Accelerometer Terminology Guide

INTRODUCTION

This is a quick reference guide introducing the key definitions for Freescale's accelerometers to help users better interpret and understand the parameters from our data sheets and application notes.

TERMINOLOGY

Acceleration: Acceleration is the rate of change of velocity (the derivative of velocity) with respect to time. It is a vector which has magnitude and direction relative to the axis of sensitivity or other reference frame. The units are length/time^2. Gravity "g" is an acceleration.

Bandwidth: This is the frequency range that the sensor operates in. Freescale accelerometers have a frequency range from DC to the mechanical resonant frequency (-3dB) defined by the sensor. This frequency range can be limited by adding an external filter on the output of the X, Y and Z axes. Some of the accelerometers already have this filter internally built in, and others have only an internal resistor which requires the consumer to choose the bandwidth desired by choosing the capacitor value.

Cross-axis Sensitivity: The output that is subjected on the sensing axis from accelerations on a perpendicular axis, expressed as a percentage of the sensitivity. Each axis has two cross axis sensitivities:

X: S_{XY}, S_{XZ}
Y: S_{YZ}, S_{YX}
Z: S_{XY}, S_{ZX}

The first subscript is the sense axis and the second subscript is the off-axis direction.

$$S_X\text{cross} = \left(\frac{S_{XY}}{S_X}\right) \times 100 \qquad S_X\text{cross} = \left(\frac{S_{XZ}}{S_X}\right) \times 100$$

ESD Tolerance: The device will remain within the specification after an electrostatic shock that is less than the specified ESD Tolerance given for the accelerometer. The human body model is used where an ESD pulse is the equivalent of that produced by a person electrically charged.

g-level: This refers to the acceleration value. +1 g is the acceleration measurement for gravity which is equal to 9.81m/s^2

g-Select: A feature on the accelerometer device that allows for the selection between more than one sensitivity. Depending on the logic of this input the internal gain is changed allowing the accelerometer to function with a higher or lower acceleration range.

Noise: Noise determines the minimum resolution of the sensor. The noise floor can be lowered by lowering the bandwidth.

Noise Density: The power spectral density is measured in $\frac{\mu g}{\sqrt{Hz}}$.

When this value is multiplied by the square root of the measurement bandwidth, this result is the RMS acceleration noise of the sensor at nominal V_{DD} and temperature. Accelerations below this value will not be resolvable.

Non-linearity: The transfer function of the sensor (input/output relationship) is not perfectly linear. The non-linearity is the maximum deviation of output voltage from a best fit straight line, which is divided by the sensitivity of the device. This is expressed as a percentage of Full-Scale Output in g's. The method for calculating the non-linearity is shown below.

$$\text{Non}-\text{linearity} = \frac{\text{MaximumDeviation(g)}}{\text{FullScaleOutput(g)}} \times 100\%$$

© Freescale Semiconductor, Inc., 2007. All rights reserved.

Offset: Offset refers to the DC output level of the accelerometer when no motion or gravity is acting on it, often called the 0g-offset.

Offset Calibration: This is a technique used to set the 0g-offset to store the known offset voltage value when there is no motion or gravity acting on the accelerometer. This voltage value is subtracted off when taking acceleration measurements for accuracy. The offset value can vary device-to-device due to trim errors, mechanical stress and temperature changes.

Offset vs. Temperature: The maximum change in the nominal zero-g output over the full operating temperature range.

Operating Temperature: This is the temperature range that the device will meet the performance specifications.

Power Consumption: This is specified device-to-device, but can be minimized by using power cycling techniques.

Ratiometricity: This means the output offset voltage and sensitivity will scale linearly with applied supply voltage. As the supply voltage increases, the sensitivity and offset increases, and as the supply voltage decreases, the sensitivity and offset decreases.

Ratiometric Error: Ideally, the sensor is ratiometric which means that the output scales by the same ratio that the V_{DD} changes. Ratiometric error is defined as the difference between the ratio that 0g offset or sensitivity changed and the ratio that V_{DD} changed, expressed as a percentage.

Offset Ratiometric Error Calculation

$$\text{Error @ }1.03V_{DD} = \left(\frac{\text{Offset @ }1.03V_{DD}}{\text{Offset @ }1.0V_{DD}} - 1.03\right) \times 100\%$$

Sensitivity Ratiometric Error Calculation

$$\text{Error @ }0.93V_{DD} = \left(\frac{\text{Sensitivity @ }0.93V_{DD}}{\text{Sensitivity @ }1.0V_{DD}} - 0.93\right) \times 100\%$$

Resolution: The smallest detectable increment in acceleration. It is necessary to know what the smallest change is that needs to be detected. The accelerometer bandwidth will determine the measurement resolution, but filtering can be used to lower the noise floor and improve resolution further. The resolution can be improved by decreasing the bandwidth of the output low-pass filter. The trade-off with better resolution is a longer enable time. The resolution is calculated by the following equation:

$$R = N \times \sqrt{BW_{LPF} \times 1.6}$$

where N is the power spectral density noise in $\frac{\mu g}{\sqrt{Hz}}$. The power spectral density noise value is characteristic of the accelerometer.

N = 350 $\frac{\mu g}{\sqrt{Hz}}$ for X, Y and Z; characteristic of the MMA73x0L.

> **NOTE:** If the resolution of the A/D converter is less than the resolution calculated for the accelerometer, then the system will be limited by the A/D converter. Otherwise the limitation is due to the noise and filter using the equations above.

Self-Test: This is a feature that provides verification of the mechanical and electrical integrity of the accelerometer. This feature is critical in applications such as hard disk drive protection where system integrity must be ensured over the life of the product. If holding the accelerometer upside down, then the Z-axis output is -1g. When the self-test function is activated, an electrostatic force is applied to each axis to cause it to deflect +1g and the final output should return to 0g in the Z-axis.

Sensitivity: The output voltage change per unit of input acceleration at nominal V_{DD} and temperature, measured in mV/g (Voltage Output per g).

How to Reach Us:

Home Page:
www.freescale.com

Web Support:
http://www.freescale.com/support

USA/Europe or Locations Not Listed:
Freescale Semiconductor, Inc.
Technical Information Center, EL516
2100 East Elliot Road
Tempe, Arizona 85284
+1-800-521-6274 or +1-480-768-2130
www.freescale.com/support

Europe, Middle East, and Africa:
Freescale Halbleiter Deutschland GmbH
Technical Information Center
Schatzbogen 7
81829 Muenchen, Germany
+44 1296 380 456 (English)
+46 8 52200080 (English)
+49 89 92103 559 (German)
+33 1 69 35 48 48 (French)
www.freescale.com/support

Japan:
Freescale Semiconductor Japan Ltd.
Headquarters
ARCO Tower 15F
1-8-1, Shimo-Meguro, Meguro-ku,
Tokyo 153-0064
Japan
0120 191014 or +81 3 5437 9125
support.japan@freescale.com

Asia/Pacific:
Freescale Semiconductor Hong Kong Ltd.
Technical Information Center
2 Dai King Street
Tai Po Industrial Estate
Tai Po, N.T., Hong Kong
+800 2666 8080
support.asia@freescale.com

For Literature Requests Only:
Freescale Semiconductor Literature Distribution Center
P.O. Box 5405
Denver, Colorado 80217
1-800-441-2447 or 303-675-2140
Fax: 303-675-2150
LDCForFreescaleSemiconductor@hibbertgroup.com

Information in this document is provided solely to enable system and software implementers to use Freescale Semiconductor products. There are no express or implied copyright licenses granted hereunder to design or fabricate any integrated circuits or integrated circuits based on the information in this document.

Freescale Semiconductor reserves the right to make changes without further notice to any products herein. Freescale Semiconductor makes no warranty, representation or guarantee regarding the suitability of its products for any particular purpose, nor does Freescale Semiconductor assume any liability arising out of the application or use of any product or circuit, and specifically disclaims any and all liability, including without limitation consequential or incidental damages. “Typical” parameters that may be provided in Freescale Semiconductor data sheets and/or specifications can and do vary in different applications and actual performance may vary over time. All operating parameters, including “Typicals”, must be validated for each customer application by customer’s technical experts. Freescale Semiconductor does not convey any license under its patent rights nor the rights of others. Freescale Semiconductor products are not designed, intended, or authorized for use as components in systems intended for surgical implant into the body, or other applications intended to support or sustain life, or for any other application in which the failure of the Freescale Semiconductor product could create a situation where personal injury or death may occur. Should Buyer purchase or use Freescale Semiconductor products for any such unintended or unauthorized application, Buyer shall indemnify and hold Freescale Semiconductor and its officers, employees, subsidiaries, affiliates, and distributors harmless against all claims, costs, damages, and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if such claim alleges that Freescale Semiconductor was negligent regarding the design or manufacture of the part.

Freescale™ and the Freescale logo are trademarks of Freescale Semiconductor, Inc. All other product or service names are the property of their respective owners.

© Freescale Semiconductor, Inc. 2007. All rights reserved.

freescale™
semiconductor

SENSORTERMSPG
Rev. 0
05/2007