ECSE426
Microprocessor Systems

Tutorial 1

3D Tilt Angle Detection with Accelerometer

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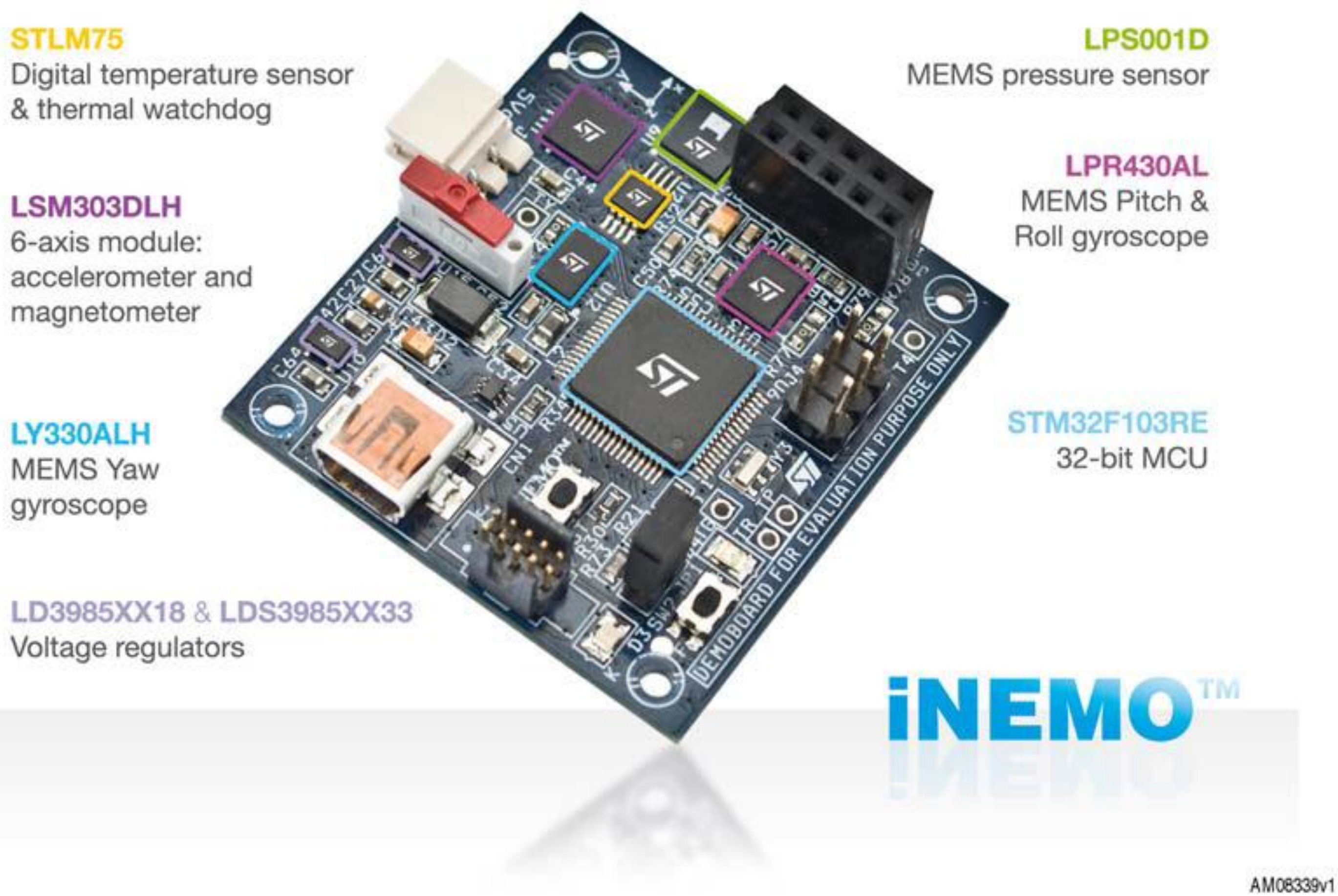
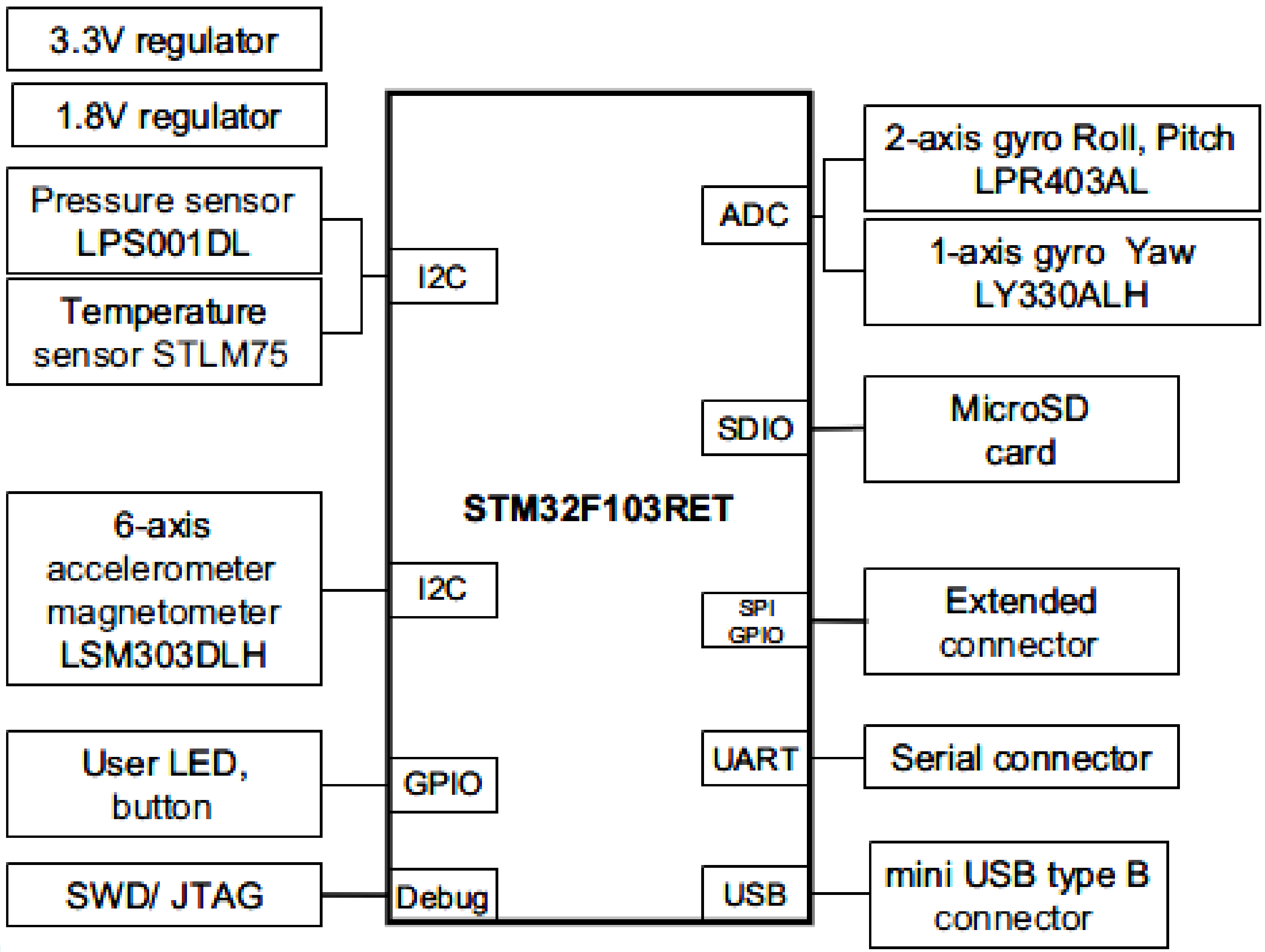
STEVAL-MKI06V2 iNEMO V2 platform



Features

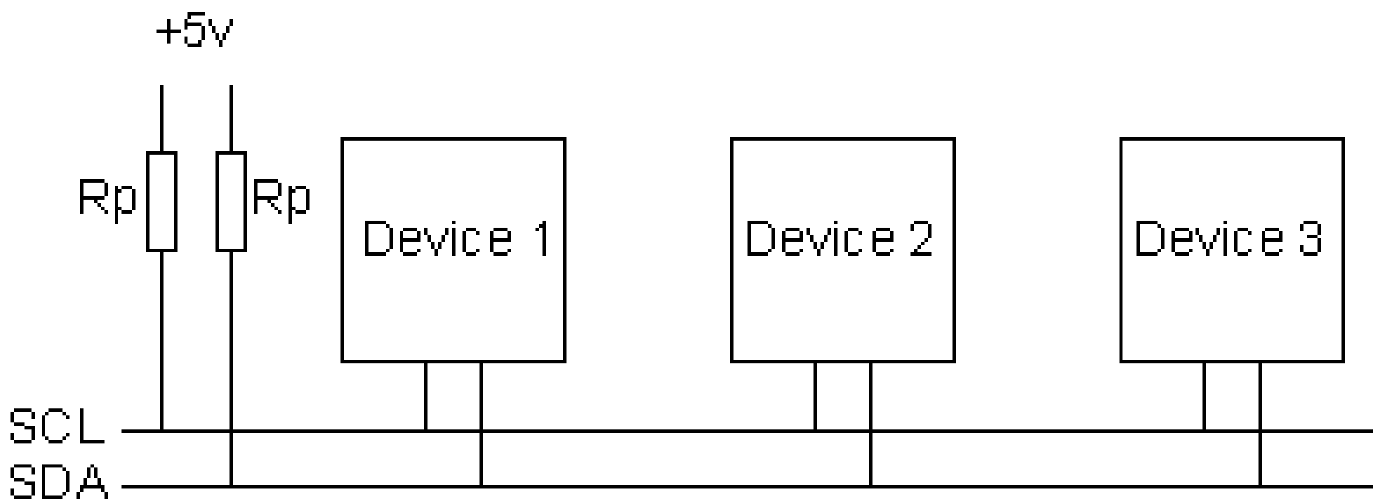
- MCU
  - STM32F103RET:
    low power high performance 32-bit microcontroller
    powered by ARM® Cortex™-M3
- Sensors
  - Accelerometer & Geomagnetic: LSM330DLH
  - Gyros: LPR430AL, LY330ALH
  - Temp: STLM75
  - Pressure: LPS001DL

Block Diagram



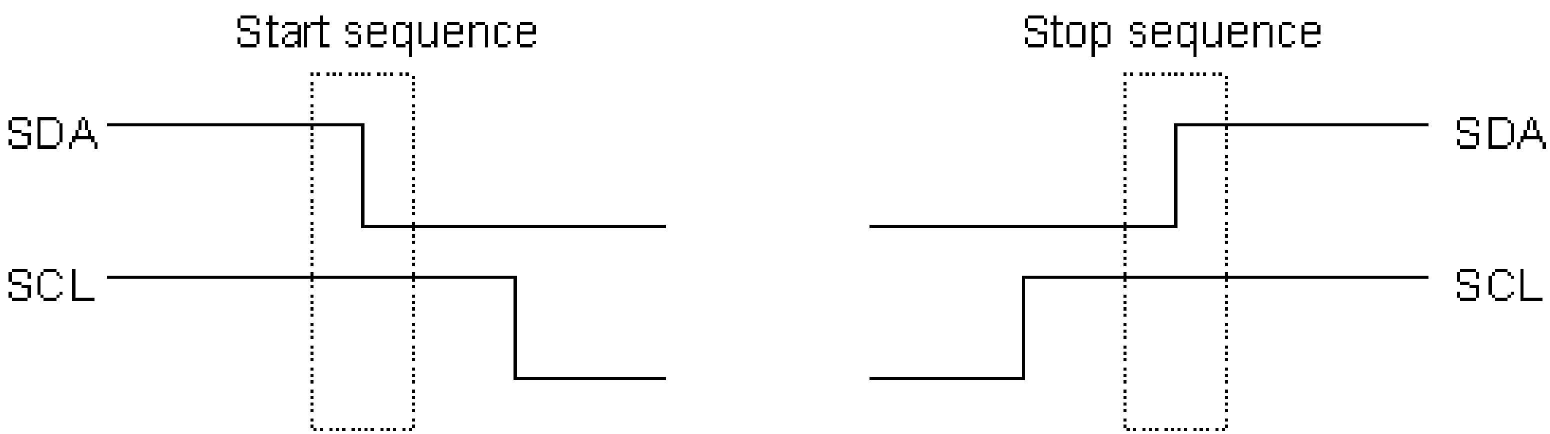
I^{2}C Interface

- I^{2}C : Inter-Integrated Circuit
- 2 Wires:
  SCL – Clock
  SDA – Data



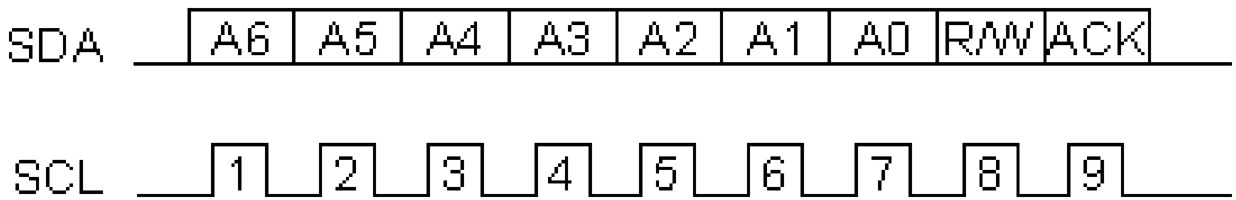
The I2C Protocol

The start and stop sequences mark the beginning and end of a transaction with the slave device

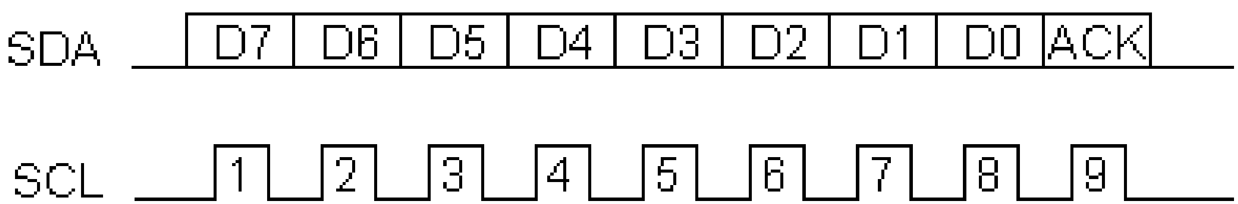


The I2C Software Protocol

I2C Device Addressing



I2C Data Transfer



I2C write to slave

1. Send a start sequence
2. Send the I2C address of the slave with the R/W bit low
3. Send the internal register number you want to write to
4. Send the data byte
5. [Optionally, send any further data bytes]
6. Send the stop sequence.

How Fast?

- The standard clock (SCL) speed for I2C

  Standard mode : up to 100KHz
  Fast mode : up to 400KHz
  High Speed mode : up to 3.4MHz

- iNemo

  7-bit serial address and supports I2C protocols with standard and fast modes (100 kHz and 400 kHz)

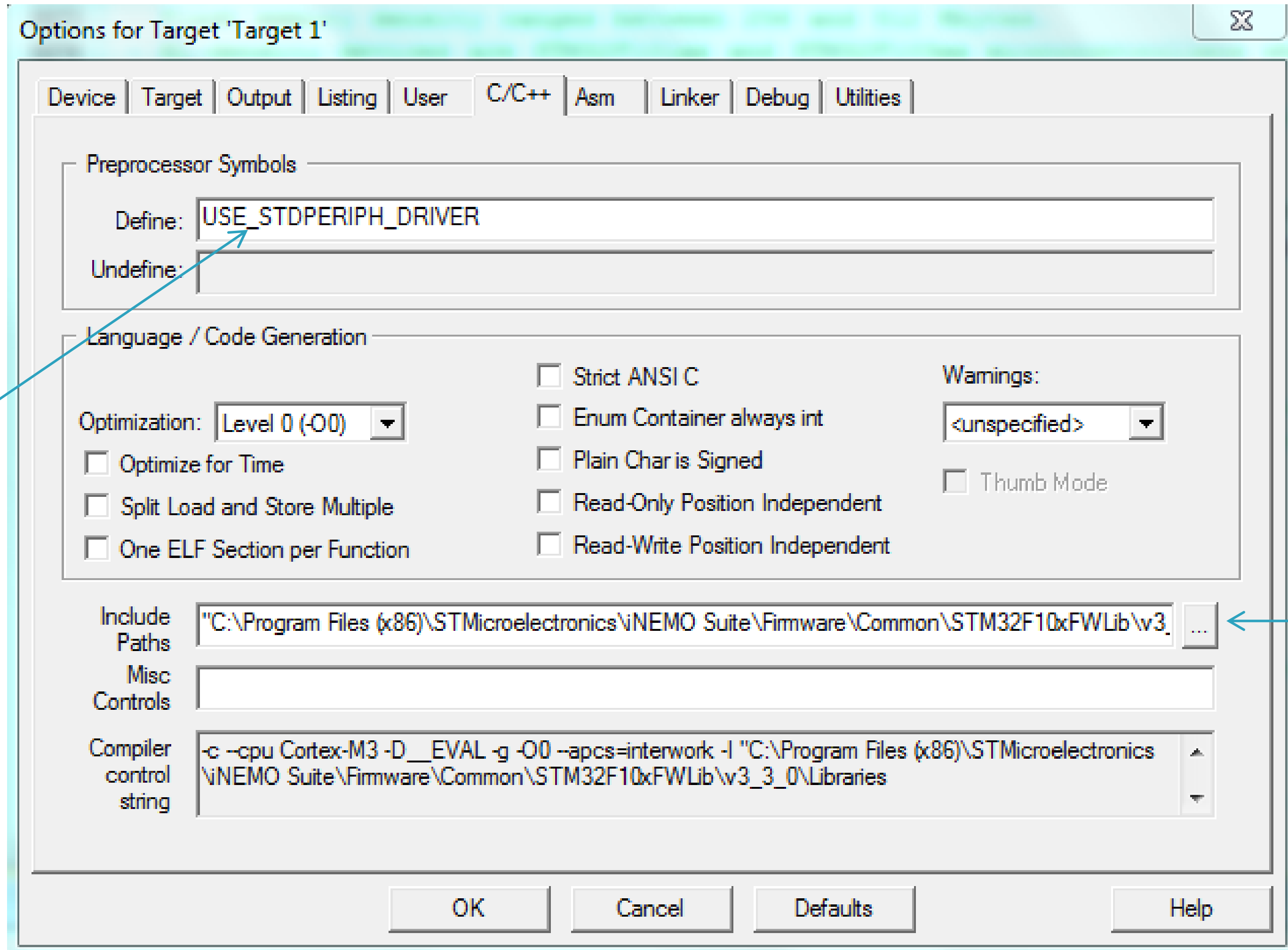
  Does not support high-speedmode (Hs).

Library Interface files

- Add these paths to your Included directories:

- "C:\Program Files\STMicroelectronics\iNEMO Suite\Firmware\Common\STM32F10xFWLib\v3_3_0\Libraries\STM32F10x_StdPeriph_Driver\inc”
- "C:\Program Files\STMicroelectronics\iNEMO Suite\Firmware\Common\STM32F10xFWLib\v3_3_0\Libraries\STM32F10x_StdPeriph_Driver\src
- "C:\Program Files\STMicroelectronics\iNEMO Suite\Firmware\Common\STM32F10xFWLib\v3_3_0\Libraries\CMSIS\CM3\DeviceSupport\ST\STM32F10x"
- "C:\Program Files\STMicroelectronics\iNEMO Suite\Firmware\iNEMO_Project\iNEMO_Project\iNEMO_Lib "

Library Interface files



Peripheral Access

- Make sure to define: USE_STDPERIPH_DRIVER on your target options

- stm32f10x.h – CMSIS Cortex-M3 Device Peripheral Access Layer Header File

```
#if !defined  USE_STDPERIPH_DRIVER
/**
 * @brief Comment the line below if you will not use the peripherals drivers.
   In this case, these drivers will not be included and the application code will
   be based on direct access to peripherals registers
   */
  /*#define USE_STDPERIPH_DRIVER*/
#endif
```

Library configuration

- stm32f10x_conf.h – Library configuration file

```
/* Uncomment the line below to enable peripheral header file inclusion */
/* #include "stm32f10x_adc.h" */
/* #include "stm32f10x_bkp.h" */
/* #include "stm32f10x_can.h" */
/* #include "stm32f10x_crc.h" */
/* #include "stm32f10x_dac.h" */
/* #include "stm32f10x_dbgmcu.h" */
/* #include "stm32f10x_dma.h" */
/* #include "stm32f10x_exti.h" */
/* #include "stm32f10x_flash.h" */
/* #include "stm32f10x_fsmc.h" */
#include "stm32f10x_gpio.h"
#include "stm32f10x_i2c.h"
/* #include "stm32f10x_iwdg.h" */
/* #include "stm32f10x_pwr.h" */
#include "stm32f10x_rcc.h"
```

Accelerometer-magnetometer module

- LSM303DLH.h & LSM303DLH.c
  - This file provides a set of functions needed to manage the communication between STM32 I2C master and LSM303DLH I2C slave.

- Basic Steps to Initialize LSM303DLH
  - Initialize I2C Bus
  - Set configuration parameters for the module
  - Read data

  - #Ref: Doc ID 16941 – LSM303DLH module manual (read Ch9.1 at least)

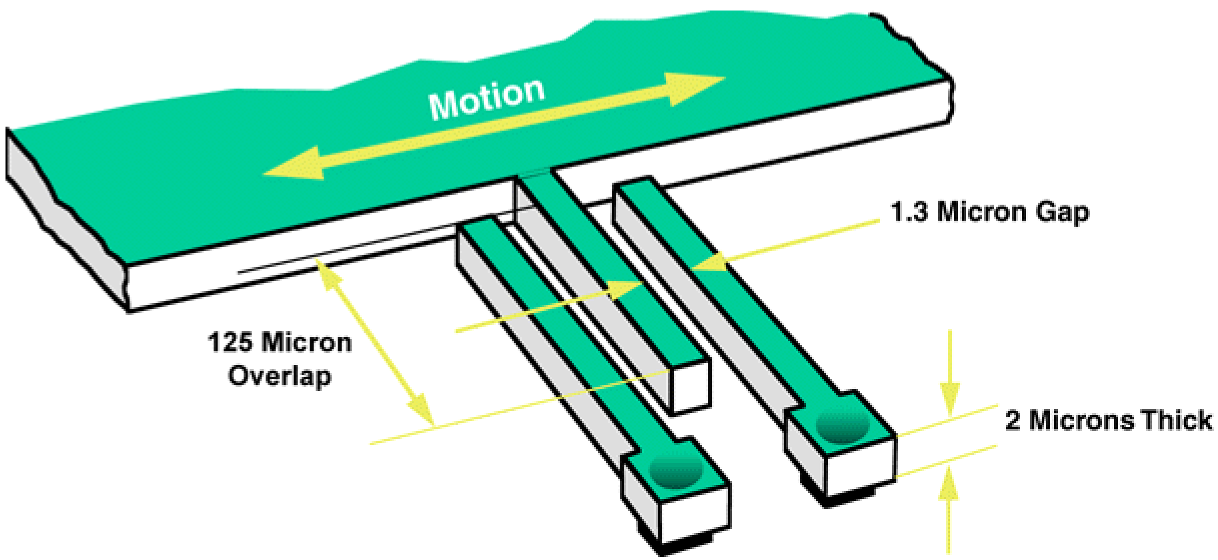
Accelerometer Init structure definition

- LSM303DLH.h

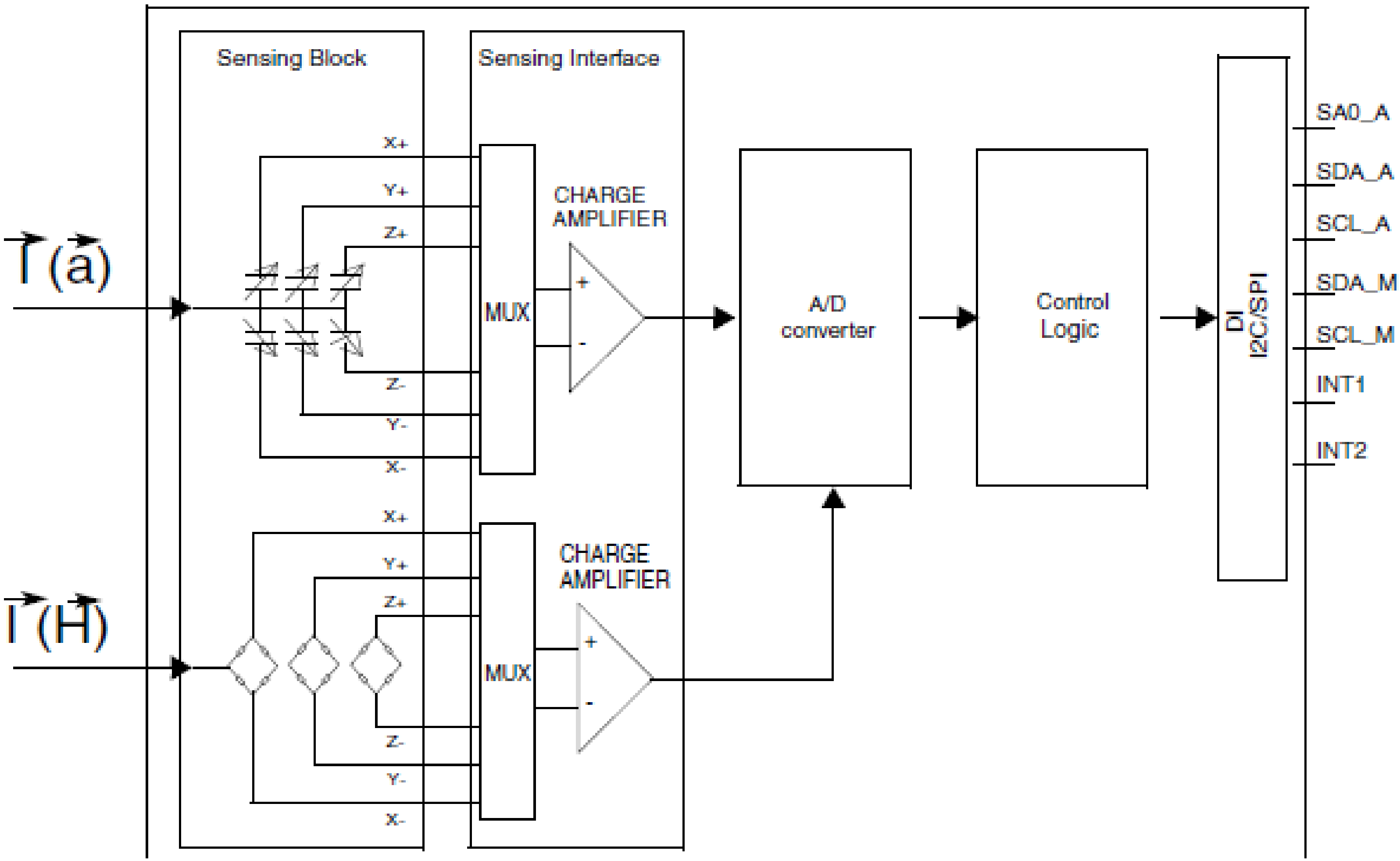
```
typedef struct
{
  u8 Power_Mode;  /*!<  Low power mode selection (see table 19
                        datasheet) */
  u8 ODR; /*!< Output Data Rate */
  u8 Axes_Enable;    /*!< Axes Enable */
  u8 FS;     /*!< Full Scale */
  u8 Data_Update;  /*!< Data Update mode : Continuos update or data
                        don`t change until MSB and LSB nex reading */
  u8 Endianess;   /*!< Endianess */
}LSM_Acc_ConfigTypeDef;
```

MEMSIC

- Micro-Electro-Mechanical Systems IC
  - The sensor element is a differential capacitor whose output is proportional to acceleration



Block diagram of LSM303DLH



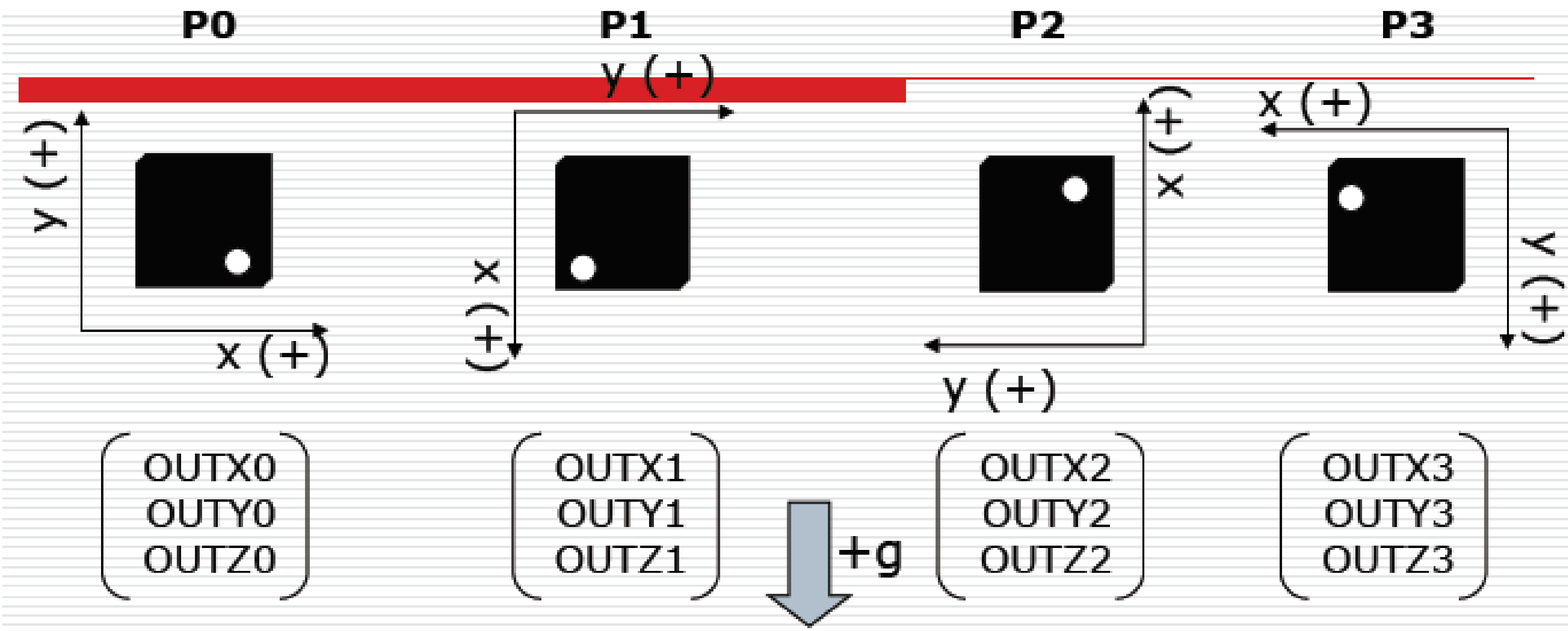
Factory calibration of LSM303DLH

The IC interface is factory calibrated for linear acceleration sensitivity (LA_So), and linear acceleration Zero-g level (LA_TyOff).

The trimming values are stored inside the device in non-volatile memory. When the device is turned on, the trimming parameters are downloaded into the registers to be used during normal operation.

This allows the use of the device without further calibration.

Position Required For Full Calibration



Calibration Formulas

- The parameters will be estimated as follow:

  OFFX = (OUTX0 + OUTX1 + OUTX2 + OUTX3)/4

  SENSX = (OUTX2 – OUTX1)/2

  CXY = (OUTX0 – OUTX3)/(2 * SENSX)

  OFFY = (OUTY0 + OUTY1 + OUTY2 + OUTY3)/4

  SENSY = (OUTY0 – OUTY3)/2

  CYX = (OUTY2 – OUTY1)/(2 * SENSY)

  Where OUTXK is the Output in the K position

- Then solve iteratively the following equations to obtain estimated acceleration value (ACCXˇ, ACCYˇ):
  - ACCXˇ = (OUTX – OFFX) / SENSX   ACCYˇ * CXY
  - ACCYˇ = (OUTY – OFFY) / SENSY   ACCXˇ * CYX

3D Tilt Calculation

- To measure the tilting independently of 3D space required to use 3-axis linear accelerometer, need to sense the vector of gravity along X,Y,Z axes

$$\alpha = \arctan\left(\frac{a_X}{\sqrt{(a_Y)^2 + (a_Z)^2}}\right)$$

$$\beta = \arctan\left(\frac{a_Y}{\sqrt{(a_X)^2 + (a_Z)^2}}\right)$$