

## **25A DC Motor Controller with CAN, SAE J1939**

### **USER MANUAL**

**P/N: AX100100**

## VERSION HISTORY

Version	Date	Author	Modifications
1.1.0	July 23, 2008	Galen Li	Initial Draft
1.1.0	August 25, 2008	A. Wilkins	Marketing Review
1.1.1	November 10, 2008	Galen Li	Update after hardware stepped to Rev. 4
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2.1.0	December 31, 2023	M Ejaz Sue Thomas	Marketing review, legacy updates, new address

## ACCRONYMS

ACK	Positive Acknowledgement
AIN	Analog Input
CFB	Current Feedback
DOUT	Digital Output (for solenoids or relays)
EA	Axiomatic Electronic Assistant (A Service Tool for Axiomatic ECUs)
ECU	Electronic Control Unit (from SAE J1939 standard)
FB	Feedback
FIN	Frequency Input
M/C	Motor Controller
NAK	Negative Acknowledgement
PDU1	A format for messages that are to be sent to a destination address, either specific or global
PDU2	A format used to send information that has been labeled using the Group Extension technique and does not contain a destination address.
PGN	Parameter Group Number (from SAE J1939 standard)
POUT	Proportional Output (for proportional solenoids)
PropB	Message that uses a Proprietary B PGN
PWM	Pulse Width Modulation
RPM	Revolution per Minute
%dc	Percent Duty Cycle

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## 1. GENERAL

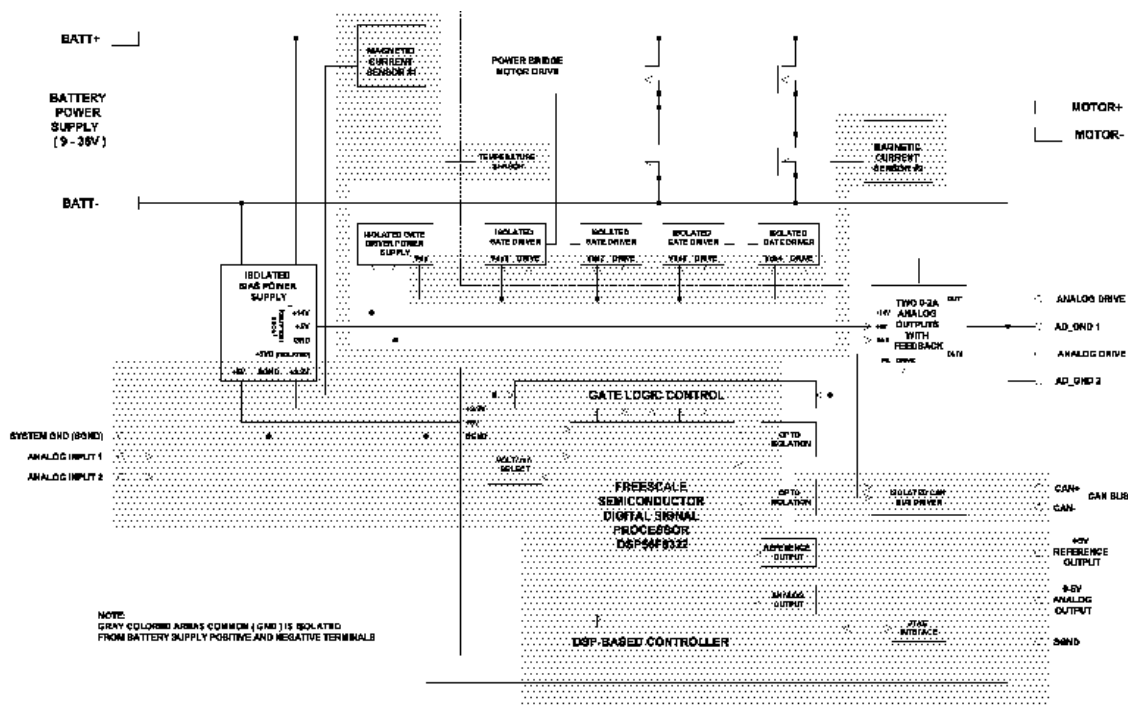
## 1.1. Overview

The Axiomatic 25A DC Motor Controller (M/C) is a rugged and versatile power electronics controller intended for use in a wide range of mobile applications. It can operate as either a standalone embedded DC motor controller or be integrated into a CAN J1939 network containing various electronic controllers.

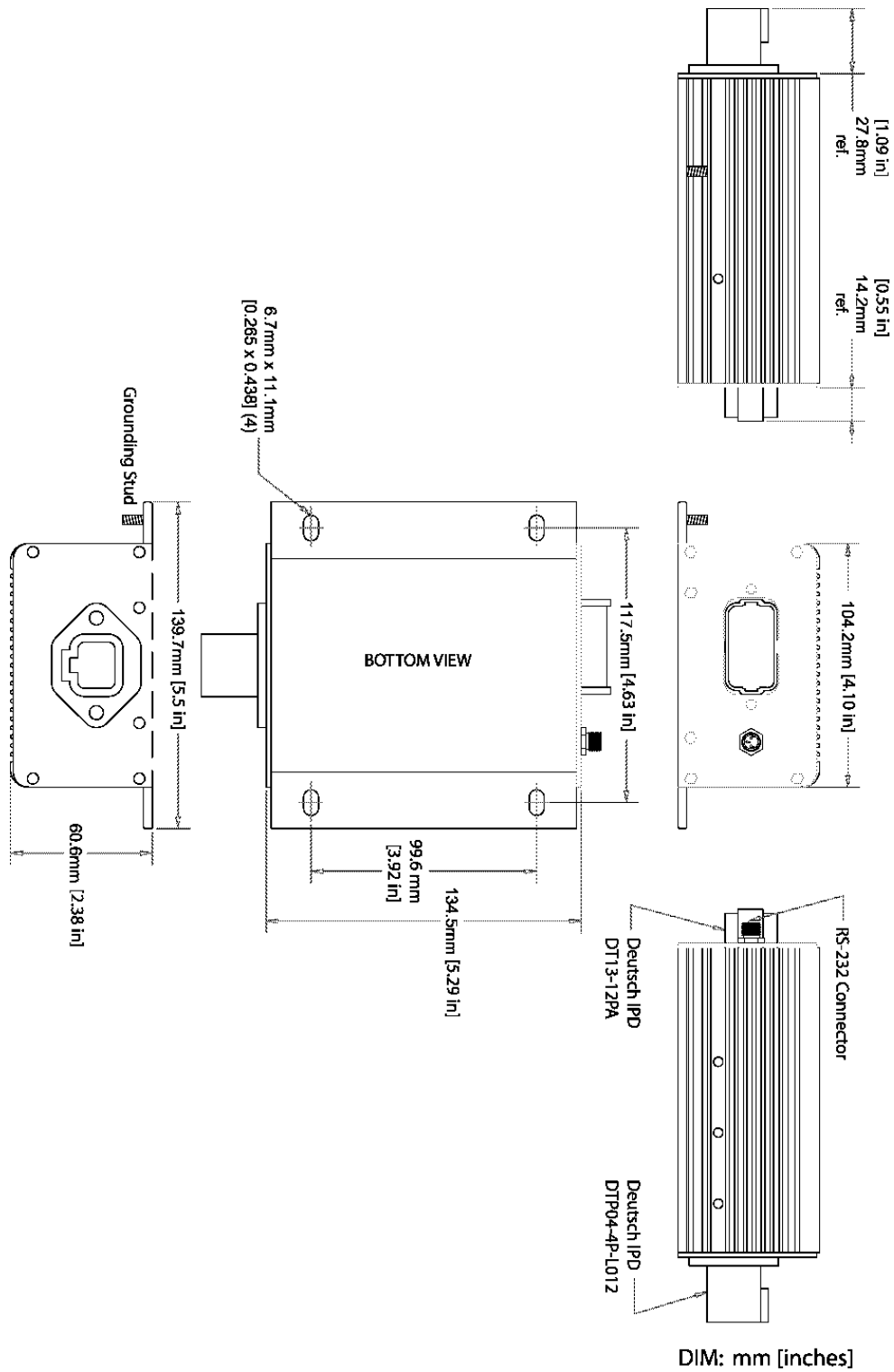
The M/C can drive a DC motor bi-directionally for up to 25A continuous armature current. It has two configurable universal inputs (0-5V, 0-10V, 0-20mA, 4-20mA, PWM, Frequency or Digital), two auxiliary proportional current outputs (0-2A each) for driving possible ancillary proportional or ON/OFF valves, and one voltage output (0-5V) mainly for monitoring purposes. The M/C supports CAN J1939 networking and RS232 serial communications. Control commands for the motor drive and/or auxiliary outputs can be either from the hardwired universal inputs, or a J1939 network, or a combination of the hardwired inputs with a network.

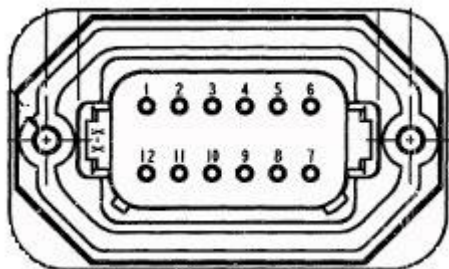
The direction of the motor rotation can be controlled via a variety of approaches. Although it is not recommended to do so, it is possible in some specific applications to start up the motor drive whenever the M/C is powered on. Acceleration and deceleration rates are user controllable through setting adequate ramp times.

### **Block Diagram**



## 1.2. Dimensions and Pinout





#### CAN and I/O Connector:

12 pin Deutsch P/N: DT13-12PA

Pin 1: CAN\_Lo

Pin 2: CAN\_High

Pin 3: CAN\_Shield

Pin 4: Analog Input 2

Pin 5: Analog\_GND 2

Pin 6: Current Output 2

(connected externally to BATT GND)

Pin 7: Current Output 1

(connected externally to BATT GND)

Pin 8: Analog\_GND 1

Pin 9: Analog Input 1

Pin 10: +5V ref.

Pin 11: Analog GND (for Vout)

Pin 12: Voltage Output

A mating wire harness including 2 meters of unterminated wires and the TE Deutsch equivalent mating connector assembly (P/N: DT06-12SA, W12S wedgelock and sockets 0462-201-16141) is available. Ordering P/N: **AX070102**

Pin#	Colour	Function
1	Blue	CAN_L
2	Orange	CAN_H
3	Empty	(CAN_Shield)
4	Yellow	AIN2
5	Black	GND2
8	Black	GND1
9	White	AIN1
10	Red	+5Vref
6	Purple	SOL2
7	Gray	SOL1
11	Black	VGND
12	Green	VOUT

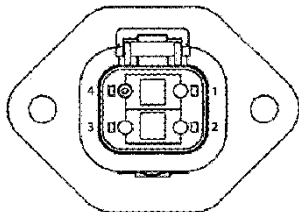


#### RS-232 port:

4 pin M8 P/N: NAN-T-3MR-M8

#### Mating Connector:

AX070101 (NAN-T-3FP-2M and a DB-9 connector)



#### Power and Motor Control:

4 pin TE Deutsch equivalent P/N: DTP04-4P-L012

Pin 1: Battery +

Pin 2: Battery -

Pin 3: Motor -

Pin 4: Motor +

A mating wire harness is available and includes 2 meters (6.5 ft.) of unterminated 12 AWG wires as well as the TE Deutsch equivalent mating connector assembly (Deutsch P/N: DTP06-4S, WP4S and four contact sockets 0462-203-12141). Ordering P/N: **AX070103**

Pin#	Colour	Function
1	Red	Batt+
2	Black	Batt-
3	White/Black	Fwd-/Rev+
4	White Red	Fwd+/Rev-

## 1.3. Mounting and Wiring Instructions

### MOUNTING

The motor controller should be mounted as close to the battery and/or the motor as possible. Install the unit with appropriate space available for servicing and for adequate wire harness access and strain relief.

Mounting ledges include holes sized for M6 or ¼ inch bolts. The bolt length will be determined by the end-user's mounting plate thickness. Typically, 20 mm (3/4 inch) is adequate.

Mask all labels if the unit is to be repainted, so label information remains visible.

### GROUNDING

Ground the chassis for safety purposes and proper EMI shielding. Make this connection using one of the mounting bolts holding the controller to the machine. Ensure that there is no paint in the mounting hole so that the mounting bolt makes connection with the frame.

### SHIELDING

CAN wiring may be shielded using a shielded twisted conductor pair. The shield could be connected to the pin on the 12-pin connector provided for this purpose. The other end of the shield wire could be left unconnected.

Other I/O wires should be shielded as required by the application. Shield wires should be connected at the source/load end and left un-terminated at the motor controller.

Shields can be ac grounded at one end and hard grounded at the opposite end to improve shielding effectiveness.

### WIRING

Note the operating temperature range. All field wiring must be suitable for that temperature range and conform to applicable standards or codes.

At least 8- or 12-gauge wires should be used for connection to the battery or motor.

At least 18- or 20-gauge wires must be used for other inputs and outputs

Refer to the respective TE Deutsch equivalent datasheets for usable insulation diameter ranges and other instructions.



**WARNING: The motor control inputs, and the processor section are fully isolated from both the power supply and the current outputs. DO NOT CONNECT a GND reference from the 12-pin connector to BATT-.**

### CAN WIRING

The CAN port is electrically isolated from all other circuits. Refer to the CAN 2.0B specification for more information.

Axiomatic recommends that multi-drop networks be constructed using a "daisy chain" or "backbone" configuration with short drop lines.

It is necessary to terminate the network; therefore, an external CAN termination is required. No more than two network terminators should be used on any one single network. A terminator is a 121Ω,

0.25 W, 1% metal film resistor placed between CAN\_H and CAN\_L terminals at the end two ECUs on a network.

#### **1.4. References**

J1939	Recommended Practice for a Serial Control and Communications Vehicle Network, SAE, January 2005
J1939/21	Data Link Layer, SAE, April 2001
J1939/71	Vehicle Application Layer, SAE, November 2006
J1939/81	Network Management, SAE, May 2003
TDAX100100	Technical Datasheet, 25A DC Motor Controller, Axiomatic Technologies
UMAX07050X	User Manual, Axiomatic Electronic Assistant and USB-CAN, Axiomatic Technologies



## 2. INPUTS

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There are two universal inputs (0-5V, 0-10V, 0-20mA, 4-20mA, PWM, Frequency or Digital) on the M/C. User can select the type of each input independently to meet their specific application requirements.

These hardwired universal inputs can be used to enable the motor drive, or to control the motor speed and/or direction of rotation. They can also be employed to control the auxiliary current outputs. Note that there is no interdependency between motor output and current outputs. Therefore, it is possible, if desired, to use the same input in both motor control and auxiliary output control functions.

### 2.1. Types of Inputs

See section [5.2](#) for information regarding input setpoints.

0 to 5 Volt:	The input is configured to accept a voltage input in the range of 0 to 5V. Signals above 5V will be trimmed to 5V. Input measurement and error detection setpoints will be interpreted in volts [V].
0 to 10 Volt:	The input is configured to accept a voltage input in the range of 0 to 10V. Signals above 10V will be trimmed to 10V. Input measurement and error detection setpoints will be interpreted in volts [V].
0 to 20 Milliamp:	The input is configured to accept a current input in the range of 0 to 20 mA. Signals above 20mA will be trimmed to 20mA. Input measurement and error detection setpoints will be interpreted in milliamps [mA].
4 to 20 Milliamp:	The input is configured to accept a current input in the range of 4 to 20 mA. Signals above 20mA will be trimmed to 20mA. Input measurement and error detection setpoints will be interpreted in milliamps [mA].
PWM Duty Cycle:	The input is configured to measure the duty cycle of a pulse width modulated (PWM) signal in the range of 0 to 100%dc. Input measurement and error detection setpoints will be interpreted as the duty cycle [%dc].
Frequency:	The input is configured to accept a frequency input in the range of 20 to 2000 Hz. Input frequencies beyond this range will not be adequately detected. Input measurement and error detection setpoints will be interpreted as hertz [Hz]. If there has been no pulse found at the input within a specified period of time ("Measuring Window"), the input frequency is treated as zero.
Digital:	The input is configured to reflect the state of an active high digital input. (Switch is connected to a +V signal when ON.) Input measurement will be interpreted as a state (OFF=0 or ON=1).

### 3. MOTOR CONTROL

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The primary function of the M/C is of course to control a motor. Because of its very flexibility, user can run a motor in different ways. Currently, only speed control, either open loop or closed loop, is supported. Torque control and/or external feedback control may be added for special applications upon request. To run a motor, three key “parameters” must be either explicitly or implicitly defined: whether the motor should be started up once the power is on; what speed is expected of the motor; and in which direction the motor should turn once commanded to run. These three key parameters are referred to as Enable Command, Control Input, and Direction Command respectively.

There are four independent ramps available, for ramping up or down, in either forward or reverse direction. Adequate ramp settings are often necessary to limit the startup current and/or smooth the mechanical movement of the load driven by the motor.

The motor direction can be selected in a variety of ways. One option is unidirectional (forward only) control. For bi-directional control, the user has the option of selecting a single input to control the motor in both forward and reverse directions, with the lower part of the input range to control the motor in one direction and the higher part of the input range to control the motor in the other direction. Alternatively, the motor direction can be explicitly selected using a switch, where the user can select ON=Forward and OFF=Reverse, or vice versa. In this case, the user can map the direction select switch to be one of the inputs on the board configured to be a digital input. Lastly, the motor direction can also be controlled by a message from the J1939 bus. See section [6](#) for more details.

There is a hardware short-circuit protection and a software overcurrent (also called current limiting) protection for the motor control part.



**NOTE: Motor open circuit detection is not enabled at this time. A hardware short-circuit shutoff is factory configurable.**

#### 3.1. Control Mode

There are two control modes available now: Open loop speed control and Closed loop speed control. For the closed loop speed control, the user will need to define where the speed feedback signal comes from. The user will also need to tune the speed PID controller for their application.

Currently, the closed loop speed control is partially implemented only. Some customizations will be needed to suit specific customer requirements on the type of speed feedback signal and/or optimization of closed loop control algorithms.

Due to the complexity of such “limited” speed closed loop control, consult Axiomatic for using this function at the time of placing the order.

#### 3.2. Control Input

The Control Input is to specify how fast the motor is desired to turn. The control input can be mapped to one of the two universal inputs. It can also be coded in a J1939 message. Where one of the universal inputs is selected to be the control input, the control input will additionally specify whether the motor is desired to turn unidirectionally or bidirectionally through the control of this single input.

### **3.3. Enable**

Normally, an “Enable” command should be used to enable the motor control part. The enable command can be mapped to one of the two universal inputs or can be obtained from a J1939 network. In the special case where the motor is desired to startup immediately whenever the M/C is powered on, the user has the option of not using an enable command.

### **3.4. Direction Control**

Where one single input is selected to control the motor running in both directions, the direction of the motor rotation is determined automatically, depending on the signal level of the control input. In other cases, motor direction can be controlled via a dedicated direction command, which can be mapped to one of the two universal inputs or obtained from a J1939 network. Where no direction command is desired, the user has an option of not using direction control and the motor will then turn forward only.

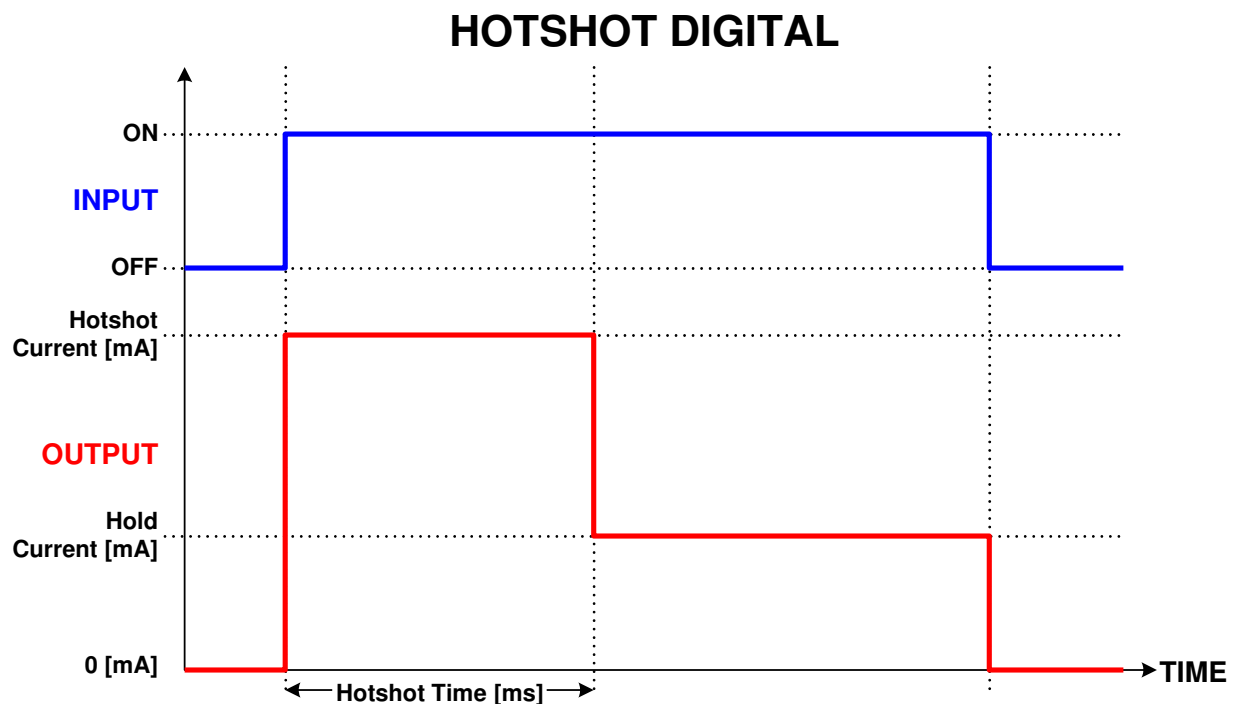
### **3.5. Dependency**

As might have been noticed, there are some dependencies amongst Control Input, Enable Command, and Direction Control. For example, a universal input cannot be used as the control input and enable command simultaneously. As a second example, when a universal input is chosen to control the motor running bidirectionally, direction command will not be permitted. In this case, the user will only have one choice of not using additional direction control command. Since these dependencies are quite intuitive, they will not be fully listed here. However, the configuration tool (EA) will automatically impose these restrictions to avoid user's any impractical selections.

## 4. ADDITIONAL OUTPUTS

The M/C is equipped with additional outputs to drive solenoids or relays for interlock or other supporting functions. There are two proportional outputs to accurately control the current through a solenoid, up to 2A, per channel. Each proportional output can be controlled by a hardwired input or a J1939 message. These outputs can also be configured to act as hotshot coil savers, in that they will drive a digital load on with a hotshot current and keep it on with a holding current. This type of output response can save energy for outputs that are on for long periods of time and is shown in Figure 1.

There is a 0-5V voltage output that is usually used for monitoring purposes. For example, it can be configured to provide a feedback signal of the PWM duty cycle being applied to the motor.



**Figure 1 – Proportional Output Used as Hotshot Digital Output**

### 4.1. Proportional Outputs

The two proportional outputs are configurable regular proportional current outputs. When they are used in their normal mode, there are several ordinary setpoints a user can set, such as ramp-up time, ramp-down time, dither amplitude, and dither frequency. However, the dither frequency can only be realized selectively. This means that the actual dither frequency may not be exactly equal to the one you selected. This limitation is in consideration of reserving the CPU' processing power for the M/C's most critical task of controlling a motor, and it should in general not affect an application's requirement of using additional outputs for auxiliary functions only. Where proportional outputs with a strictly full range of precise dither frequencies are desired, dedicated Axiomatic proportional driver products should be added to the system.

When a proportional output is configured as a Hotshot Digital output, the user has the ability of specifying the amount of hotshot current, the amount of holding current, and the length of hotshot time.

#### **4.2. Monitoring Output**

The 0-5V voltage output is mainly used as a monitoring output. It can monitor the motor PWM duty cycle, motor speed, motor torque, or any one of the universal inputs. The voltage range (0-5V) corresponds to the range of the monitored variable.

## 5. COMMONLY USED CONFIGURABLE SETPOINTS

### 5.1. Motor and Motor Control Setpoints

Below are setpoints directly related to the motor control function.

Name	Range	Default	Notes
Rated Motor RPM	0 to 20000 RPM	4200RPM	This value must be set as per the specifications of the motor. This value is very important in speed control, and if not set correctly, the motor may not behave the way as desired.
Rated Motor Current	0 to 25A	20A	This value should be set as per the specifications of the motor.
Rated Motor Voltage	12/24V	24V	This value should be set as per the specifications of the motor.
Control Mode	0 Open Loop Speed (no feedback) 1 Closed Loop Speed	0: Open Loop Speed Control	See 3.1 for more information about various control modes
Control Input	0 AIN1 Unidirectional 1 AIN2 Unidirectional 2 AIN1 Bidirectional 3 AIN2 Bidirectional 4 J1939 Speed Control	0: AIN1 Unidirectional	See 3.2 for details
Enable Command	0 Enable not used. 1 AIN1 ON Enable 2 AIN2 ON Enable 3 J1939 Enable	2: AIN2 ON Enable	See 3.3 for details
Direction Command	0 No direction control (automatic or fwd only) 1 AIN1 ON forward 2 AIN1 OFF forward 3 AIN2 ON forward 4 AIN2 OFF forward 5 J1939 direction control	0: No Direction Control	See 3.4 for details
Feedback Input	0 AIN1 feedback 1 AIN2 feedback	1: AIN 2 Feedback	This input is used for closed loop speed control only. With the default open-loop control, it is ignored. See 3.1 for more details
RPM Scaling Factor	0 to 5000	1	Gain of pulse-type speed sensor: how many pulses per revolution
Proportional Gain	> 0	0.2	This setting is used for closed loop speed control only. With the default open-loop control, it is ignored.
Integral Gain	>= 0	0	This setting is used for closed loop speed control only. With the default open-loop control, it is ignored.

Derivative Gain	$\geq 0$	0	This setting is used for closed loop speed control only. With the default open-loop control, it is ignored.
Forward Ramp Up	0 to 65000 ms	1000ms	The time it takes to ramp from zero to the maximum command. Appropriate ramp time settings are necessary to limit the startup current.
Forward Ramp Down	0 to 65000 ms	1000ms	The time it takes to ramp from the maximum command to zero. See above.
Reverse Ramp Up	0 to 65000 ms	1000ms	The time it takes to ramp from zero to the maximum command. See above.
Reverse Ramp Down	0 to 65000 ms	1000ms	The time it takes to ramp from the maximum command to zero. See above.

## 5.2. Input Setpoints

There are twelve setpoints associated with each input on the M/C. Most of them relate to how the input would be used to control an output. The rest of the setpoints relate to how the data is measured.

Name	Range	Default		Notes
Input Type (IT)	0 0 to 5V 1 0 to 10V 2 0 to 20mA 3 4 to 20mA 4 PWM Duty Cycle 5 Frequency 6 Digital (Active High)	0: 0 to 5V		See <a href="#">2.1</a> for more information on each input type.
Minimum Error	0 to Minimum Input	5% for PWM, 0 for all others		For input error diagnostics only. <b>Not used now.</b>
Minimum Input	Minimum Error to Minimum Breakpoint	IT=0 0.5V IT=1 0.5V IT=2 0mA IT=3 4mA IT=4 20.5% IT=5 20 Hz		Minimum effective input.
Minimum Breakpoint	Minimum Input to Minimum Deadband	IT=0 0.5V IT=1 0.5V IT=2 0mA IT=3 4mA IT=4 20.5% IT=5 20 Hz		For product compatibility. <b>Read only now.</b>
Minimum Deadband	Minimum Breakpoint to Maximum Deadband	IT=0 2.3V IT=1 4.7V IT=2 9mA IT=3 11mA IT=4 47.5% IT=5 950 Hz		Used only when this input is used to control motor running bidirectionally.

Maximum Deadband	Minimum Deadband to Maximum Breakpoint	IT=0 IT=1 IT=2 IT=3 IT=4 IT=5	2.7V 5.3V 11mA 13mA 52.5% 1050 Hz	Used only when this input is used to control motor running bidirectionally.
Maximum Breakpoint	Maximum Deadband to Maximum Input	IT=0 IT=1 IT=2 IT=3 IT=4 IT=5	2.7V 5.3V 11mA 13mA 52.5% 1050 Hz	For product compatibility. <b>Read only now.</b>
Maximum Input	Maximum Breakpoint to Maximum Error	IT=0 IT=1 IT=2 IT=3 IT=4 IT=5	4.5V 9.5V 20mA 20mA 79.5% 1980 Hz	Maximum effective input
Maximum Error	Maximum Input To Max Range  (100% PWM, others see defaults)	IT=0 IT=1 IT=2 IT=3 IT=4 IT=5	5.0V 10.0V 20mA 20mA 95% 2000Hz	For input error diagnostic only. <b>Not used now.</b>
Measuring Window	100 to 5000 ms	1000 ms		This setpoint is only used if the IT is set to 5: Frequency, otherwise it is ignored. If no pulse has been measured at the input within this window, the value will be treated as zero.
Filter Type	0 No Filtering 1 Moving Average 2 Repeating Average	0: No Filtering		For product compatibility only. <b>Appropriate input measurement filtering is performed inherently. This extra user configurable filtering is not supported in this controller.</b>
Filter Constant	1 to 1000	1		For product compatibility only. See above.

### 5.3. Proportional Output Setpoints

There are fourteen setpoints associated with each current output on the motor controller. Most of them relate to how the output responds to the control signal.

Name	Range	Default	Notes
Control Input	0 Not Used 1 J1939 Control 2 Input 1 3 Input 2	0: Not used	When the control input is “not used”, the output will be inactive.
Output Response	0 Proportional 1 Digital	0: Prop	See <a href="#">4.1</a> for more information
Minimum Current	0 to 2000mA	0mA	
Current at Breakpoint Command	0 to 2000mA	750mA	For product compatibility only. <b>Not used now.</b>
Maximum Current	0 to 2000mA	1500mA	
Ramp Up	0 to 10000ms	1500ms	This ramp will determine how long it would take to ramp from minimum current to maximum current.



Ramp Down	0 to 10000ms	1500ms	This ramp will determine how long it would take to ramp from maximum current to minimum current.
Dither Frequency	50 to 250Hz	125Hz	This determines the frequency of the dither superimposed on top of the output current. <b>Note that the actual dither frequency may be “trimmed” to close to this setting only.</b>
Dither Amplitude	0 to 200mA	0mA	When set to 0, dither is not used. The exact value of the dither amplitude will be partially dependent on the inductance of the load. Adjust this setpoint as required until the amplitude is sufficient to dither the coil.
Hold Current	0 to 2000mA	500mA	See " <a href="#">Hotshot Digital Profile</a> "
Hotshot Current	0 to 2000mA	2000mA	See " Hotshot Digital Profile"
Hotshot Time	0 to 10000ms	1000ms	See " Hotshot Digital Profile"
Current Feedback Filter Type	0 No Filtering 1 Moving Average 2 Repeating Average	0: No Filtering	See “Input Setpoints” for explanation of filter
Current Feedback Filter Constant	1 to 1000	3	See “Input Setpoints” for explanation of filter

#### 5.4. Monitoring Output Setpoints

The 0-5V monitoring voltage output has only one setpoint associated with it.

Name	Range	Default	Notes
Control Input	0 Not Used 1 J1939 Control 2 Input 1 3 Input 2 4 Motor Duty Cycle 5 Motor Speed 6 Motor Torque	4: Motor Duty Cycle	Output range 0-5V corresponds to the range of the selected control input (except for the choice of J1939 Control). See 4.2 for more details.

#### 5.5. Protection Setpoints

There are four setpoints associated with the protection of the motor controller.

Name	Range	Default	Notes
Motor Over Current	0 to 50A	20A	Set this value appropriately to protect the overload but leave enough margin to allow for inrush current resulting from motor startup.
Over Temperature Threshold	0 to 105 °C	85°C	When the unit temperature is above this setpoint value, the motor output will be shutoff immediately.
Over Voltage Threshold	0 to 32V	32V if motor rated voltage is 24V; 16V if motor rated voltage is 12V	Currently, this is an observation only. No action is taken. User can specify action(s) desired.

Under Voltage Threshold	0 to 32V	16V if motor rated voltage is 24V; 10V if motor rated voltage is 12V	Currently, this is an observation only. No action is taken. User can specify action(s) desired.
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## 6. J1939 NETWORKED CONTROL

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The M/C can be controlled partly or completely from a J1939 network. Control commands for motor control as well as for additional outputs are represented by pre-defined J1939 messages when operating in this manner. For flexibility, some features, such as PGN numbers, of the control messages are user configurable.

For possible inter-module control, the M/C can code the measured two universal inputs into J1939 messages and transmit them onto the network. These messages are very flexible, containing many users configurable setpoints. Therefore, only can experienced users use this advanced function.

### 6.1. Introduction to SAE J1939

***This document assumes the reader is familiar with the SAE J1939 standard. Terminology from the standard is used, but not described in detail.***

The motor controller ECU is compliant with the standard SAE J1939 and supports the following PGNs from the standard.

#### J1939-21 - Data Link Layer

- Request 59904 (\$00EA00)
- Acknowledgment 59392 (\$00E800)
- Transport Protocol – Connection Management 60416 (\$00EC00)
- Transport Protocol – Data Transfer Message 60160 (\$00EB00)
- Proprietary A 61184 (\$00EF00)
- Proprietary B 65280 (\$00FF00) to 65535 (\$00FFFF)

#### J1939-81 - Network Management

- Address Claimed/Cannot Claim 60928 (\$00EE00)
- Commanded Address 65240 (\$00FED8)

#### J1939-71 – Vehicle Application Layer

None of the standard application layer PGNs are supported since motor controllers are not defined in the J1939 Application Layer Protocol.

### 6.2. J1939 Network based Control

There is a dedicated J1939 command message for each of motor control, proportional outputs, and monitoring output. There are 4 configurable parameters for each of such messages, but only the

PGNs may need to be really changed (leave others as default whenever possible). Note that none of these commands will take effect unless the appropriate J1939 control mode(s) is selected.

### 1. Motor Control

This message integrates commands for speed control, motor on/off control (Enable), and direction control together. It has 4 or 6 effective data bytes, depending on whether or not the Custom Proprietary B Scheme (a configurable setpoint) is selected.

In the following, it is assumed that the Custom Proprietary B Scheme is not used (i.e., set as “false”).

#### *Byte 0:*

On/Off and Direction control, only Bits 1-0 are actually used, and they are coded as

- 00 – Off
- 01 – Forward
- 10 – Reverse
- 11 – Reserved

#### *Bytes 1-2:*

Speed command in RPM, with 0.5 rpm/bit as resolution and 0 as offset. Byte 1 is the LSB. For example, 0x0400 means 512 rpm commanded.

#### *Byte 3:*

Percent speed command, with 0.5%/bit as resolution and 0 as offset. Percent speed is computed against the rated motor RPM. The RPM command supersedes the percent speed command here, unless both data bytes for the RPM command above are 0xFF.

In the case where the Custom Proprietary B Scheme is selected, simply leave the first 2 bytes in the 8-byte data field of the message “empty” (filled with 0xFF) and shift the On/Off and Direction control data to the third byte (Byte 2).

### 2. Proportional Outputs

These are two very simple messages. For each of such messages, a word in the 8-byte data field (normally Bytes 0-1, see above) is used to represent the required current in mA. Resolution is 1 mA/bit and offset is zero mA. For example, 0x0400 represents a 1024 mA command.

In the case where a proportional output is configured as a digital output, any nonzero mA command will turn the output on while a zero-mA command will turn the output off.

### 3. Monitoring Output

Usually, this is a monitoring output only, as its name indicates. However, it can be controlled by a J1939 command as well. A word in the 8-byte data field (normally Bytes 0-1, see above) is used to represent the required voltage in mV. Resolution is 1 mV/bit and offset is zero mV. For example, 0x0400 represents a 1024 mV voltage command.

### 6.3. J1939 Command Message Setpoints

The integrated motor control command and command for each of the additional outputs have the following setpoints indicating how the control command received from the J1939 bus is handled. There are four setpoints identically for each command.

#### J1939 Command Message Setpoints

Name	Range	Default	Notes
Command PGN	0 to 65535	Motor Control 61184 Prop Output1 65286 Prop Output2 65287 Monitor Out 65288	<b><i>It is the user's responsibility to select a PGN that will not violate the J1939 standard</i></b>
Response Sent	0 No Response 1 Send ACK 2 Send Feedback	0: No Response	When No Response is selected, the controller will use the new command to control the output accordingly, but it will not send any message to the bus acknowledging that it has received the command. <b>The controller only supports the default option now and other options will be provided for specific applications upon request.</b>
Command Message Timeout	0 to 60000ms	0 ms	This parameter can be used to cause any application specific action(s) to be taken (upon request) if the command PGN for the channel has not been received within this timeout period.  A value of 0 ms disables the timeout feature.
Custom Proprietary B Scheme Used	True or False	False	This setpoint determines if the Axiomatic Proprietary B Scheme applies. If it does, the real command data starts at Byte [2] of the 8-byte data field, and Byte [0] and Byte [1] are reserved. Otherwise, command data starts at Byte [0].

### 6.4. J1939 Feedback Messages and Message Setpoints

Motor control feedback and feedback of all additional outputs can be coded into J1939 feedback messages and sent to the bus, using the following three setpoints.

Name	Range	Default	Notes
Feedback PGN	65280 to 65535	Motor Control FB 65290 Prop Output1 FB 65291 Prop Output2 FB 65292 Monitor Out FB 65293	Feedback messages are always sent using a Proprietary B PGN
Repetition Rate	0ms to 60000ms	0ms	This setpoint determines how often the message is sent to the bus. When set to zero, no feedback message will be sent. <b><i>It is the user's responsibility to select a repetition rate that will not disrupt bus activities.</i></b>

Custom Proprietary B Scheme Used	True or False	False	When "Custom Proprietary B Scheme Used" is TRUE, the feedback data starts at Byte [2] of the 8-byte data field, and Byte [0] and Byte [1] are reserved for the Axiomatic Proprietary B scheme. Otherwise, feedback data starts at Byte [0].
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### 1. Motor Feedback

This message packs motor on/off and direction status, measured motor speed, motor percentage speed, and measured motor controller temperature in one data frame.

In the following, it is assumed that the Custom Proprietary B Scheme is not used (i.e., set as "false").

#### *Byte 0:*

On/Off and Direction status, only Bits 1-0 are actually used, and they are coded as

- 00 – Off
- 01 – Forward
- 10 – Reverse
- 11 – Invalid

#### *Bytes 1-2:*

Actual motor speed in RPM, with 0.5 rpm/bit as resolution and 0 as offset. Byte 1 is the LSB. For example, 0x0400 means 512 rpm detected.

#### *Byte 3:*

Percent speed status, with 0.5%/bit as resolution and 0 as offset. Percent speed is computed on the base of the rated motor RPM.

#### *Bytes 4-5:*

Measured M/C temperature, with 0.03125 C/bit as resolution and -273C of offset.

In the case where the Custom Proprietary B Scheme is selected, the first 2 bytes in the 8-byte data field of the message are reserved (currently filled with 0xFF) and the On/Off and Direction status is shifted to the third byte (Byte 2) position.

### 2. Proportional Output Feedback

Each proportional output has one feedback message associated. For each of such messages, a word in the 8-byte data field (normally Bytes 0-1, see above) is used to represent the measured output current in mA. Resolution is 1 mA/bit and offset is zero mA. For example, 0x0400 represents a 1024 mA current sensed.

### 3. Monitoring Output Feedback

A word in the 8-byte data field (normally Bytes 0-1, see above) is used to represent the generated voltage onto this output. Resolution is 1 mV/bit and offset is zero mV. For example, 0x0400 represents a 1024 mV voltage generated.

## 6.5. Network Setpoints

### NAME

The motor controller has the following defaults for the J1939 NAME. The user should refer to the SAE J1939/81 standard for more information on these parameters and their ranges.

Arbitrary Address Capable	Yes
Industry Group	0, Global
Vehicle System Instance	0
Vehicle System	0, Non-specific system
Function	132, Axiomatic Motor Controller
Function Instance	22, Axiomatic AX100100
ECU Instance	0, First Instance
Manufacture Code	162, Axiomatic Technologies Corporation
Identity Number	Variable, based on ECU Serial Number

The only configurable setpoint associated with the NAME is the ECU Instance. Changing this value will allow multiple ECUs of this type to be distinguishable by other ECUs (including Axiomatic Electronic Assistant) when they are all connected on the same network.

### ECU Address

With this setpoint, the user can change the address of the ECU. The default value of this setpoint is 202 (0xCA). The EA will allow for selection of any address from 0 to 253, and ***it is the user's responsibility to select an address that complies with the standard.*** The user must also be aware that since the unit is arbitrary address capable, if another ECU with a higher priority NAME contends for the selected address, the M/C will continue to select next higher address until it find one that it can claim. See J1939/81 for more details about address claiming.

## 6.6. J1939 Universal Inputs Transmit Message Setpoints – Advanced Setup

Each Universal Input on the motor controller has the following setpoints associated with a transmission message that reflects on the input value and is sent to the J1939 bus, either simply for input measurement or mostly for inter-module control.

### J1939 Universal Input Transmit Message Setpoints

Name	Range	Default	Notes
Transmit PGN	0 to 65535	Input1 65280 Input2 65281	Note: PGN 65280 is the lowest Proprietary B message and is used for Input 1 as default. <b><i>It is the user's responsibility to select a PGN that will not violate the standard</i></b>
Repetition Rate	0ms to 60000ms	0ms	This setpoint determines how often the message is sent to the bus. When set to zero, no message will be sent. <b><i>It is the user's responsibility to select a repetition rate that will not disrupt bus activities.</i></b>
Destination Address	0 to 255 (Global Addr)	255	The user can change this setpoint if they want to send the message to a specific address on the bus. Otherwise, the messages will be sent to the Global Address (255). For all PDU2 PGNs, this setpoint is ignored.

			<b>With receiver ECUs that are arbitrary address capable, this feature must be used with caution.</b>
Proprietary B Message Type	0 Feedback 1 Command 2 Not Used	2: Not Used	If set to 2 (Not Used), the Proprietary B scheme is not used. Otherwise, the user has the option to send the measured input as either an Analog Input (\$0A) [\$0D for digital] or as a Command (\$0C) to control an output on another Axiomatic module, <b>to be thus expanded upon request.</b> <b>If the PGN is not PropB, this setpoint is ignored.</b>
Data Size	1, 2 or 4	2=WORD	This setpoint determines how the data will be coded in the message. When set to 1 Byte (BYTE) the data is sent as an unsigned char. When set to 2 Bytes (WORD) the data is sent as an unsigned int (16 bit). When set to 4 Bytes (DWORD) the data is sent as an unsigned long (32 bit). WORDs and DWORDs are sent LSB first.
Data Index in 8-BYTE Array (LSB)	0 to (8-Data Size)	0	This setpoint determines which location the LSB of the data will be loaded into the 8-Byte data array. For BYTEs, this can be set from 0 to 7. For WORDs, this can be set from 0 to 6. For DWORDs, this can be set from 0 to 4. Unused bytes in the array are loaded with \$FF. If the PropB scheme is used, and this value is less than 2, it will default to 2 automatically.
Resolution	0 to 100000	1 mV/bit 1 uA/bit 0.1 %dc/bit 1.0 Hz /bit	This setpoint determines the scaling done on the measured value before it is sent to the bus. The Input Type will determine the base unit of the setpoint before the scaling is applied. (Refer to <a href="#">2.1</a> )
Offset	-10000 to 10000	0.0	This setpoint determines the value that is <b>subtracted</b> from the data <b>before</b> it is scaled. It must be in the same unit as the measured input (i.e. mV, uA, %dc, Hz)

## 7. USING M/C WITH AXIOMATIC ELECTRONIC ASSISTANT

### 7.1. Installing the Axiomatic Electronic Assistant (EA)

Refer to the User Manual for the Axiomatic Electronic Assistant (EA) for information on how to install and use EA.

### 7.2. Selected Screen Captures

Image 7.2.1: CAN port was opened; EA has recognized the Axiomatic 25A Motor Controller

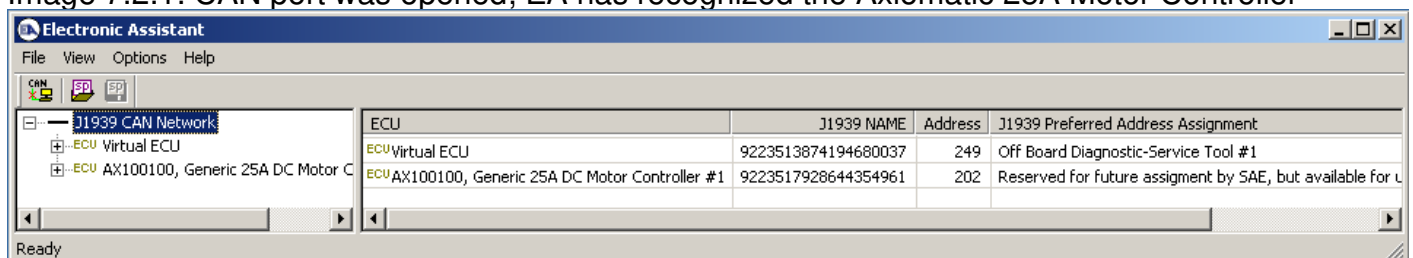
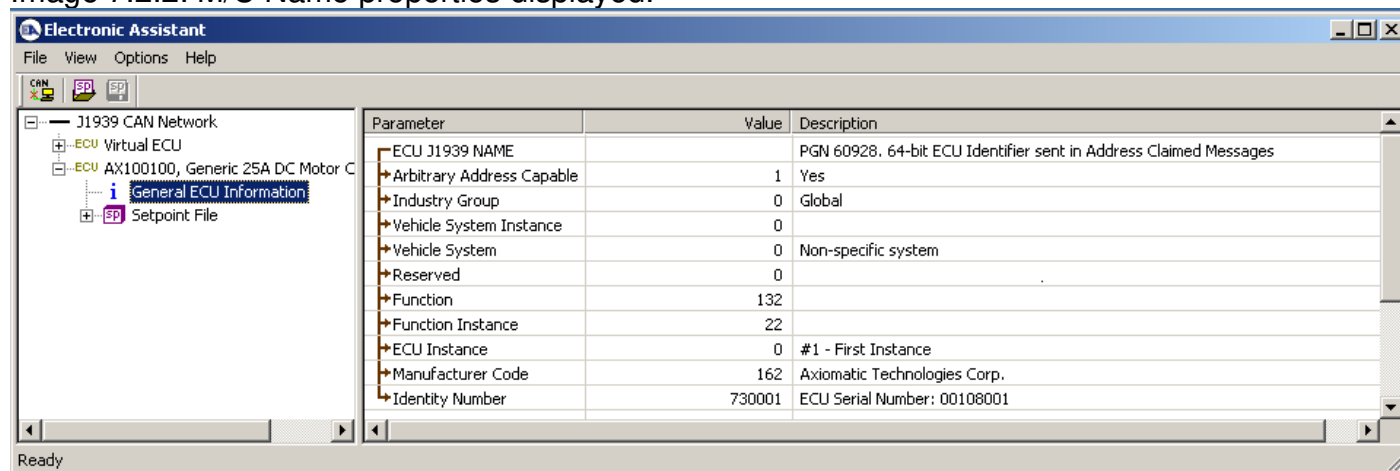


Image 7.2.2: M/C Name properties displayed.





The screenshot shows the 'Electronic Assistant' application window. The left-hand tree view is expanded to show the configuration for the 'J1939 CAN Network'. Under 'Virtual ECU', there is an 'AX100100, Generic 25A DC Motor'. Under 'General ECU Information', there is a 'Setpoint File'. The 'Setpoint File' is further expanded, showing a list of setpoints: 'Motor Parameters', 'Motor Control', 'Acceleration Control', 'Protection', 'Motor Feedback', 'Speed PID Controller', 'Universal Input 1', 'Universal Input 2', 'Proportional Output 1', 'Proportional Output 2', 'Monitoring Output', and 'Network'. The 'Network' setpoint is currently selected. The right-hand pane displays a table with three columns: 'Setpoint Name', 'Value', and 'Comment'. The table contains two rows of data for the selected 'Network' setpoint.

Setpoint Name	Value	Comment
SP ECU Instance Number	0	#1 - First Instance
SP ECU Address	202	Reserved for future assignment by SAE, but available for use by self configurable ECUs

[illegible]

Image 7.2.5: Motor Control Command Message Setpoints

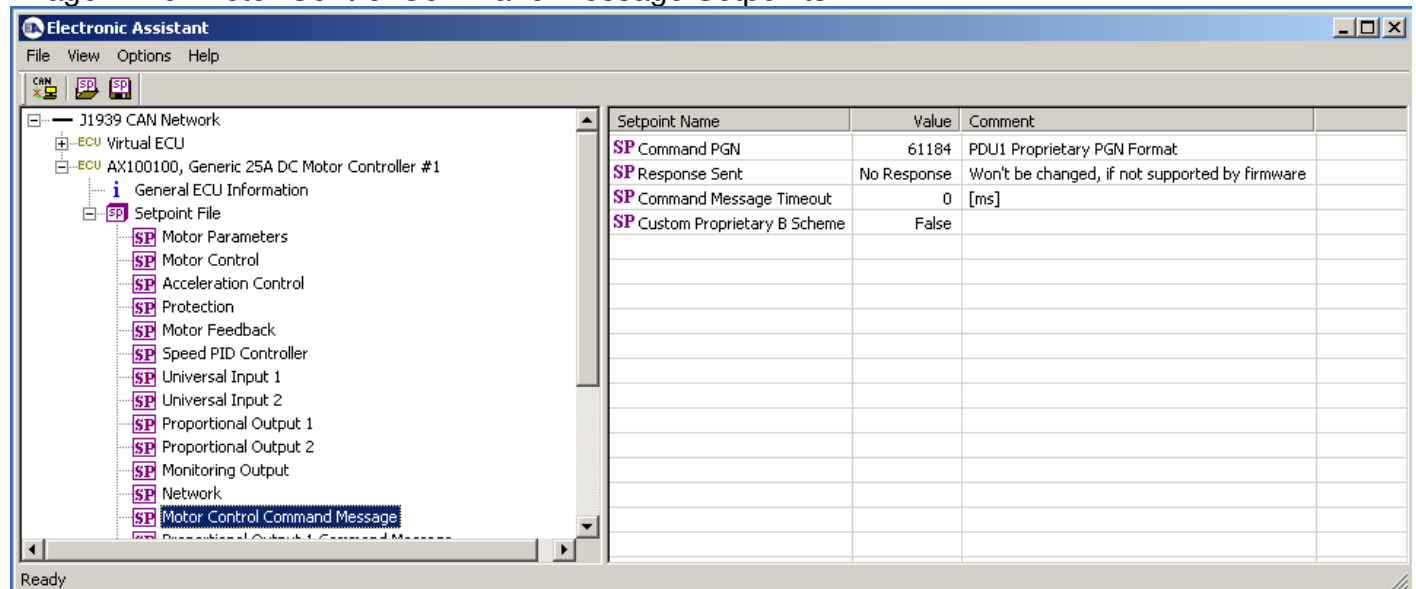
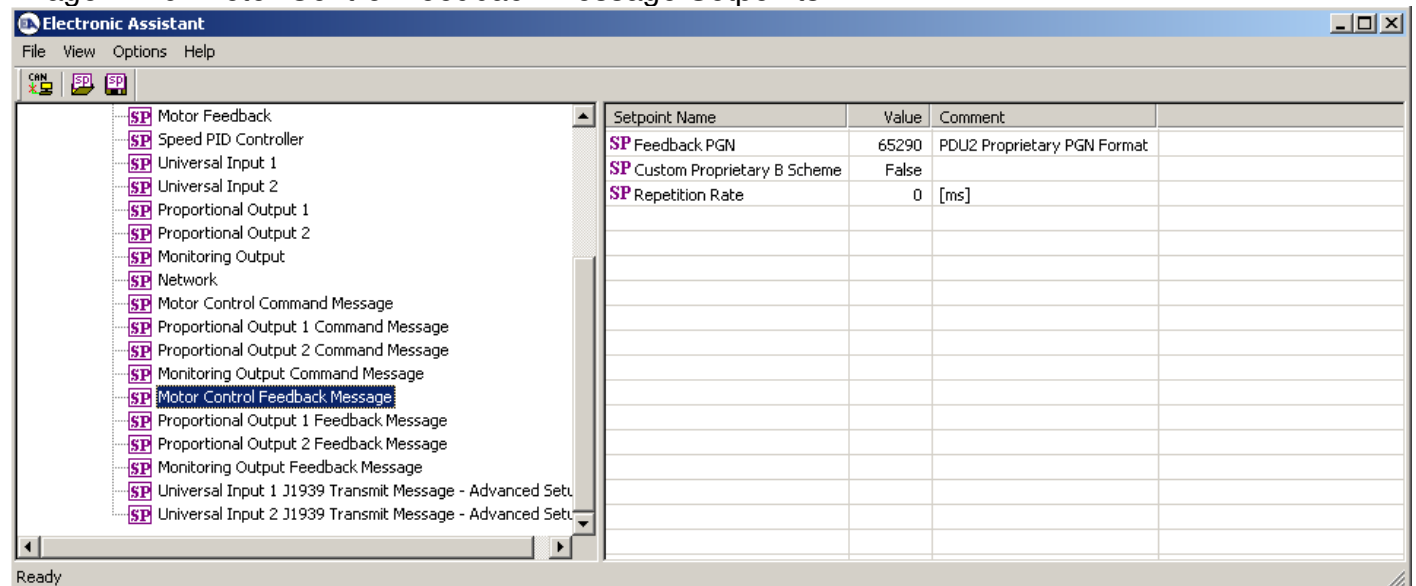


Image 7.2.6: Motor Control Feedback Message Setpoints



## 8. TECHNICAL SPECIFICATIONS

Specifications are indicative and subject to change. Actual performance will vary depending on the application and operating conditions. Users should satisfy themselves that the product is suitable for use in the intended application. All our products carry a limited warranty against defects in material and workmanship. Please refer to our Warranty, Application Approvals/Limitations and Return Materials Process as described on <https://www.axiomatic.com/service/>.

### Input Specifications

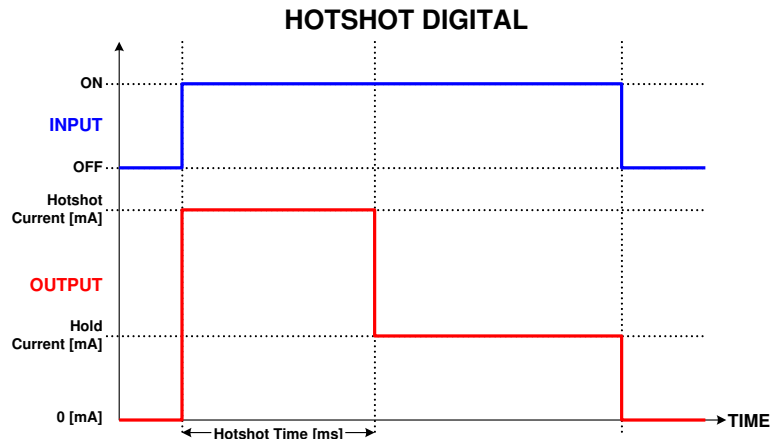
Power Supply Input - Nominal	12 or 24VDC nominal; 9...36 VDC
Surge Protection	Provided
Under-voltage Protection	Built-in
Isolation	All inputs are isolated from the power supply driving the motor and current outputs.
Command Inputs	2 universal inputs (0-5V, 0-10V, 0-20 mA, 4-20 mA or digital) Input properties are user configurable. Refer to the block diagram and Table 1.0. Any input on the controller can be coded into a Proprietary B message that can be sent to the CAN network.
Analog Ground	2 Provided NB. Do not connect Analog GND to BATTERY GND.

Table 1.0 Inputs to AX100100 (Up to 2 user selectable inputs)

Input Type	Description
Universal Analog Inputs	Up to 2 analog inputs are available. 0...5VDC or 0...10VDC The offset is in millivolts and the resolution is mV/bit, when sending a CAN message. Input measurement setpoints are interpreted in volts. 4...20mA or 0...20mA The offset is in microamps and the resolution is $\mu$ A/bit, when sending a CAN message. Input measurement setpoints are interpreted in milliamps.
Digital Inputs	Up to 2 digital inputs are available. These inputs can be used as an enable or direction command for the controller. The input accepted is active high (switch is connected to a +V signal when ON).

### Output Specifications

Output to Motor	H-bridge 50A @ 24VDC nominal for 2 minutes at room temperature 37.5 @ 24VDC nominal for 30 minutes at room temperature 25A @ 24VDC nominal for 1 hour minimum  Overcurrent protection is provided. Short circuit protection is provided. The maximum rated speed and motor rated current are configurable to suit individual motor specifications.
Motor Stop	Shut off with or without ramping
Motor Direction	Motor direction command can be mapped to any input or come from the CAN bus.
Motor Control Mode	Flexible control is provided by user configurable parameters for <ul style="list-style-type: none"><li>open loop speed control;</li><li>closed loop speed control (on request); or</li><li>external feedback control (on request).</li></ul> The control input to drive the motor can be mapped to either of the 2 universal inputs or the controller can respond to messages from a CAN bus.
Thermal Protection	Thermal protection is built-in and configurable.
Current Outputs	2 proportional (0...2A) or hotshot digital (2A) Ramp and dither setpoints are configurable. <b>Hot Shot Coil Saver Outputs</b> (Refer to Figure 2.): The outputs are on/off with a hotshot current which keeps the load ON with a holding current. This is used as an energy saving method of load control. Each output is configurable to send a feedback message to the CAN bus. The feedback is always sent as a word with a resolution of 1 mA/bit, and 0 mA offset.
Signal Output	1 0-5V signal provides feedback of the duty cycle being applied to the motor or of another selected variable. The analog output is isolated from the power supply section of the circuit. This voltage output is configurable whether to send a feedback message to the CAN bus. The feedback is always sent as a word with a resolution of 1 mV/bit, and 0 mV offset.
Reference Voltage	+5V, 10 mA is available to power a sensor or potentiometer.



**Figure 2 – Proportional Output Hotshot Digital Profile**

## General Specifications

Microcontroller	DSP56F8346
Motor Control	<p>Standard embedded software is provided. The following parameters are user configurable.</p> <p><u>Motor Direction:</u> Unidirectional or bi-directional control from an input or the CAN bus. The direction is also configurable.</p> <p><u>Enable:</u> A universal input can be configured to enable the motor when on. A CAN message can also be used as an enable input.</p> <p><u>Control Mode:</u> Open loop speed or closed loop speed control (on request) or external feedback control (on request)</p> <p><u>CAN:</u> CAN bus messages control the motor and/or auxiliary outputs instead of the analog or digital inputs</p>
User Interface	Electronic Assistant for <i>Windows</i> operating systems, P/N: AX070502 or AX070506K It comes with a royalty-free license for use.
Packaging	Encapsulated in an aluminum extrusion with stainless steel end plates
Weight	3.25 lbs. (1.47 kg)
Operating Conditions	Operating: -40 to 85°C (-40 to 185°F)
Protection Rating	IP67
CAN Interface	<p>1 CAN port (SAE J1939)</p> <p>The software was designed to provide flexibility and provides the following.</p> <ul style="list-style-type: none"> <li>• Configurable ECU Instance in the NAME (for multiple ECU's on the network)</li> <li>• Configurable Motor Control Parameters</li> <li>• Configurable Motor PID Parameters</li> <li>• Configurable Input Parameters</li> <li>• Configurable Output Parameters</li> <li>• Configurable PGN and Data Parameters</li> </ul> <p><i>Note: Configurable parameters are also called setpoints.</i></p>

## OUR PRODUCTS

AC/DC Power Supplies  
Actuator Controls/Interfaces  
Automotive Ethernet Interfaces  
Battery Chargers  
CAN Controls, Routers, Repeaters  
CAN/WiFi, CAN/Bluetooth, Routers  
Current/Voltage/PWM Converters  
DC/DC Power Converters  
Engine Temperature Scanners  
Ethernet/CAN Converters,  
Gateways, Switches  
Fan Drive Controllers  
Gateways, CAN/Modbus, RS-232  
Gyroscopes, Inclinometers  
Hydraulic Valve Controllers  
Inclinometers, Triaxial  
I/O Controls  
LVDT Signal Converters  
Machine Controls  
Modbus, RS-422, RS-485 Controls  
Motor Controls, Inverters  
Power Supplies, DC/DC, AC/DC  
PWM Signal Converters/Isolators  
Resolver Signal Conditioners  
Service Tools  
Signal Conditioners, Converters  
Strain Gauge CAN Controls  
Surge Suppressors

## OUR COMPANY

Axiomatic provides electronic machine control components to the off-highway, commercial vehicle, electric vehicle, power generator set, material handling, renewable energy and industrial OEM markets. ***We innovate with engineered and off-the-shelf machine controls that add value for our customers.***

## QUALITY DESIGN AND MANUFACTURING

We have an ISO9001:2015 registered design/manufacturing facility in Canada.

## WARRANTY, APPLICATION APPROVALS/LIMITATIONS

Axiomatic Technologies Corporation reserves the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. Users should satisfy themselves that the product is suitable for use in the intended application. All our products carry a limited warranty against defects in material and workmanship. Please refer to our Warranty, Application Approvals/Limitations and Return Materials Process at <https://www.axiomatic.com/service/>.

## COMPLIANCE

Product compliance details can be found in the product literature and/or on [axiomatic.com](http://axiomatic.com). Any inquiries should be sent to [sales@axiomatic.com](mailto:sales@axiomatic.com).

## SAFE USE

All products should be serviced by Axiomatic. Do not open the product and perform the service yourself.



This product can expose you to chemicals which are known in the State of California, USA to cause cancer and reproductive harm. For more information go to [www.P65Warnings.ca.gov](http://www.P65Warnings.ca.gov).

## SERVICE

All products to be returned to Axiomatic require a Return Materials Authorization Number (RMA#) from [sales@axiomatic.com](mailto:sales@axiomatic.com). Please provide the following information when requesting an RMA number:

- Serial number, part number
- Runtime hours, description of problem
- Wiring set up diagram, application and other comments as needed

## DISPOSAL

Axiomatic products are electronic waste. Please follow your local environmental waste and recycling laws, regulations and policies for safe disposal or recycling of electronic waste.

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