Technical Document

How to perform BMI160 self-test

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1 Introduction

BMI160 is a highly integrated low power MEMS inertial measurement unit (IMU) that includes a 16-bit 3-axis accelerometer (ACC) and a 16-bit 3-axis gyroscope (GYR). Each BMI160 is factory calibrated, trimmed and tested before being shipped to end users. Therefore, for most consumer electronics applications, it is not required to perform accelerometer and gyroscope calibration in users' production lines.

BMI160 has built-in self-test feature to quickly determine if the ACC and GYR will work properly or not after PCB reflow process without the need of physically tilting or rotating the PCB. The PCB should be stationary in the production line for self-test. If both ACC and GYR self-tests pass, then the BMI160 will operate according to the specifications in the datasheet.

The criteria for ACC self-test is as shown in Figure 1. The absolute difference between the acceleration values in positive direction and negative direction of the self-test should be larger than 2g for all three axes. The ACC self-test should be performed at ±8g full scale (FS) range and the sensitivity is 4096 LSBs/g. Therefore, 2g corresponds to 8192 LSBs.

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Table 23: Accelerometer self test minimum difference values

	x-axis signal	y-axis signal	z-axis signal
Minimum difference signal	2 g	2 g	2 g

It is recommended to perform a reset of the device after a self-test has been performed. If the reset cannot be performed, the following sequence must be kept to prevent unwanted interrupt generation: disable interrupts, change parameters of interrupts, wait for at least 50ms, enable desired interrupts.

Figure 1 BMI160 ACC self-test criteria

The GYR self-test is straightforward. After enabling GYR self-test the result can be read out from STATUS register 0x1B to see if the self-test passes or fails.

Section 2 of this document shows the evaluation board hardware and Windows demo software. BMI160 ACC and GYR self-tests are presented using these tools in Section 3. The sample pseudo codes for both ACC and GYR self-test with example data are presented in Section 4.

2 Hardware and software setup

The hardware set is as shown in Figure 2. BMI160 shuttle board is plugged onto the application board APP2.0. Then the APP2.0 board is connected to a PC USB port.

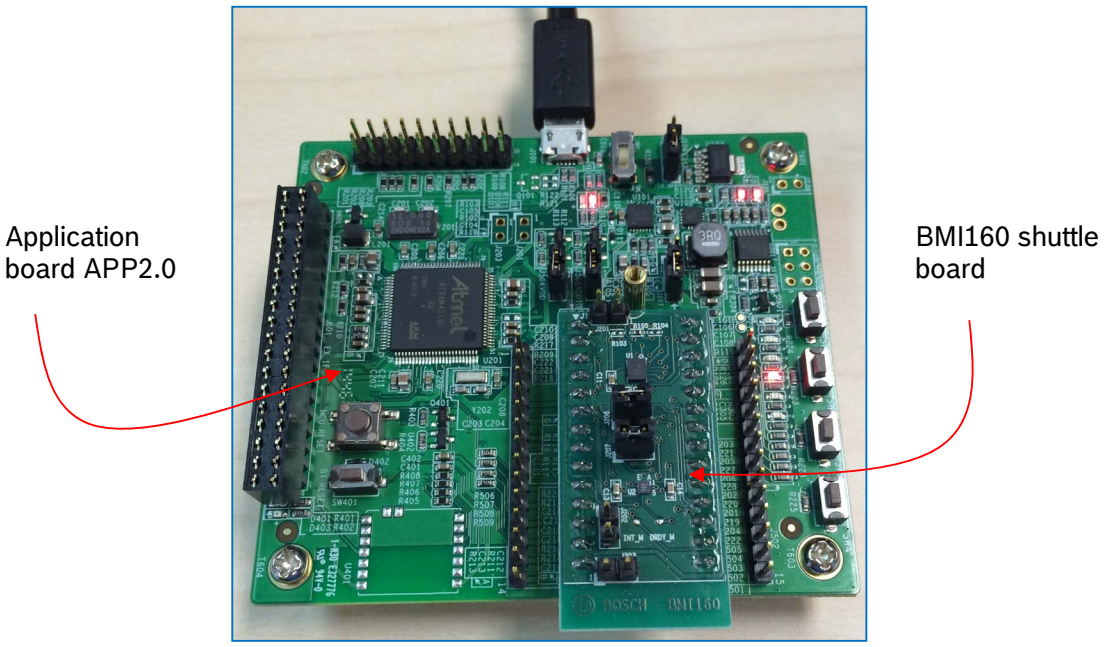

Figure 2 APP2.0 board hardware setup

The Windows demo software Development Desktop 2.0 (DD2.0) is running on the PC as shown in Figure 3. Users can configure sensors' registers and evaluate the features of each sensor.

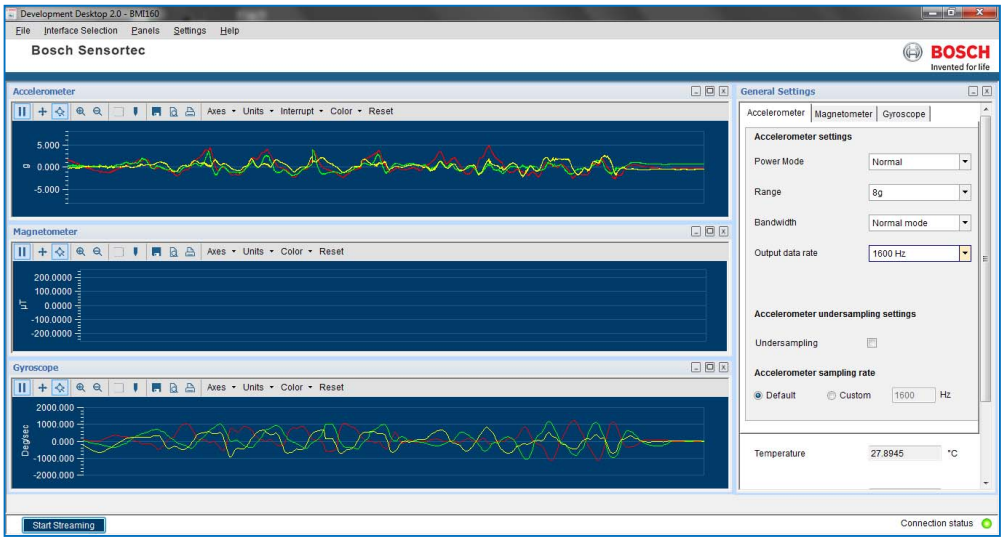

Figure 3 DD2.0 Windows demo software

3 BMI160 self-test

3.1 ACC self-test

According to the datasheet, the ACC self-test,

(1) should be performed at ±8g full scale range normal mode with 1600Hz output data rate (ODR)
(2) should have the amplitude set to high which means that the acc_self_test_amp bit in register 0x6D should be set to “1”
(3) should be triggered with any axis at positive direction, then read the acceleration values after 50ms delay
(4) should be triggered with any axis at negative direction, then read the acceleration values after 50ms delay
(5) should calculate the difference between positive direction and negative direction to see if it is larger than 2g or 8192 LSBs
(6) should have the soft reset once the self-test is done

Figure 4 shows ACC self-test at positive direction. Any axis can be used for self-test and then the acceleration values of X/Y/Z axes can be read from data registers 0x12 to 0x17.

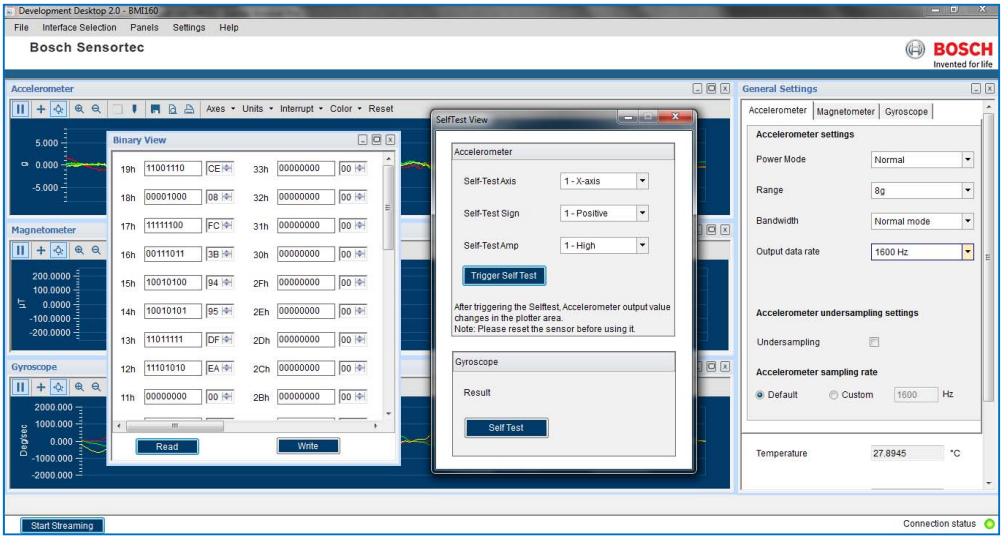

Figure 4 ACC self-test at positive direction

It can be seen in Figure 4 that,

Ax_+ = [(0x13 << 8) | 0x12] = 0xDFEA = -8214 LSBs
Ay_+ = [(0x15 << 8) | 0x14] = 0x9495 = -27499 LSBs
Az_+ = [(0x17 << 8) | 0x16] = 0xFC3B = -965 LSBs

Figure 5 shows ACC self-test at negative direction.

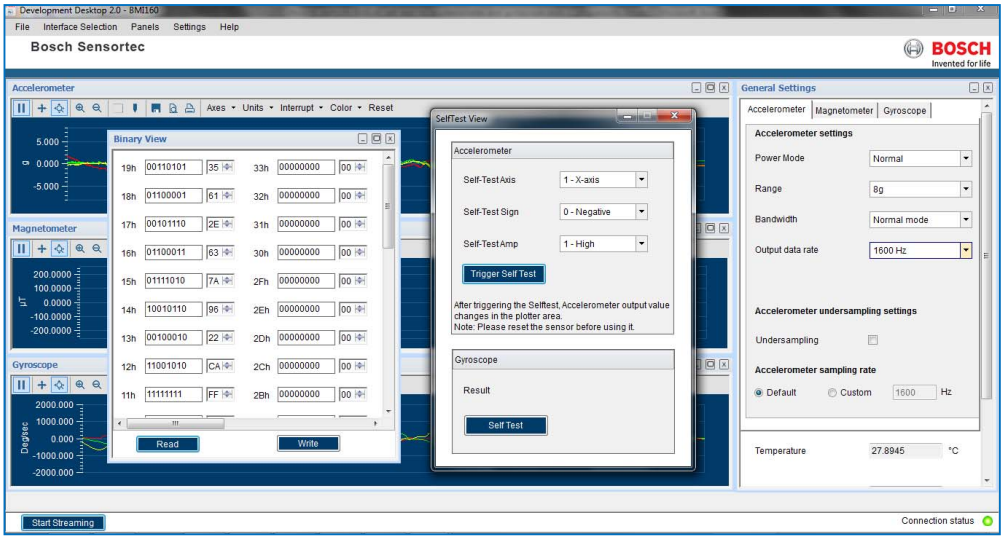

Figure 5 ACC self-test at negative direction

It can be seen in Figure 5 that,

Ax_{-} = [(0x13 << 8) | 0x12] = 0x22CA = 8906 LSBs
Ay_{-} = [(0x15 << 8) | 0x14] = 0x7A96 = 31382 LSBs
Az_{-} = [(0x17 << 8) | 0x16] = 0x2E63 = 11875 LSBs

Therefore, the ACC self-test results are,

$Ax\_selftest = abs(Ax_{+} - Ax_{-}) = abs(-8214 - 8906) = 17120$ LSBs
$Ay\_selftest = abs(Ay_{+} - Ay_{-}) = abs(-27499 - 31382) = 58881$ LSBs
$Az\_selftest = abs(Az_{+} - Az_{-}) = abs(-965 - 11875) = 12840$ LSBs

Because the ACC self-test results of X/Y/Z axes are all larger than 8192 LSBs or 2g, the ACC self-test passes.

3.2 GYR self-test

According to the datasheet, the GYR self-test,

(1) should be performed at normal mode with any full scale range and any ODR
(2) should be triggered by setting the gyr_self_test_enable bit in register 0x6D to "1"
(3) should have 20ms delay after triggering self-test
(4) should check the gyr_self_test_ok bit in STATUS register 0x1B. If the bit is "1", then it means the GYR self-test passes. Otherwise, it fails.

Figure 6 shows the GYR self-test at normal mode with default ±2000dps full scale range and 100Hz ODR. After clicking the "Self Test" button in Gyroscope panel, the result shows "PASS" immediately. This is with respect to the value in register 0x1B. The value is 0x10 before GYR self-test and 0x12 after GYR self-test.

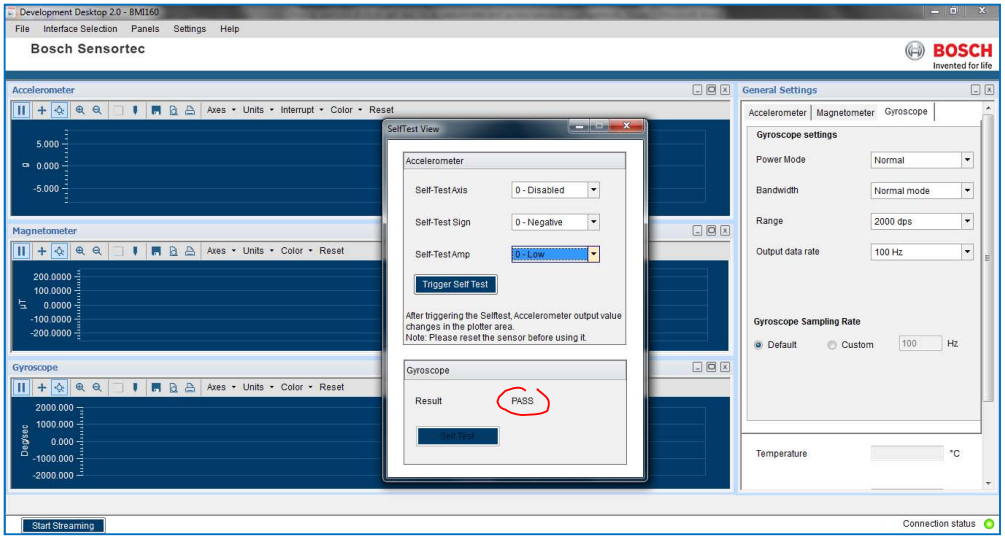

Figure 6 GYR self-test

4 Sample code for self-test

The following is the pseudo code for BMI160 ACC and GYR self-test. BMI160 is stationary during the self-test.

```
void BMI160_ACC_selftest(void)
{
    // basic configurations
    Write value of 0xB6 to register 0x7E;          // soft reset BMI160 to default settings
    Delay 50ms;
    Write value of 0x11 to register 0x7E;          // set the accelerometer to normal mode
    Delay 5ms;                                     // wait for accelerometer to stabilize
    Write value of 0x08 to register 0x41;          // set FS range to +/-8g
    Write value of 0x2C to register 0x40;          // set ODR to 1600Hz

    // start ACC self-test. The acc_self_test_amp bit in register 0x6D must be set
    Write value of 0x0D to register 0x6D;          // enable self-test at positive direction
    Delay 50ms;
    Read 6 bytes data registers from 0x12 to 0x17 as Ax+, Ay+ and Az+;
    // example:     Ax+ = [(0x13 << 8) | 0x12] = 0xDFEA = -8214 LSBs
                    Ay+ = [(0x15 << 8) | 0x14] = 0x9495 = -27499 LSBs
                    Az+ = [(0x17 << 8) | 0x16] = 0xFC3B = -965 LSBs

    Write value of 0x09 to register 0x6D;          // enable self-test at negative direction
    Delay 50ms;
    Read 6 bytes data registers from 0x12 to 0x17 as Ax-, Ay- and Az-;
    // example:     Ax- = [(0x13 << 8) | 0x12] = 0x22CA = 8906 LSBs
                    Ay- = [(0x15 << 8) | 0x14] = 0x7A96 = 31382 LSBs
```

Az- = [(0x17 << 8) | 0x16] = 0x2E63 = 11875 LSBs

```
    // calculate self-test results
    Ax_selftest = abs(Ax+ – Ax-);
    Ay_selftest = abs(Ay+ – Ay-);
    Az_selftest = abs(Az+ – Az-);
    // example:     Ax_selftest = abs(-8214 – 8906) = 17120 LSBs
                    Ay_selftest = abs(-27499 – 31382) = 58881 LSBs
                    Az_selftest = abs(-965 – 11875) = 12840 LSBs

    // conclusion: at +/-8g FS range, 2g corresponds to 8192 LSBs
    If ((Ax_selftest >= 8192 LSBs) && (Ay_selftest >= 8192 LSBs) && (Az_selftest >= 8192
    LSBs))
            BMI160 ACC self-test PASSES
    Otherwise,
            BMI160 ACC self-test FAILS

    Write value of 0xB6 to register 0x7E;       // soft reset BMI160 to default settings and
                                                exit
    Delay 50ms;
}

void BMI160_GYR_selftest(void)
{
    // basic configurations
    Write value of 0xB6 to register 0x7E;       // soft reset BMI160 to default settings
    Delay 50ms;
    Write value of 0x15 to register 0x7E;       // set the GYR to normal mode with default
                                                ±2000dps full scale range and 100Hz ODR
    Delay 55ms;                                 // wait for GYR to stabilize

    // start GYR self-test
    Write value of 0x10 to register 0x6D;       // enable GYR self-test
    Delay 20ms;                                 // wait for selftest to be done
    GYR_selftest = Read register 0x1B;          //read STATUS register 0x1B

    // conclusion:
    If ((GYR_selftest & 0x02) != 0))
            BMI160 GYR self-test PASSES
    Otherwise,
            BMI160 GYR self-test FAILS

    Write value of 0xB6 to register 0x7E;       // soft reset BMI160 and exit
    Delay 50ms;
}
```

5 Legal disclaimer

5.1 Engineering samples

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6 Document history and modification

Rev. No	Chapter	Description of modification/changes	Date
1.0		Document creation	May 28th, 2015
1.1	4	Added “Delay 55ms; // wait for GYR to stabilize” and “Delay 20ms; // wait for selftest to be done” in BMI160_GYR_selftest function	May 25th, 2016
1.2	4	Added “Delay 5ms; // wait for accelerometer to stabilize” in BMI160_ACC_selftest function	May 26th, 2016

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