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# *i*Sensor® IMU Quick Start Guide and Bias Optimization Tips

by Mark Looney

## INTRODUCTION

The *i*Sensor IMU products include ADIS1636x and ADIS1640x. These multi-axis, inertial sensing systems provide a basic building block for many different motion analysis and control applications (for example, navigation and platform stabilization).

## PHYSICAL MOUNTING AND HANDLING

The *i*Sensor IMU package has two basic parts for handling and installation into a system: an aluminum baseplate and a flexible connector (see Figure 1). The aluminum baseplate provides four mounting tabs, which accommodate a number of attachment approaches. Figure 2 and Figure 3 offer a simple method, which uses two M2 or 2-56 machine screws to secure the baseplate to the system printed circuit board. It also provides an option for using the precision alignment holes to tighten initial sensor alignment, with respect to the system's inertial reference frame in the yaw axis. Note that the dimensions in Figure 3 assume that the baseplate attaches to the same surface that has the electrical mating connector.

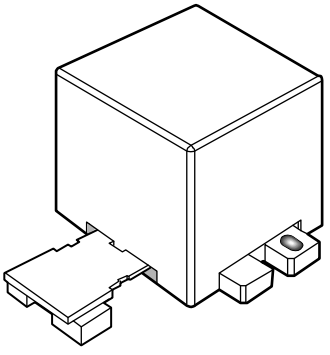



*Figure 1. IMU Package Style*

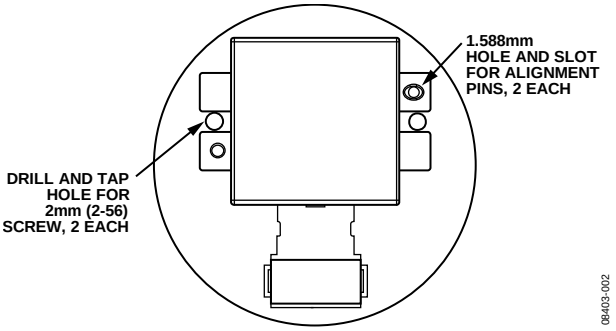



*Figure 2. Two-Screw Mounting Approach, with Alignment Pins*

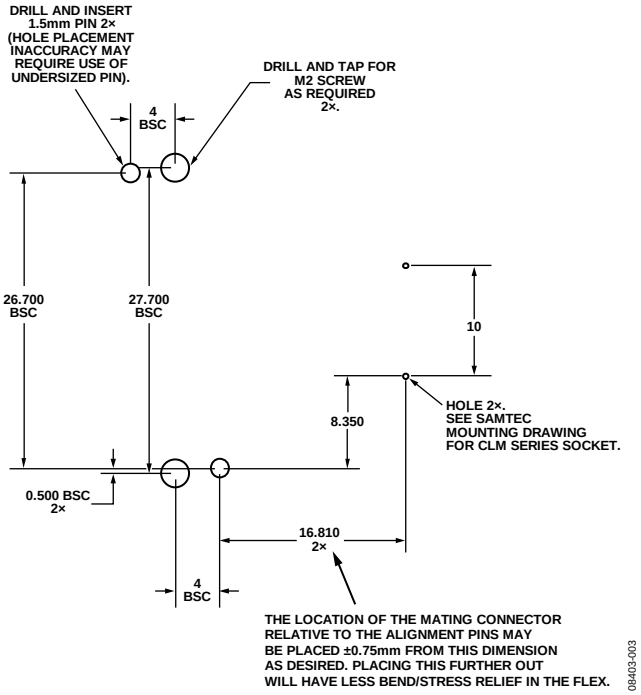



*Figure 3. Suggested Mounting Hole Locations*

Applications that anticipate high shock and vibration may require more elaborate attachment systems to eliminate mechanical resonance, but the two-screw approach provides a simple starting point to begin data collection in parallel with mechanical system design. Figure 4 provides the pad layout pattern used for the mating connector (Samtec CLM-112-02-LM-D-A) on the ADISUSBZ evaluation system.

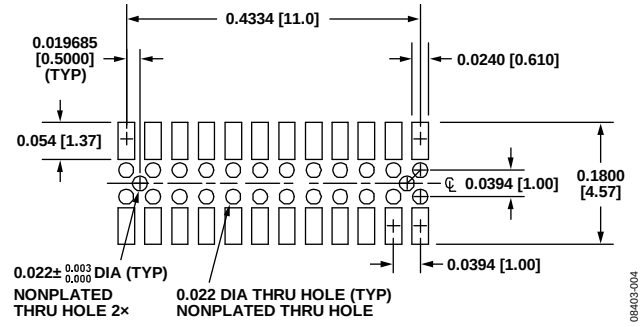



*Figure 4. Suggested Layout and Mechanical Design for Mating Connector*

## IMU INSTALLATION AND REMOVAL

IMU installation follows a two-step sequence:

1. Secure the baseplate using machine screws.
2. Press the connector into its mate.

For removal, gently pry the connector from its mate, using a small slot screwdriver. Then, remove the screws and lift the part up. Never attempt to unplug the connector by pulling on the plastic case or baseplate. While very reliable in normal operation, the flexible connector can break when subjected to unreasonable handling. When broken, there are no repair options for the flexible connector.

## ELECTRICAL HOOK-UP

When power is applied, the *i*Sensor products start up and begin producing data, independent of user inputs. Figure 5 provides a hook-up diagram, which accommodates power, ground, four serial signals, and a data-ready signal. The data-ready signal typically drives an interrupt service routine in the master processor, which ensures data coherency while optimizing processor resources.

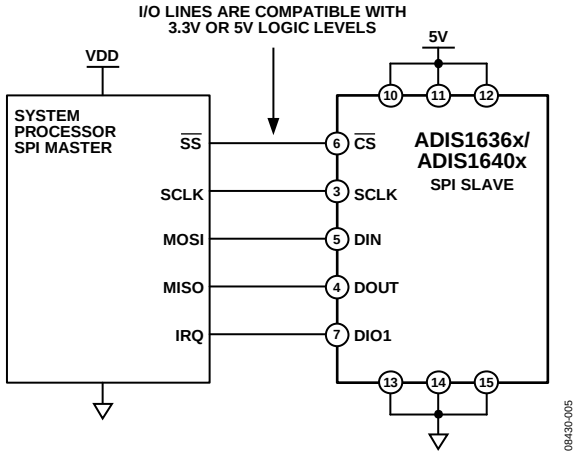



*Figure 5. Electrical Hook-Up Diagram*

**Table 1. Generic Master Processor Pin Names and Functions**

| Pin Name | Function |
|---|---|
| $\overline{SS}$ | Slave select |
| IRQ | Interrupt request |
| MOSI | Master output, slave input |
| MISO | Master input, slave output |
| SCLK | Serial clock |

## SPI INTERFACE

Table 2 provides a list of typical configuration settings that master processors require for SPI communication with *i*Sensor IMUs. These settings are normally in control registers. For example, the SPI_BAUD, SPI_CTL, and SPI_FLG registers serve this purpose in the ADSP-BF533 processor family.

**Table 2. Generic Master Processor SPI Settings**

| Processor Setting | Description |
|---|---|
| Master | The *i*Sensor IMUs operate as slaves. |
| SCLK Rate ≤ 2 MHz | Normal mode, SMPL_PRD[7:0] ≤ 0x09. |
| SPI Mode 3 | CPOL = 1 (polarity), CHPA = 1 (phase). |
| MSB-First Mode | Bit sequence. |
| 16-Bit Mode | Shift register/data length. |

Data communication requires firmware-level register management. Placing a command on DIN involves writing to the transmit buffer register (SPI_TDBR in the ADSP-BF533). Acquiring output data from DOUT involves reading the receive buffer register (SPI_RDBR in the ADSP-BF533).

## OPTIMIZING BIAS ACCURACY AND STABILITY

All of the *i*Sensor IMUs include a factory calibration that provides substantial improvements in bias accuracy over most MEMS gyroscopes. Some environmental conditions (such as temperature cycling and installation) can cause minor shifts in gyroscope output bias. A single-point adjustment can address these shifts and restore the entire calibration, including the temperature correction that comes with some parts. This involves measuring the zero-rotation gyroscope output and writing the opposite value into its offset register. There are three basic options for executing the single-point adjustment in the gyroscopes: autonull, precision autonull, and manual calibration. The following conditions/settings help assure optimum accuracy during this process:

1. Sample rate = 819.2 SPS (SMPL_PRD[7:0] = 0x01)
2. Thermal stability
   Reading the temperature output registers can help determine when this happens.
3. Zero rotation (including vibration)
   Take a small sample of data and make sure that the output noise is in agreement with the data sheet. For example, with no filtering, the ADIS1636x and ADIS1640x should have less than 1°/sec rms of noise on their gyroscopes.

Averaging multiple samples of each gyroscope helps address the uncertainty associated with gyroscope noise. The Allan variance curve provides a relationship between averaging time and bias accuracy.

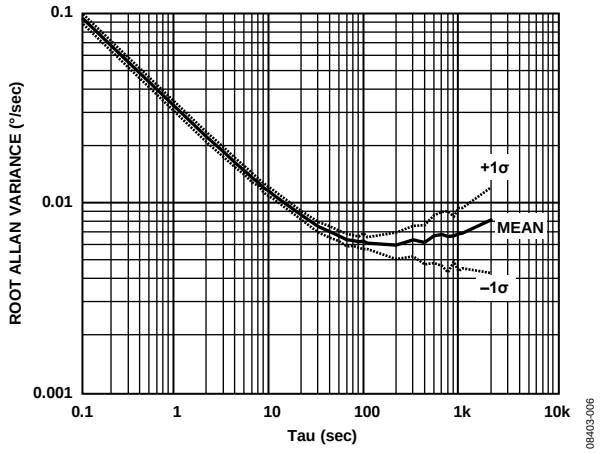



*Figure 6. ADIS1636x/ADIS1640x Allan Variance Curve*

### *Autonull Function*

The autonull function automatically reads each gyroscope output register and writes the opposite value into the appropriate user offset register. Use the following steps to obtain the best results from this option:

1. SMPL_PRD[7:0] = 0x01 (DIN = 0xB601)
2. SENS_AVG[7:0] = 0x06 (DIN = 0xB806)
3. Allow 200 ms for the internal filter taps to fill up.
4. GLOB_CMD[0] = 1 (DIN = 0xBE01)

When using this sequence, the equivalent averaging time is approximately 0.15 seconds. According to Figure 6, this produces a bias accuracy of approximately 0.08°/sec.

### *Precision Autonull Function*

The precision autonull function offers better accuracy than the autonull function by taking a 30 second average of each gyroscope output, then calculating the appropriate correction factors and automatically loading them into the user-offset register. During the 30 second measurement period, the IMU automatically sets its sample rate and filters for optimal data collection. For the ADIS1636x and ADIS1640x families, the bias correction accuracy can approach 0.008°/sec (see Figure 6, 30 second average time). Execute this function by setting GLB_CMD[4] = 1 (DIN = 0xBE10).

### *Manual Calibration*

Manual calibration offers the advantage of optimizing the bias accuracy for applications that can accommodate the extended averaging times. In reviewing the Allan variance curve (see Figure 6), a 100 second average time yields the best accuracy for a given population of parts. Use the following steps to achieve the best manual calibration results:

1. SMPL_PRD[7:0] = 0x01 (DIN = 0xB601)
2. Wait 1 min to 2 min for initial thermal settling. This may be application-dependent and require warm-up periods up to 10 min to 15 min.
3. Verify by reading the TEMP_OUT registers.
4. Read 82,000 samples at 819.2 SPS (~100 seconds)
5. Calculate the average of these values.
6. Convert this estimate into an offset correction factor. For the internal user-offset registers:
   a. Multiply the estimate by 80.
   b. Round it to the nearest integer.
   c. Convert the number to a 14-bit, twos complement format.
7. Write it to the appropriate user-offset register.
8. GLOB_CMD[3] = 1 (DIN = 0xBE04), if using the internal user-offset correction registers.

The user-offset registers offer a resolution step size of 0.0125°/sec, which is sufficient for a large majority of applications. For those who have the opportunity to perform the correction in their processor, users can achieve incremental performance gains and increase the number of parts that perform to the 0.006°/sec bias accuracy shown in Figure 6. In this case, use a 16-bit register that adds to the IMU gyroscope outputs and change the multiplication factor in Step 6a from 80 to 320.

### *Sample Rate Decimation*

The internal sample rate of 819.2 SPS is essential to preserving the best bias stability performance in these products. For applications that value lower sample rates, use the internal Bartlett window filters to limit the bandwidth and decimate the data available in the gyroscope and accelerometer output registers. One method is to use the data-ready output to drive a counter, which divides the system-level sample rate by integer levels. While each system may require specific tuning, use the number of taps per stage in the Bartlett window filter as the maximum division factor in each setup. For example, if SENS_AVG[2:0] = 100, which translates to 16 taps per stage, users can divide the sample rate by any integer number between 2 and 16 and still preserve optimum bias stability performance.

## NOTES

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