
ST's MEMS accelerometer sensor testing & self-test

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Main components	
LIS2DW12	High-performance ultra-low-power 3-axis "femto" accelerometer

Purpose and benefits

This design tip explains how to test the functionality of ST's MEMS accelerometer sensors in customer applications during production processes or during product lifetime. More precisely, it discusses how to use the embedded self-test feature and other options in the sensors with the focus on accelerometers and in particular the LIS2DW12.

Description

Sensor testing is a way of determining if the sensor is working properly after its assembly on the PCB in a customer's application during tests of final goods production or during its operation in the field after installation within a given period of time defined by the customer. Sensor testing can identify whether correct communication with the MCU can be established or if the sensor's mechanical element is working properly. There are several ways of checking the condition of the sensor which are described in the following paragraphs.

Checking serial communication

In order to determine whether serial communication with the sensor is working fine, it is sufficient to read the WHO_AM_I register and to compare it with the expected value stated in the device datasheet. A more advanced test compares values read from the device control registers with those that have been previously written to them by the customer's testing code.

Self-test feature

The self-test feature embedded in a MEMS sensor allows checking the functionality of its mechanical part without needing to apply any defined external motion. When the self-test feature is enabled, an electrostatic force deflecting the mechanical sensing element is activated inside the sensor, simulating device movement. As a consequence, output data of a fully functional device will change within limits predefined in the device datasheet. See an example for the LIS2DW12 in Figure 1.

Figure 1. Self-test limits for LIS2DW12

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
ST	Self-test positive difference		70		1500	mg

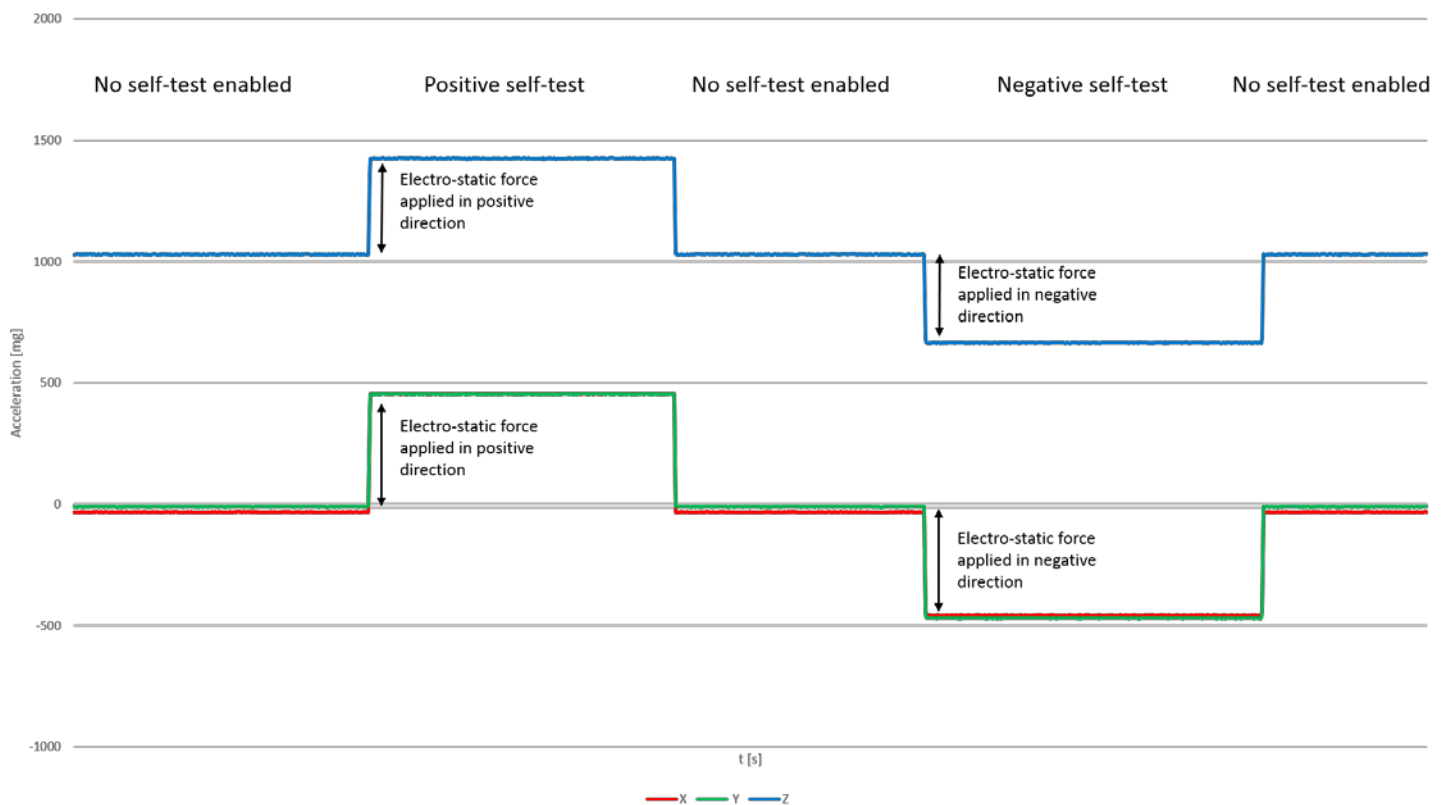
✎ These limits can be found in the datasheet of every ST MEMS sensor.
 Note that the sensor should be placed in a stable environment while conducting the self-test sequence = no motion applied externally.

The advantage of using the self-test feature is that you do not need to (actually you **must not**) physically move the device during the test. Moreover it is very fast as it takes no more than one second of data processing. During the self-test, the user also ensures that the serial communication with the device is working properly.

Positive sign and negative sign self-test

The positive and the negative sign of the self-test tells us in which direction is the mechanical part of the accelerometer deflected by the applied internal electrostatic force. The direction option is available in the sensor configuration registers and the user can select one or the other direction as preferred. The only difference is that the positive sign self-test applies static force in the positive direction and the negative sign self-test in the opposite direction, see Figure 2.

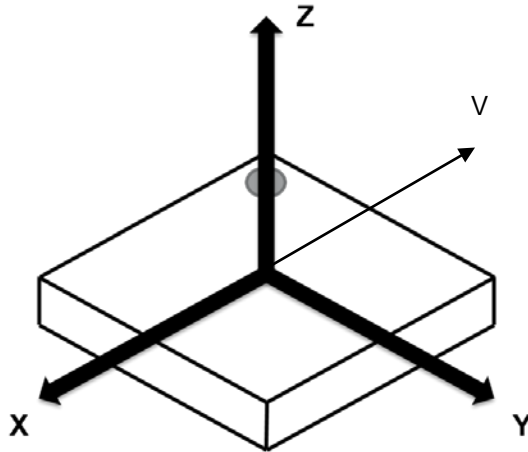
Figure 2. LIS2DW12's direction of the detectable accelerations and force vector V



Checking sensor outputs in static condition

In this test the user sets up the sensor's registers for measurement and checks that the device outputs are as expected. For an accelerometer, without applying an external motion, the user should see the Earth's gravity vector projected to one or more axes of the sensor.

Figure 3. LIS2DW12's direction of the detectable accelerations and force vector V



One of the methods to check sensor outputs in static condition is to calculate the g -force vector V .

Looking at Figure 3, you can see three axes and the force vector V . The values of X, Y and Z, which the accelerometer outputs, are a projection of the force vector V in the X, Y and Z axes.

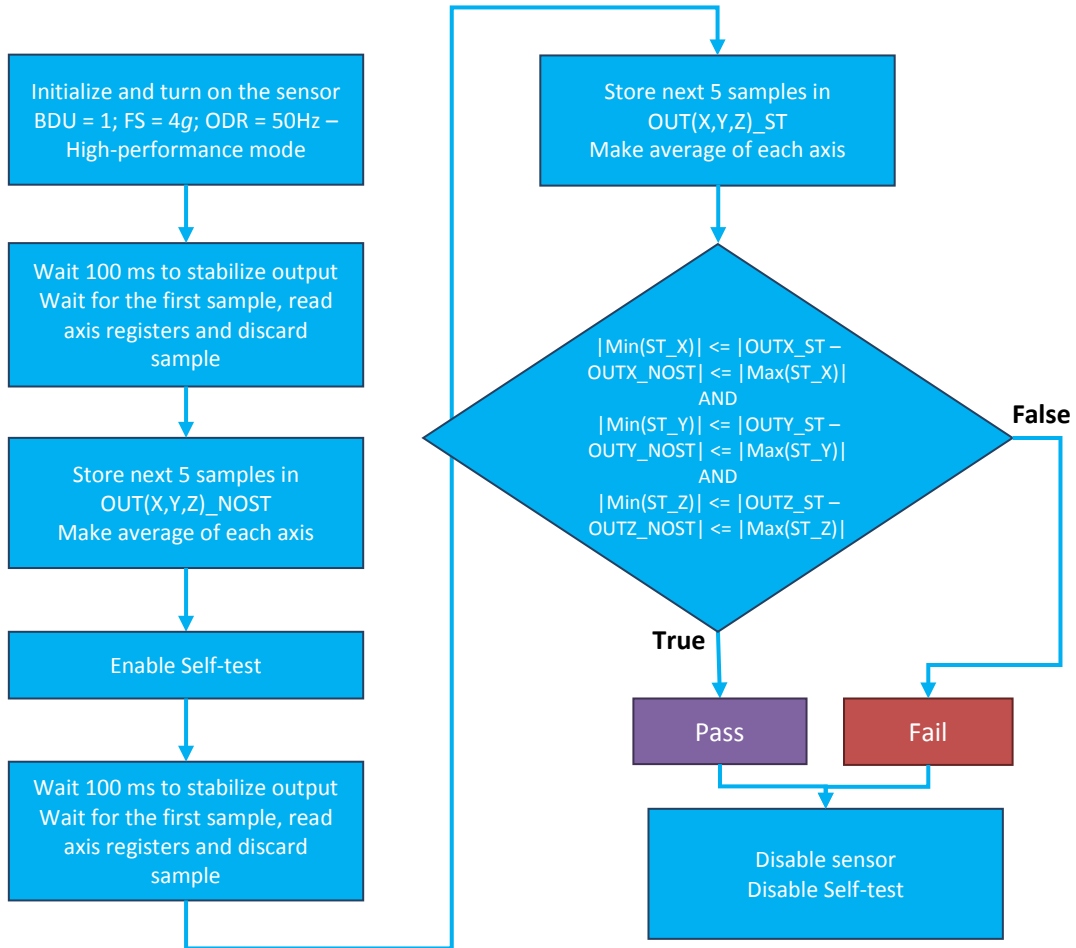
When the sensor is in a static condition, it measures only the Earth's gravitational force. The **size** of the vector of the Earth's gravitational force is approximately 9.81 m/s^2 (1 g). This size will be always the same as long as the sensor is in static position no matter how the sensor is oriented. In 3D space, the vector size is calculated by the Pythagorean Theorem: $D^2 = A^2 + B^2 + C^2$. We can apply this formula to our case as follows:
 $|V| = \sqrt{X^2 + Y^2 + Z^2}$. We will use this fact to check if the sensor is working properly.

It is important to consider that every sensor has some non-zero offset, in the case of an accelerometer, a zero- g offset. When doing comparison with sensor outputs in static condition we need to take this into account. Nevertheless if the difference between the accelerometer output vector magnitude and 1 g is too big, we can say that the sensor is not working properly.

Self-test flowchart for LIS2DW12

Important Note: The self-test of each MEMS sensor should be done according to the procedure specified in the corresponding device datasheet or application note.

Note: All of the read/write operations in this procedure are done over the device I²C or SPI interface.



Self-test pseudocode for LIS2DW12

```

int main(void)
{
    initMCU();           /* Initialize MCU clock and pins */
    LIS2DW12_RegisterReset();
    print("Starting program Self-test for LIS2DW12\r\n");

    /* Initialization */
    writeReg(0x21, 0x08); /* BDU */
    writeReg(0x25, 0x10); /* FS ±4 g */
    writeReg(0x20, 0x44); /* ODR 50Hz, High-performance */
  
```

```

/* Wait for 100ms - stabilize output */
delay(100);

/* Discard first sample */
waitForDataReady();
getAxes(X_DISCARD,Y_DISCARD,Z_DISCARD);

/* Obtain 5 no self test samples */
for ( i = 0; i < 5; i++ )
{
    waitForDataReady();
    getAxes(&X_TMP[i],&Y_TMP[i],&Z_TMP[i]);
}

/* Make average of each axis */
OUTX_NOST = getAverage(X_TMP, X_TMP_len);
OUTY_NOST = getAverage(Y_TMP, Y_TMP_len);
OUTZ_NOST = getAverage(Z_TMP, Z_TMP_len);

/* Enable positive sign self-test */
writeReg(0x22, 0x40);

/* Wait for 100ms - stabilize output */
delay(100);

/* Discard first sample */
waitForDataReady();
getAxes(X_DISCARD,Y_DISCARD,Z_DISCARD);

/* Obtain 5 self test samples */
for ( i = 0; i < 5; i++ )
{
    waitForDataReady();
    getAxes(&X_TMP[i],&Y_TMP[i],&Z_TMP[i]);
}

/* Make average of each axis */
OUTX_ST = getAverage(X_TMP, X_TMP_len);
OUTY_ST = getAverage(Y_TMP, Y_TMP_len);
OUTZ_ST = getAverage(Z_TMP, Z_TMP_len);

/* MinST_X/Y/Z and MaxST_X/Y/Z are self-test limits specified in LIS2DW12 DS */
MinST_X = MinST_Y = MinST_Z = 70;

```

```

MaxST_X = MaxST_Y = MaxST_Z = 1500;

/* Pass/fail */
if ( ( MinST_X <= abs(OUTX_ST-OUTX_NOST) <= MaxST_X ) &&
      ( MinST_Y <= abs(OUTY_ST-OUTZ_NOST) <= MaxST_Y ) &&
      ( MinST_Z <= abs(OUTZ_ST-OUTZ_NOST) <= MaxST_Z ) )
{
    /* PASS */
    print("Passed\r\n");
}
else
{
    /* FAIL */
    print("Failed\r\n");
}

/* Disable sensor and self-test */
writeReg(0x20, 0x00);
writeReg(0x22, 0x00);

while(1);
}

```

Acceleration vector calculation pseudocode

```

float vectorCalculation (float AXIS_X, float AXIS_Y, float AXIS_Z)
{
    return sqrt(AXIS_X * AXIS_X + AXIS_Y * AXIS_Y + AXIS_Z * AXIS_Z);
}

```

Support material

Related design support material
Product Evaluation board – STEVAL-MKI179V1, LIS2DW12 adapter board for a standard DIL 24 socket
Documentation
Datasheet LIS2DW12, High-performance ultra-low-power 3-axis "femto" accelerometer
Application note AN5038, LIS2DW12: MEMS digital output motion sensor ultra-low-power high-performance 3-axis "nano" accelerometer

Revision history

Date	Version	Changes
04-Feb-2019	1	Initial release

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