Anybus® X-gateway™

Application Note
J1939 Data Mapping Explained

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1. <u>Overview</u>

When setting up an engine monitoring system the task of determining which J1939 messages to use and where the engine parameters are located within these messages can be confusing at best. This document provides an explanation of how engine parameters are placed into J1939 messages and how to set up the X-gateway I/O configuration to monitor these parameters.

Using the recommendations detailed in this document will streamline your X-gateway configuration time as well as the time required to develop your application or controls logic.

2. <u>J1939 Message Terminology</u>

Parameter

A specific data element within a PGN message.
Each parameter has a description, resolution, range, scaling, offset and data size defined by the vendor. Standard parameters are defined in the SAE J1939-71 specification.

PGN

Parameter Group Number
Parameters are grouped by common purpose and assigned a PGN. The PGN is used in J1939 messages to identify the group, and hence the parameter data, that is contained in the message.

SPN

Suspect Parameter Number
Each parameter is assigned an SPN. The SPN is used in diagnostics to specify the particular item that the service code is associated with.

PGN Transmission Rate

The nominal rate at which the PGN message will be transmitted. The PGN definition specifies the transmission rate of the PGN message. Rates specified as "On Request" are only transmitted when a request for a PGN is received from another network node.

Parameter Offset

The offset into the PGN message buffer where a parameter's data is located.
A PGN message contains the data for all of the parameters in its associated parameter group. The PGN definition indicates where each parameter's data is located, based on offsets from the front of the message buffer. Note that offsets may not be on byte boundaries but may be bit based.

Parameter Length	The length of an individual parameter's data.
	A parameter's data may be contained in a single bit to multiple bytes within the PGN message buffer. Note that data length is not always in bytes but may be a number of bits.

Parameter Resolution	The scale and offset of a parameter's data.
	The parameter data included in a PGN message is raw unsigned integer data. The scale and offset define the translation to convert the raw data to engineering units.

3. J1939 PGN Message Definitions

Each PGN has a message definition that specifies the size, transmission rate, and the message layout. The message layout specifies how the data from the parameters in the group is arranged within the message buffer.

3.1 PGN and Parameter Documentation Examples

There are many different ways that PGN message definitions are documented. The examples below show typical ways that parameters in the PGN 65263 Engine Fluid Level/Pressure message may be documented.

3.1.1 J1939 Specification Example

The SAE J1939-71 specification contains the definitions for all standard PGNs. The PGN specifications appear similar to the following representation:

5.3.29 ENGINE FLUID LEVEL/PRESSURE

Transmission repetition rate:	0.5 s	
Data length:	8 bytes	
Data page:	0	
PDU format:	254	
PDU specific:	239	
Default priority:	6	
Parameter group number:	65 263 (00FEEF$_{16}$)	

Byte:	1	Fuel delivery pressure		5.2.5.27
	2	Extended crankcase blow-by pressure		5.2.5.241
	3	Engine oil level		5.2.5.72
	4	Engine oil pressure		5.2.5.28
	5,6	Crankcase pressure		5.2.5.40
	7	Coolant pressure	5.2.5.38	
	8	Coolant level		5.2.5.73

There is more information provided in the PGN definition than will be needed by the user responsible for configuring the X-gateway. The pertinent information for X-gateway configuration is the transmission rate, the PGN number, and the parameter data offsets.

It is important to note the following:

1) In the specification, the offsets for parameter data in the message buffer are defined by byte or bit numbers starting with "1". In the above example, Fuel Delivery Pressure data is at the front of the message (byte 1), while Engine Oil Pressure is in the 4th byte. When configuring X-gateway I/O, message offsets are used rather than byte numbers, with message offset"0" being the front (i.e. first byte or bit) of the message buffer.
2) Data transmitted in the PGN is "Raw" and may require scaling to arrive at the actual data value the PGN data represents. The following section defines where the scaling information is found.

The PGN definition describes where the data is located in the message; however the description of the actual data is found in the individual parameter descriptions. The section numbers to the right of the message buffer layout, specify where to find the parameter definitions.

For instance, in the above example, the parameter definition for Engine Oil Pressure is in section 5.2.5.28 and may appear as follows:

*5.2.5.28 Engine Oil Pressure*Gage pressure of oil in engine lubrication system as provided by oil pump.

Data Length:	1 byte
Resolution:	4 kPa/bit gain, 0 kPa offset
Data Range:	0 to +1000 kPa (0 to 145 psi)
Type:	Measured
Suspect Parameter Number:	100
Reference:	5.3.29

The parameter definition gives the application or controls developer the rest of the story on the data that is in the PGN message. The definition contains the actual parameter data length, the scaling used to convert the "Raw" parameter data transmitted on the J1939 network to engineering units, and the valid range of the data.

The only information detailed above, pertinent to X-gateway configuration is the data length. The scaling and range information is useful for the application or controls developer who will use scaled or "cooked" data in their application or logic for programmatic purposes or when the data will be displayed for the end customer on an HMI or other display device. Likewise the SPN may be useful for understanding diagnostics.

Note that a cross reference is included in the definition from the parameter back to the PGN definition section with which the parameter is grouped.

3.1.2 Parameter Table Example

In some cases equipment vendors and engine OEMs may provide a table that defines all of the PGNs / parameters that are available over the J1939 data link. These tables generally provide all of the information needed for X-gateway configuration and for the application or controls developer.

The following is an excerpt from a table for the parameters in the PGN 65263 Engine Fluid Level/Pressure group.

Parameter	PGN	SPN	Offset	Data Length	Update Rate	Scaling	Range
Coolant Level	65263	111	7 bytes	1 byte	500ms	0.4 %/bit 0 % offset	0-100 %
Coolant Pressure	65263	109	6 bytes	1 byte	500ms	2 kPa/bit 0 kPa offset	0-500 kPa
Crankcase Pressure	65263	101	4 bytes	2 bytes	500ms	0.0078 kPa/bit -250 kPa offset	-250-251.99 kPa
Engine Oil Level	65263	98	2 bytes	1 byte	500ms	0.4 %/bit 0 % offset	1-100 %
Engine Oil Pressure	65263	100	3 bytes	1 byte	500ms	4 kPa/bit 0 kPa offset	0-1000 kPa
Extended Crankcase blow-by Pressure	65263	22	1 byte	1 byte	500ms	0.05 kPa/bit 0 kPa offset	0-12.5 kPa
Fuel Delivery Pressure	65263	94	0 bytes	1 byte	500ms	4 kPa/bit 0 kPa offset	0-1000 kPa

For the user responsible for configuring the X-gateway, each parameter row contains the PGN number, offset into the message buffer, data length, and the expected transmission rate. For the application and controls developer, the scaling, valid range and SPN are defined for the parameters.

4. Determining the X-gateway Data Table Layout

An important task when setting up the X-gateway is determining how parameter data is going to be placed in the module's data table. Although BWConfig will allow you to start adding parameters to the X-gateway I/O tables and let the data end up where it falls, it is suggested that more thought be put into this process, to make the application or controls development more straight-forward.

Generally, placing parameters on word (16-bit) boundaries in the data table is suggested; however, this is somewhat controller dependent (i.e. some controllers are "little endian" and others are "big endian" regarding how memory values are accessed and stored). The following sections discuss suggested data table layouts for each type of controller.

Note that J1939 PGN parameter data is stored in little endian format.

4.1 Data Table Layout for Modbus RTU and Modbus TCP (Big Endian)

It is suggested that parameters be mapped on 16-bit word boundaries in the X-gateway for applications with Modbus (big endian) controllers. This will result in individual parameters being conveniently mapped to individual Modbus (16 bit) registers, which will be very useful and efficient for the application and controls developers.

The Swap I/O Bytes option (checkbox) should be set (checked) in the X-gateway configuration using BWConfig. This will ensure that data in the registers is in the proper orientation to be read by the Modbus controller.

Caveat: Parameter data with a length larger than 16 bits will span multiple Modbus registers. Although the data in each register will be oriented correctly using this approach, the order of the data in the spanned registers will need to be manipulated in the controller. The least significant word will appear first in the register table. Hence a 4 byte (2 word) value will have the low word in the first register and the high word in the second register of the data table. This is reversed from what a Modbus controller expects and will require some manipulation by the Modbus controller logic or code to properly orient the multiple register data value.

Important!   All data is swapped once the Byte Swapping option is checked, including outgoing data (i.e. data coming into the X-gateway data table from J1939 will be swapped and data sent to the X-gateway output table by the application or controller will be swapped).

4.2 Data Table Layout for EtherNet/IP (Little Endian)

When determining the mapping boundaries for EtherNet/IP it must be determined how the controller is going to use the data. ControlLogix controllers allow the connection data to be configured as bytes, 16-bit words, or 32-bit double words. Other EtherNet/IP scanners may treat the connection data as a simple string of bytes.

If the connection data is to be treated as bytes, parameter data can be mapped on 8-bit boundaries. If mapped this way, any data larger than a single byte will have to be manipulated by the controller program.

When choosing the connection data format in the controller (in the case of ControlLogix) the size of the parameters must be taken into accout. If all parameters are 8 bits or less, then the connection format can be configured as SINT (8-bit) data. If any of the parmeters are larger than 8 bits, it may be beneficial to configure the connection format as INT (16-bit) or DINT (32-bit) data. The mapping boundaries in the X-gateway should be set according to the selected connection configuration.

Important!   Do not set the Swap I/O Bytes option for EtherNet/IP. It is not required and should not be done.

4.3 Data Table Layout for PROFIBUS DP

It is suggested that parameters be mapped on 16-bit word boundaries for PROFIBUS (big endian) applications. PROFIBUS requires byte swapping of multi-byte data; hence, it is best to locate all data on 16-bit boundaries so that parameters with lengths of 8 bits or less do not get inadvertently swapped with neighboring parameters.

The Swap I/O Bytes option should be set (checked) in the X-gateway configuration using BWConfig. This will ensure that the data in the registers in the right orientation to be read by the PROFIBUS scanner.

Caveat: Parameter data with a length larger than 16 bits will span multiple words. Although the data in each word will be oriented correctly using byte swapping, the order of the data in the spanned words will need to be manipulated in the application or controller. The least significant word will appear first in the data table. Hence a 4 byte (2 word) value will have the low word first followed by the high word. This is reversed from what a PROFIBUS controller expects and will have to be manipulated by the controller logic or program.

5. Configuring the X-gateway I/O Mapping

Once the J1939 parameters have been identified, their details collected and the data table layout has been determined, all that's left is to enter all of the information into the X-gateway I/O configuration using BWConfig.

5.1 Configuration Attributes

Full details of the I/O configuration attributes can be found in the corresponding X-gateway user manual. The table below describes how the information collected above, pertains to the X-gateway configuration for input and output data points.

PGN
The PGN of the group associated with the parameter as specified in the PGN definition or by the parameter table.

Priority
The priority of the message as specified in the PGN definition.

Care should be taken when assigning the Priority to an outgoing message. If it is unclear which priority to use, consult the ECU vendor. If it is still unclear use priority 6.

Note that the Priority is only used when configuring Output I/O points; message priority is ignored when filtering messages for Input I/O points.

Data Table Offset
The offset for each parameter should be set according to the desired data table layout. e.g. If a 16-bit boundary layout is desired, the offset should be set to an even byte boundary.

Note that the table offset will auto-increment based on the data length of the previous parameter; you may or may not be required to reset the value when configuring the next parameter.

Data Length
The length of the parameter data as specified in the parameter definition.

Target Address
The address of the ECU that is producing the parameter may be specified in the parameter table or by the vendor.

When configuring Input I/O points, in most cases the address may be set to 255 (don't care) so that the parameter data will be captured regardless of its source.

When configuring Output I/O points, the address should be set as

specified by the vendor. Although it may be ok to broadcast some data, in most cases the data which the X-gateway will be sending will need to be directed to a particular ECU.

Update Rate   For input parameters, the update rate must be set if the PGN's defined transmission rate is "on request"; otherwise the update rate can be set to 0.

For output parameters, the update rate should be set according to the vendor's specification in the parameter table.

Message Offset   The offset into the message buffer for the parameter data specified by the PGN definition or by the parameter table.

5.2 Example Configuration

5.2.1 Input I/O Example

Using the information from the parameters defined for PGN 65263 above, the following example shows how to configure the X-gateway to receive the Oil Pressure, Crankcase Pressure and Fuel Pressure parameters.

J1939 Input I/O Table

Table Offset	Data Length	PGN	Target Address	Update Rate	Message Offset
0 (0,0)	8 (1,0)	65263	255	0	24 (3,0)
16 (2,0)	16 (2,0)	65263	255	0	32 (4,0)
32 (4,0)	8 (1,0)	65263	255	0	0 (0,0)

The data table is using 16-bit boundaries for parameter data. Note that the table offsets are all on even bytes. Since the Oil Pressure parameter is only 8 bits in length; a byte was skipped in the table when setting the table offset for the second parameter.

The data lengths for each parameter were taken from the parameter table. The lengths for Oil, Crankcase, and Fuel pressure are 1, 2, and 1 byte respectively.

Since PGN 65263 is transmitted every 500ms, the update rate was set to 0 since the X-gateway will not have to send a request for the PGN.

Note that it is recommended that you do not request the PGN (i.e. set the rate to other than 0) if the PGN is already being automatically transmitted by the ECU.

The message offsets have been set according to the parameter offsets in the PGN definition. BWConfig represents offsets in "bits (bytes,bits)" format. Therefore, Oil Pressure is in byte 4 of the message buffer or offset 24 bits (3 bytes, 0 bits) from the beginning of the buffer using 0 as the starting data offset. Crankcase Pressure is in bytes 5 and 6, or offset 32 bits (4 bytes, 0 bits). Fuel pressure is at the beginning of the message buffer, byte 1 or offset 0 bits (0 bytes, 0 bits) as indicated in the table shown above.

From the standpoint of a PLC scanning the X-gateway, the data will appear in input table as follows.   Note that some X-gateway's (AB7665) insert status data at the front of the table offsetting the data.

AB7665 Data Table Offset (bytes)	AB7615 Data Table Offset (bytes)	AB7665 Modbus Register	AB7612 Modbus Register	Data Description
4	0	30003	30001	Oil Pressure
6	2	30004	30002	Crankcase Pressure
8	4	30005	30003	Fuel Pressure

5.2.2 Output I/O Example

The example that follows will illustrate a configuration to allow a controller to set the engine speed using PGN 0 through the X-gateway.

The following is an excerpt from a parameters table showing the parameters in the PGN 0, Torque/Speed Control.

Parameter	PGN	SPN	Offset	Data Length	Update Rate	Scaling	Range
Control Mode	0	695	0 bits	2 bits	10ms		
Control Condition	0	696	2 bits	2 bits	10ms		
Control Priority	0	897	4 bits	2 bits	10ms		
Requested Speed / Speed Limit	0	898	1 byte	2 bytes	10ms	0.125 RPM/bit 0 RPM offset	0 – 8031 RPM
Requested Torque / Torque Limit	0	518	3 bytes	1 byte	10ms	1 %/bit -125 % offset	-125 – 125 %

The configuration will allow control of the engine speed through the X-gateway; hence the Requested Speed and the control bit parameters are mapped to the output table.

The data table is using 16-bit boundaries for parameter data. Note that the table offsets are all on even bytes. Even the control bit parameters, which are all 2 bits each, have been placed so that they are each separated into their own words.

The data lengths for each parameter were taken from the parameter table. The length for the Requested speed is 2 bytes, while each control bit parameter is 2 bits in length.

Based on the parameter table, PGN 0 is expected to be transmitted every 10ms; hence the update rate is set to 10ms in the I/O entries.

The message offsets have been set according to the parameter offsets in the PGN definition. BWConfig represents offsets in "bits (bytes,bits)" format. Therefore, Requested Speed is in byte 2 of the message buffer or offset 8 bits (1 bytes, 0 bits) from the beginning of the buffer using 0 as the starting data offset. The control bit parameters are all within the first byte of the message at 2 bit offsets.

Important Note: The PGN 0 message, like most J1939 messages, is 8 bytes. However, the X-gateway only knows about the I/O data points that have been configured. In order to force the X-gateway to produce an 8 byte message, a pad bit must be configured that is mapped to the end of the message (bit 63, or byte 7, bit 7).

From the standpoint of a PLC scanning the X-gateway, the data will appear in output table as follows. Note that some X-gateways insert Run/Idle and/or Command registers at the front of the table offsetting the data.

AB7665 Data Table Offset (bytes)	AB7615 Data Table Offset (bytes)	AB7665 Modbus Register	AB7612 Modbus Register	Data Description
4	4	30005	30001	Requested Speed
6	6	30006	30002	Speed Control Mode
8	8	30007	30003	Speed Control Condition

10	10	30008	30004	Speed Control Priority
12	12	30009	30005	Speed Control J1939 Message Padding

6. <u>Support</u>

6.1 Product Assistance

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