



# MEMS Sensor Terminology

## Accelerometers/Gyroscopes

### Accelerometer Terminology

**Zero-g Offset** — The output voltage or digital count value for zero-g input acceleration at nominal  $V_{dd}$  and temperature.

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

**Operating Temperature** — The temperature range over which the device will meet performance specifications.

**Storage Temperature** — The temperature at which the device can be stored unpowered and still meet performance specifications when powered within the operating temperature.

**Span** — The output voltage or digital count value relative to zero-g output for full scale  $\pm$  input acceleration at nominal  $V_{dd}$  and temperature.

**Range** — The input acceleration that causes the output to reach span voltage or digital count.

**Sensitivity** — The output voltage or digital count change per unit of input acceleration at nominal  $V_{dd}$  and temperature, measured in mV/g or counts/g.

**Bandwidth** — The frequency range in which the MEMS sensor operates. Kionix sensors respond from 0 Hz to a user-definable upper cutoff frequency. The maximum bandwidth is determined by the mechanical resonant frequency (-3dB) of the sensor.

**Noise Density** — When multiplied by the square root of the measurement bandwidth, this value will give the rms acceleration noise of the sensor at nominal  $V_{dd}$  and temperature. Accelerations below this value will not be resolvable.

**Resolution** — The minimum detectible change in acceleration. To be detectible, the signal must be greater than the noise of the sensor.

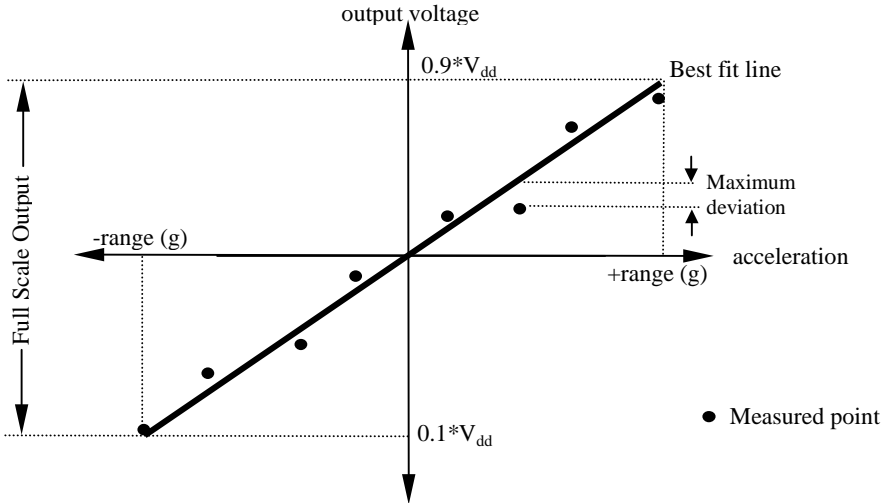
**Cross-axis Sensitivity** — The output induced on a sense axis from the application of acceleration on a perpendicular axis, expressed as a percentage of the sensitivity. There are multiple cross-axis sensitivities:  $S_{xy}$ ,  $S_{xz}$ ,  $S_{yx}$ ,  $S_{yz}$ ,  $S_{zx}$ ,  $S_{zy}$ , where the first subscript is the sense axis and the second subscript is the off-axis direction. For example, the calculation of the cross-axis sensitivity for the x-axis sensor of a tri-axis accelerometer is shown below:

$$S_{x_{cross}} = \left( \frac{\sqrt{(S_{xy}^2 + S_{xz}^2)}}{S_x} \right) * 100\%$$

**ESD Tolerance** — The device will continue to meet specifications after an electrostatic shock that is less than or equal to the ESD Tolerance. The Human Body Model (HBM), where an ESD pulse similar to that produced by a person who is electrically charged, is specified.

**Mechanical Shock** — The maximum mechanical shock applied in any direction at which the part will remain within specification when nominal  $V_{dd}$  is applied to the device.

**Non-linearity** — Sensors do not demonstrate a perfectly linear relationship between input acceleration and output voltage or digital count. This non-linearity is the maximum deviation of output voltage or digital count from the “best fit line,” the straight line defined by sensitivity, expressed in percentage of Full-Scale Output (FSO). The method for calculating non-linearity of an analog accelerometer is shown below:



$$Non - linearity = \frac{Maximum\ deviation(V)}{Full\ Scale\ Output(V)} \times 100\%$$

**Ratiometric Error** — Ideally, an analog sensor is ratiometric—the output scales by the same ratio that  $V_{dd}$  increases or decreases. For example, a 5% increase in  $V_{dd}$  results in a 5% increase in Og offset. Ratiometric error is defined as the difference between the ratio that Og offset or sensitivity changed and the ratio that  $V_{dd}$  changed, expressed as a percentage. For our specifications, ratiometric error is calculated for a  $\pm 5\%$  change in  $V_{dd}$  from nominal and can be calculated using the below equations.

### **Offset Ratiometric Error**

$$ORE(1.05V_{dd}) = \left( \left( \frac{OgOffset(@ 1.05V_{dd})}{OgOffset(@ V_{dd})} \right) - \left( \frac{1.05V_{dd}}{V_{dd}} \right) \right) * 100$$

$$ORE(0.95V_{dd}) = \left( \left( \frac{OgOffset(@ 0.95V_{dd})}{OgOffset(@ V_{dd})} \right) - \left( \frac{0.95V_{dd}}{V_{dd}} \right) \right) * 100$$

### **Sensitivity Ratiometric Error**

$$SRE(1.05V_{dd}) = \left( \left( \frac{Sensitivity(@ 1.05V_{dd})}{Sensitivity(@ V_{dd})} \right) - \left( \frac{1.05V_{dd}}{V_{dd}} \right) \right) * 100$$

$$SRE(0.95V_{dd}) = \left( \left( \frac{Sensitivity(@ 0.95V_{dd})}{Sensitivity(@ V_{dd})} \right) - \left( \frac{0.95V_{dd}}{V_{dd}} \right) \right) * 100$$

## Gyroscope Terminology

**Zero Rate Output** — The output voltage or digital count for zero rate input rotation at nominal  $V_{dd}$  and temperature.

**Zero Rate Output vs. Temperature** — The maximum change in the nominal zero rate output over the full operating temperature range.

**Operating Temperature** — The temperature range over which the device will meet performance specifications.

**Storage Temperature** — The temperature at which the device can be stored unpowered and still meet performance specifications when powered within the operating temperature.

**Span** — The output voltage or digital count value relative to zero rate output for full scale  $\pm$  input rotation at nominal  $V_{dd}$  and temperature.

**Range** — The input rotation that causes the output to reach span voltage or digital count.

**Sensitivity** — The output voltage or digital count change per unit of input rotation at nominal  $V_{dd}$  and temperature, measured in mV/deg/sec or counts/deg/sec.

**Bandwidth** — The frequency range in which the gyroscope sensor operates. Kionix sensors respond from 0 Hz to a user-definable upper cutoff frequency.

**Noise Density** — When multiplied by the square root of the measurement bandwidth, this value will give the rms rotation noise of the sensor at nominal  $V_{dd}$  and temperature. Rotations below this value will not be resolvable.

**Resolution** — The minimum detectible change in rotation. To be detectible, the signal must be greater than the noise of the sensor.

**Cross-axis Sensitivity** — The output induced on a sense axis from the application of rotation about a perpendicular axis, expressed as a percentage of the sensitivity. There are multiple cross-axis sensitivities:  $S_{xy}$ ,  $S_{xz}$ ,  $S_{yx}$ ,  $S_{yz}$ ,  $S_{zx}$ ,  $S_{zy}$ , where the first subscript is the sense axis and the second subscript is the off-axis direction. For example, the calculation of the cross-axis sensitivity for the x-axis sensor of a tri-axis gyroscope is shown below:

$$S_{x_{cross}} = \left( \frac{\sqrt{(S_{xy}^2 + S_{xz}^2)}}{S_x} \right) * 100\%$$

**ESD Tolerance** — The device will continue to meet specifications after an electrostatic shock that is less than or equal to the ESD Tolerance. The Human Body Model (HBM), where an ESD pulse similar to that produced by a person who is electrically charged, is specified.

**Mechanical Shock** — The maximum mechanical shock applied in any direction at which the part will remain within specification when nominal  $V_{dd}$  is applied to the device.

***Non-linearity*** — Sensors do not demonstrate a perfectly linear relationship between input rotation and output voltage or digital count. This non-linearity is the maximum deviation of output voltage or digital count from the “best fit line,” the straight line defined by sensitivity, expressed in percentage of Full-Scale Output (FSO). The ratio of the maximum output deviation versus the full-scale output is then specified as a percentage.