ANALOG DEVICES

AN-1042
APPLICATION NOTE

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ADIS16130 Quick Start Guide and Bias Optimization Tips
by Mark Looney

PHYSICAL MOUNTING AND HANDLING

The ADIS16130 comes in a plastic housing that provides four mounting holes accommodating either M2 or 2-56 machine screws. This package enables both connector-up and connector-down mounting approaches. Figure 2 provides a mechanical diagram for a system using the connector-down approach. In comparison, the connector-up approach uses the same hole pattern for the four mounting screws but requires an additional cable/connector interface for electrical connection. The connector provides a standard, dual-row, 1 mm pitch that offers many options for mating connectors. Figure 3 provides the suggested pad layout and hole pattern for the mating connector, assuming use of a connector from the Samtec CLM-112-02 family. The holes inside of the mounting pads prevent the pins on the ADIS16130 connector from bottoming out, which can cause mechanical stress and bias shifts.
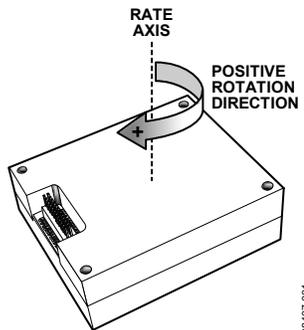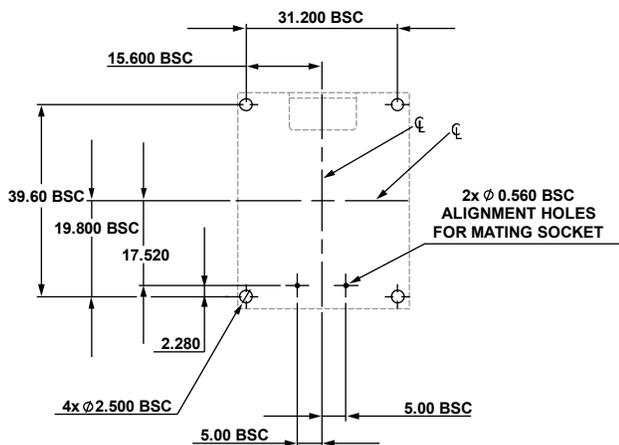

Figure 1. ADIS16130 Package Style

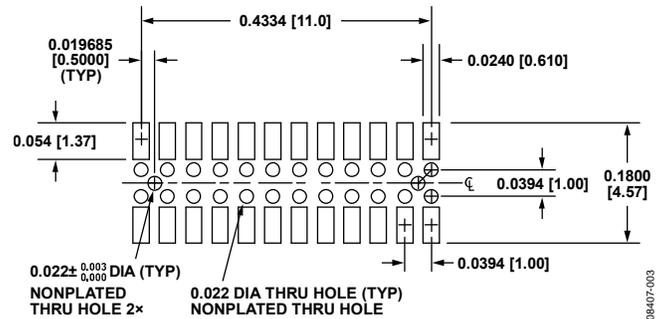Figure 2. Suggested Mounting Hole Locations

Figure 3. Suggested Layout and Mechanical Design for the Mating Connector

ELECTRICAL HOOKUP

Figure 4 provides a basic schematic for connecting the ADIS16130 to a system processor, which serves as the SPI master. Once configured, the ADIS16130 produces data autonomously and continuously updates the output data register(s). This hookup diagram accommodates the power, the ground, four serial signals, a data-ready signal, and the bandwidth reduction capacitor. The data-ready signal typically drives an interrupt service routine in the master processor, which helps optimize data coherency and processor resources.
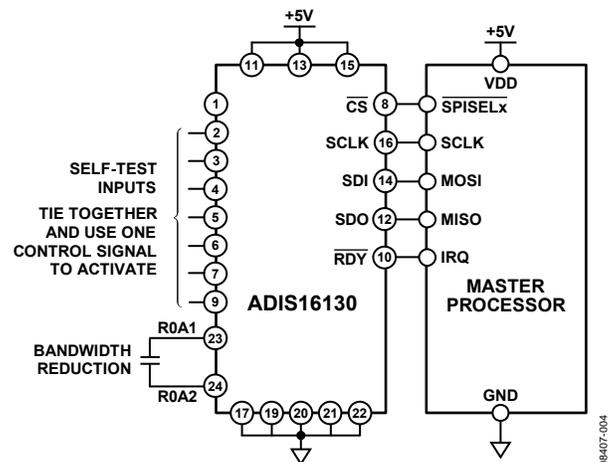

Figure 4. Electrical Hookup Diagram

Table 1. Generic Master Processor Pin Names and Functions

Pin Name	Function
SPISELx	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 the ADIS16130. 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. Refer to the ADIS16130 data sheet for timing information.

Table 2. Generic Master Processor SPI Settings

Processor Setting	Description
Master	ADIS16130 operate as slave.
SPI Mode 3	CPOL = 1 (polarity), CHPA = 1 (phase).
MSB-First Mode	Bit sequence.
8-Bit Mode	Shift register/data length.

Placing a command on SDI involves writing to the transmit buffer register (SPI_TDBR in the ADSP-BF533), and acquiring output data from SDO involves reading the receive buffer register (SPI_RDBR in the ADSP-BF533). For many processors, these commands automatically facilitate the clocks and sequencing according to the settings in the control registers.

INITIALIZATION

Initialize the ADIS16130 by writing each command that is listed in the SDI column of Table 3 to the SDI pin.

Table 3. Configuration Sequence

Step	SDI[1]	Register	Purpose
1	0x01	COM	Start a write sequence for IOP.
2	0x38	IOP	Configure the data-ready signal to pulse low when the RATEDATA and TEMPDATA output registers contain new data.
3	0x28	COM	Start a write sequence for the RATECS register.
4	0x0A	RATECS	Enable and configure the gyroscope data channel.
5	0x30	COM	Start a write sequence for the RATECONV register.
6	0x05	RATECONV	Initialize the rate conversion.
7	0x2A	COM	Start a write sequence for the TEMPCS register.
8	0x0A	TEMPCS	Enable and configure the temperature data channel.
9	0x32	COM	Start a write sequence for the TEMPCONV register.
10	0x05	TEMPCONV	Initialize the temperature conversion.
11	0x38	COM	Start a write sequence for the MODE register.
12	0x22	MODE	Establish the data output resolution to 24 bits and start the conversion process with the RATEDATA channel.

[1] The SDI column lists the hexadecimal code representation of each command.

READING OUTPUT DATA

The data ready ($\overline{RDY}$) signal indicates that new, unread data resides in the output registers. To optimize data coherency and processor resources, use this signal to drive an interrupt service routine in the master processor. It will pulse low for approximately 26 μs at a rate of 11.4 kHz, which indicates a new update in either the RATE or TEMP registers. Use the high-to-low transition to trigger action on the interrupt service routine. Read data after this signal pulses low by lowering the chip select line and then shifting (write) 0x48 onto the SDI line. Then, shift (read) the next three bytes in from SDO, which represents the resulting output data. Raise chip select between each 8-bit sequence.

The most significant byte is first in the SDO sequence, followed by the next significant, and then the least significant. When 16-bit resolution is in use, only two bytes are output from the SDO during the read sequence.
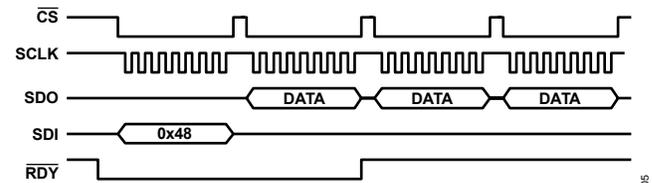

Figure 5. Read Sequence Example

DATA FORMAT

The ADIS16130 uses the offset binary data format.

$$RATE = \left[\frac{Codes - 2^{23}}{23,488} \right] \quad TEMP = \left[\frac{Codes - 2^{23}}{14,093} + 25°C \right]$$

Table 4. Gyroscope Rate Output Data Format

24-Bit (Codes)	16-Bit (Codes)	Rate Output
14,260,608	55,706	+250°/sec
8,623,488	33,686	+10°/sec
8.388,612	32,769	+0.00017030°/sec
8,388,609		+0.000042575°/sec
8,388,608	32,768	0
8,388,607		−0.000042575°/sec
8,388,604	32,767	−0.00017030°/sec
8,153,728	31,850	−10°/sec
2,516,608	9,830	−250°/sec

Table 5. Gyroscope Temperature Output Data Format

24-Bit (Codes)	16-Bit (Codes)	Rate Output
9,516,048	37,172	+105°C
9,234,188	36,071	+85°C
8,402,701	32,823	+26°C
8,388,608	32,768	+25°C
8,036,283	31,392	+0°C
7,472,563	29,189	−40°C

OPTIMIZING BIAS ACCURACY AND STABILITY

Two common sources of error in gyroscope systems are initial bias error and bias change with temperature. Figure 6 provides a simple process diagram for correcting these errors in a digital processor platform. Each ADIS16130 has unique behaviors that require characterization to optimize the correction factors in this process diagram.
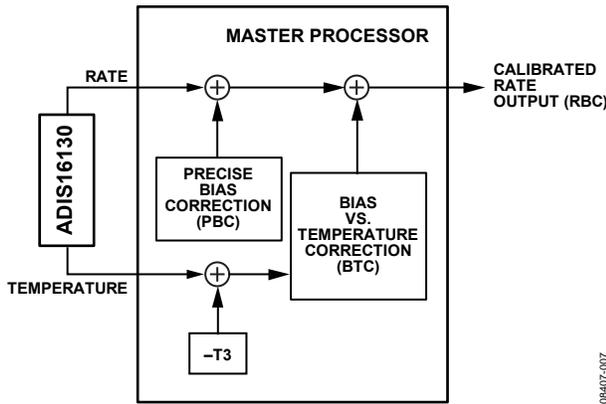

Figure 6. First-Order Bias Correction System

This calibration process results in the following mathematical relationship for the corrected gyroscope rate output:

$$RBC = RATE + PBC + (TEMP - T3) \times BTC$$

where:
RBC is the corrected output data.
$RATE$ is the ADIS16130 gyroscope output data.
$TEMP$ is the ADIS16130 temperature output data.

Bias characterization involves measuring the ADIS16130 output while it is in a zero-rotation state. Noise adds random errors to the output measurement and can influence the accuracy of bias measurements. A common approach to addressing noise in the bias measurement is through averaging sequential samples. The Allan variance curves in Figure 7 display a relationship between averaging time and bias accuracy for the ADIS16130.
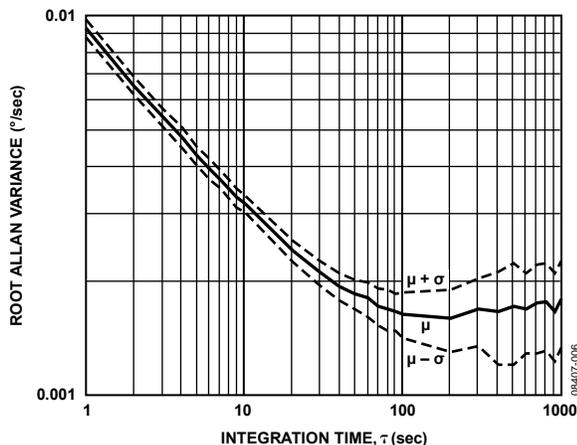

Figure 7. ADIS16130 Allan Variance Curves

While each application has its own performance criteria, the following procedure provides a basic bias calibration process for getting started:

1. Attach the ADIS16130 to a fixed platform to prevent any motion during the measurement steps.

2. Apply a stable +5 V linear supply to the ADIS16130. Note that the output bias can shift by 0.0002°/sec for every 1 mV of change in the power supply.

3. Write the initialization commands from Table 3 to the SDI pin.

4. Read TEMP and RATE data at the maximum sample rate of 5.7 kSPS for 10 sec. Average each set of data to produce a temperature estimate (T1) and a bias estimate (B1) associated with this average temperature.

5. Wait 10 minutes for the device to self-heat.

6. Repeat Step 3 to produce new estimates for temperature (T2) and output bias (B2). Then, calculate the bias temperature coefficient (BTC) by using the following equation:

$$BTC = -bias\ tempco = -\left[\frac{B2 - B1}{T2 - T1}\right]$$

Using BTC, develop a look-up table for loading the correction factor suitable for the temperature conditions. Table 6 shows an example of correction factors in a table that corrects for a 0.04°/sec/°C bias tempco, using temperature step sizes of 0.02°C.

7. Wait 40 minutes for thermal stability.

8. Read the RATE data at a sample rate of 5.7 kSPS for 150 sec. Average this data together for a precise bias estimate and multiply it by −1 to produce the precise bias correction factor (PBC).

9. Read TEMP (T3).

Table 6. Bias Correction Factors, TBIAS = 0.04°/sec per °C

Temperature Control (TEMP − T3)	Bias vs. Temperature Correction Factor (TEMP − T3) × BTC
+0.12°C	−0.0048°/sec
+0.10°C	−0.0040°/sec
+0.08°C	−0.0032°/sec
+0.06°C	−0.0024°/sec
+0.04°C	−0.0016°/sec
+0.02°C	−0.0008°/sec
0°C	0°/sec
−0.02°C	+0.0008°/sec
−0.04°C	+0.0016°/sec
−0.06°C	+0.0024°/sec
−0.08°C	+0.0032°/sec
−0.10°C	+0.0040°/sec
−0.12°C	+0.0048°/sec

ADDITIONAL TIPS

In conclusion, the simple calibration process offered in this application note enables customers to achieve substantial performance gains and helps lay the groundwork for developing more extensive calibration approaches, if necessary. Here are some additional tips that may add value:

1. The 5.7 kSPS sample rate enables filtering of resonant behaviors that can show up around 14.3 kHz.

2. Use a 0.01 μF capacitor across ROA1 and ROA2 to reduce the sensor bandwidth to 50 Hz, which reduces the noise by 50%. The 50 Hz bandwidth also enables the use of slower sample rates. For example, use the $\overline{RDY}$ signal to drive a 200× counter to reduce the read rate to 230 SPS.

3. The calibration process in this application note takes advantage of the thermal warm-up period in these devices. For better accuracy, use a controlled temperature chamber to hold the device at fixed temperatures while using longer averaging times for each bias point. This provides the opportunity for further performance optimization.

4. If the processor system cannot read both gyroscope and temperature sensor outputs at the rate of 5.7 kSPS, reduce the read rate on the temperature sensor before considering a decrease in the rate measurements. If the maximum rate of temperature change is 1°C/sec, then a sample rate of 100 SPS should be sufficient for detecting 0.02°C changes for updating thermal correction factors.

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