Low Noise, Wide Bandwidth 6D Inertial Measurement Unit with Motion Co-Processor and Sensor Fusion
QMI8610

Features

- Low 6 mdps/√Hz Gyroscope Noise and Low-Latency, Wide Bandwidth for Drone Flight Control and Gimbal Stabilization

- Low Noise 50 µg/√Hz accelerometer

- Complete Inertial Measurement Unit (IMU) with Sensor Fusion Library with Specified Orientation Accuracy of ±3º Pitch and Roll, ±5º Yaw/Heading

- High-performance XKF3 6/9-axis sensor fusion with in-run calibration for correction of gyro bias drift over-temperature and lifetime

- 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

- UniqueChipID (UID) for Serialization of Parts

- Large 1536 Byte FIFO can be used to Buffer 9DOF Sensor Data to Lower System Power Dissipation

- Motion on Demand Technology for Polling Based Synchronization

- Large Dynamic Range from ±32°/s to ±2,560°/s and ±2 g to ±16 g

- Low Power and Warm-Start Modes for Effective Power Management

- Digitally Programmable Sampling Rate and Filters

- Host Serial Interface Supporting I^{2}C or SPI

- I^{2}C Master for Interfacing External Magnetometer

- Embedded Temperature Sensor

- Wide Extended Operating Temperature Range (-40°C to 85°C)

Description

QMI8610 is a complete 6D MEMS Inertial Measurement Unit (IMU) with 9-axis sensor fusion and specified system level orientation accuracy. When using the QMI8610 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 QMI8610 is ideal for drone flight control and gimbal stabilization. It features a low 6 mdps/√Hz gyroscope noise and a low latency.

The QMI8610 incorporates a 3-axis Gyroscope and a 3-axis Accelerometer and can connect an external 3-axis magnetometer through an I^{2}C master thus forming a complete 9DOF system.

The QMI8610 also incorporates an advanced vector Digital Signal Processor (DSP) motion co-processor called the AttitudeEngine™. The AttitudeEngine efficiently encodes high frequency motion at high internal sampling rates, preserving full accuracy across any output data rate.

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

Applications

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

CONTENTS

1 General Information

1.1 Ordering Information

Table 1.   Ordering Information

Part Number	Package	Packing Method
QMI8610	LGA16	Tape & Reel

1.2 Marking Information
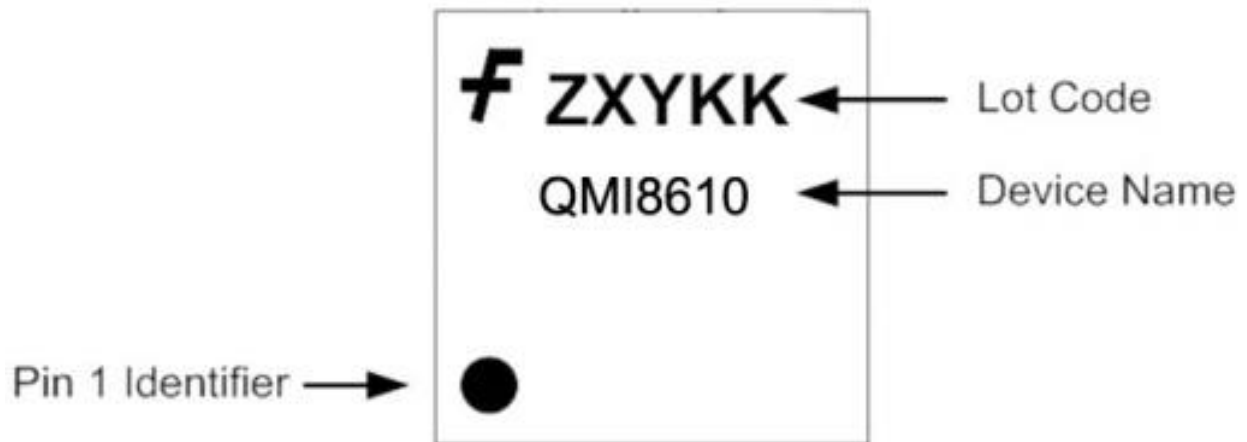
Figure 1. Top Mark

1.3 Internal Block Diagram
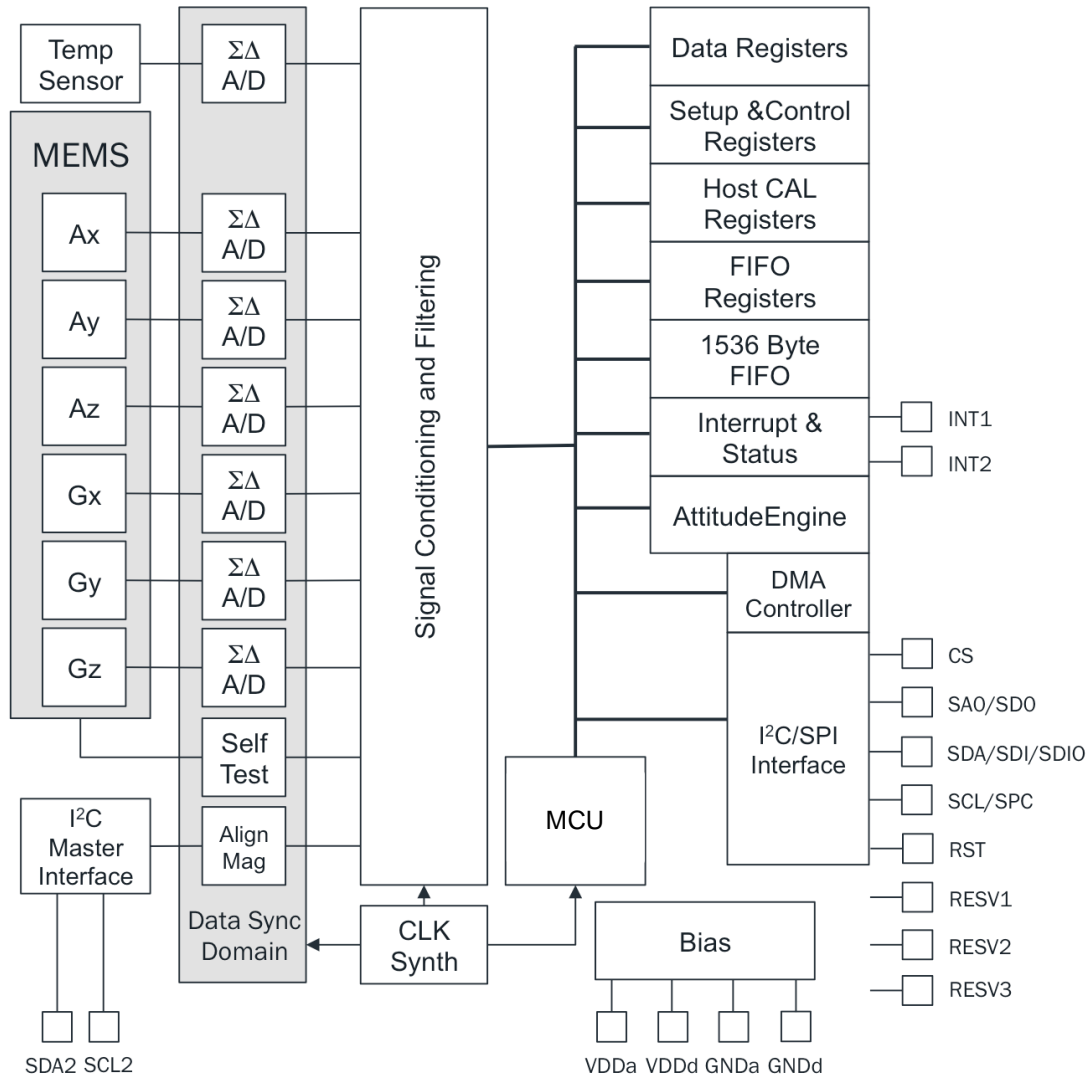
Figure 2. Internal Block Diagram

1.4 Application Diagrams
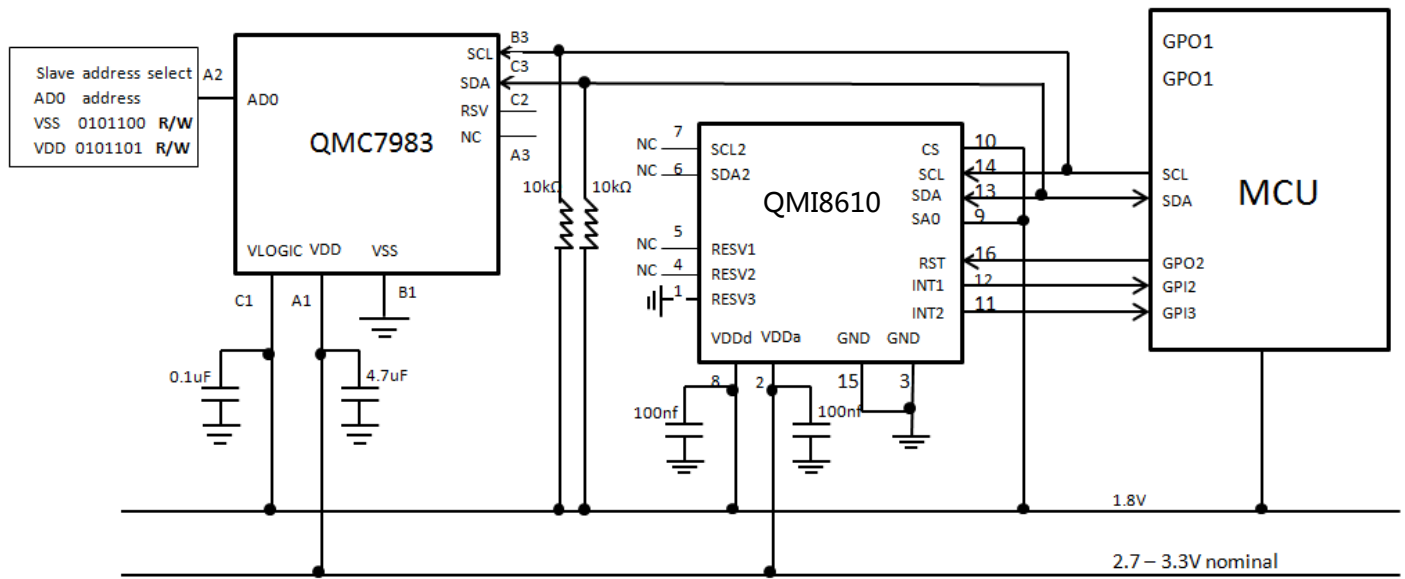
Figure 3. Typical Application Diagram Showing QMC7983 Magnetometer and QMI8610 I^{2}C Connected to the Host Processor via I^{2}C

1.5 Package & Pin Information
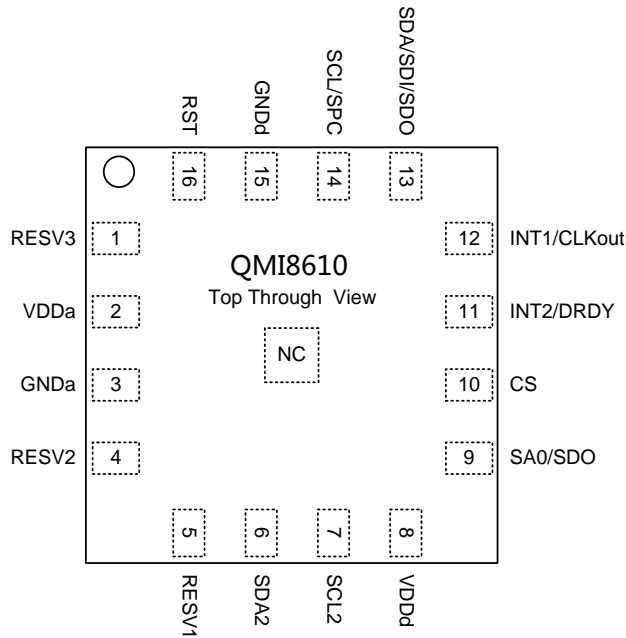
Figure 4. Pins Face Down (Top View)

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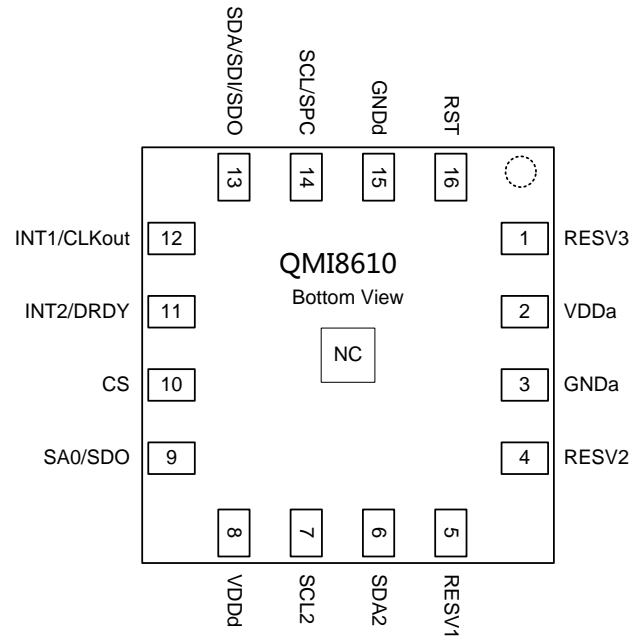
Figure 5. Pins Face Up (Bottom View)

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^2C Serial 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)

Pin #	Name	Alternate Name	Alternate Name	Description
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)	SDI(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 K pull up resistor.

2. In SPI mode (not in I^2C Mode), there is an internal pull down 200 K resistor.

3. Refer to Section 11 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
Rpu(4)(5)	Resistor	Resistance	10 KΩ

Notes:

4. Rpu is only needed when the Host Serial Interface is configured for I^{2}C. They are not needed when the Host Serial Interface is configured for SPI. See I^{2}C Interface section. If Pull-up resistors are used on SCL and SDA, then both SPI and I^{2}C Modes are possible. If a Pull-up is used on SA0, an alternate slave address is used for I^{2}C. SPI Mode will be unaltered with the use of Pull-ups for I^{2}C.

5. Actual value required for Rpu depends on capacitance on the I^{2}C bus.
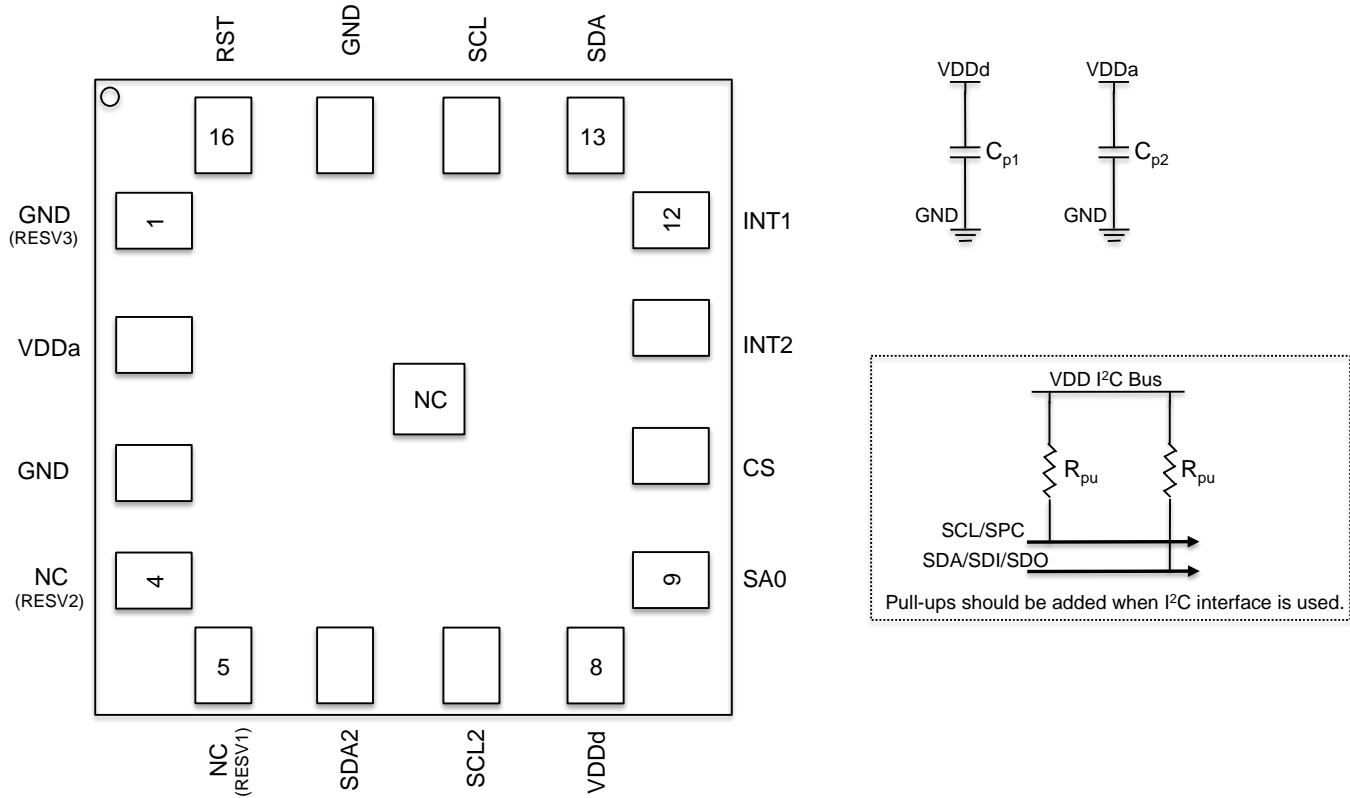
Figure 6. Typical Electrical Connections

2   QMI8610 Architecture

QMI8610 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 ±3⁰ for pitch and roll and ±5⁰ for yaw/heading.

The QMI8610 includes a microcontroller for data scheduling, combined with Direct Memory Access (DMA) in order to

allow efficient data shuttling on the chip. Multi-channel data is easily processed at rates up to 1 kHz with minimal latency in normal operation (non-OIS modes) and at 8 kHz in OIS modes.

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

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

2.1   AttitudeEngine Mode Overview

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

■ Calibration: QMI8610 applies continuous on-chip calibration of all the sensors (accelerometer, gyroscope, and magnetometer) including scale, offset, and temperature calibration. When used in conjunction with a sensor fusion filter (such as the Fairchild XKF3) running on the host processor, estimated sensor errors can be updated in-use, allowing sensor calibration to be performed in the background without any host intervention. This offloads computationally expensive per-sample re-calibration from the host processor to the QMI8610.

■ Sample Synchronization: QMI8610 automatically provides highly synchronous output between the various IMU accelerometer and gyroscope channels through the use of fully parallel ΣΔ-converters. The QMI8610 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): QMI8610 allows the host to access encoded motion data asynchronously (polling) and on demand. The motion data in the AttitudeEngine (AE) mode remains accurate even at very low output data rates. This allows easy integration and synchronization with other sensors for state-of-the-art applications such as rolling shutter camera stabilization, optical sensors software de-blurring, GNSS integration and augmented or virtual reality.

2.2   Advantages of the Attitude Engine Approach

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

■ Low-Power Architecture: Dead reckoning calculations are performed with the AE vector DSP that 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 QMI8610 Evaluation Kit (FEBQMI8610MEMS_IMU6D3X).

A restricted-use license for use of XKF3 for commercial purposes is also granted for certain applications when XKF3 is used with the QMI8610.

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 works with the FIS series of IMUs such as the QMI8610 and supported magnetometers. Refer to the FEBQMI8610 Evaluation Board document for further details.

For additional information, refer to AN-5084 application note for more details on XKF3 and its benefits

XKF3 Features:

- Continuous Sensor Auto Calibration, No User Interaction Required
- High Accuracy, Real-Time, Low-Latency Optimal estimate of 3D Orientation, up to 1 kHz output data rate
- Ultra low system power for 3D Orientation enabled by AttitudeEngine, between 8 to 64 Hz output data rate without any degradation in accuracy
- Best-in-Class Immunity to Magnetic Distortions
- Best-in-Class Immunity to Transient Accelerations
- Flexible use Scenarios, North Referenced, Unreferenced
- Extensive Status Reporting for Smooth Integration in Applications
- Optimized Library for Popular Microcontrollers
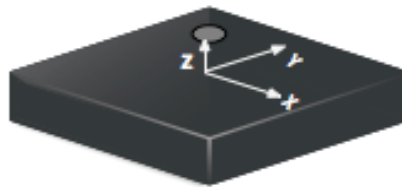
Figure 7. Chip Orientation Coordinate System

2.4 Frames of Reference and Conventions for Using QMI8610

QMI8610 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 coordinates as well. Care must be taken to make sure that QMI8610 and the magnetic sensor of choice are mounted on the board so that the coordinate systems of the two sensors are substantially orthogonal. Figure 9 shows the various frames of reference and conventions for using the QMI8610.

The accelerometer, gyroscope, and the optional external magnetometer are enabled or disabled using the aEN, gEN and mEN bits in the CTRL7 register respectively. AE Mode may be enabled or disabled using the sEN bit in CTRL7 register. The outputs available in Typical Sensor Mode and AttitudeEngine™ Modes are outlined below in Table 22 and Table 23. A list and description of QMI8610 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	-0.30	2.05	V

Symbol	Parameter		Min.	Max.	Unit
Sg(6)	Acceleration g for 0.2 ms (Un-powered)			10,000	g
ESD(7)	Electrostatic Discharge Protection Level	Human Body Model per JES001-2014	±2000		V
		Charged Device Model per JESD22-C101	±500		

Notes:

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

7.   ⚡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	(See Figure 10 for power supply sequencing requirements)	2.7	3.3	3.47	V
V_{DDd}	I/O Pins Supply Voltage		1.62	1.80	1.98	V
V_{IL}	Digital Low Level Input Voltage				0.3 *V_{DDd}	V
V_{IH}	Digital High Level Input Voltage		0.7 *V_{DDd}			V
V_{OL}	Digital Low Level Output Voltage				0.1 *V_{DDd}	V
V_{OH}	Digital High Level Output Voltage		0.9 *V_{DDd}			V

Power Supply Sequencing

VDDa

VDDa ≥90% of final value

VDDd

then VDDd may be raised
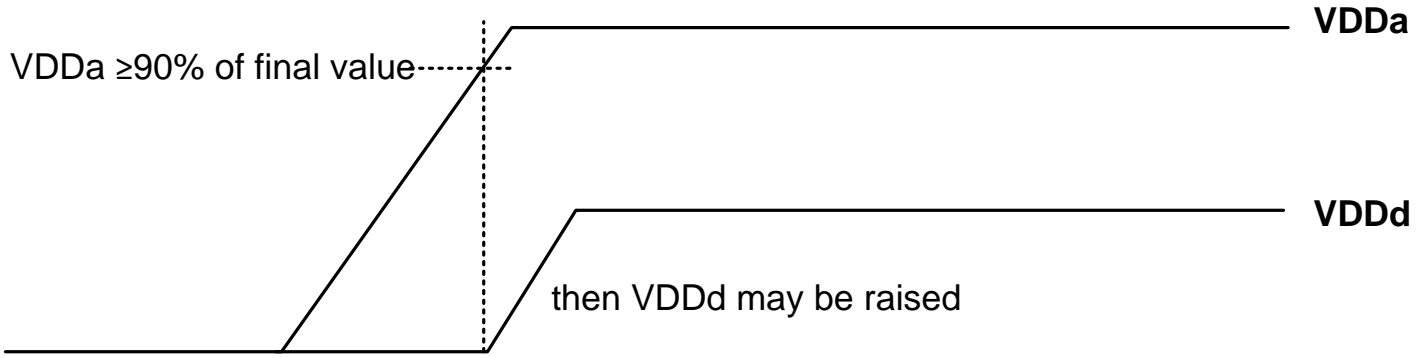
Figure 8. Power Supply Sequencing (VDDa must reach 90% of final value before VDDd is raised)

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 QMI8610 and optionally a supported 3D magnetometer used with a supported host processor, running the Fairchild XKF3 9D-sensor fusion and having executed and stored the result of the "Board Level Calibration" routine (see AN-5085 application note). The system performance specifications assume that good engineering practices for the placement conditions of the QMI8610 and 3D magnetometer are taken into account. For example, take care not to place the QMI8610 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
QMI8610+XKF3 Quaternion	Roll	±3	deg	Requires use of XKF3 software library on host processor.
	Pitch	±3	deg	Requires use of XKF3 software library on host processor.
	Yaw (Heading) Referenced to North	±5	deg	Requires use of XKF3 software library on host processor, using magnetometer, in a homogenous Earth magnetic field.
	Yaw (Heading) Unreferenced	5-25	deg/h	From Allan Variance bias instability. Does not require a magnetometer. *(See specification above for use with magnetometer.)* Fully immune to magnetic distortions.
QMI8610+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

VDDd = 1.8 V, VDDa = 3.3 V, T = 25°C unless otherwise noted. See Figure 8 for power supply sequencing requirements

Table 7. Accelerometer Electro-Mechanical Specifications

Subsystem	Parameter	Typical		Unit	Comments
Accelerometer	Noise Density	50		g/√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		
		±16 g	2,048		
	Cross-Axis Sensitivity	±1		%	
	Temperature Coefficient of Offset (TCO)	±0.5		mg/°C	Over-Temperature Range of -40°C to 85°C at Board Level
	Temperature Coefficient of Sensitivity (TCS)	±0.01		%/°C	
	Initial Offset Tolerance	±150		mg	Board Level
	Initial Sensitivity Tolerance	±1		%	Board Level
	Non-Linearity	±1		%	Best Fit Line
	System Turn On Time(8)	1.75		s	From Hardware Reset, No Power, or Power Down to Power-on Default state = t0 in Figure 11
	Accel Turn On Time	3 ms + 3/ODR		ms	Accel Turn on from Power-On Default state or from Low Power state = t2 + t5 in Figure 11.

Note:

8. System Turn On Time starts once VDDd and VDDa are within 1% of Final Value.

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		
	Natural Frequency	19.6		kHz	
	Noise Density	6		mdps/√Hz	High-Resolution Mode
	Non-Linearity	0.1		%	
	Cross-Axis Sensitivity	±2		%	
	g-Sensitivity	±0.1		dps/g	
	System Turn On Time(9)	1.75		s	From Hardware Reset, No Power, or Power Down to Power-on Default state = t0 in Figure 11
	Gyro Turn On Time	60 ms + 3/ODR		ms	Gyro Turn on from Power-On Default = t1 + t5 in Figure 11
	Gyro Warm Start Turn On Time	5 ms + 3/ODR		ms	From Gyro Warm-Start to Gyro Only or Accel + Gyro modes = t4 + t5 in Figure 11
	Temperature Coefficient of Offset (TCO)	X & Y Axis	±0.05	dps/°C	Over-Temperature Range of -40°C to 85°C
		Z Axis	±0.02		
	Temperature Coefficient of Sensitivity (TCS)	X & Y Axis	±0.05	%/°C	Over-Temperature Range of -40°C to 85°C
		Z Axis	±0.01		

Subsystem	Parameter	Typical	Unit	Comments
Gyroscope	Initial Offset Tolerance	±10	dps	Board Level
	Initial Sensitivity Tolerance	±1.5	%	Board Level

Note:

9. System Turn On Time starts once VDDd and VDDa are within 1% of Final Value

Table 9. Magnetometer and AttitudeEngine Range and Scale

Subsystem	Parameter	Typical		Unit	Comments
		Scale Setting	**Sensitivity**		
Typical Sensor Mode	Magnetometer Sensitivity Scale Factor	±32 gauss	1,024	LSB/gauss	
AE Mode	Magnetometer Sensitivity Scale Factor	±32 gauss	1,024	LSB/gauss	16 Bit Output
	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

VDDd = 1.8 V, VDDa = 3.3 V, T = 25℃ unless otherwise noted. Typical numbers are provided below unless otherwise noted. All frequencies are ±5% and are synchronized to the gyro oscillator ("drive") frequency. (See Figure 8 for power supply sequencing requirements.)

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	700	μg/√Hz

Table 11.Accelerometer Filter Characteristics(10)

Mode	High-Resolution				Low-Power				Unit
ODR	1000	250	125	31.25	125	62.5	25	3	
Bandwidth	500	125	62.5	15.625	62.5	31.25	12.5	1.5	
Bandwidth with Low-Pass Filter Enabled (aLPF=1)	200	50	25	5	25	15	5	0.6	Hz
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:

10. All frequencies are ±5% and are synchronized to the gyro oscillator ("drive") frequency.

3.6 Gyroscope Programmable Characteristics

VDDd = 1.8 V, VDDa = 3.3 V, T = 25°C, and represent typical numbers unless otherwise noted. All frequencies are ±5% and are synchronized to the gyro oscillator ("drive") frequency. (See Figure 8 for power supply sequencing requirements.)

Table 12.Gyroscope Filter Characteristics

Mode		High-Resolution				Snooze Warm-Start	OIS	OIS LL	Unit
ODR	gHPF=0	1000	250	125	31.25	Snooze	8100	8100	
Bandwidth	gLPF=0	500	125	62.5	15.625	N/A	4050	2000	Hz
	gLPF=1	200	50	25	6	N/A	345	N/A(11)	

Mode		High-Resolution				Snooze Warm-Start	OIS	OIS LL	Unit
Corner Frequency (f_c) with High-Pass Filter Enabled (gHPF=1)	gHPF01=0	2.5	0.625	0.3125	0.08	N/A	0.1	N/A(11)	Hz
	gHPF01=1	0.1	0.025	0.0125	0.0032	N/A	0.1	N/A(11)	

Note:

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

Table 13. Optical Image Stabilization (OIS) Group Delay

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

3.7 Electrical Characteristics

VDDd = 1.8 V; VDDa = 3.3 V; T = 25°C unless otherwise noted. See Figure 8 for power supply sequencing requirements

Table 14. Electrical Subsystem Characteristics

Symbol	Parameter		Min.	Typ.	Max.	Unit
f_{SPC}	Host SPI Interface Speed			10		MHz
f_{SCL}	Host I^{2}C Interface Speed	Standard Mode		100		kHz
		Fast Mode		400		
f_{SCL2}	Master I2C Interface Speed(12)	Standard Mode		25		kHz
		Fast Mode		300		

Note:

12. 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

VDDd = 1.8 V, VDDa = 3.3 V, T = 25°C unless otherwise noted. Typical numbers are provided below. (See Figure 8 for power supply sequencing requirements)

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

Mode		High-Resolution				Low-Power				Unit
ODR		1000	250	125	31.25	125	62.5	25	3	Hz
Typical Analog Current IDDa(13)		220	220	220	220	35	35	20	7	
Typical Digital Current IDDd (14)	Filters Disabled (aLPF=0; aHPF=0)	100	70	65	60	20	15	10	8	μA
	Filters Enabled (aLPF=1; aHPF=1)	108	71	66	61	21	16	10	8	

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

Mode		High-Resolution				Snooze Warm-Start	OIS, OIS LL(15)	Unit
ODR		1000	250	125	31.25	Snooze	8100	Hz
Typical Analog Current IDDa(13)		2540	2540	2540	2540	1240	2540	
Typical Digital Current IDDd (14)	Filters Disabled (gLPF=0; gHPF=0; gHPF01=0)	740	710	705	700	570	1100	μA
	Filters Enabled (gLPF=1; gHPF=1; gHPF01=0)	740	710	705	700	570	1100	

Notes:

13. IDDa is the current drawn from the analog supply VDDa.

14. IDDd is the current drawn from the digital supply VDDd.

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

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

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

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

Mode									Unit
ODR Setting		1	2	4	8	16	32	64	Hz
Typical Analog Current I$_{DDa}$		2750	2750	2750	2750	2750	2750	2750	
Typical Digital Current I$_{DDd}$	**Filters Disabled (aLPF=0; gLPF=0)**	930	930	930	930	930	930	930	μA
	Filters Enabled (aLPF=1; gLPF=1)	940	940	940	940	940	940	940	

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

Mode								Unit
ODR		1	2	4	8	16	32	Hz
Typical Analog Current I$_{DDa}$		2750	2750	2750	2750	2750	2750	
Typical Digital Current I$_{DDd}$	**With Magnetometer at 32 Hz**	990	990	990	990	990	990	μA

3.8 Temperature Sensor

The QMI8610 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 °C) or inversely, 16 LSB/ °C.

The QMI8610 outputs the internal chip temperature that the HOST can read. This external output is truncated to an 8-bit resolution so that the HOST sees 1°C per LSB resolution. This is not representative of the accuracy used internally to model and compensate for temperature effects on calibration parameters. To read the temperature, the HOST needs to access the TEMP register (see Data Output Registers in Table 21. The HOST should synchronize to the interrupt, INT2, signal to get valid temperature readings.

Table 20.Temperature Sensor Specifications

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

4 Register Map Overview

The QMI8610 has various registers that enable programming and control of the inertial measurement unit and associated on-chip signal processing. The register map may be classified into the following register categories:

- General Purpose Registers
- Setup and Control Registers: Controls various aspects of the IMU.
- Host Controlled Calibration Registers: Controls and Configures various aspects of the IMU via Host Command interface called CTRL9
- Count Register for time stamping the sensor samples
- FIFO Registers: To setup the FIFO and detect data availability and over-run.
- Data Output Registers: Contains all data for 9D sensors.

QMI8610 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^{2}C or SPI. A detailed description of each register including the register settings necessary to configure the QMI8610 operational modes is provided in Section 5.

Table 21. Register Overview

Name	Type	Register Address			Default	Comments
		Dec	**Hex**	**Binary**		
General Purpose Registers						
WHO_AM_I	r	0	00	00000000	11111100	Device Identifier
Setup and Control Registers						
CTRL1	rw	2	02	00000010	00000000	SPI Interface and Sensor Enable (for clock and power management)
CTRL2	rw	3	03	00000011	00000000	Accelerometer: Output Data Rate, Full Scale, Self Test
CTRL3	rw	4	04	00000100	00000000	Gyroscope: Output Data Rate, Full Scale, Self Test
CTRL4	rw	5	05	00000101	00000000	Magnetometer Settings: Output Data Rate, and Device Selection

Name	Type	Register Address			Default	Comment
		Dec	Hex	Binary		
CTRL5	rw	6	06	00000110	00000000	Data Processing Settings
CTRL6	rw	7	07	00000111	00000000	AttitudeEngine™ Settings: Output Data Rate, Motion on Demand
CTRL7	rw	8	08	00001000	00000000	Enable Sensors, syncSmpl
CTRL8	rw	9	09	00001001	00000000	Reserved: Not Used
CTRL9	rw	10	0A	00001010	00000000	Host commands
Host Controlled Calibration Registers (See CTRL9, Usage is Optional)						
CAL1_L	rw	11	0B	00001011	00000000	Calibration Register
CAL1_H	rw	12	0C	00001100	00000000	CAL1_L – lower 8 bits. CAL1_H – upper 8 bits.
CAL2_L	rw	13	0D	00001101	00000000	Calibration Register
CAL2_H	rw	14	0E	00001110	00000000	CAL2_L – lower 8 bits. CAL2_H – upper 8 bits.
CAL3_L	rw	15	0F	00001111	00000000	Calibration Register
CAL3_H	rw	16	10	00010000	00000000	CAL3_L – lower 8 bits. CAL3_H – upper 8 bits.
CAL4_L	rw	17	11	00010001	00000000	Calibration Register
CAL4_H	rw	18	12	00010010	00000000	CAL4_L – lower 8 bits. CAL4_H – upper 8 bits.
FIFO Registers						
FIFO_CTRL	rw	19	13	00010011	00000000	FIFO Setup
FIFO_DATA	r	20	14	00010100	00000000	FIFO Data
FIFO_STATUS	r	21	15	00010101	00000000	FIFO Status

Table 21. Register Overview (Continued)

Name	Type	Register Address			Default	Comment
		Dec	**Hex**	**Binary**		
Status Registers						
STATUS0	r	22	16	00010110	00000000	Output Data Over Run and Data Availability
STATUS1	r	23	17	00010111	00000000	Miscellaneous Status: Wake on Motion, FIFO ready, CmdDone (CTRL9 protocol bit)
Count Register						
CNT_OUT	r	24	18	00011000	00000000	Sample Time Stamp (Count Output)
Data Output Registers (16 bits 2'compliment except self test sensor data, AE-REG1 and AE_REG2)						
AX_L	r	25	19	00011001	00000000	X-axis Acceleration
AX_H	r	26	1A	00011010	00000000	AX_L – lower 8 bits. AX_H – upper 8 bits.
AY_L	r	27	1B	00011011	00000000	Y-axis Acceleration
AY_H	r	28	1C	00011100	00000000	AY_L – lower 8 bits. AY_H – upper 8 bits.
AZ_L	r	29	1D	00011101	00000000	Z-axis Acceleration
AZ_H	r	30	1E	00011110	00000000	AZ_L – lower 8 bits. AZ_H – upper 8 bits.
GX_L	r	31	1F	00011111	00000000	X-axis Angular Rate
GX_H	r	32	20	00100000	00000000	GX_L – lower 8 bits. GX_H – upper 8 bits.
GY_L	r	33	21	00100001	00000000	Y-axis Angular Rate
GY_H	r	34	22	00100010	00000000	GY_L – lower 8 bits. GY_H – upper 8 bits.
GZ_L	r	35	23	00100011	00000000	Z-axis Angular Rate
GZ_H	r	36	24	00100100	00000000	GZ_L – lower 8 bits. GZ_H – upper 8 bits.
MX_L	r	37	25	00100101	00000000	X-axis Magnetic Field
MX_H	r	38	26	00100110	00000000	MX_L – lower 8 bits. MX_H – upper 8 bits.
MY_L	r	39	27	00100111	00000000	Y-axis Magnetic Field .
MY_H	r	40	28	00101000	00000000	MY_L – lower 8 bits. MY_H – upper 8 bits.
MZ_L	r	41	29	00101001	00000000	Z-axis Magnetic Field.
MZ_H	r	42	2A	00101010	00000000	MZ_L – lower 8 bits. MZ_H – upper 8 bits.
dQW_L	r	45	2D	00101101	00000000	Quaternion Increment dQW. dQW_L – lower 8 bits. dQW_H
dQW_H	r	46	2E	00101110	00000000	– upper 8 bits; or part of UniqueChipID(16).
dQX_L	r	47	2F	00101111	00000000	Quaternion Increment dQX. dQX_L – lower 8 bits. dQX_H –
dQX_H	r	48	30	00110000	00000000	upper 8 bits; or part of UniqueChipID(16).

Name	Type	Register Address			Default	Comment
		Dec	**Hex**	**Binary**		
dQY_L	r	49	31	00110001	00000000	Quaternion Increment dQY.
dQY_H	r	50	32	00110010	00000000	dQY_L – lower 8 bits. dQY_H – upper 8 bits.
dQZ_L	r	51	33	00110011	00000000	Quaternion Increment dQZ
dQZ_H	r	52	34	00110100	00000000	dQZ_L – lower 8 bits. dQZ_H – upper 8 bits.
dVX_L	r	53	35	00110101	00000000	Velocity Increment along X-axis, or X-axis Angular Rate for
dVX_H	r	54	36	00110110	00000000	OIS LL mode, or Self-test sensor data dVX_L – lower 8 bits. dVX_H – upper 8 bits.
dVY_L	r	55	37	00110111	00000000	Velocity Increment along Y-axis, or Y-axis Angular Rate for
dVY_H	r	56	38	00111000	00000000	OIS LL mode, or Self-test sensor data dVY_L – lower 8 bits. dVY_H – upper 8 bits.
dVZ_L	r	57	39	00111001	00000000	Velocity Increment along Z-axis, or Z-axis Angular Rate for
dVZ_H	r	58	3A	00111010	00000000	OIS LL mode, or Self-test sensor data dVZ_L – lower 8 bits. dVZ_H – upper 8 bits.

Note:

16. UniqueChipID is formed by concatenating dQW_L, dQW_H, dQX_L and dQX_H. Immediately after reset and before enabling any sensor the Unique ChipID can be read from the output registers (0x2D - 0x30) which are the dQW_L, dQW_H, dQX_L and dQX_H registers

Table 21. Register Overview (Continued)

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

5 Sensor Configuration Settings and Output Data

5.1 Typical Sensor Mode Configuration and Output Data

In Typical Sensor Mode, QMI8610 outputs raw sensor values. The sensors are configured and read using the registers described below. The accelerometer, gyroscope and magnetometer can be independently configured. Table 22 summarizes these pertinent registers.

Table 22.Typical Sensor Mode Configuration and Output Data

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

Description	Registers	Unit	Comments
Angular Rate	G[X,Y,Z]_[H,L]	dps	In Sensor Frame of Reference, Right-handed Coordinate System
Magnetic Field	M[X,Y,Z]_[H,L]	gauss	In Sensor Frame of Reference, Right-handed Coordinate System
Temperature	TEMP	°C	Temperature of the sensor
FIFO Based Output	FIFO_DATA		See FIFO Description section for more details on using the FIFO to store and access multiple samples

5.2   AttitudeEngine Mode Configuration and Output Data

In AE Mode, QMI8610 outputs orientation (quaternion) and velocity increments.

Orientation increments are expressed in unit quaternion format. dQ = [QW, QX, QY, QZ] 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 23 summarizes the operation of the AttitudeEngine mode.

Table 23．AttitudeEngine Mode Configuration and Output Registers

AttitudeEngine Mode			
Configuration	Registers	Unit	Comments
Sensor Enable, SPI 3 or 4 Wire	CTRL1		Control power states, SPI communications
Enable AttitudeEngine	CTRL7		Enable the AttitudeEngine (CTRL7, sEN =1, aEN=1, gEN=1, optionally mEN=1 if external magnetometer is available)
Configure	CTRL6		AttitudeEngine Output Data Rate and Motion on Demand
Configure Accelerometer, Enable Self Test	CTRL2		Configure Full Scale; Enable Self Test
Configure Gyroscope, Enable Self Test	CTRL3		Configure Full Scale; Enable Self Test
Configure Magnetometer	CTRL4		Configure Output Data Rate and choose device

Configuration	Registers	Unit	Comments
Sensor Filters	CTRL5		Configure and Enable/Disable High Pass and Low Pass Filters
Quaternion 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)
Status	STATUS0, STATUS1		Data Availability, Data Overrun, Wake on Motion detected
Bias Update, Clipping, Overflow	AE_REG1, AEREG_2		Magnetometer and Gyroscope bias update acknowledgement, Sensor clipping acknowledgement, Velocity increment overflow
Temperature	TEMP	°C	Temperature of the sensor

5.3   General Purpose Register

Table 24. General Purpose Register Description

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

5.4   Configuration Registers

This section describes the various operating modes and register configurations of the QMI8610.

Table 25. Configuration Registers Description

Register Name			
CTRL1			**SPI Interface and Sensor Enable. Register Address: 2 (0x02)**
Bits	**Name**	**Default**	**Description**
7	SIM	1'b0	0: Enables 4-wire SPI interface 1: Enables 3-wire SPI interface
6:1	Reserved	6'b0	Reserved
0	sensorDisable	1'b0	0: Enables internal 1 MHz oscillator 1: Disables internal 1 MHz oscillator For more detail, see Table 31 and see Figure 11
CTRL2			**Accelerometer Settings: Address: 3 (0x03)**
Bits	**Name**	**Default**	**Description**
7:6	Reserved	2'b0	Reserved
5	aST	1'b0	Enable Accelerometer Self Test. For more detail, see Section 9.1
4:3	aFS<1:0>	2'b0	Set Accelerometer Full-scale: 00 - Accelerometer Full-scale = ±2 g 01 - Accelerometer Full-scale = ±4 g 10 - Accelerometer Full-scale = ±8 g 11 – Accelerometer Full-scale = ±16 g

Bits	Name	Default	Description				
2:0	aODR<2:0>(17)	3'b0	Set Accelerometer Output Data Rate (ODR):					
			Setting	ODR Rate (Hz)	Mode	LPF Bandwidth (Hz), aLPF=0	LPF Bandwidth (Hz), aLPF=1
			000	1000	High Resolution	500	200
			001	250	High Resolution	125	50
			010	125	High Resolution	62.5	25
			011	31.25	High Resolution	15.625	5
			100	125	Low Power	62.5	25
			101	62.5	Low Power	31.25	15
			110	25	Low Power	12	5
			111	3	Low Power	2	0.6

Table 25 Configuration Register Description (Continued)

Register Name		
CTRL3	**Gyroscope Settings: Address 4 (0x04)**	
Bits	Name	Default	Description
7	Reserved	1'b0	
6	gST	1'b0	Enable Gyro Self-Test. For more detail, see Section 9.2, Gyroscope Self Test
5:3	gFS<2:0>	3'b0	Set Gyroscope Full-scale: 000 - ±32 dps 001 - ±64 dps 010 - ±128 dps 011 - ±256 dps 100 - ±512 dps 101 - ±1024 dps 110 - ±2048 dps 111 - ±2560 dps

Note: The "Register Name" section above combines into the Bits/Name/Default/Description table.

Register Name			
CTRL3		**Gyroscope Settings: Address 4 (0x04)**	
Bits	**Name**	**Default**	**Description**
2:0	gODR<2:0> (17)	3'b0	Set Gyroscope Output Data Rate (ODR):

Set Gyroscope Output Data Rate (ODR):

Setting	ODR Rate (Hz)	Mode	LPF Bandwidth (Hz). gLPF=0	LPF Bandwidth (Hz), gLPF=1
000	1000	High-Resolution	500	200
001	250	High-Resolution	125	50
010	125	High-Resolution	62.5	25
011	31.25	High-Resolution	15.625	6
10X	0	Gryo Warm-Start ("Snooze")	NA	NA
110	8100	OIS	4050	345
111	8100	OIS LL(18)	2000	N/A(19)

CTRL4		**Magnetometer Settings: Address: 5 (0x05)**	
Bits	**Name**	**Default**	**Description**
7:0	Reserved	8'b0	

Notes:

17. When both the accelerometer and the gyroscope are enabled, it is typical to set the ODR rates for each sensor to be identical, such as when output rates are chosen in the range of 1 kHz to 32 Hz. In case the host requires different ODRs (for example, as with OIS mode) then, the gyroscope output rate should be chosen to be greater than or equal to the accelerometer output rate. NOTE: The accelerometer low power mode is only available when the gyroscope is disabled

18. When gODR<2:0>=111 (OIS LL mode) is selected, the gyro data will be written to dVX_L, dVX_H, dVY_L, dVY_H, dVZ_L and dVZ_H registers. See register #53 through #58 for additional details.

Table 25 Configuration Register Description (Continued)

	Register Name		
CTRL5		**Sensor Data Processing Settings. Register Address: 6 (0x06)**	
Bits	**Name**	**Default**	**Description**
7:5	Reserved	3'b0	
4	gHPF01	1'b0	Set HPF corner frequency. See Table associated with gHPF bit below.
3	gLPF	1'b0	0: Disable Gyroscope Low-Pass Filter. 1: Enable Gyroscope Low-Pass Filter.
2	gHPF	1'b0	0: Disable Gyroscope High-Pass Filter. 1: Enable Gyroscope High-Pass Filter (*see Table below*). High-Pass Filter corner frequency (f_c) with gHPF = 1 **ODR Rate (Hz)** / **gHPF01=1 (Hz)** / **gHPF01=0 (Hz)** 1000 / 0.1 / 2.5 250 / 0.0250 / 0.6250 125 / 0.0125 / 0.3125 31.25 / 0.0032 / 0.0800 8100 (gODR=110) / 0.1000 / 0.1000 8100 (gODR=111) / N/A(18) / N/A(19)
1	aLPF	1'b0	0: Disable Accelerometer Low-Pass Filter. 1: Enable Accelerometer Low-Pass Filter.
0	aHPF	1'b0	0: Disable Accelerometer High-Pass Filter 1: Enable Accelerometer High-Pass Filter.
CTRL6		**Attitude Engine ODR and Motion on Demand: Address: 7 (0x07)**	
Bits	**Name**	**Default**	**Description**
7	sMoD	1'b0	0: Disables Motion on Demand. 1: Enables Motion on Demand (Requires sEN=1).

ODR Rate (Hz)	gHPF01=1 (Hz)	gHPF01=0 (Hz)
1000	0.1	2.5
250	0.0250	0.6250
125	0.0125	0.3125
31.25	0.0032	0.0800
8100 (gODR=110)	0.1000	0.1000
8100 (gODR=111)	N/A(18)	N/A(19)

Bits	Name	Default	Description
6:3	Reserved	4'b0	
2:0	sODR<2:0>	3'b0	Attitude Engine Output Data Rate (ODR)

Attitude Engine Output Data Rate (ODR)

Setting	ODR Rate (Hz)
000	1
001	2
010	4
011	8
100	16
101	32
110	64(20)
111	NA

Notes:

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

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

Table 25 Configuration Register Description (Continued)

Register Name			
CTRL7		**Enable Sensors and Configure Data Reads. 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 QMI8610. 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 QMI8610 resumes updating the Sensor Data Output Registers and INT2 will be brought high when new data is available.
6:4	Reserved	3'b0	These bits should always be set to 0
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 Section 5.7, CTRL 9 Functionality (Executing Pre-defined Commands))

5.5 Status and Count Registers

Table 26. 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

Bits	Name	Default	Description
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 (see Section 8 for more details)
1	FIFO_rddy	1'b0	FIFO ready to be read.
0	CmdDone	1'b0	Bit read by Host Processor as part of CTRL9 register protocol. See Section 5.7 for more information.
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 (circular register 0x00-0xFF).

5.6 Sensor Data Output Registers

Table 27.Sensor Data Output Registers Description

Register Name			
A[X,Y,Z]_[H,L]		**Acceleration Output. Register Address: 25 – 30, (0x19 – 0x1E)**	
Bits	Name	Default	Description
7:0	AX_L<7:0>	0x00	X-axis acceleration in two's complement.
7:0	AX_H<15:8>	0x00	AX_L – lower 8 bits. AX_H – upper 8 bits.

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

Table 27 Sensor Data Output Registers Description (Continued)

	Register Name		
	dQ[1,2,3,4]_[H,L]		**Quaternion Output. Register Addresses: 45 – 52 (0x2D – 0x34)**
Bits	**Name**	**Default**	**Description**
7:0	dQW_L<7:0>	0x00	Quaternion Increment dQW in two's complement.
7:0	dQW_H<15:8>	0x00	dQW_L – lower 8 bits. dQW_H – upper 8 bits; or part of UniqueChipID(21)
7:0	dQX_L<7:0>	0x00	Quaternion Increment dQX in two's complement.
7:0	dQX_H<15:8>	0x00	dQX_L – lower 8 bits. dQX_H – upper 8 bits; or part of UniqueChipID(21)
7:0	dQY_L<7:0>	0x00	Quaternion Increment dQY in two's complement.
7:0	dQY_H<15:8>	0x00	dQY_L – lower 8 bits. dQY_H – upper 8 bits.
7:0	dQZ_L<7:0>	0x00	Quaternion Increment dQZ in two's complement.
7:0	dQZ_H<15:8>	0x00	dQZ_L – lower 8 bits. dQZ_H – upper 8 bits.
	dV[X,Y,Z]_[H,L]		**Delta Velocity Output. 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.
7:0	dVX_H<15:8>	0x00	dVX_L – lower 8 bits. dVX_H – upper 8 bits. When gODR=111, OIS LL Gyro X-axis data in two's complement Also used for accelerometer or gyro self test data
7:0	dVY_L<7:0>	0x00	Y-axis Velocity Increment in two's complement.
7:0	dVY_H<15:8>	0x00	dVY_L – lower 8 bits. dVY_H – upper 8 bits. When gODR=111, OIS LL Gyro Y-axis data in two's complement Also used for accelerometer or gyro self test data
7:0	dVZ_L<7:0>	0x00	Z-axis Velocity Increment in two's complement.
7:0	dVZ_H<15:8>	0x00	dVZ_L – lower 8 bits. dVZ_H – upper 8 bits. When gODR=111, OIS LL Gyro Z-axis data in two's complement Also used for accelerometer or gyro self test data
TEMP		**Temperature Output. Register Address: 59. (0x3B)**	

Bits	Name	Default	Description
7:0	TEMP<7:0>	0x00	Temperature output (°C) 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.

Note:

21. UniqueChipID is formed by concatenating dQW_L, dQW_H, dQX_L and dQX_H.   Immediately after reset and before enabling any sensor the Unique ChipID can be read from the output registers (0x2D - 0x30) which are the dQW_L, dQW_H, dQX_L and dQX_H registers

Table 27 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.

Bits	Name	Default	Description
3	mx_clip	1'b0	Mag X-axis data was clipped.
2	dvz_of	1'b0	Velocity Increment overflow along dvz.
1	dvy_of	1'b0	Velocity Increment overflow along dvy.
0	dvx_of	1'b0	Velocity Increment overflow along dvx.

Table 28.AttitudeEngine Modes and Output Table

Mode/Outputs		dQ	dV	M	CNT_OUT	Comments on CNT_OUT
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 Motion on Demand (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 commands from an external host processor on the QMI8610 is facilitated by the using the Control 9 (CTRL9) register on the QMI8610. The register is available to the host via the SPI /I^2C bus. It operates by the host writing a pre-defined value (Command) to the CTRL9 register. The firmware of the QMI8610 evaluates this Command and if a match is found it executes the corresponding pre-defined function. Once the function has been executed, the QMI8610 signals the completion of this by raising INT1 interrupt. The host must acknowledge this by reading STATUS1 register bit 0. This is the CmdDone bit. After this read, the QMI8610 pulls down the INT1 interrupt. This command presentation from the host to the QMI8610 and the subsequent execution and handshake between the host and the FIS1000 will be referred to as the "CTRL9 Protocol".

There are three types of interactions between the host and QMI8610 that follow the CTRL9 Protocol.

WCtrl9: The host needs to supply data to QMI8610 prior to the Ctrl9 protocol. (Write – Ctrl9 Protocol)

Ctrl9R: The host gets data from QMI8610 following the Ctrl9 protocol. (Ctrl9 protocol – Read)

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

Note: for CTRL9 to work properly, OIS mode (See CTRL3 register) cannot be enabled. Once CTRL9 has been executed, then OIS mode in CTRL3 register can be enabled.

Table 29.CAL Register Addresses

Register Name	Register Address	
	Dec	Hex
CAL1_H	11	0x0B
CAL1_L	12	0x0C
CAL2_H	13	0x0D

Register Name	**Register Address**	
	Dec	**Hex**
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 QMI8610. 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. In addition, 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 has executed the appropriate function based

on the command value.

3.   The host must acknowledge this by reading STATUS1 register bit 0 (CmdDone) which is then reset to 0 upon reading the register. In addition, INT1 is pulled low upon the register read, completing the CTRL9 transaction.

Data is available from the device at this time. The location of the data is specified separately for each of the Commands (see Section 5.7.5, CTRL9 Commands in Detail).

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 has executed the appropriate function based on the command value.

3.   The host must acknowledge this by reading STATUS1 register bit 0 (CmdDone) which is then reset to 0 upon reading the register. In addition, INT1 is pulled low, upon the register read, completing the CTRL9 transaction.

Table 30.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

CMND Name	CTRL9 Command Value	Protocol Type	Description
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_HOST_ACCEL_SENSITIVITY	0x14	WCtrl9	Set Accelerometer Sensitivity from Host Dynamically
CTRL_CMD_HOST_GYRO_SENSITIVITY	0x15	WCtrl9	Set Gyroscope Sensitivity 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	Set up and enable Wake on Motion

5.7.5 CTRL9 Commands in Detail

■ CTRL_CMD_RST_AHPF

This CTRL 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 offset data. 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. Once the AE_REG1[7] is set, then new bias will take effect on the next AE window.

■ 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. Once the AE_REG1[6] is set, then new bias will take effect on the next AE window.

■ CTRL_CMD_REQ_MoD

This CTRL9 command is used to retrieve motion data from the QMI8610 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 QMI8610 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 output registers 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 should be placed into the 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 a delay of up to 3 output samples 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 when 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 should be placed into

the CAL1 to CAL3 registers 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 a delay of up to 3 output samples 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 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 bits 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 bits 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 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 bits 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 0x08 to CTRL9 register 0x0A.

■ CTRL_CMD_GET_TCYCLE

This CTRL9 Command can only be issued when the QMI8610 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 is issued when the host wants to get data from the FIFO. When the FIFO is enabled it will be indicated to the host by asserting INT2 and thus signaling that a flag condition (like FIFO full) has been reached and that 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 a FIFO transaction. The host must read the STATUS1 register bit 0 (CmdDone).

At this point the host should set the FIFO_rd_mode Bit to 1 (FIFO_CTRL register 0x13 bit 7). The device will direct the FIFO data to the FIFO_DATA register 0x14 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 specified CALx registers are loaded with the appropriate data, the Command is issued by writing 0x19 to CTRL9 register 0x0A.

- CTRL_CMD_HOST_GYRO_SENSITIVITY

This CTRL9 command is issued when the host wants to tune the gyroscope sensitivity (scale factor). The incremental value of the scale should be 16 bit 2's complement format with 3 bits for unsigned integer and 13 bits fraction. The value should be placed into the CAL1 to CAL3 registers for X, Y, and Z, respectively. The new value provided here is multiplied with the gyroscope base scale factor value. The new value is used for dynamic calibration. There will be a delay of up to 3 output samples before this takes effect. Once the host has loaded the scale factor values in the CALx registers it needs to issue the CTRL9 command by writing 0x15 to CTRL9 register 0x0A. This CTRL9 command should only be executed when all sensors are disabled.

- CTRL_CMD_HOST_ACCEL_SENSITIVITY

This CTRL9 command is issued when the host wants to tune the accelerometer sensitivity (scale factor). The incremental value of the scale should be 16 bit 2's complement format with 3 bits for unsigned integer and 13 bits fraction. The value should be placed into the CAL1 to CAL3 registers for X, Y, and Z, respectively. The new value provided here is multiplied with the accelerometer base scale factor value. The new value is used for dynamic calibration. There will be a delay of up to 3 output samples before this takes effect. Once the host has loaded the scale factor values in the CALx registers it needs to issue the CTRL9 command by writing 0x14 to CTRL9 register 0x0A. This CTRL9 command should only be executed when all sensors are disabled.

5.8 Interrupts

The QMI8610 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 and INT2 are used. The following provides a summary of the INT1 and 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 5.7). For CTRL9 to work properly, OIS mode (See CTRL3 register) cannot be enabled. Once CTRL9 has been executed, then OIS mode in CTRL3 register can be enabled.

■   During gyroscope OIS mode INT1 is driven by the gyroscope ODR clock (~8 kHz). 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)

NT2 generally indicates data availability. The following indicates when INT2 will be asserted.

Register-Read Mode (FIFO Bypass Mode)

In Register-Read mode the accelerometer, gyroscope and magnetometer data are available in the Sensor Data Output registers (A[X,Y,Z]_[H,L]). The updating of these output registers and the functionality of the INT2 interrupt is controlled by the syncSmpl bit as described below.

With syncSmpl = 0 (refer to 25, CTRL7 register bit 7), 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. A rising edge on INT2 indicates that data is available and INT2 is cleared automatically after a short duration. It is the responsibility of the host to detect the rising edge and to latch the data before the next sample occurs. 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.

With syncSmpl = 1 (refer to 25, CTRL7 register bit 7), INT2 is placed into level mode: 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 QMI8610 will deassert 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 (QMI8610 keeps track) the QMI8610 will start updating the output register and setup the next INT2 when data is available in the output registers.

Note: syncSmpl is not supported for any OIS modes

FIFO Enabled Mode *(see Section 7)*

When the FIFO is enabled in the **FIFO mode** (the mode bits in FIFO_CTRL register set to 01), INT2 is asserted when the FIFO is full or when the watermark is reached.

When the FIFO is enabled in the **Streaming Mode** (the mode bits in FIFO_CTRL register set to 10), INT2 is asserted when the 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 the FIFO Mode and the Streaming 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.

Accelerometer and Gyroscope Self-Test Modes *(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.

OIS LL Mode

In this mode, the gyroscope operates in a high data rate Optical Image Stability (OIS) mode with Low Latency (LL). Data is transmitted through the SPI interface at 8.1 kHz. The SPI bus can be operated using a 3-wire or 4-wire interface by setting the CTRL1 SIM bit. Data is clocked out on the rising edge of INT2. The accelerometer may be used in this mode with a 1 kHz ODR.

6 Operating Modes

The QMI8610 offers a large number of operating modes that may be used to operate the device in a power efficient manner. These modes are described in Table 31 and are shown in Figure 11; they may be configured using the control (CTRL) registers.

Table 31.Operating Modes

Mode	Description	Suggested Configuration
Sensor Modes		
Power-On Default	All sensors off, clock is turned on. The current in this mode is typically 15 µA. Note this mode is the default state upon initial power up or after a reset.	CTRL1 sensorDisable = 0 CTRL7 aEN = 0, gEN = 0, mEN = 0, sEN=0. CTRL2 aODR=000
Low Power	Same as Power-On Default mode, except in this mode the 125 kHz clock is turned on instead of the 1 MHz clock. The current in this mode is typically 5 µA. 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	All QMI8610 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 in this mode is typically 2 µA. Host must initiate this mode by setting sensorDisable=1	CTRL1 sensorDisable =1 CTRL7 aEN = 0, gEN = 0, mEN = 0, sEN=0. CTRL2 aODR=xxx
Mode	**Description**	**Suggested Configuration**
Sensor Modes		
Accel Only	Device configured as an accelerometer only.	CTRL7 aEN =1, gEN =0, mEN =0 CTRL2 aODR=0xx
Low Power Accel Only	Device configured in low power accelerometer mode	CTRL7 aEN =1, gEN =0, mEN =0 CTRL2 aODR=1xx

Gyro Only	Device configured as a gyroscope only.	CTRL7 aEN =0, gEN =1, mEN =0 CTRL2 aODR=000
Mag Only	Device configured as a magnetometer only.	CTRL7 aEN =0, gEN =0, mEN =1 CTRL2 aODR=000
Accel + Mag	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
Accel + Gyro (IMU)	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
Accel + Gyro + Mag (9DOF)	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 (WoM)	Very low power mode used to wake-up the host by providing an interrupt upon detection of device motion. WoM Mode enabled - see CTRL_CMD_WRITE_WOM_SETTING in Section 5.7.5 and see Section 8, Wake On Motion (WoM)	CTRL7 aEN =1, gEN =0, mEN =0 CTRL2 aODR = 111
Gyro Warm Start	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 turn quickly on the gyroscope without needing to wake-up the gyroscope from the Power On Default state(see Figure 11 and Section 6.2).	CTRL3 gODR = 100 CTRL2 aODR = 0xx

Table 31 Operating Modes (Continued)

Mode	Description	Suggested Configuration
Sensor Modes		
OIS	In this mode, the gyroscope operates in a high data rate Optical Image Stability (OIS) mode. Data is transmitted through the SPI interface at 8.1 kHz. The SPI bus can be operated using a 3-wire or 4-wire interface by setting the CTRL1 SIM bit. Data is clocked out on the falling edge of INT1. The accelerometer is not available in this mode.	CTRL3 gODR = 110 CTRL2 aODR = 0xx
OIS LL	In this mode, the gyroscope operates in a high data rate Optical Image Stability (OIS) mode with Low Latency. Data is transmitted through the SPI interface at 8.1 kHz. The SPI bus can be operated using a 3-wire or 4-wire interface by setting the CTRL1 SIM bit. Data is clocked out on the rising edge of INT2. The accelerometer may be used in this mode with a 1 kHz ODR.	CTRL3 gODR = 111 CTRL2 aODR = 000
Hardware Reset	RST pin asserted	
No Power	VDDd and VDDa low	
Attitude Engine Modes		
6DOF AttitudeEngine Mode	Attitude Engine Mode with Accel and Gyro. Note that velocity increments and orientation (quaternion) increments will be output rather than sensor values	CTRL7 aEN = 1, gEN = 1, sEN = 1 CTRL2 aODR=0xx
Attitude Engine Modes		
9DOF AttitudeEngine Mode	AttitudeEngine Mode with Accel, Gyro, and Mag. Note that velocity increments, orientation (quaternion) increments and magnetic field values will be output rather than sensor values	CTRL7 aEN = 1, gEN = 1, sEN = 1, mEN = 1 CTRL4 (configure magnetometer as needed)
Motion On Demand Mode	This mode allows Host to sample AttitudeEngine data asynchronously by polling	CTRL7 aEN = 1, gEN = 1, sEN = 1 CTRL6 sMOD = 1
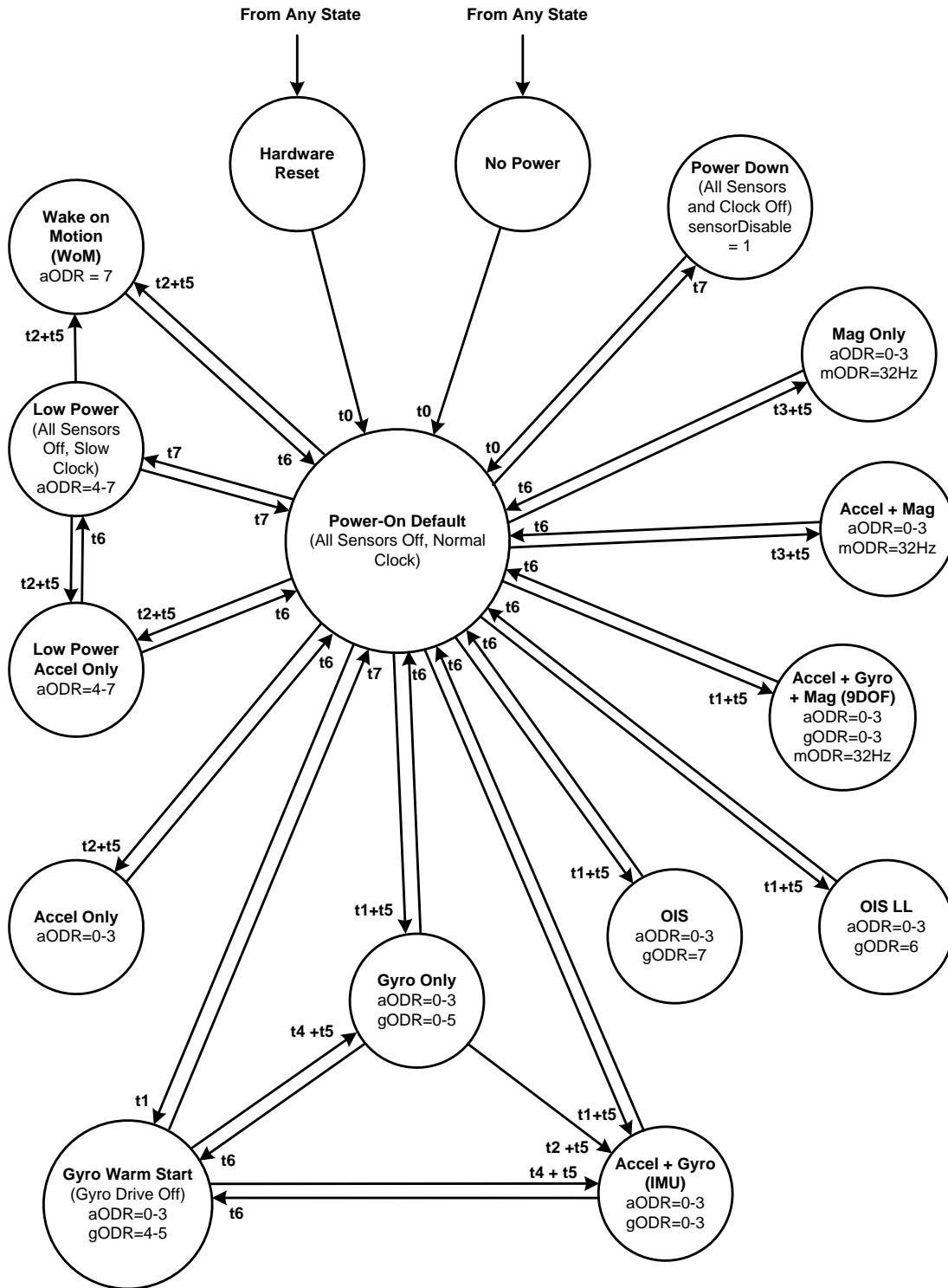
Figure 9. Operating Mode Transition Diagram

6.1 General Mode Transitioning

Upon exiting the No Power state (i.e. on first applying power to the part) or exiting a Hardware Reset state, the part will enter the Power-On Default state. From there, the sensor can be configured in the various modes described in Table 31 and as shown in Figure 9. The figure illustrates the timing associated with various mode transitions, and values for these times are given in the section below and in Table 7 and Table 8.

6.2 Transition Times

The time it takes for data to be present after a mode switch will vary and depends on which mode has been selected. For example, the time it takes for retrieving data from the accelerometer after a mode switch is less than any mode that involves the gyroscope. The times t1, t2, t3 and t4, are defined as the time it takes from INT2 going high to data being present. The time, t5 is the time it takes to have a correct representation of the inertial state. t5 is variable and is associated with the user selected Output Data Rate (ODR). We have defined t5 = (3/ODR) to generally represent that time.

t6 is the time it takes to go from a sensor-powered state to a state where the sensors are off. This time depends on the Output Data Rate (ODR) and ranges from 1/ODR to 2/ODR.

t7 is the transition time between various states where the sensors are off.

t0 is the System Turn On Time, and is the time to enter the Power-On Default state from Hardware Reset, No Power, or Power down.

■ Time t0 is the *System Turn on Time* and is 1.75 seconds. This time only needs to be done once, upon transitioning from either a No Power or Power Down state, or whenever a RST (reset) is issued, which should not be done unless the intent is to have the device to go through its entire boot sequence (see the specification System Turn On Time in both Table 7 and Table 8).

■ The *Gyro Turn on Time* (see Table 8) is comprised of t1 (the gyroscope wakeup time) and t5 (the parts filter settling time). t1 is typically 60 ms and t5 is defined as 3/ODR, where ODR is the output data rate in Hertz.

■ The *Accel Turn on Time* (see Table 7) is comprised of t2 (the accel wakeup time) and t5 (the parts filter settling time). t2 is typically 3 ms, and t5 is defined as 3/ODR, where ODR is the output data rate in Hertz.

■ Time t3 is the magnetometer wakeup time, which is typically 12 ms. Transitioning from the Power-On Default state to a Mag Only state or a Mag + Accel state takes the time t3 + t5, where t5 is defined as 3/ODR, where ODR is the output data rate in Hertz.

■ The *Gyro Warm Start Turn On Time* (see Table 8) is comprised of t4 (the gyroscope wakeup time from warm-start) and t5 (the parts filter settling time). T4 is typically 5 ms, and t5 is defined as 3/ODR, where ODR is the output data rate in Hertz.

■ The t7 transition is dependent on data transfer rates and is for I^{2}C at 400 kHz is <100 μs for SPI at 10 Mbps is around 40 μs.

7 FIFO Description

7.1 Using the FIFO

The QMI8610 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_CTRL register. 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.
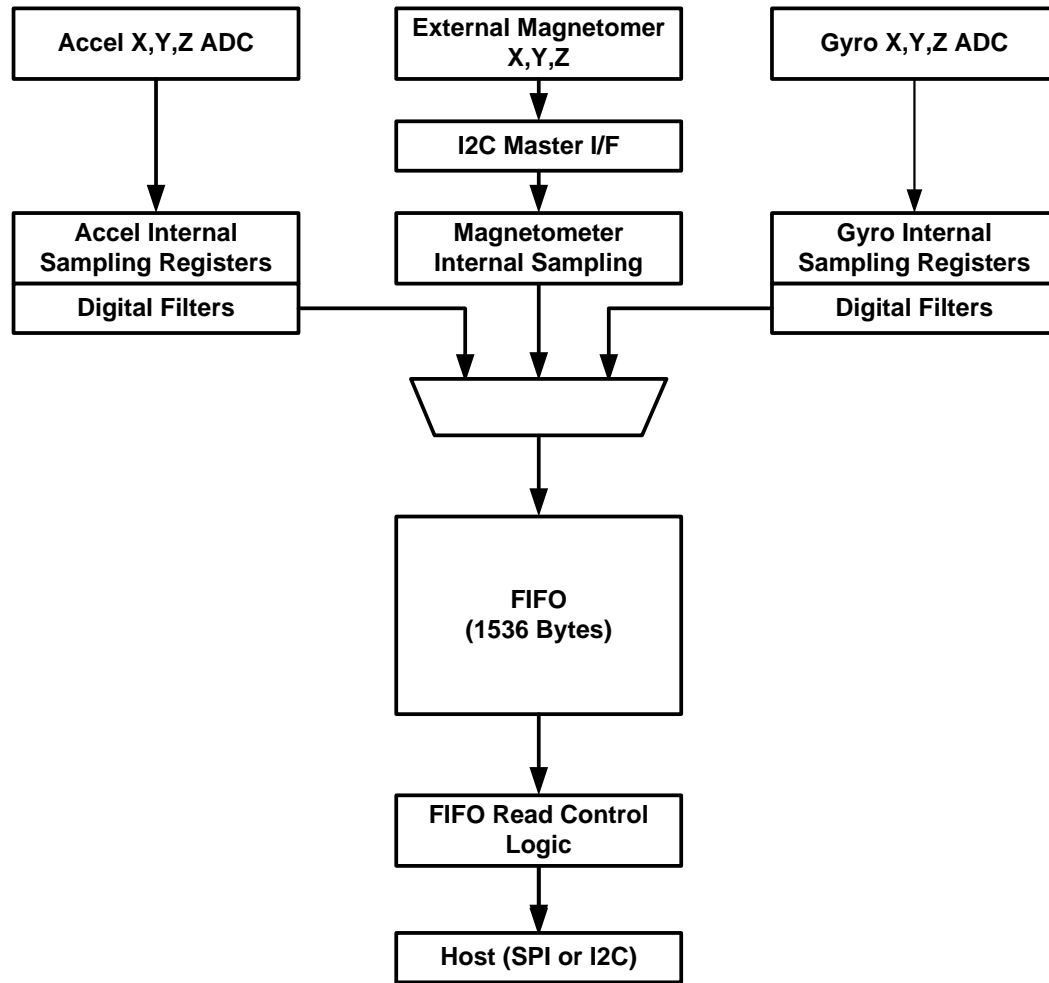
Figure 10. FIFO Data Flow

The FIFO size is configured using the FIFO_CTRL register. When the FIFO is enabled for two or more sensors, as is true for all modes that have multiple sensors active, the sensors must be set at the same Output Data Rate (ODR).

The FIFO is read through the I^2C/SPI interface by reading the FIFO_DATA register. Any time the Output Registers are read, data is erased from the FIFO memory.

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

Enabling FIFO

The FIFO is configured by writing to the FIFO_CTRL register and is enabled after the accelerometer and/or gyroscope are enabled. If the watermark function is enabled in the FIFO_CTRL register, pin INT2 is asserted when the FIFO watermark level is reached.

Reading Sensor Data from FIFO

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

■ Request access to FIFO data buffer by sending CTRL9 command 0x0D.

■ Set FIFO_rd_mode bit to 1 in FIFO_CTRL.

■ Read FIFO_DATA register to empty the FIFO.

■ After FIFO is emptied, set FIFO_rd_mode bit 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.

7.2 FIFO Register Description

Table 32. 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. (See Table 33 for more details.) 00 – Set FIFO size at 16 samples for each enabled sensor 01 – Set FIFO size at 32 samples for each enabled sensor 10 – Set FIFO size at 64 samples for each enabled sensor 11 – Set FIFO size at 128 samples for each enabled sensor (up to 2 sensors enabled only)
1:0	mode<1:0>	1'b0	Set FIFO Mode. 00 – Bypass (FIFO disable). 01 – FIFO. 10 – Streaming. 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.

Bits	Name	Default	Description
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. For more information, see Table 33.

Table 33. FIFO Storage Level Indicator fss<3:0> Description

fss<3:0> Description		Comments	
		The FIFO storage level is indicated by the bits fss<3:0> in the FIFO_STATUS register. The value of fss<3:0> represents a coarse value of the FIFO storage level. The coarseness or granularity varies based on the TOTAL FIFO size, as set by the bits size<1:0> in the FIFO_CTRL register.	
		Total FIFO size is the sum of the Accelerometer, Gyroscope and Magnetometer FIFO samples. Each sample for each sensor uses 6 bytes in the FIFO (2 bytes per axis x 3 axes). For example, with 2 sensors active and the bits size<1:0> = [11], the FIFO size is 256 samples (=2x128), which in bytes is 1536 bytes (=6*2*128).	
		In the table below, the Total FIFO Size lists the total number of sensor samples. Note that this value varies based upon the number of sensors enabled and upon the bits size<1:0> in the FIFO CTRL register .	
		The value of the bits fss<3:0> in the FIFO_STATUS register, represents a coarse sample count, whose granularity is given by the number of sensor samples per LSB, as shown below.	
FIFO_CTRL register, bits size<1:0>	No. of Sensors Enabled (A, G, or M)	Total FIFO Size (Total Number of Samples)	fss<3:0> Granularity (Number of Sensor Samples per LSB)
00	1	16	2
01	1	32	4
00	2		
00	3	48	4

FIFO_CTRL register, bits size<1:0>	No. of Sensors Enabled (A, G, or M)	Total FIFO Size (Total Number of Samples)	fss<3:0> Granularity (Number of Sensor Samples per LSB)
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 to automatically awaken when moved. In this mode the system should use very little power, yet still respond quickly to motion.

It is assumed that the system host processor is responsible for configuring the QMI8610 correctly to place it into Wake on Motion mode, and that the system host processor will reconfigure the QMI8610 as necessary following a WoM interrupt.

Wake on Motion is configured through the CTRL9 command interface (see write-up for CTRL_CMD_WRITE_WOM_SETTING in Section 5.7.5 CTRL9 Commands in Detail).

Table 34. Registers used for WoM

Register (bits)	Function
CAL1_L (0:7)	WoM Threshold: absolute value in mg (with 1mg/LSB resolution) 0x00 must be used to indicate that WoM mode is disabled
CAL1_H (7;6)	WoM interrupt select 01 – INT2 (with initial value 0) 11 – INT2 (with initial value 1) 00 – INT1 (with initial value 0) 10 - INT2 (with initial value 1)
CAL1_H (0:5)	Interrupt blanking time (in number of accelerometer samples)

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

The interrupt initial value (1 or 0) and the interrupt pin used for signaling (INT1 or INT2) 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 microcontrollers requires the use of special wake up pins that may have only a single polarity setting, and thus may not be useable for other special purposes such as timer captures.

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

8.2   Accelerometer Configuration

For additional tuning of the WoM responsiveness, the precise configuration of the accelerometer is left to the host. This gives the host processor the ability to program the desired sample rate and full-scale range.

8.3 Wake on Motion Event

When a Wake on Motion event is detected the QMI8610 will set bit 2 (WoM) in the STATUS1 register. Reading STATUS1 by the host will clear the WoM bit and will reset the chosen interrupt line (INT1 or INT2, see previous section) to the value given by the WoM interrupt initial value (see previous section).

For each WoM event, the state of the selected interrupt line is toggled. This ensures that while the system is moved, the host processor will receive wakeup interrupts regardless of whether it uses high, low, positive- or negative-edge interrupts.

The QMI8610 stays in WoM mode until commanded to enter a new mode by the host processor.

8.4 Configuration Procedure

The host processor is responsible for all configurations necessary to put the QMI8610 into WoM mode. The specific sequence of operations performed by the host processor to enable WoM is shown in Figure 11.

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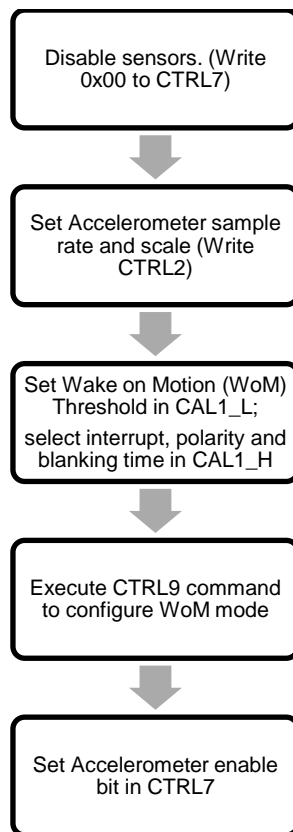
Figure 11. WoM Configuration Commands and Sequence

The WoM bit is cleared upon setting the WoM threshold to a non-zero value, and the selected interrupt pin is 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 is controlled by values written to the CAL1_x registers, as shown in Table 34.
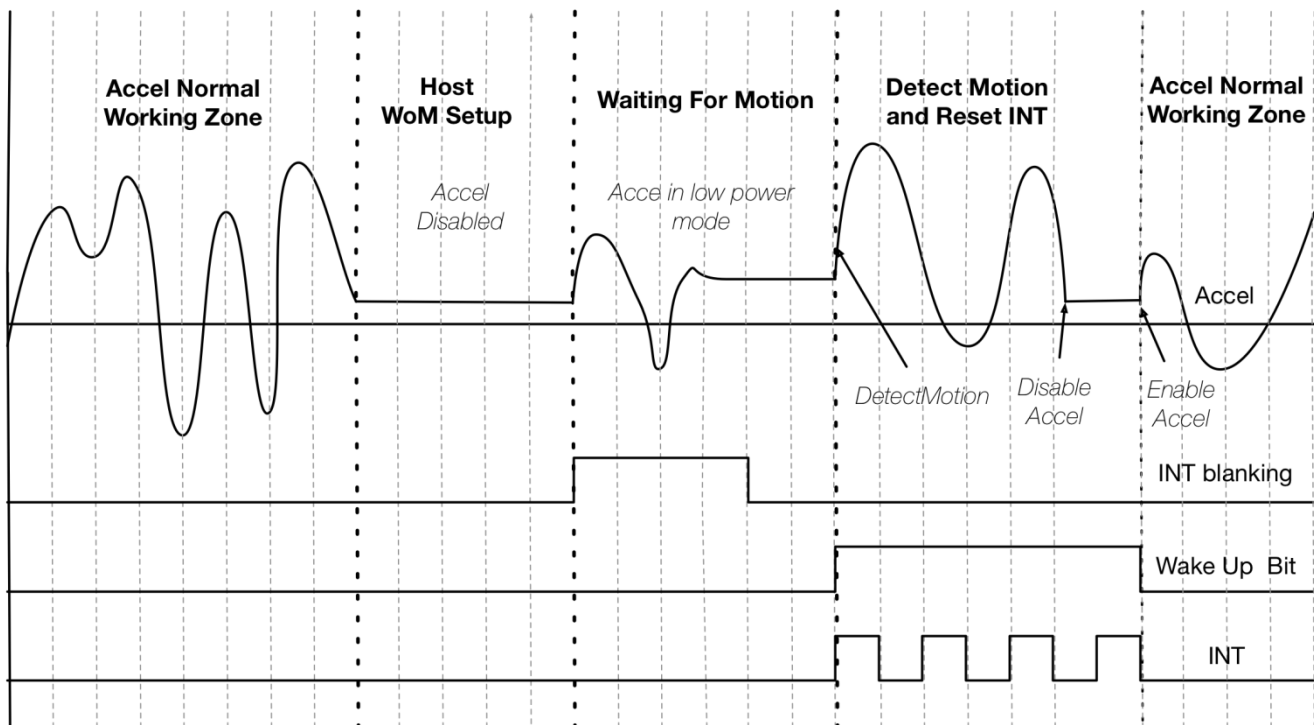
Figure 12. WoM Example Diagram

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 0x0 for the WoM Threshold (see Table 34, Registers used for WoM)and execute the WoM configuration CTRL9 command (see write-up for CTRL_CMD_WRITE_WOM_SETTING in Section 5.7.5 CTRL9 Commands in Detail). On doing this the interrupt pins will return to their normal function. After zeroing the WoM Threshold the host processor may proceed to reconfigure the QMI8610 as normal, as in the case following a reset event.

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.   Wait 1 msec.
3.   Set CTRL2 register to 0x18 (aFS =3, aODR= 0).
4.   Wait 1 msec .
5.   Set CTRL2 register to 0x38. This enables aST (accelerometer Self Test enable bit).
6.   Wait for the device to drive INT2 high.
7.   Read DVX_L, DVX_H, DVY_ L, DVY_H, DVZ_L & DVZ_H registers for the Self Test data.
8.   Set CTRL2 register to 0x18 to disable aST.
9.   INT2 will be pulled low by the QMI8610.
10. Set CTRL2 register to 0x00 (back to default value at power up)
11. Based on the data the host processor determines if the accelerometer response is greater or equal to 50 mg.
12. 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 200 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.   Wait 1 msec
3.   Set CTRL3 to 0x38 (gFS = 7, gODR= 0) (full scale = 4096 dps)
4.   Wait 1 msec
5.   Set CTRL3 register to 0x78. This enables gST (gyroscope Self Test enable bit).
6.   Wait for the device to drive INT2 high.
7.   Read DVX_L, DVX_H, DVY_ L, DVY_H, DVZ_L & DVZ_H registers for the self-test Data.
8.   Set CTRL3 register to 0x38 to disable gST.
9.   INT2 will be pulled low by device.
10.   Set CTRL3 register to 0x00 (back to default value at power up)
11.   Based on the data the host processor determines if the gyroscope response is greater or equal to 200 dps.
12.   If "yes" then the gyroscope Self Test has passed.

10 Host Serial Interface

QMI8610 Host Serial Interface supports I^{2}C 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 QMI8610 Host Serial Interface, the host can access, setup and control the QMI8610 Configuration Registers (see Table 25).

10.1   Serial Peripheral Interface (SPI)

QMI8610 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 the 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 0.

Figure 13 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 13.   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.
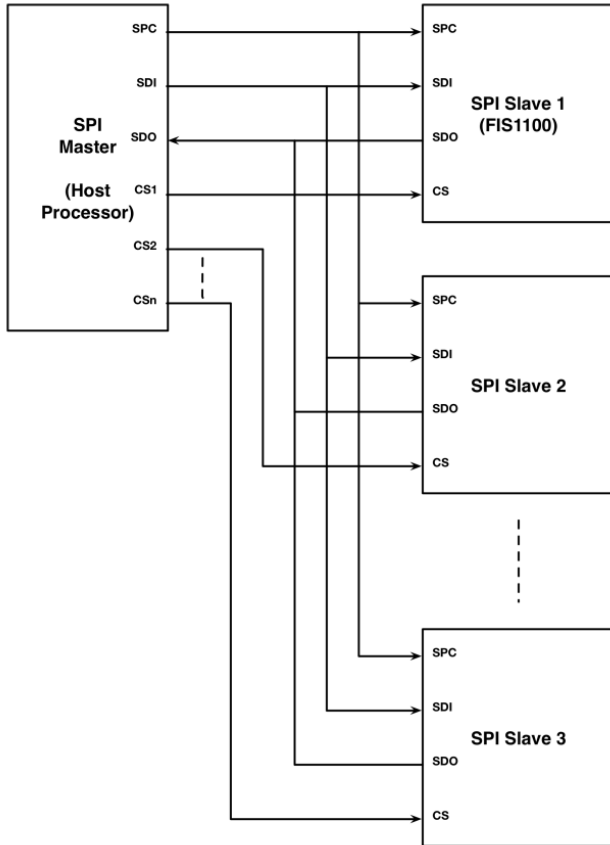
Figure 14.   Typical SPI 4-Wire Multi-Slave   Figure 15.   Typical SPI 3-Wire Multi-Slave
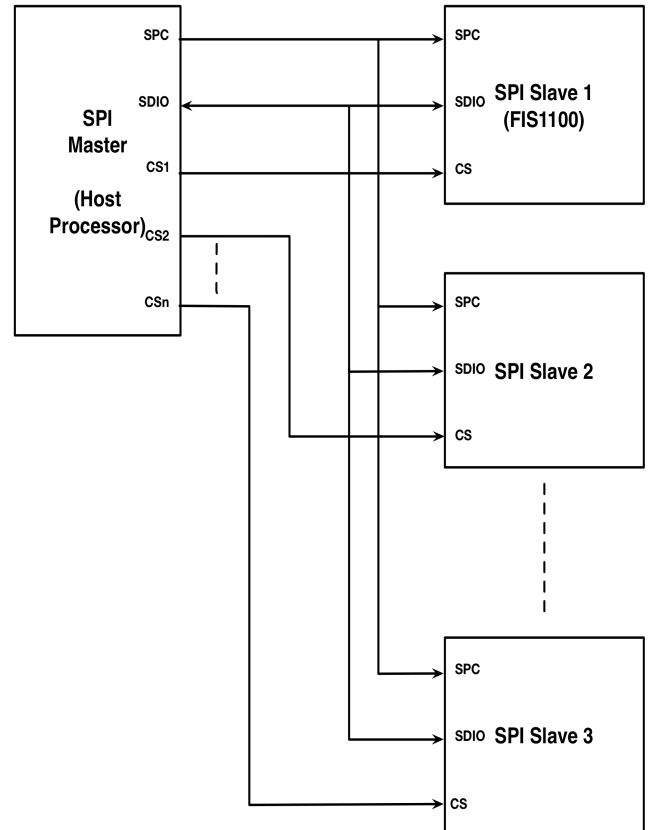
In a typical SPI Master/Slave configuration the SPI master shares the SPI clock (SPC), the serial data input (SDI), and the Serial Data Output (SDO) with all the connected SPI slaves devices. Unique Chip Select (CS) lines connect each SPI slave to the master.

Figure 14 and Figure 15 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 16 and Figure 17 illustrate the waveforms for both 4-wire and 3-wire SPI read and write transactions. Note that CS is active during the entire transaction.
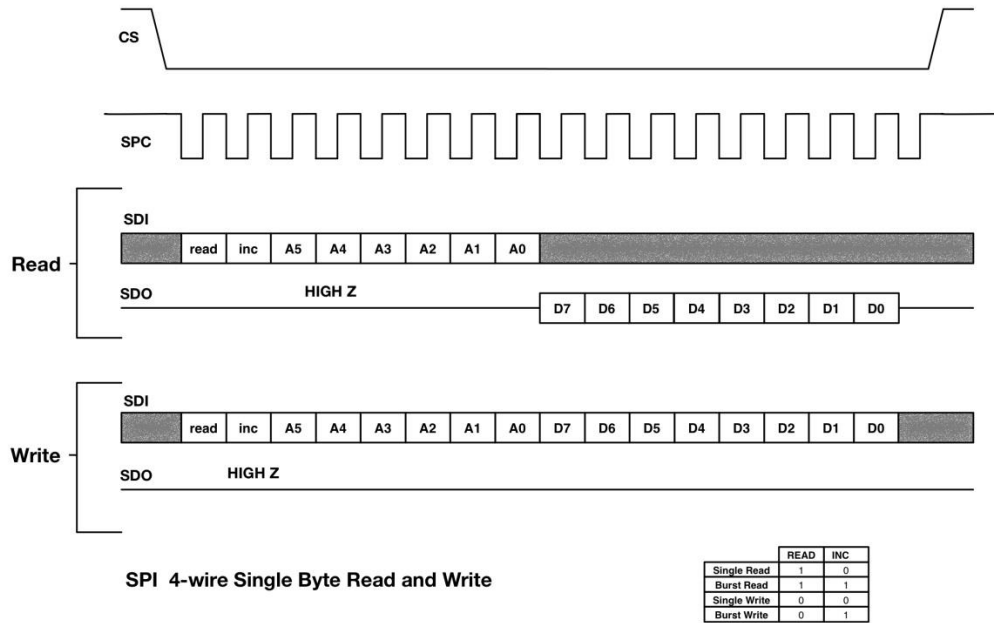

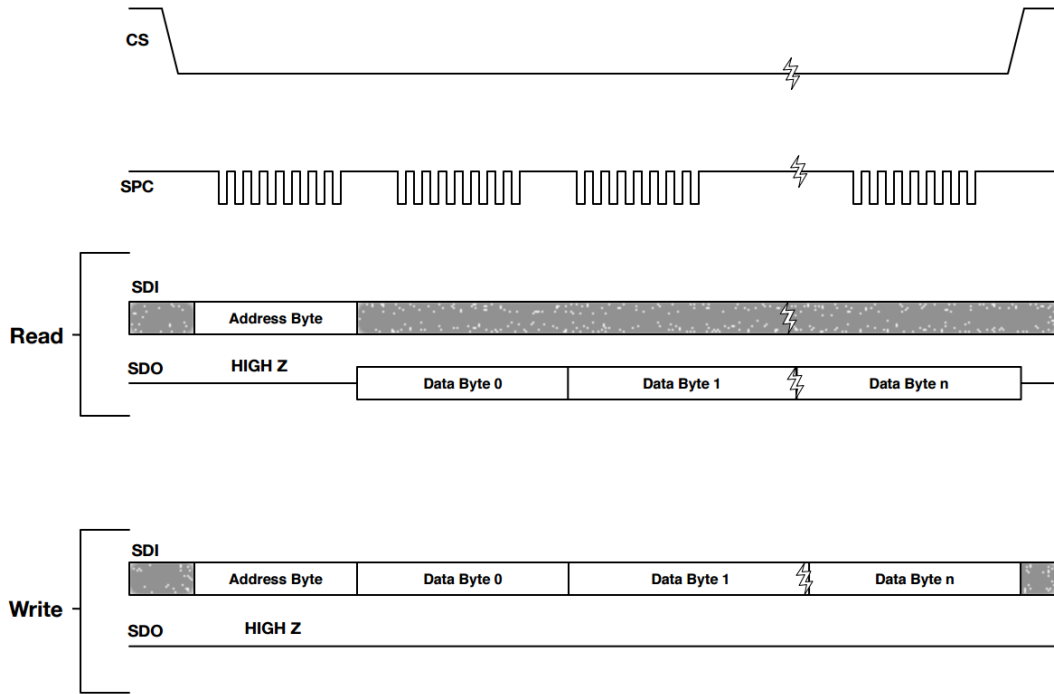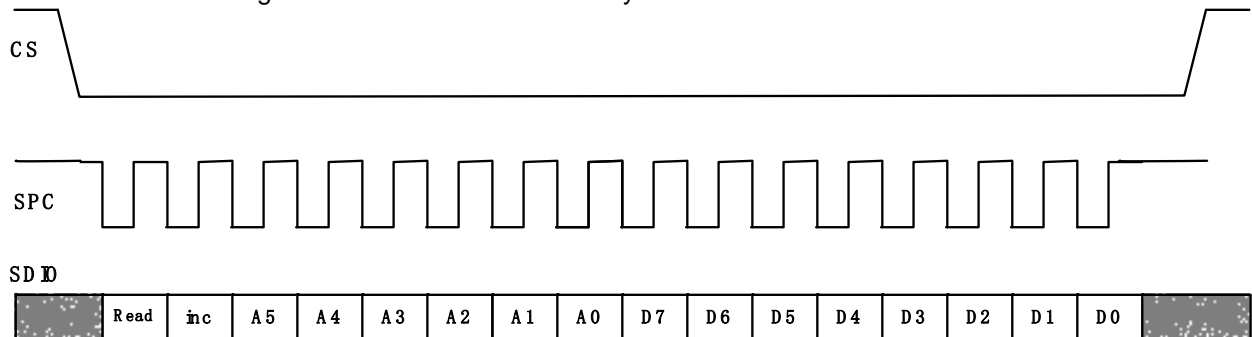Figure 16.   SPI 4-Wire Single Byte Read and Write

Figure 17.   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 18.   SPI 3-Wire Single Byte Read and Write Transactions
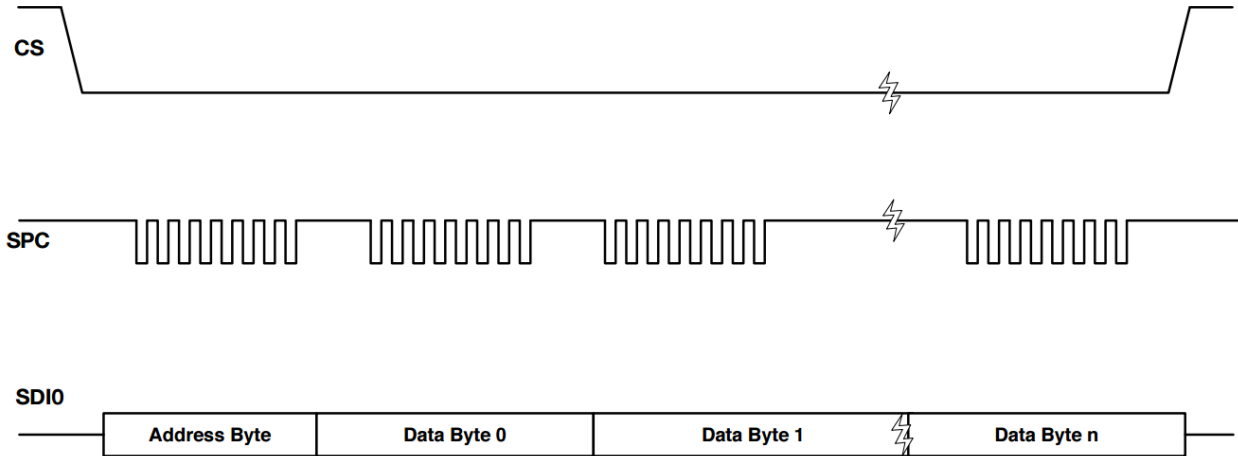
Figure 19.   SPI 3-Wire Multi-Byte Read and Write Transactions

10.1.1 SPI Timing Characteristics

The typical operating conditions for the SPI interface are provided in Table 35

VDDd = 1.8 V, T = 25°C unless otherwise noted.

Table 35. 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

Symbol	Parameter	Min.	Max.	Unit
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
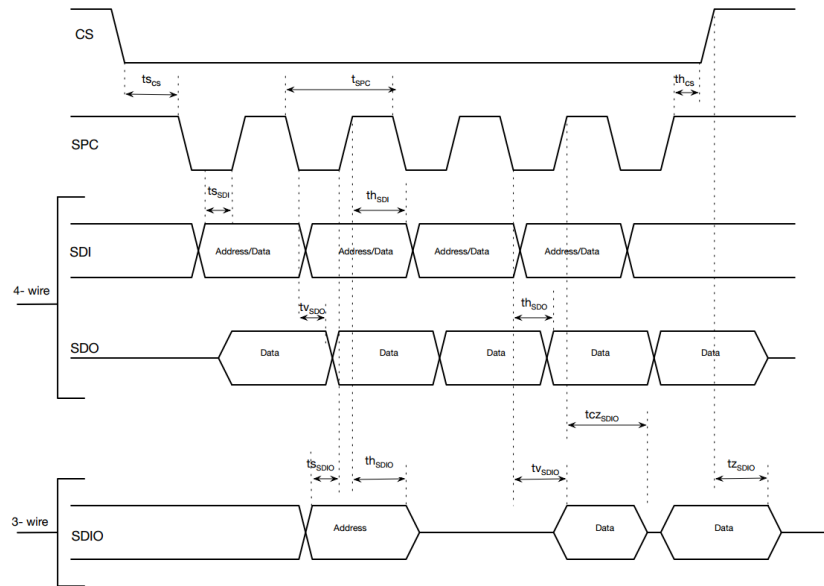
Figure 20.   Timing Characteristics for SPI 3- and 4-Wire Interfaces

10.2   I^{2}C Interface

Table 36 provides the I^{2}C interface timing characteristics while Figure 21 and Figure 22 illustrate the I^{2}C timing for both fast and standard modes, respectively.

During the slave device selection phase, the I^{2}C master supplies the 7-bit I^{2}C slave device address to enable the QMI8610. The 7-bit device address for the QMI8610 is 0x6a (0b1101010) if SA0 is left unconnected, internally there is a weak pull-down of 200 k   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 I^{2}C standard, such as pull-up resistor sizing the user is referred to "UM10204

I^{2}C-bus specification and user manual" published by NXP B.V.

Table 36. I^{2}C 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$_B$(22)		300	
t$_{FCL}$	SCL Fall Time	Standard Mode			300	ns
		Fast Mode	20 + 0.1 * C$_B$(22)		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 * CB(22)		300	

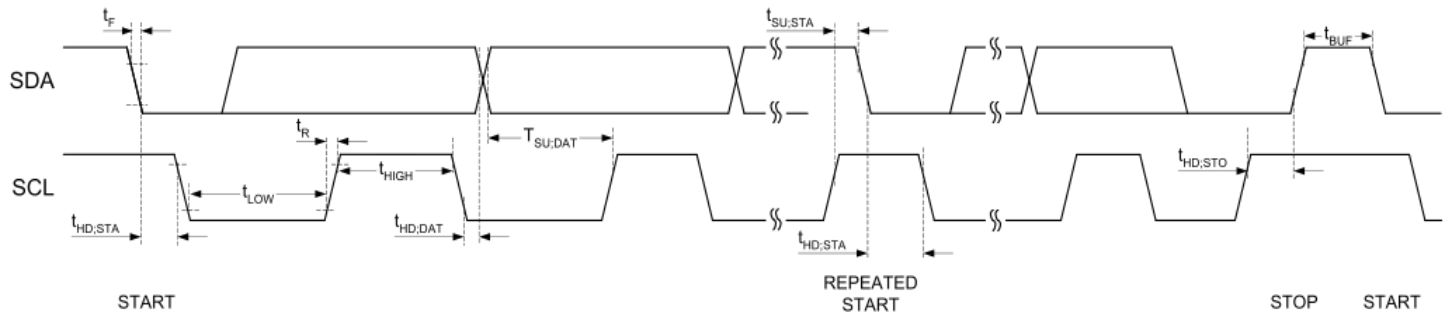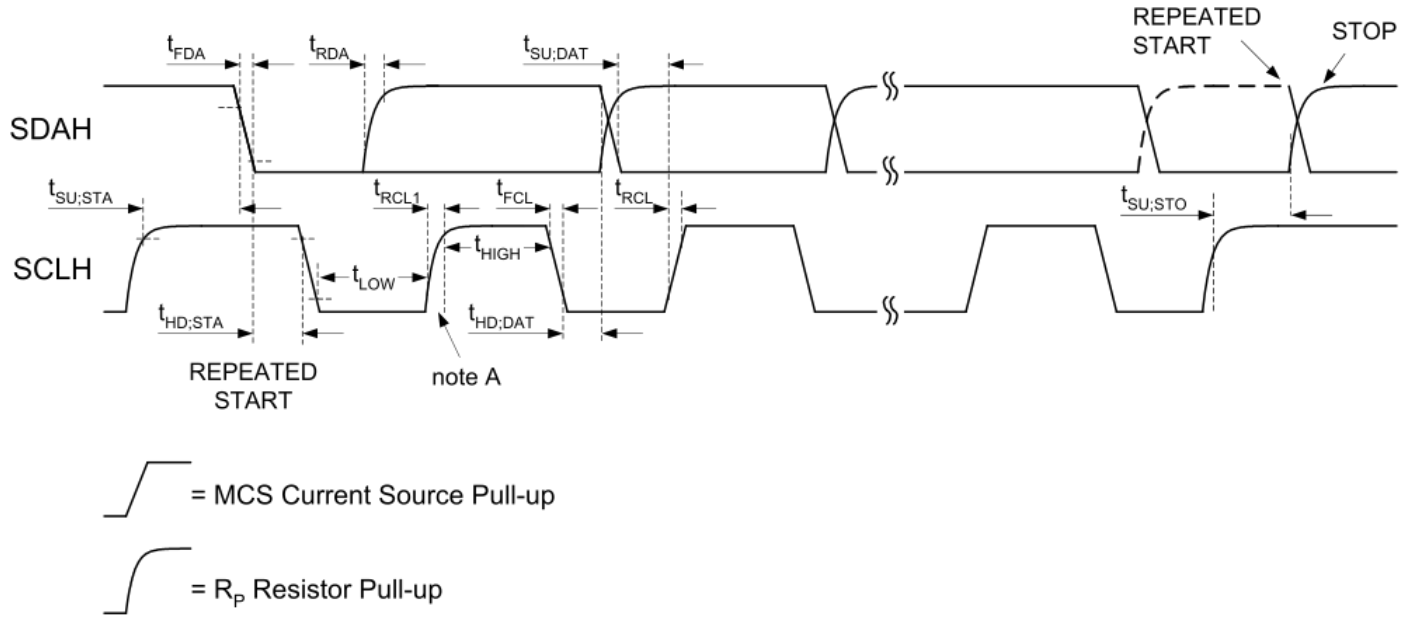| Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
t_{FDA}	SDA Fall Time	Standard Mode			300	ns
		Fast Mode	20 + 0.1 * CB(22)		300	
$t_{SU;STO}$	Stop Condition Setup Time	Standard Mode		4000		ns
		Fast Mode		600		

Note:

22. C_B is the bus capacitance.

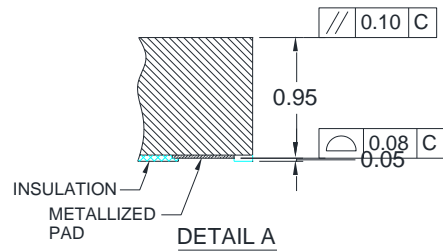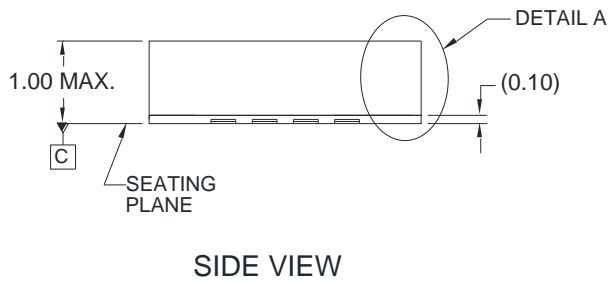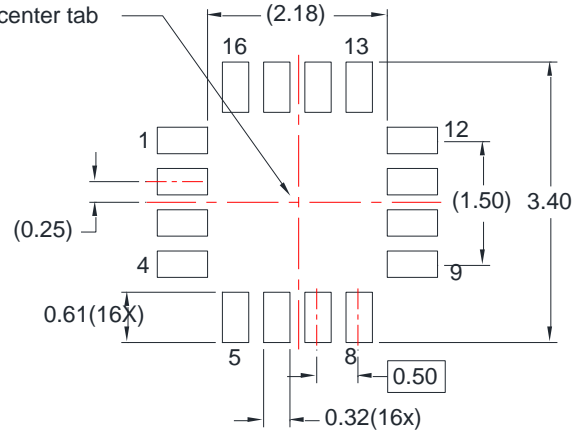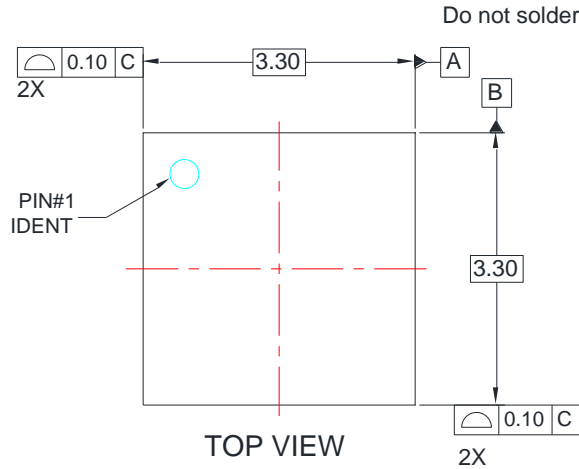Figure 21. I^{2}C Standard Mode Interface Timing

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

Figure 22. I^{2}C Fast Mode Interface Timing

11 Package and Handling

11.1   Package Drawing

TOP VIEW

SIDE VIEW

BOTTOM VIEW

RECOMMENDED LAND PATTERN

DETAIL A
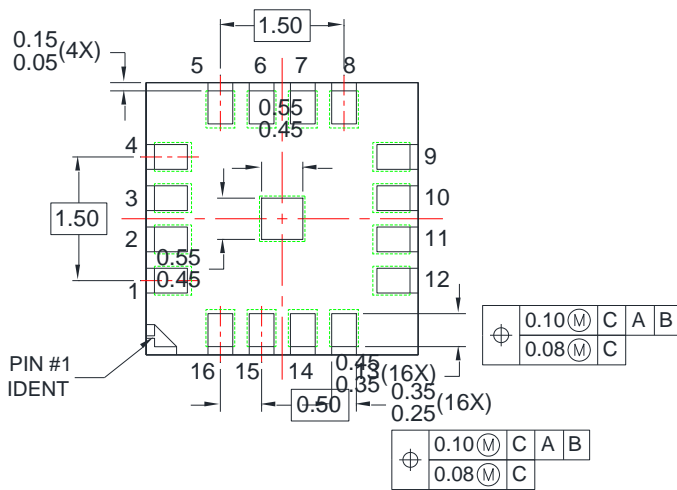
NOTES:
A. JEDEC PUBLICATION 95 DESIGN REGISTRATION
    4.25 ISSUE A, EXCEPT FOR BODY SIZE
    INCREMENT RULE APPLIES TO THIS PACKAGE.
B. DIMENSIONS ARE IN MILLIMETERS.
C. DIMENSIONS AND TOLERANCES PER
    ASME Y14.5M, 1994.
D. LAND PATTERN RECOMMENDATION IS
    BASED ON FSC DESIGN ONLY.
E. DRAWING FILENAME: MKT-LGA16Arev2.
F. FAIRCHILD SEMICONDUCTOR.

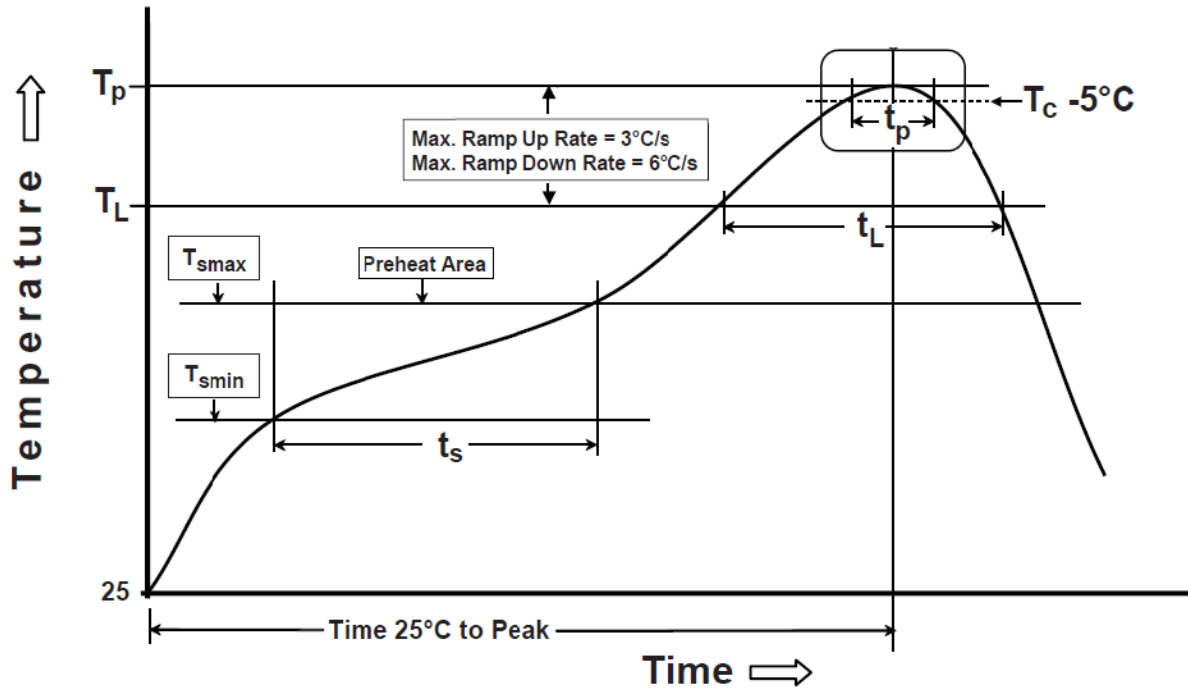Figure 23. 16 Pin LGA 3.3 x 3.3 x 1 mm Package

11.2   Reflow Specification

Figure 24.   Reflow Profile

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

Table 37. Classification Reflow Profiles

11.3　Storage Specifications

QMI8610 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.
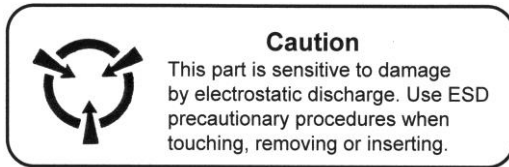
12 Related Resources

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

ORDERING INFORMATION

Ordering Number	Temperature Range	Package	Packaging
QMI8610-TR	-40℃~85℃	LGA	Tape and Reel: 3k pieces/reel

Caution
This part is sensitive to damage by electrostatic discharge. Use ESD precautionary procedures when touching, removing or inserting.

CAUTION: ESDS CAT. 1B

FIND OUT MORE

For more information on QST's Sensors contact us at 86-21-50497300.

The application circuits herein constitute typical usage and interface of QST product. QST does not provide warranty or assume liability of customer-designed circuits derived from this description or depiction.

QST reserves the right to make changes to improve reliability, function or design. QST does not assume any liability arising out of the application or use of any product or circuit described herein; neither does it convey any license under its patent rights nor the rights of others.

ISO9001 : 2008

China Patents 201510000399.8, 201510000425.7, 201310426346.3, 201310426677.7, 201310426729.0, 201210585811.3 and 201210553014.7 apply to the technology described.

QST

First Floor, Building No.2,

Chengbei Road 235, Shanghai

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QST Corporation