine Charge Air Cooler Outlet Temperature
			0.03125 °C/bit, Offset = -273 °C

Table 15.11

This feature supports three level of diagnostic code, that can be configured through the Engine monitoring mode via the Service Tool. There is also two fault diagnostic associated to this feature. Below are the associated diagnostic codes:

- 2630-3 – Auxiliary Temp 1 : Voltage above normal
- 2630-4 – Auxiliary Temp 1 : Voltage below normal
- 2630-15 – Auxiliary Temp 1 : High least severe (1)
- 2630-16 – Auxiliary Temp 1 : High moderate severity (2)
- 2630-0 – Auxiliary Temp 1 : High most severe (3)

This feature requires the usage of the correct Caterpillar Temperature sensor. The Caterpillar sensor is documented below:

	Supplier	Supplier Part Number	Quantity	CATERPILLAR Part Number
Temp Sensor	N/A	N/A	1	256-6454

Table 15.12

15.5.2 Charge Air Temperature Sensor Configuration

This feature needs to be installed through the Service Tool:

Configuration field names	Configuration Options	Default Configuration
Charge Air Cooler Outlet Temperature Sensor Installation Status	Installed Not Installed	Not Installed

Table 15.13

15.5.3 Charge Air Temperature Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5

15.6 Variable Fan Speed

15.6.1 Variable Fan Speed operation

The Engine provides Hydraulic Demand Fan support, through a proportional driver output. This feature is designed to support declutched Hydraulic Demand Fan systems, where the Fan speed increases when the Demand Fan solenoid current decreases.

The Hydraulic Demand Fan feature can control the output driver based on up to 6 temperature inputs. The output current is inversely proportional to the temperature input.

The following temperature inputs are supported:

- Coolant Temperature: On-Engine
- Intake Manifold Temperature: On-Engine
- Charge Air Outlet Temperature: Hardwired customer installed (refer to Charge Air Temperature sensor section)
- Auxiliary Temperature : Hardwired customer installed (refer to Auxiliary Temperature sensor section)
- Hydraulic Temperature: J1939
- Transmission Oil Temperature: J1939

For the J1939 supported temperatures, find the specific message below:

PGN #	PGN Description	SPN #	SPN Description
FE68	Vehicle Fluids (VF)	1638	Hydraulic Temperature
FEF8	Transmission Fluids 1 (TRF1)	177	Transmission Oil Temperature 1

Table 15.14

Each input has a minimum and maximum temperature parameter that needs to be set up using the service tool.

The driver output current is configurable between a min and max range (from 0 to 2.5A). The driver current ramp rate is also configurable to avoid a too fast repsonse on the driver.

The driver output current is a linear interpolation, based on the following set points:

- Maximum Solenoid current
- Minimum Temperature
- Minimum Solenoid current
- Maximum Temperature

The figure below ilustrates the current function

Example fan map – (0-2.5A) solenoid current against fan speed

Fan Speed RPM	500	650	800	950	1100	1250	1400	1500	1600	1700	1800	1900	2000	2100	2200
Solenoid Current	2.5	2.29687	2.09375	1.89063	1.6875	1.48439	1.28223	1.14648	1.01172	0.87697	0.74023	0.60547	0.46973	0.33496	0.19922

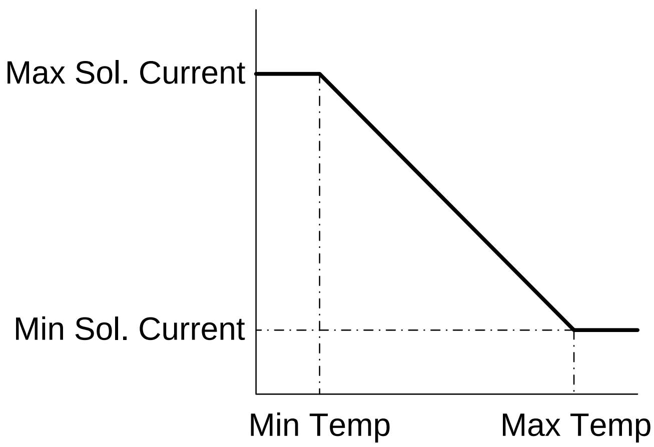


Figure 15.1 Driver current based on Temp input

The feature will evaluate the minimum current for each monitored temperature input and will be set to the lowest value.

This is an open loop controlled system, then the result speed will be based on the current output as calibrated by customer.

To improve the responsiveness of the hydraulic system, a dither can be applied to the output signal. This is achieved by adding an oscillating signal, configurable in frequency and amplitude, to the current output.

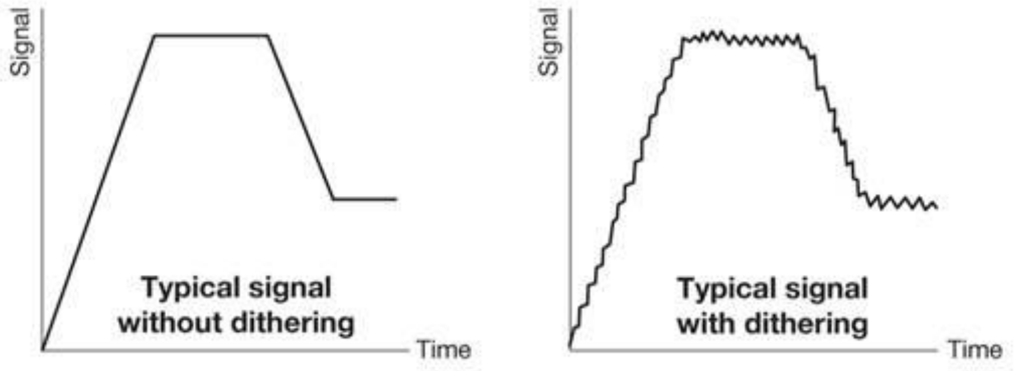


Figure 15.2 Dither

15.6.2 Variable Fan Speed Configuration

To activate this feature the parameters below must be configured with Caterpillar ET.

Configuration field names	Configuration Options	Default Configuration
Engine Fan Control	ON - OFF	OFF
Engine Fan Type configuration	Variable Hydraulic	Variable hydraulic
Fan Solenoid Min Current	0 – 2.5 amps	0.2 amps
Fan Solenoid Max Current	0 – 2.5 amps	1.8 amps
Engine Cooling Fan Solenoid Dither Frequency	30 – 500 Hz	140 Hz
Engine Cooling Fan Solenoid Dither Amplitude (Peak to Peak)	0 – 1 amp	0.2 amp
Engine Cooling Fan Temperature Error Increasing Hysteresis	0 – 100%	0%
Engine Cooling Fan Temperature Error Decreasing Hysteresis	0 – 100%	0%
Engine Cooling Fan Current Ramp Rate: Default	0 – 2.5 amps / sec	1 amp / sec
Coolant Temp control Enabled	Enabled Disabled	Disabled
Min Coolant Temp	0 – 120°C	92°C
Max Coolant Temp	0 – 120°C	102°C
Intake Manifold Temp Control Enabled	Enabled Disabled	Disabled
Min Intake Manifold Temp	0 – 120°C	92°C
Max Intake Manifold Temp	0 – 120°C	102°C
ATAAC Temp Control Enabled	Enabled Disabled	Disabled
Min ATAAC Temp	0 – 120°C	40°C
Max ATAAC Temp	0 – 120°C	45°C
Auxiliary Temp Control Enabled	Enabled Disabled	Disabled
Min Auxiliary Temp	0 – 120°C	80°C
Max Auxiliary Temp	0 – 120°C	102°C
Hydraulic Temp Control Enabled	Enabled Disabled	Disabled
Min Hydraulic Temp	0 – 120°C	80°C
Max Hydraulic Temp	0 – 120°C	102°C
Transmission Oil Temp Control Enabled	Enabled Disabled	Disabled
Min Transmission Oil Temp	0 – 120°C	80°C

Configuration field names	Configuration Options	Default Configuration
Max Transmission Oil Temp	0 – 120°C	102°C

Table 15.15

15.6.3 Variable Fan Speed Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5

15.7 Engine No Load Fuel Map Offset

15.7.1 Engine No Load Fuel Map Offset Operation

Applications such as hydraulic excavators are operated at fixed engine speed points for standard operations. Under no load (machine parasitic only) conditions it is expected that the engine speed when viewed by the operator will reflect the machine set speed.
The Engine No Load Fuel Map Offset feature is designed to allow the droop lines to be calculated based on machine no load fuelling and not engine no load fuel. With this feature the Engine speed will be as requested by machine under no load across the full Engine speed range.
When activated, the droop calculation will start after the configured offset is reached, under the offset the Engine will be responding as an Isochronous droop. The figure below ilustrates the behaviour of the Engine with the feature enabled:

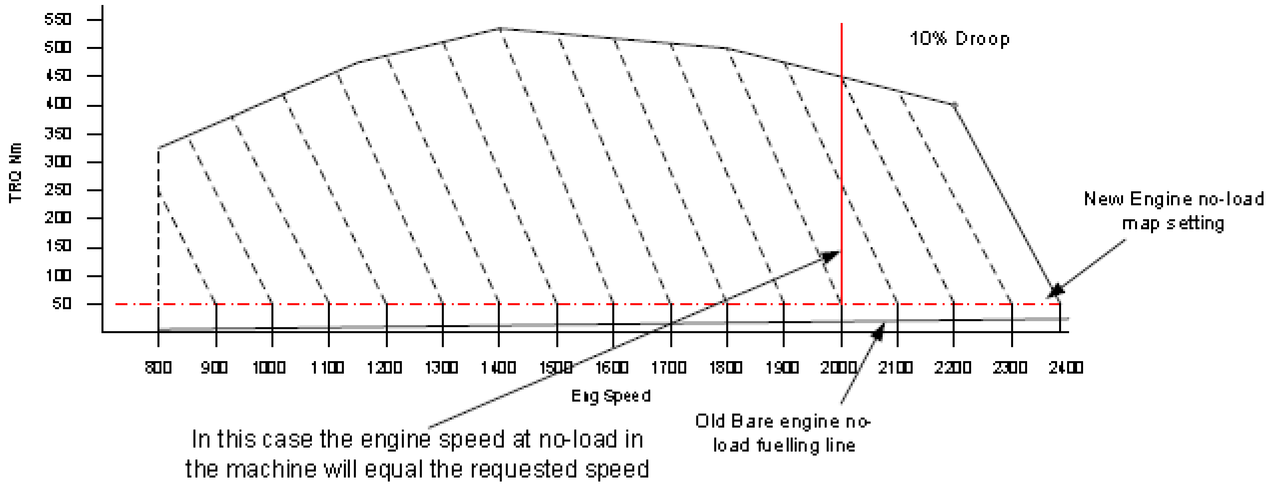


Figure 15.3 Engine behaviour with Engine No Load Fuel Map offset enabled

15.7.2 Engine No Load Fuel Map Offset Configuration

This feature needs to be configured through the Service Tool:

Configuration field names	Configuration Options	Default Configuration
Droop No Load Fuel Offset Percentage	0 – 100%	0%

Table 15.16

15.7.3 Engine No Load Fuel Map Offset Installation

No specific wiring is required for this feature.

15.8 Low Battery Voltage Elevated Idle

15.8.1 Low Battery Voltage Elevated Idle Operation

This feature monitors the current Battery voltage and will elevate the Engine Idle when the battery voltage is below the pre-configured threshold for a configurable amount of time.
Here are the pre-configured battery voltage thresholds:

- 12V System: 12.24V

- 24V System: 24.48V

The conditions to trigger the elevated idle are as follow:

- The low battery voltage elevated idle feature is enabled.
- The system battery voltage is below threshold for a specified amount of time (the debounce time).
- The work mode switch has been activated by the Hardwired or CAN option.
- The engine speed is at low idle (and has been for at least 5 minutes).

The Engine requires the “Engine Elevated Idle” (also called Machine Safe State, Work Mode,   input to be enabled to elevated the Engine Idle. The installation requirements of this input are detailed in the “Engine Elevated Idle” section.
The Low Battery Elevated Idle speed is configurable through the Service tool. When the strategy is triggered, the Engine will ramp up to the desired speed at a rate of 100rpm/s.
The Low Battery Elevated Idle will not be turned off when the Battery voltage returns to a normal level but will remain elevated until the work mode switch has been deactivated.

15.8.2 Low Battery Voltage Elevated Idle Cinfiguration

This feature needs to be configured through the Service Tool:

Configuration field names	Configuration Options	Default Configuration
Low Battery Voltage Elevated Idle	Enabled Disabled	Disable
Low Battery Voltage Elevated Idle Delay Timer	3 – 30 minutes	5 minutes
Low Battery Voltage Elevated Idle Target Speed	800 – 1200 rpm	1200 rpm

Table 15.17

15.8.3 Low Battery Voltage Elevated Idle Installation

This feature requires the right installation of the “Engine Elevated Idle” input, which is explained in the “Engine Elevated Idle” section.

15.9 Engine Running Output

15.9.1 Engine Running Output Operation

The Engine Running Output provides an easy way to identify when the Engine is running. This is particularly pratical for applications with a remote control station e.g. lift platforms
The principle of this feature is to turn on the Engine Running Output when Engine speed is over a configured threshold and to turn it off when Engine is below the configure threshold.

15.9.2 Engine Running Output Configuration

The lamp is as installed all the time, no requirement for the ECM configuration to be set for the lamp. Also, the lamp doesn’t have a configuration to set the speed, this is linked to the terminate rpm setting in the ECM configuration.

15.9.3 Engine Running Output Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5

15.10 Maintenance Indicator

15.10.1 Maintenance Indicator Operation

The maintenance indicator provides the capability to inform the operator when maintenance is required based on Engine hours since the last service.

The default Maintenance interval is set to 500 hours and can be configured by customer. When this Maintenance interval is exceeded, the J1939 message PGN FEC0 SPN 916 will be a negative hours value. The J1939 supported message is as follows:

PGN #	PGN Description	SPN #	SPN Description
FEC0	Service Information (Serv)	916	Service Delay / Operational Time Based
			1 h/bit, Offset = -32,127 h
			The time in vehicle operational time until the next vehicle service inspection is required. A negative value is transmitted if the service inspection has been passed.

Table 15.18

There are two methods to reset the Maintenance interval:

- Through the Service Tool
  The following maintenance indicator reset procedure is required in the electronic service tool; Go to "Service", "Maintenance Indicator Reset", and click "Reset Button".
- Through J1939 message
  The following maintenance indicator reset procedure is required over J1939, when this message is sent by the customer the engine software will reset the maintenance indicator timer.

PGN #	PGN Description	SPN #	SPN Description
56832	Reset	988	Trip Group 1
			Bit State 00 = Take no action Bit State 01 = Reset

Table 15.19

15.10.2 Maintenance Indicator Configuration

This feature needs to be configured through the Service Tool:

Configuration field names	Configuration Options	Default Configuration
Maintenance Indicator Mode	Off Man-Hour	Off
Maintenance Level 1 Cycle Interval Hours	5 - 1000	500

Table 15.20

15.10.3 Maintenance Indicator Installation

Please refer to the separate electrical schematics referenced in Section 2.3.5

15.11 Immobiliser

15.11.1 Immobiliser Operation

The Engine provides an immobiliser feature that will disable the injection if a specific J1939 message is not received. The Engine Injection will be disabled under the following conditions:

- J1939 Message not present
- No Network communication

After the Engine is cranked and running, the Immobiliser message is no longer monitored and the loss of this message will not stop the machine, to avoid any undesired shutdowns.

The expected J1939 message is as follows:

PGN #	PGN Description	SPN #	SPN Description

34560	Engine State Request (ESR)	5793	Desired Engine Fuelling State
			Bit State 00 = Fuelling Not Desired Bit State 01 = Fuelling Desired

Table 15.21

The Engine will communicate the status of the immobiliser through the following J1939 messages:

PGN #	PGN Description	SPN #	SPN Description
64712	Electronic Engine Controller 13 (EEC13)	5794	Feedback Engine Fuelling State
			Bit State 00 = Fuelling is or will be inhibited Bit State 01 = Engine will be kept running Bit State 10 = No active request
		5795	Engine Fuelling Inhibit Allowed
			Bit State 00 = Engine currently will not stop fuelling in response to SPN5793. Bit State 01 = Engine will stop fuelling in response to SPN 5793.

Table 15.22

The following diagram explains the feature flow:

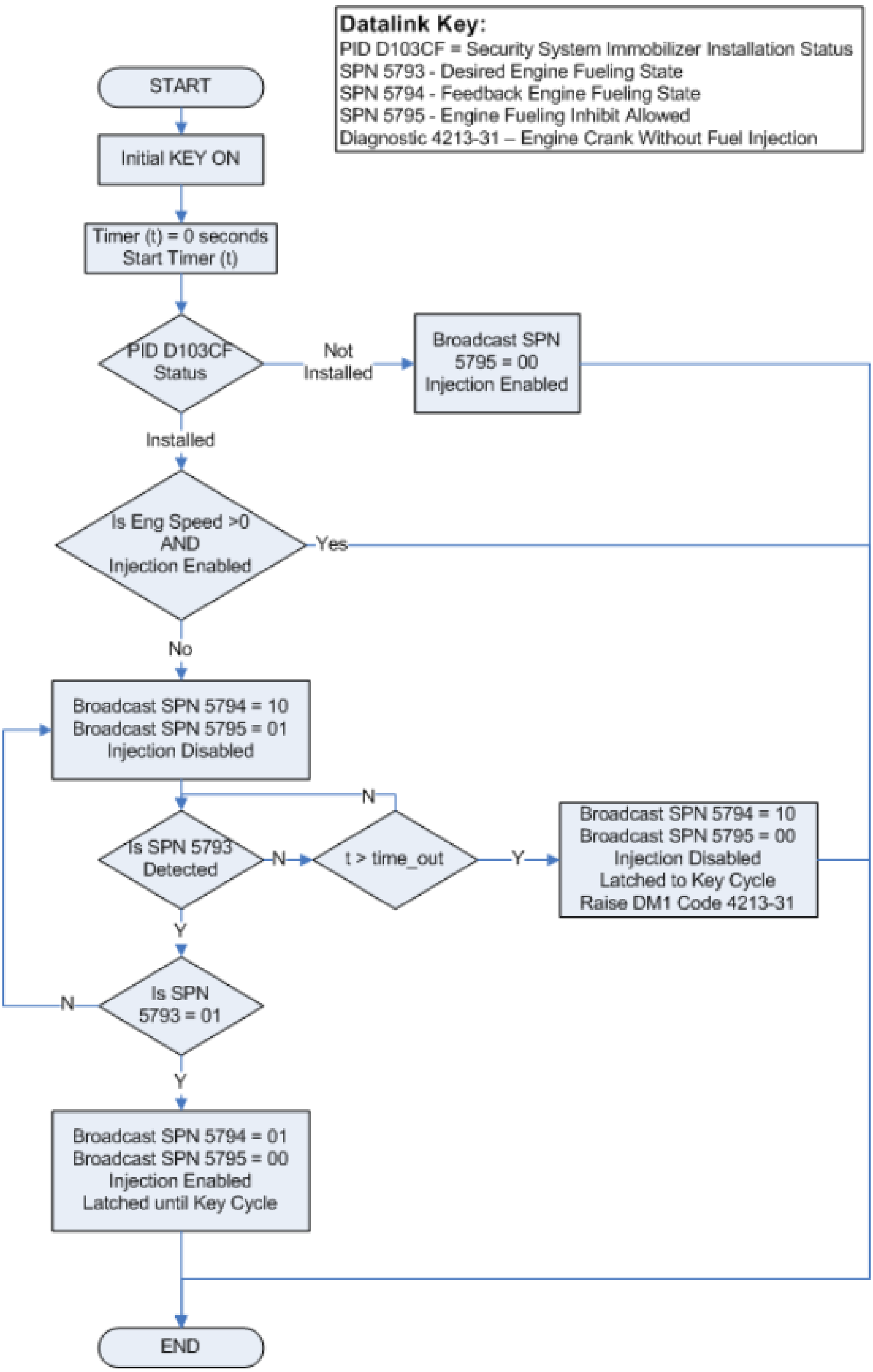


Figure 15.4Immobiliser Flow

15.11.2 Immobiliser Configuration

This feature needs to be configured through the Service Tool:

Configuration field names	Configuration Options	Default Configuration
Security System Immobiliser Installation Status	Installed Not Installed	Not Installed

Table 15.23

15.11.3 Immobiliser Installation

There is no specific wiring required for this feature.

15.12 Air Con Compressor

15.12.1 Air Con Compressor Operation

The Air Conditioning Compressor requires electrical wiring through a 2-pin connector in order to functiion. A 12V battery supply from the Main Power Relay should be provided to the Red coloured wire on the flying lead and a ground feed should be provided to the black earth wire.

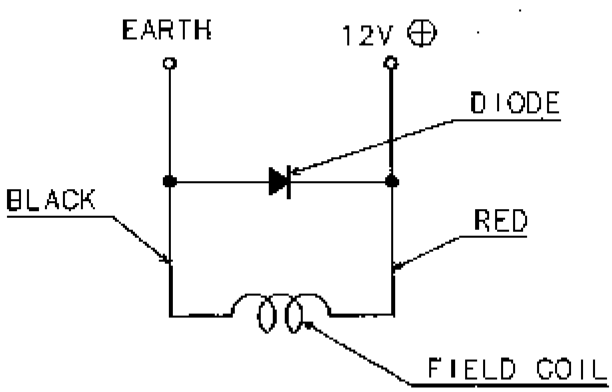


Figure 15.5 Air concompressor Flying lead wiring, 12V example

15.12.2 Air Con Compressor Configuration

No electronic configuration is required.

15.12.3 Air Con Compressor Installation

For installation requirements please refer to the wiring schematic documents referenced in Section 2.3.5

16.0 Datalink Support

The C3.6L Series product range is supplied with a customer's J1939 CAN bus connection as part of the ECU J1 connector. There is a second non-customer J1939 CANbus which is used for proprietary information between aftertreatment components and engine ECU control.
The J1939 standard is a widely used protocol, which operates on a standard CAN bus system. All J1939 enabled devices will operate on this Datalink and the remainder of this section details the basic requirements for J1939 communication.

16.1 SAE J1939

The SAE standard was initially developed for the US truck and bus industry. It has been expanded and is now the most widely used Datalink standard for industrial powertrains, with compliance from almost all engine and transmission manufacturers.
A list of SAE J1939 documentation, which should be used as reference when installing a J1939 network, is listed below.

1. J1939-11 - Physical Layer, 250Kbits/s, Twisted Shielded pair.
2. J1939-15 - Reduced Physical Layer, 250Kbits/s, Un-shielded Twisted pair.
3. J1939-21 - Data Link Layer.
4. J1939-31 - Network Layer.
5. J1939-71 - Vehicle Application Layer.
6. J1939-73 - Application Layer Diagnostics.

16.1.1 Summary of Key J1939 Application Issues

This is a summary of some of the key points and answers to frequently asked questions relating to design of a J1939 compatible network. It is intended to give a design overview and does not in any way replace or contradict the recommendations or design criteria contained within the SAE J1939 standard documents.

16.1.2 Physical layer

- The data rate is 250Kbits/sec.
- Twisted pair cable, of a 120 Ohm impedance characteristic, should be used throughout.
- It is recommended that this cable is shielded (as per J1939-11) and that the screen is grounded at a central point in the network. Unshielded twisted pair cable is used by some machine manufacturers, however (as per J1939-15), offering lower cost but lower immunity to electromagnetic noise.
- The CANbus is linear and should be terminated with 120 Ohm resistors at either end. It is a common mistake to use one 60 Ohm resistor instead of two 120 Ohm resistors. However this may not operate correctly.
- Maximum bus length is 40m.
- Network nodes are connected to the bus via stubs of maximum recommended length 3m.

16.1.3 Network Layer

- J1939 recommends a bit sample point of 87 percent. This relatively late sampling point, which gives the best immunity to noise and propagation delay. It does restrict the size of the software jump width (SJW), however.
- All nodes must have the same bit timing.
- Accurate bit timing is essential (4ms +/- 0.2 percent).
- It is recommended that the average busload is not greater than 40 percent and peak no greater than 60 percent.
- Hardware filtering (masking) of CAN messages should be used under high busload limit demands on processors.
- The engine ECU always assumes a fixed source address "00". It will not change its address in the arbitration process described in J1939-81.

- The multi 7 packet protocol (described in J1939-21) is used for sending messages with more than eight bytes of data. In the Caterpillar application this will be used principally for the diagnostic messages DM1 and DM2.
- Information may be broadcast or requested at regular intervals. For example, the engine will broadcast its 'current speed' every 10ms but it will only send 'hours run' information if another node requests it.

16.1.4 Application Layer

- The messages (PGN's) supported by the engine ECU are only a subset of the messages described in J1939-71 and J1939-73.
- Some PGN's maybe partially supported i.e. only those bytes for which the ECU has valid data will be supported.
- Unsupported data bytes are generally sent as FF (hex) and incorrect or invalid information is sent as FE (hex), information about can be referenced in J1939-71 (Table 1 – Transmitted Signal Ranges).

16.1 Connection and Use of the J1939 CAN Bus

There are two J1939 Data links available on this Caterpillar product; CANbus #1 – Customer connection and CANbus#2 – Non customer connection (Aftertreatment component communication with engine controller). The CANbus#1 Datalink can therefore be used to connect the engine ECU to machine controllers, transmission controllers, instrumentation gauges etc. All of the general installation criteria for a CAN network detailed in section 15.1 apply for this Datalink and the ECU J1 connection points are shown below in table below.

ECU J1 (K) Pin Number	Function
J1 - 59	CANbus #1 (-)
J1 - 48	CANbus #1 (+)

Table 16.1

The following figure gives an example of a typical CAN network layout.
If should be noted that 2 x 120 Ohm termination resistors are located at both ends of the CANbus, the A6E11 does not have internal CAN termination resistors.

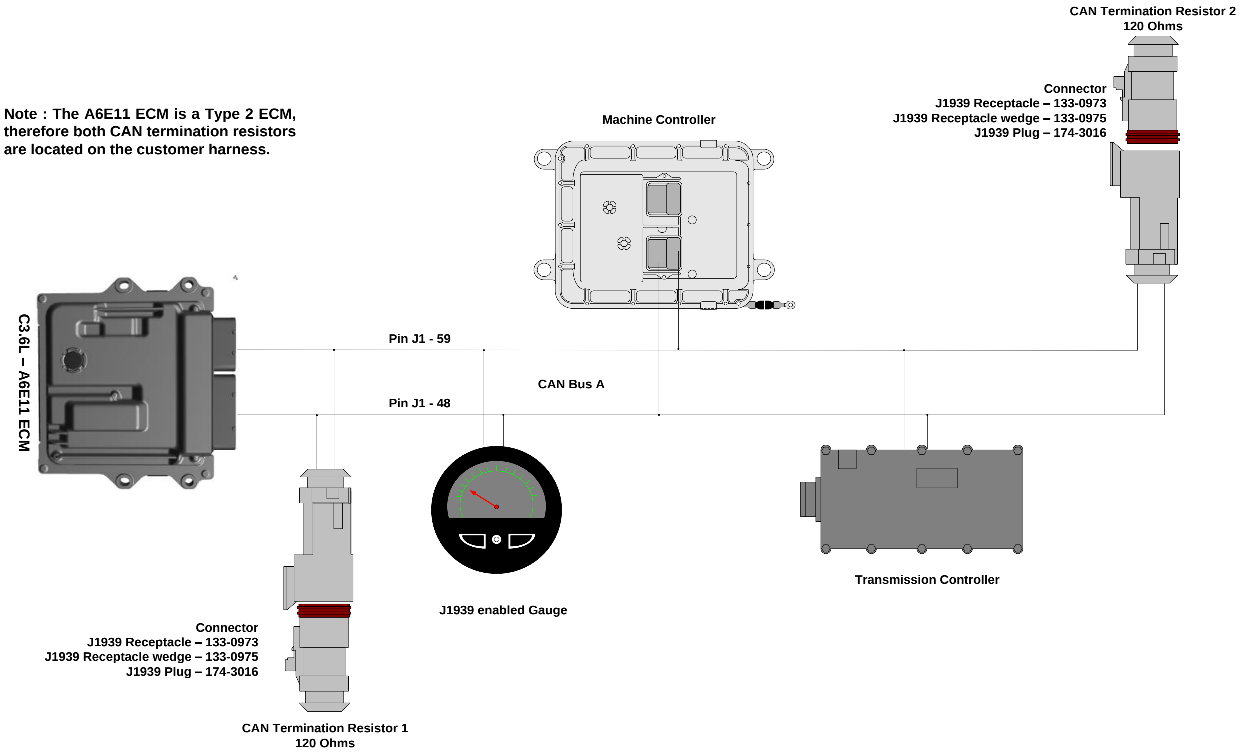


Figure 16.1

16.2 J1939 Supported Parameters Quick reference

NAME		PGN	Default Priority	Tx/Rx/ On Req	SPN	Start Byte	Length	Units	Resolution	Min Value	Max Value
ENGINE SPEED SENSOR INFORMATION	F021	61473	6	On Req							
Engine Speed 1					4201	1-2	16 bits	rpm	0.5rpm/bit	0	32127.5
Engine Speed 2					723	3-4	16 bits	rpm	0.5rpm/bit	0	32127.5
Engine Speed Sensor 1 Timing Pattern Status					4203	7.7	2 bits	N/A	4 states/2 bits	0	3
Engine Speed Sensor 2 Timing Pattern Status					4204	7.5	2 bits	N/A	4 states/2 bits	0	3
AFTERTREATMENT 1 SCR SERVICE INFORMATION 2	FCBD	64701	6	TBD							
Aftertreatment 1 Total Diesel Exhaust Fluid Used					5963	1.1	32 bits	Liters	0.5L/bit	0	2105540607.5
DIAGNOSTIC READINESS 2 (DM21)	C100	49408	6	On Req							
Minutes Run By Engine While MIL Activated					3295	5-6	16 bits	km	1km/bit	0	64255
ELECTRONIC ENGINE CONTROLLER 1 (EEC1)	F004	61444	3	Tx							
Actual Engine - Percent Torque					513	3	8 bits	%	1%/bit	-125	125
Engine Speed					190	4-5	16 bits	rpm	0.125rpm/bit	0	8031.875
AFTERTREATMENT 1 HISTORICAL INFORMATION	FD98	64920	6	On Req							
Aftertreatment 1 Total Fuel Used					3522	1-4	32 bits	Liters	0.5L/bit	0	2105540607.5
FUEL CONSUMPTION (LIQUID) (LFC)	FEE9	65257	6	On Req							
Engine Total Fuel Used					250	5-8	32 bits	Liters	0.5L/bit	0	2105540607.5
FUEL ECONOMY (LIQUID)	FEF2	65266	6	Tx							
Engine Fuel Rate					183	1-2	16 bits	L/h	0.05L/h/bit	0	3212.75
Engine Throttle Valve 1 Position					51	7	8 bits	%	0.4%/bit	0	100
ELECTRONIC ENGINE CONTROLLER 3 (EEC3)	FEDF	65247	6	Tx							
Engine’s Desired Operating Speed					515	2-3	16 bits	rpm	0.125rpm/bit	0	8031.875

Nominal Friction – Percent Torque					514	1	8 bits	%	1%/bit -125% Offset	-125	125
AMBIENT CONDITIONS	FEF5	65269	6	Tx							
Barometric Pressure					108	1	8 bits	kPa	0.5kPa/bit	0	125kPa
Ambient Air Temperature					171	4-5	16 bits	°C	0.03125DegC/ bit -273DegC Offset	-273	1734.96875
Engine Intake Air Temperature					172	6	8 bits	°C	1DegC/bit -40DegC Offset	-40	210
INTAKE/EXHAUST CONDITIONS 1	FEF6	65270	6	Tx							
Engine Intake Manifold #1 Pressure					102	2	8 bits	kPa	2kPa/bit	0	500
Engine Intake Air Pressure					106	4	8 bits	°C	2kPa/bit	0	500
Engine Intake Manifold 1 Temperature					105	3	8 bits	°C	1DegC/bit -40DegC Offset	-40	210
ENGINE FLUID LEVEL/PRESSURE 1	FEEF	65263	6	Tx							
Engine Oil Pressure					100	4	8 bits	kPa	4kPa/bit	0	1000
Coolant Level					111	8	8 bits	%	0.4%/bit	0	100
ENGINE TEMPERATURE 1	FEEE	65262	6	Tx							
Engine Coolant Temperature					110	1	8 bits	°C	1DegC/bit -40DegC Offset	-40	210
Engine Fuel Temperature 1					174	2	8 bits	°C	1DegC/bit -40DegC Offset	-40	210
AFTERTREATMENT 1 INTAKE GAS 2	FDB4	64948	6	Tx							
Aftertreatment 1 Diesel Particulate Filter Intake Gas Temperature					3242	3-4	16 bits	°C	0.03125DegC/ bit -273DegC Offset	-273	1734.96875
ENGINE FLUID LEVEL/PRESSURE 2	FEDB	65243	6	Tx							
Engine Injector Metering Rail 1 Pressure					157	3-4	16 bits	Mpa	1/253Mpa/bit	0	250.996
AFTERTREATMENT 1 DIESEL EXHAUST FLUID TANK 1 INFORMATION	FE56	65110	6	Tx							
Aftertreatment 1 Diesel Exhaust Fluid Tank Level					1761	1	8 bits	%	0.4%/bit	0	100

Aftertreatment 1 Diesel Exhaust Fluid Tank Temperature					3031	2	8 bits	°C	1DegC/bit -40DegC Offset	-40	210
Aftertreatment Diesel Exhaust Fluid Tank Low Level Indicator					5245	5.6	3 bits	states	8 states/3 bit	0	7
Aftertreatment Selective Catalytic Reduction Operator Inducement Active					5246	6.6	3 bits	states	8 states/3 bit	0	7
ENGINE FUEL/LUBE SYSTEMS (EFS)	FE6A	65130	6	Tx							
Engine Oil Priming State					3551	6.3	2 bits	states	4 states/2 bit, Offset = 0	0	3
Fuel Pump Prime Status					4083	7.4	2 bits	states	4 states/2 bit, Offset = 0	0	3
AFTERTREATMENT 1 SCR DOSING SYSTEM INFORMATION 1	F023	61475	3	Tx							
Aftertreatment 1 SCR System State					4332	3.1	4 bits	states	16 states/4 bit	0	15
ENGINE TEMPERATURE 3 (ET3)	FE69	65129	6	Tx							
Engine Charge Air Cooler 1 Outlet Temperature					2630	7-8	16 bits	°C	0.03125DegC/bit -273DegC Offset	-273	1734.96875
AFTERTREATMENT 1 SCR EXHAUST GAS TEMPERATURE 1	FD3E	64830	5	Tx							
Aftertreatment 1 SCR Catalyst Intake Gas Temperature					4360	1-2	16 bits	°C	0.03125DegC/bit -273DegC Offset	-273	1734.96875
VEHICLE ELECTRICAL POWER 1	FEF7	65271	6	Tx							
Battery Potential / Power Input 1					168	5-6	16 bits	V	0.05V/bit	0	3212.75
Keyswitch Battery Potential					158	7-8	16 bits	V	0.05V/bit	0	3212.75
SENSOR ELECTRICAL POWER #1	FD9D	64925	6	Tx							
Sensor supply voltage 1					3509	1-2	16 bits	V	0.05V/bit	0	3212.75
Sensor supply voltage 2					3510	3-4	16 bits	V	0.05V/bit	0	3212.75
ELECTRONIC ENGINE CONTROLLER 5	FDD5	64981	6	Tx							
Engine Exhaust Gas Recirculation 1 Valve 1 Control 1					2791	5-6	16 bits	%	0.0025%/bit	0	160.6375

AFTERTREATMENT 1 SCR ELECTRONIC CONTROL MODULE INFORMATION	FCBB	64699	6	Tx							
Aftertreatment 1 Diesel Exhaust Fluid Control Module Relay Control					5965	1.1	2 bits	states	4 states/2 bits	0	3
Aftertreatment 1 Diesel Exhaust Fluid Control Module Power Supply					5966	1.3	2 bits	states	4 states/2 bits	0	3
COLD START AIDS	FDC6	64966	6	As Req							
Engine Start Enable Device 1					626	1.1	2 bits	states	4 states/2 bits	0	3
Engine Start Enable Device 1 Configuration					2899	2.1	4 bits	states	16 states/4 bits	0	15
Engine Start Enable Device 2					1804	1.3	2 bits	states	4 states/2 bits	0	3
Engine Start Enable Device 2 Configuration					2898	2.5	4 bits	states	16 states/4 bits	0	15
ELECTRONIC ENGINE CONTROLLER 12	FCCC	64716	6	On Req							
Aftertreatment 1 Intake Gas Sensor Power Supply					5758	1.1	2 bits	states	4 states/2 bits	0	3
Aftertreatment 1 Outlet Gas Sensor Power Supply					5759	1.3	2 bits	states	4 states/2 bits	0	3
AFTERTREATMENT 1 DIESEL OXIDATION CATALYST (A1DOC)	FD20	64800	6	Tx							
Aftertreatment 1 Diesel Oxidation Catalyst Intake Temperature					4765	1-2	16 bits	°C	0.03125DegC/bit -273DegC Offset	-273	1734.96875
IDLE OPERATION	FEDC	65244	6	On Req							
Engine Total Idle Fuel Used					236	1-4	32 bits	Litres	0.5L/bit	0	2105540607.5
Engine Total Idle Hours					235	5-8	32 bits	Hr	0.05hr/bit	0	210554060.75
AFTERTREATMENT SYSTEM INFORMATION	FC31	64561	6	Tx							
Aftertreatment Engine Speed Increase Request					7502	1.5	2 bits	states	4 states/2 bits	0	3
Aftertreatment Engine Load Request					7503	1.7	2 bits	states	4 states/2 bits	0	3
Aftertreatment Thermal Management Status					7332	1.1	2 bits	states	4 states/2 bits	0	3
TURBOCHARGER WASTEGATE (TCW)	FE96	65174	6	Tx							
Engine Turbocharger Wastegate Actuator 1 Position					1188	1	4 bits	%	0.4%/bit	0	100
ENGINE CONFIGURATION 1 (EC1)	FEE3	65251	6	Tx							
Engine Speed At Idle, Point 1					188	1-2	16 bits	rpm	0.125rpm/bit	0	8031.875

Percent Torque at Idle Point 1					539	3	8 bits	%	1%/bit	-125	125
Engine Speed At Point 2					528	4-5	16 bits	rpm	0.125rpm/bit	0	8031.875
Percent Torque At Point 2					540	6	8 bits	%	1%/bit	-125	125
Engine Speed At Point 3					529	7-8	16 bits	rpm	0.125rpm/bit	0	8031.875
Percent Torque At Point 3					541	9	8 bits	%	1%/bit	-125	125
Engine Speed At Point 4					530	10-11	16 bits	rpm	0.125rpm/bit	0	8031.875
Percent Torque At Point 4					542	12	8 bits	%	1%/bit	-125	125
Engine Speed At Point 5					531	13-14	16 bits	rpm	0.125rpm/bit	0	8031.875
Percent Torque At Point 5					543	15	8 bits	%	1%/bit	-125	125
Engine Speed At High Idle, Point 6					532	16-17	16 bits	rpm	0.125rpm/bit	0	8031.875
Reference Engine Torque					544	20-21	16 bits	Nm	1Nm/bit	0	64255
Engine Requested Speed Control Range Lower Limit					535	25	8 bits	rpm	10rpm/bit	0	2500
Engine Requested Speed Control Range Upper Limit					536	26	8 bits	rpm	10rpm/bit	0	2500
POWER TAKEOFF INFORMATION	FEF0	65264	6	TBC							
Engine PTO Governor Enable Switch					980	6.1	2 bits	states	4 states/2 bits	0	3
Engine PTO Governor Accelerate Switch					981	7.7	2 bits	states	4 states/2 bits	0	3
Engine PTO Resume Switch					982	7.5	2 bits	states	4 states/2 bits	0	3
Engine PTO Governor Coast / Decelerate Switch					983	7.3	2 bits	states	4 states/2 bits	0	3
Engine PTO Governor Set Switch					984	7.1	2 bits	states	4 states/2 bits	0	3
COMPONENT IDENTIFICATION	FEEB	65259	6	On Req							
Make					586	a	5 Bytes	ASCII	N/A	0	255
Model					587	b	200 Bytes	ASCII	N/A	0	255
Serial Number					588	c	200 Bytes	ASCII	N/A	0	255
SHUTDOWN	FEE4	65252	6	Tx							
Engine Over speed Test					2812	7.7	2 bits	states	4 states/2 bits	0	3
Engine Wait To Start Lamp					1081	4.1	2 bits	states	4 states/2 bits	0	3
SOFTWARE IDENTIFICATION	FEDA	65242	6	On Req							
Software Identification					234	2 Onwards	200 Bytes	ASCII	N/A	0	255
Number Of Software Identification Fields					965	1	8 bits	step	1 step/bit	0	250
SERVICE INFORMATION	FEC0	65216	6	On Req							
Service Delay/Operational Time Based					916	7-8	16 bits	Hr	1 hr/bit -32128hr Offset	-32127	32128

AUXILIARY ANALOG INFORMATION	FE8C	65164	7	On Req							
Auxiliary Temperature 1					441	1	8 bits	°C	1DegC/bit -40DegC Offset	-40	210
Auxiliary Pressure 1					1387	3	8 bits	kPa	16kPa/bit	0	4000
ELECTRONIC ENGINE CONTROLLER 2	F003	61443	3	Tx							
Accelerator Pedal Position 1					91	2	8 bits	%	0.4%/bit	0	100
Engine % Load At Current Speed					92	3	8 bits	%	1%/bit	0	250
Accelerator Pedal Position 2					29	5	8 bits	%	0.4%/bit	0	100
Accelerator Pedal 1 Low Idle Switch					558	1.1	2 bits	States	4 states/2 bit	0	3
Accelerator Pedal 2 Low Idle Switch					2970	1.7	2 bits	States	4 states/2 bit	0	3
SCR Thermal Management Active					5400	6.7	2 bits	States	4 states/2 bit	0	3
Actual Maximum Available Engine - Percent Torque					3357	7	1 byte	%	0.4 %/bit, Offset = 0 %	0	100
ELECTRONIC BRAKE CONTROLLER 1	F001	61441	6	Rx							
Engine Auxiliary Shutdown Switch					970	4.5	2 bits	States	4 states/2 bit	0	3
CAB MESSAGE 1	E000	57344	6	Rx							
Requested Percent Fan Speed					986	1	8 bits	%	0.4%/bit	0	100
Aftertreatment Regeneration Inhibit Switch					3695	6.1	2 bits	States	4 states/2 bit	0	3
CAB MESSAGE 2	8500	34048	6	RX							
Elevated Engine Speed Allowed Switch					7579	4.5	2 bits	states	4 states/2 bits	0	3
OPERATOR INDICATORS	FEFF	65279	6	Tx							
Water In Fuel Indicator					97	1.1	2 bits	States	4 states/2 bit	0	3
ENGINE HOURS	FEE5	65253	6	On Req							
Engine Total Hours Of Operation					247	1-4	32 bits	hour	0.05h/bit	0	210,554,060.75
ENGINE OPERATING INFORMATION (EOI)	FD92	64914	3	Tx							
Engine Operating State					3543	1.1	4 bits	States	11 states/4 bit	0000	0000 & 0100 only
OFF HIGHWAY ENGINE CONTROL SELECTION (OHECS)	FDCB	64971	6	Rx							
Engine Operating Mode Command					6808	5.5	4 bits	States	16 states/4 bit	0	4

Engine Alternate Low Idle Switch					2883	1.5	2 bits	States	4 states/2 bits	0	1
OFF HIGHWAY ENGINE CONTROL SELECTION STATES (OHCSS)	FDC7	64967	6	Tx							
Engine Operating Mode Selection					8694	5.5	4 bits	States	16 states/4 bit	0000	0100
Engine Alternate Low Idle Select State					2891	1.5	2 bits	States	4 states/2 bit	00	01
Engine State Request (ESR)	8700	34560	6	Rx							
Desired Engine Fuelling State					5793	1.1	2 bits	States	4 states/2 bit	0	1
Electronic Engine Controller 13 (EEC13)	FCC8	64712	6	Tx							
Feedback Engine Fuelling State					5794	1.1	2 bits	States	4 states/2 bit	0	1
Engine Fuelling Inhibit Allowed					5795	1.3	2 bits	States	4 states/2 bit	0	1
DIRECT LAMP CONTROL COMMAND 1 (DLCC1)	FD07	64775	6	Tx							
Engine Air Filter Restriction Lamp Command					5086	3.5	2 bits	States	4 states/2 bit	0	1
Direct Lamp Control Data 1 (DLCD1#)	FD05	64773	6	Tx							
Engine Oil Pressure Low Lamp Data					5099	2.5	2 bits	States	4 states/2 bit	0	1
Engine Coolant Level Low Lamp Data					5101	3.1	2 bits	States	4 states/2 bit	00	2
ENGINE START CONTROL (ENGSC)	F0ED	61677	4	Rx / Tx							
Engine Start Request				Rx	7745	1.1	2 bits	States	4 states/2 bit	0	3
Engine Start Consent				Rx	7746	1.3	3 bits	States	8 states/3 bit	0	7
Engine Start Abort Request				Rx	7747	2.1	2 bits	States	4 states/2 bit	0	3
Engine Starter 1 Feeback				Tx	7748	2.3	3 bits	States	8 states/3 bit	0	7
RESET (RESET)	DE00	56832	7	Rx							
Engine Ignition Control Maintenance Hours Reset					6219	3.7	2 bits	States	4 states/2 bit	0	3
Fan Drive #1 (FD1)	FEBD	65213	6	Tx							
Engine Fan 1 Estimated Percent Speed					975	1	1 byte	%	0.4 %/bit, Offset = 0 %	0	100
Fan Drive State					977	2.1	4 bits	States	16 states/4 bit	0	15
DIESEL PARTICULATE FILTER CONTROL 1 (DPFC1)	FD7C	64892	6	Tx							
Diesel Particulate Filter Lamp Command					3697	1.1	3 bits	States	8 states/3 bit, Offset = 0	0	7

Aftertreatment Diesel Particulate Filter Active Regeneration Status					3700	2.3	2 bits	States	4 states/2 bit	0	3
Aftertreatment Diesel Particulate Filter Status					3701	2.5	3 bits	States	8 states/3 bit	0	7
Diesel Particulate Filter Active Regeneration Inhibited Due to Inhibit Switch					3703	3.3	2 bits	States	4 states/2 bit	0	3
Diesel Particulate Filter Active Regeneration Inhibited Due to Temporary System Lockout					3714	6.1	2 bits	States	4 states/2 bit	0	3
Diesel Particulate Filter Active Regeneration Inhibited Due to Permanent System Lockout					3715	6.3	2 bits	States	4 states/2 bit	0	3
TORQUE SPEED CONTROL 1	0	0	3	Rx							
Override Control Mode					695	1.1	3 bits	States	4 states/2 bit	0	3
Requested Speed Control Conditions					696	1.3	2 bits	States	4 states/2 bit	0	3
Override Control Mode Priority					897	1.5	2 bits	States	4 states/2 bit	0	3
Requested Speed / Speed Limit					898	2-3	16 bits	rpm	0.125 rpm per bit, Offset = 0 rpm	0	8,031.875
Requested Torque / Torque Limit					518	4	8 bits	%	1 %/bit, Offset = -125 %	-125	125
TSC1 Transmission Rate					3349	5.1	3 bits	States	8 states/3 bit, Offset = 0	0	7
TSC1 Control Purpose					3350	5.4	5 bits	States	32 states/5 bit, Offset = 0	0	31
Message Counter					4206	8.1	4 bits	Count	1 count/bit, Offset = 0 count	0	15
Message Checksum					4207	8.5	4 bits	Count	1 count/bit, Offset = 0 count	0	15
ECU IDENTIFICATION INFORMATION (ECUID)	FDC5	64965	6	On Req							
ECU Part Number					2901	a	Variable	ASCII	Offset = 0	0	255 per byte
ECU Serial Number					2902	b	Variable	ASCII	Offset = 0	0	255 per byte
ECU Manufacturer Name					4304	e	Variable	ASCII	Offset = 0	0	255 per byte
VEHICLE FLUIDS (VF)	FE68	65128	6	Rx							
Hydraulic Temperature					1638	1	8 bits	°C	1DegC/bit -40DegC Offset	-40	210
TRANSMISSION FLUIDS 1 (TRF1)	FEF8	65272	6	Rx							

Transmission Oil Temperature 1					177	5-6	16bits	°C	0.03125 °C/bit, Offset = -273 °C	-273	1734.96875
CONTINUOUS TORQUE & SPEED LIMIT REQUEST (CTL)	CF00	52992	6	Tx							
Engine Speed Limit Request - Minimum Continuous					1784	1	8 bits	rpm	32rpm per bit, Offset = 0rpm	0	8000
ELECTRONIC ENGINE CONTROLLER 4 (EEC4)	FEBE	65214	7	On Req							
Engine Rated Power					166	1-2	16 bits	kW	0.5 kW per bit, Offset = 0 kW	0	32127.5
AFTERTREATMENT 1 SERVICE 1 (AT1S1)	FD7B	64891	6	On Req							
Aftertreatment 1 Diesel Particulate Filter Soot Load Percent					3719	1	8 bits	%	1%/bit	0	250

Table 16.2 J1939 Broadcasted Parameters

DIAGNOSTIC MESSAGES										
Active Diagnostic Trouble Codes (DM1)	FECA	65226	6							
Malfunction Indicator Lamp Status				1213	1.7	2 bits	States	2 states/2 bit	0	1
Red Stop Lamp Status				623	1.5	2 bits	States	2 states/2 bit	0	1
Amber Warning Lamp Status				624	1.3	2 bits	States	2 states/2 bit	0	1
Protect Lamp Status				987	1.1	2 bits	States	2 states/2 bit	0	1
Flash Malfunction Indicator				3038	2.7	2 bits	States	4 states/2 bit	0	4
Flash Red Stop Indicator				3039	2.5	2 bits	States	4 states/2 bit	0	4
Flash Amber Warning Indicator				3040	2.3	2 bits	States	4 states/2 bit	0	4
Flash Protect Indicator				3041	2.1	2 bits	States	4 states/2 bit	0	4
Suspect Parameter Number*				1214	3-5.6	19 bits	Status	1 SPN/bit	0	524287
Failure Mode Identifier				1215	5.1	5 bits	Status	1 FMI/bit	0	31
Occurrence Count				1216	6.1	7 bits	Status	1 Count/bit	0	126
Previously Active Diagnostic Trouble Codes (DM2)	FECB	65227	6							
Suspect Parameter Number*				1214	3-5.6	19 bits	Status	1 SPN/bit	0	524287
Failure Mode Identifier				1215	5.1	5 bits	Status	1 FMI/bit	0	31
Occurrence Count				1216	6.1	7 bits	Status	1 Count/bit	0	126

Table 16.3 J1939 Diagnostic Messages

16.3 J1939 Parameters – Detailed Descriptions

Note: The PGN numbers are written in some documents in decimal form (e.g.61444). This document will use the Hexadecimal form (e.g. F004) as it is easier to remember and simpler to decode when using tools to analyse traffic on the CAN J1939 bus.

16.3.1 Sending Messages to the Engine ECU

The engine ECU supports a large number of different J1939 PGN's and SPN's including messages such as TSC1, OHECS, and DM1 etc. Some of these messages are requests from external devices such as TSC1 and others are generated on transmitted by the ECU itself. Messages intended to be sent to the engine ECU require that the correct source and destination addresses are used.

16.3.1.1 Source Addressing

The source address is used to identify different components and electronic control modules on a CAN bus, source address assignment is given in appendix B of SAE J1939. Engine #1 source address is 00, and the service tool source address is FA. Preferred J1939 source addresses vary between industry groups, when designing a system, check tables B1-B7 in the SAE J1939 standard to ensure the correct source address is allocated. The ECU will accept messages from modules with any source address as long as it is different to the source address of the engine ECU.

16.3.1.2 Destination Addressing

For messages controlling the engine functionality, such a TSC1 and OHECS, the engine will only respond to these messages when sent with a destination address of 00.

The Request PGN message is also sensitive to the population of the destination address field. When the engine #1 destination 00 is requested, then the engine ECU responds with the RTS Transport protocol message, and will not release the requested information until the handshake message CTS is returned.

When the global destination is given for a Request PGN message FF (Global), then the engine ECU responds by sending the requested message. If the message is larger than 8 bytes then it will be released via the Transport Protocol BAM message. When the global destination is used, there is no need to use the RTS/CTS protocol.

16.3.2 J1939 Section 71 – TSC1 Operation

16.3.2.1 Torque Speed Control (TSC1) Operating Principles

The TSC1 message is a J1939 PGN designed to allow the Torque/Speed control of an engine via the CAN bus. This message can be used by any electronic control module to request or limit the engine speed / torque output. Some of the features primary uses are; direct engine speed control via a machine controller (removes the need for a fixed throttle connection to the engine ECU), or the limiting of engine speed / torque during transmission gear changes.

The OEM is responsible for ensuring that the implementation of TSC1 speed control is safe and appropriate for the engine and machine. Furthermore it is necessary for the OEM to perform a risk assessment validation of the machine software and hardware used to control the engine speed via TSC1.

16.3.2.1.1 *Engine Speed Control*

When correctly configured the speed control feature of the TSC1 message will directly control the engine speed. This means that desired engine speed will be set to the value contained within the TSC1 message. The engine will then respond to this request and attempt to reach the desired engine speed value. It should be noted that the TSC1 speed control message will override all other engine speed demand inputs such as analogue / PWM throttles.

16.3.2.1.2 *Engine Torque Control*

TSC1 torque control offers the user the same type of function as the speed control feature but with the input being a torque control value. By controlling engine torque output the controlling device is actually requesting an engine delivered fuel quantity from the engine ECU. Care must be taken when operating this mode as controlling engine fuelling can lead to unpredictable engine behaviour (and speed) especially when implemented under transient load conditions.

Note: This feature must not be implemented without consulting the Caterpillar Applications Engineering department and a full FMEA/risk assessment must be carried out by the customer.

16.3.2.1.3 ***Engine Speed Limiting***

Engine speed limiting is a feature, which enables a machine controller to request a physical engine speed limit value as opposed to a speed control. Under this configuration the additional throttle inputs available on the machine will remain active, only up until the TSC1 transmitted speed limit is reached.

For example; if the TSC1 message is set to Speed limit with a value of 1800rpm, the operator's foot throttle will remain active and the engine will respond to any speed requests from the pedal. However if an engine speed above 1800rpm is requested then the engine speed will not respond and be limited to 1800rpm.

16.3.2.1.4 ***Engine Torque Limiting***

The Engine Torque limiting function, when configured limits the max torque output of the engine to a value determined as a percentage of the max available torque for the particular rating curve being operated. The graph below is an example of an engine torque curve and the resulting engine response once an 80% torque limit is transmitted via TSC1. As with the speed limiting function the engine will operate as normal while the engine torque requirement is less than 80% but will limit the engine torque output to 80%.

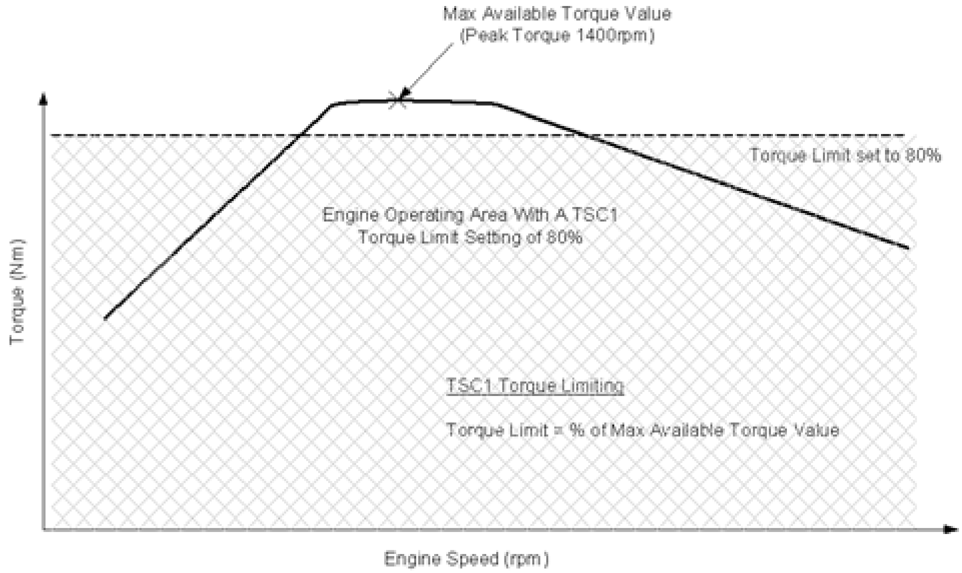


Figure 16.2

16.3.2.1.5 ***Dynamic Engine Torque Limiting***

The TSC1 torque limiting feature can be used dynamically to effectively shape a torque curve that provides the same or less torque capability across the operating speed range. To do this the TSC1 torque limit must be varied based on a given engine speed.

Implementation will require a machine controller and a form of Torque map based on engine speed.

Calibration of this map will most likely require dyno connection and a full understanding of the following J1939 SPN's for the correct Torque limit to be applied.

SPN's transmitted to support dynamic torque limiting and general torque availability are:

Parameter	PGN	SPN	Description
Actual Engine % Torque	61444	513	Torque transmitted by engine as a % of Indicated Reference Torque (Peak Torque).
Nominal Friction % Torque	65247	514	Friction Torque losses internal to engine transmitted as a % of indicated Reference Torque.
Engine Reference Torque	65251	544	Max Torque defined as Indicated Torque (Flywheel Torque + Frictional Torque).
Engine % Load At Current Engine Speed	61443	92	The ratio of actual engine % torque against max available at current engine speed. All torques are indicated values.
Actual Maximum Available Engine - Percent Torque	61443	3357	This is the maximum amount of torque that the engine can immediately deliver as a percentage of the reference engine torque (SPN 544). The Actual Maximum Available Engine - Percent Torque takes into consideration all engine torque limitations such as air-fuel-ratio and enforced derates.
Engine Speed Requested Torque Limit	0	518	TSC1 SPN used to communicate the require Torque limit values to the engine ECU.
Engine Override Control Mode	0	695	TSC1 setting to allow the use of Torque limiting.

Table 16.4

Terminology:

Indicated Torque is the total torque generated by the engine including the torque required to overcome internal friction.

Flywheel Torque is the advertised torque available at the flywheel and can be determined by subtracting the frictional torque from the indicated torque value.

16.3.2.1.5.1 Enabling TSC1 Torque Limiting

To enable engine torque limiting TSC1 must be sent from the machine controller at a rate and format as detailed in Chapter 17. When TSC1 Torque limiting is required the TSC1 PGN should be set with the settings shown below;

- **SPN 695** = 11 (binary) Speed/torque limit control required
- **SPN 518** = Required Torque limit value
- **SPN 3350** = 11111 (binary) TSC1 Control Purpose set to P32 Temporary Power Train Control

16.3.2.1.5.2 Calculating a Dynamic Torque Limit

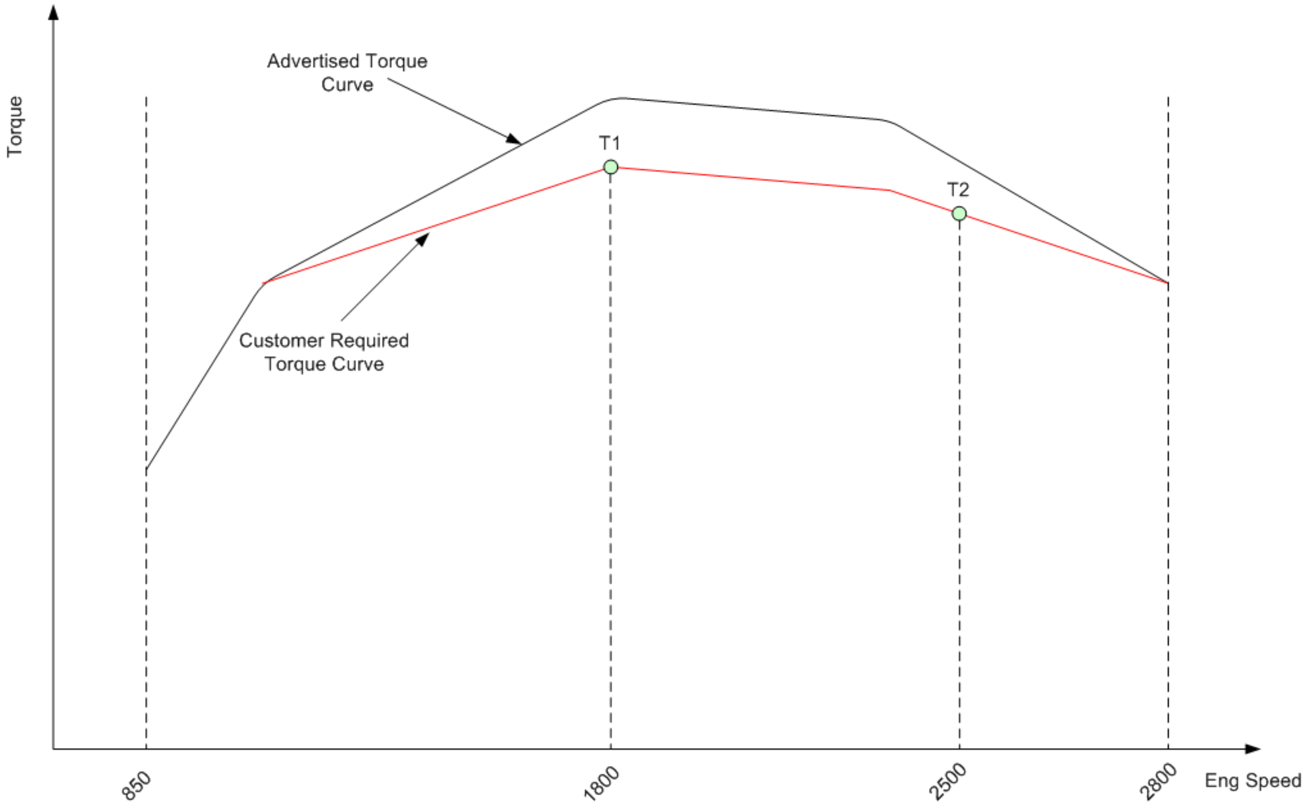
To calculate a dynamic Torque value OEM needs to determine the required max torque limits across the machine operating speed range and transmit a varying Torque limit via TSC1.

As the transmitted torque values and TSC1 torque limits are set based on Indicated torque %, the following calculations need to be made to translate machine T requirements into a TSC1 torque limit.

Example:

Using Figure 17.2 and the following customer T requirements for T1 and T2 the TSC1 torque limit % can be calculated as follows:

- Advertised curve T1 = 208Nm
- Customer required curve T1 = 198Nm
- Advertised curve T2 = 190Nm
- Customer required curve T2 = 180Nm



Note: T1 and T2 are examples only and in reality the customer will need to provide torque limits across the engine speed range in order for a shaped Torque curve as shown by the red line is to be achieved.

Figure 16.3

Calculation T1

TSC1 Torque limit needs to be set as a % of indicated Torque (indicated T = flywheel T + Frictional T). Customer requirement is for max T of 198Nm flywheel Torque.

1) Calculate Frictional Torque at T1
- Data taken from CAN bus at 1800rpm
- Engine Reference Torque SPN 544 = 239Nm
- Engine friction Torque SPN 514 = 13%
- Engine friction Torque (Nm) = 239Nm * 0.13 = 31Nm

2) Calculate using CAN bus data machines Torque limit as a function of indicated Torque.
- Indicated Torque Customer T1 = T1 flywheel T + T1 frictional torque
- Indicated Torque Customer T1 = 198Nm + 31Nm
- Indicated Torque Customer T1 = 229Nm

3) Format customer required Torque limit as a function of advertised reference torque for TSC1 message.
- TSC1 Torque Limit T1 % = (Indicated Torque Customer T1 / Engine Ref Torque)x100
- TSC1 Torque Limit T1 % = (229Nm / 239Nm)x100
- TSC1 Torque Limit T1 % = 96%

4) So for a T limit of 198Nm at 1800rpm TSC1 SPN 518 needs to be set to 96%.

Calculation T2

1) Calculate Frictional Torque at T2
   - Data taken from CAN bus at 2500rpm
   - Engine Reference Torque SPN 544 = 239Nm
   - Engine friction Torque SPN 514 = 16%
   - Engine friction Torque (Nm) = 239Nm * 0.16 = 38Nm

1) Calculate using CAN bus data machines Torque limit as a function of indicated Torque.
   - Indicated Torque Customer T2 = T2 flywheel T + T2 frictional torque
   - Indicated Torque Customer T2 = 180Nm + 38Nm

    - Indicated Torque Customer T2 = 218Nm
2) Format customer required Torque limit as a function of advertised reference torque for TSC1 message.
    - TSC1 Torque Limit T2 % = (Indicated Torque Customer T2 / Engine Ref Torque)x100
    - TSC1 Torque Limit T2 % = (218Nm / 239Nm)x100
    - TSC1 Torque Limit T2 % = 91%

So for a T limit of 180Nm at 2500rpm TSC1 SPN 518 needs to be set to 91%.

16.3.2.1.6 *Arbitration For Multiple TSC1 Messages*

Some OEM applications require the engine to respond to TSC1 messages sent from more than one controller. The Caterpillar product range can support TSC1 messages sent from more than 1 source address and the arbitration applied adheres to the flow chart specified within the SAEJ1939-71 section Appendix D. For more information please consult the SAE J1939-71 standard. If multiple controllers are used to send TSC1 messages to the engine ECU the following rules must be applied.

- Each controller must have an individual Source Address
- Override control mode priority must be used to determine which controller is master i.e. highest priority wins.

Please Contact your Caterpillar Applications Engineer for more information.

16.3.2.1.7 *Multiple J1939 TSC1 messages – Simultaneous Speed Control and Torque Limiting*

It is recognized that the J1939 TSC1 is more and more used to control Engine speed through the J1939 Network. However, there is also a need to be able to limit the output torque of the Engine to support the modern Transmission and Machine Strategies. In order to support this kind of usage of the TSC1 message, Caterpillar has included the usage of the SPN 3350 to differentiate the TSC1 Control Purpose of each message and offers an alternative to have the Engine control Speed and limit the Torque through the J1939 TSC1 message. How the message needs to be configured to ensure the right behaviour of the Engine is explained below. To ensure the feature works correctly the two TSC1 messages must also be sent from different Source Addresses, see details below.

To permanently control the Engine Speed through the TSC1 message, the Speed request message should be set as follows:

- **SPN 695** = 01 (binary) Speed Control required
- **SPN 898** = Required Speed value
- **SPN 3350** = 00000 (binary) TSC1 Control Purpose set to P1 Accelerator Pedal
- **<u>Source address for this message must be 0x03</u>**

In addition to this message, a second TSC1 message can be sent by the Machine controller to set the Torque Limit (or Speed Limit.) This message should be set as follows:

- **SPN 695** = 11 (binary) Speed/torque limit control required
- **SPN 518** = Required Torque limit value
- **SPN 3350** = 11111 (binary) TSC1 Control Purpose set to P32 Temporary Power Train Control
- **<u>Source address for this message must be different and can be anything except for: 0x00, 0x03 or 0xFA</u>**

It is critical that the TSC1 message with the P32 Temporary Power Train control purpose is used only for Torque limiting purpose. If this control mode is used with a speed request, then the speed request will take priority over the torque limit and the torque limit will not be applied.

16.3.2.2 Torque Speed Control (TSC1) Message Configuration & Control

The Torque/Speed control #1 (TSC1) PGN allows electronic control devices connected to the CAN network to request / limit engine speed and / or torque. This feature is often used as part of a closed loop engine control system with broadcast message parameters such as engine speed (EEC1). Usage is particularly common in machines that have complex hydraulic systems.

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
0C 00 00 xx	10	000000	3	0	0	See above	00

Table 16.5

Send	Receive	Parameter name	Byte	Bit	Length	State	Units	Resolution (unit/bit)	Range Min	Range Max
	X	**Override Control Mode (spn 695)**	1	1	2					
	X	Override Disabled				00				
	X	Speed Control				01				
	X	Torque Control				10				
	X	Speed/Torque Limit Control				11				
		Requested Speed Control Conditions (spn 696)		3	2					
	X	**Override Control Mode Priority (spn 897)**		5	2					
	X	Highest Priority				00				
	X	High Priority				01				
	X	Medium Priority				10				
	X	Low Priority				11				
		Not Defined		7..8						
	X	**Requested Speed / Speed Limit (spn 898)**	2	1	16		Rpm	0.125	0	8032
	X	**Requested Torque / Torque Limit (spn 518)**	4	1	8		%	1	-125	+125
	X	**TSC1 Control Purpose (spn 3350)**	5	4	5					
	X	P1 Accelerator Pedal/Operator Selection				00000				
	X	P32 =Temporary Power Train Control				11111				
	X	**Message Counter (spn 4206)**	8	1	4		Count		0	15
	X	**Message Checksum (spn 4207)**	8	5	4		Count		0	15

Table 16.6

16.3.2.2.1 *ECU Response Time to TSC1 Request*

The mean response time for the ECU to alter the desired speed following a TSC1 request is 52 ms +/-5 ms. Note: there will be a further delay in the engine's actual speed response due to the driving of mechanical components. If TSC1 response time is critical to transmission development and operation, contact your Caterpillar Application Engineering Department for further information.

16.3.2.2.2 *TSC1 Configuration*

TSC1 is always available as a speed demand input, and given that a J1939 diagnostic code is not active, the engine will prioritize the TSC1 request above all other speed demand inputs. In effect, TSC1 overrides all other configured throttle inputs.

Configuration field names	Configuration Options	Default Configuration	ECU / Fleet Replacement File	Password Level
TSC1 Continuous Fault Handling	Enabled Disabled	Disabled	Yes	1

Table 16.7

16.3.2.2.3 *TSC1 Continuous Fault Handling: [Disabled] (Default)*

This mode is also known as transient fault detection. It is suitable for applications where there is more than one throttle input into the ECU, for instance, in a wheeled excavator where the analogue throttle is used to control road speed, but TSC1 is used to control the machine hydraulics. The TSC1 message will override any other speed demand such as Analogue / PWM throttle pedal. TSC1 override is switched on and off using the override control mode SPN.

For this configuration the TSC1 transmission can be stopped during engine operation using the Override control mode as explained in Section 16.3.2.2.4 below. During engine shutdown TSC1 message transmission can stop as soon as the ECM keyswitch is off, the Override Control Mode SPN does not need to be set to 0.

To ensure 639-9 faults are not triggered during shutdown due to TSC1 stopping before the ECM has recognised the keyswitch is off, it is recommended that a TSC1 throttle is powered from the ECM Main Power Relay, not the Keyswitch.

Remote Torque Speed Control Enable Status should be set to Disabled in the Service Tool for this type of Fault Handling.

16.3.2.2.4 *End of Transmission – Fault Detection*

The ECU needs to differentiate between the end of a transmission by another controller and an intermittent failure. The ECU expects, therefore, that when a controller no longer wishes to demand engine speed then it will terminate with at least one message with the Control Override Mode SPN set to 00. If the engine sees that TSC1 messages have stopped, for **90ms** or more, and TSC1 has not been terminated correctly, the ECU will recognize this as a fault, a 639-9 diagnostic code will be raised and the ECU will not accept any TSC1 speed requests for the remainder of the key cycle.

16.3.2.2.5 *TSC1 Continuous Fault Handling: [Enabled]*

This mode is also known as *Continuous* fault detection, it is suitable for applications where TSC1 is the only throttle used and so TSC1 speed control is always used. In this mode TSC1 cannot be switched off using the Override Control Mode SPN. For instance, in a wheeled excavator, the analogue throttle is connected to the machine ECU that sends the TSC1 message to control road speed, and to control the machine hydraulics. When TSC1 continuous fault handling is active, other throttles will be permanently overridden, and will only become available if a TSC1 fault is detected.

To ensure 639-9 faults are not triggered during shutdown due to TSC1 stopping before the ECM has recognised the keyswitch is off, it is recommended that a TSC1 throttle is powered from the ECM Main Power Relay, not the Keyswitch.

Remote Torque Speed Control Enable Status should be set to Enabled in the Service Tool for this type of Fault Handling.

16.3.2.2.6 *TSC1 Message Counter*

The message counter is used to detect situations where the transmitting ECU malfunction repeats the same frame all the time. The receiver of the information may use the counter parameter to detect this situation. The transmitting device will increase the message counter in every cycle. The message counter will count from 0 to 7 and then wrap.

The values 8h thru Eh are SAE reserved and should be ignored by the receiver.

Value Fh (all bits set to 1) will indicate that the message counter is not available. For compatibility purposes, TSC1 will operate as normal if the message counter is not available from the transmitting device (as per previous use of TSC1.)

If the transmitting device sends ‘FF’ then the ECU will not monitor this SPN.

16.3.2.2.7 *TSC1 Message Checksum*

The message checksum is used to verify the signal path from the transmitting device to the receiving device. The message checksum is calculated using the first 7 data bytes, the message counter and the bytes of the message identifier. It is calculated as follows:

Checksum = (Byte1 + Byte2 + Byte3 + Byte4 + Byte5 + Byte6 + Byte7 + (message counter & 0Fh) + message ID low byte + message ID mid low byte + message ID mid high byte + message ID high byte)

Message Checksum = (((Checksum >> 6) & 03h) + (Checksum >>3) + Checksum) & 07h

Value Fh (all bits set to 1) will indicate that the message checksum is not available. For compatibility purposes, TSC1 will operate as normal if the message counter is not available from the transmitting device (as per previous use of TSC1.)

If the transmitting device sends ‘FF’ then the ECU will not monitor this SPN.

16.3.2.2.8 *Example TSC1 speed control Message format*

When transmitting TSC1 all 8 data bytes should be included in the PGN. Those not supported or not required should be set to FFh.

- Identifier format: c000017h
- Identifier priority: 3
- PGN: 0
- Destination address: 00 (Engine#1 address)
- Source address: See table 17.1

Data byte number	1	2	3	4	5	6	7	8
Data	01	A0	28	FF	07 Or FF	FF	FF	FF

Figure 16.4

- Byte 1: Override Control Mode (SPN 695) = 01 (Speed Control)
- Byte 2-3: Requested Engine Speed (SPN 898) = 28A0h (1300rpm)
- Byte 4: Requested Torque Limit (SPN 518) = FF not required
- Byte 5: TSC1 Control Purpose (SPN 3350) = 07 (Accelerator pedal) or FF (Temporary Power Train Control)
- Byte 6: Engine Requested Torque (SPN4191) = FF not required
- Byte 7: Not required
- Byte 8: Message Counter and Checksum

16.3.2.2.9 *Example TSC1 Checksum Calculation*

Binary operations are required to do the calculation:

& as a function must be done by converting the figures into binary and then using an AND function to combine the binary numbers

2 & 03 in binary is 10 AND 11 -> 10, which in HEX is 2

>> means bit-shift right and << means bit shift left, <<2 means bit shift left twice.

3 in binary is 11 <<2 makes 1100 which is C in HEX

Worked Example

Message ID – C000003x

Byte1 – FD

Byte2 – B0

Byte3 – 1D

Byte4 – E1

Byte5 - FD

Byte6 – FF

Byte7 - FF

Message Counter – 1

message ID low byte -> source address - > 03
message ID mid low byte -> first two bytes of pgn -> 0 (pgn in hex 0000)
message ID mid high byte -> last two bytes of pgn ->0
message ID high byte -> (message priority << 2) -> 3 << 2 - > C

Checksum = (Byte1 + Byte2 + Byte3 + Byte4 + Byte5 + Byte6 + Byte7 + (message counter & 0Fh) + message ID low byte + message ID mid low byte + message ID mid high byte + message ID high byte)

Message Checksum = (((Checksum >> 6) & 03h) + (Checksum >>3) + Checksum) & 07h

Checksum = FD + B0 + 1D + E1 + FD + FF + FF + (1&F) + 3 + 0 + 0 + C

1&F in binary is 1 AND 1111 -> 1 which in HEX is also 1

Checksum = 5B6

Note: because checksum is unsigned_8 use only fist 2 bytes

Checksum = B6

Message Checksum = (((B6 >> 6) & 03h) + (B6 >>3) + B6) & 07h

B6 >> 6 in binary 10110110 >>6 is 10 which is 2 in HEX.

B6 >> 3 in binary 10110110 >>3 is 10 which is 16 in HEX.

Message Checksum = ((2 & 03h) + 16 + B6) & 07h

Message Checksum = ((2 & 03h) + CC) & 07h

2 & 03 in binary is 10 AND 11 -> 10, which in HEX is 2

Message Checksum = (2 + CC) & 07h

Message Checksum = CE & 07h

CE & 07 in binary is 11001110 AND 111 -> 110 which in HEX is 6

Message Checksum = 6

17.0 Lamp and LED Specification

Maximum lamp driver current for the following pins are as follows;

Descriptions	Pin Allocation	Maximum Current	Leakage Current
Engine Warning Lamp	J1-51	<0.45A	1.1mA @32V
Engine Shutdown Lamp	J1-38	<0.4A	0.18mA @32V
Low DEF Lamp	J1-63	<0.45A	1.1mA
Engine Oil Pressure	J1-39	<0.4A	0.18mA @32V
Engine Wait to Start Lamp	J2-60	<0.4A	1.5mA @32V
Emission System Malfunction Lamp	J2-59	<0.4A	1.5mA @32V
Wait To Disconnect Lamp	N/A	N/A	N/A
Engine Running Output Lamp	J2-104	<1A	190Ua @32V
DPF Lamp	J1-14	<0.4A	0.18mA @32V
Aftertreatment Regen Active Lamp	J2-71	<1A	150uA @ 32V
Regen Inhibit Lamp	J2-49	<0.4A	2mA @ 32V

Table 17.1

To correctly use a Light Emitting Diode (LED) with a ECU output driver, the LED will need a resistor in series (RS) and a resistor in parallel (RP).

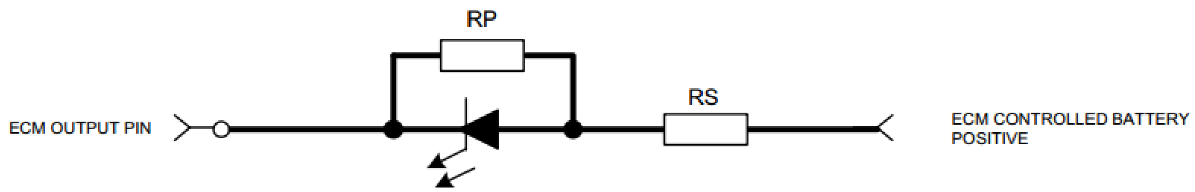


Figure 17.1

The series resistor (RS) is used to limit the current that will go through the LED and prevent it from burning out. This resistor is often called a current limiting resistor. To calculate the resistance required, use the following calculation, where $V_{LED\ Forward}$ is the voltage drop across the LED, given by the manufacture of the LED and I_{MAX} is the max current rating of the ECU driver.

$$RS = \frac{(V_{BATT} - V_{LED\ Forward})}{I_{MAX}}$$

Special consideration should be given when connecting a LED to the engine ECU lamp output driver. LED's are particularly sensitive to low currents and may light dimly even when the ECU output driver is off. This is due to a small leakage current through the internal circuit of the ECU. Additionally, when the output driver is on it is necessary to ensure that there is minimum circuit current. The minimum circuit current is required to ensure that the circuit diagnostics function correctly. LED's may be used if connected in parallel with an appropriate resistor (RP), the leakage and diagnostic current will then flow through the parallel resistor. This resistor is often called a shunt resistor. To calculate the resistance required, use the following calculation, where $I_{leakage}$ is the current leakage from the driver in the OFF state, given by Table 17.1.

$$RP = \frac{V_{LED\ Forward}}{I_{leakage}}$$

When selecting the resistors, attention will need to be made to the power rating. The selection of resistor will have to be capable of handling the expected power seen on the circuit. This can be worked out using the simple calculation below, where Vmax is the maxium voltage on the electrical system. Maximum voltage for 12V systems it is 18V and for 24V systems it is 32V.

$$Power\ Rating = V_{Max} \times I_{Max}$$

18.0 Connector List Information

Please refer to the separate electrical schematics referenced in Section 2.3.5

19.0 Appendix – Update Table

Detail	Manual Version	Section
Max Current Draw and Voltages updated	00	4.3
ECU and Injector Resistance Design Limits corrected	00	4.9
ECU Connector Orientation Options added	00	5.4
Fuel Lift Pump Control Options Corrected	00	6.6.1
NOx Sensor Endbell provision corrected	00	7.2.3.1
DPF Delta P Sensor Link Harness requirements clarified	00	7.4.4
DEF Heated Line Numbering corrected	00	7.7.1
Engine Coolant Diverter Valve Inlet/Outlet labelling corrected	00	7.9.1
DEF Reversing Valve Relay spec corrected	00	7.11.2
Starter Motor Control Configuration field names corrected	00	8.1.1.3
Starter Motor Control Wiring added for J1939 crank requests	00	8.1.1.5
Throttle Lock (PTO Mode) usage rules updated	00	9.3
Multi Position Throttle Switch usage rules and config updated	00	9.4
Manual Throttle Arbitration Switch configuration corrected	00	9.6
Glow Plug Relay spec updated	00	10.1.2
Heated Breather option added	00	10.3
Engine & Aftertreatment Mandatory and optional Lamps updated	00	100
Regen Active Lamp and Regen Inhibit Lamp added	00	11.3.1, 11.3.2, 11.3.13, 11.3.14
Wait To Disconnect Indicator wiring corrected	00	11.3.11
Engine Monitoring System feature updated	00	12.0
DPF Regeneration Logic updated and new configurations added	00	13.1
Elevated Idle Secondary Speed added	00	13.1.6
DPF Regeneration Escalation Overview added	00	13.2
DPF Regeneration Inhibit Feature added	00	13.3
Coolant Level switch feature updated	00	15.2.1
Low Battery Voltage Elevated Idle functionality updated	00	15.8.1
Maintenance Indicator operation updated	00	15.10.1
J1939 Messages updated	00	16.2
TSC1 Message Support for Counter and Checksum added	00	16.3.2.2, 16.3.2.2.6, 16.3.2.2.7
TSC1 End of Transmission Fault Detection updated	00	16.3.2.2.4
Lamp and LED leakage current information added	00	17.0
Glowplug fusing for 12V corrected	01	10.1.2
DPF Regen Escalation Strategy updated	01	13.2
Inhibit Regen Switch functionality updated	01	13.3.1
Low Idle Shutdown Events added	01	8.2.6
J1939 Quick Reference Table updated/corrected	01	16.2
Heated Breather installation details updated	01	10.3

Injector Resistance limit wording corrected to measure from ECM to EIC and to include all injector wires	01	4.8
Electric Lift /Prime Pump configuration wording corrected to align with Service Tool	01	6.6.2
Hydraulic Oil and Transmission Oil Temp J1939 message details added for Demand Fan support	01	16.2
All schematic installation diagrams removed as these are duplicated in the main schematic documents referenced in Section 2.3.5	01	Multiple
DPF Lamp installation changed to mandatory to support DPF Regen Escalation strategy	01	3.2 / 11.4.12.2 / 11.1
TSC1 Speed Control with Torque Limit feature requirements updated	01	16.3.2.1.7
All sections updated to include directions for the Stage IIIA equivalent engine variant	01	Multiple
DPF Regen J1939 Message summary added	01	13.4
Analogue Throttle IVS Compatibility Test added	01	9.1.4
Electric Lift/Prime Pump Fusing updated	01	4.3.11/6.6.3
DEF Quality Indicator support removed as it is no longer supported	01	11.4
Mandatory and Optional Components updated – Inhibit Switch, Inhibit Lamp and Regen Active Lamp moved to Optional Table	01	3.2 and 3.3
New DEF Pump Wiring requirements included to ensure correct diagnostic capability	01	7.6.4
Mode Selection feature safety advice added	02	14.5.1
User Defined Shutdown safety advice added	02	8.2.3.1
Elevated Idle Speed setting PGN/SPN updated to SPN1784	02	16.2
New Requirement to configure Elevated Idle Input Method	02	13.1.6 and 8.2.6.3
Running Out Indicator J1939 supported states corrected	02	11.4.14.3 and 16.2
Regen Inhibit Indicator pinout corrected	02	17.0
TSC1 Fault Handling explanation improved and additional guidance added	02	16.3.2.2.2, 16.3.2.2.3, 16.3.2.2.4
TSC1 Checksum Calculation example added	02	16.3.2.2.9
Functional Safety Content and Requirements added	02	1.2
DPF Lamp Flash and Fast Flash states added to announce when locked to idle speed	02	11.4.11, 13.2
J1939 Messages updated. Oil Pressure lamp SPN updated to 5099	02	11.4.2, 11.4.7.3, 16.2
Explanation for SPN3357 added – instantaneous max available torque	02	16.3.2.1.5
Injector Circuit Resistance guidance re-worded for more clarity on requirements	02	4.7
Oil Pressure Monitoring feature updated. L1 and L2 events no longer raised as not appropriate for an oil pressure switch. L3 event is only event supported.	02	12.2.2
DEF Purge max time updated from 120 to 70 seconds	02	13.5
High Coolant temp trip points and ranges updated	02	12.1.3
Mode Selection setup with multi rating flash file advisory warning added	02	14.5.1

ECM Output driver connection warning added	02	4.16
Glowplug Relay part numbers added	02	10.1.2
DEF Pump Supply Connector photo added to explain why only 10 pins visible	02	7.6.1
PWM Throttle Frequency ranges updated. Guidance on using 8-32V PWM sensor added.	02	9.2.3
Relay coil max current draw added for Main Relay, SCR Relay and DEF Reversing Valve Relay	02	6.1.1.2, 7.10.3, 7.11.2
DPF Regen Escalation Configuration updated to add choice for final engine behaviour following a quick restart when bypassing idle lockout	02	13.2.1
DEF Level Inducement table updated to make level 2 clearer with regard to Reduced Time or Reduced Performance behaviour	02	12.3.2.1
Max inrush current for ECM updated	02	4.3.1
Fuel Pump Solenoid wiring requirements clarified – same circuit resistance requirement as Injector circuit	02	4.8
Guidance on how to integrate elevated idle permission in a machine updated	02	13.1.7
Guidance note on how to configure the elevated idle speeds added which refers to the Exhaust Temperature Drop A&I Test	02	13.1.6.2
Aftertreatment Regeneration Assist Engine Minimum Speed Configurable ranges updated	02	13.1.6.2
PTO Mode (Throttle Lock) Feature description improved	02	9.3
Air Conditioning Compressor information added	02	15.12
Starter Motor Control J1939 SPN bits updated to remove option for ‘automatic’ start request	02	8.1.1.6
Backshell details added	03	6.2.3
Starter Motor Control Configuration updated to include the new options of the starting system type in Table 8.1. New configuration option table included to show how to set Starter Motor Hardwired Control (8.1.1.4) or Starter Motor J1939 Control (8.1.1.5).	03	8.1.1.3
Important note added to state service tool tests and procedures need elevated idle message for safe state but doesn't send parasitic load request message	03	13.1.7
Aftertreatment Regeneration Assist Engine Minimum Speed Configuration Range updated in Table 19.3	03	13.1.6.2
Bit State information for SPN 8608 added under SPN Description in Table 14.3	03	14.5.4
New section added – Open/Closed Circuit Breather	03	10.4
New sub-section added – Radiator Adaptor	03	15.2.3.1
Figure showing an alternative installation setup deleted	03	8.1.1.4
Statement regarding SPN166 added, SPN166 added to Table 16.2	04	14.5.4, 16.2
Information related to unstable machine throttle input / fast transient response for demanded speed added.	04	9.0
Aftertreatment Regeneration Assist Engine Minimum Speed Configurable ranges updated in Table 13.3	04	13.1.6.2
Minor changes to the text for better understanding of the Regen Inhibit Operation.	04	13.3.1
Emergency Inducement Override sub-section added	05	12.3.7
SPN 3719 added to Table 16.2	05	16.2

L2 severity correction in Table 12.8	05	12.2.3.1
Configuration section corrected	06	15.9.2
Add China NR4 info (74.4 / 82kW) to all <56kW and DOC / DPF references	07	
Section 12.3.8 China NR4 Inducement Strategy	07	12.3.8
Diagnostic connector info	07	6.4.2
Level 3 inducement tables updated	08	12.3.2.1/2
As shipped configuration updated – Lift Pump	08	6.6.2
As shipped configuration updated – DEF Tank	08	7.8.2
As shipped configuration updated – Start System	08	8.1.1.3
As shipped configuration updated – Idle Speed	08	9.9.1.2
Update NOx Sensor limits -Change 85C to 110C	08	7.2.3
Applicable States updated in Table 11.11	09	11.4.10
Updated Figure 13.4 and 13.5	09	13.5.3
Driver output current range change to 0-2.5A	09	15.6.1
Example fan map added	09	15.6.1
Fan solenoid min and max currents configuration options changed to 0-2.5A	09	15.6.2
Engine cooling fan current ramp rate configuration options changed to 0-2.5A/sec	09	15.6.2
Configuration options corrected in table 6.8	09	6.6.2
Updated Engine Idle values and tables	10	13.2
Updated wait to disconnect to say that it is only mandatory or systems with DEF.	10	11.4.10
Corrected reference to the configuration screen	10	14.3
Updated contents references to correct errors	11	Contents Page
Added statement about peak busload.	11	16.1.3
Removed outdated reference from title	12	2.3.5
Added extra clarification on Nox sensor cabling	12	7.2.3.1

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