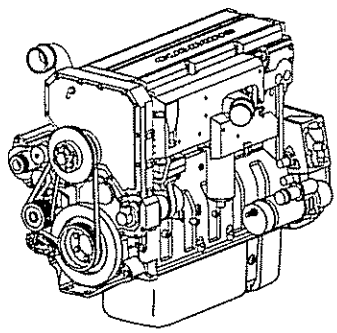
Application Engineering Bulletin

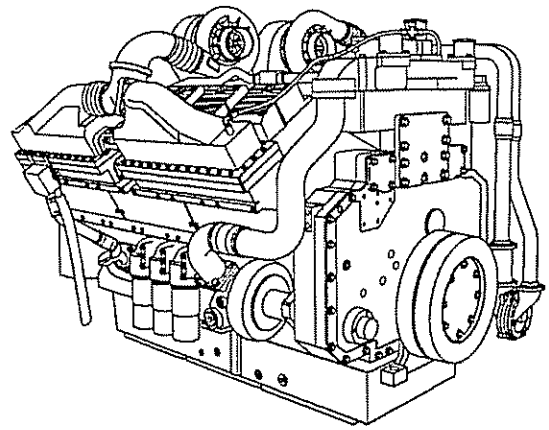
Subject	This AEB is for the following applications:
Electronic Features Package Generator-Drive Control System QSX15, QSK45, QSK60 Engines	☐ **Automotive** ☐ **Industrial** ☒ **Power Generation**

Date 3 May 2000	Page 1 of 36	AEB Number 150.03

Engine Models included: QSX15, QSK45, and QSK60 Generator-Drive Engines

Fuel Systems included: HPI-TP (QSX15), HPI-PT (QSK45 & QSK60)





The following pages describe the electronic features package of the Generator-Drive Control System (GCS) for QSX15, QSK45, and QSK60 engines. This information is intended for use by customers of Cummins Generator-Drive Engines fitted with the GCS to provide an understanding of the capabilities and features of the GCS.

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Table of Contents

Introduction 9

Control Features 12

Switch Inputs 12
Run/Stop 12
Crank 12
Idle/Rated Speed 12
Alternate Frequency 13
Fault Acknowledge 13
Diagnostic Mode (Fault Flash Out Enable) 14

Adjustable Inputs 14
Droop Adjust 14
Frequency Adjust 14
Governor Gain Adjust 15

Load Sharing/Autosynchronization Speed Bias Inputs 15
±2.5V Speed Bias 15
±0.2V Speed Bias 16

Miscellaneous Outputs 16
Starter Control 16
Battery Charging Alternator Flashout 17

Configurable Features 17
Idle Speed Adjust 17
Isochronous and Droop Speed Governing 17
Crank-to-Rated Speed Ramp 17
Idle-to-Rated Speed Ramp 18
Rated-to-Idle Speed Ramp 18

Fault Diagnostics & Troubleshooting 19

Service Tool Interface 19

Fault Codes 19

Snapshot Data 19

Diagnostic LEDs 20
Overspeed (OS) 20
Low Oil Pressure (LOP) 20
High Engine Temperature (HET) 20
Shutdown 20
Warning 20

Engine Protection & Safety 21

Alarm Lamp/Relay Drivers 21
Engine Shutdown Alarms 21
Common Shutdown Alarm 21
Engine Warning Alarms 21
Common Warning Alarm 22

Table of Contents

Emergency Shutdown/Start inhibit 22
Local Emergency Stop 22
Remote Emergency Stop 22
Backup Start Disconnect 22
Shutdown Override 23

Engine Monitoring *24*

Analog Meter Drivers 24

Modbus Communications Datalink 24
Engine Sensor Parameters 24
Switch Input States 25
Adjustable Input Settings 25
Speed Bias Inputs 25
Lamp/Relay Driver States 25
Actuator Driver States 25
Fault/Diagnostic Data 25
Other GCS/ECM data 25

System Check-Out/Test *26*

Built-In Test (BIT) 26
Lamp/Relay Driver Start-Up Test 26
Outputs Test 26
Fuel Shut-Off Test 27
Starter Test 27

Electronic Control Module Mounting *28*

Electronic Control Module Harness Interface/Connectors *32*

Engine ECM Connectors 32
Connector 02 32
Connector 05 32

Customer ECM Connectors 33
Connector 03 33
Connector 06 33

Extension Harness 33

Engine-Side Extension Harness In-Line Connectors 34

ECM-Side Extension Harness In-Line Connectors 34

Operating, Electrical & Environmental Specifications *35*

Operation 35

Power 35

Environmental 35

Physical 36

Protection 36

Table of Contents

Standards Compliance **36**

List of Figures

Figure 1: GCS Interfaces 10
Figure 2: ECM Electronic Features 11
Figure 3: Diagnostic LED Display Window Label 20
Figure 4: Analog Meter Driver Calibration 24
Figure 5: Analog Output Test Profile 26
Figure 6: Discrete Output Test Profile 27
Figure 7: ECM Mounted Flush to Base of Heat Sink 28
Figure 8: ECM Envelope & Mounting Bracket Hole Dimensions 29
Figure 9: Panel Cut-Out Template for Mounting ECM Flush with Base of Heat-Sink 30
Figure 10: Side-View of ECM Mounted with Base of Heat-Sink Flush to Panel 31

List of Acronyms

AEB ..... Application Engineering Bulletin
Amps ..... Amperes
B+ ..... Battery Positive
BIT ..... Built-In Test
CE ..... Communauté Européene or Conformité Européene
CSA ..... Canadian Standards Association
ECM ..... Electronic Control Module
EFT ..... Electrical Fast Transient
EMI ..... Electromagnetic Interference
ESD ..... Electro-Static Discharge
FSO ..... Fuel Shut-Off
GCS ..... Generator-Drive Control System
GND ..... Ground
HET ..... High Engine Temperature
HPI-PT ..... High Pressure Injection - Pressure Timing
HPI-TP ..... High Pressure Injection - Time Pressure
Hz ..... Hertz
IP53 ..... Ingress Protection - Dust-Protected & Spraying Water
IP54 ..... Ingress Protection - Dust-Protected & Splashing Water
kHz ..... kilo-Hertz
LED ..... Light Emitting Diode
LOP ..... Low Oil Pressure
mA ..... milli-Amperes
NEMA ..... National Electric Manufacturers Association
NFPA ..... National Fire Protection Association
OR ..... Boolean logical OR operator
OS ..... Overspeed
p-p ..... peak-to-peak. peak-to-peak
rpm ..... rotations per minute
URL ..... Universal Resource Locator
VDC ..... Voltage - Direct Current
WWW ..... World-Wide-Web

Referenced Cummins Publications

Publication Title	Bulletin Number
InPower™ for Generator-Drive Control System Manual	3397100
QSK45/60 Generator-Drive Control System Wiring Diagram	3666347
QSX15 Generator-Drive Control System Wiring Diagram	3666349
QSX15, QSK45, QSK60 Generator Drive Control System Application Manual	3884960
QSX15, QSK45, QSK60 Generator-Drive Control System Troubleshooting and Repair Manual	3666393

Referenced Documents & Standards

Document Title	Document Number
Electrical Characteristics of Generators and Receivers for use in Balanced Digital Multi-Point Systems	EIA-485
Modicon Modbus Protocol Reference Guide	PI-MBUS-300

Introduction

This Application Engineering Bulletin (AEB) provides a description of the electronic features for the Generator-Drive Control System (GCS) Electronic Control Module (ECM). The information focuses on "customer interface" features such as those requiring the use of analog and bi-state discrete signals for control and monitoring of the engine (i.e. potentiometers, switches, lamps, relays, meters), those which use the Modbus serial data communications link to read engine and system information from the ECM, and those which can be configured by the customer using the Cummins InPower™ Electronic Service Tool.

The feature descriptions in this bulletin are divided into seven functional categories, each appearing in individual sections:

- Control Features
- Fault Diagnostics & Troubleshooting
- Engine Protection & Safety
- Engine Monitoring
- System Check-Out/Test
- Electronic Control Module Mounting
- Electronic Control Module Harness Interface/Connectors

Note: The defined categories do not distinguish signal inputs or outputs as unique functions. The use of inputs or outputs is explained in each feature description where they are required to implement the particular feature.

Several features have customer configurable parameters that can be adjusted using the Cummins InPower™ Electronic Service Tool. The Cummins InPower™ Electronic Service Tool can also be used to access information about the engine and the GCS. Please refer to the InPower™ for Generator-Drive Control System Manual (Cummins Bulletin No. 3397100) for further details on the use of the Cummins InPower™ Electronic Service Tool. Additional details required to configure specific features are included in the QSX15, QSK45, QSK60 Generator-Drive Control System Application Manual (Cummins Bulletin No. 3884960).

Figure 1 is a diagram showing the GCS interfaces between the engine, alternator, electronic control module, generator set controls, and the Cummins InPower™ Electronic Service Tool.

There are two different GCS ECM's for use with two separate fuel systems; the HPI-TP fuel system on the QSX15 engine and the HPI-PT fuel system on QSK45 and QSK60 engines. The customer interfaces are the same for either ECM so that differences between ECM's are transparent to the customer (the same pin assignments and feature trims are used for the customer features).

Introduction

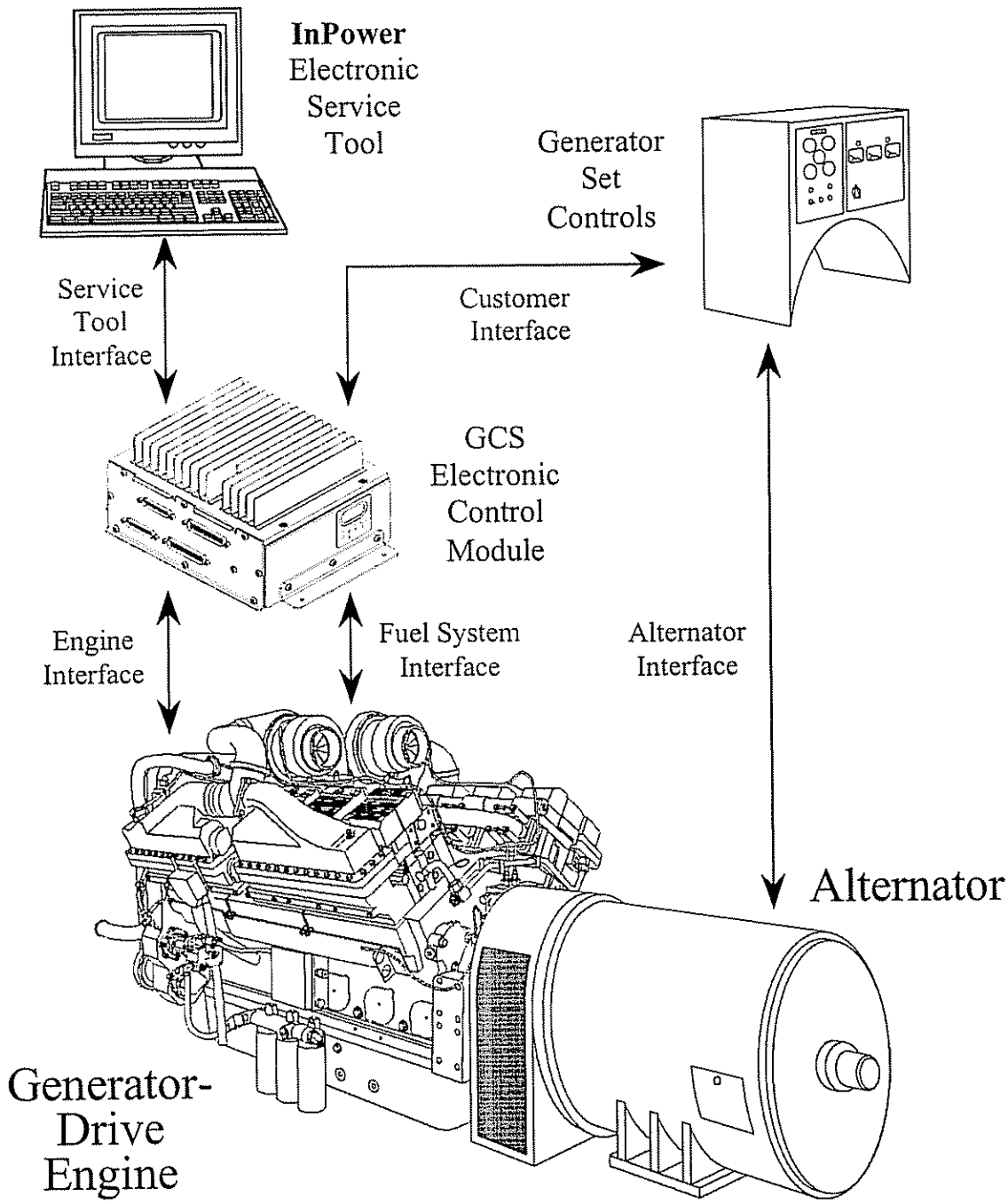


Figure 1: GCS Interfaces

Introduction

Figure 2 shows the features implemented via hardwired interconnections to the ECM, including the on-module Diagnostic LED's and the ECM mounting brackets.

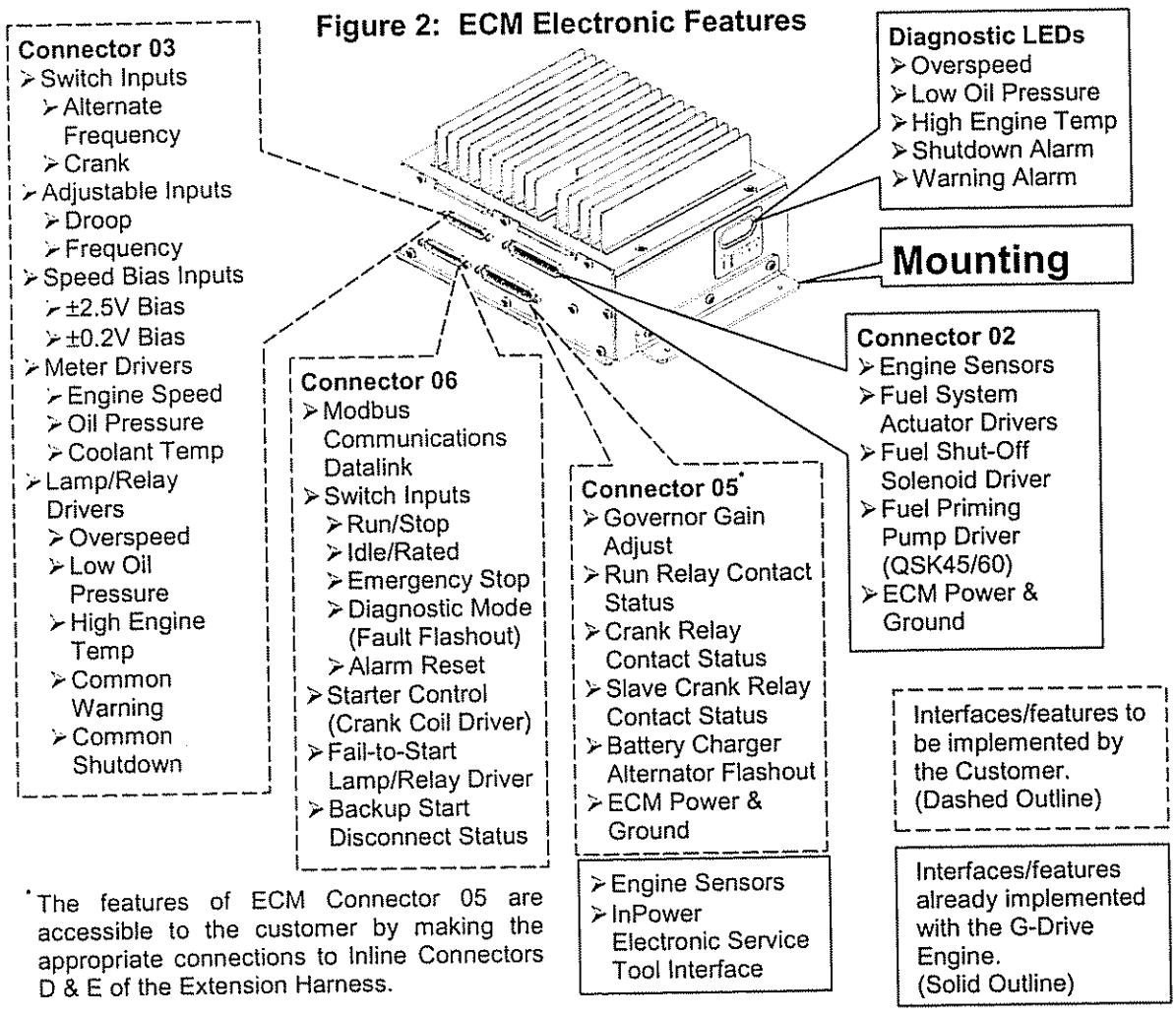
This bulletin references the applicable ECM connector where each feature requiring a hard-wired interface to the ECM is implemented. Refer to the QSX15 and the QSK45/60 Generator-Drive Control System Wiring Diagrams (Cummins Publication No.'s 3666349 and 3666347, respectively) for ECM pin connections and a schematic representation of the external component wiring for each engine.

There are pins on the ECM connectors that provide a ground (GND) for all hard-wired interfaces requiring a ground reference or signal return path.

⚠ CAUTION ⚠

The use of the ECM GND pins is required when implementing the hard-wired interfaces. The ground reference or signal path for these interfaces must not be connected directly to the battery ground post or other ground points such as the engine block. Using the ECM GND pins is necessary to reduce the adverse effects of electrical noise on the proper operation of the electronic features.

Figure 2: ECM Electronic Features



*The features of ECM Connector 05 are accessible to the customer by making the appropriate connections to Inline Connectors D & E of the Extension Harness.

Control Features

Switch Inputs

The customer can implement the following features by providing a bi-state discrete (switched) input signal for each feature:

Run/Stop

A Run/Stop input is provided to enable starting, running, and stopping the engine (GND = Run, Open = Stop). The Run/Stop feature interface is accessible at ECM connector 06.

When used in conjunction with the Crank switch input, when the Run/Stop switch input is in the Run state, the ECM will enable the Starter Control and fueling control for starting and running the engine (See the Crank feature description for further detail). In Stop mode, the ECM will command the engine to stop running and inhibit starting once the engine has stopped.

Crank

A Crank switch input is provided to command the ECM to initiate the Starter Control feature for starting the engine (GND = Crank, Open = No Crank). The Crank feature interface is accessible at ECM connector 03. A momentary (normally open) bi-state signal must be used for this input.

When the Crank switch input transitions from the "No Crank" state to the "Crank" state while the engine is stopped, and the Run/Stop switch input is in the Run state, the ECM will initiate the engine starting sequence (See the Starter Control feature description for further details). There is no effect on engine operation if the Crank switch input transitions from "No Crank" to "Crank" while the engine is already running.

There is also no effect on engine operation when the Crank switch input transitions from "Crank" to "No Crank" once the engine has already started. If this switch transition occurs prior to the engine starting after the crank sequence has already been initiated, the crank sequence will cease immediately.

Idle/Rated Speed

An Idle/Rated speed input is provided to allow control of the engine speed (GND = Idle, Open = Rated). The Idle/Rated feature interface is accessible at ECM connector 06.

When the Idle/Rated switch input is in the "Idle" state when starting the engine, the engine speed will accelerate to achieve idle speed as quickly as possible based on the governor gain settings and the generator set performance.

When the Idle/Rated switch input is in the "Rated" state when starting the engine, the rate at which the engine will ramp-up (accelerate) to rated speed is based on the Crank-to-Rated Speed Ramp rate setting. See the Crank-to-Rated Speed Ramp feature description for further details.

When the engine is running at idle speed, and the Idle/Rated switch input transitions from "Idle" to "Rated" the engine speed will ramp-up (accelerate)

Control Features

from the idle speed to rated speed at a rate based on the Idle-to-Rated Speed Ramp rate setting. See the Idle-to-Rated Speed Ramp feature description for further details.

When the engine is already running at rated speed, and the Idle/Rated switch input transitions from "Rated" to "Idle" the engine speed will ramp-down (decelerate) from the rated speed to idle speed at a rate based on the Rated-to-Idle Speed Ramp rate setting. See the Rated-to-Idle Speed Ramp feature description for further details.

Alternate Frequency

An Alternate Frequency input is provided to allow selecting between one of two generator set frequency settings (GND = Alternate, Open = Normal). The Alternate Frequency feature interface is accessible at ECM connector 03.

NOTE: The alternate frequency selection feature is only enabled for engines that have been rated for dual frequency operation. For engines rated for a single operating frequency, the Alternate Frequency input is non-operational and no connection needs to be made to this input.

When the Alternate Frequency input is in the "Normal" state, the speed at which the engine will run when operating at rated speed is determined by the "Normal" frequency setting. When the Alternate Frequency input is in the "Alternate" state, the engine will run at the speed corresponding to the "Alternate" frequency setting while operating at rated speed.

The engine speeds corresponding to the "Normal" and "Alternate" frequencies can be adjusted using the Cummins InPower Electronic Service Tool. Refer to the QSX15, QSK45, QSK60 Generator Drive Control System Application Manual for further details on how to adjust the speeds for "Normal" and "Alternate" frequencies.

NOTE: If the frequency selection using the Alternate Frequency input changes while the engine is running, the selected frequency setting will not take effect until after the engine is stopped and re-started.

The frequency settings for the Normal/Alternate states of the Alternate Frequency input can also be reversed (e.g. Normal = 50Hz / Alternate = 60Hz changed to Normal = 60Hz / Alternate = 50Hz) using the Cummins InPower™ Electronic Service Tool.

Fault Acknowledge

A Fault Acknowledge input is provided to allow a means of resetting the Warning and Shutdown lamp/relay driver outputs and Diagnostic Warning and Shutdown LED's that activate due to a fault condition. This feature is also used to acknowledge a shutdown condition and allow a re-start of the engine after it has shutdown due to an Emergency Shutdown. The Fault Acknowledge feature interface is accessible at ECM connector 06. A momentary (normally open) bi-state signal must be used for this input (GND

Control Features

= Acknowledge, Open = Not Acknowledge).

The Fault Acknowledge can also be activated using the Cummins InPower™ electronic service tool. Refer to the QSX15, QSK45, QSK60 Generator-Drive Control System Troubleshooting and Repair Manual (Cummins Bulletin No. 3666393) for further details.

NOTE: The Warning (Pre-alarm) indications can be acknowledged when the engine is stopped or while the engine is still running. The Shutdown (Alarm) indications can only be acknowledged when the engine is stopped. Activation of the Fault Acknowledge input does not clear fault codes. The Cummins InPower Electronic Service Tool must be used to clear fault codes. Refer to the QSX15, QSK45, QSK60 Generator-Drive Control System Troubleshooting and Repair Manual (Cummins Bulletin No. 3666393) for details.

Diagnostic Mode (Fault Flash Out Enable)

A Diagnostic Mode input is provided to allow a means of visually annunciating fault codes using the Warning and Shutdown LEDs on the ECM. The Diagnostic Mode feature interface is accessible at ECM connector 06 (GND = Fault Flash Out Enabled, Open = Fault Flash Out Inhibited). See the Fault Codes feature description for further details on Fault Flash Out.

Adjustable Inputs

The following features are implemented by providing a variable analog signal input (i.e. using a 5k ohm potentiometer). The feature adjustment level is proportional to the input signal level.

Droop Adjust

An adjustable signal input is provided to control the governor speed droop. The speed droop is adjustable from 0 to 10%. The Droop Adjust feature is accessible at ECM connector 03.

The speed droop can also be set by changing a trim value electronically using the Cummins InPower™ electronic service tool. Either the analog input or the electronic trim may be used to determine the speed droop, but not both simultaneously. Refer to the QSX15, QSK45, QSK60 Generator-Drive Control System Application Manual (Cummins Bulletin No. 3884960) for further details on how to set-up this feature.

Frequency Adjust

An adjustable signal input is provided to adjust the generator set frequency. The frequency is adjustable within ±9Hz of the base frequency. The Frequency Adjust feature is accessible at ECM connector 03.

The governor frequency is adjustable by ±9Hz using a combination of both an analog input and an electronic trim that can be set using the Cummins InPower™ electronic service tool. The analog input allows an adjustment range of ±3Hz, while the electronic trim allows an additional adjustment range of ±6Hz.

Control Features

NOTE: The Frequency Adjust feature is different from the Droop Adjust and Governor Gain Adjust features in that both the analog input and the electronic trim can be used simultaneously. The effect of the potentiometer setting and the electronic trim setting is additive. For example, if the analog input were set to provide a +3Hz adjustment and the electronic trim where set to +4Hz, the overall frequency adjustment would be equal to +7Hz. Using another example, if the analog input where set to provide a -1Hz adjustment and the electronic trim where set to +6Hz, the overall frequency adjustment would be equal to +5Hz.

Governor Gain Adjust

An adjustable signal input is provided to adjust the governor gain. The governor gain is adjustable from 0.05 to 10.00. The Governor Gain Adjust feature is accessible at the Inline D connector. The Inline D connector is located on the Extension Harness. See the "ECM Interface/Connectors" section below for further details regarding the Extension Harness.

The governor gain can also be set by changing a trim value electronically using the Cummins InPower™ electronic service tool. Either the analog input or the electronic trim may be used to determine the governor gain, but not both simultaneously. Refer to the QSX15, QSK45, QSK60 Generator-Drive Control System Application Manual (Cummins Bulletin No. 3884960) for further details on how to set-up this feature.

Load Sharing/Autosynchronization Speed Bias Inputs

The ECM provides two types of speed bias inputs making it compatible for use with off-the-shelf isochronous load share equipment (i.e. Woodward and Barber-Colman speed governing and load sharing controls).

NOTE: The speed bias signal and the signal return conductors must be protected from EMI by a common shield. One end of the shield must be attached to GND and the other end must be left open-ended (not attached to GND). The open-end of the shield must terminate as close as possible to the connector of the interfacing device. To accommodate grounding the shield at the ECM end of the interface a shield ground is provided at ECM connector 03. It is highly recommended that the shield be terminated at the ECM, which provides a common low impedance shield ground point.

The ECM provides a +5VDC (±2%) supply voltage at connector 03. This supply voltage is to be used as the signal reference for both the ±2.5V and ±0.2V speed bias signals. The supply is rated to provide the specified voltage at 50 $mV_{(p-p)}$ max. ripple voltage, and 25 mA max. power.

±2.5V Speed Bias

A ±2.5V speed bias signal input is provided for interfacing with Woodward and Woodward compatible speed governing and load share controls. The

Control Features

±2.5V speed bias signal represents a full scale speed bias control range of ±3Hz. The speed bias signal and signal return lines interface to the ECM at connector 03.

±0.2V Speed Bias

A ±0.2V signal input is provided for interfacing with Barber-Colman and Barber-Colman compatible speed governing and load share controls. The ±0.2V speed bias signal represents a full scale speed bias control range of ±7.38Hz. The speed bias signal and signal return lines interface to the ECM at connector 03.

In addition to the +5VDC reference supply voltage, the ECM also provides a +8VDC (±5%) power supply at connector 03. This supply voltage is provided as a means to power the electronic circuits on analog load share equipment. The supply is rated to provide the specified voltage at 50 $mV_{(p-p)}$ max. ripple voltage, and 15 mA max. power.

Miscellaneous Outputs

Starter Control

The Starter Control feature provides the means to control the engine starter solenoid and the cranking routine during engine start-up. The Starter Control cranking routine is initiated based on the state of the Crank and Run/Stop switch inputs. See the feature descriptions for these two switch inputs for further details.

When cranking is commanded, the crank coil relay driver output at connector 05 provides a signal path to GND which energizes the relay coil when the relay coil high side is connected to B+ (i.e. when the Local E-Stop, Remote E-Stop or Backup Starter Disconnect switches are all closed). The crank relay will then provide power to the crank slave relay (magnetic switch) coil, which in turn will supply power to the starter motor switch, causing the starter motor to engage and to begin cranking the engine. Once the engine speed has reached a pre-programmed starter disconnect speed, the crank relay coil driver will de-energize the crank relay. In turn, the crank slave relay will de-energize and the starter will disengage as the engine speed continues to ramp-up to either the idle or rated speed depending upon the state of the Idle/Rated switch input. See the Idle/Rated Switch Input feature description for further details.

This feature allows the use of either continuous or cycle cranking routines, which are selected and set-up using the Cummins InPower™ electronic service tool.

The **Continuous Cranking** routine provides the capability to engage the starter only once for a specified length of time. The engage time can be set from 2 to 20 seconds.

The **Cycle Cranking** routine provides the capability to perform a maximum of seven starting attempts with specified starter engage and rest times. The engage time can be set from 2 to 20

Control Features

seconds, and the rest time can be set from 7 to 40 seconds.

Battery Charging Alternator Flashout

The Alternator Flashout output is used with some battery charging alternators to provide the additional energy required to turn on the alternator voltage regulator at low speeds. Not all charging alternators will use this signal. The Alternator Flashout output supplies B+ to the battery charging alternator through the 1-pin Weather-Pack connector on the Extension Harness when the customer supplied Run Relay contacts at Connector Inline D (pins C & D) are closed.

The Battery Charging Alternator Flashout output is implemented by making the appropriate connection between the 1-pin Weather Pack connector on the Extension Harness and the battery charging alternator. See the "ECM Interface/Connectors" section below for further details regarding the Extension Harness.

Configurable Features

The following Configurable features are those control features that can only be set-up with the use of the Cummins InPower™ electronic service tool. Refer to the QSX15, QSK45, QSK60 Generator-Drive Control System Application Manual (Cummins Bulletin No. 3884960) for further details on how to set-up these features.

There are several control features that are controlled via hard-wired interfaces to the ECM and can be set-up and adjusted using the Cummins InPower™ electronic service tool as well (i.e. Alternate Frequency, Droop Adjust, Frequency Adjust, Governor Gain Adjust). Such features are not included in this sub-section, but are described in the applicable sub-sections elsewhere in this bulletin.

Idle Speed Adjust

The idle speed can be set at any speed from 700 to 900 rpm in 1 rpm increments.

Isochronous and Droop Speed Governing

The ECM is capable of operating in either an isochronous or a droop speed governing mode. The isochronous mode is selected by adjusting the droop speed setting to 0% droop. See the Droop Adjust feature description for further details.

Crank-to-Rated Speed Ramp

During starting with the Idle/Rated Switch Input set to "Rated", the engine will ramp-up (accelerate) to rated speed at the Crank-to-Rated Speed Ramp rate. The Crank-to-Rated ramp rate is adjustable from 0 to 30 seconds.

If the ramp rate is set at or near 0 seconds, the engine speed will accelerate to achieve rated speed as quickly as possible based on the governor gain settings and the generator set performance. The customer can increase or decrease the governor gain using the Gain Adjust feature described in this bulletin.

Control Features

Idle-to-Rated Speed Ramp

When the engine is at idle speed and the Idle/Rated Switch Input state transitions from "Idle" to "Rated", the engine speed will ramp-up (accelerate) to rated speed at the Idle-to-Rated Speed Ramp rate. The Idle-to-Rated ramp rate is adjustable from 0 to 30 seconds.

If the ramp rate is set at or near 0 seconds, the engine speed will accelerate to achieve rated speed as quickly as possible based on the governor gain settings and the generator set performance. The customer can increase or decrease the governor gain using the Gain Adjust feature described in this bulletin.

Rated-to-Idle Speed Ramp

When the engine is at rated speed and the Idle/Rated Switch Input state transitions from "Rated" to "Idle", the engine speed will ramp-down (decelerate) to idle speed at the Rated-to-Idle Speed Ramp rate. The Rated-to-Idle ramp rate is adjustable from 0 to 30 seconds.

If the ramp rate is set at or near 0 seconds, the engine speed will decelerate to achieve idle speed as quickly as possible based on the governor gain settings and the generator set performance. The customer can increase or decrease the governor gain using the Gain Adjust feature described in this bulletin.

Fault Diagnostics & Troubleshooting

NOTE: To prevent loss of valuable diagnostic information, such as Fault Codes and Snapshot Data, power must be available to the ECM at all times during normal engine operation and for at least one minute following an engine shutdown.

Service Tool Interface

A 9-pin circular connector is accessible on the Engine Harness to provide a means of interfacing the ECM with the Cummins InPower electronic service tool. Refer to the QSX15, QSK45, QSK60 Generator-Drive Control System Troubleshooting and Repair Manual (Cummins Bulletin No. 3666393) for further details.

Fault Codes

The ECM can record and annunciate certain detectable diagnostic conditions. These conditions are annunciated as fault codes, which can be used to assist in engine and control system troubleshooting. Refer to the QSX15, QSK45, QSK60 Generator-Drive Control System Troubleshooting and Repair Manual (Cummins Bulletin No. 3666393) for a listing of the ECM fault codes.

Diagnostic codes can be accessed in three different ways:

- Diagnostic Mode (Fault Flash Out)
- Cummins InPower Electronic Service Tool
- Modbus Communications Datalink

To "Flash Out" a fault code, the ECM must be put into the diagnostic mode. The diagnostic mode is enabled by setting the Diagnostic Mode switch input to the "Fault Flash Out Enable" state (See the Diagnostic Mode Switch Input feature description for further details). The diagnostic mode can also be enabled by removing the protective covers from the Diagnostic Mode Enable connectors on the Engine Harness, and plugging the two connectors together (the Diagnostic Mode Enable connectors are opposite genders). Once the diagnostic mode has been enabled, the Warning LED will flash once signifying the start of a new fault code, and then the fault code will flash out on the Shutdown LED.

The Cummins InPower electronic service tool can also be used to read the fault codes. Refer to the InPower for Generator-Drive Control System Manual (Cummins Bulletin No. 3397100) for detailed instructions on how to use the Cummins InPower electronic service tool to read fault codes.

A third means of reading the fault codes is available via the RS-485 Modbus communications datalink. See the feature description for the Modbus Communications Datalink for further details.

Snapshot Data

Snapshot data allows the relationship between the fault condition and the state of the ECM inputs and outputs, at the time the condition occurred, to be captured and viewed to assist in troubleshooting. When a fault code is recorded in the ECM, a "snapshot" of data is also recorded by the ECM.

The snapshot data is read using the Cummins InPower electronic service tool. Refer to the InPower for Generator-Drive Control System Manual (Cummins Bulletin No. 3397100) for detailed instructions on

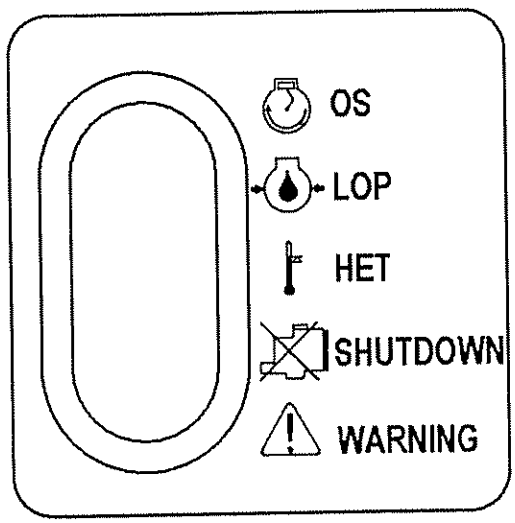
Fault Diagnostics & Troubleshooting

how to use the Cummins InPower electronic service tool to read snapshot data.

Diagnostic LEDs

There are five diagnostic LED's on the side of the ECM that are visible through a clear viewing window. Figure 3 shows the symbols appearing on the viewing window label, identifying each LED. These LED's are used for annunciating the following diagnostic conditions.

Figure 3: Diagnostic LED Display Window Label



Overspeed (OS)

The red OS diagnostic LED will activate when an engine overspeed shutdown fault occurs.

Low Oil Pressure (LOP)

The red LOP diagnostic LED will activate when an engine Low Oil Pressure shutdown fault occurs.

High Engine Temperature (HET)

The red HET diagnostic LED will activate when a high engine temperature shutdown fault occurs.

Shutdown

The red Shutdown diagnostic LED will activate when any fault that results in an engine shutdown occurs.

Warning

The amber Warning diagnostic LED will activate when any fault with a warning level of urgency occurs.

Engine Protection & Safety

GCS controlled engines are equipped with an engine protection system. The system monitors critical temperatures, pressures, and engine speed and will log diagnostic information when an over-normal or under-normal operating condition exists. If an out-of-range condition exists, the Common Warning lamp/relay driver output is energized. The Common Shutdown lamp/relay driver output will be energized when an out-of-range condition continues to worsen resulting in an engine shutdown. Refer to the QSX15, QSK45, QSK60 Generator-Drive Control System Troubleshooting and Repair Manual (Cummins Bulletin No. 3666393) for a description of fault conditions that result in Warning pre-alarms or Shutdown alarms.

Alarm Lamp/Relay Drivers

The following lamp/relay driver outputs are accessible at connector 03, except for the Fail-to-Start driver output, which is accessible at connector 06. There is a dedicated supply voltage output available at connector 03 to provide power for the lamp/relay loads.

Each lamp/relay driver is rated to handle a maximum continuous voltage equivalent to Battery Positive (B+), a maximum transient voltage of 65VDC (during inductive switching of relay loads), and 200 mA maximum continuous sink current.

Engine Shutdown Alarms

Outputs are provided for annunciating three Engine Shutdown Alarms for the following conditions:

- High Engine Temperature (HET)[1]
- Low Oil Pressure (LOP)
- Overspeed (OS)

A condition that causes an HET, LOP or OS Engine Warning Alarm will activate the relay or lamp connected to the respective lamp/relay driver output.

Common Shutdown Alarm

An output is provided for annunciating a Common Shutdown Alarm. The Common Shutdown Alarm activates when:

- Any Engine Shutdown Alarm condition is active
- The Local or Remote Emergency Stop Input is activated

Engine Warning Alarms

Outputs are provided for annunciating three Engine Warning Alarms for the following conditions:

- Pre-High Engine Temperature (Pre-HET)[2]
- Pre-Low Oil Pressure (Pre-LOP)
- Fail-to-Start

---

[1] The High Engine Temperature condition is a logical OR of the High Intake Manifold Temperature and High Coolant Temperature shutdown alarm conditions.

[2] The Pre-High Engine Temperature condition is a logical OR of the Pre-High Intake Manifold Temperature and Pre-High Coolant Temperature warning pre-alarm conditions.

Engine Protection & Safety

A condition which causes a Pre-HET or Pre-LOP Engine Warning Alarm will activate the relay or lamp connected to the respective output. The Fail-to-Start output activates when more than two failed attempts to engage the starter have occurred.

Common Warning Alarm

An output is provided for annunciating a Common Warning Alarm. The Common Warning Alarm activates when any Engine Warning Alarm condition is active.

Emergency Shutdown/Start inhibit

The Emergency Shutdown and Start Inhibit features are implemented using a series circuit of several discrete electrical components (to be supplied by the customer). The Emergency Shutdown and Start Inhibit features are accessible at connector 06. Refer to the QSX15 and the QSK45/60 Generator-Drive Control System Wiring Diagrams for ECM pin connections and a schematic representation of the wiring of each component.

The ECM is able to detect that any of the series switches (Remote E-Stop, Local E-Stop, or Backup Start Disconnect) have been opened and will discontinue fueling the engine and cause the Fuel Shut-Off (FSO) solenoid driver to de-energize the FSO solenoid. In this event, B+ is also removed from the Crank Coil solenoid, inhibiting Start Control, and preventing the engine from being started until the condition has been corrected (all switches in the series are returned to their normally-closed state).

NOTE: Prior to re-starting the engine following an Emergency Shutdown, the shutdown must be acknowledged by setting the Fault Acknowledge switch input to the "Acknowledge" state then back to "Not Acknowledge" state. The engine will not start following an Emergency Shutdown until this procedure has been performed. See the Fault Acknowledge feature description for further details.

Further details of the individual features are explained below. Connecting the switches for each feature as described allows the ECM to monitor the status of the individual switches, providing a means to detect a commanded engine shutdown.

Local Emergency Stop

The Local Emergency Stop, or Local E-Stop, feature is implemented by providing a normally-closed momentary bi-state switched signal (Closed = No E-Stop, Open = E-Stop). This switch signal provides a means to immediately shutdown the engine during an emergency condition by opening the Local E-Stop switch located at the operator panel.

Remote Emergency Stop

Similar to the Local E-Stop switch, the Remote E-Stop feature is implemented by providing a normally-closed momentary bi-state switched signal (Closed = No E-Stop, Open = E-Stop). This switch signal provides a means to immediately shutdown the engine during an emergency condition by opening the Remote E-Stop switch located at a location remote from the operator panel.

Backup Start Disconnect

The Backup Start Disconnect is implemented by providing a bi-state

Engine Protection & Safety

switched signal (Closed = Starting Enabled, Open = Starting Disabled). This feature provides a means to manually disengage the starter by removing power to it when the Backup Start Disconnect switch located on the operator panel is "open". This feature is intended to save the starter from damage in case the Starter Control feature does not automatically disengage the starter when the engine reaches the required start disconnect speed. See the Starter Control feature description for further details.

Shutdown Override

△ CAUTION △

The product warranty does not cover damage to the GCS or the engine resulting from the use of the Shutdown Override feature.

The ECM can be configured to allow continued engine operation while most shutdown faults are active. Even when enabled, the Shutdown Override feature does not allow engine operation while overspeed or loss of engine speed faults are active, or while the ECM detects that the Local E-Stop, Remote E-Stop, or Backup Start Disconnect switches are in an "open" state. All other shutdown faults are overriden when this feature is enabled. The Shutdown Override feature is enabled using the Cummins InPower™ electronic service tool. Refer to the QSX15, QSK45, QSK60 Generator-Drive Control System Application Manual (Cummins Bulletin No. 3884960) for further details.

Engine Monitoring

Analog Meter Drivers

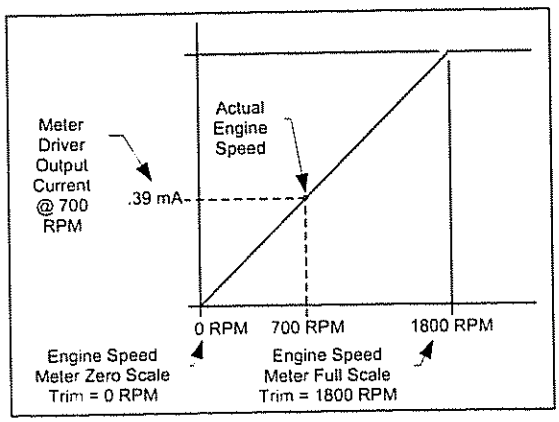
Analog Meter Drivers are provided for monitoring the following three engine parameters:

- Engine Speed
- Coolant Temperature
- Oil Pressure

These parameters can be monitored by interfacing with the respective driver outputs and driver signal returns on connector 03. The driver outputs are rated at 0-1mA full-scale reading and a maximum load impedance of 1k ohm.

The meter drivers are calibrated using the Cummins InPower™ electronic service tool to set the parameter trim values for the lower and upper parameter limits corresponding to 0 and 1 mA current levels. For example, Figure 4 is a diagram depicting the driver response when calibrated to monitor the Engine Speed, using 0 and 1800 RPM as the trim setting values.

Figure 4: Analog Meter Driver Calibration



Refer to the QSX15, QSK45, QSK60 Generator Drive Control System Application Manual (Cummins Bulletin No. 3884960) for further details on how to use the Cummins InPower electronic service tool to calibrate the meter drivers.

The meter driver outputs can also be tested using the Built-In Test (BIT) capability of the ECM, initiated using the Cummins InPower™ electronic service tool. The driver tests are described in detail in the System Check-Out/Test section of this bulletin.

Modbus Communications Datalink

The ECM contains data that can be read using a remote device communicating with the ECM via Modbus protocol on a two-wire half-duplex RS-485 serial communications bus. In this arrangement, the remote device is the master, and the ECM is a slave, supplying data to the master when requested. For further details refer to the Modbus master-slave technique described in the Modbus Protocol Reference Guide (Modicon Document No. PI-MBUS-300).

The Modbus datalink allows the customer to eliminate additional wiring and assembly costs while improving overall product reliability.

The following engine and ECM information can be monitored using the Modbus datalink:

Engine Sensor Parameters

- Engine Speed
- Coolant Temperature
- Oil Pressure
- Ambient Air Pressure
- Intake Manifold Pressure
- Intake Manifold Temperature

Engine Monitoring

- Fuel Outlet Pressure[3]
- Oil Temperature[3]
- Aftercooler Water Inlet Temperature[4]
- Blowby Flow[4]
- Coolant Pressure[4]
- Fuel Pump Pressure[4]
- Fuel Rail Pressure[4]
- Fuel Inlet Temperature[4]
- Timing Rail Pressure[4]
- Coolant Level

Switch Input States

- Idle/Rated
- Run/Stop
- Remote Emergency Stop

Adjustable Input Settings

- Frequency Adjust Pot
- Droop Adjust Pot
- Governor Gain Adjust Pot

Speed Bias Inputs

- ±0.2V Speed Bias Signal
- ±2.5V Speed Bias Signal

Lamp/Relay Driver States

- Common Shutdown
- Common Warning

Actuator Driver States

- Fuel Shut-Off Solenoid

Fault/Diagnostic Data

- Active Warning Fault Events
- Active Shutdown Fault Events
- Most Recent Fault Events

Other GCS/ECM data

- Battery Voltage

[3] These data are only available for the QSX15.

[4] These data are only available for the QSK45 and QSK60.

- Operator Interface Mode
- Engine Running Time
- ECM On-Time
- Base Frequency
- Base Speed
- Final Speed Reference
- Estimated Torque
- Load Profile Monitor
- Fuel Consumption Rate
- Cumulative Fuel Consumption

The customer can implement the RS-485 physical interface by connecting the shielded twisted-pair serial communications bus wires (RS485+ and RS485-) and the bus shield to the appropriate pins of connector 06.

The Modbus operates at a communications rate of 9600 baud. At this data rate, the maximum length of the data communications bus is 4000 ft. [1219m]. If the ECM is connected at either end of the communications bus, Term 1 & Term 2 of connector 06 are to be jumpered by shorting these two pins together. If the ECM is not connected at either end of the bus, Term 1 and Term 2 should both be left unconnected.

For further details regarding RS-485 implementation and applications, refer to Electronic Industries Association Standard EIA-485, "Electrical Characteristics of Generators and Receivers for use in Balanced Digital Multi-Point Systems". Additional information can be found on the World-Wide-Web (WWW) at the B&B Electronics Manufacturing Company web-site. Refer to the "RS-422 and RS-485 Application Note" accessible on-line at Universal Resource Locator (URL) http://www.bb-elec.com/bb-elec/literature/485appnote.pdf.

System Check-Out/Test

Built-In Test (BIT)

The following Built-In Tests are provided for the purpose of checking specific ECM electronic features:

- Lamp/Relay Driver Start-Up Test
- Stationary Test
- Cranking Test

The Lamp/Relay Driver Start-Up Test is automatically performed whenever the engine is started. It is also the first test conducted in the sequence of tests performed during the Stationary and Cranking Tests. Refer to the QSX15, QSK45, QSK60 Generatore-Drive Control System Application Manual (Cummins Bulletin No. 3884960) for instructions on how to initiate the Stationary and Cranking Tests using the Cummins InPower™ electronic service tool.

When the Stationary Test is initiated, the Lamp/Relay Driver Start-Up Test, Outputs Test, and Fuel Shut-Off Test, as described below, will be performed sequentially in the respective order shown.

When the Cranking Test is initiated, the Lamp/Relay Driver Start-Up Test, Outputs Test, Fuel Shut-Off Test, and Starter Test, as described below, will be performed sequentially in the respective order shown.

The Stationary or Cranking Tests can be aborted at any moment when commanded to do so using the Cummins InPower™ electronic service tool.

While conducting each test, the standard ECM diagnostic routines are performed. If any faults are detected during this time, the faults are recorded and annunciated using the means described in the Fault Diagnostics & Troubleshooting section of this bulletin.

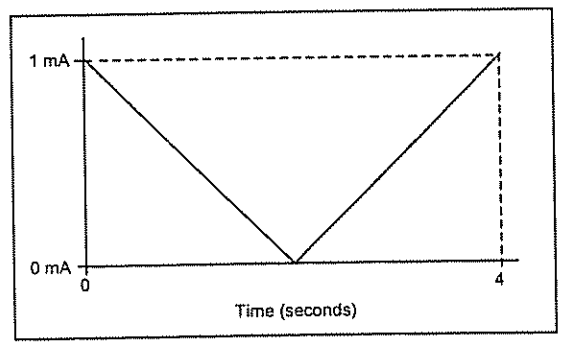
Lamp/Relay Driver Start-Up Test

The lamp/relay driver supply voltage at connector 03 is normally on when the ECM is powered. During engine start-up the ECM will turn this supply voltage off for a 1.5 second interval as a means of testing the lamps/relays driven by the supply. Any Lamp/Relay Driver output that is active during this test will extinguish/de-energize during the 1.5 second test duration.

Outputs Test

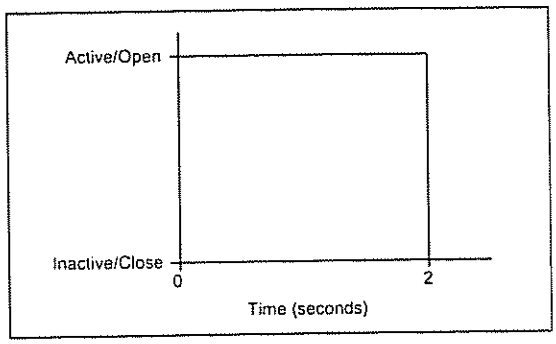
During the Outputs Test all meter drivers, lamp/relay drivers, and diagnostic LEDs will be exercised. The meter driver output test will respond according to the profile shown in Figure 5. The lamp/relay drivers and LEDs will respond according to the profile shown in Figure 6. Note that the Outputs Test for the meters, the lamps/relays and LED's are performed simultaneously. The Fuel Shut-Off Test is initiated following the completion of the Outputs Test.

Figure 5: Analog Output Test Profile



System Check-Out/Test

Figure 6: Discrete Output Test Profile



Fuel Shut-Off Test

Immediately following the Output Tests, the Fuel Shut-Off Test will be initiated. During this test, the FSO driver will respond according to the profile shown in Figure 6.

Starter Test

The Starter Test will be performed Immediately following the Fuel Shut-Off Test, but only when the Cranking Test is being conducted. For this test, the Crank Solenoid driver output will respond according to the profile shown in Figure 6.

⚠ WARNING ⚠

The Starter Test will cause the engine to crank over for 2 seconds, although the engine will not start. All barring devices should be removed from the engine and personnel should be a safe distance away from the engine prior to initiating the Cranking Test.

Electronic Control Module Mounting

The ECM is provided as a kitted part and needs to be installed by the customer.

⚠ CAUTION ⚠

The ECM must NOT be mounted directly to the engine. It is the customer's responsibility to provide proper mounting and ensure that the mounting method complies with the environmental specifications (e.g. vibration, ambient air temperatures, etc.) defined in this bulletin.

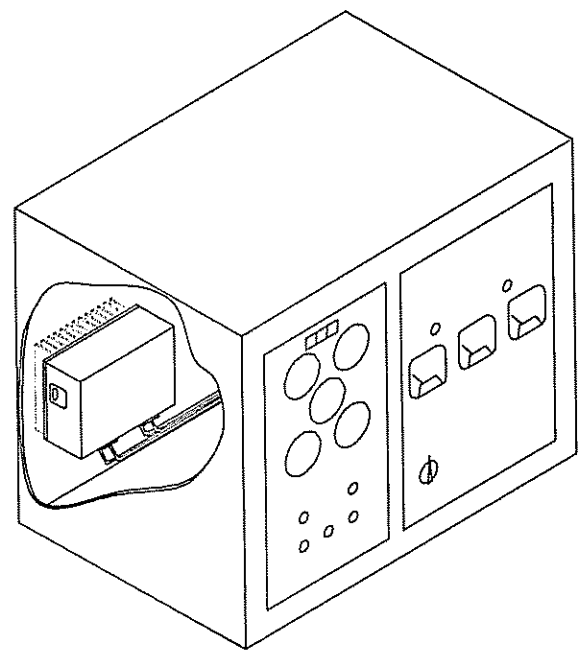
The ECM measures 8.98 x 7.19 x 3.66 in. [228.0 x 182.5 x 92.9 mm], excluding the mounting brackets, with a heat sink height of 1.45 in. [36.8 mm]. The hole size on the ECM mounting brackets is 0.165" [4.2 mm]. Figure 8 shows the ECM envelope and mounting bracket hole dimensions. The ECM kit includes the brackets for mounting the backside of the ECM flush to a mounting surface. An alternate installation is to mount the ECM to a panel with the base of the heat sink flush with the panel surface, and the heat sink protruding through a cut-out in the panel. A template showing the dimensions of the required panel cut-out is shown in Figure 9. Figure 10 is a side-view showing the ECM mounted in this manner.

To comply with IP53 and NEMA-3 enclosure spray angle requirements, the ECM must be mounted with the connectors facing down. The customer must ensure proper support of all harnesses connected to the ECM in order to prevent undue stress or strain on both the harnesses and the ECM connectors.

⚠ CAUTION ⚠

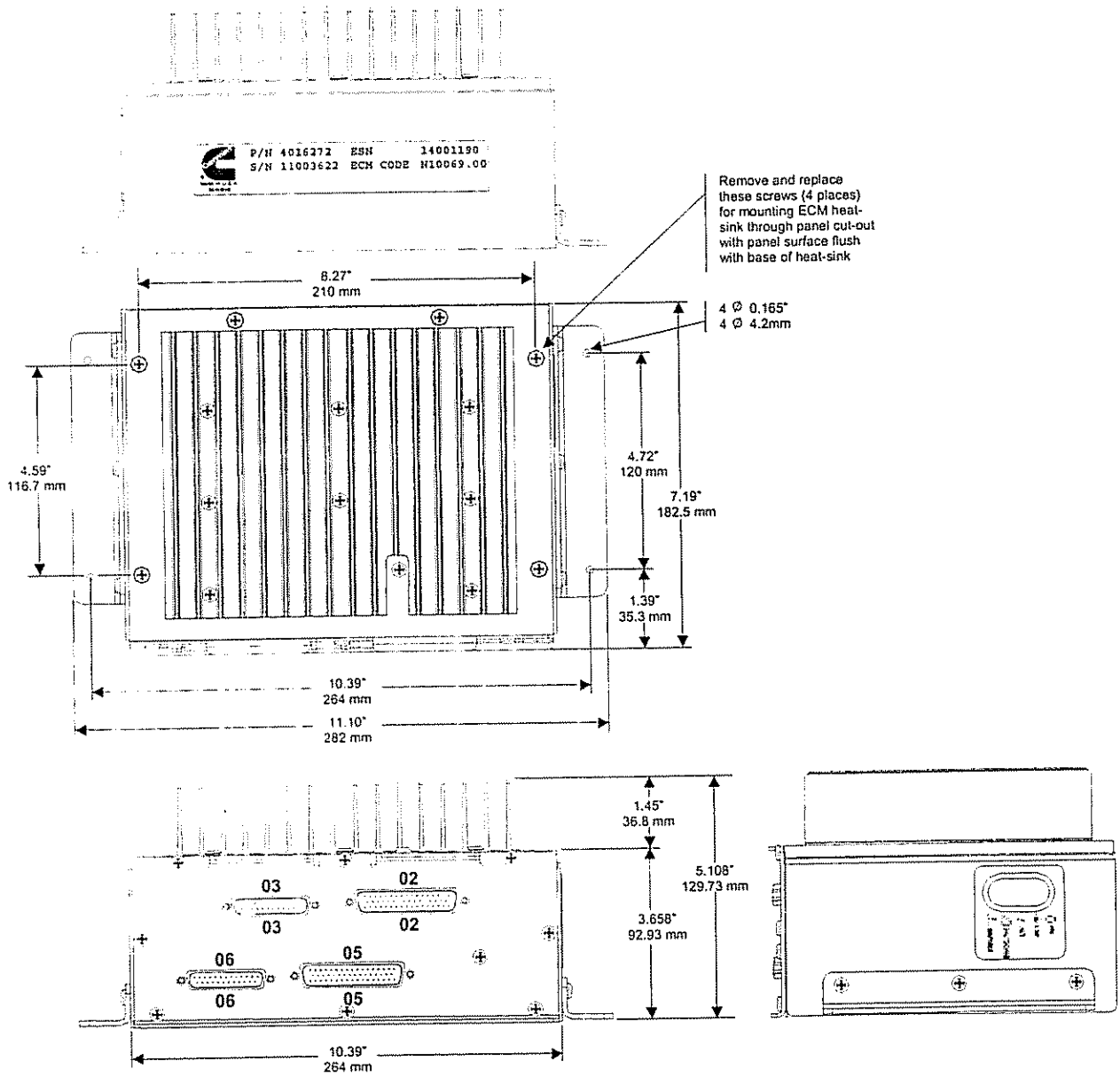
Close attention must be paid to the difference in the ambient cooling air requirements for the ECM and the heat sink to prevent damage to the ECM. More importantly, pay attention to the maximum expected surface temperature of the heat sink to avoid personal injury. See the Environmental Specifications section at the end of this bulletin for further details.

Figure 7: ECM Mounted Flush to Base of Heat Sink



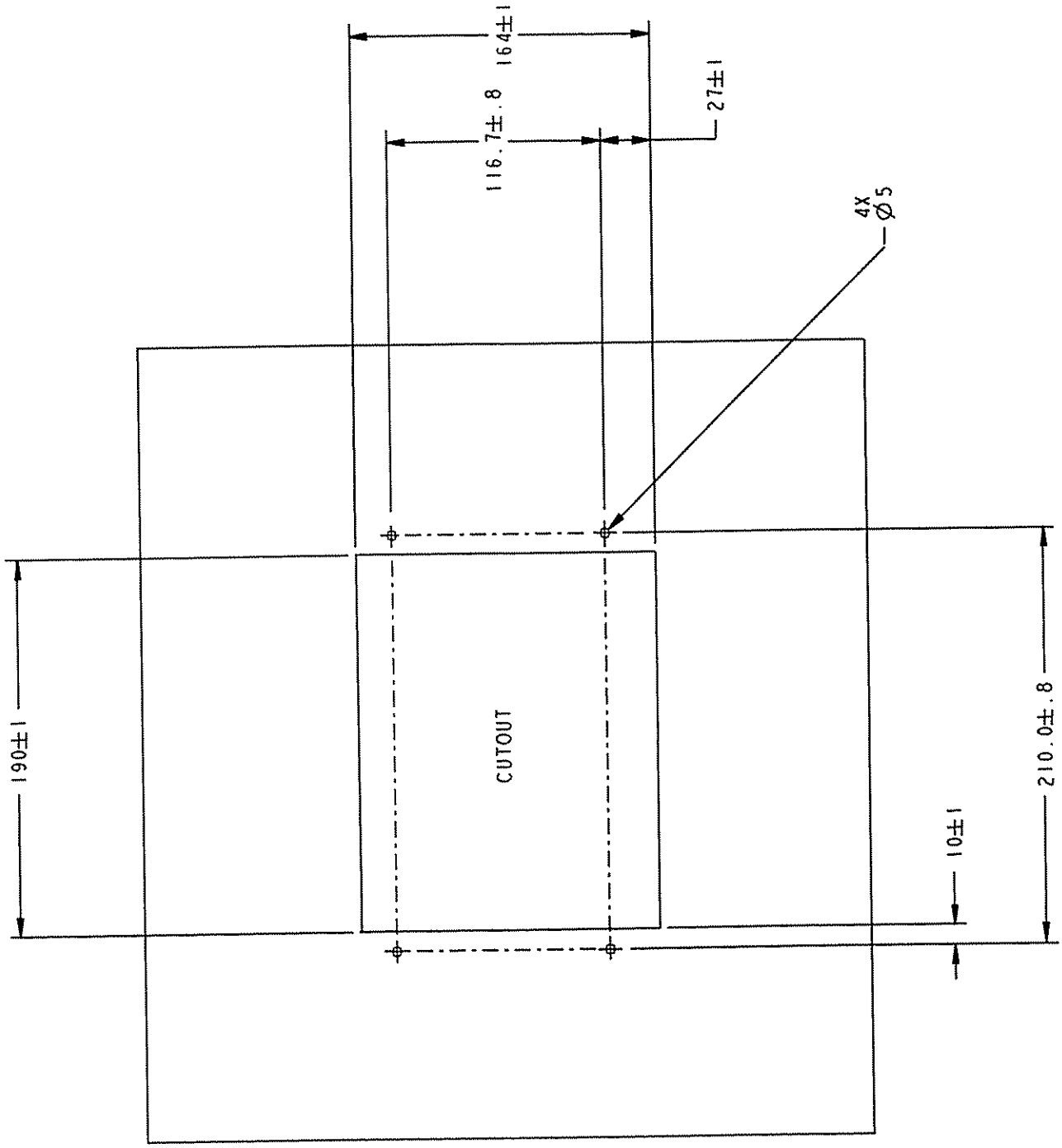
Electronic Control Module Mounting

Figure 8: ECM Envelope & Mounting Bracket Hole Dimensions



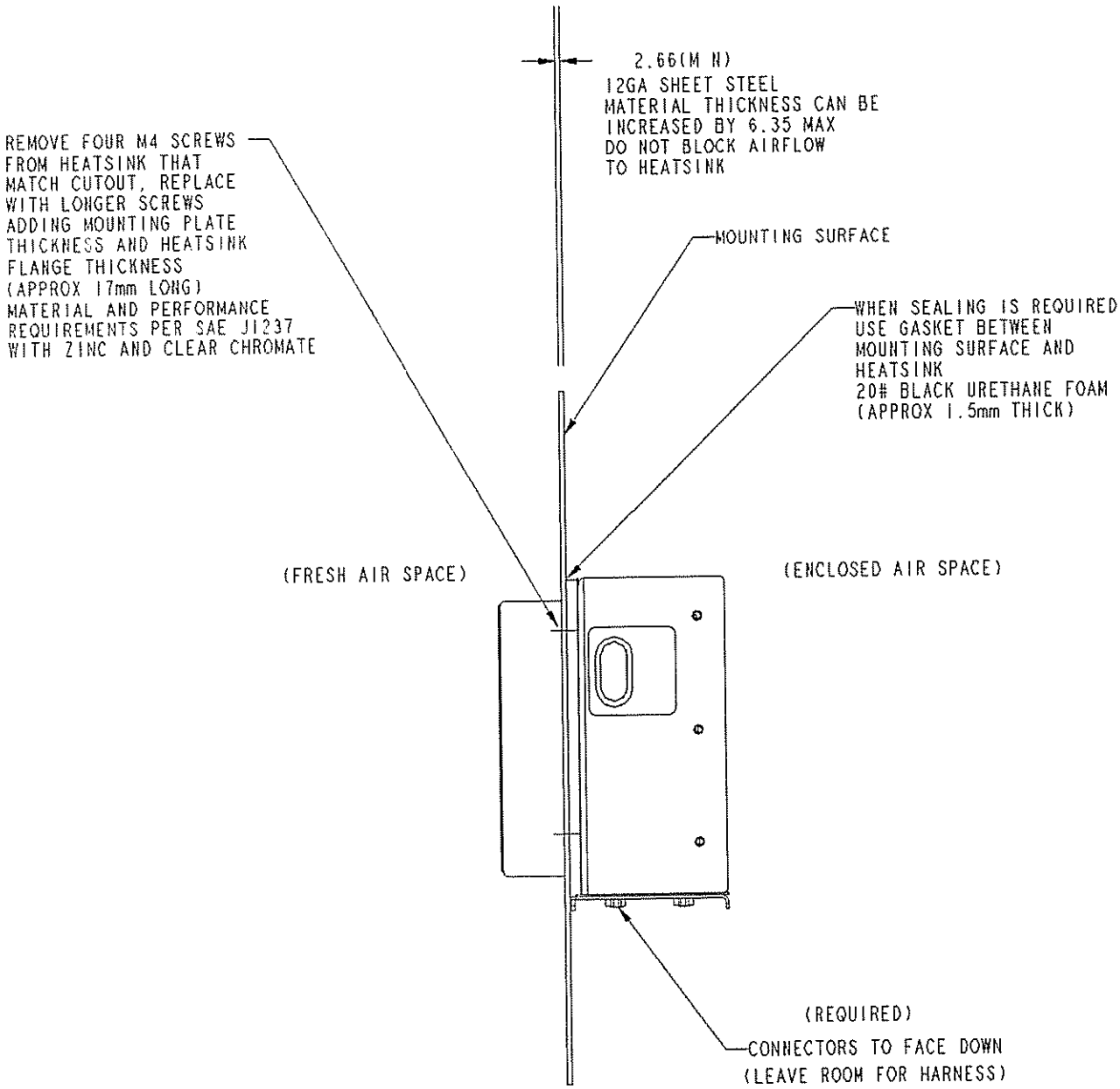
Electronic Control Module Mounting

Figure 9: Panel Cut-Out Template
for Mounting ECM Flush with Base of Heat-Sink
(All dimensions shown are millimeters)



Electronic Control Module Mounting

Figure 10: Side-View of ECM Mounted with Base of Heat-Sink Flush to Panel



Electronic Control Module Harness Interface/Connectors

The ECM has 4 connectors, two Engine ECM connectors (02 & 05) and two Customer ECM connectors (05 & 06). The connector numbers are identified on the connector keying plate attached to the ECM on the same side with the connectors. The connector keying plate provides a connector polarizing feature that prevents incorrect harness connections to the ECM.

The Engine ECM connectors directly interface with the Extension Harness. In conjunction with the Extension Harness, Engine Harness, engine mounted sensors, and engine fuel system, these connectors are used to provide engine sensor information to the ECM and fueling control commands from the ECM to the engine fuel system. Several customer features are implemented by indirectly interfacing to ECM connector 05 through Inline connectors on the Extension Harness, as explained below.

The Customer ECM connectors provide access to customer features of the ECM. **It is the customer's responsibility to provide a harness that interfaces directly with these Customer ECM connectors.** The maximum length between the ECM and the location for customer feature terminations (i.e. control panel, switches, potentiometers, speed bias signals, etc.) is 50 ft. [15.24 m].

Customer connector kits are included with each engine. The connector kits contain all of the necessary connector hardware required for the customer to interface with the two Customer ECM connectors. This includes the two 25-position mating connectors, a grommet for each connector, the necessary quantity of contacts, and the connector backshells. The Connector kits do not include the wires, or the hardware required to terminate the wires at the opposite end of the wiring harness (i.e. control panel terminations).

The connector contacts provided in the kits accept 0.93 mm O.D. (20 Ga.) conductor wire. **The contacts are a non-standard part meeting high quality requirements. Substitute contacts must not be used.**

The connector backshells provided with the connector kits have a polarized keying feature that, when properly installed on the Customer Interface harness, prevents incorrect harness connections to the ECM.

Note: The customer is required to build the Customer Interface harness using the hardware provided with the factory supplied connector kits. **Warranty claims related to incorrect or unreliable connections to the Customer ECM connectors will not be honored unless the connector kit parts are used and assembled in accordance with the instructions supplied with the kits.**

Engine ECM Connectors

Connector 02

Engine ECM Connector 02 (Fuel Systems Board connector) is a male 50-pin D-subminiature plug. The mate-with female connector on the Extension Harness is a 50-pin D-subminiature receptacle.

Connector 05

Engine ECM Connector 05 (Base Board connector) is a male 50-pin D-subminiature plug. The mate-with female connector on the Extension

Electronic Control Module Harness Interface/Connectors

Harness is a 50-pin D-subminiature receptacle.

Note: Both connectors 02 & 05, which are part of the factory supplied Engine Harness assembly, have a keying feature that prevents them from unintentionally being interchanged with one another.

Customer ECM Connectors

Connector 03

Customer ECM Connector 03 (Fuel Systems Board connector) is a male 25-pin D-subminiature plug. The mate-with female connector is a 25-pin D-subminiature receptacle.

The following customer features are accessible via interface to Connector 03:

- Alternate Frequency Switch
- Crank Switch
- Droop Adjust
- Frequency Adjust
- ±2.5V Speed Bias
- ±0.2V Speed Bias
- Engine Speed, Oil Pressure, and Coolant Temperature Meter Drivers
- OS, LOP and HET Shutdown Lamp/Relay Drivers
- Pre-LOP and Pre-HET Warning Lamp/Relay Drivers
- Common Warning Lamp/Relay Driver
- Common Shutdown Lamp/Relay Driver

Connector 06

Customer ECM Connector 06 (Base Board connector) is a male 25-pin D-subminiature. The mate-with female connector is a 25-pin D-subminiature receptacle.

The following customer features are accessible via interface to Connector 06:

- Modbus RS-485 Communications Datalink
- Run/Stop Switch
- Idle/Rated Switch
- Emergency Stop Switch
- Diagnostic Mode Switch (Fault Flashout Enable)
- Fault Acknowledge Switch
- Starter Control (Crank Coil Driver)
- Fail-to-Start Lamp/Relay Driver
- Backup Start Disconnect Status

Note: As mentioned prior, the factory supplied connector kits for connectors 03 & 06 include backshells with a keying feature that, when properly installed on the Customer Interface harness, prevents them from unintentionally being interchanged with one another.

Extension Harness

The Extension Harness provides the means for mounting the ECM off of the engine, elsewhere on the generator set or some other remote location. This is accomplished by extending the circuits from the Engine Harness Inline connectors, located near the engine's flywheel housing, to ECM Connectors 02 & 05. The Inline Connectors comply with IP54/NEMA-4 specifications.

The Extension Harness allows access to the following customer features of ECM connector 05 (including both connectors 02 & 05 for ECM B+ and GND) via interface to

Electronic Control Module Harness Interface/Connectors

Inline Connectors D, E, and the 1-Pin Weather-Pack connector:

- Inline D
  - Governor Gain Adjust
  - Run Relay Contact Status
  - Crank Relay Contact Status
- Inline E
  - Crank Slave Relay Coil Supply Voltage
  - Crank Slave Relay Contact Status
  - ECM Power (B+)
  - ECM Ground (GND)
- 1-Pin Weather-Pack
  - Battery Charging Alternator Flashout

The QSX15, QSK45, and QSK60 engines will be shipped with a factory mounted Engine Harness and kit containing the ECM, Extension Harness, including the mate-with connectors, contacts, and connector accessories (keyed backshell and hardware) required for interfacing with ECM connectors 03 and 06. The Extension Harness will be 10 ft. [3.0 m] in length. **The customer is responsible for manufacturing the harness required for interfacing with ECM connectors 03 and 06.**

A wiring harenss that integrates the features of Inline connector E, the 1-pin Weather-Pack (as required), and other option components pre-installed and delivered with the engine (i.e. Crank Slave Coil, Starting Motor(s), and Battery Charging Alternator) is supplied, and factory installed, when certain options are purchased with the engine. If these options are not purchased with the engine, it is the customer's responsibility to manufacture and install the required wiring harness to interface with all required engine electrical components. All applicable application guidelines and practices must be strictly followed.

If the customer prefers to build their own Extension Harness, it will be the customer's responsibility to ensure the harness complies with published Cummins' specifications, and utilizes the required connector kit parts.

△ CAUTION △

No attempt should be made to bypass existing engine sensors or actuators or to operate the engine using 3rd-Party governor control systems.

Engine-Side Extension Harness In-Line Connectors

Inline A (33-pin) Deutsch circular connector
Inline B (33-pin) Deutsch circular connector
Inline C (19-pin) Deutsch circular connector
Inline D (6-pin) Weather-Pack connector
Inline E (4-pin) Weather-Pack connector
1-Pin Weather-Pack connector

ECM-Side Extension Harness In-Line Connectors

Connector 02	D-Subminiature Connector (50-pin)
Connector 05	D-Subminiature Connector (50-pin)

The specified D-subminiature connectors are a non-standard part. Substitute connectors must not be used.

Operating, Electrical & Environmental Specifications

Operation

Governor Mode	Isochronous to 10% Droop
Governor Gain Adjust	0.05 to 10.00
Idle Speed Adjust (Using InPower™)	700 to 900 rpm (1 rpm increments)
Frequency Adjust Range	± 9 Hz (± 3 Hz Using External Pot, ± 6 Hz Using InPower™)
Speed Bias Reference Voltage	+5 VDC (± 2%); 50 $mV_{(p-p)}$ Max. Ripple
± 2.5V Speed Bias Signal	5.0 V ± 2.5 V (± 3 Hz full scale)
± 0.2V Speed Bias Signal	5.0 V ± 0.2 V (± 7.38 Hz full scale)
Minimum Mag Pickup Speed Signal Input	1.5 $V_{(p-p)}$ @ 200 rpm, 6.5 $V_{(p-p)}$ @ 1800 rpm

Power

Nominal Operating Voltage	+24 VDC
Operating Voltage Range	+18 to +35 VDC (+6.4 VDC Min. during engine starting)
Maximum Continuous Voltage	+35 VDC
Ground Polarity	Negative Ground (convertible to Isolated Ground)
Nominal Operating Current	3.5 amps at +24 VDC
Maximum Operating Current	6.0 amps at +24 VDC
Sleep Mode Operating Current	60 mA (nominal)
Ready Mode Operating Current [Module On & Engine Not Running]	350 mA (nominal)
Run Mode Operating Current [Module On & Engine Running]	5.5 A (nominal)

Environmental

Ambient ECM Housing Operating Temp.	-40^0 to158^0 F [-40^0 to 70^0 C]
Ambient ECM Heat Sink Operating Temp.	-40^0 to 140^0 F [-40^0 to 60^0 C]
Max. Heat Sink Surface Temperature	167^0 F [75^0 C] with 140^0 F [60^0 C] ambient air temperature
Storage Temperature	-67^0 to 176^0 F [-55^0 to 80^0 C]
Vibration (Rigidly Mounted; no vibration isolators)	2-100 Hz, 31 mm/sec; 0.1-2 kHz, 1.1g
Relative Humidity	0-95% Non-Condensing
Salt Fog Resistant	150 Hours, 5% salt @ 95^0 F
Radiated Susceptibility	TBD
Conducted Susceptibility	ENV 50141
Radiated Emissions	EN55022
Electrical Fast Transient (EFT)	EN61000-4-4 (Level 3)
Mounting (Off Engine)	IP53/NEMA-3R (connectors down)

Operating, Electrical & Environmental Specifications

Physical

Dimensions (Including Heat Sink; excluding mounting brackets)	8.98 in. X 7.19 in. X 5.11 in. (228 mm X 183 mm X 130 mm)
Weight	9.16 lb. [4.15 kg]
Housing Metal	Sheet Steel
Heat Sink Metal	Aluminum

Protection

Voltage Surge Protection	per EN61000-4-5 and +63 V DC supply surge voltage
Reverse Polarity Protection	+28 VDC Maximum
High Voltage Protection	+35 VDC Maximum Continuous
Electrostatic Discharge (ESD)	per EN61000-4-2 (4 kV direct contact, 15 kV air discharge)

Standards Compliance

CE	Low Voltage Directive (73/23/EEC), EN50081-1, EN50081-2, EN50082-1, EN50082-2
NEMA	IP53 (ECM Housing), IP54 (Harness Inline Connectors)
CSA[5]	C282-M (1989)
NFPA[5]	76A

[5] The Generator-Drive Control System is suitable for use with generator products intended to comply with the specified standards.