SELF-POWERED WIRELESS SENSOR NODE FOR VIBRATION LEVEL MONITORING

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DECLARATION

I hereby, declared this report entitled "Self-Powered Wireless Sensor Node For Vibration Level Monitoring" is the results of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Electronic and Computer Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Electronic Engineering (Industrial Electronic). The member of the supervisory is as follow:

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DEDICATION

To my beloved parents and all my family members who always encourage and support me during my project.

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ABSTRAK

Getaran adalah sejenis kesan sifat mesin pemampat yang beroperasi dengan pergerakan. Oleh itu, jika mesin yang bekerja tidak tepat, getaran yang menjana membentuk mesin akan berbeza dengan getaran yang menjana apabila beroperasi dalam keadaan normal. Jika isyarat awal ini tidak dikesan oleh orang-orang yang mengendalikan mesin ini, ia boleh menyebabkan kemalangan besar seperti letupan. Sebab itu, mesin ini perlu dipantau dan memerlukan penyelenggaraan dari semasa ke semasa. Projek ini bertujuan untuk mereka bentuk dan membina nod sensor tanpa wayar yang berupaya menjana kuasa untuk memantau tahap getaran sumber tiruan tunggal. Nod sensor ialah julur piezoelektrik yang boleh menjana kuasa sendiri. Ia telah menjalani ujian yang mudah di dalam makmal untuk mencirikan sifat-sifatnya. Oleh itu, apabila julur piezoelektrik menuai tenaga yang cukup dari sumber getaran, ia mampu untuk memberi kuasa kepada pemancar untuk menghantar denyutan untuk mencetuskan nod penerima yang dibuat dari jarak yang jauh. Semua data yang dikumpul dan hantar melalui IOT. Oleh itu, apabila tahap getaran mencapai frekuensi resonans julur piezoelektrik, nadi yang telah menghantar kepada orang yang sedang memantau tahap getaran dari sumber. Selain itu, IOT dilaksanakan dalam projek ini bagi membolehkan data yang diterima sebagai akses kepada pangkalan data rangkaian yang luas untuk memantau.

ABSTRACT

Vibration is a nature effect of machine or a compressor that operate with movement. Therefore, if the machine is work unproperly, the vibration that generate form the machine will be different with the vibration that generate when it is operate under normal condition. If this early signal didn't detect by the people who operate these machine, it may cause a major accident such as explosion. Therefore, these machines have to be monitor and require maintenance from time to time. This project aims to design and build a self-powered wireless sensor node for monitoring the vibration level of a single artificial source. The sensor node is a piezoelectric cantilever that is self-powered. It was going through a simple test in laboratory to characterise its properties. Hence, when the piezoelectric cantilever harvests enough energy from the vibration source, it is able to power up transmitter to transmit pulses to trigger a receiver node that placed from a distance away. All the data is collected and send via IoT. Hence, when the vibration level reaches the resonance frequency of piezoelectric cantilever, a pulse was send to the person who is monitoring the vibration level of the source. Besides that, IoT is implemented in this project in order to enable the data received to be access to network database for wide range monitoring.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

AC	-	Alternating Current
DC	-	Direct Current
Hz	-	Hertz
IoT	-	Internet of Things
LT	-	Linear Technology
MCU	-	Microcontroller Unit
PV	-	Photovoltaic
RF	-	Radio Frequency
Vrms	-	Root Mean Square Voltage
Wi-Fi	-	Wireless Fidelity
WSN	-	Wireless Sensor Node

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CHAPTER 1

INTRODUCTION

This chapter mainly covers the general background of this project, the problem statement, project objectives, work scopes, project significance and conclusion.

1.1 Introduction

Traditional vibration monitoring system functioned with wired sensor nodes which installed at machineries and workers is required to work around to collect the data. Try to imagine a big machinery plant like oil and gas and factories of industry where their machinery and compressor are all operate with high pressure. The workers have to monitoring these machineries one by one and also day by day. Just in case that if one of the machine was checked by the workers just now, but it had been used unproperly just after the checking process and caused malfunction of the machine. How the people who monitor the machine notice immediately in order to prevent tragedy occur.

Therefore, a self-powered wireless sensor node for vibration level monitoring is proposed in this project. With the use of self-powered sensor node, it is intentionally designed to help in monitor all of these machinery at once. This provides an efficient way to monitor and ensure the condition of each of the machineries.

The piezoelectric cantilever is applied in the sensor node. Each of the nodes is able to generate power by itself from the vibration source. and able to power up the transmitter to enable it to communicate with receiver. Besides, WSN is widely used in monitoring the condition for a larger area place such as the example given previously, monitoring in plant of oil and gas.

This wireless sensor node will be developed to monitor the vibration level at a shaker that acts as vibration source. Transmitter that integrated with self-powered sensor node will be used to transmit data from vibration source. The data is then pass to the receiver node which is then monitoring through IoT.

1.2 Motivation

Traditional vibration monitoring system functioned with wired sensor nodes which installed at machineries and workers is required to work around to collect the data. Try to imagine a big machinery plant like oil and gas and factories of industry where their machinery and compressor are all operate at high pressure. It is become complex and costly to hire people to maintain the performance for each of these machines.

This time, try to imagine a modern factory with different shape and size of machineries operating in the factory floor. The job of monitoring all of the machineries to prevent the breakdown seen to be a tedious work for the worker. Same with previous example, by using wireless sensor node but monitoring in vibration level, this problem can also be solved. Functionality of all of the machineries can be monitored at once. This provides a more efficient way in ensuring the condition of the machineries.

The motivation behind this project is to introduce self-powered technology into present monitoring system. For existing monitoring system was manual monitoring system. It involves large number of labour to monitor these machineries. A monitoring system that contain self-powered material to supporting the whole network. All of this wire made the trouble in installing not to mention for maintaining. By going self-

powered, the disadvantage of huge number of labour use and maintenance of the existing system that trouble in maintaining the system can be reduced.

1.3 Problem Statement

Ambient vibration source occur in the environment are very random. Whereas the piezoelectric cantilever can only generate voltage at the range of its resonance frequency. Therefore, piezoelectric cantilever may not generate useful electricity at random frequency and vibration magnitude. So, the piezoelectric cantilever need to be characterised to know their working principle in order to achieve their maximum operation effect.

Next, the voltage and current generate from the piezoelectric cantilever is in AC form. However, the AC voltage cannot be used to power up transmitter and the voltage form that need to power up transmitter is in DC form. Hence, the voltage generate from the piezoelectric cantilever has to be transformed from AC to DC with a designed circuit so that it can become useful voltage. At the end, a power conditioning circuit has to be designed in order to generate applicable voltage.

Lastly, it is costly to hire large number of labours to monitor the vibration level by observing the receiver one by one. In addition, these labours also need to have a well training to operate and observe the vibration level of machine or compressor. Besides that, Internet of Things (IoT) is in the trend of technology that applied in many systems recently.

1.4 Objectives

Based on the problem statements, the objectives of the project are as below:

- To characterize piezoelectric cantilever to operate at resonance frequency.
- To design a power conditioning circuit that able to provide a steady voltage for components.
- To prototype vibration monitoring alert system working with IoT.

1.5 Significant of Project

The significant of this project lies here in the self-powered sensor node part. The piezoelectric cantilever can act as a sensor to detect the vibration at certain level and also can generate the power by itself. Therefore, the use of piezoelectric cantilever that can generate power itself rather than using battery which need to be replaced from time to time would greatly increase the lifetime of the sensor node. Moreover, with the integrated of IoT, it is now possible to investigate the condition of sensor node in multiple amount by observing the bits received by each of the receiver, this is expected to reduce the fee in development and the maintenance.

1.6 Scope of Project

Piezoelectric has many different types and sizes to harvest different energy. However, in this project, only one piezoelectric cantilever with a size of 31.8mm x 12.7mm x 2.5mm is applied. A LTC3588 is used to transform AC voltage from the piezoelectric cantilever to steady DC voltage. For this vibration level monitoring project, it contains only one self-powered wireless sensor node which are the piezoelectric cantilever to generate energy for transmit data use. Whereas the receiver node was place at the other side to receive pulse. These nodes are communicated through Radio Frequency (RF) wave. Hence, all the data can be transmitted from vibration sources to a receiver via radio frequency module.

The project is tested inside the laboratory using the vibration generator, oscilloscope, power amplifier, industrial accelerometer and data acquisition (DAQ) device that are available in there. Vibration generator is the vibration source set for testing. The shaker's frequency and amplitude can be tuned to provide a known magnitude of vibration and frequency in steady sine wave to piezoelectric cantilever. Apart from that, non-linear processing of piezoelectric is not consider in this project.

The data received can be send to internet and then alert with the person who monitors the system when vibration reached at the known vibration magnitude and frequency level. Besides, a Wi-Fi module will be applied to enable data to be access

to internet. Moreover, the receiver and Wi-Fi module are integrated with a PIC 16F microcontroller. The system was implemented with IoT and prototype in a size with about 80mm x 55mm x 30mm (L x W x H).

Although vibration level monitoring system can be applied into many fields, only the experiment in laboratory will be considered in this project. In order to complete this project in one year, these are the few aspects will be focus on.

1.7 Thesis Outline

Chapter 1 described about Project Introduction which provides an overview of this project. It helps reader to understand the project's structure in an easier way. Motivation and significant of the project is also discussed to describe the reason of suggestion for this project to reader. Scope and limitation also listed in this section to act as boundary line for this final year project.

Next is Chapter 2 which explains about Literature Review of this project. This section presents some explanation on perspective and method used in previous research. It also discussed how much this project is related to those researches.

Chapter 3, Research Methodology, the method used for designing the circuit, collecting data, and analysing it is presented. The considerations for selecting suitable way to run the experiment will also be discussed.

Next, the result and discussions part will provide all the final result in the project and present in formal and simple way. The result will be used to justify the achievement of the objective in the project.

Lastly, the conclusion and suggestion will provide the summary of the project. Suggestion for further research in the project will be given in this part also.

1.8 Concluding Remarks

With all the information stated in this chapter, the reader will be able to understand the basic idea of this vibration monitoring system. The next chapter covers the review of past researches done and how they are related to this project.

CHAPTER 2

LITERATURE REVIEW

This chapter will present the past researches and background information that had done by other researchers. All these resources all found from reference book, website, and journal articles. There are three parts in this chapter, namely, "Self-Powered", "Sensor Node", and "Piezoelectric Cantilever".

2.1 Self-Powered

The development of green technology has enable human to apply renewable energy greatly in their daily life. Rather than using non-renewable source that end up to become tons of wastage on the world, harvesting reusable energy from the environment would be a better consideration to sustain the life of the earth. There are many kinds of energy that are able to harvest by the developed technology.

2.1.1 Photovoltaic

The most known renewable energy by human is the solar energy. It can be said is widely available renewable energy resource that can be utilized. The solar energy is able to produce enough amount of energy to be consumed by human society. Photovoltaic (PV) process is a process that convert solar energy into electricity by a semiconductor. These solar cells are developed to work with multiple p-n junction to

reduce energy loss as much as possible and increase its efficiency. However, the high efficiency is cancelled out by its complexity and manufacturing cost. Therefore, it is At the same time, in order to increase the efficiency with low cost, many efforts have been pour into the development for PV technology [22].

2.2 Wireless Technology

This section gives a simple explanation of what Wireless Sensor Network (WSN) is. The performance targets that must be hit when designing a WSN and what factors affect the design are mentioned here. This section also reviews the work of the four wireless protocols that are widely used in today's world.

2.1.1 Wireless Sensor Network

Sensors is almost everywhere in this modern age. Normal office building has sensors to monitor occupancy, temperature, smoke, or even fire. The cars on the road contain nearly hundreds of sensors that monitors engine performance, passenger safety equipment and braking. Nowadays, sensors have become much smaller, cheaper and lower power consumption.

A wireless sensor node is the simplest unit of a wide network called wireless sensor networks (WSN). WSN is usually made up of hundreds or thousands of sensor nodes, whereby each sensor node is connected to at least one kind of sensor. It can be temperature sensor, humidity sensor, light sensor, or in this project, vibration sensor.

Each node may or may not be capable of processing data or possesses different types of memory. Nodes are connected to each other in a WSN through wireless communication and are coded to be self-organise after being deployed in an ad hoc manner [1]. WSN is commonly used to monitor the environmental condition of a wide area, for example, monitoring a huge part of the forest for any possible indication of forest fire or even military uses [2].

To develop a system that collects data wirelessly, one must kept in mind a few performance targets. For starters, it must be reliable enough. In industrial applications,

usually 99.9 percent of the data sent must be received, as missing data can lead to unwanted alarm conditions being trigger. Next, a certain throughput, the number of data packets that can be sent per second, is required by the system. Third, the data packets sent must be received within a limited time window in order to be useful. Many processes are very dependent on fresh data. For example, in control system, outdated data does not help at all. Finally, the systems should be able to operate in challenging environments that has intrinsic safety constraints or huge temperature differences. If the system meets all four of these criteria, only then it is considered suitable for further development [3].

Wireless sensor network has a huge improvement over traditional sensors since it can be deployed in the following two ways. Firstly, sensors can be placed far from the actual phenomenon, otherwise known as sense perception. Complex technique is required by the sensor to differentiate the intended data from environmental noise in this method. Secondly, a group of sensors that only carry out sensing can be deployed. The communications topology and positions of the sensors needs to be planned beforehand. Data collected by them are transmitted to a central node where the data are analysed.

WSN may have a wide variety of sensors such as seismic, visual, radar, thermal, and acoustic. This allows WSN to monitor a wide variety of ambient conditions such as, pressure, temperature, humidity, or noise levels. Though it is capable of all these amazing feats, researchers cannot just throw a multi sensing sensor node into the environment and monitor as much physical data as they want. Designing a WSN involves a lot of factors are, namely, scalability, operating environment, transmission media, and hardware constraints. Other factors also include production costs, sensor network topology and power consumption.

Though this project only develops a single sensor node with receiving node, note that wireless sensor node is essentially that smallest part of a big wireless sensor network. Therefore, it is a good practice to bear in mind all those factors and limitations of network when designing the wireless sensor node. This is because, it is time consuming to consider and apply all those constraints into each node after a network is developed. Modifying every single node in a network waste a lot of time that is

better spend in optimizing the communication within network and the whole system instead.

2.1.2 Wireless communication

This section will review of Bluetooth, UWB, ZigBee, and Wi-Fi." These papers are related to this project and are helpful as it provides an overview of the four protocols. Wi-Fi (over IEEE 802.11), Bluetooth (over IEEE 802.15.1), ultra-wideband (UWB, over IEEE 802.15.3), and ZigBee (over IEEE 802.15.4), are four low power consumption protocol standards for short range wireless communications. Usually, a wireless mouse or keyboard and even headset make use of Bluetooth, whereas, UWB is implemented mainly in high-bandwidth links. ZigBee is designed to provide reliable communication for wireless monitoring and control networks, and as for Wi-Fi, it focuses on computer-to-computer connections that are recently substituting cabled networks.

2.1.2.1 Bluetooth

Bluetooth technology is designed for short-range wireless communication using frequency-hopping spread spectrum (FHSS). This technology eased the process of connection between the devices with low power. Besides, it is also an inexpensive technology to replace cables for electronic devices, such as cellular phone, mouse, and personal digital assistants (PDAs). Piconet is use in network architecture. In piconet, one of the communicating device is acts as the Master and the other devices are act as slaves. A scatternet is formed when two or more piconets are linked together by one of the device in each piconet which acts as a bridge in between two piconets [4].

2.1.2.2 Ultra-Wide Band (UWB)

UWB is known for its capability to function indoor as a short-range high-speed wireless communication. It has bandwidth of over 110Mbps which can allows