

FEATURES

- Triaxial, digital gyroscope, $\pm 450^\circ/\text{sec}$ dynamic range**
 - $< \pm 0.05^\circ$ orthogonal alignment
 - 6°/hr in-run bias stability
 - 0.3°/√hr angular random walk
 - 0.01% nonlinearity
- Triaxial, digital accelerometer, $\pm 18 g$**
- Triaxial, delta angle and delta velocity outputs**
- Triaxial, digital magnetometer, ± 2.5 gauss**
- Digital pressure sensor, 300 mbar to 1100 mbar**
- Fast start-up time, ~ 500 ms**
- Factory-calibrated sensitivity, bias, and axial alignment**
 - Calibration temperature range: -40°C to $+70^\circ\text{C}$
- SPI-compatible serial interface**
- Embedded temperature sensor**
- Programmable operation and control**
 - Automatic and manual bias correction controls
 - 4 FIR filter banks, 120 configurable taps
 - Digital I/O: data-ready alarm indicator, external clock
 - Alarms for condition monitoring
 - Power-down/sleep mode for power management
 - Optional external sample clock input: up to 2.4 kHz
 - Single-command self-test
- Single-supply operation: 3.0 V to 3.6 V**
- 2000 g shock survivability**
- Operating temperature range: -40°C to $+85^\circ\text{C}$**

APPLICATIONS

- Platform stabilization and control
- Navigation
- Personnel tracking
- Instrument
- Robotics

GENERAL DESCRIPTION

The [ADIS16488](#) iSensor® device is a complete inertial system that includes a triaxis gyroscope, a triaxis accelerometer, triaxis magnetometer, and pressure sensor. Each inertial sensor in the [ADIS16488](#) combines industry-leading iMEMS® technology with signal conditioning that optimizes dynamic performance. The factory calibration characterizes each sensor for sensitivity, bias, alignment, and linear acceleration (gyroscope bias). As a result, each sensor has its own dynamic compensation formulas that provide accurate sensor measurements.

The [ADIS16488](#) provides a simple, cost-effective method for integrating accurate, multi-axis inertial sensing into industrial systems, especially when compared with the complexity and investment associated with discrete designs. All necessary motion testing and calibration are part of the production process at the factory, greatly reducing system integration time. Tight orthogonal alignment simplifies inertial frame alignment in navigation systems. The SPI and register structure provide a simple interface for data collection and configuration control.

The [ADIS16488](#) uses the same footprint and connector system as the [ADIS16375](#), which greatly simplifies the upgrade process. It comes in a module that is approximately 47 mm × 44 mm × 14 mm and has a standard connector interface.

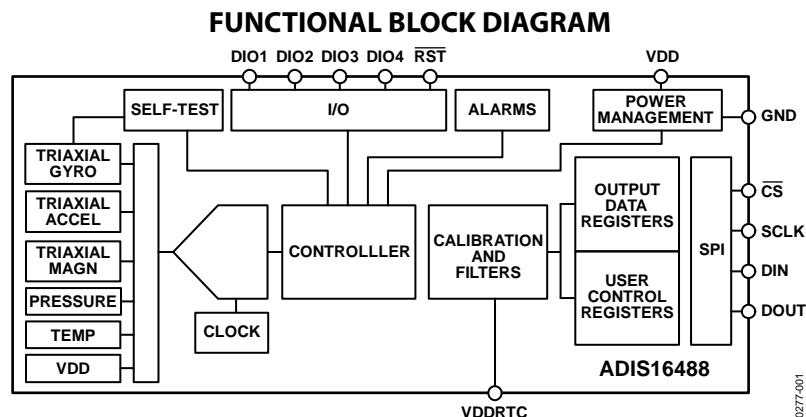


Figure 1.

Rev. B

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REVISION HISTORY

2/12—Rev. A to Rev. B

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10/11—Revision 0: Initial Version

SPECIFICATIONS

$T_A = 25^\circ\text{C}$, $V_{DD} = 3.3\text{ V}$, angular rate = $0^\circ/\text{sec}$, dynamic range = $\pm 450^\circ/\text{sec} \pm 1\text{ g}$, 300 mbar to 1100 mbar, unless otherwise noted.

Table 1.

| Parameter | Test Conditions/Comments | Min | Typ | Max | Unit |
|-------------------------------------|---|-----------|------------------------|-----------|--|
| GYROSCOPES | | | | | |
| Dynamic Range | | ± 450 | | ± 480 | $^\circ/\text{sec}$ |
| Sensitivity | x_GYRO_OUT and x_GYRO_LOW (32-bit) | | 3.052×10^{-7} | | $^\circ/\text{sec}/\text{LSB}$ |
| Initial Sensitivity Tolerance | | | | ± 1 | % |
| Sensitivity Temperature Coefficient | $-40^\circ\text{C} \leq T_A \leq +70^\circ\text{C}$, 1σ | | ± 35 | | $\text{ppm}/^\circ\text{C}$ |
| Misalignment | Axis-to-axis | | ± 0.05 | | Degrees |
| | Axis-to-frame (package) | | ± 1.0 | | Degrees |
| Nonlinearity | Best-fit straight line, $FS = 450^\circ/\text{sec}$ | | 0.01 | | % of FS |
| Initial Bias Error | 1σ | | ± 0.2 | | $^\circ/\text{sec}$ |
| In-Run Bias Stability | 1σ | | 6.25 | | $^\circ/\text{hr}$ |
| Angular Random Walk | 1σ | | 0.3 | | $^\circ/\sqrt{\text{hr}}$ |
| Bias Temperature Coefficient | $-40^\circ\text{C} \leq T_A \leq +70^\circ\text{C}$, 1σ | | ± 0.0025 | | $^\circ/\text{sec}/^\circ\text{C}$ |
| Linear Acceleration Effect on Bias | Any axis, 1σ (CONFIG[7] = 1) | | 0.009 | | $^\circ/\text{sec}/\text{g}$ |
| Output Noise | No filtering | | 0.16 | | $^\circ/\text{sec rms}$ |
| Rate Noise Density | $f = 25\text{ Hz}$, no filtering | | 0.0066 | | $^\circ/\text{sec}/\sqrt{\text{Hz rms}}$ |
| 3 dB Bandwidth | | | 330 | | Hz |
| Sensor Resonant Frequency | | | 18 | | kHz |
| ACCELEROMETERS | | | | | |
| Dynamic Range | Each axis | ± 18 | | | <i>g</i> |
| Sensitivity | x_ACCL_OUT and x_ACCL_LOW (32-bit) | | 1.221×10^{-8} | | <i>g</i> /LSB |
| Initial Sensitivity Tolerance | | | | ± 0.5 | % |
| Sensitivity Temperature Coefficient | $-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$, 1σ | | ± 25 | | $\text{ppm}/^\circ\text{C}$ |
| Misalignment | Axis-to-axis | | ± 0.035 | | Degrees |
| | Axis-to-frame (package) | | ± 1.0 | | Degrees |
| Nonlinearity | Best-fit straight line, $\pm 10\text{ g}$ | | 0.1 | | % of FS |
| | Best-fit straight line, $\pm 18\text{ g}$ | | 0.5 | | % of FS |
| Initial Bias Error | 1σ | | ± 16 | | mg |
| In-Run Bias Stability | 1σ | | 0.1 | | mg |
| Velocity Random Walk | 1σ | | 0.029 | | $\text{m}/\text{sec}/\sqrt{\text{hr}}$ |
| Bias Temperature Coefficient | $-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$ | | ± 0.1 | | $\text{mg}/^\circ\text{C}$ |
| Output Noise | No filtering | | 1.5 | | mg rms |
| Noise Density | $f = 25\text{ Hz}$, no filtering | | 0.067 | | $\text{mg}/\sqrt{\text{Hz rms}}$ |
| 3 dB Bandwidth | | | 330 | | Hz |
| Sensor Resonant Frequency | | | 5.5 | | kHz |
| MAGNETOMETER | | | | | |
| Dynamic Range | | ± 2.5 | | | gauss |
| Sensitivity | | | 0.1 | | mgauss/LSB |
| Initial Sensitivity Tolerance | | | | ± 2 | % |
| Sensitivity Temperature Coefficient | 1σ | | 275 | | $\text{ppm}/^\circ\text{C}$ |
| Misalignment | Axis to axis | | 0.25 | | Degrees |
| | Axis to frame (package) | | 0.5 | | Degrees |
| Nonlinearity | Best fit straight line | | 0.5 | | % of FS |
| Initial Bias Error | 0 gauss stimulus | | ± 15 | | mgauss |
| Bias Temperature Coefficient | $-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$, 1σ | | 0.3 | | $\text{mgauss}/^\circ\text{C}$ |
| Output Noise | No filtering | | 0.45 | | mgauss |
| Noise Density | $f = 25\text{ Hz}$, no filtering | | 0.054 | | $\text{mgauss}/\sqrt{\text{Hz}}$ |
| 3 dB Bandwidth | | | 330 | | Hz |

| Parameter | Test Conditions/Comments | Min | Typ | Max | Unit |
|-------------------------------------|---|------------------|----------------------|------|---------------|
| BAROMETER | | | | | |
| Pressure Range | | 300 | | 1100 | mbar |
| | Extended | 10 | | 1200 | mbar |
| Sensitivity | BAROM_OUT and BAROM_LOW (32-bit) | | 6.1×10^{-7} | | mbar/LSB |
| Error with Supply | | | 0.04 | | %/V |
| Total Error | | | 4.5 | | mbar |
| Relative Error ¹ | -40°C to +85°C | | 2.5 | | mbar |
| Linearity ² | Best fit straight line, FS = 1100 mbar | | 0.1 | | % of FS |
| | -40°C to +85°C | | 0.2 | | % of FS |
| Linear-g Sensitivity | $\pm 1 g, 1 \sigma$ | | 0.005 | | mbar/g |
| Noise | | | 0.025 | | mbar rms |
| TEMPERATURE SENSOR | | | | | |
| Scale Factor | Output = 0x0000 at 25°C ($\pm 5^\circ\text{C}$) | | 0.00565 | | °C/LSB |
| LOGIC INPUTS³ | | | | | |
| Input High Voltage, V_{IH} | | 2.0 | | | V |
| Input Low Voltage, V_{IL} | | | | 0.8 | V |
| \overline{CS} Wake-Up Pulse Width | | 20 | | | μs |
| Logic 1 Input Current, I_{IH} | $V_{IH} = 3.3 \text{ V}$ | | | 10 | μA |
| Logic 0 Input Current, I_{IL} | $V_{IL} = 0 \text{ V}$ | | | 10 | μA |
| All Pins Except \overline{RST} | | | | | μA |
| \overline{RST} Pin | | | 0.33 | | mA |
| Input Capacitance, C_{IN} | | | 10 | | pF |
| DIGITAL OUTPUTS | | | | | |
| Output High Voltage, V_{OH} | $I_{SOURCE} = 0.5 \text{ mA}$ | 2.4 | | | V |
| Output Low Voltage, V_{OL} | $I_{SINK} = 2.0 \text{ mA}$ | | | 0.4 | V |
| FLASH MEMORY | | | | | |
| Data Retention ⁵ | Endurance ⁴ | 100,000 | | | Cycles |
| | $T_J = 85^\circ\text{C}$ | 20 | | | Years |
| FUNCTIONAL TIMES⁶ | | | | | |
| Power-On Start-up Time | Time until data is available | | 500 | | ms |
| Reset Recovery Time | | | 500 | | ms |
| Sleep Mode Recovery Time | | | 500 | | μs |
| Flash Memory Update Time | | | 375 | | ms |
| Flash Memory Test Time | | | 50 | | ms |
| Automatic Self-Test Time | Using internal clock, 100 SPS | | 12 | | ms |
| CONVERSION RATE | | | | | |
| Initial Clock Accuracy | | | 2.46 | | kSPS |
| Temperature Coefficient | | | 0.02 | | % |
| Sync Input Clock | | 0.7 ⁷ | | 2.4 | kHz |
| POWER SUPPLY, VDD | | | | | |
| Power Supply Current ⁸ | Operating voltage range | 3.0 | | 3.6 | V |
| | Normal mode, $V_{DD} = 3.3 \text{ V}, \mu \pm \sigma$ | | 254 | | mA |
| | Sleep mode, $V_{DD} = 3.3 \text{ V}$ | | 12.2 | | mA |
| | Power-down mode, $V_{DD} = 3.3 \text{ V}$ | | 45 | | μA |
| POWER SUPPLY, VDDRTC | | | | | |
| Real-Time Clock Supply Current | Operating voltage range | 3.0 | | 3.6 | V |
| | Normal mode, $V_{DDRTC} = 3.3 \text{ V}$ | | 13 | | μA |

¹ The relative error assumes that the initial error, at 25°C, is corrected in the end application.

² Linearity errors assume a full scale (FS) of 1000 mbar.

³ The digital I/O signals are driven by an internal 3.3 V supply, and the inputs are 5 V tolerant.

⁴ Endurance is qualified as per JEDEC Standard 22, Method A117, and measured at -40°C, +25°C, +85°C, and +125°C.

⁵ The data retention specification assumes a junction temperature (T_J) of 85°C as per JEDEC Standard 22, Method A117. Data retention lifetime decreases with T_J .

⁶ These times do not include thermal settling and internal filter response times, which may affect overall accuracy.

⁷ Device functions at clock rates below 0.7 kHz, but at reduced performance levels.

⁸ Supply current transients can reach 450 mA for 400 μs during start-up and reset recovery.

TIMING SPECIFICATIONS

T_A = 25°C, VDD = 3.3 V, unless otherwise noted.

Table 2.

| Parameter | Description | Min ¹ | Normal Mode | | Unit |
|-----------------------------------|---|------------------|-------------|------------------|------|
| | | | Typ | Max ¹ | |
| f _{SCLK} | Serial clock | 0.01 | | 15 | MHz |
| t _{STALL} | Stall period between data | 2 | | | μs |
| t _{CLS} | Serial clock low period | 31 | | | ns |
| t _{CHS} | Serial clock high period | 31 | | | ns |
| t _{CS} | Chip select to clock edge | 32 | | | ns |
| t _{DAV} | DOUT valid after SCLK edge | | | 10 | ns |
| t _{DSU} | DIN setup time before SCLK rising edge | 2 | | | ns |
| t _{DHD} | DIN hold time after SCLK rising edge | 2 | | | ns |
| t _{DR} , t _{DF} | DOUT rise/fall times, ≤100 pF loading | | 3 | 8 | ns |
| t _{DSOE} | CS assertion to data out active | 0 | | 11 | ns |
| t _{HD} | SCLK edge to data out invalid | 0 | | | ns |
| t _{DSHI} | CS deassertion to data out high impedance | 0 | | 9 | ns |
| t ₁ | Input sync pulse width | 5 | | | μs |
| t ₂ | Input sync to data-ready output | | | 490 | μs |
| t ₃ | Input sync period | 417 | | | μs |

¹ Guaranteed by design and characterization, but not tested in production.

Timing Diagrams

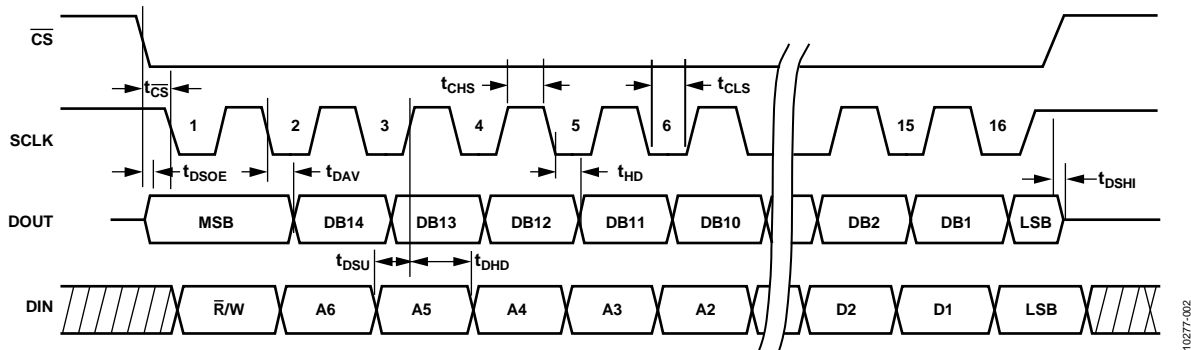


Figure 2. SPI Timing and Sequence

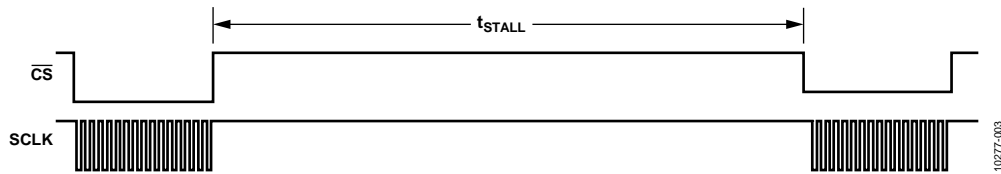


Figure 3. Stall Time and Data Rate

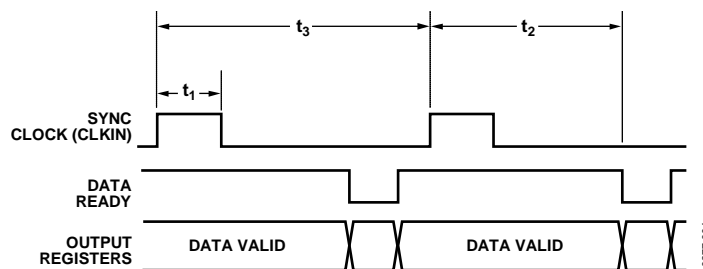


Figure 4. Input Clock Timing Diagram

ABSOLUTE MAXIMUM RATINGS

Table 3.

| Parameter | Rating |
|-------------------------------|------------------------------|
| Acceleration | |
| Any Axis, Unpowered | 2000 <i>g</i> |
| Any Axis, Powered | 2000 <i>g</i> |
| VDD to GND | −0.3 V to +3.6 V |
| Digital Input Voltage to GND | −0.3 V to VDD + 0.2 V |
| Digital Output Voltage to GND | −0.3 V to VDD + 0.2 V |
| Operating Temperature Range | −40°C to +85°C |
| Storage Temperature Range | −65°C to +150°C ¹ |
| Barometric Pressure | 6 bar |

¹ Extended exposure to temperatures that are lower than −40°C or higher than +105°C can adversely affect the accuracy of the factory calibration.

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Table 4. Package Characteristics

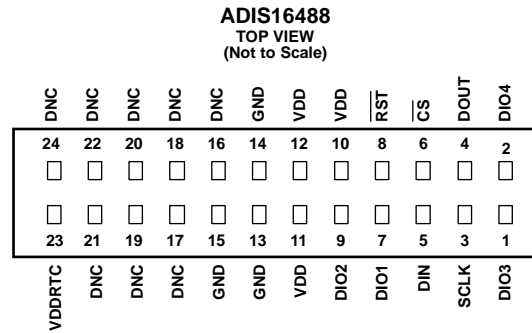
| Package Type | θ_{JA} | θ_{JC} | Device Weight |
|--------------------------|---------------|---------------|---------------|
| 24-Lead Module (ML-24-6) | 22.8°C/W | 10.1°C/W | 48 g |

ESD CAUTION



ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS



- NOTES**
1. THIS REPRESENTATION DISPLAYS THE TOP VIEW PINOUT FOR THE MATING SOCKET CONNECTOR.
 2. THE ACTUAL CONNECTOR PINS ARE NOT VISIBLE FROM THE TOP VIEW.
 3. MATING CONNECTOR: SAMTEC CLM-112-02 OR EQUIVALENT.
 4. DNC = DO NOT CONNECT TO THESE PINS.

Figure 5. Mating Connector Pin Assignments

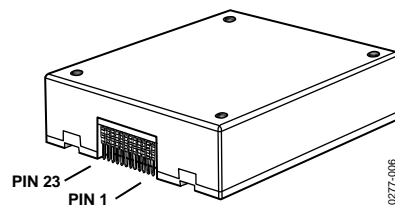


Figure 6. Axial Orientation (Top Side Facing Up)

Table 5. Pin Function Descriptions

| Pin No. | Mnemonic | Type | Description |
|--------------|----------|----------------|--|
| 1 | DIO3 | Input/output | Configurable Digital Input/Output. |
| 2 | DIO4 | Input/output | Configurable Digital Input/Output. |
| 3 | SCLK | Input | SPI Serial Clock. |
| 4 | DOUT | Output | SPI Data Output. Clocks output on SCLK falling edge. |
| 5 | DIN | Input | SPI Data Input. Clocks input on SCLK rising edge. |
| 6 | CS | Input | SPI Chip Select. |
| 7 | DIO1 | Input/output | Configurable Digital Input/Output. |
| 8 | RST | Input | Reset. |
| 9 | DIO2 | Input/output | Configurable Digital Input/Output. |
| 10, 11, 12 | VDD | Supply | Power Supply. |
| 13, 14, 15 | GND | Supply | Power Ground. |
| 16 to 22, 24 | DNC | Not applicable | Do Not Connect to These Pins. |
| 23 | VDDRTC | Supply | Real-Time Clock Power Supply. |

TYPICAL PERFORMANCE CHARACTERISTICS

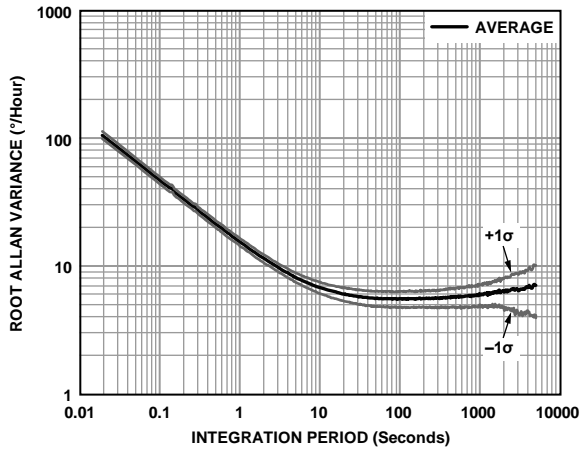


Figure 7. Gyroscope Allan Variance, 25°C

10277-007

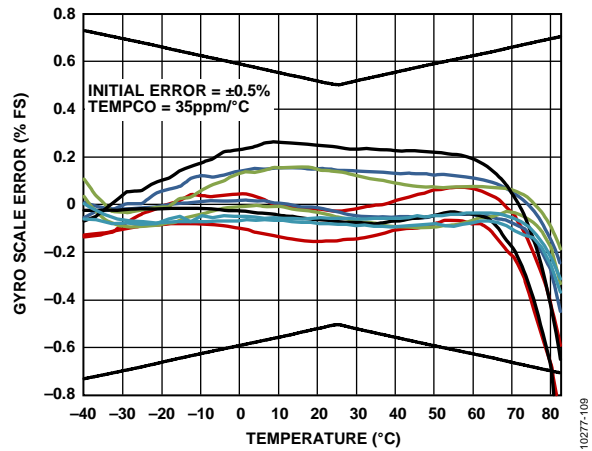


Figure 9. Gyroscope Scale (Sensitivity) Error and Hysteresis vs. Temperature

10277-108

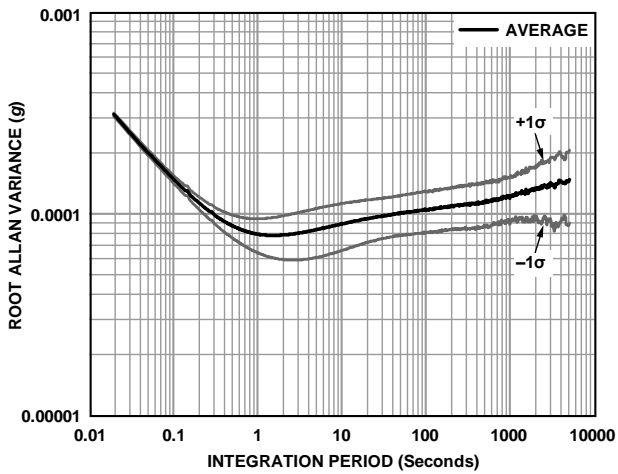


Figure 8. Accelerometer Allan Variance, 25°C

10277-008

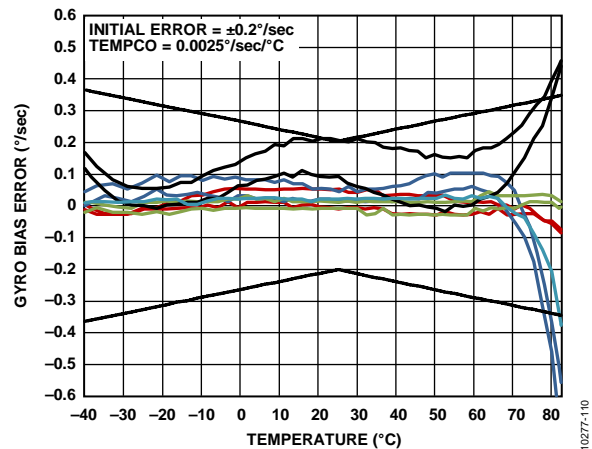


Figure 10. Gyroscope Bias Error and Hysteresis vs. Temperature

10277-110

BASIC OPERATION

The ADIS16488 is an autonomous sensor system that starts up on its own when it has a valid power supply. After running through its initialization process, it begins sampling, processing, and loading calibrated sensor data into the output registers, which are accessible using the SPI port. The SPI port typically connects to a compatible port on an embedded processor, using the connection diagram in Figure 11. The four SPI signals facilitate synchronous, serial data communication. Connect \overline{RST} (see Table 5) to VDD or leave it open for normal operation. The factory default configuration provides users with a data-ready signal on the DIO2 pin, which pulses high when new data is available in the output data registers.

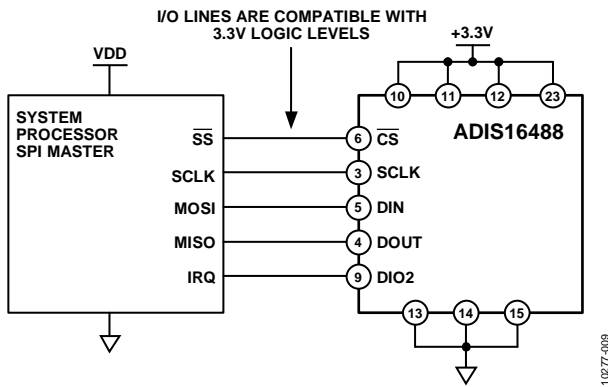


Figure 11. Electrical Connection Diagram

Table 6. Generic Master Processor Pin Names and Functions

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

Embedded processors typically use control registers to configure their serial ports for communicating with SPI slave devices such as the ADIS16488. Table 7 provides a list of settings, which describe the SPI protocol of the ADIS16488. The initialization routine of the master processor typically establishes these settings using firmware commands to write them into its serial control registers.

Table 7. Generic Master Processor SPI Settings

| Processor Setting | Description |
|--------------------|--|
| Master | The ADIS16488 operates as a slave. |
| SCLK \leq 15 MHz | Maximum serial clock rate. |
| SPI Mode 3 | CPOL = 1 (polarity), and CPHA = 1 (phase). |
| MSB-First Mode | Bit sequence. |
| 16-Bit Mode | Shift register/data length. |

REGISTER STRUCTURE

The register structure and SPI port provide a bridge between the sensor processing system and an external, master processor. It contains both output data and control registers. The output data registers include the latest sensor data, a real-time clock, error flags, alarm flags, and identification data. The control registers include sample rate, filtering, input/output, alarms, calibration, and diagnostic configuration options. All communication between the ADIS16488 and an external processor involves either reading or writing to one of the user registers.

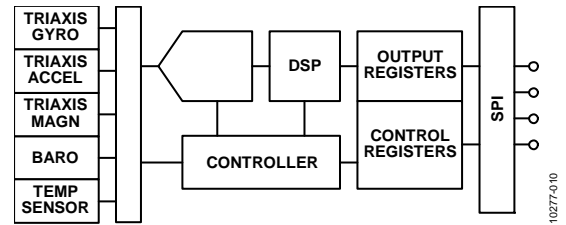


Figure 12. Basic Operation

The register structure uses a paged addressing scheme that is composed of 13 pages, with each one containing 64 register locations. Each register is 16 bits wide, with each byte having its own unique address within that page's memory map. The SPI port has access to one page at a time, using the bit sequence in Figure 17. Select the page to activate for SPI access by writing its code to the PAGE_ID register. Read the PAGE_ID register to determine which page is currently active. Table 8 displays the PAGE_ID contents for each page, along with their basic functions. The PAGE_ID register is located at Address 0x00 on every page.

Table 8. User Register Page Assignments

| Page | PAGE_ID | Function |
|------|---------|--|
| 0 | 0x00 | Output data, clock, identification |
| 1 | 0x01 | Reserved |
| 2 | 0x02 | Calibration |
| 3 | 0x03 | Control: sample rate, filtering, I/O, alarms |
| 4 | 0x04 | Serial number |
| 5 | 0x05 | FIR Filter Bank A Coefficient 0 to Coefficient 59 |
| 6 | 0x06 | FIR Filter Bank A, Coefficient 60 to Coefficient 119 |
| 7 | 0x07 | FIR Filter Bank B, Coefficient 0 to Coefficient 59 |
| 8 | 0x08 | FIR Filter Bank B, Coefficient 60 to Coefficient 119 |
| 9 | 0x09 | FIR Filter Bank C, Coefficient 0 to Coefficient 59 |
| 10 | 0x0A | FIR Filter Bank C, Coefficient 60 to Coefficient 119 |
| 11 | 0x0B | FIR Filter Bank D, Coefficient 0 to Coefficient 59 |
| 12 | 0x0C | FIR Filter Bank D, Coefficient 60 to Coefficient 119 |

SPI COMMUNICATION

The SPI port supports full duplex communication, as shown in Figure 17, which enables external processors to write to DIN while reading DOUT, if the previous command was a read request. Figure 17 provides a guideline for the bit coding on both DIN and DOUT.

DEVICE CONFIGURATION

The SPI provides write access to the control registers, one byte at a time, using the bit assignments shown in Figure 17. Each register has 16 bits, where Bits[7:0] represent the lower address (listed in Table 9) and Bits[15:8] represent the upper address. Write to the lower byte of a register first, followed by a write to its upper byte second. The only register that changes with a single write to its lower byte is the PAGE_ID register. For a write command, the first bit in the DIN sequence is set to 1. Address Bits[A6:A0] represent the target address, and Data Command Bits[DC7:DC0] represent the data being written to the location. Figure 13 provides an example of writing 0x03 to Address 0x00 (PAGE_ID [7:0]), using DIN = 0x8003. This write command activates the control page for SPI access.

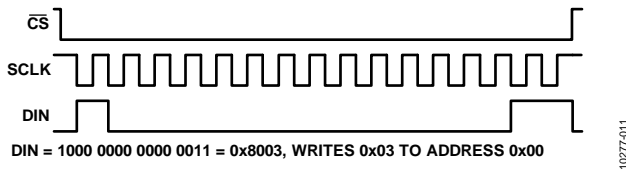


Figure 13. SPI Sequence for Activating the Control Page (DIN = 0x8003)

Dual Memory Structure

Writing configuration data to a control register updates its SRAM contents, which are volatile. After optimizing each relevant control register setting in a system, use the manual flash update command, which is located in GLOB_CMD[3] on Page 3 of the register map. Activate the manual flash update command by turning to Page 3 (DIN = 0x8003) and setting GLOB_CMD[3] = 1 (DIN = 0x8208, then DIN = 0x8300). Make sure that the power supply is within specification for the entire 375 ms processing time for a flash memory update. Table 9 provides a memory map for all of the user registers, which includes a column of flash backup information. A yes in this column indicates that a register has a mirror location in flash and, when backed up properly, automatically restores itself during startup or after a reset. Figure 14 provides a diagram of the dual memory structure used to manage operation and store critical user settings.

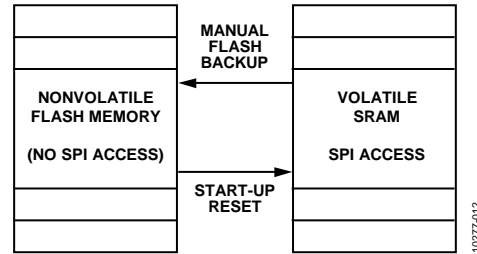


Figure 14. SRAM and Flash Memory Diagram

READING SENSOR DATA

The ADIS16488 automatically starts up and activates Page 0 for data register access. Write 0x00 to the PAGE_ID register (DIN = 0x8000) to activate Page 0 for data access after accessing any other page. A single register read requires two 16-bit SPI cycles. The first cycle requests the contents of a register using the bit assignments in Figure 17, and then the register contents follow DOUT during the second sequence. The first bit in a DIN command is zero, followed by either the upper or lower address for the register. The last eight bits are don't care, but the SPI requires the full set of 16 SCLKs to receive the request. Figure 15 includes two register reads in succession, which starts with DIN = 0x1A00 to request the contents of the Z_GYRO_OUT register and follows with 0x1800 to request the contents of the Z_GYRO_LOW register.

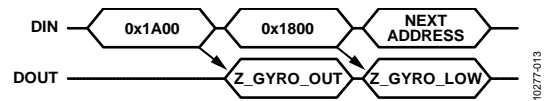


Figure 15. SPI Read Example

Figure 16 provides an example of the four SPI signals when reading PROD_ID in a repeating pattern. This is a good pattern to use for troubleshooting the SPI interface setup and communications because the contents of PROD_ID are predefined and stable.

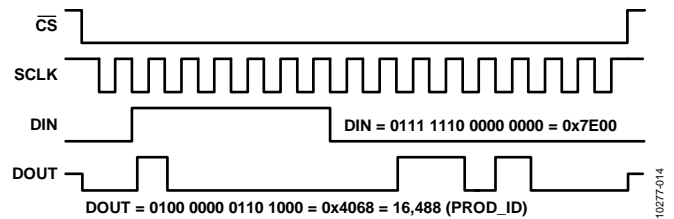
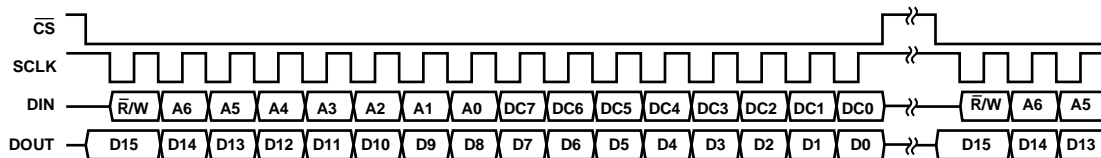


Figure 16. SPI Read Example, Second 16-Bit Sequence



NOTES

1. DOUT BITS ARE PRODUCED ONLY WHEN THE PREVIOUS 16-BIT DIN SEQUENCE STARTS WITH $\bar{R}/W = 0$.
2. WHEN \bar{CS} IS HIGH, DOUT IS IN A THREE-STATE, HIGH IMPEDANCE MODE, WHICH ALLOWS MULTIFUNCTIONAL USE OF THE LINE FOR OTHER DEVICES.

Figure 17. SPI Communication Bit Sequence

USER REGISTERS

Table 9. User Register Memory Map (N/A = Not Applicable)

| Name | R/W | Flash | PAGE_ID | Address | Default | Register Description | Format |
|---------------|-----|-------|---------|--------------|---------|---|-----------|
| PAGE_ID | R/W | No | 0x00 | 0x00 | 0x00 | Page identifier | N/A |
| Reserved | N/A | N/A | 0x00 | 0x02 to 0x04 | N/A | Reserved | N/A |
| SEQ_CNT | R | No | 0x00 | 0x06 | N/A | Sequence counter | Table 56 |
| SYS_E_FLAG | R | No | 0x00 | 0x08 | 0x0000 | Output, system error flags | Table 47 |
| DIAG_STS | R | No | 0x00 | 0x0A | 0x0000 | Output, self-test error flags | Table 48 |
| ALM_STS | R | No | 0x00 | 0x0C | 0x0000 | Output, alarm error flags | Table 49 |
| TEMP_OUT | R | No | 0x00 | 0x0E | N/A | Output, temperature | Table 45 |
| X_GYRO_LOW | R | No | 0x00 | 0x10 | N/A | Output, x-axis gyroscope, low word | Table 14 |
| X_GYRO_OUT | R | No | 0x00 | 0x12 | N/A | Output, x-axis gyroscope, high word | Table 10 |
| Y_GYRO_LOW | R | No | 0x00 | 0x14 | N/A | Output, y-axis gyroscope, low word | Table 15 |
| Y_GYRO_OUT | R | No | 0x00 | 0x16 | N/A | Output, y-axis gyroscope, high word | Table 11 |
| Z_GYRO_LOW | R | No | 0x00 | 0x18 | N/A | Output, z-axis gyroscope, low word | Table 16 |
| Z_GYRO_OUT | R | No | 0x00 | 0x1A | N/A | Output, z-axis gyroscope, high word | Table 12 |
| X_ACCL_LOW | R | No | 0x00 | 0x1C | N/A | Output, x-axis accelerometer, low word | Table 21 |
| X_ACCL_OUT | R | No | 0x00 | 0x1E | N/A | Output, x-axis accelerometer, high word | Table 17 |
| Y_ACCL_LOW | R | No | 0x00 | 0x20 | N/A | Output, y-axis accelerometer, low word | Table 22 |
| Y_ACCL_OUT | R | No | 0x00 | 0x22 | N/A | Output, y-axis accelerometer, high word | Table 18 |
| Z_ACCL_LOW | R | No | 0x00 | 0x24 | N/A | Output, z-axis accelerometer, low word | Table 23 |
| Z_ACCL_OUT | R | No | 0x00 | 0x26 | N/A | Output, z-axis accelerometer, high word | Table 19 |
| X_MAGN_OUT | R | No | 0x00 | 0x28 | N/A | Output, x-axis magnetometer, high word | Table 38 |
| Y_MAGN_OUT | R | No | 0x00 | 0x2A | N/A | Output, y-axis magnetometer, high word | Table 39 |
| Z_MAGN_OUT | R | No | 0x00 | 0x2C | N/A | Output, z-axis magnetometer, high word | Table 40 |
| BAROM_LOW | R | No | 0x00 | 0x2E | N/A | Output, barometer, low word | Table 44 |
| BAROM_OUT | R | No | 0x00 | 0x30 | N/A | Output, barometer, high word | Table 42 |
| Reserved | N/A | N/A | 0x00 | 0x32 to 0x3E | N/A | Reserved | N/A |
| X_DELTANG_LOW | R | No | 0x00 | 0x40 | N/A | Output, x-axis delta angle, low word | Table 28 |
| X_DELTANG_OUT | R | No | 0x00 | 0x42 | N/A | Output, x-axis delta angle, high word | Table 24 |
| Y_DELTANG_LOW | R | No | 0x00 | 0x44 | N/A | Output, y-axis delta angle, low word | Table 29 |
| Y_DELTANG_OUT | R | No | 0x00 | 0x46 | N/A | Output, y-axis delta angle, high word | Table 25 |
| Z_DELTANG_LOW | R | No | 0x00 | 0x48 | N/A | Output, z-axis delta angle, low word | Table 30 |
| Z_DELTANG_OUT | R | No | 0x00 | 0x4A | N/A | Output, z-axis delta angle, high word | Table 26 |
| X_DELTVEL_LOW | R | No | 0x00 | 0x4C | N/A | Output, x-axis delta velocity, low word | Table 35 |
| X_DELTVEL_OUT | R | No | 0x00 | 0x4E | N/A | Output, x-axis delta velocity, high word | Table 31 |
| Y_DELTVEL_LOW | R | No | 0x00 | 0x50 | N/A | Output, y-axis delta velocity, low word | Table 36 |
| Y_DELTVEL_OUT | R | No | 0x00 | 0x52 | N/A | Output, y-axis delta velocity, high word | Table 32 |
| Z_DELTVEL_LOW | R | No | 0x00 | 0x54 | N/A | Output, z-axis delta velocity, low word | Table 37 |
| Z_DELTVEL_OUT | R | No | 0x00 | 0x56 | N/A | Output, z-axis delta velocity, high word | Table 33 |
| Reserved | N/A | N/A | 0x00 | 0x58 to 0x76 | N/A | Reserved | N/A |
| TIME_MS_OUT | R | Yes | 0x00 | 0x78 | N/A | Factory configuration time: minutes/seconds | Table 124 |
| TIME_DH_OUT | R | Yes | 0x00 | 0x7A | N/A | Factory configuration date/time: day/hour | Table 125 |
| TIME_YM_OUT | R | Yes | 0x00 | 0x7C | N/A | Factory configuration date: year/month | Table 126 |
| PROD_ID | R | Yes | 0x00 | 0x7E | 0x4068 | Output, product identification (16,488) | Table 53 |
| Reserved | N/A | N/A | 0x01 | 0x00 to 0x7E | N/A | Reserved | N/A |
| PAGE_ID | R/W | No | 0x02 | 0x00 | 0x00 | Page identifier | N/A |
| Reserved | N/A | N/A | 0x02 | 0x02 | N/A | Reserved | N/A |
| X_GYRO_SCALE | R/W | Yes | 0x02 | 0x04 | 0x0000 | Calibration, scale, x-axis gyroscope | Table 71 |
| Y_GYRO_SCALE | R/W | Yes | 0x02 | 0x06 | 0x0000 | Calibration, scale, y-axis gyroscope | Table 72 |
| Z_GYRO_SCALE | R/W | Yes | 0x02 | 0x08 | 0x0000 | Calibration, scale, z-axis gyroscope | Table 73 |
| X_ACCL_SCALE | R/W | Yes | 0x02 | 0x0A | 0x0000 | Calibration, scale, x-axis accelerometer | Table 81 |
| Y_ACCL_SCALE | R/W | Yes | 0x02 | 0x0C | 0x0000 | Calibration, scale, y-axis accelerometer | Table 82 |
| Z_ACCL_SCALE | R/W | Yes | 0x02 | 0x0E | 0x0000 | Calibration, scale, z-axis accelerometer | Table 83 |

| Name | R/W | Flash | PAGE_ID | Address | Default | Register Description | Format |
|---------------|-----|-------|---------|--------------|---------------------|---|-----------|
| XG_BIAS_LOW | R/W | Yes | 0x02 | 0x10 | 0x0000 | Calibration, offset, gyroscope, x-axis, low word | Table 67 |
| XG_BIAS_HIGH | R/W | Yes | 0x02 | 0x12 | 0x0000 | Calibration, offset, gyroscope, x-axis, high word | Table 64 |
| YG_BIAS_LOW | R/W | Yes | 0x02 | 0x14 | 0x0000 | Calibration, offset, gyroscope, y-axis, low word | Table 68 |
| YG_BIAS_HIGH | R/W | Yes | 0x02 | 0x16 | 0x0000 | Calibration, offset, gyroscope, y-axis, high word | Table 65 |
| ZG_BIAS_LOW | R/W | Yes | 0x02 | 0x18 | 0x0000 | Calibration, offset, gyroscope, z-axis, low word | Table 69 |
| ZG_BIAS_HIGH | R/W | Yes | 0x02 | 0x1A | 0x0000 | Calibration, offset, gyroscope, z-axis, high word | Table 66 |
| XA_BIAS_LOW | R/W | Yes | 0x02 | 0x1C | 0x0000 | Calibration, offset, accelerometer, x-axis, low word | Table 78 |
| XA_BIAS_HIGH | R/W | Yes | 0x02 | 0x1E | 0x0000 | Calibration, offset, accelerometer, x-axis, high word | Table 75 |
| YA_BIAS_LOW | R/W | Yes | 0x02 | 0x20 | 0x0000 | Calibration, offset, accelerometer, y-axis, low word | Table 79 |
| YA_BIAS_HIGH | R/W | Yes | 0x02 | 0x22 | 0x0000 | Calibration, offset, accelerometer, y-axis, high word | Table 76 |
| ZA_BIAS_LOW | R/W | Yes | 0x02 | 0x24 | 0x0000 | Calibration, offset, accelerometer, z-axis, low word | Table 80 |
| ZA_BIAS_HIGH | R/W | Yes | 0x02 | 0x26 | 0x0000 | Calibration, offset, accelerometer, z-axis, high word | Table 77 |
| HARD_IRON_X | R/W | Yes | 0x02 | 0x28 | 0x0000 | Calibration, hard iron, magnetometer, x-axis | Table 84 |
| HARD_IRON_Y | R/W | Yes | 0x02 | 0x2A | 0x0000 | Calibration, hard iron, magnetometer, y-axis | Table 85 |
| HARD_IRON_Z | R/W | Yes | 0x02 | 0x2C | 0x0000 | Calibration, hard iron, magnetometer, z-axis | Table 86 |
| SOFT_IRON_S11 | R/W | Yes | 0x02 | 0x2E | 0x0000 | Calibration, soft iron, magnetometer, S11 | Table 88 |
| SOFT_IRON_S12 | R/W | Yes | 0x02 | 0x30 | 0x0000 | Calibration, soft iron, magnetometer, S12 | Table 89 |
| SOFT_IRON_S13 | R/W | Yes | 0x02 | 0x32 | 0x0000 | Calibration, soft iron, magnetometer, S13 | Table 90 |
| SOFT_IRON_S21 | R/W | Yes | 0x02 | 0x34 | 0x0000 | Calibration, soft iron, magnetometer, S21 | Table 91 |
| SOFT_IRON_S22 | R/W | Yes | 0x02 | 0x36 | 0x0000 | Calibration, soft iron, magnetometer, S22 | Table 92 |
| SOFT_IRON_S23 | R/W | Yes | 0x02 | 0x38 | 0x0000 | Calibration, soft iron, magnetometer, S23 | Table 93 |
| SOFT_IRON_S31 | R/W | Yes | 0x02 | 0x3A | 0x0000 | Calibration, soft iron, magnetometer, S31 | Table 94 |
| SOFT_IRON_S32 | R/W | Yes | 0x02 | 0x3C | 0x0000 | Calibration, soft iron, magnetometer, S32 | Table 95 |
| SOFT_IRON_S33 | R/W | Yes | 0x02 | 0x3E | 0x0000 | Calibration, soft iron, magnetometer, S33 | Table 96 |
| BR_BIAS_LOW | R/W | Yes | 0x02 | 0x40 | 0x0000 | Calibration, offset, barometer, low word | Table 99 |
| BR_BIAS_HIGH | R/W | Yes | 0x02 | 0x42 | 0x0000 | Calibration, offset, barometer, high word | Table 98 |
| Reserved | N/A | N/A | 0x02 | 0x44 to 0x72 | N/A | Reserved | N/A |
| USER_SCR_1 | R/W | Yes | 0x02 | 0x74 | 0x0000 | User Scratch Register 1 | Table 120 |
| USER_SCR_2 | R/W | Yes | 0x02 | 0x76 | 0x0000 | User Scratch Register 2 | Table 121 |
| USER_SCR_3 | R/W | Yes | 0x02 | 0x78 | 0x0000 | User Scratch Register 3 | Table 122 |
| USER_SCR_4 | R/W | Yes | 0x02 | 0x7A | 0x0000 | User Scratch Register 4 | Table 123 |
| FLSHCNT_LOW | R | Yes | 0x02 | 0x7C | N/A | Diagnostic, flash memory count, low word | Table 115 |
| FLSHCNT_HIGH | R | Yes | 0x02 | 0x7E | N/A | Diagnostic, flash memory count, high word | Table 116 |
| PAGE_ID | R/W | No | 0x03 | 0x00 | 0x0000 | Page identifier | N/A |
| GLOB_CMD | W | No | 0x03 | 0x02 | N/A | Control, global commands | Table 114 |
| Reserved | N/A | N/A | 0x03 | 0x04 | N/A | Reserved | N/A |
| FNCTIO_CTRL | R/W | Yes | 0x03 | 0x06 | 0x000D | Control, I/O pins, functional definitions | Table 117 |
| GPIO_CTRL | R/W | Yes | 0x03 | 0x08 | 0x00X0 ¹ | Control, I/O pins, general purpose | Table 118 |
| CONFIG | R/W | Yes | 0x03 | 0x0A | 0x00C0 | Control, clock, and miscellaneous correction | Table 74 |
| DEC_RATE | R/W | Yes | 0x03 | 0x0C | 0x0000 | Control, output sample rate decimation | Table 55 |
| NULL_CNFG | R/W | Yes | 0x03 | 0x0E | 0x070A | Control, automatic bias correction configuration | Table 70 |
| SLP_CNT | R/W | No | 0x03 | 0x10 | N/A | Control, power-down/sleep mode | Table 119 |
| Reserved | N/A | N/A | 0x03 | 0x12 to 0x14 | N/A | Reserved | N/A |
| FILTR_BNK_0 | R/W | Yes | 0x03 | 0x16 | 0x0000 | Filter selection | Table 57 |
| FILTR_BNK_1 | R/W | Yes | 0x03 | 0x18 | 0x0000 | Filter selection | Table 58 |
| Reserved | N/A | N/A | 0x03 | 0x1A to 0x1E | N/A | Reserved | N/A |
| ALM_CNFG_0 | R/W | Yes | 0x03 | 0x20 | 0x0000 | Alarm configuration | Table 110 |
| ALM_CNFG_1 | R/W | Yes | 0x03 | 0x22 | 0x0000 | Alarm configuration | Table 111 |
| ALM_CNFG_2 | R/W | Yes | 0x03 | 0x24 | 0x0000 | Alarm configuration | Table 112 |
| Reserved | N/A | N/A | 0x03 | 0x26 | N/A | Reserved | N/A |
| XG_ALM_MAGN | R/W | Yes | 0x03 | 0x28 | 0x0000 | Alarm, x-axis gyroscope threshold setting | Table 100 |
| YG_ALM_MAGN | R/W | Yes | 0x03 | 0x2A | 0x0000 | Alarm, y-axis gyroscope threshold setting | Table 101 |
| ZG_ALM_MAGN | R/W | Yes | 0x03 | 0x2C | 0x0000 | Alarm, z-axis gyroscope threshold setting | Table 102 |

| Name | R/W | Flash | PAGE_ID | Address | Default | Register Description | Format |
|---------------|-----|-------|---------|--------------|---------|--|-----------|
| XA_ALM_MAGN | R/W | Yes | 0x03 | 0x2E | 0x0000 | Alarm, x-axis accelerometer threshold | Table 103 |
| YA_ALM_MAGN | R/W | Yes | 0x03 | 0x30 | 0x0000 | Alarm, y-axis accelerometer threshold | Table 104 |
| ZA_ALM_MAGN | R/W | Yes | 0x03 | 0x32 | 0x0000 | Alarm, z-axis accelerometer threshold | Table 105 |
| XM_ALM_MAGN | R/W | Yes | 0x03 | 0x34 | 0x0000 | Alarm, x-axis magnetometer threshold | Table 106 |
| YM_ALM_MAGN | R/W | Yes | 0x03 | 0x36 | 0x0000 | Alarm, y-axis magnetometer threshold | Table 107 |
| ZM_ALM_MAGN | R/W | Yes | 0x03 | 0x38 | 0x0000 | Alarm, z-axis magnetometer threshold | Table 108 |
| BR_ALM_MAGN | R/W | Yes | 0x03 | 0x3A | 0x0000 | Alarm, barometer threshold setting | Table 109 |
| Reserved | N/A | N/A | 0x03 | 0x3C to 0x76 | N/A | Reserved | N/A |
| FIRM_REV | R | Yes | 0x03 | 0x78 | N/A | Firmware revision | Table 50 |
| FIRM_DM | R | Yes | 0x03 | 0x7A | N/A | Firmware programming date: day/month | Table 51 |
| FIRM_Y | R | Yes | 0x03 | 0x7C | N/A | Firmware programming date: year | Table 52 |
| Reserved | N/A | N/A | 0x03 | 0x7E | N/A | Reserved | N/A |
| Reserved | N/A | N/A | 0x04 | 0x00 to 0x18 | N/A | Reserved | N/A |
| SERIAL_NUM | R | Yes | 0x04 | 0x20 | N/A | Serial number | Table 54 |
| Reserved | N/A | N/A | 0x04 | 0x22 to 0x7F | N/A | Reserved | N/A |
| FIR_COEF_Axxx | R/W | Yes | 0x05 | 0x00 to 0x7E | N/A | FIR Filter Bank A, Coefficients 0 through 59 | Table 59 |
| FIR_COEF_Axxx | R/W | Yes | 0x06 | 0x00 to 0x7E | N/A | FIR Filter Bank A, Coefficients 60 through 119 | Table 59 |
| FIR_COEF_Bxxx | R/W | Yes | 0x07 | 0x00 to 0x7E | N/A | FIR Filter Bank B, Coefficients 0 through 59 | Table 60 |
| FIR_COEF_Bxxx | R/W | Yes | 0x08 | 0x00 to 0x7E | N/A | FIR Filter Bank B, Coefficients 60 through 119 | Table 60 |
| FIR_COEF_Cxxx | R/W | Yes | 0x09 | 0x00 to 0x7E | N/A | FIR Filter Bank C, Coefficients 0 through 59 | Table 61 |
| FIR_COEF_Cxxx | R/W | Yes | 0x0A | 0x00 to 0x7E | N/A | FIR Filter Bank C, Coefficients 60 through 119 | Table 61 |
| FIR_COEF_Dxxx | R/W | Yes | 0x0B | 0x00 to 0x7E | N/A | FIR Filter Bank D, Coefficients 0 through 59 | Table 62 |
| FIR_COEF_Dxxx | R/W | Yes | 0x0C | 0x00 to 0x7E | N/A | FIR Filter Bank D, Coefficients 60 through 119 | Table 62 |

¹ The GPIO_CTRL[7:4] bits reflect the logic levels on the DIOx lines and do not have a default setting.

OUTPUT DATA REGISTERS

After the ADIS16488 completes its start-up process, the PAGE_ID register contains 0x0000, which sets Page 0 as the active page for SPI access. Page 0 contains the output data, real-time clock, status, and product identification registers.

INERTIAL SENSOR DATA FORMAT

The gyroscope, accelerometer, delta angle, delta velocity, and barometer output data registers use a 32-bit, twos complement format. Each output uses two registers to support this resolution. Figure 18 provides an example of how each register contributes to each inertial measurement. In this case, X_GYRO_OUT is the most significant word (upper 16 bits), and X_GYRO_LOW is the least significant word (lower 16 bits). In many cases, using the most significant word registers alone provide sufficient resolution for preserving key performance metrics.

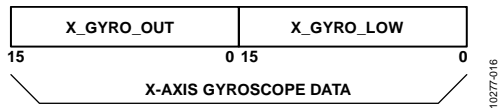


Figure 18. Gyroscope Output Format Example, DEC_RATE > 0

The arrows in Figure 19 describe the direction of the motion, which produces a positive output response in each sensor's output register. The accelerometers respond to both dynamic and static forces associated with acceleration, including gravity. When lying perfectly flat, as shown in Figure 19, the z-axis accelerometer output is 1 g, and the x and y accelerometers are 0 g.

ROTATION RATE (GYROSCOPE)

The registers that use the x_GYRO_OUT format are the primary registers for the gyroscope measurements (see Table 10, Table 11, and Table 12). When processing data from these registers, use a 16-bit, twos complement data format. Table 13 provides x_GYRO_OUT digital coding examples.

Table 10. X_GYRO_OUT (Page 0, Base Address = 0x12)

| Bits | Description |
|--------|---|
| [15:0] | X-axis gyroscope data; twos complement, $\pm 450^\circ/\text{sec}$ range, $0^\circ/\text{sec} = 0x0000$, 1 LSB = $0.02^\circ/\text{sec}$ |

Table 11. Y_GYRO_OUT (Page 0, Base Address = 0x16)

| Bits | Description |
|--------|---|
| [15:0] | Y-axis gyroscope data; twos complement, $\pm 450^\circ/\text{sec}$ range, $0^\circ/\text{sec} = 0x0000$, 1 LSB = $0.02^\circ/\text{sec}$ |

Table 12. Z_GYRO_OUT (Page 0, Base Address = 0x1A)

| Bits | Description |
|--------|---|
| [15:0] | Z-axis gyroscope data; twos complement, $\pm 450^\circ/\text{sec}$ range, $0^\circ/\text{sec} = 0x0000$, 1 LSB = $0.02^\circ/\text{sec}$ |

Table 13. x_GYRO_OUT Data Format Examples

| Rotation Rate | Decimal | Hex | Binary |
|---------------|---------|--------|---------------------|
| +450°/sec | +22,500 | 0x57E4 | 0101 0111 1110 0100 |
| +0.04°/sec | +2 | 0x0002 | 0000 0000 0000 0010 |
| +0.02°/sec | +1 | 0x0001 | 0000 0000 0000 0001 |
| 0°/sec | 0 | 0x0000 | 0000 0000 0000 0000 |
| -0.02°/sec | -1 | 0xFFFF | 1111 1111 1111 1111 |
| -0.04°/sec | -2 | 0xFFFE | 1111 1111 1111 1110 |
| -450°/sec | -22,500 | 0xA81C | 1010 1000 0001 1100 |

The registers that use the x_GYRO_LOW naming format provide additional resolution for the gyroscope measurements (see Table 14, Table 15, and Table 16). The MSB has a weight of $0.01^\circ/\text{sec}$, and each subsequent bit has $\frac{1}{2}$ the weight of the previous one.

Table 14. X_GYRO_LOW (Page 0, Base Address = 0x10)

| Bits | Description |
|--------|---|
| [15:0] | X-axis gyroscope data; additional resolution bits |

Table 15. Y_GYRO_LOW (Page 0, Base Address = 0x14)

| Bits | Description |
|--------|---|
| [15:0] | Y-axis gyroscope data; additional resolution bits |

Table 16. Z_GYRO_LOW (Page 0, Base Address = 0x18)

| Bits | Description |
|--------|---|
| [15:0] | Z-axis gyroscope data; additional resolution bits |

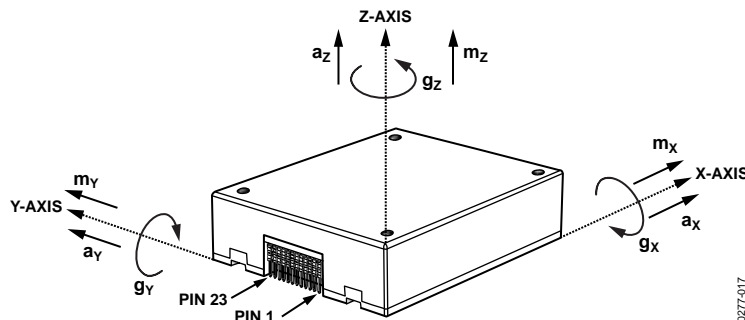


Figure 19. Inertial Sensor Direction Reference Diagram

ACCELERATION

The registers that use the x_ACCL_OUT format are the primary registers for the accelerometer measurements (see Table 17, Table 18, and Table 19). When processing data from these registers, use a 16-bit, twos complement data format. Table 20 provides x_ACCL_OUT digital coding examples.

Table 17. X_ACCL_OUT (Page 0, Base Address = 0x1E)

| Bits | Description |
|--------|---|
| [15:0] | X-axis accelerometer data; twos complement, ±18 g range, 0 g = 0x0000, 1 LSB = 0.8 mg |

Table 18. Y_ACCL_OUT (Page 0, Base Address = 0x22)

| Bits | Description |
|--------|---|
| [15:0] | Y-axis accelerometer data; twos complement, ±18 g range, 0 g = 0x0000, 1 LSB = 0.8 mg |

Table 19. Z_ACCL_OUT (Page 0, Base Address = 0x26)

| Bits | Description |
|--------|---|
| [15:0] | Z-axis accelerometer data; twos complement, ±18 g range, 0 g = 0x0000, 1 LSB = 0.8 mg |

Table 20. x_ACCL_OUT Data Format Examples

| Acceleration | Decimal | Hex | Binary |
|--------------|---------|--------|---------------------|
| +18 g | +22,500 | 0x57E4 | 0101 0111 1110 0100 |
| +1.6 mg | +2 | 0x0002 | 0000 0000 0000 0010 |
| +0.8 mg | +1 | 0x0001 | 0000 0000 0000 0001 |
| 0 mg | 0 | 0x0000 | 0000 0000 0000 0000 |
| -0.8 mg | -1 | 0xFFFF | 1111 1111 1111 1111 |
| -1.6 mg | -2 | 0xFFFE | 1111 1111 1111 1110 |
| -18 g | -22,500 | 0xA81C | 1010 1000 0001 1100 |

The registers that use the x_ACCL_LOW naming format provide additional resolution for the accelerometer measurements (see Table 21, Table 22, and Table 23). The MSB has a weight of 0.4 mg, and each subsequent bit has ½ the weight of the previous one.

Table 21. X_ACCL_LOW (Page 0, Base Address = 0x1C)

| Bits | Description |
|--------|---|
| [15:0] | X-axis accelerometer data; additional resolution bits |

Table 22. Y_ACCL_LOW (Page 0, Base Address = 0x20)

| Bits | Description |
|--------|---|
| [15:0] | Y-axis accelerometer data; additional resolution bits |

Table 23. Z_ACCL_LOW (Page 0, Base Address = 0x24)

| Bits | Description |
|--------|---|
| [15:0] | Z-axis accelerometer data; additional resolution bits |

DELTA ANGLES

The delta angle outputs represent an integration of the gyroscope measurements and use the following formula for all three axes (x-axis displayed):

$$\Delta\theta_x = \frac{\Delta t_s}{2} \times (\omega_{x,n+1} + \omega_{x,n}); \Delta t_s = \frac{DEC_RATE + 1}{f_s}$$

where:

ω_x is the gyroscope, x-axis.

Δt_s is the time between samples.

When using the internal sample clock, f_s is equal to 2.46 kHz. When using the external clock option, the time between samples is the time between active edges on the input clock signal, as measured by the internal clock (252 MHz). See Table 55 for more information on the DEC_RATE register. The registers that use the x_DELTANG_OUT format are the primary registers for the delta angle calculations. When processing data from these registers, use a 16-bit, twos complement data format (see Table 24, Table 25, and Table 26). Table 27 provides x_DELTANG_OUT digital coding examples.

Table 24. X_DELTANG_OUT (Page 0, Base Address = 0x42)

| Bits | Description |
|--------|--|
| [15:0] | X-axis delta angle data; twos complement, ±720° range, 0° = 0x0000, 1 LSB = 720°/2 ¹⁵ = ~0.022° |

Table 25. Y_DELTANG_OUT (Page 0, Base Address = 0x46)

| Bits | Description |
|--------|--|
| [15:0] | Y-axis delta angle data; twos complement, ±720° range, 0° = 0x0000, 1 LSB = 720°/2 ¹⁵ = ~0.022° |

Table 26. Z_DELTANG_OUT (Page 0, Base Address = 0x4A)

| Bits | Description |
|--------|--|
| [15:0] | Z-axis delta angle data; twos complement, ±720° range, 0° = 0x0000, 1 LSB = 720°/2 ¹⁵ = ~0.022° |

Table 27. x_DELTANG_OUT Data Format Examples

| Angle (°) | Decimal | Hex | Binary |
|--|---------|--------|---------------------|
| +720 × (2 ¹⁵ - 1)/2 ¹⁵ | +32,767 | 0x7FFF | 0111 1111 1110 1111 |
| +1440/2 ¹⁵ | +2 | 0x0002 | 0000 0000 0000 0010 |
| +720/2 ¹⁵ | +1 | 0x0001 | 0000 0000 0000 0001 |
| 0 | 0 | 0x0000 | 0000 0000 0000 0000 |
| -720/2 ¹⁵ | -1 | 0xFFFF | 1111 1111 1111 1111 |
| -1440/2 ¹⁵ | -2 | 0xFFFE | 1111 1111 1111 1110 |
| -720 | -32,768 | 0x8000 | 1000 0000 0000 0000 |

The registers that use the x_DELTANG_LOW format provide additional resolution for the gyroscope measurements (see Table 28, Table 29, and Table 30). The MSB has a weight of $\sim 0.011^\circ$ ($720^\circ/2^{16}$), and each subsequent bit carries a weight of $\frac{1}{2}$ of the previous one.

Table 28. X_DELTANG_LOW (Page 0, Base Address = 0x40)

| Bits | Description |
|--------|---|
| [15:0] | X-axis delta angle data; additional resolution bits |

Table 29. Y_DELTANG_LOW (Page 0, Base Address = 0x44)

| Bits | Description |
|--------|---|
| [15:0] | Y-axis delta angle data; additional resolution bits |

Table 30. Z_DELTANG_LOW (Page 0, Base Address = 0x48)

| Bits | Description |
|--------|---|
| [15:0] | Z-axis delta angle data; additional resolution bits |

DELTA VELOCITY

The delta velocity outputs represent an integration of the accelerometer measurements and use the following formula for all three axes (x-axis displayed):

$$\Delta\theta_x = \frac{\Delta t_s}{2} \times (a_{x,n+1} + a_{x,n}); \Delta t_s = \frac{DEC_RATE + 1}{f_s}$$

where:

a_x is the accelerometer, x-axis.

Δt_s is the time between samples.

When using the internal sample clock, f_s is equal to 2.46 kHz. When using the external clock option, the time between samples is the time between active edges on the input clock signal, as measured by the internal clock (252 MHz). See Table 55 for more information on the DEC_RATE register. The registers that use the x_DELTVEL_OUT format are the primary registers for the delta velocity calculations. When processing data from these registers, use a 16-bit, twos complement data format (see Table 31, Table 32, and Table 33). Table 34 provides x_DELTVEL_OUT digital coding examples.

Table 31. X_DELTVEL_OUT (Page 0, Base Address = 0x4E)

| Bits | Description |
|--------|---|
| [15:0] | X-axis delta velocity data; twos complement, ± 200 m/sec range, 0 m/sec = 0x0000 1 LSB = $200 \text{ m/sec} \div (2^{15} - 1) = \sim 6.104 \text{ mm/sec}$ |

Table 32. Y_DELTVEL_OUT (Page 0, Base Address = 0x52)

| Bits | Description |
|--------|---|
| [15:0] | Y-axis delta velocity data; twos complement, ± 200 m/sec range, 0 m/sec = 0x0000 1 LSB = $200 \text{ m/sec} \div (2^{15} - 1) = \sim 6.104 \text{ mm/sec}$ |

Table 33. Z_DELTVEL_OUT (Page 0, Base Address = 0x56)

| Bits | Description |
|--------|---|
| [15:0] | Z-axis delta velocity data; twos complement, ± 200 m/sec range, 0 m/sec = 0x0000 1 LSB = $200 \text{ m/sec} \div (2^{15} - 1) = \sim 6.104 \text{ mm/sec}$ |

Table 34. x_DELTVEL_OUT, Data Format Examples

| Velocity (m/sec) | Decimal | Hex | Binary |
|-----------------------------------|---------|--------|---------------------|
| $+160 \times (2^{15} - 1)/2^{15}$ | +32,767 | 0x7FFF | 0111 1111 1111 1111 |
| $+400/2^{15}$ | +2 | 0x0002 | 0000 0000 0000 0010 |
| $+200/2^{15}$ | +1 | 0x0001 | 0000 0000 0000 0001 |
| 0 | 0 | 0x0000 | 0000 0000 0000 0000 |
| $-200/2^{15}$ | -1 | 0xFFFF | 1111 1111 1111 1111 |
| $-400/2^{15}$ | -2 | 0xFFFE | 1111 1111 1111 1110 |
| -160 | -32,768 | 0x8000 | 1000 0000 0000 0000 |

The registers that use the x_DELTVEL_LOW naming format provide additional resolution for the gyroscope measurements (see Table 35, Table 36, and Table 37). The MSB has a weight of $\sim 3.052 \text{ mm/sec}$ ($200 \text{ m/sec} \div 2^{16}$), and each subsequent bit carries a weight of $\frac{1}{2}$ of the previous one.

Table 35. X_DELTVEL_LOW (Page 0, Base Address = 0x4C)

| Bits | Description |
|--------|--|
| [15:0] | X-axis delta velocity data; additional resolution bits |

Table 36. Y_DELTVEL_LOW (Page 0, Base Address = 0x50)

| Bits | Description |
|--------|--|
| [15:0] | Y-axis delta velocity data; additional resolution bits |

Table 37. Z_DELTVEL_LOW (Page 0, Base Address = 0x54)

| Bits | Description |
|--------|--|
| [15:0] | Z-axis delta velocity data; additional resolution bits |

MAGNETOMETERS

The registers that use the `x_MAGN_OUT` format are the primary registers for the magnetometer measurements. When processing data from these registers, use a 16-bit, twos complement data format. Table 38, Table 39, and Table 40 provide each register's numerical format, and Table 41 provides `x_MAGN_OUT` digital coding examples.

Table 38. X_MAGN_OUT (Page 0, Base Address = 0x28)

| Bits | Description |
|--------|---|
| [15:0] | X-axis magnetometer data; twos complement, ± 3.2767 gauss range, 0 gauss = 0x0000, 1 LSB = 0.1 mgauss |

Table 39. Y_MAGN_OUT (Page 0, Base Address = 0x2A)

| Bits | Description |
|--------|---|
| [15:0] | Y-axis magnetometer data; twos complement, ± 3.2767 gauss range, 0 gauss = 0x0000, 1 LSB = 0.1 mgauss |

Table 40. Z_MAGN_OUT (Page 0, Base Address = 0x2C)

| Bits | Description |
|--------|---|
| [15:0] | Z-axis magnetometer data; twos complement, ± 3.2767 gauss range, 0 gauss = 0x0000, 1 LSB = 0.1 mgauss |

Table 41. x_MAGN_OUT Data Format Examples

| Magnetic Field | Decimal | Hex | Binary |
|----------------|---------|--------|---------------------|
| +3.2767 gauss | +32,767 | 0x7FFF | 0111 1111 1111 1111 |
| +0.2 mgauss | +2 | 0x0002 | 0000 0000 0000 0010 |
| +0.1 mgauss | +1 | 0x0001 | 0000 0000 0000 0001 |
| 0 gauss | 0 | 0x0000 | 0000 0000 0000 0000 |
| -0.1 mgauss | -1 | 0xFFFF | 1111 1111 1111 1111 |
| -0.2 mgauss | -2 | 0xFFFE | 1111 1111 1111 1110 |
| -3.2768 gauss | -32,768 | 0x8000 | 1000 0000 0000 0000 |

BAROMETER

The `BAROM_OUT` register (see Table 42) and `BAROM_LOW` register (see Table 44) provide access to the barometric pressure data. These two registers combine to provide a 32-bit, twos complement format. Some applications are able to use `BAROM_OUT` by itself. For cases where the finer resolution available from `BAROM_LOW` is valuable, combine them in the same manner as the gyroscopes (see Figure 18). When processing data from the `BAROM_OUT` register alone, use a 16-bit, twos complement data format. Table 42 provides the numerical format in `BAROM_OUT`, and Table 43 provides digital coding examples.

Table 42. BAROM_OUT (Page 0, Base Address = 0x30)

| Bits | Description |
|--------|--|
| [15:0] | Barometric pressure; twos complement, ± 1.31 bar range, 0 bar = 0x0000, 40 μ bar/LSB |

Table 43. BAROM_OUT Data Format Examples

| Pressure (bar) | Decimal | Hex | Binary |
|--------------------------------|---------|--------|---------------------|
| $+0.00004 \times (2^{15} - 1)$ | +32,767 | 0x7FFF | 0111 1111 1110 1111 |
| +0.00008 | +2 | 0x0002 | 0000 0000 0000 0010 |
| +0.00004 | +1 | 0x0001 | 0000 0000 0000 0001 |
| 0 | 0 | 0x0000 | 0000 0000 0000 0000 |
| -0.00004 | -1 | 0xFFFF | 1111 1111 1111 1111 |
| -0.00008 | -2 | 0xFFFE | 1111 1111 1111 1110 |
| -0.00004×2^{15} | -32,768 | 0x8000 | 1000 0000 0000 0000 |

The `BAROM_LOW` register provides additional resolution for the barometric pressure measurement. The MSB has a weight of 20 μ bar, and each subsequent bit carries a weight of $\frac{1}{2}$ of the previous one.

Table 44. BAROM_LOW (Page 0, Base Address = 0x2E)

| Bits | Description |
|--------|---|
| [15:0] | Barometric pressure; additional resolution bits |

INTERNAL TEMPERATURE

The `TEMP_OUT` register provides an internal temperature measurement that can be useful for observing relative temperature changes inside of the [ADIS16488](#) (see Table 45). Table 46 provides `TEMP_OUT` digital coding examples. Note that this temperature reflects a higher temperature than ambient, due to self-heating.

Table 45. TEMP_OUT (Page 0, Base Address = 0x0E)

| Bits | Description |
|--------|---|
| [15:0] | Temperature data; twos complement, 0.00565°C per LSB, 25°C = 0x0000 |

Table 46. TEMP_OUT Data Format Examples

| Temperature (°C) | Decimal | Hex | Binary |
|------------------|---------|--------|---------------------|
| +85 | +10,619 | 0x297B | 0010 1001 0111 1011 |
| +25 + 0.0113 | +2 | 0x0002 | 0000 0000 0000 0010 |
| +25 + 0.00565 | +1 | 0x0001 | 0000 0000 0000 0001 |
| +25 | 0 | 0x0000 | 0000 0000 0000 0000 |
| +25 - 0.00565 | -1 | 0xFFFF | 1111 1111 1111 1111 |
| +25 - 0.0113 | -2 | 0xFFFE | 1111 1111 1111 1110 |
| -40 | -11,504 | 0xD310 | 1101 0011 0001 0000 |

STATUS/ALARM INDICATORS

The SYS_E_FLAG register in Table 47 provides the system error flags and new data bits for the magnetometer and barometer outputs. The new data flags are useful for triggering data collection of the magnetometer and barometer (x_MAGN_OUT and BARO_xxx registers) because they update at a fixed rate that is not dependent on the DEC_RATE setting. Note that reading SYS_E_FLAG also resets it to 0x0000.

Table 47. SYS_E_FLAG (Page 0, Base Address = 0x08)

| Bits | Description (Default = 0x0000) |
|---------|--|
| [15] | Watch dog timer flag (1 = timed out) |
| [14:10] | Not used |
| 9 | New data flag, barometer (1 = new, unread data) ¹ |
| 8 | New data flag, magnetometer (1 = new, unread data) ² |
| 7 | Processing overrun (1 = error) |
| 6 | Flash memory update, result of GLOB_CMD[3] = 1 (1 = failed update, 0 = update successful) |
| 5 | Inertial self-test failure (1 = DIAG_STS ≠ 0x0000) |
| 4 | Sensor overrange (1 = at least one sensor overranged) |
| 3 | SPI communication error (1 = error condition, when the number of SCLK pulses is not equal to a multiple of 16) |
| [2:1] | Not used |
| 0 | Alarm status flag (1 = ALM_STS ≠ 0x0000) |

¹ This flag restores to zero after reading the contents on BAROM_OUT.

² This flag restores to zero after reading one x_MAGN_OUT register.

The DIAG_STS register in Table 48 provides the flags for the internal self-test function, which is from GLOB_CMD[1] (see Table 114). Note that the barometer's flag, DIAG_STS[11], only updates after start-up and reset operations. Note that reading DIAG_STS also resets it to 0x0000.

Table 48. DIAG_STS (Page 0, Base Address = 0x0A)

| Bits | Description (Default = 0x0000) |
|---------|---|
| [15:12] | Not used |
| 11 | Self-test failure, barometer (1 = failed at start-up) |
| 10 | Self-test failure, Z-axis magnetometer (1 = failure) |
| 9 | Self-test failure, Y-axis magnetometer (1 = failure) |
| 8 | Self-test failure, X-axis magnetometer (1 = failure) |
| [7:6] | Not used |
| 5 | Self-test failure, Z-axis accelerometer (1 = failure) |
| 4 | Self-test failure, Y-axis accelerometer (1 = failure) |
| 3 | Self-test failure, X-axis accelerometer (1 = failure) |
| 2 | Self-test failure, Z-axis gyroscope (1 = failure) |
| 1 | Self-test failure, Y-axis gyroscope (1 = failure) |
| 0 | Self-test failure, X-axis gyroscope (1 = failure) |

The ALM_STS register in Table 49 provides the alarm bits for the programmable alarm levels of each sensor. Note that reading ALM_STS also resets it to 0x0000.

Table 49. ALM_STS (Page 0, Base Address = 0x0C)

| Bits | Description (Default = 0x0000) |
|---------|---|
| [15:12] | Not used |
| 11 | Barometer alarm flag (1 = alarm is active) |
| 10 | Z-axis magnetometer alarm flag (1 = alarm is active) |
| 9 | Y-axis magnetometer alarm flag (1 = alarm is active) |
| 8 | X-axis magnetometer alarm flag (1 = alarm is active) |
| [7:6] | Not used |
| 5 | Z-axis accelerometer alarm flag (1 = alarm is active) |
| 4 | Y-axis accelerometer alarm flag (1 = alarm is active) |
| 3 | X-axis accelerometer alarm flag (1 = alarm is active) |
| 2 | Z-axis gyroscope alarm flag (1 = alarm is active) |
| 1 | Y-axis gyroscope alarm flag (1 = alarm is active) |
| 0 | X-axis gyroscope alarm flag (1 = alarm is active) |

FIRMWARE REVISION

The FIRM_REV register (see Table 50) provides the firmware revision for the internal processor. Each nibble represents a digit in this revision code. For example, if FIRM_REV = 0x0102, the firmware revision is 1.02.

Table 50. FIRM_REV (Page 3, Base Address = 0x78)

| Bits | Description |
|---------|------------------------------------|
| [15:12] | Binary, revision, 10's digit |
| [11:8] | Binary, revision, 1's digit |
| [7:4] | Binary, revision, tenths digit |
| [3:0] | Binary, revision, hundredths digit |

The FIRM_DM register (see Table 51) contains the month and day of the factory configuration date. FIRM_DM[15:12] and FIRM_DM[11:8] contain digits that represent the month of factory configuration. For example, November is the 11th month in a year and represented by FIRM_DM[15:8] = 0x11. FIRM_DM[7:4] and FIRM_DM[3:0] contain digits that represent the day of factory configuration. For example, the 27th day of the month is represented by FIRM_DM[7:0] = 0x27.

Table 51. FIRM_DM (Page 3, Base Address = 0x7A)

| Bits | Description |
|---------|---|
| [15:12] | Binary, month 10's digit, range: 0 to 1 |
| [11:8] | Binary, month 1's digit, range: 0 to 9 |
| [7:4] | Binary, day 10's digit, range: 0 to 3 |
| [3:0] | Binary, day 1's digit, range: 0 to 9 |

The FIRM_Y register (see Table 52) contains the year of the factory configuration date. For example, the year of 2013 is represented by FIRM_Y = 0x2013.

Table 52. FIRM_Y (Page 3, Base Address = 0x7C)

| Bits | Description |
|---------|--|
| [15:12] | Binary, year 1000's digit, range: 0 to 9 |
| [11:8] | Binary, year 100's digit, range: 0 to 9 |
| [7:4] | Binary, year 10's digit, range: 0 to 9 |
| [3:0] | Binary, year 1's digit, range: 0 to 9 |

PRODUCT IDENTIFICATION

The PROD_ID register (see Table 53) contains the binary equivalent of the part number (16,488 = 0x4068), and the SERIAL_NUM register (see Table 54) contains a lot-specific serial number.

Table 53. PROD_ID (Page 0, Base Address = 0x7E)

| Bits | Description (Default = 0x4068) |
|--------|---------------------------------|
| [15:0] | Product identification = 0x4068 |

Table 54. SERIAL_NUM (Page 4, Base Address = 0x20)

| Bits | Description |
|--------|----------------------------|
| [15:0] | Lot-specific serial number |

DIGITAL SIGNAL PROCESSING GYROSCOPES/ACCELEROMETERS

Figure 20 provides a signal flow diagram for all of the components and settings that influence the frequency response for the accelerometers and gyroscopes. The sample rate for each accelerometer and gyroscope is 9.84 kHz. Each sensor has its own averaging/decimation filter stage, which reduces the update rate to 2.46 kSPS. When using the external clock option (FNCTIO_CTRL[7:4], see Table 117), the input clock drives a 4-sample burst at a sample rate of 9.84kSPS, which feeds into the 4x averaging/decimation filter. This results in a data rate that is equal to the input clock frequency.

AVERAGING/DECIMATION FILTER

The DEC_RATE register (see Table 55) provides user control for the final filter stage (see Figure 20), which averages and decimates the accelerometers, gyroscopes, delta angle, and delta velocity data. The output sample rate is equal to $2460 / (\text{DEC_RATE} + 1)$. When using the external clock option (FNCTIO_CTRL[7:4], see Table 117), replace the “2460” number in this relationship, with the input clock frequency. For example, turn to Page 3 (DIN = 0x8003), and set DEC_RATE = 0x18 (DIN = 0x8C18, then DIN = 0x8D00) to reduce the output sample rate to 98.4 SPS ($2460 \div 25$).

Table 55. DEC_RATE (Page 3, Base Address = 0x0C)

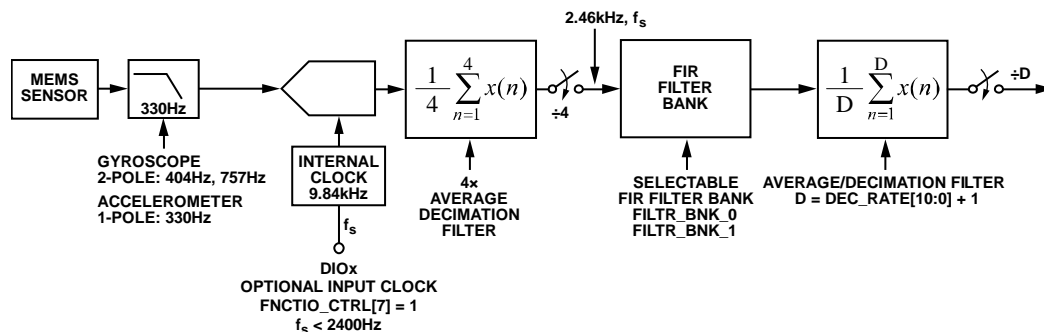
| Bits | Description (Default = 0x0000) |
|---------|---|
| [15:11] | Don't care |
| [10:0] | Decimation rate, binary format, maximum = 2047 See Figure 20 for impact on sample rate |

MAGNETOMETER/BAROMETER

When using the internal sampling clock, the magnetometer output registers (xMAGN_OUT) update at a rate of 102.5 SPS and the barometer output registers (BARO_XXX) update at a rate of 51.25 SPS. When using the external clock, the magnetometers update at a rate of 1/24th of the input clock frequency and the barometers update at a rate that is 1/48th of the input clock frequency. The update rates for the magnetometer and barometers do not change with the DEC_RATE register settings. SYS_E_FLAG[9:8] (see Table 47) offers new data bits for these registers and the SEQ_CNT register provides a counter function to help determine when there is new data in the magnetometer and barometer registers. When SEQ_CNT = 0x0001, there is new data in the magnetometer and barometer output registers. The SEQ_CNT register can be useful during initialization to help synchronize read loops for new data in both magnetometer and barometer outputs. When beginning a continuous read loop, read SEQ_CNT, then subtract this value from the maximum value shown (range) in Table 56 to calculate the number of internal sample cycles until both magnetometer and barometer data is new.

Table 56. SEQ_CNT (Page 0, Base Address = 0x06)

| Bits | Description |
|---------|--|
| [15:11] | Don't care |
| [6:0] | Binary counter: range = 1 to $48 / (\text{DEC_RATE} + 1)$ |



NOTES

1. WHEN FNCTIO_CTRL[7] = 1, EACH CLOCK PULSE ON THE DESIGNATED DIOx LINE (FNCTIO_CTRL[5:4]) STARTS A 4-SAMPLE BURST, AT A SAMPLE RATE OF 9.84kHz. THESE FOUR SAMPLES FEED INTO THE 4x AVERAGE/DECIMATION FILTER, WHICH PRODUCES A DATA RATE THAT IS EQUAL TO THE INPUT CLOCK FREQUENCY.

10277-018

Figure 20. Sampling and Frequency Response Block Diagram

FIR FILTER BANKS

The ADIS16488 provides four configurable, 120-tap FIR filter banks. Each coefficient is 16 bits wide and occupies its own register location with each page. When designing a FIR filter for these banks, use a sample rate of 2.46 kHz and scale the coefficients so that their sum equals 32,768. For filter designs that have less than 120 taps, load the coefficients into the lower portion of the filter and start with Coefficient 1. Make sure that all unused taps are equal to zero, so that they do not add phase delay to the response. The FILTR_BNK_x registers provide three bits per sensor, which configure the filter bank (A, B, C, D) and turn filtering on and off. For example, turn to Page 3 (DIN = 0x8003), then write 0x0057 to FILTR_BNK_0 (DIN = 0x9657, DIN = 0x9700) to set the x-axis gyroscope to use the FIR filter in Bank D, to set the y-axis gyroscope to use the FIR filter in Bank B, and to enable these FIR filters in both x- and y-axis gyroscopes. Note that the filter settings update after writing to the upper byte; therefore, always configure the lower byte first. In cases that require configuration to only the lower byte of either FILTR_BNK_0 or FILTR_BNK_1, complete the process by writing 0x00 to the upper byte.

Table 57. FILTR_BNK_0 (Page 3, Base Address = 0x16)

| Bits | Description (Default = 0x0000) |
|---------|---|
| 15 | Don't care |
| 14 | Y-axis accelerometer filter enable (1 = enabled) |
| [13:12] | Y-axis accelerometer filter bank selection: 00 = Bank A, 01 = Bank B, 10 = Bank C, 11 = Bank D |
| 11 | X-axis accelerometer filter enable (1 = enabled) |
| [10:9] | X-axis accelerometer filter bank selection: 00 = Bank A, 01 = Bank B, 10 = Bank C, 11 = Bank D |
| 8 | Z-axis gyroscope filter enable (1 = enabled) |
| [7:6] | Z-axis gyroscope filter bank selection: 00 = Bank A, 01 = Bank B, 10 = Bank C, 11 = Bank D |
| 5 | Y-axis gyroscope filter enable (1 = enabled) |
| [4:3] | Y-axis gyroscope filter bank selection: 00 = Bank A, 01 = Bank B, 10 = Bank C, 11 = Bank D |
| 2 | X-axis gyroscope filter enable (1 = enabled) |
| [1:0] | X-axis gyroscope filter bank selection: 00 = Bank A, 01 = Bank B, 10 = Bank C, 11 = Bank D |

Table 58. FILTR_BNK_1 (Page 3, Base Address = 0x18)

| Bits | Description (Default = 0x0000) |
|---------|---|
| [15:12] | Don't care |
| 11 | Z-axis magnetometer filter enable (1 = enabled) |
| [10:9] | Z-axis magnetometer filter bank selection: 00 = Bank A, 01 = Bank B, 10 = Bank C, 11 = Bank D |
| 8 | Y-axis magnetometer filter enable (1 = enabled) |
| [7:6] | Y-axis magnetometer filter bank selection: 00 = Bank A, 01 = Bank B, 10 = Bank C, 11 = Bank D |
| 5 | X-axis magnetometer filter enable (1 = enabled) |
| [4:3] | X-axis magnetometer filter bank selection: 00 = Bank A, 01 = Bank B, 10 = Bank C, 11 = Bank D |
| 2 | Z-axis accelerometer filter enable (1 = enabled) |
| [1:0] | Z-axis accelerometer filter bank selection: 00 = Bank A, 01 = Bank B, 10 = Bank C, 11 = Bank D |

Filter Memory Organization

Each filter bank uses two pages of the user register structure. See Table 59, Table 60, Table 61, and Table 62 for the register addresses in each filter bank.

Table 59. Filter Bank A Memory Map

| Page | PAGE_ID | Address | Register |
|------|---------|--------------|-----------------------------------|
| 5 | 0x05 | 0x00 | PAGE_ID |
| 5 | 0x05 | 0x02 to 0x07 | Not used |
| 5 | 0x05 | 0x08 | FIR_COEF_A000 |
| 5 | 0x05 | 0x0A | FIR_COEF_A001 |
| 5 | 0x05 | 0x0C to 0x7C | FIR_COEF_A002 to FIR_COEF_A058 |
| 5 | 0x05 | 0x7E | FIR_COEF_A059 |
| 6 | 0x06 | 0x00 | PAGE_ID |
| 6 | 0x06 | 0x02 to 0x07 | Not used |
| 6 | 0x06 | 0x08 | FIR_COEF_A060 |
| 6 | 0x06 | 0x0A | FIR_COEF_A061 |
| 6 | 0x06 | 0x0C to 0x7C | FIR_COEF_A062 to FIR_COEF_A118 |
| 6 | 0x06 | 0x7E | FIR_COEF_D119 |

Table 60. Filter Bank B Memory Map

| Page | PAGE_ID | Address | Register |
|------|---------|--------------|-----------------------------------|
| 7 | 0x07 | 0x00 | PAGE_ID |
| 7 | 0x07 | 0x02 to 0x07 | Not used |
| 7 | 0x07 | 0x08 | FIR_COEF_B000 |
| 7 | 0x07 | 0x0A | FIR_COEF_B001 |
| 7 | 0x07 | 0x0C to 0x7C | FIR_COEF_B002 to FIR_COEF_B058 |
| 7 | 0x07 | 0x7E | FIR_COEF_B059 |
| 8 | 0x08 | 0x00 | PAGE_ID |
| 8 | 0x08 | 0x02 to 0x07 | Not used |
| 8 | 0x08 | 0x08 | FIR_COEF_B060 |
| 8 | 0x08 | 0x0A | FIR_COEF_B061 |
| 8 | 0x08 | 0x0C to 0x7C | FIR_COEF_B062 to FIR_COEF_B118 |
| 8 | 0x08 | 0x7E | FIR_COEF_B119 |

Table 61. Filter Bank C Memory Map

| Page | PAGE_ID | Address | Register |
|------|---------|--------------|-----------------------------------|
| 9 | 0x09 | 0x00 | PAGE_ID |
| 9 | 0x09 | 0x02 to 0x07 | Not used |
| 9 | 0x09 | 0x08 | FIR_COEF_C000 |
| 9 | 0x09 | 0x0A | FIR_COEF_C001 |
| 9 | 0x09 | 0x0C to 0x7C | FIR_COEF_C002 to FIR_COEF_C058 |
| 9 | 0x09 | 0x7E | FIR_COEF_C059 |
| 10 | 0x0A | 0x00 | PAGE_ID |
| 10 | 0x0A | 0x02 to 0x07 | Not used |
| 10 | 0x0A | 0x08 | FIR_COEF_C060 |
| 10 | 0x0A | 0x0A | FIR_COEF_C061 |
| 10 | 0x0A | 0x0C to 0x7C | FIR_COEF_C062 to FIR_COEF_C118 |
| 10 | 0x0A | 0x7E | FIR_COEF_C119 |

Table 62. Filter Bank D Memory Map

| Page | PAGE_ID | Address | Register |
|------|---------|--------------|-----------------------------------|
| 11 | 0x0B | 0x00 | PAGE_ID |
| 11 | 0x0B | 0x02 to 0x07 | Not used |
| 11 | 0x0B | 0x08 | FIR_COEF_D000 |
| 11 | 0x0B | 0x0A | FIR_COEF_D001 |
| 11 | 0x0B | 0x0C to 0x7C | FIR_COEF_D002 to FIR_COEF_D058 |
| 11 | 0x0B | 0x7E | FIR_COEF_D059 |
| 12 | 0x0C | 0x00 | PAGE_ID |
| 12 | 0x0C | 0x02 to 0x07 | Not used |
| 12 | 0x0C | 0x08 | FIR_COEF_D060 |
| 12 | 0x0C | 0x0A | FIR_COEF_D061 |
| 12 | 0x0C | 0x0C to 0x7C | FIR_COEF_D062 to FIR_COEF_D118 |
| 12 | 0x0C | 0x7E | FIR_COEF_D119 |

Default Filter Performance

The FIR filter banks have factory-programmed filter designs. They are all low-pass filters that have unity dc gain. Table 63 provides a summary of each filter design, and Figure 21 shows the frequency response characteristics. The phase delay is equal to ½ of the total number of taps.

Table 63. FIR Filter Descriptions, Default Configuration

| FIR Filter Bank | Taps | -3 dB Frequency (Hz) |
|-----------------|------|----------------------|
| A | 120 | 310 |
| B | 120 | 55 |
| C | 32 | 275 |
| D | 32 | 63 |

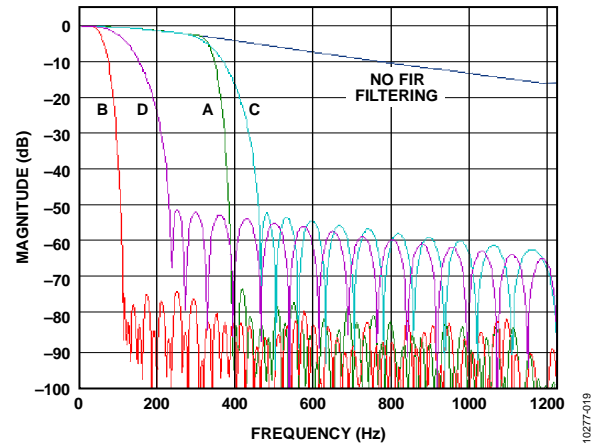


Figure 21. FIR Filter Frequency Response Curves

CALIBRATION

The ADIS16488 factory calibration produces correction formulas for the gyroscopes, accelerometers, magnetometers, and barometers, and then programs them into the flash memory. In addition, there are a series of user-configurable calibration registers, for in-system tuning.

GYROSCOPES

The user-calibration for the gyroscopes includes registers for adjusting bias and sensitivity, as shown in Figure 22.

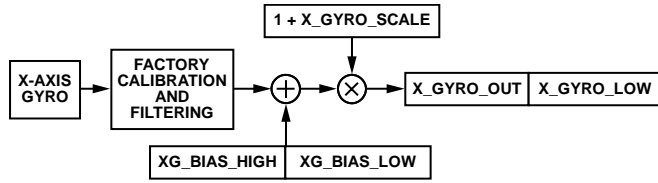


Figure 22. User Calibration Signal Path, Gyroscopes

Manual Bias Correction

The xG_BIAS_HIGH registers (see Table 64, Table 65, and Table 66) and xG_BIAS_LOW registers (see Table 67, Table 68, and Table 69) provide a bias adjustment function for the output of each gyroscope sensor.

Table 64. XG_BIAS_HIGH (Page 2, Base Address = 0x12)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | X-axis gyroscope offset correction, upper word twos complement, 0°/sec = 0x0000, 1 LSB = 0.02°/sec |

Table 65. YG_BIAS_HIGH (Page 2, Base Address = 0x16)

| Bits | Description (Default = 0x0000) |
|--------|---|
| [15:0] | Y-axis gyroscope offset correction, upper word; twos complement, 0°/sec = 0x0000, 1 LSB = 0.02°/sec |

Table 66. ZG_BIAS_HIGH (Page 2, Base Address = 0x1A)

| Bits | Description (Default = 0x0000) |
|--------|---|
| [15:0] | Z-axis gyroscope offset correction, upper word; twos complement, 0°/sec = 0x0000, 1 LSB = 0.02°/sec |

Table 67. XG_BIAS_LOW (Page 2, Base Address = 0x10)

| Bits | Description (Default = 0x0000) |
|--------|---|
| [15:0] | X-axis gyroscope offset correction, lower word; twos complement, 0°/sec = 0x0000, 1 LSB = 0.02°/sec ÷ 2 ¹⁶ = ~0.000000305°/sec |

Table 68. YG_BIAS_LOW (Page 2, Base Address = 0x14)

| Bits | Description (Default = 0x0000) |
|--------|---|
| [15:0] | Y-axis gyroscope offset correction, lower word; twos complement, 0°/sec = 0x0000, 1 LSB = 0.02°/sec ÷ 2 ¹⁶ = ~0.000000305°/sec |

Table 69. ZG_BIAS_LOW (Page 2, Base Address = 0x18)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | Z-axis gyroscope offset correction, lower word twos complement, 0°/sec = 0x0000, 1 LSB = 0.02°/sec ÷ 2 ¹⁶ = ~0.000000305°/sec |

Bias Null Command

The continuous bias estimator (CBE) accumulates and averages data in a 64-sample FIFO. The average time (t_A) for the bias estimates relies on the sample time base setting in NULL_CNFG[3:0] (see Table 70). Users can load the correction factors of the CBE into the gyroscope offset correction registers (see Table 64, Table 65, Table 66, Table 67, Table 68, and Table 69) using the bias null command in GLOB_CMD[0] (see Table 114). NULL_CNFG[13:8] provide on/off controls for the sensors that update when issuing a bias null command. The factory default configuration for NULL_CNFG enables the bias null command for the gyroscopes, disables the bias null command for the accelerometers, and establishes the average time to ~26.64 seconds.

Table 70. NULL_CNFG (Page 3, Base Address = 0x0E)

| Bits | Description (Default = 0x070A) |
|---------|---|
| [15:14] | Not used |
| 13 | Z-axis acceleration bias correction enable (1 = enabled) |
| 12 | Y-axis acceleration bias correction enable (1 = enabled) |
| 11 | X-axis acceleration bias correction enable (1 = enabled) |
| 10 | Z-axis gyroscope bias correction enable (1 = enabled) |
| 9 | Y-axis gyroscope bias correction enable (1 = enabled) |
| 8 | X-axis gyroscope bias correction enable (1 = enabled) |
| [7:4] | Not used |
| [3:0] | Time base control (TBC), range: 0 to 13 (default = 10); t _B = 2 ^{TBC} /2460, time base, t _A = 64 × t _B , average time |

Turn to Page 3 (DIN = 0x8003) and set GLOB_CMD[0] = 1 (DIN = 0x8201, then DIN = 0x8300) to update the user offset registers with the correction factors of the CBE. Make sure that the inertial platform is stable during the entire average time for optimal bias estimates.

Manual Sensitivity Correction

The x_GYRO_SCALE registers enable sensitivity adjustment (see Table 71, Table 72, and Table 73).

Table 71. X_GYRO_SCALE (Page 2, Base Address = 0x04)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | X-axis gyroscope scale correction; twos complement, 0x0000 = unity gain, 1 LSB = 1 ÷ 2 ¹⁵ = ~0.0003052% |

Table 72. Y_GYRO_SCALE (Page 2, Base Address = 0x06)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | Y-axis gyroscope scale correction; twos complement, 0x0000 = unity gain, 1 LSB = 1 ÷ 2 ¹⁵ = ~0.0003052% |

Table 73. Z_GYRO_SCALE (Page 2, Base Address = 0x08)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | Z-axis gyroscope scale correction; twos complement, 0x0000 = unity gain, 1 LSB = 1 ÷ 2 ¹⁵ = ~0.0003052% |

Linear Acceleration on Effect on Gyroscope Bias

MEMS gyroscopes typically have a bias response to linear acceleration that is normal to their axis of rotation. The ADIS16488 offers an optional compensation function for this effect. Turn to Page 3 (DIN = 0x8003) and set CONFIG[7] = 1 (DIN = 0x9080, DIN = 0x9100).

Table 74. CONFIG (Page 3, Base Address = 0x0A)

| Bits | Description (Default = 0x00C0) |
|--------|--|
| [15:8] | Not used |
| 7 | Linear-g compensation for gyroscopes (1 = enabled) |
| 6 | Point of percussion alignment (1 = enabled) |
| [5:2] | Not used |
| 1 | Real-time clock, daylight savings time (1: enabled, 0: disabled) |
| 0 | Real-time clock control (1: relative/elapsed timer mode, 0: calendar mode) |

ACCELEROMETERS

The user-calibration for the accelerometers includes registers for adjusting bias and sensitivity, as shown in Figure 23.

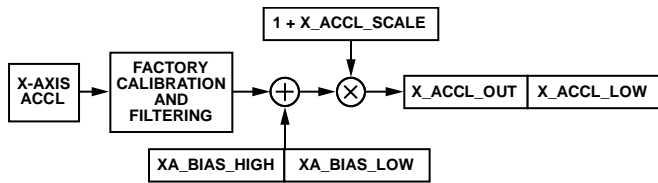


Figure 23. User Calibration Signal Path, Gyroscopes

Manual Bias Correction

The xA_BIAS_HIGH (see Table 75, Table 76, and Table 77) and xA_BIAS_LOW (see Table 78, Table 79, and Table 80) registers provide a bias adjustment function for the output of each gyroscope sensor. The xA_BIAS_HIGH registers use the same format as x_ACCL_OUT registers. The xA_BIAS_LOW registers use the same format as x_ACCL_LOW registers.

Table 75. XA_BIAS_HIGH (Page 2, Base Address = 0x1E)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | X-axis accelerometer offset correction, high word, Twos complement, 0 g = 0x0000, 1 LSB = 0.8 mg |

Table 76. YA_BIAS_HIGH (Page 2, Base Address = 0x22)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | Y-axis accelerometer offset correction, high word, Twos complement, 0 g = 0x0000, 1 LSB = 0.8 mg |

Table 77. ZA_BIAS_HIGH (Page 2, Base Address = 0x26)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | Z-axis accelerometer offset correction, high word, Twos complement, 0 g = 0x0000, 1 LSB = 0.8 mg |

Table 78. XA_BIAS_LOW (Page 2, Base Address = 0x1C)

| Bits | Description (Default = 0x0000) |
|--------|---|
| [15:0] | X-axis accelerometer offset correction, low word, Twos complement, 0 g = 0x0000, 1 LSB = 0.8 mg ÷ 2 ¹⁶ = ~0.0000122 mg |

Table 79. YA_BIAS_LOW (Page 2, Base Address = 0x20)

| Bits | Description (Default = 0x0000) |
|--------|---|
| [15:0] | Y-axis accelerometer offset correction, low word, Twos complement, 0 g = 0x0000, 1 LSB = 0.8 mg ÷ 2 ¹⁶ = ~0.0000122 mg |

Table 80. ZA_BIAS_LOW (Page 2, Base Address = 0x24)

| Bits | Description (Default = 0x0000) |
|--------|---|
| [15:0] | Z-axis accelerometer offset correction, low word, Twos complement, 0 g = 0x0000, 1 LSB = 0.8 mg ÷ 2 ¹⁶ = ~0.0000122 mg |

Manual Sensitivity Correction

The x_ACCL_SCALE registers enable sensitivity adjustment (see Table 81, Table 82, Table 83).

Table 81. X_ACCL_SCALE (Page 2, Base Address = 0x0A)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | X-axis accelerometer scale correction, Twos complement, 0x0000 = unity gain, 1 LSB = 1 ÷ 2 ¹⁵ = ~0.0003052% |

Table 82. Y_ACCL_SCALE (Page 2, Base Address = 0x0C)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | Y-axis accelerometer scale correction, Twos complement, 0x0000 = unity gain, 1 LSB = 1 ÷ 2 ¹⁵ = ~0.0003052% |

Table 83. Z_ACCL_SCALE (Page 2, Base Address = 0x0E)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | Z-axis accelerometer scale correction, Twos complement, 0x0000 = unity gain, 1 LSB = 1 ÷ 2 ¹⁵ = ~0.0003052% |

MAGNETOMETERS

The user calibration registers enable both hard-iron and soft-iron correction, as shown in the following relationship:

$$\begin{bmatrix} M_{XC} \\ M_{YC} \\ M_{ZC} \end{bmatrix} = \begin{bmatrix} 1 + S_{11} & S_{12} & S_{13} \\ S_{21} & 1 + S_{22} & S_{23} \\ S_{31} & S_{32} & 1 + S_{33} \end{bmatrix} \times \begin{bmatrix} M_X \\ M_Y \\ M_Z \end{bmatrix} + \begin{bmatrix} H_X \\ H_Y \\ H_Z \end{bmatrix}$$

The M_x, M_y, and M_z variables represent the magnetometer data, prior to application of the user correction formula. The M_{xc}, M_{yc}, and M_{zc} represent the magnetometer data, after the application of the user correction formula.

Hard-Iron Correction

Table 84, Table 85, and Table 86 describe the register format for the hard-iron correction factors: H_x, H_y, and H_z. These registers use a twos complement format. Table 87 provides some numerical examples for converting the digital codes for these registers into their decimal equivalent.

Table 84. HARD_IRON_X (Page 2, Base Address = 0x28)

| Bits | Description (Default = 0x0000) |
|--------|---|
| [15:0] | X-axis magnetometer hard-iron correction factor, H _x Twos complement, ±3.2767 gauss range, 0.1 mgauss/LSB, 0 gauss = 0x0000 (see Table 87) |

Table 85. HARD_IRON_Y (Page 2, Base Address = 0x2A)

| Bits | Description (Default = 0x0000) |
|--------|---|
| [15:0] | Y-axis magnetometer hard-iron correction factor, H _y Twos complement, ±3.2767 gauss range, 0.1 mgauss/LSB, 0 gauss = 0x0000 (see Table 87) |

Table 86. HARD_IRON_Z (Page 2, Base Address = 0x2C)

| Bits | Description (Default = 0x0000) |
|--------|---|
| [15:0] | Z-axis magnetometer hard-iron correction factor, H _z Twos complement, ±3.2767 gauss range, 0.1 mgauss/LSB, 0 gauss = 0x0000 (see Table 87) |

Table 87. x_MAGN_OUT Data Format Examples

| Magnetic Field | Decimal | Hex | Binary |
|----------------|---------|--------|---------------------|
| +3.2767 gauss | +32,767 | 0x7FFF | 0111 1111 1111 1111 |
| +0.2 mgauss | +2 | 0x0002 | 0000 0000 0000 0010 |
| +0.1 mgauss | +1 | 0x0001 | 0000 0000 0000 0001 |
| 0 gauss | 0 | 0x0000 | 0000 0000 0000 0000 |
| -0.1 mgauss | -1 | 0xFFFF | 1111 1111 1111 1111 |
| -0.2 mgauss | -2 | 0xFFFE | 1111 1111 1111 1110 |
| -3.2768 gauss | -32,768 | 0x8000 | 1000 0000 0000 0000 |

Soft-Iron Correction Matrix

The soft-iron correction matrix contains correction factors for both sensitivity (S₁₁, S₂₂, S₃₃) and alignment (S₁₂, S₁₃, S₂₁, S₂₃, S₃₁, S₃₂). The registers that represent each soft-iron correction factor are in Table 88 (S₁₁), Table 89 (S₁₂), Table 90 (S₁₃), Table 91 (S₂₁), Table 92 (S₂₂), Table 93 (S₂₃), Table 94 (S₃₁), Table 95 (S₃₂), and Table 96 (S₃₃). Table 97 offers some numerical examples for converting between the digital codes and their effect on the magnetometer output, in terms of percent-change.

Table 88. SOFT_IRON_S11 (Page 2, Base Address = 0x2E)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | Magnetometer soft-iron correction factor, S ₁₁ Twos complement format, see Table 97 for examples |

Table 89. SOFT_IRON_S12 (Page 2, Base Address = 0x30)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | Magnetometer soft-iron correction factor, S ₁₂ Twos complement format, see Table 97 for examples |

Table 90. SOFT_IRON_S13 (Page 2, Base Address = 0x32)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | Magnetometer soft-iron correction factor, S ₁₃ Twos complement format, see Table 97 for examples |

Table 91. SOFT_IRON_S21 (Page 2, Base Address = 0x34)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | Magnetometer soft-iron correction factor, S ₂₁ Twos complement format, see Table 97 for examples |

Table 92. SOFT_IRON_S22 (Page 2, Base Address = 0x36)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | Magnetometer soft-iron correction factor, S ₂₂ Twos complement format, see Table 97 for examples |

Table 93. SOFT_IRON_S23 (Page 2, Base Address = 0x38)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | Magnetometer soft-iron correction factor, S ₂₃ Twos complement format, see Table 97 for examples |

Table 94. SOFT_IRON_S31 (Page 2, Base Address = 0x3A)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | Magnetometer soft-iron correction factor, S ₃₁ Twos complement format, see Table 97 for examples |

Table 95. SOFT_IRON_S32 (Page 2, Base Address = 0x3C)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | Magnetometer soft-iron correction factor, S ₃₂ Twos complement format, see Table 97 for examples |

Table 96. SOFT_IRON_S33 (Page 2, Base Address = 0x3E)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | Magnetometer soft-iron correction factor, S ₃₃ Twos complement format, see Table 97 for examples |

Table 97. Soft Iron Correction, Numerical Examples

| Delta (%) | Decimal | Hex | Binary |
|--------------------------|---------|--------|---------------------|
| +100 - 1/2 ¹⁶ | +32,767 | 0x7FFF | 0111 1111 1111 1111 |
| +200/2 ¹⁵ | +2 | 0x0002 | 0000 0000 0000 0010 |
| +100/2 ¹⁵ | +1 | 0x0001 | 0000 0000 0000 0001 |
| 0 | 0 | 0x0000 | 0000 0000 0000 0000 |
| -100/2 ¹⁵ | -1 | 0xFFFF | 1111 1111 1111 1111 |
| -200/2 ¹⁵ | -2 | 0xFFFE | 1111 1111 1111 1110 |
| -100 | -32,768 | 0x8000 | 1000 0000 0000 0000 |

BAROMETERS

The BR_BIAS_HIGH register (see Table 98) and BR_BIAS_LOW register (Table 99) provide an offset control function and use the same format as the output registers, BAROM_OUT and BAROM_LOW.

Table 98. BR_BIAS_HIGH (Page 2, Base Address = 0x42)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | Barometric pressure bias correction factor, high word Twos complement, ±1.3 bar measurement range, 0 bar = 0x0000, 1 LSB = 40 μbar |

Table 99. BR_BIAS_LOW (Page 2, Base Address = 0x40)

| Bits | Description (Default = 0x0000) |
|--------|---|
| [15:0] | Barometric pressure bias correction factor, low word Twos complement, ±1.3 bar measurement range, 0 bar = 0x0000, 1 LSB = 40 μbar ÷ 2 ¹⁶ = ~0.00061 μbar |

RESTORING FACTORY CALIBRATION

Turn to Page 3 (DIN = 0x8003) and set GLOB_CMD[6] = 1 (DIN = 0xA240, DIN = 0xA300) to execute the factory calibration restore function. This function resets each user calibration register to zero, resets all sensor data to 0, and automatically updates the flash memory within 72 ms. See Table 114 for more information on GLOB_CMD.

POINT OF PERCUSSION ALIGNMENT

CONFIG[6] offers a point of percussion alignment function that maps the accelerometer sensors to the corner of the package identified in Figure 24. To activate this feature, turn to Page 3 (DIN = 0x8003), then set CONFIG[6] = 1 (DIN = 0x8A40, DIN = 0x8B00). See Table 74 for more information on the CONFIG register.

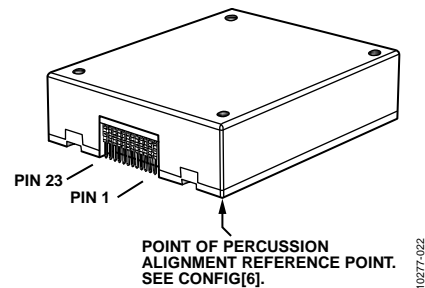


Figure 24. Point of Percussion Reference Point

ALARMS

Each sensor has an independent alarm function that provides controls for alarm magnitude, polarity, and enabling a dynamic rate-of-change option. The ALM_STS register (see Table 49) contains the alarm output flags and the FNCTIO_CTRL register (see Table 117) provides an option for configuring one of the digital I/O lines as an alarm indicator.

STATIC ALARM USE

The static alarm setting compares each sensor's output with the trigger settings in the xx_ALM_MAGN registers (see Table 100, Table 101, Table 102, Table 103, Table 104, Table 105, Table 106, Table 107, Table 108, and Table 109) of that sensor. The polarity controls for each alarm are in the ALM_CNFG_x registers (see Table 110, Table 111, Table 112). The polarity establishes whether greater than or less than produces an alarm condition. The comparison between the xx_ALM_MAGN value and the output data only applies to the upper word or 16 bits of the output data.

DYNAMIC ALARM USE

The dynamic alarm setting provides the option of comparing the change in each sensor's output over a period of 48.7 ms with that sensor's xx_ALM_MAGN register.

Table 100. XG_ALM_MAGN (Page 3, Base Address = 0x28)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | X-axis gyroscope alarm threshold settings, Twos complement, 0°/sec = 0x0000, 1 LSB = 0.02°/sec |

Table 101. YG_ALM_MAGN (Page 3, Base Address = 0x2A)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | Y-axis gyroscope alarm threshold settings, Twos complement, 0°/sec = 0x0000, 1 LSB = 0.02°/sec |

Table 102. ZG_ALM_MAGN (Page 3, Base Address = 0x2C)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | Z-axis gyroscope alarm threshold settings, Twos complement, 0°/sec = 0x0000, 1 LSB = 0.02°/sec |

Table 103. XA_ALM_MAGN (Page 3, Base Address = 0x2E)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | X-axis accelerometer alarm threshold settings, Twos complement, 0 g = 0x0000, 1 LSB = 0.8 mg |

Table 104. YA_ALM_MAGN (Page 3, Base Address = 0x30)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | Y-axis accelerometer alarm threshold settings, Twos complement, 0 g = 0x0000, 1 LSB = 0.8 mg |

Table 105. ZA_ALM_MAGN (Page 3, Base Address = 0x32)

| Bits | Description (Default = 0x0000) |
|--------|--|
| [15:0] | Z-axis accelerometer alarm threshold settings, Twos complement, 0 g = 0x0000, 1 LSB = 0.8 mg |

Table 106. XM_ALM_MAGN (Page 3, Base Address = 0x34)

| Bits | Description (Default = 0x0000) |
|--------|---|
| [15:0] | X-axis magnetometer alarm threshold settings, Twos complement, 0 gauss = 0x0000, 1 LSB = 0.1 mgauss |

Table 107. YM_ALM_MAGN (Page 3, Base Address = 0x36)

| Bits | Description (Default = 0x0000) |
|--------|---|
| [15:0] | Y-axis magnetometer alarm threshold settings, Twos complement, 0 gauss = 0x0000, 1 LSB = 0.1 mgauss |

Table 108. ZM_ALM_MAGN (Page 3, Base Address = 0x38)

| Bits | Description (Default = 0x0000) |
|--------|---|
| [15:0] | Z-axis magnetometer alarm threshold settings, Twos complement, 0 gauss = 0x0000, 1 LSB = 0.1 mgauss |

Table 109. BR_ALM_MAGN (Page 3, Base Address = 0x3A)

| Bits | Description (Default = 0x0000) |
|--------|---|
| [15:0] | Z-axis barometer alarm threshold settings, Twos complement, 0 bar = 0x0000, 1 LSB = 40 μbar |

Table 110. ALM_CNFG_0 (Page 3, Base Address = 0x20)

| Bits | Description (Default = 0x0000) |
|------|--|
| 15 | X-axis accelerometer alarm (1 = enabled) |
| 14 | Not used |
| 13 | X-axis accelerometer alarm polarity (1 = greater than) |
| 12 | X-axis accelerometer dynamic enable (1 = enabled) |
| 11 | Z-axis gyroscope alarm (1 = enabled) |
| 10 | Not used |
| 9 | Z-axis gyroscope alarm polarity (1 = greater than) |
| 8 | Z-axis gyroscope dynamic enable (1 = enabled) |
| 7 | Y-axis gyroscope alarm (1 = enabled) |
| 6 | Not used |
| 5 | Y-axis gyroscope alarm polarity (1 = greater than) |
| 4 | Y-axis gyroscope dynamic enable (1 = enabled) |
| 3 | X-axis gyroscope alarm (1 = enabled) |
| 2 | Not used |
| 1 | X-axis gyroscope alarm polarity (1 = greater than) |
| 0 | X-axis gyroscope dynamic enable (1 = enabled) |

Table 111. ALM_CNFG_1 (Page 3, Base Address = 0x22)

| Bits | Description (Default = 0x0000) |
|------|--|
| 15 | Y-axis magnetometer alarm (1 = enabled) |
| 14 | Not used |
| 13 | Y-axis magnetometer alarm polarity (1 = greater than) |
| 12 | Y-axis magnetometer dynamic enable (1 = enabled) |
| 11 | X-axis magnetometer (1 = enabled) |
| 10 | Not used |
| 9 | X-axis magnetometer alarm polarity (1 = greater than) |
| 8 | X-axis magnetometer dynamic enable (1 = enabled) |
| 7 | Z-axis accelerometer alarm (1 = enabled) |
| 6 | Not used |
| 5 | Z-axis accelerometer alarm polarity (1 = greater than) |
| 4 | Z-axis accelerometer dynamic enable (1 = enabled) |
| 3 | Y-axis accelerometer alarm (1 = enabled) |
| 2 | Not used |
| 1 | Y-axis accelerometer alarm polarity (1 = greater than) |
| 0 | Y-axis accelerometer dynamic enable (1 = enabled) |

Table 112. ALM_CNFG_2 (Page 3, Base Address = 0x24)

| Bits | Description (Default = 0x0000) |
|--------|---|
| [15:8] | Not used |
| 7 | Barometer alarm (1 = enabled) |
| 6 | Not used |
| 5 | Barometer alarm polarity (1 = greater than) |
| 4 | Barometer dynamic enable (1 = enabled) |
| 3 | Z-axis magnetometer alarm (1 = enabled) |
| 2 | Not used |
| 1 | Z-axis magnetometer alarm polarity (1 = greater than) |
| 0 | Z-axis magnetometer dynamic enable (1 = enabled) |

Alarm Example

Table 113 offers an alarm configuration example, which sets the Z-axis gyroscope alarm to trip when $Z_GYRO_OUT > 131.1^\circ/\text{sec}$ (0x199B).

Table 113. Alarm Configuration Example

| DIN | Description |
|--------|------------------------------|
| 0xAC9B | Set ZG_ALM_MAGN[7:0] = 0x9B |
| 0xAD19 | Set ZG_ALM_MAGN[15:8] = 0x19 |
| 0xA000 | Set ALM_CNFG_0[7:0] = 0x00 |
| 0xA103 | Set ALM_CNFG_0[15:8] = 0x03 |

SYSTEM CONTROLS

The ADIS16488 provides a number of system-level controls for managing its operation, which include reset, self-test, calibration, memory management, and I/O configuration.

GLOBAL COMMANDS

The GLOB_CMD register (see Table 114) provides trigger bits for several operations. Write 1 to the appropriate bit in GLOB_CMD to start a function. After the function completes, the bit restores to 0.

Table 114. GLOB_CMD (Page 3, Base Address = 0x02)

| Bits | Description | Execution Time |
|--------|-----------------------------|----------------|
| [15:8] | Not used | Not applicable |
| 7 | Software reset | 120 ms |
| 6 | Factory calibration restore | 75 ms |
| [5:4] | Not used | Not applicable |
| 3 | Flash memory update | 375 ms |
| 2 | Flash memory test | 50 ms |
| 1 | Self-test | 12 ms |
| 0 | Bias null | See Table 70 |

Software Reset

Turn to Page 3 (DIN = 0x8003) and then set GLOB_CMD[7] = 1 (DIN = 0x8280, DIN = 0x8300) to reset the operation, which removes all data, initializes all registers from their flash settings, and starts data collection. This function provides a firmware alternative to the RST line (see Table 5, Pin 8).

Automatic Self-Test

Turn to Page 3 (DIN = 0x8003) and then set GLOB_CMD[1] = 1 (DIN = 0x8202, then DIN = 0x8300) to run an automatic self-test routine, which executes the following steps:

1. Measure output on each sensor.
2. Activate self-test on each sensor.
3. Measure output on each sensor.
4. Deactivate the self-test on each sensor.
5. Calculate the difference with self-test on and off.
6. Compare the difference with internal pass/fail criteria.
7. Report the pass/fail results for each sensor in DIAG_STS.

After waiting 12 ms for this test to complete, turn to Page 0 (DIN = 0x8000) and read DIAG_STS using DIN = 0x0A00. Note that using an external clock can extend this time. When using an external clock of 100 Hz, this time extends to 35 ms. Note that 100 Hz is too slow for optimal sensor performance.

MEMORY MANAGEMENT

The data retention of the flash memory depends on temperature and the number of write cycles. Figure 25 characterizes the dependence on temperature, and the FLSHCNT_LOW and FLSHCNT_HIGH registers (see Table 115 and Table 116) provide a running count of flash write cycles. The flash updates every time GLOB_CMD[6], GLOB_CMD[3], or GLOB_CMD[0] is set to 1.

Table 115. FLSHCNT_LOW (Page 2, Base Address = 0x7C)

| Bits | Description |
|--------|---|
| [15:0] | Binary counter; number of flash updates, lower word |

Table 116. FLSHCNT_HIGH (Page 2, Base Address = 0x7E)

| Bits | Description |
|--------|---|
| [15:0] | Binary counter; number of flash updates, upper word |

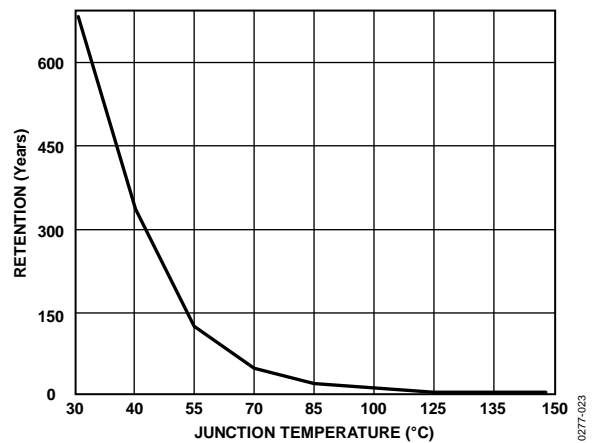


Figure 25. Flash Memory Retention

Flash Memory Test

Turn to Page 3 (DIN = 0x8003), and then set GLOB_CMD[2] = 1 (DIN = 0x8204, DIN = 0x8300) to run a checksum test of the internal flash memory, which compares a factory-programmed value with the current sum of the same memory locations. The result of this test loads into SYS_E_FLAG[6]. Turn to Page 0 (DIN = 0x8000) and use DIN = 0x0800 to read SYS_E_FLAG.

GENERAL-PURPOSE I/O

There are four general-purpose I/O lines: DIO1, DIO2, DIO3, and DIO4. The FNCTIO_CTRL register controls the basic function of each I/O line, which provides a number of useful functions. Each I/O line will only support one function at a time. In cases where a single line has two different assignments, the enable bit for the lower-priority function will automatically reset to zero and be disabled. The priority is (1) data-ready, (2) sync clock input, (3) alarm indicator, and (4) general-purpose, where 1 identifies the highest priority and 4 indicates the lowest priority.

Table 117. FNCTIO_CTRL (Page 3, Base Address = 0x06)

| Bits | Description (Default = 0x000D) |
|---------|--|
| [15:12] | Not used |
| 11 | Alarm indicator: 1 = enabled, 0 = disabled |
| 10 | Alarm indicator polarity: 1 = positive, 0 = negative |
| [9:8] | Alarm indicator line selection: 00 = DIO1, 01 = DIO2, 10 = DIO3, 11 = DIO4 |
| 7 | Sync clock input enable: 1 = enabled, 0 = disabled |
| 6 | Sync clock input polarity: 1 = rising edge, 0 = falling edge |
| [5:4] | Sync clock input line selection: 00 = DIO1, 01 = DIO2, 10 = DIO3, 11 = DIO4 |
| 3 | Data-ready enable: 1 = enabled, 0 = disabled |
| 2 | Data-ready polarity: 1 = positive, 0 = negative |
| [1:0] | Data-ready line selection: 00 = DIO1, 01 = DIO2, 10 = DIO3, 11 = DIO4 |

Data-Ready Indicator

FNCTIO_CTRL[3:0] provide some configuration options for using one of the DIOx lines as a data-ready indicator signal, which can drive a processor's interrupt control line. The factory default assigns DIO2 as a positive polarity, data-ready signal. Use the following sequence to change this assignment to DIO1 with a negative polarity: turn to Page 3 (DIN = 0x8003) and set FNCTIO_CTRL[3:0] = 1000 (DIN = 0x8608, then DIN = 0x8700). The timing jitter on the data-ready signal is $\pm 1.4 \mu\text{s}$.

Input Sync/Clock Control

FNCTIO_CTRL[7:4] provide some configuration options for using one of the DIOx lines as an input synchronization signal for sampling inertial sensor data. For example, use the following sequence to establish DIO4 as a positive polarity, input clock pin and keep the factory default setting for the data-ready function: turn to Page 3 (DIN = 0x8003) and set FNCTIO_CTRL[7:0] = 0xFD (DIN = 0x86FD, then DIN = 0x8700). Note that this command also disables the internal sampling clock, and no data sampling takes place without the input clock signal. When selecting a clock input frequency, consider the 330 Hz sensor bandwidth, because under sampling the sensors can degrade noise and stability performance.

General-Purpose I/O Control

When FNCTIO_CTRL does not configure a DIOx pin, GPIO_CTRL provides register controls for general-purpose use of the pin. GPIO_CTRL[3:0] provides input/output assignment controls for each line. When the DIOx lines are inputs, monitor their level by reading GPIO_CTRL[7:4]. When the DIOx lines are used as outputs, set their level by writing to GPIO_CTRL[7:4]. For example, use the following sequence to set DIO1 and DIO3 as high and low output lines, respectively, and set DIO2 and DIO4 as input lines. Turn to Page 3 (DIN = 0x8003) and set GPIO_CTRL[7:0] = 0x15 (DIN = 0x8815, then DIN = 0x8900).

Table 118. GPIO_CTRL (Page 3, Base Address = 0x08)

| Bits | Description (Default = 0x00X0) ¹ |
|--------|--|
| [15:8] | Don't care |
| 7 | General-Purpose I/O Line 4 (DIO4) data level |
| 6 | General-Purpose I/O Line 3 (DIO3) data level |
| 5 | General-Purpose I/O Line 2 (DIO2) data level |
| 4 | General-Purpose I/O Line 1 (DIO1) data level |
| 3 | General-Purpose I/O Line 4 (DIO4) direction control (1 = output, 0 = input) |
| 2 | General-Purpose I/O Line 3 (DIO3) direction control (1 = output, 0 = input) |
| 1 | General-Purpose I/O Line 2 (DIO2) direction control (1 = output, 0 = input) |
| 0 | General-Purpose I/O Line 1 (DIO1) direction control (1 = output, 0 = input) |

¹ GPIO_CTRL[7:4] reflects levels on DIOx lines.

POWER MANAGEMENT

The SLP_CNT register (see Table 119) provides controls for both power-down mode and sleep modes. The trade-off between power-down mode and sleep mode is between idle power and recovery time. Power-down mode offers the best idle power consumption but requires the most time to recover. Also, all volatile settings are lost during power-down but are preserved during sleep mode.

For timed sleep mode, turn to Page 3 (DIN = 0x8003), write the amount of sleep time to SLP_CNT[7:0] and then, set SLP_CNT[8] = 1 (DIN = 0x9101) to start the sleep period. For a timed power-down period, change the last command to set SLP_CNT[9] = 1 (DIN = 0x9102). To power down or sleep for an indefinite period, set SLP_CNT[7:0] = 0x00 first, then set either SLP_CNT[8] or SLP_CNT[9] to 1. Note that the command takes effect when the $\overline{\text{CS}}$ line goes high. To awaken the device from sleep or power-down mode, use one of the following options to restore normal operation:

- Assert $\overline{\text{CS}}$ from high to low.
- Pulse RST low, then high again.
- Cycle the power.

For example, set SLP_CNT[7:0] = 0x64 (DIN = 0x9064), then set SLP_CNT[8] = 1 (DIN = 0x9101) to start a sleep period of 100 seconds.

Table 119. SLP_CNT (Page 3, Base Address = 0x10)

| Bits | Description |
|---------|---|
| [15:10] | Not used |
| 9 | Power-down mode |
| 8 | Normal sleep mode |
| [7:0] | Programmable time bits; 1 sec/LSB; 0x00 = indefinite |

If the sleep mode and power-down mode bits are both set high, the normal sleep mode (SLP_CNT[8]) bit takes precedence.

General-Purpose Registers

The USER_SCR_x registers (see Table 120, Table 121, Table 122, and Table 123) provide four 16-bit registers for storing data.

Table 120. USER_SCR_1 (Page 2, Base Address = 0x74)

| Bits | Description |
|--------|--------------|
| [15:0] | User-defined |

Table 121. USER_SCR_2 (Page 2, Base Address = 0x76)

| Bits | Description |
|--------|--------------|
| [15:0] | User-defined |

Table 122. USER_SCR_3 (Page 2, Base Address = 0x78)

| Bits | Description |
|--------|--------------|
| [15:0] | User-defined |

Table 123. USER_SCR_4 (Page 2, Base Address = 0x7A)

| Bits | Description |
|--------|--------------|
| [15:0] | User-defined |

Real-Time Clock Configuration/Data

The VDDRTC power supply pin (see Table 5, Pin 23) provides a separate supply for the real-time clock (RTC) function. This enables the RTC to keep track of time, even when the main supply (VDD) is off. Configure the RTC function by selecting one of two modes in CONFIG[0] (see Table 74). The real-time clock data is available in the TIME_MS_OUT register (see Table 124), TIME_DH_OUT register (see Table 125), and TIME_YM_OUT register (see Table 126). When using the elapsed timer mode, the time data registers start at 0x0000 when the device starts up (or resets) and begin keeping time in a manner that is similar to a stopwatch. When using the clock/calendar mode, write the current time to the real-time registers in the following

sequence: seconds (TIME_MS_OUT[5:0]), minutes (TIME_MS_OUT[13:8]), hours (TIME_DH_OUT[5:0]), day (TIME_DH_OUT[12:8]), month (TIME_YM_OUT[3:0]), and year (TIME_YM_OUT[14:8]). The updates to the timer do not become active until a successful write to the TIME_YM_OUT[14:8] byte. The real-time clock registers reflect the newly updated values only after the next seconds tick of the clock that follows the write to TIME_YM_OUT[14:8] (year). Writing to TIME_YM_OUT[14:8] activates all timing values; therefore, always write to this location last when updating the timer, even if the year information does not require updating.

Write the current time to each time data register after setting CONFIG[0] = 1 (DIN = 0x8003, DIN = 0x8A01). Note that CONFIG[1] provides a bit for managing daylight savings time. After the CONFIG and TIME_xx_OUT registers are configured, set GLOB_CMD[3] = 1 (DIN = 0x8003, DIN = 0x8204, DIN = 0x8300) to back these settings up in flash, and use a separate 3.3 V source to supply power to the VDDRTC function. Note that access to time data in the TIME_xx_OUT registers requires normal operation (VDD = 3.3 V and full startup), but the timer function only requires that VDDRTC = 3.3 V when the rest of the ADIS16488 is turned off.

Table 124. TIME_MS_OUT (Page 0, Base Address = 0x78)

| Bits | Description |
|---------|---------------------------------------|
| [15:14] | Not used |
| [13:8] | Minutes, binary data, range = 0 to 59 |
| [7:6] | Not used |
| [5:0] | Seconds, binary data, range = 0 to 59 |

Table 125. TIME_DH_OUT (Page 0, Base Address = 0x7A)

| Bits | Description |
|---------|-------------------------------------|
| [15:13] | Not used |
| [12:8] | Day, binary data, range = 1 to 31 |
| [7:6] | Not used |
| [5:0] | Hours, binary data, range = 0 to 23 |

Table 126. TIME_YM_OUT (Page 0, Base Address = 0x7C)

| Bits | Description |
|--------|---|
| [15] | Not used |
| [14:8] | Year, binary data, range = 0 to 99, relative to 2000 A.D. |
| [7:4] | Not used |
| [3:0] | Month, binary data, range = 1 to 12 |

APPLICATIONS INFORMATION

PROTOTYPE INTERFACE BOARD

The ADIS16488/PCBZ includes one ADIS16488AMLZ, one interface printed circuit board (PCB), and four M2 × 0.4 × 18 mm machine screws. The interface PCB provides four holes for ADIS16488AMLZ attachment and four larger holes for attaching the interface PCB to another surface. The ADIS16488AMLZ attachment holes are pre-tapped for M2 × 0.4 mm machine screws and the four larger holes, located in each corner, support attachment with M2.5 or #4 machine screws. J1 is a dual-row, 2 mm (pitch) connector that works with a number of ribbon cable systems, including 3M Part Number 152212-0100-GB (ribbon crimp connector) and 3M Part Number 3625/12 (ribbon cable). Note that J1 has 16 pads but currently uses a 12-pin connector. The extra pins accommodate future evaluation system plans.

Figure 27 provides the pin assignments for J1. The pin descriptions match those listed in Table 5. The C1 and C2 locations provide solder pads for extra capacitors, which can provide additional filtering for start-up transients and supply noise.

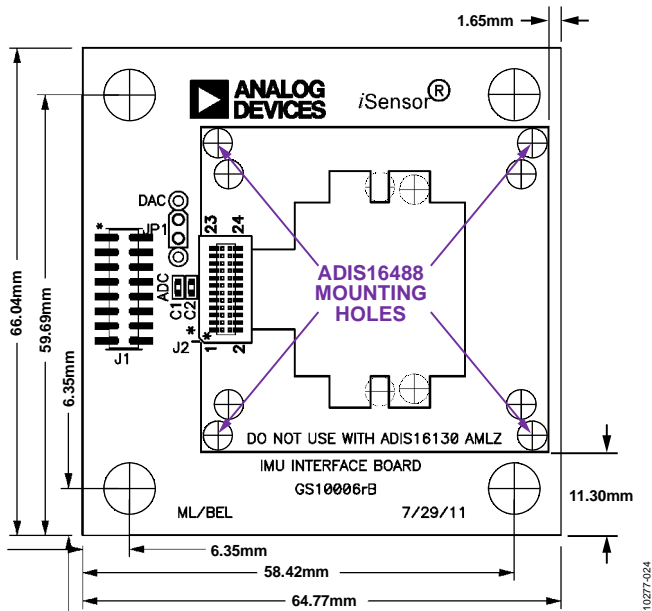


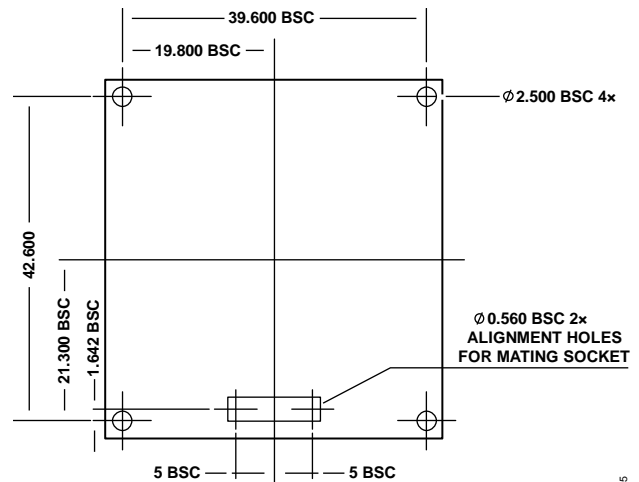
Figure 26. Physical Diagram for the ADIS16488/PCBZ

| J1 | | | |
|------|----|----|------|
| RST | 1 | 2 | SCLK |
| CS | 3 | 4 | DOUT |
| DNC | 5 | 6 | DIN |
| GND | 7 | 8 | GND |
| GND | 9 | 10 | VDD |
| VDD | 11 | 12 | VDD |
| DIO1 | 13 | 14 | DIO2 |
| DIO3 | 15 | 16 | DIO4 |

Figure 27. ADIS16488/PCBZ J1 Pin Assignments

INSTALLATION TIPS

Figure 28 and Figure 29 provide the mechanical design information used for the ADIS16488/PCBZ. Use these figures when implementing a connector-down approach, where the mating connector and the ADIS16488AMLZ are on the same surface. When designing a connector-up system, use the mounting holes shown in Figure 28 as a guide in designing the bulkhead mounting system and use Figure 29 as a guide in developing the mating connector interface on a flexible circuit or other connector system. The suggested torque setting for the attachment hardware is 40 inch-ounces, or 0.2825 N-m.



NOTES
1. ALL DIMENSIONS IN mm UNITS.

Figure 28. Suggested Mounting Hole Locations, Connector Down

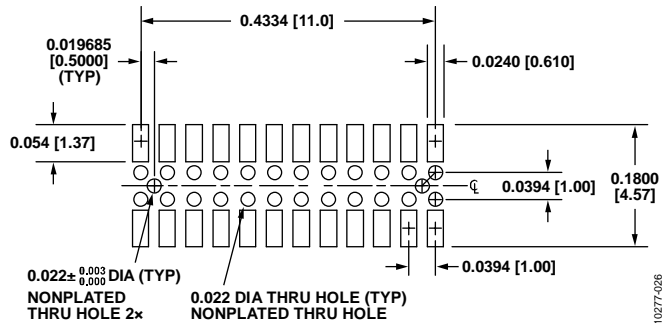


Figure 29. Suggested Layout and Mechanical Design for the Mating Connector

OUTLINE DIMENSIONS

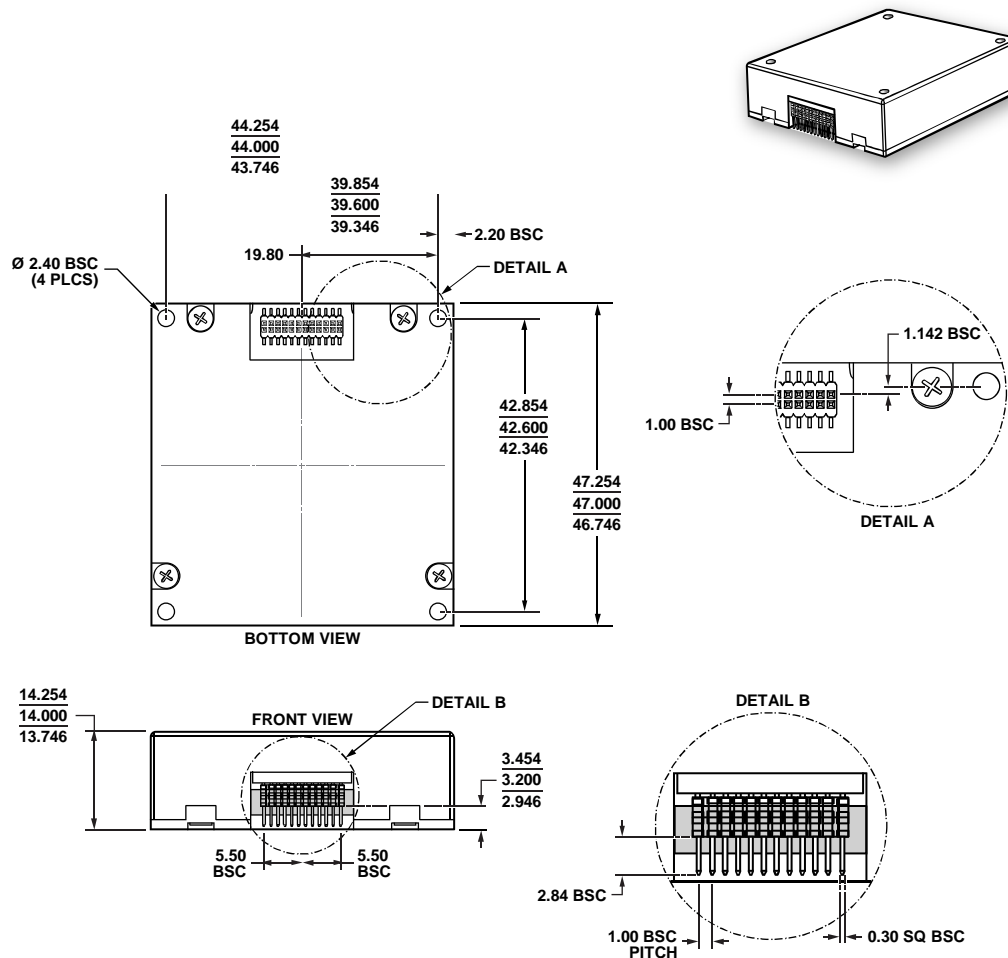


Figure 30. 24-Lead Module with Connector Interface [MODULE]
(ML-24-6)
Dimensions shown in millimeters

10-20-2010-B

ORDERING GUIDE

| Model ^{1, 2} | Temperature Range | Package Description | Package Option |
|-----------------------|-------------------|--|----------------|
| ADIS16488AMLZ | -40°C to +85°C | 24-Lead Module with Connector Interface [MODULE] | ML-24-6 |
| ADIS16488/PCBZ | | Interface PCB | |

¹ Z = RoHS Compliant Part.

² The ADIS16488/PCBZ includes one ADIS16488AMLZ and one interface board PCB. See Figure 26 for more information on the interface PCB.

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