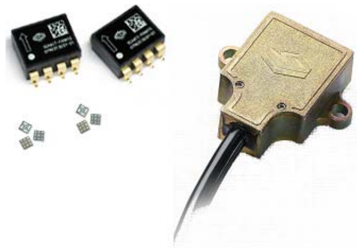
Cross-axis Compensation



OBJECTIVE

This document describes how to measure and calculate the cross-axis sensitivity of an inclinometer. The second part of this is document describes how to compensate for the cross-axis error in applications.

The cross-axis definition is valid for all of VTI's inclinometers and accelerometers. The cross-axis compensation can be applied for dual axis inclinometers such as the SCA100T series.

DESCRIPTION

The cross-axis sensitivity shows how much perpendicular acceleration or inclination is coupled to the signal. This error is caused by a mounting error of the sensor element and the actual component. In applications that need accurate information about the plane's tilt positioning, the cross-axis error may cause inaccuracy.

Cross-axis sensitivity is defined bellow as follows:

$$CrSens = \frac{\sqrt{S_Y^2 + S_Z^2}}{S_X} \cdot 100\% \tag{1}$$

where S_X is the measured sensitivity in measuring direction, S_Y and S_Z are the measured sensitivities in cross-axis directions. Sensitivities used in cross-axis calculation should be in the [V/g] unit.

The measurement and calculation of SCA100T-D02 cross-axis sensitivity is used as an example. SCA100T X-channel measuring direction and cross-axis directions for X-channel are presented in figure 1.

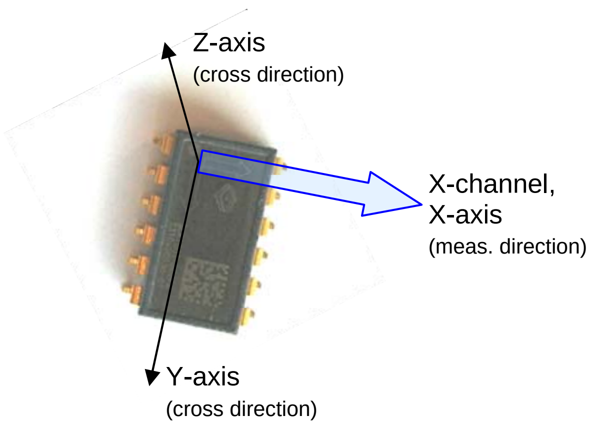


Figure 1. SCA100T X-channel measuring direction.

Sensitivities in equation 1 are measured by tilting the sensor equally in two positions (*tilt1* and *tilt2*). Tilt position should be selected so that the sensor output is still within measuring range.

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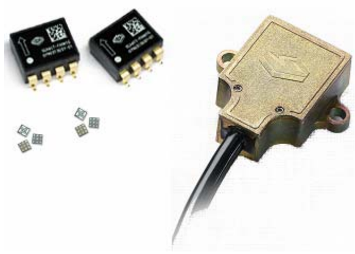
Sensor output is measured in tilt positions. Sensitivities are calculated as follows:



$$S = \frac{Vout_{tilt1} - Vout_{tilt2}}{\sin(tilt1) + \sin(tilt2)} = \frac{Vout_{tilt1} - Vout_{tilt2}}{2 \cdot \sin(tilt1)} \qquad (2)$$

where S is the sensitivity in [V/g], $Vout_{tilt1}$ is the measured output in $tilt1$ position, $Vout_{tilt2}$ is the measured output in $tilt2$ position. The $tilt$ in equation 2 is the amount of tilt angle in degrees.

If ±90° tilt positions are used the equation 2 is reduced to

$$S = \frac{Vout_{tilt1} - Vout_{tilt2}}{\sin(90^{\circ}) + \sin(90^{\circ})} = \frac{Vout_{tilt1} - Vout_{tilt2}}{1+1} = \frac{Vout_{tilt1} - Vout_{tilt2}}{2g} \qquad (3)$$

Figures 2, 3 and 4 present the measuring positions for X-channel cross-axis sensitivity. Measure X-CHANNEL OUTPUT in each position in figures 2, 3 and 4.

Sensitivity in measurement direction (X-axis) is measured in positions presented in figure 2.

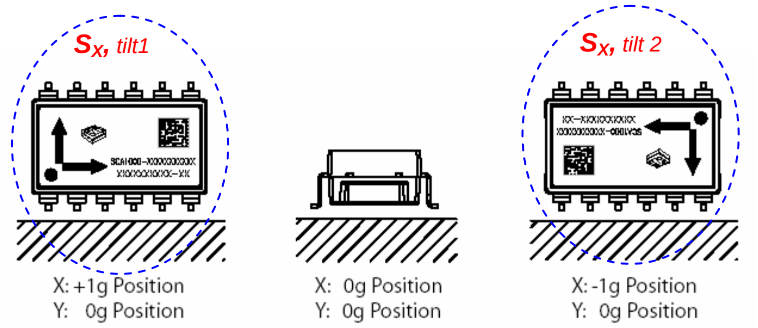


Figure 2. Measure X-channel output for X-axis sensitivity (positions for S_X).

Cross sensitivity in Y-axis direction is measured in positions presented in figure 3.

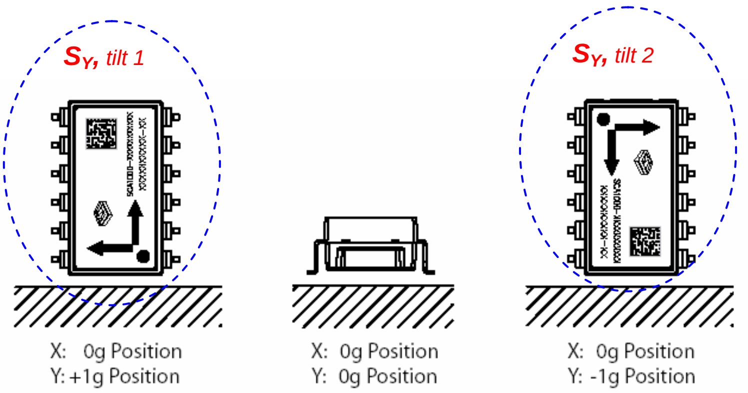


Figure 3. Measure X-channel output for Y-axis cross sensitivity (positions for S_Y).

Cross sensitivity in Z-axis direction is measured in positions presented in figure 4.

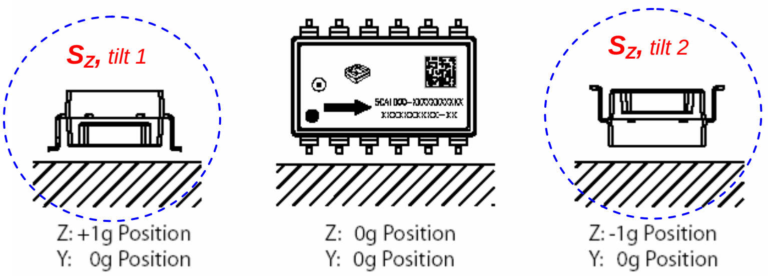
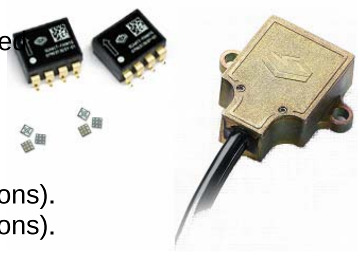


Figure 4. Measure X-channel output for Z-axis cross sensitivity (positions for S_Z).

VTI TECHNOLOGIES

SOLUTION



The inaccuracy due to cross-axis sensitivity in plane positioning can be compensated for in the application.

In order to compensate for the X-axis cross-axis error,
the following measurements need to be made:

1. Measure X-channel sensitivity in Y-axis direction (figure 5 *tilt1* and *tilt2* positions).
2. Measure Y-channel sensitivity in Y-axis direction (figure 5 *tilt1* and *tilt2* positions).
3. Calculate X-channel sensitivity in Y-axis direction (equation 2).
4. Calculate Y-channel sensitivity in Y-axis direction (equation 2).

All sensitivities measured above need to be in [V/g] units. The two tilt positions needed for the measurements are presented below in figure 5.

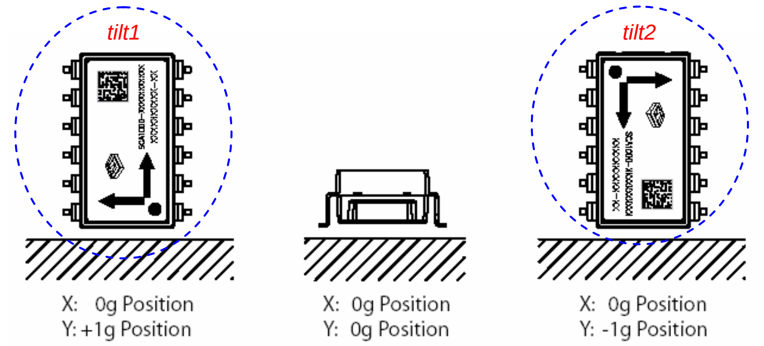


Figure 5. Measure X-and Y-channel outputs for X-channel cross-axis error compensation.

The X-channel cross-axis error can be compensated using the following procedure:

5. Measure X- and Y-channel outputs.
6. Calculate the tilt angle of the plane in to Y-axis direction by using the Y-channel output information and the equation below

$$\alpha_{Y-axis} = \operatorname{asin}\left(\frac{Vout_{Y\text{-}axis} - Voffset_{Y\text{-}axis}}{Sens_{Y\text{-}axis}}\right) \quad (4)$$

   where $\alpha_{Y\text{-}axis}$ is the tilt angle in Y-axis direction, $Vout_{Y\text{-}axis}$ is the measured Y-channel output value in [V], $Voffset_{Y\text{-}axis}$ is the Y-channel offset value in [V] and $Sens_{Y\text{-}axis}$ is the Y-channel sensitivity value in [V/g].

7. Compensate for the cross-axis error from the measured X-channel output value by using the equation below

$$Xout_{Comp} = Vout_{X-axis} + X_{ch}Sens_{Y-axis} \cdot \sin(\alpha_{Y-dir}) \quad (5)$$

   where $Xout_{Comp}$ is the compensated X-channel output value in [V], $Vout_{X\text{-}axis}$ is the measured X-channel output value in [V], $X_{ch}Sens_{Y\text{-}axis}$ is the X-channel sensitivity in Y-axis direction in [V/g] value (see step 3) and $\alpha_{Y\text{-}dir}$ is the tilt angle in Y-axis direction (from equation 4).

   By using equation 4, the cross-axis compensated X-channel output can be calculated as presented in equation 6,

$$Xout_{Comp} = Vout_{X-axis} + X_{ch}Sens_{Y-axis} \cdot \frac{Vout_{Y\text{-}axis} - Voffset_{Y\text{-}axis}}{Sens_{Y\text{-}axis}} \quad (6)$$

   where $Xout_{Comp}$ is the compensated X-channel output value in [V], $Vout_{X\text{-}axis}$ is the measured X-channel output value in [V], $X_{ch}Sens_{Y\text{-}axis}$ is the X-channel sensitivity in Y-axis direction in [V/g] value (see step 3), $Vout_{Y\text{-}axis}$ is the measured Y-channel output value in [V], $Voffset_{Y\text{-}axis}$ is the Y-channel offset value in [V] and $Sens_{Y\text{-}axis}$ is the Y-channel sensitivity value in [V/g].

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