Migrating from the 3DM-GX3™ to the 3DM-GX4™

How to introduce LORD MicroStrain's newest inertial sensors into your application

Introduction

The 3DM-GX4™ is the latest generation of the very popular 3DM-GX series of IMU/VG, AHRS, and GPS-INS. We have made every effort to design this as a "drop-in" replacement for the previous-generation GX3 inertial sensors, making it easier to upgrade. However, there are a few key performance and API differences between the GX3 and GX4 series.

Performance Differences

There are several critical, performance-related differences between the GX3 and GX4 inertial sensors. If you have an application that is directly impacted by any of these performance areas, you should be aware of how the performance difference may affect your application.

Better Gyros

By far, the most evident sensor improvement is with the gyros. The gyros used in the GX4 line are better in almost every aspect to those in the GX3. The bias instability is 10°/hour (vs. 18°/hour) and the rate noise density is 0.005°/second/√Hz (vs. 0.02°/second/√Hz). The bandwidth, however, is lower (160 Hz vs. 440 Hz max for the GX3); this is worth consideration for applications that need to accurately measure rapid changes in angular rate such as high frequency oscillation.

GPS-INS Extended Kalman Filter (EKF) Improvement

The GX4-45 GPS-INS model has a much more sophisticated Kalman Filter than the GX3 series. The improvements include a much higher maximum data rate (500 Hz vs. 100 Hz for the GX3-45), increased number of states (25 states vs. 12 states for the GX3), inclusion of adaptive technologies for the accelerometer and magnetometer, antenna offset error tracking, pressure altimeter, and Standard Atmospheric Model (SAM) for more accurate pressure readings.

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AHRS Adaptive Kalman Filter Outputs

The GX4-25 AHRS and GX4-15 IMU/VG models introduce an entirely new set of computed outputs from an on-board Adaptive Kalman Filter (AKF). These outputs have the same benefits as those from a GPS-INS Kalman Filter, including: optimum accuracy for a given operating regime, error estimation values, data validity flags, localization optimization (via the built-in World Magnetic Model for the magnetometer and the WGS84 gravitational model for the Accel vector), optional gyro ZUPT, adjustable sensor noise parameters, and adaptive rejection of sensor anomalies. The localization optimization allows for precise magnetic and gravitational field measurement; this is important because it allows the Kalman Filter to reject field anomalies, substantially stabilizing the attitude output in dynamic conditions.

It is important to note that the original Complementary Filter outputs from our GX3 sensors have been retained on the GX4 line. The AKF outputs are an *additional* new set of data quantities. If you are unable to change your code to use the AKF outputs, you can continue using the Complementary Filter outputs. At any time you can start developing for the AKF outputs and take advantage of the adaptive controls for optimum performance in your application.

Different Magnetometer

The GX4 uses an *integrated* digital magnetometer whereas the GX3 uses an *analog* magnetometer. The difference in magnetometers has virtually no effect on the position, velocity, or attitude outputs of the two devices.

Pressure Altimeter

The GX4-15, -25, and -45 each includes a pressure altimeter; the GX3 line does not.

Broader Temperature Range

The GX4 line has an operating temperature range of -40° to +85°C. The GX3 line has a narrower temperature range. The upper limit for the GX3-45/-35 is +65°C. The upper limit for the GX3-25/-15 is +70°C.

Higher Reliability

All of the GX4 standard housing models are packaged in a fully-enclosed aluminum case. The internal construction is less complex than the GX3 with more reliable components. The MTBF of the GX4-15/-25 is 1.2 million hours *(Telcordia GL Environment)*; the MTBF of the GX3 is not available. Also, the GX4 is designed to withstand higher shock and vibration.

Broader Supply Range

The GX4 can utilize a power supply in the range of 3.2 to 36 VDC, whereas the GX3 is limited to a max of 16 VDC. The GX4-45 consumes about 100mW less power than the GX3-45. The GX4-25/-15 consume about 100mW *more* power than their GX3 counterpart.

Smaller Size and Weight

The GX4 is, on average, 2 grams lighter than the corresponding GX3 model. The GX4-45 has a 2.5mm lower profile than the GX3-45, and the GX4-25/15 are 8mm shorter than the GX3-25/15.

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Different Range Options

The GX4 currently offers four Angular Rate options and two Accelerometer Range options. The GX3 offers four Angular Rate options and four Accelerometer Range options. The options do not completely overlap, and this may be a consideration for your application:

	GX4	GX3
Angular Rate Options	75°, 150°, 300°, 900°/second	50°, 300°, 600°, 1200°/second
Accelerometer Options	5*g*, 16*g*	1.7*g*, 5*g*, 16*g*, 50*g*

API Differences

IMU/AHRS Signal Conditioning Settings (0x0C35)

While this command is not itself supported on the GX4, the functionality has been distributed to several new commands for improved ease of use and flexibility:

- Enabling/disabling orientation and quaternion calculations is now automatically enabled in the GX4.
- Enabling/disabling finite size corrections is not used in the GX4.
- Enabling/disabling coning and sculling calculations is a separate new command. *See **Coning and Sculling Enable (0x0C, 0x3E) in the Data Communications Protocol (DCP).***
- The accel/gyro/magnetometer filter settings are replaced with a new filter setting command that allows individual values for each sensor. *See **Low Pass Filter Settings (0x0C50) in the DCP.***
- Gravity and Heading correction settings are contained in a new command. *See **Complementary Filter Settings (0x0C, 0x51) in the DCP**.*
- The option to choose between high and low magnetometer bandwidth is no longer supported.
- Enabling/disabling the magnetometer is now automatic.

Set Initial Attitude from AHRS (0x0D04)

This command is not supported on the GX4. The functionality is redundant with the Auto-Initialization Control command (0x0D19). If desired, the same functionality of the 0x0D04 command can be manually implemented by polling (0x0C01) the CF Euler Angles (0x800C) followed by the Set Initial Attitude command (0x0D02).

Data Quantities

The following data quantities are not supported on the GX4 (but are supported on the GX3):

- Raw Accelerometer Vector (0x80, 0x01)
- Raw Gyro Vector (0x80, 0x02)
- Raw Magnetometer Vector (0x80, 0x03)
- Orientation Update Matrix (0x80, 0x0B)
- Internal Timestamp (0x80, 0x0E)
- Beaconed Timestamp (0x80, 0x0F)

The new AKF data outputs on the GX4-25 include the following:

- Filter Status (0x82, 0x10)
- Filter GPS Timestamp (0x82, 0x11)

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- Estimated Quaternion (0x82, 0x03)
- Estimated Orientation Matrix (0x82, 0x04)
- Estimated Euler Angles (0x82, 0x05)
- Estimated Gyro Bias (0x82, 0x06)
- Estimated Attitude Uncertainty (Euler Angles) (0x82, 0x0A)
- Estimated Attitude Uncertainty (Quaternion Elements) (0x82, 0x12)
- Estimated Gyro Bias Uncertainty (0x82, 0x0B)
- Estimated Linear Acceleration (0x82, 0x0D)
- Estimated Angular Rate (0x82, 0x0E)
- WGS84 Local Gravity Magnitude (0x82, 0x0F)
- Estimated Gravity Vector (0x82, 0x13)
- Heading Update Source State (0x82, 0x14)
- Magnetic Model Solution (0x82, 0x15)
- Pressure Altitude (0x82, 0x21)

The new EKF data outputs on the GX4-45 include the following:

- Compensated Linear Acceleration (0x82, 0x1C)
- Standard Atmosphere Model (0x82, 0x20)
- Pressure Altitude (0x82, 0x21)
- GPS Antenna Offset Correction (0x82, 0x30)
- GPS Antenna Offset Correction Uncertainty (0x82, 0x31)

FAQ

Q: Will the 3DM-GX3 still be available?

A: Yes, we will continue to build the GX3 and have no immediate plans to retire the line.

Q: Are the connector and the mounting the same?

A: Yes, the GX4 and GX3 have the exact same connector and pin-out. The only difference is that the voltage range on Vaux (pin 6) is higher on the GX4. If you plug a GX3 into a connector that supplies more than 16 volts on Vaux, you may damage the device. The GX4 and GX3 also have the exact same mounting hole, alignment pin size, and pin location. *Note: The GX4-25/-15 is 8mm shorter (length-wise) than the GX3-25/15. This means that the micro-DB9 connector must be able to extend 4mm further than it did with the GX3-25/-15.*

Q: Are the data rates the same?

A: The data rates available on all devices are determined by their “base rate”. The data rates available are the base rate divided by an integer, so (for example) if the base rate of the IMU/AHRS message is 1000, you can have data rates of 1000/1, 1000/2, …. 1000/1000. The maximum data rate is the same as the base rate. The base rates of the GX4 and GX3 are compared below:

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Device	IMU/AHRS message	GPS message	CF Message	EF Message
GX4-45	**500 Hz**	**4 Hz**	**500 Hz**	**500 Hz**
GX3-45	100 Hz	4 Hz	100 Hz	100 Hz
GX4-25	**1000 Hz**	**-**	**1000 Hz**	**500 Hz**
GX3-25	1000 Hz	-	500 Hz	-
GX4-15	**1000 Hz**	**-**	**1000 Hz**	**500 Hz**
GX3-15	1000 Hz	-	500 Hz	-

Q: What is the difference between an AKF and EKF? What about AKF and CF?
A: All of the filters mentioned above are “estimation filters” (**EF**). When talking about estimation filters, one can quickly get mired in alphabet soup.

- A **Kalman Filter** is a linear quadratic estimation algorithm that operates recursively on noisy data and produces an estimate of a system’s current state that is statistically more precise than what a single measurement could produce.
- **EKF** stands for **Extended Kalman Filter**. This term is used generically to describe any estimation filter based on the Kalman Filter model that can handle **non-linear elements**. Almost all inertial estimation filters are fundamentally EKFs.
- **AKF** stands for **Adaptive Kalman Filter**. Technically speaking, this filter is also an EKF but it contains a high dependency on “adaptive” elements. “Adaptive” technology refers to the ability of a filter to selectively trust a given measurement more or less based on a “trust” threshold when compared to another measurement that is used as a reference. The GX4-25 and -15 rely on adaptive control elements to improve their estimations and hence we refer to the estimation filter used in those devices as an “AKF”. Technically speaking it is an “EKF with heavy reliance on adaptive elements” or possibly an “Adaptive Extended Kalman Filter”. We just call it an AKF.
- **CF** stands for **Complementary Filter** which is commonly used as a term for an algorithm that combines the readings from multiple sensors to produce a solution. These filters usually contain simple filtering elements to smooth out the effects of sensor over-ranging or anomalies in the magnetic field.

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