

---

## Getting started with MotionAC accelerometer calibration library in X-CUBE-MEMS1 expansion for STM32Cube

### Introduction

The MotionAC is a middleware library part of X-CUBE-MEMS1 software and runs on STM32. It provides real-time accelerometer calibration through offset and scale factor coefficients used to correct accelerometer data.

This library is intended to work with ST MEMS only.

The algorithm is provided in static library format and is designed to be used on STM32 microcontrollers based on the ARM Cortex-M3 or ARM Cortex-M4 architecture.

It is built on top of STM32Cube software technology that ease portability across different STM32 microcontrollers.

The software comes with sample implementation running on X-NUCLEO-IKS01A1 (with optional STEVAL-MKI160V1) or X-NUCLEO-IKS01A2 expansion board on a NUCLEO-F401RE, NUCLEO-L476RG or NUCLEO-L152RE development board.

## 1 Acronyms and abbreviations

---

**Table 1. List of acronyms**

Acronym	Description
API	Application programming interface
BSP	Board support package
GUI	Graphical user interface
HAL	Hardware abstraction layer
IDE	Integrated development environment

## 2 MotionAC middleware library in X-CUBE-MEMS1 software expansion for STM32Cube

### 2.1 MotionAC overview

The MotionAC library expands the functionality of the X-CUBE-MEMS1 software.

The library acquires data from the accelerometer and calculates the offset and scale factor coefficients together with the calibration quality value. Calibration can be done in two modes: dynamic calibration and 6-point calibration. The offset and scale factor coefficients are then used to compensate raw data coming from accelerometer.

The library is designed for ST MEMS only. Functionality and performance when using other MEMS sensors are not analyzed and can be significantly different from what described in the document.

Sample implementation is available on X-NUCLEO-IKS01A2 and X-NUCLEO-IKS01A1 (with optional STEVAL-MKI160V1) expansion boards, mounted on a NUCLEO-F401RE, NUCLEO-L476RG or NUCLEO-L152RE development board.

### 2.2 MotionAC library

Technical information fully describing the functions and parameters of the MotionAC APIs can be found in the MotionAC\_Package.chm compiled HTML file located in the Documentation folder.

#### 2.2.1 MotionAC library description

The MotionAC accelerometer calibration library manages data acquired from accelerometer; it features:

- offset compensation up to 0.2 g
- scale factor compensation, in range from 0.8 to 1.2 in every direction
- update frequency from 20 to 100 Hz
- occupies 11 kB of code and 2 kB of data memory

*Note:* Real size might differ for different IDE (toolchain)

- available for ARM Cortex-M3 and Cortex-M4 architectures

#### 2.2.2 MotionAC APIs

The MotionAC APIs are:

- `uint8_t MotionAC_GetLibVersion(char *version)`
  - retrieves the version of the library
  - `*version` is a pointer to an array of 35 characters
  - returns the number of characters in the version string
- `void MotionAC_Initialize(uint8_t enable)`
  - performs MotionAC library initialization and setup of the internal mechanism
  - the CRC module in STM32 microcontroller (in RCC peripheral clock enable register) has to be enabled before using the library
  - Note:* This function must be called before using the accelerometer calibration library.
  - `enable` parameter enables (1) or disables (0) the library
- `void MotionAC_Update (MAC_input_t *data_in, uint8_t *is_calibrated)`
  - executes accelerometer calibration algorithm
  - `*data_in` parameter is a pointer to a structure with input data
  - the parameters for the structure type `MAC_input_t` are:

- `Acc[3]` is an array of accelerometer sensor value in g
- `TimeStamp` parameter is the timestamp for accelerometer output values in ms
- `*is_calibrated` parameter is a pointer to a value which returns 1 if calibration is done with current sample, 0 otherwise

**Note:** This function has to be called periodically at the same period that is indicated in the initialization function.

- `uint8_t MotionAC_SetKnobs(MAC_knobs_t*knobs)`
  - sets current knob settings
  - returns 1 in case of success and the library is running, 0 otherwise
  - `*knobs` parameter is a pointer to a structure with settings
  - the parameters for the structure type `MAC_knobs_t` are:
    - `Run6PointCal` should be 1 in case of 6-point calibration, 0 in case of dynamic calibration (slow motion of the device)
    - `Sample_ms` parameter is the accelerometer sensor sample period in ms
    - `MoveThresh_g` parameter is recommended to be kept between 0.15 - 0.30 g; a higher value loosens the condition on data selection for the calibration but reduces the accuracy (around `moveThresh_g / 10`)
- `void MotionAC_GetCalParams (MAC_output_t *data_out)`
  - retrieves the accelerometer calibration coefficients for offset and scale factor compensation and calibration quality factor
  - `*data_out` parameter is a pointer to a structure with input data
  - the parameters for the structure type `MAC_output_t` are:
    - `AccBias[3]` is an array of the offset for each axis in g
    - `SF_Matrix[3][3]` is the scale factor correction 3x3 matrix (diagonal matrix)
    - `CalQuality` is the calibration quality factor:
      - `MAC_CALQSTATUSUNKNOWN = 0`; accuracy of calibration parameters is unknown
      - `MAC_CALQSTATUSPOOR = 1`; accuracy of calibration parameters is poor, cannot be trusted
      - `MAC_CALQSTATUSOK = 2`; accuracy of calibration parameters is OK
      - `MAC_CALQSTATUSGOOD = 3`; accuracy of calibration parameters is good.

### 2.2.3 Storing and loading calibration parameters

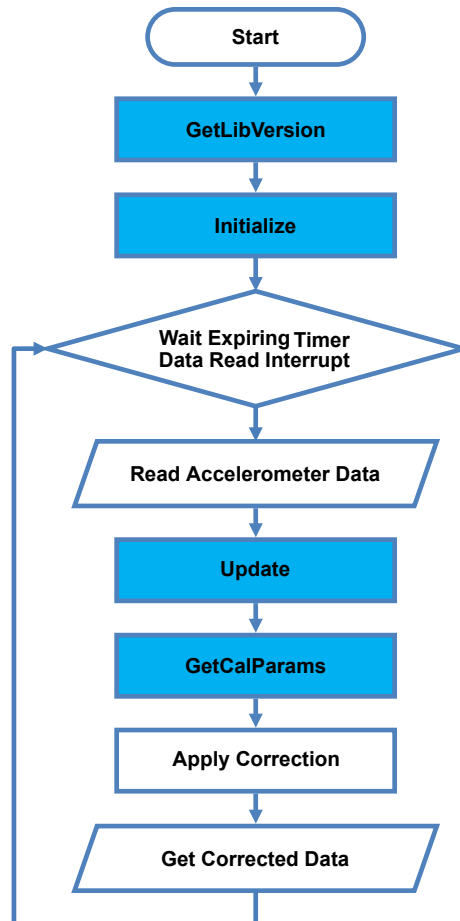
The following functions have to be implemented specifically for each target platform:

- `char MotionAC_LoadCalFromNVM (unsigned short int dataSize, unsigned int *data)`
  - the function is used to retrieve the accelerometer calibration parameters from storage
  - `dataSize` is the data size
  - `*data` is the data location pointer
  - returns 0 for correct loading, 1 otherwise
- `char MotionAC_SaveCalInNVM (unsigned short int dataSize, unsigned int *data)`
  - the function is used to save the accelerometer calibration parameters in storage
  - `dataSize` is the data size
  - `*data` is the data location pointer
  - returns 0 for correct loading, 1 otherwise

These functions need to be implemented but should not be called; the accelerometer calibration library decides when to call these functions. They may be implemented as empty (always return 0) if saving and loading calibration coefficients is not needed.

## 2.2.4 API flow chart

Figure 1. MotionAC API logic sequence



## 2.2.5 Demo code

The following demonstration code reads data from accelerometer sensor and calculates compensated data.

```

[...]

#define VERSION_STR LENG      35
#define REPORT_INTERVAL      20

[...]

/** Initialization */
char lib_version[VERSION_STR LENG];
MAC_knobs_t Knobs;

/* Accelerometer calibration API initialization function */
MotionAC_Initialize(1);
MotionAC_GetKnobs(&Knobs);
Knobs.Sample_ms = REPORT_INTERVAL;
(void)MotionAC_SetKnobs(&Knobs);

/* Optional: Get version */
MotionAC_GetLibVersion(lib_version);
  
```

```
[...]

/** Using accelerometer calibration algorithm */
Timer_OR_DataRate_Interrupt_Handler()
{
    MAC_input_t data_in;
    MAC_output_t data_out;;
    float acc_cal_x, acc_cal_y, acc_cal_z;

    /* Get acceleration X/Y/Z in g */
    MEMS_Read_AccValue(data_in.Acc[0], data_in.Acc[1], data_in.Acc[2]);

    /* Accelerometer calibration algorithm update */
    MotionAC_Update(&data_in);

    /* Get Calibration coefficients */
    MotionAC_GetCalParams(&data_out);

    /* Apply correction */
    acc_cal_x = (data_in.Acc[0] - data_out.AccBias[0]) * data_out.SF_Matrix[0][0];
    acc_cal_x = (data_in.Acc[1] - data_out.AccBias[1]) * data_out.SF_Matrix[1][1];
    acc_cal_x = (data_in.Acc[2] - data_out.AccBias[2]) * data_out.SF_Matrix[2][2];
}
```

## 2.2.6 Calibration process

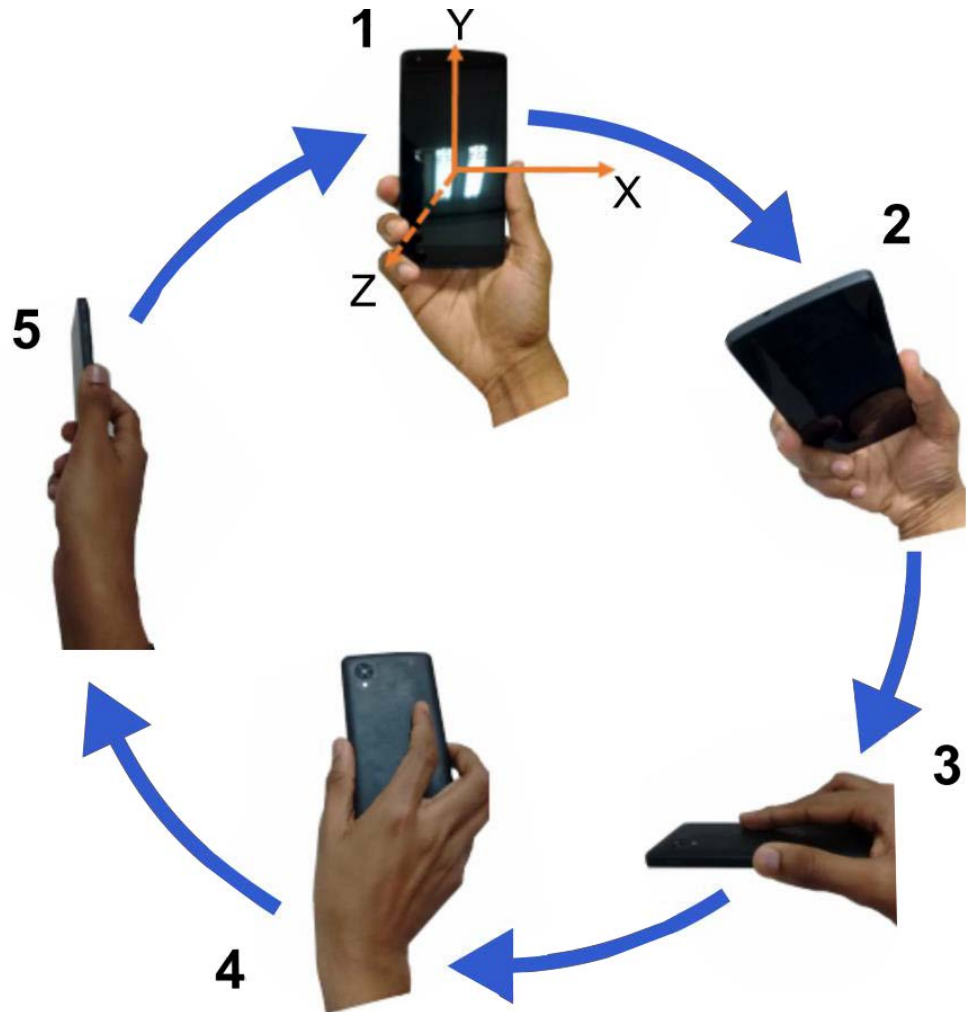
This calibration algorithm uses the normal motion of the three orthogonal axes of a stationary accelerometer sensor exposed to Earth's gravitation field.

- Step 1.** Hold the device firmly as shown in position 1.
- Step 2.** Gently rotate the device by 180° around the YZ plane such that in position 4, the device is flipped to its back side.
- Step 3.** Rotate the device by 180° in a clockwise fashion around the XZ plane to reach position 1.

**Important:** *Try to rotate the device along a smooth path and at a constant speed.*

You can also perform standard six point calibration, holding the module stationary in six different directions (positive and negative X,Y and Z directions).

Figure 2. Calibration movement



### 2.2.7 Algorithm performance

Table 2. Elapsed time ( $\mu$ s) algorithm

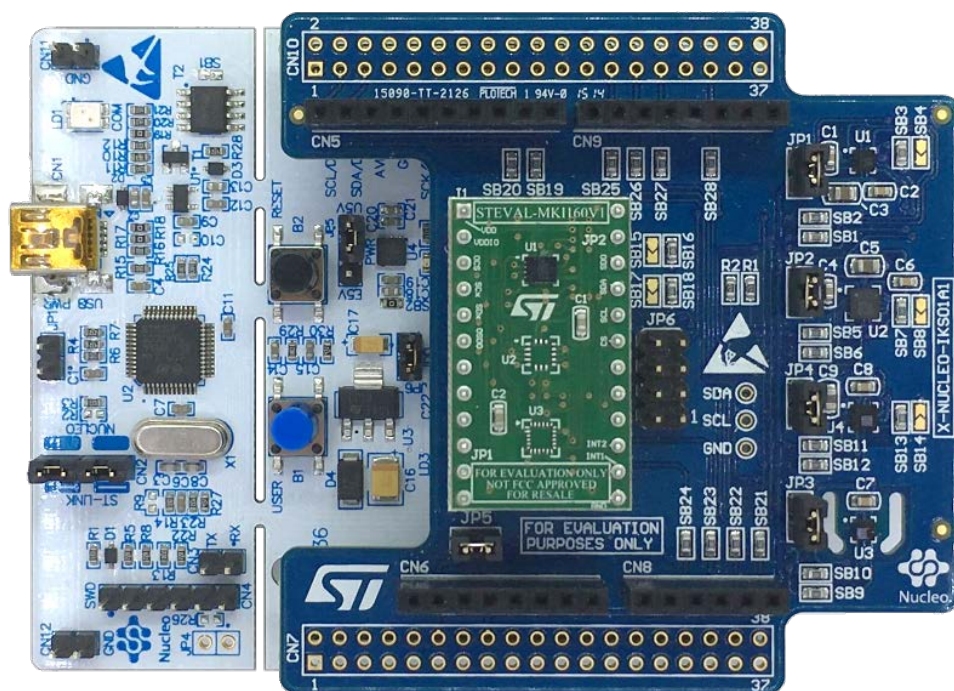
Cortex-M4 STM32F401RE at 84 MHz									Cortex-M3 STM32L152RE at 32 MHz								
SW4STM32 1.13.1 (GCC 5.4.1)			IAR EWARM 7.80.4			Keil $\mu$ Vision 5.22			SW4STM32 1.13.1 (GCC 5.4.1)			IAR EWARM 7.80.4			Keil $\mu$ Vision 5.22		
Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max
1	21	1131	1	21	1105	1	39	2219	23	401	22394	16	302	19752	15	468	27850

### 3 Sample application

The MotionAC middleware can be easily manipulated to build user applications; a sample application is provided in the Application folder.

It is designed to run on a NUCLEO-F401RE, NUCLEO-L476RG or NUCLEO-L152RE development board connected to an X-NUCLEO-IKS01A1 (based on LSM6DS0) or an X-NUCLEO-IKS01A2 (based on LSM6DSL) expansion board, with optional STEVAL-MKI160V1 board (based on LSM6DS3).

**Figure 3. Sensor expansion board and adapter connected to the STM32 Nucleo**



Accelerometer algorithm output data may be displayed in real-time through a specific GUI.

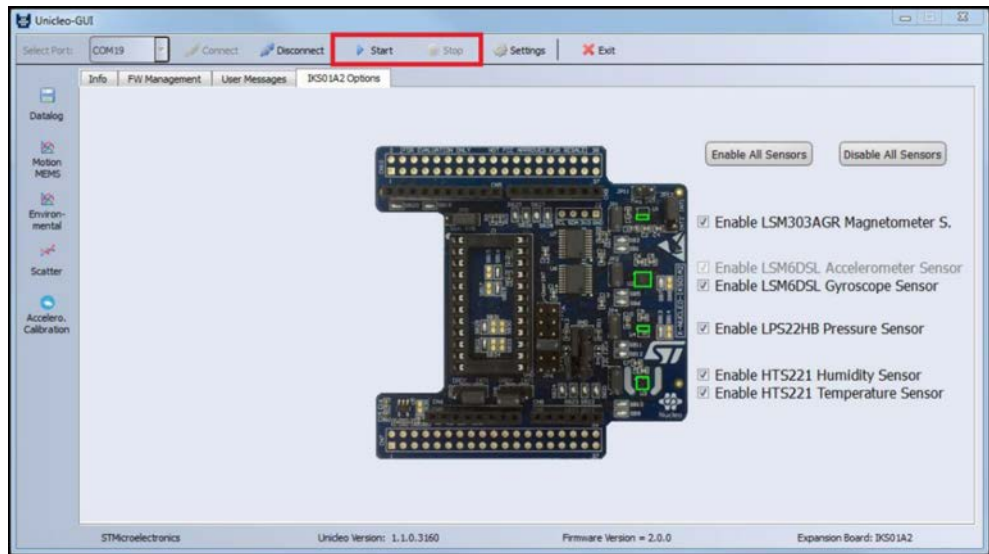
#### 3.1 Unicleo-GUI application

The sample application uses the Windows Unicleo-GUI utility, which can be downloaded from [www.st.com](http://www.st.com).

- Step 1.** Ensure that the necessary drivers are installed and the STM32 Nucleo board with appropriate expansion board is connected to the PC.
- Step 2.** Launch the Unicleo-GUI application to open the main application window.  
If an STM32 Nucleo board with supported firmware is connected to the PC, it is automatically detected and the appropriate COM port is opened.

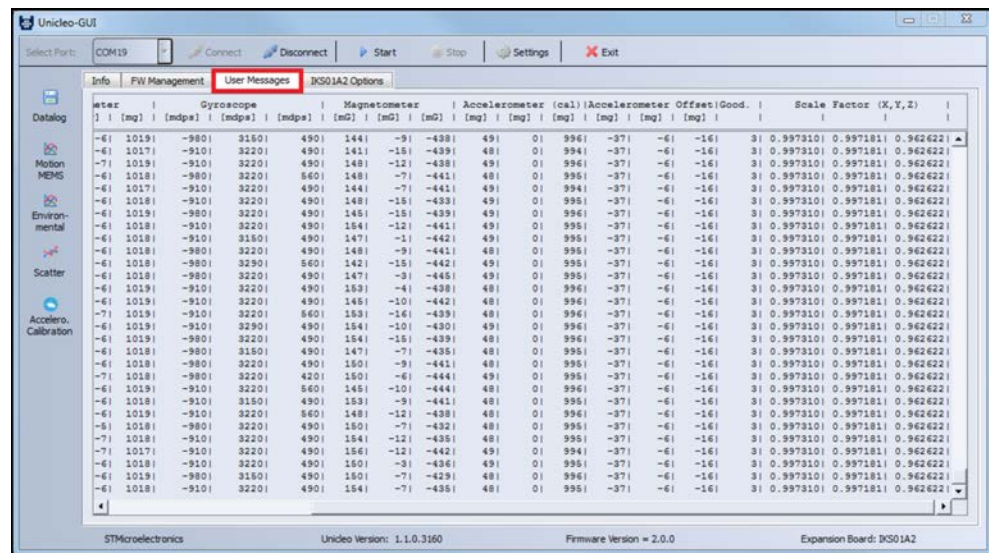


Figure 4. Unicleo main window



**Step 3.** Start and stop data streaming by using the appropriate buttons on the vertical tool bar. The data coming from the connected sensor can be viewed in the User Messages tab.

Figure 5. User Messages tab



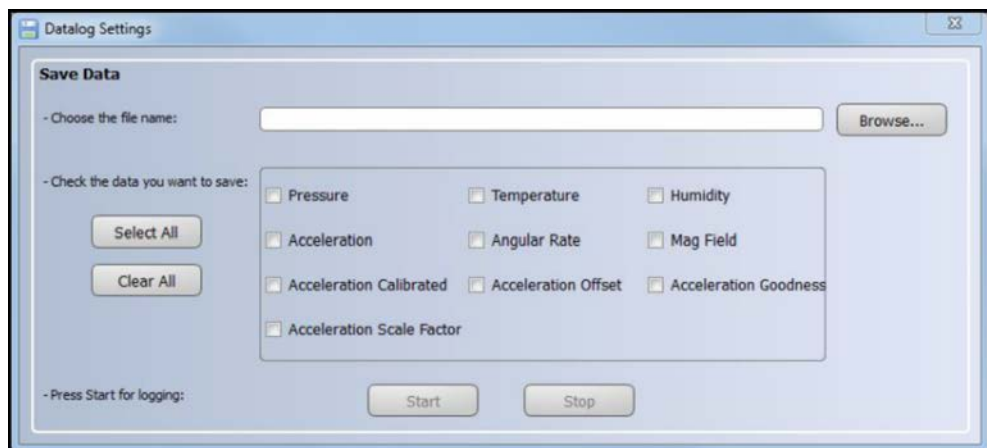
**Step 4.** Click on the Accelerometer Calibration icon in the vertical tool bar to open the dedicated application window. The window is split into one section with uncalibrated data, another with the calibrated data, another section with offset, scale factor and quality of calibration information and the last section with radio button to switch the desired calibration mode.

Figure 6. Accelerometer calibration window



- Step 5.** Click on the Datalog icon in the vertical tool bar to open the datalog configuration window: you can select which sensor and activity data to save in files. You can start or stop saving by clicking on the corresponding button.

Figure 7. Datalog window



## 4 References

---

All of the following resources are freely available on [www.st.com](http://www.st.com).

1. UM1859: Getting started with the X-CUBE-MEMS1 motion MEMS and environmental sensor software expansion for STM32Cube
2. UM1724: STM32 Nucleo-64 board
3. UM2128: Getting started with Unicleo-GUI for motion MEMS and environmental sensor software expansion for STM32Cube

## Revision history

**Table 3. Document revision history**

Date	Version	Changes
10-Apr-2017	1	Initial release.
26-Jan-2018	2	Updated Section 2.2.2 MotionAC APIs, Section 2.2.5 Demo code, Section 3.1 Unicleo-GUI application. Added references to NUCLEO-L152RE development board and Section 2.2.7 Algorithm performance.
20-Mar-2018	3	Updated <a href="#">Section • Introduction</a> and <a href="#">Section 2.1 MotionAC overview</a> .

## Contents

<b>1</b>	<b>Acronyms and abbreviations</b>	<b>2</b>
<b>2</b>	<b>MotionAC middleware library in X-CUBE-MEMS1 software expansion for STM32Cube</b>	<b>3</b>
<b>2.1</b>	MotionAC overview	3
<b>2.2</b>	MotionAC library	3
<b>2.2.1</b>	MotionAC library description	3
<b>2.2.2</b>	MotionAC APIs	3
<b>2.2.3</b>	Storing and loading calibration parameters	4
<b>2.2.4</b>	API flow chart	4
<b>2.2.5</b>	Demo code	5
<b>2.2.6</b>	Calibration process	6
<b>2.2.7</b>	Algorithm performance	7
<b>3</b>	<b>Sample application</b>	<b>8</b>
<b>3.1</b>	Unicleo-GUI application	8
<b>4</b>	<b>References</b>	<b>11</b>
	<b>Revision history</b>	<b>12</b>

## List of tables

<b>Table 1.</b>	List of acronyms . . . . .	2
<b>Table 2.</b>	Elapsed time ( $\mu\text{s}$ ) algorithm . . . . .	7
<b>Table 3.</b>	Document revision history . . . . .	12

## List of figures

Figure 1.	MotionAC API logic sequence . . . . .	5
Figure 2.	Calibration movement . . . . .	7
Figure 3.	Sensor expansion board and adapter connected to the STM32 Nucleo . . . . .	8
Figure 4.	Unicleo main window . . . . .	9
Figure 5.	User Messages tab . . . . .	9
Figure 6.	Accelerometer calibration window . . . . .	10
Figure 7.	Datalog window . . . . .	10

**IMPORTANT NOTICE – PLEASE READ CAREFULLY**

STMicroelectronics NV and its subsidiaries (“ST”) reserve the right to make changes, corrections, enhancements, modifications, and improvements to ST products and/or to this document at any time without notice. Purchasers should obtain the latest relevant information on ST products before placing orders. ST products are sold pursuant to ST’s terms and conditions of sale in place at the time of order acknowledgement.

Purchasers are solely responsible for the choice, selection, and use of ST products and ST assumes no liability for application assistance or the design of Purchasers’ products.

No license, express or implied, to any intellectual property right is granted by ST herein.

Resale of ST products with provisions different from the information set forth herein shall void any warranty granted by ST for such product.

ST and the ST logo are trademarks of ST. All other product or service names are the property of their respective owners.

Information in this document supersedes and replaces information previously supplied in any prior versions of this document.

© 2018 STMicroelectronics – All rights reserved