



USER MANUAL UMAX100280
USER MANUAL UMAX100280-01
USER MANUAL UMAX100280-02

48V BLDC MOTOR CONTROLLER with CAN, SAE J1939

USER MANUAL

P/N: AX100280

P/N: AX100280-01 – J1939 500kb/s Baud Rate

P/N: AX100280-02 – Custom J1939 Baud Rate, 1Mbits/s

VERSION HISTORY

Version	Date	Author	Modification
1.0.0	Jan 19, 2021	Antti Keränen	Initial version.
1.0.1	Jan 20, 2021	Antti Keränen	TD section and a note concerning the IGNITION pin added.
1.0.2	September 1, 2023	Kiril Mojsov	Performed Legacy Updates

ACRONYMS

ACK	Positive Acknowledgement (from SAE J1939 standard)
BATT +/-	Battery positive (a.k.a. Vps) or Battery Negative (a.k.a. GND)
DIN	Digital Input used to measure active high or low signals
DM	Diagnostic Message (from SAE J1939 standard)
DTC	Diagnostic Trouble Code (from SAE J1939 standard)
EA	The Axiomatic Electronic Assistant (A Service Tool for Axiomatic ECUs)
ECU	Electronic Control Unit (from SAE J1939 standard)
GND	Ground reference (a.k.a. BATT-)
I/O	Inputs and Outputs
MAP	Memory Access Protocol
NAK	Negative Acknowledgement (from SAE J1939 standard)
PDU1	A format for messages that are to be sent to a destination address, either specific or global (from SAE J1939 standard)
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)
PropA	Message that uses the Proprietary A PGN for peer-to-peer communication
PropB	Message that uses a Proprietary B PGN for broadcast communication
PWM	Pulse Width Modulation
RPM	Rotations per Minute
SPN	Suspect Parameter Number (from SAE J1939 standard)
TP	Transport Protocol
UIN	Universal input used to measure voltage, current, frequency or digital inputs
Vps	Voltage Power Supply (a.k.a. BATT+)
%dc	Percent Duty Cycle (Measured from a PWM input)

Note:

An Axiomatic Electronic Assistant KIT may be ordered as P/N: AX070502, or AX070506K

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J1939	Recommended Practice for a Serial Control and Communications Vehicle Network, SAE, April 2011
J1939/21	Data Link Layer, SAE, December 2010
J1939/71	Vehicle Application Layer, SAE, March 2011
J1939/73	Application Layer-Diagnostics, SAE, February 2010
J1939/81	Network Management, SAE, March 2013
TDAX100280	Technical Datasheet, 48V BLDC Motor Controller with CAN, Axiomatic Technologies 2016
UMAX07050x	User Manual, Axiomatic Electronic Assistant and USB-CAN, Axiomatic Technologies, 2023

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



NOTE: This product is supported by Axiomatic Electronic Assistant V5.xx.yy.0 and higher.

1. OVERVIEW OF CONTROLLER

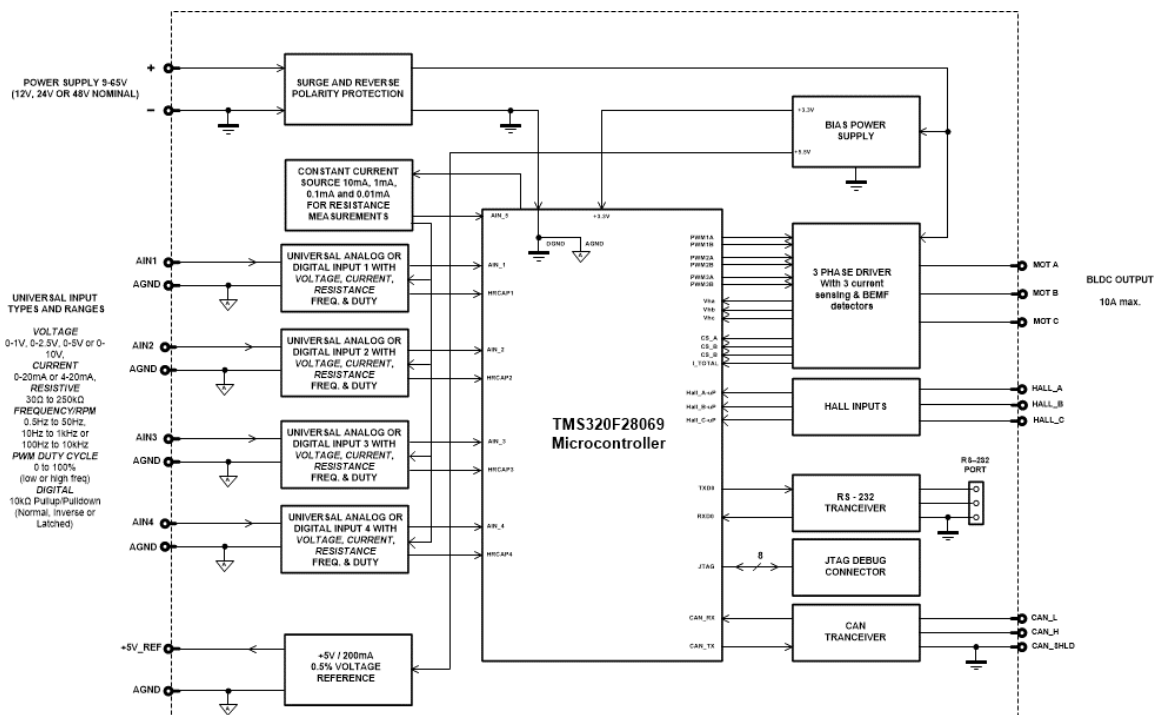


Figure 1 – AX100280 Block Diagram

The BLDC Motor Controller has four Universal Inputs that can be configured to measure voltage, current, frequency, PWM duty cycle, resistance or digital voltage level (on/off). Measured input data can be sent to a SAE J1939 CAN Network as is or used in the BLDC controller function blocks for controlling how the BLDC motor is driven.

The *Windows*-based Axiomatic Electronic Assistant (EA) is used to configure the controller via an USB-CAN (AX070501) device. Configurable properties, Axiomatic EA setpoints, are outlined in chapter 4. Setpoint configuration can be saved in a file which can be used to easily program the same configuration into another 48V BLDC Controller. Throughout this document, Axiomatic EA setpoint names are referred to with bolded text in double-quotes, and the setpoint option is referred to with italicized text in single-quotes. For example, “**Input Sensor Type**” setpoint set to option ‘*Frequency/RPM 100Hz to 10kHz*’.

In this document the configurable properties of the ECU are divided into function blocks, namely Input Function Block, Diagnostic Function Block, CAN Transmit Message Function Block and CAN Receive Message Function Block. These function blocks are presented in detail in next subchapters.

The BLDC Motor Controller can be ordered using the following part numbers depending on the application.

AX100280	Controller with the default J1939 baud rate (250kbits/s).
AX100280-01	Controller with the 500kbits/s J1939 baud rate.
AX100280-02	Controller with a custom 1Mbits/s J1939 baud rate.

1.1. BLDC Motor Control Functionality

The 48V BLDC Controller can drive brushless DC motors equipped with Hall sensors. Also, sensorless motor control using Back-EMF rotor position detection is supported. There are multiple setpoints accessible with the Axiomatic EA that allow the user to configure the 48V BLDC controller to drive a variety of different BLDC motors.

The Motor Parameters setpoint group (see section 4.5) supports the configuration of the main motor parameters, such as number of pole pairs, rotor position detection, rated RPM of the motor, PWM frequency to use in Motor Phase drive, commutation sequence to use (Hall sensor method only) and whether to use HW current protection.

“**Number of pole pairs**” has direct influence on how the 48V BLDC Controller picks up the motor RPM, this parameter should be always set to correspond the motor driven by the controller.

The “**Rated RPM**” setpoint is used for normalizing the RPM data in the function blocks. It does not have other influence how the motor is driven by the controller.

The “**PWM Frequency**” sets the frequency to use in the Phase outputs’ PWM signal.

In case the over current protection gets triggered, the “**Over current event clear time**” specifies the time in milliseconds after which the controller clears the over current status and resumes normal operation. If the event clear time is set to 0ms, the over current status won’t be cleared (a power cycle is required to resume normal operation).



The **IGNITION** pin (**Black connector, pin 7**, see Table 12 – AX100280 Connector Pinout) **needs to be connected to VPS** for powering on the AX100280 controller. If this pin is floating / connected to GND, the controller will stay OFF.

1.1.1. Hall Sensor Based Control

Hall sensor based control implements a commutation scheme that can be offset using setpoint “**Commutation Sequence**”. It is on the user’s responsibility to select the proper one for the motor in question.

The commutation sequence with no offset is shown in Table 1. The offset defined using the “**Commutation Sequence**” setpoint is added to internal state.

Hall C	Hall B	Hall A	Phase A	Phase B	Phase C	internal state
1	0	1	PWM	LOW	OFF	0
0	0	1	PWM	OFF	LOW	1
0	1	1	OFF	PWM	LOW	2
0	1	0	LOW	PWM	OFF	3
1	1	0	LOW	OFF	PWM	4
1	0	0	OFF	LOW	PWM	5

Table 1: Commutation sequence, no offset

1.1.2. Sensorless Control

The sensorless motor control is based on detecting the back emf voltage on the free phase while the motor is running. While this voltage is available only when the motor is running, the startup procedure is carried out without knowing whether the rotor actually rotates or not. Depending on the motor in question, the user has to tune the startup parameters in “**Speed Acceleration Control**” setpoint group (see section 4.9).

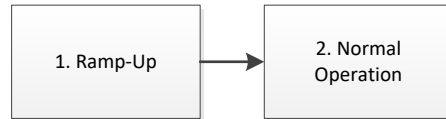


Figure 2 - Sensorless drive startup steps

The sensorless startup is carried out in two steps, namely:

1. Ramp-Up

During the ramp-up period, the motor is driven in open loop configuration for picking up speed and for making the back emf signals available for the sensorless control. The speed of the ramp up, together with initial and target commutation speed can be configured in “**Speed Acceleration Control**”. The “**Initial startup ramp step length**” defines the commutation interval in the start of the ramp up phase. The “**Final startup ramp step length**” defines the commutation interval in the end of the ramp up phase. The unit value for these setpoints depends on the selected PWM frequency for the motor output. The “**Startup ramp acceleration**” defines the delay for decrementing the ramp by one (i.e. commutation is speeded up).

The ramp-up phase duration is determined by the following formula, in which 10kHz is the default execution speed of the low level commutation algorithm (“**PWM Frequency**” setpoint in Motor Parameters).

$$t_{ramp-up} = \frac{((Initial\ st.\ up\ ramp\ step\ length - Final\ st.\ up\ ramp\ step\ length) * St.\ up\ ramp\ acceleration)}{10kHz}$$

With default settings, the ramp-up phase duration is 600ms.

2. Normal Operation

After the ramp-up is done, the rotor should be rotating. At this point the controller switches over to normal operation in which the rotor position is picked up by the back emf algorithm and the PWM drive signals are applied accordingly. In this mode the motor driving signals’ PWM duty cycle is determined by the Speed and/or Current controller, as configured.

When sensorless control is used, the firmware provides an option to measure the motor RPM using Hall A signal instead of measuring it using the back emf. If this style of RPM measurement is required, the “**RPM pickup style**” setpoint in Motor Parameters should be set to *1 – Use Hall A*.

1.2. Input Function Blocks

Universal Input setpoint groups have the “**Input Sensor Type**” setpoint, which is used to configure input type. Selecting input type effects on other setpoints and how they are interpreted and should thus be selected first on this block. The input sensor types for Universal Inputs are listed in Table 2.

0	<i>Disabled</i>
12	<i>Voltage 0 to 5 V</i>
13	<i>Voltage 0 to 10 V</i>
20	<i>Current 0 to 20 mA</i>
21	<i>Current 4 to 20 mA</i>
30	<i>Resistance</i>
40	<i>Frequency 0.5Hz to 50Hz</i>
41	<i>Frequency 10Hz to 1kHz</i>
42	<i>Frequency 100Hz to 10kHz</i>
50	<i>PWM (below 1kHz)</i>
51	<i>PWM (above 100Hz)</i>
60	<i>Digital (normal)</i>
61	<i>Digital (inverse)</i>
62	<i>Digital (latched)</i>
80	<i>Quadrature Decoder Counter</i>
81	<i>Quadrature Decoder Direction</i>
82	<i>Quadrature Decoder Speed</i>

Table 2 – Universal Input Sensor Type Options

On Universal Inputs analog voltage (i.e. 0-5V, 0-10V) or current (0-20mA, 4-20mA) signals go directly to a 12-bit analog-to-digital converter (ADC) on the processor. The voltage input is a high impedance input protected against shorts to GND or Vcc. In current mode, a 249Ω resistor is used to measure the input signal. Analog signals should be connected to the GND reference pins provided on the connector, per Table 12.

Frequency/RPM or Pulse Width Modulated (PWM) “**Input Sensor Type**” options connect an input to 16-bit timer pin on the processor. “**Pulses Per Revolution**” setpoint is only associated with the frequency input type. If the setpoint is set to *True*, then the input data will be reported as in rotations-per-minute (RPM). Otherwise, frequency inputs are measured in Hertz.

Universal Inputs have three Digital “**Input Sensor Type**” options: Normal, Inverse and Latched. With digital input sensor types, the input measurement is given, either 1 (ON) or 0 (OFF). The Universal inputs measure digital voltage with a 3V threshold.

On Frequency, PWM and digital input modes 10kΩ pull-up or pull-down resistors can be enabled or disabled by setting the value of the “**Pullup/Pulldown Resistor**” setpoint. Setpoint options are given in Table 3. By default pull-down resistors are enabled for all inputs.

0	<i>Pullup/down Off</i>
1	<i>10 kΩ Pullup</i>
2	<i>10 kΩ Pulldown</i>

Table 3 – Pullup/Pulldown Resistor Options

“**Active High/Active Low**” setpoint is used to configure how signal high and low are interpreted. Setpoint options are given in Table 4. By default all inputs are selected to be Active High, which means that signal high is interpreted as 1(ON) and signal low as 0(OFF).

0	Active High
1	Active Low

Table 4 – Active High/Low Options

Table 5 shows the effect of different digital input types on input signal measurement interpretation with recommended “**Pullup/Pulldown Resistor**” and “**Active High/Low**” combinations. Fault diagnostics are not available for digital input types.

Input Sensor Type		Pulldown Active High	Pullup Active Low	Input measured (state)
6	<i>Digital (normal)</i>	High	Low or Open	1 (ON)
		Low or Open	High	0 (OFF)
61	<i>Digital (inverse)</i>	High or Open	Low	1 (ON)
		Low	High or Open	0 (OFF)
62	<i>Digital (latched)</i>	High to Low	Low to High	0 (no change)
		Low to High	High to Low	1 (state change)

Table 5 – Digital Input Sensor Type versus Input State

Software filters can be applied to the measured input signal. Setpoints “**Software Filter Type**” and “**Software Filter Constant**” are used to configure the software filter. By default no filter is applied to the signal. Software filtering is described in detail in section below.

The AX100280 supports reading of Quadrature Encoder signals. Universal Input #1 and #2 can be connected to Encoder Signals (QA and QB in Figure 3). Input #3 is optional Index pin. The available decoder data is available from the inputs as configured.

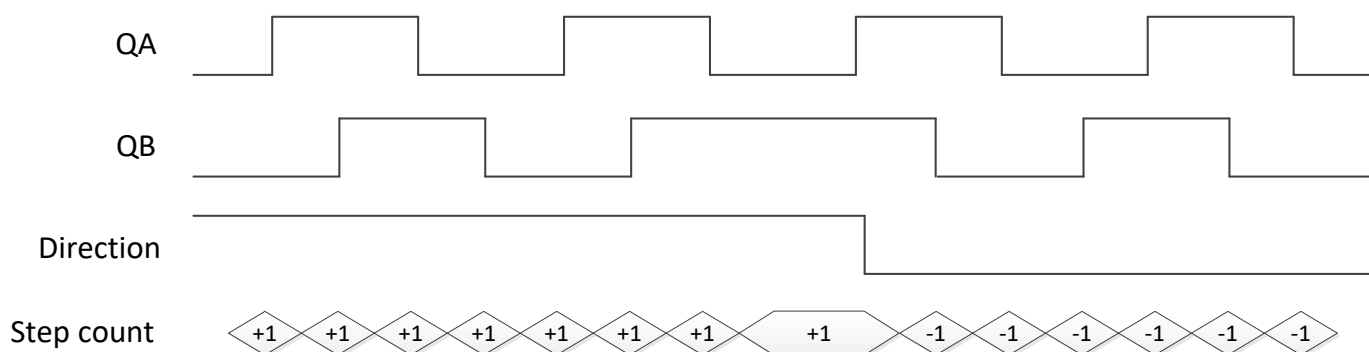


Figure 3 – Quadrature Decoder signals

The Quadrature Decoder block can be configured to start the count from an offset specified by the “**Quadrature Decoder Offset**” setpoint. The “**Quadrature Decoder Direction**” changes the direction of the count and “**Quadrature Decoder Scaler**” defines the number of steps to add / subtract on every detected edge. The “**Quadrature Decoder pulses per revolution**” affects the reported Quadrature Decoder speed value.

1.3. Input Filtering

Measured input data from universal inputs can be filtered to form desired CAN message data. Input filters are configured with “**Filter Type**” and “**Filter Constant**” setpoints. Filters are configured for each input individually.

0	<i>No Filtering</i>
1	<i>Moving Average</i>
2	<i>Repeating Average</i>

Table 6 – Filter Type Options

“**Filter Type**” setpoint defines the type of software filter used. Setpoint options are ‘*No Filtering*’, ‘*Moving Average*’ and ‘*Repeating Average*’. The ‘*No Filtering*’ option applies no filtering to the measured input data. The ‘*Moving Average*’ option applies the transfer function below to the measured input data, where $Value_N$ is the current value of the CAN message data, $Value_{N-1}$ is the previous CAN message data and Filter Constant is the value of the “**Filter Constant setpoint**”.

Equation 1 - Moving Average Transfer Function:

$$Value_N = Value_{N-1} + \frac{(Input - Value_{N-1})}{Filter\ Constant}$$

Equation 2 - Repeating Average Transfer Function:

$$Value = \frac{\sum_0^N Input_N}{N}$$

The ‘*Repeating Average*’ option applies the transfer function above to the measured input data, where N is value of the “**Filter Constant**” setpoint. At every reading of the input value, the value is added to the sum. At every Nth read, the sum is divided by N, and the result is new CAN message data. The sum is set to zero for the next read and summing is started again.

1.4. PID Controller Block

The PID Control function block is an independent logic block, but it is normally intended to be associated with proportional output control blocks described earlier. When the “**Control Source**” for an output has been setup as a ‘*PID Function Block*’, the command from the selected PID block drives the physical output on the 48V BLDC Controller.

The “**PID Target Command Source**” and “**PID Target Command Number**” setpoints determine control input and the “**PID Feedback Input Source**” and “**PID Feedback Input Number**” setpoints determine the established the feedback signal to the PID function block. The “**PID Response Profile**” will use the selected inputs as per the options listed in Table 7. When active, the PID algorithm will be called every “**PID Loop Update Rate**” in milliseconds.

0	<i>Single Output</i>
1	<i>Dual Output</i>
2	<i>Setpoint Control</i>
3	<i>On When Over Target</i>
4	<i>On When Below Target</i>

Table 7 – PID Response Options

When a ‘*Single Output*’ response is selected, the Target and Feedback inputs do not have to share the same units. In both cases, the signals are converted to a percentage values based on the minimum and maximum values associated with the source function block.

For example, a CAN command could be used to set the target value, in which case it would be converted to a percentage value using “**Receive Data Min**” and “**Receive Data Max**” setpoints in the appropriate ‘*CAN Receive X*’ function block. The closed-loop feedback signal (i.e. a 0-5V input) could be connected to ‘*Universal Input 1*’ and selected as the feedback source. In this case the value of the input would be converted to a percentage based on the “**Minimum Range**” and “**Maximum Range**” setpoints in the input block. The output of the PID function would depend on the difference between the commanded target and the measured feedback as a percentage of each signals range. In this mode, the output of the block would be a value from 0% to 100%.

The ‘*Dual Output*’ response is identical to the ‘*Single Output*’ case, however the PID block output in ‘*Dual Output*’ mode can be a value from -100% to 100%.

When a ‘*Setpoint Control*’ response is selected, the “**PID Target Command Source**” automatically gets updated to ‘*Control Constant Data*’ and cannot be changed. The value set in the associated constant in the Constant Data List function block becomes the desired rpm target value. In this case, the target value is scaled using the configured “**Rated motor RPM**” value. In this mode, the output of the block would be a value from 0% to 100%.

The last two response options, ‘*On When Over Target*’ and ‘*On When Under Target*’, are designed to allow the user to combine the two proportional outputs as a push-pull drive for a system. Both outputs must be setup to use the same control input (linear response) and feedback signal in order to get the expected output response. In this mode, the output would be between 0% to 100%.

In Order to allow the output to stabilize, the user can select a non-zero value for “**PID Delta Tolerance**”. If the absolute value of $Error_K$ is less than this value, $Error_K$ in the formula below will be set to zero.

The PID algorithm used is shown below, where **G**, **Ki**, **Ti**, **Kd**, **Td** and **Loop_Update_Rate** are configurable parameters.

$$PIDOutput_k = P_k + I_k + D_k$$

$$P_k = P_Gain * Error_k$$

$$I_k = I_Gain * ErrorSum_k$$

$$D_k = D_Gain * (Error_k - Error_{k-1})$$

$$Error_k = Target - Feedback$$

$$ErrorSum_k = ErrorSum_{k-1} + Error_k$$

$$P_Gain = G$$

$$I_Gain = Ki * T/Ti$$

$$D_Gain = Kd * T/Td$$

$$T = Loop_Update_Rate * 0.001$$

Equation 3 - PID Control Algorithm

Each system will have to be turned for the optimum output response. Response times, overshoots and other variables will have to be decided by the customer using an appropriate PID tuning strategy. Axiomatic is not responsible for tuning the control system.

1.5. Diagnostic Function Blocks

The 48V BLDC Controller supports diagnostic messaging. DM1 message is a message, containing Active Diagnostic Trouble Codes (DTC) that is sent to the J1939 network in case a fault has been detected. A Diagnostic Trouble Code is defined by the J1939 standard as a four byte value.

In addition to supporting the DM1 message, the following are supported:

SPN	Suspect Parameter Number	(user defined)
FMI	Failure Mode Identifier	(see Table 9 and Table 10)
CM	Conversion Method	(always set to 0)
OC	Occurrence Count	(number of times the fault has happened)
DM2	Previously Active Diagnostic Trouble Codes	Sent only on request
DM3	Diagnostic Data Clear/Reset of Previously Active DTCs	Done only on request
DM11	Diagnostic Data Clear/Reset for Active DTCs	Done only on request

Fault detection and reaction is a standalone functionality that can be configured to monitor and report diagnostics of various controller parameters. The 48V BLDC Controller supports 4 Diagnostics Definitions, each freely configurable by the user.

By default, the diagnostic blocks are configured for monitoring only power supply voltage, processor temperature and communications timeouts. All of the diagnostics blocks can be freely configured by the user to suit the application.

There are 4 fault types that can be used, “**Minimum and maximum error**”, “**Absolute value error**”, and “**State error**”.

Minimum and maximum error has two thresholds, “MIN Shutdown” and “MAX Shutdown” that have configurable, independent diagnostics parameters (SPN, FMI, Generate DTCs, delay before flagging status). In case the parameter to monitor stays between these two thresholds, the diagnostic is not flagged.

Absolute value error has one configurable threshold with configurable parameters. In case the parameter to monitor stays below this threshold, the diagnostic is not flagged.

State error is similar to the Absolute value error, the only difference is that State error does not allow the user to specify specific threshold values; thresholds ‘1’ and ‘0’ are used instead. This is ideal for monitoring state information, such as received message timeouts.

There are built in error status flags for power supply and CPU temperature monitoring. In case any of the diagnostics blocks is measuring these two parameters, the corresponding internal error status flags can be used for shutting down the unit in case of failure.

While there are no active DTCs, the 48V BLDC Controller sends DM1 messages with no SPNs, at a rate of one message per second. If a previously inactive DTC becomes active, a DM1 will be sent immediately to reflect this. As soon as the last active DTC goes inactive, a DM1 indicating that there are no more active DTCs will be sent.

If there is more than one active DTC at any given time, the regular DM1 message will be sent using a multipacket message to the Requester Address using the Transport Protocol (TP).



At power up, the DM1 message will not be broadcasted until after 5 second delay. This is done to prevent any power up or initialization conditions from being flagged as an active error on the network.

When the fault is linked to a DTC, a non-volatile log of the occurrence count (OC) is kept. As soon as the controller detects a new (previously inactive) fault, it will start decrementing the “**Delay before Event is flagged**” timer for that Diagnostic function block. If the fault has remained present during the delay time, then the controller will set the DTC to active, and will increment the OC in the log. A DM1 will immediately be generated that includes the new DTC. The timer is provided so that intermittent faults do not overwhelm the network as the fault comes and goes, since a DM1 message would be sent every time the fault shows up or goes away.

By default, the fault flag is cleared when error condition that has caused it goes away. The DTC is made Previously Active and is it is no longer included in the DM1 message. To identify a fault having happened, even if the condition that has caused is one away, the “**Event Cleared only by DM11**” setpoint can be set to ‘*True*’. This configuration enables DTC to stay Active, even after the fault flag has been cleared, and be included in DM1 message until a Diagnostic Data Clear/Reset for Active DTCs (DM11) has been requested.

As defined by J1939 Standard the first byte of the DM1 message reflects the Lamp status. “**Lamp Set by Event**” setpoint determines the lamp type set in this byte of DTC. “**Lamp Set by Event**” setpoint options are listed in Table 8. By default, the ‘*Amber, Warning*’ lamp is typically the one set be any active fault.

0	<i>Protect</i>
1	<i>Amber Warning</i>
2	<i>Red Stop</i>
3	<i>Malfunction</i>

Table 8 – Lamp Set by Event in DM1 Options

“**SPN for Event**” defines suspect parameter number used as part of DTC. The default value zero is not allowed by the standard, thus no DM will be sent unless “**SPN for Event**” in is configured to be different from zero. **It is user’s responsibility to select SPN that will not violate J1939 standard.** When the “**SPN for Event**” is changed, the OC of the associated error log is automatically reset to zero.

0	<i>Data Valid But Above Normal Operational Range - Most Severe Level</i>
1	<i>Data Valid But Below Normal Operational Range - Most Severe Level</i>
2	<i>Data Intermittent</i>
3	<i>Voltage Above Normal, Or Shorted To High Source</i>
4	<i>Voltage Below Normal, Or Shorted To Low Source</i>
5	<i>Current Below Normal Or Open Circuit</i>
6	<i>Current Above Normal Or Grounded Circuit</i>
7	<i>Mechanical Error</i>
8	<i>Abnormal Frequency Or Pulse Width Or Period</i>
9	<i>Abnormal Update Rate</i>
10	<i>Abnormal Rate Of Change</i>
11	<i>Root Cause Not Known</i>
12	<i>Bad Component</i>
13	<i>Out Of Calibration</i>
14	<i>Special Instructions</i>
15	<i>Data Valid But Above Normal Operating Range – Least Severe Level</i>
16	<i>Data Valid But Above Normal Operating Range – Moderately Severe Level</i>
17	<i>Data Valid But Below Normal Operating Range – Least Severe Level</i>
18	<i>Data Valid But Below Normal Operating Range – Moderately Severe Level</i>
19	<i>Network Error</i>
20	<i>Data Drifted High</i>
21	<i>Data Drifted Low</i>
31	<i>Condition Exists</i>

Table 9 – FMI for Event Options

Every fault has associated a default FMI with them. The used FMI can be configured with “**FMI for Event**” setpoint, presented in Table 9. When an FMI is selected from Low Fault FMIs in Table 10 for a fault that can be flagged either high or low occurrence, it is recommended that the user would select the high occurrence FMI from the right column of Table 10. There is no automatic setting of High and Low FMIs in the firmware, the user can configure these freely.

Low Fault FMIs	High Fault FMIs
<i>FMI=1, Data Valid But Below Normal Operation Range – Most Severe Level</i>	<i>FMI=0, Data Valid But Above Normal Operational Range – Most Severe Level</i>
<i>FMI=4, Voltage Below Normal, Or Shorted to Low Source</i>	<i>FMI=3, Voltage Above Normal, Or Shorted To High Source</i>
<i>FMI=5, Current Below Normal Or Open Circuit</i>	<i>FMI=6, Current Above Normal Or Grounded Circuit</i>
<i>FMI=17, Data Valid But Below Normal Operating Range – Least Severe Level</i>	<i>FMI=15, Data Valid But Above Normal Operating Range – Least Severe Level</i>
<i>FMI=18, Data Valid But Below Normal Operating Level – Moderately Severe Level</i>	<i>FMI=16, Data Valid But Above Normal Operating Range – Moderately Severe Level</i>
<i>FMI=21, Data Drifted Low</i>	<i>FMI=20, Data Drifted High</i>

Table 10 – Low Fault FMIs and corresponding High Fault FMIs

1.6. CAN Transmit Message Function Block

The CAN Transmit function block is used to send any output from another function block (i.e. input, CAN receive) to the J1939 network. The AX100280 ECU has two CAN Transmit Messages and each message has four completely user defined signals.

1.6.1. CAN Transmit Message Setpoints

Each CAN Transmit Message setpoint group includes setpoints that effect the whole message and are thus mutual for all signals of the message. These setpoints are presented in this section. The setpoints that configure an individual signal are presented in next section.

The “**Transmit PGN**” setpoint sets PGN used with the message. **User should be familiar with the SAE J1939 standard, and select values for PGN/SPN combinations as appropriate from section J1939/71.**

“**Repetition Rate**” setpoint defines the interval used to send the message to the J1939 network. If the “**Repetition Rate**” is set to zero, the message is disabled unless it shares its PGN with another message. In case of a shared PGN repetition rate of the LOWEST numbered message are used to send the message ‘bundle’.



At power up, transmitted message will not be broadcasted until after a 2 second delay. This is done to prevent any power up or initialization conditions from creating problems on the network.

By default, first message is configured to report UIn1 value, Motor RPM and current.

1.6.2. CAN Transmit Signal Setpoints

Each CAN transmit message has four associated signals, which define data inside the Transmit message. “**Control Source**” setpoint together with “**Control Number**” setpoint define the signal source of the message. “**Control Source**” and “**Control Number**” options are listed in Table 11. Setting “**Control Source**” to ‘*Control Not Used*’ disables the signal.

“**Transmit Data Size**” setpoint determines how many bits signal reserves from the message. “**Transmit Data Index in Array**” determines in which of 8 bytes of the CAN message LSB of the signal is located. Similarly “**Transmit Bit Index in Byte**” determines in which of 8 bits of a byte the LSB is located. These setpoints are freely configurable, therefore **it is the User’s responsibility to ensure that signals do not overlap and mask each other.**

“**Transmit Data Resolution**” setpoint determines the scaling done on the signal data before it is sent to the bus. “**Transmit Data Offset**” setpoint determines the value that is subtracted from the signal data before it is scaled. Offset and Resolution are interpreted in units of the selected source signal.

1.7. CAN Receive Function Block

The CAN Receive function block is designed to take any SPN from the J1939 network, and use it as an input to another function block (i.e. Outputs).

The “**Receive Message Enabled**” is the most important setpoint associated with this function block and it should be selected first. Changing it will result in other setpoints being enabled/disabled as appropriate. By default ALL receive messages are disabled.

Once a message has been enabled, a Lost Communication fault will be flagged if that message is not received off the bus within the “**Receive Message Timeout**” period. This could trigger a Lost Communication event as described in section 0. In order to avoid timeouts on a heavily saturated network, it is recommended to set the period at least three times longer than the expected update rate. To disable the timeout feature, simply set this value to zero, in which case the received message will never trigger a Lost Communication fault.

The “**Receive Data Size**”, “**Receive Data Index in Array (LSB)**”, “**Receive Bit Index in Byte (LSB)**”, “**Receive Resolution**” and “**Receive Offset**” can all be used to map any SPN supported by the J1939 standard to the output data of the Received function block.

As mentioned earlier, a CAN receive function clock can be selected as the source of the control input for the output function blocks. When this is case, the “**Received Data Min (Off Threshold)**” and “**Received Data Max (On Threshold)**” setpoints determine the minimum and maximum values of the control signal. As the names imply, they are also used as the On/Off thresholds for digital output types. These values are in whatever units the data is AFTER the resolution and offset is applied to CAN receive signal.

The 48V BLDC Controller supports up to four unique CAN Receive Messages.

1.8. Available Control Sources

Many of the Function Blocks have selectable input signals, which are determined with “[Name] Source” and “[Name] Number” setpoints. Together, these setpoints uniquely select how the I/O of the various function blocks are linked together. “[Name] Source” setpoint determines the type of the source and “[Name] Number” selects the actual source if there is more than one of the same type. Available “[Name] Source” options and associated “[Name] Number” ranges are listed in Table 11. All sources are available for all blocks. Though input Sources are freely selectable, it must be remembered that not all options would make sense in all cases, and it is up to the user to program the controller in a logical and functional manner.

Sources	Number Range	Notes
<i>0: Control Not Used</i>	N/A	When this is selected, it disables all other setpoints associated with the signal in question.
<i>1: Received CAN Message</i>	1 to 4	User must enable the function block, as it is disabled by default.
<i>2: Universal Input Measured</i>	1 to 4	
<i>3: Control Constant Data</i>	1 to 8	1 = FALSE, 2 = TRUE, 3 to 8 = User Selectable
<i>4: Motor RPM Value</i>	1	Measured RPM reading.
<i>5: Motor Current Feedback</i>	1	Measured motor current in Amps.
<i>6: Power Supply Measured</i>	1	Measured power supply value in Volts.
<i>7: Temperature Measured</i>	1	Measured processor temperature in °C.
<i>8: CAN Reception Timeout</i>	1	
<i>9: Additional Control Data</i>	1 to 16	User must enable the function block, as it is disabled by default.
<i>10: PID Function Block</i>	1	User must enable the function block, as it is disabled by default.

Table 11 – Available Control Sources and Numbers

Control Constant Data has no unit nor minimum and maximum assigned to it, therefore user has to assign appropriate constant values according to intended use.

2. INSTALLATION INSTRUCTIONS

2.1. Dimensions and Pinout

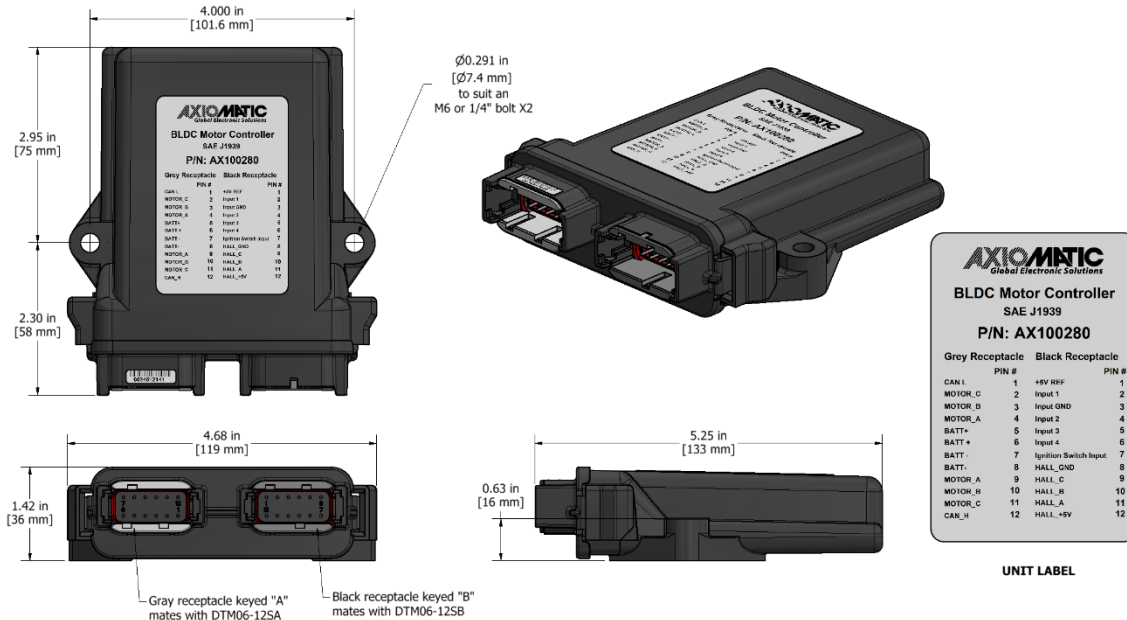


Figure 4 – AX100280 Dimensional Drawing

Grey Connector PIN #	Function	Black Connector PIN #	Function
12	CAN_H	12	Hall +5V Supply
11	Motor PWM (Phase C)	11	Hall A
10	Motor PWM (Phase B)	10	Hall B
9	Motor PWM (Phase A)	9	Hall C
8	Battery -	8	Hall GND
7	Battery -	7	IGNITION
6	Battery +	6	Universal Input 4
5	Battery +	5	Universal Input 3
4	Motor PWM (Phase A)	4	Universal Input 2
3	Motor PWM (Phase B)	3	Analog GND
2	Motor PWM (Phase C)	2	Universal Input 1
1	CAN_L	1	+5V Reference

Table 12 – AX100280 Connector Pinout

3. OVERVIEW OF J1939 FEATURES

The software was designed to provide flexibility to the user with respect to messages sent from the ECU by providing:

- Configurable ECU Instance in the NAME (to allow multiple ECUs on the same network)
- Configurable Input Parameters
- Configurable PGN and Data Parameters
- Configurable Diagnostic Messaging Parameters, as required
- Diagnostic Log, maintained in non-volatile memory

3.1. Introduction to Supported Messages

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

From J1939-21 – Data Link Layer

- | | | |
|--|------------|----------|
| • Request | 59904 | 0x00EA00 |
| • Acknowledgement | 59392 | 0x00E800 |
| • Transport Protocol – Connection Management | 60416 | 0x00EC00 |
| • Transport Protocol – Data Transfer Message | 60160 | 0x00EB00 |
| • Proprietary B | from 65280 | 0x00FF00 |
| | to 65535 | 0x00FFFF |

From J1939-73 – Diagnostics

- | | | |
|--|-------|----------|
| • DM1 – Active Diagnostic Trouble Codes | 65226 | 0x00FECA |
| • DM2 – Previously Active Diagnostic Trouble Codes | 65227 | 0x00FECB |
| • DM3 – Diagnostic Data Clear/Reset for Previously Active DTCs | 65228 | 0x00FECC |
| • DM11 – Diagnostic Data Clear/Reset for Active DTCs | 65235 | 0x00FED3 |
| • DM14 – Memory Access Request | 55552 | 0x00D900 |
| • DM15 – Memory Access Response | 55296 | 0x00D800 |
| • DM16 – Binary Data Transfer | 55040 | 0x00D700 |

From J1939-81 – Network Management

- | | | |
|--------------------------------|-------|----------|
| • Address Claimed/Cannot Claim | 60928 | 0x00EE00 |
| • Commanded Address | 65240 | 0x00FED8 |

From J1939-71 – Vehicle Application Layer

- | | | |
|---------------------------|-------|----------|
| • Software Identification | 65242 | 0x00FEDA |
|---------------------------|-------|----------|

None of the application layer PGNs are supported as part of the default configurations, but they can be selected as desired for transmit function blocks.

Setpoints are accessed using standard Memory Access Protocol (MAP) with proprietary addresses. The Axiomatic Electronic Assistant (EA) allows for quick and easy configuration of the unit over CAN network.

3.2. NAME, Address and Software ID

The 48V BLDC Controller has the following default 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	12, Axiomatic AX100280
ECU Instance	0, First Instance
Manufacture Code	162, Axiomatic Technologies
Identity Number	Variable, uniquely assigned during factory programming for each ECU

The ECU Instance is a configurable setpoint associated with the NAME. Changing this value will allow multiple ECUs of this type to be distinguishable from one another when they are connected on the same network.

The default value of the “ECU Address” setpoint is 128 (0x80), which is the preferred starting address for self-configurable ECUs as set by the SAE in J1939 tables B3 and B7. The Axiomatic EA supports the selection of any address between 0 and 253. ***It is 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 48V BLDC Controller will continue select the next highest address until it finds one that it can claim. See J1939/81 for more details about address claiming.

Software Identifier

PGN 65242		Software Identification	- SOFT
Transmission Repetition Rate:		On request	
Data Length:		Variable	
Extended Data Page:		0	
Data Page:		0	
PDU Format:		254	
PDU Specific:		218 PGN Supporting Information:	
Default Priority:		6	
Parameter Group Number:		65242 (0xFEDA)	
Start Position	Length	Parameter Name	SPN
1	1 Byte	Number of software identification fields	965
2-n	Variable	Software identification(s), Delimiter (ASCII “**”)	234

Byte 1 is set to 5, and the identification fields are as follows.

(Part Number)*(Version)*(Date)*(Owner)*(Description)

The Axiomatic EA shows all this information in “General ECU Information”, as shown below.

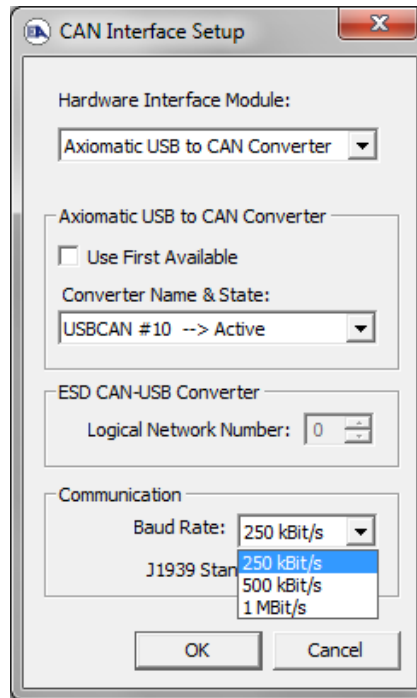
Note: The information provided in the Software ID is available for any J1939 service tool which supports the PGN -SOFT.

4. ECU SETPOINTS ACCESSED WITH THE AXIOMATIC ELECTRONIC ASSISTANT

This section describes in detail each setpoint, and their default and ranges. Default values presented in tables are values used when setpoint in question is active. Many of the setpoints are dependent on other setpoints and they may not be active by default. Associated Figures show screen capture of initial operation, however some of the setpoints are not in default condition as they are set differently to activate more setpoints for the image. The setpoints are divided into setpoint groups as they are shown in the Axiomatic EA. For more information on how each setpoint is used by the 48V BLDC Controller, refer to the relevant section in this user manual.

4.1. Accessing the ECU Using the Axiomatic EA

ECU with P/N AX100280 does not need any specific setup for the Axiomatic EA. In order to access the high speed versions, AX100280-01 and/or AX100280-02, the CAN bus Baud Rate needs to be set accordingly. The CAN Interface Setup can be found from “Options” menu in the EA.



4.2. J1939 Network Parameters

“ECU Instance Number” and “ECU Address” setpoints and their effect are defined in Section 3.2.

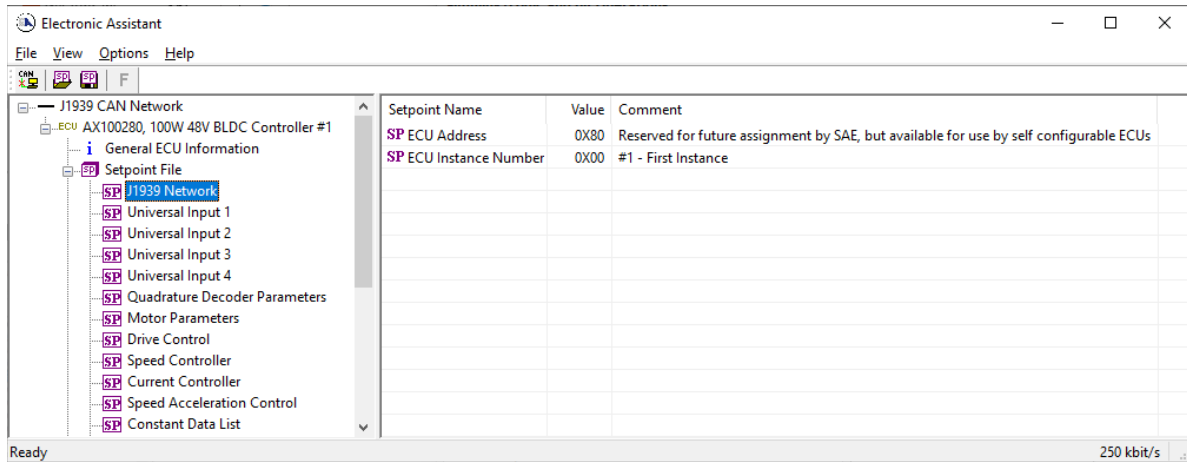


Figure 5 - Screen Capture of J1939 Setpoints

Name	Range	Default	Notes
ECU Address	0-253	0x80	Preferred address for a self-configurable ECU
ECU Instance	0-7	0x00	Per J1939-81

Table 13 – J1939 Network Setpoints

If non-default values for the “ECU Instance Number” or “ECU Address” are used, they will be mirrored during a setpoint file flashing, and will only take effect once the entire file has been downloaded to the unit. After the setpoint flashing is complete, the unit will claim the new address and/or re-claim the address with the new NAME. If these setpoints are changing, it is recommended to close and re-open the CAN connection on the Axiomatic EA after the file is loaded so that only the new NAME and address appear in the J1939 CAN Network ECU list.

4.3. Universal Input Setpoints

For detailed description of Universal Inputs, please refer to section 0.

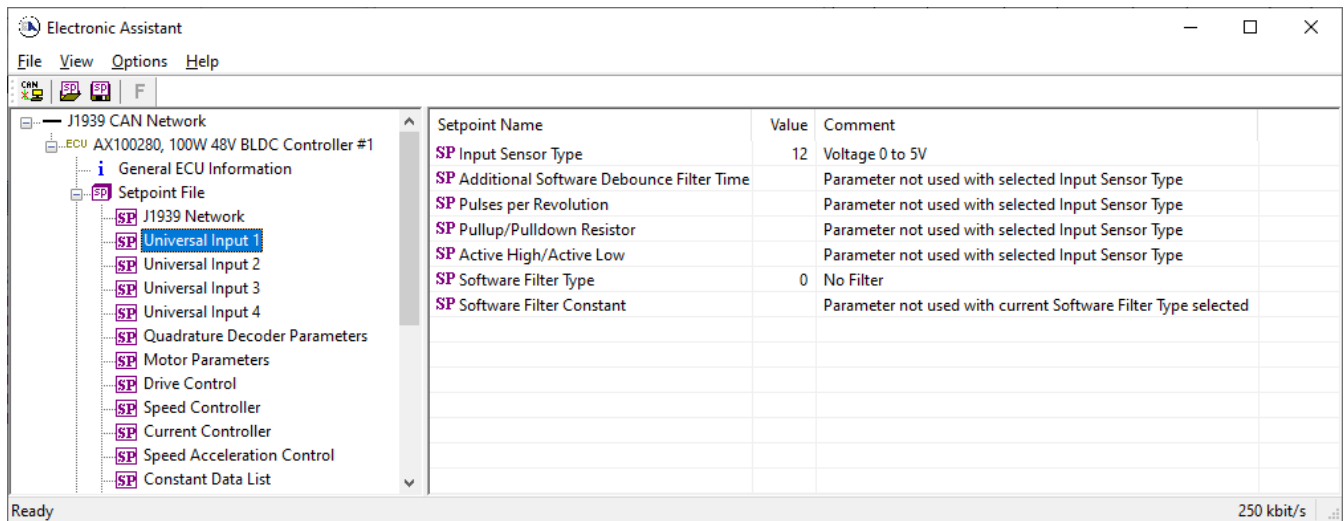


Figure 6 - Screen Capture of Universal Input Setpoints

Name	Range	Default	Notes
Input Sensor Type	Drop List	Digital Normal Logic	See Table 2
Additional Software Debounce Filter Time	Drop List	0ms	See Error! Reference source not found.
Pulses per Revolution	Drop List	FALSE	See Section 0
Pullup/Pulldown Resistor	Drop List	No pull up/down	See Table 3
Active High/Active Low	Drop List	Active High	See Table 4
Software Filter Type	Drop List	No Filtering	See Table 6
Software Filter Constant	1...1000	1	

Table 14 – Universal Input Setpoints

4.4. Quadrature Decoder Setpoints

For description of Quadrature decoder input, please refer to section 0.

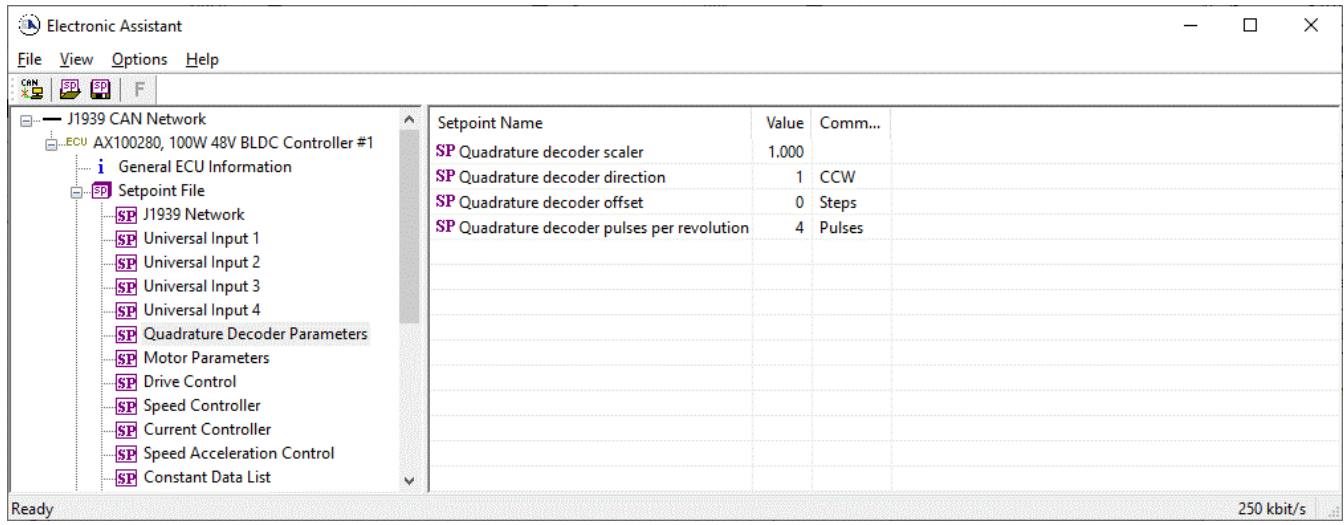


Figure 7 - Screen Capture of Quadrature Decoder Setpoints

Name	Range	Default	Notes
Quadrature decoder scaler	UINT32	1.000	
Quadrature decoder direction	Drop List	1	
Quadrature decoder offset	Drop List	0	
Quadrature decoder pulses per revolution	UINT32	4	

Table 15 – Quadrature Decoder Setpoints

4.5. Motor Parameter Setpoints

The detailed description of Motor Parameters, please refer to section 0.

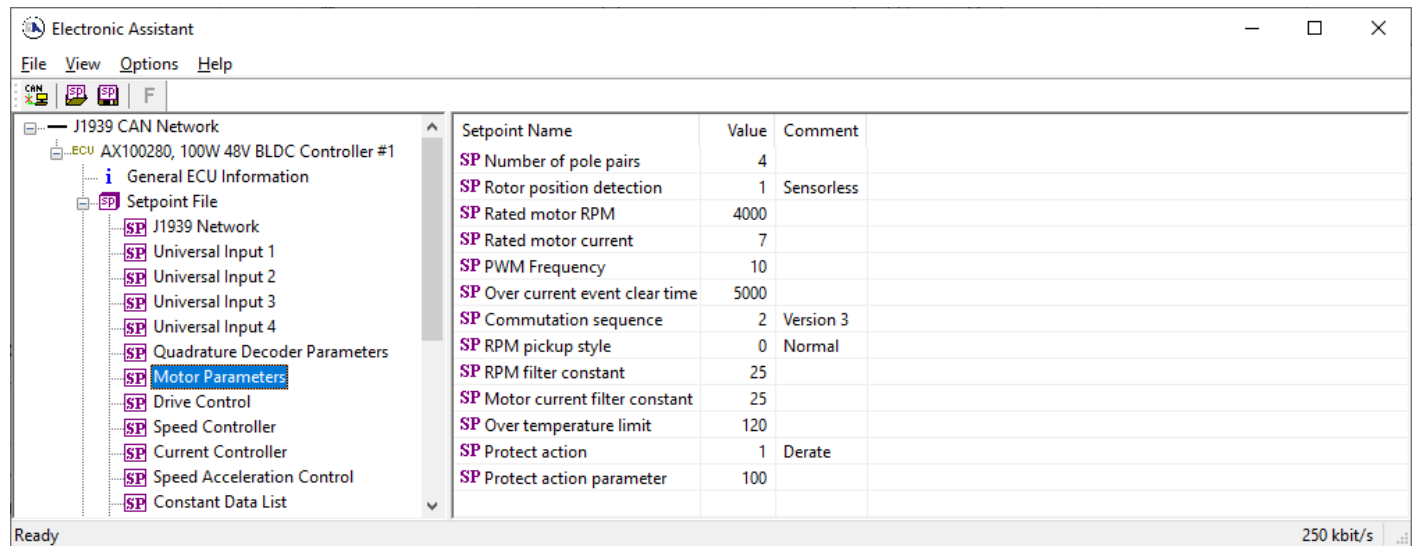


Figure 8 - Screen Capture of Motor Parameter Setpoints

Name	Range	Default	Notes
Number of pole pairs	0...255	4	
Rotor position detection	Drop List	1 – Sensorless	
Rated motor RPM	0...20000	6000	RPM
Rated motor current	0...14	7	A
PWM Frequency	5...20	10	kHz
Over current event clear time		5000	ms
Commutation sequence	Drop List	2 – Version 3	
RPM pickup style	Drop List	0 – Normal	If sensorless rotor position detection is used, the speed can be still picked up using Hall A signal.
RPM filter constant	25		No. of samples in moving average filter
Motor current filter constant	25		No. of samples in moving average filter
Over temperature limit		120	Celsius
Protect action	Drop List	1 – Derate	
Protect action parameter	0 ... 60000	100	Max current derate slope coefficient

Table 16 – Motor Parameter Setpoints

4.6. Drive Control Setpoints

The Drive Control Setpoints let the user to specify which control signals are responsible for the motor driving. In case SPN 7991 style direction+enable signal needs to be used, the 'Direction Control Source' setpoint should be set to 'Control not Used'. This forces the controller to read in the direction control signal together with enable signal. This feature is targeted to be used when direction+enable is received as a CAN message.

In case 'Direction Control Source' should be set as constantly true or false, the Control Constant Data sources #1 (FALSE) and #2 (TRUE) can be used for this purpose.

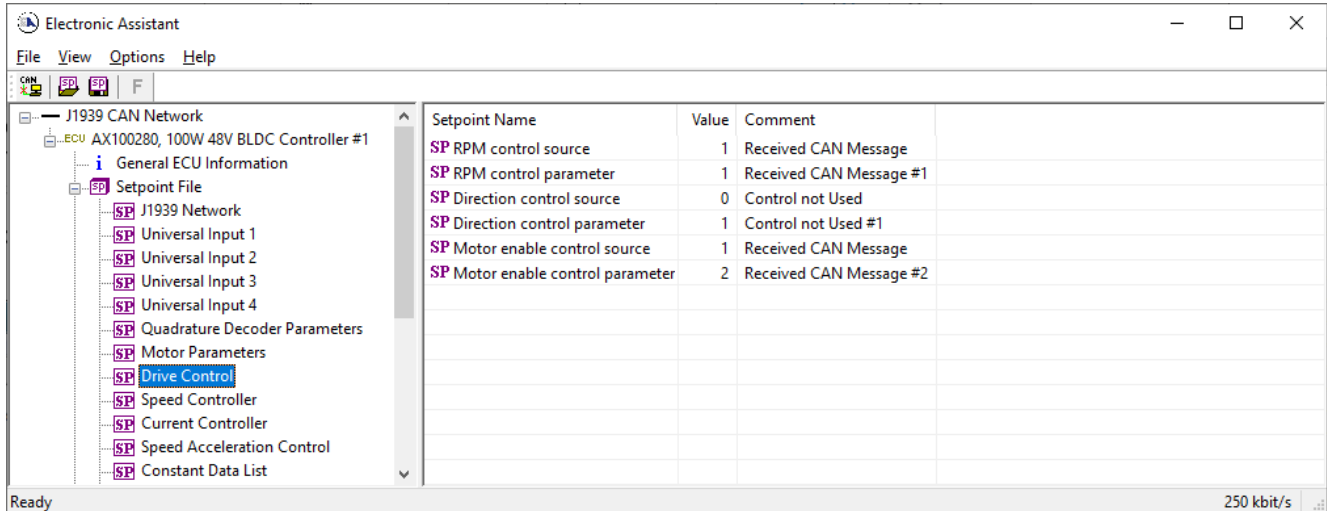


Figure 9 - Screen Capture of Drive Control Setpoints

Name	Range	Default	Notes
RPM control source	Drop List	2	Universal Input Measured
RPM control source parameter	Depends on source	1	Input #1
Direction control source	Drop List	2	Universal Input Measured. Set to '0' if direction data should be read in together with enable data in a CAN message (SPN 7991 support)
Direction control source parameter	Depends on source	2	Input #2
Enable control source	Drop List	2	Universal Input Measured
Enable control source parameter	Depends on source	3	Input #3

Table 17 – Drive Control Setpoints

SPN 7991 data	Function
0	Drive disabled
1	Drive enabled, normal direction
2	Drive enabled, reverse direction
3	Reserved

Table 18 – SPN 7991 style Enable+Direction command

4.7. Speed Controller Setpoints

These setpoints configure the Open and Closed Loop speed control. The closed loop PI controller gains depend on the application in question, and it is on the user's responsibility to find out the correct gains. The closed loop PI controller is executed at 10ms intervals.

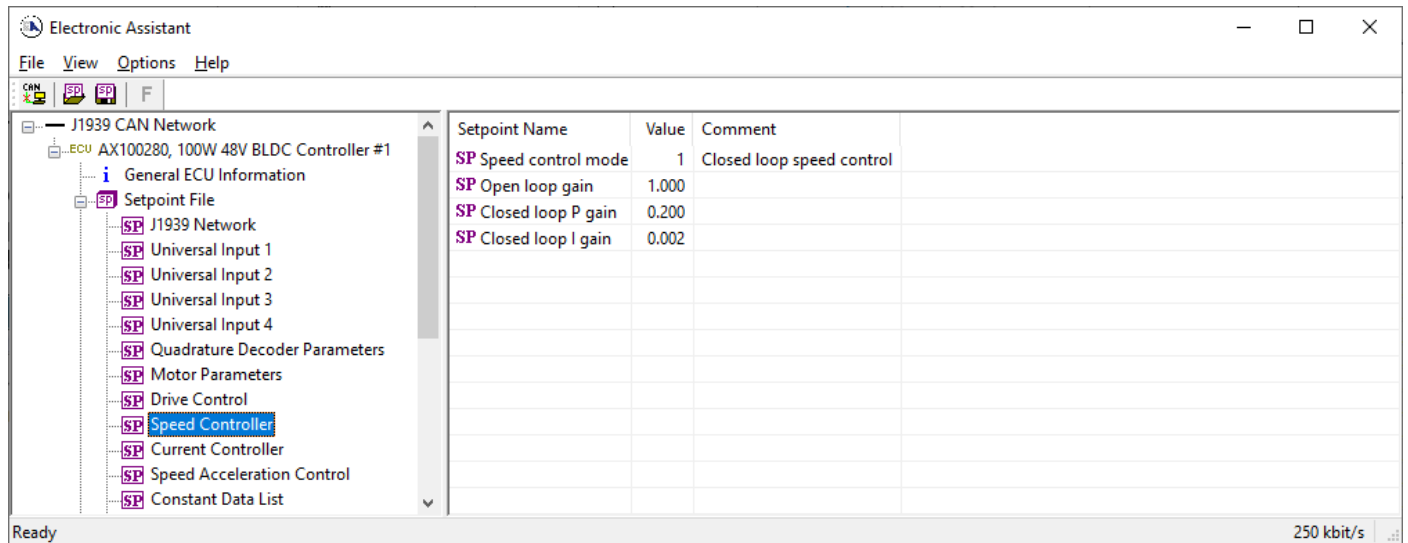


Figure 10 - Screen Capture of Speed Controller Setpoints

Name	Range	Default	Notes
Speed control mode	Drop List	0	Open loop control
Open loop gain	0 ... 100.0	1.0	
Closed loop P gain	0.0 ... 100.0	1.0	
Closed loop I gain	0.0 ... 100.0	0.0	

Table 19 – Speed Controller Setpoints

4.8. Current Controller Setpoints

These setpoints configure the Open and Closed Loop current control. The closed loop PI controller gains depend on the application in question, and it is on the user's responsibility to find out the correct gains. The closed loop PI controller is executed at 10ms intervals.

The closed loop current control is applied only when the measured motor current exceeds the "Closed loop current threshold" value. If the measured current stays below that limit, the current control is not applied.

When the current control is not applied, the PWM duty cycle for motor driving depends only on the speed controller block.

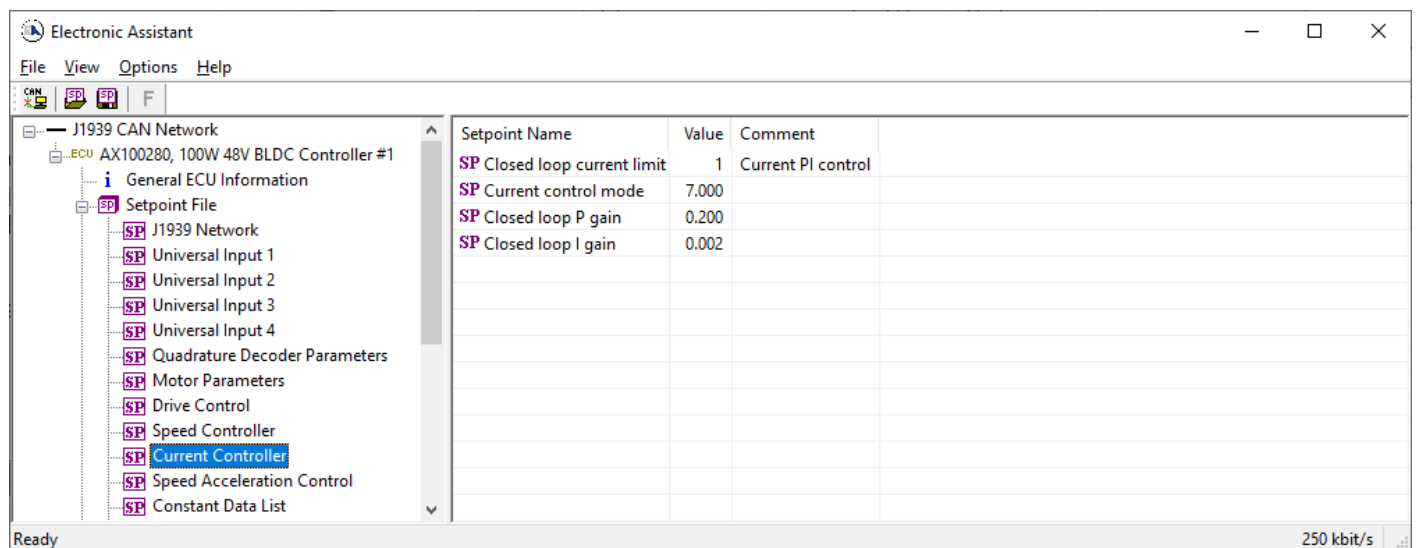


Figure 11 - Screen Capture of Current Controller Setpoints

Name	Range	Default	Notes
Current control mode	Drop List	0	No current control
Closed loop current threshold	0.0 ... 8.0	7.0	[A]
Closed loop P gain	0.0 ... 100.0	1.0	
Closed loop I gain	0.0 ... 100.0	0.0	

Table 20 – Current Controller Setpoints

4.9. Speed Acceleration Control Setpoints

For detailed description of Speed Acceleration Control, please refer to section 0.

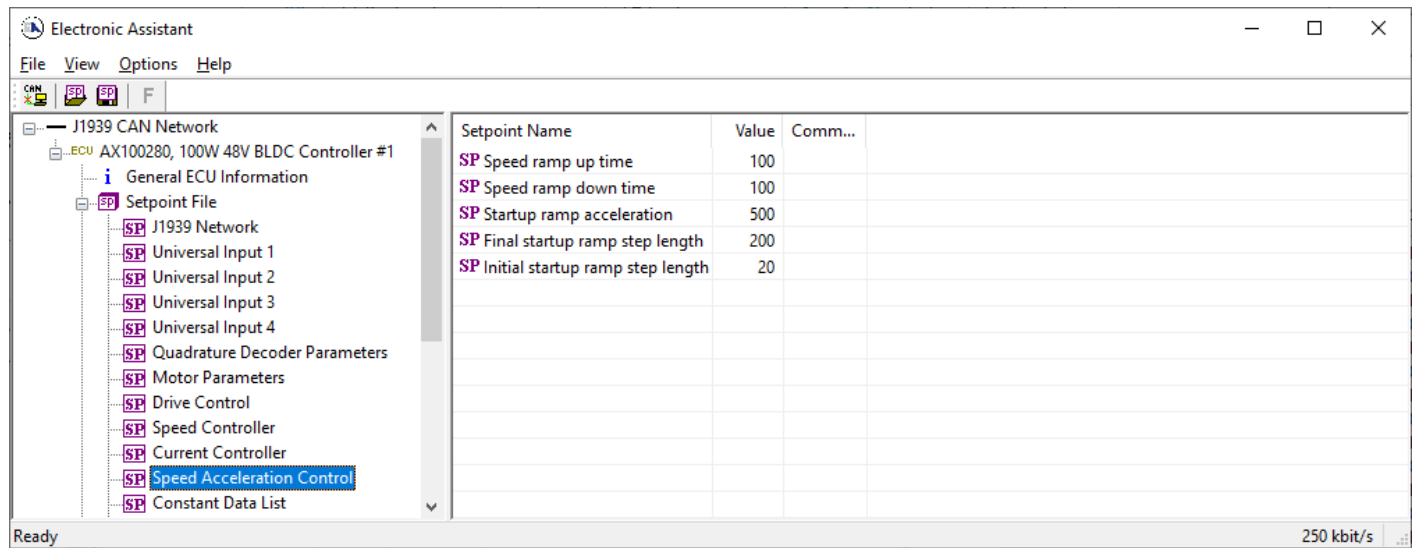


Figure 12 - Screen Capture of Speed Acceleration Control Setpoints

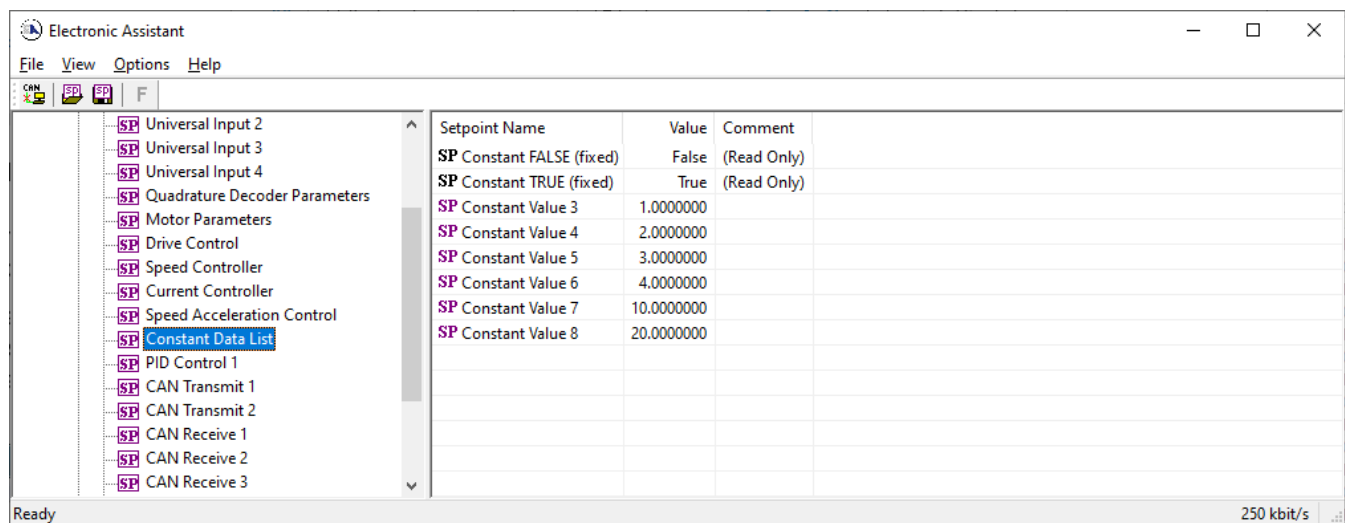
Name	Range	Default	Notes
Speed ramp up time	0...60000	100	milliseconds
Speed ramp down time	0...60000	100	milliseconds
Initial startup ramp step length	0...32767	500	ISR ticks
Final startup ramp step length	0...32767	200	ISR ticks
Startup ramp acceleration	0...32767	20	ISR ticks

Table 21 – Speed Acceleration Control Setpoints

4.10. Constant Data List

The Constant Data List Function Block is provide to allow the user to select values as desired for various logic block functions.

The first two constants are fixed values of 0 (False) and 1 (True) for use in binary logic. The remaining 6 constants are fully user programmable to any value between +/- 1 000 000. The default values (shown in Figure 13) are arbitrary and should be configured by the user as appropriate for their application.



The screenshot shows the 'Electronic Assistant' software interface. The 'Constant Data List' function block is selected in the left-hand tree view. The main window displays a table of setpoints with the following data:

Setpoint Name	Value	Comment
SP Constant FALSE (fixed)	False	(Read Only)
SP Constant TRUE (fixed)	True	(Read Only)
SP Constant Value 3	1.0000000	
SP Constant Value 4	2.0000000	
SP Constant Value 5	3.0000000	
SP Constant Value 6	4.0000000	
SP Constant Value 7	10.0000000	
SP Constant Value 8	20.0000000	

Figure 13 - Screen Capture of Constant Data List Setpoints

4.11. PID Control 1

The PID Control Function Block is defined in Section 1.4. Please refer there for detailed information about how all these setpoints are used.

Command Source is set to '*Control Not Used*' by default. To enable a PID Control, select appropriate "**PID Target Command Source**" and "**PID Feedback Input Source**".

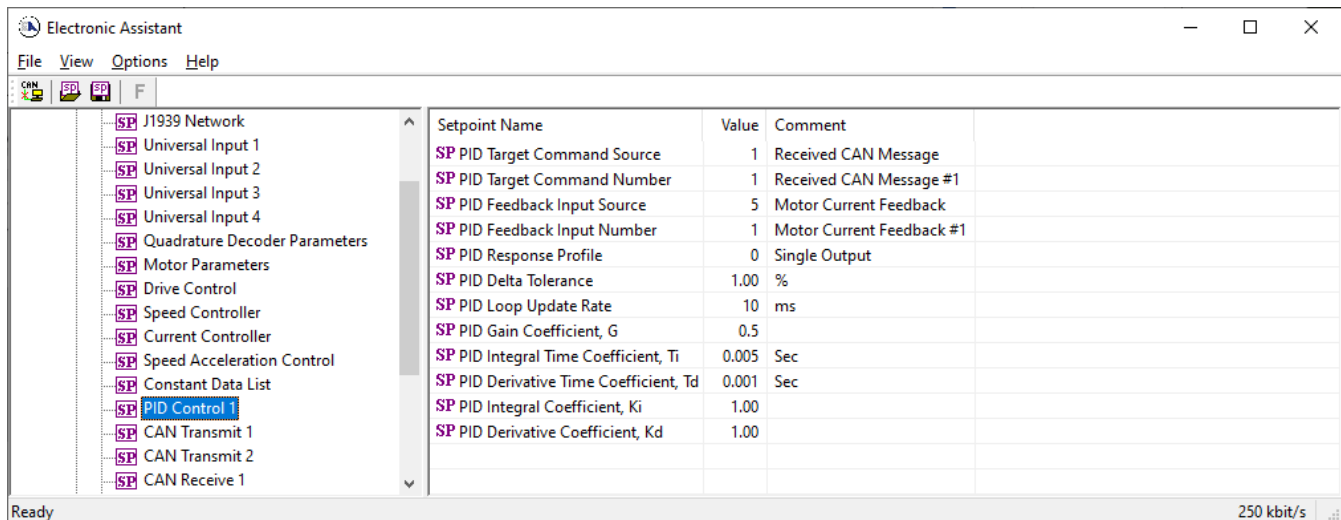


Figure 14 - Screen Capture of PID Control Setpoints

Name	Range	Default	Notes
PID Target Command Source	Drop List	Control Not Used	See Table 11
PID Target Command Number	Depends on control source	1	See Table 11
PID Feedback Input Source	Drop List	Control Not Used	See Table 11
PID Feedback Input Number	Depends on control source	1	See Table 11
PID Response Profile	Drop List	Single Output	See Table 7
PID Delta Tolerance	0 to 100	1.00 %	%
PID Loop Update Rate	1 to 60 000 ms	10ms	1 ms resolution
PID Gain Coefficient, G	0.1 to 10	0.5	
PID Integral Time Coefficient, Ti	0.001 to 10 Sec	0.005 Sec	0.001 Sec (1ms) resolution
PID Derivative Time Coefficient, Td	0.001 to 10 Sec	0.001 Sec	0.001 Sec (1ms) resolution
PID Integral Coefficient, Ki	0 to 10	1.00	0 disables integral, PD ctrl
PID Derivative Coefficient, Kd	0 to 10	1.00	0 disables derivative, PI ctrl

Table 22 – PID Control Setpoints

4.12. CAN Transmit Setpoints

Please refer to section 1.6 for detailed information how these setpoints are used. “**Transmit Repetition Rate**” is 0ms by default, thus no message will be sent.

The screenshot shows the Electronic Assistant software interface. On the left, a tree view displays the project structure for a J1939 CAN Network. The 'CAN Transmit' setpoint is selected and highlighted in blue. The main area on the right displays a table of setpoints for this selected setpoint.

Setpoint Name	Value	Comment
SP Transmit PGN	0xFF80	Transmit PGN: 65408
SP Transmit Repetition Rate	100	ms
SP Transmit Message Priority	6	
SP Destination Address (PDU1)	255	Destination ECU Address: 0xFF
SP Signal 1 Data Source	4	Motor RPM Value
SP Signal 1 Data Number	1	Motor RPM Value #1
SP Signal 1 Type	2	CAN signal continuous
SP Signal 1 Byte Position	0	1st Byte Position
SP Signal 1 Bit Position	0	1st Bit Position
SP Signal 1 Data Size	16	
SP Signal 1 Transmit Data Resolution	0.5000000	
SP Signal 1 Transmit Data Offset	0.0000000	
SP Signal 1 Transmit Data Minimum	0.0000000	
SP Signal 1 Transmit Data Maximum	32127.5000000	
SP Signal 2 Data Source	5	Motor Current Feedback
SP Signal 2 Data Number	1	Motor Current Feedback #1
SP Signal 2 Type	2	CAN signal continuous
SP Signal 2 Byte Position	2	3rd Byte Position
SP Signal 2 Bit Position	0	1st Bit Position
SP Signal 2 Data Size	16	
SP Signal 2 Transmit Data Resolution	0.0010000	
SP Signal 2 Transmit Data Offset	-10.0000000	
SP Signal 2 Transmit Data Minimum	-10.0000000	
SP Signal 2 Transmit Data Maximum	10.0000000	
SP Signal 3 Data Source	7	Temperature Measured
SP Signal 3 Data Number	1	Temperature Measured
SP Signal 3 Type	2	CAN signal continuous
SP Signal 3 Byte Position	4	5th Byte Position
SP Signal 3 Bit Position	0	1st Bit Position
SP Signal 3 Data Size	16	
SP Signal 3 Transmit Data Resolution	1.0000000	
SP Signal 3 Transmit Data Offset	-40.0000000	
SP Signal 3 Transmit Data Minimum	-40.0000000	
SP Signal 3 Transmit Data Maximum	210.0000000	

The status bar at the bottom left shows 'Ready' and the bottom right shows '250 kbit/s'.

Figure 15 - Screen Capture of CAN Transmit Message Setpoints

Name	Range	Default	Notes
Transmit PGN	0xff00 ... 0xffff	Different for each	
Transmit Repetition Rate	0 ... 65000 ms	0ms	0ms disables transmit
Transmit Message Priority	0...7	6	
Destination Address	0...255	255	Not used by default
Signal 1 Data Source	Drop List	Different for each	See Table 11
Signal 1 Data Number	Drop List	Different for each	
Signal 1 Type	Drop List	2	Continuous data
Signal 1 Byte Position	0-7	0	
Signal 1 Bit Position	0-7	0	
Signal 1 Data Size	Drop List	16 bits	
Signal 1 Transmit Data Resolution	-100000.0 to 100000	Different for each	
Signal 1 Transmit Data Offset	-10000 to 10000	0.0	
Signal 1 Transmit Data Minimum	-100000.0 to 100000	0.0	
Signal 1 Transmit Data Maximum	-100000.0 to 100000	Different for each	
Signal 2 Data Source	Drop List	Different for each	See Table 11
Signal 2 Data Number	Drop List	Different for each	
Signal 2 Type	Drop List	2	Continuous data
Signal 2 Byte Position	0-7	0	
Signal 2 Bit Position	0-7	0	
Signal 2 Data Size	Drop List	16 bits	
Signal 2 Transmit Data Resolution	-100000.0 to 100000	Different for each	
Signal 2 Transmit Data Offset	-10000 to 10000	0.0	
Signal 2 Transmit Data Minimum	-100000.0 to 100000	0.0	
Signal 2 Transmit Data Maximum	-100000.0 to 100000	Different for each	
Signal 3 Data Source	Drop List	Different for each	See Table 11
Signal 3 Data Number	Drop List	Different for each	
Signal 3 Type	Drop List	2	Continuous data
Signal 3 Byte Position	0-7	0	
Signal 3 Bit Position	0-7	0	
Signal 3 Data Size	Drop List	16 bits	
Signal 3 Transmit Data Resolution	-100000.0 to 100000	Different for each	
Signal 3 Transmit Data Offset	-10000 to 10000	0.0	
Signal 3 Transmit Data Minimum	-100000.0 to 100000	0.0	
Signal 3 Transmit Data Maximum	-100000.0 to 100000	Different for each	
Signal 4 Data Source	Drop List	Different for each	See Table 11
Signal 4 Data Number	Drop List	Different for each	
Signal 4 Type	Drop List	2	Continuous data
Signal 4 Byte Position	0-7	0	
Signal 4 Bit Position	0-7	0	
Signal 4 Data Size	Drop List	16 bits	
Signal 4 Transmit Data Resolution	-100000.0 to 100000	Different for each	
Signal 4 Transmit Data Offset	-10000 to 10000	0.0	
Signal 4 Transmit Data Minimum	-100000.0 to 100000	0.0	
Signal 4 Transmit Data Maximum	-100000.0 to 100000	Different for each	

Table 23 – CAN Transmit Message Setpoints

4.13. CAN Receive Setpoints

Please refer to section 0 for detailed information about how these setpoints are used. “**Receive Message Timeout**” is set to 0ms by default. To enable Receive message set “**Receive Message Timeout**” that differs from zero.

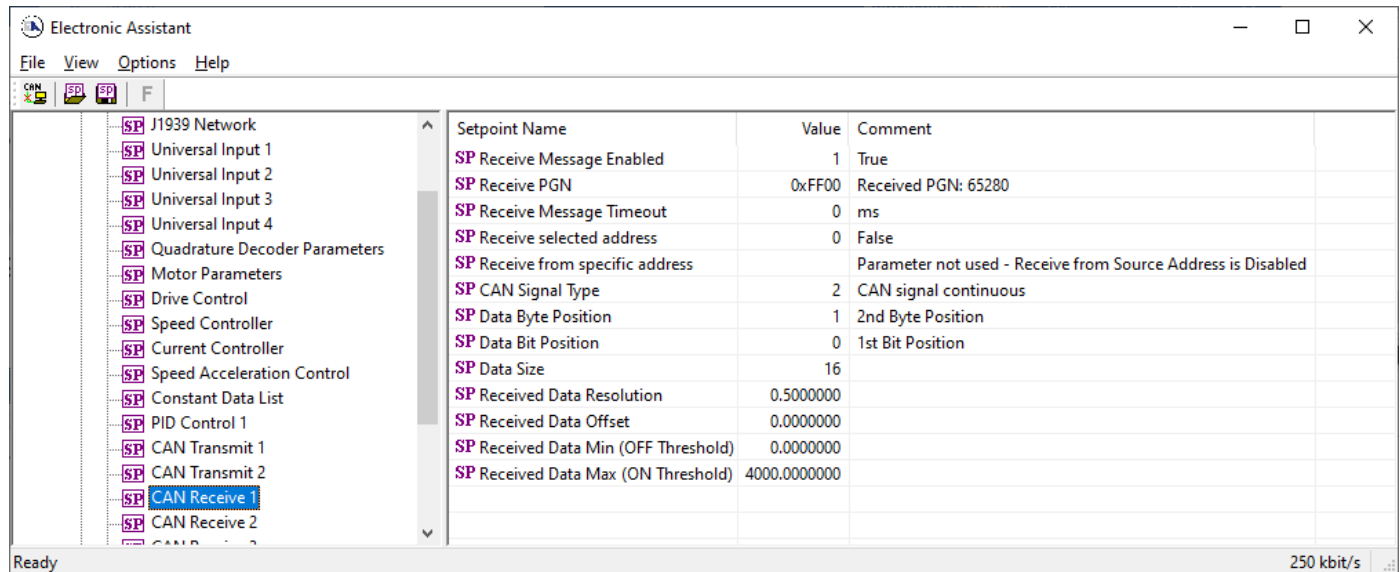


Figure 16 - Screen Capture of CAN Receive Message Setpoints

Name	Range	Default	Notes
Received Message Enabled	Drop List	False	
Received PGN	0 to 65536	Different for each	
Received Message Timeout	0 to 60 000 ms	0ms	
Receive selected address	Drop List	False	
Receive from specific address	0 to 255	254 (0xFE, Null Addr)	
CAN Signal Type	Drop List	2 – Continuous data	
Data Byte Position	0-7	0	
Data Bit Position	0-7	0	
Data Size	0-32	8 bits	
Received Data Resolution	-100000.0 to 100000	0.01	
Received Data Offset	-10000 to 10000	0.0	
Received Data Min (OFF Threshold)	-1000000 to Max	0.0	
Received Data Max (ON Threshold)	-100000 to 100000	2.5	

Table 24 – CAN Receive Setpoints

4.14. Diagnostics Blocks

There are 3 Diagnostics blocks that can be configured to monitor various parameters of the Controller. The Diagnostic Function Block is defined in section 0. Please refer there for detailed information how these setpoints are used.

Setpoint Name	Value	Comment
SP Fault Detection is Enabled	1	True
SP Function Type to Monitor	9	Additional Control Data
SP Function Parameter to Monitor	1	Additional Control Data #1
SP Enable Source	0	Control not Used
SP Enable Number		Parameter not used with current Enable Source selected
SP Enable Response		Parameter not used with current Enable Source selected
SP Maximum Value for Diagnostic Data	48.00	
SP Minimum Value for Diagnostic Data	0.00	
SP Fault Detection Type	1	Min and Max Error
SP Use Hysteresis When Defining Thresholds	1	True
SP Hysteresis	2.00	
SP Event Cleared Only by DM11	0	False
SP High threshold, Set Limit	32.00	
SP High threshold, Clear Limit		Parameter not used - Hysteresis used when defining thresholds
SP Low threshold, Clear Limit		Parameter not used - Hysteresis used when defining thresholds
SP Low threshold, Set Limit	9.00	
SP High threshold, Event Generates a DTC in DM1	1	True
SP High threshold, Lamp Set by Event	0	Protect
SP High threshold, SPN for Event	0x007F004	SPN: 520196
SP High threshold, FMI for Event	3	Voltage Above Normal, Or Shorted To High Source
SP High threshold, Delay Before Event is Flagged	2000	ms
SP Low threshold, Event Generates a DTC in DM1	1	True
SP Low threshold, Lamp Set by Event	0	Protect
SP Low threshold, SPN for Event	0x007F004	SPN: 520196
SP Low threshold, FMI for Event	4	Voltage Below Normal, Or Shorted To Low Source
SP Low threshold, Delay Before Event is Flagged	2000	ms

Figure 17 - Screen Capture of Diagnostic Block Setpoints

Name	Range	Default	Notes
Fault Detection is Enabled	Drop List	False	
Function Type to Monitor	Drop List	0 – Control not used	
Function parameter to Monitor	Drop List	0 – No selection	
Fault Detection Type	Drop List	1 – Min and Max Error	See section 0
Maximum Value for Diagnostic Data	Minimum Value for Diagnostic Data ... 4.28e ⁹	5.0	
Minimum Value for Diagnostic Data	0.0 ... Maximum Value for Diagnostic Data	0.0	
Use Hysteresis When Defining Thresholds	Drop List	False	
Hysteresis	0.0 ... Maximum Value for Diagnostic Data	0.0	
Event Cleared only by DM11	Drop List	False	
High Threshold, Set Limit	Minimum Value for Diagnostic Data ... Maximum Value for Diagnostics Data	32.0	
High Threshold, Clear Limit	Minimum Value for Diagnostic Data ... Maximum Value for Diagnostics Data	0.0	
Low Threshold, Clear Limit	Minimum Value for Diagnostic Data ... Maximum Value for Diagnostics Data	0.0	
Low Threshold, Set Limit	Minimum Value for Diagnostic Data ... Maximum Value for Diagnostics Data	9.0	
High Threshold, Event Generates a DTC in DM1	Drop List	True	
High Threshold, Lamp Set by Event	Drop List	0 – Protect	See Table 8
High Threshold, SPN for Event	0...524287	520448 (\$7F100)	It is the user's responsibility to select an SPN that will not violate the J1939 standard.
High Threshold, FMI for Event	Drop List	3, Voltage Above Normal	See Table 9
High Threshold, Delay Before Event is Flagged	0...60000 ms	1000	
Low Threshold, Event Generates a DTC in DM1	Drop List	True	
Low Threshold, Lamp Set by Event	Drop List	Amber Warning	See Table 8
Low Threshold, SPN for Event	0...524287	521216 (\$7F400)	It is the user's responsibility to select an SPN that will not violate the J1939 standard.
Low Threshold, FMI for Event	Drop List	4, Voltage Below Normal	See Table 9
Low Threshold, Delay Before Event is Flagged	0...60000 ms	1000	

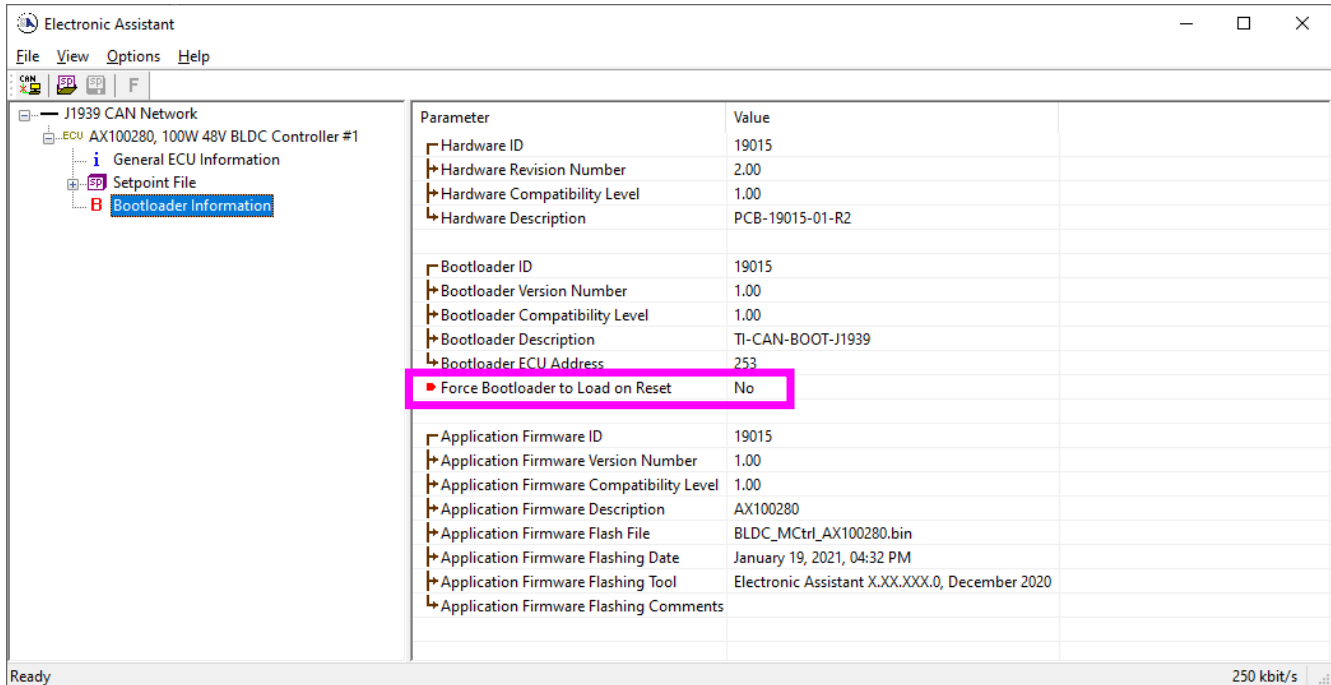
Table 25 – Diagnostic Block Setpoints

5. REFLASHING OVER CAN WITH THE AXIOMATIC EA BOOTLOADER

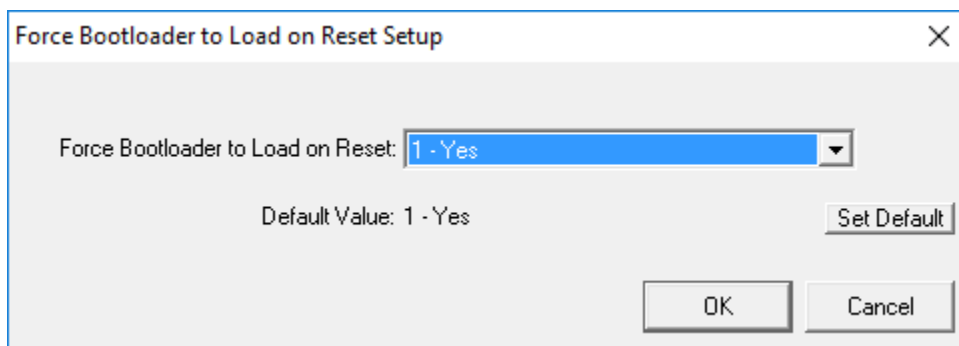
The AX100280 can be upgraded with new application firmware using the **Bootloader Information** section. This section details the simple step-by-step instructions to upload new firmware provided by Axiomatic onto the unit via CAN, without requiring it to be disconnected from the J1939 network.

Note: To upgrade the firmware use Axiomatic Electronic Assistant V5.xx.yy.0 or higher.

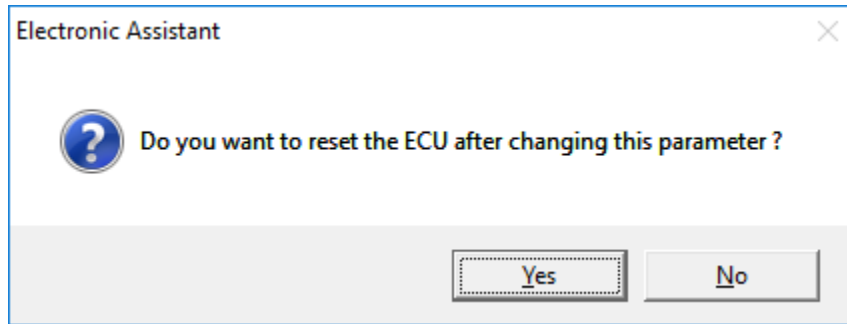
1. When the Axiomatic EA first connects to the ECU, the **Bootloader Information** section will display the following information.



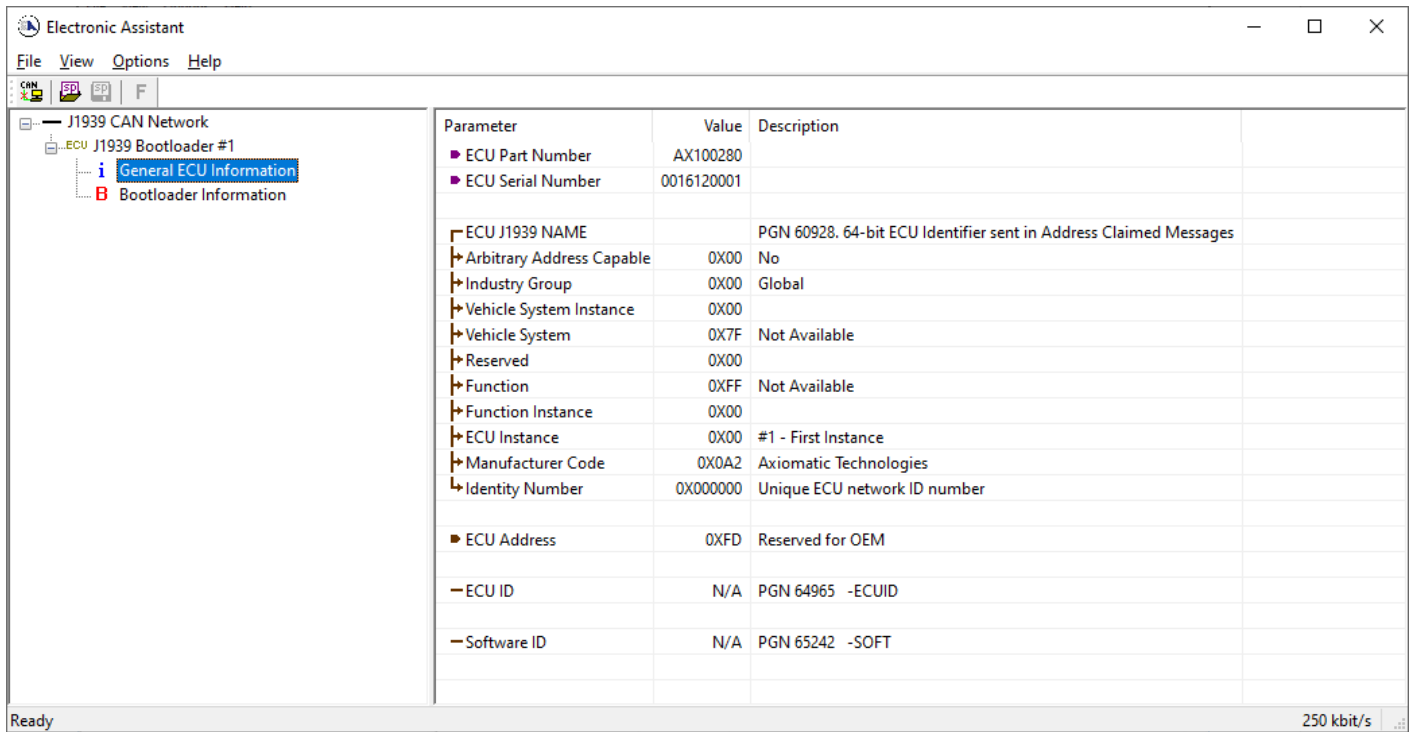
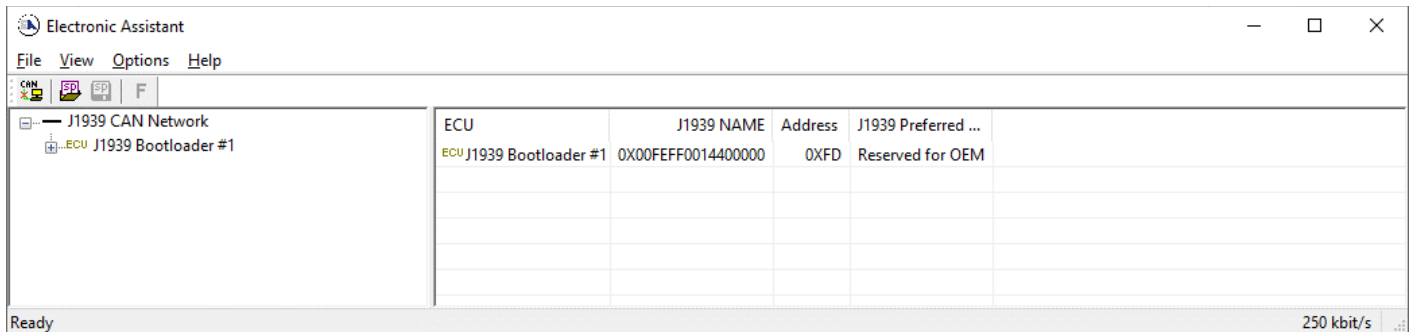
2. To use the bootloader to upgrade the firmware running on the ECU, change the variable “**Force Bootloader To Load on Reset**” to Yes.



3. When the prompt box asks if you want to reset the ECU, select Yes.

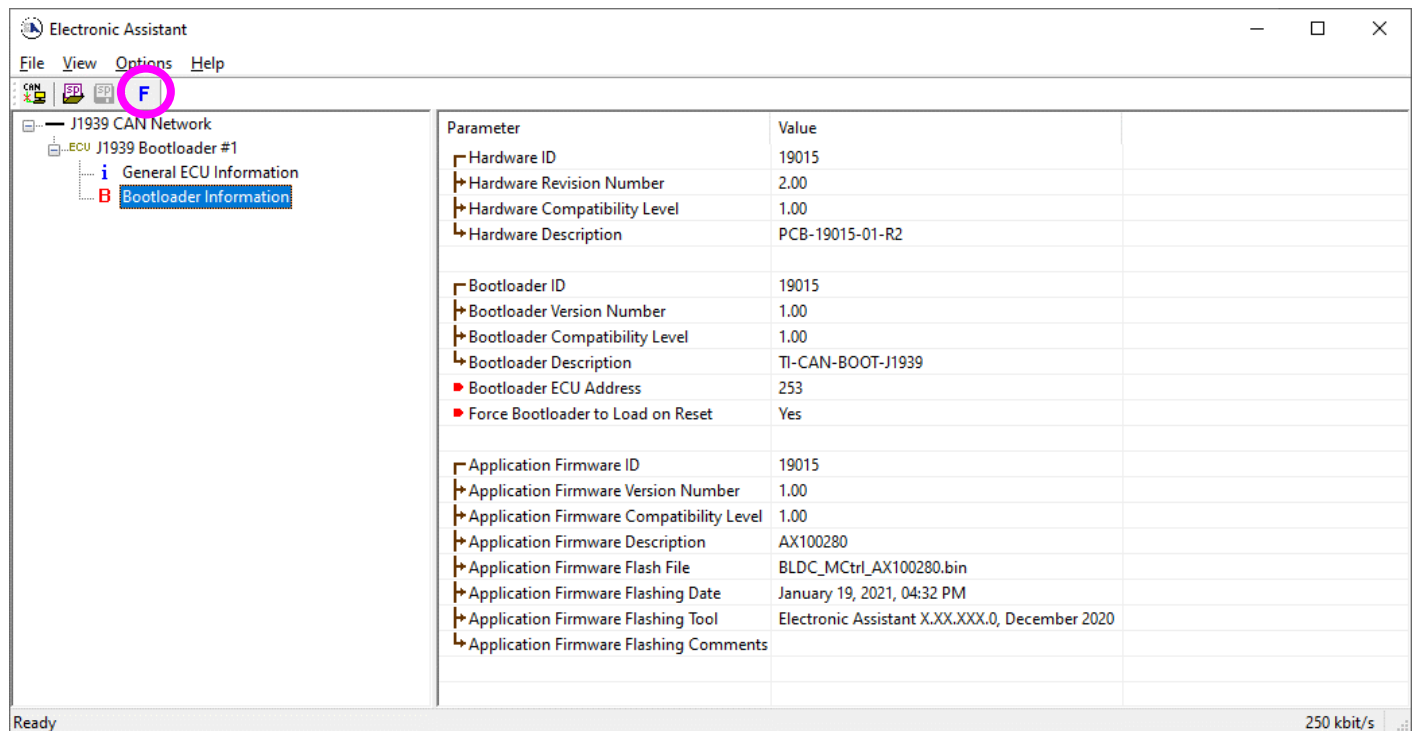


4. Upon reset, the ECU will no longer show up on the J1939 network as an AX100280 but rather as **J1939 Bootloader #1**.



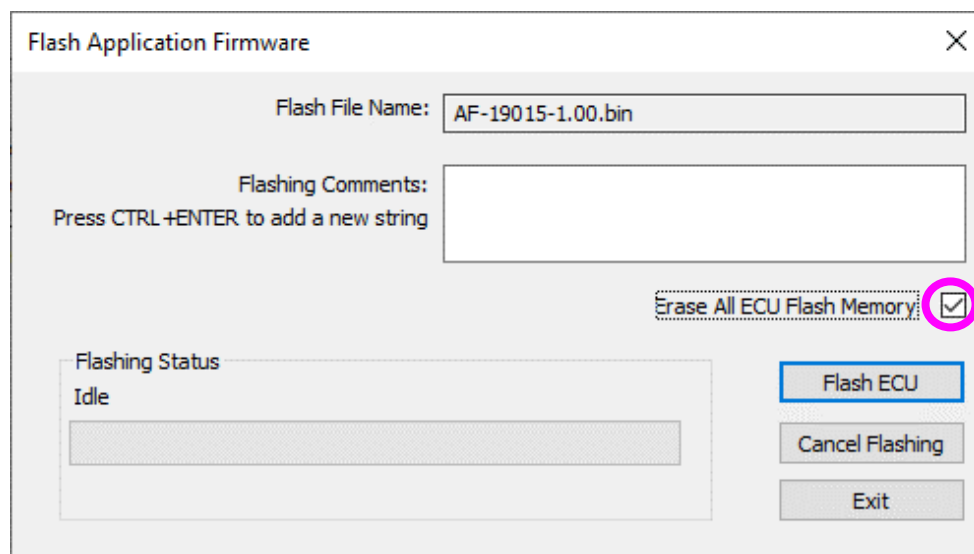
Note that the bootloader is NOT Arbitrary Address Capable. This means that if you want to have multiple bootloaders running simultaneously (not recommended) you would have to manually change the address for each one before activating the next, or there will be address conflicts. And only one ECU would show up as the bootloader. Once the 'active' bootloader returns to regular functionality, the other ECU(s) would have to be power cycled to re-activate the bootloader feature.

5. When the **Bootloader Information** section is selected, the same information is shown as when it was running the AX100280 firmware, but in this case the **Flashing** feature has been enabled.



6. Select the **Flashing** button and navigate to where you had saved the **AF-19015-x.xx.bin** file sent from Axiomatic. (Note: only binary (.bin) files can be flashed using the Axiomatic EA tool.)
7. Once the Flash Application Firmware window opens, you can enter comments such as “Firmware upgraded by [Name]” if you so desire. This is not required, and you can leave the field blank if you do not want to use it.

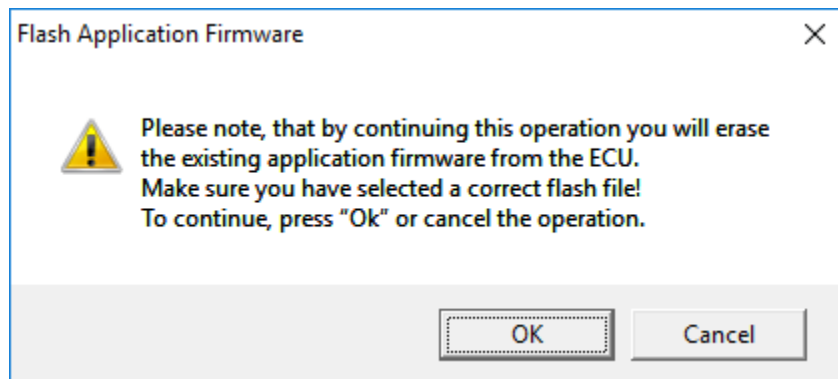
Note: You do not have to date/timestamp the file, as this is done automatically by the Axiomatic EA tool when you upload the new firmware.



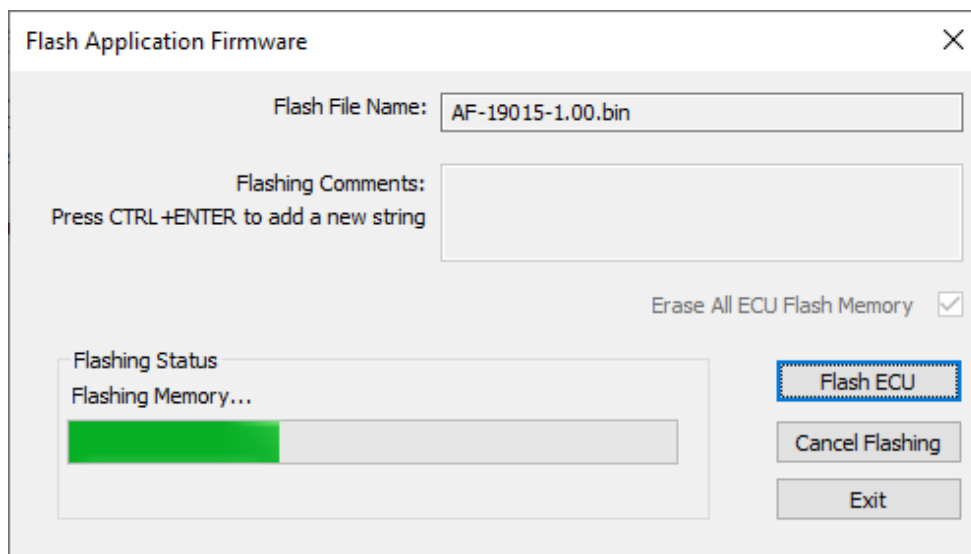


NOTE: Please make sure that the “Erase All ECU Flash Memory” box is checked. Selecting this will erase ALL data stored in non-volatile flash. It will also erase any configuration of the setpoints that might have been done to the ECU and reset all setpoints to their factory defaults. **If this box is left unchecked, the firmware upload will FAIL.**

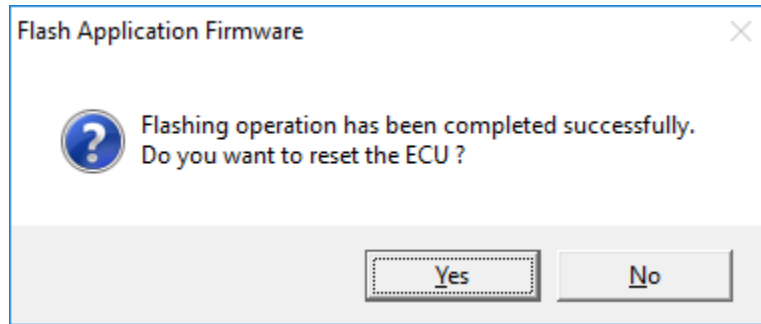
When proceeding to flashing with the “Erase All ECU Flash Memory” option checked, the Axiomatic EA will warn the user about erasing all setpoint data.



A progress bar will show how much of the firmware has been sent as the upload progresses. The more traffic there is on the J1939 network, the longer the upload process will take.



Once the firmware has finished uploading, a message will pop up indicating the successful operation. If you select to reset the ECU, the new version of the AX100280 application will start running, and the ECU will be identified as such by the Axiomatic EA. Otherwise, the next time the ECU is power-cycled, the AX100280 application will run rather than the bootloader function.



Note: If at any time during the upload the process is interrupted, the data is corrupted (bad checksum) or for any other reason the new firmware is not correct, i.e. bootloader detects that the file loaded was not designed to run on the hardware platform, the bad or corrupted application will not run. Rather, when the ECU is reset or power-cycled the **J1939 Bootloader** will continue to be the default application until valid firmware has been successfully uploaded into the unit.

APPENDIX A - TECHNICAL SPECIFICATION

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 www.axiomatic.com/service.html.

Input Specifications

Power Supply Input - Nominal	12, 24 or 48Vdc nominal (9...65Vdc)
Reverse Polarity Protection	Provided up to -100Vdc
Surge Protection	Provided
Under-voltage Protection	Built-in
Signal Inputs	<p>Four (4) universal inputs are user selectable as: Voltage; Current; Resistive; PWM; Frequency; or Digital types.</p> <p>12-bit Analog to Digital resolution Protected against short to ground Amplitude: up to +Vsupply</p> <p>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.</p>
Analog/Digital Ground	One (1) is provided.
Ignition Switch Input	The ignition key input turns the unit power ON. Minimum 2.5V, maximum +Vps
Motor Feedback	<p>Hall Effect Sensor Standard open collector/drain hall input type +5V supply and ground connection pins are provided. 1K Pullup to +5V per input</p> <p>Sensorless operation is also available.</p>

Table 1.0 Inputs (Up to 4 user selectable inputs)	
Inputs	Description
universal Signal Inputs 1-4	<p>Up to 4 universal signal inputs are available.</p> <p>Voltage Input Types: 0...5VDC or 0...10VDC 1mV resolution, accuracy +/- 1% error The offset is in millivolts and the resolution is mV/bit, when sending a CAN message. Input measurement setpoints are interpreted in volts.</p> <p>Current Input Types: 4...20mA or 0...20mA 1uA resolution, accuracy +/- 1% error The offset is in microamps and the resolution is μA/bit, when sending a CAN message. Input measurement setpoints are interpreted in milliamps. Current sense resistor 249Ω</p> <p>Resistive Type with Auto Ranging and Self Calibration: 20 Ω to 250KΩ, +/- 1% error</p> <p>PWM Input Type: PWM Signal Frequency: 0Hz to 10kHz PWM Duty Cycle: 0 to 100% 0.01% resolution, accuracy +/- 1% error</p> <p>Frequency Input Type: 1.3kHz to 15kHz</p> <p>Digital Input Types: Normal, Inverse and Latched Active High with 10K Pullup resistor or Active Low with 10K Pulldown resistor 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).</p>

Output Specifications

Output to Motor	<p>3 phase, H-bridge, current sensing per each phase 10A @ 48Vdc nominal continuous 16A @ 24Vdc nominal continuous 16A @ 12Vdc nominal continuous</p> <p>480W nominal power rating Sensorless or hall sensor operation</p> <p>Overcurrent protection is provided at 24A. Short circuit protection is provided. The maximum rated speed and motor rated current are configurable to suit individual motor specifications.</p>
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	<p>Flexible control is provided by user configurable parameters for Open loop speed Closed loop speed; Current control; Position control; or PID control.</p> <p>The control input to drive the motor can be mapped to any of the universal inputs or the controller can respond to messages from a CAN bus.</p>
Thermal Protection	Thermal protection is built-in and configurable.
Reference Voltage	1 +5V, +/- 0.5%, 200 mA

General Specifications

Microprocessor	TI TMS320F28069, 32-bit, 256 KB flash program memory, 100 KB RAM
Motor Control	<p>Standard embedded software is provided.</p> <p>The configurable properties of the controller are divided into function blocks, namely, the Input Function Block, the Control Logic Block, the Diagnostic Function Block, the CAN Transmit Message Function Block and the CAN Receive Message Function Block.</p> <p>The Motor Parameters setpoint group supports the configuration of the main motor parameters, such as number of pole pairs, rotor position detection, rated RPM of the motor, PWM frequency to use in Motor Phase drive, commutation sequence to use (Hall sensor method only) and whether to use HW current protection.</p> <p>The following parameters are user configurable. <u>Motor Direction</u>: Unidirectional or bi-directional control from an input or the CAN bus. The direction is also configurable. <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. <u>Control Mode</u>: Open loop speed, closed loop speed, current, position or PID control <u>CAN</u>: CAN bus messages control the motor instead of the signal inputs</p>
Diagnostics	There are 3 Diagnostic blocks that can be configured to monitor various parameters of the Controller. Refer to the User Manual for details.
User Interface	Via the Axiomatic Electronic Assistant for <i>Windows</i> operating systems It comes with a royalty-free license for use.
Flashing over CAN	The controller software can be reflashed over the CAN connection using the Axiomatic EA.
CAN port	1 CAN port (SAE J1939) Auto baud rate detect functionality for SAE J1939 networks Model AX100281 (CANopen®)

Weight	0.60 lb. (0.27 kg) preliminary
Operating Conditions	-40°C to +125°C (-40°F to 257°F)
Protection Rating	IP67
Enclosure and Dimensions	High Temperature Nylon PCB Enclosure – (Equivalent TE Deutsch P/N: EEC-325X4B) 4.68 x 5.25 x 1.42 inches 119 x 133 x 36 mm (W x L x H excluding mating plugs) <i>Refer to Installation Instructions.</i>
Electrical Connections	24-pin receptacle (equivalent TE Deutsch P/N: DTM13-12PA-12PB-R008) <i>Refer to Installation Instructions for pinout.</i> Wires should be of the appropriate gauge to meet requirements of applicable electric codes and suit the specifications of the connector(s).
Mating Plug Kit	A mating plug kit comprised of all mating connectors is available as P/N: PL-DTM06-12SA-12SB. It is equivalent to the TE Deutsch P/Ns: DTM06-12SA; DTM06-12SB: 2 wedgelocks WM12S; and 24 contacts 0462-201-20141. 20 AWG wire is recommended for use with contacts 0462-201-20141.
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 holes sized for ¼ inch or M6 bolts. The bolt length will be determined by the end-user's mounting plate thickness. The mounting flange of the controller is 0.63 inches (16 mm) thick. If the module is mounted without an enclosure, it should be mounted vertically with connectors facing left and right to reduce likelihood of moisture entry. The CAN wiring is considered intrinsically safe. The power wires are not considered intrinsically safe and so in hazardous locations, they need to be located in conduit or conduit trays at all times. The module must be mounted in an enclosure in hazardous locations for this purpose. All field wiring should be suitable for the operating temperature range.

Notes:

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Gateways, CAN/Modbus, RS-232
Gyroscopes, Inclinometers
Hydraulic Valve Controllers
Inclinometers, Triaxial
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Motor Controls, Inverters
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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. Any inquiries should be sent to 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.

SERVICE

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