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FIS1100

6D Inertial Measurement Unit with Motion Co-Processor and Sensor Fusion Library

Features

- World's First Complete Consumer Inertial Measurement Unit (IMU) with Sensor Fusion Library to Specify Orientation Accuracy: $\pm 3^\circ$ Pitch and Roll, $\pm 5^\circ$ Yaw/Heading
- 3-Axis Gyroscope and 3-Axis Accelerometer in a Small 3.3 x 3.3 x 1 mm LGA Package
- Integrated AttitudeEngine™ Motion Co-processor with Vector DSP Performs Sensor Fusion at 1 kHz Sampling Rate, while Outputting Data to Host Processor at a Lower Rate – Improving Accuracy while Reducing Processor MIPS, Power, and Interrupt Requirements
- High-Performance XKF3 6/9-Axis Sensor Fusion with in-Run Calibration for Correction of Gyro Bias Drift Over Temperature and Lifetime
- Low Latency, Wide Bandwidth, Low Noise OIS Mode for Camera and Drone Gimbal Stabilization
- Low Noise 50 $\mu\text{g}/\sqrt{\text{Hz}}$ Accelerometer and 10 mdps/ $\sqrt{\text{Hz}}$ Gyroscope
- New Motion on Demand Technology for Polling Based Synchronization
- Large 1536 Byte FIFO can be used to Buffer 9DOF Sensor Data to Lower System Power Dissipation
- Large Dynamic Range from $\pm 32^\circ/\text{s}$ to $\pm 2,560^\circ/\text{s}$ and $\pm 2 \text{ g}$ to $\pm 8 \text{ g}$
- Low Power and Warm-Start Modes for Effective Power Management
- Digitally Programmable Sampling Rate and Filters
- Host Serial Interface Supporting I²C or SPI
- I²C Master for Interfacing External Magnetometer
- Embedded Temperature Sensor
- Wide Extended Operating Temperature Range (-40°C to 85°C)

Description

FIS1100 is the world's first complete consumer 6D MEMS Inertial Measurement Unit (IMU) with sensor fusion to specify system level orientation accuracy. When using the FIS1100 in combination with the supplied XKF3 9D sensor fusion, the system features an accurate $\pm 3^\circ$ pitch and roll orientation, and a $\pm 5^\circ$ yaw/heading typical specification.

The FIS1100 incorporates a 3-axis Gyroscope and a 3-axis Accelerometer and can connect an external 3-axis magnetometer through an I²C master thus forming a complete 9DOF system.

The FIS1100 also incorporates an advanced vector Digital Signal Processor (DSP) motion co-processor called the AttitudeEngine™. The AttitudeEngine efficiently encodes high frequency motion at high internal sampling rates, preserving full accuracy across any output data rate.

This enables the application to utilize low Output Data Rates (ODR) or on-demand (host polling) and still acquire accurate 3D motion data. The AttitudeEngine allows reducing the data processing and interrupt load on a host processor with no compromises in 3D motion tracking accuracy. The result is very low total system power in combination with high accuracy, which are essential to many portable and battery powered applications.

Applications

- Drone Flight Control and Gimbal Stabilization
- Optical Image Stabilization (OIS) and Electrical Image Stabilization (EIS)
- Virtual Reality and Augmented Reality
- Robotic Orientation and Position Tracking
- Sport & Fitness Wearables
- Pedestrian Navigation and GNSS Augmentation

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1 General Information

1.1 Ordering Information

Table 1. Ordering Information

| Part Number | Package | Packing Method |
|-------------|---------|----------------|
| FIS1100 | LGA16 | Tape & Reel |

1.2 Marking Information

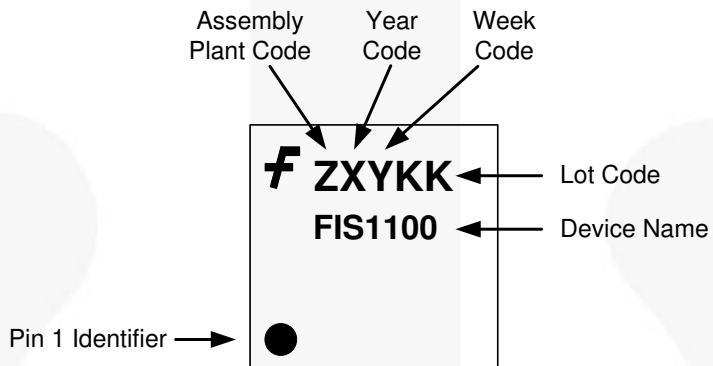


Figure 1. Top Mark

1.3 Internal Block Diagram

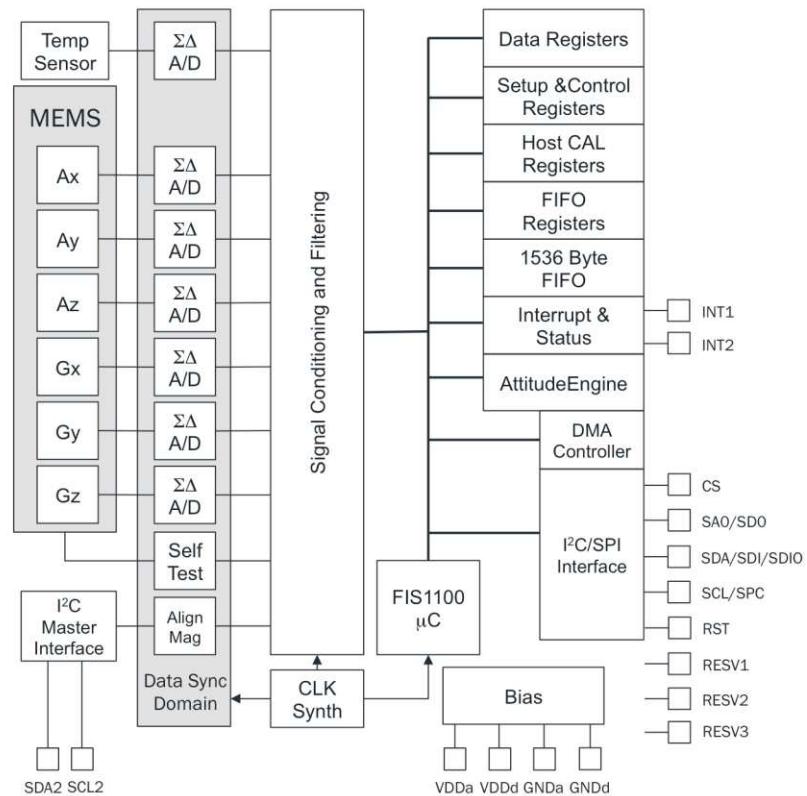


Figure 2. Internal Block Diagram

1.4 Application Diagram

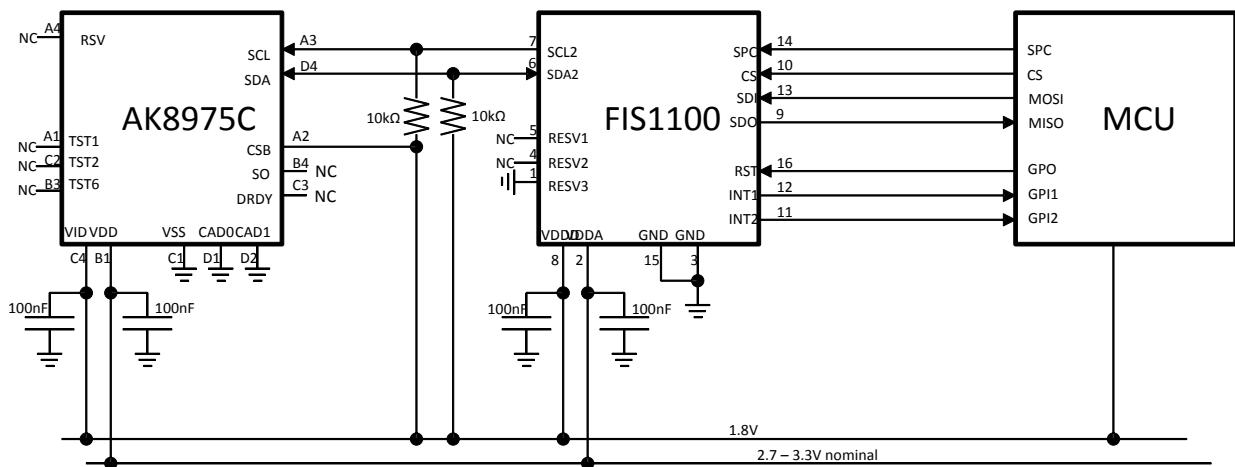


Figure 3. Typical Application Diagram (Showing Magnetometer Connected through FIS1100 Master I²C and a SPI 4 Wire Interface Connected to the Host Processor)

1.5 Package & Pin Information

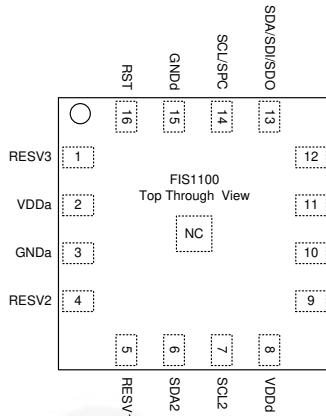


Figure 4. Pins Face Down (Top View)
Do Not Solder Center Pin (NC)

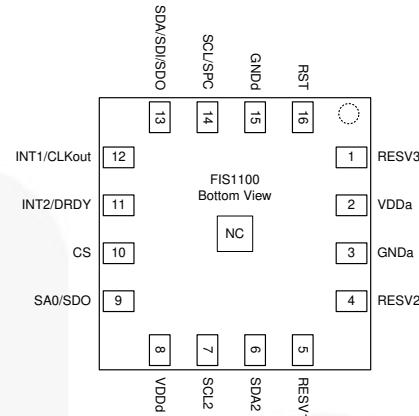


Figure 5. Pins Face Up (Bottom View)
Do Not Solder Center Pin (NC)

Table 2. Pin Definitions

| Pin # | Name | Alternate Name | Alternate Name | Description |
|-------------------|-----------------------|-----------------------|------------------------|--|
| 1 | RESV3 | | | Reserved. Connect to Board Ground (GND) |
| 2 | VDDa | | | Power Supply for Analog |
| 3 | GNDa | | | Ground for Analog |
| 4 | RESV2 | | | Reserved. No Connection (NC) |
| 5 | RESV1 | | | Reserved. No Connection (NC) |
| 6 | SDA2 | | | Master I ² C Serial Data |
| 7 | SCL2 | | | Master I ² C Serial Clock |
| 8 | VDDd | | | Power Supply for Digital and IO Pins |
| 9 | SA0 ⁽¹⁾⁽³⁾ | SDO | | Host I ² C Slave Address LSB (SA0); Host 4-Wire SPI Serial Data Output (SDO) |
| 10 ⁽¹⁾ | CS | | | Host SPI Chip Select (1 = I ² C Mode). See <i>SPI Mode Configuration section</i> |
| 11 | INT2 | DRDY | | Interrupt2. Data Ready/FIFO Interrupt |
| 12 | INT1 | CLKout | | Interrupt1. General Purpose Interrupt. Clock out in OIS Mode |
| 13 | SDA | SDI ⁽²⁾⁽³⁾ | SDIO ⁽²⁾⁽³⁾ | Host I ² C Serial Data (SDA); Host 4-Wire SPI Serial Data Input (SDI); Host 3-Wire SPI Serial Data Output (SDIO) |
| 14 | SCL | SPC ⁽²⁾⁽³⁾ | | Host I ² C Serial Clock (SCL); Host SPI Serial Clock (SPC) |
| 15 | GNDd | | | Ground |
| 16 | RST *** | | | Reset Input. Assert for at least 5 µs. Part ready for communication 50 µs after assertion. After RST, the device will go through its boot process, please refer to Table 7 and Table 8 for wakeup times. |

Notes:

1. This pin has an internal 200 KΩ pull up resistor.
2. In SPI mode (not in I²C Mode), there is an internal pull down 200 KΩ resistor.
3. Refer to Section 1 for detailed configuration information.

1.6 Recommended External Components

Table 3. Recommended External Components

| Component | Description | Parameter | Typical |
|----------------|-------------|-------------|---------|
| C_{p1} | Capacitor | Capacitance | 100 nF |
| C_{p2} | Capacitor | Capacitance | 100 nF |
| $R_{pu}^{(4)}$ | Resistor | Resistance | 10 KΩ |

Note:

4. R_{pu} is only needed when the Host Serial Interface is configured for I²C. They are not needed when the Host Serial Interface is configured for SPI. See I²C Interface section. If Pull-up resistors are used on SCL and SDA, then both SPI and I²C Modes are possible. If a Pull-up is used on SA0, an alternate slave address is used for I²C. SPI Mode will be unaltered with the use of Pull-ups for I²C.

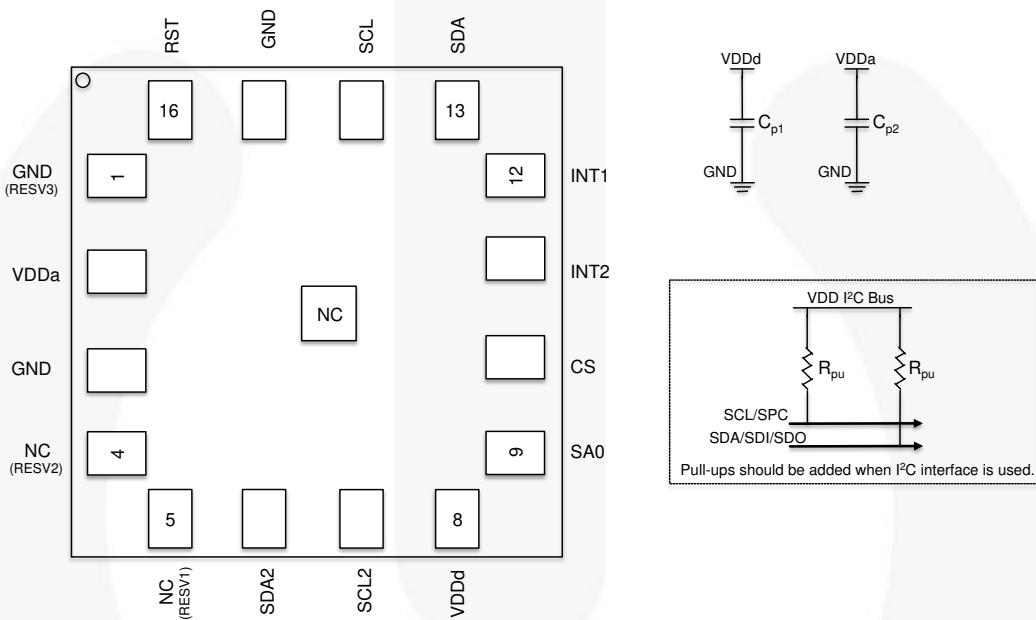


Figure 6. Typical Electrical Connections

2 FIS1100 Architecture

FIS1100 is a smart sensor that combines a high-performance IMU with a powerful Single Instruction Multiple Data (SIMD) based Vector DSP motion co-processor referred to as the AttitudeEngine™ (AE).

Included sensor fusion software (XKF3) allows the device to achieve orientation accuracies of $\pm 3^\circ$ for pitch and roll and $\pm 5^\circ$ for yaw/heading.

The FIS1100 includes a microcontroller for data scheduling, combined with Direct Memory Access (DMA) in order to allow efficient data shuttling on the chip. Multi-channel data is easily processed at rates up to 1 kHz with minimal latency in normal operation (non-OIS modes) and at 8 kHz in OIS modes.

An internal block diagram is shown in Figure 2. The MEMS elements are amplified and converted by $\Sigma\Delta$ A/D converters which are synchronized to a common clock so that all the motion measurements of acceleration, angular rate and magnetic heading are sampled at the same time minimizing any skew between channels. The data is then sent to a signal processing chain that accomplishes decimation, filtering and calibration.

Once the data has been processed, it can be sent to the host processor depending on additional configuration settings, such as, enabling the FIFO or using the AttitudeEngine.

2.1 AttitudeEngine Mode Overview

Brief descriptions of the major functions of the AttitudeEngine are discussed below, for more detail see Application note AN-5083. Note that the AttitudeEngine may be enabled or disabled and configured using the CTRL6 register.

- **Calibration:** FIS1100 applies continuous on-chip calibration of all the sensors (accelerometer, gyroscope, and magnetometer) including scale, offset, and temperature calibration. When used in conjunction with a sensor fusion filter (such as the Fairchild XKF3) running on the host processor, estimated sensor errors can be updated in-use, allowing sensor calibration to be performed in the background without any host intervention. This offloads computationally expensive per-sample re-calibration from the host processor to the FIS1100.
- **Sample Synchronization:** FIS1100 automatically provides highly synchronous output between the various IMU accelerometer and gyroscope channels through the use of fully parallel $\Sigma\Delta$ -converters. The FIS1100 also provides time synchronization of data between the IMU and the external magnetometer.

- **Motion Encoder:** Performs 32-bit high-speed dead reckoning calculations at 1 kHz data rates allowing accurate capture of high frequency and coning effects. Orientation and velocity increments are calculated with full coning and sculling compensation and the magnetic field vector from the external magnetometer is rotated to the sensor frame of reference. This allows the lossless encoding (compression) of 6D motion to a low output data rate, while maintaining the accuracy provided by the 1 kHz input and data processing rate. Motion data encoded by the AttitudeEngine is available at a user programmable data rate (1 Hz to 64 Hz). The orientation and velocity increments from the AttitudeEngine are suitable for any 3D motion tracking application (orientation, velocity and position) and may be further fused by the user with information from other sources such as a GNSS receiver or barometer in an optimal estimator.
- **Motion on Demand (MoD):** FIS1100 allows the host to access encoded motion data asynchronously (polling) and on demand. The motion data in the AttitudeEngine (AE) mode remains accurate even at very low output data rates. This allows easy integration and synchronization with other sensors for state-of-the-art applications such as rolling shutter camera stabilization, optical sensors software de-blurring, GNSS integration and augmented or virtual reality.

2.2 Advantages of the Attitude Engine Approach

The advantages of the AttitudeEngine (AE) approach over the traditional sensor approach are many and are briefly discussed below, for more detail see Application note [AN-5083](#).

- **Low-Power Architecture:** Dead reckoning calculations are performed with the AE vector DSP which is designed to perform essential calculations while achieving high-accuracy and low power simultaneously. The AE approach enables a typical interrupt rate reduction to the host processor of 10x and can be up to 100x for some applications. This significantly enhances the operational life of battery powered devices without any compromises in 3D motion tracking accuracy.
- **High Performance:** The motion encoder and sample synchronizer enable highly accurate strap down integration that can be fully compensated for coning and sculling artifacts.

2.3 9D Sensor Fusion and Auto-Calibration using XKF3

XKF3 is a sensor fusion algorithm, based on Extended Kalman Filter theory that fuses 3D inertial sensor data (orientation and velocity increments) and 3D magnetometer, also known as '9D', data to optimally estimate 3D orientation with respect to an Earth fixed frame.

A license to use XKF3 in a CMSIS compliant library form for Cortex M0+, M3, M4, M4F, for commercial purposes is provided with the FIS1100 Evaluation Kit ([FEBFIS1100MEMS IMU6D3X](#)).

A restricted-use license for use of XKF3 for commercial purposes is also granted for certain applications when XKF3 is used with the FIS1100.

XKF3 is developed by Xsens™, a pioneering company in inertial based 3D motion tracking. The first generation 9D sensor fusion algorithms were developed by Xsens more than 15 years ago and have been proven in demanding 24/7 continuous use for a broad range of applications; from unmanned underwater robotics to accurate joint angle measurements for rehabilitation and sports. The XKF3 algorithm is wholly owned by Fairchild.

XKF3 only works with the FIS1100 and supported magnetometers. Refer to the FEBFIS1100 Evaluation Board document for further details.

For additional information, refer to [AN-5084](#) application note for more details on XKF3 and its benefits

XKF3 Features:

- Continuous Sensor Auto Calibration, No User Interaction Required
- High Accuracy, Real-Time, Low-Latency Optimal estimate of 3D Orientation, up to 1 kHz output data rate
- Ultra low system power for 3D Orientation enabled by AttitudeEngine, between 8 to 64 Hz output data rate without any degradation in accuracy
- Best-in-Class Immunity to Magnetic Distortions
- Best-in-Class Immunity to Transient Accelerations
- Flexible use Scenarios, North Referenced, Unreferenced
- Extensive Status Reporting for Smooth Integration in Applications
- Optimized Library for Popular Microcontrollers



Figure 7. Chip Orientation Coordinate System

2.4 Frames of Reference and Conventions for Using FIS1100

FIS1100 uses a right-handed coordinate system as the basis for the sensor frame of reference. Acceleration (a_x, a_y, a_z) are given with respect to the X-Y-Z coordinate system shown above. Increasing accelerations along the positive X-Y-Z axis are considered positive. Angular Rate ($\omega_x, \omega_y, \omega_z$) around the counter clockwise direction are considered positive. Magnetic fields (m_x, m_y, m_z) can be configured to be expressed in the sensor X-Y-Z coordinates as well. Care must be taken to make sure that FIS1100 and the magnetic sensor of choice are mounted on the board so that the coordinate systems of the two sensors are substantially orthogonal.

Figure 7 shows the various frames of reference and conventions for using FIS1100.

The accelerometer, gyroscope, and the optional external magnetometer are enabled or disabled using the aEN, gEN and mEN bits in the CTRL7 register respectively. AE Mode may be enabled or disabled using the sEN bit in CTRL7 register. The outputs available in Typical Sensor Mode and AttitudeEngine™ Modes are outlined below in Table 22 and Table 23. A list and description of FIS1100 Operational Modes is provided in Table 32. A FIFO buffer is also available to store sample history. The FIFO may be configured separately using FIFO_CTRL, FIFO_STATUS and FIFO_DATA. The FIFO control is described in detail in the FIFO Description section.

3 System, Electrical and Electro-Mechanical Characteristics

3.1 Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions. Stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only.

Table 4. Absolute Maximum Ratings

| Symbol | Parameter | | Min. | Max. | Unit |
|-------------------------------|--|--------------------------------------|-------|--------|------|
| T _{STG} | Storage Temperature | | -40 | +125 | °C |
| T _{Pmax} | Lead Soldering Temperature, 10 Seconds | | | +260 | °C |
| V _{DDa} | Supply Voltage | | -0.3 | 3.6 | V |
| V _{DDd} | I/O Pins Supply Voltage | | -0.3 | 2.05 | V |
| S _g ⁽⁵⁾ | Acceleration g for 0.2 ms (Un-powered) | | | 10,000 | g |
| ESD ⁽⁶⁾ | Electrostatic Discharge Protection Level | Human Body Model per JES001-2014 | ±2000 | | V |
| | | Charged Device Model per JESD22-C101 | ±500 | | |

Notes:

- 5. △ This is a mechanical shock (g) sensitive device. Proper handling is required to prevent damage to the part.
- 6. ✕ This is an ESD-sensitive device. Proper handling is required to prevent damage to the part.

3.2 Recommended Operating Conditions

The Recommended Operating Conditions table defines the conditions for actual device operation. Recommended operating conditions are specified to ensure optimal performance. Fairchild does not recommend exceeding them or designing to Absolute Maximum Ratings.

Table 5. Recommended Operating Conditions

| Symbol | Parameter | Min. | Typ. | Max. | Unit |
|------------------|-----------------------------------|-----------------------|------|-----------------------|------|
| V _{DDa} | Supply Voltage | 2.4 | 2.7 | 3.47 | V |
| V _{DDd} | I/O Pins Supply Voltage | 1.62 | 1.80 | 1.98 | V |
| V _{IL} | Digital Low Level Input Voltage | | | 0.3 *V _{DDd} | V |
| V _{IH} | Digital High Level Input Voltage | 0.7 *V _{DDd} | | | V |
| V _{OL} | Digital Low Level Output Voltage | | | 0.1 *V _{DDd} | V |
| V _{OH} | Digital High Level Output Voltage | 0.9 *V _{DDd} | | | V |

3.3 System Level Specifications

System level specifications are provided to give guidance on the system performance in a recommended and typical configuration. The recommended system configuration is the FIS1100 and optionally a supported 3D magnetometer used with a supported host processor, running the Fairchild XKF3 9D sensor fusion and having executed and stored the result of the “Board Level Calibration” routine (see [AN-5085](#) application note). The system performance specifications assume that good engineering practices

for the placement conditions of the FIS1100 and 3D magnetometer are taken into account. For example, take care not to place the FIS1100 where strong vibrations may occur or even be amplified; take care not to place the 3D magnetometer where magnetic fields other than the Earth magnetic field may be measured. Typical numbers are provided below unless otherwise noted.

Table 6. System Level 3D Orientation Accuracy Specifications

| Subsystem | Parameter | Typical | Unit | Comments |
|-------------------------|--------------------------------------|----------|-------|--|
| FIS1100+XKF3 quaternion | Roll | ± 3 | deg | Requires use of XKF3 software library on host processor. |
| | Pitch | ± 3 | deg | Requires use of XKF3 software library on host processor. |
| | Yaw (Heading) Referenced to North | ± 5 | deg | Requires use of XKF3 software library on host processor, using magnetometer, in a homogenous Earth magnetic field. |
| | Yaw (Heading) Unreferenced | 5-25 | deg/h | From Allan Variance bias instability. Does not require a magnetometer. (See specification above for use with magnetometer.) Fully immune to magnetic distortions. |
| FIS1100+XKF3 quaternion | Output Data Rate | 8 - 1000 | Hz | To benefit from the power saving using the AttitudeEngine, use a max ODR of 64 Hz. |

3.4 Electro-Mechanical Specifications

$V_{DDd} = 1.8$ V, $V_{DDa} = 2.7$ V, $T = 25^\circ\text{C}$ unless otherwise noted.

Table 7. Accelerometer Electro-Mechanical Specifications

| Subsystem | Parameter | Typical | | Unit | Comments |
|---------------|--|---------------------------|-------------|--------------------------------|--|
| Accelerometer | Noise Density | 50 | | $\mu\text{g}/\sqrt{\text{Hz}}$ | High-Resolution Mode |
| | Sensitivity Scale Factor | Scale Setting | Sensitivity | LSB/g | 16-Bit Output |
| | | ± 2 g | 16,384 | | |
| | | ± 4 g | 8,192 | | |
| | | ± 8 g | 4,096 | | |
| | Cross-Axis Sensitivity | ± 2 | | % | |
| | Temperature Coefficient of Offset (TCO) | ± 1 (X and Y Axis) | | $\text{mg}/^\circ\text{C}$ | Over-Temperature Range of -40°C to 85°C at Board Level |
| | | ± 2.5 (Z-Axis) | | | |
| | Temperature Coefficient of Sensitivity (TCS) | ± 0.01 (X and Y Axis) | | $\%/\text{ }^\circ\text{C}$ | |
| | | ± 0.02 (Z Axis) | | | |
| | Initial Offset Tolerance | ± 50 | | mg | Component Level |
| | Initial Sensitivity Tolerance | ± 1 (X and Y Axis) | | % | Board Level |
| | | ± 3 (Z Axis) | | | |
| | Non-Linearity | ± 1 | | % | Best Fit Line |
| | System Turn On Time (VDDd and VDDa within 1% of Final Value) | 1.75 | | s | From Hardware Reset, No Power, or Power Down to Power-on Default state. = t0 in Figure 8 |

Table 7. Accelerometer Electro-Mechanical Specifications (Continued)

| Subsystem | Parameter | Typical | Unit | Comments |
|------------------|--------------------|----------------|-------------|---|
| | Accel Turn On Time | 3ms + 3/ODR | ms | Accel Turn on from Power-On Default state or from Low Power state. = t2 + t5 in Figure 8. |

Table 8. Gyroscope Electro-Mechanical Specifications

| Subsystem | Parameter | Typical | | Unit | Comments | |
|------------------|--|----------------|-------------|-------------|--|--|
| Gyroscope | Sensitivity | Scale Setting | Sensitivity | LSB/dps | 16-Bit Output | |
| | | ±32 dps | 1024 | | | |
| | | ±64 dps | 512 | | | |
| | | ±128 dps | 256 | | | |
| | | ±256 dps | 128 | | | |
| | | ±512 dps | 64 | | | |
| | | ±1024 dps | 32 | | | |
| | | ±2048 dps | 16 | | | |
| | | ±2560 dps | 8 | | | |
| | Minimum Natural Frequency | > 19.3 | | kHz | | |
| | Noise Density | 10 | | mdps/√Hz | High-Resolution Mode | |
| | | 10 | | | OIS Mode with gLPF=1 | |
| | | 13.5 | | | OIS LL Mode, 2 kHz BW | |
| | Non-Linearity | < 0.2 | | % | FSO=2560 dps | |
| | Cross-Axis Sensitivity | ±2 | | % | | |
| | System Turn On Time (VDDd and VDDa within 1% of Final Value) | 1.75 | | s | From Hardware Reset, No Power, or Power Down to Power-on Default state. = t0 in Figure 8 | |
| | Gyro Turn On Time | 60ms + 3/ODR | | ms | Gyro Turn on from Power-On Default = t1 + t5 in Figure 8. | |
| | Gyro Warm Start Turn On Time | 5ms + 3/ODR | | ms | From Gyro Warm-Start to Gyro Only or Accel + Gyro modes. = t4 + t5 in Figure 8. | |
| | Temperature Coefficient of Offset (TCO) | X & Y Axis | ±0.1 | dps/°C | Over-Temperature Range of -40°C to 85°C | |
| | | Z Axis | ±0.02 | | | |
| | Temperature Coefficient of Sensitivity (TCS) | X & Y Axis | ±0.07 | %/°C | Over-Temperature Range of -40°C to 85°C | |
| | | Z Axis | ±0.02 | | | |
| | Initial Offset Tolerance | X & Y Axis | ±10 | dps | Board Level | |
| | | Z Axis | ±1 | | | |
| | Initial Sensitivity Tolerance | X & Y Axis | ±3 | % | Board Level | |
| | | Z Axis | ±1 | | | |

Table 9. Magnetometer and Attitude Engine Range and Scale

| Subsystem | Parameter | Typical | | Unit | Comments |
|---------------------|---|---------------|-------------|-----------|---------------|
| | | Scale Setting | Sensitivity | | |
| Typical Sensor Mode | Magnetometer Sensitivity Scale Factor | ±16 gauss | 2,048 | LSB/gauss | 16 Bit Output |
| AE Mode | Magnetometer Sensitivity Scale Factor | ±16 gauss | 2,048 | LSB/gauss | |
| | Orientation Increment (quaternion) Sensitivity Scale Factor | ±1 | 16,384 | LSB/unit | |
| | Velocity Increment Sensitivity Scale Factor | ±32 | 1,024 | LSB/ms | |

3.5 Accelerometer Programmable Characteristics

$V_{DDd} = 1.8$ V, $V_{DDa} = 2.7$ V, $T = 25^\circ\text{C}$ unless otherwise noted. Typical numbers are provided below unless otherwise noted. All frequencies are ±5% and are synchronized to the gyro oscillator (“drive”) frequency.

Table 10. Accelerometer Noise Density

| Mode | High-Resolution | | | | Low-Power | | | | Unit | |
|-----------------------|-----------------|------|-----|-----|-----------|-----|------|-----|------|--------------------------------|
| | ODR | 1000 | 250 | 125 | 31.25 | 125 | 62.5 | 25 | 3 | |
| Typical Noise Density | | 50 | 50 | 50 | 50 | 125 | 180 | 285 | 820 | $\mu\text{g}/\sqrt{\text{Hz}}$ |

Table 11. Accelerometer Filter Characteristics⁽⁷⁾

| Mode | High-Resolution | | | | Low-Power | | | | Unit |
|--|-----------------|------|------|--------|-----------|-------|------|-------|------|
| | ODR | 1000 | 250 | 125 | 31.25 | 125 | 62.5 | 25 | 3 |
| Bandwidth | 500 | 125 | 62.5 | 15.625 | 62.5 | 31.25 | 12.5 | 1.5 | |
| Bandwidth with Low-Pass Filter Enabled (aLPF=1) | 200 | 50 | 25 | 5 | 25 | 15 | 5 | 0.6 | |
| Corner Frequency(f_c) with High-Pass Filter Enabled (aHPF=1) | 2.50 | 0.60 | 0.30 | 0.08 | 0.30 | 0.15 | 0.10 | 0.013 | |

Note:

7. All frequencies are ±5% and are synchronized to the gyro oscillator (“drive”) frequency.

3.6 Gyroscope Programmable Characteristics

$V_{DDd} = 1.8$ V, $V_{DDa} = 2.7$ V, $T = 25^\circ\text{C}$, and represent typical numbers unless otherwise noted. All frequencies are $\pm 5\%$ and are synchronized to the gyro oscillator (“drive”) frequency.

Table 12. Gyroscope Filter Characteristics

| Mode | | High-Resolution | | | | Snooze Warm-Start | OIS | OIS LL | Unit |
|---|-----------------|-----------------|-------|--------|--------|----------------------|------|--------------------|------|
| ODR | gHPF=0 | 1000 | 250 | 125 | 31.25 | Snooze | 8100 | 8100 | Hz |
| Bandwidth | gLPF=0 | 500 | 125 | 62.5 | 15.625 | N/A | 4050 | 2000 | |
| | gLPF=1 | 200 | 50 | 25 | 6 | N/A | 345 | N/A ⁽⁸⁾ | |
| Corner Frequency (f_c) with High-Pass Filter Enabled (gHPF=1) | gHPF01=0 | 2.5 | 0.625 | 0.3125 | 0.08 | N/A | 0.1 | N/A ⁽⁸⁾ | |
| | gHPF01=1 | 0.1 | 0.025 | 0.0125 | 0.0032 | N/A | 0.1 | N/A ⁽⁸⁾ | |

Note:

8. For OIS LL mode, no filters can be enabled. gLPF=0 and gHPF=0 should be maintained.

Table 13. Optical Image Stabilization (OIS) Group Delay

| Group Delay | At Frequency (Hz) | | Filter Bandwidth (Hz) | Typical | Unit |
|-------------|-------------------|--|-----------------------|---------|------|
| | 10 | | 4050 | 0.11 | ms |
| | | | 2000 (OIS LL) | 0.5 | |
| | | | 345 | 1.1 | |

3.7 Electrical Characteristics

$V_{DDd} = 1.8 \text{ V}$; $V_{DDa} = 2.7 \text{ V}$; $T = 25^\circ\text{C}$ unless otherwise noted.

Table 14. Electrical Subsystem Characteristics

| Symbol | Parameter | | Min. | Typ. | Max. | Unit |
|------------|--|---------------|------|------|------|------|
| f_{SPC} | Host SPI Interface Speed | | | 10 | | MHz |
| f_{SCL} | Host I ² C Interface Speed | Standard Mode | | 100 | | kHz |
| | | Fast Mode | | 400 | | |
| f_{SCL2} | Master I ² C Interface Speed ⁽⁹⁾ | Standard Mode | | 25 | | kHz |
| | | Fast Mode | | 300 | | |

Note:

9. When only accelerometer is enabled, I²C master operates at 25 kHz. When gyroscope is enabled, I²C master operates at 300 kHz.

3.7.1 Current Consumption

$V_{DDd} = 1.8 \text{ V}$, $V_{DDa} = 2.7 \text{ V}$, $T = 25^\circ\text{C}$ unless otherwise noted. Typical numbers are provided below.

Table 15. Current Consumption for Accelerometer Only Typical Sensor Mode (Gyroscope Disabled)

| Mode | | High-Resolution | | | | Low-Power | | | | Unit |
|--|-----------------------------------|-----------------|-----|-----|-------|-----------|------|----|---|---------------|
| ODR | | 1000 | 250 | 125 | 31.25 | 125 | 62.5 | 25 | 3 | Hz |
| Typical Analog Current $I_{DDa}^{(10)}$ | | 220 | 220 | 220 | 220 | 35 | 35 | 20 | 7 | μA |
| Typical Digital Current $I_{DDd}^{(11)}$ | Filters Disabled (aLPF=0; aHPF=0) | 100 | 70 | 65 | 60 | 20 | 15 | 10 | 8 | |
| | Filters Enabled (aLPF=1; aHPF=1) | 108 | 71 | 66 | 61 | 21 | 16 | 10 | 8 | |

Table 16. Current Consumption for Gyroscope Only Typical Sensor Mode (Accelerometer Disabled)

| Mode | | High-Resolution | | | | Snooze Warm-Start | OIS, OIS LL ⁽⁸⁾ | Unit |
|--|---|-----------------|------|------|-------|-------------------|----------------------------|---------------|
| ODR | | 1000 | 250 | 125 | 31.25 | Snooze | 8100 | Hz |
| Typical Analog Current $I_{DDa}^{(10)}$ | | 2540 | 2540 | 2540 | 2540 | 1240 | 2540 | μA |
| Typical Digital Current $I_{DDd}^{(11)}$ | Filters Disabled (gLPF=0; gHPF=0; gHPF01=0) | 740 | 710 | 705 | 700 | 570 | 1100 | |
| | Filters Enabled (gLPF=1; gHPF=1; gHPF01=0) | 740 | 710 | 705 | 700 | 570 | 1100 | |

Notes:

10. I_{DDa} is the current drawn from the analog supply V_{DDa} .
 11. I_{DDd} is the current drawn from the digital supply V_{DDd} .

Table 17. Current Consumption for 6DOF Typical Sensor Mode (Accelerometer and Gyroscope Enabled)

| Mode | | High-Resolution | | | | Unit |
|-----------------------------------|---|---------------------|-----|-----|-----|---------------|
| ODR | | 1000 250 125 31.25 | | | | Hz |
| Typical Analog Current I_{DDa} | | 2750 2750 2750 2750 | | | | μA |
| Typical Digital Current I_{DDd} | Filters Disabled (aLPF=0; gLPF=0; aHPF=0; gHPF=0; gHPF01=0) | 815 | 780 | 780 | 780 | |
| | Filters Enabled (aLPF=1; gLPF=1; aHPF=1; gHPF=1; gHPF01=0) | 830 | 790 | 780 | 780 | |

Table 18. Current Consumption for 6DOF Attitude Engine Mode (without Magnetometer)

| Mode | | | | | | | | | Unit |
|-----------------------------------|--------------------------------------|------|------|------|------|------|------|------|---------|
| ODR Setting | | 1 | 2 | 4 | 8 | 16 | 32 | 64 | Hz |
| Typical Analog Current I_{DDa} | | 2750 | 2750 | 2750 | 2750 | 2750 | 2750 | 2750 | |
| Typical Digital Current I_{DDd} | Filters Disabled (aLPF=0; gLPF=0) | 930 | 930 | 930 | 930 | 930 | 930 | 930 | μ A |
| | Filters Enabled (aLPF=1; gLPF=1) | 940 | 940 | 940 | 940 | 940 | 940 | 940 | |

Table 19. Current Consumption for 9DOF Attitude Engine Mode (with Magnetometer)

| Mode | | | | | | | | | Unit |
|-----------------------------------|----------------------------|------|------|------|------|------|------|------|---------|
| ODR | | 1 | 2 | 4 | 8 | 16 | 32 | Hz | |
| Typical Analog Current I_{DDa} | | 2750 | 2750 | 2750 | 2750 | 2750 | 2750 | 2750 | |
| Typical Digital Current I_{DDd} | With Magnetometer at 32 Hz | 990 | 990 | 990 | 990 | 990 | 990 | 990 | μ A |

3.8 Temperature Sensor

The FIS1100 is equipped with an internal 12-bit embedded temperature sensor that is automatically turned on by default whenever the accelerometer or gyroscope is enabled. The temperature sensor is used internally to correct the temperature dependency of calibration parameters of the accelerometer and gyroscope. The temperature compensation is optimal in the range of -40°C to 85°C with a resolution of 0.0625°C (1/16) or inversely, 16 LSB/°C.

The FIS1100 outputs the internal chip temperature that the HOST can read. This external output is truncated to an 8-bit resolution so that the HOST sees 1°C per LSB resolution. This is not representative of the accuracy used internally to model and compensate for temperature effects on calibration parameters. To read the temperature, the HOST needs to access the TEMP register (see *Data Output Registers in Table 21*. The HOST should synchronize to the interrupt, INT2, signal to get valid temperature readings.

Table 20. Temperature Sensor Specifications

| Subsystem | Parameter | Typical | Unit |
|----------------------------|-----------------------|------------|--------|
| Digital Temperature Sensor | Range | -40 to +85 | °C |
| | Internal Resolution | 12 | Bits |
| | Internal Sensitivity | 16 | LSB/°C |
| | Output Register Width | 8 | Bits |
| | Output Sensitivity | 1 | LSB/°C |
| | Refresh Rate | 10 | Hz |

4 Register Map Overview

The FIS1100 has various registers that enable programming and control of the inertial measurement unit and associated on-chip signal processing. The register map may be classified into the following register categories:

- General Purpose Registers
- Setup and Control Registers: Controls various aspects of the IMU.
- Host Controlled Calibration Registers: Controls and Configures various aspects of the IMU via Host Command interface called CTRL9

- Count Register for time stamping the sensor samples
- FIFO Registers: To setup the FIFO and detect data availability and over-run.
- Data Output Registers: Contains all data for 9D sensors.

FIS1100 registers are divided into two banks of 64 registers with the second register bank reserved for future use. Both register banks may be accessed from I²C or SPI. A detailed description of each register including the register settings necessary to configure the FIS1100 operational modes is provided in Section 5.

Table 21. Register Overview

| Name | Type | Register Address | | | Default | Comment |
|---|------|------------------|-----|----------|----------|---|
| | | Dec | Hex | Binary | | |
| General Purpose Registers | | | | | | |
| WHO_AM_I | r | 0 | 00 | 00000000 | 11111100 | Device Identifier |
| Setup and Control Registers | | | | | | |
| CTRL1 | rw | 2 | 02 | 00000010 | 00000000 | SPI Interface and Sensor Enable (for clock and power management) |
| CTRL2 | rw | 3 | 03 | 00000011 | 00000000 | Accelerometer: Output Data Rate, Full Scale, Self Test |
| CTRL3 | rw | 4 | 04 | 00000100 | 00000000 | Gyroscope: Output Data Rate, Full Scale, Self Test |
| CTRL4 | rw | 5 | 05 | 00000101 | 00000000 | Magnetometer Settings: Output Data Rate, and Device Selection |
| CTRL5 | rw | 6 | 06 | 00000110 | 00000000 | Data Processing Settings |
| CTRL6 | rw | 7 | 07 | 00000111 | 00000000 | AttitudeEngine™ Settings: Output Data Rate, Motion on Demand |
| CTRL7 | rw | 8 | 08 | 00001000 | 00000000 | Enable Sensors, syncSmpl |
| CTRL8 | rw | 9 | 09 | 00001001 | 00000000 | Reserved: Not Used |
| CTRL9 | rw | 10 | 0A | 00001010 | 00000000 | Host commands |
| Host Controlled Calibration Registers (See CTRL9, Usage is Optional) | | | | | | |
| CAL1_L | rw | 11 | 0B | 00001011 | 00000000 | Calibration Register CAL1_L – lower 8 bits. CAL1_H – upper 8 bits. |
| CAL1_H | rw | 12 | 0C | 00001100 | 00000000 | |
| CAL2_L | rw | 13 | 0D | 00001101 | 00000000 | Calibration Register CAL2_L – lower 8 bits. CAL2_H – upper 8 bits. |
| CAL2_H | rw | 14 | 0E | 00001110 | 00000000 | |
| CAL3_L | rw | 15 | 0F | 00001111 | 00000000 | Calibration Register CAL3_L – lower 8 bits. CAL3_H – upper 8 bits. |
| CAL3_H | rw | 16 | 10 | 00010000 | 00000000 | |
| CAL4_L | rw | 17 | 11 | 00010001 | 00000000 | Calibration Register CAL4_L – lower 8 bits. CAL4_H – upper 8 bits. |
| CAL4_H | rw | 18 | 12 | 00010010 | 00000000 | |
| FIFO Registers | | | | | | |
| FIFO_CTRL | rw | 19 | 13 | 00010011 | 00000000 | FIFO Setup |
| FIFO_DATA | r | 20 | 14 | 00010100 | 00000000 | FIFO Data |
| FIFO_STATUS | r | 21 | 15 | 00010101 | 00000000 | FIFO Status |

Table 21. Register Overview (Continued)

| Name | Type | Register Address | | | Default | Comment |
|---|------|------------------|-----|----------|----------|---|
| | | Dec | Hex | Binary | | |
| Status Registers | | | | | | |
| STATUS0 | r | 22 | 16 | 00010110 | 00000000 | Output Data Over Run and Data Availability |
| STATUS1 | r | 23 | 17 | 00010111 | 00000000 | Miscellaneous Status: Wake on Motion, FIFO ready, CmdDone (CTRL9 protocol bit) |
| Count Register | | | | | | |
| CNT_OUT | r | 24 | 18 | 00011000 | 00000000 | Sample Time Stamp (Count Output) |
| Data Output Registers (16 bits 2'compliment except self test sensor data, AE-REG1 and AE_REG2) | | | | | | |
| AX_L | r | 25 | 19 | 00011001 | 00000000 | X-axis Acceleration |
| AX_H | r | 26 | 1A | 00011010 | 00000000 | AX_L – lower 8 bits. AX_H – upper 8 bits. |
| AY_L | r | 27 | 1B | 00011011 | 00000000 | Y-axis Acceleration |
| AY_H | r | 28 | 1C | 00011100 | 00000000 | AY_L – lower 8 bits. AY_H – upper 8 bits. |
| AZ_L | r | 29 | 1D | 00011101 | 00000000 | Z-axis Acceleration |
| AZ_H | r | 30 | 1E | 00011110 | 00000000 | AZ_L – lower 8 bits. AZ_H – upper 8 bits. |
| GX_L | r | 31 | 1F | 00011111 | 00000000 | X-axis Angular Rate |
| GX_H | r | 32 | 20 | 00100000 | 00000000 | GX_L – lower 8 bits. GX_H – upper 8 bits. |
| GY_L | r | 33 | 21 | 00100001 | 00000000 | Y-axis Angular Rate |
| GY_H | r | 34 | 22 | 00100010 | 00000000 | GY_L – lower 8 bits. GY_H – upper 8 bits. |
| GZ_L | r | 35 | 23 | 00100011 | 00000000 | Z-axis Angular Rate |
| GZ_H | r | 36 | 24 | 00100100 | 00000000 | GZ_L – lower 8 bits. GZ_H – upper 8 bits. |
| MX_L | r | 37 | 25 | 00100101 | 00000000 | X-axis Magnetic Field |
| MX_H | r | 38 | 26 | 00100110 | 00000000 | MX_L – lower 8 bits. MX_H – upper 8 bits. |
| MY_L | r | 39 | 27 | 00100111 | 00000000 | Y-axis Magnetic Field . |
| MY_H | r | 40 | 28 | 00101000 | 00000000 | MY_L – lower 8 bits. MY_H – upper 8 bits. |
| MZ_L | r | 41 | 29 | 00101001 | 00000000 | Z-axis Magnetic Field. |
| MZ_H | r | 42 | 2A | 00101010 | 00000000 | MZ_L – lower 8 bits. MZ_H – upper 8 bits. |
| dQW_L | r | 45 | 2D | 00101101 | 00000000 | Quaternion Increment dQW. |
| dQW_H | r | 46 | 2E | 00101110 | 00000000 | dQW_L – lower 8 bits. dQW_H – upper 8 bits. |
| dQX_L | r | 47 | 2F | 00101111 | 00000000 | Quaternion Increment dQX. |
| dQX_H | r | 48 | 30 | 00110000 | 00000000 | dQX_L – lower 8 bits. dQX_H – upper 8 bits. |
| dQY_L | r | 49 | 31 | 00110001 | 00000000 | Quaternion Increment dQY. |
| dQY_H | r | 50 | 32 | 00110010 | 00000000 | dQY_L – lower 8 bits. dQY_H – upper 8 bits. |
| dQZ_L | r | 51 | 33 | 00110011 | 00000000 | Quaternion Increment dQZ |
| dQZ_H | r | 52 | 34 | 00110100 | 00000000 | dQZ_L – lower 8 bits. dQZ_H – upper 8 bits. |
| dVX_L | r | 53 | 35 | 00110101 | 00000000 | Velocity Increment along X-axis, or X-axis Angular Rate for OIS LL mode, or Self test sensor data |
| dVX_H | r | 54 | 36 | 00110110 | 00000000 | dVX_L – lower 8 bits. dVX_H – upper 8 bits. |
| dVY_L | r | 55 | 37 | 00110111 | 00000000 | Velocity Increment along Y-axis, or Y-axis Angular Rate for OIS LL mode, or Self test sensor data |
| dVY_H | r | 56 | 38 | 00111000 | 00000000 | dVY_L – lower 8 bits. dVY_H – upper 8 bits. |
| dVZ_L | r | 57 | 39 | 00111001 | 00000000 | Velocity Increment along Z-axis, or Z-axis Angular Rate for OIS LL mode, or Self test sensor data |
| dVZ_H | r | 58 | 3A | 00111010 | 00000000 | dVZ_L – lower 8 bits. dVZ_H – upper 8 bits. |

Table 21. Register Overview (Continued)

| Name | Type | Register Address | | | Default | Comment |
|--|------|------------------|-----|----------|----------|---------------------------|
| | | Dec | Hex | Binary | | |
| Data Output Registers (Continued) | | | | | | |
| TEMP | r | 59 | 3B | 00111011 | 00000000 | Temperature Output Data |
| AE_REG1 | r | 60 | 3C | 00111100 | 00000000 | AttitudeEngine Register 1 |
| AE_REG2 | r | 61 | 3D | 00111101 | 00000000 | AttitudeEngine Register 2 |

5 Sensor Configuration Settings and Output Data

5.1 Typical Sensor Mode Configuration and Output Data

In Typical Sensor Mode, FIS1100 outputs raw sensor values. The sensors are configured and read using the registers described below. The accelerometer, gyroscope and magnetometer can be independently configured. Table 22 summarizes these pertinent registers.

Table 22. Typical Sensor Mode Configuration and Output Data

| Typical Sensor Configuration and Output Data | | | |
|--|---------------------|-------|--|
| Description | Registers | Unit | Comments |
| Sensor Enable, SPI 3 or 4 Wire | CTRL1 | | Control power states, configure SPI communications |
| Enable Sensor, Configure Data Reads | CTRL7 | | Enable sensor mode (sEN = 0). Configure data reads from Sensor Data Output Registers with syncSmpl. Individually enable/disable the Accelerometer, Gyroscope and Magnetometer using aEN, gEN, and mENbits, respectively. |
| Configure Accelerometer, Enable Self Test | CTRL2 | | Configure Full Scale and Output Data Rate; Enable Self Test |
| Configure Gyroscope, Enable Self Test | CTRL3 | | Configure Full Scale and Output Data Rate; Enable Self Test |
| Configure Magnetometer | CTRL4 | | Configure Output Data Rate and choose device |
| Sensor Filters | CTRL5 | | Configure and Enable/Disable High Pass and Low Pass Filters |
| Status | STATUS0, STATUS1 | | Data Availability, Data Overrun, FIFO ready to be read, CTRL9 Protocol Bit |
| Time Stamp | CNT_OUT | | Sample Time Stamp (circular register 0-FF) |
| Acceleration | A[X,Y,Z]_[H,L] | g | In Sensor Frame of Reference, Right-handed Coordinate System |
| Angular Rate | G[X,Y,Z]_[H,L] | dps | In Sensor Frame of Reference, Right-handed Coordinate System |
| Magnetic Field | M[X,Y,Z]_[H,L] | gauss | In Sensor Frame of Reference, Right-handed Coordinate System |
| Temperature | TEMP | °C | Temperature of the sensor |
| FIFO Based Output | FIFO_DATA | | See FIFO Description section for more details on using the FIFO to store and access multiple samples |

5.2 AttitudeEngine Mode Configuration and Output Data

In AE Mode, FIS1100 outputs orientation (quaternion) and velocity increments.

Orientation increments are expressed in unit quaternion format. $d\mathbf{Q} = [QW, QX, QY, QZ]^T$ where QW is the scalar component of the quaternion increment and QX, QY and QZ are the (imaginary) vector components of the unit quaternion. Velocity increments are expressed in vector format $d\mathbf{V} = [VX, VY, VZ]$.

Table 23 summarizes the operation of the AttitudeEngine mode.

Table 23. AttitudeEngine Mode Configuration and Output Registers

| AttitudeEngine Mode | | | |
|---|--------------------------------|--------------------|--|
| Configuration | Registers | Unit | Comments |
| Sensor Enable, SPI 3 or 4 Wire | CTRL1 | | Control power states, SPI communications |
| Enable AttitudeEngine | CTRL7 | | Enable the AttitudeEngine (CTRL7, sEN =1, aEN=1, gEN=1, optionally mEN=1 if external magnetometer is available) |
| Configure | CTRL6 | | AttitudeEngine Output Data Rate and Motion on Demand |
| Configure Accelerometer, Enable Self Test | CTRL2 | | Configure Full Scale; Enable Self Test |
| Configure Gyroscope, Enable Self Test | CTRL3 | | Configure Full Scale; Enable Self Test |
| Configure Magnetometer | CTRL4 | | Configure Output Data Rate and choose device |
| Sensor Filters | CTRL5 | | Configure and Enable/Disable High Pass and Low Pass Filters |
| Quaternion Increment | $d\mathbf{Q}[W,X,Y,Z]_{[H,L]}$ | | Unit Quaternion format in sensor frame |
| Velocity Increment | $d\mathbf{V}[X,Y,Z]_{[H,L]}$ | ms^{-1} | Rotation compensated velocity increment (based on specific force), rotated to sensor frame of reference |
| Magnetic Field | $\mathbf{M}[X,Y,Z]_{[H,L]}$ | gauss | Rotation compensated magnetic field (rotated to sensor frame of reference) |
| Status | STATUS0, STATUS1 | | Data Availability, Data Overrun, Wake on Motion detected |
| Bias Update, Clipping, Overflow | AE_REG1, AEREG_2 | | Magnetometer and Gyroscope bias update acknowledgement, Sensor clipping acknowledgement, Velocity increment overflow |
| Temperature | TEMP | $^{\circ}\text{C}$ | Temperature of the sensor |

5.3 General Purpose Register

Table 24. General Purpose Register Description

| Register Name | | | |
|---|-------------|----------------|---|
| WHO_AM_I Register Address: 0 (0x00) | | | |
| Bits | Name | Default | Description |
| 7:0 | WHO_AM_I | 0xFC | Device identifier FC - to identify the device is a Fairchild sensor |

5.4 Configuration Registers

This section describes the various operating modes and register configurations of the FIS1100.

Table 25. Configuration Registers Description

| Register Name | | | | |
|---------------|---------------------------|--|---|----------------------------|
| CTRL1 | | SPI Interface and Sensor Enable. Register Address: 2 (0x02) | | |
| Bits | Name | Default | Description | |
| 7 | SIM | 1'b0 | 0: Enables 4-wire SPI interface 1: Enables 3-wire SPI interface | |
| 6:1 | Reserved | 6'b0 | Reserved | |
| 0 | sensorDisable | 1'b0 | 0: Enables internal 1 MHz oscillator 1: Disables internal 1 MHz oscillator For more detail, see Table 32 and see Figure 8 | |
| CTRL2 | | Accelerometer Settings: Address: 3 (0x03) | | |
| Bits | Name | Default | Description | |
| 7:6 | Reserved | 2'b0 | Reserved | |
| 5 | aST | 1'b0 | Enable Accelerometer Self Test. For more detail, see Section 9.1 | |
| 4:3 | aFS<1:0> | 2'b0 | Set Accelerometer Full-scale: 00 - Accelerometer Full-scale = ± 2 g 01 - Accelerometer Full-scale = ± 4 g 10 - Accelerometer Full-scale = ± 8 g 11 - Accelerometer Full-scale = ± 8 g | |
| 2:0 | aODR<2:0> ⁽¹²⁾ | 3'b0 | Set Accelerometer Output Data Rate (ODR): | |
| Setting | ODR Rate (Hz) | Mode | LPF Bandwidth (Hz), aLPF=0 | LPF Bandwidth (Hz), aLPF=1 |
| 000 | 1000 | High Resolution | 500 | 200 |
| 001 | 250 | High Resolution | 125 | 50 |
| 010 | 125 | High Resolution | 62.5 | 25 |
| 011 | 31.25 | High Resolution | 15.625 | 5 |
| 100 | 125 | Low Power | 62.5 | 25 |
| 101 | 62.5 | Low Power | 31.25 | 15 |
| 110 | 25 | Low Power | 12 | 5 |
| 111 | 3 | Low Power | 2 | 0.6 |

Table 25 Configuration Register Description (Continued)

| Register Name | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---------------|---------------------------|--|---|----------------------------|--|---------|---------------|-------------|----------------------------|----------------------------|---------|------|-----------------|-----|-----|-----|-----|-----------------|-----|----|-----|-----|-----------------|------|----|-----|-------|-----------------|--------|---|-----|---|----------------------------|----|----|-----|------|-----|------|-----|-----|------|------------------------|------|---------------------|
| CTRL3 | | Gyroscope Settings: Address 4 (0x04) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bits | Name | Default | Description | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | Reserved | 1'b0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | gST | 1'b0 | Enable Gyro Self-Test. For more detail, see Section 9.2, Gyroscope Self Test | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5:3 | gFS<2:0> | 3'b0 | Set Gyroscope Full-scale: 000 - ±32 dps 001 - ±64 dps 010 - ±128 dps 011 - ±256 dps 100 - ±512 dps 101 - ±1024 dps 110 - ±2048 dps 111 - ±2560 dps | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2:0 | gODR<2:0> ⁽¹²⁾ | 3'b0 | Set Gyroscope Output Data Rate (ODR): | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | <table border="1"> <thead> <tr> <th>Setting</th><th>ODR Rate (Hz)</th><th>Mode</th><th>LPF Bandwidth (Hz). gLPF=0</th><th>LPF Bandwidth (Hz), gLPF=1</th></tr> </thead> <tbody> <tr> <td>000</td><td>1000</td><td>High-Resolution</td><td>500</td><td>200</td></tr> <tr> <td>001</td><td>250</td><td>High-Resolution</td><td>125</td><td>50</td></tr> <tr> <td>010</td><td>125</td><td>High-Resolution</td><td>62.5</td><td>25</td></tr> <tr> <td>011</td><td>31.25</td><td>High-Resolution</td><td>15.625</td><td>6</td></tr> <tr> <td>10X</td><td>0</td><td>Gryo Warm-Start (“Snooze”)</td><td>NA</td><td>NA</td></tr> <tr> <td>110</td><td>8100</td><td>OIS</td><td>4050</td><td>345</td></tr> <tr> <td>111</td><td>8100</td><td>OIS LL⁽¹³⁾</td><td>2000</td><td>N/A⁽¹⁴⁾</td></tr> </tbody> </table> | | | Setting | ODR Rate (Hz) | Mode | LPF Bandwidth (Hz). gLPF=0 | LPF Bandwidth (Hz), gLPF=1 | 000 | 1000 | High-Resolution | 500 | 200 | 001 | 250 | High-Resolution | 125 | 50 | 010 | 125 | High-Resolution | 62.5 | 25 | 011 | 31.25 | High-Resolution | 15.625 | 6 | 10X | 0 | Gryo Warm-Start (“Snooze”) | NA | NA | 110 | 8100 | OIS | 4050 | 345 | 111 | 8100 | OIS LL ⁽¹³⁾ | 2000 | N/A ⁽¹⁴⁾ |
| Setting | ODR Rate (Hz) | Mode | LPF Bandwidth (Hz). gLPF=0 | LPF Bandwidth (Hz), gLPF=1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 000 | 1000 | High-Resolution | 500 | 200 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 001 | 250 | High-Resolution | 125 | 50 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 010 | 125 | High-Resolution | 62.5 | 25 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 011 | 31.25 | High-Resolution | 15.625 | 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10X | 0 | Gryo Warm-Start (“Snooze”) | NA | NA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 110 | 8100 | OIS | 4050 | 345 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 111 | 8100 | OIS LL ⁽¹³⁾ | 2000 | N/A ⁽¹⁴⁾ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| CTRL4 | | Magnetometer Settings: Address: 5 (0x05) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bits | Name | Default | Description | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7:6 | Reserved | 2'b0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5:4 | mDEV<1:0> | 2'b0 | Designate External Magnetometer Device: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | <table border="1"> <thead> <tr> <th>Setting</th><th>Vendor</th><th>Part Number</th></tr> </thead> <tbody> <tr> <td>00</td><td>AKM</td><td>AK8975</td></tr> </tbody> </table> | | | Setting | Vendor | Part Number | 00 | AKM | AK8975 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Setting | Vendor | Part Number | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 00 | AKM | AK8975 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3:2 | Reserved | 2'b0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1:0 | mODR<1:0> | 2'b0 | Set Recommended Magnetometer Output Data Rate (ODR): | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | <table border="1"> <thead> <tr> <th>Setting</th><th>ODR Rate (Hz)</th><th>Description</th></tr> </thead> <tbody> <tr> <td>10</td><td>31.25</td><td>AKM8975</td></tr> </tbody> </table> | | | Setting | ODR Rate (Hz) | Description | 10 | 31.25 | AKM8975 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Setting | ODR Rate (Hz) | Description | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 | 31.25 | AKM8975 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Note:

12. When both the accelerometer and the gyroscope are enabled, it is typical to set the ODR rates for each sensor to be identical, such as when output rates are chosen in the range of 1kHz to 32Hz. In case the host requires different ODRs (for example, as with OIS mode) then, the gyroscope output rate should be chosen to be greater than or equal to the accelerometer output rate. NOTE: The accelerometer low power mode is only available when the gyroscope is disabled.
13. When gODR<2:0>=111 (OIS LL mode) is selected, the gyro data will be written to dVX_L, dVX_H, dVY_L, dVY_H, dVZ_L and dVZ_H registers. See register #53 through #58 for additional details.

Table 25 Configuration Register Description (Continued)

| Register Name | | | | | | | | | | | | | | | | | | | | | | | | | |
|-----------------|---------------------|---|--|--|---------------|---------------|---------------|------|-----|-----|-----|--------|--------|-----|--------|--------|-------|--------|--------|--------------------|--------|--------|-----------------|---------------------|---------------------|
| CTRL5 | | Sensor Data Processing Settings. Register Address: 6 (0x06) | | | | | | | | | | | | | | | | | | | | | | | |
| Bits | Name | Default | Description | | | | | | | | | | | | | | | | | | | | | | |
| 7:5 | Reserved | 3'b0 | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | gHPF01 | 1'b0 | Set HPF corner frequency. See Table associated with gHPF bit below. | | | | | | | | | | | | | | | | | | | | | | |
| 3 | gLNF | 1'b0 | 0: Disable Gyroscope Low-Pass Filter. 1: Enable Gyroscope Low-Pass Filter. | | | | | | | | | | | | | | | | | | | | | | |
| 2 | gHPF | 1'b0 | 0: Disable Gyroscope High-Pass Filter. 1: Enable Gyroscope High-Pass Filter (see Table below). High-Pass Filter corner frequency (f_c) with gHPF = 1 | | | | | | | | | | | | | | | | | | | | | | |
| | | | <table border="1"> <thead> <tr> <th>ODR Rate (Hz)</th> <th>gHPF01=1 (Hz)</th> <th>gHPF01=0 (Hz)</th> </tr> </thead> <tbody> <tr> <td>1000</td> <td>0.1</td> <td>2.5</td> </tr> <tr> <td>250</td> <td>0.0250</td> <td>0.6250</td> </tr> <tr> <td>125</td> <td>0.0125</td> <td>0.3125</td> </tr> <tr> <td>31.25</td> <td>0.0032</td> <td>0.0800</td> </tr> <tr> <td>8100 (gODR=110)</td> <td>0.1000</td> <td>0.1000</td> </tr> <tr> <td>8100 (gODR=111)</td> <td>N/A⁽¹⁴⁾</td> <td>N/A⁽¹⁴⁾</td> </tr> </tbody> </table> | | ODR Rate (Hz) | gHPF01=1 (Hz) | gHPF01=0 (Hz) | 1000 | 0.1 | 2.5 | 250 | 0.0250 | 0.6250 | 125 | 0.0125 | 0.3125 | 31.25 | 0.0032 | 0.0800 | 8100 (gODR=110) | 0.1000 | 0.1000 | 8100 (gODR=111) | N/A ⁽¹⁴⁾ | N/A ⁽¹⁴⁾ |
| ODR Rate (Hz) | gHPF01=1 (Hz) | gHPF01=0 (Hz) | | | | | | | | | | | | | | | | | | | | | | | |
| 1000 | 0.1 | 2.5 | | | | | | | | | | | | | | | | | | | | | | | |
| 250 | 0.0250 | 0.6250 | | | | | | | | | | | | | | | | | | | | | | | |
| 125 | 0.0125 | 0.3125 | | | | | | | | | | | | | | | | | | | | | | | |
| 31.25 | 0.0032 | 0.0800 | | | | | | | | | | | | | | | | | | | | | | | |
| 8100 (gODR=110) | 0.1000 | 0.1000 | | | | | | | | | | | | | | | | | | | | | | | |
| 8100 (gODR=111) | N/A ⁽¹⁴⁾ | N/A ⁽¹⁴⁾ | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | aLPF | 1'b0 | 0: Disable Accelerometer Low-Pass Filter. 1: Enable Accelerometer Low-Pass Filter. | | | | | | | | | | | | | | | | | | | | | | |
| 0 | aHPF | 1'b0 | 0: Disable Accelerometer High-Pass Filter 1: Enable Accelerometer High-Pass Filter. | | | | | | | | | | | | | | | | | | | | | | |
| CTRL6 | | Attitude Engine ODR and Motion on Demand: Address: 7 (0x07) | | | | | | | | | | | | | | | | | | | | | | | |
| Bits | Name | Default | Description | | | | | | | | | | | | | | | | | | | | | | |
| 7 | sMoD | 1'b0 | 0: Disables Motion on Demand. 1: Enables Motion on Demand (Requires sEN=1). | | | | | | | | | | | | | | | | | | | | | | |
| 6:3 | Reserved | 4'b0 | | | | | | | | | | | | | | | | | | | | | | | |
| 2:0 | sODR<2:0> | 3'b0 | Attitude Engine Output Data Rate (ODR) <table border="1"> <thead> <tr> <th>Setting</th> <th>ODR Rate (Hz)</th> </tr> </thead> <tbody> <tr> <td>000</td> <td>1</td> </tr> <tr> <td>001</td> <td>2</td> </tr> <tr> <td>010</td> <td>4</td> </tr> <tr> <td>011</td> <td>8</td> </tr> <tr> <td>100</td> <td>16</td> </tr> <tr> <td>101</td> <td>32</td> </tr> <tr> <td>110</td> <td>64⁽¹⁵⁾</td> </tr> <tr> <td>111</td> <td>NA</td> </tr> </tbody> </table> | | Setting | ODR Rate (Hz) | 000 | 1 | 001 | 2 | 010 | 4 | 011 | 8 | 100 | 16 | 101 | 32 | 110 | 64 ⁽¹⁵⁾ | 111 | NA | | | |
| Setting | ODR Rate (Hz) | | | | | | | | | | | | | | | | | | | | | | | | |
| 000 | 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| 001 | 2 | | | | | | | | | | | | | | | | | | | | | | | | |
| 010 | 4 | | | | | | | | | | | | | | | | | | | | | | | | |
| 011 | 8 | | | | | | | | | | | | | | | | | | | | | | | | |
| 100 | 16 | | | | | | | | | | | | | | | | | | | | | | | | |
| 101 | 32 | | | | | | | | | | | | | | | | | | | | | | | | |
| 110 | 64 ⁽¹⁵⁾ | | | | | | | | | | | | | | | | | | | | | | | | |
| 111 | NA | | | | | | | | | | | | | | | | | | | | | | | | |

Notes:

14. For OIS LL mode, no filters can be enabled. gLPF=0 and gHPF=0 should be maintained.
 15. This ODR should not be used if magnetometer is enabled