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Microcontroller Based Tilt Measurement

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ABSTRACT : *Tilt monitoring is an important exercise in many industrial applications as well as in our daily lives. An accelerometer is a device which measures the acceleration in terms of m/s². There are many MEMS-based (Micro-electro-mechanical systems) Accelerometers available in the market. MEMS-based Accelerometers convert the tilt signal to an electrical signal which can be used for measurement. The output electrical signal generated is a digital signal in most cases. The MEMS Accelerometer contains on-board signal processing units which convert the mechanical signal to a digital format. This digital signal will further require processing so that we can extract the measurement information from the signal. The objective of this project is to use this signal from the accelerometer to present the measured degree of tilt on an electronic display. A low bandwidth tilt sensor is used along with an inaccurate rate gyro to obtain the measurement. The rate gyro has an inherent bias along with sensor noise. The tilt sensor uses an internal pendulum and therefore has its own slow dynamics. These sensor dynamics were identified experimentally and combined to achieve high bandwidth measurements using an optimal linear state estimator. Potential uses of the measurement technique range from robotics, to rehabilitation, to vehicle control.*
KEYWORDS *- Introduction, System development, Advantages, Disadvantages, Applications, Conclusion. A*

I. INTRODUCTION

The Microchip-based Tilt Measurement Device aims to design a prototype version of a tilt display device. MEMS-based Accelerometers consists of a movable mass kept in position with springs that is suspended over a static mass which forms a capacitor type of arrangement. The movable mass is constructed from polysilicon, while the static mass is constructed from silicon wafers. The ADXL202EB [5] Accelerometer Evaluation Board from the analog devices was used as the accelerometer and forms the core of this project.

This application note explains the importance of understanding how to acquire a reliable and accurate tilt reading for accelerometer applications by comparing the advantages and disadvantages of various tilt measurement techniques. Accelerometers used for tilt sensing require high resolution to meet the demands of many new emerging applications such as tilt enabled computer mouse/pointers,
motion enabled video game solutions and PDA-cell phone/ mp3 player screen navigation.

The overall benefit of the accelerometer for tilting applications used in PDAs for screen navigations is a new method to view, scroll, select and move with a minimum number of buttons required. This concept affords a PDA with a larger screen area for viewing. Navigation through menus is made easier with the ability to make selections based on tilt. The choices are highlighted and then can be selected either by using a physical "execute" button on the PDA or by using click or double click tap detection of the accelerometer.

The user can make selections in a menu driven environment this way. Also the accelerometer can also be used to sense the tilt of the PDA to change from landscape to portrait using gravity to change the screen orientation for viewing.

Interactive video games are becoming increasingly popular. Accelerometers are used to detect the tilting motions of the joystick for the game. This has created games where the user can feel more immersed in the game.

Tilt is a static measurement. The force of gravity is used as an input to determine the orientation of an object calculating the degree of tilt. The accelerometer will experience acceleration in the range from -1g to +1g through 180° of tilt.

$$1g = -9.8 \text{ m/s2}$$

Accelerometers are sensitive to both linear acceleration and the local gravitational field. The former provides information on taps and other handset motions allowing the development of 'gesture' user interfaces while the latter provides information on the accelerometer orientation which allows a smart phone or tablet display to automatically switch between portrait and landscape settings.

Many modern mechanical control systems use orientation feedback relative to an inertial reference frame. For systems connected to the ground, measuring orientation is not difficult since an encoder can be attached between ground and a rotating link to directly give orientation. However for any untethered system, or one that can move about freely in space, determining its orientation is not trivial. In our case ,we are designing a hopping robot with a single actuator ,capable of balancing despite inherent open-loop instability [6].

This robot requires accurate orientation and rate feedback at a relatively high bandwidth in order to achieve stable balance control. In this paper we develop a state space estimation approach that meets these requirements using inexpensive components. We focus our attention on planar motions, since sensing in 3-dimensions first requires sensing in the plane [7].

One option for planar orientation measurement is the use of a tilt sensor, such as a pendulum type inclinometer, but these sensors have their own dynamics with limited bandwidth and therefore cannot provide the correct tilt information at high frequencies. Another approach is to use a gyroscope to infer the tilt angle of the robot. In theory ,integrating the angular velocity output of a gyroscope (hereafter referred to as a gyro or rate gyro) should provide an accurate tilt angle, even when the system is moving or oscillating quickly. In practice, low-cost gyros have an unknown bias (offset) and or scaling in their output, as well as signal noise. Integrating the gyro output results in a angle estimate plus a drift term.

This means that it is not practical to sense inclination angle from a gyro alone. Another approach is to use a Z-axis accelerometer to measure the direction of gravity in a rotating reference frame [8]. Because accelerometers have a relatively high bandwidth and low cost, they are often used in this manner as tilt sensors.

In practice, however, we have found them to be sensitive to vibrations, and relatively difficult to use since they require a nonlinear arctangent evaluation in the control loop. Ojeda and Borenstein [11] have used accelerometers as tilt sensors to reset their gyros when their robot is not moving. They also found that vibrations during motion were problematic.

1.1 Necessity

Accelerometers have a well established market, mainly 50g devices for airbag modules.

- Accelerometer market is expanding from its base in the automotive industry to industrial and consumer applications.
- Most non-automotive applications require high sensitivity, low g-Accelerometer.
- The change in requirements represents an opportunity for new accelerometer technology.

Explains the importance of understanding how to acquire a reliable and accurate tilt reading for accelerometer applications by comparing the advantages and disadvantages of various tilt measurement techniques.

Accelerometers used for tilt sensing require high resolution to meet the demands of many new emerging applications such as tilt enabled computer mouse/pointers, motion enabled video game solutions and PDA-cell phone/ mp3 player screen navigation.

1.2 Objective

The objective of this project is to use this signal from the accelerometer to present the measured degree of tilt on an electronic display.

The tilt measurement device can find many applications where we have to maintain stability. Coupling the application with our device will provide the application user with the tilt information on the display. Hence, he can manually work towards achieving stability, or design a separate control system with the same purpose. The user can confirm that the control system is functioning correctly by monitoring the visual readout provided by our device.

II. SYSTEM DEVELOPMENT

Acceleration is a measure of how quickly speed changes. Just as a speedometer is a meter that measures speed, an accelerometer is a meter that measures acceleration. You can use an accelerometer's ability to sense acceleration to measure a variety of things that are very useful to electronic and robotics projects and designs:

· Acceleration

· Tilt and tilt angle

· Incline

- Rotation
- Vibration
- Collision
- Gravity

Step counting is a widely used method to assess physical activity. Very simple and cheap pedometer devices are available for any person to wear during running exercise or during daily activities to record the number of steps taken. The benefit of using such a device is mostly the improvement in motivation to increase physical activity.

These devices are also used in rehabilitation and disease management. For example, physical activity assessment is important for the prevention or treatment of diabetes. Pedometers have also been used to assess mobility of the elderly.

Pedometer devices are typically worn on the hip clipped to a belt or trousers. The hip is an excellent place for sensing steps as the accelerations there correlate well with steps and the interfering accelerations are small. Another good location for a step counter sensor is on the foot, where even more details, like stride length, can be measured.

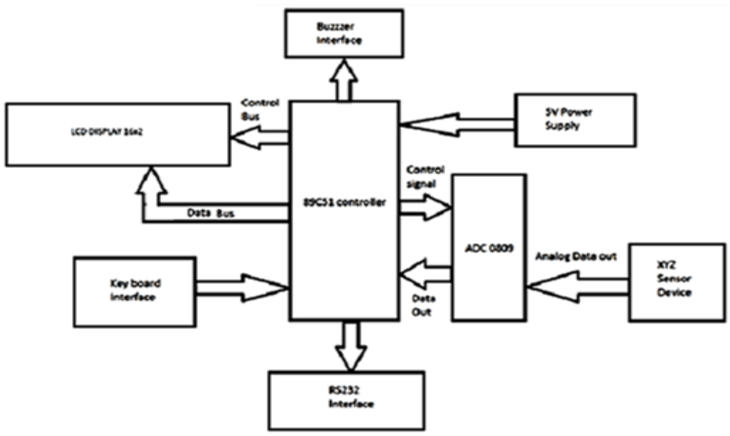

Fig -1 Basic block diagram of Accelerometer

Accelerometers can be used for measuring both dynamic and static measurements of acceleration. Tilt is a static measurement where gravity is the acceleration being measured. Therefore, to achieve the highest degree resolution of a tilt measurement, a low-g, high sensitivity accelerometer is required. The Freescale MMA6200Q and MMA7260Q series accelerometers are good solutions for XY and XYZ tilt sensing. These devices provide a sensitivity of 800 mV/g in 3.3V applications. The MMA2260D and MMA1260D are also good solutions for 5 V applications providing a sensitivity of 1200mV/g for X and Z, respectively.

All of these accelerometers will experience acceleration in the range of +1g to -1g as the device is tilted from -90 degrees to +90 degrees.

1g = 9.8 m/s

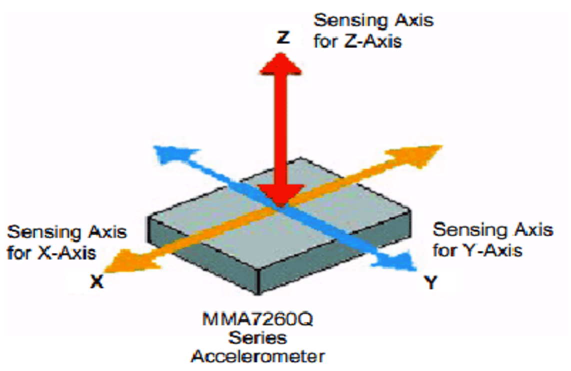

Fig -2: Sensing axis for the MMA7260Q Accelerometer with X, Y & Z-Axis for sensing acceleration

2.1 Principle of Operation:

The Free scale accelerometer is a surface-micro machined integrated-circuit accelerometer. The device consists of two surface micro machined capacitive sensing cells (g-cell) and a signal conditioning ASIC contained in a single integrated circuit package.

The g-cell is a mechanical structure formed from semiconductor materials (polysilicon) using semiconductor processes (masking and etching). It can be modeled as a set of beams attached to a movable central mass that move between fixed beams. The movable beams can be deflected from their rest position by subjecting the system to acceleration figure (3.3).

As the beams attached to the central mass move, the distance from them to the fixed beams on one side will increase by the same amount that the distance to the fixed beams on the other side decreases. The change in distance is a measure of acceleration.

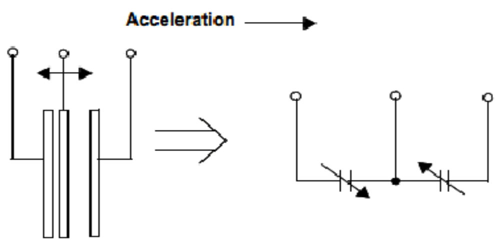

Fig -3: Simple Transducer Physical Model

III. ADVANTAGES

- The user can confirm that the control system is functioning correctly by monitoring the visual readout provided by our device.
- Flexibility to select 1.5g, 2g, 4g and 6g of acceleration for multifunctional applications.
- Low power for extended battery life
- Fast power-up response time
- Sleep mode is ideal for handheld battery-powered electronics
- Low component count saves cost, saves space
- Highly sensitive with low noise
- Adaptable functionality
- High frequency and resolution for accurate fall, tilt, motion, positioning, shock and vibration sensing.
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IV. DISADVANTAGES

- Design of measuring tilt with three axis is complex and lengthy.
- Implementation needs full knowledge of trigonometry and accurate calculations required.
- Calibration with the distance step counting with the different ages people like the adult and the children.
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V. APPLICATIONS

- Robotics
- Machine monitoring
- Construction industry
- Defense industry
- Consumer Electronics
- Distance or height measurement
- Measuring drilling angle in well-logging
- Platform or antenna stabilization
- Compass correction
- High speed tilting train control
- Weapon security system
- Level measurements
- Tilt-mode game controllers
- Model airplane auto pilot
- Crash detection/airbag deployment

VI. CONCLUSIONS

The tilt measurement device can find many applications where we have to maintain stability. Coupling the application with our device will provide the application user with the tilt information on the display. Hence, he can manually work towards achieving stability, or design a separate control system with the same purpose.

The user can confirm that the control system is functioning correctly by monitoring the visual readout provided by our device.

This may be due to ambiguity in the digits to be displayed at that particular instant. Trying to use another push button to switch between the X-Axis and the Y-Axis displays, but this made the display unstable i.e. the readings were displayed only momentarily and seemed to be correct. This may be due to the debouncing of the push button switch. Using an electronic switch instead would solve this problem.

Many applications require storage of the tilt values to a database. We can incorporate RS-232 Communication between the PIC and the PC. The tilt values will be serially transmitted using this protocol. Visual Basic is the preferred software for creating a GUI to view the transmitted information on the PC. We can store these readings to a database created in Microsoft Access or Excel.

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