

Caterpillar C4.4, C6.6 & C7.1 Tier 4 Interim Series

ELECTRICAL & ELECTRONIC A&I GUIDE

Four & Six cylinder diesel engines for agricultural, industrial, construction applications

Developed to meet EEC off-road mobile machinery Stage IIIB and EPA off-road Tier 4 Interim legislation **Note:** Information in this manual is preliminary and is subject to change or withdrawal.

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CONTENTS

1.0 INTRODUCTION AND PURPOSE	9
1.1 APPLICABLE ENGINES	9
1.2 ELECTRONIC APPLICATIONS CONTACTS.....	9
1.3 SAFETY	9
1.3.1 Warning – Welding.....	10
1.3.2 Warning - Electrostatic Paint Spraying.....	10
1.3.3 Warning – Jump Starting.....	10
2.0 ENGINE & AFTERTREATMENT COMPONENT OVERVIEW	11
2.1 MAIN ENGINE SENSOR AND ACTUATOR DETAILS	11
2.1.1 Electronic Control Module (ECM).....	12
2.1.2 Fuel System.....	12
2.1.3 Engine Speed	12
2.1.4 Core Engine System.....	13
2.1.5 NRS (Nox Reduction System).....	13
2.1.6 Air System.....	14
2.1.7 Emissions System Assist Devices	14
2.2 AFTERTREATMENT SYSTEM SENSOR & ACTUATOR DETAILS.....	15
2.2.1 ARD (Auxiliary Regeneration Device) System	15
2.2.2 DPF System	15
2.3 SYSTEM COMPONENT DIAGRAMS AND SCHEMATICS.....	17
2.3.1 C4.4 Factory Installed Wiring and Components	17
2.3.2 C4.4 Customer Installed Aftertreatment Wiring & Components.....	18
2.3.3 C6.6 Factory Installed Wiring and Components	19
2.3.4 C6.6 Customer Installed Aftertreatment Wiring & Components.....	20
2.3.5 C7.1 Factory Installed Wiring and Components	21
2.3.6 C7.1 Customer Installed Aftertreatment Wiring & Components.....	22
2.4 ENGINE & AFTERTREATMENT COMPONENT LAYOUT DIAGRAMS	23
2.4.1 C4.4 Principle Engine Electronic Components.....	23
2.4.2 C6.6 Principle Engine Electronic Components.....	24
2.4.3 C7.1 Principle Engine And Aftertreatment.....	25
2.4.4 C7.1 CCEM Principle Electronic Components	26
3.0 CUSTOMER SYSTEM OVERVIEW KEY ELEMENTS.....	27
3.1 AFTERTREATMENT CONNECTIONS	27
3.2 CONNECTION, POWER AND GROUNDING	27
3.3 INDICATION, STARTING AND STOPPING THE ENGINE.....	27
3.4 CONTROLLING THE ENGINE.....	28
3.5 AFTERTREATMENT OPERATION AND REGENERATION	28
3.8 OPTIONAL CUSTOMER INSTALLED COMPONENTS	30
3.9 TYPICAL CUSTOMER INSTALLED COMPONENT DIAGRAM	31
3.9.1 Example OEM Schematic	31
3.9.2 Example 1 Basic Engine Application.....	31
3.9.3 Example 2 Construction Application.....	31
3.9.4 Example 3 Industrial Open Power Unit Application.....	31
3.9.5 Example 4 Agricultural Application.....	31
3.9.6 Example 1 - Basic Schematic OEM Harness.....	32
3.9.7 Example 2 - Construction Schematic OEM Harness.....	33
3.9.8 Example 3 – IOPU Schematic OEM Harness.....	34
3.9.9 Example 4 - Agricultural Schematic OEM Harness.....	35
4.0 POWER AND GROUNDING CONSIDERATIONS	36
4.1 ENGINE BLOCK GROUNDING	36
4.1.1 Ground stud on Starter Motor.....	36
4.1.2 Ground Connection to Tapping on engine Block	36
4.1.3 CEM Grounding C7.1.....	38
4.2 VOLTAGE AND CURRENT REQUIREMENTS	39

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

4.3 ECM POWER SUPPLY CIRCUIT RESISTANCE	40
4.3.1 Important Voltage Supply Circuit Considerations	42
4.3.2 Battery (+) Connection.....	42
4.3.3 Battery (-) Connection.....	44
4.3.4 Correct method of ECM battery connection.....	45
4.3.5 Incorrect method of ECM battery connection.	45
4.4 ENGINE ECM POWER SUPPLY CIRCUIT RESISTANCE TEST	46
4.4.1 Test Procedure.....	47
4.4.2 Suppression of Voltage Transients	47
4.5 DIRECT BATTERY CONNECTION REQUIREMENTS	49
4.6 POWERING THE ENGINE ECM VIA AUXILIARY POWER SUPPLIES	49
4.7 SENSOR COMMON CONNECTIONS.....	49
4.7.1 Actuator Driver Return.....	50
4.7.2 Analogue Sensor Return	50
4.7.3 Switch Return.....	50
4.7.4 Digital Return.....	51
4.8 MANDATORY FUEL LIFT PUMP INSTALLATION	51
4.8.1 Fuel Lift Pump Operation.....	51
4.8.2 Fuel Lift Pump Configuration	51
4.8.3 Fuel Lift Pump Installation.....	52
5.0 CONNECTORS AND WIRING HARNESS REQUIREMENTS	54
5.1 ENGINE ECM J1 CONNECTOR	54
5.1.1 Connector Layout	55
5.1.2 Tightening the OEM Connector.....	55
5.1.3 ECM connector Wire Gauge Size	55
5.1.4 Terminal Retention	56
5.1.5 Hand Crimping For Prototype machines and Low Volume Production:	56
5.1.6 ECM connector sealing plug installation guidelines.....	56
5.1.7 OEM harness Dress Cover With Integrated Strain Relief.....	56
5.1.8 Machine Crimping For High Volume Production	57
5.2 ENGINE TO AFTERTREATMENT CONNECTORS C7.1 ONLY.....	58
5.2.1 40 Way CEM Connector Layout C7.1	58
5.2.2 Engine Harness 31 pin Connector Layout C7.1	59
5.2.3 Tightening the Connectors.....	59
5.2.4 Aftertreatment Connectors Wire Gauge Size.....	59
5.2.5 Connector Sealing Plug Installation Guidelines	60
5.2.6 OEM Harness Retention.....	60
5.2.7 Harness Routing and Length Restrictions	60
5.3 DIAGNOSTIC CONNECTOR	61
5.3.1 Diagnostic Connector Layout.....	61
5.3.2 Diagnostic Connector Wire Gauge Size	62
5.3.3 Pin Information	62
5.4 CONNECTOR TERMINAL CONTACTS	63
5.5 HARNESS WIRING STANDARDS	64
5.4.1 Connectors.....	64
5.4.2 Harness Bends Near Connectors.....	64
5.4.3 Cable routing.....	65
5.4.5 Electromagnetic Compliance (EMC).....	66
5.4.6 Insulation Selection and Thermal Protection	66
6.0 CONNECTING TO ENGINE AFTERTREATMENT	67
6.1 C4.4 AND C6.6 EMISSION CRITICAL AFTERTREATMENT INSTALLATION	68
6.1.1 Low Temperature Regeneration System Overview	68
6.1.2 Low Temperature Regeneration	69
6.1.3 System Connection and Harness Design	70
6.1.4 Aftertreatment Wiring Schematic	71
6.2 C7.1 EMISSION CRITICAL AFTERTREATMENT	72
6.2.1 High Temperature Regenerations System Overview	72
6.2.2 High Temperature ARD Regeneration	73

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

6.2.3 C7.1 High Temperature Regeneration System Connection and Harness Design.....	74
6.2.4 Aftertreatment Wiring Schematic	78
6.4 AUXILIARY SENSOR INSTALLATION AND CONNECTION	79
6.4.1 DPF Soot Sensor	79
6.4.2 Air Inlet Temperature Sensor	83
6.4.3 DPF Inlet Temperature Sensor.....	84
6.4.4 DPF Identification Module.....	86
6.4.5 ARD Fuel Pump.....	87
7.0 STARTING AND STOPPING THE ENGINE	92
7.1 STARTING THE ENGINE.....	92
7.2 STOPPING THE ENGINE (AND PREVENTING RESTART)	93
7.2.1 Ignition Keyswitch.....	93
7.2.2 Battery Isolation Switches	94
7.2.3 User Defined Shutdown Switch (Remote Shutdown)	94
7.2.4 Intake Air Shutoff Valve.....	95
7.2.5 Overspeed Verify Switch.....	96
7.2.6 Datalink stops.....	96
7.2.7 Common problems with the application of stop devices.....	97
8.0 MACHINE FAN CONTROL	98
8.1 HYDRAULIC FAN CONTROL.....	98
8.1.1 Hydraulic Fan Operation	98
8.1.2 Hydraulic Fan Configuration	98
8.1.3 Hydraulic Fan Installation	98
8.2 VISCOUS FAN CONTROL.....	99
8.2.1 Viscous Fan Operation.....	99
8.2.2 Viscous Fan Configuration.....	99
8.2.3 Viscous Fan Installation.....	99
9.0 ENGINE SPEED DEMAND	100
9.1 ANALOGUE SENSOR	101
9.1.1 Analogue Sensor Operation.....	101
9.1.2 Analogue Sensor Configuration	101
9.1.3 Analogue Sensor Installation.....	102
9.1.4 Evaluating Component Compatibility (Testing).....	102
9.2 PWM SENSOR - COMPATIBILITY	105
9.2.1 PWM Sensor Operation.....	105
9.2.2 PWM Sensor Configuration.....	106
9.2.3 PWM Sensor Installation.....	106
9.3 THROTTLE LOCK (PTO MODE).....	107
9.3.1 Throttle Lock Mode Operation.....	107
9.3.2 Throttle Lock Mode Configuration.....	111
9.3.2 Throttle Lock Mode Installation	111
9.3.3 Throttle Lock Operation Under Engine Load.....	112
9.4 MULTI POSITION THROTTLE SWITCH (MPTS).....	113
9.4.1 MPTS Operation.....	113
9.4.2 MPTS Configuration.....	114
9.4.3 MPTS Installation.....	114
9.5 TORQUE SPEED CONTROL TSC1 (SPEED CONTROL OVER CAN).....	115
9.6 ARBITRATION OF SPEED DEMAND.....	115
9.6.1 Manual Throttle Selection Switch.....	115
9.7 ACCELERATION AND DECELERATION RAMP RATES	115
9.8 THROTTLE BEHAVIOR DURING ENGINE GOVERNOR CHANGES	116
9.9.1 Throttle Parameter Description	119
9.9.2 Throttle Calibration Function	120
9.9.3 Idle Validation Switch	124
9.10 DEFINITION OF ENGINE SPEED POINTS	125
9.10.1 Engine Low Idle.....	126

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

9.10.2 Engine High Idle.....	126
9.10.3 Engine Rated Speed.....	127
10.0 COLD WEATHER ENGINE OPERATION & STARTING AIDS	128
10.1 CONTROL OF GLOW PLUGS BY THE ENGINE ECM.....	130
10.1.1 Glow Plug System Operation.....	130
10.1.2 Glow Plug System Configuration	132
10.1.3 Glow Plug System Installation.....	132
10.2 ETHER COLD START SYSTEMS	134
10.2.1 Ether start Operation.....	134
10.2.2 Ether start Configuration	134
10.2.3 Ether start Installation.....	134
10.3 REGENERATION AID FOR COLD TEMPERATURE OPERATION.....	136
11.0 ENGINE & AFTERTREATMENT MONITORING – HIGH LEVEL INDICATORS & OPERATOR DISPLAYS.....	137
11.1 ENGINE MANAGEMENT SYSTEM STATUS INDICATION	137
11.1.1 Engine Monitoring System Fault Status Levels	137
11.1.2 Hardwired Lamp Monitoring System Display	138
11.1.3 Data Link Driven J1939 Monitoring System Display.....	138
11.2 GAUGE DRIVERS	140
11.2.1 Datalink Driven Intelligent Displays.....	140
11.2.2 Minimum Functional Specification for J1939 display.....	140
11.2.3 Customer Triggered Engine Fault codes.....	141
11.3 LAMP OUTPUTS	142
11.3.1 ISO Reference For Aftertreatment Symbols.....	142
11.3.2 Indicator lamps Logic.....	143
11.3.3 Engine Shutdown Lamp	146
11.3.4 Engine Warning Lamp.....	146
11.3.5 Wait to Start Lamp.....	147
11.3.6 Low Oil Pressure Lamp	147
11.3.7 DPF Lamp	148
11.3.8 HEST (High Exhaust System Temperature) Lamp.....	148
11.3.9 DPF Regeneration Disable lamp.....	149
11.4 ACTIVATION OF J1939 INDICATORS	150
12.0 ENGINE AND AFTERTREATMENT MONITORING SYSTEM	151
12.1 GENERAL INFORMATION	151
12.1.1 Engine Monitoring Level.....	151
12.1.2 Parameter Severity Levels	152
12.1.3 Monitoring System Example	153
12.2 ENGINE MONITORING & PROTECTION.....	154
12.2.1 Coolant Temperature.....	154
12.2.2 Engine Oil Pressure.....	155
12.2.3 Intake Manifold Temperature.....	156
12.2.4 Engine Overspeed.....	157
12.3 AFTERTREATMENT MONITORING & PROTECTION	158
13.0 MONITORED INPUTS FOR CUSTOMER FITTED SENSORS.....	159
13.1 AIR FILTER SERVICE INDICATOR – AIR INTAKE RESTRICTION SWITCH	160
13.1.1 Air Intake Restriction Switch Operation.....	160
13.1.2 Air Intake Restriction Switch Configuration.....	161
13.1.3 Air Intake Restriction Switch Installation.....	161
13.2 COOLANT LEVEL SWITCH	162
13.2.1 Coolant Level Switch Operation.....	162
13.2.2 Coolant Level Switch Configuration.....	162
13.2.3 Coolant Level Switch Installation.....	163
13.3 WATER IN FUEL TRAP SWITCH	164
13.3.1 Water In Fuel Trap Switch Operation.....	164

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

13.3.2	Water In Fuel Trap Switch Configuration.....	164
13.3.3	Water In Fuel Trap Switch Installation	164
13.4	AUXILIARY TEMPERATURE SENSOR	165
13.4.1	Auxiliary Temperature Sensor Operation.....	165
13.4.2	Auxiliary Temperature Sensor Configuration	165
13.4.3	Auxiliary temperature Sensor Installation.....	166
13.5	AUXILIARY PRESSURE SENSOR	168
13.5.1	Auxiliary Pressure Sensor Operation.....	168
13.5.2	Auxiliary Pressure Sensor Configuration.....	168
13.5.3	Auxiliary pressure Sensor Installation	169
13.6	OIL LEVEL SWITCH	170
13.6.1	Oil Level Switch Operation	170
13.6.2	Oil Level Switch Configuration	170
13.6.3	Oil Level Switch Installation	170
13.7	FUEL FILTER DIFFERENTIAL PRESSURE SWITCH.....	171
13.7.1	Fuel Filter Differential Pressure Switch Operation	171
13.7.2	Fuel Filter Differential Pressure Switch Configuration.....	172
13.7.3	Fuel Filter Differential Pressure Switch Installation	172
14.0	REGENERATION SYSTEM & CUSTOMER INTERFACE	174
14.1	LOW TEMPERATURE REGENERATION SYSTEM OPERATION	174
14.1.1	Low Temperature Regeneration System Overview.....	174
14.2	LOW TEMPERATURE REGENERATION OPERATOR INTERFACE	175
14.2.1	Low Temp Regeneration Lamp Strategy.....	175
14.3	LOW TEMPERATURE REGENERATION SYSTEM OPERATION EXAMPLE.....	175
14.4	HIGH TEMPERATURE DPF REGENERATION SYSTEM OPERATION.....	177
14.4.1	High Temperature Regeneration System Overview.....	177
14.5	HIGH TEMPERATURE REGENERATION SYSTEM CUSTOMER INTERFACE	181
14.5.1	Lamp Strategy.....	181
14.5.2	Regeneration Interface Switch.....	182
14.5.3	OK To Elevate Idle Input.....	183
14.5.4	High Speed Regeneration Enable Input (HSR Input)	184
14.5.5	DPF Soot Loading Indicator	185
14.5.6	Integrated Machine Solutions Over J1939	186
14.6	TOTAL SYSTEM OPERATION EXAMPLE.....	187
15.0	ENGINE GOVERNOR	190
15.1	MIN/MAX GOVERNING.....	190
15.1.1	Operation.....	190
15.1.2	Configuration	191
15.1.3	Installation.....	191
15.2	ALL SPEED.....	192
15.2.1	Operation.....	192
15.2.2	Configuration	194
15.2.3	Installation.....	194
15.3	AUXILIARY GOVERNOR.....	194
15.4	RATING SELECTION VIA SERVICE TOOL.....	194
15.5	ENGINE HIGH SPEED GOVERNOR (GOVERNOR RUN-OUT).....	195
15.5.1	Engine High Speed Governor Operation.....	195
15.5.2	Engine High Speed Governor Configuration	195
15.6	MODE SELECTION	195
15.6.1	Operation.....	195
15.6.2	Configuration	196
15.6.3	Installation.....	196
15.6.4	Rating and Droop changes requested via the J1939 datalink	197
16.0	TIER 4 INTERIM SERVICE TOOL FEATURES.	198
16.1	INTRODUCTION.....	198
16.2	SERVICE TOOL FEATURES FOR A C7.1.....	198

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

16.3 SERVICE TOOL FEATURES FOR A C4.4-C6.6.....	198
17.0 DATALINK SUPPORT	199
17.1 SAE J1939.....	199
17.1.1 Summary of Key J1939 Application Issues.....	199
17.1.2 Physical layer.....	199
17.1.3 Network Layer.....	200
17.1.4 Application Layer.....	200
17.2 CONNECTION AND USE OF THE J1939 CAN BUS.....	201
18.0 J1939 SUPPORTED PARAMETERS QUICK REFERENCE	202
19.0 J1939 PARAMETERS – DETAILED DESCRIPTIONS	211
19.1 SENDING MESSAGES TO THE ENGINE ECM.....	211
19.1.1 Source Addressing.....	211
19.1.2 Configurable ECM Source Addressing.....	211
19.1.3 Destination Addressing.....	211
19.2 J1939 SECTION 71 – TSC1 OPERATION.....	212
19.2.1 Torque Speed Control (TSC1) Operating Principles.....	212
19.2.1 Torque Speed Control (TSC1) Message Configuration & Control	214
19.3 J1939 ENGINE ECM TRANSMIT PGN SUPPORT.....	216
19.3.1 Electronic Brake Controller 1 (EBC1) (61441).....	216
19.3.2 Electronic Engine Controller 2 (EEC2) (61443).....	216
19.3.3 Electronic Engine Controller 1 (EEC1) (61444).....	217
19.3.4 Turbocharger Wastegate (TCW) (65174).....	218
19.3.5 Auxiliary Discrete IO state (AUXIO) (65241).....	218
19.3.6 Software Identification (SOFT) (65242).....	220
19.3.7 Engine Fluid Level / Pressure 2 (EFL/P2) (65243).....	220
19.3.8 Electronic Engine Controller 3 (EEC3) (65247).....	221
19.3.9 Engine Configuration (EC) (65251).....	222
19.3.10 Shutdown (SHUTDOWN) (65252).....	223
19.3.11 Engine Hours / Revolutions (HOURS) (65253).....	224
19.3.12 Fuel Consumption (LFC) (65257).....	224
19.3.13 Component ID (CI) (65259).....	225
19.3.14 Vehicle Identification (VI) (65260).....	225
19.3.15 Engine Temperature (ET1) (65262).....	226
19.3.16 Engine Fluid Level / Pressure (EFL/P1) (65263).....	226
19.3.17 PTO information (PTO) (65264).....	227
19.3.18 Fuel Economy (LFE) (65266).....	228
19.3.19 Inlet / Exhaust Conditions (IC) (65270).....	228
19.3.20 Vehicle Electrical Power (VEP) (65271).....	229
19.3.21 Operator Primary Intermediate Speed (ISCS) (64968).....	229
19.3.22 Off highway Engine control selection state (OHCSS) (64967).....	230
19.3.23 Reset (Maintenance Indicator Feature) (56832).....	231
19.3.24 Electronic Control Module Information (CMI) (64969).....	231
19.3.25 Service 2 (Maintenance Indicator Feature) (S2) (65166).....	232
19.3.26 Service Information (Maintenance Indicator Feature) (SERV) (65216).....	232
19.3.27 Engine Gas Flow Rate (EGF1) (61450).....	233
19.3.28 Aftertreatment 1 Historical Information (AHII) (64920).....	233
19.3.29 Aftertreatment 1 Fuel Control AFC1 (64929).....	233
19.3.30 Electronic Engine Controller 5 (EEC5) (64981).....	234
19.3.31 Engine Information (EI) (65170).....	234
19.3.32 Ambient Conditions (AMB) (65269).....	235
19.3.33 Auxiliary Analogue (AAI) (65164).....	235
19.3.34 Engine Speed Sensor Information (ESSI) (61473).....	236
19.3.35 Engine Configuration 2 (EC2) (64895).....	236
19.3.36 Engine Operating Information (EOI) (64914).....	236
19.3.37 Electronic Engine Controller 7 (EEC7) (64916).....	237
19.3.38 ECU Identification Information (ECUID) (64965).....	237
19.3.39 Intermediate Speed Control (ISC) (64970).....	237

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

19.3.40 Electronic Engine Controller 4 (EEC4) (65214).....	238
19.3.41 Aftertreatment 1 Fuel Control 2 (AT1FC2) (64869)	238
19.3.42 Aftertreatment 1 Air Control 2 (AT1AC2) (64877).....	238
19.3.43 Aftertreatment 1 Service (ATIS) (64891)	239
19.3.44 Diesel Particulate Filter Control 1 (DPFC1) (64892).....	239
19.3.45 Aftertreatment 1 Intake Gas 2 (AT1IG2) (64948).....	240
19.3.46 Engine Throttle / Fuel Actuator Control Command (TFAC) (61466).....	240
19.3.47 Engine Temperature 2 (ET2) (65188)	240
19.3.48 Engine Fluid Level / Pressure 3 (EFL/P3) (64961).....	241
19.3.49 Engine Temperature 3 (ET3) (65129)	241
19.3.50 Cruise Control / Vehicle speed Setup (CCSS) (65261).....	241
19.3.51 Cruise Control / Vehicle Speed (CCVS) (65265).....	242
19.4 J1939 ENGINE ECM RECEIVE PGN SUPPORT.....	243
19.4.1 Electronic Transmission Controller 1 (ETC1) (61442).....	243
19.4.2 Electronic Transmission Controller 2 (ETC2) (61445).....	243
19.4.3 Transmission Configuration 2 (TCFG2) (65099).....	243
19.4.4 Cab Message 1 (CMI) (57344)	244
19.4.5 Off highway engine control selection (OHECS) (64971)	244
19.5 J1939 SECTION 73 - DIAGNOSTIC LAYER.....	246
19.5.1 Active Diagnostics Trouble Codes (DM1).....	246
19.5.2 Previously Active Diagnostic Trouble Codes (DM2)	247
19.5.3 Diagnostic Data Clear / Reset of Previously Active DTCs (DM3).....	247
19.6 SUPPORTED PARAMETERS – SECTION 21 - SIMPLIFIED DESCRIPTIONS.....	249
19.6.1 Transport Protocol – Connection Management (TP.CM_BAM).....	249
19.6.2 Transport Protocol – Data Transfer (TP.DT).....	249
19.6.3 Proprietary A.....	249
19.6.4 Acknowledge.....	249
19.6.5 Request PGN	249
19.7 SUPPORTED PARAMETERS – SECTION 81 NETWORK MANAGEMENT - DETAILED DESCRIPTIONS	250
20.0 APPENDICES	251
20.1 APPENDIX 1 - ECM J1 CONNECTOR TERMINAL ASSIGNMENTS	251
20.2 APPENDIX 2 – ECM J2 TERMINAL ASSIGNMENT	253
20.3 APPENDIX 3 - ELECTRONIC OPTIONS SELECTION FORM.....	255
20.4 APPENDIX 4 – LIST OF DIAGNOSTIC AND EVENT CODES.....	256
20.5 LIST OF MAJOR CHANGES PER RELEASE	260

1.0 Introduction and Purpose

This document is intended to provide the information necessary for correct electrical and electronic installation of the C4.4 to C7.1 Caterpillar Industrial engines into an off-highway machine. Caterpillar expects that there will be some additions and modifications to this document as the engine program development continues, and as OEM requests for information not currently addressed are added. The Information herein is the property of Caterpillar and/or its subsidiaries. Without written permission, any copying, transmission to others, and any use except that for which it is loaned is prohibited.

1.1 Applicable Engines

The information contained is the best available at the time of authoring to describe the application and installation requirements of production representative engine and software. During development stages please ensure the Applications engineering department are consulted before implementing any of the features contained within this document.

Early project engines will not have all the features described in this document enabled. Contact the Electronic Applications Team for latest information on software feature release dates.

1.2 Electronic Applications Contacts

If the information in this document is incomplete, incorrect, or further details are required, then please contact your Applications Engineer.

1.3 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.

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.

1.3.1 Warning – Welding

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

- Turn the engine OFF. Place the ignition keyswitch 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.

DO NOT use electrical components in order to ground the welder. Do not use the ECM or sensors or any other electronic components in order to ground the welder.

1.3.2 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.

The following precautions should be taken when using electrostatic paint spraying techniques on engines:

- Connect all 70 pins of the ECM J1 Connector directly to the spraying booth ground.
- Connect the engine block to ground at 2 points. Ensure that good screwed connections onto bright metal are used.

1.3.3 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 the ECM.

2.0 Engine & Aftertreatment Component Overview

2.1 Main Engine Sensor and Actuator Details

Component	Sub System	Product Range
A5:E2 Engine ECM	ECM	All
Electronic Unit Injectors	Fuel System	All
Electric Fuel Lift Pump	Fuel System	All
Fuel Temperature Sensor	Fuel System	All
Fuel Rail Pump Control valve	Fuel System	All
Fuel Rail Pressure Sensor	Fuel System	All
Water In Fuel Switch	Fuel System	All
Crank Speed / Timing Sensor	Engine Speed	All
Cam Shaft Speed Sensor	Engine Speed	All
Engine Oil Pressure Sensor	Core Engine System	All
Engine Coolant Temperature Sensor	Core Engine System	All
Barometric pressure Sensor	Core Engine System	All
NRS Inlet Absolute Pressure sensor	NRS System	All
NRS Differential Pressure Sensor	NRS System	C7.1 only
NRS Outlet Absolute Pressure Sensor	NRS System	C4.4 C6.6 only
NRS Temperature Sensor	NRS System	All
NRS Metering Valve	NRS System	All
Intake Manifold Temperature Sensor	Air System	All
Intake Manifold Pressure Sensor	Air System	All
Turbocharger Wastegate Regulator Valve	Air System	All
Exhaust back pressure Valve	Emissions System Assist Devices	C4.4 and C6.6 only
Air Intake Throttle Valve	Emissions System Assist Devices	C7.1 only

2.1.1 Electronic Control Module (ECM)

The A5E2 ECM 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 ECM is situated on the left hand side rear of the engine. The device has two connection sockets, one for the engine wiring harness (J2) and the other for the OEM machine wiring harness (J1). Two versions of the A5E2 ECM are available a fuel cooled and air cooled, the choices of which depends upon the maximum ambient temperature the unit will be exposed to (see mechanical installation guide for details of fuel system connection requirements and temperature restrictions).

2.1.2 Fuel System

The engine fuel system comprises of an electronic lift 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 ECM via the fuel pump solenoid controls this fuel pump delivery and the resulting rail pressure. The engine ECM 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 section 8.0 of the mechanical A&I Guide and section 4.0 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 ECM deliver a controlled measure of fuel for combustion. Voltages applied by the ECM to activate the injectors are high around 70V 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 Tier 4 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 ECM J1 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.

2.1.4 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 barometric sensor, coolant temperature sensor and the oil pressure sensor.

The barometric sensor is located near the ECM. 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 sensor measures engine oil pressure in kPa. Oil pressure is used for engine protection whereby if insufficient oil pressure is measured for a given speed, an event for low oil pressure would be raised.

2.1.5 NRS (Nox Reduction System)

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

- NRS Intake Absolute Pressure Sensor
- NRS Outlet Absolute Pressure Sensor C6.6 & C4.4 only
- NRS Differential Pressure Sensor C7.1 only
- NRS Temperature Sensor
- NRS metering Valve

Both the temperature and pressure sensor measurements are required by the engine control system to control NRS metering valve. There are subtle differences between the <130Kw and >130Kw engine NRS pressure measurement. The >130Kw engine range requires the use of the differential pressure sensor as well as an intake absolute pressure sensor, whereas the <130Kw engines use the intake and outlet absolute pressure sensors only. 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.

2.1.6 Air System

The engine air system contains the following electronic components.

- Intake Manifold Temperature Sensor
- Intake Manifold Pressure Sensor
- Turbocharger Wastegate Regulator

The intake manifold pressure sensor measures the air pressure inside the intake manifold, after the turbo and NRS mixer. There are two sensor options dependent upon the choice of rating. The pressure sensor is used in a number of engine management control strategies contained within the engine ECM. The intake manifold temperature sensor measures the temperature of the mixed air inside the inlet manifold. The sensor measurement range is –40 to 150°C

The regulator valve controls the pressure in the intake manifold to a value that is determined by the ECM. The Wastegate regulator provides the interface between the ECM and the mechanical system that regulates intake manifold pressure to the desired value that is determined by the engine software.

2.1.7 Emissions System Assist Devices

The C4.4 and C6.6 product range are fitted with a low temperature regeneration system, which uses an exhaust back pressure valve to control the exhaust gas temperature passing through the DPF. The back pressure valve is controlled by the engine ECM.

The C7.1 engine range is fitted with an Air intake throttle valve. This valve is used to assist with the management of engine fuel air ratio. As with the back pressure valve the air intake throttle is controlled by the engine ECM.

2.2 Aftertreatment System Sensor & Actuator Details

Component	Sub System	Product Range
ARD Main Fuel Pressure Control Valve	ARD (Auxiliary Regeneration Device)	C7.1 only
ARD Pilot Fuel Pressure Control Valve	ARD (Auxiliary Regeneration Device)	C7.1 only
ARD Main Fuel Pressure Sensor	ARD (Auxiliary Regeneration Device)	C7.1 only
ARD Pilot Fuel Pressure Sensor	ARD (Auxiliary Regeneration Device)	C7.1 only
ARD Secondary Air Pressure Sensor	ARD (Auxiliary Regeneration Device)	C7.1 only
ARD Air Pressure Control Valve	ARD (Auxiliary Regeneration Device)	C7.1 only
ARD Combustion Detection Temperature Sensor	ARD (Auxiliary Regeneration Device)	C7.1 only
ARD Ignition Spark Plug	ARD (Auxiliary Regeneration Device)	C7.1 only
ARD Fuel Injector Heater Relay	ARD (Auxiliary Regeneration Device)	C7.1 only
ARD Fuel Injector Heater Wire	ARD (Auxiliary Regeneration Device)	C7.1 only
Aftertreatment ID module	DPF (Diesel Particulate Filter)	All
DPF Intake Pressure Sensor	DPF (Diesel Particulate Filter)	C7.1 only
DPF Intake Temperature Sensor	DPF (Diesel Particulate Filter)	All

2.2.1 ARD (Auxiliary Regeneration Device) System

The engine Aftertreatment systems supplied with engine >130Kw are designed with a High temperature regeneration system, which includes both the aftertreatment DPF and an ARD (Auxiliary Regeneration Device). All engine supplied below the 130Kw breakpoint are supplied with a low temperature regeneration system, which does not require the use of the ARD.

The ARD is used to elevate the engine exhaust gas temperature to levels at which a regeneration of the DPF can take place. This process involves the use of a both a pilot and a main fueling event supplied by a single nozzle and a spark plug to ignite the delivered fuel within the engine exhaust system. The various sensors and actuators housed in and around the ARD unit are used to control / measure the air and fuel supplied for combustion.

2.2.2 DPF System

The Diesel Particulate Filter Intake Temperature Sensor measures exhaust temperature entering the Particulate Trap. This is used to help determine

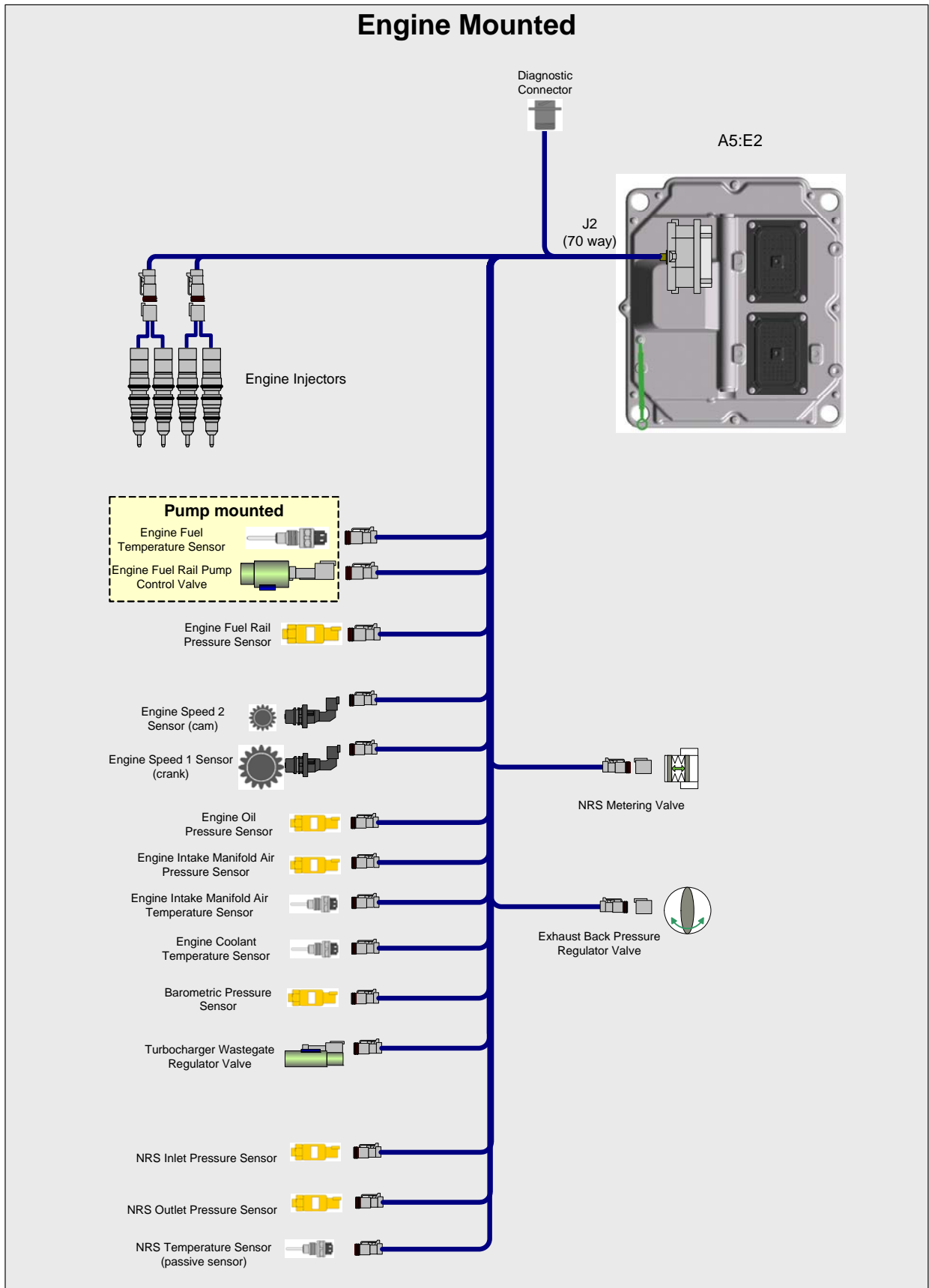
when conditions are right for the system to regenerate the DPF. This sensor is used to help control emissions.

The Diesel Particulate Filter Intake Pressure Sensor measures exhaust gas pressure before the Particulate Trap and is only required for engines fitted with a high temperature regeneration system. This is used to control the ARD combustion during an active regeneration of the DPF. This sensor is used to help control emissions. This sensor also provides an indication of when the DPF intake pressure gets very high so that appropriate events can be triggered to protect the after-treatment system.

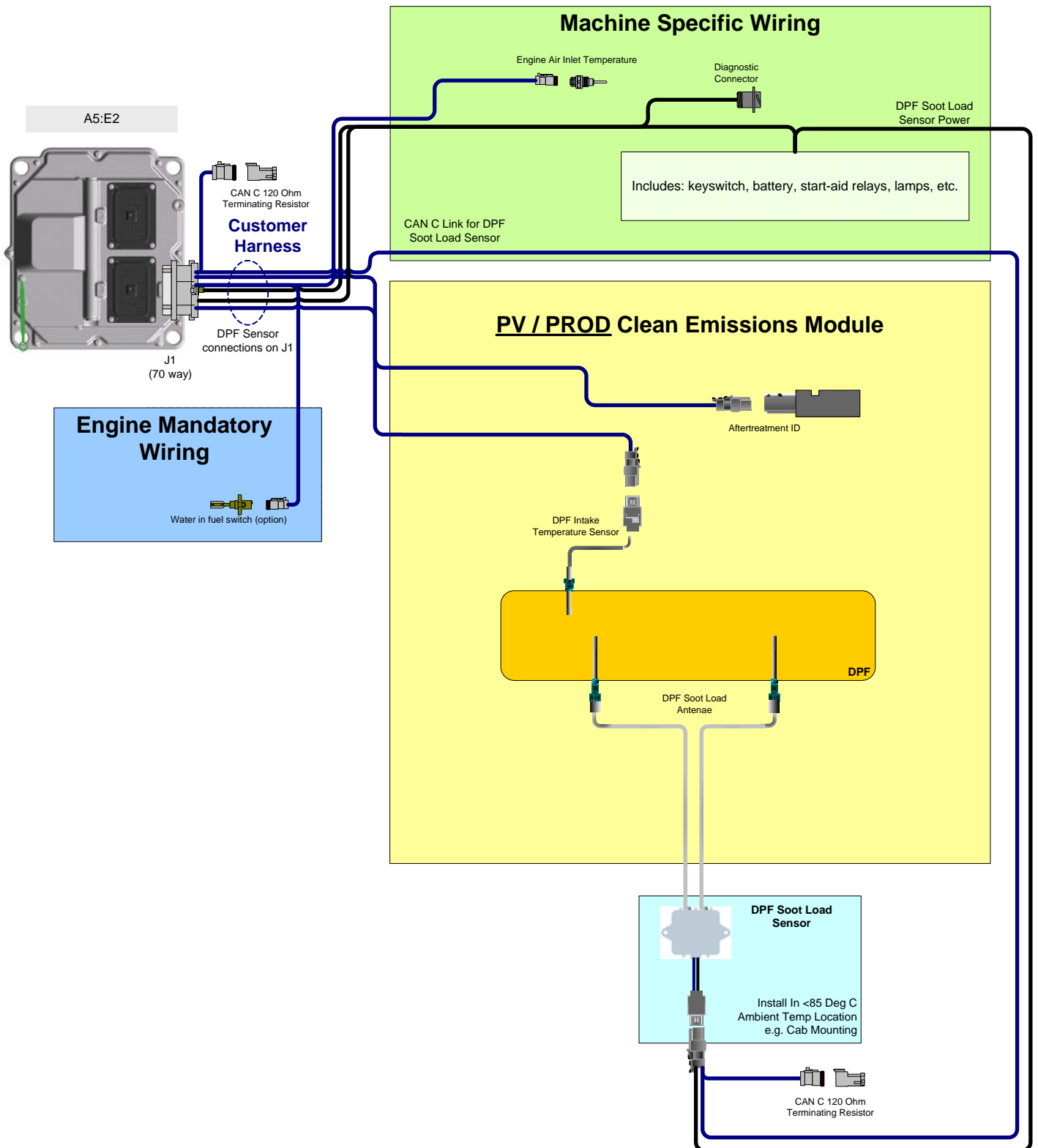
Other components such as the Aftertreatment ID module and the DPF Soot Load sensor are also required for the engine regeneration system to operate correctly. These components are discussed in more detail in section 6 of this document.

2.3 System Component Diagrams and Schematics

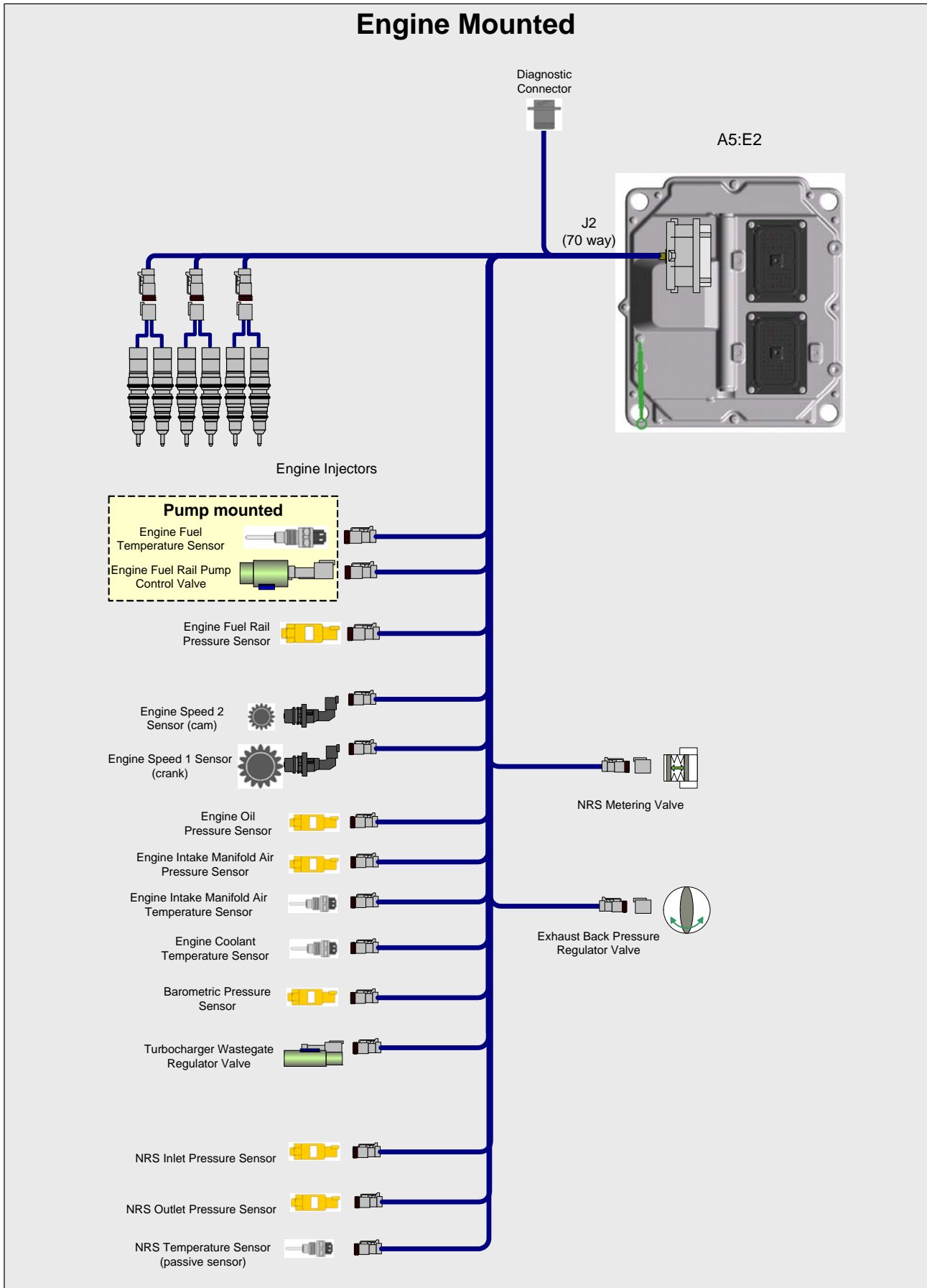
2.3.1 C4.4 Factory Installed Wiring and Components



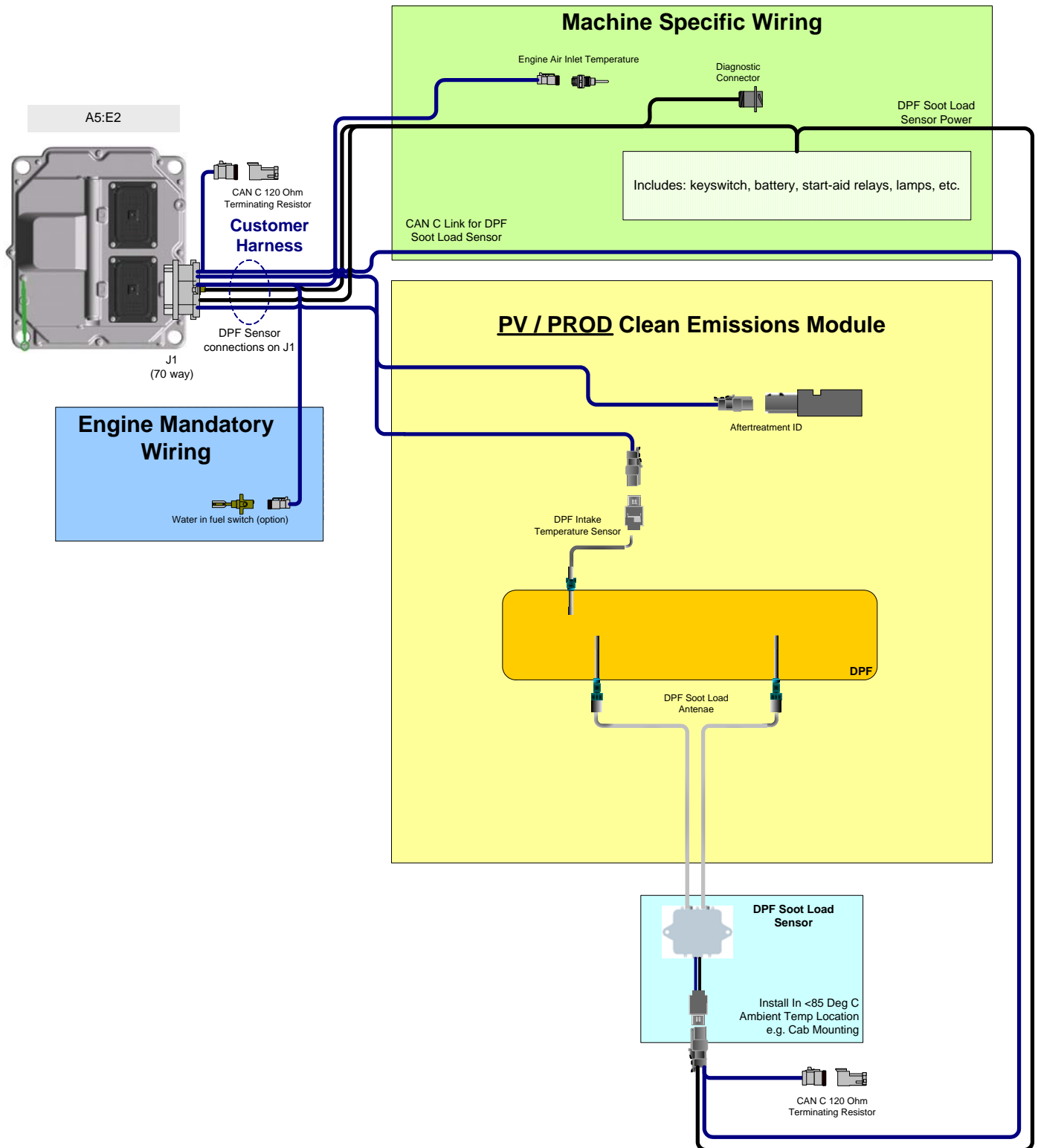
2.3.2 C4.4 Customer Installed Aftertreatment Wiring & Components



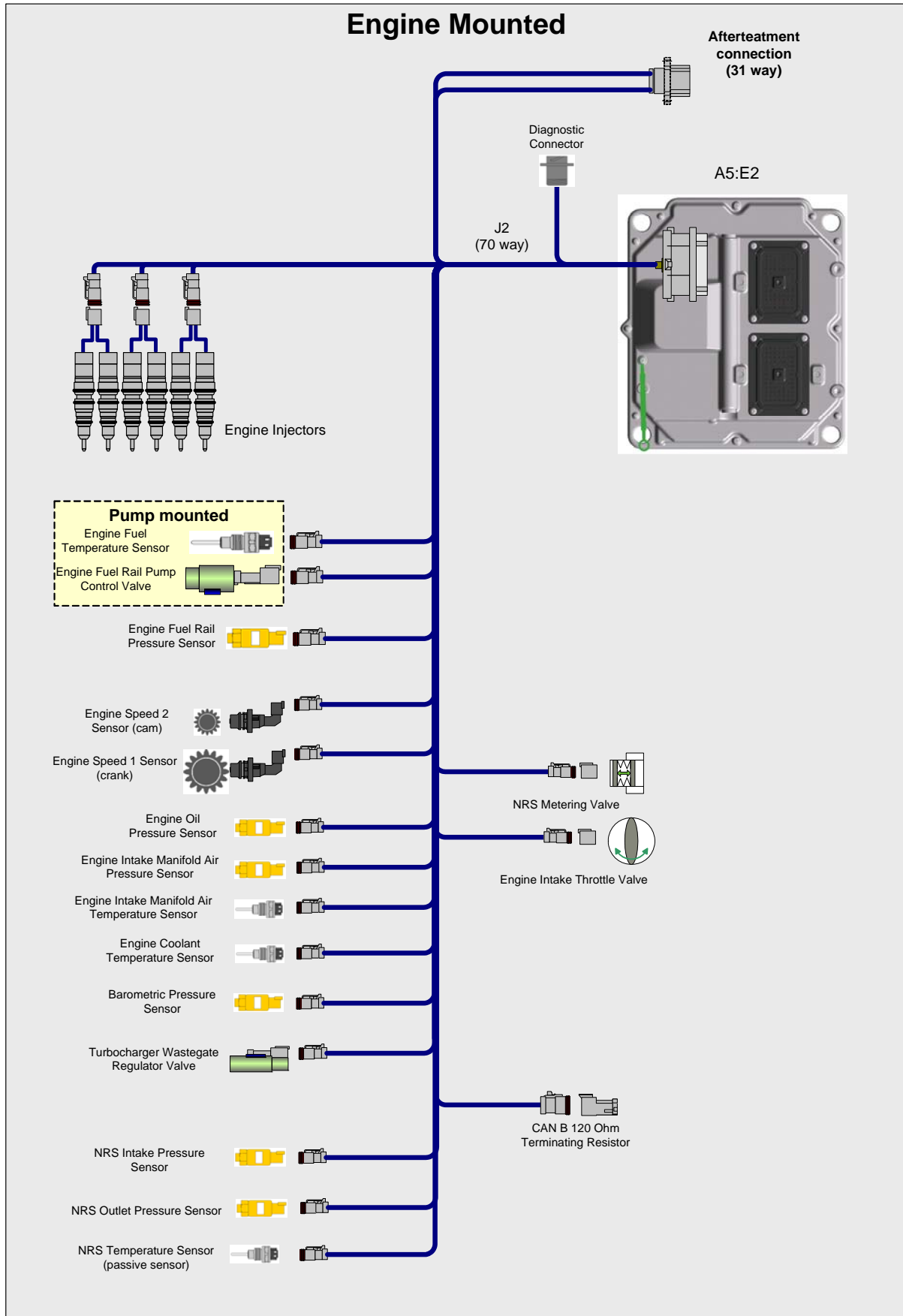
2.3.3 C6.6 Factory Installed Wiring and Components



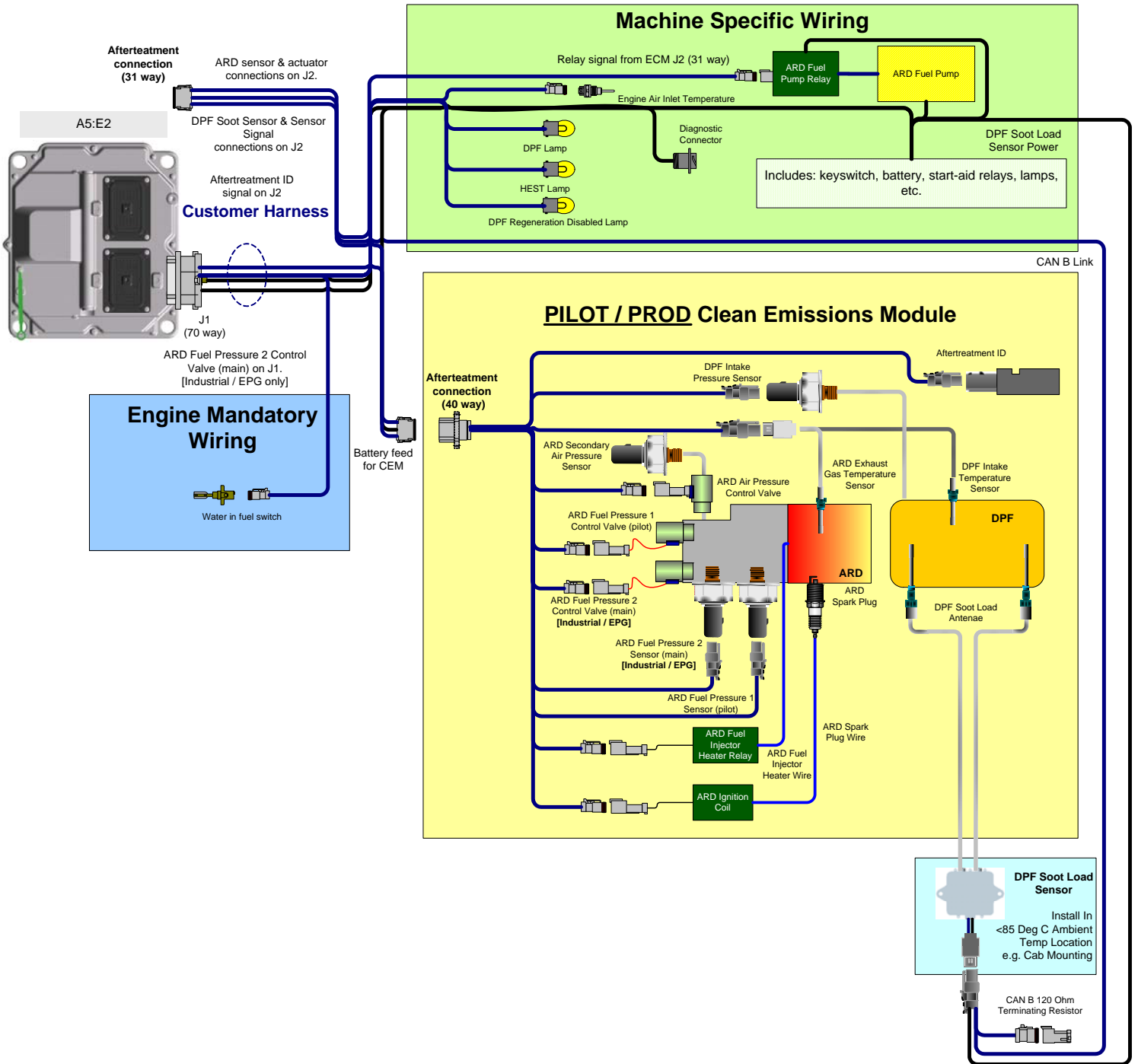
2.3.4 C6.6 Customer Installed Aftertreatment Wiring & Components



2.3.5 C7.1 Factory Installed Wiring and Components

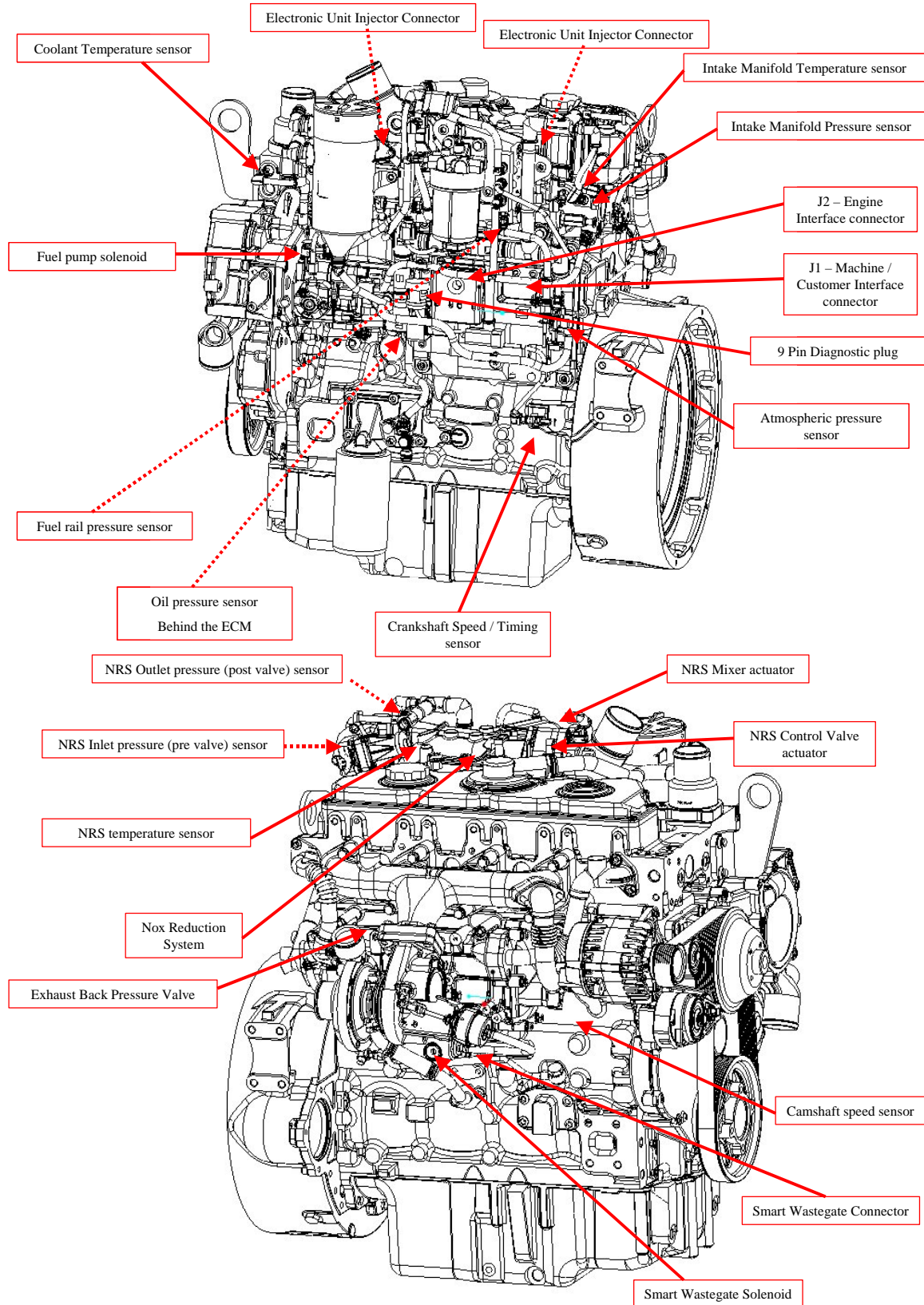


2.3.6 C7.1 Customer Installed Aftertreatment Wiring & Components

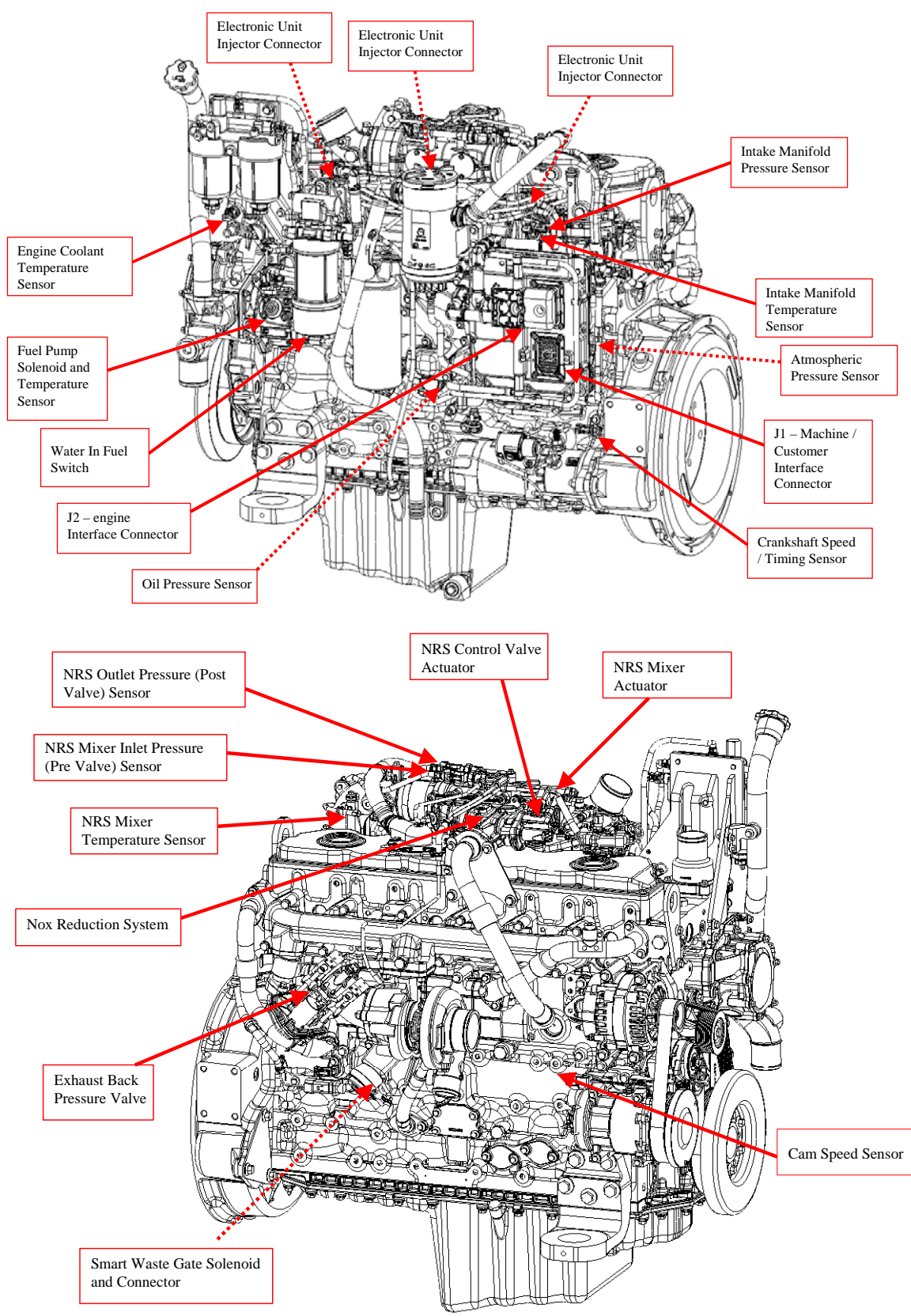


2.4 Engine & Aftertreatment Component Layout Diagrams

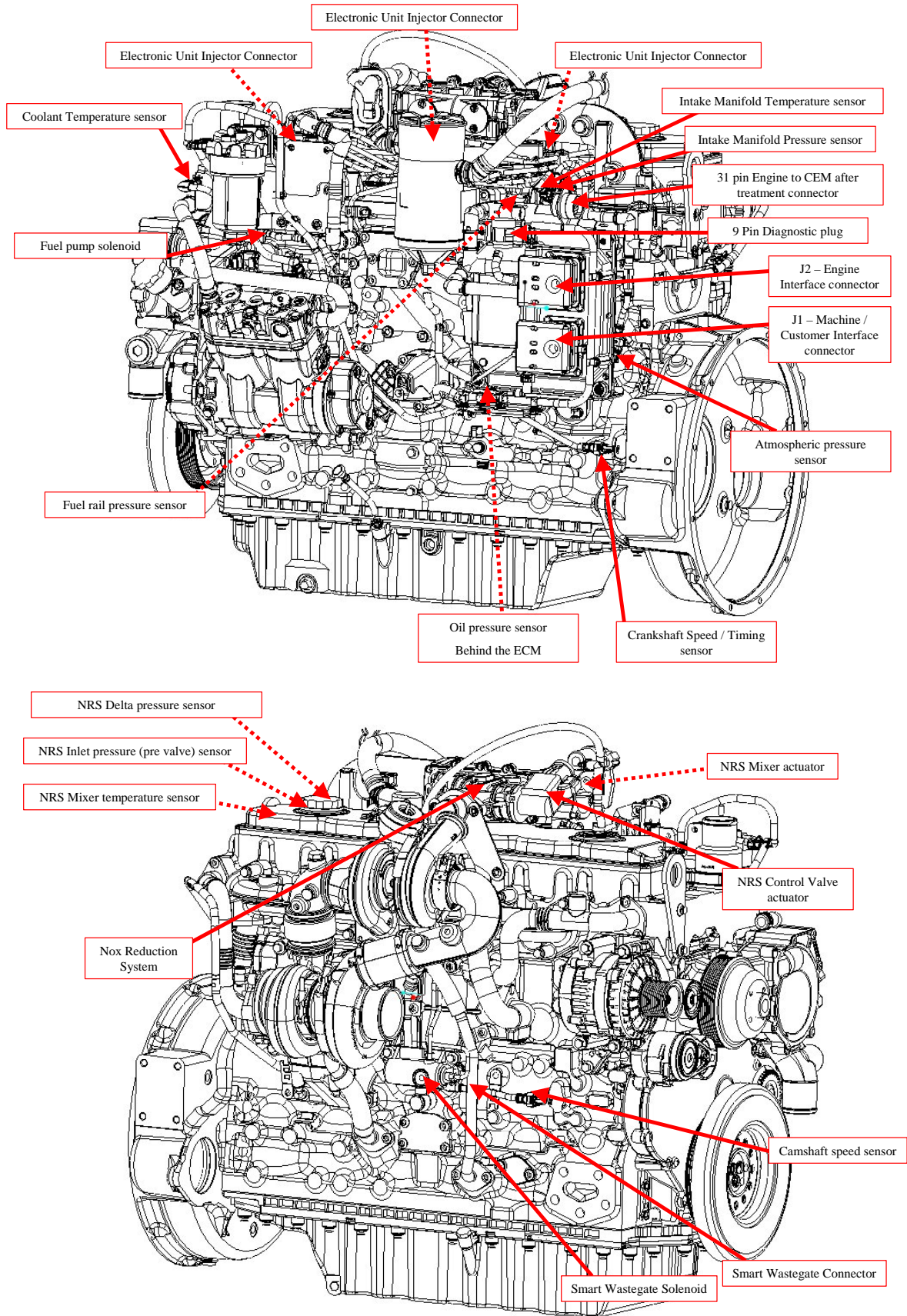
2.4.1 C4.4 Principle Engine Electronic Components



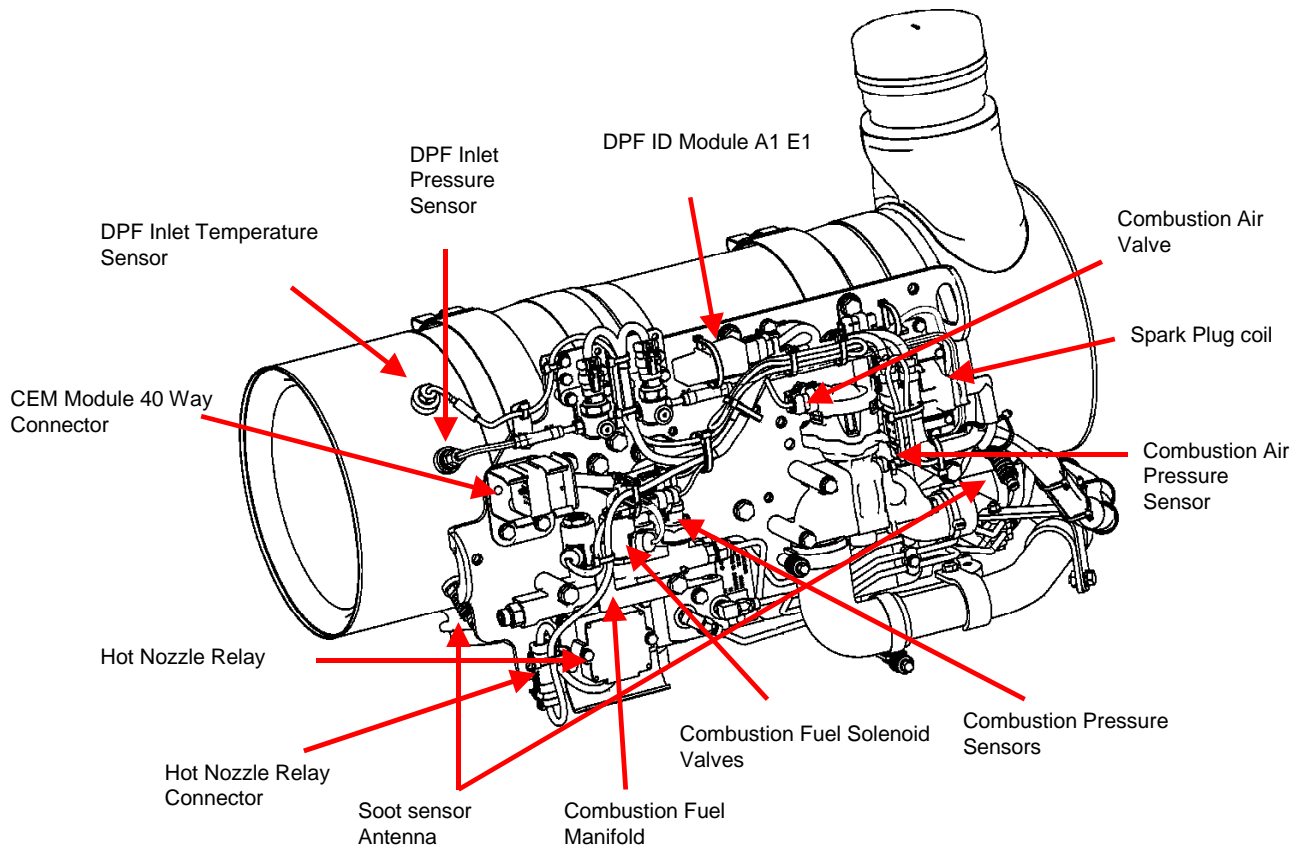
2.4.2 C6.6 Principle Engine Electronic Components



2.4.3 C7.1 Principle Engine And Aftertreatment



2.4.4 C7.1 CCEM Principle Electronic Components



3.0 Customer System Overview Key Elements

There are two key sections to the customer system and they can be defined as mandatory and application specific options. Mandatory requirements cover areas such as Power and grounding and aftertreatment connections. Application specific options however cover features such as the selection of speed control and remote shutdown etc. Throughout the remainder of this document both the mandatory and application specific options will be covered in more detail. The remainder of this section describes the key elements to be considered during installation.

3.1 Aftertreatment Connections

For an engine to be certified as Tier 4 Interim compliant, it must demonstrate a particulate matter output of less than 0.02g/Kw.hr and a Nox output of less than 2.0g/Kw.hr for engine below 560Kw and above 130kw and 3.4g/kw.hr for engines between 130kw and 50kw. 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.

Various configurations of aftertreatment hardware are available across the C4.4 to C7.1 engine range. Table 3.1 shows the technologies used for each engine range and the method of ECM connection. More details on the customer wiring requirements are given in sections 4, 5 and 6 of this document. For more information on the mechanical installation of the aftertreatment system please refer to the (Mechanical A&I Guide).

Engine Family	DOC	DPF	ARD	Connection Requirements
C4.4	✓	✓		Engine ECM J1
C6.6	✓	✓		Engine ECM J1
C7.1		✓	✓	Engine ECM J1 & J2

Table 3.1 Engine Family Aftertreatment Hardware

3.2 Connection, Power and Grounding

The engine ECM requires electrical power. The requirements for powering the ECM need careful review. It is important to understand how to connect the ECM to the machine battery, more details are given in the power and grounding section of this document (Section 4).

3.3 Indication, Starting and Stopping the Engine

With the battery connected, a single connection to the ECM is required to initialize the ECM in the form of an ignition input. Once initialized the ECM will be ready to control the engine. It is important to consider how the power to ignition pin is controlled, most machines use a simple key-switch to start and & stop the engine. There are specific recommendations for stopping the

engine that are specified in the starting and stopping section of this guide. Mandatory requirements regarding operator indication are in place; see the operator display section of this document.

Note: There are some engine calibration strategies that will maintain engine ECM activity once the ignition key supply has been removed. More details relating to these specific strategies and their operation are given in section 7.0 of this guide.

3.4 Controlling the Engine

There are specific requirements in this document for controlling engine speed, and auxiliary components. Further information is available in the speed demand section of this document.

3.5 Aftertreatment Operation and Regeneration

To enable the correct and safe operation of the engine aftertreatment system various configuration options are available for the C4.4, C6.6 and C7.1 engine ranges. Each system comes with it's own installation and operational requirements these range from a standard autonomous unit, to units offering a level of control over the operation of the aftertreatment. Due to the Legislative and safety critical nature of these systems all installation requirements are mandatory. Further information on the installation of the electronic system components are given in sections 5 and 6 whilst the system operation is covered within Regeneration System Customer Interface Section (section 14) of this document.

3.6 Required Components to Install Mandatory Requirements

Mandatory or Required Components	Engine Family	A&I Guide Section
Battery	All	Power and Grounding Considerations
Circuit Protection	All	Power and Grounding Considerations
Electric Fuel Lift Pump	All	Power and Grounding Considerations
Key Switch	All	Starting the Engine
Warning Lamp	All	Operator Displays
Shutdown Lamp	All	Operator Displays
Wait to Start Lamp	All	Operator Displays
Glow Plug Relay	All	Cold Starting Aid
Speed Demand Input	All	Engine Speed Demand
DPF Lamp	C7.1	Operator Displays
HEST Lamp	C7.1	Operator Displays
DPF Disabled Lamp	C7.1	Operator Displays
Regeneration Inhibited Switch	C7.1	Regeneration System Customer Interface
Regeneration Forced Switch	C7.1	Regeneration System customer Interface
High Temperature Regeneration System Fuel Lift Pump and Relay	C7.1	Connecting to Engine Aftertreatment
DPF Soot Sensor	All	Connecting to Engine Aftertreatment
DPF Inlet Temperature Sensor	C6.6 & C4.4	Connecting to Engine Aftertreatment
Water in Fuel Sensor	All	Monitored Inputs For Customer fitted Sensors
Air Inlet Temperature Sensor	All	Connecting to Engine Aftertreatment

3.8 Optional Customer Installed Components

Optional Components	A&I Guide Section
Low Oil Pressure Lamp	Operator Displays
Maintenance Due Lamp	Operator Displays
Remote Shutdown Switch (Normally Open)	Stopping the Engine
Coolant Level Switch	Monitored Inputs for Customer Fitted Sensors
Air Filter Restriction (Inlet Depression) Switch / Sensor	Monitored Inputs for Customer Fitted Sensors
PWM Throttle Position Sensor	Engine Speed Demand
Analogue Throttle Position Sensor with Idle Validation Switch (1)	Engine Speed Demand
Analogue Throttle Position Sensor with Idle Validation Switch (2)	Engine Speed Demand
Throttle Arbitration Switch	Engine Speed Demand
Multi-Position Switch	Engine Speed Demand
PTO On/Off Switch	Engine Speed Demand
PTO Set/Lower Switch	Engine Speed Demand
PTO Raise/Resume Switch	Engine Speed Demand
PTO Speed Select Switch	Engine Speed Demand
PTO Disengage Switch	Engine Speed Demand
Mode Switch (1)	Engine Governor
Mode Switch (2)	Engine Governor
Intermediate Engine Speed Switch	Engine Speed Demand
Ether Start	Cold Starting Aids
Oil Level Switch	Monitored Inputs for Customer Fitted Sensors
Auxiliary Temperature	Monitored Inputs for Customer Fitted Sensors
Auxiliary Pressure	Monitored Inputs for Customer Fitted Sensors
Fuel Filter Differential Pressure	Monitored Inputs for Customer Fitted Sensors
Overspeed Verify Switch	Engine Speed Demand

3.9 Typical Customer Installed Component Diagram

3.9.1 Example OEM Schematic

The engine can be configured and wired in many different ways depending upon the application features selected. The following examples act as a guide for the OEM and also show an example of the OEM wiring required to connect to the C7.1 engine aftertreatment.

3.9.2 Example 1 Basic Engine Application

This solution is suitable for applications where very little integration or additional engineering is a requirement when compared to the solution used for a mechanical engine. This solution can be used in most mechanically governed engine replacement situations. The OEM needs to consider only basic functions: power supply, operator indication, cold start aid, a method of controlling the engine and as with all Tier 4 applications a mandatory interface to the engine aftertreatment system.

3.9.3 Example 2 Construction Application

An application where the engine, in response to an arrangement of switched inputs will operate at one of a range of defined speeds. This is suitable for applications where the device has multiple operating speeds that are defined for the specific output reasons, for simplicity of operator use, or for operation dependent upon the environment e.g., quiet modes this could include auxiliary engine on-road sweeper, multiple speed water pumps etc. There are sixteen possible set speeds based on four discrete ECM inputs. In addition to the keyswitch a separate engine shutdown switch is used to stop the engine.

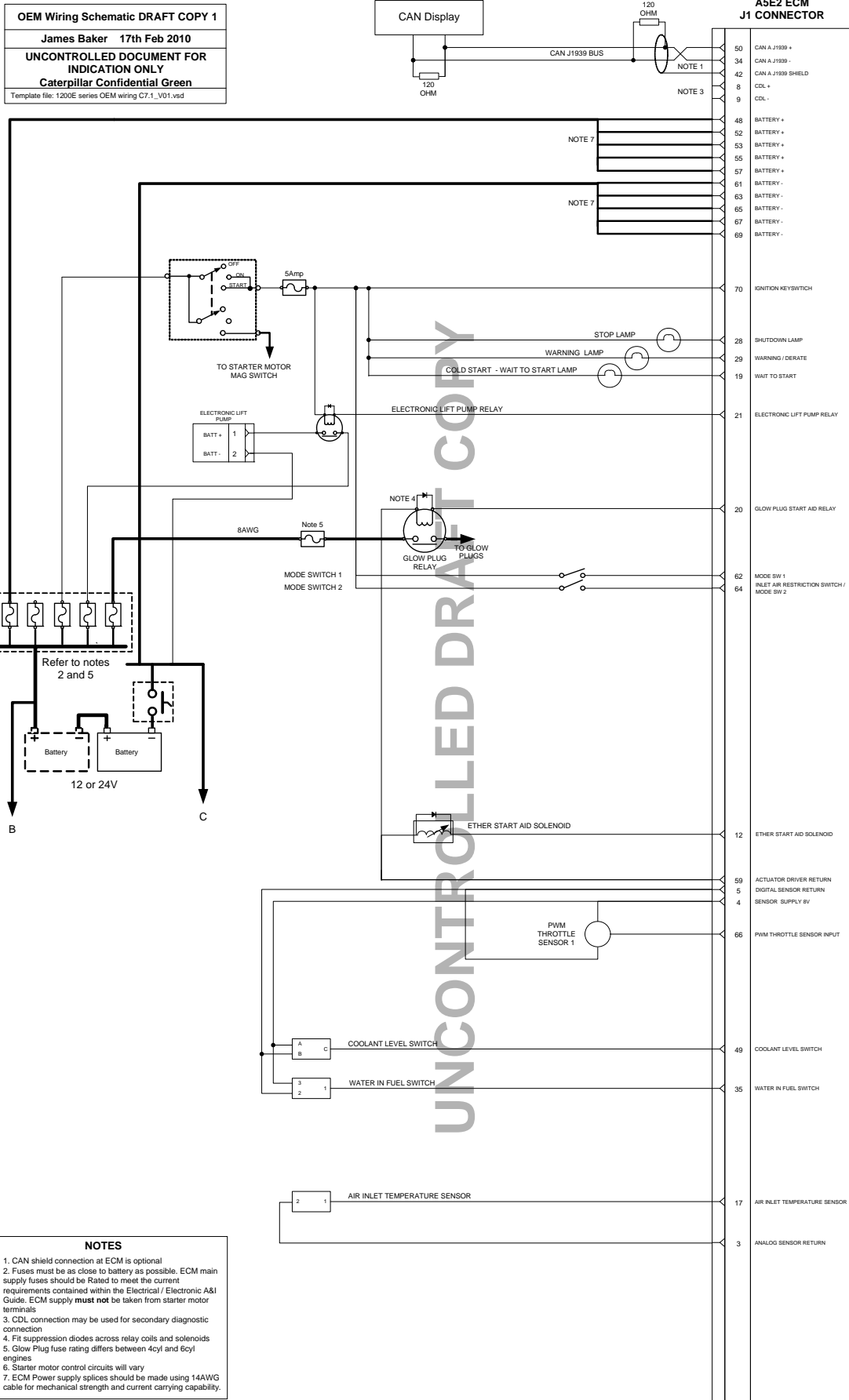
3.9.4 Example 3 Industrial Open Power Unit Application

An application where the engine, in response to a control input such as a depression of a button accelerates from idle speed up to the pre-defined operating engine speed. Once at the pre-defined operating speed, the engine speed may be raised or lowered by increment/decrement buttons. This functionality may benefit the user when they wish to use a 'set speed operation', but with the capability to adjust the set speed manually. Applications could include concrete pumps and hydraulic driven machines.

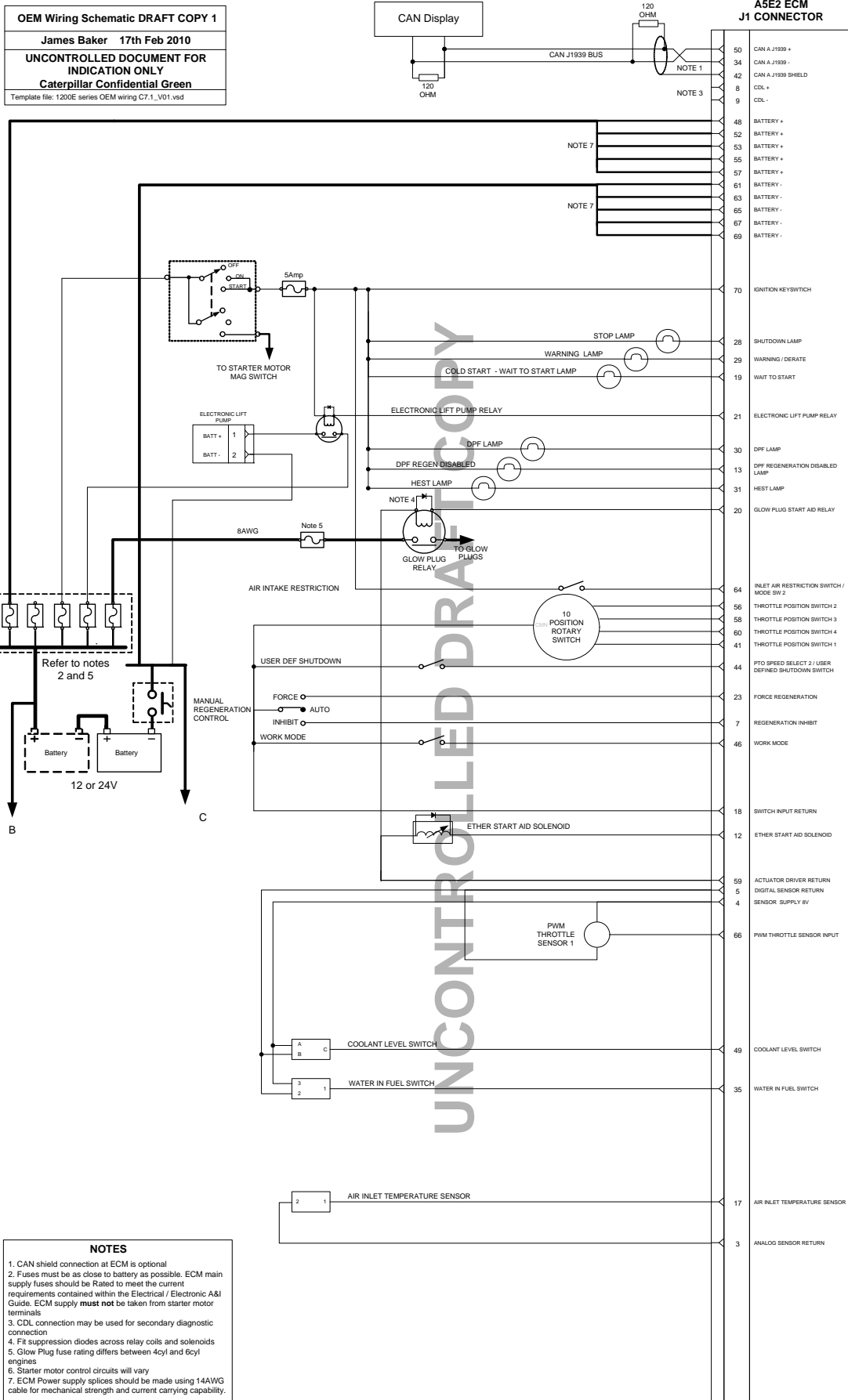
3.9.5 Example 4 Agricultural Application

The application will allow single or twin throttles, engine twin set speed control, multi mode operation, integrated display drive, etc. This set-up is suitable for applications where the customer requires a high degree of operator control over the machine's behavior. It is one of the most complex applications. Typically this is used in mobile applications that may be driven to the place of work and require operator selectable speed operation while performing their chosen task. Applications include tractors, combines and backhoe loaders.

3.9.6 Example 1 - Basic Schematic OEM Harness

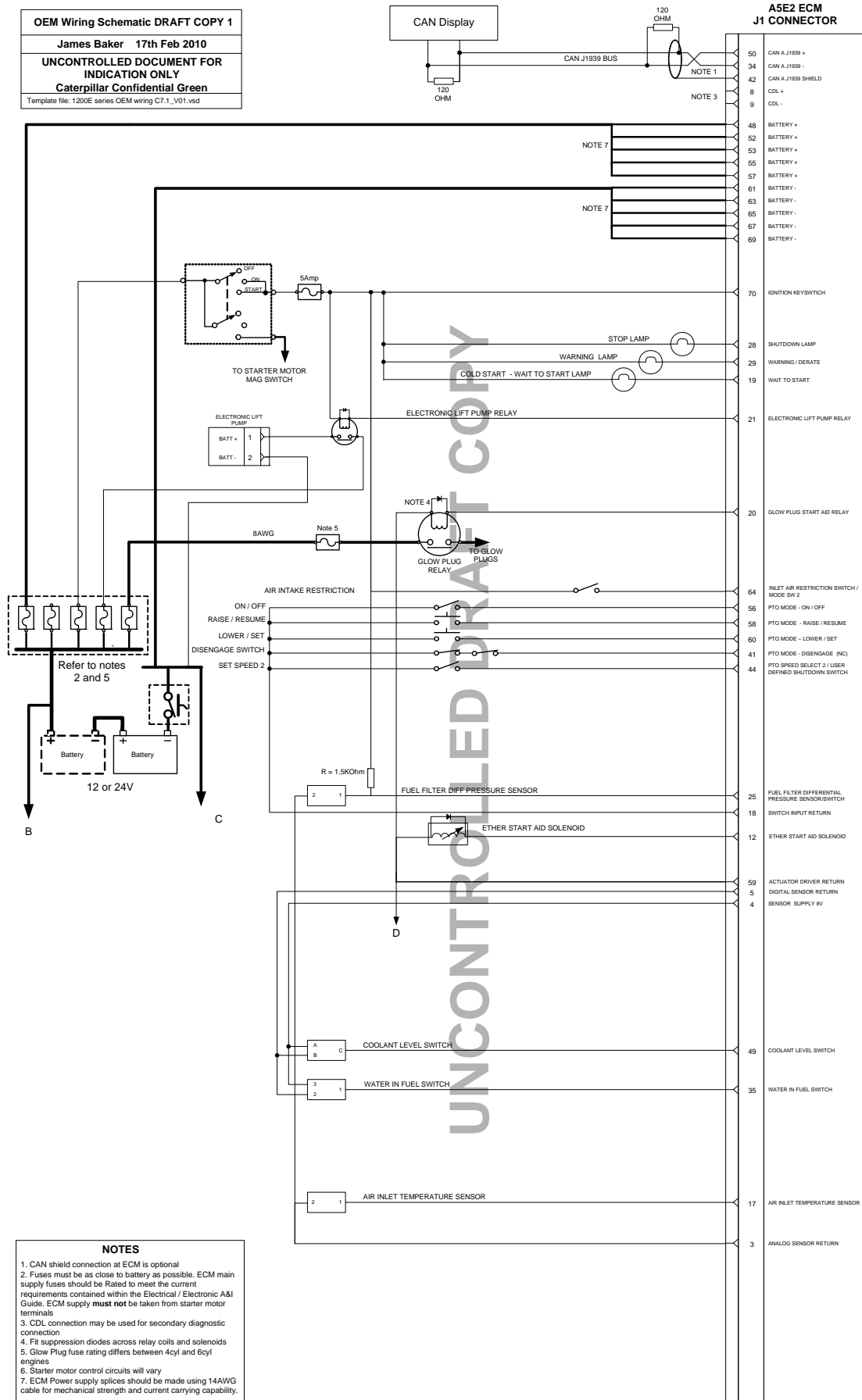


3.9.7 Example 2 - Construction Schematic OEM Harness



3.9.8 Example 3 – IOPU Schematic OEM Harness

OEM Wiring Schematic DRAFT COPY 1
 James Baker 17th Feb 2010
 UNCONTROLLED DOCUMENT FOR INDICATION ONLY
 Caterpillar Confidential Green
 Template file: 1200E series OEM wiring C7.1_V01.vsd

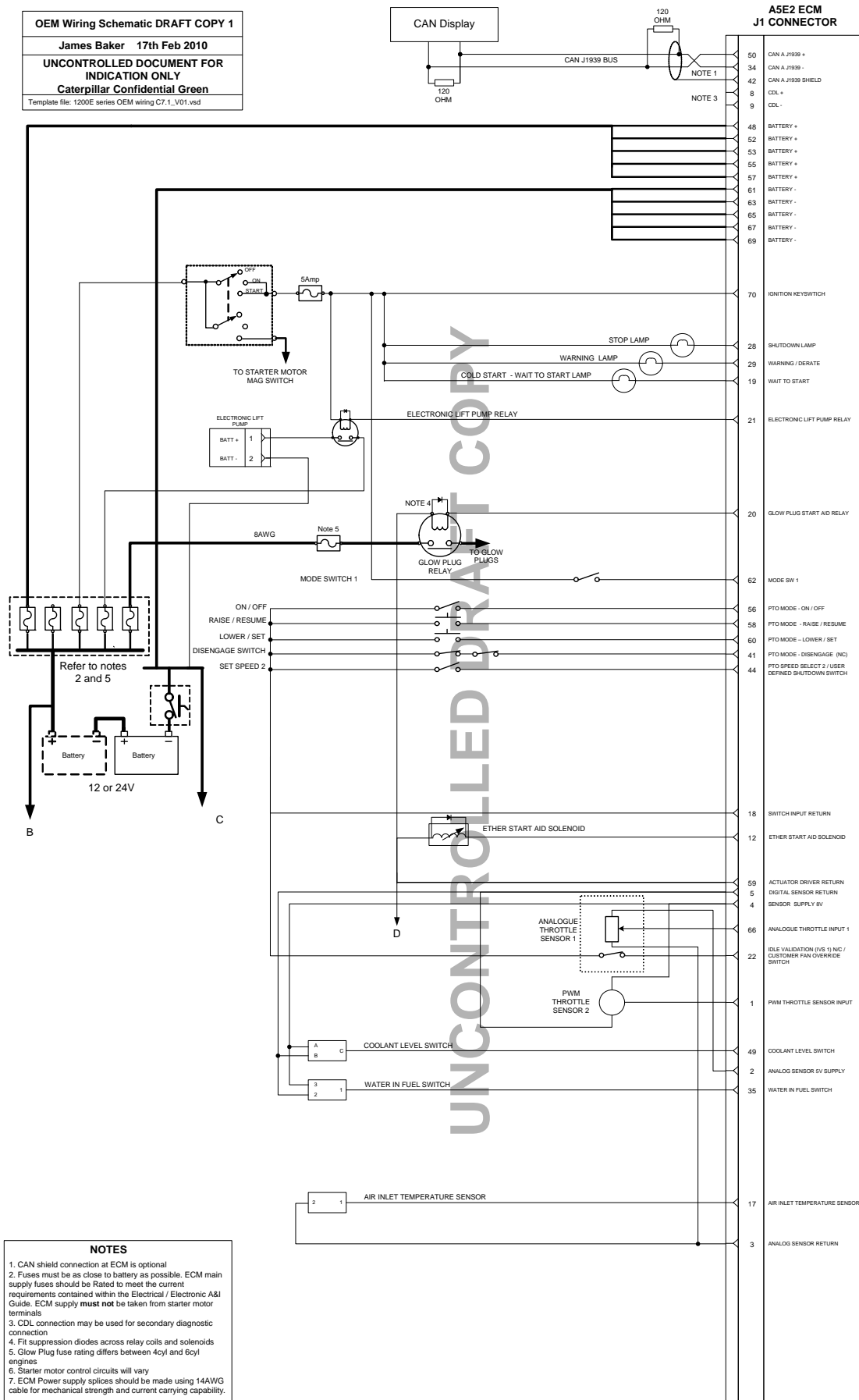


NOTES

- CAN shield connection at ECM is optional
- Fuses must be as close to battery as possible. ECM main supply fuses should be Rated to meet the current requirements contained within the Electrical / Electronic A&I Guide. ECM supply **must not** be taken from starter motor terminals
- CDL connection may be used for secondary diagnostic connection
- Fit suppression diodes across relay coils and solenoids
- Glow Plug fuse rating differs between 4cyl and 6cyl engines
- Starter motor control circuits will vary
- ECM Power supply splices should be made using 14AWG cable for mechanical strength and current carrying capability.

3.9.9 Example 4 - Agricultural Schematic OEM Harness

OEM Wiring Schematic DRAFT COPY 1
 James Baker 17th Feb 2010
 UNCONTROLLED DOCUMENT FOR INDICATION ONLY
 Caterpillar Confidential Green
 Template file: 12X0E series OEM wiring C7.1_V01.vsd



- NOTES**
- CAN shield connection at ECM is optional
 - Fuses must be as close to battery as possible. ECM main supply fuses should be Rated to meet the current requirements contained within the Electrical / Electronic A&I Guide. ECM supply **must not** be taken from starter motor terminals
 - CDL connection may be used for secondary diagnostic connection
 - Fit suppression diodes across relay coils and solenoids
 - Glow Plug fuse rating differs between 4cyl and 6cyl engines
 - Starter motor control circuits will vary
 - ECM Power supply splices should be made using 14AWG cable for mechanical strength and current carrying capability.

4.0 Power and Grounding Considerations

4.1 Engine Block Grounding

Although the engine electronics are all directly grounded via the ECM connector, it is also necessary to ensure that the engine block be 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 through paint.

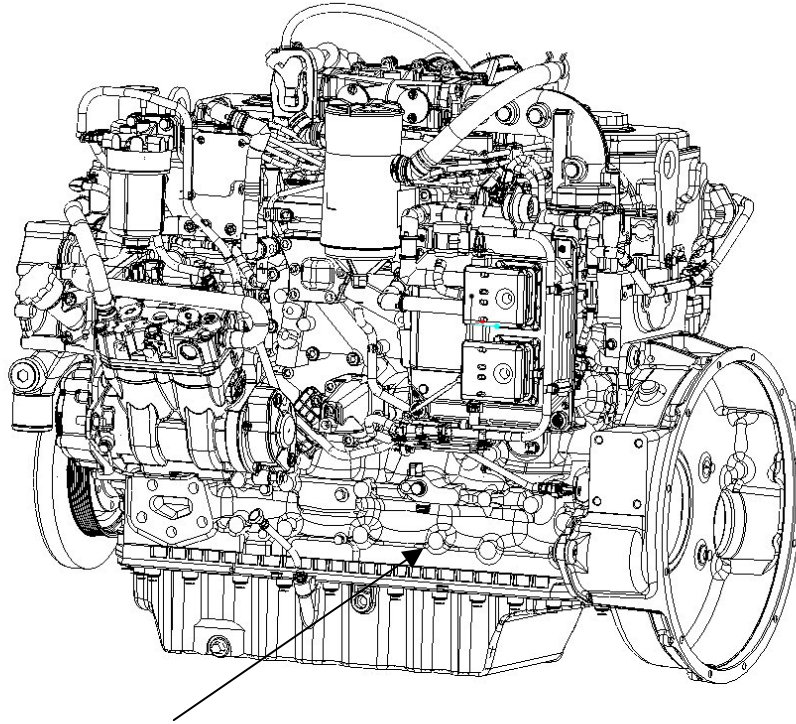
The ground cable should be of sufficient cross sectional area to ensure that the total starter motor supply circuit resistance does not exceed 1.7mOhms for a 12V system and 3.4mOhm for a 24V system.

Please refer to the Starting and Charging Systems A&I Guide for further information on starter motor, alternator, battery and complete system installation guidelines.

4.1.2 Ground Connection to Tapping on engine Block

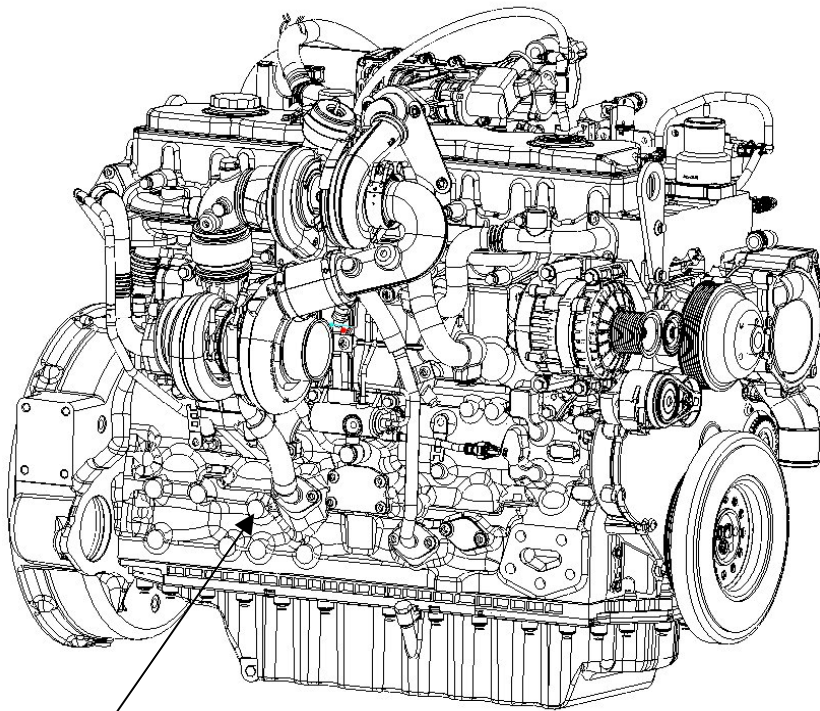
A separate engine block ground should be used in addition to the starter motor ground. A ground cable direct from the battery negative or starter ground terminal should be connected to a ring terminal, which connects to one of the two tapings shown in figures 4.1 and 4.2. The tapped holes will be reserved for customer use and can be used for grounding purposes.

If a tapping is used it should be checked to ensure it is free from lacquer, paint and dirt before the connection is made. An M10 metric screw plated with zinc should be used. A washer should retain the ring terminal and the screw tightened to 44Nm (32 lb-ft).



Ground Point Option 1

Figure 4.1 Left Hand Side Grounding Point



Grounding Point Option 2

Figure 4.2 Right Hand Side Grounding Point

4.1.3 CEM Grounding C7.1

All engines fitted with a CEM module will require a dedicated ground connection for the aftertreatment module itself. The ground connection for this module can be made via the 40-way CEM module connector and should be made using a wire gauge size of 14AWG (2mm²). As with the ground connection on the engine block the surface of the machine chassis must be free from lacquer, paint and dirt before connection is made. For more information regarding the CEM grounding pins and the connection list for the aftertreatment CEM 40 way connector please see section 6.1 of this document.

4.2 Voltage and Current requirements

The ECM power supply requirements must be carefully considered when designing the 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 A5:E2 ECM.

VOLTAGE SUPPLY SYSTEM	C7.1		C6.6 & C4.4	
	12V	24V	12V	24V
Max Peak Current (500uS)	68A	67A	55A	54A
Max Peak Current (150mS)	46A	45A	40A	39A
Peak Current Cranking	11A	9A	11A	9A
Max RMS Current*	31A	26A	26A	22A
Suggested Fuse Rating**	40A	30A	30A	30A
Sleep Current	<5mA	<4mA	<5mA	<4mA
Key On Current Engine Off	<1A	<1A	<1A	<1A
Min Running Voltage	9V	18V	9V	18V
Max Running Voltage***	16V	32V	16V	32V
Minimum Batt Voltage during Cranking ****	7.3V	7.3V	7.3V	7.3V
Maximum total ECM power circuit wire resistance	50mOhm	100mOhm	50mOhm	100mOhm
Target circuit resistance	40mOhm	80mOhm	40mOhm	80mOhm

Table 4.1 System Electrical Parameters

* All Current measurements have been taken from Tier 4a C4.4-C7.1 Electronic System – ECM Current Draw for Engine Alternator Sizing and are estimations only. Max RMS current is based upon a 2500rpm regeneration for the C7.1 and running at rated speed for the C6.6 and 4.4. 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 accounted for.

** Suggested fuse rating are based on automotive blade type fuses and are for guidance only.

***The ECM can survive higher voltages. ECM will survive for at least 5 minutes on a supply voltage of 60V.

**** Please refer to the Starting and Charging System A&I guide for more information regarding the engine starting system installation requirements.

4.3 ECM power supply circuit resistance

Often during engine cranking the battery voltage will drop to values much lower than the normal system operating voltage. Under these special conditions the ECM will operate with a minimum battery voltage of 7.3V. In this mode the ECM has reduced functionality to enable the use of a low supply voltage. It should be noted however that the ECM will reset and inhibit starting if the voltage seen at it's power pins drops to 5.5V or below. To prevent excessive voltage drop ECM power supply circuit resistance must be closely controlled. Once the engine enters 'run' mode the minimum ECM voltage required to enable full ECM functionality increases to 9V.

The maximum permissible circuit resistance including positive and negative wires is 50mOhms for 12V systems and 100mOhms for 24V systems, however Caterpillar recommends that this value should not be targeted during design, as it is often difficult to predict the final circuit resistance when considering other factors such as fuse holders, connector resistance and aging. A target calculated circuit resistance including wire and connections of 40mOhms for 12V systems 80mOhms for 24V systems is recommended. The table below provides typical wire resistance for various cross sections of copper wire.

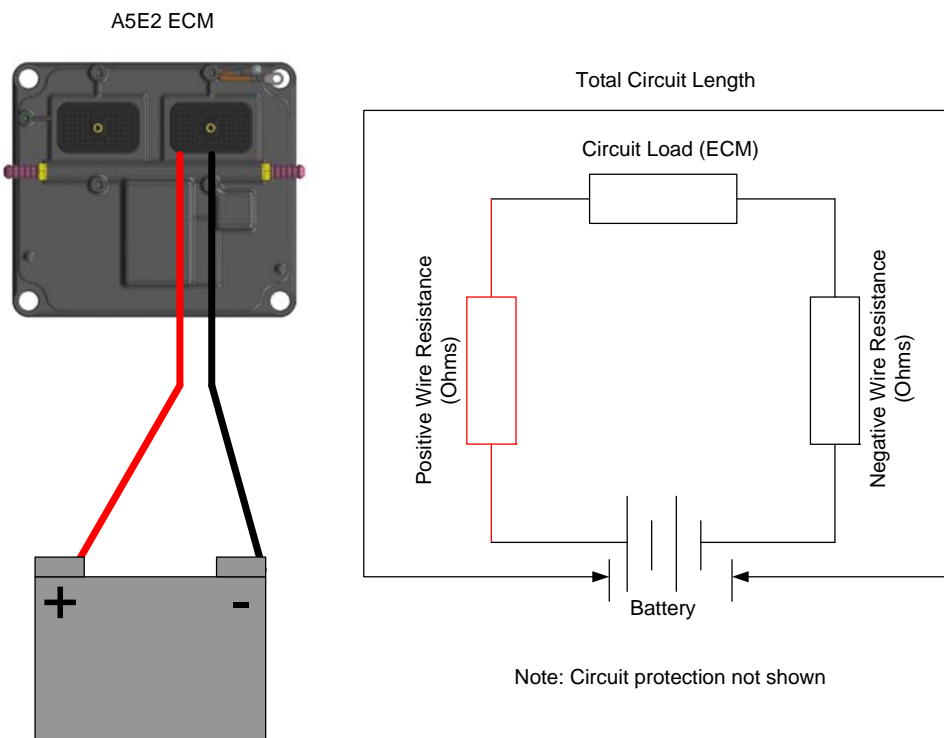
Conductor CSA	Material	mohm/m at 20Deg C	mOhm at 20Deg C for Cable Length				
			2m	4m	6m	8m	10m
2	Ni-plated Copper	9.82	19.64	39.28	58.92	78.56	98.2
2.5	Ni-plated Copper	7.92	15.84	31.68	47.52	63.36	79.2
3	Ni-plated Copper	6.41	12.82	25.64	38.46	51.28	64.1
4	Ni-plated Copper	4.91	9.82	19.64	29.46	39.28	49.1
5	Ni-plated Copper	4.11	8.22	16.44	24.66	32.88	41.1
6	Ni-plated Copper	3.27	6.54	13.08	19.62	26.16	32.7
10	Ni-plated Copper	1.9	3.8	7.6	11.4	15.2	19
16	Ni-plated Copper	1.21	2.42	4.84	7.26	9.68	12.1
25	Ni-plated Copper	0.774	1.548	3.096	4.644	6.192	7.74
35	Ni-plated Copper	0.549	1.098	2.196	3.294	4.392	5.49
50	Ni-plated Copper	0.383	0.766	1.532	2.298	3.064	3.83
70	Ni-plated Copper	0.27	0.54	1.08	1.62	2.16	2.7
95	Ni-plated Copper	0.204	0.408	0.816	1.224	1.632	2.04
120	Ni-plated Copper	0.159	0.318	0.636	0.954	1.272	1.59

Table 4.2 Metric Cross Sectional Area Estimated Cable Resistance

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

American Wire Gauge	Material	mohm/m at 20Deg C	mOhm at 20Deg C for Cable Length				
			2m	4m	6m	8m	10m
14	Ni-plated Copper	9.82	19.64	39.28	58.92	78.56	98.2
12	Ni-plated Copper	6.41	12.82	25.64	38.46	51.28	64.1
10	Ni-plated Copper	4.11	8.22	16.44	24.66	32.88	41.1
8	Ni-plated Copper	2.59	5.18	10.36	15.54	20.72	25.9
6	Ni-plated Copper	1.55	3.1	6.2	9.3	12.4	15.5
4	Ni-plated Copper	1.06	2.12	4.24	6.36	8.48	10.6
2	Ni-plated Copper	0.62	1.24	2.48	3.72	4.96	6.2
0	Ni-plated Copper	0.383	0.766	1.532	2.298	3.064	3.83
00	Ni-plated Copper	0.27	0.54	1.08	1.62	2.16	2.7
000	Ni-plated Copper	0.204	0.408	0.816	1.224	1.632	2.04
0000	Ni-plated Copper	0.159	0.318	0.636	0.954	1.272	1.59

Table 4.3 American Wire Gauge Estimated Cable Resistance



Note: Circuit protection not shown

Figure 4.3 ECM Supply Circuit

As with all electrical circuits wire should be selected so that the rated maximum conductor temperature is not exceeded for any combination of electrical loading, ambient temperature, heating effects of bundled cables, protective braid, conduit and other enclosures. Consult wire manufacturers data sheets for further information.

4.3.1 Important Voltage Supply Circuit Considerations

Poorly designed or installed ECM supply circuitry can lead to intermittent engine problems and reduce the engine ECM's ability to maintain optimum performance under harsh conditions such as cold ambient and low battery voltage.

To ensure that the integrity of the electrical supply circuit is not compromised during design and installation the following recommendations should be adhered to.

- Supply cable wire gauge or CSA must be capable of meeting the maximum electrical requirement demanded by the engine ECM under all conditions.
- When specifying ECM circuit supply and return cables, which are to be routed around hot components or form part of a machine wiring harness bundle the appropriate cable current carrying capacity derate should be applied.
- All ECM power pins must be connected to the main battery supply to ensure a complete and robust electrical circuit is made.
- When splicing the ECM supply or return cables the main supply cable must be rated to carry the total circuit current to the ECM and provide the correct amount of mechanical durability for the number of splices made.
- The total ECM circuit resistance must meet the stated limits (50mOhms for 12V and 100mOhms for 24V systems) to ensure that voltage drop across these cables is minimized.

It should also be noted that the ECM supply circuit must be routed directly back to the application battery to maintained optimum system performance under all conditions. Failure to do so will lead to excessive system voltage drop and high circuit resistance as well as increased levels of supply circuit noise.

4.3.2 Battery (+) Connection

The ECM requires five un-switched battery positive inputs; the inputs should be permanently connected to the machine battery. When the ignition key switch is off the ECM is in a sleep mode during which it draws a very small residual current through the five battery connections. When the ignition key switch is turned on the ECM will become active. It is recommended, therefore that the ignition keyswitch is turned to the off position when connecting or disconnecting the ECM J1 connector, to prevent large sparks which may cause damage to the pins.

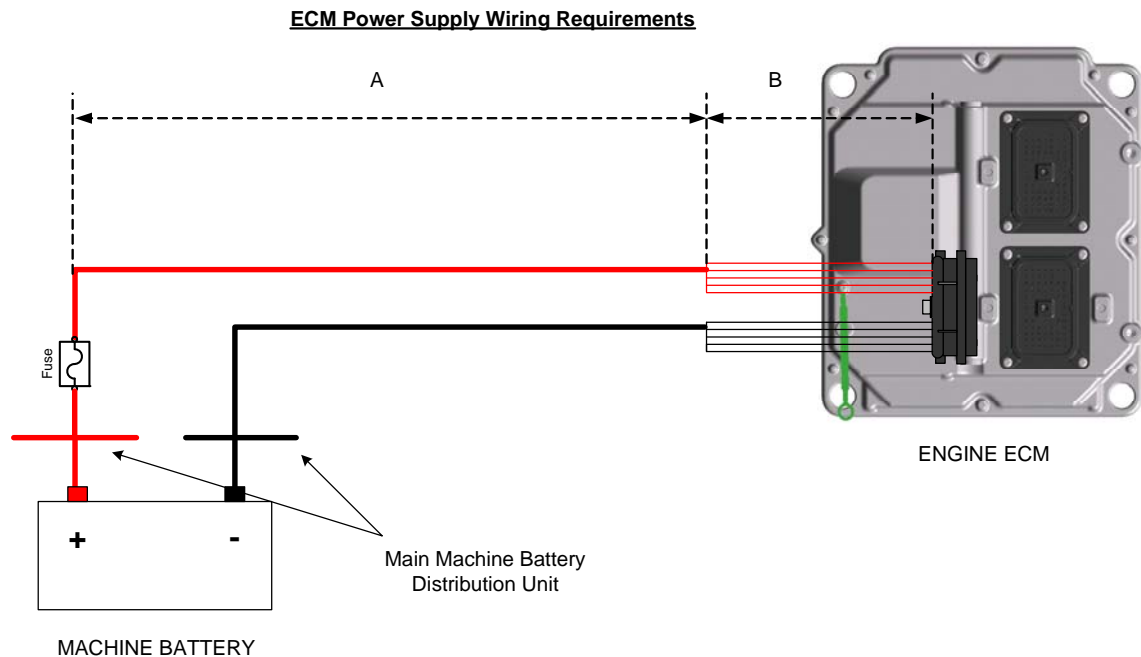
The power supply to the ECM should be taken from the battery, and not from the starter motor terminals to avoid unnecessary system noise and voltage drops. Note that there are 5 ECM pins allocated for battery positive. All 5 pins must be used.

The correct system voltage must be applied (12V or 24V), as the following components on the engine are system voltage sensitive:

- Wastegate Regulator
- Inlet Throttle
- Exhaust Back Pressure Valve
- Induction Metering Valve
- Fuel Pump

It is recommended that two supply cables from the battery be used. These supply cables should then be spliced as shown in figure 4.4. Recommended wire gauge is also shown in figure 4.4. These values have been calculated to ensure that the max circuit resistance is not exceeded, the current requirements of the ECM are met and the min voltage required by the ECM during engine operation is always achieved.

Please note that it is the customer's responsibility to ensure that the ECM supply circuitry meets the limits stated within table 4.1. For this reason in some cases it may be necessary to increase the supply cable AWG (CSA) in order to meet the system design criteria.



Note: Diagram shown is an example only of the ECM supply and ground connection. All Fuses must be chosen in conjunction with the data shown in table 4.1. Fuses must be rated to protect the ECM supply cables and not the engine ECM.

Note A: Ensure cable splices are made using 14AWG wire and are kept to a minimum length.

Note B: Ensure that the main supply cable is correctly specified in terms of length, resistance, voltage drop and current carrying capacity.

Figure 4.4 Recommended ECM Power Supply Wiring and Protection

4.3.3 Battery (-) Connection

The ECM requires five un-switched battery negative inputs; the inputs should be permanently connected to the machine battery and all inputs must be used to ensure the ECM is supplied with an adequate connection to ground.

Failure to use all five inputs could result in intermittent communication and or driver operation.

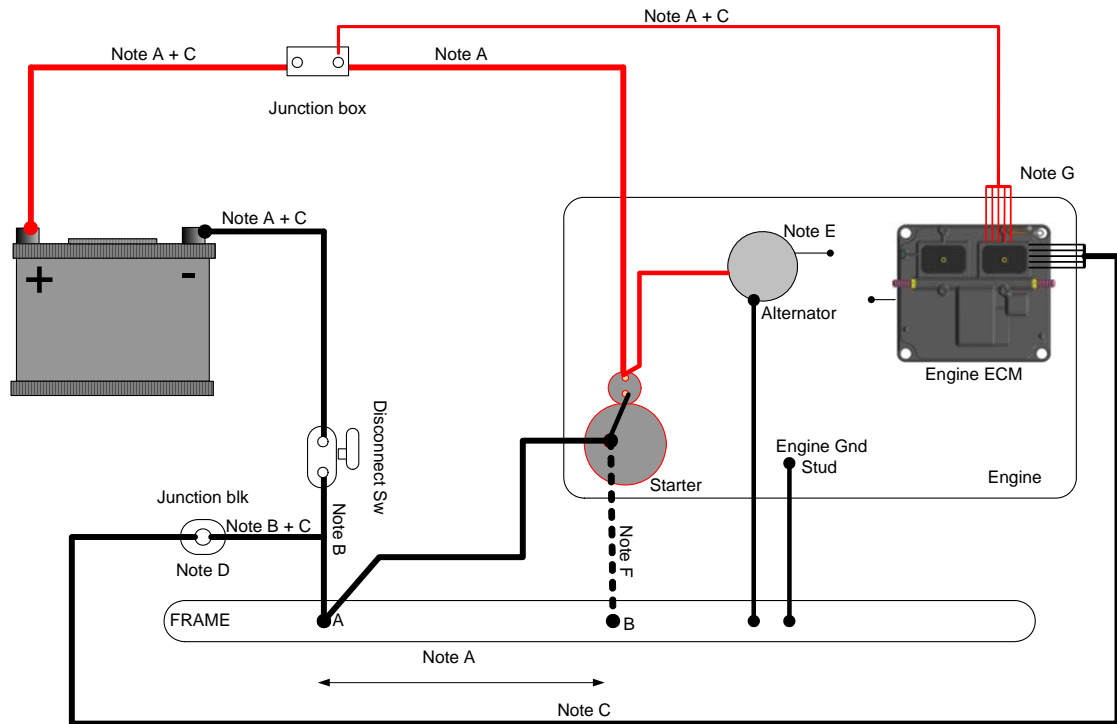
The ECM negative inputs must be connected back to the main batt – terminal on the application batteries and not through application chassis. The consistent quality of the ground path cannot be guaranteed when grounding the negative return through the chassis, which may cause intermittent system failures and excessive noise levels on the ECM supply circuit. Caterpillar will not approve installations, which do not meet this requirement. Section 4.3.4 shows the correct method of supplying both power and ground connections to the ECM.

Battery Connection – Do Not supply power to the ECM from the starter motor connections

4.3.4 Correct method of ECM battery connection.

Correct Power Supply Wiring

- ECM Positive wires connected direct to battery, not via starter motor
- Power supply wires go to all 5 positive pins and all 5 negative pins on the ECM Connector
- ECM Negative is wired to the battery rather than return through chassis
- The engine is grounded to machine chassis



Note A: Keep to a minimum distance
 Note B: Keep to a minimum distance
 Note C: Observe maximum resistance
 Note D: Specify maximum number of terminals and maximum load

Note E: Case Ground or Strap Ground – Check Alternator Spec.
 Note F: Starter motor grounding may be made through the machine chassis as long as the total circuit resistance for 12V system does not exceed 1.7mOhm and for 24V 3.4mOhm (C4.4 – C7.1).
 Note G: The number of ECM supply and return connections varies between engine families. Please refer to the ECM J1 connection list for details on the number of connections required for each specific engine range.

This diagram is for discussion regarding 12V electrical systems, Items such as circuit protection have been removed for clarity.

Figure 4.5 System Power Supply and Grounding Requirements

4.3.5 Incorrect method of ECM battery connection.

Incorrect wiring

- Positive wired via starter motor. High volt drop to ECM on starting
- Single pin on ECM used for each of positive and negative supply. Possibly exceeding pin ratings and possible risk of arcing or over heating.
- ECM return through chassis – risk of conducted noise and also additional voltage drop.
- Engine not grounded – risk of engine component damage.

4.4 Engine ECM Power Supply Circuit Resistance Test

Component	Caterpillar part number	Quantity
J1 Receptacle	133-8751	1
2.2 Ohm Resistor 200W	N/A	1
Relay (low contact resistance)	N/A	1
Pushbutton	N/A	1
Voltmeter	N/A	2

Table 4.4 ECM Power Supply Circuit Test Components

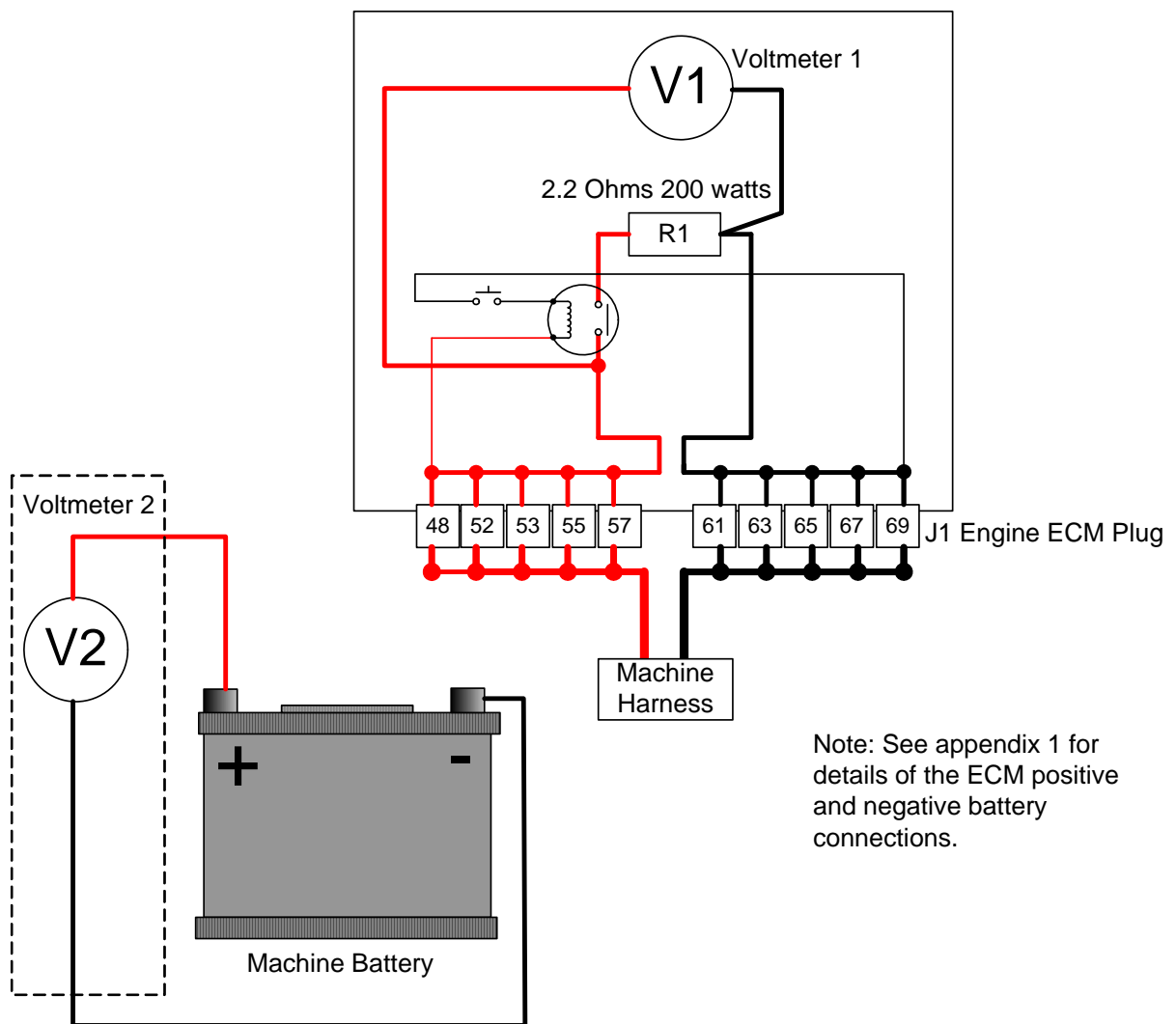


Figure 4.6 ECM Power Supply Circuit Resistance Testing

Note: The total ECM supply circuit resistance forms part of the Application Appraisal. Circuits which do not meet the 50mOhm requirement for a 12V system and 100mOhm's for 24V will be classed as a failure during the Appraisal sign off.

4.4.1 Test Procedure

Record the measured resistance value of the test resistor used. Disconnect the J1 engine ECM plug from the ECM and connect the test apparatus as shown in figure 4.6. Press the button for three seconds and at the same time record the voltage measured from Voltmeter 1 and Voltmeter 2.

Formula:

$$\text{Power Supply Circuit Resistance (mOhms)} = 1000 * (R1 * (V2 - V1) / V1)$$

V1 = Voltmeter 1 Measured Value

V2 = Voltmeter 2 Measured Value

R1 = Measured Resistor Value

Worked Example

V1 = 11.8

V2 = 12

R1 = 2.21 Ohms

$$1000 * (2.21 * (12 - 11.8) / 11.8)$$

$$1000 * (2.21 * 0.01695)$$

$$1000 * (0.0375)$$

Harness Resistance = 37.5 mOhms

4.4.2 Suppression of Voltage Transients

Note: The installation of transient suppression at the source of the transient is required. Caterpillar follows a stringent electrical environment standard that is similar to SAE recommended practices.

The use of inductive devices such as relays and solenoids can result in the generation of voltage transients in electrical circuits. Voltage transients that are not suppressed can exceed SAE specifications and lead to a degradation in performance of the electronic control system.

The customer should specify relays and solenoids with built-in voltage transient suppression. Refer to figure 4.7 for ways to minimise voltage transients from relays and solenoids without built-in voltage transient suppression. Techniques include the installation of a diode or resistor of the proper size in parallel with the solenoid or the relay coil.

Diodes and resistors accomplish suppression in different ways. Diodes clamp the voltage across the coil to approximately -0.7V when the switch opens. The current circulates in the loop until it eventually diminishes. Suppression resistors will allow the transient voltage to increase to a value determined by the forward current flow through the coil and the value of the resistance of the suppression resistor. However, resistor suppression causes the current in the loop to diminish much faster than would a diode.

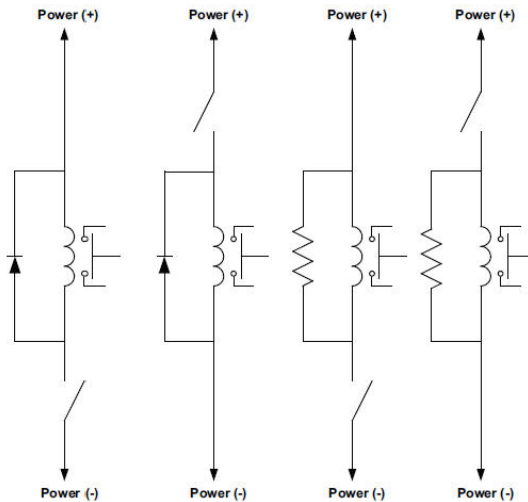


Figure 4.7 Voltage Suppression Diagram

Diode selection should be based on the normal voltage and current seen by the coil. For example, if the normal voltage applied to the coil is 24V and the coil has a resistance of 50Ohms, then the current passing through the coil is 480mA ($I = V/R$). The diode then would need to be able to withstand a reverse voltage of 24V and a forward current of 480mA when the current to the coil is interrupted by the opening of the switch since the collapse of the coil's magnetic field will attempt to maintain that current.

Suppression resistors are a low-cost alternative and can be less stressful on relay coils. Resistor selection should be determined by the voltage applied across the coil, the resistance of the coil, maximum power dissipation allowed, and the level of transient voltage to be tolerated. For example, if the coil is 50Ohms and the voltage applied is 24V, an 82Ohm suppression resistor would allow the transient voltage to reach $-39.6V$ ($V = IR = -.48A \times 82Ohms$, the voltage is shown as negative since the polarity reverses once the switch opens). Using a 330Ohm resistor would allow a $-158V$ transient but the current would diminish in the loop faster. For power dissipation concerns, the resistor's power rating should be considered. For example, if 24V were applied across a 330Ohm resistor, the power dissipated by the resistor would be 1.75W ($P = V^2/R$). Therefore a 330Ohm resistor should be selected with the capability of dissipating at least 2W. The heat generated by the resistor should be considered when selecting a resistor.

Note: If the resistance of the suppression resistor is too low, the driver circuitry in the ECM may be loaded to a point where the relay or solenoid does not function properly. If the resistance is too high, the transient voltage may reach undesirable levels.

There are other techniques that can be used for transient suppression. Snubbers, Zener diodes, and varistors are all methods that have characteristics that make them better suited for some applications. But for simple applications of relays or solenoids, diodes or resistors should suffice.

Inductive devices such as relays or solenoids should be located as far as possible from the components of the electronic control system. Wiring harnesses that are installed by the customer should be routed as far as possible from the wiring harness of the electronic control system in order to avoid problems that are associated with electrical noise.

4.5 Direct Battery connection requirements

The following components require a power supply direct from the application battery, these components are voltage dependant.

- Fuel System Electric Fuel Pump
- DPF Soot Sensor
- ARD Fuel Lift pump
- Starter Motor
- Alternator

More information regarding the installation requirements for the DPF Soot sensor and the ARD fuel lift pump can be found in section 6 of this document.

4.6 Powering The Engine ECM Via Auxiliary Power Supplies

If the engine is to be supplied with electrical power via any other means than a standard machine battery arrangement, care must be taken when choosing the power supply. Engine ECM's powered by devices such as switch mode power supplies can be particularly troublesome due to the intermittent high current load demands of the engine ECM during engine operation. To ensure that the power supply operates correctly, management of these intermittent high current spikes is employed. For more assistance when implementing auxiliary power supplies please contact the Electronic Applications Engineering Department.

4.7 Sensor Common Connections

Certain components that interface directly with the ECM require connection to one of the dedicated sensor/switch return pins on the ECM customer machine interface connector J1. Separate sensor/switch returns are provided for analogue and digital signals. All components requiring connection to one of the ECM ground connections must be connected to the correct ground path to ensure the correct operation of the component.

4.7.1 Actuator Driver Return

All of the following features must be connected back to the engine ECM J1 Actuator Driver return pin (59).

ECM Feature	J1 Pin Location
Fan Reversing Solenoid / Air Shutoff Solenoid	J1 – 10
ARD Main Fuel Valve	J1 – 11
Ether Start Valve Solenoid	J1 – 12
Glow Plug Start Aid Relay	J1 – 20

Table 4.5 Engine Actuator Connections

4.7.2 Analogue Sensor Return

All of the following Features and switches must be connected back to the engine ECM J1 Analogue return pin (3).

ECM Feature	J1 Pin Location
Analogue Throttle 2	J1 – 1
Auxiliary Pressure Sensor	J1 – 15
Auxiliary Temperature Sensor	J1 – 16
Air Inlet Temperature Sensor	J1 – 17
Water in Fuel Switch	J1 – 35
Oil Level Switch	J1 – 47
Analogue Throttle 1	J1 – 66

Table 4.6 Analogue Sensor Connections

4.7.3 Switch Return

All of the following Features and switches must be connected back to the engine ECM J1 GND switch return pin (18).

ECM Feature	J1 Pin Location
CRS Inhibit switch	J1 – 7
Idle Validation switch 1 / Customer Fan Override	J1 – 22
Force Regeneration Switch	J1 – 23
Idle Validation Switch 2 / Throttle Arbitration Switch	J1 – 40
MPTS 1 / PTO Disengage	J1 – 41
User Defined Shutdown Switch / PTO Mode Speed 1 & 2 Select	J1 – 44
Throttle Arbitration 2	J1 – 45
Regeneration Readiness	J1 - 46
Fan Reverse Switch /	J1 – 54

Overspeed Verify Switch	
MPTS 2 / PTO Mode On / Off Switch	J1 – 56
MPTS 3 / PTO Raise / Resume	J1 – 58
MPTS 4 / PTO Set / Lower / Intermediate Speed Limit	J1 - 60

Table 4.7 Switch to Ground Connections

4.7.4 Digital Return

All of the following Features and switches must be connected back to the engine ECM J1 digital return pin (5).

ECM Feature	J1 Pin Location
PWM Throttle 1	J1 – 66
PWM Throttle 2	J1 – 1
Coolant Level Switch	J1 – 49

Table 4.8 Digital Signal Connections

4.8 Mandatory Fuel Lift Pump Installation

4.8.1 Fuel Lift Pump Operation

The fuel lift pump is a mandatory installation component which needs to be mounted by the customer remotely from the engine. The fuel pump is used to ensure a continuous fuel flow is provided to the engine fuel pump. The pump is available in 12 and 24V options, with both pumps requiring a Battery + connection made via a fuel lift pump relay. The relay operation is controlled by the engine ECM.

The electric lift pump is energised whenever the ignition key switch supply to pin 70 of the J1 ECM connector is activated. This enables the pump to be used as an electric fuel priming feature when required (120seconds 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 120seconds without seeing the engine speed increase from 0rpm. If the engine speed does not exceed 0rpm within 120seconds then the lift pump will turn off. The lift pump will then re-start as soon as the engine ECM sees the actual engine speed exceed 0rpm.

4.8.2 Fuel Lift Pump Configuration

There is no service tool configuration required to enable the fuel lift pump feature. The service tool does however provide a means of overriding the engine ECM control of the pump relay to aid system diagnostics. This override parameters can be found in the following 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

4.8.3 Fuel Lift Pump Installation

The fuel lift pump requires a fused battery positive and battery negative connection. The control of the lift pump is provided by the engine ECM via the ECM J1 connector and a fuel pump supply control relay which requires machine mounting by the customer.

Caterpillar recommend the use of the relays shown in table 4.9 below. When mounting the relay the following must be considered;

- Both relays have an ambient temperature limit of 85°C and a 4.5Grms vibration limit.
- 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.

In the event of a third party relay being selected for fuel lift 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 pump.

Component	CAT Part Number	Max Current Draw	Recommended Cable Size
12V Lift Pump Relay	115-1615	10A	14AWG
24V Lift Pump Relay	3E-5239	5A	16AWG

Table 4.9

The fuel lift pump is supplied with a 2 pin Deutsch connector for ease of electrical connection. The mating connector part numbers are shown below in table 4.10.

Component	CAT Part Number
2-Way Plug Kit	155-2270
2-Way Plug	155-2269
Wedge Lock	155-2261
14 – 18AWG Sockets	9X-3402

Table 4.10

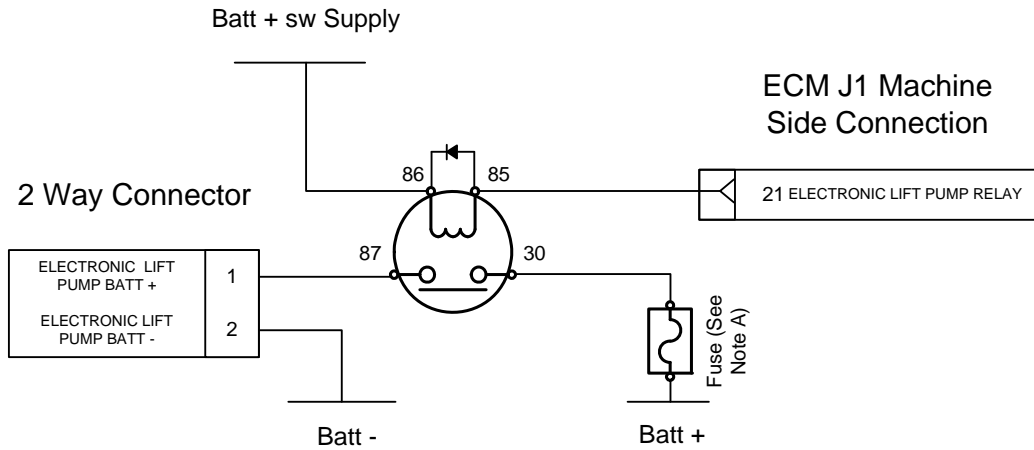


Figure 4.8

Note A: The lift pump supply cables and the associated fuse rating will be dependant upon the overall system voltage. Table 4.9 gives details of the max continuous current rating for each pump. The fuse rating selected should be specified to protect the cable size used.

Note: For more information regarding mechanical installation and mounting please refer to section 8 of the Mechanical A&I Manual.

5.0 Connectors and Wiring Harness Requirements

5.1 Engine ECM J1 connector

The A5E2 engine ECM has an integral rectangular 70-pin connector which is used by the customer / OEM as the connection point to the engine ECM J1 socket for machine control and diagnostics. To make a connection to the engine ECM the components listed in table 5.1 below are required.

Qty	Description	CAT Part Number
1	Plug Assembly	235-1081
1	Wire Dress Cover with integrated strain relief	343-1867
1	Cable Tie	N/A
N/A	Contact Socket stamped and formed option for high volume machine crimping only.	126-1766
N/A	Contact Socket #14 machined option (gold) for hand crimping with CH11155	126-1768
N/A	Contact Socket #16 / #18 machined option (gold) for hand crimping with CH11155	9X-3402
N/A	Sealing Plug	8T-8737

Table 5.1 ECM J1 Connection Parts List

The A5E2 ECM is also fitted with wiring harness strain relief bracket, through which all customer wiring from the J1 connector should be routed to prevent pin fretting and the possibility of premature connector failure. The wiring harness dress cover with integrated strain relief and associated cable tie are detailed in the table above.

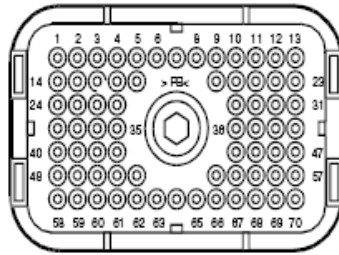
The above components are available in kit form. The kit will provide all the necessary components to make one basic engine connection.

Description	CAT Part Number
Connector Kit	TBD

The wiring harness dress cover must be fitted to prevent direct exposure to dirt and dust, as well as jet washing onto the rear connector seals.

5.1.1 Connector Layout

The diagram below illustrates the pin layout, looking from the rear of the connector. The connector is keyed to ensure correct connector to ECM engagement.



5.1.2 Tightening the OEM Connector

A central 4mm allen key screw retains the connector. This screw should be tightened to a torque of 6Nm+/- 1. CAT does not recommend the use of “non conductive grease” with the ECM connector. Due to the low tightening torque for this connection it is recommended that the use of ball ended allen keys and air tools are restricted as they could lead to the connector being over tightened.

5.1.3 ECM connector Wire Gauge Size

Wire gauge sizes for customer ECM connections are dependant upon their function and the current carrying capacity that is required. The customer J1 connection to the ECM is capable of supporting and sealing 14AWG through to 18AWG (3mm² – 0.8mm²) with GXL insulation (SAE J1128). To ensure the sealing properties of the connector are maintained the overall cable diameter used must have a minimum diameter of 2.26mm and maximum of 3.94mm. Table 5.2 below gives guidance on the wire gauge size recommend for each ECM circuit function.

Circuit Function	Size (AWG)
Battery Negative	14 GXL
Battery Positive	14 GXL
Battery Positive Switched	18 GXL – 14 GXL
Digital Sensor Power	18 GXL
Digital Sensor Return	18 GXL
Analogue Sensor Power	18 GXL
Cat Data Link	18 GXL
J1939 (CAN) Data Link	18 GXL
Switch to Ground Input	18 GXL
Low Side (300mA) Driver	18 GXL
High Side (2A) Driver	18 GXL
Active Analogue Input	18 GXL
Passive Analogue Input	18 GXL
PWM Input	18 GXL

Table 5.2 ECM Wire Gauge Requirements

Min / Max outside diameter (Inc Insulation) = 2.26mm / 3.94mm

5.1.4 Terminal Retention

The ECM J1 customer Interface connector is constructed to ensure terminals are retained once correctly seated without the need for external locking devices. To activate the terminal retention mechanism ensure that the terminals are pushed fully home and check location by gently tugging on cable.

5.1.5 Hand Crimping For Prototype machines and Low Volume Production:

A hand crimping tool and appropriate die are required for crimping contact sockets. The hand crimping tool and the socket removal tool part numbers are shown below in table 5.3. These components can be ordered via the CAT system.

Component	CAT Part Number
Contact socket	126-1768
	9X-3402
Crimp Tool number	1U5804
Removal tool	151-6320

Table 5.3 Hand Crimping Tool Part Numbers

Note: The insulation should be stripped to 5mm from the end of the wire. Only a single wire must be crimped into each terminal.

5.1.6 ECM connector sealing plug installation guidelines

All unused cavities must be filled with sealing plugs in order to ensure that the connector is sealed. To seal the connector cavities plugs 8T-8737 should be used. 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 ECM.

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

5.1.7 OEM harness Dress Cover With Integrated Strain Relief

To ensure that the machine wiring harness is correctly supported and protected at the ECM connector, the dress cover with integrated strain relief shown in figure 5.1 must be used. This dress cover is a mandatory fit item. The part number for the component is 343-1867 and has a tightening torque to the ECM of 6.5Nm +/- 0.5Nm.



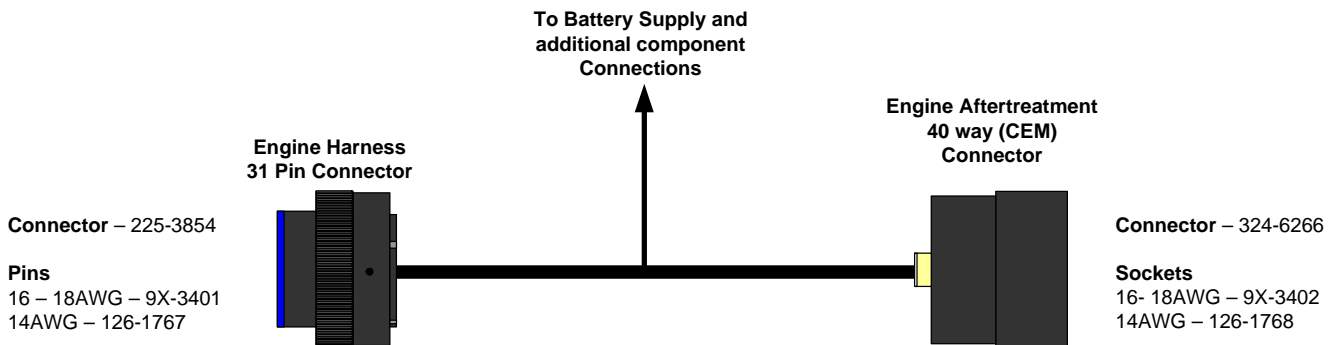
Figure 5.1 ECM J1 Customer Harness Dress Cover and Strain Relief

5.1.8 Machine Crimping For High Volume Production

For high volume and automated crimping solutions please contact the contact supplier directly for tooling details.

5.2 Engine to Aftertreatment Connectors C7.1 Only

All C7.1 engines are supplied with a Clean Emissions Module (CEM) aftertreatment package. The CEM is a complete high temperature aftertreatment package comprising of the Auxiliary Regeneration Device ARD and DPF. The electrical connections for this module are provided pre-terminated to a 40 way connector. The majority of the output connections from the 40 way CEM connector require connection to a 31 pin connector mounted on the engine harness. Figure 5.2 shows the two main connectors required to connect the engine aftertreatment to the engine ECM. The following sections provide details on the specific wiring requirements for these two aftertreatment connectors.



Note: All pins and sockets used here are to be gold plated

Figure 5.2 Aftertreatment 40 way CEM connection to engine harness 31 pin connector.

For more details on the specific wiring requirements for this mandatory link harness please see section 6.0 of this document.

5.2.1 40 Way CEM Connector Layout C7.1

The 40 way CEM connector shown below in figure 5.3 is required for connection to the C7.1 high temperature CEM package. The part number for the connector and its interface pins are shown in table 5.4

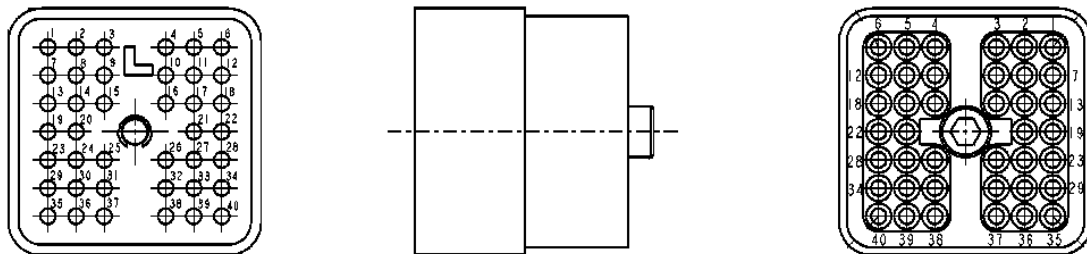


Figure 5.3 CEM 40 Way Mating Connector

Description	CAT Part Number
40 Way Deutsch	324-6266
Sockets 14AWG	126-1768
Sockets 18/16 AWG	9X-3402

Table 5.4 CEM 40 Way Connector Part Number

5.2.2 Engine Harness 31 pin Connector Layout C7.1

The 31 pin connector shown below in figure 5.4 is used to connect the C7.1 high temperature CEM module to the engine wiring harness. The connector is a Deutsch connector, which can be ordered using the part numbers shown in table 5.5.

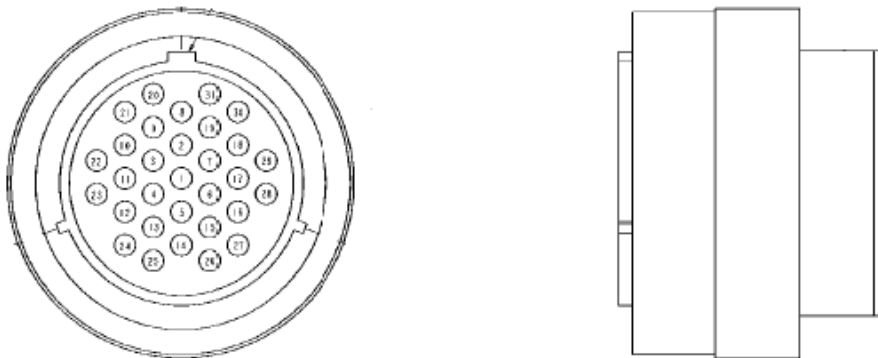


Figure 5.4 Engine Harness 31 Pin Mating Plug

Description	CAT Part Number
31 Way Deutsch	225-3854
Pins 18/16 AWG	9X-3401

Table 5.5 31 Pin Connector Part Number

5.2.3 Tightening the Connectors

The 31 pin connector is located using a rotating collar, which locks the two halves of the connector together.

The 40 Way CEM connector used to connect to the C7.1 CEM is locked using a threaded central connection that requires a tightening torque of 6Nm +/- 1Nm. Due to the low tightening torque for this connection it is recommended that the use of ball ended allen keys and air tools are restricted as they could lead to the connector being over tightened.

5.2.4 Aftertreatment Connectors Wire Gauge Size

All connectors used as part of the engine aftertreatment system are specified to allow the use of 14 -18AWG cable or metric 0.8mm – 2mm with GXL insulation. However it should be noted that to ensure the sealing properties of the connectors are maintained the overall cable diameter used must have a minimum diameter of 2.26mm and maximum of 3.94mm.

For more details on the specific wire gauge and insulation requirements please consult section 6 of this A&I Guide.

5.2.5 Connector Sealing Plug Installation Guidelines

All unused cavities must be filled with sealing plugs in order to ensure that the connector is sealed. To seal the connector cavities plugs 8T-8737 should be used. 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 ECM.

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

5.2.6 OEM Harness Retention

The OEM wiring harness must be supported at regular intervals along its routing to ensure that all connections are not placed under excessive strain. Care must also be taken to ensure that the cables feeding each of the harness connectors do not bend close to the connector body as this could compromise the connectors sealing capabilities.

5.2.7 Harness Routing and Length Restrictions

All engine, machine and aftertreatment wiring harnesses where possible should be routed so as to protect them from exposure to excessive heat or debris. The length of the wiring harnesses should also be kept to a minimum to reduce the effects of voltage drop. If long wiring harness lengths are required (5m or more) due to Application design please contact your Applications Engineer. More details on wiring harness design and installation best practice are detailed in section 5.5.

5.3 Diagnostic Connector

A 9 pin diagnostic connector is fitted to the engine wiring harness on all industrial engines. The diagnostic connector enables connection to both the proprietary CDL data links via ET service tools and the J1939 data link, which can be accessed by most third party diagnostic tools.

If the connector is inaccessible when the engine is in the application or no connector is fitted to the engine wire harness, provisions should be made to allocate an alternative location for diagnostic connection. In this case 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 OEM 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 ECM J1 connector.

5.3.1 Diagnostic Connector Layout

The engine diagnostic connector is a 9 pin Deutsch connector, which must be fitted to either the engine harness or as part of the machine harness. For those applications wishing to mount a diagnostic connector as part of the machine harness (mounted under the dashboard etc) the receptacle with a flange is recommended for secure mounting. The part numbers for both connectors (with and without flange) are shown below in table 5.6.

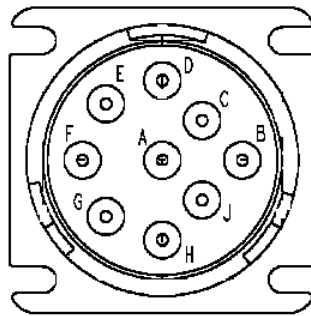


Figure 5.5 Diagnostic Connector Front View

Description	CAT Part Number
Receptacle (with flange)	9W-1951
Receptacle	8T-8736
Receptacle End Cap	8C-6354

Table 5.6 Diagnostic Connector Part Numbers

5.3.2 Diagnostic Connector Wire Gauge Size

All cables supplying the diagnostic connector are required to be no smaller than 18 AWG and should conform to the GXL insulation specification. Larger cables for the diagnostic power supply are not required, as diagnostic hardware should draw no more than 1Amp total.

5.3.3 Pin Information

Please note that all pins shown below in table 5.7 must be connected when installing a diagnostic connector. Care should also be taken when installing the connector as incorrect connections at the back of the connector are easily made.

Pin Description	Diagnostic Connector	J1 OEM 70 way Connector
Switched Battery +	Pin A	
Switched Battery -	Pin B	
PDL/CDL +	Pin D	8
PDL/CDL -	Pin E	9
J1939 -	Pin F	34
J1939 +	Pin G	50

Table 5.7 Engine Diagnostic Connector Connection List

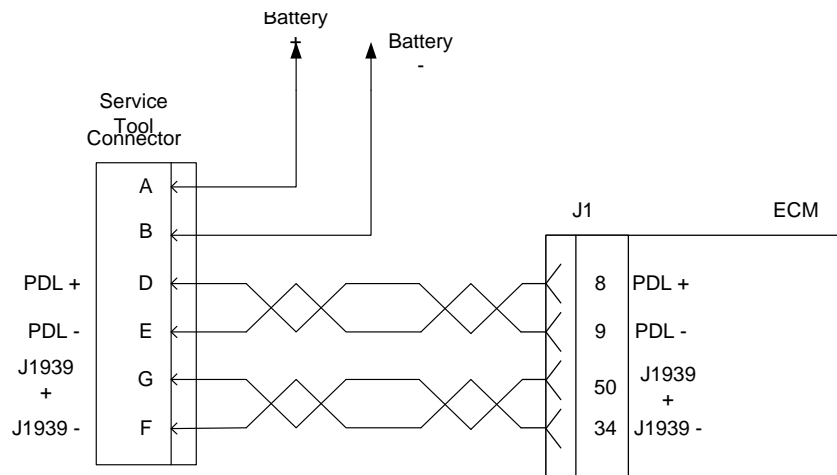


Figure 5.6 Diagnostic Connector Wiring Diagram

Note: Power supply for the diagnostic connector should be taken from a switched battery supply and not directly from battery.

5.4 Connector Terminal Contacts

There are a number of different terminals available to suit each connector. These terminals and their part numbers are shown in table 5.8. The stamped and formed terminals are available for highly automated harness assembly and should not be used for low volume or field repair of wiring harnesses. Machined terminals are available for these instances and must be used in conjunction with the Caterpillar crimp tool 1U5804.

The machined terminals are also available with nickel and gold plating. Gold plated terminals are preferred due to their low contact resistance and their superior resistance to corrosion when compared with nickel. Gold plated terminals must be used for all component connections except those listed below where a nickel contact maybe used.

- ECM Power Supply
- ECM switched battery outputs
- ECM 2A digital outputs such as glow plug relay
- ECM Lamp outputs

Gold plating has a reduced resistance to electrical current flow when compared to nickel so the use of these pins and sockets will ensure a robust electrical connection is made.

Wire Usage (AWG-type)	Contact	Type	Plating	CAT P/N
ECU Connector J1				
16/18 SXL	Socket	Stamped & Formed	Gold	126-1766
14/16/18 GXL	Socket	Stamped & Formed	Gold	126-1766
14	Socket	Machined	Gold	126-1768
16/18	Socket	Machined	Gold	9X-3402
HD-10 / DT Connector Standard / Amp Seal				
14	Socket	Machined	Nickel	9W-0844
14	Pin	Machined	Nickel	9W-0852
16/18	Socket	Machined	Nickel	186-3736
16/18	Pin	Machined	Nickel	186-3735
14	Socket	Machined	Gold	126-1768
14	Pin	Machined	Gold	126-1767
16/18	Socket	Machined	Gold	9X-3402
16/18	Pin	Machined	Gold	9X-3401

Table 5.8 Wiring Harness Pins and Sockets List

5.5 Harness Wiring Standards

The following are general “good practice” for wire harnesses. 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. These specific requirements are covered in section 6.

5.4.1 Connectors

It is strongly recommended that high quality sealed connectors are used throughout. Automotive standard components are not necessarily suitable as they are often only designed for a very low number of disconnect/reconnect cycles.

Connectors should be horizontally mounted rather than vertically mounted to prevent ingress of water/chemicals. 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.

5.4.2 Harness Bends Near Connectors

Harness bends within 25mm of the ECM J1 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 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 pullout failures. To avoid these problems pre-form the harness to the required bend radius.

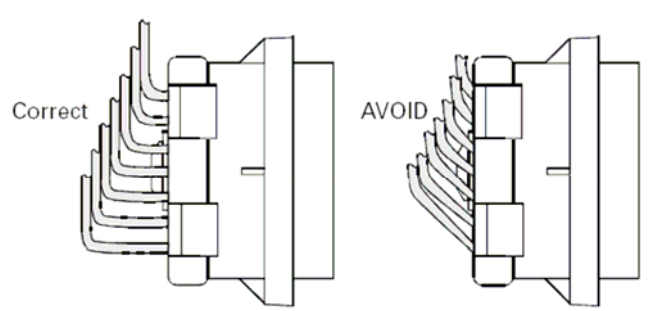


Figure 5.7 Connector Wire Routing and Tension

5.4.3 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.

5.4.5 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.

5.4.6 Insulation Selection and Thermal Protection

Care must be taken when routing the underhood 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 GXL 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 Connecting to Engine Aftertreatment

With the introduction of Tier 4 emissions legislation the use of engine exhaust aftertreatment has been made mandatory for certain engine power ratings. Each Cat engine family, for example C6.6 etc uses a different hardware set, software strategy or a combination of them both to meet these engine emission restrictions. Table 6.1 gives an indication of the number of aftertreatment critical electrical connections that need to be made for each of the engine ranges and whether these connections interface back to the engine ECM J1 connector, engine wiring harness 31 way plug or direct back to battery.

Engine Family	Component	Interface connector	Cat Part Number	Mating Interfaces
C7.1	CEM	40 Way Plug	324-6266	Engine Harness 31 Way plug
				Battery +
				Machine Chassis Ground
	Air Inlet Temperature	2 Way Plug	230-4011	Engine ECM J1
	DPF Soot sensor	6 Way Plug	281-8811	Engine Harness 31 Way plug
				SW Battery +
	ARD Fuel Lift Pump	2 Way Plug	177-9648 (12V) 281-8801 (24V)	Battery -
Battery +				
J1939 Termination Resistor	3 Way Plug	174-3016	N/A	
	3 Way Receptacle	133-0973		
C6.6 / C4.4	Aftertreatment ID	6 Way Plug	281-8811	Engine ECM J1
	DPF Inlet Temperature	4 Way Plug	239-7349	Engine ECM J1
	DPF Soot Sensor	6 Way Plug	281-8811	Engine ECM J1
				SW Battery +
	J1939 Termination Resistor x 2	3 Way Plug	174-3016	N/A
		3 Way Receptacle	133-0973	
Air Inlet Temperature	2 Way Plug	230-4011	Engine ECM J1	

Table 6.1 Engine Family Aftertreatment Connections

It can be seen that some of the component hardware is used for more than one engine range, such as the DPF Soot sensor, however the mating interface is different. The following sections describe in specific detail the components, connections and wiring required for each of the engine ranges.

6.1 C4.4 and C6.6 Emission Critical Aftertreatment Installation

6.1.1 Low Temperature Regeneration System Overview

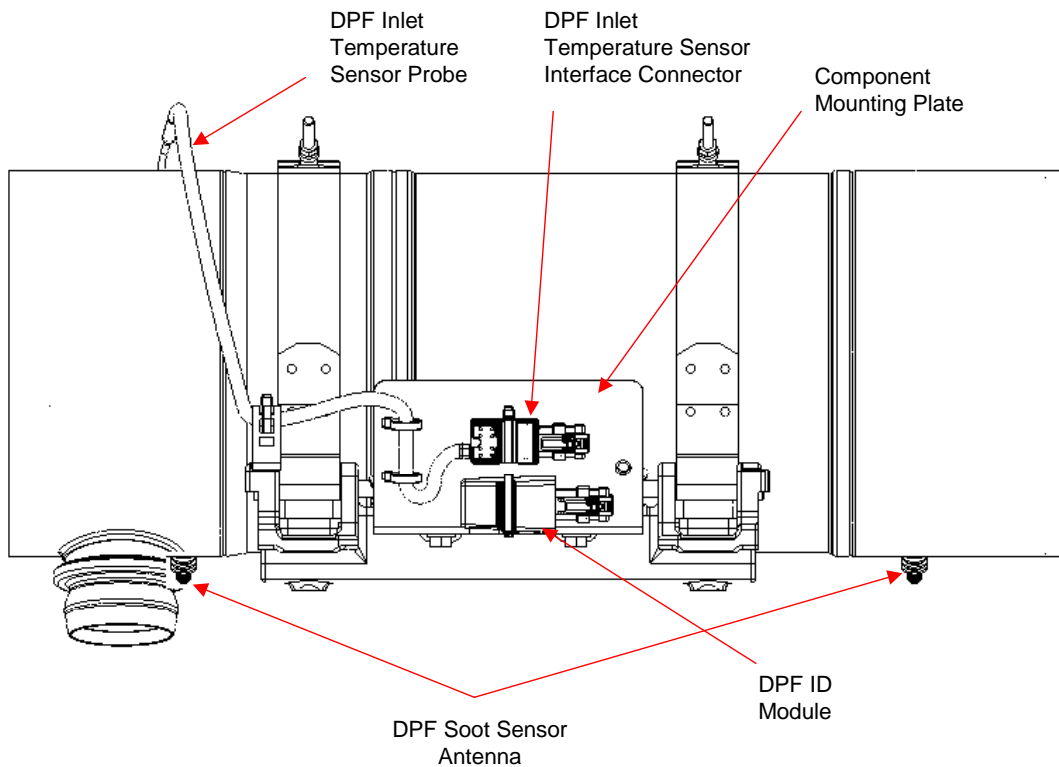


Figure 6.1 Low Temperature System Diagram

All engines designed for a power output between 61.5 and 130Kw (82.5 - 175 hp) are supplied with a Diesel Oxidation Catalyst (DOC) and a Diesel Particulate Filter (DPF) as a single canister. Mufflers may also be supplied. This system uses a number of sensors and actuators to control the temperature of the engine exhaust gas in order to initiate DPF regeneration events without any requirement for operator intervention.

All aftertreatment arrangements are supplied with a mounting bracket and a sensor mounting plate. Attached to this plate are the DPF Identification module and the DPF inlet temperature sensor.

In addition to the Cat CEM there are a number of components requiring an application specific location and wiring which necessitates the need for these components to be customer installed, these are;

- DPF Soot Sensor and J1939 termination resistor
- Air Inlet Temperature Sensor (Ambient)

6.1.2 Low Temperature Regeneration

There are two electronic devices supplied attached and pre terminated to the DPF hardware. These are the DPF ID module, which is terminated with a 6 Way Socket and a DPF inlet temperature sensor terminated with a 4 Way socket. In addition to these components there is a requirement for an inlet air temperature sensor and the DPF Soot sensor to be remote mounted away from the DPF system (due to temperature limits). The connection of these components to the engine ECM J1 connector is the responsibility of the customer. Their pin allocation is shown in table 6.2 below.

Component	Function	Pin Allocation		
		Component Connector	ECM 70-Way J1 Connector	Batt Connection
DPF ID Module	Sensor 5V Supply	1	2	-
	Not Used	2	-	-
	Aftertreatment ID Digital Signal	3	14	-
	Not Used	4	-	-
	Not Used	5	-	-
	Sensor 0V Return	6	5	-
DPF Inlet Temperature Sensor	Sensor 5V Supply	1	2	-
	Sensor 0V Return	2	3	-
	DPF Inlet Temperature	3	26	-
	Not Used	4	-	-
DPF Soot Sensor	Sensor Vbatt+ Supply	1	-	Y
	Ground	2	-	Y
	Not Used	3	-	-
	CAN -	4	38	-
	CAN +	5	37	-
	CAN Shield	6	-	-
Air Inlet Temperature Sensor	Analogue 5V Sensor Supply	1	3	-
	Air Inlet Temperature	2	17	-

Table 6.2 Low Temperature Aftertreatment Connection Interfaces

More information regarding the mounting and possible location of these components can be found in sections 6.4.1 and 6.4.2 of this document and section 5 of the mechanical A&I guide.

6.1.3 System Connection and Harness Design

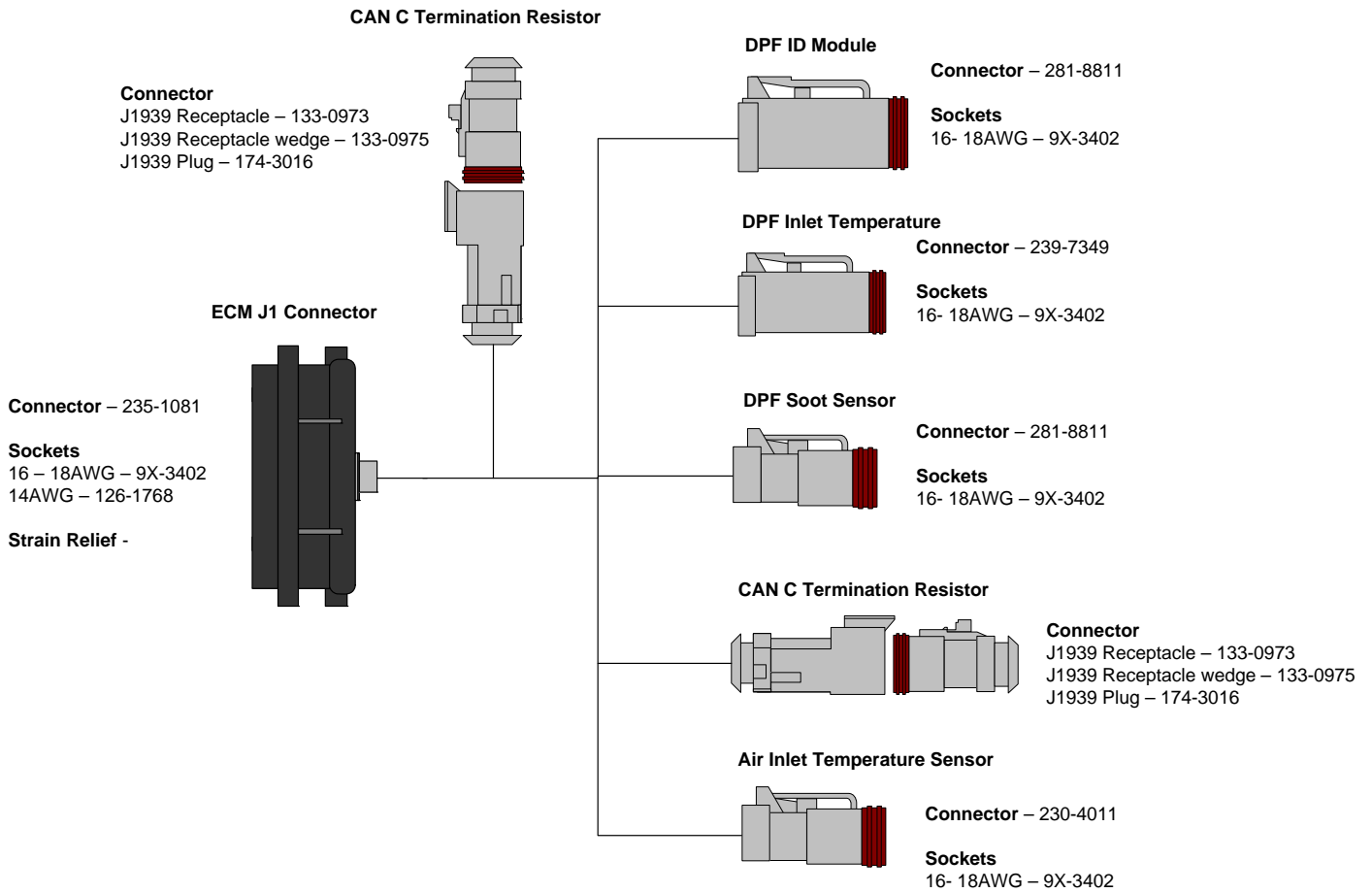


Figure 6.2 Low Temperature Emissions Critical Layout Diagram

Note: All connectors shown here are fitted with a standard wire seal. Some connectors may require a reduced diameter wire seal if there is a requirement for high temp cabling to be used such as Teflon.

6.1.4 Aftertreatment Wiring Schematic

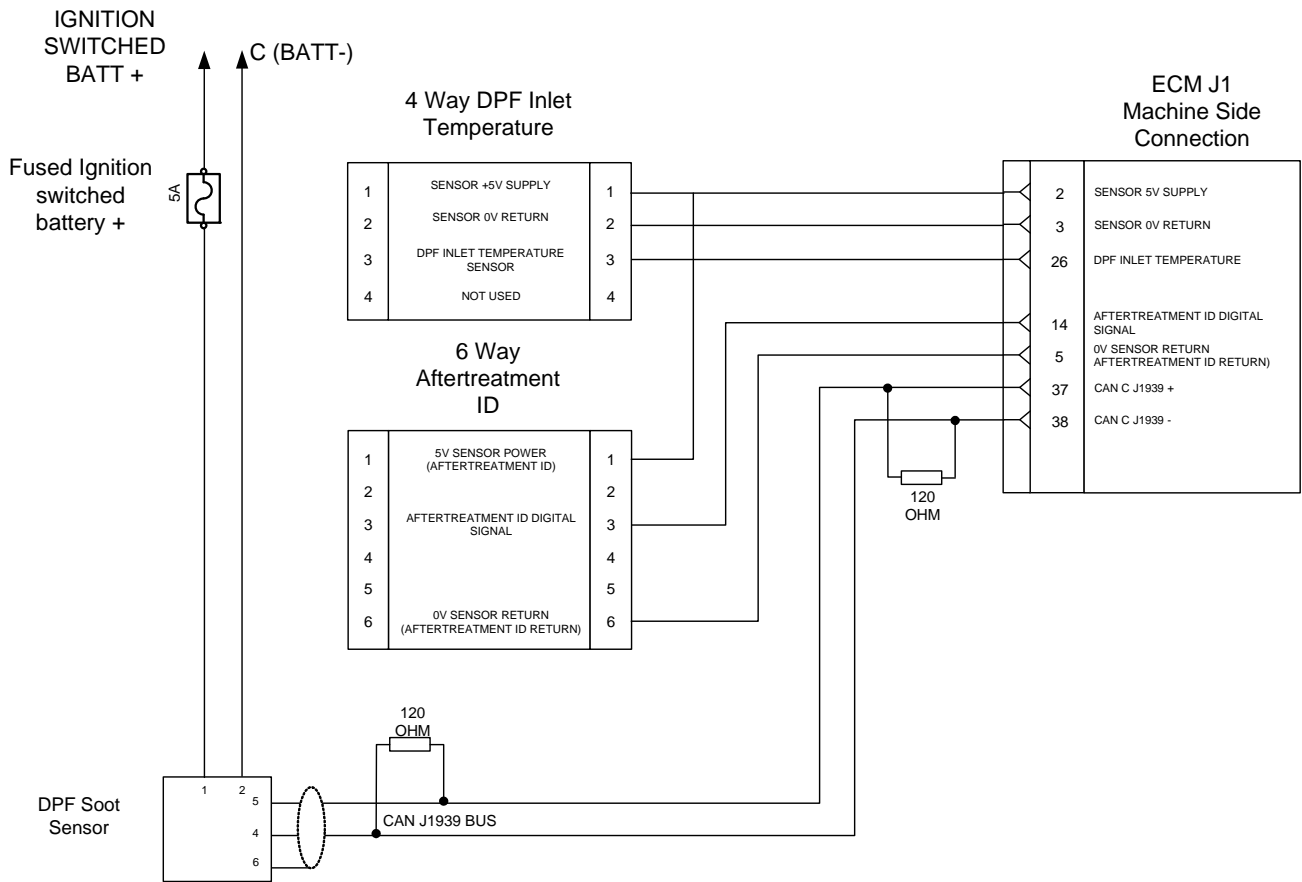


Figure 6.3 Low Temperature Regeneration System Wiring Schematic

6.2 C7.1 Emission Critical Aftertreatment

The Cat Clean Emission Module (Cat CEM) is capable of regenerating in two different modes of operation. These modes are called High Speed and Low Speed regeneration. The same Cat CEM will be used for both modes and therefore the installation requirements are identical.

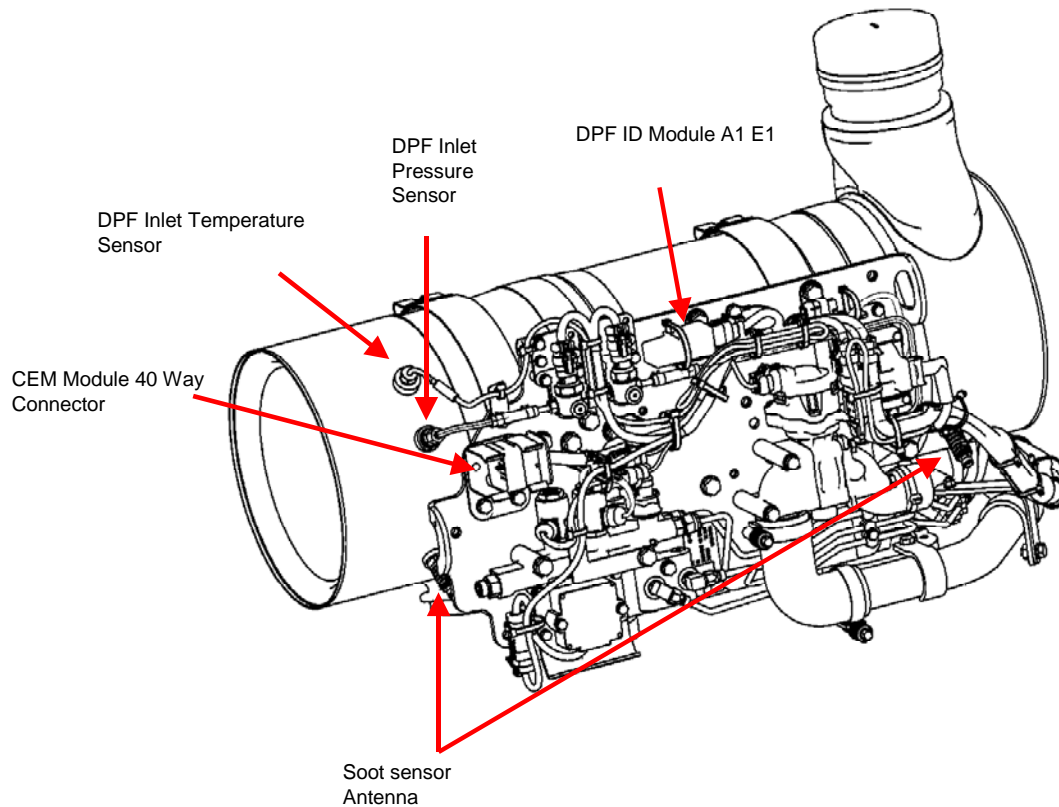


Figure 6.4 CEM electrical Component Layout

6.2.1 High Temperature Regenerations System Overview

All engines designed for a power output between 130Kw and 559 kW (175 - 750hp) are supplied with a Diesel Oxidation Catalyst (DOC), a Diesel Particulate Filter (DPF) as a single canister and an auxiliary regeneration system as standard. Mufflers may also be supplied.

The controls, actuators and sensing devices used to operate this system are supplied pre-wired to a 40-way Cat CEM Connector, for ease of connection to the engine management system.

In addition to the Cat CEM there are a number of components requiring an application specific location and wiring which necessitates the need for these components to be customer installed, these are;

- DPF Soot Sensor and J1939 termination resistor
- Air Inlet Temperature Sensor (Ambient)
- ARD Fuel Supply Pump and Relay

6.2.2 High Temperature ARD Regeneration

The Cat CEM requires connection to both the engine harness 31 way plug and the ECM application interface connector (J1), as well as direct application battery connections. All electrical connections are made via the 40 way connector mounted on the Cat CEM.

The connection of the Cat CEM 40 way connector to the engine harness is provided via a 31-pin interface connector. It is the customer's responsibility to connect the Cat CEM module to the engine harness 31-pin connector, ECM J1 connector and the machine battery via an interconnect harness. Table 6.3 gives the function of each pin on the Cat CEM module and it's interface to the rest of the application.

Function	Pin Allocation			
	CCEM 40 Way	Engine Harness 31 Way	Engine ECM J1 Connection	Batt Connections
Sensor +5V Supply	1	1		
Sensor 0V Return	2	2		
ARD Fuel Main Pressure Sensor	3	3		
DPF Intake Pressure Sensor	4	4		
ARD Combustion Detection Temperature Sensor	5	5		
DPF Inlet Temperature Sensor	6	6		
NOT USED				
ARD combustion Air Pressure Sensor	8	8		
ARD Combustion Air Control Valve	9	9		
ARD Hot Nozzle	10	10		
ARD Combustion Air Control Valve +	11	11		
ARD Combustion Air Control Valve -	12	12		
ARD Spark Plug Ignition Coil +	13	13		
ARD Spark Plug Ignition Coil -	14	14		
ARD Main Fuel Pressure Control Valve +	15		11	
ARD Main Fuel Pressure Control Valve -	16		59	
NOT USED				
Battery +	18			Y
Actuator Return	19	19		
ARD Pilot Fuel Pressure Sensor	20	20		
ARD Fuel Pressure Control Valve +	21	21		
ARD Fuel Pressure Control Valve -	22	22		
CAN +, DPF Soot Sensor	-	23		
CAN -, DPF Soot Sensor	-	24		
CEM To Machine Chassis Return	25			Y
ARD Fuel Lift Pump Relay	-	26		
Aftertreatment ID Digital Signal	27	27		
Aftertreatment ID Digital Return	28	28		

Table 6.3 Aftertreatment connection Interfaces

6.2.3 C7.1 High Temperature Regeneration System Connection and Harness Design

There are 7 connections required for the connection of the Cat CEM to the engine ECM. Each of these connections is the responsibility of the OEM and must be installed to enable the operation of the engine. A layout diagram is shown in figure 6.5 along with the connector part numbers and pin/socket information.

Note: The overall length of the engine to CEM link harness must not exceed 4.0m in length. If the application requires a harness length in excess of 4.0m please contact your Applications Engineering department.

The bulk of the engine aftertreatment connections are made via the CEM 40 Way to the engine 31 Way connector, which is attached to the engine wiring harness. The pin and socket connection lists for each of these connectors are shown in tables 6.4, 6.5 and 6.6. Some components however which require application specific mounting locations are connected to the engine ECM J1 connector via the 40 Way CEM plug or require a feed directly back to the engine ECM J1 plug via the customer's machine harness.

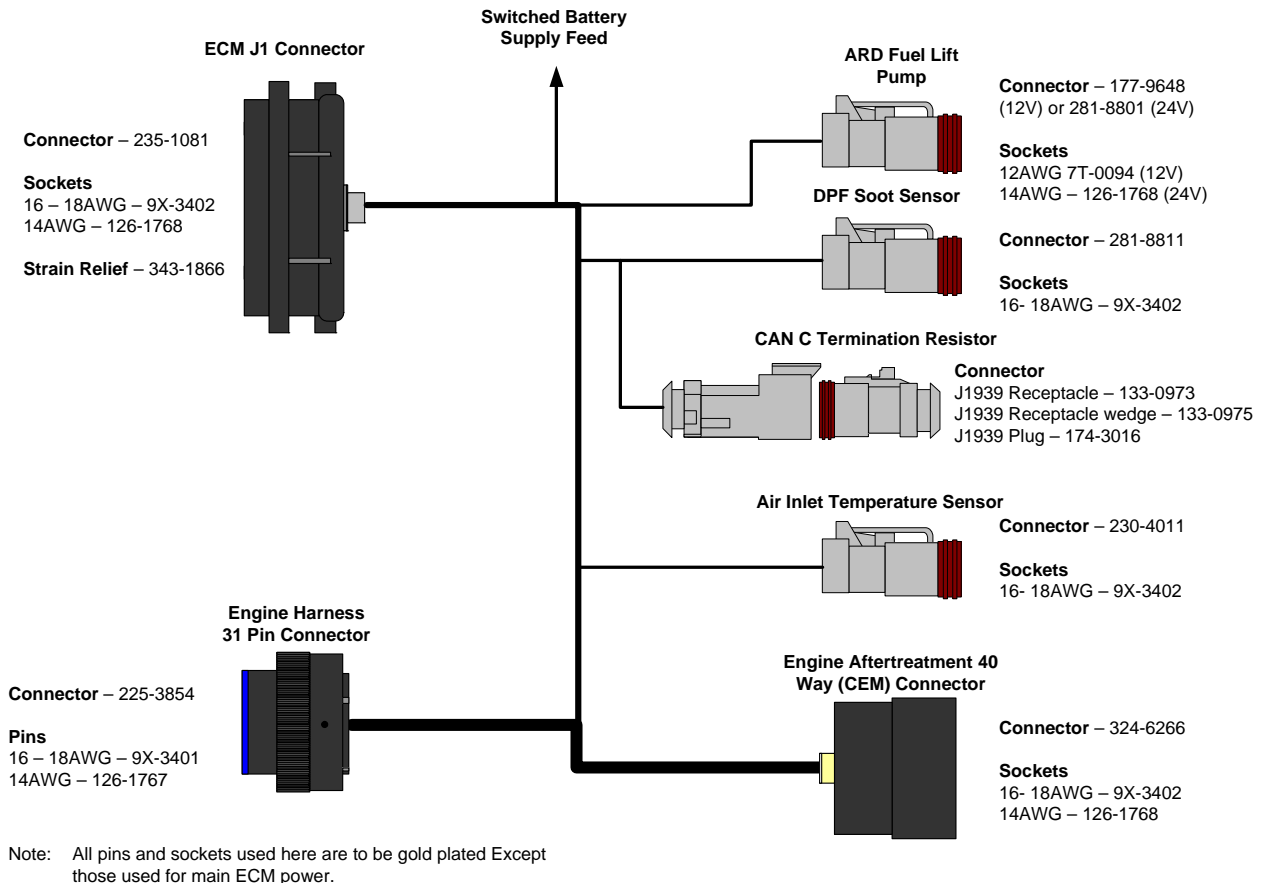


Figure 6.5 C7.1 Emissions Critical Layout Diagram

Specific Installation details for the customer fit components shown in figure 6.5 are shown in section 6.4 of this document. For mechanical installation instructions please refer to the mechanical A&I Guide.

31 Way Pin Assignment Table

PIN	31 Way Connector Assignment	WIRE GAUGE	TERMINAL	PART NUMBER
1	Sensor +5V supply	18	PIN	9X-3401
2	Sensor 0V return	18	PIN	9X-3401
3	ARD main fuel pressure sensor	18	PIN	9X-3401
4	DPF Intake Pressure Sensor	18	PIN	9X-3401
5	ARD combustion detection temperature sensor	18	PIN	9X-3401
6	DPF inlet temperature sensor	18	PIN	9X-3401
7	NOT USED			
8	ARD combustion air pressure sensor	18	PIN	9X-3401
9	ARD combustion air control valve	18	PIN	9X-3401
10	ARD hot nozzle	18	PIN	9X-3401
11	ARD combustion air control valve +	18	PIN	9X-3401
12	ARD combustion air control valve -	18	PIN	9X-3401
13	ARD spark plug ignition coil +	18	PIN	9X-3401
14	ARD spark plug ignition coil -	18	PIN	9X-3401
15	NOT USED	X	X	X
16	NOT USED	X	X	X
17	NOT USED	X	X	X
18	NOTUSED	X	X	X
19	Actuator return	18	PIN	9X-3401
20	ARD pilot fuel pressure sensor	18	PIN	9X-3401
21	ARD pilot fuel control valve +	18	PIN	9X-3401
22	ARD pilot fuel control valve -	18	PIN	9X-3401
23	DPF Soot sensor (J1939) +	18	PIN	9X-3401
24	DPF Soot sensor (J1939) -	18	PIN	9X-3401
25	NOT USED	X	X	X
26	ARD fuel lift pump	18	PIN	9X-3401
27	Aftertreatment ID digital signal	18	PIN	9X-3401
28	Aftertreatment ID digital return	18	PIN	9X-3401
29	NOT USED	X	X	X
30	NOT USED	X	X	X
31	NOT USED	X	X	X

Table 6.4 Engine Harness 31 Way Aftertreatment Connector Pin Allocation

40 Way CEM Side Pin Assignment Table

PIN	40 Way CEM Pin Assignment	WIRE GAUGE	TERMINAL	PART NUMBER
1	Sensor +5V supply	18	SOCKET	9X-3402
2	Sensor 0V return	18	SOCKET	9X-3402
3	ARD main fuel pressure sensor	18	SOCKET	9X-3402
4	DPF Intake Pressure Sensor	18	SOCKET	9X-3402
5	ARD combustion detection temperature sensor	18	SOCKET	9X-3402
6	DPF inlet temperature sensor	18	SOCKET	9X-3402
7	NOT USED	X	X	X
8	ARD combustion air pressure sensor	18	SOCKET	9X-3402
9	ARD combustion air control valve	18	SOCKET	9X-3402
10	ARD hot nozzle	18	SOCKET	9X-3402
11	ARD combustion air control valve +	18	SOCKET	9X-3402
12	ARD combustion air control valve -	18	SOCKET	9X-3402
13	ARD spark plug ignition coil +	18	SOCKET	9X-3402
14	ARD spark plug ignition coil -	18	SOCKET	9X-3402
15	ARD main fuel pressure control valve +	18	SOCKET	9X-3402
16	ARD main fuel pressure control valve -	18	SOCKET	9X-3402
17	NOT USED	X	X	X
18	Switched Battery +	16	SOCKET	9X-3402
19	Actuator return	16	SOCKET	9X-3402
20	ARD pilot fuel pressure sensor	18	SOCKET	9X-3402
21	ARD fuel pressure control valve +	18	SOCKET	9X-3402
22	ARD fuel pressure control valve -	18	SOCKET	9X-3402
23	NOT USED	X	X	X
24	NOT USED	X	X	X
25	CEM to Machine Chassis Return	14	SOCKET	126-1768
26	NOT USED	X	X	X
27	Aftertreatment ID digital signal	18	SOCKET	9X-3402
28	Aftertreatment ID digital return	18	SOCKET	9X-3402
29	NOT USED	X	X	X
30	NOT USED	X	X	X
31	NOT USED	X	X	X
32	NOT USED	X	X	X
33	NOT USED	X	X	X
34	NOT USED	X	X	X
35	NOT USED	X	X	X
36	NOT USED	X	X	X
37	NOT USED	X	X	X
38	NOT USED	X	X	X
39	NOT USED	X	X	X
40	NOT USED	X	X	X

Table 6.5 Aftertreatment CEM 40 Way Connector Pin Allocation

ECM J1 Connections

PIN	ECM J1 Pin Assignment	WIRE GAUGE	TERMINAL	PART NUMBER
11	ARD Fuel Pressure 2 Control Valve	18	SOCKET	9X-3402
59	ARD Fuel Pressure 2 Control Valve Return	18	SOCKET	9X-3402

Table 6.6 ECM 70 Way J1 Connector Pin Allocation

6.2.4 Aftertreatment Wiring Schematic

The wiring schematic shown below (Figure 6.6) details the mandatory wiring harness connections required to connect the aftertreatment ARD system to the Engine control architecture.

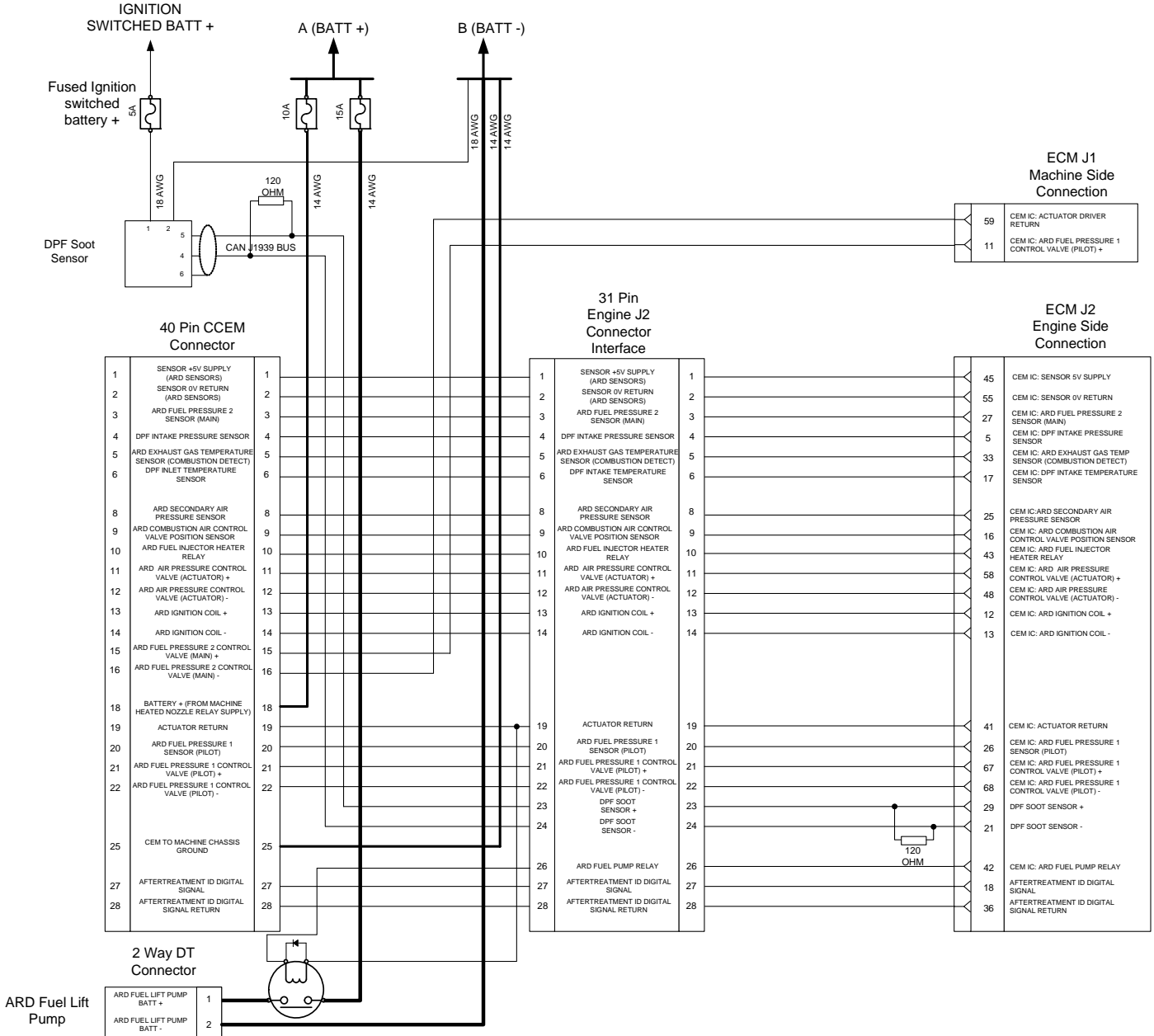


Figure 6.6 High Temperature Regeneration System Wiring Schematic

Note: All cables are 18AWG unless otherwise stated

Note: For more information on the mounting requirements for the DPF Soot sensor and the air inlet temperature sensor please refer to section 6.4.

6.4 Auxiliary Sensor Installation and Connection

This section provides details on the installation and wiring requirements for each of the mandatory fit aftertreatment system sensors. It should be noted that not all sensors are required for each engine family. For more information regarding the sensors required for each engine range and the customers specific installation responsibilities please refer to the relevant section of chapter 6.

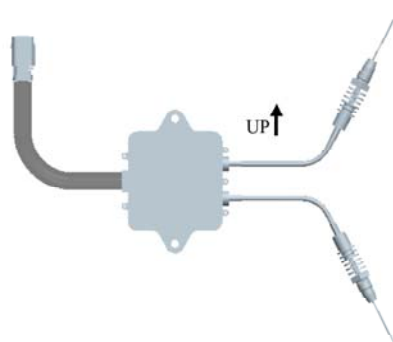
6.4.1 DPF Soot Sensor

6.4.1.1 DPF Soot Sensor Operation

The function of the DPF Soot sensor is to provide information for the determination of the amount of soot in a diesel particulate filter. Two antennas are installed in the diesel particulate filter, one upstream and one downstream of the filter section. The Soot sensor is connected to the antennas and the engine electronic control module (see wiring schematic for specific engine family for more details).

The Soot sensor cables are coaxial cables. The connection of these cables to the antennas is non-polarity specific and so can be connected to the antennas interchangeably. The order is insignificant to the sensor function.

The coaxial cables used to connect the antennas to the main body of the sensor are supplied attached to the sensor body and are available in two lengths 1.5m and 2.5m.



The Soot sensor is designed to operate with specific combinations of diesel particulate filters and engine software. The sensor is calibrated to each individual installation to ensure accuracy. The monitor outputs its measurement in SAE J1939 publicly approved messages over a Controller Area Network (CAN) bus.

6.4.1.2 DPF Soot Sensor Configuration

The soot sensor requires an initial calibration upon first operation of the engine and aftertreatment system, when installed into application. This clean calibration process is required to adjust the soot sensor calibration to allow for installation and manufacturing tolerances.

The clean calibration process must be completed within the first 25 hours of aftertreatment connection (this time is measured from the point at which the engine ECM first recognizes the aftertreatment system).

The operating conditions required for the clean calibration to take place are;

- DPF Inlet temperature must be between 0 and 100°C.
- Engine coolant must be below 90°C.
- The correct aftertreatment system must be fitted to the engine as verified by the aftertreatment ID module.
- There are no active soot sensor related faults.

Note: The engine ECM does not need to see engine speed for this calibration to take place. The complete engine and aftertreatment system must be electrically active meaning this calibration can be carried out within a customer's manufacturing facility.

Until the soot sensor clean calibration is complete the service tool will display the fault code 268-2 (CDL) or 630-2 (J1939). This fault code will activate the engine warning lamp and is cleared once the calibration has been completed.

If the calibration is not completed within the first 20 minutes of engine running there is a risk that the DPF has accumulated soot, and the clean calibration will be locked out. In the event of a clean calibration lock out the Caterpillar ET service tool must be used to run a DPF soot loading sensor calibration procedure which can be found at the following location.

- Service/Service Procedures/DPF Soot Loading Sensor Service Regeneration

6.4.1.3 DPF Soot Sensor Installation

The preferred mounting orientation for the electronic boxes is shown in the picture below. Having the cables and harness lead wires both exiting horizontally is the preferred method to avoid water collecting on the wire seals. Fasten the control box using washers and two M6 bolts to a tightening torque of 6 +/-1Nm.

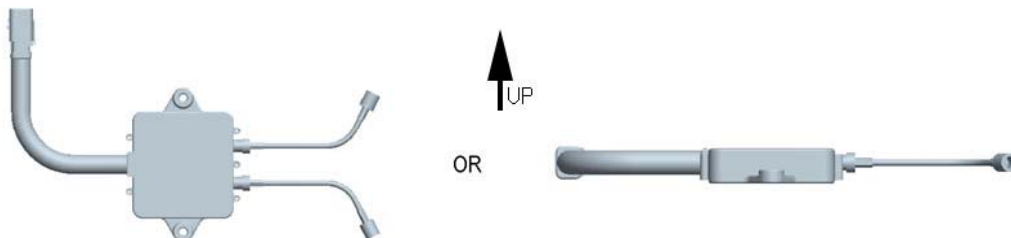


Figure 6.7 DPF Soot Sensor Orientations

The Electronic control box has a maximum ambient operating temperature of 85°C and a minimum of -40°C. It must be mounted in a location where it will not exceed this temperature. The antennas will be screwed into the DPF.

They have been designed with heat sinks to shed enough heat so they can withstand the 200°C skin temperature. The cables between the antennas are high temperature coaxial cable. They are capable of surviving temperatures up to 200°C.

The Soot sensor is designed to be mounted to a rigid member, such as a major frame member. It should not be mounted to less rigid members such as large sheet metal panels. Areas that are known to be especially hostile should be avoided. Maximum vibration limits for the DPF Soot sensor electronic box is 10Grms.

Coaxial cables should not have harsh bends or twists in them or it may damage the internal conductor or insulator. The minimum wire bend radius for this cable is 51mm. Any extra cable should be coiled, not bundled to conform to the 51mm minimum wire bend radius.

The Soot sensor must be fastened using M6 or 1/4" bolts and appropriate washers. The installation torque is 12 Nm +/- 3 Nm.

This sensor currently uses a 6-pin, key 3 receptacle. The part number for the mating connector is: 281-8811 as shown in Figure 6.8.

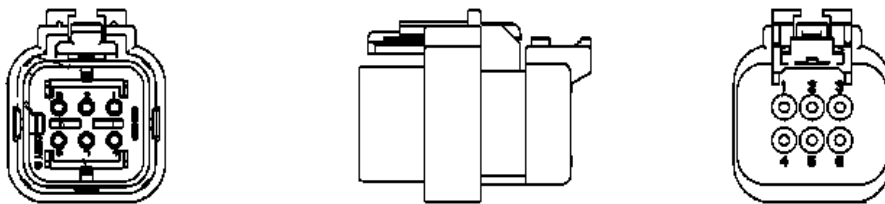


Figure 6.8 DPF Soot Sensor Interface Connector

Description	CAT Part Number
6 Way Amp Seal	281-8811
Sockets 18AWG	9X-3402

Connector Pin	Assignment
1	Vbat
2	Ground
3	Unused
4	CAN -
5	CAN +
6	CAN Shield (if supported)

Table 6.7 DPF Soot Sensor Pin Allocation and Connector Part Numbers

There are two different length antenna cables available for the sensor, to accommodate various mounting locations on machine. Please note however that where possible the shortest length cable (1.5m) should be used. The part numbers for each of the antenna cables are shown below;

- 340-0623: 1.5 meter antenna cables
- 340-0624: 2.5 meter antenna cables

To ensure the correct routing and support the following P-clip should be used, 349-0951 (fig 6.9). These P-clips have been designed specifically to support the DPF Soot sensor antenna cables and to withstand the high temperatures possible around the engine exhaust and aftertreatment equipment.

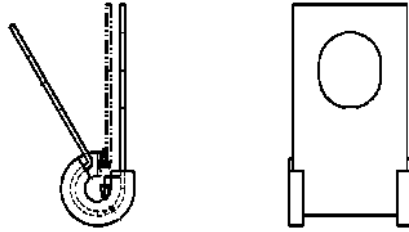


Figure 6.9 P-Clip

The wiring schematics for the DPF Soot sensor are shown in figure 6.10

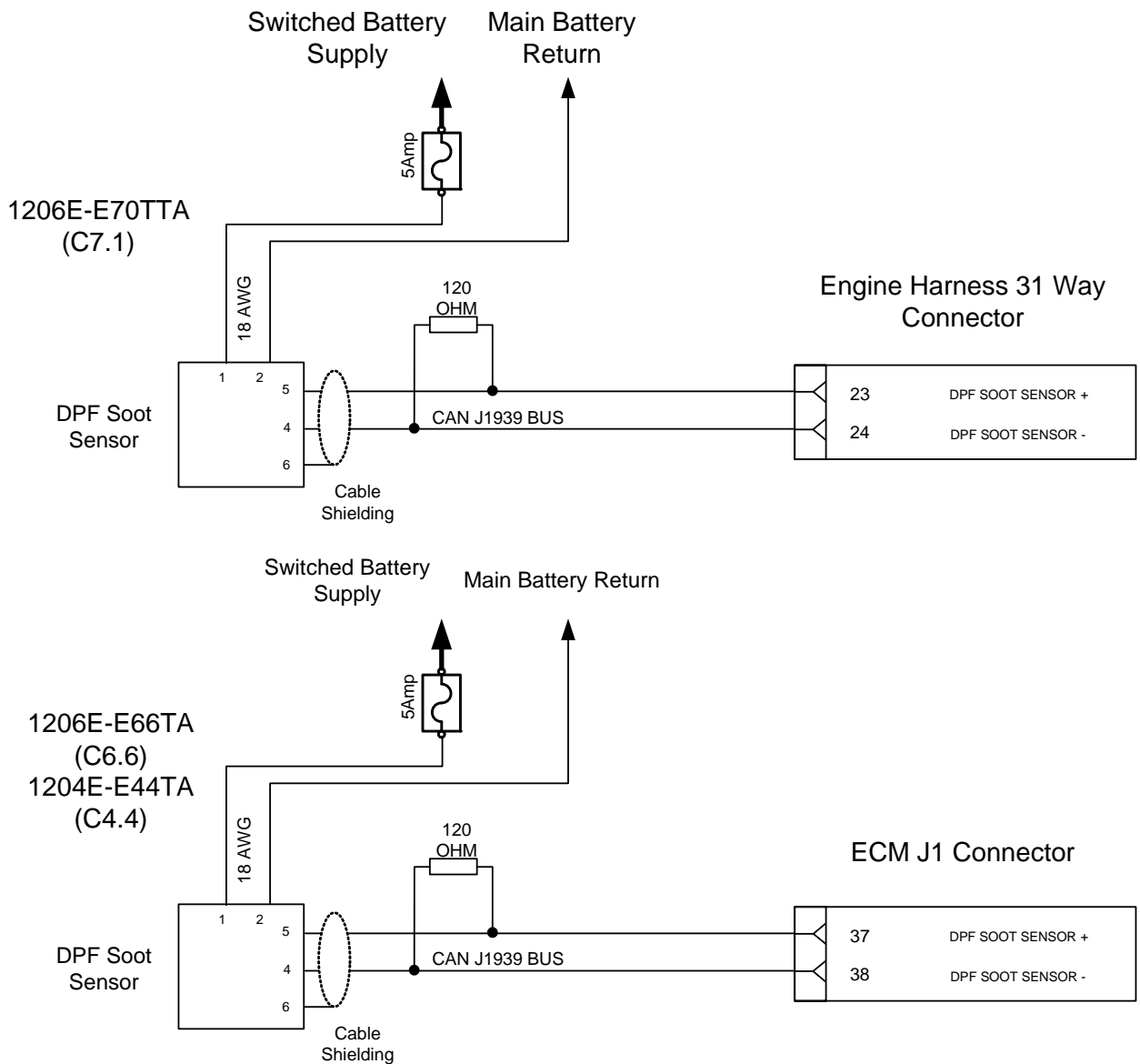


Figure 6.10 Aftertreatment DPF Soot Sensor Wiring Schematic For Each Engine Family

6.4.2 Air Inlet Temperature Sensor

6.4.2.1 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 such as engine cold starting. 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 125°C, as temperatures above the limit will exceed the temperature rating of the sensor connector.

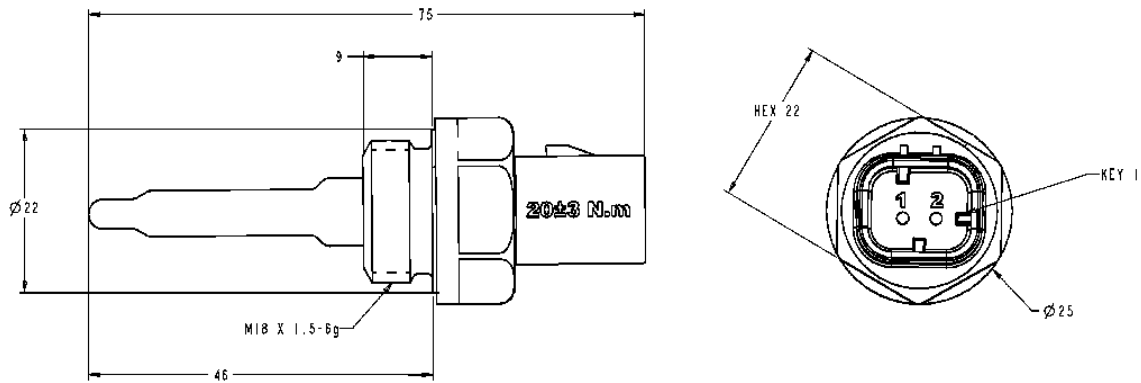


Figure 6.11 Air Inlet Temperature Sensor

6.4.2.2 Air Inlet Temperature Sensor Configuration

No ET configuration is required for this component as it is always enabled. Failure to install the sensor will result in an engine fault code being generated and a monitoring system action will be evoked such as engine derating (TBD)

6.4.2.3 Air Inlet Temperature Sensor Installation

The air inlet temperature sensor should be installed within the outlet pipe from the application air filter. The sensor must be mounted as close to the air cleaner outlet as possible to ensure that a valid ambient air temperature reading is taken. There are two sensor part numbers available, with the only difference being the external thread. Both sensor part numbers are shown in table 6.8.

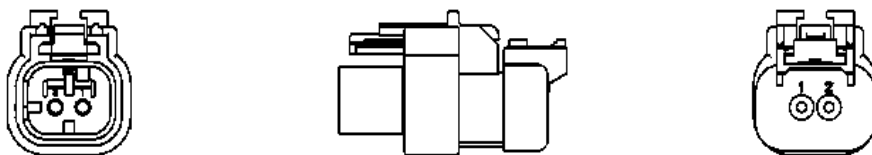


Figure 6.12 Air Inlet Temperature Sensor Mating Connector

Description	CAT Part Number
Sensor metric	256-6454
Sensor Imperial	256-6453
Sensor O-ring	228-7103
2 Way Amp Seal	230-4011
Sockets 18AWG	9X-3402

Table 6.8 Air Inlet Temperature Mating Connector Part Number

Please note that this sensor will form part of the standard customer J1 machine harness.

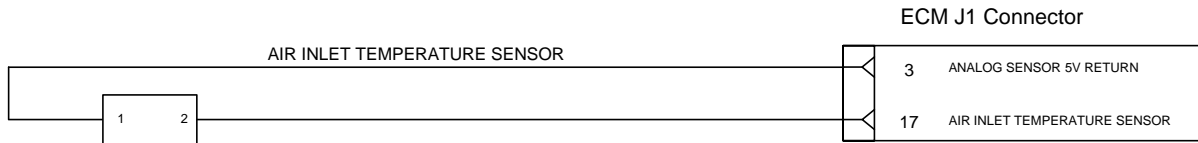


Figure 6.13 Air Inlet Temperature Installation Wiring

The sensor requires a M18 x 1.5 (metric) or 3/4 -16 (Imperial) thread and should be installed after the air cleaner with a tightening torque of 20+/-3Nm. It should be noted that the sensor is supplied without an O-ring. An O-ring must be used and the material should be selected to suit the application environment. An example CAT part number is shown in table 6.8.

6.4.3 DPF Inlet Temperature Sensor

6.4.3.1 DPF Inlet Temperature Sensor Operation

The Diesel Particulate Filter Intake Temperature Sensor measures exhaust temperature, entering the Particulate Trap. This measurement is used to help to determine the exhaust air inlet temperature to the DPF and where necessary feed this signal back into the control algorithm for the engine Aftertreatment system. The backpressure valve will when required elevate and regulate the exhaust gas temperature to enable DPF regeneration. This sensor is used to help control emissions. The component part number used for the Low temperature regeneration system is 341-4827.

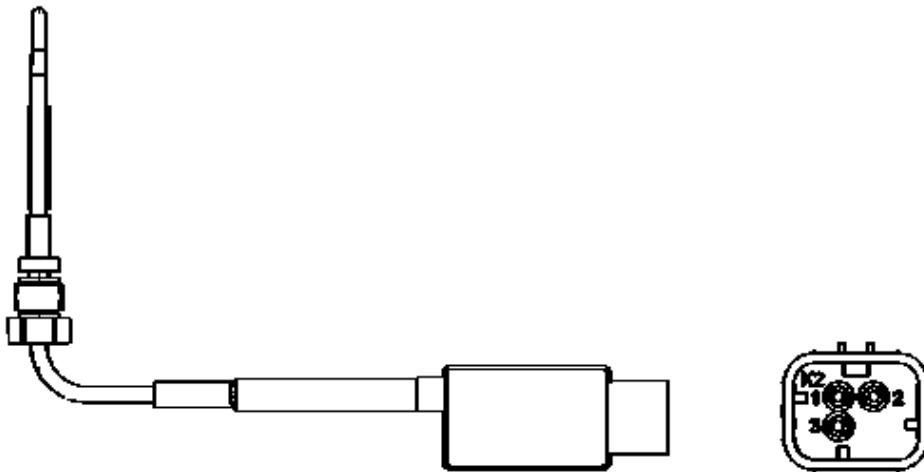


Figure 6.14 DPF Inlet Temperature

6.4.3.2 DPF Inlet Temperature Sensor Configuration

NO ET or EST configuration is required for this component. The DPF inlet temperature sensor is a mandatory fit item for all C4.4 and C6.6 engine families.

6.4.3.3 DPF Inlet Temperature Sensor Installation

The DPF inlet temperature sensor is delivered pre-fitted to the inlet of the DPF and the sensor connector mounted to a mounting plate, which is attached to the DPF. The sensor connector is capable of withstanding temperatures up to 125°C and must not be removed from the mounting plate provided.

It is the customer's responsibility to connect the DPF inlet temperature sensor back to the ECM J1 connector and a wiring schematic for the inlet sensor is shown below figure 6.15. For a full low temperature regeneration system schematic please refer to section 6.1.4.

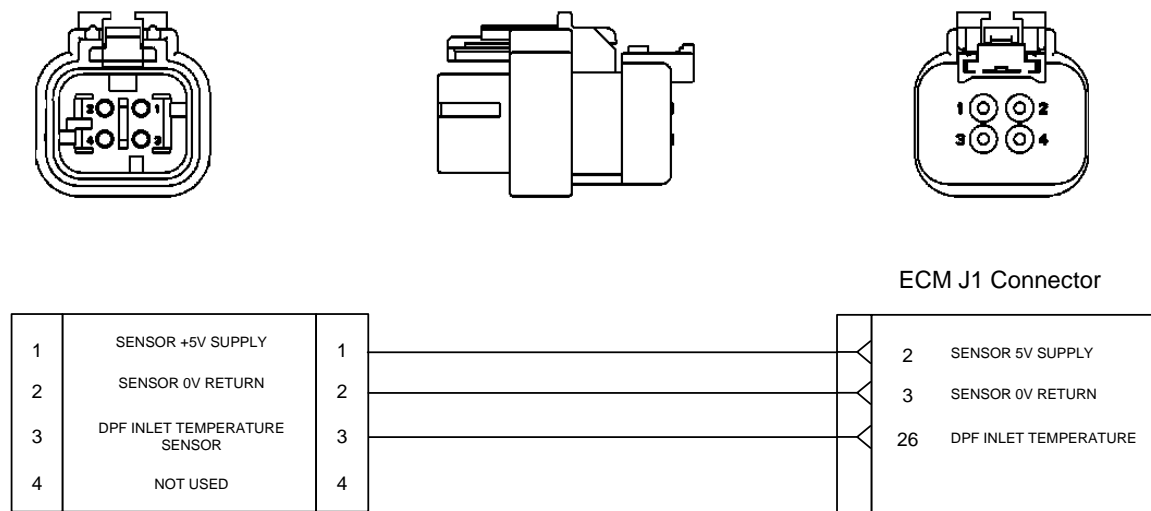


Figure 6.15 DPF Inlet Temperature Sensor Mating Interface

The DPF inlet temperature sensor is fitted with a 4 way connector. The mating connector part number is shown in table 6.9 and 18AWG cable should be used.

Description	CAT Part Number
4 Way Amp Seal)	239-7349
Sockets 18AWG	9X-3402

Table 6.9 DPF Inlet temperature Interface Part Numbers

Note: If the cable routing passes through any area of the installation with a surface or ambient temperature exceeding that of the standard GXL cable insulation limits (Cross linked polyethylene, -50 – 120°C) then high temperature cabling must be used. In this instance there maybe a requirement for a reduced diameter seal connector to maintain the mating connectors sealing capabilities. Please consult you Applications Engineer for more information.

6.4.4 DPF Identification Module

6.4.4.1 DPF Identification Module Operation

The DPF identification module is supplied fitted to all engines requiring a diesel particulate filter. The module is used on engine start-up to verify that the aftertreatment serial number corresponds to that stored within the engine ECM. The ECM carries out the serial number verification for the first 25 hours of engine operation only. If the engine ECM detects that the wrong aftertreatment has been fitted to the engine then a fault code indicating the mismatch is raised and the engine derates by 100%.

6.4.4.2 DPF Identification Module Configuration

No DPF identification module configuration is required all data contained within the ID module is pre programmed prior to delivery of aftertreatment hardware.

6.4.4.3 DPF Identification Module Installation

The module is supplied attached to a sensor mounting plate, which forms part of the overall aftertreatment system. No ID module installation is required by the OEM. The OEM is responsible however for connecting the DPF ID module to the engine ECM J1 connector as part of the machine wiring harness. Connection to the Aftertreatment ID module is made via a 6 way plug as shown in figure 6.18 (for the C4.4 and C6.6 engines only) and connector part number in table 6.10. Figure 6.16 also shows the wiring schematic for connection of the module back to the engine ECM.

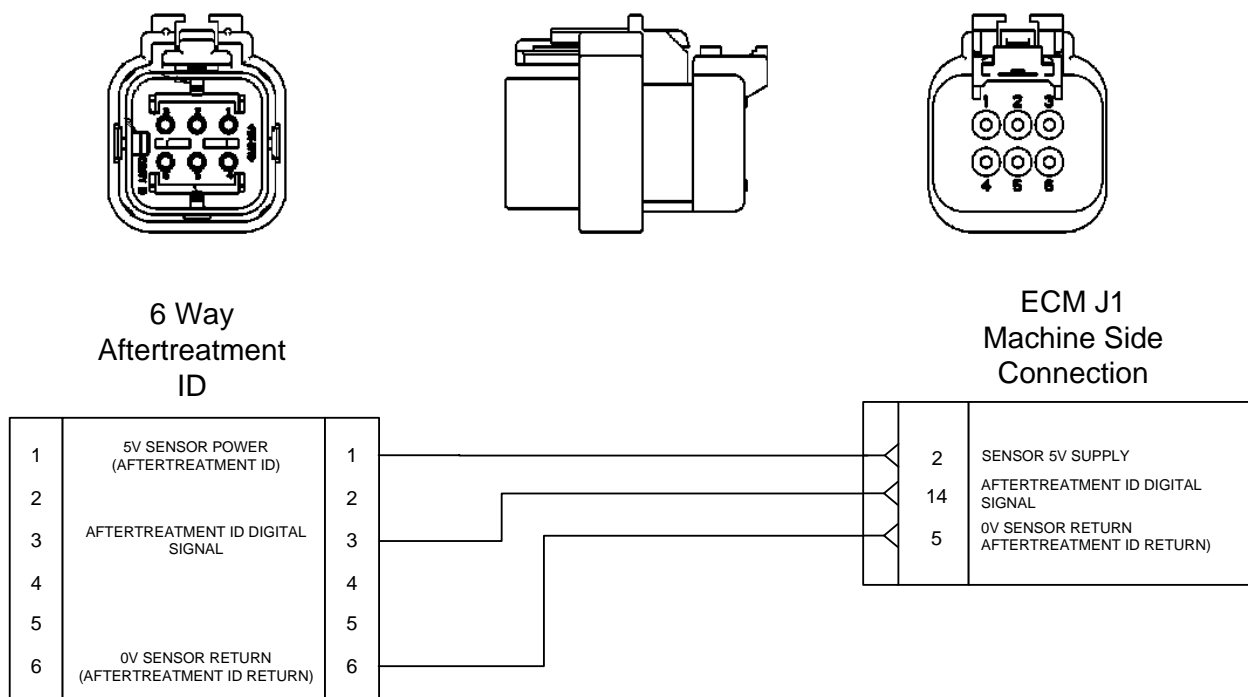


Figure 6.16 DPF Identification Module Mating Interface

Description	CAT Part Number
6 Way Amp Seal	281-8811
Sockets 18/16 AWG	9X-3402

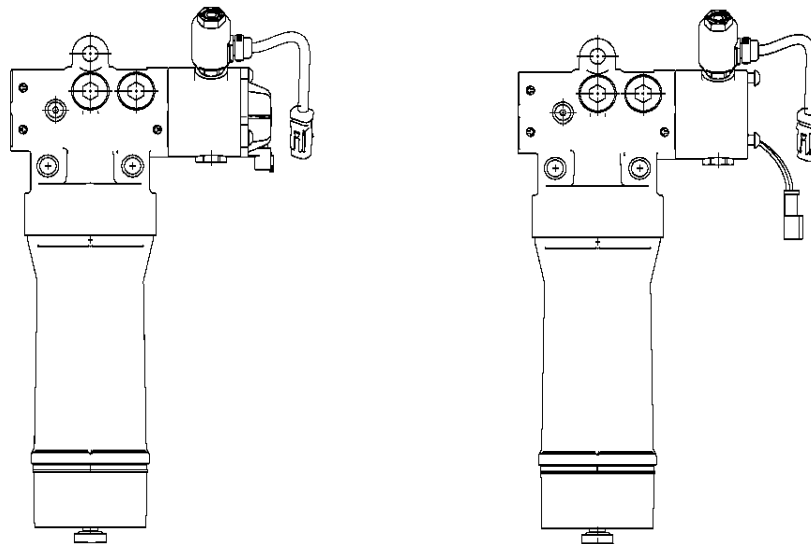
Table 6.10 DPF Identification Interface Part Numbers

6.4.5 ARD Fuel Pump

6.4.5.1 ARD Fuel Pump Operation

The Auxiliary Regeneration Device requires it's own fuel pump to supply pressurized fuel for the high temperature regeneration process to take place. The fuel pump is not supplied connected to the CEM and must be mounted remotely on the application by the customer. For more information regarding the mounting requirements for the pump please consult section 8 (Fuel System) of the mechanical A&I Guide.

There are two fuel pumps available, one for 12V applications and the other for 24V systems. Both pumps are shown below in figure 6.17, which also indicates the two different connectors used for on each pump.



24V Fuel Pump with 2 pin Connector

12V Fuel Pump with 2 pin Connector

Figure 6.17 ARD Fuel Lift Pump

The electrical fuel lift pumps both require an unswitched fused battery supply connection. Both the 12 and 24V pump options electrical characteristics are shown in table 6.11.

Electrical requirements

Power requirements	12V	24V	Units
Voltage	12 +/-2	24 +/-5	Volts DC
Minimum Voltage	9VDC	16VDC	Volts DC
Maximum Voltage	18VDC	32VDC	Volts DC
2-pin Control Signal	12 +/-2	24 +/-5	Volts DC
Fuse Rating	20	15	Amps
Max Current	24	12	Amps
Cable Size	12	14	AWG

Table 6.11 ARD Fuel Lift Pump Electrical Requirements

6.4.5.2 ARD Fuel Pump Configuration

No ET configuration is required for this component. The ARD fuel pump is a mandatory fit item for all C7.1 engines.

6.4.5.3 ARD Fuel Pump Installation

Both the 12 and 24V fuel pumps provide a 2 pin connection for battery power supply. The 24V option is fitted with a 2 pin Amp Seal connector and the 12V option is supplied with a 2 pin Deutsch connector. A diagram of the two mating connectors is shown in figure 6.18 and the part numbers for use in table 6.12.

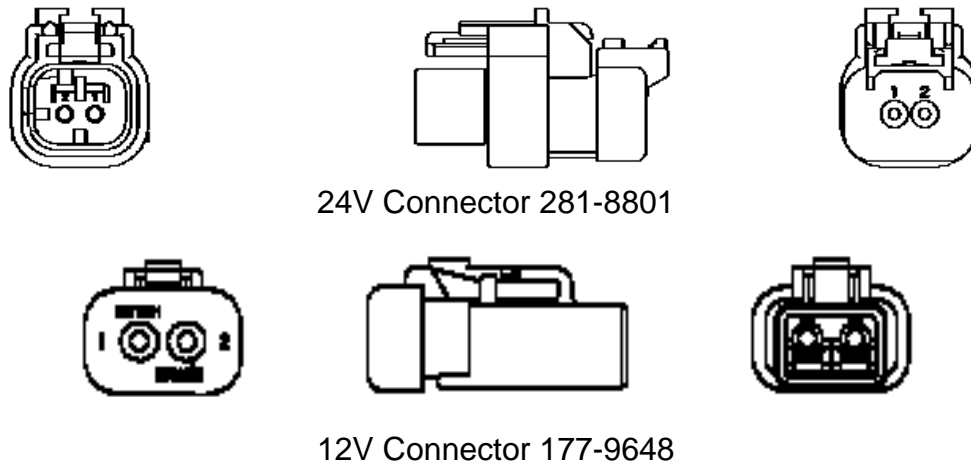


Figure 6.18 ARD Fuel Lift Pump Mating Connector

Description	CAT Part Number
12V Pump	345-8045
2 Way Deutsch Plug	177-9646
Wedge Lock	177-9647
Kit (connector & Lock)	177-9648
Sockets 12AWG	7T-0094
24V Pump	345-8046
2 Way Amp Seal Plug Key 4	281-8801
Sockets 14AWG	126-1768

Table 6.12 ARD Fuel Lift Pump Part Numbers

To operate the ARD fuel lift pump a relay is also required. The part numbers for the relay, base plate and terminals is shown in table 6.12. If a non CAT supplied relay is to be used care must be taken to ensure that both the coil and the contacts are specified to cope with the electrical requirements detailed in table 6.11.

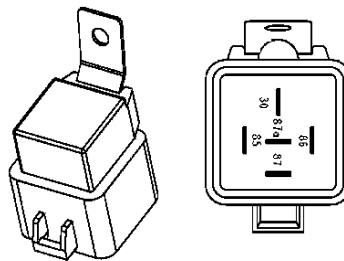


Figure 6.19 Fuel Pump Control Relay

The Relay is specified to withstand temperatures of between -40°C and $+85^{\circ}\text{C}$ and so must be mounted in a location where this temperature will not be exceeded.

The relay can withstand vibration levels upto 4.5Grms and must not be mounted to the engine.

When fully assembled the relay has an IP rating of IP67. However it is good practice to ensure that the relay is mounted in a position, which is not exposed to harsh abrasives or fluids. To ensure that fluids do not collect around the base of the relay and the relay contacts, which cause corrosion, the unit must be mounted so that the terminals are facing downwards.

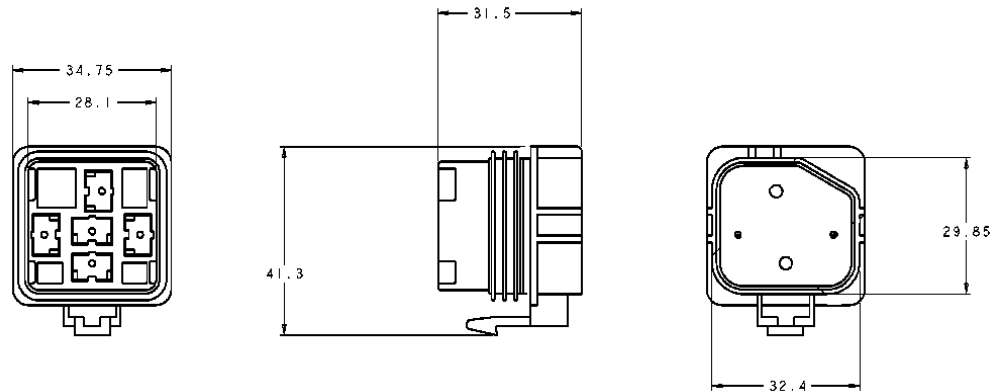


Figure 6.20 ARD Fuel Pump Control Relay Connector

Description	CAT Part Number
12V Relay	115-1615
24V Relay	3E-5239
Plug Connector	9X-1054
12AWG Terminal	9X-1055
14 – 16AWG Terminal	9X-1056
Crimp Tool	TBD

Table 6.13 ARD Fuel Lift Pump Relay and Connection Part Numbers

When installing the ARD fuel pump and relay the following relay contacts must be used along with the corresponding Terminal as shown below;

- T30 – Main Battery Supply Feed (Terminal 9x-1055)
- T87 – Main Battery Feed to ARD Pump via N/O Contact (Terminal 9X-1055)
- T85 – Relay Coil Control (Terminal 9X-1056)
- T86 – Relay Coil Control (Terminal 9X-1056)

The wiring schematics for each of the two fuel pump voltage options are shown in figure 6.20.

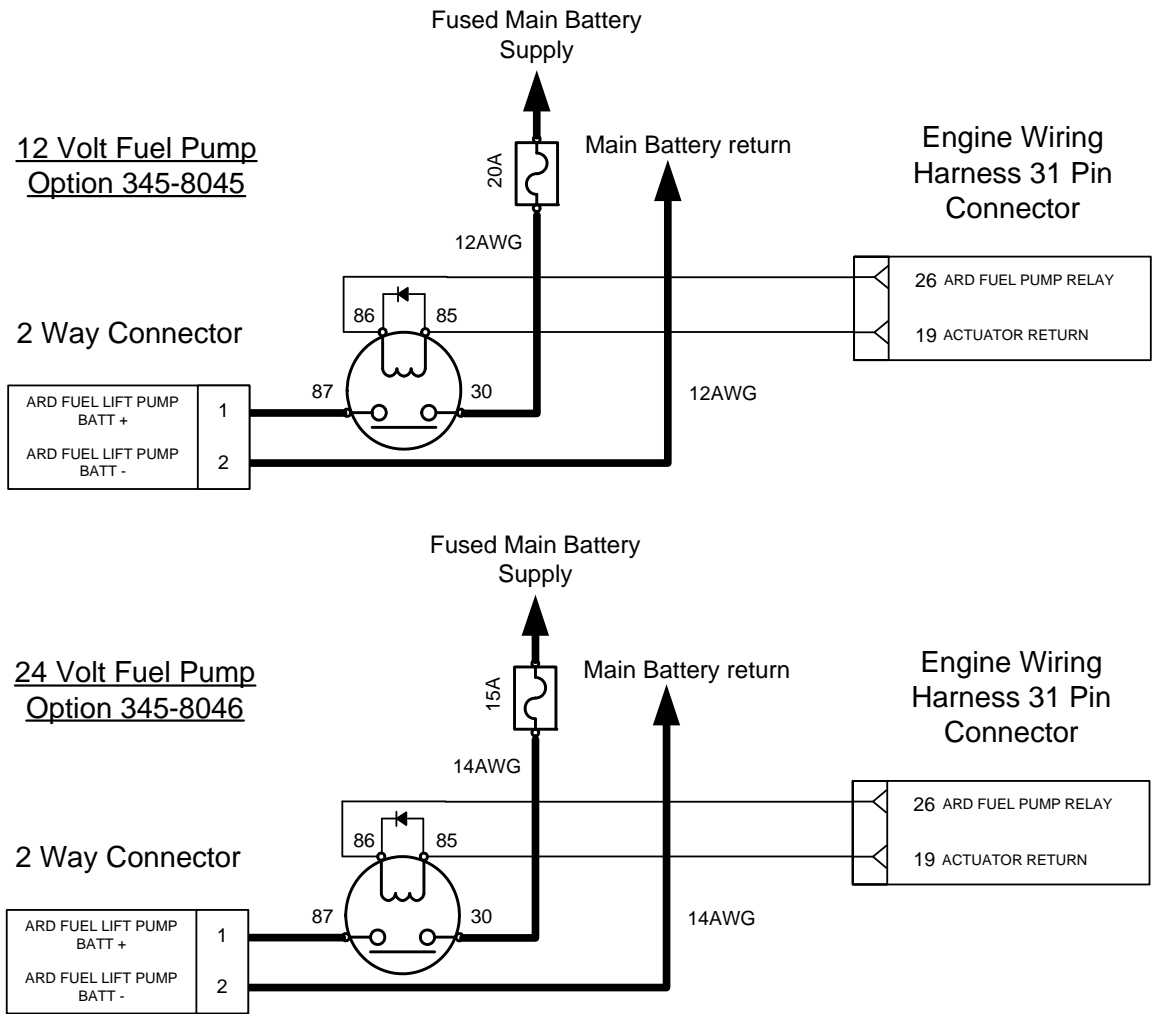


Figure 6.20 ARD Fuel Pump Wiring Schematics

7.0 Starting and Stopping the Engine

7.1 Starting the Engine

Unlike mechanically controlled fuel systems no customer connection to the fuel pump solenoid is necessary. To activate the engine ECM unswitched battery voltage needs to be constantly supplied to pins 48, 52, 53, 55, 56 (Batt +) and 61, 63, 65, 67, 69 (Batt -), as well as constant switched battery voltage applied to pin 70. When the ECM 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 ECM has determined engine cranking speed and engine position, fuel pressure and delivery will be controlled.

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 keyswitch input and the starter motor circuit. Some application may require a 4-position switch to run auxiliary equipment when the engine is not running.

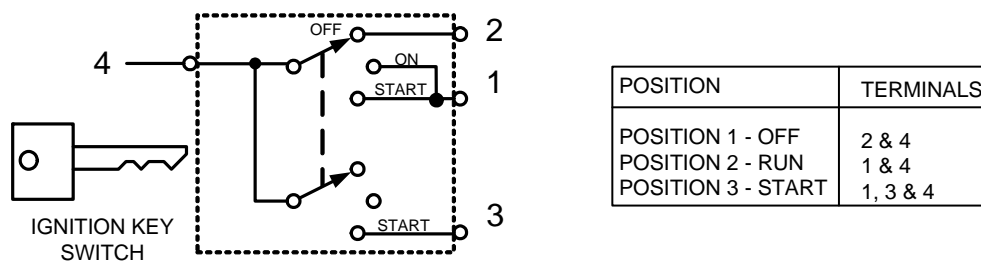


Figure 7.1 typical Ignition Key Switch Contact Configuration

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

The ECM 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.

7.2 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 Keyswitch
- Battery Isolation Switch
- Remote Stop Button
- Datalink stop
- Engine Air Shutoff

Each of these devices is described below to assist the OEM in selecting the method that is most suitable for his machine and his market. It remains, however, the responsibility of the OEM to ensure compliance of the machine with legislation in 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: Cutting all electrical power from the engine whilst it is running will result in an uncontrolled shutdown of the high pressure fuel system. Uncontrolled fuel system shutdowns are likely to compromise the reliability of the high pressure fuel pump. Therefore the methods detailed below are the only recommended ways of stopping the engine.

It should be noted that under certain circumstances the engine ECM 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 ECM supply power (unswitched battery) must not be removed during normal engine stopping. Removing the ECM 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 ECM is operated for long periods without performing these calibrations, engine performance may be affected and a diagnostic will be raised. During this period the engine ECM 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.

7.2.1 Ignition Keyswitch

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 Keyswitch. When the keyswitch is turned to the off position or when the key is removed, power **must** be removed from the ignition keyswitch pin (pin 70) of the ECM J1 connector.

Additional switching devices may also be placed in series with the ignition keyswitch input to provide a remote stop feature. Its recommended that the

switch is a latched type, as closing the switch while the engine is running down will result in a restart.

7.2.2 Battery Isolation Switches

Battery Isolation switches are usually fitted in 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 isolation switch is as follows:

- Prevent battery discharge during vehicle shipping or storage
- Protect service technicians from danger caused by inadvertent engine crank or start .To offer good protection of service personnel is it 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 ECM may continue to operate with power generated by the alternator.

It is also possible that opening the battery isolation 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

Battery isolation switches are normally fitted in the negative path, close to the battery.

7.2.3 User Defined Shutdown Switch (Remote Shutdown)

7.2.3.1 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 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 (or if a button is stopped for longer than 150msec), then the engine will stop. The ECM 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.

The red “mushroom” emergency stop buttons must not be used for remote stop functions as they may be mistaken for emergency stop buttons as described above.

7.2.3.2 User Defined Shutdown Switch Configuration

The user defined shutdown feature must be enabled within the engine ECM using the service tool. The feature can be enabled at the following file location within the service tool.

Note: The user defined shutdown feature shares ECM I/O with the PTO speed select function. Only one of these features can be activated on a particular engine. If the user defined shutdown feature is required then the PTO mode speed select feature must be disabled.

7.2.3.3 User Defined Shutdown Switch Installation

A single switch to ground input on pin 44 of the ECM J1 Connector (Several stop buttons can therefore be connected in parallel).

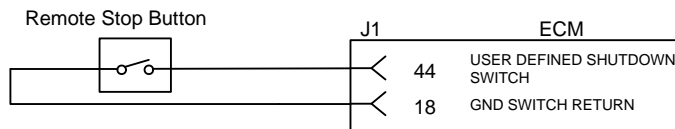


Figure 7.2 Remote Stop Feature Installation wiring

7.2.4 Intake Air Shutoff Valve

7.2.4.1 Intake Air Shutoff Valve Operation

There are industries where flammable gases could be inhaled by the engine, potentially resulting in engine speed runaway. The engine software shall monitor engine speed. If a predefined engine speed is exceeded the engine software shall invoke the shutoff process, this involves disabling fuelling and closing an intake shutoff valve (valve installed by the customer). This feature will aid stopping the engine in a runaway condition.

Some regulatory requirements in Mining and Petrochemical industries stipulate the use of an engine intake shutoff. This feature allows the user to control an air shutoff system, by monitoring engine speed and activating the air shutoff valve output driver when required.

Once installed using the service tool the engine software monitors the measured engine speed and compares it to a maximum engine speed limit, which must also be configured using the service tool. When the engine exceeds the configured engine overspeed shutdown value, the fuel injection is disabled and the air shutoff valve activated. Once the shutoff valve is activated the key switch must be cycled to de-activate the solenoid control.

7.2.4.2 Intake Air Shutoff Valve Configuration

One parameter must be configured using the service tool prior to using the intake air shutoff solenoid. Within the 'configuration screen', air shutoff defaults to "disabled" and must be set to "enabled".

Once installed the engine monitoring system parameter for engine overspeed maybe changed to establish the level of protection necessary for the specific installation. Please refer to section 12 for more information regarding the configuration of the engine overspeed limit.

7.2.4.3 Intake Air Shutoff Valve Installation

The intake air shutoff valve is controlled by the engine ECM using an electrical solenoid. The solenoid requires electrical connection to the engine ECM as shown in figure 7.3.

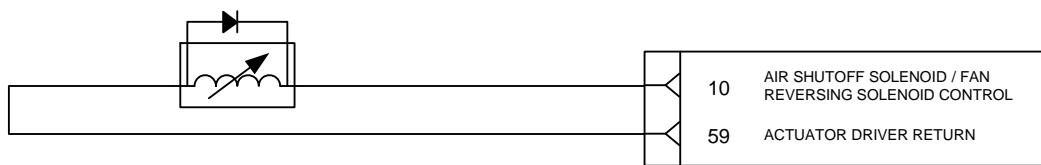


Figure 7.3 Intake Air Shutoff Valve Installation Wiring

7.2.5 Overspeed Verify Switch

The overspeed verify switch compliments the Air Intake Shutoff feature. The overspeed verify switch allows the user to verify that the shutoff feature is operating correctly without exceeding or reaching the engine overspeed speed limit. The switch input allows the user to test the air intake shutoff feature at 75 percent of the engine speed limit. The switch is a normally open switch. When the switch is closed and the actual engine speed is equal to or exceeds 75 percent, of the pre-programmed limit, the air intake shutoff feature is activated. Figure 7.4 shows the Wiring required for this feature to be activated.

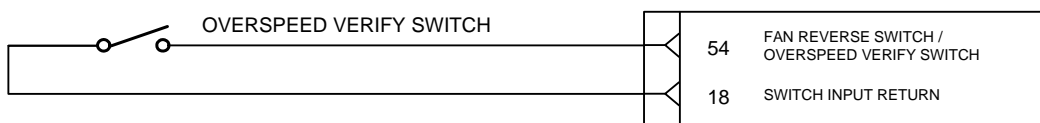


Figure 7.4 Overspeed Verify Switch Installation Wiring

7.2.6 Datalink stops

As with the remote stop button, described above, the datalink stop is not fail safe 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. 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.

7.2.7 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 gradeability (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 ECM and ignition, but is released while the engine is still turning, it is possible for the engine to continue to run.

8.0 Machine Fan Control

Include details here of all the components required to be installed by the customer such as the ATAAC outlet temperature sensor and the control valve solenoid. These components apply to all fan strategies.

8.1 Hydraulic Fan Control

Include here any specific requirements for the fan valve with regards to operating range and current requirements, including resolution. List any approved valves if we have any.

8.1.1 Hydraulic Fan Operation

Need to include here a system diagram including all possible feature inputs and the resulting output.

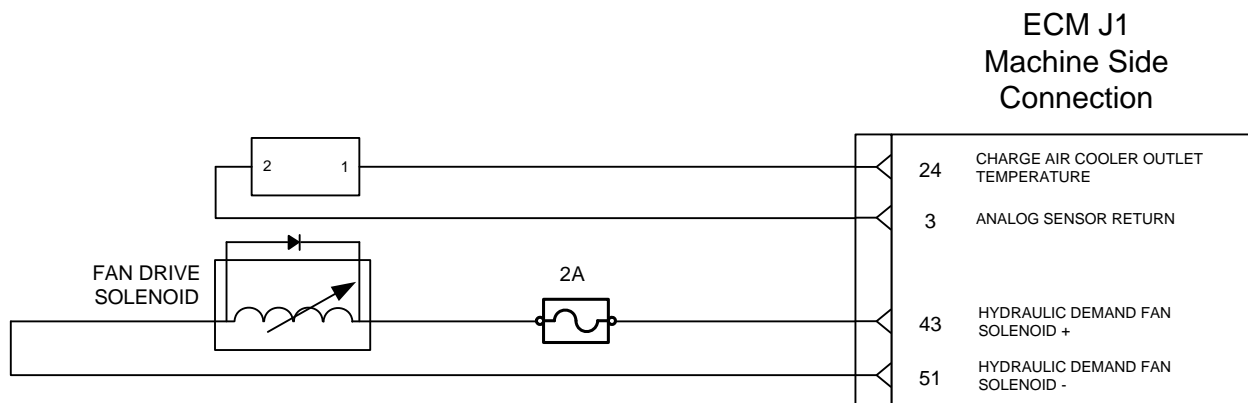
This section should also provide details of the configurable parameters that are available within the service tool and their function.

8.1.2 Hydraulic Fan Configuration

Provide details here of all of the configurable parameters which need to be adjusted using the service tool.

8.1.3 Hydraulic Fan Installation

Include detail of all the basic installation requirements but also refer to the fact that the standard set-up will not suit everyone and a certain level of system calibration is going to be required.



8.2 Viscous Fan Control

Feature not yet defined. Placeholder only.

8.2.1 Viscous Fan Operation

8.2.2 Viscous Fan Configuration

8.2.3 Viscous Fan Installation

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 ECM. There are five types of speed demand input:

- Pulse Width Modulation (PWM) Sensor
- Analogue Sensor
- Throttle lock (PTO mode) - also known as “engine speed cruise control” or “set speed control”.
- Multi Position Throttle Switches (MPTS)
- Torque Speed Control - TSC1 (Speed control over CAN J1939)

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/PWM 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.

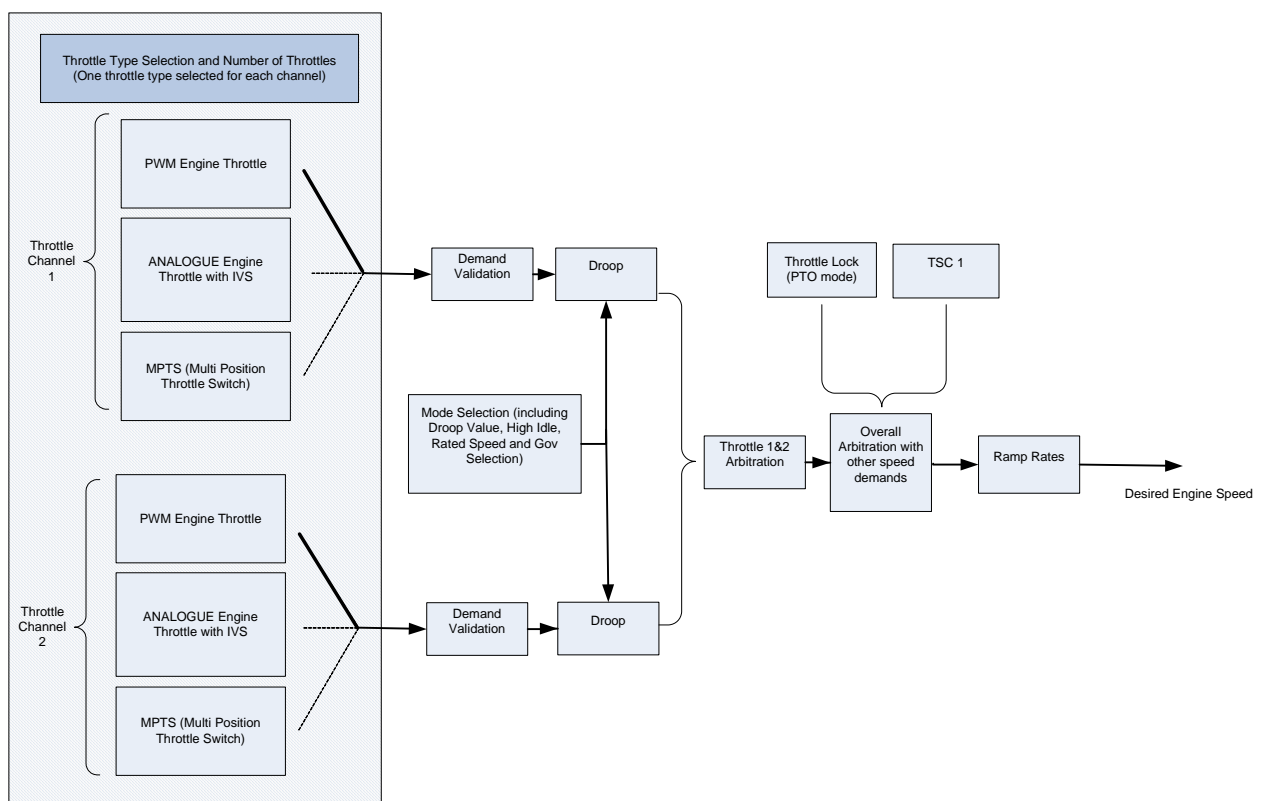


Figure 9.1 Engine Speed Demand Software Control

9.1 Analogue Sensor

9.1.1 Analogue 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 0.5 to 4.5 volts, when connected to the engine ECM. The ECM provides a regulated 5V 200mA power supply.

The Analog sensor should use non-contact Hall effect technology. Robust potentiometer contact sensors designed for use in vehicles may be considered **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 kickdown switches are not monitored by the engine ECM.

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 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.

9.1.2 Analogue Sensor Configuration

Before an analogue throttle can be used the configurable parameters must be programmed into the ECM via the service tool. These parameters are selectable in the main throttle configuration screen. For more details on the parameters and their use please refer to section 8.8 of this guide.

9.1.3 Analogue Sensor Installation

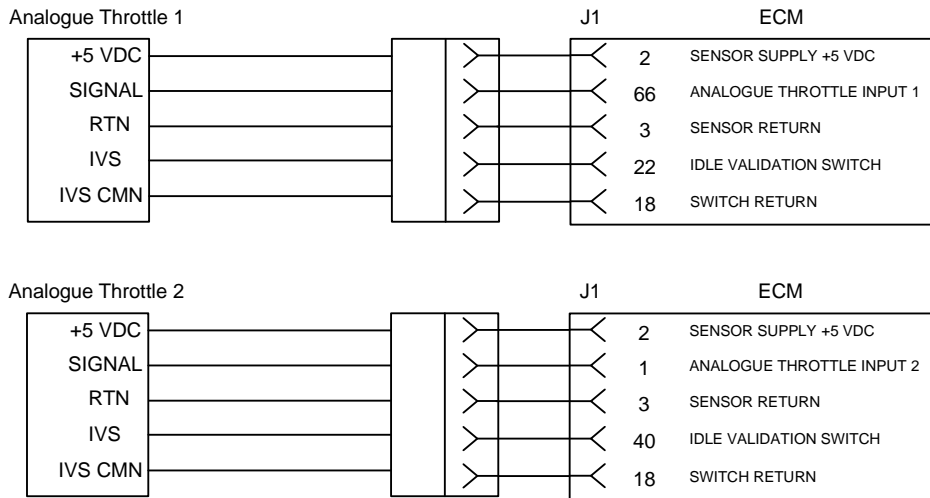


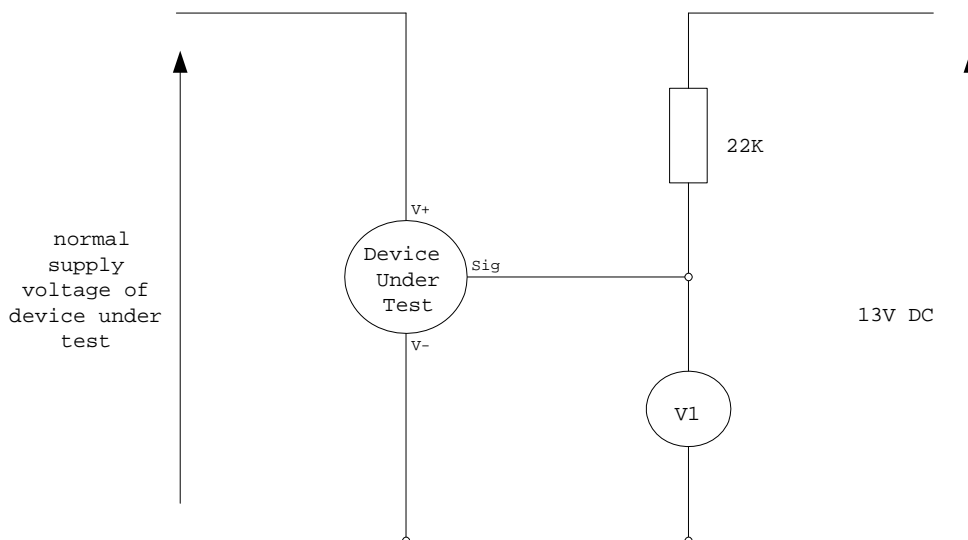
Figure 9.2 Analogue Throttle Sensor wiring Diagram

9.1.4 Evaluating Component Compatibility (Testing)

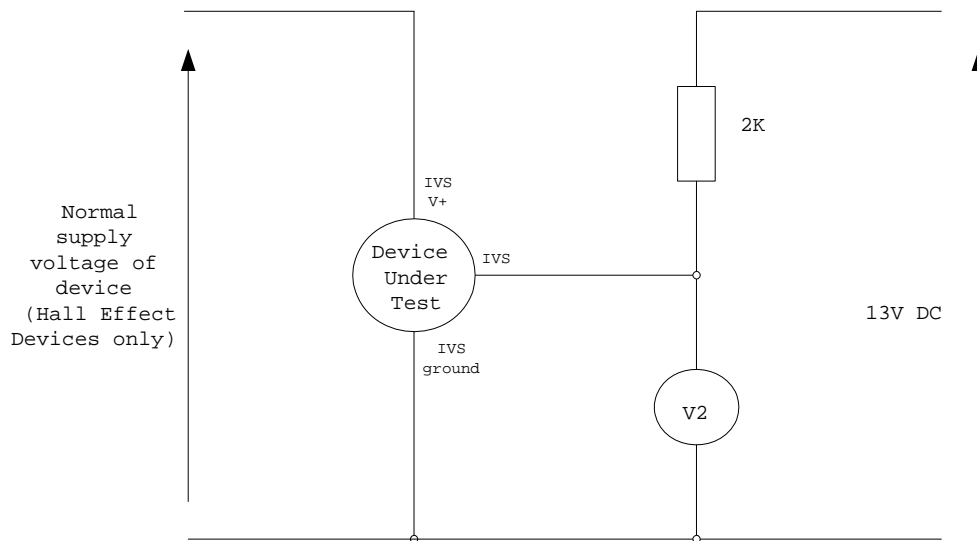
The following procedure should be used to evaluate whether an Analogue throttle is compatible with the engine ECM. This may be used either by the OEM in selecting components or by the manufacturer of devices which are to be connected to the engine.

The following test circuits must be used when evaluating Analogue throttle devices.

Analogue Input Test circuit



Idle Validation Switch Test Circuit



9.1.4.1 Test Procedure

Test 1: Output at Min position

Place the Device Under Test (DUT) in its minimum or “released” condition. Measure the voltage V1.

Test 2: Output at Min position: forced

Without causing damage, pull the pedal/ handle hard against the minimum travel end stop. Measure the voltage V1.

Test 3: Output at Max position

Place the DUT in its maximum or “fully depressed” condition. Measure the voltage V1.

Test 4: Output at Max position: forced

Without causing damage push the pedal/ handle hard against the maximum travel end stop. Measure the voltage V1.

Test 5: IVS switch Closed Voltage

Place the DUT in its minimum or “released” condition. Measure the voltage V2.

Test 6: IVS switch Opening Threshold

Place the DUT in its minimum or “released” condition.

Test 7: IVS switch Open Voltage

Place the DUT in its maximum or “fully depressed” condition. Measure the voltage V2.

Test 8: IVS switch Closing Threshold

Place the DUT in its minimum or “released” condition.

Test 9: track resistance (potentiometer type sensors only)

If the DUT is a potentiometer type device, disconnect it from the test circuit and measure the resistance across the track (from V+ to V-).

9.1.4.2 Required Values

If the results obtained from the tests above are in the ranges specified below, then the device will be compatible with the default values in the ECM.

Test	Parameter	Units	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	-
4	Output at Max position: forced	Volts	-	4	4.5
5	IVS switch Closed Voltage	Volts	0	0.5	1.2
6	IVS switch Opening Threshold	Volts	1.08	1.15	1.22
7	IVS switch Open Voltage	Volts	4	10	24
8	IVS switch Closing Threshold	Volts	1.08	1.15	1.22
9	Potentiometer Track resistance	K Ohms	1	2.5	3

Table 9.1 Analogue Throttle Configuration Parameters

If the results of the tests are not in the range specified in the table above, then the device will not be compatible with the default settings in the ECM. Contact the electronic applications team to determine whether it will be possible to configure the input to meet the device needs.

9.2 PWM Sensor - Compatibility

9.2.1 PWM Sensor Operation

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 figure 9.3.

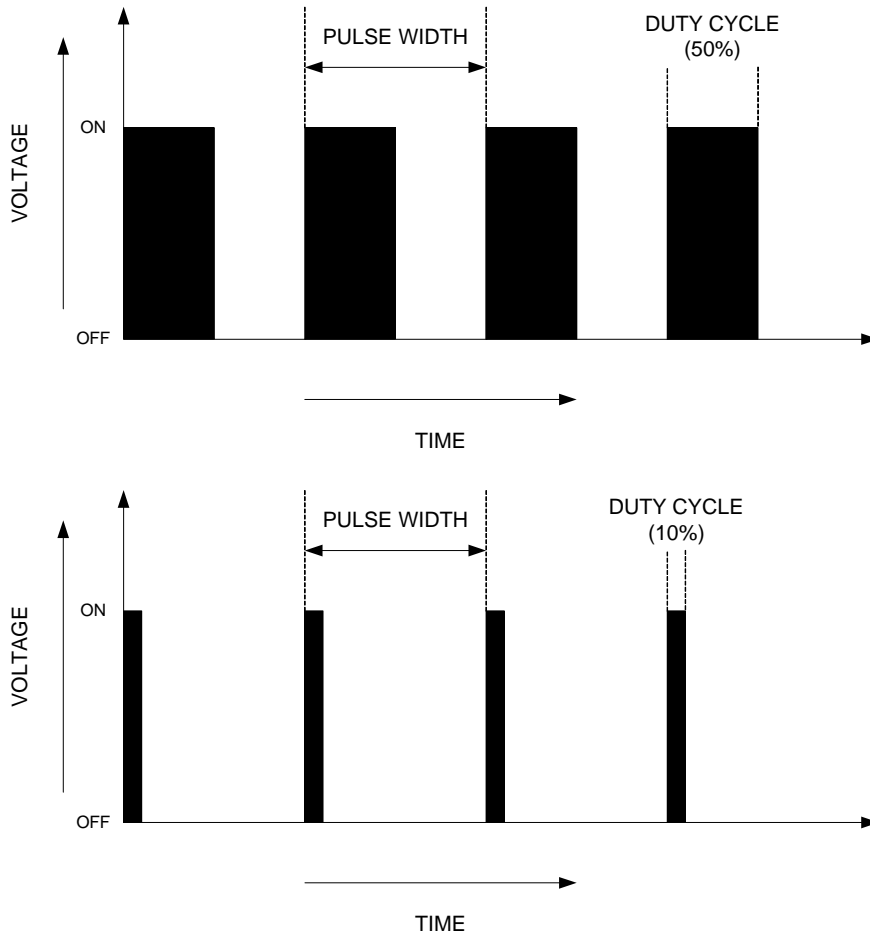


Figure 9.3 Pulse Width Modulation Waveform

Figure 9.3 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.

9.2.2 PWM Sensor Configuration

When mounted on the pedal and lever the target duty cycle should be as shown in figure 9.2. It is possible however to deviate from these values by adjusting the throttle configuration within ET.

All PWM sensors used should have a sinking driver with a frequency of 500Hz (+/- 50Hz). The sensor must give a valid output within 150ms of the main power being supplied to the sensor.

Position	Acceptable signal duty cycle range
Released (Low Idle)	10 to 22%
Fully Depressed	75 to 90%

Table 9.2 PWM Throttle Parameter Configuration

9.2.3 PWM Sensor Installation

There are two PWM throttle inputs available allowing a maximum of two PWM throttles to be connected directly to the engine ECM. These devices may be pedal, lever or cable operated. A regulated 8V, 100mA power supply is provide by the ECM.

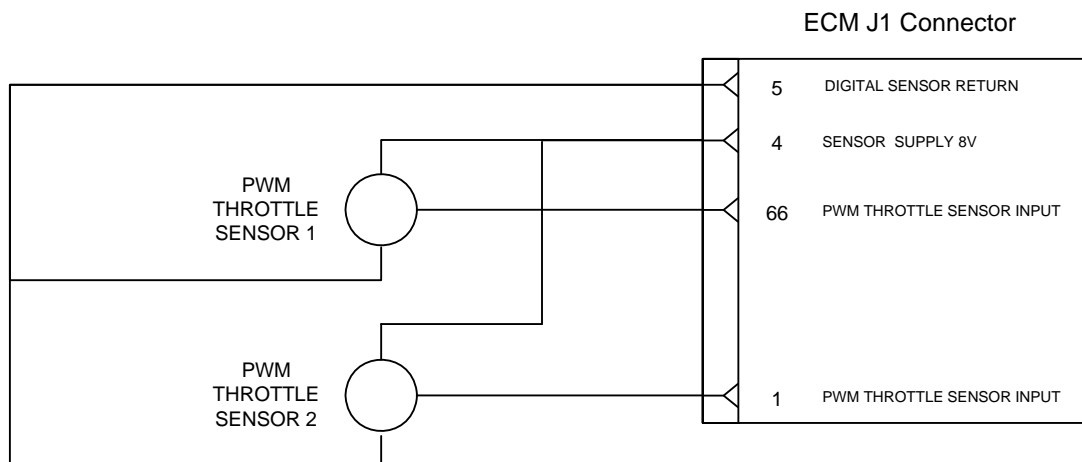


Figure 9.4 PWM Throttle Wiring Diagram

9.3 Throttle Lock (PTO mode)

9.3.1 Throttle Lock Mode Operation

Throttle Lock mode has also previously been 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.

The feature is operated by 5 switches / pushbutton and an optional second speed switch, which are shown below in table 9.3

Switch description	ECM Pin Number	Throttle Lock Mode Configuration	
		Raise / Lower mode	Set / Resume Mode
On / Off Switch	56	Enables and disables the Throttle Lock mode function	Enables and disables the Throttle Lock mode function
Raise / Resume	58	Raise only Function	Raises the desired engine speed and functions as a resume when set speeds are stored
Lower / Set	60	Lower only Function	Lowers the desired engine speed and functions as a set or memorise current speed demand.
Disengage	41	N/A	Disengages the current Throttle Lock mode.
Speed Toggle	44	N/A	Allows the operator to select between two Throttle Lock mode set speeds if programmed.

Table 9.3 Throttle Lock Mode Configuration

Table 9.3 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 this switch input is open then the Throttle Lock feature cannot be engaged, and none of the other buttons will have any effect. When the switch is turned off, any adjusted memorized speed will be lost.

9.3.1.2 Raise / Resume Button

When Throttle Lock has been switched ON, but not engaged, pressing the Resume button will ramp the speed to the configured preset speed. Note: Any overall ramp rates will only be applied to this ramp in speed (configured separately from Throttle Lock feature).

If the Throttle Lock mode has already been engaged by the set button, then the Raise / Resume button can be pressed or held down to increase the engine speed. The ramp rates configured in the Throttle Lock feature will be applied as well as any overall ramp rates (i.e. which ever is lowest).

After the mode has been disengaged using the disengage switch described below, then pressing the Raise / Resume button will set the engine speed to the last memorised speed.

9.3.1.3 Lower / Set Button

When the Throttle Lock mode is on but not engaged, the first time that the set button is pressed it will save the current engine speed as the memorized speed, and the engine will try to run at this speed.

Once that a Throttle Lock speed has been engaged, if the button is pressed again, or if it is held down, then the engine speed will be lowered. The ramp rates configured in the Throttle Lock feature will be applied as well as any overall ramp rates (i.e. which ever is lowest).

9.3.1.4 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

The disengage switch may be a operator panel switch, or may be a micro switch on the brake, clutch, or other component of the application

9.3.1.5 Speed Toggle Switch

The Speed toggle switch enables the operator to select between two configurable Set Speeds. This enables the operator to manually set two Throttle Lock speeds and manually switch between them via a single switch. Each of the two speeds can be set with a default RPM value via the service tool, and then new values set by pressing the Set button whilst the engine is in operation. When the Set button is pressed the actual engine speed will be stored as the new Set speed value for which ever Set speed channel is selected at the time (1 or 2). Note, when the ECM is switched off any new set speed values will be lost and the ECM will revert to the default value set via the service tool.

When the resume button is then pressed, the desired engine speed will ramp to the Set Speed value stored.

9.3.1.6 Preset Speed

The preset speed is programmed via the service tool. A speed may be selected such that if the resume button is pressed, before the set button has been pressed, then the engine speed will jump straight to this speed.

9.3.1.7 Throttle Lock Mode Speed Ramp Rates

The Throttle Lock mode 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.

Note: Any overall ramp rates configured outside of this feature will also be applied to the overall speed demand.

The ramp rates can be configured to operate at rates between 20 and 600rpm/second. This function is operated when holding down the raise or lower buttons.

9.3.1.8 Example of Throttle Lock Mode Operation

It is recognized that the precise function of the PTO mode is difficult to understand from a written text document, especially for Engineers for whom English is not their first language. The following table illustrates the operation of the PTO mode feature. In this example the preset speed 1 has been set on the service tool to 1800rpm.

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

On/Off Switch	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	
Interrupt Switch	1	1	1	1	1	1	1	1	1	Quickly open	1	Quickly open	1	1	1	1	1	1	
Set/Lower Switch	0	0	0	0	0	0	0	0	Quick Close	0	0	0	Quick Close	Quick Close	0	0	0	Quick Close	
Raise resume	0	0	Quick Close	0	0	0	Quick Close	Hold Close 3 secs	0	0	Quick Close	0	0	0	Hold Close 3 secs	0	Quick Close	0	Quick Close
Throttle Pedal demand	1200	1200	1200	1200	1900	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
Memorised Speed	1800	1800	1800	1800	1800	1800	1820	2050	2030	2030	2030	2030	1200	1180	2430	1800	1800	1800	1800
Resulting engine speed	1200	1200	1800	1800	1900	1800	1820	2050	2030	1200	2030	1200	1200	1200	2430	1200	1200	1200	1200
Comments	<p>PTO mode not enabled</p> <p>PTO mode disengaged</p> <p>PTO jumps to memorised speed</p> <p>Pedal overrides PTO (max wins)</p> <p>Speed raised by 20 RPM</p> <p>Speed ramps up</p> <p>Lowered by 20 RPM</p> <p>Disengage - speed returns to next highest demand (Throttle pedal)</p> <p>Resumes to 2030</p> <p>Disengage - speed returns to next highest demand (Throttle pedal)</p> <p>Sets memorised speed to current speed</p> <p>Memorized speed lowered by 20RPM but now pedal is highest wins</p> <p>Speed ramps up</p> <p>PTO mode switched off. Preset memorised speed now</p> <p>no effect as PTO mode is not enabled</p> <p>PTO mode disengaged</p> <p>no effect. if both buttons are pressed at once</p>																		

9.3.2 Throttle Lock Mode Configuration

Four parameters must be configured in Caterpillar ET prior to using the Throttle Lock feature. The parameters are listed in the main *configuration* screen and are shown below.

Throttle Lock and PTO Mode Parameters		
EST Description	Range or Option	Description
Throttle Lock Feature Installation Status	Not Installed/Installed	Used to install the Throttle Lock feature
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	1 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	1 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	10 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	10 to 200 rpm/sec	Speed at which the engine will increment or decrement when the raise or lower button is pressed quickly.

Table 9.4 Throttle Lock And PTO Configurable Parameters

Note: The Throttle Lock feature shares the same hardware ECM J1 pins, as the Multi Position Switch Feature and so can not be used if the MPTS feature is enabled.

9.3.2 Throttle Lock Mode Installation

Figure 9.5 shows the installation wiring required to implement the full Throttle Lock function. It should be noted that as a minimum pins 56,58 and 60 must be installed for the function to operate.

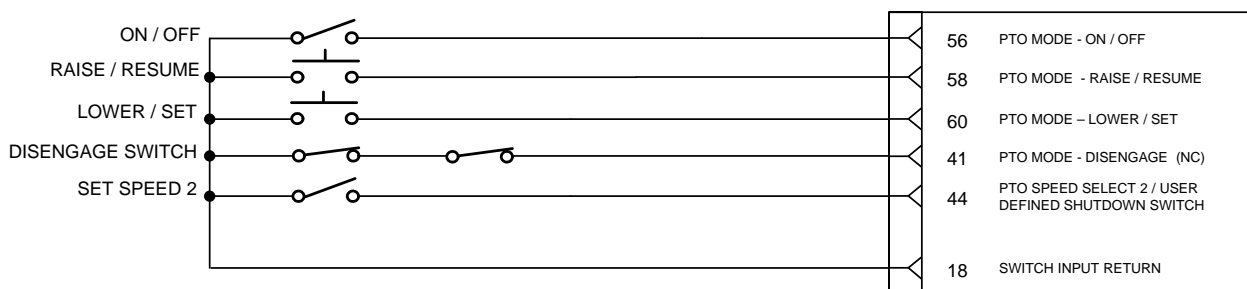


Figure 9.5 Throttle Lock Mode Wiring Diagram

9.3.3 Throttle Lock Operation Under Engine Load

The Throttle Lock mode set and resume functions are used to provide the operator with a method of storing a required engine speed and resuming operation at this speed by the use of a simple interface. Care must be taken however when using this function under engine load conditions as the engine load may mean that the desired engine speed is not achieved (lug curve operation). The example below describes the feature operation under load conditions.

Example

The operator using the 'raise/resume' switch increases desired engine speed to 2000rpm. Load is applied to the engine, which lugs the engine speed down to 1500rpm. The operator tries to increase the speed of the engine (still under load) back up to 2000rpm by pressing the 'raise/resume' switch. However as the engine is lugging back under load, the engine speed cannot increase and will remain at 1500rpm. Once the operator releases the 'raise/resume' switch, because the actual engine speed is still at 1500rpm, the Throttle Lock set speed will now be set to 1500rpm.

If the engine load now decreases, because the set speed has been lowered to 1500rpm the engine speed will not increase back up to 2000rpm but remain at 1500rpm. The operator can now increase engine speed back to 2000rpm using the 'raise/resume' button. Figure 9.6 illustrates the Throttle Lock mode operation.

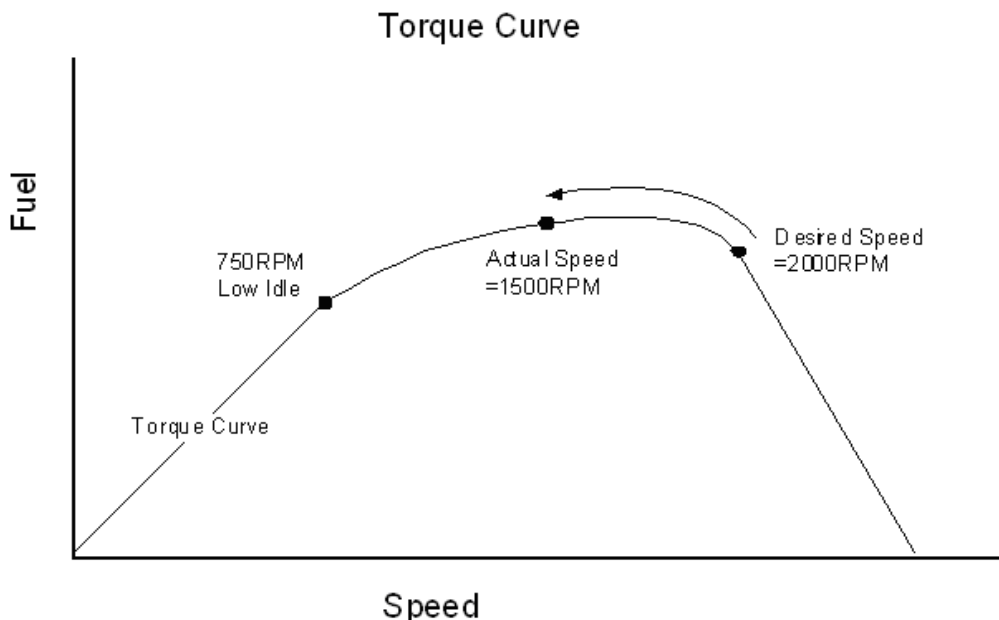


Figure 9.6 Throttle Lock Mode Operation Under Engine Load

The Throttle Lock feature is configured to operate in this way to prevent the engine from sudden increases in engine speed due to the raise Throttle Lock speed button being pressed whilst the engine is under load and lugging back

along the torque curve. This operation also ensures that the engine ECM can maintain safe engine operation under all conditions.

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. A rotary encoded 10 position switch component is available for this function. Please contact the electronic applications team for further details.
- 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 “Not Valid” then a fault code will be raised (91-2 or 774-2) and the ECM will ignore the MPTS for the rest of the key cycle.

9.4.1.1 Intermediate Speed Function

The MPTS function can be installed to provide an intermediate set speed option via pin 60 of the ECM J1 connector. This function gives the option of a single set speed that overrides all other speed requests including TSC1. This function can be activated when required via the switching of input pin 60 to ground.

This feature can be used in conjunction with the MPTS, however if both functions are required pin 60 will be dedicated to the intermediate speed function leaving the remaining three inputs for the MPTS function. This will reduce the number of MPTS set speeds available for selection from 16 to 8.

9.4.2 MPTS Configuration

The MPTS option can be configured using the ET service tool by selecting the following menu location *Service / Throttle Settings*.

The table below gives an example of how the four switchable inputs can be configured to give a range of set engine speeds.

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

Table 9.5 MPTS Switch Configuration

The MPTS feature defaults to four configurable switch inputs as standard and this is non configurable. If less than four switched inputs are required then the unused programmable speed settings should be programmed with the physical position enabled set to 'NO'.

9.4.3 MPTS Installation

Four switch inputs are available on the ECM for a switch-controlled throttle. The ECM may be configured so that different combinations of switch inputs will relate to different engine speed demands. There are 16 different combinations of states of these 4 switches, although not all of these combinations need to be programmed.

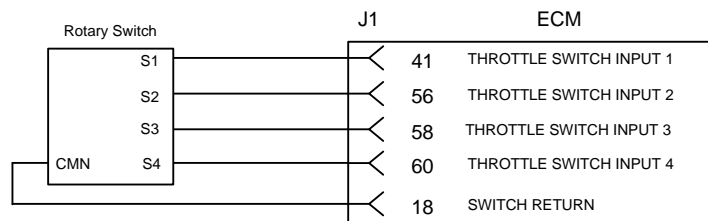


Figure 9.7 MPTS wiring Diagram

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 19 of this application and installation guide.

9.6 Arbitration of speed demand

In applications where there is more than one source of engine speed demand, it is necessary to arbitrate between the different demands. The speed arbitration does not apply to the PTO speed demand feature. There are 4 methods of arbitration:

- Max Wins. The highest speed demand is the one that controls the engine. This is the default configuration
- Manual Selection switch. A switch input can be used to define which speed input has control. This is particularly useful in applications where there are 2 driver seat positions.
- TSC1 override. As described above, the TSC1 message over J1939 will override speed demand from any other source.
- Intermediate engine speed switch. Used as part of the MPTS function but will override all speed demands when operated including TSC1.
- Lowest wins. In this case the low engine speed demanded will be the overall speed selected.

9.6.1 Manual Throttle Selection Switch

TBD

9.7 Acceleration and Deceleration Ramp Rates

It is possible to limit the overall acceleration rate of the engine speed. The acceleration limit applies to overall engine speed, irrespective of applied strategy. The rate may be configured in ET. The rate is defined in units of rpm per second. 0 rpm/s represents no limit to engine acceleration (i.e. turns off the feature.) The default ramp rate will be 0 rpm/s.

When ramp rates are being used within the PTO function it should be noted that if overall acceleration and deceleration ramp rates are also being used the engine software will apply the lower of the two values.

9.8 Throttle Behavior During Engine Governor Changes

To protect the engine and drivetrain system during engine governor selection changes, interlocks between engine speed demand and governor mode have been employed. It should be noted therefore that when changing between governor modes via the mode switches or J1939 message, the following throttle features are enabled / disabled.

Governor Mode	PTO Mode Availability	MPTS Availability
All Speed Governing	Yes	Yes
Min / Max Governing	No	No

Table 9.6 Throttle Features and Governor Compatibility

To switch between engine governing modes the actual engine speed must be returned to it's low idle setting under all circumstances. If this condition is not met then the governor mode will not change regardless of the switched input state. For more information on engine governing and its configuration please refer to section 15 of this document.

9.9 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 ECM 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

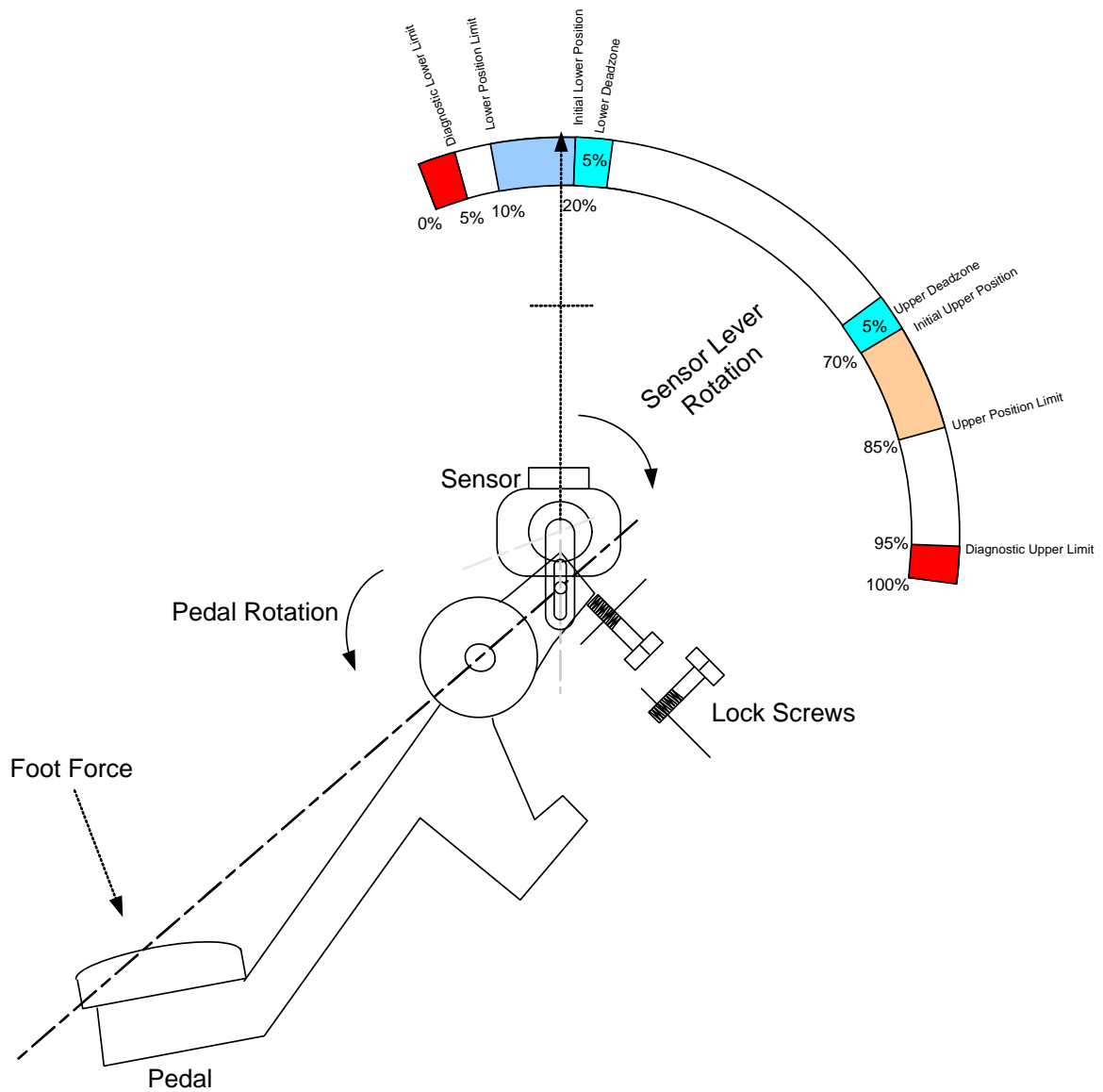


Figure 9.8 Analogue Throttle Setup Example

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:

9.9.1 Throttle Parameter Description

Diagnostic Lower Limit

The lower diagnostic limit is the absolute minimum raw value accepted as a valid signal by the engine ECM. 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 ECM. 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.

9.9.2 Throttle Calibration Function

When the engine ECM 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 ECM 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.

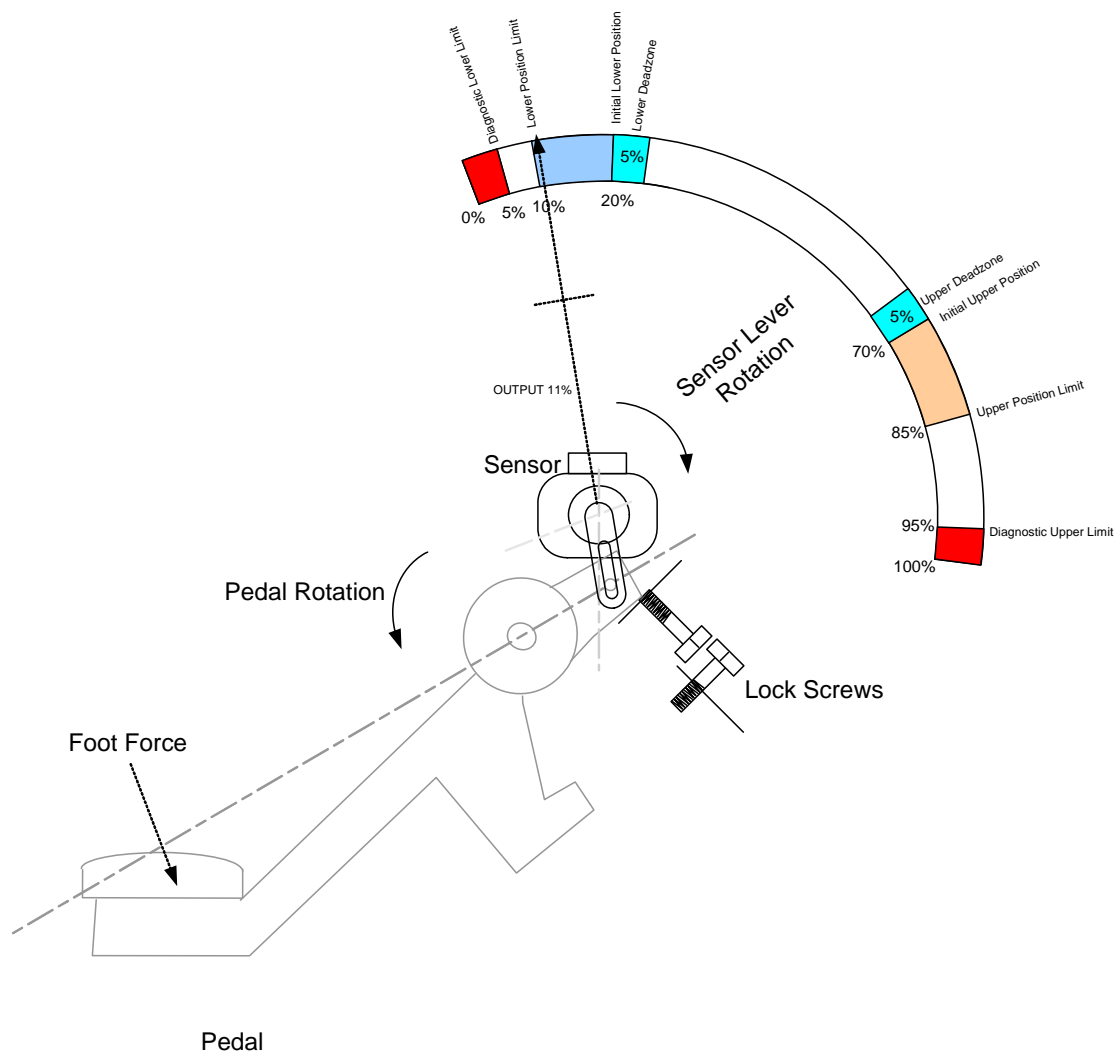


Figure 9.9 Analogue Throttle Lower Calibration Prior to Calibration

Diagram A, *before calibration*, the sensor output falls within the lower calibration region, without auto calibration the 'initial lower position limit' is

used by the engine ECM 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.

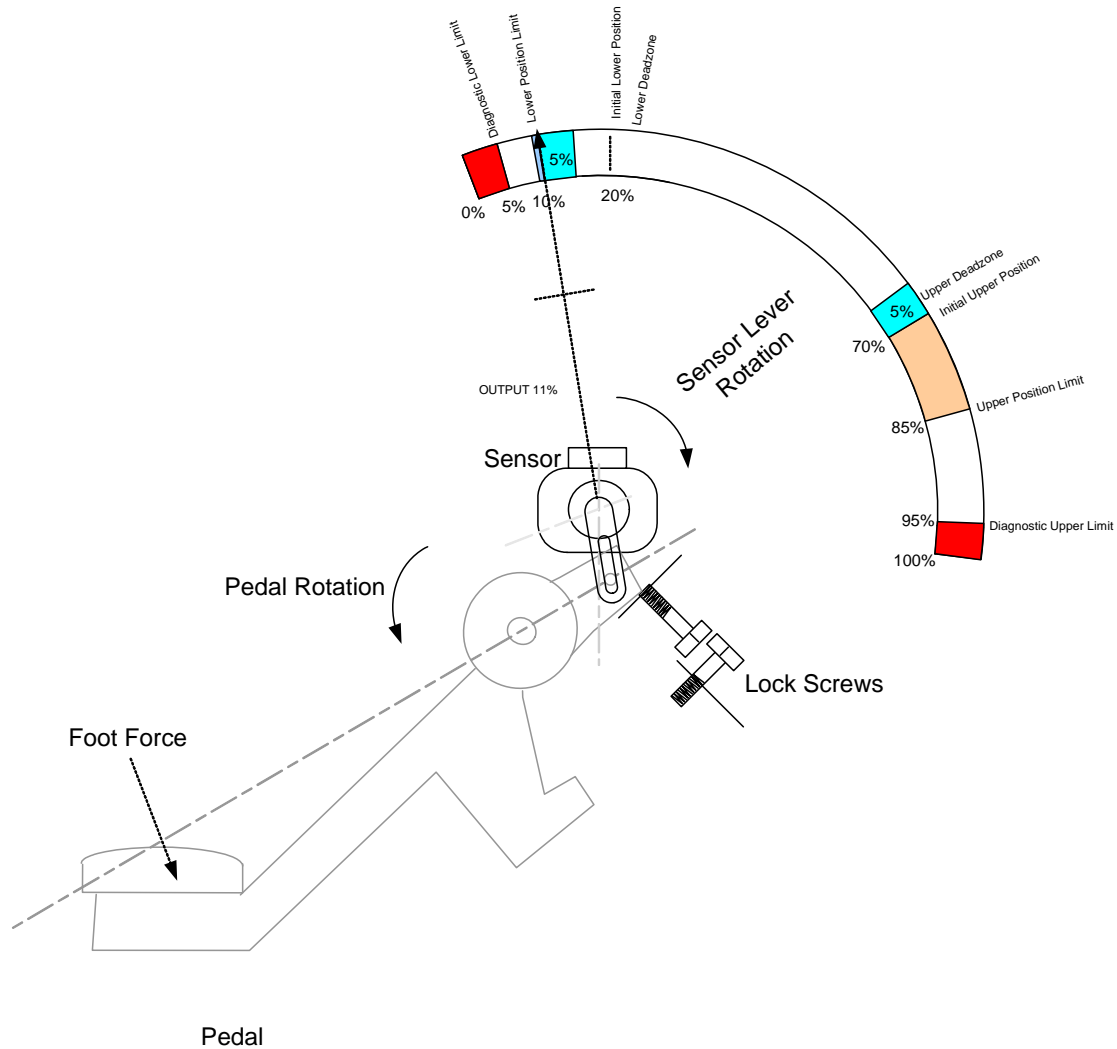


Figure 9.10 Analogue Throttle Lower Calibration Post Configuration

Diagram B, *after calibration*, the start position used by the engine ECM 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.

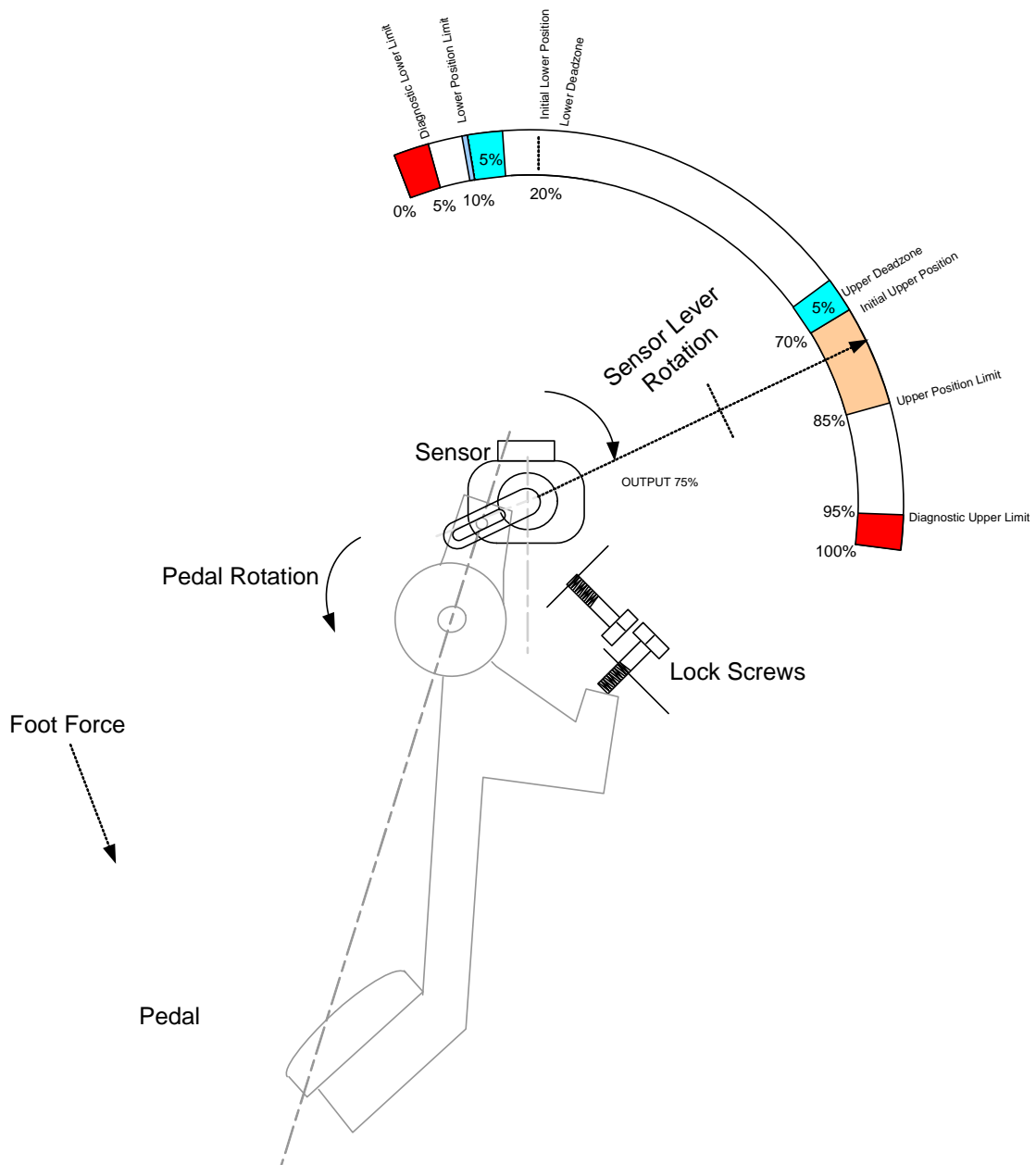


Figure 9.11 Analogue Throttle Upper Calibration Prior to Adjustment

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

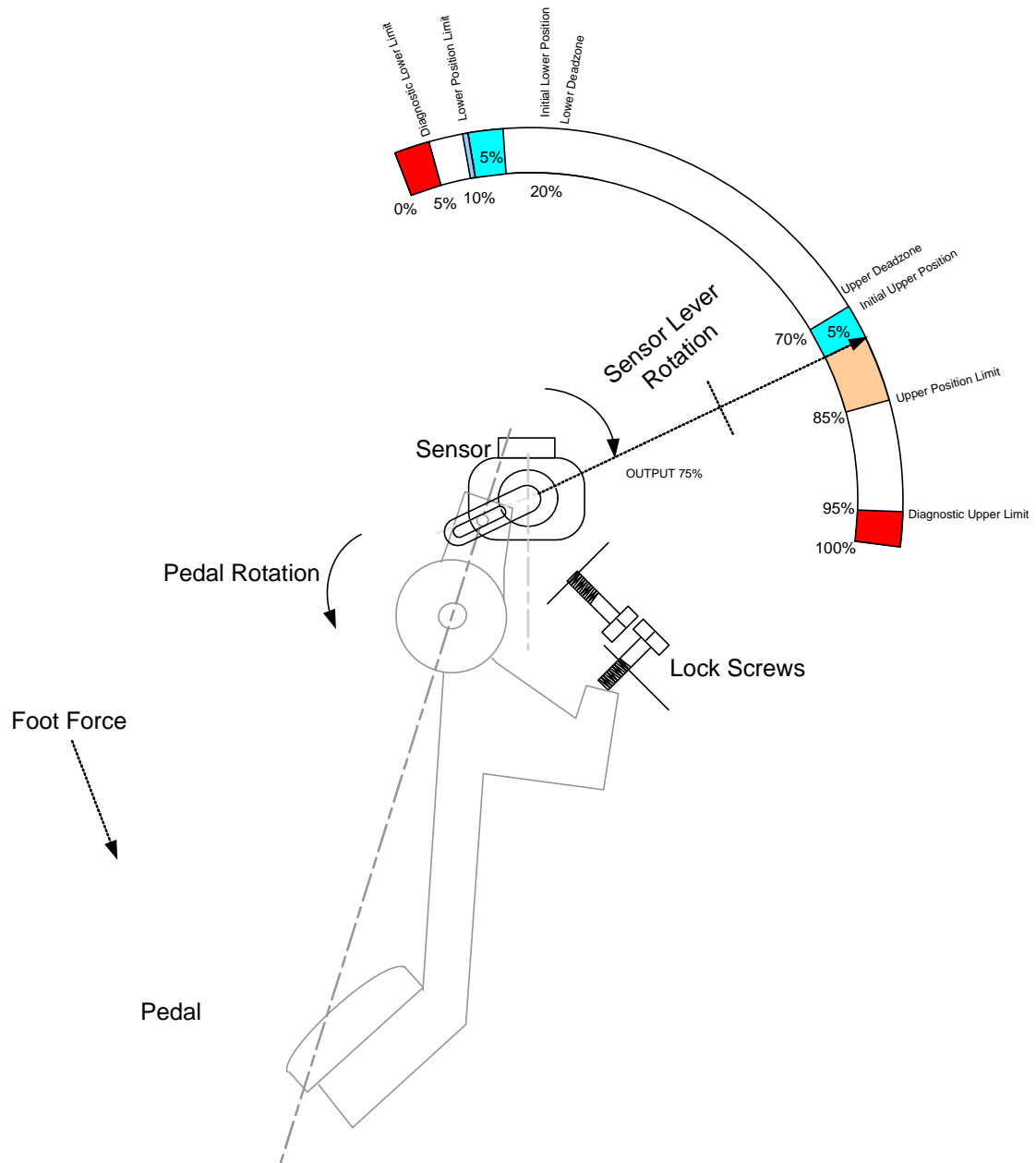


Figure 9.12 Analogue Throttle Upper Calibration Post Configuration

Diagram D, *after calibration*, the maximum position used by the engine ECM has changed; with this new initial upper position the lever needs to travel through the deadzone only. Once clear of the deadzone 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 ECM is recycled.

9.9.3 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 ECM 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 ECM 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 ECM 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 ECM 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 ECM will invoke the limp home strategy and the throttle will not respond.

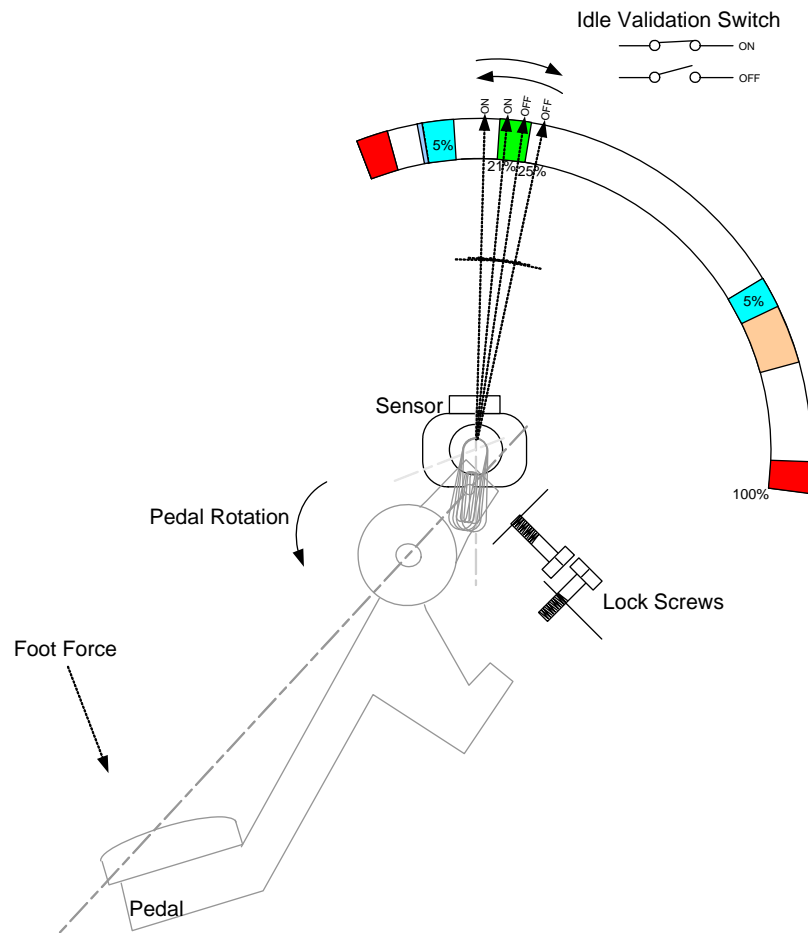


Figure 9.13 Idle validation switch transition

9.10 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 figure 9.14 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 (RSL)
- Rated Speed Upper Limit (RSUL)

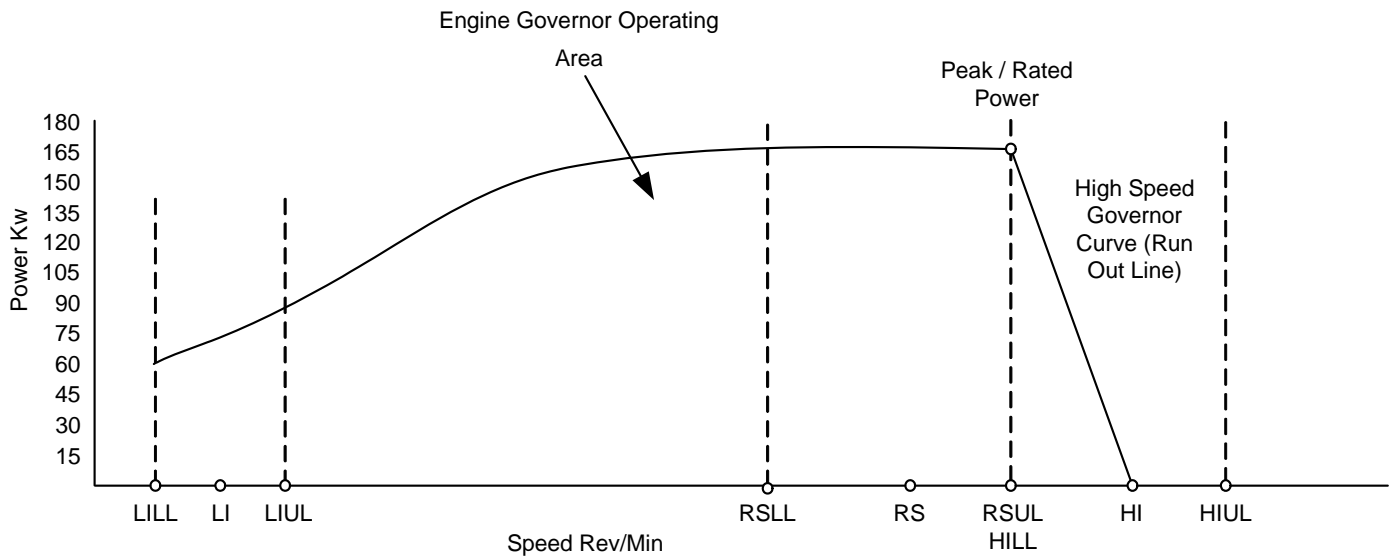


Figure 9.14 Example Power Curve With All Available Speed Settings

9.10.1 Engine Low Idle

9.10.1.1 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 ECM (assuming the engine is running) and there is no load on the engine the engine will idle at the set low idle speed.

The selectable low idle engine speed is confined to the limits set by the Low idle lower limit and the low idle upper limit. These values are fixed in software and are not configurable.

9.10.1.2 Engine Low Idle Configuration

The desired engine low idle speed can be set using the service tool via the configuration screen. The low idle speed defaults to 750 and can be programmed to any value between 700 and 1200 step size of 10 rpm.

9.10.2 Engine High Idle

9.10.2.1 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: For more information regarding the interaction between the RS and HI settings along with the HSG please refer to section 15.0.

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.

9.10.2.2 Engine High Idle configuration

The desired engine High Idle Speed can be set using the service tool via the configuration screen. The engine High Idle speed defaults to rated speed 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 + 12%. This means that the max HI setting available for any engine is RS + 12%.

9.10.3 Engine Rated Speed

9.10.3.1 Engine Rated Speed Operation

The engine rated speed determines the point at which the High speed governor cuts in. This speed setting is normally pre defined as the point at which the maximum engine power is obtained (normally set to 2200rpm). In many cases this value is fixed due to the specific rating development. However some ratings do offer the possibility of adjusting the engine rated speed within the limits of the Rated Speed Lower Limit and the rated Speed Upper limit. The values are set within the engine software and are non configurable.

It should be noted that for those ratings, which support the configuration of the engine rated speed, the power and torque produced by the engine across the adjustable speed range is not always constant. For this reason a through investigation into the applications power and torque requirement compared to that given by the engine at the new rated speed point must be made. Consideration must also be made to the availability of Torque back-up when reducing the engines rated speed.

9.10.3.2 Engine Rated speed Configuration

The configuration of the engine Rated Speed setting can be made using the service tool (only for those engine ratings supporting this feature) via the engine mode selection feature. Please refer to section 15.0 Engine Governor for more information on the configuration and use of the engine mode selection feature.

The Engine rated speed for those engine ratings supporting the feature can be configured to limits set by the RSL (1800rpm) and RSUL (2200rpm). These are fixed limits set within the engine software and cannot be altered.

10.0 Cold Weather Engine Operation & Starting Aids

There are two types of start aid available for all Tier 4 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 only used from +5°C
- Ether start activation is based on temperature and barometric pressure but in general will activate at temperatures below –25°C

When selecting both start aids the control shown in figure 10.1 applies.

In addition to the aids required for engine starting there is also a need for an engine regeneration aid for the following engine ranges.

- C4.4 Low temperature regeneration system
- C6.6 Low temperature regeneration system

This regeneration aid is only required for applications wishing to operate below –25Deg ambient with light parasitic loading. Further details on the operation of this system and its electrical installation are given in section 10.3. More information can also be found detailed within section 14 of the mechanical A&I Guide.

Start Aid Control

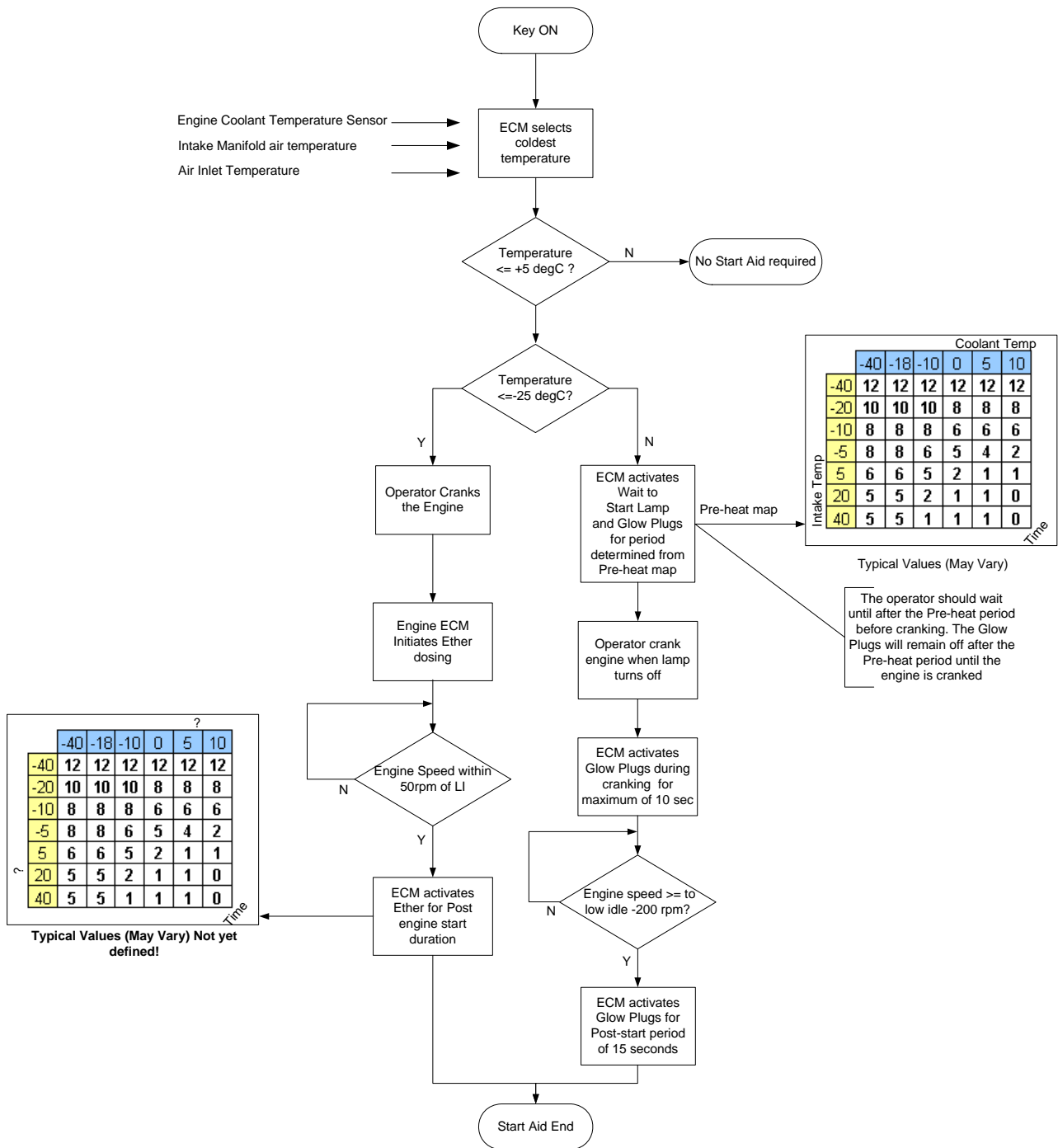


Figure 10.1 ECM Start Aid Control

10.1 Control of Glow Plugs by the Engine ECM

10.1.1 Glow Plug System Operation

Glow plugs are fitted as standard to all Tier 4 Interim engines.

When the ignition keyswitch is on, the engine ECM will monitor the coolant temperature and the inlet air temperature and decide whether the glow plugs are required. If so, the ECM will activate the glow plug relay and supply current to the engine glow plugs.

On a cold start when the ECM decides that it is necessary for the glow plugs to be activated prior to starting, a lamp output will indicate to the operator that they need to 'wait to start'. Note that it is possible that the start aids will also be used either during cranking or when the engine has started. Under these conditions however the lamp will not be active. The control strategy for start aid control is shown in figure 10.2

Start Aid Control

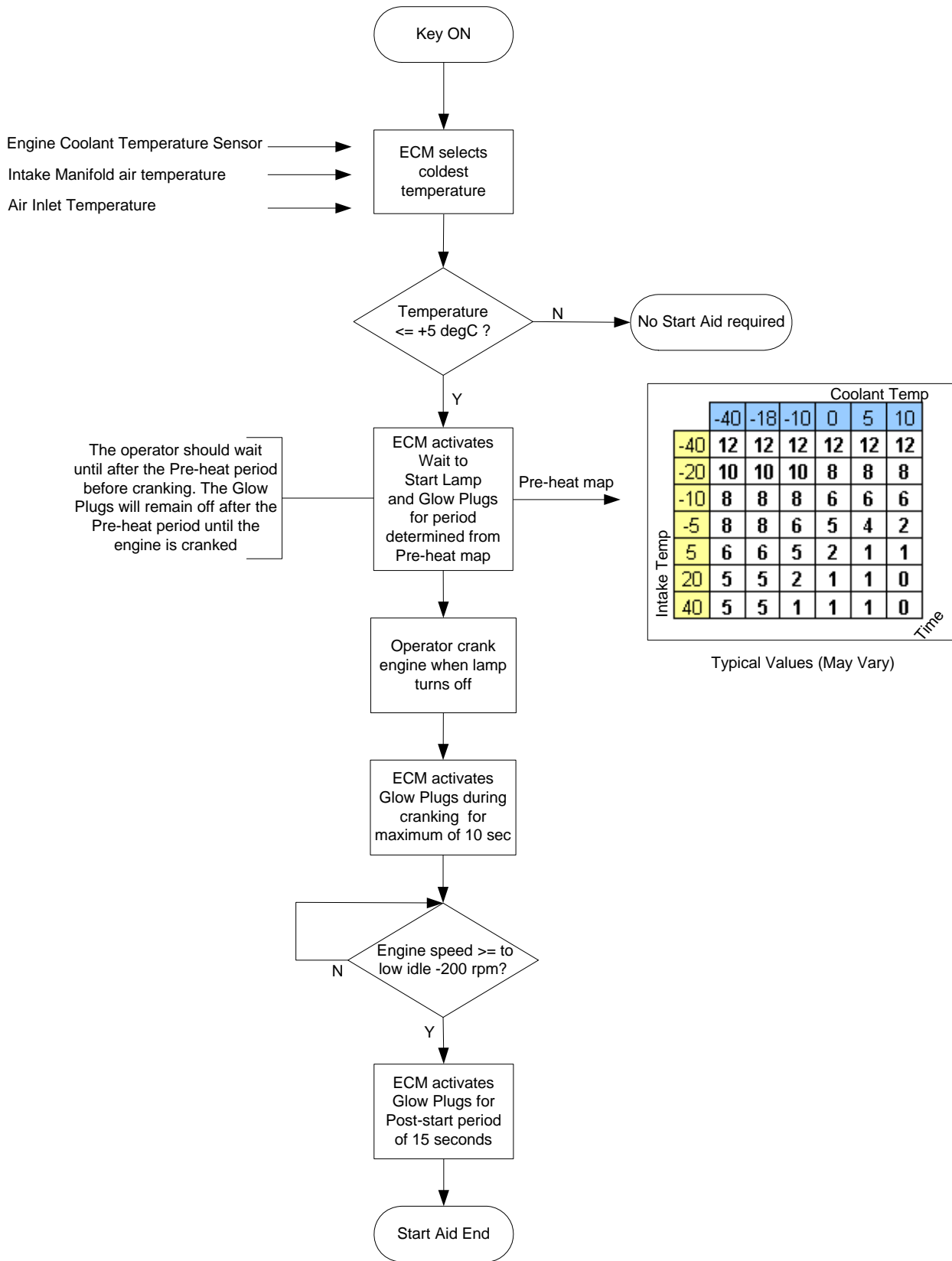


Figure 10.2 ECM Glow Plug Control

10.1.2 Glow Plug System Configuration

If operation of engine glow plugs is not required, then no control hardware is required to be installed. Please note that whilst both Glow plugs and ether can be fitted to the same engine, the start aids can not be operated at the same time for safety reasons. Please do not under any circumstances bypass the ECM control of either start aid.

10.1.3 Glow Plug System Installation

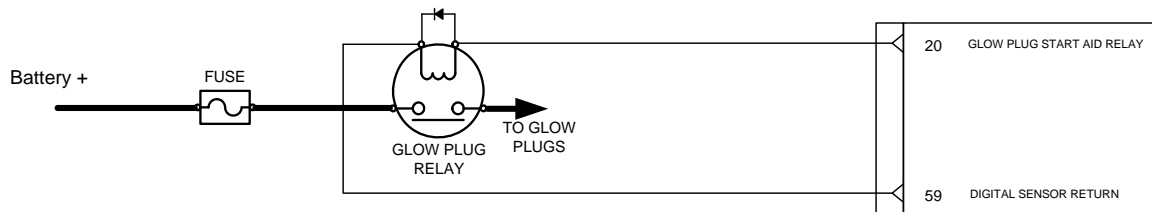


Figure 10.3 Glow Plug Relay electrical Connection

The relay coil must not draw more than 1A and should be fitted with either a resistor or diode to suppress flyback energy (back emf).

As the glow plugs may be active during cranking, when the battery voltage may be low, it is recommended that the relay is specified such that it will close at a voltage equivalent to 60% of nominal battery voltage or lower.

The relay contacts should be rated to withstand the current characteristics outlined in the table below. Note that for the purpose of relay specification, the glow plugs are a purely resistive load (no inductive element).

Although the glow plugs are normally operated for a short time only, in cold ambient conditions, best practice would be to size the cable to withstand the stabilized glow plug current permanently. This will allow for a relay that fails closed. For example a 4 cylinder 12V application should have a wire size capable of carrying 50A. Refer to the recommended cable sizes in the table below.

Engine:	C4.4		C6.6 or C7.1	
	12V	24V	12V	24V
Supply Voltage:	12V	24V	12V	24V
Current - Initial	82A	36A	122A	54A
Current after 4 sec	64A	29A	97A	43A
Current after 8 sec	50A	24A	74A	36A
Recommended Fuse To SAEJ1888 (slow blow)	50A	30A	80A	40A
Recommended min cable gauge - mm ² (SAE J1128 GLX cable)	5mm ²	2mm ²	8mm ²	3mm ²

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

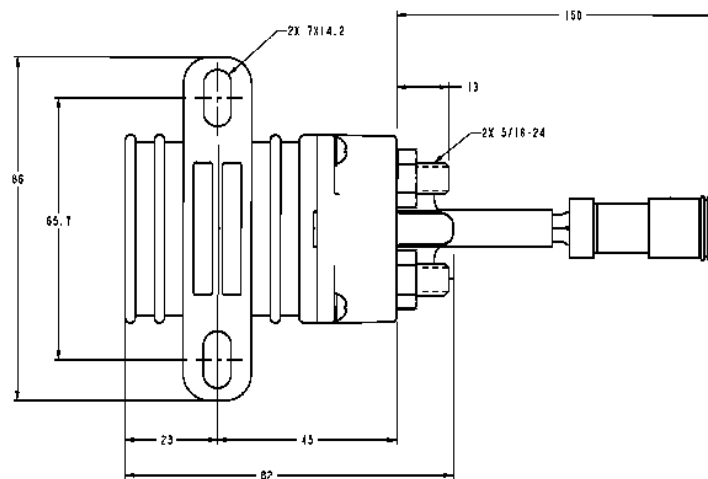
A Caterpillar recommended glow plug relay is also available for use with the C4.4 to C7.1 engine range. There are two part numbers available as shown in table ? Both relays are supplied with a two pin connector for easy connection of the relay coil control circuit.

The relays must be remote mounted from the engine and have a maximum ambient temperature limit of +85°C and vibration levels less than 15.3Grms.

Both relays are also fitted with suppression diodes.

Component	Caterpillar Part Number
12V Glow Plug Relay	241-8367
24V Glow Plug Relay	241-8368
2 Way Plug Kit	155-2270
2 Way Plug	155-2269
Wedge Lock	155-2261
Sockets	9X-3402

Table ?



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 ECM controls the ether solenoid control output when conditions dictate the use of a 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 ECM the option must be selected using the service tool. This achieved by double clicking the Ether start option displayed as part of the main configuration screen and selecting the 'Installed' option.

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 ECM 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 figure 10.4.

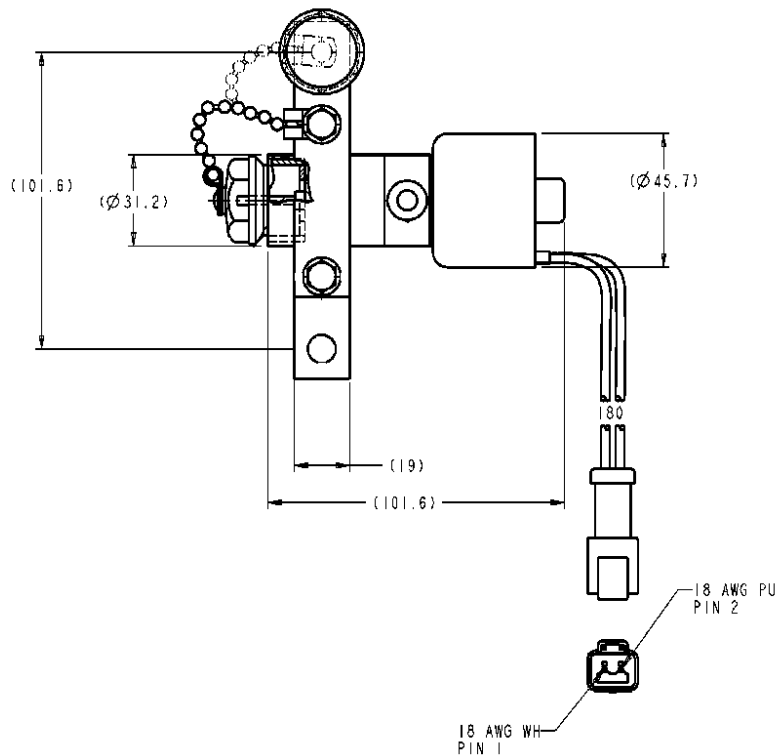


Figure 10.4 Example Ether Control Valve

The mating connector for both the 12 and 24V Ether solenoid options available for the C4.4 to C7.1 product range are shown below in figure 10.5. The part numbers required for the ether solenoid connection are also shown in table 10.1.

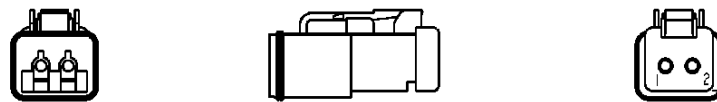


Figure 10.5 Mating Electrical Connector 155-2269

Component	CAT P/N
Ether control Valve 24V	239-1134
Ether control Valve 12V	260-1844
2 Way Plug Kit	155-2270
2 Way Plug	155-2269
Wedge Lock	155-2261
Sockets	9X-3402

Table 10.1 Mating Connection Part Numbers

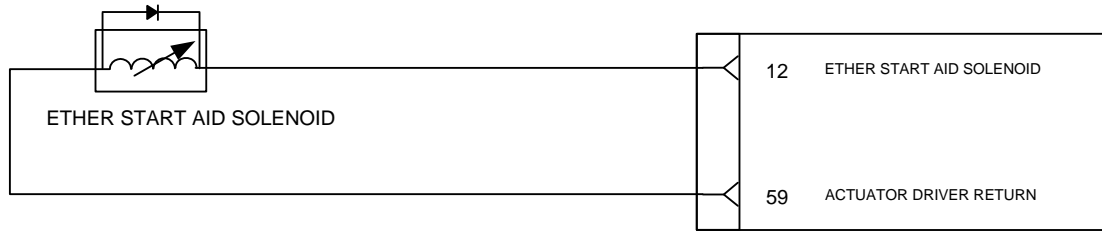


Figure 10.6 Ether Solenoid Electrical Connection

10.3 Regeneration Aid For Cold Temperature Operation

Insert details for V5 of A&I Guide.

Relay details 12V = 115-1615 with 85°C Temp limit and vibration limit of ?
 24V = 3E-5239 with 85°C Temperature limit and vibration limit of ?

Description	CAT Part Number
12V Relay	115-1615
24V Relay	3E-5239
Plug Connector	9X-1054
12AWG Terminal	9X-1055
14 – 16AWG Terminal	9X-1056
Crimp Tool	TBD

Table ?

Need to insert here a wiring diagram and the part number for the cold weather part as opposed to the individual part number for the components.

11.0 Engine & Aftertreatment Monitoring – High Level Indicators & Operator Displays

11.1 Engine Management System Status Indication

The engine ECM is configured to monitor a number of core engine critical and application configurable parameters. This monitoring system enables the engine to take actions such as warn the operator, derate the engine or shutdown completely. The configuration of this system is discussed further in section 12 of this document and the remainder of this section is focused around the display of these engine monitoring system states.

It should be noted that due to the increased complexity of the engine system required to meet Tier 4 emissions standards, additional lamp outputs must be used to indicate the status of the aftertreatment system. These lamps are in addition to the mandatory core engine lamps. Table 11.1 gives an overview of the mandatory fit indicators required for each Tier 4 engine family. Section 11.2 gives more details on the interaction between the Core engine and Aftertreatment indicators.

Please note that whilst the use of the hard wired lamp outputs are not mandatory, the indication of each of the following lamp status is mandatory. Whether using a hardwired or J1939 driven system all status indicators must use the aftertreatment symbols shown in section 11.2.1.

Engine Family	Core Engine Lamps	Aftertreatment Lamps
C7.1	Engine Warning Lamp	DPF Lamp
	Engine Shutdown Lamp	HEST Lamp
	Wait to start Lamp	DPF Disabled
C6.6 & C4.4	Engine Warning Lamp	N/A
	Engine Shutdown Lamp	N/A
	Wait to start Lamp	N/A

Table 11.1 Mandatory engine and Aftertreatment Status Indicators

11.1.1 Engine Monitoring System Fault Status Levels

The engine management system provides numerical codes to detail specific engine or aftertreatment diagnostics and system events. These codes are split into two categories, a system diagnostic code and an event code.

Diagnostic Code – A diagnostic code is raised when a malfunction with one or more of the engine or aftertreatment electronic components enters a fault condition.

Event Code – An engine event code is raised when one or more of the engine or aftertreatment electronic components measures a value, which is outside of a pre-configured threshold.

Each of these engine system codes has a severity applied to them, which corresponds to a physical engine action and monitoring system status indicator display. These severity levels are defined by three levels,

- Level 1 – Warn only (No immediate action is required, the system may need attention soon)
- Level 2 – Derate the engine by a specific error determined percentage (change machine operation or perform maintenance to the system)
- Level 3 – Activate or advise an engine shutdown be implemented for engine protection (Immediately perform a safe machine shutdown)

The remainder of this section deals specifically with the display of these engine states. For more information regarding the configuration of these thresholds and the actual engines physical response to specific error levels please refer to section 12.

11.1.2 Hardwired Lamp Monitoring System Display

For applications implementing a hardwired lamp system direct to the engine ECM J1 connector, two lamps are used to display both the fault status indicator level and the resulting severity. These lamps are the stop lamp and the warning lamp. Table 11.2 shows how the engine management system triggers the operation of these lamps depending upon the engine / aftertreatment status. Upon activation of an engine management system diagnostic or event status level a fault code is also generated.

Fault status indicator Level	Severity Level (3=Most Severe)	Engine Lamps	
		Stop Lamp	Warning Lamp
Diagnostic	1		ON
	2		FLASH
	3	ON	FLASH
Event	1		ON
	2		FLASH
	3	ON	FLASH

Table 11.2 Hardwired Lamp Operation

Note: ON = Lamp on solid, FLASH = Increase in severity

11.1.3 Data Link Driven J1939 Monitoring System Display

OEM's wishing to use the J1939 DM1 message to display the fault status indicator level must ensure that the machine controller / display is configured to monitor the following lamp outputs, Stop lamp, Warning lamp and / or protect lamp. The operation of the J1939 defined lamps are shown in table 11.3.

Fault status indicator Level	Severity Level (3=Most Severe)	Engine Lamps		
		Stop Lamp	Warning Lamp	Protect Lamp
Diagnostic	1		ON	
	2		FLASH	
	3	ON	FLASH	
Event	1		ON	ON
	2		FLASH	FLASH
	3	ON	FLASH	FLASH

Table 11.3 J1939 Lamp Operation

Note: ON = Lamp on solid, FLASH = Increase in severity

Both the warning and protect lamp use the flash functionality which is available through J1939 to indicate an increase in diagnostic or event status severity. The J1939 flash functionality is provided by the following SPN's.

- SPN 3040 Amber Warning Lamp Flash
- SPN 3041 Protect Lamp Flash

The J1939 specification for SPN's 3040 and 3041 provides the ability to operate the warning and protect lamps in the following ways

- 00 Slow Flash (1Hz – 0.5 sec on / 0.5 sec off)
- 01 Fast Flash (2Hz or faster – 0.25 sec on / 0.25 sec off)
- 10 Reserved
- 11 Unavailable / Do Not Flash

Caterpillar uses the Fast flash and do not flash states only from these SPN's. Please see section 19.5.1 for more information regarding the specific configuration of the DM1 message.

11.2 Gauge Drivers

OEMs are increasingly selecting datalink-driven intelligent displays for their applications instead of traditional gauges and lamps directly driven from sensors or the engine ECM.

If a needle type analogue gauge is required to display an engine parameter such as engine speed, oil pressure, or coolant temperature, it is recommended that the OEM use a gauge or display that can use the parameters broadcast by the ECM 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 Electronic Applications team 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.

11.2.1 Datalink Driven Intelligent Displays

J1939 enabled operator display / gauge units can be connected to the engine J1939 datalink. Caterpillar offers lamp information which conforms to the J1939 standard PGN and SPN messaging system. For more information on the J1939 messages supported via the ECM J1939 data bus please refer to section 19 of this document.

Devices that are connected to the J1939 datalink should meet the following standard if the OEM does not intend fitting the indicator lamps.

11.2.2 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 of 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).

Caterpillar will under no circumstances change the engine J1939 implementation in order to resolve compatibility issues with gauges or displays other than those supplied directly by Caterpillar.

Gauge manufacturers may contact the electronic applications team, however for information and assistance in ensuring that their products are compatible with the engine ECM.

To support new standards and requirements, Caterpillar may add to the fault code table. Therefore, any active engine fault codes including those not recognized or referenced should be displayed.

11.2.3 Customer Triggered Engine Fault codes

The engine will raise fault codes (event codes) when its design limits are exceeded; for example, excessive coolant temperature. The fault code algorithms are carefully designed and validated so that they do not cause spurious codes when there is in fact no fault.

Some intelligent instrument clusters available on the market are also capable of raising fault codes themselves, based on the information that the engine transmits on the J1939 datalink, such as 'engine coolant temperature'. The machine designer could set a limit that is more conservative than the warning threshold defined by Caterpillar. This raises the possibility that the display will say that the engine has a fault when the engine is in fact running within its design limits. This is undesirable as it may result in a service technician being called to resolve a problem when in fact no problem exists, potentially causing damage to the reputation of Caterpillar and the PEM.

Caterpillar recommends therefore, that intelligent displays DO NOT have their own fault detection for engine over temperature/oil pressure etc, but that they use the fault codes generated by the engine sent within the J1939 'Diagnostic Message' (DM1).

11.3 Lamp Outputs

There are a number of lamp outputs available direct from the engine ECM. Some of these lamps are a mandatory requirement such as the engine stop lamp, while others are optional. Table 11.4 lists the lamp outputs available from the engine ECM and which engine families they are applicable to.

Lamp Description	Mandatory Fit Engine Family	Pin Allocation
Shutdown Lamp	All	28
Warning Lamp	All	29
Wait to Start Lamp (Cold Start Aid)	All	19
Oil Pressure Lamp	Optional	36
Maintenance Due Lamp	Optional	21
DPF Lamp	C7.1	30
HEST Lamp	C7.1	31
DPF Disabled Lamp	C7.1	13

Table 11.4 Lamp Output Pin Allocation

11.3.1 ISO Reference For Aftertreatment Symbols

Shown below in table 11.5 are the standard ISO symbols and terminology used for the aftertreatment system. The table also shows the ISO number used to represent each symbol and it's use.

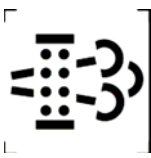

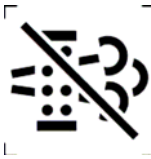
Symbol	Symbol Title (ISO)	Symbol Title (CAT)	Description	ISO Ref
	Engine Emissions System Filter	Diesel Particulate Filter	To indicate that the DPF is in need of regeneration	ISO 7000-2433
	Engine emissions System Temperature	High Exhaust System Temperature	Indicates that a regeneration is underway and that emission system temps are elevated	ISO 7000-2844A
	Engine Emission filter Active Regeneration Disabled	DPF Disabled Lamp	Indicates that a regeneration has been inhibited	ISO 7000-2947

Table 11.5 ISO Specified Aftertreatment System Indicator Symbols

11.3.2 Indicator lamps Logic













Warning Lamp (Also known as Alert Lamp)	Shutdown Lamp/buzzer (Also known as Action Lamp)	Lamp State	Description of what Lamp Status is Indicating	Engine State
 On	 On	Lamp Check	When the keyswitch is moved to the ON position, the lamps come on for a period of 5 seconds and the lamps will then go off.	The keyswitch is in the ON position but the engine has not yet been cranked.
 Off	 Off	No Faults Present.	With the engine in operation, there are no active warnings, diagnostic codes or event codes.	The engine is operating with no detected faults.
 On	 Off	Active Diagnostic	If the warning lamp comes on during engine operation, this indicates that an active diagnostic code (an electrical fault) is present.	The engine is operating normally but there are one or more faults with the electronic management system for the engine. (SDG - Level 1)
 Flash	 Off	Derate.	If the warning lamp flashes during engine operation, this indicates that the current engine operating condition is sufficiently serious in order to cause an engine derate.	The engine is operating but there is one or more active diagnostic or event codes that have initiated an engine derate. (SDG - Level 2)
 Flash	 On	Shutdown	If the amber warning lamp is flashing and the red shutdown lamp comes on during engine operation, this indicates one of the following conditions. If “shutdown” enabled After a short period of time, the engine will shut down. If “shutdown” is NOT enabled The Engine has reached a critical point of operation and needs to be shutdown by the operator.	The engine is either shutdown or an engine shutdown is imminent. One or more monitored engine parameters have exceeded the limit for an engine shutdown. This pattern of lamps can be caused by the detection of a serious active diagnostic code. (SDG - Level 3)
 Flash	 Off	Flash Codes	TBD	TBD

Table 11.6 Basic engine Lamp Logic

11.3.2.1 C4.4 and C6.6 Engine / Aftertreatment Lamp Logic









Warning Lamp (Also known as Alert Lamp)	Shutdown Lamp/buzzer (Also known as Action Lamp)	State Description
 On	 On	Lamp Check
 Off	 Off	No Faults Present.
 Flash	 Off	DPF Above 100% Soot Loading due to regeneration system malfunction (covers loss of catalytic activity (sulphation), high soot load, inability to achieve regeneration conditions, etc)
 Flash	 On	DPF Above 120% Soot Loading due to regeneration system malfunction (covers loss of catalytic activity (sulphation), high soot load, inability to achieve regeneration conditions, etc) engine shutdown

Table 11.7 C4.4 & C6.6 Lamp Logic

11.3.2.2 C7.1 Engine / Aftertreatment Lamp Logic




































Warning Lamp (Also known as Alert Lamp)	Shutdown Lamp/buzzer (Also known as Action Lamp)	Regeneration Active (Also known as HEST Lamp)	Diesel Particulate Filter	DPF Disabled	State Description
 On	 On	 On	 On	 On	Lamp Check
 Off	 Off	 Off	 Off	 Off	No Faults Present.
 Off	 Off	 On	 Off	 Off	High Exhaust Temperature On During Active Regeneration if machine stationary Or during cool down immediately following an active regeneration until DPF out temperature falls below 450°C, or machine goes back to work.
 Off	 Off	 Off	 On	 Off	DPF Above 80% Soot loading, warns the operator that regeneration is required
 Off	 Off	 Off	 Off	 On	Regeneration disabled by operator or machine
 Flash	 Off	 Off	 On	 Off	DPF Above 100% Soot Loading, engine power derates dependent on soot load, regeneration required
 Flash	 On	 Off	 On	 Off	DPF Above 116% Soot Loading, engine shutdown

Table 11.8 C7.1 Engine Lamp Logic

11.3.3 Engine Shutdown Lamp

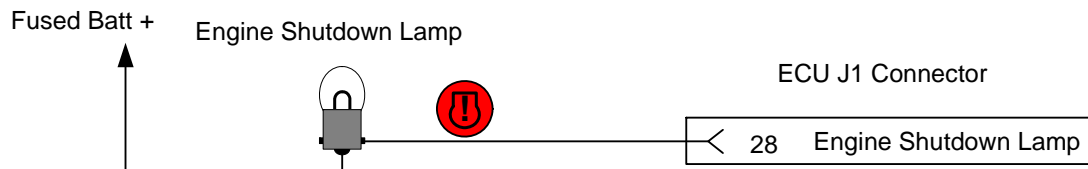
11.3.3.1 Engine Stop Lamp Operation

The engine shutdown lamp is operated upon the engine entering a operating / fault condition which requires the engine to shutdown for control / safety reasons. If the engine monitoring system is configured to a level 3 (warn, derate and shutdown) then a number of these conditions are configurable within the engine monitoring system. Some parameters are non configurable however such as DPF soot loading exceeds 116%. Further details on these parameters can be found in section 12.

11.3.3.2 Engine Stop Lamp Configuration

The engine stop lamp is a mandatory fit item unless a this function is displayed via a data link driven device. Once installed the lamp can also be operated via the service tool using the ECM output override test.

11.3.3.3 Engine Stop Lamp Installation



11.3.4 Engine Warning Lamp

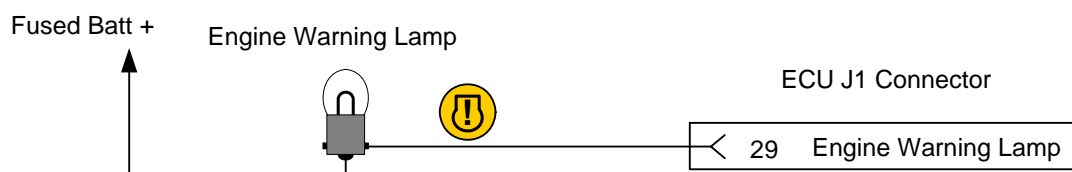
11.3.4.1 Engine Warning Lamp Operation

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

11.3.4.2 Engine Warning Lamp Configuration

The engine warning lamp is a mandatory fit item unless displayed via a data link driven device. Once installed the lamp can also be operated via the service tool using the ECM output override test.

11.3.4.3 Engine Warning Lamp Installation



11.3.5 Wait to Start Lamp

11.3.5.1 Wait To Start Lamp Operation

All engines are provided with a wait to start engine lamp driver within the ECM. The lamp is a mandatory fit component, which is used to indicate to the operator that the engine is ready to start. The lamp 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 lamp operation please refer to section 10 glow plug operation.

11.3.5.2 Wait To Start Lamp Configuration

There is no CAT ET configuration required for the wait to start lamp. Once installed the lamp can also be operated via the service tool using the ECM output override test.

11.3.5.3 Wait To Start Lamp Installation



11.3.6 Low Oil Pressure Lamp

11.3.6.1 Low Oil Pressure Lamp Operation

The low engine oil pressure lamp 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. Details of the threshold levels are given in section 12 of this document. The lamp will illuminate once this threshold is exceeded and remain on until the pressure has stabilized again above the threshold level.

11.3.6.2 Low Oil Pressure Lamp Configuration

The Threshold level for the lamp activation are set within the engine software and are non configurable. There is no configuration required within the service tool. However once installed the lamp output can be overridden by the service tool to validate its operation.

11.3.6.3 Low Oil Pressure Lamp Installation



11.3.7 DPF Lamp

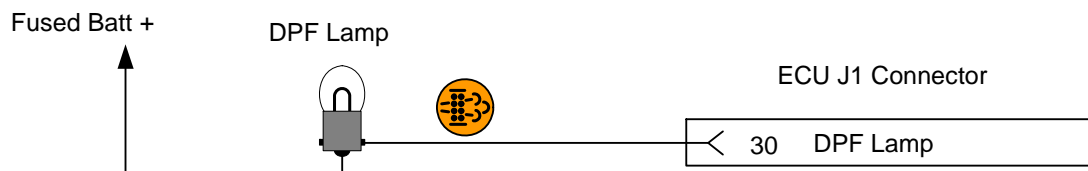
11.3.7.1 DPF Lamp Operation

The engine DPF lamp is only required for the C7.1 engine range and is used to indicate that the engine system DPF has reached a soot loading point at which a regeneration is required (roughly 80% full). The lamp will remain activated until a regeneration is completed.

11.3.7.2 DPF Lamp Configuration

There is no CAT ET configuration required for the DPF lamp. Once installed the lamp can also be operated via the service tool using the ECM output override test.

11.3.7.3 DPF Lamp Installation



11.3.8 HEST (High Exhaust System Temperature) Lamp

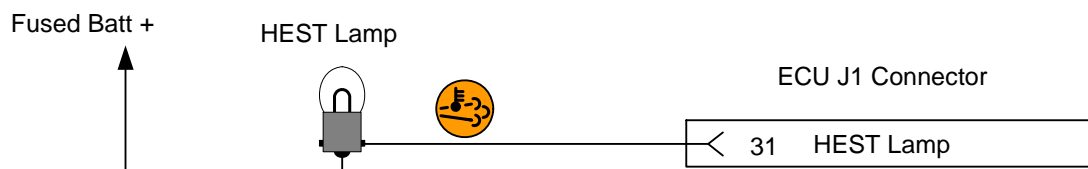
11.3.8.1 HEST Lamp Operation

The HEST lamp (High Exhaust System Temperature) is activated when the exhaust system temperature exceeds 450°C during a regeneration event. The lamp will remain illuminated until the exhaust temperature falls below this threshold. The HEST lamp is only required for the C7.1 engine family. Note the HEST lamp will not operate if the engine exhaust temperature exceeds 450°C during normal operation.

11.3.8.2 HEST Lamp Configuration

There is no CAT ET configuration required for the HEST lamp. Once installed the lamp can also be operated via the service tool using the ECM output override test.

11.3.8.3 HEST Lamp Installation



11.3.9 DPF Regeneration Disable lamp

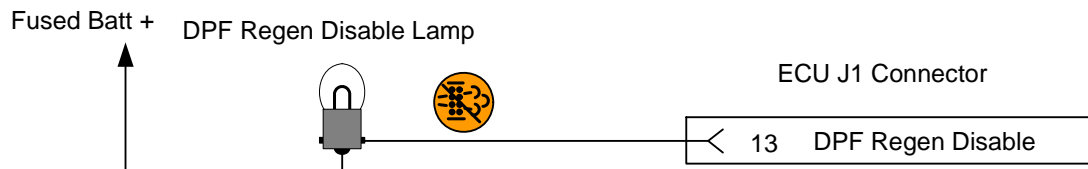
11.3.9.1 Regeneration Disable Lamp Operation

The regeneration disable lamp is only required for the C7.1 engines and is used to indicate to the operator that the automatic regeneration function has been disabled / inhibited by the aftertreatment interface switch within the application. For more information on the operation of this switch please see section 14.2.2 of this document.

11.3.9.2 Regeneration Disable Lamp Configuration

There is no CAT ET configuration required for the regeneration disabled lamp. Once installed the lamp can also be operated via the service tool using the ECM output override test.

11.3.9.3 Regeneration Disable Lamp Installation



11.4 Activation of J1939 Indicators

The table shown below details the J1939 PGN and SPN's provided for use with an integrated J1939 machine system.

Lamp	PGN	Description	SPN	Description
Engine warning	FECA (65226)	Active Diagnostics Trouble codes	N/A Byte 1 & 2 of DM1	Used to display active engine diagnostics
Engine shutdown	FECA (65226)	Active Diagnostics Trouble codes	N/A Byte 1 & 2 of DM1	Used to indicate engine shutdown or recommend engine shutdown
Engine Protect	FECA (65226)	Active Diagnostics Trouble codes	N/A Byte 1 & 2 of DM1	Used to display active engine events
Engine Warning Lamp flash	FECA (65226)	Active Diagnostics Trouble codes	3040	Used to display active engine diagnostics
Engine Protect Lamp Flash	FECA (65226)	Active Diagnostics Trouble codes	3041	Used to display active engine events
Wait to start	FEE4 (65252)	Shutdown	1081	Wait to start lamp
Low Oil Pressure	Not available*			
Maintenance Due	Not available*			
DPF	FD7C (64892)	Diesel Particulate filter Control 1	3697	DPF Lamp Command
HEST			3698	HEST Lamp Command
Regeneration disabled			3703	DPF inhibited due to inhibit switch

Table 11.9 J1939 Indicator SPN's

* Low oil pressure and maintenance due indicators are not available via the J1939 network. To activate the oil pressure lamp the corresponding DM1 fault code should be used (100-1). The maintenance due function requires the machine to control the indicator activation.

12.0 Engine and Aftertreatment Monitoring System

Both the engine and aftertreatment are fitted with a number of different sensing devices, which feed back signals to the engine ECM. These feed back signals are not only used to control the engine performance but in some cases provide critical information about the health of the engine and aftertreatment system as well as the installation. Engine sensors that provide such information include the Coolant temperature sensor and the Oil pressure sensor. To take advantage of these signals the engine ECM is configured to operate using a pre-defined monitoring system

12.1 General Information

The engine monitoring system includes two parts. The first part can be configured via the Monitoring Mode screen in the service tool and shows the individual parameters being monitored, the levels of severity that can be activated and the trip points at which these warnings will activate. In some cases these parameters can be changed by the user.

The second part is configured through the main configuration screen and is where the engines response to the severity level can be set. If a level 2 (moderate severity) becomes active then a derate of the engines power can be enabled. If a level 3 warning (most severe) becomes active then an engine shut down can be enabled. In both cases these configurations can be disabled so regardless of warning level the engine will continue to operate until it is unable to do so.

12.1.1 Engine Monitoring Level

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;

- Warn (Always active)
- Derate
- Shutdown

Engine warning is always active and can not be disabled. The derate and shutdown parameters can however be enabled or disabled using the service tool as shown below in table 12.1.

Monitoring Mode - ET Configurable Parameters

Monitoring Mode (listed under Miscellaneous in ET)		
ET Description	Range or Option	Description
Monitoring Mode Shutdowns	Disabled/Enabled	Switches on or off the shutdown feature
Monitoring Mode Derates	Enabled/Enabled	Switches on/off the derate feature

Table 12.1 Monitoring Mode Configuration

12.1.1.1 Warning

The Engine Monitoring warning is always active and can not 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 ECM and the appropriate lamp driver is activated.

12.1.1.2 De-rate

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 ECM 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.

12.1.1.3 Shutdown

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 ECM 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 upto three possible severity levels for each of the configurable system parameters. These levels are defined as severity level 1 (least server), 2 (moderate severity) and 3 (most server). 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 levels 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 can not 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.

The table below details the Monitoring system parameters that are available for configuration by the customer. The table is split into two sections, the first showing those parameters which offer both a threshold configuration and an engine action configuration, and those which offer an engine action configuration only.

Monitoring System Parameters	Configurable Threshold	Severity Level		
		Level 1	Level 2	Level 3
Engine Coolant Temperature	Yes	Yes	Yes	Yes
Engine Over speed	Yes	Yes	No	Yes
Intake Manifold Air Temperature	Yes	Yes	Yes	No
Parameters which have Fixed Factory Set Thresholds				
Oil Pressure	No	Yes	No	Yes

Table 12.2 Available Engine Monitoring System Parameters

It should be noted that when engine shutdowns are enabled the following system response is true.

- Severity Level 1 (least server) = Engine warning
- Severity Level 2 (moderate severity) = Engine Derate
- Severity Level 3 (most server) = Engine Shutdown

12.1.3 Monitoring System Example

Customer requires the engine to warn the operator and de-rate the engine (where applicable) upon the engine measuring a monitoring system parameter above a defined threshold. This threshold in some cases such as the Engine Coolant Temperature is configurable between a trip threshold min and max value.

Using the service tool Engine de-rates are activated as shown below (warnings are always active).

Miscellaneous			
Monitoring Mode Shutdowns	Disabled		0
Monitoring Mode Derates	Enabled		0

The severity levels for the coolant temperature monitoring can be viewed using the service tool via the Monitoring Mode screen. In this case level 1, 2 and 3 are available and programmed.

High Engine Coolant Temperature			
Least Severe (1)	Always On	113 Deg C	10 Sec
Moderate Severity (2)	Always On	114 Deg C	10 Sec
Most Severe (3)	Always On	118 Deg C	10 Sec

Default values are;

- Level 1 = 108°C
- Level 2 = 110°C
- Level 3 = 114°C

Engine is now operated and the engine coolant temperature rises to a value above the severity level 1 threshold.

- Engine action = Event code E361-1 is raised and the engine warning lamp is activated. Engine ECM stores the Event code.

Engine coolant temperature rises to a value above the severity level 2 threshold.

- Engine action = Event code E361-2 is raised and the engine warning lamp is activated. The engine now begins a derate according to the coolant temperature derate map.

Engine coolant temperature rises to a value above the severity level 3 threshold.

- Engine action = Event code E361-3 is raised and the engine warning lamp is activated. The engine stores the event code but does not begin to shutdown due to the engine monitoring system shutdowns being disabled.

12.2 Engine Monitoring & Protection

The following section provides details on all engine and aftertreatment sensors, which are supplied as part of the engine system. All of the components / parameters shown here offer some level of configurability and / or are effected by the configuration of the engine monitoring system levels i.e. warn, derate and shutdown.

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.

Parameter	Temp °C	De-rate %
Severity L1	108	0
Severity L2	110	0
	111	25
	112	50
	113	75
Severity L3	114	100
	115	100

Table 12.3 Coolant Temperature Monitoring Mode Derate Operation

Once the engine ECM 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

The high engine coolant temperature threshold settings are available for adjustment within CAT ET for all monitoring system severity levels. There are however upper and lower limits outside of which the thresholds can not be set these are shown below

Monitoring Mode Level	Trip Threshold Min	Trip Threshold Max
Severity L1	85°C	108°C
Severity L2	85°C	110°C
Severity L3	85°C	114°C

Table 12.5 Coolant Temperature Monitoring Mode Configuration

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 ECM to protect the engine from operating without sufficient oil pressure, as low oil pressure could lead to catastrophic engine failure. The minimum oil pressure is defined as a function of engine speed, which is factory set and non configurable. Once these values are tripped 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	Engine Speed (rpm)	Trigger Pressure (kPa)
Severity L1	700	100
	900	150
	1000	175
	1200	200
	1400	250
Severity L3	700	70
	900	100
	1000	100

	1200	100
	1400	100

Table 12.6 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 L1	100	17	E360-1	Warning Lamp Only
		Severity L3	100	01	E360-3	Engine Shutdown

Table 12.7 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 can not 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. The values shown below are factory set values, where the max temperature is set to 129°C. This value is non configurable.

Parameter	Temp °C	De-rate %
Severity L1	123	0
Severity L2	125	0
	126	20
	127	30
	128	40
	129	50

Table 12.8 Intake Manifold Temperature Monitoring Mode Derate Operation

Once the engine ECM 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	E539-3	Engine Shutdown

Table 12.9 Intake Manifold Temperature Monitoring

12.2.3.2 Intake Manifold Temperature Monitoring Mode Configuration

Using the CAT ET service tool the following parameters can be configured.

The Maximum Intake manifold temperature limit is set within the ECM software and can not be adjusted however the trigger points for severity L1 and severity L2 functions can be configured below this value within the following range shown below.

Engine Range	Monitoring Mode Level	Trip Threshold Min	Trip Threshold Max
All	Severity L1	100°C	123°C
All	Severity L2	100°C	125°C

Table 12.10 Intake Manifold Temperature Monitoring Mode Configuration

12.2.3.3 Intake Manifold Temperature Monitoring Mode Installation

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

12.2.4 Engine Overspeed

12.2.4.1 Engine Overspeed Monitoring Mode Operation

The engine ECM will automatically monitor engine speed to protect the engine from exceeding a pre-defined maximum value. This function is employed to protect both the engine and the drivetrain components from high engine speeds. The Engine Overspeed function can be configured at both Severity L1 and Severity L3.

Once the engine ECM detects that the engine speed 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)
Engine Overspeed	Engine Speed	Severity L1	190	15	E362-1	Warning Lamp Only
Engine Overspeed	Engine Speed	Severity L3	190	00	E362-3	Engine Shutdown

Table 12.11 engine Overspeed Monitoring

12.2.4.2 Engine Overspeed Monitoring Mode Configuration

Using the CAT ET service tool the following parameters can be configured.

The Maximum engine overspeed limit is set within the ECM software and can not be adjusted however the trigger points for both Severity L1 and Severity L3 can be configured below this value within the following range shown below.

Engine Range	Trip Threshold Min	Trip Threshold Max
All	2600rpm	3000rpm

Table 12.12 engine Overspeed Monitoring Mode Configuration

12.2.4.3 Engine Overspeed Monitoring Mode Installation

No installation is required for the engine overspeed monitoring function.

12.3 Aftertreatment Monitoring & Protection

All details regarding the aftertreatment system and the engines response to DPF soot loading are cover in sections 11 and 14 of this document. For more information regarding aftertreatment system fault codes please see appendix 20.4.

13.0 Monitored Inputs for Customer Fitted Sensors

This section covers the optional switches and sensors available for the customer to install / connect. All optional switches and sensors are available within the Caterpillar parts system and available for order. Some of the switches and sensors require the customer to both install them and provide the wiring harness connection to the engine ECM. Others are factory fitted and require the customer to provide a connection to the ECM only. It should also be noted that not all switches and sensors are available across the product range, these components are highlighted in table 13.1.

Component	Engine Range	Part No	Customer Fit	Component Type
Air Intake Restriction	All	296-2735	Yes	Switch
Engine Coolant Level	All	331-7352	Yes	Switch
Water In Fuel	All (Mandatory)	350-6604	No Mandatory	Switch
Oil Level	C6.6 / C7.1	213-0677	No	Switch
Fuel Filter Differential Pressure	All	350-5719	No	Switch
Auxiliary Temperature	All	145-7028	Yes	Active Sensor
Auxiliary Pressure	All	320-3064	Yes	Passive Sensor

Table 13.1 Customer Installation Monitored Inputs

Each switch / sensor can be individually configured to provide the desired level of monitoring via the standard monitoring system parameters as described in section 12. It should be noted that not all sensors and switches offer all 3 severity levels of monitoring as shown in table 13.2.

Component	Input	State	De bounce Time (secs)	Severity Level Support			J1 Pin Assignment
				L1	L2	L3	
Air Intake Restriction	SW Batt+	Normally Open	30	Yes	Yes	No	J1-64
Engine Coolant Level Low	SWG	Normally Closed	30	Yes	No	Yes	J1-49
Water in Fuel	Active Analogue	Normally Open	30	Yes	No	No	J1-35
Auxiliary Temp	Passive Analogue	N/A	Configurable 1 to 120sec	Yes	Yes	Yes	J1-16
Auxiliary Pressure	Active Analogue	N/A	Configurable 1 to 120sec	Yes	Yes	Yes	J1-15
Oil Level	Active Analogue	Normally Open	N/A	Yes	No	No	J1-47
Fuel Filter Differential Pressure	Active Analogue	Normally Closed	60Sec	Yes	Yes	No	J1-24

Table 13.2 Monitored Inputs Detailed Support

13.1 Air Filter Service Indicator – Air Intake Restriction Switch

13.1.1 Air Intake 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 is configurable from Normally open to normally closed depending upon the type of switch selected.

Upon indication of a blocked intake the ECM will raise a severity level and associated event code (as shown below in table 13.3).

Service Tool Description	J1939 description	Status	SPN (J1939)	FMI (J1939)	Event Code	Engine Action (if enabled)
Air Intake Restriction Switch	Engine Air Filter 1	Severity L1	107	15	E172-1	Warning Lamp Only
	Differential Pressure	Severity L2	N/A	N/A	N/A	N/A
		Severity L3	N/A	N/A	N/A	N/A

Table 13.3 Air Filter Restriction Switch Monitoring

13.1.2 Air Intake Restriction Switch Configuration

To enable the operation of this switch the configuration of the Air Filter Restriction switch must be altered within the service tool from 'Not Installed' to 'Installed'. Once installed the following configuration alteration can be made.

The polarity of the switch can be altered from normally closed to normally open.

Note: All Air Filter Restriction switches supplied by CAT are normally closed.

13.1.3 Air Intake Restriction Switch Installation

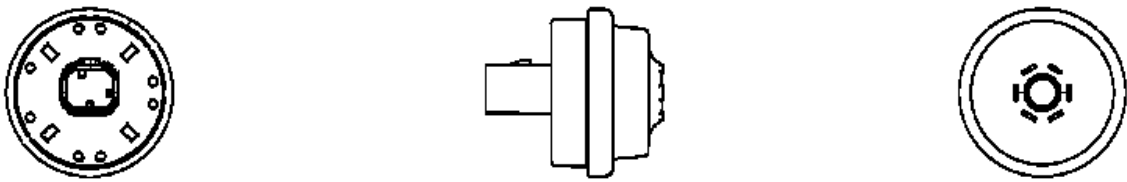


Figure 13.1 Air Filter Restriction Switch 296-2735

Whilst it is possible for the customer to source their own air filter restriction switch, CAT recommend and supply the switch shown in figure 13.1. This switch has been validated and approved for use with the C4.4 to C7.1 product ranges. All Part numbers and connectors required to install this component are shown in table 13.4.

REQUIRED PARTS		
CAT Part Number	Description	Qty
296-2735	Air Filter Restriction Switch	1
230-4011	Connector Plug Kit	1
9X-3402	Connector Socket (Gold)	3

Table 13.4 Air Filter Restriction Switch Installation Parts List

The Air intake restriction switch is a 2 wire switch which requires connection to the switched battery + and pin 64 of the ECM J1 connector as shown in figure 13.2.



Figure 13.2 Air Intake Restriction Switch Installation wiring

13.2 Coolant Level Switch

13.2.1 Coolant Level Switch Operation

The coolant level switch enables the ECM to monitor the coolant level within the radiator or expansion tank to protect the engine against operation with low or no coolant. The switch is to be mounted so that it is immersed during all normal operating conditions. If the switch is not fully immersed then the ECM will take action as configured within the engine monitoring system. The engine must have been running for 60 seconds before a fault condition can be triggered. The coolant level switch (part number 331-7352) is a normally closed switch, however the polarity of the ECM connection can be modified within the service tool to normally open in the event of the customer fitting a third party switch.

The coolant level switch supports the activation of the severity levels shown in table 13.5. Table 13.5 also shows the possible engine reactions to these severity levels if configured within the engine software using the service tool, i.e. derate and shutdown options.

Service Tool Description	J1939 description	Status	SPN (J1939)	FMI (J1939)	Event Code	Engine Action (If enabled)
Coolant Level	Engine Coolant Level	Severity L1	111	15	E2143-1	Warning Lamp Only
		Severity L2	111	16	E2143-2	Engine % derate
		Severity L3	111	01	E2143-3	Engine Shutdown

Table 13.5 Coolant Level Switch Monitoring

13.2.2 Coolant Level Switch Configuration

To enable the operation of this switch the configuration of the coolant level switch must be altered within the service tool from 'Not Installed' to 'Installed'. Once installed the following configuration alterations can be made

The polarity of the switch can be altered from normally closed to normally open.

In addition the time delay to 'take action' can also be set using the service tool. The configurable range and the default set points are shown in table 13.6.

Note: The time delay for Severity L1, L2 and L3 are triggered simultaneously. If a delay between these levels is required then the associated activation times must be increased. For example if the Severity L1 delay is 10sec, L2 delay 20sec and the L3 delay 30sec and engine derates and shutdowns are enabled, an L2 event and the associated derate % will occur 10 seconds after the L1 event and the L3 event and associated shutdown will occur 10 seconds after the L2 event. As a default the delay time for all functions is 10sec.

Low Coolant Level Monitoring Configuration					
Status	Default Value	Time Delay (sec)		Set Points	
		Range	Default	Range	Default
Severity L1	On	1 to 120sec	10	N/A	N/A
Severity L2	On	1 to 120sec	10		
Severity L3	Off	1 to 120sec	10		

Table 13.6 Low Coolant Level Monitoring Mode Operation Configuration

13.2.3 Coolant Level Switch Installation

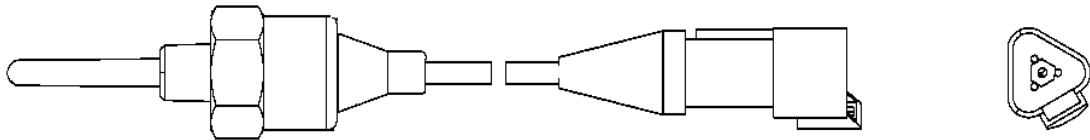


Figure 13.3 Coolant Level Switch 331-7352

To ensure the correct operation of the engine monitoring system for the coolant level switch the Caterpillar approved part shown in table 13.6 must be used. Table 13.6 also provides the part numbers required to connect to the coolant level switch.

REQUIRED PARTS		
CAT Part Number	Description	Qty
331-7352	Coolant Level Switch	1
155-2260	Connector Plug Kit	1
155-2267	Plug	1
155-2276	Wedge Lock	1
9X-3402	Connector Socket (Gold)	3

Table 13.6 Coolant level switch Installation Parts List

The coolant level switch is a three wire switch which requires connection to the ECM J1 analogue 5V sensor supply and ground pins as shown in figure 13.4

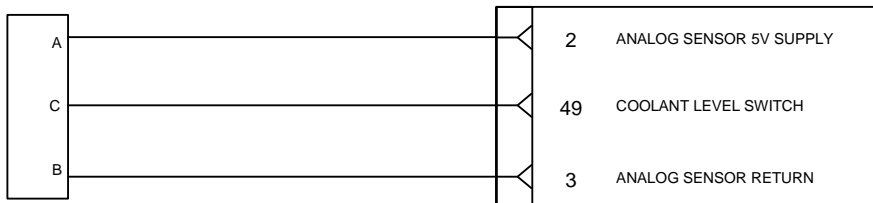


Figure 13.4 Coolant Level Switch Installation Wiring

13.3 Water In Fuel Trap Switch

13.3.1 Water In Fuel Trap 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). The WIF switch is supplied assembled to all engines and is a mandatory installation item. The electrical connection of the switch to the engine ECM is the responsibility of the customer and should form part of the machine wiring harness connection to the ECM J1 connector.

Service Tool Description	J1939 description	Status	SPN (J1939)	FMI (J1939)	Event Code	Engine Action (If enabled)
Water in Fuel switch	Water In Fuel Indicator	Severity L1	97	15	E232-1	Warning Lamp Only
		Severity L2	N/A	N/A	N/A	N/A
		Severity L3	N/A	N/A	N/A	N/A

Table 13.7 Water In Fuel Trap Monitoring

13.3.2 Water In Fuel Trap Switch Configuration

The water in fuel switch is a mandatory item, which is always installed. No configuration is required.

13.3.3 Water In Fuel Trap Switch Installation

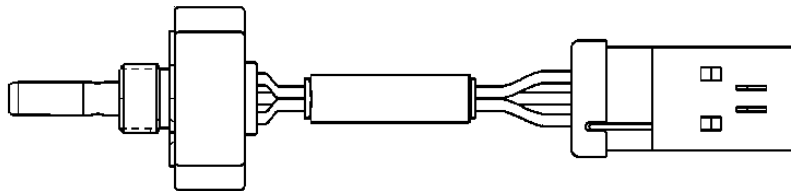


Figure 13.5 Water In Fuel Switch 350-6604

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 ECM J1 connector. The part numbers required to connect the switch to the ECM are shown in table 13.8.

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.

REQUIRED PARTS		
CAT Part Number	Description	Qty
281-8803	Plug	1
9X-3402	Connector Socket (Gold)	3

Table 13.8 Water In Fuel Switch Installation Parts List

The WIF switch is a three wire switch which requires connection to the ECM J1 connector analogue 8V supply and ground pins as shown in figure 13.6.

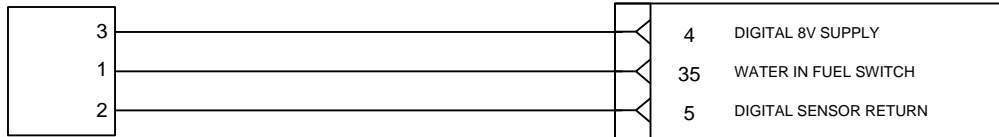


Figure 13.6 Water In Fuel Installation Wiring

13.4 Auxiliary Temperature Sensor

13.4.1 Auxiliary Temperature Sensor Operation

The auxiliary temperature sensor feature is provided so the engine can monitor any external temperature and provide that temperature information on the J1939 CAN data link. The ECM can also protect the system from excessive temperature by raising the severity levels as configured within the engine monitoring system as shown in table 13.9. As with all engine monitoring system parameters the engine ECM will raise an event code once a severity level threshold is exceeded.

Service Tool Description	J1939 description	Status	SPN (J1939)	FMI (J1939)	Event Code	Engine Action (If enabled)
Auxiliary Temperature	Auxiliary Temperature #1	Severity L1	441	15	445-1	Warning Lamp Only
		Severity L2	441	16	445-2	Engine % Derate
		Severity L3	441	00	445-3	Engine Shutdown

Table 13.9 Auxiliary Temperature Sensor Monitoring

When enabled the engine ECM is able to respond with either an engine derate or shutdown upon receiving a temperature value, which is above a pre defined threshold.

13.4.2 Auxiliary Temperature Sensor Configuration

The default condition for this sensor option is 'uninstalled'. Before any configuration of the monitoring system for the temperature sensor can take place this status must be changed using the service tool to 'Installed'. This option can be found on the main configuration screen within the service tool. Once 'Installed' the following parameters can be configured;

- Time delay or 'debounce' time before the ECM acts upon the inputted temperature signal.
- The Aux Temperature sensor severity level set points can be set.

Table 13.10 Provides details on each of the configurable elements, their configurable range and default settings.

High Auxiliary Temperature Monitoring Configuration					
Status	Default Value	Delay Time (sec)		Set Points	
		Range	Default	Range	Default
Severity L1	On If Installed	1 to 120sec	4	0°C to 140°C	105°C
Severity L2	Off	1 to 120sec	4		106°C
Severity L3	Off	1 to 120sec	4		107°C

Table 13.10 Auxiliary Temperature Monitoring Mode Operation Configuration

13.4.3 Auxiliary temperature Sensor Installation

The Caterpillar auxiliary temperature sensor part number must be used in order to accurately measure temperature. Third party sensors will not be compatible with the hardware and software. The CAT auxiliary temperature sensor is a 0-5V passive analogue sensor with an operating range of -30 to 140°C (-22 to 248°F). The auxiliary temperature sensor is shown in figure 13.7 and table 13.11 indicates the components required to connect to the sensor.

NOTE: Do not splice the sensor signal wire for input to third party devices.

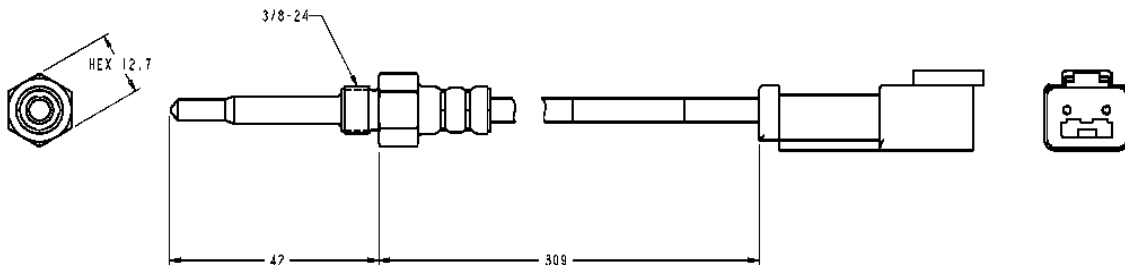


Figure 13.7 Auxiliary Temperature Sensor 145-7028

REQUIRED PARTS		
CAT Part Number	Description	Qty
145-7028	Temperature Sensor (Auxiliary)	1
155-2270	Connector Plug Kit	1
155-2269	Connector Plug	1
155-2261	Wedge Lock	1
9X-3402	Connector Socket (Gold)	2

Table 13.11 Auxiliary Temperature Sensor Installation Parts List

The following harness design and routing guidelines are recommended for best accuracy of passive analogue devices:

- Use of gold sockets is strongly recommended.
- Sensor wires should be shielded or they should be routed in a separate harness bundle from switching currents that are greater than 100mA.
- Maximum allowable wire length from the ECM to the sensor is 3.65m (12ft).
- Preferred wire gauge is 16AWG (1.5mm²).
- The maximum allowable number of connector junctions is two.

As this sensor incorporates a pigtail harness the following installation instructions must also be observed:

The connector interface should never be tied directly to a vibrating member. The pigtail wire lead should be tied down on only one side of the connector interface. It is recommended that one of the following locations are selected, midpoint on the sensor pigtail or 150mm from the connector on the harness side.

The Auxiliary temperature sensor is a 2 wire sensor and figure 13.8 shows the wiring required to connect the sensor to the engine ECM J1 connector.

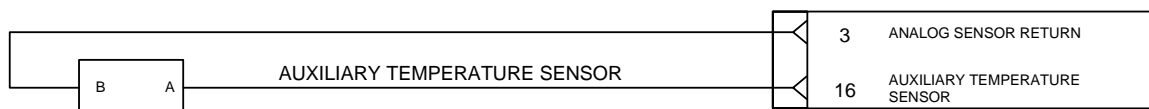


Figure 13.8 Auxiliary Temperature Sensor Installation Wiring

13.5 Auxiliary Pressure Sensor

13.5.1 Auxiliary Pressure Sensor Operation

The auxiliary pressure sensor feature is provided so the engine can monitor any external pressure and provide that pressure information via the J1939 CAN data link. The ECM can also protect the system in the event of excessive pressure by taking any action configured within the engine monitoring system as shown below in table 13.12

Service Tool Description	J1939 description	Status	SPN (J1939)	FMI (J1939)	Event Code	Engine Action (If enabled)
Auxiliary Pressure	Auxiliary Pressure #1	Severity L1	1387	15	443-1	Warning Lamp Only
		Severity L2	1387	16	443-2	Engine % Derate
		Severity L3	1387	00	443-3	Engine Shutdown

Table 13.12 Auxiliary Pressure Sensor Monitoring

13.5.2 Auxiliary Pressure Sensor Configuration

The default condition for this sensor option is 'uninstalled'. Before any configuration of the monitoring system for the pressure sensor can take place this status must be changed using the service tool to 'Installed'. This option can be found on the main configuration screen within the service tool. Once 'Installed' the following parameters can be configured;

- Time delay or 'debounce' time before the ECM acts upon the inputted pressure signal.
- The Aux pressure sensor severity level set points can be set.

Table 13.13 Provides details on each of the configurable elements, there configurable range and default settings.

High Auxiliary Pressure Monitoring Configuration					
Status	Default Value	Delay Time (sec)		Set Points	
		Range	Default	Range	Default
Severity L1	On If Installed	1 to 120sec	4	3150kPa	1500kPa
Severity L2	Off	1 to 120sec	3		
Severity L3	Off	1 to 120sec	3		

Table 13.13 Auxiliary Pressure Sensor Monitoring Mode Operation Configuration

13.5.3 Auxiliary pressure Sensor Installation

The Caterpillar auxiliary pressure sensor part number must be used in order to accurately measure pressure. Third party sensors will not be compatible with the hardware and software. The CAT auxiliary pressure sensor is an analogue sensor with an operating range of 0 to 3150kPa (0 to 442 psi).

Note: Do not splice the sensor signal wire for input to third party devices.

This sensor as with the auxiliary temperature sensor incorporates a pigtail harness as part of the sensor assembly. Special installation considerations for this type of sensor are given in section 13.4.3 of this document. An example of the auxiliary pressure sensor and the length of the pigtail is shown in figure 13.9 and the components required to connect the sensor to the engine ECM are shown in table 13.14

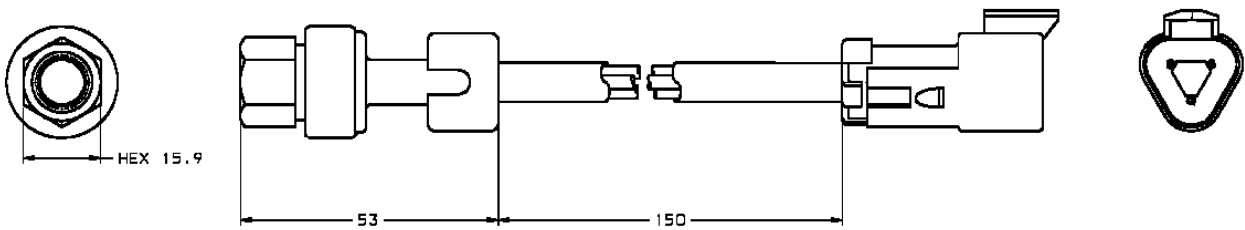


Figure 13.9 Auxiliary Pressure Sensor 161-9932

REQUIRED PARTS		
CAT Part Number	Description	Qty
320-3064	Pressure Sensor (Auxiliary)	1
230-4013	Connector Plug	1
9X-3402	Connector Socket (Gold)	3

Table 13.14 Auxiliary Pressure Sensor Installation Parts List

The auxiliary pressure sensor is a three wire active sensor which requires connection to the ECM J1 analogue sensor 5V supply and ground pins as shown in figure 13.10.

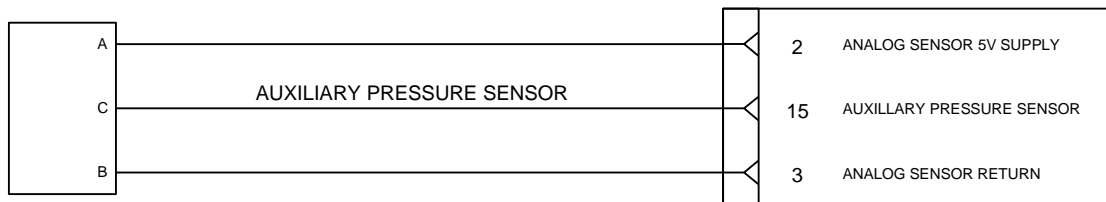


Figure 13.10 Auxiliary Pressure Sensor Installation Wiring

13.6 Oil Level Switch

This option is only available with selected sump options, for more information regarding product compatibility please refer to the relevant product Engine Sales Manual.

13.6.1 Oil Level Switch Operation

The oil level switch is an optional fit switch, which is used to determine the engine sump oil level. The switch is installed to indicate to the operator the current level of the oil within the sump. In the event of the low oil level switch being activated a severity L1 will be raised along with the associated event code and the engine warning lamp, as shown below in table 13.15. The Oil Level switch is configured to operate only while the engine speed is equal to 0rpm. This is to ensure that the oil level readings are not affected by machine operation and give a true engine oil level reading.

Service Tool Description	J1939 description	Status	SPN (J1939)	FMI (J1939)	Event Code	Engine Action (If enabled)
Oil Level	Engine Oil Level	Severity L1	98	15		Warning Lamp Only
		Severity L2	N/A	N/A	N/A	N/A
		Severity L3	N/A	N/A	N/A	N/A

Table 13.15 Oil Level Switch Monitoring

13.6.2 Oil Level Switch Configuration

The default condition for this sensor option is 'uninstalled'. Before any configuration of the monitoring system for the pressure sensor can take place this status must be changed using the service tool to 'Installed'. This option can be found on the main configuration screen within the service tool.

13.6.3 Oil Level Switch Installation

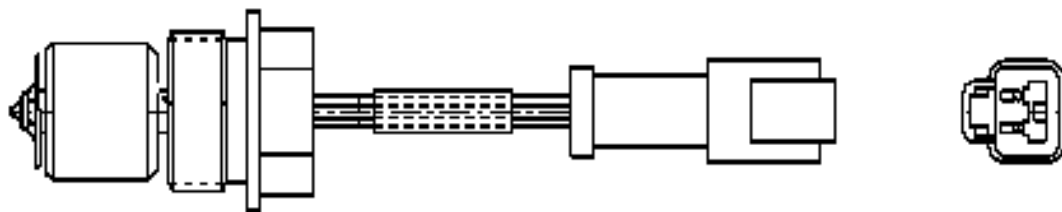


Figure 13.11 Oil Level Switch 213-0677

To ensure the correct operation of the oil level feature the Caterpillar recommended part must be used. An example of the recommended switch is shown in figure 13.11 and the parts required to connect the switch to the engine ECM are detailed within table 13.16.

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.

REQUIRED PARTS		
Cat Part Number	Description	Qty
213-0677	Oil Level Switch	1
155-2270	Plug Connector Kit	1
155-2269	Plug Connector	1
155-2261	Wedge Lock	1
9X-3402	Connector Socket (Gold)	2

Table 13.16 Oil Level Switch Installation Parts List

The oil level switch is a 2 wire switch and the wire required to connect the switch to the engine ECM J1 connector are shown in figure 13.12.

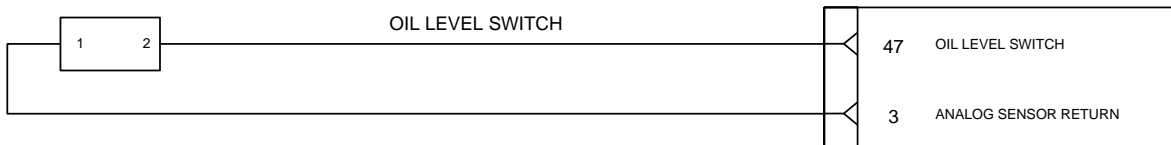


Figure 13.12 Oil Level Switch Installation Wiring

13.7 Fuel filter Differential Pressure Switch

Please note that this switch, where required is fitted by Caterpillar. The customer however is responsible for its connection to the ECM via the machine wiring harness connection to the ECM J1 connector.

13.7.1 Fuel Filter Differential Pressure Switch Operation

The fuel filter differential pressure sensor is part of the secondary fuel filter assembly and measures the pressure difference across the filter element to detect clogging of the filter and warn the operator that a change of filter is required. The sensor is supplied as part of the engine assembly where required and requires connection to the ECM J1 connector by the customer. The switch is configured to produce a severity level 1 and 2 as shown in table 13.17. If the engine monitoring system derates are enabled and a level 2 severity event code is raised then the engine will latch into the derate condition until an ignition key cycle takes place. There are a number of conditions, which must be achieved before the fuel filter differential pressure switch monitoring system will activate a severity L1 or L2 to prevent incorrect switch activation and these conditions are listed below.

- Start-up delay of 60seconds.
- Engine speed must be 700 rpm or greater.
- Fuel flow rate must be 10 lpm or greater.

Service Tool Description	J1939 description	Status	SPN (J1939)	FMI (J1939)	Event Code	Engine Action (If enabled)
Fuel Filter Differential Pressure	Engine Fuel Filter Differential Pressure	Severity L1	95	15	390-1	Warning Lamp Only
		Severity L2	95	16	390-2	Engine % derate
		Severity L3	N/A	N/A	N/A	N/A

Table 13.17 Fuel Filter Differential Pressure Switch Monitoring

13.7.2 Fuel Filter Differential Pressure Switch Configuration

The fuel filter differential pressure switch is a customer selectable option and is therefore configured within the ECM to a default of 'not installed', for the switch to be activated this must be changed using the service tool to 'installed'.

13.7.3 Fuel Filter Differential Pressure Switch Installation

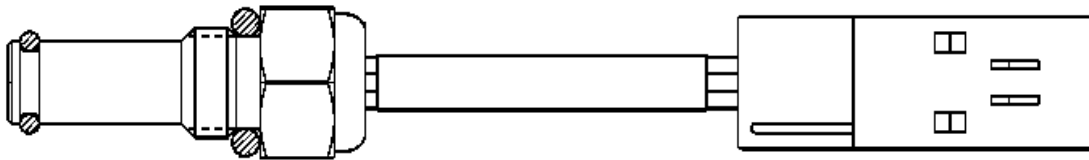


Figure 13.13 Fuel Filter Diff Pressure Switch 350-5719

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.

REQUIRED PARTS		
CAT Part Number	Description	Qty
350-5719	Fuel Filter Differential Pressure Switch	1
230-4011	Plug Connector	1
9X-3402	Connector Socket (Gold)	2

Table 13.18 Fuel Filter Diff Pressure Switch Installation Parts List

The fuel filter delta pressure switch must be installed as shown in figure 13.14. Pin 1 of the switch must be connected to pin 25 of the ECM J1 connector and a connection must also be made in parallel to the ignition switch battery + supply via a 1.5Kohm resistor. The resistor must be installed for both 12 and 24V systems and connection should be made post the 5A fuse recommended for ECM ignition circuit supply.

Please note that the chosen resistor must have a power rating of at least 2W and in some cases this may need to be increased depending upon the chosen resistors tolerance rating.

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

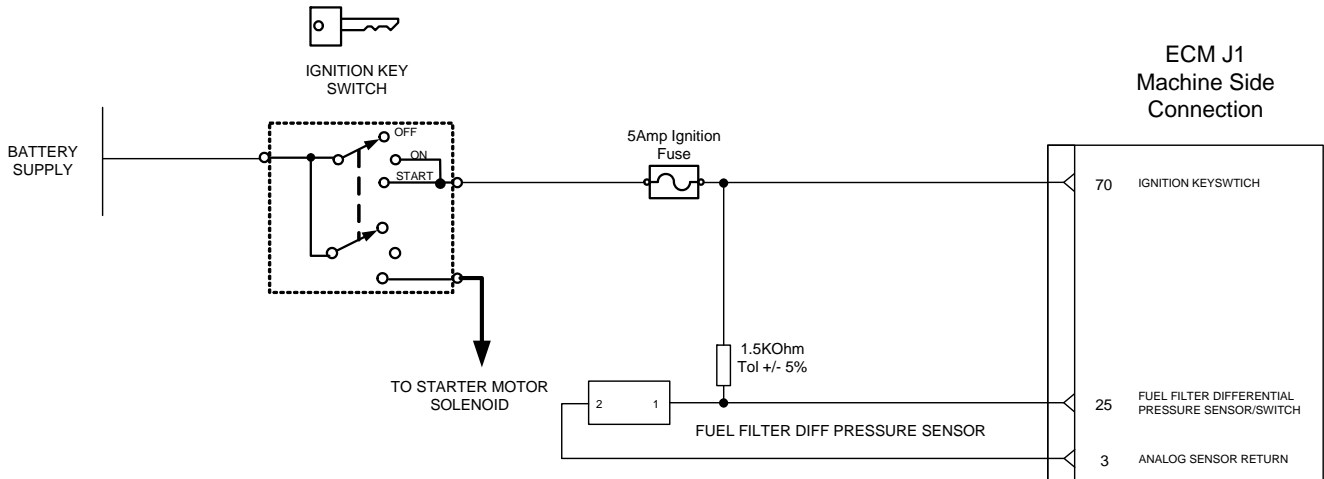


Figure 13.14 Fuel Filter Diff Pressure Switch Installation Wiring

The calculation used to determine the required power rating of the installed resistor is shown below;

R = Bottom tolerance resistor value (as specified by the resistor manufacturer).

V = Max voltage (accounting for jump starting i.e. 48V for 24V system etc).

$$\text{Power rating} = V^2/R$$

14.0 Regeneration System & Customer Interface

14.1 Low Temperature Regeneration System Operation

The low temperature regeneration system is only available with the C4.4 and C6.6 engine families and operates using an integrated control strategy, which ensures that the engine aftertreatment system is regenerated during normal machine operation without any operator interaction. This strategy also employs mechanisms to ensure that when required the engine exhaust temperature can be raised to ensure regeneration takes place.

14.1.1 Low Temperature Regeneration System Overview

To aid the effectiveness of the regeneration system all <130Kw engines are fitted with a back pressure valve. This valve will be activated automatically depending upon the DPF soot loading to raise the exhaust temperatures to temperatures between 250 - 400°C. At which point the DPF regeneration can begin.

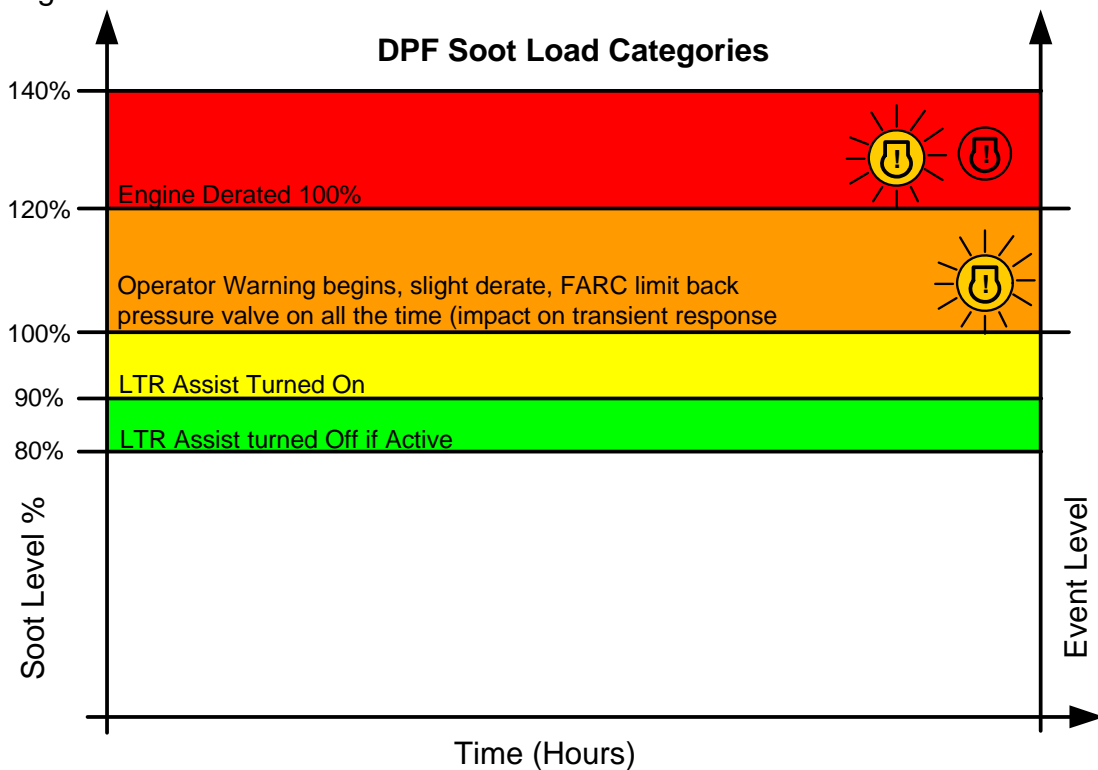


Figure 14.1 Low Temperature Regeneration System Control Overview

14.2 Low Temperature Regeneration Operator Interface

14.2.1 Low Temp Regeneration Lamp Strategy

The low temperature regeneration strategy requires no operator intervention, the engine management system will activate the engine back pressure valve continuously to attempt to raise exhaust temperatures to a level where regeneration can take place.

It should also be noted that the DPF soot loading can be displayed via a J1939 enabled gauge as with the C7.1 engine range if required. This is not however a mandatory installation requirement.

14.3 Low Temperature Regeneration System Operation Example

The DPF soot loading example shown in figure 14.2 indicates three scenarios of operation (please note that real life operation is likely to be a combination of these scenarios but they have been split here for information purposes). The three scenarios are;

- An engine being used with a moderate to high duty cycle that is not exposed to low ambient temperature operation.
- An engine being used with a low duty cycle, with operation in cold ambient conditions.
- A soot load trace for an engine being used with high sulphur fuel or regeneration system failure.

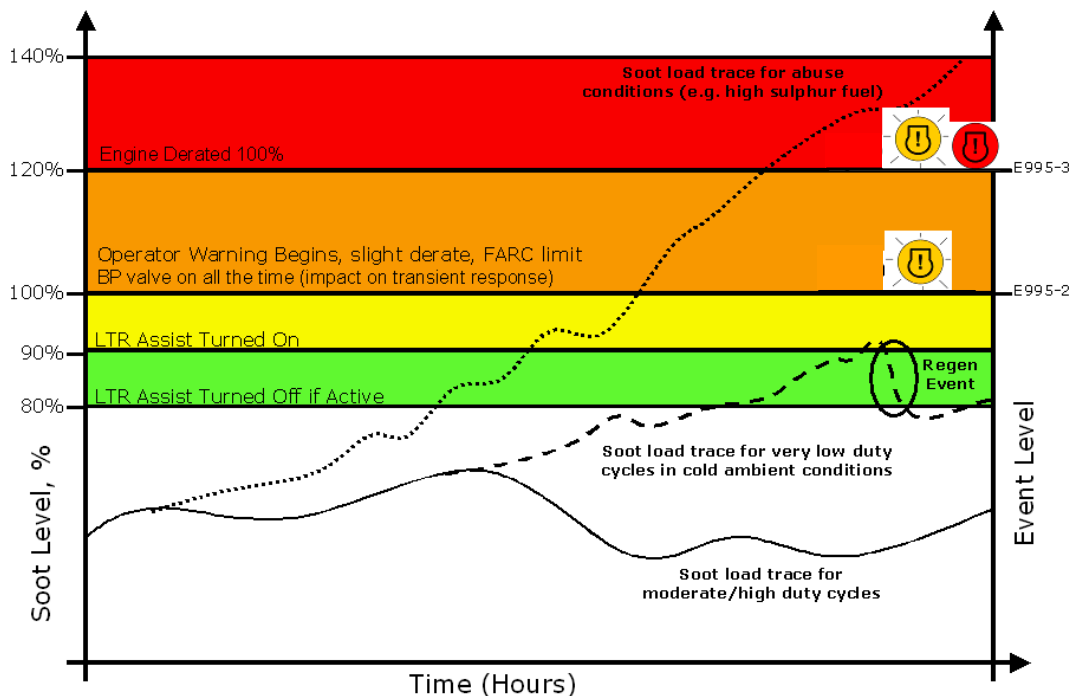


Figure 14.2 DPF Soot Loading Examples

Table 14.1 describes the system operation as the DPF soot loading increases and decreases throughout the monitoring system loading categories.

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range




DPF Soot Load	System Description	Engine % Derate	Lamp status
0 < 79%	From 0 to 79% soot loading applications requiring a moderate to high duty cycle should regenerate without any control system intervention. In some cases (low duty cycle or cold ambient) to DPF soot loading may exceed 79%.	N/A	N/A
80 < 89%	The Low Temperature regeneration system may take action to oxidize soot, depending on the machine operating conditions.	N/A	N/A
90 < 99%	Back pressure valve is operated as required. The back pressure valve is disabled as soon as the soot loading reduces to 79% or below.		
100 < 116%	The low temperature regeneration system takes more aggressive actions to attempt to reduce soot load. The engine will derate slightly and transient response may be affected. The engine management system raises an event code at this point (E995-2) which in turn the engine warning lamp. The lamp remain active until the DPF soot load is below 90%	Slight derate affecting transient response	 Flashing Engine Warning Lamp
116 < 140%	Once the engine exceeds 116% the engine will be 100% derated and an event code (E955-3) is raised. Both the warning and shutdown lamps are also operated. If configured the engine will shutdown and regeneration will be inhibited	100%	 Flashing engine Warning Lamp  Engine Shutdown Lamp

Table 14.1 Low Temperature Regeneration Operation Description

14.4 High Temperature DPF Regeneration System Operation

The high temperature regeneration system is only available for the C7.1 engine range. The high temperature system uses a fuel burner to raise and maintain the exhaust gas temperature to levels where a regeneration of the DPF can take place. For more information regarding the high temperature system hardware and the process of DPF regeneration please refer to the Mechanical A&I Guide Section 5.

14.4.1 High Temperature Regeneration System Overview

The High temperature regeneration system is configured as standard to monitor the DPF soot loading and take the necessary actions to clear the DPF when safe and conditions allow it. To ensure that the engine and aftertreatment achieves optimum performance and is protected against long term damage the control system strategy calculates the DPF soot loading during operation and takes actions depending upon the soot loading profile as shown in figure 14.3.

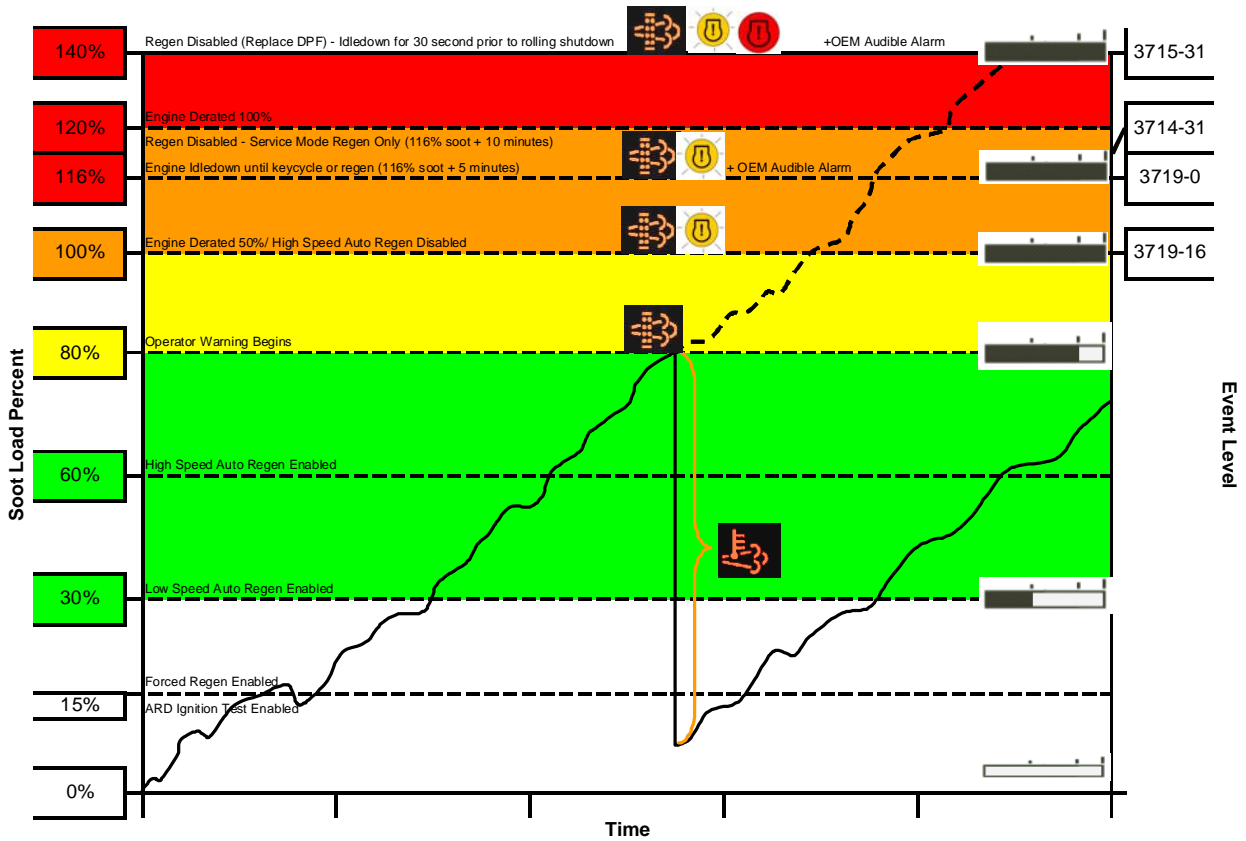


Figure 14.3 High temperature System Soot Loading Profile

The soot loading profile is configured to operate as follows;

DPF Soot Load	Profile Level	Engine Response
0 - 30%	Level 0	Engine Operates Normally and no auto regeneration will take place.
15%*	Force Switch Regen Threshold	Operator Forced Regeneration when conditions allow.
15 – 120%*	Force Switch Regen Range	
30% - 100%	LSR becomes active	Engine will attempt to initiate an Automatic LSR , but only when conditions allow.
60% - 100%	HSR becomes active	Engine will attempt to initiate an Automatic HSR or LSR , but only when conditions allow.
80% - 100%	Level 1	Engine will indicate to the operator that regeneration is required by turning on the DPF lamp and in automatic mode the engine will attempt to regenerate when conditions allow.
100% - 116%	Level 2	Engine will indicate to the operator that the engine has entered a derate condition. Engine will be limited to approximately 75% engine power.
116% + 5 minutes		Engine will idle down. The operator must turn the key switch off and back on. Then the engine will continue to run with derated power.
116% + 10 minutes		Engine's regeneration system will be locked out. Regeneration will require Cat ET to be connected.
120%	Level 3	Engine will be limited to approximately 50% engine power.
140%	Level 3	The DPF is now unserviceable and must be replaced. Engine will be idled down for 30 seconds, then shutdown. The engine will be allowed to restart and run for 30sec. However; the engine will then go into a rolling shutdown mode. Allowing only a few moments of run time.

Table 14.2 High Level engine Response to DPF Soot Loading

* Manual Operation Profile – Operator manually forces regeneration using the required Forced Regeneration Switch. Operator must allow enough regeneration time for soot level to be reduced below 50%. Fault code will be generated if soot load does not reach 50%.

It should be noted that if the DPF enters the region above 140% soot loading then the DPF becomes unserviceable and must be replaced.

The strategy shown above in table 14.2 indicates the basic control strategy used by the engine ECM to protect the aftertreatment system. The use of operator controls and indicators is discussed in section 14.5.

14.4.1.1 Low Speed High Temperature Regeneration (LSR)

A low speed high temperature regeneration system is designed to allow DPF regeneration to take place when the following application conditions are met:

Cat CEM Operating Conditions

- Soot Load – 30-120% (15-120% Force regeneration)
- No Active Cat RS Regeneration
- No Aborted Regeneration Delay Time - >10 min. since last regeneration attempt.
- DPF Inlet Temp >50C
- No Cat RS Head Faults – No Active regeneration events in Cat ET
- No Active Cat RS Heater - Force Regeneration Switch will override and start regeneration within 3 min. (Heater will deactivate if active)

Engine Operating Conditions

- Steady State (SS) Load and Speed for 1-5 min. (see chart below)
- Engine RPM within 1000 – 1400 RPM
- Engine Load 50 - 400 nm
- Coolant Temp Above Threshold
- No Cat NOx Reduction or Air Valve Service Test Active
- Cat ET set for Regeneration
- Force/Inhibit Switch in Auto Mode – Inhibit Mode is latched until Force Mode is depressed even if it was returned to Auto position after Inhibit depressed and key switch cycled.

14.4.1.2 High Speed High Temperature Regeneration (HSR)

The high speed regeneration solution is capable of initiating a DPF regeneration event at engine speeds greater than 1400rpm. As with the low speed solution the engine must hold a Steady State (SS) load and speed condition for the regeneration event to take place. More details on the operation of the high speed solution can be found in section 10.0 of the mechanical A&I Guide.

The following table outlines the Operating Requirements for Active Regeneration of Cat CEM for Low Speed Regeneration and High Speed Regeneration:

Active Regen Operation	Required Operating Parameters					
	Soot Load %	Regen Interface Pin	Engine RPM	Engine	Eng Load (Delivered Fuel Volume mm ³ /~NM)	Delta Boost
LSR	15 Minimum for Forced Regen	46 "Ok to Elevate"	1000* - 1400	C7.1	Min 10/~50	SS (Steady State)
	30 for Auto Regen			C7.1	Max <65/400	SS
HSR	60 - 80	45 "HSR Enable"	1000 - 2310	C7.1	Up to Near Lug Crv	<40kPa/sec for ~3 min
			1400 - 2099		Any - TBD	
	80 - 100		1400 - 2299		Any - TBD	<60kPa/sec for ~60 sec.

* Engine will elevate idle if idle is <1000 RPM – Pin 46 must be returned to Digital Sensor Return
 Table 14.3 LSR and HSR Require Operating Parameters

If the engine is idling at < 1,000 RPM desired engine speed, then before LSR can take place Engine ECM J1/P1 46 must be returned to J1/P1 GND switch return as shown below. This pin must only be taken to GND switch return if it is acceptable to increase engine speed up to 1,400 RPM.

Before HSR regeneration can take place the Engine ECM J1/P1 47 must be returned to J1/P1 GND switch return as shown below. This enables HSR Feature. Regen will not activate until the conditions are acceptable for regen to take place.

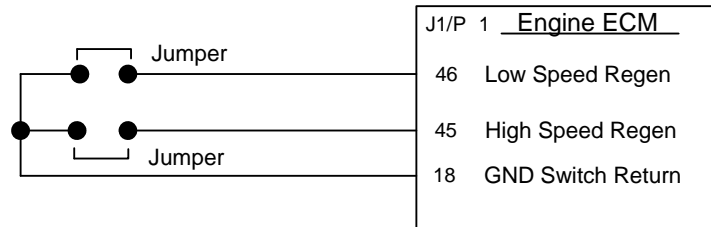


Figure 14.4 LSR and HSR Wiring Requirements

14.5 High Temperature Regeneration System Customer Interface

14.5.1 Lamp Strategy

The C7.1 high temperature regeneration system requires the customer to install three extra lamps in addition to the engine warning and shutdown lamps. These lamps are specific to the engine aftertreatment system and are used to indicate to the operator the status of the DPF soot loading and the exhaust system. These lamps and their symbols are shown in table 14.4.




Lamp description	Symbol	ISO Symbol Reference
DPF Lamp		ISO 7000-2433
DPF Regeneration Disabled		ISO 7000-2947
HEST (High Exhaust System Temperature)		ISO 7000-2844A

Table 14.4 Aftertreatment Lamp Symbols

Please note that further information regarding the installation of these lamps and their interaction with the engine system is detailed within chapter 11 of this A&I Guide.

Each of the lamps above, are used to indicate the following;

DPF Lamp - Elevated Soot Loading of DPF >80%
- DPF lamp will remain illuminated until the DPF regeneration is complete.

HEST Lamp - Turned on during an active regeneration
- Remains on during exhaust system cool down immediately following an active regeneration until the DPF temps falls below 400°C or the machine goes back to work.

DPF Regeneration Disabled - Anytime the automatic regeneration is disabled. This can be from the inhibit operator input or by setting the Aftertreatment Regeneration configuration within CAT ET to Manual.

14.5.2 Regeneration Interface Switch

14.5.2.1 Regeneration Interface Switch Operation

All C7.1 installations must be installed with either hard-wired devices or software driven devices capable of providing the operator with the opportunity to inhibit or force a DPF regeneration event. This hardware switch or J1939 enabled device gives the application operator a level of control over the Cat CEM regeneration process. Dedicated ECM I/O is available for hard-wired solutions. Each application solution must provide the operator with the following functions

Automatic mode – Default position, which is only overridden when either the force or inhibit inputs are activated and operates between 30 and 100% soot loading.

Inhibit Regeneration – Operating this function will inhibit the engine regeneration process. Once the ECM received this input and activated the inhibit lamp there are 2 ways to return to Automatic Regeneration (un-inhibited). First, provide the ECM with a “Force Regen Input. Once the ECM receives this input it will attempt a regeneration event and turn the automatic regeneration strategy back on. Second, shut the engine down and restart. Cycling switched power will reset the inhibit command and turn the automatic strategy back on again.

Force Regeneration – Operating this function forces the engine into an active regeneration. This function is usually used in conjunction with the inhibit function. The Force function is made active and can be selected once the DPF soot loading reaches 15% and remains active until the DPF soot loading reaches 120%.

14.5.2.2 Regeneration Interface Switch Configuration

All C7.1 engines have this feature default “Installed” through Cat ET.

Cat ET must have this switch enabled if they plan to use a hard wired switch. It must be programmed to “Not Installed” in Cat ET if no hard wired switch is installed and J1939 indicators are to be used.

Applications using the J1939 control option should refer to J1939 Applications Integration section 14.5.6 of this document for more information on the PGN and SPN’s used to control this function.

14.5.2.3 Regeneration Interface Switch Installation

CAT provides a switch designed to provide both the force and inhibit functions to the machine operator. This component is available via the CAT parts system and can be ordered using the part numbers shown below (Table 14.5).

Component	CAT P/N
ARD Switch	327-6999
Terminals	185-1860
Wire Grommet	185-1860
Plug Connector	223-4778
Crimp Tooling	TBD

Table 14.5 Regeneration Interface Switch Assembly Part Numbers

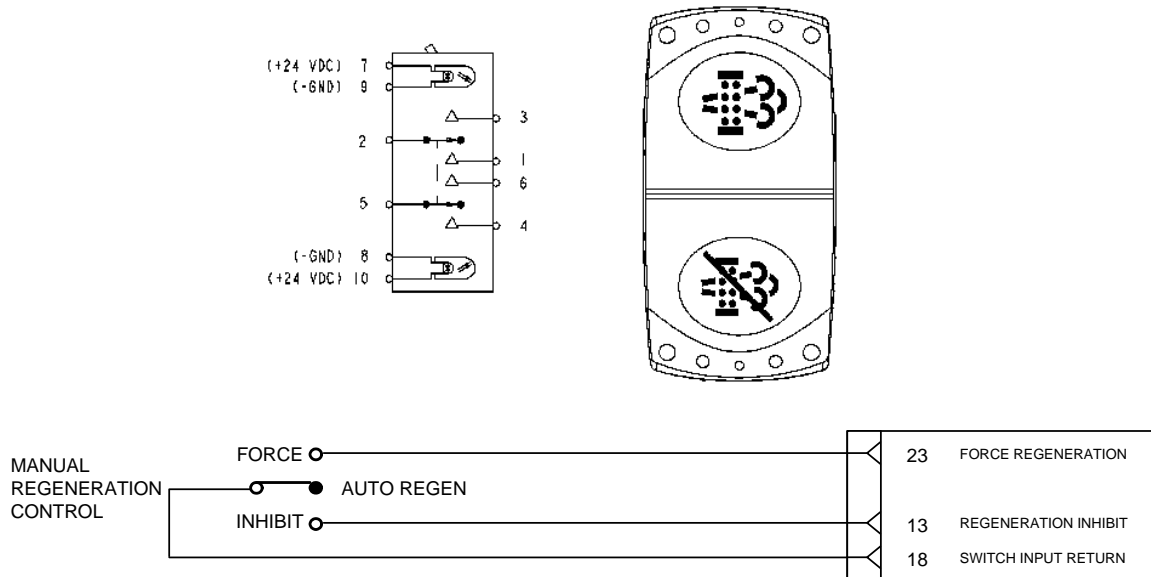


Figure 14.5 Regeneration Switch Installation Wiring

For OEM's wishing to supply their own interface switch, with a directly wired input to the engine ECM must ensure that the switch mechanism used incorporates a momentary switch contact design and not latching. The Symbols shown in figure 14.5 must also be mounted on or near to the switch mechanism to ensure that the operator is aware of their function.

14.5.3 OK To Elevate Idle Input

14.5.3.1 OK To Elevate Idle Input Operation

This input does not affect HSR (High Speed Regen). This input is provided to allow an OEM to integrate with the engine's regeneration strategy. In certain operating conditions, the engine may need to increase its speed in order to facilitate regeneration. Grounding this Ok to Elevate input communicates to the engine that a speed increase of up to 1,400 RPM is acceptable. Depending upon atmospheric conditions as well as engine operating conditions, engine speed will elevate within an engine speed range of 1,000 – 1,400 RPM. This range is not programmable.

Once engine speed has been increased to 1,000 – 1,400 RPM there are 3 ways to stop the regeneration and return speed control to an operator.

1. Provide the Regen Inhibit input to the ECM
2. Disconnect the Ok to Elevate input from Ground

3. Increase engine speed using another speed demand input to > 1,400 RPM.

Any of these actions will stop the regeneration event.

If engine speed increases within this defined window are unacceptable, then the OEM should not ground this pin. In this case, the installation will have to perform its DPF regeneration with HSR (High Speed Regeneration) mode.

If the engine never operates at < 1,400 RPM it is recommended to ground this pin.

14.5.3.2 OK To Elevate Idle Input Configuration

There is no CAT ET configuration required for this parameter to operate.

14.5.3.3 OK To Elevate Idle Input Installation

The OK to elevate idle input to the engine ECM (pin 46) must be connected to the ECM J1 GND switch return pin 18 for this feature to be enabled, as shown below.

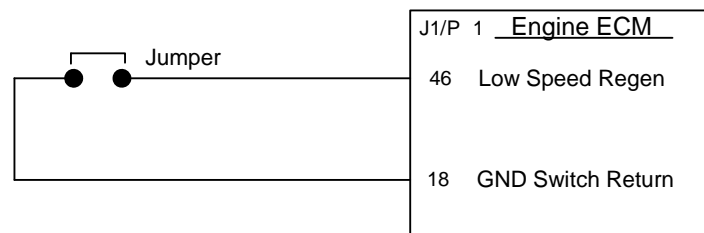


Figure 14.6 Low Speed Regeneration Installation Wiring

14.5.4 High Speed Regeneration Enable Input (HSR Input)

14.5.4.1 High Speed Regeneration Enable Input Operation

This input does not affect LSR (Low Speed Regen). This input must be grounded in order for HSR to be active. In addition, when this input is grounded the ECM will temporarily enforce a low engine speed limit of 1,000 RPM. This input should not be grounded if this temporary low speed limit of 1,000 RPM is unacceptable to the OEM.

Note: If this input is not grounded, then the engine will not attempt any regeneration events at engine speeds in excess of 1,400 RPM.

If this pin is grounded then HSR events will trigger under certain operating conditions. Several factors are considered before a HSR is initiated. One of those factors is engine speed. In order to initiate a HSR engine speed must be greater than 1,400 RPM. However, HSR be allowed to continue if engine speed is reduced to 1,000 – 1,400 RPM. This allows for regeneration events which were started during an engine working cycle to continue if the engine is returned to idle.

If this input is grounded, and the temporary low speed limit of 1,000 RPM has been invoked then the operator may override this by providing the regeneration inhibit input to the ECM.

14.5.4.2 High Speed Regeneration Enable Input Configuration

There is no CAT ET configuration required for this parameter to operate.

14.5.4.3 High Speed Regeneration Enable Input Installation

The High speed regeneration enable input to the engine ECM (pin 45) must be connected to the ECM J1 GND switch return pin 18 for this feature to be enabled, as shown below.

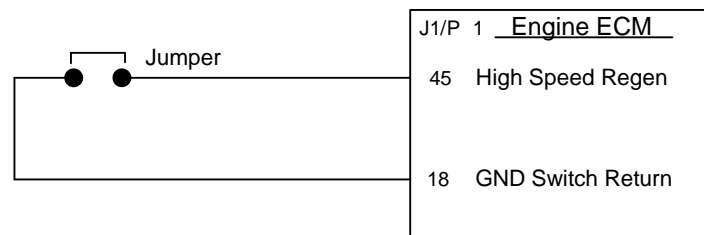


Figure 14.7 High Speed Regeneration Installation Wiring

14.5.5 DPF Soot Loading Indicator

For applications that wish to indicate the current level of soot within the DPF the following J1939 parameter is provided;

PGN - Aftertreatment 1 Service 64891 (FD7B)

SPN - Diesel particulate filter 1 soot load percent 3719

This PGN and SPN can be used to indicate an estimated DPF soot loading level for the machine operator. Used correctly this message may help the operator to optimise the time at which a regeneration is initiated and machine productivity. The use of a soot gauge is not a mandatory requirement, however its use should be considered for operator information purposes. Please consult your Applications Engineer for more information.

14.5.6 Integrated Machine Solutions Over J1939

All machines wishing to integrate the regeneration interface via the J1939 datalink can do so by using the following PGN's and SPN's shown in table 14.6.

PGN	PGN Description	SPN	SPN Description	Function
CM1 (57344)	Cab Message 1	3695	Diesel Particulate Filter Inhibit Switch	Used as an input to the ECM to indicate that the operator wishes to inhibit the DPF Regeneration
		3696	Diesel Particulate Filter Regeneration Force Switch	Used as an input to the ECM to indicate that the operator wishes to force the DPF regeneration
DPFC1 (64892)	Diesel Particulate Filter Control 1	3697	Diesel Particulate Filter Lamp Command	Used to activate the DPF indicator when required
		3698	Exhaust System High Temperature Lamp Command	Used to activate the HEST indicator when required
		3703	Diesel Particulate Filter Active Regeneration Inhibited due to Inhibit Switch	Used to activate the Regeneration disabled lamp when the inhibit function has been selected.

Table 14.6 J1939 Regeneration Interface PGN and SPN Support

14.6 Total System Operation Example

The following section explains the complete regeneration system operation and the role of the customer interface system as the regeneration takes place.

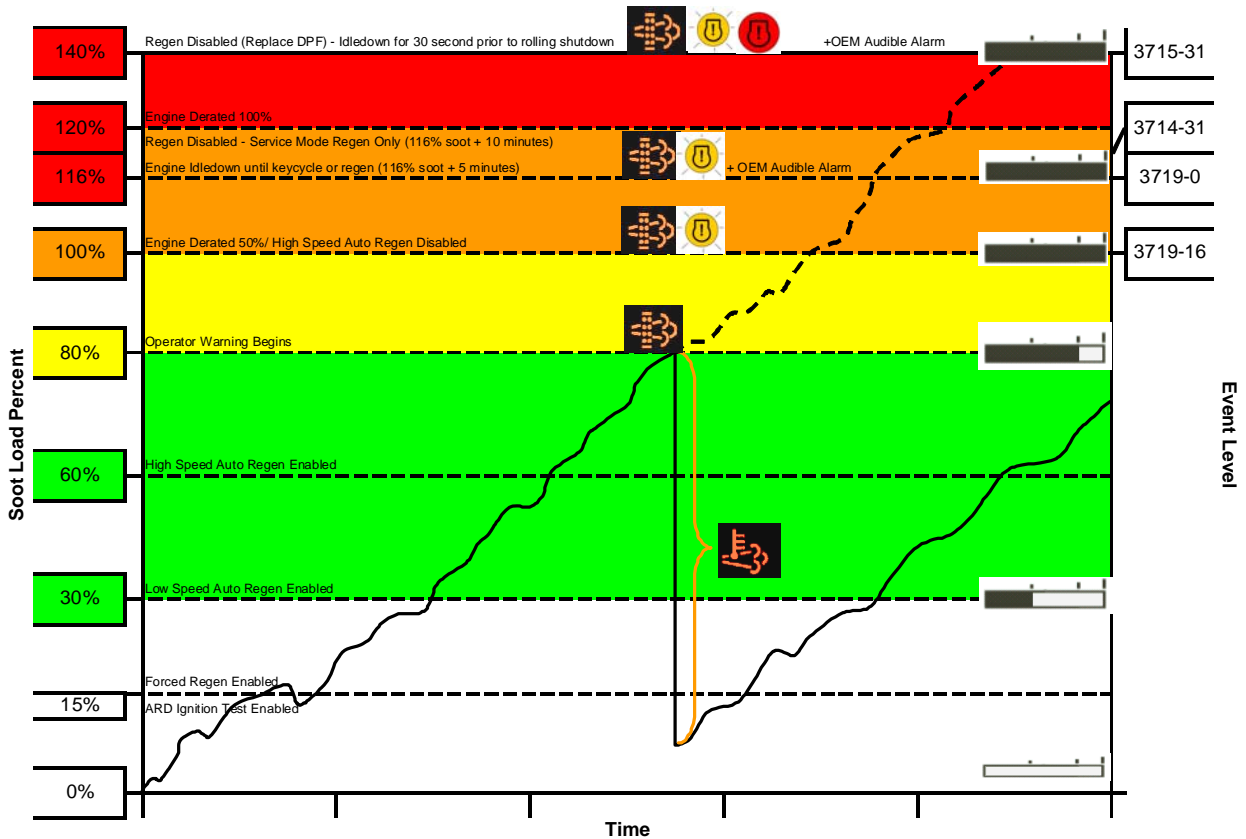


Figure 14.8 Customer Interface Behavior During Soot Loading and Regeneration

The response of the engine monitoring system to the level of soot loading within the DPF is controlled by the engine management software. The status of the engine aftertreatment system is communicated to the operator both as the DPF is being filled with soot and during a regeneration event. The engine monitoring system behaves differently depending upon the level of soot contained within the DPF. Figure 14.8 above coupled with the table 14.7 and 14.8 describe the reaction of the system at various stages of the soot loading profile.

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range











Soot Level	Timer	Operator Indication	Engine De-Rate Strategy	Engine Shutdown Strategy	Engine Protection
<80 %	NA				
80 %	NA				
100 %	NA	 	Engine De-Rate begins at 50 %		Low Soot Mode
116 %	NA	  		Pre-Emptive Engine Idle Down	
116 %	+5min	OEM		REGEN Disabled Service Level REGEN Only	
116 %	+10min				
120 %	NA			Engine De-Rate at 100 %	
140 %	NA	  		Engine Shutdown Replace DPF * 30s Rolling Shutdowns	

Table 14.7 Regeneration Operation Description

Note: If the DPF soot loading is allowed to reach 140% or above the DPF is no longer serviceable and must be replaced.

The engine monitoring system response shown in table 8.4.1 applies for both an automatic and a manual regeneration.

Soot Loading	J1939 Event Codes	Lamps Future (Hardwired)	Future J1939
140%	3715-31	Warning (Amber) Blink & Shutdown (Red) ON	Stop Lamp ON & Amber Warning (or Protect) Lamp Fast Flashing
116% + 10 min	3714-31	Warning (Amber) Blink	Amber Warning (or Protect) Lamp Slow Flashing
116%	3719-0	Warning (Amber) Blink	Amber Warning (or Protect) Protect Lamp Fast Flashing
100% + disable switch	3703-31	Warning (Amber) Blink	Amber Warning (or Protect) Lamp Slow Flashing
100 %	3719-16	Warning (Amber) Blink	Amber Warning (or Protect) Lamp Slow Flashing

Table 14.8 Soot Loading Lamp and J1939 Strategy

The Soot Loading Lamp and J1939 table above indicates soot loading annunciation via lamp activity and associated J1939 Event codes when soot loading exceeds 100%.

Note: If the DPF soot loading is allowed to reach 140% or above the DPF is no longer serviceable and must be replaced.

15.0 Engine Governor

15.1 Min/Max Governing

15.1.1 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.

Figure 15.1 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 figure 15.1 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).

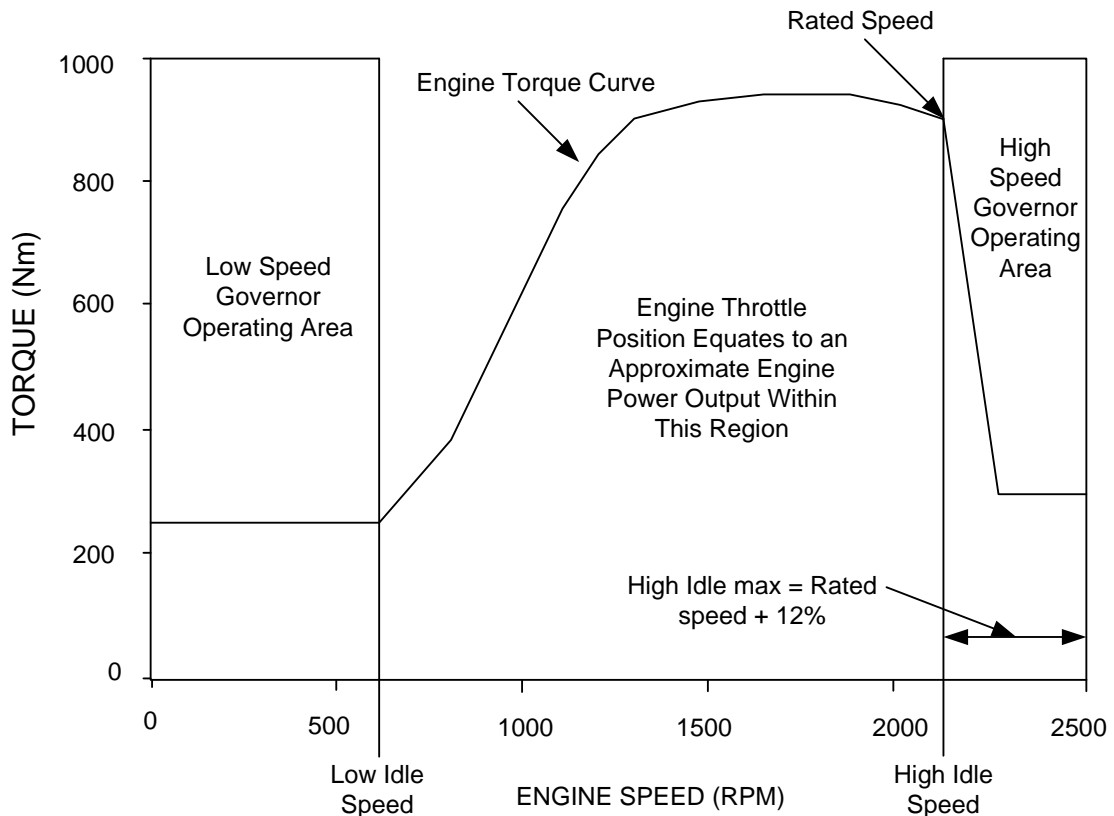


Figure 15.1 Min Max Governor Operating Regions

15.1.2 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. Please refer to the mode selection section of this document for more information on the configuration of these switches.

15.1.3 Installation

The Min/Max governing feature requires no special installation other than a method of engine speed demand. Please refer to the engine speed demand section of this document for more information on the methods supported by the engine ECM.

15.2 All speed

The default governor type is an All Speed Governor, also known as a variable Speed Governor. The diagrams and text below in figures 15.2 and 15.3 illustrate the torque and speed characteristics of this governor.

15.2.1 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 9.0 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' by CAT 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 (this is fixed for each rating and can not be altered) 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 can not exceed RS+12%. This HIUL is specified to ensure governor stability is maintained throughout the engine operating range.

Example Governing1 - showing droop and HSG slopes approximately equal.

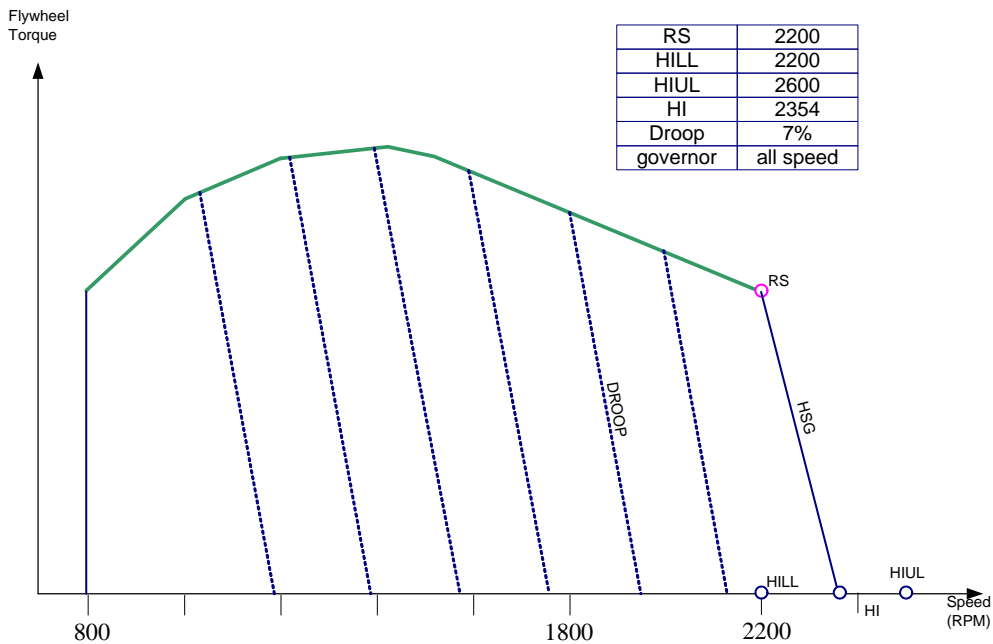


Figure 15.2 Engine with Droop settings

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

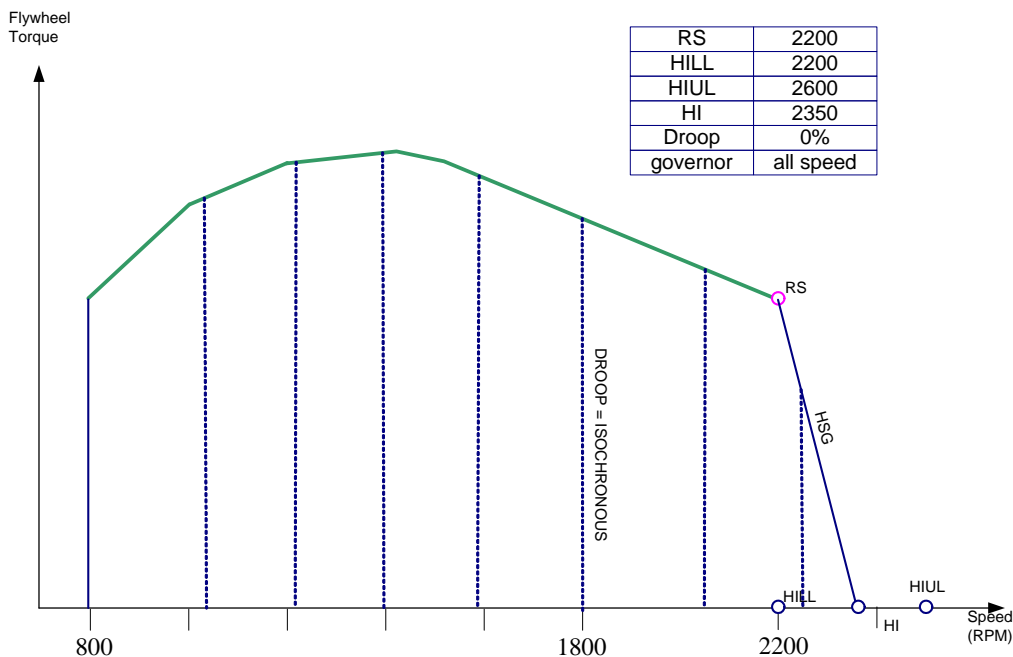


Figure 15.3 Isochronous Droop Settings

15.2.2 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. Please refer to the mode selection section 15.4 of this document for more information on the configuration of these switches.

15.2.3 Installation

The All Speed engine governing feature requires no special installation other than a method of engine speed demand. Please refer to the engine speed demand section 9.0 of this document for more information on the methods supported by the engine ECM.

15.3 Auxiliary Governor

It is possible to control the engine speed by the output shaft speed of another module. Caterpillar does not offer a speed sensor for this component, nor is there any direct speed sensor input, for the following reasons:

- There are a wide variety of speeds to be measured.
- Speed sensor's output signals are low in amplitude and sensitive to electromagnetic interference.
- The engine is often not close to the output shaft to be measured, resulting in poor quality speed signals.

The recommended solution for this requirement is as follows;

The speed measured close to the output shaft by a third party electronic control module, which would give an engine speed demand to the engine, using J1939 TSC1 speed control or PTO mode raise and lower inputs. The third party module could also incorporate a display and/or operator control buttons. The electronic Applications team can give advice on specifying and selecting the third party electronic module for this function. The advantage of this approach is that, although the initial cost of the module is higher than a direct speed input, the cost of the additional components is reasonable and the advantages in reliability and ease of commissioning outweigh the disadvantages.

15.4 Rating selection via Service Tool

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 "rating" parameter on the configuration screen with ET. 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.

15.5 Engine High Speed Governor (Governor Run-out)

15.5.1 Engine High Speed Governor Operation

The Caterpillar Tier 4 series engine range offers the ability to configure the run-put 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. Figure 15.4 Shows a HSG run out line with the same rated speed and two different HI settings.

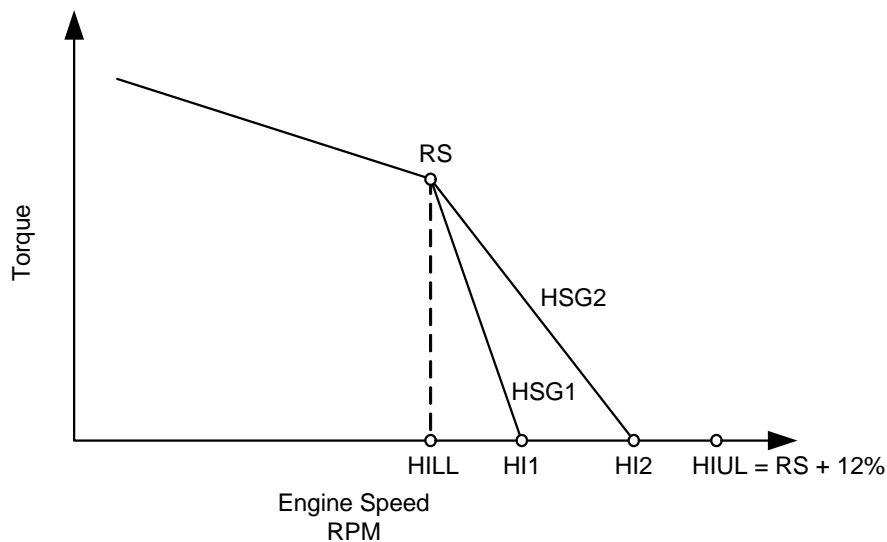


Figure 15.4 HSG Run out Example

15.5.2 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 as described in section 15.6 of this document. This is achieved by modifying RS or HI or both. It should be noted that HI can not be configured to be less than RS and no higher than RS + 12%.

15.6 Mode Selection

15.6.1 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 on the C4.4, C6.6 and C7.1 engines. 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 ECM J1 switched inputs 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.

- Engine % Droop
- Engine T Curve Rating (If multi ratings are enabled)
- Engine rated speed (Only if the rating supports multiple rated speeds)
- Engine speed governing mode (Min / Max or All Speed)
- High Idle

Mode Selection Number	Mode Selection Switch Input 1	Mode Selection Switch Input 2	Enabled	Rating Number	Rated Speed (RPM)	High Idle	Throttle 1 Droop Percentag	Throttle 2 Droop Percentag	TSC1 Droop Percentag	Governor Type
1	Open	Open	Yes	1	2200	2420	10	10	10	All Speed
2	Open	Closed	Yes	1	1800	1800	0	0	0	All Speed
3	Closed	Open	No	1	0	0	0	0	0	All Speed
4	Closed	Closed	No	1	0	0	0	0	0	All Speed

Table 15.1 Engine Mode Selection Table

It should be noted that the engine mode switch 2 input is also used for the following feature;

Mode Switch 2 or Inlet Air Restriction Switch

If this alternative feature is required then associated mode switch function can not be used.

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.

IMPORTANT

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.

15.6.2 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

15.6.3 Installation

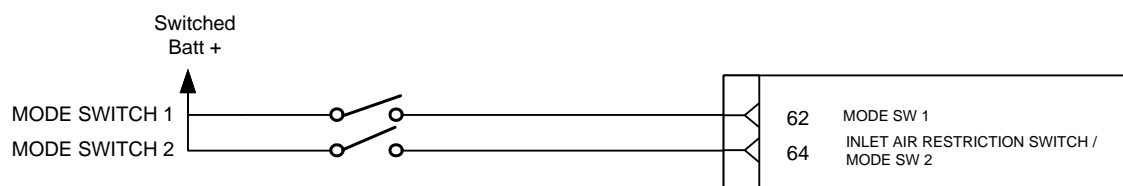


Figure 15.5 Mode switch Installation Wiring

15.6.4 Rating and Droop changes requested via the J1939 datalink

For those applications wishing to use the J1939 CAN Bus system during machine integration, the engine rating and droop settings can be adjusted using the Off Highway Engine Control Selection (OHECS) message PGN FDCB. For more information on configuring the J1939 messages please refer to section 19 of this document.

NOTE if a rating is selected over J1939 the last programmed rated speed will be applied, as rated speed cannot be changed over J1939.

16.0 Tier 4 Interim Service Tool Features.

16.1 Introduction

This section gives a very brief overview of the new service tool engine and aftertreatment test and calibration features available for the Tier 4 Interim product range. For further information on when and how to operate these tests please refer to the Caterpillar troubleshooting guide.

16.2 Service tool features for a C7.1

TBD

16.3 Service tool features for a C4.4-C6.6

The following service tool tests will be made available for all engines installed with a low temperature regeneration system.

- Low temperature aftertreatment regeneration device verification test
- Low temperature regeneration verification test
- Fuel quality verification test
- Aftertreatment de-sulphation procedure

17.0 Datalink Support

There are two datalinks available for the OEM to connect to the engine ECM, these are the J1939 datalink and the CAT datalink CDL. The J1939 standard is a widely used protocol, which operates on a standard CANBus system. All J1939 enabled devices will operate on this datalink and the remainder of this section details the basic requirements for J1939 communication. The CAT datalink is a proprietary datalink, which can be used with specialist devices available through CAT aftermarket networks.

It should be noted that these are currently the only two datalinks supported by the ECM hardware and the incorporation of the engine into systems operating on protocols such as ModBus will require a gateway to convert the protocol to J1939 for ECM communication.

17.1 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 power trains, 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 are listed below.

SAE J1939-11	Physical Layer, 250Kbits/s, Twisted Shielded pair.
SAE J1939-15	Reduced Physical Layer, 250Kbits/s, Un-shielded Twisted pair.
SAE J1939-21	Data Link Layer.
SAE J1939-31	Network Layer.
SAE J1939-71	Vehicle Application Layer.
SAE J1939-73	Application Layer Diagnostics.

17.1.1 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.

17.1.2 Physical layer

- The data rate is 250Kbits/sec
- Twisted pair cable, of a 120Ohm impedance characteristic, should be used throughout. Note that most commercially available twisted pair cable is not suitable.
- It is recommend 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 bus is linear and should be terminated with 120Ohm resistors at either end. It is a common mistake to use one 60Ohm resistor instead of two 120Ohm resistors. This does not work correctly however.
- Maximum bus length is 40m.
- The terminating resistors should not be contained in network nodes.
- Network nodes are connected to the bus via stubs of maximum recommended length 1m.

17.1.3 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.
- Hardware filtering (masking) of CAN messages should be used under high busload limit demands on processors.
- The engine ECM always assumes a fixed address zero. 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 maybe broadcast or requested at regular intervals. For example, the engine will broadcast its 'current speed' every 20ms but it will only send 'hours run' information if another node requests it.

17.1.4 Application Layer

- The messages (PGN's) supported by the engine ECM 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 ECM has valid data will be supported.
- Unsupported data bytes are generally sent as FF (hex) and incorrect or invalid information is sent as FE.

17.2 Connection and Use of the J1939 CAN Bus

There is one J1939 Datalink available for customer connection on each of the engine families and this is CAN A. The CAN A datalink can therefore be used to connect the engine ECM to machine controllers, transmission controllers, instrumentation gauges etc. All of the general installation criteria for a CAN network detailed in section 17.1 applies for this datalink and the ECM J1 connection points are shown below in table 17.1.

ECM J1 Pin Number	Function
34	CAN A (-)
50	CAN A (+)

Table 17.1 ECM J1 CAN A Connection List

Figure 17.1 also gives an example of a typical CAN network layout. It should be noted that the 120Ohm termination resistors are to be located at either end of the CAN bus.

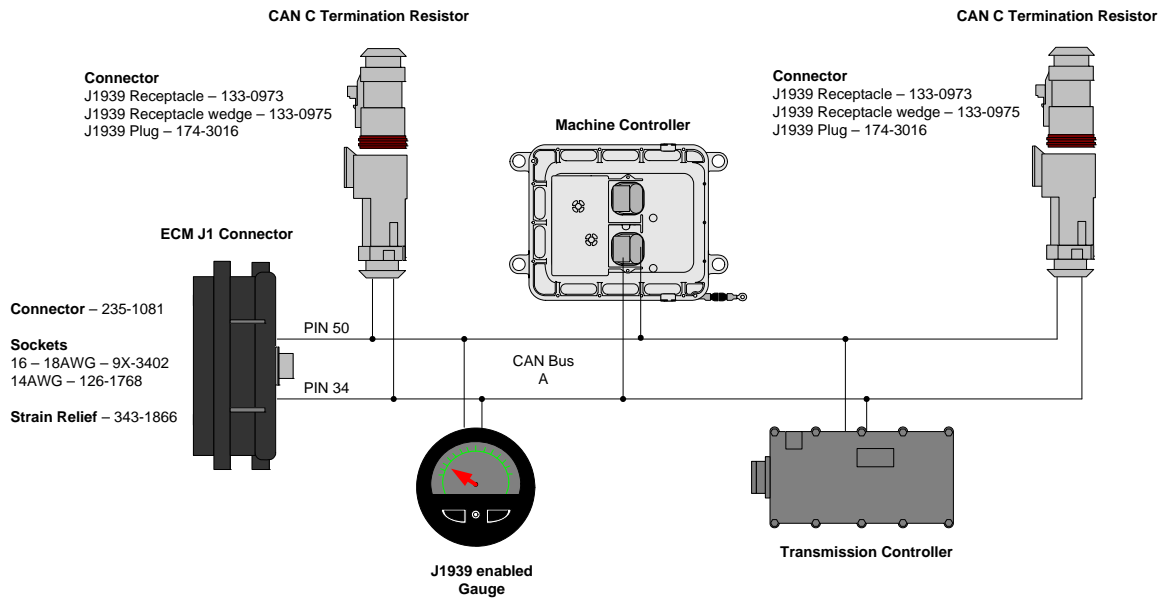


Figure 17.1 Example CAN Network Layout

18.0 J1939 Supported Parameters Quick reference

Identification	PGN		Description	SPN	Parameter
	Decimal	Hex			
TSC1	0	0	Torque Speed control		
				695	Override Control Mode
				696	Requested Speed Control conditions
				897	Override Control Mode Priority
				898	Requested Speed / speed Limit
				518	Requested Torque / Torque Limit
EEC2	61443	F003	Elec Engine Controller 2		
				558	Accelerator Pedal 1 low idle switch
				2970	Accelerator pedal 2 low idle switch
				91	Accelerator pedal position 1
				92	Engine percent load at current speed
				29	Accelerator pedal position 2
EEC1	61444	F004	Elec Engine Controller 1		
				899	Engine Torque Mode
				512	Drivers Demand Engine – Percent Torque
				513	Actual engine percent torque
				190	Engine speed
				2432	Engine demand - percent torque
TCW	65174	FE96	Turbocharger wastegate		
				1188	Turbocharger 1 Wastegate drive
AUXIO	65241	FED9	Auxiliary Discrete IO State		
				701	Auxiliary I/O 1
				702	Auxiliary I/O 2
				703	Auxiliary I/O 3
				704	Auxiliary I/O 4
				705	Auxiliary I/O 5
				706	Auxiliary I/O 6
				707	Auxiliary I/O 7
				708	Auxiliary I/O 8

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

				709	Auxiliary I/O 9
				710	Auxiliary I/O 10
				711	Auxiliary I/O 11
				713	Auxiliary I/O 13
				714	Auxiliary I/O 14
				1083	Auxiliary I/O Channel #1
				1084	Auxiliary I/O Channel #2
SOFT	65242	FEDA	Software Identification		
				965	Number of software identification fields
				234	Software identification
EFL/P2	65243	FEDB	Engine Fluid Level / Pressure 2		
				157	Injector metering rail 1 pressure
EEC3	65247	FEDF	Elec Engine Controller 3		
				514	Nominal Friction – Percent Torque
				515	Engines desired operating speed
				2978	Estimated Engine Parasitic Losses – Percent Torque
EC	65251	FEE3	Engine Configuration		
				188	Engine speed at idle point 1
				539	Percent torque at idle point 1
				528	Engine speed at point 2
				540	Percent torque at point 2
				529	Engine speed at point 3
				541	Percent torque at point 3
				530	Engine speed at point 4
				542	Percent torque at point 4
				531	Engine speed at point 5
				543	Percent torque at point 5
				532	Engine speed at high idle, point 6
				544	Reference engine torque
				534	Maximum Momentary Override Time

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

					Limit
				1846	Engine Default Torque Limit
SHUTDOWN	65252	FEE4	Shutdown		
				1081	Wait to start lamp
HOURS	65253	FEE5	Engine Hours / Revolutions		
				247	Total engine hours
LFC	65257	FEE9	Fuel Consumption		
				182	Engine trip fuel
				250	Total fuel used
CI	65259	FEEB	Component ID		
				586	Make
				587	Model
				588	Serial number
VI	65260	FEEC	Vehicle Identification		
				237	Vehicle identification number
ET1	65262	FEEE	Engine Temperature		
				110	Engine coolant temperature
EFL/P1	65263	FEFF	Engine Fluid Level / Pressure		
				100	Engine oil pressure
PTO	65264	FEF0	PTO Information		
				980	PTO enable switch
				984	PTO set switch
				983	PTO coast / decelerate switch
				982	PTO resume switch
				981	PTO accelerate switch
LFE	65266	FEF2	Fuel Economy		
				183	Fuel rate
IC	65270	FEF6	Inlet / Exhaust Conditions		
				102	Boost pressure
				105	Intake manifold temperature
				106	Air inlet pressure
VEP	65271	FEF7	Vehicle Electrical Power		
				168	Electrical potential (voltage)
				158	Battery potential (voltage) switched
ISCS	64968	FDC8	Operator Primary Intermediate Speed		
				2892	Operator primary

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

					intermediate speed select state
OHECS	64971	FDCB	Off Engine Control Selection		
				2882	Alternate rating select
				2881	Alternate droop accelerate 1 select
				2879	Alternate droop accelerator 2 select
				2886	Alternate droop remote accelerator select
OHCSS	64967	FDC7	Off Highway Engine Control Selection Rate		
				2888	Alternate rating select state
				2889	Alternate droop accelerator 1 select state
				2893	Alternate droop accelerator 2 select state
				2894	Alternate droop remote accelerator select state
RESET	56832	DE00	Reset (Maintenance Indicator Feature)		
				1584	Service component identification
CMI	64969	FDC9	Electronic Control Module Information		
				2887	Total count of configuration changes made
S2	65166	FE8E	Service 2 (Maintenance Indicator Feature)		
				1350	Time since last service
SERV	65216	FEC0	Service Information (Maintenance Indicator Feature)		
				916	Service delay / operational time based
DM1	65226	FECA	Active Diagnostics Trouble Codes		
				987	Protect lamp

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

				623	Stop lamp
				624	Warning lamp
				1214	SPN
				1215	FMI
				1216	Occurrence count
				1706	SPN conversion method
				3040	Amber Warning Lamp Flash
				3041	Protect Lamp Flash
DM2	65227	FECB	Previously Active Diagnostic Trouble Codes		
				1214	SPN
				1215	FMI
				1216	Occurrence count
				1706	SPN conversion method
DM3	65228	FECC	Diagnostic Data Clear / Reset of Previously Active DTCs		
DM4	65229	FECD	Freeze Frame Parameters		
TP.CM_BAM	60416	EC00	Transport Protocol - Connection Management		
TP.DT	60160	EB00	Transport Protocol - Data Transfer		
	61184	EF00	Proprietary A		
	59392	E800	Acknowledge		
	59904	EA00	Request PGN		
EGF1	61450	F00A	Engine Gas Flow Rate		
				2659	Engine Exhaust Gas Recirculation (EGR) Mass Flow Rate
				132	Engine inlet air mass flow rate
AHI1	64920	FD98	Aftertreatment Historical Information		
				3522	Aftertreatment 1 Total Fuel Used
				3523	Aftertreatment 1 Total Regeneration Time
				3524	Aftertreatment 1 Total Disabled Time
				3525	Aftertreatment 1 Total Number of Active

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

					Regenerations
AFC1	64929	FDA1	Aftertreatment 1 Fuel Control		
				3480	Aftertreatment 1 fuel pressure
				3481	Aftertreatment 1 fuel rate
				3479	Aftertreatment 1 fuel pressure control
				3484	Aftertreatment 1 ignition
				3483	Aftertreatment 1 regeneration status
				3482	Aftertreatment 1 fuel enable actuator
EEC5	64981	FDD5	Electronic Engine Controller 5		
				2791	Engine exhaust gas recirculation (EGR) valve control
EI	65170	FE92	Engine Information		
				1242	Instantaneous estimated brake power
AMB	65269	FEF5	Ambient Conditions		
				108	Barometric pressure
				172	Engine air inlet temperature
AAI	65164	FE8C	Auxiliary Analogue		
				441	Auxiliary temperature 1
				442	Auxiliary temperature 2
				1387	Auxiliary pressure #1
				1388	Auxiliary pressure #2
				3087	Auxiliary level
CM1	57344	E000	Cab Message 1		
				986	Requested Percent fan Speed
				3695	Diesel particulate filter regeneration inhibit switch
				3696	Diesel particulate filter regeneration force switch
ESSI	61473	F021	Engine Speed Sensor Information		

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

				4201	Engine speed 1
				723	Engine speed 2
				4204	Engine Speed Sensor 2 Timing Pattern Status
				4203	Engine Speed Sensor 1 Timing Pattern Status
EC2	64895	FD7F	Engine Configuration		
				3670	Maximum crank attempts per start attempt
EOI	64914	FD92	Engine Operating Information		
				3543	Engine operating state
EEC7	64916	FD94	Electronic Engine Controller 7		
				27	Engine exhaust gas recirculation valve position
ECUID	64965	FDC5	ECU Identification Information		
				2901	ECU part number
				2902	ECU serial number
ISC	64970	FDCA	Intermediate Speed Control		
				2880	Engine operator primary intermediate speed select
TCFG2	65099	FE4B	Transmission Configuration 2		
				1845	Transmission torque limit
EEC4	65214	FEBE	Electronic Engine Controller 4		
				166	Engine rated power
				189	Engine rated speed
				3669	Engine rotation direction
				3671	Crank attempt count on present start attempt
AT1FC2	64869	FD65	Aftertreatment 1 Fuel Control 2		
				4077	Aftertreatment 1 fuel pressure 2
AT1AC2	64877	FD6D	Aftertreatment 1 Air Control 2		
				3830	Aftertreatment 1 Secondary air differential pressure
				3831	Aftertreatment 1

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

					secondary air temperature
				3832	Aftertreatment 1 secondary air mass flow
				3837	Aftertreatment 1 secondary air pressure
AT1S	64891	FD7B	Aftertreatment 1 Service		
				3719	Diesel particulate filter 1 soot load percent
				3720	Diesel particulate filter 1 ash load percent
				3721	Diesel particulate filter 1 time since last active regeneration
DPFC1	64892	FD7C	Diesel Particulate Filter Control 1		
				3697	Diesel particulate filter lamp command
				3700	Diesel particulate filter active regeneration
				3701	Diesel Particulate Filter Status
				3703	Diesel particulate filter active regeneration inhibited due to inhibit switch
				3698	Exhaust system high temperature lamp command
AT1I2	64948	FDB4	Aftertreatment 1 Intake Gas 2		
				3242	Aftertreatment 1 Diesel Particulate Filter Intake Gas Temperature
				3241	Aftertreatment 1 exhaust Gas Temperature 1
				3243	Exhaust Gas Temperature 1 Preliminary FMI
TFAC	61466	F01A	Engine Throttle / Fuel actuator Control Command		
				3464	Engine Throttle Actuator 1 Control Command
ET2	65188	FEA4	Engine		

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

			Temperature 2		
				411	Engine Exhaust Gas Recirculation Differential Pressure
				412	Engine Exhaust Gas Recirculation Temperature
EFL / P3	64961	FDC1	Engine Fluid Level / Pressure 3		
				3358	Engine Exhaust Gas Recirculation Inlet Pressure
EBC1	61441	F001	Electronic Brake Controller 1		
				970	Engine Auxiliary Shutdown
ET3	65129	FE69	Engine Temperature 3		
				2630	Engine Charge Air Cooler Outlet Temperature
CCSS	65261	FEED	Cruise Control / Vehicle speed Setup		
				74	Maximum Speed Limit
CCVS	65265	FEF1	Cruise Control / Vehicle Speed		
				84	Wheel Based Vehicle Speed
ETC1	61442	F002	Electronic Transmission Controller 1		
				191	Transmission Output Shaft Speed
				606	Engine Momentary Overspeed Enable
ETC2	61445	F005	Transmission Current Gear		
				523	Transmission Current Gear

19.0 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.

19.1 Sending Messages to the Engine ECM

The engine ECU supports a large number of different J1939 PGN's and SPN's including messages such as TSC1, OHECS, DM1 etc. Some of these messages are requests from external devices such as TSC1 and others are generated on transmitted by the ECM itself. Messages intended to be sent to the engine ECM require that the correct source and destination addresses are used.

19.1.1 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 F0. 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 ECM will accept messages from modules with any source address as long as it is different to the source address of the engine ECM.

19.1.2 Configurable ECM Source Addressing

For applications requiring the use of multiple engines during operation there is the option for the engine ECM source address to be modified from the default setting of 00. This can be modified using the ET service tool.

19.1.3 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 (unless the ECM address has been changed using the service tool).

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 ECM 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 ECM 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.

19.2 J1939 Section 71 – TSC1 Operation

19.2.1 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 ECM), 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.

19.2.1.1 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 and PWM throttles. The only speed input available which is not overridden by the TSC1 message is the intermediate engine speed feature as described in section 9 of this guide.

19.2.1.2 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 ECM. Care must be taken when operating this mode as controlling engine fuelling can lead to unpredictable engine behavior (and speed) especially when implemented under transient load conditions.

Note: This feature must not be implemented without consulting the Applications Engineering department and a full FMEA/risk assessment must be carried out by the customer.

19.2.1.3 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.

19.2.1.4 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. Figure 19.0 shows an example of an engine torque curve and the resulting engine

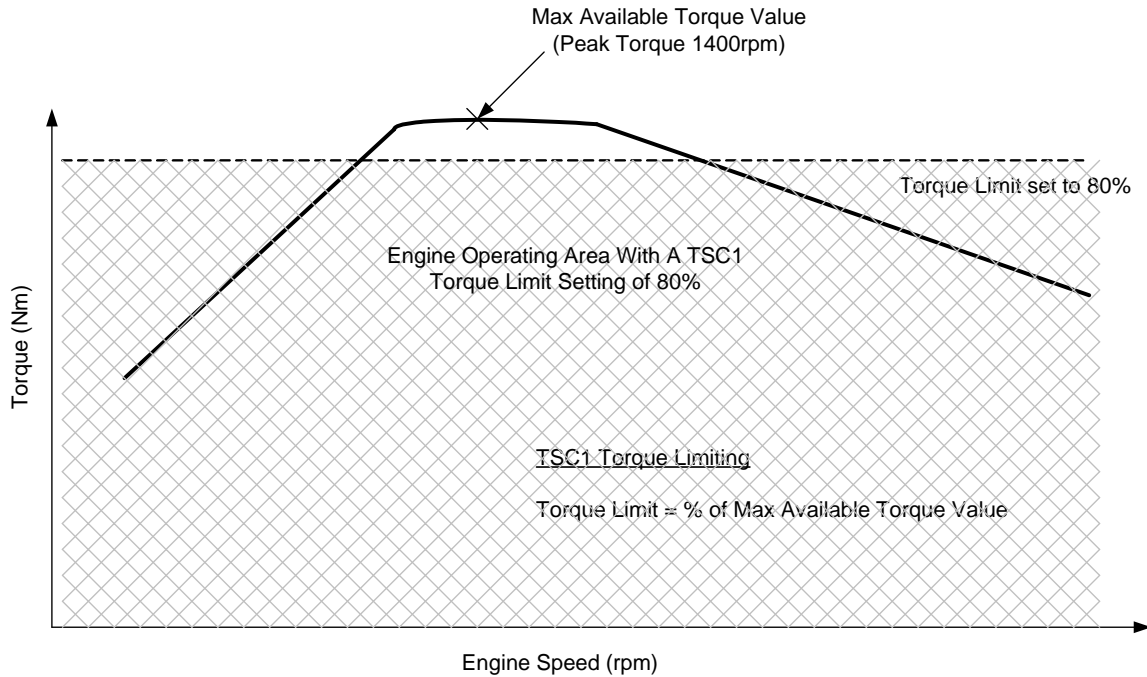


Figure 19.0 TSC1 Torque Limiting Operation

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%.

19.2.1 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 or limit engine speed. 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 notes	00

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	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					
	X	Requested Speed Control Conditions (spn 696)		3	2						
	X	Override Control Mode Priority (spn 897)		5	2						A
	X	Highest Priority				00					A
	X	High Priority				01					A
	X	Medium Priority				10					A
	X	Low Priority				11					A
		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	B

Figure ?

19.2.1.1 ECM Response Time To TSC1 Request

The mean response time for the ECM to alter the desired speed following a TSC1 request is 52ms +/-5ms. 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 Electronic Applications Engineer.

19.2.1.2 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 over-rides all other configured throttle inputs.

There are currently 2 TSC1 fault-handling options available in the service tool, these are described as 'TSC1 Continuous Fault Handling: Disabled or Enabled'.

19.2.1.3 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 ECM, 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 PWM throttle pedal. TSC1 override is switched on and off using the Override Control Mode SPN.

19.2.1.4 End of Transmission – Fault Detection

The ECM needs to differentiate between the end of a transmission by another controller and an intermittent failure. The ECM 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 then the ECM will recognize this as a fault, a J1939 Diagnostic code will be raised and the ECM will not accept any TSC1 speed requests for the remainder of the key cycle.

19.2.1.5 TSC1 Continuous Fault Handling: [Enabled]

This mode is also known as *Continuous* fault detection, it is suitable for applications where either TSC1 is the only throttle used or where TSC1 is continuously used to limit the top engine speed. The TSC1 speed control / speed limit cannot be switched off using the Override Control Mode SPN. For instance, in a wheeled excavator the analogue throttle is connected to the machine ECM 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 over-ridden, and will only become available if a TSC1 fault is detected.

19.2.1.6 Rating and Droop Control

In addition to Torque Speed Control, the complimentary message 'OHECS' allows droop and rating selection over J1939 with a similar effect to the hard-wired 'Mode Selection' feature. The OHECS PGN is described later in this section.

19.3 J1939 Engine ECM Transmit PGN Support

19.3.1 Electronic Brake Controller 1 (EBC1) (61441)

The EBC1 message is normally used to control a machine braking system. The auxiliary engine shutdown switch SPN allows an external component on the J1939 network to shutdown the engine without using the keyswitch and sending the ECM into sleep mode. The resulting stop should not be used as a safety related fail safe stop function.

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
		61441					-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
x		Engine Auxiliary Shutdown (SPN 970)	4	5	2		state	4 states/2 bit	0	3	
		Off				00					
		On				01					
		Error				10					
		Not Available				11					

19.3.2 Electronic Engine Controller 2 (EEC2) (61443)

EEC2 identifies electronic engine control related parameters, including pedal position and IVS status for throttle 1 and 2 as well as the percent load at the current engine speed.

Note that the name accelerator pedal is not always accurate for off-highway machines. Accelerator pedal 1 refers to any pedal, lever or device that uses either the analogue 1 or PWM 1 throttle input. Likewise accelerator pedal position 2 refers to any device using the throttle 2 input.

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
0C F0 03 00	50	00F003	3	0	0	00	-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
X		Accelerator Pedal Low Idle Switch 1 (spn 558)	1	1	2		state	4 states/2 bit	0	3	C
X		Accelerator pedal <u>not</u> in low idle condition				00					
X		Accelerator pedal in low idle condition				01					
X		Error indicator				10					
X		Not available or not installed				11					
		Accelerator Pedal Kickdown Switch		3	2						

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

X	Accelerator Pedal Low Idle Switch 2 (spn 2970)	1	7	2		state	4 states/2 bit	0	3	A
X	Accelerator pedal <u>not</u> in low idle condition					00				
X	Accelerator pedal in low idle condition					01				
X	Error indicator					10				
X	Not available or not installed					11				
X	Accelerator Pedal Position 1 (spn 91)	2	1	8		%	0.4%/bit	0	100	
X	Percent Load at Current Speed (spn 92)	3	1	8		%	1%/bit	0	125	B
	Remote Accelerator	4	1	8						
X	Accelerator Pedal Position 2 (spn 29)	5	1	8		%	0.4%/bit	0	100	A,

Note A: Accelerator pedal low idle 2 and accelerator pedal position 2 are new parameters only recently defined by The SAE. The start byte / bit of accelerator pedal low idle switch 2 is still to be defined.

Note B: Percent load at current speed is estimated from the steady state engine calibration maps. This parameter is not accurate at low loads or during transient conditions.

Note C: When there is a discrepancy between the pedal position and the idle validation switch position the accelerator pedal low idle switch parameter will be transmitted as 10 (error state) and the accelerator pedal position will be transmitted as FE (error state). However if a pedal is not configured then it will be transmitted as not supported. This applies to both accelerator 1 and 2.

19.3.3 Electronic Engine Controller 1 (EEC1) (61444)

EEC1 identifies the electronic engine control related parameters including engine torque mode, actual engine percent torque, actual engine speed, drivers demand engine percent torque.

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
0C F0 04 00	20	00F004	3	0	0	00	

S e n d e i v e	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
X		Engine Torque Mode (SPN899)	1	1	4		state	16 states/4 bit	0	15	B
		Low Idle Governor					0000				B
		Accelerator Pedal 1					0001				B
		Cruise Control					0010				
		PTO Governor					0011				B
		Road Speed Governing					0100				
		ASR Control					0101				
		Transmission Control					0110				B
		ABS Control					0111				
		Torque Limiting					1000				B
		High Speed Governor					1001				B
		Brake System					1010				
		Not defined (1011 – 1101)									

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

	Other				1110				
	Not available				1111				
	Not Defined		5..8						
X	Drivers Demand Engine - Percent Torque (SPN 512)	2	1	8		%	1%/bit	0	125
X	Actual Engine - Percent Torque (SPN 513)	3	1	8		%	1%/bit	0	125
X	Engine Speed (SPN 190)	4	1	16		rpm	0.125rpm/bit	0	8,031.875
	Source Address of Controlling Device for Engine Control (SPN 1483)	6	1	8		None	1	0	253
	Engine Starter Mode (SPN 1675)	7	1	4					
X	Engine demand – percent torque (SPN 2432)	8	1	8		%	1%/bit	0	125

Note A: The J1939 standard describes the frequency of transmission of this PGN as engine speed dependant. The ECM actually transmits the message every 20ms, however, irrespective of engine speed.

Note B: During the engine cranking cycle while the ECM is detecting engine position and speed, engine speed is transmitted as FE00 or “Unavailable”. When this value is converted to engine speed it gives the value of 8128rpm.

19.3.4 Turbocharger Wastegate (TCW) (65174)

TCW contains the SPN, turbocharger 1 wastegate drive. This transmitted value directly equates to the PWM duty cycle of the smart wastegate solenoid. A value of 0% represents fully closed and a value of 100% represents fully open. Due to the fact that the wastegate is also intake manifold pressure dependent, this value does not necessarily align to the actual position of the smart wastegate.

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18FE9600	100	FE96	6	0	0	00	-

Send	Receive	Parameter name	Byte	Bit	Length	Start	Units	Resolution (unit/bit)	Range		Note
									Min	Max	
X		Turbocharger 1 Wastegate Drive (spn 1188)	1	1	8		%	0.4%/bit	0	100	
		Turbocharger 2 Wastegate Drive	2	1	8						
		Turbocharger 3 Wastegate Drive	3	1	8						
		Turbocharger 4 Wastegate Drive	4	1	8						
		Turbocharger Wastegate Act Control Pressure	5	1	8						

19.3.5 Auxiliary Discrete IO state (AUXIO) (65241)

The AUXIO PGN is used to transmit the status of all the customer side switch inputs and two of the analogue voltage inputs of the engine ECM, irrespective of whether the input is used by the ECM for an application software feature. The spare inputs of the ECM are available for use by the machine designer as additional input channels for non-engine systems. The table below indicates the inputs, the switch connectors and the associated J1939 SPN.

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18FED900	Note A	FED9	6	0	0	00	-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
X		Auxiliary I/O #04 (spn 704)	1	1	2						B
X		Auxiliary I/O #03 (spn 703)	1	3	2						B
X		Auxiliary I/O #02 (spn 702)	1	5	2						B
X		Auxiliary I/O #01 (spn 701)	1	7	2						B
X		Auxiliary I/O #08 (spn 708)	2	1	2						B
X		Auxiliary I/O #07 (spn 707)	2	3	2						B
X		Auxiliary I/O #06 (spn 706)	2	5	2						B
X		Auxiliary I/O #05 (spn 705)	2	7	2						B
		Auxiliary I/O #12 (spn 712)	3	1	2						B
X		Auxiliary I/O #11 (spn 711)	3	3	2						B
X		Auxiliary I/O #10 (spn 710)	3	5	2						B
X		Auxiliary I/O #09 (spn 709)	3	7	2						B
		Auxiliary I/O #16 (spn 716)	4	1	2						B
		Auxiliary I/O #15 (spn 715)	4	3	2						B
X		Auxiliary I/O #14 (spn 714)	4	5	2						B
X		Auxiliary I/O #13 (spn 713)	4	7	2						B
X		Auxiliary I/O Channel #1 (spn 1083)	5,6	1	16				0	64255	C
X		Auxiliary I/O Channel #2 (spn 1084)	7,8	1	16				0	64255	C

Note A: The message will be sent at a frequency of 100ms, and additionally when any of the supported switch inputs (spn's 701 through 716) change state

Note B: Each of the switch inputs is transmitted as 00 if it the switch is open (or not connected) and 01 if it is closed.

Note C: The analogue channels are scaled at 0.955Volts per bit with a 0.5V offset. For example a voltage of 2.5Volts would be transmitted as (2.5volts – 0.5 v offset)/0.000955 volts/bit = 2094₁₀ or 82E₁₆

Table of Input pins to SPN's

Input name	ECM J1 Connector Pin	J1939 SPN
SWG1	TBD	701
SWG2	TBD	702
SWG3	TBD	703
SWG4	TBD	704
SWG5	TBD	705
SWG6	TBD	706
SWG7	TBD	707
SWG8	TBD	708
SWG9	TBD	709
SWG10	TBD	710

SWG11	TBD	711
SWB1	TBD	713
SWB2	TBD	714
AIN_ACT5	TBD	1083
AIN_ACT4	TBD	1084

19.3.6 Software Identification (SOFT) (65242)

The software identification PGN is requested via the request PGN message, the message includes the software part number and the software version release date. This PGN has more than 8 bytes of data; therefore the message content is returned using the transport protocol. The message format is shown below.

ASCII code as follows:

02 SWPN:123456701*SWDT:MAY05*

Software part number (SWPN) will be of the form 123456701

Software release date (SWDT) will be of the form MAY05

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18FEDA00	On Req	FEDA	6	0	0	00	-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
X		Number of software identification fields (spn 965)	1	1	8				0	250	A
X		Software Identification (spn 234)	2	1	N		ASCII		0	255	B

Note A: The number of software identification fields will be transmitted as “02”

Note B: The software identification is ASCII text, with the fields delimited by a “**”

19.3.7 Engine Fluid Level / Pressure 2 (EFL/P2) (65243)

EFL/P2 includes the injector metering rail 1 pressure SPN, which indicates the gauge pressure of the fuel in the high pressure fuel rail.

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18FEDB00	500	FEDB	6	0	0	00	-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
		Injector Control Pressure	1	1	16						
X		Injector Metering Rail 1 Pressure	3	1	16		Mpa	1/256Mpa/Bit	0	251	

	(spn157)									
	Injector Timing Rail 1 Pressure	5	1	16						
	Injector Metering Rail 2 Pressure	7	1	16						

19.3.8 Electronic Engine Controller 3 (EEC3) (65247)

EEC3 identifies the electronic engine control related parameter, engine desired operating speed as well as the estimated nominal friction torque % and the estimated parasitic losses as a torque %. Engine desired operating speed is calculated as requested speed demand from the throttle input i.e. the speed at which the engine would run if all load were removed and the current speed demand conditions maintained.

Both nominal friction torque and the estimated parasitic losses SPN's are calculated within the engine ECM and are approximations only.

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18 FE DF 00	250	FEDF	6	0	0	00	-

S e n d e r i v e	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
x		Nominal friction – Percent Torque (spn 514)	1	1	8		%	1%/bit	-125	+125	
X		Engine's Desired Operating Speed (spn 515)	2	1	16		Rpm	.125rpm/bit	0	8031.875	A
		Engine's Operating Speed Asymmetry Adjustment (spn 519)	4	1	8		Ratio	1/bit	0	250	
x		Estimated Engine Parasitic Losses - Percent Torque (spn 2978)	5	1	8		%	1%/bit	-125	+125	

Note A: Engine desired operating speed will be the speed at which the engine would run if all load were removed and current speed demand conditions maintained.

19.3.9 Engine Configuration (EC) (65251)

The engine configuration PGN describes the stationary behaviour of the engine via an engine speed torque map, by transmitting both the torque and speed values at several points on the torque curve. This map is only valid for steady state engine operation and with maximum boost pressure. The values will change if a different torque curve is selected or to reflect the engine entering a derate condition due to excessive engine coolant temperature for example. This PGN is more than 8 bytes long and so it will always be transmitted via the transport protocol.

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
See Note A	See Note B	FEE3	6	0	0	00	-

S	R	Parameter name	B	B	L	S	U	Resolution (unit/bit)	Range		N
									yte	it	
X		Engine Speed at Idle, Point 1 (spn 188)	1	1	16		Rpm	0.125rpm/bit	0	8031	
X		Percent Torque at Idle, Point 1 (spn 539)	3	1	8		%	1%/bit	-125	+125	
X		Engine Speed at Point 2 (spn 528)	4	1	16		Rpm	0.125rpm/bit	0	8031	D
X		Percent Torque at Point 2 (spn 540)	6	1	8		%	1%/bit	-125	+125	D
X		Engine Speed at Point 3 (spn 529)	7	1	16		Rpm	0.125rpm/bit	0	8031	
X		Percent Torque at Point 3 (spn 541)	9	1	8		%	1%/bit	-125	+125	
X		Engine Speed at Point 4 (spn 530)	10	1	16		Rpm	0.125rpm/bit	0	8031	
X		Percent Torque at Point 4 (spn 542)	12	1	8		%	1%/bit	-125	+125	
X		Engine Speed at Point 5 (spn 531)	13	1	16		Rpm	0.125rpm/bit	0	8031	
X		Percent Torque at Point 5 (spn 543)	15	1	8		%	1%/bit	-125	+125	
X		Engine Speed at High Idle, Point 6 (spn 532)	16	1	16		Rpm	0.125rpm/bit	0	8031	D
		Gain (KP) of the Endspped Governor (spn 545)	18	1	16		%/rpm	0.0007813%/rpm/bit	0	50.2	
X		Reference Engine Torque (spn 544)	20	1	16		Nm	1Nm/bit	0	64255	C
		Maximum Momentary Engine Override Speed, Point 7 (spn 533)	22	1	16		Rpm	0.125rpm/bit	0	8031	
x		Maximum Momentary Override Time Limit (spn 534)	24	1	8		S	0.1sec/bit	0	25	
		Requested Speed Control Range Lower Limit (spn 535)	25	1	8		Rpm	10rpm/bit	0	2500	
		Requested Speed Control Range Upper Limit (spn 536)	26	1	8		Rpm	10rpm/bit	0	2500	
		Requested Torque Control Range Lower Limit (spn 537)	27	1	8		%	1%/bit	-125	+125	
		Requested Torque Control Range Upper Limit (spn 538)	28	1	8		%	1%/bit	-125	125	
x		Engine Default Torque Limit (SPN 1846)	33	1	16		Nm	1Nm/bit	0	64,255	

Note A: This PGN is sent every 5 seconds but also whenever there is a change in active torque limit map.

Note B: Engine reference torque is the advertised bare engine torque of the highest “enabled” rating in the box. That is the highest rating that can be selected via mode switches or J1939, whilst the engine is running.

Note C: As both point 2 and point 6 are supported, and Gain (Kp) of Endspped Governor is not, the support of this message conforms to Engine Configuration Characteristic Mode 1 as described in the J1939-71 specification

19.3.10 Shutdown (SHUTDOWN) (65252)

The shutdown PGN contains the SPN wait to start lamp output. This indicates that the engine is too cold to start and the operator should wait until the signal becomes inactive (turn off).

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18 FE E4 00	1000	FEE4	6	0	0	00	-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
		Idle shutdown has shut down engine (spn 593)	1	1	2						
		Idle shutdown driver alert mode (spn 594)		3	2						
		Idle shutdown timer override (spn 592)		5	2						
		Idle shutdown timer state (spn 590)		7	2						
		Idle shutdown timer function (spn 591)		7	2						
		A/C high pressure fan switch (spn 985)	3	1	2						
		Refrigerant low pressure switch (spn 875)		3	2						
		Refrigerant high pressure switch (spn 605)		5	2						
X		Wait to start lamp (spn 1081)	4	1	2		state	4 states/2 bit	0	3	
X		Off				00					
X		On				01					
		Engine protection system has shut down engine (spn 1110)	5	1	2						
		Engine protection system approaching shutdown (spn 1109)		3	2						
		Engine protection system timer override (spn 1108)		5	2						
		Engine protection system timer state (spn 1107)		7	2						
		Engine protection system configuration (spn 1111)		7	2						

19.3.11 Engine Hours / Revolutions (HOURS) (65253)

HOURS PGN contains the PSN total engine hours. The SAE defines this PGN as being sent on request. However, there are some gauges and displays on the market, which require this to be broadcast. Consequently this message is broadcast at a low update rate, to ensure compatibility with these devices.

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18 FE E5 00	1000	FEE5	6	0	0	00	-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
X		Total engine hours (spn 247)	1	1	32		Hr	0.05hr/bit	0	210,554,060	
X		Total engine revolutions	5	1	32		Rev	1000r/bit	0	4,211,081,215,000	

19.3.12 Fuel Consumption (LFC) (65257)

The fuel consumption PGN contains the SPN total fuel used and trip fuel. Both of these measurements are not direct measurements. Trip fuel is the fuel used for a given key cycle and total fuel used is an accumulative value, which is not reset upon key cycle. Both of these parameters are calculated from standard test fuel at standard test temperatures. The characteristics of most fuels in the field will differ from the test fuel, particularly at very high or very low temperatures. It is recommended, therefore, that this value is taken to be an indication only of the fuel used by an engine.

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18 FE E9 00	On Req	00FEE9	6	0	0	00	-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
X		Trip fuel (spn 182)	1	1	32		L	0.5l/bit	0	2,105,540,607	
X		Total fuel used (spn 250)	5	1	32		L	0.5l/bit	0	2,105,540,607	

19.3.13 Component ID (CI) (65259)

The component identification PGN is requested via the request PGN message. The message includes the engine make, engine model number and the engine serial number. This PGN has more than 8 bytes of data, therefore the message content is returned using the transport protocol. The format of the content is given below;

All these parameters are supported as ASCII text delimited by “*”

“Make” will be transmitted as “CTRPL”

“Model” will be transmitted in the form “1106D” or “1104D”

“Serial Number” will be the engine serial number as marked on the nameplate of the engine

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18 FE EB 00	On Req	00FEEB	6	0	0	00	-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
X		Make (spn 586)					ASCII	None			A
X		Model (spn 587)					ASCII	None			A
X		Serial Number (spn 588)					ASCII	None			A
		Unit Number (spn 233)					ASCII	None			

19.3.14 Vehicle Identification (VI) (65260)

The vehicle identification PGN is requested via the request PGN message. The message includes only the vehicle identification number PGN. This PGN has more than 8 bytes of data, therefore the message content is returned using the transport protocol. This PGN may be requested from the ECU but currently the message will simply contain the ASCII text “NOT PROGRAMMED”.

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18FEEC00	On request	FEEC	6	0	0	00	-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
X		Vehicle Identification number (SPN 237)	1		N		ASCII	None	0	255	A

Note A: Byte; 1-n Vehicle Identification number delimiter (ASCII “*”))

19.3.15 Engine Temperature (ET1) (65262)

ET1 contains the SPN engine coolant temperature, this SPN contains the engine coolant temperature as sensed by the engine control system.

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18 FE EE 00	1000	FEEE	6	0	0	00	-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
X		Engine Coolant Temperature (spn 110)	1	1	8		deg C	1DegC/bit	-40	210	
		Fuel Temperature	2	1	8		deg C	1	-40	210	
		Engine Oil Temperature	3	1	16		deg C	.03125	-273	1735	
		Turbo Oil Temperature	5	1	16		deg C	.03125	-273	1735	
		Engine Intercooler Temperature	7	1	8		deg C	1	-40	210	
		Engine Intercooler Thermostat Opening	8	1	8		%	.4	0	100	

19.3.16 Engine Fluid Level / Pressure (EFL/P1) (65263)

EFL/P1 contains the SPN engine oil pressure. This SPN contains the oil pressure as sensed by the engine control system.

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18 FE EF 00	500	FEEF	6	0	0	00	-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
		Fuel Delivery Pressure	1	1	8		KPA	4	0	1000	
		Extended Crankcase Blow-by Pressure	2								
		Engine Oil Level	3	1	8		%	.4	0	100	
X		Engine Oil Pressure (spn 100)	4	1	8		KPa	4kPa/bit	0	1000	
		Crankcase Pressure	5	1	16						
		Coolant Pressure	7	1	8		kPa	2	0	500	
		Coolant Level	8	1	8		%	.4	0	100	

19.3.17 PTO information (PTO) (65264)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18FEF000	100	FEF0	6	0	0	00	-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
		Power Takeoff Oil Temperature (spn 90)	1	1	8						
		Power Takeoff Speed (spn 186)	2	1	16						
		Power Takeoff Set Speed (spn 187)	4	1	16		Rpm	Rpm	0	8031	
X		PTO Enable Switch (spn 980)	6	1	2		state	4 states/2 bit	0	3	
X		Off				00					
X		On				01					
		Error				10					
		Not Available				11					
		Remote PTO preprogrammed Speed Control Switch (spn 979)	6	3	2						
		Remote PTO variable Speed Control Switch (spn 978)	6	5	2						
X		PTO set switch (spn 984)	7	1	2		state	4 states/2 bit	0	3	A
X		Off				00					
X		On				01					
		Error				10					
		Not Available				11					
X		PTO Coast / Decelerate Switch (spn 983)	7	3	2		state	4 states/2 bit	0	3	A
X		Off				00					
X		On				01					
		Error				10					
		Not Available				11					
X		PTO Resume Switch (spn 982)	7	5	2		state	4 states/2 bit	0	3	A
X		Off				00					
X		On				01					
		Error				10					
		Not Available				11					
X		PTO Accelerate Switch (spn 981)	7	7	2		state	4 states/2 bit	0	3	A
X		Off				00					
X		On				01					
		Error				10					
		Not Available				11					

Note A: Some of the PTO mode switch inputs on the ECM have dual functions. For example, one button provides both SET and LOWER functions and another button provides both RAISE and RESUME functions. When the SET/LOWER button is pressed, both SPN 984 and SPN 938 will go to the active state, for at least one message transmission. Similarly, when the RAISE/RESUME button is pressed then both SPN 982 and SPN 981 will go to the active state.

As per normal J1939 protocol '10' and '11' should be used to signify 'unsupported' and 'fault' respectively. As such support for these SPNs should only be seen when PTO mode is configured to be 'on'.

19.3.18 Fuel Economy (LFE) (65266)

LFE contains the PGN fuel rate. This parameter is not a direct measurement it is calculated from a standard test fuel at standard test temperatures. The characteristics of most fuels in the field will differ from the test fuel, particularly at very high or very low temperatures. Its is recommended, therefore that this value is taken to be an indication only for the fuel used by an engine.

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18 FE F200	100	FEF2	6	0	0	00	-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e	
									Min	Max		
X		Fuel Rate (spn 183)	1	1	16		L/hr	0.05l/h/bit	0	3212		
		Instantaneous Fuel Economy		3	1	16		km/kg	1/512	0	125.5	
		Average Fuel Economy		5	1	16		km/kg	1/512	0	125.5	
		Throttle Position		7	1	8		%	.4	0	100	

19.3.19 Inlet / Exhaust Conditions (IC) (65270)

IC1 contains the SPN's boost pressure, intake manifold temperature and air inlet pressure. All of these parameters are broadcast as sensed by the engine control system.

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18 FE F6 00	500	FEF6	6	0	0	00	-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
		Particulate Trap Inlet Pressure	1	1	8		kPa	0.5kPa/bit	0	125	
X		Boost Pressure (spn 102)	2	1	8		kPa	2kPa/bit	0	500	B
X		Intake Manifold Temperature (spn 105)	3	1	8		deg C	1DegC/bit	-40	210	
X		Air Inlet Pressure (spn 106)	4	1	8		kPa	2kPa/bit	0	500	A
		Air Filter Differential Pressure	5	1	8		kPa	0.05kPa/bit	0	12.5	
		Exhaust Gas Temperature	6	1	16		deg C	0.03125DegC/bit	-273	1735	
		Coolant Filter Differential Pressure	8	1	8		kPa	0.5kPa/bit	0	125	

Note A: Inlet air pressure will be supported as the absolute pressure as measured by the inlet manifold pressure sensor.

Note B: Boost pressure will be calculated from inlet manifold temperature. Boost pressure will never be transmitted as a negative number, even though a slight depression at the inlet is possible for some engines when running at low idle speed.

19.3.20 Vehicle Electrical Power (VEP) (65271)

VEP contains the SPN's electrical potential and battery potential. Electrical potential and battery potential parameters are both supported with the same value, which is the voltage measured between the battery (+) and battery (-) terminals of the ECM.

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18 FE F7 00	1000	FEF7	6	0	0	00	-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
		Net Battery Current	1	1	16		Amp	1A/bit	-125	125	
		Alternator Potential (Voltage)	3	1	16		V	0.05V/bit	0	3212	
X		Electrical Potential (Voltage) (spn 168)	5	1	16		V	0.05V/bit	0	3212	
X		Battery Potential (Voltage), Switched (spn 158)	7	1	16		V	0.05V/bit	0	3212	

19.3.21 Operator Primary Intermediate Speed (ISCS) (64968)

This PGN is used to describe the logical state of the throttle position switch input (also known as multi-position throttle switch).

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18FDC800	1000	FDC8	6	0	0	00	-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
X		Operator Primary Intermediate Speed Select State (spn 2892)	1	1	4		state	16 states/4 bit	0	15	
		Intermediate speed not requested				0000					A
X		Logical Position 1				0001					
X		Logical Position 2				0010					
X		Logical Position 3				0011					
X		Logical Position 4				0100					
X		Logical Position 5				0101					
X		Logical Position 6				0110					
X		Logical Position 7				0111					

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

X	Logical Position 8				1000					
X	Logical Position 9				1001					
X	Logical Position 10				1010					
X	Logical Position 11				1011					
X	Logical Position 12				1100					
X	Logical state 13, 14, 15 or 16				1101					B
	Reserved				1110					
X	Not available				1111					C

Note A: “intermediate speed not requested” state is not supported. Note however, that on most applications where throttle position switch is used, logical position 1 will be all four switches in the open position and will equate to engine idle.

Note B: There are only 13 states available but 16 possible combinations of the 4 switch inputs. No known application has used more than 10 states however, or is expected to use more than 10 states in the future, so this is not envisaged that this will cause a problem. If 16 states are use then logical states 14, 15 and 16 will be transmitted as 13.

Note C: If the throttle position switch is not configured on an application then the ECM will send 1111₂ not available.

19.3.22 Off highway Engine control selection state (OHCSS) (64967)

OHCSS broadcasts the SPN’s corresponding engine rating select and droop select. When the engine is controlled by the hard-wired mode selection, then OHCSS will contain this data. However when the OHECS PGN is used to control rating and droop select, the OHCSS message will mirror the override information.

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18FDC700	500	FDC7	6	0	0	00	-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
		Auxillary Governor State	1	1	2						
		Multi-Unit Synch State	1	3	2						
		Alternate Low Idle Select State	1	5	2						
X		Alternate Rating Select State (spn 2888)	2	1	8		state	256 states/8 bit	0	255	
X		Alternate Droop Accelerator 1 Select State (spn 2889)	3	1	4						A
X		Alternate Droop Accelerator 2 Select State (spn 2893)	3	5	4						A
X		Alternate Droop Remote Accelerator Select State (spn 2894)	4	1	4						A
		Alternate Droop Auxillary Input Select State	4	5	4						A

Note A: These spn's are populated in the same manner as those transmitted within the OHECS message.

19.3.23 Reset (Maintenance Indicator Feature) (56832)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18DE0000	On request	DE00	7	0	0	00	-

S e n d e r	R e c e i v e r	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
		Trip Group 1 (SPN 988)	1	1	2						
		Trip Group 2 (SPN 989)	1	3	2						
x		Service Component Identification (SPN 1584)	2	1	8		ID	1ID/bit	0	250	
		Engine Build Hours Reset (SPN 1211)	3	1	2						

Note: This message requires an Acknowledgement response (See J1939 21, PGN 59392) from the receiving node. The use of individual proprietary protocols can still be used instead of the "trip reset" PGN to maintain security.

19.3.24 Electronic Control Module Information (CMI) (64969)

The CMI PGN is used to transmit the total count of configuration changes made SPN. This SPN is a running count of the number of electronic configuration changes made via a service tool. This value represents the total tattletale value shown with the service tool.

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18FDC900	On request	FDC9	7	0	0	00	-

S e n d e r	R e c e i v e r	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
x		Total Count of Configuration Changes Made (spn 2887)	1	1	16		count	1count/bit	0	64,255	

19.3.25 Service 2 (Maintenance Indicator Feature) (S2) (65166)

The S2 PGN is transmitted with the time since last service SPN. This SPN indicates in hours the time accrued since the last engine service took place.

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18FE8E00	On request	FE8E	7	0	0	00	-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
		Service Component Identification (SPN 1379)	1		8						
X		Time Since Last Service (SPN 1350)	2	1	16		hours	1hr/bit	-32,127	32,128	

19.3.26 Service Information (Maintenance Indicator Feature) (SERV) (65216)

Transmitted with the service component identification that has the nearest time until the next service inspection.

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18FEC000	On request	FEC0	6	0	0	00	-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
		Service Component Identification (SPN 911)	1		8						
		Service Distance (SPN 914)	2		16						
		Service Component Identification (SPN 912)	4		8						
		Service Delay/Calendar Time Based (SPN 915)	5		8						
		Service Component Identification (SPN 913)	6		8						
X		Service Delay/Operational Time Based (SPN 916)	7	1	16		hours	1hr/bit	-32,127	32,128	

Note: There are two acceptable formats for the Service PGN. Format 1 has only 8 bytes of data and reports the component most in need of service for each of the three categories. Format 2, however, uses the transport layer as necessary in order to repeat these 8 bytes of service component information until all supported service components in each category have been transmitted.

19.3.27 Engine Gas Flow Rate (EGF1) (61450)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
OCF00A00	50	F00A	3			00	-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
x		Engine Exhaust Gas Recirculation (EGR) Mass Flow Rate (SPN 2659)	1	1	16		Kg/h	0.05kg/h per bit, 0 offset	0	3212.75	
X		Engine Inlet Air Mass Flow Rate (SPN 132)	3	1	16		Kg/h	0.05kg/h per bit, 0 offset	0	3212.75	Will we be using this?

19.3.28 Aftertreatment 1 Historical Information (AH11) (64920)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18FD9800	Request	64920	6				-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
x		Aftertreatment 1 Total Fuel Used (SPN 3522)	1		32		L	0.5L/bit	0	2,105,540,607.5	
x		Aftertreatment 1 Total Regeneration Time (SPN 3523)	5		32		sec	1sec/bit	0	4,211,081,215	
x		Aftertreatment 1 Total Disabled Time (SPN 3524)	9		32		sec	1sec/bit	0	4,211,081,215	
x		Aftertreatment 1 Total Number of Active Regenerations (SPN 3525)	13		32		count	1 count/bit	0	4,294,967,295	

19.3.29 Aftertreatment 1 Fuel Control AFC1 (64929)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18FDA100	500	64929	6				-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
x		Aftertreatment 1 Fuel Pressure (SPN 3480)	1	1	16		kPa	0.1kPa/bit	0	6,425.5	

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

x	Aftertreatment 1 Fuel Rate (SPN 3481)	3	1	16		L/h	0.05L/h/bit	0	3,212.75	
x	Aftertreatment 1 Fuel Pressure Control (SPN 3479)	5	1	16		%	0.0025%/bit	0	160.6375	
x	Aftertreatment 1 Ignition (SPN 3484)	7	3	2		state	4 states/2 bit	0	3	
X	Not Active									
X	Active									
	Reserved									
	Not Available									
x	Aftertreatment 1 Regeneration Status (SPN 3483)	7	5	2		state	4 states/2 bit	0	3	
X	Not Active									
X	Active									
	Reserved									
	Not Available									
X	Aftertreatment 1 Fuel Enable Actuator (SPN 3482)	7	7	2		state	4 states/2 bit	0	3	
X	Not Active									
X	Active									
	Reserved									
	Not Available									

19.3.30 Electronic Engine Controller 5 (EEC5) (64981)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18FDD500	Request	64981	6				-

S e n c e i v e	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
		Engine Turbocharger 1 Calculated Turbine Inlet Temperature (SPN 2789)	1	1	16						
		Engine Turbocharger 1 Calculated Turbine Outlet Temperature (SPN 2790)	3	1	16						
x		Engine Exhaust Gas Recirculation (EGR) Valve Control (SPN 2791)	5	1	16		%	0.0025%/bit	0	160.6375	
		Engine Variable Geometry Turbocharger (VGT) Air Control Shutoff Valve (SPN 2792)	7	1	2						
		Engine Variable Geometry Turbocharger (VGT) 1 Actuator Position (SPN 2795)	8	1	8						

19.3.31 Engine Information (EI) (65170)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
ICFE9200	100	65170	7				-

S e n c e i v e	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
		Engine Pre-Filter Oil Pressure (SPN 1208)	1	1	8						
		Engine Exhaust Gas Pressure (SPN 1209)	2	1	16						

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

		Engine Fuel Rack Position (SPN 1210)	4	1	8					
		Engine Gas Mass Flow Rate 1 (SPN 1241)	5	1	16					
x		Instantaneous Estimated Brake Power (SPN 1242)	7	1	16		kW	0.5kW/bit	0	32,127.5

19.3.32 Ambient Conditions (AMB) (65269)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18FEF500	1000	65269	6				-

S	R	Parameter name	B	B	L	S	U	Resolution (unit/bit)	Range		N
									y	i	
e	e		t	t	n	a	i		Min	Max	t
n	c		e	g	t	t	t				e
d	e		h	e	s	s					
i	i										
v	v										
e	e										
x		Barometric Pressure (SPN 108)	1	1	8		kPa	0.5kPa/bit	0	125	
		Cab Interior Temperature (SPN 170)	2	1	16						
x		Ambient Air Temperature (SPN 171)	4	1	16						
x		Engine Air Inlet Temperature (SPN 172)	6	1	8		Deg C	1DegC/bit	-40	210	-40 DegC offset

19.3.33 Auxiliary Analogue (AAI) (65164)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
1CFE8C00	Request	65164	7				-

S	R	Parameter name	B	B	L	S	U	Resolution (unit/bit)	Range		N
									y	i	
e	e		t	t	n	a	i		Min	Max	t
n	c		e	g	t	t	t				e
d	e		h	e	s	s					
i	i										
v	v										
e	e										
x		Auxiliary Temperature 1 (SPN 441)	1		8		DegC	1DegC/bit	-40	210	-40 DegC Offset
x		Auxiliary Temperature 2 (SPN 442)	2		8		DegC	1DegC/bit	-40	210	-40 DegC Offset
x		Auxiliary Pressure #1 (SPN 1387)	3		8		kPa	16kPa/bit	0	4000	
x		Auxiliary Pressure #2 (SPN 1388)	4		8		kPa	16kPa/bit	0	4000	
x		Auxiliary Level (SPN 3087)	5		16		mm	0.1mm/bit	0	6,425.5	

19.3.34 Engine Speed Sensor Information (ESSI) (61473)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
		61473					-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
x		Engine Speed 1 (SPN 4201)	2		16		rpm	0.5rpm/bit	0	32,127.5	
x		Engine Speed 2 (SPN 723)	2		16		rpm	0.5rpm/bit	0	32,127.5	
x		Engine Speed Sensor 2 Timing Pattern Status (SPN 4204)	7	5	2		state	4 states/2 bit	0	3	
		Not OK						00			
		OK						01			
		Error						10			
		Not Available						11			
x		Engine Speed Sensor 1 Timing Pattern Status (SPN 4203)	7	7	2		state	4 states/2 bit	0	3	
		Not OK						00			
		OK						01			
		Error						10			
		Not Available						11			

19.3.35 Engine Configuration 2 (EC2) (64895)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
		64895					-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
x		Maximum Crank Attempts per Start Attempt (SPN 3670)	1	1	8		count	1 count/bit	0	250	

19.3.36 Engine Operating Information (EOI) (64914)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
		64914					-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
x		Engine Operating State (SPN 3543)	1	1	4		sec	1sec/bit	0	64,255	

19.3.37 Electronic Engine Controller 7 (EEC7) (64916)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
		64916					-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
x		Engine Exhaust Gas Recirculation Valve Position (SPN 27)	1	1	16		%	0.0025%/bit	0	160.6375	

19.3.38 ECU Identification Information (ECUID) (64965)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
	On request	64965					-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
x		ECU Part Number (SPN 2901)	A		16		ASCII	ASCII	0	255/byte	
x		ECU Serial Number (SPN 2902)	B		16		ASCII	ASCII	0	255/byte	

19.3.39 Intermediate Speed Control (ISC) (64970)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
	1	64970					-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
x		Engine Operator Primary Intermediate Speed Select (spn 2880)	1	1	4		state	16 states/4 bit	0	15	

0000 – indicates that the ISC functionality is not requested, engine operates normally
 0001 thru 1101 – indicates that the ISC Setting 1 thru 13 (in sequential order) is selected
 1110 – error condition
 1111 – not available

19.3.40 Electronic Engine Controller 4 (EEC4) (65214)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
	On request	65214					-

S e n d e r i d e n t i f i c e r	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
x		Engine Rated Power (SPN 166)	1	1	16		kW	05kW/bit	0	32,127.5	
x		Engine Rated Speed (SPN 189)	3	1	16		rpm	0.125rpm/bit	0	8,031.875	
x		Engine Rotation Direction (SPN 3669)	5	1	2		states	4 states/2 bit	0	3	
		CounterClockWise (CCW)				00					
		ClockWise (CW)				01					
		Reserved				10					
		Not Available				11					
x		Crank Attempt Count on Present Start Attempt (SPN 3671)	6	1	8		count	1 count/bit	0	250	

19.3.41 Aftertreatment 1 Fuel Control 2 (AT1FC2) (64869)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
	On request	64869					-

S e n d e r i d e n t i f i c e r	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
x		Aftertreatment 1 Fuel Pressure 2 (SPN 4077)	1	1	16		kPa	0.1kPa/bit	0	6,425.5	

19.3.42 Aftertreatment 1 Air Control 2 (AT1AC2) (64877)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
		64877					-

S e n d e r i d e n t i f i c e r	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
x		Aftertreatment 1 Secondary Air Differential Pressure (SPN 3830)	1	1	16		kPa	1/128kPa/bit	-250	251.99	
x		Aftertreatment 1 Secondary Air Temperature (SPN 3831)	3	1	16		DegC	0.03125DegC/bit	-273	1734.96875	
x		Aftertreatment 1 Secondary Mass Flow (SPN 3832)	5	1	16		kg	0.2kg/h/bit	0	12851	

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

x	Aftertreatment 1 Secondary Air Pressure (SPN 3837)	7	1	16		kPa	0.1kPa/bit	0	6,425.5	
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19.3.43 Aftertreatment 1 Service (AT1S) (64891)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
		64891					-

S e n d i v e	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
x		Diesel Particulate Filter 1 Soot Load Percent (SPN 3719)	1	1	8		%	1%/bit	0	250	
x		Diesel Particulate Filter 1 Ash Load Percent (SPN 3720)	2	1	8		%	1%/bit	0	250	
x		Diesel Particulate Filter 1 Time Since Last Active Regeneration (SPN 3721)	3	1	32			sec	1sec/bit	0	4,211,081,215
x		Time until regeneration (new)									

19.3.44 Diesel Particulate Filter Control 1 (DPFC1) (64892)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
		64892					-

S e n d i v e	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
x		Diesel Particulate Filter Lamp Command (SPN 3697)	1	1	3		state	8 states/3 bit	0	7	
		Off				000					
		On - Solid				001					
x		Diesel Particulate Filter Active Regeneration Status (SPN 3700)	2	3	2		state	4 states/2 bit	0	3	
		Not Active				00					
		Active				01					
		Regeneration Needed				10					
		Not Available				11					
x		Diesel Particulate Filter Status (SPN 3701)	2	5	3		state	8 states/3 bit	0	7	
		Regeneration Not Needed				000					
		Regeneration Needed – Lowest Level				001					
		Regeneration Needed – Moderate Level				010					
		Regeneration Needed – Highest Level				011					
x		Diesel Particulate Filter Active Regeneration Inhibited Due to Inhibit Switch (SPN 3703)	3	3	2		state	4 states/2 bit	0	3	
		Not Inhibited				00					
		Inhibited				01					
		Reserved				10					
		Not Available				11					
x		Exhaust System High Temperature Lamp Command (SPN 3698)	7	3	3		state	8 states/3 bit	0	7	
		Off				000					

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

	On - Solid				001				
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19.3.45 Aftertreatment 1 Intake Gas 2 (AT1IG2) (64948)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
		64948					-

S e n c e i v e	R	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
x		Aftertreatment 1 Diesel Particulate Filter Intake Gas Temperature (SPN 3242)									
x		Aftertreatment 1 Exhaust Gas Temperature 1 (SPN 3241)	1	1	16		DegC	0.03125DegC/bit	-273	1734.96875	
x		Exhaust Gas Temperature 1 Preliminary FMI (SPN 3243)	5	1	5		Binary	Binary	0	31	

19.3.46 Engine Throttle / Fuel Actuator Control Command (TFAC) (61466)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
		61466					-

S e n c e i v e	R	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
x		Engine Throttle Actuator 1 Control Command (SPN 3464)	1	1	16		%	0.0025%/bit	0	160.6375	

19.3.47 Engine Temperature 2 (ET2) (65188)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
		65188					-

S e n c e i v e	R	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
x		Engine Exhaust Gas Recirculation Differential Pressure (SPN 411)	5	1	16		kPa	1/128kPa/bit	-250	251.99	
x		Engine Exhaust Gas Recirculation Temperature (SPN 412)	7	1	16		DegC	0.03125DegC/bit	-273	1734.96875	

19.3.48 Engine Fluid Level / Pressure 3 (EFL/P3) (64961)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
		64961					-

S e n d i v e	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
x		Engine Exhaust Gas Recirculation Inlet Pressure (SPN 3358)	3	1	8		kPa	2kPa/bit	0	500	

19.3.49 Engine Temperature 3 (ET3) (65129)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
		65129					-

S e n d i v e	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
x		Engine Charge Air Cooler Outlet Temperature (SPN 2630)	7	1	16		DegC	0.03125DegC/bit	-273	1734.96875	

19.3.50 Cruise Control / Vehicle speed Setup (CCSS) (65261)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
		65261					-

S e n d i v e	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
x		Maximum Vehicle Speed Limit (SPN 74)	1	1	8		km	1km/h/bit	0	250	

19.3.51 Cruise Control / Vehicle Speed (CCVS) (65265)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
		65265					-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
x		Wheel-Based Vehicle Speed (SPN 84)	2	1	16		km	1km/h/bit	0	250.996	

Wheel based vehicle speed as calculated from wheel of tailshaft speed.

19.4 J1939 Engine ECM Receive PGN Support

19.4.1 Electronic Transmission Controller 1 (ETC1) (61442)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
		61442					-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
	x	Transmission Output Shaft Speed (SPN 191)	2	1	16		rpm	0.125rpm/bit	0	8,031.875	
	x	Engine Momentary Overspeed Enable (SPN 606)	5	1	2		state	4 state/2 bit	0	3	
		Momentary Engine Overspeed Is Disabled				00					
		Momentary Engine Overspeed Is Enabled				01					
		Reserved				10					
		Take No Action				11					
	x	Transmission Input Shaft Speed	6	1	16		rpm	0.125rpm/bit	0	8,031.875	

19.4.2 Electronic Transmission Controller 2 (ETC2) (61445)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
		61445					-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
	x	Transmission Current Gear (SPN 523)	4	1	8		Gear value	1 gear value/bit	-125	125	

Operational range is –125 to 125. negative numbers are reverse gears, positive values are forward gears, neutral is 0 and 251 is reserved for park.

19.4.3 Transmission Configuration 2 (TCFG2) (65099)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
	On request	65099					-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
	x	Transmission Torque Limit (SPN 1845)	1	1	16		Nm	1Nm/bit	0	64,255	

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

X	Accel 1-Default Droop (default)				0000					
X	Accel 1 –Alternate Droop 1 through 10 = 1% through 10%				0001 - 1010					
X	Accel 1 –Alternate Droop 11 (Isochorous)				1011					
	Error				1110					
X	Not Available				1111					
X	Alternate Droop Accelerator 2 Select (spn 2879)	3	5	4		state	16 states/4 bit	0	15	
X	Accel 12-Default Droop (default)				0000					
X	Accel 2 –Alternate Droop 1 through 10 = 1% through 10%				0001 - 1010					
X	Accel 2 –Alternate Droop 11 (Isochorous)				1011					
	Error				1110					
X	Not Available				1111					
X	Alternate Droop Remote Accelerator Select (spn 2886)	4	1	4		state	16 states/4 bit	0	15	
X	Remote Accel-Default Droop (default)				0000					
X	Remote Accel –Alternate Droop 1 through 10 = 1% through 10%				0001 - 1010					
X	Remote Accel Alternate Droop 11 (Isochorous)				1011					
	Error				0011					
X	Not Available				0100					
	Alternate Droop Auxillary Input Select	4	5	4						

Note A: Ratings 1 to n are populated with all the ratings available in the ECM with “1” being the lowest and “n” being the highest rating. If the ECM receives the “0” then the rating value entered through the mode selection switches should be used.

19.5 J1939 Section 73 - Diagnostic Layer

19.5.1 Active Diagnostics Trouble Codes (DM1)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
See Note A	See note B	00FEC A	6	0	0	00	-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
		Malfunction indicator lamp (SPN 1213)	1	7	2						C
X		Protect lamp (SPN 987)	1	1	2						C
X		Stop lamp (SPN 623)	1	5	2						C
X		Warning lamp (SPN 624)	1	3	2						C
X		SPN (SPN 1214)	3	1	19						
X		FMI (SPN 1215)	5	1	5						
X		Occurrence Count (SPN 1216)	6	1	7						
X		SPN conversion method (SPN 1706)	6	8	1						
X		Amber Warning lamp flash (SPN 3040)	2	3	2						
X		Protect lamp flash (SPN 3041)	2	1	2						

Note A: If a single fault code is present then DM1 will be sent as single message with the identifier 18FECA00. If there is more than one fault code present then the DM1 message will be longer than 8 bytes thus the transport protocol (BAM) will be used to send the message.

This is different from tier 2 functionality where the transport protocol is used to send all DM1 messages, even if only one fault code is active

Note B: A DM1 message is sent when a new active fault is detected, and approximately every 1second after that. The DM1 message is not sent if there are no active fault codes.

Note C: This is not supported as per J1939 – Implementation is supported as follows:

Diagnostic and Event codes have been split into 3 categories of severity called “Warning Category Indicators (WCI)” .

The lowest level (Level 1) is used for “warning” level faults, such as when engine design limits for temperature have been reached, or for a sensor short circuit.

The highest level (Level 3) is used for events where the severity merits the machine and the engine being immediately stopped.

Level 2 is an intermediate level used particularly for events or diagnostic which cause an engine derate

The status lamps in the DM1 message will be switched on according to the following table:

WCI	Protect Lamp	Warning Lamp	Shutdown Lamp
1	ON	ON	OFF
2	FLASH	FLASH	OFF
3	FLASH	FLASH	ON

19.5.2 Previously Active Diagnostic Trouble Codes (DM2)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
See note A	On Req	FECB	6	0	0	00	-

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
		Malfunction indicator lamp (SPN 1213)									
		Protect lamp (SPN 987)									
		Stop lamp (SPN 623)									
		Warning lamp (SPN 624)									
X		SPN (SPN 1214)		3	1	19					
X		FMI (SPN 1215)		5	1	5					
X		Occurrence Count (SPN 1216)		6	1	7					
X		SPN conversion method (SPN 1706)		6	8	1					

Note A: Lamp support as per DM1

The information transmitted within DM2 is limited to the previously active trouble codes and is available only on request. The data contained within the message shows all previously active trouble codes with an occurrence count greater than 0. This message may be transmitted using the multipacket transport protocol.

19.5.3 Diagnostic Data Clear / Reset of Previously Active DTCs (DM3)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
See Note A	On req	FECC	6	0	0	-	00

S e n d	R e c e i v e	Parameter name	B y t e	B i t	L e n g t h	S t a t e	U n i t s	Resolution (unit/bit)	Range		N o t e
									Min	Max	
X		Request to clear fault codes									B

Note A: This message is sent as a request PGN.

Note B: when the ECM receives a DM3 message it will clear all Diagnostic codes and also all Event codes that are not factory password protected.

Diagnostic codes are those that relate to faults of the electronic system (e.g. sensor failure). Event codes are those where there is a problem with the engine operation (e.g. coolant temperature high warning).

Factory password protected event codes can only be cleared with the service tool.

19.6 Supported Parameters – Section 21 - Simplified Descriptions

19.6.1 Transport Protocol – Connection Management (TP.CM_BAM)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
1CECFF00	-	EC00	7	0	0	-	-

Support as per J1939 – 21. Note that this mechanism is used principally as a multipacket protocol for sending messages larger than 8 bytes of data for example to send diagnostic messages DM1 and DM2 or for the Engine Configuration PGN. This uses the Broadcast Announce Message (BAM) as shown in the example below:

19.6.2 Transport Protocol – Data Transfer (TP.DT)

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
1CEBFF00	See note A	EB00	7	0	0	-	-

Note A: If a module is required to decode any information that is sent via the transport protocol, then it must be capable of receiving and processing messages with the same identifier within 50 ms.

19.6.3 Proprietary A

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18EF00xx	-	EF00	6	0	0	-	-

This message is used for communication between the ECM and the service tool. **It must not be used by any other electronic system on the machine, as this may cause unpredictable operation when the service tool is connected.**

19.6.4 Acknowledge

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18E8xxxx	-	E800	6	0	0	-	-

Both Acknowledge (ACK) and negative acknowledge (NACK) are supported as per the J1939 specification

19.6.5 Request PGN

Identifier	Rate (msec)	PGN	Default Priority	R1	DP	Source	Destination
18EA00xx	-	EA00	6	0	0	-	00

Supported as per the J1939 specification. This PGN is sent to the ECM to request parameters that are only sent “on-request”. For example if an

electronic module on the machine requires engine hours information then it must send a Request PGN for the Engine Hours/ Revolutions PGN

19.7 Supported Parameters – Section 81 Network Management - Detailed Descriptions

The engine does support the network initialization requirements as outlined in Specification J1939-81.

This includes the claiming of addresses. The engine will always claim address zero and will not accept any other address.

Most off-highway machines do not implement this section of the specification. If further information on this subjected is required, however, then please contact the Electronic Applications Team Directly

20.0 Appendices

20.1 Appendix 1 - ECM J1 Connector Terminal Assignments

ECM J1 Pin	Function	Assignment
1	Active analogue / PWM In	Analogue / PWM Throttle 2
2	5V analogue Power Supply	5V Sensor Power
3	Analogue Return	5V Sensor return
4	8V Digital power Supply	PWM Throttle Supply
5	Digital return	PWM Throttle Return
6	Unused	Unused
7	GND Switch 1	ARD Regen Inhibit Switch
8	CDL +	CDL +
9	CDL -	CDL -
10	Dout: 2A Source 1	Fan Reversing Solenoid control / Air Shut off Solenoid
11	Dout: 2A Source / PWM	ARD Main Fuel Valve
12	Dout: 2A Source 3	Ether Solenoid
13	Dout: 0.3A Sink / PWM 1	Regeneration Inhibit Lamp
14	Active Analogue / PWM In 2	Aftertreatment ID Signal
15	Active Analogue 1 (30Hz)	Aux Pressure Sensor
16	Passive Analogue 1 (30Hz)	Aux Temperature Sensor
17	Passive Analogue 2 (30Hz)	Air Inlet Temperature Sensor
18	GND Switch Return	Switch Input Return
19	Dout: 0.3A Sink / PWM 2	Wait to Start Lamp
20	Dout: 2A Source 2	Glow Plug Relay
21	Dout: 0.3A Sink / PWM 3	Electronic Lift Pump Relay
22	GND Switch 2	IVS Switch 1 / customer Fan Override
23	GND Switch 3	ARD Force Regeneration Switch
24	Passive Analogue 3 (30Hz)	Air Charge Cooler Outlet Temperature Sensor
25	Active Analogue 2 (30Hz)	Fuel Filter Differential Pressure Switch
26	Active Analogue 3 (30Hz)	DPF Inlet Temperature Sensor (C7.1)
27	Active Analogue 4 (30Hz)	Unused
28	Dout: 0.3A Sink / PWM 4	Shutdown Lamp
29	Dout: 0.3A Sink / PWM 5	Warning Lamp
30	Dout: 0.3A Sink / PWM 6	DPF Lamp (C7.1)
31	Dout: 0.3A Sink / PWM 7	HEST Lamp / Cold Weather Pack Grid Heater Control (Low temp regen system only)
32	Diff Speed +	Fan Speed Sensor (Passive) +
33	Diff Speed -	Fan Speed Sensor (Passive) -
34	CAN A -	J1939 -
35	Active Analogue 5 (30Hz)	Water In Fuel Switch
36	Dout: 0.3A Sink / PWM 8	Oil Pressure Lamp
37	CAN C +	DPF Soot Sensor
38	CAN C -	DPF Soot Sensor
39	CAN C Shield	DPF Soot Sensor
40	GND Switch 4	IVS Switch 2 / Throttle arbitration 1
41	GND switch 5	MPTS 1 / PTO disengage
42	CAN A Shield	Reserved
43	Curr. Cont. PWM 2 HS	Hydraulic demand Fan Solenoid +
44	GND Switch 6	User defined Shutdown Switch / PTO Speed 1 & 2 Select
45	GND Switch 7	Unused
46	GND Switch 8	Work Mode Input
47	Active Analogue / PWM In 3	Oil Level Switch

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

48	Batt +	ECM Power Supply
49	GND Switch 9	Coolant Level Switch
50	CAN A +	Reserved
51	Curr. Cont PWM 2 LS	Hydraulic Demand Fan Solenoid -
52	Batt +	ECM Power Supply
53	Batt +	ECM Power Supply
54	GND Switch 10	Fan Reverse switch / Overspeed Verify Switch
55	Batt +	ECM Power Supply
56	GND Switch 11	MPTS 2 / PTO Mode ON / Off Switch
57	Batt +	ECM Power Supply
58	GND Switch 12	MPTS 3 / PTO Mode Raise Resume
59	DOUT Return	Actuator driver return
60	GND Switch 13	MPTS 4 / PTO Set / Lower / Intermediate Engine Speed Limit
61	Batt -	ECM Power Supply
62	Sw Batt 1 +	Mode Switch 1
63	Batt -	ECM Power Supply
64	Sw Batt 2 +	Mode Switch 2 / Air Inlet Restriction Switch
65	Batt -	ECM Power Supply
66	Active Analogue / PWM In 4	Analogue / PWM Throttle 1
67	Batt -	ECM Power Supply
68	Fan Speed In	Fan Speed Sensor
69	Batt -	ECM Power Supply
70	Key Switch	Ignition Key Switch

20.2 Appendix 2 – ECM J2 Terminal Assignment

ECM J2 Pin	Function	Assignment
1	H-bridge 1B	Engine Intake Throttle Valve -
2	H-bridge 1A	Engine Intake Throttle Valve +
3	Active Analogue 15 (200 Hz)	Engine Intake Throttle Valve Position Sensor
4	Active Analogue 16 (200 Hz)	Engine Intake Manifold Air Pressure Sensor
5	Active Analogue 17 (200 Hz)	CEM IC: DPF Intake Pressure Sensor
6	Active Analogue 18 (200 Hz)	NRS Intake Pressure Sensor
7	Active Analogue 19 (200 Hz)	NRS Differential Pressure Sensor / NRS Outlet Pressure Sensor
8	Passive Analogue 7 (200 Hz)	NRS Temperature Sensor
9	Passive Analogue 5 (30 Hz)	Engine Coolant Temperature Sensor
10	Passive Analogue 6 (30 Hz/Opt.)	Engine Fuel Temperature Sensor
11	Reserved	Reserved
12	CRS HS	CEM IC: ARD Ignition Coil +
13	CRS LS	CEM IC: ARD Ignition Coil -
14	H-bridge 3B	Turbocharger Wastegate Regulator Valve -
15	Active Analogue 12 (200 Hz)	NRS Valve Position Sensor
16	Active Analogue 13 (200 Hz)	CEM IC: ARD Air Pressure Control Valve Position Sensor
17	Active Analogue 14 (200 Hz)	CEM IC: DPF Intake Temperature Sensor
18	Active Analogue / PWM In 5	CEM IC: Aftertreatment ID Digital Signal
19	Passive Analogue 4 (30 Hz)	Engine Intake Manifold Air Temperature Sensor
20	CDL -	Diagnostic Connector
21	CAN B -	CEM IC: DPF Soot Load Sensor -
22	CAN B Shield	
23	CAN A Shield	
24	H-bridge 3A	Turbocharger Wastegate Regulator Valve +
25	Active Analogue 9 (30 Hz)	CEM IC: ARD Secondary Air Pressure Sensor
26	Active Analogue 10 (30 Hz)	CEM IC: ARD Fuel Pressure 1 Sensor (pilot)
27	Active Analogue 11 (30 Hz)	CEM IC: ARD Fuel Pressure 2 Sensor
28	CDL +	Diagnostic Connector
29	CAN B +	CEM IC: DPF Soot Load Sensor +
30	CAN A +	Diagnostic Connector
31	CAN A -	Diagnostic Connector
32	H-bridge 2B	NRS Valve -
33	Active Analogue 6 (30 Hz)	CEM IC: ARD Exhaust Gas Temperature Sensor
34	Active Analogue 7 (30 Hz)	Barometric Pressure Sensor
35	Active Analogue 8 (30 Hz)	Engine Oil Pressure Sensor
36	Digital Return	CEM IC: Aftertreatment ID Digital Return
37	Active Analogue 20 (500 Hz/Opt.)	Engine Fuel Rail Pressure Sensor
38	Hall 1	Engine Speed 1 Sensor (crank)
39	Hall 2	Engine Speed 2 Sensor (cam)

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

40	H-bridge 2A	NRS Valve +
41	Dout Return	CEM IC: Actuator
42	Dout: 2A Source 5	CEM IC: ARD Fuel Pump Relay
43	Dout: 2A Source 4	CEM IC: ARD Fuel Injector Heater Relay
44	8V Sensor Supply (Engine)	Sensor +8V supply
45	5V Sensor Supply (Engine)	CEM IC: Sensor +5V supply
46	5V Sensor Supply (Engine)	Sensor +5V supply
47	5V Sensor Supply (Engine)	Sensor +5V supply
48	H-bridge 4B	CEM IC: ARD Air Pressure Control Valve -
49	Injector BankA LS2	Engine Injector Cylinder #6 -
50	Injector BankA HS2	Engine Injector Cylinder #6 +
51	Injector BankB LS2	Engine Injector Cylinder #2 -
52	Injector BankB HS2	Engine Injector Cylinder #2 +
53	Comm. Adapter Supply	Diagnostic Connector
54	Comm. Adapter Supply Return	Diagnostic Connector
55	Analogue Return	CEM IC: Sensor 0V return
56	Analogue Return	Sensor 0V return
57	Analogue Return	Sensor 0V return
58	H-bridge 4A	CEM IC: ARD Air Pressure Control Valve +
59	Injector BankA LS1	Engine Injector Cylinder #1 -
60	Injector BankA HS1	Engine Injector Cylinder #1 +
61	Injector BankB LS1	Engine Injector Cylinder #5 -
62	Injector BankB HS1	Engine Injector Cylinder #5 +
63	Injector BankC HS1	Engine Injector Cylinder #3 +
64	Injector BankC LS1	Engine Injector Cylinder #3 -
65	Injector BankC LS2	Engine Injector Cylinder #4 -
66	Injector BankC HS2	Engine Injector Cylinder #4 +
67	Curr. Cont. PWM 1 HS	CEM IC: ARD Fuel Pressure 1 Control Valve (pilot) +
68	Curr. Cont. PWM 1 LS	CEM IC: ARD Fuel Pressure 1 Control Valve (pilot) -
69	Pump HS	Engine Fuel Rail Pump Control Valve +
70	Pump LS	Engine Fuel Rail Pump Control Valve -

Note: All CEM connections are not required for the C4.4 and C7.1 <130Kw engine ranges.

20.3 Appendix 3 - Electronic Options Selection Form

The Electronic Option Selection process is currently under development for all Tier 4 products. At the time of this document release further information is not available. If you have any questions please contact your Applications Engineer.

20.4 Appendix 4 – List of Diagnostic and Event codes

Note that in some cases there are differences in the codes which are transmitted on the J1939 bus and those that are transmitted on the CDL bus (those normally viewed on the service tool) additionally codes may be added on later software that are not present on this table.

Type	CID/EID	J1939 SPN	FMI	Lamp Flash Code [future]	Component	Description
Diagnostic	91	91	2	154	Throttle Position Sensor	data erratic intermittent or incorrect
Diagnostic	91	91	3	154	Throttle Position Sensor	Voltage above normal or shorted high
Diagnostic	774	91	3	155	Secondary throttle position sensor	Voltage above normal or shorted high
Diagnostic	91	91	4	154	Throttle Position Sensor	Voltage below normal or shorted low
Diagnostic	774	91	4	155	Secondary throttle position sensor	Voltage below normal or shorted low
Diagnostic	91	91	8	154	Throttle Position Sensor	abnormal frequency, pulse width, or period
Diagnostic	774	91	8	155	Secondary throttle position sensor	abnormal frequency, pulse width, or period
Diagnostic	91	91	12	154	Throttle Position Sensor	Bad Device or component
Diagnostic	774	91	12	155	Secondary throttle position sensor	Bad Device or component
Diagnostic	100	100	3	157	Engine Oil pressure Sensor	voltage above normal or shorted high
Diagnostic	100	100	4	157	Engine Oil pressure Sensor	voltage below normal or shorted low
Diagnostic	100	100	10	157	Engine Oil pressure sensor	Engine oil pressure sensor 5V supply connection open circuit
Event	360	100	17	n/a	Engine Oil pressure sensor	low oil pressure - WARNING
Event	360	100	18	n/a	Engine Oil pressure sensor	Low oil Pressure - DERATE
Event	360	100	1	n/a	Engine Oil pressure sensor	Low Oil Pressure - SHUTDOWN
Event	539	105	15	n/a	Inlet Manifold Air Temp Sensor	High Intake manifold temperature - WARNING
Event	539	105	16	n/a	Inlet Manifold Air Temp Sensor	High Intake manifold temperature - DERATE
Diagnostic	172	105	3	133	Inlet Manifold Air Temp Sensor	voltage above normal or shorted high
Diagnostic	172	105	4	133	Inlet Manifold Air Temp Sensor	voltage below normal or shorted low
Diagnostic	1785	106	3	135	Inlet Manifold Pressure Sensor	voltage above normal or shorted high
Diagnostic	1785	106	4	135	Inlet Manifold Pressure Sensor	voltage below normal or shorted low
Diagnostic	1785	106	10	135	Inlet Manifold Pressure Sensor	Inlet Manifold Pressure Sensor 5V supply connection open circuit
Event	361	110	15	n/a	Engine Coolant Temp Sensor	High coolant temp - WARNING
Event	361	110	16	n/a	Engine Coolant Temp Sensor	High coolant temp - DERATE

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

Diagnostic	110	110	3	169	Engine Coolant Temp Sensor	voltage above normal or shorted high
Event	361	110	0	n/a	Engine Coolant Temp Sensor	High coolant temp - SHUTDOWN
Diagnostic	110	110	4	169	Engine Coolant Temp Sensor	voltage below normal or shorted low
Diagnostic	1797	157	3	n/a	Fuel Rail pressure sensor	Voltage above normal or shorted high
Diagnostic	1797	157	4	n/a	Fuel Rail pressure sensor	Voltage below normal or shorted low
Diagnostic	1834	158	2	439	Keyswitch	data erratic, intermittent, or incorrect
Diagnostic	168	168	0	422	ECM battery power	Excessive battery power
Diagnostic	168	168	1	422	ECM battery power	Low battery power
Diagnostic	168	168	2	422	ECM battery power	intermittent
Diagnostic	190	190	8	141	Speed/Timing sensor	abnormal signal frequency
Event	362	190	15	n/a	Engine Speed	Engine Overspeed - WARNING
Diagnostic	91	558	2	154	Throttle Position Sensor	Idle validation switch
Diagnostic	774	558	2	155	Secondary throttle position sensor	data erratic, intermittent, or incorrect
Diagnostic	268	630	2	527	Customer or system parameters	data incorrect
Diagnostic	253	631	2	415	Engine software	data incorrect
Diagnostic	247	639	9	514	SAE J1939 data link	Abnormal update
Diagnostic	526	646	5	177	Turbo Wastegate	Solenoid Current Low
Diagnostic	526	646	6	177	Turbo Wastegate	Solenoid Current High
Diagnostic	526	1188	7	177	Turbo Wastegate	Turbo Wastegate not responding
Diagnostic	1	651	2	n/a	Cylinder #1 Injector	Injector Data Incorrect
Diagnostic	1	651	5	n/a	Cylinder #1 Injector	Injector Current Low
Diagnostic	1	651	6	n/a	Cylinder #1 Injector	Injector Current High
Diagnostic	1	651	7	n/a	Cylinder #1 Injector	Injector not responding
Diagnostic	1	651	2	n/a	Cylinder #2 Injector	Injector Data Incorrect
Diagnostic	2	652	5	n/a	Cylinder #2 Injector	Injector Current Low
Diagnostic	2	652	6	n/a	Cylinder #2 Injector	Injector Current High
Diagnostic	2	652	7	n/a	Cylinder #2 Injector	Injector not responding
Diagnostic	1	651	2	n/a	Cylinder #3 Injector	Injector Data Incorrect
Diagnostic	3	653	5	n/a	Cylinder #3 Injector	Injector Current Low
Diagnostic	3	653	6	n/a	Cylinder #3 Injector	Injector Current High
Diagnostic	3	653	7	n/a	Cylinder #3 Injector	Injector not responding
Diagnostic	1	651	2	n/a	Cylinder #4 Injector	Injector Data Incorrect
Diagnostic	4	654	5	n/a	Cylinder #4 Injector	Injector Current Low
Diagnostic	4	654	6	n/a	Cylinder #4 Injector	Injector Current High
Diagnostic	4	654	7	n/a	Cylinder #4 Injector	Injector not responding
Diagnostic	1	651	2	n/a	Cylinder #5 Injector	Injector Data Incorrect
Diagnostic	5	655	5	n/a	Cylinder #5 Injector	Injector Current Low
Diagnostic	5	655	6	n/a	Cylinder #5 Injector	Injector Current High
Diagnostic	5	655	7	n/a	Cylinder #5 Injector	Injector not responding
Diagnostic	1	651	2	n/a	Cylinder #6 Injector	Injector Data Incorrect
Diagnostic	6	656	5	n/a	Cylinder #6 Injector	Injector Current Low
Diagnostic	6	656	6	n/a	Cylinder #6 Injector	Injector Current High
Diagnostic	6	656	7	n/a	Cylinder #6 Injector	Injector not responding
Diagnostic	41	678	3	517	8V DC supply	ECM 8V DC supply – voltage above normal or shorted high
Diagnostic	41	678	4	517	8V DC supply	ECM 8V DC supply – voltage below normal or shorted low

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

Diagnostic	190	190	8	143	Primary Engine Speed Sensor	abnormal signal frequency
Diagnostic	342	723	8	142	Secondary Engine Speed Sensor	abnormal signal frequency
Diagnostic	262	1079	3	516	5V sensor DC supply	voltage above normal or shorted high
Diagnostic	262	1079	4	516	5V sensor DC supply	voltage below normal or shorted low
Diagnostic	261	637	11	143	Primary to secondary speed sig	calibration fault
Diagnostic	261	637	13	143	Primary to secondary speed sig	Calibration required
Diagnostic	1779	1347	5	162	Fuel Rail Pump	Output current low
Diagnostic	1779	1347	6	162	Fuel Rail Pump	Output current high
Diagnostic	1779	1347	7	162	Fuel Rail Pump	Not responding
Diagnostic	2246	676	5	199	Glow Plug Start Aid relay	Current Low
Diagnostic	2246	676	6	199	Glow Plug Start Aid relay	Current High
Event	194	2789	15	185	Exhaust	High Temperature
Event	398	157	18	159	Fuel Rail pressure sensor	Low Fuel Rail Pressure
Event	396	157	16	159	Fuel Rail pressure sensor	High Fuel Rail Pressure
Event	1045	102	18	135	Intake Manifold pressure sensor	Low Intake Manifold Pressure
Event	1044	102	16	135	Intake Manifold pressure sensor	High Intake Manifold Pressure
Diagnostic	1785	102	10	197	Intake Manifold pressure sensor	Pressure Abnormal Rate of Change
Diagnostic	1834	158	2	439	Key Switch	Erratic

Diagnostic and Events	Derate	Latch until next key cycle?
Turbo Wastegate		
Engine Turbocharger 1 wastegate drive current low	100%	No
Engine Turbocharger 1 wastegate drive current high	100%	No
Engine Turbocharger 1 wastegate drive voltage high	100%	No
Engine Fuel System		
High fuel rail pressure	100%	Yes
Low fuel rail pressure	100%	Yes
High Fuel Temperature	TBD	TBD
Aftertreatment		
Nox Reduction System		
Engine exhaust gas recirculation valve position voltage above normal	30%	TBD
Engine exhaust gas recirculation valve position voltage below normal	30%	TBD
Engine exhaust gas recirculation valve voltage high	30%	No
Engine exhaust gas recirculation valve	30%	No

Electrical Electronic A&I Guide Tier 4 Interim C4.4 – C7.1 Product Range

current low		
Engine exhaust gas recirculation valve current high	30%	No
Engine exhaust gas recirculation inlet pressure incorrect	30%	No
Engine exhaust gas recirculation outlet pressure incorrect	30%	No
Others		
Engine Throttle valve voltage high	30%	No
Engine Throttle valve current low	30%	No
Engine Throttle valve current high	30%	No
Engine Intake Throttle valve position voltage above normal	30%	TBD
Engine Intake Throttle valve position voltage below normal	30%	TBD
Sensor supply 1 voltage high	100%	No
Sensor supply 1 voltage low	100%	No

