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Structural health monitoring using wireless sensor networks

To cite this article: K Sreevallabhan *et al* 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **263** 052015

IOP Conf. Series: Materials Science and Engineering **263** (2017) 052015 doi:10.1088/1757-899X/263/5/052015

Structural health monitoring using wireless sensor networks

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Abstract. Monitoring and analysing health of large structures like bridges, dams, buildings and heavy machinery is important for safety, economical, operational, making prior protective measures, and repair and maintenance point of view. In recent years there is growing demand for such larger structures which in turn make people focus more on safety. By using Microelectromechanical Systems (MEMS) Accelerometer we can perform Structural Health Monitoring by studying the dynamic response through measure of ambient vibrations and strong motion of such structures. By using Wireless Sensor Networks (WSN) we can embed these sensors in wireless networks which helps us to transmit data wirelessly thus we can measure the data wirelessly at any remote location. This in turn reduces heavy wiring which is a cost effective as well as time consuming process to lay those wires. In this paper we developed WSN based MEMS- accelerometer for Structural to test the results in the railway bridge near VIT University, Vellore campus.

1. Introduction

Civil structures like buildings, bridges are using despite of their aging, deterioration. As the aging of such structures increases past beyond their designed life it may causes great damage if any sudden change in structure properties occurs, thus continuous monitoring of such structures is required for life safety, economic point of view [1]. This process of continuous monitoring of such structures response is called as structural health monitoring. Structural health monitoring is very important concept in the advancement of science in the area of disaster management as it involves saving people's life directly or indirectly by properly maintain and replacement of structures if necessary [12] [13] [14].

The process of structural health monitoring is collecting the data of various sensors which is placed at various locations of structure. In general the sensors, signal conditioning and data acquisition all the components are physically linked together. In the past decade there are so many researchers have implemented structural health monitoring using wired network. But wired network itself has lot of limitations which include Installation of lengthy cables for longer transmission, time consumption to install such cables is large and if any damage to such cables due to deterioration, causes great issue to repair and maintenance. Due to such limitations there is need for wireless transmission of data using wireless transmission we can acquire data easily and monitoring of such data in any remote location from the source of data is quite easy [2]. Generally as we obtain lower frequencies from the larger structures, the choice of selecting transmitter and receiver module is very critical as many of them have poor characteristics over larger frequency range. As the monitoring of complex structures like bridges is performed in harsh environments, SAW based wireless sensors are best suited for this type of environment as its dipoles are of loop or patch or dipole type which does not require any additional power supply.

2. Methodology

In Figure 1. wireless sensor network is configured into two major components as Transmitter board connected with sensor module and receiving module board at remote location. In Figure 1. the first block represents the transmitter board which consists of four major components 1) sensing device 2) signal conditioning 3) microcontroller unit for computational core and finally 4) radio transmission for transmitting the data. The second part in Figure 1 represents receiving board which works in opposite way to that of transmission board. While in the receiver board first the receiver receives the data and which is sent to the microcontroller and the microcontroller reconstruct the original signal and further sent to the data acquisition system for the human information where the person monitors whole data [8] [9].

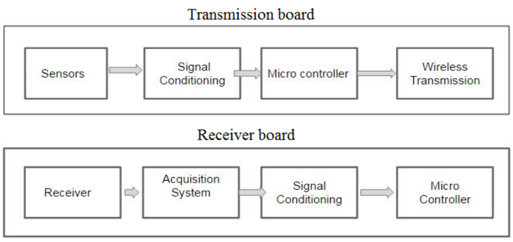

Figure 1. System Basic functional diagram

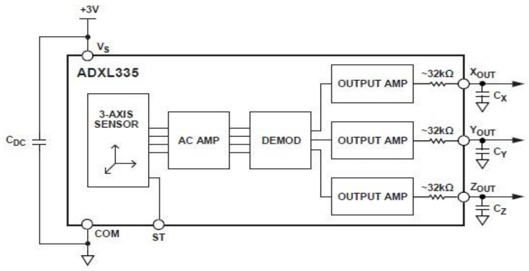

Figure 2. 3-Axis Accelerometer sensor board

Sensor is the core component in structural health monitoring converts actual physical quantity into equivalent electrical signal. Most generally used sensors are accelerometer, strain gauges, anemometers, temperature sensors. In this paper we are using piezoelectric accelerometer as a sensor and for WSN we are proposing a RF transmitter and receiver tuned at variable resonant frequency [11] [15].

2.1. *Accelerometer sensor board*

Accelerometer sensor used in the project is ADXL335 which consumes less power, and works over wide range of acceleration input. By using Xout, Yout, Zout pins 3 axis of orientation [3]. This accelerometer is widely used in application which involves motion detection, vibration and shock measurements. Different types of accelerometers available in the market like mechanical accelerometer, piezoelectric accelerometer and capacitive type. Among all these types, piezoelectric stands out best due to its accuracy over wide range of frequencies and as well as it is active transducer which does not require any additional power supply as it operates on its own without consuming power supply[4]. Here Figure 2 represents accelerometer sensor along with signal conditioning unit. Generally, this piezoelectric sensor will be attached to a seismic mass to which a spring is attached on its top. Whenever the seismic mass experiences stress through the spring attached to it the piezoelectric crystal also experiences that stress and produces the voltage that is proportional to the applied stress or vibrations [7] [10].

2.2. *Microcontroller unit*

In this paper, we have used ATMEL AT-MEGA 328P board as processor. Here Figure 3 gives architectural information about ATMEL AT-MEGA 328P processor board. It contains fourteen digital output and input pins in which includes a power jack, an ISCP header ,a reset button,6 analog inputs and a 16 MHZ crystal oscillator and an USB connection. It uses Atmega8u2 programmed as USB to serial converter instead of FIDI chip which makes it different when compared to other processing boards [5].

Basically, we can give supply through a battery or through an AC to DC converter. The operating voltage is 5v and the voltage range is 6-20 volts. But if we manage to give only five volts, the board may become unstable [16]. If we give more than 12 volts, it results in overheating of voltage regulator

IOP Conf. Series: Materials Science and Engineering **263** (2017) 052015 doi:10.1088/1757-899X/263/5/052015

which may cause damage to the board. This board provides 14 digital pins which can be used either as inputs or outputs by using the functions like digital write (), digitalread (), Pinmode (). It contains 32 KB flash memory in which boot loader consumes 0.5 kb of memory. The clock speed of the board is 16MHZ and 1KB of EEPROM capacity [17]. It contains RX and TX pins to know the status of the board i.e. whether it is receiving or transmitting data.

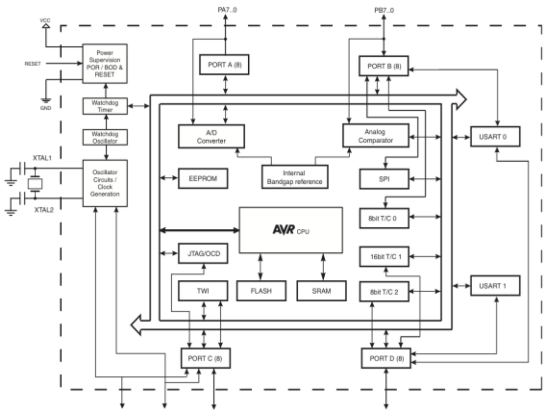

Figure 3. AT-MEGA 328P microcontroller

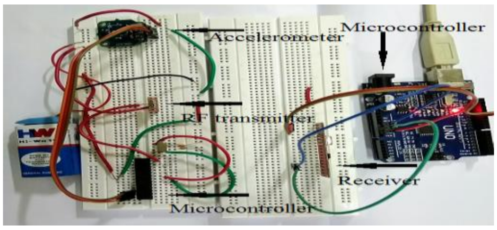

Figure 4. Hardware setup

2.3. *Radio transceiver*

It is basically an electronic device which is used for communication or for exchange of information between two devices. Generally, it transmits or receives information in terms of radio signals. Basically; it is available in receiver, transmitter, and system on chip and transceiver module. Antenna and control module are the integral parts of the transceiver [6] [18]. The transmitter along with sensor is mounted on the structure on which is going to be monitored as shown in Figure 5(a) and the transmitter sends the data regarding the vibrations of the structure to the receiver which is located in the main module. The transmitter transmits the data to the receiver in the form of radio signal which is initially in the form of electrical signal [19] [20]. At the receiver part, this radio signal is again converted back into electrical signal. Here Figure 5(b) represents the architecture of receiver part in radio transceiver.

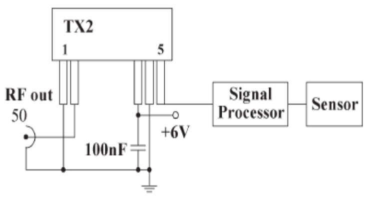

Figure 5(a). Transmitter

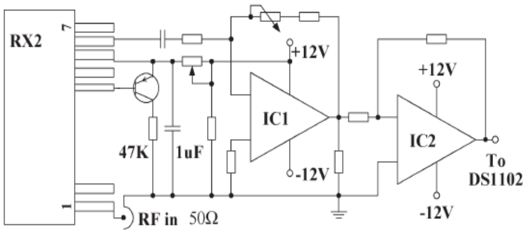

Figure 5(b). Receiver

3. Results and discussion

Here Figure 4 represents the prototype model. Here 3-axis accelerometer sensor which is connected to microcontroller which is connected to power supply it starts sensing the variation of motion in its 3-axis. When this accelerometer subjected to vibrations it shows the vibration in terms of change in the gravity of accelerometer. Once sensor detects the vibration it sends the data to the microcontroller. In microcontroller the un-calibrated signal which is received from the accelerometer is calibrated. Figure 4 and Figure 6 shows the accelerometer analysis of with and without vibration.

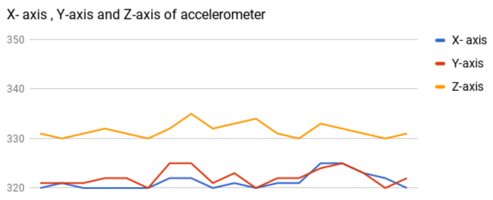

Figure 6. Without vibrations

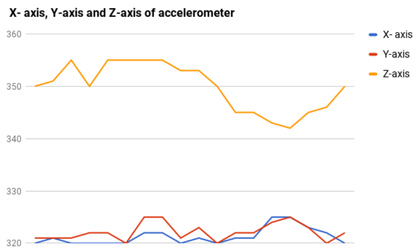

Figure 7. With vibrations

4. Conclusion

As the structural health monitoring is gaining more and more interest by many people for safety point the SHM technique which we implemented in this paper is low cost, easy to monitor the data, less maintenance required. As the whole network works on Wireless Sensor Networks we can setup the sensor board at any place in the structure and also further extension of more sensors to the WSN network is also quite easy. As the data transmission and receiving from the multiple sensors at different locations is easy through WSN ugliness due to large wiring is avoided. Further usage of WSN results to monitoring of the data at any time is easily achieved.

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