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USER MANUAL

Single Valve Controller

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ACRONYMS

CAN	Controller Area Network
CANopen®	CAN-based higher layer protocol supported by CAN in Automation (CiA) Note: CANopen® is a registered community trademark of CAN in Automation e.V.
DM	Diagnostic message. Defined in J1939/73 standard
EA	The Axiomatic Electronic Assistant. The EA is a PC application software from Axiomatic, used to view and program Axiomatic control setpoints through CAN bus using J1939 Memory Access Protocol
ECU	Electronic control unit
EMI	Electromagnetic Interference
ISO	International Organization for Standardization
LSB	Less Significant Byte
MAP	Memory Access Protocol. Defined in J1939/73 standard
OSI	Open System Interconnection
PC	Personal Computer
PGN	Parameter Group Number. Defined in J1939 standard
PID	Proportional–integral–derivative (regulator)
PWM	Pulse-width modulation
RS-232	PC serial port interface
SAE J1939	CAN-based higher level protocol designed and supported by Society of automobile Engineers (SAE)
USB	Universal Serial Bus
UTP	Un-shielded twisted pair

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1 INTRODUCTION

The following manual describes: architecture, functionality, and setpoint programming of the Single Valve Controller. It also contains technical specification and installation instructions and intended to provide users with all necessary information to build a custom solution on the base of this controller.

The manual is valid for a specific major firmware version. Please, ensure that the firmware version installed on your controller is covered by this manual. This can be done by using the Axiomatic EA software.

The controller supports SAE J1939 CAN interface. It is assumed, that the user is familiar with the J1939 group of standards; the terminology from these standards is widely used in this manual.

2 CONTROLLER DESCRIPTION

The controller is designed to control one proportional or on/off solenoid valve using control signals transmitted over the CAN bus. The PWM output provides high efficiency of the valve control.

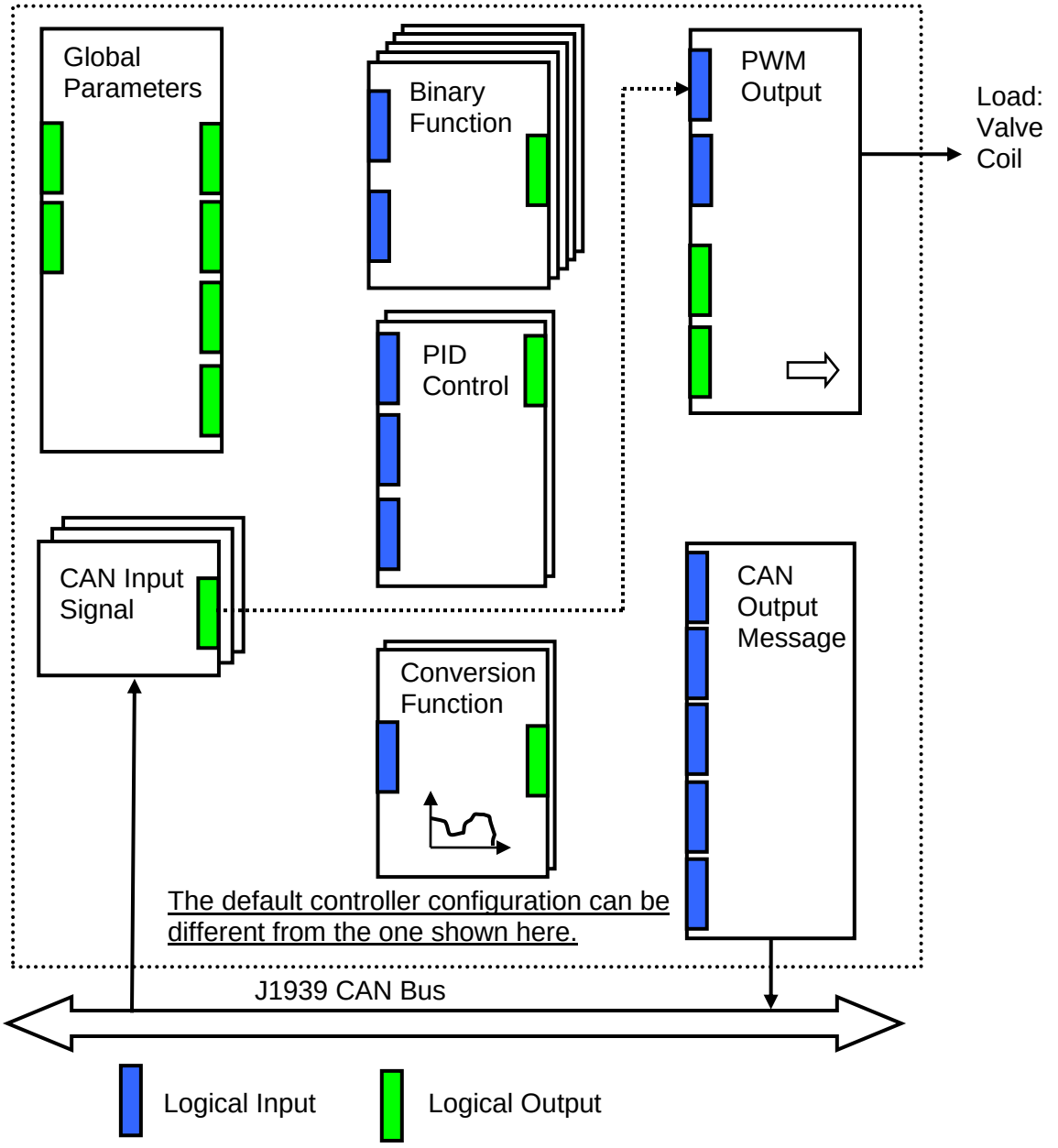
The Single Valve Controller belongs to a family of Axiomatic user-customizable smart controllers. The programmable internal architecture provides users with an ultimate flexibility, allowing them to build their own custom controller with a required functionality from a set of predefined internal functional blocks using the PC-based Axiomatic EA software.

All application programming is performed through CAN interface, without disconnecting the controller from the user's system.

Besides reading control signals transmitted on the CAN bus, the controller can also transmit a CAN application message carrying signals internally generated by the controller. This feature can be used for monitoring and debugging purposes.

3 CONTROLLER ARCHITECTURE

From the software prospective, the controller consists of a set of internal functional blocks, which can be individually programmed and arbitrarily connected together to achieve the required system functionality, see Figure 1.



As an example, the logical output of the CAN Input Signal functional block is connected to the logical input of the PWM Output functional block, providing a direct path for the CAN input signal to the controller output.

Figure 1.The Controller Internal Structure

Each functional block is absolutely independent and has its own set of programmable parameters, or setpoints. The setpoints can be viewed and changed through CAN using the Axiomatic Electronic Assistant (EA) software.

There are two types of the controller functional blocks. One type represents the controller hardware resources, for example the PWM Output block. The other type is purely logical – these functional blocks are included to program the user defined functionality of the controller. The number and functional diversity of these functional blocks are only limited by the system resources of the internal microcontroller. They can be added or modified on the customer's request to accommodate user-specific requirements.

The user can build virtually any type of a custom control by logically connecting inputs and outputs of the functional blocks. This approach gives the user an absolute freedom of customization and an ability to fully utilize the controller hardware resources in a user's application.

Depending on the block functionality, a functional block can have: logical inputs, logical outputs or any combinations of them. The connection between logical inputs and outputs is defined by logical input setpoints. The following rules apply:

- A logical input can be connected to any logical output using a logical input setpoint.
- Two or more logical inputs can be connected to one logical output.
- Logical outputs do not have their own setpoints controlling their connectivity. They can only be chosen as signal sources by logical inputs.

To provide data flow between logical inputs and outputs, all logical output signals are normalized to [0;1] data range using the following equation:

$$Yn = (Y - Ymin) / (Ymax - Ymin),$$

where: Yn – normalized output value,
Y – original output value,
Ymax – maximum output value,
Ymin – minimum output value.

The original output values are restored, if necessary, at the logical inputs using the following reverse linear transformation:

$$X = Xn \bullet (Xmax - Xmin) + Xmin,$$

where: X – original restored input value,
Xn – normalized input value, Xn=Yn,
Xmax – maximum input value, Xmax=Ymax,
Xmin – minimum input value, Xmin=Ymin.

All functional blocks have (Xmax, Xmin) and (Ymax, Ymin) setpoint pairs controlling the normalization process. They will be called "normalization parameters" further in the setpoint descriptions.

For discrete logical inputs and outputs the normalization parameters are not required, since the discrete signals can take only two values: {0,1}. When a regular logical output of a functional block is connected to a discrete logical input, it is assumed that the input values below 0.5 represent state 0 and above 0.5 – state 1:

Discrete Logical Input	Logical State
< 0.5	0
≥ 0.5	1

For additional flexibility, in a majority of functional blocks, logical input signals can be inverted using the following inversion function:

Inv(Xn,I), I∈ {Yes,No},

Inv(Xn,I)={1-Xn, if I=Yes; Xn, if I=No}

In addition to signal values in the range of [0;1], the logical inputs and outputs also carry information on the state of the data source. This information can show that the source is not available or there is an error in data, or the data source is in a special state.

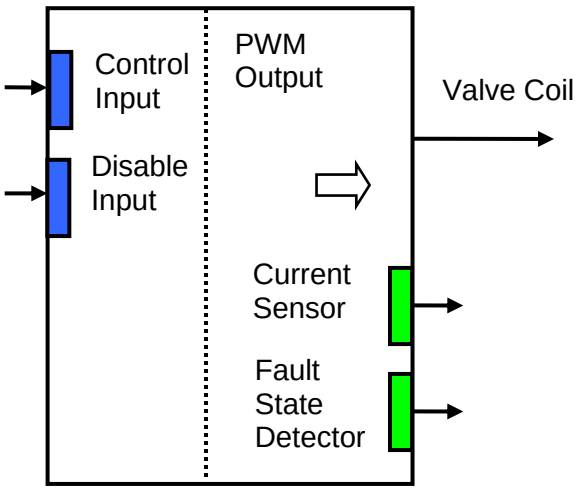
When the data source does not carry a valid data, the output signal value is always set to 0 and the inversion operation on the signal in suppressed. In this case, instead of the signal value, the logical signal carries a signal state code, associated with its signal state, see the table below:

Signal State	**Signal Value, Xn**	**Signal State Code**	**Inverted Signal Value**	
			Xn'=Inv(Xn,Yes)	**Xn'=Inv(Xn,No)**
Valid Data	[0;1]	0	1-Xn	Xn
Special	0	0…4294967295 (0…0xFFFFFFFF) – Special State Code	0	0
Error	0	0…4294967295 (0…0xFFFFFFFF) – Error Code	0	0
Not Available	0	0	0	0

The states of the data source other than the "Valid Data" are primary used by CAN functional blocks to report that a CAN input signal is absent on the bus, is out of range, etc. Other functional blocks usually use only the "Error" state to show an error condition.

3.1 PWM Output

There is one PWM Output functional block representing the hardware PWM output stage of the controller. It has a control and a disable inputs to control the load, and two logical outputs: one providing data from the current sensor connected to the load, and the other – from the fault state detector:



The user can select: the output mode, minimum and maximum output values, dither parameters, and ramps. Also, PID coefficients can be set to control the output current in the “Output Current” mode. For the current sensor, the user can define an averaging time to minimize effect of the output dither on the sensor readings.

The PWM Output functional block has the following set of setpoints:

Name	Default Value	Range	Units	Description
Output Mode	Output Current	{Output Disable, Discrete On/Off, Output Current, Output Voltage, Output PWM Duty Cycle}	–	Specifies a control mode of the controller PWM output stage
Reverse Action	No	{Yes, No}	–	Defines a reverse control (increasing the input signal will decrease the output value: from Imax to Imin, etc.)
Control Input Source	CAN Input #1	Any logical output of any functional block or “Not Connected”	–	Defines a source of the control input signal. This signal controls the PWM output
Control Input Inversion	No	{Yes, No}	–	Specifies, whether the control input signal is inverted
Disable Input Source	Not Connected	Any logical output of any functional block or “Not Connected”	–	Defines a source of the disable input signal. This signal immediately brings the output to its original “Disabled” state[5].
Disable Input Inversion	No	{Yes, No}	–	Specifies, whether the disable input signal is inverted
Imax – Max Output Current	1.0	[0; 3], but Imax>Imin	A	Normalization parameters for Output Current mode. Imax is limited, if DithAmp is high[1].
Imin – Min Output Current	0	[0;3], but Imin<Imax	A	
Vmax – Max Output Voltage	24.0	[0; 60], but Vmax>Vmin	V	Normalization parameters for Output Voltage mode.
Vmin – Min Output	0.0	[0; 60], but Vmin<Vmax	V	

Name	Default Value	Range	Units	Description
Voltage				
Dmax – Max PWM Duty Cycle	100.0	[0; 100], but Dmax<Dmin	%	Normalization parameters for Output PWM Duty Cycle mode.
Dmin – Min PWM Duty Cycle	0.0	[0; 100], but Dmin<Dmax	%	
RampUp – Ramp Up Time	10.0	[0; 100000]	ms	Time, during which the output ramps from its minimum to maximum value.
RampDown – Ramp Down Time	10.0	[0; 100000]	ms	Time, during which the output ramps from its maximum to minimum value.
DithFreq – Dither Frequency	100.0	[20; 400]	Hz	Frequency of the superimposed dither[2]
DithAmp – Dither Amplitude	5.0	[0; 40]	%	Point-to-point amplitude of the superimposed dither. Defined in % of the maximum output value[4]. Limited in the Output Current mode, if Imax is high[1].
Proportional Gain	0.8	[0; 1000]	–	Proportional PID parameter. Password Protected[3].
Integral Time Constant	0.03	[0; 10]	s	Integral PID parameter. Password Protected[3].
Derivative Time Constant	0.001	[0; 10]	s	Derivative PID parameter Password Protected[3].
Current Sensor Averaging Time	100	[0; 1000]	ms	Current sensor output will be updated every specified averaging period of time with an average value calculated on the previous averaging time interval.
Current Sensor Max	3.0	–	A	Normalization parameters for the current sensor output. Read only.
Current Sensor Min	0	–	A	

[1]Due to a limited dynamic range of the current control circuit, Imax and DithAmp values should satisfy the following equation:

$$Imax \cdot (1 + DithAmp/100) \leq 3.15,$$

where: 3.15 – internal control constant.

[2]A global parameter for all PWM outputs.

[3]To avoid accidental changing of the PID parameters, they are password protected. The password is: PIDSetupNow, case sensitive. PID control loop is only used in the Output Current mode.

[4]The maximum output value is defined by the Output Mode. It is equal to: Imax in the Output Current mode, Vmax – in the Output Voltage mode and Dmax – in the Output PWM Duty Cycle mode.

[5]This state corresponds to the zero output, if Reverse Action is not activated (default). If the Reverse Action is activated, the output will be set to the maximum value, which is the value of the output when the control signal is equal to zero in this mode.

3.1.1 Fault State Detector

A fault-state detector changes its state from 0 to 1, when the PWM output is connected to ground or to the battery terminal. In case the PWM output is shorted to ground, it may be necessary to drive the output with some control signal to detect the fault condition.

The fault-state detector does not come on in an overvoltage or under-voltage condition when the supply voltage goes beyond the specified power supply voltage range. In this condition, the PWM output is temporary shut down as a protective measure.

3.2 Conversion Function

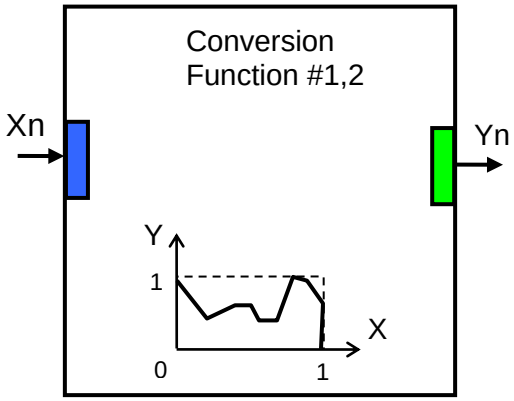
The Conversion Function functional block allows the user to perform a linearization of an input signal, apply a user-defined control profile, and to do a hotshot control, if necessary. There are two Conversion Function blocks available in the current version of the controller.

Each function block one logical input, one output and implements a function:

$$Yn = F(Xn),$$

where:

Xn – normalized input signal (can be inverted by the inversion function),
Yn – normalized output signal.



The function F(x) is defined using a piecewise linear approximation in up to 11 points. Each point is presented by three parameters:

$$P_i = (State_i, Xn_i, Yn_i),\ i = 0\ldots 10,$$

where: P_i – i-th point of the function F,
$State_i$ – state of the i-th point. $State_i \in \{Off, On\}$,
Xn_i – normalized input value at the i-th point.
Yn_i – normalized output value at the i-th point.
If the $State_i$=Off, the point is not active and is not used in the function approximation.

The function values between active points (with $State_i$=On) are defined the following way:

$$Yn = A_j \bullet Xn + B_j ,\ j = 0\ldots N,\ N \le 10,$$

$$A_j = (Yn_j - Yn_{(j+1)}) / (Xn_j - Xn_{(j+1)}) ,$$

$$B_j = (Yn_{(j+1)} \bullet Xn_j - Yn_j \bullet Xn_{(j+1)}) / (Xn_j - Xn_{(j+1)}) ,$$

$Xn \in [Xn_j ; Xn_{(j+1)}[$, $State_j$=On, $State_{(j+1)}$=On.

where: A_j, B_j – linear approximation coefficients between j and (j+1) active points.
N – number of active points.

The conversion function functional block is also capable to implement a hotshot control. For this purpose the user can specify two values for the last, 10-th, function point. The first value is a normalized output value at the 10-th point and the second one is the value that will be assigned to the output if the input remains Xn =1.0 for a hotshot time.

The Conversion Function functional block has the following set of setpoints:

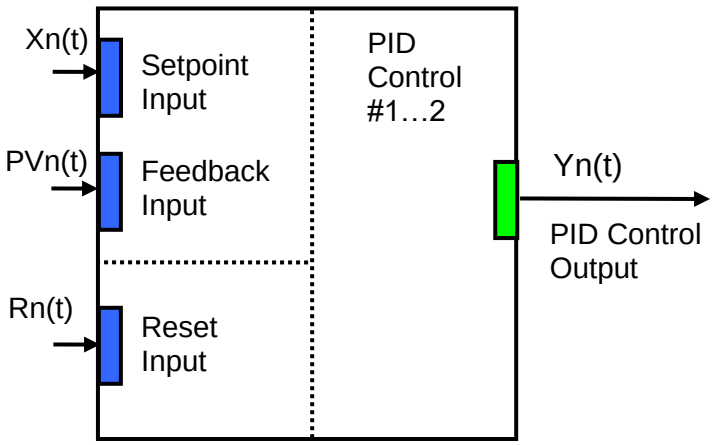
Name	Default Value	Range	Units	Description
Input Source	Not Connected	Any logical output of any functional block or "Not Connected"	–	Defines a source of the input signal Xn
Input Inversion	No	{Yes, No}	–	Specifies, whether the input signal Xn is inverted
Point 0 State	On	–	–	$State_0$. Read only parameter
Point 0 X	0	–	–	Xn_0. Read only parameter
Point 0 Y	0	[0;1]	–	Yn_0
Point 1 State	Off	{Off, On}	–	$State_1$
Point 1 X	0.1	[Xn_0; Xn_2]	–	Xn_1
Point 1 Y	0	[0;1]	–	Yn_1
Point 2 State	Off	{Off, On}	–	$State_2$
Point 2 X	0.2	[Xn_1; Xn_3]	–	Xn_2
Point 2 Y	0	[0;1]	–	Yn_2
Point 3 State	Off	{Off, On}	–	$State_3$
Point 3 X	0.3	[Xn_2; Xn_4]	–	Xn_3
Point 3 Y	0	[0;1]	–	Yn_3
Point 4 State	Off	{Off, On}	–	$State_4$
Point 4 X	0.4	[Xn_3; Xn_5]	–	Xn_4
Point 4 Y	0	[0;1]	–	Yn_4
Point 5 State	Off	{Off, On}	–	$State_5$
Point 5 X	0.5	[Xn_4; Xn_6]	–	Xn_5
Point 5 Y	0	[0;1]	–	Yn_5
Point 6 State	Off	{Off, On}	–	$State_6$
Point 6 X	0.6	[Xn_5; Xn_7]	–	Xn_6
Point 6 Y	0	[0;1]	–	Yn_6
Point 7 State	Off	{Off, On}	–	$State_7$
Point 7 X	0.7	[Xn_6; Xn_8]	–	Xn_7
Point 7 Y	0	[0;1]	–	Yn_7

Name	Default Value	Range	Units	Description
Point 8 State	Off	{Off, On}	–	$State_8$
Point 8 X	0.8	[Xn_7; Xn_9]	–	Xn_8
Point 8 Y	0	[0;1]	–	Yn_8
Point 9 State	Off	{Off, On}	–	$State_9$
Point 9 X	0.9	[Xn_8; Xn_{10}]	–	Xn_9
Point 9 Y	0	[0;1]	–	Yn_9
Point 10 State	On	–	–	$State_{10}$. Read only parameter
Point 10 X	1	–	–	Xn_{10}. Read only parameter
Point 10 Y	0	[0;1]	–	Yn_{10}
Hotshot Delay	0	0…10000	ms	Undefined if 0
Hotshot Y	0	[0;1]	–	Yn_{10}, if Xn=1.0 for Time>Hotshot Delay, and Hotshot Delay ≠ 0

3.3 PID Control

To provide the user with means to build generic closed loop PID regulators, two PID Control functional blocks were added to the controller.

A PID Control functional block has: setpoint and feedback inputs, manual control mode and a reset input to bring the regulator into its initial state. The user can also adjust the time resolution for fast or slow responding closed loop systems.



The normalized output of the PID Control functional block Yn(t), as a function of time, can be described by the following formula:

$$Yn(t)=Clip(Y(t)),$$

$$Y(t) = P\bullet[\, e(t) + 1/T_I\bullet\int e(t)dt - T_D\bullet dPVn(t)/dt \,],$$

where:

Clip(Y(t))={Y(t), if $0\le Y(t)\le 1$; 0, if $Y(t)<0$; 1, if $Y(t)>1$} – clipping function;
e(t) = Xn(t) – PVn(t) – error function, where
Xn(t) – normalized setpoint variable, set by the Setpoint Input,
PVn(t) – normalized process variable, set by the Feedback Input,

P – proportional gain,
T_I – integral time,
T_D – derivative time.

All PID Control logical inputs can be inverted.

To avoid saturation of the output due to the integral term of the PID regulator, an anti-windup algorithm is implemented. The integrator is stopped when the output saturates and the error function moves the output to further saturation:

$Y(t)>1$ and $e(t)>0$ or $Y(t)<0$ and $e(t)<0$.

When the Reset Input is activated, the integral part of the PID regulator is reset to zero and the output of the PID Control functional block is brought to zero, too:

$\int e(t)dt=0$, $Y(t) = 0$, when $Rn(t)\geq 0.5$,

where:

Rn(t) – normalized reset variable, set by the Reset Input.

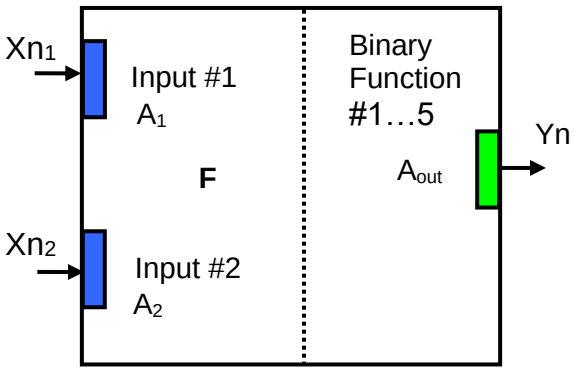
Setpoints of the PID Control functional block are presented in the following table:

Name	Default Value	Range	Units	Description
Setpoint Input Source	Not Connected	Any logical output of any functional block or “Not Connected”	–	Source of a setpoint input signal
Setpoint Input Inversion	No	{Yes, No}	–	Specifies, whether to invert the setpoint signal
Feedback Input Source	Not Connected	Any logical output of any functional block or “Not Connected”	–	Source of a feedback input signal
Feedback Input Inversion	No	{Yes, No}	–	Specifies, whether to invert the feedback signal
Reset Input Source	Not Connected	Any logical output of any functional block or “Not Connected”	–	Source of a reset input signal. The signal brings the regulator into its initial state.
Reset Input Inversion	No	{Yes, No}	–	Specifies, whether to invert the reset signal
Manual Control	No	{Yes, No}	–	Put the PID control in a manual control mode. In this mode the PID regulator is off and the PID output is equal to the value of the “Manual Control Output” setpoint
Manual Control Output	0.5	[0;1]	–	Output of the PID control in the manual control mode
Proportional Gain	1.0	[0;100000]	–	Proportional PID parameter
Integral Time Constant	0.1	[0;100000]	s	Integral PID parameter
Derivative Time Constant	0.01	[0;100000]	s	Derivative PID parameter. Derivation from the process

Name	Default Value	Range	Units	Description
				variable is used.
Time Resolution	0.001	[0.001;10]	s	Time interval between PID control cycles

3.4 Binary Function

There are five Binary Function functional blocks added to the controller to support advanced control algorithms. Each Binary Function functional block takes two logical input signals, scales them, and performs an arithmetic or logical operation. Then it outputs the result, which can be scaled as well.



The normalized output signal Yn of the Binary Function functional block can be presented by the following formula:

$$Yn=Clip(Y),$$

$$Y = A_{out} \bullet F[A_1 \bullet Xn_1, A_2 \bullet Xn_2]$$

where:

Clip(Y)={Y, if $0 \le Y \le 1$; 0, if $Y<0$; 1, if $Y>1$} – clipping function;
Xn_1, Xn_2 – normalized signal values of the input sources (can be inverted);
A_1, A_2 – input scale coefficients;
A_{out} – output scale coefficient;
F[x, y] – binary function of the scaled input signals: $x=A_1 \bullet Xn_1$, $y=A_2 \bullet Xn_2$.

In case one of the input sources is not connected, the output signal of the functional block is not available and its signal value is equal to Yn=0.

The Binary Function functional block has the following set of setpoints:

Name	Default Value	Range	Units	Description
Input #1 Source	Not Connected	Any logical output of any functional block or “Not Connected”	–	Source of the input #1 signal
Input #1 Inversion	No	{Yes, No}	–	Specifies, whether to invert the input #1 signal
Input #1 Scale	1.0	Any value	–	Input #1 signal scale

Name	Default Value	Range	Units	Description
				coefficient
Input #2 Source	Not Connected	Any logical output of any functional block or “Not Connected”	–	Source of the input #2 signal
Input #2 Inversion	No	{Yes, No}	–	Specifies, whether to invert the input #2 signal
Input #2 Scale	1.0	Any value	–	Input #2 signal scale coefficient
Function	+	{+, ∗,÷, Max, Min, OR, AND, XOR, <, ≤, =, >, ≥}	–	Binary function of the input #1 scaled signal and the input #2 scaled signal
Output Scale	1.0	Any value	–	Output signal scale coefficient

The binary functions F[x,y] have the following implementation specifics.

In the division function, to avoid ambiguity in dividing by 0, the dividend and the divisor are not allowed to be less than δ:

$$F^{(\div)}[x,y] = \max(x,\delta)/\max(y,\delta),$$

where: δ =1.0E-6 is a specially introduced computational constant.

For logical functions {OR, AND, XOR} values $X_i \geq 0.5$ (i=1,2) are treated as 1 (true) and $X_i < 0.5$ – as 0 (false).

To minimize influence of computational errors during normalization, comparison functions {≤, =, ≥ } are defined the following way:

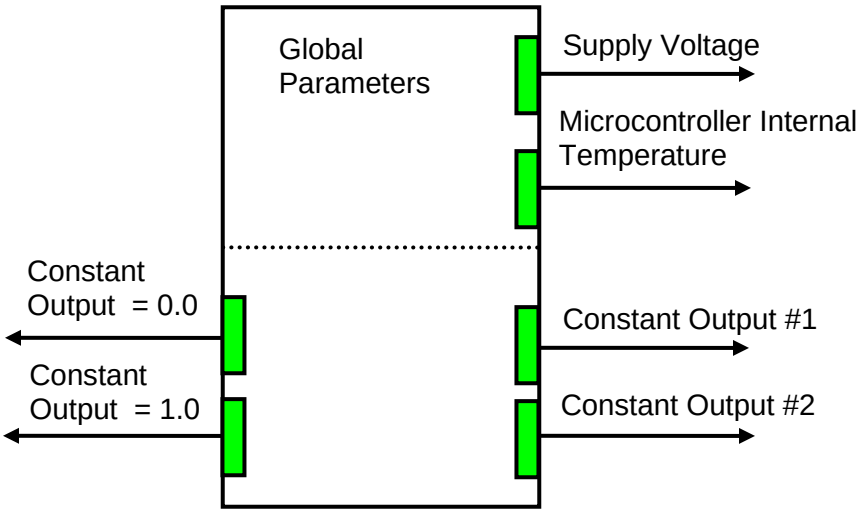
$$F^{(\leq)}[x,y] = \{1, \text{if } x \leq y+\delta;\ 0, \text{if } x > y+\delta\},$$

$$F^{(=)}[x,y] = \{1, \text{if } |x-y| \leq \delta;\ 0, \text{if } |x-y| > \delta\},$$

$$F^{(\geq)}[x,y] = \{1, \text{if } x \geq y-\delta;\ 0, \text{if } x < y-\delta\}.$$

3.5 Global Parameters

The Global Parameters functional block gives the user access to the controller supply voltage and the microcontroller internal temperature as well as to a set of four constant logical outputs. These outputs can be used by other functional blocks as constant input sources. For example, they can be used to set up threshold values in Binary Function functional blocks.



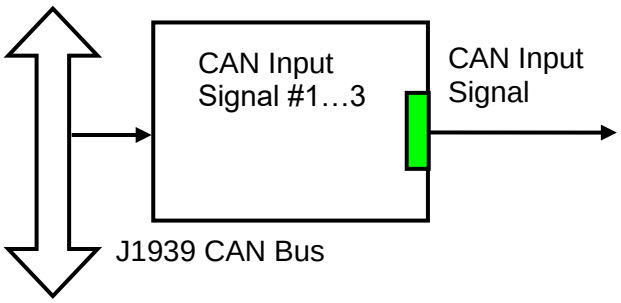
Two out of four constant logical outputs are user programmable. Other two represent logical one and logical zero outputs.

The setpoints for the Global Parameters functional block are presented in the following table:

Name	Default Value	Range	Units	Description
Constant Output #1	0.0	[0…1]	–	Logical output with a constant value.
Constant Output #2	0.0	[0…1]	–	Logical output with a constant value.
Vsmax – Max Supply Voltage	100	–	V	Normalization parameters for the inclinometer supply voltage. Read only parameters.
Vsmin – Min Supply Voltage	0	–	V	
Tmax – Max Microcontroller Temperature	150	–	°C	Normalization parameters for the microcontroller embedded temperature sensor. Read only parameters.
Tmin – Min Microcontroller Temperature	-50	–	°C	

3.6 CAN Input Signals

There are three CAN Input Signal functional blocks supported by the controller. Each functional block can be programmed to read single-frame CAN messages and extract CAN signal data presented in virtually any user-defined signal data format. The functional block then outputs the signal data to its logical output for processing by other functional blocks of the controller.



The CAN Input Signal functional block has an ability to filter out signals transmitted only from a selected address. This way, it can be bound to a specific ECU on the CAN network. It can also automatically reset the input signal data in case the signal has been absent or lost for more than a specific period of time.

CAN application specific messages transmitted by the controller itself are also processed by this functional block. The only difference in processing of the internal messages is that they are not sampled from the CAN bus and therefore their processing does not depend on a state of the CAN bus.

The setpoints of the CAN Input Signal functional block are presented in the following table:

Name	Default Value	Range	Units	Description
Signal Type	Undefined	{Undefined, 1-Bit Discrete, 2-Bit Discrete, 4-Bit Discrete, 1-Byte Continuous, 2-Byte Continuous, 4-Byte Continuous}	–	Type of the CAN input signal
PGN	65280	Any J1939 PGN value	–	PGN of the single frame CAN messages carrying the CAN input signal
PGN From Selected Address	No	{No, Yes}	–	Only CAN messages from the selected address will be accepted, if “Yes”
Selected Address	0	[0; 253]	–	Address of the ECU transmitting CAN messages carrying the CAN input signal
Data Position Byte	1	[1; 8]	–	Input signal data position byte within the CAN message data frame. LSB for continuous input signals
Data Position Bit	1	[1; 8]	–	Less significant input signal data position bit within the “Data Position Byte” for discrete input signals[1]
Resolution	1	Any value	Signal Units / Bit	CAN continuous signal resolution
Offset	0	Any value	Signal Units	CAN continuous signal offset

Name	Default Value	Range	Units	Description
Signal Max Value	1	Any value, but: Signal Max Value > Signal Min Value	Signal Units	Normalization parameters for the CAN input signal. Valid only for continuous signals
Signal Min Value	0	Any value, but: Signal Min Value < Signal Max Value	Signal Units	
Autoreset Time	500	[0; 10000]	ms	Time interval, after which the output signal will be automatically reset to “Not Available”, if a new CAN message, carrying the signal, has not arrived. If 0 – autoreset is disabled.

[1]Discrete input signals should be within the “Data Position Byte” borders, not split between the adjacent bytes.

By default, the output of the first CAN Input Signal functional block is connected to the input of the PWM Output #1 functional block. It provides the simplest controller configuration with a direct control of the signal output by the CAN input signal. The second and third CAN Input Signal functional blocks, not connected by default, can be engaged in more complicated CAN signal acquisition and processing algorithms involving Binary Function functional blocks and other controller resources.

According to the J1939/71 standard, CAN signals can carry not only signal values, but also special indicators, including: error indicator, “signal not available” indicator, etc. CAN signal types, supported by the controller, have the following CAN signal code mapping to the controller logical signals:

CAN Signal Type	CAN Signal Code	Logical Signal		
		State	Value	Signal State Code
1-Bit Discrete*	0…1	Valid Data	0…1 (=CANSignalCode)	0
2-Bit Discrete	0…1	Valid Data	0…1 (=CANSignalCode)	0
	2	Error	0	0
	3	Not Available	0	0
4-Bit Discrete*	0…1	Valid Data	0…1 (=CANSignalCode)	0
	2…13 (0x02…0x0D)	Special	0	0…11 =CANSignalCode-2
	14 (0x0E)	Error	0	0
	15 (0x0F)	Not Available	0	0
1-Byte Continuous	0…250 (0…0xFA)	Valid Data	[0;1] - normalized signal code	0
	251…253 (0xFB…0xFD)	Special	0	0…2 =CANSignalCode-251
	254 (0xFE)	Error	0	0
	255 (0xFF)	Not Available	0	0
2-Byte Continuous	0…64255 (0…0xFAFF)	Valid Data	[0;1] - normalized signal code	0

CAN Signal Type	CAN Signal Code	Logical Signal		
		State	Value	Signal State Code
	64256…65023 (0xFB00…0xFDFF)	Special	0	0…267 =CANSignalCode-64256
	65024…65279 (0xFExx)	Error	0	0…255 =CANSignalCode-65024
	65280…65535 (0xFFxx)	Not Available	0	0
4-Byte Continuous	0…4211081215 (0… 0xFAFFFFFF)	Valid Data	[0;1] - normalized signal code	0
	4211081216… 4261412863 (0xFB000000… 0xFDFFFFFF)	Special	0	0…50331647 =CANSignalCode-4211081216
	4261412864… 4278190079 (0xFExxxxxx)	Error	0	0…16777215 =CANSignalCode-4261412864
	4278190080… 4294967295 (0xFFxxxxxx)	Not Available	0	0

*CAN signal code mapping for these types is specific to this control.

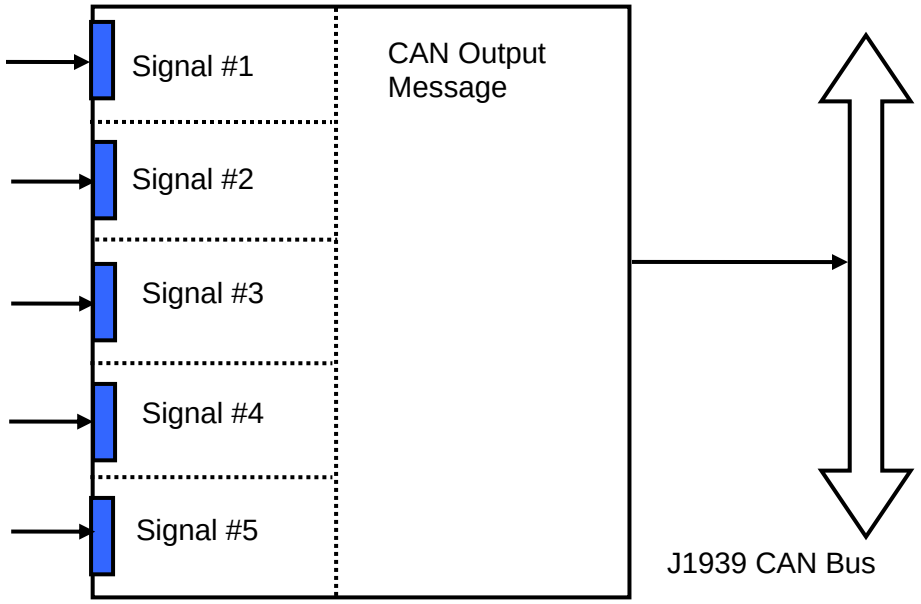
This mapping closely follows the J1939/71 standard for the 2-bit Discrete and all continuous CAN signal types, dividing the CAN code in similar ranges to represent different states of the signal. For the 1-bit and 4-bit Discrete signal types there are no generic rules specified by the J1939/71 standard to encode special indicators. The control uses its own mapping scheme for these types.

The J1939 standard does not specify how to encode the error codes and parameter specific indicators within the special indicator ranges. The control uses its own simple way of encoding, converting parameter specific and error indicators into absolute signal state codes. This allows to receive and transmit the same codes using different CAN signal types in a consistent way.

For example, if the logical signal is in the “Error” state with the error code equal to 1, the CAN signal code carrying this error will be 650251 (0xFE01) for the “2-Byte Continuous” CAN signal type or 4261412865 (0xFE00 0001) – for the “4-Byte Continuous” CAN signal type. See also the CAN Output Message functional block for reverse conversion of the logical signals into the CAN signal codes.

3.7 CAN Output Message

There is one CAN Output Message functional block, which allows the controller to send a single frame application specific CAN message to the CAN bus. The messages can be sent continuously or upon request. It contains up to five user defined CAN signals.



The message does not have a specific destination address. In case the PGN of the message is presented in the PDU1 format, the message is sent to the global address.

The setpoints of the CAN Output Message functional block are presented in the following table:

Name	Default Value	Range	Units	Description
PGN	65281	Any J1939 PGN value	–	CAN output message PGN
Transmission Enable	No	{Yes, No}		Enables the CAN output message transmission
Transmission Rate	0	[0;10000]		CAN output message transmission rate. If 0 – transmission is upon request
Signal #1 Type	Undefined	{Undefined, 1-Bit Discrete, 2-Bit Discrete, 4-Bit Discrete, 1-Byte Continuous, 2-Byte Continuous, 4-Byte Continuous}	–	Type of the CAN output signal #1
Signal #1 Source	Not Connected	Any logical output of any functional block or “Not Connected”	–	Source of the CAN output signal #1
Signal #1 Inversion	No	{Yes, No}	–	Specifies, whether to invert the output signal #1
Signal #1 Data Position Byte	1	[1; 8]	–	Signal #1 data position byte within the CAN message data frame. LSB for continuous output signals
Signal #1 Data Position Bit	1	[1; 8]	–	Less significant signal #1 data position bit within the “Signal #1 Data Position Byte” for discrete output signals[1]

Name	Default Value	Range	Units	Description
Signal #1 Resolution	1	Any value, except 0	Signal Units / Bit	CAN output signal #1 resolution. Valid only for continuous signals
Signal #1 Offset	0	Any value	Signal Units	CAN output signal #1 offset. Valid only for continuous signals
Signal #1 Max Value	1	Any value, but: Signal #1 Max Value > Signal #1 Min Value	Signal Units	Normalization parameters for the CAN output signal #1. Valid only for continuous signals
Signal #1 Min Value	0	Any value, but: Signal #1 Min Value < Signal #1 Max Value	Signal Units	
Signal #2 Type	Undefined	{Undefined, 1-Bit Discrete, 2-Bit Discrete, 4-Bit Discrete, 1-Byte Continuous, 2-Byte Continuous, 4-Byte Continuous}	–	Type of the CAN output signal #2
Signal #2 Source	Not Connected	Any logical output of any functional block or “Not Connected”	–	Source of the CAN output signal #2
Signal #2 Inversion	No	{Yes, No}	–	Specifies, whether to invert the output signal #2
Signal #2 Data Position Byte	1	[1; 8]	–	Signal #2 data position byte within the CAN message data frame. LSB for continuous output signals
Signal #2 Data Position Bit	1	[1; 8]	–	Less significant signal #2 data position bit within the “Signal #2 Data Position Byte” for discrete output signals[1]
Signal #2 Resolution	1	Any value, except 0	Signal Units / Bit	CAN output signal #2 resolution. Valid only for continuous signals
Signal #2 Offset	0	Any value	Signal Units	CAN output signal #2 offset. Valid only for continuous signals
Signal #2 Max Value	1	Any value, but: Signal #2 Max Value > Signal #2 Min Value	Signal Units	Normalization parameters for the CAN output signal #2. Valid only for continuous signals
Signal #2 Min Value	0	Any value, but: Signal #2 Min Value < Signal #2 Max Value	Signal Units	
Signal #3 Type	Undefined	{Undefined, 1-Bit Discrete, 2-Bit Discrete, 4-Bit Discrete, 1-Byte Continuous, 2-Byte Continuous, 4-Byte Continuous}	–	Type of the CAN output signal #3

Name	Default Value	Range	Units	Description
Signal #3 Source	Not Connected	Any logical output of any functional block or “Not Connected”	–	Source of the CAN output signal #3
Signal #3 Inversion	No	{Yes, No}	–	Specifies, whether to invert the output signal #3
Signal #3 Data Position Byte	1	[1; 8]	–	Signal #3 data position byte within the CAN message data frame. LSB for continuous output signals
Signal #3 Data Position Bit	1	[1; 8]	–	Less significant signal #3 data position bit within the “Signal #3 Data Position Byte” for discrete output signals[1]
Signal #3 Resolution	1	Any value, except 0	Signal Units / Bit	CAN output signal #3 resolution. Valid only for continuous signals
Signal #3 Offset	0	Any value	Signal Units	CAN output signal #3 offset. Valid only for continuous signals
Signal #3 Max Value	1	Any value, but: Signal #3 Max Value > Signal #3 Min Value	Signal Units	Normalization parameters for the CAN output signal #3. Valid only for continuous signals
Signal #3 Min Value	0	Any value, but: Signal #3 Min Value < Signal #3 Max Value	Signal Units	
Signal #4 Type	Undefined	{Undefined, 1-Bit Discrete, 2-Bit Discrete, 4-Bit Discrete, 1-Byte Continuous, 2-Byte Continuous, 4-Byte Continuous}	–	Type of the CAN output signal #4
Signal #4 Source	Not Connected	Any logical output of any functional block or “Not Connected”	–	Source of the CAN output signal #4
Signal #4 Inversion	No	{Yes, No}	–	Specifies, whether to invert the output signal #4
Signal #4 Data Position Byte	1	[1; 8]	–	Signal #4 data position byte within the CAN message data frame. LSB for continuous output signals
Signal #4 Data Position Bit	1	[1; 8]	–	Less significant signal #4 data position bit within the Signal #4 Data Position Byte for discrete output signals[1]
Signal #4 Resolution	1	Any value, except 0	Signal Units / Bit	CAN output signal #4 resolution. Valid only for continuous signals
Signal #4 Offset	0	Any value	Signal Units	CAN output signal #4 offset. Valid only for continuous

Name	Default Value	Range	Units	Description
				signals
Signal #4 Max Value	1	Any value, but: Signal #4 Max Value > Signal #4 Min Value	Signal Units	Normalization parameter for the CAN output signal #4. Valid only for continuous signals
Signal #4 Min Value	0	Any value, but: Signal #4 Min Value < Signal #4 Max Value	Signal Units	
Signal #5 Type	Undefined	{Undefined, 1-Bit Discrete, 2-Bit Discrete, 4-Bit Discrete, 1-Byte Continuous, 2-Byte Continuous, 4-Byte Continuous}	–	Type of the CAN output signal #5
Signal #5 Source	Not Connected	Any logical output of any functional block or “Not Connected”	–	Source of the CAN output signal #5
Signal #5 Inversion	No	{Yes, No}	–	Specifies, whether to invert the output signal #5
Signal #5 Data Position Byte	1	[1; 8]	–	Signal #5 data position byte within the CAN message data frame. LSB for continuous output signals
Signal #5 Data Position Bit	1	[1; 8]	–	Less significant signal #5 data position bit within the “Signal #5 Data Position Byte” for discrete output signals[1]
Signal #5 Resolution	1	Any value, except 0	Signal Units / Bit	CAN output signal #5 resolution. Valid only for continuous signals
Signal #5 Offset	0	Any value	Signal Units	CAN output signal #5 offset. Valid only for continuous signals
Signal #5 Max Value	1	Any value, but: Signal #5 Max Value > Signal #5 Min Value	Signal Units	Normalization parameter for the CAN output signal #5. Valid only for continuous signals.
Signal #5 Min Value	0	Any value, but: Signal #5 Min Value < Signal #5 Max Value	Signal Units	

[1]CAN discrete signals should be within the “Data Position Byte” borders, not split between the adjacent bytes.

The logical signals can carry not only signal values but also error and special codes reflecting different states of the logical signal. The logical signals are converted into CAN signal codes the same way as in the CAN Input Signal functional block, closely following the J1939/71 standard when possible. See the table below:

CAN Signal Type	Logical Signal			CAN Signal Code
	State	Value	Signal State Code	
1-Bit Discrete	Valid Data	[0;1]	0	0, if Value<0.5

CAN Signal Type	Logical Signal			CAN Signal Code
	State	Value	Signal State Code	
				1, if Value≥0.5
	Special*	0	0…4294967295 (0…0xFFFFFFFF)	1
	Error*	0	0…4294967295 (0…0xFFFFFFFF)	1
	Not Available*	0	0	1
2-Bit Discrete	Valid Data	[0;1]	0	0, if Value<0.5 1, if Value≥0.5
	Special*	0	0…4294967295 (0…0xFFFFFFFF)	3 (Same as “Not Available”)
	Error	0	0…4294967295 (0…0xFFFFFFFF)	2
	Not Available	0	0	3
4-Bit Discrete*	Valid Data	[0;1]	0	0, if Value<0.5 1, if Value≥0.5
	Special	0	0…4294967295 (0…0xFFFFFFFF)	2…13 (0x02…0x0D) =SignalStateCode+2, if SignalStateCode<12 =13, if SignalStateCode ≥12
	Error	0	0…4294967295 (0…0xFFFFFFFF)	14 (0x0E)
	Not Available	0	0	15 (0x0F)
1-Byte Continuous	Valid Data	[0;1]	0	0…250 (0…0xFA) – calculated from the Value using normalization parameters
	Special	0	0…4294967295 (0…0xFFFFFFFF)	251…253 (0xFB…0xFD) = SignalStateCode+251, if SignalStateCode<3, =253, if SignalStateCode ≥3
	Error	0	0…4294967295 (0…0xFFFFFFFF)	254 (0xFE)
	Not Available	0	0	255 (0xFF)
2-Byte Continuous	Valid Data	[0;1]	0	0…64255 (0…0xFAFF) – calculated from the Value using normalization parameters
	Special	0	0…4294967295 (0…0xFFFFFFFF)	64256…65023 (0xFB00…0xFDFF) = SignalStateCode+64256, if SignalStateCode<768, =65023, if SignalStateCode ≥768
	Error	0	0…4294967295 (0…0xFFFFFFFF)	65024…65279 (0xFExx) = SignalStateCode+65024, if SignalStateCode<256, =65279, if SignalStateCode ≥256
	Not Available	0	0	65535 (0xFFFF)
4-Byte Continuous	Valid Data	[0;1]	0	0…4211081215 (0… 0xFAFFFFFF) – calculated from the Value using normalization parameters
	Special	0	0…4294967295 (0…0xFFFFFFFF)	4211081216… 4261412863 (0xFB000000… 0xFDFFFFFF)

CAN Signal Type	Logical Signal			CAN Signal Code
	State	Value	Signal State Code	
				=SignalStateCode+4211081216, if SignalStateCode<50331648, =4261412863, if SignalStateCode ≥50331648
	Error	0	0…4294967295 (0…0xFFFFFFFF)	4261412864… 4278190079 (0xFExxxxxx) =SignalStateCode+4261412864, if SignalStateCode<16777216, =4278190079, if SignalStateCode ≥16777216
	Not Available	0	0	4294967295 (0xFFFFFFFF)

*Conversion rules are specific to this control. They are not defined by the J1939/71 standard.

4 NETWORK SUPPORT

The controller is designed to work on the J1939 CAN network. When connected to the network or upon power up, it automatically recognizes the network connection, claims a network address, and then starts a network communication.

The network part of the controller is compliant with Bosch CAN protocol specification, Rev.2.0, Part B, and the following J1939 standards:

ISO/OSI Network Model Layer	J1939 Standard
Physical	J1939/11 – Physical Layer, 250K bit/s, Twisted Shielded Pair. Rev. SEP 2006. J1939/15 - Reduced Physical Layer, 250K bits/sec, Un-Shielded Twisted Pair (UTP). Rev. AUG 2008.
Data Link	J1939/21 – Data Link Layer. Rev. DEC 2006
	The controller supports Transport Protocol for Commanded Address messages (PGN 65240) and software identification -SOFT messages (PGN 65242). It also supports responses on PGN Requests (PGN 59904).
Network	J1939, Appendix B – Address and Identity Assignments. Rev. FEB 2010. J1939/81 – Network Management. Rev. 2003-05.
	The controller is an Arbitrary Address Capable ECU. It can dynamically change its network address in real time to resolve an address conflict with other ECUs. The controller supports: Address Claimed Messages (PGN 60928), Requests for Address Claimed Messages (PGN 59904) and Commanded Address Messages (PGN 65240).
Transport	N/A in J1939.
Session	N/A in J1939.
Presentation	N/A in J1939.
Application	J1939/71 – Vehicle Application Layer. Rev. FEB 2010
	The controller can receive application specific PGNs with input signals and transmit application specific PGNs with up to five output signals. All application specific PGNs are user programmable.
	J1939/73 – Application Layer – Diagnostics. Rev. FEB 2010
	Memory access protocol (MAP) support: DM14, DM15, DM16 messages used by the Axiomatic EA to program setpoints.

4.1 J1939 Name and Address

Upon connecting to the network, before sending and receiving any application data, the controller claims its network address with the unique J1939 Name. The Name fields are presented in the table bellow:

Field Name	Field Length	Field Value	User Programmable
Arbitrary Address Capable	1 bit	1 (Capable)	No

Field Name	Field Length	Field Value	User Programmable
Industry Group	3 bit	0 (Global)	No
Vehicle System Instance	4 bit	0 (First Instance)	No
Vehicle System	7 bit	0 (Nonspecific System)	No
Reserved	1 bit	0	No
Function	8 bit	66 (I/O Controller)	No
Function Instance	5 bit	20 (Twenty first Instance)	No
ECU Instance	3 bit	0 (First Instance)	Yes
Manufacturer Code	11 bit	162 (Axiomatic Technologies Corp.)	No
Identity Number	21 bit	Calculated on the base of the Unit Serial Number	No[1]

[1]Programmed through the RS232 service interface in production

The user can change the controller ECU instance using the Axiomatic EA to accommodate multiple controllers on the same CAN network.

The controller takes its network address from a pool of addresses assigned to self configurable ECUs. The address is preset to 155, but the controller can change it during an arbitration process or upon receiving a commanded address message. The new address value is then stored in a non-volatile memory and is used during the next address claim procedure. The user can also change the controller network address using the Axiomatic EA, if necessary.

4.2 Slew Rate Control

To adjust the controller to the parameters of the CAN physical network, the controller has a setpoint controlling the CAN transceiver slew rate. It can be set to “Fast” or “Slow” slew rate according to the following table:

Setpoint Value	Slew Rate
Fast	19 V/µs
Slow	4 V/ µs

For the majority of J1939 CAN applications the slow slew rate is preferable due to the reduced EMI of the transceiver.

4.3 Network Bus Terminating Resistors

An absence of the CAN bus terminating resistors is the most common source of the CAN bus communication errors.

The controller does not have an embedded 120 Ohm CAN bus terminating resistor. The appropriate resistors should be installed externally on both ends of the CAN twisted pair cable according to the J1939/11 or J1939/15 standards.

Even if the length of the CAN network is short and the signal reflection from both ends of the cable can be ignored, at least one 120 Ohm resistor is required for the majority of CAN transceivers to operate properly.

4.4 Network Setpoint Group

The following table summarizes the Axiomatic EA programmable setpoints controlling the controller CAN network functionality:

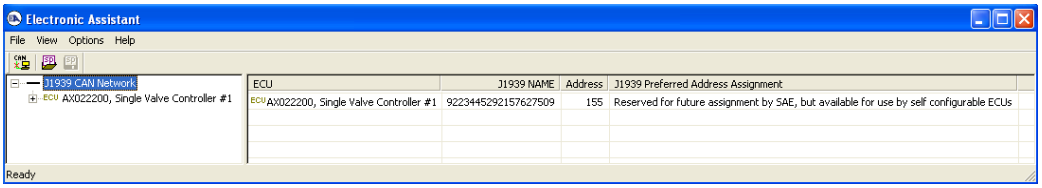
Name	Default Value	Range	Units	Description
ECU Instance Number	0	[0…7]	–	ECU Instance field of the J1939 ECU Name.
ECU Address	155	[0…253]		ECU Address
Slew Rate	Slow	{Slow, Fast}	–	Slew rate control of the CAN transceiver

5 SETPOINT PROGRAMMING

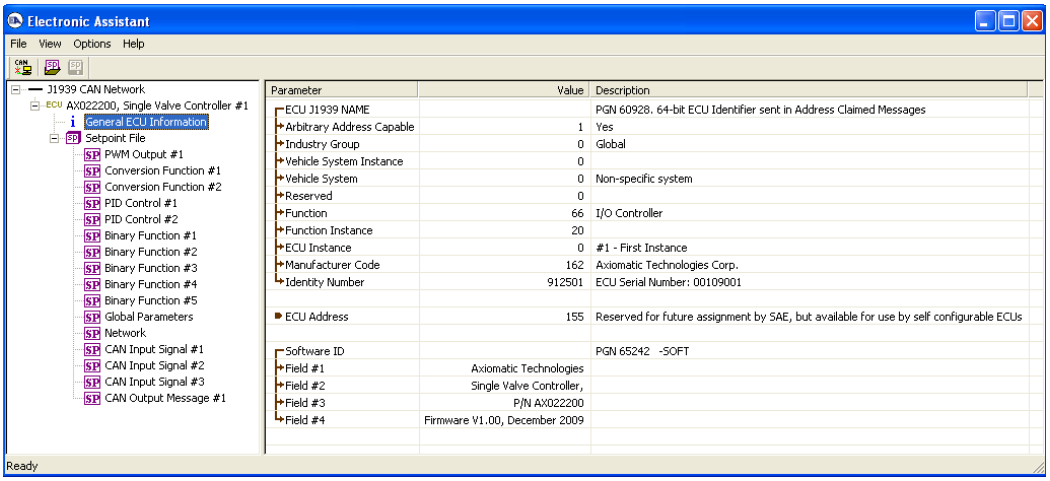
The controller setpoints can be viewed and programmed using the standard J1939 memory access protocol through the CAN bus. Axiomatic provides PC-based Electronic Assistant (EA) software, together with a USB-CAN converter, to accommodate this task. Please, refer to the Axiomatic EA User Manual for a detailed description of the Axiomatic EA's functionality and for network connection troubleshooting.

5.1 Axiomatic EA Software

After successfully connecting to the controller, the Axiomatic EA will show the following screen:



The user then can open the General ECU Information folder in the left pane to check the ECU information including the controller firmware version.



The user should check whether this version is supported by the manual. Otherwise, a different user manual is required to program the controller.

The Axiomatic EA software is regularly updated to support the new Axiomatic controllers and the new firmware versions. It is important to use either recommended or the most contemporary version of the EA to ensure that the current controller firmware is supported. A list of recommended EA versions for different firmware versions is presented in the following table:

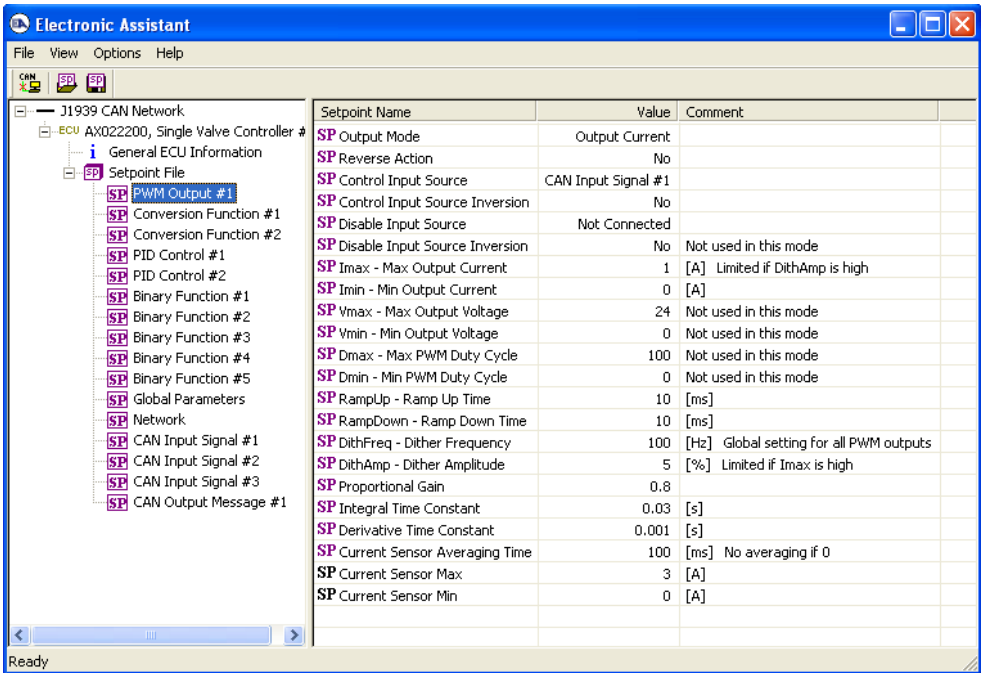
Firmware Version	1.xx - 2.xx
Recommended Axiomatic EA Version	3.0.30.0

Although all necessary steps are taken to avoid incompatibility issues, the newest version of Axiomatic EA may support a newer version of the controller firmware and may not be absolutely

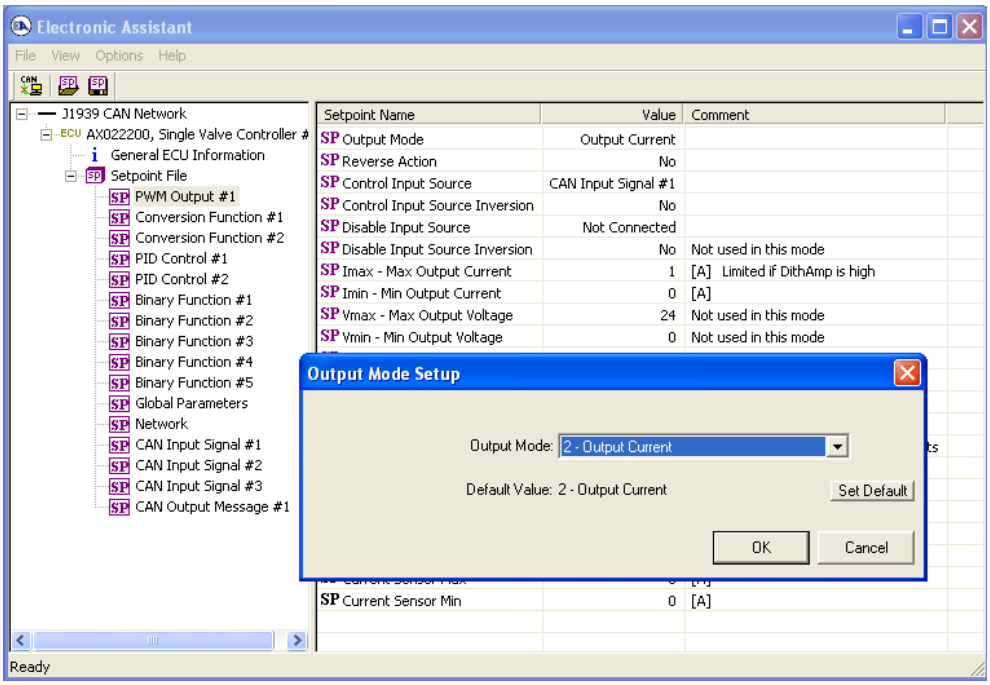
compatible with the current controller firmware version. In this case, to program the controller, instead of using the most contemporary EA version, the user should return to the recommended EA version, which was specifically designed and tested to support the current version of the controller firmware.

5.2 Controller Functional Blocks in the Axiomatic EA

Each functional block of the controller is presented by its own folder in the Setpoint File root folder. The individual setpoints of the functional blocks can be accessed through these folders:



The user can view and, when necessary, change these setpoints by double-clicking on the appropriate setpoint name activating the setpoint editing dialog box:



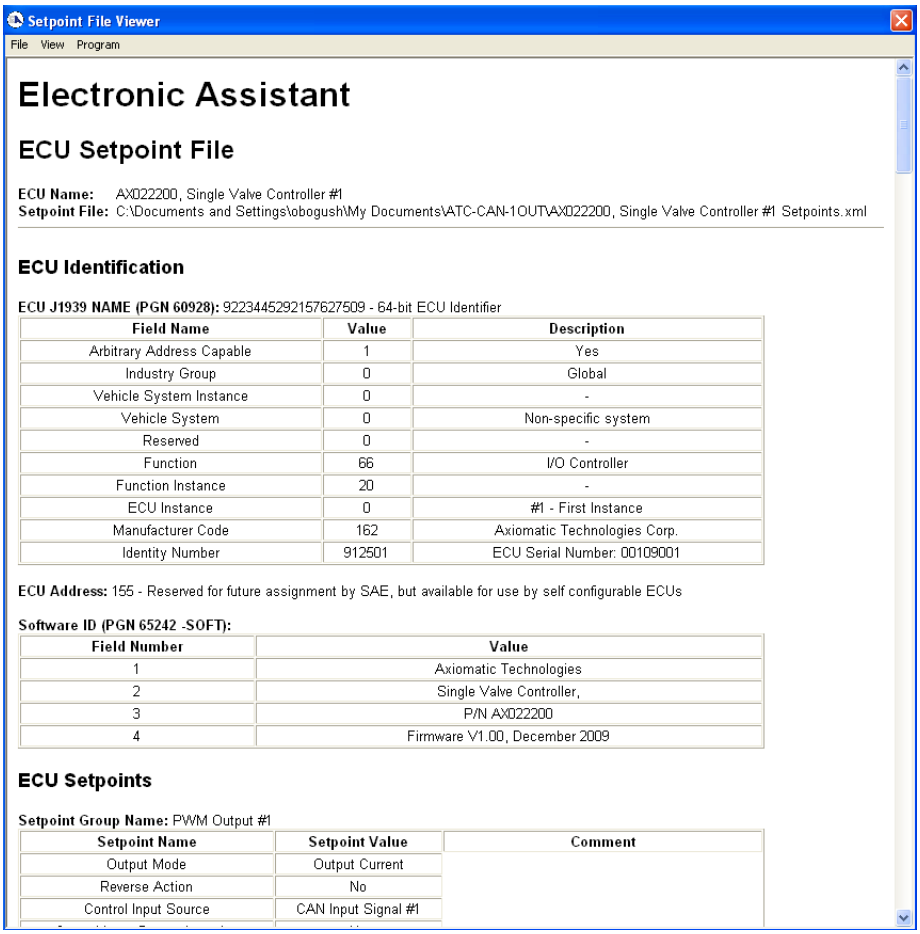
The controller will perform an internal reset of all functional blocks after each change of the setpoints. If the new setpoint affects the network identification, the controller will reclaim its network address with a new network identification message, see J1939 Name and Address.

All controller functional blocks are described in the appropriate subsections of the Controller Architecture section. The Network setpoint group is described in the Network Setpoint Group subsection of the Network Support section of this manual.

5.3 Setpoint File

The Axiomatic EA can store all controller setpoints 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 Axiomatic EA menu or toolbar. The user then can open the setpoint file, view or print it and flash the setpoint file into the controller.



Setpoint File Viewer

File View Program

Electronic Assistant

ECU Setpoint File

ECU Name: AX022200, Single Valve Controller #1
Setpoint File: C:\Documents and Settings\obogush\My Documents\ATC-CAN-1OUT\AX022200, Single Valve Controller #1 Setpoints.xml

ECU Identification

ECU J1939 NAME (PGN 60928): 9223445292157627509 - 64-bit ECU Identifier

Field Name	Value	Description
Arbitrary Address Capable	1	Yes
Industry Group	0	Global
Vehicle System Instance	0	-
Vehicle System	0	Non-specific system
Reserved	0	-
Function	66	I/O Controller
Function Instance	20	-
ECU Instance	0	#1 - First Instance
Manufacturer Code	162	Axiomatic Technologies Corp.
Identity Number	912501	ECU Serial Number: 00109001

ECU Address: 155 - Reserved for future assignment by SAE, but available for use by self configurable ECUs

Software ID (PGN 65242 -SOFT):

Field Number	Value
1	Axiomatic Technologies
2	Single Valve Controller,
3	P/N AX022200
4	Firmware V1.00, December 2009

ECU Setpoints

Setpoint Group Name: PWM Output #1

Setpoint Name	Setpoint Value	Comment
Output Mode	Output Current	
Reverse Action	No	
Control Input Source	CAN Input Signal #1	

To ensure correctness of the flashing operation, a setpoint file should be transferred between controllers with the same major firmware version using the recommended Axiomatic EA version. Otherwise, a manual inspection of all setpoints is recommended after the setpoint flashing operation.

The network identification and “read-only” setpoints are not transferrable using this operation. Also, the controller will perform one or several internal resets of all functional blocks during the setpoint flashing operation.

5.4 Default Setpoints

The controller is preprogrammed by the manufacturer with default setpoint values. These values can be found for each internal functional block in the Controller Architecture section of this manual.

The default setpoint values form a default controller configuration. In this configuration, the PWM Output #1 is enabled and set to the Current Output mode with the 0…1A output current range. Its control input source is connected to the logical output of the CAN Input Signal #1 functional block (Figure 2). The CAN Input Signal #1 functional block is disabled through the *Signal Type* setpoint, which is set to the “Undefined” value. As the result, the output of the PWM Output #1 functional block is always 0A independently of CAN input signals.

This configuration does not provide any useful system functionality. It is intended to be used only as a template to build a user-specific system configuration.

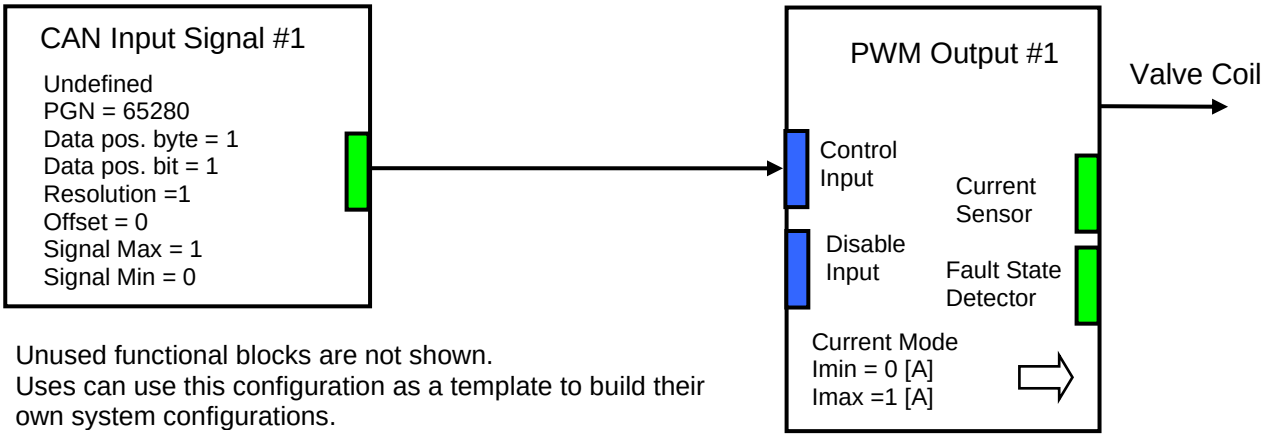


Figure 2. The Block Diagram of the Default Controller Configuration

5.5 Setpoint Programming Example

The controller should be programmed to perform the required system functionality before being used in the system. A detailed description of the controller setpoint programming process is presented bellow, as an example.

5.5.1 User Requirements

Let us assume that the controller should be programmed to control current in a proportional valve from a CAN message. The message has a control signal, one byte long, with values 0-250, where 0 represents the maximum current and 250 – zero current. Also, a second CAN signal, in a different CAN message, should be able to switch the valve off, bringing the output control current to zero. Also, when the first CAN signal is absent for any reason: CAN bus error, etc., the valve should be switched off to the zero current, as well.

For consistency, let us specify:

- Valve coil maximum and minimum currents: Imax=1 and Imin=0 [A].
- CAN control signal: PGN=65280, continuous, 1 byte long, start position 1.
- CAN disable signal: PGN=65281, discrete, 2-bit long, start position: 2.1.

5.5.2 Programming Steps

First, create a block diagram of the required controller configuration using the controller functional blocks (Figure 3).

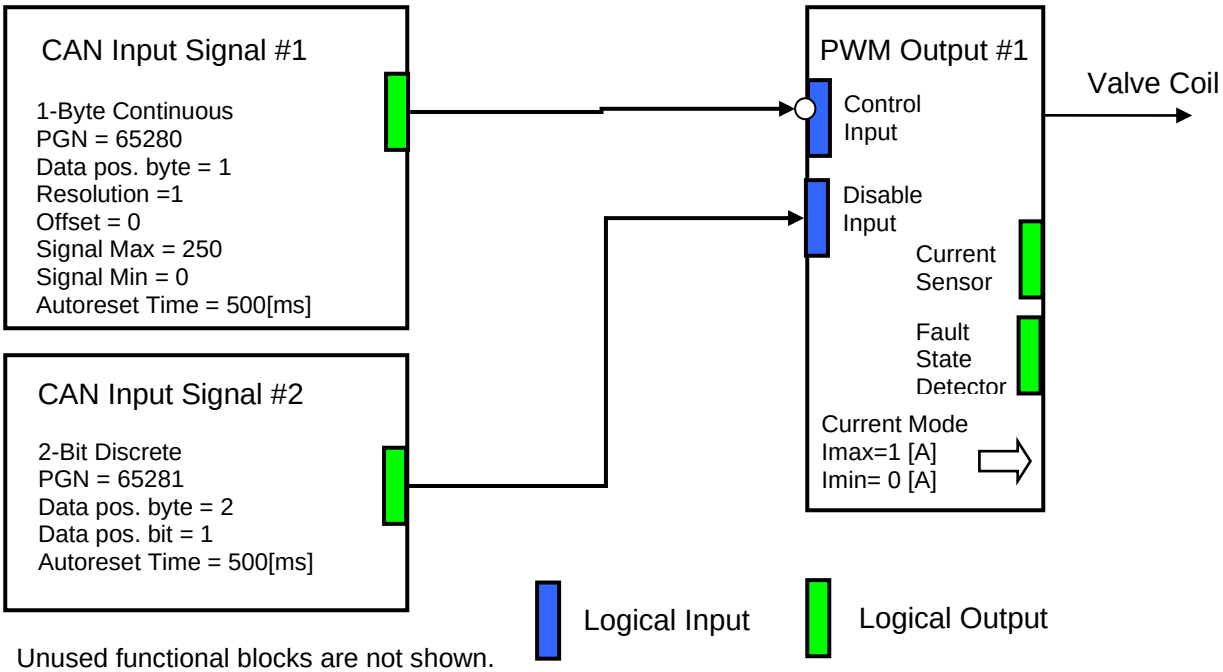
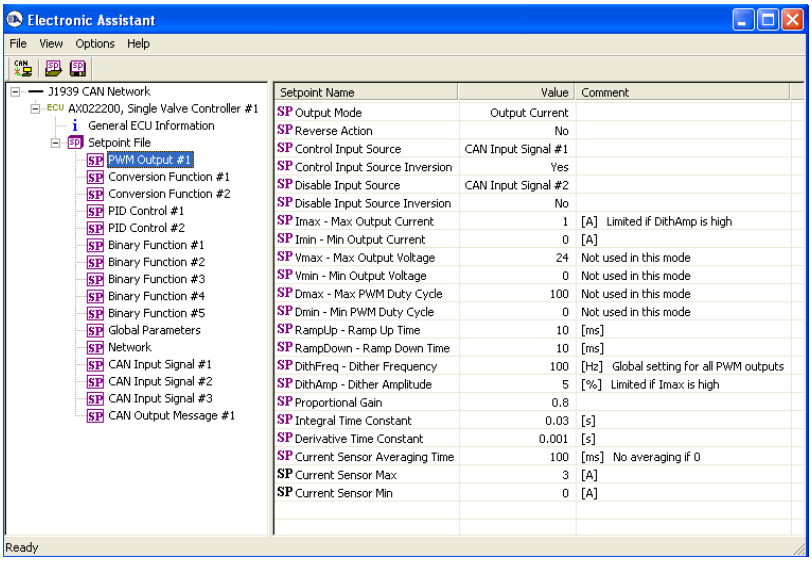


Figure 3. The Block Diagram of the Controller Configuration for the Setpoint Programming Example.

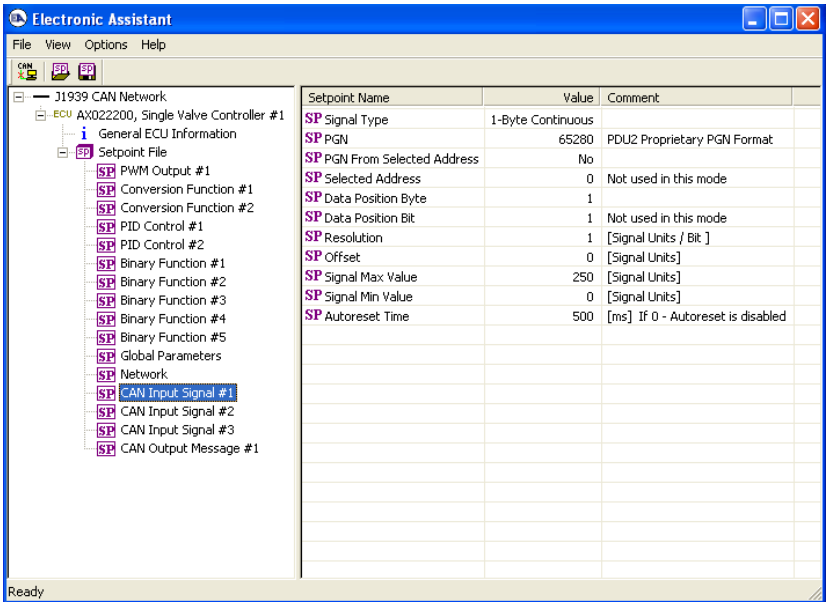
Then, configure the controller PWM Output #1 functional block:



Set the *Output Mode* setpoint to “Output Current”, the *Imin – Min Output Current* to 0 A, and the *Imax – Max Output Current* to 1 A. Also, connect the control logical input of this functional block to the logical output of the CAN Input Signal #1 functional block using the *Control Input Source* setpoint. Perform inversion of the control input signal using the *Control Input Source Inversion* Setpoint, by assigning it “Yes” value. Finally, connect the disable logical input to the CAN Input Signal #2 functional block using the *Disable Input Source* setpoint.

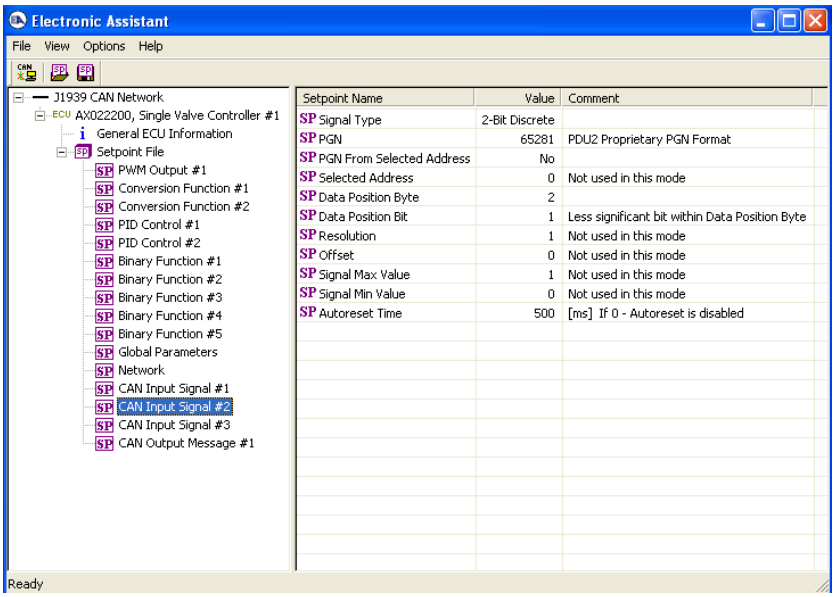
Now, configure the CAN Input Signal #1 and CAN Input Signal #2 functional blocks to accept control and disable signals from the CAN bus.

Use CAN Input Signal #1 functional block for the control signal. Set *Signal Type* setpoint to “1-Byte Continuous”. Then, set the *PGN* setpoint to 65280, the *Data Position Byte* – to 1, the *Resolution* – to 1 [Signal Units/Bit] and the *Offset* – to 0 [Signal Units]. Finally, set normalization setpoints *Signal Max Value* and *Signal Min Value* to 250 and 0, to cover the entire data range of the valve control signal.



Keep the default value “No” for the *PGN From Selected Address* setpoint unless you have several sources of the control messages on the network and the PGN filtering is required. Also, keep *Autoreset Time* setpoint at the default value of the 500ms to reset the logical output signal of the functional block when the CAN signal is absent.

Similarly configure the CAN Input Signal #2 functional block for receiving the disable signal. Set *Signal Type* setpoint to “2-Bit Discrete”. Then, set the *PGN* setpoint to 65281, the *Data Position Byte* – to 2, and the *Data Position Bit* – to 1.

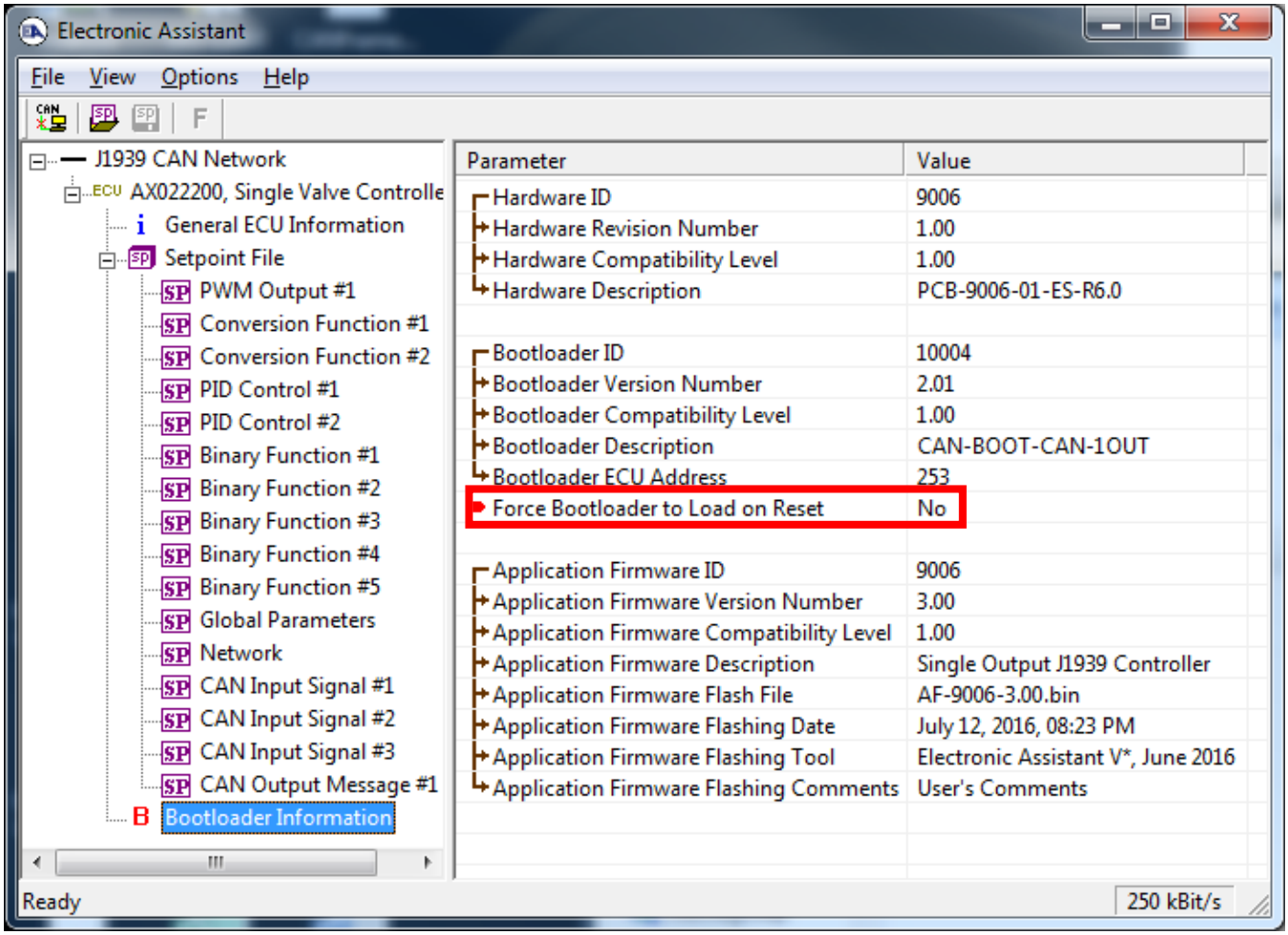


The controller setpoints are now programmed. The user can save the controller setpoint configuration into a setpoint file for the future reference or for programming the other controllers.

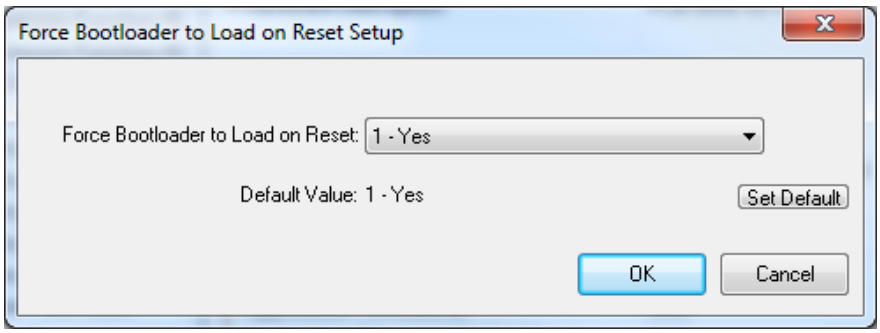
6 REFLASHING OVER CAN WITH THE AXIOMATIC EA BOOTLOADER

The AX022200 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.

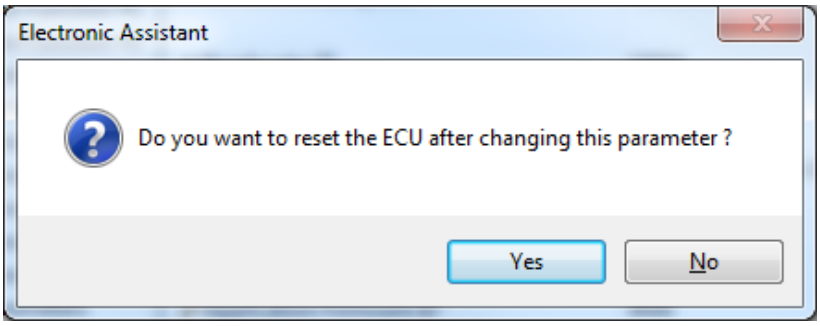
1. When the Axiomatic EA first connects to the ECU, the **Bootloader Information** section will display the following information.



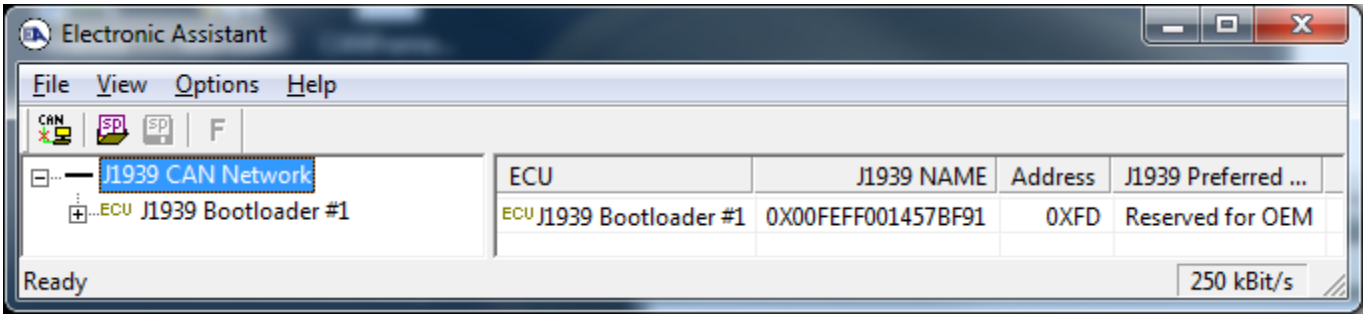
2. To use the bootloader to upgrade the firmware running on the ECU, change the variable **"Force Bootloader To Load on Reset**" to *Yes.*

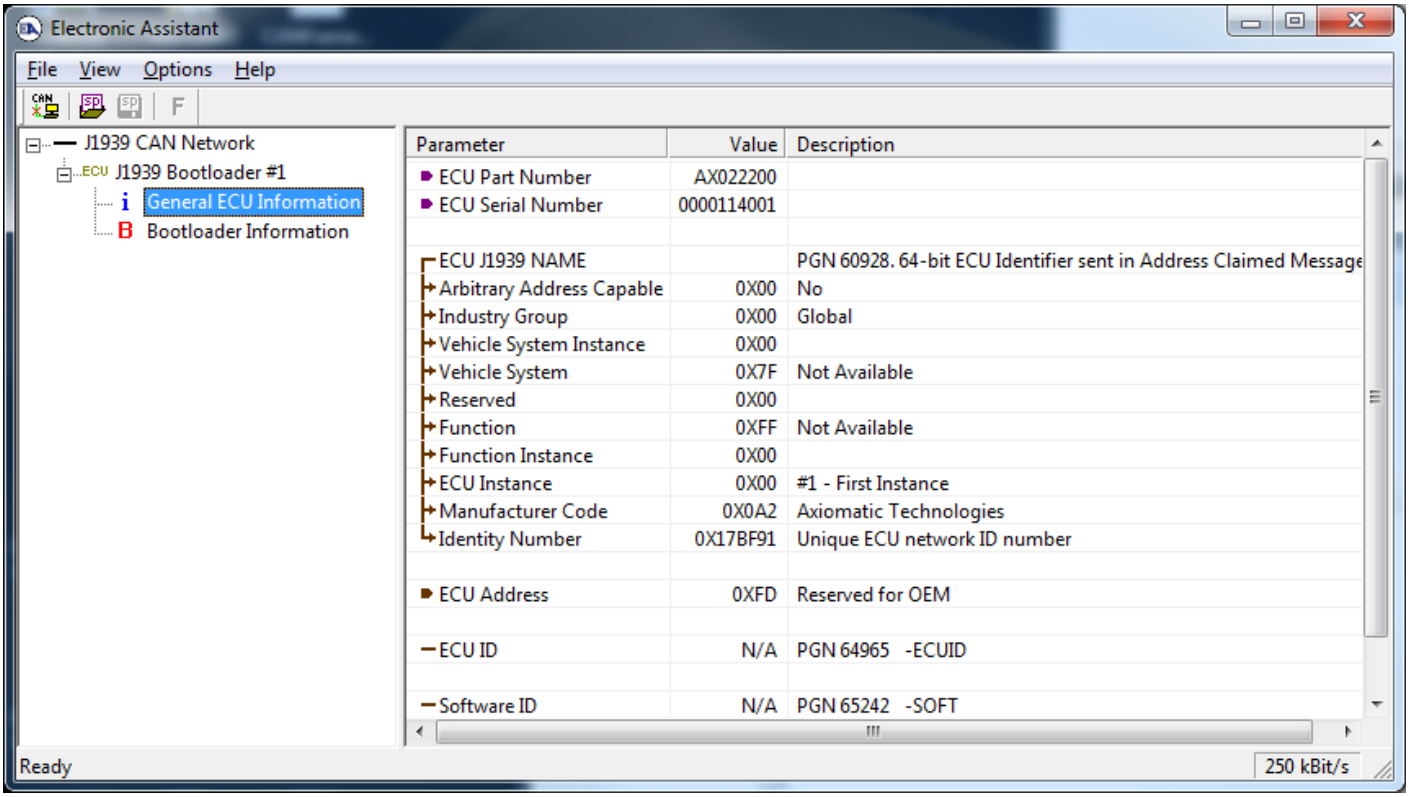


3. When the prompt box asks if you want to reset the ECU, select *Yes*.



4. Upon reset, the ECU will no longer show up on the J1939 network as an AX022200 but rather as **J1939 Bootloader #1**.

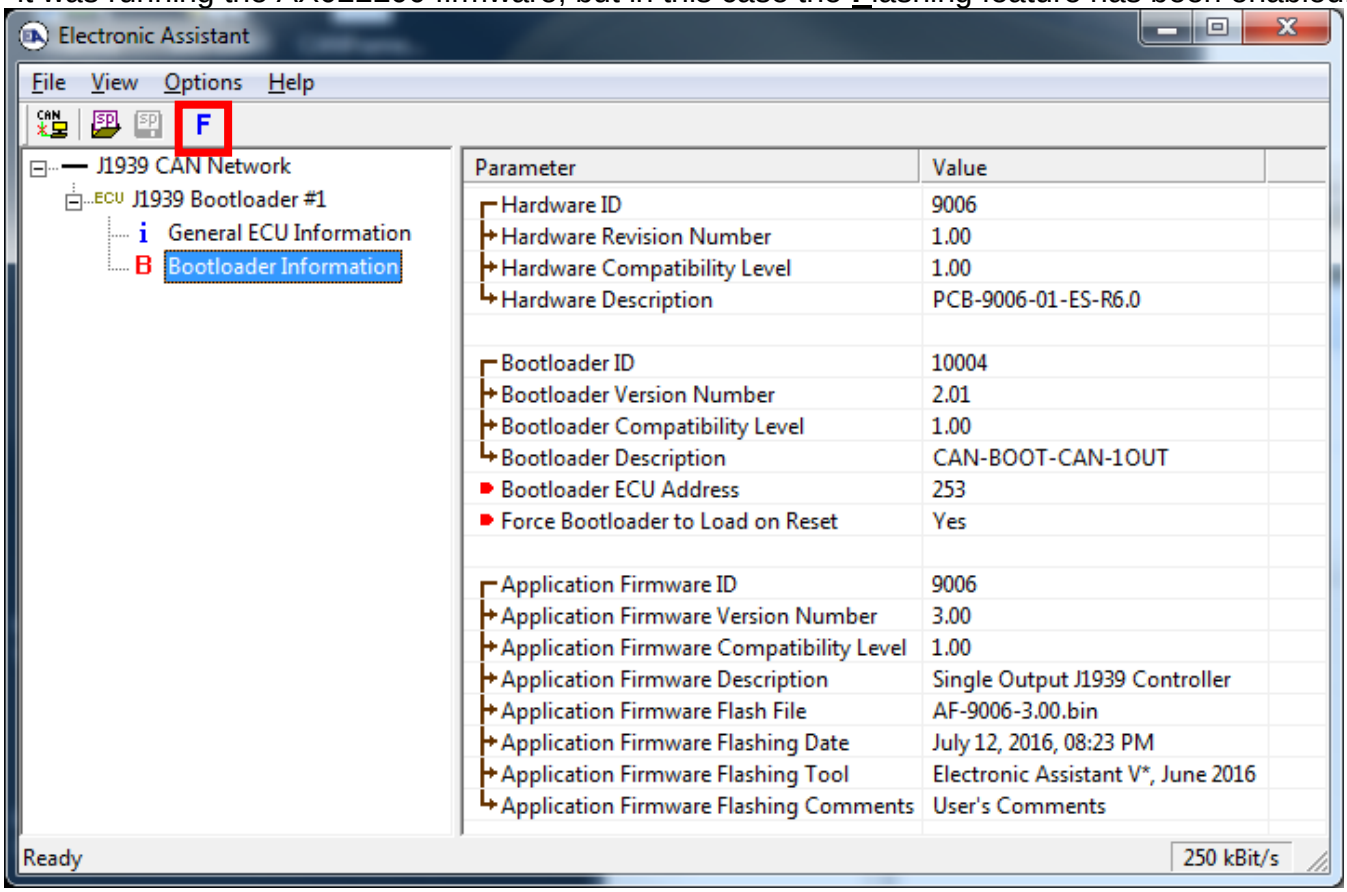




Note that the bootloader is NOT Arbitrary Address Capable. This means that if you want to have multiple bootloaders running simultaneously (not recommended) you would have to manually

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.

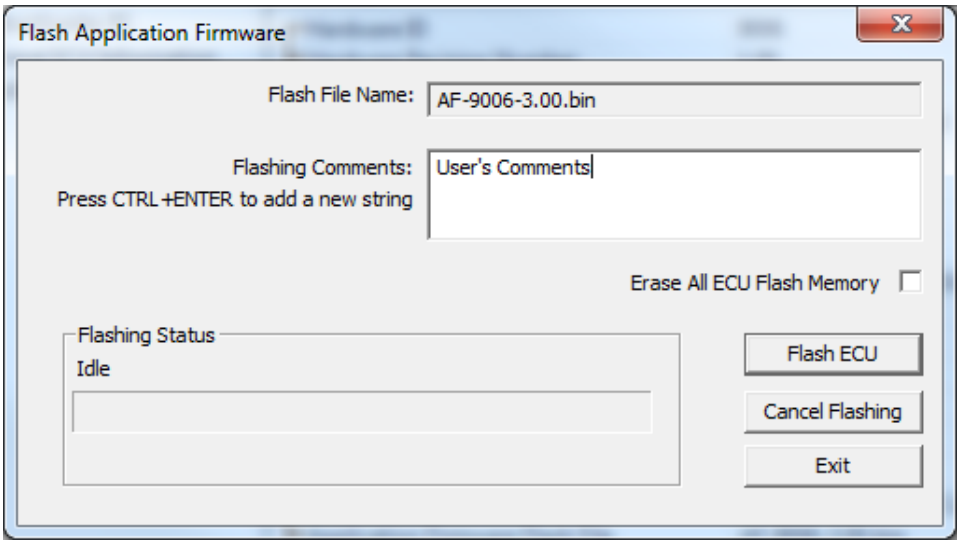
5. When the **Bootloader Information** section is selected, the same information is shown as when it was running the AX022200 firmware, but in this case the **F**lashing feature has been enabled.



6. Select the **F**lashing button and navigate to where you had saved the **AF-9006-x.yy.bin** file sent from Axiomatic. (Note: only binary (.bin) files can be flashed using the Axiomatic EA tool)

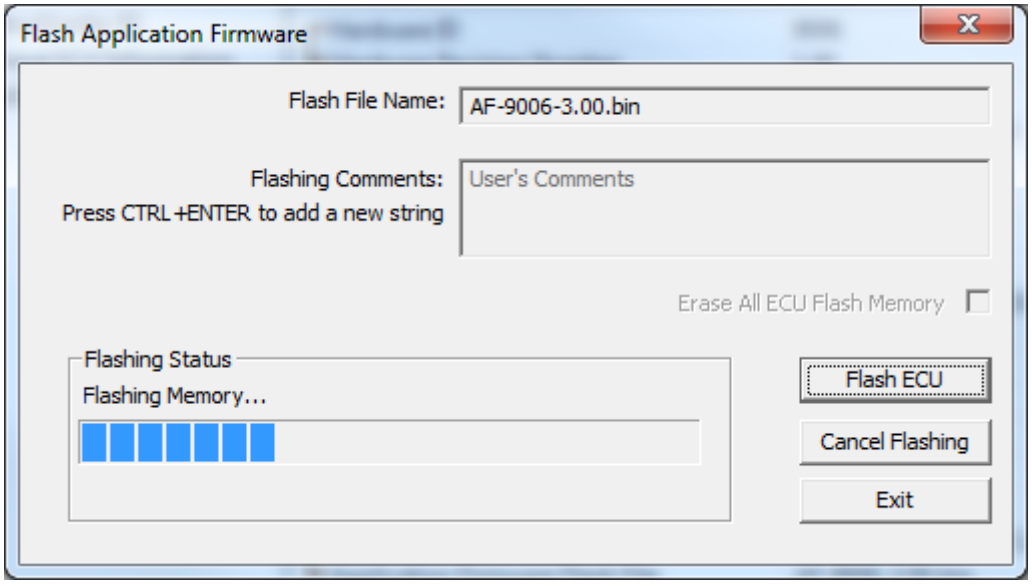
7. Once the Flash Application Firmware window opens, you can enter comments such as "Firmware upgraded by [Name]" if you so desire. This is not required, and you can leave the field blank if you do not want to use it.

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

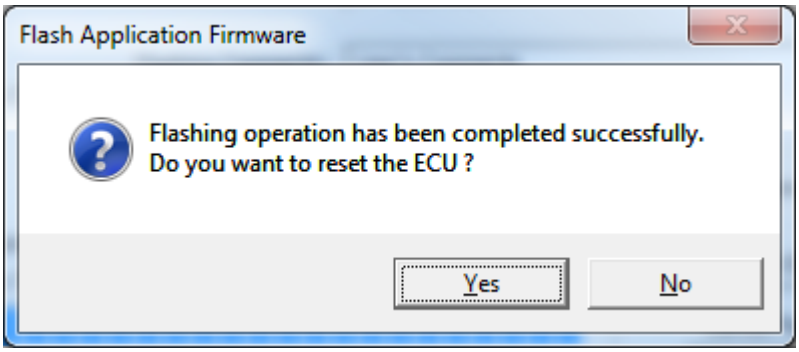


WARNING: Do not check the "Erase All ECU Flash Memory" box unless instructed to do so by your Axiomatic contact. Selecting this will erased ALL data stored in non-volatile flash. It will also erase any configuration of the setpoints that might have been done to the ECU and reset all setpoints to their factory defaults. By leaving this box unchecked, none of the setpoints will be changed when the new firmware is uploaded.

8. 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.



9. Once the firmware has finished uploading, a message will popup indicating the successful operation. If you select to reset the ECU, the new version of the AX022200 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 AX022200 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.

7 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/.

Input Specifications

Power Supply Input	12V. 24V or 48VDC nominal (9…60 VDC power supply range)
Protection	Transient and reverse polarity protection is provided.
CAN	SAE J1939 Signals and Control Commands The output can be controlled by one or several application specific single frame CAN messages.

Output Specifications

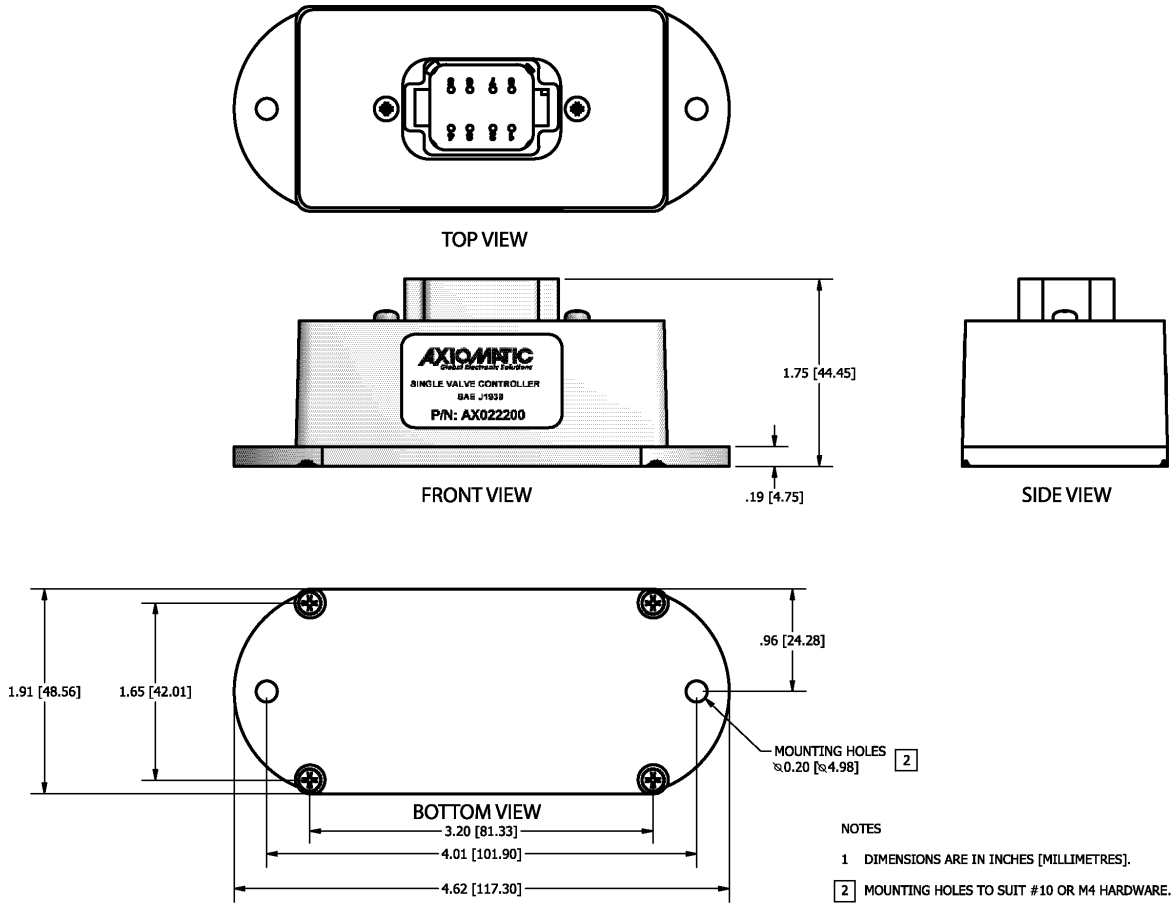
Output	1 PWM Proportional (up to 2A) or On/Off Output (up to 3A) High Side Switch, Current Sensing, Grounded Load The user can select the following options for output using the Axiomatic EA. • Output Disable • Discrete Output (On, Off) • Output Current (PID loop*, with current sensing) • Output Voltage • Output PWM Duty Cycle *Parameters are password protected. Overvoltage/undervoltage shutdown of the output load is provided.
Output Accuracy	Output Current mode ≤2% Output Voltage mode ≤3% Output PWM Duty Cycle mode ≤ 3%
Protection for Output + Terminal	Fully protected against short circuit to ground and short circuit to power supply rail. Unit will fail safe in the case of a short circuit condition, self-recovering when the short is removed.

General Specifications

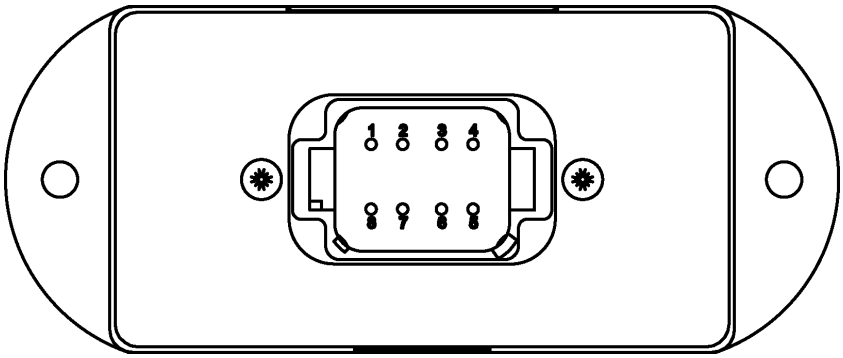
Microprocessor	32-bit, 128 KByte flash program memory
Control Logic	Standard embedded software is provided. Refer to Figure 1.0. (Application-specific control logic or factory programmed setpoints are available on request.) The controller belongs to a family of Axiomatic smart controllers with programmable internal architecture. This provides users with an ultimate flexibility, allowing them to build their own custom controller with a required functionality from a set of predefined internal functional blocks using the PC-based Axiomatic Electronic Assistant software tool. Application programming is performed through CAN interface, without disconnecting the controller from the user's system.
CAN	1 CAN port (SAE J1939), CANopen® is available on request.
Slew Rate	To adjust the controller to the CAN physical network, the slew rate can be configured as fast or slow. Refer to the User Manual for details.
Network Termination	It is necessary to terminate the network with external termination resistors. The resistors are 120 Ohm, 0.25W minimum, metal film or similar type. They should be placed between CAN_H and CAN_L terminals at both ends of the network.
User Interface	The controller setpoints can be viewed and programmed using the standard J1939 memory access protocol through the CAN port and the PC-based Axiomatic Electronic Assistant. For default setpoints, refer to the User Manual. The Axiomatic EA can store all controller setpoints 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 Axiomatic 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 Axiomatic Electronic Assistant for *Windows* operating systems comes with a royalty-free license for use on multiple computers. It requires an Axiomatic USB-CAN converter to link the device's CAN port to a *Windows*-based PC. **P/N: AX070502**, one of the Axiomatic Configuration KITs, includes the following. USB-CAN Converter P/N: AX070501 1 ft. (0.3 m) USB Cable P/N: CBL-USB-AB-MM-1.5 12 in. (30 cm) CAN Cable with female DB-9 P/N: CAB-AX070501 AX070502IN CD P/N: CD-AX070502, includes: Axiomatic Electronic Assistant software; Axiomatic EA & USB-CAN User Manual UMAX07050X; USB-CAN drivers & documentation; CAN Assistant (Scope and Visual) software & documentation; and the

	SDK Software Development Kit.
Quiescent Current Draw	Typical: 33 mA @ 12V, 19 mA @ 24V, 13 mA @ 48V
Weight	0.65 lbs. (0.29 kg)
Operating Conditions	-40 to 85 °C (-40 to 185 °F)
Storage Temperature	-55 to 125 °C (-67 to 257°F)
EMC Compliance	CE mark
Protection	IP67 rating for the product assembly NOTE: TE Deutsch connectors are rated at IP67 for submersion (3 ft., 0.9 m) and IP69K for high pressure, high temperature wash down applications.
Enclosure	Encapsulated Cast Aluminum housing with mounting holes 4.62 x 1.91 x 1.76 inches (117.30 x 48.56 x 44.73 mm) L x W x H including integral connector
Mounting	Mounting holes – The controller accepts 2 #10 or M4 screws. The CAN wiring is considered intrinsically safe. The power wires are not considered intrinsically safe and so in hazardous locations, they need to be located in conduit or conduit trays at all times. The module must be mounted in an enclosure in hazardous locations for this purpose. All field wiring should be suitable for the operating temperature range. Install the unit with appropriate space available for servicing and for adequate wire harness access (6 inches or 15 cm) and strain relief (12 inches or 30 cm).

Dimensional Drawing



Electrical Connections



8-pin plug (equivalent TE Deutsch P/N: DT15-8PA)

Mating plug KIT: Axiomatic P/N AX070112
(Equivalent to the TE Deutsch P/Ns: DT016-8SA socket, wedge W8S, 7 solid contact sockets 0462-201-16141 and 1 sealing plug 114017.)

16-18 AWG wire is recommended for use with sockets 0462-201-16141.

Use dielectric grease on the pins when installing the controller.
Wiring to these mating plugs must be in accordance with all applicable local codes. Suitable field wiring for the rated voltage and current must be used. The rating of the connecting cables must be at least 70°C. Use field wiring suitable for both minimum and maximum ambient temperature.

PIN #	Name	FUNCTION
1	POUT+	VALVE OUTPUT +
8	BAT+	POWER +
2	POUT-	VALVE OUTPUT -
7	BAT-	POWER -
3	CAN_SHLD	CAN Shield
6	CAN_L	CAN Low
4	--------	NOT USED
5	CAN_H	CAN High

8 REVISION HISTORY

Firmware	Manual Revision	Date	Author	Changes
1.xx	A	Dec 21, 2009	Olek Bogush	Initial release.
	B	Dec 31, 2009	Olek Bogush	Updated the Acronyms Section
2.xx	A	June 18, 2010	Olek Bogush	• In the PID Control functional block, the anti-windup algorithm was changed from simply clamping the integral part to stopping the integration process when the output of the functional block saturates and the control error contributes to its further saturation. • Added the number of the functional blocks available in the controller inside the graphical presentation of the functional blocks. • The inversion function formula Inv(...) was removed from all logical inputs of all functional blocks for simplicity. It was mentioned instead that the inputs can be inverted. • Updated Fig. 1…3. Added Conversion Functions on Fig. 1 (which were omitted). • Corrected Inverted Signal Value in a table describing signal inversion. • Changed some functional block drawings. • Clarified descriptions of the Conversion Function. • Clarified descriptions of the Binary Function. • Clarified descriptions of the PID Function. • Clarified the Disable Input in the PWM Output functional block. • J1939 standard document revisions were updated in the Network Support section. • Added hyperlinks to functional block names. • Updated a list of recommended Axiomatic EA versions for different firmware versions.
	B	Sept. 2, 2010	Olek Bogush	• The internal service port description and usage was clarified in Firmware Flashing section. • Changed Revision History presentation to include all previously released manuals.
-	-	Sept. 29, 2010	Amanda Wilkins	• Created User Manual from Programming Manual • Added in Technical Specifications
	C	Oct 14, 2010	Olek Bogush	• Explained discrete logical inputs in the Controller Architecture section. • Clarified the Reset Input of the PID Control functional block. • Corrected Introduction section.
	D	Nov. 29, 2010	Amanda Wilkins	• Proportional output rated at 2A.
	E	January 3, 2014	Amanda Wilkins	• EMC compliant (CE mark) – Revision B hardware
3.xx	F	July 12,	Gustavo	• Added Section for re-flashing over J1939

		2016	Del Valle	bootloader via Electronic Assistant
-	G	August 9, 2023	Kiril Mojsov	• Performed Legacy Updates

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Hydraulic Valve Controllers

Inclinometers, Triaxial

I/O Controls

LVDT Signal Converters

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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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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.

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All products to be returned to Axiomatic require a Return Materials Authorization Number (RMA#) from sales@axiomatic.com. Please provide the following information when requesting an RMA number:

- Serial number, part number
- Runtime hours, description of problem
- Wiring set up diagram, application and other comments as needed

DISPOSAL

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

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