MEMS

How to evaluate the resolution of an accelerometer

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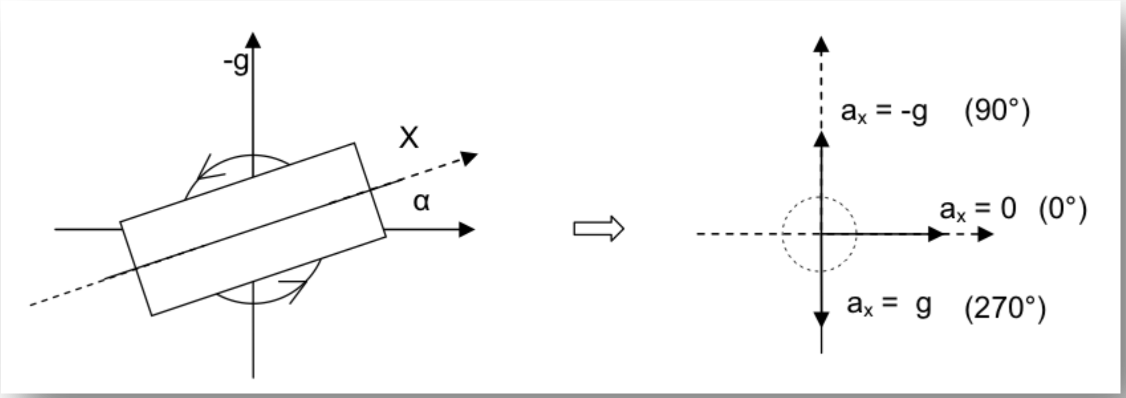
Summary

- Ideal Inclinometer: calculation of sensitivity mg / ° for an accelerometer (single axis, two-axis and three-axis)

- Real Inclinometer: key parameters to be considered in order to evaluate sensitivity and accuracy in measuring the inclination

Single axis sensing



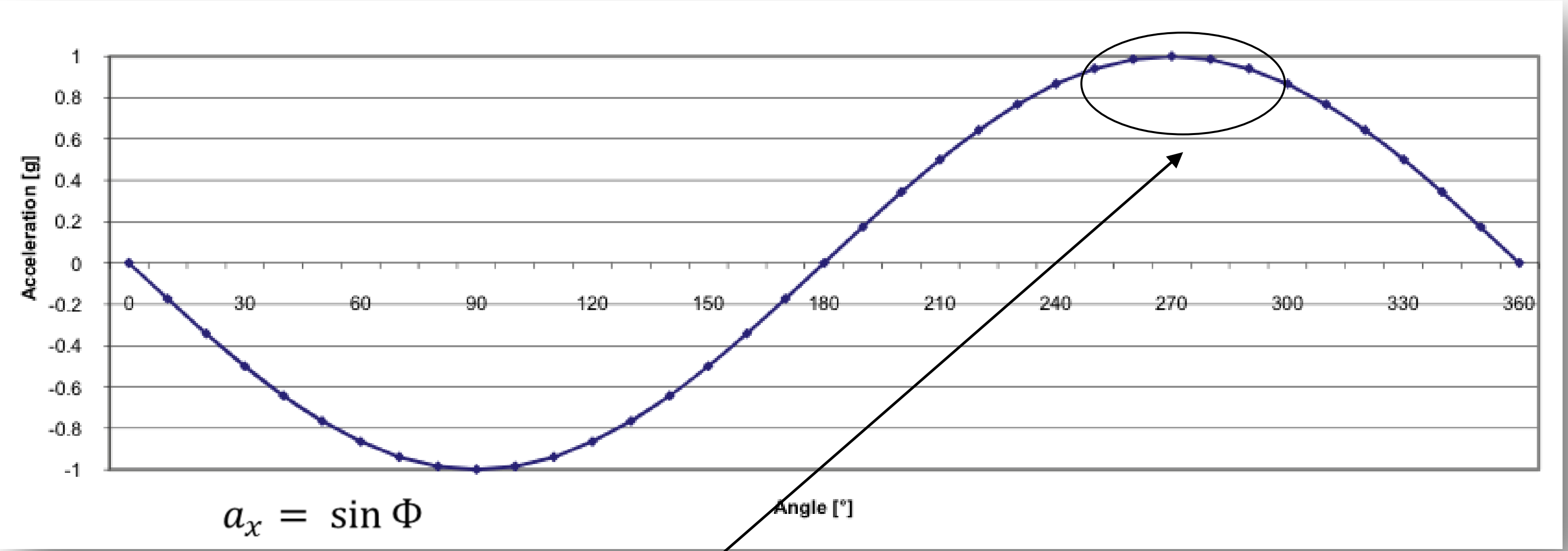
The X axis detects an acceleration equal to :

$$a_x = \sin \Phi$$

An accelerometer with sensing on a single axis does not allow to:

- Having a capacity of sensing constant to the variation of Φ: a_x/° that depends on the function $\sin \Phi$
- does not distinguish between angles Φ and $(180 - \Phi)$

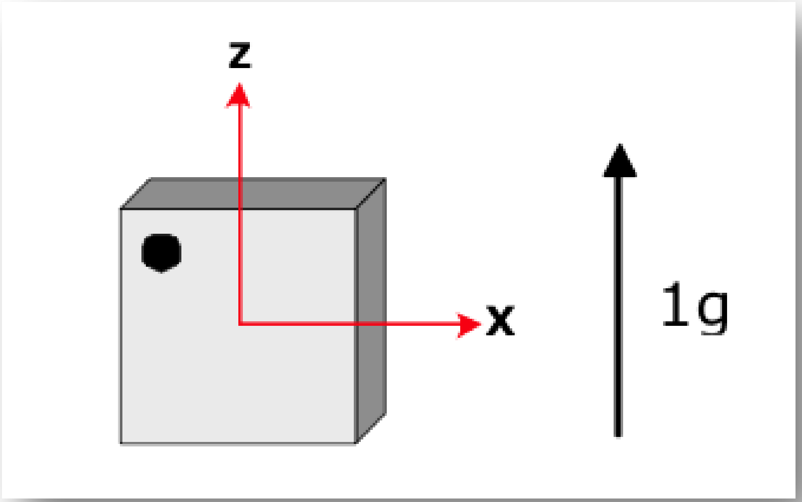
Single axis sensing



Φ	a_x [g]	Δa_x/° [mg/°]
0	0.000	17.452
15	0.259	16.818
30	0.500	15.038
45	0.707	12.233
60	0.866	8.594
75	0.966	4.37
90	1.000	- 0.152

The sensor is less sensitive when its axis has a direction close to that of $\vec{g}$

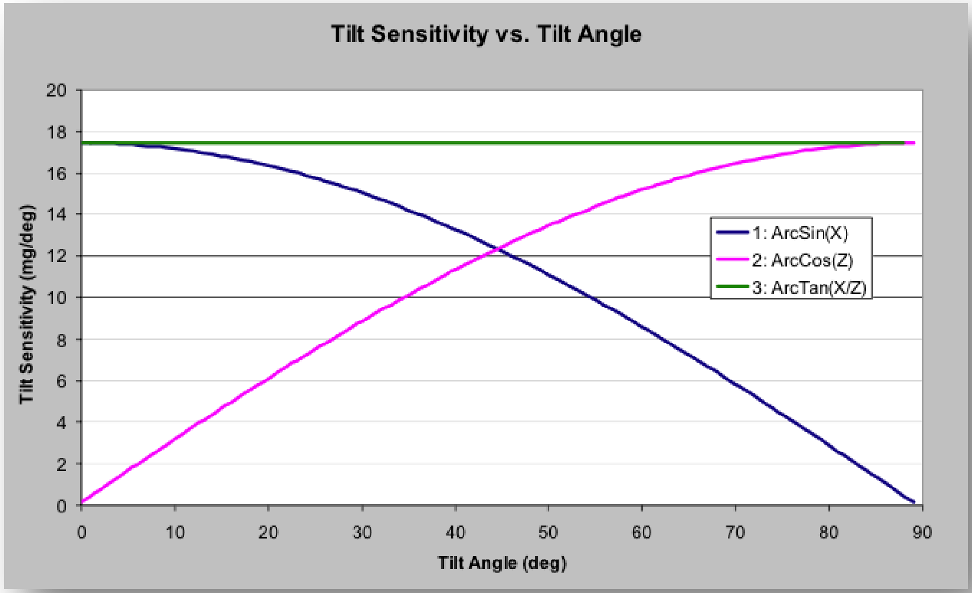
Two axes sensing



$$a_x = \sin\Phi$$
$$a_z = \cos\Phi$$

The use of two axes, one parallel and one perpendicular to $\vec{g}$ allows to have a constant sensing Φ angle (on the plane x -z). This allows you to uniquely distinguish all the angle degrees.

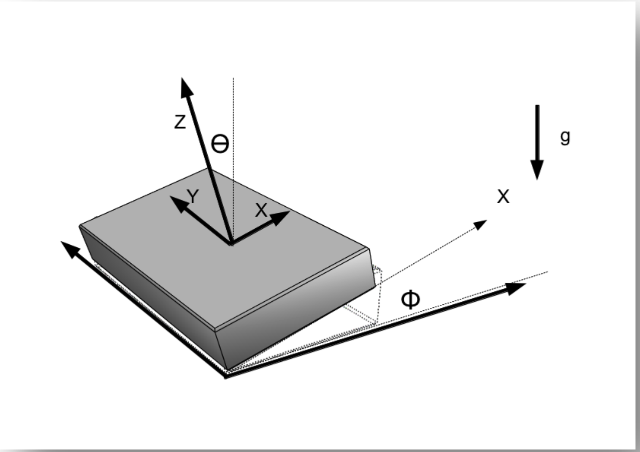
Two axes sensing

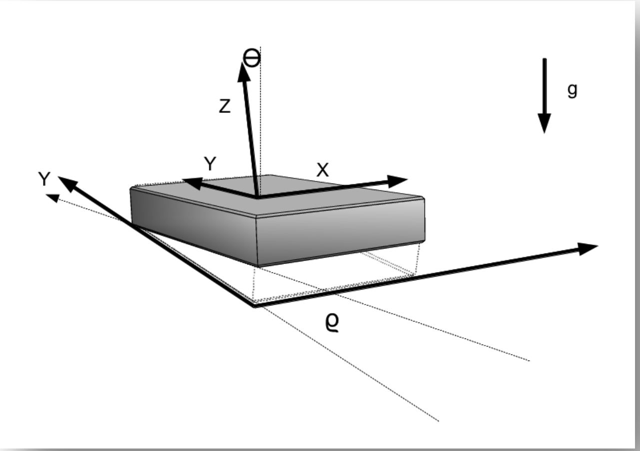


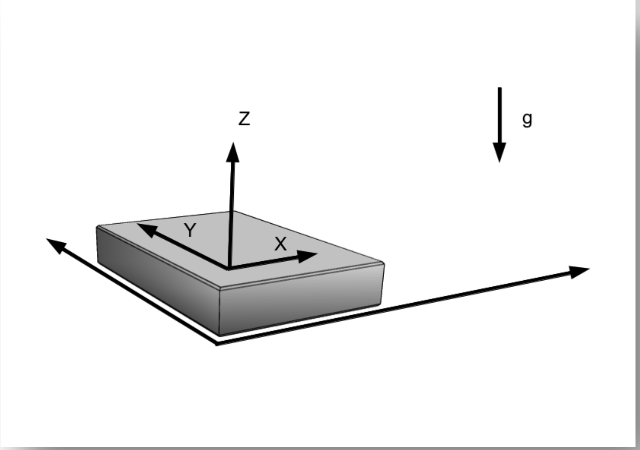
Φ	a_x [g]	Δa_x/° [mg/°]	a_z [g]	Δa_z/° [mg/°]
0	0.000	17.452	1	-0.152
15	0.259	16.818	0.966	-4.664
30	0.500	15.038	0.866	-8.858
45	0.707	12.233	0.707	-12.448
60	0.866	8.594	0.500	-15.19
75	0.966	4.37	0.259	-16.897
90	1.000	0.152	0.000	-17.452

With the use of two axes x and z get a tilt sensing constant independent of the angle of rotation of approximately **17,45 mg / °**

Three axis sensing







The reasoning can be extended on the axis y - z:

$$\Phi = \arctan\left(\frac{Ax1}{\sqrt{(Ay_1)^2+(Az_1)^2}}\right)$$

$$\varrho = \arctan\left(\frac{Ax1}{\sqrt{(Ax_1)^2+(Az_1)^2}}\right)$$

Accelerometer: key parameters

ODR (output data rate): typical value 100Hz
BW (bandwidth of the signal to be measured): typical ODR/2 or ODR/4
FS (full scale range): for example $\pm 2g$
SO (sensitivity): expressed in mg/LSB, indicates the variation of mg which must have to obtain a variation of one LSB

Resolution at: $1\,\sigma \Rightarrow A_n \cdot \sqrt{BW}$

The parameter **1σ** corresponds statistically to (68.2% of samples), you should consider the value **3σ** (99.7% of samples)

Accelerometer: key parameters

LIS331DLH: calculation resolution *(a 3σ)*

ODR = 50 Hz
BW = 25 Hz (ODR/2)

$$3 \cdot A_n \cdot \sqrt{BW} = 3{,}27\ mg$$

The accelerometer, taking into account the noise input, has a resolution of 3.27 mg.
Therefore, the resolution expressed in degrees will be:

$$\frac{3{,}27\ mg}{17{,}45\ mg/°} = 0{,}187°$$

Symbol	Parameter	Test conditions	Min.	Typ.[2]	Max.	Unit
FS	Measurement range[3]	FS bit set to 00		±2.0		*g*
		FS bit set to 01		±4.0		
		FS bit set to 11		±8.0		
So	Sensitivity	FS bit set to 00 12 bit representation	0.9	1	1.1	m*g*/digit
		FS bit set to 01 12 bit representation	1.8	2	2.2	
		FS bit set to 11 12 bit representation	3.5	3.9	4.3	
TCSo	Sensitivity change vs temperature	FS bit set to 00		±0.01		%/°C
TyOff	Typical zero-*g* level offset accuracy[4],[5]	FS bit set to 00		±20		m*g*
TCOff	Zero-*g* level change vs temperature	Max delta from 25 °C		±0.1		m*g*/°C
An	Acceleration noise density	FS bit set to 00		218		μ*g*/$\sqrt{Hz}$
Vst	Self-test output change[6],[7],[8]	FS bit set to 00 X axis	120	300	550	LSb
		FS bit set to 00 Y axis	120	300	550	LSb
		FS bit set to 00 Z axis	140	350	750	LSb
Top	Operating temperature range		-40		+85	°C
Wh	Product weight			20		mgram