Technical Document

How to use BMA253 orientation interrupt for screen rotation

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1 Introduction

Like freefall detection, high acceleration shock detection and any motion wakeup features, screen rotation detection is another typical feature for a 3-axis MEMS accelerometer. It has been widely used in handheld devices such as smartphones, cameras and other PDAs.

Currently most MEMS accelerometers have built-in orientation interrupts. When it is running in high output data rate (ODR), there will be some false interrupts triggered by shaking the device in 3D space. Therefore, usually smartphones use algorithm to determine the orientation of the device rather than using the interrupts. One example is at http://tekeye.uk/android/examples/ui/android-portrait-landscape-screens.

This technical document explains the meaning of BMA253 built-in orientation interrupt configurations and presents how to test BMA253 orientation interrupt in normal mode. BMA253 low power mode 1 is not recommended due to false triggers.

1.1 Definition of screen rotation

The definition of screen rotation is as shown in Figure 1.

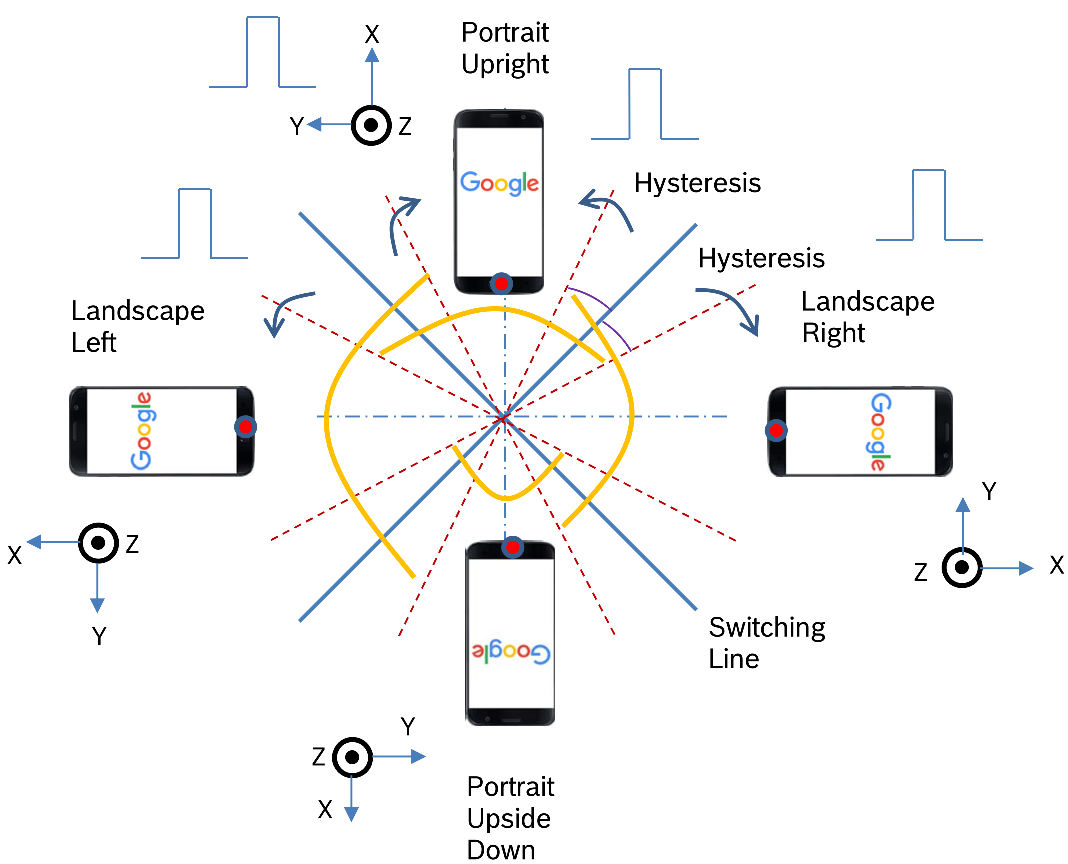

Figure 1 Screen rotation definition

Portrait Upright:	The device is in portrait mode, with the device held upright and the home button at the bottom.
Portrait Upside Down:	The device is in portrait mode but upside down, with the device held upright and the home button at the top.
Landscape Left:	The device is in landscape mode, with the device held upright and the home button on the right side.
Landscape Right:	The device is in landscape mode, with the device held upright and the home button on the left side.

Figure 1 shows symmetrical configuration of the orientation of the device with Z axis pointing out from the paper. This means that the switching line is at 45° with "X" shape (blue bold lines). Due to the noise of accelerometer, hysteresis needs to be considered. Otherwise, the screen of the device will be switching in different orientations back and forth unexpectedly.

Looking at the first quadrant of Figure 1, assuming the device is in Landscape Right and moving towards Portrait Upright along Z axis, the screen will not rotate at the switching line. Instead, it will switch after the switching line plus hysteresis (the upper red dotted line). Then rotating back and forth within the Portrait Upright zone (the up orange arc), the screen will not change. This means that the accelerometer orientation interrupt will be generated when crossing the upper red dotted line to Portrait Upright orientation and there will be no more interrupts generated when rotating back and forth inside the Portrait Upright zone.

Assuming the device is rotating back to Landscape Right along Z axis, then the screen will not rotate at the switching line. Instead, it will switch after the switching line minus hysteresis (the lower red dotted line). Then rotating back and forth within the Landscape Right zone (the right orange arc), the screen will not change. This means that the accelerometer orientation interrupt will be generated when crossing the lower red dotted line to Landscape Right orientation and there will be no more interrupts generated when rotating back and forth inside the Landscape Right zone.

Similarly, this applies to other orientation zones as well.

1.2 BMA253 orientation configurations

BMA253 is a 12-bit 3-axis digital accelerometer. It has built-in orientation interrupt feature. There are two registers to configure the orientation interrupt: 0x2C and 0x2D.

The definition of register 0x2C is as shown below:

Bit	**Bit-7**	**Bit-6**	**Bit-5**	**Bit-4**	**Bit-3**	**Bit-2**	**Bit-1**	**Bit-0**
Access	RW	RW	RW	RW	RW	RW	RW	RW
Reset value	0	0	0	1	1	0	0	0
Content	reserved	orient_hyst<2:0>			orient_blocking<1:0>		orient_mode<1:0>	

DATA	**Bits**	**Description**
orient_hyst<2:0>	<6:4>	1LSB corresponds to 62.5mg which is about 5° of hysteresis on the switching line. 2LSBs correspond to 125mg which is about 10° of hysteresis on the switching line.
orient_blocking<1:0>	<3:2>	00b – no blocking 01b – theta blocking, or acceleration in any axis > 1.5g 10b – theta blocking, or acceleration slope in any axis > 0.2g, or acceleration in any axis > 1.5g 11b – theta blocking, or acceleration slope in any axis > 0.2g, or acceleration in any axis > 1.5g and value of orient is not stable for at least 100ms
orient_mode<1:0>	<1:0>	01b – symmetrical 10b – high-asymmetrical 10b – low-asymmetrical 11b – symmetrical

Regarding hysteresis, we can look at the first quadrant in figure 1 as an example. At switching line X axis will have the measurement of sin(45°) * 1g = 0.707g.

- When hysteresis is 1LSB or 62.5mg, then the real switching angle will be asin(0.707g + 0.0625g) = 50.3° and asin(0.707g – 0.0625g) = 40.1°. So it is about ±5° with respect to the 45° switching line.

- When hysteresis is 2LSBs or 125mg, then the real switching angle will be asin(0.707g + 0.125g) = 56.3° and asin(0.707g – 0.125g) = 35.6°. So it is about ±10° with respect to the 45° switching line.

Regarding blocking, the device needs to be tilted so that Z axis of the accelerometer is not parallel to the gravity vector. This is so called theta blocking. If the tilt angle theta is smaller than the blocking_theta angle, then there will be no accelerometer orientation interrupt generated. In figure 1 the tilt angle theta of Z axis is 90°.

If the acceleration of any axis is greater than 1.5g or the slope of the acceleration is greater than 0.2g, then it can also be blocked which means that there will be no false orientation interrupts generated.

Regarding high-asymmetrical and low-asymmetrical, the switching line is not at 45°. Instead, they are at 63° and 27° respectively.

The definition of register 0x2D is as shown below:

Bit	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0
Access	RW	RW	RW	RW	RW	RW	RW	RW
Reset value	0	1	0	0	1	0	0	0
Content	reserved	orient_ud_en	orient_theta<5:0>					

DATA	Bits	Description
orient_ud_en	<6>	change of up/down bit. ‘1’ means to generate an orientation interrupt when Z axis changes direction from up to down or vice versa, ‘0’ means to ignore Z axis change of direction
orient_theta<5:0>	<5:0>	defines the blocking_theta angle between 0° and 44.8°. The default value of 001000b corresponds to 19°

In addition to the orientation interrupt for 4 orientations when Z axis of the accelerometer is tilted more than blocking_theta angle, BMA253 can also generate orientation interrupt when Z axis is pointing to sky from pointing to ground or from pointing to ground to pointing to sky if the orient_ud_en bit is set. Otherwise, there is no orientation interrupt generated when Z axis is flipping up and down.

Regarding blocking_theta angle, it can be calculated as $a\tan(\frac{\sqrt{orient\_theta}}{8})$. For example, orient_theta has maximum value of 63, then blocking_theta = atan(sqrt(63) / 8) = 44.77°. The default value of 001000b or 8LSBs corresponds to blocking_theta of atan(sqrt(8) / 8) = 19.47°.

The blocking_theta angle is shown in Figure 2.

Figure 2 Screen rotation blocking theta angle

1.3 BMA253 orientation interrupt

The orientation status can be retrieved from register 0x0C is as shown below:

Bit	Bit-7	Bit-6	Bit-5	Bit-4	Bit-3	Bit-2	Bit-1	Bit-0
Access	RW	RW	RW	RW	RW	RW	RW	RW
Reset value	0	0	0	1	1	0	0	0
Content	flat	orient<2:0>			high_sign	high_first_z	high_first_y	high_first_x

DATA	Bits	Description
flat	<7>	device is in ‘1’ -> flat, or ‘0’ -> non flat position with respect to Z axis
orient<2>	<6>	orientation value of Z axis: ‘0’ -> upward looking, or ‘1’ -> downward looking
orient<1:0>	<5:4>	00b Portrait upright 01b Portrait upside down 10b Landscape left 11b Landscape right

The orientation condition is as shown in Figure 3 without considering hysteresis.

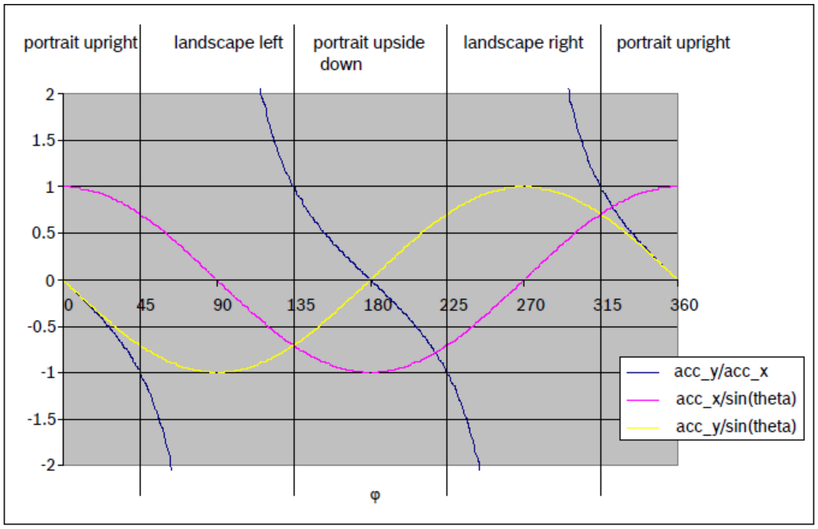

Figure 3 Orientation condition

In Figure 3, if theta is 90°, then sin(theta) = 1. It is the same as blocking_theta in Figure 2. The orientation conditions are described below.

- At Portrait Upright orientation zone, the absolute X axis values (magenta color) is greater than the absolute Y axis values (yellow color) and X values are positive.
- At Landscape Left orientation zone the absolute X axis values are smaller than the absolute Y axis values and Y axis values are negative.
- At Portrait upside down orientation zone, the absolute X axis values is greater than the absolute Y axis values and X values are negative.
- At Landscape Right orientation zone the absolute X axis values are smaller than the absolute Y axis values and Y axis values are positive.

The orientation interrupt can be enabled by setting orient_en bit-6 in register 0x16 to ‘1’. And the orientation interrupt will be generated when the orient<2:0> bits from bit-4 to bit-6 in register 0x0C have changed if the orient_ud_en bit-6 in register 0x2D is set. If the orient_ud_en bit-6 in register 0x2D is cleared, then the change of bit-6 in register 0x0C will not generate orientation interrupt. Only the change of bit-5 and bit-4 will generate orientation interrupts.

The orientation interrupt signal will last 1/ODR and it can be temporarily latched or latched. If the orientation interrupt when Z axis is flipping from upward looking to downward looking or vice versa, then the orient_ud_en bit-6 should be cleared.

The orientation interrupt should be used in normal mode (130uA), not in low power mode 1, because there will be some false orientation interrupts triggered when shaking the device in 3D space.

2 Sample code

Below is the pseudo code to initialize BMA253 for orientation interrupt. The settings can be fine-tuned to meet the requirements in different applications.

```
// BMA253 initialization routine
void init_BMA253(void)
{
        // configure common control registers
        Write 0x03 to register 0x0F;        // default value for ±2g full scale range
        Write 0x08 to register 0x10;        // set to 7.81Hz bandwidth or 15.6Hz ODR (130uA)
        Write 0x00 to register 0x11;        // default value for normal mode

        // configure interrupt registers
        Write 0x40 to register 0x19;        // route orientation interrupt to INT1 pin
        Write 0x80 to register 0x1A;        // route data ready interrupt to INT2 pin (optional)
        Write 0x05 to register 0x20;        // default value for active-high, push-pull INT1,2 pins
        Write 0x28 to register 0x2C;        // set 2LSBs for orient_hyst (+/-10° hysteresis),
                                            symmetrical mode and theta blocking with
                                            acceleration slope in any axis > 0.2g or acceleration
                                            in any axis > 1.5g blocking
        Write 0x08 to register 0x2D;        // set 19° blocking_theta and disable Z axis flipping
                                            to generate orientation interrupt

        // enable orientation interrupt
        Write 0x40 to register 0x16;        // enable orientation interrupt
}

// Interrupt service routine
void isr_BMA253(void)
{
        char val;

        val = read register 0x0C;           // read orientation status register
        val = (val & 0x30) >> 4;            // retrieve orientation information
        switch(val)
        {
                case 0: output Portrait Upright; break;
                case 1: output Portrait upside down; break;
                case 2: output Landscape Left; break;
                case 3: output Landscape Right; break;
        }
}
```

3 Test results

The hardware setup is shown in Figure 4. The Bluetooth version of APP2.0 base board is used together with BMA253 shuttle board plugged in. The X/Y/Z axes of BMA253 are shown in on the top of the orthogonal plastic box.

The development desktop DD2.0 GUI software talks to the APP2.0 base board through Bluetooth virtual COM port.

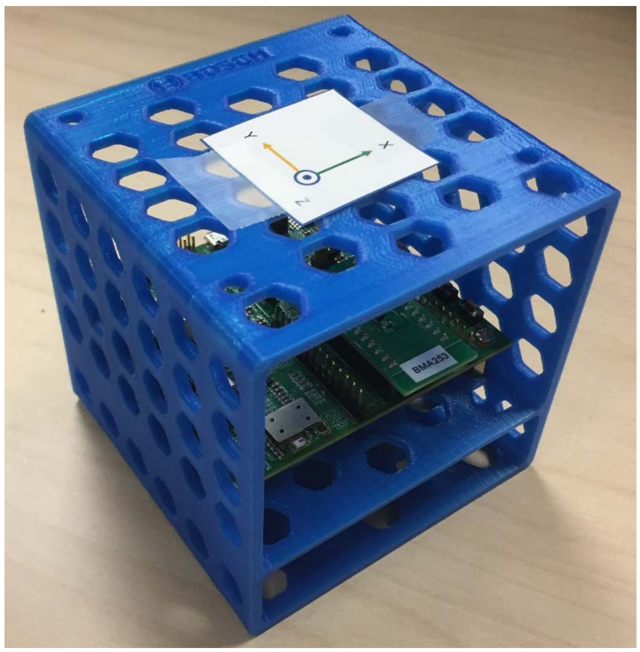

Figure 4 Hardware setup

Figure 5 is the screenshot of DD2.0 GUI. It shows the BMA253 raw data (X – green, Y – yellow, Z – red) and the orientation interrupt signal on INT1 pin and data ready interrupt on INT2 pin. When rotating the plastic box along X-Y plane with Z axis flat, the orientation interrupt triggers when entering the four zones. As it can be seen, the orientation interrupt aligns to the orientation conditions in Section 1.3.

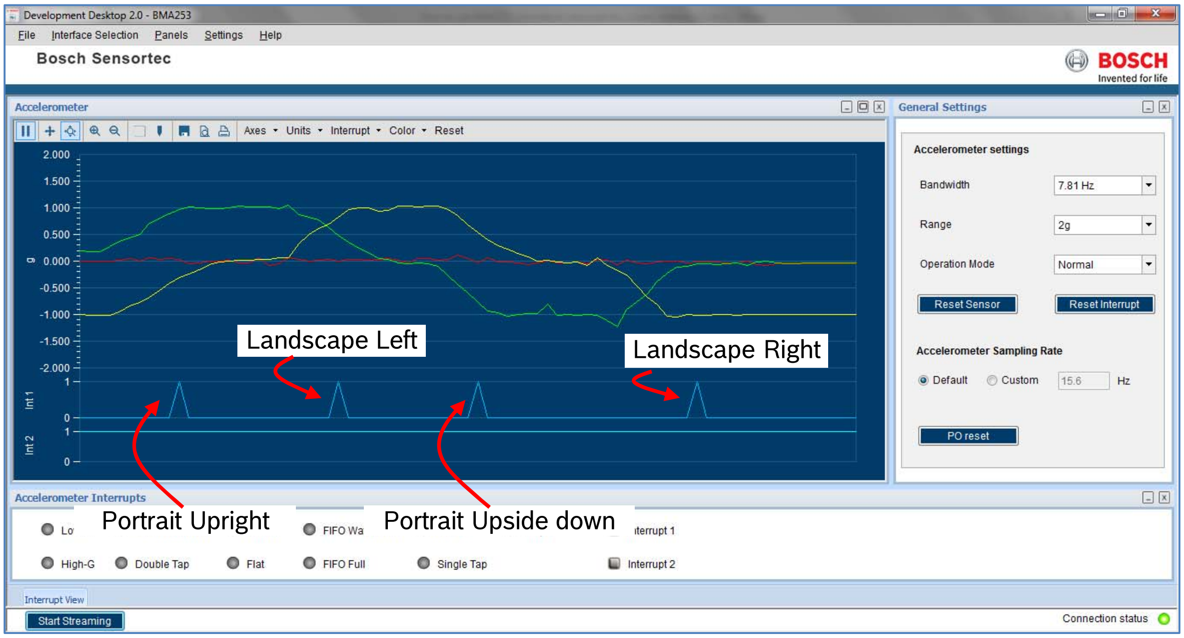

Figure 5 Orientation interrupts

Figure 6 is the screenshot of the logic analyzer. When orientation interrupt happens on INT1 pin it lasts about 1/ODR = 1/15.625Hz = 64ms and the interrupt rising edge is aligned to the data ready signal on INT2 pin.

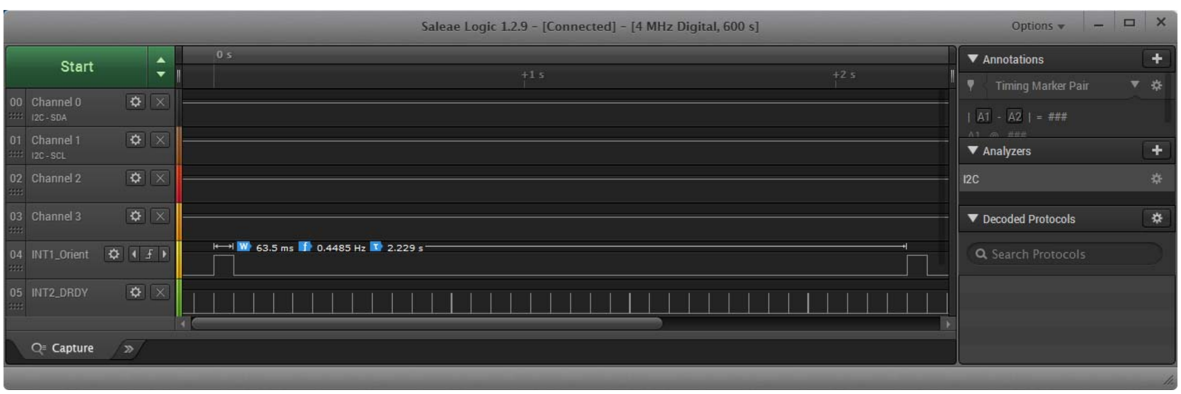

Figure 6: Logic analyzer screenshot

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5 Document history and modification

Rev. No	Chapter	Description of modification/changes	Date
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