7 Inputs, 3 RTD, 2 Outputs

CAN Controller with SAE J1939

<u>USER MANUAL</u>

P/N: AX180010

ACRONYMS

ACK   Positive Acknowledgement

CSR   CAN Status Report

DM   Diagnostic Message (from SAE J1939 standard)

DTC   Diagnostic Trouble Code

FMI   Failure Mode Identifier

OC   Occurrence Count

EA   The Axiomatic Electronic Assistant (Service Tool for Axiomatic ECUs)

ECU   Electronic Control Unit (from SAE J1939 standard)

MAP   Memory Access Protocol

NAK   Negative Acknowledgement

PDU1   A format for messages that are to be sent to a destination address,
                either specific or global

PDU2   A format used to send information that has been labeled using the Group Extension
                technique and does not contain a destination address.

PGN   Parameter Group Number (from SAE J1939 standard)

PropB   Message that uses a Proprietary B PGN

SPN   Suspect Parameter Number (from SAE J1939 standard)

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1.1. Introduction to AX180010 Features

The following user manual describes architecture, functionality, configuration parameters and flashing instructions for the 7UIN-3RTD-2UOUT-CAN electronic control unit (ECU) with SAE J1939 CAN communication links. It also contains controller technical specifications and installation instructions to help users build a custom solution on the base of this controller. The hardware supports 7 universal inputs, 3 RTD inputs and 2 universal outputs. Each of the two outputs have current feedback to the microprocessor.

The ECU has been designed to allow the maximum amount of versatility to optimize the performance of the machine. Numerous configurable variables, called setpoints, have been provided which are accessible using Axiomatic Technologies' Electronic Assistant. Information about the setpoint defaults and ranges is outlined in Section 3. The Axiomatic EA communicates with the controller over the J1939 CAN bus and uses Memory Access Protocol (MAP) to read/write each setpoint. Once the ECU has been setup as desired, the setpoints can be saved to a file, and flashed into other controllers over the CAN bus using the EA.

The ECU is an arbitrary address capable ECU, which can perform dynamic address allocation at the run time. It also provides all necessary network support required by the J1939 standard.

J1939 Network – Diagnostic Broadcast

Diagnostic messages are triggered by the internal function blocks and then broadcasted on the CAN bus network. However, in some applications this broadcast may not be required and so the user has the option to disable or enable this feature.

1.2. Hardware Block Diagram

The controller contains 7 universal inputs, 3 RTD inputs and 2 universal outputs, one CAN, transient and surge suppression polarity protection and a protected power supply. An embedded 32-bit microcontroller provides necessary processing power to the controller.
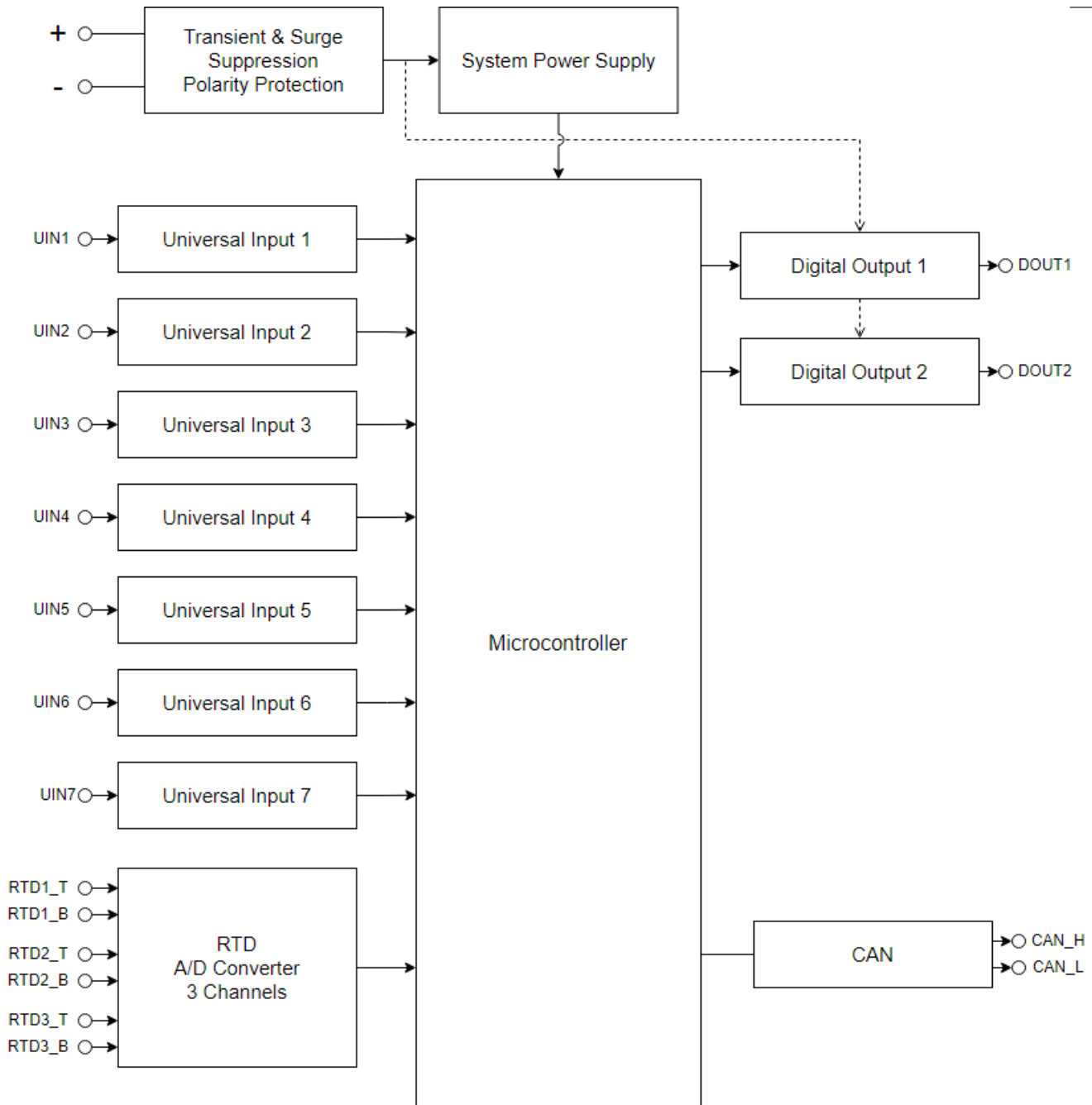

Figure 1. Block diagram

1.3. Control Sources

The different function blocks in the ECU are commanded by a set of Control Sources. This section lists the different available control sources for these functions and their respective ranges.

Value	Meaning	Source Range
0	Control Not Used	[0]
1	Universal Input	[1..7]
2	RTD Input	[1…3]
3	Universal Output	[1…2]
4	Output Current Feedback	[1…2]
5	CAN Receive	[1…10]
6	CAN DTC React	[1…5]
7	PID Functional Block	[1…2]
8	Lookup Table	[1…15]
9	Math Functional Block	[1…6]
10	Logic Functional Block	[1…4]
11	Set-Reset Latch	[1…4]
12	Constant Continuous Data	[0] - Constant Signal = 0.0 [1] - Constant Signal = 1.0 [2…7] - Data
13	Constant Discrete Data	[1…5]
14	Supply Voltage	[1…4]
15	Microcontroller Temperature	[1…2]

Table 1: Control Sources

1.4. Global Parameters

The Global Parameters Block contains configurable constant data setpoints which can be used as a control source for other functions. While they are available as a control source to all functions, it is recommended not to use constant data as a control source for the Set-Reset Latch Block or Global Constant Signals 0/1 could be used.

1.5. Universal Input Function Blocks

The *Universal Input* function block translates physical input signals into the internal function block output signal that can be used by other function blocks of the controller.

There are 7 independent *Universal Input* function blocks presenting their own universal physical inputs. The internal function block output signal type and units of measurement are presented below.

Input Parameter	Type	Units
Voltage	Continuous	V
Current	Continuous	mA
Resistance	Continuous	Ohm
Discrete Voltage Level	Discrete	{0,1}
Frequency	Continuous	Hz
PWM Duty Cycle	Continuous	%

Table 2. Universal Input Function Block Output Signal

Each *Universal Input* function block has the following configuration parameters.

Parameter	Default Value	Range	Units	Description
Input Parameter	1 - Voltage	0 - Input Disabled, 1 - Voltage, 2 - Current, 3 – Resistance, 4 - Discrete Voltage Level, 5 - Frequency, 6 - PWM Duty Cycle	–	Defines the input physical parameter that will be measured by the function block.
Voltage Range	0 - 0…5V	0 - 0…5 V, 1 - 0…10 V	bit/s	Used in the "Voltage" mode
Current Range[1]	0 - 0…20 mA	0 - 0…20mA, 1 - 4…20 mA	mA	Used in the "Current" mode
Resistance Range[2]	0 - Auto Range	0 – Auto Range, 1 - 0…250Ohm, 2 - 0…2.5kOhm, 3 - 0…25kOhm, 4 - 0…250kOhm	Ohm	Used in the "Resistance" mode
Voltage LoZ Input	0 - No	0 - No, 1 - Yes	–	Activates a 10kOhm pull-down resistor to avoid ghost voltages in the "Voltage" mode. Warning: Measurement accuracy will be decreased!
Analog Input Filter	0 - Disabled	0 - Disabled, 1 - 50Hz Noise Rejection, 2 - 60Hz Noise Rejection, 3 - Both: 60Hz and 50Hz Noise Rejection	–	Noise Rejection in "Voltage", "Current" and "Resistance" modes

Parameter	Default Value	Range	Units	Description
Pull-Up/Pull-Down Resistor	0 - Disabled	0 - Disabled, 1 - 10kOhm Pull-Up, 2 - 10kOhm Pull-Down	–	Used in "Discrete Voltage Level", "Frequency", and "PWM Duty Cycle" modes.
Input Polarity	0 - Active High	0 - Active High, 1 - Active Low	–	Used in "Discrete Voltage Level", "Frequency", and "PWM Duty Cycle" modes.
Discrete Input Debounce Time	50ms	0…1000	ms	Used in "Discrete Voltage Level" mode. If 0 - no debouncing.
Frequency Range[3]	0 - 100Hz…10kHz	0 - 100Hz…10kHz, 1 - 10Hz…1kHz, 2 - 1Hz…100Hz	Hz	A 16-bit counter is used. Used in "Frequency", and "PWM Duty Cycle" modes.
Frequency/PWM Debounce Filter[3]	0 - Disabled	0 - Disabled, 1 - 142ns, 2 - 1.14us, 3 - 6.10us	–	Used in "Frequency", and "PWM Duty Cycle" modes.
Frequency/PWM Averaging	0 - No Averaging	0 - No Averaging, 1 - 3 Readings, 2 - 5 Readings, 3 - 10 Readings	–	Defines a moving average filer used in "Frequency", and "PWM Duty Cycle" modes.

Table 3. Universal Input Function Block Configuration Parameters

[1] Input currents below 3mA are output as 0mA when 4…20 mA current range is set.
[2] Resistance below 10Ohm will be measured as 0 in the "Auto Range" or "0…250Ohm" resistance range.
[3] Read-only in the *Universal Input #5* and *8*. Set in the *Universal Input #2* and *#1*, respectively.

1.5.1. Voltage Measurements

The *Universal Inputs* can measure voltages in voltage ranges set by the *Voltage Range* configuration parameter.

To avoid an influence of ghost voltages, the *Voltage LoZ Input* configuration parameter can be activated. This will reduce the accuracy of voltage measurements due to the influence of the 10kOhm pull-down shunt resistor and should be used only after careful consideration of the shunt resistor influence on the measured circuit.

The user can set the *Analog Input Filter* configuration parameter to reduce noise in voltage and other analog signal measurements. The filter is designed to suppress noise from industrial offline voltages. Even when the analog input filter is disabled, the minimum signal filtering is performed by the function block. The parameters of the analog input filter are presented below.

Analog Input Filter	Cut-off Frequency (at -3dB)	Settling Time (to 100% of Final Value)	Output Signal Update Rate
Disabled[1]	70Hz	10ms	1.67ms
50Hz Noise Rejection	12Hz	76.7ms	3.33ms
60Hz Noise Rejection	14Hz	63.3ms	3.33ms
Both: 60Hz and 50Hz Noise Rejection	2.3Hz	396.7ms	16.67ms

Table 4. Universal Input Analog Input Filter Parameters

[1] Minimum filtering is still performed.

1.5.2. Current Measurements

There are two standard current ranges available for current measurements. When the current is below 3mA in the "4…20mA" current range, the output will be forced to zero to facilitate detection of an open circuit condition on the *Universal Input*.

The *Analog Input Filter* can be set to reduce the input noise.

1.5.3. Resistance Measurements

The *Universal Inputs* can measure slowly changing input resistance, for example, a signal coming from a resistive temperature sensor.

The resistance measurements can be done in an auto-range or a predefined range mode set by the *Resistance Range* configuration parameter.

When the *Resistance Range* is set to "Auto Range", a special algorithm is used to dynamically switch between resistance ranges to ensure that the resistance value is measured with the best accuracy and resolution, see the table below.

Input Resistance	Resistance Range	
	Low-to-High Resistance Change	High-to-Low Resistance Change
< 225 Ohm	0…250Ohm	
225…275Ohm	0…250Ohm	0…2.5kOhm
275Ohm…2.25kOhm	0…2.5kOhm	
2.25kOhm…2.75kOhm	0…2.5kOhm	0…25kOhm
2.75kOhm…22.5kOhm	0…25kOhm	
22.5kOhm…27.5kOhm	0…25kOhm	0…250kOhm
>27.5kOhm	0…250kOhm	

Table 5. Resistance Ranges as a Function of Input Resistance in the Auto Range Mode

If switching between the measurement ranges is not desirable or it is necessary to reduce the measurement time, the *Resistance Range* can be set to one of the predefined measurement ranges.

The *Analog Input Filter* configuration parameter can be used to reduce the measurement noise. However, it can also add a delay that can be significant when several universal inputs are used to measure resistance.

There is only one current source shared with all *Universal Inputs* for resistance measurements. When more then one *Universal Input* is used to measure resistance, the current source is switched between inputs dramatically increasing the measurement time, see the table below.

Resistance Measurement	Measurement Delay
No channel or range switching	$0 - No\ delay$
Range switching only	$\begin{cases} T_{sw} + T_s, & during\ range\ switching\ only \\ 0, & all\ other\ time - no\ delay \end{cases}$ $T_{sw} = 30ms - switching\ time,\ T_s - analog\ filter\ settling\ time$
Channel switching (with or without range switching)	$\sum_{n=1}^{N} (T_{sw} + T_{s_n}),\qquad N > 1,\qquad N - number\ of\ channels$ $n - channel\ number$

<div align="center">

Table 6. Universal Input Resistance Measurement Delay

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For example, if 5 universal inputs are used to measure resistance and *Analog Input Filter* is set to "Both: 60Hz and 50Hz Noise Rejection" in all universal inputs, the total delay between consequent measurements will be $5 * (30 + 396.7) = 2133.5\ ms$ or more than 2 seconds.

1.5.4. Discrete Voltage Level

The *Universal Inputs* can accept discrete voltage levels. The user should specify the input polarity and define whether the pull-up/pull-down resistor is necessary on the input.

When the "10kOhm Pull-Up" is selected, the pull-up resistor is connected to the internal +14V power supply.

The input states are sampled every 1ms. If debouncing is required, it is set by the *Discrete Input Debounce Time* configuration parameter. If the *Discrete Input Debounce Time* is zero, the discrete voltage level input is not debounced.

1.5.5. Frequency and PWM

The frequency and PWM duty cycle measurements are performed by counting high-frequency internal clock pulses on every period of the input signal.

All universal inputs use 16-bit counters with the same set of frequency ranges configured by the *Frequency Range* configuration parameter. *Universal Inputs #5* and *6* share their counter base together with the *Frequency Range* and *Frequency/PWM Debounce Filter* settings with other inputs, see the table below.

Function Block	Counter	Frequency Range	Counter Base	Shared Input	Frequency Range and Debounce Filter Setting

Function Block	Counter	Frequency Range	Counter Base	Shared Input	Frequency Range and Debounce Filter Setting
Universal Input #1	16-bit	100Hz…10kHz, 10Hz…1kHz, 1Hz…100Hz	Dedicated	N/A	Same input
Universal Input #2			Dedicated	N/A	Same input
Universal Input #3			Dedicated	N/A	Same input
Universal Input #4			Dedicated	N/A	Same input
Universal Input #5			Dedicated or Shared	Universal Input #6	Same input
Universal Input #6			Shared Only	Universal Input #5	Universal Input #5
Universal Input #7			Dedicated	N/A	Same input

Table 7. Universal Input Function Block Counters

When the counter base is in the dedicated mode, the counter is synchronized with the input signal. This allows more accurate frequency and PWM duty cycle measurements. If the counter base is shared, the counter is free running. This causes a small jitter in the input measurements. To avoid this jitter, use counters with the dedicated counter base when possible in the customer's applications.

To measure frequency or PWM duty cycle, the user should first select the *Frequency Range* parameter and then define how the *Pull-Up/Pull-Down Resistor*, *Frequency/PWM Debounce Filter*, and the *Frequency/PWM Averaging* parameters should be set.

For the *Universal Input #6,* with the shared only counter base, the user should configure the *Frequency Range* and *Frequency/PWM Debounce Filter* parameters in the *Universal Input #5* function blocks. These settings will be shared between inputs.

The *Input Polarity* defines the active edge of the input signal. The *Pull-Up/Pull-Down Resistor* can be used to pull the input to a no-signal state to avoid an undefined input condition when the signal source is disconnected. The *Input Polarity* and *Pull-Up/Pull-Down Resistor* are normally set the following way.

Input Polarity	Pull-Up/Pull-Down Resistor
Active High	"Disabled" or "10kOhm Pull-Down"
Active Low	"Disabled" or "10kOhm Pull-Up"

Table 8. Setting Pull-Up/Pull-Down Resistor for Selected Input Polarity. Universal Inputs

The frequency/PWM debounce filter is used to filter out parasitic spikes that can be present in a noisy input signal. It can be helpful to prevent the input from going into the Recovery state (see 1.5.6 Special Conditions) when, for example, mechanical switches are used to commutate the input signal.

The debounce filter should be used with caution since it can reduce the accuracy and resolution of frequency and PWM measurements if the debouncing time is not significantly less than the period of the input signal.

When a frequency or PWM signal presents a slowly changing parameter, setting an additional moving average filter using the *Frequency/PWM Averaging* configuration parameter can be helpful in smoothing the results of the input measurements.

1.5.6. Special Conditions

Frequencies below the Minimum Frequency value will be measured as zero and frequencies above the Maximum Frequency value will saturate at the Maximum Frequency value for the selected *Frequency Range*, see

Frequency Range	Counter	Minimum Frequency	Maximum Frequency	Maximum Recovery Time
100Hz…10kHz		91.55Hz	12.5kHz	10.9ms
10Hz…1kHz	16-bit	9.155Hz	1.25kHz	109ms
1Hz…100Hz		0.9155Hz	125Hz	1.09s

Table 9 and

Input Mode	Signal Frequency (F_s)			
	$F_s = 0$ Zero Frequency (DC)	$0 < F_s < F_{min}$ Below Minimum Frequency F_{min}	$F_{min} \leq F_s \leq F_{max}$ Working Frequency	$F_s > F_{max}$ Above Maximum Frequency F_{max}
Measured Frequency F_m	$F_m = 0$	$F_m = 0$	$F_m = F_s$	$F_m = F_{max}$ Recovery state
Measured PWM Duty Cycle D_m	$D_m = \{0, 100\}$	Undefined (not allowed)	$D_m = D_s$, D_s – signal duty cycle	$D_m = 0$ Recovery state

Table 10.

Frequency Range	Counter	Minimum Frequency	Maximum Frequency	Maximum Recovery Time
100Hz…10kHz		91.55Hz	12.5kHz	10.9ms
10Hz…1kHz	16-bit	9.155Hz	1.25kHz	109ms
1Hz…100Hz		0.9155Hz	125Hz	1.09s

Table 9. Maximum, Minimum Frequencies and Maximum Recovery Time for Universal Inputs

Frequencies above the Maximum Frequency value will switch the input to the Recovery state. The input will stay in the Recovery state until the upcoming counter saturation event when the frequency will be measured again. The input will leave the Recovery state if the measured frequency value is below the Maximum Frequency.

Input Mode	Signal Frequency (F_s)			
	$F_s = 0$ Zero Frequency (DC)	$0 < F_s < F_{min}$ Below Minimum Frequency F_{min}	$F_{min} \leq F_s \leq F_{max}$ Working Frequency	$F_s > F_{max}$ Above Maximum Frequency F_{max}
Measured Frequency F_m	$F_m = 0$	$F_m = 0$	$F_m = F_s$	$F_m = F_{max}$ Recovery state
Measured PWM Duty Cycle D_m	$D_m = \{0, 100\}$	Undefined (not allowed)	$D_m = D_s$, D_s – signal duty cycle	$D_m = 0$ Recovery state

Table 10. Frequency and PWM Measurements for Universal Inputs. Special Conditions

The time between two consequent counter saturation events defines the Maximum Recovery Time, see

Frequency Range	Counter	Minimum Frequency	Maximum Frequency	Maximum Recovery Time
100Hz…10kHz		91.55Hz	12.5kHz	10.9ms
10Hz…1kHz	16-bit	9.155Hz	1.25kHz	109ms
1Hz…100Hz		0.9155Hz	125Hz	1.09s

Table 9. This time is the maximum transient time when the measured frequency will stay equal to the Maximum Frequency value.

When the PWM signal is absent, the duty cycle is measured as 0 or 100% based on the voltage level on the input and the selected *Input Polarity*. The voltage level is sampled on the counter saturation events until the PWM signal is back on the input.

The transient time between the PWM signal duty cycle and the duty cycle of the DC level when the signal disappears can be up to the Maximum Recovery Time. During the transient time, the measured value will stay equal to the last measured value of the PWM signal duty cycle.

The PWM input signal with a frequency above zero but below the Minimum Frequency value is not allowed. The duty cycle will not be measured, instead, it will be jumping between 0% and 100% depending on the voltage level at the input on the counter saturation events.

When the PWM input signal frequency exceeds the Maximum Frequency value, the input goes into the Recovery state and the PWM duty cycle is measured as 0%. Like frequency measurements, the input will stay in the Recovery state for up to the Maximum Recovery Time before the duty cycle is measured again.

1.6. RTD Input Function Block

The RTD Input Function Block reads analog signal from two RTD sensor inputs and process them into the temperature data. The AX180010 supports the PT100 sensor type in 2-wire configuration.

The user can specify approximation parameters for each individual sensor connected to the unit using setpoint parameters. Axiomatic EA software is used for this purpose. The setpoint parameters are kept in a non-volatile memory of the RTD unit and are automatically loaded on power-up.

1.6.1. RTD Coefficients

By default, the values for Callendar-Van Dusen Coefficients A, B, and C are standard (IEC 0.00385).

Name	Default Value	Range	Description
Callendar – Van Dusen coefficient A	3.908300	-100…100	Callendar – Van Dusen coefficient A for the selected standard coefficient set. Editable, if the coefficient set is "User Defined".
Callendar – Van Dusen coefficient B	-5.77500	-100…100	Callendar – Van Dusen coefficient B for the selected standard coefficient set. Editable, if the coefficient set is "User Defined".
Callendar – Van Dusen coefficient C	-4.183010	-100…100	Callendar – Van Dusen coefficient C for the selected standard coefficient set. Editable, if the coefficient set is "User Defined".

Table 11 The Default Value of Coefficients

1.7. Universal Output Function Block

The controller has 2 Universal outputs. "**Output Type**" setpoint determines what kind of signal the output produces. Changing this setpoint causes other setpoints in the setpoint 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 12.

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

Table 12. Output Type Options for Universal Output

'*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 (25 kHz), with the low frequency dither superimposed on top. The dither frequency will match exactly what is programmed into the setpoint, but the exact amplitude of the dither will depend on the properties of the load coil. When adjusting the dither amplitude value, select one that is high enough to ensure an immediate response to the coil to small changes in the control inputs, but not so large as to affect the accuracy or stability of the output. Refer to the coil's datasheet for more information.

The '*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. If the output is running at a high frequency (for example 25 kHz), the voltage can be easily averaged using a simple low pass filter.

The '*PWM Duty Cycle*' option allows the user to run the output at fixed frequency configure with "**PWM Output Frequency**" setpoint, while the duty cycle changes depending on the control signal. "**PWM Output Frequency**" is editable only if none of the outputs in the output group is set to '*Current*' or '*Hotshot Digital*' type. Configuring output to '*Current*' or '*Hotshot Digital*' type changes frequency if the output group automatically to 25 kHz.

There are also two types of digital responses possible. 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.

If a digital "**Output Type**" has been selected the "**Digital Response**" setpoint will be enabled as shown in Table 13.

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

Table 13. 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.

The "**High-Side/Low-Side Output Setting**" setpoint defines whether the output will have high or low side sourcing. When 'High' is selected there will be high side sourcing and selecting 'Low' will configure the output to have a low side source.

0	Low
1	High

<div align="center">Table 14. High-Side/Low-Side Output Setting</div>

The "**Digital Out Delay**" and "**Delay Polarity**" setpoints are associated with 'Normal' "**Digital Response**". The "**Digital Out Delay**" defines output state change delay in milliseconds. Setting "**Digital Out Delay**" to 0ms applies no state change delay. The "**Delay Polarity**" setpoint defines which edge the state change delay will be applied. For example, selecting 'Rising Edge' for "**Delay Polarity**" and setting "**Digital Out Delay**" value >0ms, applies defined delay when driving output signal state changes form OFF to ON.

0	Rising Edge
1	Falling Edge

<div align="center">Table 15. Delay Polarity</div>

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 command 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.
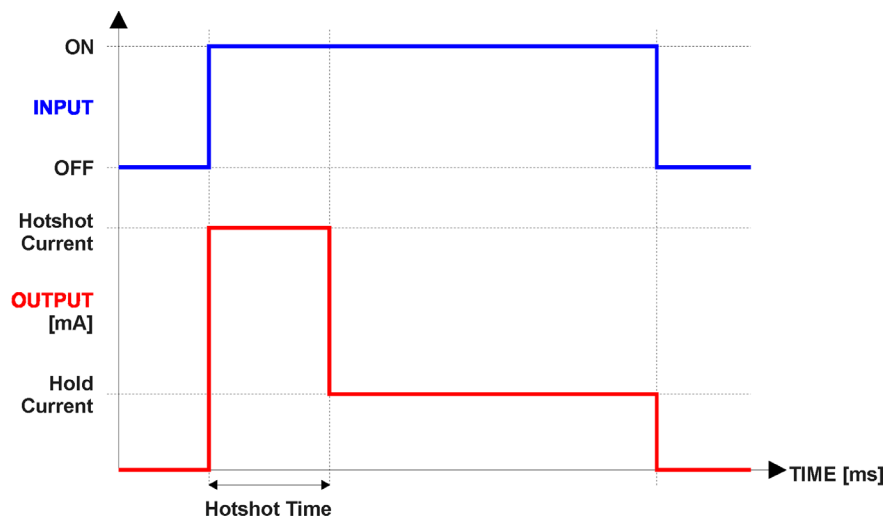

<div align="center">Figure 2. Hotshot Digital Profile</div>

For output signal minimum and maximum values are configured with "**Output At Minimum Command**" and "**Output At Maximum Command**" setpoints. Value range for both 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 1.

$$y = mx + a$$

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

$$a = Ymin - m * Xmin$$

Equation 1. 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 the output to follow the 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 '*Programmable Logic'* and "**Control Number**" to '*1*', connects output signal from Programmable Logic 1 to the output in question. 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, Universal 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 Table 16. If a non-digital signal is selected as Enable signal the signal is interpreted as shown below:

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 16. 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 in Table 17. 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 17. Override Response Options

If a fault is detected in any of the active inputs (Control/Enable/Override) the output will respond per "**Output Fault Response**" setpoint as outlined in Table 18.

0	Shutoff Output
1	Apply Fault Value
2	Hold Last Value

Table 18. Fault Response Options

Regardless of a selected output type, current through the load is available as Output Current Feedback signal and can be selected as input for a Diagnostic Block as described in section 1.13. 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 Voltage Fault** function block. Also, if the **Over Temperature Fault** function block is enabled, then a microprocessor over-temperature reading disables all the outputs until it has cooled back to the operating range.

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

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

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

1.8. PID Control Function Block

The PID Control function block is an independent logic block, but it is normally intended to be associated with Universal 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 Controller.

The "Target Source" and "Target Number" setpoints determine control input and the "Feedback Source" and "Feedback Number" setpoints determine the established the feedback signal to the PID function block. The "Control Response" will use the selected inputs as per the options listed in Table 19. When active, the PID algorithm will be called every "Cycle Time" in milliseconds.

0	Single Output
1	On When Over Target
2	On When Below Target

Table 19. 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 value based on the minimum and maximum values associated with the source function block.

For example, output of a Math Function Block could be used to set the target value, in which case it would be converted to a percentage value using "Math Output Minimum Range" and "Math Output Maximum Range" setpoints. The closed-loop feedback signal could be connected a 'CAN Receive Message' and selected as the feedback source. In this case the value of the message data would be converted to a percentage based on the "Data Minimum" and "Data Maximum" setpoints in the CAN Receive block. The output of the PID function would depend on the difference between the commanded target and the measured feedback as a percentage of each signals range. In this mode, the output of the block would be a value from -100% to 100%.

The last two response options, 'On When Over Target' and 'On When Under Target', are designed to allow the user to combine the two Universal 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 will be between 0% and 100%.

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

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

$$PIDOutput_k = P_k + I_k + D_k$$

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

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

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

$$T = Cycle\_Time * 0.001$$

Equation 2. 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.

1.9. 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 1.9.

Lookup tables have two differing modes defined by "X-Axis Type" setpoint, given in Table 20**Error! Reference source not found.**. 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 20. 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 21. 'Ramp To' gives a linearized slope between points, whereas 'Jump to' gives a point-to-point response, where any input value between XN-1 and XN will result Lookup Table output being YN. "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 21. PointN – Response Options

The X values are limited by minimum and maximum range of the selected input source if the source is 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 -100000 and 1000000. 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 X10 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 1.7). Ignored points are not considered for min and max values.

1.10. Programmable Logic Function Block

The Programmable Logic Function Block is very powerful tool. 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 "Logic Enabled" setpoint must be set to 'True'. By default, all Logic blocks are disabled.
The three associated tables are selected by setting "Table Number X" 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 22. 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 22. Table X – Condition Y Operator Options

The three conditions are evaluated and if the result satisfies logical operation defined with "Logical Operator X" setpoint, given in Table 23, 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 23. 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.

1.11. Math Function Block

Mathematical function blocks allow the user to define basic algorithms. A math function block can take up to six input signals. Each input is then scaled according to the associated limit and scaling setpoints.

Inputs are converted into percentage value based on the "**Input X Minimum**" and "**Input X Maximum**" values selected. For additional control the user can also adjust the "**Input X Decimal Digits**" setpoint to increase the resolution of the input data and the min and max values.

A mathematical function block includes three selectable functions, in which each implements equation $A\ operator\ B$, where A and B are function inputs and operator is function selected with a setpoint "**Math Function X**". The functions are connected, 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

Table 24. Math function X Operator Options

For logic operations (6, 7, and 8) scaled input greater than 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 (0 to 100%) and saturate the output result.

When dividing, a zero divider will always result in a 100% output value for the associated function. Lastly the resulting mathematical calculation, presented as a percentage 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 is selected as the input source for another function block.

1.12. Set / Reset Latch Function Block

Set-Reset Block consists of only 2 control sources: **Reset Source** and **Set Source**. The purpose of these blocks is to simulate a modified latching function in which the 'Reset Signal' has more precedence. The 'latching' function works as per the Table 25 below.

'Set Signal'	'Reset Signal'	'Set-Reset Block Output' (Initial State: *OFF*)
OFF	*OFF*	*Latched State*
OFF	*ON*	*OFF*
ON	*OFF*	*ON*
ON	*ON*	*OFF*

Table 25. Set-Reset Function block operation

The **Reset** and **Set** sources have associated with them a minimum and maximum threshold values which determine the ON and OFF state. For the **Reset Source** are **Reset Minimum Threshold** and **Reset Maximum Threshold**. Similarly, for the **Set Source** are **Set Minimum Threshold** and **Set Maximum Threshold**. These setpoints also allow to have a dead band in between ON/OFF states and they are in terms of percentage of input selected.

As seen in Table 25 above, the 'Reset Signal' has more precedence over the 'Set Signal' - if the state of 'Reset Signal' is *ON*, the state of 'Set-Reset Block Output' will be *OFF*. To create an *ON* state in 'Set-Reset Block Output' the state of 'Reset Signal' must be *OFF* while the state of 'Set Signal' is *ON*. In this case, the state of 'Set-Reset Block Output' will remain *ON* even if 'Set Signal' turns *OFF* if 'Reset Signal' remains *OFF*. As soon as the 'Reset Signal' turns *ON* the 'Set-Reset Block Output' will turn *OFF* regardless of the state of 'Set Signal'.

1.13. Diagnostic Function Blocks

 The Diagnostic Input function blocks are used to setup the diagnostic messages for the controller.

There are several types of diagnostics supported by the controller. Fault detection and reaction is associated with input and output drives. In addition to I/O faults, the drive can also detect/react to power supply and lost communication events.
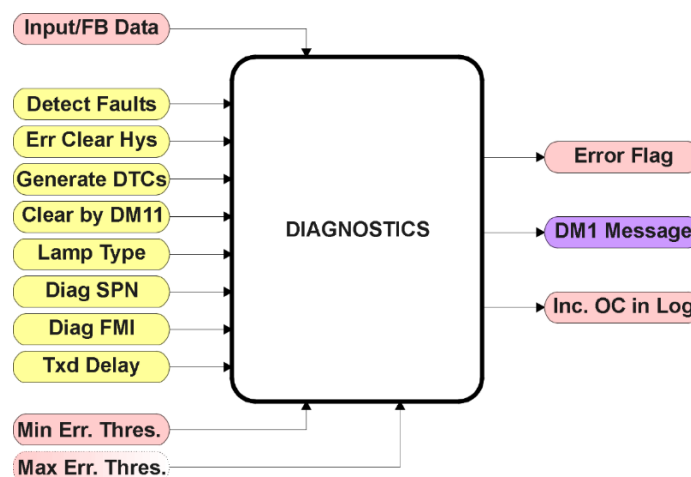

Figure 3. Function Block

The **"Event Generates a DTC in DM1"** 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. When disabled, all diagnostic behaviour associated with the I/O or event in question is ignored.

Types of diagnostics supported by the controller are shown in Table 26.

Function Block	Minimum Threshold	Maximum Threshold	SPN
Universal Input 1 out of range	Minimum error	Maximum error	520193 (0x7F001)
Universal Input 2 out of range	Minimum error	Maximum error	520194 (0x7F002)
Universal Input 3 out of range	Minimum error	Maximum error	520195 (0x7F003)
Universal Input 4 out of range	Minimum error	Maximum error	520196 (0x7F004)
Universal Input 5 out of range	Minimum error	Maximum error	520197 (0x7F005)
Universal Input 6 out of range	Minimum error	Maximum error	520198 (0x7F006)
Universal Input 7 out of range	Minimum error	Maximum error	520199 (0x7F007)
RTD 1 warning	Minimum error	Maximum error	520209 (0x7F011)
RTD 1 shutdown	Minimum error	Maximum error	520210 (0x7F012)
RTD 2 warning	Minimum error	Maximum error	520211 (0x7F013)
RTD 2 shutdown	Minimum error	Maximum error	520212 (0x7F014)
RTD 3 warning	Minimum error	Maximum error	520213 (0x7F015)
RTD 3 shutdown	Minimum error	Maximum error	520214 (0x7F016)
Output 1 Open Circuit Fault	N/A	N/A	520225 (0x7F021)
Output 1 Short Circuit Fault	N/A	N/A	520226 (0x7F022)
Output 2 Open Circuit Fault	N/A	N/A	520227 (0x7F023)
Output 2 Short Circuit Fault	N/A	N/A	520228 (0x7F024)
Over Temperature Fault	N/A	Temperature Shutdown	520450 (0x7F102)
VPS out of range	VPS Undervoltage	VPS Overvoltage	524273 (0x7FFF1)
Lost Communication Fault	N/A	Received Message Timeout	524287 (0x7FFFF)

Table 26. Diagnostic Blocks and Fault Detection Thresholds

When applicable, a hysteresis setpoint is provided to prevent the rapid setting and clearing of the error flag when an input or feedback value is right near the fault detection threshold. For the low end, once a fault has been flagged, it will not be cleared until the measured value is greater than or equal to the Minimum Threshold **+ "Hysteresis to Clear Fault."** For the high end, it will not be cleared until the measured value is less than or equal to the Maximum Threshold **- "Hysteresis to Clear Fault."** The minimum, maximum and hysteresis values are always measured in the units of the fault in question.

The next setpoint in this function block is the **"Event Generates a DTC in DM1."** If and only if this is set to true will the other setpoints in the function block be enabled. They are all related to the data that is sent to the J1939 network as part of the DM1 message, Active Diagnostic Trouble Codes.

A Diagnostic Trouble Code (DTC) is defined by the J1939 standard as a four-byte value which is a combination of:

SPN	Suspect Parameter Number	(first 19 bits of the DTC, LSB first)
FMI	Failure Mode Identifier	(next 5 bits of the DTC)
CM	Conversion Method	(1 bit, always set to 0)
OC	Occurrence Count	(7 bits, number of times the fault has happened)

In addition to supporting the DM1 message, the controller also supports:

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**

So long as even one Diagnostic function block has **"Event Generates a DTC in DM1"** set to True, the controller will send the DM1 message every one second, regardless of whether there are any active faults, as recommended by the standard. While there are no active DTCs, the controller will send the "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, it will send a DM1 indicating that there are no more active DTCs.

If there is more than one active DTC at any given time, the regular DM1 message will be sent using a multipacket Broadcast Announce Message (BAM). If the controller receives a request for a DM1 while this is true, it will send the multipacket message to the Requester Address using the Transport Protocol (TP).

> NOTE: At power up, the DM1 message will not be broadcasted until after a 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 Sending DM1**" 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.

Previously active DTCs (any with a non-zero OC) are available upon request for a **DM2** message. If there is more than one previously active DTC, the multipacket DM2 will be sent to the Requester Address using the Transport Protocol (TP).

Should a **DM3** be requested, the occurrence count of all previously active DTCs will be reset to zero. The OC of currently active DTCs will not be changed.

The Diagnostic function block has a setpoint **"Event Cleared only by DM11."** By default, this is always set to False, which means that as soon as the condition that caused an error flag to be set goes away, the DTC is automatically made Previously Active, and is no longer included in the DM1 message. However, when this setpoint is set to True, even if the flag is cleared, the DTC will not be made inactive, so it will continue to be sent on the DM1 message. Only when a DM11 has been requested will the DTC go inactive. This feature may be useful in a system where a critical fault needs to be clearly identified as having happened, even if the conditions that caused it went away.

In addition to all the active DTCs, another part of the DM1 message is the first byte which reflects the Lamp Status. Each Diagnostic function block has the setpoint **"Lamp Set by Event in DM1"** which determines which lamp will be set in this byte while the DTC is active. The J1939 standard

defines the lamps as *'Malfunction', 'Red, Stop', 'Amber, Warning'* or *'Protect'.* By default, the *'Amber, Warning'* lamp is typically the one set by any I/O fault.

By default, every Diagnostic function block has associated with it a proprietary SPN. However, this setpoint **"SPN for Event used in DTC"** is fully configurable by the user should they wish it to reflect a standard SPN define in J1939-71 instead. If the SPN is changed, the OC of the associate error log is automatically reset to zero.

Every Diagnostic function block also has associated with it a default FMI. The only setpoint for the user to change the FMI is **"FMI for Event used in DTC,"** even though some Diagnostic function blocks can have both high and low errors as shown in Table 27. In those cases, the FMI in the setpoint reflect that of the low-end condition, and the FMI used by the high fault will be determined per Table 15. If the FMI is changed, the OC of the associate error log is automatically reset to zero.

FMI for Event used in DTC – Low Fault	Corresponding FMI used in DTC – High Fault
FMI=1, Data Valid But Below Normal Operational 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 Range - 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 27. Low Fault FMI versus High Fault FMI

> ⚠️ **IF THE FMI USED IS ANYTHING OTHER THAN ONE OF THOSE IN TABLE 24, THEN BOTH THE LOW AND HIGH FAULTS WILL BE ASSIGNED THE SAME FMI. THIS CONDITION SHOULD BE AVOIDED, AS THE LOG WILL STILL USE DIFFERENT OC FOR THE TWO TYPES OF FAULTS, EVEN THOUGH THEY WILL BE REPORTED THE SAME IN THE DTC. IT IS THE USER'S RESPONSIBILITY TO MAKE SURE THIS DOES NOT HAPPEN.**

When the output state is ON, all outputs are subject to open circuit faults, which are determined by the feedback current.

1.14. Diagnostic Trouble Code (DTC) React

The DTC React function block will allow a received DTC sent from another ECU on a DM1 message to be used as an input source to control and/or enable/disable any output signal. Up to five (5) SPN/FMI/LAMP combinations can be selected. Should a DM1 message be received with the right **SPN/FMI/LAMP to Trigger Reaction** combination, the corresponding DTC State will be set to ON. Once ON, if the same SPN/FMI/LAMP combination has not been received again after 3 seconds, the DTC State will be reset to OFF. A source address between 1 and 253 can be set with **Specific Source Address That Sends**. 255 means disable **Specific Source Address**.

1.15. CAN Transmit Function Block

The ECU provides up to 10 fully configurable CAN Transmit messages. Each block has its own **PGN**. Different transmit messages that share a PGN will be broadcast together as one message.

The CAN transmit message is always enabled and the **Repetition Rate** defines which time in milliseconds the CAN transmit message is repeated. The CAN message will not transmit on the J1939 network in case all CAN transmits have the same PGN and the **Repetition Rate** of the first CAN transmit is set to zero. In the case of shared PGNs the rate of the lowest number CAN Transmit is used, i.e. if CAN Transmit 1 and CAN Transmit 4 share a PGN, the Repetition Rate of CAN Transmit 1 is used.

The CAN Transmit messages can be sent on any Proprietary A or B PGN as broadcast messages. By default, the **Message Priority** is set to 6 (low priority).

The **Destination Address** of the J1939 Identifier can be changed to any value between 0…255.

The **Data Size**, **Data Index in Array (LSB)**, **Bit Index in Byte (LSB), Resolution**, and **Offset** can all be used to map any SPN supported message by the J1939 standard from any **Data Source/Number** of the Transmit Function Block.

1.16. CAN Receive Function Block

The ECU supports up to 10 unique fully configurable CAN Receive Messages. The CAN Receive function block is designed to take any SPN from the J1939 network and use it as a **Control Source** for any relay outputs or CAN transmits.

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 within the **Receive Message Timeout** period if this has been set to 10ms or higher. This will trigger a Lost Communication event and the output data of the CAN Receive message will be set to 0. To avoid timeouts (if set to 10ms or higher) 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 timeout and will never trigger a Lost Communication event.

By default, all control messages are expected to be sent to the ECU on Proprietary B PGNs. However, should a PDU1 message be selected, the ECU can be configured 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 **Data Size**, **Data Index in Array (LSB)**, **Bit Index in Byte (LSB)**, **Resolution** and **Offset** can all be used to map any SPN supported by the J1939 standard to the output data of the Received function block.

The **Data Min** (Off Threshold) and **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 level types. These values are in whatever units the incoming data is **after** the resolution and offset are applied to the CAN Receive signal.

To have a CAN Receive message trigger, a relay output ON or OFF is to make sure the **Data Min (OFF Threshold)** and **Data Max (ON Threshold)** parameters are adjusted to the user's application. When the CAN Receive message (after having the resolution and offset applied to it), anything at **Data Max (ON Threshold)** parameter or higher, will trigger an ON command. Similarly, anything at **Data Min (OFF Threshold)** parameter or lower will trigger an OFF command. Any data in between will not change the state, thus providing a hysteresis. Figure 4 illustrates this behaviour.
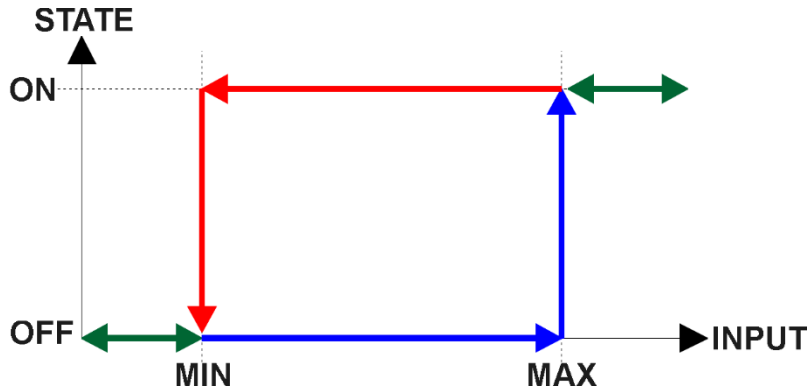
Figure 4: CAN Receive Message to Digital Output State

2. OVERVIEW OF J1939 FEATURES

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

- Configurable ECU Instance in the NAME (to allow multiple ECUs on the same network)
- Configurable Transmit PGN and SPN Parameters
- Configurable Receive PGN and SPN Parameters
- Sending DM1 Diagnostic Message Parameters
- Reading and reacting to DM1 messages sent by other ECUs
- Diagnostic Log, maintained in non-volatile memory, for sending DM2 messages

2.1. Introduction To Supported Messages

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

From J1939-21 - Data Link Layer
- Request   59904 ($00EA00)
- Acknowledgment   59392 ($00E800)
- Transport Protocol – Connection Management   60416 ($00EC00)
- Transport Protocol – Data Transfer Message   60160 ($00EB00)
- PropB Receive, Default Control Source Data Message   65280 ($00FF00)
- PropB Receive, Default Control Source Data Message   65280 ($00FF01)
- PropB Transmit, Default Digital I/O State Feedback   65280 ($00FF10)
- PropB Transmit, Default Digital I/O State Feedback   65280 ($00FF20)
- PropB Transmit, Default Digital I/O State Feedback   65280 ($00FF30)
- PropB Transmit, Default Digital I/O State Feedback   65280 ($00FF40)
-

Note: Any Proprietary B PGN in the range 65280 to 65535 ($00FF00 to $00FFFF) can be selected
Note: The Proprietary A PGN 61184 ($00EF00) can also be selected for any CAN Receive or CAN Transmit messages.

From J1939-73 - Diagnostics
- DM1 – Active Diagnostic Trouble Codes   65226 ($00FECA)
- DM2 – Previously Active Diagnostic Trouble Codes   65227 ($00FECB)
- DM3 – Diagnostic Data Clear/Reset for Previously Active DTCs   65228 ($00FECC)
- DM11 – Diagnostic Data Clear/Reset for Active DTCs   65235 ($00FED3)
- DM14 – Memory Access Request   55552 ($00D900)
- DM15 – Memory Access Response   55296 ($00D800)
- DM16 – Binary Data Transfer   55040 ($00D700)

From J1939-81 - Network Management
- Address Claimed/Cannot Claim   60928 ($00EE00)

Commanded Address   65240 ($00FED8)

From J1939-71 – Vehicle Application Layer
- Software Identification   65242 ($00FEDA)

None of the application layer PGNs are supported as part of the default configurations, but they can be selected as desired for either transmit or received 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 the CAN network.

2.2. J1939 Name, Address and Software ID

The controller has a J1939 name which is broadcasted at power up and/or when its ECU Address has been changed. The Software ID PGN gives useful information regarding the controller.

2.2.1. J1939 Name

The ECU has the following defaults for the J1939 Name. The user should refer to the SAE J1939/81 standard for more information on these parameters and their ranges.

Arbitrary Address Capable	Yes
Industry Group	0, Global
Vehicle System Instance	0
Vehicle System	0, Non-specific system
Function	127, Axiomatic I/O Controller
Function Instance	2, AX180010, 7 Universal Inputs,3RTD,2 Universal Outputs Controller
ECU Instance	**0, First Instance**
Manufacture Code	162, Axiomatic Technologies Corporation
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 by other ECUs (including the Axiomatic Electronic Assistant) when they are all connected on the same network.

2.2.2. ECU Address

The default value of this setpoint is 128 (0x80), which is the preferred starting address for self-configurable ECUs as set by the SAE in J1939 tables B3 to B7. The Axiomatic EA supports the selection of any address between 0 to 253, and *it is the user's responsibility to select an address that complies with the standard*. The user must also be aware that since the unit is arbitrary address capable, if another ECU with a higher priority NAME contends for the selected address, the controller will continue select the next highest address until it finds one that it can claim. See J1939/81 for more details about address claiming.

2.2.3. 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

For the ECU, Byte 1 is set to 1, and the identification fields are as follows

(Version)*

The Axiomatic EA shows all this information in "General ECU Information", as shown below

Parameter	Value	Description
ECU Part Number	AX022101	
ECU Serial Number	0000122001	
⌐ECU J1939 NAME		PGN 60928. 64-bit ECU Identifier sent in Address Claimed Message
⊦Arbitrary Address Capable	0X01	Yes
⊦Industry Group	0X00	Global
⊦Vehicle System Instance	0X00	
⊦Vehicle System	0X00	Non-specific system
⊦Reserved	0X00	
⊦Function	0X7F	Axiomatic IO Controller
⊦Function Instance	0X02	
⊦ECU Instance	0X00	#1 - First Instance
⊦Manufacturer Code	0X0A2	Axiomatic Technologies
⌐Identity Number	0X088D90	Unique ECU network ID number
ECU Address	0XC8	Reserved for future assignment by SAE, but available for use by sel
⌐ECU ID		PGN 64965 -ECUID
⊦ECU Part Number	AX022101	
⊦ECU Serial Number	0000122001	
⊦ECU Type	Controller	
⌐ECU Manufacturer Name	Axiomatic	
⌐Software ID		PGN 65242 -SOFT
⊦Field #1	AX180010, 7 Uin,3 RTD,2 U...	
⌐Field #2	Firmware: V1.00, May 2022	

J1939 CAN Network
  ECU AX180010, 7 Uin,3 RTD,2 Uout C
    i General ECU Information
    SP Setpoint File
    B Bootloader Information

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

3. ECU SETPOINTS ACCESSED WITH THE AXIOMATIC ELECTRONIC ASSISTANT

Many setpoints have been reference throughout this manual. This section describes in detail each setpoint, their defaults and ranges. For more information on how each setpoint is used by the ECU, refer to the relevant section of the User Manual.

3.1. J1939 Network Setpoints

The J1939 Network setpoints deal with the setpoints such as *ECU Instance Number* and *ECU Address*. Figure 5 and Table 28: Default J1939 Network Setpoints Function blocks in the Axiomatic EA below will explain these setpoints and their ranges.
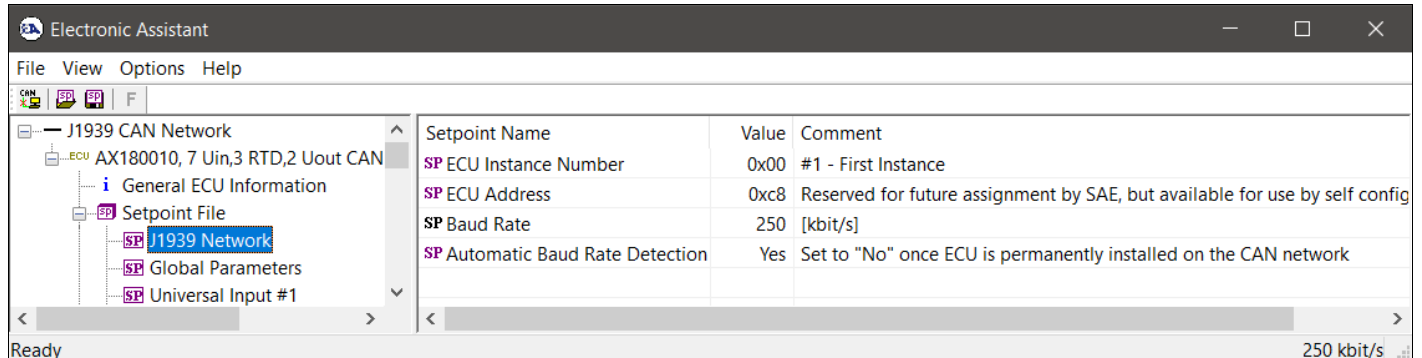
Figure 5: Screen Capture of Default J1939 Network Setpoints

Name	Range	Default	Notes
ECU Address	0x80	0..253	Preferred address for a self-configurable ECU
ECU Instance	0..7	0x00	Per J1939-81
Baud Rate(read only)	{250, 500, 667, 1000}	250	Current baud rate on the CAN network.
Automatic Baud Rate Detection	0 - No, 1 - Yes	1 - Yes	Set to "No" once ECU is permanently installed on the CAN network.

Table 28: Default J1939 Network Setpoints Function blocks in EA

Each controller function block is presented by its own setpoint group in the *Setpoint File* main group. Individual configuration parameters (setpoints) of a function block can be accessed through the function block setpoint group, see Figure 6.
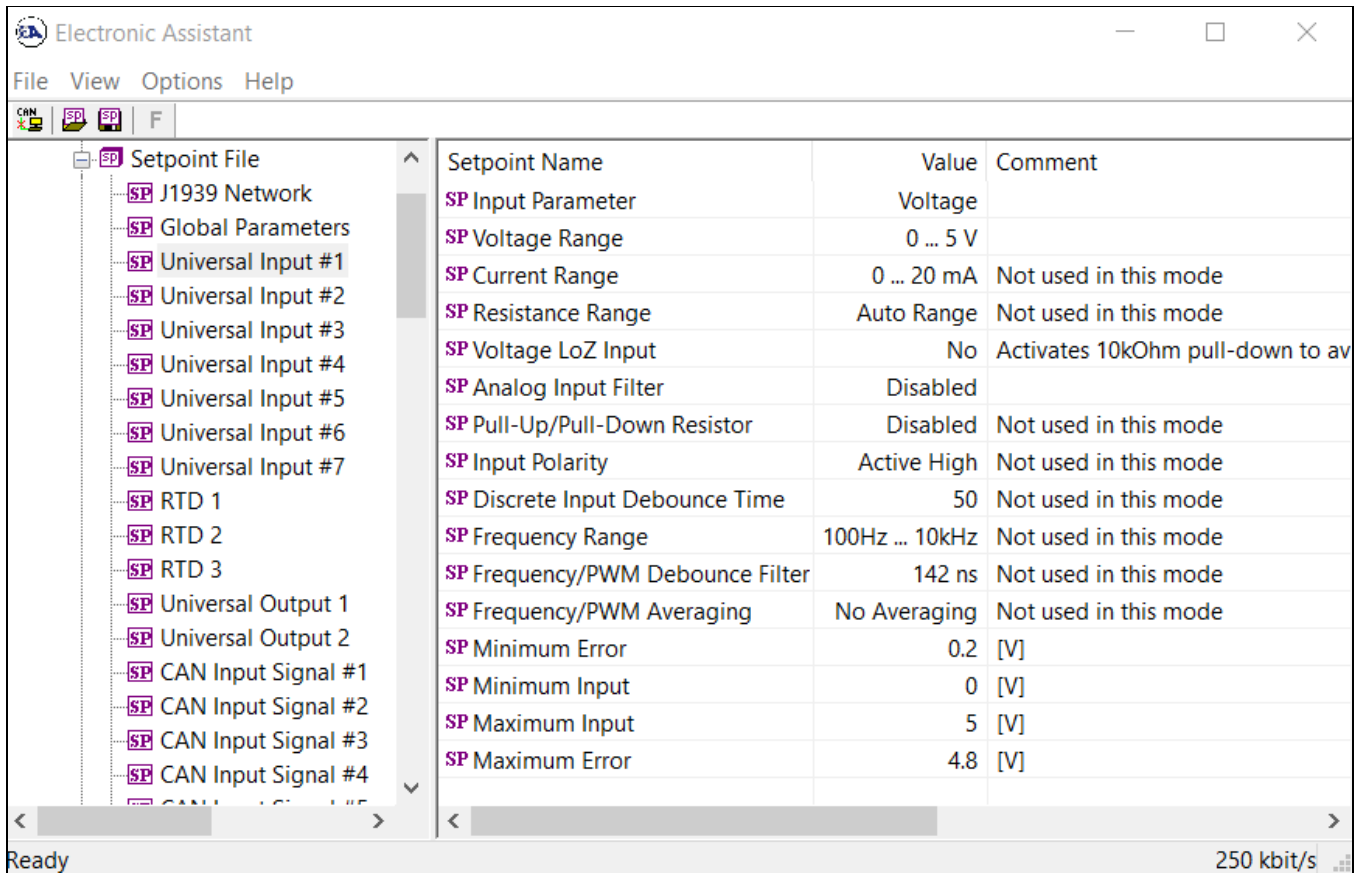
Figure 6. Universal Input #1 Function Block in EA

The user can view and, when necessary, change configuration parameters by double-clicking on the appropriate setpoint name. A pop-up dialog window will appear, see Figure 7.
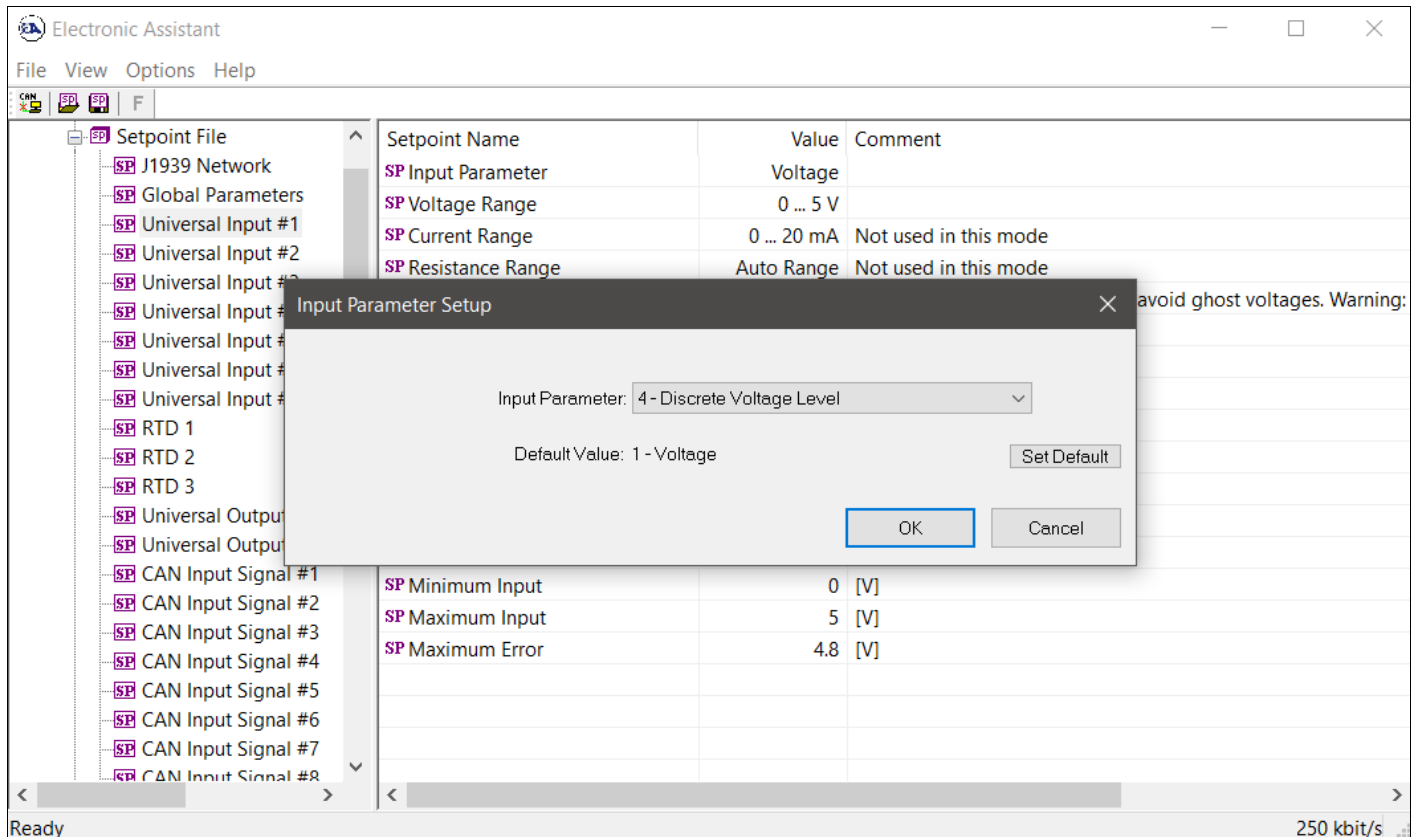
Figure 7. Changing a Configuration Parameter in EA

If the user changes the configuration parameter, the new value will be stored in a non-volatile memory and used immediately by the converter.

The controller will reset all relevant function blocks after each change of the configuration parameters. The exception is the *Ethernet* function block that requires a manual reset by cycling the controller power to apply the new Ethernet configuration parameters.

If the new configuration parameter affects the CAN network identification, the controller will reclaim its network address with a new network identification message.

3.2. Setpoint File

The Axiomatic EA can store all converter configuration parameters in one setpoint file and then flash them into the controller in one operation.

The setpoint file is created and stored on disk using a command *Save Setpoint File* from the EA menu or toolbar. The user then can open the setpoint file, view or print it, and flash the setpoint file into the controller

The CAN network identification and "read-only" configuration parameters are not transferrable using this operation. Also, the controller will perform one or several internal resets of all function blocks during the setpoint flashing operation.

There can be small differences in configuration parameters between different versions of the application firmware. It is recommended that the user manually inspect all configuration parameters after flashing if the setpoint file was created by a different version of the application firmware.

A setpoint file containing default configuration parameters is available upon request.

3.3. Configuration Example

A simple configuration example configuring CAN messages to output the controller input signals is presented below.

Let the controller is required to output voltage in 0…5V range from *Universal Input #1* in a proprietary PGN 65296(0xFF10) and a discrete voltage level from *Universal Input #2* in a proprietary PGN 65312(0xFF20). The PGN details are presented below.

Transmission Repetition Rate:	100 ms
Data Length:	16
Default Priority:	6
Parameter Group Number:	65296(0xFF10) (Proprietary B)

Start Position	Length	Parameter Name	SPN
1	2 bytes	VoltageOnUIn1	N/A

Parameter Name:	VoltageOnUIn1
Data Length:	2 bytes
Resolution:	0.01 V/bit
Offset:	0 V

Transmission Repetition Rate:	500 ms
Data Length:	8
Default Priority:	6
Parameter Group Number:	65312(0xFF20) (Proprietary B)

Start Position	Length	Parameter Name	SPN
1.1	2 bits	DiscreteVLevelOnUIn2	N/A

Parameter Name:	DiscreteVLevelOnUIn2
Data Length:	1 bit

Bit 1	
0	Off – No voltage on *Universal Input #2.* Input is disconnected.
1	On – Positive voltage on *Universal Input #2*

As a first step, we need to configure each individual function block. Start with the *Universal Input #1*.

Set the *Input Parameter* to "Voltage" and *Voltage Range* to "0…5V", see Figure 8.
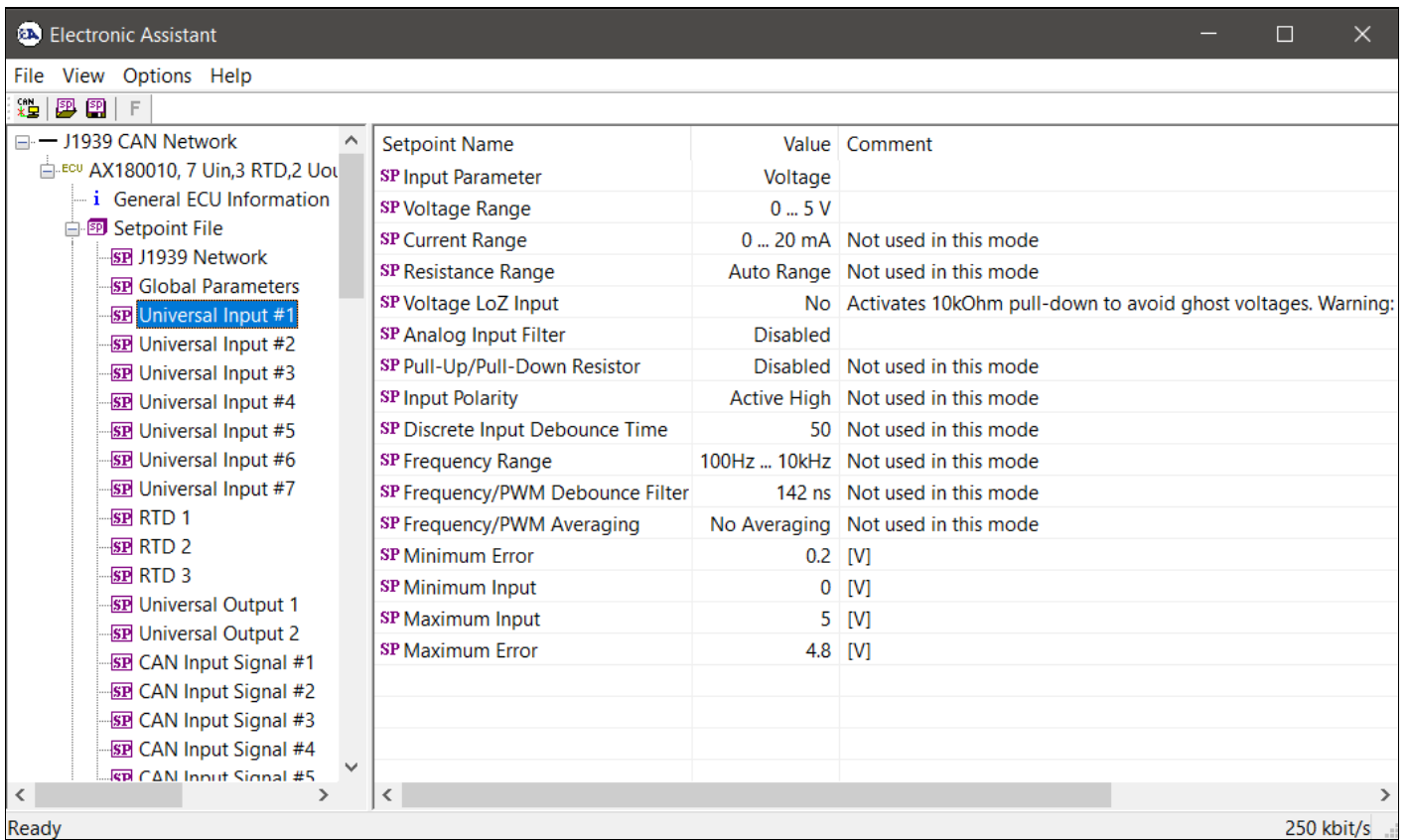
Figure 8. Universal Input #1 Example Configuration

Then configure the *Universal Input #2* to input the discrete voltage level. Set the *Input Parameter* to "Discrete Voltage Level" and *Pull-Up/Pull-Down Resistor* to "10 kOhm Pull-Down" to maintain zero voltage level when the input is disconnected. Keep the *Input Polarity* at "Active High" and *Discrete Input Debounce Time* at the default value, see Figure 9.
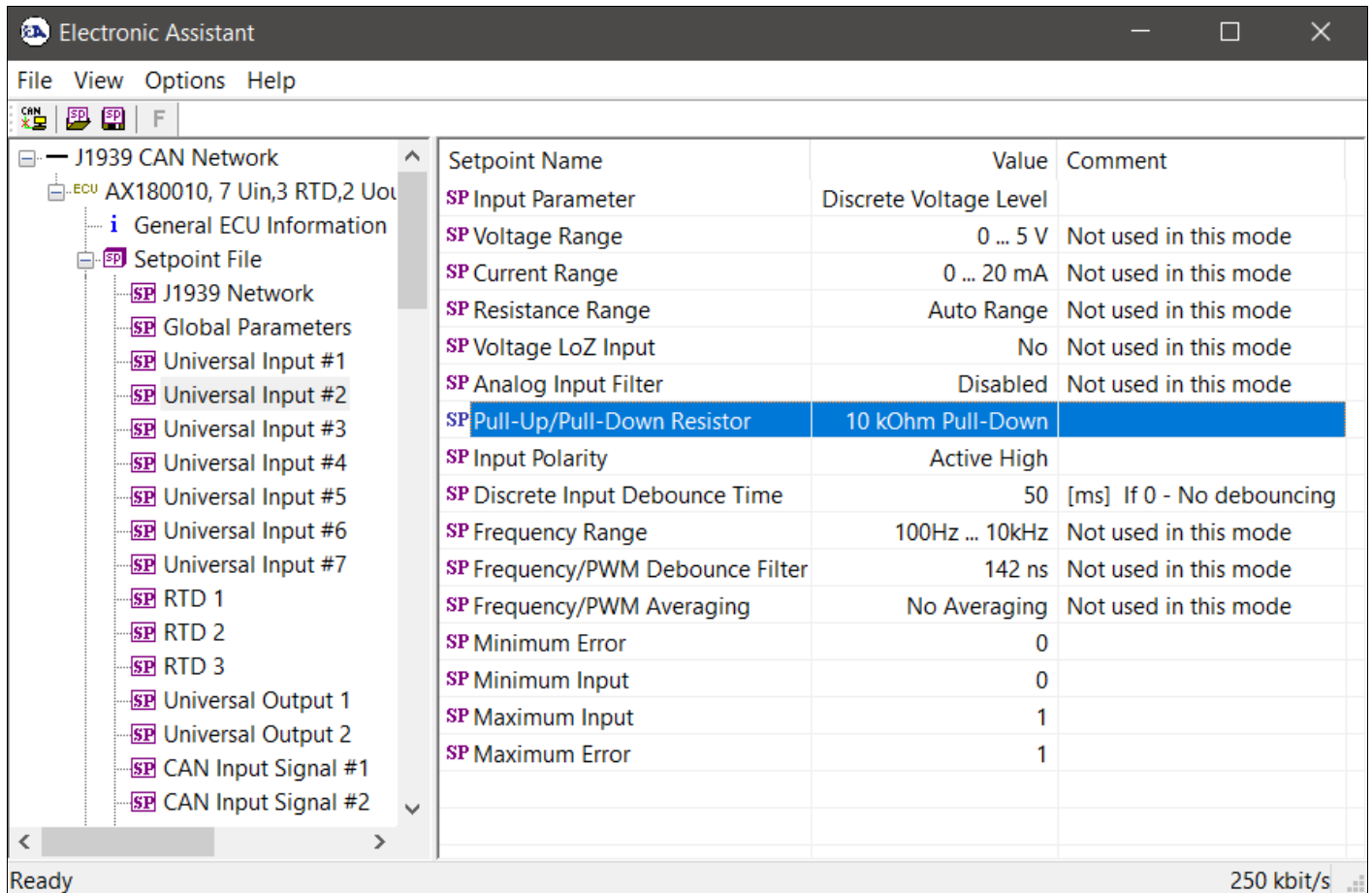
Figure 9. Universal Input #2 Example Configuration

Now configure CAN output messages. Configure *CAN Output Message #1*. First set common parameters to all CAN output signals. Set *PGN* to 65296(0xFF10), *Transmission Enable* to "Yes", Transmission Rate to 100 ms. Keep default values for *Length* (8 bytes) and *Priority* (6), see Figure 10.
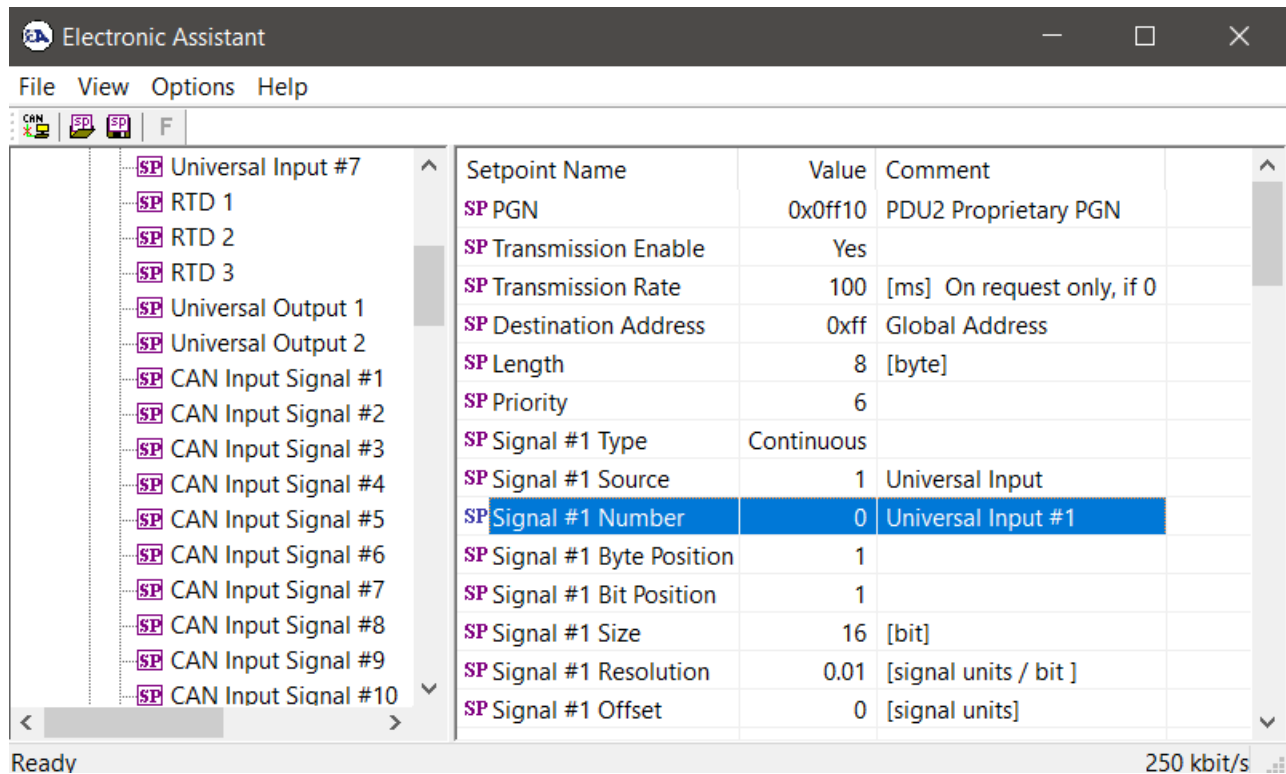
Figure 10. CAN Output Message #1 Example Configuration

Then configure the first CAN output signal. Set the *Signal #1 Type* to "Continuous", connect the signal input to the *Universal Input #1* by setting *Signal #1 Source* to "Universal Input #1", set *Signal #1 Byte Position* to 1, *Signal #1 Bit Position* to 1, *Signal #1 Size* to 16 bits, *Signal #1 Resolution* to 0.01 V/bit.

Then configure *CAN Output Message #2*. Set common parameters: *PGN* to 65312(0xFF20), *Transmission Enable* to "Yes", Transmission Rate to 500 ms. Keep default values for *Length* (8 bytes) and *Priority* (6), see Figure 11.
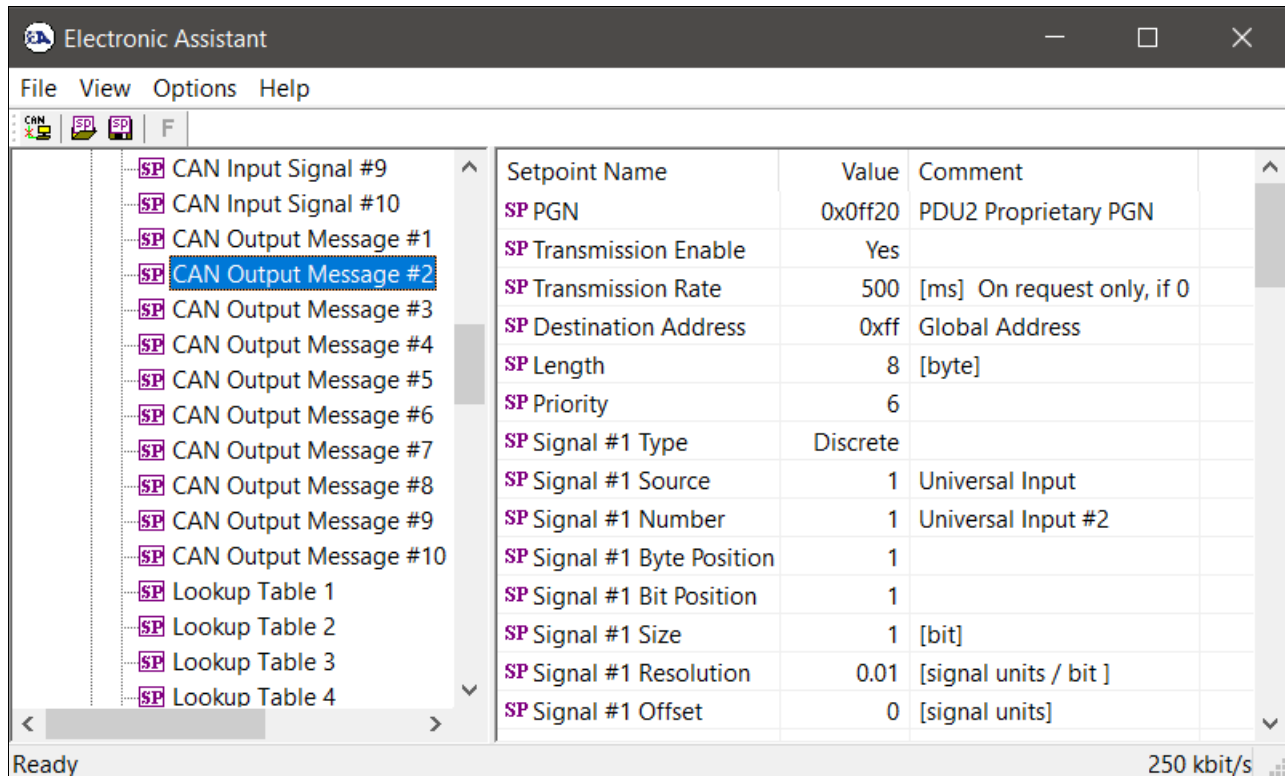
Figure 11. CAN Output Message #2 Example Configuration

Set the CAN output signal. Set the *Signal #1 Type* to "Discrete", connect the signal input to the *Universal Input #1* by setting *Signal #1 Source* to "Universal Input #1", set *Signal #1 Byte Position* to 1, *Signal #1 Bit Position* to 1, and *Signal #1 Size* to 1 bit. Keep all other CAN signals in the default undefined state.

The controller configuration is finished. Now the controller operates according to the new user requirements. The configuration parameters are already written to the non-volatile controller memory. The users can write them to a setpoint file for future use, if necessary.

The setpoint file for this example is available upon request. The user can monitor the controller performance using Axiomatic CAN Assistant – Scope (P/N AX070501SCO) and CAN Assistant – Visual (P/N AX070501VIS). The software is available for download from the Axiomatic website www.axiomatic.com.

3.4. FLASHING NEW FIRMWARE

When the new firmware becomes available, the user can replace the inclinometer firmware in the field using the unit embedded bootloader. The firmware file can be received from Axiomatic on request.

To flash the new firmware, the user should activate the embedded bootloader. To do so, start the Axiomatic EA and, in the *Bootloader Information* group screen, click on the *Force Bootloader to Load on Reset* parameter. The following dialog will appear, see Figure 12.
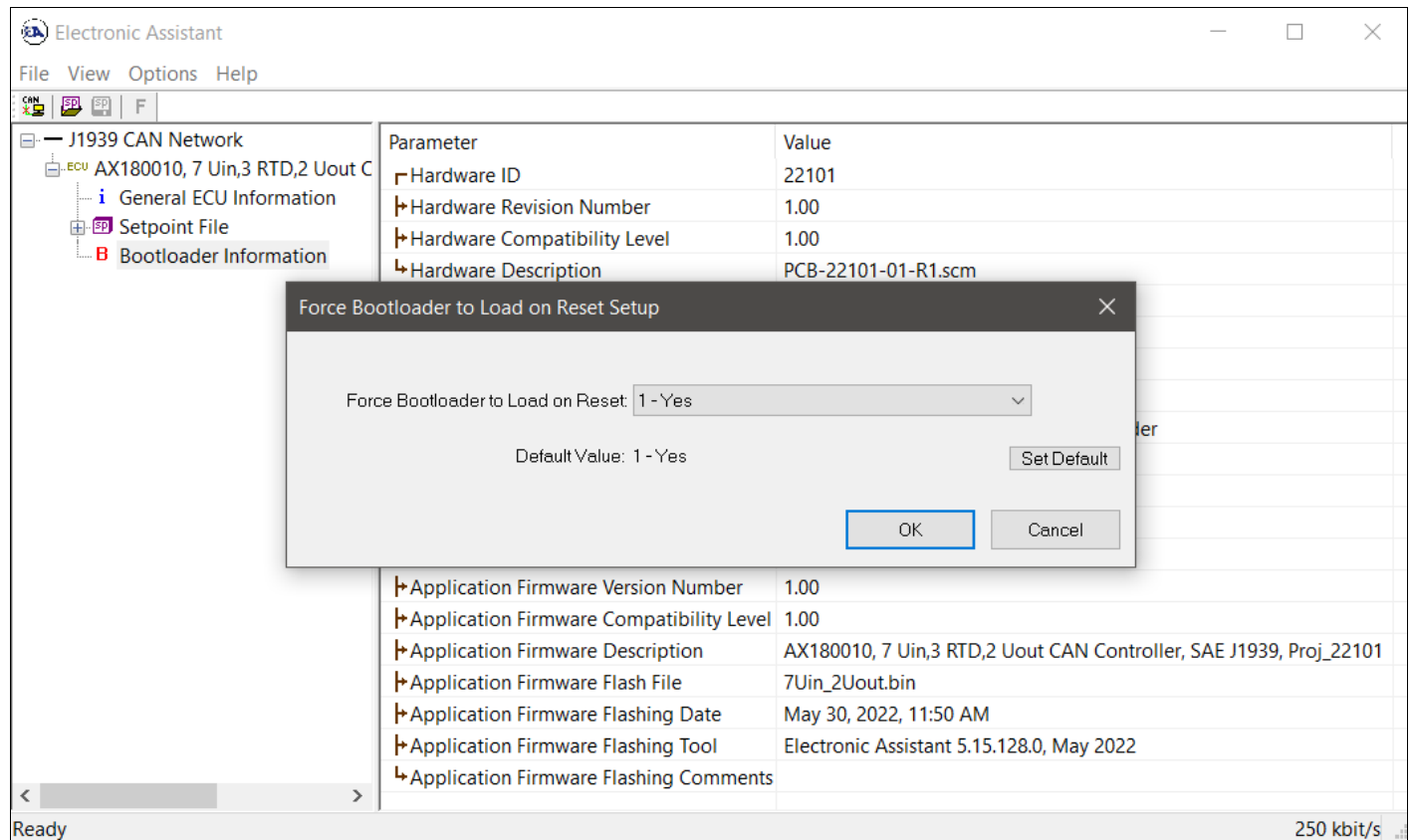
Figure 12. Bootloader Activation. First Step

The EA will prompt the user to change the *Force Bootloader to Load on Reset* parameter flag to "Yes". This will automatically activate the bootloader on the next ECU reset. After accepting the change, the next screen will ask the user if the reset is required. Select "Yes".

After automatic reset, instead of *2 Bipolar, 8 Universal Signal Input Controller, SAE J1939, Ethernet*, the user will see *J1939 Bootloader* ECU in the *J1939 CAN Network* top-level group in the EA. This means that the bootloader is activated and ready to accept the new firmware.

All the bootloader specific information: controller hardware, bootloader details, and the currently installed application firmware remains the same in the bootloader mode and the user can read it in the *Bootloader Information* group screen, see Figure 13. The information can be slightly different for different versions of the bootloader.
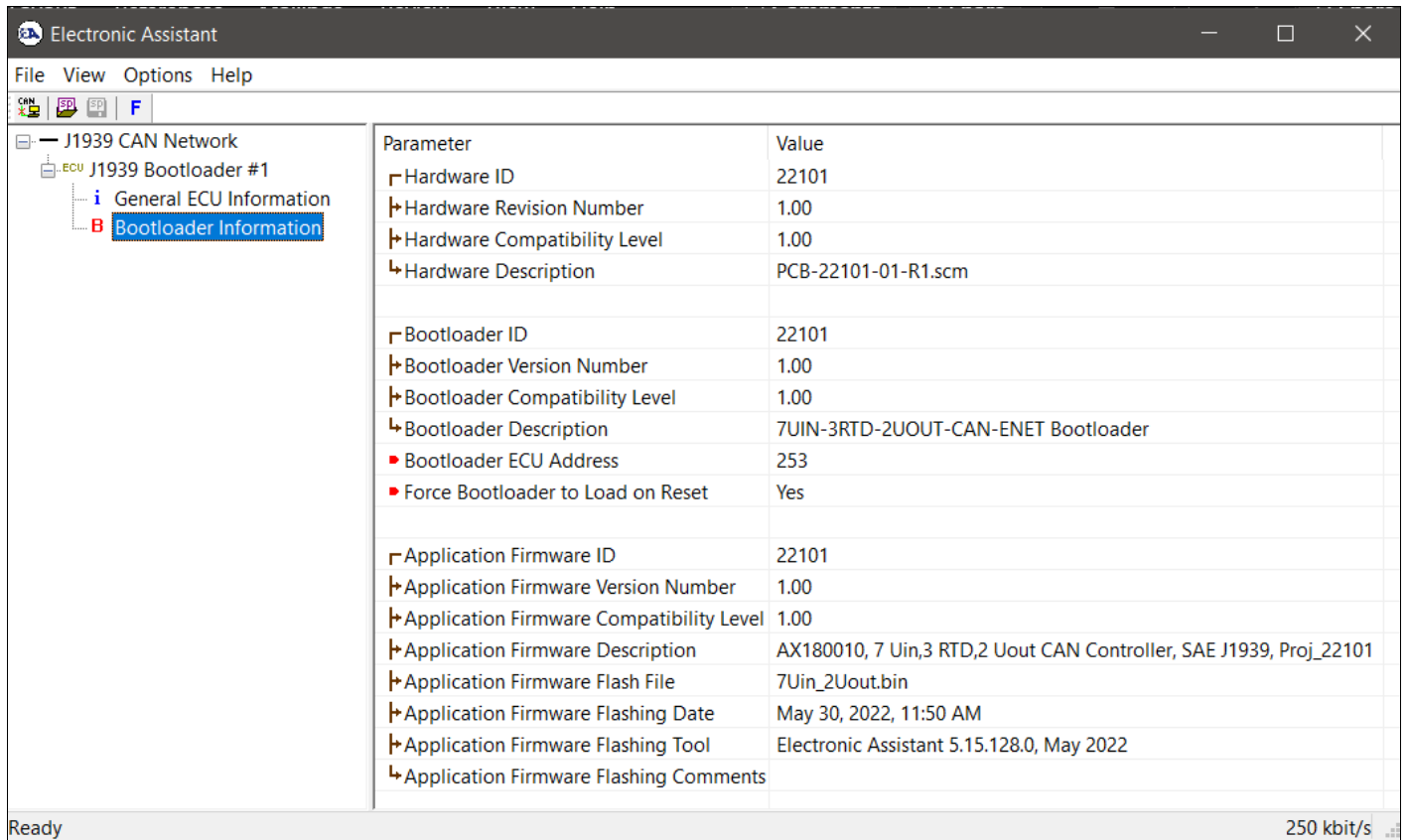
Figure 13. Bootloader Information Screen

At this point, the user can return to the installed controller firmware by changing the *Force Bootloader to Load on Reset* flag back to *No* and resetting the ECU.

To flash the new firmware, the user should click on F toolbar icon or from the *File* menu select the *Open Flash File* command. The *Open Application Firmware Flash File* dialog will appear. Pick up the flash file with the new converter firmware and confirm the selection by pressing the *Open* button. The *Flash Application Firmware* dialog window will appear[1], see Figure 14.
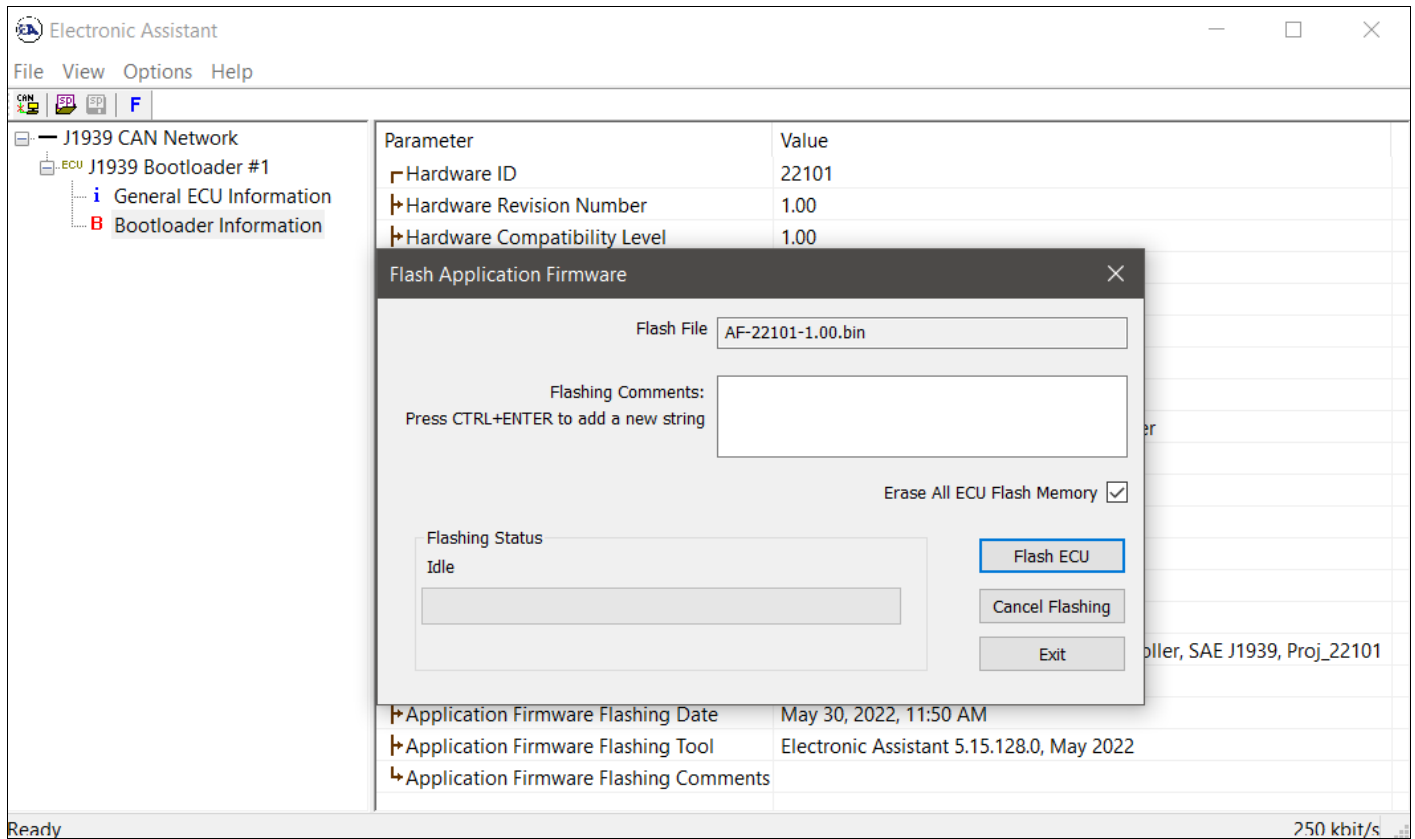
Figure 14. Flashing New Firmware. Preparation

[1] *In this example, instead of the new firmware, the old firmware V1.00 is being simply re-flashed.*

Now the user can add any comments to the flashing operation in the *Flashing Comments* field. They will be stored in the *Bootloader Information* group after flashing.

The user can also check the *Erase All ECU Flash Memory* flag to erase all inclinometer flash memory. This operation, used in other products to reset configuration parameters kept in the flash memory to their default values, has no effect on this product. This is because the configuration parameters of the inclinometer are stored in a separate EEPROM memory.

Select the *Flash ECU* button to start flashing. A reminder that the old application firmware will be destroyed by the flashing operation will appear. Press *Ok* to continue and watch the dynamics of the flashing operation in the *Flashing Status* field. When flashing is done, the following screen will appear prompting the user to reset the ECU, see Figure 15.
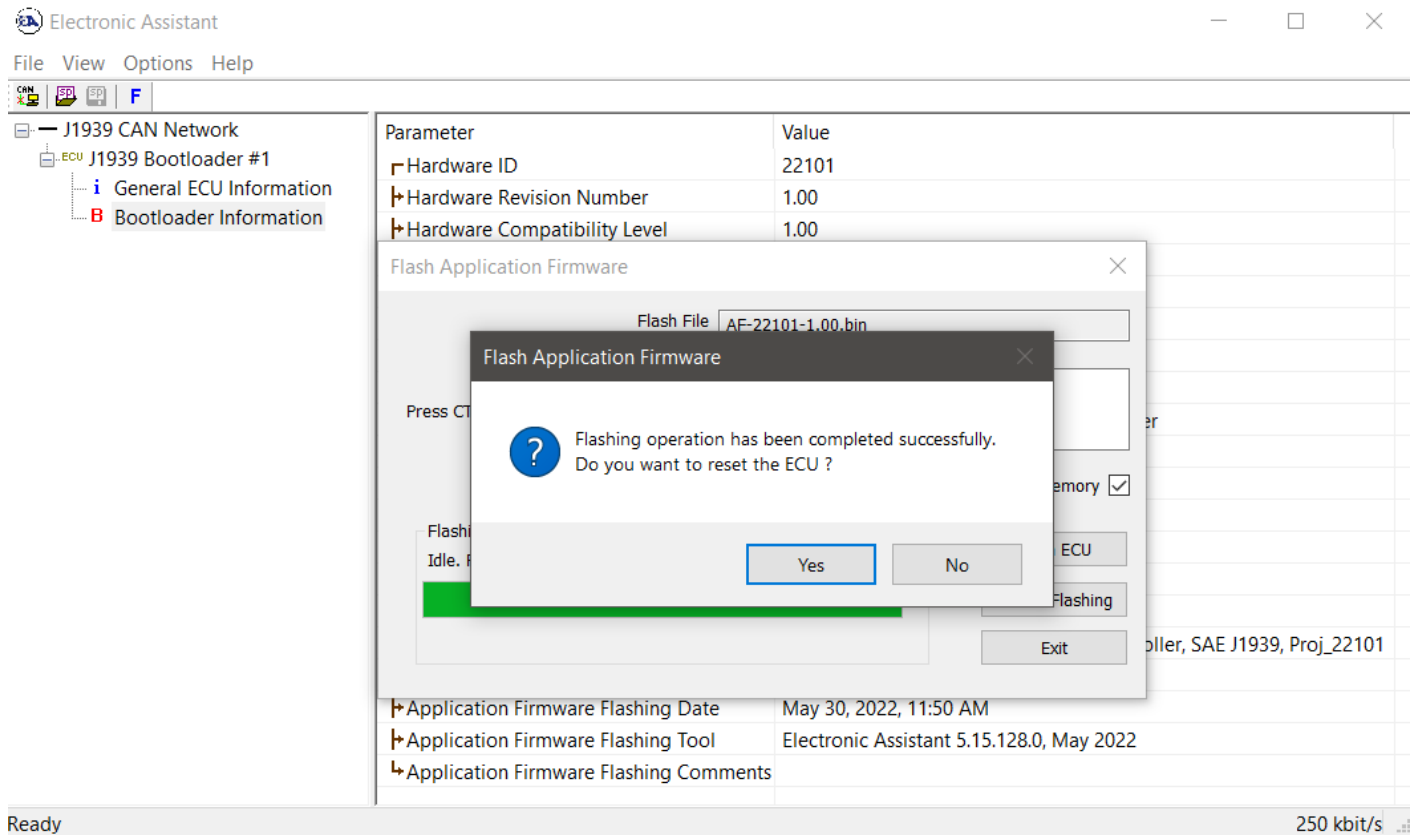
Figure 15. Flashing New Firmware. Final Reset.

Select *Yes* and see the ECU running the new firmware, see Figure 16. This will indicate that the flashing operation has been performed successfully.
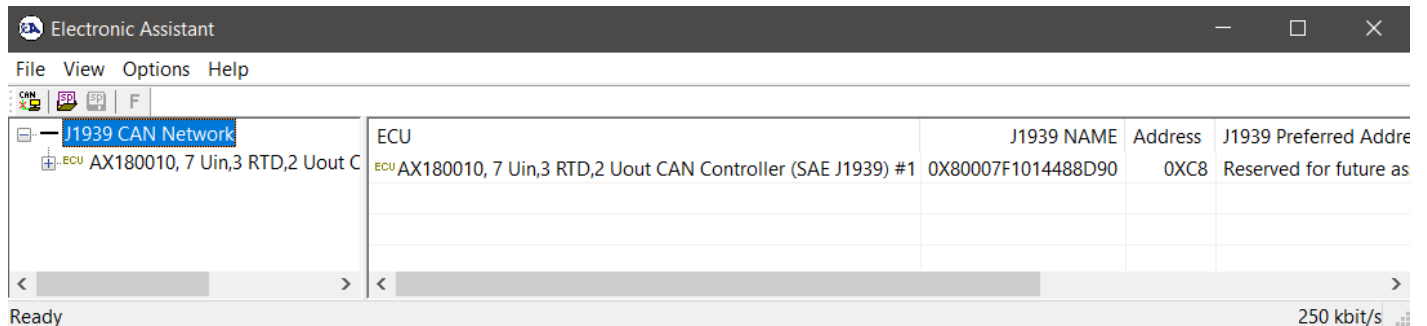

Figure 16. Firmware has been Updated. New Firmware Screen

For more information, see the *J1939 Bootloader* section of the EA user manual.

4. TECHNICAL SPECIFICATIONS

Stated at 25°C unless otherwise specified.

4.1. Power Supply

Parameter	Value	Remarks
Supply Voltage	8…36 VDC	12V, 24V – nominal.
Supply Current	50 mA	Typical at 24V.
	100 mA	Typical at 12V.
Protection	Reverse polarity, Transients	

0.012% at 10kHz for the 32-bit counter.
[2] Resolution can be affected by the debouncing filter settings.

4.2. Universal Inputs

Parameter	Value		
Analog Input Modes	Voltage, Current, Resistance		
Voltage Input	Input Range	Input Impedance	Resolution
	0…5V	>1MOhm (High Z)[1]	<1.5mV
	0…10V	204kOhm[1]	<3 mV
	[1]10kOhm LoZ option is available.		
Current Input	Input Range	Input Impedance	Resolution
	0…20mA	249Ohm	<12uA
	4…20mA		
Resistance Input	Input Range	Resolution	
	Auto Range 10…250kOhm[1,2]	–	
	0…250Ohm[2]	<0.15 Ohm	
	0…2.5kOhm	<1.5 Ohm	
	0…25kOhm	<15 Ohm	
	0…250kOhm	<150 Ohm	
	[1] Resolution and accuracy depend on the automatically selected Input Range. [2] Resistance <10 Ohm is measured as 0.		
Analog Update Rate	1.67ms minimum[1]. [1] Depends on the analog filter settings. In resistive mode also depends on the number of resistive inputs.		
Digital Input Modes	Discrete Voltage Level, Frequency, PWM Duty Cycle		
Input Polarity	Active High, Active Low		
Input Impedance	>1MOhm – High Z, 10kOhm pull down, 10kOhm pull-up to +14V		
Input Level	5V CMOS Compatible. A direct connection to the power supply is acceptable.		
Discrete Voltage Level Input	1ms sampling rate. Configurable debouncing		

Parameter	Value				
Frequency Input	Input Number	Counter Resolution	Frequency Range	Resolution[1,2]	Accuracy
	Universal Input #1…7	16-bit	100Hz…10kHz	<0.0017…0.17%	<0.01%
			10Hz…1kHz		
			1Hz…100Hz		
PWM Duty Cycle Input	Input Number	Counter Resolution	Frequency Range	Resolution[1,2]	
	Universal Input #1…7	16-bit	100Hz…10kHz	<0.0017…0.17%	
			10Hz…1kHz		
			1Hz…100Hz		
	0…100% Duty Cycle Range. DC is included.				
Protection	+36V maximum. Forward voltage only. No reverse polarity protection				

[1] The relative resolution value is linearly proportional to the signal frequency: 0.0017% at 100Hz and 0.17% at 10kHz for the 16-bit counter.
[2] Resolution can be affected by the debouncing filter settings.

4.3. Voltage Reference Outputs

Parameter	Value	Remarks
Number of Outputs	2	
Output Voltage	+5V	
Voltage tolerance	1%	At 1mA
Supply Current	100mA	Nominal
Protection	Short circuit	Connection to the power supply is prohibited.

4.4. CAN Interface

Parameter	Value	Remarks
Number of Ports	1	Reading inputs, configuring the device, updating firmware
LED Indicator	Error/Link (Activity)	Red/Green
Communication Standards	SAE J1939	Full support for J1939 ECU. User-configurable PGNs.
	Baud Rate	250, 500, 667kbit/s, 1Mbit/s. Automatic baud rate detection
	ISO 11898	120Ohm terminated twisted pair, baud rate up to 1Mbit/s. External 120Ohm termination is required.
	Bosch CAN protocol specification 2.0, Part A, B.	For the internal CAN controller.
Protection	Short circuit to ground	
	Connection to the power supply	Only for 12V systems, 24V max.

4.5. General Specifications

| Parameter	Value	Remarks	
Internal Logic	User-Configurable	Interface	
		J1939 CAN	Axiomatic Electronic Assistant, P/Ns: AX070502 or AX070506K
Firmware Update	In-system, through J1939 CAN	Via the Axiomatic Electronic Assistant, P/Ns: AX070502 or AX070506K	
LED Indicators	CAN/System	Red/Green – CAN or System error/CAN link(activity). Flashing green/red– bootloader mode.	
Operating Temperature	-40…+85 °C	Industrial temperature range	
Environmental Protection	IP20	EN 60259	
Housing	Phoenix Contact ME MAX 22,5 G 2-2 KMGY - 2713638	Polyamide, Flammability V0 UL94, UL Recognized, EAC, China RoHS	
Electrical Connectors	Phoenix Contact MCO 1,5/5-G1L-3,5 - 2278380	J3 (Power/CAN/Ref#1), J5 (Bi/Univ Inputs)	
	Phoenix Contact MCO 1,5/5-G1R-3,5 - 2278351	J4 (Univ Inputs), J6 (Univ Inputs/Ref#2)	
	RJ-45	Ethernet, CAT5 (IEC 11801:2002)	
Installation	DIN Rail TH35-7.5 or TH35-15	EN 60715. Mounting Rail: 35 x 7.5mm or 35 x 15mm.	
Size	114.5 x 22.5 x 99 mm (4.508 x 0.89 x 3.898 in)	L(D) x W x H. See dimensional drawing	
	107 mm (4.213 in)	Depth from the top edge of DIN rail. See dimensional drawing	
Weight	0.136 kg (0.30 lb)		
Compliance	CE mark (pending) RoHS Directive		

4.6. Enclosure
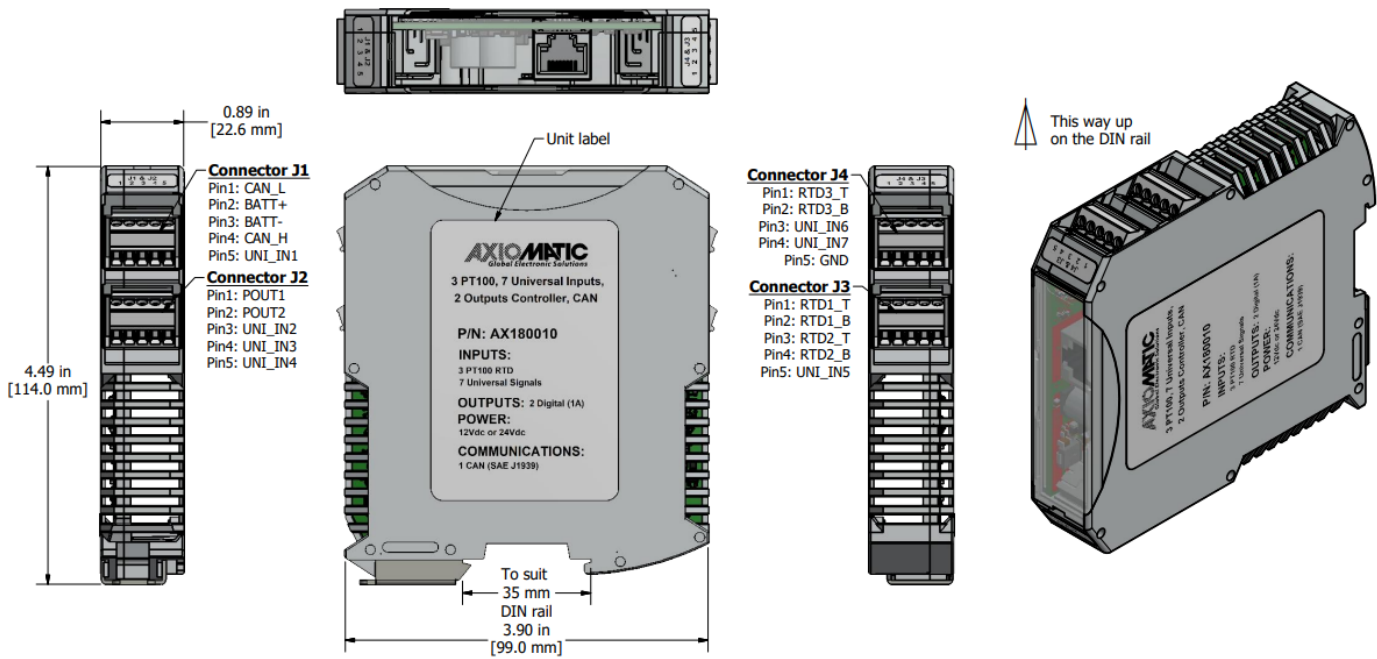
Figure 17. Dimensional Drawing

4.7. Electrical Connections

The controller has four 5-pin electrical connectors with the following pinouts.

Connector Pin Number	Connector Name			
	J1	J2	J3	J4
1	CAN_L	Universal Output #1	RTD #1_T	RTD #3_T
2	BAT+	Universal Output #2	RTD #1_B	RTD #3_B
3	BAT-	Universal Input #2	RTD #2_T	Universal Input #6
4	CAN_H	Universal Input #3	RTD #2_B	Universal Input #7
5	Universal Input #1	Universal Input #4	Universal Input #5	Analog GND

Table 29. Connector Pinouts

Recommended mating connectors for J3…J6 are 5-pin 3.5 mm Phoenix Contact MC 1,5/5-ST-3,5 GY7035 – 1769087 screw terminal connectors with tension sleeves. They accept 28-16 AWG wires. A standard RJ-45 CAT5 or better plug can be used as a mating Ethernet connector.

4.8. Installation

For mechanical installation see information on the dimensional drawing. The CAN bus should be terminated on both sides with 120 Ohm resistors (0.25W minimum, metal film or similar type) between CAN_H and CAN_L.

5. VERSION HISTORY

User Manual Version	Firmware version	Date	Author	Modifications
1	1.xx	June, 2022	Viktor Rogachov	• Initial release
1.01	-	August 30, 2023	Kiril Mojsov	• Legacy Updates

OUR PRODUCTS

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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.

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

COMPLIANCE
Product compliance details can be found in the product literature and/or on axiomatic.com. Any inquiries should be sent to sales@axiomatic.com.

SAFE USE
All products should be serviced by Axiomatic. Do not open the product and perform the service yourself.

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

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

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