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Motion and Freefall Detection Using the MMA8450Q

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1.0 Introduction

The MMA8450Q has two (2) embedded functions for both Motion and/or Freefall along with a very flexible interrupt routing scheme. Motion is often used to simply alert the main processor that the device is currently in use. This can be accomplished with the Motion function and/or with the Transient function, described in AN3918. The motion detection is an embedded function that can save overall system power by using an interrupt scheme. This feature alerts the main processor when a motion/tilt threshold or Freefall event has occurred.

Result: This feature saves the system processor from reading out the XYZ data continually and running a software algorithm to compare data with thresholds.

1.1 Key Words

Motion, Freefall, Interrupt, Transient Detection, Acceleration, Tumble, Debounce, Embedded, Tilt, Configuration Registers, DBCNTM bit, Threshold, Sensor

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1.2 Summary

A. The advantage of having two embedded functions to detect either Motion or linear Freefall which are routed to the choice of two interrupt pins allows for many combinations of events to be detected meeting the needs of many different use cases. For example: The embedded Motion/Freefall function can be used to detect a tumble using both the linear Freefall on one channel and the Motion detection to detect the spin on another channel.

B. The status register for the Motion/Freefall function is only read when a change has occurred.

C. Less processing is required on the microcontroller or processor with the embedded function since the condition is detected internally. The XYZ registers are not polled and data is not manipulated by the processor to detect the events.

D. The threshold and debounce counter are changeable in either the active or standby mode to allow for adjustments after the part has transitioned from the wake to the sleep mode.

E. Motion detection varies from Transient detection. The motion detection can trigger on a change in a static acceleration value such as tilt.

F. The latch will hold the EA bit until the status register is read to indicate an event is active, but the other bits in the status register are never latched. The status must be read immediately to determine the condition of the axes when an event occurs.

2.0 MMA8450Q Consumer 3-axis Accelerometer 3 x 3 x 1 mm

The MMA8450Q has a selectable dynamic range of ±2g, ±4g and ±8g with sensitivities of 1024 counts/g, 512 counts/g and 256 counts/g respectively. The device offers either 8-bit or 12-bit XYZ output data for algorithm development. The chip shot and pinout are shown in Figure 1.

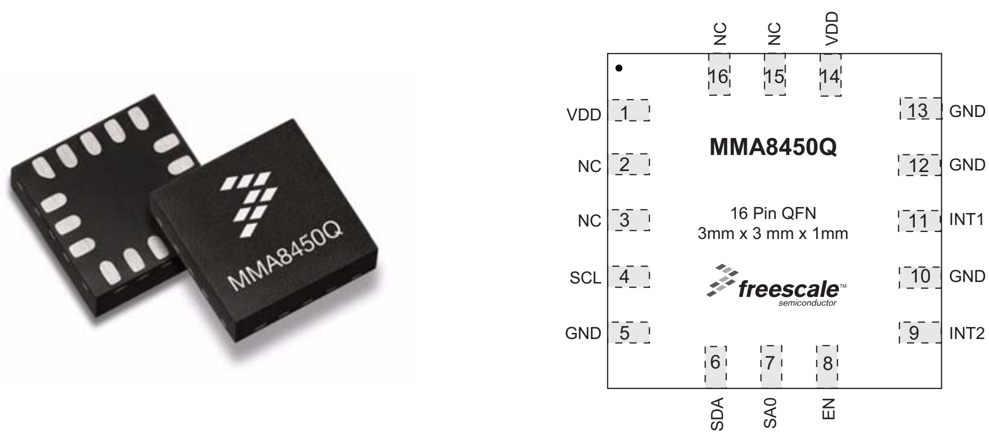

Figure 1. MMA8450Q Consumer 3-axis Accelerometer 3 x 3 x 1 mm

2.1 Key Features of the MMA8450Q

1. Shutdown Mode: Typical < 1 µA, Standby Mode 3 µA
2. Low Power Mode current consumption ranges from 27 µA (1.56 - 50 Hz) to 120 µA (400 Hz)
3. Normal Mode current consumption ranges from 42 µA (1.56 - 50 Hz) to 225 µA (400 Hz)
4. I^2C digital output interface (operates up to 400 kHz Fast Mode)
5. 12-bit and 8-bit data output, 8-bit high pass filtered data output
6. Post Board Mount Offset < ±50 mg typical
7. Self Test X, Y and Z axes

2.2 Two (2) Programmable Interrupt Pins for 8 Interrupt Sources

1. Embedded 4 channels of Motion detection
   a. Freefall or Motion detection: 2 channels
   b. Tap detection: 1 channel
   c. Transient detection: 1 channel
2. Embedded orientation (Portrait/Landscape) detection with hysteresis compensation
3. Embedded automatic ODR change for auto-wake-up and return-to-sleep
4. Embedded 32 sample FIFO
5. Data Ready Interrupt

2.3 Application Notes for the MMA8450Q

The following is a list of Freescale Application Notes written for the MMA8450Q:

- **AN3915**, *Embedded Orientation Detection Using the MMA8450Q*
- **AN3916**, *Offset Calibration of the MMA8450Q*
- **AN3917**, ***Motion and Freefall Detection Using the MMA8450Q***
- **AN3918**, *High Pass Filtered Data and Transient Detection Using the MMA8450Q*
- **AN3919**, *MMA8450Q Single/Double and Directional Tap Detection*
- **AN3920**, *Using the 32 Sample First In First Out (FIFO) in the MMA8450Q*
- **AN3921**, *Low Power Modes and Auto-Wake/Sleep Using the MMA8450Q*
- **AN3922**, *Data Manipulation and Basic Settings of the MMA8450Q*
- **AN3923**, *MMA8450Q Design Checklist and Board Mounting Guidelines*

3.0 Motion and Freefall Applications Using the MMA8450Q Accelerometer

There are many applications that could potentially use Motion and/or Freefall. Some examples are the following:

- Simpler motion signatures for gesturing (tilt thresholds, generic motions, linear freefalls
- Human motion monitoring (specific parameters for motion and freefall)
- Tamper detection on doors (detecting a threshold is exceeded or a change in tilt)
- Shock detection or motion detection tracking assets (a threshold is exceeded)
- Risk of an object falling: hard disk drives (linear freefall and motion)
- Field meter monitoring for large motion/falls of the meters (tilt threshold change)

3.1 Freefall Detection

The Freefall function of the MMA8450Q detects linear freefall when X and Y and Z are ***below*** a set threshold. Typically this set threshold is below 0.35g. Although Freefall is often considered to be linear, this is often not entirely true in many fall use cases. Many falls can be tumbles which may cause the object to spin while falling.

3.2 Motion Detection

Motion detection can be used to alert that the device has exceeded a specific acceleration. This event could be due to a tilt or due to an acceleration that exceeds a value from a linear motion as shown Figure 2.

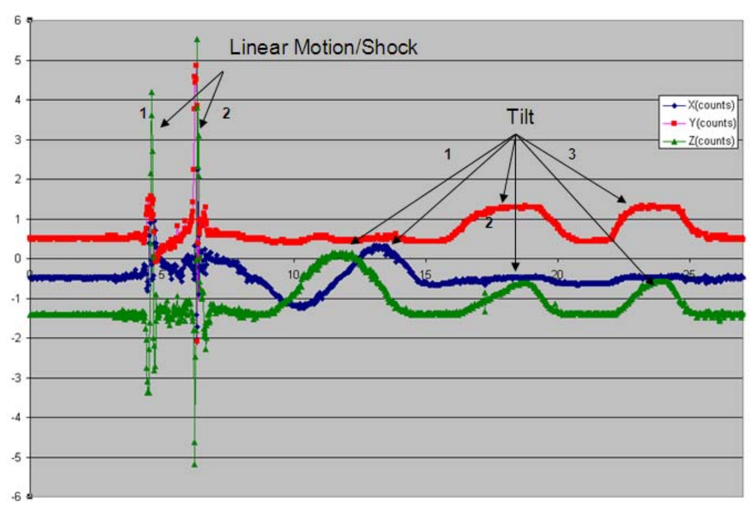

Figure 2. Motion Detection per Tilt or Linear Acceleration

The **motion function** can be used for detecting tumble. The signature of a tumble is shown in Figure 3. During the rotation of the tumble the magnitude of the three axes is much greater than 0g. In order to detect tumble, for example, the motion detection condition must be set to detect for X or Y or Z > 2g. It is also important to set the debounce counter to about 100 ms to avoid false readings. The debounce counter acts like a filter to determine whether the condition exists for 100 ms or longer.

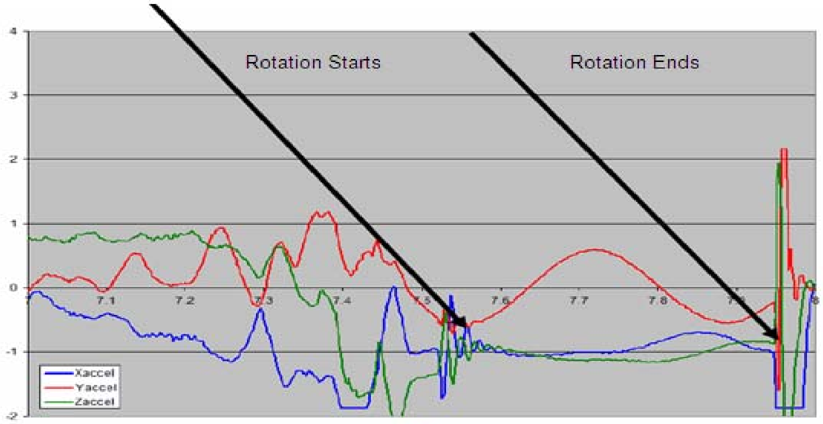

Figure 3. Rotational Freefall Signature

3.3 Signature of Linear Freefall and Rotational Fall

Figure 4, shows the signature of a Linear Freefall and a Rotational Fall. Both are falling events that require different conditions for detection. To be able to capture either a Linear Freefall or a Rotational Fall, the Motion/Freefall1 embedded function can be used to detect the Linear Freefall while the Motion/Freefall2 can be used to detect the Rotational Fall (motion) or vise versa. Each function can be routed to the same interrupt pin or routed to separate interrupt pins.

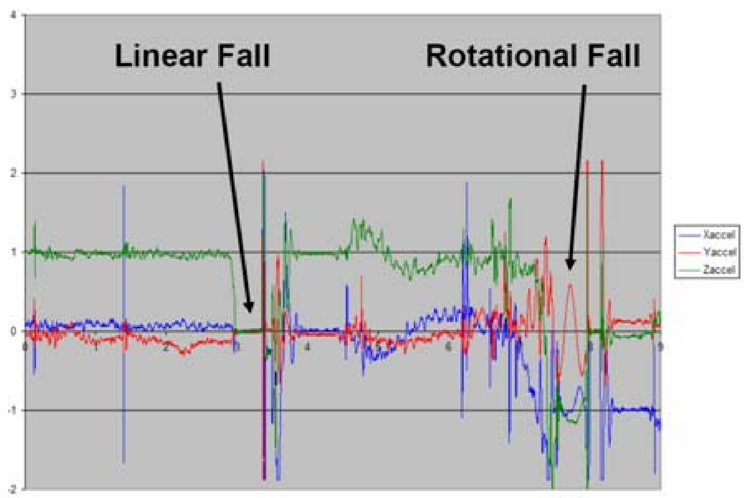

Figure 4. Fall Event Showing Linear and Rotational Fall

3.4 Motion/Freefall Embedded Function

The Motion function of the MMA8450Q compares the enabled X, Y, and/or Z-axis to determine if the acceleration output is greater than the set threshold. *It does not compare a change in acceleration.* Therefore, a tilt value could exceed the threshold to make this condition true. If an exact change in acceleration is the desired output the embedded transient detection can be used to configure the change in acceleration level for Motion detection. The transient detection eliminates the effects of gravity by passing the data through a high pass filter to eliminate static accelerations.

4.0 Register Settings for the Motion/ Freefall Function

There are four (4) registers associated with the Motion/Freefall embedded function.
Note the Motion Freefall1 and the Motion/Freefall2 have the same configuration and functionality.

1. Register 0x23 **FF/MT Config 1** - Motion/Freefall Configuration
2. Register 0x25 **FF_MT_THS_1** - Setting the Threshold
3. Register 0x26 **FF_MT_COUNT_1** - Setting the Debounce Counter
4. Register 0x24 **FF_MT_SRC_1** - Motion/Freefall Source Detection

Refer to Table 11 for the complete list of all registers that can be used with Motion/Freefall.

4.1 Register 0x23: FF/MT Config 1 - Configuration Register

The first register is the Motion/Freefall Configuration Register shown in Table 1. This register determines which axes to enable with regards to three (3) conditions:

1. Which axes will be involved,
2. Whether the event will be a linear freefall or a motion and,
3. Whether the event detected should be latched or not into the source register.

Table 1. Register 0x23: FF/MT Config 1 - Configuration Register (Read/Write) and Description

Reg 0x23	ELE	OAE	ZHEFE	ZLEFE	YHEFE	YLEFE	XHEFE	XLEFE
Motion	1	1	0	0	1	0	1	0
Freefall	1	0	0	1	0	1	0	1

4.1.1 Configuring the MMA8450Q for Motion Detection

For Motion detection the condition should be set for the enabled axes to **exceed** the threshold. The logic will be an **"OR"** condition to make the condition true. The "high" condition bits should be enabled only, since Motion is detecting a (**>) greater than** threshold condition. Therefore **ZHEFE**, **YHEFE** and **XHEFE** are valid for Motion detection. Note the low condition bits such as **XLEFE**, **YLEFE** and **ZLEFE** are not valid. In this example shown in Table 2. only the X and Y axes are considered.

Table 2. Motion Example 1: X or Y > 3g

Reg 0x23	ELE	OAE	ZHEFE	ZLEFE	YHEFE	YLEFE	XHEFE	XLEFE
Motion	1	1	0	0	1	0	1	0

Example Code: IIC_RegWrite(0x23, 0xCA); //Enable Latch, Motion, X-axis, Y-axis

4.1.2 Configuring the MMA8450Q for Freefall Detection

For Freefall detection the condition should be set so that the enabled axes have an acceleration value **below** (**<**) the threshold. The logic will be an **"And"** condition to make the condition true. Note that all axes do not necessarily need to be enabled, but for a true freefall condition it is advised to set all three axes. In the Freefall Mode the **ZLEFE**, **YLEFE** and **XLEFE** bits are valid. Note that the **ZHEFE**, **YHEFE** and **XHEFE** are not valid since they are used for Motion detection only. An example of linear freefall is shown in Table 3.

Table 3. Freefall Example 1: X AND Y AND Z < 0.2g

Reg 0x23	ELE	OAE	ZHEFE	ZLEFE	YHEFE	YLEFE	XHEFE	XLEFE
Freefall	1	0	0	1	0	1	0	1

Example Code: IIC_RegWrite(0x23, 0x95); //Enable Latch, Freefall, X-axis, Y-axis and Z-axis

4.2 Register 0x25 FF_MT_THS_1 Register (Read/Write) - Setting the Threshold

The threshold for the event is set in Register 0x25, shown in Table 4. The minimum threshold resolution is dependent on the selected acceleration g range and the threshold register has a range of 0 to 127 counts.

Therefore:

- If the selected acceleration g range is 8g mode (**FS** = 11), the minimum threshold resolution is 0.063g/LSB. The maximum threshold is 8g.
- If the selected acceleration g range is 4g mode (**FS** = 10), the minimum threshold resolution is 0.0315g/LSB. The maximum threshold is 4g
- If the selected acceleration g range is 2g mode (**FS** = 01), the minimum threshold resolution is 0.01575g/LSB. The maximum threshold is 2g.

Table 4. Register 0x25 FF_MT_THS_1 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

Note:

- For Motion detection the condition is > Threshold (Figure 5)
- For Freefall the condition is < Threshold (Figure 5)
- All thresholds are absolute value.

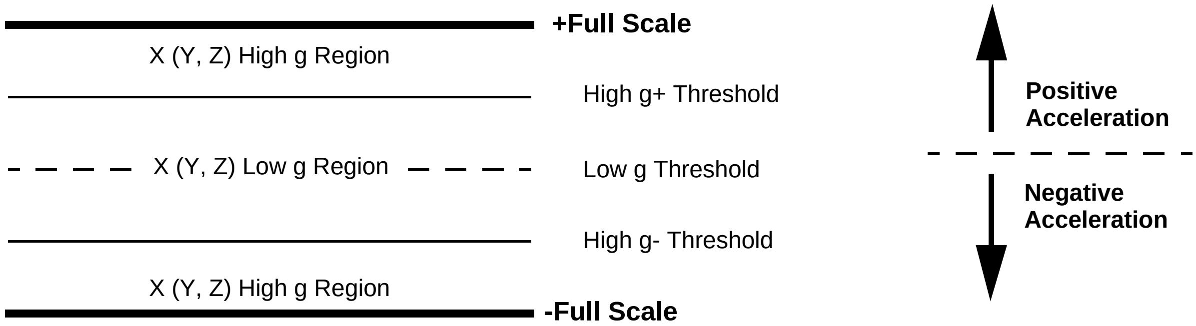

Figure 5. Freefall Condition (Illustration)

The **DCNTM** bit is best understood from the diagram in Figure 6. The default value is for the counter to be in the increment/decrement mode.

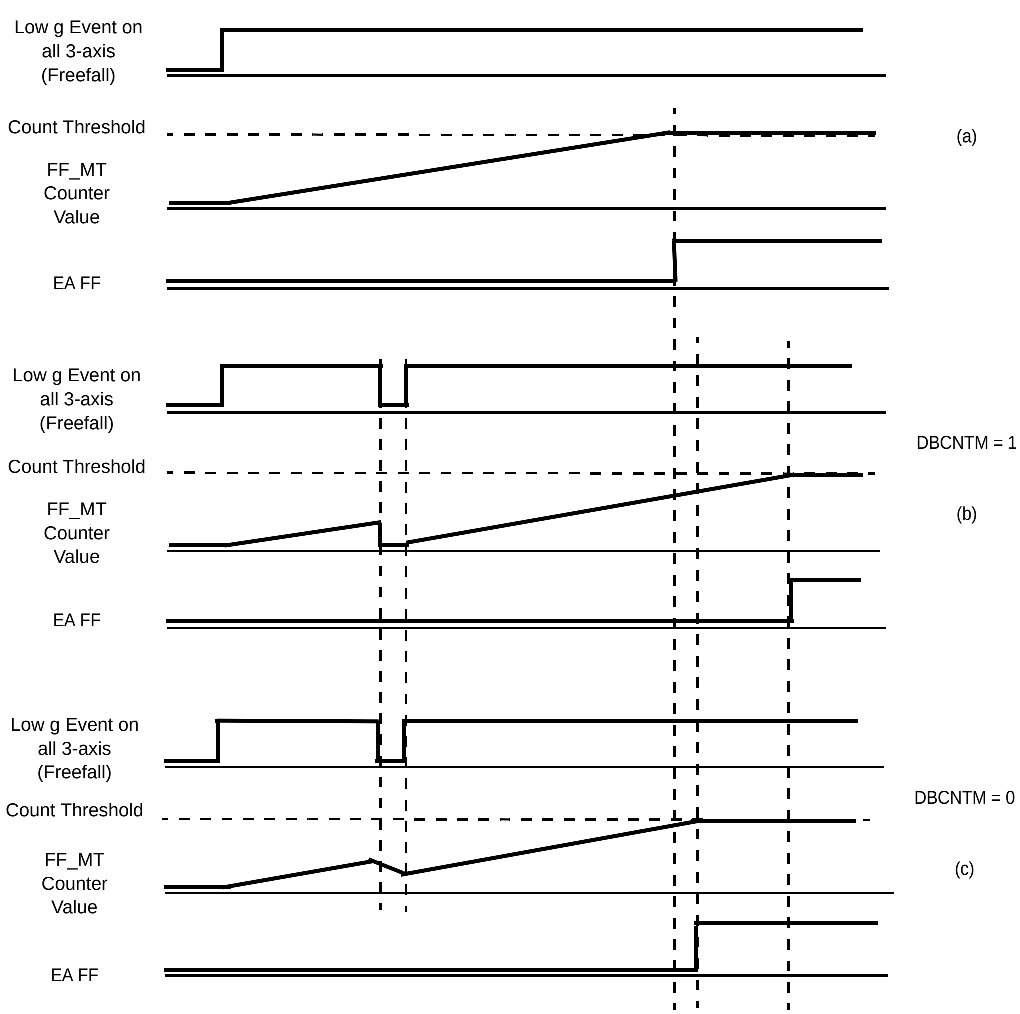

Figure 6. DBCNTM Bit Function (Illustration)

4.2.1 Example: Setting the Threshold for Motion Detection

Motion Example 1: X or Y > 3g

The device must be in either 4g or 8g mode. Assuming the device is in 4g mode, therefore, the step count would be 0.0315g/LSB; therefore 3g/0.0315g = 95.2, which can be rounded to 96 counts. Note the threshold can be changed in either the Active or the Standby Mode. This may be useful for readjusting the threshold while in the active mode after an event has occurred. The **DBCNTM** bit will be kept cleared.

Example Code: IIC_RegWrite(0x25, 0x60); //Set Threshold to 96 counts

4.2.2 Example: Setting the Threshold for Freefall Detection

Freefall Example 1: X AND Y AND Z < 0.2g

In this example the device could be either 2g, 4g, or 8g mode. Assuming 2g mode, the step count is 0.01575g/LSB. Therefore 0.2g/0.01575g = 12.7, which rounds to 13 counts. Also for this example the **DBCNTM** bit will be kept cleared to filter out spurious noise.

Example Code: IIC_RegWrite(0x25, 0x0D); // Set Threshold to 13 counts

4.3 Register 0x26 FF_MT_COUNT_1 Register (Read/Write) - Setting the Debounce Counter

Register 0x26 shown in Table 5 is an 8-bit counter used for low pass filtering.

Table 5. Register 0x26 FF_MT_COUNT_1 (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

The time step used for the debounce sample count depends on the ODR chosen. The relationship is shown inTable 6.

Table 6. FF_MT_COUNT_1 Relationship with the ODR

Output Data Rate (Hz)	Step	Duration Range
400	2.5 ms	2.5 ms – 0.637s
200	5 ms	5 ms – 1.275s
100	10 ms	10 ms – 2.55s
50	20 ms	20 ms – 5.1s
12.5	80 ms	80 ms – 20.4s
1.56	640 ms	640 ms – 163s

An ODR of 100 Hz and a **FF_MT_COUNT_1** value of 10 would result in minimum debounce response time of 100 ms.

Note: the debounce counter can be changed in the active or the standby mode. This may be desirable when the device changes from the wake mode to the sleep mode as the ODR may change. This will change the timing of the debounce counter.

Example Code: IIC_RegWrite(0x26, 0x0A); // 100 ms debounce timing

4.4 Register 0x24 FF_MT_SRC_1 Register (Read Only) - Motion/Freefall Source Detection Register

Register 0x24 shown in Table 7 keeps track of the acceleration events which trigger. The **EA** (Event Active) bit is used in combination with the **INT_EN_FF_MT_1** bit (Register 0x3B) and **INT_CFG_FF_MT_1** bit (Register 0x3C) to generate the Freefall/Motion interrupt in register 0x15 (System Status Interrupt Register). **Note:** When the latch is enabled in Register 0x23 (Bit 7 **ELE**) only the "**EA**" bit, Bit 6 will remain set until the source register is read. Reading the source register clears the interrupt in Register 0x15 and clears the **EA** bit in Register 0x24.

Table 7. Events Detected in the Motion/Freefall Source Detection Register (Read Only) and Legend

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
—	EA	ZHE	ZLE	YHE	YLE	XHE	XLE

5.0 Configuring the Motion/Freefall to an Interrupt Pin

In order to set up the system to route to a hardware interrupt pin, the System Interrupt (Bit 1or 2 in Reg 0x3B) must be enabled. The MMA8450Q allows for eight (8) separate types of interrupts. Two (2) of these are reserved for Motion/Freefall. There is one for Motion/Freefall1 and one for Motion/Freefall2. For example, to configure the Motion/Freefall1 function, the following two steps should be followed.

Step 1: Enable the Interrupt Bit 1 and/or Bit 2 in Register 0x3B shown in Table 8.

Table 8. 0x3B CTRL_REG4 Register (Read/Write) – Interrupt Enable Description and Legend

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_1**	**INT_EN_FF_MT_2**	INT_EN_DRDY

The corresponding interrupt enable bit allows the Motion/Freefall interrupt to route its event detection flag to the interrupt controller of the system. The interrupt controller routes the enabled function to the INT1 or INT2 pin. To enable the Freefall/Motion1 function, set Bit 2 in Register 0x3B as follows:

Example Code: IIC_RegWrite(0x3B, 0x04);

Step 2: Route the interrupt to INT1 or to INT2. This is done in register 0x3C shown in Table 9.

Table 9. 0x3C CTRL_REG5 Register (Read/Write)

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_1**	**INT_CFG_FF_MT_2**	INT_CFG_DRDY

Note: To set Motion/Freefall1 to INT1 set Bit 2 in register 0x3C.

Example Code: IIC_RegWrite(0x3C,0x04);

5.1 Reading the System Interrupt Status Source Register

In the interrupt source register shown in Table 10 the status of the various embedded functions can be determined. The bits that are set (logic '1') indicate which function has asserted an interrupt; conversely, the bits that are cleared (logic '0') indicate which function has not asserted or has de-asserted an interrupt. The interrupts are rising edge sensitive. The bits are set by a low to high transition and are cleared by reading the appropriate interrupt source register.

Table 10. 0x15 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_1**	**SRC_FF_MT_2**	SRC_DRDY

6.0 Details for Configuring the MMA8450Q for Motion/Freefall Detection

The registers of importance for configuring the MMA8450Q for Motion detection or Freefall detection are listed in Table 11.

Table 11. Registers of Importance for Setting up the Motion/Freefall Detection

Reg	Name	Definition	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
15	INT_SOURCE	Interrupt Status R	SRC_ASLP	SRC_FIFO	SRC_TRANS	SRC_LNDPRT	SRC_PULSE	**SRC_FF_MT_1**	**SRC_FF_MT_2**	SRC_DRDY
23	FF_MT_CFG_1	FF/Motion Config 1 R/W	ELE	OAE	ZHEFE	ZLEFE	YHEFE	YLEFE	XHEFE	XLEFE
24	FF_MT_SRC_1	FF/Motion Source 1 R	—	EA	ZHE	ZLE	YHE	YLE	XHE	XLE
25	FF_MT_THS_1	FF/Motion Threshold 1 R/W	DBCNTM	THS6	THS5	THS4	THS3	THS2	THS1	THS0
26	FF_MT_COUNT_1	FF/Motion Debounce R/W	D7	D6	D5	D4	D3	D2	D1	D0
27	FF_MT_CFG_2	FF/Motion Config 2 R/W	ELE	OAE	ZHEFE	ZLEFE	YHEFE	YLEFE	XHEFE	XLEFE
28	FF_MT_SRC_2	FF/Motion Source 2 R	—	EA	ZHE	ZLE	YHE	YLE	XHE	XLE
29	FF_MT_THS_2	FF/Motion Threshold 2 R/W	DBCNTM	THS6	THS5	THS4	THS3	THS2	THS1	THS0
2A	FF_MT_COUNT_2	FF/Motion Debounce 2 R/W	D7	D6	D5	D4	D3	D2	D1	D0
3B	CTRL_REG4	Control Reg4 R/W (Interrupt Enable Map)	INT_EN _ASLP	INT_EN _FIFO	INT_EN _TRANS	INT_EN_LNDPRT	INT_EN_PULSE	**INT_EN_FF_MT_1**	**INT_EN_FF_MT_2**	INT_EN_DRDY
3C	CTRL_REG5	Control Reg5 R/W (Interrupt Configuration)	INT_CFG_ASLP	INT_CFG_FIFO	INT_CFG_TRANS	INT_CFG_LNDPRT	INT_CFG_PULSE	**INT_CFG_FF_MT_1**	**INT_CFG_FF_MT_2**	INT_CFG_DRDY

6.1 Example Steps for Configuring Motion Detection

X or Y >3g using MFF1Function 4g, 100 Hz ODR

Step 1: Put the device into Standby Mode: Register 0x38 CtrlReg1

IIC_RegWrite(0x38, 0x08); // Set the device in 100 Hz ODR, Standby

Step 2: Set Configuration Register for Motion Detection by setting the “OR” condition OAE = 1, enabling XHigh and YHigh and the latch

IIC_RegWrite(0x23,0xCA)

Step 3: Threshold Setting Value for the Motion detection of > 3g

Note: In 4g mode each count is 31.5 mg

- 3g/0.0315g = 95.2; // Round up to 96

IIC_RegWrite(0x25, 0x60)

Step 4: Set the debounce counter to eliminate false readings for 100 Hz sample rate with a requirement of 100 ms timer.

Note: 100 ms/10 ms (steps) = 10 counts

IIC_RegWrite(0x26, 0x0A);

Step 5: Enable Motion/Freefall1 Interrupt Function in the System (Ctrl Reg4)

IIC_RegWrite(0x3B, 0x04);

Step 6: Route the Motion/Freefall1 Interrupt Function to INT 1 hardware pin (CtrlReg5)

IIC_RegWrite(0x3C, 0x04);

Step 7: Put the device in 4g Active Mode

IIC_RegWrite(0x38, 0x0A); //100Hz, 4g Mode

Step 8: Write Interrupt Service Routine Reading the System Interrupt Status and the Motion/Freefall1 Status

```
Interrupt void isr_KBI (void)
{
      //clear the interrupt flag
      CLEAR_KBI_INTERRUPT;
      //Determine source of interrupt by reading the system interrupt
      IntSourceSystem=IIC_RegRead(0x15);
      // Set up Case statement here to service all of the possible interrupts
      if ((Int_SourceSystem &0x04)==0x04)
      {
            //Perform an Action since Motion Flag has been set
            //Read the Motion/Freefall1 Function to clear the interrupt
            IntSourceMFF1=IIC_RegRead(0x24);
            //Can parse out data to perform a specific action based on the
            //axes that made the condition true
      }
}
```

6.2 Example Steps for Configuring Linear Freefall Detection

X AND Y AND Z <0.2g using MFF2Function 2g Mode, 50Hz ODR

Step 1: Put the device in Standby Mode: Register 0x38 CtrlReg1

IIC_RegWrite(0x38, 0x0C); // Set the device in 50 Hz ODR, Standby

Step 2: Configuration Register set for Freefall Detection enabling "AND" condition, OAE = 0, Enabling XLow, YLow, ZLow, and the Latch

IIC_RegWrite(0x27, 0x95);

Step 3: Threshold Setting Value for the resulting acceleration < 0.2g

Note: In 2g mode each count is 15.75 mg

- 0.2g/0.01575 = 12.7 counts // Round up to 13 counts

IIC_RegWrite(0x29, 0x0D);

Step 4: Set the debounce counter to eliminate false positive readings for 50Hz sample rate with a requirement of 120 ms timer.

Note: 120 ms/20 ms (steps) = 6 counts

IIC_RegWrite(0x2A, 0x06);

Step 5: Enable Motion/Freefall2 Interrupt Function in the System (Ctrl Reg 4)

IIC_RegWrite(0x3B, 0x02);

Step 6: Route the Motion/Freefall2 Interrupt Function to INT 2 hardware pin (CtrlReg5)

IIC_RegWrite(0x3C, 0x00);

Step 7: Put the device in 2g Active Mode, 50 Hz

IIC_RegWrite(0x38, 0x0D);

Step 8: Write Interrupt Service Routine Reading the System Interrupt Status and the Motion/Freefall2 Status

```
Interrupt void isr_KBI (void)
{
      //clear the interrupt flag
      CLEAR_KBI_INTERRUPT;
      //Determine source of the interrupt by first reading the system interrupt
      IntSourceSystem=IIC_RegRead(0x15);
      // Set up Case statement here to service all of the possible interrupts
      if ((IntSourceSystem&0x02)==0x02)
      {
            //Perform an Action since Freefall Flag has been set
            //Read the Motion/Freefall2 Function to clear the interrupt
            IntSourceMFF2=IIC_RegRead(0x28);
            //Can parse out data to perform a specific action based on the axes
      }
      }
```

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