



Hardware Manual

**Digital Min/Max Flo-Tech™ Control
8400-511**

for Cummins Jade/Bravo Engines

Manual 04168

IMPORTANT



This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety messages that follow this symbol to avoid possible injury or death.

DEFINITIONS

- **DANGER**—Indicates a hazardous situation which, if not avoided, will result in death or serious injury.
- **WARNING**—Indicates a hazardous situation which, if not avoided, could result in death or serious injury.
- **CAUTION**—Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.
- **NOTICE**—Indicates a hazard that could result in property damage only (including damage to the control).
- **IMPORTANT**—Designates an operating tip or maintenance suggestion.

WARNING

The engine, turbine, or other type of prime mover should be equipped with an overspeed shutdown device to protect against runaway or damage to the prime mover with possible personal injury, loss of life, or property damage.

The overspeed shutdown device must be totally independent of the prime mover control system. An overtemperature or overpressure shutdown device may also be needed for safety, as appropriate.



Read this entire manual and all other publications pertaining to the work to be performed before installing, operating, or servicing this equipment. Practice all plant and safety instructions and precautions. Failure to follow instructions can cause personal injury and/or property damage.



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Any unauthorized modifications to or use of this equipment outside its specified mechanical, electrical, or other operating limits may cause personal injury and/or property damage, including damage to the equipment. Any such unauthorized modifications: (i) constitute "misuse" and/or "negligence" within the meaning of the product warranty thereby excluding warranty coverage for any resulting damage, and (ii) invalidate product certifications or listings.

NOTICE

To prevent damage to a control system that uses an alternator or battery-charging device, make sure the charging device is turned off before disconnecting the battery from the system.

NOTICE

To prevent damage to electronic components caused by improper handling, read and observe the precautions in Woodward manual 82715, *Guide for Handling and Protection of Electronic Controls, Printed Circuit Boards, and Modules*.

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Electrostatic Discharge Awareness

All electronic equipment is static-sensitive, some components more than others. To protect these components from static damage, you must take special precautions to minimize or eliminate electrostatic discharges.

Follow these precautions when working with or near the control.

1. Before doing maintenance on the electronic control, discharge the static electricity on your body to ground by touching and holding a grounded metal object (pipes, cabinets, equipment, etc.).
2. Avoid the build-up of static electricity on your body by not wearing clothing made of synthetic materials. Wear cotton or cotton-blend materials as much as possible because these do not store static electric charges as much as synthetics.
3. Keep plastic, vinyl, and Styrofoam materials (such as plastic or Styrofoam cups, cup holders, cigarette packages, cellophane wrappers, vinyl books or folders, plastic bottles, and plastic ash trays) away from the control, the modules, and the work area as much as possible.
4. Do not remove the printed circuit board (PCB) from the control cabinet unless absolutely necessary. If you must remove the PCB from the control cabinet, follow these precautions:
 - Do not touch any part of the PCB except the edges.
 - Do not touch the electrical conductors, the connectors, or the components with conductive devices or with your hands.
 - When replacing a PCB, keep the new PCB in the plastic antistatic protective bag it comes in until you are ready to install it. Immediately after removing the old PCB from the control cabinet, place it in the antistatic protective bag.

NOTICE

To prevent damage to electronic components caused by improper handling, read and observe the precautions in Woodward manual 82715, *Guide for Handling and Protection of Electronic Controls, Printed Circuit Boards, and Modules*.

Chapter 1.

General Information

Introduction



The Digital Min/Max Flo-Tech™ control system is equipped with an overspeed shutdown feature that operates to protect against runaway or damage to the engine. Failure to properly install and operate the control system could result in possible personal injury or loss of life.

This hardware manual describes the capabilities of the Woodward Digital Min/Max Flo-Tech™ control, model 8400-511, for Cummins Jade/Bravo engines.

Application

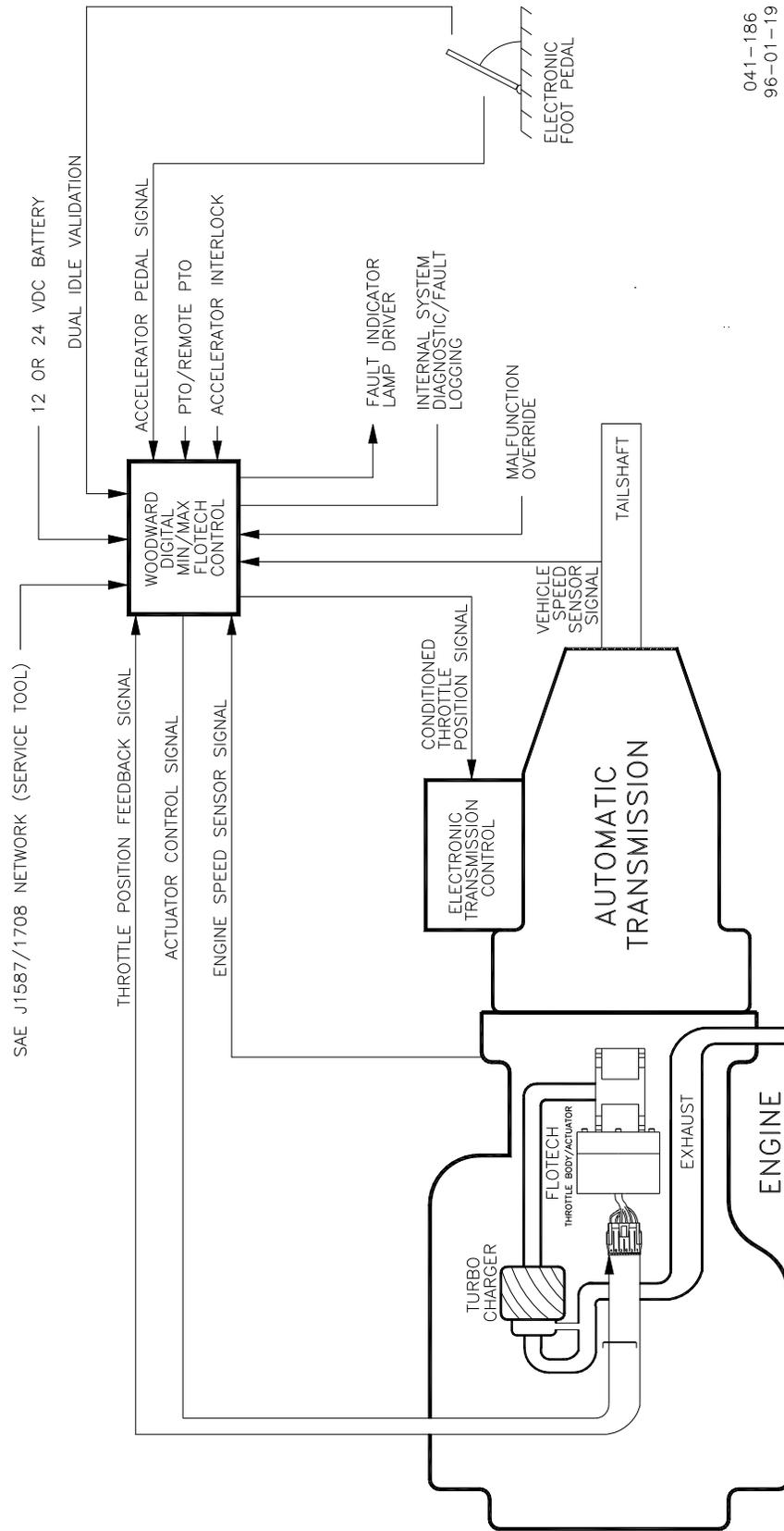
The Woodward Digital Min/Max Flo-Tech control (DMMF) permits efficient idle, fast-idle, and maximum engine-speed control of spark-ignited gas engines. Most installations are on city buses or other vehicles fueled by natural gas.

The DMMF provides features which add to the convenience and protection of vehicle operations. Note that all features may not be available with every application. Key features are:

- **Accelerator Interlock**—De-activates the foot pedal and forces the engine to idle when the bus door is open.
- **Remote PTO (power take-off)**—Sets a second idle speed to handle parasitic loads such as air conditioning, air compressor, and alternator while the vehicle is parked. This could also be used for operation of a power take off used with handicapped access lifts or “kneeling buses”. The throttle is disabled during this selection.
- **Transmission Signal**—Provides a voltage or current signal to transmit a conditioned throttle position to the transmission.
- **Protection Features**—Fault detection is built into the control to prevent damage or overspeed from possible faults in the actuator or foot pedal control. An override contact input is provided to make it possible to “limp” off the road with a speed-sensor or wiring problem.
- **System Malfunction**—A discrete output indicates when a failure has occurred. The control flashes a two-digit code through a user-provided shutdown lamp to indicate which problem(s) have occurred.
- **SAE J1587-1708 Serial Network**—The DMMF provides an SAE J1587-1708 serial data link to allow communication with other networked control modules, if needed. The network also provides the only means to change and monitor set points within the control.
- **Fault Logging**—The control maintains a fault count that may be retrieved (and cleared) through the use of the PC service tool software or a generic SAE 1587-1708 hand held service tool.
- **Cruise Control**—Offers the driver the ability to maintain a desired road speed, accelerate, decelerate, or resume a speed previously set.
- **PTO**—For applications like mixers, dump, and waste disposal vehicles, PTO control lets you control engine speed through the cruise control switches.

DIGITAL MIN/MAX FLOTECH CONTROL

TYPICAL SYSTEM BLOCK DIAGRAM CUMMINS JADE/BRAVO SPEED/THROTTLE CONTROL FOR NATURAL GAS POWERED VEHICLES



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Figure 1-1. Typical System Layout

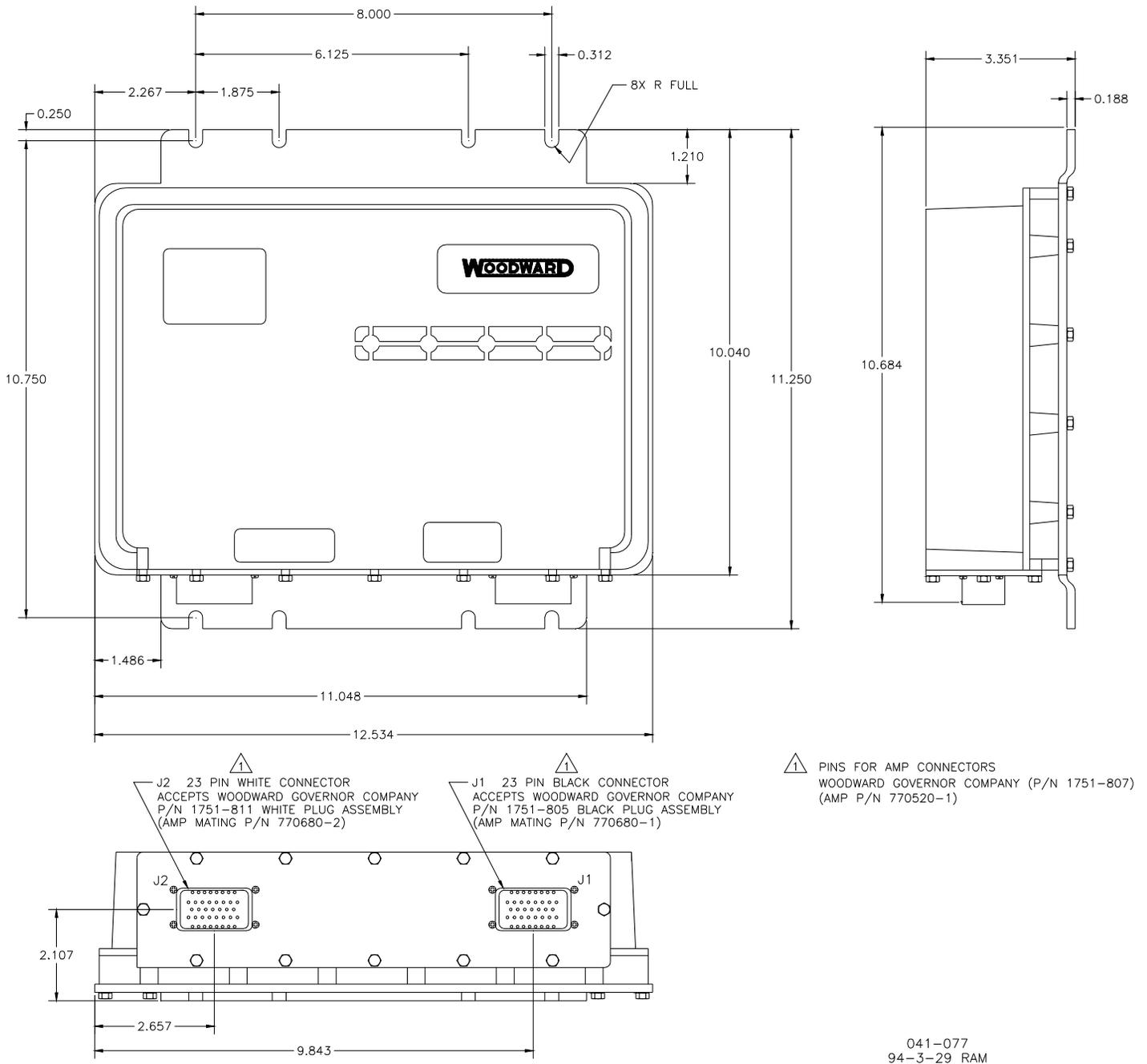
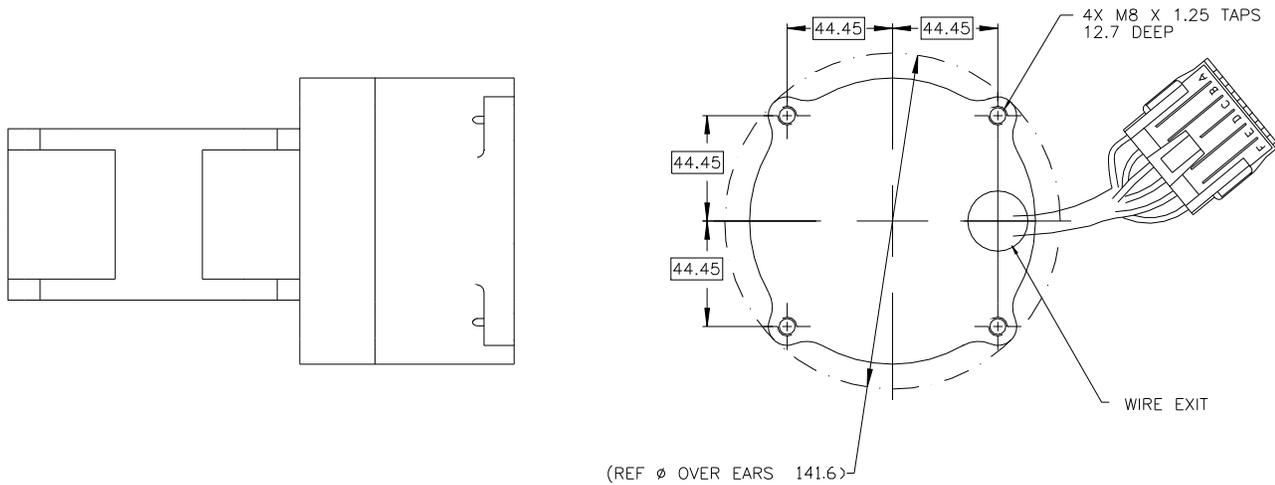
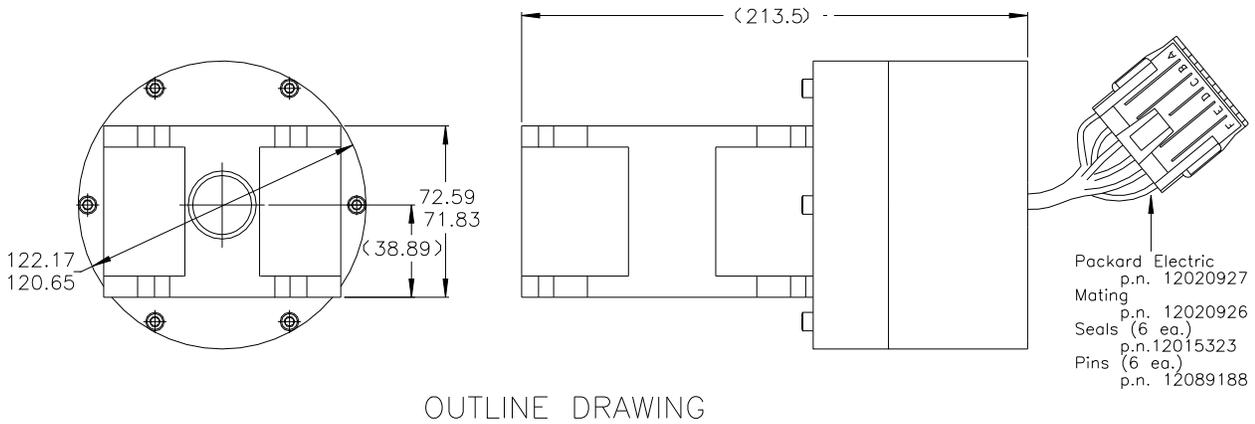
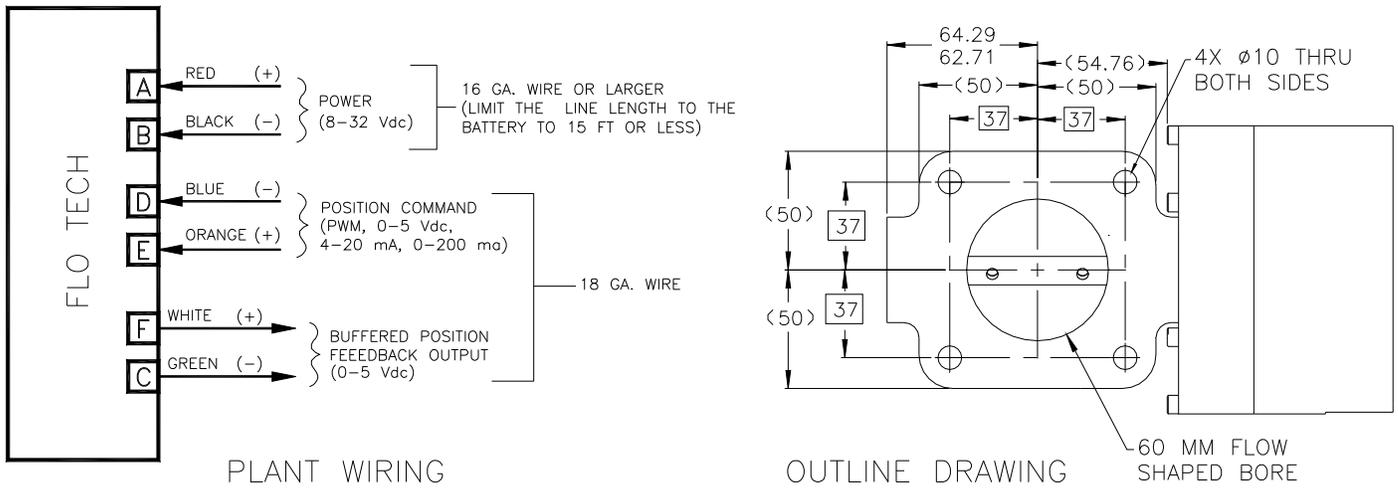


Figure 1-2. Digital Min/Max Flo-Tech Control Box



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Figure 1-3. Typical Flo-Tech Outline Drawing

GENERIC J1587-1708 NETWORK CONNECTION EXAMPLE

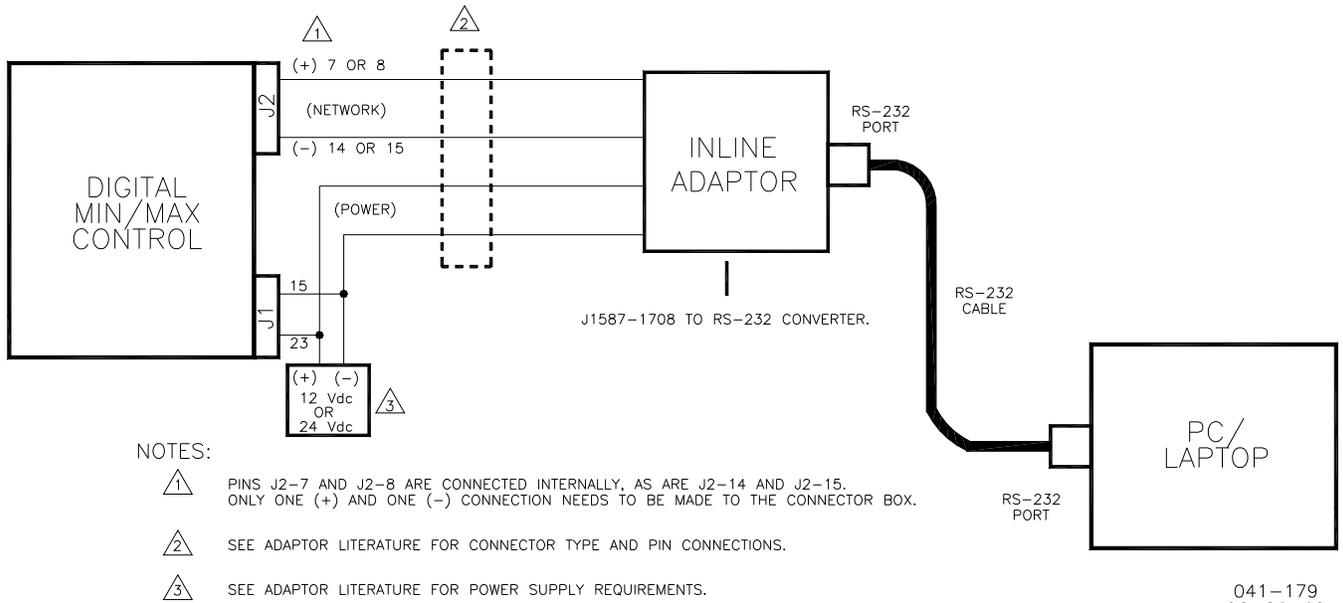


Figure 1-4. Network Connection Example

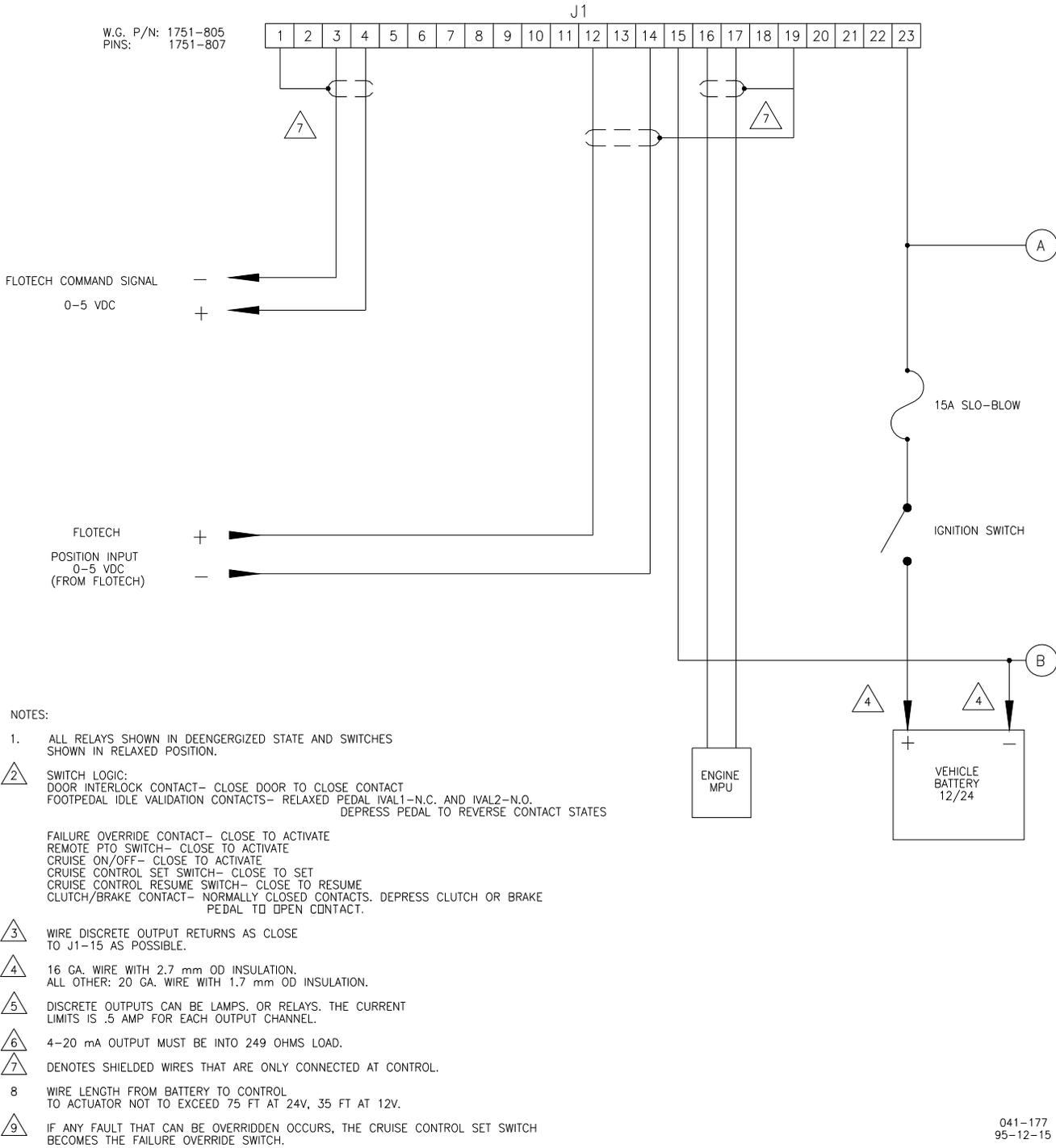


Figure 1-5a. Plant Wiring Diagram

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Chapter 2. Installation

Scope

This chapter contains general installation instructions for the Digital Min/Max Flo-Tech™ control. Power requirements, temperature limits, and location considerations are included to help you determine the best location for the control. Additional information includes unpacking instructions, electrical connections, and installation checkout procedures.

Unpacking

Before handling the control, read page ii, Electrostatic Discharge Awareness. Be careful when unpacking the electronic control. Check the control for signs of damage such as bent panels, scratches, and loose or broken parts. If any damage is found, immediately notify the shipper.

The Flo-Tech actuator is shipped in a separate carton. Inspect the carton for damage. The actuator is a rugged, heavy device and shipping damage is unlikely. Particularly inspect the receptacle and terminal shaft for possible damage.

Power Requirements

The DMMF control system requires a voltage source of 8 to 32 Vdc (12 or 24 Vdc nominal). The system consumes a maximum of 23 watts nominal.

Mounting the Control

The control box is designed to operate within a temperature range of –40 to +60 °C (–40 to +140 °F).

Mount the control in a location with space for wiring access. Do not expose the control to sources of radiant heat such as exhaust manifolds or turbochargers. Mount the control close enough to the actuator and battery to meet the wire-length requirements (see wiring instructions in this chapter). The control box is normally installed in the passenger compartment. Install the control where it is protected from rain or frost. The control box does not have to be adjusted after the completion of the installation and adjustment procedure unless changing the setup.

The bolts holding the control must ground to the vehicle chassis.

The control generates a little heat and surfaces must be open to normal air movement. No special ventilation is required.

Ideally, the control should be mounted flush to the metal side of a control cabinet close to the engine. The location should provide protection from high-voltage or high-current devices, or devices which produce electromagnetic interference.

Do not install the control box directly on the engine.

Mounting the Flo-Tech Actuator/Throttle Body

The Flo-Tech actuator is designed to operate within a temperature range of -40 to $+105^{\circ}\text{C}$ (-40 to $+221^{\circ}\text{F}$). Do not expose the actuator to sources of excessive heat.

Actuator location must allow installation of suitable linkage or direct coupling to the butterfly.

WARNING

To prevent possible loss of life, personal injury, or damage to the engine resulting from an engine overspeed, make absolutely sure that the control and actuator/Flo-Tech throttle body and linkage are properly connected and functioning correctly before starting the engine.

Magnetic Pickups

Install the magnetic pickup to work with the selected gear through a housing or rigid bracket. Make sure the sensed gear is of ferromagnetic material (material that reacts to a magnetic field). Set the gap between the gear and the end of the magnetic pickup according to instructions which accompany the pickup.

Connectors

The DMMF interfaces to the engine and vehicle systems through two 23-pin AMP connectors. The Woodward part numbers for these parts as well as the actuator connector part number(s) are located on the plant wiring diagram (Figure 1-5). The part numbers also list the pins required for the 23-pin DMMF connector.

Wiring Instructions

The plant wiring diagram (Figure 1-5) shows external wiring connections and shielding requirements. These wiring connections and shielding requirements are explained in the balance of this chapter.

Always check for correct actuator movement before attempting to start the engine. With the power removed from the DMMF control, verify that the actuator and throttle body linkage return to minimum rotation.

Electromagnetic interference (EMI) is the undesirable interaction of electronic circuits with each other and sometimes with themselves. Woodward Governor Company has established procedures to prevent most EMI that can affect engine control circuits. Follow all of the shielding instructions to ensure maximum efficiency and dependability of the electronic governing system.

IMPORTANT

Maximum wire length is 4.6 m (15 ft) from battery to Flo-Tech.

Shielded Wiring

All shielded cable must be twisted conductor pairs. Do not attempt to tin the braided shield. All signal lines should be shielded to prevent picking up stray signals from adjacent equipment. Wire exposed beyond the shield should be as short as possible, not exceeding 50 mm (2 inches). The other end of the shields must be left open and insulated from any other conductor. DO NOT run shielded signal wires along with other wires carrying large currents. See Woodward application note 50532, *Interference Control in Electronic Governing Systems*, for more information.

Where shielded cable is required, cut the cable to the desired length and prepare the cable as instructed below.

1. Strip outer insulation from BOTH ENDS, exposing the braided or spiral wrapped shield. DO NOT CUT THE SHIELD.
2. Using a sharp, pointed tool, carefully spread the strands of the shield.
3. Pull inner conductor(s) out of the shield. If the shield is the braided type, twist it to prevent fraying.
4. Remove 6 mm (1/4 inch) of insulation from the inner conductors.

Installations with severe electromagnetic interference (EMI) may require additional shielding precautions. Contact Woodward for more information.

Chapter 3.

Description of Operation

Introduction

This chapter provides a description of the Digital Min/Max Flo-Tech™ system hardware as well as the operational theory.

Digital Min/Max Flo-Tech Control

The Digital Min/Max Flo-Tech control is a 16-bit microprocessor-based digital electronic control designed to provide precision engine speed control over a broad range of torsional loadings, driving conditions, ambient temperatures, and engine dynamics.

The control's cast aluminum enclosure contains the control electronics on two surface-mount, multi-layered printed circuit boards. All adjustments to the control are made through an SAE J1587-1708 network, using a PC (personal computer) with PC Service software and serial-link device. Logged faults may be checked or cleared by a Cummins E-check service tool using a standard SAE J1587-1708 cartridge.

For control layout and wiring, see the plant wiring diagram (Figure 1-5).

The control operates on either 12 or 24 Vdc vehicle battery systems within a range of 8 to 32 Vdc.

Control Adjustment (PC Service Tool)

The DMMF control is adjustable through a software PC Service Tool. All adjustments to the control are made over an SAE J1587-1708 network.

For adjustment procedures, and how to use the PC Service Tool, see the PC Service software manual.

The Flo-Tech Actuator

The Flo-Tech 60 is designed with flow shaping to assist in engine idle stability. The system will provide equivalent max flow rate of standard 60 mm throttle bodies. The system contains a return spring to fully comply with DOT 571.124 specifications.

The Flo-Tech 60 is designed to be the throttle body for gaseous engines with 60 mm throttle body bore. The system is designed for direct replacement of manual throttle bodies. The Flo-Tech 60 requires no actuators or linkage.

The Flo-Tech 60 will accept an 8–32 Vdc (12/24 Vdc nominal) input power supply and a positioning command signal. The driver will produce an output signal to indicate throttle position.

The Flo-Tech 60 is configured to work with a command signal of 0–5 Vdc. Woodward part numbers for the DMMF Flo-Tech are:

- 8235-113—Jade
- 8235-123—Bravo

Return Spring

The Flo-Tech actuator has an internal return spring designed to move the actuator toward minimum fuel in case the electronic control should fail. The return spring forces the actuator toward minimum fuel should the control fail.

Control Operation

The DMMF is programmed with both minimum and maximum engine speed governor set points. The minimum governor set point controls both the speed of the engine and the position of the Flo-Tech actuator under idle conditions when the throttle pedal is resting at its minimum position. Similarly, the maximum governor set point controls engine speed and actuator position if the maximum speed set point is reached. Between these two set points, the position of the Flo-Tech actuator is directly proportional to the position of the throttle pedal. If a foot pedal fault is detected, the engine is forced to idle speed.

If the control detects an actuator short or position sensor fault, the control drives the actuator to minimum position. A power-up reset is necessary to clear the fault. If the control detects a speed sensor fault, the control drives the actuator to minimum position.

Other features are described in the next section.

IMPORTANT

All features may not be available with every application.

Control Features

Accelerator Interlock Contact

This contact input indicates when the vehicle door is open. The control receives a battery (+) signal from a door-activated switch when the door is closed. No signal (open) is received by the control when the door is open. While the door is open, the throttle pedal is disabled and the engine is forced to an idle condition.

Remote PTO Contact

This contact input indicates when a higher remote PTO (power take-off/fast idle) idle speed is desired. The control receives a battery (+) signal, typically from a user-supplied remotely-mounted switch, when remote PTO speed is needed. The accelerator pedal is disabled during remote PTO operation.

Idle Validation Contact #1

This contact indicates to the control when the throttle pedal has been moved off of its minimum stop. A signal is received by the control from a user-supplied foot pedal with idle validation contacts. A battery (+) signal indicates an on-the-minimum-stop condition.

Idle Validation Contact #2

This contact is the complement of Idle Validation Contact #1. A battery (+) signal indicates an off-the-minimum-stop condition.

Fault Override Contact (also Cruise Control/PTO Set Contact)

This contact allows the vehicle to operate for a predetermined amount of time after a fault has occurred. Refer to the software manual for overridable fault conditions. A momentary battery (+) signal is sent to the control when override is desired. This contact is multiplexed with the Cruise Control/PTO Set switch (only if these features are enabled).

Cruise Control On/Off Contact (also PTO On/Off Contact)

This contact input indicates to the control when the user enables the Cruise Control feature. The control receives a battery (+) signal, typically from a dash-mounted toggle switch, when Cruise Control is desired.

Cruise Control Set Contact (also PTO Set Contact)

This contact input indicates to the control when the user enables the Set function of the Cruise Control feature. The control receives a battery (+) signal, typically from a dash-mounted momentary switch, when Set is desired.

Cruise Control Remote Contact (also PTO Resume Contact)

This contact input indicates to the control when the user enables the Resume function of the Cruise Control feature. The control receives a battery (+) signal, typically from a dash-mounted momentary switch, when Resume is desired.

Transmission Signal Output

This voltage output sends an analog signal that represents a conditioned throttle position to an automatic transmission that accepts a programmable voltage input between 0 and 6 Vdc (forward or reverse acting).

Fault Indications

The DMMF provides a discrete output of 500 mAdc. This output is typically wired to a resistive lamp and is used to indicate when a fault has occurred. See your software manual for a table of the available fault codes and what they indicate.

Speed Control Dynamics

The algorithms used in the DMMF are designed specifically for vehicle applications. The control automatically varies its control dynamics as functions of both speed and actuator position to provide better performance over the operation range of the engine.

The DMMF provides two complete sets of dynamic adjustments. One set is in operation at the low idle governor set point, while the other is in control at the maximum governor set point. Each set of dynamics provides different gain mapping, stability, compensation, gain ratio, and gain window settings. This allows precise engine control from low idle no load to max speed full load.

Chapter 4. Service Options

General

The user of the Woodward Digital Min/Max Flo-Tech system should contact your Cummins distributor in the local area regarding repairs or returns. Your Cummins distributor handles repairs, replacements, and warranties, and handles sending the control through Cummins Engine Company to Woodward.

Packing a Control

Use the following materials when returning a control:

- packing materials that will not damage the surface of the unit;
- at least 100 mm (4 inches) of tightly packed, industry-approved packing material;
- a packing carton with double walls;
- a strong tape around the outside of the carton for increased strength.

Appendix.

DMMF Specifications

Control Specifications

Environmental:

Operating Temperature	-40 to +60 °C (-40 to +140 °F)
Storage Temperature	-55 to +100 °C (-67 to +212 °F)
Vibration	random sweep profile, 20 hours/axis at 5–2000 Hz
Thermal Cycle	alternating two-hour cycles between -40 and +85 °C for 24 hours
Mechanical Shock	11 ms 20 G sawtooth shock pulse applied three times in each of six orthogonal axes without damage
Humidity	95% ±5% for ten 24-hour cycles between -40 and +85 °C
Corrosion Resistance	5% salt spray at 35 °C for 96 hours

EMI/RFI:

Electromagnetic Compatibility	all tests performed to the methods of US MIL-STD-462
Conducted Emissions	US MIL-STD-461C Part 2, CEO3
Radiated Susceptibility	not susceptible to radiated emissions up to 100 V/m in the range of 20 kHz to 400 MHz, and 50 V/m from 400 MHz to 1 GHz at an amplitude of 50 V/m
Conducted Susceptibility	-from 30 Hz to 50 kHz, at an amplitude of 1 Vrms, not to exceed 10 W into a 0.5 Ω load -from 50 kHz to 50 MHz, at an amplitude of 1 Vrms, not to exceed 1 W into a 50 Ω load
Electrostatic Discharge (ESD)	not susceptible to 21 kV ESD to the chassis structure

Actuator Specifications

Environment

Weight	6 kg (13 lb)
Operating Temperature	-20 to +105 °C (-4 to +221 °F)
Storage Temperature	-55 to +105 °C (-67 to +221 °F)
EMI/RFI Susceptibility	IEC 801 US MIL-STD-461C
Shock and Vibration	SAE J1455
Temperature and Humidity	SAE J1455

Typical Control Characteristics

Inputs

Power Supply	8 to 32 Vdc (12/24 Vdc nominal)
Position Command	0–5 Vdc, 4–20 mA, 0–200 mA, or PWM (greater than 300 Hz, 5% to 95% duty cycle)

Outputs

Proportional Indication Signal	0–5 Vdc Nominal
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Input/Output Specifications

I/O Parameter:	Flo-Tech Position Input
Input Type:	0–5 Vdc
Connections:	J1-14 (–), C (Flo-Tech connector) J1-12 (+), F (Flo-Tech connector) J1-19 (shield)
I/O Parameter:	Engine Speed Input
Input Type:	Magnetic Pickup (MPU)
Voltage Range:	1.020 Vac rms
Input Range:	8–3000 rpm
Frequency range:	5.3–25.6 kHz
Input Impedance:	200 k Ω
Engine Speed Sensing Gear:	direct engine speed, must have 40–512 teeth
Connections:	J1-16 (signal) (non-polarized) J1-17 (signal) J1-19 (shield) use 2-wire twisted shielded pair
I/O Parameter:	DMMF Control Power Input
Input Type:	dc voltage (typically vehicle battery voltage)
Range:	8–32 Vdc
Interrupt Time:	80 ms max at 24 Vdc
Connections:	J1-23 (+), with 15 A slow-blow fuse or circuit breaker in series J1-15 (–)
I/O Parameter:	Foot Pedal Input
Input Type:	0–5 Vdc
Wiper Input Impedance:	50 k Ω \pm 5%
Supply Voltage:	5 V at 80 mA (supplied by the DMMF control— Vehicle Sensor Supply)
Connections:	J2-16 (+), C (pedal connector) J2-3 (0), B (pedal connector) J2-17 (–), A (pedal connector) J2-18 (shield) use 3-wire twisted shielded pair
I/O Parameter:	Remote PTO Switch
Input Type:	contact input
Input Impedance:	greater than 1 k Ω
Contact Input Response time:	50 ms \pm 25%
Min Input High Voltage:	8 Vdc
Connections:	J2-4, through remotely mounted switch to battery (+) (typically)
I/O Parameter:	Accelerator Interlock Switch
Input Type:	contact input
Input Impedance:	greater than 1 k Ω
Contact Input Response time:	50 ms \pm 25%
Min Input High Voltage:	8 Vdc
Connections:	J2-12, through door activated switch to battery (+) (typically)
I/O Parameter:	Failure Override Switch OR Cruise Control Set Switch
Input Type:	contact input
Input Impedance:	greater than 1 k Ω
Contact Input Response time:	50 ms \pm 25%
Min Input High Voltage:	8 Vdc
Connections:	J2-5, through dash mounted momentary switch to battery (+) (typically). Multiplexed with Cruise Control Set switch.

I/O Parameter:	Idle Validation Switch #1
Input Type:	contact input
Input Impedance:	greater than 1 k Ω
Contact Input Response time:	50 ms \pm 25%
Min Input High Voltage:	8 Vdc
Connections:	J2-13, through foot pedal idle validation switch #1 to battery (+) (typically)
I/O Parameter:	Idle Validation Switch #2
Input Type:	contact input
Input Impedance:	greater than 1 k Ω
Contact Input Response time:	50 ms \pm 25%
Min Input High Voltage:	8 Vdc
Connections:	J2-20, through foot pedal idle validation switch #2 to battery (+) (typically)
I/O Parameter:	Flo-Tech Driver Output
Output Type:	analog, dc voltage, 0–5 Vdc
Min Load Impedance:	10 k Ω
Output Voltage:	0.5 Vdc
Output Current:	10 mA max
Connections:	J1-4 (+), E (Flo-Tech connector) J1-3 (–), D (Flo-Tech connector)
I/O Parameter:	Fault Indicator
Output Type:	dc voltage (same as control input supply voltage)
Maximum Current:	500 mA
Max Load Impedance:	7.5 k Ω at 32 Vdc
Min Load Impedance:	16 Ω at 8 Vdc
Connections:	J2-9 (fault indicator) other side of load to control supply voltage (–)
I/O Parameter:	Transmission Signal
Output Type:	analog–dc voltage, 0–6 Vdc, software trimmable
Min Load Impedance:	200 Ω
Max Load Impedance:	5 k Ω
Max Resolution:	1/1024 of full range
Connections:	J2-19 (+) J2-17 (–), the control may also have other connections to this pin
I/O Parameter:	Road Speed Input, MPU Signal
Voltage Range:	1.0–20 Vac rms
Frequency Range:	5.3 Hz to 25.6 kHz
Speed Range:	8–3000 rpm
Gear Teeth Range:	40–512 teeth
Input Impedance:	200 Ω
Connections:	J2-22 (signal; non-polarized) J2-23 (signal) J2-18 (shield) Use two-wire twisted shielded pair
I/O Parameter:	Clutch/Brake Switch
Input Type:	contact input
Input Impedance:	greater than 1 k Ω
Contact Input Response time:	50 ms \pm 25%
Min Input High Voltage:	8 Vdc
Connections:	J2-11, through normally-closed clutch and brake switches in series to battery (+) (typically)

I/O Parameter:	Cruise Control On/Off Switch
Input Type:	contact input
Input Impedance:	greater than 1 k Ω
Contact Input Response time:	50 ms \pm 25%
Min Input High Voltage:	8 Vdc
Connections:	J2-21, through dash mounted switch to battery (+) (typically)

I/O Parameter:	Cruise Control Resume Switch
Input Type:	contact input
Input Impedance:	greater than 1 k Ω
Contact Input Response time:	50 ms \pm 25%
Min Input High Voltage:	8 Vdc
Connections:	J2-6, through dash mounted momentary switch to battery (+) (typically).

We appreciate your comments about the content of our publications.

Send comments to: icinfo@woodward.com

Please reference publication **04168**.



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