USER MANUAL UMAX10060X
Version 2

5A DC Motor Controller

SAEJ1939®

USER MANUAL

P/N: AX10060X (250kbps)
P/N: AX10060X-01 (500kbps)
P/N: AX10060X-02 (1Mbps)

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VERSION HISTORY

Version	Date	Author	Modifications
1.0.0p	Dec 16, 2010	Galen Li	Pre-release Initial Draft (to Dealers)
1.0.0	May 20, 2011	Galen Li	Initial Draft for Internal Release
1.0.1	June 29, 2011	Galen Li	First Engineering Release
-	July 11, 2011	Amanda Wilkins	Added Technical Specifications
2	December 7, 2016	Gustavo Del Valle	Updated Status Message to include description of last 2 bytes composed of data from Inputs 1 and 2. Added Part Numbers reflecting higher baud rates
-	December 13, 2016	Amanda Wilkins	Added quiescent current, updated dimensional drawing and weight

ACCRONYMS

ACK	Positive Acknowledgement
AIN	Analog Input
CFB	Current Feedback
EA	Axiomatic Electronic Assistant®, KIT p/n AX070502 (A Service Tool for Axiomatic ECUs)
ECU	Electronic Control Unit (from SAE J1939 standard)
FB	Feedback
FIN	Frequency Input
MC	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)
PWM	Pulse Width Modulation
RPM	Revolution per Minute
UIN	Universal Input
%dc	Percent Duty Cycle

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1. GENERAL

1.1. Overview

The Axiomatic 5A DC Motor Controller (MC) AX10060x is a rugged and multi-functional motion controller intended for use in a wide range of mobile applications. It can either operate as a standalone embedded speed or position controller, or be integrated into a CAN J1939 network as a networked motion controller.

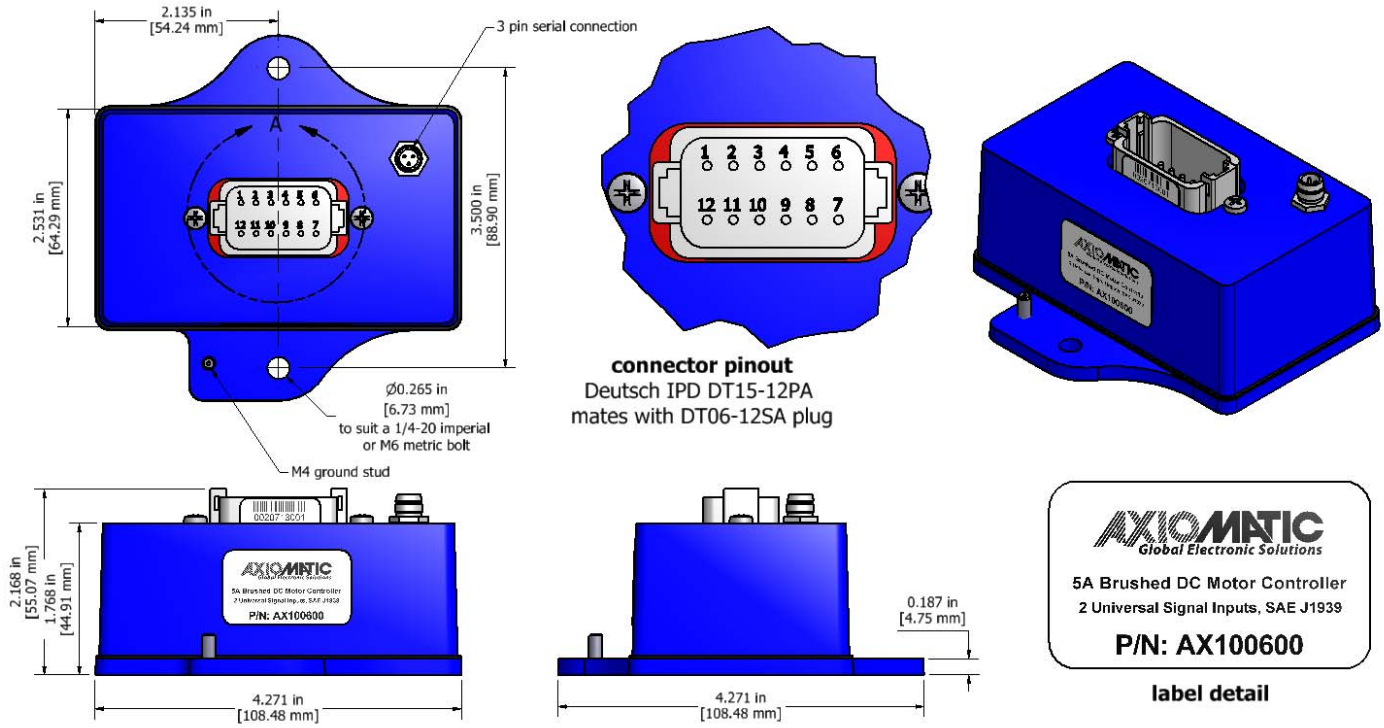
The MC can control a DC motor bi-directionally for up to 5A continuous armature current. In majority of applications, it is to be used as a positional controller to control a DC motor driven actuator. In other applications, it may be used as a variable speed drive for small or compact DC motors.

It has two configurable universal inputs (0-5V, 0-10V, 0-20mA, 4-20mA, Frequency, PWM, or Discrete Digital), and 1 +5V reference voltage output additionally. Both CAN J1939 networking and RS232 serial communications are supported. The CAN interface may serve both control and monitoring purposes. The RS232 link is provided for diagnostics and/or field update of controller firmware.

Control commands are obtained from either two hardwired universal inputs, or a J1939 network, or a combination of one or two hardwired inputs with a network. When MC is used as a positional controller, a position feedback is required and the position feedback must be tied to one of the two physical inputs.

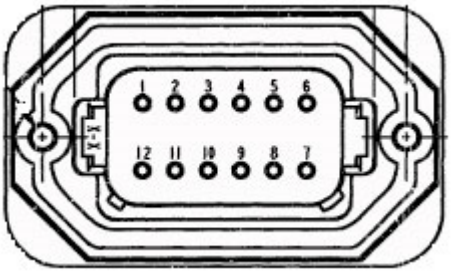
The controller is user configurable through a proprietary Windows based Axiomatic Electronic Assistant (EA). A number of operational parameters, such as motor control modes as well as acceleration and deceleration rates, are user controllable through setting adequate setpoint values.

1.2. Dimensions and Pinout



Main Connector: 12 pin Deutsch IPD connector P/N: DT15-12PA
Mating Plug Kit: P/N **AX070105** (DT06-12SA, W12S, 12 0462-201-16141, 3 plugs)

Pin #	Description
1	Output to Motor -
2	+5V Reference (10 mA)
3	BOOT
4	CAN_Shield
5	CAN_Low
6	CAN_High
7	Universal Input 1+
8	Universal Input 2+
9	Analog Ground
10	Power -
11	Power +
12	Output to Motor+



RS-232 port: 3 pin M8 P/N: NAN-T-3MR-M8
1 – TXD, 3 – RXD, 4 – GND
Mating Harness: P/N **AX070101** (NAN-T-3FP-2M and a DB-9 connector)

1.3. Mounting and Wiring Instructions

MOUNTING
The motor controller should be mounted as close to the battery and/or the motor (actuator) 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 the designated Ground Stud (M4) or one of the mounting bolts holding the controller onto the machine. Ensure that there is no paint around the “grounding point” so that the point really 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 where there is no shield connection on the other end.

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 14 gauge wires should be used for connection to the battery or motor.
At least 20 gauge wires must be used for other inputs and outputs.
Refer to the respective Deutsch IPD datasheets for usable insulation diameter ranges and other instructions.

CAN WIRING
Refer to the CAN 2.0B specification for more information on CAN.

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 two end 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
TDAX10060x	Technical Datasheet, 5A DC Motor Controller, Axiomatic Technologies 2011
UMAX07050X	User Manual, Electronic Assistant® and USB-CAN Converter, Axiomatic Technologies, 2008

2. INPUTS

2.1. Introduction

There are two universal inputs (0-5V, 0-10V, 0-20mA, 4-20mA, Frequency, PWM, or Discrete Digital) on the MC. 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 controller, to command the motor position, speed, and/or direction of rotation where applicable. In the case of positional control, one of these two universal inputs must be connected to a position feedback device and must not be a discrete digital input.

With AX100600 (the standard version), when any of these universal inputs is configured as Frequency, PWM, or Discrete Digital input, TTL logic levels are assumed. In no case should a higher than 12V digital signal be allowed at any input!

Instead, AX100601 allows for higher-voltage Frequency, PWM, or Discrete Digital signal on one of the universal inputs, while AX100602 allows for higher-voltage Frequency, PWM, or Discrete Digital on both universal inputs. In the high-voltage-digital-input case, the digital signal levels may go up to 24V nominal (30V maximum). When an input is high-voltage-digital-capable, it will no longer accommodate 0-20mA, 4-20mA, or Active-Low Digital input types.

Since the motor position, speed, and direction of rotation are not, or not fully, independent from each other, there is no such a case that you will be asked to give three separate commands to control all these three variables. Nevertheless, there exist cases where three inputs may be needed in total if a user wants to use the “enable” control command. When this happens, one or more commands will have to be obtained from a J1939 network since there are only two universal inputs available.

See “Motor Control” chapter for more information on what and how many inputs are needed for various operations.

2.2. 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 hard-trimmed to 5V. There are two other setpoints, namely minimum input and maximum input, to denote the lower- and upper-end input voltages acceptable to a particular application. Signals beyond such bounded range will be further soft-trimmed to the minimum or maximum input voltage in that given application. Input measurement and minimum and maximum input 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 hard-trimmed to 10V. Same as above 0-5V input

range, there are also two other input setpoints. Input measurement and minimum and maximum input 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 hard-trimmed to 20mA. There are two other setpoints, namely minimum input and maximum input, to denote the lower- and upper-end input currents acceptable to a particular application. Signals beyond such bounded range will be further soft-trimmed to the minimum or maximum input current in that given application. Input measurement and minimum and maximum input setpoints will be interpreted in milliamps [mA]. Note that AX100601 does not support this input type on Universal Input #2 and AX100602 does not support this input type on both Universal Input #1 and Universal Input #2.

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 hard-trimmed to 20mA. Same as the above 0-20mA input range, there are also two other input setpoints. Input measurement and minimum and maximum input setpoints will be interpreted in milliamps [mA]. Note that AX100601 does not support this input type on Universal Input #2 and AX100602 does not support this input type on both Universal Input #1 and Universal Input #2.

Frequency: The input is configured to accept a frequency input in the range of 100 Hz to 10 kHz. There are two other setpoints, namely minimum input and maximum input, to denote the lower- and upper-end input frequencies acceptable to a particular application. Signals beyond such bounded range will be soft-trimmed to the minimum or maximum input frequency in that given application. Input measurement and minimum and maximum input setpoints will be interpreted in hertz [Hz]. Note that AX100601 supports high voltage (up to 24V nominal) frequency input on Universal Input #2 and AX100602 supports high voltage (up to 24V nominal) frequency input on both Universal Input #1 and Universal Input #2. Also note that frequencies beyond the range of 100 Hz to 10 kHz should not be used or measurement errors may be introduced, except for zero hertz which is allowed.

PWM: The input is configured to accept a PWM input in the range of 0% to 100%. There are two other setpoints, namely minimum input and maximum input, to denote the lower- and upper-end input duty cycles acceptable to a particular application. Signals beyond such bounded range will be soft-trimmed to the minimum or maximum input duty cycle in that given application. Input measurement and minimum and maximum input setpoints will be interpreted in percent duty cycle [%]. Note that AX100601 supports high voltage (up to 24V nominal) PWM input on Universal Input #2 and AX100602 supports high voltage (up to 24V nominal) PWM input on both Universal Input #1 and Universal Input #2. Also note that the frequency of the PWM input should fall within the range of 100 Hz to 10 kHz or measurement errors may be introduced, except for zero hertz which is allowed.

Digital – Active High: The input is configured to reflect the state of an active high digital input (switch is connected to a +5V voltage when ON). Input measurement will be interpreted as a logic state (OFF or ON). Note that AX100601 supports high voltage (up to 24V nominal) discrete digital input on Universal Input #2 and AX100602 supports high voltage (up to 24V nominal) discrete digital input on both Universal Input #1 and Universal Input #2.

Digital – Active Low: The input is configured to reflect the state of an active low digital input (switch is connected to Ground when ON). Input measurement will be interpreted as a logic state (OFF or ON). Note that AX100601 does NOT support active low discrete digital input on Universal Input #2 and AX100602 does NOT support active low discrete digital input on both Universal Input #1 and Universal Input #2.

3. MOTOR CONTROL

3.1. Introduction

The motor controller AX10060x can be employed in either position or speed control applications, although in majority of practical situations the MC may be more often used as a positional controller to drive an actuator for various positioning purposes.

A user may run the MC in three different operational modes, namely “Supervisory Positioning”, “Closed Loop Position Servo”, or “Speed Control”. Apparently, the first two operation modes are all about positional control. The third mode is in fact to enable the MC to be used as a compact variable speed drive. Only open loop speed control is supported while in this mode.

For either positional control mode, a position feedback is required and the position feedback must be connected to one of the two universal inputs. Instead, in the speed control mode, one may want to specify in which direction the motor is expected to turn.

Therefore, there are possibly logic commands for position, speed, direction of rotation, as well as a position feedback where applicable, which may need to be connected to the universal inputs and/or coded in a J1939 command message. In addition, an “Enable” (MC On/Off) control is provided to give added safety in safety-critical applications. This command may as well come either from one of the universal inputs or from a J1939 network.

There are two independent ramp rates available for ramping up or down the position or speed command, depending on the operational mode selected. Adequate ramp rates are often necessary to limit the startup current and/or smooth the mechanical movement of the load driven by the motor.

There are a hardware short-circuit protection and a software overcurrent protection for the motor controller. It is recommended that best efforts be always given to avoid the MC from running into any of these protection modes. The motor may behave abnormally if the MC is working in the short-circuit protection mode. And the motor controller will be automatically shut off if the software overcurrent protection is taking effect. Setting proper ramp rates is one of the ways to suppress surge currents and to avoid activation of these protection modes.

3.2. Supervisory Positioning

In supervisory positioning operation mode, the MC will drive the motor so as to position the load to a commanded location. A position feedback, often in the form of a 0-5V voltage, will tell what position the output shaft or the load is currently at. The MC keeps watching the position command as well as the position feedback, and drives the motor towards a match, until the positioning error falls within a prescribed tolerance.

Therefore, two inputs will be mandatory – a position command and a position feedback. The position command can come from any of the universal inputs. It can also be specified to come from a J1939 position command obtained off a CAN network. Instead, the position feedback must be connected to one of the two universal inputs, and this input, intuitively, must not be configured as a discrete digital (ON/OFF) input.

Depending on whether there is a critical safety concern, a MC “Enable” control may be used. This command can be either obtained from a physical input configured as “Discrete Digital” or decoded from a J1939 ON/OFF and Direction command. Where no “Enable” control is employed, the MC will be always ON. Note that the MC being “always ON” does not necessarily mean always moving. If the motor is already positioned at the commanded position, the MC may be actually at halt.

There are two configurable parameters: Positioning Tolerance and Positioning Velocity Gain, to control the positioning performance in this mode. A user will need to tune these two parameters for satisfactory performance in their particular application.

It is noted that a direction match-up procedure is often needed during the initial setup. This is to make sure that both position command and position feedback change in the same direction. In other words, the position feedback should increase as the position command increases.

3.3. Closed Loop Position Servo

The closed-loop position servo operation mode is a more advanced position control mode, where a PID position regulator is employed to achieve possible servo control performance. Like supervisory positioning, two mandatory inputs – a position command and a position feedback, and one optional input – MC Enable, are required. Similarly, these input signals can be mapped to any available universal inputs or obtained from a J1939 command message, except that the position feedback must be tied to one of the two universal inputs as always.

The PID position regulator must be properly tuned for each application. Inadequate PID controller parameters may cause the controlled system to persistently oscillate. They may also unexpectedly trigger the hardware short-circuit protection built in the MC, which will in turn prevent the MC from running normally. In the extreme case, the MC may be put in an exposure to risk of damage resulting from the stress of recurrent surge currents brought up by the poor controller parameters.

Therefore, extra care must be exercised in tuning the PID controller. It is recommended that the user familiarize him or her with the fundamental principles of their control system before using this operation mode. It is also recommended that a P controller with a very small proportional gain be virtually used as a start point where this operational mode is required.

One of the other notable differences between the supervisory positioning and closed-loop position servo operation modes is that the MC will never be at halt in practice when it is operated in the closed-loop position servo control mode, unless it is turned off by the “Enable” command used.

3.4. Speed Control

The speed control operation mode is to enable the MC to be used as a variable speed drive to control the speed of a compact or small-capacity DC motor. In this mode, a speed command input and often a direction command input are necessary. Although the MC “Enable” command may often be really optional in either positional control mode, it is highly recommended that the “Enable” command be always employed for safety in the speed control mode.

The speed command, direction command, and enable command, can each be mapped to one of the two universal inputs or obtained from a J1939 command message. When the direction command or enable command comes from one of the two universal inputs, naturally that universal input should be configured as a discrete digital input and a digital signal should be really applied to that input.

If a universal input, configured as “Discrete Digital”, is used as the direction command, input “OFF” will drive the motor forward while “ON” will drive the motor reverse.

Where no direction command is desired (for example, in a unidirectional application), the user has an option of not using direction command (i.e., configuring this command input as “NONE”) and the motor will then always turn forward. Clearly, a similar direction match-up procedure mentioned before may be needed, to ensure that the “forward” direction determined by the MC is the right direction required by the application.

3.5. Configuration Rationality and Consistency

As might have already been noticed, a user cannot specify any single universal input for more than one control purpose. For example, it is not logical to use a single universal input as both direction command and enable command.

It is noted, however, one can use all J1939 commands, except that the position feedback, if applicable, must be always connected to one of the universal inputs.

Since some restrictions are quite intuitive, they will not be fully listed here. The configuration tool (EA) will automatically impose these restrictions in most cases to avoid a user’s impractical attempt.

What is worthwhile to stress is the configuration rationality and consistency, which must be followed.

In each positional control mode, for example, there must be neither speed command nor direction command specified. The positional controller will automatically determine the speed and direction needed. However, both a position command and a position feedback must be specified.

In speed control mode, on the other hand, there must be no position command or position feedback specified. Instead, a speed command must be defined. And there may be an optional direction command needed.

If a logical command, such as the position or speed command, is not supposed to be used in a given operation mode, it should be set to “NONE” at configuration. In most cases, EA will actually configure all unwanted logical commands as “NONE” automatically.

In the event that a user is attempting to change configuration from one operation mode to another, he or she may need to first free up the universal input(s) from the prior configuration setup before he or she may reassign this input(s) for a different purpose. User may achieve this by using “NONE” or “J1939 signal” as a temporary assignment to any logic command that was already using the required universal input (the input to be reassigned in the new operation mode).

It is not mandatory but recommended that the motor controller be restarted each time it is changed from one operation mode to another.

Also, it is always a good practice to disconnect the MC from the driven motor before reconfiguring the MC, where possible, except that one is only performing a tuning task. EA will not allow for changes to any critical setpoints such as motor parameters or input types, if a motor is already being driven.

4. REFERENCE OUTPUT

4.1. Reference Output

The MC provides a +5V reference voltage output for powering a position feedback sensor. Although it may also be used to power a command device like a potentiometer, the total current draw from this reference output must not exceed 10mA.

It is prohibited that this +5V reference output be used to power any digital input or digital device.

5. COMMONLY USED CONFIGURABLE SETPOINTS

5.1. Motor and Motor Control Setpoints

Below is a collection of all motor parameters and control setpoints.

Name	Range	Default	Notes
Rated Motor RPM	0 to 4000 RPM	1500 RPM	This value must be set as per the specifications of the motor. This value is very important. If not set properly, the motor may not behave the way as desired, or may even behave abnormally.
Rated Motor Current	0 to 5 A	5 A	This value should be set as per the specifications of the motor.
MC Operation Mode	0 Speed Control (no feedback) 1 Supervisory Positioning 2 Closed Loop Position Servo	1: Supervisory Positioning	See 3.1 – 3.4 for more information about various operational modes
Enable Command	0 NONE 1 UIN1 2 UIN2 3 J1939 Enable	0: NONE	See 3.1 – 3.4 for details
Ramp Up	0 to 60000 ms	500 ms	Time it takes to ramp from zero to the maximum command. Appropriate ramp time settings are necessary to limit the startup current.
Ramp Down	0 to 60000 ms	500 ms	Time it takes to ramp from the maximum command to zero. See above.
Position Command	0 NONE 1 UIN1 2 UIN2 3 J1939 Position	1: UIN1	See 3.2 and 3.3 for details
Position Feedback	0 NONE 1 UIN1 2 UIN2	2: UIN 2	See 3.2 and 3.3 for details
Positioning Tolerance	0 to 100 %	5%	Percentage of full trip in the form of percentage of full scale of position feedback. Only applicable in Supervisory Positioning control mode.
Positioning Velocity Gain	0 to 10000	200	Positioning error to speed gain. Only applicable in Supervisory Positioning control mode.
Proportional Gain	> 0	200	This setting is used for closed loop position control only. Ignored otherwise.
Integral Gain	>= 0	0	This setting is used for closed loop position control only. Ignored otherwise.

Derivative Gain	>= 0	0	This setting is used for closed loop position control only. Ignored otherwise.
Speed Command	0 NONE 1 UIN1 2 UIN2 3 J1939 Speed	0: NONE	See 3.4 for details
Direction Command	0 NONE 1 UIN1 2 UIN2 3 J1939 Direction	0: NONE	See 3.4 for details

5.2. Input Setpoints

There are three setpoints for each universal input on the MC.

Name	Range	Default		Notes
Input Type (IT)	0 0 to 5V 1 0 to 10V 2 0 to 20mA 3 4 to 20mA 4 Frequency 5 PWM Duty Cycle 6 Digital (Active High) 7 Digital (Active Low)	0: 0 to 5V		See 2.2 for more information on each input type. AX100600 supports all these input types on both universal input channels. TTL logic levels are assumed when any of these inputs is configured as Frequency, PWM, or Digital input. AX100601 does not support mA current as well as active-low digital inputs on Universal Input #2, but supports high voltage (up to 24V nominal) Frequency, PWM, or Active-High Digital input on it instead. AX100602 does not support mA current as well as active-low digital inputs on both universal input channels, but supports high voltage (up to 24V nominal) Frequency, PWM, or Active-High Digital input on them instead.
Minimum Input		IT=0 IT=1 IT=2 IT=3 IT=4 IT=5	0.5V 0.5V 0mA 4mA 1000 Hz 20.5%	Minimum effective input. Any input value below this point will be trimmed to the minimum input.
Maximum Input		IT=0 IT=1 IT=2 IT=3 IT=4 IT=5	4.5V 9.5V 20mA 20mA 10000 Hz 79.5%	Maximum effective input. Any input value above this point will be trimmed to the maximum input.

5.3. Protection Setpoints

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

Name	Range	Default	Notes
Motor Over Current	0 to 10A	7A	When an over-current is detected, the MC will shut off automatically. Set this value appropriately to protect the overload but leave enough margins to allow for inrush current resulting from motor startup.
Over Temperature Threshold	0 to 85 ºC	65ºC	When the unit temperature is above this setpoint value, the MC will be shutoff automatically.
Over Voltage Threshold	0 to 60V	32V	When the supply voltage is above this setpoint value, the MC will be shutoff automatically.
Under Voltage Threshold	0 to 32V	9V	When the supply voltage is below this setpoint value, the MC will be shutoff automatically.

6. J1939 NETWORKED CONTROL

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 details.

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 is supported, since motor controllers are not defined in the J1939 Application Layer Protocol.

6.2. J1939 Network based Control

The MC may be controlled partly or completely from a J1939 network. Control commands for motor position, speed, direction, and enable (ON/OFF) are all packed in one single PDU1 proprietary (Proprietary A) message. Furthermore, the direction and on/off commands are combined as two coded binary bits of a data byte and are collectively called J1939 ON/OFF and Direction command.

For flexibility, some parameters of the J1939 position, J1939 speed, and J1939 ON/OFF and Direction commands, such as data size, data position, resolution or offset, are user configurable.

It is recommended that only experienced users be allowed to change any of these configurable parameters.

Note that none of these commands will actually take effect unless they are already selected in appropriate configuration transactions.

J1939 ON/OFF and Direction Command
One-byte data. The byte location in the 8-byte data area of the integral Proprietary A command message is user configurable.

Only Bits 1-0 of the data byte are actually used and they are coded as

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

J1939 Position Command
The position command data is fully configurable, meaning that the data size, data start location in the 8-byte data area of the integral command message, resolution, and offset are all configurable.

The J1939 position command is always mapped into the position feedback domain. Therefore, it is not really meaningful to attempt to code a J1939 Position Command before the nature of the position feedback (0-5V or 0-10V, for example) is determined.

J1939 Speed Command
Speed in RPM. Two-byte data with 0.5 rpm/bit as resolution and 0 as offset. For example, 0x0400 means a speed of 512 rpm commanded.

The start location of the speed command data in the 8-byte data area of the integral command message is configurable.

6.3. J1939 Command Message Setpoints

Name	Range	Default	Notes
ON/OFF and Direction Command Byte Location	0 to 7	0	This setpoint determines the location of the ON/OFF and Direction command in the 8-byte data area of the Motor Control Command message
Position Command Start Location	0 to 7	4	This setpoint determines the startup location of the position command in the 8-byte data area of the Motor Control Command message
Position Command Data Size	1, 2, 4 bytes	2	This setpoint determines the data size of the position command
Position Command Resolution	>0	0.01	This setpoint determines the resolution of the position command
Position Command Offset		0	This setpoint determines the offset of the position command

Speed Command Start Location	0 to 6	2	This setpoint determines the startup location of the speed command in the 8-byte data area of the Motor Control Command message

Example
Assume that the MC is configured to accept both position command and enable command from a J1939 network and that a 0-5V position feedback is connected to one of the universal inputs. Also assume that the MC uses the default Node address, 0xD0, and that all J1939 command message setpoints are at their defaults.

The following Motor Control Command message will then drive the load to the "middle" position (where the position feedback device would output a 2.5V voltage):

08EFD005 FD FF FF FF FA 00 FF FF

The direction information and speed command in the above message are ignored.

6.4. J1939 Report Messages and Message Setpoints

The MC status and position feedback can be coded into J1939 report messages and sent to the network, using the following setpoints.

Name	Range	Default		Notes
Report PGN	65280 to 65535	Position Report MC Status Report	65280 65281	Report messages are always sent using a PDU2 Proprietary (B) PGN
Repetition Rate	0 to 60000 ms	0 ms		This setpoint determines how often the message is sent to the bus. When set to zero, no report message will be sent. ***It is the user's responsibility to select a repetition rate that will not disrupt bus activities.***
Position Report Start Location	0 to 4	4		This setpoint determines the startup location of the position report data in the 8-byte data area of the Position Report message
Position Report Data Size	1, 2, 4 bytes	2		This setpoint determines the size of the position report data
Position Report Resolution	>0	0.01		This setpoint determines the resolution of the position report data
Position Report Offset		0		This setpoint determines the offset of the position report data

MC Status Report
This predetermined message packs motor on/off and direction status, commanded motor speed, and measured motor controller temperature into one data frame.

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:
Commanded 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.

Byte 3:
Reserved.

Bytes 4-5:
Measured MC temperature, with 0.03125 C/bit as resolution and -273C of offset.

Byte 6 & Byte 7:
Universal Input Measured 1 & 2 are transmitted in the range of 0-200 representing the Universal Input's full range within 1byte data, respectively. The resolution and offset are based on the Universal Input's *Input Maximum* and *Input Minimum* ranges as follows:

Resolution = ((0.5 *(*Input Maximum-Input Minimum)) [10mV/bit, in case Voltage type is selected]*
Offset = *Input Minimum*

Position Report
This is a fully configurable report message as described in the above setpoint table.

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	29, Axiomatic AX10060x
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 208 (0xD0). 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 MC will continue to select next higher address until it finds one that it can claim. See J1939/81 for more details about address claiming.

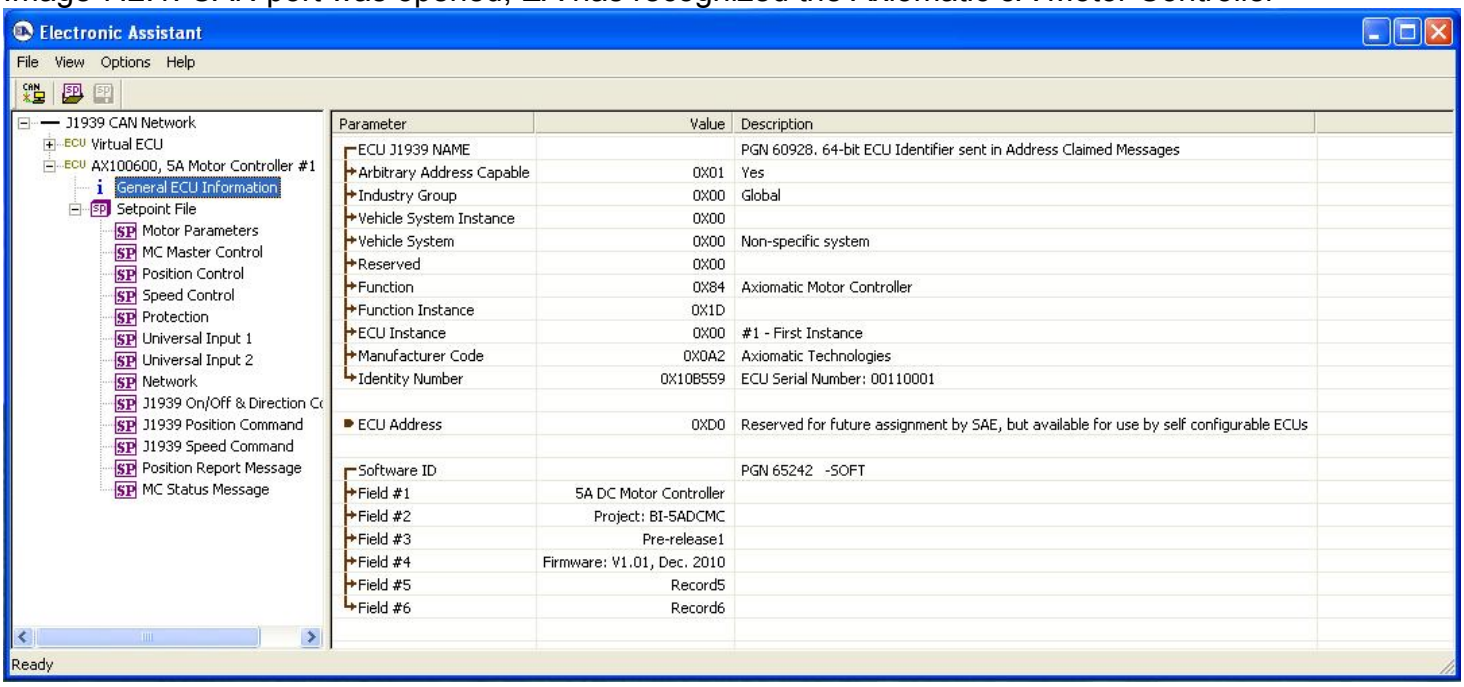
7. USING MC WITH AXIOMATIC ELECTRONIC ASSISTANT®

7.1. Installing the Electronic Assistant® (EA)

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

7.2. Selected Setup Screen Captures

Image 7.2.1: CAN port was opened; EA has recognized the Axiomatic 5A Motor Controller



Note that the Software ID displayed in the above image may not exactly match the Software ID of the user's particular unit, since this UM covers multiple firmware versions.

Image 7.2.2: MC Network Setup

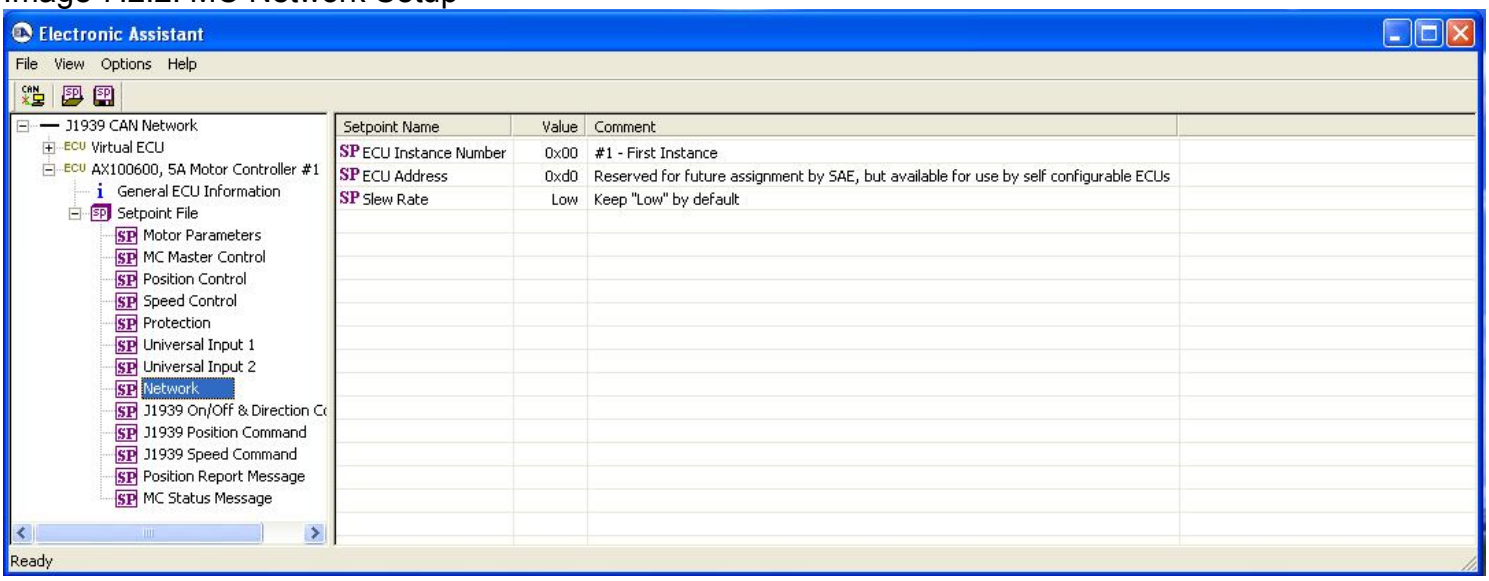
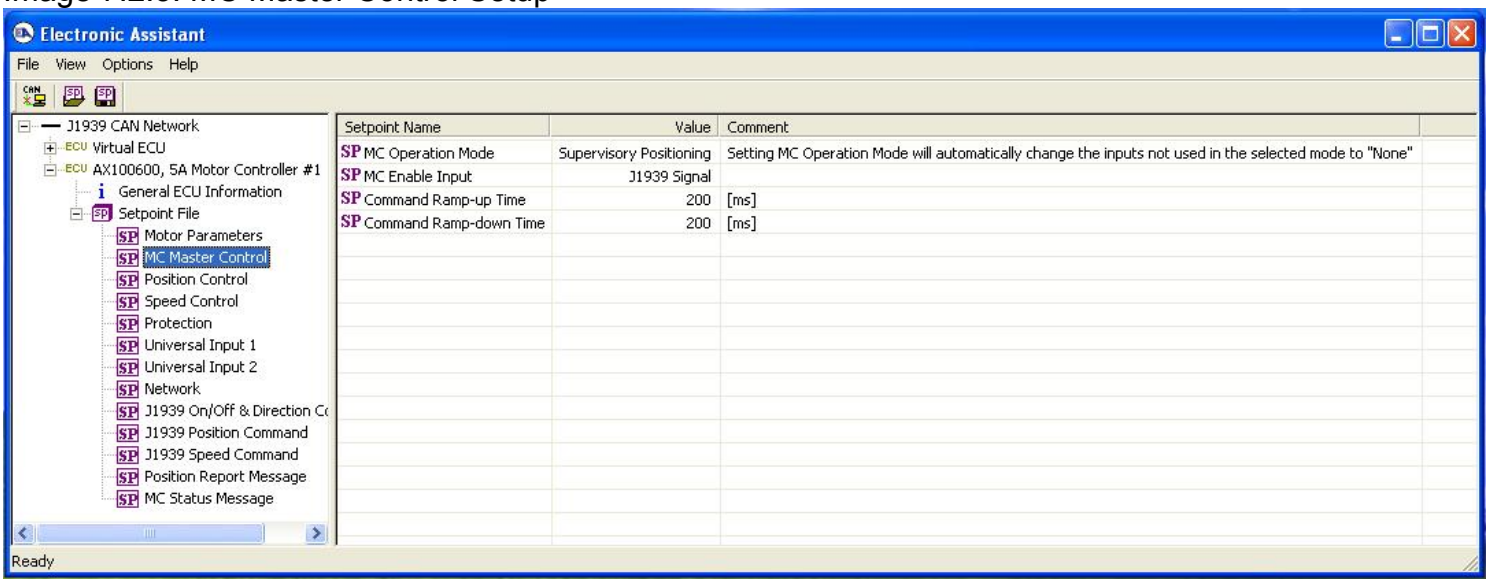
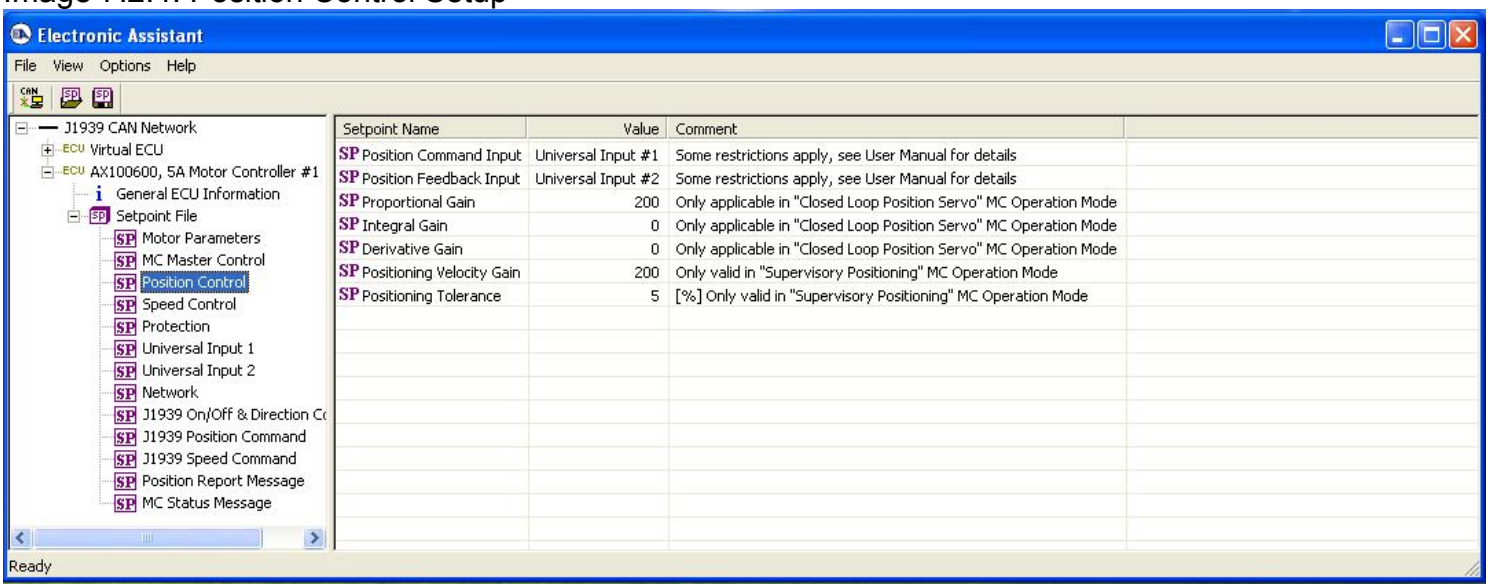


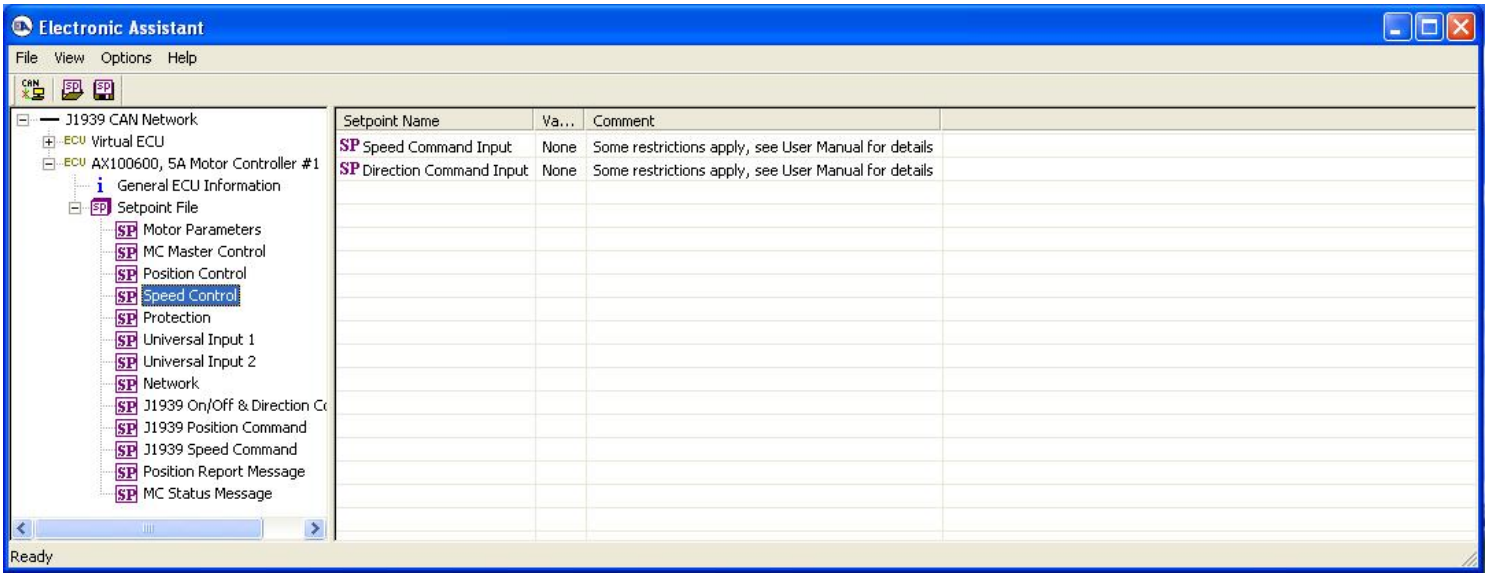
Image 7.2.3: MC Master Control Setup



This example shows that the MC is set to “Supervisory Positioning” operation mode and accepting ON/OFF control from a J1939 network.

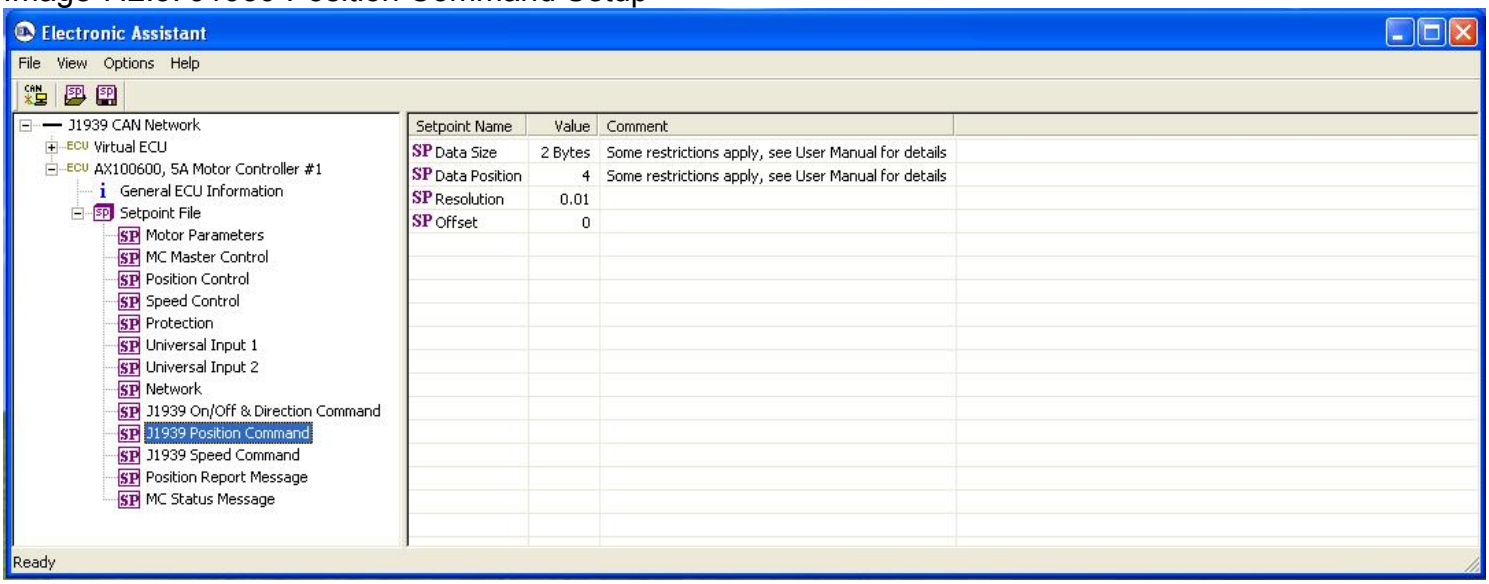
Image 7.2.4: Position Control Setup





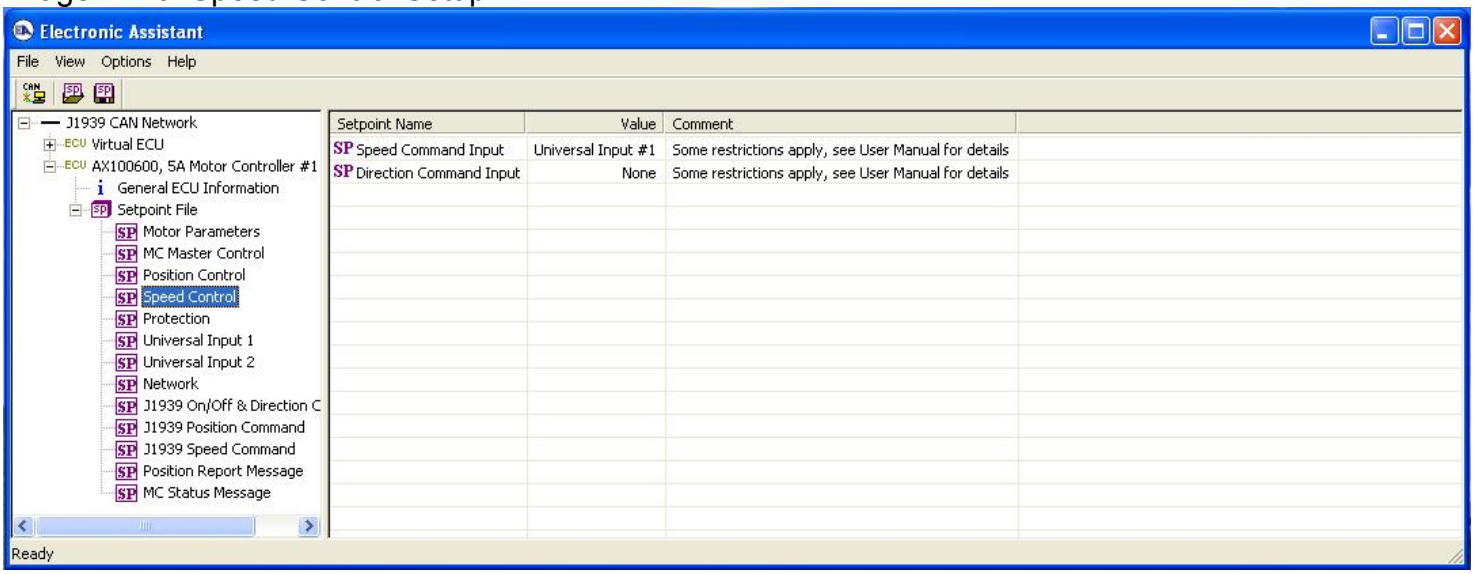
When the MC is configured for positional control, both speed command and direction command must be set to “NONE”.

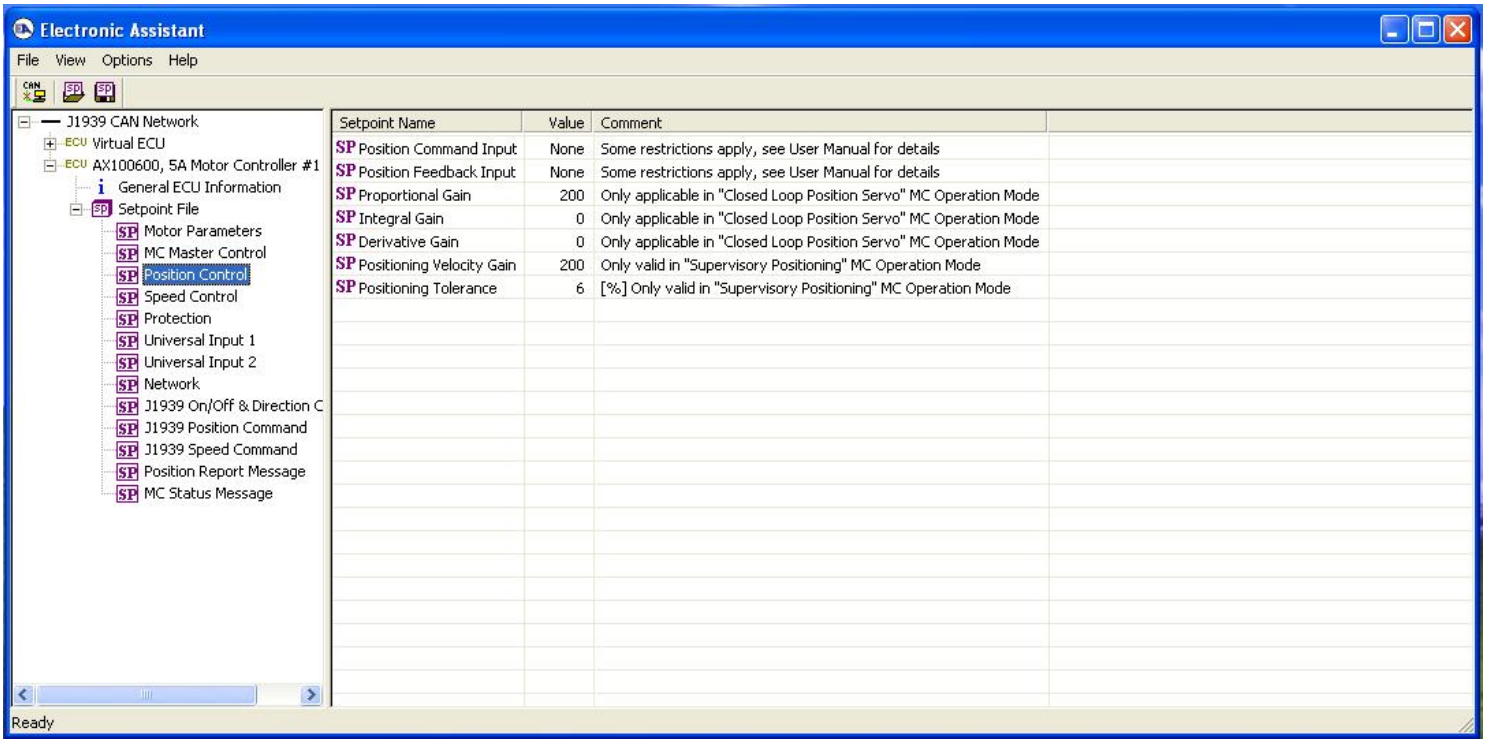
Image 7.2.5: J1939 Position Command Setup



This is needed only when the J1939 Position Command is selected in the Position Control Setup step.

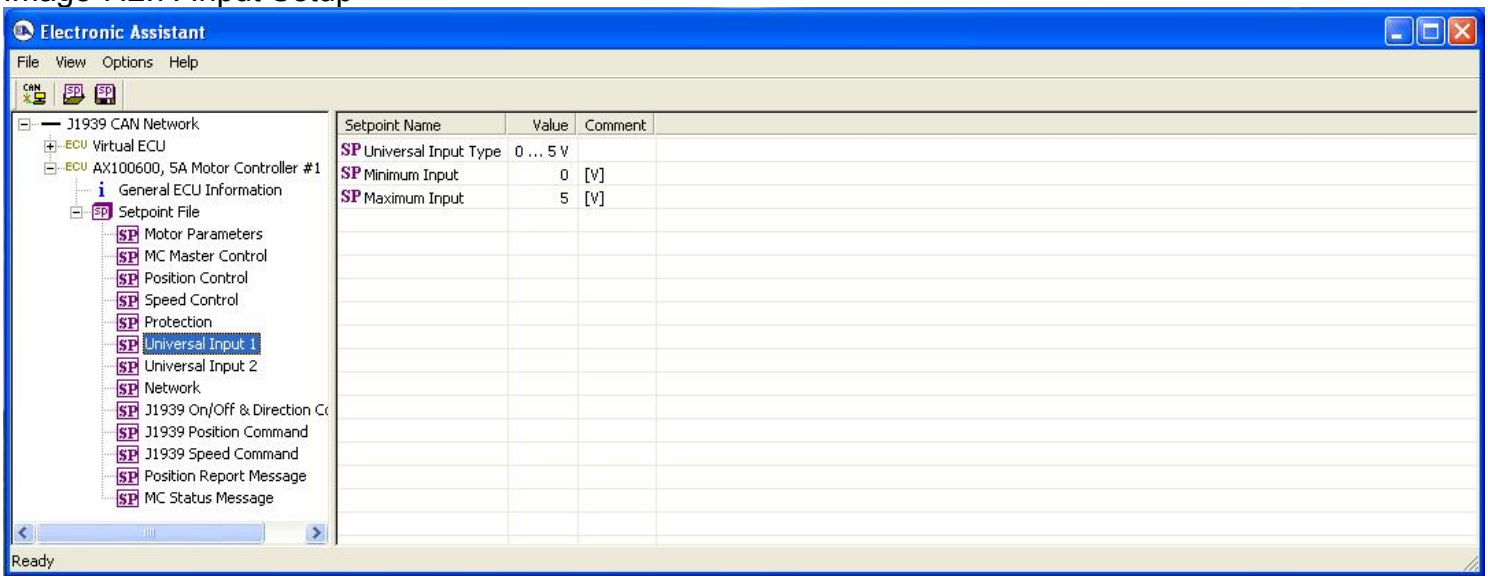
Image 7.2.6: Speed Control Setup





When the MC is configured for speed control, both position command and position feedback must be set to “NONE”. And of course, the “Speed Control” mode must be selected in the MC Master Control Setup. Note that the direction command is optional and it is not used in the example shown above.

Image 7.2.7: Input Setup



8. SERIAL DIAGNOSTICS

8.1. Serial Diagnostics

The MC is capable of interfacing with a serial (RS232) port of a master PC or laptop for diagnostic purposes.

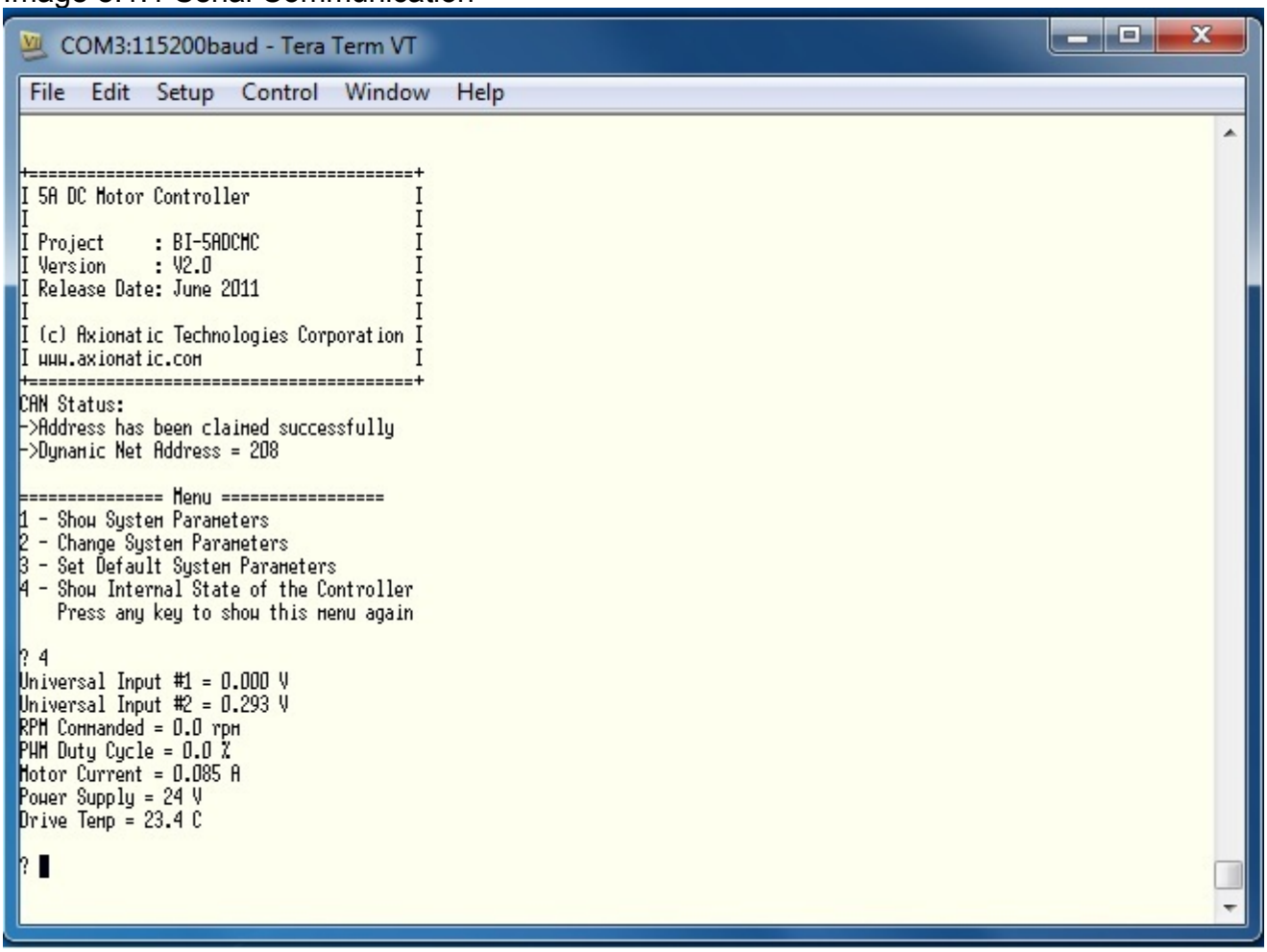
A serial terminal program, such as Tera Term, will need to run on the master to communicate with MC. The following serial setup parameters must be used: Baud rate 115200, 8N1, and no flow control.

Whenever the MC is powered up, a main screen with a short command menu will be popped up. A user can invoke this main screen by typing virtually almost any key at any time.

Follow the instructions on the main screen to get diagnostic information from the MC.

Some controller parameters may be changed through serial commands as well, but this should be prohibited in normal case unless otherwise instructed by the manufacturer.

Image 8.1.1 Serial Communication



Note that the MC's serial link also provides a means for field update of the controller firmware. Follow separate instructions on firmware field update when applicable.

9. TECHNICAL SPECIFICATIONS

Inputs

Power Supply Input	12V or 24VDC nominal (9…60 VDC power supply range)
Protection	Reverse polarity protection Overvoltage protection up to 60V Overvoltage (undervoltage) shutdown
Inputs	2 Inputs are provided to command the motor position, direction, speed and/or enable. One of the inputs is used for position feedback, where applicable. *Model AX100600:* 2 Universal Signal Inputs *Model AX100601:* 1 Universal Signal Input, 1 High Voltage Digital Input *Model AX100602:* 2 High Voltage Digital Inputs Refer to Table 1.0. The input is user selectable.
Analog Ground	1 provided
CAN port	CAN messages can command the motor and/or report motor status. Refer to the User Manual for details.

Table 1.0 – **Inputs – User Selectable Options**

Analog Input Functions	Voltage Input or Current Input
Voltage Input	0-5V (Impedance 200 KOhm) 0-10V (Impedance 150 KOhm)
Current Input	*Model AX100600:* 0-20 mA (Impedance 130 Ohm) 4-20 mA (Impedance 130 Ohm) *Models AX100601:* Current input is supported on Input 1 only. *Model AX100602:* Current input is NOT supported on either input.
Digital Input Functions	Discrete Input, PWM Input, Frequency Input
Digital Input Level	*Model AX100600:* 5V TTL on Input 1 and 2 *Model AX100601:* 5V TTL on Input 1 Up to 24V nominal on Input 2 *Model AX100602:* Up to 24V nominal on Input 1 and 2
PWM Input	0 to 100% 100 Hz to 10 kHz
Frequency Input	100 Hz to 10 kHz
Digital Input	*Model AX100600:* Active High or Active Low with 10 kOhm pull-up or pull-down on Input 1 and 2 *Model AX100601:* Active High or Active Low with 10 kOhm pull-up or pull-down on Input 1 Active High (only) with 10 kOhm pull-up or pull-down on Input 2 *Model AX100602:* Active High (only) with 10 kOhm pull-up or pull-down on Input 1 and 2
Input Accuracy	$\leq$ 1%
Input Resolution	12-bit

Outputs

Output	H-bridge 5A @ 24VDC nominal continuous at room temperature 7.5A @ 24VDC for 5 minutes at room temperature Overcurrent protection is provided. Short circuit protection is provided. The maximum rated speed and motor rated current are configurable to suit individual motor specifications.
Voltage Reference	+5V, 10 mA Short circuit protected (current limited to 50 mA)
Protection for Output Terminals	Fully protected against short circuit to ground and short circuit to power supply rail. Unit will fail safe in the case of a short circuit condition, self-recovering when the short is removed.

General Specifications

Microprocessor	32-bit, 128 KByte flash memory
Typical Quiescent Current	22 µA @ 24 Vdc
Control Logic	Standard embedded software is provided.
Communications	1 RS-232 port for monitoring and software updates 1 CAN port (SAE J1939) AX100600: 250 kbps baud rate AX100600-01: 500 kbps baud rate AX100600-02: 1 Mbps baud rate
Network Termination	It is necessary to terminate the network with external termination resistors. The resistors are 120 Ohm, 0.25W minimum, metal film or similar type. They should be placed between CAN_H and CAN_L terminals at both ends of the network.
User Interface	The controller setpoints can be viewed and programmed using the standard J1939 memory access protocol through the CAN port and the PC-based Axiomatic Electronic Assistant®. For default setpoints, refer to the User Manual. The EA can store all controller setpoints in one setpoint file and then flash them into the controller in one operation. The setpoint file is created and stored on disk using a command *Save Setpoint File* from the EA menu or toolbar. The user then can open the setpoint file, view or print it and flash the setpoint file into the controller. The Electronic Assistant® for *Windows* operating systems comes with a royalty-free license for use on multiple computers. It requires an Axiomatic USB-CAN converter to link the device's CAN port to a *Windows*-based PC. **P/N: AX070502**, the Axiomatic Configuration KIT includes the following. USB-CAN Converter P/N: AX070501 1 ft. (0.3 m) USB Cable P/N: CBL-USB-AB-MM-1.5 12 in. (30 cm) CAN Cable with female DB-9 P/N: CAB-AX070501 AX070502IN CD P/N: CD-AX070502, includes: Electronic Assistant® software; EA & USB-CAN User Manual UMAX07050X; USB-CAN drivers & documentation; CAN Assistant (Scope and Visual) software & documentation; and the SDK Software Development Kit.
Operating Conditions	-40 to 85 °C (-40 to 185 °F)
Packaging	Aluminum enclosure, integral Deutsch IPD connector Encapsulated 4.27 x 4.27 x 2.17 inches 108.49 x 108.49 x 55.07 mm L x W x H including integral 12-pin connector
Protection	IP67 rating for the product assembly
Weight	1.40 lbs. (0.635 kg)
Installation	For mounting information, refer to the dimensional drawing in Installation Instructions. If the module is mounted without an enclosure, it should be mounted to reduce the likelihood of moisture entry. Install the unit with appropriate space available for servicing and for adequate wire harness access (6 inches or 15 cm) and strain relief (12 inches or 30 cm). All field wiring should be suitable for the operating temperature range of the module. All chassis grounding should go to a single ground point designated for the machine and all related equipment.

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Actuator Controls

Battery Chargers

CAN bus Controls, Gateways

CAN/Wifi, CAN/Bluetooth

Current Converters

DC/DC Power Converters

DC Voltage/Current Signal Converters

Engine Temperature Scanners

Ethernet/CAN Converters

Fan Drive Controllers

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I/O Controls

LVDT Simulators

Machine Control Systems

Motor Controls

PID Controls

Position Sensors, Angle Measurement Inclinometers

Power Supplies

PWM Signal Converters/Isolators

Resolver Signal Conditioners

Service Tools

Signal Conditioners

Strain Gauge CAN Controls

Surge Suppressors

OUR COMPANY

Axiomatic provides electronic machine controls, components, and systems to the off-highway, commercial vehicle, electric vehicle, power generator set, material handling, renewable energy and industrial OEM markets.

We provide efficient, innovative solutions that focus on adding value for our customers.

We emphasize service and partnership with our customers, suppliers, and employees to build long term relationships and mutual trust.

QUALITY DESIGN AND MANUFACTURING

Axiomatic is an ISO 9001:2008 registered facility.

SERVICE

All products to be returned to Axiomatic require a Return Materials Authorization Number (RMA#).

Please provide the following information when requesting an RMA number:

- Serial number, part number
- Axiomatic invoice number and date
- Hours of operation, description of problem
- Wiring set up diagram, application
- Other comments as needed

When preparing the return shipping paperwork, please note the following. The commercial invoice for customs (and packing slip) should state the harmonized international HS (tariff code), valuation and return goods terminology, as shown in italics below. The value of the units on the commercial invoice should be identical to their purchase price.

Goods Made In Canada (or Finland)
Returned Goods for Warranty Evaluation, HS: 9813.00
Valuation Identical Goods
Axiomatic RMA#

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 as described on www.axiomatic.com/service.html.

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