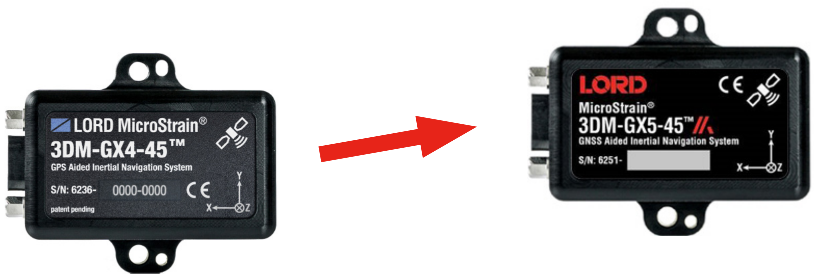
LORD TECHNICAL NOTE

Migrating from the 3DM-GX4™ to the 3DM-GX5™

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

Introduction

The 3DM-GX5 is the latest generation of the very popular 3DM-GX series of IMU, VG, AHRS, and GPS-INS. This is truly a "drop-in" replacement for the previous-generation GX4 inertial sensors, making it extremely simple to upgrade. However, there are a few key performance and API improvements that you should know about to extract the best performance from the GX5 series.



Performance Differences

There are several critical, performance-related differences between the GX4 and GX5 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 Accelerometers

By far, the most significant sensor improvement in the GX5 is the accelerometers. The accels are state-of-the-art new technology with a bias instability of <±0.04 mg and a noise density which is an industry leading 25 μg/√Hz for the 2g version. This noise density is only slightly higher for the 8g version (35 μg/√Hz). These improvements, combined with the associated improvements in the Kalman Filter result in extremely accurate position, velocity, and attitude accuracy even with aiding anomalies and outages, rivaling the performance of systems more than three times the cost.

Better Gyro Performance

The gyros used in the GX5 are the same high performance gyros used in the GX4 series, however we have extracted even better performance in the GX5 by moving to an ultra-high performance 24-bit ADC and adding other improvements to the data conditioning circuit. The room temperature bias instability has improved from 10°/hour to 7°/hour and overall bias drift is half of what it was before.

Multi-Constellation GNSS tracking

The GX5-45 GNSS-INS and GX5-35 GNSS-AHRS include a state-of-the-art multi-constellation receiver that can simultaneously track up to 32 satellites from the GPS, GLONASS, BeiDou, or Galileo constellations in addition to the SBAS systems such as WAAS, EGNOS, and MSAS. By comparison, the GX4 tracked 16 satellites and the GPS constellation only. This increased access to positioning information makes the performance in areas of restricted sky view such as urban canyons much more reliable and accurate. Even in open sky, the accuracy and acquisition times are much improved over earlier receivers.

Auto-Adaptive EKF

The GX5-45 GNSS-INS, GX5-25 AHRS, and GX5-15 VRU share LORD Sensing's new auto-adaptive EKF with up to 34 states (vs 25 for the GX4-45). The added states allow the GX5 to track and correct for more error

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sources. This ability allows the GX5 to automatically adjust error thresholds for detecting anomalies in the gravity vector measurement and the magnetic heading measurement.

Auto-Calibrating Magnetometer
Because of the added states in the EKF and the increased processing power of the Cortex M7 MCU, the GX5 can auto-calibrate the magnetometer in-run and in-situ. The ability to recalibrate in the field at any time without any external calibration tools, and the ability to continually calibrate, and the auto-adaptive monitoring of magnetic anomalies, makes the magnetometer a much more accurate heading reference in challenging applications.

Different Range Options
The GX5 currently offers four gyro rate range options and five accelerometer range options. The GX4 offers four gyro rate range options and two accelerometer range options.

	GX5	GX4
Gyro Rate Range Options	±75°, 150°, 300°, 900°/second	±75°, 150°, 300°, 900°/second
Accelerometer Range Options	±2g, 4g, 8g, 20g, 40g	±5g, 16g

What Hasn't Changed
The GX5 shares the same extended temperature range operation, footprint, rugged aluminum case, reliability, low power, broad voltage supply, power/communication cabling, weight, and MIP API as the 3DM-GX4 making it a true drop-in replacement. Please note that to take advantage of many of the new features of the GX5, some MIP API commands have been expanded, and others have been added.

API Differences

GX5 MIP API: New Commands:

Get Extended Device Descriptor Sets (0x01, 0x07)
This command returns additional descriptors that are not included in the base Get Device Descriptor Sets command.

GNSS Constellation Settings (0x0C, 0x21)
Provides options for controlling the number of satellites to track in each constellation.

GNSS SBAS Settings (0x0C, 0x22)
Provides options for controlling the individual SBAS satellites tracking.

GNSS Assisted Fix Control (0x0C, 0x23)
Enable or Disable the GNSS assisted fast start capability. This feature keeps information about satellite trajectories on-board the device so that when the power is cycled, the time to first fix (TTFF) is greatly educed.

GNSS Assisted Time Update (0x0C, 0x24)
Allows the host to send current time to the device on power up to help reduce the time to first fix (TTFF).

Pitch-Roll Aiding Control (0x0D, 0x4B)
Gives the user the choice of Pitch and Roll aiding source. The choices are None or Gravity Vector.

Altitude Aiding Control (0x0D, 0x47)
Gives the user the choice of altitude aiding source. The choices are None or Pressure Altimeter.

Gravity Noise Standard Deviation (0x0D, 0x28)
Sets the expected gravity noise value.

Pressure Altitude Noise Standard Deviation (0x0D, 0x29)
Sets the expected pressure altimeter noise value.

Hard Iron Offset Process Noise (0x0D, 0x2B)
Sets the expected magnetometer hard-iron (offset) noise values.

Soft Iron Matrix Process Noise (0x0D, 0x2C)
Sets the expected magnetometer soft-iron (scale factor) noise values.

GX5 MIP API: Extensions to Existing Command:

Estimation Control Flags (0x0D, 0x14)
In addition to the switches available on the GX4, there are two new switches to turn on hard iron and soft iron error tracking for auto-mag calibration on the GX5.

Heading Update Control (0x0D, 0x18)
In addition to the choices available in the GX4, there are four additional choices on the GX5. These new choices allow the use of multiple simultaneous heading sources.

Gravity Magnitude Error Adaptive Measurement (0x0D, 0x44)
In addition to the choices available in the GX4, there is an additional choice to select "Auto-Adaptive".

Device Specific Status (0x0C, 0x64)
As with all Inertial Devices, this Device Status message is slightly different for all devices and tightly coupled to the model number. Make sure you refer to the DCP for your device to check for compatibility of status fields returned by the device.

GX5 MIP API: New Data Quantities

The new EKF data outputs include the following:

- **Mag Auto Hard Iron Offset (0x82, 0x25)**
- **Mag Auto Hard Iron Offset Uncertainty (0x82, 0x28)**
- **Mag Auto Soft Iron Matrix (0x82, 0x26)**
- **Mag Auto Soft Iron Matrix Uncertainty (0x82, 0x29)**

FAQ

Q: Will the 3DM-GX4 still be available?
A: Yes, we will continue to build the GX4 and have no immediate plans to retire the line.

Q: Are the connector and the mounting the same?
A: Yes, the GX5 and GX4 have the exact same micro-DB9 connector and pin-out. The GX5 and GX4 also have the exact same mounting hole, alignment pin size, and pin location.

Q: Are the data rates the same?

A: Yes, the data rates are identical on the GX5 and GX4. (See table on next page. GX3 data rates are provided for reference.):

Device	IMU/AHRS message	GNSS message	Estimation Filter Message
GX5-45	**500**	**4**	**500**
GX4-45	500	4	500
GX3-45	100	4	100
GX5-25	**1000**	**-**	**500**
GX4-25	1000	-	500
GX3-25	1000	-	-
GX5-15	**1000**	**-**	**500**
GX4-15	1000	-	500
GX3-15	1000	-	-

Q: What is the difference between "Auto-Adaptive" and "Adaptive"?
A: The Adaptive feature of the GX4 allows the user to enter thresholds that are used to determine if the gravity vector or magnetometer vector are too large or pointing in an unexpected direction. When exceeding those thresholds, the Kalman Filter ignores them as references and relies on the inertial solution to determine attitude. This feature is retained on the GX5, however an "automatic" option has been added. This feature dynamically sets the adaptive thresholds by tracking the errors on the gravity vector and magnetometer. This makes it much easier for a user to utilize the adaptive features effectively without needing to determine the thresholds manually. The auto-adaptive magnetometer and auto-calibrating magnetometer features combine to make the magnetometer a much more reliable and accurate heading reference. The auto-adaptive gravity greatly improves the pitch-roll accuracy during dynamic maneuvers.

Q: I am migrating from the 3DM-GX3. What do I do?
A: There are some critical differences between the GX3 and the GX4/GX5. In most cases, a GX4 or GX5 is a drop-in replacement, but there were a few commands and data quantities that were deprecated and replaced by equivalent but enhanced commands. Please see the document "Migrating From a 3DM-GX3® Series Sensor to a 3DM-GX4™" which can be found by going to www.microstrain.com/documents/inertial and selecting your current GX3 device from the drop-down menu. Migrating from the GX3 to the GX5 is identical to migrating from the GX3 to the GX4 although the GX5 has more features and options as outlined in this document.

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

• **KF** stands for **Kalman Filter**. It 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 3DM 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.

• **AA EKF** stands for **Auto-Adaptive Extended Kalman Filter**. This is an adaptive EKF that, like the AKF described above, has "adaptive" elements that selectively trust given measurements more or less based on comparison to reference inputs. The difference with the auto-adaptive filter is that the "trust" thresholds are automatically determined by the filter itself. The filter collects error metrics on all the measurements and uses this to determine appropriate trust thresholds. This feature makes tuning a Kalman Filter for optimum performance much easier than manually determining these thresholds. The GX5 series introduces the Auto-Adaptive feature whereas the GX4 has fixed adaptive thresholds.

• **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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