



MMA8450Q Single/Double and Directional Tap Detection

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1.0 Introduction

Tapping is a new way that users employ interacting with hand held products that have an integrated accelerometer. For example, a single tap can be used to silence the sound; a double tap could be used to send an incoming call directly to voicemail. Directional tapping from the positive and negative directions of X, Y, and Z can be used in gaming for motion inputs or for changing pictures in slide show mode or as other generic functions. Tap as an input to the product device allows users to enjoy a more advanced and interactive user experience. The tap replaces the need for the mouse to point and click and select options.

The MMA8450Q has embedded single tap and double tap capabilities. Directional tap is not embedded in the device but directional tap can be accomplished using the embedded tap while flushing the FIFO after the event occurs to extract the direction information. Examples and explanations of how to configure the device for the embedded tap as well as the software algorithm for directional tap will be given in this application note. Note that in the data sheet the register names for tap are sometimes referred to as "pulse". The signature of the tap signal from the accelerometer looks like a pulse, and that is where this reference derives. Pulse and double pulse are considered the same as tap and double tap in the literature.

1.1 Key Words

Accelerometer, Output Data Rate, Current Consumption, Tap, Directional Tap, Double Tap, Pulse, Double Pulse, Menu Selection, Threshold, Timing Window, Latency Timer, Second Tap, Sample Rate, Double Pulse Abort, Interrupt, FIFO

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1.2 Summary

- A. A tap signature has a fast response time: sampling speed is important. The timing windows and conditions for detecting single and double tap are adjustable in the MMA8450Q to eliminate false taps
- B. The signature of a tap is somewhat dependent on the user as well as on the mounting conditions of the accelerometer in the product.
- C. The embedded single tap and the FIFO are used for directional tap which saves on current consumption. The event is interrupt driven and the processor can go into a low power mode until the event occurs.
- D. The MMA8450Q can be configured to detect a single tap only, a double tap only or both single and double taps to the same interrupt pin. It can also detect the direction of the tap from an interrupt in conjunction with analyzing the direction thresholds from the FIFO data.
- E. The conditions for double tap detection and rejection are given in various scenario diagrams to assist the user to configure the tap feature appropriately.
- F. The latch (**ELE** bit set) will hold the **EA** bit (event active) in the status register until the status register is read, but the other bits in the status register are never latched. The status must be read before the user definable latency timer times out to determine the condition of the axes when the event occurs.
- G. The X, Y, and Z tap thresholds for single and double tap can be changed in either active or standby mode.

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

The MMA8450Q has a selectable dynamic range of $\pm 2g$, $\pm 4g$ and $\pm 8g$ 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](#).

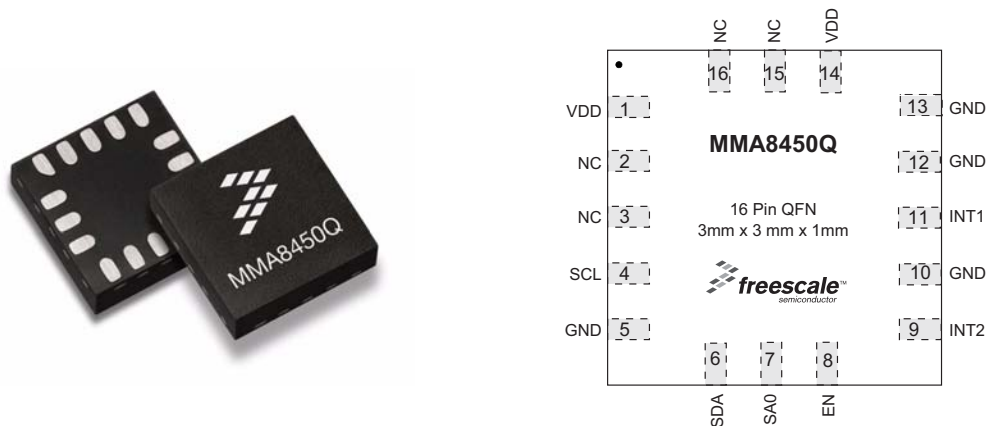


Figure 1. MMA8450Q Consumer 3-axis Accelerometer 3 x 3 x 1 mm

2.1 Key Features of the MMA8450Q

- 1. Shutdown Mode: Typical $< 1 \mu A$, Standby Mode $3 \mu A$
- 2. Low Power Mode current consumption ranges from $27 \mu A$ (1.56 - 50 Hz) to $120 \mu A$ (400 Hz)
- 3. Normal Mode current consumption ranges from $42 \mu A$ (1.56 - 50 Hz) to $225 \mu A$ (400 Hz)
- 4. I²C 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 $< \pm 50$ 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 Tap Detection Applications Using the MMA8450Q Accelerometer

Figure 2 shows the signature of a tap event. This data was collected on an analog sensor at 2 kHz to show a very complete signature of the waveform. It is important to note that the tap signature from the Z data of the accelerometer can look somewhat different depending on the mechanics and mounting conditions of the sensor. To analyze the tap signature for writing algorithms, it is beneficial to mount the accelerometer under the conditions of the final product to do testing and analyze various similar waveforms. This data was collected by tapping on the back of our standard Sensor Toolbox Demo Boards. There are a few things to notice about the signature of the waveform:

- The time period of the entire event in this case lasts for about 10 ms.
- There is a sharp downward acceleration followed by an immediate rebound in a short time. Then the waveform settles.
- The embedded algorithms for single and double tap analyze the tap waveform comparing thresholds and timing conditions.

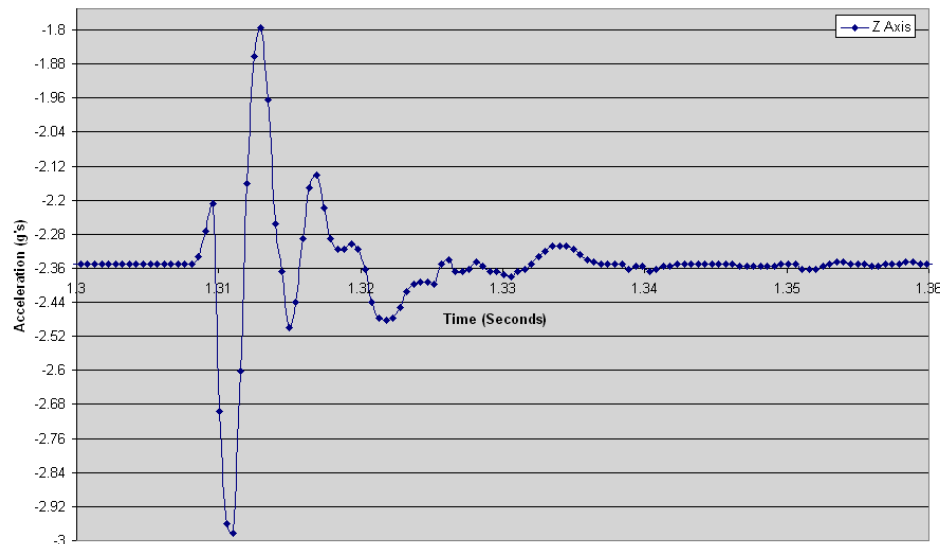


Figure 2. Tap Signature Z-axis Sample Rate 2 kHz

3.1 Single Tap

For a single tap event there are three key parameters to consider.

1. Time Window for the tap signature to cross a threshold and drop below it (**PULSE_TMLT**)
2. Threshold Value to Trigger the event (**PULSE_THSX**, **PULSE_THSY**, **PULSE_THSZ**)
3. Latency time to hold the event conditions (**PULSE_LTCY**)

Single tap is embedded in the design of the MMA8450Q. The tap event function must first be enabled to detect a single tap event with the corresponding axes enabled. A single tap event is configured by specifying two things; the threshold to be crossed and the time duration that it lasts. A single tap event is detected when the acceleration value is greater than the value set in the **PULSE_THSX** (Reg 0x31), **PULSE_THSY** (Reg 0x32) and **PULSE_THSZ** (Reg 0x33) registers. The time period of the event must be shorter than the time set in the **PULSE_TMLT** (Reg 0x34) time limit register.

When configured for a single tap event, an interrupt is generated when the input acceleration on the selected axis exceeds the programmed threshold, and returns below it within a time window defined by **PULSE_TMLT**. If the **ELE** bit (bit 6) of the **PULSE_CFG** (Reg 0x2F) register is not set, the interrupt is kept high for the duration of the Latency window **PULSE_LTCY** (Reg 0x35). The latency window is a user-definable period of delay after each pulse. This latency window applies either for single pulse or double pulse detection. If the **ELE** bit is set, the interrupt (**EA** bit) is kept high until the **PULSE_SRC** (Reg 0x30) register is read.

Figure 3, shows a valid and invalid pulse condition.

- A. Note in condition (a) the interrupt is asserted since the acceleration due to a pulse exceeds the specified acceleration threshold (value set in the **PULSE_THSX**) and crosses up and down before the specified Pulse Time Limit (value set in **PULSE_TMLT**) expires.
- B. Note that in condition (b) the acceleration due to a pulse exceeds the specified acceleration threshold limit, but does not go below the threshold before the specified Pulse Time Limit expires. Therefore, this is an invalid pulse and the interrupt will not be triggered. Also note that the Latency is not shown for this example.

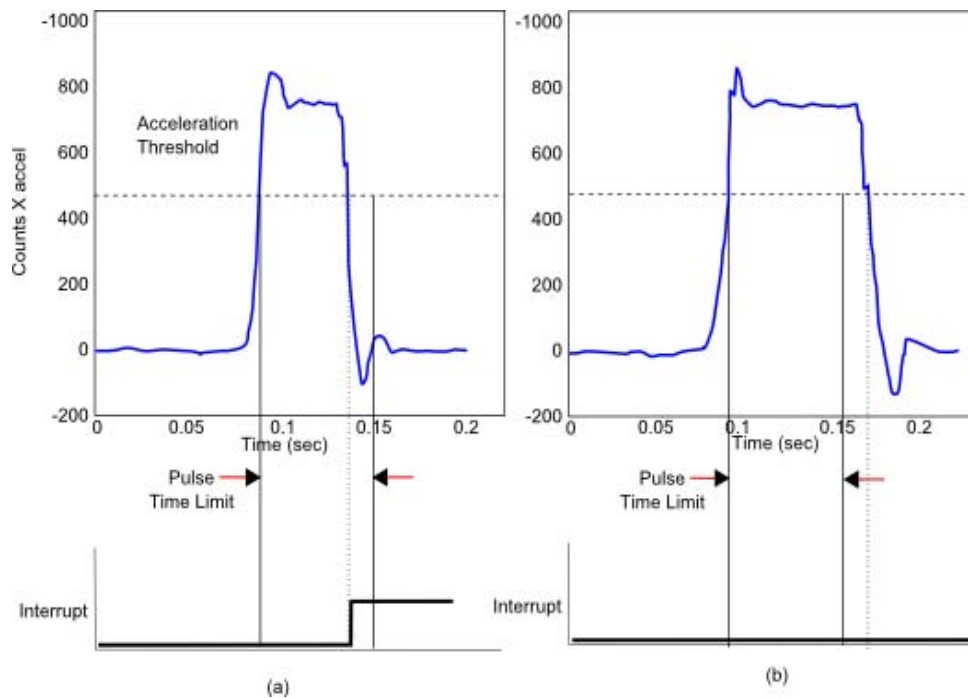


Figure 3. Single Tap Detection Conditions

3.2 Double Tap

A double tap event is detected when the device is configured for two single taps within defined time periods. The second time must occur after the time specified by the **PULSE_LTCY** (Reg 0x35) register, but also within the time limit of the **PULSE_WIND** (Reg 0x36) register.

If the device is configured for double tap detection, an interrupt is generated after both taps are recognized. The recognition of the second tap occurs only if the event satisfies the constraints defined by the Pulse Latency, Pulse Time Limit and Double Pulse Abort. In particular, after the first tap has been recognized, the second tap detection procedure is delayed for an interval defined by the Latency register. This means that after the first tap has been recognized, the second tap detection procedure will start only if the input acceleration exceeds the threshold after the Pulse Latency window but before the Pulse Window has expired or if the acceleration is still above the threshold after the Latency has expired.

Once the second pulse detection procedure is initiated, the second pulse will be recognized with the same rule as the first: the acceleration must return below the threshold before the Time Limit has expired. Appropriately defining the Latency window is important to avoid unwanted pulses due to spurious bouncing of the input signal.

Figure 4 illustrates a single pulse event (a) and a double pulse event (b). The device is able to distinguish between (a) and (b) by changing the settings of the **PULSE_CFG** register from single to double pulse recognition.

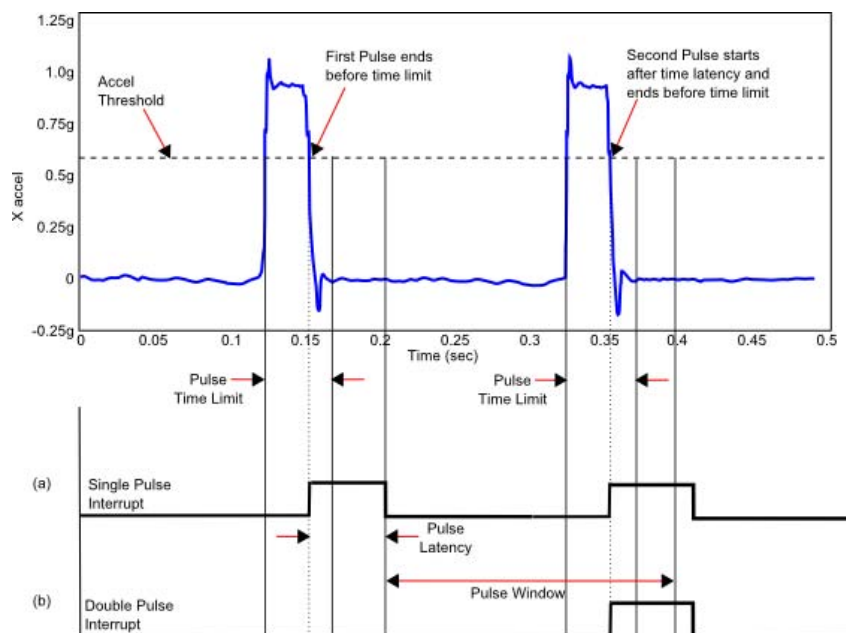


Figure 4. Single and Double Pulse Recognition

3.3 Various Scenarios Using Double Pulse Abort Conditions

The next image series illustrates various scenarios using the double pulse abort condition. Please refer to Tables 5, 6, 7, 8 and 9.

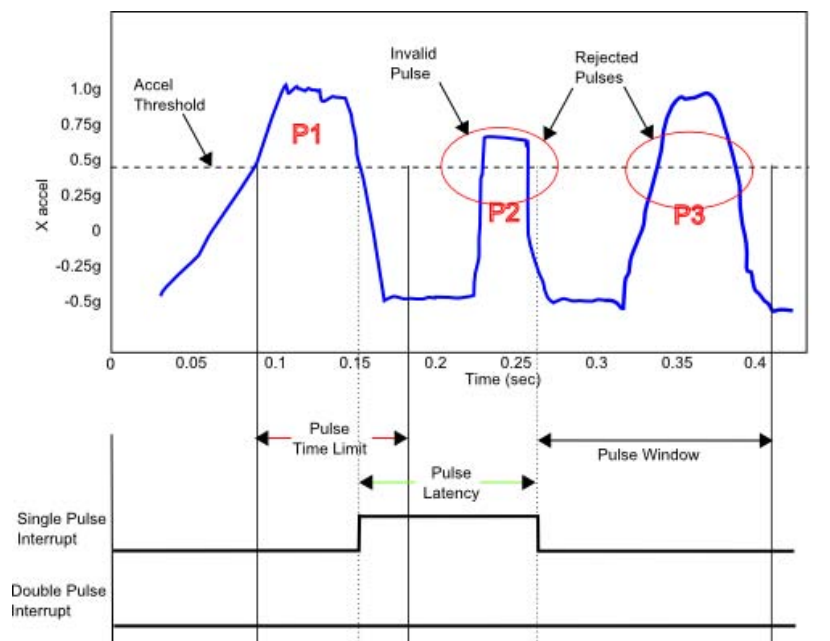


Figure 5. Double Pulse Aborted Due to Invalid Pulse During the Pulse Latency Phase (DPA = 1)

Note: In Figure 5, the Pulse P2 is rejected because the start of pulse P2 was detected during the **PULSE_LTCY** period.

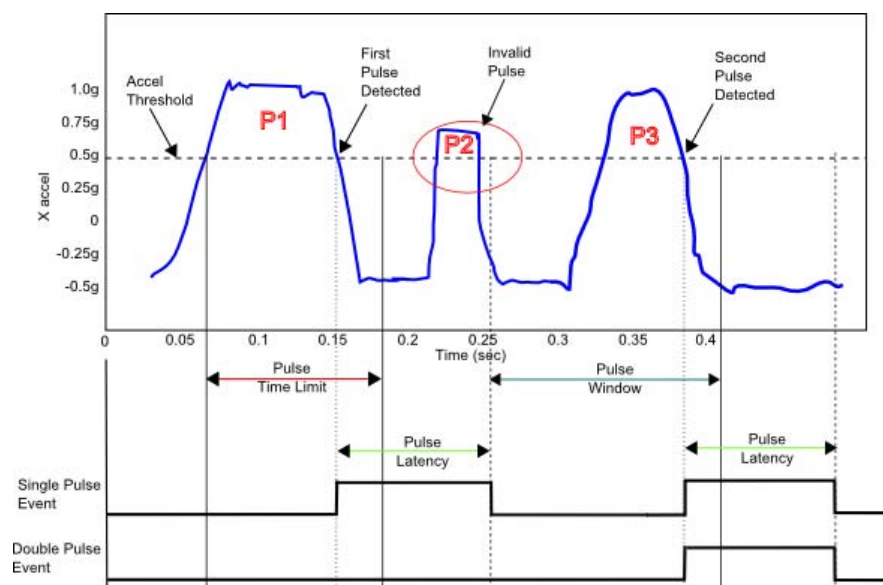


Figure 6. Double Pulse Detected Irrespective of the Invalid Pulse Status (DPA = 0)

Note: In Figure 6, Pulse P1 is detected as a valid single pulse, P2 is ignored because it occurs during the time period specified by the **PULSE_LTCY** register; but pulse P3 is detected as double pulse because the **DPA** bit is set to 0 and pulse P2 was ignored.

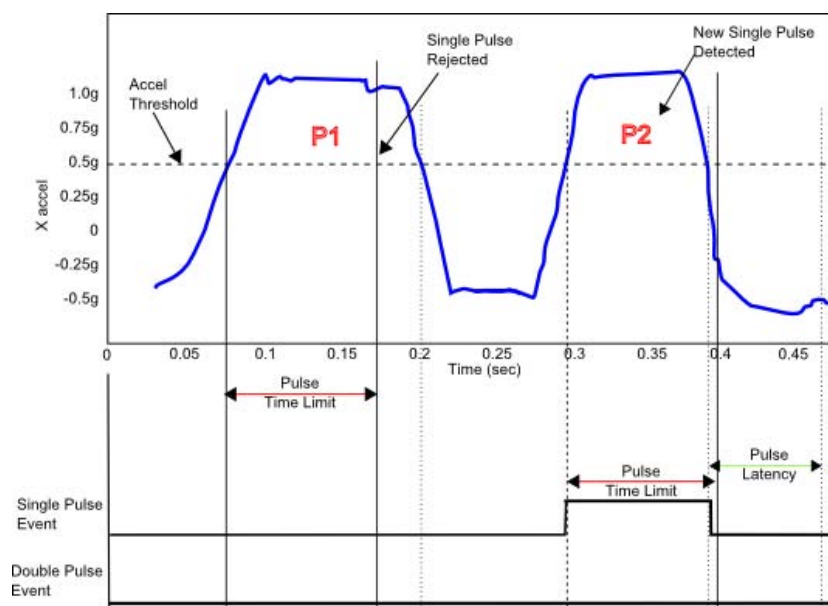


Figure 7. Double Pulse Rejected Due to Second Pulse Width Exceeding Pulse_TMLT Period (DPA = 1)

Note: In Figure 7, the second pulse is rejected because its pulse width is longer than the time period specified by the **PULSE_TMLT** register. After the **PULSE_WIND** period has expired, a new single pulse detection can begin.

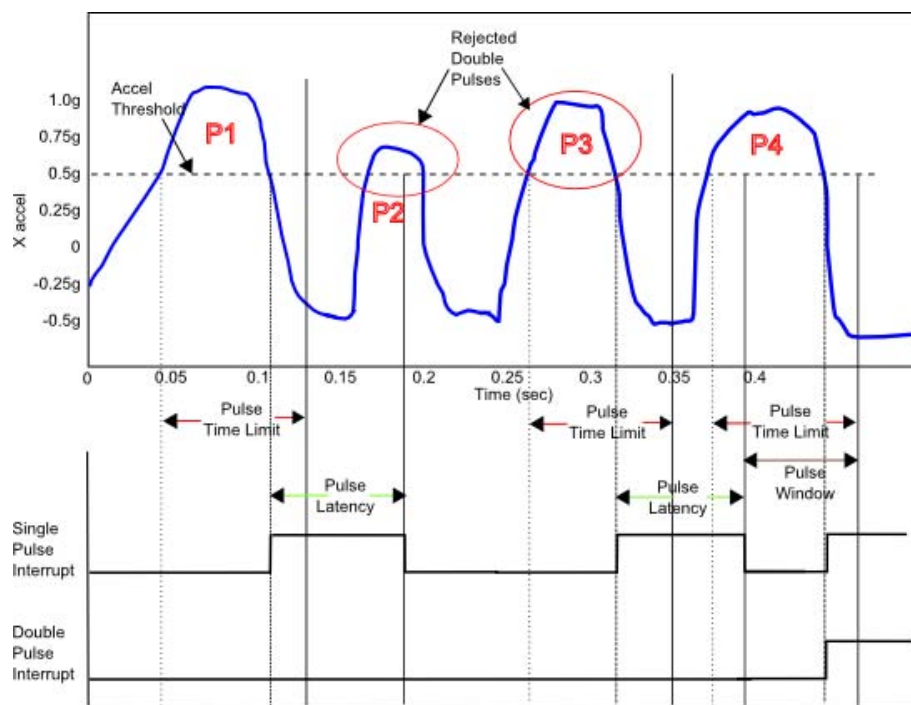


Figure 8. Double Pulse Rejected Due to Invalid Pulse During the Pulse Latency Phase (DPA = 1)

Note: In Figure 8, Pulse P2 is rejected as a double pulse because it starts before the expiration of the time period specified by the **PULSE_LTCY** register. Pulse P3 is detected as a new single pulse while pulse P4 is detected as a single and double pulse.

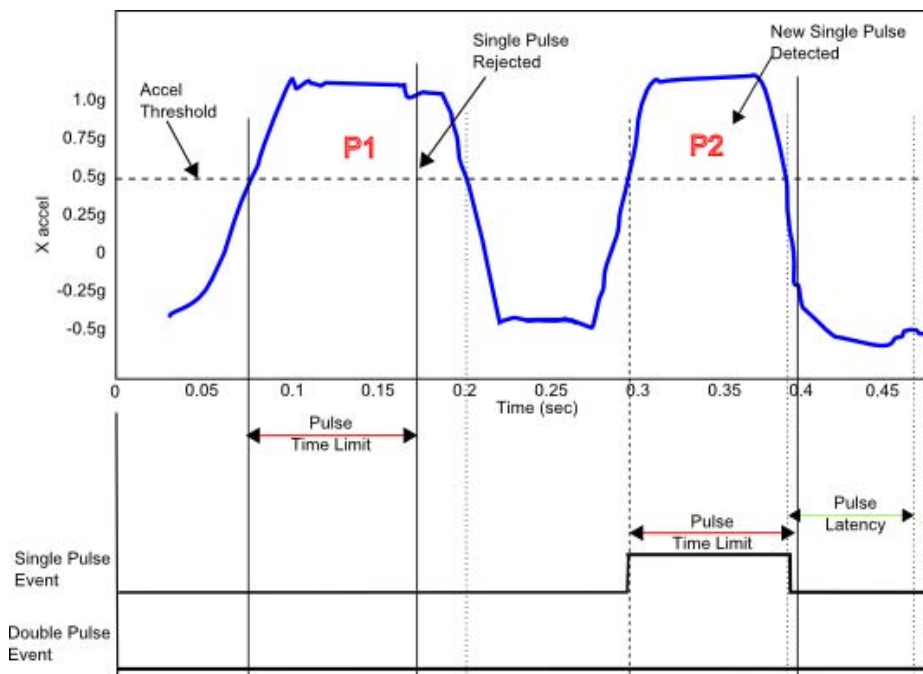


Figure 9. Single Pulse Rejected Due to First Pulse Width Exceeding Pulse_TMLT Period (DPA = 1)

Note: In Figure 9, Pulse P1 is rejected because its pulse width is longer than the time period specified by the **PULSE_TMLT** register.

4.0 Configuring Registers for Single and Double Tap Detection

To utilize the single and/or double tap detection the following eight (8) registers must be configured.

1. Register 0x2F: **PULSE_CFG** The Pulse Configuration Register
2. Register 0x30: **PULSE_SRC** Pulse Source Register
3. Register 0x31-0x33: **PULSE_THSX,Y,Z** Pulse Threshold for X, Y and Z Registers
4. Register 0x34: **PULSE_TMLT** Pulse Time Window 1 Register
5. Register 0x35: **PULSE_LTCY** Pulse Latency Timer Register
6. Register 0x36: **PULSE_WIND** Second Pulse Time Window Register

4.1 Register 0x2F: PULSE_CFG Pulse Configuration Register

This register configures the event flag for the tap detection interrupt function for enabling/disabling single and double pulse on each of the axes. This register determines the following:

- Which axes will be involved
- Whether the event to detect is a single tap or a double tap
- Whether the event active bit will be latched or not in the source register, [Table 1](#) provides an example for enabling:
 - Single tap only
 - Double tap only or,
 - Both single and double tap by combining the two, setting Register 0x2F to 0x7F

Table 1. Register 0x2F PULSE_CFG Register (Read/Write) and Description

Tap Enable	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
	DPA	ELE	ZDPEFE	ZSPEFE	YDPEFE	YSPEFE	XDPEFE	XSPEFE
Single Tap	0	1	0	1	0	1	0	1
Double Tap	0	1	1	0	1	0	1	0
Both S & D	0	1	1	1	1	1	1	1

4.1.1 Example Settings for Configuration of Single and/or Double Pulse Detection

Example X, Y and Z configured for Single Tap with Latch enabled

Code Example: `IIC_RegWrite(0x2F, 0x55);`

Example X, Y and Z configured for Double Tap with Latch enabled

Code Example: `IIC_RegWrite(0x2F, 0x6A);`

Example X, Y and Z configured for Single Tap and Double Tap with Latch enabled

Code Example: `IIC_RegWrite(0x2F, 0x7F);`

4.2 Registers 0x31-0x33 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. This allows for the same change in acceleration for all axes to be set regardless of the static orientation. The threshold values range from 0 to 31 (5 bits expressed as an absolute value) with steps of 0.258g/LSB at a **fixed 8g acceleration range**.

The **PULSE_THSX**, **PULSE_THSY** and **PULSE_THSZ** registers define the threshold for each of the axes. These are shown in [Tables 2, 3, and 4](#).

Note: The thresholds can be changed in either standby or active mode. This is very useful since if there is a change in orientation the thresholds can all be changed immediately to compensate without interrupting the detection process.

Table 2. Register 0x31 PULSE_THSX Register (Read/Write)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0	THSX4	THSX3	THSX2	THSX1	THSX0

Table 3. Register 0x32 PULSE_THSY Register (Read/Write)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0	THSY4	THSY3	THSY2	THSY1	THSY0

Table 4. Register 0x33 PULSE_THSZ Register (Read/Write)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0	THSZ4	THSZ3	THSZ2	THSZ1	THSZ0

4.2.1 Example: Set the tap detection threshold for 2g on X, 2g on Y and 3g on Z

$$2g/0.258g/\text{count} = 8 \text{ counts}$$

$$3g/0.258g/\text{count} = 12 \text{ counts}$$

Code Example: `IIC_RegWrite(0x31, 0x08); //Set X Threshold to 8 counts or 2g`

Code Example: `IIC_RegWrite(0x32, 0x08); //Set Y Threshold to 8 counts or 2g`

Code Example: `IIC_RegWrite(0x33, 0x0C); //Set Z Threshold to 12 counts or 3g`

4.3 Register 0x34: PULSE_TMLT Pulse Time Window 1 Register

The byte **PULSE_TMLT** (bit fields defined as 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 axes of acceleration must go back below the specified threshold.

Table 5. Register 0x34 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

The minimum time step for the pulse time limit is defined in Table 6. Maximum time for a given ODR is the minimum time step multiplied by 255. **The time steps available are dependent on whether the device is in Normal Power Mode or in Low Power Mode.** Notice in Table 6 that the time step is twice as long in Low Power Mode.

Table 6. Time Step for PULSE Time Limit at ODR and Power Mode

ODR (Hz)	Step at Normal Mode	Step LP Mode	Max Time Normal Mode	Max Time LP Mode
400	0.625 ms	1.25 ms	159.375 ms	318.75 ms
200	1.25 ms	2.5 ms	318.75 ms	637.5 ms
100	2.5 ms	5.0 ms	637.5 ms	1275 ms
50	5 ms	10 ms	1275 ms	2550 ms
12.5	5 ms	10 ms	1275 ms	2550 ms
1.56	5 ms	10 ms	1275 ms	2550 ms

Therefore, an ODR setting of 400 Hz with normal power mode would result in a maximum pulse time limit of $(0.625 \text{ ms} * 255) \geq 159 \text{ ms}$.

4.3.1 Example Settings for the Pulse Time Limit

Example: To set the Pulse Time Limit for 30 ms at 200 Hz ODR in Normal Mode

A. $30 \text{ ms} / 1.25 \text{ ms} = 24 \text{ counts}$

Code Example: `IIC_RegWrite(0x34, 0x18);`

4.4 Register 0x35: PULSE_LTCY Pulse Latency Timer Register

The Pulse Latency Timer Register is the time duration that the tap event can be read from the source register to detect the X, Y, and Z for single pulse or double pulse events. The source register only latches the “event active” bit; therefore, by increasing the latency time, the events will remain in the source register for a longer time period. The duration of any specified latency time is valid each time a single or double pulse occurs. The latency time duration for every pulse is the value specified by Register 0x35 shown in Table 7.

Table 7. Register 0x35 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

The Pulse Latency Register (bit fields defined as Ltcy7 through Ltcy0) defines the time interval that starts after the first pulse detection, from which point the pulse detection function ignores the start of new pulses. ***This register must be set for single pulse and for double pulse.***

The minimum time step for the pulse latency is defined in [Table 8](#). The maximum time is the minimum time step at the ODR and Power Mode multiplied by 255. Notice that the time step is twice the duration of that in Normal Mode when operating in Low Power Mode.

Table 8. Time step for PULSE Latency at ODR and Power Mode

ODR (Hz)	Step at Normal Mode	Step at LP Mode	Max Time Normal Mode	Max Time LP Mode
400	1.25 ms	2.5 ms	318.75ms	637.5s
200	2.5 ms	5.0 ms	637.5ms	1.275s
100	5.0 ms	20 ms	1.275s	2.55s
50	10 ms	20 ms	2.55s	5.1s
12.5	10 ms	20 ms	2.55s	5.1s
1.56	10 ms	20 ms	2.55s	5.1s

4.4.1 Example Settings for Pulse Latency Timer

Set the Pulse Latency Timer to 200 ms, 200 Hz ODR Low Power Mode

200 ms/5.0 ms = 40 counts

Code Example: `IIC_RegWrite(0x35, 0x28);`

4.5 Register 0x36: PULSE_WIND Second Pulse Time Window Register

Table 9. Register 0x36 PULSE_WIND Register (Read/Write)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Wind7	Wind6	Wind5	Wind4	Wind3	Wind2	Wind1	Wind0

The **PULSE_WIND** register with (bit fields Wind7 through Wind0) defines the maximum interval of time that can elapse after the end of the latency interval within which the start of the second pulse event must be detected (provided the device has been configured with double pulse detection enabled). The detected second pulse width must be shorter than the time limit constraints specified by the **PULSE_TMLT** register, but the double pulse need not cross the threshold within the time specified by the **PULSE_WIND** register. The minimum time step for the pulse window is defined in [Table 10](#). The maximum time is the time step at the ODR and Power Mode multiplied by 255.

Table 10. Time Step for PULSE Detection Window at ODR and Power Mode

ODR (Hz)	Step at Normal Mode	Step at LP Mode	Max Time Normal Mode	Max Time LP Mode
400	1.25 ms	2.5 ms	318.75 ms	637.5 ms
200	2.5 ms	5.0 ms	637.5 ms	1.275s
100	5.0 ms	20 ms	1.275s	2.55s
50	10 ms	20 ms	2.55s	5.1s
12.5	10 ms	20 ms	2.55s	5.1s
1.56	10 ms	20 ms	2.55s	5.1s

4.5.1 Example Settings for Pulse Window for Detecting a Double Tap

Set the Pulse window to 300 ms, 100 Hz ODR Low Power Mode

300 ms/20 ms = 15 counts

Code Example: `IIC_RegWrite(0x36, 0x0F);`

4.6 Register 0x30: PULSE_SRC Pulse Source Register

This register sets a flag for the appropriate bit if a double or single pulse event has occurred on any axis. Note: The corresponding axis and event has to be enabled above in Register 0x2F for the event to be seen in the source register. The event active flag will remain high if the latch is enabled but the status of the X,Y, Z single and double pulse events will automatically clear after the latency time specified in the **PULSE_LTCY** expires.

Table 11. Register 0x30 PULSE_SRC Register (Read Only) and Description

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	EA	ZDPE	ZSPE	YDPE	YSPE	XDPE	XSPE

Register 0x30 must be read immediately after the interrupt (i.e., after the **EA** bit goes high) to determine the source of the interrupt.

5.0 Configuring the Tap Detection to an Interrupt Pin

In order to set up the system to route to a hardware interrupt pin, the System Interrupt (bit 3 in Reg 0x3B) must be enabled. The MMA8450Q allows for eight (8) separate types of interrupts. One (1) of these is reserved for tap.

Step 1: Enable the Interrupt in Register 0x3B.

Table 12. 0x3B CTRL_REG4 Register (Read/Write) and Description

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 **INT_EN_PULSE** interrupt enable bit allows the tap function to route its event detection flag to the interrupt controller of the system. The interrupt controller routes the enabled function to either the INT1 or INT2 pin. To enable the Pulse (Tap) block, set bit 3 in Register 0x3B as follows:

Code Example: `IIC_RegWrite(0x3B, 0x08);`

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

Table 13. 0x3C CTRL_REG5 Register (Read/Write) and Description

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 route the Tap I to INT1 set bit 3 in register 0x3C. Clear bit 3 to route tap to INT2.

Code Example: `IIC_RegWrite(0x3C,0x08); // Set Tap to INT1`

5.1 Reading the System Interrupt Status Source Register

In the interrupt source register, 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 14. 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 Single and Double Tap

The registers of importance for configuring the MMA8450Q for tap detection are listed below in [Table 15](#).

Table 15. Registers of Importance for Embedded Single and Double Tap Detection

Reg	Name	Definition	Bit 7	Bit 6	Bit 5	Bit4	Bit3	Bit 2	Bit 1	Bit0
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
2F	PULSE_CFG	Pulse Config R/W	DPA	ELE	ZDPEFE	ZSPEFE	YDPEFE	YSPEFE	XDPEFE	XSPEFE
30	PULSE_SRC	Pulse Source R	-	EA	ZDPE	ZSPE	YDPE	YSPE	XDPE	XSPE
31	PULSE_THSX	Pulse X Threshold R/W	0	0	0	THSX4	THSX3	THSX2	THSX1	THSX0
32	PULSE_THSY	Pulse Y Threshold R/W	0	0	0	THSY4	THSY3	THSY2	THSY1	THSY0
33	PULSE_THSZ	Pulse Z Threshold R/W	0	0	0	THSZ4	THSZ3	THSZ2	THSZ1	THSZ0
34	PULSE_TMLT	Pulse First Timer R/W	Tmlt7	Tmlt6	Tmlt5	Tmlt4	Tmlt3	Tmlt2	Tmlt1	Tmlt0
35	PULSE_LTCY	Pulse Latency R/W	Ltcy7	Ltcy6	Ltcy5	Ltcy4	Ltcy3	Ltcy2	Ltcy1	Ltcy0
36	PULSE_WIND	Pulse 2nd Window R/W	Wind7	Wind6	Wind5	Wind4	Wind3	Wind2	Wind1	Wind0
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 Single Tap Only: 8g mode, 400 Hz ODR

Step 1: To set up any configuration make sure to be in Standby Mode.

```
IIC_RegWrite(0x38, 0x00); // 400Hz Standby Mode
```

Step 2: Enable X and Y and Z Single Pulse

```
IIC_RegWrite(0x2F, 0x15);
```

Step 3: Set Threshold 1.55g on X and 2.58g on Z

Note: Each step is 0.258g per count

- $1.55g / 0.258g = 6$ counts

- $2.58g / 0.258g = 10$ counts

```
IIC_RegWrite(0x31, 0x06); // Set X Threshold to 1.55g
```

```
IIC_RegWrite(0x32, 0x06); // Set Y Threshold to 1.55g
```

```
IIC_RegWrite(0x33, 0x0A); // Set Z Threshold to 2.58g
```

Step 4: Set Time Limit for Tap Detection to 50 ms

- Data Rate 400 Hz, time step is 0.625 ms

- $50 \text{ ms} / 0.625 \text{ ms} = 80$ counts

```
IIC_RegWrite(0x34, 0x50); // 50ms
```

Step 5: Set Latency Time to 300 ms

- Data Rate 400 Hz, time step is 1.25 ms

- $300 \text{ ms} / 1.25 \text{ ms} = 240$ counts

```
IIC_RegWrite(0x35, 0xF0); // 300 ms
```

Step 6: Route INT1 to System Interrupt

```
IIC_RegWrite(0x3B, 0x08); // Enable Pulse Interrupt Block in System Ctrl Reg4
```

```
IIC_RegWrite(0x3C, 0x08); // Route Pulse Interrupt Block to INT 1 hardware Pin CtrlReg5
```

Step 7: Active Mode 8g, 400 Hz ODR

```
IIC_RegWrite(0x38, 0x03);
```

6.2 Double Tap Only: 8g mode, 400 Hz ODR - Procedure

Step 1: To set up any configuration make sure to be in Standby Mode.

IIC_RegWrite(0x38, 0x00); // 400Hz, Standby Mode

Step 2: Enable X, Y and Z Double Pulse with DPA = 0 no double pulse abort

IIC_RegWrite(0x2F, 0x2A);

Step 3: Set Threshold 3g on X and Y and 5g on Z

Note: Every step is 0.258g

• $3.10\text{g}/0.258\text{g} = 12$ counts

• $5.16\text{g}/0.258\text{g} = 20$ counts

IIC_RegWrite(0x31, 0x0C); // Set X Threshold to 3.10g

IIC_RegWrite(0x32, 0x0C); // Set Y Threshold to 3.10g

IIC_RegWrite(0x33, 0x14); // Set Z Threshold to 5.16g

Step 4: Set Time Limit for Tap Detection to 60 ms

Note: 400 Hz ODR, Time step is 0.625 ms per step

• $60\text{ ms}/0.625\text{ ms} = 96$ counts

IIC_RegWrite(0x34, 0x60); // 60ms

Step 5: Set Latency Time to 200 ms

Note: 400 Hz ODR, Time step is 1.25 ms per step

• $200\text{ ms}/1.25\text{ ms} = 160$

IIC_RegWrite(0x35, 0xA0); // 200ms

Step 6: Set Time Window for second tap to 300 ms

Note: 400 Hz ODR, Time step is 1.25 ms per step

• $300\text{ ms}/1.25\text{ ms} = 240$ counts

IIC_RegWrite(0x36, 0xF0); // 300ms

Step 7: Route INT1 to System Interrupt

IIC_RegWrite(0x3B, 0x08); // Enable Pulse Interrupt in System Ctrl Reg4

IIC_RegWrite(0x3C, 0x08); // Route Pulse Interrupt to INT 1 hardware Pin CtrlReg5

Step 8: Set Active Mode 8g, 400 Hz ODR

IIC_RegWrite(0x38, 0x03);

6.3 Single Tap and Double Tap 8g mode, 200 Hz ODR - Procedure

Step 1: Go to Standby Mode to change configuration settings.

IIC_RegWrite(0x38, 0x04); // 200Hz, Standby Mode

Step 2: Enable X, Y, Z Single Pulse and X, Y and Z Double Pulse with DPA = 0 no double pulse abort

IIC_RegWrite(0x2F, 0x3F);

Step 3: Set Threshold 2.06g on X and Y and 4.13g on Z

Note: Every step is 0.258g

• $2.063\text{g} / 0.258\text{g} = 8$ counts

• $4.13\text{g} / 0.258\text{g} = 16$ counts

IIC_RegWrite(0x31, 0x08); // Set X Threshold to 2.06g

IIC_RegWrite(0x32, 0x08); // Set Y Threshold to 2.06g

IIC_RegWrite(0x33, 0x10); // Set Z Threshold to 4.13g

Step 4: Set Time Limit for Tap Detection to 60 ms

Note: 200 Hz ODR, Time step is 1.25 ms per step

- 60 ms /1.25 ms = 48 counts

IIC_RegWrite(0x34,0x30); // 60ms

Step 5: Set Latency Timer to 200 ms

Note: 200 Hz ODR, Time step is 2.5 ms per step

- 200 ms/ 2.5 ms = 80 counts

IIC_RegWrite(0x35,0x50); // 200ms

Step 6: Set Time Window for Second Tap to 300 ms

Note: 200 Hz ODR, Time step is 2.5 ms per step

- 300 ms/2.5 ms = 120 counts

IIC_RegWrite(0x36,0x78); // 300ms

Step 7: Route INT1 to System Interrupt

IIC_RegWrite(0x3B, 0x08); // Enable Pulse Interrupt Block in System Ctrl Reg4

IIC_RegWrite(0x3C, 0x08); // Route Pulse Interrupt Block to INT 1 hardware Pin CtrlReg5

Step 8: Active Mode 8g, 200 Hz ODR

IIC_RegWrite(0x38, 0x07);

Step 9: Write an Interrupt Service Routine

Interrupt void isr_KBI (void)

```
{
    //clear the interrupt flag
    CLEAR_KBI_INTERRUPT;
    //Determine the source of the interrupt by first reading the system
    interrupt register
    Int_SourceSystem =IIC_RegRead(0x15);
    //Set up Case Statement to service all the possible interrupts
    if((Int_SourceSystem&0x08)==0x08)
    {
        //Perform an Action since Pulse Flag has been Set
        //Read the Pulse Status Register to clear the system interrupt
        Int_SourcePulse=IIC_RegRead(0x30);
        // Can parse out the data here to perform a specific action
        //based on the flags set on each axis.
    }
}
```


7.0 Writing an Algorithm to Detect Directional Tap

Directional tap detection has various challenges due to the mechanics and vibration and placement of the sensor. The orientation that the object is tapped may not be on the axis where the accelerometer is placed. This can cause challenges in designing a repeatable algorithm for directional tap on all 6 faces of a 3D object. The MMA8450Q does not have a directional tap algorithm internally but by using the 32 sample FIFO and the embedded single tap detection the directional information can be extracted.

7.1 Sampling Rate Requirements for Tap Signatures

In order to detect the full signature of a tap a sample rate of 600 Hz or greater is required. The tap function sample rate is 1600 Hz internally when the ODR is set at 400 Hz. The tap signature shown in [Figure 2](#) was sampled at 2 kHz from an analog accelerometer to show the full signature of the tap. Therefore, trying to write a tap algorithm purely by using the FIFO data at 400 Hz may be somewhat limiting in that the faster taps and some of the signature of the tap may be missing. By using the embedded tap detection at 400 Hz with the FIFO, the directional information can be extracted without the need for continuous data polling. The tap is detected internally at 1600 Hz, while the directional information is analyzed at 400 Hz flushing the FIFO.

In many applications such as menu selections, typically there is only one or maybe two axes of importance. This simplifies the algorithm. For example, on a remote control to change the channel tapping in one axis in both directions is the only input. For simplified applications such as this the directional tap can work very well. There are larger challenges when all axes are enabled at the same time to reliably detect the axis of interest. There is often a lot of cross coupling due to vibrations and mounting of the accelerometer and also from the variation arising due to how different users tap.

7.2 Procedure for Directional Tap using the MMA8450Q

- Step 1:** Configure the accelerometer to be in 400 Hz 8g Mode, either Low Power Mode or Normal Mode depending on extra power savings required.
- Step 2:** Configure the FIFO to be in Circular Buffer Mode so that the data continuously overwrites. Refer to AN3920.
- Step 3:** Configure the embedded single pulse detection for detecting X, Y, Z single pulse with $X, Y = 3.67g$ and $Z = 6.19g$. Set the Time Limit to 50 ms for the pulse and set the latency to 500 ms.
- Step 4:** Set up the Pulse Detection in the System Interrupt Detection to detect on INT1.
- Step 5:** Configure the MCU to stay in Sleep Mode until INT1 is asserted if this is desired for additional current savings.
- Step 6:** When INT1 is asserted while the MCU is in sleep mode, wake the MCU/processor (3 ms max)
- Step 7:** Read the Pulse Source Register to determine which axes asserted the tap.
- Step 8:** Flush the FIFO approximately 12 ms after the interrupt is detected to collect the full signature of the tap.
- Step 9:** Read out the FIFO data and store it in a 32 sample buffer.
- Step 10:** Look at the Max and Min values of each axis whose flag was detected in the pulse source register.
- Step 11:** Determine the direction: If the first peak is greater in absolute value than the second peak, it is a positive tap, otherwise it is a negative tap.
- Step 12:** If more than one axis has triggered a valid tap, determine which event occurred first by analyzing the FIFO data.
- Step 13:** If the taps all occurred at the same time, the axis with the largest value calculating max-min is the axis the event occurred on.

For more in-depth details of developing a robust directional tap algorithm please contact Freescale for further assistance. There is a demo available in the Sensor Toolbox Software.

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