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Tri-axis MEMS Accelerometer for Vehicle Accident Monitoring

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Abstract – *The usage of MEMS accelerometer in automobile was for the air bag system. The advantage and the capability of accelerometer and gyrometer were used in medical and automobile fields up from last decade. Now in this paper we are going to see how the 3-axis MEMS accelerometer helps the user to intimate the emergency contacts when the user met with an accident by interpreting the values of the velocity and tilt readings. With the help of a microcontroller and ADC (Analog to Digital Converter) they are processed and sent to the GPS & GSM system to track a vehicle and send the exact location of the vehicle as a text message. This dynamic accelerometer continuously measures gravitational pull of Earth the define the angle at which vehicle is tilted and with respect to the ground.*

Key Words: Accelerometer, gyrometer.

1.INTRODUCTION

The common sensor we use in the automobiles for the air bag system is AIS1200DS which has a sensitivity of 400mV/g [6] sufficient for the sensing of external force applied and to activate the airbag system. If the acceleration change occurred is beyond the critical point, then the air bag system responds to release the air bags. But this accelerometer is not capable of sensing the tilt. The sensitivity range of AIS1200D is not sufficient to sense the small acceleration change occurred to the vehicle. Hence we use the 3-axis piezoelectric MEMS accelerometer MMA7260QT. This accelerometer have high sensitivity of 800mV/g which will be useful to measure the small vibrations and minute tilt change in the body [4] which is very important for this application. MMA2760QT has also an advantage of temperature compensation and selectable sensitivity/ g-select (1.5g to 6g). The accelerometer can sense the change at the rate of 800mV/g @ 1.5g which leads to high precision and efficient output.

The sensing of the acceleration change or tilt is done within the accelerometer itself and the values we get are given to ADC to get DC signals as the output. When the sensor experience any external force beyond threshold or tilt or any sudden change in the acceleration it senses and check whether it should activate the system or not. If the force is beyond the critical point the sensor reads the information from the 3-axis (roll, pitch and yaw) and send to the ADC (Analog to Digital Converter) where the analog data is converted into digital bits and send them to the microcontroller. The microcontroller helps to drive the GPS and GSM modem using a converter (MAX 232) to convert the serial port signals to compatible logic devices input. The GPS modem gets the location of the place and using the GSM modem a text message will be sent to the emergency contacts.

Detail information of the devices and the complete process will be given in a step-by-step manner.

1.1 Accelerometer

Accelerometer is a device/ instrument use to measure acceleration and to identify a change in acceleration of a body. MMA7260QT Is the IC we use as the accelerometer as well as the tilt sensor too. It is piezoelectric MEMS in which PZT (Lead Zirconate Titanate) is used as sensing elements which produce electric signals as output under acceleration. The high sensitivity of this IC (80mV/g) help to respond for the small tilt and acceleration change. The noise levels are very low and frequency response is inversely proportional to the noise level [4] [5]. The g-select option in the sensor allows to use the four-different range of sensitivities one at a time and the selection can be done by varying the inputs.Various kinds of g- inputs and the response of the accelerometer is given in the following table.

Table -1: g-select Pin descriptions

g-select 2	g-select 1	g-Range	Sensitivity
0	0	1.5g	800mV/g
0	1	2g	600mV/g
1	0	4g	300mV/g
1	1	6g	200mV/g

MEMS is designed such that it has 3-axis and a mass suspended by four beams doped with piezo-electric material [2]. When a sudden external force is applied on the vehicle, sensor experiences the change and the mass in the center of the device change its position due to which the three axis readings are change and the four beams doped with piezo-

electric attached to it generates some relative voltage signals. Those generated signals are sent to the microcontroller to do the threshold algorithm and decide its severity [5].

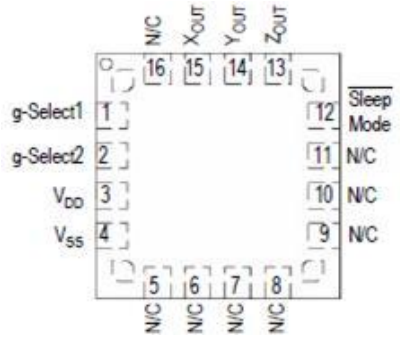

Fig -1: Pin Diagram of MMA7260QT

1.2 Tilt sensing

The 3-axis roll (ϕ), pitch (θ) and yaw (φ) are the basic parameters of tilt sensing, which are nothing but x, y and z axis respectively in general. Initially, when body is at rest the roll is along the body axis, yaw is pointed to gravity so that it aligns with the vehicle and the pitch will be an angle such that it makes exactly 90° so that they form a right-handed coordinate system. The output of roll and pitch will be 1.65V and the output of yaw will be 2.25V due to the earth's gravity [1] [5].

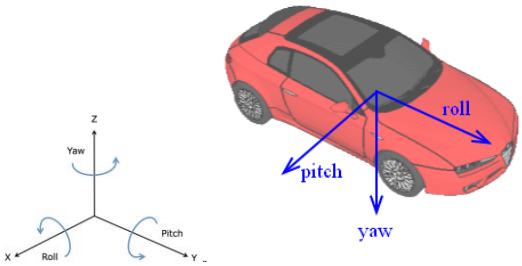

Fig -2: the orientation of tri-axis

When the vehicle lifts from the ground, the sensor activates and measures the difference in the angles of the axis. Those new values will be sending to the controller to classify and takes decision whether to activate the system or not. The basic matrix equation that tilt sensor use to calculate the vehicle undergoing linear acceleration $\mathbf{a_r}$ regarding the earth's reference **r** and gravitational field **g** is

$$G_p = \begin{pmatrix} G_{px} \\ G_{py} \\ G_{pz} \end{pmatrix} = R(g - a_r) \qquad \text{- Eq (1)}$$

R is the rotation matrix describing the orientation of the vehicle with respect to earth's coordinate frame [5].

Roll, pitch and yaw matrices, which transform a vector under rotation of coordinate system by angle ϕ, θ and φ are

$$R_x(\phi) = \begin{pmatrix} 1 & 0 & 0 \\ 0 & cos\phi & sin\phi \\ 0 & -sin\phi & cos\phi \end{pmatrix}$$

$$R_y(\theta) = \begin{pmatrix} cos\theta & 0 & -sin\theta \\ 0 & 1 & 0 \\ sin\theta & 0 & cos\theta \end{pmatrix}$$

$$R_z(\varphi) = \begin{pmatrix} cos\varphi & sin\varphi & 0 \\ -sin\varphi & cos\varphi & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Using all the above the matrices there will be six major probabilities to categorize the tilt and make the controller to decide the severity. If the angle change is a normal change the sensor just indicate the user or else the rest of the system activates.

2. Microcontroller

The microcontroller used in this concept is AT89C52 which is low power high performance 8-bit microcomputer [3]. The output values of the sensor (x, y and z readings) are sent to microcontroller through a ADC (analog to digital converter) so that it may be converted into binary input which will be the input of microcontroller. Using the linear acceleration and the threshold algorithm (Eq. 1) the microcontroller decides to stop or to proceed

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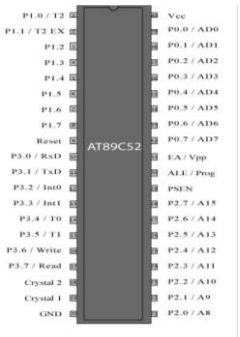

Fig -3: pin diagram of AT89C52 microcontroller

3. GPS

The Global Positioning System (GPS) is a space-based global navigation satellite system (GNSS) that provides reliable location and time information in all weather and always and anywhere on or near the Earth. GPS is considered as a dual-use technology, since it has significant military and civilian application. GPS system is already inbuilt in most of the new

model cars which we can interlink it with the controller. If the vehicle doesn't have any inbuilt GPS system, an external GPS modem **SIM900** will be fixed which works on the input voltage of 3.2- 4.8V and 2A. The microcontroller signals make the GPS on/off. An external antenna is fixed to the modem which can take a signal having a frequency up to 1900 MHz [7]. At last the obtained coordinates of the location are sent to the GSM modem so that they can be sent to the emergency contacts.

4.GSM

Global system for mobile communication (GSM) is a globally accepted standard for digital cellular communication. Same as like GPS modem, GSM modem can be fixed to the vehicle interlinked with microcontroller and GPS modem so that controller turns ON the GSM modem and the input can be obtained from the GPS modem. **SIM900** can be used as both GPS and GSM modem. The sim module has a frequency range of 1850- 1900 MHz [7]. The bit rate of the signal sent by the modem is 270Kbps.

A sim card will be inserted in the modem so that the text messages can be sent through that sim. The numbers to which the message to be sent will be programmed in the controller itself.

3. CONCLUSIONS

An idea has been proposed in this paper which is based on MEMS accelerometer. A theoretical view is given how the idea may be implemented and a clear view of the capability of device and their compatibility are given. By trigging a pulse at regular intervals to the controller can helps to track the vehicle continuously.

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