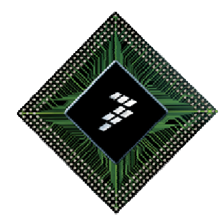
November 2010

Sensor Toolbox (Part 2): Inertial Sensors

AMF-ENT-T1118



Michael Steffen

MCU & Sensor Field Application Engineer Expert

Session Objectives

Learn:

- How an accelerometer works
- How to interface an accelerometer to a microcontroller
- The top customer questions and application challenges

Gain Hand-On Experience:

- Calibration: Resolution, accuracy
- Tilt: Non-linear effects
- Motion: Current consumption, signal analysis
- Fall: Data logging, interpreting results

Session Outline

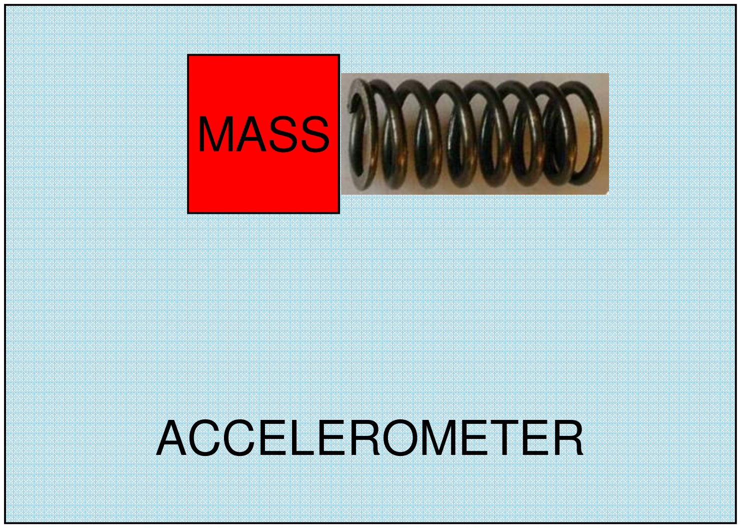
1. What is an **accelerometer**?
2. How to interface the **accelerometer to a microcontroller**
3. Top Questions & Application Challenges

4. Using the **Sensor Toolbox**: Hands-On Labs
   "Cal Lab"
   "Tilt Lab"
   "Motion Lab"
   "Fall Lab"

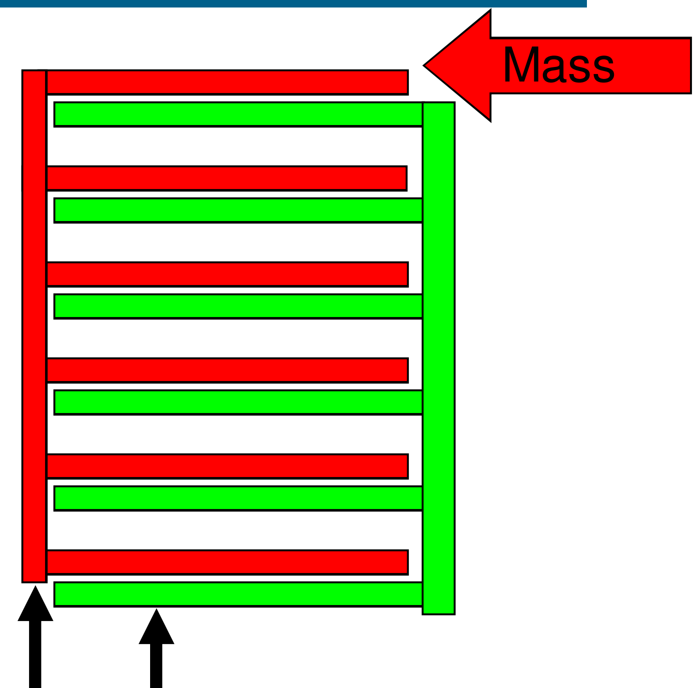
1. What is an Accelerometer?

How an Accelerometer Works

Accelerometers measure the acceleration of a movable mass.
The spring compresses proportionally to acceleration.



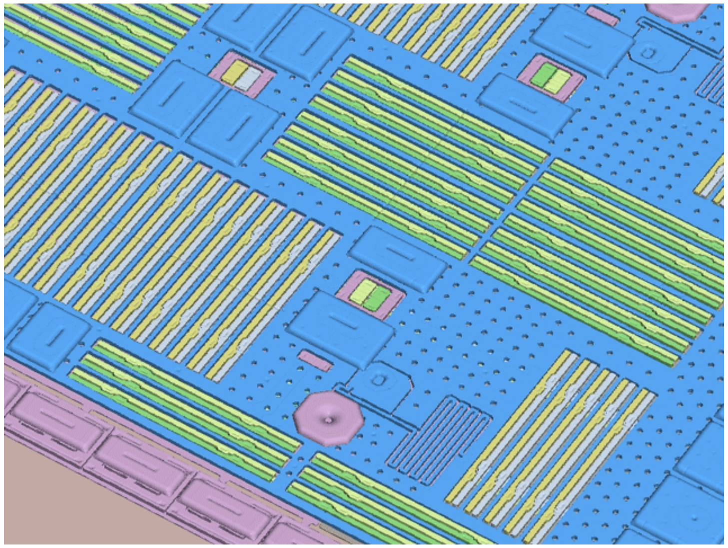
Dynamic Acceleration



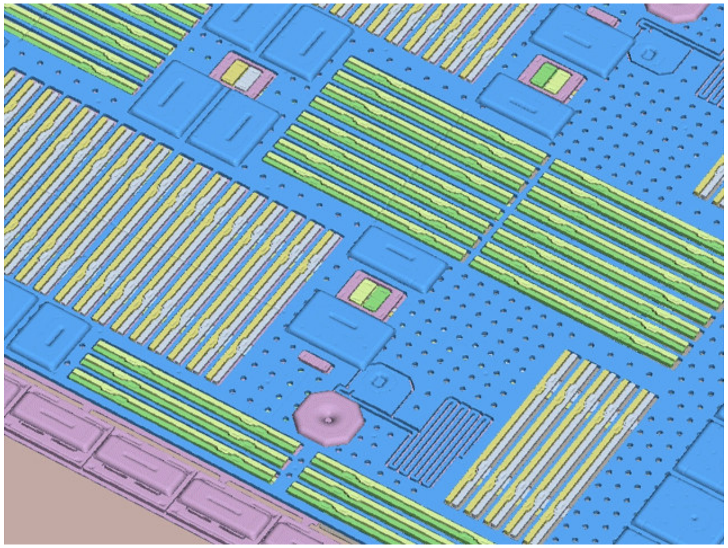
Fingers inside measure change in capacitance

X,Y, & Z Axis Movement

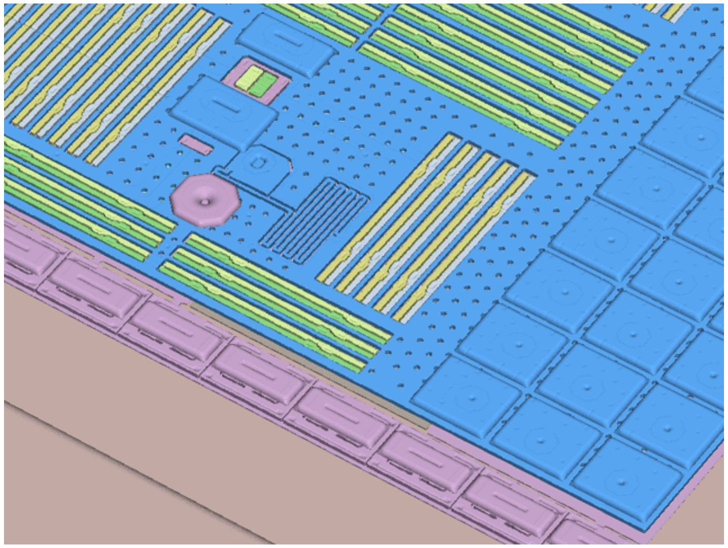
X Axis



Y Axis

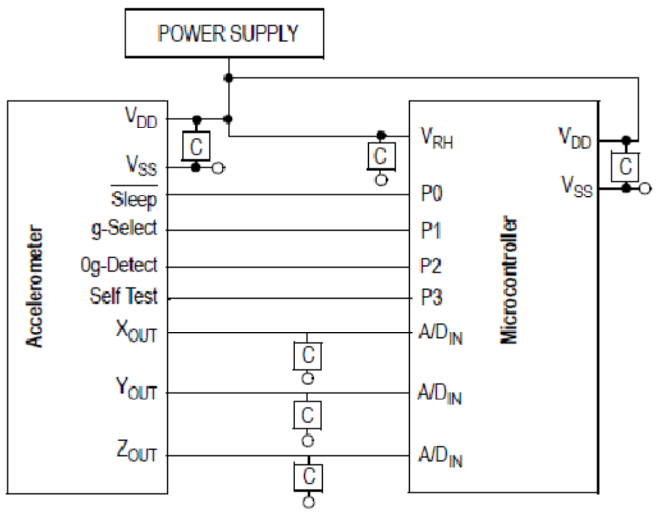


Z Axis

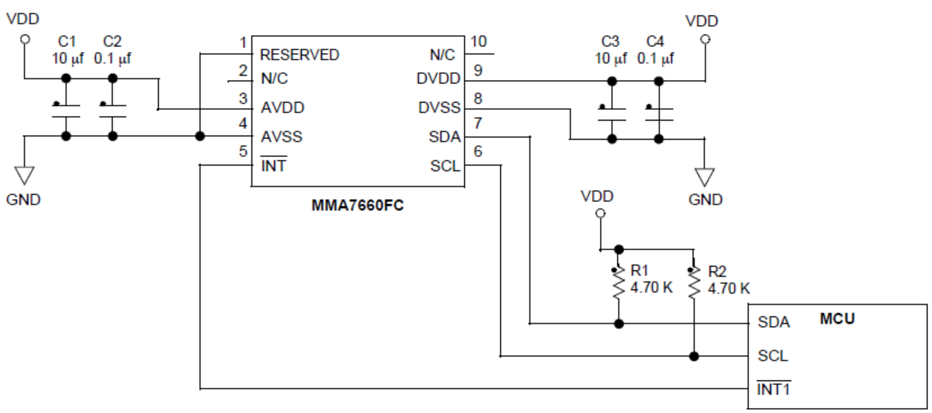


2. How to Interface our Accelerometers to a Microcontroller

Analog and Digital Accelerometers



Analog Accelerometer



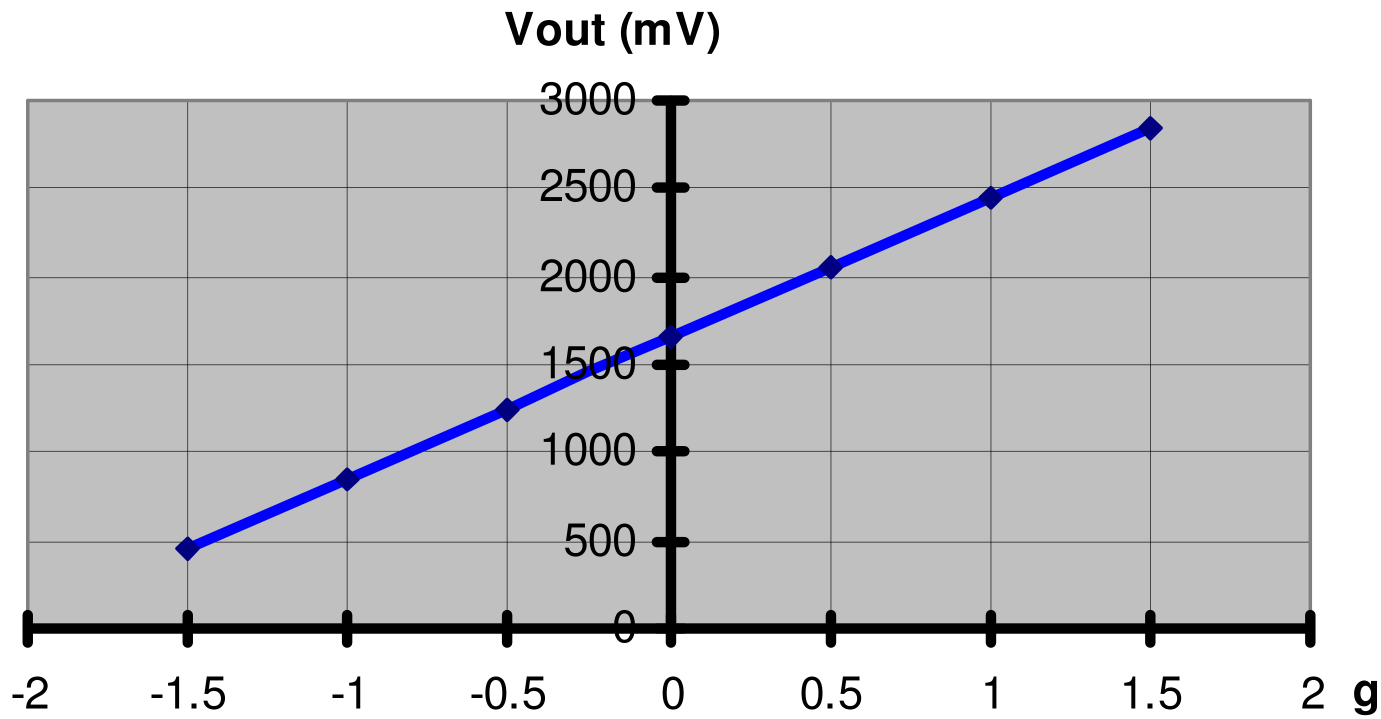
Digital Accelerometer

What is the output of Accelerometers?

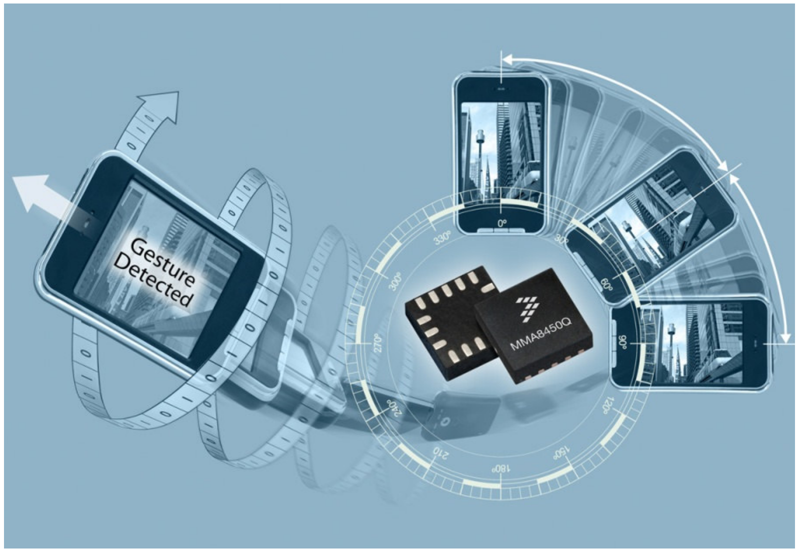
$V_{out} = V_{DD}/2 + \text{Sensitivity} \times \text{Acceleration}$

Vout=f(g)

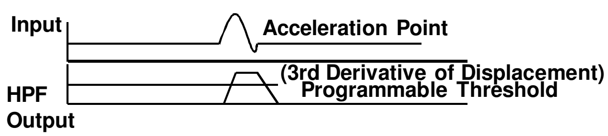
V_{DD}=3.3V



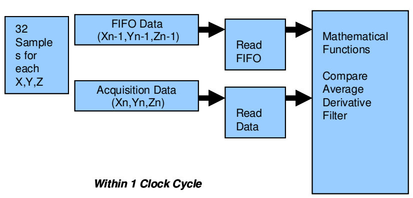
MMA8450Q Accelerometer Overview



High Pass Filter enables Rapid Gesture Detection and Enhanced Tap Detection

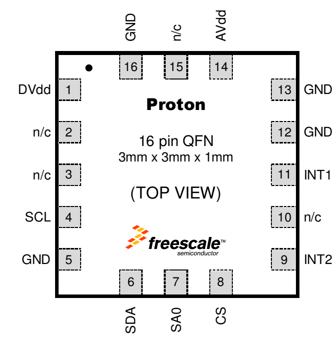


Embedded 32 data point FIFO reduces processor cycles, reduces system power, and reduces I^{2}C bus congestion.



Features

- 1.71V to 1.89V supply voltage
- ±2g/±4g/±8g dynamically selectable full-scale
- Output data rate (ODR) from 400Hz to 1.563Hz
- 300µg/√Hz noise at normal mode ODR=400Hz
- 12-bit digital output
- I²C digital output interface (operates up to 400KHz Fast Mode)
- Programmable 2 interrupt pins for 8 interrupt sources
- Embedded 4 channels of motion detection
  - Freefall or motion detection: 2 channels
  - Pulse detection: 1 channel
  - Transient detection : 1 channel
- Embedded orientation (Portrait/Landscape) detection with hysteresis
- Embedded automatic ODR change for auto-wake-up and return-to-sleep
- Embedded 32 sample FIFO simplifies position tracking analysis
- Embedded self test
- 10,000g high shock survivability



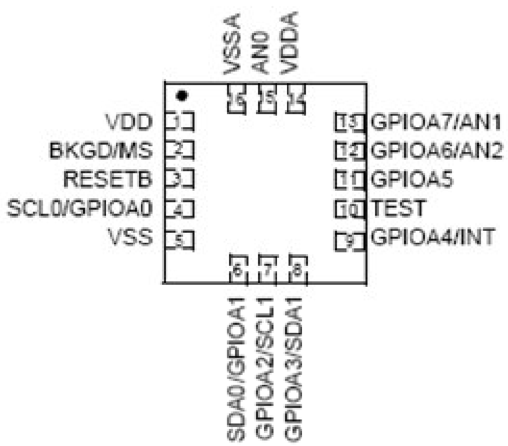
Package

- 3mm x 3mm DFN, 1.00mm max height
- -40°C to +85°C Operating Temp
- RoHS compliant

MMA9550L Specification Overview

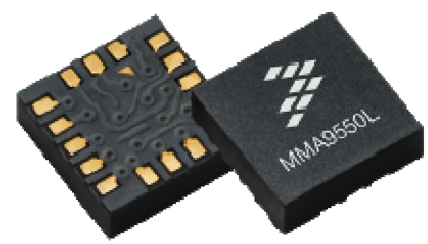
Features

- ► +/-2g, 4g, 8g configurable dynamic ranges available
- ► Configurable 8-, 10, 12-, 14-bit resolution
- ► Configurable sample rate 0.24 to 1953 sample/s
- ► 1.71 – 1.89V for AVdd and DVdd or single supply
- ► 2 uA standby current (I^2C active)
- ► 20 uA operating current at 14-bit, 1 samples/s
- ► < 150 uA operating current at 14-bit, 64 samples/s
- ► Internal low power oscillator
- ► Slave I^2C and SPI
- ► Master I^2C
- ► 32-bit CPU core with multiply accumulator block
- ► Full enablement suite of tools
- ► Software libraries of sensor algorithms
- ► Downloadable software upgrades

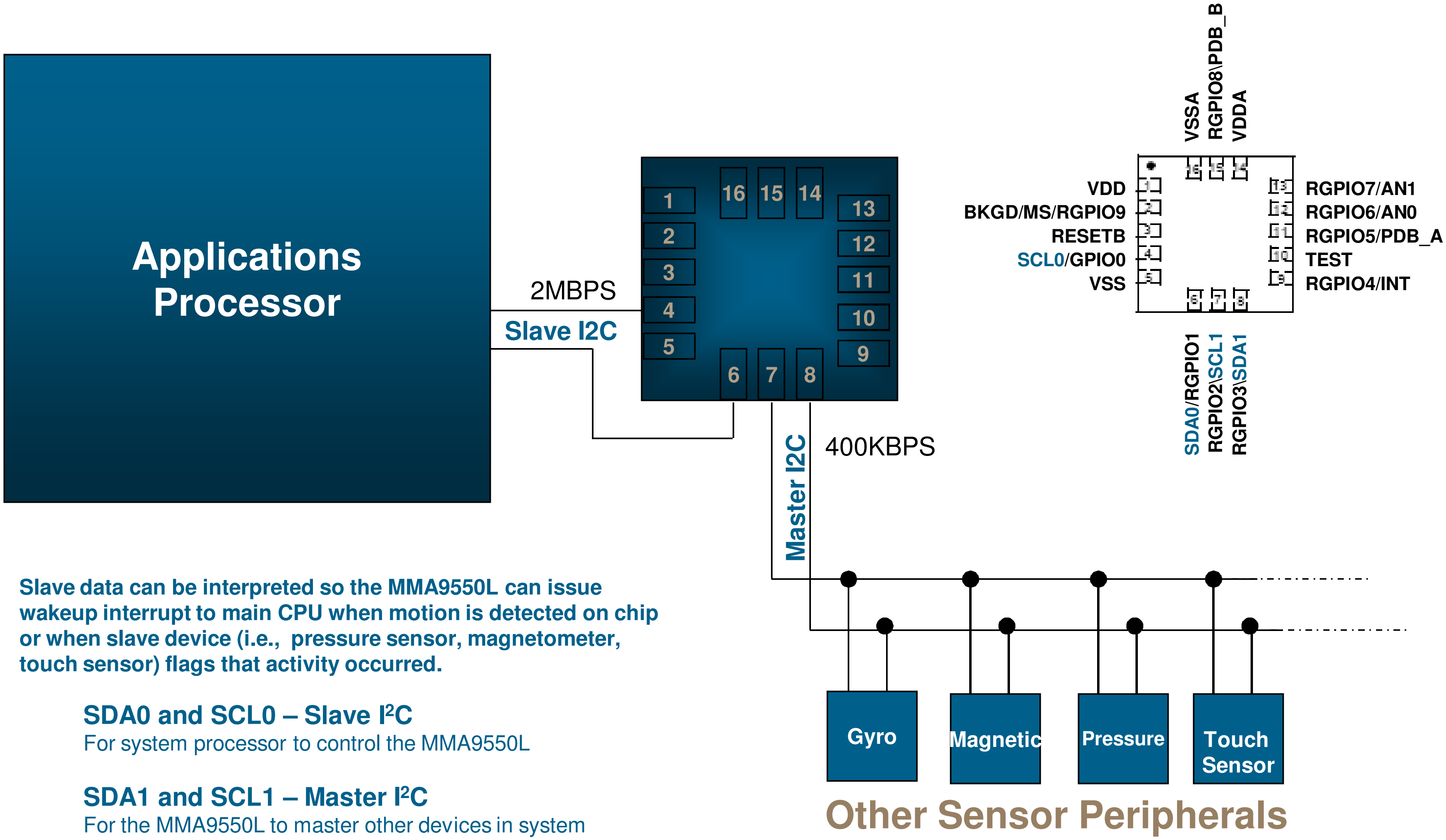


Package

- ► 3x3x1mm LGA package
- ► -40℃ to 85℃ operating temp
- ► RoHS compliant



MMA9550L has both Master and Slave I²C Capability



Slave data can be interpreted so the MMA9550L can issue wakeup interrupt to main CPU when motion is detected on chip or when slave device (i.e., pressure sensor, magnetometer, touch sensor) flags that activity occurred.

SDA0 and SCL0 – Slave I²C
For system processor to control the MMA9550L

SDA1 and SCL1 – Master I²C
For the MMA9550L to master other devices in system

3. Top Customer Questions and Application Challenges

What is Offset and Sensitivity of an Accelerometer?

It is crucial to auto-zero the offset voltage **

Tilt Application (0 – 45 degrees)

Parameter	Min	Typ	Max	Unit
Offset	1485	1650	1815	mV
Sensitivity	740	800	860	mV

Offset → **causes 21 degrees of error!**

Sensitivity → causes 4 degrees of error

MMA7260Q, T_A=25degC, V_{DD}=3.3V

** MMA8450 is has very low OFFSET and good accuracy

freescale™ semiconductor

For Digital Accelerometers, Resolution vs. Accuracy?

Is your focus resolution only, or also accuracy?

On the MMA8450 the 14-bit ADC system using 3 axes (X,Y, and Z) can achieve:

→ Tilt **Resolution** of +/- Up to 0.02º Resolution at 1.56Hz (Hi Res mode)
→ Tilt **Accuracy** of +/-2% 0.244mg (2g range: 4096 counts/g) Ex. 45º ± 0.9º

Accuracy determined by all sources of error from the accelerometer

- A/D resolution limitations
- Zero-g offset error
- Sensitivity error
- Noise error
- Temperature coefficient offset error
- Temperature coefficient sensitivity error
- Cross axis sensitivity error
- Non-Linearity error

Total Error: RMS of all errors

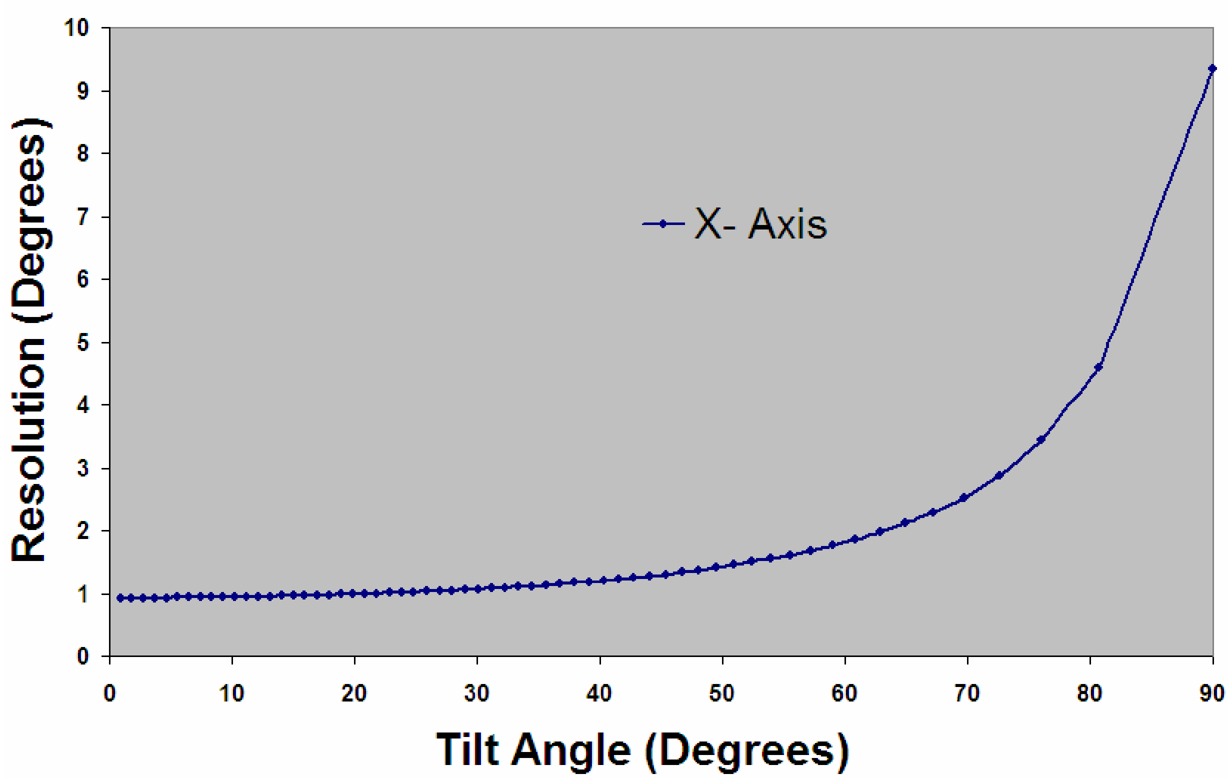
3. Calibration, Tilt, Motion, and Freefall

Tilt

Single axis tilt

Only the X-axis is used to determine tilt. The tilt a $\theta = \sin^{-1}(A_X)$

The graph here below shows that due to the non-linearity of the arcsine function, the tilt angle resolution degrades significantly as you approach 90 degrees.



Motion

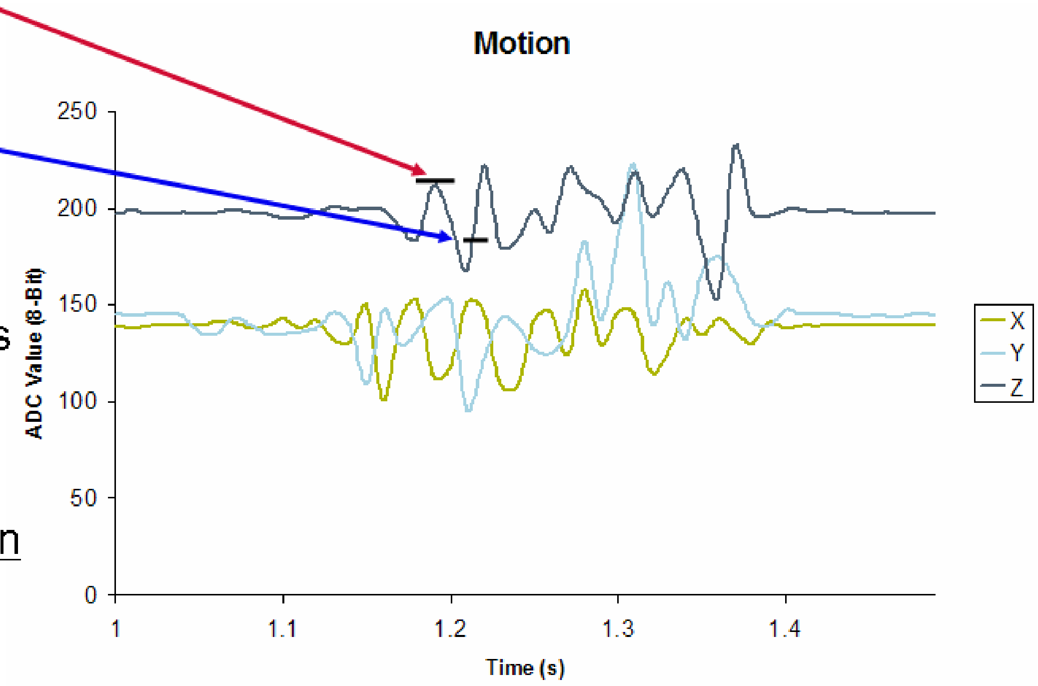
Variation between readings

We compare the current reading to the previous reading and determine motion or shock by the variation between the two: The delta between values will be fairly low for motion (1 to 10) and much higher for shock (10 to 254).

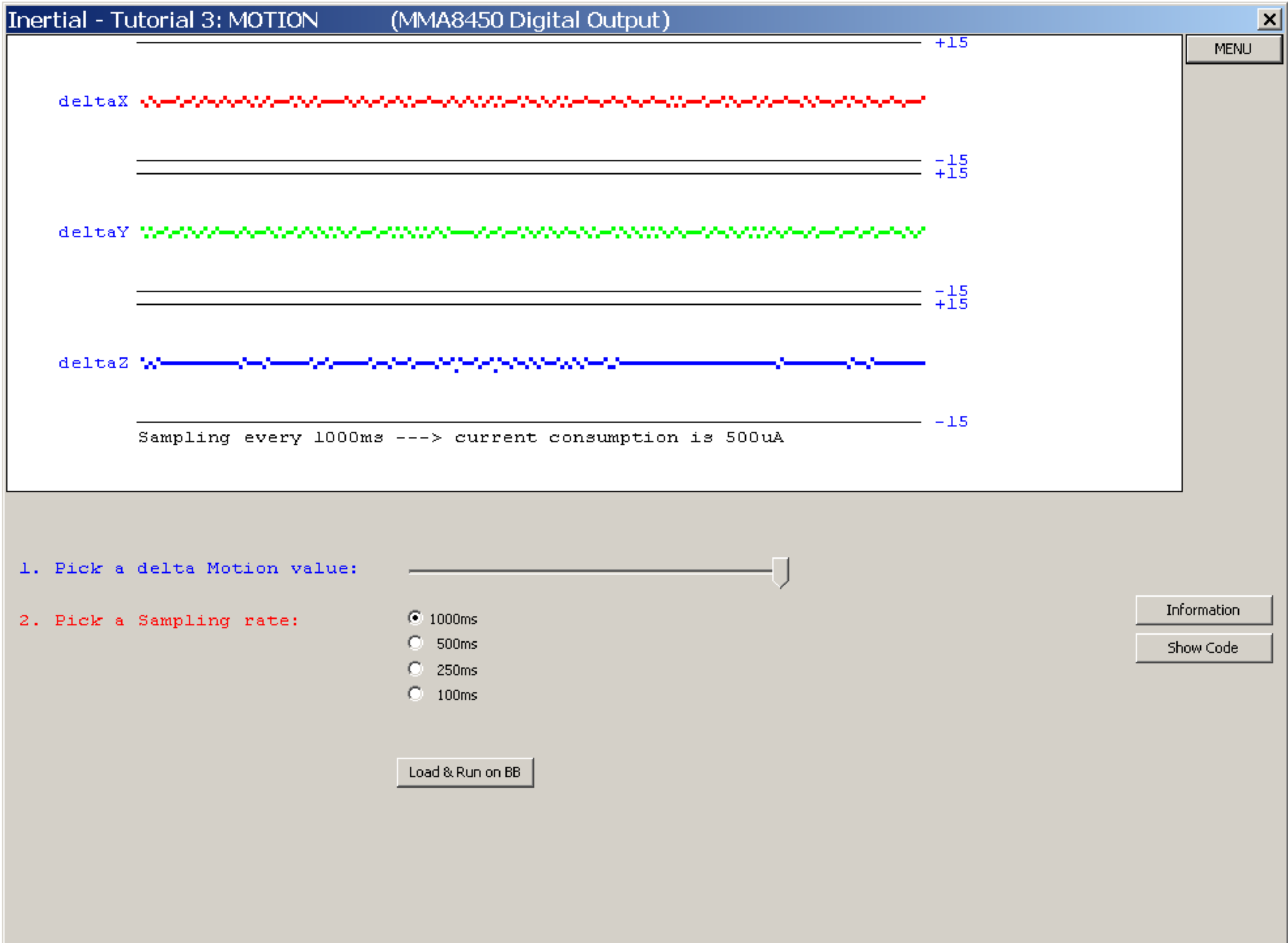
Previous sample

Current sample

Compare current sample with previous sample: if difference is greater than predefined threshold then you have Motion



MOTION TUTORIAL

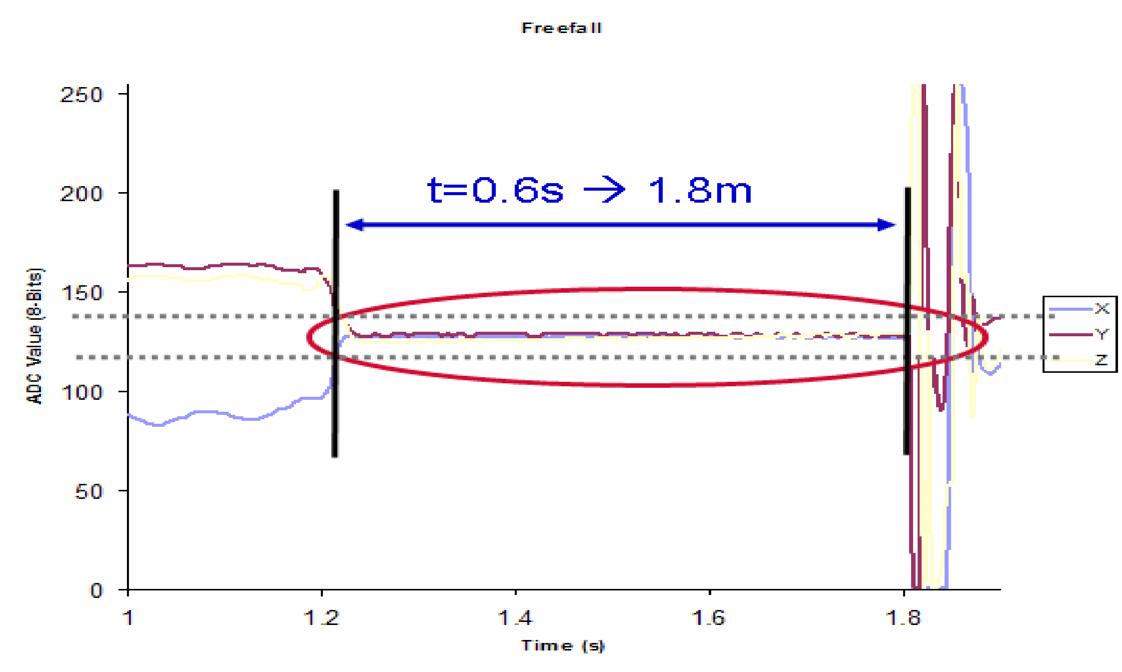


Freefall

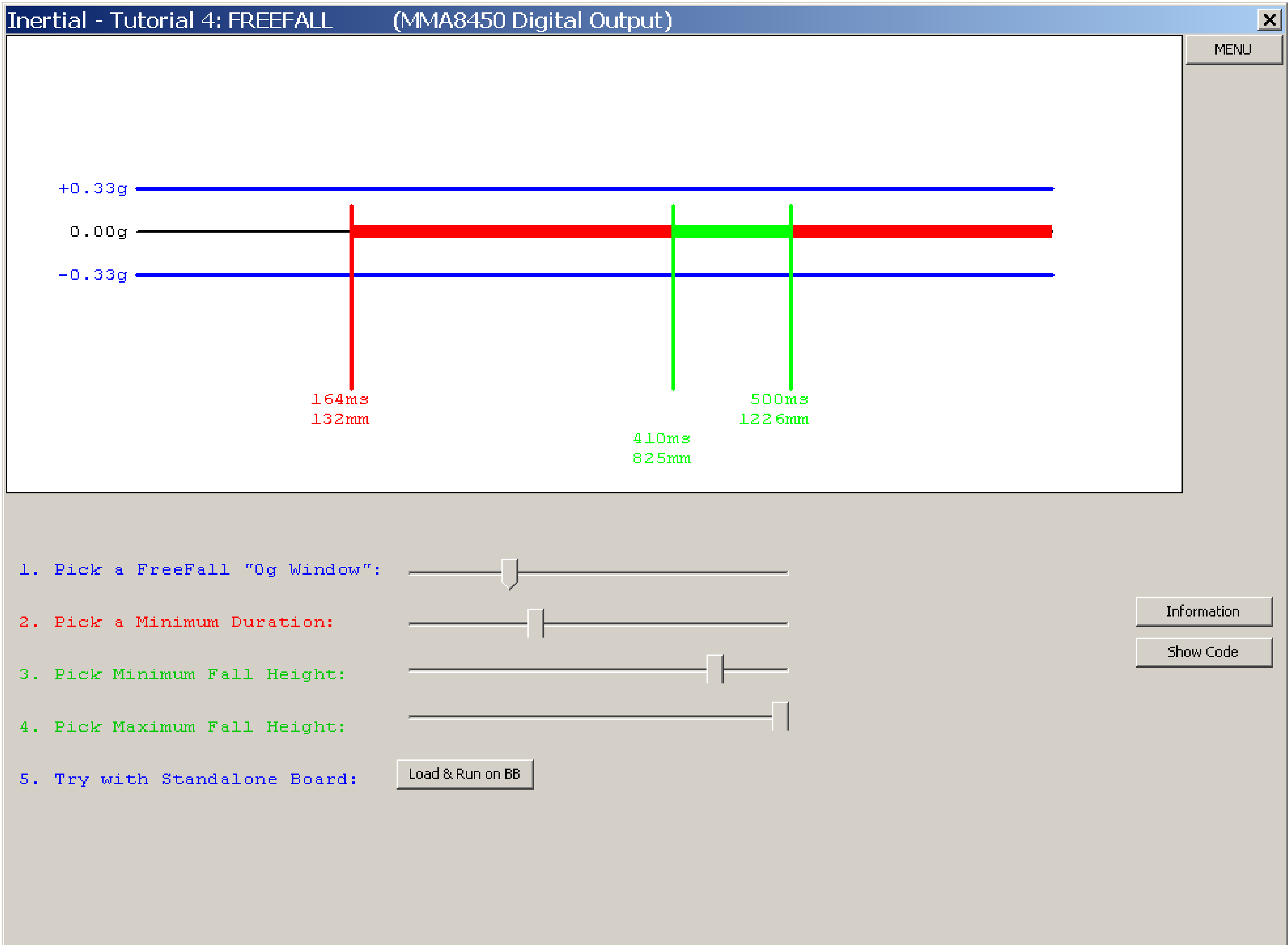
Linear Fall

This is when the board falls straight down with no spin or rotational component.

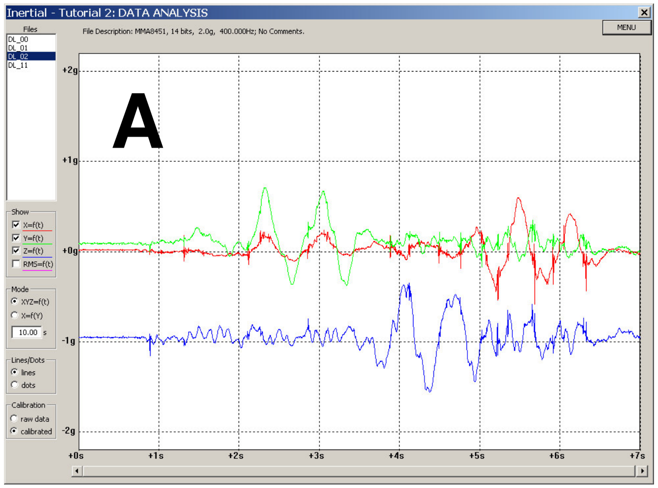
We will be looking for a condition where all three axes come close to 0g.

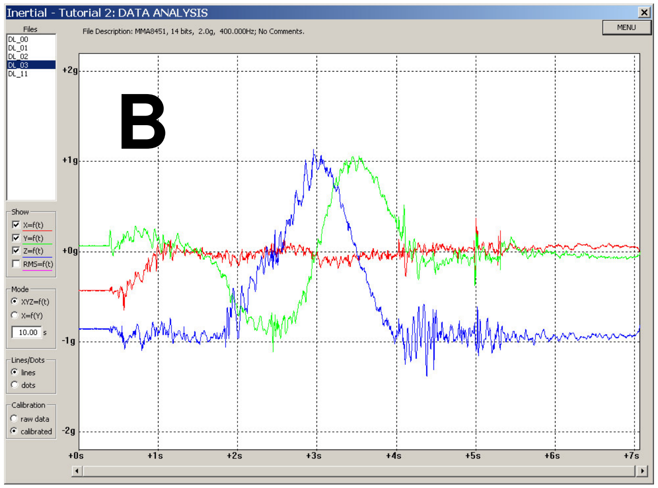


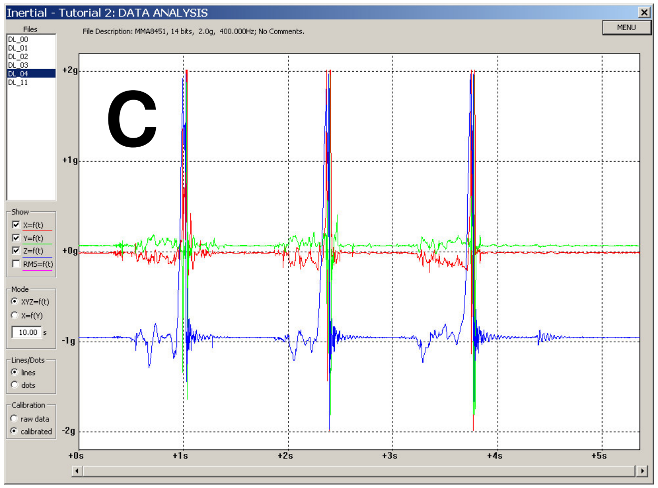
FREEFALL TUTORIAL

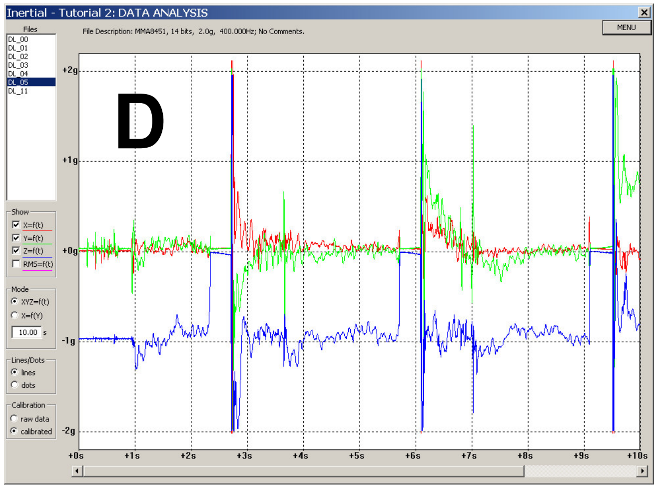


DATA LOGGING EXAMPLE – TEST YOUR KNOWLEDGE





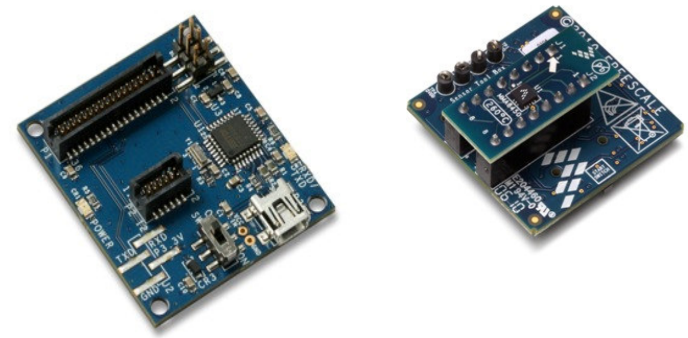




EVENTS
- Freefall
- Motion
- Shock
- Rotation

LET’S GET THE LAB STARTED !!!

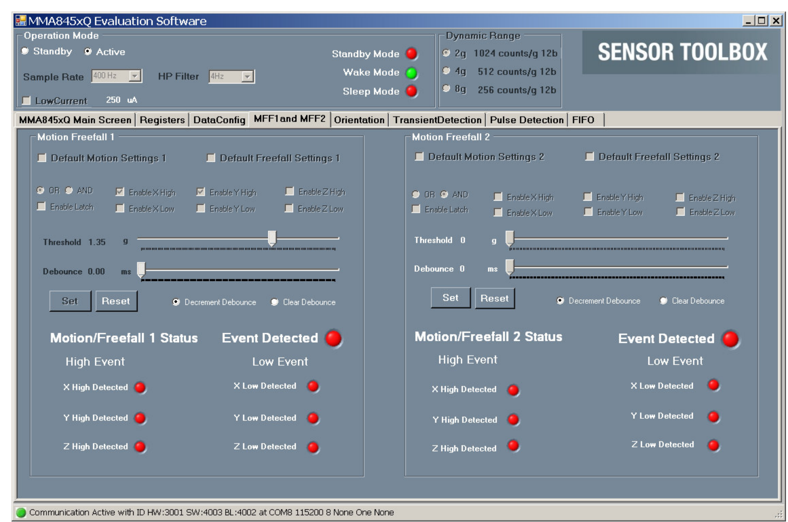
1. **Please unpack the Boards.**



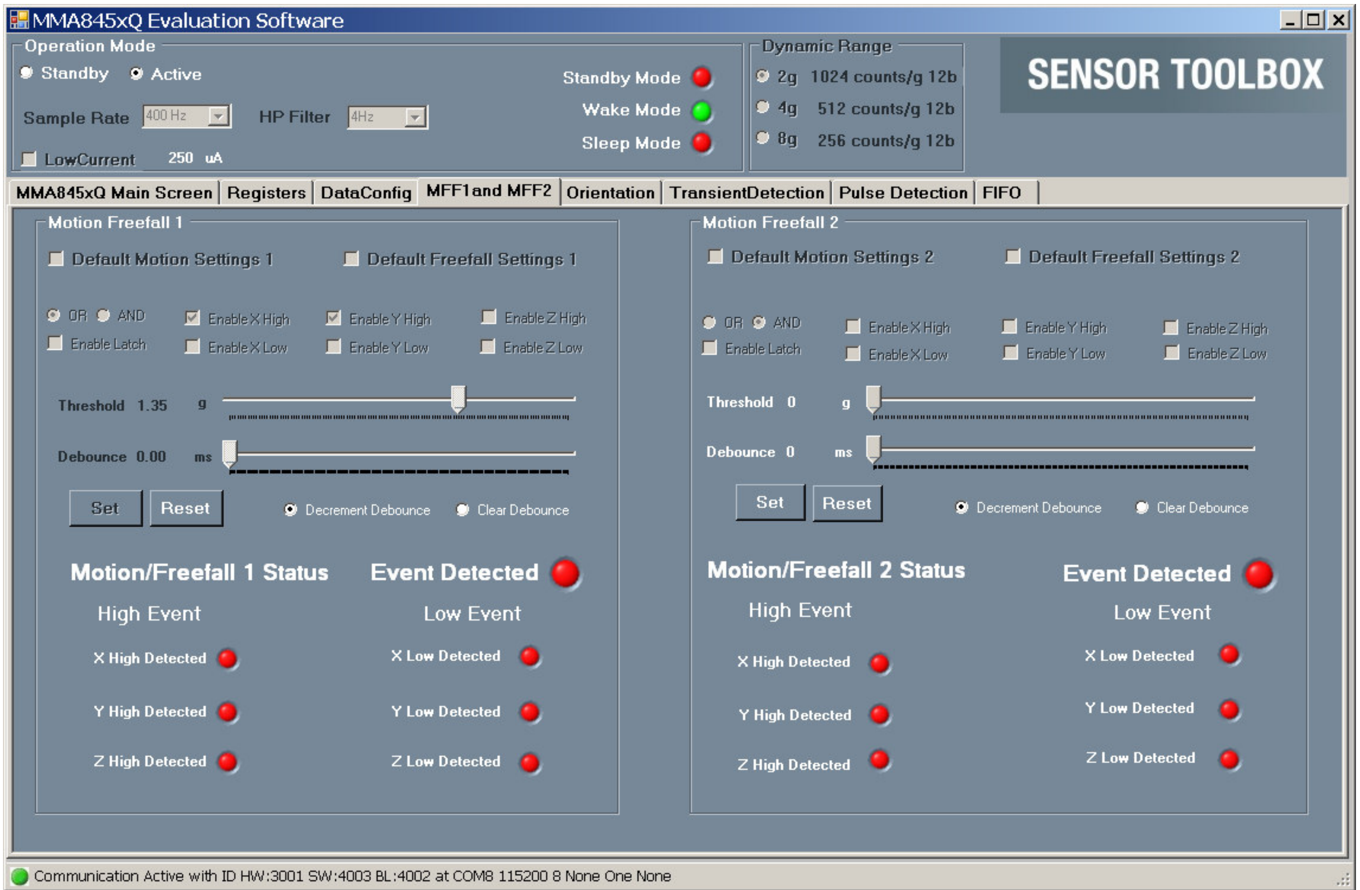
2. **Plug in USB into the touch board and to PC**

3. **Connect numbered Keypad to touch board**

4. **Launch “Sensor Toolbox” ICON on the Desktop**



HANDS-ON LABS USING the MMA8450 and Sensor Toolbox CALIBRATION, TILT, MOTION, AND FREEFALL



Thank you !

Please complete the FTF survey to receive the new Xtrinsic sensor brand t-shirt!

freescale™ semiconductor

freescale™
semiconductor