# BLDC MOTOR CONTROLLER
# with CAN, SAE J1939

## USER MANUAL

**P/N: AX100260**

**P/N: AX100260-01 – J1939 500kbits/s Baud Rate**

**P/N: AX100260-02 – Custom J1939 Baud Rate, 1Mbits/s**

**VERSION HISTORY**

| Version | Date | Author | Modification |
|---------|------|--------|--------------|
| 1.0.0. | Feb 17, 2016 | Antti Keränen | Initial Draft |
| 1.0.1. | Feb 26, 2016 | Antti Keränen | Diagnostics description corrected, sensorless control startup procedure description updated. |
| 1.0.2. | Feb 29, 2016 | Antti Keränen | Motor parameters updated. |
| - | March 10, 2016 | Amanda Wilkins | Added Technical Specification |
| - | March 11, 2016 | Antti Keränen | Input frequency range updated in Technical Specification |
| 1.0.3 | Jan 9, 2017 | Antti Keränen | Axiomatic EA version info and firmware reflashing instructions updated. |
| 1.0.4. | Feb 2, 2017 | Antti Keränen | Control Logic and Drive Control Blocks' description updated. |
| 1.0.5. | Mar 7, 2017 | Antti Keränen | Sections 1.1.2 & 1.7 and Axiomatic EA Motor Parameters' description updated. |
| 1.0.6. | May 5, 2017 | Antti Keränen | Figure 14 and section 1.1.2 updated. |
| 1.1.0 | September 1, 2023 | Kiril Mojsov | Performed Legacy Updates |

## ACRONYMS

| | |
|---|---|
| ACK | Positive Acknowledgement (from SAE J1939 standard) |
| BATT +/- | Battery positive (a.k.a. Vps) or Battery Negative (a.k.a. GND) |
| DIN | Digital Input used to measure active high or low signals |
| DM | Diagnostic Message (from SAE J1939 standard) |
| DTC | Diagnostic Trouble Code (from SAE J1939 standard) |
| EA | The Axiomatic Electronic Assistant (A Service Tool for Axiomatic ECUs) |
| ECU | Electronic Control Unit (from SAE J1939 standard) |
| GND | Ground reference (a.k.a. BATT-) |
| I/O | Inputs and Outputs |
| MAP | Memory Access Protocol |
| NAK | Negative Acknowledgement (from SAE J1939 standard) |
| PDU1 | A format for messages that are to be sent to a destination address, either specific or global (from SAE J1939 standard) |
| PDU2 | A format used to send information that has been labeled using the Group Extension technique, and does not contain a destination address. |
| PGN | Parameter Group Number (from SAE J1939 standard) |
| PropA | Message that uses the Proprietary A PGN for peer-to-peer communication |
| PropB | Message that uses a Proprietary B PGN for broadcast communication |
| PWM | Pulse Width Modulation |
| RPM | Rotations per Minute |
| SPN | Suspect Parameter Number (from SAE J1939 standard) |
| TP | Transport Protocol |
| UIN | Universal input used to measure voltage, current, frequency or digital inputs |
| Vps | Voltage Power Supply (a.k.a. BATT+) |
| %dc | Percent Duty Cycle (Measured from a PWM input) |

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**Note:**

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

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**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, May 2003 |
| TDAX100260 | Technical Datasheet, BLDC Motor Controller with CAN, Axiomatic Technologies 2016 |
| UMAX07050x | User Manual, Axiomatic Electronic Assistant and USB-CAN, Axiomatic Technologies, 2023 |
| SLOS719 | Datasheet for Three Phase Pre-Driver with Dual Current Shunt Amplifiers and Buck Regulator, DRV8301, Texas Instruments, August 2011 |

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

> NOTE: This product is supported by Axiomatic Electronic Assistant V5.13.85.0 and higher.

# 1. OVERVIEW OF CONTROLLER
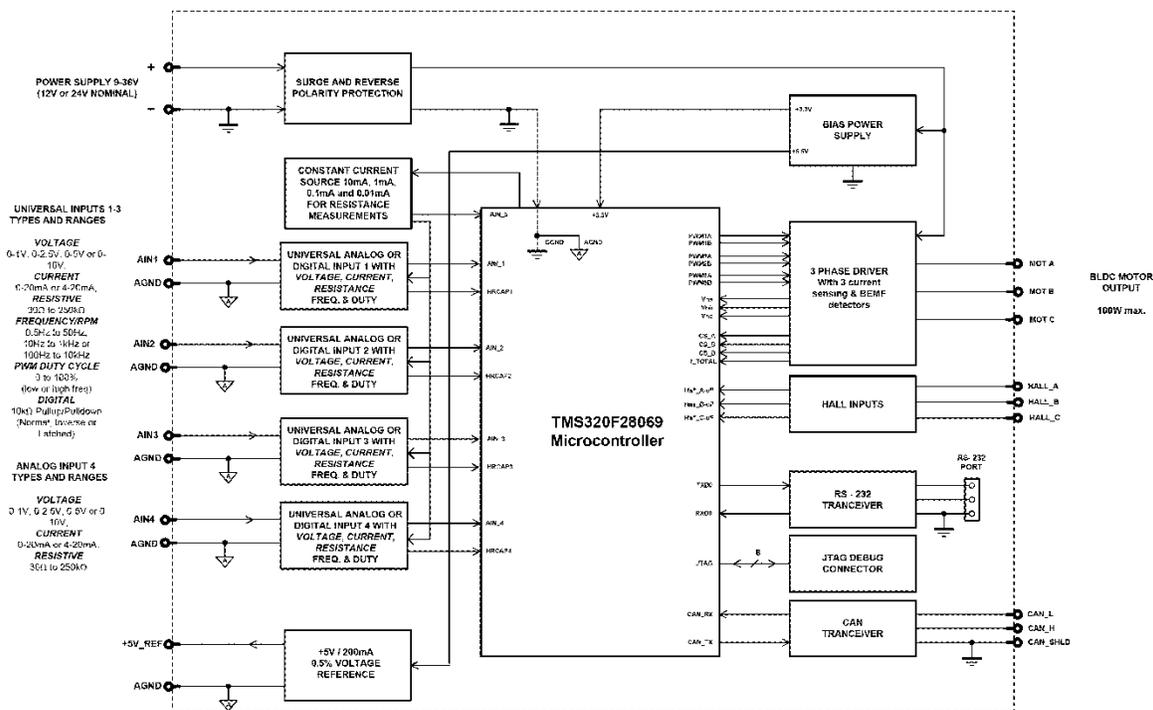


**Figure 1 – AX100260 Block Diagram**

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

The *Windows*-based Axiomatic Electronic Assistant (EA) is used to configure the controller via an USB-CAN (AX070501) device. Configurable properties, Axiomatic EA setpoints, are outlined in chapter 4. Setpoint configuration can be saved in a file which can be used to easily program the same configuration into another 6A BLDC Controller. Throughout this document, Axiomatic EA setpoint names are referred to with bolded text in double-quotes, and the setpoint option is referred to with italicized text in single-quotes. For example "**Input Sensor Type**" setpoint set to option '*Frequency/RPM 1.3kHz to 15kHz*'.

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

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

| AX100260 | Controller with the default J1939 baud rate (250kbits/s). |
|---|---|
| AX100260-01 | Controller with the 500kbits/s J1939 baud rate. |
| AX100260-02 | Controller with a custom 1Mbits/s J1939 baud rate. |

## 1.1. BLDC Motor Control Functionality

The 6A BLDC Controller is capable of driving brushless DC motors equipped with Hall sensors. Also sensorless motor control using Back-EMF rotor position detection is supported. There are multiple setpoints accessible with the Axiomatic EA that allow the user to configure the 6A BLDC controller to drive a variety of different BLDC motors.

The Motor Parameters setpoint group (see section 4.4) supports the configuration of the main motor parameters, such as number of pole pairs, rotor position detection, rated RPM of the motor, PWM frequency to use in Motor Phase drive, commutation sequence to use (Hall sensor method only) and whether to use HW current protection.

"**Number of pole pairs**" has direct influence on how the 6A BLDC Controller picks up the motor RPM, this parameter should be always set to correspond the motor driven by the controller.

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

The "**PWM Frequency**" sets the frequency to use in the Phase outputs' PWM signal.

"**HW current protection**" setpoint allows the user to disable the hardware over current protection, which is set to 12A. In case the over current protection is enabled and 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).

### 1.1.1. Hall Sensor Based Control

Hall sensor based control implements two different commutation schemes. It is on the user's responsibility to select the proper one for the motor in question.

The two available options are "0) Version 1":

| Hall C | Hall B | Hall A | Phase A | Phase B | Phase C |
|--------|--------|--------|---------|---------|---------|
| 1 | 0 | 1 | **PWM** | OFF | **LOW** |
| 0 | 0 | 1 | OFF | **PWM** | **LOW** |
| 0 | 1 | 1 | **LOW** | **PWM** | OFF |
| 0 | 1 | 0 | **LOW** | OFF | **PWM** |
| 1 | 1 | 0 | OFF | **LOW** | **PWM** |
| 1 | 0 | 0 | **PWM** | **LOW** | OFF |

**Table 1: Commutation sequence, version 1**

And "1) Version 2":

| Hall C | Hall B | Hall A | Phase A | Phase B | Phase C |
|--------|--------|--------|---------|---------|---------|
| 1 | 0 | 1 | **LOW** | **PWM** | OFF |
| 0 | 0 | 1 | **LOW** | OFF | **PWM** |
| 0 | 1 | 1 | OFF | **LOW** | **PWM** |
| 0 | 1 | 0 | **PWM** | **LOW** | OFF |
| 1 | 1 | 0 | **PWM** | OFF | **LOW** |
| 1 | 0 | 0 | OFF | **PWM** | **LOW** |

**Table 2: Commutation sequence, version 2**

## 1.1.2. Sensorless Control

The sensorless motor control is based on detecting the Back EMF voltage on the free phase while the motor is running. While this voltage is available only when the motor is running, the startup procedure is carried out without knowing whether the rotor actually rotates or not. Depending on the motor in question, the user has to tune the startup parameters in "**Speed Acceleration Control**" setpoint group (see section 4.8).



**Figure 2 - Sensorless drive startup steps**

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

1. *Rotor Alignment*

   The first step is the rotor alignment, during which a constant Phase drive is applied (one out of the six possible phase drive combinations). The PWM duty cycle applied in this step can be configured using the "**Startup Alignment PWM Drive**" setpoint in the "**Speed Acceleration Control**". The idea is to make the rotor to align to a known position before the startup ramp is started.

   The alignment phase duration is 820ms, which is currently a constant parameter.

2. *Ramp-Up*

   During the ramp-up period, the motor is driven in open loop configuration for picking up speed and for making the Back EMF signals available for the sensorless control. The speed of the ramp up, together with initial and target commutation speed can be configured in "**Speed Acceleration Control**". The PWM drive during this phase is defined by what is configured in "**Initial Maximum PWM Drive**" setpoint. The "**Startup Period Setpoint**" defines the commutation interval in the start of the ramp up phase. The "**Startup Period Target**" defines the commutation interval in the end of the ramp up phase. The unit value for these setpoints is 25us. The "**Output PWM Ramp Time**" defines how fast the ramp is decremented (i.e. commutation is speeded up).

   The ramp-up phase duration is determined by the following formula, in which 40kHz is the fixed execution speed of the low level commutation algorithm.

   $$t_{ramp-up} = \frac{\left((Startup\ Period\ Setpoint - Startup\ Period\ Target) * Output\ PWM\ Ramp\ Time\right)}{40kHz}$$

   With default settings, the ramp-up phase duration is 20ms.

3. *Normal Operation*

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

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

## 1.2. Inverter (Texas Instruments DRV8301)

The 6A BLDC Controller uses Texas Instruments DRV8301 chip to generate driving signals for the output FETs. The "**Inverter Specific Protection**" allows the configuration of some of the parameters of that chip.

The "**OC Protection Mode**" sets the method how the DRV8301 chip responds to the over current situation. The default setting is *Report Only*.

The motor over current detection is handled by measuring the Vds voltage of the output FETs. The available settings for "**Overcurrent Vds**" are listed in Figure 3.

| Control Bit (D6–D10) (0xH) | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Vds (V) | 0.060 | 0.068 | 0.076 | 0.086 | 0.097 | 0.109 | 0.123 | 0.138 |
| Control Bit (D6–D10) (0xH) | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Vds (V) | 0.155 | 0.175 | 0.197 | 0.222 | 0.250 | 0.282 | 0.317 | 0.358 |
| Control Bit (D6–D10) (0xH) | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| Vds (V) | 0.403 | 0.454 | 0.511 | 0.576 | 0.648 | 0.730 | 0.822 | 0.926 |
| Code Number (0xH) | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| Vds (V) | 1.043 | 1.175 | 1.324 | 1.491 | 1.679 | 1.892 | 2.131 | 2.400 |

**Figure 3 - DRV8301 Overcurrent adjustment (from DRV8301 datasheet SLOS719)**

The "**Warning Trigger**" setpoint defines which events produce the warning signal from the DRV8301 chip. Available options include over current, over temperature and both.

## 1.3. Input Function Blocks

Universal Input setpoint groups have the "**Input Sensor Type**" setpoint, which is used to configure input type. Selecting input type effects on other setpoints and how they are interpreted and should thus be selected first on this block. The input sensor types for Universal Inputs are listed in Table 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 | *Resistance* |
| 40 | *Frequency 1.2kHz to 15kHz* |
| 50 | *PWM* |
| 60 | *Digital (normal)* |
| 61 | *Digital (inverse)* |
| 62 | *Digital (latched)* |

**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 249Ω resistor is used to measure the input signal. Analog signals should be connected to the GND reference pins provided on the connector, per Table 15.

An additional software debounce filter can be used with Digital Input types for filtering the inputs using long time constants. The available software implemented debounce times are listed in Table 4.

| 0 | 0ms |
|---|---|
| 1 | 10ms |
| 2 | 20ms |
| 3 | 40ms |
| 4 | 100ms |
| 5 | 200ms |
| 6 | 400ms |
| 7 | 1000ms |

**Table 4 - Software Debounce Filter Times**

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

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

On Frequency, PWM and digital input modes 10kΩ pull-up or pull-down resistors can be enabled or disabled by setting the value of the "**Pullup/Pulldown Resistor**" setpoint. Setpoint options are given in Table 5. By default pull-down resistors are enabled for all inputs.

| 0 | Pullup/down Off |
|---|---|
| 1 | 10 kΩ Pullup |
| 2 | 10 kΩ Pulldown |

**Table 5 – 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 6. 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 6 – Active High/Low Options**

Table 7 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 7 – Digital Input Sensor Type versus Input State**

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

## 1.4. Input Filtering

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

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

**Table 8 – Filter Type Options**

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

Equation 1 - Moving Average Transfer Function:

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

Equation 2 - Repeating Average Transfer Function:

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

The '*Repeating Average*' option applies the transfer function above to the measured input data, where N is value of the **"Filter Constant"** setpoint. At every reading of the input value, the value is

added to the sum. At every N<sup>th</sup> read, the sum is divided by N, and the result is new CAN message data. The sum is set to zero for the next read and summing is started again.

## 1.5.    PID Controller Block

The PID Control function block is an independent logic block, but it is normally intended to be associated with proportional output control blocks described earlier. When the "**Control Source**" for an output has been setup as a '*PID Function Block*', the command from the selected PID block drives the physical output on the 6A 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 9. When active, the PID algorithm will be called every "**PID Loop Update Rate**" in milliseconds.

| 0 | Single Output |
|---|---|
| 1 | Setpoint Control |
| 2 | On When Over Target |
| 3 | On When Below Target |

**Table 9 – PID Response Options**

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

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

When a '*Setpoint Control*' response is selected, the "**PID Target Command Source**" automatically gets updated to '*Control Constant Data*' and cannot be changed. The value set in the associated constant in the Constant Data List function block becomes the desired target value. In this case, both the target and the feedback values are assumed to be in same units and range. The minimum and maximum values for the feedback automatically become the constraints on the constant target. In this mode, the output of the block would be a value from 0% to 100%.

For example, if the feedback was setup as a 4-20mA input, a "**Constant Value X**" setpoint set to 14.2 would automatically be converted to 63.75%. The PID function would adjust the output as neede to have the measured feedback to maintain that target value.

The last two response options, '*On When Over Target'* and '*On When Under Target'*, are designed to allow the user to combine the two proportional outputs as a push-pull drive for a system. Both

outputs must be setup to use the same control input (linear response) and feedback signal in order to get the expected output response. In this mode, the output would be between 0% to 100%.

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

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

$$PIDOutput_k = P_k + I_k + D_k$$

$$P_k = P\_Gain * Error_k$$
$$I_k = I\_Gain * ErrorSum_k$$
$$D_k = D\_Gain * (Error_k - Error_{k-1})$$

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

$$P\_Gain = G$$
$$I\_Gain = G * Ki * T/Ti \quad \text{(Note: If Ti is zero, I\_Gain = 0)}$$
$$D\_Gain = G * Kd * Td/T$$

$$T = Loop\_Update\_Rate * 0.001$$

**Equation 3 - PID Control Algorithm**

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

## 1.6.  Diagnostic Function Blocks

The 6A 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 11 and Table 12) | |
| 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 6A BLDC Controller supports 16 Diagnostics Definitions, each freely configurable by the user.

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

There are 4 fault types that can be used, "**Minimum and maximum error**", "**Absolute value error**", "**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, delay before flagging status). In case the parameter to monitor stays between these two thresholds, the diagnostic is not flagged.

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

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

**Double minimum and maximum error** lets user to specify four thresholds, each with independent diagnostic parameters. The diagnostic status and threshold values is determined and expected as show in Figure 4 below.
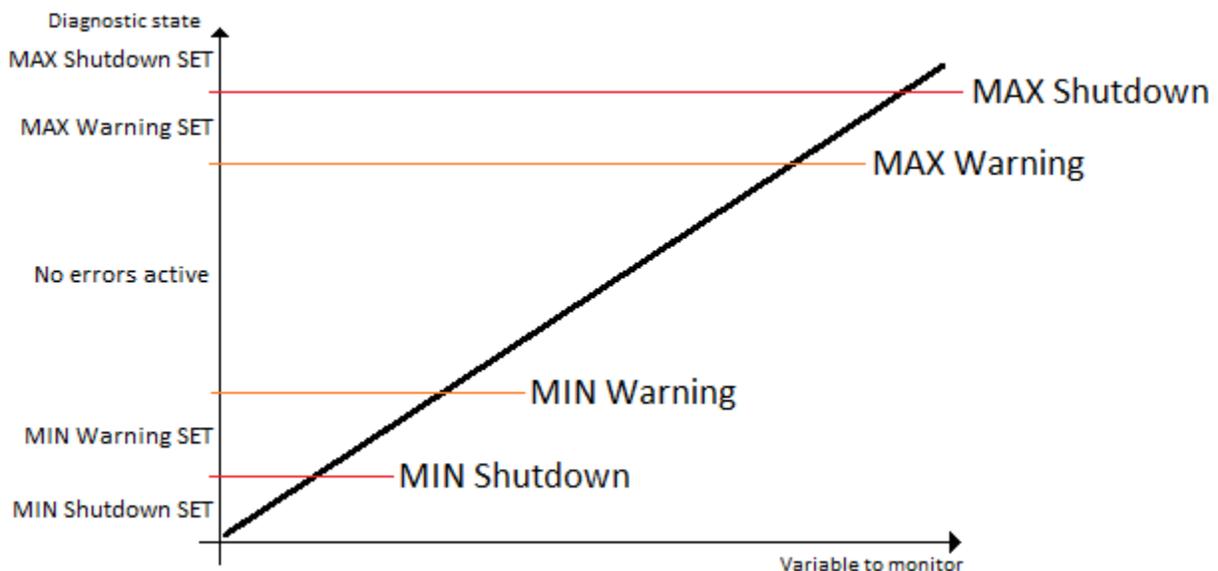


**Figure 4 – Double Minimum and Maximum Error Thresholds**

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

While there are no active DTCs, the 6A BLDC Controller sends DM1 messages with no SPNs, at a rate of one message per second. If a previously inactive DTC becomes active, a DM1 will be sent immediately to reflect this. As soon as the last active DTC goes inactive, a DM1 indicating that there are no more active DTCs will be sent.

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

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

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

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

As defined by J1939 Standard the first byte of the DM1 message reflects the Lamp status. "**Lamp Set by Event**" setpoint determines the lamp type set in this byte of DTC. "**Lamp Set by Event**" setpoint options are listed in Table 10. 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 10 – 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 11 – 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 11. When an FMI is selected from Low Fault FMIs in Table 12 for a fault that can be flagged either high or low occurrence, it is recommended that the user would select the high occurrence FMI from the right column of Table 12. There is no automatic setting of High and Low FMIs in the firmware, the user can configure these freely.

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

**Table 12 – Low Fault FMIs and corresponding High Fault FMIs**

## 1.7. Control Logic Block

The Control Logic function block implements simple control and enable logic that can be used for creating control signals for the other function blocks.
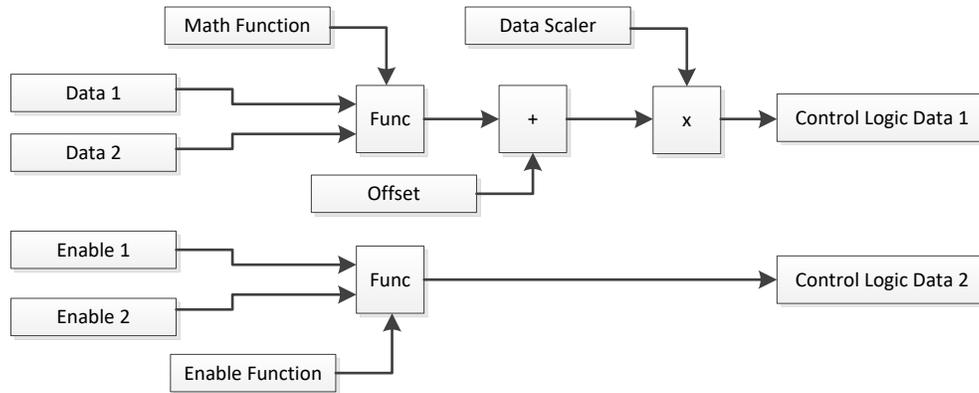


**Figure 5 – Control Logic block diagram**

The Control Logic function block includes two user selectable sources for Data and two user selectable sources for enable data. The data and enable sources are connected to Math functions, both of which implement equation $A\ operator\ B$, where A and B are function inputs and operator is function selected with setpoint "**Math/Enable function to use**". Setpoint options are presented in Table 13.

$$Logic\ Block\ Output\ 1 = \big((A\ op\ B) + Offset\big) \times Scaler$$

$$Logic\ Block\ Output\ 2 = (A\ op\ B)$$

| 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) |

**Table 13 – Math/Enable function to use 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). For the arithmetic functions (9 to 14), the output value will be limited between maximum of 32767 and minimum of -32768.

When dividing, a zero divider will always result in a maximum output value for the associated function.

The "**Data Scaler**" setpoint can be used for scaling the Control Logic output value into the preferred range. The other function blocks, such as the target RPM setting for the motor, expect data values in range 0…1.

There is also special data available in the Control Logic Data, that can be used for example transmitting the controller status over CAN using CAN Transmit Messages. *RotorTargetRPM* is the internal target RPM after ramp function, speed control loop and current control loop. *MotorStalled* is a flag (0/1) indicating if the controller has detected motor stalled condition. *DFuncDesired* is the PWM drive value applied to the output driver FETs (range 0x0 … 0x7FFF). *DRV8301_Flags* are the status flags of the motor control chip, for further details please see section 0. The calculated motor power is available in Control Logic Data #7.
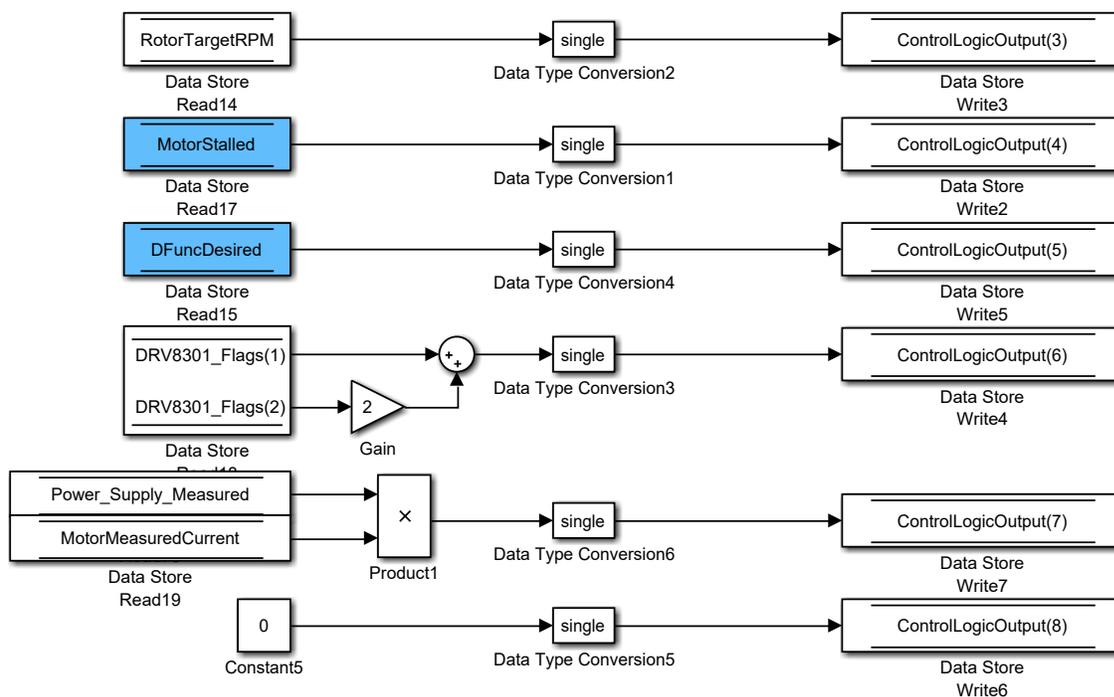


**Figure 6 – Special data available in Control Logic Data**

## 1.8.  CAN Transmit Message Function Block

The CAN Transmit function block is used to send any output from another function block (i.e. input, CAN receive) to the J1939 network. The AX100260 ECU has two CAN Transmit Messages and each message has four completely user defined signals.

## 1.8.1. CAN Transmit Message Setpoints

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

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

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

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

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

## 1.8.2. 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 14. 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.

## 1.9. CAN Receive Function Block

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

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

Once a message has been enabled, a Lost Communication fault will be flagged if that message is not received off the bud within the "**Receive Message Timeout**" period. This could trigger a Lost Communication event as described in section 1.6. In order to avoid timeouts on a heavily saturated network, it is recommended to set the period at least three times longer than the expected update rate. To disable the timeout feature, simply set this value to zero, in which case the received message will never trigger a Lost Communication fault.

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

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

The 6A BLDC Controller supports up to four unique CAN Receive Messages.


## 1.10. 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 14. 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 | User must enable the function block, as it is disabled by default. |
| *2: Universal Input Measured* | 1 to 4 | |
| *3: Control Logic Data* | 1 to 8 | User must enable the function block, as it is disabled by default. |
| *4: PID Function Block* | 1 | User must enable the function block, as it is disabled by default. |
| *5: Control Constant Data* | 1 to 8 | 1 = FALSE, 2 = TRUE, 3 to 15 = User Selectable |
| *6: Motor RPM Value* | 1 to 255 | Measured RPM reading. The Parameter sets the threshold in N*100RPM to compare with. |
| *7: Motor Current Feedback* | 1 to 255 | Measured motor current in Amps. The Parameter sets the threshold in N*50mA to compare with. |
| *8: Power Supply Measured* | 1 to 255 | Measured power supply value in Volts. The Parameter sets the threshold in Volts to compare with. |
| *9: Processor Temperature Measured* | 1 to 255 | Measured processor temperature in °C. The Parameter sets the threshold in Celcius to compare with. |
| *10: CAN Reception Timeout* | N/A | |

**Table 14 – Available Control Sources and Numbers**

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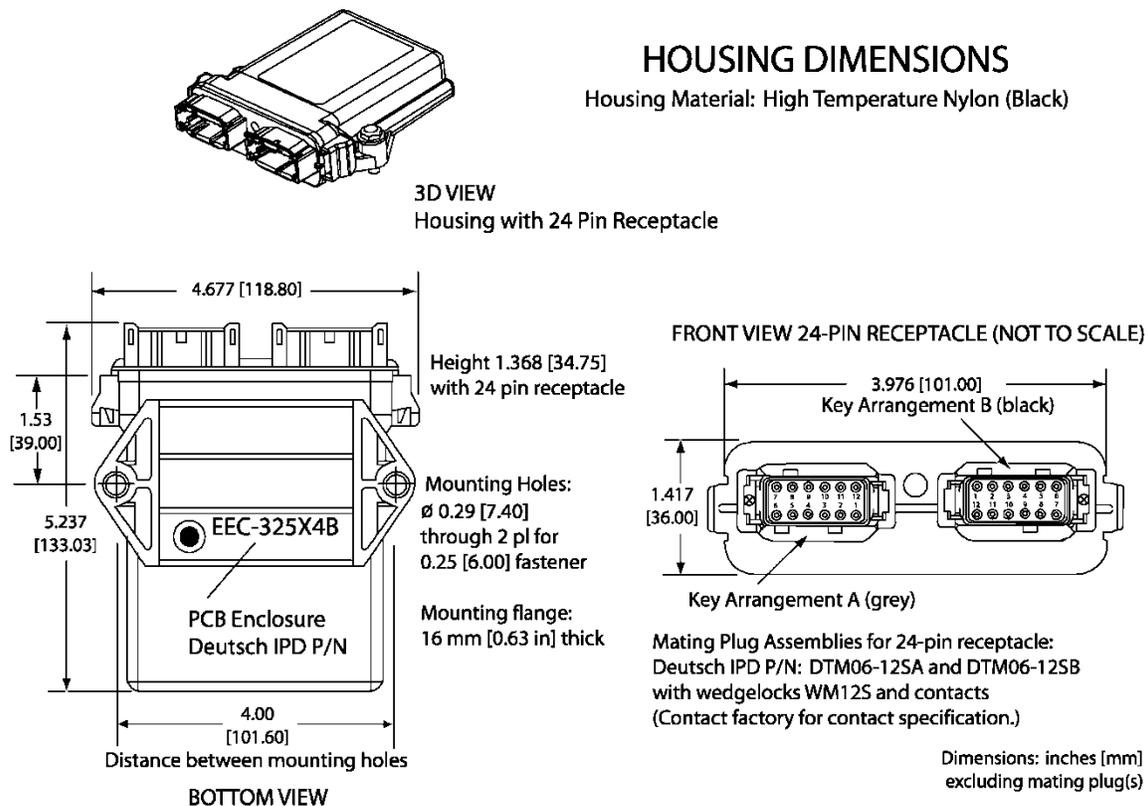
## 2. INSTALLATION INSTRUCTIONS

## 2.1. Dimensions and Pinout



**Figure 7 – AX100260 Dimensional Drawing**

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

**Table 15 – AX100260 Connector Pinout**

# 3. OVERVIEW OF J1939 FEATURES

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

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

## 3.1. Introduction to Supported Messages

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

**From J1939-21 – Data Link Layer**
- Request                                              59904    0x00EA00
- Acknowledgement                                       59392    0x00E800
- Transport Protocol – Connection Management            60416    0x00EC00
- Transport Protocol – Data Transfer Message            60160    0x00EB00
- Proprietary B                              from  65280    0x00FF00
                                             to    65535    0x00FFFF

**From J1939-73 – Diagnostics**
- DM1 – Active Diagnostic Trouble Codes                               65226    0x00FECA
- DM2 – Previously Active Diagnostic Trouble Codes                    65227    0x00FECB
- DM3 – Diagnostic Data Clear/Reset for Previously Active DTCs        65228    0x00FECC
- DM11 – Diagnostic Data Clear/Reset for Active DTCs                  65235    0x00FED3
- DM14 – Memory Access Request                                        55552    0x00D900
- DM15 – Memory Access Response                                       55296    0x00D800
- DM16 – Binary Data Transfer                                         55040    0x00D700

**From J1939-81 – Network Management**
- Address Claimed/Cannot Claim                          60928    0x00EE00
- Commanded Address                                     65240    0x00FED8

**From J1939-71 – Vehicle Application Layer**
- Software Identification                               65242    0x00FEDA

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

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

## 3.2. NAME, Address and Software ID

The 6A 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 | 3, Axiomatic AX100260 |
| 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 6A 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.
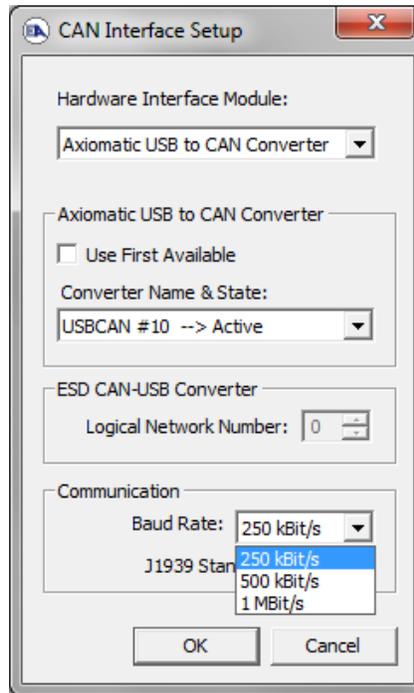
*Note: The information provided in the Software ID is available for any J1939 service tool which supports the PGN -SOFT.*

# 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 6A BLDC Controller, refer to the relevant section in this user manual.

## 4.1. Accessing the ECU Using the Axiomatic EA

ECU with P/N AX100260 does not need any specific setup for the Axiomatic EA. In order to access the high-speed versions, AX100260-01 and/or AX100260-02, the CAN bus Baud Rate needs to be set accordingly. The CAN Interface Setup can be found from "Options" menu in the EA.

## 4.2. J1939 Network Parameters

"**ECU Instance Number**" and "**ECU Address**" setpoints and their effect are defined in Section 3.2.



**Figure 8 - 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 16 – J1939 Network Setpoints**

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

## 4.3.    Universal Input Setpoints

For detailed description of Universal Inputs, please refer to section 1.3.
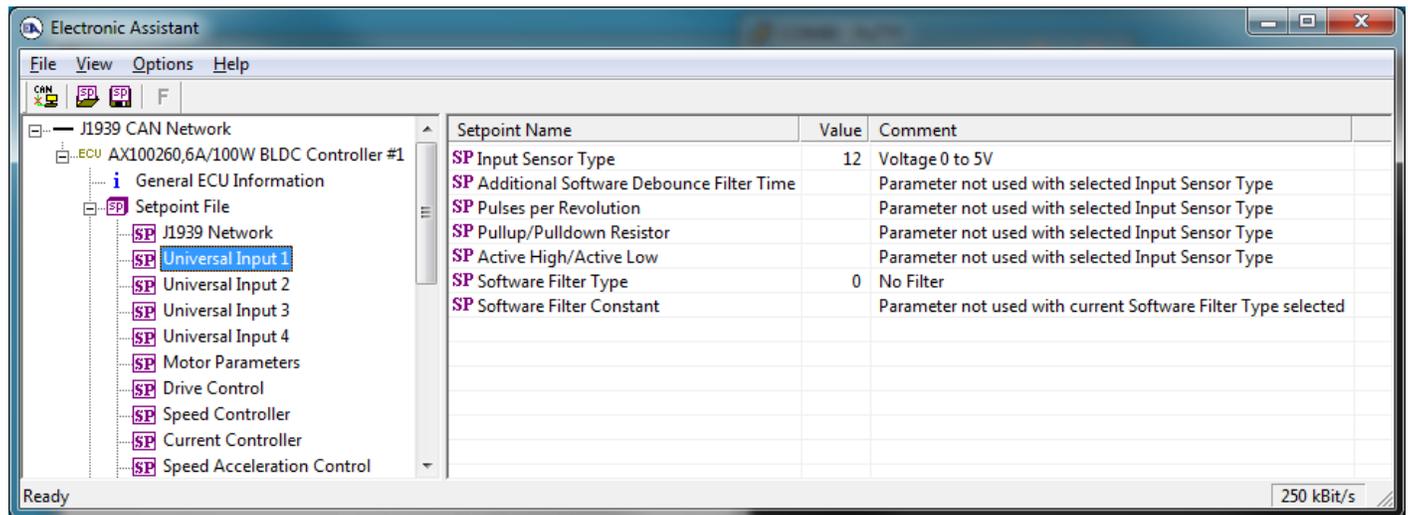


**Figure 9 - Screen Capture of Universal Input Setpoints**

| Name | Range | Default | Notes |
|---|---|---|---|
| Input Sensor Type | Drop List | Digital Normal Logic | See Table 3 |
| Additional Software Debounce Filter Time | Drop List | 0ms | See Table 4 |
| Pulse per Revolution | Drop List | FALSE | See Section 1.1 |
| Pullup/Pulldown Resistor | Drop List | No pull up/down | See Table 5 |
| Active High/Active Low | Drop List | Active High | See Table 6 |
| Software Filter Type | Drop List | No Filtering | See Table 8 |
| Software Filter Constant | 1...1000 | 1 | |

**Table 17 – Universal Input Setpoints**

## 4.4. Motor Parameter Setpoints

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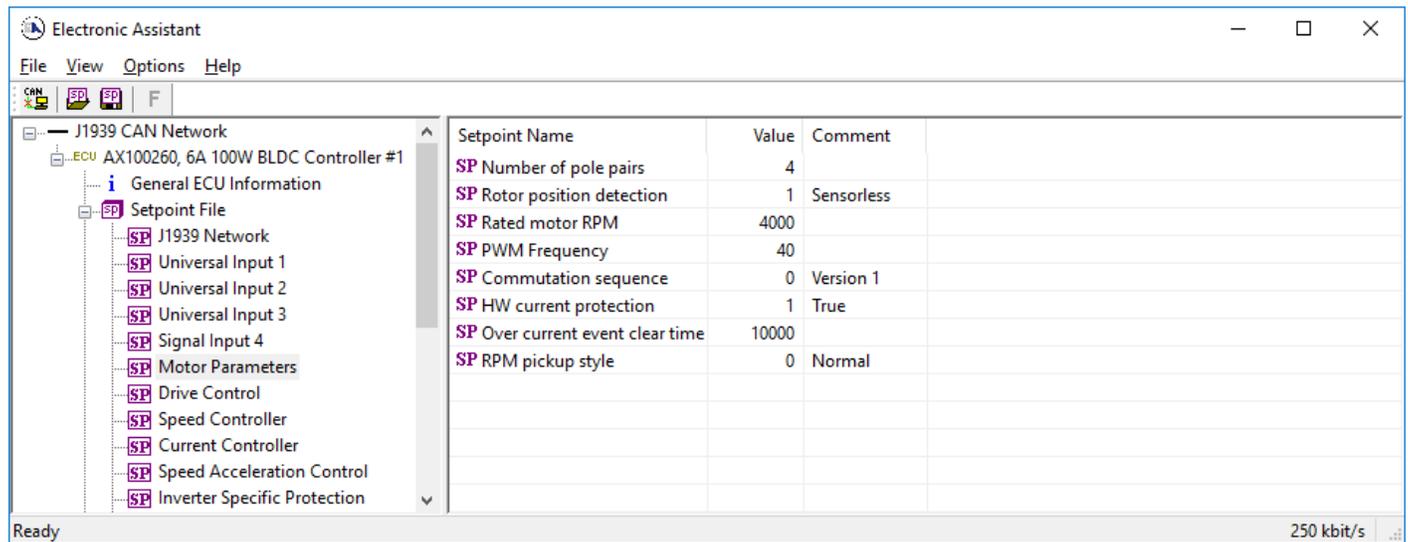


**Figure 10 - Screen Capture of Motor Parameter Setpoints**

| Name | Range | Default | Notes |
|---|---|---|---|
| Number of pole pairs | 0…255 | 4 | |
| Rotor position detection | Drop List | 1 – Sensorless | |
| Rated motor RPM | 0…20000 | 6000 | RPM |
| PWM Frequency | 10…80 | 20 | kHz |
| Commutation sequence | Drop List | 0 – Version 1 | |
| HW current protection | Drop List | 1 – True | |
| Over current event clear time | 0 … 60000 | 10000 | ms |
| RPM pickup style | Drop List | 0 – Normal | If sensorless rotor position detection is used, the speed can be still picked up using Hall A signal. |

**Table 18 – Motor Parameter Setpoints**

## 4.5. Drive Control Setpoints

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

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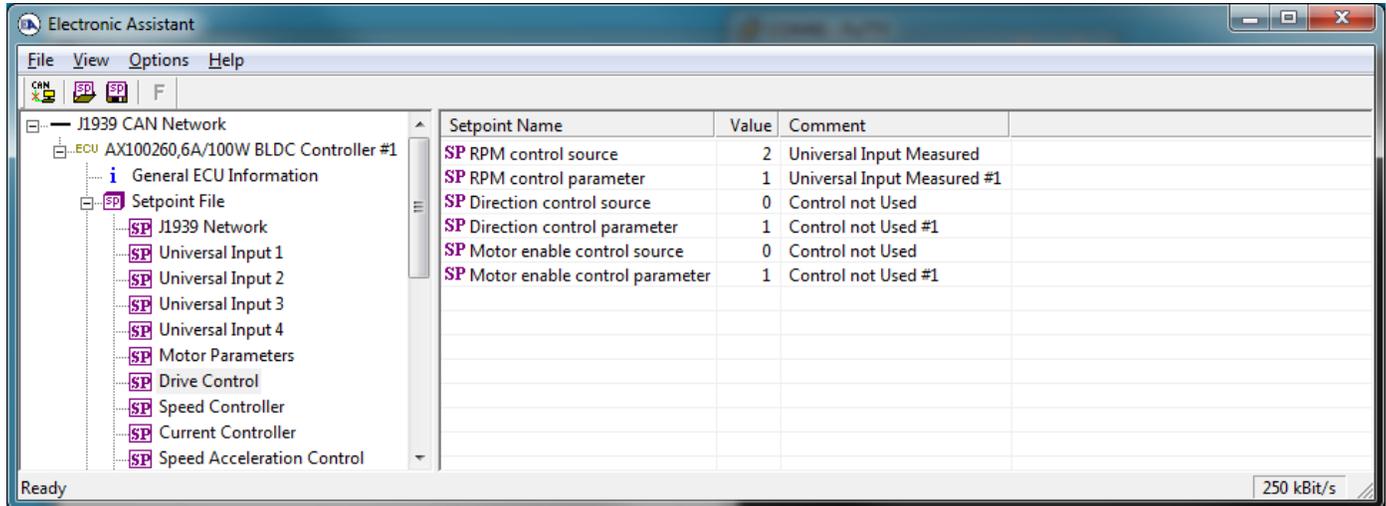


**Figure 11 - Screen Capture of Drive Control Setpoints**

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

**Table 19 – Drive Control Setpoints**

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

**Table 20 – SPN 7991 style Enable+Direction command**

## 4.6. Speed Controller Setpoints

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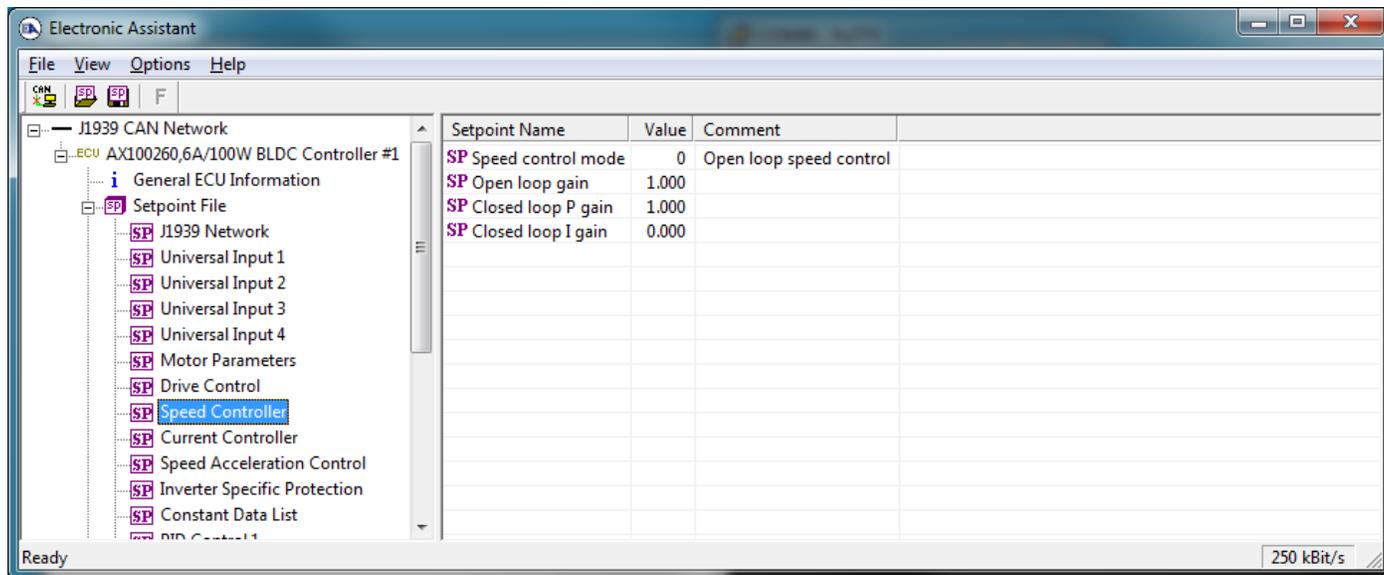


**Figure 12 - Screen Capture of Speed Controller Setpoints**

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

**Table 21 – Speed Controller Setpoints**

## 4.7. Current Controller Setpoints

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

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

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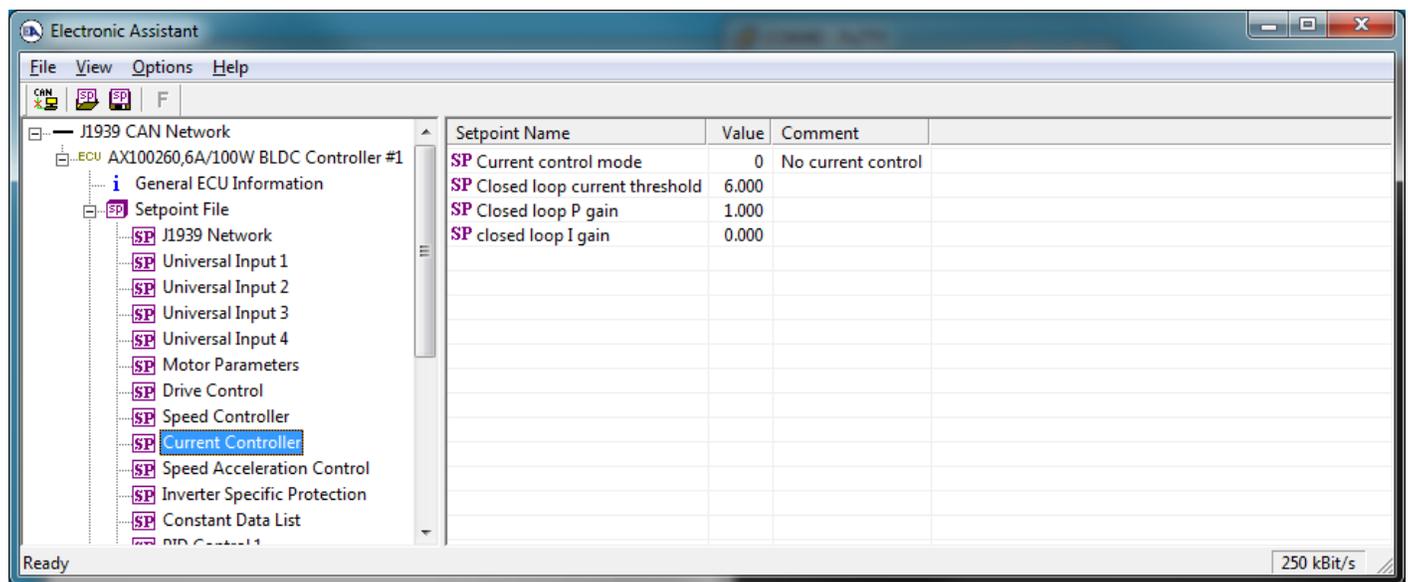


**Figure 13 - Screen Capture of Current Controller Setpoints**

| Name | Range | Default | Notes |
|---|---|---|---|
| Current control mode | Drop List | 0 | No current control |
| Closed loop current threshold | 0.0 … 6.0 | 6.0 | [A] |
| Closed loop P gain | 0.0 ... 100.0 | 1.0 | |
| Closed loop I gain | 0.0 ... 100.0 | 0.0 | |

**Table 22 – Current Controller Setpoints**

## 4.8. Speed Acceleration Control Setpoints

For detailed description of Speed Acceleration Control, please refer to section 1.1.
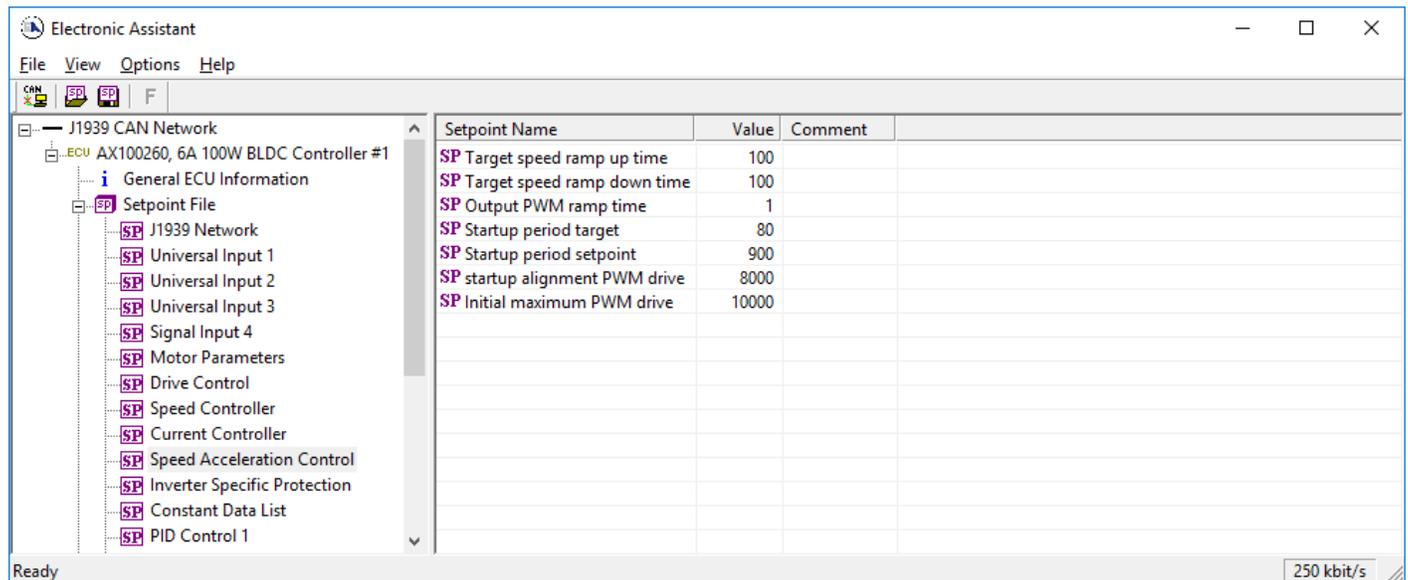


**Figure 14 - Screen Capture of Speed Acceleration Control Setpoints**

| Name | Range | Default | Notes |
|---|---|---|---|
| Target speed ramp up time | 0…60000 | 100 | milliseconds |
| Target speed ramp down time | 0…60000 | 100 | milliseconds |
| Output PWM ramp time | 0…32767 | 1 | |
| Startup period target | 0…32767 | 80 | |
| Startup period setpoint | 0…32767 | 900 | |
| Startup alignment PWM drive | 0…32767 | 8000 | |
| Initial maximum PWM drive | 0…32767 | 10000 | |

**Table 23 – Speed Acceleration Control Setpoints**

## 4.9. Inverter Specific Protection Setpoints

For detailed description of Inverter Specific Protection, please refer to section 0.
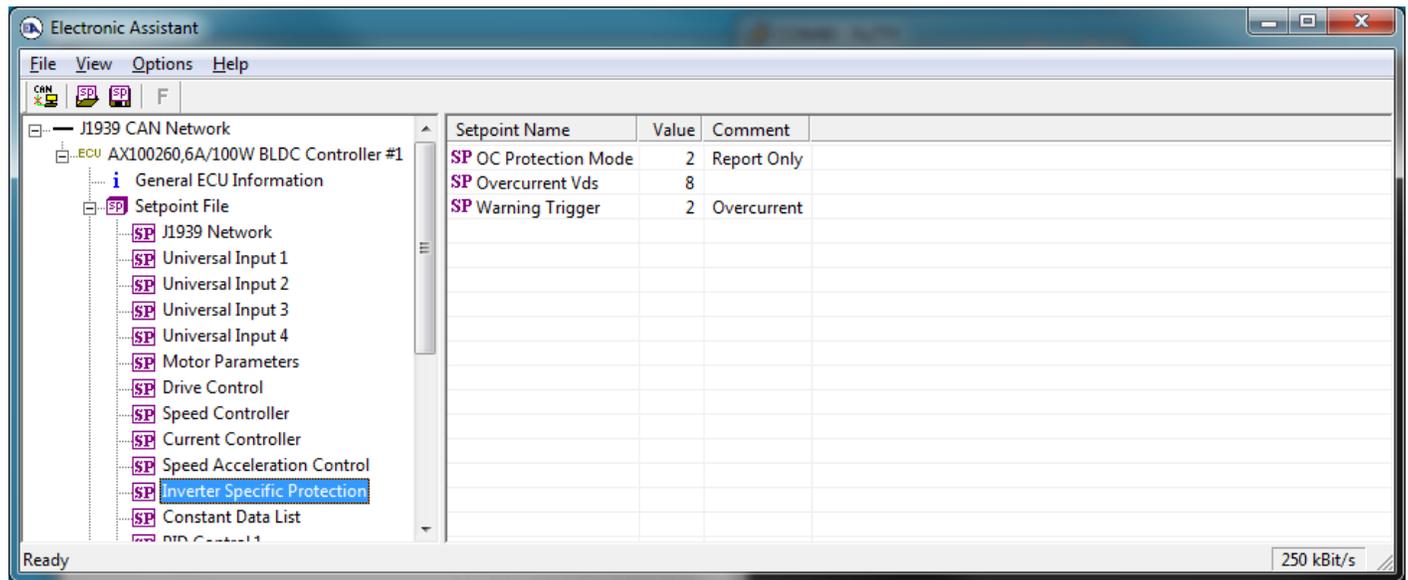


**Figure 15 - Screen Capture of Inverter Specific Protection Setpoints**

| Name | Range | Default | Notes |
|---|---|---|---|
| OC Protection Mode | Drop List | 2 | Report only |
| Overcurrent Vds | 0…31 | 8 | 8 == 0.155V |
| Warning Trigger | Drop List | 2 | Overcurrent |

**Table 24 – Inverter Specific Protection Setpoints**

## 4.10. Constant Data List

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

The first two constants are fixed values of 0 (False) and 1 (True) for use in binary logic. The remaining 6 constants are fully user programmable to any value between +/- 1 000 000. The default values (shown in Figure 16) are arbitrary and should be configured by the user as appropriate for their application.
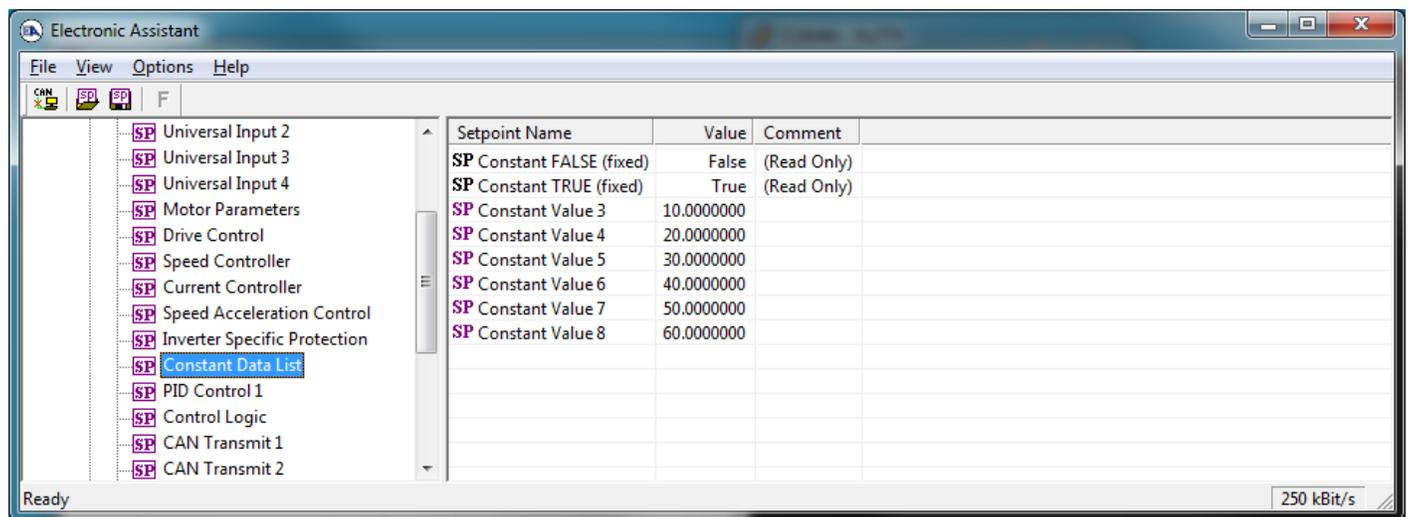


**Figure 16 - Screen Capture of Constant Data List Setpoints**

## 4.11. PID Control 1

The PID Control Function Block is defined in Section **Error! Reference source not found.**. Please refer there for detailed information about how all these setpoints are used.

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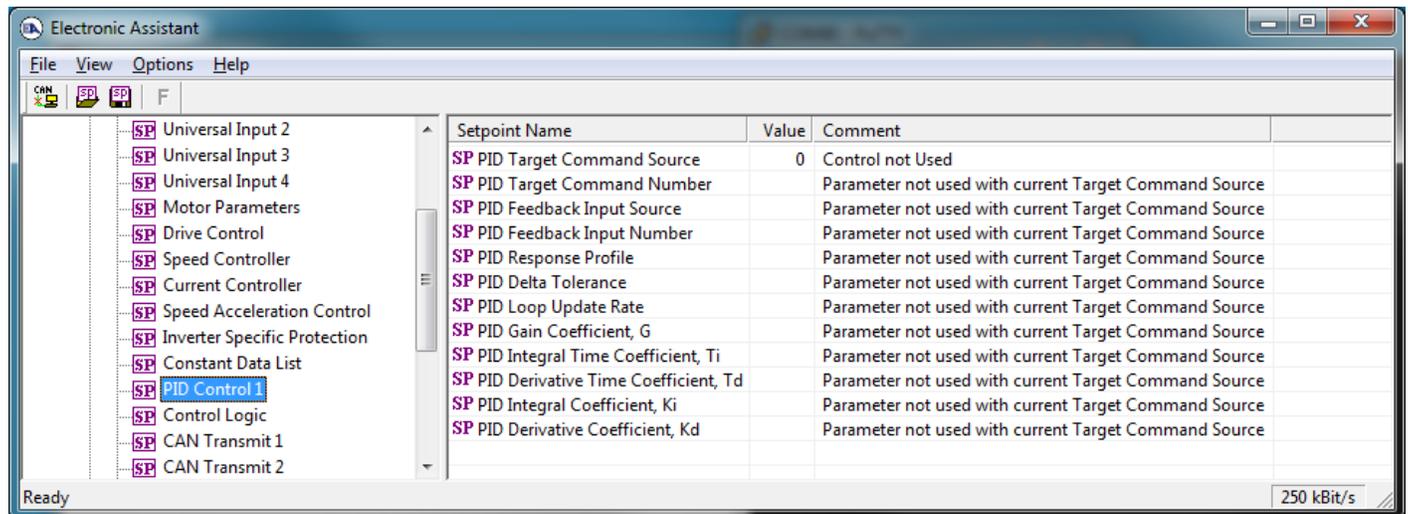


**Figure 17 - Screen Capture of PID Control Setpoints**

| Name | Range | Default | Notes |
|---|---|---|---|
| PID Target Command Source | Drop List | Control Not Used | See Table 14 |
| PID Target Command Number | Depends on control source | 1 | See Table 14 |
| PID Feedback Input Source | Drop List | Control Not Used | See Table 14 |
| PID Feedback Input Number | Depends on control source | 1 | See Table 14 |
| PID Response Profile | Drop List | Single Output | See Table 9 |
| PID Delta Tolerance | 0 to 100 | 1.00 % | % |
| PID Loop Update Rate | 1 to 60 000 ms | 10ms | 1 ms resolution |
| PID Gain Coefficient, G | 0.1 to 10 | 0.5 | See Equation 3 |
| PID Integral Time Coefficient, Ti | 0.001 to 10 Sec | 0.005 Sec | 0.001 Sec (1ms) resolution |
| PID Derivative Time Coefficient, Td | 0.001 to 10 Sec | 0.001 Sec | 0.001 Sec (1ms) resolution |
| PID Integral Coefficient, Ki | 0 to 10 | 1.00 | 0 disables integral, PD ctrl |
| PID Derivative Coeffecient, Kd | 0 to 10 | 1.00 | 0 disables derivative, PI ctrl |

**Table 25 – PID Control Setpoints**

## 4.12. Control Logic Setpoints

Please refer to section 1.7 for detailed information how these setpoints are used.
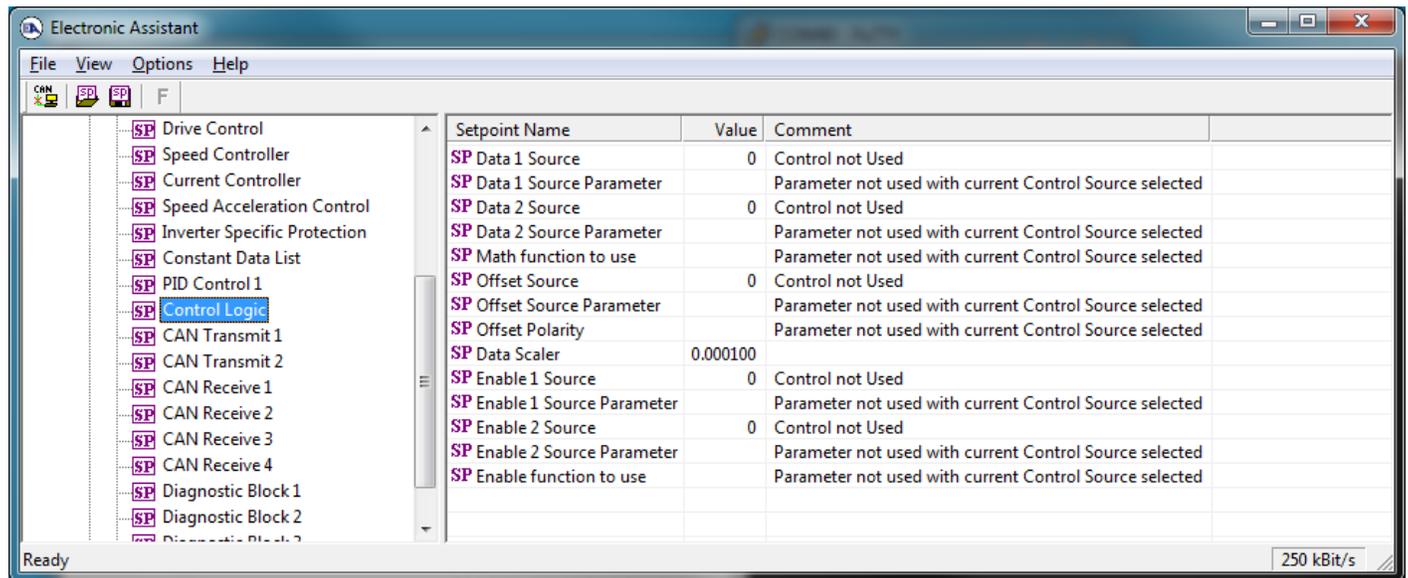


**Figure 18 - Screen Capture of Control Logic Setpoints**

| Name | Range | Default | Notes |
|---|---|---|---|
| Data 1 Source | Drop List | 0 | Control not used |
| Data 1 Source Parameter | Depends on source | 1 | |
| Data 2 Source | Drop List | 0 | Control not used |
| Data 2 Source Parameter | Depends on source | 1 | |
| Math function to use | Drop List | 0 (=) | See Table 13 |
| Offset Source | Drop List | 0 | Control not used |
| Offset Source Parameter | Depends on source | 1 | |
| Offset Polarity | Drop List | + | |
| Data Scaler | -100000 … 100000 | 1.0 | |
| Enable 1 Source | Drop List | 0 | Control not used |
| Enable 1 Source Parameter | Depends on source | 1 | |
| Enable 2 Source | Drop List | 0 | Control not used |
| Enable 2 Source Parameter | Depends on source | 1 | |
| Enable function to use | Drop List | 0 (=) | See Table 13 |

**Table 26 – Control Logic Setpoints**

## 4.13. CAN Transmit Setpoints

Please refer to section 1.8 for detailed information how these setpoints are used. "**Transmit Repetition Rate**" is 0ms by default, thus no message will be sent.



**Figure 19 - Screen Capture of CAN Transmit Message Setpoints**

| Name | Range | Default | Notes |
|---|---|---|---|
| Transmit PGN | 0xff00 … 0xffff | Different for each | See Section 0 |
| 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 14 |
| Signal 1 Data Number | Drop List | Different for each | See 1.8.2 |
| 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 14 |
| Signal 2 Data Number | Drop List | Different for each | See 1.8.2 |
| 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 14 |
| Signal 3 Data Number | Drop List | Different for each | See 1.8.2 |
| 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 14 |
| Signal 4 Data Number | Drop List | Different for each | See 1.8.2 |
| 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 27 – CAN Transmit Message Setpoints**

## 4.14. CAN Receive Setpoints

Please refer to section 1.9 for detailed information about how these setpoints are used. "**Receive Message Timeout**" is set to 0ms by default. To enable Receive message set "**Receive Message Timeout**" that differs from zero.
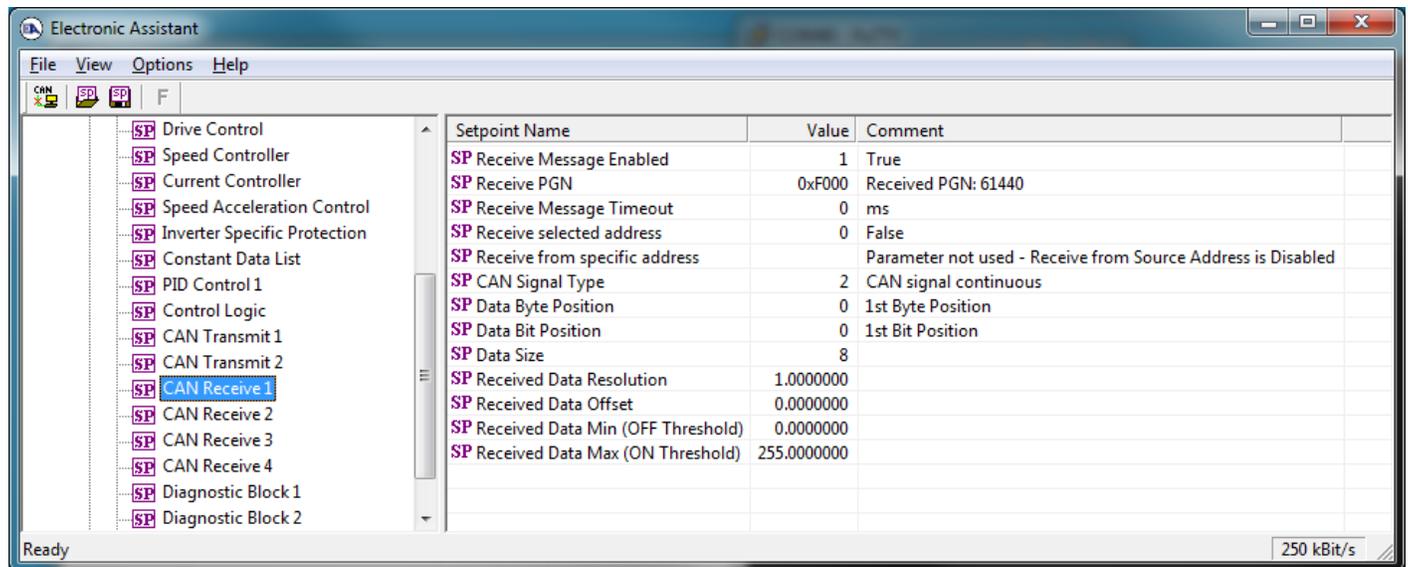


**Figure 20 - Screen Capture of CAN Receive Message Setpoints**

| 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 | |
| Receive Transmit Data Index in Array | 0-7 | 0 | |
| Receive Transmit Bit Index In Byte | 0-7 | 0 | |
| Data Size | 0-32 | 8 bits | |
| Receive Transmit Data Resolution | -100000.0 to 100000 | 0.01 | |
| Receive Transmit Data Offset | -10000 to 10000 | 0.0 | |
| Receive Data Min (Off Threshold) | -1000000 to Max | 0.0 | |
| Receive Data Max (On Threshold) | -100000 to 100000 | 2.5 | |

**Table 28 – CAN Receive Setpoints**

## 4.15. Diagnostics Blocks

There are 3 Diagnostics blocks that can be configured to monitor various parameters of the Controller. The Diagnostic Function Block is defined in section 1.6. Please refer there for detailed information how these setpoints are used.



**Figure 21 - 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 1.6 |
| Maximum Value for Diagnostic Data | Minimum Value for Diagnostic Data … $4.28e^9$ | 5.0 | |
| Minimum Value for Diagnostic Data | 0.0 … Maximum Value for Diagnostic Data | 0.0 | |
| Use Hysteresis When Defining Thresholds | Drop List | False | |
| Hysteresis | 0.0 … Maximum Value for Diagnostic Data | 0.0 | |
| Event Cleared only by DM11 | Drop List | False | |
| Set Limit for MAXIMUM SHUTDOWN | Minimum Value for Diagnostic Data … Maximum Value for Diagnostics Data | 4.8 | |
| Clear Limit for MAXIMUM SHUTDOWN | Minimum Value for Diagnostic Data … Maximum Value for Diagnostics Data | 4.6 | |
| Set Limit for MAXIMUM WARNING | Minimum Value for Diagnostic Data … Maximum Value for Diagnostics Data | 0.0 | |
| Clear Limit for MAXIMUM WARNING | Minimum Value for Diagnostic Data … Maximum Value for Diagnostics Data | 0.0 | |
| Clear Limit for MINIMUM 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 | |
| Clear Limit for MINIMUM SHUTDOWN | Minimum Value for Diagnostic Data … Maximum Value for Diagnostics Data | 0.4 | |
| 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 10 |
| 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 11 |
| MAXIMUM SHUTDOWN, Delay Before Event is Flagged | 0...60000 ms | 1000 | |
| MAXIMUM WARNING, Event Generates a DTC in DM1 | Drop List | True | |
| MAXIMUM WARNING, Lamp Set by Event | Drop List | 0 – Protect | See Table 10 |
| 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 11 |
| MAXIMUM WARNING, Delay Before Event is Flagged | 0...60000 ms | 1000 | |
| MINIMUM WARNING, Event Generates a DTC in DM1 | Drop List | True | |
| MINIMUM WARNING, Lamp Set by Event | Drop List | 0 – Protect | See Table 10 |
| MAXIMUM 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 11 |
| MINIMUM WARNING, Delay Before Event is Flagged | 0...60000 ms | 1000 | |
| MINIMUM SHUTDOWN, Event Generates a DTC in DM1 | Drop List | True | |
| MINIMUM SHUTDOWN, Lamp Set by Event | Drop List | Amber Warning | See Table 10 |
| 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 11 |
| MINIMUM SHUTDOWN, Delay Before Event is Flagged | 0...60000 ms | 1000 | |

**Table 29 – Diagnostic Block Setpoints**

# 5. REFLASHING OVER CAN WITH THE AXIOMATIC EA BOOTLOADER

The AX100260 can be upgraded with new application firmware using the **Bootloader Information** section. This section details the simple step-by-step instructions to upload new firmware provided by Axiomatic onto the unit via CAN, without requiring it to be disconnected from the J1939 network.

*Note: To upgrade the firmware use Axiomatic Electronic Assistant V5.13.85.0 or higher.*

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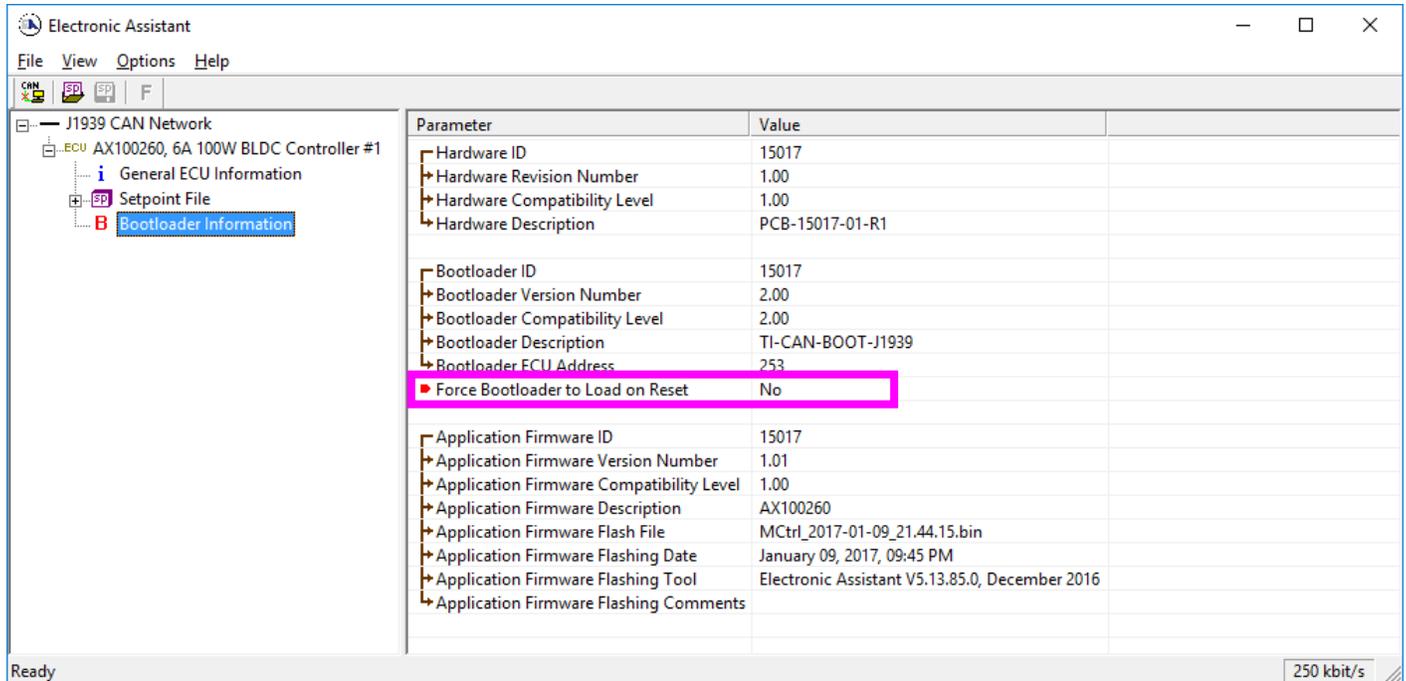


2. To use the bootloader to upgrade the firmware running on the ECU, change the variable **"Force Bootloader To Load on Reset"** to *Yes.*
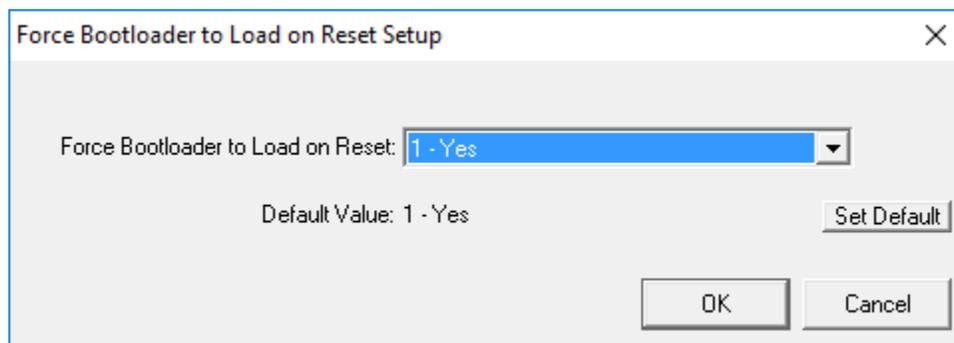


3. When the prompt box asks if you want to reset the ECU, select *Yes*.

**Electronic Assistant**

**?**  Do you want to reset the ECU after changing this parameter ?

[ Yes ]    [ No ]
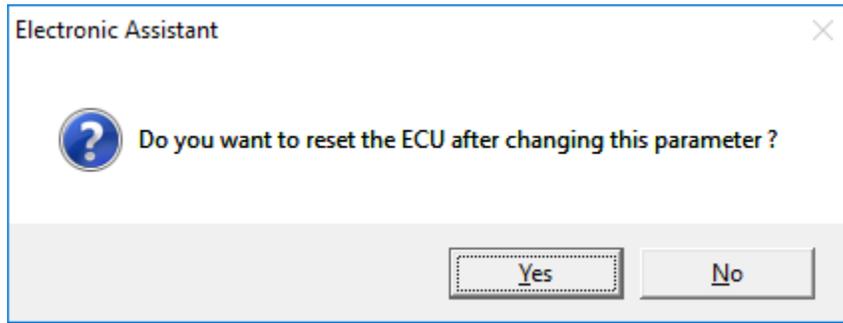
4. Upon reset, the ECU will no longer show up on the J1939 network as an AX100260 but rather as **J1939 Bootloader #1**.

**Electronic Assistant**

File  View  Options  Help

| ECU | J1939 NAME | Address | J1939 Preferred Addre... |
|---|---|---|---|
| ECU J1939 Bootloader #1 | 0X00FEFF0014400000 | 0XFD | Reserved for OEM |

☐─── J1939 CAN Network
  ⊞ ECU J1939 Bootloader #1

Ready                                                          250 kbit/s

**Electronic Assistant**

File  View  Options  Help

☐─── J1939 CAN Network
  ☐ ECU J1939 Bootloader #1
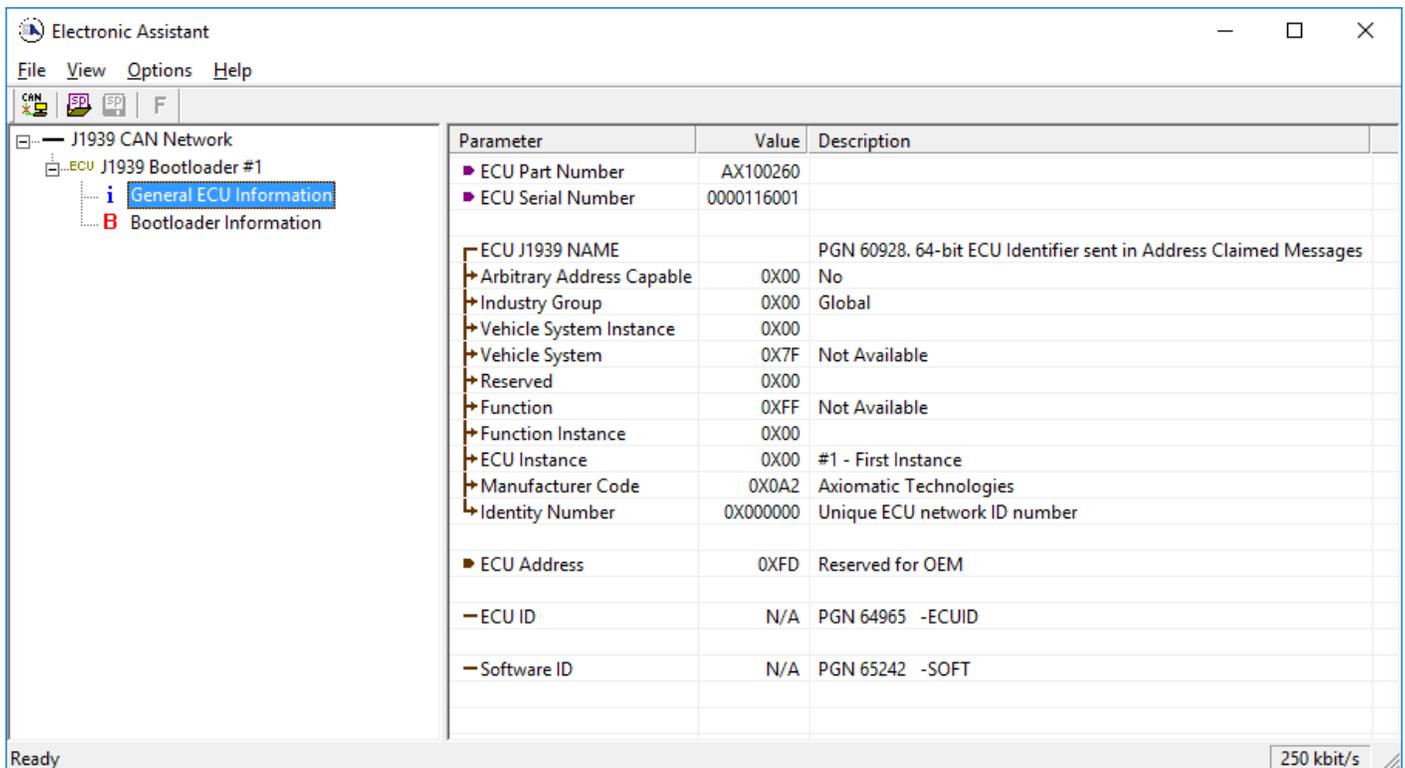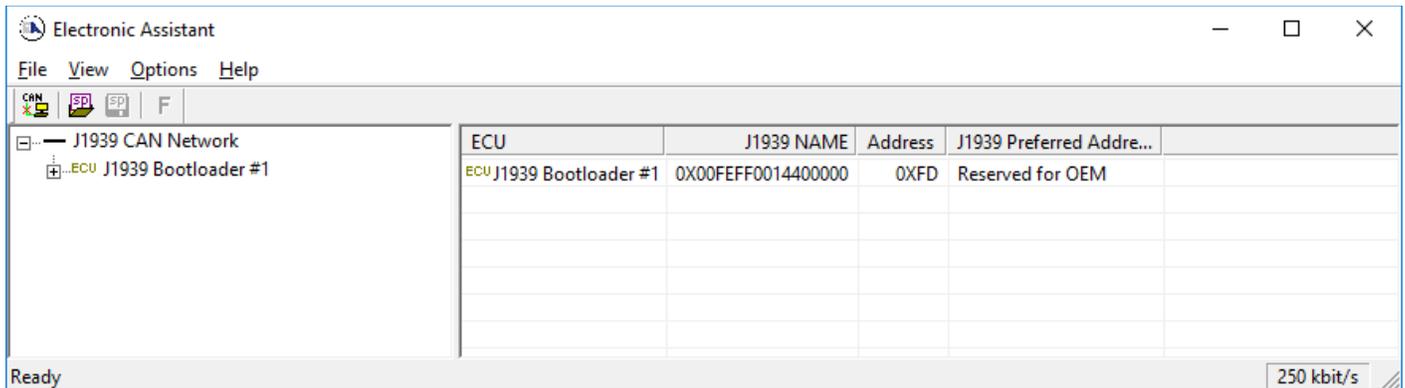    i  General ECU Information
    B  Bootloader Information

| Parameter | Value | Description |
|---|---|---|
| ▶ ECU Part Number | AX100260 | |
| ▶ ECU Serial Number | 0000116001 | |
| ┌ ECU J1939 NAME | | PGN 60928. 64-bit ECU Identifier sent in Address Claimed Messages |
| ┣ Arbitrary Address Capable | 0X00 | No |
| ┣ Industry Group | 0X00 | Global |
| ┣ Vehicle System Instance | 0X00 | |
| ┣ Vehicle System | 0X7F | Not Available |
| ┣ Reserved | 0X00 | |
| ┣ Function | 0XFF | Not Available |
| ┣ Function Instance | 0X00 | |
| ┣ ECU Instance | 0X00 | #1 - First Instance |
| ┣ Manufacturer Code | 0X0A2 | Axiomatic Technologies |
| └ Identity Number | 0X000000 | Unique ECU network ID number |
| ▶ ECU Address | 0XFD | Reserved for OEM |
| ─ ECU ID | N/A | PGN 64965  -ECUID |
| ─ Software ID | N/A | PGN 65242  -SOFT |

Ready                                                          250 kbit/s

*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 AX100260 firmware, but in this case the <u>F</u>lashing feature has been enabled.
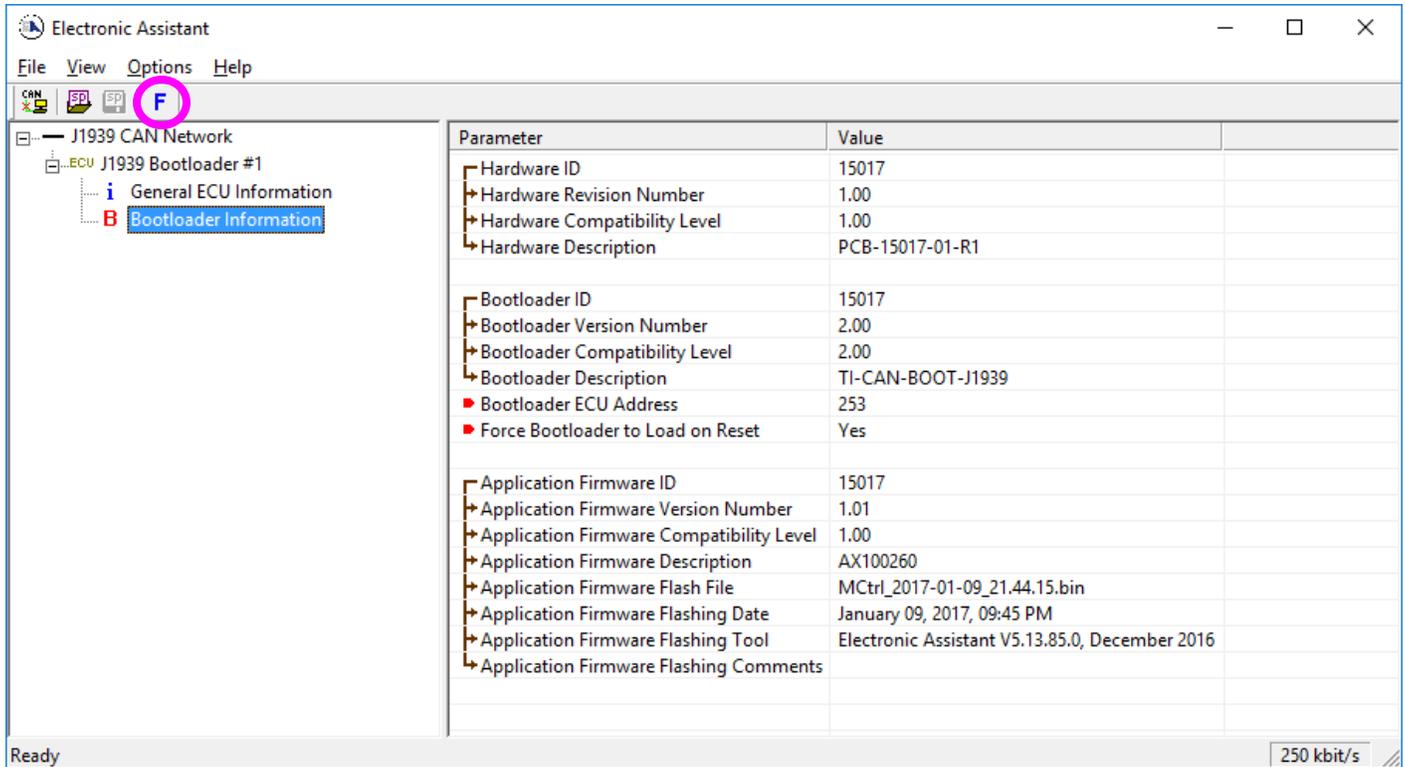


6. Select the <u>F</u>lashing button and navigate to where you had saved the **AF-15017-x.xx.bin** file (or AF-16109-x.xx.bin / AF-16110-x.xx.bin, depending on the CAN bus speed) sent from Axiomatic. (Note: only binary (.bin) files can be flashed using the Axiomatic EA tool.)

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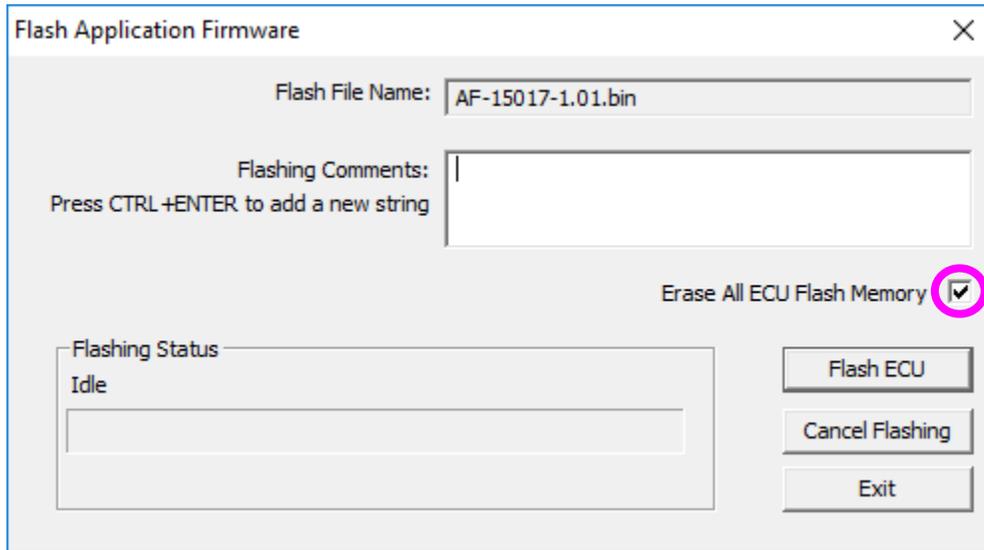
NOTE: Please make sure that the "Erase All ECU Flash Memory" box is checked. Selecting this will erase ALL data stored in non-volatile flash. It will also erase any configuration of the setpoints that might have been done to the ECU and reset all setpoints to their factory defaults. **If this box is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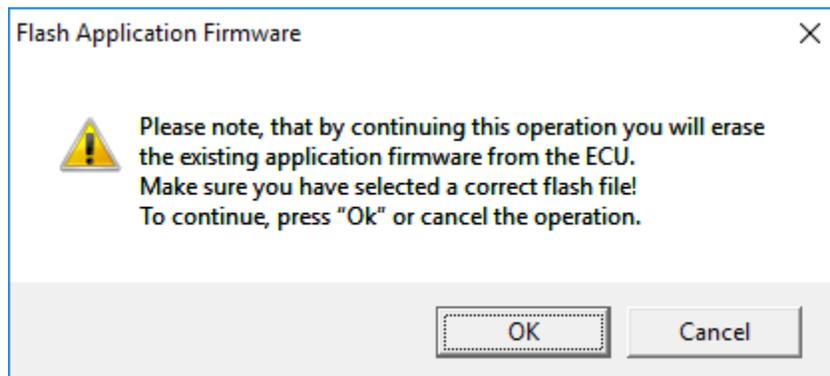


A progress bar will show how much of the firmware has been sent as the upload progresses. The more traffic there is on the J1939 network, the longer the upload process will take.
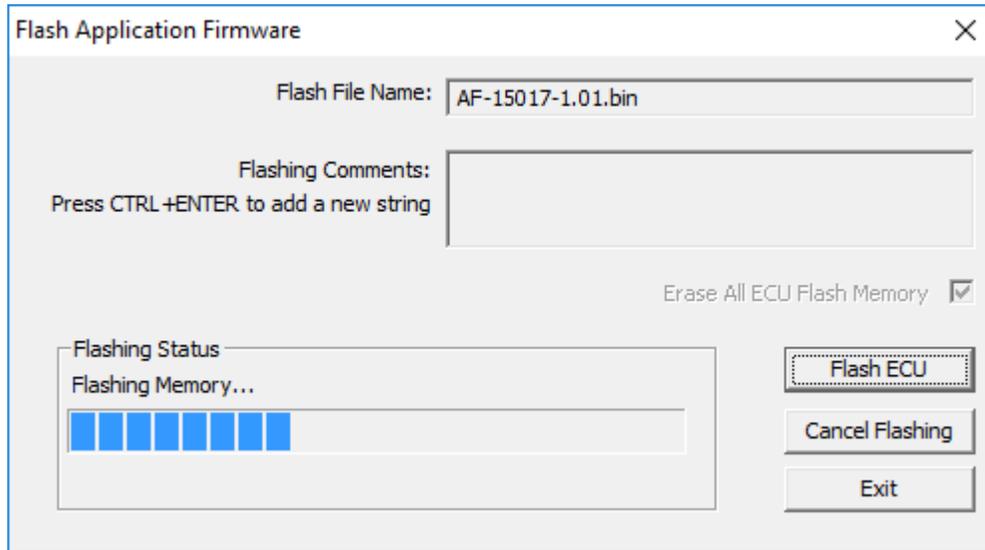
Once the firmware has finished uploading, a message will pop up indicating the successful operation. If you select to reset the ECU, the new version of the AX100260 application 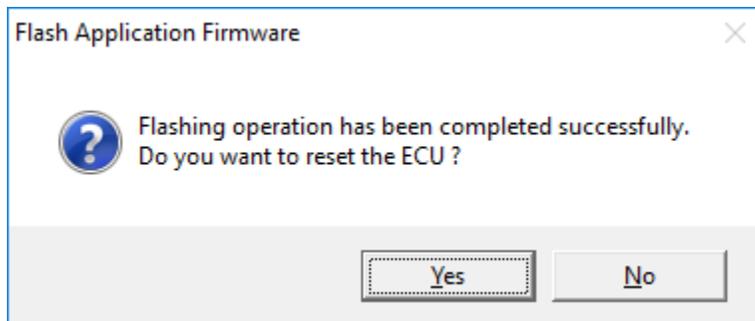will start running, and the ECU will be identified as such by the Axiomatic EA. Otherwise, the next time the ECU is power-cycled, the AX100260 application will run rather than the bootloader function.



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

# APPENDIX A - TECHNICAL SPECIFICATION

## Technical Specifications:

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

## Input Specifications

| Power Supply Input - Nominal | 12 or 24Vdc nominal (9…36Vdc) |
|---|---|
| Reverse Polarity Protection | Provided up to -80Vdc |
| Surge Protection | Provided |
| Under-voltage Protection | Built-in |
| Signal Inputs | Three (3) universal  inputs are user selectable as:<br>Voltage; Current;  Resistive;  PWM; Frequency; or Digital types.<br>One (1) input is user configurable as:<br>Voltage; Current; or Resistive types.<br><br>12-bit Analog to Digital resolution<br>Protected against short to ground<br>Amplitude: up to +Vsupply<br>Input properties are user configurable.  Refer to Table 28.0.<br>Any input on the controller can be coded into a Proprietary B message that can be sent to the CAN network. |
| Analog/Digital Ground | Four (4) are provided. |
| Motor Feedback | Hall Effect Sensor<br>Standard open collector/drain hall input type<br>+5V supply and ground connection pins are provided.<br>10K Pullup to +5V per input<br>Sensorless operation is also available. |

| Table 28.0 Inputs to AX100260 (Up to 4 user selectable inputs) | |
|---|---|
| **Inputs** | **Description** |
| Universal Signal Inputs 1-3 | Up to 3 universal signal inputs are available.<br><br>Voltage Input Types: 0…5VDC or 0…10VDC<br>1mV resolution, accuracy +/- 1% error<br>The offset is in millivolts and the resolution is mV/bit, when sending a CAN message.<br>Input measurement setpoints are interpreted in volts.<br><br>Current Input Types: 4…20mA or 0…20mA<br>1uA resolution, accuracy +/- 1% error<br>The offset is in microamps and the resolution is µA/bit, when sending a CAN message.<br>Input measurement setpoints are interpreted in milliamps.<br>Current sense resistor 249Ω<br><br>Resistive Type with Auto Ranging and Self Calibration:<br>20 Ω  to 250K Ω,   +/- 1% error<br><br>PWM Input Type:<br>PWM Signal Frequency: 1.3kHz – 15kHz<br>PWM Duty Cycle: 0 to 100%<br>0.01% resolution, accuracy +/- 1% error<br><br>Frequency Input Type: 1.3kHz to 15kHz<br><br>Digital Input Types: Normal, Inverse and Latched<br>Active High  with 10K Pullup resistor<br>or Active Low with 10K Pulldown resistor<br>These inputs can be used as an enable or direction command for the controller.  The input accepted is active high (switch is connected to a +V signal when ON). |
| Signal Input 4 | Signal Input 4 is user selectable as:<br><br>Voltage Input Types: 0…5VDC or 0…10VDC<br>1mV resolution, accuracy +/- 1% error<br>The offset is in millivolts and the resolution is mV/bit, when sending a CAN message.<br>Input measurement setpoints are interpreted in volts.<br><br>Current Input Types: 4…20mA or 0…20mA<br>1uA resolution, accuracy +/- 1% error<br>The offset is in microamps and the resolution is µA/bit, when sending a CAN message.<br>Input measurement setpoints are interpreted in milliamps.<br>Current sense resistor 249Ω<br><br>Resistive Type with Auto Ranging and Self Calibration:<br>20 Ω  to 250K Ω,   +/- 1% error |

## Output Specifications

| | |
|---|---|
| Output to Motor | 3 phase, H-bridge, current sensing per each phase<br>6A @ 24VDC nominal continuous<br>6A @ 12VDC nominal continuous<br><br>100W nominal power rating<br>Sensorless or hall sensor operation<br><br>Overcurrent protection is provided at 12A.<br>Short circuit protection is provided.<br>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<br>&#10095;   Open loop speed<br>&#10095;   Closed loop speed;<br>&#10095;   Current control;<br>&#10095;   Position control; or<br>&#10095;   PID control.<br>The control input to drive the motor can be mapped to any of the universal inputs or the controller can respond to messages from a CAN bus. |
| Thermal Protection | Thermal protection is built-in and configurable. |
| Reference Voltage | 1 +5V, +/- 0.5%, 200 mA<br>Four connection points are provided for each of installation. |

## General Specifications

| | |
|---|---|
| Microprocessor | TI TMS320F28069, 32-bit, 256 KB flash program memory, 100 KB RAM |
| Motor Control | Standard embedded software is provided. |
| Diagnostics | There are 3 Diagnostic blocks that can be configured to monitor various parameters of the Controller. |
| Simulink | The product was developed with Simulink. **Simulink** is a model-based design tool from Mathworks. Refer to the User Manual *Axiomatic Hardware Interface Library for Mathworks Simulink* for details. |
| User Interface | Via the Axiomatic Electronic Assistant for *Windows* operating systems<br>It comes with a royalty-free license for use.<br><br>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 EA and Axiomatic USB-CAN as a kit (P/N AX070502), which includes all interconnecting cables. |
| Flashing over CAN | The controller software can be reflashed over the CAN connection using the EA. |
| CAN port | 1 CAN port (SAE J1939) (CANopen® on request.) |
| Weight | 0.60 lb. (0.27 kg) |
| Operating Conditions | -40°C to +125°C (-40°F to 257°F) |
| Protection Rating | IP67 |
| Enclosure and Dimensions | High Temperature Nylon PCB Enclosure - (equivalent TE Deutsch P/N: EEC-325X4B)<br>4.62 x 5.24 x 1.43 inches   117.42 x 133.09 x 36.36 mm<br>(W x L x H excluding mating plugs) |
| Electrical Connections | 24-pin receptacle (equivalent TE Deutsch P/N: DTM13-12PA-12PB-R008)<br>*Refer to Installation Instructions* section. |
| Mating Plug Kit | A mating plug kit comprised of all mating connectors is available as P/N: PL-DTM06-12SA-12SB. It is equivalent to the TE Deutsch P/Ns: DTM06-12SA; DTM06-12SB: 2 wedgelocks WM12S; and 24 contacts 0462-201-20141. 20 AWG wire is recommended for use with contacts 0462-201-20141. |
| Mounting | The motor controller should be mounted as close to the battery and/or the motor as possible. Install the unit with appropriate space available for servicing and for adequate wire harness access and strain relief.<br><br>Mounting holes sized for ¼ inch or M6 bolts.  The bolt length will be determined by the end-user's mounting plate thickness.  The mounting flange of the controller is 0.63 inches (16 mm) thick.  If the module is mounted without an enclosure, it should be mounted vertically with connectors facing left and right to reduce likelihood of moisture entry.  The CAN wiring is considered intrinsically safe.  The power wires are not considered intrinsically safe and so in hazardous locations, they need to be located in conduit or conduit trays at all times. The module must be mounted in an enclosure in hazardous locations for this purpose.<br><br>All field wiring should be suitable for the operating temperature range. |

Note: 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.

## SERVICE
All products to be returned to Axiomatic require a Return Materials Authorization Number (RMA#) from sales@axiomatic.com. Please provide the following information when requesting an RMA number:
- Serial number, part number
- Runtime hours, description of problem
- Wiring set up diagram, application and other comments as needed

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

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