USER MANUAL UMAX105000
USER MANUAL UMAX105000-01
USER MANUAL UMAX105000-02

# 150A DC MOTOR CONTROLLER WITH CAN, SAE J1939

## USER MANUAL

**P/N: AX105000**

**P/N: AX105000-01 – J1939 500kbits/s Baud Rate**

**P/N: AX105000-02 – Custom J1939 Baud Rate, 1Mbits/s**


Axiomatic Technologies Oy
Höytämöntie 6
33880 LEMPÄÄLÄ, Finland
Tel. +358 103 375 750
salesfinland@axiomatic.com
www.axiomatic.fi

Axiomatic Technologies Corporation
1445 Courtneypark Dr. E.
Mississauga, ON Canada L5T 2E3
Tel. 1 905 602 9270
sales@axiomatic.com
www.axiomatic.com

## VERSION HISTORY

| Version | Date | Author | Modification |
|---|---|---|---|
| 1.0.0 | Feb 25, 2020 | Antti Keränen | Initial Version |
| -- | June 11, 2021 | Amanda Wilkins | Updated dimensional drawing for P3 |
| -- | April 14, 2023 | M Ejaz | Fixed legacy issues<br>Copied Technical Specifications from TDAX105000 into Appendix A |
| 1.0.1 | September 6, 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) |

**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 2013 |
| TDAX105000 | Technical Datasheet, 150A DC Motor Controller with CAN, Axiomatic Technologies 2021 |
| UMAX07050x | User Manual, Axiomatic Electronic Assistant and USB-CAN, Axiomatic Technologies, 2023 |


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

NOTE: This product is supported by Axiomatic Electronic Assistant V5.15.xxx.0 and higher.

## 1. Overview Of The Controller

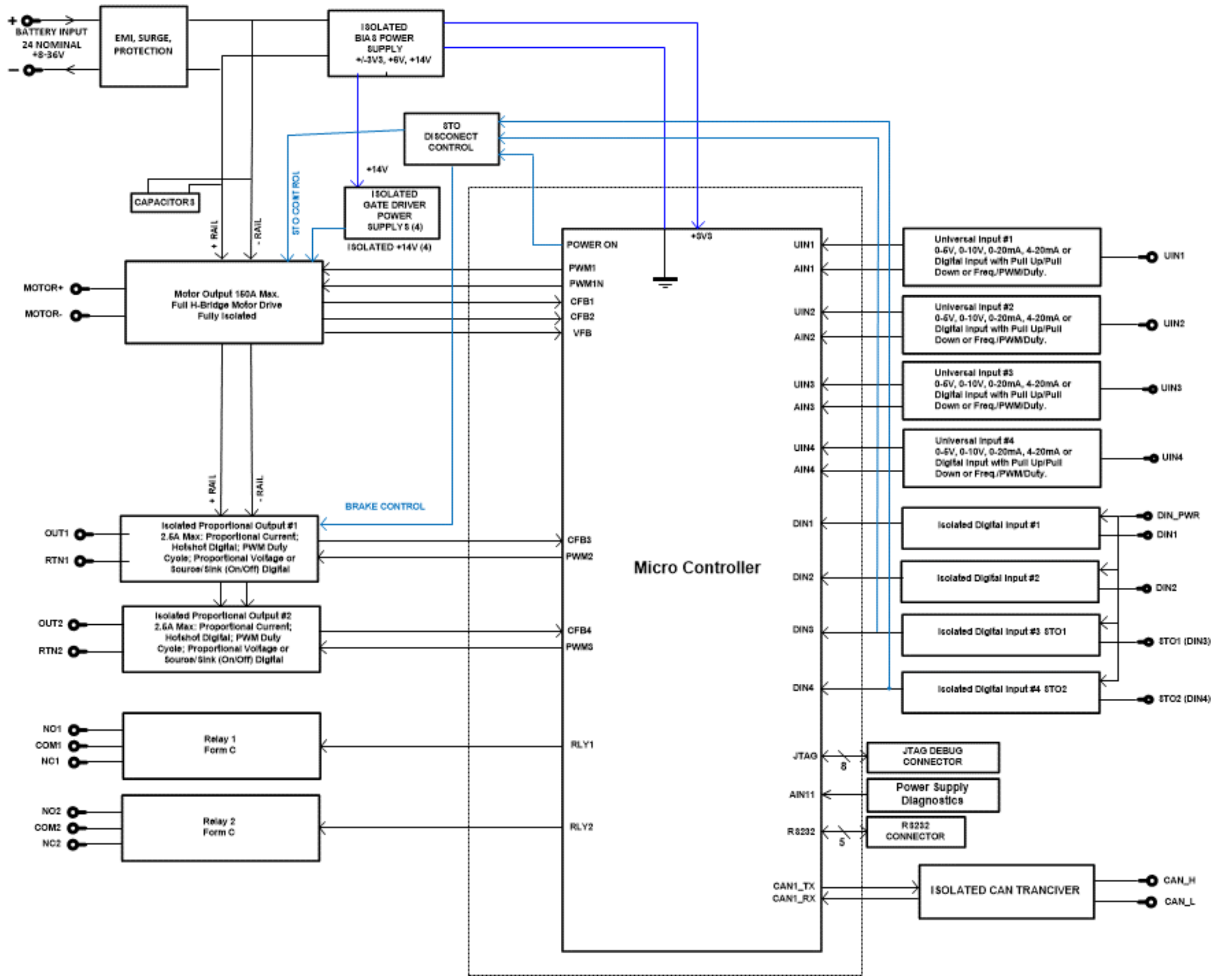



**Figure 1 – AX105000 Block Diagram**

The 150A DC Motor Controller is designed for versatile control of a DC motor or other load up to 150A current. In addition to the motor control output, there are two proportional current outputs, two universal inputs and six digital inputs. For the universal inputs, controller's flexible circuit design gives the user a wide range of configurable input types. The sophisticated control algorithms allow the user to program the controller for a wide range of applications without the need for custom software.

The controller has two Universal inputs that can be configured to measure analog voltage or current, frequency/PMW or digital signal and six Digital inputs that are fixed to measure digital on/off signals. Measured input data can be sent to a SAE J1939 CAN or used to drive the outputs directly or through the configurable control algorithms.

The motor control output is of H-bridge type with capability of driving up to 150A continuous current through the load in both directions. The proportional outputs can be configured to source current signals up to 2A. Any of the outputs can be configured to use any of the on-board inputs as either a control signal or an enable signal as well as SAE J1939 CAN data.

The *Windows*-based Axiomatic Electronic Assistant (EA) is used to configure the controller via a 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 150A DC Motor Controller. Throughout this document, 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 '*Voltage 0 to 5V*'.

In this document, the configurable properties of the ECU are divided into function blocks, namely Motor Control Function Block, Input Function Block, Output Function Block, Diagnostic Function Block, PID Control Function Block, Lookup Table Function Block, Programmable Logic Function Block, Math Function Block, DTC React Function Block, CAN Transmit Message Function Block and CAN Receive Message Function Block. These function blocks are presented in detail in next subchapters.

The 150A DC Motor Controller can be ordered using the following part numbers depending on the application.

| | |
|---|---|
| AX105000 | Controller with the default J1939 baud rate (250kbits/s). |
| AX105000-01 | Controller with the 500kbits/s J1939 baud rate. |
| AX105000-02 | Controller with a custom 1Mbits/s J1939 baud rate. |

### 1.1. Motor Control Function Block

The motor control output can drive a motor or other load with continuous 150A current. The maximum instantaneous current can go beyond this limit.

The Motor Control setpoint group has settings for configuring how the motor control output is driven. The **"Output At Minimum Command"** is the output response when the minimum control value (-100) is fed into the output control block. The **"Output At Maximum Command"** is the equivalent with maximum control value (100). Both setpoint values are given in milliamps. The motor control algorithm will limit the output current if it tries to rise above these limits.

**"Output At Override Command"** is the output target current when the override command is used by configuring the **"Override Source"** and **"Override Number"** setpoints. There is a current limiting functionality with this feature too.

**"Ramp Up"** and **"Ramp Down"** setpoints define the ramp duration for the motor control output current to rise to its target or fall back to zero. Please note if the enable function is used to stop the motor, the ramp function is not applied because the enable functionality utilizes hardware feature for disabling the motor.

**"Control Source"** and **"Control Number"** setpoints define the control source for motor driving. The allowed values for these setpoints are listed in Table 23.

**"Direction Source"** and **"Direction Number"** define how the direction of motor current flow is controlled. **"Enable Source"** and **"Enable Number"** define the motor driving enable signal source. Both the direction and enable interpret the 'control signal == 0' as the one drive value and 'control signal > 0' the other.

**"Invert Motor Direction"** setpoint can be used to change the default direction of motor rotation.

**"Maximum Driver Stage Temperature"** and **"Drive Stage Temperature Hysteresis"** define the maximum value for the driver FET temperature and the hysteresis value for clearing this error condition. When the driver FETs exceed the configured maximum temperature, the motor driving is disabled until the temperature has fallen below the maximum value minus the configured hysteresis.

**"Motor Current Filter Constant"** setpoint defines the filter characteristic in motor current measurement. Smaller constant shows the peaks in the measured motor current, higher constants give more stable measurement results.

**"Stable Drive Values Before Changing Direction"** setpoint defines the number of target drive values that must have same sign (direction info) before the value is really applied to motor driving FETs. This will implement dead time while changing direction of rotation, during which the motor terminals are connected to GND via the driver FETs.

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 Source"** to *Control Not Used* and **"Enable Source"** to *Received CAN Message*. With this configuration, the received CAN message values are used as listed in Table 1.

| | |
|---|---|
| 0 | *Disabled* |
| 1 | *Motor enabled in forward direction* |
| 2 | *Motor enabled in reverse direction* |
| 3 | *Reserved* |

**Table 1 – Combined enable and direction signals**

**"Override Source"**, **"Override Number"** and **"Override Response"** allow the user to define an additional control source for overriding the motor output control source set in **"Control Source"** and **"Control Number"** setpoints. The **"Override Response"** can be configured to a negative or to a positive current value. The sign will define the direction of motor driving during override.

**NOTE**: The motor control output has E-STOP functionality built in. To enable the motor drive, the STO inputs 1 & 2 need to be pulled low. Otherwise the motor driving output will remain disabled by hardware.

The motor control algorithm has software implementation for suppressing current peaks from triggering over current detection in some cases. In practice the suppression algorithm masks out current peaks higher than 300A for 25ms and peaks higher than 270A for 250ms. After the suppression time has elapsed, the hardware over current detection circuitry takes over. The hardware over current limit is set to 350A.

## 1.2. Input Function Blocks

The controller has altogether eight inputs. The four Universal Inputs can be configured to measure voltage, current, frequency, pulse width (pwm) or digital signal (on/off). The four Digital Inputs are fixed to measure digital high / low voltage signals.

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

| | |
|---|---|
| 0 | *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* |
| 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 2 – Universal Input Sensor Type Options**

On Universal Inputs, analog voltage (i.e. 0-5V, 0-10V) or current (0-20mA, 4-20mA) signals go directly to a 12-bit analog-to-digital converter (ADC) on the processor. The voltage input is a high impedance input protected against shorts to GND or Vcc. In current mode, a 250Ω resistor is used to measure the input signal. Input signals should be connected to the GND reference pins provided on the connector, per

| | |
|---|---|
| 0 | *None* |
| 1 | *111ns* |
| 2 | *1.78us* |
| 3 | *14.22us* |

**Table 3 – Debounce Time Options**

An additional software debounce filter can be used with Universal Input types when configured to detect digital signals for filtering the inputs using longer time constants than with the default debounce filter. 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.

The "**Pulses/Units Per Revolution**" setpoint can be used with all input types. If this setpoint is set to a value greater than zero, then the input data will be multiplied by this value, resulting the input to be read in rotations-per-minute (RPM). This feature can be used for scaling the measured input value to RPM reading without having to use a lookup table. If this setpoint is set to zero, the inputs are measured and reported using the corresponding units (volts, milliamps, hertz…).

Universal Inputs have all available 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 22kΩ 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 | *22 kΩ Pullup* |
| 2 | *22 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**

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 types 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. Software filtering is described in detail in section 1.3 below.

### 1.2.1. Digital Inputs

The controller has six digital inputs. The digital inputs don't have as many setpoints for configuration as the Universal Inputs have, however there is some configurability.

The **"Input Sensor Type"** setpoint allows to select between different input types as listed in Table 7 above. There is also **"Software Debounce Filter Time"** available, functionality is identical to Universal Inputs' software debounce filtering. The **"Active High/Active Low"** setpoint defines whether a high or low input reading is interpreted as digital high.

**NOTE**: All digital inputs will need external power supplied to the controller using the pin 1 of the "I/O Connector" (grey TE Deutsch equivalent connector). If this pin is left not powered (not connected to VPS), all digital inputs will read as '0'. This will also keep the motor control output disabled.

## 1.3. Input Filtering

Measured input data from both universal and analog 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**".

<u>Equation 1 - Moving Average Transfer Function:</u>

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

Equation 2 - Repeating Average Transfer Function:

$$\text{Value}=\frac{\sum_0^N \text{Input}_N}{N}$$

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 CAN message data. The sum is set to zero for the next read and summing is started again.

## 1.4. Output Function Blocks

In addition to the Motor Control output, the controller has two proportional current outputs and two relay outputs. The proportional current outputs are capable of driving currents up to 2.5A whereas the relay outputs support currents up to 2A.

"**Output Type**" setpoint determines what kind of signal the output produces. Changing this 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 9.

| | |
|---|---|
| 0 | *Disabled* |
| 1 | *Proportional Current (0-2.5A)* |
| 2 | *Digital Hotshot (0-2.5A)* |
| 3 | *PWM Duty Cycle (0-100%)* |
| 4 | *Proportional Voltage (0-Vps)* |
| 5 | *Digital On/off (0-Vps)* |

**Table 9 – 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. Both outputs run on same dither frequency, thus changing it to one output does change it for other outputs as well. 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 ‘*Proportional Voltage’* uses the measured value of the power supply and adjusts the duty cycle of the output such that the average value will match the target output voltage. Note, that the ‘*Proportional Voltage*’ output is essentially a pwm output and thus won’t be suitable for driving loads that require pure analog voltage.

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. Both outputs run on same output frequency, thus changing the frequency for one output changes frequency of the others as well. “**PWM Output Frequency**” is editable only if neither of the outputs is set to ‘*Proportional Current’ or ‘Hotshot Digital’* 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 10.

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

**Table 10 – 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 2. 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 2.

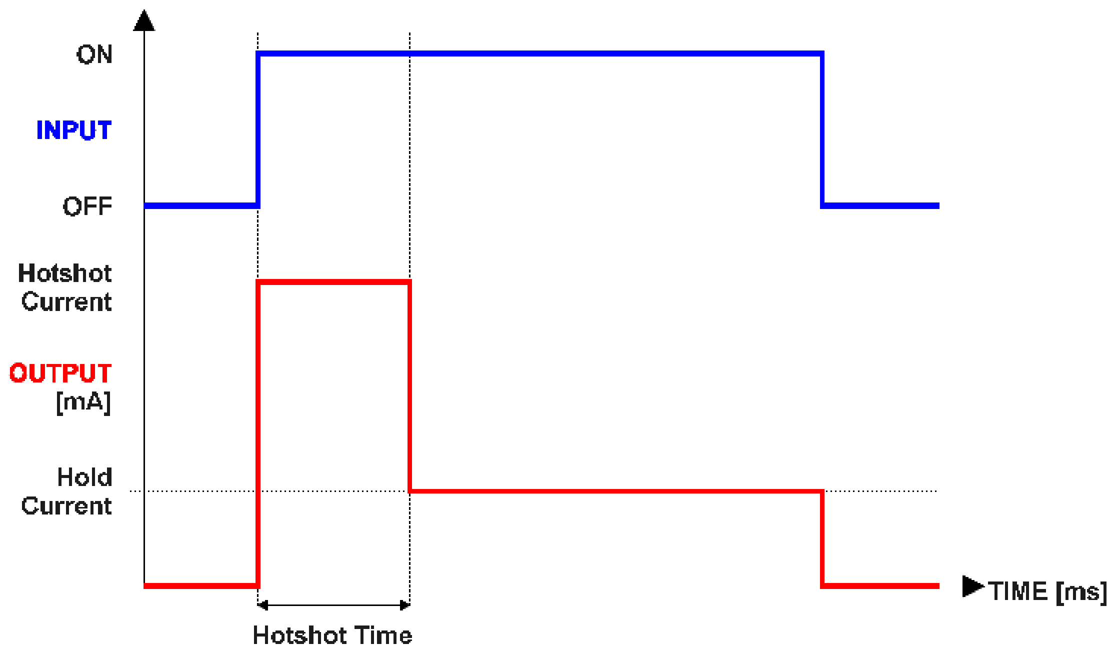



**Figure 2 – Hotshot Digital Profile**

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 11. If a non-digital signal is selected as Enable signal the signal is interpreted as shown in Figure 4.

| | |
|---|---|
| 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 11 – 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 12. 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 12 – 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 13. 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 13 – Fault Response Options**

Another fault response that can be enabled is that a power supply over voltage or under voltage will automatically disable ALL outputs. Note: this setpoint is associated with the **Power Supply Diag** function block. Also, if the **Over Temperature Diag** function block is enabled, then a microprocessor over-temperature reading disables all the outputs until it has cooled back to the operating range.

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 1.5.

The proportional 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. Diagnostic Function Blocks

The 150A DC Motor 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 15 and Table 16) |
| 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 150A DC Motor Controller supports 8 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, 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** let user to specify four thresholds, each with independent diagnostic parameters. The diagnostic status and threshold values is determined and expected as show in Figure 3 below.

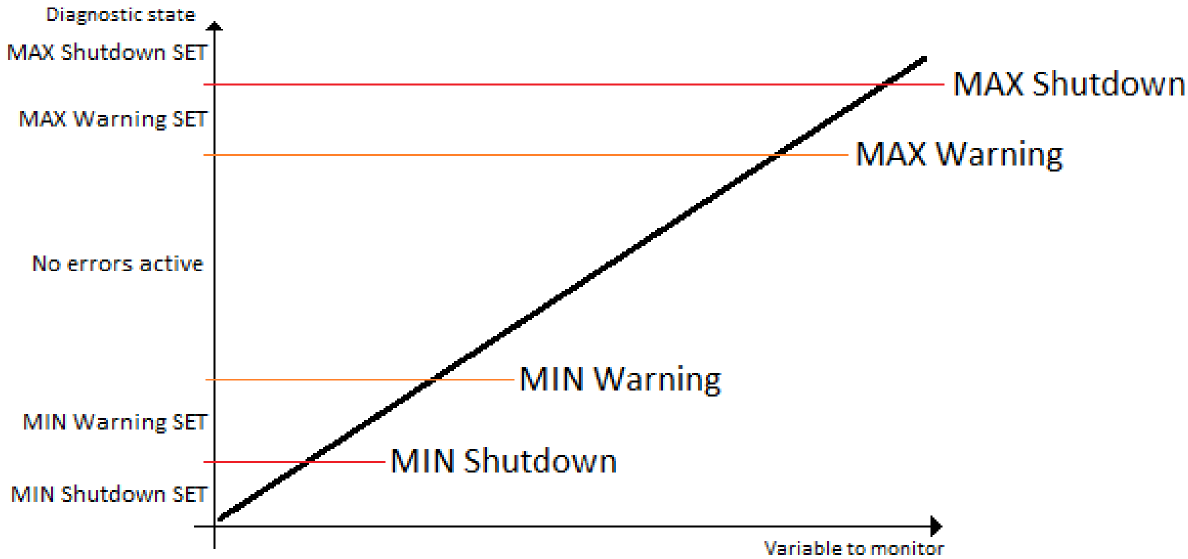



**Figure 3 – Double Minimum and Maximum Error Thresholds**

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 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”.

There is also 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. The setpoints “**Power Fault Disables Outputs**” and “**Over Temperature Shutdown**” can be used for enabling the shutdown of the unit (shutdown == output driving is turned off).

While there are no active DTCs, the 150A DC Motor 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).

| | |
|---|---|
| ℹ | 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 14. 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 14 – 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 15 – 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 15. When an FMI is selected from Low Fault FMIs in Table 16 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 16. 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 16 – Low Fault FMIs and corresponding High Fault FMIs**

## 1.6. PID Control Function 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 150A DC Motor 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**

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

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

In order to have the block output 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 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 needed 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 $\mathrm{Error}_K$ is less than this value, $\mathrm{Error}_K$ 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.

$$PIDOutput_k = P_k + I_k + D_k$$

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

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

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

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

**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. Lookup Table Function Block

Lookup Tables are used to give output response up to 10 slopes per input. If more than 10 slopes are required, A Programmable Logic Block can be used to combine up to three tables to get 30 slopes as described in Section 1.8.

Lookup tables have two differing modes defined by "**X-Axis Type**" setpoint, given in Table 18. 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 18 – 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 19. ‘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 19 – 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 X values are limited by minimum and maximum range of the selected input source if the source is one of the Input Blocks or a Math Function Block. For the fore mentioned sources X-Axis data will be redefined when ranges are changed, therefore inputs should be adjusted before changing X-Axis values. For other sources Xmin and Xmax 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 Xmin and Xmax values in linear calculation, Section 1.4). Ignored points are not considered for min and max values.

### 1.8. Programmable Logic Function Block

A Programmable Logic can be linked to up to three Lookup Tables, any of which would be selected only under given conditions. Thus, output of a Programmable Logic at any given time will be the output of the Lookup Table selected by defined logic. Therefore, up to three different responses to the same input, or three different responses to different inputs, can become the input to another function block.

In order to enable any one of the Programmable Logic blocks, the “**Programmable Logic Enabled**” setpoint must be set to ‘*True*’. By default, all Logic blocks are disabled.

The three associated tables are selected by setting “**Table X – Lookup Table Block Number**” setpoint to desired Lookup Table number, for example selecting *1* would set Lookup Table 1 as TableX.

For each TableX there are three conditions that define the logic to select the associated Lookup Table as Logic output. Each condition implements function $Argument1\ Operator\ Argument2$ where

Operator is logical operator defined by setpoint "**Table X – Condition Y, Operator**". Setpoint options are listed in Table 20. Condition arguments are selected with "**Table x – Condition Y, Argument Z Source**" and "**Table x – Condition Y, Argument Z Number**" setpoints. If '*0 – Control not Used*' option is selected as "**Table x – Condition Y, Argument Z Source"** the argument is interpreted as 0.

| | |
|---|---|
| 0 | *=, Equal* |
| 1 | *!=, Not Equal* |
| 2 | *>, Greater Than* |
| 3 | *>=, Greater Than or Equal* |
| 4 | *<, Less Than* |
| 5 | *<=, Less Than or Equal* |

**Table 20 – Table X – Condition Y, Operator Options**

The three conditions are evaluated and if the result satisfies logical operation defined with "**Table X – Conditions Logical Operator**" setpoint, given in Table 21, the associated Lookup Table is selected as output of the Logical block. Option '*0 – Default Table*' selects associated Lookup Table in all conditions.

| | |
|---|---|
| 0 | *Default Table (Table1)* |
| 1 | *Cnd1 And Cnd2 And Cnd3* |
| 2 | *Cnd1 Or Cnd2 Or Cnd3* |
| 3 | *(Cnd1 And Cnd2) Or Cnd3* |
| 4 | *(Cnd1 Or Cnd2) And Cnd3* |

**Table 21 – Table X – Conditions Logical Operator Options**

The three logical operations are evaluated in order and the first to satisfy gets selected, thus if Table1 logical operation is satisfied, the Lookup Table associated with Table1 gets selected regardless of two other logical operations. In addition, if none of the logical operations is satisfied the Lookup Table associated with Table1 gets selected.

### 1.9. Math Function Block

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

The mathematical block's input signal value can have values in range -1000 to 1000. In case the signal value is larger than that, the "**Function X Input Y Minimum**" and "**Function X Input Y Maximum**" values can be used to rescale the value. 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 four selectable functions, which each implements equation $\mathrm{A\ operator\ B}$, where A and B are function inputs and operator is function selected with setpoint "**Math function X Operator**". Setpoint options are presented in Table 22. The functions are connected together, so that result of the preceding function goes into Input A of the next function. Thus Function 1 has both Input A and Input B selectable with setpoints, where Functions 2 to 4 have only Input B selectable. Input is selected by setting "**Function X Input Y Source**" and "**Function X Input Y**

**Number**”. If “**Function X Input B Source**” is set to 0 ‘*Control not used’* signal goes through function unchanged.

$$Math\ Block\ Output = \Big(\big((A1\ op1\ B1)op2\ B2\big)op3\ B3\ \Big)\ op4\ B4$$

| | |
|---|---|
| 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 22 – Math function X Operator Options**

For logic operations (6, 7, 8) scaled 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), it is recommended to scale the data such that the resulting operation will not exceed full scale (-1e6 to 1e6) and saturate the output result.

When dividing, a zero divider will always result in a full (1e6) output value for the associated function.

Lastly the resulting mathematical calculation, presented as real value, can be scaled into the appropriate physical units using the “**Math Output Minimum Range**” and “**Math Output Maximum Range**” setpoints. These values are also used as the limits when the Math Function I selected as the input source for another function block.

## 1.10. Control Variable Data Blocks

In case run time settable, non-volatile data is required in the control algorithm, the Control Variable Data Blocks offer one possible solution. These function blocks contain a single variable with rules for updating the value at run time, without the need for the user to trigger the variable update process as it is done with the Control Constant Data Blocks.

The **“Variable Value”** setpoint shows the current value for the variable. This setpoint is user configurable, so it is possible to modify the value using the Axiomatic EA.

**“Variable Value Data Source”** and **“Variable Data Data Number”** define the source from which the new Variable Data value is read at update event.

The variable data update process is controlled using the next five setpoints, namely **“Variable Value Update Trigger Source”**, **“Variable Value Update Trigger Number”**, **“Variable Value Update**

**Trigger Threshold Source"**, **"Variable Value Update Trigger Threshold Number"** and **"Variable Value Update Function"**. The trigger number and source define the control signal to be compared with the trigger threshold control signal. The comparison is done using the logical (or mathematical) operator that can be selected using **"Variable Value Update Function"** setpoint.

In case the logical operation evaluates as *True* (for the Math functions, greater than zero) the variable data value is updated from the selected data source and the new value is stored into Flash memory. The save is done only once per evaluating the update function as *True*. Before the next save can happen, the update function must evaluate as *False* (for the Math functions, equal to zero) at least once. Also, the minimum time between two variable data saving events is set to 10 seconds (not user configurable limit).

## 1.11. DTC React

The DTC React function block is a very simple function which will allow a received DTC, sent from another ECU on a DM1 message, to disable an output or be used as input to another type of logic block. Up to five SPN/FMI combinations can be selected.

Should a DM1 message be received with the SPN/FMI combination defined, the corresponding DTC State will be set to ON. Once ON, if the same SPN/FMI combination has not been received again after 3 seconds, the DTC State will be reset to OFF.

The DTC could be used as a digital (on/off) input for any function block as appropriate.

## 1.12. 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 AX105000 ECU has six CAN Transmit Messages and each message has four completely user defined signals.

### 1.12.1. 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 5 second delay. This is done to prevent any power up or initialization conditions from creating problems on the network.

By default, all messages are sent on Proprietary B PGNs as broadcast messages. Thus "**Transmit Message Priority**" is always initialized to 6 (low priority) and the "**Destination Address**" setpoint is not used. This setpoint is only valid when a PDU1 PGN has been selected, and it can be set either to the Global Address (0xFF) for broadcasts or sent to a specific address as setup by the user.

### 1.12.2. 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 23. 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, thus **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.

## 1.13. 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 1.5. 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.

By default, all control messages are expected to be sent to the 150A DC Motor Controller on Proprietary B PGNs. However, should a PDU1 message be selected, the 150A DC Motor Controller can be setup to receive it from any ECU by setting the "**Specific Address that sends the PGN**" to the Global Address (0xFF). If a specific address is selected instead, then any other ECU data on the PGN will be ignored.

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 150A DC Motor Controller I/O supports up to eight unique CAN Receive Messages.

### 1.14. 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 23. All sources, except "CAN message reception timeout", are available for all blocks, including output control blocks and CAN Transmit messages. Thought input Sources are freely selectable, not all options would make sense for any particular input, 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 8 | User must enable the function block, as it is disabled by default. |
| *2: Universal Input Measured* | 1 to 4 | |
| *3: Digital Input Detected* | 1 to 8 | 1-2 = DIN1-2, 3-4 = STO1-2,<br>5 = OC (Motor), 6-7 = SC1-2 (Prop. Outputs),<br>8 = Combined ‘Motor enable’ (0x01) and ‘Clear fault’ (0x02) flags. |
| *4: PID Function Block* | 1 to 2 | User must enable the function block, as it is disabled by default. |
| *5: Lookup Table* | 1 to 4 | |
| *6: Programmable Logic Block* | 1 to 2 | User must enable the function block, as it is disabled by default. |
| *7: Math Function Block* | 1 to 6 | User must enable the function block, as it is disabled by default. |
| *8: Control Constant Data* | 1 to 15 | 1 = FALSE, 2 = TRUE,<br>3 to 15 = user configurable |
| *9: Diagnostic Trouble Code* | 1 to 5 | Will only be valid if the corresponding DTC has a non-zero SPN |
| *10: Output Target Value* | 1 to 3 | 1-2 = Prop. Outputs,<br>3 = Motor Output |
| *11: Output Current Feedback* | 1 to 3 | Measured Feedback current from the proportional output in mA, used in Output Diagnostics.<br>1-2 = Prop. Outputs,<br>3 = Motor Output |
| *12: Power Supply Measured* | 0 to 255 | Measured power supply value in Volts. The Parameter sets the threshold in Volts to compare with. In case Parameter is set to ‘0’, the measured value is used as is. |
| *13: Processor Temperature Measured* | 0 to 255 | Measured processor temperature in °C. The Parameter sets the threshold in Celcius to compare with. In case Parameter is set to ‘0’, the measured value is used as is. |
| *14: CAN Reception Timeout* | N/A | |
| *15: Control Variable Data* | 1 to 2 | Variable data. |

**Table 23 – Available Control Sources and Numbers**

If a non-digital signal is selected to drive a Universal Input in digital input mode, the signal is interpreted to be OFF at or below the minimum of selected source and ON at or above the maximum of the selected source, and it will not change in between those points. Thus, analog to digital interpretation has a built in hysteresis defined by minimum and maximum of the selected source, as shown in Figure 4. A Universal Input signal is interpreted to be ON at or above “Maximum Range” and OFF at or below “Minimum Range”.

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

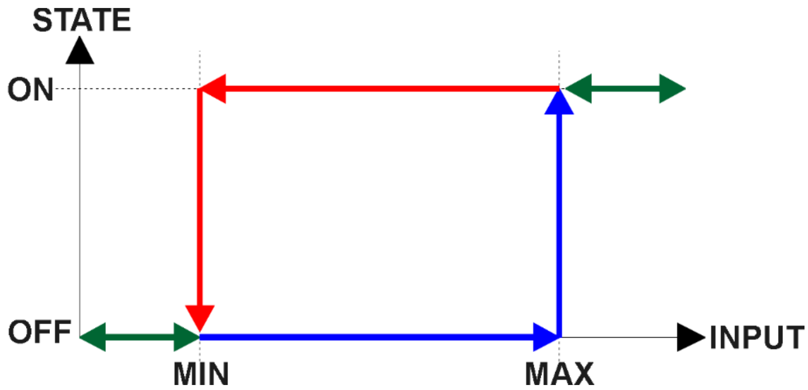



**Figure 4 – Analog source to Digital input**

## 2. Installation Instructions

### 1.1. Dimensions and Pinout

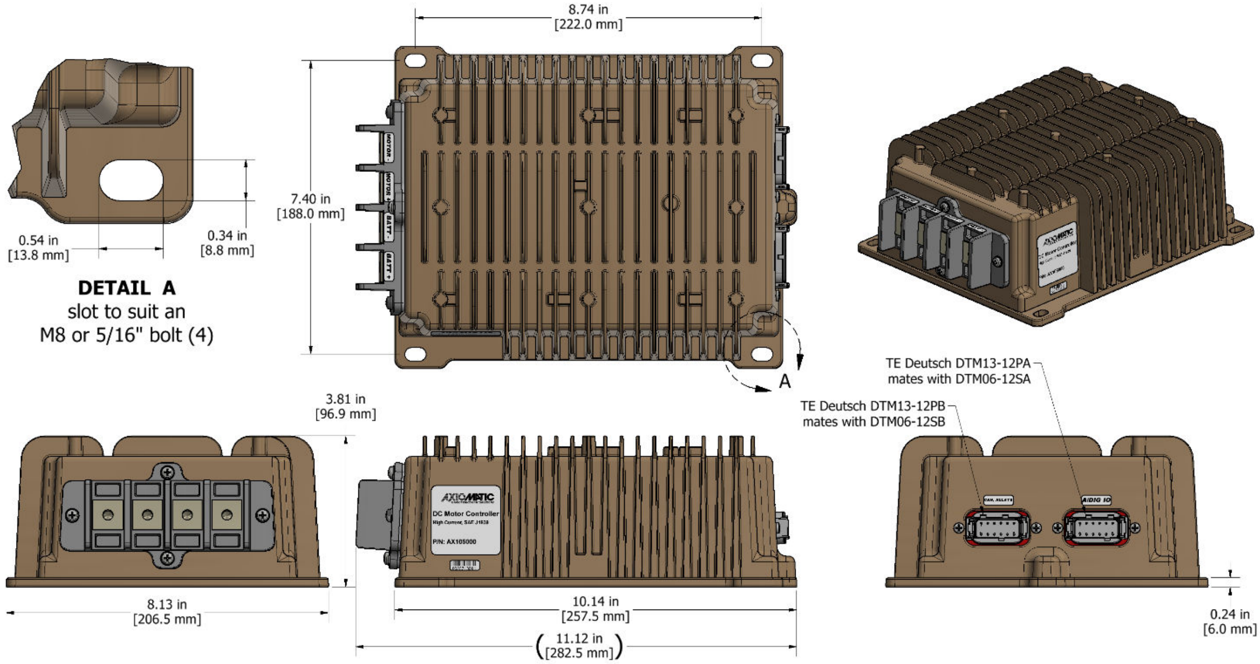



**Figure 5 – AX105000 Dimensional Drawing**

| | |
|---|---|
| **I/O CONNECTOR**<br>12-pin connector (equivalent to TE Deutsch P/N: DTM13-12PA)<br>Pin 1: DIG IN POWER<br>Pin 2: DIG IN 1<br>Pin 3: STO IN 2<br>Pin 4: UNIVERSAL SIGNAL IN 2<br>Pin 5: UNIVERSAL SIGNAL IN 3<br>Pin 6: +5V REF<br>Pin 7: SIGNAL INPUT GND<br>Pin 8: SIGNAL INPUT GND<br>Pin 9: UNIVERSAL SIGNAL IN 4<br>Pin 10: UNIVERSAL SIGNAL IN 1<br>Pin 11: DIG IN 2<br>Pin 12: STO IN 1<br><br>**CAN & RELAY CONNECTOR**<br>12-pin connector (equivalent to TE Deutsch P/N: DTM13-12PB)<br>Pin 1: CAN_H<br>Pin 2: Output 1+<br>Pin 3: Output 1 Return<br>Pin 4: NC_2<br>Pin 5: NO_2<br>Pin 6: COM_2<br>Pin 7: COM_1<br>Pin 8: NO_1<br>Pin 9: NC_1<br>Pin 10: Output 2 Return<br>Pin 11: Output 2+<br>Pin 12: CAN_L | **Power and Motor Control**<br>4 Aluminum power pass-through blocks accessible via M8 tapped holes in enclosure. Wire lugs should be attached to these.<br><br>Refer to the figure above for orientation of holes to access Aluminum power pass through blocks.<br>Motor -<br>Motor +<br>Battery -<br>Battery +<br><br>WARNING: Wiring the motor in upside down (i.e. all connections backwards) will result in the motor running in full forward with NO control from the processor! |
| Mating Plug Kit | **PL-DTM06-12SA-12SB** Mating Plug KIT is comprised of 1 DTM06-12SA, 1 DTM06-12SB, 2 WM12S, 24 Contacts, and Sealing Plugs. |

**Table 24 – AX105000 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

### 2.1. 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.

## 2.2. NAME, Address and Software ID

The 150A DC Motor Controller I/O ECU 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 DC Motor Controller |
| Function Instance | 8, Axiomatic AX105000 |
| 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 the user’s responsibility to select an address that complies with the standard***. The user must also be aware that since the unit is arbitrary address capable, if another ECU with a higher priority NAME contends for the selected address, the 150A DC Motor Controller I/O 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.

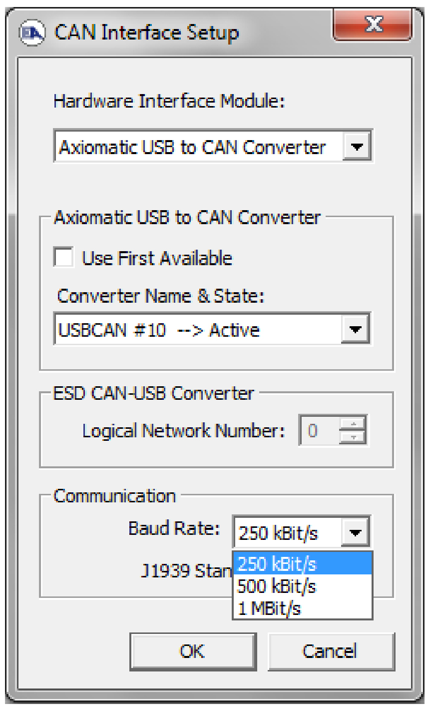
*Note: The information provided in the Software ID is available for any J1939 service tool which supports the PGN -SOFT.*

## 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 150A DC Motor controller, refer to the relevant section in this user manual.

### 3.1. Accessing the ECU Using the Axiomatic EA

ECU with P/N AX105000 does not need any specific setup for the Axiomatic EA. In order to access the high-speed versions, AX105000-01 and/or AX105000-02, the CAN bus Baud Rata needs to be set accordingly. The CAN Interface Setup can be found from "Options" menu in the EA.



## 3.2. J1939 Network Parameters

"**ECU Instance Number**" and "**ECU Address**" setpoints and their effect are defined in Section 2.2.

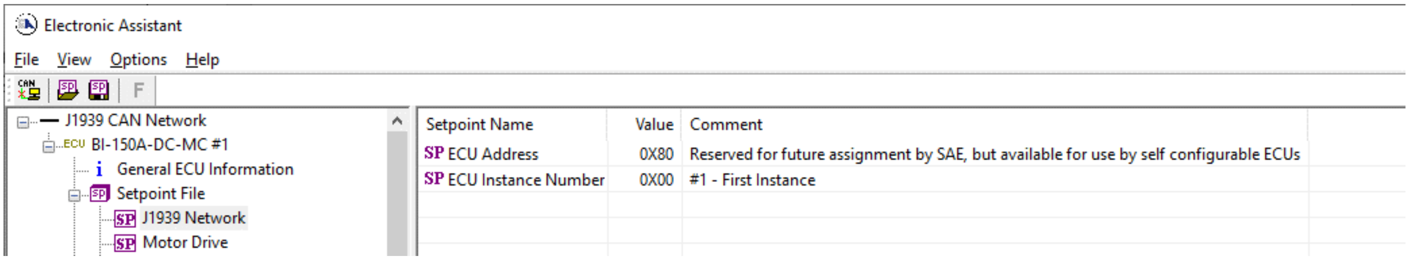



**Figure 6 – Screen Capture of J1939 Setpoints**

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

**Table 25 – 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.

## 3.3. Motor Drive Setpoints

The Motor Control function block is explained in more detail in section 1.1.

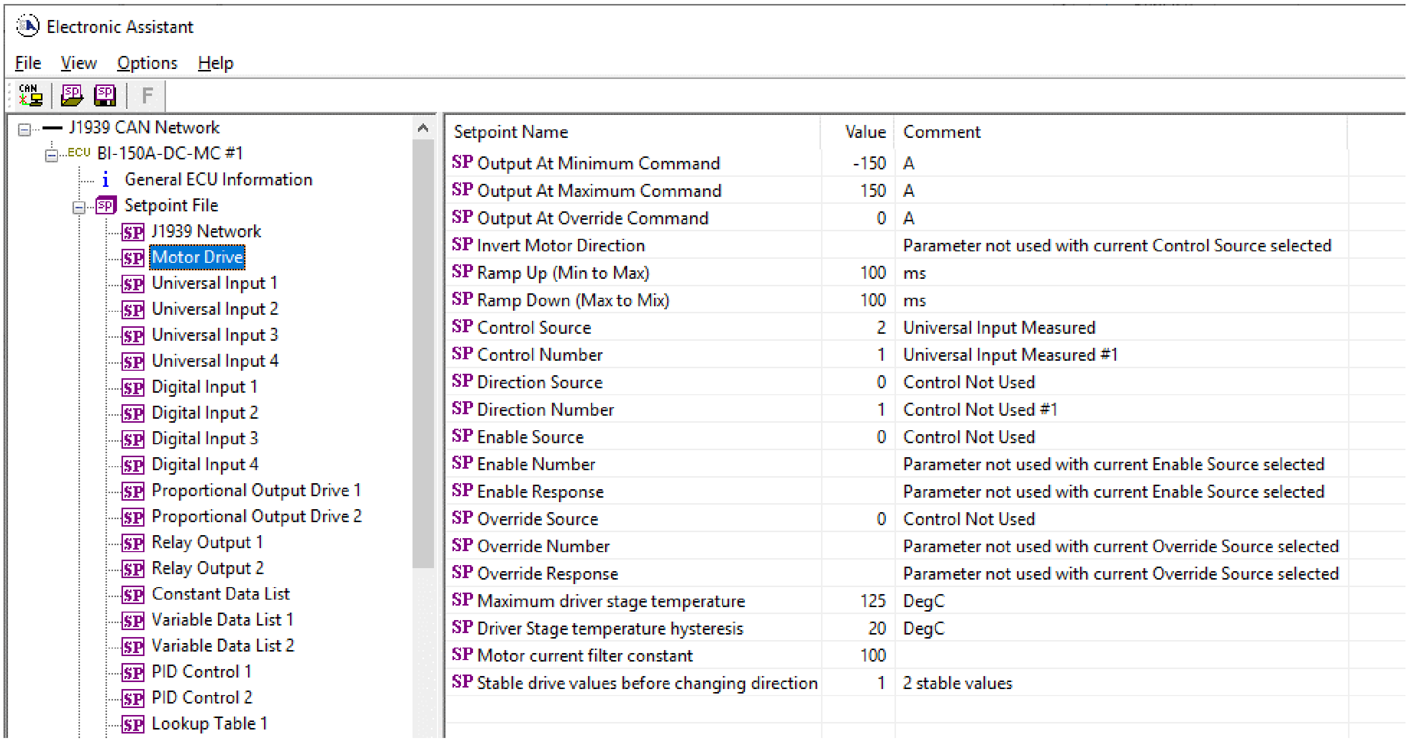



**Figure 7 – Screen Capture of Motor Drive Setpoints**

| Name | Range | Default | Notes |
|---|---|---|---|
| Output At Minimum Command | -300A to 0mA | -150A | |
| Output At Maximum Command | 0mA to 300A | 150A | |
| Output At Override Command | -300A to 300A | 0A | |
| Invert Motor Direction | Drop List | False | |
| Ramp Up (Min to Max) | 0…60000ms | 100ms | |
| Ramp Down (Max to Min) | 0…60000ms | 100ms | |
| Control Source | Drop List | Control Not Used | See Section 1.14 |
| Control Number | Drop List | 1 | See Section 1.14 |
| Direction Source | Drop List | Control Not Used | See Section 1.14 |
| Direction Number | Drop List | 1 | See Section 1.14 |
| Enable Source | Drop List | Control Not Used | See Section 1.14 |
| Enable Number | Drop List | 1 | See Section 1.14 |
| Enable Response | Drop List | 0 | See Table 11 |
| Override Source | Drop List | Control Not Used | See Section 1.14 |
| Override Number | Drop List | 1 | See Section 1.14 |
| Override Response | Drop List | 0 | See Table 12 |
| Maximum driver stage temperature | 0…135°C | 125°C | |
| Driver stage temperature hysteresis | 0…100°C | 20°C | |
| Motor current filter constant | 100 | 1…10000 | |
| Stable drive values before changing direction | Drop List | 1 | |

**Table 26 – Motor Drive Setpoints**

## 3.4. Universal Input Setpoints

The Universal Inputs are defined in Section 1.2.

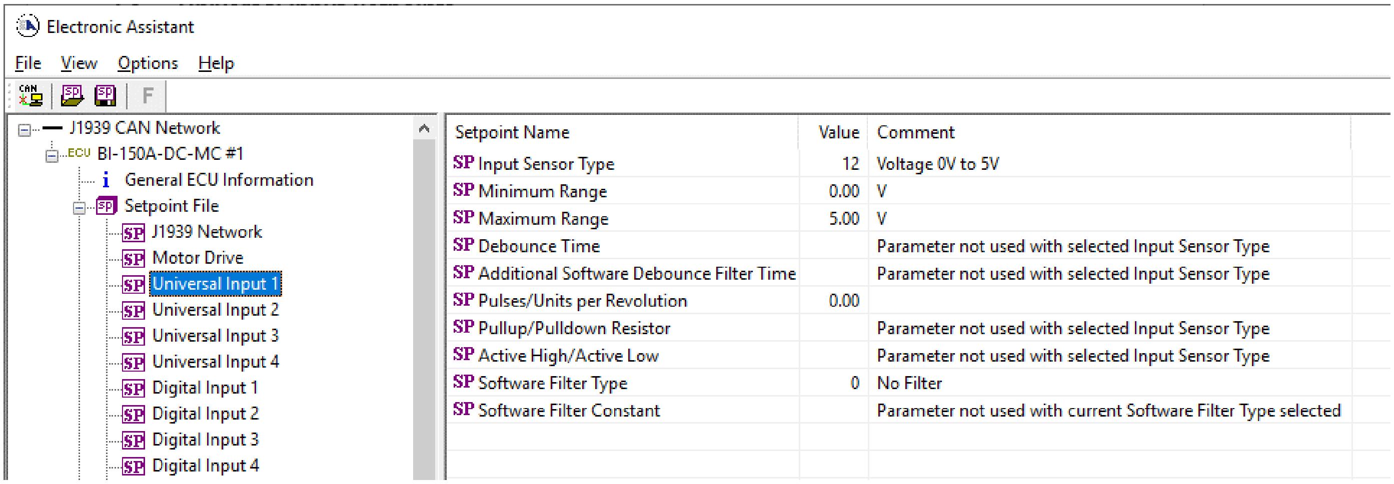



**Figure 8 – Screen Capture of Universal Input Setpoints**

| Name | Range | Default | Notes |
|---|---|---|---|
| Input Sensor Type | Drop List | VOLTAGE_0_TO_5V | See Table 2 |
| 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 | |
| Debounce Time | Drop List | None | See Table 3 |
| Additional Software Debounce Filter Time | Drop List | 0ms | See Table 4 |
| Pulses/Units per Revolution | Drop List | 0 | See Section 0 |
| Pullup/Pulldown Resistor | Drop List | 22kΩ Pulldown | 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 27 – Universal Input Setpoints**

## 3.5. Digital Input Setpoints

The Digital Inputs are defined in Section 1.2.1.

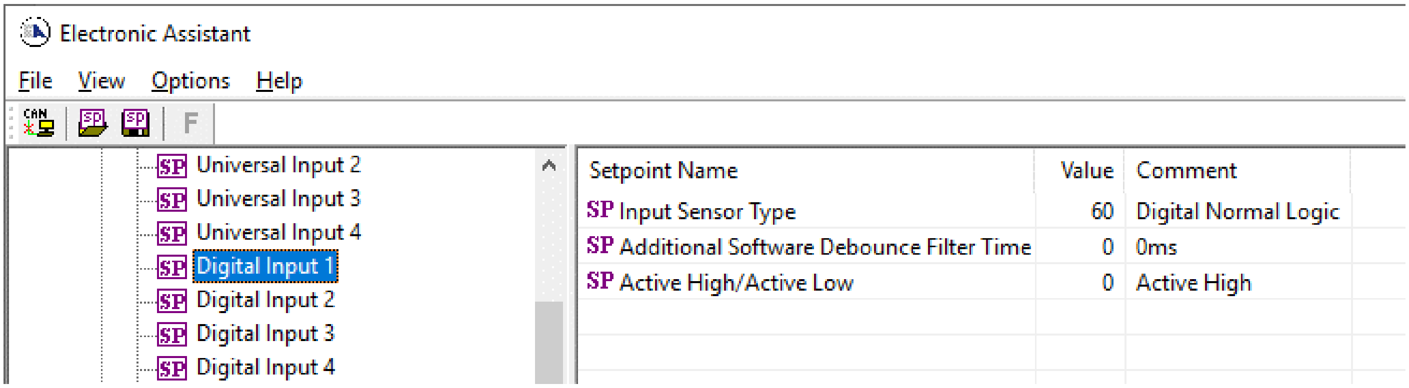



**Figure 9 – Screen Capture of Analog Input Setpoints**

| Name | Range | Default | Notes |
|---|---|---|---|
| Input Sensor Type | Drop List | Digital Normal Logic | See Table 2 |
| Additional Software Debounce Filter Time | Drop List | 0ms | See Table 4 |
| Active High/Active Low | Drop List | 0 | |

**Table 28 – Universal Input Setpoints**

## 3.6. Proportional Output Drive Setpoints

The Proportional Output Function Block is defined in Section 1.4. Please refer there for detailed information about how these setpoints are used. Outputs are disabled by default. To enable an output “**Output Type**” and “**Control Source**” must be chosen.

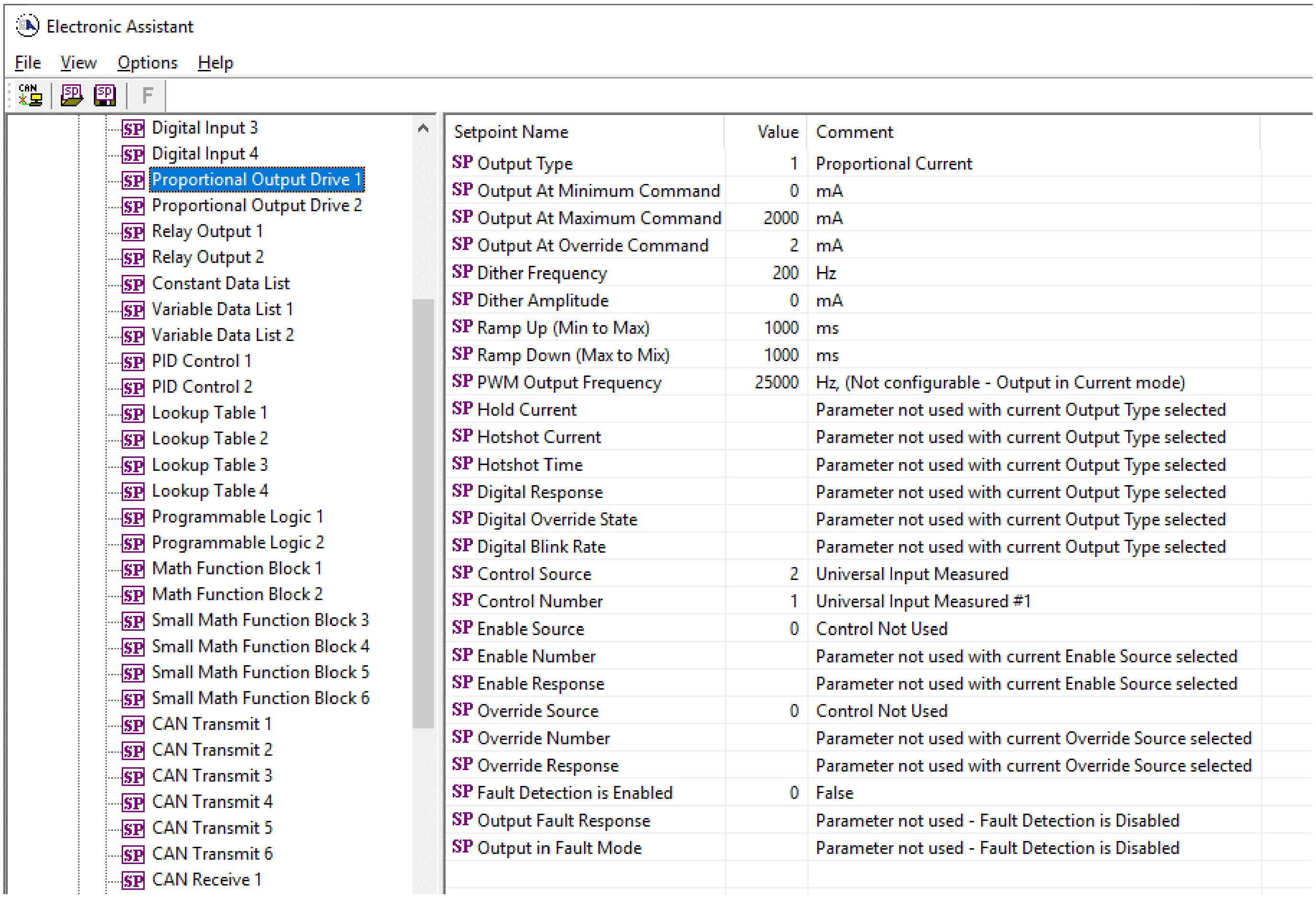



**Figure 10 – Screen Capture of Proportional Output Setpoints**

| Name | Range | Default | Notes |
|---|---|---|---|
| Output Type | Drop List | Proportional Current | See Table 9 |
| Output At Minimum Command | 0 to Limit | 0mA | |
| Output At Maximum Command | 0 to Limit | 2000mA | |
| 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 | |
| PWM Output Frequency | 1 to 25000Hz | 25000Hz | |
| Control Source | Drop List | Universal Input Measured | See Table 23 |
| Control Number | Depends on control source | 1 | See Table 23 |
| Enable Source | Drop List | Control not used | See Table 23 |
| Enable Number | Depends on enable source | 1 | See Table 23 |
| Enable Response | Drop List | Enable When On, else Shutoff | See Table 11 |
| Override Source | Drop List | Control not used | See Table 23 |
| Override Number | Depends on enable source | 1 | See Table 23 |
| Override Response | Drop List | Override When On | See Table 12 |
| Output Fault Response | Drop List | Shutoff Output | See Table 13 |
| Output in Fault Mode | Depends on Output type | 0mA | |
| Fault Detection is Enabled | Drop List | True | |

**Table 29 – Proportional Output Setpoints**

### 3.7. Relay Output Setpoints

Relay Output function block is covered in more detail in section 1.4.

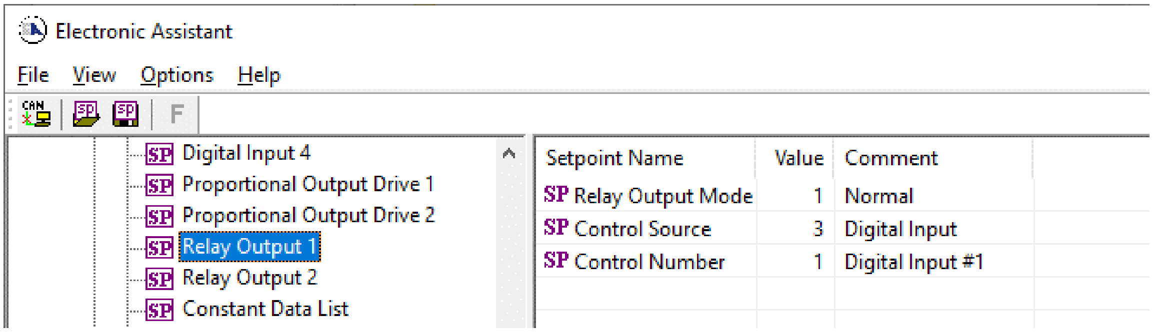



**Figure 11 – Screen Capture of Relay Output Setpoints**

| Name | Range | Default | Notes |
|---|---|---|---|
| Relay Output Mode | Drop List | 0 | See Table 9 |
| Control Source | Drop List | Control Not Used | See Table 23 |
| Control Number | Depends on control source | 1 | See Table 23 |

**Table 30 – Relay Output Setpoints**

## 3.8. Constant Data List Setpoints

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 13 constants are fully user programmable to any value between +/. 1 000 000. The default values are arbitrary and should be configured by the user as appropriate for their application.

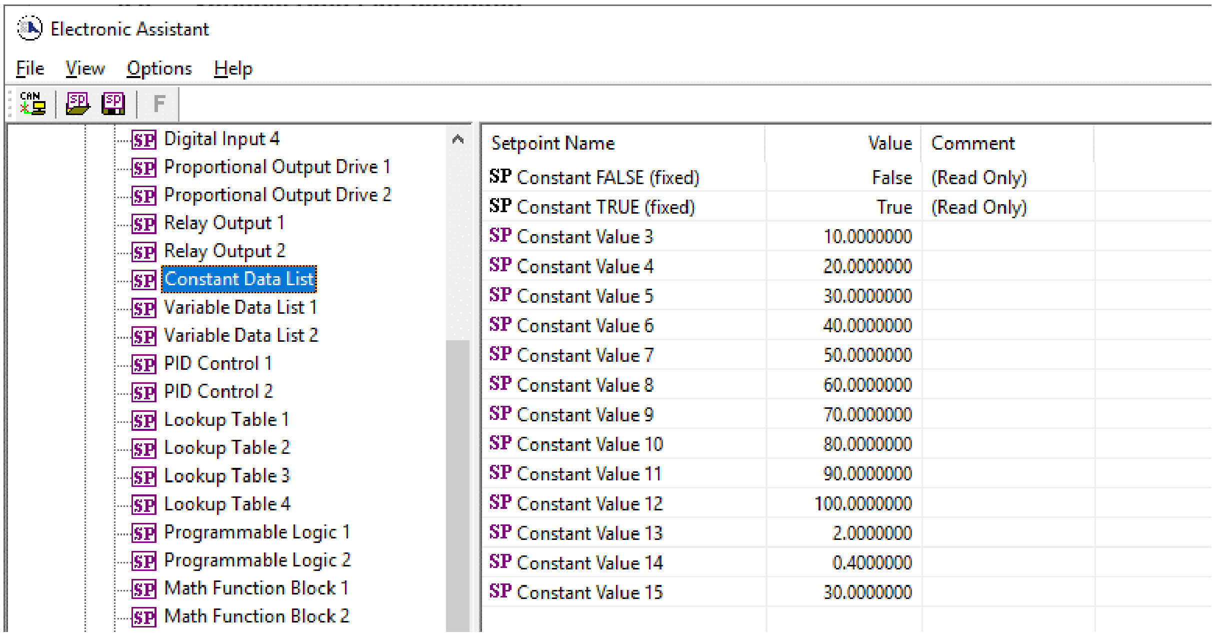



**Figure 12 - Screen Capture of Constant Data List Setpoints**

## 3.9. Variable Data List Setpoints

The Variable Data List Function Block is provided to allow the user to select values as desired for various logic block functions and defining rule for updating this data at run time. This functionality is explained in more detail in section 1.10.

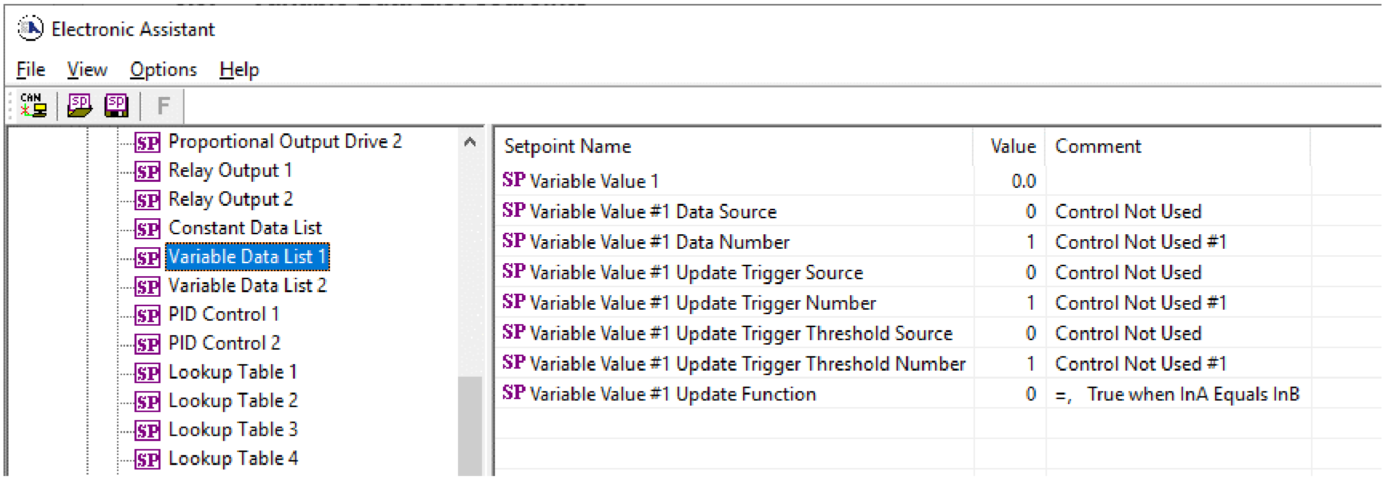



**Figure 13 – Screen Capture of Variable Data List Setpoints**

| Name | Range | Default | Notes |
|---|---|---|---|
| Variable Value | | 0 | |
| Variable Value Data Source | Drop List | Control Not Used | See Table 23 |
| Variable Value Data Number | Depends on control source | 1 | See Table 23 |
| Variable Value Update Trigger Source | Drop List | Control Not Used | See Table 23 |
| Variable Value Update Trigger Number | Depends on control source | 1 | See Table 23 |
| Variable Value Update Trigger Threshold Source | Drop List | Control Not Used | See Table 23 |
| Variable Value Update Trigger Threshold Number | Depends on control source | 1 | See Table 23 |
| Variable Value Update Function | 0…17 | 0 | See Table 22 |

**Table 31 – Variable Data Setpoints**

## 3.10. PID Control

The PID Control Function Block is defined in Section 1.6. Please refer there for detailed information about how all these setpoints are used.

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

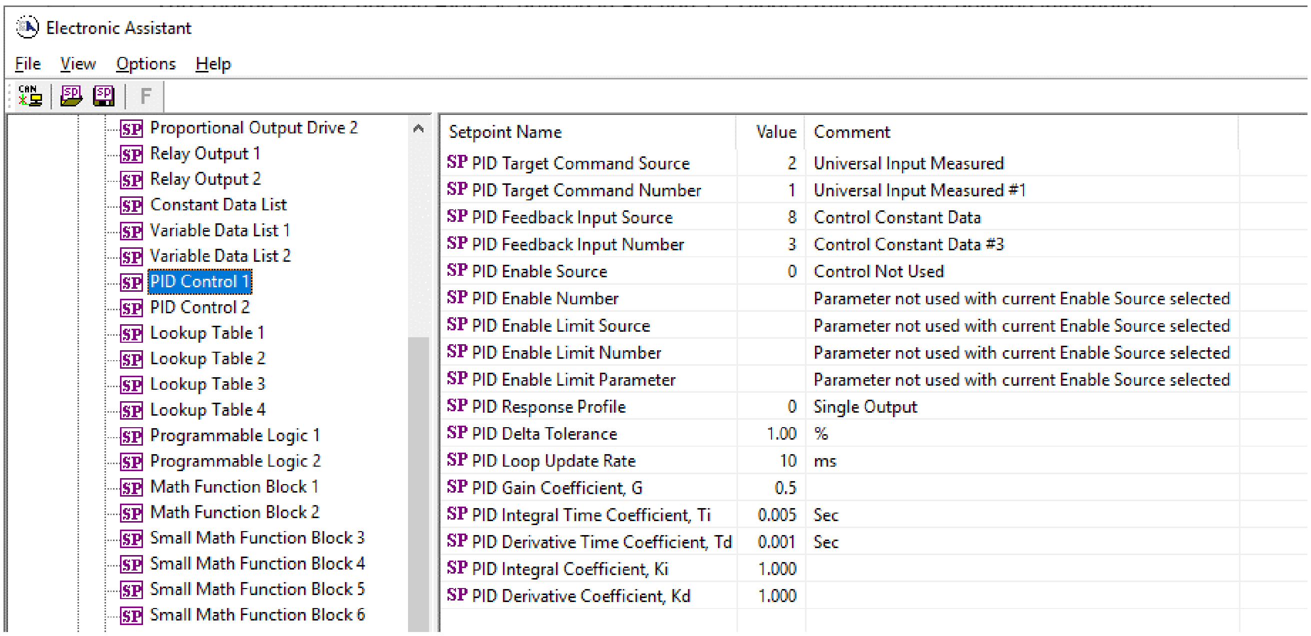



**Figure 14 – Screen Capture of PID Control Setpoints**

| Name | Range | Default | Notes |
|---|---|---|---|
| PID Target Command Source | Drop List | Control Not Used | See Table 23 |
| PID Target Command Number | Depends on control source | 1 | See Table 23 |
| PID Feedback Input Source | Drop List | Control Not Used | See Table 23 |
| PID Feedback Input Number | Depends on control source | 1 | See Table 23 |
| PID Enable Source | Drop List | Control Not Used | See Table 23 |
| PID Enable Number | Depends on control source | 1 | See Table 23 |
| PID Enable Limit Source | Drop List | Control Not Used | See Table 23 |
| PID Enable Limit Number | Depends on control source | 1 | See Table 23 |
| PID Enable Limit Parameter | Drop List | 0 | |
| 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 | 10ms | 1 ms resolution |
| PID Gain Coefficient, G | 0.1 to 1000 | 0.5 | See Equation 4 |
| 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 | 1.000 | 0 disables integral, PD ctrl |
| PID Derivative Coefficient, Kd | 0 to 10 | 1.000 | 0 disables derivative, PI ctrl |

**Table 32 – PID Control Setpoints**

## 3.11. Lookup Table

The Lookup Table Function Block is defined in Section 1.7. Please refer there for detailed information about how all these setpoints are used. "**X-Axis Source**" is set to '*Control Not Used*' by default. To enable a Lookup Table, select appropriate "**X-Axis Source**".

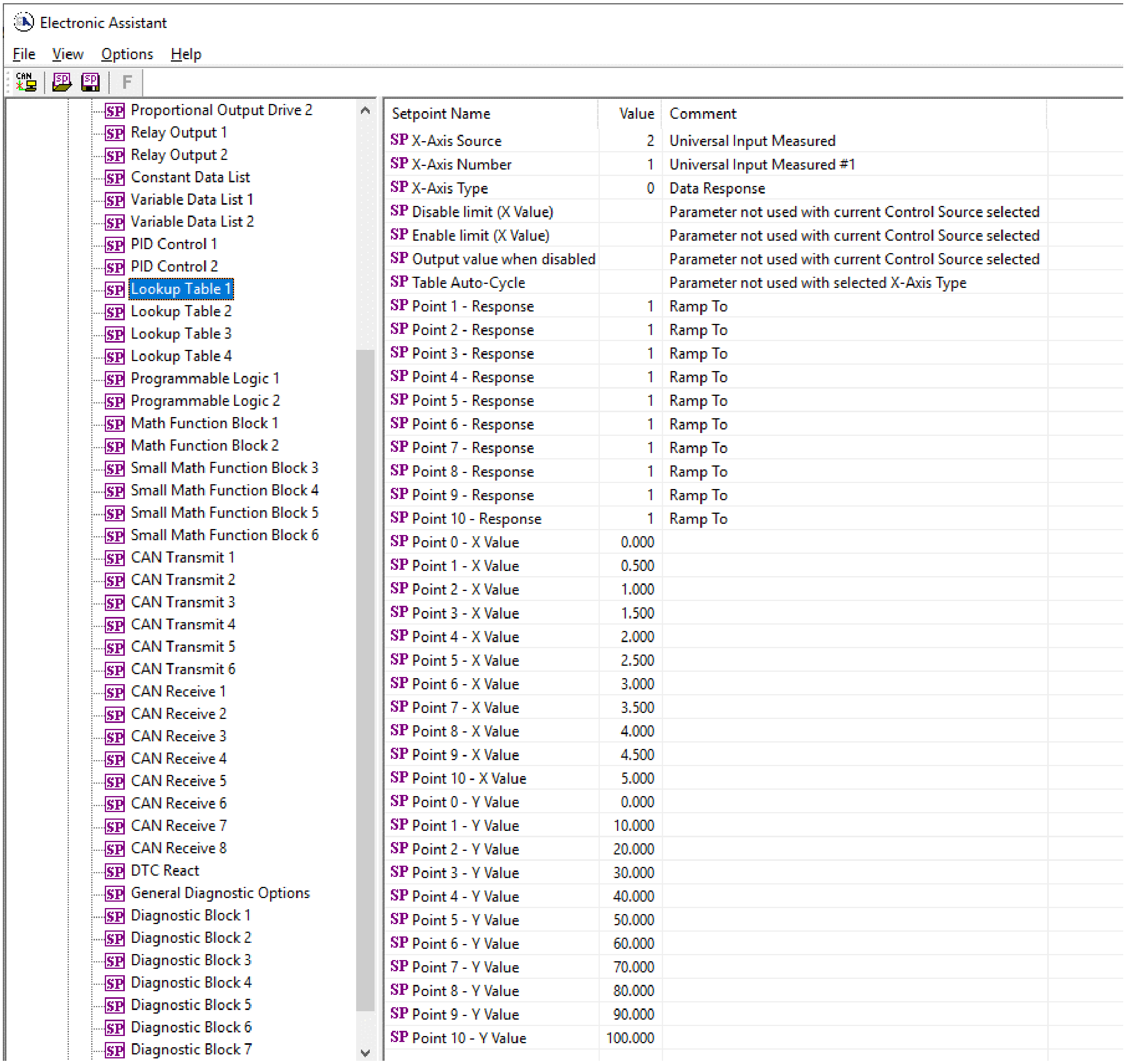



**Figure 15 – Screen Capture of Lookup table Setpoints**

| Name | Range | Default | Notes |
|---|---|---|---|
| X-Axis Source | Drop List | Control Not Used | See Table 23 |
| X-Axis Number | Depends on control source | 1 | See Table 23 |
| X-Axis Type | Drop List | Data Response | See Table 18 |
| Table Auto-Cycle | Drop List | 0 | |
| Point 1 - Response | Drop List | Ramp To | See Table 19 |
| Point 2 - Response | Drop List | Ramp To | See Table 19 |
| Point 3 - Response | Drop List | Ramp To | See Table 19 |
| Point 4 - Response | Drop List | Ramp To | See Table 19 |
| Point 5 - Response | Drop List | Ramp To | See Table 19 |
| Point 6 - Response | Drop List | Ramp To | See Table 19 |
| Point 7 - Response | Drop List | Ramp To | See Table 19 |
| Point 8 - Response | Drop List | Ramp To | See Table 19 |
| Point 9 - Response | Drop List | Ramp To | See Table 19 |
| Point 10 - Response | Drop List | Ramp To | See Table 19 |
| Point 0 - X Value | From X-Axis source minimum to Point 1 - X Value | X-Axis source minimum 0.000 | See Section 1.7 |
| Point 1 - X Value | From Point 0 - X Value to Point 2 - X Value | 0.500 | See Section 1.7 |
| Point 2 - X Value | From Point 1 - X Value to Point 3 - X Value | 1.000 | See Section 1.7 |
| Point 3 - X Value | From Point 2 - X Value to Point 4 - X Value | 1.500 | See Section 1.7 |
| Point 4 - X Value | From Point 3 - X Value to Point 5 - X Value source | 2.000 | See Section 1.7 |
| Point 5 - X Value | From Point 4 - X Value to Point 6 - X Value | 2.500 | See Section 1.7 |
| Point 6 - X Value | From Point 5 - X Value to Point 7 - X Value | 3.000 | See Section 1.7 |
| Point 7 - X Value | From Point 6 - X Value to Point 8 - X Value | 3.500 | See Section 1.7 |
| Point 8 - X Value | From Point 7 - X Value to Point 9 - X Value | 4.000 | See Section 1.7 |
| Point 9 - X Value | From Point 8 - X Value to Point 10 - X Value | 4.500 | See Section 1.7 |
| Point 10 - X Value | From Point 9 - X Value to X-Axis source maximum | X-Axis source maximum 5.000 | See Section 1.7 |
| 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 33 – Lookup Table Setpoints**

## 3.12. Programmable Logic

The Programmable Logic function block is defined in Section 1.8. Please refer there for detailed information about how all these setpoints are used. "**Programmable Logic Enabled**" is '*False*' by default. To enable Logic set "**Programmable Logic Enabled**" to '*True*' and select appropriate "**Argument Source**".

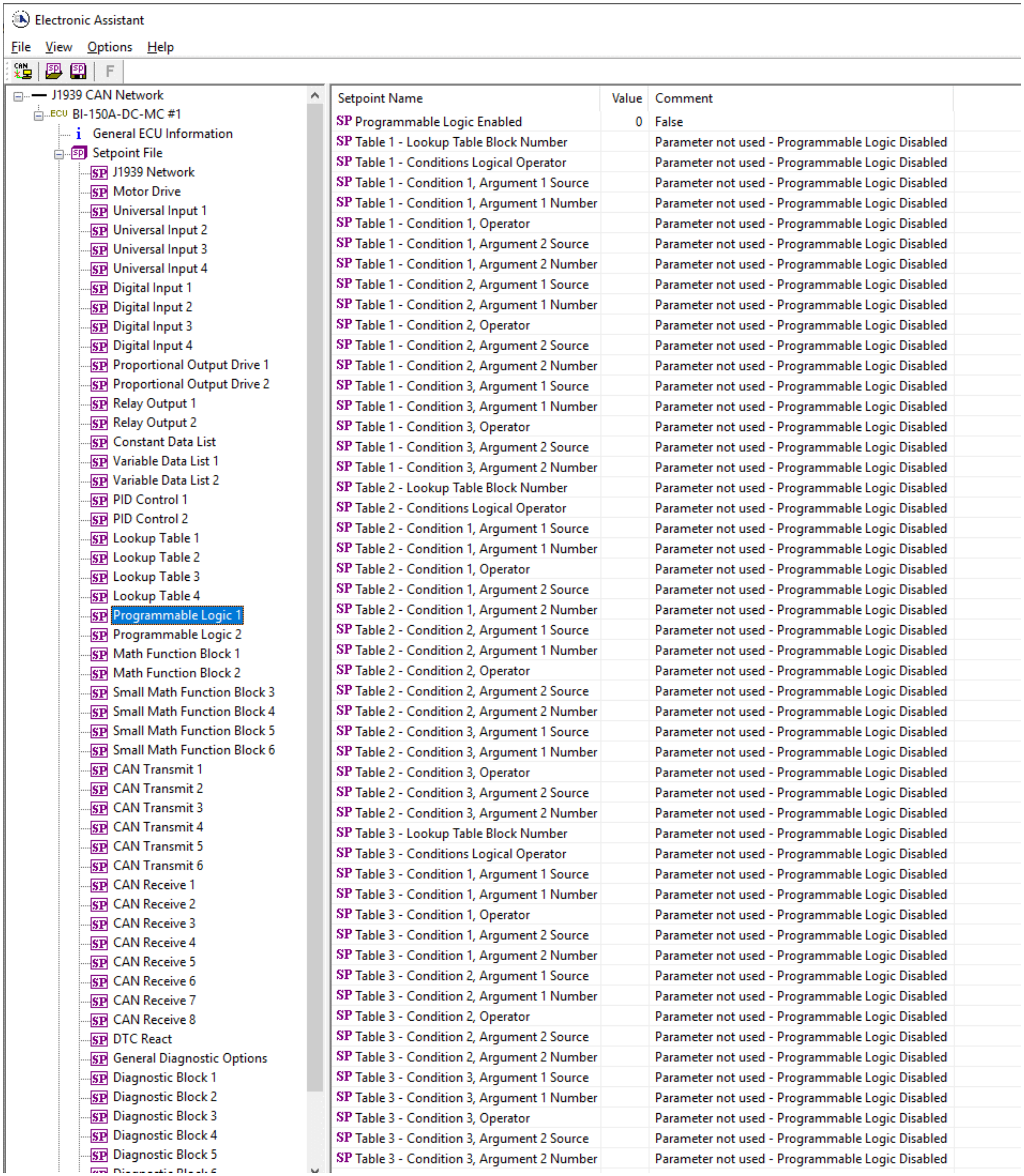



**Figure 16 – Screen Capture of Programmable Logic Setpoints**

Setpoint ranges and default values for Programmable Logic Blocs are listed in Table 34. Only "**Table1**" setpoint are listed, because other "**TableX**" setpoints are similar, except for the default value of the "**Lookup Table Block Number**" setpoint, which is X for "**TableX**".

| **Name** | **Range** | **Default** | **Notes** |
|---|---|---|---|
| Programmable Logic Enabled | Drop List | False | |
| Table1 - Lookup Table Block Number | 1 to 4 | Look up Table 1 | |
| Table1 - Conditions Logical Operation | Drop List | Default Table | See Table 21 |
| Table1 - Condition1, Argument 1 Source | Drop List | Control Not Used | See Table 23 |
| Table1 - Condition1, Argument 1 Number | Depends on control source | 1 | See Table 23 |
| Table1 - Condition1, Operator | Drop List | =, Equal | See Table 20 |
| Table1 - Condition1, Argument 2 Source | Drop List | Control Not Used | See Table 23 |
| Table1 - Condition1, Argument 2 Number | Depends on control source | 1 | See Table 23 |
| Table1 - Condition2, Argument 1 Source | Drop List | Control Not Used | See Table 23 |
| Table1 - Condition2, Argument 1 Number | Depends on control source | 1 | See Table 23 |
| Table1 - Condition2, Operator | Drop List | =, Equal | See Table 20 |
| Table1 - Condition2, Argument 2 Source | Drop List | Control Not Used | See Table 23 |
| Table1 - Condition2, Argument 2 Number | Depends on control source | 1 | See Table 23 |
| Table1 - Condition3, Argument 1 Source | Drop List | Control Not Used | See Table 23 |
| Table1 - Condition3, Argument 1 Number | Depends on control source | 1 | See Table 23 |
| Table1 - Condition3, Operator | Drop List | =, Equal | See Table 20 |
| Table1 - Condition3, Argument 2 Source | Drop List | Control Not Used | See Table 23 |
| Table1 - Condition3, Argument 2 Number | Depends on control source | 1 | See Table 23 |

**Table 34 – Programmable Logic Setpoints**

## 3.13. Math Function Block

The Math Function Block is defined in Section 1.9. Please refer there for detailed information about how all these setpoints are used. "**Math Function Enabled**" is 'False' by default. To enable a Math Function Block, set "**Math Function Enabled**" to 'True' and select appropriate "**Input Source**".

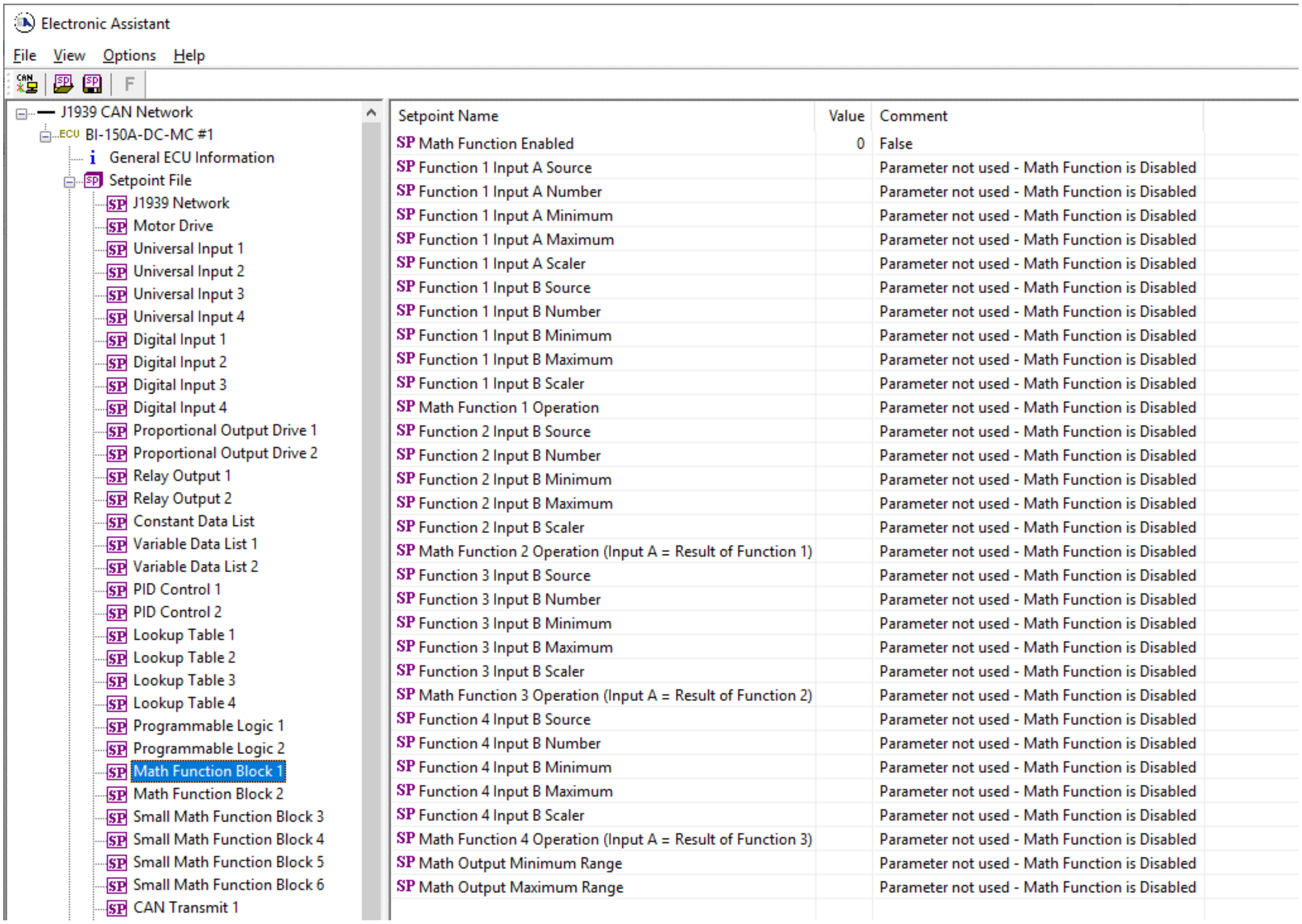



**Figure 17 – Screen Capture of Math Function Block Setpoints**

| Name | Range | Default | Notes |
|---|---|---|---|
| Math Function Enabled | Drop List | False | |
| Function 1 Input A Source | Drop List | Control not used | See Table 23 |
| Function 1 Input A Number | Depends on control source | 1 | See Table 23 |
| 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 23 |
| Function 1 Input B Number | Depends on control source | 1 | See Table 23 |
| 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 22 |
| Function 2 Input B Source | Drop List | Control not used | See Table 23 |
| Function 2 Input B Number | Depends on control source | 1 | See Table 23 |
| Function 2 Input B Minimum | $-10^6$ to $10^6$ | 0.0 | |
| Function 2 Input B Maximum | $-10^6$ to $10^6$ | 100.0 | |
| Function 2 Input B Scaler | -1.00 to 1.00 | 1.00 | |
| Math Function 3 Operation | Drop List | =, True when InA Equals InB | See Table 22 |
| Function 3 Input B Source | Drop List | Control not used | See Table 23 |
| Function 3 Input B Number | Depends on control source | 1 | See Table 23 |
| Function 3 Input B Minimum | $-10^6$ to $10^6$ | 0.0 | |
| Function 3 Input B Maximum | $-10^6$ to $10^6$ | 100.0 | |
| Function 3 Input B Scaler | -1.00 to 1.00 | 1.00 | |
| Math Function 3 Operation | Drop List | =, True when InA Equals InB | See Table 22 |
| Function 4 Input B Source | Drop List | Control not used | See Table 23 |
| Function 4 Input B Number | Depends on control source | 1 | See Table 23 |
| Function 4 Input B Minimum | $-10^6$ to $10^6$ | 0.0 | |
| Function 4 Input B Maximum | $-10^6$ to $10^6$ | 100.0 | |
| Function 4 Input B Scaler | -1.00 to 1.00 | 1.00 | |
| Math Function 4 Operation | Drop List | =, True when InA Equals InB | See Table 22 |
| Math Output Minimum Range | $-10^6$ to $10^6$ | 0.0 | |
| Math Output Maximum Range | $-10^6$ to $10^6$ | 100.0 | |

**Table 35 – Math Function Setpoints**

## 3.14. Small Math Function Block

The Small Math Function Block is defined in Section 1.9, it is a simplified version of the full Math Block. Please refer there for detailed information about how all these setpoints are used. "**Math Function Enabled**" is 'False' by default. To enable a Math Function Block, set "**Math Function Enabled**" to 'True' and select appropriate "**Input Source**".

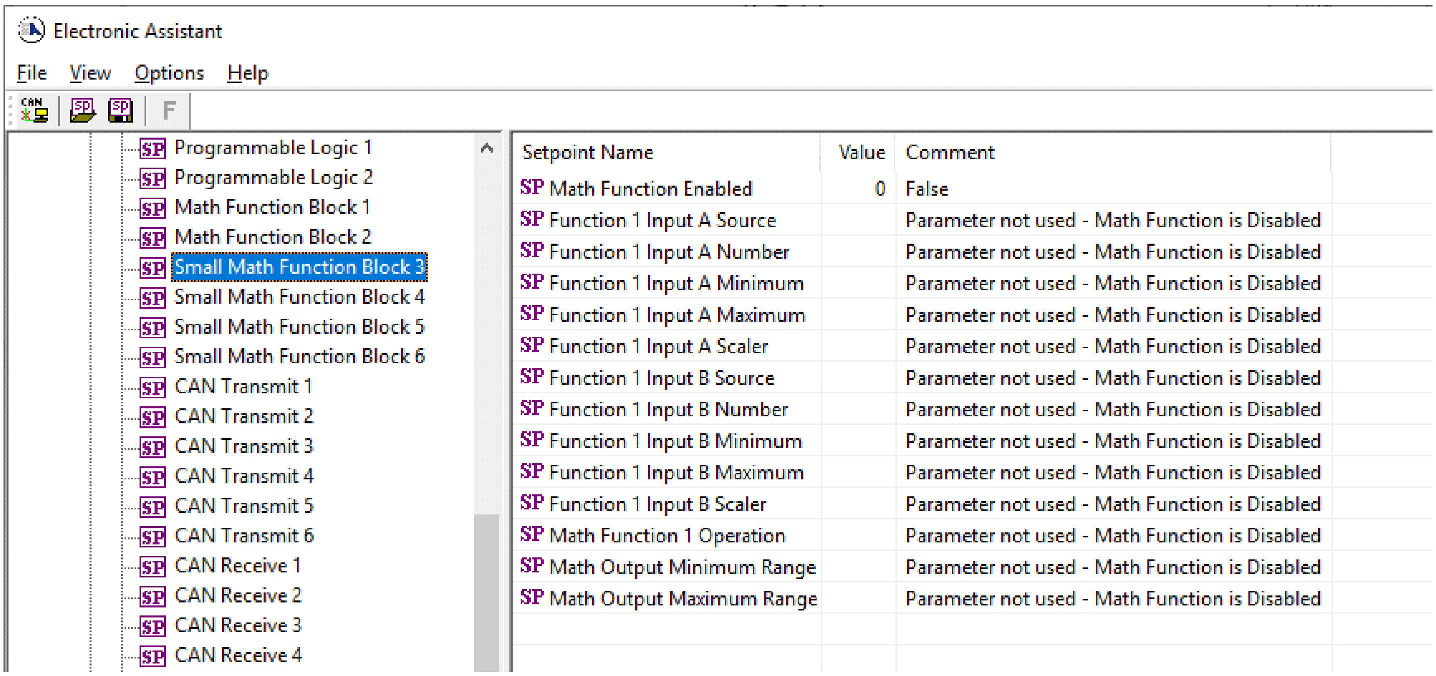


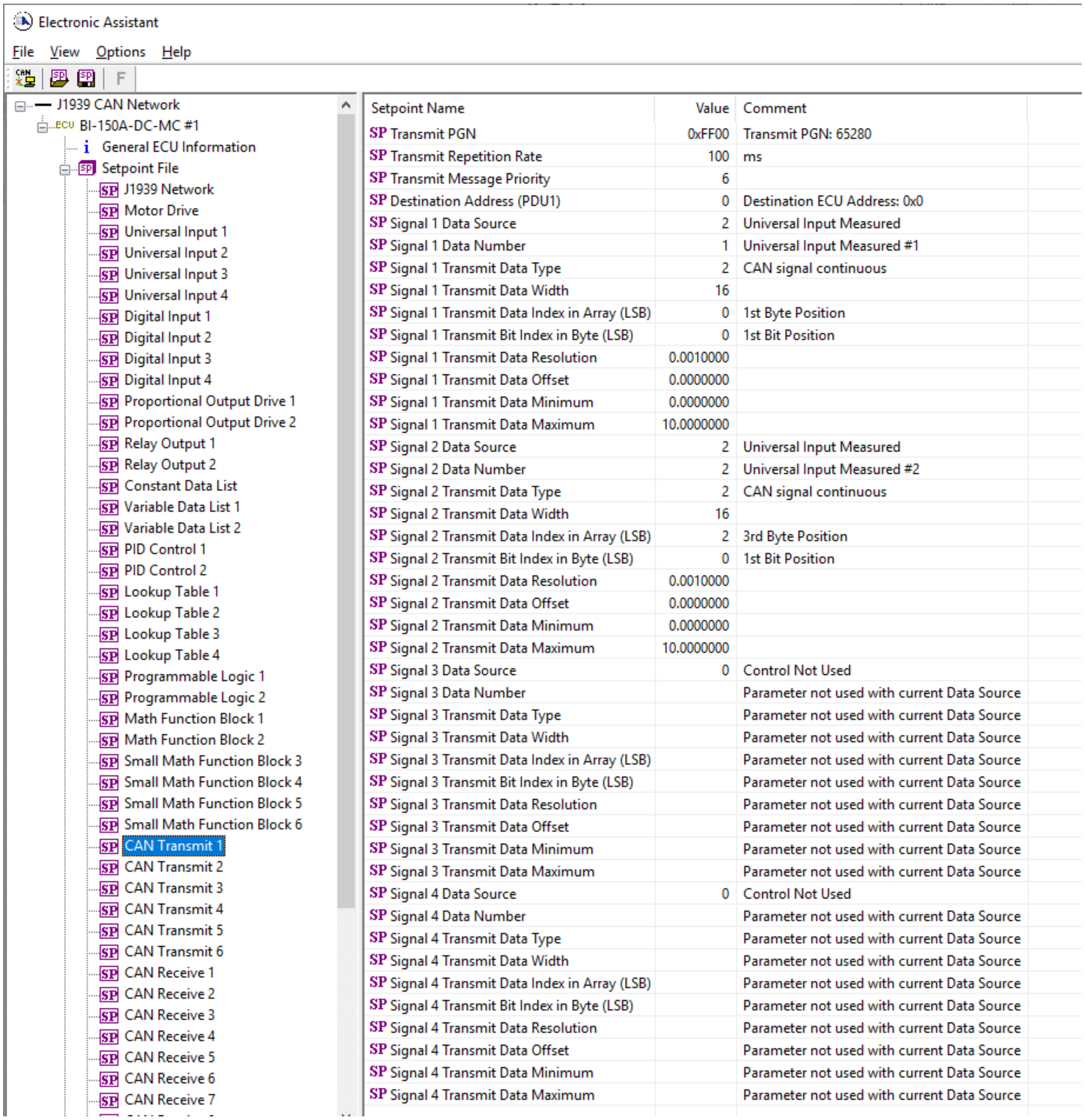

**Figure 18 – Screen Capture of Small Math Function Block Setpoints**

| Name | Range | Default | Notes |
|---|---|---|---|
| Math Function Enabled | Drop List | False | |
| Function 1 Input A Source | Drop List | Control not used | See Table 23 |
| Function 1 Input A Number | Depends on control source | 1 | See Table 23 |
| 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 23 |
| Function 1 Input B Number | Depends on control source | 1 | See Table 23 |
| 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 22 |
| 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 Function Setpoints**

## 3.15. CAN Transmit Setpoints

CAN Transmit Message Function Block is presented in section 1.12. Please refer there for detailed information how these setpoints are used. “**Transmit Repetition Rate**” is 0ms by default, thus no message will be sent.




| Setpoint Name | Value | Comment |
|---|---|---|
| SP Transmit PGN | 0xFF00 | Transmit PGN: 65280 |
| SP Transmit Repetition Rate | 100 | ms |
| SP Transmit Message Priority | 6 | |
| SP Destination Address (PDU1) | 0 | Destination ECU Address: 0x0 |
| SP Signal 1 Data Source | 2 | Universal Input Measured |
| SP Signal 1 Data Number | 1 | Universal Input Measured #1 |
| SP Signal 1 Transmit Data Type | 2 | CAN signal continuous |
| SP Signal 1 Transmit Data Width | 16 | |
| SP Signal 1 Transmit Data Index in Array (LSB) | 0 | 1st Byte Position |
| SP Signal 1 Transmit Bit Index in Byte (LSB) | 0 | 1st Bit Position |
| SP Signal 1 Transmit Data Resolution | 0.0010000 | |
| SP Signal 1 Transmit Data Offset | 0.0000000 | |
| SP Signal 1 Transmit Data Minimum | 0.0000000 | |
| SP Signal 1 Transmit Data Maximum | 10.0000000 | |
| SP Signal 2 Data Source | 2 | Universal Input Measured |
| SP Signal 2 Data Number | 2 | Universal Input Measured #2 |
| SP Signal 2 Transmit Data Type | 2 | CAN signal continuous |
| SP Signal 2 Transmit Data Width | 16 | |
| SP Signal 2 Transmit Data Index in Array (LSB) | 2 | 3rd Byte Position |
| SP Signal 2 Transmit Bit Index in Byte (LSB) | 0 | 1st Bit Position |
| SP Signal 2 Transmit Data Resolution | 0.0010000 | |
| SP Signal 2 Transmit Data Offset | 0.0000000 | |
| SP Signal 2 Transmit Data Minimum | 0.0000000 | |
| SP Signal 2 Transmit Data Maximum | 10.0000000 | |
| SP Signal 3 Data Source | 0 | Control Not Used |
| SP Signal 3 Data Number | | Parameter not used with current Data Source |
| SP Signal 3 Transmit Data Type | | Parameter not used with current Data Source |
| SP Signal 3 Transmit Data Width | | Parameter not used with current Data Source |
| SP Signal 3 Transmit Data Index in Array (LSB) | | Parameter not used with current Data Source |
| SP Signal 3 Transmit Bit Index in Byte (LSB) | | Parameter not used with current Data Source |
| SP Signal 3 Transmit Data Resolution | | Parameter not used with current Data Source |
| SP Signal 3 Transmit Data Offset | | Parameter not used with current Data Source |
| SP Signal 3 Transmit Data Minimum | | Parameter not used with current Data Source |
| SP Signal 3 Transmit Data Maximum | | Parameter not used with current Data Source |
| SP Signal 4 Data Source | 0 | Control Not Used |
| SP Signal 4 Data Number | | Parameter not used with current Data Source |
| SP Signal 4 Transmit Data Type | | Parameter not used with current Data Source |
| SP Signal 4 Transmit Data Width | | Parameter not used with current Data Source |
| SP Signal 4 Transmit Data Index in Array (LSB) | | Parameter not used with current Data Source |
| SP Signal 4 Transmit Bit Index in Byte (LSB) | | Parameter not used with current Data Source |
| SP Signal 4 Transmit Data Resolution | | Parameter not used with current Data Source |
| SP Signal 4 Transmit Data Offset | | Parameter not used with current Data Source |
| SP Signal 4 Transmit Data Minimum | | Parameter not used with current Data Source |
| SP Signal 4 Transmit Data Maximum | | Parameter not used with current Data Source |

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

| Name | Range | Default | Notes |
|---|---|---|---|
| Transmit PGN | 0xff00 … 0xffff | Different for each | See Section 1.12.1 |
| Transmit Repetition Rate | 0 … 65000 ms | 0ms | 0ms disables transmit |
| Transmit Message Priority | 0...7 | 6 | Proprietary B Priority |
| Destination Address | 0...255 | 255 | Not used by default |
| Signal 1 Control Source | Drop List | Different for each | See Table 23 |
| Signal 1 Control Number | Drop List | Different for each | See 1.12.2 |
| Signal 1 Transmit Data Type | Drop List | 0 | |
| Signal 1 Transmit Data Width | 1-32 | 1 | |
| Signal 1 Transmit Data Index in Array | 0-7 | 2 | |
| Signal 1 Transmit Bit Index In Byte | 0-7 | 0 | |
| Signal 1 Transmit Data Resolution | -100000.0 to 100000 | 0.001 | |
| Signal 1 Transmit Data Offset | -10000 to 10000 | 0.0 | |
| Signal 2 Control Source | Drop List | Signal undefined | See Table 23 |
| Signal 2 Control Number | Drop List | Signal undefined | See 1.12.2 |
| Signal 2 Transmit Data Type | Drop List | 0 | |
| Signal 2 Transmit Data Width | 1-32 | 1 | |
| Signal 2 Transmit Data Index in Array | 0-7 | 0 | |
| Signal 2 Transmit Bit Index In Byte | 0-7 | 0 | |
| Signal 2 Transmit Data Resolution | -100000.0 to 100000 | 0.001 | |
| Signal 2 Transmit Data Offset | -10000 to 10000 | 0.0 | |
| Signal 3 Control Source | Drop List | Signal undefined | See Table 23 |
| Signal 3 Control Number | Drop List | Signal undefined | See 1.12.2 |
| Signal 3 Transmit Data Type | Drop List | 0 | |
| Signal 3 Transmit Data Width | 1-32 | 1 | |
| Signal 3 Transmit Data Index in Array | 0-7 | 0 | |
| Signal 3 Transmit Bit Index In Byte | 0-7 | 0 | |
| Signal 3 Transmit Data Resolution | -100000.0 to 100000 | 0.001 | |
| Signal 3 Transmit Data Offset | -10000 to 10000 | 0.0 | |
| Signal 4 Control Source | Drop List | Signal undefined | See Table 23 |
| Signal 4 Control Number | Drop List | Signal undefined | See 1.12.2 |
| Signal 4 Transmit Data Type | Drop List | 0 | |
| Signal 4 Transmit Data Width | 1-32 | 1 | |
| Signal 4 Transmit Data Index in Array | 0-7 | 0 | |
| Signal 4 Transmit Bit Index In Byte | 0-7 | 0 | |
| Signal 4 Transmit Data Resolution | -100000.0 to 100000 | 0.001 | |
| Signal 4 Transmit Data Offset | -10000 to 10000 | 0.0 | |

**Table 37 – CAN Transmit Message Setpoints**

## 3.16. CAN Receive Setpoints

The Math Function Block is defined in Section 1.13. Please refer there 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.

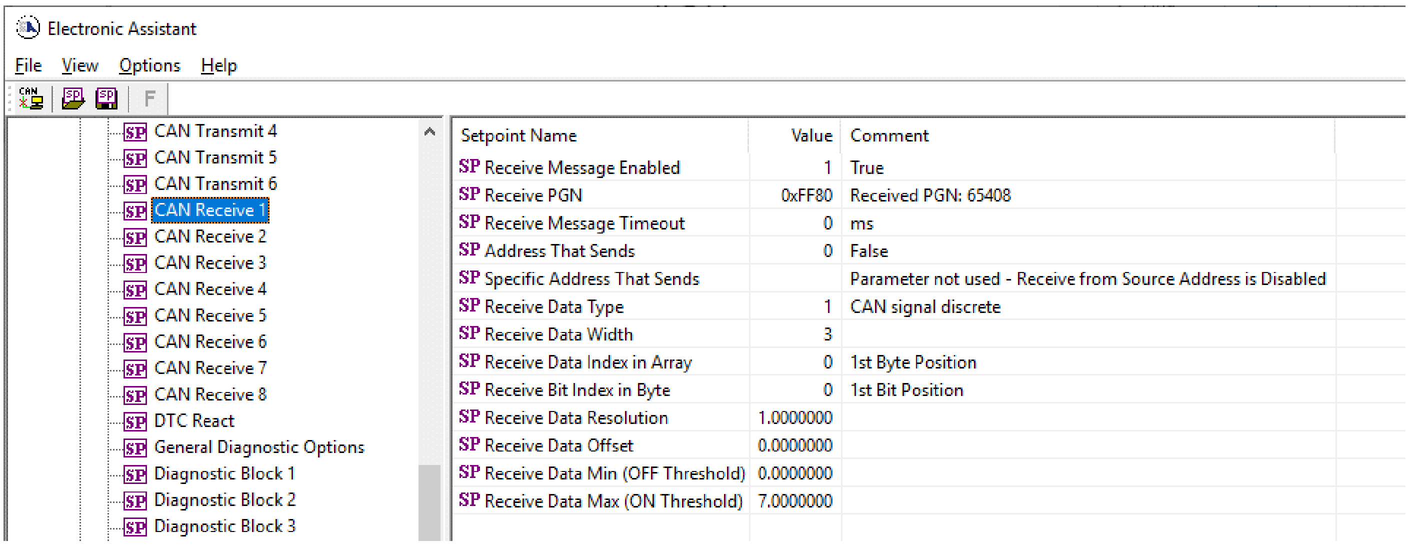



**Figure 20 – Screen Capture of CAN Receive Message Setpoints**

| **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 | |
| Specific Address That Sends | Drop List | False | |
| Address That Sends | 0 to 255 | 254 (0xFE, Null Addr) | |
| Receive Data Type | Drop List | 0 | |
| Receive Data Width | 1-32 | 1 | |
| Receive Data Index in Array | 0-7 | 0 | |
| Receive Transmit Bit Index In Byte | 0-7 | 0 | |
| Receive Transmit Data Resolution | -100000.0 to 100000 | 0.001 | |
| 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 | 2.0 | |

**Table 38 – CAN Receive Setpoints**

## 3.17. DTC React

The DTC React Function Block is defined in Section 1.11. Please refer there for detailed information about how these setpoints are used.

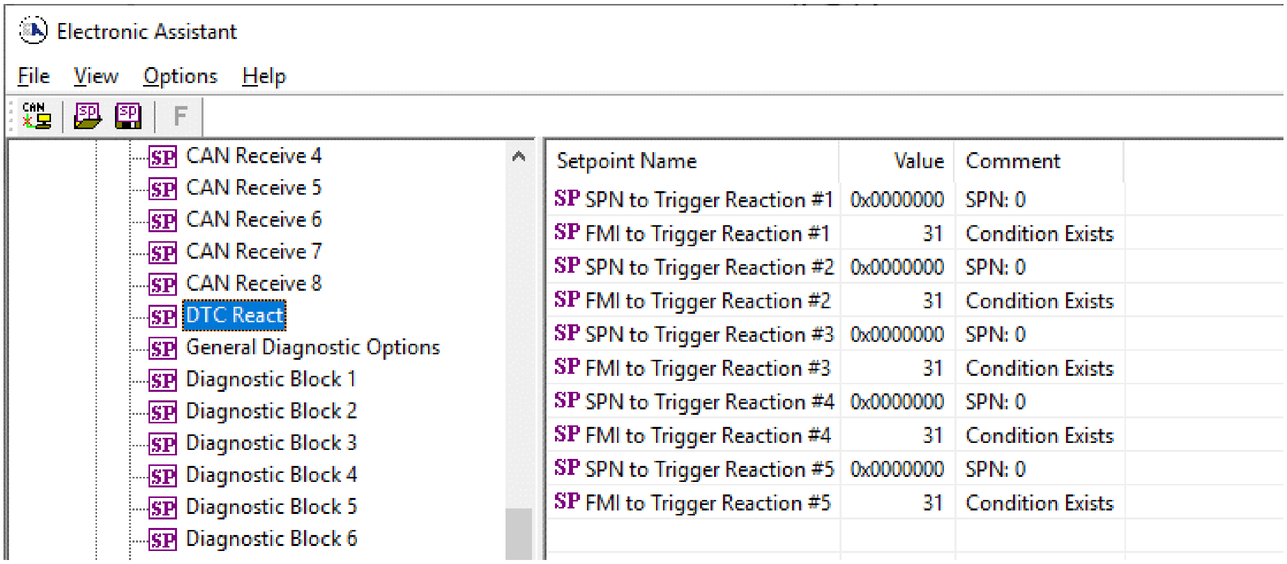



**Figure 21 – Screen Capture of DTC React Setpoints**

| Name | Range | Default | Notes |
|---|---|---|---|
| SPN to Trigger Reaction #X | 0 to 524287 | 0 | 0 is an illegal value, and disables the DTC |
| FMI to Trigger Reaction #X | Drop List | 31, Condition Exists | Supports all FMIs in the J1939 standard |

**Table 39 – DTC React Setpoints**

## 3.18. General Diagnostics Options

These setpoints control the shutdown of the ECU in case of a power supply or CAN bus related errors. Refer to section 1.5 for more info.

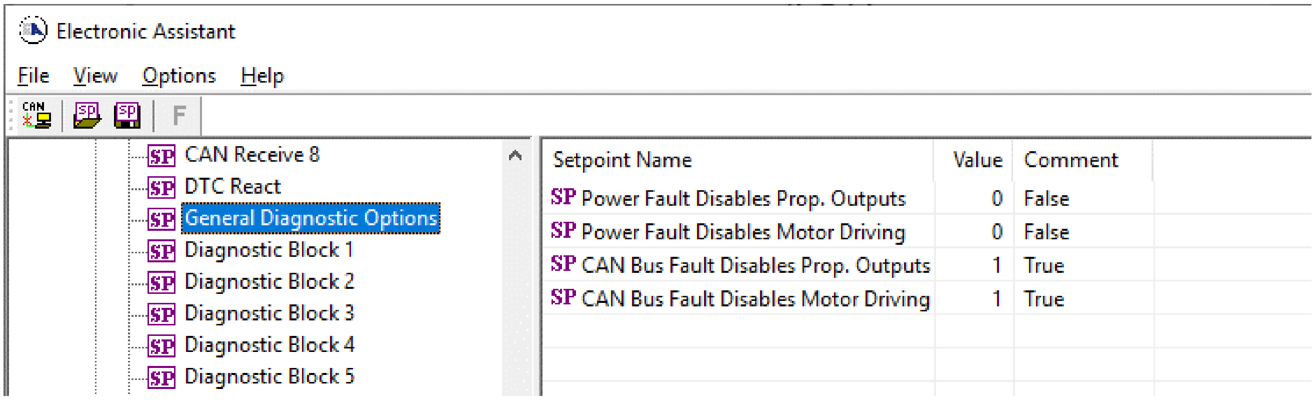


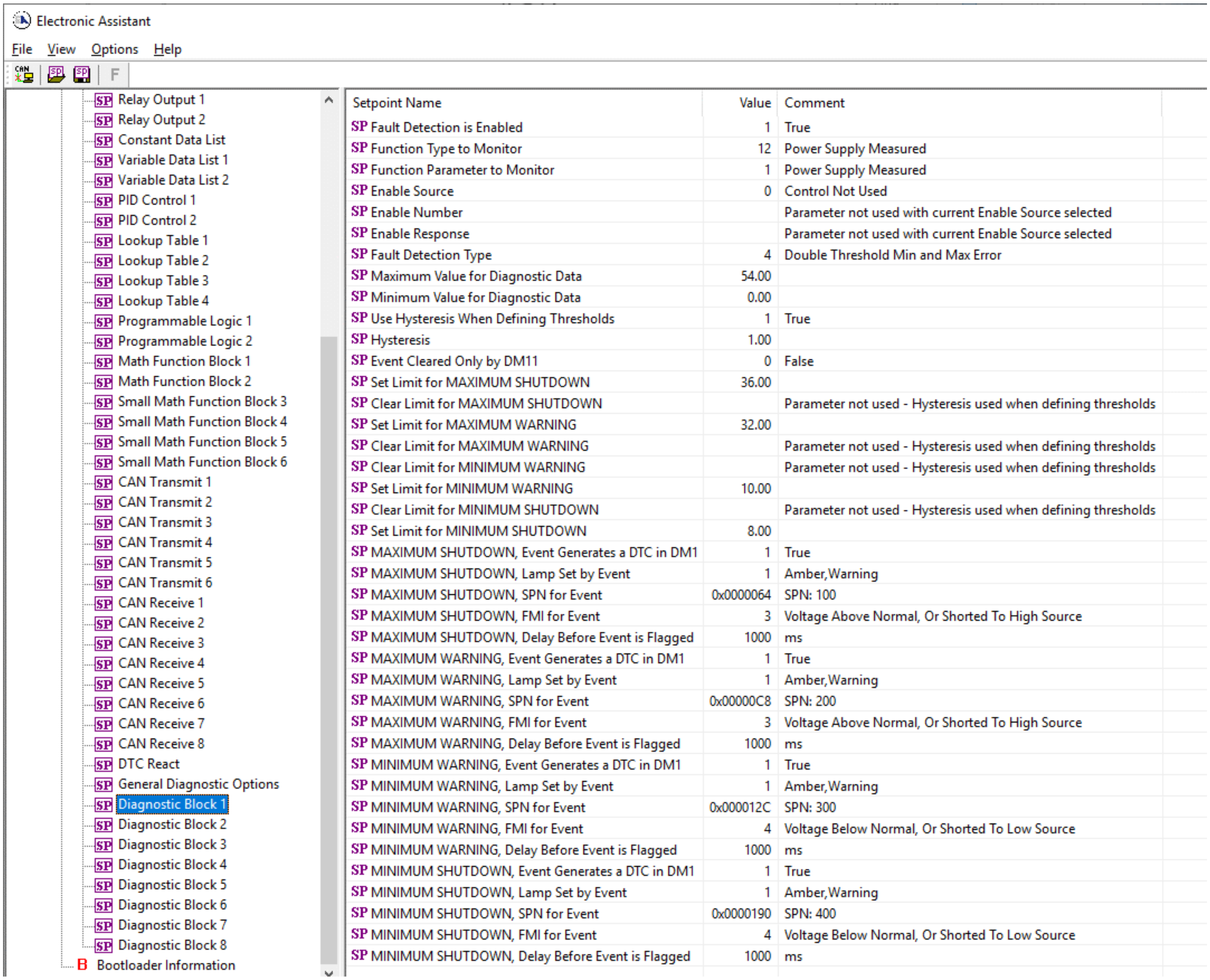

**Figure 22 – Screen Capture of General Diagnostics Options Setpoints**

| Name | Range | Default | Notes |
|---|---|---|---|
| Power Fault Disables Prop. Outputs | Drop List | 0 | |
| Power Fault Disables Motor Driving | Drop List | 0 | |
| CAN Bus Fault Disables Prop. Outputs | Drop List | 1 | |
| CAN Bus Fault Disables Motor Driving | Drop List | 1 | |

**Table 40 – General Diagnostics Options Setpoints**

## 3.19. Diagnostics Blocks

There are 8 Diagnostics blocks that can be configured to monitor various parameters of the Controller. The Diagnostic Function Block is defined in section 1.5. Please refer there for detailed information how these setpoints are used.




| Setpoint Name | Value | Comment |
|---|---|---|
| SP Fault Detection is Enabled | 1 | True |
| SP Function Type to Monitor | 12 | Power Supply Measured |
| SP Function Parameter to Monitor | 1 | Power Supply Measured |
| SP Enable Source | 0 | Control Not Used |
| SP Enable Number | | Parameter not used with current Enable Source selected |
| SP Enable Response | | Parameter not used with current Enable Source selected |
| SP Fault Detection Type | 4 | Double Threshold Min and Max Error |
| SP Maximum Value for Diagnostic Data | 54.00 | |
| SP Minimum Value for Diagnostic Data | 0.00 | |
| SP Use Hysteresis When Defining Thresholds | 1 | True |
| SP Hysteresis | 1.00 | |
| SP Event Cleared Only by DM11 | 0 | False |
| SP Set Limit for MAXIMUM SHUTDOWN | 36.00 | |
| SP Clear Limit for MAXIMUM SHUTDOWN | | Parameter not used - Hysteresis used when defining thresholds |
| SP Set Limit for MAXIMUM WARNING | 32.00 | |
| SP Clear Limit for MAXIMUM WARNING | | Parameter not used - Hysteresis used when defining thresholds |
| SP Clear Limit for MINIMUM WARNING | | Parameter not used - Hysteresis used when defining thresholds |
| SP Set Limit for MINIMUM WARNING | 10.00 | |
| SP Clear Limit for MINIMUM SHUTDOWN | | Parameter not used - Hysteresis used when defining thresholds |
| SP Set Limit for MINIMUM SHUTDOWN | 8.00 | |
| SP MAXIMUM SHUTDOWN, Event Generates a DTC in DM1 | 1 | True |
| SP MAXIMUM SHUTDOWN, Lamp Set by Event | 1 | Amber,Warning |
| SP MAXIMUM SHUTDOWN, SPN for Event | 0x0000064 | SPN: 100 |
| SP MAXIMUM SHUTDOWN, FMI for Event | 3 | Voltage Above Normal, Or Shorted To High Source |
| SP MAXIMUM SHUTDOWN, Delay Before Event is Flagged | 1000 | ms |
| SP MAXIMUM WARNING, Event Generates a DTC in DM1 | 1 | True |
| SP MAXIMUM WARNING, Lamp Set by Event | 1 | Amber,Warning |
| SP MAXIMUM WARNING, SPN for Event | 0x00000C8 | SPN: 200 |
| SP MAXIMUM WARNING, FMI for Event | 3 | Voltage Above Normal, Or Shorted To High Source |
| SP MAXIMUM WARNING, Delay Before Event is Flagged | 1000 | ms |
| SP MINIMUM WARNING, Event Generates a DTC in DM1 | 1 | True |
| SP MINIMUM WARNING, Lamp Set by Event | 1 | Amber,Warning |
| SP MINIMUM WARNING, SPN for Event | 0x000012C | SPN: 300 |
| SP MINIMUM WARNING, FMI for Event | 4 | Voltage Below Normal, Or Shorted To Low Source |
| SP MINIMUM WARNING, Delay Before Event is Flagged | 1000 | ms |
| SP MINIMUM SHUTDOWN, Event Generates a DTC in DM1 | 1 | True |
| SP MINIMUM SHUTDOWN, Lamp Set by Event | 1 | Amber,Warning |
| SP MINIMUM SHUTDOWN, SPN for Event | 0x0000190 | SPN: 400 |
| SP MINIMUM SHUTDOWN, FMI for Event | 4 | Voltage Below Normal, Or Shorted To Low Source |
| SP MINIMUM SHUTDOWN, Delay Before Event is Flagged | 1000 | ms |

**Figure 23 – 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 1.5 |
| 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 14 |
| 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 15 |
| 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 14 |
| 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 15 |
| 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 14 |
| 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 15 |
| 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 14 |
| 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 15 |
| MINIMUM SHUTDOWN, Delay Before Event is Flagged | 0...60000 ms | 1000 | |

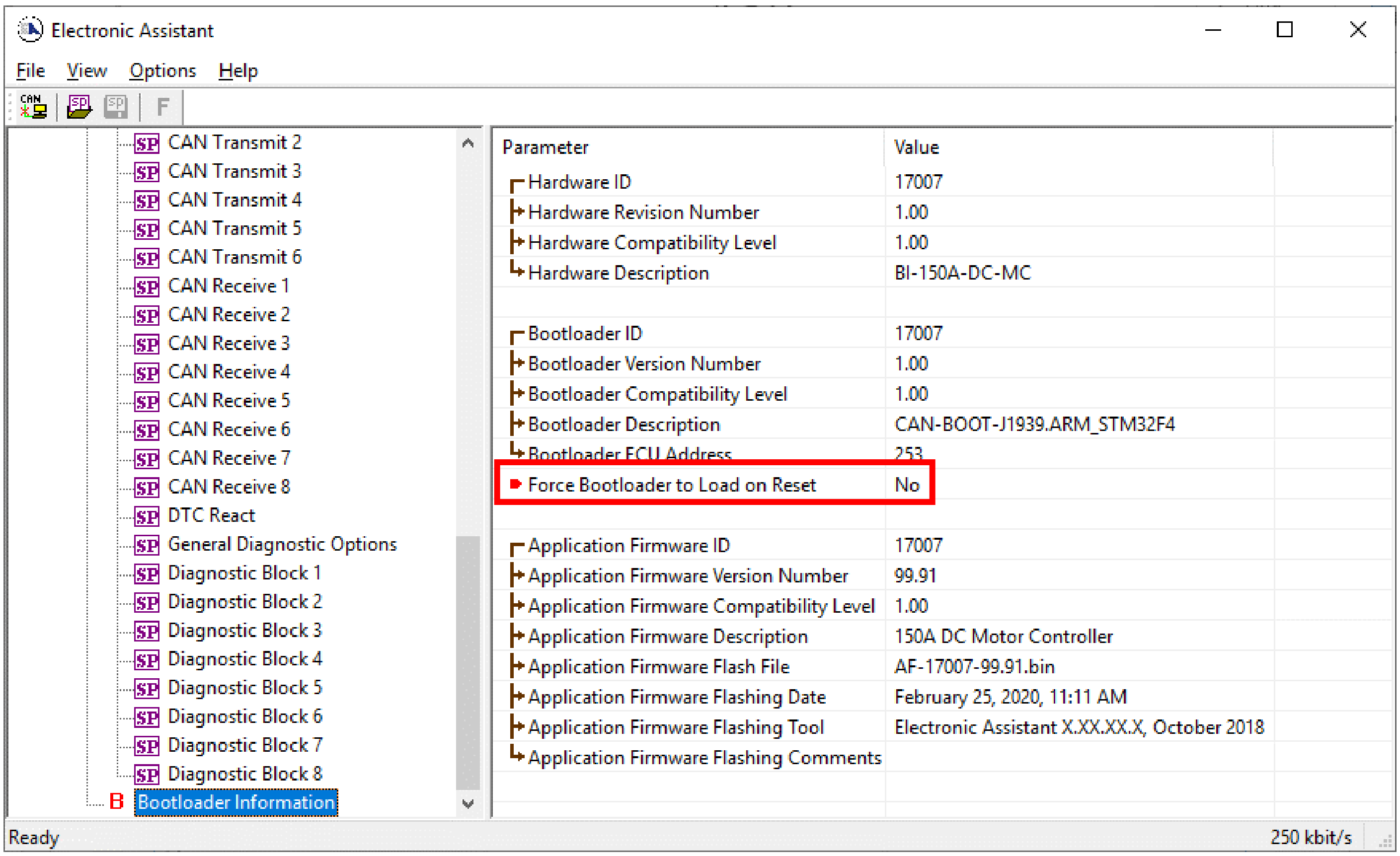
**Table 41 – Diagnostic Block Setpoints**

## 5. Reflashing Over CAN With the Axiomatic EA Bootloader

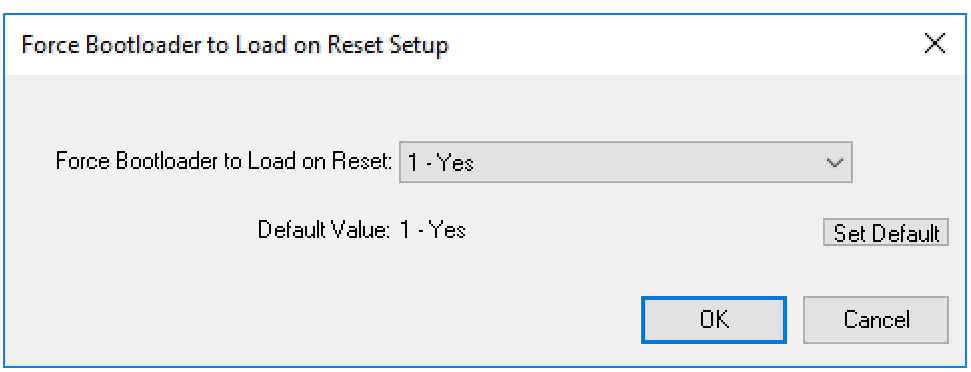
The AX105000 can be upgraded with new application firmware using the **Bootloader Information** section. This section details the simple step-by-step instructions to upload new firmware provided by Axiomatic onto the unit via CAN, without requiring it to be disconnected from the J1939 network.

*Note: To upgrade the firmware use Axiomatic Electronic Assistant V5.15.xxx.0 or higher.*

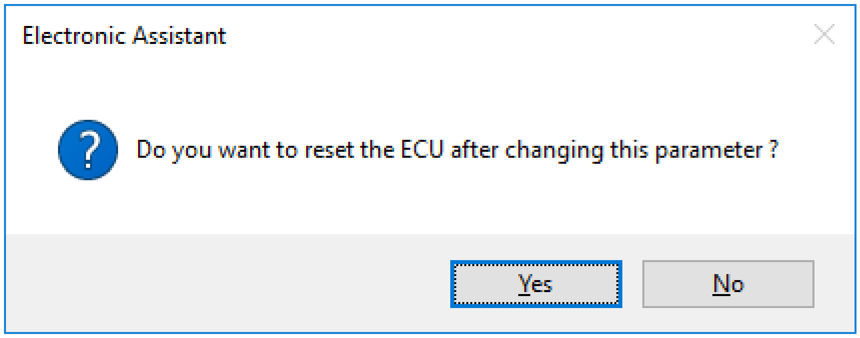
1. When the Axiomatic EA first connects to the ECU, the **Bootloader Information** section will display the following information.



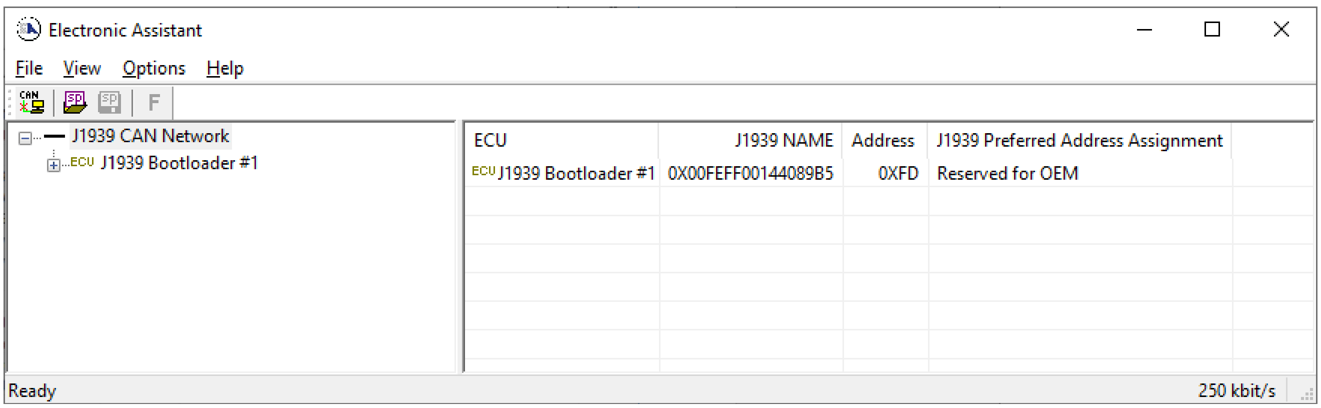

2. To use the bootloader to upgrade the firmware running on the ECU, change the variable **"Force Bootloader To Load on Reset**" to *Yes.*

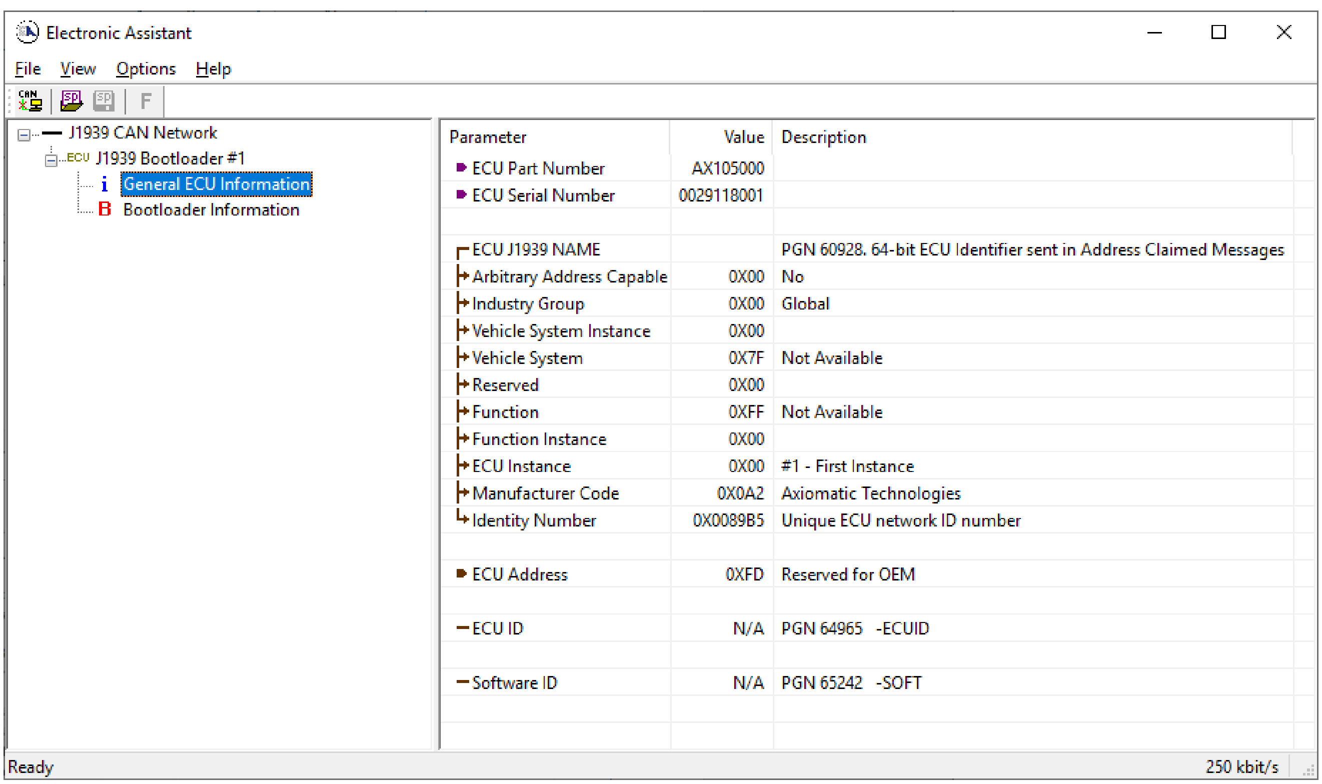



3. When the prompt box asks if you want to reset the ECU, select *Yes.*



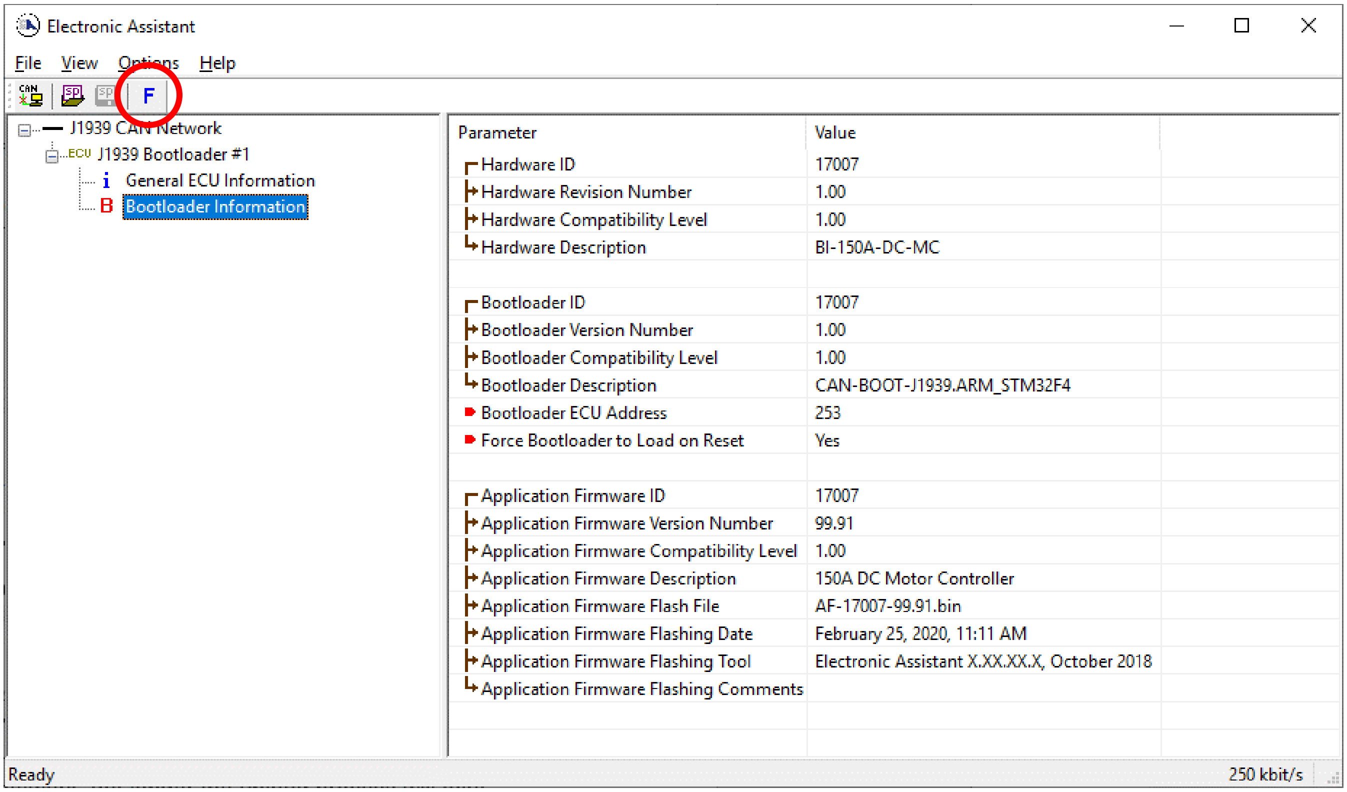

4. Upon reset, the ECU will no longer show up on the J1939 network as an AX105000 but rather as **J1939 Bootloader #1**.



*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.*

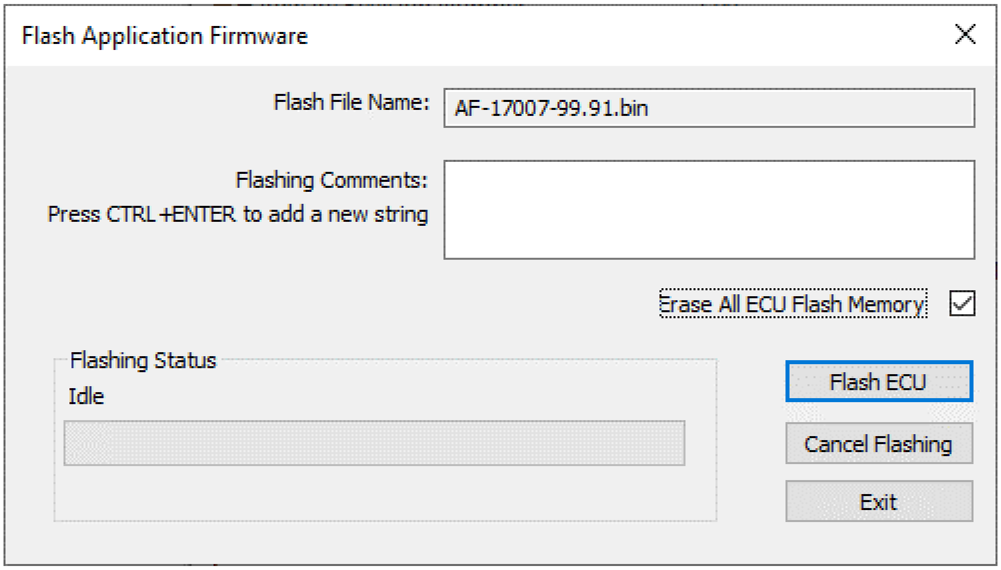
5. When the **Bootloader Information** section is selected, the same information is shown as when it was running the AX105000 firmware, but in this case the **F**lashing feature has been enabled.




6. Select the **F**lashing button and navigate to where you had saved the **AF-17007-x.xx.bin** (or equivalent) file sent from Axiomatic. (Note: only binary (.bin) files can be flashed using the Axiomatic EA tool.)

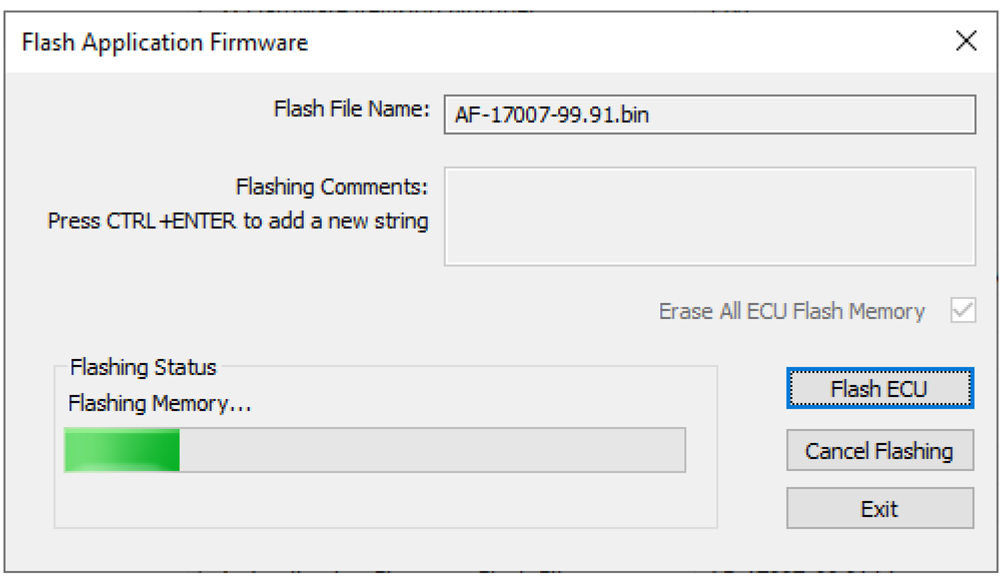
7. Once the Flash Application Firmware window opens, you can enter comments such as "Firmware upgraded by [Name]" if you so desire. This is not required, and you can leave the field blank if you do not want to use it.

   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.

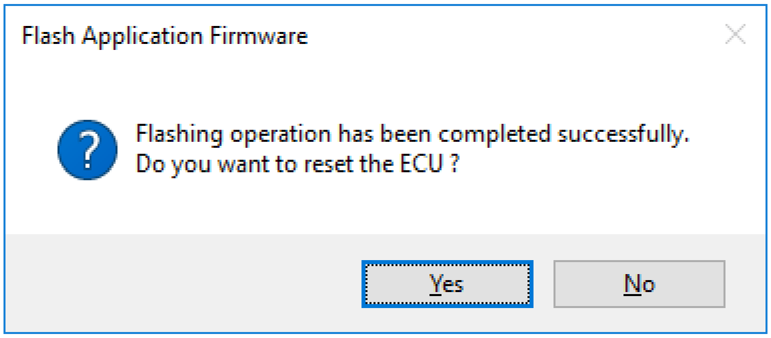



NOTE: It is good practice to tick the “Erase All ECU Flash Memory” box. Please note, that selecting this option will **erase ALL data stored in non-volatile flash**. It will also erase any configuration of the setpoints that might have been done to the ECU and reset all setpoints to their factory defaults. In case the controller contains custom settings, those settings need to be saved to PC before reflashing.

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 AX105000 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 AX105000 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.

## 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 | 12 Vdc or 24 Vdc nominal (8 Vdc to 36 Vdc) |
| Quiescent Current | 100 mA @ 24 V typical; 150 mA @ 12 V typical |
| Surge Protection | Provided |
| Under-voltage Protection | Provided |
| Over-voltage Protection | Provided |
| Over-current Protection | Provided, hardware shutdown @ +/- 300 A |
| Isolation | All inputs are isolated from the power supply driving the motor and current outputs. |
| Universal Inputs | 4 Universal Signal Inputs. Inputs are isolated from the power supply.<br>User selectable as: Voltage; Current; PWM or Digital types.<br>12-bit Analog to Digital (voltage, current)<br>Protected against shorts to GND or +Vsupply<br><br>Voltage Types: 1 mV resolution, accuracy +/- 1% error<br>0-5 V or 0-10 V.<br><br>Current Types: 1 uA resolution, accuracy +/- 1% error<br>0-20 mA or 4-20 mA<br>Current sense resistor 124 Ω<br><br>PWM Signal Frequency: 1 – 20,000 Hz<br>PWM Duty Cycle: 0 to 100%<br>PWM Input: 0.01% resolution, accuracy +/- 1% error<br><br>Digital Input: Active High to Vsupply or Active Low to GND<br>Amplitude: 3.3 V to +Vsupply<br><br>Inputs are sampled every 1 msec.<br><br>Refer to the block diagram and the user manual for details. |
| Ground | 1 Provided<br>Note: Do not connect SIGNAL INPUT GND to BATTERY GND. |
| Input Impedances | 0-5 V @ 1MΩ<br>0-20 mA @ 250 Ω<br>Frequency @ 10 kΩ pullup |

| | |
|---|---|
| Digital Inputs | 4 fully isolated<br>2 inputs are dedicated as STO (Safe Torque Off) and E-Brake safety interlocks inputs<br>Opto-isolated input, normally not active for safety.<br>A power connection is provided which will accept 9 to 36 Vdc from an external power supply or from the battery. If this cable is disconnected, the MOTOR remains OFF.<br>Amplitude: min. 9 Vdc to max. 36 Vdc<br>Input current max. 8 mA<br>The input accepted is active low (input is connected to digital input supply GND when ON). |
| Digital Common | Provided for connection to the digital input power supply. |

## Output Specifications

| | |
|---|---|
| Output to Motor | 1 output for brushed DC motors<br><br>Full H-bridge for forward and reverse motor or brake operation<br>Hz is programmable<br><br>150 A @ 24 Vdc nominal for 5 hours<br>100 A @ 24 Vdc nominal continuous<br><br>Overcurrent protection is provided in software. It is user configurable up to +/-300 A at each output leg.<br><br>Safety interlock provided with 2 dedicated STO inputs that independently shut off the top and bottom side of the H-bridge output.<br><br>Current measurement is provided.<br>Supply voltage measurement is provided.<br><br>User configurable, independent ramps soften changes in motor voltage and current, in either forward or reverse directions.<br><br>The maximum rated speed is configurable to suit individual motor specifications. |
| Motor Direction | Refer to the user manual for details. |
| Thermal Protection | Thermal protection is built in.<br>Overtemperature shutdown is set at 125°C. (default)<br>It is user configurable up to 150°C. |
| Universal Outputs | Two outputs selectable as: Proportional Current; Hotshot Digital; PWM Duty Cycle; Proportional Voltage; or On/Off Digital<br><br>Output #1 has dedicated E-Stop Brake hardware protection function<br>Half-bridge output, current sensing, grounded load.<br>High side sourcing up to 2.5 A<br>Overcurrent protection |

| | |
|---|---|
| | Short circuit protection in hardware<br><br>Current Outputs: 1 mA resolution, accuracy +/- 1% error<br><br>Voltage Outputs: 0.1 V resolution, accuracy +/- 5% error<br><br>High frequency drive<br>PWM Outputs: 0.1% resolution, accuracy +/- 0.1% error<br><br>Digital On/Off: Sourcing from power supply or output off<br>Load at supply voltage must not draw more than 2.5 A. |
| Relay Outputs | 2 Form C relay outputs<br>Maximum 2 A @ 250 Vac or 30 Vdc |
| Reference Voltage | +5 V, 100 mA is available to power a sensor or potentiometer and is referenced to Frequency GND |

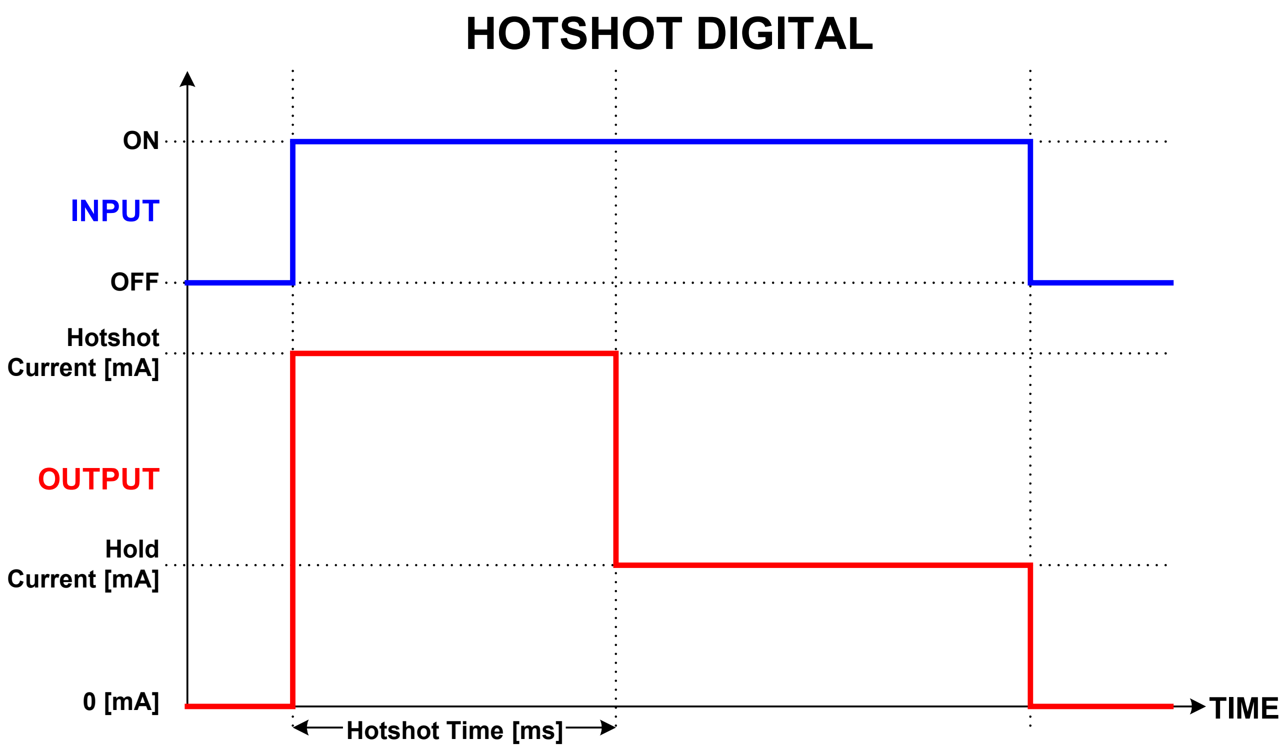



*Figure 1 – Proportional Output Hotshot Digital Profile*

## General Specifications

| | |
|---|---|
| Microcontroller | STM32F407VG |
| Efficiency | >95% |
| Motor Control Logic | Standard embedded software is provided.<br><br>The motor controller is a highly programmable controller, allowing the user to configure it for their application. Its sophisticated control algorithms allow for open or closed loop drive of the motor and proportional outputs. All I/O on the unit are inherently independent from one another but can be programmed to interact in a large number of ways.<br><br>All configurable parameters are user selectable using the Axiomatic Electronic Assistant. Refer to the user manual for details. |
| Diagnostics | Each input and output channel can be configured to send diagnostic messages to the CAN network if the I/O goes out of range. Diagnostic data is stored in a non-volatile log. Refer to the user manual for details. |
| Additional Fault Feedback | There are several types of faults that the controller will detect and provide a response: unit over temperature; power supply undervoltage and overvoltage; hardware shutdown and lost communication. |
| CAN User Interface | Via the Axiomatic Electronic Assistant for *Windows* operating systems 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 Axiomatic Electronic Assistant and Axiomatic USB-CAN as a kit (P/N: AX070502 or AX070506K), which includes all interconnecting cables. Refer to Figure 2 details. |

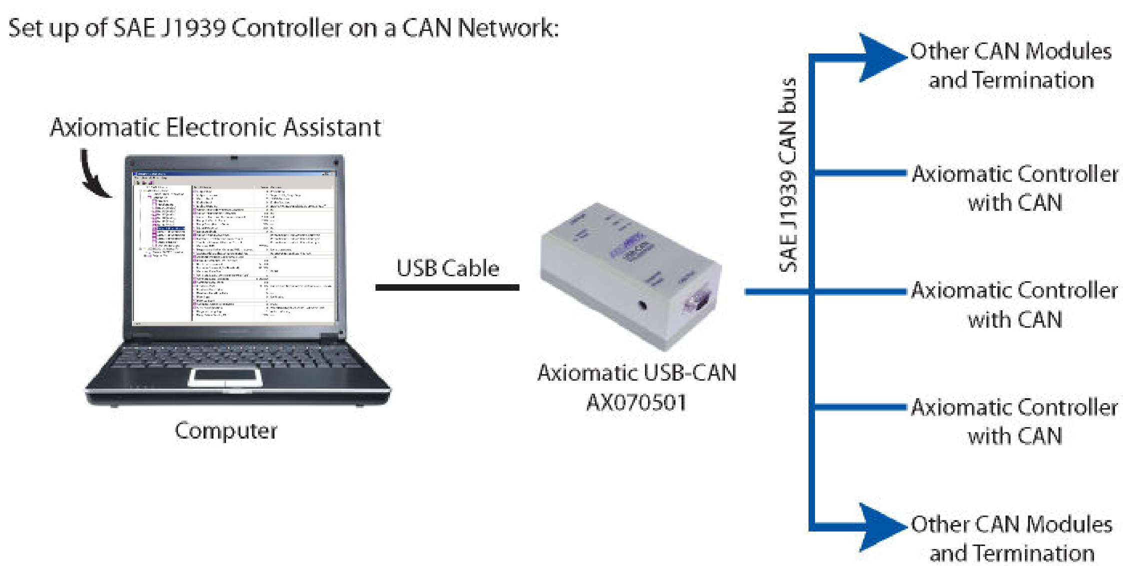



***Figure 2 - User Configuration Using the Axiomatic Electronic Assistant***

| | |
|---|---|
| Communications | 1 SAE J1939 port (CANopen® is available on request.)<br>Model AX105000: 250 kbps baud rate<br>Model AX105000-01: 500 kbps<br>Model AX105000-02: 1 Mbps |
| Electrical Connections | Refer to Table 1.<br>Wires should be of the appropriate gauge to meet requirements of applicable<br>electrical codes and suit the specifications of the connector(s). |
| Mounting | The controller has 4 mounting holes. The holes are sized for 5/16 inch or M8 bolts. The bolt length will be determined by the end-user's mounting plate thickness. Typically, 20 mm (3/4 inch) is adequate.<br><br>To ground the device to the machine, connect the grounding strap via the 4 x M8 or 5/16 inch mounting bolts. The use of a star washer on one or more of the bolts along with the grounding strap will ensure a solid ground connection. |
| Enclosure and Dimensions | Hard anodized die cast aluminum, molded EPDM gasket<br>Refer to Figure 3. |
| Weight | 9.45 lb. (4.286 kg) |
| Operating Conditions | Operating: -40°C to 85°C (-40°F to 185°F) |
| Protection Rating | IP67 |

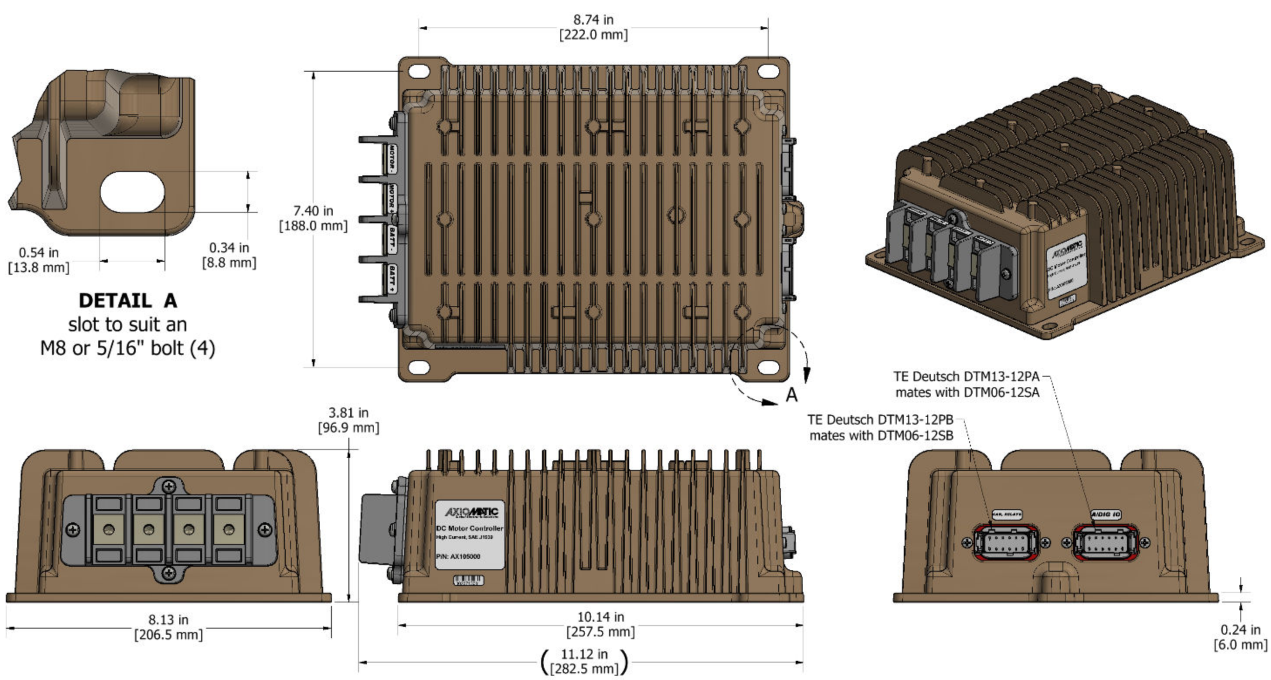



***Figure 3 – Dimensions***

*Table 1 - Electrical Pin Out Chart*

| | |
|---|---|
| I/O **CONNECTOR**<br>12-pin connector (equivalent to TE Deutsch P/N: DTM13-12PA)<br>Pin 1: DIG IN POWER<br>Pin 2: DIG IN 1<br>Pin 3: STO IN 2<br>Pin 4: UNIVERSAL SIGNAL IN 2<br>Pin 5: UNIVERSAL SIGNAL IN 3<br>Pin 6: +5 V REF<br>Pin 7: SIGNAL INPUT GND<br>Pin 8: SIGNAL INPUT GND<br>Pin 9: UNIVERSAL SIGNAL IN 4<br>Pin 10: UNIVERSAL SIGNAL IN 1<br>Pin 11: DIG IN 2<br>Pin 12: STO IN 1<br><br>**CAN & RELAY CONNECTOR**<br>12-pin connector (equivalent to TE Deutsch P/N: DTM13-12PB)<br>Pin 1: CAN_H<br>Pin 2: Output 1+<br>Pin 3: Output 1 Return<br>Pin 4: NC_2<br>Pin 5: NO_2<br>Pin 6: COM_2<br>Pin 7: COM_1<br>Pin 8: NO_1<br>Pin 9: NC_1<br>Pin 10: Output 2 Return<br>Pin 11: Output 2+<br>Pin 12: CAN_L | **Power and Motor Control:**<br>4 Aluminum power pass-through blocks accessible via M8 tapped holes in enclosure. Wire lugs should be attached to these.<br><br>Refer to Figure 3 for orientation of holes to access Aluminum power pass through blocks.<br>Motor -<br>Motor +<br>Battery -<br>Battery +<br><br>**WARNING: Wiring the motor in upside down (i.e. all connections backwards) will result in the motor running in full forward with NO control from the processor!** |
| Mating Plug Kit | **PL-DTM06-12SA-12SB** (includes 1 DTM06-12SA, 1 DTM06-12SB, 2 WM12S, 24 Contacts, and Sealing Plugs) |

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

**AXIOMATIC** *Global Electronic Solutions*

## 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 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.

## CONTACTS

**Axiomatic Technologies Corporation**
1445 Courtneypark Drive E.
Mississauga, ON
CANADA L5T 2E3
TEL: +1 905 602 9270
FAX: +1 905 602 9279
www.axiomatic.com
sales@axiomatic.com

**Axiomatic Technologies Oy**
Höytämöntie 6
33880 Lempäälä
FINLAND
TEL: +358 103 375 750
www.axiomatic.com
salesfinland@axiomatic.com