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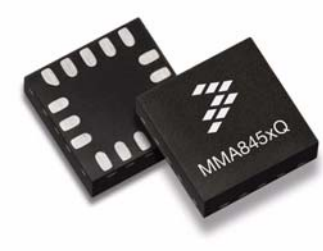
Xtrinsic MMA8452Q 3-Axis, 12-bit/8-bit Digital Accelerometer

MMA8452Q

The MMA8452Q is a smart, low-power, three-axis, capacitive, micromachined accelerometer with 12 bits of resolution. This accelerometer is packed with embedded functions with flexible user programmable options, configurable to two interrupt pins. Embedded interrupt functions allow for overall power savings relieving the host processor from continuously polling data.

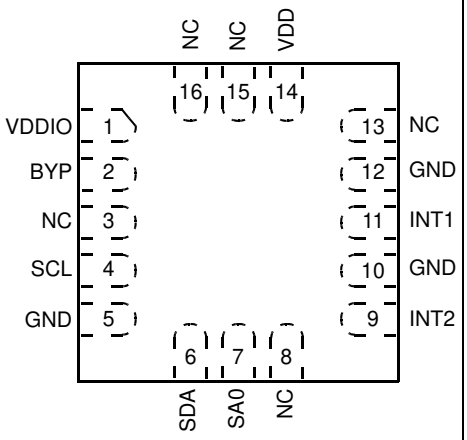
The MMA8452Q has user selectable full scales of ±2g/±4g/±8g with high-pass filter filtered data as well as non-filtered data available real-time. The device can be configured to generate inertial wakeup interrupt signals from any combination of the configurable embedded functions allowing the MMA8452Q to monitor events and remain in a low power mode during periods of inactivity. The MMA8452Q is available in a 3 mm x 3 mm x 1 mm QFN package.

Top and Bottom View



16 PIN QFN
3 mm x 3 mm x 1 mm
CASE 2077-02

Top View



Pin Connections

Features

- 1.95V to 3.6V supply voltage
- 1.6V to 3.6V interface voltage
- ±2g/±4g/±8g dynamically selectable full-scale
- Output Data Rates (ODR) from 1.56 Hz to 800 Hz
- 99 µg/√Hz noise
- 12-bit and 8-bit digital output
- I^2C digital output interface
- Two programmable interrupt pins for six interrupt sources
- Three embedded channels of motion detection
  - Freefall or Motion Detection: 1 channel
  - Pulse Detection: 1 channel
  - Transient Detection: 1 channel
    - Orientation (Portrait/Landscape) detection with set hysteresis
    - Automatic ODR change for Auto-WAKE and return to SLEEP
    - High-Pass Filter Data available real-time
    - Self-Test
    - RoHS compliant
    - Current Consumption: 6 µA to 165 µA

Typical Applications

- E-Compass applications
- Static orientation detection (Portrait/Landscape, Up/Down, Left/Right, Back/Front position identification)
- Notebook, e-reader, and Laptop Tumble and Freefall Detection
- Real-time orientation detection (virtual reality and gaming 3D user position feedback)
- Real-time activity analysis (pedometer step counting, freefall drop detection for HDD, dead-reckoning GPS backup)
- Motion detection for portable product power saving (Auto-SLEEP and Auto-WAKE for cell phone, PDA, GPS, gaming)
- Shock and vibration monitoring (mechatronic compensation, shipping and warranty usage logging)
- User interface (menu scrolling by orientation change, pulse detection for button replacement)

ORDERING INFORMATION			
Part Number	**Temperature Range**	**Package Description**	**Shipping**
MMA8452QT	-40°C to +85°C	QFN-16	Tray
MMA8452QR1	-40°C to +85°C	QFN-16	Tape and Reel

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freescale Xtrinsic

Contents

Related Documentation

The MMA8452Q device features and operations are described in a variety of reference manuals, user guides, and application notes. To find the most-current versions of these documents:

1. Go to the Freescale homepage at:

   http://www.freescale.com/

2. In the Keyword search box at the top of the page, enter the device number MMA8452Q.
3. In the Refine Your Result pane on the left, click on the Documentation link.

1 Block Diagram and Pin Description

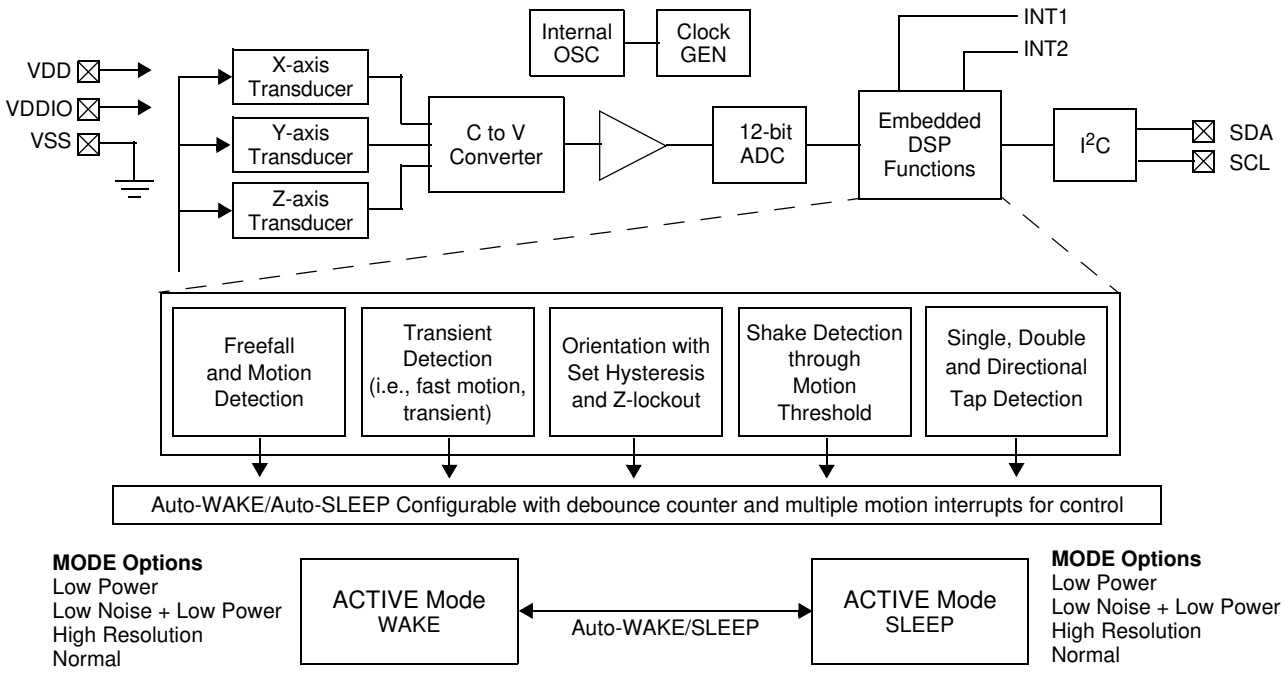

Figure 1. Block Diagram

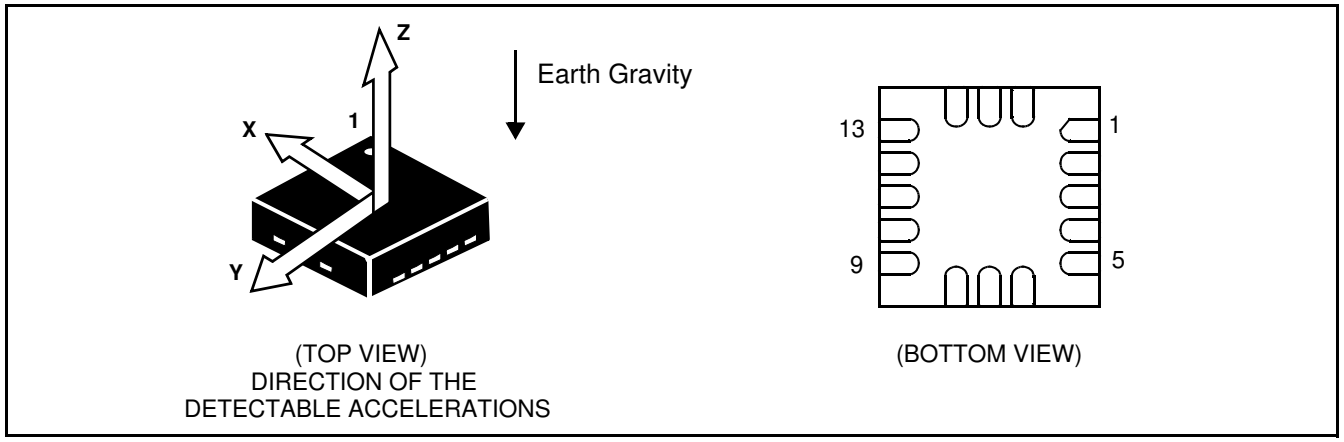

Figure 2. Direction of the Detectable Accelerations

Figure 3 shows the device configuration in the six different orientation modes. These orientations are defined as the following: PU = Portrait Up, LR = Landscape Right, PD = Portrait Down, LL = Landscape Left, BACK and FRONT side views. There are several registers to configure the orientation detection and are described in detail in the register setting section.

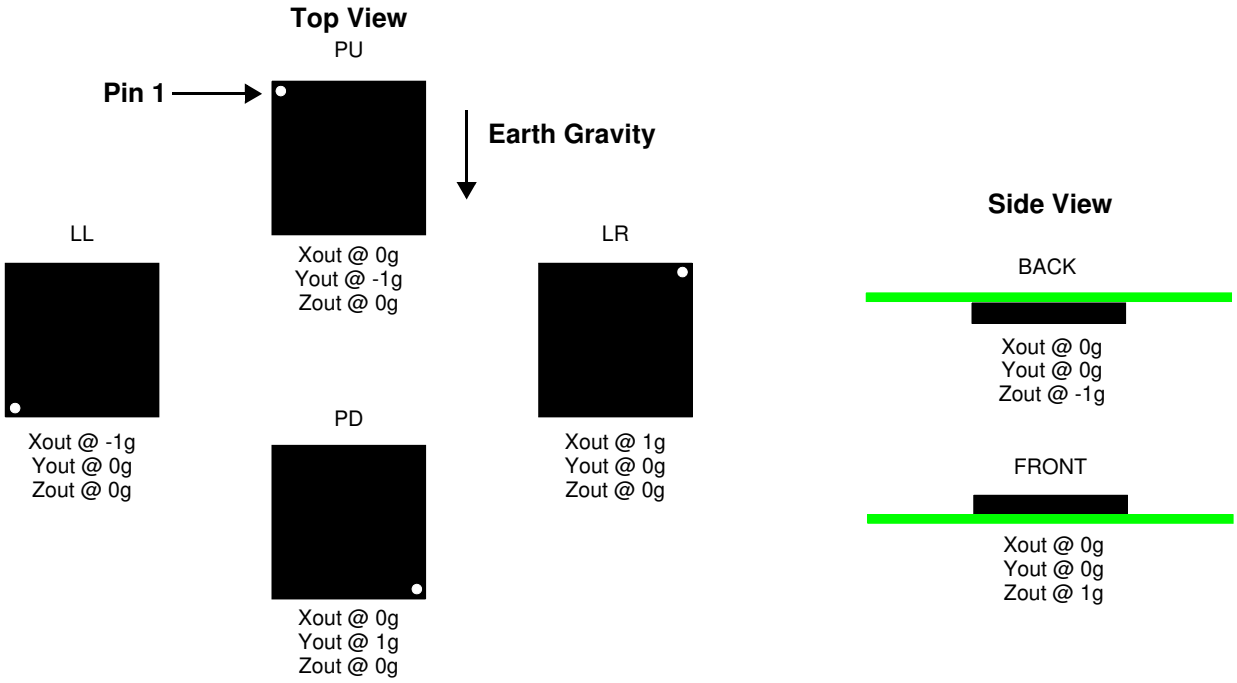

Figure 3. Landscape/Portrait Orientation

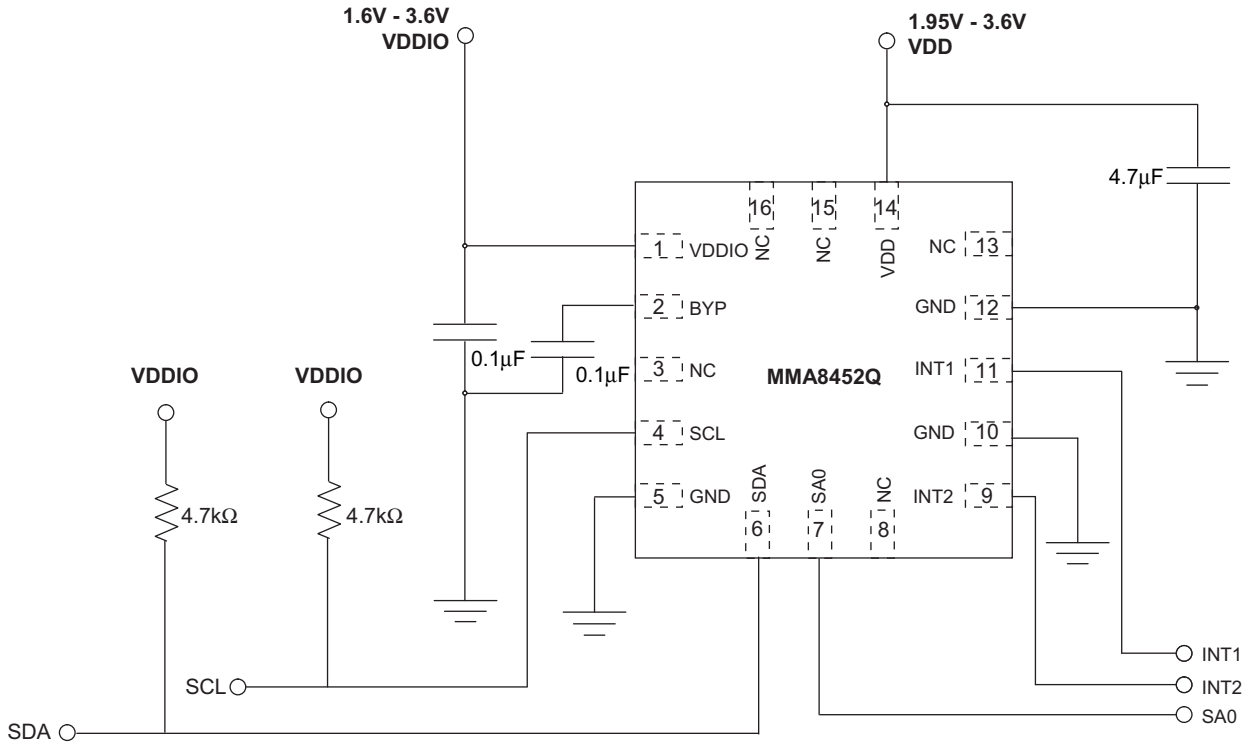

Figure 4. Application Diagram

Table 1. Pin Descriptions

Pin #	Pin Name	Description	Pin Status
1	VDDIO	Power Supply for IO pins (1.62V - 3.6V)	Input
2	BYP	Bypass capacitor (0.1 µF)	Input
3	NC	Leave open. Do not connect.	Open
4	SCL	I^2C Serial Clock	Open Drain
5	GND	Connect to Ground	Input
6	SDA	I^2C Serial Data	Open Drain
7	SA0	I^2C Least Significant Bit of the Device I^2C Address	Input
8	NC	Internally not connected (can be GND or VDD)	Input
9	INT2	Inertial Interrupt 2	Output
10	GND	Connect to Ground	Input
11	INT1	Inertial Interrupt 1	Output
12	GND	Connect to Ground	Input
13	NC	Internally not connected (can be GND or VDD)	Input
14	VDD	Internal Power Supply (1.95V to 3.6V)	Input
15	NC	Internally not connected (can be GND or VDD)	Input
16	NC	Internally not connected (can be GND or VDD)	Input

The device power is supplied through VDD line. Power supply decoupling capacitors (100 nF ceramic plus 4.7 µF bulk, or a single 4.7 µF ceramic) should be placed as near as possible to the pins 1 and 14 of the device.

The control signals SCL, SDA, and SA0 are not tolerant of voltages more than VDDIO + 0.3V. If VDDIO is removed, the control signals SCL, SDA, and SA0 will clamp any logic signals with their internal ESD protection diodes.

The functions, the threshold and the timing of the two interrupt pins (INT1 and INT2) are user programmable through the I^2C interface. The SDA and SCL I^2C connections are open drain and therefore require a pullup resistor as shown in the application diagram in Figure 4.

1.1 Soldering Information

The QFN package is compliant with the RoHS standard. Please refer to AN4077.

2 Mechanical and Electrical Specifications

2.1 Mechanical Characteristics

Table 2. Mechanical Characteristics @ VDD = 2.5V, VDDIO = 1.8V, T = 25°C unless otherwise noted.

Parameter	Test Conditions	Symbol	Min	Typ	Max	Unit
Measurement Range(1)	FS[1:0] set to 00 2g Mode	FS		±2		g
	FS[1:0] set to 01 4g Mode			±4		
	FS[1:0] set to 10 8g Mode			±8		
Sensitivity	FS[1:0] set to 00 2g Mode	So		1024		counts/g
	FS[1:0] set to 01 4g Mode			512		
	FS[1:0] set to 10 8g Mode			256		
Sensitivity Accuracy(2)		Soa		±2.64		%
Sensitivity Change vs. Temperature	FS[1:0] set to 00 2g Mode	TCSo		±0.008		%/°C
	FS[1:0] set to 01 4g Mode					
	FS[1:0] set to 10 8g Mode					
Zero-g Level Offset Accuracy(3)	FS[1:0] 2g, 4g, 8g	TyOff		±17		mg
Zero-g Level Offset Accuracy Post Board Mount(4)	FS[1:0] 2g, 4g, 8g	TyOffPBM		±20		mg
Zero-g Level Change vs. Temperature	-40°C to 85°C	TCOff		±0.15		mg/°C
Self-Test Output Change(5) X Y Z	FS[1:0] set to 0 4g Mode	Vst		 +181 +255 +1680		LSB
ODR Accuracy 2 MHz Clock				±2		%
Output Data Bandwidth		BW	ODR/3		ODR/2	Hz
Output Noise	Normal Mode ODR = 400 Hz	Noise		126		µg/√Hz
Output Noise Low-Noise Mode(1)	Normal Mode ODR = 400 Hz	Noise		99		µg/√Hz
Operating Temperature Range		Top	-40		+85	°C

1. Dynamic Range is limited to 4g when the Low-Noise bit in Register 0x2A, bit 2 is set.
2. Sensitivity remains in spec as stated, but changing Oversampling mode to Low Power causes 3% sensitivity shift. This behavior is also seen when changing from 800 Hz to any other data rate in the Normal, Low Noise + Low Power or High Resolution mode.
3. Before board mount.
4. Post Board Mount Offset Specifications are based on an 8 Layer PCB, relative to 25°C.
5. Self-Test is one direction only.

2.2 Electrical Characteristics

Table 3. Electrical Characteristics @ VDD = 2.5V, VDDIO = 1.8V, T = 25°C unless otherwise noted.

Parameter	Test Conditions	Symbol	Min	Typ	Max	Unit
Supply Voltage		VDD[1]	1.95	2.5	3.6	V
Interface Supply Voltage		VDDIO[1]	1.62	1.8	3.6	V
Low-Power Mode	ODR = 1.56 Hz	I_{dd}LP		6		µA
	ODR = 6.25 Hz			6		
	ODR = 12.5 Hz			6		
	ODR = 50 Hz			14		
	ODR = 100 Hz			24		
	ODR = 200 Hz			44		
	ODR = 400 Hz			85		
	ODR = 800 Hz			165		
Normal Mode	ODR = 1.56 Hz	I_{dd}		24		µA
	ODR = 6.25 Hz			24		
	ODR = 12.5 Hz			24		
	ODR = 50 Hz			24		
	ODR = 100 Hz			44		
	ODR = 200 Hz			85		
	ODR = 400 Hz			165		
	ODR = 800 Hz			165		
Current during Boot Sequence, 0.5 mSec max duration using recommended Bypass Cap	VDD = 2.5V	Idd Boot			1	mA
Value of Capacitor on BYP Pin	-40°C 85°C	Cap	75	100	470	nF
STANDBY Mode Current @25°C	VDD = 2.5V, VDDIO = 1.8V STANDBY Mode	I_{dd}Stby		1.8	5	µA
Digital High Level Input Voltage SCL, SDA, SA0		VIH	0.7*VDDIO			V
Digital Low-Level Input Voltage SCL, SDA, SA0		VIL			0.3*VDDIO	V
High Level Output Voltage INT1, INT2	I_O = 500 µA	VOH	0.9*VDDIO			V
Low-Level Output Voltage INT1, INT2	I_O = 500 µA	VOL			0.1*VDDIO	V
Low-Level Output Voltage SDA	I_O = 500 µA	VOLS			0.1*VDDIO	V
Power on Ramp Time			0.001		1000	ms
Time from VDDIO on and VDD > Vmin until I^2C ready for operation	Cbyp = 100 nF	BT	—	350	500	µs
Turn-on time (STANDBY)[2]		Ton_{Stby}			1.1/ODR	s
Turn-on time (Power Down to STANDBY)		Ton			2	ms
Operating Temperature Range		Top	-40		+85	°C

1. There is no requirement for power supply sequencing. The VDDIO input voltage can be higher than the VDD input voltage.
2. Note that the first sample is typically not very precise. Depending on ODR/MODS settings, a minimum of three samples is recommended for full precision.

2.3 I²C interface characteristics

Table 4. I²C slave timing values(1)

Parameter	Symbol	I²C Fast Mode		Unit
		Min	Max	
SCL clock frequency	f_{SCL}	0	400	kHz
Bus-free time between STOP and START condition	t_{BUF}	1.3		µs
(Repeated) START hold time	$t_{HD;STA}$	0.6		µs
Repeated START setup time	$t_{SU;STA}$	0.6		µs
STOP condition setup time	$t_{SU;STO}$	0.6		µs
SDA data hold time	$t_{HD;DAT}$	0.05	0.9 (2)	µs
SDA setup time	$t_{SU;DAT}$	100		ns
SCL clock low time	t_{LOW}	1.3		µs
SCL clock high time	t_{HIGH}	0.6		µs
SDA and SCL rise time	t_r	20 + 0.1 C_b(3)	300	ns
SDA and SCL fall time	t_f	20 + 0.1 C_b(3)	300	ns
SDA valid time (4)	$t_{VD;DAT}$		0.9 (2)	µs
SDA valid acknowledge time (5)	$t_{VD;ACK}$		0.9 (2)	µs
Pulse width of spikes on SDA and SCL that must be suppressed by internal input filter	t_{SP}	0	50	ns
Capacitive load for each bus line	Cb		400	pF

1.All values referred to $V_{IH(min)}$ ($0.3V_{DD}$) and $V_{IL(max)}$ ($0.7V_{DD}$) levels.
2.This device does not stretch the LOW period (t_{LOW}) of the SCL signal.
3.C_b = total capacitance of one bus line in pF.
4.$t_{VD;DAT}$ = time for data signal from SCL LOW to SDA output (HIGH or LOW, depending on which one is worse).
5.$t_{VD;ACK}$ = time for Acknowledgement signal from SCL LOW to SDA output (HIGH or LOW, depending on which one is worse).

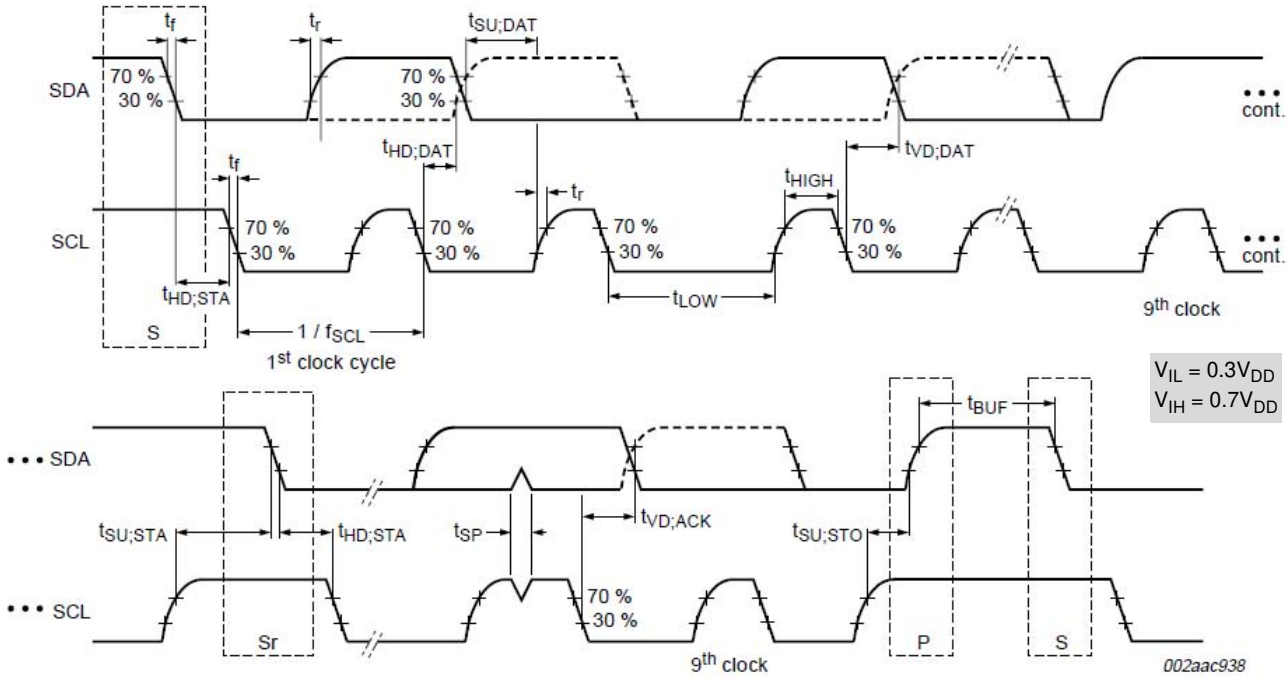

Figure 5. I²C slave timing diagram

2.4 Absolute Maximum Ratings

Stresses above those listed as “absolute maximum ratings” may cause permanent damage to the device. Exposure to maximum rating conditions for extended periods may affect device reliability.

Table 5. Maximum Ratings

Rating	Symbol	Value	Unit
Maximum Acceleration (all axes, 100 μs)	g_{max}	5,000	g
Supply Voltage	VDD	-0.3 to + 3.6	V
Input voltage on any control pin (SA0, SCL, SDA)	Vin	-0.3 to VDDIO + 0.3	V
Drop Test	D_{drop}	1.8	m
Operating Temperature Range	T_{OP}	-40 to +85	°C
Storage Temperature Range	T_{STG}	-40 to +125	°C

Table 6. ESD and Latchup Protection Characteristics

Rating	Symbol	Value	Unit
Human Body Model	HBM	±2000	V
Machine Model	MM	±200	V
Charge Device Model	CDM	±500	V
Latchup Current at T = 85°C	—	±100	mA

This device is sensitive to mechanical shock. Improper handling can cause permanent damage of the part or cause the part to otherwise fail.

This device is sensitive to ESD, improper handling can cause permanent damage to the part.

3 Terminology

3.1 Sensitivity

The sensitivity is represented in counts/g. In 2g mode the sensitivity is 1024 counts/g. In 4g mode the sensitivity is 512 counts/g and in 8g mode the sensitivity is 256 counts/g.

3.2 Zero-g Offset

Zero-g Offset (TyOff) describes the deviation of an actual output signal from the ideal output signal if the sensor is stationary. A sensor stationary on a horizontal surface will measure 0g in X-axis and 0g in Y-axis whereas the Z-axis will measure 1g. The output is ideally in the middle of the dynamic range of the sensor (content of OUT Registers 0x00, data expressed as 2's complement number). A deviation from ideal value in this case is called Zero-g offset. Offset is to some extent a result of stress on the MEMS sensor and therefore the offset can slightly change after mounting the sensor onto a printed circuit board or exposing it to extensive mechanical stress.

3.3 Self-Test

Self-Test checks the transducer functionality without external mechanical stimulus. When Self-Test is activated, an electrostatic actuation force is applied to the sensor, simulating a small acceleration. In this case, the sensor outputs will exhibit a change in their DC levels which are related to the selected full scale through the device sensitivity. When Self-Test is activated, the device output level is given by the algebraic sum of the signals produced by the acceleration acting on the sensor and by the electrostatic test-force.

4 Modes of Operation

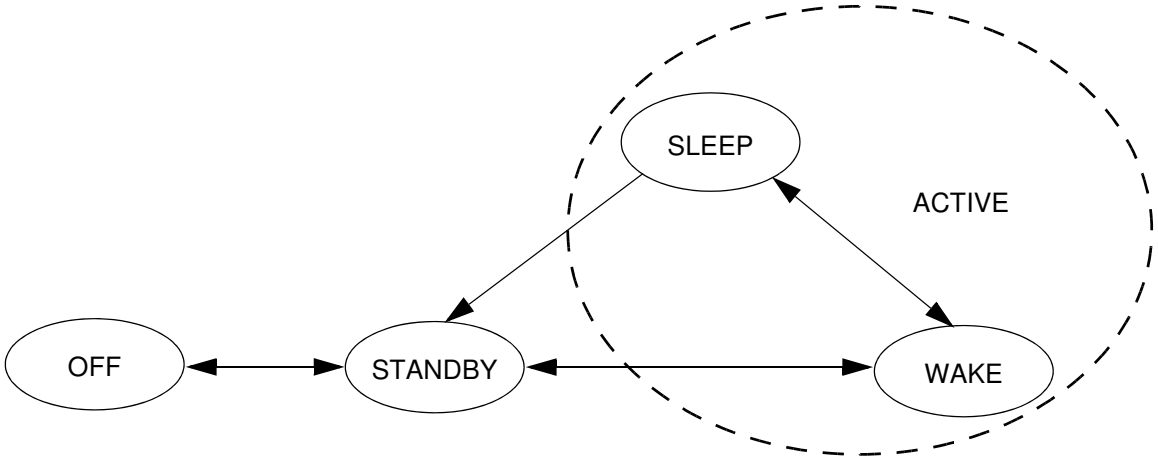

Figure 6. MMA8452Q Mode Transition Diagram

Table 7. Mode of Operation Description

Mode	I^2C Bus State	VDD	VDDIO	Function Description
OFF	Powered Down	<1.8V	VDDIO Can be > VDD	The device is powered off. All analog and digital blocks are shutdown. I^2C bus inhibited.
STANDBY	I^2C communication with MMA8452Q is possible	ON	VDDIO = High VDD = High ACTIVE bit is cleared	Only digital blocks are enabled. Analog subsystem is disabled. Internal clocks disabled.
ACTIVE (WAKE/SLEEP)	I^2C communication with MMA8452Q is possible	ON	VDDIO = High VDD = High ACTIVE bit is set	All blocks are enabled (digital, analog).

All register contents are preserved when transitioning from ACTIVE to STANDBY mode. Some registers are reset when transitioning from STANDBY to ACTIVE. These are all noted in the device memory map register table. The SLEEP and WAKE modes are ACTIVE modes. For more information on how to use the SLEEP and WAKE modes and how to transition between these modes, please refer to the functionality section of this document.

5 Functionality

The MMA8452Q is a low-power, digital output 3-axis linear accelerometer with a I^2C interface and embedded logic used to detect events and notify an external microprocessor over interrupt lines. The functionality includes the following:

- 8-bit or 12-bit data which includes High-Pass Filtered data
- 4 different oversampling options for compromising between resolution and current consumption based on application requirements
- Additional Low-Noise mode that functions independently of the Oversampling modes for higher resolution
- Low Power and Auto-WAKE/SLEEP modes for conservation of current consumption
- Single-/Double-pulse with directional information 1 channel
- Motion detection with directional information or Freefall 1 channel
- Transient detection based on a high-pass filter and settable threshold for detecting the change in acceleration above a threshold with directional information 1 channel
- Portrait/Landscape detection with trip points fixed at 30° and 60° for smooth transitions between orientations.

All functionality is available in 2g, 4g or 8g dynamic ranges. There are many configuration settings for enabling all the different functions. Separate application notes have been provided to help configure the device for each embedded functionality.

Table 8. Features of the MMA845xQ devices

Feature List	MMA8451	MMA8452	MMA8453
Digital Resolution (Bits)	14	12	10
Digital Sensitivity (Counts/g)	4096	1024	256
Data-Ready Interrupt	Yes	Yes	Yes
Single-Pulse Interrupt	Yes	Yes	Yes
Double-Pulse Interrupt	Yes	Yes	Yes
Directional-Pulse Interrupt	Yes	Yes	Yes
Auto-WAKE	Yes	Yes	Yes
Auto-SLEEP	Yes	Yes	Yes
Freefall Interrupt	Yes	Yes	Yes
32 Level FIFO	Yes	No	No
High-Pass Filter	Yes	Yes	Yes
Low-Pass Filter	Yes	Yes	Yes
Orientation Detection Portrait/Landscape = 30°, Landscape to Portrait = 60°, and Fixed 45° Threshold	Yes	Yes	Yes
Programmable Orientation Detection	Yes	No	No
Motion Interrupt with Direction	Yes	Yes	Yes
Transient Detection with High-Pass Filter	Yes	Yes	Yes
Low Power Mode	Yes	Yes	Yes

5.1 Device Calibration

The device interface is factory calibrated for sensitivity and Zero-g offset for each axis. The trim values are stored in Non Volatile Memory (NVM). On power-up, the trim parameters are read from NVM and applied to the circuitry. In normal use, further calibration in the end application is not necessary. However, the MMA8452Q allows the user to adjust the Zero-g offset for each axis after power-up, changing the default offset values. The user offset adjustments are stored in 6 volatile registers. For more information on device calibration, refer to Freescale application note, AN4069.

5.2 8-bit or 12-bit Data

The measured acceleration data is stored in the OUT_X_MSB, OUT_X_LSB, OUT_Y_MSB, OUT_Y_LSB, OUT_Z_MSB, and OUT_Z_LSB registers as 2's complement 12-bit numbers. The most significant 8-bits of each axis are stored in OUT_X (Y, Z)_MSB, so applications needing only 8-bit results can use these 3 registers and ignore OUT_X,Y, Z_LSB. To do this, the F_READ bit in CTRL_REG1 must be set. When the F_READ bit is cleared, the fast read mode is disabled.

When the full-scale is set to 2g, the measurement range is -2g to +1.999g, and each count corresponds to 1g/1024 (1 mg) at 12-bits resolution. When the full-scale is set to 8g, the measurement range is -8g to +7.996g, and each count corresponds to 1g/256 (3.9 mg) at 12-bits resolution. The resolution is reduced by a factor of 16 if only the 8-bit results are used. For more information on the data manipulation between data formats and modes, refer to Freescale application note, AN4076. There is a device driver available that can be used with the Sensor Toolbox demo board (LFSTBEB8451, 2, 3Q).

5.3 Low-Power Modes vs. High-Resolution Modes

The MMA8452Q can be optimized for lower power modes or for higher resolution of the output data. High resolution is achieved by setting the LNOISE bit in Register 0x2A. This improves the resolution but be aware that the dynamic range is limited to 4g when this bit is set. This will affect all internal functions and reduce noise. Another method for improving the resolution of the data is by oversampling. One of the oversampling schemes of the data can activated when MODS = 10 in Register 0x2B which will improve the resolution of the output data only. The highest resolution is achieved at 1.56 Hz.

There is a trade-off between low power and high resolution. Low Power can be achieved when the oversampling rate is reduced. The lowest power is achieved when MODS = 11 or when the sample rate is set to 1.56 Hz. For more information on how to configure the MMA8452Q in Low-Power mode or High-Resolution mode and to realize the benefits, refer to Freescale application note, AN4075.

5.4 Auto-WAKE/SLEEP Mode

The MMA8452Q can be configured to transition between sample rates (with their respective current consumption) based on four of the interrupt functions of the device. The advantage of using the Auto-WAKE/SLEEP is that the system can automatically transition to a higher sample rate (higher current consumption) when needed but spends the majority of the time in the SLEEP mode (lower current) when the device does not require higher sampling rates. Auto-WAKE refers to the device being triggered by one of the interrupt functions to transition to a higher sample rate. This may also interrupt the processor to transition from a SLEEP mode to a higher power mode.

SLEEP mode occurs after the accelerometer has not detected an interrupt for longer than the user definable time-out period. The device will transition to the specified lower sample rate. It may also alert the processor to go into a lower power mode to save on current during this period of inactivity.

The Interrupts that can WAKE the device from SLEEP are the following: Pulse Detection, Orientation Detection, Motion/Freefall, and Transient Detection. Refer to AN4074, for more detailed information for configuring the Auto-WAKE/SLEEP.

5.5 Freefall and Motion Detection

MMA8452Q has flexible interrupt architecture for detecting either a Freefall or a Motion. Freefall can be enabled where the set threshold must be less than the configured threshold, or motion can be enabled where the set threshold must be greater than the threshold. The motion configuration has the option of enabling or disabling a high-pass filter to eliminate tilt data (static offset). The freefall does not use the high-pass filter. For details on the Freefall and Motion detection with specific application examples and recommended configuration settings, refer to Freescale application note, AN4070.

5.5.1 Freefall Detection

The detection of "Freefall" involves the monitoring of the X, Y, and Z axes for the condition where the acceleration magnitude is **below** a user specified threshold for a user definable amount of time. Normally, the usable threshold ranges are between ±100 mg and ±500 mg.

5.5.2 Motion Detection

Motion is often used to simply alert the main processor that the device is currently in use. When the acceleration exceeds a set threshold the motion interrupt is asserted. A motion can be a fast moving shake or a slow moving tilt. This will depend on the threshold and timing values configured for the event. The motion detection function can analyze static acceleration changes or faster jolts. For example, to detect that an object is spinning, all three axes would be enabled with a threshold detection of > 2g. This condition would need to occur for a minimum of 100 ms to ensure that the event wasn't just noise. The timing value is set by a configurable debounce counter. The debounce counter acts like a filter to determine whether the condition exists for configurable set of time (i.e., 100 ms or longer). There is also directional data available in the source register to detect the direction of the motion. This is useful for applications such as directional shake or flick, which assists with the algorithm for various gesture detections.

5.6 Transient Detection

The MMA8452Q has a built-in high-pass filter. Acceleration data goes through the high-pass filter, eliminating the offset (DC) and low frequencies. The high-pass filter cutoff frequency can be set by the user to four different frequencies which are dependent on the Output Data Rate (ODR). A higher cutoff frequency ensures the DC data or slower moving data will be filtered out, allowing only the higher frequencies to pass. The embedded Transient Detection function uses the high-pass filtered data allowing the user to set the threshold and debounce counter. The Transient detection feature can be used in the same manner as the motion detection by bypassing the high-pass filter. There is an option in the configuration register to do this. This adds more flexibility to cover various customer use cases.

Many applications use the accelerometer's static acceleration readings (i.e., tilt) which measure the change in acceleration due to gravity only. These functions benefit from acceleration data being filtered with a low-pass filter where high-frequency data is considered noise. However, there are many functions where the accelerometer must analyze dynamic acceleration. Functions such as tap, flick, shake and step counting are based on the analysis of the change in the acceleration. It is simpler to interpret these functions dependent on dynamic acceleration data when the static component has been removed. The Transient Detection function can be routed to either interrupt pin through bit 5 in CTRL_REG5 register (0x2E). Registers 0x1D – 0x20 are the dedicated Transient Detection configuration registers. The source register contains directional data to determine the direction of the acceleration, either positive or negative. For details on the benefits of the embedded Transient Detection function along with specific application examples and recommended configuration settings, please refer to Freescale application note, AN4071.

5.7 Pulse Detection

The MMA8452Q has embedded single/double and directional pulse detection. This function has various customizing timers for setting the pulse time width and the latency time between pulses. There are programmable thresholds for all three axes. The pulse detection can be configured to run through the high-pass filter and also through a low-pass filter, which provides more customizing and tunable pulse-detection schemes. The status register provides updates on the axes where the event was detected and the direction of the tap. For more information on how to configure the device for pulse detection, please refer to Freescale application note, AN4072.

5.8 Orientation Detection

The MMA8452Q has an orientation detection algorithm with the ability to detect all 6 orientations. The transition from portrait to landscape is fixed with a 45° threshold angle and a ±14° hysteresis angle. This allows the for a smooth transition from portrait to landscape at approximately 30° and then from landscape to portrait at approximately 60°.

The angle at which the device no longer detects the orientation change is referred to as the "Z-Lockout angle". The device operates down to 29° from the flat position. All angles are accurate to ±2°.

For further information on the orientation detection function refer to Freescale application note, AN4068.

Figure 8 shows the definitions of the trip angles going from Landscape to Portrait (A) and then also from Portrait to Landscape (B).

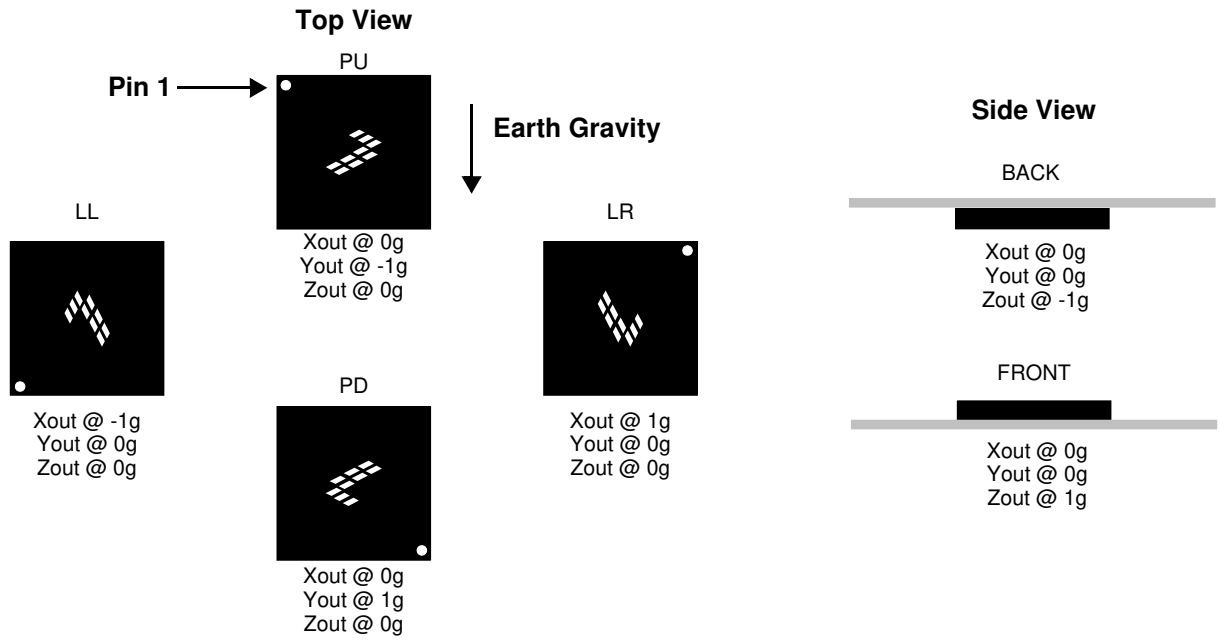

Figure 7. Landscape/Portrait Orientation

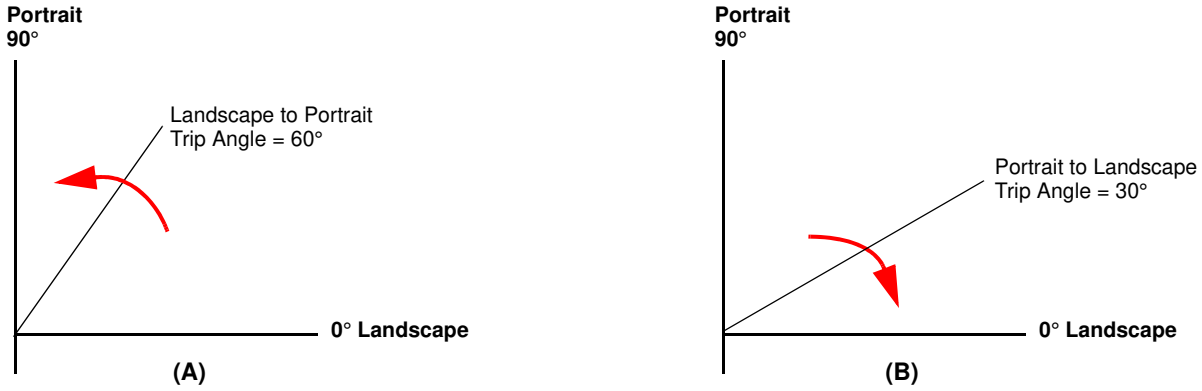

Figure 8. Illustration of Landscape to Portrait Transition (A) and Portrait to Landscape Transition (B)

Figure 9 illustrates the Z-angle lockout region. When lifting the device upright from the flat position it will be active for orientation detection as low as 29° from flat. .

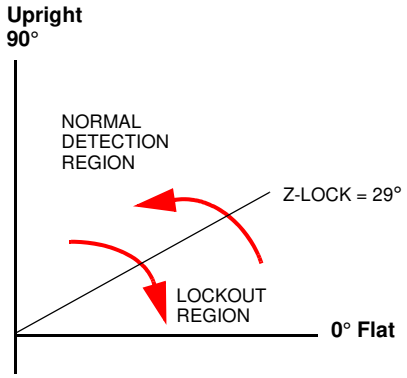

Figure 9. Illustration of Z-Tilt Angle Lockout Transition

5.9 Interrupt Register Configurations

There are six configurable interrupts in the MMA8452Q: Data Ready, Motion/Freefall, Pulse, Orientation, Transient, and Auto-SLEEP events. These six interrupt sources can be routed to one of two interrupt pins. The interrupt source must be enabled and configured. If the event flag is asserted because the event condition is detected, the corresponding interrupt pin, INT1 or INT2, will assert.

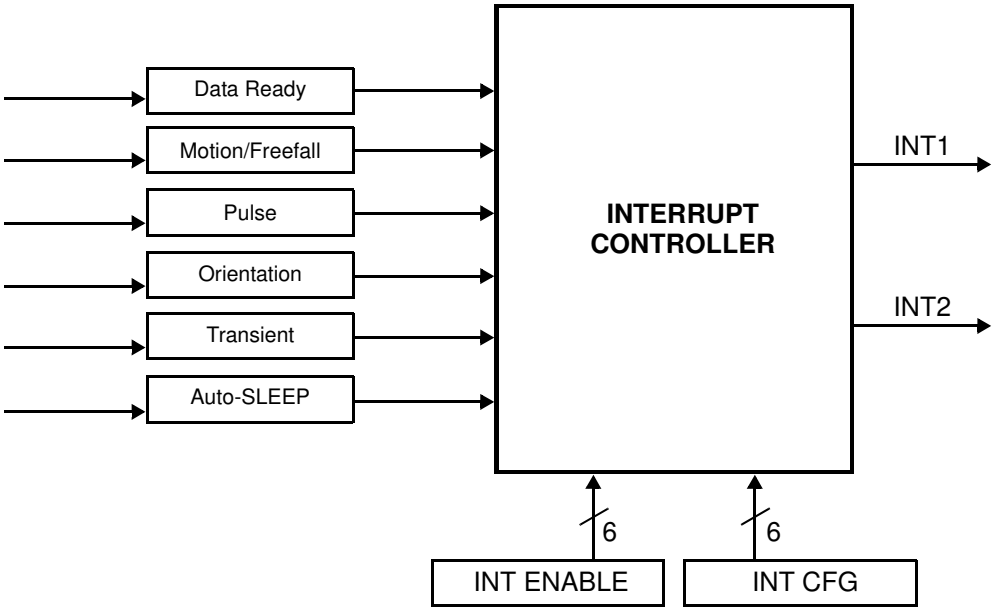

Figure 10. System Interrupt Generation Block Diagram

5.10 Serial I²C Interface

Acceleration data may be accessed through an I²C interface thus making the device particularly suitable for direct interfacing with a microcontroller. The MMA8452Q features an interrupt signal which indicates when a new set of measured acceleration data is available thus simplifying data synchronization in the digital system that uses the device. The MMA8452Q may also be configured to generate other interrupt signals accordingly to the programmable embedded functions of the device for Motion, Freefall, Transient, Orientation, and Pulse.

The registers embedded inside the MMA8452Q are accessed through the I²C serial interface (Table 9). To enable the I²C interface, VDDIO line must be tied high (i.e., to the interface supply voltage). If VDD is not present and VDDIO is present, the MMA8452Q is in off mode and communications on the I²C interface are ignored. The I²C interface may be used for communications between other I²C devices and the MMA8452Q does not affect the I²C bus.

Table 9. Serial Interface Pin Description

Pin Name	Pin Description
SCL	I²C Serial Clock
SDA	I²C Serial Data
SA0	I²C least significant bit of the device address

There are two signals associated with the I²C bus; the Serial Clock Line (SCL) and the Serial Data line (SDA). The latter is a bidirectional line used for sending and receiving the data to/from the interface. External pullup resistors connected to VDDIO are expected for SDA and SCL. When the bus is free both the lines are high. The I²C interface is compliant with fast mode (400 kHz), and Normal mode (100 kHz) I²C standards (Table 5).

5.10.1 I²C Operation

The transaction on the bus is started through a start condition (START) signal. START condition is defined as a HIGH to LOW transition on the data line while the SCL line is held HIGH. After START has been transmitted by the Master, the bus is considered busy. The next byte of data transmitted after START contains the slave address in the first 7 bits, and the eighth bit tells whether the Master is receiving data from the slave or transmitting data to the slave. When an address is sent, each device in the system compares the first seven bits after a start condition with its address. If they match, the device considers itself addressed by the Master. The 9th clock pulse, following the slave address byte (and each subsequent byte) is the acknowledge (ACK). The transmitter must release the SDA line during the ACK period. The receiver must then pull the data line low so that it remains stable low during the high period of the acknowledge clock period.

A LOW to HIGH transition on the SDA line while the SCL line is high is defined as a stop condition (STOP). A data transfer is always terminated by a STOP. A Master may also issue a repeated START during a data transfer. The MMA8452Q expects repeated STARTs to be used to randomly read from specific registers.

The MMA8452Q's standard slave address is a choice between the two sequential addresses 0011100 and 0011101. The selection is made by the high- and low-logic level of the SA0 (pin 7) input respectively. The slave addresses are factory programmed and alternate addresses are available at customer request. The format is shown in Table 10.

Single Byte Read

The MMA8452Q has an internal ADC that can sample, convert and return sensor data on request. The transmission of an 8-bit command begins on the falling edge of SCL. After the eight clock cycles are used to send the command, note that the data returned is sent with the MSB first once the data is received. Figure 11 shows the timing diagram for the accelerometer 8-bit I²C read operation. The Master (or MCU) transmits a start condition (ST) to the MMA8452Q, slave address ($1D), with the R/W bit set to “0” for a write, and the MMA8452Q sends an acknowledgement. Then the Master (or MCU) transmits the address of the register to read and the MMA8452Q sends an acknowledgement. The Master (or MCU) transmits a repeated start condition (SR) and then addresses the MMA8452Q ($1D) with the R/W bit set to “1” for a read from the previously selected register. The Slave then acknowledges and transmits the data from the requested register. The Master does not acknowledge (NAK) the transmitted data, but transmits a stop condition to end the data transfer.

Multiple Byte Read

When performing a multi-byte read or “burst read”, the MMA8452Q automatically increments the received register address commands after a read command is received. Therefore, after following the steps of a single byte read, multiple bytes of data can be read from sequential registers after each MMA8452Q acknowledgment (AK) is received until a no acknowledge (NAK) occurs from the Master followed by a stop condition (SP) signaling an end of transmission.

Single Byte Write

To start a write command, the Master transmits a start condition (ST) to the MMA8452Q, slave address ($1D) with the R/W bit set to “0” for a write, the MMA8452Q sends an acknowledgement. Then the Master (MCU) transmits the address of the register to write to, and the MMA8452Q sends an acknowledgement. Then the Master (or MCU) transmits the 8-bit data to write to the designated register and the MMA8452Q sends an acknowledgement that it has received the data. Since this transmission is complete, the Master transmits a stop condition (SP) to the data transfer. The data sent to the MMA8452Q is now stored in the appropriate register.

Multiple Byte Write

The MMA8452Q automatically increments the received register address commands after a write command is received. Therefore, after following the steps of a single byte write, multiple bytes of data can be written to sequential registers after each MMA8452Q acknowledgment (ACK) is received.

Table 10. I^2C Device Address Sequence

Command	[7:2] Device Address	[1] SA0	[7:1] Device Address	R/W	[7:0] 8-bit Final Value
Read	001110	0	0x1C	1	0x39
Write	001110	0	0x1C	0	0x38
Read	001110	1	0x1D	1	0x3B
Write	001110	1	0x1D	0	0x3A

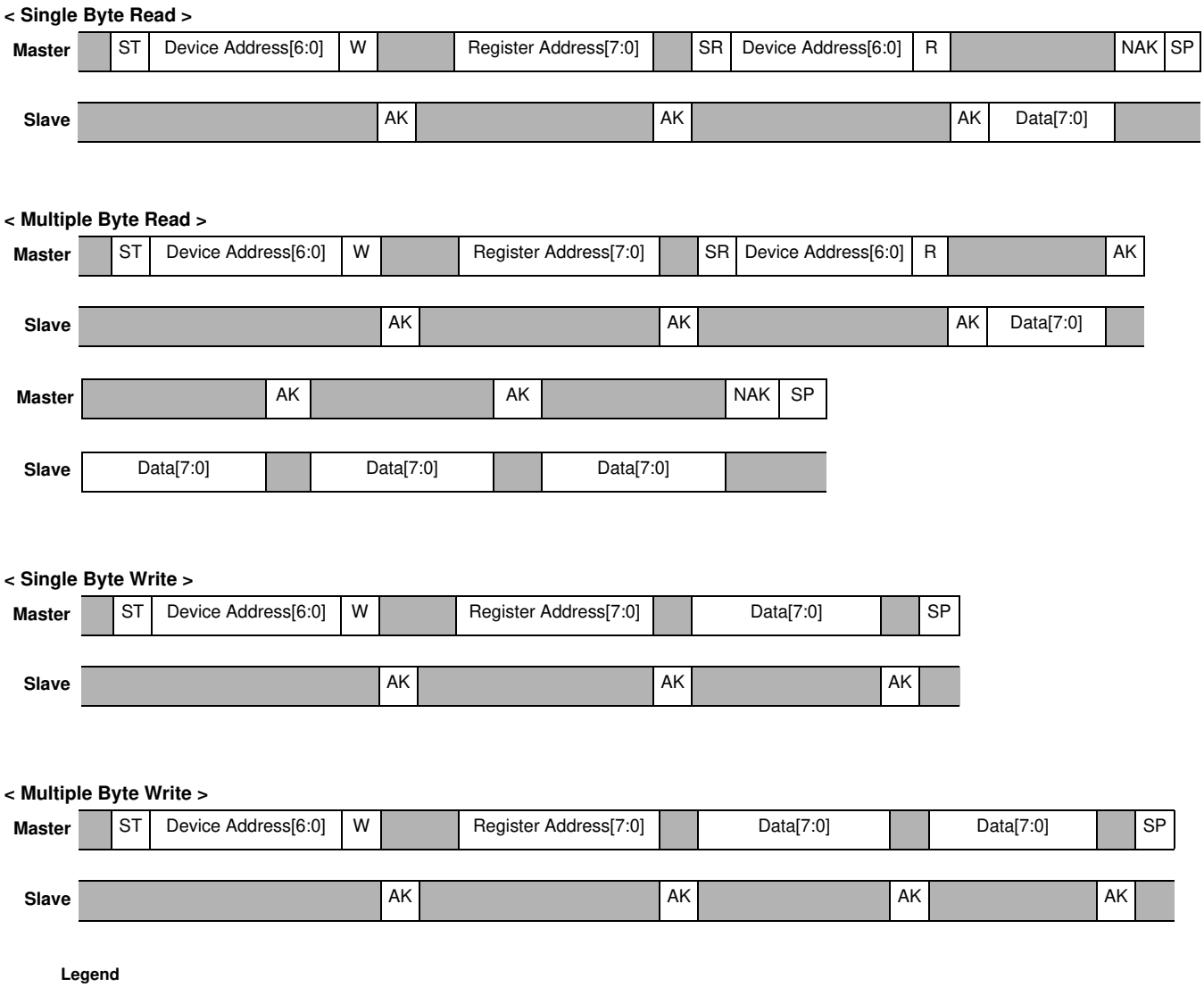

Figure 11. I^2C Timing Diagram

6 Register Descriptions

Table 11. Register Address Map

Name	Type	Register Address	Auto-Increment Address		Default	Hex Value	Comment
			F_READ=0	F_READ=1			
STATUS(1)(2)	R	0x00	0x01		00000000	0x00	Real time status
OUT_X_MSB(1)(2)	R	0x01	0x02	0x03	Output	—	[7:0] are 8 MSBs of 12-bit sample.
OUT_X_LSB(1)(2)	R	0x02	0x03	0x00	Output	—	[7:4] are 4 LSBs of 12-bit sample.
OUT_Y_MSB(1)(2)	R	0x03	0x04	0x05	Output	—	[7:0] are 8 MSBs of 12-bit sample.
OUT_Y_LSB(1)(2)	R	0x04	0x05	0x00	Output	—	[7:4] are 4 LSBs of 12-bit sample.
OUT_Z_MSB(1)(2)	R	0x05	0x06	0x00	Output	—	[7:0] are 8 MSBs of 12-bit sample.
OUT_Z_LSB(1)(2)	R	0x06	0x00		Output	—	[7:4] are 4 LSBs of 12-bit sample.
Reserved	R	0x07	—		—	—	Reserved. Read return 0x00.
Reserved	R	0x08	—		—	—	Reserved. Read return 0x00.
SYSMOD	R	0x0B	0x0C		00000000	0x00	Current System Mode
INT_SOURCE(1)(2)	R	0x0C	0x0D		00000000	0x00	Interrupt status
WHO_AM_I	R	0x0D	0x0E		00101010	0x2A	Device ID (0x2A)
XYZ_DATA_CFG(3)(4)	R/W	0x0E	0x0F		00000000	0x00	HPF Data Out and Dynamic Range Settings
HP_FILTER_CUTOFF(3)(4)	R/W	0x0F	0x10		00000000	0x00	Cutoff frequency is set to 16 Hz @ 800 Hz
PL_STATUS(1)(2)	R	0x10	0x11		00000000	0x00	Landscape/Portrait orientation status
PL_CFG(3)(4)	R/W	0x11	0x12		10000000	0x80	Landscape/Portrait configuration.
PL_COUNT(3)(4)	R	0x12	0x13		00000000	0x00	Landscape/Portrait debounce counter
PL_BF_ZCOMP(3)(4)	R	0x13	0x14		01000100	0x44	Back-Front, Z-Lock Trip threshold
P_L_THS_REG(3)(4)	R	0x14	0x15		10000100	0x84	Portrait to Landscape Trip Angle is 29°
FF_MT_CFG(3)(4)	R/W	0x15	0x16		00000000	0x00	Freefall/Motion functional block configuration
FF_MT_SRC(1)(2)	R	0x16	0x17		00000000	0x00	Freefall/Motion event source register
FF_MT_THS(3)(4)	R/W	0x17	0x18		00000000	0x00	Freefall/Motion threshold register
FF_MT_COUNT(3)(4)	R/W	0x18	0x19		00000000	0x00	Freefall/Motion debounce counter
Reserved	R	0x19 - 0x1C	—		—	—	Reserved. Read return 0x00.
TRANSIENT_CFG	R/W	0x1D	0x1E		00000000	0x00	Transient functional block configuration
TRANSIENT_SRC(1)(2)	R	0x1E	0x1F		00000000	0x00	Transient event status register
TRANSIENT_THS(3)(4)	R/W	0x1F	0x20		00000000	0x00	Transient event threshold
TRANSIENT_COUNT(3)(4)	R/W	0x20	0x21		00000000	0x00	Transient debounce counter
PULSE_CFG(3)(4)	R/W	0x21	0x22		00000000	0x00	ELE, Double_XYZ or Single_XYZ
PULSE_SRC(1)(2)	R	0x22	0x23		00000000	0x00	EA, Double_XYZ or Single_XYZ
PULSE_THSX(3)(4)	R/W	0x23	0x24		00000000	0x00	X pulse threshold
PULSE_THSY(3)(4)	R/W	0x24	0x25		00000000	0x00	Y pulse threshold
PULSE_THSZ(3)(4)	R/W	0x25	0x26		00000000	0x00	Z pulse threshold
PULSE_TMLT(3)(4)	R/W	0x26	0x27		00000000	0x00	Time limit for pulse
PULSE_LTCY(3)(4)	R/W	0x27	0x28		00000000	0x00	Latency time for 2nd pulse

Table 11. Register Address Map

PULSE_WIND[3][4]	R/W	0x28	0x29	00000000	0x00	Window time for 2nd pulse
ASLP_COUNT[3][4]	R/W	0x29	0x2A	00000000	0x00	Counter setting for Auto-SLEEP
CTRL_REG1[3][4]	R/W	0x2A	0x2B	00000000	0x00	Data Rate, ACTIVE Mode
CTRL_REG2[3][4]	R/W	0x2B	0x2C	00000000	0x00	Sleep Enable, OS Modes, RST, ST
CTRL_REG3[3][4]	R/W	0x2C	0x2D	00000000	0x00	Wake from Sleep, IPOL, PP_OD
CTRL_REG4[3][4]	R/W	0x2D	0x2E	00000000	0x00	Interrupt enable register
CTRL_REG5[3][4]	R/W	0x2E	0x2F	00000000	0x00	Interrupt pin (INT1/INT2) map
OFF_X[3][4]	R/W	0x2F	0x30	00000000	0x00	X-axis offset adjust
OFF_Y[3][4]	R/W	0x30	0x31	00000000	0x00	Y-axis offset adjust
OFF_Z[3][4]	R/W	0x31	**0x0D**	00000000	0x00	Z-axis offset adjust
Reserved (do not modify)		0x40 – 7F	—	—	—	Reserved. Read return 0x00.

1. Register contents are reset when transition from STANDBY to ACTIVE mode occurs.
2. This register data is only valid in ACTIVE mode.
3. Register contents are preserved when transition from ACTIVE to STANDBY mode occurs.
4. Modification of this register's contents can only occur when device is STANDBY mode except CTRL_REG1 ACTIVE bit and CTRL_REG2 RST bit.

Note: Auto-increment addresses which are not a simple increment are highlighted in **bold**. The auto-increment addressing is only enabled when device registers are read using I^2C burst read mode. Therefore the internal storage of the auto-increment address is cleared whenever a STOP condition is detected.

6.1 Data Registers

The following are the data registers for the MMA8452Q. For more information on data manipulation of the MMA8452Q, refer to application note, AN4076.

0x00: STATUS Data Status Register (Read Only)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ZYXOW	ZOW	YOW	XOW	ZYXDR	ZDR	YDR	XDR

Table 12. STATUS Description

ZYXOW	X, Y, Z-axis Data Overwrite. Default value: 0 0: No data overwrite has occurred 1: Previous X, Y, or Z data was overwritten by new X, Y, or Z data before it was read
ZOW	Z-axis Data Overwrite. Default value: 0 0: No data overwrite has occurred 1: Previous Z-axis data was overwritten by new Z-axis data before it was read
YOW	Y-axis Data Overwrite. Default value: 0 0: No data overwrite has occurred 1: Previous Y-axis data was overwritten by new Y-axis data before it was read
XOW	X-axis Data Overwrite. Default value: 0 0: No data overwrite has occurred 1: Previous X-axis data was overwritten by new X-axis data before it was read
ZYXDR	X, Y, Z-axis new Data Ready. Default value: 0 0: No new set of data ready 1: A new set of data is ready
ZDR	Z-axis new Data Available. Default value: 0 0: No new Z-axis data is ready 1: A new Z-axis data is ready
YDR	Y-axis new Data Available. Default value: 0 0: No new Y-axis data ready 1: A new Y-axis data is ready
XDR	X-axis new Data Available. Default value: 0 0: No new X-axis data ready 1: A new X-axis data is ready

ZYXOW is set whenever a new acceleration data is produced before completing the retrieval of the previous set. This event occurs when the content of at least one acceleration data register (i.e., OUT_X, OUT_Y, OUT_Z) has been overwritten. ZYXOW is cleared when the high-bytes of the acceleration data (OUT_X_MSB, OUT_Y_MSB, OUT_Z_MSB) of all the active channels are read.

ZOW is set whenever a new acceleration sample related to the Z-axis is generated before the retrieval of the previous sample. When this occurs the previous sample is overwritten. ZOW is cleared anytime OUT_Z_MSB register is read.

YOW is set whenever a new acceleration sample related to the Y-axis is generated before the retrieval of the previous sample. When this occurs the previous sample is overwritten. YOW is cleared anytime OUT_Y_MSB register is read.

XOW is set whenever a new acceleration sample related to the X-axis is generated before the retrieval of the previous sample. When this occurs the previous sample is overwritten. XOW is cleared anytime OUT_X_MSB register is read.

ZYXDR signals that a new sample for any of the enabled channels is available. ZYXDR is cleared when the high-bytes of the acceleration data (OUT_X_MSB, OUT_Y_MSB, OUT_Z_MSB) of all the enabled channels are read.

ZDR is set whenever a new acceleration sample related to the Z-axis is generated. ZDR is cleared anytime OUT_Z_MSB register is read.

YDR is set whenever a new acceleration sample related to the Y-axis is generated. YDR is cleared anytime OUT_Y_MSB register is read.

XDR is set whenever a new acceleration sample related to the X-axis is generated. XDR is cleared anytime OUT_X_MSB register is read.

Data Registers: 0x01: OUT_X_MSB, 0x02: OUT_X_LSB, 0x03: OUT_Y_MSB, 0x04: OUT_Y_LSB, 0x05: OUT_Z_MSB, 0x06: OUT_Z_LSB

These registers contain the X-axis, Y-axis, and Z-axis 12-bit output sample data expressed as 2's complement numbers. The sample data output registers store the current sample data.

0x01: OUT_X_MSB: X_MSB Register (Read Only)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
XD11	XD10	XD9	XD8	XD7	XD6	XD5	XD4

0x02: OUT_X_LSB: X_LSB Register (Read Only)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
XD3	XD2	XD1	XD0	0	0	0	0

0x03: OUT_Y_MSB: Y_MSB Register (Read Only)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
YD11	YD10	YD9	YD8	YD7	YD6	YD5	YD4

0x04: OUT_Y_LSB: Y_LSB Register (Read Only)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
YD3	YD2	XD1	XD0	0	0	0	0

0x05: OUT_Z_MSB: Z_MSB Register (Read Only)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ZD11	ZD10	ZD9	ZD8	ZD7	ZD6	ZD5	ZD4

0x06: OUT_Z_LSB: Z_LSB Register (Read Only)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ZD3	ZD2	ZD1	ZD0	0	0	0	0

OUT_X_MSB, OUT_X_LSB, OUT_Y_MSB, OUT_Y_LSB, OUT_Z_MSB, and OUT_Z_LSB are stored in the auto-incrementing address range of 0x01 to 0x06 to reduce reading the status followed by 12-bit axis data to 7 bytes. If the F_READ bit is set (0x2A bit 1), auto-increment will skip over LSB registers. This will shorten the data acquisition from 7 bytes to 4 bytes. The LSB registers can only be read immediately following the read access of the corresponding MSB register. A random read access to the LSB registers is not possible. Reading the MSB register and then the LSB register in sequence ensures that both bytes (LSB and MSB) belong to the same data sample, even if a new data sample arrives between reading the MSB and the LSB byte.

0x0B: SYSMOD System Mode Register

The system mode register indicates the current device operating mode. Applications using the Auto-SLEEP/WAKE mechanism should use this register to synchronize the application with the device operating mode transitions.

0x0B: SYSMOD: System Mode Register (Read Only)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0	0	0	0	SYSMOD1	SYSMOD0

Table 13. SYSMOD Description

SYSMOD[1:0]	System Mode. Default value: 00. 00: STANDBY mode 01: WAKE mode 10: SLEEP mode

0x0C: INT_SOURCE System Interrupt Status Register

In the interrupt source register the status of the various embedded features can be determined. The bits that are set (logic '1') indicate which function has asserted an interrupt and conversely the bits that are cleared (logic '0') indicate which function has not asserted or has deasserted an interrupt. **The bits are set by a low to high transition and are cleared by reading the appropriate interrupt source register.** The SRC_DRDY bit is cleared by reading the X, Y and Z data. It is not cleared by simply reading the Status Register (0x00).

0x0C: INT_SOURCE: System Interrupt Status Register (Read Only)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
SRC_ASLP	0	SRC_TRANS	SRC_LNDPRT	SRC_PULSE	SRC_FF_MT	0	SRC_DRDY

Table 14. INT_SOURCE Description

INT_SOURCE	Description
SRC_ASLP	Auto-SLEEP/WAKE interrupt status bit. Default value: 0. Logic '1' indicates that an interrupt event that can cause a WAKE to SLEEP or SLEEP to WAKE system mode transition has occurred. Logic '0' indicates that no WAKE to SLEEP or SLEEP to WAKE system mode transition interrupt event has occurred. **WAKE to SLEEP** transition occurs when no interrupt occurs for a time period that exceeds the user specified limit (ASLP_COUNT). This causes the system to transition to a user specified low ODR setting. **SLEEP to WAKE** transition occurs when the user specified interrupt event has woken the system; thus causing the system to transition to a user specified high ODR setting. Reading the SYSMOD register clears the SRC_ASLP bit.
SRC_TRANS	Transient interrupt status bit. Default value: 0. Logic '1' indicates that an acceleration transient value greater than user specified threshold has occurred. Logic '0' indicates that no transient event has occurred. This bit is asserted whenever "EA" bit in the TRANS_SRC is asserted and the interrupt has been enabled. This bit is cleared by reading the TRANS_SRC register.
SRC_LNDPRT	Landscape/Portrait Orientation interrupt status bit. Default value: 0. Logic '1' indicates that an interrupt was generated due to a change in the device orientation status. Logic '0' indicates that no change in orientation status was detected. This bit is asserted whenever "NEWLP" bit in the PL_STATUS is asserted and the interrupt has been enabled. This bit is cleared by reading the PL_STATUS register.
SRC_PULSE	Pulse interrupt status bit. Default value: 0. Logic '1' indicates that an interrupt was generated due to single and/or double pulse event. Logic '0' indicates that no pulse event was detected. This bit is asserted whenever "EA" bit in the PULSE_SRC is asserted and the interrupt has been enabled. This bit is cleared by reading the PULSE_SRC register.
SRC_FF_MT	Freefall/Motion interrupt status bit. Default value: 0. Logic '1' indicates that the Freefall/Motion function interrupt is active. Logic '0' indicates that no Freefall or Motion event was detected. This bit is asserted whenever "EA" bit in the FF_MT_SRC register is asserted and the FF_MT interrupt has been enabled. This bit is cleared by reading the FF_MT_SRC register.
SRC_DRDY	Data Ready Interrupt bit status. Default value: 0. Logic '1' indicates that the X, Y, Z data ready interrupt is active indicating the presence of new data and/or data overrun. Otherwise if it is a logic '0' the X, Y, Z interrupt is not active. This bit is asserted when the ZYXOW and/or ZYXDR is set and the interrupt has been enabled. This bit is cleared by reading the X, Y, and Z data.

0x0D: WHO_AM_I Device ID Register

The device identification register identifies the part. The default value is 0x2A. This value is factory programmed. Consult the factory for custom alternate values.

0x0D: WHO_AM_I Device ID Register (Read Only)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	1	0	1	0	1	0

0x0E: XYZ_DATA_CFG Register

The XYZ_DATA_CFG register sets the dynamic range and sets the high-pass filter for the output data. When the HPF_OUT bit is set. The data registers 0x01 - 0x06 will contain high-pass filtered data when this bit is set.

0x0E: XYZ_DATA_CFG (Read/Write)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0	HPF_OUT	0	0	FS1	FS0

Table 15. XYZ Data Configuration Descriptions

HPF_OUT	Enable High-Pass output data 1 = output data high-pass filtered. Default value: 0
FS[1:0]	Output buffer data format full scale. Default value: 00 (2g).

The default full scale value range is 2g and the high-pass filter is disabled.

Table 16. Full Scale Range

FS1	FS0	Full Scale Range
0	0	2
0	1	4
1	0	8
1	1	Reserved

0x0F: HP_FILTER_CUTOFF High-Pass Filter Register

This register sets the high-pass filter cutoff frequency for removal of the offset and slower changing acceleration data. The output of this filter is indicated by the data registers (0x01-0x06) when bit 4 (HPF_OUT) of Register 0x0E is set. The filter cutoff options change based on the data rate selected as shown in Table 18. For details of implementation on the high-pass filter, refer to Freescale application note, AN4071.

0x0F: HP_FILTER_CUTOFF: High-Pass Filter Register (Read/Write)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	Pulse_HPF_BYP	Pulse_LPF_EN	0	0	SEL1	SEL0

Table 17. High-Pass Filter Cutoff Register Descriptions

Pulse_HPF_BYP	Bypass High-Pass Filter for Pulse Processing Function. 0: HPF enabled for Pulse Processing, 1: HPF Bypassed for Pulse Processing Default value: 0.
Pulse_LPF_EN	Enable Low-Pass Filter for Pulse Processing Function. 0: LPF disabled for Pulse Processing, 1: LPF Enabled for Pulse Processing Default value: 0.
SEL[1:0]	HPF Cutoff frequency selection. Default value: 00 (see Table 18).

Table 18. High-Pass Filter Cutoff Options

Oversampling Mode = Normal									
SEL1	SEL0	800 Hz	400 Hz	200 Hz	100 Hz	50 Hz	12.5 Hz	6.25 Hz	1.56 Hz
0	0	16 Hz	16 Hz	8 Hz	4 Hz	2 Hz	2 Hz	2 Hz	2 Hz
0	1	8 Hz	8 Hz	4 Hz	2 Hz	1 Hz	1 Hz	1 Hz	1 Hz
1	0	4 Hz	4 Hz	2 Hz	1 Hz	0.5 Hz	0.5 Hz	0.5 Hz	0.5 Hz
1	1	2 Hz	2 Hz	1 Hz	0.5 Hz	0.25 Hz	0.25 Hz	0.25 Hz	0.25 Hz
Oversampling Mode = Low Noise Low Power									
0	0	16 Hz	16 Hz	8 Hz	4 Hz	2 Hz	0.5 Hz	0.5 Hz	0.5 Hz
0	1	8 Hz	8 Hz	4 Hz	2 Hz	1 Hz	0.25 Hz	0.25 Hz	0.25 Hz
1	0	4 Hz	4 Hz	2 Hz	1 Hz	0.5 Hz	0.125 Hz	0.125 Hz	0.125 Hz
1	1	2 Hz	2 Hz	1 Hz	0.5 Hz	0.25 Hz	0.063 Hz	0.063 Hz	0.063 Hz
Oversampling Mode = High Resolution									
0	0	16 Hz	16 Hz	16 Hz	16 Hz	16 Hz	16 Hz	16 Hz	16 Hz
0	1	8 Hz	8 Hz	8 Hz	8 Hz	8 Hz	8 Hz	8 Hz	8 Hz
1	0	4 Hz	4 Hz	4 Hz	4 Hz	4 Hz	4 Hz	4 Hz	4 Hz
1	1	2 Hz	2 Hz	2 Hz	2 Hz	2 Hz	2 Hz	2 Hz	2 Hz
Oversampling Mode = Low Power									
0	0	16 Hz	8 Hz	4 Hz	2 Hz	1 Hz	0.25 Hz	0.25 Hz	0.25 Hz
0	1	8 Hz	4 Hz	2 Hz	1 Hz	0.5 Hz	0.125 Hz	0.125 Hz	0.125 Hz
1	0	4 Hz	2 Hz	1 Hz	0.5 Hz	0.25 Hz	0.063 Hz	0.063 Hz	0.063 Hz
1	1	2 Hz	1 Hz	0.5 Hz	0.25 Hz	0.125 Hz	0.031 Hz	0.031 Hz	0.031 Hz

6.2 Portrait/ Landscape Embedded Function Registers

For more details on the meaning of the different user configurable settings and for example code refer to Freescale application note, AN4068.

0x10: PL_STATUS Portrait/Landscape Status Register

This status register can be read to get updated information on any change in orientation by reading Bit 7, or on the specifics of the orientation by reading the other bits. For further understanding of Portrait Up, Portrait Down, Landscape Left, Landscape Right, Back and Front orientations please refer to Figure 3. The interrupt is cleared when reading the PL_STATUS register.

0x10: PL_STATUS Register (Read Only)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
NEWLP	LO	0	0	0	LAPO[1]	LAPO[0]	BAFRO

Table 19. PL_STATUS Register Description

NEWLP	Landscape/Portrait status change flag. Default value: 0. 0: No change, 1: BAFRO and/or LAPO and/or Z-Tilt lockout value has changed
LO	Z-Tilt Angle Lockout. Default value: 0. 0: Lockout condition has not been detected. 1: Z-Tilt lockout trip angle has been exceeded. Lockout has been detected.
LAPO[1:0](1)	Landscape/Portrait orientation. Default value: 00 00: Portrait Up: Equipment standing vertically in the normal orientation 01: Portrait Down: Equipment standing vertically in the inverted orientation 10: Landscape Right: Equipment is in landscape mode to the right 11: Landscape Left: Equipment is in landscape mode to the left.
BAFRO	Back or Front orientation. Default value: 0 0: Front: Equipment is in the front facing orientation. 1: Back: Equipment is in the back facing orientation.

1. The default power up state is BAFRO = 0, LAPO = 0, and LO = 0.

NEWLP is set to 1 after the first orientation detection after a STANDBY to ACTIVE transition, and whenever a change in LO, BAFRO, or LAPO occurs. NEWLP bit is cleared anytime PL_STATUS register is read. The Orientation mechanism state change is limited to a maximum 1.25g. LAPO BAFRO and LO continue to change when NEWLP is set. The current position is locked if the absolute value of the acceleration experienced on any of the three axes is greater than 1.25g.

0x11: Portrait/Landscape Configuration Register

This register enables the Portrait/Landscape function and sets the behavior of the debounce counter.

0x11: PL_CFG Register (Read/Write)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
DBCNTM	PL_EN	0	0	0	0	0	0

Table 20. PL_CFG Description

DBCNTM	Debounce counter mode selection. Default value: 1 0: Decrements debounce whenever condition of interest is no longer valid. 1: Clears counter whenever condition of interest is no longer valid.
PL_EN	Portrait/Landscape Detection Enable. Default value: 0 0: Portrait/Landscape Detection is Disabled. 1: Portrait/Landscape Detection is Enabled.

0x12: Portrait/Landscape Debounce Counter

This register sets the debounce count for the orientation state transition. The minimum debounce latency is determined by the data rate set by the product of the selected system ODR and PL_COUNT registers. Any transition from WAKE to SLEEP or vice versa resets the internal Landscape/Portrait debounce counter. **Note:** The debounce counter weighting (time step) changes based on the ODR and the Oversampling mode. Table 22 explains the time step value for all sample rates and all Oversampling modes.

0x12: PL_COUNT Register (Read/Write)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
DBNCE[7]	DBNCE[6]	DBNCE[5]	DBNCE[4]	DBNCE[3]	DBNCE[2]	DBNCE[1]	DBNCE[0]

Table 21. PL_COUNT Description

DBCNE[7:0]	Debounce Count value. Default value: 0000_0000.

Table 22. PL_COUNT Relationship with the ODR

ODR (Hz)	Max Time Range (s)				Time Step (ms)			
	Normal	LPLN	HighRes	LP	Normal	LPLN	HighRes	LP
800	0.319	0.319	0.319	0.319	1.25	1.25	1.25	1.25
400	0.638	0.638	0.638	0.638	2.5	2.5	2.5	2.5
200	1.28	1.28	0.638	1.28	5	5	2.5	5
100	2.55	2.55	0.638	2.55	10	10	2.5	10
50	5.1	5.1	0.638	5.1	20	20	2.5	20
12.5	5.1	20.4	0.638	20.4	20	80	2.5	80
6.25	5.1	20.4	0.638	40.8	20	80	2.5	160
1.56	5.1	20.4	0.638	40.8	20	80	2.5	160

0x13: PL_BF_ZCOMP Back/Front and Z Compensation Register

The Z-Lock angle compensation is set to 29°. The Back to Front trip angle is set to ±75°.

0x13: PL_BF_ZCOMP Register (Read Only)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
BKFR[1]	BKFR[0]	0	0	0	ZLOCK[2]	ZLOCK[1]	ZLOCK[0]

Table 23. PL_BF_ZCOMP Description

BKFR[1:0]	Back Front Trip Angle Fixed Threshold = 01 which is ≥ ±75°.
ZLOCK[2:0]	Z-Lock Angle Fixed Threshold = 100 which is 29°.

Note: All angles are accurate to ±2°.

0x14: P_L_THS_REG Portrait/Landscape Threshold and Hysteresis Register

This register represents the Portrait to Landscape trip threshold.

0x14: P_L_THS_REG Register (Read Only)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
P_L_THS[4]	P_L_THS[3]	P_L_THS[2]	P_L_THS[1]	P_L_THS[0]	HYS[2]	HYS[1]	HYS[0]

Table 24. P_L_THS_REG Description

P_L_THS[7:3]	Portrait/Landscape Fixed Threshold angle = 1_0000 (45°).
HYS[2:0]	This is a fixed angle added to the threshold angle for a smoother transition from Portrait to Landscape and Landscape to Portrait. This angle is fixed at ±14°, which is 100.

Table 25. Trip Angles with Hysteresis for 45° Angle

Hysteresis Register Value	Hysteresis ± Angle Range	Landscape to Portrait Trip Angle	Portrait to Landscape Trip Angle
4	±14	59°	31°

6.3 Motion and Freefall Embedded Function Registers

The freefall/motion function can be configured in either freefall or motion detection mode via the **OAE** configuration bit (0x15 bit 6). The freefall/motion detection block can be disabled by setting all three bits ZEFE, YEFE, and XEFE to zero.

Depending on the register bits **ELE** (0x15 bit 7) and **OAE** (0x15 bit 6), each of the freefall and motion detection block can operate in four different modes:

Mode 1: Freefall Detection with ELE = 0, OAE = 0

In this mode, the **EA** bit (0x16 bit 7) indicates a freefall event after the debounce counter is complete. The ZEFE, YEFE, and XEFE control bits determine which axes are considered for the freefall detection. Once the EA bit is set, and DBCNTM = 0, the EA bit can get cleared only after the delay specified by FF_MT_COUNT. This is because the counter is in decrement mode. If DBCNTM = 1, the EA bit is cleared as soon as the freefall condition disappears, and will not be set again before the delay specified by FF_MT_COUNT has passed. Reading the FF_MT_SRC register does not clear the EA bit. The event flags (0x16) ZHE, ZHP, YHE, YHP, XHE, and XHP reflect the motion detection status (i.e. high-g event) without any debouncing, provided that the corresponding bits ZEFE, YEFE, and/or XEFE are set.

Mode 2: Freefall Detection with ELE = 1, OAE = 0

In this mode, the **EA** event bit indicates a freefall event after the debounce counter. Once the debounce counter reaches the time value for the set threshold, the EA bit is set, and remains set until the FF_MT_SRC register is read. When the FF_MT_SRC register is read, the EA bit and the debounce counter are cleared and a new event can only be generated after the delay specified by FF_MT_CNT. The ZEFE, YEFE, and XEFE control bits determine which axes are considered for the freefall detection. While EA = 0, the event flags ZHE, ZHP, YHE, YHP, XHE, and XHP reflect the motion detection status (i.e., high-g event) without any debouncing, provided that the corresponding bits ZEFE, YEFE, and/or XEFE are set. The event flags ZHE, ZHP, YHE, YHP, XHE, and XHP are latched when the EA event bit is set. The event flags ZHE, ZHP, YHE, YHP, XHE, and XHP will start changing only after the FF_MT_SRC register has been read.

Mode 3: Motion Detection with ELE = 0, OAE = 1

In this mode, the **EA** bit indicates a motion event after the debounce counter time is reached. The ZEFE, YEFE, and XEFE control bits determine which axes are taken into consideration for motion detection. Once the **EA** bit is set, and DBCNTM = 0, the EA bit can get cleared only after the delay specified by FF_MT_COUNT. If DBCNTM = 1, the **EA** bit is cleared as soon as the motion high-g condition disappears. The event flags ZHE, ZHP, YHE, YHP, XHE, and XHP reflect the motion detection status (i.e., high-g event) without any debouncing, provided that the corresponding bits ZEFE, YEFE, and/or XEFE are set. Reading the FF_MT_SRC does not clear any flags, nor is the debounce counter reset.

Mode 4: Motion Detection with ELE = 1, OAE = 1

In this mode, the EA bit indicates a motion event after debouncing. The ZEFE, YEFE, and XEFE control bits determine which axes are taken into consideration for motion detection. Once the debounce counter reaches the threshold, the EA bit is set, and remains set until the FF_MT_SRC register is read. When the FF_MT_SRC register is read, all register bits are cleared and the debounce counter are cleared and a new event can only be generated after the delay specified by FF_MT_CNT. While the bit EA is zero, the event flags ZHE, ZHP, YHE, YHP, XHE, and XHP reflect the motion detection status (i.e., high-g event) without any debouncing, provided that the corresponding bits ZEFE, YEFE, and/or XEFE are set. When the EA bit is set, these bits keep their current value until the FF_MT_SRC register is read.