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Advanced Embedded System for Detection of Tilt and Vibration

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***Abstract* – This paper builds a smart tilt measurement and vibration detection system for environment monitoring. There are a number of smart measurement systems established for smart grids, bridges or machine system management, temperature/ humidity monitoring and so on. 3axes accelerometer has many applications such as in vehicles for motion control, mobile phones for motion activated functions, computers, medical appliances like pace maker and home appliances. It measures the acceleration in x and z direction and processes data. Depending upon gravitational acceleration along individual axis the tilt level and vibration levels are decided.**

***Keywords* — PSoC, 3-Axes Accelerometer, GPRS, GPS, GSM**

INTRODUCTION

The mixed-signal programmable system-on-chip (PSoC) architecture for high-volume low-cost applications is presented. Programmable analog, digital, and clocking circuits are combined with flash memory and a microcontroller to provide a platform for single-chip solutions for low-cost consumer applications. Both programmable analog and digital circuits are designed to support a moderate level of abstraction, balancing flexibility against cost and performance. A rough comparison of alternative approaches based on functionality and cost is presented.

Accelerometers are electromechanical devices that measure different kinds of acceleration for instance static and dynamic acceleration.Currently there are few systems existing to measure tilt or orientation of the object and to detect the vibration using 3-axis accelerometer. One of the systems available is to design acceleration sensor with the help of Data Acquisition System. But it is not always possible to wire sensor directly to acquisition equipment when the sensors are to be located on a rotating member and in very hostile environment – very high temperature, volatile liquids, and high humidity.

The objective of this paper is to explore the monitoring system for "Tilt Measurement and Vibration Detection using PSoC" for any object like bridges, machines etc. Bridges in a city are important engineering solutions for basic civil life, with safety as critical factor. The Programmable System On Chip (PSoC) chip is a self-selecting digital or analog input and output unit that can significantly decrease the number of required peripheral parts and quickly fulfill the design needs [1].

Some applications in which accelerometers are used are as follows:

Mobile Phones: Used for motion activated functions, gaming, free-fall detection, and vibration control.

Vehicles: Used for crash testing, robotics, motion control, and skid detection.

Computers: Used in computers and computer peripherals such as mouse, for motion activated functions, gaming, and tilt sensing.

Medical Appliances: Used in pacemaker and blood pressure measurement applications.

Home Appliances: Used in appliances such as washing machines for spin and vibration measurement.

RELATED WORK

A lot of researches work has been in PSoC (Programmable System-on-Chip) is a family of mixed-signal arrays first made by Cypress MicroSystems (CMS), a subsidiary of Cypress Semiconductors. This features a microcontroller and configurable integrated analog and digital peripherals. PSoC is software configured, mixed-signal array with a built-in MCU core. The core is a Cypress proprietary, 8-bit Harvard architecture design called the M8C. PSoC has three separate memory spaces: paged SRAM for data, Flash

memory for instructions and fixed data, and I/O Registers for controlling and accessing the configurable logic blocks and functions. This is a self-selecting digital or analog input and output unit that can significantly reduce the number of required peripheral parts and quickly fulfill the design needs [1]. PSoC also consists of digital and analog programmable blocks like filters, Analog-to-Digital Converter (ADC) and Digital-to-Analog Converter (DAC)s, inverting, non-inverting and operational amplifiers, counters, timers etc.. It also supports Inter integrated circuit (I2C), Serial Peripheral Interconnect (SPI), Universal Asynchronous Receiver Transmitter (UART), Universal Serial Bus (USB) communications along with Radio Frequency (RF) [2]. Qiu. D., Gao, L have presented the Virtual Reality Technology in the paper 'Application of virtual reality technology in bridge structure safety monitoring'. The dangers of bridge transition section deformation hazards prevalent in the national highways. It affects not only the safety of traffic, speed, comfort, performance, highway transport efficiency, but also affects the life of the vehicles. More seriously it may lead to accidents. So the deformation monitoring of the bridge approach has become an important research topic for urban highway operation. Virtual reality technology is an immersive interactive technology which is based on computer technology and data processing technology. Virtual reality technology is used to build the three dimensional model of the bridge, and on this basis, the advanced safety monitoring of bridge is implemented [3].Thiesse, F., Michahelles, F have mentioned in the paper 'Embedded interaction interacting with the internet of things' that in addition to bridge monitoring, there are great number of three axis accelerometer applications, one of which, provides a force and torque analysis suggestion when reducing the ingredients. This literature presents the underlying concepts of embedded interaction, the technological and conceptual phenomena of seamlessly integrating the means for interaction into everyday artifacts. Technically, this requires embedding sensing, actuation, processing, and networking into common objects. Conceptually, it requires embedding interaction into user's everyday tasks [4]. Rong Liu have presented in the paper 'The Analysis and Design of Urban Bridge Safety Early-warning' that the security issues relating to the urban bridge have aroused the attention of the engineering field and bridge management institutions all over the world, and one of the hotspot questions discussed at home and abroad comes to the establishment of safety early-warning system for urban bridge. Urban bridges are crucial lifeline works for a city, whose security impact on citizen's essential life and they play an indispensable role in extreme situations, such as natural disasters and war. During construction stages and service time, urban bridges will be damaged or destroyed by environmental effect, chemical reactions, vehicles, human activities, and so on[5].

SYSTEM ARCHITECTURE

Figure 1 shows the block diagram of this paper. G-sensor is nothing but 3-axes accelerometer. It senses the acceleration in x,y and z direction. Depending upon the value of acceleration along individual axis the tilt level and vibration level is decided.

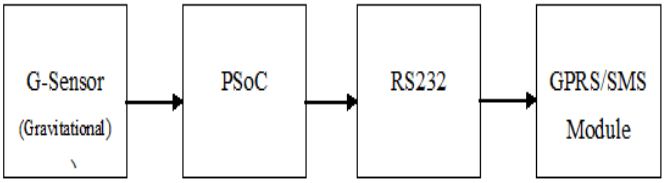

Fig.1. System Architecture

The purpose of the system is to sense the respective acceleration levels along the X and Z directions, that is, it can be employed to detect whether the object is horizontally or vertically oriented or the vibration level. Check the absolute value of G of X-axis, and Z-axis. According to standard values, send the message of excess tilt or earthquake.

.*Types of Accelerometers*

Accelerometers are divided based on their output type, sensing method, manufacturing technology, and other properties. When output type is considered, accelerometers can have either analog

or digital output. The analog output accelerometers often have voltage as the output, while digital output accelerometers have Pulse Width Modulated (PWM) waveform, I2C, or SPI. The choice between the analog and digital type depends on the interface hardware.

- Analog accelerometers output the most raw data form and their measurement is highly flexible. The speed and accuracy with which the analog output is measured changes with the hardware it is interfaced with the accelerometer.
- Digital PWM output accelerometers involve intensive computation and timing analysis to get the acceleration from the waveform.
- Accelerometers with digital communication output (I2C/SPI) have Analog to Digital Convertors (ADC) and digital communication modules integrated into the chip along with the basic analog output accelerometer. This added hardware is fixed function and increases the cost of the accelerometer. These accelerometers provide easy interface to a larger digital system, but are least flexible. With digital accelerometers, parameters such as resolution, sampling speed, bandwidth, and SNR are limited to a narrow selection range.

Currently there are few systems available to measure tilt or orientation of the object and to detect the vibration using 3-axis accelerometer. One of the systems available is to design acceleration sensor with the help of Data Acquisition System. But it is not always possible to wire sensor directly to acquisition equipment when the sensors are to be located on a rotating member and in very hostile environment – very high temperature, volatile liquids, and high humidity.

Accelerometers are electromechanical devices that measure different types of acceleration such as static and dynamic acceleration. Static acceleration includes the orientation with respect to earth and dynamic acceleration involves movement and vibration.

Microprocessors with some external hardware can interface with the digital communication output accelerometers. However, this does not work with digital PWM and analog output accelerometers. Microcontrollers can interface with digital PWM and digital communication output types, but not to the analog output accelerometers. The PSoC device has the flexibility of interfacing with all types of accelerometers.

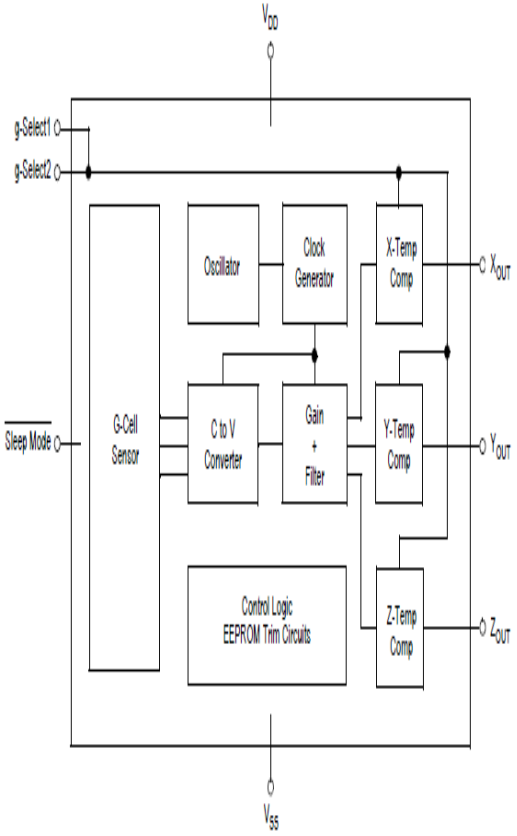

Fig 2 Functional Diagram of Accelerometer

The sensor element in the accelerometer works on the principle of differential capacitance. Here, the acceleration causes displacement in the silicon structure, resulting in a change in capacitance. The ASIC is included inside the package to convert change in capacitance into analog voltage, which is proportional to acceleration. It also features a programmable low pass filter. Thus the output voltages can be read directly by the ADC and processed accordingly.

The voltages on the X and Z axes are measured directly with a single ADC by multiplexing the input ports. The accelerometer has

an internal low pass filter and thus it is not implemented in PSoC. The block diagram of the system is shown in fig.

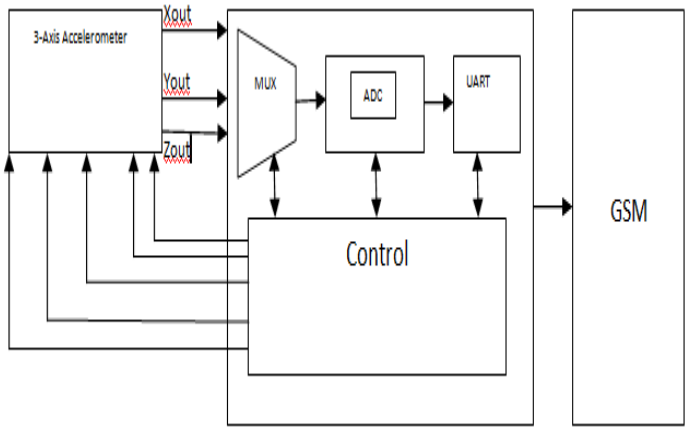

Fig 3: Interfacing of 3 Axes accelerometer with PSoC

The output of the ADC block can be processed using digital blocks, displayed using an LCD module, or transmitted using the UART, I2C, or SPI digital communication modules available in this chip. The example project makes use of I2C UM and transfers the data via the external I2C-USB Bridge hardware. The output is then plotted using the Cypress I2C-USB Bridge software.

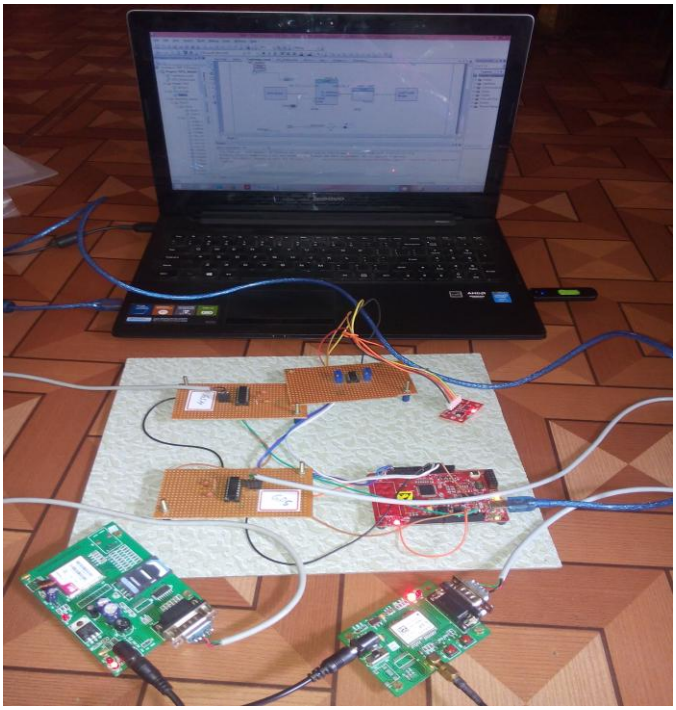

Fig. 4: Hardware Set-up

IV.HARDWARE DESCRIPTION

GPS module:- L10 GPS Protocol is being used in this work. The version of the protocol is v1.01. L10 is full featured module with super sensitivity while low power consumption and compact size. It supports location and navigation applications and could be widely used for tracing, tracking and telemetry GIS applications and security etc. In our work we are using the GPS module to find out the latitude and longitude of particular location where the tilt and vibration is occurred. Serial communication block UART is used to interface the PsoC module and GPS module. NMEA standard supports the controlling and configuration of L10 GPS module. We extract the latitude and longitude from standard GPS data frame. Latitude and longitude are mentioned in degree and minutes format.

GSM module:- In our project we are using SIM900 GSM module. We are sending the messages of excess tilt and earthquake detection through this GSM module. SIM900 provides frequency bands of 850/900/1800/1900 MHz for voice, SMS, data and fax. We are using AT command interface. The interface available with SIM900 are SPI, serial interface, I2C, GPIO, PWM and ADC.

3-Axes Accelerometer:- The sensor MMA7620QT is used as gravitational sensor. It is having two logic inputs g-select1 and g-select-2. By these two logic inputs it is operated in four modes with different sensitivities. Those four modes are 1.5g, 2g, 4g, 6g. Sleep mode, filtering and ratiometricity are some of the features provided by this sensor. The output is in the form of accelerations along the 3-Axes X, Y and Z i.e Xout, Yout and Zout. These outputs are interfaced with PsoC module through RC filtering. Thus we calculate the acceleration along the three axes and decide the gravitational constants.

4. PsoC module:- Architecture PsoC 4 module is used for this project and the chip is CY8C4245AXI

by Cypress Semiconductors. This chip belongs to 4200 family. PsoC 4 is a scalable and reconfigurable platform architecture for a family of mixed-signal programmable embedded system controllers with an ARM Cortex-M0 CPU. It combines programmable and reconfigurable analog and digital blocks with flexible automatic routing. The PSoC 4200 product family, based on this platform, is a combination of a microcontroller with digital programmable logic, high-performance analog-to-digital conversion, opamps with Comparator mode, and standard communication and timing peripherals. The PSoC 4200 products will be fully upward compatible with members of the PSoC 4 platform for new applications and design needs. The programmable analog and digital sub-systems allow flexibility and in-field tuning of the design. Provides up to 32 kB of flash with Read Accelerator up to 4 kB of SRAM. 32-bit MCU subsystem, programmable digital, programmable analog low power operation, capacitive sensing, segment LCD drive, serial communication, timing and pulse width modulation, upto 36 programmable GPIOs, PsoC creator design environment are some of the special features. Fig.4 shows the block diagram of PSoC 4 architecture.

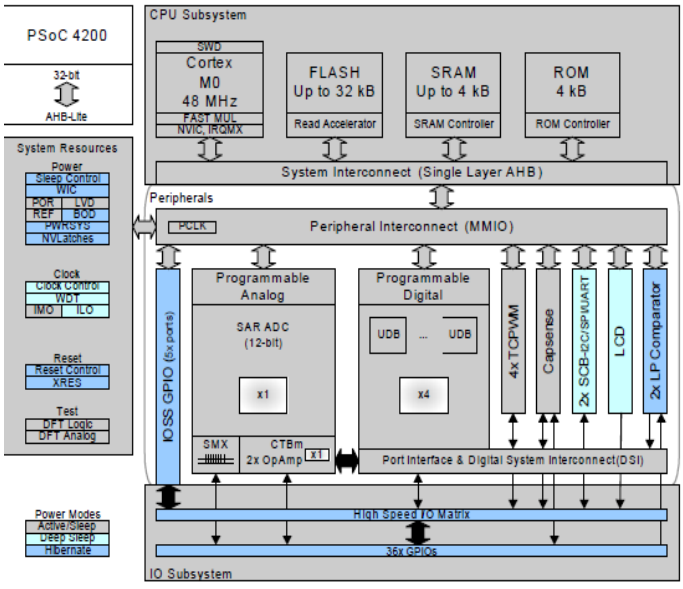

Fig.5. Block Diagram of PSoC 4 architecture.

V.SOFTWARE DESCRIPTION

PSoC Creator:- PSoC Creator is a free Windows-based Integrated Design Environment (IDE). It enables concurrent hardware and firmware design of PSoC 3, PSoC 4, and PSoC 5LP based systems. Create designs using classic, familiar schematic capture supported by over 100 pre-verified, production-ready PSoC Components; we can see the list of component datasheets. Figure 5 shows the system design with PSoC creator.

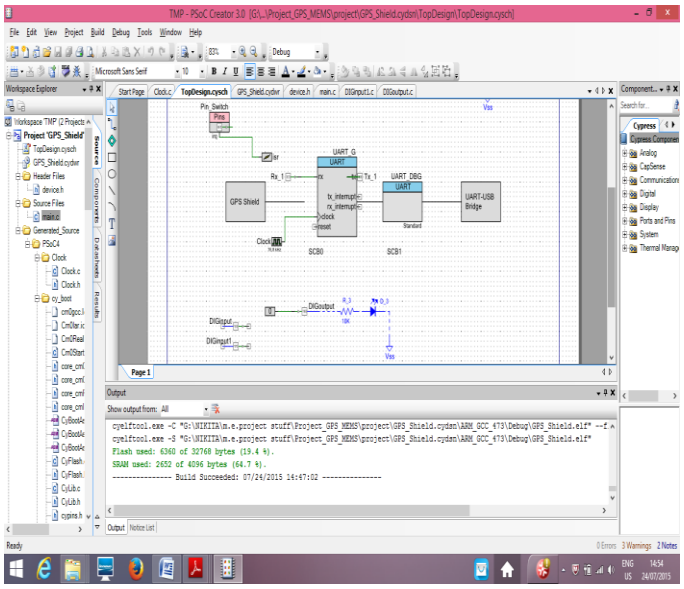

Fig 6. Designing system with PSoC creator

With PSoC Creator, we can:

1. Drag and drop component icons to build your hardware
system design in the main design workspace.
2. Co design your application firmware with the PSoC hardware, using the PSoC Creator IDE C compiler.
3. Configure components using the configuration tools.
4. Explore the library of 100+ components.
5. Review component datasheets.

VI .EXPERIMENTAL RESULTS

Response time of the circuit is very low. And the system is more reliable because of use of GSM module. When the reference voltage along Z-

axis is more than or equal to 0.8 volts then the excess tilt will be detected. And when the reference voltage along X-axis is more than or equal to 1.8 volts then the earthquake is detected.

As soon as the movement of the sensor is detected, we can receive the results on our mobile through GSM module on our mobile. We have connected the GPS module to receive the latitude and longitude of particular location where excess tilt and vibration is taking place.

Thus the safety of bridges can be obtained. If the original position of the bridge is changed because of heavier traffic then the tilt is detected. We will come to know whether the bridge is safe or not for use.

Even for the huge machines in the factories this type of safety can be obtained. We will come to know whether that machine is tilted from its original position or not. So that workers working around that machine can be aware.

Experimental results are obtained as follows:

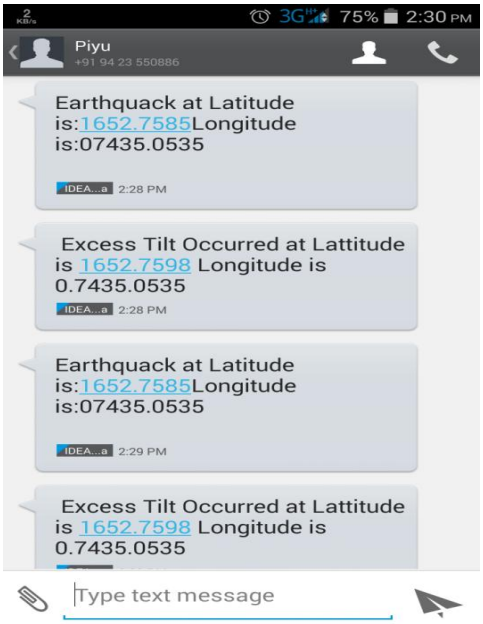

Fig.7: Experimental Results

VII CONCLUSION

This paper employed a CY8C4245AXI development module with chip number CY8C4245AXI-483 to establish a tilt and vibration monitoring. When any movement is sensed at particular location then the message regarding the movement is received on the mobile phone. Message will be received for excess tilt and earthquake with the latitude and longitude of the location.

Safety issues of bridge engineering are closely related to the people's safety of lives and properties. Bridge accidents occur frequently, so new idea or new mechanism must be introduced into management system to improve bridge security, and then to protect the safety of public possessions and lives, which is the uppermost aim.

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