

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/time². 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_{ZY} , S_{ZX}

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

$$S_{Xcross} = \left(\frac{S_{XY}}{S_X} \right) \times 100 \quad S_{Xcross} = \left(\frac{S_{XZ}}{S_X} \right) \times 100$$

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/s²

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.

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

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.

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

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).

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