



DESCRIPTION

The GravityGyro™ Dynamic Inclinometer provides true clean three axis orientation (elevation, roll, yaw) even in the presence of high shock, magnetic interference, acceleration and vibration.

The system employs high stability temperature compensated ceramic packaged MEMS accelerometers and gyroscopes for excellent long-term performance and reliability.

The complexity of multi-axis inertial calibrations, quaternion angles, Kalman filters, and dynamic adaptive sensor fusion is handled by the sensor itself. The GravityGyro™ AHRS is the ultimate drop-in upgrade for legacy, inclinometers and magnetic AHRS systems.

KEY FEATURES

- High accuracy while moving - across full temp. range

APPLICATIONS

- Measuring angle on moving vehicles in harsh environments
- Excavators, mining vehicles, skid-steers, mobile cranes

HARDWARE OPTIONS

- Rugged, IP68/69K (aluminum or stainless steel)
- Internal CAN terminator (software or hardware)
- M12 or Deutsch (single or dual connectors)

OUTPUT OPTIONS

- CAN bus (J1939, CANOpen, and custom)
- RS232, RS485, 0 – 5V, 0 – 10V, 4 – 20 mA

SPECIFICATIONS OVERVIEW

Parameter	Specification
Axes	Three (Elevation, Roll, Yaw)
Range	Elevation: +/-90° (internal) Roll: +/-180° (internal) Yaw: +/-180° (internal)
Static tilt accuracy	0.1° RMS (Elevation, Roll)
Dynamic tilt accuracy	0.5° RMS
Shock, acceleration and vibration use conditions	<ul style="list-style-type: none"> 1 gRMS random vibration 5 Hz to 500 Hz 1 g acceleration 1 second 20 g ½ sin 10 mSec 100 g ½ sin 0.1 mSec
Output rate	100 Hz (default rate, J1939 messages)
Shock survival	1000 g ½ sin 0.1 mSec, 3x any axis
Temperature range	-40° to 85° C
Voltage	5 – 36 V
Current	30 mA typ. @ 12 VDC
Protection	IP68/69K

DESIGNED FOR HEAVY VEHICLES

- Technology leader and market leader – SignalQuest produces more dynamic inclinometers than all competitors combined
- Primary tier 1 supplier to more than half of the world's leading heavily vehicles OEMs
- Specifically designed, tested, and qualified to meet the unique environmental operating requirements of commercial, construction, military, agricultural and mining vehicles.



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COMMUNICATION PROTOCOL

This sensor communicates using a protocol based on SAE J1939. This section describes only those aspects of SAE J1939 that pertain to this sensor.

On a J1939 network, each device (Electronic Control Unit, or ECU) is assigned a unique 8-bit address, ranging from 0 to 253. The address 254 is reserved for network management, and the address 255 is reserved as a global address. Note that a device may contain more than one ECU, but this sensor contains only one ECU.

The J1939 8-bit address is normally assigned as part of an address claim procedure. The address claim procedure of this sensor differs slightly from that used by J1939, as described in this document.

The J1939 8-bit address is used as part of the 29-bit CAN ID used to transmit packets on the bus. For each message, the complete 29-bit field of the CAN ID consists of a 3-bit priority, an 18-bit Parameter Group Number (PGN), and the 8-bit address of the ECU transmitting the message (the Source Address).

J1939 CAN ID format

28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Priority (0 ~ 7)			Parameter Group Number (PGN) (18 bits)																		Source Address of this message (8 bits, 0 ~ 255)							

The priority field controls the CAN arbitration. If two or more devices attempt to transmit on the bus simultaneously, the device with the lower CAN ID will win arbitration. The losing devices will re-try the transmission at the next available idle time. The three priority bits, being the most significant bits of the CAN ID provide the first opportunity specify the priority of a message in the arbitration scheme.

The PGN field in the message identifies the type of message, whether it is being transmitted to a single ECU, or being broadcast to all, and when being sent to a single ECU, contains the address of the destination ECU.

The Source Address is generally the address of the device sending the message. The Source Address may be 254 (0xFE) for network management purposes if no address has been successfully claimed.

There are two general types of PGN, designated as Protocol Data Units (PDU's), PDU1 or PDU2. PDU1 message are generally addressed to a specific ECU on the bus, PDU2 messages are broadcast for any ECU that is interested. Note that a PDU1 type can also be broadcast to all listeners, by sending the Destination Address as 0xFF.

The format of the 18-bit PGN is as follows:

J1939 18-bit PGN format

17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	DP	PDU Format (PF), 8 bits								PDU Specific (PS), 8 bits							
0	0	0x00 ~ 0xEE: PDU1 (destination-specific) defined by SAE								Destination Address (DA), or 0xFF to broadcast to all							
0	0	0xEF: PDU1 (destination-specific) defined by manufacturer								Destination Address (DA), or 0xFF to broadcast to all							
0	0	0xF0~0xFE: PDU2 (broadcast) defined by SAE								(Low 8 bits of 16-bit PDU2 code)							
0	0	0xFF: PDU2 (broadcast) defined by manufacturer								(Low 8 bits of 16-bit PDU2 code)							

DP = Data Page, there are two pages of PGN's that follow these same guidelines. This sensor uses only Data Page 0.

When PGN's are documented, the convention is to express the PGN as a 24-bit number, with the high 6 bits being 0. For type PDU1, the PGN number is represented with the low 8 bits (the destination address) as 0. For type PDU2, the PGN number is represented with all significant 18 bits.

For SAE-defined PGN's, the complete format of the message, including which parameters are transmitted, how the data is encoded, how often the message is transmitted, and which bits in the CAN 64-bit field are used by each parameter, are all

predefined. Each parameter that appears in an SAE-defined message is assigned a Suspect Parameter Number (SPN), and SAE maintains a complete database of SPN's and their mappings into SAE-defined PGN's.

The format of a manufacturer-defined PDU is determined by each manufacturer.

PARAMETER GROUP NUMBERS

This sensor uses the following PGN's:

J1939 PGNs used by this device

Purpose	PGN	Type	Notes
Request for PGN (SAE-defined)	59904 (0x00EA00)	PDU1	Used to request claimed addresses from all ECUs. Broadcast to all (DA = 0xFF), request PGN 60928.
Transport Connection Data (SAE-defined)	60160 (0x00EB00)	PDU1	Used to send multi-packet messages (Commanded Address).
Transport Connection Management (SAE-defined)	60416 (0x00EC00)	PDU1	Used for starting a multi-packet Commanded Address transaction.
Address Claimed or Address Claim Fail (SAE-defined)	60928 (0x00EE00)	PDU1	Always broadcast to all (DA = 0xFF), on priority 6. Source Address is 254 (0xFE) to signal failure.
Configuration and Control (Manufacturer-defined)	61184 (0x00EF00)	PDU1	Sent to the sensor and sent by the sensor in reply.
Slope Sensor Information (SAE-defined)	61459 (0x00F013)	PDU2	Message transmitted using priority 3. Provides angle measurement outputs.
Angular Rate Information (SAE-defined)	61482 (0x00F02A)	PDU2	Message transmitted using priority 3. Provides angular rate measurement outputs.
Commanded Address (SAE-defined)	65240 (0x00FED8)	PDU2	Sent using multi-packet transport protocol.
Vehicle Speed 1 (SAE-defined)	65265 (0x00FEF1)	PDU2	Received by the sensor to provide velocity-aiding input.
Vehicle Heading Input (Manufacturer-defined)	65504 (0x00FFE0)	PDU2	Received by the sensor to provide heading-aiding input.
Yaw Output (Manufacturer-defined)	65505 (0x00FFE1)	PDU2	Message transmitted using priority 3. Provides yaw measurement outputs.

These messages are described in more detail in the following sections.

ADDRESS CLAIM

The Unique J1939 NAME

To operate on a J1939 bus, each ECU requires a unique 8-bit address. To ensure a unique address, each ECU must stake a claim to that address. As part of the claim process, each device uses a unique pre-defined 64-bit physical address, called by J1939 the “NAME”. If two or more ECUs stake a claim to the same address, the one with the lower numeric NAME wins, and the loser must find another address.

The NAME may also be used by other ECUs or controllers on the bus to identify devices supplying functions that are important to it. The 64 bits of the NAME are composed of 10 fields. The following table shows the 64-bits (first row) divided into fields; the number of bits in each field (second row); the J1939 specified use of each field (third row); and the how the field is defined in this sensor (fourth row).

J1939 64-bit NAME Used by SignalQuest

63	62~60	59~56	55~49	48	47~40	39~35	34~32	31~21	20~0
1 bit	3 bits	4 bits	7 bits	1 bit	8 bits	5 bits	3 bits	11 bits	21 bits
ARB	Industry Group	System Instance	Vehicle System	Resrv'd	Function	Function Instance	ECU Instance	Manufacturer Code	Identity Number
1	0 (General)	0	0 (0 = non-specific)	0	0x91 (145 = inertial sensor)	0	0	0x1BB (SignalQuest)	Unique Identifier (UID) Derived from Serial Number

The ARB bit indicates that this unit is arbitrary-address capable, meaning it can claim an address on its own without external action.

The Industry Group code indicates the industry this device is designed to serve:

J1939 Industry Group Codes

Industry Group #	Industry
0	Global, any industry
1	On-Highway Equipment (Used for this Sensor)
2	Agricultural and Forestry Equipment
3	Construction Equipment
4	Marine
5	Industrial-Process Control Stationary Equipment
6 ~ 7	Reserved

The Unique Identifier (UID)

The UID is a unique 21-bit number, derived from the SignalQuest serial number.

SignalQuest Serial Numbers consist of a two-digit week number, a two-digit year number, and then 5 digits that provide a unique serial number of each device manufactured that week. For example, 221600964 would be assigned to a sensor manufactured in the 22nd week of 2016, having a unique 5-digit serial number 00964.

To compute the UID, the serial number is separated into its component parts: Week, Year, Number.

The UID is computed from:

$$\text{UID} = ((\text{Year} - 15) * 53 + \text{Week}) * 2048 + \text{Mod}(\text{Number}, 2048)$$

Example:

Serial Number 221600964

Week = 22

Year = 16

Number = 964

UID = ((Year – 15) * 53 + Week) * 2048 + Mod(Number, 2048)

UID = ((16 – 15) * 53 + 22) * 2048 + Mod(964, 2048)
 = 153600 + 964
 = 154564
 = 0x25BC4

EXAMPLE: CREATING NAME FROM UID

63	62~60	59~56	55~49	48	47~40	39~35	34~32	31~21	20~0
1 bit	3 bits	4 bits	7 bits	1 bit	8 bits	5 bits	3 bits	11 bits	21 bits
ARB	Industry Group	System Instance	Vehicle System	Res.	Function	Function Instance	ECU Instance	Manufacturer Code	Identity Number
1	0	0	0x00	0	0x91	0	0	0x1BB	UID = 0x025BC4
1	000	0000	0000 000	0	1001 0001	0000 0	000	0011 0111 011	0 0010 0101 1011 1100 0100

Generating NAME:

B#	63~60	59~56	55~52	51~48	47~44	43~40	39~36	35~32	31~28	27~24	23~20	19~16	15~12	11~8	7~4	3~0
Bin	1000	0000	0000	0000	1001	0001	0000	0000	0011	0111	0110	0010	0101	1011	1100	0100
0x	8	0	0	0	9	1	0	0	3	7	6	2	5	B	C	4

NAME = 0x8000910037625BC4

Address Claim Process

Whenever an arbitrary-address capable ECU powers up or resets on the network, it must execute the Address Claim procedure. To do so, it must first internally choose an address to attempt to claim. An address is chosen from the following list, in order or priority:

1. The last address that was successfully claimed by the ECU, which is stored in non-volatile memory. This address defaults to 0xE2 at the factory.
2. Addresses in the range 0xE0 through 0xF7.
Note that although J1939 provides a wider range of addresses for arbitrary-address capable ECU's that ranges from 0x80 through 0xF7, this sensor is restricted to the range 0xE0 to 0xF7.

To claim the address, the ECU transmits an Address Claim message (PGN 60928, or 0x00EE00) containing the 64-bit name in the data field, and placing the claimed address in the Source Address field of the CAN-ID. The Destination Address should be set for 0xFF, so that all other ECUs handle it. It then listens for a period of 250mS for any other ECU to contest its claim.

If no other ECU on the bus is using the address, then no contesting claim will be received for 250mS, and the ECU may begin operating using that address.

If another ECU on the bus (call it 'B') is using the address, and it has a NAME value that is higher than the NAME value of the new ECU attempting to claim that address (call it 'A'), then ECU 'A' wins. In this case, the original owner of the address, 'B', must begin the procedure to claim another address. ECU 'A' will not receive a higher-priority claim in 250mS, so it may begin operating using that address.

If another ECU on the bus (call it 'B') is using the address, and it has a NAME value that is lower than the NAME value of the new ECU attempting to claim that address (call it 'A'), then ECU 'B' wins. It will transmit its own Address Claim message, contesting the claim of ECU 'A'. When ECU 'A' receives this claim, it will know it lost, and must try again with the next preferred address.

For each address that the ECU attempts to claim, if the claim fails (because an ECU with a lower-value name already has that address) the losing ECU should try the next address in numeric order, and in order of the address-claim list above. If every attempt has failed, and the list is exhausted, the ECU must give up, and issue an Address Claim Failed message, which may prompt the host to assign it an address.

An Address Claim Failed message is nearly identical to an Address Claim message. It uses PGN 60928, and its data field contains the 64-bit NAME. The only differences are that it contains the Source Address 0xFE (which is how it signals failure to claim any viable address), and it is transmitted after a random delay from 0 to 153mS.

Note that if an Address Claim results in a change of address, the new address will be stored in non-volatile memory so that it will claim the same address on subsequent power-on events.

EXAMPLE: ADDRESS CLAIM MESSAGE FOR A SENSOR ATTEMPTING TO CLAIM ADDRESS 0xE3
 (NAME derived from serial number 221600964, as shown in previous examples).

Priority 6, PGN 60928 (0x00EE00), Destination 0xFF, Source 0xE3, NAME 0x8000910037625BC4

CAN ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
0x18EEFFE3	0xC4	0x5B	0x62	0x37	0x00	0x91	0x00	0x80

EXAMPLE: ADDRESS CLAIM FAILED MESSAGE

Priority 6, PGN 60928 (0x00EE00), Destination 0xFF, Source 0xFD, NAME 0x8000910037625BC4

CAN ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
0x18EEFFFE	0xC4	0x5B	0x62	0x37	0x00	0x91	0x00	0x80

COMMANDED ADDRESS PROTOCOL

Should a sensor fail to find an address through the arbitration process described above, it will give up, and transmit an announcement on the bus that it was unable to claim an address (Address Claim Failed message). In this situation, the bus master may assign an address to the ECU. To do so, it uses the Commanded Address Protocol.

The PGN for the Commanded Address message is 65240 (0x00FED8). In order to ensure that the address is assigned to the proper ECU, the message must contain the unique NAME (which the master gets from the Address Claim Failed Message), and the new address. The NAME is 8 bytes, and the new address is 1 byte – a total of 9 bytes of data, which do not fit in an ordinary CAN message frame that supports only 8 bytes.

J1939 supports a transport protocol capable of transmitting messages containing greater than 8 bytes of data, and that is used to issue the Commanded Address message. The transport protocol uses two PGN's: 60160 (0x00EB00) for transporting the data in multiple packets, and 60416 (0x00EC00) to start, stop, and control the flow of the multiple-packet transport process.

The full transport protocol has the capability of performing flow control, detecting dropped messages and handling timeouts. However, for the purpose of describing the Commanded Address protocol, only a subset of these capabilities are needed.

The Commanded Address Protocol consists of three messages: one to start the multi-packet transport protocol, and two to transport the 9 bytes of data.

The start message has the following format. Note that it is broadcast to all listeners because the ECU being targeted does not have an address on the bus yet.

CAN ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
0x18ECFFYY	0x20	0x09	0x00	0x02	0xFF	0xD8	0xFE	0x00
	Start Transfer	9 bytes of data		2 transfer packets	Reserved	PGN of multi-packet message is 0x00FED8, the Commanded Address message.		

YY represents the address of the bus master that is sending the Commanded Address.

This message is followed by two more packets, which are used to transfer the 9 bytes of data. The first byte of each packet is the packet number, so only 7 bytes are carried in each transfer.

CAN ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
0x18EBFFYY	0x01	XX	XX	XX	XX	XX	XX	XX
	Packet #1	NAME LSB	NAME	NAME	NAME	NAME	NAME	NAME

YY represents the address of the bus master that is sending the Commanded Address.

CAN ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
0x18EBFFYY	0x02	XX	XX	0xFF	0xFF	0xFF	0xFF	0xFF
	Packet #2	NAME MSB	New Address	Unused	Unused	Unused	Unused	Unused

YY represents the address of the bus master that is sending the Commanded Address.

All unused bytes at the end of a multi-packet message should be 0xFF. The host must ensure that each packet is transmitted within 500mS of the previous one, so that no timeout occurs.

Once it receives the message, the unit that matches the NAME will attempt to claim the assigned address through the regular address claim process. If that fails (if there is already another ECU on the newly-assigned address with a lower NAME) the ECU will transmit an address claim failed message again.

EXAMPLE: ECU with NAME 0x8000910037625BC4 has failed to find an address, so it transmits an address claim failed message. Upon hearing this, a host on address 0x02 commands it to use address 0x09:

ECU Sends Address Claim Failed

Priority 6, PGN 60928 (0x00EE00), Destination 0xFF, Source 0xFE, NAME 0x8000910037625BC4

CAN ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
0x18EEFFFE	0xC4	0x5B	0x62	0x37	0x00	0x91	0x00	0x80

Master Starts Multi-Packet Transport Protocol For Commanded Address

Priority 6, PGN 60416 (0x00EC00), Destination 0xFF, Source 0x02, Multi-Packet PGN 0x00FED8

CAN ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
0x18ECFF02	0x20	0x09	0x00	0x02	0xFF	0xD8	0xFE	0x00

Master Sends First of Two Packets For Commanded Address Data Field

Priority 6, PGN 60160 (0x00EB00), Destination 0xFF, Source 0x02

CAN ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
0x18EBFF02	0x01	0xC4	0x5B	0x62	0x37	0x00	0x91	0x00

Master Sends Second of Two Packets For Commanded Address Data Field

Priority 6, PGN 60160 (0x00EB00), Destination 0xFF, Source 0x02

CAN ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
0x18EBFF02	0x02	0x80	0x09	0xFF	0xFF	0xFF	0xFF	0xFF

ECU Tries to Claim Address 0x09

Priority 6, PGN 60928 (0x00EE00), Destination 0xFF, Source 0x09, NAME 0x8000910037625BC4

CAN ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
0x18EEFF09	0xC4	0x5B	0x62	0x37	0x00	0x91	0x00	0x80

REQUEST FOR ADDRESS CLAIMED

Some ECU's powering-up on a bus may need to determine the addresses of other units already on the bus. These ECU's may transmit a Request for Claimed Address, which is a PGN 59904 (0x00EA00) message addressed to the global address (0xFF).

PGN 59904 is "Request for PGN", and the data field contains the requested PGN. In this case, the request is for PGN 60928, which is the Address Claim PGN (described above). The requested PGN is transmitted as a 24-bit (3 byte) value.

All ECU's receiving this request will respond by transmitting an Address Claim message. Any ECUs that have not (yet) successfully claimed an address will transmit an Address Claim failed message, after a random delay from 0 to 153mS.

EXAMPLE: REQUEST FOR CLAIMED ADDRESS

Priority 6, PGN 59904 (0x00EA00), Destination 0xFF, Source 0x01

CAN ID	Byte 1	Byte 2	Byte 3
0x18E AFF01	0x00	0xEE	0x00

Note: this sensor does not transmit this message but will obey it if it is transmitted on the network.

CONFIGURATION AND CONTROL MESSAGE

The configuration and control message is used to set or read various controls or settings of the sensor. It is transmitted using PGN 61184; and is both sent to and transmitted by the sensor.

The data field in the message will always contain 8 bytes. Even if fewer bytes are needed, the remaining unused bytes should still be included.

In each message, the data field contains a 4-byte Function Code, and 4 bytes of data.

Data Field of PGN 61184 Configuration and Control Message

Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
LSB	MSB	LSB	MSB
Function Code (High bit set to Write a value)				Data Field (Always 4 bytes, unused bytes are 0)			

When sending a message to the sensor, if the function code accesses a setting that may be read or written, the high bit of the code controls whether the message is to write that value (high bit set) or read it (high bit clear).

Whether a value is read or written, the sensor will generate a reply that contains the current value of the setting or control. The reply has the same format. The high bit of the function code will not be set in the reply. However, no reply is generated when setting the Device Address, or when issuing any of the write-only commands.

All data is transmitted least-significant byte first.

When a setting is written, you should issue a Save Settings command to write the setting to non-volatile memory, so they are restored the next time the sensor is power cycled.

The following table summarizes the available settings.

Description	Function Code	R/W	Data Size	Data Range	Units	Comments
Device Address	0x220014E0 0xA20014E0	Read Write	1	0x80 ~ 0xF7 Factory Default: 0xE2	N/A	Sensor will store the new address to non-volatile memory, reboot and attempt to claim the new address, following the claim procedure described above. No other reply is generated when this value is written, instead the address claim message is transmitted. It is not necessary to issue a Save to Non-Volatile Memory command after writing this value.
Terminator	0x210014E5 0xA10014E5	Read Write	1	0x00 or 0x01 Factory Default: 0x01	N/A	0x00 to ENABLE the built-in CAN terminator 0x01 to DISABLE the built-in CAN terminator This setting must be saved, and the sensor power-cycled or reset before the terminator is enabled or disabled.
Slope-Sensor Information Output Rate	0x220014D0 0xA20014D0	Read Write	2	0 ~ 65535 Factory Default: 10	mSec	Sets the Output Data Rate (ODR) for the Slope Sensor Information message (PGN 61459). If set to 0, the message is not transmitted. This setting takes effect immediately. It must be saved to non-volatile memory if desired.
Angular Rate Information Output Rate	0x220014D2 0xA20014D2	Read Write	2	0 ~ 65535 Factory Default: 10	mSec	Sets the Output Data Rate (ODR) for the Slope Sensor Information message (PGN 61482). If set to 0, the message is not transmitted. This setting takes effect immediately. It must be saved to non-volatile memory if desired.
Yaw Output Rate	0x220014D4 0xA20014D4	Read Write	2	0 ~ 65535 Factory Default: 10	mSec	Sets the Output Data Rate (ODR) for the Yaw Output message (PGN 65505). If set to 0, the message is not transmitted. This setting takes effect immediately. It must be saved to non-volatile memory if desired.
Orientation	0x210014DC 0xA10014DC	Read Write	1	0 ~ 23 Factory Default: 0	N/A	Set the orientation for one of 24 different possible settings. The setting must be saved, and the sensor power-cycled or reset before the new orientation takes effect. See the section titled "Device Orientation".
Yaw Reset	0xA0FFFFFF0	Write	4	"YRES" (0x59 0x52 0x45 0x53)	N/A	Resets the yaw output integrator to 0.
Yaw Hold On	0xA0FFFFFF0	Write	4	"YHON" (0x59 0x48 0x4F 0x4E)	N/A	Sets Yaw Hold on. This should be done only when it is known that the vehicle is not moving. If used, this command improves the accuracy of the yaw integrator.
Yaw Hold Off	0xA0FFFFFF0	Write	4	"YHOF" (0x59 0x48 0x4F 0x46)	N/A	Sets Yaw Hold off. This should be done if Yaw Hold is ON, before the vehicle starts moving again.
Cold Boot	0xA0FFFFFF0	Write	4	"COLD" (0x43 0x4F 0x4C 0x44)	N/A	Reboots the sensor as if it were power cycled. No reply is generated when this command is sent.
Save to Non-Volatile Memory	0xA0FFFFFF0	Write	4	"SAVE" (0x53 0x41 0x56 0x45)	N/A	Saves all settings listed in this table, except Device Address, to non-volatile memory. No reply is generated when this command is sent.

EXAMPLE: SET ORIENTATION FOR #21 (0x15) AND SAVE IT TO NON-VOLATILE MEMORY

The following message is sent to the sensor:

PGN 61184 (0x00EF00), Destination 0xE2, Source 0x01

CAN ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
0xEFE201	0xDC	0x14	0x00	0xA1	0x15	0x00	0x00	0x00

A reply is generated to this message, as follows:

Reply PGN 61184 (0x00EF00), Destination 0x01, Source 0xE2

CAN ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
0xEF01E2	0xDC	0x14	0x00	0x21	0x15	0x00	0x00	0x00

Finally, a command is sent to the sensor, to write the new orientation setting to non-volatile memory:

PGN 61184 (0x00EF00), Destination 0xE2, Source 0x01

CAN ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
0xEFE201	0xF0	0xFF	0xFF	0xA0	0x53	0x41	0x56	0x45

No reply is returned to this message.

SLOPE SENSOR INFORMATION (ANGLE) OUTPUT MESSAGE

This message is transmitted only if the following are true:

- 1) An address has been successfully claimed.
- 2) The Slope-Sensor Information Output Rate has been set to a non-zero value.

The Slope-Sensor Information message is transmitted at the designated rate using PGN 61459, Priority 3. It has the following format:

PGN 61459 (0x00F013), Priority 3, Device Address 0xNN

CAN ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
0xCF013NN	Elevation Angle (16-bit unsigned integer)		Roll Angle (16-bit unsigned integer)		Elevation Rate (16-bit unsigned integer)		Measurement Flags	Roll/Elev Latency

The Elevation Rate represents the rate, measured by gyros, that elevation is increasing or decreasing, in degrees per second.

The Elevation Angle, Roll Angle, and Elevation Rate values are encoded as unsigned 16-bit unsigned integers, as follows:

1. The value is limited to the range -64.0 to +64.51. Values beyond this range will be set to the nearest limit (e.g. -100 would be set to -64.0).
2. Add 64 to the value.
3. Multiply by 500.
4. Round to the nearest integer.

For example, 0.0 degrees becomes: $(0.0 + 64) * 500 = 32000$.

The Measurement Flags byte in this sensor is hard-coded to 0, which indicates that all measurements are operational.

The Roll/Elevation Latency represents the delay between the sensor reading that generated the measurement, and the queuing of the message for transmission on the CAN bus. It does not include additional latencies that might exist because of CAN bus speed, or CAN bus message arbitration. It is an unsigned 8-bit integer, representing the latency in steps of 0.5msec.

EXAMPLE: ELEVATION = +30.1°, ROLL = -50.7°, ELEVATION RATE = 0.1°/sec, LATENCY = 11mS

Elevation is encoded as 0xB7CA, Roll as 0x19FA, Elevation Rate as 0x7D32 and Latency as 22 (0x16).

PGN 61459 (0x00F013), Priority 3, Device Address 0xE2

CAN ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
0xCF013E2	0xCA	0xB7	0xFA	0x19	0x32	0x7D	0x00	0x16

ANGULAR RATE (GYRO) INFORMATION OUTPUT MESSAGE

This message is transmitted only if the following are true:

- 1) An address has been successfully claimed.
- 2) The Angular Rate Output Rate has been set to a non-zero value.

The Angular Rate message is transmitted at the designated rate using PGN 61482, Priority 3. It has the following format:

PGN 61482 (0x00F02A), Priority 3, Device Address 0xNN

CAN ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
0xCF02ANN	Elevation Rate (16-bit unsigned integer)		Roll Rate (16-bit unsigned integer)		Yaw Rate (16-bit unsigned integer)		Measurement Flags	Angular Rate Latency

The Angular Rate values are encoded as unsigned 16-bit unsigned integers, as follows:

1. The value is limited to the range -250.0 to +250.992. Values beyond this range will be set to the nearest limit (e.g. -100 would be set to -250.0).
2. Add 250 to the value.
3. Multiply by 128.
4. Round to the nearest integer.

For example, 0.0 degrees becomes: $(0.0 + 250) * 128 = 32000$.

The Measurement Flags byte in this sensor is hard-coded to 0xC0, which indicates that all measurements are operational (the high 2 bits are unused).

The Angular Rate Latency represents the delay between the sensor reading that generated the measurement, and the queuing of the message for transmission on the CAN bus. It does not include additional latencies that might exist because of CAN bus speed, or CAN bus message arbitration. It is an unsigned 8-bit integer, representing the latency in steps of 0.5msec.

EXAMPLE: ELEVATION RATE = -10.3°/sec, ROLL RATE = +2.1°/sec, YAW RATE = -0.5°/sec, LATENCY = 11mS

Elevation Rate is encoded as 0x77DA, Roll Rate as 0x7E0D, Yaw Rate as 0x7CC0 and Latency as 22 (0x16).

PGN 61482 (0x00F02A), Priority 3, Device Address 0xE2

CAN ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
0xCF02AE2	0xDA	0x77	0x0D	0x7E	0xC0	0x7C	0xC0	0x16

YAW MEASUREMENTS

Unlike normal inclinometer measurements, Yaw is measured in a plane that is perpendicular to gravity. Thus, gravity cannot be used as a reference for the measurement. Instead this device relies upon gyros to measure rotation in the Yaw plane, relative to some reference direction. Gyros are inherently subject to an effect known as “Angular Random Walk”, a source of error that accumulates the longer the device runs without any other reference.

Because the GravityGyro™ cannot directly measure heading, its unaided Yaw angle output is relative to the initial heading of the sensor at power-up. When the sensor is power-cycled or reset, the direction of the +X internal axis is assumed to be coincident with North (0° Yaw).

The Earth-Referenced Yaw Measurement is a relative measurement of the angle swept by the internal X-axis in the plane perpendicular to the local gravity vector. This angle is not body-referenced; the roll and pitch measurements are used to compensate for the inclination of the sensor in the computation of the yaw integral.

The Body-Referenced Yaw Measurement is a relative measurement of the rotation about the sensor’s internal Z-axis.

Some features in this sensor help to improve the accuracy of the Yaw Measurement.

Yaw Reset

The Yaw Reset command may be issued that will reset the yaw measurement (and the integrator) to 0. This happens automatically when the sensor is powered up or reset. This command should be used any other time you wish to establish a reference point for your yaw measurement.

Yaw Hold

A Yaw Hold command allows your system to turn off updates to the Yaw measurement, any time the system has knowledge that the sensor is not moving. While Yaw Hold is ON, the Yaw measurement will not be affected by Angular Random Walk. But it won’t be updated in response to real motion either, so it is important that you turn off Yaw Hold before the sensor starts to move, otherwise significant errors in the Yaw Measurement will occur.

Additionally, the sensor uses the command “Yaw Hold On” to improve the dynamic accuracy of the sensor. Issuing a Yaw Hold On command causes the sensor to refine its gyroscope calibration while the platform is known to be stationary. Thus, a Yaw Hold can be intentionally performed before a vehicle maneuver to improve the dynamic accuracy of the sensor.

Heading Aiding

If you have an independent measurement of the vehicle heading, you may also choose to use the Heading Aiding command.

External measurements of heading are processed by the onboard data-fusion algorithm to align the sensor’s Yaw angle output with the reference input. When aided, the Yaw angle solution provided by the sensor is a blended solution that combines the high-rate gyroscope signal with the low-rate Heading input. The gyroscope effectively smooths/interpolates the Heading reference providing a high-bandwidth, high-data-rate Yaw angle output with accuracy and stability bounded by that of the reference input.

See the section on Heading Aiding for more information.

YAW OUTPUT MESSAGE

This message is transmitted only if the following are true:

- 1) An address has been successfully claimed.
- 2) The Yaw Output Rate has been set to a non-zero value.

The Yaw Output message is transmitted at the designated rate using PGN 65505, Priority 3. It has the following format:

PGN 65505 (0x00FFE1), Priority 3, Device Address 0xNN

CAN ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
0xCFFE1NN	Body-Referenced Yaw (16-bit unsigned integer)		0xFFFF (unused) (16-bit unsigned integer)		Yaw Rate (16-bit unsigned integer)		Measurement Flags	Yaw Latency

The Yaw and Yaw Rate values are encoded as unsigned 16-bit unsigned integers, as follows:

1. The value is limited to the range -180.0 to +180.0.
2. Add 250 to the value.
3. Multiply by 128.
4. Round to the nearest integer.

For example, 0.0 degrees becomes: $(0.0 + 250) * 128 = 32000$.

The Measurement Flags byte in this sensor is hard-coded to 0, which indicates that all measurements are operational.

The Yaw Latency represents the delay between the sensor reading that generated the measurement, and the queuing of the message for transmission on the CAN bus. It does not include additional latencies that might exist because of CAN bus speed, or CAN bus message arbitration. It is an unsigned 8-bit integer, representing the latency in steps of 0.5msec.

EXAMPLE: YAW = -60.2°, YAW RATE = 25.0°/sec, LATENCY = 11mS

Yaw is encoded as 0x5EE6, Yaw Rate as 0x8980 and Latency as 22 (0x16).

PGN 65505 (0x00FFE1), Priority 3, Device Address 0xE2

CAN ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
0xCFFE1E2	0xE6	0x5E	0xFF	0xFF	0x80	0x89	0x00	0x16

HEADING AIDING

Heading Aiding can be used to improve the dynamic accuracy of angle measurements, and to establish a reference for the sensor’s Yaw measurement.

To use Heading Aiding, a Vehicle Heading Input message should be periodically transmitted on the bus, containing a measurement of the current heading, and the standard deviation of that heading measurement. When the sensor detects Vehicle Heading Input messages, it will activate Heading Aiding, and start using the heading updates to stabilize the angle measurements.

The first data packet with a Heading Aiding measurement provided to the sensor after a power-cycle, reset, or outage of heading updates will slave the heading output, causing the sensor’s Yaw output to immediately “snap” to the commanded value.

If no Vehicle Heading Input messages are detected for 1.5 seconds, Heading Aiding will be turned off, but the sensor will continue to maintain its heading solution from the current heading reference.

The Vehicle Heading Input message should be transmitted with a minimum of delay and jitter.

For yaw rates of 6 °/s, keep delay / jitter below 250 ms.
 For yaw rates of 90 °/s, keep delay / jitter below 16.8 ms.

Exceeding these limits will result in degraded or erratic behavior.

VEHICLE HEADING INPUT MESSAGE

The sensor monitors the CAN bus for Vehicle Heading Input messages, which is a message using PGN 65504. If this message is detected, then Heading Aiding will be enabled, and the provided heading will be used to improve the sensor’s performance.

PGN 65504 (0x00FFE0), Priority 0xPP, Source Address 0xSS

CAN ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6
0xPPFFE0SS	Heading (16-bit unsigned integer)		Heading Standard Deviation (16-bit unsigned integer)		Heading Timestamp Age (16-bit unsigned integer)	

Note: PP is priority, shifted into the upper three bits of the 29-bit CAN ID, e.g. 0x18 represents priority 6.

Heading and Heading Standard Deviation are represented as 16-bit unsigned integers. These fields are converted to integer format as follows:

1. The value should be wrapped to the range -180 to +180 degrees.
2. Add 180 degrees to the value.
3. Multiply by 100.
4. Round to the nearest integer.

For example: 0 degrees becomes: $(0 + 180) * 100 = 18000$.

Integer values outside the range 0 to 36000 will be treated as invalid. An exception is the special value 0xFFFF for Heading Standard Deviation (see paragraph Force Align, below).

Heading Timestamp Age is a measure of the Heading “age of data”. This timestamp is always a positive number and represents the amount of time prior to transmission of the heading aiding message that the heading measurement was made.

$$\text{Heading Timestamp Age} = (\text{Time of PGN 65504 Transmit}) - (\text{Heading Time of Validity})$$

Heading Timestamp Age is represented as a 16-bit unsigned integer and converted to integer format as follows:

1. The value should be on the interval between 0 and 1,500 milliseconds (the maximum accepted delay).
2. Multiply by 10.
3. Round to the nearest integer.

For example: 178 milliseconds becomes: $(178) * 10 = 1780$.

Integer values outside the range 0 to 15000 will be treated as invalid.

FORCE ALIGN

It is possible to Force Align the sensor heading to a commanded input. A force alignment will bypass the internal Kalman filter and slave the sensor heading to match the commanded input. This special command simply overwrites the internal heading with the input value and may be used to force-reset the heading output of the sensor, if needed.

To issue a Force Align command, use the special value 0xFFFF for Heading Standard Deviation. In this case, the sensor will assume that the heading was exactly equal to the specified value, at the time indicated by the Heading Timestamp Age.

EXAMPLE: HEADING = -102.3°, HEADING STANDARD DEVIATION = 1.2°, HEADING VALID 23mSec AGO
 Heading is encoded as 0x1E5A; Heading Standard Deviation is encoded as 0x46C8; and Age is encoded is 0x00E6.

PGN 65504 (0x00FFE0), Priority 0, Source Address 0x03

CAN ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6
0x0FFE003	0x5A	0x1E	0xC8	0x46	0xE6	0x00

EXAMPLE: FORCE HEADING TO = 10.7°

Heading is encoded as 0x4A7E; Heading Standard Deviation is set to 0xFFFF to force align the heading, and the time-stamp is sent as 0 (for NOW).

PGN 65504 (0x00FFE0), Priority 0, Source Address 0x03

CAN ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6
0x0FFE003	0x7E	0x4A	0xFF	0xFF	0x00	0x00

VELOCITY AIDING

For ground-based driving vehicle applications, the sensor’s accuracy can be further enhanced with velocity aiding.

To use Velocity Aiding, a Vehicle Speed message should be periodically transmitted on the bus, containing the vehicle’s forward velocity. When the sensor detects Vehicle Speed messages, it will activate Velocity Aiding, and start using the velocity updates to correct the angle measurements.

Vehicle Speed messages should be transmitted at the highest rate possible, preferably 100Hz. The minimum rate should be 20Hz, unless your vehicle is moving very slowly.

To use Velocity Aiding, the sensor’s Internal X axis (see the section on Orientation) must be aligned with the forward direction of the vehicle.

The value written to this object must represent a velocity less than or equal to 30 meters/second (about 67 miles per hour, or 108 kilometers per hour). If no valid velocity is received for a period of 500mS Velocity Aiding will be turned off.

VEHICLE SPEED MESSAGE

The sensor monitors the CAN bus for Vehicle Speed 1 messages, which is a message using PGN 65265. If this message is detected, then Velocity Aiding will be enabled, and the provided velocity values will be used to improve the sensor’s performance.

Note that the default rate for SAE J1939 PGN 65265 is 10 Hz, which is below our recommended velocity message rate. For vehicles which are not very agile, or that don’t accelerate or decelerate very rapidly, a 10Hz rate should be sufficient.

PGN 65265 (0x00FEF1), Priority 6 (default priority for this message), Source Address 0xSS

CAN ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
0x18FEF1SS	XX	Vehicle Speed (unsigned 16-bit integer)		XX	XX	XX	XX	XX

XX = “Don’t care”. All 8 bytes should be present but these are not used by this sensor. They do have a purpose in SAE PGN 65265. This message may be transmitted with any priority.

The Vehicle Speed is represented as a 16-bit unsigned integer, that represents the speed in steps of 1/256 kilometers per hour.

EXAMPLE: VEHICLE SPEED OF 40.2336 KM/HOUR

$40.2336 \times 256 = 10299.8$, rounded to integer $10300 = 0x283C$.

PGN 65265 (0x00FEF1), Priority 6, Source Address 0x04

CAN ID	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
0x18FEF104	0x00	0x3C	0x28	0x00	0x00	0x00	0x00	0x00

ABSOLUTE MAXIMUM RATINGS

PARAMETER	NOTES	MIN	MAX	UNITS
Supply voltage		-30	36	VDC
Voltage on CANH, CANL with respect to GND		-3	15	VDC
CANH-CANL Differential		-6	+6	VDC

ELECTRICAL CHARACTERISTICS

V+ = 5 to 36V, Analog Output R_L = ∞, T_A = -40 to +85°C, unless otherwise specified.

PARAMETER	NOTES	MIN	TYP	MAX	UNITS
Supply voltage (V+)		5		36	VDC
Supply current	V+ = 12V V+ = 9 to 36V	25 10	30	35 45	mA
CAN bus rate			250		kbps

OUTPUT CHARACTERISTICS

PARAMETER	SPECIFICATION	UNITS	NOTES
Axes	2		
Elevation Range J1939 CAN	-64.0 to +64.51	°	
Roll Range J1939 CAN	-64.0 to +64.51	°	Roll valid only when Elevation is between -75° and +75°.
Yaw Range (J1939 CAN only)	-180 to +180	°	Yaw valid only when Elevation is between -75° and +75°. Yaw reference valid only if sensor is receiving Vehicle Heading Input messages.
Angular Resolution J1939 CAN (Elevation, Roll) J1939 CAN (Yaw)	0.002 0.0078	° °	
Output data rate J1939 CAN	0.015 to 1000	Hz	CAN output rate is programmable, default is 100Hz
Case Null Alignment	0.1*	°	
Static Accuracy (Elevation, Roll)	0.1*	°	
Zero Point Temp Drift	0.3*	°	Over full temperature range
Settling Time	0.1	Sec	
Transverse Sensitivity	<1	%	At 30°C

* 1 sigma

CONNECTOR DIAGRAM

M12, Male and Female, 5-pin Connectors, (A-coded):



PIN DESCRIPTIONS (MALE AND FEMALE)

PIN	NAME	DESCRIPTION
1	Shield	Shield (Case)
2	V+	Supply Voltage
3	GND	Ground (Power Return)
4	CAN H	CAN Bus High
5	CAN L	CAN Bus Low

Note: The male connector has an Industry Standard M12 CAN Bus Pinout and is compliant with industry standard DeviceNetTM or CANopen network cabling standards and products.

CAN TERMINATION:

This device contains an Internal CAN Terminator that is not activated in the default configuration.

A properly terminated CAN bus network has a pair of 120 Ohm terminators at the two points furthest from each other on the CAN network.

In typical CAN networks either none of the devices have internal CAN Termination enabled (external dedicated CAN terminators are used) or at most 2 device(s) have internal CAN terminator(s) enabled.

Typical CAN network installations have separate terminators designed into the network to simply debugging and improve reliability since the removal or failure of a device containing an internal CAN terminator will usually cause the network to fail to function properly and be difficult to debug until a CAN terminator is installed (to replace the one lost in the failed device).

SENSOR WIRE HARNESS SHIELDING & WIRING REQUIREMENTS

SignalQuest has tested and recommends one of the following three options for use with the sensors. The three options are listed in order of recommendation.

1. Two Shielded Twisted pairs with Drain wire, 5 wires total (1 pair for power, 1 pair for CANH/CANL, 1 Shield/Drain wire)
 - a. DeviceNet, CANopen compatible wiring, or SAE J1939/11 wiring with the addition of a shielded twisted pair for power, with shield connected to case ground via grounding lug on case.
2. Two Unshielded Twisted pairs, 4 wires total, (1 pair for power, 1 pair for CANH/CANL)
 - a. SAE J1939/15 compliant wiring with the addition of a twisted pair for power.
3. Four Wire Spiral Wound, 22 AWG, 1 to 3 twists per foot. This option is not supported by the J1939 specifications but is widely used by industry.

Shielded twisted pair (Option 1 above) provides the best performance. Options 2 and 3 are sufficient for certain cost conscious applications where shielded wiring is not desirable.

In order to meet certain high field immunity requirements beyond the specifications listed above, the following installation requirements must be observed:

1. The SHIELD signal (if used) must have a direct connection to GND at some point in the wiring harness and this point should be as close as possible to the power supply (or battery) negative terminal.
2. Shielded cabling for all communications/power signals between the sensor and the CAN bus controller is required.
3. It is also required to strap the sensor's enclosure to a chassis ground via the 0.25" deep 6-32 screw hole available on the surface of the sensor. Use of a screw, washer, lock washer and braided copper mesh to attach the enclosure to a bare metal tapped hole in the vehicle's metal floor is recommended. Conductive epoxy may be useful to prevent the screws from corroding or coming loose over time.
4. Many customers have met EMI/RFI requirements without Shielded cable (2 above) or grounding at the sensor (3 above). Likewise requirements have been met using Wiring Option 2 (2 unshielded twisted pairs per SAE J1939/15). The customer is responsible for testing to prove this.

DEVICE ORIENTATION

TERMINOLOGY

Label X means a vector parallel to the “X” arrow printed on the housing label.

Label Y means a vector parallel to the “Y” arrow printed on the housing label.

Label Z means a vector passing through the housing, from the label side, pointing toward the potted side opposite the label. (Indicated by the ⊗ symbol on the label).

Internal X means a vector parallel to the internal X axis, whose relationship to a label axis is set by the Orientation.

Internal Y means a vector parallel to the internal Y axis, whose relationship to a label axis is set by the Orientation.

Internal Z means a vector parallel to the internal Z axis, whose relationship to a label axis is set by the Orientation.

Gravity means a vector pointing from the device toward the center of the earth.

Horizontal means a vector pointing at a right angle to gravity.

Elevation is the angle between the Internal X axis and a plane that is horizontal (perpendicular to gravity).

Roll is right-handed rotation about the Internal X axis.

Home Position is the angle for Elevation or Roll that is at the center of the measurement range (0°).

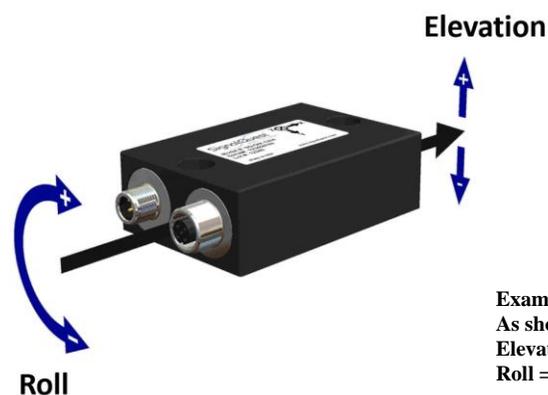
The Home Position for Elevation is where the Internal X axis is in a plane that is horizontal. Elevation increases when the Internal +X axis is tilted up, away from the surface of the earth.

The Home Position for Roll is when the Internal Y axis is horizontal (perpendicular to gravity) and the Internal Z axis is within 90° of the gravity vector, toward the surface of the earth. Right-handed rotation means that Roll increases when the sensor is rotated clockwise about the Internal X axis, with the Internal X axis pointing away from the viewer.

The complete sensor Home Position is when both Elevation and Roll are in the Home Position, where the Internal X and Y axes are both horizontal, and the Internal +Z axis is parallel to gravity, pointing toward the surface of the earth.

Gimbal Lock occurs when Elevation is 90° away (in either direction) from the Elevation Home Position (also meaning that the Internal X Axis is parallel to gravity, pointing up or down). When the device is near the Gimbal Lock position, Roll cannot be measured. The Roll measurement may be stable, or it may drift about at random, but it cannot be relied upon in Gimbal Lock. The specified valid range for Elevation measurements (-75° to +75°) avoids the gimbal lock position.

Orientation is a setting that maps each of the three internal axes to one of the labeled axes, each in a positive or negative direction. There are 24 orientation settings, numbered 0 to 23 (0x00 to 0x17) as documented in the chart on page 14.



NOTES:

- Mounting Reference Surfaces are the labeled +Z Axis surface (lid side, opposite of Label) and the labeled +X Axis surface (front side, opposite of Connector).
- SQ-GIX-2094 is shipped Oriented per SignalQuest Standard Orientation # 0

Example: Orientation #0

As shown (Label +Z axis down toward the Earth):

Elevation = 0°

Roll = 0°

ORIENTATION CONFIGURATION CHART

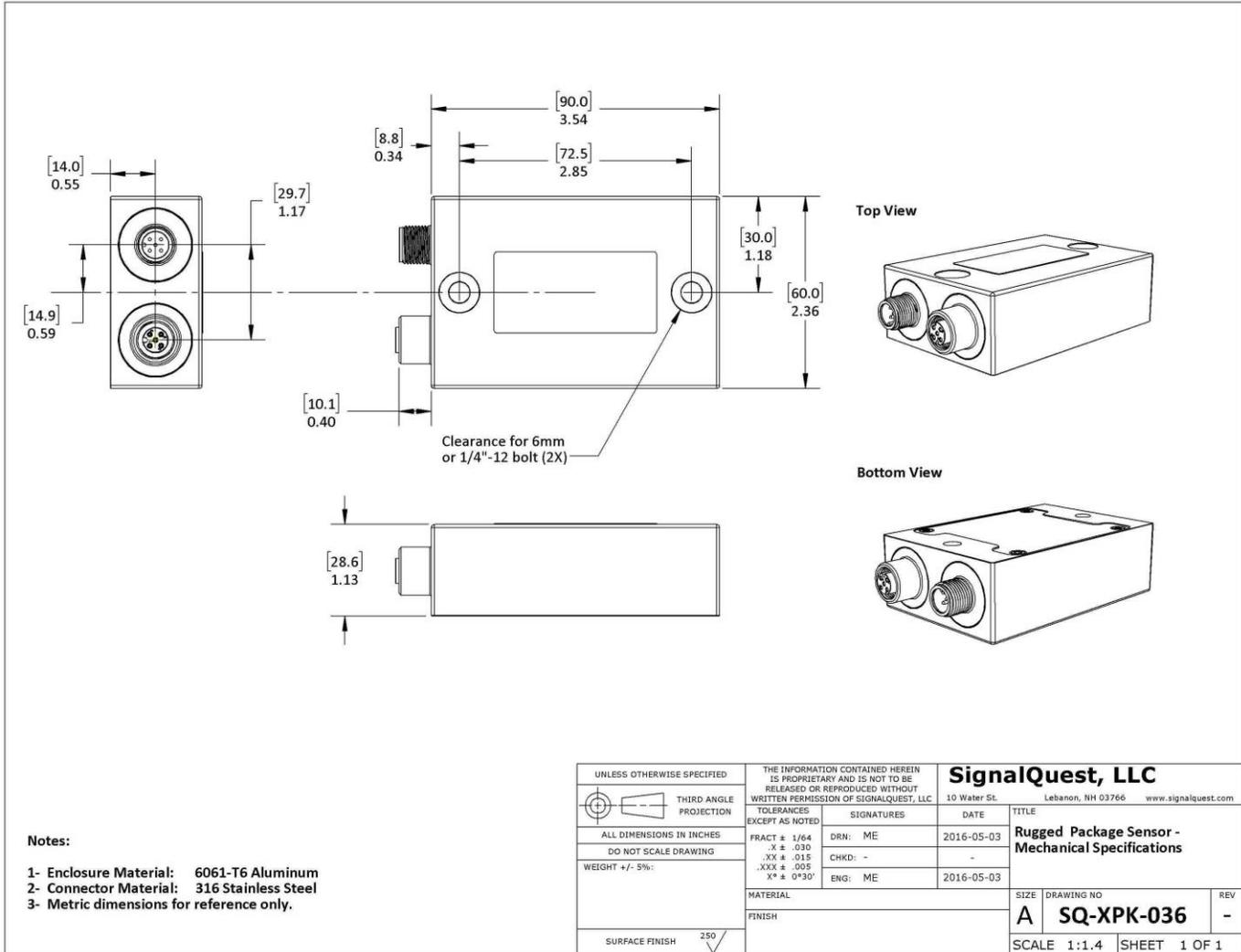
To configure the orientation of the device:

- Choose the Labeled Roll Axis which Roll will rotate about (+X, -X, +Y, -Y, +Z, -Z)
- Choose the Labeled Down Axis which will point down in the given orientation (+X, -X, +Y, -Y, +Z, -Z)
- When the Roll Axis is horizontal and Labeled Down Axis is pointing towards the Earth the angle outputs are zero.
- Select the corresponding Orientation Number for that orientation
- Send the Assign Device Orientation command

Labeled Down Axis	Labeled Roll Axis	Orientation Number (Decimal)	Orientation Number (Hex)
+Z	+X	0	00
+Z	+Y	1	01
+Z	-X	2	02
+Z	-Y	3	03
-Z	+X	4	04
-Z	-Y	5	05
-Z	-X	6	06
-Z	+Y	7	07
+Y	+X	8	08
+Y	-Z	9	09
+Y	-X	10	0A
+Y	+Z	11	0B
-Y	+X	12	0C
-Y	+Z	13	0D
-Y	-X	14	0E
-Y	-Z	15	0F
+X	-Z	16	10
+X	+Y	17	11
+X	+Z	18	12
+X	-Y	19	13
-X	+Z	20	14
-X	+Y	21	15
-X	-Z	22	16
-X	-Y	23	17

Labeled Roll Axis	Labeled Down Axis	Orientation Number (Decimal)	Orientation Number (Hex)
+X	+Z	0	00
+X	-Z	4	04
+X	+Y	8	08
+X	-Y	12	0C
+Y	+Z	1	01
+Y	-Z	7	07
+Y	+X	17	11
+Y	-X	21	15
+Z	+Y	11	0B
+Z	-Y	13	0D
+Z	+X	18	12
+Z	-X	20	14
-X	+Z	2	02
-X	-Z	6	06
-X	+Y	10	0A
-X	-Y	14	0E
-Y	+Z	3	03
-Y	-Z	5	05
-Y	+X	19	13
-Y	-X	23	17
-Z	+Y	9	09
-Z	-Y	15	0F
-Z	+X	16	10
-Z	-X	22	16

PACKAGING



ENVIRONMENT PROTECTION AND TESTING

Reports available upon request.

LIMITATIONS AND WARNINGS

TESTING

The performance of each system is verified through build-time testing. Each system is tested before and after factory calibration to ensure reliable performance.

SYSTEM INTEGRATION TESTING

Thorough testing should be carried out prior to product release to ensure system integration has not introduced unforeseen problems. The system integrator assumes the ultimate responsibility for the safety of the target application.

NOTICE

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REVISION TABLE SQ-GIX-2094

Rev. #	Rev. Date	Revised By:	Test Report	Description	Lot Numbers
A	2018-11-06	PBT		Initial Release – PRELIMINARY	
B	2019-01-14	PBT		Fixed up J1939 NAME parameters. Fix example of Address Claim Failed message. Added section on Commanded Address. PRELIMINARY.	
C	2019-05-31	PBT		Yaw range is +/-180. Resolution is 1/128. Remove analog output. Both connectors are CAN. Remove Body-referenced Yaw. Clarify Pitch/Elevation rate parameter. Add Yaw output rate function code. Add detailed heading aiding message information.	