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Design and Analysis of Wireless System for Detecting Vibrations from a Distance

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Abstract

This paper describes the design of a wireless system for detecting vibration which may be useful in many applications. Here we are going to see one of the applications for detecting vibration i.e. Structural Health Monitoring system using wireless communication. Structural health monitoring (SHM) systems have excellent potential to improve the regular operation and maintenance of structures. Wireless networks (WNs) have been used to avoid the high cost of traditional generic wired systems. The most important limitation of SHM wireless systems is time synchronization accuracy, scalability, and reliability. To avoid unexpected problem of aging and deficient infrastructure has demonstrated the need for an improved system to maintain these structures. This paper is mainly proposed for three modules. These system is developed using PIC (peripheral interface controller), GSM module and vibration sensor and for analyzing results we are using visual basic platform.

Index Terms– Wireless system, structural health monitoring, Wireless networks (WN) vibration sensor, GSM module, Visual Basic

I. INTRODUCTION

Wireless communication is the transfer of information between two or more points that are not connected by an electrical conductor. Wireless operations permit services, such as long-range communications, that are impossible or impractical to implement with the use of wires. The term is commonly used in the telecommunications industry to refer to telecommunications systems (e.g. radio transmitters and receivers, remote controls etc.) which use some form of energy (e.g. radio wave, acoustic energy, etc.) to transfer information without the use of wires. Information is transferred in this manner over both short and long distances. Type of Networks includes following networks.

PAN: a personal area network is a Computer Network (CN) Used for communication among computer devices (including Telephones and personal digital assistants) close to one person Technologies: USB and Fire wire (wired), IrDA and Bluetooth (wireless)

Local area network (LAN) is a CN covering a small area, like a home, office, or group of buildings. Metropolitan Area Networks (MAN) large CNs usually spans a city. Wide Area Network (WAN) is a CN that covers continents, e.g. countries, continents.

Structural health monitoring (SHM) systems have excellent potential to improve the regular operation and maintenance of structures [1], [2] such as bridges, tunnels, buildings, and dams. It encompasses damage detection, identification and prevention of structures from natural disasters like earth quake and rain. Structural health monitoring systems leads to the function of safety maintenance and extending the life time of real time buildings. In general structural monitoring includes the change of structures in properties at the geometrical and material level. In addition to that structural monitoring system should reduce the energy consumption [3].Long term bridge structural health monitoring systems have been implemented to provide secured and safety operation. In addition to that it also provides the functionality of an early alert on the damage of the structures. Damage monitoring in any civil structures includes, corrosion monitoring, crack monitoring, vibration and strain measurement [4]. The main principle of structural health monitoring system is vibration analysis.

At present, practical use of SHM systems is limited due to unavailability of specialized data acquisition equipment and the high cost of generic wired instrumentation coupled with high installation costs. According to the study in [5], up to 25% of the total system cost and 75% of the installation time can be attributed exclusively to the installation of system cables. Some of the first efforts made to reduce costs were related to wireless networks (WNs) [6]. Since these early efforts, numerous researchers have developed smart sensing platforms. In [7], over 150 papers on WNs for SHM conducted at over50 research institutes worldwide are referenced. As Lynch says, smart sensors with wireless communication capability are reported to reduce installation effort to a great extent and help to create a dense array of sensors. WN has been the subject of intensive research in the SHM community. The reasons for this are the following.

- No cables are required for data transfer because the communication is wireless.
- System setup and maintenance cost is reduced.
- Data processing and interpretation can be distributed across the network nodes.
- System becomes more faults tolerant. In the case of a partial system failure, the rest of the system is capable of performing its task independently.
- Overall system response time improves due to anomaly detection through data processing on the nodes instead of the central base station.

Besides, advantages there are some limitations in WN that has to be considered for further evaluation.

- SHM requires a tremendous amount of data to be sent at central station and is not scalable to large numbers of sensors.

- Time-synchronization accuracy may not be suitable for some applications.
- Packet loss may severely affect the performance of SHM system.
- Each node has a limited battery life that has to be preserved by efficient consumption.
- Collisions may occur when measurements are sent to the several base stations.
- Communication bandwidth is limited.

Vibration causes machine damage, early replacement, low performance, and inflicts a major hit on accuracy. Using vibration analysis as a tool to determine the specific cause and location of machinery problems can repairs and minimize costs. Vibration sensors can measure and analyze displacement, linear velocity, and acceleration. The two basic piezoelectric materials used in vibration sensors today are synthetic piezoelectric ceramics and quartz. Identifying vibrations may be helpful to many applications as to sense underground vibrations for detecting earthquake type of seismic activities, to sense vibrations of machine parts to find and predict its breakdown time, to find the resonating conditions and the most unstable working condition of industrial machine like mixer, hopper, conveyor belt, grinders etc.

II. RELATED WORK

Structural health monitoring with wireless networks involves many advantages. But it has great limitation related to time synchronization. In online structural monitoring system there is need to divide the main building into sub structures. This has been achieved by NS-KALMAN algorithm. It will leads to high power consumption. Number of steps in KALMAN algorithm depends upon the number of substructures. So it is not well suited for large number of sub structures. Damage monitoring in civil structures includes corrosion monitoring, crack monitoring, vibration and strain measurement. In Real Time Bridge health monitoring system ZIGBEE is used to transmit the data about the different types of sensors that has measure the structural health parameters. Time synchronization is the main disadvantage of structural health monitoring system. This has been overcome by two algorithm called ARX (auto-regressive model with exogenous input) and ARMAV (autoregressive moving vector). This algorithm is used to record the seismic response of the data from the real time structures. Sensing system has to be installed permanently in the building. It is one of the drawbacks economically. Then it should consume low power to reduce the cost of replacing the batteries.

III. SYSTEM OVERVIEW

The overall block diagram of proposed structural health monitoring of building is illustrated in fig 1. In wireless sensor there is need to use batteries for power management. Three modules are namely as sensing module, acquisition module, wireless module and output module.

Sensing module consist of different types of sensors, which is used to measure the different parameters that are affecting the health of structure. Sensor modules senses environment signals and then it send to the acquisition module. It involves vibration analysis, damage detection and power consumption. Vibration analysis is used to predict the start of an earth quake. Damage detection identifies the damage caused by an earth quake or any other external load. Sensing module should be embedded with the monitoring area. Acquisition module which consist of controller, signal conditioning unit and analog to digital controller. Mainly signal conditioning unit performs three major operations. They are filtering, amplifying and isolation.

For the secured wireless communication GSM module is used. Therefore pair of GSM modules can be placed in both sensing unit and server unit. The final module is the output module.

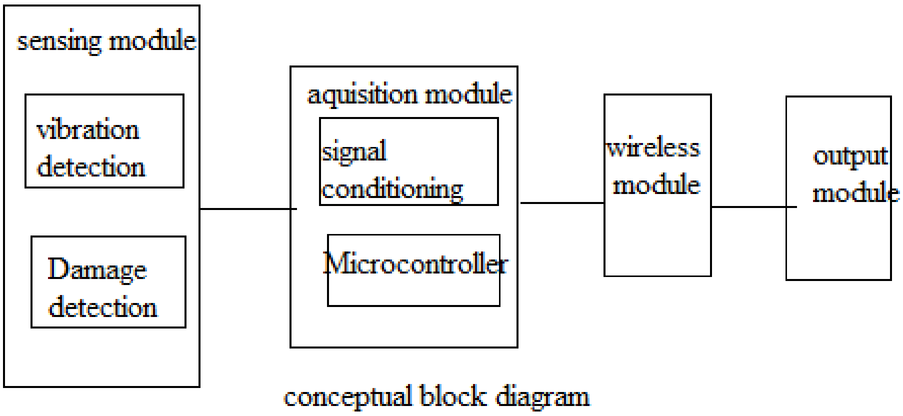


Fig.1. System receiver block diagram.

IV. DESIGN AND IMPLEMENTATION

The proposed module of vibration detection system is shown in fig 2. This module is mainly predicting the structural damage before known by the human knowledge. It can measure the start of damage in building or an earth quake. So it is need to identify the vibration which is induced by an structural damage.

To measure these vibrations we can use accelerometer, strain sensor and switch mode sensors.The overall vibration detection system having hardware and software design. The hardware system is primarily divided into two parts the transmitter section and the receiver section.

Transmitter section is developed using PIC (peripheral interface controller), GSM module and vibration sensor. As we discussed earlier in system overview that vibration sensor is under the sensing module. PIC is come under the acquisition module. For wireless module we are using GSM modules and output module is worked on PC. Receiver section is developed using GSM module and PC. The PC contains database for storage of vibration index.

Hardware section consists of four modules sensing module, acquisition module, wireless module and output module. Primary sensor module includes vibration detection, damage detection for that we are using vibration sensor. The vibration sensor is connected on the subject to perform structural health analysis. The system reads vibration in the form of pulse width. Higher the pulse width higher is the vibrations. The PIC (Peripheral Interface Controller) counts the pulse width of vibration sensor, calibrates it for index 0-9 and sends the vibration index to the GSM module. The GSM module transmits vibration information, SIM number, date, time etc. to the main machine. The GSM module of central server receives vibration information via SMS.

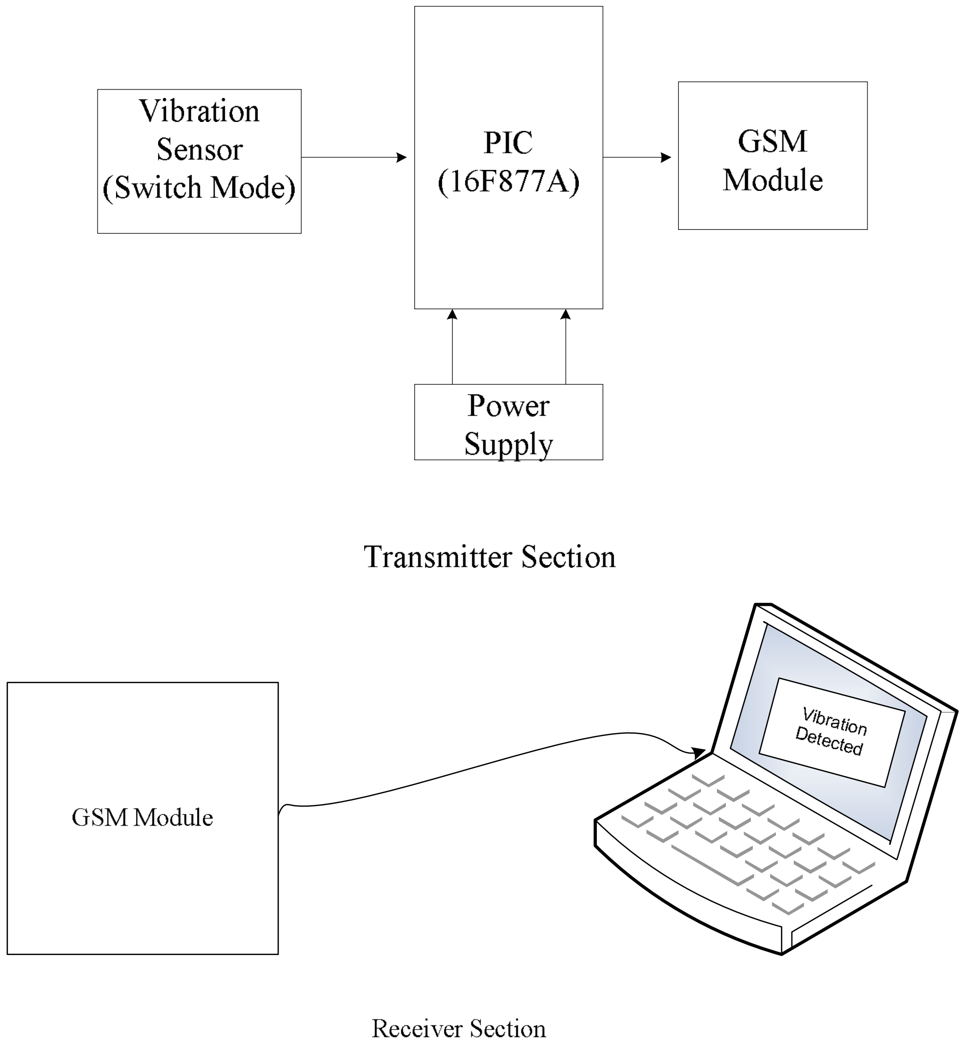


Fig.2. Transmitter and receiver block diagram.

To measure this vibration accelerometer and strain sensor is used. Accelerometers are placed in every floor of the building and strain sensors are mounted in base of the building. The aim of using accelerometer is to predict the initial stage of an earth quake. If the accelerometer exerts high level of floor vibration beyond the threshold it can send the alert command to the base station wirelessly. If the vibration exceeds 10-25 Hz it can send the alert command to the base station. Same as that of acceleration sensing module strain sensors are used to measure the ground vibration. Strain sensor can mount on the base of the building. Depends upon the area of building multiple number of sensors are used. If the ground vibration level exceeds the threshold level it can intimate to the base station through GSM module in wireless. Both acceleration sensing and strain sensing can be done using earth quake detection algorithm. An Accelerometer is a device that can measure the vibration or acceleration. Accelerometer has been used in many industrial and science application. In the field of civil engineering, it can be used to measure the vibration induced by an external load like earth quake or typhoons. Accelerometer is a representative type of sensor that can measure the structural vibration. In structural health monitoring system we can use three different types of accelerometer depending upon where it is used and the range of measurement. Different type of accelerometer includes force balanced type, Piezoelectric type and MEMS type. This proposed method use switch mode vibration sensor to measure vibration. Figure shows the connection between vibration sensor and PIC 16F877A.

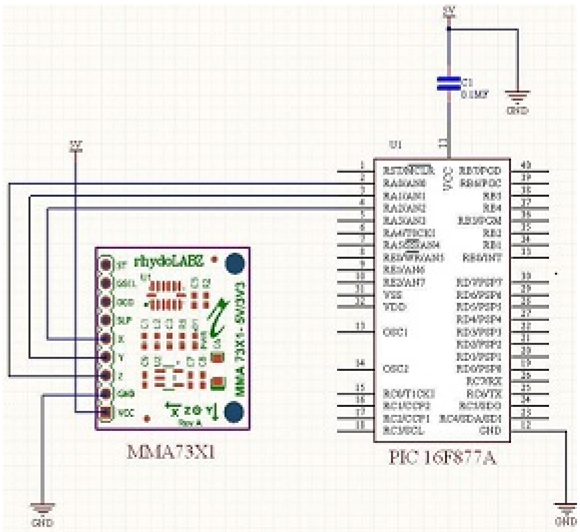
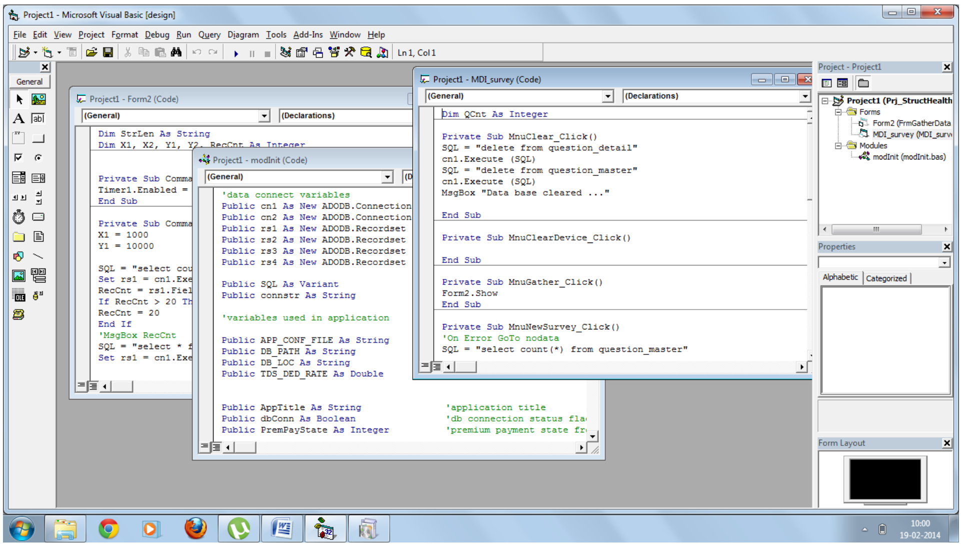


Fig.3. Interfacing diagram.

This type of sensor includes Wheatstone bridge, temperature sensor and amplifier circuit. PIC 16F877A type of PIC microcontroller is used to process the signal acquired from the accelerometer and strain sensor. It has the feature of high performance RISC CPU and it has only simple 35 instructions to use in programming. The operating speed is DC-20 MHz clock input and it has eight levels deep hardware stacks. The main feature is power saving mode that is sleep mode. It can with stand in commercial and industrial temperature ranges.

Software platform for this proposed work is based on the visual basic platform i.e. VB application and for programming in PIC we use MPLAB IDE V 8.36. MPLAB IDE is a windows based integrated development environment for the microchip technology incorporated PIC microcontroller.

The world turn to graphic user interface (GUI), visual basic is one of the languages that changes to accommodate the shift. Visual Basic is designed to allow the program run under the windows without the complexity generally associated with windows programming. The designed screen can holds standard windows button such as command buttons, check boxes, option buttons, text boxes, and so on. Each of these windows object, operates as expected, producing a “standard” windows user interface. Visual basic is one versatile and popular programming language. It provides standard windows graphic user interface that will make the program become user friendly.



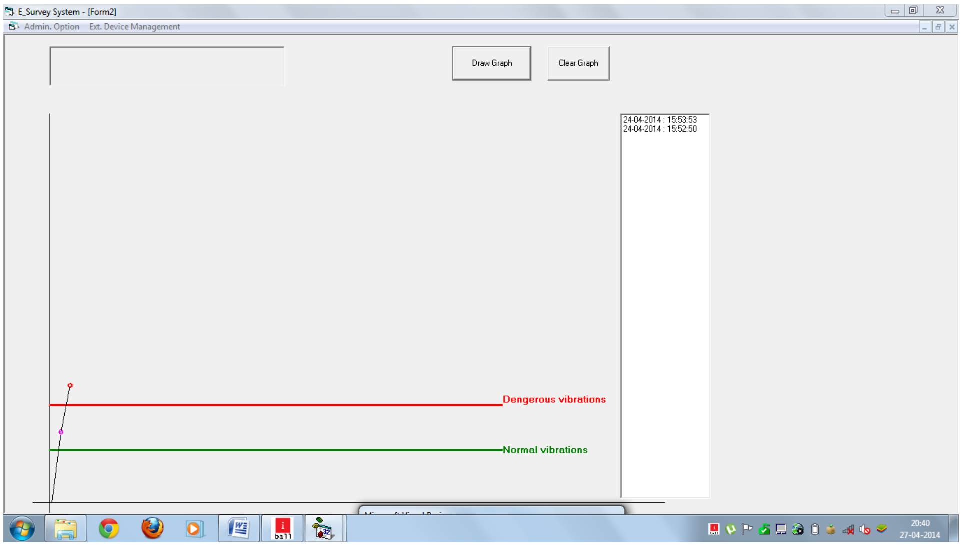


Fig.4. GUI Snapshot.

V. RESULT ANALYSIS

The vibration analysis for this proposed paper is shown in following table. Table shows database for storage of vibration index, GSM module transmits all information like date, time and vibration index to the main machine. Main machine reads the message and separates vibration index. From this analysis we can maintain the structures.

Vibration Analysis

recID	VibrnIndex	Vdate	Vtime
1	4	1/28/2014	11:54:56 AM
2	3	1/28/2014	11:55:33 AM
3	3	1/28/2014	12:11:19 PM
4	3	1/28/2014	12:36:48 PM
6	4	1/28/2014	12:41:54 PM
7	4	1/28/2014	12:42:25 PM
9	4	1/28/2014	1:35:46 PM

VI. CONCLUSION

We have to design wireless system for detecting vibrations from a distance for that we used GSM module for transmitting and receiving data. In most of the papers they used ZIGBEE technology and results are shown using that technology. Here we are using GSM module. The proposed work is based on the structural health monitoring application. For future work we can also use crack sensor and moisture sensor on building.

- In any real time structural health monitoring system the main issue is the time synchronization. This paper also proposes to overcome the general issue arises in structural health monitoring system.
- In real time structural health monitoring system all the data from sensor should have exact time of data. Each sensor has its own oscillator based on timing signal.
- Oscillator frequency is varied based on their own clock pulses.
- In this proposed work vibrations are obtained in the form of pulse width. Higher the pulse width higher is the vibrations. Time, date and vibration index of vibration is detected in database.

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