Discrete Input/Output, SAE J1939

12 Digital Inputs, 8 Relay Outputs

USER MANUAL

P/N: AXDIO128

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VERSION HISTORY

Version	Date	Author	Modifications
2.0.0	October 9, 2007	Anna Murray	Initial Draft
2.0.1	November 13, 2007	Anna Murray	Updated Technical Specification to match datasheet and include UL Regulations
2.0.2	March 10, 2009	Manraj S. Pannu	Dimensional drawing updated. Registered trademark (®) added to Electronic Assistant.
2.0.3	April 19, 2010	A. Wilkins	Changed to p/n AXDIO128 to reflect new revision to power supply PCB. Updated relay output ratings to reflect new internal relays. Removed UL mark while file is being updated by UL for new power supply PCB.
2.0.4	September 22, 2010	A. Wilkins	Added UL mark and current accepted rating by UL (2A@125VAC and 2A@32VDC)
3.0.0	December 20, 2011	A. Wilkins	Updated for new UL rating to include 2A @277VAC and new hardware with EMC compliance
--	November 19, 2012	A. Wilkins	Added marine type approvals
--	October 22, 2015	A. Wilkins	Upgraded rating to IP67 based on testing

ACCRONYMS

ACK Positive Acknowledgement

DIO Discrete-Input-Output

DM Diagnostic Message (from SAE J1939 standard)

DTC Diagnostic Trouble Code

EA 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)

TABLE OF CONTENTS

References

J1939	Recommended Practice for a Serial Control and Communications Vehicle Network, SAE, January 2005
J1939/21	Data Link Layer, SAE, April 2001
J1939/71	Vehicle Application Layer, SAE, December 2004
J1939/73	Application Layer-Diagnostics, SAE, March 2004
J1939/81	Network Management, SAE, May 2003
TDAXDIO128	Technical Datasheet, Discrete Input/Output, Axiomatic Technologies 2007
UMAX07050X	User Manual, Electronic Assistant and USB-CAN, Axiomatic Technologies, 2007

It is assumed that the reader is familiar with J1939 terminology widely used in this document.

1. GENERAL

1.1. Introduction to AXDIO128 Features

The Discrete Input-Output Module (DIO) is designed to provide a simple interface between J1939 CAN network and discrete electronic devices in a power generator set or industrial environment. It can translate voltage levels on the twelve inputs into single-frame J1939 application specific PDU2 type messages[1]. The 8 relay outputs can either be controlled by any input on the DIO, or it can receive and processes single-frame application messages to control the relays.

The DIO is a versatile controller with a number of setpoints that will allow the user to configure it according to their application. The tool used to configure the unit is the Axiomatic Electronic Assistant® . The EA communicates with the DIO over the J1939 CAN bus, and uses Memory Access Protocol (MAP) to read/write each setpoint. Once the DIO has been setup as desired, the setpoints can be saved to a file, and flashed into other DIOs over the CAN bus.

Depending on how they set it up, the user can easily switch from having the relays respond to CAN commands, to using the discrete inputs to drive some or all of the outputs, to having all of them go to an individually preset state, or to disable them all. Changing from one method of controlling the relays to another can be done either by a “Mode Select” message that is received from the network, or by an override switch that manually sends the controller into another mode.

On the network side, DIO acts as an arbitrary address capable ECU, which can perform dynamic address allocation at the run time. It also provides all necessary network support required by J1939 standard. To reduce EMI, DIO CAN transceiver has a programmable slew rate.

The DIO supports a standard way of retrieving software identification through PGN65242 (-SOFT). For simplicity, a single-frame software ID is used.

There are two types of predefined structures for the data in the messages that are sent/received by the DIO for the I/O channels. With “compact” data, the structure is similar to PGN65241 (-AUXIO) where each channel has two bits per byte, resulting in up to four channels being read/controlled by one byte of data. However, if “expanded” data is used, each I/O channel is read/controlled by an individual byte in a message. (See section 2 for more information on the message data)

The PGNs that are used for “Input State”, “Relay Control” or “Mode Select” messages used/recognized by the DIO are individually configurable by the user.

A front panel bi-color LED indicator allows user to observe the current state of DIO and easily identify a normal operating condition and situations when there is a network error or absence of network traffic.

In case of an error on the network, power glitch or other emergency situation, DIO will self-recover immediately after the normal condition is restored. In case of a network error, the controller will automatically transition to “Discrete”, “Fault” or “Disabled” mode, as configured by the user. (See section 3 for more information on the different operation modes.)

1.2. LED Indicator

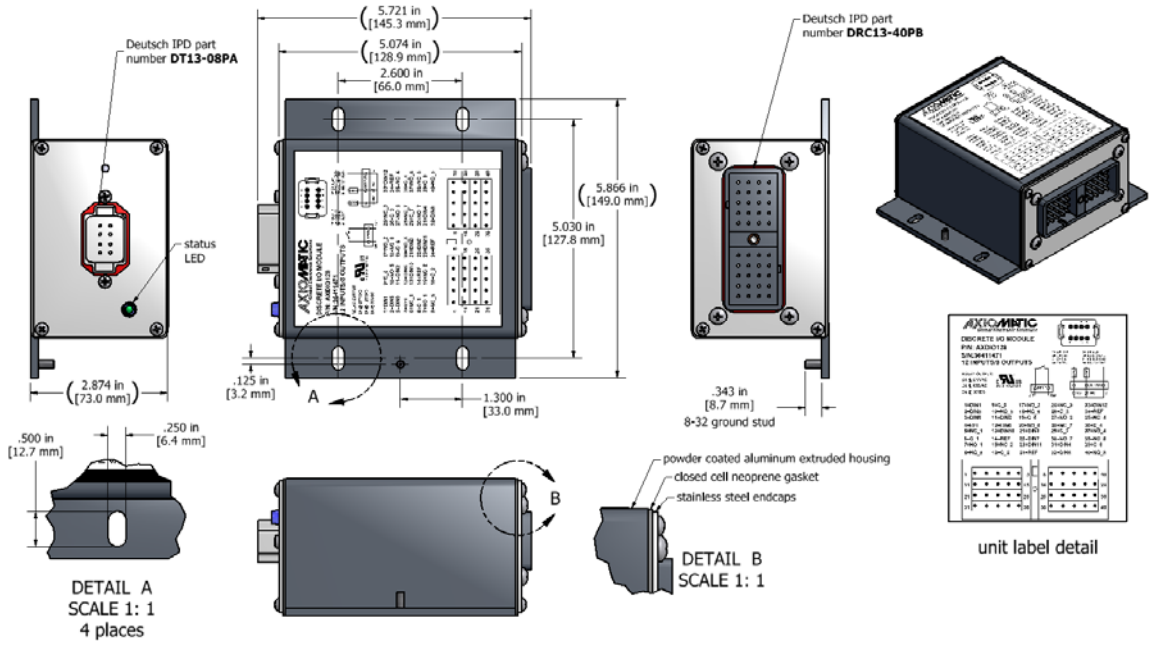
A red-green LED indicator is mounted on DIO front panel. It reflects internal state of DIO the following way:

Indicator	DIO State
Black	DIO is Off.
Green Constant Light	Normal operation. Input state PGN is sent continuously. Other traffic is present on the network.
Green Blinking	No network traffic. DIO is sending input state PGNs, but no other traffic is visible to it (due to message filtering only traffic sent to the global address and DIO related traffic can be reliably identified by the module).
Red Constant	Network Error. DIO is not able to send and receive messages due to a severe network error. It will constantly try to recover the network connection in this state.

1.3. Technical Specifications

Power	DIO is a battery powered device with special ability to withstand long time engine cranking. Reverse polarity and transient protected. • Supply voltage: 9-32 V. Nominal: 12Vdc and 24Vdc. • Typical supply current at 12V: 90 mA + 50mA per active relay • Typical supply current at 24V: 50 mA + 30mA per active relay
Digital Inputs	12 digital active-low inputs with pull-up resistors. • ON voltage level: 0-0.8 V • OFF voltage level: 3.75V to +BAT • Input resistance: more than 5 kOhm The inputs have internal over and under voltage protection.
Relay Outputs	8 Form C relay outputs. Resistive load: • 2A NO)/2 A (NC) at 277 VAC • 2 A (NO)/2 A (NC) at 125 VAC • 2 A (NO)/2 A (NC) at 30 VDC Dielectric strength: • 4,000 VAC, 50/60 Hz for 1 min between coil and contacts • 750 VAC, 50/60 Hz for 1 min between contacts of same polarity There is no special overcurrent/overvoltage protection on the relay outputs. The user is advised to provide a fast acting 3A fuse or an adequate external protection if necessary.
CAN	Bosch CAN protocol specification, Rev.2.0, Part A and B. Baud Rate: 250 bit/sec. Other requirements – according to SAE J1939 standard.
Indicator	Front panel Red-Green LED indicator.
Control Logic	User programmable functionality using Axiomatic Electronic Assistant®
User Interface	Electronic Assistant®, P/N: AX070502 Updates for the EA are found on www.axiomatic.com under the log-in tab.
CAN	1 CAN 2.0Bport, protocol SAE J1939
RS-232	1 RS-232 port available, ASCII Text Format, 115200 Baud Rate Data – 8 bit, Parity – None, Stop – 1 bit. Flow Control – Xon/Xoff. Short circuit protection to ground.
Operating Temperature	-40 to 85 ºC (-40 to 185 ºF)
Storage Temperature	-50 to 120 ºC (-58 to 248 ºF)
Humidity	Protected against 95% humidity non-condensing, 30 ºC to 60 ºC
Enclosure	Rugged aluminum housing, stainless steel end plates, neoprene gaskets Conformal coated PCB assemblies and partially encapsulated 145.30 x 149.00 x 73.00 mm (5.72 x 5.86 x 2.87”) L x W x H Connectors, Deutsch IPD P/N: 1 8-pin DT13-08PA, 1 40-pin DRC13-40PB
Protection	IP67 Pollution Degree 3 rating per UL508 *The marine type approval process tested to IP56.*
Vibration	4.3 G for off-engine mounting *The marine type approval process tested to 4.0 G per IEC 60068-2-6, Test Fc.*
Weight	2.73 lbs. (1.24 kg)
UL and cUL Compliance	UL508 (April 2010) (FTPM2) – Controls for Stationary Engine Driven Assemblies cUL C22.2 No. 14-10 (2010)
CE Compliance	2004/108/EC (EMC Directive) 2011/65/EU (RoHS Directive)
Marine Type Approval	Lloyd’s Register, DNV, ABS, RINA, GL, BV, CCS, IRS, RS *The AXDIO128 meets the environmental, EMC and vibration requirements of generator set applications in marine installations.*

1.4. Dimensions and Pinout

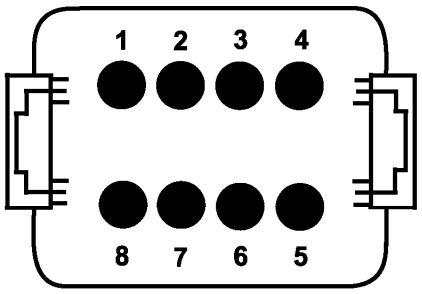


A mating plug kit, P/N: **AX070200**, is available. This kit includes the following items. *NB. The sealing plugs are only needed in cases where less than the 40 pins are required.*

Deutsch IPD P/N:	*Description:*
0462-201-16141	48 16AWG SOCKETS SOLID 16-20AWG WIRE 6mm
114017	24 SEALING PLUGS SIZE 12-16 CAVITIES 12-18 AWG
DRC16-40S	40-PIN PLUG, No Key
DT06-08SA	DT SERIES PLUG 8 CONTACT
W8S	WEDGELOCK FOR DT 8 PIN PLUG

These items are also available from a local Deutsch IPD distributor.
A crimping tool from Deutsch IPD is required to connect wiring to the sockets, P/N: HDT 48-00 or equivalent (not supplied).

Typical Connections – Power and CAN

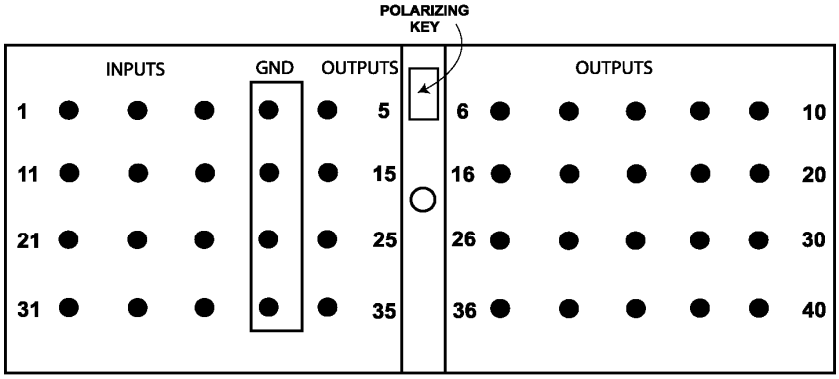


1 = PWR+ 5 = SHIELD
2 = CAN-H 6 = RS-232 GND
3 = CAN-L 7 = RS-232 TXD
4 = PWR- 8 = RS-232 RXD

FRONT VIEW
MODULE MOUNTED CONNECTOR
DEUTSCH P/N: DT13-08PA
(Mating plug is DT06-08SA with wedge W8S and sockets 0462-201-16141)

Typical Connections – Inputs and Outputs

FRONT VIEW OF
MODULE MOUNTED CONNECTOR
DEUTSCH P/N: DRC13-40PB

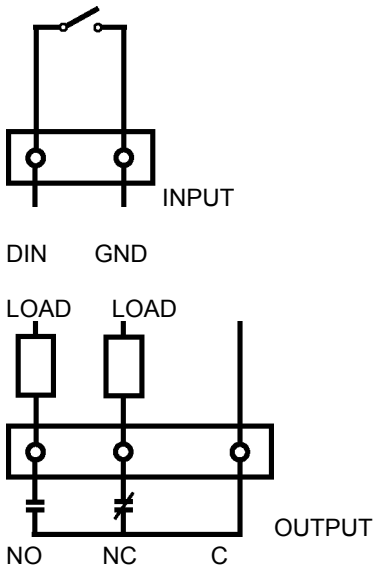


NO - Normally Open
NC - Normally Closed
C - Common

INPUTS	Pin
DIN1	1
DIN2	11
DIN3	21
DIN4	31
DIN5	2
DIN6	12
DIN7	22
DIN8	32
DIN9	3
DIN10	13
DIN11	23
DIN12	33
GND	4
GND	14
GND	24
GND	34

OUTPUTS	Pin
NC_1	5
C_1	6
NO_1	7
NC_2	15
C_2	16
NO_2	17
NC_3	25
C_3	26
NO_3	27
NC_4	35
C_4	36
NO_4	37
NC_5	8
C_5	9
NO_5	10
NC_6	18
C_6	19
NO_6	20
NC_7	28
C_7	29
NO_7	30
NC_8	38
C_8	39
NO_8	40

Connections – I/O



1.5. Installation Instructions

NOTES & WARNINGS

- Do not install near high-voltage or high-current devices.
- Ground the chassis for safety purposes and proper EMI shielding.
- Note the operating temperature range. All field wiring must be suitable for that temperature range.
- Install the unit with appropriate space available for servicing and for adequate wire harness access (15 cm) and strain relief (30 cm).
- Do not connect or disconnect the unit while the circuit is live, unless the area is known to be non-hazardous.

MOUNTING

The module is designed for mounting on the engine. If it is mounted without an enclosure, the DIO should be mounted vertically with connectors facing left and right to reduce likelihood of moisture entry.

The I/O wires and CAN communication cable are considered intrinsically safe. The power wires are not considered intrinsically safe.

Mask all labels if the unit is to be repainted, so label information remains visible.

Mounting ledges include holes sized for M6 or ¼ inch bolts. The bolt length will be determined by the end-user's mounting plate thickness. Typically 20 mm (3/4 inch) is adequate.

If the module is mounted off-engine, no wire or cable in the harness should exceed 30 meters in length. The power input wiring should be limited to 10 meters.

CONNECTIONS

Use the following Deutsch IPD mating plugs to connect to the integral receptacles. 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 85°C. Use field wiring suitable for both minimum and maximum ambient temperature.

Receptacle	Mating Socket (Refer to www.laddinc.com for more information on the wedgelock and contacts for this mating plug.)
Power and CAN bus: DT13-08PA	DT06-08SA with wedgelock W8S
I/O Interface Receptacle: DRC13-40PB	DRC16-40SB DRC18-40SB with sockets 0462-201-16141

Axiomatic offers a mating connector plug kit, P/N **AX070200**, that includes the 8 pin and 40 pin (unkeyed) plugs and sockets.

NOISE – ELECTRICAL CONNECTIONS

To reduce noise, separate all I/O wires from power wires. Shielded I/O wires will protect against ignition and injector noise.

GROUNDING

Protective Earth (PE) must be connected to the module's grounding lug to reduce the risk of electric shock. The conductor providing the connection must have a ring lug and wire larger than or equal to 4 mm^2 (12 AWG). The ring lug should be placed between the nut and a star washer.

All chassis grounding should go to a single ground point designated for the engine and all related equipment.

The ground strap that provides a low impedance path for EMI should be a ½ inch wide, flat, hollow braid, no more than 12 inches long with a suitable sized ring lug for the module's grounding lug. It may be used in place of the PE grounding conductor and would then perform both PE and EMI grounding functions.

SHIELDING

The I/O and CAN wiring should be shielded using a twisted conductor pair. All I/O wire shields should be terminated on the shield wire available on the 40-pin connector. The I/O wires should not be exposed for more than 50 mm (2 inches) without shielding. The shield may be cut off at the DIO end as it does not require termination at that end.

Shields can be AC grounded at one end and hard grounded at the opposite end to improve shielding effectiveness.

If the module is installed in a cabinet, shielded wiring can be terminated at the cabinet (earth ground), at the entry to the cabinet or at the DIO.

INPUT POWER

The main input to the power supply must be of low-impedance type for proper operation. If batteries are used, an alternator or other battery-charging device is necessary to maintain a stable supply voltage.

Central suppression of any surge events should be provided at the system level.

The installation of the equipment must include overcurrent protection between the power source and the DIO by means of a series connection of properly rated fuses or circuit breakers. Input power switches must be arranged external to the DIO.

The power input wiring should be limited to 10 meters.

Note the operating temperature range. All field wiring must be suitable for that temperature range.

INPUT WIRING

Wiring for the inputs must be shielded cable, 16 or 18 AWG. Cable lengths should be less than 30 meters. Shielding should be unbroken.

CAN WIRING

The CAN port is electrically isolated from all other circuits. The isolation is SELV rated with respect to product safety requirements. Refer to the CAN specification for more information.

Use CAN compatible cabling. J1939 cable is recommended as it is rated for on-engine use.

Shielded CAN cable is required. The DIO provides the CAN port shield connection ac coupled to chassis ground. The chassis ground stud located on the mounting foot must be tied directly to Earth Ground.

FUSING

When installing the unit, an external 3A, 32Vdc fuse is required.

NETWORK CONSTRUCTION

Axiomatic recommends that multi-drop networks be constructed using a “daisy chain” or “backbone” configuration with short drop lines.

TERMINATION

It is necessary to terminate the network. An external CAN termination is required. No more than 2 network terminations are recommended on any one network. Termination is a 121 Ohm, 0.25 W, 1% metal film resistor placed between CAN_H and CAN_L terminals at the end two units on the network.

2. NETWORK OPERATION

The DIO is designed to work either as a stand-alone module, or on J1939 CAN network. When connected to the network, it automatically recognizes network connection, claims a network address and can be configured to perform the following application tasks:

- Continuously broadcasts the current state of digital inputs using a proprietary InputPGN.
- Receives and processes OutputPGNs to control DIO output relays.

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

ISO/OSI Network Model Layer	J1939 Standard
Physical	• J1939/11 – Physical Layer, 250K bit/s, Twisted Shielded Pair. • J1939/15 - Reduced Physical Layer, 250K bits/sec, Un-Shielded Twisted Pair (UTP).
Data Link	**J1939/21 – Data Link Layer.**
	DIO supports Transport Protocol for Commanded Address messages (PGN 65240). It also supports responses on PGN Requests (PGN 59904).
Network	J1939, Appendix B – Address and Identity Assignments. **J1939/81 – Network Management.**
	DIO is an Arbitrary Address Capable ECU. It can dynamically change its network address in real time. DIO 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.**
	It transmits Software ID PGN65242 (-SOFT) only on request. DIO can constantly transmits the state of digital inputs in a user defined PDU2 PGN, set to proprietary B PGN 65440 by default. DIO can receive user defined PDU2 PGN controlling output relays, set to 65448 by default. DIO can receive mode select commands or send mode status feedback in a user defined PDU2 PGN, set to proprietary B PGN 65456 by default.
	J1939/73 – Application Layer – Diagnostics.
	DIO uses Memory Access Protocol (MAP) for setpoint programming from the Axiomatic Electronic Assistant®

2.1. J1939 NAME

The DIO uses a unique J1939 Name and a dynamically configurable network ECU Address to identify itself on the network. The DIO J1939 Name is a 64-bit parameter broadcast by the module in Address Claimed Messages (PGN 60928) during the address claim procedure or upon request. Data fields of the name are presented in the following table:

Name Field	Length	Value	Setpoint Type
Arbitrary Address Capable	1 bit	1 (Capable)	Read-Only
Industry Group	3 bit	0 (Global)	Read-Only
Vehicle System Instance	4 bit	0 (First Instance)	Read-Only
Vehicle System	7 bit	0 (Nonspecific System)	Read-Only
Reserved	1 bit	0	Read-Only
Function	8 bit	66 (I/O Controller)	Read-Only
Function Instance	5 bit	4 (Fifth Instance)	Read-Only
ECU Instance	3 bit	0 (First Instance)	User programmable through MAP
Manufacturer Code	11 bit	162 (Axiomatic Technologies Corp.)	Read-Only
Identity Number	21 bit	Calculated on the base of ECU Serial Number	Should be programmed only by the manufacturer and reflect a serial number printed on DIO label.

2.2. Network Address

During the first connection to a J1939 network, the DIO claims a user configurable ECU Address (default value 128 – Start of dynamic address assignment range for self-configurable ECUs). If the address is taken, the module tries to use another available network address until it finds a free one. This address will be stored in nonvolatile memory as a new ECU Address and will be claimed next time the module is connected to the network.

DIO network address can also be changed using Commanded Address Messages (PGN 65240) sent by any ECU on the network or using J1939 Memory Access Protocol.

2.3. Software Identifier

After the DIO establishes communication on the network, other ECUs can retrieve DIO software identifier through PGN65242 (-SOFT). For simplicity, DIO identification is sent in a single-frame message. The message has the following format:

Transmission Repetition Rate: On request
Data Length: 8 bytes
Data Page: 0
PDU Format: 254
PDU Specific: 218
Default Priority: 6
Parameter Group Number: 65242 ($0x00FEDA_{16}$)

Bit Start Position / Bytes	Length	Value	SPN Description	SPN
1	1 byte	0x01	Required by the standard.	965
			Number of Software Id Fields. Only one in this case since TP protocol is not supported	
2-4	3 bytes	ModuleID	Proprietary formatted field.	234
			Three-character module ID with first character at byte 2. Spaces should be put in place of unused positions. DIO module ID is 'DIO'.	
5	1 byte	HardwareRevisionCode	Proprietary formatted field.	
			ASCII symbol for BCD presentation of Hardware Revision Code.	
6	1 byte	SoftVersionMajorCode	Proprietary formatted field.	
			ASCII symbols for BCD presentation of Software Version Major Code.	
7	1 byte	SoftVersionMinorCode	Proprietary formatted field.	
			ASCII symbol for BCD presentation of Software Version Minor Code.	
8	1 byte	*	Required by the standard.	
			Software ID field delimiter.	

For example, DIO with hardware version 2 and software version V1.5 will reply on the PGN65242 request the following way:

Position	1	2	3	4	5	6	7	8
Character		D	I	O	2	1	5	*
Byte	0x01	0x44	0x49	0x4F	0x32	0x31	0x35	0x2A

2.4. Digital Input State Message

The DIO can be setup to transmit the state of the digital inputs through a proprietary InputPGN.

Transmission Repetition Rate: Configurable, Default 250ms
Data Length: 8 bytes
Data Page: 0
PDU Format: PDU2 format (240-255). 255 by default. Depends on PGN
PDU Specific: Depends on PGN
Default Priority: 6
Parameter Group Number: Configurable "InputPGN", Default 65440 [0xFFA0]

The InputPGN is always available on request. If the transmission repetition rate is set to zero, it is only available on request.

The content of the message depends on a configurable parameter that tells the DIO how is data is to be sent. There are two methods of sending data on the Digital Input State message, either in a “Compact” or “Expanded” format.

COMPACT DATA

Compact data is sent using a proprietary format similar to PGN65241 (-AUXIO). Here, 4 separate input channels are sent on the same Byte in the message, as per the table below.

Bit Start Position / Bytes	Length	SPN Description	SPN
1.1	2 bits	Input #04	Not assigned
1.3	2 bits	Input #03	Not assigned
1.5	2 bits	Input #02	Not assigned
1.7	2 bits	Input #01	Not assigned
2.1	2 bits	Input #08	Not assigned
2.3	2 bits	Input #07	Not assigned
2.5	2 bits	Input #06	Not assigned
2.7	2 bits	Input #05	Not assigned
3.1	2 bits	Input #12	Not assigned
3.3	2 bits	Input #11	Not assigned
3.5	2 bits	Input #10	Not assigned
3.7	2 bits	Input #09	Not assigned
4-8	5 bytes	Reserved (always set to 0xFF)	Not assigned

EXPANDED DATA

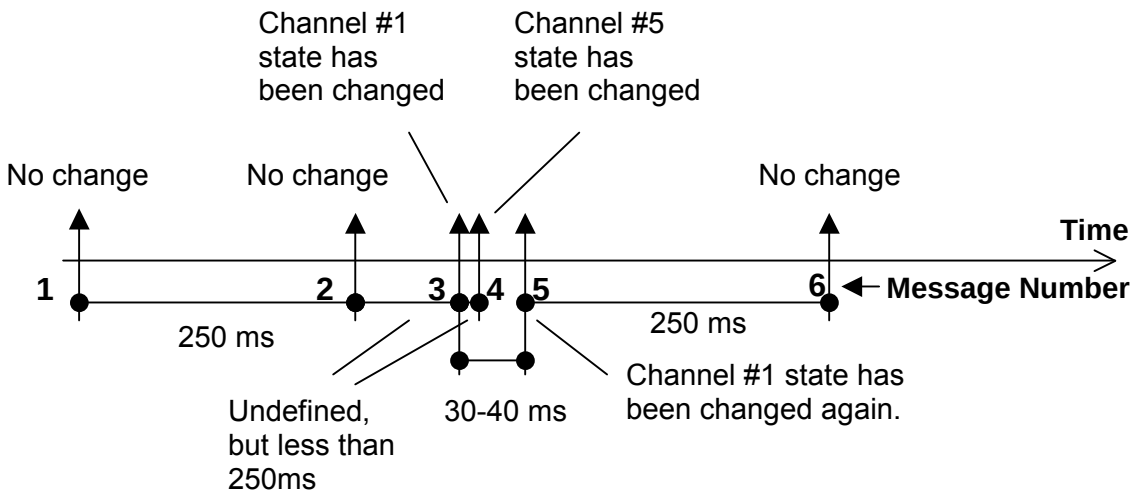
Expanded data is sent using 1 Byte/Input. Since there are twelve inputs on the DIO, the upper 4 channels are actually sent on a different PGN, which is the “Input PGN” + 1. The data is sent as per the table below

PGN	Byte Index	SPN Description	SPN
InputPGN	0	Input #1	Not assigned
InputPGN	1	Input #2	Not assigned
InputPGN	2	Input #3	Not assigned
InputPGN	3	Input #4	Not assigned
InputPGN	4	Input #5	Not assigned
InputPGN	5	Input #6	Not assigned
InputPGN	6	Input #7	Not assigned
InputPGN	7	Input #8	Not assigned
InputPGN+1	0	Input #9	Not assigned
InputPGN+1	1	Input #10	Not assigned
InputPGN+1	2	Input #11	Not assigned
InputPGN+1	3	Input #12	Not assigned
InputPGN+1	4 to 7	Reserved (always set to 0xFF)	Not assigned

In either data conversion method, each Input SPN can be in one of the following states:

Name	Value
Input OFF	0
Input ON	1
Error Indicator	2 – Not used
Not available	3 – Not used

If digital inputs do not change their states, the InputPGN is sent continuously at the configured transmission rate. If state of any digital input changes from 0 to 1 or from 1 to 0, a new message reflecting this change is sent immediately without the transmission delay. However, a debouncing control will not allow a digital input to change its state faster than once in 30-40 ms, see the following example:



2.5. Relay Control Message

The DIO can be setup to response to a control message received from the J1939 bus that was sent on a proprietary OutputPGN.

Transmission Repetition Rate:	Configurable, Default 250ms (Expected transmission rate from external ECUs)
Data Length:	8 bytes
Data Page:	0
PDU Format:	PDU2 format (240-255). 255 by default. Depends on PGN
PDU Specific:	Depends on PGN
Default Priority:	6
Parameter Group Number:	Configurable “OutputPGN”, Default 65448 [0xFFA8]

The “OutputPGN” is available on request, and when requested, the DIO will send the states of each relay at the time the request was received.

How the DIO interprets the content of the message depends on a configurable parameter that tells the DIO how is data is to be received. There are two methods of receiving data on the Relay Control Message, either in a “Compact” or “Expanded” format.

COMPACT DATA

Compact data is received using a proprietary format similar to PGN65241 (-AUXIO). Here, 4 separate output channels are controlled on the same Byte in the message, as per the table below.

Bit Start Position / Bytes	Length	SPN Description	SPN
1.1	2 bits	Output #04 Commanded State	Not assigned
1.3	2 bits	Output #03 Commanded State	Not assigned
1.5	2 bits	Output #02 Commanded State	Not assigned
1.7	2 bits	Output #01 Commanded State	Not assigned
2.1	2 bits	Output #08 Commanded State	Not assigned
2.3	2 bits	Output #07 Commanded State	Not assigned
2.5	2 bits	Output #06 Commanded State	Not assigned
2.7	2 bits	Output #05 Commanded State	Not assigned
3-8	6 bytes	Reserved (not processed)	Not assigned

When the DIO receives a request for the OutputPGN, in Compact data mode it will respond with the state of 4 separate output channels on the same Byte in the message, as per the table below.

Bit Start Position / Bytes	Length	SPN Description	SPN
1-6	6 bytes	Reserved (always set to 0xFF)	Not assigned
7.1	2 bits	Output #04 Actual State	Not assigned
7.3	2 bits	Output #03 Actual State	Not assigned
7.5	2 bits	Output #02 Actual State	Not assigned
7.7	2 bits	Output #01 Actual State	Not assigned
8.1	2 bits	Output #08 Actual State	Not assigned
8.3	2 bits	Output #07 Actual State	Not assigned
8.5	2 bits	Output #06 Actual State	Not assigned
8.7	2 bits	Output #05 Actual State	Not assigned

EXPANDED DATA

Expanded data is received using 1 Byte/Output. The data is interpreted as per the table below

PGN	Byte Index	SPN Description	SPN
OutputPGN	0	Output #01 Commanded State	Not assigned
OutputPGN	1	Output #02 Commanded State	Not assigned
OutputPGN	2	Output #03 Commanded State	Not assigned
OutputPGN	3	Output #04 Commanded State	Not assigned
OutputPGN	4	Output #05 Commanded State	Not assigned
OutputPGN	5	Output #06 Commanded State	Not assigned
OutputPGN	6	Output #07 Commanded State	Not assigned
OutputPGN	7	Output #08 Commanded State	Not assigned

When the DIO receives a request for the OutputPGN, in Expanded data mode it will respond with the state of each output channels on its own Byte in the message, as per the table below.

PGN	Byte Index	SPN Description	SPN
OutputPGN	0	Output #01 Actual State	Not assigned
OutputPGN	1	Output #02 Actual State	Not assigned
OutputPGN	2	Output #03 Actual State	Not assigned
OutputPGN	3	Output #04 Actual State	Not assigned
OutputPGN	4	Output #05 Actual State	Not assigned
OutputPGN	5	Output #06 Actual State	Not assigned
OutputPGN	6	Output #07 Actual State	Not assigned
OutputPGN	7	Output #08 Actual State	Not assigned

In either data conversion method, each Output SPN can be in one of the following states:

Name	Value
Relay OFF	0
Relay ON	1
Error Indicator	2 – Not Processed
Not available	3

If the DIO is configured to expect the OutputPGN message at a particular update rate, the message must be present on the bus in that timeframe in order to keep the controlled relays energized. It is assumed, that two different ECUs will not try to control the same relay independently; it is against J1939 standard and DIO has no support to handle this situation.

Normally, once energized by Relay ON command in OutputPGN message, a relay should be de-energized by Relay OFF command. The expected value of the delay between a command, sent through the network, and the action on the command is around 20ms and depends on: relay switching, network transmission and message processing delays.

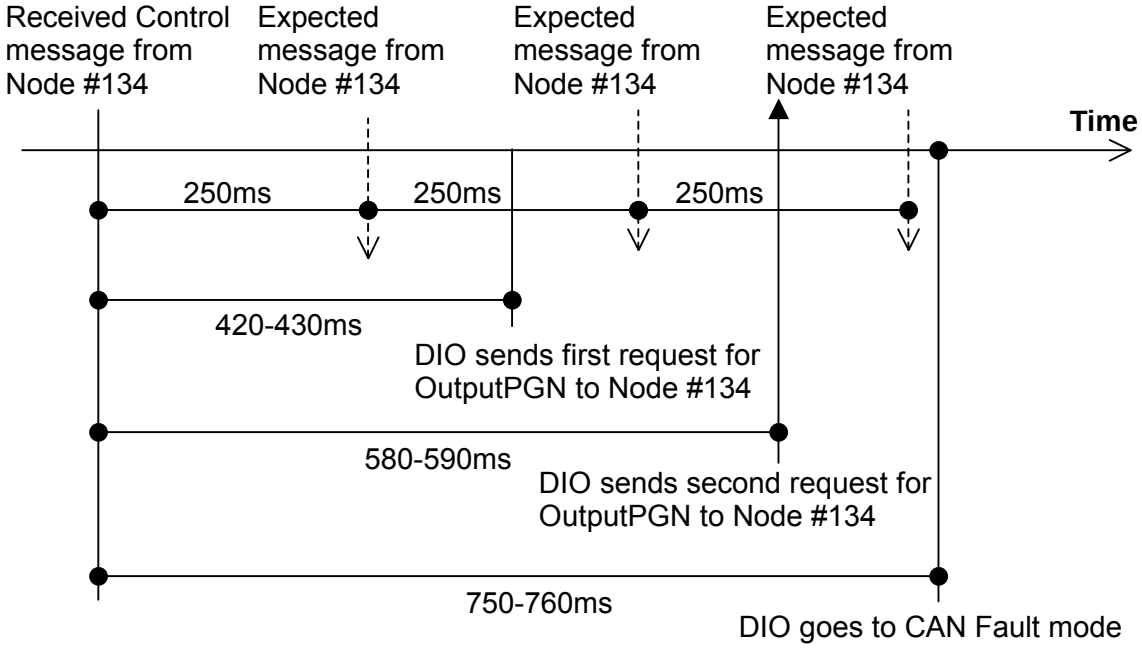
In case a relay was energized, but DIO has not received any Relay ON or Relay OFF messages for approximately three time the expect receive rate, it will automatically go into the configured "CAN Fault" mode. (See Section 3 for more information) To avoid situation when a control message is lost due to very heavy network traffic, the DIO will request twice the OutputPGN from the node controlling the relay before going into the fault mode.

The times at which the DIO will send the requests for the OutputPGN are determined by the following formula (where ETR = Expected Transmission Rate).

Request 1 sent at $\frac{1}{3}(3\text{xETR} - \text{ETR}) + \text{ETR}$

Request 2 sent at $\frac{2}{3}(3\text{xETR} - \text{ETR}) + \text{ETR}$

For example, if the DIO expects to get the Relay Control message every 250ms (default), then it will request the OutputPGN at approximately 420-430ms and 580-590ms, before going into the configured CAN Fault mode in approximately 750-760ms after the last message was received.



2.6. Mode Select/Status Message

The DIO can operate in one of four different modes at any given time. (See Section 3 for more information about the different modes.) Sending a "Mode Select" message to DIO can automatically cause the DIO to change the mode. The message would be received on a proprietary ModePGN.

Transmission Repetition Rate:	Configurable, Default 250ms (Expected transmission rate from external ECUs for Select) (Transmission rate from DIO for Status)
Data Length:	8 bytes
Data Page:	0
PDU Format:	PDU2 format (240-255). 255 by default. Depends on PGN
PDU Specific:	Depends on PGN
Default Priority:	6
Parameter Group Number:	Configurable "ModePGN", Default 65456 [0xFFB0]

By default, the **first byte** of the ModePGN message will be the command to the DIO for the new mode. The different modes will be as per the table below. All other bytes in the message will be ignored, and should be sent with 0xFF.

Name	Value
Normal	0
Discrete	1
Fault	2
Disabled	3

The DIO will try to enter the new mode right away. The DIO can be configured to either acknowledge the Mode Select message, in which case it will send a positive acknowledgement (ACK) upon a successful transition to the new mode. If it cannot enter the new mode for some reason (i.e. override switch is on), it will send a negative acknowledgement (NAK).

Alternately, the DIO can be configured to respond with the Mode Status message, in which case the actual mode of the DIO will be sent back upon receiving the Mode Select message.

By default, the Mode Status message will be sent on the **second byte** of the ModePGN message. All other bytes in the message are not used, will be sent with 0xFF.

The Mode Status message could be configured to be transmitted periodically. It is always available on request of the ModePGN. If the transmission repetition rate is set to zero, it is only available on request.

The DIO can be configured to expect to see the Mode Select message within a certain timeframe. As with the Relay Control message, if it is not seen within the expected period, the DIO will send two requests for the ModePGN at times determined by the formulas shown in section 2.5. If the Mode Select message was not seen within three times the expected transmission rate, the DIO will automatically enter the CAN Fault mode, as described in Section 3.

3. OPERATIONAL MODES

There are four types of operational modes in which the DIO can operate. The control of the relay outputs will vary, depending on which mode the DIO is in at any given time.

3.1. Normal Mode (aka CAN Mode)

Control of the relays from the J1939 CAN bus, as described in Section 2.5, can only occur in this mode. In all other modes, CAN messages will have no effect on the relays. Even in this mode, a relay will only respond to the Relay Control message if and only if the "Control Input" was set to "J1939 Command"

If the "Control Input" for any given output is set to any one of the inputs on the DIO, then that output will be turned ON/OFF by the input. In this mode, an individual output can only be controlled either by the Relay Control message OR a discrete input. However, a combination of both methods is possible between all the outputs.

There are four ways in which the output can be configured to respond to the state of the control input, (be it from a discrete input or the J1939 Relay Control message) as shown below.

Name	Value
Disabled	0
Normal ON/OFF	1
Inverted ON/OFF	2
Latched	3

- In "Disabled", the relay is always OFF.
- In "Normal ON/OFF", the relay turns ON when the control input is ON, and OFF with the input is OFF.
- In "Inverted ON/OFF", the relay turns OFF when the control input is ON, and ON with the input is OFF.
- In "Latched", the output will change state every time the control input transitions from OFF to ON.

In this mode, the outputs can also be Enabled/Disabled by a discrete input on the DIO. The default configuration does not use an "Enable Input", but the option is available if necessary.

Each output has four setpoints associated with it that determine the "Control Input", the "Control Response", the "Enable Input" and the "Enable Response" for that relay.

3.2. Discrete Mode

Discrete mode is identical to normal mode, except the relays can ONLY be controlled by a discrete input on the DIO. Relay Control messages received from the J1939 bus are ignored.

Each output has two additional setpoints associated with it that determine the "Control Input" and the "Enable Input" for that relay while in discrete mode.

3.3. Fault Mode

In fault mode, the relay is driven to a particular state, as defined by a configurable “Fault Mode State” setpoint available for each output on the DIO.

3.4. Disabled Mode

In disabled mode, all output relays are de-energized.

3.5. Transitioning Between Modes

There are three ways in which the DIO will transition between operational modes. The startup mode of the DIO is determined by a configurable setpoint “Startup Mode”

1. The DIO receives a valid Mode Select message from the J1939 bus as described in Section 2.6. If possible, the DIO enters the new operational mode immediately.

2. A CAN network error is detected. This could be either a sever error, where the DIO cannot send or receive any messages, or from a timeout condition caused by not having received the Relay Control and/or the Mode Select messages within the expected timeframes. Should a CAN error occur, the DIO will enter the user configurable “Transitional Mode” if the “Transition Time” is a non-zero value. After the transition time elapses, it will enter the “Default Mode” and stay in it until a valid Mode Select message has been received. (For Transition Time = 0, the Default mode will automatically be entered)

3. The “Override Input” is ON in which case the DIO will immediately enter the “Override Mode.” When the override input goes OFF, the DIO will revert back to the “Startup Mode.”

4. ECU SETPOINTS

4.1. Network Setpoints

There are three setpoints that are associated with the network and how the ECU behaves on the J1939 bus.

Name	Range	Default	Notes
ECU Instance Number	0 to 7	0	J1939 NAME Parameter
ECU Address	0 to 253	128 [0x80]	
Slew Rate	0 to 1	1	0 = Slow, 1 = Fast

4.2. Output Setpoints

There are seven setpoints per channel that are associated with the output and how it responds.

Name	Range	Default	Notes
Control Input	1 to 13 Input 1 to Input 12 13: J1939 Command	13: J1939 Command	In Normal Mode, the output relays would be controlled from the CAN bus
Control Response	0: Disabled 1: Normal On/Off 2: Inverted On/Off 3: Latched	1: Normal On/Off	See section 3.1
Enable Input	0 to 12 0: Enable Not Used Input 1 to Input 12	0: Enable Not Used	Must be a discrete input on the DIO
Enable Response	0: Not Used 1: Input ON=Enabled 2: Input ON=Disabled	0: Not Used	
Output State in Fault Mode	0 or 1	0	0 = OFF, 1 = ON
Control Input in Discrete Mode	1 to 12 Input 1 to Input 12	1 to 8	Input number is the same as the output number (i.e. Input 4 controls Output 4)
Enable Input in Discrete Mode	0 to 12 0: Enable Not Used Input 1 to Input 12	0: Enable Not Used	Must be a discrete input on the DIO

4.3. Logic Setpoints

There are eighteen setpoints that are grouped under the heading “Logic.” How they affect the behaviour of the DIO are described in detail in earlier sections of this document.

Name	Range	Default	Notes
J1939 Data Representation	0: Compact 1: Expanded	1: Expanded	See section 2.4 and 2.5
Digital Input PGN	65280 to 65520 0xFF00 to 0xFFF0	65440 0xFFA0	aka “InputPGN”, see section 2.4
Digital Output PGN	65280 to 65520 0xFF00 to 0xFFF0	65448 0xFFA8	aka “OutputPGN” , see section 2.5
Mode Select/Status PGN	65280 to 65520 0xFF00 to 0xFFF0	65456 0xFFB0	aka “ModePGN”, see section 2.6
Mode Select Response	0: No Response 1: Send ACK Message 2: Send Mode Status	0: No Response	See section 2.6
Mode Select Data Index	0 to 7	0	See section 2.6
Mode Status Data Index	0 to 7	1	See section 2.6
Input Status Send Rate	0 to 60000 [ms]	250 [ms]	See section 2.4
Output Status Send Rate	0 to 60000 [ms]	0 [ms]	On Request Only, See section 2.5
Mode Status Send Rate	0 to 60000 [ms]	0 [ms]	On Request Only, See section 2.6
Relay Control Message Receive Rate	0 or 250 to 60000 [ms]	250 [ms]	See section 2.5, If zero, the DIO will never enter CAN Fault mode because it did not receive this message
Relay Control Message Receive Rate	0 or 250 to 60000 [ms]	0 [ms]	See section 2.6, If zero, the DIO will never enter CAN Fault mode because it did not receive this message
Startup Operation Mode	0: Normal 1: Discrete 2: Fault 3: Disabled	1: Discrete	The default operation of the DIO is for all the outputs to be controlled by the inputs on the module
Mode Override Input	1 to 12 Input 1 to Input 12	Input 9	Must be a discrete input on the DIO
Override Mode	1: Discrete 2: Fault 3: Disabled	3: Disabled	By default, when Input 9 comes on, all the relays are de-energized
Transition Mode when CAN Fault Detected	1: Discrete 2: Fault 3: Disabled	2: Fault	Outputs are driven to the Fault State
Default Mode when CAN Fault Detected	1: Discrete 2: Fault 3: Disabled	3: Disabled	By default, a CAN Fault will de-energize all the relays (while in Normal Mode only)
Transition Time when CAN Fault Detected	0 to 60000 [ms]	0 [ms]	When zero, the DIO automatically goes to the Default Fault mode

5. USING ECU WITH AXIOMATIC ELECTRONIC ASSISTANT®

5.1. Installing the Electronic Assistant®

For instruction on how to install and use the Axiomatic Electronic Assistant® ., refer to User Manual AX07050X. The EA describes the AXDIO128 as p/n DIO128.

5.2. Screen Captures

Image 5.1: CAN port was opened, programmer has recognized the Axiomatic ECU

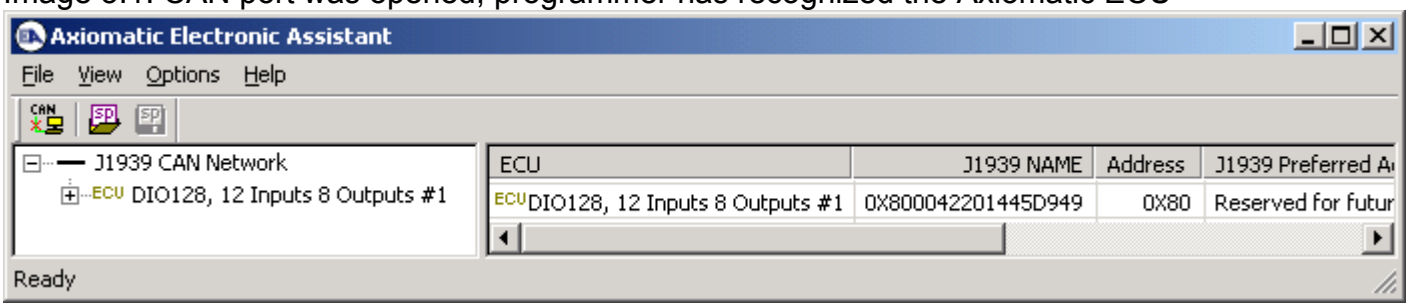


Image 5.2: ECU Name properties displayed

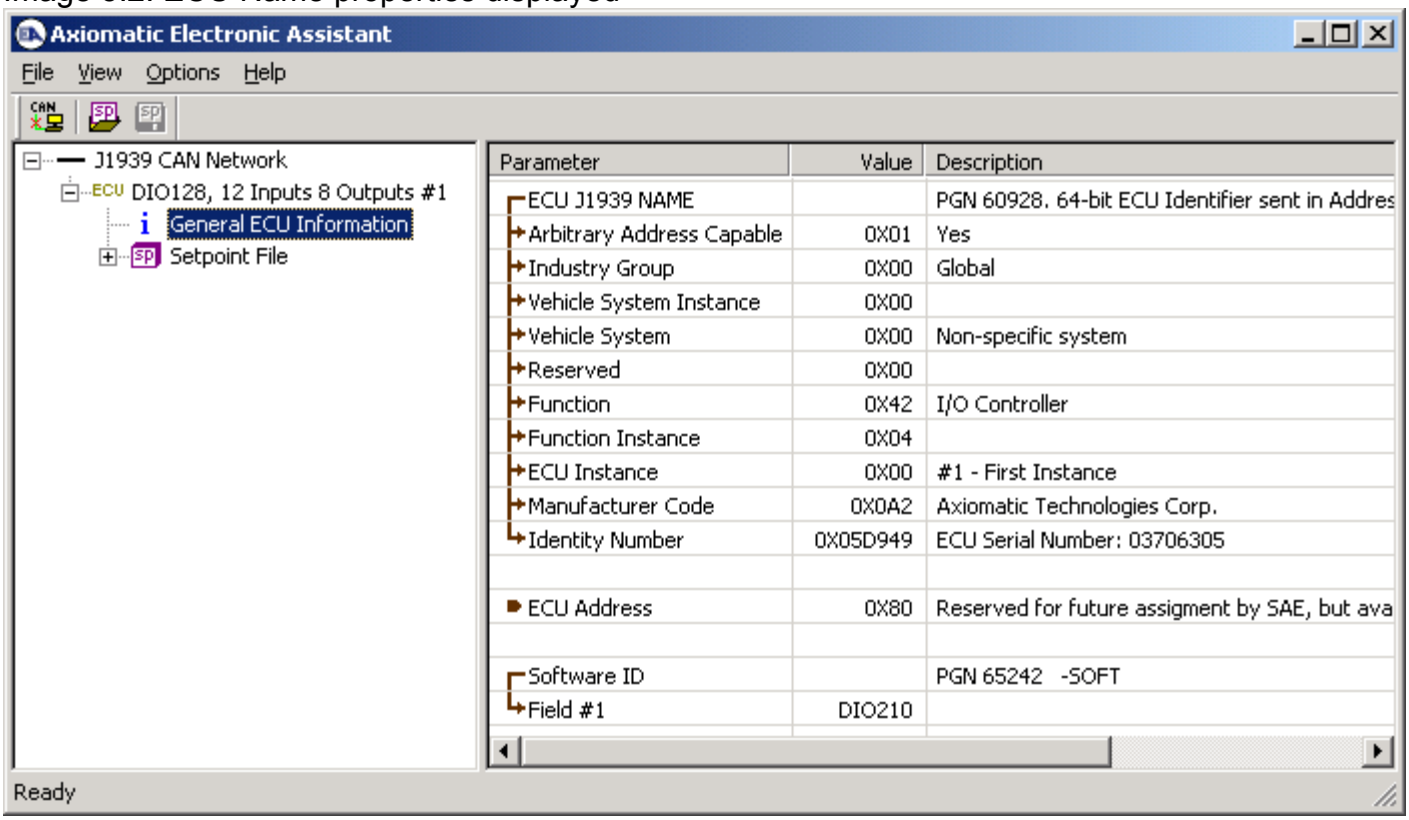


Image 5.3: Network Setpoints

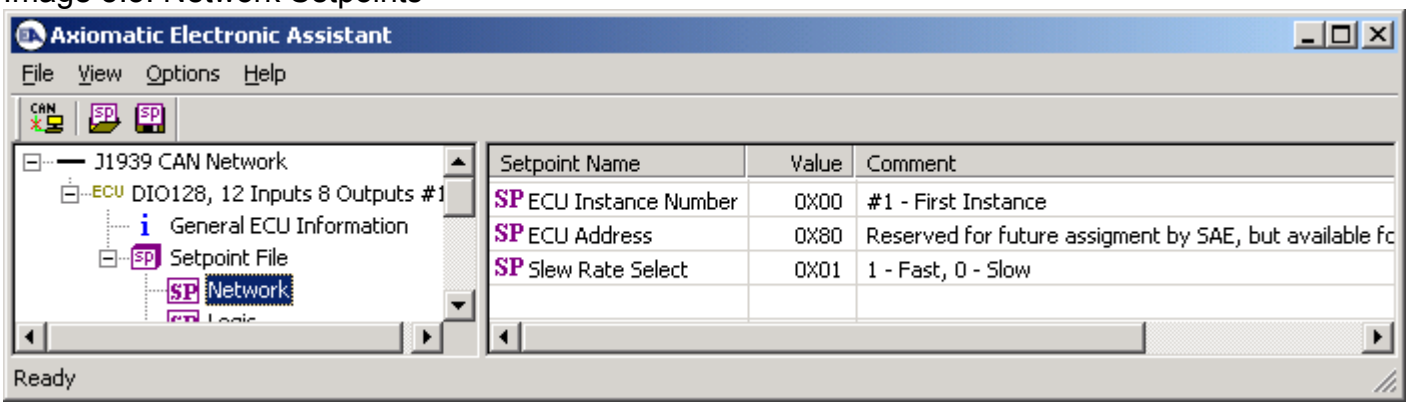


Image 5.4: Output Setpoints

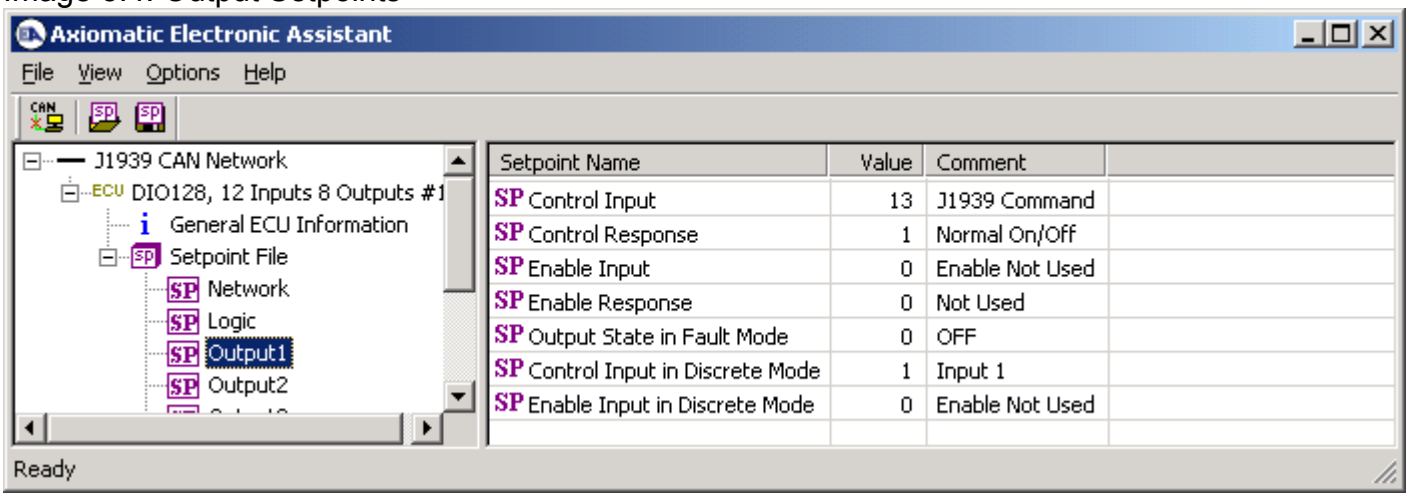


Image 5.5: Logic Setpoints

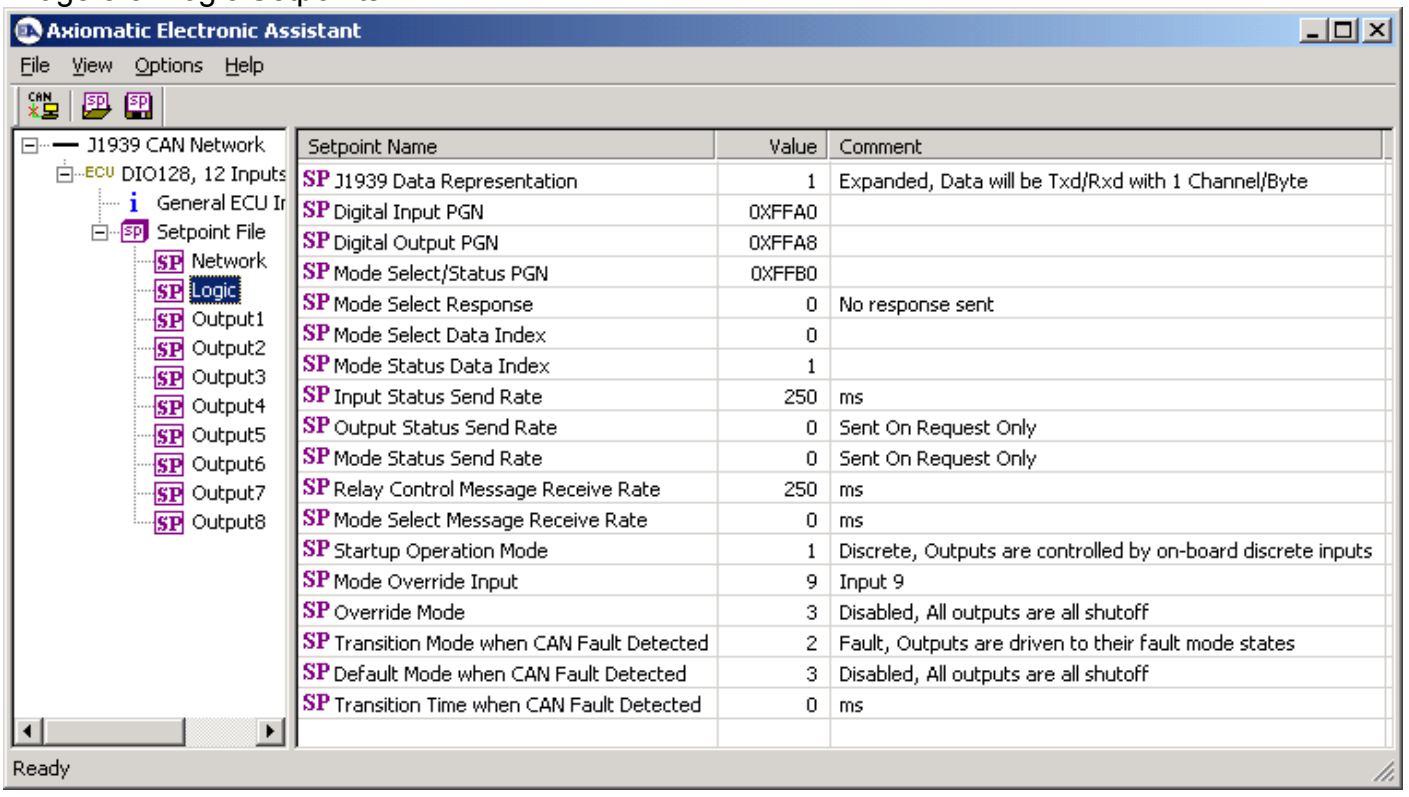
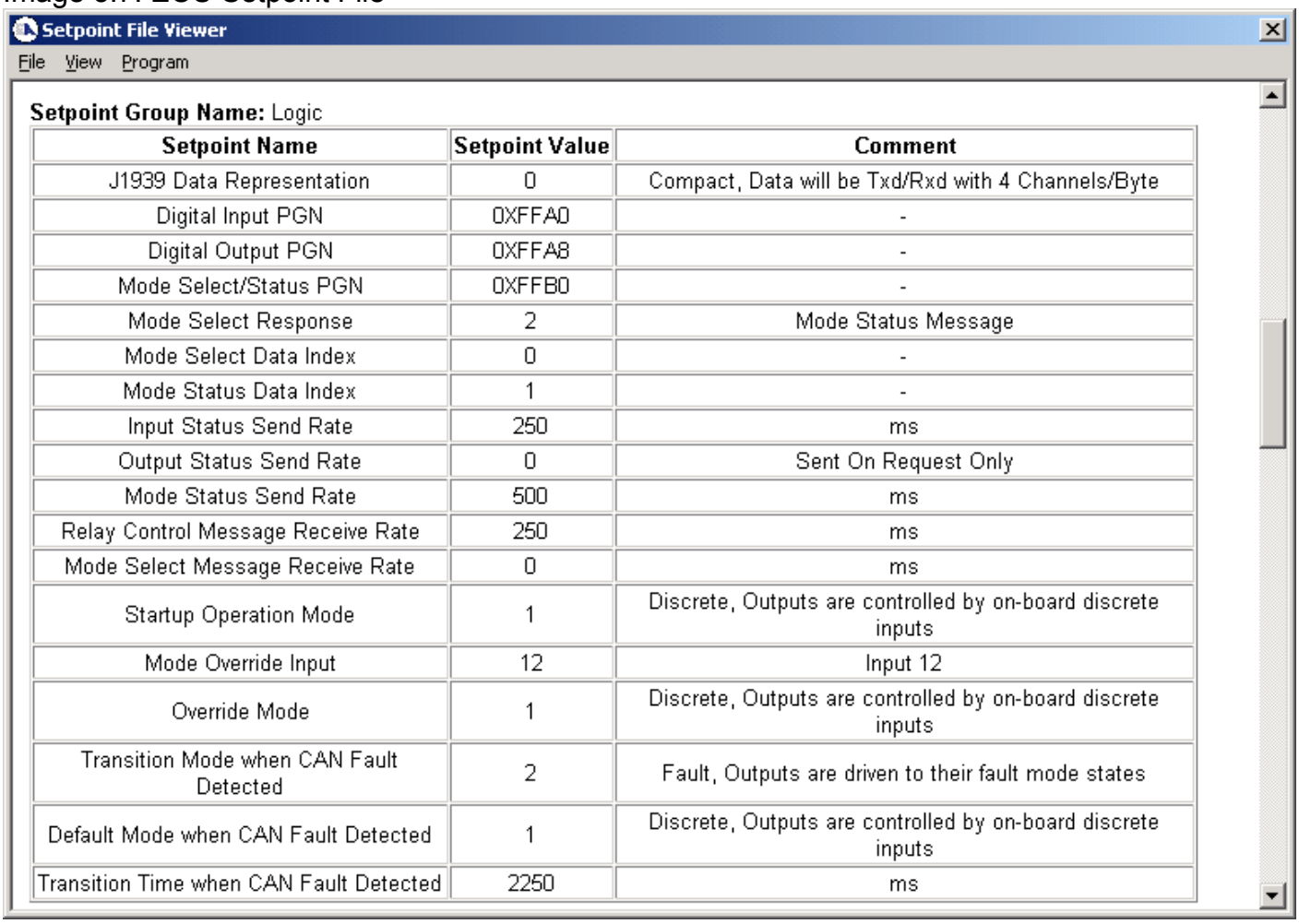
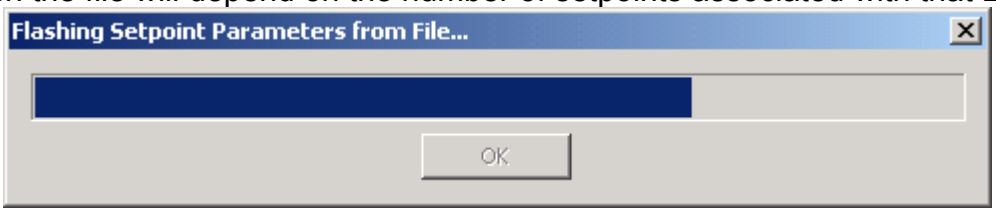


Image 5.7: ECU Setpoint File



Setpoint Name	Setpoint Value	Comment
J1939 Data Representation	0	Compact, Data will be Txd/Rxd with 4 Channels/Byte
Digital Input PGN	0XFFA0	-
Digital Output PGN	0XFFA8	-
Mode Select/Status PGN	0XFFB0	-
Mode Select Response	2	Mode Status Message
Mode Select Data Index	0	-
Mode Status Data Index	1	-
Input Status Send Rate	250	ms
Output Status Send Rate	0	Sent On Request Only
Mode Status Send Rate	500	ms
Relay Control Message Receive Rate	250	ms
Mode Select Message Receive Rate	0	ms
Startup Operation Mode	1	Discrete, Outputs are controlled by on-board discrete inputs
Mode Override Input	12	Input 12
Override Mode	1	Discrete, Outputs are controlled by on-board discrete inputs
Transition Mode when CAN Fault Detected	2	Fault, Outputs are driven to their fault mode states
Default Mode when CAN Fault Detected	1	Discrete, Outputs are controlled by on-board discrete inputs
Transition Time when CAN Fault Detected	2250	ms

A setpoint file can be flashed to an ECU by the Program option in the menu. The length of time it will take to flash the file will depend on the number of setpoints associated with that ECU.



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Signal Conditioners

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- Other comments as needed

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