April 2015

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: ±3º Pitch and Roll, ±5º 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
- Complete System Solution for 3D Motion Tracking, Optimized 9D Sensor Fusion Library (XKF3) Featuring in-use Auto-Calibration Enabling Accurate 3D Orientation (quaternion) and High-Pass 3D Velocity Motion Tracking
- Large 1536 Byte FIFO can be used to Buffer 9DOF Sensor Data to Lower System Power Dissipation
- New Motion on Demand Technology for Polling Based Synchronization
- Large Dynamic Range from ±32°/s to ±2,560°/s and ±2 g to ±8 g
- Low Latency, High-Resolution OIS Mode
- Low Noise 50 μg/√Hz Accelerometer and 10 mdps/√Hz Gyroscope
- Low Power and Warm-Start Modes for Effective Power Management
- Digitally Programmable Sampling Rate and Filters
- Host Serial Interface Supporting I^2C or SPI
- I^2C 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 ±3° pitch and roll orientation, and a ±5° 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 I^2C 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

- Sport & Fitness Tracking
- Wearable and Health Monitoring
- Pedestrian Navigation
- Light Industrial, Robotics and Autonomous Machines
- Natural User Interfaces, Gaming, VR/AR
- GNSS Augmentation and Dead Reckoning
- Optical Video and Image Stabilization

Table of Contents

1 General Information

1.1 Ordering Information

Table 1. Ordering Information

Part Number	Package	Packing Method
FIS1100	LGA16	Tape & Reel

1.2 Marking Information

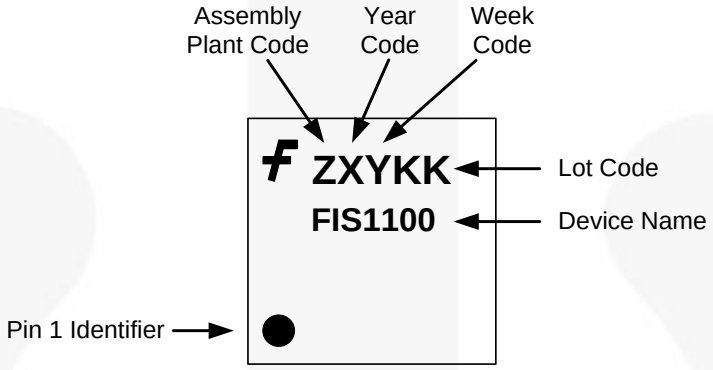


Figure 1. Top Mark

1.3 Internal Block Diagram

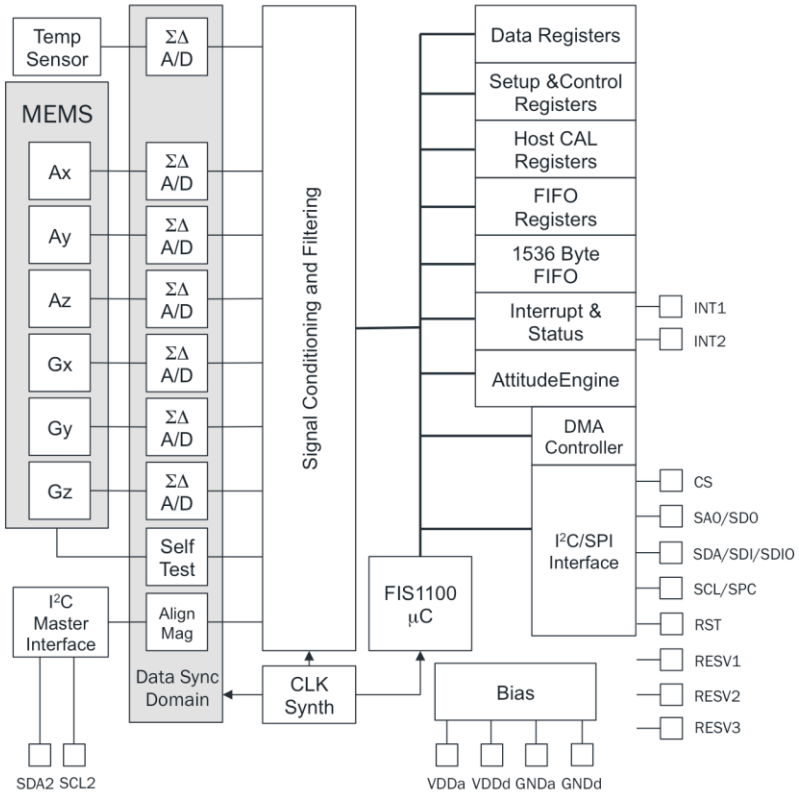


Figure 2. Internal Block Diagram

1.4 Application Diagram

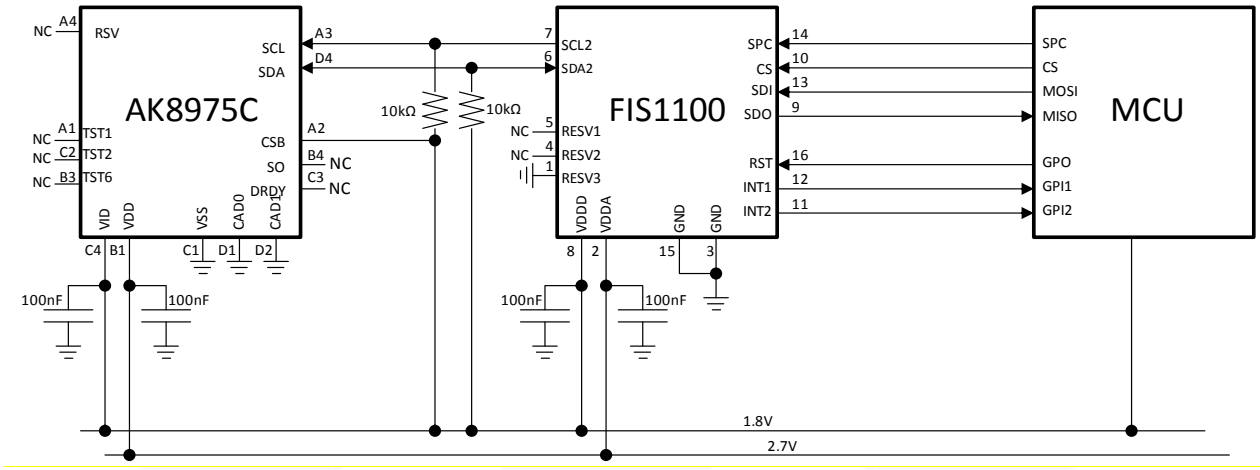


Figure 3. Typical Application Diagram (Showing Magnetometer Connected through FIS1100 Master I²C and a SPI 4 Wire Interface Connected to the Host Processor)

1.5 Package & Pin Information

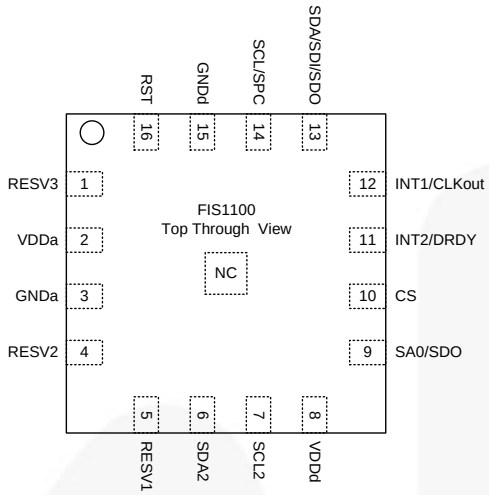


Figure 4. Pins Face Down (Top View) Do Not Solder Center Pin (NC)

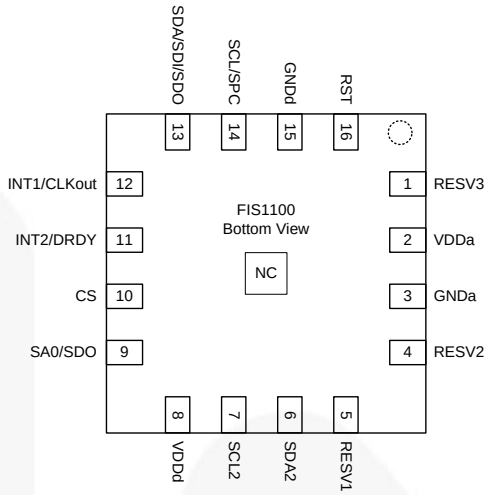


Figure 5. Pins Face Up (Bottom View) Do Not Solder Center Pin (NC)

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^2C Serial Data
7	SCL2			Master I^2CSerial Clock
8	VDDd			Power Supply for Digital and IO Pins
9	SA0(1)(3)	SDO		Host I^2C Slave Address LSB (SA0); Host 4-Wire SPI Serial Data Output (SDO)
10(1)	CS			Host SPI Chip Select (1 = I^2C Mode). *See SPI Mode Configuration section*
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^2C 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^2C 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 I^2C 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 I^2C. They are not needed when the Host Serial Interface is configured for SPI. See I^2C Interface section. If Pull-up resistors are used on SCL and SDA, then both SPI and I^2C Modes are possible. If a Pull-up is used on SA0, an alternate slave address is used for I^2C. SPI Mode will be unaltered with the use of Pull-ups for I^2C.

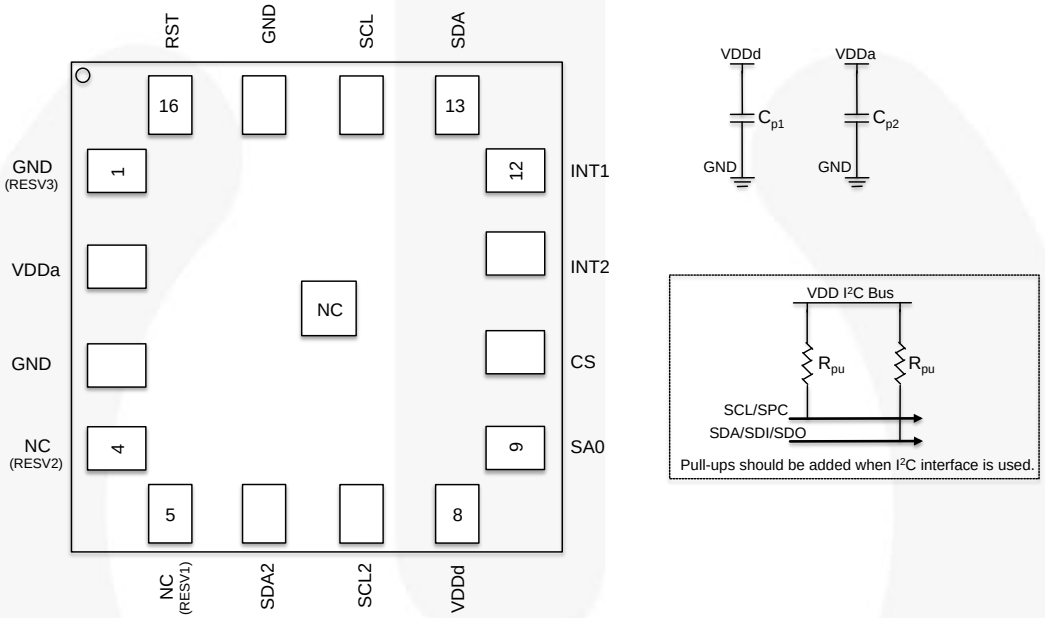


Figure 6. Typical Electrical Connections

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 ±3° for pitch and roll and ±5° for yaw/heading.

The FIS1100 includes a micro-controller 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 mode and at 8 kHz in OIS mode.

An internal block diagram is shown in Figure 2. The MEMS elements are amplified and converted by ΣΔ 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 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 FIS1100.
- **Sample Synchronization**: FIS1100 automatically provides highly synchronous output between the various IMU accelerometer and gyroscope channels due to fully parallel ΣΔ-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 manifold 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).

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
- Real-Time, Low-Latency Optimal estimate of 3D Orientation
- 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

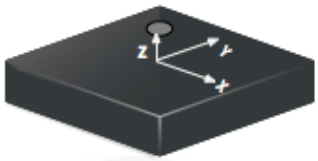


Figure 7. Chip Orientation Coordinate System

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 co-ordinate system shown above. Increasing accelerations along the positive X-Y-Z axis are considered positive. Angular Rate (ω_x, ω_y, ω_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 co-ordinates 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 co-ordinate 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 and AttitudeEngine™ Modes are outlined below in Table 23 and Table 24. 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	3.0	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 (AN-5085 application note). The system performance guidance assumes 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 spec 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°C unless otherwise noted.

Table 7. Accelerometer Electro-Mechanical Specifications

Subsystem	Parameter	Typical		Unit	Comments
Accelerometer	Noise Density	50		µg/√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)		mg/°C	Over-Temperature Range of-40°C to 85°C at Board Level
		±2.5 (Z-Axis)			
	Temperature Coefficient of Sensitivity (TCS)	0.01		%/°C	
	Initial Offset Tolerance	±50		mg	Component Level
	Initial Sensitivity Tolerance	±3		%	Board Level
	Non-Linearity	±1		%	Best Fit Line
	Wakeup Time (to 1% of Final Value)	1		s	From Reset to Ready-Mode
		3		ms	From Ready-Mode

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
	Non-Linearity	< 0.2		%	@WC, FSO=2560 dps
	Cross-Axis Sensitivity	±2		%	
	Wakeup Time (to 1% of Final Value)	1		s	From Reset to Ready-Mode
		60		ms	From Ready-Mode
		5		ms	From Warm-Start
	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 AttitudeEngine 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°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	Hz
Typical Noise Density	50	50	50	50	125	180	285	820	μg/√Hz

Table 11. Accelerometer Filter Characteristics(7)

Mode	High-Resolution				Low-Power				Unit
ODR	1000	250	125	31.25	125	62.5	25	3	Hz
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°C, and represent typical numbers unless otherwise noted. All frequencies are ±5% and are synchronized to the gyro oscillator (“drive”) frequency.

Table 12. Gyroscope Noise Density

Mode	High-Resolution				Snooze Warm-Start	OIS	Unit
ODR	1000	250	125	31.25	Snooze	8100	Hz
Typical Rate Noise Density	10	10	10	10	N/A	10	mdps/√Hz

Table 13. Gyroscope Filter Characteristics

Mode		High-Resolution				Snooze Warm-Start	OIS	Unit
ODR		1000	250	125	31.25	Snooze	8100	Hz
Bandwidth		500	125	62.5	15.625	N/A	4050	
Bandwidth with Low-Pass Filter Enabled (gLPF=1)		200	50	25	6	N/A	345	
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	
	gHPF01=1	0.1	0.025	0.0125	0.0032	N/A	0.1	

Table 14. Optical Image Stabilization (OIS) Group Delay

	At Frequency (Hz)	Filter Bandwidth (Hz)	Typical	Unit
Group Delay	10	4050	0.11	ms
		345	1.1	

3.7 Electrical Characteristics

V_{DDd} = 1.8 V; V_{DDa} = 2.7 V; T = 25°C unless otherwise noted.

Table 15. Electrical Subsystem Characteristics

Symbol	Parameter		Min.	Typ.	Max.	Unit
f_{SPC}	Host SPI Interface Speed			10		MHz
f_{SCL}	Host I^2C Interface Speed	Standard Mode		100		kHz
		Fast Mode		400		
f_{SCL2}	Master I^2C Interface Speed(8)	Standard Mode		25		kHz
		Fast Mode		300		

Note:

8. When only accelerometer is enabled, I^2C master operates at 25 kHz. When gyroscope is enabled, I^2C master operates at 300 kHz.

3.7.1 Current Consumption

V_{DDd} = 1.8 V, V_{DDa} = 2.7 V, T = 25°C unless otherwise noted. Typical numbers are provided below.

Table 16. 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}(9)		220	220	220	220	35	35	20	7	µA
Typical Digital Current I_{DDd} (10)	**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 17. Current Consumption for Gyroscope Only Typical Sensor Mode (Accelerometer Disabled)

Mode		High-Resolution				Snooze Warm-Start	OIS	Unit
ODR		1000	250	125	31.25	Snooze	8100	Hz
Typical Analog Current I_{DDa}(9)		2540	2540	2540	2540	1240	2540	µA
Typical Digital Current I_{DDd} (10)	**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:

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

Table 18. 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 19. 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	µA
Typical Digital Current I_{DDd}	Filters Disabled (aLPF=0; gLPF=0)	930	930	930	930	930	930	930	
	Filters Enabled (aLPF=1; gLPF=1)	940	940	940	940	940	940	940	

Table 20. 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	µA
Typical Digital Current I_{DDd}	With Magnetometer at 32 Hz	990	990	990	990	990	990	

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 will also output the internal chip temperature that the HOST can read. This external output is truncated to an 8-bit resolution so that the HOST would see 1°C per LSB resolution. This is not representative to 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 22.* The HOST should synchronize to the interrupt, INT2, signal to get valid temperature readings.

Table 21. 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 easy programming and control of the inertial measurement unit and associated on-chip inertial 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
- FIFO Registers: To setup the FIFO and detect data availability and over-run.
- Data Output Registers: Contains all datum for 9D sensor.

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 I^2C 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 22. 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	General & Power management / modes
CTRL2	rw	3	03	00000011	00000000	Accelerometer Settings: Output Data Rate, and Full Scale
CTRL3	rw	4	04	00000100	00000000	Gyroscope Settings: Output Data Rate, and Full Scale
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, other controls
CTRL7	rw	8	08	00001000	00000000	Enable Sensors
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
Status Registers						
STATUS0	r	22	16	00010110	00000000	Output Data Over Run and Availability
STATUS1	r	23	17	00010111	00000000	Miscellaneous Status

Table 22. Register Overview (Continued)

Name	Type	Register Address			Default	Comment
		Dec	Hex	Binary		
Data Output Registers						
CNT_OUT	r	24	18	00011000	00000000	Sample Time Stamp (Count Output)
AX_L	r	25	19	00011001	00000000	X-axis Acceleration. AX_L – lower 8 bits. AX_H – upper 8 bits.
AX_H	r	26	1A	00011010	00000000	
AY_L	r	27	1B	00011011	00000000	Y-axis Acceleration. AY_L – lower 8 bits. AY_H – upper 8 bits.
AY_H	r	28	1C	00011100	00000000	
AZ_L	r	29	1D	00011101	00000000	Z-axis Acceleration. AZ_L – lower 8 bits. AZ_H – upper 8 bits.
AZ_H	r	30	1E	00011110	00000000	
GX_L	r	31	1F	00011111	00000000	X-axis Angular Rate. GX_L – lower 8 bits. GX_H – upper 8 bits.
GX_H	r	32	20	00100000	00000000	
GY_L	r	33	21	00100001	00000000	Y-axis Angular Rate. GY_L – lower 8 bits. GY_H – upper 8 bits.
GY_H	r	34	22	00100010	00000000	
GZ_L	r	35	23	00100011	00000000	Z-axis Angular Rate. GZ_L – lower 8 bits. GZ_H – upper 8 bits.
GZ_H	r	36	24	00100100	00000000	
MX_L	r	37	25	00100101	00000000	X-axis Magnetic Field. MX_L – lower 8 bits. MX_H – upper 8 bits.
MX_H	r	38	26	00100110	00000000	
MY_L	r	39	27	00100111	00000000	Y-axis Magnetic Field. MY_L – lower 8 bits. MY_H – upper 8 bits.
MY_H	r	40	28	00101000	00000000	
MZ_L	r	41	29	00101001	00000000	Z-axis Magnetic Field. MZ_L – lower 8 bits. MZ_H – upper 8 bits.
MZ_H	r	42	2A	00101010	00000000	
dQW_L	r	45	2D	00101101	00000000	Quaternion Increment dQW. dQW_L – lower 8 bits. dQW_H – upper 8 bits.
dQW1_H	r	46	2E	00101110	00000000	
dQXL	r	47	2F	00101111	00000000	Quaternion Increment dQX. dQX_L – lower 8 bits. dQX_H – upper 8 bits.
dQX_H	r	48	30	00110000	00000000	
dQY_L	r	49	31	00110001	00000000	Quaternion Increment dQY. dQY_L – lower 8 bits. dQY_H – upper 8 bits.
dQY_H	r	50	32	00110010	00000000	
dQZ_L	r	51	33	00110011	00000000	Quaternion Increment dQZ. dQZ_L – lower 8 bits. dQZ_H – upper 8 bits.
dQZ_H	r	52	34	00110100	00000000	
dVX_L	r	53	35	00110101	00000000	Velocity Increment along X-axis. dVX_L – lower 8 bits. dVX_H – upper 8 bits.
dVX_H	r	54	36	00110110	00000000	
dVY_L	r	55	37	00110111	00000000	Velocity Increment along Y-axis. dVY_L – lower 8 bits. dVY_H – upper 8 bits.
dVY_H	r	56	38	00111000	00000000	
dVZ_L	r	57	39	00111001	00000000	Velocity Increment along Z-axis. dVZ_L – lower 8 bits. dVZ_H – upper 8 bits.
dVZ_H	r	58	3A	00111010	00000000	
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 using CTRL2-CTRL5 registers as described below. The accelerometer, gyroscope and magnetometer can be independently configured. Table 23 summarizes the operation of Typical Sensor mode.

Table 23. Typical Sensor Mode Configuration and Output Registers

Typical Sensor Mode			
Description	**Registers**	**Unit**	**Comments**
Enable Individual Sensors	CTRL7		Enabling the Typical Sensor mode (CTRL7, sEN =0). Accelerometer, Gyroscope and Magnetometer can be individually turned on or off using CTRL7 aEN, gEN, mEN bits.
Configure Accelerometer	CTRL2		Configure Full Scale and Output Data Rate (ODR)
Configure Gyroscope	CTRL3		Configure Full Scale and Output Data Rate (ODR)
Configure Magnetometer	CTRL4		Configure Full Scale and Output Data Rate (ODR)
Sensor filters	CTRL5		Configure High Pass and Low Pass Filters
Status	STATUS0, STATUS1		Data Availability and Data Overrun
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 Co-ordinate System
Angular Rate	G[X,Y,Z]_[H,L]	dps	In Sensor Frame of Reference, Right-handed Co-ordinate System
Magnetic Field	M[X,Y,Z]_[H,L]	gauss	In Sensor Frame of Reference, Right-handed Co-ordinate System
Temperature	TEMP	°_	Temperature of the sensor
FIFO Based Output	FIFO_DATA		See FIFO 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. dQ = [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 dV = [VX, VY, VZ].

Table 24 summarizes the operation of the AttitudeEngine mode.

Table 24. AttitudeEngine Mode Configuration and Output Registers

AttitudeEngine Mode			
Configuration	**Registers**	**Unit**	**Comments**
Enable	CTRL7		Enabling the Typical Sensor Mode (CTRL7,sEN =1, aEN=1, gEN=1, optionally mEN=1 if external magnetometer is available)
Configure	CTRL6		AE ODR and Motion on Demand
Orientation Increment	dQ[W,X,Y,Z]_[H,L]		Unit Quaternion format in sensor frame
Velocity Increment	dV[X,Y,Z]_[H,L]	ms^{-1}	Rotation compensated velocity increment (based on specific force), rotated to sensor frame of reference
Magnetic Field	M[X,Y,Z]_[H,L]	gauss	Rotation compensated magnetic field (rotated to sensor frame of reference)
Clipping Detection	AE_CLIPPING		Clipping in acceleration or rate detected
Overflow Detection	AE_OVERFLOW		Clipping in magnetic field or velocity increment detected

5.3 General Purpose Registers

Table 25. 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 for FIS1100

5.4 Configuration Registers

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

Table 26. Configuration Registers Description

Register Name			
CTRL1		**General and Power Management Modes. 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
CTRL2		**Accelerometer Settings: Address: 3 (0x03)**	
Bits	**Name**	**Default**	**Description**
7:6	Reserved	3'b0	Reserved
5	aST	1'b0	Enable Accelerometer Self Test
4:3	aFS<1:0>	2'b0	Sets 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>(11)	3'b0	Sets 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 26 Configuration Register Description (Continued)

<table>
<tr><td colspan="2">Register Name</td><td colspan="2"></td></tr>
<tr><td colspan="2">CTRL3</td><td colspan="2">Gyroscope Settings: Address 4 (0x04)</td></tr>
<tr><td>Bits</td><td>Name</td><td>Default</td><td>Description</td></tr>
<tr><td>7</td><td>Reserved</td><td>1’b0</td><td></td></tr>
<tr><td>6</td><td>gST</td><td>1’b0</td><td>Enable Gyro Self-Test</td></tr>
<tr><td>5:3</td><td>gFS<2:0></td><td>3’b0</td><td>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</td></tr>
<tr><td>2:0</td><td>gODR<2:0> (11)</td><td>3’b0</td><td>Sets Gyroscope Output Data Rate (ODR)
<table>
<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>
<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>Snooze Warm-Start</td><td>NA</td><td>NA</td></tr>
<tr><td>11X</td><td>8100</td><td>OIS</td><td>4050</td><td>345</td></tr>
</table></td></tr>
<tr><td colspan="2">CTRL4</td><td colspan="2">Magnetometer Settings: Address: 5 (0x05)</td></tr>
<tr><td>Bits</td><td>Name</td><td>Default</td><td>Description</td></tr>
<tr><td>7:6</td><td>Reserved</td><td>2’b0</td><td></td></tr>
<tr><td>5:4</td><td>mDEV<1:0></td><td>2’b0</td><td>Designates External Magnetometer Device.
<table>
<tr><th>Setting</th><th>Vendor</th><th>Part Number</th></tr>
<tr><td>00</td><td>AKM</td><td>AK8975</td></tr>
</table></td></tr>
<tr><td>3:2</td><td>Reserved</td><td>2’b0</td><td></td></tr>
<tr><td>1:0</td><td>mODR<1:0></td><td>2’b0</td><td>Sets Recommended Magnetometer Output Data Rate (ODR).
<table>
<tr><th>Setting</th><th>ODR Rate (Hz)</th><th>Description</th></tr>
<tr><td>10</td><td>31.25</td><td>AKM8975</td></tr>
</table></td></tr>
</table>

Note:

11. When both accelerometer and gyroscope are enabled it is the host’s responsibility to set the gODR<2:0> and the aODR<2:0> to be identical values (which can be 0, 1, 2, or 3). This means, no low power accelerometer mode is available when gyroscope is enabled. NOTE: If the ODR values setting for gODR and aODR are NOT identical the output values of accelerometer and gyroscope will not be correct

Table 26 Configuration Register Description (Continued)

<table>
<tr><th colspan="2">Register Name</th><th colspan="2"></th></tr>
<tr><td colspan="2">CTRL5</td><td colspan="2">Sensor Data Processing Settings. Register Address: 6 (0x06)</td></tr>
<tr><th>Bits</th><th>Name</th><th>Default</th><th>Description</th></tr>
<tr><td>7:5</td><td>Reserved</td><td>3’b0</td><td></td></tr>
<tr><td>4</td><td>gHPF01</td><td>1’b0</td><td>Set HPF corner frequency of 0.1 Hz.
See Table under gHPF below.</td></tr>
<tr><td>3</td><td>gLPF</td><td>1’b0</td><td>0: Disable Gyroscope Low-Pass Filter.
1: Enable Gyroscope Low-Pass Filter.</td></tr>
<tr><td>2</td><td>gHPF</td><td>1’b0</td><td>0: Disable Gyroscope High-Pass Filter.
1: Enable Gyroscope High-Pass Filter (see Table).
High-Pass Filter corner frequency (f_c) with gHPF = 1
<table>
<tr><th>ODR Rate (Hz)</th><th>gHPF01=1 (Hz)</th><th>gHPF01=0 (Hz)</th></tr>
<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</td><td>0.1000</td><td>0.1000</td></tr>
</table></td></tr>
<tr><td>1</td><td>aLPF</td><td>1’b0</td><td>0: Disable Accelerometer Low-Pass Filter.
1: Enable Accelerometer Low-Pass Filter.</td></tr>
<tr><td>0</td><td>aHPF</td><td>1’b0</td><td>0: Disable Accelerometer High-Pass Filter
1: Enable Accelerometer High-Pass Filter.</td></tr>
<tr><td colspan="2">CTRL6</td><td colspan="2">Attitude Engine Settings: Address: 7 (0x07)</td></tr>
<tr><th>Bits</th><th>Name</th><th>Default</th><th>Description</th></tr>
<tr><td>7</td><td>sMoD</td><td>1’b0</td><td>0: Disables Motion on Demand.
1: Enables Motion on Demand. Requires sEN=1.</td></tr>
<tr><td>6:3</td><td>Reserved</td><td>4’b0</td><td></td></tr>
<tr><td>2:0</td><td>sODR<2:0></td><td>3’b0</td><td>Attitude Engine Output Data Rate (ODR)
<table>
<tr><th>Setting</th><th>ODR Rate (Hz)</th></tr>
<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(12)</td></tr>
<tr><td>111</td><td>NA</td></tr>
</table></td></tr>
</table>

Note:

12. This ODR should not be used if magnetometer is enabled

Table 26 Configuration Register Description (Continued)

Register Name			
CTRL7		**Enable Sensors. Register Address: 8 (0x08)**	
Bits	**Name**	**Default**	**Description**
7	syncSmpl	1'b0	This bit determines how data are read out of Sensor Data Output Registers of the FIS1100. 0: INT2 is placed into edge trigger mode: the Sensor Data Output Registers are updated at the Output Data Rate (ODR), and INT2 is pulsed at the ODR rate 1: INT2 is placed into level mode: the Sensor Data Output Registers are updated at the ODR until the STATUS0 register is read by the host. Reading STATUS0 causes the Sensor Data Output Registers register to stop updating and causes INT2 to be brought low. The Sensor Data Output Registers are not updated until the last byte has been read from them. Once this read is complete, the FIS1100 resumes updating the Sensor Data Output Registers and INT2 will be brought high when new data is available.
6:4	Reserved	3'b0	
3	sEN	1'b0	0: Disable AttitudeEngine orientation and velocity increment computation 1: Enable AttitudeEngine orientation and velocity increment computation
2	mEN	1'b0	0: Magnetometer placed in Standby or Power-down Mode. 1: Enable Magnetometer
1	gEN	1'b0	0: Gyroscope placed in Standby or Power-down Mode. 1: Enable Gyroscope.
0	aEN	1'b0	0: Accelerometer placed in Standby or Power-down Mode. 1: Enable Accelerometer.
CTRL8		**Reserved – Special Settings. Register Address: 9 (0x09)**	
Bits	**Name**	**Default**	**Description**
7:0	Reserved	0x00	Not Used
Register Name			
CTRL9		**Host Commands. Register Address: 10 (0x0A) (*See CTRL9 Section*)**	

5.5 Status and Count Registers

Table 27. Status and Time Stamp Registers

Register Name			
STATUS0		**Output Data Status Register Address: 22 (0x16)**	
Bits	**Name**	**Default**	**Description**
7	aeOVRN	1'b0	0: No overrun 1: AE data overrun. Previous data overwritten before it was read.
6	mOVRN	1'b0	0: No overrun 1: Magnetometer data overrun. Previous data overwritten before it was read.
5	gOVRN	1'b0	0: No overrun 1: Gyroscope data overrun. Previous data overwritten before it was read.
4	aOVRN	1'b0	0: No overrun 1: Accelerometer data overrun. Previous data overwritten before it was read.
3	aeDA	1'b0	AE new data available 0: No updates since last read. 1: New data available.
2	mDA	1'b0	Valid Magnetometer data available 0: Magnetometer data is NOT Valid 1: Valid Magnetometer data is available at every ODR. If Mag ODR is lower than accelerometer and gyroscope ODR previous valid Magnetometer data will be repeated until new data is available
1	gDA	1'b0	Gyroscope new data available 0: No updates since last read. 1: New data available.
0	aDA	1'b0	Accelerometer new data available 0: No updates since last read. 1: New data available.
STATUS1		**Miscellaneous Status. Register Address 23 (0x17)**	
Bits	**Name**	**Default**	**Description**
7:3	Reserved	5'b0	
2	WoM	1'b0	Wake on Motion detected
1	FIFO_rddy	1'b0	FIFO ready to be read.
0	CmdDone	1'b0	Flag command sent to CTRL9 register completed.
CNT_OUT		**Sample Time Stamp – Output Count. Register Address: 24 (0x18)**	
Bits	**Name**	**Default**	**Description**
7:0	CNT_OUT<7:0>	0x00	Sample time stamp. Count incremented by one for each sample (x, y, z data set) from sensor with highest ODR.

5.6 Sensor Data Output Registers

Table 28. Sensor Data Output Registers Description

Register Name			
A[X,Y,Z]_[H,L]		**Acceleration Output in 2's Complement. Register Address: 25 – 30, (0x19 – 0x1E)**	
Bits	**Name**	**Default**	**Description**
7:0	AX_L<7:0>	0x00	X-axis acceleration in two's complement. AX_L – lower 8 bits. AX_H – upper 8 bits.
7:0	AX_H<15:8>	0x00	
7:0	AY_L<7:0>	0x00	Y-axis acceleration in two's complement. AY_L – lower 8 bits. AY_H – upper 8 bits.
7:0	AY_H<15:8>	0x00	
7:0	AZ_L<7:0>	0x00	Z-axis acceleration in two's complement. AZ_L – lower 8 bits. AZ_H – upper 8 bits.
7:0	AZ_H<15:8>	0x00	
Register Name			
G[X,Y.Z]_[H,L]		**Angular Rate Output in 2's Complement. Register Address: 31 – 36 (0x1F – 0x24)**	
Bits	**Name**	**Default**	**Description**
7:0	GX_L<7:0>	0x00	X-axis angular acceleration in two's complement. GX_L – lower 8 bits. GX_H – upper 8 bits.
7:0	GX_H<15:8>	0x00	
7:0	GY_L<7:0>	0x00	Y-axis angular acceleration in two's complement. GY_L – lower 8 bits. GY_H – upper 8 bits.
7:0	GY_H<15:8>	0x00	
7:0	GZ_L<7:0>	0x00	Z-axis angular acceleration in two's complement. GZ_L – lower 8 bits. GZ_H – upper 8 bits.
7:0	GZ_H<15:8>	0x00	
Register Name			
M[X,Y,Z]_[H,L]		**Magnetometer Output in 2's Complement. Register Address: 37 - 42. (0x25 – 0x2A)**	
Bits	**Name**	**Default**	**Description**
7:0	MX_L<7:0>	0x00	X-axis magnetic field data in two's complement. MX_L – lower 8 bits. MX_H – upper 8 bits.
7:0	MX_H<15:8>	0x00	
7:0	MY_L<7:0>	0x00	Y-axis magnetic field data in two's complement. MY_L – lower 8 bits. MY_H – upper 8 bits.
7:0	MY_H<15:8>	0x00	
7:0	MZ_L<7:0>	0x00	Z-axis magnetic field data in two's complement. MZ_L – lower 8 bits. MZ_H – upper 8 bits.
7:0	MZ_H<15:8>	0x00	

Continued on the following page…

Table 28 Sensor Data Output Registers Description (Continued)

Register Name			
dQ[1,2,3,4]_[H,L]		**Quaternion Output in 2's Complement. Register Addresses: 45 – 52 (0x2D – 0x34)**	
Bits	**Name**	**Default**	**Description**
7:0	dQW_L<7:0>	0x00	Quaternion Increment QW in two's complement. dQW_L – lower 8 bits. dQW_H – upper 8 bits.
7:0	dQW_H<15:8>	0x00	
7:0	dQX_L<7:0>	0x00	Quaternion Increment QX in two's complement. dQX_L – lower 8 bits. dQX_H – upper 8 bits.
7:0	dQX_H<15:8>	0x00	
7:0	dQY_L<7:0>	0x00	Quaternion Increment QY in two's complement. dQY_L – lower 8 bits. dQY_H – upper 8 bits.
7:0	dQY_H<15:8>	0x00	
7:0	dQZ_L<7:0>	0x00	Quaternion Increment QZ in two's complement. dQZ_L – lower 8 bits. dQZ_H – upper 8 bits.
7:0	dQZ_H<15:8>	0x00	
dV[X,Y,Z]_[H,L]		**Delta Velocity Output in 2's Complement. Register Address: 53 – 58 (0x35– 0x3A)**	
Bits	**Name**	**Bits**	**Name**
7:0	dVX_L<7:0>	0x00	X-axis Velocity Increment in two's complement. dVX_L – lower 8 bits. dVX_H – upper 8 bits.
7:0	dVX_H<15:8>	0x00	
7:0	dVY_L<7:0>	0x00	Y-axis Velocity Increment in two's complement. dVY_L – lower 8 bits. dVY_H – upper 8 bits.
7:0	dVY_H<15:8>	0x00	
7:0	dVZ_L<7:0>	0x00	Z-axis Velocity Increment in two's complement. dVZ_L – lower 8 bits. dVZ_H – upper 8 bits.
7:0	dVZ_H<15:8>	0x00	
TEMP		**Temperature Output Data in 2's Complement. Register Address: 59. (0x3B)**	
Bits	**Name**	**Default**	**Description**
7:0	TEMP<7:0>	0x00	Temperature output in two's complement.
AE_REG1		**AttitudeEngine Register 1, Address: 60 (0x3C)**	
Bits	**Name**	**Default**	**Description**
7	MagBiasAck	1'b0	Acknowledgement that Mag Bias was updated during this time period.
6	GyroBiasAck	1'b0	Acknowledgement that Gyro Bias was updated during this time period.
5	wz_clip	1'b0	Gyroscope Z-axis data was clipped during the dQ calculation.
4	wy_clip	1'b0	Gyroscope Y-axis data was clipped during the dQ calculation.
3	wx_clip	1'b0	Gyroscope X-axis data was clipped during the dQ calculation.
2	az_clip	1'b0	Accelerometer Z-axis data was clipped during the dQ calculation.
1	ay_clip	1'b0	Accelerometer Y-axis data was clipped during the dQ calculation.
0	ax_clip	1'b0	Accelerometer X-axis data was clipped during the dQ calculation.

Table 28 Sensor Data Output Registers Description (Continued)

Register Name			
AE_REG2		**AttitudeEngine Register 2, Address: 61 (0x3D)**	
Bits	**Name**	**Default**	**Description**
7	Reserved	1'b0	
6	Reserved	1'b0	
5	mz_clip	1'b0	Mag Z-axis data was clipped.
4	my_clip	1'b0	Mag Y-axis data was clipped.
3	mx_clip	1'b0	Mag X-axis data was clipped.
2	dvz_of	1'b0	Velocity Increment over-flow along dvz.
1	dvy_of	1'b0	Velocity Increment over-flow along dvy.
0	dvx_of	1'b0	Velocity Increment over-flow along dvx.

Table 29. AttitudeEngine Modes and Output Table

Mode/Outputs		dQ	dV	M	CNT_OUT	Comments
AttitudeEngine in ODR Mode (Accelerometer and Gyroscope Enabled)						
CTRL6 Register	sEN=1	Quaternion Increment	Velocity Increment	No Data	AttitudeEngine Sample count	8-bit data. Count starts at 1, 256 count wraps to 0, i.e. Mod(256)
	sMoD=0					
CTRL7 Register	aEN=1					
	gEN=1					
	mEN=0					
AttitudeEngine in MoD mode (Accelerometer and Gyroscope enabled)						
CTRL6 Register	sEN=1	Quaternion Increment	Velocity Increment	No Data	Gyroscope Samples in Integration Window	8-bit data. Count starts at 1, 256 count wraps to 0, i.e. Mod(256)
	sMoD=1					
CTRL7 Register	aEN=1					
	gEN=1					
	mEN=0					
AttitudeEngine with Raw Magnetometer in ODR Mode (Accelerometer, Gyroscope and Magnetometer Enabled)						
CTRL6 Register	sEN=1	Quaternion Increment	Velocity Increment	Initial Raw Mag Data	AttitudeEngine Sample Count	8-bit data. Count starts at 1, 256 count wraps to 0, i.e. Mod(256)
	sMoD=0					
CTRL7 Register	aEN=1					
	gEN=1					
	mEN=1					

5.7 CTRL 9 Functionality (Executing Pre-defined Commands)

5.7.1 CTRL 9 Description

The protocol for executing predefined command from an external host processor on the FIS1100 is facilitated by the using an 8 bit register called Control 9 (Ctrl9) register on the FIS1100. The register is available to the host via the SPI /I^2C bus. The host writes a pre-defined value (Command) to the Ctrl9 register. The firmware of the FIS1100 evaluates this Command and if a match is found it executes a corresponding pre-defined function. Once the function has been executed the FIS1100 communicates the completion of this by raising INT1 interrupt. The host must acknowledge this by reading status1 register bit 0. This is the CmdDone bit. The FIS1100 pulls down the INT1 interrupt. This command presentation from the host to the FIS1100 and the subsequent execution and handshake between the host and FIS1000 will be referred to as the "*Ctrl9 protocol*".

There are three types of interactions between host and FIS1100 that follow the Ctrl9 protocol.

WCtrl9: The host needs to supply data to FIS1100 prior to the Ctrl9 protocol. (**Write – Ctrl9 Protocol**)

Ctrl9R: The host gets data from FIS1100 following the Ctrl9 protocol. (**Ctrl9 protocol – Read**)

Ctrl9: No data transaction is required prior to or following the Ctrl9 protocol. (**Ctrl9**).

Table 30. CAL Register Addresses

Register Name	Register Address	
	Dec	Hex
CAL1_H	11	0x0B
CAL1_L	12	0x0C
CAL2_H	13	0x0D
CAL2_L	14	0x0E
CAL3_H	15	0x0F
CAL3_L	16	0x10
CAL4_H	17	0x11
CAL4_L	18	0x12

5.7.2 WCtrl9 (Write – CTRL9 Protocol)

1. The host needs to provide the required data for this command to the FIS1100. The host typically does this by placing the data in a set of registers called the CAL buffer. Currently 8 CAL registers are used the following table provides the name and addresses of these registers.
2. Write Ctrl9 register 0x0a with the appropriate Command value.
3. The Device will raise INT1 and set Bit 0 in STATUS1 reg, to 1 once it have executed the appropriate function based on the command value.
4. The host must acknowledge this by reading STATUS1 register bit 0(CmdDone) which is reset to 0 on reading the register. Also INT1 is pulled low, completing the CTRL9 transaction.
5. If any data is expected from the device it will be available at this time. The location of the data is specified separately for each of the Commands.

5.7.3 Ctrl9R (CTRL9 Protocol - Read)

1. Write Ctrl9 register 0x0a with the appropriate Command value.
2. The Device will raise INT1 and set Bit 0 in STATUS1 register, to 1 once it have executed the appropriate function based on the command value.
3. The host must acknowledge this by reading STATUS1 register bit 0(CmdDone) which is reset to 0 on reading the register. Also INT1 is pulled low, completing CTRL9 transaction.
   Data is available from the device at this time. The location of the data is specified separately for each of the Commands.

5.7.4 Ctrl9 (CTRL9 Protocol Acknowledge)

1. Write Ctrl9 register 0x0a with the appropriate Command value.
2. The Device will raise INT1 and set Bit 0 in STATUS1 register, to 1 once it have executed the appropriate function based on the command value.
3. The host must acknowledge this by reading STATUS1 register bit 0(CmdDone) which is reset to 0 on reading the register. Also INT1 is pulled low, completing the CTRL9 transaction.

Table 31. CTRL9 Register CMND Values:

CMND Name	Ctrl9 Command Value	Protocol Type	Description
CTRL_CMD_RST_AHPF	0x03	Ctrl9	Reset Accelerometer High Pass Filter from Host
CTRL_CMD_RST_GHPF	0x04	Ctrl9	Reset Gyroscope High Pass Filter from Host
CTRL_CMD_AE_MAG_OFFSET	0x0b	WCtrl9	Set Magnetometer Offset from Host
CTRL_CMD_AE_GYRO_OFFSET	0x0e	WCtrl9	Set Gyroscope Offset from Host for most accurate computation of dQ by AE
CTRL_CMD_REQ_MoD	0x0c	Ctrl9R	Get AE Data from Device in MoD Mode
CTRL_CMD_HOST_ACCEL_OFFSET	0x12	WCtrl9	Set Accelerometer Offset from Host Dynamically
CTRL_CMD_HOST_GYRO_OFFSET	0x13	WCtrl9	Set Gyroscope Offset from Host Dynamically
CTRL_CMD_MAG_SKOR_X	0x06	WCtrl9	Set X Magnetometer, Offset and Skew from Host
CTRL_CMD_MAG_SKOR_Y	0x07	WCtrl9	Set Y Magnetometer, Offset and Skew from Host
CTRL_CMD_MAG_SKOR_Z	0x08	WCtrl9	Set Z Magnetometer, Offset and Skew from Host
CTRL_CMD_GET_TCYCLE	0x18	Ctrl9R	Get TCYCLE time from Device
CTRL_CMD_REQ_FIFO	0x0d	Ctrl9R	Get FIFO data from Device
CTRL_CMD_RST_FIFO	0x02	Ctrl9	Reset FIFO from Host
CTRL_CMD_WRITE_WoM_SETTING	0x19	WCtrl9	Setup and enable Wake on Motion

5.7.5 CTRL9 Commands in Detail

CTRL_CMD_RST_AHPF
This Ctrl9 command of writing 0x03 to the Ctrl9 register 0x0a allows the host to instruct the device to reset the accelerometer high-pass filter.

CTRL_CMD_RST_GHPF
This Ctrl9 command of writing 0x04 to the Ctrl9 register 0x0a allows the host to instruct the device to reset the gyroscope high-pass Filter.

CTRL_CMD_AE_MAG_OFFSET
This Ctrl9 Command is issued to configure the AE with specific magnetometer. The X,Y & Z magnetometer offset are provided to the device from the host. They are 16 bit each and programmed into the CAL1 to CAL3 registers respectively.

CTRL_CMD_AE_GYRO_OFFSET
This Ctrl9 Command is issued to configure the AE with specific Gyro offset data required for dQ computations. The X,Y & Z gyro bias specific for AE engine are provided to the device from the host. They are 16 bit each and programmed into the CAL1 to CAL3 registers respectively.

CTRL_CMD_REQ_MoD
This Ctrl9 command is used to retrieve motion data from the FIS1100 when Motion on Demand mode (MoD) is

enabled. To enable MoD the device should have the AttitudeEngine orientation enabled. This can be done by enabling the AttitudeEngine by setting Ctrl7 Bit 3 (sEN) to 1. Then the MoD mode can be enabled by setting Ctrl6 Bit 7 (sMoD) to 1. The CTRL_CMD_REQ_MoD command is then issued by writing 0x0c to Ctrl9 register 0x0a. This indicates to the FIS1100 that it is required to supply the motion data to the host. The device immediately makes available the orientation and velocity increments it has computed so far to the host by making it available at the output register 0x25 to 0x3d and raise the INT1 to indicate to the host that valid data is available.

CTRL_CMD_HOST_ACCEL_OFFSET
This Ctrl9 command is issued when the host wants to tune the accelerometer offset. The incremental value of the offset should be 16 bit 2's complement format with 5 bits for signed integer and 11 bits fraction. The value will be in CAL1 to CAL3 register for X, Y, and Z respectively. The new value provided here will be subtracted from the accelerometer base offset value. The new value is used for dynamic calibration. There will be up 3 ODR delay before this takes effect. Once the host has loaded the offset values in the CALx registers it needs to issue the Ctrl9 command by writing the 0x12 to Ctrl9 register 0x0a.

CTRL_CMD_HOST_GYRO_OFFSET
This Ctrl9 command is issued the host wants to tune the gyroscope offset. The incremental value of the offset should be 16 bit 2's complement format with 10 bits for signed integer and 6 bits fraction. The value is in CAL1 to CAL3 register for X, Y, and Z respectively. The new value provided here is subtracted from the gyroscope base offset value. The new value is used for dynamic calibration. There will be up 3 ODR delay before this takes effect. Once the host has loaded the offset values in the CALx registers it needs to issue the Ctrl9 command by writing the 0x13 to Ctrl9 register 0x0a.

CTRL_CMD_MAG_SKOR_X
This Ctrl9 Command is issued to configure the Magnetometer device calibration value. The X Offset, Scale and 2 skew values are provided to the device from the host. They are 16 bit each and programmed into the CAL1 to CAL4 registers. Once the host has loaded the offset values in the CALx registers it needs to issue the Ctrl9 command by writing the 0x06 to Ctrl9 register 0x0a.

CTRL_CMD_MAG_SKOR_Y
This Ctrl9 Command is issued to configure the magnetometer device with the calibration value. The Y offset, scale and 2 skew values are provided to the device from the host. They are 16 bit each and programmed into the CAL1 to CAL4 registers. Once the host has loaded the offset values in the CALx registers it needs to issue the Ctrl9 command by writing the 0x07 to Ctrl9 register 0x0a.

CTRL_CMD_MAG_SKOR_Z
This Ctrl9 Command is issued to configure the magnetometer device with the calibration value. The Z offset, scale and 2 skew values are provided to the device from the host. They are 16 bit each and programmed into the CAL1 to CAL4 registers. Once the host has loaded the offset values in the CALx registers it needs to issue the Ctrl9 command by writing the 0x08 to Ctrl9 register 0x0a.

CTRL_CMD_GET_TCYCLE
This Ctrl9 Command can only be issued when the FIS1100 is in the AE Mode. The Host can issue this command to get the exact time in milliseconds between samples (for example 1 Hz ODR may not be exactly 1 sec but could be 0.998 seconds). This command is issued by writing 0x18 to Ctrl9 register 0x0a.

CTRL_CMD_REQ_FIFO
This Ctrl9 Command issued when the host wants to get data from the FIFO. When the FIFO is enabled it will indicate to the host by asserting INT2 that a flag condition (like FIFO full) has been reached and data is available to be read by the host. This Command is issued by writing 0x0d to the Ctrl9 register 0x0a. The device will raise INT1 to indicate that it is ready for FIFO transaction. The host must read the STATUS1 register bit0 (CmdDone). At this point the host should set the FIFO_rd_mode Bit to 1 (Config FIFO register 0x19 BIT 7). The device will direct the FIFO data to the FIFO_DATA register 0x15 until the FIFO is empty. The host must now set FIFO_rd_mode to 0 which will cause the INT2 to be de-asserted.

CTRL_CMD_RST_FIFO
This Ctrl9 command of writing 0x02 to the Ctrl9 register 0x0a allows the host to instruct the device to reset the FIFO.

CTRL_CMD_WRITE_WOM_SETTING
This Ctrl9 Command is issued when the host wants to enable/modify the trigger thresholds or blanking interval of the Wake on Motion Feature of the device. Please refer to Section 8 for details for setting up this feature. Once the proper CALx registers are loaded with the appropriate data, the Command is issued by writing 0x19 to Ctrl9 register 0x0a.

5.8 Interrupts

The FIS1100 has two Interrupt lines; INT1 and INT2. INT1 is used as a general purpose interrupt. The details are described in the specific sections where INT1 / INT2 are used. The following provides a summary of the INT1 / INT2 usage.

5.8.1 Interrupt 1 (INT1)

The following summarizes the use of INT1:

Set high for ~4 ms after reset to indicate that the chip is ready for normal operation.

If any operation has set INT1 it will always be cleared by reading STATUS1 register

Used as part of the CTRL9 handshake protocol (*see section 0)*

During gyroscope OIS mode INT1 is driven by gyroscope ODR clock (~8 MHz). In this mode all normal INT1 functions are disabled.

When Wake on Motion (WoM) is enabled, INT1 can be selected to indicate WoM *(see section 8)*.

5.8.2 Interrupt 2 (INT2)

INT2 generally indicates the data availability. The following indicates when INT2 will be asserted.

Normal Operation (FIFO Bypass Mode)

In normal operation the accelerometer, gyroscope and magnetometer data is available in the output registers and the INT2 interrupt behaves as follows;

Rising edge indicates that data is available and will be cleared automatically after a short duration. It is the responsibility of the host to detect the rising edge and latch the data. Also note that the INT2 pulse width is dependent on the ODR and the sensor. It is not recommended to depend on the level to determine if INT2 has occurred. In this mode the SyncSmpl is disabled.

In the SyncSmpl mode (*refer to Table 22, Ctrl7 register bit 7)*.

The INT2 is asserted when data is available and remains asserted until the host reads STATUS0 register.

The device continues to refresh the output data until the STATUS0 register is read by host.

Once the STATUS0 is read by host the FIS1100 will de-assert INT2 and stop refreshing the output data.

Once the host detects INT2 has been de-asserted it can start reading the output data.

Once the last byte of data is read by the host (FIS1100 keeps track) the FIS1100 will start updating the output register and setup the next INT2 when data is available in the output registers.

FIFO Enabled Mode *(see section 7)*

When the FIFO is enabled in the FIFO mode (the mode bits in FIFO_CTRL register set to 1), INT2 is asserted when the FIFO is full or when the watermark is reached.

When the FIFO is enabled in the Stream Mode (the mode bits in FIFO_CTRL register set to 2), INT2 is asserted when watermark is reached but not when the FIFO is full because in the stream mode the FIFO will continue to fill by overwriting the oldest data in the FIFO.

INT2 is cleared in both FIFO mode and stream mode by clearing the FIFO_rd_mode bit in the FIFO_CTRL register. This is done as part of the CTRL9 command CTRL_CMD_REQ_FIFO *(see section 5.7.5 for details)*.

Accelerometer/Gyroscope Self Test Mode *(see section 9)*

INT2 is asserted to indicate availability of self-test data and is cleared by resetting the aST and gST bits in CTRL2 and CTRL3 registers respectively.

AE Mode

In AE Mode INT2 is asserted when data is available.

6 Operational Modes

The FIS1100 offers a large number of operational modes that may be used to operate the device in a power efficient manner. These modes are described in Table 32 and may be configured using the control (CTRL) registers.

Table 32. Operational Modes

Mode	Description	Suggested Configuration
Typical Sensor Modes		
Power-On Mode (Default on)	Similar to Ready Mode however the 1 MHz clock is turned on. The current in this mode is typically 15 µA. Note this mode is the default state upon initial power up.	CTRL1 sensorDisable = 0 CTRL7 aEN = 0, gEN = 0, mEN = 0, sEN=0. CTRL2 aODR=000
Ready Mode	Same as Power-On Mode except in this mode the 125 kHz clock is turned on. The current in this mode is typically 5 µA. Note to enter this mode requires host interaction to set CTRL2 aODR=1xxx.	CTRL1 sensorDisable =0 CTRL7 aEN = 0, gEN = 0, mEN = 0, sEN=0. CTRL2 aODR=1xx
Power-Down Mode	All FIS1100 functional blocks are switched off to minimize power consumption. Digital interfaces remain on allowing communication with the device. All configuration register values are preserved and output data register values are maintained. The current is this mode is typically 2 µA. Note host must initiate this mode by setting sensorDisable=1	CTRL1 sensorDisable =1 CTRL7 aEN = 0, gEN = 0, mEN = 0, sEN=0. CTRL2 aODR=xxx
Accelerometer Only Mode	Device configured as an accelerometer only.	CTRL7 aEN =1, gEN =0, mEN =0 CTRL2 aODR=xxx
Gyroscope Only Mode	Device configured as a gyroscope only.	CTRL7 aEN =0, gEN =1, mEN =0 CTRL2 aODR=000
Magnetometer Only Mode	Device configured as a magnetometer only.	CTRL7 aEN =0, gEN =0, mEN =1 CTRL2 aODR=000
Stabilized Compass Mode (Virtual Gyroscope or A+M)	Device configured as an accelerometer and magnetometer combination only. Device can be used as a (stabilized) compass.	CTRL7 aEN =1, gEN =0, mEN =1 CTRL2 aODR=0xx
IMU (A+G) Mode	Device configured as an Inertial Measurement Unit, i.e. an accelerometer and gyroscope combination sensor.	CTRL7 aEN =1, gEN =1, mEN =0 CTRL2 aODR=0xx
9DOF (A+G+M) Mode	Accelerometer and gyroscope are enabled and combined with an external magnetometer and the device can be used as a 9D orientation sensor (Attitude and Heading Reference).	CTRL7 aEN =1, gEN =1, mEN =1 CTRL2 aODR=0xx
Wake on Motion Mode	Very low power mode used to wake-up the host by providing an interrupt upon detection of device motion.	CTRL7 aEN =1, gEN =0, mEN =0 CTRL2 aODR = 111 WoM Mode enabled (ref. WoM section)
Gyroscope Warm-Start ("Snooze") Mode	This mode turns on the gyroscope drive and shuts off the sense path of the gyroscope. This mode can be used as a low-power mode to quickly turn on the gyroscope without needing to wake-up the gyroscope from deep sleep	CTRL3 gODR = 100 CTRL2 aODR=0xx
Gyroscope OIS Mode	In this mode, the gyroscope operates in a high data rate optical image stability or OIS mode. Data is transmitted through the SPI interface at high data rates 8.1 kHz, a special low group-delay low pass filter can be enabled on the gyroscope which extends the bandwidth to 350 Hz. The SPI bus can be operated using a 3-wire or 4-wire interface by setting the CTRL1 SIM bit.	CTRL3 gODR = 110 CTRL2 aODR=0xx

Table 32. Operational Modes (Continued)

Attitude Engine Modes		
6DOF Sensor Fusion Mode	Enables the Attitude Engine. Note that velocity and orientation (quaternion) increments will be output rather than calibrated sensor values	CTRL7 aEN = 1, gEN = 1, sEN = 1 CTRL2 aODR=0xx
9DOF Sensor Fusion Mode	Enables the AttitudeEngine. Note that velocity and orientation (quaternion) increments and magnetic field values will be output rather than calibrated sensor values	CTRL7 aEN = 1, gEN = 1, sEN = 1, mEN = 1 CTRL4 configure magnetometer as needed CTRL2 aODR=0xx
Motion On Demand Mode	Allows Host to sample AttitudeEngine data asynchronously by polling	CTRL7 aEN = 1, gEN = 1, sEN = 1 CTRL6 sMOD = 1 CTRL2 aODR=0xx

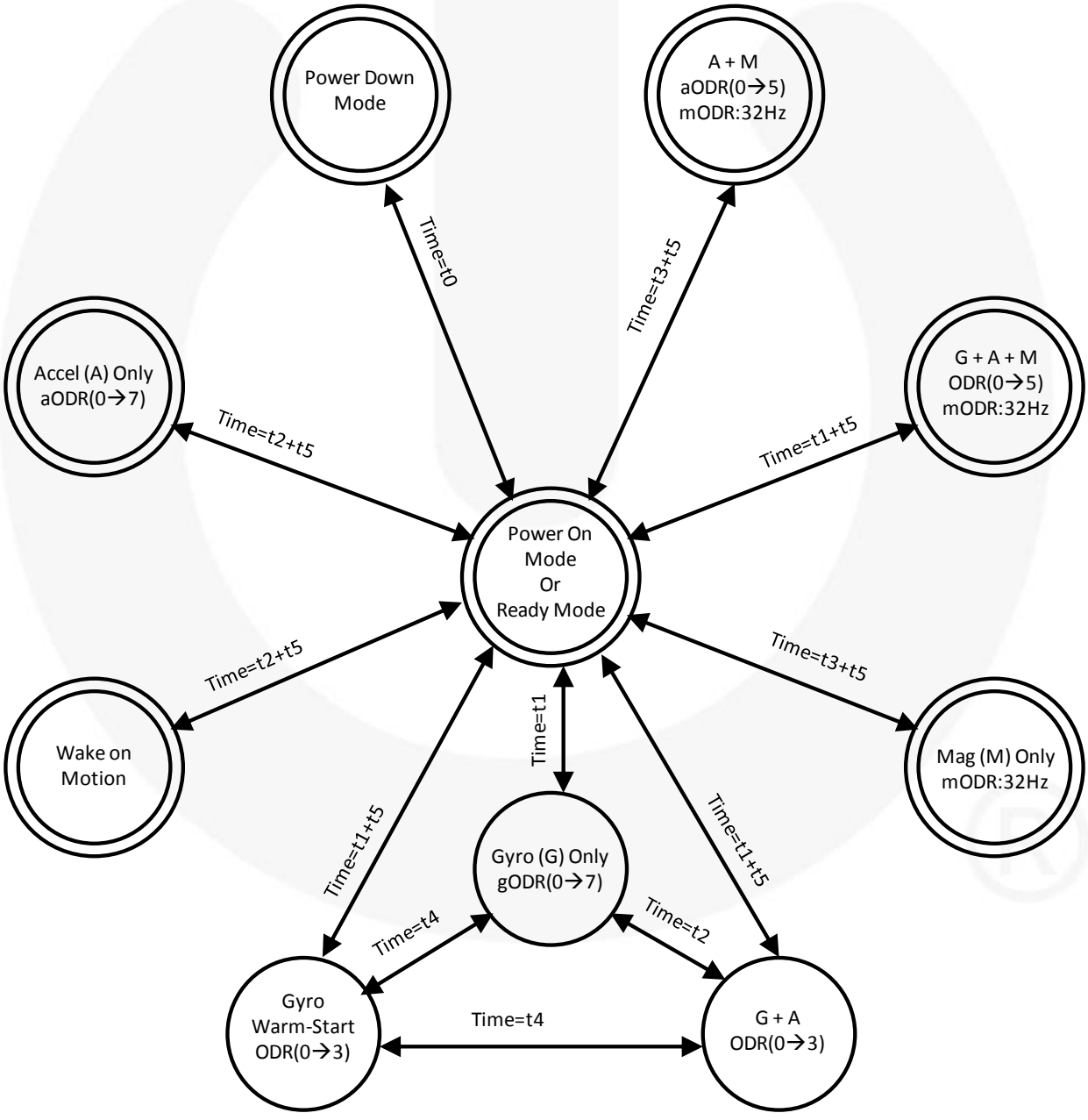


Figure 8. Operation Mode Transition Diagram

6.1 General Mode Transitioning

From a Power Down state or "**Power Down Mode**" the part will enter the "**Ready Mode**" from there the sensor can be configured in various different modes, as described in Table 30. In Figure 8, a diagram is provided to help illustrate how to handle transitioning the sensor from any mode to another. The modes that are depicted with a double circle specifically identifies that to exit that mode the part must transition through the "**Ready Mode**" prior to entering any other mode. To show and enforce this relationship, the "**Ready Mode**" is also shown with a double circle.

6.2 Transition Times

The time it takes for data to be present will vary and does depend on which mode you have selected. For example, the time it takes for establish data for the accelerometer is for less than any mode that involves the gyroscope. In this device there are six different times associated with the different mode transitions. The times t1, t2, t3 and t4, are defined as the time it takes for the INT2 to go high and data to be present. The time, t5 is the time it takes and to have a correct representation of the inertial state. This time is variable and is associated with the user selected ODR. We have defined t5=(3/ODR) to generally represent that time. The times are specifically denoted as t0, t1, t2, t3, t4 and t5 on Figure 8.

- Time t0 is the system boot time of 1 second. This only needs to be done once upon power up or whenever a RST is issued which should not be done unless the intent is to have the device to go through its entire boot sequence.
- Time t1 is the gyroscope wakeup time from cold-start which is typically 60 ms
- Time t2 is the accelerometer wakeup time which is typically 3 ms
- Time t3 is the magnetometer wakeup time which is typically 12 ms
- Time t4 is the gyroscope wakeup time from a gyroscope snooze or warm-start state which is typically 5 ms.
- Time t5 is defined as 3/ODR, where ODR is the output data rate in Hertz.

7 FIFO Description

7.1 Using the FIFO

The FIS1100 contains a programmable 1536 byte data buffer which can be used as a FIFO buffer. The FIFO's operating mode and configuration are set via the FIFO configuration registers. FIFO data may consist of gyroscope, accelerometer and magnetometer data and is accessible via the serial interfaces. The FIFO also supports burst reads. The host must complete its burst read prior to the next sensor data period. This time period is defined by the ODR selected. Depending on how many sensors are enabled, the host will need to read increments of 6, 12 or 18 bytes, corresponding to one, two and three sensors active at the same time. This feature helps reduce overall system power consumption by enabling the host processor to read and process the sensor data in bursts and then enter a low-power mode. The interrupt function may be used to alert when new data is available.

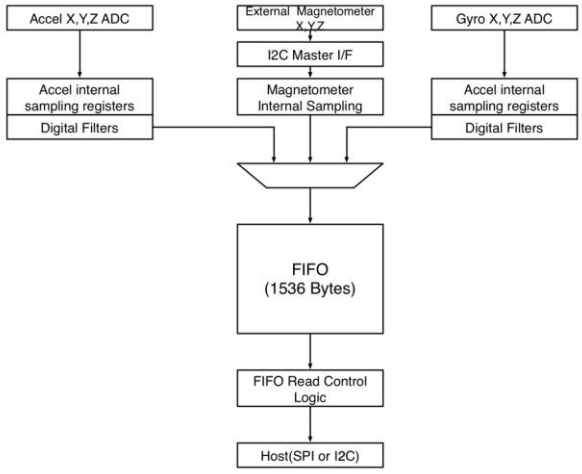


Figure 9. FIFO Data Flow

The FIFO size is configured using the FIFO configuration registers. When the FIFO is enabled for 2 or greater sensors, as is true for all modes that have multiple sensors active, they must be set at same the ODR.

The FIFO is read through the I2C/SPI interface by reading FIFO_DATA. Any time the Output Registers are read, data is erased from the FIFO memory.

The FIFO has multiple operating modes: Bypass mode, FIFO mode, streaming mode and streaming-to-FIFO mode. The operating modes are set using the mode<1:0> bits in FIFO_CTRL.

Enabling FIFO

The FIFO is configured by writing to the FIFO_CTRL register and is enabled after the accelerometer and/or gyroscope are enabled. When the FIFO watermark level is hit, pin INT2 is asserted

Reading Sensor Data from FIFO

Sensor data is read from the FIFO through the following command sequence. *(For additional information, see the Section 5.7.5 for CTRL9 description).*

- Request access to FIFO data buffer by sending CTRL9 command 0xd.
- Set FIFO_rd_mode bit in FIFO_CTRL bit 7.
- Read FIFO_DATA register to empty the FIFO.
- After FIFO is emptied, set fifoRdMode to 0.

Note that when only the accelerometer or gyroscope is enabled, the sensor data format at the host interface is:

AX_L[0] →AX_H[0]] →AY_L[0] →AY_H[0] →AZ_L [0] →AZ_H[0] →AX_L[1] →…

When 2 sensors are enabled, the sensor data format is:

AX_L[0] →AX_H[0] →AY_L[0] →AY_H[0] →

AZ_L[0] →AZ_H[0] →GX_L[0] →GX_H[0] →

GY_L[0] →GY_H[0] →GZ_L[0] →GZ_H[0] →

AX_L[1] →AX_H[1] →…

When 3 sensors are enabled, the sequence will be extended to include the 6 corresponding magnetometer samples.

Bypass Mode

In bypass mode, the FIFO is not operational and, therefore, remains empty. Sampled data from the gyroscope and/or A\accelerometer are stored directly in the Output Registers. When new data is available, the old data is overwritten.

FIFO Mode

In FIFO mode, data from the sensors are stored in the FIFO. The watermark interrupt, if enabled, is triggered when the FIFO is filled to the level specified by the value of wtm<1:0> in the FIFO_CTRL register. The FIFO continues filling until it is full. When full, the FIFO stops collecting data from the input channels. Data collection restarts when FIFO is emptied.

Streaming Mode

In streaming mode, data from the gyroscope and accelerometer are stored in the FIFO. A watermark interrupt can be enabled and set as in FIFO mode. The FIFO continues filling until full. In this mode, the FIFO acts as a circular buffer, when full, the FIFO discards the older data as the new data arrives. Programmable watermark level events can be enabled to generate dedicated interrupts on the DRDY/INT2 pin (configured through CTRL6 and CTRL7).

7.2 FIFO Register Description

Table 33. FIFO Registers Description

Register Name			
FIFO_CTRL		**Configure FIFO. Register Address: 19 (0x13)**	
Bits	**Name**	**Default**	**Description**
7	FIFO_rd_mode	1'b0	0: Disable FIFO read via FIFO_DATA register. 1: Enable FIFO read via FIFO_DATA register.
6	Reserved	1'b0	Reserved
5:4	wtm<1:0>	2'b0	Set Watermark level. 00 – Do not use. 01 – Set watermark at ¼ of FIFO size. 10 – Set watermark at ½ of FIFO size. 11 – Set watermark at ¾ of FIFO size.
3:2	size<1:0>	2'b0	Set FIFO size. 00 – Set FIFO size at 16 samples. 01 – Set FIFO size at 32 samples. 10 – Set FIFO size at 64 samples. 11 – Set FIFO size at 128 samples (Two Sensors only).
1:0	mode<1:0>	1'b0	Set FIFO Mode. 00 – BYPASS Mode (FIFO disable). 01 – FIFO Mode. 10 – Stream Mode. 11 – Not Used
FIFO_DATA		**FIFO Data Register. Register Address: 20 (0x14)**	
Bits	**Name**	**Default**	**Description**
7:0	data<7:0>	8'b0	Read this register to read sensor data out of FIFO.
FIFO_STATUS		**FIFO Status. Register Address: 21 (0x15)**	
Bits	**Name**	**Default**	**Description**
7	resv	1'b0	Reserved
6	wtm	1'b0	Watermark level hit.
5	overflow	1'b0	FIFO over-flow condition.
4	not_empty	1'b0	FIFO not empty.
3:0	fss<3:0>	4'b0	Indicates FIFO storage level. See FIFO Storage Level Indicator fss <3:0> description

Table 34. FIFO Storage Level Indicator fss<3:0> Description

fss<3:0> Description		Comments	
		The FIFO storage level is indicated by fss<3:0> as noted FIFO register description. The value of fss<3:0> represents a coarse value of the FIFO storage level. Coarseness or granularity varies based on the TOTAL FIFO size. Total FIFO size is the sum of the Accelerometer, Gyroscope and Magnetometer FIFO sizes. Each sample for each sensor X,Y,Z takes 6 bytes in the FIFO. For example, with 2 sensors active and a FIFO size=[11], the FIFO total sample size is 256 and in bytes is 6*128*2 bytes or 1536 bytes. The total FIFO size is represents the number of samples. The Fss value represents a coarse sample count.	
FIFO Size <1:0>	**No. of Sensors (A, G, M)**	**Total FIFO Sample Size**	**Fss Granularity**
00	1	16	2
01	1	32	4
00	2		
00	3	48	4
10	1	64	8
01	2		
01	3	96	8
11	1	128	16
10	2		
10	3	192	16
11	2	256	32

8 Wake On Motion (WoM)

8.1 Wake on Motion Introduction

The purpose of the Wake on Motion (WoM) functionality is to allow a system to enter a low power sleep state while the system is static and then automatically awaken when moved by the user. In this mode the system should use very little power, yet still respond quickly to user interaction by motion.

It is assumed that the system host processor is responsible for configuring the FIS1100 correctly to place it into Wake on Motion mode, and that the system host processor will reconfigure the FIS1100 as necessary following a WoM interrupt.

Wake on Motion shall be configured through the CTRL9 command interface.

Table 35. Registers used for WoM

Register (bits)	Function
CAL1L (0:7)	WoM Threshold value in absolute value in (1/1024), 1mg/LSB, resolution 0x00 must be used to indicate that WoM mode be disabled
CAL1H (6)	WoM interrupt select 1 – INT2 0 – INT1
CAL1H (0:5)	Interrupt blanking time in accelerometer samples

The threshold value is configurable to make the amount of motion required to wake the device configurable by the host application. The special threshold value of 0x00 can be used to indicate that WoM mode be disabled, returning interrupt pins to their normal functionality.

The interrupt initial value and pin are selectable to make it easy for system integrators to use the WoM motion mode to wake the host processor from its deepest sleep level. Using the lowest power mode on many micro-controllers require the use of special wake up pins that may have only a single polarity setting, and may not be useable for other specialist purposes such as timer captures.

The interrupt blanking time is a number of accelerometer samples to ignore on starting WoM mode so that no spurious wake-up events are generated by startup transients.

8.2 Accelerometer Configuration

The precise accelerometer configuration is left to the driver/application to configure. This means that the host processor can configure different sample rates or full-scale range. By selecting a different sample rate allows for additional tuning of the WoM responsiveness.

8.3 Wake on Motion Event

When a Wake on Motion event is detected the FIS1100 will set bit2 (WoM) in the STATUS1 register. Reading STATUS1 should clear the WoM bit. Clearing the WoM bit in STATUS1 should reset the INT line to the value given in by the WoM interrupt initial value.

For each WoM event the state of the selected INT line is be toggled. This ensures that while the user keeps moving the system the host processor will receive wakeup interrupts whether it uses high, low, positive or negative edge interrupts.

The FIS1100 stays in WoM mode until commanded to enter a new mode by the host processor. Additional WoM events may thus be generated.

8.4 Configuration Procedure

The host processor shall be responsible for all configurations necessary to put the FIS1100 in WoM mode. The specific sequence of operations performed by the host processor to enable WoM is described in Figure 10.

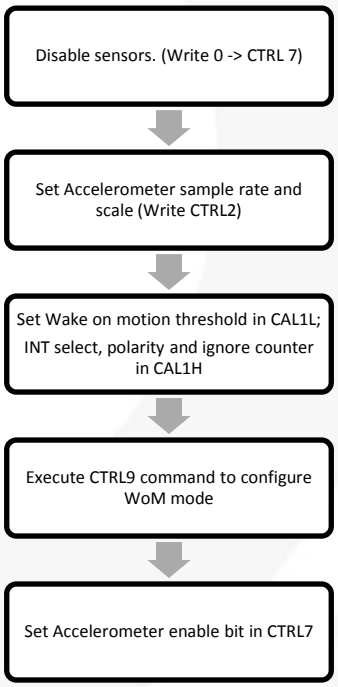


Figure 10. WoM Configuration Commands and Sequence

The WoM bit is cleared on setting the WoM threshold to a non-zero value, and the interrupt pins configured according to the settings. Special care has been taken that the WoM interrupt does not activate due to any transients when the accelerometer is first enabled. An interrupt blanking time is included that prevents such spurious interrupts to propagate

8.5 Wake on Motion Control Registers

The WoM configuration shall be controlled by values written to the CAL registers in Table 35.

8.6 Exiting Wake on Motion Mode

To exit WoM mode the host processor must first clear CTRL7 to disable all sensors, and then write a threshold value of 0x00 to the WoM threshold register and execute the WoM configuration CTRL9 command. On doing this the interrupt pins shall return to their normal function. After zeroing the WoM threshold register the host processor may proceed to reconfigure the FIS1100 as normal, as in the case following a reset event.

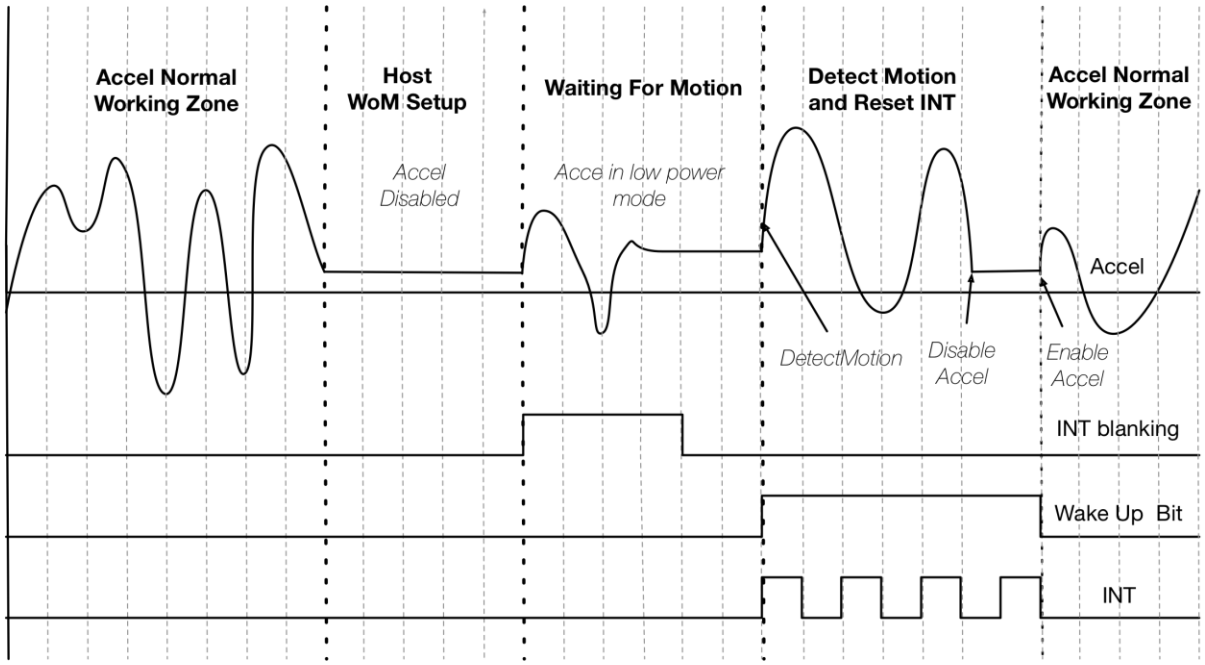


Figure 11. WoM Example Diagram

9 Performing Device Self Test

9.1 Accelerometer Self Test

The accelerometer Self Test is used to determine if the accelerometer is functional and working within acceptable parameters. It does this by using an electrostatic force to actuate the inputs of each axis, AX, AY, and AZ. If the accelerometer mechanical structure responds to this input stimulus by sensing 50 mg or greater we can conclude that the accelerometer is functional. The accelerometer Self Test data is available to be read at registers dVX_L, dVX_H, dVY_L, dVY_H, dVZ_L and dVZ_H. The Host can initiate the Self Test at anytime by using the following procedure.

Procedure for accelerometer Self Test:

1. Set Ctrl7 register to 0x00;
2. Set Ctrl2 register to 0x20 this enable a ST (accelerometer Self Test enable bit).
3. Wait for the device to drive INT2 high.
4. Read DVX_L, DVX_H, DVY_ L, DVY_H, DVZ_L & DVZ_H registers for the Self Test data.
5. Set Ctrl2 resister to 0x00 to disable aST.
6. INT2 will be pulled low by the FIS1100.
7. Based on the data the host processor determines if the accelerometer response is greater or equal to 50 mg. Note the full scale setting is set to ±2 g.
8. If “yes”, then the accelerometer Self Test has passed.

9.2 Gyroscope Self Test

The gyroscope Self Test is used to determine if the gyroscope is functional and working within acceptable parameters. It does this by applying an electrostatic force to actuate each of the three X, Y, and Z axis of the gyroscope and measures the mechanical response on the corresponding X, Y, and Z axis. If the equivalent magnitude of the output is greater than 300 dps for each axis then we can assume that the gyroscope is functional within acceptable parameters. The gyroscope Self Test data is available to be read at output registers dVX_L, dVX_H, dVY_L, dVY_H, dVZ_L & dVZ_H.

The Host can initiate the self test at anytime by using the following procedure.

Procedure for gyroscope Self Test:

1. Set Ctrl7 reg. to 0x00;
2. Set Ctrl3 reg. to 0x40 this enable gST (gyroscope Self Test enable bit).
3. Wait for the device to drive INT2 high.
4. Read DVX_L, DVX_H, DVY_ L, DVY_H, DVZ_L & DVZ_H registers for the self test Data.
5. Set Ctrl3 res to 0x00 to disable gST.
6. INT2 will be pulled low by device.
7. Based on the data the host processor determines if the gyroscope response is greater or equal to 300 dps. Note the full scale setting is set to ±2560 dps.
8. If “yes” then the gyroscope Self Test has passed.

10 Magnetometer Setup

10.1 Magnetometer Description

The FIS1100 provides an I^2C master interface to connect with an external magnetometer. Currently the FIS1100 offers support for an AKM AK8975 magnetometer *(see Figure 3)*. The FIS1100 supports the AK8975 in the 31.25 Hz ODR mode only.

The FIS1100 is used to:

1. Calibrate the magnetometer data as per the equations described below and to time align magnetometer samples with the gyroscope and accelerometer samples.
2. When FIS1100 is used in the AE mode the magnetometer data along with the accelerometer and gyroscope data is fused to generate the AE data and available to the host at a significantly reduced ODR without loss of accuracy.

10.2 Magnetometer Calibration

The raw data from the magnetometer is calibrated as per the follow equations.

$$M_x = S_{TG}(S_xM_{xr} + O_x + K_{xy}M_{yr} + K_{xz}M_{zr})$$

$$M_y = S_{TG}(S_yM_{yr} + O_y + K_{yx}M_{xr} + K_{yz}M_{zr})$$

$$M_z = S_{TG}(S_zM_{zr} + O_z + K_{zx}M_{xr} + K_{zy}M_{yr})$$

where
M_{xr}, M_{yr}, M_{zr} are the values available un-calibrated (raw) magnetometer values from AK8975.

M_x, M_y, M_z are the calibrated values available in the magnetometer output register.

S_x ,S_y, S_z are the scale factor
O_x,O_y, O_z are the offsets
K_{xy}, K_{xz}, y and z cross axis scale factor for M_x
K_{yx}, K_{yz}, x and z cross axis scale factor for M_y
K_{zx}, K_{zy}, x and y cross axis scale factor for M_z

S_{TG} is a conversion factor to convert from micro-Tesla format to Gauss format. S_{TG} = 1.536

The S, O, and K values are provided by the user as the SKOR values

SKOR_X -> {Sx, Ox, Kxy, Kxz}
SKOR_Y -> {Sy, Oy, Kyx, Kyz}
SKOR_Z -> {Sz, Oz, Kzx, Kzy}

Table 36. Magnetometer Scale and Sensitivity Settings

SKOR	Scale Setting	Sensitivity	Unit
Scale	+8	8192	lsb/unit
Offset	±16	2048	lsb/unit
Skew1	±4	8192	lsb/unit
Skew2	±4	8192	lsb/unit

11 Host Serial Interface

FIS1100 Host Serial Interface supports I2C and SPI slave interfaces. For SPI, it supports both 3-wire and 4-wire modes. The basic timing characteristics for each interface are described below. Through the FIS1100 Host Serial Interface, the host can access, setup and control the FIS1100 Configuration Registers *(see Table 26).*

11.1 Serial Peripheral Interface (SPI)

FIS1100 supports both 3- and 4-wire modes in the SPI slave interface. The SPI 4-wire mode uses two control lines (CS, SPC) and two data lines (SDI, SDO). The SPI 3-wire mode uses the same control lines and one bi-directional data line (SDIO). The SDI /SDIO pin is used for both 3- and 4-wire modes and is configured based on mode selected. The SPI interface has been validated at 10 MHz and the timing parameters are measured at that interface frequency.

SPI 3- or 4-wire modes are configured by writing to bit-7 of CTRL1 register. 3-wire mode is selected when bit-7 is 1. The default configuration is 4-wire mode, i.e. bit-7 of CTRL1 is 1.

Figure 12 shows the SPI address and data formats.

SPI Features

- Data is latched on the rising edge of the clock
- Data should change on falling edge of clock
- Maximum frequency is 10 MHz
- Data is delivered MSB first
- Support single read/writes and multi cycle (Burst) read/writes***. NOTE:*** *burst writes to Configuration registers are NOT supported. These registers should be written in single cycle mode only.*
- Supports 6-bit Address format and 8-bit data format

Address Format

MSB							LSB
read	inc	A5	A4	A3	A2	A1	A0

read — indicates a read(1) or a write(0) transaction relative to the SPI master

inc — data from consecutive incremental address(1) during burst read/write cycles

Data Format

MSB							LSB
D7	D6	D5	D4	D3	D2	D1	D0

Figure 12. SPI Address and Data Form

In a single cycle read or write transaction, the inc address bit should be set to 0. During a burst read, the master indicates to the slave that the master expects data from the incremented address locations during a read by setting inc to 1. During a burst write, if the inc bit is set to 1, the master indicates to the slave that it is providing data from incremented address locations. Similarly, when the inc bit is set to 0, the master indicates that data is expected from or is available from the same address respectively during a burst read or write cycle.

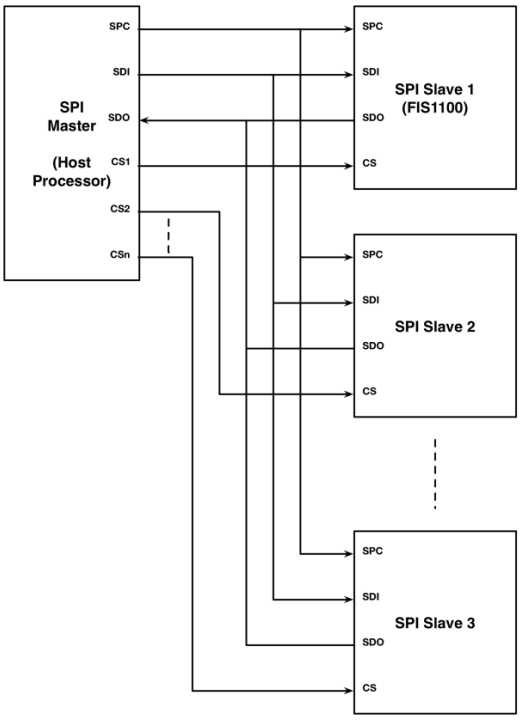


Figure 13. Typical SPI 4-Wire Multi-Slave

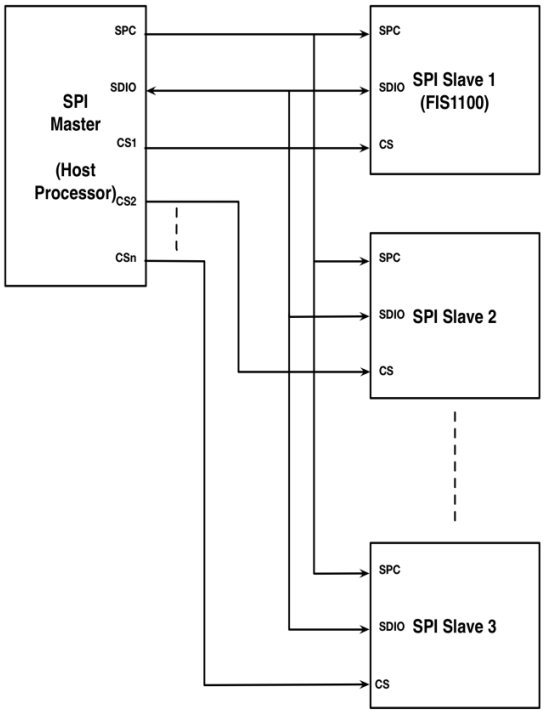


Figure 14. Typical SPI 3-Wire Multi-Slave

In a typical SPI Master/Slave configuration the SPI master shares the SPI clock (SPC), the serial data input (SDI), and the Serial Data Output (SDO) with all the connected SPI slaves devices. Unique Chip Select (CS) lines connect each SPI slave to the master.

Figure 13 and Figure 14 show typical multi-slave 4- and 3-wire configurations. The primary difference between the two configurations is that the SDI and SDO lines are replaced by the bi-directional SDIO line. The SDIO line is driven by the master with both address and data when it is configured for write mode. During read mode, the SDIO line is driven by the master with the address, and subsequently driven by the "addressed" slave with data.

Figure 15 and Figure 16 illustrate the waveforms for both 4-wire and 3-wire SPI read and write transactions. Note that CS is active during the entire transaction.

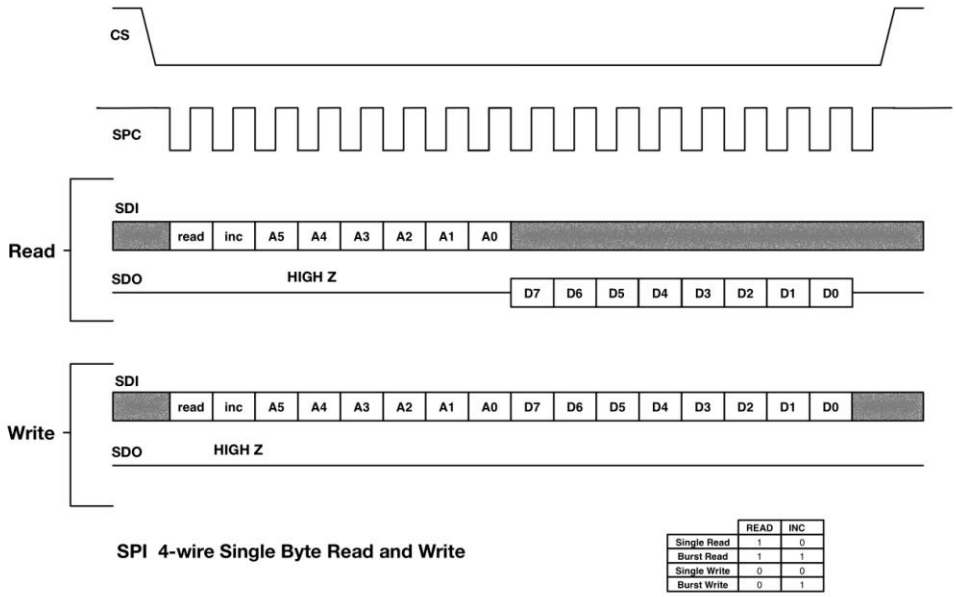


Figure 15. SPI 4-Wire Single Byte Read and Write

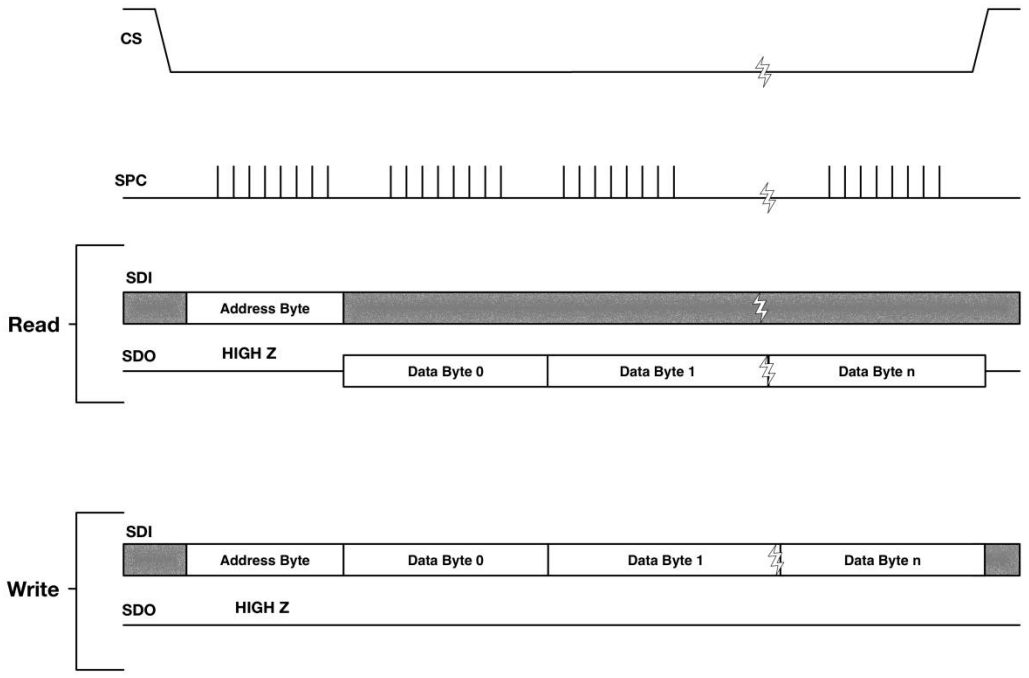
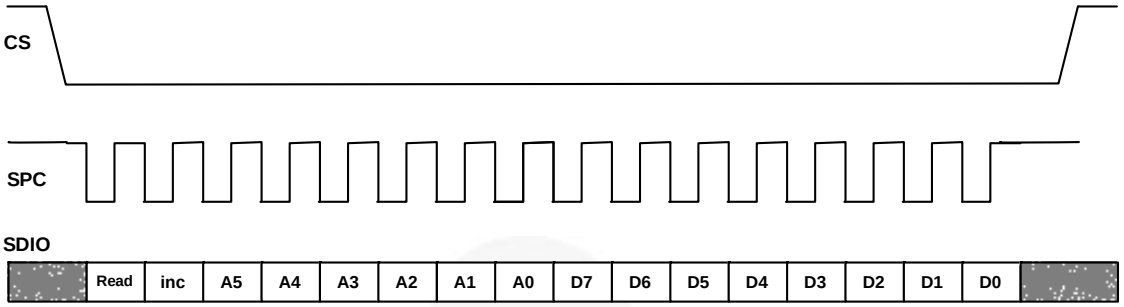


Figure 16. SPI 4-Wire Multi-Byte Read and Write Transactions



SPI 3-wire Single Byte Read and Write

	READ	INC
Single Read	1	0
Burst Read	1	1
Single Write	0	0
Burst Write	0	1

Figure 17. SPI 3-Wire Single Byte Read and Write Transactions

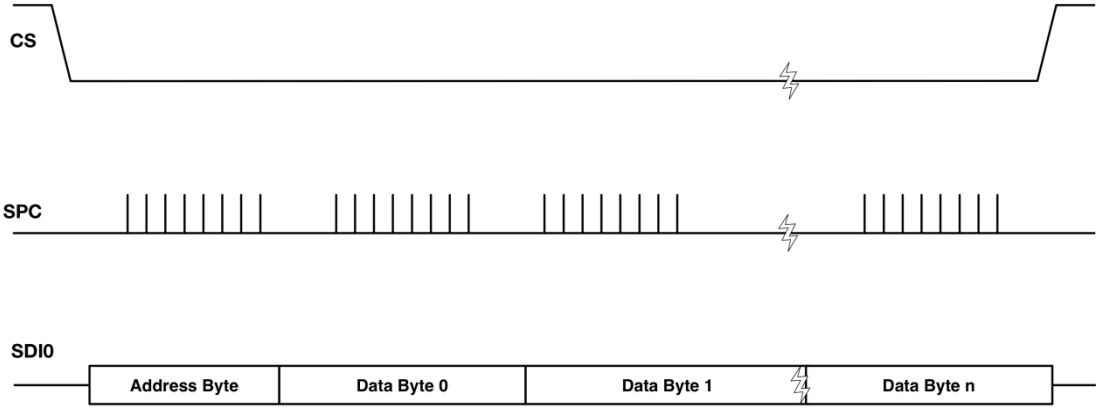


Figure 18. SPI 3-Wire Multi-Byte Read and Write Transactions

11.1.1 SPI Timing Characteristics

The typical operating conditions for the SPI interface are provided in Table 37

V_{DDd} = 1.8 V, T = 25°C unless otherwise noted.

Table 37. SPI Interface Timing Characteristics

Symbol	Parameter	Min.	Max.	Unit
t_{SPC}	SPI Clock Cycle	100		ns
f_{SPC}	SPI Clock Frequency		10	MHz
ts_{CS}	CS Setup Time	6		ns
th_{CS}	CS Hold Time	8		ns
ts_{SDI}	SDI Input Setup Time	5		ns
th_{SDI}	SDI Input Hold Time	15		ns
tv_{SDO}	SDO Time for Valid Output		50	ns
th_{SDO}	SDO Hold Time for Output	9		ns
td_{SDO}	SDO Disable Time for Output		50	ns
ts_{SDIO}	SDIO Address Setup Time	5		ns
th_{SDIO}	SDIO Address Hold Time	15		ns
tv_{SDIO}	SDIO Time for Valid Data		50	ns
tcz_{SDIO}	SDIO Time from SPC to High Z		50	ns
tz_{SDIO}	SDIO Time from CS to High Z		50	ns

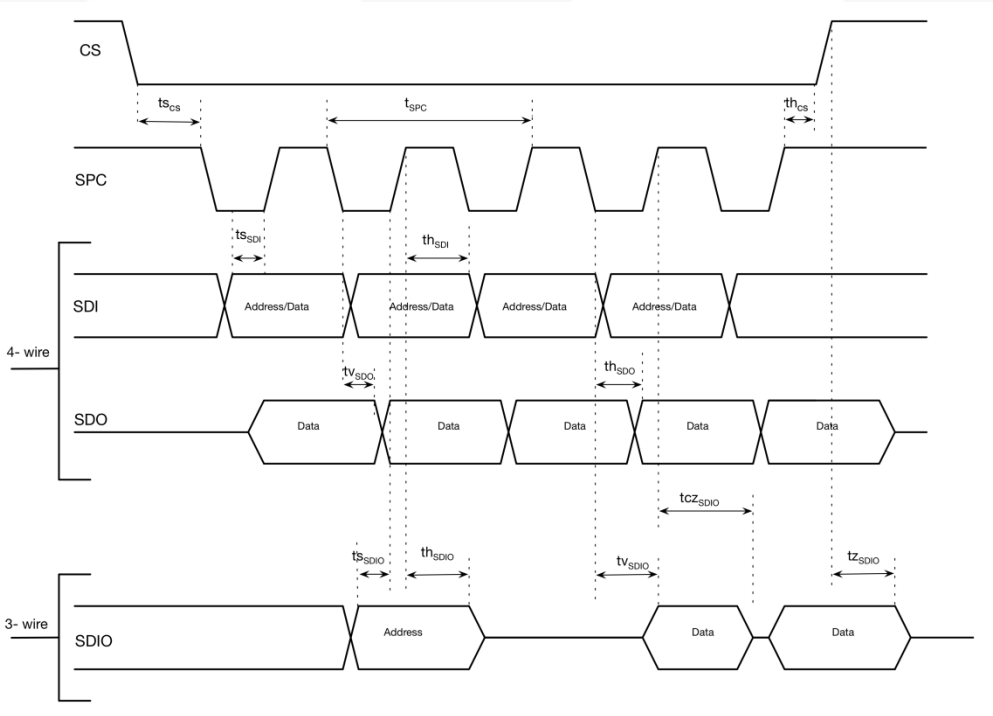


Figure 19. Timing Characteristics for SPI 3- and 4-Wire Interfaces

11.2 I²C Interface

Table 38 provides the I²C interface timing characteristics while Figure 20 and Figure 21 illustrate the I²C timing for both fast and standard modes respectively.

During the slave device selection phase, the I²C master supplies the 7-bit I²C slave device address to enable the FIS1100. The 7-bit device address for the FIS1100 is 0x6a (0b1101010) if SA0 is left unconnected, internally there is a weak pull-down of 200 kΩ thereby selecting bit-0=0. In case of a slave device ID conflict, SA0 may be used to change bit-0 of the device address. When SA0 is pulled up externally, the 7-bit device address becomes 0x6b (0b1101011).

During the slave register address phase bit-7 of the address is used to enable auto-increment of the target address. When bit-7 is set to 1 the target address is automatically incremented by one.

For additional technical details about the I²C standard, such as pull-up resistor sizing the user is referred to "UM10204 I²C-bus specification and user manual" published by NXP B.V.

Table 38. I2C Timing Characteristics

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
f_{SCL}	SCL Clock Frequency	Standard Mode			100	kHz
		Fast Mode			400	
t_{BUF}	Bus-Free Time between STOP and START Conditions	Standard Mode		4700		ns
		Fast Mode		1300		
$t_{HD;STA}$	START or Repeated START Hold Time	Standard Mode		4000		ns
		Fast Mode		600		
t_{LOW}	SCL LOW Period	Standard Mode		4700		ns
		Fast Mode		1300		
t_{HIGH}	SCL HIGH Period	Standard Mode		4000		ns
		Fast Mode		600		
$t_{SU;STA}$	Repeated START Setup Time	Standard Mode		4700		ns
		Fast Mode		600		
$t_{SU;DAT}$	Data Setup Time	Standard Mode		250		ns
		Fast Mode		100		
$t_{HD;DAT}$	Data Hold Time	Standard Mode	0		3450	ns
		Fast Mode	0		900	
t_{RCL}, t_R	SCL Rise Time	Standard Mode			1000	ns
		Fast Mode	$20 + 0.1 * C_B$ (13)		300	
t_{FCL}	SCL Fall Time	Standard Mode			300	ns
		Fast Mode	$20 + 0.1 * C_B$ (13)		300	
t_{RDA}, t_{RCL1}	SDA Rise Time. Rise Time of SCL after a Repeated START Condition and after ACK Bit	Standard Mode			1000	ns
		Fast Mode	$20 + 0.1 * C_B$ (13)		300	
t_{FDA}	SDA Fall Time	Standard Mode			300	ns
		Fast Mode	$20 + 0.1 * C_B$ (13)		300	
$t_{SU;STO}$	Stop Condition Setup Time	Standard Mode		4000		ns
		Fast Mode		600		

Note:

13. C_B is the bus capacitance.

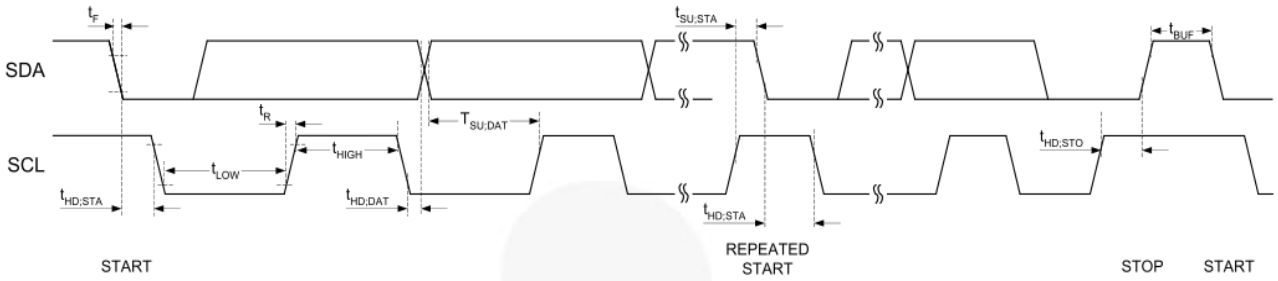
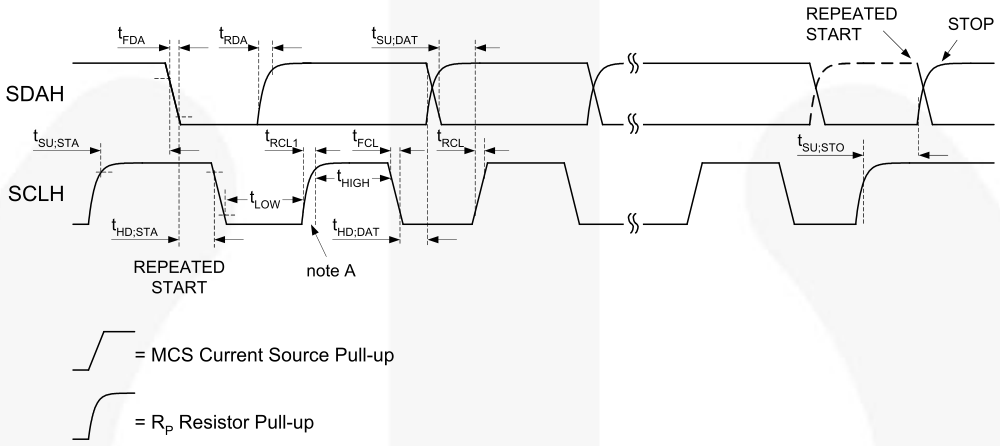


Figure 20. I^2C Standard Mode Interface Timing



Note A: First rising edge of SCLH after Repeated Start and after each ACK bit.

Figure 21. I^2C Fast Mode Interface Timing

12 Package and Handling

12.1 Package Drawing

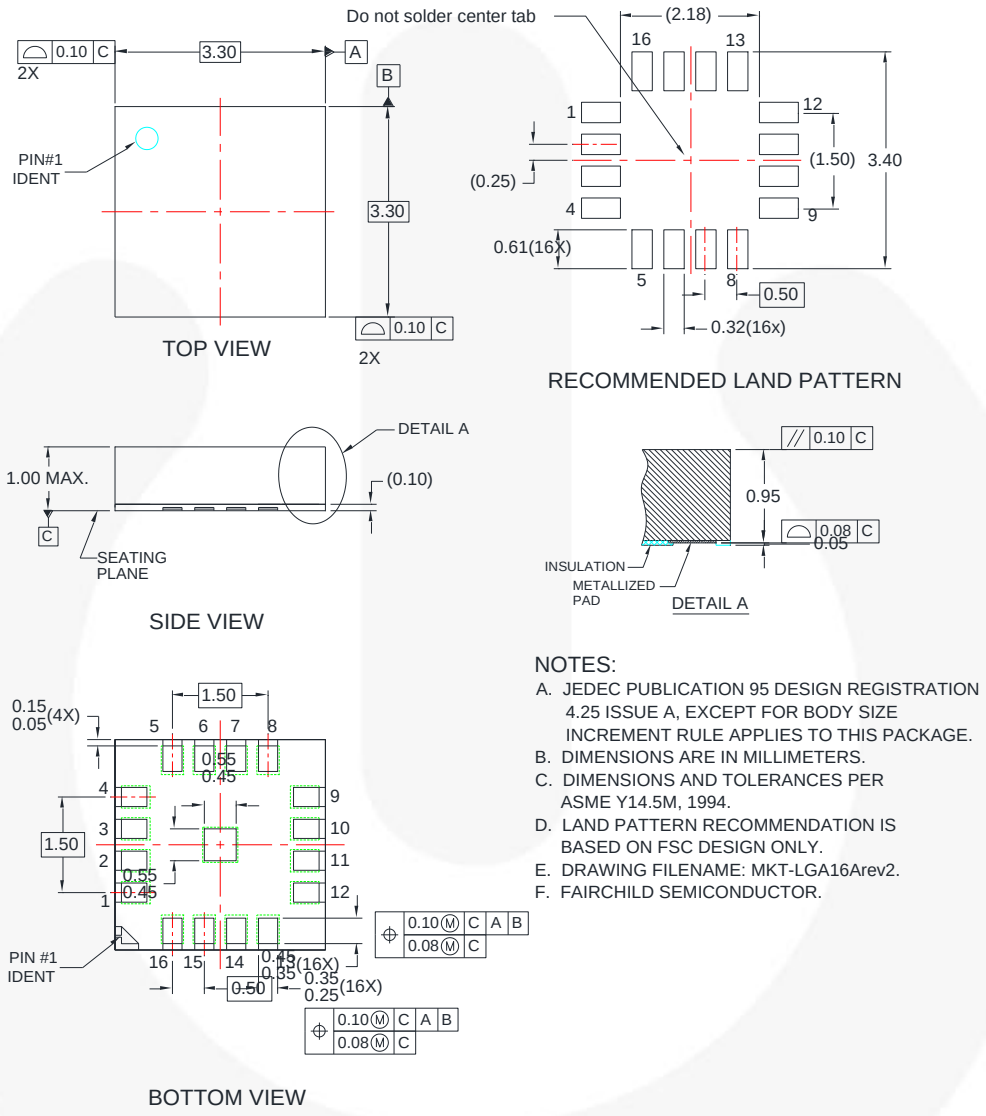
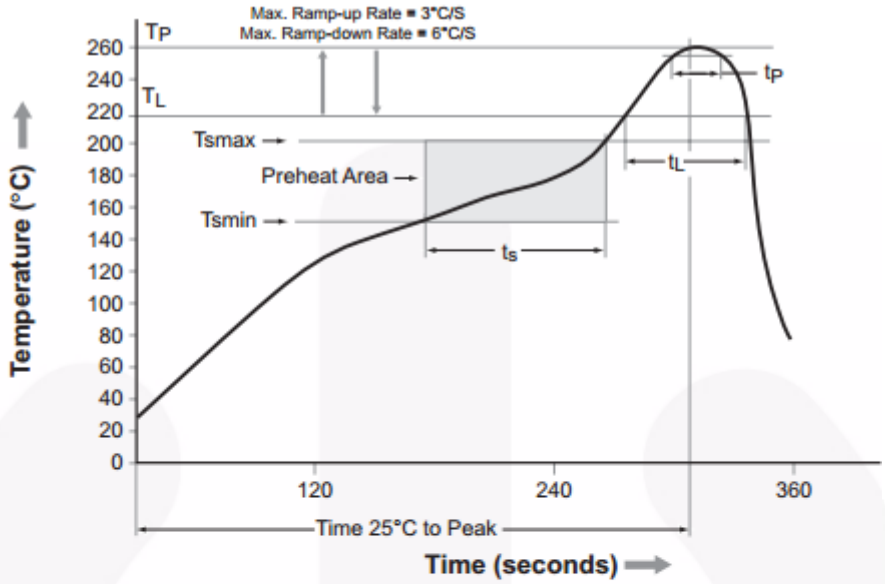


Figure 22. 16 Pin LGA 3.3 x 3.3 x 1 mm Package

12.2 Reflow Specification



Profile Freature	Pb-Free Assembly Profile
Temperature Min. (Tsmin)	150°C
Temperature Max. (Tsmax)	200°C
Time (t_S) from (Tsmin to Tsmax)	60–120 seconds
Ramp-up Rate (t_L to t_P)	3°C/second max.
Liquidous Temperature (T_L)	217°C
Time (t_L) Maintained Above (T_L)	60–150 seconds
Peak Body Package Temperature	260°C +0°C / –5°C
Time (t_P) within 5°C of 260°C	30 seconds
Ramp-down Rate (T_P to T_L)	6°C/second max.
Time 25°C to Peak Temperature	8 minutes max.

Figure 23. Reflow Profile

12.3 Storage Specifications

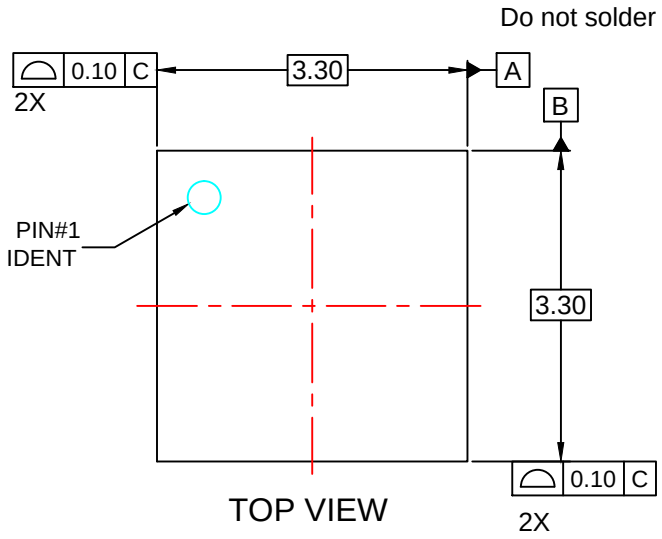
FIS1100 storage specification conforms to IPC/JEDEC J-STD-020D.01 Moisture Sensitivity Level (MSL) 3. Floor life after opening the moisture-sealed bag is 168 hours with storage conditions: Temperature: ambient to ≤30°C and Relative Humidity: 60%RH.

13 Related Resources

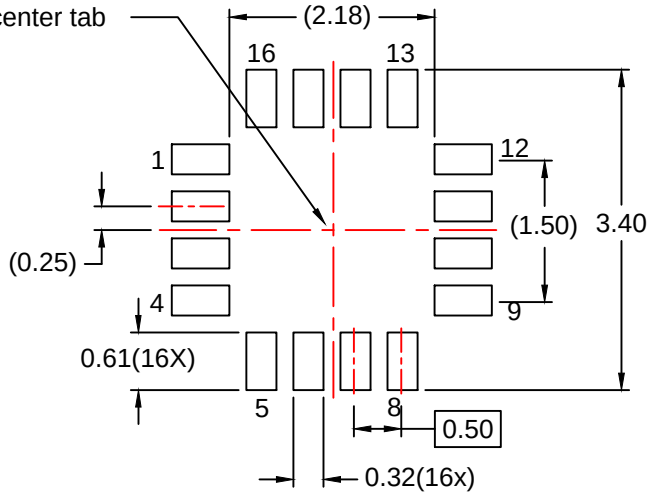
AN-5083 — Low Power Motion Co-Processor for High Accuracy Tracking Applications

AN-5084 — XKF3 Low-Power, Optimal Estimation of 3D Orientation using Inertial and Magnetic Sensing

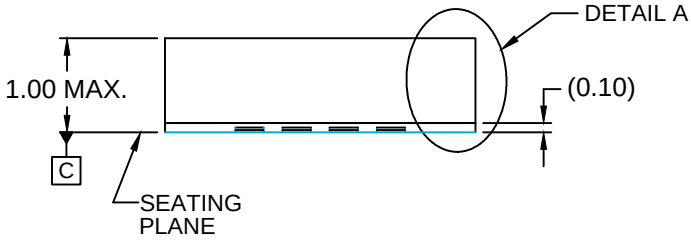
AN-5085 — FIS1100 Board Level Calibration



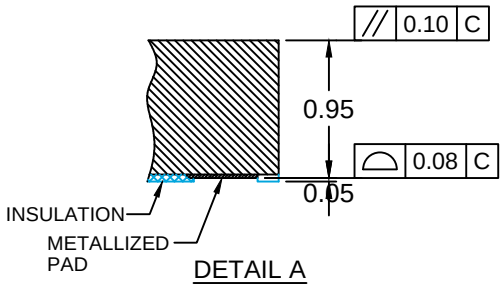
TOP VIEW

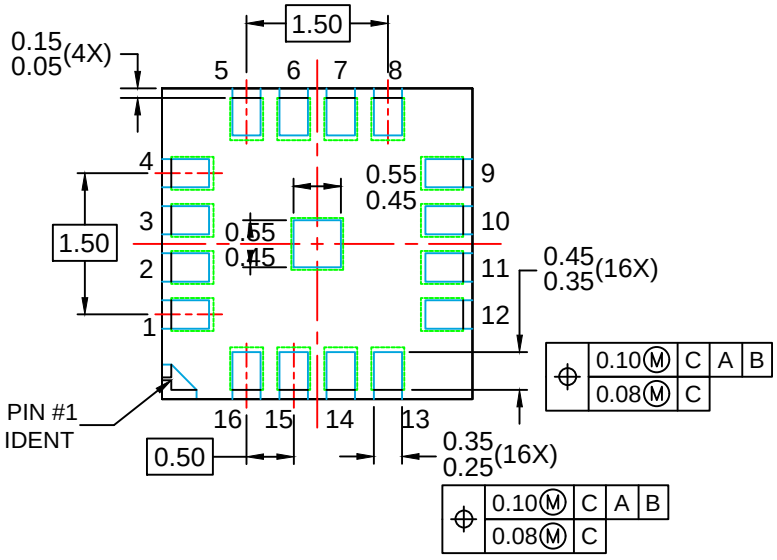


RECOMMENDED LAND PATTERN



SIDE VIEW





BOTTOM VIEW

NOTES:

A. JEDEC PUBLICATION 95 DESIGN REGISTRATION 4.25 ISSUE A, EXCEPT FOR BODY SIZE INCREMENT RULE APPLIES TO THIS PACKAGE.

B. DIMENSIONS ARE IN MILLIMETERS.

C. DIMENSIONS AND TOLERANCES PER ASME Y14.5M, 1994.

D. LAND PATTERN RECOMMENDATION IS BASED ON FSC DESIGN ONLY.

E. DRAWING FILENAME: MKT-LGA16Arev2.

F. FAIRCHILD SEMICONDUCTOR.

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