HUMAN TRACKING SYSTEM WITH ENERGY HARVESTING FROM PIEZOELECTRIC MATERIAL

BY

LIM HONG JIAN

A REPORT

SUBMITTED TO

Universiti Tunku Abdul Rahman

in partial fulfillment of the requirements

for the degree of

BACHELOR OF INFORMATION TECHNOLOGY (HONS) COMPUTER ENGINEERING

Faculty of Information and Communication Technology

(Perak Campus)

MAY 2017

UNIVERSITI TUNKU ABDUL RAHMAN

FACULTY OF INFORMATION & COMMUNICATION TECHNOLOGY (PERAK CAMPUS)

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I declare that this report entitled "**HUMAN TACKING SYSTEM WITH ENERGY HARVESTING FROM PIEZOELECTRIC MATERIAL**" is my own work except as cited in the references. The report has not been accepted for any degree and is not being submitted concurrently in candidature for any degree or other award.

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ACKNOWLEDGEMENTS

I would like to express my sincere thanks and appreciation to my supervisors, Mr Lee Wai Kong who has given me this bright opportunity to engage in an Ambient Energy Harvesting project. It is my first step to establish a study in this field. A million thanks to you.

To my family, I would like to say thanks for their spiritual and material support. Thank you for always standing by my side since I started my degree programme.

Last but not least, thanks to my friends and schoolmate for helping and accompanying each other in my university life.

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Faculty of Information and Communication Technology (Perak Campus), UTAR

iii

ABSTRACT

Energy is important in our daily life especially in this era of information technology. As Internet of Things become more and more popular nowadays, the demand for wearable and portable devices significantly increase. For wearable and portable devices, energy storage and supply is always an issue, it is because the size and weight of wearable device is directly proportional to the energy sources. So, here come renewable energy technology, which can harvest renewable energy and apply it on electronic devices. There are some energy which is commonly harvested from human body, for example, vibrational energy, thermal energy and so on. Although we cannot harvest large amount of these energy, but we can use it to extends the life of device's battery.

The first part of this project focuses on harvesting energy by using piezoelectric material. Piezoelectric material used in this project is piezoelectric plate, it will be placed under shoe sole. When human apply pressure on the plate, electrical energy will be converted into DC and store into a battery. Therefore, whenever user walks or runs with the piezoelectric shoes, energy will be harvested and stored. The outcome of first part is to charge battery with piezoelectric material and make the battery last longer for any application.

Second part is to build a GPS tracker to track human position. This GPS tracker will be powered by a rechargeable battery which can also be charged by piezoelectric material. GPS tracker use microcontroller and module that will consume energy, so, power consumption of this project is one of the most important part. We need to make sure this device is low power consumption so that the piezoelectric battery circuit can support it for longer time.

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Faculty of Information and Communication Technology (Perak Campus), UTAR

iv

TABLE OF CONTENTS

Bachelor of Informan Technology (Hons) Computer Engineering
Faculty of Information and Communication Technology (Perak Campus), UTAR

v

Bachelor of Informan Technology (Hons) Computer Engineering
Faculty of Information and Communication Technology (Perak Campus), UTAR

vi

LIST OF FIGURES

Bachelor of Informan Technology (Hons) Computer Engineering
Faculty of Information and Communication Technology (Perak Campus), UTAR

Bachelor of Informan Technology (Hons) Computer Engineering
Faculty of Information and Communication Technology (Perak Campus), UTAR

viii

LIST OF TABLES

Bachelor of Informan Technology (Hons) Computer Engineering
Faculty of Information and Communication Technology (Perak Campus), UTAR

ix

LIST OF SYMBOLS

m   milli

μ   micro

Bachelor of Informan Technology (Hons) Computer Engineering
Faculty of Information and Communication Technology (Perak Campus), UTAR

x

LIST OF ABBREVIATION

mAh	Milliampere per Hour
AC	Alternating current
DC	Direct current
IoT	Internet of Things
SDLC	System Development Life Cycle
LED	Light-emitting diode
US	United States
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSM	Global System for Mobile
REST	Representational State Transfer
PHP	Personal Home Page
CSS	Cascading Style Sheet
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
API	Application Program Interface

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Faculty of Information and Communication Technology (Perak Campus), UTAR

xi

CHAPTER 1 INTRODUCTION

1.1 Problem statement and motivation

Nowadays, Internet of Things technology is growing fast, most objects become "smart" object even clothes, shoes and other wearable outfit. Peoples attached sensor and microcontroller on these outfit to allow them to collect data from surrounding and communicate to internet, this is also why we call them "smart". Most of the leading technology companies have already launched smart wearable gadgets, Google Glass and Apple Watch are the most popular examples of it. Talking about wearable and portable gadget, energy efficiency is always a challenge. Wearable gadget are usually expected to be reachable by others devices at most of the time, to satisfy this requirement, gadget consumes electrical energy even though it is not in use for its main function. Other than that, wearable devices have to be light and small, this limits its battery size. So, most of the wearable smart devices need to be recharged quite frequently. Even the latest generation Apple Watch, its battery only has 18 hours life time according to Apple's tests. Furthermore, there are devices like a pacemaker which is implanted in human body for medical purpose. These devices are implanted through surgery, so it is not possible to replace or recharge it frequently. Thus, a battery that can recharge by itself will definitely benefit to the user as it can prevent surgery to take out the device's battery.

All the cases above encounter the energy source problem, it will be better if there exists a solution to make battery last longer or even no need to be recharged. Hence, harvesting renewable energy is one of the possible solution.

1.2 Background

1.2.1 Ambient Energy Harvesting

Ambient energy harvesting is one of the method to reduce and solve the energy issues. It contains several methods to harvest and recycle ambient waste energy. Energy is everywhere, these energy can be heat, radio frequency waves, vibration and so on. They are waste energy which we can recycle and convert into electrical energy, we store it into energy storage and use whenever we need. Harvesting ambient energy on human body is one of the field of harvesting ambient energy, this field grow fast due to its

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1

importance to IoT technology. Piezoelectric energy harvester is one of the method harvest ambient energy.

1.2.2 Piezoelectric Sensor

To harvest ambient energy, sensor is a must. For example, solar panel harvest solar energy, antenna harvest wave energy and many more. The major technology involved in this project is also a sensor which is piezoelectric motion sensor. Piezoelectric plate is the sensor to collect and convert the energy, it is a sensor that based on piezoelectric effect. Piezoelectric sensor sense the changes of pressure, force, strain and converting them into electrical energy. In piezoelectric sensor, there is a crystal materials which usually is ceramic material. When the crystal is squeezed, the positive and negative charge balance will break down, and causing the electric charge flows, this is the piezoelectric effect. Besides that, this effect also appears reversely when squeezed crystal go back to its original shape. The sensor always produces alternating current output.

1.2.3 Energy Storage

The storage used to store energy is as important as the harvesting method. Normally, there are 3 types of storage devices is chosen for harvesting ambient energy project, which are capacitor, supercapacitor and battery.

The weakness of capacitor is its capacity, it only has very low capacity so it is not suitable to use in this project which is target to supply long term power. For super capacitor, it can store thousand times higher than a regular capacitor. Furthermore, it has fast charging speed compare to both capacitor and battery. However, discharging speed is a drawback of it, especially for the system of harvesting ambient energy. Energy harvesting in this project is implemented to endure the battery lifetime, so the discharging time factor is not suitable for this project. Li-ion battery is normally used for phone battery, pros of Li-ion battery is its storage capability and it has better leakage current compare to supercapacitor. The weakness of it is temperature sensitive and charging time, it has lower charging speed compare to supercapacitor. Considering the factors above, battery is the most suitable storage device to use in this project.

1.2.4 GPS Tracking System

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2

GPS tracking system is a very common technology nowadays, most people use it for car tracking. Other than that, some of the system is used to track animals for science research purpose and many more. GPS tracking system normally uses Global Navigation Satellite System (GNSS) network, this is a network created by the United States government by using plenty of satellite. GNSS is free to use with GPS receiver but US government can selectively block the access of certain system. The data to represent the position or location is longitude, latitude and time, by combining and calculate these data, we can get a real time position information and show it on world map.

1.3 Objectives

1.3.1 Build an energy harvester (using piezoelectric generator) and store the energy generated from body movement in battery.

This project is aimed to build a circuit that can harvest energy from human body, then use it to charge a battery, and make the battery lasts as long as possible. In order to make the battery last longer, we need to make the circuit harvest more energy.

First and foremost, we need to achieve is to build a piezoelectric generator which exactly generate energy. Then, we need to construct a circuit that can maximize the energy which is generated by piezoelectric generator and minimize the energy waste. Last but not least, we do experiment to collect data of how much energy generated.

1.3.2 Build a human tracking system using GPS module

After that, an application which is suitable to use the harvested energy will be implemented in advanced. The application we decided to build for the energy harvester is human tracking system. For this system, it need to receive location information of human and upload it to database. This system should be low power consumption so that it can effectively use the energy of energy harvester. To make it consume lower power, sleep mode, active mode and power of module need to be controlled nicely.

1.3.3 Integrate the energy harvester and human tracking system, then evaluate the energy efficiency of entire system

Last but not least, energy efficiency of the system and energy harvester have to be integrated. For part 1, energy harvester should harvest as much energy as possible and part 2 should consume the least energy.

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3

1.4 Proposed approach/study
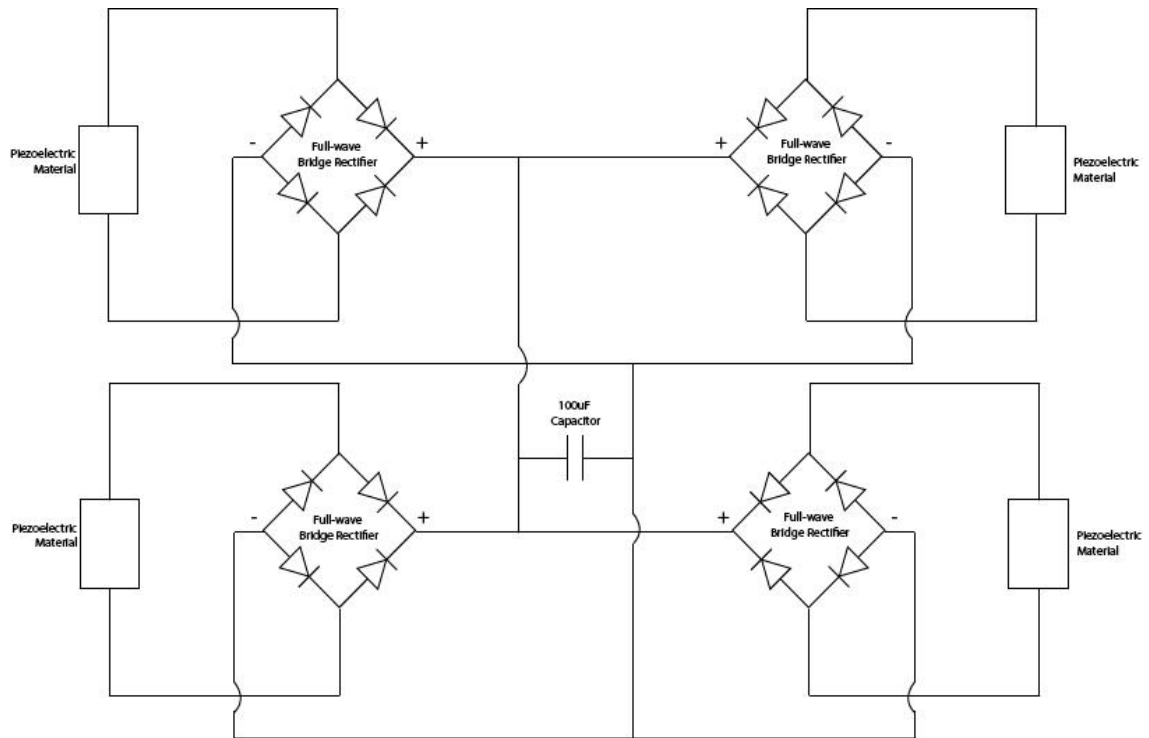
1.4.1 Energy Harvester Design

figure 1.4.1 Energy Harvester circuit

To build an efficient footstep energy harvester, multiple piezoelectric material will be connected parallel to increase current output. Full wave bridge rectifier is needed to convert AC to DC current because piezoelectric material generate AC current but battery only consume DC current. For each piezoelectric material, a bridge rectifier is a must to prevent current back flow to other piezoelectric material. Therefore, this project will use 4 piezoelectric material with 4 full wave bridge rectifier. Lastly, the whole parallel circuit will be connected to a 100uF capacitor, this capacitor do its role to protect battery. Piezoelectric material can generate high voltage which can harm battery, in the case of this project, the piezoelectric material used can generate up to 8V however the battery only can afford maximum 4.2V. Capacitor will first charged up to the voltage of battery then discharged electrical energy to battery. The completed circuit design is showed in *figure 1.4.1.*

1.4.2 GPS Tracking System Design

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4

There are some requirement for the GPS tracking system. Firstly, it can collect location data (longitude and latitude). Secondly, it should upload data into online database. Lastly, the system need a user interface for user to observe the data.

For the first requirement, GPS module can be used to get location data. When it get data, a microcontroller is a must to manage those data. At here, Arduino Pro Mini was used to control the whole system due to its low power consumption. Then, the system has to upload data to online database, this step need internet access. This project planned to access internet through GPRS, although GPRS is slow but it is definitely enough to upload small longitude and latitude data set. GSM module and SIM card with internet access package was used to run GPRS service. User interface will be designed by using simple Html, Css and Javascript. A map API will probably be used to show location.

1.4.3 Energy Efficiency Improvement

To improve efficiency of the system, energy harvester has to harvest more energy. Piezoelectric circuit connection will be experimented to achieve higher current output. It will be experimented with connecting serial and parallel.

On the other hand, GPS tracking system has to be low power consumption. The system's program will be written with power sleep mode the decrease power consumption. GPS and GSM module should sleep while they are idle.

Finally, power consumption of tracking system and current output of energy harvester will be measured and calculated to understand the efficiency.

1.5 Achievement

At the end of the project, piezoelectric footstep energy harvester has been implemented and improved. It is proved that the energy is able to be used to power or charge the load. Other than that, Human Tracking System has been designed and attached to energy harvester circuit. A MySQL database with HTTP Request service was successful created and hosted on an online free web hosting server named Hostinger. HTTP Request service was written by using PHP, data of the service is transfer in the form of JSON format. The tracking system is able to capture longitude and latitude of user and upload it to database through GPRS service. Lastly, a simple website with a map was

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5

designed to visualised location data, the website is designed by using Html, Javascript, Css and Google Map API.

1.6 Report organization

The report is organized as below. Chapter 1 above had described the motivation and project background of this project. In Chapter 2 is some literature review of related project, good and bad of the related work were study to improve the project. Chapter 3 contains the system design of project, details of the system flow, implementation and material used is written there. Chapter 4 is about the design specification, we discuss about the requirement and methodology of the system design. Besides that, chapter 5 conducted experiment and calculation to get the efficiency of energy harvesting. Last but not least, chapter 6 conclude the project.

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6

CHAPTER 2 LITERATURE REVIEW

2.1 Review of previous work

2.1.1 Vibrational Energy

There are various kind of methods in harvesting vibrational energy from human body, for example, electromagnetic, electrostatic and piezoelectric generator.

Works presented by Jo, S.E. & Kim, M.S. and Kim, Y.J. (2012) proposed an energy harvester that harvests energy from human movement by using magnetic spring. S.E. Jo et al use a coil and a magnet to create an electromagnetic transducer. Electromagnetic transducer generate electricity through the relative motion (z) of the coil and magnet (emf). The relationship between them is stated below.

$$emf = K\frac{dz}{dt}$$

Normally, vibrational energy from this harvesters can generate few mill watts (Jo, S.E. & Kim, M.S. & Kim, Y.J. , 2012)

Method	Energy storage density (mJ/cm^3)
Electromagnetic	24.8
Electrostatic	4
Piezoelectric	35.4

table 2.1.1 Energy storage density comparison (Livingston, J.J & Hemalatha, M, 2014)

Refer to research paper of J. John Livingston and M.Hemalatha (2014, pp. 945-948), Table II.1 shows that piezoelectric method has highest energy storage density. This is the reason why piezoelectric method is chosen in this project. In addition, piezoelectric generator is affordable and it gives good efficiency. Weakness of piezoelectric generator is it cannot transfer energy wirelessly.

2.1.2 Piezoelectric Harvesting in Airport Terminals

At some busy place full with people walking around, for example, airport terminal. There are a lot of motion energy that we can capture through piezoelectric technology. In order to harvest those walking energy, piezoelectric devices is installed underneath the floor of terminal. Different from the shoe sole project, this project install hundred

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6

or even thousands of piezoelectric sensor, everyday there will have thousands of foot print step on the sensor. The electrical energy from piezoelectric devices will be sent back to the power grid through inverters, then, it need convert the DC power into AC power which can support the lighting systems. The harvested energy is planned to support the power of lighting systems of airports.

2.1.3 Energy Floor

figure 2.1.3 Energy Floor (Anon., 2016)

In Rotterdam of Netherland, there is a club named Club Watt, they applied piezoelectric technology to build Energy Floor for their flooring system. Energy Floor convert kinetic energy into electricity from the dancer in the club, the energy harvested from the flooring system is used to light up their LED lighting system. It also claims that LEDs embedded in the floor are entirely sustained by around 20 watt generated by each person (Christopher.s, Jeffrey.I and et al, 2009). Besides that, Club Watt is also the first sustainable dance club in the world.

2.1.4 GPS SmartSole

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7

figure 2.1.4 GPS SmartSole (Anon., 2010)

GPS SmartSole is an actual product which is developed by GTX Corp, GTX Corp is a company famous for their wearable smart device. GPS SmartSole is a wearable technology with GPS tracking function. It uses cellular data to update location information of GTX Corp Monitoring System. This system allows user access to view the position of SmartSole with online account or mobile application. The battery life time of this device is 18 to 48 hours and it takes 2 to 4 hours to fully charge the SmartSole.

GPS SmartSole is quite similar to this project application which is also a shoe sole GPS tracker. But this project targeted to build a GPS tracker which will use some harvested energy through piezoelectric material, and this will allow the battery to have a longer life time.

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8

2.2 Highlight and compare proposed study with previous work

In the literature review above, *section 2.1.4* mentioned about an actual product of GPS Smart Sole. This is a similar product we want to achieve at the end of the project. It shrinks everything perfectly in a shoes sole which is impressive. All of the function of the Smart Sole is pretty similar to what this project needed. But, the weakness of the product is its power life time, it only supports for 18 to 48 hours of and need to be recharged quite frequently. To solve the problem, ambient energy harvester is a good solution. Since it is a shoe sole, harvest motion energy of foot step is pretty suitable.

In *section 2.1.1*, 3 types of human body motion energy harvesting method were studied. The 3 methods are electromagnetic, electrostatic and piezoelectric. By comparing the result of the study, piezoelectric method harvest the highest amount of energy. Although the harvested energy has to be transfer through wire, but it does not matter because the ideal product will be placed under shoe sole. Therefore, piezoelectric harvesting method is chosen in this project. With piezoelectric energy harvester, battery life time will be extended.
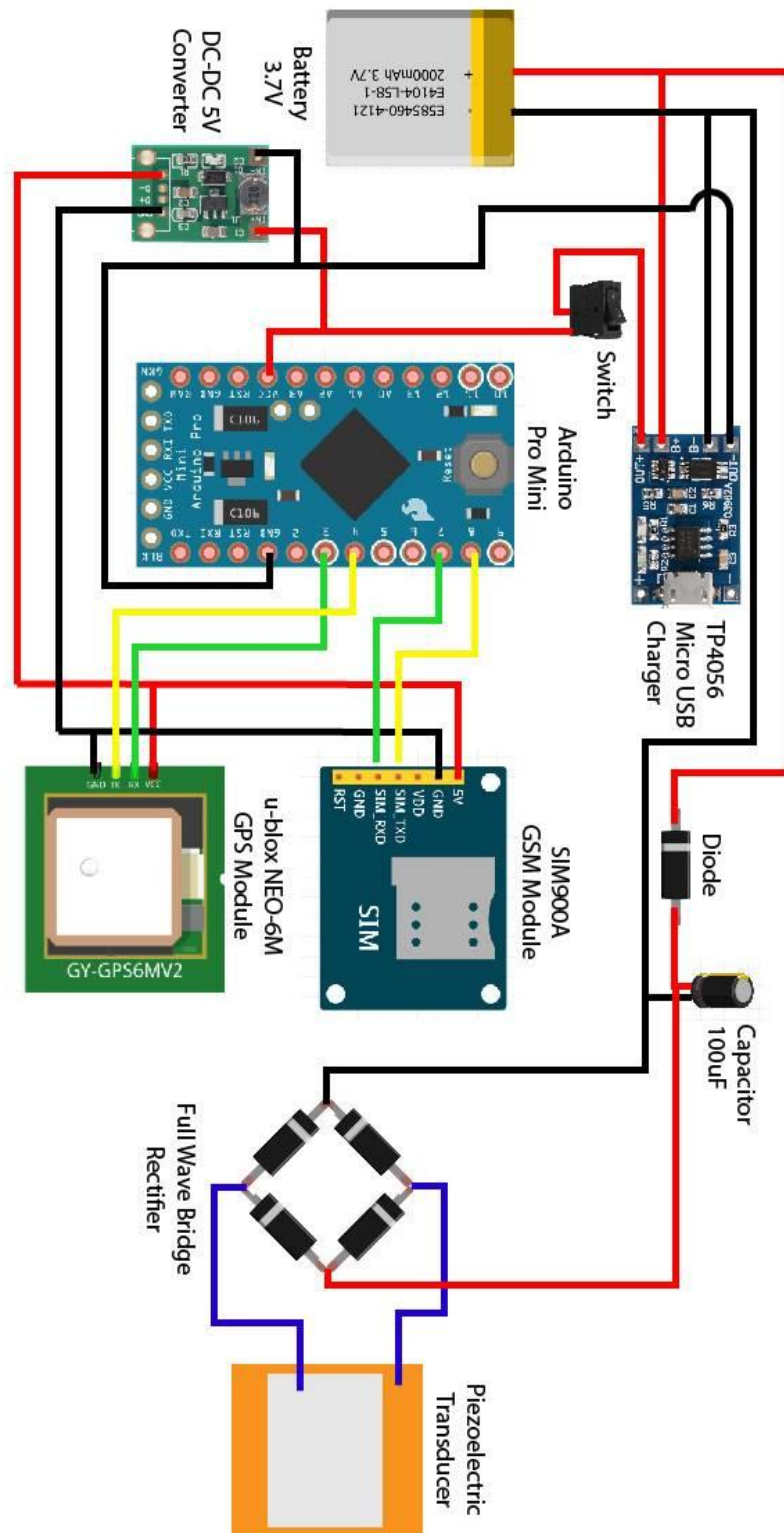
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9

CHAPTER 3 SYSTEM DESIGN

figure 3-1 System Design

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10

As we can see from above, *figure 3-1* showed the whole system design. The project's components and connection are exactly same as the figure.

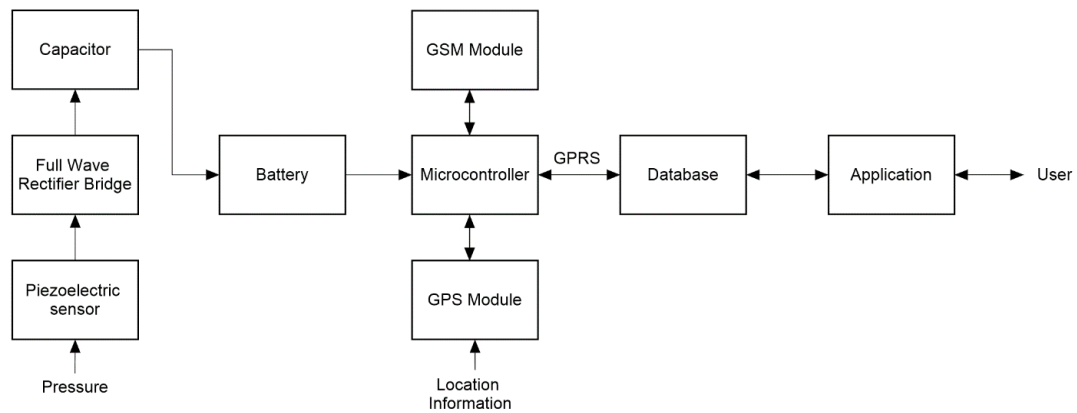*figure 3-2 System Design Flow*

On the other hand, the flow of the system is basically like *figure 3-2*. The left hand side is the energy harvester and the right hand side is the GPS tracking system.

For left hand side, battery is supported by piezoelectric harvester circuit, so it recharges whenever pressure is apply on piezoelectric sensor. The circuit needs a rectifier bridge to efficiently convert energy from AC to DC. Capacitor in circuit is responsible to limit the voltage and make the ripple output of piezoelectric material to become stable before it is used to charge battery.

At right hand side, battery supply power for microcontroller and microcontroller control the running of whole GPS tracking system. GPS module is needed to receive location data and GSM module provide GPRS for microcontroller to transmit data. Location data will be transmit to database, whenever user need the data, they can access it through an application or directly get it from database.

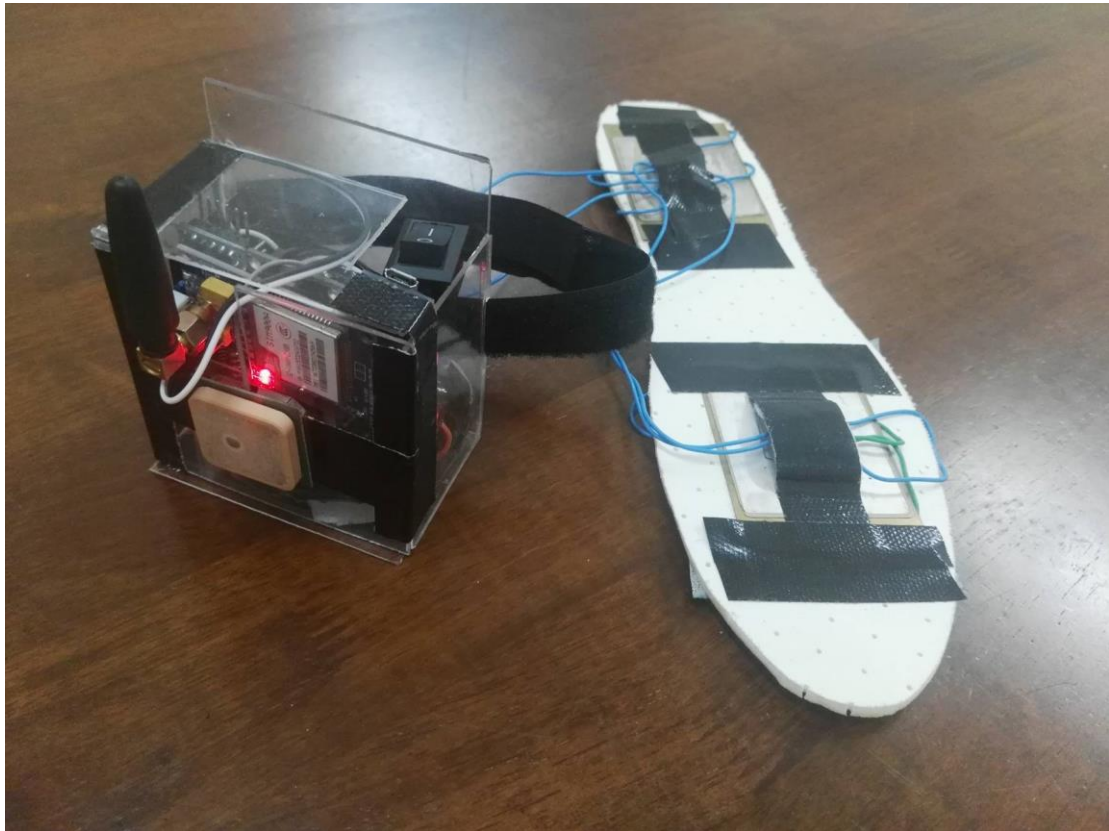The prototype of the whole system is showed in *figure 3-3* below.

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11

figure 3-3 Human Tracking System with Piezoelectric Energy Harvester Prototype
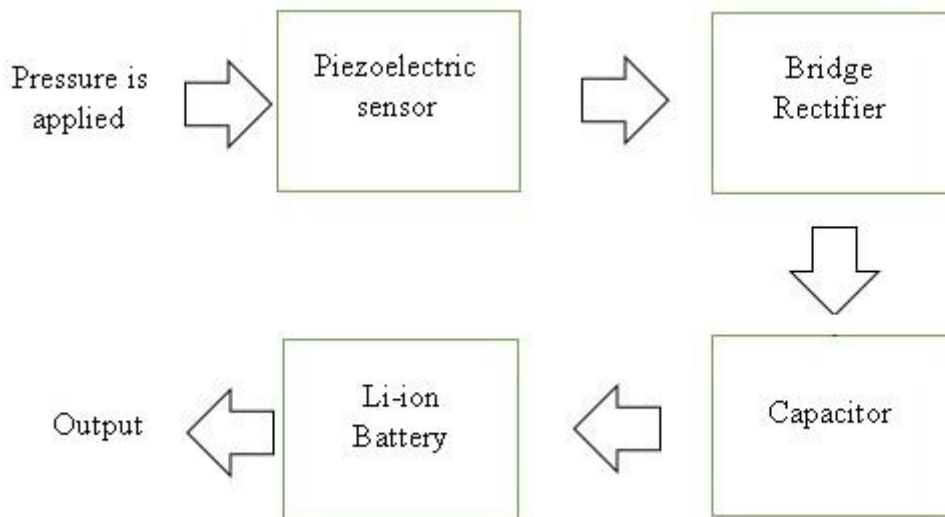
3.1 Piezoelectric Energy Generator

figure 3.1-1 Piezoelectric Energy Generator Flow

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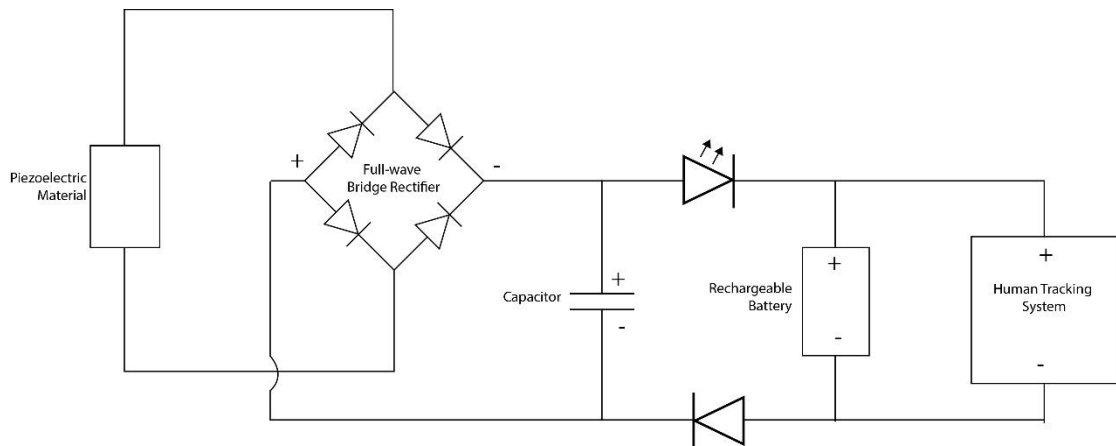Faculty of Information and Communication Technology (Perak Campus), UTAR

12

figure 3.1-2 Piezoelectric Harvester Circuit

For the very first part of this project, piezoelectric sensor received force and pressure from body motion, then it converts the force into electrical energy. Following figure 3.1-2, piezoelectric sensor connect to full wave bridge rectifier.

Then, the next part is full wave bridge rectifier which is built by 4 diodes. We need bridge rectifier because piezoelectric sensor will only generate AC but we need DC to store energy into battery. Electric charge in AC change direction periodically, so the voltage is also periodically reversed.
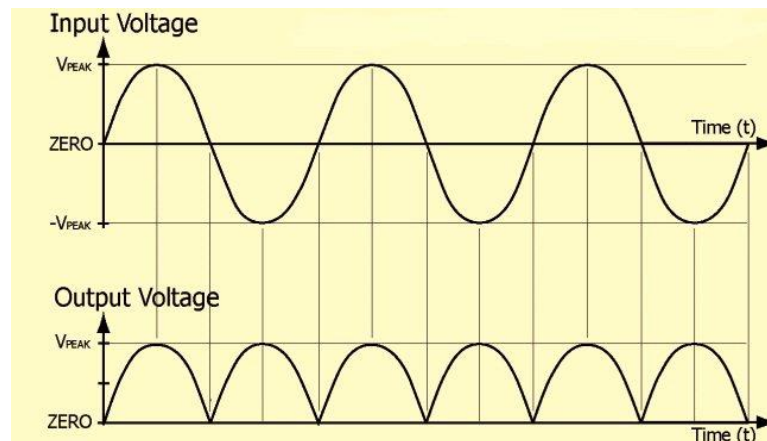
figure 3.1-3 AC to DC

By using bridge rectifier, AC is converted to DC just like figure 3.1-3. As we can see, although it is DC but it is still ripple DC.

So, we need a capacitor filter to solve the ripple DC problem. The ripple DC will first store in capacitor, after that, capacitor only output straight DC to load which is rechargeable battery. Finally, we can connect load which is the battery parallel to the

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Faculty of Information and Communication Technology (Perak Campus), UTAR

capacitor. For the threshold voltage of capacitor to output current, it depends on the voltage of load and battery. At here, threshold voltage without LED in the circuit is 4.2V assume 3.7V battery is fully charged.

Other than that, diode is put between battery and capacitor to prevent battery backward charging capacitor. Capacitor discharge fast, so it might drain battery energy if there is no diode. LED in the circuit is to indicate whether the harvester reach threshold voltage and start charging battery or power device. If the LED light up, it means there is current flow through load, else, the harvester is just charging capacitor till it reach threshold voltage.

Consider piezoelectric material and bridge rectifier as 1 unit of harvester, 4 unit of harvester were connected parallel in this project. To harvest more energy, current has to be as high as possible, this is why piezoelectric harvesters were stacked parallel but not serial, connecting them serial only boost the voltage.
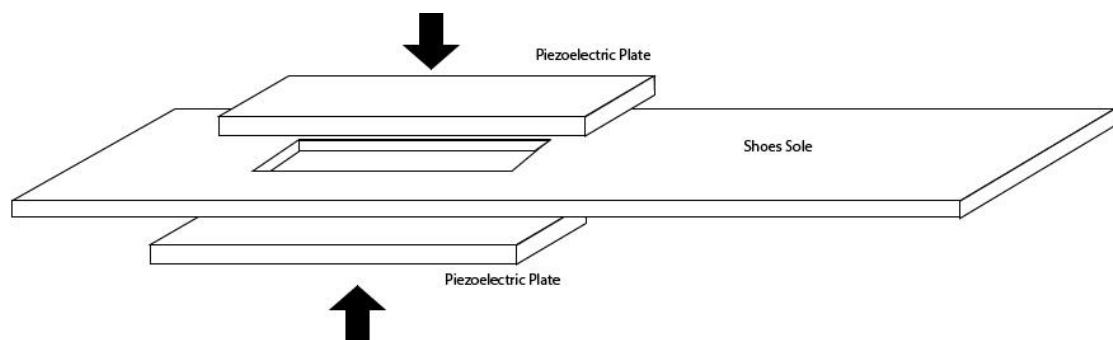

figure 3.1-4 Stacking Piezoelectric Plate

To minimize the size of energy harvester circuit, piezoelectric plate were stack as *figure 3.1-4*. Whenever pressure is applied on the shoe sole, foot will press the upper piezoelectric plate and the reaction force will press the bottom piezoelectric plate. Stack number of piezoelectric material can still be increased but in this project only 2 pieces of piezoelectric plates will be stacked together. The prototype of the shoe sole harvester is showed below in *figure 3.1-5*.
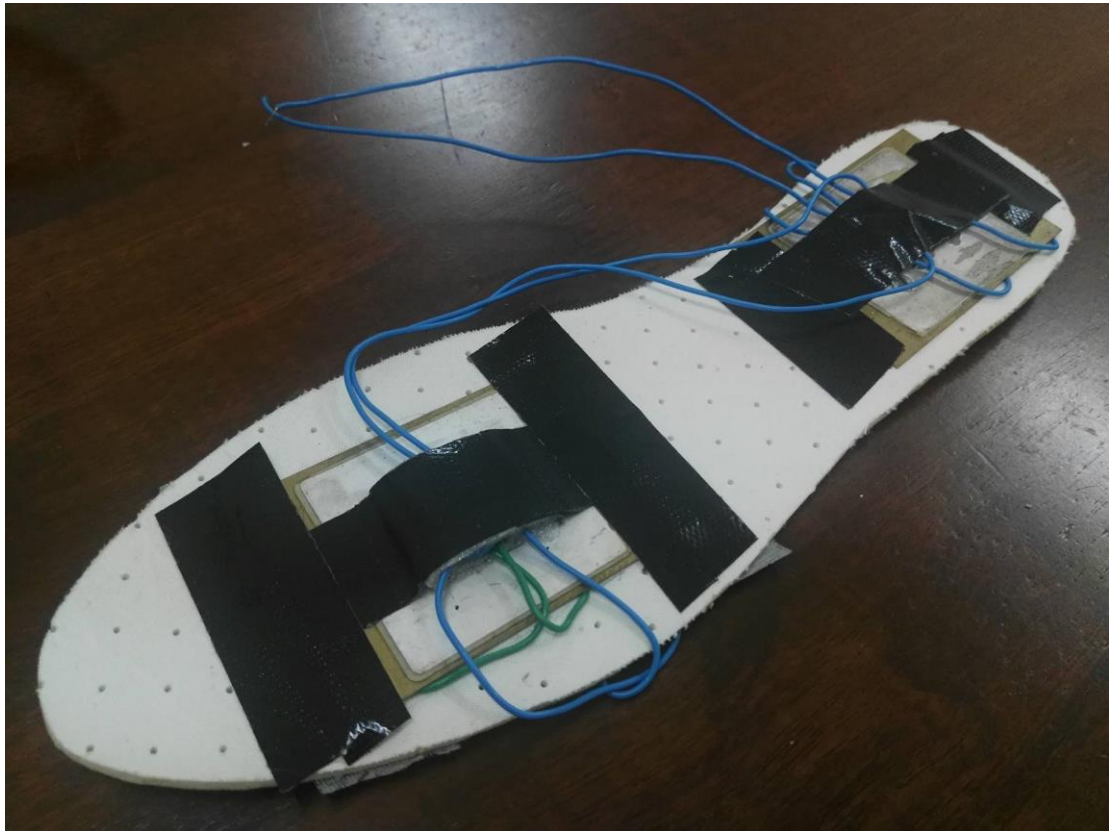
Bachelor of Informan Technology (Hons) Computer Engineering
Faculty of Information and Communication Technology (Perak Campus), UTAR

14

figure 3.1-5 Shoe Sole Piezoelectric Energy Harvester Prototype
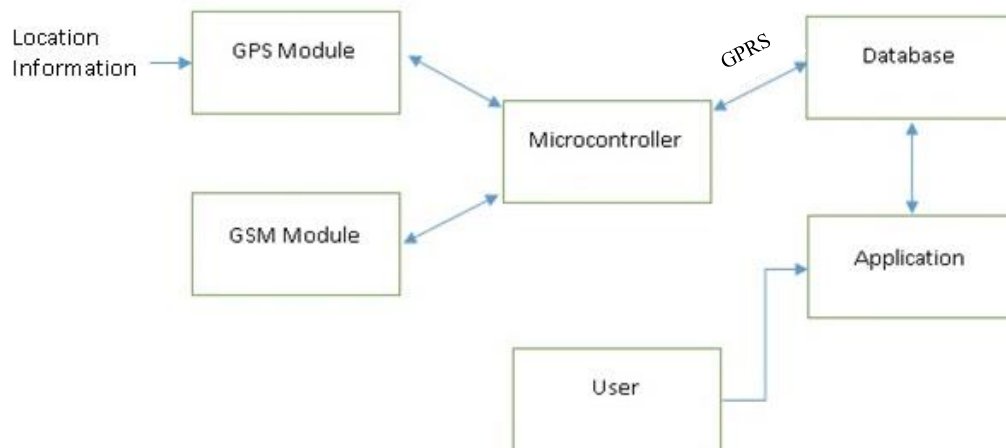
3.2 GPS Tracking System

figure 3.2-1 GPS Tracking System Flow

The data flow of Human GPS Tracker will be same as the diagram shows above. At the very beginning, microcontroller will turn on the GPS module and asks GPS to receive location data. After the data was transferred back to microcontroller, data will be

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15

forwarded to database. However, microcontroller itself does not have features to communicate with internet, so this is also why we need GSM module. GSM module with SIM card provide GPRS service to microcontroller to transmit data to database. Lastly, user who wish to know the location can check for the data through an application connected to database or straightly through database. Prototype of GPS tracking system is showed below in *figure 3.2-2*.
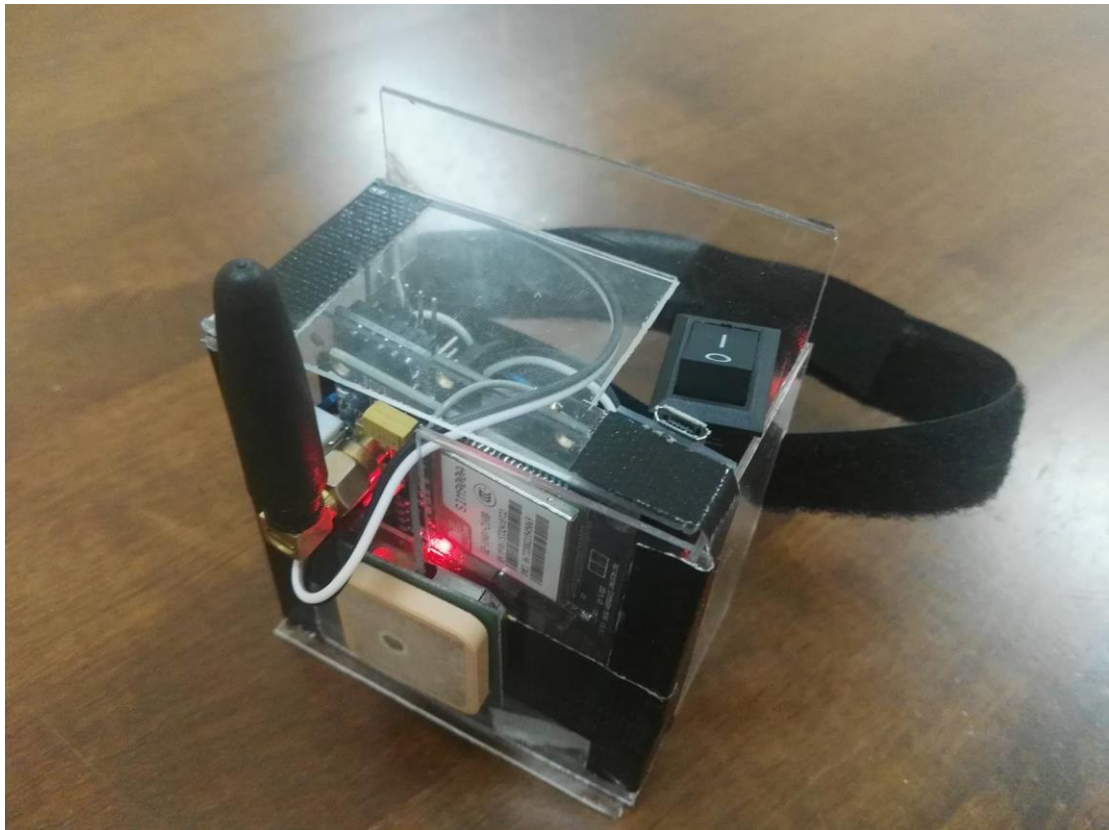

figure 3.2-2 GPS Tracking System Prototype

3.2.1 Arduino Pro Mini Microcontroller

To program microcontroller Arduino Pro Mini, USB to UART TTL Converter is needed because Arduino Pro Mini does not come with USB port for programming.
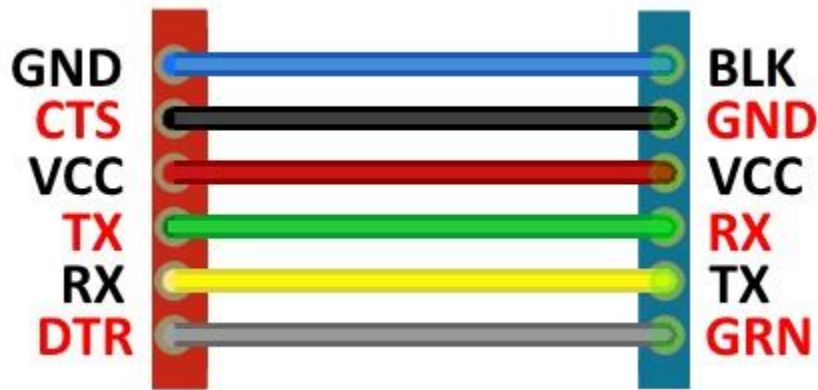
figure 3.2.1 Arduino Pro Mini with UC00B USB to UART Serial Converter Connection

After that, Arduino IDE is needed to upload sketch into Arduino through UC00B, it can be downloaded free on Arduino official website. For the computer which use UC00B for the first time, UC00B driver needed to be installed manually. Driver of UC00B can be found on Cytron website and it is free to download (Anon., 2007). Serial Monitor of Arduino IDE had been used to debug and observe serial data transfer between microcontroller, GSM and GPS module. Correct baud rate have to be set to observe serial data, GSM module uses 19200 baud rate, GPS module uses 9600 baud rate. Arduino's baud rate need to be the same as different module to observe serial data. For example, when communicate with GPS module, Arduino baud rate has to be set to 9600, communicate with GSM module, baud rate need to be 19200.

The microcontroller's sketch of this project can be found on *Appendices A*. In the sketch, setup() function run first and once only when the system started. setup() function set Serial communication baud rate of GPS, GSM module and Arduino itself. Besides that, setup() also run wdt_setup() to configure watchdog timer. After setup(), loop() function loop continuously until the system power down. loop() function use while loop to read GPS module serial data. While GPS module data is available with longitude and latitude, displayInfo() will be run to display and store GPS data. If more than 10 GPS location data were received, avgLocation() function is used to calculate average of the 10 location. Then, postData() is run to upload data to database server by using GSM module.

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17

The system is designed with power down sleep mode which can decrease power consumption of microcontroller. Some built in Arduino library are used to configure sleep mode, those library are avr/sleep.h, avr/power.h and avr/wdt.h. Firstly, wdt_setup() is used to configure watchdog timer, watchdog timer is an independent timer, it runs by itself when microcontroller enter power down mode. So it is used to wake up microcontroller from power down mode. The watchdog timer set in the sketch is 8 seconds. enterSleep() function here is to make the microcontroller enter sleep mode, after watchdog timer counted 8 seconds, microcontroller will be triggered to wake up from sleep mode. Watchdog timer can only be triggered maximum 8 seconds, to implement sleep mode more than 8 seconds, for loop is used to enter sleep mode for multiple time. Without sleep mode, Arduino Pro Mini consume 12mA. In power down mode, Arduino consume only 5mA.

3.2.2 GPS Module

GPS module has to communicate with Arduino by using serial data transfer. 2 digital pins of Arduino were set up as serial communication pin by using SoftwareSerial.h library. Pin D4 was set as RX and D3 as TX. The connection can be found in *figure 3-1.*

In the sketch of microcontroller, TinyGPS++.h library was used to decode GPS data. TinyGPS++.h is an open sources library which contain function to read and extract data from u-blox NEO 6M GPS module. Whenever serial data come from GPS module can be encoded by TinyGPS++ library encode() function, location(), time() and date() function were used to obtain data.

3.2.3 Web Hosting Server

This project need to be able to access online, it needs a web hosting server to host the database and website. There are many free web hosting server available online, the server used in this project is hostinger.in. Although free web hosting account provided has limited function, but it is enough for this simple project.

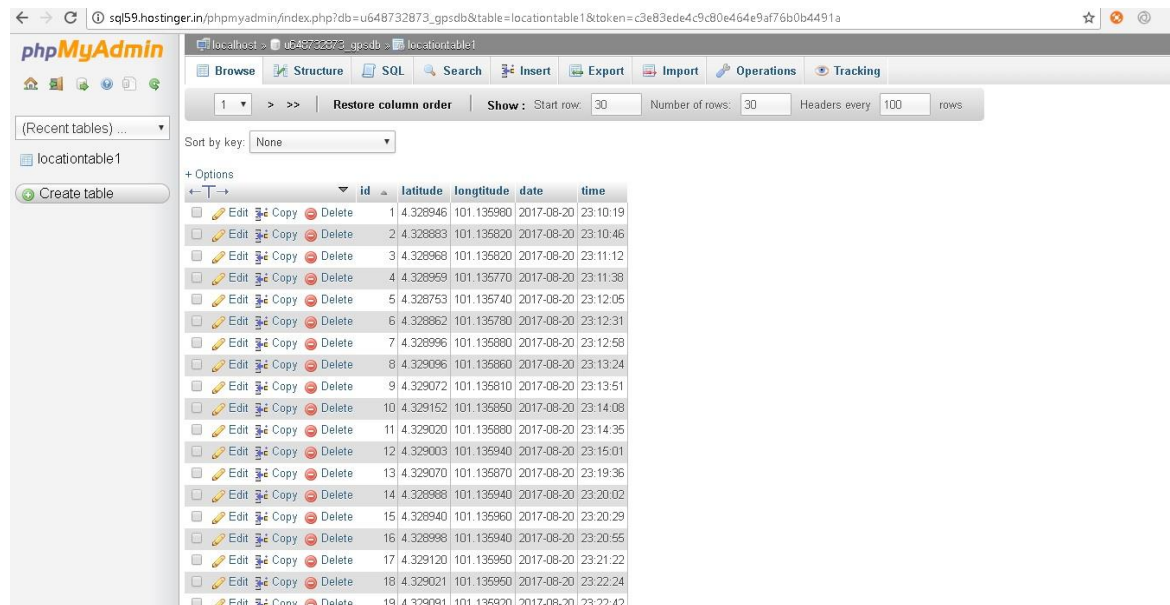Here is the URL link: https://www.hostinger.in/free-web-hosting. (Anon., 2004)

Free account can be registered at the link above.

3.2.4 Database

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Database in the project is written by using MySQL. REST Http service is implemented by using PHP language. To manage the database easier, Hostinger server allowed user to use MyPhpAdmin to create and modify database.

Only 1 database table is needed in this project. The table contains attributes of longitude, latitude, time and date.

figure 3.2.4 Database Sample Results

To insert data into database, RESTful service is written in PHP language. PHP code can be found in *Appendices B.* Firstly, the service has to connect to database by using mysqli_connect() with appropriate username, password and so on. If Http GET services is called, it will detect if it is to upload or query data. All of the data are passed in format of JSON. Function delivery_response() is used to return service feedback, it is used to detect if the RESTful service is performed without problem.

3.2.5 GSM Module

First of all, GSM module need SIM card with internet service provider service. Then, it can only access GPRS service. Program to perform Http GET service can be found in *Appendices A*. GSM module SIM900A used AT command to perform task like phone calling, sms and also web service. Hence, microcontroller will send AT command by serial communication to GSM module to perform Http GET and insert data to database. Since, it receives data by using serial communication, Arduino need 2 digital pins as

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19

well to transfer data. In this project, Arduino's digital pin 8 is used as TX and digital pin 7 as RX.
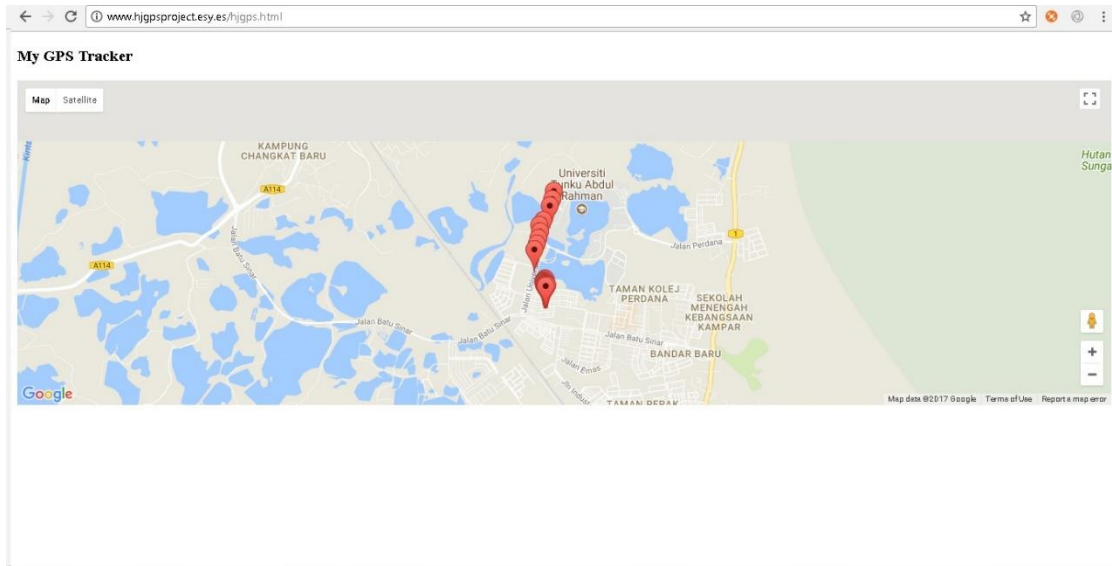
3.2.6 Website Design

figure 3.2.6 Website Sample Result

Figure 3.2.6 shows the sample result of the GPS tracking system. The code of website design is put in *Appendices C*. The development of website design involved of javascript, css and html. Other than that, Google Map API is used to visualize location data. Google map API is free to use with limited function, it can show location on Google map by using longitude and latitude data.

To use Google map API, developer has to register a Google account and enable Google Map Javascript API service on their API website. API key is a must to run Google API, it can be obtained while the user enable certain Google API services. Below is the URL of Google API: https://console.developers.google.com/apis/dashboard (Anon., 1998)

At the beginning of the website javascript program, the website perform XMLHttpRequest() to obtain data from database which include longitude, latitude, time and date. Once the data is get in the format of JSON, it is passed into JSON.parse() function to make it become an object. JSON format is just a set of string which javascript cannot understand, it only can be used when it is an object. Lastly, initMap() function is run with parameter of location data object to request API service.

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20

CHAPTER 4 DESIGN SPECIFICATION

4.1 Methodology

System development life cycle (SDLC) describe the stages of development project. The life cycle defines a methodology for improving the quality of overall development process. By using SDLC model, project can be implemented efficiently and smoothly. Various SDLC model have been developed to help the processes of developing system, for example, waterfall model, spiral model, prototyping model and so on. In this project Prototyping model is used.
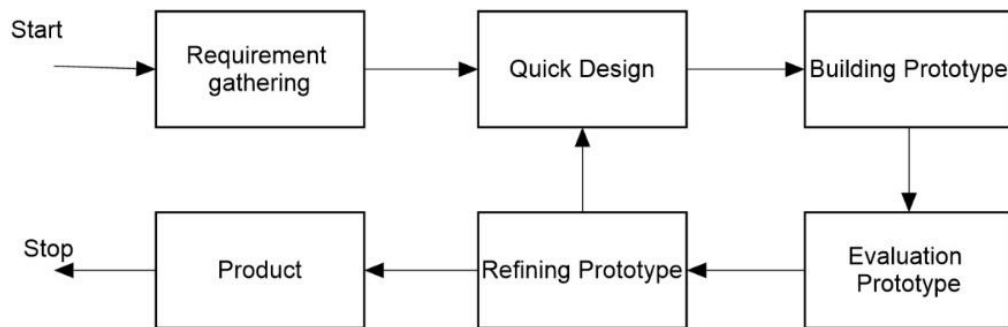

figure 4.1.1 Prototyping Model

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21
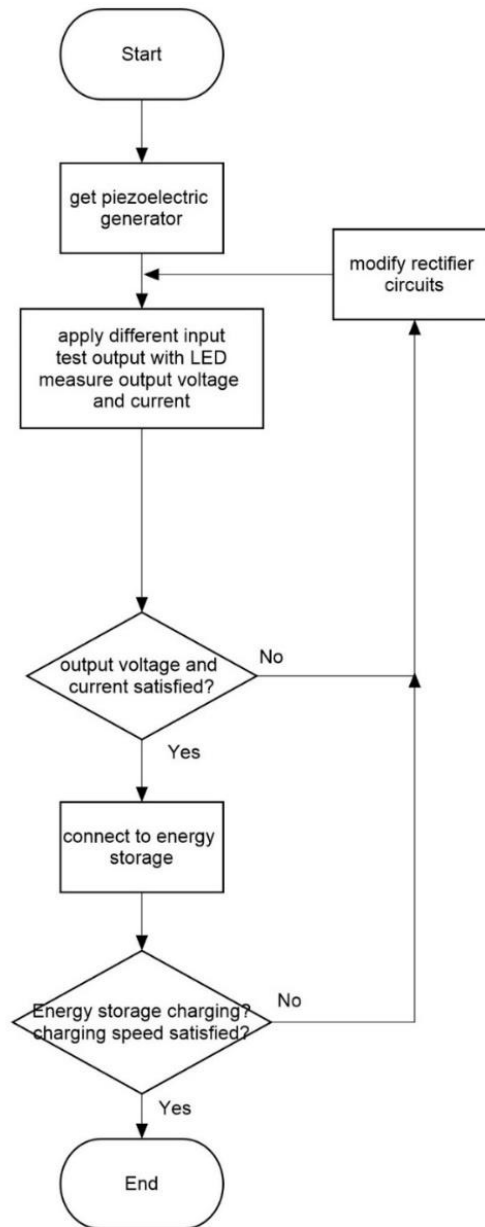
figure 4.1.2 Design Flow

Prototyping model build a prototype and evaluate it, if the result is not satisfied, then we will modify it and repeat this cycle until the final product is complete. This model is helpful at scenario when some of the requirements for product is still unknown, then the researcher need to do trial and make the product better.

4.2 Tools

4.2.1 Piezoelectric Sensor

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22

figure 4.2.1 Piezoelectric Sensor
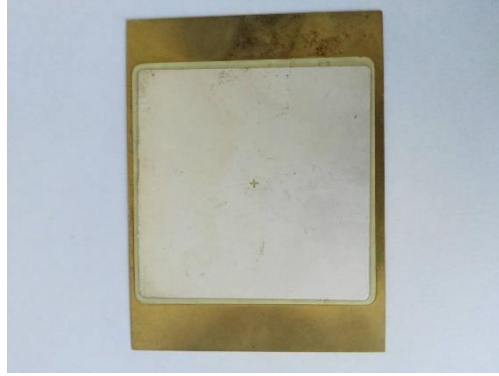
Piezoelectric sensor is not a new technology nowadays, we can buy it easily through internet with a cheap price. There are few shapes of piezoelectric sensor, for example, disc, plate, film and so on. The piezoelectric sensor we used here is in shape of plate.

4.2.2 Diode

figure 4.2.2-1 Diode
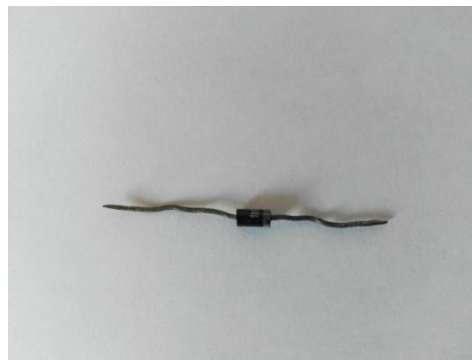
The function of a diode is to limit the direction of current flow, current will only pass through diode when the direction is correct, or else it will be blocked. Diode used in this project is IN4002.
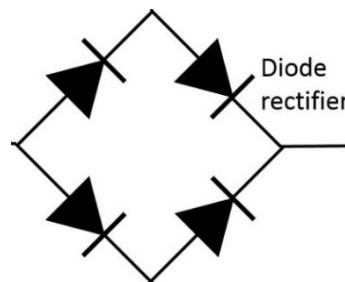

figure 4.2.2-2 Full Wave Bridge Rectifier

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23

For this project, diode is used to build a full wave bridge rectifier, which has a function to convert AC into DC, the output voltage will also be higher and steady.
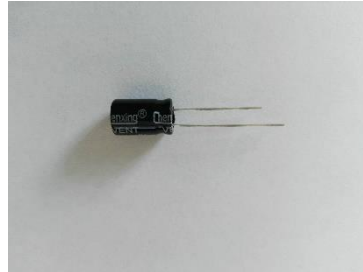
4.2.3 Capacitor

figure 4.2.3 Capacitor

Capacitor can store electrical energy. In this circuit, capacitor acts as temporary energy storage and voltage filter to smooth the spike voltage of piezoelectric sensor. It filters and controls the voltage output to load to prevent spike voltage destroy battery or devices. Capacitor here does not need to have large capacity, we use 100 µF capacitor to build the circuit.

4.2.4 Rechargeable Li-ion Battery

figure 4.2.4 18650 Li-ion Battery 2600mAh

Rechargeable Li-ion battery acts as main energy storage, which is also load in the circuit. This battery has capacity of 2600 mAh and outputs 3.7 V of voltage. There are 2 pin wires for positive and negative pole, connect method of the battery is exactly same as normal battery. The voltage of battery is not enough to power GSM and GPS module, hence, voltage step up converter is a must in this project.

4.2.5 Multimeter

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24

figure 4.2.5 Multimeter

Multimeter is a tool which has function to measure current, resistance and voltage. This project has a lot of electric circuit, so this tool is extremely important.

4.2.6 Arduino Pro Mini 5V 16MHz
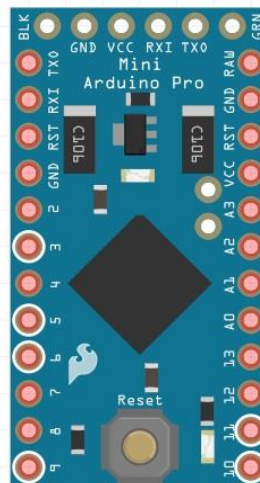
figure 4.2.6 Arduino Pro Mini 5V/3.3V 16/8MHz

In order to build a GPS tracker that can communicate with database, microcontroller is a must. Microcontroller will be powered by piezoelectric harvesting battery in this project. Microcontroller controls the GPS module and GSM module to perform GPS data logging. Besides that, microcontroller supposed to have 2 modes, active mode and sleep mode to lower the power consumption of the system. Power consumption of 5V Arduino Pro Mini is 20mA in active mode, 5mA in power down mode. When the microcontroller enters power down mode, most of the function is disabled. Hence, it can only be woke up by using watchdog timer.

4.2.7 U-blox NEO 6M GPS Module

figure 4.2.7 U-blox NEO 6M GPS Module

GPS module is needed to collect location data such as longitude and latitude. GPS module supposed to be powered off by microcontroller when it is not used. The data received through GPS tracker will be forwarded to database by using GSM module through GPRS. The module used in the project need at least 5V of power supply, it communicates through digital pin serially with 9600 baudrate. The module come with voltage regulator, voltage more than 5V is acceptable but not exceed 7.4V. Power consumption of the GPS module is around 60mA.

4.2.8 SIM900A GSM Module

figure 4.2.8 SIM900A GSM Module

To transmit data online to database server, we need GSM module which provides GPRS service by using SIM card's cellular data. Same as GPS module, this module supposes to power off when it is not used to save energy. The module used in the project need 5V of power supply and it communicates through digital serial pin with 19200 baudrate. Power consumption of the module is around 50-60mA.

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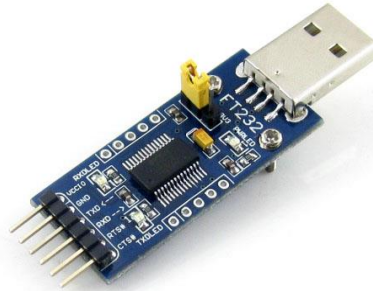
26

4.2.9 UC00B USB to UART Converter

figure 4.2.9 UC00B USB to UART Converter

Arduino Pro Mini does not come with USB port. To upload sketch into Arduino Pro Mini, UC00B is a must. It also allows device to perform serial communication with calculator, serial monitor makes debug of program easier and more convenient. Other than that, calculator normally will not install UC00B driver automatically, so user must install the driver manually before using the converter. Driver of UC00B can be downloaded from www.cytron.com.

4.2.10 DC-DC 5V Voltage Step Up Converter
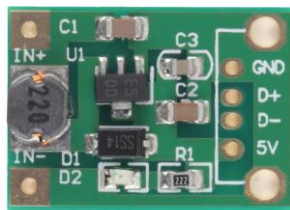
figure 4.2.10 DC-DC 5V Voltage Step Up Converter

As the project is using 3.7V battery, voltage step up converter is needed if we want to power 5V GPS and GSM module. The converter used in the project can step up minimum 1V to 5V. It is better if we can use 5V power supply directly because this is a low power project, voltage step up converter waste quite lot of energy.

4.2.11 TP4056 Micro USB 5V 1A Battery Charger

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27

figure 4.2.11 TP4056 Micro USB 5v 1A Battery Charger

TP4056 battery charger is a very popular component to DIY power bank. TP4056 absorb current from micro USB port and maintain the current supply to become 1A. It is important to provide correct current ampere to battery as high current can easily burn a bare battery without any protection. Besides that, the charger also solder with led indicator, to detect whether the charger is charging something. B plus and minus port is connected to battery directly, OUT plus and 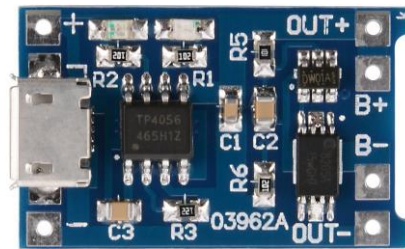minus is used to supply battery power to load. The battery charger cannot be charged and drained at the same time, it might destroy itself. Although this is an energy harvesting project, but the harvested energy is insufficient for the load. So, battery have to be charged in a certain period.

4.2.12 Arduino IDE

Arduino IDE is used to program Arduino microcontroller, the language used is C/C++. This software is an open source IDE which is powered by Arduino. There are a lot of open source function that can be found in Arduino library, those function make programming easier.

4.2.13 MySQL Database

In this project, a database server was designed to support the GPS tracking system. It is responsible to store some simple data like longitude, latitude, time and date. The data will then be shown on an application to user. Database in the project is built by using MySQL, PHP language is used to write the API to communicate with the database server. PHPMyAdmin is used to manage the database.

4.2.14 Google Map API

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28

API stands for Application Programming Interface. Google provide free API service of their Google Map with limited usage. GPS tracking system of this project need an interface to display the location data to user, hence, Google Map API is used. In the website of the project, longitude and latitude are visualized in Google map for easy observation.

4.2.15 Hostinger Web Hosting Server

Hostinger is a Web Hosting provider, they provide free and charged web hosting service. In this project, device has to log data to database, so it is a must to host a database server online. Although Hostinger free web hosting service has very limited function, but it is enough for the simple database of this project. URL of the website used in this project is www. hostinger.in.

4.3 Requirement

4.3.1 Arduino Pro Mini 5V 16MHz

Microcontroller	ATmega329
RAW pin power supply	5 - 12V
VCC pin power supply	5V
Operating voltage	5V
Clock speed	16MHz

table 4.3.1 Requirement of Arduino Pro Mini

4.3.2 SIM900A GSM Module

Module	SIM900A
Operating voltage	5V
Current consumption	60 – 120mA
Operating condition	Outdoor – Strong, Indoor - Weak
Communication protocol	UART
Baud rate	19200bps

table 4.3.2 Requirement of GSM Module

4.3.3 u-blox NEO 6M GPS Module

Module	NEO 6M

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Faculty of Information and Communication Technology (Perak Campus), UTAR

Operating voltage	3.3 – 5V
Current consumption	60mA
Operating condition	Outdoor
Communication protocol	UART
Baud rate	9600bps

table 4.3.3 Requirement of GPS Module

4.3.4 Battery

Voltage	3.7 – 5V

table 4.3.4 Requirement of Battery

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30

CHAPTER 5 IMPLEMENTATION AND TESTING

5.1 Experiment and calculation

Some experiments were conducted to ensure the result of this project. Firstly, because of energy harvesting is the major part of this project, energy harvesting amount is one of the most important factor. We need to understand the energy harvested value then we can only modify the harvesting circuit to make it better. On the other hands, power consumption of GPS tracking system is important as well. As mentioned in Chapter 1, objective of this project is to build a GPS tracking system which can be powered for a long period of time. Therefore, the lower the power consumed by GPS tracking system, the longer time it can sustain.

5.1.1 Calculate harvested energy output
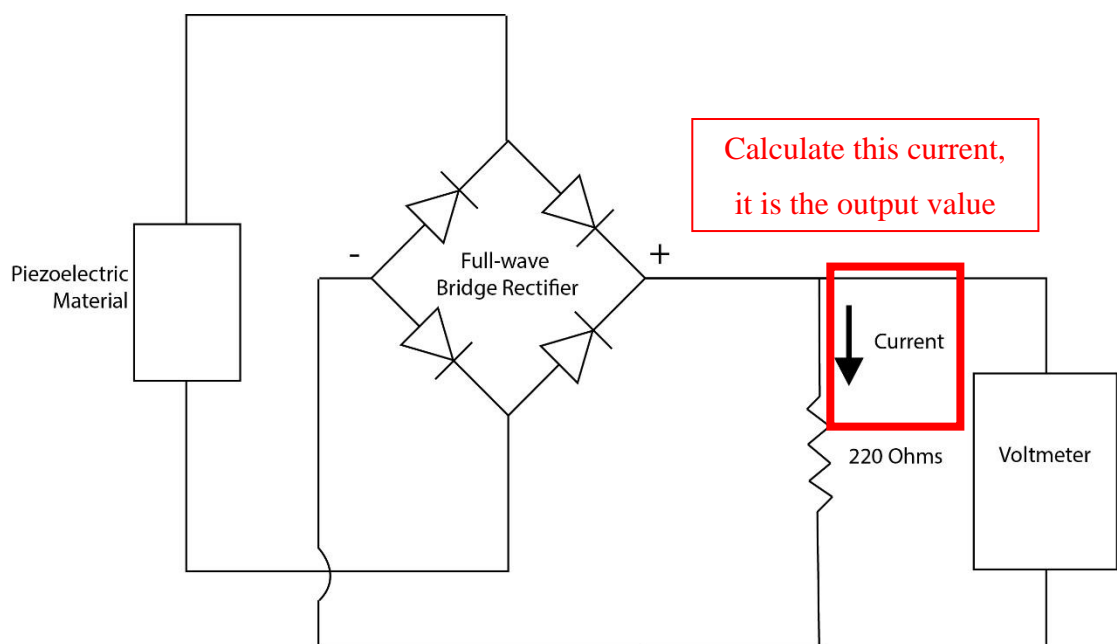
figure 5.1.1-1 Measurement of Harvesting Energy

For piezoelectric energy harvester, we cannot directly measure the current by using a multimeter or amp meter. It is because piezoelectric material produce short burst current which is too fast that the multimeter cannot capture. So, to measure and calculate how much energy it can be harvested through the piezoelectric harvesting circuit, the circuit design in *figure 5.1.1* was set up. Short burst current of piezoelectric material is too

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31

difficult to measure, so we have to get the current through calculation. Instead of current, voltage of resistor was measured in the circuit above.

Maximum voltage = 70~80mV (2 piezoelectric material stack),

Average voltage = 75mV,

Multiply by two stacks, front foot and back heel,

Total voltage = 150mV/step,

Apply Ohm's Law,
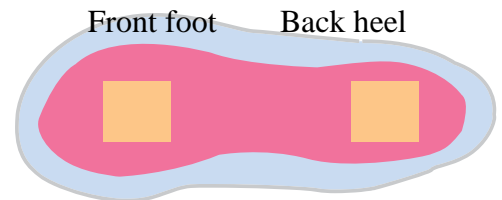
figure 5.1.1-2 Shoe Sole Piezoelectric Energy Harvester

$$I = \frac{V}{R}$$

$$I = \frac{150mV}{220 Ohm}$$

$I = 0.682mA$/step

As a result, each step of walking can roughly produce 0.682mA of current. Piezoelectric material produce more energy when more pressure is applied. Therefore, running will produce more energy compare to walking.

5.1.2 Verifying current flows into battery/load

figure 5.1.2 Proving of Current Flowing Direction

After measured and calculated the output of energy harvester, this experiment is conducted to prove that the current is flowing into load or battery. The experiment is

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32

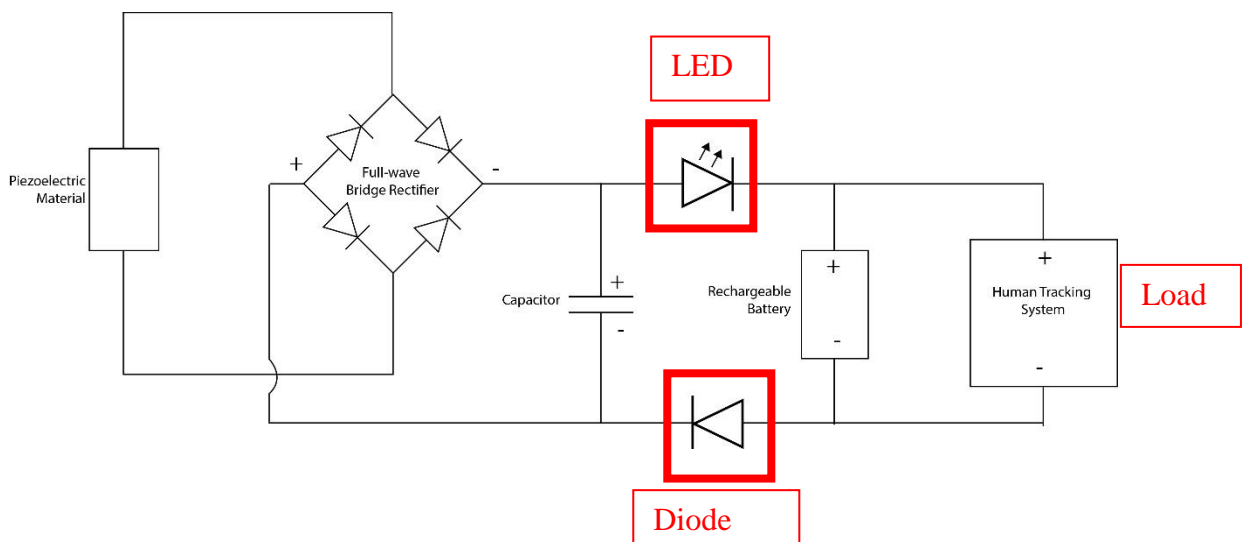necessary because electrical current is not visible to human eyes, we cannot make sure the direction of current flowing is right into load or battery. Circuit of *figure 5.1.2* was connected. Diode is used to prevent battery back flowing recharge capacitor, LED is the indicator of current flowing. At the very beginning when capacitor is empty, applying pressure on piezoelectric material will only charge up the capacitor. Then, after capacitor reach the threshold voltage which is 3.7V of battery.

5.2 Power Efficiency of Arduino GPS Tracking System

	Active	Sleep
Arduino Pro Mini 5V 16MHz(Vcc Pin)	12mA	5mA
SIM900A GSM Module	60mA~120mA	-
u-blox NEO 6M GPS Module	60mA~70mA	-

table 5.2 Power Consumption of GPS Tracking System

For the GPS tracking system, it consume around 150mA to 200mA. The result is directly measure by using digital multimeter. Although the sleep mode of Arduino microcontroller can be controlled by software successfully, but it only save around 7mA from the whole system.

The system supposed to use npn transistor as a switch for GSM and GPS module which can be software controlled by Arduino digital pin. However, due to unknown reason GSM and GPS module become unstable while they are connected with transistor. So, the average power consumption of GPS tracking system is around 150mA.

Energy harvested from 1 step $\approx$ 0.682mA

Energy consumption of GPS tracking system $\approx$ 150mA

Efficiency of Energy Harvester $= \frac{0.682mA}{150mA} \times 100\%$

$$= 0.455\%$$

As a conclusion, Shoe sole energy harvester of GPS tracking system extends the battery life by 0.455%.

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33

5.3 GPS Accuracy

To calculate accuracy of GPS module, a set of data in *figure 5.3* were captured. Red colour highlight shows the largest value and blue colour highlight shows the lowest value.

index	latitude	longitude	date	time
1	**4.328771**	**101.136220**	2017-08-25	23:11:31
2	4.328928	101.136120	2017-08-25	23:11:49
3	4.328931	101.136050	2017-08-25	23:12:06
4	4.328899	101.135940	2017-08-25	23:12:23
5	4.329005	101.135870	2017-08-25	23:12:40
6	**4.329366**	101.136090	2017-08-25	23:16:12
7	4.329082	101.135860	2017-08-25	23:17:18
8	4.329000	101.135860	2017-08-25	23:18:36
9	4.329019	**101.135850**	2017-08-25	23:18:54
10	4.328971	101.135860	2017-08-25	23:19:19
11	4.328982	101.135900	2017-08-25	23:19:36
12	4.329162	101.135870	2017-08-25	23:20:58

figure 5.3-1 GPS Sample Data

decimal places	degrees	distance
0	1.0	111km
1	0.1	11.1km
2	0.01	1.11km
3	0.001	111m
4	0.0001	11.1m
5	0.00001	1.11m
6	0.000001	0.111m
7	0.0000001	1.11cm

figure 5.3-2 Decimal Degrees Distance

Figure above shows the relationship between distance and longitude and latitude. By using ruler of *figure 5.3-2* and value of *figure 5.3-1,* accuracy of GPS module can be calculated.

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34

For Latitude:

maximum latitude – minimum latitude = 4.329366 – 4.328771 x 111km

$$= 0.000595 \text{ x } 111\text{km}$$

$$= 0.066\text{km}$$

$$= 66\text{m}$$

For Longitude:

maximum longitude – minimum longitude = 101.136220 – 101.135850 x 111km

$$= 0.00037 \text{ x } 111\text{km}$$

$$= 0.037\text{km}$$

$$= 37\text{m}$$

From the experiment above, the accuracy of GPS module is around a few tens of meter.

5.4 Data Updating Period

According to the datasheet of u-blox NEO 6M, it has a cold starting time of 27s. So, When the GPS module first power up, it takes around 27s to receive first location data. However, it is also affected by signal strength, if the signal of the system position is weak, it may take longer time to search for the signal.

Besides of GPS signal, GSM signal is also important to update database data. GSM module for this project can search signal faster compare to GPS module. Even in indoor condition, GSM module can search for signal with around 10s of starting time. It is largely depends on the SIM card service provider's signal. In this project, Maxis SIM card was used and the signal is good in Kampar. To perform Http GET request by using GSM module, the request takes around 2s to upload the data. However, if the signal is weak, it may take longer or even fail to do Http GET.

CHAPTER 6 CONCLUSION

6.1 Project Review, Discussion and Conclusion

There are a few reason why renewable and ambient energy harvesting is so important and fast trending. First and foremost, Global warming and climate changes are the greatest threat to earth nowadays, make good use of renewable energy will slow down this serious issue. Renewable and ambient energy are all environmentally friendly, it will not cause pollution like non-renewable energy sources such as petroleum, coal and many more. Other than that, limitation of portable energy storage is a pullback for wearable devices. The ambient energy harvesting technology is one of the solution for the energy storage problem, it can extends life time of battery or even removed battery from the wearable devices.

In this project, piezoelectric energy harvesting method is not that hard to implement and all the materials to build the circuit is low cost. The challenge part of this project is the improvement. We only need piezoelectric sensor, diodes and capacitor to build the circuit, but it is hard to maximize the current output. From the calculation result in *Chapter 5* the energy harvested is not that much and the efficiency is considered low. However, it still can extend battery life time or power up low power devices. To apply it in a formal application, the circuit design need to be improved in order to maximize the energy that we can harvest. Furthermore, the size of the GPS tracking system need to shrink down to make it suit into the sole of a shoe. Especially for the size and weight of the GPS tracking system in this project, it is too large for an actual product.

6.2 Future Work

For the future work, there are some improvement can be done. Firstly, piezoelectric material can be stacked with more pieces to increase the energy output. Besides that, a lot of diode were used in the harvester circuit, diode will cause power loss. Hence, diode with higher efficiency can improve the amount of energy harvesting. In addition, microcontroller and modules used in this project are all for development purpose. So, there are a lot of unwanted load which will consume power, for example, voltage regulator. Self-implemented circuit board with necessary component for GSM, GPS and microcontroller will definitely decrease a lot of power consumption and the size of device. For the selection of battery, prevent using lower or higher voltage that the system wanted because voltage regulator or converter cause energy loss too.

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36

In a nutshell, this project technology is possible and worth to develop due to the factors stated above.

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37

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38

APPENDICES A ARDUINO SKETCH

```
#include<TinyGPS++.h>

#include <SoftwareSerial.h>

#include <avr/sleep.h>

#include <avr/power.h>

#include <avr/wdt.h>


volatile char response[200];

volatile int dataCount=0;

volatile double lng_a[20];

volatile double lat_a[20];

volatile double lng_avg;

volatile double lat_avg;


String time_a;

String date_a;

volatile int day_flag = 0;

volatile int hr;

String hr_s;

volatile int mn;

String mn_s;

volatile int sc;

String sc_s;


volatile int dy;

volatile int mo;

volatile int yr;

int count = 1;

static const uint32_t GPSBaud = 9600;

int gpsCtrl = 10;

int gsmCtrl = 9;
```

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Faculty of Information and Communication Technology (Perak Campus), UTAR

39

```
// The TinyGPS++ object
TinyGPSPlus gps;


// The serial connection to the GPS device
SoftwareSerial ss(4, 3);
SoftwareSerial gsmSerial(8, 7);


ISR(WDT_vect)
{
  Serial.begin(9600);
  gsmSerial.begin(19200);
  ss.begin(GPSBaud);
  Serial.println(F("Wake up"));
  delay(1);
}


void enterSleep(void)
{
  for(int i=0; i<count; i++){
  Serial.println(F("Sleep"));
  delay(100);
  Serial.end();
  ss.end();
  gsmSerial.end();
  set_sleep_mode(SLEEP_MODE_PWR_DOWN);      /* EDIT: could also use
SLEEP_MODE_PWR_DOWN for lowest power consumption. */
  sleep_enable();
  /* Now enter sleep mode. */
  sleep_mode();
  /* The program will continue from here after the WDT timeout*/
  sleep_disable(); /* First thing to do is disable sleep. */
  /* Re-enable the peripherals. */
  power_all_enable();
```

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Faculty of Information and Communication Technology (Perak Campus), UTAR

40

```
  }
}


void wdt_setup(){
 /*** Setup the WDT ***/
 /* Clear the reset flag. */
 MCUSR &= ~(1<<WDRF);
 /* In order to change WDE or the prescaler, we need to
  * set WDCE (This will allow updates for 4 clock cycles).
  */
 WDTCSR |= (1<<WDCE) | (1<<WDE);
 /* set new watchdog timeout prescaler value */
 WDTCSR = 1<<WDP3 | 1<<WDP0; /* 8.0 seconds */
 /* Enable the WD interrupt (note no reset). */
 WDTCSR |= _BV(WDIE);
}


void setup()
{
 Serial.begin(9600);
 ss.begin(GPSBaud);
 gsmSerial.begin(19200);
 pinMode(gpsCtrl, OUTPUT);
 digitalWrite(gpsCtrl, HIGH);
 pinMode(gsmCtrl, OUTPUT);
 digitalWrite(gsmCtrl, LOW);


 Serial.println(F("GPS Project"));
 Serial.println();
 wdt_setup();
}


void loop()
```

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Faculty of Information and Communication Technology (Perak Campus), UTAR

41

```
{
  while (ss.available() > 0){
    if (gps.encode(ss.read())){
      displayInfo();
      delay(1);
      if(gps.location.isValid())
        dataCount++;
    }
  }
  if(dataCount > 10){
    avgLocation();
    postData();
    dataCount = 0;
    enterSleep();
  }
  if (millis() > 5000 && gps.charsProcessed() < 10)
  {
    //Serial.println(F("No GPS detected: check wiring."));
    //while(true);
  }
}

void avgLocation()
{
  double lng_total = 0;
  double lat_total = 0;
  for(int i=0; i<dataCount; i++){
    lng_total += lng_a[i];
    lat_total += lat_a[i];
  }
  lng_avg = lng_total/dataCount;
  lat_avg = lat_total/dataCount;
  Serial.print(F("Location: "));
```

Bachelor of Informan Technology (Hons) Computer Engineering
Faculty of Information and Communication Technology (Perak Campus), UTAR

```
  Serial.print(lat_avg, 6);
  Serial.print(F(","));
  Serial.println(lng_avg, 6);
 }


 void displayInfo()
 {
  Serial.print(F("Location: "));
  if (gps.location.isValid())
  {
   lng_a[dataCount] = gps.location.lng();
   lat_a[dataCount] = gps.location.lat();
   Serial.print(lat_a[dataCount], 6);
   Serial.print(F(","));
   Serial.print(lng_a[dataCount], 6);
  }
  else
  {
   Serial.print(F("INVALID"));
  }
  Serial.print(F(" "));
  if (gps.time.isValid())
  {
   hr = gps.time.hour() + 8;
   if(hr >= 24){
     hr -= 24;
     day_flag = 1;
   }
   else{
     day_flag = 0;
   }
   if(hr < 10){
     hr_s = "0" + String(hr);
```

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Faculty of Information and Communication Technology (Perak Campus), UTAR

43

```
    }
    else{
      hr_s = String(hr);
    }
    mn = gps.time.minute();
    if(mn < 10){
      mn_s = "0" + String(mn);
    }
    else{
      mn_s = String(mn);
    }
    sc = gps.time.second();
    if(sc < 10){
      sc_s = "0" + String(sc);
    }
    else{
      sc_s = String(sc);
    }
    time_a = hr_s + ":" + mn_s + ":" + sc_s;
    Serial.print(F("  Time/Date: "));
    Serial.print(time_a + " ");
  }
  else
  {
    Serial.print(F("INVALID"));
  }

  Serial.print(F(" "));
  if (gps.date.isValid())
  {
    dy = gps.date.day();
    if(day_flag == 1){
      dy += 1;
```

```
    if(dy > 31){
      dy -= 31;
      }
    }
  mo = gps.date.month();
  if(day_flag == 1&&dy>31){
    mo += 1;
    if(mo > 12){
      mo -= 12;
      }
    }
  yr = gps.date.year();
  date_a = String(yr) + "-" + String(mo) + "-" + String(dy);
  Serial.print(date_a);
  //Serial.print(gps.date.month());
  //Serial.print(F("/"));
  //Serial.print(gps.date.day());
  //Serial.print(F("/"));
  //Serial.print(gps.date.year());
 }
 else
 {
  Serial.print(F("INVALID"));
 }
 Serial.println();
}


void toSerial()
{
 int i=0;
 //memset(response, 0, sizeof(response));
 while(gsmSerial.available())
 {
```

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45

```
    response[i] = gsmSerial.read();

    Serial.write(response[i]);

    //Serial.print(response[i]);

    i++;

  }

}


void postData(){

  gsmSerial.println("AT+IPR=19200");    // Tell the SIM900 not to autobaud

  delay(100);

  toSerial();

  gsmSerial.println("AT+SAPBR=3,1,\"Contype\",\"GPRS\"");

  delay(100);

  toSerial();

  gsmSerial.println("AT+SAPBR=3,1,\"APN\",\"www\"");

  delay(100);

  toSerial();

  gsmSerial.println("AT+SAPBR=1,1");

  delay(100);

  toSerial();

  gsmSerial.println("AT+SAPBR=2,1");

  delay(100);

  toSerial();

  gsmSerial.println("AT+HTTPINIT");

  delay(100);

  toSerial();

  gsmSerial.println("AT+HTTPPARA=\"CID\",1");

  delay(100);

  toSerial();


 gsmSerial.print("AT+HTTPPARA=\"URL\",\"http://hjgpsproject.esy.es/locationdat

 a.php?longtitude=");

  gsmSerial.print(String(lng_avg, 6));
```

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46

```
  gsmSerial.print("&latitude=");
  gsmSerial.print(String(lat_avg,6));
  gsmSerial.print("&date=");
  gsmSerial.print(date_a);
  gsmSerial.print("&time=");
  gsmSerial.print(time_a);
  gsmSerial.println("\"");
  delay(100);
  toSerial();
  gsmSerial.println("AT+HTTPACTION=0");
  delay(2000);
  toSerial();
}
```

APPENDICES B RESTful SERVICE PHP CODE

```php
<?php
	header("Content-Type: application/json");


	$localhost = 'mysql.hostinger.in';

	$user = 'u648732873_hjian';

	$pass = 'casio0329';

	$db = 'u648732873_gpsdb';

	$table = 'locationtable1';


	$con = mysqli_connect($localhost, $user, $pass, $db) or die('Unable to
connect.');


	if($_SERVER['REQUEST_METHOD'] === 'GET'){
		$id = $_GET['id'];
		$longtitude = $_GET['longtitude'];
		$latitude = $_GET['latitude'];
		$date = $_GET['date'];
		$time = $_GET['time'];


	if(!empty($longtitude)&&!empty($latitude)&&!empty($time)&&!empty($d
ate)){
			$sql = mysqli_query($con, "INSERT INTO
locationtable1(longtitude, latitude, date, time) VALUES ('$longtitude', '$latitude',
'$date', '$time')");
			if($sql){
				deliver_response(200, "success",
[$longtitude,$latitude]);
			}else{
				deliver_response(200, "fail", NULL);
			}
		}
```

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48

Appendices B: Database PHP code

```php
        elseif(empty($longtitude)&&empty($latitude)&&empty($time)&&!empty($date)){
                $query = mysqli_query($con, "SELECT * FROM
`locationtable1` WHERE `date`='$date'") or die(mysqli_error($con));
                $results = array();
                while($line = mysqli_fetch_array($query,
MYSQL_ASSOC)){
                        $results[] = $line;
                }
                if($query){
                        deliver_response(200, "id found", $results);

                }else{
                        deliver_response(200, "id not found", NULL);
                }
    }
      }

      function deliver_response($status, $status_message, $data)
      {
                header("HTTP/1.1 $status $status_message");

                $response['status'] = $status;
                $response['status_message'] = $status_message;
                $response['data'] = $data;

                $json_response = json_encode($response);
                echo $json_response;
      }
?>
```

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49

APPENDICES C WEBSITE DESIGN CODE

```
<!DOCTYPE html>
<html>
  <head>
    <style>
      #map {
       height: 400px;
       width: 100%;
      }
    </style>
  </head>
  <body>
    <h3>My GPS Tracker</h3>
    <div id="map"></div>
    <script>
              var xhr = new XMLHttpRequest();
              xhr.open('GET', "https://cors-
anywhere.herokuapp.com/http://hjgpsproject.esy.es/locationdata.php?date=2017-
08-25", true);
              xhr.send();
              xhr.onreadystatechange = processRequest;
              function processRequest(e) {
                      if(xhr.readyState == 4 && xhr.status == 200) {
                              var response = JSON.parse(xhr.responseText);
                              initMap(response);
                      }
              }
              function initMap(response) {
              //alert(parseFloat(response.data[2].latitude));
      var center = {lat: parseFloat(response.data[0].latitude), lng:
 parseFloat(response.data[0].longtitude)};
      var map = new google.maps.Map(document.getElementById('map'), {
```

```
      zoom: 14,
      center: center
    });
                var locations = new Array();


                for(i=0; i<response.data.length; i++){
                        locations[i] = {lat: null, lng:null, time: null, date: null};
                        locations[i].lat = parseFloat(response.data[i].latitude);
                        locations[i].lng = parseFloat(response.data[i].longtitude);
                        locations[i].time = response.data[i].time;
                        locations[i].date = response.data[i].time;
                }
                var infowindow = new google.maps.InfoWindow();
                var marker, i;
                for (i = 0; i < locations.length; i++) {
                 marker = new google.maps.Marker({
                        position: new google.maps.LatLng(locations[i].lat,
 locations[i].lng),

                        map: map
                 });


                 google.maps.event.addListener(marker, 'click', (function(marker, i)
{

                        return function() {
                         infowindow.setContent(locations[i].time);
                         infowindow.open(map, marker);
                        }
                 })(marker, i));
                }
                }
   </script>
   <script async defer
```

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Faculty of Information and Communication Technology (Perak Campus), UTAR

51

Appendices C: Website Design Code

```
src="https://maps.googleapis.com/maps/api/js?key=AIzaSyDolfGjacQBvu9bUvU5
lq-PorI16U0Ag8I&callback=initMap">
    </script>
  </body>
</html>
```

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52

APPENDICES D POSTER

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53

Plagiarism Check Result

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54