APPLICATION NOTES

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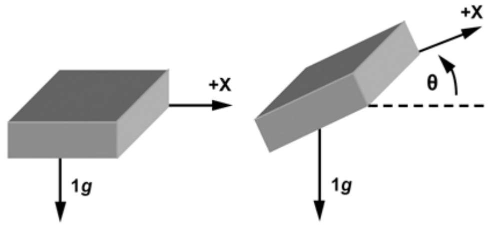
Application Note 273 Using BioNomadix Tri-axial Accelerometer as a Tilt Sensor Inclinometer

Tilt angle or inclination sensing uses measurements of gravity, and its trigonometric projection on the axes of a tri-axial accelerometer (such as BN-ACCL3), to determine tilt angle in all three spatial dimensions (X, Y and Z).

The following picture illustrates a single axis tilt measurement using a single acceleration measurement.

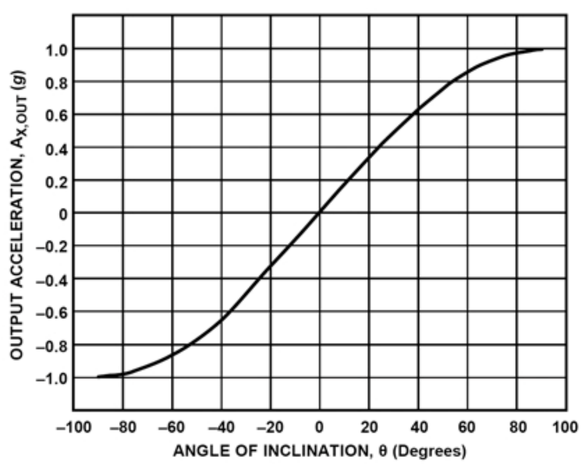


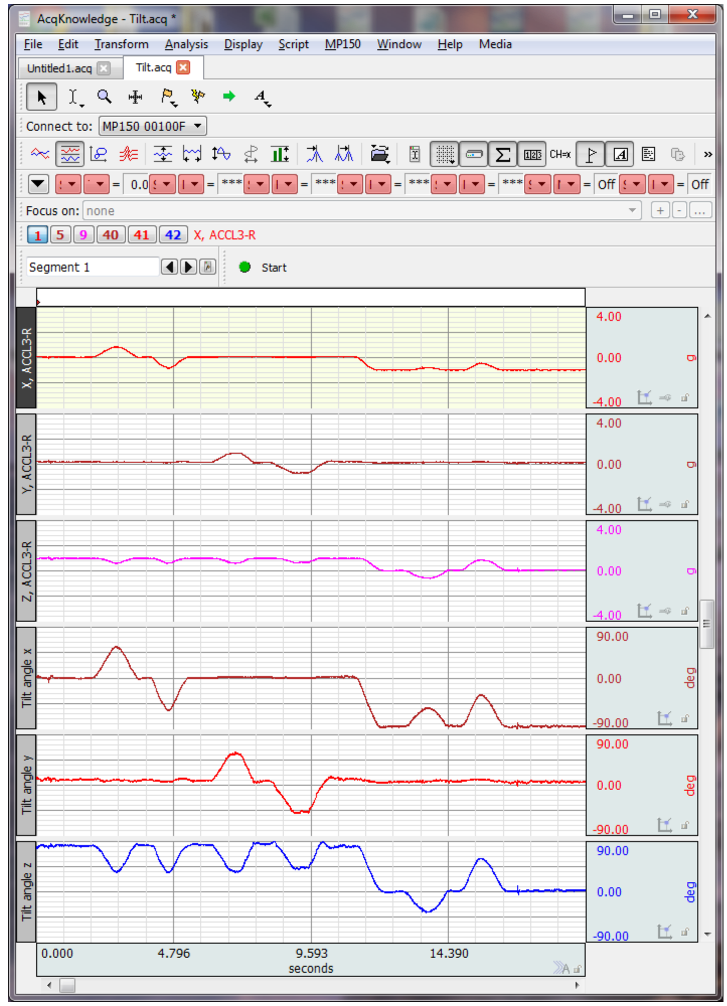
In this case, the following formula applies:

Ax = 1g * sin(Øx)

Namely, the acceleration measured along the X-axis (Ax) is equal to the gravity vector (1g) multiplied by the sine of the tilt angle with respect to the X-axis (Øx).

The following graph illustrates the output acceleration reported by the X-axis of a tri-axial accelerometer, as the accelerometer is tilted from -90 degrees to +90 degrees, assuming 0 degree tilt is parallel to the orientation of the X-axis. Note the point of maximum sensitivity is when the accelerometer is near 0 degrees tilt angle (angle of inclination).





Collected Data – Acceleration and Tilt Angles for X, Y and Z Axis

For a single axis tilt measurement, using just the X-axis of the accelerometer, the following formula can be employed to calculate tilt angle or angle of inclination (Øx) from the acceleration measured along the X-axis:

Øx = arcsin(Ax)

However, this above formula has associated problems: 1) Assumes alignment with plane of gravity; 2) Variable sensitivity based upon tilt angle (note flattening at ±90 degrees). To remove these factors, all the axis of the accelerometer can be used. The following calculations can be setup in the Acq*Knowledge* calculation channels to calculate up to 3 orientations of tilt simultaneously, in real-time, using the BN-ACCL or any other BIOPAC tri-axial accelerometer, such as TSD109C2.

X-axis tilt: $Øy = \arctan(Ax/\mathrm{sqrt}(Ay^2 + Az^2))$
Y-axis tilt: $Øx = \arctan(Ay/\mathrm{sqrt}(Ax^2 + Az^2))$
Z-axis tilt: $Øz = \arctan(Az/\mathrm{sqrt}(Ax^2 + Ay^2))$

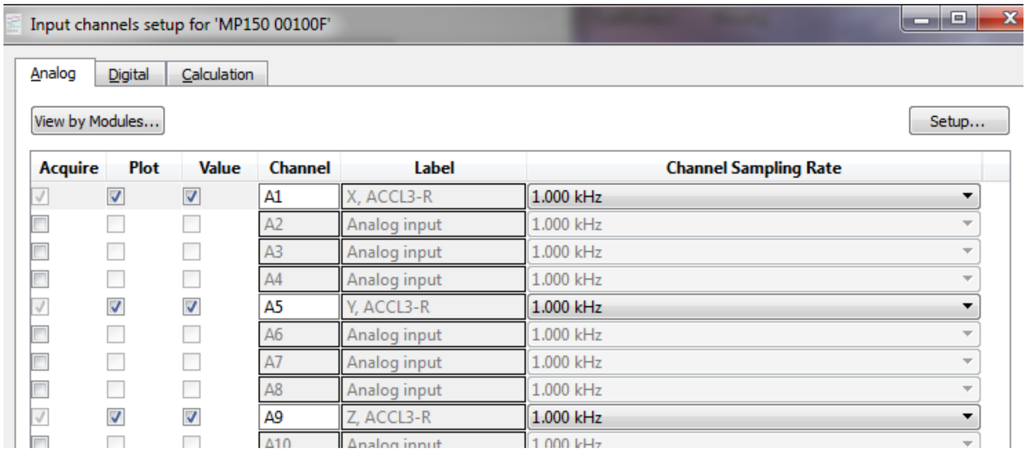
These measurements are performed in radians, so to convert to degrees, use the following conversion factor:

Pi (radians) = 180 degrees

X-axis tilt degrees: $Øx = (180/Pi)*\arctan(Ax/\mathrm{sqrt}(Ay^2 + Az^2))$
Y-axis tilt degrees: $Øy = (180/Pi)*\arctan(Ay/\mathrm{sqrt}(Ax^2 + Az^2))$
Z-axis tilt degrees: $Øz = (180/Pi)*\arctan(Az/\mathrm{sqrt}(Ax^2 + Ay^2))$

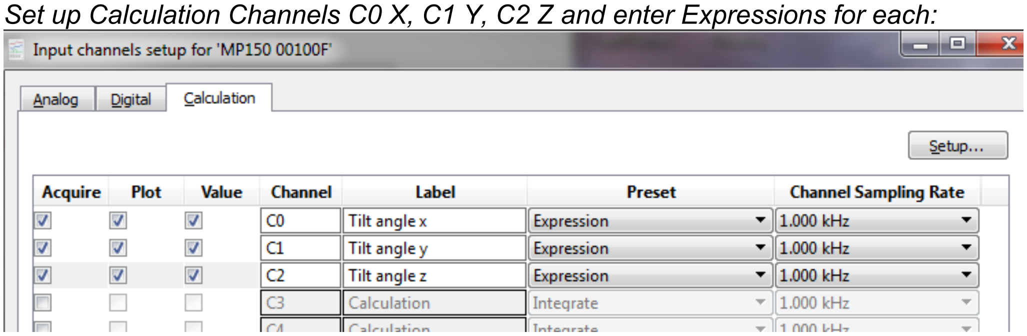
Acq*Knowledge* Setup

1) *Set up Analog Channels A1 X, A5 Y, A9 Z:*

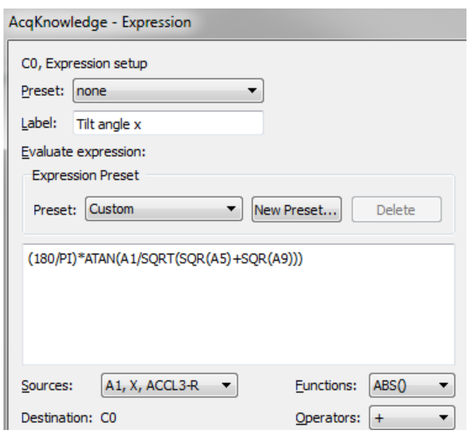


Input Channel Setup for BN-ACCL

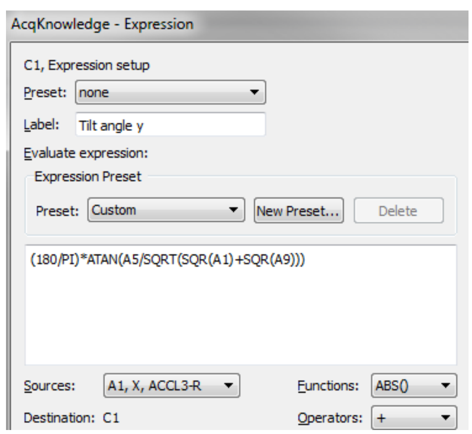
2) *Set up Calculation Channels C0 X, C1 Y, C2 Z and enter Expressions for each:*



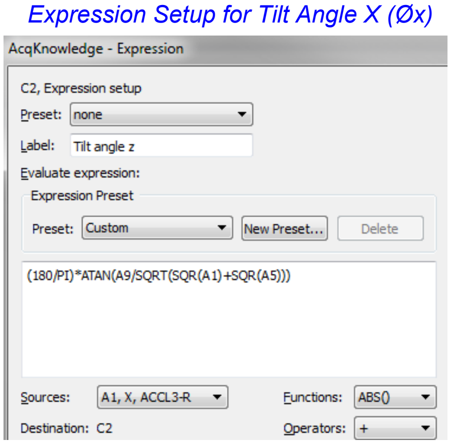
Calculation Channel Setup for BN-ACCL – Tilt Measurement



Expression Setup for Tilt Angle X (Øx)



Expression Setup for Tilt Angle Y (Øy)



Expression Setup for Tilt Angle Z (Øz)