Using the TRIAX Evaluation Board

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INTRODUCTION

Using micro machining and integrated circuit technology, Freescale produces highly reliable, capacitive, acceleration sensors. Freescale's accelerometers were initially designed for front- and side-impact airbags in the automotive arena, but now there are extensive applications in medical, appliance, consumer, and industrial areas such as high-end washing machines, gaming devices, LCD projectors, robotics, and fitness equipment.

TRIAX Board Overview

The TRIAX demo was built to combine many of the demos that we have available for accelerometers. These modules enable you to see how accelerometers can add additional functionality to many applications in different industries. By thinking of accelerometer applications in terms of the measurements performed, they can be grouped into five categories — **Tilt, Position, Movement, Vibration, and Shock**. This document describes the different demos available for each of the five categories of accelerometer measurement and how they can be demonstrated using the TRIAX board.

The TRIAX board is designed for three-axis sensing. Freescale offers three-axis sensing in several different ways. A three accelerometer solution can be achieved using two X-axis accelerometers in a 16-pin SOIC package, with one device rotated 90 degrees from the other to achieve X and Y axis sensing, and a Z-axis accelerometer in a 16-pin SOIC package. A two accelerometer solution is achieved using the MMA6260D, which is an X and Y-axis device and a Z-axis accelerometer, both in 6x6x2mm QFN packages. Sensor Products is in development with three-axis sensing in a single package.

Tilt

Tilt Applications refer to Inclinometers, Anti-Theft Devices, Game pads for Video Games or Joysticks, Sports Diagnostics and Physical Therapy Applications, PDAs, LCD Projection, and Camcorder Stability.

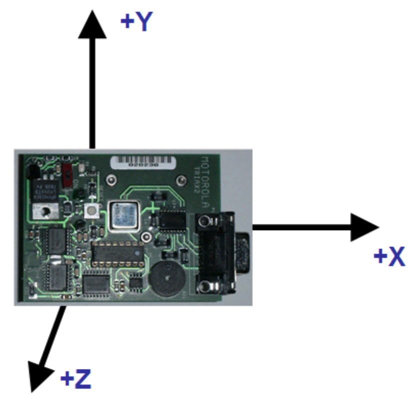


Figure 1. TRIAX Board and Corresponding Axis

Medical Applications for tilt range from Physical Therapy devices to Medical Equipment monitoring, where the accelerometers are used to ensure that the equipment is being used properly. For example, wrist mounted heartbeat monitors obtain the most accurate measurement if the blood pressure sensing device is at the same elevation as your heart. By using an accelerometer to measure the angle of your arm, the monitor can guide the user to the correct arm position before taking the measurement. The accuracy and the repeatability of the blood pressure measurement is greatly increased by using that tilt information to tell users exactly where to position their arms. In addition, the accelerometer is also able to stop a measurement if a user's wrist shifts out of the proper position by constantly sensing motion and position. Through software the monitor can tell not only at what angle it is mounted, but also if it is moving significantly or if the angle has changed.

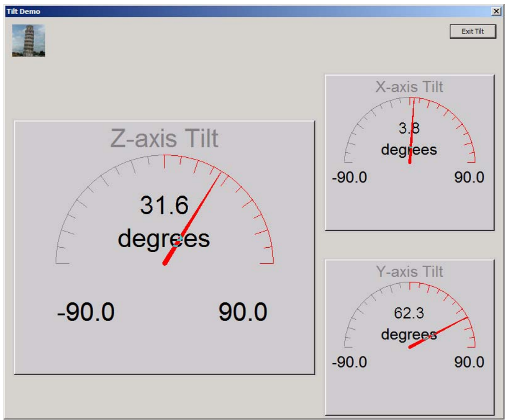


Figure 2. Tilt Demo Interface

Another large consumer application for Tilt is represented in the PDA Module. New cell phones and PDAs will be designed with fewer buttons, leaving room for a larger screen. Accelerometers can be used for many new functions—one being menu navigation. The user would simply navigate through a list of items simply by tilting the phone. The PDA Module uses the Z-axis accelerometer output data to extract the degree of tilt and moves the cursor on the list displayed on the PC up or down.

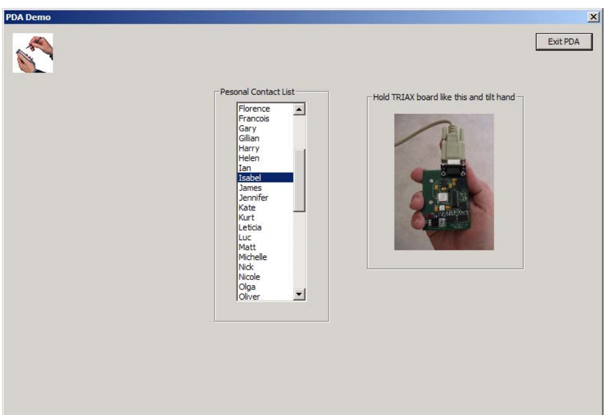


Figure 3. PDA Demo Interface

The Digitally Filtered Tilt Module will measure tilt in lawnmowers, forklifts, and other industrial equipment where there is vibration that can distort the accelerometer output. Using software filtering algorithms, the tilt information can be more accurately determined. In addition, the accelerometer can also be used to extract information on whether the motor is running or if the blades are engaged.

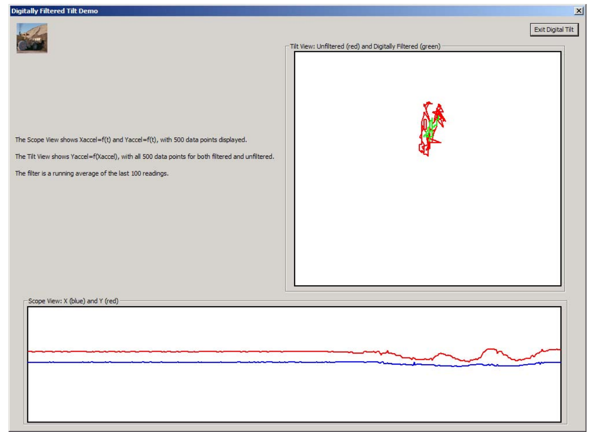


Figure 4. Digitally Filtered Tilt Demo Interface

The Anti-Theft Alarm Module is a stand-alone demo that can be used in laptops or other electronic equipment for added security features. The accelerometer is used to detect when the laptop is lifted. When the Anti-Theft Alarm Module is selected, the serial cable can be removed. The microcontroller constantly samples the accelerometer for static tilt information. If the TRIAX board is tilted 15 degrees, then the piezohorn will sound.

Position

Personal navigation applications are Car navigation, Back-up GPS, and Map Tracking.

An accelerometer can be used to measure position values by using software algorithms to integrate the accelerometer signal. Since integration introduces errors over time, the accuracy of the derived velocity and position values decrease as the integration interval increases.

To obtain postion data, first velocity data is obtained through integration. Then position is obtained through a second integration. The accelerometer accuracy is approximated based on the integration interval and the desired velocity accuracy by either of the following equations:

$a = v / (9.807 * t)$, where $v = m/sec,\ t = sec,\ a = G's$

Similarly, for position measurements, the required accelerometer accuracy can be approximated based on the integration interval and the desired position accuracy by:

$a = x / (9.807 * t * t)$, where $x = m,\ t = sec,\ a = G's$

Motion

Some MOTION Applications are Braking Systems (trailer brakes), Pedometers, Accidental Drop Protection, Battery Conservation, Robotics and Motion Control, and Virtual Reality.

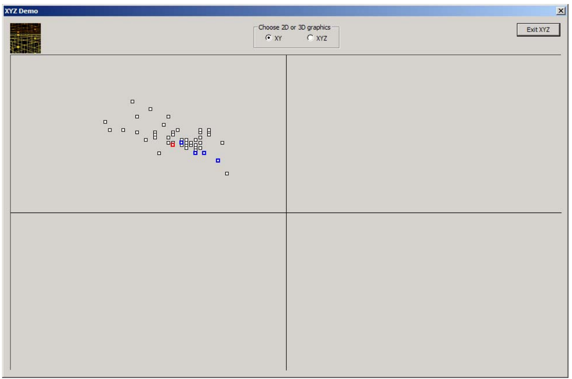


Figure 5. Positioning Demo Interface

Translation of accelerometer motion can be used for further calculation of position or speed. The Positioning Demo uses the TRIAX Board to show the first step for determining position.

Another application of movement measurement is pedometers. Mechanical pedometers simply count the number of steps taken. The pedometer displays either the number of steps taken or the distance traveled by using simple multiplication based on the average length of the user's stride. For this reason, they are not exceptionally accurate; if stride length varies, these mechanical pedometers may have a margin of error greater than 10 percent.

Using accelerometers, a pedometer can be designed with two-axis sensing for determining not only distance, but speed as well. One axis, measuring in the Z-axis, would determine the number of steps taken. A second accelerometer, sensing movement in the X-axis direction, parallel to the ground can be used with the Z-axis device to determine the length, the speed, and the impact of each stride. With all this information, pedometers can be more accurate and provide more functionality as well.

Movement can be detected using the accelerometer, but with that, also lack of movement can be detected as well. This is demonstrated in the Battery Saver Module. The X, Y, and Z-axis accelerometers are sampled by the microcontroller. When there is movement detected, the piezohorn is turned on signaling the movement detected. When there is no movement detected, the horn is silent. This module is used to demonstrate how the accelerometer can be effectively used in applications with full power and low power mode options, such as cell phones or GPS equipment. The cell phone or GPS device will detect motion and run in full power mode or continually receive satellite updates for positioning information. When there is no movement detected, they will run in low power mode and will not receive Satellite updates as often.

Rotational Acceleration

Rotational Acceleration is another measurement of movement that is obtained from accelerometers. Applications that can be enhanced by rotational acceleration data are Washing Machines for load imbalance and rotational compensation for Video Camera Stability.

Washing Machine load imbalance can be determined with an accelerometer after the fact by measuring the vibration. However, the accelerometer is used more effectively to predict the imbalance before it occurs. The accelerometer monitors the rotational orbit of the tub, extracting the RPM and elliptic geometric figures of merit to predict a load imbalance condition. The Load Imbalance Module (see Figure 6) monitors the rotational orbit of the TRIAX board, displaying the RPMs and a graphical elliptical display to demonstrate the application.

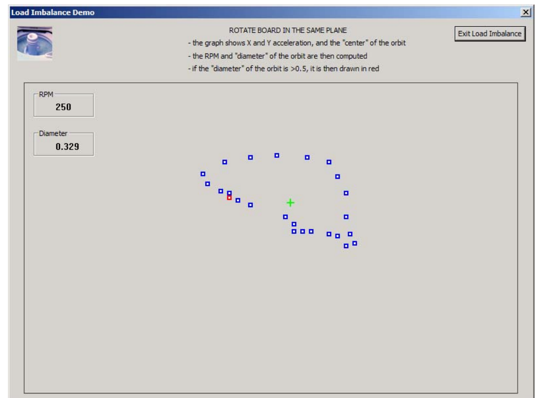


Figure 6. Load Imbalance Demo Interface

Vibration Measurement

Applications measuring vibration are Seismic Activity for earthquake detection, Smart Motor Preventive Maintenance, Hard Disk Drive Vibration Correction, and Acoustics Measurement and Control.

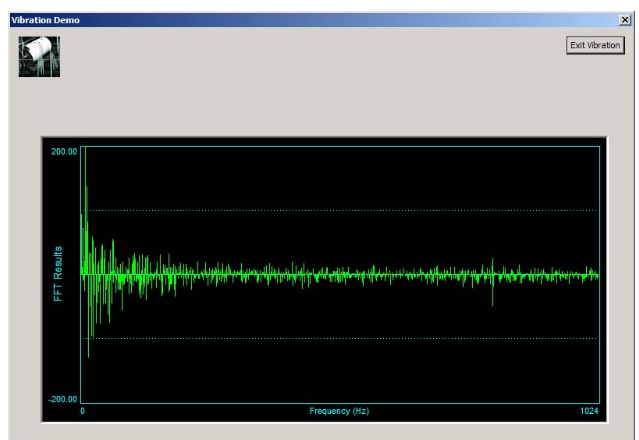


Figure 7. Vibration Demo Interface

Smart Motor Preventive Maintenance can be demonstrated using the Vibration Analysis Module (see Figure 7). Structural resonance in rotating machinery often increases noise and vibration levels leading to premature failure. An accelerometer can be used to not only detect when a rotating machine is failing from increased vibration, but an accelerometer can predict the failure by recognizing the vibration signature. Every motion has a vibration signature that is comprised of various levels of harmonics of vibration. The accelerometer is able to determine the harmonics of the motor and monitor when the values have changed, predicting a problem with the machinery before a failure occurs. The Music Pitch Analysis Demo uses an accelerometer to detect the harmonics from a vibration. This can be quickly demonstrated using tuning forks with the TRIAX board. For example, striking an “A” tuning fork and placing it next to the TRIAX board, the highest amplitude frequency recognized by the accelerometer would be 440 Hz and the check box corresponding to an “A” would be selected. See Figure 8.

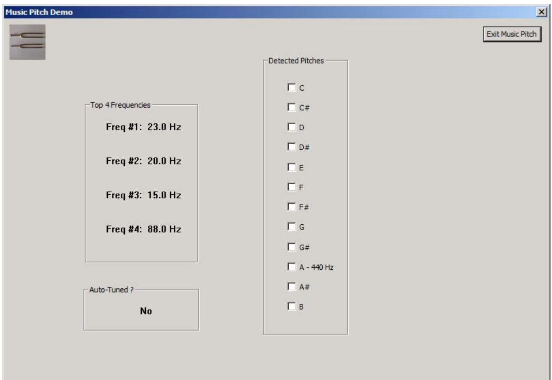


Figure 8. Music Pitch Analysis Demo

Accelerometers can also be used to detect the rotational vibration (RV) of hard disk drives (HDDs). When the RV characteristics of an operational HDD becomes too large or contains certain spectral content, the drive’s performance is often compromised. Poor seek times, read/write errors, and lost data can be the result of excessive RV. The accelerometer detects the RV and enables the HDD to adjust the drive for better operation.

Shock Measurement

Shock Applications range from Black Boxes and Event Data Recorders, Hard Disk Drive Protection, and Shipping & Handling Monitors to record shock levels experienced during transportation of fragile products.

The Shock Detection Module provides a simple demonstration of using the accelerometer to not only detect shock, but also to detect which axis the shock occurred. This is a stand-alone module. Therefore, once the Shock Detection Module is selected, the serial cable can be disconnected for the demonstration. The TRIAX board beeps once when the impact occurs in the X-axis, twice when it occurs in the Y-axis and three times when the impact occurs in the Z-axis.

This demonstration can be further enhanced by adding software to sample the signal for shock recognition features that would determine different actions for different types of shock. The accelerometers available on the TRIAX board are ±1.5g, therefore the shock conditions are anything above 1g. For many applications, a higher g-range is necessary. Freescale offers accelerometers from ±1.5g all the way up to ±250g. For applications requiring a higher g range, there are devices available.

Circuit Description

The TRIAX board is used to demonstrate many different applications; therefore it was not optimally designed for one specific application. The basic components are three low g accelerometers, a microcontroller, serial communication circuitry, EEPROM for data collection, and a piezohorn. This TRIAX board displays the three-axis solution with three accelerometers in the 16-pin SOIC. The microcontroller selected was the MC68908KX8. It was selected because it has an SCI required for the serial communication, four 8-bit ADC channels, three of which are required for the three accelerometer voltage outputs, and 8 Kb of on-chip, in-circuit programmable FLASH memory that is used for calibration data and remembering which software module was last run using the PC.

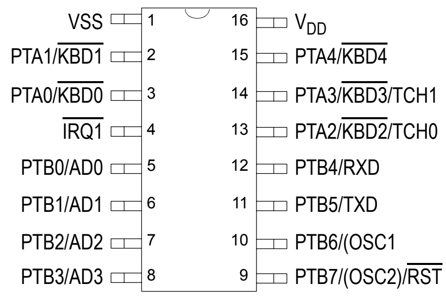


Figure 9. MC68HC908KX8 PDIP and SOIC Pin Assignments

Calibration

The zero g offset for the MMA1260D and the MMA2260D accelerometers are specified with a typical value of 2.5 V ±.

Follow these steps to determine the calibration values. Write down the A/D values for the X, Y, and Z outputs at 0g and 1g:

1. Start the RAW data software module.
2. Enter the A/D values for X, Y, and Z when experiencing 0g and 1g of static acceleration. Refer to Table 1 to see how to position the TRIAX boards to achieve the correct values.
3. Write the value in a similar table as show in Figure 10.
4. Close the RAW data module.
5. Start the CALIBRATE software module.
6. Fill in the A/D values that were determined. See Figure 11 for typical values.
7. Press the Calibration button.
8. Close the CALIBRATE software module.

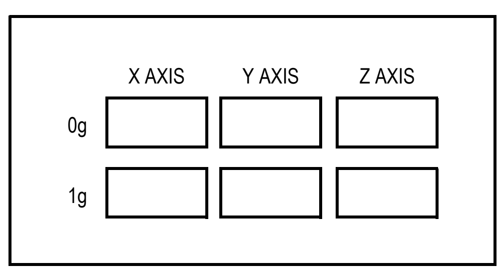
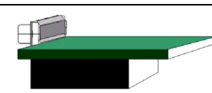


Figure 10. Calibration Data Table

Table 1. TRIAX Board Calibration Positions

0g		
X at 0g	Place the TRIAX board on a flat surface so the components are face up and the battery is resting on the table.	
Y at 0g	Place the TRIAX board on a flat surface so the components are face up and the battery is resting on the table.	
Z at 0g	Hold the TRIAX board on its side so that the serial cable is at the top. The TRIAX board is perfectly horizontal when X has a maximum voltage without being shaken.	
1g		
X at 1g	Hold the TRIAX board perpendicular so that the serial cable is at the top. The TRIAX board is perfectly horizontal when Y has a maximum voltage without being shaken.	
Y at 1g	Hold the TRIAX board on its side so that the serial cable is at the top. The TRIAX board is perfectly horizontal when X has a maximum voltage without being shaken.	
Z at 1g	Place the TRIAX board on a flat surface so the components are face up and the battery is resting on the table.	

The table in Figure 11 provides *typical values*. These typical values enable the TRIAX board to work with the PC software; however, accurately calibrating the accelerometers is necessary to find the exact values for the board. Use these values as a reference to enure the values that were obtained using the RAW DATA module were gathered by holding the board correctly.

	X AXIS	Y AXIS	Z AXIS
0g	128	128	128
1g	189	189	189

Figure 11. Typical A/D Values for Calibrating the TRIAX Board

Serial Connection and PC Operation

The TRIAX boards have serial circuitry and a DB9 connector for serial communication with the PC. The microcontroller is programmed with different modules that transmit data to the PC at different speeds and with different accelerometer data, depending on the current module selected with the PC interface.

To set up the system for PC operation, follow these steps:

1. Connect the TRIAX board to the PC using a DB9 male/female serial cable.
2. Launch the PC Software Executable program TRIAX3.2.exe.
3. Slide the TRIAX board switch in the On position.
4. Confirm that a data handshake occurs when the piezohorn beeps.

Before any module is started, a handshake occurs with the PC and the TRIAX board. If S2 is pressed after Reset and before the Handshake, then the system goes into Sample Mode (X&Y 100x/s 40.96s).

A Handshake occurs by the microcontroller waiting for the character *R*. When recognized, it responds with a character that represents the version of the microcontroller software available. For Version 2 (TRIAX07.asm), the microcontroller returns an *N*. (i.e., *M* for TRIAX06.asm) and it beeps once. When the connection between the TRIAX board and the PC is established, the microcontroller waits for a character from the PC. Each character received tells the microcontroller which firmware module should be run. Then the selected firmware module will continue to run until the microcontroller is restarted.

Stand Alone Operation

There is a feature on the TRIAX board that does not require the PC. It allows two demonstrations to run. The first demonstration that is always available in stand-alone operation is the free-fall demonstration. The second demonstration is the most recently used stand-alone application that was selected using the PC software.

To run the free-fall demonstration without the PC connected, turn the TRIAX board on while holding the pushbutton. Continue holding the pushbutton for 10 seconds. When the piezohorn sounds, the Free-fall Module is activated. To allow the user to drop and catch the TRIAX board, it sounds the piezohorn when the free-fall conditions are met. The Free-fall Module continues to run until the board is restarted.

To run the most recently used stand-alone operation, hold down the pushbutton while turning on the TRIAX board. For example, if the battery saver demo was the last module run, then you will be able to run the battery saver module or the Free-fall Module. To run the battery saver module, hold the pushbutton while turning on the TRIAX board and then quickly release the pushbutton. The piezohorn automatically starts beeping to signal that movement is detected. The battery saver module continues to run until the board is restarted.

SUMMARY

There are many new applications being designed using accelerometers. The TRIAX board is designed to demonstrate some of the general accelerometer applications. This application note describes these applications using the software programs available for the TRIAX board. After reading this application note, the user will be able to use the TRIAX board to demonstrate the existing accelerometer applications and be able to demonstrate their own design ideas.

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