

# 3-Axis, 14-bit/8-bit Digital Accelerometer

The MMA8451Q is a smart low-power, three-axis, capacitive micromachined accelerometer with 14 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. There is access to both low pass filtered data as well as high pass filtered data, which minimizes the data analysis required for jolt detection and faster transitions. The device can be configured to generate inertial wake-up interrupt signals from any combination of the configurable embedded functions allowing the MMA8451Q to monitor events and remain in a low power mode during periods of inactivity. The MMA8451Q is available in a 3 mm x 3 mm x 1 mm QFN package.

## Features

- 1.95 V to 3.6 V supply voltage
- 1.6 V to 3.6 V interface voltage
- $\pm 2g/\pm 4g/\pm 8g$  dynamically selectable full-scale
- Output Data Rates (ODR) from 1.56 Hz to 800 Hz
- 99  $\mu g/\sqrt{Hz}$  noise
- 14-bit and 8-bit digital output
- I<sup>2</sup>C digital output interface (operates to 2.25 MHz with 4.7 k $\Omega$  pull-up)
- 2 programmable interrupt pins for 7 interrupt sources
- 3 embedded channels of motion detection
  - Freelfall or Motion Detection: 1 channel
  - Pulse Detection: 1 channel
  - Jolt Detection: 1 channel
- Orientation (Portrait/Landscape) detection with programmable hysteresis
- Automatic ODR change for Auto-WAKE and return to SLEEP
- 32 sample FIFO
- High Pass Filter Data available per sample and through the FIFO
- Self-Test
- RoHS compliant
- Current Consumption: 6  $\mu A$  – 165  $\mu A$

## 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 Freelfall Detection
- Real-time orientation detection (virtual reality and gaming 3D user position feedback)
- Real-time activity analysis (pedometer step counting, freelfall 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, tap detection for button replacement)

| ORDERING INFORMATION |                   |                     |               |
|----------------------|-------------------|---------------------|---------------|
| Part Number          | Temperature Range | Package Description | Shipping      |
| MMA8451QT            | -40°C to +85°C    | QFN-16              | Tray          |
| MMA8451QR1           | -40°C to +85°C    | QFN-16              | Tape and Reel |

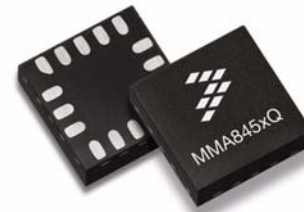
This document contains certain information on a new product. Specifications and information herein are subject to change without notice.

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## MMA8451Q

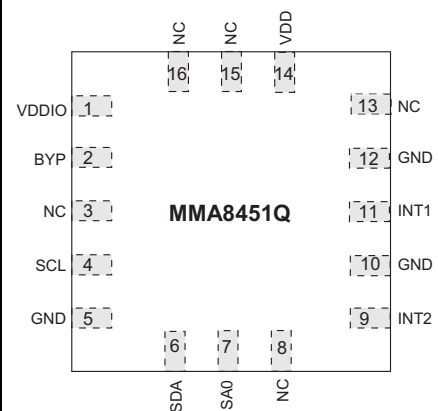
**MMA8451Q: 3-AXIS DIGITAL  
ACCELEROMETER**  
 $\pm 2g/\pm 4g/\pm 8g$

### Top and Bottom View



**16 PIN QFN**  
**3 mm x 3 mm x 1 mm**  
**CASE 2077-01**

### Top View



### Pin Connections

# Contents

[查询"MMA8451Q"供应商](#)

|  |           |
|--|-----------|
| <b>Application Notes for Reference</b> .....                     | <b>6</b>  |
| <b>1 Block Diagram and Pin Description</b> .....                 | <b>6</b>  |
| 1.1 Block Diagram .....  | 6         |
| Figure 1. Block Diagram .....                                    | 6         |
| 1.2 Pin Description .....  | 6         |
| Figure 2. Direction of the Detectable Accelerations .....        | 6         |
| Figure 3. Landscape/Portrait Orientation .....                   | 7         |
| Figure 4. Application Diagram .....                              | 7         |
| Table 1. Pin Description .....                                   | 8         |
| 1.3 Soldering Information .....                                  | 8         |
| <b>2 Mechanical and Electrical Specifications</b> .....          | <b>9</b>  |
| 2.1 Mechanical Characteristics .....                             | 9         |
| Table 2. Mechanical Characteristics .....                        | 9         |
| 2.2 Electrical Characteristics .....                             | 10        |
| Table 3. Electrical Characteristics.....                         | 10        |
| 2.3 I <sup>2</sup> C Interface Characteristic .....              | 11        |
| Table 4. I <sup>2</sup> C Slave Timing Values .....              | 11        |
| Figure 5. I <sup>2</sup> C Slave Timing Diagram .....            | 12        |
| 2.4 Absolute Maximum Ratings .....                               | 12        |
| Table 5. Maximum Ratings .....                                   | 12        |
| Table 6. ESD and Latch-Up Protection Characteristics .....       | 12        |
| <b>3 Terminology</b> .....                                       | <b>13</b> |
| 3.1 Sensitivity .....  | 13        |
| 3.2 Zero-g Offset .....  | 13        |
| 3.3 Self-Test .....  | 13        |
| <b>4 Modes of Operation</b> .....                                | <b>13</b> |
| Figure 6. MMA8451Q Mode Transition Diagram .....                 | 13        |
| Table 7. Mode of Operation Description .....                     | 13        |
| <b>5 Functionality</b> .....                                     | <b>14</b> |
| 5.1 Device Calibration .....                                     | 14        |
| 5.2 8-bit or 14-bit Data .....                                   | 14        |
| 5.3 Internal FIFO Data Buffer .....                              | 14        |
| 5.4 Low Power Modes vs. High Resolution Modes .....              | 15        |
| 5.5 Auto-WAKE/SLEEP Mode .....                                   | 15        |
| 5.6 Freelfall and Motion Detection .....                         | 15        |
| 5.6.1 Freelfall Detection .....                                  | 15        |
| 5.6.2 Motion Detection .....                                     | 15        |
| 5.7 Transient Detection .....                                    | 16        |
| 5.8 Tap Detection .....  | 16        |
| 5.9 Orientation Detection .....                                  | 16        |
| Figure 7. Landscape/Portrait Orientation .....                   | 16        |
| Figure 8. Illustration of Landscape to Portrait Transition ..... | 17        |
| Figure 9. Illustration of Portrait to Landscape Transition ..... | 17        |
| Figure 10. Illustration of Z-Tilt Angle Lockout Transition ..... | 17        |
| 5.10 Interrupt Register Configurations .....                     | 18        |
| Figure 11. System Interrupt Generation Block Diagram .....       | 18        |
| 5.11 Serial I <sup>2</sup> C Interface .....                     | 18        |
| Table 8. Serial Interface Pin Description .....                  | 18        |
| 5.11.1 I <sup>2</sup> C Operation .....                          | 19        |
| Table 9. I <sup>2</sup> C Address Selection Table .....          | 19        |
| Single Byte Read .....   | 19        |
| Multiple Byte Read .....   | 19        |
| Single Byte Write .....  | 19        |
| Multiple Byte Write .....  | 20        |
| Table 10. I <sup>2</sup> C Device Address Sequence .....         | 20        |
| Figure 12. I <sup>2</sup> C Timing Diagram .....                 | 20        |

|          |  |           |
|----------|--|-----------|
| <b>6</b> | <b>Register Descriptions</b>   | <b>21</b> |
|          | Table 11. Register Address Map   | 21        |
| 6.1      | Data Registers   | 22        |
|          | F_MODE = 00: 0X00 STATUS: Data Status Register (Read Only)                     | 22        |
|          | Table 12. STATUS Description   | 23        |
|          | Data Registers: 0x01 OUT_X_MSB, 0x02 OUT_X_LSB, 0x03 OUT_Y_MSB, 0x04 OUT_Y_LSB | 24        |
|          | 0x01 OUT_X_MSB: X_MSB Register (Read Only)                                     | 24        |
|          | 0x02 OUT_X_LSB: X_LSB Register (Read Only)                                     | 24        |
|          | 0x03 OUT_Y_MSB: Y_MSB Register (Read Only)                                     | 24        |
|          | 0x04 OUT_Y_LSB: Y_LSB Register (Read Only)                                     | 24        |
|          | 0x05 OUT_Z_MSB: Z_MSB Register (Read Only)                                     | 24        |
|          | 0x06 OUT_Z_LSB: Z_LSB Register (Read Only)                                     | 24        |
| 6.2      | 32 Sample FIFO   | 24        |
|          | F_MODE > 0 0x00: F_STATUS FIFO Status Register                                 | 24        |
|          | 0x00 F_STATUS: FIFO STATUS Register (Read Only)                                | 24        |
|          | Table 13. FIFO Flag Event Description  | 25        |
|          | Table 14. FIFO Sample Count Description  | 25        |
|          | 0x09: F_SETUP FIFO Set-up Register   | 25        |
|          | 0x09 F_SETUP: FIFO Set-up Register (Read/Write)                                | 25        |
|          | Table 15. F_SETUP Description  | 25        |
|          | 0x0A: TRIG_CFG   | 26        |
|          | 0x0A: TRIG_CFG Trigger Configuration Register (Read/Write)                     | 26        |
|          | Table 16. Trigger Configuration Description                                    | 26        |
|          | 0x0B: SYSMOD System Mode Register  | 26        |
|          | 0x0B SYSMOD: System Mode Register (Read Only)                                  | 26        |
|          | Table 17. SYSMOD Description   | 26        |
|          | 0x0C: INT_SOURCE System Interrupt Status Register                              | 27        |
|          | Table 18. INT_SOURCE Description   | 27        |
|          | 0x0D: WHO_AM_I Device ID Register  | 28        |
|          | 0x0D: WHO_AM_I Device ID Register (Read Only)                                  | 28        |
|          | 0x0E: XYZ_DATA_CFG Register  | 28        |
|          | 0x0E: XYZ_DATA_CFG (Read/Write)  | 28        |
|          | Table 19. XYZ Data Configuration Descriptions                                  | 28        |
|          | Table 20. Full Scale Range   | 28        |
|          | 0x0F: HP_FILTER_CUTOFF High Pass Filter Register                               | 28        |
|          | 0x0F HP_FILTER_CUTOFF: High Pass Filter Register (Read/Write)                  | 28        |
|          | Table 21. High Pass Filter Cut-off Register Descriptions                       | 28        |
|          | Table 22. High Pass Filter Cut-off Options                                     | 29        |
| 6.3      | Portrait/ Landscape Embedded Function Registers                                | 29        |
|          | 0x10: PL_STATUS Portrait/Landscape Status Register                             | 29        |
|          | 0x10 PL_STATUS Register (Read Only)  | 29        |
|          | Table 23. PL_STATUS Register Description                                       | 29        |
|          | 0x11 Portrait/Landscape Configuration Register                                 | 30        |
|          | 0x11 PL_CFG Register (Read/Write)  | 30        |
|          | Table 24. PL_CFG Description   | 30        |
|          | 0x12 Portrait/Landscape Debounce Counter                                       | 30        |
|          | 0x12 PL_COUNT Register (Read/Write)  | 30        |
|          | Table 25. PL_COUNT Description   | 30        |
|          | Table 26. PL_COUNT Relationship with the ODR                                   | 30        |
|          | 0x13: PL_BF_ZCOMP Back/Front and Z Compensation Register                       | 30        |
|          | 0x13: PL_BF_ZCOMP Register (Read/Write)  | 30        |
|          | Table 27. PL_BF_ZCOMP Description  | 30        |
|          | Table 28. Z-Lock Threshold Angles  | 31        |
|          | Table 29. Back/Front Orientation Definition                                    | 31        |
|          | 0x14: P_L_THS_REG Portrait/Landscape Threshold and Hysteresis Register         | 31        |
|          | 0x14: P_L_THS_REG Register (Read/Write)  | 31        |
|          | Table 30. P_L_THS_REG Description  | 31        |
|          | Table 31. Threshold Angle Thresholds Look-up Table                             | 31        |
|          | Table 32. Trip Angles with Hysteresis for 45° Angle                            | 31        |

|     |   |    |
|-----|---|----|
| 6.4 | Motion and Frefall Embedded Function Registers .....  | 32 |
|     | Mode 1: Frefall Detection with ELE = 0, OAE = 0 .....   | 32 |
|     | Mode 2: Frefall Detection with ELE = 1, OAE = 0 .....   | 32 |
|     | Mode 3: Motion Detection with ELE = 0, OAE = 1 .....  | 32 |
|     | Mode 4: Motion Detection with ELE = 1, OAE = 1 .....  | 32 |
|     | 0x15 FF_MT_CFG Frefall/Motion Configuration Register .....  | 33 |
|     | 0x15 FF_MT_CFG Register (Read/Write) .....  | 33 |
|     | Table 33. FF_MT_CFG Description .....   | 33 |
|     | Figure 13. FF_MT_CFG High and Low g Level .....   | 33 |
|     | 0x16 FF_MT_SRC Frefall/Motion Source Register .....   | 33 |
|     | 0x16: FF_MT_SRC Frefall and Motion Source Register (Read Only) .....                                  | 33 |
|     | Table 34. Frefall/Motion Source Description .....   | 34 |
|     | 0x17: FF_MT_THS Frefall and Motion Threshold Register .....   | 34 |
|     | 0x17 FF_MT_THS Register (Read/Write) .....  | 34 |
|     | Table 35. FF_MT_THS Description .....   | 34 |
|     | 0x18 FF_MT_COUNT Debounce Register .....  | 35 |
|     | 0x18 FF_MT_COUNT_Register (Read/Write) .....  | 35 |
|     | Table 36. FF_MT_COUNT Description .....   | 35 |
|     | Table 37. FF_MT_COUNT Relationship with the ODR .....   | 35 |
|     | Figure 14. DBCNTM Bit Function .....  | 36 |
| 6.5 | Transient (HPF) Acceleration Detection .....  | 37 |
|     | 0x1D: Transient_CFG Register .....  | 37 |
|     | 0x1D TRANSIENT_CFG Register (Read/Write) .....  | 37 |
|     | Table 38. TRANSIENT_CFG Description .....   | 37 |
|     | 0x1E TRANSIENT_SRC Register .....   | 37 |
|     | 0x1E TRANSIENT_SRC Register (Read Only) .....   | 37 |
|     | Table 39. TRANSIENT_SRC Description .....   | 37 |
|     | 0x1F TRANSIENT_THS Register .....   | 38 |
|     | 0x1F TRANSIENT_THS Register (Read/Write) .....  | 38 |
|     | Table 40. TRANSIENT_THS Description .....   | 38 |
|     | 0x20 TRANSIENT_COUNT .....  | 38 |
|     | 0x20 TRANSIENT_COUNT Register (Read/Write) .....  | 38 |
|     | Table 41. TRANSIENT_COUNT Description .....   | 38 |
|     | Table 42. TRANSIENT_COUNT Relationship with the ODR .....   | 38 |
| 6.6 | Single, Double and Directional Tap Detection Registers .....  | 39 |
|     | 0x21: PULSE_CFG Pulse Configuration Register .....  | 39 |
|     | 0x21 PULSE_CFG Register (Read/Write) .....  | 39 |
|     | Table 43. PULSE_CFG Description .....   | 39 |
|     | 0x22: PULSE_SRC Pulse Source Register .....   | 39 |
|     | 0x22 PULSE_SRC Register (Read Only) .....   | 39 |
|     | Table 44. PULSE_SRC Description .....   | 39 |
|     | 0x23 - 0x25: PULSE_THSX, Y, Z Pulse Threshold for X, Y & Z Registers .....                            | 40 |
|     | 0x23 PULSE_THSX Register (Read/Write) .....   | 40 |
|     | Table 45. PULSE_THSX Description .....  | 40 |
|     | 0x24 PULSE_THSY Register (Read/Write) .....   | 40 |
|     | Table 46. PULSE_THSY Description .....  | 40 |
|     | 0x25 PULSE_THSZ Register (Read/Write) .....   | 40 |
|     | Table 47. PULSE_THSZ Description .....  | 40 |
|     | 0x26: PULSE_TMLT Pulse Time Window 1 Register .....   | 40 |
|     | 0x26 PULSE_TMLT Register (Read/Write) .....   | 40 |
|     | Table 48. PULSE_TMLT Description .....  | 40 |
|     | Table 49. Time Step for PULSE Time Limit (Reg 0x0F) Pulse_LPF_EN = 1 .....                            | 40 |
|     | Table 50. Time Step for PULSE Time Limit (Reg 0x0F) Pulse_LPF_EN = 0 .....                            | 41 |
|     | 0x27: PULSE_LTCY Pulse Latency Timer Register .....   | 41 |
|     | 0x27 PULSE_LTCY Register (Read/Write) .....   | 41 |
|     | Table 51. PULSE_LTCY Description .....  | 41 |
|     | Table 52. Time Step for PULSE Latency @ ODR and Power Mode (Reg 0x0F) Pulse_LPF_EN = 1 .....          | 41 |
|     | Table 53. Time Step for PULSE Latency @ ODR and Power Mode (Reg 0x0F) Pulse_LPF_EN = 0 .....          | 41 |
|     | 0x28 PULSE_WIND Register (Read/Write) .....   | 42 |
|     | Table 54. PULSE_WIND Description .....  | 42 |
|     | Table 55. Time Step for PULSE Detection Window @ ODR and Power Mode (Reg 0x0F) Pulse_LPF_EN = 1 ..... | 42 |
|     | Table 56. Time Step for PULSE Detection Window @ ODR and Power Mode (Reg 0x0F) Pulse_LPF_EN = 0 ..... | 42 |

|     |  |           |
|-----|--|-----------|
| 6.7 | Auto-WAKE/SLEEP Detection .....  | 43        |
|     | 0x29 ASLP_COUNT Register (Read/Write) .....  | 43        |
|     | Table 57. ASLP_COUNT Description .....   | 43        |
|     | Table 58. ASLP_COUNT Relationship with ODR .....   | 43        |
|     | Table 59. SLEEP/WAKE Mode Gates and Triggers .....   | 43        |
| 6.8 | Control Registers .....  | 44        |
|     | 0x2A: CTRL_REG1 System Control 1 Register .....  | 44        |
|     | 0x2A CTRL_REG1 Register (Read/Write) .....   | 44        |
|     | Table 60. CTRL_REG1 Description .....  | 44        |
|     | Table 61. SLEEP Mode Rate Description .....  | 44        |
|     | Table 62. System Output Data Rate Selection .....  | 44        |
|     | Table 63. Full Scale Selection .....   | 44        |
|     | 0x2B: CTRL_REG2 System Control 2 Register .....  | 45        |
|     | 0x2B CTRL_REG2 Register (Read/Write) .....   | 45        |
|     | Table 64. CTRL_REG2 Description .....  | 45        |
|     | Table 65. MODS Oversampling Modes .....  | 45        |
|     | Table 66. MODS Oversampling Modes Current Consumption and Averaging Values at each ODR ..... | 45        |
|     | 0x2C: CTRL_REG3 Interrupt Control Register .....   | 46        |
|     | 0x2C CTRL_REG3 Register (Read/Write) .....   | 46        |
|     | Table 67. CTRL_REG3 Description .....  | 46        |
|     | 0x2D: CTRL_REG4 Register (Read/Write) .....  | 46        |
|     | 0x2D CTRL_REG4 Register (Read/Write) .....   | 46        |
|     | Table 68. Interrupt Enable Register Description .....  | 46        |
|     | 0x2E CTRL_REG5 Register (Read/Write) .....   | 47        |
|     | 0x2E: CTRL_REG5 Interrupt Configuration Register .....                                       | 47        |
|     | Table 69. Interrupt Configuration Register Description .....                                 | 47        |
| 6.9 | User Offset Correction Registers .....   | 47        |
|     | 0x2F: OFF_X Offset Correction X Register .....   | 47        |
|     | 0x2F OFF_X Register (Read/Write) .....   | 47        |
|     | Table 70. OFF_X Description .....  | 47        |
|     | 0x30: OFF_Y Offset Correction Y Register .....   | 47        |
|     | 0x30 OFF_Y Register (Read/Write) .....   | 47        |
|     | Table 71. OFF_Y Description .....  | 47        |
|     | 0x31: OFF_Z Offset Correction Z Register .....   | 47        |
|     | 0x31 OFF_Z Register (Read/Write) .....   | 47        |
|     | Table 72. OFF_Z Description .....  | 47        |
|     | Table 73. MMA8451Q Register Map .....  | 48        |
|     | Table 74. Accelerometer Output Data .....  | 49        |
|     | <b>Package Dimensions.....</b>   | <b>50</b> |

## Application Notes for Reference

查询 MMA8451Q 供应商 <http://www.freescale.com> Freescale Application Notes written for the MMA8451, 2, 3Q:

- AN4068, *Embedded Orientation Detection Using the MMA8451, 2, 3Q*
- AN4069, *Offset Calibration of the MMA8451, 2, 3Q*
- AN4070, *Motion and Freefall Detection Using the MMA8451, 2, 3Q*
- AN4071, *High Pass Data and Functions Using the MMA8451, 2,3Q*
- AN4072, *MMA8451, 2, 3Q Single/Double and Directional Tap Detection*
- AN4073, *Using the 32 Sample First In First Out (FIFO) in the MMA8451Q*
- AN4074, *Auto-Wake/Sleep Using the MMA8451, 2, 3Q*
- AN4075, *How Many Bits are Enough? The Trade-off Between High Resolution and Low Power Using Oversampling Modes*
- AN4076, *Data Manipulation and Basic Settings of the MMA8451, 2, 3Q*
- AN4077, *MMA8451, 2, 3Q Design Checklist and Board Mounting Guidelines*

## 1 Block Diagram and Pin Description

### 1.1 Block Diagram

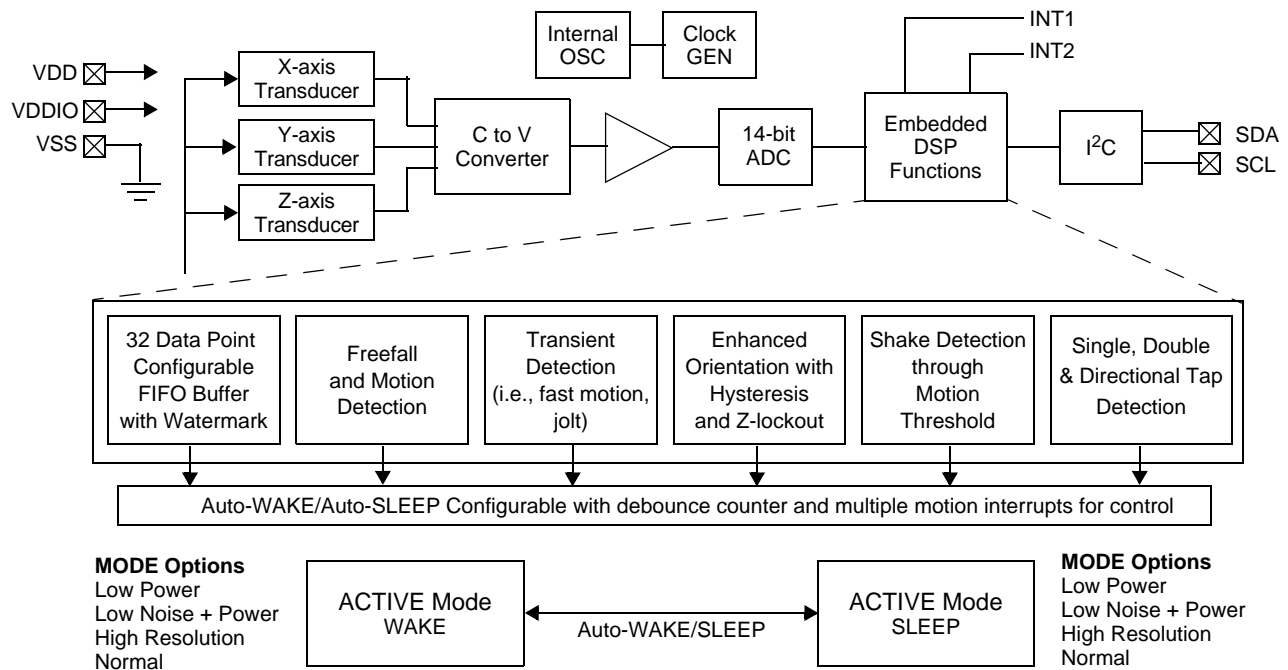


Figure 1. Block Diagram

### 1.2 Pin Description

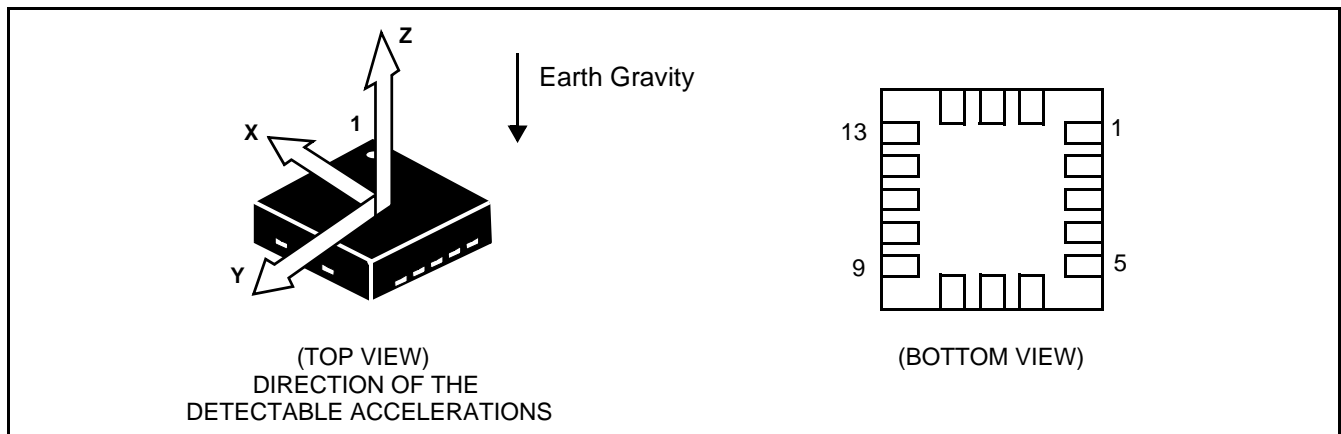


Figure 2. Direction of the Detectable Accelerations

Figure 3 shows the device configuration in the 6 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.

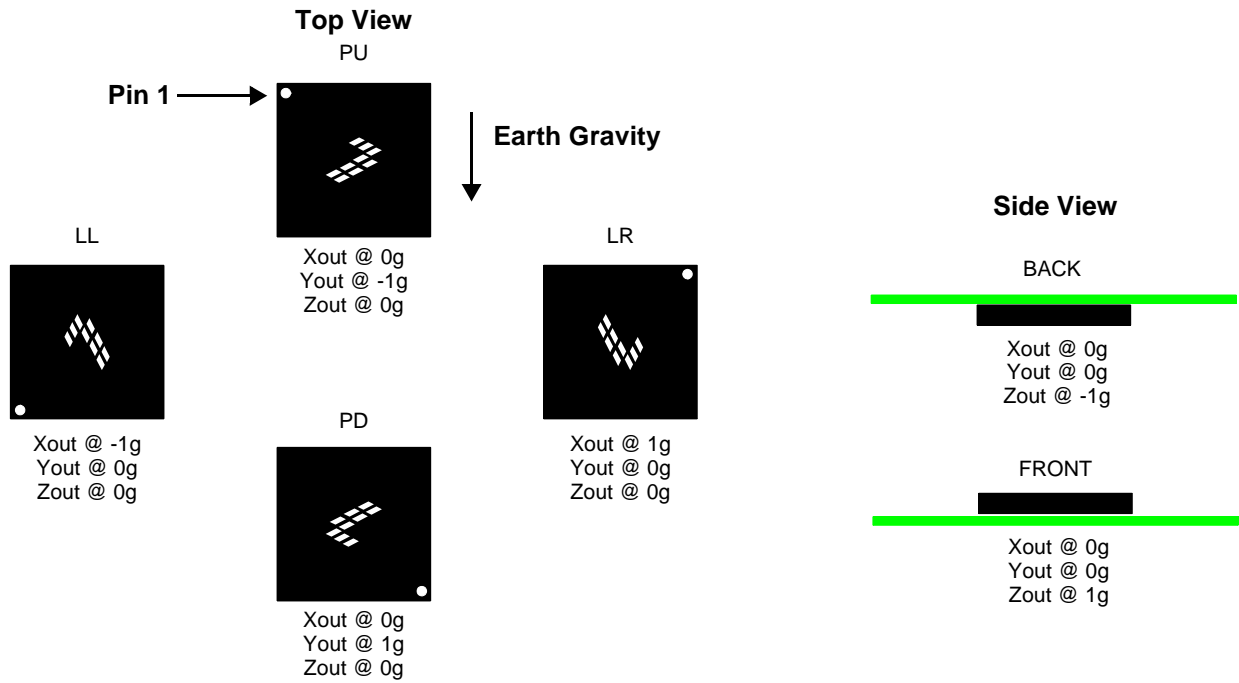


Figure 3. Landscape/Portrait Orientation

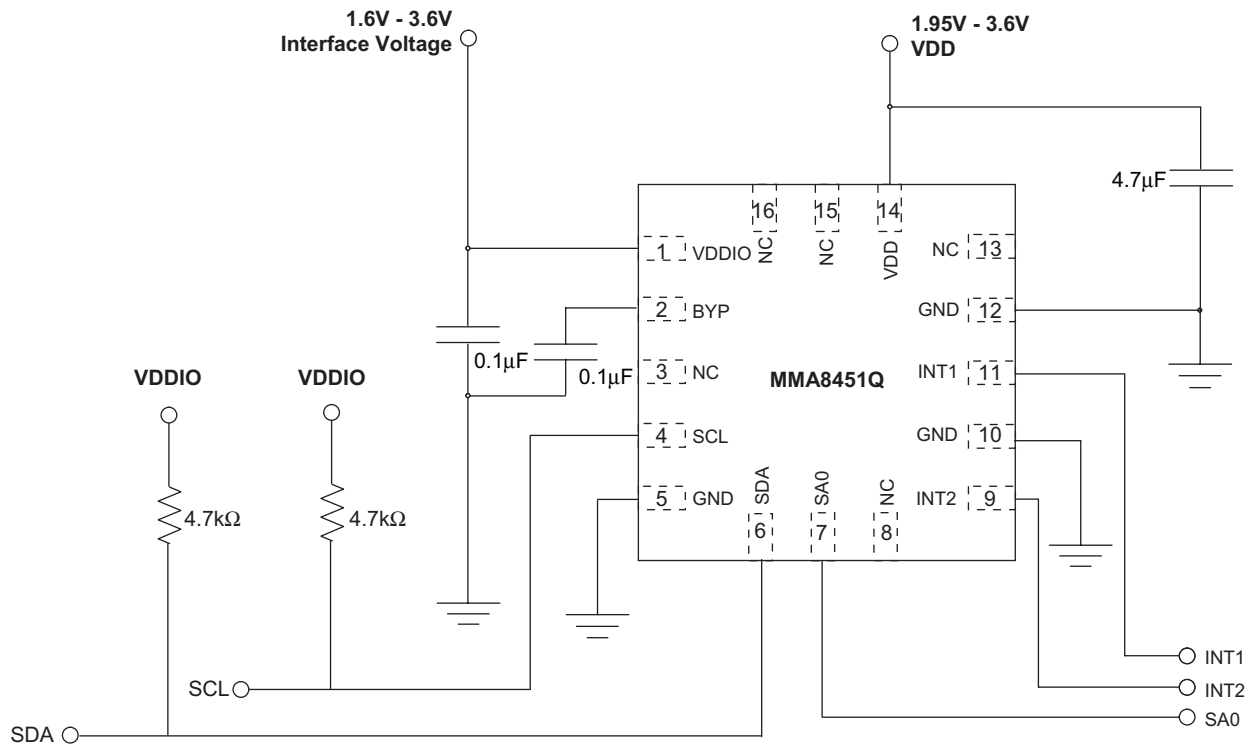


Figure 4. Application Diagram

Table 1. Pin Description

| Pin # | Pin Name | Description   | Pin Status |
|-------|----------|---|------------|
| 1     | VDDIO    | Internal Power Supply (1.62 V - 3.6 V)  | Input      |
| 2     | BYP      | Bypass capacitor (0.1 $\mu$ F)  | Input      |
| 3     | NC       | Leave open. Do not connect  | Open       |
| 4     | SCL      | I <sup>2</sup> C Serial Clock   | Open Drain |
| 5     | GND      | Connect to Ground   | Input      |
| 6     | SDA      | I <sup>2</sup> C Serial Data  | Open Drain |
| 7     | SA0      | I <sup>2</sup> C Least Significant Bit of the Device I <sup>2</sup> C 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      | Power Supply (1.95 V - 3.6 V)   | 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  $\mu$ F bulk, or a single 4.7  $\mu$ F 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 + 0.3 V. 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<sup>2</sup>C interface. The SDA and SCL I<sup>2</sup>C connections are open drain and therefore require a pull-up resistor as shown in the application diagram in [Figure 4](#).

### 1.3 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 = 2.5 V, VDDIO = 1.8 V, T = 25°C unless otherwise noted.

| Parameter  | Test Conditions              | Symbol   | Min   | Typ                   | Max   | Unit     |
|--|------------------------------|----------|-------|-----------------------|-------|----------|
| Measurement Range <sup>(1)</sup>                             | FS[1:0] set to 00<br>2g Mode | FS       |       | ±2                    |       | g        |
|  | FS[1:0] set to 01<br>4g Mode |          |       | ±4                    |       |          |
|  | FS[1:0] set to 10<br>8g Mode |          |       | ±8                    |       |          |
| Sensitivity  | FS[1:0] set to 00<br>2g Mode | So       |       | 4096                  |       | counts/g |
|  | FS[1:0] set to 01<br>4g Mode |          |       | 2048                  |       |          |
|  | FS[1:0] set to 10<br>8g Mode |          |       | 1024                  |       |          |
| Sensitivity Accuracy <sup>(2)</sup>                          |                              | Soa      |       | ±2.5                  |       | %        |
| Sensitivity Change vs. Temperature                           | FS[1:0] set to 00<br>2g Mode | TCSO     |       | ±0.008                |       | %°C      |
|  | FS[1:0] set to 01<br>4g Mode |          |       |                       |       |          |
|  | FS[1:0] set to 10<br>8g Mode |          |       |                       |       |          |
| Zero-g Level Offset Accuracy <sup>(3)</sup>                  | FS[1:0] 2g, 4g, 8g           | TyOff    |       | ±20                   |       | mg       |
| Zero-g Level Offset Accuracy Post Board Mount <sup>(4)</sup> | FS[1:0] 2g, 4g, 8g           | TyOffPBM |       | ±30                   |       | mg       |
| Zero-g Level Change vs. Temperature                          | -40°C to 85°C                | TCOff    |       | ±0.15                 |       | mg/°C    |
| Self-Test Output Change <sup>(5)</sup><br>X<br>Y<br>Z        | FS[1:0] set to 0<br>4g Mode  | Vst      |       | +181<br>+255<br>+1680 |       | LSB      |
| ODR Accuracy<br>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 <sup>(1)</sup>                   | Normal Mode ODR = 400 Hz     | Noise    |       | 99                    |       | µg/√Hz   |
| Operating Temperature Range                                  |                              | Top      | -40   |                       | +85   | °C       |

- Dynamic Range is limited to 4g when the Low Noise bit in Register 0x2A, bit 2 is set.
- 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.
- Before board mount.
- Post Board Mount Offset Specifications are based on an 8 Layer PCB, relative to 25°C.
- Self-Test is one direction only.

## 2.2 Electrical Characteristics

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

| Parameter  | Test Conditions                            | Symbol               | Min        | Typ          | Max       | Unit |
|--|--|----------------------|------------|--------------|-----------|------|
| Supply Voltage   |  | VDD <sup>(1)</sup>   | 1.95       | 2.5          | 3.6       | V    |
| Interface Supply Voltage   |  | VDDIO <sup>(1)</sup> | 1.62       | 1.8          | 3.6       | V    |
| Low Power Mode   | ODR = 1.56 Hz                              | I <sub>ddLP</sub>    |            | 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 <sub>dd</sub>      |            | 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 = 2.5 V                                | I <sub>dd Boot</sub> |            |              | 1         | μA   |
| Value of Capacitor on BYP Pin  | -40°C 85°C                                 | Cap                  | 75         | 100          | 470       | nF   |
| STANDBY Mode Current @25°C   | VDD = 2.5 V, VDDIO = 1.8 V<br>STANDBY Mode | I <sub>ddStby</sub>  |            | 1.8          | 5         | μA   |
| Digital High Level Input Voltage<br>SCL, SDA, SA0  |  | VIH                  | 0.75*VDDIO |              |           | V    |
| Digital Low Level Input Voltage<br>SCL, SDA, SA0   |  | VIL                  |            |              | 0.3*VDDIO | V    |
| High Level Output Voltage<br>INT1, INT2  | I <sub>O</sub> = 500 μA                    | VOH                  | 0.9*VDDIO  |              |           | V    |
| Low Level Output Voltage<br>INT1, INT2   | I <sub>O</sub> = 500 μA                    | VOL                  |            |              | 0.1*VDDIO | V    |
| Low Level Output Voltage<br>SDA  | I <sub>O</sub> = 500 μA                    | VOLS                 |            |              | 0.1*VDDIO | V    |
| Power on Ramp Time   |  |                      | 0.001      |              | 1000      | ms   |
| Time from VDDIO on and VDD > V <sub>min</sub> until I <sup>2</sup> C ready for operation | C <sub>byp</sub> = 100 nF                  | BT                   | —          | 350          | 500       | μs   |
| Turn-on time (STANDBY to ACTIVE)   |  | T <sub>on</sub>      |            | 2/ODR + 1 ms |           | s    |
| Turn-on time (Power Down to ACTIVE Mode)   |  | T <sub>on</sub>      |            | 2/ODR + 2 ms |           | s    |
| Operating Temperature Range  |  | T <sub>op</sub>      | -40        |              | +85       | °C   |

1. There is no requirement for power supply sequencing. The VDDIO input voltage can be higher than the VDD input voltage.

## 2.3 I<sup>2</sup>C Interface Characteristic

Table 1. I<sup>2</sup>C Slave Timing Values<sup>(1)</sup>

| Parameter  | Symbol              | I <sup>2</sup> C Fast Mode |                    | Unit |
|--|---------------------|----------------------------|--------------------|------|
|  |                     | Min                        | Max                |      |
| SCL Clock Frequency<br>Pull-up = 4.7 kΩ, Cb = 20 pF                          | f <sub>SCL</sub>    | 0                          | 2.250              | MHz  |
| Pull-up = 4.7 kΩ, Cb = 40 pF   |                     | 0                          | 100                | kHz  |
| Pull-up = 4.7 kΩ, Cb = 400 pF  |                     | 0                          | Non-functional     | —    |
| Pull-up = 1 kΩ, Cb = 20 pF   |                     | 0                          | 4.50               | MHz  |
| Pull-up = 1 kΩ, Cb = 400 pF  |                     | 0                          | 750                | kHz  |
| Bus Free Time between STOP and START Condition                               | t <sub>BUF</sub>    | 1.3                        |                    | μs   |
| Repeated START Hold Time   | t <sub>HD;STA</sub> | 0.6                        |                    | μs   |
| Repeated START Set-up Time   | t <sub>SU;STA</sub> | 0.6                        |                    | μs   |
| STOP Condition Set-up Time   | t <sub>SU;STO</sub> | 0.6                        |                    | μs   |
| SDA Data Hold Time <sup>(2)</sup>  | t <sub>HD;DAT</sub> | 50                         | <sup>(3)</sup>     | μs   |
| SDA Valid Time <sup>(4)</sup>  | t <sub>VD;DAT</sub> |                            | 0.9 <sup>(3)</sup> | μs   |
| SDA Valid Acknowledge Time <sup>(5)</sup>                                    | t <sub>VD;ACK</sub> |                            | 0.9 <sup>(3)</sup> | μs   |
| SDA Set-up Time  | t <sub>SU;DAT</sub> | 100 <sup>(6)</sup>         |                    | ns   |
| SCL Clock Low Time   | t <sub>LOW</sub>    | 4.7                        |                    | μs   |
| SCL Clock High Time  | t <sub>HIGH</sub>   | 4                          |                    | μs   |
| SDA and SCL Rise Time  | t <sub>r</sub>      |                            | 1000               | ns   |
| SDA and SCL Fall Time <sup>(7)</sup> <sup>(8)</sup>                          | t <sub>f</sub>      |                            | 300                | ns   |
| Pulse width of spikes on SDA and SCL that must be suppressed by input filter | t <sub>SP</sub>     |                            | 50                 | ns   |

- All values referred to VIH (min) and VIL (max) levels.
- t<sub>HD;DAT</sub> is the data hold time that is measured from the falling edge of SCL, applies to data in transmission and the acknowledge.
- The maximum t<sub>HD;DAT</sub> could be 3.45 μs and 0.9 μs for Standard mode and Fast mode, but must be less than the maximum of t<sub>VD;DAT</sub> or t<sub>VD;ACK</sub> by a transition time.
- t<sub>VD;DAT</sub> = time for Data signal from SCL LOW to SDA output (HIGH or LOW, depending on which one is worse).
- t<sub>VD;ACK</sub> = time for Acknowledgement signal from SCL LOW to SDA output (HIGH or LOW, depending on which one is worse).
- A Fast mode I<sup>2</sup>C device can be used in a Standard mode I<sup>2</sup>C system, but the requirement t<sub>SU;DAT</sub> 250 ns must then be met. This will automatically be the case if the device does not stretch the LOW period of the SCL signal. If such a device does stretch the LOW period of the SCL signal, it must output the next data bit to the SDA line t<sub>r(max)</sub> + t<sub>SU;DAT</sub> = 1000 + 250 = 1250 ns (according to the Standard mode I<sup>2</sup>C specification) before the SCL line is released. Also the acknowledge timing must meet this set-up time
- Cb = total capacitance of one bus line in pF.
- The maximum t<sub>f</sub> for the SDA and SCL bus lines is specified at 300 ns. The maximum fall time for the SDA output stage t<sub>f</sub> is specified at 250 ns. This allows series protection resistors to be connected in between the SDA and the SCL pins and the SDA/SCL bus lines without exceeding the maximum specified t<sub>f</sub>.

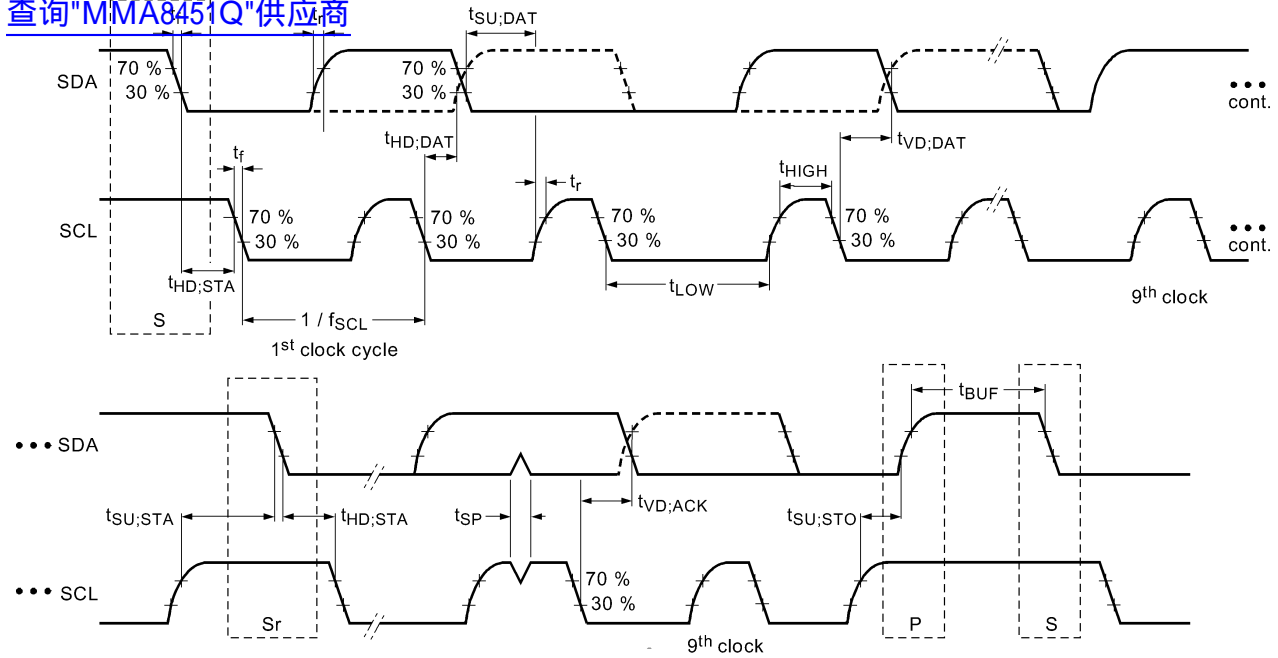


Figure 5. I<sup>2</sup>C Slave Timing Diagram

## 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 Latch-Up Protection Characteristics

| Rating                       | Symbol | Value | Unit |
|------------------------------|--------|-------|------|
| Human Body Model             | HBM    | ±2000 | V    |
| Machine Model                | MM     | ±200  | V    |
| Charge Device Model          | CDM    | ±500  | V    |
| Latch-up 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 is an ESD sensitive, 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 4096 counts/g. In 4g mode the sensitivity is 2048 counts/g and in 8g mode the sensitivity is 1024 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

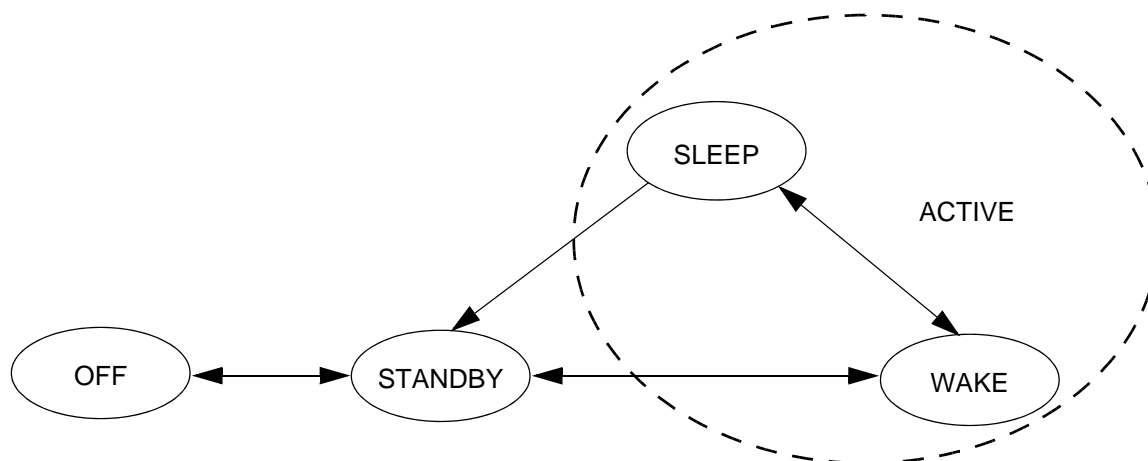


Figure 6. MMA8451Q Mode Transition Diagram

Table 7. Mode of Operation Description

| Mode                   | I <sup>2</sup> C Bus State                               | VDD    | VDDIO   | Function Description   |
|------------------------|--|--------|---|--|
| OFF                    | Powered Down   | <1.8 V | VDDIO Can be > VDD                                  | The device is powered off. All analog and digital blocks are shutdown. I <sup>2</sup> C bus inhibited. |
| STANDBY                | I <sup>2</sup> C communication with MMA8451Q is possible | ON     | VDDIO = High<br>VDD = High<br>ACTIVE bit is cleared | Only digital blocks are enabled.<br>Analog subsystem is disabled. Internal clocks disabled.            |
| ACTIVE<br>(WAKE/SLEEP) | I <sup>2</sup> C communication with MMA8451Q is possible | ON     | VDDIO = High<br>VDD = High<br>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

查询"MMA8451Q"供应商  
The MMA8451Q is a low-power, digital output 3-axis linear accelerometer with a I<sup>2</sup>C interface and embedded logic used to detect events and notify an external microprocessor over interrupt lines. The functionality includes the following:

- 8-bit or 14-bit data, High Pass Filtered data, 8-bit or 14-bit configurable 32 sample FIFO
- 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 for conservation of current consumption
- Single/Double tap with directional information 1 channel
- Motion detection with directional information or Freefall 1 channel
- Transient/Jolt detection based on a high pass filter and settable threshold for detecting the change in acceleration above a threshold with directional information 1 channel
- Flexible user configurable portrait landscape detection algorithm addressing many use cases for screen orientation

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.

### 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 MMA8451Q 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 14-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 14-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 +1.99975g, and each count corresponds to 1g/4096 (0.25 mg) at 14-bits resolution. When the full-scale is set to 8g, the measurement range is -8g to +7.999g, and each count corresponds to 1g/1024 (0.98 mg) at 14-bits resolution. The resolution is reduced by a factor of 64 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) with this application note.

### 5.3 Internal FIFO Data Buffer

MMA8451Q contains a 32 sample internal FIFO data buffer minimizing traffic across the I<sup>2</sup>C bus. The FIFO can also provide power savings of the system by allowing the host processor/MCU to go into a SLEEP mode while the accelerometer independently stores the data, up to 32 samples per axis. The FIFO can run at all output data rates. There is the option of accessing the full 14-bit data or for accessing only the 8-bit data. When access speed is more important than high resolution the 8-bit data read is a better option.

The FIFO contains four modes (Fill Buffer Mode, Circular Buffer Mode, Trigger Mode, and Disabled Mode) described in the F\_SETUP Register 0x09. Fill Buffer Mode collects the first 32 samples and asserts the overflow flag when the buffer is full and another sample arrives. It does not collect any more data until the buffer is read. This benefits data logging applications where all samples must be collected. The Circular Buffer Mode allows the buffer to be filled and then new data replaces the oldest sample in the buffer. The most recent 32 samples will be stored in the buffer. This benefits situations where the processor is waiting for an specific interrupt to signal that the data must be flushed to analyze the event. The trigger mode will hold the last data up to the point when the trigger occurs and can be set to keep a selectable number of samples after the event occurs.

The MMA8451Q FIFO Buffer has a configurable watermark, allowing the processor to be triggered after a configurable number of samples has filled in the buffer (1 to 32).

For details on the configurations for the FIFO buffer as well as more specific examples and application benefits, refer to Freescale application note, AN4073.

## 5.4 Low Power Modes vs. High Resolution Modes

The MMA8451Q 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 be 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. When MODS = 11 the lowest power is achieved. The lowest power is achieved when the sample rate is set to 1.56 Hz. For more information on how to configure the MMA8451Q in Low Power mode or High Resolution mode and to realize the benefits, refer to Freescale application note, AN4075.

## 5.5 Auto-WAKE/SLEEP Mode

The MMA8451Q 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: Tap Detection, Orientation Detection, Motion/Freefall, and Transient Detection. The FIFO can be configured to hold the data in the buffer until it is flushed if the FIFO Gate bit is set in Register 0x2C but the FIFO cannot WAKE the device from SLEEP.

The interrupts that can keep the device from falling asleep are the same interrupts that can wake the device with the addition of the FIFO. If the FIFO interrupt is enabled and data is being accessed continually servicing the interrupt then the device will remain in the WAKE mode. Refer to AN4074, for more detailed information for configuring the Auto-WAKE/SLEEP.

## 5.6 Freefall and Motion Detection

MMA8451Q 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.

### 5.6.1 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  $\pm 100$  mg and  $\pm 500$  mg.

### 5.6.2 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 a 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.

## 5.7 Transient Detection

The MMA8451Q 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 cut-off frequency can be set by the user to four different frequencies which are dependent on the Output Data Rate (ODR). A higher cut-off 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.

## 5.8 Tap Detection

The MMA8451Q has embedded single/double and directional tap 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 tap detection can be configured to run through the high pass filter and also through a low pass filter, which provides more customizing and tunable tap 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 tap detection please refer to Freescale application note AN4072.

## 5.9 Orientation Detection

The MMA8451Q incorporates an advanced algorithm for orientation detection (ability to detect all 6 orientations) with configurable trip points. The embedded algorithm allows the selection of the mid point with the desired hysteresis value.

The MMA8451Q Orientation Detection algorithm confirms the reliability of the function with a configurable Z-lockout angle. Based on known functionality of linear accelerometers, it is not possible to rotate the device about the Z-axis to detect change in acceleration at slow angular speeds. 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 14° from the flat position.

For further information on the configuration settings of the orientation detection function, including recommendations for configuring the device to support various application use cases, refer to Freescale application note, AN4068.

Figure 8 and Figure 9 show the definitions of the trip angles going from Landscape to Portrait and then also from Portrait to Landscape.

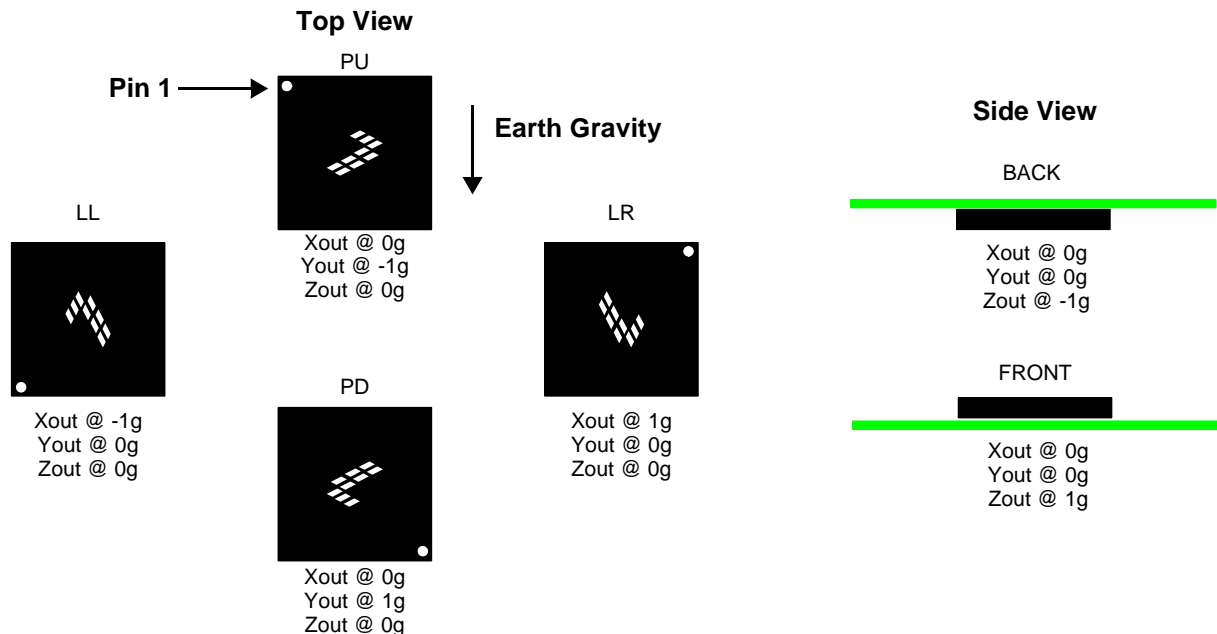


Figure 7. Landscape/Portrait Orientation



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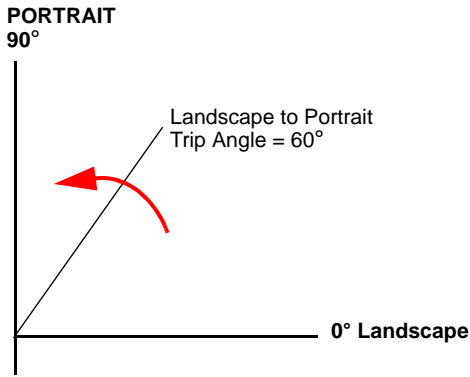


Figure 8. Illustration of Landscape to Portrait Transition

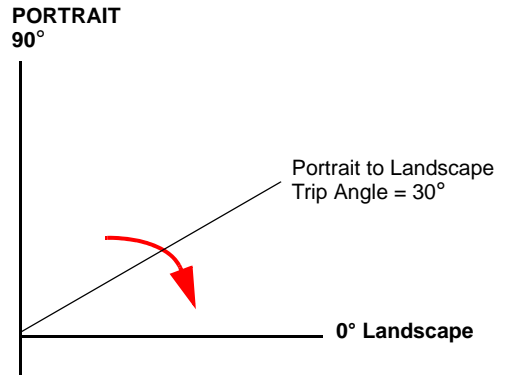


Figure 9. Illustration of Portrait to Landscape Transition

Figure 10 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 14° from flat. This is user configurable. The default angle is 29° but it can be set as low as 14°.

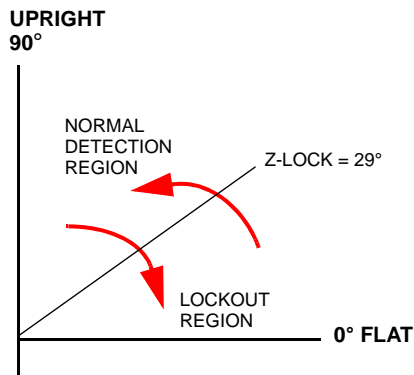


Figure 10. Illustration of Z-Tilt Angle Lockout Transition

## 5.10 Interrupt Register Configurations

There are seven configurable interrupts in the MMA8451Q: Data Ready, Motion/Freefall, Tap (Pulse), Orientation, Transient, FIFO and Auto-SLEEP events. These seven 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.

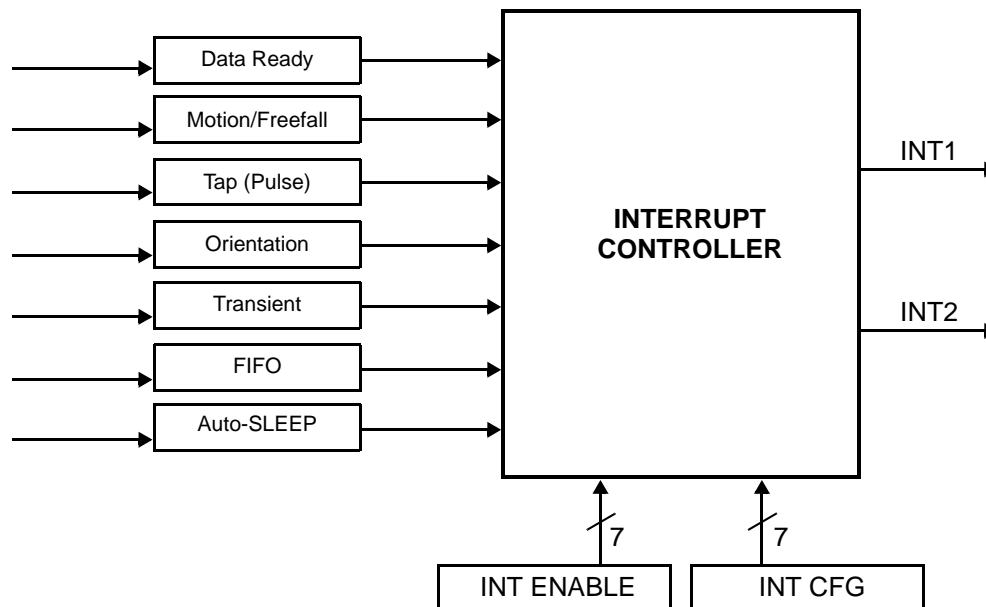


Figure 11. System Interrupt Generation Block Diagram

## 5.11 Serial I<sup>2</sup>C Interface

Acceleration data may be accessed through an I<sup>2</sup>C interface thus making the device particularly suitable for direct interfacing with a microcontroller. The MMA8451Q 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 MMA8451Q may also be configured to generate other interrupt signals accordingly to the programmable embedded functions of the device for Motion, Freefall, Transient, Orientation, and Tap.

The registers embedded inside the MMA8451Q are accessed through the I<sup>2</sup>C serial interface (Table 8). To enable the I<sup>2</sup>C interface, VDDIO line must be tied high (i.e., to the interface supply voltage). If VDD is not present and VDDIO is present, the MMA8451Q is in off mode and communications on the I<sup>2</sup>C interface are ignored. The I<sup>2</sup>C interface may be used for communications between other I<sup>2</sup>C devices and the MMA8451Q does not affect the I<sup>2</sup>C bus.

Table 8. Serial Interface Pin Description

| Pin Name | Pin Description  |
|----------|--|
| SCL      | I <sup>2</sup> C Serial Clock                                |
| SDA      | I <sup>2</sup> C Serial Data                                 |
| SA0      | I <sup>2</sup> C least significant bit of the device address |

There are two signals associated with the I<sup>2</sup>C 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 pull-up resistors connected to VDDIO are expected for SDA and SCL. When the bus is free both the lines are high. The I<sup>2</sup>C interface is compliant with Fast mode (400 kHz), and Normal mode (100 kHz) I<sup>2</sup>C standards (Table 4).

## 5.11.1 I<sup>2</sup>C Operation

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A data transfer 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 MMA8451Q expects repeated STARTs to be used to randomly read from specific registers.

The MMA8451Q'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 9](#).

**Table 9. I<sup>2</sup>C Address Selection Table**

| Slave Address (SA0 = 0) | Slave Address (SA0 = 1) | Comment         |
|-------------------------|-------------------------|-----------------|
| 0011100 (0x1C)          | 0011101 (0x1D)          | Factory Default |

### Single Byte Read

The MMA8451Q 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 12](#) shows the timing diagram for the accelerometer 8-bit I<sup>2</sup>C read operation. The Master (or MCU) transmits a start condition (ST) to the MMA8451Q, slave address (\$1D), with the R/W bit set to "0" for a write, and the MMA8451Q sends an acknowledgement. Then the Master (or MCU) transmits the address of the register to read and the MMA8451Q sends an acknowledgement. The Master (or MCU) transmits a repeated start condition (SR) and then addresses the MMA8451Q (\$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 MMA8451Q 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 MMA8451Q 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 MMA8451Q, slave address (\$1D) with the R/W bit set to "0" for a write, the MMA8451Q sends an acknowledgement. Then the Master (MCU) transmits the address of the register to write to, and the MMA8451Q sends an acknowledgement. Then the Master (or MCU) transmits the 8-bit data to write to the designated register and the MMA8451Q 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 MMA8451Q is now stored in the appropriate register.

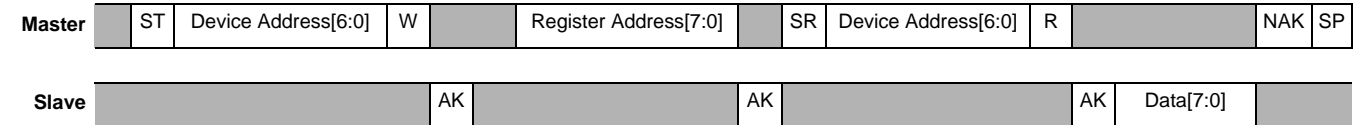
## Multiple Byte Write

The MMA8451Q 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 MMA8451Q acknowledgment (ACK) is received.

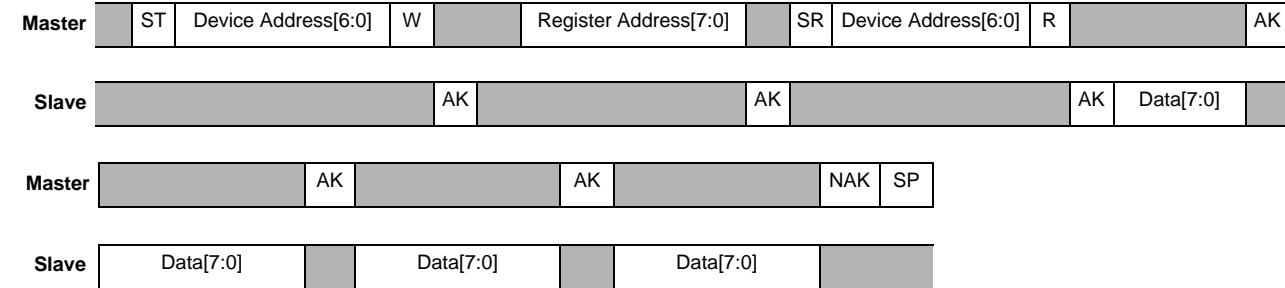
**Table 10. I<sup>2</sup>C Device Address Sequence**

| Command | [6:1]<br>Device Address | [0]<br>SA0 | [6:0]<br>Device Address | R/W | 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              |

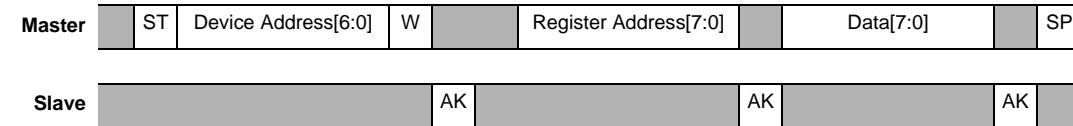
### < Single Byte Read >



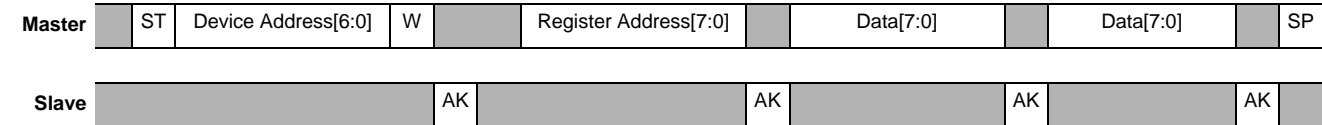
### < Multiple Byte Read >



### < Single Byte Write >



### < Multiple Byte Write >



#### Legend

ST: Start Condition      SR: Repeated Start Condition      AK: Acknowledge

SP: Stop Condition      NAK: No Acknowledge      R: Read = 1

W: Write = 0

**Figure 12. I<sup>2</sup>C Timing Diagram**

## 6 Register Descriptions

Table 11. Register Address Map

| Name                               | Type | Register Address | Auto-Increment Address  |                         |                         |                         | Default  | Hex Value | Comment   |
|------------------------------------|------|------------------|-------------------------|-------------------------|-------------------------|-------------------------|----------|-----------|---|
|                                    |      |                  | FMODE = 0<br>F_READ = 0 | FMODE > 0<br>F_READ = 0 | FMODE = 0<br>F_READ = 1 | FMODE > 0<br>F_READ = 1 |          |           |   |
| STATUS/F_STATUS <sup>(1)(2)</sup>  | R    | 0x00             | 0x01                    |                         |                         |                         | 00000000 | 0x00      | FMODE = 0, real time status<br>FMODE > 0, FIFO status             |
| OUT_X_MSB <sup>(1)(2)</sup>        | R    | 0x01             | 0x02                    | 0x01                    | 0x03                    | 0x01                    | Output   | —         | [7:0] are 8 MSBs of 14-bit sample. Root pointer to XYZ FIFO data. |
| OUT_X_LSB <sup>(1)(2)</sup>        | R    | 0x02             | 0x03                    |                         | 0x00                    |                         | Output   | —         | [7:2] are 6 LSBs of 14-bit real-time sample                       |
| OUT_Y_MSB <sup>(1)(2)</sup>        | R    | 0x03             | 0x04                    |                         | 0x05                    | 0x00                    | Output   | —         | [7:0] are 8 MSBs of 14-bit real-time sample                       |
| OUT_Y_LSB <sup>(1)(2)</sup>        | R    | 0x04             | 0x05                    |                         | 0x00                    |                         | Output   | —         | [7:2] are 6 LSBs of 14-bit real-time sample                       |
| OUT_Z_MSB <sup>(1)(2)</sup>        | R    | 0x05             | 0x06                    |                         | 0x00                    |                         | Output   | —         | [7:0] are 8 MSBs of 14-bit real-time sample                       |
| OUT_Z_LSB <sup>(1)(2)</sup>        | R    | 0x06             | 0x00                    |                         |                         |                         | Output   | —         | [7:2] are 6 LSBs of 14-bit real-time sample                       |
| Reserved                           | R    | 0x07             | —                       | —                       | —                       | —                       | —        | —         | Reserved. Read return 0x00.                                       |
| Reserved                           | R    | 0x08             | —                       | —                       | —                       | —                       | —        | —         | Reserved. Read return 0x00.                                       |
| F_SETUP <sup>(1)(3)</sup>          | R/W  | 0x09             | 0x0A                    |                         |                         |                         | 00000000 | 0x00      | FIFO set-up   |
| TRIG_CFG <sup>(1)(4)</sup>         | R/W  | 0x0A             | 0x0B                    |                         |                         |                         | 00000000 | 0x00      | Map of FIFO data capture events                                   |
| SYSMOD <sup>(1)(2)</sup>           | R    | 0x0B             | 0x0C                    |                         |                         |                         | 00000000 | 0x00      | Current System Mode   |
| INT_SOURCE <sup>(1)(2)</sup>       | R    | 0x0C             | 0x0D                    |                         |                         |                         | 00000000 | 0x00      | Interrupt status  |
| WHO_AM_I <sup>(1)</sup>            | R    | 0x0D             | 0x0E                    |                         |                         |                         | 00011010 | 0x1A      | Device ID (0x1A)  |
| XYZ_DATA_CFG <sup>(1)(4)</sup>     | R/W  | 0x0E             | 0x0F                    |                         |                         |                         | 00000000 | 0x00      | Dynamic Range Settings  |
| HP_FILTER_CUTOFF <sup>(1)(4)</sup> | R/W  | 0x0F             | 0x10                    |                         |                         |                         | 00000000 | 0x00      | Cut-off frequency is set to 16 Hz @ 800 Hz                        |
| PL_STATUS <sup>(1)(2)</sup>        | R    | 0x10             | 0x11                    |                         |                         |                         | 00000000 | 0x00      | Landscape/Portrait orientation status                             |
| PL_CFG <sup>(1)(4)</sup>           | R/W  | 0x11             | 0x12                    |                         |                         |                         | 10000000 | 0x80      | Landscape/Portrait configuration.                                 |
| PL_COUNT <sup>(1)(3)</sup>         | R/W  | 0x12             | 0x13                    |                         |                         |                         | 00000000 | 0x00      | Landscape/Portrait debounce counter                               |
| PL_BF_ZCOMP <sup>(1)(4)</sup>      | R/W  | 0x13             | 0x14                    |                         |                         |                         | 01000100 | 0x44      | Back/Front, Z-Lock Trip threshold                                 |
| P_L_THS_REG <sup>(1)(4)</sup>      | R/W  | 0x14             | 0x15                    |                         |                         |                         | 10000100 | 0x84      | Portrait to Landscape Trip Angle is 29°                           |
| FF_MT_CFG <sup>(1)(4)</sup>        | R/W  | 0x15             | 0x16                    |                         |                         |                         | 00000000 | 0x00      | Freefall/Motion functional block configuration                    |
| FF_MT_SRC <sup>(1)(2)</sup>        | R    | 0x16             | 0x17                    |                         |                         |                         | 00000000 | 0x00      | Freefall/Motion event source register                             |
| FF_MT_THS <sup>(1)(3)</sup>        | R/W  | 0x17             | 0x18                    |                         |                         |                         | 00000000 | 0x00      | Freefall/Motion threshold register                                |
| FF_MT_COUNT <sup>(1)(3)</sup>      | R/W  | 0x18             | 0x19                    |                         |                         |                         | 00000000 | 0x00      | Freefall/Motion debounce counter                                  |
| Reserved                           | R    | 0x19             | —                       | —                       | —                       | —                       | —        | —         | Reserved. Read return 0x00.                                       |
| Reserved                           | R    | 0x1A             | —                       | —                       | —                       | —                       | —        | —         | Reserved. Read return 0x00.                                       |
| Reserved                           | R    | 0x1B             | —                       | —                       | —                       | —                       | —        | —         | Reserved. Read return 0x00.                                       |
| Reserved                           | R    | 0x1C             | —                       | —                       | —                       | —                       | —        | —         | Reserved. Read return 0x00.                                       |
| TRANSIENT_CFG <sup>(1)(4)</sup>    | R/W  | 0x1D             | 0x1E                    |                         |                         |                         | 00000000 | 0x00      | Transient functional block configuration                          |
| TRANSIENT_SRC <sup>(1)(2)</sup>    | R    | 0x1E             | 0x1F                    |                         |                         |                         | 00000000 | 0x00      | Transient event status register                                   |

**Table 11. Register Address Map**

| Register Name                     | Access | Address   | Value       | Mask     | Description |  |
|-----------------------------------|--------|-----------|-------------|----------|-------------|--|
| TRANSIENT_COUNT <sup>(1)(3)</sup> | R/W    | 0x20      | 0x20        | 00000000 | 0x00        | Transient event threshold              |
| PULSE_CFG <sup>(1)(4)</sup>       | R/W    | 0x21      | 0x21        | 00000000 | 0x00        | Transient debounce counter             |
| PULSE_SRC <sup>(1)(2)</sup>       | R      | 0x22      | 0x22        | 00000000 | 0x00        | ELE, Double_XYZ or Single_XYZ          |
| PULSE_THSX <sup>(1)(3)</sup>      | R/W    | 0x23      | 0x23        | 00000000 | 0x00        | EA, Double_XYZ or Single_XYZ           |
| PULSE_THSY <sup>(1)(3)</sup>      | R/W    | 0x24      | 0x24        | 00000000 | 0x00        | X pulse threshold                      |
| PULSE_THSZ <sup>(1)(3)</sup>      | R/W    | 0x25      | 0x25        | 00000000 | 0x00        | Y pulse threshold                      |
| PULSE_TMLT <sup>(1)(4)</sup>      | R/W    | 0x26      | 0x26        | 00000000 | 0x00        | Z pulse threshold                      |
| PULSE_LTCY <sup>(1)(4)</sup>      | R/W    | 0x27      | 0x27        | 00000000 | 0x00        | Time limit for pulse                   |
| PULSE_WIND <sup>(1)(4)</sup>      | R/W    | 0x28      | 0x28        | 00000000 | 0x00        | Latency time for 2 <sup>nd</sup> pulse |
| ASLP_COUNT <sup>(1)(4)</sup>      | R/W    | 0x29      | 0x29        | 00000000 | 0x00        | Window time for 2nd pulse              |
| CTRL_REG1 <sup>(1)(4)</sup>       | R/W    | 0x2A      | 0x2A        | 00000000 | 0x00        | Counter setting for Auto-SLEEP         |
| CTRL_REG2 <sup>(1)(4)</sup>       | R/W    | 0x2B      | 0x2B        | 00000000 | 0x00        | ODR = 800 Hz, STANDBY Mode.            |
| CTRL_REG3 <sup>(1)(4)</sup>       | R/W    | 0x2C      | 0x2C        | 00000000 | 0x00        | Sleep Enable, OS Modes, RST, ST        |
| CTRL_REG4 <sup>(1)(4)</sup>       | R/W    | 0x2D      | 0x2D        | 00000000 | 0x00        | Wake from Sleep, IPOL, PP_OD           |
| CTRL_REG5 <sup>(1)(4)</sup>       | R/W    | 0x2E      | 0x2E        | 00000000 | 0x00        | Interrupt enable register              |
| OFF_X <sup>(1)(4)</sup>           | R/W    | 0x2F      | 0x2F        | 00000000 | 0x00        | Interrupt pin (INT1/INT2) map          |
| OFF_Y <sup>(1)(4)</sup>           | R/W    | 0x30      | 0x30        | 00000000 | 0x00        | X-axis offset adjust                   |
| OFF_Z <sup>(1)(4)</sup>           | R/W    | 0x31      | <b>0x0D</b> | 00000000 | 0x00        | Y-axis offset adjust                   |
| Reserved (do not modify)          |        | 0x40 – 7F | —           | —        | —           | Z-axis offset adjust                   |
|                                   |        |           |             |          |             | Reserved. Read return 0x00.            |

1. Register contents are preserved when transition from ACTIVE to STANDBY mode occurs.
2. Register contents are reset when transition from STANDBY to ACTIVE mode occurs.
3. Register contents can be modified anytime in STANDBY or ACTIVE mode. A write to this register will cause a reset of the corresponding internal system debounce counter.
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<sup>2</sup>C burst read mode. Therefore the internal storage of the auto-increment address is cleared whenever a stop-bit is detected.

## 6.1 Data Registers

The following are the data registers for the MMA8451Q. For more information on data manipulation of the MMA8451Q, refer to application note, AN4076.

When the F\_MODE bits found in Register 0x09 (F\_SETUP), bits 7 and 6 are both cleared (the FIFO is not on). Register 0x00 reflects the real-time status information of the X, Y and Z sample data. When the F\_MODE value is greater than zero the FIFO is on (in either Fill, Circular or Trigger mode). In this case Register 0x00 will reflect the status of the FIFO. It is expected when the FIFO is on that the user will access the data from Register 0x01 (X\_MSB) for either the 14-bit or 8-bit data. When accessing the 8-bit data the F\_READ bit (Register 0x2A) is set which modifies the auto-incrementing to skip over the LSB data. When F\_READ bit is cleared the 14-bit data is read accessing all 6 bytes sequentially (X\_MSB, X\_LSB, Y\_MSB, Y\_LSB, Z\_MSB, Z\_LSB).

### F\_MODE = 00: 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<br>0: No data overwrite has occurred<br>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<br>0: No data overwrite has occurred<br>1: Previous Z-axis data was overwritten by new Z-axis data before it was read               |
| YOW   | Y-axis Data Overwrite. Default value: 0<br>0: No data overwrite has occurred<br>1: Previous Y-axis data was overwritten by new Y-axis data before it was read               |
| XOW   | X-axis Data Overwrite. Default value: 0<br>0: No data overwrite has occurred<br>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<br>0: No new set of data ready<br>1: A new set of data is ready   |
| ZDR   | Z-axis new Data Available. Default value: 0<br>0: No new Z-axis data is ready<br>1: A new Z-axis data is ready  |
| YDR   | Y-axis new Data Available. Default value: 0<br>0: No new Y-axis data ready<br>1: A new Y-axis data is ready   |
| XDR   | X-axis new Data Available. Default value: 0<br>0: No new X-axis data ready<br>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

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These registers contain the X-axis, Y-axis, and Z-axis 14-bit output sample data expressed as 2's complement numbers.

**Note:** The sample data output registers store the current sample data if the FIFO data output register driver is disabled, but if the FIFO data output register driver is enabled (F\_MODE > 00) the sample data output registers point to the head of the FIFO buffer (Register 0x01 X\_MSB) which contains the previous 32 X, Y, and Z data samples. Data Registers F\_MODE = 00

### 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 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| XD13  | XD12  | XD11  | XD10  | XD9   | XD8   | XD7   | XD6   |

### 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 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| XD5   | XD4   | XD3   | XD2   | XD1   | XD0   | 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 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| YD13  | YD12  | YD11  | YD10  | YD9   | YD8   | YD7   | YD6   |

### 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 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| YD5   | YD4   | YD3   | YD2   | YD1   | YD0   | 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 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| ZD13  | ZD12  | ZD11  | ZD10  | ZD9   | ZD8   | ZD7   | ZD6   |

### 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 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| ZD5   | ZD4   | ZD3   | ZD2   | ZD1   | ZD0   | 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 14-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.

If the FIFO is enabled (F\_MODE > 00), Register 0x01 points to the FIFO read pointer, while registers 0x02, 0x03, 0x04, 0x05, 0x06 return a value of zero when read. If the F\_READ bit is set (0x2A bit 1), auto increment will skip over LSB registers to access the MSB data only.

## 6.2 32 Sample FIFO

The following registers are used to configure the FIFO. For more information on the FIFO please refer to AN4073.

### F\_MODE > 0 0x00: F\_STATUS FIFO Status Register

When F\_MODE > 0, Register 0x00 becomes the FIFO Status Register which is used to retrieve information about the FIFO. This register has a flag for the overflow and watermark. It also has a counter that can be read to obtain the number of samples stored in the buffer when the FIFO is enabled.

### 0x00 F\_STATUS: FIFO STATUS Register (Read Only)

| Bit 7 | Bit 6       | Bit 5  | Bit 4  | Bit 3  | Bit 2  | Bit 1  | Bit 0  |
|-------|-------------|--------|--------|--------|--------|--------|--------|
| F_OVF | F_WMRK_FLAG | F_CNT5 | F_CNT4 | F_CNT3 | F_CNT2 | F_CNT1 | F_CNT0 |



**Table 13. FIFO Flag Event Description**

| F_OVF | F_WMRK_FLAG | Event Description  |
|-------|-------------|--|
| 0     | —           | No FIFO overflow events detected.  |
| 1     | —           | FIFO event detected; FIFO has overflowed.  |
| —     | 0           | No FIFO watermark events detected.   |
| —     | 1           | FIFO Watermark event detected. FIFO sample count is greater than watermark value.<br>If F_MODE = 11, Trigger Event detected. |

The F\_OVF and F\_WMRK\_FLAG flags remain asserted while the event source is still active, but the user can clear the FIFO interrupt bit flag in the interrupt source register (INT\_SOURCE) by reading the F\_STATUS register. In this case, the SRC\_FIFO bit in the INT\_SOURCE register will be set again when the next data sample enters the FIFO. Therefore the F\_OVF bit flag will remain asserted while the FIFO has overflowed and the F\_WMRK\_FLAG bit flag will remain asserted while the F\_CNT value is equal to or greater than then F\_WMRK value. If the FIFO overflow flag is cleared and if F\_MODE = 11 then the FIFO overflow flag will remain 0 before the trigger event even if the FIFO is full and overflows. If the FIFO overflow flag is set and if F\_MODE is = 11, the FIFO has stopped accepting samples.

**Table 14. FIFO Sample Count Description**

|            |   |
|------------|---|
| F_CNT[5:0] | FIFO sample counter. Default value: 00_0000.<br>(00_0001 to 10_0000 indicates 1 to 32 samples stored in FIFO) |
|------------|---|

**F\_CNT[5:0]** bits indicate the number of acceleration samples currently stored in the FIFO buffer. Count 000000 indicates that the FIFO is empty.

**0x09: F\_SETUP FIFO Set-up Register**

**0x09 F\_SETUP: FIFO Set-up Register (Read/Write)**

| Bit 7   | Bit 6   | Bit 5   | Bit 4   | Bit 3   | Bit 2   | Bit 1   | Bit 0   |
|---------|---------|---------|---------|---------|---------|---------|---------|
| F_MODE1 | F_MODE0 | F_WMRK5 | F_WMRK4 | F_WMRK3 | F_WMRK2 | F_WMRK1 | F_WMRK0 |

**Table 15. F\_SETUP Description**

| BITS                          | Description  |
|-------------------------------|--|
| F_MODE[1:0] <sup>(1)(2)</sup> | FIFO buffer overflow mode. Default value: 0.<br><b>00:</b> FIFO is disabled.<br><b>01:</b> FIFO contains the most recent samples when overflowed (circular buffer). Oldest sample is discarded to be replaced by new sample.<br><b>10:</b> FIFO stops accepting new samples when overflowed.<br><b>11:</b> Trigger mode. The FIFO will be in a circular mode up to the number of samples in the watermark. The FIFO will be in a circular mode until the trigger event occurs after that the FIFO will continue to accept samples for 32-WMRK samples and then stop receiving further samples. This allows data to be collected both before and after the trigger event and it is definable by the watermark setting.<br>The FIFO is flushed whenever the FIFO is disabled, during an automatic ODR change (Auto-WAKE/SLEEP), or transitioning from STANDBY mode to ACTIVE mode.<br>Disabling the FIFO (F_MODE = 00) resets the F_OVF, F_WMRK_FLAG, F_CNT to zero.<br>A FIFO overflow event (i.e., F_CNT = 32) will assert the F_OVF flag and a FIFO sample count equal to the sample count watermark (i.e., F_WMRK) asserts the F_WMRK_FLAG event flag. |
| F_WMRK[5:0] <sup>(2)</sup>    | FIFO Event Sample Count Watermark. Default value: 00_0000.<br>These bits set the number of FIFO samples required to trigger a watermark interrupt. A FIFO watermark event flag is raised when FIFO sample count F_CNT[5:0] ≥ F_WMRK[5:0] watermark.<br>Setting the F_WMRK[5:0] to 00_0000 will disable the FIFO watermark event flag generation.<br>Also used to set the number of pre-trigger samples in Trigger mode.  |

1. Bit field can be written in ACTIVE mode.
2. Bit field can be written in STANDBY mode.

The FIFO mode can be changed while in the active state. The mode must first be disabled F\_MODE = 00 then the mode can be switched between Fill mode, Circular mode and Trigger mode.

A FIFO sample count exceeding the watermark event does not stop the FIFO from accepting new data. The FIFO update rate is dictated by the selected system ODR. In ACTIVE mode the ODR is set by the DR bits in the CTRL\_REG1 register. When Auto-SLEEP is active the ODR is set by the ASLP\_RATE field in the CTRL\_REG1 register.

When a byte is read from the FIFO buffer the oldest sample data in the FIFO buffer is returned and also deleted from the front of the FIFO buffer, while the FIFO sample count is decremented by one. It is assumed that the host application shall use the I<sup>2</sup>C multi-byte read transaction to empty the FIFO.

### 0x0A: TRIG\_CFG

In the trigger configuration register the bits that are set (logic '1') control which function may trigger the FIFO to its interrupt and conversely bits that are cleared (logic '0') indicate which function has not asserted its interrupt.

The bits set are rising edge sensitive, and are set by a low to high state change and reset by reading the appropriate source register.

#### 0x0A: TRIG\_CFG Trigger Configuration Register (Read/Write)

| Bit 7 | Bit 6 | Bit 5      | Bit 4       | Bit 3      | Bit 2      | Bit 1 | Bit 0 |
|-------|-------|------------|-------------|------------|------------|-------|-------|
| —     | —     | Trig_TRANS | Trig_LNDPRT | Trig_PULSE | Trig_FF_MT | —     | —     |

Table 16. Trigger Configuration Description

| INT_SOURCE  | Description  |
|-------------|--|
| Trig_TRANS  | Transient interrupt trigger bit. Default value: 0                      |
| Trig_LNDPRT | Landscape/Portrait Orientation interrupt trigger bit. Default value: 0 |
| Trig_PULSE  | Pulse interrupt trigger bit. Default value: 0                          |
| Trig_FF_MT  | Freefall/Motion trigger bit. Default value: 0                          |

### 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. The System mode register also indicates the status of the FIFO gate error and number of samples since the gate error occurred.

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

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1   | Bit 0   |
|-------|-------|-------|-------|-------|-------|---------|---------|
| FGERR | FGT_4 | FGT_3 | FGT_2 | FGT_1 | FGT_0 | SYSMOD1 | SYSMOD0 |

Table 17. SYSMOD Description

|             |   |
|-------------|---|
| FGERR       | FIFO Gate Error. Default value: 0.<br>0: No FIFO Gate Error detected.<br>1: FIFO Gate Error was detected.<br>Emptying the FIFO buffer clears the FGERR bit in the SYS_MOD register.<br>See section <a href="#">0x2C: CTRL_REG3 Interrupt Control Register</a> for more information on configuring the FIFO Gate function. |
| FGT[4:0]    | Number of ODR time units since FGERR was asserted. Reset when FGERR Cleared. Default value: 0_0000  |
| SYSMOD[1:0] | System Mode. Default value: 00.<br>00: STANDBY mode<br>01: WAKE mode<br>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 de-asserted 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 | SRC_FIFO | SRC_TRANS | SRC_LNDPRT | SRC_PULSE | SRC_FF_MT | —     | SRC_DRDY |

Table 18. INT\_SOURCE Description

| INT_SOURCE | Description   |
|------------|---|
| SRC_ASLP   | Auto-SLEEP/WAKE interrupt status bit. Default value: 0.<br>Logic '1' indicates that an interrupt event that can cause a WAKE to SLEEP or SLEEP to WAKE system mode transition has occurred.<br>Logic '0' indicates that no WAKE to SLEEP or SLEEP to WAKE system mode transition interrupt event has occurred.<br><b>WAKE to SLEEP</b> 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.<br><b>SLEEP to WAKE</b> 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.<br>Reading the SYSMOD register clears the SRC_ASLP bit. |
| SRC_FIFO   | FIFO interrupt status bit. Default value: 0.<br>Logic '1' indicates that a FIFO interrupt event such as an overflow event or watermark has occurred. Logic '0' indicates that no FIFO interrupt event has occurred.<br>FIFO interrupt event generators: FIFO Overflow, or (Watermark: F_CNT = F_WMRK) and the interrupt has been enabled.<br>This bit is cleared by reading the F_STATUS register.  |
| SRC_TRANS  | Transient interrupt status bit. Default value: 0.<br>Logic '1' indicates that an acceleration transient value greater than user specified threshold has occurred. Logic '0' indicates that no transient event has occurred.<br>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.<br>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.<br>This bit is asserted whenever "NEWLP" bit in the PL_STATUS is asserted and the interrupt has been enabled.<br>This bit is cleared by reading the PL_STATUS register.  |
| SRC_PULSE  | Pulse interrupt status bit. Default value: 0.<br>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.<br>This bit is asserted whenever "EA" bit in the PULSE_SRC is asserted and the interrupt has been enabled.<br>This bit is cleared by reading the PULSE_SRC register.  |
| SRC_FF_MT  | Freefall/Motion interrupt status bit. Default value: 0.<br>Logic '1' indicates that the Freefall/Motion function interrupt is active. Logic '0' indicates that no Freefall or Motion event was detected.<br>This bit is asserted whenever "EA" bit in the FF_MT_SRC register is asserted and the FF_MT interrupt has been enabled.<br>This bit is cleared by reading the FF_MT_SRC register.  |
| SRC_DRDY   | Data Ready Interrupt bit status. Default value: 0.<br>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.<br>This bit is asserted when the ZYXOW and/or ZYXDR is set and the interrupt has been enabled.<br>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 0x1A. 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     | 0     | 1     | 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, both the FIFO and DATA registers will contain high pass filtered data.

#### 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 19. 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 20. 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 cut-off 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 cut-off options change based on the data rate selected as shown in [Table 22](#). 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 21. High Pass Filter Cut-off Register Descriptions**

|               |  |
|---------------|--|
| Pulse_HPF_BYP | Bypass High Pass Filter (HPF) for Pulse Processing Function.<br>0: HPF enabled for Pulse Processing, 1: HPF Bypassed for Pulse Processing<br>Default value: 0. |
| Pulse_LPF_EN  | Enable Low Pass Filter (LPF) for Pulse Processing Function.<br>0: LPF disabled for Pulse Processing, 1: LPF Enabled for Pulse Processing<br>Default value: 0.  |
| SEL[1:0]      | HPF Cut-off frequency selection.<br>Default value: 00 (see <a href="#">Table 22</a> ).   |

**Table 22. High Pass Filter Cut-off Options**

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| 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 |

### 6.3 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    | —     | —     | —     | LAPO[1] | LAPO[0] | BAFRO |

**Table 23. PL\_STATUS Register Description**

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

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### 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 | —     | —     | —     | —     | —     | —     |

**Table 24. PL\_CFG Description**

|        |  |
|--------|--|
| DBCNTM | Debounce counter mode selection. Default value: 1<br>0: Decrements debounce whenever condition of interest is no longer valid.<br>1: Clears counter whenever condition of interest is no longer valid. |
| PL_EN  | Portrait/Landscape Detection Enable. Default value: 0<br>0: Portrait/Landscape Detection is Disabled.<br>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 26 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 25. PL\_COUNT Description**

|            |   |
|------------|---|
| DBNCE[7:0] | Debounce Count value. Default value: 0000_0000. |
|------------|---|

**Table 26. 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 bits allow the user to adjust the Z-lockout region from 14° up to 43°. The default Z-lockout angle is set to the default value of 29° upon power up. The Back to Front trip angle is set by default to ±75° but this angle also can be adjusted from a range of 65° to 80° with 5° step increments.

### 0x13: PL\_BF\_ZCOMP Register (Read/Write)

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

**Table 27. PL\_BF\_ZCOMP Description**

|            |  |
|------------|--|
| BKFR[7:6]  | Back/Front Trip Angle Threshold. Default: <b>01</b> ≥ ±75°. Step size is 5°. Range: ±(65° to 80°).                                   |
| ZLOCK[2:0] | Z-Lock Angle Threshold. Range is from 14° to 43°. Step size is 4°. Default value: <b>100</b> ≥ 29°. Maximum value: <b>111</b> ≥ 43°. |

**Note:** All angles are accurate to ±2°.

**Table 28. Z-Lock Threshold Angles**

| Z-Lock Value | Threshold Angle |
|--------------|-----------------|
| 0x00         | 14°             |
| 0x01         | 18°             |
| 0x02         | 21°             |
| 0x03         | 25°             |
| 0x04         | 29°             |
| 0x05         | 33°             |
| 0x06         | 37°             |
| 0x07         | 42°             |

**Table 29. Back/Front Orientation Definition**

| BKFR | Back/Front Transition | Front/Back Transition |
|------|-----------------------|-----------------------|
| 00   | Z < 80° or Z > 280°   | Z > 100° and Z < 260° |
| 01   | Z < 75° or Z > 285°   | Z > 105° and Z < 255° |
| 10   | Z < 70° or Z > 290°   | Z > 110° and Z < 250° |
| 11   | Z < 65° or Z > 295°   | Z > 115° and Z < 245° |

**0x14: P\_L\_THS\_REG Portrait/Landscape Threshold and Hysteresis Register**

This register represents the Portrait to Landscape trip threshold register used to set the trip angle for transitioning from Portrait to Landscape and Landscape to Portrait. This register includes a value for the hysteresis.

**0x14: P\_L\_THS\_REG Register (Read/Write)**

| 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 30. P\_L\_THS\_REG Description**

|              |  |
|--------------|--|
| P_L_THS[7:3] | Portrait/Landscape trip threshold angle from 15° to 75°. See <a href="#">Table 31</a> for the values with the corresponding approximate threshold angle. Default value: 1_0000 (45°).    |
| HYS[2:0]     | This angle is added to the threshold angle for a smoother transition from Portrait to Landscape and Landscape to Portrait. This angle ranges from 0° to ±24°. The default is 100 (±14°). |

[Table 31](#) is a look-up table to set the threshold. This is the center value that will be set for the trip point from Portrait to Landscape and Landscape to Portrait. The default Trip Angle is 45° (0x10). The default hysteresis is ±14°.

**Note:** THS + HYS > 0 and THS + HYS < 32 for the Landscape/Portrait detection to work correctly. All angles are accurate to ±2°.

**Table 31. Threshold Angle Thresholds Look-up Table**

| Threshold Angle (approx.) | 5-bit Register value |
|---------------------------|----------------------|
| 15°                       | 0x07                 |
| 20°                       | 0x09                 |
| 30°                       | 0x0C                 |
| 35°                       | 0x0D                 |
| 40°                       | 0x0F                 |
| <b>45°</b>                | <b>0x10</b>          |
| 55°                       | 0x13                 |
| 60°                       | 0x14                 |
| 70°                       | 0x17                 |
| 75°                       | 0x19                 |

**Table 32. Trip Angles with Hysteresis for 45° Angle**

| Hysteresis Register Value | Hysteresis ± Angle Range | Landscape to Portrait Trip Angle | Portrait to Landscape Trip Angle |
|---------------------------|--------------------------|----------------------------------|----------------------------------|
| 0                         | ±0                       | 45°                              | 45°                              |
| 1                         | ±4                       | 49°                              | 41°                              |
| 2                         | ±7                       | 52°                              | 38°                              |
| 3                         | ±11                      | 56°                              | 34°                              |
| <b>4</b>                  | <b>±14</b>               | <b>59°</b>                       | <b>31°</b>                       |
| 5                         | ±17                      | 62°                              | 28°                              |
| 6                         | ±21                      | 66°                              | 24°                              |
| 7                         | ±24                      | 69°                              | 21°                              |

## 6.4 Motion and Freefall Embedded Function Registers

The freefall/motion condition 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.



## 0x15 FF\_MT\_CFG Freefall/Motion Configuration Register

This is the Freefall/Motion configuration register for setting up the conditions of the freefall or motion function.

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### 0x15 FF\_MT\_CFG Register (Read/Write)

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| ELE   | OAE   | ZEFE  | YEFE  | XEFE  | —     | —     | —     |

Table 33. FF\_MT\_CFG Description

|      |  |
|------|--|
| ELE  | Event Latch Enable: Event flags are latched into FF_MT_SRC register. Reading of the FF_MT_SRC register clears the event flag EA and all FF_MT_SRC bits. Default value: 0.<br>0: Event flag latch disabled; 1: event flag latch enabled |
| OAE  | Motion detect / Freefall detect flag selection. Default value: 0. (Freefall Flag)<br>0: Freefall Flag (Logical AND combination)<br>1: Motion Flag (Logical OR combination)   |
| ZEFE | Event flag enable on Z Default value: 0.<br>0: event detection disabled; 1: raise event flag on measured acceleration value beyond preset threshold  |
| YEFE | Event flag enable on Y event. Default value: 0.<br>0: Event detection disabled; 1: raise event flag on measured acceleration value beyond preset threshold   |
| XEFE | Event flag enable on X event. Default value: 0.<br>0: event detection disabled; 1: raise event flag on measured acceleration value beyond preset threshold   |

**OAE** bit allows the selection between Motion (logical OR combination) and Freefall (logical AND combination) detection.

**ELE** denotes whether the enabled event flag will to be latched in the FF\_MT\_SRC register or the event flag status in the FF\_MT\_SRC will indicate the real-time status of the event. If ELE bit is set to a logic '1', then the event flags are frozen when the EA bit gets set, and are cleared by reading the FF\_MT\_SRC source register.

**ZHFE, YEFE, XEFE** enable the detection of a motion or freefall event when the measured acceleration data on X, Y, Z channel is beyond the threshold set in FF\_MT\_THS register. If the ELE bit is set to logic '1' in the FF\_MT\_CFG register new event flags are blocked from updating the FF\_MT\_SRC register.

**FF\_MT\_THS** is the threshold register used to detect freefall motion events. The unsigned 7-bit **FF\_MT\_THS** threshold register holds the threshold for the freefall detection where the magnitude of the X and Y and Z acceleration values is lower or equal than the threshold value. Conversely, the **FF\_MT\_THS** also holds the threshold for the motion detection where the magnitude of the X or Y or Z acceleration value is higher than the threshold value.

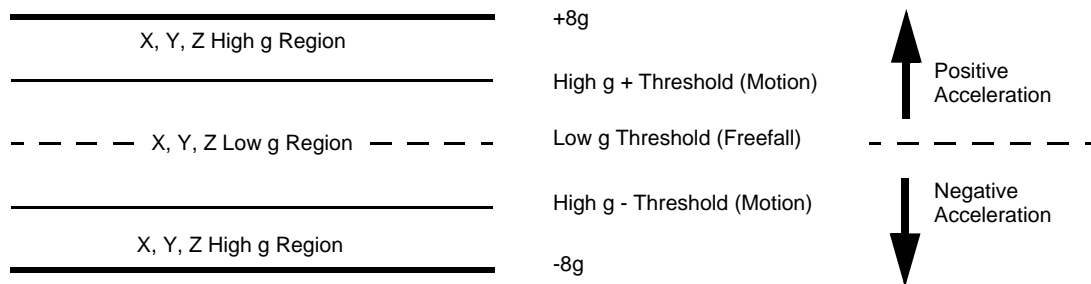


Figure 13. FF\_MT\_CFG High and Low g Level

## 0x16 FF\_MT\_SRC Freefall/Motion Source Register

### 0x16: FF\_MT\_SRC Freefall and Motion Source Register (Read Only)

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| EA    | —     | ZHE   | ZHP   | YHE   | YHP   | XHE   | XHP   |

**Table 34. Freefall/Motion Source Description**

|     |   |
|-----|---|
| EA  | Event Active Flag. Default value: 0.<br>0: No event flag has been asserted; 1: one or more event flag has been asserted.<br>See the description of the OAE bit to determine the effect of the 3-axis event flags on the EA bit. |
| ZHE | Z Motion Flag. Default value: 0.<br>0: No Z Motion event detected, 1: Z Motion has been detected<br>This bit reads always zero if the ZEFE control bit is set to zero   |
| ZHP | Z Motion Polarity Flag. Default value: 0.<br>0: Z event was Positive g, 1: Z event was Negative g<br>This bit read always zero if the ZEFE control bit is set to zero   |
| YHE | Y Motion Flag. Default value: 0.<br>0: No Y Motion event detected, 1: Y Motion has been detected<br>This bit read always zero if the YEFE control bit is set to zero  |
| YHP | Y Motion Polarity Flag. Default value: 0<br>0: Y event detected was Positive g, 1: Y event was Negative g<br>This bit reads always zero if the YEFE control bit is set to zero  |
| XHE | X Motion Flag. Default value: 0<br>0: No X Motion event detected, 1: X Motion has been detected<br>This bit reads always zero if the XEFE control bit is set to zero  |
| XHP | X Motion Polarity Flag. Default value: 0<br>0: X event was Positive g, 1: X event was Negative g<br>This bit reads always zero if the XEFE control bit is set to zero   |

This register keeps track of the acceleration event which is triggering (or has triggered, in case of ELE bit in FF\_MT\_CFG register being set to 1) the event flag. In particular EA is set to a logic '1' when the logical combination of acceleration events flags specified in FF\_MT\_CFG register is true. This bit is used in combination with the values in INT\_EN\_FF\_MT and INT\_CFG\_FF\_MT register bits to generate the freefall/motion interrupts.

An X,Y, or Z motion is true when the acceleration value of the X or Y or Z channel is higher than the preset threshold value defined in the FF\_MT\_THS register.

Conversely an X, Y, and Z low event is true when the acceleration value of the X and Y and Z channel is lower than or equal to the preset threshold value defined in the FF\_MT\_THS register.

**0x17: FF\_MT\_THS Freefall and Motion Threshold Register**

**0x17 FF\_MT\_THS Register (Read/Write)**

| Bit 7  | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|--------|-------|-------|-------|-------|-------|-------|-------|
| DBCNTM | THS6  | THS5  | THS4  | THS3  | THS2  | THS1  | THS0  |

**Table 35. FF\_MT\_THS Description**

|          |  |
|----------|--|
| DBCNTM   | Debounce counter mode selection. Default value: 0.<br>0: increments or decrements debounce, 1: increments or clears counter. |
| THS[6:0] | Freefall /Motion Threshold: Default value: 000_0000.   |

The threshold resolution is 0.063g/LSB and the threshold register has a range of 0 to 127 counts. The maximum range is to 8g. Note that even when the full scale value is set to 2g or 4g the motion detects up to 8g. If the Low Noise bit is set in Register 0x2A then the maximum threshold will be limited to 4g regardless of the full scale range.

DBCNTM bit configures the way in which the debounce counter is reset when the inertial event of interest is momentarily not true.

When DBCNTM bit is a logic '1', the debounce counter is cleared to 0 whenever the inertial event of interest is no longer true as shown in Figure 14, (b). While the DBCNTM bit is set to logic '0' the debounce counter is decremented by 1 whenever the inertial event of interest is no longer true (Figure 14, (c)) until the debounce counter reaches 0 or the inertial event of interest becomes active.

Decrementing the debounce counter acts as a median enabling the system to filter out irregular spurious events which might impede the detection of inertial events.

### 0x18 FF\_MT\_COUNT Debounce Register

This register sets the number of debounce sample counts for the event trigger.

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#### 0x18 FF\_MT\_COUNT\_Register (Read/Write)

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| D7    | D6    | D5    | D4    | D3    | D2    | D1    | D0    |

Table 36. FF\_MT\_COUNT Description

|        |                                       |
|--------|---------------------------------------|
| D[7:0] | Count value. Default value: 0000_0000 |
|--------|---------------------------------------|

This register sets the minimum number of debounce sample counts of continuously matching the detection condition user selected for the freefall, motion event.

When the internal debounce counter reaches the FF\_MT\_COUNT value a Freefall/Motion event flag is set. The debounce counter will never increase beyond the FF\_MT\_COUNT value. Time step used for the debounce sample count depends on the ODR chosen and the Oversampling mode as shown in Table 37.

Table 37. FF\_MT\_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  |

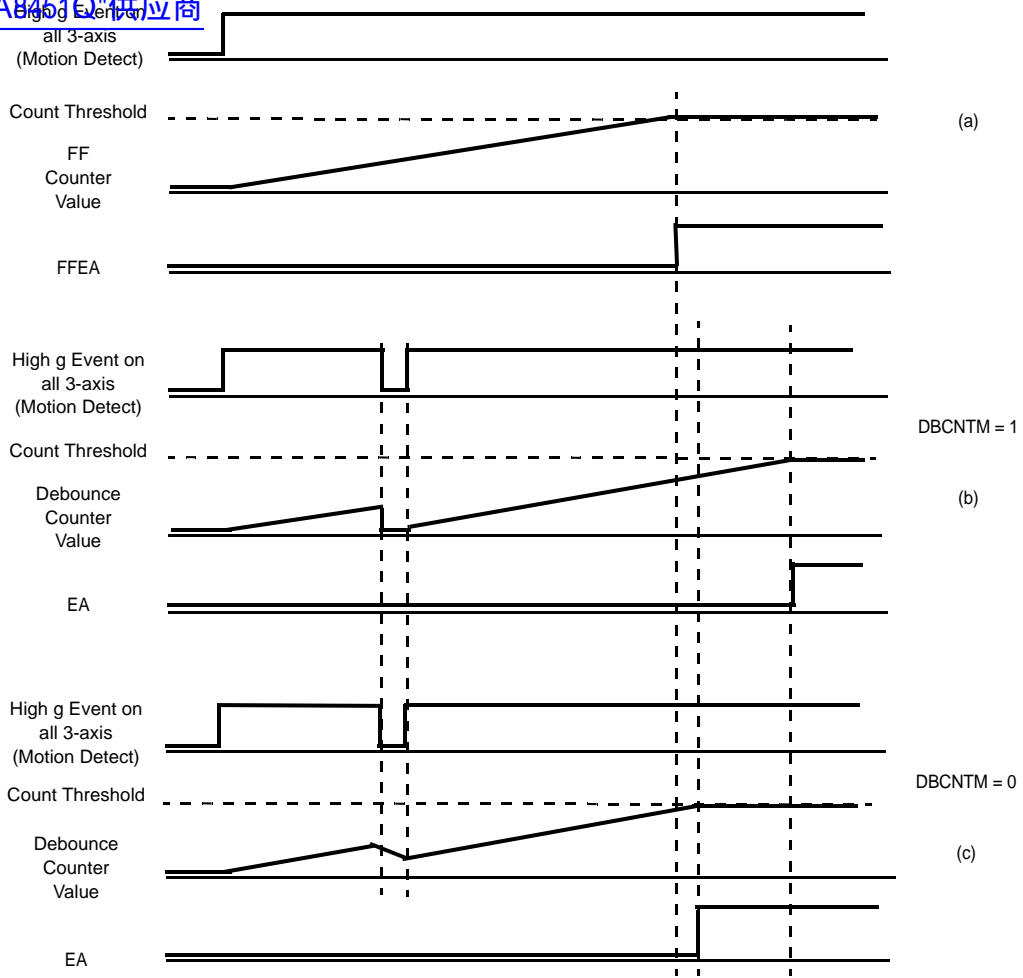


Figure 14. DBCNTM Bit Function

## 6.5 Transient (HPF) Acceleration Detection

For more information on the uses of the transient function please review application note AN4071. This function is similar to the motion detection except that high pass filtered data is compared. There is an option to disable the high pass filter through the function. In this case the behavior is the same as the motion detection. This allows for the device to have 2 motion detection functions.

### 0x1D: Transient\_CFG Register

The transient detection mechanism can be configured to raise an interrupt when the magnitude of the high pass filtered acceleration threshold is exceeded. The TRANSIENT\_CFG register is used to enable the transient interrupt generation mechanism for the 3 axes (X, Y, Z) of acceleration. There is also an option to bypass the high pass filter. When the high pass filter is bypassed, the function behaves similar to the motion detection.

#### 0x1D TRANSIENT\_CFG Register (Read/Write)

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0   |
|-------|-------|-------|-------|-------|-------|-------|---------|
| —     | —     | —     | ELE   | ZTEFE | YTEFE | XTEFE | HPF_BYP |

**Table 38. TRANSIENT\_CFG Description**

|         |  |
|---------|--|
| ELE     | Transient event flags are latched into the TRANSIENT_SRC register. Reading of the TRANSIENT_SRC register clears the event flag. Default value: 0.<br>0: Event flag latch disabled; 1: Event flag latch enabled                     |
| ZTEFE   | Event flag enable on Z transient acceleration greater than transient threshold event. Default value: 0.<br>0: Event detection disabled; 1: Raise event flag on measured acceleration delta value greater than transient threshold. |
| YTEFE   | Event flag enable on Y transient acceleration greater than transient threshold event. Default value: 0.<br>0: Event detection disabled; 1: Raise event flag on measured acceleration delta value greater than transient threshold. |
| XTEFE   | Event flag enable on X transient acceleration greater than transient threshold event. Default value: 0.<br>0: Event detection disabled; 1: Raise event flag on measured acceleration delta value greater than transient threshold. |
| HPF_BYP | Bypass High Pass filter Default value: 0.<br>0: Data to transient acceleration detection block is through HPF 1: Data to transient acceleration detection block is NOT through HPF (similar to motion detection function)          |

### 0x1E TRANSIENT\_SRC Register

The Transient Source register provides the status of the enabled axes and the polarity (directional) information. When this register is read it clears the interrupt for the transient detection. When new events arrive while EA = 1, additional \*TRANSE bits may get set, and the corresponding \*\_Trans\_Pol flag become updated. However no \*TRANSE bit may get cleared before the TRANSIENT\_SRC register is read.

#### 0x1E TRANSIENT\_SRC Register (Read Only)

| Bit 7 | Bit 6 | Bit 5   | Bit 4       | Bit 3   | Bit 2       | Bit 1   | Bit 0       |
|-------|-------|---------|-------------|---------|-------------|---------|-------------|
| —     | EA    | ZTRANSE | Z_Trans_Pol | YTRANSE | Y_Trans_Pol | XTRANSE | X_Trans_Pol |

**Table 39. TRANSIENT\_SRC Description**

|             |   |
|-------------|---|
| EA          | Event Active Flag. Default value: 0.<br>0: no event flag has been asserted; 1: one or more event flag has been asserted.                        |
| ZTRANSE     | Z transient event. Default value: 0.<br>0: no interrupt, 1: Z Transient acceleration greater than the value of TRANSIENT_THS event has occurred |
| Z_Trans_Pol | Polarity of Z Transient Event that triggered interrupt. Default value: 0.<br>0: Z event was Positive g, 1: Z event was Negative g               |
| YTRANSE     | Y transient event. Default value: 0.<br>0: no interrupt, 1: Y Transient acceleration greater than the value of TRANSIENT_THS event has occurred |
| Y_Trans_Pol | Polarity of Y Transient Event that triggered interrupt. Default value: 0.<br>0: Y event was Positive g, 1: Y event was Negative g               |
| XTRANSE     | X transient event. Default value: 0.<br>0: no interrupt, 1: X Transient acceleration greater than the value of TRANSIENT_THS event has occurred |
| X_Trans_Pol | Polarity of X Transient Event that triggered interrupt. Default value: 0.<br>0: X event was Positive g, 1: X event was Negative g               |

When the EA bit gets set while ELE = 1, all other status bits get frozen at their current state. By reading the TRANSIENT\_SRC register, all bits get cleared.

### 0x1F TRANSIENT\_THS Register

The Transient Threshold register sets the threshold limit for the detection of the transient acceleration. The value in the TRANSIENT\_THS register corresponds to a g value which is compared against the values of High Pass Filtered Data. If the High Pass Filtered acceleration value exceeds the threshold limit an event flag is raised and the interrupt is generated if enabled.

#### 0x1F TRANSIENT\_THS Register (Read/Write)

| Bit 7  | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|--------|-------|-------|-------|-------|-------|-------|-------|
| DBCNTM | THS6  | THS5  | THS4  | THS3  | THS2  | THS1  | THS0  |

**Table 40. TRANSIENT\_THS Description**

|          |   |
|----------|---|
| DBCNTM   | Debounce counter mode selection. Default value: 0. 0: increments or decrements debounce; 1: increments or clears counter. |
| THS[6:0] | Transient Threshold: Default value: 000_0000.   |

The threshold THS[6:0] is a 7-bit unsigned number, 0.063g/LSB. The maximum threshold is 8g. Even if the part is set to full scale at 2g or 4g this function will still operate up to 8g. If the Low Noise bit is set in Register 0x2A the maximum threshold to be reached is 4g.

### 0x20 TRANSIENT\_COUNT

The TRANSIENT\_COUNT sets the minimum number of debounce counts continuously matching the condition where the unsigned value of high pass filtered data is greater than the user specified value of TRANSIENT\_THS.

#### 0x20 TRANSIENT\_COUNT Register (Read/Write)

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| D7    | D6    | D5    | D4    | D3    | D2    | D1    | D0    |

**Table 41. TRANSIENT\_COUNT Description**

|        |  |
|--------|--|
| D[7:0] | Count value. Default value: 0000_0000. |
|--------|--|

The time step for the transient detection debounce counter is set by the value of the system ODR and the Oversampling mode.

**Table 42. TRANSIENT\_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  |

## 6.6 Single, Double and Directional Tap Detection Registers

For more details of how to configure the tap detection and sample code please refer to Freescale application note, AN4072. The tap detection registers are referred to as "Pulse".

### 0x21: PULSE\_CFG Pulse Configuration Register

This register configures the event flag for the tap detection for enabling/disabling the detection of a single and double pulse on each of the axes.

#### 0x21 PULSE\_CFG Register (Read/Write)

| Bit 7 | Bit 6 | Bit 5  | Bit 4  | Bit 3  | Bit 2  | Bit 1  | Bit 0  |
|-------|-------|--------|--------|--------|--------|--------|--------|
| DPA   | ELE   | ZDPEFE | ZSPEFE | YDPEFE | YSPEFE | XDPEFE | XSPEFE |

**Table 43. PULSE\_CFG Description**

|        |   |
|--------|---|
| DPA    | Double Pulse Abort. Default value: 0.<br>0: Double Pulse detection is not aborted if the start of a pulse is detected during the time period specified by the PULSE_LTCY register.<br>1: Setting the DPA bit momentarily suspends the double tap detection if the start of a pulse is detected during the time period specified by the PULSE_LTCY register and the pulse ends before the end of the time period specified by the PULSE_LTCY register. |
| ELE    | Pulse event flags are latched into the PULSE_SRC register. Reading of the PULSE_SRC register clears the event flag.<br>Default value: 0.<br>0: Event flag latch disabled; 1: Event flag latch enabled   |
| ZDPEFE | Event flag enable on double pulse event on Z-axis. Default value: 0.<br>0: Event detection disabled; 1: Event detection enabled   |
| ZSPEFE | Event flag enable on single pulse event on Z-axis. Default value: 0.<br>0: Event detection disabled; 1: Event detection enabled   |
| YDPEFE | Event flag enable on double pulse event on Y-axis. Default value: 0.<br>0: Event detection disabled; 1: Event detection enabled   |
| YSPEFE | Event flag enable on single pulse event on Y-axis. Default value: 0.<br>0: Event detection disabled; 1: Event detection enabled   |
| XDPEFE | Event flag enable on double pulse event on X-axis. Default value: 0.<br>0: Event detection disabled; 1: Event detection enabled   |
| XSPEFE | Event flag enable on single pulse event on X-axis. Default value: 0.<br>0: Event detection disabled; 1: Event detection enabled   |

### 0x22: PULSE\_SRC Pulse Source Register

This register indicates a double or single pulse event has occurred and also which direction. The corresponding axis and event must be enabled in Register 0x21 for the event to be seen in the source register.

#### 0x22 PULSE\_SRC Register (Read Only)

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| EA    | AxZ   | AxY   | AxX   | DPE   | PolZ  | PolY  | PolX  |

**Table 44. PULSE\_SRC Description**

|      |   |
|------|---|
| EA   | Event Active Flag. Default value: 0.<br>(0: No interrupt has been generated; 1: One or more interrupt events have been generated)                                 |
| AxZ  | Z-axis event. Default value: 0.<br>(0: No interrupt; 1: Z-axis event has occurred)  |
| AxY  | Y-axis event. Default value: 0.<br>(0: No interrupt; 1: Y-axis event has occurred)  |
| AxX  | X-axis event. Default value: 0.<br>(0: No interrupt; 1: X-axis event has occurred)  |
| DPE  | Double pulse on first event. Default value: 0.<br>(0: Single Pulse Event triggered interrupt; 1: Double Pulse Event triggered interrupt)                          |
| PolZ | Pulse polarity of Z-axis Event. Default value: 0.<br>(0: Pulse Event that triggered interrupt was Positive; 1: Pulse Event that triggered interrupt was negative) |
| PolY | Pulse polarity of Y-axis Event. Default value: 0.<br>(0: Pulse Event that triggered interrupt was Positive; 1: Pulse Event that triggered interrupt was negative) |
| PolX | Pulse polarity of X-axis Event. Default value: 0.<br>(0: Pulse Event that triggered interrupt was Positive; 1: Pulse Event that triggered interrupt was negative) |

When the EA bit gets set while ELE = 1, all status bits (AxZ, AxY, AxZ, DPE, and PolX, PolY, PolZ) are frozen. Reading the PULSE\_SRC register clears all bits. Reading the source register will clear the interrupt.

### 0x23 - 0x25: PULSE\_THSX, Y, Z Pulse Threshold for X, Y & Z Registers

The pulse threshold can be set separately for the X, Y and Z axes. The PULSE\_THSX, PULSE\_THSY and PULSE\_THSZ registers define the threshold which is used by the system to start the pulse detection procedure.

#### 0x23 PULSE\_THSX Register (Read/Write)

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| 0     | THSX6 | THSX5 | THSX4 | THSX3 | THSX2 | THSX1 | THSX0 |

**Table 45. PULSE\_THSX Description**

|           |   |
|-----------|---|
| THSX[6:0] | Pulse Threshold on X-axis. Default value: 000_0000. |
|-----------|---|

#### 0x24 PULSE\_THSY Register (Read/Write)

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| 0     | THSY6 | THSY5 | THSY4 | THSY3 | THSY2 | THSY1 | THSY0 |

**Table 46. PULSE\_THSY Description**

|           |   |
|-----------|---|
| THSY[6:0] | Pulse Threshold on Y-axis. Default value: 000_0000. |
|-----------|---|

#### 0x25 PULSE\_THSZ Register (Read/Write)

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| 0     | THSZ6 | THSZ5 | THSZ4 | THSZ3 | THSZ2 | THSZ1 | THSZ0 |

**Table 47. PULSE\_THSZ Description**

|           |   |
|-----------|---|
| THSZ[6:0] | Pulse Threshold on Z-axis. Default value: 000_0000. |
|-----------|---|

The threshold values range from 1 to 127 with steps of 0.63g/LSB at a fixed 8g acceleration range, thus the minimum resolution is always fixed at 0.063g/LSB. If the Low Noise bit in Register 0x2A is set then the maximum threshold will be 4g. The PULSE\_THSX, PULSE\_THSY and PULSE\_THSZ registers define the threshold which is used by the system to start the pulse detection procedure. The threshold value is expressed over 7-bits as an unsigned number.

### 0x26: PULSE\_TMLT Pulse Time Window 1 Register

#### 0x26 PULSE\_TMLT Register (Read/Write)

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| TMLT7 | TMLT6 | TMLT5 | TMLT4 | TMLT3 | TMLT2 | TMLT1 | TMLT0 |

**Table 48. PULSE\_TMLT Description**

|           |   |
|-----------|---|
| TMLT[7:0] | Pulse Time Limit. Default value: 0000_0000. |
|-----------|---|

The bits TMLT7 through TMLT0 define the maximum time interval that can elapse between the start of the acceleration on the selected axis exceeding the specified threshold and the end when the acceleration on the selected axis must go below the specified threshold to be considered a valid pulse.

The minimum time step for the pulse time limit is defined in [Table 49](#) and [Table 50](#). Maximum time for a given ODR and Oversampling mode is the time step pulse multiplied by 255. The time steps available are dependent on the Oversampling mode and whether the Pulse Low Pass Filter option is enabled or not. The Pulse Low Pass Filter is set in Register 0x0F.

**Table 49. Time Step for PULSE Time Limit (Reg 0x0F) Pulse\_LPF\_EN = 1**

| 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  |



Table 50. Time Step for PULSE Time Limit (Reg 0x0F) Pulse\_LPF\_EN = 0

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| ODR (Hz) | Max Time Range (s) |       |         |       | Time Step (ms) |       |         |       |
|----------|--------------------|-------|---------|-------|----------------|-------|---------|-------|
|          | Normal             | LPLN  | HighRes | LP    | Normal         | LPLN  | HighRes | LP    |
| 800      | 0.159              | 0.159 | 0.159   | 0.159 | 0.625          | 0.625 | 0.625   | 0.625 |
| 400      | 0.159              | 0.159 | 0.159   | 0.319 | 0.625          | 0.625 | 0.625   | 1.25  |
| 200      | 0.319              | 0.319 | 0.159   | 0.638 | 1.25           | 1.25  | 0.625   | 2.5   |
| 100      | 0.638              | 0.638 | 0.159   | 1.28  | 2.5            | 2.5   | 0.625   | 5     |
| 50       | 1.28               | 1.28  | 0.159   | 2.55  | 5              | 5     | 0.625   | 10    |
| 12.5     | 1.28               | 5.1   | 0.159   | 10.2  | 5              | 20    | 0.625   | 40    |
| 6.25     | 1.28               | 5.1   | 0.159   | 10.2  | 5              | 20    | 0.625   | 40    |
| 1.56     | 1.28               | 5.1   | 0.159   | 10.2  | 5              | 20    | 0.625   | 40    |

0x27: PULSE\_LTCY Pulse Latency Timer Register

0x27 PULSE\_LTCY Register (Read/Write)

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| LTCY7 | LTCY6 | LTCY5 | LTCY4 | LTCY3 | LTCY2 | LTCY1 | LTCY0 |

Table 51. PULSE\_LTCY Description

|           |  |
|-----------|--|
| LTCY[7:0] | Latency Time Limit. Default value: 0000_0000 |
|-----------|--|

The bits LTCY7 through LTCY0 define the time interval that starts after the first pulse detection. During this time interval, all pulses are ignored. **Note:** This timer must be set for single pulse and for double pulse.

The minimum time step for the pulse latency is defined in Table 52 and Table 53. The maximum time is the time step at the ODR and Oversampling mode multiplied by 255. The timing also changes when the Pulse LPF is enabled or disabled.

Table 52. Time Step for PULSE Latency @ ODR and Power Mode (Reg 0x0F) Pulse\_LPF\_EN = 1

| ODR (Hz) | Max Time Range (s) |       |         |       | Time Step (ms) |      |         |     |
|----------|--------------------|-------|---------|-------|----------------|------|---------|-----|
|          | Normal             | LPLN  | HighRes | LP    | Normal         | LPLN | HighRes | LP  |
| 800      | 0.638              | 0.638 | 0.638   | 0.638 | 2.5            | 2.5  | 2.5     | 2.5 |
| 400      | 1.276              | 1.276 | 1.276   | 1.276 | 5              | 5    | 5       | 5   |
| 200      | 2.56               | 2.56  | 1.276   | 2.56  | 10             | 10   | 5       | 10  |
| 100      | 5.1                | 5.1   | 1.276   | 5.1   | 20             | 20   | 5       | 20  |
| 50       | 10.2               | 10.2  | 1.276   | 10.2  | 40             | 40   | 5       | 40  |
| 12.5     | 10.2               | 40.8  | 1.276   | 40.8  | 40             | 160  | 5       | 160 |
| 6.25     | 10.2               | 40.8  | 1.276   | 81.6  | 40             | 160  | 5       | 320 |
| 1.56     | 10.2               | 40.8  | 1.276   | 81.6  | 40             | 160  | 5       | 320 |

Table 53. Time Step for PULSE Latency @ ODR and Power Mode (Reg 0x0F) Pulse\_LPF\_EN = 0

| ODR (Hz) | Max Time Range (s) |       |         |       | Time Step (ms) |      |         |      |
|----------|--------------------|-------|---------|-------|----------------|------|---------|------|
|          | Normal             | LPLN  | HighRes | LP    | Normal         | LPLN | HighRes | LP   |
| 800      | 0.318              | 0.318 | 0.318   | 0.318 | 1.25           | 1.25 | 1.25    | 1.25 |
| 400      | 0.318              | 0.318 | 0.318   | 0.638 | 1.25           | 1.25 | 1.25    | 2.5  |
| 200      | 0.638              | 0.638 | 0.318   | 1.276 | 2.5            | 2.5  | 1.25    | 5    |
| 100      | 1.276              | 1.276 | 0.318   | 2.56  | 5              | 5    | 1.25    | 10   |
| 50       | 2.56               | 2.56  | 0.318   | 5.1   | 10             | 10   | 1.25    | 20   |
| 12.5     | 2.56               | 10.2  | 0.318   | 20.4  | 10             | 40   | 1.25    | 80   |
| 6.25     | 2.56               | 10.2  | 0.318   | 20.4  | 10             | 40   | 1.25    | 80   |
| 1.56     | 2.56               | 10.2  | 0.318   | 20.4  | 10             | 40   | 1.25    | 80   |

## 0x28 PULSE\_WIND Register (Read/Write)

### 0x28 PULSE\_WIND Second Pulse Time Window Register

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| WIND7 | WIND6 | WIND5 | WIND4 | WIND3 | WIND2 | WIND1 | WIND0 |

**Table 54. PULSE\_WIND Description**

|           |   |
|-----------|---|
| WIND[7:0] | Second Pulse Time Window. Default value: 0000_0000. |
|-----------|---|

The bits WIND7 through WIND0 define the maximum interval of time that can elapse after the end of the latency interval in which the start of the second pulse event must be detected provided the device has been configured for double pulse detection. The detected second pulse width must be shorter than the time limit constraints specified by the PULSE\_TMLT register, but the end of the double pulse need not finish within the time specified by the PULSE\_WIND register.

The minimum time step for the pulse window is defined in Table 55 and Table 56. The maximum time is the time step at the ODR, Oversampling mode and LPF Filter Option multiplied by 255.

**Table 55. Time Step for PULSE Detection Window @ ODR and Power Mode (Reg 0x0F) Pulse\_LPF\_EN = 1**

| ODR (Hz) | Max Time Range (s) |       |         |       | Time Step (ms) |      |         |     |
|----------|--------------------|-------|---------|-------|----------------|------|---------|-----|
|          | Normal             | LPLN  | HighRes | LP    | Normal         | LPLN | HighRes | LP  |
| 800      | 0.638              | 0.638 | 0.638   | 0.638 | 2.5            | 2.5  | 2.5     | 2.5 |
| 400      | 1.276              | 1.276 | 1.276   | 1.276 | 5              | 5    | 5       | 5   |
| 200      | 2.56               | 2.56  | 1.276   | 2.56  | 10             | 10   | 5       | 10  |
| 100      | 5.1                | 5.1   | 1.276   | 5.1   | 20             | 20   | 5       | 20  |
| 50       | 10.2               | 10.2  | 1.276   | 10.2  | 40             | 40   | 5       | 40  |
| 12.5     | 10.2               | 40.8  | 1.276   | 40.8  | 40             | 160  | 5       | 160 |
| 6.25     | 10.2               | 40.8  | 1.276   | 81.6  | 40             | 160  | 5       | 320 |
| 1.56     | 10.2               | 40.8  | 1.276   | 81.6  | 40             | 160  | 5       | 320 |

**Table 56. Time Step for PULSE Detection Window @ ODR and Power Mode (Reg 0x0F) Pulse\_LPF\_EN = 0**

| ODR (Hz) | Max Time Range (s) |       |         |       | Time Step (ms) |      |         |      |
|----------|--------------------|-------|---------|-------|----------------|------|---------|------|
|          | Normal             | LPLN  | HighRes | LP    | Normal         | LPLN | HighRes | LP   |
| 800      | 0.318              | 0.318 | 0.318   | 0.318 | 1.25           | 1.25 | 1.25    | 1.25 |
| 400      | 0.318              | 0.318 | 0.318   | 0.638 | 1.25           | 1.25 | 1.25    | 2.5  |
| 200      | 0.638              | 0.638 | 0.318   | 1.276 | 2.5            | 2.5  | 1.25    | 5    |
| 100      | 1.276              | 1.276 | 0.318   | 2.56  | 5              | 5    | 1.25    | 10   |
| 50       | 2.56               | 2.56  | 0.318   | 5.1   | 10             | 10   | 1.25    | 20   |
| 12.5     | 2.56               | 10.2  | 0.318   | 20.4  | 10             | 40   | 1.25    | 80   |
| 6.25     | 2.56               | 10.2  | 0.318   | 20.4  | 10             | 40   | 1.25    | 80   |
| 1.56     | 2.56               | 10.2  | 0.318   | 20.4  | 10             | 40   | 1.25    | 80   |

## 6.7 Auto-WAKE/SLEEP Detection

The ASLP\_COUNT register sets the minimum time period of inactivity required to change current ODR value from the value specified in the DR[2:0] register to ASLP\_RATE register value, provided the SLPE bit is set to a logic '1' in the CTRL\_REG2 register. See Table 52 for functional blocks that may be monitored for inactivity in order to trigger the "return to SLEEP" event.

### 0x29 ASLP\_COUNT Register (Read/Write)

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| D7    | D6    | D5    | D4    | D3    | D2    | D1    | D0    |

Table 57. ASLP\_COUNT Description

|        |   |
|--------|---|
| D[7:0] | Duration value. Default value: 0000_0000. |
|--------|---|

D7-D0 defines the minimum duration time to change current ODR value from DR to ASLP\_RATE. Time step and maximum value depend on the ODR chosen as shown in Table 58.

Table 58. ASLP\_COUNT Relationship with ODR

| Output Data Rate (ODR) | Duration  | ODR Time Step | ASLP_COUNT Step |
|------------------------|-----------|---------------|-----------------|
| 800 Hz                 | 0 to 81s  | 1.25 ms       | 320 ms          |
| 400 Hz                 | 0 to 81s  | 2.5 ms        | 320 ms          |
| 200 Hz                 | 0 to 81s  | 5 ms          | 320 ms          |
| 100 Hz                 | 0 to 81s  | 10 ms         | 320 ms          |
| 50 Hz                  | 0 to 81s  | 20 ms         | 320 ms          |
| 12.5 Hz                | 0 to 81s  | 80 ms         | 320 ms          |
| 6.25 Hz                | 0 to 81s  | 160 ms        | 320 ms          |
| 1.56 Hz                | 0 to 162s | 640 ms        | 640 ms          |

Table 59. SLEEP/WAKE Mode Gates and Triggers

| Interrupt Source | Event restarts timer and delays Return to SLEEP | Event will WAKE from SLEEP |
|------------------|---|----------------------------|
| FIFO_GATE        | Yes   | No                         |
| SRC_TRANS        | Yes   | Yes                        |
| SRC_LNDPRT       | Yes   | Yes                        |
| SRC_PULSE        | Yes   | Yes                        |
| SRC_FF_MT        | Yes   | Yes                        |
| SRC_ASLP         | No*   | No*                        |
| SRC_DRDY         | No  | No                         |

\* If the FIFO\_GATE bit is set to logic '1', the assertion of the SRC\_ASLP interrupt does not prevent the system from transitioning to SLEEP or from WAKE mode; instead it prevents the FIFO buffer from accepting new sample data until the host application flushes the FIFO buffer.

In order to wake the device, the desired function or functions must be enabled in CTRL\_REG4 and set to WAKE to SLEEP in CTRL\_REG3. All enabled functions will still function in SLEEP mode at the SLEEP ODR. Only the functions that have been selected for WAKE from SLEEP will **WAKE** the device.

MMA8451Q has 4 functions that can be used to keep the sensor from falling asleep namely, Transient, Orientation, Tap and Motion/Freefall. One or more of these functions can be enabled. In order to WAKE the device, 4 functions are provided namely, Transient, Orientation, Tap, and the Motion/Freefall. Note that the FIFO does not WAKE the device. The Auto-WAKE/SLEEP interrupt does not affect the WAKE/SLEEP, nor does the data ready interrupt. The FIFO gate (bit 7) in Register 0x2C, when set, will hold the last data in the FIFO before transitioning to a different ODR. After the buffer is flushed, it will accept new sample data at the current ODR. See Register 0x2C for the WAKE from SLEEP bits.

If the Auto-SLEEP bit is disabled, then the device can only toggle between STANDBY and WAKE mode. If Auto-SLEEP interrupt is enabled, transitioning from ACTIVE mode to Auto-SLEEP mode and vice versa generates an interrupt.

## 6.8 Control Registers

**Note:** Except for STANDBY mode selection, the device must be in STANDBY mode to change any of the fields within CTRL\_REG1 (0x2A).

### 0x2A: CTRL\_REG1 System Control 1 Register

#### 0x2A CTRL\_REG1 Register (Read/Write)

| Bit 7      | Bit 6      | Bit 5 | Bit 4 | Bit 3 | Bit 2  | Bit 1  | Bit 0  |
|------------|------------|-------|-------|-------|--------|--------|--------|
| ASLP_RATE1 | ASLP_RATE0 | DR2   | DR1   | DR0   | LNOISE | F_READ | ACTIVE |

**Table 60. CTRL\_REG1 Description**

|                |   |
|----------------|---|
| ASLP_RATE[1:0] | Configures the Auto-WAKE sample frequency when the device is in SLEEP Mode. Default value: 00. See Table 61 for more information. |
| DR[2:0]        | Data rate selection. Default value: 000. See Table 62 for more information.   |
| LNOISE         | Reduced noise reduced Maximum range mode. Default value: 0. (0: Normal mode; 1: Reduced Noise mode)                               |
| F_READ         | Fast Read mode: Data format limited to single Byte Default value: 0. (0: Normal mode 1: Fast Read Mode)                           |
| ACTIVE         | Full Scale selection. Default value: 00. (0: STANDBY mode; 1: ACTIVE mode)  |

**Table 61. SLEEP Mode Rate Description**

| ASLP_RATE1 | ASLP_RATE0 | Frequency (Hz) |
|------------|------------|----------------|
| 0          | 0          | 50             |
| 0          | 1          | 12.5           |
| 1          | 0          | 6.25           |
| 1          | 1          | 1.56           |

It is important to note that when the device is Auto-SLEEP mode, the system ODR and the data rate for all the system functional blocks are overridden by the data rate set by the **ASLP\_RATE** field.

**DR[2:0]** bits select the Output Data Rate (ODR) for acceleration samples. The default value is **000 for a data rate of 800 Hz**.

**Table 62. System Output Data Rate Selection**

| DR2 | DR1 | DR0 | ODR     | Period  |
|-----|-----|-----|---------|---------|
| 0   | 0   | 0   | 800 Hz  | 1.25 ms |
| 0   | 0   | 1   | 400 Hz  | 2.5 ms  |
| 0   | 1   | 0   | 200 Hz  | 5 ms    |
| 0   | 1   | 1   | 100 Hz  | 10 ms   |
| 1   | 0   | 0   | 50 Hz   | 20 ms   |
| 1   | 0   | 1   | 12.5 Hz | 80 ms   |
| 1   | 1   | 0   | 6.25 Hz | 160 ms  |
| 1   | 1   | 1   | 1.56 Hz | 640 ms  |

**ACTIVE** bit selects between STANDBY mode and ACTIVE mode. The default value is 0 for STANDBY mode.

**Table 63. Full Scale Selection**

| Active | Mode    |
|--------|---------|
| 0      | STANDBY |
| 1      | ACTIVE  |

**LNoise** bit selects between normal full dynamic range mode and a high sensitivity, Low Noise mode. In Low Noise mode the maximum signal that can be measured is  $\pm 4g$ . **Note:** Any thresholds set above 4g will not be reached.

**F\_Read** bit selects between normal and Fast Read mode. When selected, the auto increment counter will skip over the LSB data bytes. Data read from the FIFO will skip over the LSB data, reducing the acquisition time. Note F\_READ can only be changed when FMODE = 00. The F\_READ bit applies for both the output registers and the FIFO.

## 0x2B: CTRL\_REG2 System Control 2 Register

0x2B CTRL\_REG2 Register (Read/Write)

| Bit 7 | Bit 6 | Bit 5 | Bit 4  | Bit 3  | Bit 2 | Bit 1 | Bit 0 |
|-------|-------|-------|--------|--------|-------|-------|-------|
| ST    | RST   | 0     | SMODS1 | SMODS0 | SLPE  | MODS1 | MODS0 |

**Table 64. CTRL\_REG2 Description**

|            |   |
|------------|---|
| ST         | Self-Test Enable. Default value: 0.<br>0: Self-Test disabled; 1: Self-Test enabled                                  |
| RST        | Software Reset. Default value: 0.<br>0: Device reset disabled; 1: Device reset enabled.                             |
| SMODS[1:0] | SLEEP mode power scheme selection. Default value: 00.<br>See <a href="#">Table 65</a> and <a href="#">Table 66</a>  |
| SLPE       | Auto-SLEEP enable. Default value: 0.<br>0: Auto-SLEEP is not enabled;<br>1: Auto-SLEEP is enabled.                  |
| MODS[1:0]  | ACTIVE mode power scheme selection. Default value: 00.<br>See <a href="#">Table 65</a> and <a href="#">Table 66</a> |

**ST** bit activates the self-test function. When ST is set, X, Y, and Z outputs will shift. **RST** bit is used to activate the software reset. The reset mechanism can be enabled in STANDBY and ACTIVE mode.

When the reset bit is enabled, all registers are reset and are loaded with default values. Writing '1' to the RST bit immediately resets the device, no matter whether it is in ACTIVE/WAKE, ACTIVE/SLEEP, or STANDBY mode.

The I<sup>2</sup>C communication system is reset to avoid accidental corrupted data access.

At the end of the boot process the RST bit is de-asserted to 0. Reading this bit will return a value of zero.

The **(S)MODS[1:0]** bits select which Oversampling mode is to be used shown in [Table 65](#). The Oversampling modes are available in both WAKE Mode MOD[1:0] and also in the SLEEP Mode SMOD[1:0].

**Table 65. MODS Oversampling Modes**

| (S)MODS1 | (S)MODS0 | Power Mode          |
|----------|----------|---------------------|
| 0        | 0        | Normal              |
| 0        | 1        | Low Noise Low Power |
| 1        | 0        | High Resolution     |
| 1        | 1        | Low Power           |

**Table 66. MODS Oversampling Modes Current Consumption and Averaging Values at each ODR**

| Mode    | Normal (00)     |          | Low Noise Low Power (01) |          | High Resolution (10) |          | Low Power (11)  |          |
|---------|-----------------|----------|--------------------------|----------|----------------------|----------|-----------------|----------|
|         | Current $\mu$ A | OS Ratio | Current $\mu$ A          | OS Ratio | Current $\mu$ A      | OS Ratio | Current $\mu$ A | OS Ratio |
| 1.56 Hz | 24              | 128      | 8                        | 32       | 165                  | 1024     | 6               | 16       |
| 6.25 Hz | 24              | 32       | 8                        | 8        | 165                  | 256      | 6               | 4        |
| 12.5 Hz | 24              | 16       | 8                        | 4        | 165                  | 128      | 6               | 2        |
| 50 Hz   | 24              | 4        | 24                       | 4        | 165                  | 32       | 14              | 2        |
| 100 Hz  | 44              | 4        | 44                       | 4        | 165                  | 16       | 24              | 2        |
| 200 Hz  | 85              | 4        | 85                       | 4        | 165                  | 8        | 44              | 2        |
| 400 Hz  | 165             | 4        | 165                      | 4        | 165                  | 4        | 85              | 2        |
| 800 Hz  | 165             | 2        | 165                      | 2        | 165                  | 2        | 165             | 2        |

## 0x2C: CTRL\_REG3 Interrupt Control Register

### 0x2C CTRL\_REG3 Register (Read/Write)

| Bit 7     | Bit 6      | Bit 5       | Bit 4      | Bit 3      | Bit 2 | Bit 1 | Bit 0 |
|-----------|------------|-------------|------------|------------|-------|-------|-------|
| FIFO_GATE | WAKE_TRANS | WAKE_LNDPRT | WAKE_PULSE | WAKE_FF_MT | —     | IPOL  | PP_OD |

**Table 67. CTRL\_REG3 Description**

|             |  |
|-------------|--|
| FIFO_GATE   | 0: FIFO gate is bypassed. FIFO is flushed upon the system mode transitioning from WAKE to SLEEP mode or from SLEEP to WAKE mode. Default value: 0.<br>1: The FIFO input buffer is blocked when transitioning from WAKE to SLEEP mode or from SLEEP to WAKE mode until the FIFO is flushed. Although the system transitions from WAKE to SLEEP or from SLEEP to WAKE the contents of the FIFO buffer are preserved, new data samples are ignored until the FIFO is emptied by the host application.<br>If the FIFO_GATE bit is set to logic '1' and the FIFO buffer is not emptied before the arrival of the next sample, then the FGERR bit in the SYS_MOD register (0x0B) will be asserted. The FGERR bit remains asserted as long as the FIFO buffer remains un-emptied.<br>Emptying the FIFO buffer clears the FGERR bit in the SYS_MOD register. |
| WAKE_TRANS  | 0: Transient function is bypassed in SLEEP mode. Default value: 0.<br>1: Transient function interrupt can wake up system   |
| WAKE_LNDPRT | 0: Orientation function is bypassed in SLEEP mode. Default value: 0.<br>1: Orientation function interrupt can wake up system   |
| WAKE_PULSE  | 0: Pulse function is bypassed in SLEEP mode. Default value: 0.<br>1: Pulse function interrupt can wake up system   |
| WAKE_FF_MT  | 0: Freefall/Motion function is bypassed in SLEEP mode. Default value: 0.<br>1: Freefall/Motion function interrupt can wake up  |
| IPOL        | Interrupt polarity ACTIVE high, or ACTIVE low. Default value: 0.<br>0: ACTIVE low; 1: ACTIVE high  |
| PP_OD       | Push-Pull/Open Drain selection on interrupt pad. Default value: 0.<br>0: Push-Pull; 1: Open Drain  |

**IPOL** bit selects the polarity of the interrupt signal. When IPOL is '0' (default value) any interrupt event will signaled with a logical 0.

**PP\_OD** bit configures the interrupt pin to Push-Pull or in Open Drain mode. The default value is 0 which corresponds to Push-Pull mode. The Open Drain configuration can be used for connecting multiple interrupt signals on the same interrupt line.

## 0x2D: CTRL\_REG4 Register (Read/Write)

### 0x2D CTRL\_REG4 Register (Read/Write)

| Bit 7       | Bit 6       | Bit 5        | Bit 4         | Bit 3        | Bit 2        | Bit 1 | Bit 0       |
|-------------|-------------|--------------|---------------|--------------|--------------|-------|-------------|
| INT_EN_ASLP | INT_EN_FIFO | INT_EN_TRANS | INT_EN_LNDPRT | INT_EN_PULSE | INT_EN_FF_MT | —     | INT_EN_DRDY |

**Table 68. Interrupt Enable Register Description**

| Interrupt Enable | Description  |
|------------------|--|
| INT_EN_ASLP      | Interrupt Enable. Default value: 0.<br>0: Auto-SLEEP/WAKE interrupt disabled; 1: Auto-SLEEP/WAKE interrupt enabled.                                      |
| INT_EN_FIFO      | Interrupt Enable. Default value: 0.<br>0: FIFO interrupt disabled; 1: FIFO interrupt enabled.  |
| INT_EN_TRANS     | Interrupt Enable. Default value: 0.<br>0: Transient interrupt disabled; 1: Transient interrupt enabled.  |
| INT_EN_LNDPRT    | Interrupt Enable. Default value: 0.<br>0: Orientation (Landscape/Portrait) interrupt disabled.<br>1: Orientation (Landscape/Portrait) interrupt enabled. |
| INT_EN_PULSE     | Interrupt Enable. Default value: 0.<br>0: Pulse Detection interrupt disabled; 1: Pulse Detection interrupt enabled                                       |
| INT_EN_FF_MT     | Interrupt Enable. Default value: 0.<br>0: Freefall/Motion interrupt disabled; 1: Freefall/Motion interrupt enabled                                       |
| INT_EN_DRDY      | Interrupt Enable. Default value: 0.<br>0: Data Ready interrupt disabled; 1: Data Ready interrupt enabled   |

The corresponding functional block interrupt enable bit allows the functional block to route its event detection flags to the system's interrupt controller. The interrupt controller routes the enabled functional block interrupt to the INT1 or INT2 pin.

## 0x2E CTRL\_REG5 Register (Read/Write)

### 0x2E CTRL\_REG5 Interrupt Configuration Register

| Bit 7        | Bit 6        | Bit 5         | Bit 4          | Bit 3         | Bit 2         | Bit 1 | Bit 0        |
|--------------|--------------|---------------|----------------|---------------|---------------|-------|--------------|
| INT_CFG_ASLP | INT_CFG_FIFO | INT_CFG_TRANS | INT_CFG_LNDPRT | INT_CFG_PULSE | INT_CFG_FF_MT | —     | INT_CFG_DRDY |

**Table 69. Interrupt Configuration Register Description**

| Interrupt Configuration | Description  |
|-------------------------|--|
| INT_CFG_ASLP            | INT1/INT2 Configuration. Default value: 0.<br>0: Interrupt is routed to INT2 pin; 1: Interrupt is routed to INT1 pin |
| INT_CFG_FIFO            | INT1/INT2 Configuration. Default value: 0.<br>0: Interrupt is routed to INT2 pin; 1: Interrupt is routed to INT1 pin |
| INT_CFG_TRANS           | INT1/INT2 Configuration. Default value: 0.<br>0: Interrupt is routed to INT2 pin; 1: Interrupt is routed to INT1 pin |
| INT_CFG_LNDPRT          | INT1/INT2 Configuration. Default value: 0.<br>0: Interrupt is routed to INT2 pin; 1: Interrupt is routed to INT1 pin |
| INT_CFG_PULSE           | INT1/INT2 Configuration. Default value: 0.<br>0: Interrupt is routed to INT2 pin; 1: Interrupt is routed to INT1 pin |
| INT_CFG_FF_MT           | INT1/INT2 Configuration. Default value: 0.<br>0: Interrupt is routed to INT2 pin; 1: Interrupt is routed to INT1 pin |
| INT_CFG_DRDY            | INT1/INT2 Configuration. Default value: 0.<br>0: Interrupt is routed to INT2 pin; 1: Interrupt is routed to INT1 pin |

The system's interrupt controller shown in [Figure 11](#) uses the corresponding bit field in the CTRL\_REG5 register to determine the routing table for the INT1 and INT2 interrupt pins. If the bit value is logic '0' the functional block's interrupt is routed to INT2, and if the bit value is logic '1' then the interrupt is routed to INT1. One or more functions can assert an interrupt pin; therefore a host application responding to an interrupt should read the INT\_SOURCE (0x0C) register to determine the appropriate sources of the interrupt.

## 6.9 User Offset Correction Registers

For more information on how to calibrate the 0g Offset refer to AN4069 Offset Calibration Using the MMA8451Q. The 2's complement offset correction registers values are used to realign the Zero-g position of the X, Y, and Z-axis after device board mount. The resolution of the offset registers is 2 mg per LSB. The 2's complement 8-bit value would result in an offset compensation range  $\pm 256$  mg.

### 0x2F: OFF\_X Offset Correction X Register

#### 0x2F OFF\_X Register (Read/Write)

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| D7    | D6    | D5    | D4    | D3    | D2    | D1    | D0    |

**Table 70. OFF\_X Description**

|        |  |
|--------|--|
| D[7:0] | X-axis offset value. Default value: 0000_0000. |
|--------|--|

### 0x30: OFF\_Y Offset Correction Y Register

#### 0x30 OFF\_Y Register (Read/Write)

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| D7    | D6    | D5    | D4    | D3    | D2    | D1    | D0    |

**Table 71. OFF\_Y Description**

|        |  |
|--------|--|
| D[7:0] | Y-axis offset value. Default value: 0000_0000. |
|--------|--|

### 0x31: OFF\_Z Offset Correction Z Register

#### 0x31 OFF\_Z Register (Read/Write)

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-------|-------|-------|-------|-------|-------|-------|-------|
| D7    | D6    | D5    | D4    | D3    | D2    | D1    | D0    |

**Table 72. OFF\_Z Description**

|        |  |
|--------|--|
| D[7:0] | Z-axis offset value. Default value: 0000_0000. |
|--------|--|

Table 73. MMA8451Q Register Map

| Reg | Name             | Definition                                    | Bit 7        | Bit 6        | Bit 5         | Bit 4          | Bit 3         | Bit 2         | Bit 1    | Bit 0        |
|-----|------------------|---|--------------|--------------|---------------|----------------|---------------|---------------|----------|--------------|
| 00  | STATUS/F_STATUS  | Data Status R                                 | ZYXOW        | ZOW          | YOW           | XOW            | ZYXDR         | ZDR           | YDR      | XDR          |
| 01  | OUT_X_MSB        | 14 bit X Data R                               | XD13         | XD12         | XD11          | XD10           | XD9           | XD8           | XD7      | XD6          |
| 02  | OUT_X_LSB        | 14 bit X Data R                               | XD5          | XD4          | XD3           | XD2            | XD1           | XD0           | 0        | 0            |
| 03  | OUT_Y_MSB        | 14 bit Y Data R                               | YD13         | YD12         | YD11          | YD10           | YD9           | YD8           | YD7      | YD6          |
| 04  | OUT_Y_LSB        | 14 bit Y Data R                               | YD5          | YD4          | YD3           | YD2            | YD1           | YD0           | 0        | 0            |
| 05  | OUT_Z_MSB        | 14 bit Z Data R                               | ZD13         | ZD12         | ZD11          | ZD10           | ZD9           | ZD8           | ZD7      | ZD6          |
| 06  | OUT_Z_LSB        | 14 bit Z Data R                               | ZD5          | ZD4          | ZD3           | ZD2            | ZD1           | ZD0           | 0        | 0            |
| 09  | F_SETUP          | FIFO Set-up R/W                               | F_MODE1      | F_MODE0      | F_WMRK5       | F_WMRK4        | F_WMRK3       | F_WMRK2       | F_WMRK1  | F_WMRK0      |
| 0A  | TRIG_CFG         | FIFO Triggers R/W                             | —            | —            | Trig_TRANS    | Trig_LNDPRT    | Trig_PULSE    | Trig_FF_MT    | —        | —            |
| 0B  | SYSMOD           | System Mode R                                 | FGERR        | FGT_4        | FGT_3         | FGT_2          | FGT_1         | FGT_0         | SYSMOD1  | SYSMOD0      |
| 0C  | INT_SOURCE       | Interrupt Status R                            | SRC_ASPL     | SRC_FIFO     | SRC_TRANS     | SRC_LNDPRT     | SRC_PULSE     | SRC_FF_MT     | —        | SRC_DRDY     |
| 0D  | WHO_AM_I         | ID Register R                                 | 0            | 0            | 0             | 1              | 1             | 0             | 1        | 0            |
| 0E  | XYZ_DATA_CFG     | Data Config R/W                               | —            | —            | —             | HPF_Out        | —             | —             | FS1      | FS0          |
| 0F  | HP_FILTER_CUTOFF | HP Filter Setting R/W                         | —            | —            | Pulse_HPF_BYP | Pulse_LPF_EN   | —             | —             | SEL1     | SEL0         |
| 10  | PL_STATUS        | PL Status R                                   | NEWLP        | LO           | —             | —              | —             | LAPO[1]       | LAPO[0]  | BAFRO        |
| 11  | PL_CFG           | PL Configuration R/W                          | DBCNTM       | PL_EN        | —             | —              | —             | —             | —        | —            |
| 12  | PL_COUNT         | PL DEBOUNCE R/W                               | DBNCE[7]     | DBNCE[6]     | DBNCE[5]      | DBNCE[4]       | DBNCE[3]      | DBNCE[2]      | DBNCE[1] | DBNCE[0]     |
| 13  | PL_BF_ZCOMP      | PL Back/Front Z Comp R/W                      | BKFR[1]      | BKFR[0]      | —             | —              | —             | ZLOCK[2]      | ZLOCK[1] | ZLOCK[0]     |
| 14  | P_L_THS_REG      | PL THRESHOLD R/W                              | 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]       |
| 15  | FF_MT_CFG        | Freefall/Motion Config R/W                    | ELE          | OAE          | ZEFE          | YEFE           | XEFE          | —             | —        | —            |
| 16  | FF_MT_SRC        | Freefall/Motion Source R                      | EA           | —            | ZHE           | ZHP            | YHE           | YHP           | XHE      | XHP          |
| 17  | FF_MT_THS        | Freefall/Motion Threshold R/W                 | DBCNTM       | THS6         | THS5          | THS4           | THS3          | THS2          | THS1     | THS0         |
| 18  | FF_MT_COUNT      | Freefall/Motion Debounce R/W                  | D7           | D6           | D5            | D4             | D3            | D2            | D1       | D0           |
| 1D  | TRANSIENT_CFG    | Transient Config R/W                          | —            | —            | —             | ELE            | ZTEFE         | YTEFE         | XTEFE    | HPF_BYP      |
| 1E  | TRANSIENT_SRC    | Transient Source R                            | —            | EA           | ZTRANSE       | Z_Trans_Pol    | YTRANSE       | Y_Trans_Pol   | XTRANSE  | X_Trans_Pol  |
| 1F  | TRANSIENT_THS    | Transient Threshold R/W                       | DBCNTM       | THS6         | THS5          | THS4           | THS3          | THS2          | THS1     | THS0         |
| 20  | TRANSIENT_COUNT  | Transient Debounce R/W                        | D7           | D6           | D5            | D4             | D3            | D2            | D1       | D0           |
| 21  | PULSE_CFG        | Pulse Config R/W                              | DPA          | ELE          | ZDPEFE        | ZSPEFE         | YDPEFE        | YSPEFE        | XDPEFE   | XSPEFE       |
| 22  | PULSE_SRC        | Pulse Source R                                | EA           | AxZ          | AxY           | AxX            | DPE           | Pol_Z         | Pol_Y    | Pol_X        |
| 23  | PULSE_THSX       | Pulse X Threshold R/W                         | —            | THSX6        | THSX5         | THSX4          | THSX3         | THSX2         | THSX1    | THSX0        |
| 24  | PULSE_THSY       | Pulse Y Threshold R/W                         | —            | THSY6        | THSY5         | THSY4          | THSY3         | THSY2         | THSY1    | THSY0        |
| 25  | PULSE_THSZ       | Pulse Z Threshold R/W                         | —            | THSZ6        | THSZ5         | THSZ4          | THSZ3         | THSZ2         | THSZ1    | THSZ0        |
| 26  | PULSE_TMLT       | Pulse First Timer R/W                         | TMLT7        | TMLT6        | TMLT5         | TMLT4          | TMLT3         | TMLT2         | TMLT1    | TMLT0        |
| 27  | PULSE_LTCY       | Pulse Latency R/W                             | LTCY7        | LTCY6        | LTCY5         | LTCY4          | LTCY3         | LTCY2         | LTCY1    | LTCY0        |
| 28  | PULSE_WIND       | Pulse 2nd Window R/W                          | WIND7        | WIND6        | WIND5         | WIND4          | WIND3         | WIND2         | WIND1    | WIND0        |
| 29  | ASLP_COUNT       | Auto-SLEEP Counter R/W                        | D7           | D6           | D5            | D4             | D3            | D2            | D1       | D0           |
| 2A  | CTRL_REG1        | Control Reg1 R/W                              | ASLP_RATE1   | ASLP_RATE0   | DR2           | DR1            | DR0           | LNOISE        | F_READ   | ACTIVE       |
| 2B  | CTRL_REG2        | Control Reg2 R/W                              | ST           | RST          | —             | SMODS1         | SMODS0        | SLPE          | MODS1    | MODS0        |
| 2C  | CTRL_REG3        | Control Reg3 (WAKE Interrupts from SLEEP) R/W | FIFO_GATE    | WAKE_TRANS   | WAKE_LNDPRT   | WAKE_PULSE     | WAKE_FF_MT    | —             | IPOL     | PP_OD        |
| 2D  | CTRL_REG4        | Control Reg4 (Interrupt Enable Map) R/W       | INT_EN_ASPL  | INT_EN_FIFO  | INT_EN_TRANS  | INT_EN_LNDPRT  | INT_EN_PULSE  | INT_EN_FF_MT  | —        | INT_EN_DRDY  |
| 2E  | CTRL_REG5        | Control Reg5 (Interrupt Configuration) R/W    | INT_CFG_ASPL | INT_CFG_FIFO | INT_CFG_TRANS | INT_CFG_LNDPRT | INT_CFG_PULSE | INT_CFG_FF_MT | —        | INT_CFG_DRDY |
| 2F  | OFF_X            | X 8-bit offset R/W                            | D7           | D6           | D5            | D4             | D3            | D2            | D1       | D0           |
| 30  | OFF_Y            | Y 8-bit offset R/W                            | D7           | D6           | D5            | D4             | D3            | D2            | D1       | D0           |
| 31  | OFF_Z            | Z 8-bit offset R/W                            | D7           | D6           | D5            | D4             | D3            | D2            | D1       | D0           |



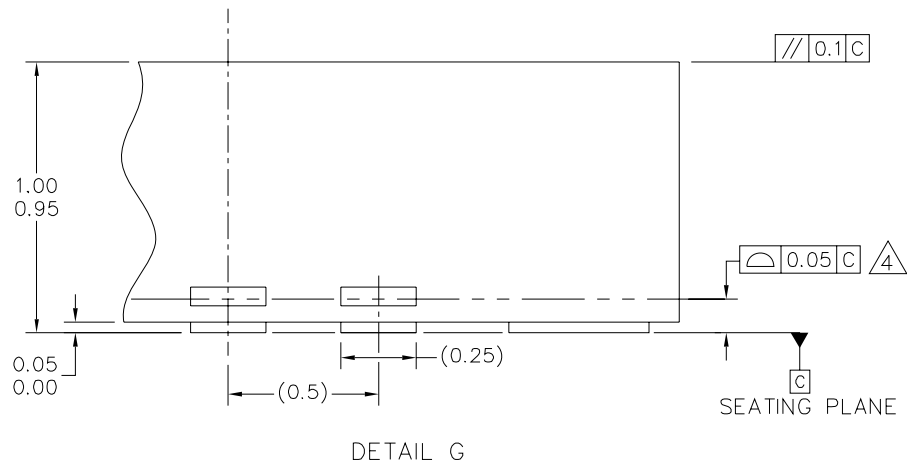
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**Table 74. Accelerometer Output Data**

| 14-bit Data       | Range $\pm 2g$ (0.25 mg)                   | Range $\pm 4g$ (0.5 mg)                     | Range $\pm 8g$ (1.0 mg)                    |
|-------------------|--|---|--|
| 01 1111 1111 1111 | 1.99975g                                   | +3.9995g                                    | +7.999g                                    |
| 01 1111 1111 1110 | 1.99950g                                   | +3.9990g                                    | +7.998g                                    |
| ...               | ...  | ...   | ...  |
| 00 0000 0000 0001 | 0.00025g                                   | +0.0005g                                    | +0.001g                                    |
| 00 0000 0000 0000 | 0.00000g                                   | 0.00000g                                    | 0.000g                                     |
| 11 1111 1111 1111 | -0.00025g                                  | -0.0005g                                    | -0.001g                                    |
| ...               | ...  | ...   | ...  |
| 10 0000 0000 0001 | -1.99975g                                  | -3.9995g                                    | -7.999g                                    |
| 10 0000 0000 0000 | -2.00000g                                  | -4.0000g                                    | -8.000g                                    |
| <b>8-bit Data</b> | <b>Range <math>\pm 2g</math> (15.6 mg)</b> | <b>Range <math>\pm 4g</math> (31.25 mg)</b> | <b>Range <math>\pm 8g</math> (62.5 mg)</b> |
| 0111 1111         | 1.9844g                                    | +3.9688g                                    | +7.9375g                                   |
| 0111 1110         | 1.9688g                                    | +3.9375g                                    | +7.8750g                                   |
| ...               | ...  | ...   | ...  |
| 0000 0001         | +0.0156g                                   | +0.0313g                                    | +0.0625g                                   |
| 0000 0000         | 0.000g                                     | 0.0000g                                     | 0.0000g                                    |
| 1111 1111         | -0.0156g                                   | -0.0313g                                    | -0.0625g                                   |
| ...               | ...  | ...   | ...  |
| 1000 0001         | -1.9844g                                   | -3.9688g                                    | -7.9375g                                   |
| 1000 0000         | -2.0000g                                   | -4.0000g                                    | -8.0000g                                   |



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
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Freescale Semiconductor China Ltd.  
Exchange Building 23F  
No. 118 Jianguo Road  
Chaoyang District  
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