A. Title Page

Final Report for Design, Construction, and Verification of a Digital Accelerometer

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B. Restatement of problem researched or creative activity

Vehicle traffic accidents have become a serious problem that threatens people and their property at an accelerating rate. In the United States, motor vehicle accidents are the leading cause of death for college age people.[1] Globally, traffic accidents are the second leading cause of death for young people between the ages of 18-25.[2-3] In response, automakers are continually designing vehicles with added safety features such as front and side air bags, crumple zones, anti-lock brakes, and safety data recorders. These new design features are the result of information gathered from both controlled crash test and real-world accidents.

One of the most important parameters to measure is the amount of friction available between tires and road surface. In the past investigators have used a device known as a drag sled to measure the coefficient of friction. A drag sled consist of a portion of a tire that has been weighted down with a solid mass. This contraption is then connected to a spring scale and then drag at a constant speed by the user along the roadway. The resultant scale reading can then be equated to the frictional force and used to calculate the coefficient of friction between the tire and road surface. Unfortunately this technique suffers from many possible errors during making the measurements. Specifically, the user must apply horizontal force while pulling the sled at a constant velocity and simultaneously trying to record the scale reading. Obviously, this task can be very difficult and prone to error.

What is needed is a highly sensitive, reproducible, and user friendly method to measure the coefficient of friction between a vehicle's tires and road surface. In this project we propose to construct a mobile, digital accelerometer that can be carried specific accident sites and measure the coefficient of friction.

Recent advances in Micro-Electro-Mechanical Systems (MEMS) have led to the design of compact accelerometers that are incorporated in the architecture of a microchip. Some of the MEMS based accelerometers use the piezoelectric effect - they contain microscopic crystal structures that get stressed by accelerative forces, which causes a voltage to be generated. Another type of MEMS accelerometer measures changes in capacitance. In this type of device two microstructures, of known capacitances are produced adjacent to each other. If an accelerative force moves one of the structures, then the capacitance will change. This change in capacitance is measured and converted into a voltage that is related to the acceleration. The goal of this project was to design construct and verify an accurate, portable, accelerometer.

C. Brief review of the research procedure utilized

We purchased a MEMS accelerometer device, mother board and computer interface software from Parallax (shown in Figure 1), we also purchased a pre calibrated accelerometer from Visual Statement as a reference for the performance of our device.

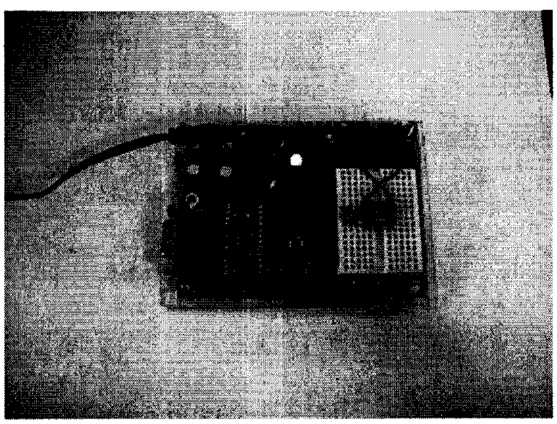

Figure 1 Picture of MEMS based accelerometer built for this project.

After all the supplies were received we began to write the code that would control our accelerometer (code is included as Appendix A) we also machined a Plexiglas mount for the electronics. After debugging the code we began to devise a test to check the values for acceleration of our device. We constructed a sled that would travel on an air track. The sled is connected to a weight via a string at one end that would provide the force to produce acceleration. Our electronics were fastened to the sled in order to measure the acceleration (the experimental setup is shown in Figure 2). This acceleration was then compared to the theoretical value as well as the measured value from the pre-calibrated accelerometer purchased from Visual Statement.

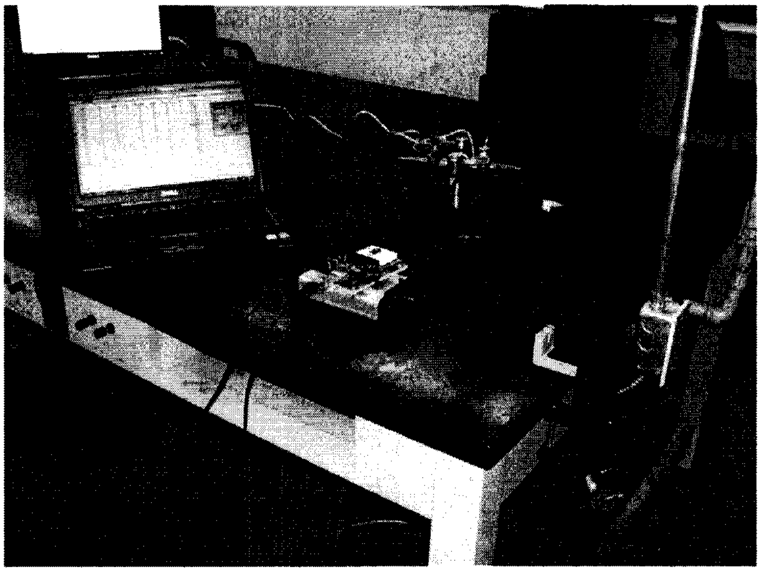

Figure 2 Picture of experimental setup to verify accelerometer data.

D. Summary of findings

The accelerometer built for this project agrees very well with the theoretical predictions of accelerations used to measure road friction. On average over the range of ± 2*g's* of acceleration, the device recorded an error of 1-2 %. Additionally, the device also has similar readings to the pre-calibrated accelerometer purchased from Visual Statement.

E. Conclusions and recommendations

We have successfully constructed a portable easy to use accelerometer for use in measuring roadway friction. We hope to develop a new accelerometer that can read crash pulse information. This will require a faster sampling rate and a robust construction able to withstand impact forces.

REFERENCES

1. Center for Disease Control, "Leading Causes of Death Annual Report", http://webappa.cdc.gov
2. World Health Organization, "Faces behind the figures: voices of road traffic crash victims and their families", (2007)
3. Center for Disease Control, "The Incidence and Economic Burden of Injury in the United States", http://www.cdc.gov/ncipc/factsheets/CostBook/Economic_Burden_of_Injury.htm

APPENDIX A

```
{$STAMP BS2}
'{$PBASIC 2.5}
'===================================================================
'Code compiled, organized, and modified to fit memsic accelerometer application by Shane Hendrix.

'Arkansas Tech University Physical Science Department

'===================================================================
'Accelerometer Definitions
'===================================================================
Xin       PIN   8      ' X input from Memsic 2125
Yin       PIN   9      ' Y input from Memsic 2125

HiPulse    CON   1      ' measure high-going pulse
LoPulse    CON   0
DegSym     CON   176    ' degrees symbol


xRaw      VAR   Word   ' pulse from Memsic 2125
xmG       VAR   Word   ' g force (1000ths)
xTilt     VAR   Word   ' tilt angle

yRaw      VAR   Word
ymG       VAR   Word
yTilt     VAR   Word

disp      VAR   Byte   ' displacement (0.0 - 0.99)
angle     VAR   Byte   ' tilt angle



'===================================================================
'Data Acquisition Definitions
'===================================================================
sPin  CON  16      'Serial Pin - P16, Programming port
Baud  CON  84      'Baud mode for a rate of 9600, 8-N-1
                   'BS2P, BS2SX use 240 for 9600, 8-N-1
Row   VAR  Word    'Variable to hold row data



'===================================================================
'Data Acquisition Main Program Code
'===================================================================
```

```
PAUSE 1000                    'Allow data communications to stabilize
SEROUT sPin,Baud,[CR]             'Send a lone CR to ensure PLX-DAQ buffer is ready

    'Label 3 columns with TIME, GForce X, GForce Y, Tilt X, Tilt Y.
SEROUT sPin,Baud,[CR,"LABEL,Time,Timer,xRaw,Tilt X,GForce X,yRaw, GForce Y,Tilt Y",CR]
SEROUT sPin,Baud,["CLEARDATA",CR]     'Clear all data columns (A-J) in Excel
SEROUT sPin,Baud,["RESETTIMER",CR]    'Reset Timer to 0

DO
  GOSUB Read_Tilt


  ' Send String with data for Excel
  SEROUT sPin,Baud,["DATA,TIME,TIMER,", DEC xRaw, ",",
                    (xTilt.BIT15 * 13 + " "),DEC ABS xTilt,",",
                    DEC (ABS xmG / 1000),".", DEC3 (ABS xmG), ",",
                    DEC yRaw, ",",
                    DEC (ABS ymG / 1000),".", DEC3 (ABS ymG),",",
                    (yTilt.BIT15 * 13 + " "),DEC ABS yTilt, CR]

LOOP



'=========================================================================
'Subroutines
'=========================================================================
    'Subroutines Courtesy of Parallax, Inc. (www.parallax.com)
Read_Tilt:
 GOSUB Read_G_Force

 ' restrict displacement to unit circle (0.0 - 1.0)

 disp = ABS xmG / 10 MAX 100          ' x displacement
 GOSUB Arcsine
 xTilt = angle * (-2 * xmG.BIT15 + 1)     ' fix sign
 disp = ABS ymG / 10 MAX 100          ' y displacement
 GOSUB Arcsine
 yTilt = angle * (-2 * ymG.BIT15 + 1)     ' fix sign
 RETURN


Read_G_Force:
 PULSIN Xin, HiPulse, xRaw            ' read pulse output
 xmG = ((xRaw / 5) - 500) * 8         ' convert to 1/1000 g
 PULSIN Yin, HiPulse, yRaw
 ymG = ((yRaw / 5) - 500) * 8
```

```
 RETURN

'=====================================================================
'Trigonometry Subroutines
'=====================================================================
        ' Trig routines courtesy Tracy Allen, PhD. (www.emesystems.com)

Arccosine:
 disp = disp */ 983 / 3              ' normalize input to 127
 angle = 63 - (disp / 2)             ' approximate angle
 DO                           ' find angle
  IF (COS angle <= disp) THEN EXIT
  angle = angle + 1
 LOOP
 angle = angle */ 360                ' convert brads to degrees
 RETURN


Arcsine:
 GOSUB Arccosine
 angle = 90 - angle
 RETURN
'=====================================================================
'End
'=====================================================================
```