Development of MEMS Based 3-Axis Accelerometer for Hand Movement Monitoring

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Abstract: This project develops a hand movement monitoring system, which feeds the data into the computer and gives the 3D image rotation according to the direction of the tilt and hence monitoring the movement of the hand in context to its tilt. Advancement of MEMS Technology has enabled us to get very small and low cost accelerometer ICs which is based on capacitive principle. Accelerometer based Tilt sensor ADXL335 is used in this paper, based on MEMS technology and the project emphasis on the development of the MEMS based accelerometer to measure the tilt, interfacing the hardware with the LabVIEW and showing the 3D rotation to the user, which is in his understandable form and tilt data can be saved in the computer. It provides an experience of working on emerging technologies like MEMS and design software like LabVIEW.

Keywords: *MEMS Accelerometer, Tilt sensor ADXL335, LabVIEW simulation, 3D Animation*

Introduction: With modern nanotechnology, it is now possible to bring sensors, their signal conditioning and processing circuits on single silicon based platform. The technology used for this purpose is called as micro electro mechanical (MEMS) system. Due to its small size and ease of operation, MEMS accelerometer sensor is commonly used in gaming applications to enhance the effect, mobile handsets, even implemented on human body to analyse tremors and other physical activities.

The 3 axis accelerometer is based on the principle of capacitive sensing. The fig.1 shows basic principle of accelerometer sensor. The sensor is made of spring loaded, micro machined structure, mounted on silicon base. Force on the structure changes the position of seismic mass attached on the spring. This deflection is measured using fixed plate capacitor sensors. The change in acceleration unbalances capacitor plate distance, observed by modulation/demodulation circuits and thus, resulted in output proportional to acceleration. The sensing can be static (gravity) or dynamic (forced acceleration).

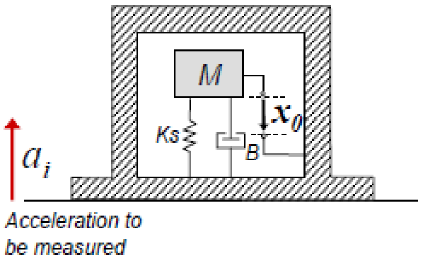

Figure 1 Accelerometer Principle

Tilt Experiment:

To test the accuracy of the accelerometer tilt measurements, the accelerometer is tilted in various angles in all direction. The data was read through LabVIEW and stored in a text file. The results obtained are as follows. The fig. 2 shown below is the interfacing of the ADXL335 with the Ni DAQ cards.

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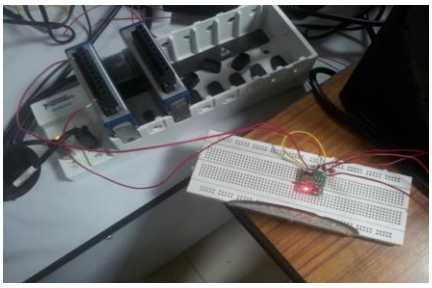

Figure 2 Interfacing with NI DAQ CARDS

Test Results

Tilt given (YZ plane)	Tilt obtained
0	0
30	27.55
60	58.01
90	85.25
120	56.58
150	19.22
180	0

Table 1 Tilt Angles obtained from the LabVIEW

	Mean	Standard Deviation	Variance
Tilt Error	3.06	1.47	2.18

Table 2 Mean error deviation

Accelerometer Evaluation ADXL335: A number of factors were considered for acceleration sensor selection. Sensor with small measurement range was selected as resolution degrades with increase in the sensing capability. Additionally, power supply and thermal stability with optimum bias were the important parameters to be considered for the experiment. The accelerometer used for the research is ADXL335 from Analog Devices. ADXL335 is tri axial accelerometer sensor with built-in amplifiers and demodulator. ADXL335 has a range of ±3g in each axis. The output shows ratio metric characteristics thus, output voltage changes depending on the change in supply voltage. Nominally, at zero g, output voltage is half of the supply voltage. Each axis has a separate bandwidth adjustments. The capacitor in series with output decides the bandwidth of each axis. Bandwidth range of 200 Hz to 1 KHz is used. The analog voltage output from three different axes is fed to NiDAQ USB 9201 for sampling and signal conditioning. Fig3. Shows basic block diagram of ADXL335 as mentioned in the data sheet. The chip has in-built coupling capacitor between supply voltage and ground; thus reducing the noise at the power supply line. It contains micro machined three axis sensor along with signal conditioning circuitry. The sensor output data is acquired using LabVIEW and DAQ card. The capacitor value is selected as 0.1µF for sensor frequency of 50 Hz.

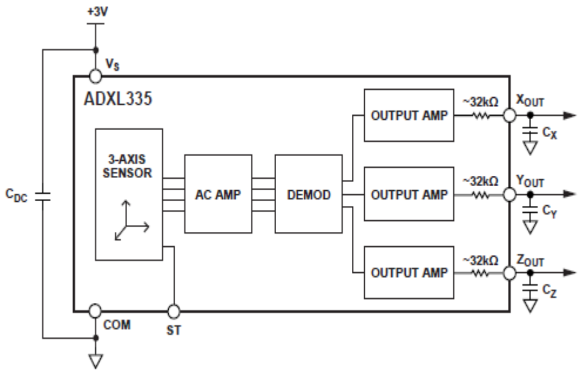

Figure 3 Block Diagram of ADXL335

System Description and Principle Behind it: The accelerometer sensor used here is a polysilicon surface-micro machined structure built on top of a silicon wafer. Deflection of the structure is measured using a differential capacitor. The differential capacitor involves the interdigitation of moving fingers attached to the proof mass with fixed fingers attached to the frame. The differential capacitance is proportional to the overlapping area and the distance between the moving and fixed fingers. Acceleration deflects the moving mass and unbalances the differential capacitor resulting in a sensor output whose amplitude is proportional to acceleration.

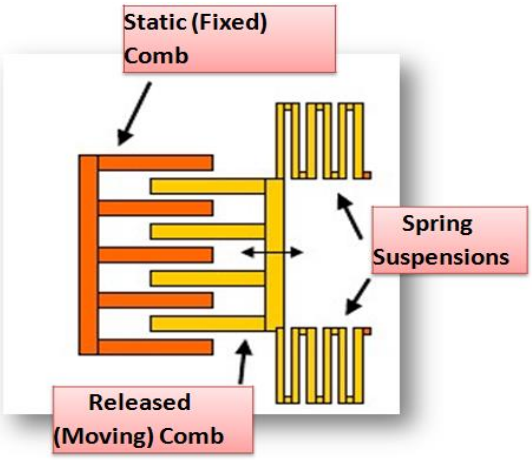

Figure 4 Differential capacitor sensor

According to the Tilt we get voltage readings i.e. for different tilt angle we get different voltage readings. In order to acquire accurate and high resolution measurements, the accelerometer parameters must be calibrated accurately. Each axis of the accelerometer has two parameters that need to be measured in order to convert analog voltage readings to acceleration reading correctly, namely Axis Offset and Axis Sensitivity. The ADXL335 accelerometer outputs a voltage between 0 and Vcc volts for each axis, and zero acceleration for the axis occurs at approximately ½ Vcc. Therefore, each voltage output contains an offset that must be specifically calibrated for each axis. To convert a measured voltage reading to acceleration, Axis Sensitivity is also required, a conversion constant that must also be measured specifically for each axis. The approximate sensitivity of each axis depends on the type of accelerometer. The ADXL335 Accelerometer has an approximate Axis Sensitivity of 330mV/g, where g is the acceleration due to gravity equal to 9.81m/s2.

Calibration Measurements

To calibrate the ADXL335 accelerometer, the accelerometer was supplied by a voltage supply of Vcc =3.0V. Accelerometer calibration was complete with a voltage supply of Vcc = 3.0V (DC). To determine the sensitivity of each axis, the accelerometer was positioned in various ways such that outputs of -1g and +1g were captured for each axis. To determine the offset of each axis, the accelerometer was positioned to capture a 0g for x axis, y axis and 1g for z axis.
As x & y has 0g acceleration: Offset = Input
As z has 1g acceleration: Offset = Input - Sensitivity

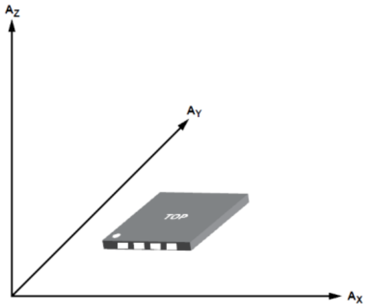

Figure 5 Sensor Axis

Ni DAQ Interfacing with LabVIEW

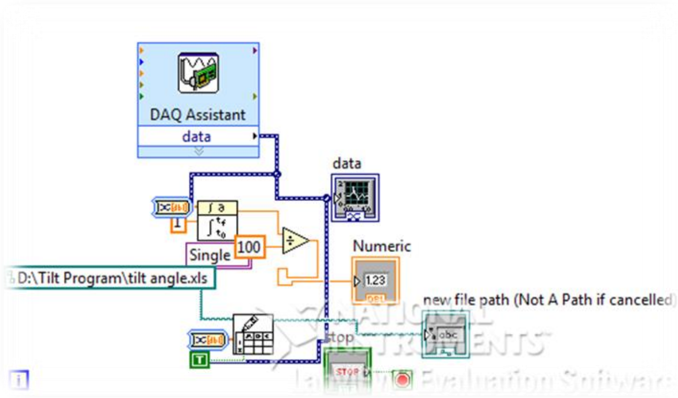

Figure 6 Interfacing Program

Measuring Angle of Rotation using ADXL335 Accelerometer:

To measure the angle of rotation of theADXL335 about the z-axis, the maximum sensitivity is obtained my measuring tilt using all three axes of the accelerometer. Measuring tilt about the z-axis using all three axes of acceleration provides the greatest resolution, and the angle of tilt calculated is independent of the direction rotated from the z-axis. Using basic trigonometry to derive the equation, rotation about the z-axis using calculated using the following equation:

$$\theta = \operatorname{atan}(\frac{\sqrt{Ax2 + Ay2}}{Az})$$

$$where\ Ax, Ay\ and\ Az\ are\ acceleration\ in\ x, y\ and\ z\ directions\ respectively, given\ by$$

$$A = \frac{Vin - Voffset}{Sensitivity}$$

Θ gives angle of tilt. For finding the angle of rotation, we need angle in x, y and z with respect to ground. These are given by:

$$\theta x = \frac{Ax}{\sqrt{Ay^2 + Az^2}}$$

$$\theta y = \frac{Ay}{\sqrt{Ax^2 + Az^2}}$$

$$\theta z = \frac{\sqrt{Ax^2 + Ay^2}}{Az}$$

The angles thus found will need adjustments based on the signs of acceleration obtained.

Ax	**Ay**	**Az**	**θx**	**Θy**	**θz**
+	+	+	θx	-θy	θz
+	+	-	θx	-θy	180+θz
+	-	-	θx	- θy	-(θz+180)
+	-	-	θx	180-θy	θz
-	-	-	θx	-θy	-(180+θz)

Table 3 Table forAngle Calculation

For getting a proper rotation, we need to follow a particular sequence. i.e.

	axis	**angle**
applied first	heading	yaw
applied second	attitude	pitch
applied last	bank	roll

Table 4 Sequence of rotation

Here as the axis of LabVIEW and the sensor are different, we have found out the below mentioned sequence for the project.

Sequence	**Axis of LabVIEW**	**Angle of sensor**
1	Y	-θy (Roll)
2	-Z	θx (Pitch)
3	-X	θz (Yaw)

Table 5 Sequence of rotation used in our system

3D Results

0 deg: 30 deg 120 deg

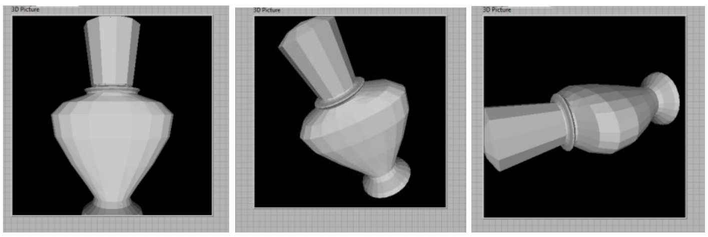

Figure 7 Final result

The Figure 7 shown above is the final result which is shown in the form of 3D image

Conclusion: Accelerometer sensor used in this project help us to monitor the movement of the hand which can be beneficial in accessing the muscle control and further helpful in gamming field. The system developed has the ability to access the movement of hand up to 180 degrees. The data obtained from the system is interfaced with the LabVIEW, and further implementation of the software allows the output to be viewed in 3D rotational format. The use of the software allows the user to record the data and further can be accessed for future works.

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