DEVELOPMENT OF ACOUSTIC SENSOR MICRO BENDING MEASUREMENT SYSTEM FOR FLEXIBLE PRINRTED CIRCUIT BOARD

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DEVELOPMENT OF ACOUSTIC SENSOR MICRO BENDING MEASUREMENT SYSTEM FOR FLEXIBLE PRINRTED CIRCUIT BOARD

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DEDICATION

To my beloved

friends

and family

ABSTRACT

Nowadays, the flexible printed circuit (FPC) technology becomes wider used in the world and demands of the market increased. In the other hand, the disadvantages of the FPC is when the FPC is damage on the surface or route, the workers do not need to check it one by one by using the multimeter and other instruments. Due to this, this project is going to develop an acoustic sensor micro bending measurement system for the flexible printed circuit (FPC). In this project, two piezoelectric plates are used as actuator and sensor to measure the micro bending of FPC. Due to the weak propagation of acoustic wave across the FPC, the AC signal pick up by the sensor is very low and consists of noises. Therefore, a filter and amplifier circuit had been designed. Before designing the circuit, the signal generated by piezoelectric sensor need to be characterized which done with the spectrum analyzer. Once the signals are conditioned, the resonance frequency of the FPC at different bending angle is identified. For the experiment, the piezoelectric coupling device is placed at the surface of each end of FPC. One of the piezoelectric plates acts as a transducer and connected to the piezo amplifier which vibrates and generates an acoustic wave. If any changes on the path of the acoustic wave, the vibration frequency will be affected. The other side of piezoelectric plate acts as the sensor to pick up the vibration signal to detect the pattern of vibration frequency's changes with the changing of bending angle of FPC. After that, the signal is being sent to the analog-digital converter (ADC) and observed by using Raspberry Pi. The Raspberry Pi based oscilloscope was being done by scripting will plot the data receive by ADC lively. At the end of the project, the maximum angle of the FPC is 45° and the range of resonance frequency is around 24 to 25 kHz.

ABSTRAK

Pada masa kini, teknologi litar bercetak fleksibel (FPC) telah digunapakai luas di dunia dan permintaan pasaran semakin meningkat. Sebaliknya, keburukan FPC adalah apabila permukaan atau litar FPC mempunyai kerosakkan, pekerja tidak perlu menyemak satu persatu dengan menggunakan multimeter dan instrumen lain. Oleh itu, projek ini akan membangunkan sistem pengukuran mikro pengukur mikro akustik untuk litar bercetak fleksibel (FPC). Dalam projek ini, dua keping plat piezoelektrik digunakan sebagai penggerak dan sensor untuk mengukur pembengkokan FPC. Oleh kerana penyebaran gelombang akustik yang lemah melalui FPC, isyarat AC yang diterima oleh sensor adalah sangat rendah dan mempunyai gangguan. Oleh itu, litar penapis dan penguat telah direka bentuk. Sebelum membentukan litar, isyarat yang dijana oleh sensor piezoelektrik perlu dicirikan dengan penganalisis spektrum. Apabila isyarat dikondisikan, frekuensi resonans FPC pada sudut lenturan yang berbeza telah dikenalpasti. Untuk bahagian eksperimen, peranti gandingan piezoelektrik telah diletakkan pada permukaan setiap hujung FPC. Salah satu plat piezoelektrik bertindak sebagai transduser dan disambungkan dengan penguat piezo yang bergetar dan menghasilkan gelombang akustik. Sekiranya ada perubahan pada laluan gelombang akustik, frekuensi getaran akan terjejas. Bahagian pinggir piezoelektrik bertindak sebagai sensor untuk mengambil isyarat getaran untuk mengesan corak perubahan frekuensi getaran dengan perubahan sudut lenturan FPC. Selepas itu, isyarat dihantar ke penukar digital analog (ADC) dan diperhatikan dengan menggunakan Raspberry Pi. Osiloskop berdasarkan Raspberry Pi sedang dilakukan dengan menulis skrip dan akan merancang data yang diterima oleh ADC. Pada akhir projek, sudut maksimum FPC ialah 45° *dan julat frekuensi resonans adalah sekitar 24 hingga 25 kHz.*

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LIST OF ABBREVIATIONS

FPC Flexible Printed Circuit

OpenCv Open Source Computer Vision

TIV Total Industry Volume

PC Printed Circuit

MPS Monolithic Piezoelectric Sensors

BAW Bulk Acoustic Wave

PAW Plate Acoustic Wave

PAW Surface Acoustic Wave

IDT Inter-Digital Transducer

GPIO General Purpose Input/Output

ADC Analogue Digital Converter

HD High Definition

RAM Random Access Memory

USB Universal Serial Bus

CPU Central Processing Unit

GPU Graphic Processing Unit

UART Universal Asynchronous Receiver/Transmitter

SD Standard Definition

IO/PWM Input Output/Pulse Width Modulation

OSMC Open Source Media Center

OpenELEC Open Embedded Linux Entertainment Center

RISC Reduced Instruction Set Computer

OS Operating System

OOP Object-Oriented Programming

LT Linear Technology

PCB Pinted Circuit Board

ISIS Schematic Capture

ARES PCB Layout

SPI Serial Peripheral Interface

CLK Serial Clock

MISO Master in Slave out

MOSI Master out Slave in

CS Chip Select

UTeM Universiti Teknikal Malaysia Melaka

CHAPTER 1

INTRODUCTION

This chapter consists of the basic theory and information about this project. Firstly, the background will be written in this project to describe the general area of study and the reason why this project is being chosen. Next, the objectives also will be included in this section to identify and solve the problem facing in this project. Besides, this sector also will discuss the scope, project significant and project outline.

1.1 Background

Flexible printed circuit (FPC) is not rigid therefore it prompts to the formation of bends and curves on a hanging condition, which can cause signal integrity issues. FPCs are commonly used in automotive industry. One of the examples of FPC application is to be used in engine management system in order to improve the performance of the engine, to minimize the cost and increase reliability. However, damaging of FPC is difficult to detect by the human naked eyes. Besides, bending of FPC may affect the performance of the FPC. Therefore, this project is to provide a solution in measuring micro bending using frequency response technique to detect changes of bending angle corresponding to its resonance frequency.

Resonance Frequency will affect by all of the matter which has bulk properties. Therefore, the resonance frequency can be used to indicate the characteristic of the matter. In addition, the piezoelectric sensors will produce acoustic wave when utilizing energy source. This acoustic wave is active with the instrument and measurement of the interest. The frequency produced by acoustic wave is used to monitor the condition of the FPC.

This project is an analysis project which uses the concept of acoustic sensor and resonance frequency in measuring the micro bending and studies the integrity of the FPC. Next, the piezoelectric plates are placed on the surface of each end of the FPC. One of the piezoelectric plates is a transducer which connected to the function generator to produce acoustic wave signal and the other plate which act as the piezoelectric sensor will pick up the signal and connect to a spectrum analyzer to observe the output waveform. If there have any changes in the angle of the FPC, the vibration frequency will change.

After that, the signal in the waveform pattern that observed in the spectrum analyzer will be read out and analyze in Raspberry Pi to study the integrity of FPC and relationship between different angle and resonance frequency. Repeated experiment testing can verify the result after data analysis.

1.2 Problem Statement

Flexible Printed Circuit (FPC) is made of flexible insulating base material and it also is upgraded of the rigid printed circuit board. It has brought many advantages that many of rigid PCBs do not have but at the other side, it also brings us some of the disadvantages.

Firstly, the FPC is easy to be damaged. This is because the FPC is very thin and it will be easily damaged during the mounting procedure but the damaging of FPC sometimes cannot be detected by naked eyes and no specific method to detect it correctly. At the same time, it is hard to amend or repair.

Besides that, the overbending of the FPC also will cause the layer of the flexible circuit to damage. Therefore, this point motivates an idea to develop a sensor signal readout system and using this system to analyses the level of damage by observing the output response of the system with changing the bending angle of FPC. With the help of this system, the design of FPC can be improving in term of their flexibility.

In addition, the used of the piezoelectric actuator and piezoelectric sensor may consist of a lot of disturbance. At the same time, the amplitude of the signal produced by the piezoelectric sensor is very low. Therefore, the design of filter and amplifier is required to improve the accuracy of the result because the low amplitude and noise may affect the data analysis process. Other than that, the resonance frequency at different frequency range will represent different information, therefore the signal picked up by piezoelectric sensor might be changed in different condition.

1.3 Objectives

The aim of this project is to characterize the output signal of the acoustic sensor measurement system on FPC. After fully understanding the characteristic of the piezoelectric sensor on FPC, the next objective is to design the circuit of filter and amplifier to increase the amplitude of the signal and reduce the noise in order to improve the analysis process. Then, the last objective is to analyze the sensor signal readout using Raspberry Pi.

1.4 Scope of Project

This project is focus mainly on the sensor signal readout using Raspberry Pi and analyzes the relationship between output signals with the micro-bending of the flexible printed circuit at the different angle. The equipment and apparatus are used in this project are two pieces of piezoelectric plates which are going to use as actuator and sensor on the surface of FPC. A spectrum analyzer is going to use to characterize the output signal of the acoustic sensor measurement system on a flexible printed circuit. Next, the Raspberry Pi is used to show the output signal waveform of the acoustic sensor on FPC. Lastly, the monitor is being used for the display of output signal. Be-

sides that, software part also covered in this project. Python has been installing as the programming language of Raspberry Pi and Open Source Computer Vision (OpenCV) library also be install in Raspberry Pi which is interfacing with python. Lastly, the LTspice software is used for simulation of circuit design.

On the other hand, this project is limited in a certain situation. First, the piezoelectric has the voltage limitation, therefore it only can provide the highest voltage that can drive a piezoceramic sheet in low-frequency operation which is 0 to 5 KHz. Second, the frequency of the acoustic wave device used in this experiment starts at 12kHz to 35kHz. Next, the bending angle of the FPC is testing around 0° to 90°. Besides, the crack of the FPC is not considered therefore only one material is used. Lastly, this project is only to build an experimental sample for experimental testing instead of real product due to the constraint of time and cost and the fabrication of the sensor is not covered in this project.

1.5 Project Significance

Acoustic wave analysis with piezoelectric coupling sensor can be used to measure the effect of bending angle toward the FPC by observing the changing in the resonance frequency. The piezoelectric actuator will start to vibrate and generate acoustic wave signal when an electrical signal is given while piezoelectric sensor will pick up the signal from an actuator. When two piezoelectric plates attach to the surface, any matter used as the medium will affect the acoustic wave signal. Therefore, the change in acoustic wave signal will cause the change in resonance frequency of matter. The changes of resonance frequency will give some useful information above the FPC.

Besides that, this project has a lot of potentials to go further for investigation where the FPC with piezoelectric technology which is useful in many industries such as field of automotive products and program can be used to solve the problem of maintenances, services, and safety in Malaysia. Based on Honda Company's sales figures in the year 2017, it is on track to achieve its sales target of 100000 units and to maintain its No. 1 position in the Non-National segment and No.2 in overall Total Industry Volume (TIV) this year [1]. This shows that FPC and it relevant system have a huge

market in the future. Therefore, this system can be considered as an economic system.

Next, this project is relevant to sustainability and environmentally friendly because the program used in this projects can be reprogrammed and modifying easily. In addition, this system also easy to install because Raspberry Pi is a small computer board that only needed the Operating System, library and programming language to operate it. Therefore, it can consider as a pro-long application. Besides that, using the microprocessor to detect the damaging of FPC is convenient and more effective for the user. This microprocessor also can link the data to monitoring center or cloud to help the user to monitor the condition of FPC and does not need to check the integrity of FPC one by one and always replace it. Thus, it can be said environmental friendly.

1.6 Thesis Outline

In this section, the overview of the thesis will be given. Chapter 1 is the introduction which consists of the general overview of the project. The problem statement also will be stated which explain the problem faced in the market now and project. Besides, the objective of this project is to provide the method of solving the problem and reason for doing this project. The scope of the project is discussing the hardware, software, and limitation of this project in order to prevent any misunderstanding about the project. Next, the project significant is to emphasize the benefits and future of doing this project.

The next chapter which named as literature review is to provide the details theory and information of acoustic wave, piezoelectric coupling device, and Raspberry Pi. In this chapter, the information about analysis signal processing also provided as well as the critical review of other researchers about the related technology. This part will allow people to briefly understand the newest technology and future trend of this project.

After study all the paper and resources, the methodology was started which is placed in the next chapter. In this chapter, the details procedure to complete this project is provided. There is a flowchart of overall progress which is set according to problems

that want to be solved. The procedures of this project include the characterizing output signal of piezoelectric coupling device on FPC, designing of circuit sensor, signal readout and verify results.

Chapter 4 is the results and discussion part of this project. All of the final results of this project will be provided in this section informal and simple way. The results will be used to justify the achievement of the objective of the project.

Lastly, the conclusions and recommendations were being covered in the last chapter of this project. In this chapter, the future work will be stated in it and the achievement of the objective also will be mention to prove the progress is successful or not.