40A BLDC MOTOR CONTROLLER
with CAN, SAE J1939

USER MANUAL

P/N: AX100250

P/N: AX100250-01 – J1939 500kbits/s Baud Rate

P/N: AX100250-02 – Custom J1939 Baud Rate, 1Mbits/s

VERSION HISTORY

Version	Date	Author	Modification
1.0.0	Mar 29, 2022	Antti Keränen	Initial version.
1.0.1	Jun 13, 2022	Antti Keränen	Dimensions and pinout section updated.
-	Jun 13, 2022	Amanda Wilkins	Added quiescent current and weight
-	December 2, 2022	Sabrina Tang	Changed specification
1.0.2	September 1, 2023	Kiril Mojsov	Performed Legacy Updates
1.0.3	January 4, 2024	M Ejaz	Updated block diagram to remove reverse polarity protection
1.0.4	February 22, 2024	Antti Keränen	Added Torque and RPM control source description.
1.0.5	February 29, 2024	M Ejaz	Updated weight Updated technical specifications

ACRONYMS

ACK	Positive Acknowledgement (from SAE J1939 standard)
BATT +/-	Battery positive (a.k.a. Vps) or Battery Negative (a.k.a. GND)
BEMF	Back Electromotive Force / Counter-electromotive Force
DM	Diagnostic Message (from SAE J1939 standard)
DTC	Diagnostic Trouble Code (from SAE J1939 standard)
EA	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
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

TABLE OF CONTENTS

REFERENCES

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 2017
TDAX100250	Technical Datasheet, 40A BLDC Motor Controller with CAN, Axiomatic Technologies
UMAX07050x	User Manual, Axiomatic Electronic Assistant and USB-CAN, Axiomatic Technologies

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.

1. OVERVIEW OF CONTROLLER
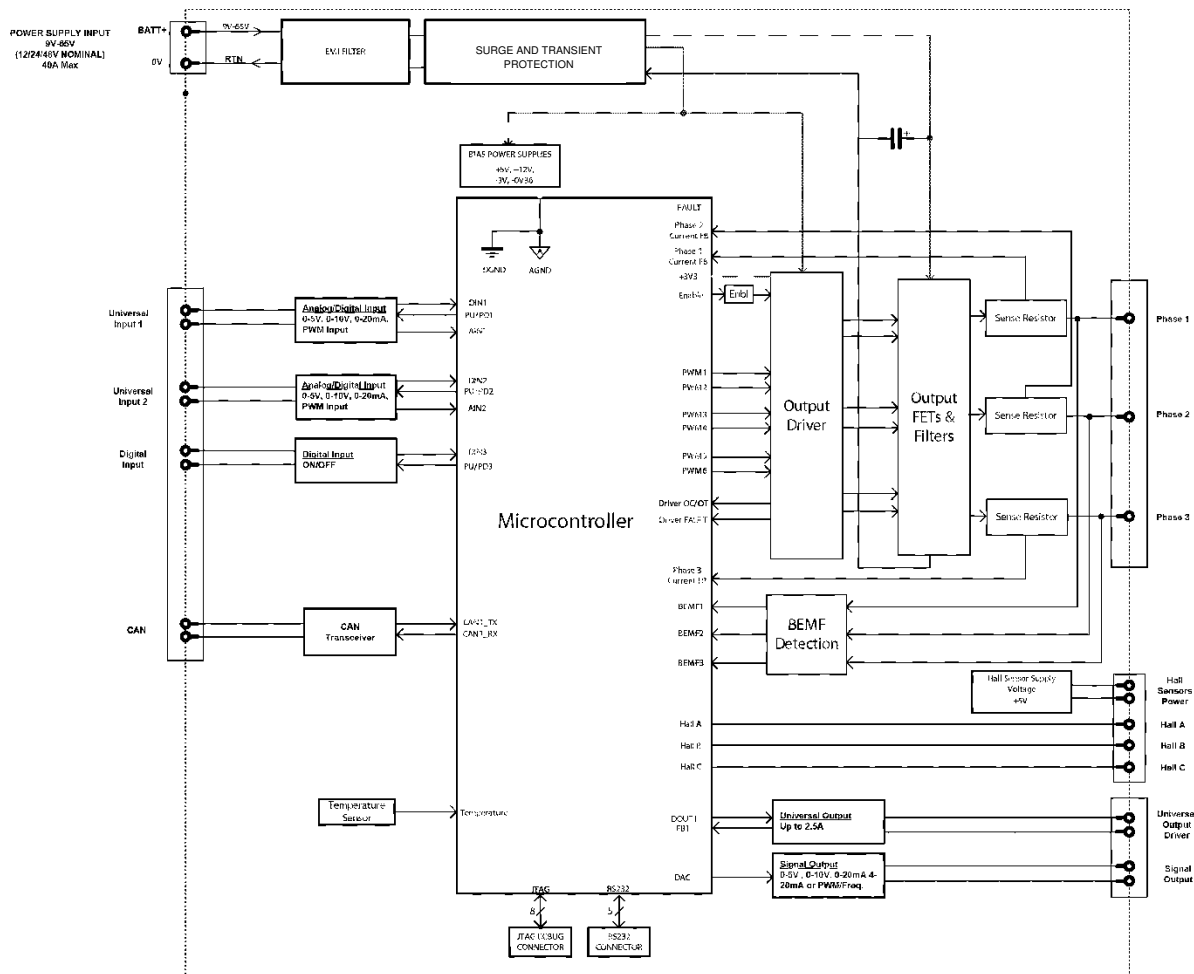
Figure 1 – AX100250 Block Diagram

The AX100250 BLDC motor controller implements the 6 step sensorless BLDC commutation algorithm, it supports controlling a BLDC motor with Hall sensors or using sensorless motor control. In addition to the CAN bus interface, the BLDC controller has three inputs (two universal and one digital) and two outputs (one proportional current and one analog signal) that can be used for interfacing the controller.

The *Windows*-based Axiomatic Electronic Assistant (EA) is used to configure the controller via an USB-CAN (AX070501) device. Setpoint configuration can be saved in a file which can be used to easily program the same configuration into another 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, "**Rotor position detection**" setpoint set to option '*Sensorless*'.

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

AX100250	Controller with the default J1939 baud rate (250kbits/s).
AX100250-01	Controller with the 500kbits/s J1939 baud rate.
AX100250-02	Controller with a custom 1Mbits/s J1939 baud rate.

1.1. Motor Control Functionality

There are multiple setpoints accessible with the Axiomatic EA that allow the user to configure the 40A BLDC controller to drive a variety of different BLDC motors.

The Motor Parameters setpoint group (see section 4.3) supports the configuration of the main motor parameters, such as number of pole pairs, rated RPM of the motor and PWM frequency to use in motor drive.

"**Number of pole pairs**" has direct influence on how the 40A BLDC controller picks up the motor RPM, this parameter should be always set to correspond the motor driven by the controller.

"**Rotor position detection**" selects the algorithm for position detection, the options are '*Hall sensors*' and '*Sensorless*'.

"**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.

"**Rated motor current**" defines the max current to use when driving the motor. This current limit is used together with the PI Current Controller current limit to define the hardware over current limit to use (the smaller one of the two is used).

"**PWM Frequency**" sets the frequency to use in the Phase outputs' PWM signal in kHz. This also sets the ISR tick time used in sensorless startup parameters (see section 4.9), 1 tick time = 1k * PWM Frequency^{-1}

"**Commutation sequence**" sets the offset to the Hall sensor states vs. phase drive sequence. Most motors will work with the default setting, '*0 – Version 1*'. This setting offsets the 'Hall, combined' values in Table 1.

The Hall sensor states have the following default values and the phase outputs are driven like shown in Table 1. The column "Hall, combined" shows the value programmed with the Axiomatic EA. The combined Hall state is calculated using:

$$Hall, combined = (Hall_A) \ll 2 + (Hall_B) \ll 1 + Hall_C$$

Hall, combined	Hall C	Hall B	Hall A	Phase A	Phase B	Phase C
2	0	1	0	**PWM**	OFF	**LOW**
3	1	1	0	OFF	**PWM**	**LOW**
1	1	0	0	**LOW**	**PWM**	OFF
5	1	0	1	**LOW**	OFF	**PWM**
4	0	0	1	OFF	**LOW**	**PWM**
6	0	1	1	**PWM**	**LOW**	OFF

Table 1 – Default commutation sequence

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).

"**Over temperature threshold**" defines the max drive stage temperature. If the temperature rises above this limit, motor driving is derated and a diagnostic status can be flagged using the Diagnostics Blocks.

"**Motor Current Filter Constant**" and "**Motor RPM Filter Constant**" define filter coefficients for repeating average filters used in motor current and motor rpm measurements.

The motor can be controlled using two control sources. When the motor is driven in open loop mode, the **"Motor Torque Control Source"** sets the motor drive, and the **"Motor RPM Control Source"** is not used. In closed loop control, the torque control source sets the maximum motor pwm drive and speed control source sets the target rpm.

In closed loop current control, the **"Closed loop current limit"** setpoint sets the maximum motor current limit. The motor current PI controller keeps the motor current at this value or below it, depending on the motor speed and load.

In case there is a need to use a combined direction and enable signaling, for example a CAN message containing both information, this is possible to configure by setting the **"Direction Control Source"** to '*Control Not Used'* and **"Motor Enable Control Source"** to '*Received CAN Message.*' With this configuration, the received CAN message values are used as listed in Table 2. CAN Receive Messages #1 and #2 are configured to implement this type of control by default.

CAN rx data	Resulting motor drive
0	*Disabled*
1	*Motor enabled in forward direction*
2	*Motor enabled in reverse direction*
3	*Reserved (disabled)*

Table 2 – Combined enable and direction signals

1.1.1. Sensorless Control

The sensorless motor control is based on detecting the back emf voltage on the free phase while the motor is running. The sensorless motor control uses trapezoidal commutation, in a similar fashion that the Hall sensor-based motor control does. While the back emf voltage is available only when the motor is running, the startup procedure is carried out without knowing whether the rotor rotates or not. Depending on the motor in question, the user must tune the startup parameters in "**Sensorless startup parameters**" setpoint group (see section 4.9).

rpm

start command

open -> closed loop

t = ((1000-300) * 20) / 10kHz = 1.4s
in which 1000, 300 and 20 are parameters for the forced angle drive,
namely the 'Initial startup ramp step length',
'final startup step length' and 'startup ramp acceleration'. 10kHz is the
pwm drive frequency

rpm controlled by speed
controller (open/closed loop)

rpm controlled by forced angle
drive.

time
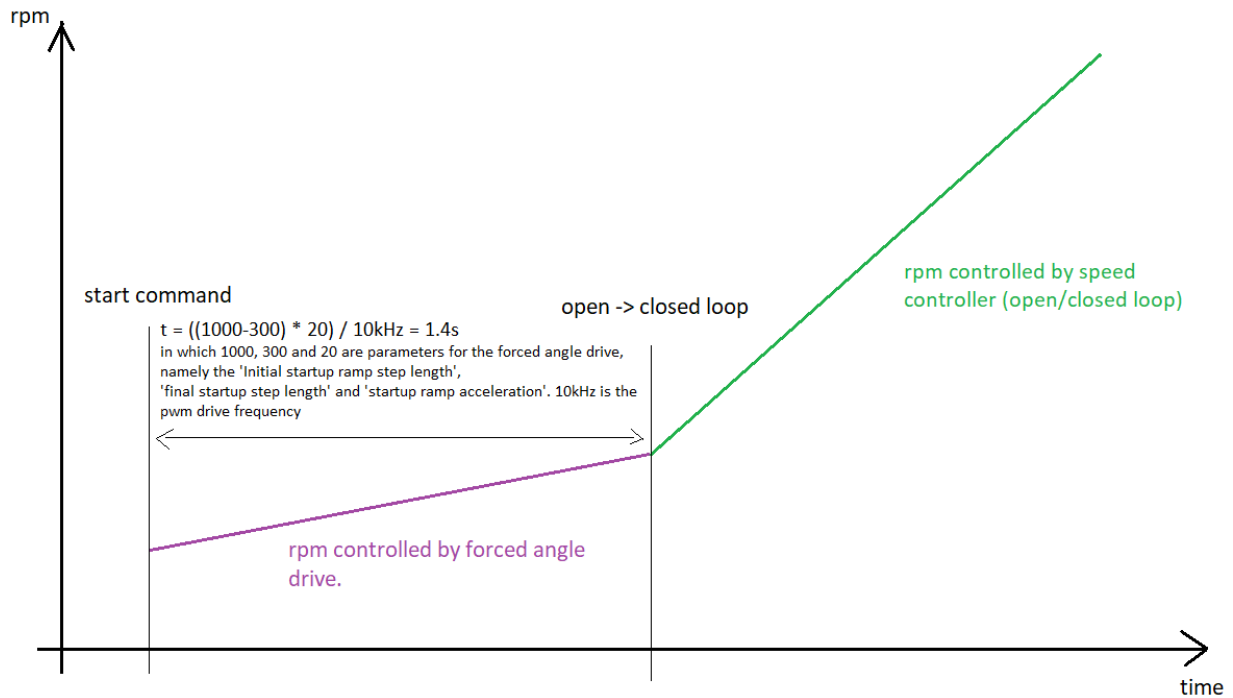
Figure 2 – Sensorless drive startup steps

The sensorless startup is carried out like this:

1. *Forced angle drive*

    During the initial forced angle drive 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 forced angle drive, together with initial and final rotor speed can be configured in "**Sensorless startup parameters**". 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 forced angle drive duration and the rotor speed is determined by the following formulas, in which 10kHz is the default execution speed of the low-level commutation algorithm ("**PWM Frequency**" setpoint in Motor Parameters) and coefficient '6' is the number of drive states in one electrical revolution.

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

$$rpm_{ramp-start} = \frac{10kHz * 60}{Initial\ st.up\ ramp\ step\ length * 6 * Number\ of\ pole\ pairs}$$

$$rpm_{ramp-end} = \frac{10kHz * 60}{Final\ st.up\ ramp\ step\ length * 6 * Number\ of\ pole\ pairs}$$

With default settings, the ramp-up phase duration is 1.4s.

2. Normal Operation

After the forced angle drive 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.

1.2. Universal Inputs

Selecting input type using the "**Input Sensor Type**" setpoint influences 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 3.

0	*Disabled*
12	*Voltage 0 to 5 V*
13	*Voltage 0 to 10 V*
20	*Current 0 to 20 mA*
21	*Current 4 to 20 mA*
30	*Resistive*
40	*Frequency 0.5 to 50 Hz*
41	*Frequency 10 Hz to 1 kHz*
42	*Frequency 100 Hz to 10 kHz*
50	*PWM Low Frequency (<1kHz)*
51	*PWM High Frequency (>100Hz)*
60	*Digital (normal)*
61	*Digital (inverse)*
62	*Digital (latched)*
80	*Quadrature Decoder*

Table 3 – 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 250Ω resistor is used to measure the input signal.

Frequency/RPM or Pulse Width Modulated (PWM) "**Input Sensor Type**" options connect an input to 16-bit timer pin on the processor.

The "**Pulses/Units Per Revolution**" setpoint can be used with Frequency input types. If this setpoint is set to '*yes*', then the input data will be expressed in rpm instead of Hz.

Universal Inputs have also 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 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 4. By default, pull-down resistors are enabled for all inputs.

0	*Pullup/down Off*
1	*10 kΩ Pullup*
2	*10 kΩ Pulldown*
3	*10 kΩ Pullup+pulldown*

Table 4 – 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 5. 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 5 – Active High/Low Options

Table 6 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	*Digital (normal)*	High	Low or Open	1 (ON)
		Low or Open	High	0 (OFF)
61	*Digital (inverse)*	High or Open	Low	1 (ON)
		Low	High or Open	0 (OFF)
62	*Digital (latched)*	High to Low	Low to High	0 (no change)
		Low to High	High to Low	1 (state change)

Table 6 – Digital Input Sensor Type versus Input State

The "**Minimum Range**" and "**Maximum Range**" setpoints are used to define range of the signal input outputs as a control source. For example, if "**Maximum Range**" is set to 4V for an input, the control signal is saturated at 4V if input signal rises above 4V. The "**Minimum Range**" and "**Maximum Range**" setpoints are interpreted in input type of units, thus they should be re-adjusted after editing "**Input Sensor Type**".

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.

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

0	*No Filtering*
1	*Moving Average*
2	*Repeating Average*

Table 7 – 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 control data, $Value_{N-1}$ is the previous control 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 N^{th} read, the sum is divided by N, and the result is new control data. The sum is set to zero for the next read and summing is started again.

1.2.1. Digital Input

The input sensor types for Digital Inputs are listed in Table 8. Other than the different input type list, the Digital Input supports the same configuration options than the Universal Inputs.

0	*Disabled*
40	*Frequency 0.5 to 50 Hz*
41	*Frequency 10 Hz to 1 kHz*
42	*Frequency 100 Hz to 10 kHz*
50	*PWM Low Frequency (<1kHz)*
51	*PWM High Frequency (>100Hz)*
60	*Digital (normal)*
61	*Digital (inverse)*
62	*Digital (latched)*

Table 8 – Digital Input Sensor Type Options

1.3. Signal Output

The analog signal output can generate either a voltage or a current signal. The signal is generated using a 16-bit DAC.

0	*Disabled*
1	*Voltage 0-5V*
2	*Voltage 0-10V*
3	*Current 0-20mA*
4	*Current 4-20mA*

Table 9 – Analog Signal Output Type Options

In addition to the "**Output Control Source**" and "**Output Control Number**" setpoints, the analog signal output has five scaling setpoints.

The "**Analog Output Signal Max**" defines the maximum signal output from the output pin. To have 1-to-1 scaling, this setpoint needs to be set to match the selected output range maximum. For example, with a 0-10V output, this setpoint needs to be set to 10.0. The same applies for the "**Analog Output Signal Min**", for 0-10V output range, this setpoint needs to be set to 0.0.

The "**Analog Output Data Max**" and "**Analog Output Data Min**" define the maximum and minimum limits for the controlling signal. The default settings use motor rpm as the control source. In this case, the maximum control source value is 6600 rpm, as set by the "Rated Motor RPM" setpoint. The "**Analog Output Data Offset**" can be used for adding static offset to the control data.

1.4. Proportional Current Output

Changing the "**Output Type**" setpoint causes other setpoints in the group to update to match selected type, thus the "**Output Type**" should be selected before configuring other setpoints within the setpoint group. "**Output Type**" setpoint options are listed in Table 10.

0	*Disabled*
1	*Proportional Current (0-2.5A)*
2	*Digital Hotshot (0-2.5A)*
3	*PWM Duty Cycle (0-100%)*
4	*Digital On/Off (0-Vps)*

Table 10 – Output Type Options for Proportional Output

'*Proportional Current*' type has associated with it two setpoints not used by other types, which are the "**Dither Frequency**" and "**Dither Amplitude**" values. The output is controlled by high frequency signal (25kHz), with the low frequency dither superimposed on top. The dither frequency will match exactly what is programmed into the setpoint, but the exact amplitude of the dither will depend on the properties of the load coil. When adjusting the dither amplitude value, select one that is high enough to ensure an immediate response to the coil to small changes in the control inputs, but not so large as to affect the accuracy or stability of the output. Refer to the coil's datasheet for more information.

The '*PWM Duty Cycle*' option allows the user to run the output at fixed frequency configured with "**PWM Output Frequency**" setpoint. While the duty cycle changes depending on the control signal, the "**PWM Output Frequency**" is editable only using the setpoint if the output is set to '*PWM Duty Cycle*' type. Configuring output to '*Proportional Current*' or '*Hotshot Digital*' type changes frequency automatically to 25kHz.

Instead of proportional output control, there are also two types of digital responses possible as well. With the '*Digital On/Off*' type, should the control require the output to be on, it will be turned on at whatever the system power supply is. The output will source whatever current is required by the load, up to 2.5A.

If a digital **"Output Type"** has been selected the **"Digital Response"** setpoint will be enabled as shown in Table 11.

| 0	Normal On/Off
1	Inverse Logic
2	Latched Logic
3	Blinking Logic

Table 11 – Digital Response Options

In a '*Normal*' response, when the Control input commands the output ON, then the output will be turned ON. However, in an '*Inverse*' response, the output will be ON unless the input commands the output ON, in which case it turns OFF.

If a '*Latched*' response is selected, when the input commands the state from OFF to ON, the output will change state.

If a '*Blinking*' response is selected, then while the input commands the output ON, it will blink at the rate in the **"Digital Blink Rate"** setpoint. When commanded OFF, the output will stay off. A blinking response is only available with a '*Digital On/Off*' type of output (not a Hotshot type.)

The '*Hotshot Digital*' type is different from in simple '*Digital On/Off*' in that it still controls the current through the load. This type of output is used to turn on a coil then reduce the current so that the valve will remain open, as shown in Figure 3. Since less energy is used to keep the output engaged, this type of response is very useful to improve overall system efficiency. With this output type there are associated three setpoints: "**Hold Current**", "**Hotshot Current**" and "**Hotshot Time**" which are used to configure form of the output signal as shown in Figure 3.
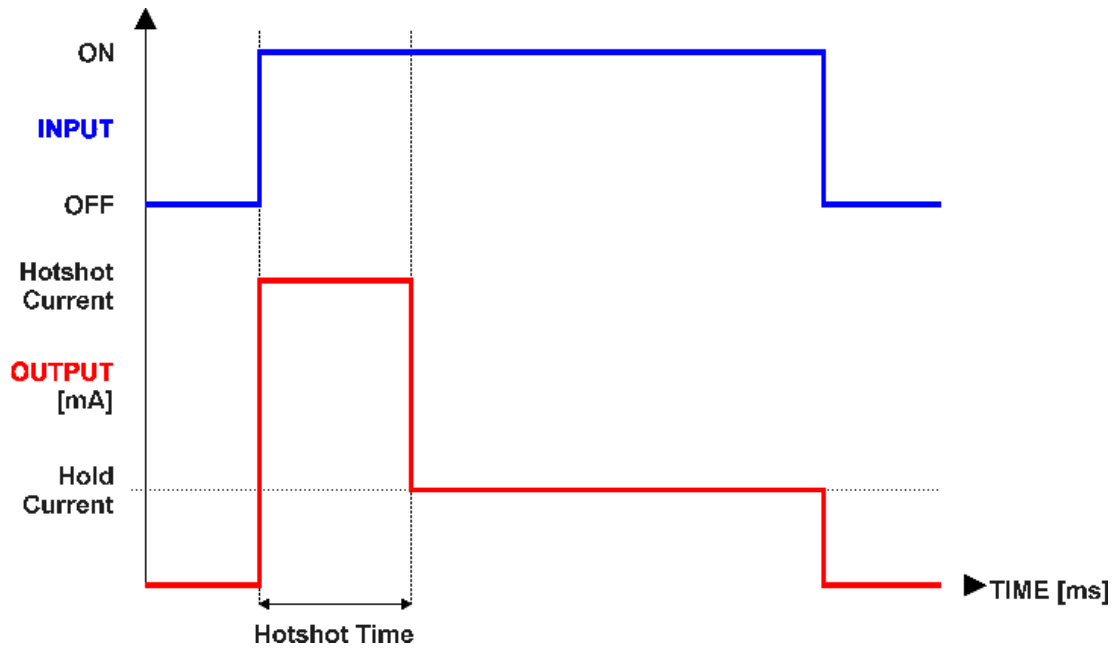
Figure 3 – Hotshot Digital Profile

For Proportional outputs signal minimum and maximum values are configured with "**Output At Minimum Command**" and "**Output At Maximum Command**" setpoints. Value range for both setpoints is limited by selected "**Output Type**".

Regardless of what type of control input is selected, the output will always respond in a linear fashion to changes in the input per Equation 3.

$$y = mx + a$$

$$m = \frac{Ymax - Ymin}{Xmax - Xmin}$$

$$a = Ymin - m * Xmin$$

Equation 3 - Linear Slope Calculations

In the case of the Output Control Logic function block, X and Y are defined as

Xmin = Control Input Minimum   Ymin = "**Output at Minimum Command**"

Xmax = Control Input Maximum   Ymax = "**Output at Maximum Command**"

In all cases, while X-axis has the constraint that Xmin < Xmax, there is no such limitation on the Y-axis. Thus configuring "**Output At Minimum Command**" to be greater than "**Output At Maximum Command**" allows output to follow control signal inversely.

In order to prevent abrupt changes at the output due to sudden changes in the command input, the user can choose to use the independent up or down ramps to smooth out the coil's response. The "**Ramp Up**" and "**Ramp Down**" setpoints are in milliseconds, and the step size of the output change will be determined by taking the absolute value of the output range and dividing it by the ramp time.

The "**Control Source**" setpoint together with "**Control Number**" setpoint determine which signal is used to drive the output. For example, setting "**Control Source**" to '*Universal Input Measured'* and "**Control Number**" to '*1*', connects signal measured from Universal Input1 to the output in question. The input signal is scaled per input type range between 0 and 1 to form control signal. Outputs respond in a linear fashion to changes in control signal. If a non-digital signal is selected to drive digital output the command state will be 0 (OFF) at or below the "**Output At Minimum Command**", 1 (ON) at or above "**Output At Maximum Command**" and will not change in between those points.

In addition to the Control input, Proportional Outputs also support Enable and Override inputs.

The "**Enable Source**" setpoint together with "**Enable Number**" setpoint determine the enable signal for the output in question. The "**Enable Response**" setpoint is used to select how output will respond to the selected Enable signal. "**Enable Response**" setpoint options are listed in Table 12.

0	*Enable When On, Else Shutoff*
1	*Enable When On, Else Rampoff*
2	*Enable When Off, Else Shutoff*
3	*Enable When Off, Else Rampoff*
4	*Enable When On, Else Ramp To Min*
5	*Enable When On, Else Ramp To Max*

Table 12 – Enable Response Options

Override input allows the output drive to be configured to go to a default value in the case of the override input being engaged/disengaged, depending on the logic selected in "**Override Response**", presented on Table 13. When active, the output will be driven to the value in "**Output at Override Command**" regardless of the value of the Control input. The "**Override Source**" and "**Override Number**" together determine the Override input signal.

0	*Override When On*
1	*Override When Off*

Table 13 – Override Response Options

If a fault is detected in any of the active inputs (Control/Enable/Override) the output will respond per "**Control Fault Response**" setpoint as outlined in Table 14. Fault Value is defined by "**Output in Fault Mode**" setpoint value, which is interpreted in selected output units.

0	*Shutoff Output*
1	*Apply Fault Value*
2	*Hold Last Value*

Table 14 – Fault Response Options

Fault detection is available for current output types. A current feedback signal is measured and compared to desired output current value. Fault detection and associated setpoints are presented in section 0.

The outputs are inherently protected against a short to GND or +Vps by circuitry. In case of a dead short, the hardware will automatically disable the output drive, regardless of what the processor is commanding for the output. When this happens, the processor detects output hardware shutdown and commands off the output in question. It will continue to drive non-shorted outputs normally and periodically (every 5 seconds) try to re-engage the short load, if still commanded to do so. If the fault has gone away since the last time the output was engaged while shorted, the controller will automatically resume normal operation.

In the case of an open circuit, there will be no interruption of the control for any of the outputs. The processor will continue to attempt to drive the open load.

The measured current through the load is available to be broadcasted on a CAN message if desired. It is also used as the input to the diagnostic function block for each output, and an open or shorted output can be broadcasted in a DM1 message on the CAN network.

1.5. Lookup Tables

Lookup tables are used to give output response up to 10 slopes per input. They have two differing modes defined by "**X-Axis Type**" setpoint, given in Table 15. Option '0 – Data Response' is the normal mode where block input signal is selected with the "**X-Axis Source**" and "**X-Axis Number**" setpoints and X values present directly input signal values. With option '1 – Time Response' the input signal is time and X values present time in milliseconds. And selected input signal is used as digital enable.

0	Data Response
1	Time Response

Table 15 – X-Axis Type Options

The slopes are defined with (x, y) points and associated point response. X value presents input signal value and Y value corresponding Lookup Table output value. "PointN – Response" setpoint defines type of the slope from preceding point to the point in question. Response options are given in Table 16. 'Ramp To' gives a linearized slope between points, whereas 'Jump to' gives a point-to-point response, where any input value between X_{N-1} and X_N will result Lookup Table output being Y_N. "Point0 – Response" is always 'Jump To' and cannot be edited. Choosing 'Ignored' response causes associated point and all the following points to be ignored.

0	Ignore
1	Ramp To
2	Jump To

Table 16 – PointN – Response Options

In case Time Response is used, the "**Autocycle**" setpoint can be used for generating a repeating, cyclic output while the selected control source enables the time response output of the lookup table.

The values for X-min and X-max are 0 and 1000. The X-Axis is constraint to be in rising order, thus value of the next index is greater than or equal to preceding one. Therefore, when adjusting the X-Axis data, it is recommended that X_{10} is changed first, then lower indexes in descending order.

$$Xmin <= X_0 <= X_1 <= X_2 <= X_3 <= X_4 <= X_5 <= X_6 <= X_7 <= X_8 <= X_9 <= X_{10} <= Xmax$$

The Y-Axis has no constraints on the data it presents, thus inverse, decreasing, increasing or other response can be easily established. The Smallest of the Y-Axis values is used as Lookup Table output min and the largest of the Y-Axis values is used as Lookup Table output max (i.e. used as X-min and X-max values in linear calculation. Ignored points are not considered for min and max values.

1.6. PID Function Blocks

The PID Control function block is an independent logic block, but it is normally intended to be associated with proportional output and motor drive 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 40A 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 17. When active, the PID algorithm will be called every "**PID Loop Update Rate**" in milliseconds.

0	Single Output
1	Dual Output
2	Setpoint Control
3	On When Over Target
4	On When Below Target

Table 17 – PID Response Options

In overall, the Target and Feedback inputs do not have to share the same units. The signals are converted to 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 (for example 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 value 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 only exception is the Control Constant Data as an input to the PID block. The Control Constant Data values are expected to be in range -100% … 100% (values in range -100 … 100 configured to the Control Constant Data setpoints).

To have the PID block output a value in range -100% to 100%, the '*Dual Output*' response needs to be selected. Other than the output range, the '*Dual Output*' mode is equivalent to the '*Single Output*' mode.

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 target 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 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 to get the expected output response. In this mode, the output would be between 0% to 100%.

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 4 - 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.

1.7.   Math Function Blocks

There are two mathematical function blocks that allow the user to define basic algorithms. A math function block can take up to two input signals. Each input is then limited and scaled according to the associated limits and scaling setpoints.

The maximum and minimum values for the input signal are defined using "**Function X Input Y Minimum**" and "**Function X Input Y Maximum**" setpoints. The math block implementation supports values in range -5e5 to 5e5. For additional control the user can also adjust the "**Function X Input Y Scaler**". By default, each input has a scaling 'weight' of 1.0 However, each input can be scaled from -1.0 to 1.0 as necessary before it is applied in the function.

A mathematical function block includes one selectable function, which implements equation A operator B, where A and B are function inputs and operator is function selected with setpoint "**Math function X Operator**". Setpoint options are presented in Table 18. Input is selected by setting "**Function X Input A Source**" and "**Function X Input A Number**". If "**Function X Input B Source**" is set to 0 '*Control not used*' signal goes through function unchanged.

$$Math\ Block\ Output = A1\ op\ B1$$

0	*=, True when InA equals InB*
1	*!=, True when InA not equal InB*
2	*>, True when InA greater than InB*
3	*>=, True when InA greater than or equal InB*
4	*<, True when InA less than InB*
5	*<=, True when InA less than or equal InB*
6	*OR, True when InA or InB is True*
7	*AND, True when InA and InB are True*
8	*XOR, True when either InA or InB is True, but not both*
9	*+, Result = InA plus InB*
10	*-, Result = InA minus InB*
11	*x, Result = InA times InB*
12	*/, Result = InA divided by InB*
13	*MIN, Result = Smallest of InA and InB*
14	*MAX, Result = Largest of InA and InB*
15	*MAX-MIN, Result = Absolute value of (InA – InB)*
16	*ATAN2, Result = atan2(InA, InB)*

Table 18 – Math function X Operator Options

For logic operations (6, 7, 8) input greater or equal to 1 is treated as TRUE. For logic operations (0 to 8), the result of the function will always be 0 (FALSE) of 1 (TRUE).

When dividing, a zero divider will always result in a full (5e5) output value for the associated function.

The setpoints "**Math Output Minimum Range**" and "**Math Output Maximum Range**" are used for defining the math block output value range for other control blocks to use. Please note, that if the math block output exceeds the limits, the math block output data validity is reset and the data can't be used for controlling other blocks.

1.8. Diagnostic Function Blocks

The 40A 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 20 and **Error! Reference source not found.**)
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 40A BLDC Controller supports 3 Diagnostics Definitions, each freely configurable by the user.

By default, the monitoring of operating voltage, CPU temperature and receive message timeouts is configured to diagnostics blocks 1, 2 and 3., In case any of these three diagnostics blocks are needed for some other use, the default settings can be adjusted by the user to suit the application.

There are 4 fault types that can be used, "**Minimum and maximum error**", "**Absolute value error**", "**State error**" and "**Double minimum and maximum error**".

Minimum and maximum error has two thresholds, "MIN Shutdown" and "MAX Shutdown" that have configurable, independent diagnostics parameters (SPN, FMI, Generate DTCs). 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 like 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.

Double minimum and maximum error supports four thresholds, each with independent diagnostic parameters. The diagnostic status and threshold values is determined and expected as show in Figure 4 below.
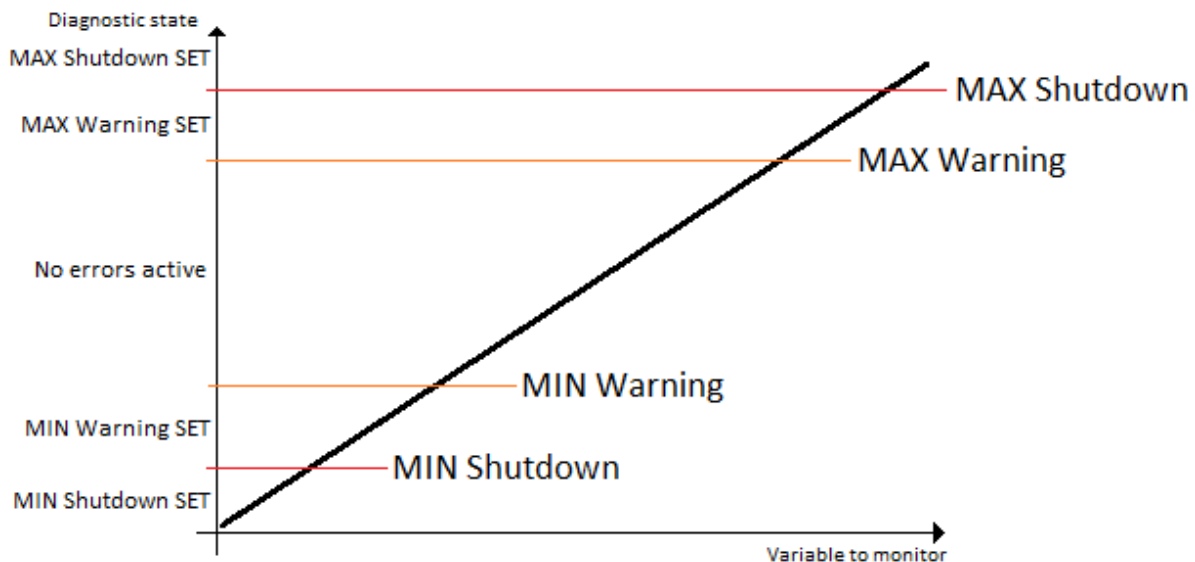
Figure 4 – Double Minimum and Maximum Error Thresholds

In case any of the Diagnostics blocks is configured to monitor Output Current Feedback, there is an internal error status flag maintained automatically for that particular output. This internal flag can be used for driving the output to a specified state in case of diagnostic event using Proportional Current Output setpoints "**Control Fault Response**", "**Output in Fault Mode**" and "**Fault Detection Enabled**".

While there are no active DTCs, the 40A BLDC Controller will send "No Active Faults" message. 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 19. By default, the '*Amber, Warning'* lamp is typically the one set be any active fault.

0	*Protect*
1	*Amber Warning*
2	*Red Stop*
3	*Malfunction*

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

Table 20 – 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 20.

1.9. CAN Transmit Message Function Block

The CAN Transmit function block is used to send any output from another function block (for example measured motor data, CAN receive) to the J1939 network. The AX100250 ECU has four CAN Transmit Messages, and each message has four completely user defined signals.

1.9.1. 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, the first CAN transmit message is configured to report Universal Inputs #1 and #2, motor rpm and motor current.

1.9.2. 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 21. 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.

1.10. 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 (for example for motor drive).

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.

Once a message has been enabled, the previously received data is reset if that message is not received within the "**Receive Message Timeout**" period. 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 is held until the reception of the next message (or a power cycle).

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 40A BLDC controller supports up to four unique CAN Receive Messages.

1.11. 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 21. 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
0: Control Not Used	N/A	When this is selected, it disables all other setpoints associated with the signal in question.
1: Received CAN Message	1 to 4	
2: Universal/Digital Input Measured	1 to 3	
3: PID Function Block	1 to 2	
4: Lookup Table	1 to 2	
5: Math Function Block	1 to 2	
6: Motor RPM Value	1	Measured RPM reading.
7: Motor Current Feedback	1 to 2	Measured motor current in Amps; 1 = phase current, 2 = combined motor current
8: Control Constant Data	1 to 8	1 = FALSE, 2 = TRUE, 3 to 8 = User Selectable
9: Output Target Drive	1 to 2	1 = Prop.output target drive, 2 = Motor target drive
10: Measured Prop. Output Current	1	Measured Proportional Current Output's current (pin
11: Power Supply Voltage	1	Measured power supply value in Volts.
12: Board Temperature	1	Drive stage temperature in °C.
13: CPU Temperature	1	CPU temperature in °C.
14: CAN Reception Timeout	1	

Table 21 – Available Control Sources and Numbers

2. INSTALLATION INSTRUCTIONS

2.1. Dimensions and Pinout
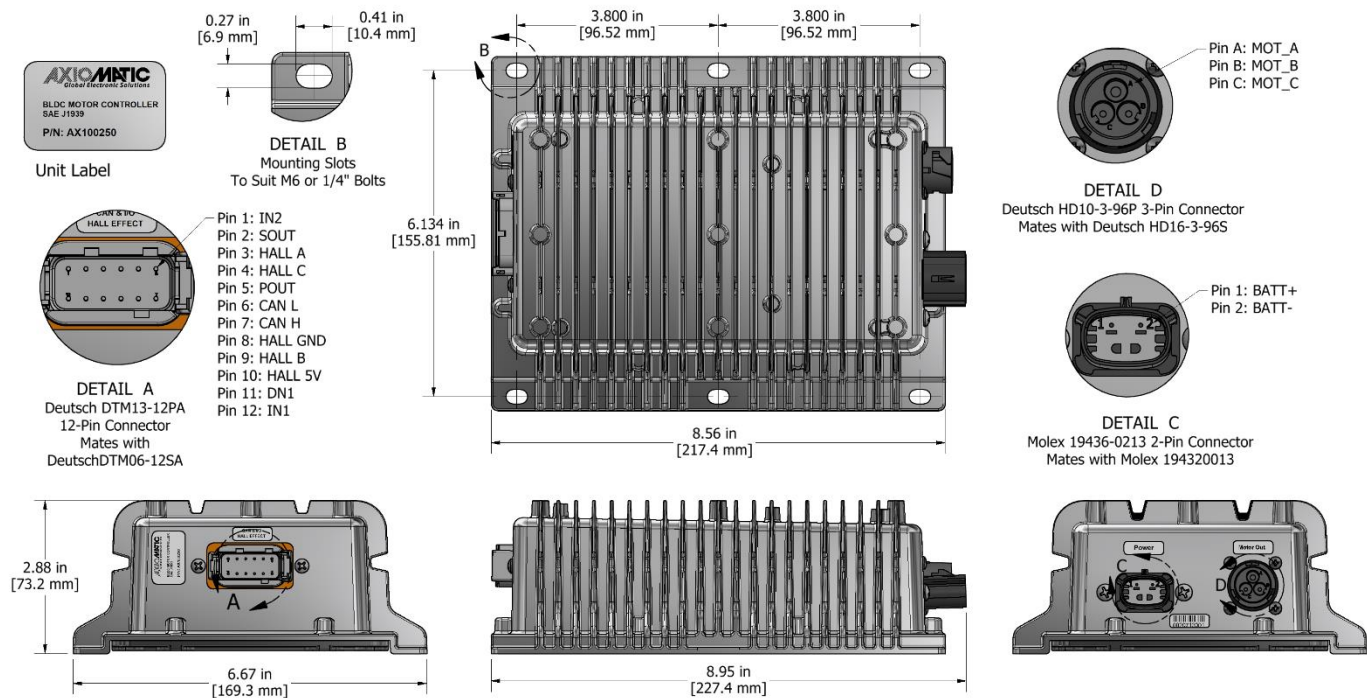
Figure 5 – AX100250 Dimensional Drawing

Power Connector: Molex P/N: 19436-0213	**Signal, Hall Effect and CAN Connector**: Equivalent TE Deutsch P/N: DTM13-12PA

Power Connector:
Molex P/N: 19436-0213

Pin#	Function
1	Batt+
2	Batt-

Motor Connector:
Equivalent TE Deutsch P/N: HD10-3-96P

Pin#	Function
1	Motor A Out
2	Motor B Out
3	Motor C Out

Signal, Hall Effect and CAN Connector:
Equivalent TE Deutsch P/N: DTM13-12PA

Pin#	Function
1	INPUT 2
2	SIGNAL OUT
3	HALL A
4	HALL C
5	POUT
6	CAN L
7	CAN H
8	HALL GND
9	HALL B
10	HALL 5V
11	DIGITAL IN1
12	INPUT 1

Table 22 – AX100250 Connectors' Pinouts

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 40A 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	27, Axiomatic AX100250
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 40A 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 BLDC Controller, refer to the relevant section in this user manual.

4.1.   Accessing the ECU Using the Axiomatic EA

ECU with P/N AX100250 does not need any specific setup for the Axiomatic EA. To access the high-speed versions, AX100250-01 and/or AX100250-02, the CAN bus Baud Rate needs to be set accordingly. The CAN Interface Setup can be found from "Options" menu in the EA.
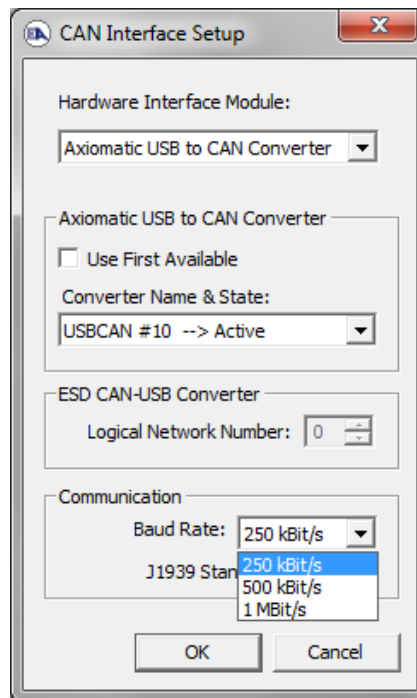
4.2. J1939 Network Parameters

"**ECU Instance Number**" and "**ECU Address**" setpoints and their effect are defined in Section 0.
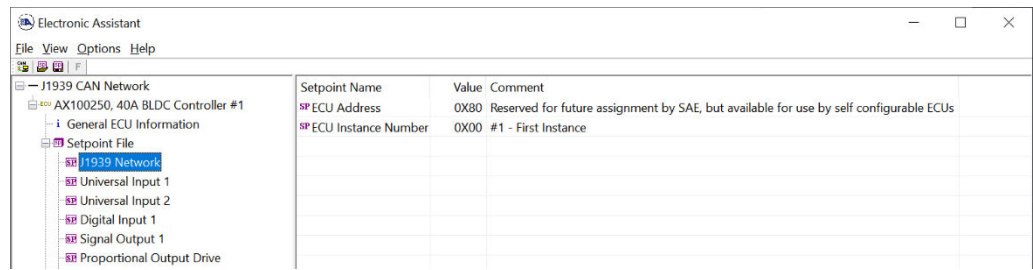
Figure 6 - Screen Capture of J1939 Setpoints

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 23 – 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
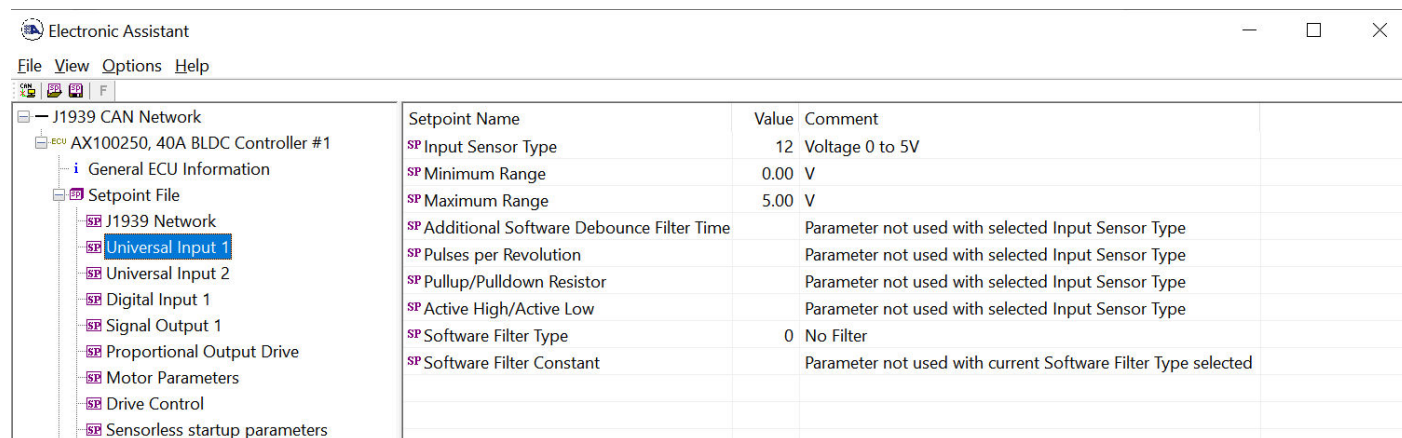
Figure 7 - Screen Capture of Universal Input Setpoints

Name	Range	Default	Notes
Input Sensor Type	Drop List	VOLTAGE_0_TO_5V	See Table 3
Minimum Range	From Minimum Error to Maximum Range	Depends on Input Sensor Type	
Maximum Range	From Minimum Range to Maximum Error	Depends on Input Sensor Type	
Additional Software Debounce Filter Time	Drop List	0ms	See section 1.2
Pulses per Revolution	Drop List	FALSE	See section 1.2
Pullup/Pulldown Resistor	Drop List	22kΩ Pulldown	See Table 4
Active High/Active Low	Drop List	Active High	See Table 5
Software Filter Type	Drop List	No Filtering	See Table 7
Software Filter Constant	1..1000	1	

Table 24 – Universal Input Setpoints

4.4. Digital Input Setpoints
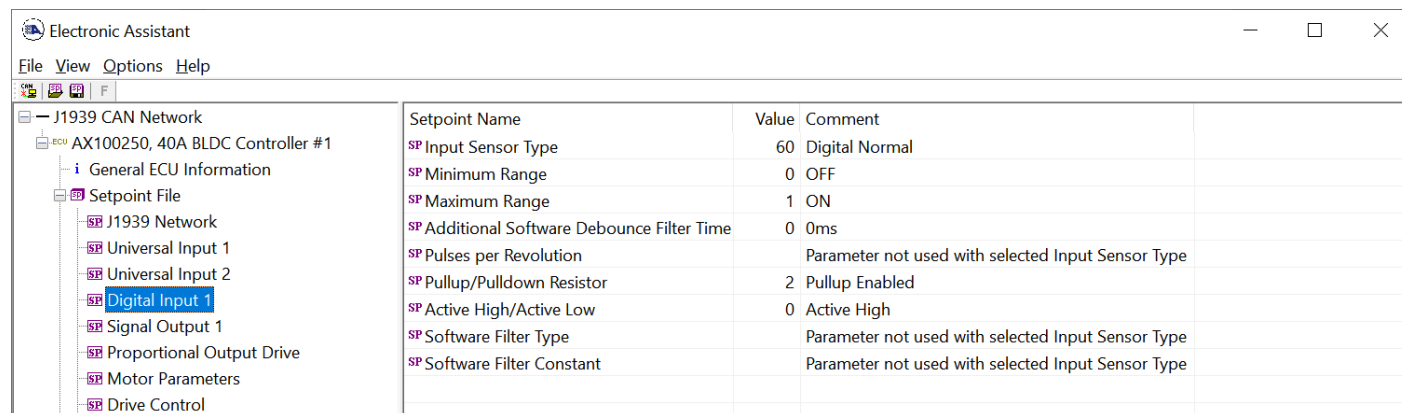
Figure 8 - Screen Capture of Digital Input Setpoints

Name	Range	Default	Notes
Input Sensor Type	Drop List	VOLTAGE_0_TO_5V	See Table 3
Minimum Range	From Minimum Error to Maximum Range	Depends on Input Sensor Type	
Maximum Range	From Minimum Range to Maximum Error	Depends on Input Sensor Type	
Additional Software Debounce Filter Time	Drop List	0ms	See section 1.2
Pulses per Revolution	Drop List	FALSE	See section 1.2
Pullup/Pulldown Resistor	Drop List	10kΩ Pulldown	See Table 4
Active High/Active Low	Drop List	Active High	See Table 5
Software Filter Type	Drop List	No Filtering	See Table 7
Software Filter Constant	1..1000	1	

Table 25 – Digital Input Setpoints

4.5. Signal Output Setpoints
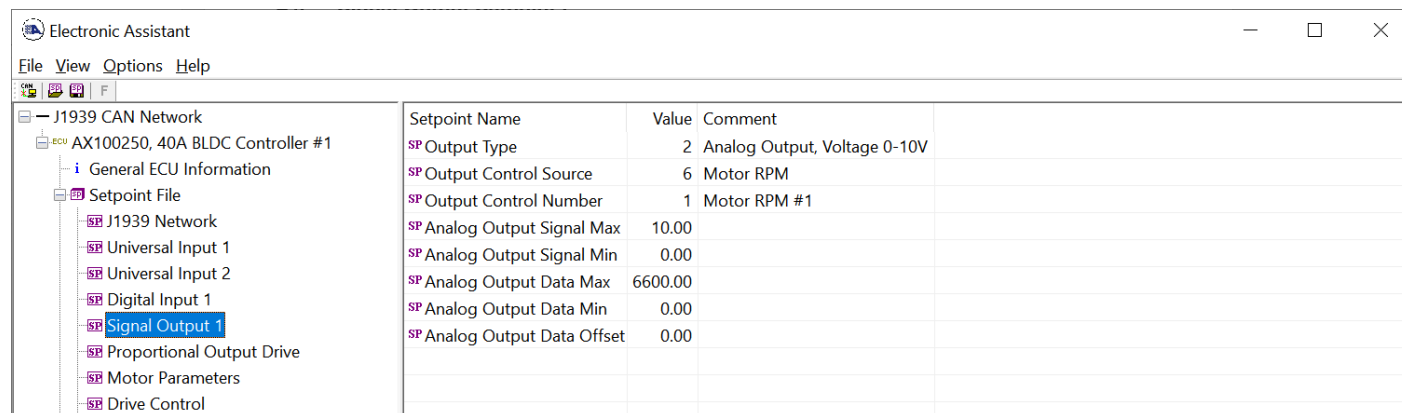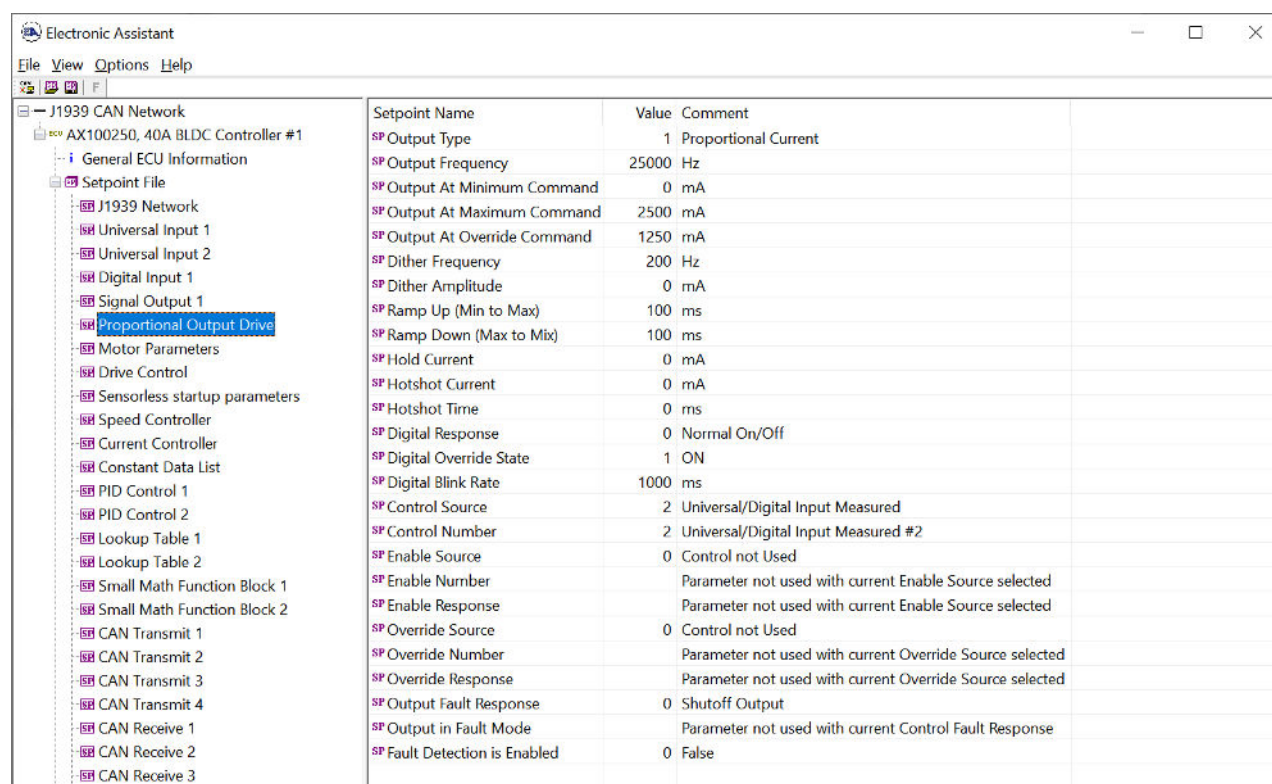
Figure 9 - Screen Capture of Signal Output Setpoints

Name	Range	Default	Notes
Output Type	Drop List	2 – Analog Output 0-10V	
Output Control Source	Drop List	6 – Motor RPM	
Output Control Number	Depends on Control Source	1	
Analog Output Signal Max	<Float32>	10.0 V	
Analog Output Signal Min	<Float32>	0.0 V	
Analog Output Data Max	<Float32>	6600.0 rpm	
Analog Output Data Min	<Float32>	0.0 rpm	
Analog Output Data Offset	<Float32>	0.0 rpm	

Table 26 – Signal Output Setpoints

4.6. Proportional Output Drive Setpoints

Figure 10 - Screen Capture of Proportional Output Drive Setpoints

Name	Range	Default	Notes
Output Type	Drop List	Proportional Current -400mA…400mA	See Table 10
Output At Minimum Command	0 to Limit	-400mA	
Output At Maximum Command	0 to Limit	400mA	
Output At Override Command	0 to Limit	0mA	
Dither Frequency	50 to 400Hz	200Hz	
Dither Amplitude	0 to 500 mA	0	
Ramp Up (Min to Max)	0 to 10 000ms	1000ms	
Ramp Down (Max to Min)	0 to 10 000ms	1000ms	
Control Source	Drop List	Universal Input Measured	See Table 21
Control Number	Depends on control source	1	See Table 21
Enable Source	Drop List	Control not used	See Table 21
Enable Number	Depends on enable source	1	See Table 21
Enable Response	Drop List	Enable When On, else Shutoff	See Table 12
Override Source	Drop List	Control not used	See Table 21
Override Number	Depends on enable source	1	See Table 21
Override Response	Drop List	Override When On	See Table 13
Output Fault Response	Drop List	Shutoff Output	See Table 14
Output in Fault Mode	Depends on Output type	0mA	
Fault Detection is Enabled	Drop List	True	

Table 27 – Proportional Output Drive Setpoints

4.7. Motor Parameter Setpoints

The detailed description of Motor Parameters, please refer to section 1.1.

Figure 11 - Screen Capture of Motor Parameter Setpoints

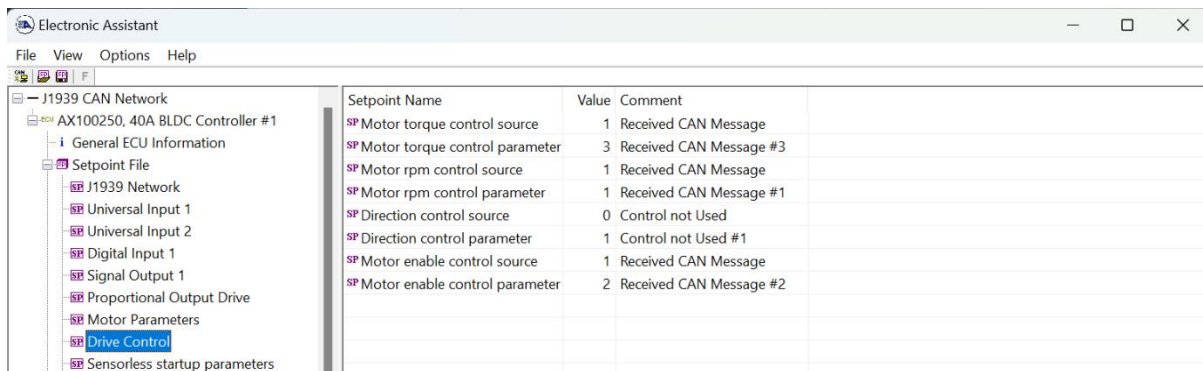| Name	Range	Default	Notes
Motor Type	Drop List	0 – BLDC	0 – BLDC, 1 – DC
Number of pole pairs	0…255	4	
Rated motor RPM	0…20000	4000	RPM
Rated motor current	0…7	7	A
PWM Frequency	5…20	16	kHz
Commutation sequence	0…5	0	See section 1.1
Over current event clear time		5000	ms
Over temperature threshold		130	Celsius
RPM filter constant	25		No. of samples in moving average filter
Motor current filter constant	25		No. of samples in moving average filter

Table 28 – Motor Parameter Setpoints

4.8. 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.

Motor rpm control source has an effect to the motor driving only in closed loop Speed Control.

Figure 12 - Screen Capture of Drive Control Setpoints

Name	Range	Default	Notes
Motor torque control source	Drop List	1	CAN receive message
Motor torque control parameter	Depends on source	3	CAN Rx #3
Motor rpm control source	Drop List	1	CAN receive message
Motor rpm control parameter	Depends on source	1	CAN Rx #1
Direction control source	Drop List	0	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	1	
Enable control source	Drop List	1	CAN receive message
Enable control source parameter	Depends on source	2	CAN Rx #2

Table 29 – Drive Control Setpoints

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

Table 30 – SPN 7991 style Enable+Direction command

4.9. Sensorless Startup Parameters

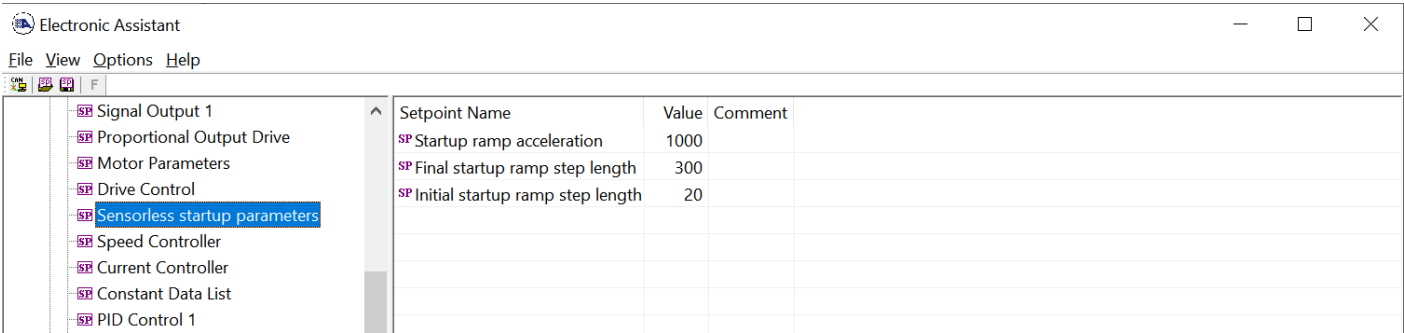For detailed description of sensorless startup parameters, please refer to section 0

Figure 13 - Screen Capture of Sensorless Startup Parameter Setpoints

Name	Range	Default	Notes
Startup ramp acceleration	0…32767	20	ISR ticks (default tick = 0.1ms)
Initial startup ramp step length	0…32767	300	ISR ticks (default tick = 0.1ms)
Final startup ramp step length	0…32767	1000	ISR ticks (default tick = 0.1ms)

Table 31 – Sensorless Startup Parameter Setpoints

4.10. Speed Controller Setpoints

The closed loop PI controller is executed at 0.1ms intervals (default). 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.
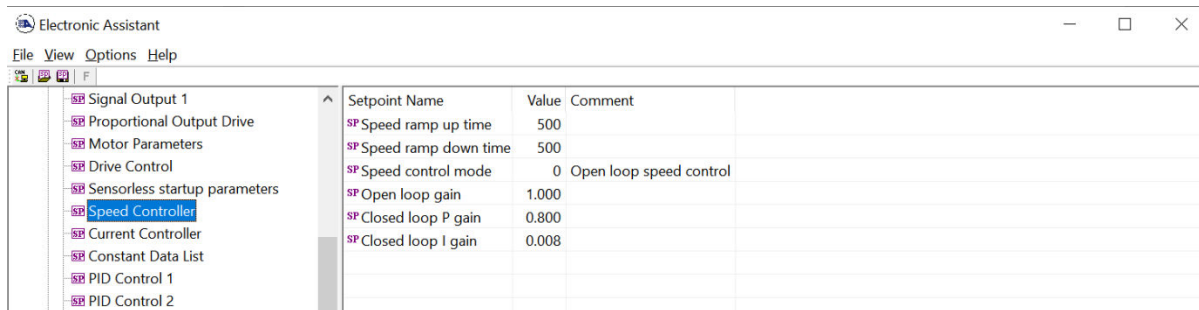
Figure 14 - Screen Capture of Speed Controller Setpoints

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	0.800	
Closed loop I gain	0.0 ... 100.0	0.008	

Table 32 – Speed Controller Setpoints

4.11. Current Controller Setpoints

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.

The closed loop PI controller is executed at 0.1ms intervals (default). 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.
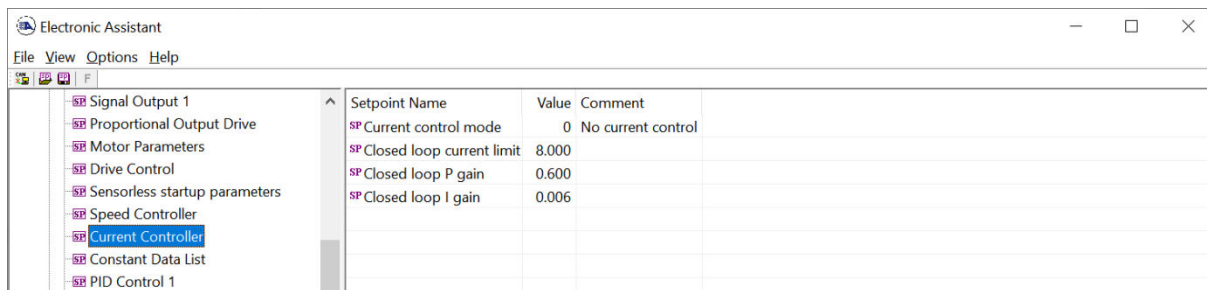
Figure 15 - Screen Capture of Current Controller Setpoints

Name	Range	Default	Notes
Current control mode	Drop List	0	No current control
Closed loop current threshold	0.0 … 40.0	8.0	[A]
Closed loop P gain	0.0 ... 100.0	0.600	
Closed loop I gain	0.0 ... 100.0	0.006	

Table 33 – Current Controller Setpoints

4.12. Constant Data List

The Constant Data List Function Block is provided 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 16) are arbitrary and should be configured by the user as appropriate for their application.
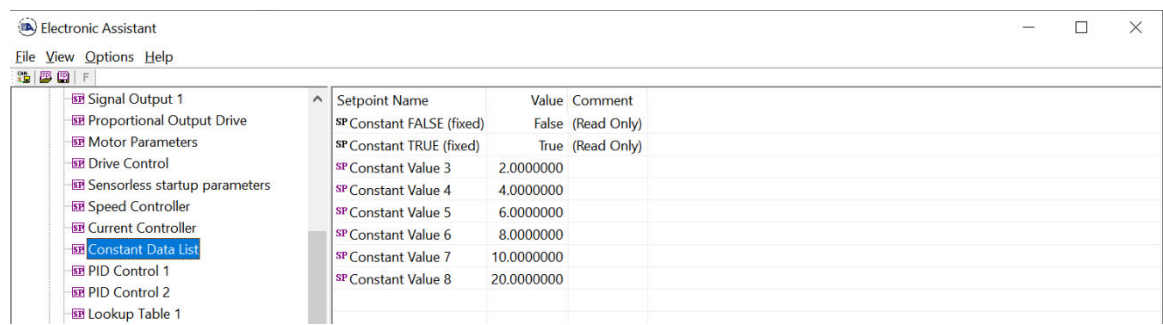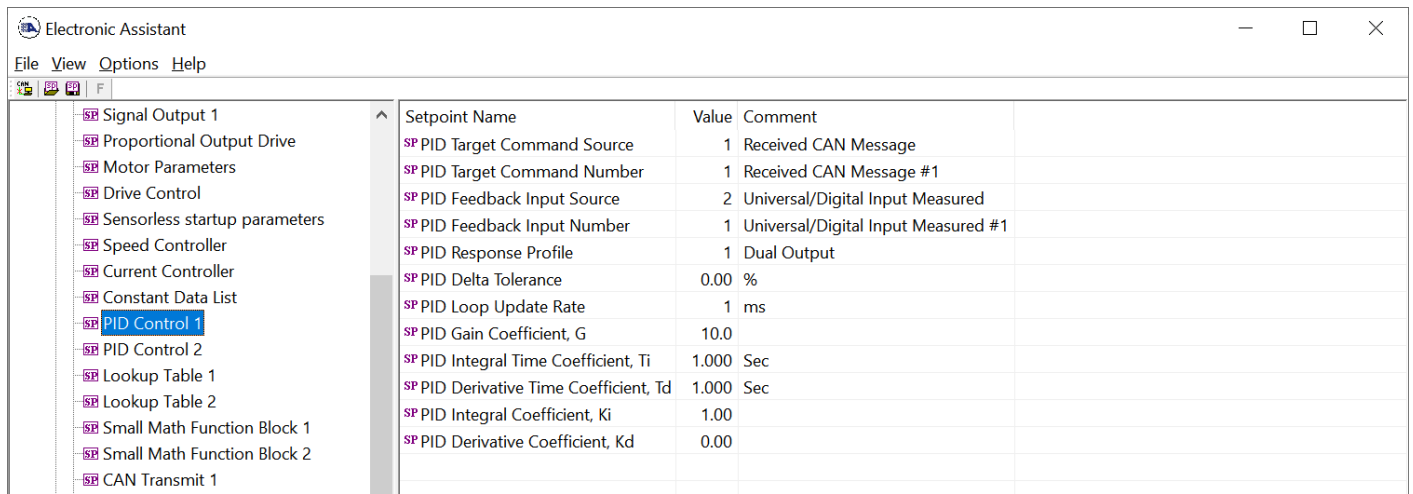

Figure 16 - Screen Capture of Constant Data List Setpoints

4.13. PID Controller Setpoints

Figure 17 - Screen Capture of PID Controller Setpoints

Name	Range	Default	Notes
PID Target Command Source	Drop List	Control Not Used	See Table 21
PID Target Command Number	Depends on control source	1	See Table 21
PID Feedback Input Source	Drop List	Control Not Used	See Table 21
PID Feedback Input Number	Depends on control source	1	See Table 21
PID Response Profile	Drop List	Single Output	See Table 17
PID Delta Tolerance	0 to 100	1.00 %	%
PID Loop Update Rate	1 to 60 000 ms	1ms	1 ms resolution
PID Gain Coefficient, G		10.0	See Equation 4
PID Integral Time Coefficient, Ti	1 to 10 Sec	1 Sec	
PID Derivative Time Coefficient, Td	1 to 10 Sec	1 Sec	
PID Integral Coefficient, Ki		1.00	0 disables integral, PD ctrl
PID Derivative Coefficient, Kd		0.00	0 disables derivative, PI ctrl

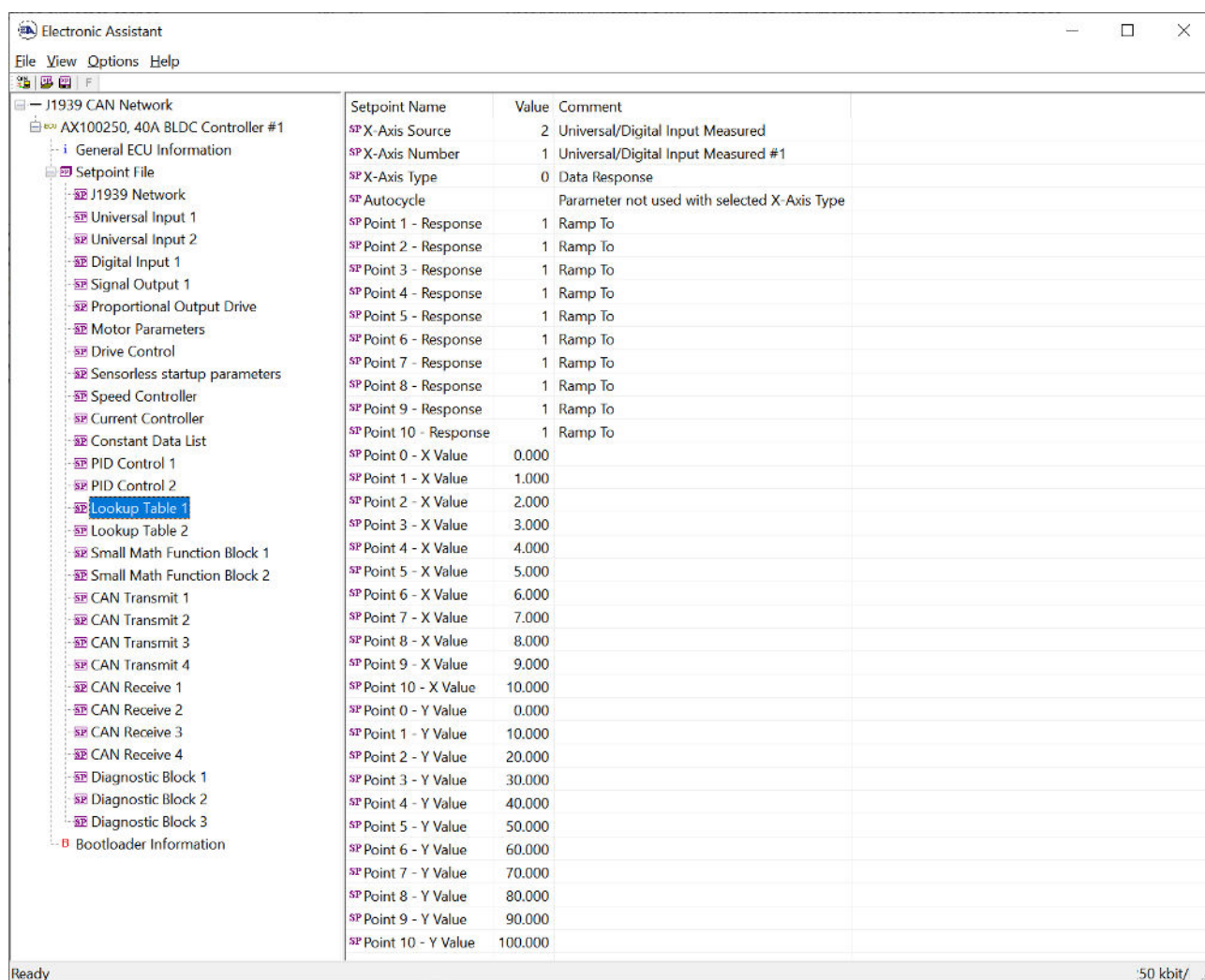**Table 34 – PID Controller Setpoints**

4.14. Lookup Table Setpoints

Figure 18 - Screen Capture of Lookup Table Setpoints

Name	Range	Default	Notes
X-Axis Source	Drop List	Control Not Used	See Table 21
X-Axis Number	Depends on control source	1	See Table 21
X-Axis Type	Drop List	Data Response	See Table 15
Table Auto-Cycle	Drop List	0	
Point 1 - Response	Drop List	Ramp To	See Table 16
Point 2 - Response	Drop List	Ramp To	See Table 16
Point 3 - Response	Drop List	Ramp To	See Table 16
Point 4 - Response	Drop List	Ramp To	See Table 16
Point 5 - Response	Drop List	Ramp To	See Table 16
Point 6 - Response	Drop List	Ramp To	See Table 16
Point 7 - Response	Drop List	Ramp To	See Table 16
Point 8 - Response	Drop List	Ramp To	See Table 16
Point 9 - Response	Drop List	Ramp To	See Table 16
Point 10 - Response	Drop List	Ramp To	See Table 16
Point 0 - X Value	From X-Axis source minimum to Point 1 - X Value	X-Axis source minimum 0.000	See section 1.5
Point 1 - X Value	From Point 0 - X Value to Point 2 - X Value	0.500	See section 1.5

Point 2 - X Value	From Point 1 - X Value to Point 3 - X Value	1.000	See section 1.5
Point 3 - X Value	From Point 2 - X Value to Point 4 - X Value	1.500	See section 1.5
Point 4 - X Value	From Point 3 - X Value to Point 5 - X Value source	2.000	See section 1.5
Point 5 - X Value	From Point 4 - X Value to Point 6 - X Value	2.500	See section 1.5
Point 6 - X Value	From Point 5 - X Value to Point 7 - X Value	3.000	See section 1.5
Point 7 - X Value	From Point 6 - X Value to Point 8 - X Value	3.500	See section 1.5
Point 8 - X Value	From Point 7 - X Value to Point 9 - X Value	4.000	See section 1.5
Point 9 - X Value	From Point 8 - X Value to Point 10 - X Value	4.500	See section 1.5
Point 10 - X Value	From Point 9 - X Value to X-Axis source maximum	X-Axis source maximum 5.000	See section 1.5
Point 0 - Y Value	-10^6 to 10^6	0.000	
Point 1 - Y Value	-10^6 to 10^6	10.000	
Point 2 - Y Value	-10^6 to 10^6	20.000	
Point 3 - Y Value	-10^6 to 10^6	30.000	
Point 4 - Y Value	-10^6 to 10^6	40.000	
Point 5 - Y Value	-10^6 to 10^6	50.000	
Point 6 - Y Value	-10^6 to 10^6	60.000	
Point 7 - Y Value	-10^6 to 10^6	70.000	
Point 8 - Y Value	-10^6 to 10^6	80.000	
Point 9 - Y Value	-10^6 to 10^6	90.000	
Point 10 - Value	-10^6 to 10^6	100.000	

Table 35 – Lookup Table Setpoints

4.15. Small Math Block Setpoints
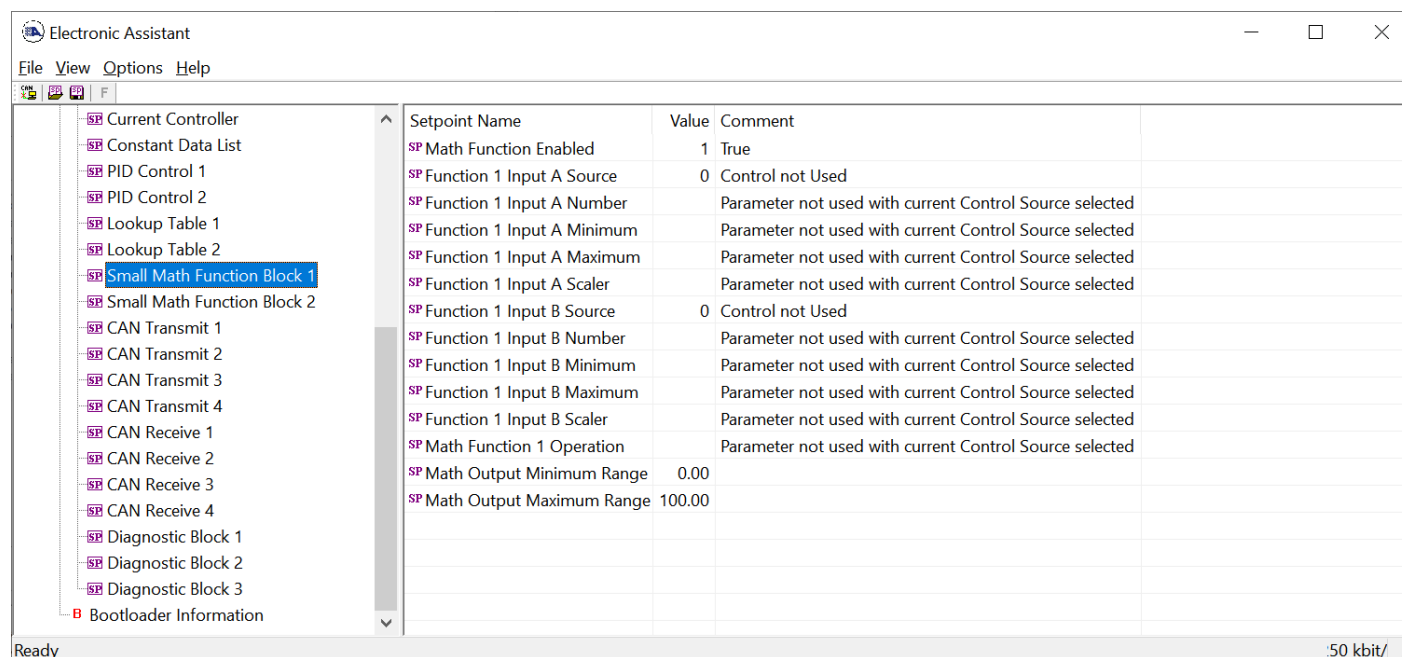
Figure 19 - Screen Capture of Small Math Block Setpoints

Name	Range	Default	Notes
Math Function Enabled	Drop List	False	
Function 1 Input A Source	Drop List	Control not used	See Table 21
Function 1 Input A Number	Depends on control source	1	See Table 21
Function 1 Input A Minimum	-10^6 to 10^6	0.0	
Function 1 Input A Maximum	-10^6 to 10^6	100.0	
Function 1 Input A Scaler	-1.00 to 1.00	1.00	
Function 1 Input B Source	Drop List	Control not used	See Table 21
Function 1 Input B Number	Depends on control source	1	See Table 21
Function 1 Input B Minimum	-10^6 to 10^6	0.0	
Function 1 Input B Maximum	-10^6 to 10^6	100.0	
Function 1 Input B Scaler	-1.00 to 1.00	1.00	
Math Function 1 Operation	Drop List	=, True when InA Equals InB	See Table 18
Math Output Minimum Range	-10^6 to 10^6	0.0	
Math Output Maximum Range	-10^6 to 10^6	100.0	

Table 36 – Small Math Block Setpoints

4.16. CAN Transmit Setpoints

Figure 20 - 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 21
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 21
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 21
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 21
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 37 – CAN Transmit Message Setpoints
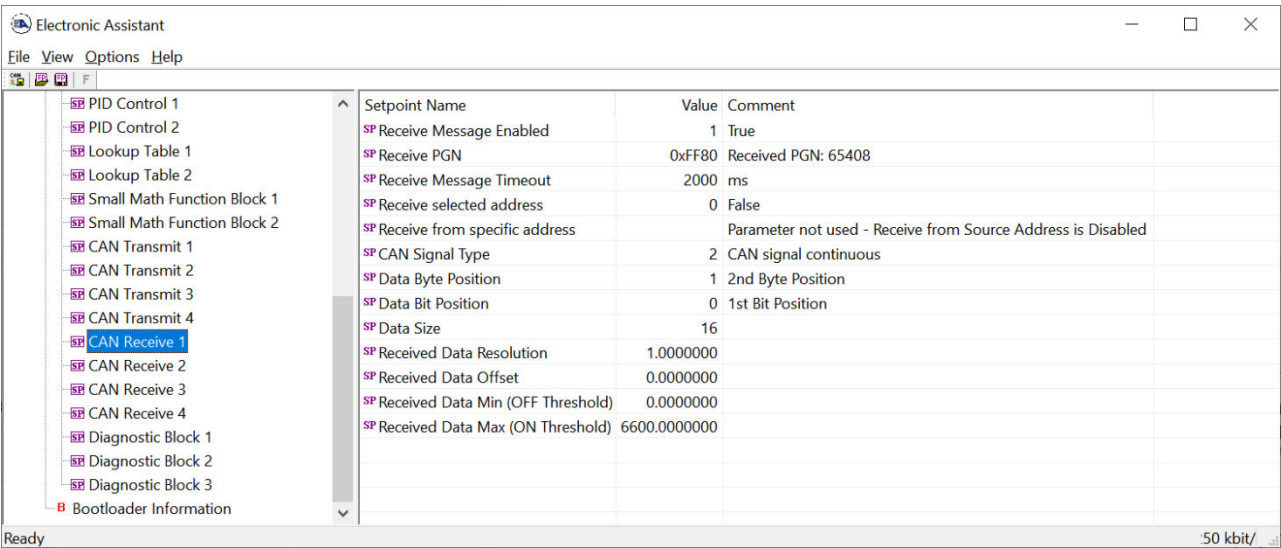
4.17. CAN Receive Setpoints

Figure 21 - 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 38 – CAN Receive Setpoints

4.18. Diagnostic Block Setpoints
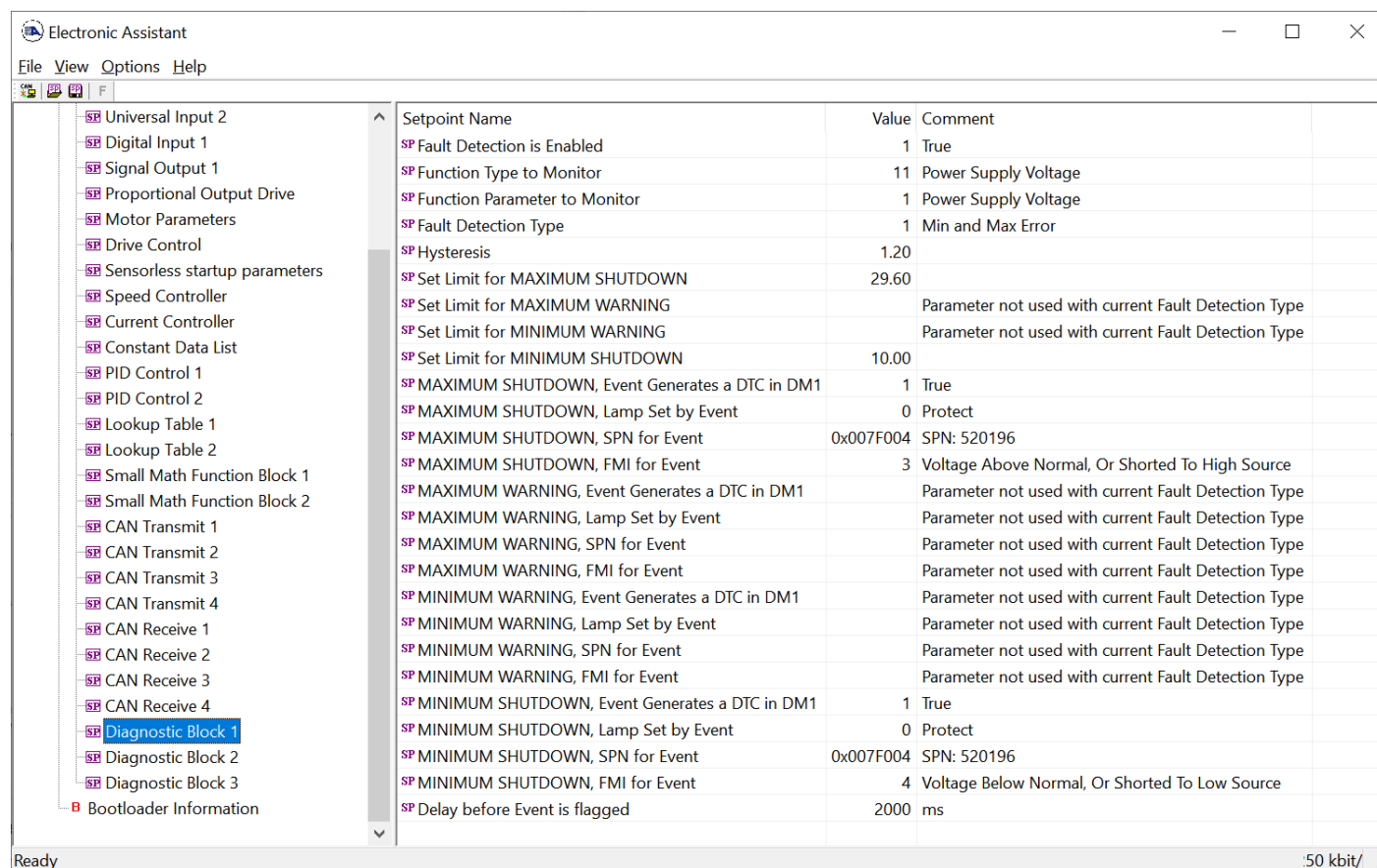
Figure 22 - Screen Capture of Diagnostic Block Setpoints

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
Hysteresis	0.0 … Maximum Value for Diagnostic Data	0.0	
Set Limit for MAXIMUM SHUTDOWN	Minimum Value for Diagnostic Data … Maximum Value for Diagnostics Data	4.8	
Set Limit for MAXIMUM WARNING	Minimum Value for Diagnostic Data … Maximum Value for Diagnostics Data	0.0	
Set Limit for MINIMUM WARNING	Minimum Value for Diagnostic Data … Maximum Value for Diagnostics Data	0.0	
Set Limit for MINIMUM SHUTDOWN	Minimum Value for Diagnostic Data … Maximum Value for Diagnostics Data	0.2	

|			
MAXIMUM SHUTDOWN, Event Generates a DTC in DM1	Drop List	True	
MAXIMUM SHUTDOWN, Lamp Set by Event	Drop List	0 – Protect	See Table 19
MAXIMUM SHUTDOWN, SPN for Event	0...524287	520448 ($7F100)	It is the user's responsibility to select an SPN that will not violate the J1939 standard.
MAXIMUM SHUTDOWN, FMI for Event	Drop List	3, Voltage Above Normal	See Table 20
MAXIMUM WARNING, Event Generates a DTC in DM1	Drop List	True	
MAXIMUM WARNING, Lamp Set by Event	Drop List	0 – Protect	See Table 19
MAXIMUM WARNING, SPN for Event	0...524287	520704 ($7F200)	It is the user's responsibility to select an SPN that will not violate the J1939 standard.
MAXIMUM WARNING, FMI for Event	Drop List	3, Voltage Above Normal	See Table 20
MINIMUM WARNING, Event Generates a DTC in DM1	Drop List	True	
MINIMUM WARNING, Lamp Set by Event	Drop List	0 – Protect	See Table 19
MINIMUM WARNING, SPN for Event	0...524287	520960 ($7F300)	It is the user's responsibility to select an SPN that will not violate the J1939 standard.
MINIMUM WARNING, FMI for Event	Drop List	4, Voltage Below Normal	See Table 20
MINIMUM SHUTDOWN, Event Generates a DTC in DM1	Drop List	True	
MINIMUM SHUTDOWN, Lamp Set by Event	Drop List	Amber Warning	See Table 19
MINIMUM SHUTDOWN, SPN for Event	0...524287	521216 ($7F400)	It is the user's responsibility to select an SPN that will not violate the J1939 standard.
MINIMUM SHUTDOWN, FMI for Event	Drop List	4, Voltage Below Normal	See Table 20
Delay Before Event is Flagged	0...60000 ms	1000	

Table 39 – Diagnostic Block Setpoints

## 5. REFLASHING OVER CAN WITH THE AXIOMATIC EA BOOTLOADER

The AX100250 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.*

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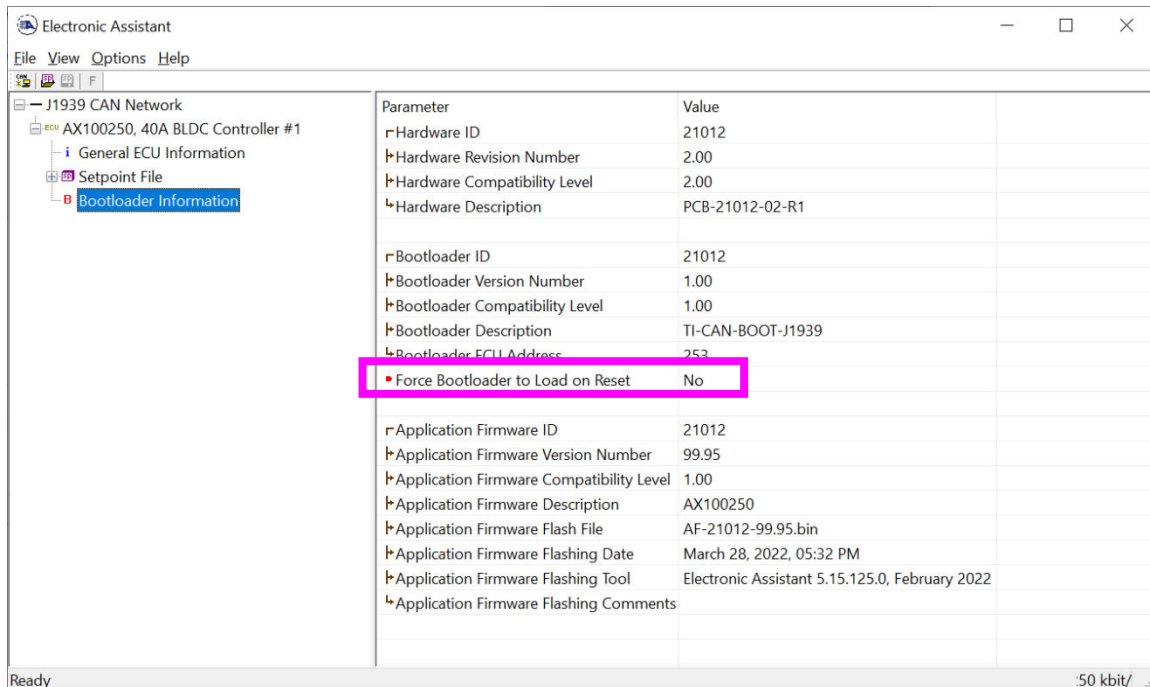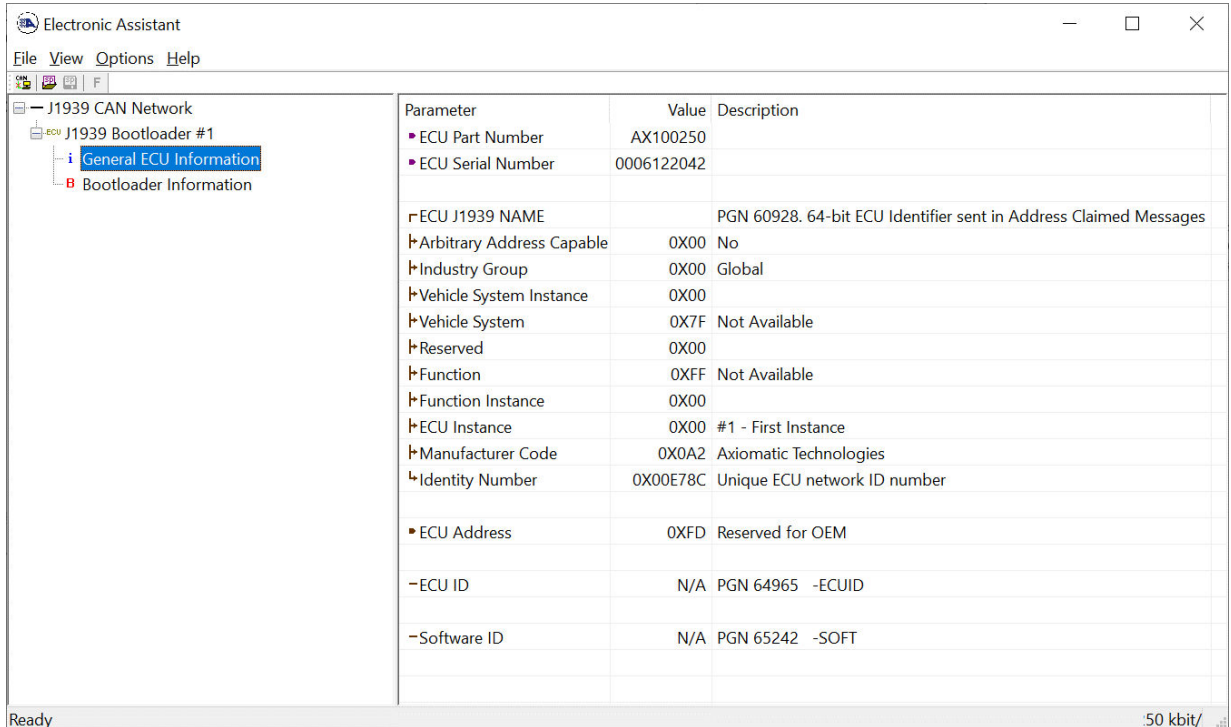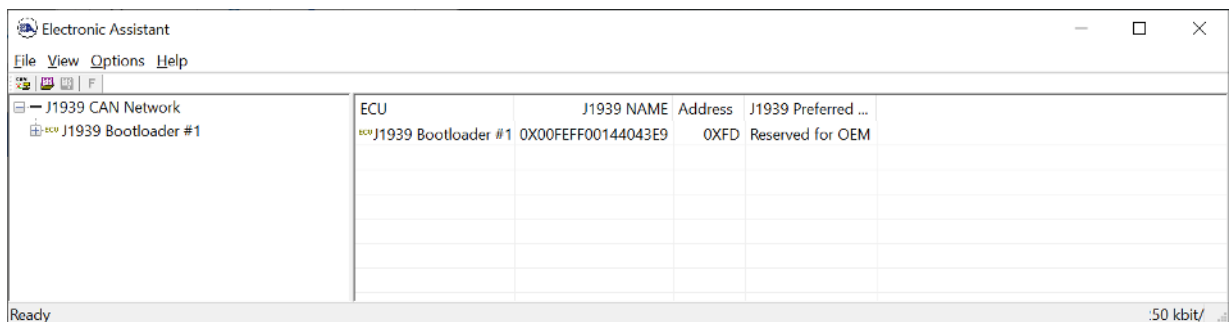

2. To use the bootloader to upgrade the firmware running on the ECU, change the variable **"Force Bootloader To Load on Reset"** to *Yes.*
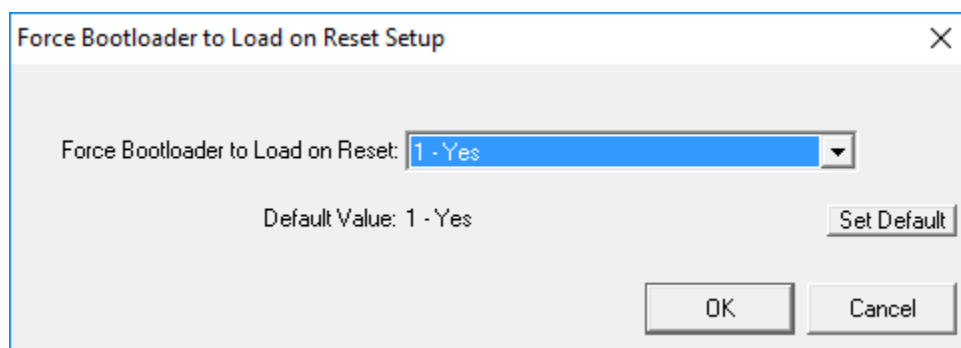
3. When the prompt box asks if you want to reset the ECU, select *Yes*.
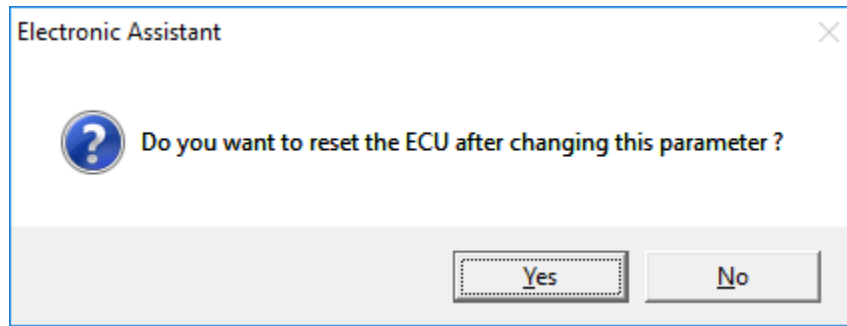
4. Upon reset (a power cycle may be required), the ECU will no longer show up on the J1939 network as an AX100250 but rather as **J1939 Bootloader #1**.

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.
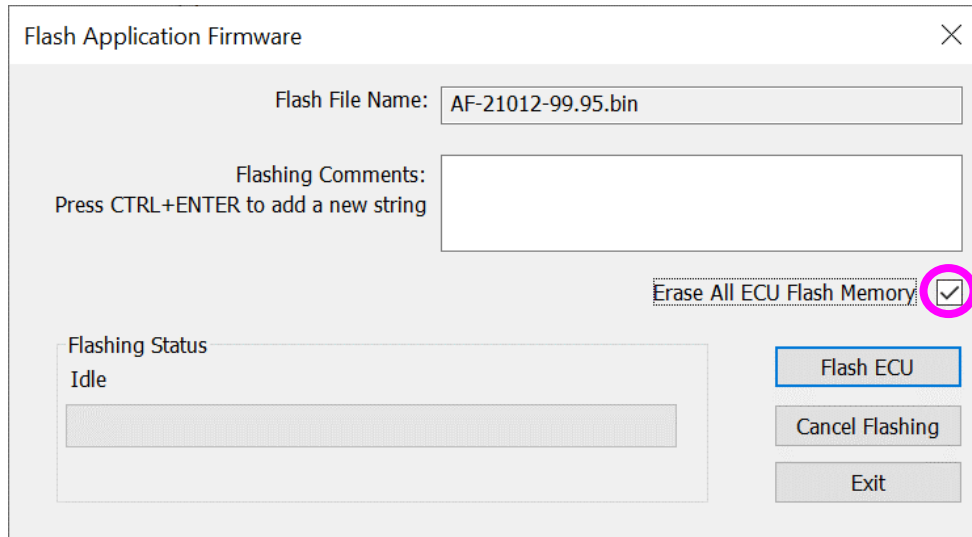
5. When the **Bootloader Information** section is selected, the same information is shown as when it was running the AX100250 firmware, but in this case the <u>F</u>lashing feature has been enabled.
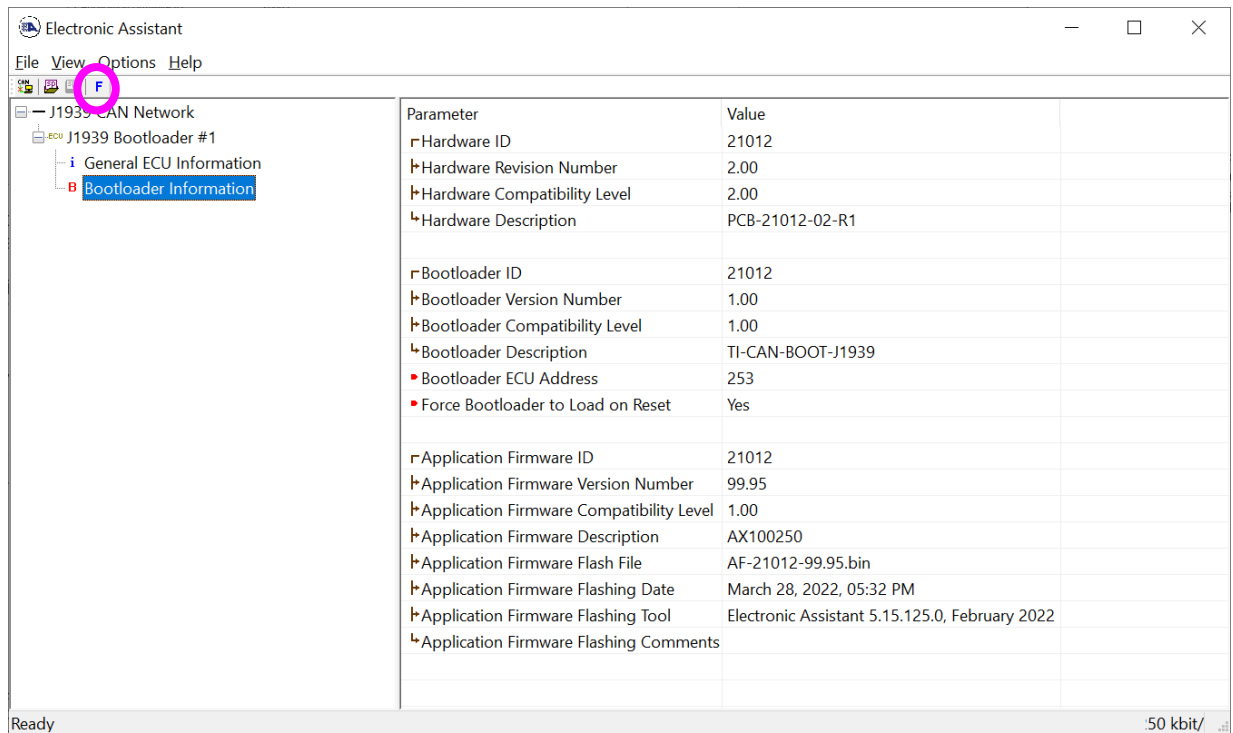
6. Select the <u>F</u>lashing button and navigate to where you had saved the **AF-21012-x.xx.bin** file sent from Axiomatic. (Note: only binary (.bin) files can be flashed using the Axiomatic EA tool.)

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/time-stamp the file, as this is done automatically by the Axiomatic EA tool when you upload the new firmware.
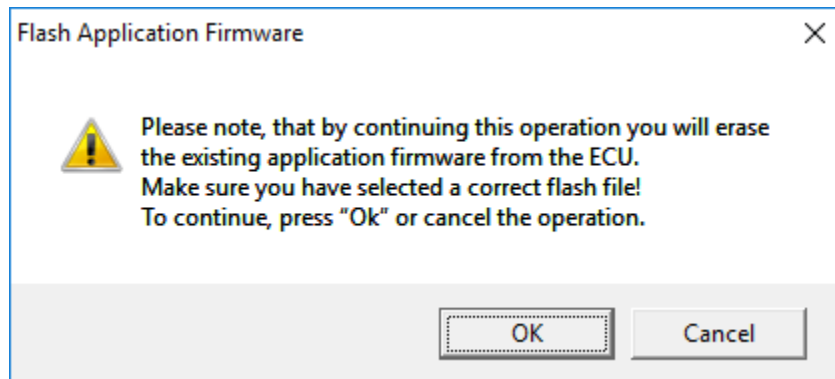
> ⚠️ **NOTE:** Please make sure that the "Erase All ECU Flash Memory" box is checked. Selecting this will erase ALL data stored in non-volatile flash. It will also erase any configuration of the setpoints that might have been done to the ECU and reset all setpoints to their factory defaults. **If this box is left unchecked, the firmware upload will <u>FAIL</u>**.

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.
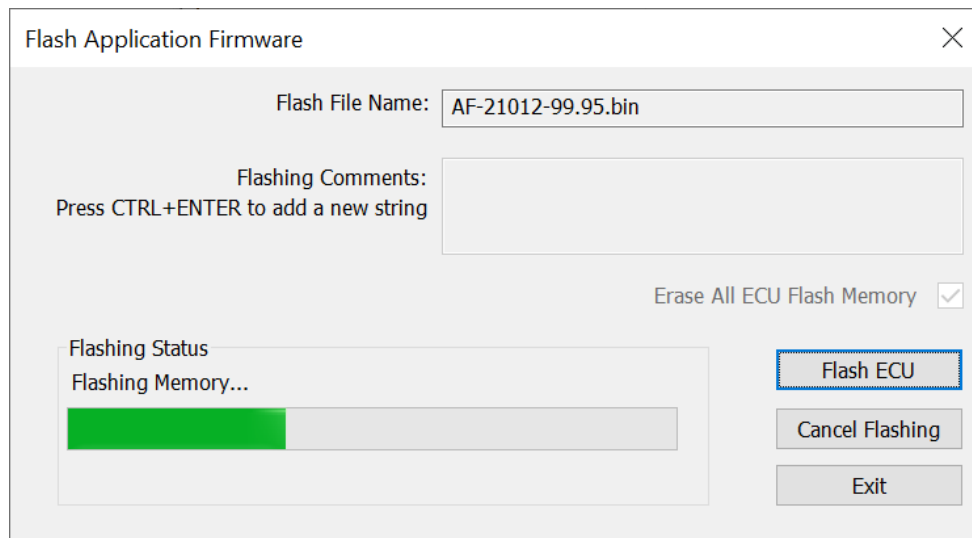

A progress bar will show how much of the firmware has been sent as the upload progresses. The more traffic there is on the J1939 network, the longer the upload process will take.

Flash Application Firmware

Flash File Name: AF-21012-99.95.bin

Flashing Comments:
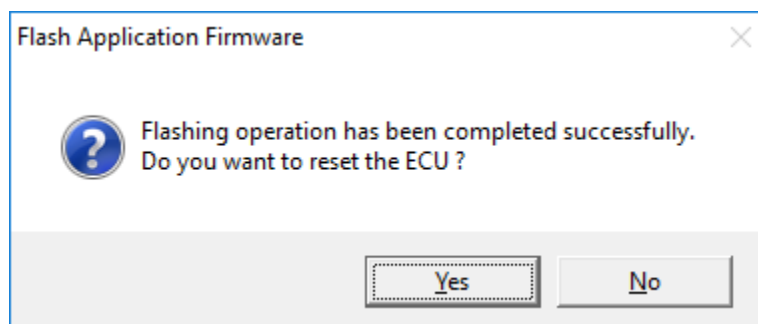Press CTRL+ENTER to add a new string

Erase All ECU Flash Memory ☑

Flashing Status
Flashing Memory...

[Flash ECU]
[Cancel Flashing]
[Exit]

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 AX100250 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 AX100250 application will run rather than the bootloader function.

Flash Application Firmware

Flashing operation has been completed successfully.
Do you want to reset the ECU ?

[Yes]   [No]

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

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

All specifications are typical at nominal input voltage and 25 degrees C unless otherwise specified.

Power

Power Supply Input	12, 24, or 48 VDC nominal (9 to 65 VDC)
Quiescent Current	61.49 mA @ 12Vdc; 32.29 mA @ 24Vdc typical
Surge Protection	120 VDC

Input

Universal Signal Inputs	2 universal signal input properties are user configurable. Refer to the block diagram and information below. Any input on the controller can be coded into a Proprietary B message that can be sent to the CAN network. 12-bit analog to digital resolution Protected against shorts Voltage Input: Range: 0-5 VDC or 0-10 VDC Resolution:1 mV Accuracy: ±1% Current Input: Range: 4-20 mA or 0-20 mA Resolution:1 µA Accuracy: ±1% Current sense resistor: 249 Ω Frequency Input: Auto-Ranging: 0.1-10,000 Hz Resolution: 0.01% Accuracy: ±1% PWM Signal: Range: 0.5-10,000 Hz Duty Cycle : 0 to 100% Resolution: 0.01% Accuracy: ±1% Digital Input: Active high with 10 KΩ pull-up resistor or active low with 10 KΩ pull-down resistor Amplitude: up to +Vps These can be configured to act as an encoder input. Input 1 is the Encoder A and input 2 is the Encoder B interface.
Digital / PWM / Frequency Inputs	1 input is provided Frequency Input: Auto-Ranging: 0.1-10,000 Hz Resolution: 0.01% Accuracy: ±1% PWM Signal: Range: 0.1-10,000 Hz Duty Cycle : 0 to 100% Resolution: 0.01% Accuracy: ±1% Digital Input: Active high with 10 KΩ pull-up resistor or active low with 10 KΩ pull-down resistor Amplitude: up to +Vps These inputs can be used as an enable or direction command for the controller.

Motor Feedback	Hall effect sensor 10 KΩ pull-up to +5 V per input A +5 V supply and ground connection is provided. Sensorless control using back EMF is also available in the standard model.

Output

Output to BLDC Motor	H-bridge 40A @ 48VDC nominal continuous 40A @ 24VDC nominal continuous 40A @ 12VDC nominal continuous Overcurrent protection is provided at 50A. Short circuit protection is provided. The maximum rated speed and motor rated current are configurable to suit individual motor specifications.
Motor Stop	Shut off with or without ramping
Motor Direction	Motor direction command can be mapped to any input or come from the CAN bus.
Motor Control Mode	Flexible control is provided by user configurable parameters for speed and torque control loops. The control input to drive the motor can be mapped to either of the 2 universal inputs or the controller can respond to messages from a CAN bus.
Thermal Protection	Thermal protection is built-in and configurable.
Universal Output	1 output is selectable as: Proportional Current: Range: 0-2.5 A Resolution:1 mA Accuracy: ±1% Hotshot Digital: Current: 2.5 A PWM Duty Cycle: Current: 2.5 A Resolution: 0.01% Accuracy: ±1% On/Off Digital: Current: 2.5 A Sourcing from power supply or output off Half-Bridge Output: Current sensing, grounded load. High side sourcing up to 2.5 A High frequency drive Load at supply voltage must not draw more than 2.5A Ramp and dither setpoints are configurable. Overcurrent protection Short circuit protection **Hotshot Coil Saver Output:** The output is on/off with a hotshot current which keeps the load ON with a holding current. This is used as an energy saving method of load control. The output is configurable to send a feedback message to the CAN bus. The feedback is always sent as a word with a resolution of 1 mA/bit and 0 mA offset. Refer to Proportional Output Hotshot Digital Profile.
Signal Output	1 voltage or current output is provided to follow the rotation speed of the motor. 12-bit digital to analog (voltage, current) Protected against short to GND or +Vcc 1 signal output GND is provided. Voltage Output: Range: 0-5 VDC or 0-10 VDC Resolution:1 mV Accuracy: ±1% Current Output: Range: 4-20 mA or 0-20 mA Resolution:1 µA Accuracy: ±1% Current sense resistor: 249 Ω

General Specifications

Microcontroller	TMS320F280049
Motor Control	Standard embedded software is provided. The following parameters are user configurable. Motor Direction: Uni-directional or bi-directional control from an input or the CAN bus. The direction is also configurable. Enable: A universal input can be configured to enable the motor when on. A CAN message can also be used as an enable input. Control Mode: Open loop speed or closed loop speed, open loop torque or closed loop torque CAN: CAN bus messages control the motor and/or auxiliary outputs instead of the analog or digital inputs
Communication	1 CAN port (SAE J1939) with Auto-baud-rate detection. CANopen® model: **AX100251**
User Interface	The Axiomatic Electronic Assistant for *Windows* operating systems It comes with a royalty-free license for use. The Axiomatic Electronic Assistant requires a USB-CAN converter to link the device's CAN port to a *Windows*-based PC for initial configuration. Order the Axiomatic EA and Axiomatic USB-CAN as a kit (P/Ns: **AX070502** or **AX070506K**), which includes all interconnecting cables.
Operating Conditions	-40°C to 85°C (-40°F to 185°F)
Storage Temperature	-50°C to 125°C (-58°F to 257°F)
Weight	3.75 lb. (1.695 kg)
Protection	IP67
Enclosure and Dimensions	Encapsulated in an anodized aluminum extrusion with gasket 8.95 in x 6.67 in x 2.88 in (227.4 mm x 169.3 mm x 73.2 mm) (W x L x H including connectors, excluding mating connectors) Refer to Dimensional Drawing.
Electrical Connections	Power Connector: Molex equivalent P/N: 19436-0213 Mates with Molex P/N: 19432-0013 Motor Connector: TE Deutsch equivalent P/N: HD10-3-96P Mates with TE Deutsch equivalent P/N: HD16-3-96S Signal, Hall Effect and CAN Connector: TE Deutsch equivalent P/N: DTM13-12PA Mates with TE Deutsch equivalent P/N: DTM06-12SA Wires should be of the appropriate gauge to meet requirements of applicable electrical codes and suit the specifications of the connector(s).
Mating Cables	A mating plug kit comprised of all mating connectors is available as P/N: **AX070450** (includes 1 plug DTM06-12SA, 1 socket HD16-3-96S, 1 wedgelock WM12S, 12 contacts 0462-201-20141, 3 contacts 0462-201-16141, 1 wedgelock 19432-0013, 2 terminals 19434-0003).
Mounting	The motor controller should be mounted as close to the battery and/or the motor as possible. Install the unit with appropriate space available for servicing and for adequate wire harness access and strain relief. Mounting ledges include holes sized for M6 or ¼ inch bolts. The bolt length will be determined by the end-user's mounting plate thickness. Typically, 20 mm (3/4 inch) is adequate.

CANopen® is a registered community trademark of CAN in Automation e.V.

OUR PRODUCTS

AC/DC Power Supplies

Actuator Controls/Interfaces

Automotive Ethernet Interfaces

Battery Chargers

CAN Controls, Routers, Repeaters

CAN/WiFi, CAN/Bluetooth, Routers

Current/Voltage/PWM Converters

DC/DC Power Converters

Engine Temperature Scanners

Ethernet/CAN Converters,
Gateways, Switches

Fan Drive Controllers

Gateways, CAN/Modbus, RS-232

Gyroscopes, Inclinometers

Hydraulic Valve Controllers

Inclinometers, Triaxial

I/O Controls

LVDT Signal Converters

Machine Controls

Modbus, RS-422, RS-485 Controls

Motor Controls, Inverters

Power Supplies, DC/DC, AC/DC

PWM Signal Converters/Isolators

Resolver Signal Conditioners

Service Tools

Signal Conditioners, Converters

Strain Gauge CAN Controls

Surge Suppressors

OUR COMPANY

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

QUALITY DESIGN AND MANUFACTURING
We have an ISO9001:2015 registered design/manufacturing facility in Canada.

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

COMPLIANCE
Product compliance details can be found in the product literature and/or on axiomatic.com. 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 rma@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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