# DESIGN AND FABRICATION OF (TAPSS): TRAINER FOR ADVANCED POWER SUPPLY SYSTEM

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# DESIGN AND FABRICATION OF (TAPSS): TRAINER FOR ADVANCED POWER SUPPLY SYSTEM

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## ABSTRACT


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| Title | : | DESIGN AND FABRICATION OF (TAPSS): TRAINER FOR ADVANCED POWER SUPPLY SYSTEM |
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An Electronics laboratory should be well equipped with different apparatuses such as oscilloscope and signal generator for the student to do the experiment that will build their fundamental understanding on the subject. The major setback of these equipment is their cost effectiveness making it harder for public schools and universities to avail. However, the development of trainers intended for utilizing the features of signal generator and oscilloscope were developed. It was proven by the National Academies of Science Engineering Medicine in United States of America, that with the correct equipment and integration of instructional sequence and trainers it can significantly boost the student's learning in a specific subject or area, thus proving their effectiveness. The Development of Advance Power Supply System trainer can be used as an alternative device to perform different experiments based on the course outline of the subject "Advanced Power Supply Systems". This is a student friendly trainer that will make it easier for them to build the experiment circuits. The trainer is composed of a signal generator that has a maximum amplitude of 24 Vpeak and can output of up to 5Khz of frequency of sine, square and saw tooth wave. A waveform display that can measure up to 25 Vpeak. The GUI of the waveform display will be the android device that has the application installed.

Keywords: Android application, Function Generator, Oscilloscope, Power Supply, Trainer

## TABLE OF CONTENTS

## LIST OF TABLES

# LIST OF FIGURES

## Chapter 1
## THE PROBLEM AND ITS SETTING

This chapter presented background, purposes and significances of the study mainly, moreover, and also stated the theoretical and the conceptual frameworks of device simply.

### Introduction

The great philosopher Confucius once said that “I hear and I forget, I see and I remember, I do and I understand.” the quote explains that for us to learn we need to experience it first. This express how laboratory equipment and trainers is essential in student learning. Hence, with the emerging technology, educational instruments are necessary for better understanding of each topic, for students to gain sufficient hands on training and experience that can help to develop and improve their skills.

The overall agenda of engineering education is to prepare the students to practice engineering and, in particular, to deal with the forces and materials of nature. Thus, from the primary days of engineering education, instructional laboratories have been an essential part of learnings. The importance for this matter on engineering education have been in demand by then (Feisel and Rosa, 2005) and According to the study conducted by The National Academies of Sciences Engineering Medicine in United States of America, the integration of instructional sequence and trainers that include laboratory experiences in representations and simulations are most successful in supporting student learning (The National Academies Press, 2006).

Science education such as engineering requires university to have appropriate laboratory equipment and materials to cater and facilitate comprehension effectively (Alerta et al., 2017). In accordance to CHED memorandum order 86 series of 2017 under article 2 section 2, the Higher Educational Institution shall provide laboratories with areas that will suit the class size, to allow the student perform to design and perform experiments and exercises as provided in the approved curriculum. In addition, under the same article with the compliance of the minimum standards each school/college shall have a program for maintenance and continuing modernization of the laboratory (CHED, 2017).

Laboratory works in coordination with laboratory simulations and trainers may likely increase the positive learning outcome. A better laboratory learning interaction with instructional simulations and trainers can help the students understand a real system, process, or phenomenon (Alerta et. al, 2017). Moreover, for the electronic subject it is expected to use different learning aids and teaching tools that will help the student. Hence, an instructional trainer is one of the examples of such learning tools, it helps the student to easily visualize and experience the specific circuits or topics. In addition to this, the innovations in laboratory teaching especially in electronics laboratories have ascended hand-in-hand for they offer actual simulations of the topic being discussed. This enable the students safely to explore their curiosity and nourish developing skills (Avelino et al., 2015).

Engineering laboratory trainers are expensive to run and maintain. Due to the high cost of training kit and facilities, laboratory is a strictly scheduled commodity. The complete setup of power electronics trainers alone available in the market starts at the price of Php 17,000 (SBP Engineers, 1992). In India, the market price per modules of the trainers rise up to Php 4,000 which is too costly for a standalone product. Hence, this expensive equipment can only be accessible for two to three hours per week by most of the students; and it is difficult for students to get extra time if they need it or want to use it for their experiment. Nonetheless, the subject do not just required one module to be experimented, with this it is expected for public schools to let their funds be used on other necessary laboratory equipment that are cheaper and affordable.

In result, Philippines public schools and university conceived an absence of science educational equipment and laboratory modules (Gamba, 2017). Lack of training equipment makes it difficult to develop human resources with practical skills and application ability required by the industry (JICA, 2016). The public schools Electronics (ECE) Laboratory mostly lacks equipment needed to have the student enough necessary knowledge of the subject (Bolen et al., 2017). Moreover, in the Philippines there are no certain Advance power supply trainer available in the Market and According to the inventory of laboratory equipment in the DHVSU ECE laboratory, the lab does not have specific trainer for the subject Power Electronics and/or Advance Power Supply System with these in mind the trainer will be essential in learning the subject.

It is this for reason that the proponent thought of developing a trainer that would enable the students to experience hands-on learning in the subject Advance Power Supply System and to appreciate the importance of this subject in the field of electronics engineering. Furthermore, the training module will not only guide the student to the connection of the circuit proper but also, to the analysis of each circuit. Since the knowledge about the said subject is fundamental to the training of the students, having a trainer on how to utilize and implement this subject will be convenient and efficient in an electronics engineering laboratory.

**Theoretical Framework**

DDS or Direct Digital Synthesizer is a method used by frequency synthesizers for creating different waveforms from a single reference fixed-frequency reference clock. The signal generator on the trainer uses this method to create different waveforms from the input of +/- 12 volts' dc input.

Nyquist Theorem or sampling theorem is a principle that the proponent followed on deciding the microcontroller used on the waveform display circuit. This theorem is useful when dealing with analog to digital conversion (ADC) of signals for an ideal reproduction of the signal, tiny slices of the analog signal must be taken continuously, this are called samples. The rate at which each sample is taken is called the sampling rate. In approximation based on the Nyquist theorem the sampling rate should be two (2) times of the original signal. The arduino UNO with 9.8 kHz sampling rate based on the nyquist theorem can convert analog signals of upto 4.5 kHz but in reality, it is lesser than the ideal

The proponent used Kirchhoff's Current Law to design the waveform display circuit of the trainer.

The thesis is a trainer for the subject Advanced Power Supply System that consist of different circuits and circuit application based on the curriculum set in the CHED memorandum order 101. The project will offer an alternative way of learning for the electronics engineering student for the said subject by utilizing the use of android device. The project can provide monitoring capability of the output waveform parameters such as peak-to-peak voltage, RMS voltage, and frequency using microcontroller's sampling capability, then display's the data gathered through Android application and a wireless communication via Bluetooth communication making the project more advanced in interacting with the user, giving them a comprehensive study of their subject. The android application will also provide the experiments and discussion of each of topics for comprehensive learning of the student.

**Conceptual Framework**

## INPUT

**Knowledge Requirement:**

- Research on the problem of the study (Lack of Lab equipment and solution to it)
- Target output or objectives (build a more convenient, cheaper & comprehensive trainer)
- Hardware & Software knowledge (circuit knowledge & programming language)

**Software Requirement:**

- Identification of software to be used on the project and designing the project (MIT app inventor 2, kiCAD & Multism)

**Hardware Requirement:**

- PC/Laptop Specifications must be able to run MIT app inventor 2, kiCAD & Multism
- Android device Specifications must be able to run the created android application
- Circuit Specs, Schematics & Knowledge

## PROCESS

**Planning:**

- Preliminary investigation on the lack of lab equipment and its result

**Project Analysis:**

- Using alternative and convenient tools such as trainers

**Project Design:**

- The project will utilize different circuits to be used in experiments base on the course outline then will use android app as GUI via Bluetooth communication

**Coding/Programming**

- By establishing stable Bluetooth connection android app will display necessary details and instructions for the user

**Testing:**

- Test used in the methodology

**Application:**

- Implementation of the project in schools

## OUTPUT

**Development of Power Electronics Kit for Electronics Engineering Department with Android Application and Wireless Waveform Display**

**Figure 1. Input, Process, Output**

The input, process, output describes how the project will be finished by the researchers. On the first block the input, are the necessary skills, knowledge and resources needed for the project. On the second block the process shows how the proponent will use the resources to do and finish the project. On the output block, it shows the final product of the project made by the proponent.

## Statement of the Problem

1. What trainer could be designed and developed to simulate the course content of Advanced Power Supply System based on CHED Memorandum #101 series of 2017 in terms of the following aspects:

   1.1. Hardware requirements; and,

   1.2. Software requirements?

2. What is the effectiveness of the designed and developed Advanced Power Supply System Trainer in terms of the following indicators:

   2.1. Functionality; and,

   2.2. Accuracy; and,

   2.3. Reliability; and,

   2.4. User friendliness?

3. What are the benefits that could be derived from the developed trainer in terms in terms of the following:

   3.1. Maintainability

   3.2. Sustainability

## Scope and Limitation of the Study

### Scope

**Hardware and Software**

Primarily, sampling method is used for the Analog-to-Digital Conversion needed for the Output waveform. The proponent used Arduino Uno as the hardware for the microcontroller to acquire the output waveform. For the connection of hardware and software the proponent used HC-05 Bluetooth module to connect the microcontroller from the Arduino to the user interface which is an Android Application developed using MIT App Inventor.

The Android App can only measure a peak voltage up to positive and negative 25V. It can only show the output waveform in sine wave, square wave and triangular wave. Moreover, the output parameters such as the minimum voltage, maximum voltage, peak-to-peak voltage and the peak voltage will be shown in the Android application.

**Experiment**

The whole research was entirely focused on the subject "Advanced Power Supply System" which are in line with the course outline given in the CHED MO 101 series of 2017. Under the subject Advanced Power Supply System the topics are Semiconductor Switches, Passive components, Rectifiers, Phase controlled rectifiers and converters, Switch-Mode Power Supply, Inverters, Resonant Converters and Power Conditioners and UPS.

**Limitations**

**Hardware and Software**

The sampling rate of the oscilloscope will rely on how fast the microcontroller used which is ARDUINO UNO. The supply, signal and measuring instrument of the trainer are only tested for the experiment circuit provided by the proponent. In addition, the frequency range the oscilloscope ability to capture will be based on the clock speed of the microcontroller used. This limits the use of oscilloscope because the waveform frequency counter is just based on the comparator and if the voltage reference is not reach or no readings, then there will be no measurement if the waveform is in negative half cycle, thus, limiting to display the frequency of the waveform in the Android Application. Furthermore, the app cannot measure or display millivolts or less than 1 volt and it will only run in android operating system that is supported by application made through MIT app inventor 2, which is Android 2.3 (Gingerbread) or higher.

**Experiments**

There are 10 experiments provided by the proponent under the elective subject “Advance Power Supply System”. Every experiment, there are developed circuit modules for the students to practice in order to understand the concept and principle of every topics in the subject. Below are the listing of the experiments and the preset parameters that the proponent have gathered while performing a test onto the circuit modules.

**Experiment 1:**

Experiment 1 is about the operation of the semiconductor switches, Experiment 1.1 SCR as Light Dimmer and Experiment 1.2 TRIAC Gate

Triggering both uses 12 AC volts for their inputs and their output is 10 volts while their maximum current both flowing into their circuits is 0.1 A.

**Experiment 2:**

Experiment 2 focuses on the triggering of Semiconductor Switches in AC Source. Experiment 2.1 highlighted the Programmable Unijunction Transistor while Unijunction transistor was used for 2.2. The input voltage for these two circuits is 15 DC volts and the output voltage for 2.1 is 8 volts while 11 volts was measured as the output voltage for 2.2. 0.1 A is the measured current for the both circuits.

**Experiment 3:**

The input voltage for this experiment is 12 VAC. The output voltage will not exceed the input voltage since the passive components limits the flow of electrical current. Since experiment 3 is dedicated for passive components with these the values are variable.

**Experiment 4:**

The topic for experiment 4 is about the rectifiers. The proponent incorporated the two well-known rectifiers in Power supply system which are: Half-wave and Full-wave rectifier. Experiment 4.1 is a circuit of half wave rectifier while 4.2 is for the full wave. The input voltage for these two circuits is 12 AC volts and the output voltage of the two is 11 volts pulsating DC.

**Experiment 5:**

Experiment 5 is about Phase Controlled Rectifier. In this topic the proponent developed three experiment circuits. Experiment 5.1 is a Full Venn Bridge circuit, Experiment 5.2 is a Symmetrical half Controlled Semiconverter, and 5.3 is Asymmetrical Half Controlled Semiconverter. The input voltage for these three experiment ranges from 16 to 20 peak voltage and the measured output voltage varies from 13 to 17 peak voltage. The maximum current that is measured from the testing is 0.1 A.

**Experiment 6:**

A Switch-Mode Power Supply circuit was developed for experiment 6. The input voltage for this experiment is 24 VAC and the output voltage is 5VDC. The current of the supply is maximized up to 1A.

**Experiment 7:**

Experiment 7 is about inverters. The proponent developed a single phased inverter for this certain topic. The two inverters are Parallel inverters and H-inverters. The input for these two inverters ranges from 5VDC to 12VDC and the expected based from the testing varies from 4V up to 11 V peak AC. The maximum current that flows from the circuit is 50mA.

**Experiment 8:**

Experiment 8 is narrowed into three distinct circuits namely: Buck Converter, Boost converter and Buck-boost converter. Experiment 8.1 is buck converter, the input voltage for the circuit is 5 to 12 VDC and the measured output for this converter is 5 VDC with 7mA flowing through its circuit. In the boost converter under experiment 8.2 the input voltage for this is 5 VDC and has boosted for 11.65 VDC with a flowing current of 0.4 A. On the other hand, the Buck-boost has two voltage inputs for the buck mode the input voltage must be 12 VDC and for the boost mode it must be 5 VDC. The output voltage for buck mode is

5VDC and 12VDC for the boost mode. The maximum flowing current from the circuit is 0.5 A.

**Experiment 9:**

Uninterruptable Power Supply is the topic for experiment 9. The input voltage for this experiment is 10 -15VAC and the output will be 12 VDC the maximum current that can flow from this circuit is 1A.

**Experiment 10:**

In this experiment it shows how the stepper motor works. The higher the resistance the higher the voltage it will have on the motor. The higher the henrys the higher the voltage it will have.

## Significance of the Study

### Education

The development of the project will significantly help in the field of education, for the student will have an actual exposure with the different experiments in utilizing comprehensively the trainer to understand topics such as power supply, regulators, converters etc. Moreover, the student will develop knowledge and equip skills that they can use for further projects.

### Technology

The project will contribute to the advancement of the technology by utilizing the use of android device as an interface for the experiments in the trainer, through wireless connection; furthermore, it promotes the use of microcontroller.

### Government

By introducing, the project to the government new teaching method will occur that can be adapted the Commission of Higher Education. One of the standards of CHED for the laboratories is the modernization of equipment (CMO 86 s.2017 article 2) this project offers the utilization of modern android device for studying. Furthermore, this allows student to have an access on different tools to allow them to do the experiments thus complying with the standards of the Commission of Higher Education (CMO 86 s.2017 articles 2)

**Definition of Terms**

**Android operating system** - is a mobile operating system that was developed by Google (GOOGL) to be primarily used for touchscreen devices, cell phones, and tablets. Its design lets users manipulate the mobile devices intuitively, with finger movements that mirror common motions, such as pinching, swiping, and tapping.

data stored in one or more computerize files in a way that can be accessed by users

**Arduino Uno** – is an open-source microcontroller board based on the Microchip ATmega328P microcontroller. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits.

**Bluetooth** - This wireless technology enables communication between Bluetooth-compatible devices.

**System –** a set of things working together as a mechanism or a network, in which programs are interconnected to attain its functionality.

**TRAINER KIT** - is a self-contained set of electronic circuits that can be interlinked by students to create working circuits.

## Chapter 2

## REVIEW OF LITERATURE AND STUDIES

This chapter stated a wide variety related articles of air and noise pollutions estimator device, and also presented some reports and data of environment pollution.

One of the four key tactical points initiated by CHED is the expanding access to quality education. Hence, to achieve this, upgrading of instructional and laboratory facilities of state universities and colleges and the availability of equivalency must be delivered (CHED, 2017). According to the investigation of The National Academies of Sciences Engineering Medicine, several tools including representations of complex phenomena, simulations, and student interaction with large scientific databases can support students' learning. Moreover, the integration of instructional sequence and trainers that include laboratory experiences in representations and simulations are most successful in supporting student learning (The National Academies Press, 2006). According to the Commission on Higher Education (CHED) Memorandum Order no. 86 series of 2017 section 2.2.1.1, In order to meet the compliance with minimum standard for main laboratories the Higher Education Institution shall conform with support facilities required for the laboratory courses such as functional equipment, apparatus, supplies, tools, and other materials inside the engineering laboratories. These objectives will help the students to better understand the topic (CHED, 2017).

However, it is difficult to schedule traditional laboratories for students to perform lab assignments individually due to the demand on laboratory facilities and instruction/faculty resources (JICA, 2016). One of the considered aspects why students cannot attain the enough knowledge that required is because of the lack of equipment at the laboratory (Bolen et al., 2017). Lack of training equipment makes it difficult to develop human resources with practical skills and application ability required by the industry (JICA, 2017). The most vital variable of all variables is a source of learning and practice equipment, which can be manipulated in order to induce change in behavior of the various characteristics of different students. Furthermore, providing a practice experience for students to encapsulate knowledge and skill from the equipment practices, which includes the availability of, complete information relating to the knowledge to be mastered is an important characteristic of learning resources (Siagan, 2014). Siagan also added that the availability of module and trainer as the source of theoretical knowledge should be considered as a factor that affects the results of learning students.

According to the Commission of higher Education (CHED), Memorandum Order No.101 series of 2017 section 10. The Electronics Engineering curriculum also mandated general education and elective courses as connected to the desired program outcomes – to ensure depth and focus to a certain field of Electronics Engineering discipline, a completion of at least one specialized field with elective courses is required. Under section 11, Power Electronics is categorized as one of the specialized fields in Technical Elective Courses (CHED, 2017). Power Electronics is considered as the art, science and technology of converting power from the available form to the required form. Power Electronics involves the study of electronic circuit intended to control the flow of electrical energy. These circuits handle power flow at levels much higher than the individual device ratings (Rashid, 2001). In general; the task of power electronics is to process and control the flow of electric energy by supplying voltages and currents in a form that is optimally suited for user loads. In the recent years, the field of power electronics has experienced a large and demanding growth due to the confluence of several factors (Mohan et al., 1995). Furthermore, a remarkable emphasis on power electronics applications in the areas of industrial, residential, commercial, transportation, aerospace, military and electric utility systems will affect globally. The future innovation will lead to increasing demand for this field of electronics. Power electronics have now established major recognition and discipline in electrical and electronics engineering. Bose stated that the part of power electronics in our society in the future will be as significant as computers, gadgets, and communication and information technologies today (Bose, 2010).

**Synthesis**

The anticipation for the increasing demand in the field of Power Electronics led the researcher in developing an educational trainer for the students with continuous growth of the technology, teaching materials and practices, also advances. The following studies and literatures show improvement of the learning tools and what & how it can affect the performance of each student and professors in an educational institution.

The quality education is the utmost priority of every higher education institution and achieving this quality education comes for a worth to develop it. In order to attain this, upgrading such instructional and laboratory facilities is relevant and appropriate. The student interaction with representations and simulations for complex phenomena can increase their student learning and development. However, due to lack of instructional tools and equipment make it difficult to develop the practical skills and application ability required by most of the industry. Hence, trainers and other learning and practice equipment can provide a practice experience for students to harness knowledge and skills. Additionally, the learnings can affect by the availability of the modules and trainers for the source of theoretical knowledge.

Electronic Training Kits and Modules were developed and designed to improve the learning capability of the student about the instrument operation and measurement techniques. Henceforth, Mustaffa et al proposed an integration of design and implementation of wireless oscilloscope. Similarly, Abhayasinghe and Seneviratne embedded for a portable oscilloscope using Android Application, which has a two-channel mode. In another study conducted by Balcel et al, they developed a conventional trainer using digital signal processing platform that allows delivering higher power than other educational power electronics kit. Moreover, on the research proposed by Bhutto et al, the researchers designed a low-cost power electronic module for practical approaches of power semiconductor.

Elseways, Barnacha et al. proposed a project that covers a topic for the course of electronics engineering based on the CMO 101 s. 2017. The project is Advance Power Supply Trainer that has a built-in Function Generator and Oscilloscope that can provide the waveform parameters such as the peak-to-peak voltage, RMS voltage and the frequency. The researchers also developed circuits' module for the application of the trainer. The project offers an alternative way of learning for the Electronics Engineering student for the said subject by utilizing the use of android device. Moreover, the safety of using the trainer is the utmost priority in constructing the project.

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Educational instrument is inevitable in every major fields of specialization in better to understand the specific topic where student could have actual training to develop and improve their individual knowledge and skills (Celestial, 2015). According to the study of Siagan, to improve the student-learning outcome the use of module and trainers are effective and efficient. The trainer gives the opportunity to students to perform practice activities until further understanding the concepts by showing the facts in actual performance (Siagan, 2014). The Electronic trainer kits were developed and designed to improve the learning of the student about instrument operation and measurement techniques (Bolen et al., 2017). Analog trainers and digital trainers are the two basic types of electronic trainers. Analog trainer contains a complete function generator capable of generating sine, square and triangular waveform. On the other hand, the digital trainer has the essential functions to do digital designs (Berg and Boughton, 2001).

Analog and digital electronic trainers contain prototyping board, power supplies, function generators, potentiometers and switches. However, in upper division courses, such as communications and power electronics, circuit gets complicated. Laboratory budgets are limited. Thus, doing computer simulations are easy and inexpensive. Building demonstration circuits on solderless prototype were crucial and labor intensive (Berg and Boughton, 2001).

In the prototype designed by Limberis, Warren and Yao, the trainer or kit can work equivalently like the bench-top electronic test and measurement equipment. The developed kit was named as “The Portable Electronic Experiment Kit” (PEEK) which includes digital multimeters, oscilloscopes, function generators, and many more. The kit set includes three primary components such as the Rapid Analysis and Signal Conditioning Library (RASCL), Data Acquisition Unit (myDAQ) and a laptop with National Instruments’ Educational Laboratory Virtual Instrumentation Suite (Jayson et al., 2011).

Oscilloscopes, multimeters, and function generators are the bench top electronic equipment. Virtual instruments on laptop and a supplementary collection of portable hardware serve as good supplements. It can provide a new way of laboratory experience that emancipates student from traditionally constricted settings and expands laboratory activities into more omnipresent learning environment that allows students to accomplish laboratory objectives and complete the associated task at their own pace (Jayson et al., 2011).

According to the study of Mustaffa, Othman and Yahaya oscilloscope is a type of electronic test instrument that allows observation of constantly varying signal voltages. Stated on the research that nowadays, oscilloscopes are bulky, inconvenient, and not portable and involves high power consumption. The researchers proposed an integration of design and implementation of wireless oscilloscope. Android application will be used and controlled by Arduino. The system offers a low power, low cost and portable wireless oscilloscope consisting of hardware and software application (Mustaffa et al., 2017). With the aggressive innovation of technology, mobile devices have become instruments that allow new way of interacting with institutional services (Alwadani et al., 2017).

Seneviratne and Abhayasinghe used Bluetooth embedded for portable oscilloscope. They implemented a device with Bluetooth module as a communication media in an android OS platform; and used two modes of operations, which can select mode from the application. The first operation used is namely single channel mode which particularly channel one is only operational. The second operation is both operational (Abhayasinghe and Seneviratne, 2013).

Due to modernization, the researchers designed a low cost, low power oscilloscope consisting of software application and hardware device equipped with a Bluetooth module HC-06 running the Android operating system (OS). The Android OS display the waveform such as Square Waveforms and Triangular Waveforms etc. (Hatwar and Wani, 2014).

Android Bluetooth Oscilloscope is a development of an oscilloscope using Bluetooth. It is proposed to implement a system that measures signals and display it on android phone. The input will be processed by embedded system and it will transmit in Bluetooth Module (Bishes and Patil, 2017). The Bluetooth network stack is included in the supported platform of the Android. On the other hand, the application framework provides access to the functionality of the Bluetooth through the Android Bluetooth API's enabling a point-to-point and multipoint wireless feature which these APIs let applications wirelessly connect to other Bluetooth devices (Ashok, 2019). Android 4.3 (API level) introduces built-in platform supporting Bluetooth Low Energy (BLE) in central role which is designed to provide significantly lower power consumption (Android Studio, 2018).

Several studies show positive feedback from the project as it demonstrates several prospects in enhancing the learning outcome of the students when using a trainer.

Researchers from Spain designed an equipment for power electronics application which is opposite with conventional trainer using digital signal processing (DSP) based equipment. This platform allows delivering higher power than other educational power electronics kits, which ease the interaction between the student and the platform. Also, describe the different control modules, which integrate the development of power electronics kit like three phase Mos Bridge, and power supply (Balcells et al., 2008).

The researchers designed a lost-cost basic power electronic training module that will train the under graduate and post graduate for industries, the trainer will help the target group to be trained with power semiconductors and will help them to be familiarized for the practical approaches of power semiconductors devices and their properties. This trainer has a built in multimeter and will work on 220-240 volts at approximately 1A ratings (Bhutto et al., 2010).

In the study conducted by Bolen et.al, they developed a student friendly device that can be used as alternative equipment when performing and practicing laboratory experiments. The trainer kit is composed of an adjustable output voltage power supply, a breadboard, graphical user interface (GUI) of oscilloscope, function generator, and DC voltmeter and ammeter. Through research experiment and several testing the GUI of oscilloscope has an average accuracy of 99.35%, 98.54% for function generator which are higher than 95.5% as required by the NRC (Bolen et al., 2017).

**Synthesis**

The quality education is the utmost priority of every higher education institution and achieving this quality education comes for a worth to develop it. In order to attain this, upgrading such instructional and laboratory facilities is relevant and appropriate. The student interaction with representations and simulations for complex phenomena can increase their student learning and development. However, due to lack of instructional tools and equipment make it difficult to develop the practical skills and application ability required by most of the industry. Hence, trainers and other learning and practice equipment can provide a practice experience for students to harness knowledge and skills. Additionally, the learnings can affect by the availability of the modules and trainers for the source of theoretical knowledge.

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# Chapter 3

# METHODOLOGY

This chapter introduced functions and components of air and noise pollutions estimator device simply. Moreover, it presented how to deal with data collected by device and website, and also described the technique and the method of analyze data.

## 3.1 Research Design

This study will apply engineering design, planning, and analysis to obtain the objectives of the study. It will be done by taking into considerations several parameters such as the sampling rate of the microcontroller, the signal generated from the signal generator, the signal displayed on the GUI of the android-based oscilloscope and the current drawn from the experiment modules. Aside from these a measurement for safety was considered throughout the development of the study.

### 3.1.1 Hardware Design of the System

#### 3.1.1.1 Casing materials used

**a. 3D Printed Body**

**Acrylonitrile Butadiene Styrene (ABS Polymer)**

It is a material commonly used in personal or household 3d printing, which is done using primarily FDM or FFF 3d printers. This common thermoplastic material is popular because of it great material properties. ABS is lightweight and has good impact strength. It is abrasion resistant and affordable compared to other types of plastic. Moreover, ABS Polymer can withstand several chemical formulas.

**b. Trainer Case**

The case will be made up of acrylic fiber glass for the support of the casing this was considered due to its durability and cost effectively that yields quality support for the casing. Leatherette was used for the outer cover and the inside of the casing was made up of Suede which is a type of animal leather that has a great protection for electrostatic discharge (ESD).

**3.1.1.2 Design Considerations**

**a. Design of the Trainer**

The design of the trainer will be dependent on the sizes of the modules and circuit used. The length, width and height is 350 mm, 220 mm, 180 mm respectively. The length is divided by three sections which is the upper part, the center and the bottom part of the trainer. Both upper and bottom length measures 110 mm and the center, where the experiment circuit will be plugged in, measures 130 mm with 0.5 cm clearance from the sides. The center height is only 80 mm and the rest is 180 mm resulting of U-Shape when looking at the side views of the trainer.

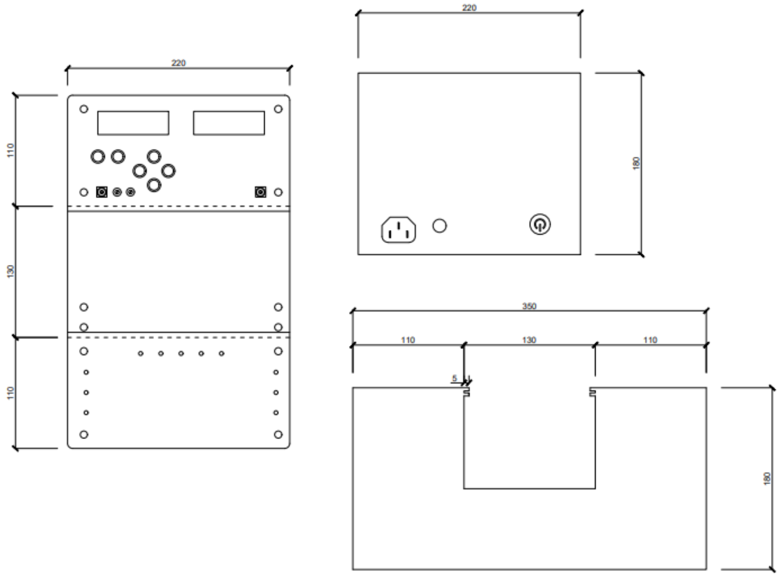

**Figure 2. Orthographic View of the Trainer**

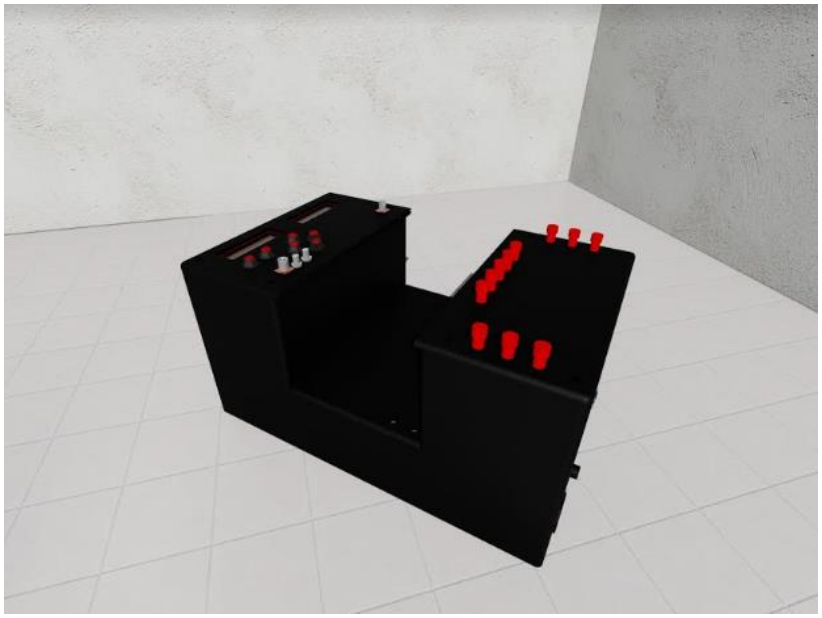

**Figure 3. 3D View of the Trainer**

**b. 3D Parametric Consideration**

Since in the 3d printing, the maximum allowable volume that can be printed is only 220x220x240 LWH, the design was maximized and divided into four parts.

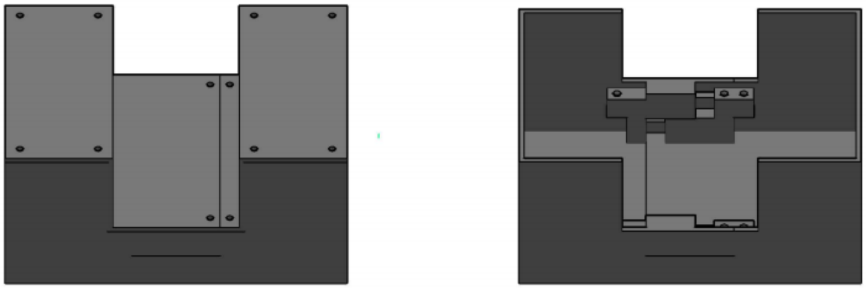

**Figure 4. Top View of the Trainer**

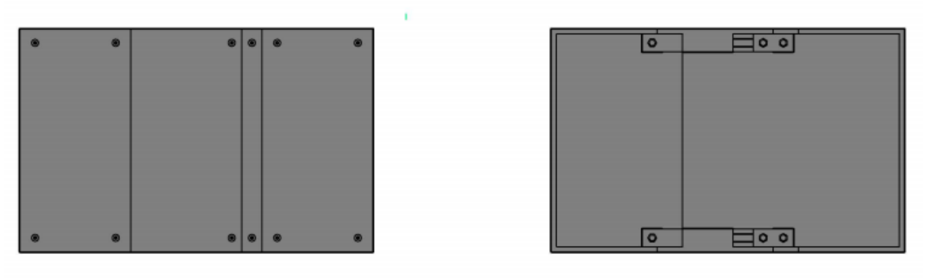

**Figure 5. Bottom View of the Trainer**

**c. Design of the Experiment Circuit**

The dimensions for the PCB Experiment modules are 170 mm by 130 mm. The thickness of the PCB is 1.6 mm which is a standard thickness for PCB.

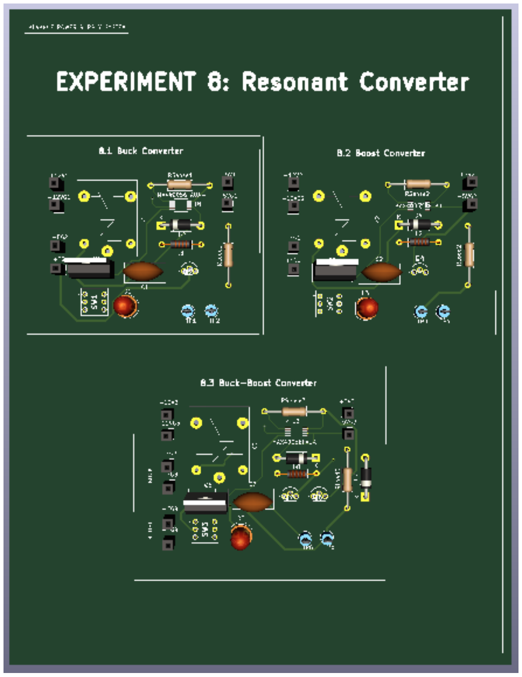


**Figure 6. 3D of the Printed Circuit Board**

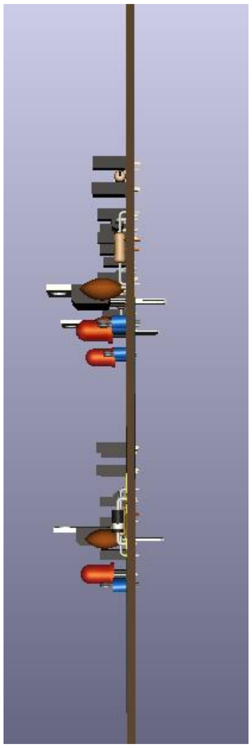

**Figure 7. Thickness of the Printed Circuit Board for the Experiment**

**3.1.1.3 Power Supply Unit**

**a. AC to DC Conversion**

Converting Alternating Current (AC) power to a Direct Current (DC) power involves a series of steps that mostly includes rectification to straighten the sinusoidal wave of an AC power. Throughout the history different techniques were developed to make AC to DC conversion more efficient. Different types of power supply unit were used to convert AC to DC in the project to supply the power needed of the trainer for signal generator, waveform display circuit and experiment circuits.

**b. Transient Voltage Suppressor**

Transient Voltage Suppressor Transient Voltage Suppressor (TVS) are generally group of devices that are used to respond on sudden or momentary overvoltage conditions. TVS reacts to overvoltage faster than common overvoltage protection components such as a simple Zener diode or Metal Oxide Varistors (MOV). TVS diodes are used are used for unidirectional and bidirectional overvoltage protection. TVS will be used on the project as voltage suppression for the input supply of the signal generator of the trainer, to prevent spike of voltage on the signal generator.

**c. Linear Power Supply**

Linear Power Supply used in the project made use of step-down transformer to lower the voltage of the AC mains then rectified it using bridge rectifier and filtered the pulsating DC by the capacitors and regulated it using the 78 and 79 series voltage regulators. The linear power supply will be used to power the signal generator, DC and AC supply of the trainer.

**d. Switch Mode Power Supply**

Switch Mode Power Supply is an electronic power supply that can convert AC mains power to efficiently regulate the voltage. SMPS uses switching transistor to regulate the voltage then control the output Vrms through the on and off cycle of the switch. The faster the switching the higher the Vrms can be, SMPS exclude the use of huge transformer making it smaller and lightweight than the regular linear power supply. Furthermore, discussion of SMPS will be seen on the experiment manual of the project.

**e. Halo Power Switch**

Halo power switch is the main switch of the whole trainer; it has a blue LED that when it lights up indicates that it is ON or closed circuit. This switch is powered by 12 volts DC supply taken from the linear power supply of the trainer.

**3.1.1.4 Signal Generator Circuit**

**a. Two Stage Power Amplifier**

The signal generator module output is amplified by the two-stage power amplifier which is the OPA541 power amplifier module, this amplifier not only isolates the output of the signal generator to prevent loading effect and protect the experiment circuit.

**b. Waveform Display Circuit**

The waveform display circuit consist of attenuator, op amp comparator as frequency counter, Arduino to process the data, ac to dc power supply and the Bluetooth module.

**c. Waveform Display Attenuator Circuit**

The circuit used a simple configuration of resistors and buffer op amp to attenuate the input signal of a maximum of +/-25 volts and make it +5v that can be read by the Arduino UNO's built in ADC. Only +5 volts can be read by the Arduino UNO's analog input and convert it to a digital signal that can be processed by the microcontroller.

d. **Waveform Display Frequency Counter**

An op amp configure as a comparator is used to the circuit as a counter of the frequency. The signal fed through the input probe is converted to square wave via the said op amp, this square wave will be fed on the digital pin of the Arduino

UNO. The UNO will measure the time high and low the square wave signal, this time will be used to get the period and frequency of the input signal.

**e. Arduino UNO and Bluetooth module**

The attenuated signal that is fed on the analog input and the square wave fed on the digital pin of the Arduino UNO will be processed. The processed data will be sent to the android device through Bluetooth connection via an external Bluetooth module. The module is connected on the Universal Asynchronous Receiver-Transmitter (UART) of the Arduino UNO for the serial communication of the android device and the device itself.

**f. Power Supply**

The power supply of the waveform display circuit should be isolated from the power supply used on the experiment circuit because this can cause the loading effect which can make the measurement of the signal inaccurate. The supply is just a simple linear power supply that makes 220 Vac to 5Vdc, waveform display circuit used two of these to supply the two Op Amp LM741 with 10 volts and 5 volts' railings.

**3.1.1.5 Software of the System**

**a. Interface Design**

The graphic user interface of the android application (GUI) for the trainer is designed base on how to easily use and understand each of the figures in the android application. Each panels and buttons on the GUI corresponds to different functions such as user manual, experiment manuals, tutorials and waveform display.

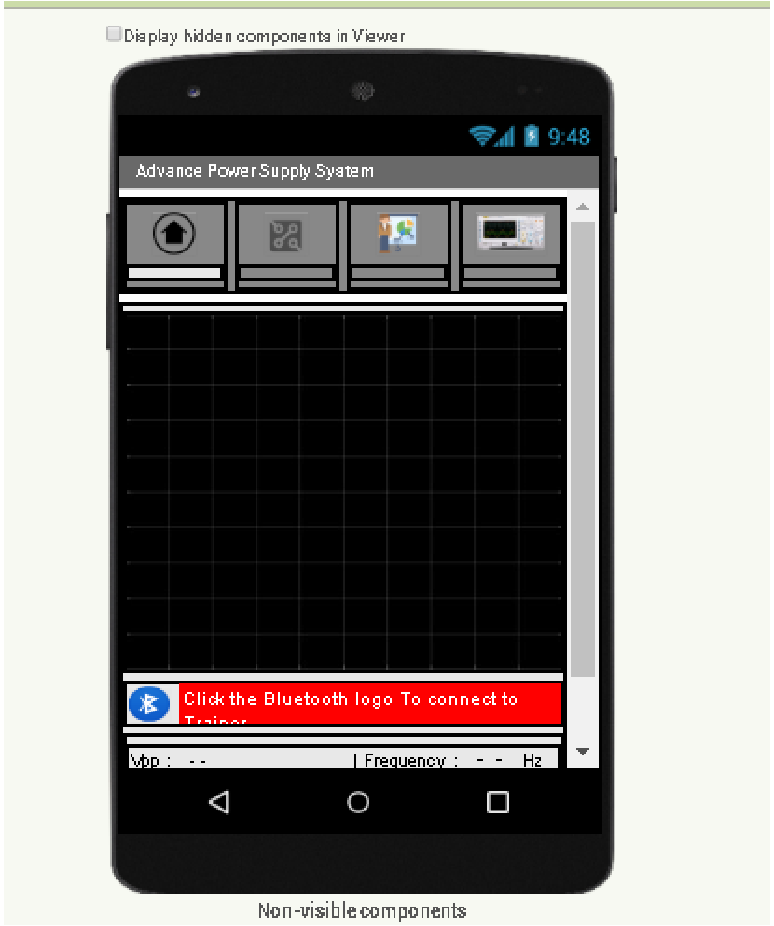


**Figure 8. GUI of the Android App**

### b. Android Application

The android application is designed to display the tutorials, user manual and experiment manual, in addition to displaying the waveform of the measured signal. The android application will be used as a display for the waveform fed on the input probe of the circuit, furthermore the android application contains tutorials for the experiment, user and experiment manuals. It will get the data send through Bluetooth connection from the trainer then display necessary details on the screen.

### c. Arduino

The Arduino will convert the input signal through its built-in Analog to Digital Converter (ADC) the conversion of the signal will rely on the sampling rate of the Arduino UNO itself. Furthermore, the square wave signal fed on the digital pin of the Arduino that is used to count the frequency of the input signal will be processed by the Arduino. These data that was processed by the Arduino will be sent to the android waiting to receive through Bluetooth connection.

**3.1.1.6 Statistical Analysis**

a. **User Acceptance Testing**

In order for the researcher to determine the effectiveness of the prototype the study will use the User Acceptance Testing experimental design. The User Acceptance Testing (UAT) is a form of design usability testing used after design completion with the intention to validate the study. The UAT is based on the ISO 25010 to meet the requirements needed of the prototype and the program.

**b. Percentage Error**

Percent error or percentage error expresses as a percentage the difference between an approximate or measured value and an exact or known value. It is used in science to report the difference between a measured or experimental value and a true or exact value. Here is how to calculate percent error, with an example calculation.

**3.1.1.7 Theoretical Consideration**

The following are theories that are followed by the proponent to design the circuit used on the experiment, on the power supply of the trainer and the waveform display circuit.

**a. Direct Digital Synthesizer**

DDS or Direct Digital Synthesizer is a method used by frequency synthesizers for creating different waveforms from a single reference fixed-frequency reference clock. The signal generator on the trainer uses this method to create different waveforms from the input of +/- 12 volts' dc input.

**b. Nyquist Theorem**

Nyquist Theorem or sampling theorem is a principle that the proponent followed on deciding the microcontroller used on the waveform display circuit. This theorem is useful when dealing with analog to digital conversion (ADC) of signals for an ideal reproduction of the signal, tiny slices of the analog signal must be taken continuously, this are called samples. The rate at which each sample is taken is called the sampling rate. In approximation based on the Nyquist theorem the sampling rate should be two (2) times of the original signal. The arduino UNO with 9.8 kHz sampling rate based on the nyquist theorem can convert analog signals of upto 4.5 kHz but in reality, it is lesser than the ideal

**c. Kirchhoff's Current Law**

The proponent used this law to design the waveform display circuit of the trainer. Refer to appendix for the schematic and solving.

**3.2 Participant**

All the respondents will be selected based on their profession. A total of ten participants were be approached and all of them agreed to take part, (100% positive response). This comprised of 3 instructors of Electronics Engineering, 4 Professionals, 3 Chairman from an Electronics Engineering Institution and 1 Electronics Technician.

The instructors gave their approval for the circuits used in the trainer wherein each instructor was given a copy of circuits including their schematic diagram and waveforms. The professionals assessed and tested the project and compare it on the trainers that they have on their respective companies. The instructors and technicians from different universities assessed the trainer if it can be easily and safely used by the students.

**.3. Materials**

**3.3.1 Tools**

**a. Oscilloscope**

Oscilloscope is bulky laboratory equipment that is commonly used to display and analyse the waveform of the signal. Hence, this device draws a graph of instantaneous signal voltage as a function of time. Typically, an oscilloscope can measure or display an alternating current (AC) or direct current (DC) waveforms from a frequency ranging as low as approximately 1 Hz or as high as several megahertz. This device was used in order to display the waveform in testing the experiment circuit.

**b. Signal Generator**

A signal generator is an instrument that is used to create or generate electrical signal in the form of waves. This instrument is served as the stimulus for the item being tested especially the experiment circuits. It can create different signal forms such as triangular, square-wave, saw-tooth and the conventional sine wave. Moreover, the proponent used a function generator to simply generate repetitive waveforms.

**c. Multimeter**

Multimeter is another significant instrument that can measure voltage, current, and resistance. The proponent used Digital Multimeter for the greater precision of measuring the parametric variables needed for the data. This instrument was entirely used throughout the developments stage of the project up to the testing stage and troubleshooting the system.

**3.3.2 Software Used**

The system is composed of two major parts which is the hardware and the software. Hardware tackles the physical components and the modules that perform specific part in the project. However, without the software other parts of the research would not be existed as it may seem further. The proponent used several software programs in developing the research.

**a. Microsoft Word**

Microsoft Word is used for the word processing and document creation. It is a simple application that is widely known for its simplicity and easy to understand ample number of instructions. Through using the function of this application, the proponent were able to make written reports, simple tables and other memorandums that needed to be printed.

**b. Microsoft Excel**

This is one of the best statistical tools that the proponent applied in terms of the graphical interpretation of the data, easier way of computing statistics and formulation of the tables needed for the analysis. Furthermore, this application was also used for the computation of the proponent Bill of Materials.

**c. Microsoft Visio**

Microsoft Visio is another application from Microsoft that is responsible for creating the flowcharts and block diagrams of a circuit or a system.

**d. KiCAD**

KiCAD is free electronic design automation (EDA) software that facilitates the schematic for the experiment circuits and their conversion to PCB. This software has an integrated environment for schematic capture and PCB layout designs. Moreover, it has a wide range of libraries for footprint that made the process of designing a circuit board much easier and effective.

**e. EasyEDA**

EasyEDA is EDA software that was used by the proponent. This is online software that also caters schematic for experiment circuit and their conversion to PCB. However, since the software is online the number of libraries for components is larger than KiCAD.

**h. Multisim**

Multism is an electronic capture and computer circuit simulation programs. This application was used to simulate the schematic circuit before executing the circuit in actual to avoid errors and gather some data’s.

**i. Arduino IDE**

Arduino IDE is an open source software platform that is used to write codes and upload it on to the Arduino board. The proponent wrote the codes for the program of the system in this platform to execute the program such as the connection of the trainer and the Android application.

**3.3.3. Standards and Memorandums**

**a. CHED Memorandum No. 86 and CHED Memorandum No. 101**

These memorandums serve as the framework for the program-specific policies, standards and guidelines in engineering and engineering technology. Under article 2.2 of CMO86, HEI was allowed every student to perform all the basic laboratory exercises required for each laboratory course. Hence, there shall be sufficient functional equipment, apparatus, supplies, tools, and other materials to achieve the objectives. The proponent used this alongside with CMO 101 to establish the study.

**3.3.4 Sources of Data**

In this study, both primary and secondary data are used. The primary data are collected from Professionals and Instructors of Electronics Engineering and Electronics Technology. The secondary data are collected from the records of the school library. The primary and secondary data is gathered to cover every aspect of this study.

**a. Primary Data**

The data were acquired based on the assessment and feedback of each respondent during and after the beta test of the system. Another source of data the proponent gathered was from the simulation and testing of the circuits.

**b. Secondary Data**

The data were acquired from the internet, books, magazines and articles available for the proponent. Different published studies in the internet were used by the proponent to support the research. Different reference books were used by the proponent for the analysis of components and circuits used on the designing phase of the system.

**3.3.5 Procedures**

**a. Data gathering procedure**

One of the most decisive parts of the research is the data gathering because, it is where the objective of the research will be developed further. The proponent used different methods on gathering data necessary to have a firm grasp on the research they are working. The researchers used internet method at first to have initial knowledge on the objectives that needs to be developed. Internet method is useful for introduction of data needed in the research. On the other hand, the library method that the proponent also used develops a firm grasp on the topics needed to do the research, a deeper understanding on the researcher should be develop on this stage. One of the result of the researchers' data gathering using these methods is that trainers can significantly affect the student's prowess on a specific area or subject, this results on having a firmer goal of the research. Another way of gathering data is the interview method, the researchers used this method to have information that can only be obtain from the experts and professionals. The proponent need expert to validate the project if it is in line with the target subject.

**b. Designing and Simulation of the circuit procedure**

On designing the circuit for the power supply of the trainer, experiment circuit, and the circuit for the waveform display the proponent tread different steps before arriving to the final design of the circuits. Multisim is software that can simulate circuits that contains electronics devices; this software can almost simulate all the available electronic components in the market. The proponent used this software to simulate the initial design of the circuit based on the ideal assumption and solving that the proponent desired. After acquiring the desired output on the software simulation using Multisim the proponent move to the simulation on the breadboard. The ideal data that are obtained through solving are different from the data gathered on the breadboard simulation, due to this scenario few more adjustment was made during the breadboard simulation of the circuits. kiCAD and easyEDA are software are used to design the board of the circuit, all of the circuits that are already finished testing were immediately brought to this stage. The two softwares were used simultaneously for designing due to limitations of each softwares. Footprint of some components was not found on either of the two softwares.

**c. Calibration and Accuracy Testing**

Following the board designing is another testing of the circuits that are already on the circuit board. The proponent will use digital oscilloscope to test each circuit, if the desired output is obtaining then the circuit is not faulty. On the waveform display circuit were calibration is needed the laboratory equipment are necessary to test its accuracy, the proponent gathered the data on both the digital oscilloscope and the designed waveform display circuit.

**d. Designing of Android application and other programming**

The proponent will use the MIT app inventor, online software used for designing android application; this is where the proponent designed the application that will be the Graphic User Interface of the trainer. This software utilizes the use of block programming where the block represents a pre-set code and the user just needs to connect or combine the compatible blocks based on the algorithm that the user needs. The proponent will also use Arduino IDE software that is used to program the Arduino UNO, this is where the algorithm of counting frequency, input signal processing and sending the processed data on the android device via Bluetooth communication of the waveform display circuit. The system's android application will be uploaded to the internet; the download link of the application will be seen on the printed user manual of the system. The application will not be uploaded to mobile app store for the time being.

**e. Data processing and comparison for Accuracy Testing**

The proponent used t-test which is the comparison of the mean average of two variables, to compare the measured parameters using the trainer and the measured parameter using the digital oscilloscope, this test proves that the measurement using the trainer is almost as accurate as the test equipment on the laboratories. Another method of testing is done by the proponent and this is the User Acceptance Test, in this test the end user needs to evaluate the project itself and verify it if the required parameters are met, by the trainer itself. The population of this test are professionals in the industry, instructors and technicians on different universities. With the user acceptance test accepted by the population that were tested the research was deemed to be useful for the target subject.

**Flow Chart**

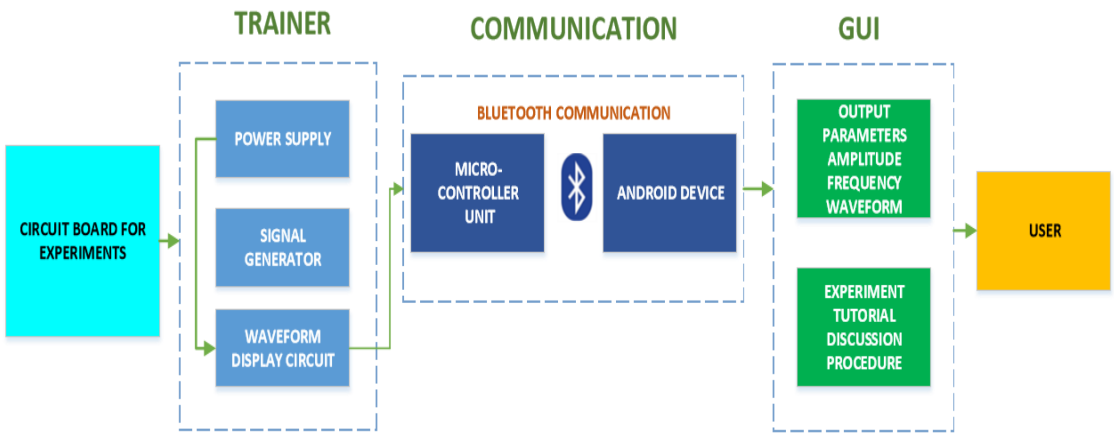


**Figure 9. Block Diagram**

The system block diagram shows that with the component as hardware input of the trainer for the specific experiments and circuit used. The microcontroller will gather the data from the circuit then convert it so that it can be transferred through BLE and process it to be display on the android app. By communication of the app and circuit the experiment shall be done.

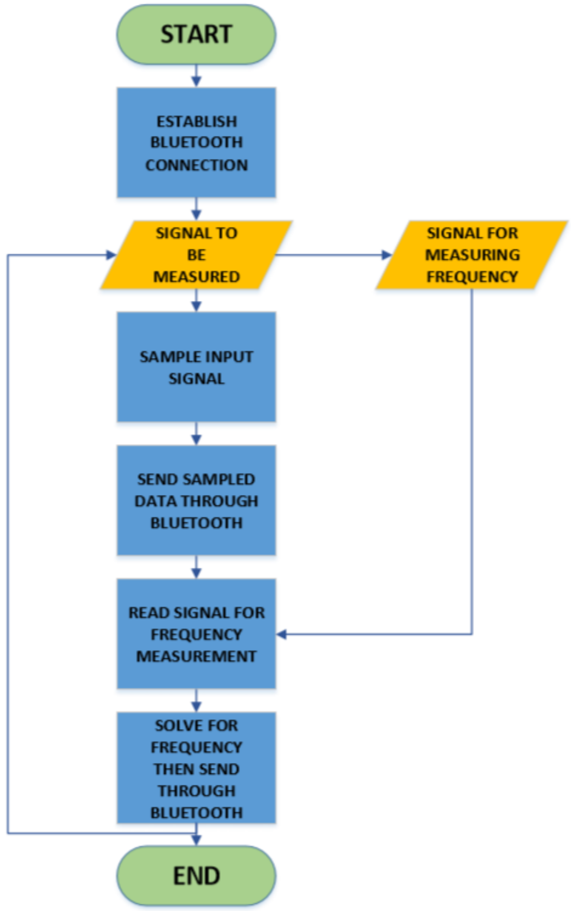


**Figure10. Arduino Uno Flow Chart**

Upon establishing Bluetooth connection between the android device and the Arduino, the built-in ADC of the Arduino will sample the input signal fed on the analog input of the Arduino. Upon sampling the program will use this sampled data to send it to the android device through Bluetooth communication. After sending the data for the waveform capturing the Arduino will read signal that will count frequency through its digital pin. After reading the input signal from the digital pin the program will output the measured frequency and send it to the android device through Bluetooth. This cycle of reading and sending data will repeat until the circuit or the Arduino is turned off.

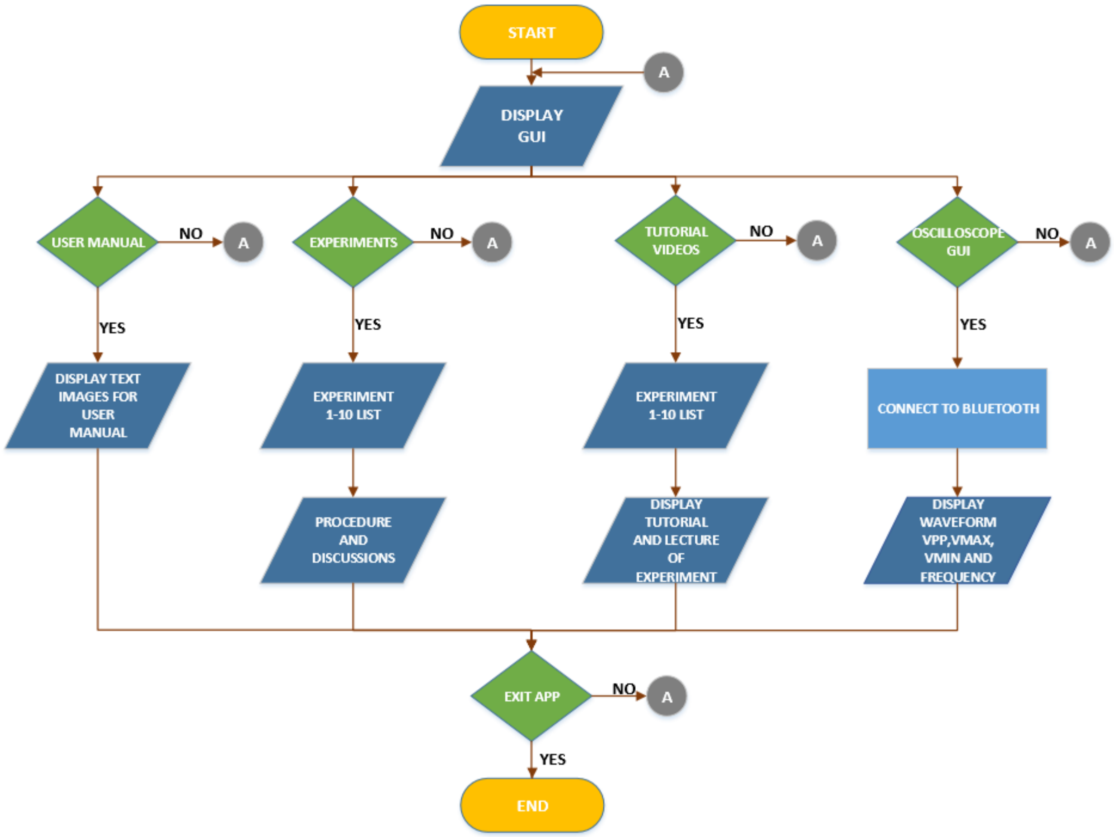


**Figure 11. Android Application Flow Chart**

Upon starting the android application, there will be tabs for the user to select, these are user manual tab, experiments tab, tutorial tabs, and waveform display tab. On the user manual tab, upon clicking it, the user manual will be shown on the screen, the manual contains how to use the whole trainer, safety precautions and other notes of the proponent for the user. When the experiment tab is clicked, it will show the list of the available experiments prepared by the proponent, on the list of the experiment clicking any of those will show the procedure and discussion for the specific experiment. When the tutorial videos tab, it will show the list of the available experiment then clicking one item on the list will show the video tutorial for that experiment. Upon clicking the waveform display tab it will show the list of the paired Bluetooth devices, then by clicking the right Bluetooth device, the android device will start to receive data from the Arduino and plot it to show the waveform and other parameters.

## Chapter 4
## RESULT AND DISCUSSION

This chapter includes all the data of each experiment. These are numerical values that every experiment, it has its frequency, maximum and minimum voltage, average voltage and peak-to-peak voltage and series of trials and test for each of the experiment board.

TABLE 1 EXPERIMENT 1.1: SCR as Light Dimmer

| Trial | Resistance (1kohm interval) | Average Frequency | Average Vp | Average Vpp |
|---|---|---|---|---|
| 1-50 | 0-50kohm | 59.881Hz | 6.819V | 6.965V |

Table 1 shows the average data of SCR as light dimmer that needs the loads controlled by the SCR measured using digital oscilloscope.

TABLE 2 EXPERIMENT 1.1: SCR as Light Dimmer

| Trial | Resistance (1kohm interval) | Average Frequency | Average Vp | Average Vpp |
|---|---|---|---|---|
| 1-50 | 0-50kohm | 60Hz | 7.0914V | 6.9521V |

Table 2 shows the average data of SCR as light dimmer that needs the loads controlled by the SCR measured using the prototype.

$$\frac{59.881-60}{59.881} \times 100\% = 0.1987\% \; error\ in\ terms\ of\ average\ frequency$$

$$\frac{7.0914-6.819}{6.819} \times 100\% = 3.99\% \; error\ in\ terms\ of\ average\ Vp$$

$$\frac{6.9521-6.965}{6.965} \times 100\% = 0.1852\% \; error\ in\ terms\ average\ Vpp$$

TABLE 3 EXPERIMENT 1.2**:** Triac Gate Triggering

| Trial | Resistance (1kohm interval) | Average Frequency | Average Vp | Average Vpp |
|---|---|---|---|---|
| 1-50 | 1-50kohm | 59.6724 Hz | -6.82758V | 16.810V |

Table 3 This shows the data of triac gate triggering and the effect of AC on the circuit. The Triac controls the circuit and and how it conducts in both direction measured using digital oscilloscope.

TABLE 4 EXPERIMENT 1.2**:** Triac Gate Triggering

| Trial | Resistance (1kohm interval) | Average Frequency | Average Vp | Average Vpp |
|---|---|---|---|---|
| 1-50 | 1-50kohm | 59.7759 Hz | -6.6379V | 16.386V |

Table 4 This shows the data of triac gate triggering and the effect of AC on the circuit. The Triac controls the circuit and and how it conducts in both direction measured using digital oscilloscope measured using the prototype.

$$\frac{59.7759\ -59.6724}{59.6724} \times 100\% = 0.1734\%\ error\ in\ terms\ of\ average\ frequency$$

$$\frac{-6.1379 - -6.82758}{-6.82758} \times 100\% = 2.7781\%\ error\ in\ terms\ of\ average\ Vp$$

$$\frac{16.386 - 16.810}{16.810} \times 100\% = 2.5223\%\ error\ in\ terms\ average\ Vpp$$

TABLE 5 EXPERIMENT 2.1: Programmable Unijunction Transistor

| Trial | Resistance (1kohm interval) | Average Frequency | Average Vp | Average Vpp |
|---|---|---|---|---|
| 1-50 | 1-50kohm | 51.588 Hz | 2.4315V | 1.6925V |

Table 5 Programmable Unijunction Transistor the data shows how the PUT controls the circuit measured using digital oscilloscope.

TABLE 6 EXPERIMENT 2.1: Programmable Unijunction Transistor

| Trial | Resistance (1kohm interval) | Average Frequency | Average Vp | Average Vpp |
|---|---|---|---|---|
| 1-50 | 1.50kohm | 52.5 Hz | 2.4291V | 1.6886V |

Table 6 Programmable Unijunction Transistor the data shows how the PUT controls the circuit measured using the prototype.

$$\frac{52.5 \quad - 51.588}{51.588} \times 100\% = 1.7678\% \; error\ in\ terms\ of\ average\ frequency$$

$$\frac{2.4291 - 2.4315}{2.4315} \times 100\% = 0.0987\% \; error\ in\ terms\ of\ average\ Vp$$

$$\frac{1.6886 - 1.6925}{1.6925} \times 100\% = 0.2304\% \; error\ in\ terms\ average\ Vpp$$

TABLE 7 EXPERIMENT 2.2**:** Unijunction Transistor

| Trial | Resistance (1kohm interval) | Average Frequency | Average Vp | Average Vpp |
|---|---|---|---|---|
| 1-50 | 1-50kohm | 323.9 | 3.2256V | 1.5416V |

Table 7 Unijunction Transistor this data shows how the UJT control the circuit measured using digital oscilloscope.

TABLE 8 EXPERIMENT 2.2**:** Unijunction Transistor

| Trial | Resistance (1kohm interval) | Average Frequency | Average Vp | Average Vpp |
|---|---|---|---|---|
| 1-50 | 0-50kohms | 313.86 | 3.248 | 1.5744 |

Table 8 Unijunction Transistor this data shows how the UJT control the circuit measured using the prototype.

$$\frac{313.86 \quad - 323.9}{323.9} \times 100\% = 3.0997\% \, error\ in\ terms\ of\ average\ frequency$$

$$\frac{3.248 - 3.2256}{3.2256} \times 100\% = 0.6944\% \, error\ in\ terms\ of\ average\ Vp$$

$$\frac{1.5744 - 1.5416}{1.5416} \times 100\% = 2.1276\% \, error\ in\ terms\ average\ Vpp$$

TABLE 9 EXPERIMENT 4.1**:** Half Bridge Rectifier

| TRIAL | Average Frequency (Hz) | Average Vp (V) | Average Vpp (V) |
|---|---|---|---|
| 1-50 | 59.84 | 6.9488 | 7.1168 |

Table 9 Half Bridge Rectifier this data shows how the half wave rectifier flows to the circuit measured using digital oscilloscope.

TABLE 10 EXPERIMENT 4.1**:** Half Bridge Rectifier

| TRIAL | Average Frequency (Hz) | Average Vp (V) | Average Vpp (V) |
|---|---|---|---|
| 1-50 | 59.86 | 6.9412 | 7.1024 |

Table 10 Half Bridge Rectifier this data shows how the half wave rectifier flows to the circuit measured using digital oscilloscope.

$$\frac{59.86 \quad - 59.84}{59.84} \times 100\% = 0.0334\% \, error\ in\ terms\ of\ average\ frequency$$

$$\frac{6.9412 - 6.9488}{6.9488} \times 100\% = 0.1094\% \, error\ in\ terms\ of\ average\ Vp$$

$$\frac{7.1024 - 7.1168}{7.1168} \times 100\% = 0.2023\% \, error\ in\ terms\ average\ Vpp$$

TABLE 11 EXPERIMENT 4.2: Full Bridge Rectifier

| TRIAL | Average Frequency (Hz) | Average Vp (V) | Average Vpp (V) |
|---|---|---|---|
| 1-50 | 119.76 | 6.639 | 6.8784 |

Table11 Full Bridge Rectifier, the data show how the rectifier flows to the circuit measured using digital oscilloscope.

TABLE 12 EXPERIMENT 4.2**:** Full Bridge Rectifier

| TRIAL | Average Frequency (Hz) | Average Vp (V) | Average Vpp (V) |
|---|---|---|---|
| 1-50 | 119.78 | 6.6416 | 6.8016 |

Table 12 Full Bridge Rectifier, the data show how the rectifier flows to the circuit measured using the prototype.

$$\frac{119.78 \quad - 119.76}{119.76} \times 100\% = 0.0167\% \; error\ in\ terms\ of\ average\ frequency$$

$$\frac{6.6416 - 6.639}{6.639} \times 100\% = 0.0391\% \; error\ in\ terms\ of\ average\ Vp$$

$$\frac{6.8016 - 6.8784}{6.8784} \times 100\% = 1.1165\% \; error\ in\ terms\ average\ Vpp$$

**Phase Controlled Rectifier**

TABLE 13 EXPERIMENT 5.1: Single-Phase Full-Wave Bridge Controlled Rectifier

| TRIAL | Average Vin(min) Vpeak | Average Vin(max) Vpeak) | Average Vout(min) Vpeak) | Average Vout(max) Vpeak |
|---|---|---|---|---|
| 1-30 | 15.679 | 19.489 | 12.57 | 16.514 |

Table 13 contents were measured using a digital oscilloscope.

TABLE 14 EXPERIMENT 5.1: Single-Phase Full-Wave Bridge Controlled Rectifier

| TRIAL | Average Vin(min) Vpeak | Average Vin(max) Vpeak) | Average Vout(min) Vpeak) | Average Vout(max) Vpeak |
|---|---|---|---|---|
| 1-30 | 15.7297 | 19.563 | 12.66 | 16.5527 |

Table 14 contents were measured using the prototype.

$$\frac{15.7297 \quad - 15.679}{15.679} \times 100\% = 0.3234\% \, error\ in\ terms\ of\ average\ Vin(min)\ Vpeak$$

$$\frac{19.563 - 19.489}{19.489} \times 100\% = 0.3797\% \, error\ in\ terms\ of\ average\ Vin(max)\ Vpeak$$

$$\frac{12.66 - 12.57}{12.57} \times 100\% = 0.716\% \, error\ in\ terms\ average\ Vout(min)\ Vpeak$$

$$\frac{16.5527 - 16.514}{16.514} \times 100\% = 0.2343\% \, error\ in\ terms\ of\ average\ Vout(max)\ Vpeak$$

TABLE 15 EXPERIMENT 5.2: B) Symmetrical Halfwave Controlled Semi-converter Rectifier

| TRIAL | Average Vin(min) Vpeak | Average Vin(max) Vpeak) | Average Vout(min) Vpeak) | Average Vout(max) Vpeak |
|---|---|---|---|---|
| 1-30 | 15.4157 | 19.3459 | 12.35 | 16.3697 |

Table 15 contents were measured using a digital oscilloscope.

TABLE 16 EXPERIMENT 5.2: B) Symmetrical Halfwave Controlled Semi-converter Rectifier

| TRIAL | Average Vin(min) Vpeak | Average Vin(max) Vpeak) | Average Vout(min) Vpeak) | Average Vout(max) Vpeak |
|---|---|---|---|---|
| 1-30 | 15.355 | 19.299 | 12.35 | 16.3307 |

Table 16 contents were measured using the prototype.

$$\frac{15.355 \quad - 15.4157}{15.4157} \times 100\% = 0.3937\% \; error\ in\ terms\ of\ average\ Vin(min)\ Vpeak$$

$$\frac{19.299 - 19.3459}{19.3459} \times 100\% = 0.2424\% \; error\ in\ terms\ of\ average\ Vin(max)\ Vpeak$$

$$\frac{12.35 - 12.35}{12.35} \times 100\% = 0\% \; error\ in\ terms\ average\ Vout(min)\ Vpeak$$

$$\frac{16.3307 - 16.3697}{16.3697} \times 100\% = 0.2383\% \; error\ in\ terms\ of\ average\ Vout(max)\ Vpeak$$

TABLE 17 EXPERIMENT 5.3: C) Asymmetrical Halfwave Controlled Semi-converter Rectifier

| TRIAL | Average Vin(min) Vpeak | Average Vin(max) Vpeak) | Average Vout(min) Vpeak) | Average Vout(max) Vpeak |
|---|---|---|---|---|
| 1-30 | 15.509 | 19.470 | 12.406 | 16.6 |

Table 17 contents were measured using a digital oscilloscope.

TABLE 18 EXPERIMENT 5.3: C) Asymmetrical Halfwave Controlled Semi-converter Rectifier

| TRIAL | Average Vin(min) Vpeak | Average Vin(max) Vpeak) | Average Vout(min) Vpeak) | Average Vout(max) Vpeak |
|---|---|---|---|---|
| 1-30 | 15.55 | 19.432 | 12.324 | 16.651 |

Table 18 contents were measured using the prototype.

$$\frac{15.55 \quad - 15.509}{15.509} \times 100\% = 0.2644\% \; error\ in\ terms\ of\ average\ Vin(min)\ Vpeak$$

$$\frac{19.432 - 19.470}{19.470} \times 100\% = 0.1952\% \; error\ in\ terms\ of\ average\ Vin(max)\ Vpeak$$

$$\frac{12.324 - 12.406}{12.406} \times 100\% = 1.3864\% \; error\ in\ terms\ average\ Vout(min)\ Vpeak$$

$$\frac{16.651 - 16.6}{16.6} \times 100\% = 0.3072\% \; error\ in\ terms\ of\ average\ Vout(max)\ Vpeak$$

TABLE 19 EXPERIMENT 6: Switch mode power supply

| TRIAL | Average Vin(max) Vac | Average Vout Vdc |
|---|---|---|
| 1-30 | 23.762 | 4.805 |

Table 19 contents were measured using a digital oscilloscope.

TABLE 20 EXPERIMENT 6: Switch mode power supply

| TRIAL | Average Vin(max) Vac | Average Vout Vdc |
|---|---|---|
| 1-30 | 23.815 | 4.795 |

Table 20 contents were measured using the prototype.

$$\frac{23.815 \quad - 23.762}{23.762} \times 100\% = 0.223\% \; error \; in \; terms \; of \; Average \; Vin(max)Vac$$

$$\frac{4.795 - 4.805}{4.805} \times 100\% = 0.2081\% \; error \; in \; terms \; of \; Average \; Vout \; Vdc$$

**Single Phase Inverter**

TABLE 21 EXPERIMENT 7.1: A) Parallel inverter

| TRIAL | Average Vin(min) Vpeak | Average Vin(max) Vpeak) | Average Vout(min) Vpeak) | Average Vout(max) Vpeak |
|---|---|---|---|---|
| 1-30 | 4.76 | 11.7733 | 3.80067 | 10.786 |

Table 21 contents were measured using a digital oscilloscope.

TABLE 22 EXPERIMENT 7.1: A) Parallel inverter

| TRIAL | Average Vin(min) Vpeak | Average Vin(max) Vpeak) | Average Vout(min) Vpeak) | Average Vout(max) Vpeak |
|---|---|---|---|---|
| 1-30 | 4.798 | 11.804 | 3.9 | 10.8377 |

Table 22 contents were measured using the prototype.

$$\frac{4.798 \ - 4.76}{4.76} \times 100\% = 0.7983\% \ error \ in \ terms \ of \ average \ Vin(min) \ Vpeak$$

$$\frac{11.804 - 11.7733}{11.7733} \times 100\% = 0.2608\% \ error \ in \ terms \ of \ average \ Vin(max) \ Vpeak$$

$$\frac{3.9 - 3.80067}{3.80067} \times 100\% = 2.6135\% \ error \ in \ terms \ average \ Vout(min) \ Vpeak$$

$$\frac{10.8377 - 10.786}{10.786} \times 100\% = 0.6473\% \ error \ in \ terms \ of \ average \ Vout(max) \ Vpeak$$

TABLE 23 EXPERIMENT 7.2: H-Bridge Inverter

| TRIAL | Average Vin(min) Vpeak | Average Vin(max) Vpeak) | Average Vout(min) Vpeak) | Average Vout(max) Vpeak |
|---|---|---|---|---|
| 1-30 | 4.8197 | 11.4147 | 3.837 | 10.7737 |

Table 23 contents were measured using a digital oscilloscope.

TABLE 24 EXPERIMENT 7.2: H-Bridge Inverter

| TRIAL | Average Vin(min) Vpeak | Average Vin(max) Vpeak) | Average Vout(min) Vpeak) | Average Vout(max) Vpeak |
|---|---|---|---|---|
| 1-30 | 4.802 | 11.503 | 3.765 | 10.8567 |

Table 24 contents were measured using the prototype.

$$\frac{4.802 \ - 4.8197}{4.8197} \times 100\% = 0.3672\% \ error \ in \ terms \ of \ average \ Vin(min) \ Vpeak$$

$$\frac{11.503 - 11.4147}{11.4147} \times 100\% = 0.7736\% \ error \ in \ terms \ of \ average \ Vin(max) \ Vpeak$$

$$\frac{3.765 - 3.837}{3.837} \times 100\% = 4.222\% \ error \ in \ terms \ average \ Vout(min) \ Vpeak$$

$$\frac{10.8567 - 10.7737}{10.7737} \times 100\% = 0.7704\% \ error \ in \ terms \ of \ average \ Vout(max) \ Vpeak$$

**Resonant Converter**

TABLE 25 EXPERIMENT 8.1: Buck Converter

| TRIAL | Average Vin | Average Vout |
|---|---|---|
| 1-30 | 11.6303 | 4.864 |

Table 25 contents were measured using a digital oscilloscope.

TABLE 26 EXPERIMENT 8.1: Buck Converter

| TRIAL | Average Vin(max) Vac | Average Vout Vdc |
|---|---|---|
| 1-30 | 11.5756 | 4.765 |

Table 26 contents were measured using the prototype.

$$\frac{11.5756 \quad - 11.6303}{11.6303} \times 100\% = 0.4703\% \; error \; in \; terms \; of \; Average \; Vin(max)Vac$$

$$\frac{4.765 - 4.864}{4.864} \times 100\% = 2.0353\% \; error \; in \; terms \; of \; Average \; Vout \; Vdc$$

TABLE 27 EXPERIMENT 8.2: Boost Converter

| TRIAL | Average Vin | Average Vout |
|---|---|---|
| 1-30 | 4.8097 | 11.7397 |

Table 27 contents were measured using a digital oscilloscope.

TABLE 28 EXPERIMENT 8.2: Boost Converter

| TRIAL | Average Vin(max) Vac | Average Vout Vdc |
|---|---|---|
| 1-30 | 4.873 | 11.823 |

Table 28 contents were measured using the prototype.

$$\frac{4.873 \ - 4.8097}{4.8097} \times 100\% = 1.3161\% \; error \; in \; terms \; of \; Average \; Vin(max)Vac$$

$$\frac{11.823 - 11.7397}{11.7397} \times 100\% = 0.7096\% \; error \; in \; terms \; of \; Average \; Vout \; Vdc$$

TABLE 29 EXPERIMENT 8.3: Buck boost Converter

| TRIAL | Average Vin(max)Vdc Boost Mode | Average Vin(max)Vdc Buck Mode | Average Vout(max)Vdc Boost Mode | Average Vout(max)Vdc Buck Mode |
|---|---|---|---|---|
| 1-30 | 4.7557 | 11.8477 | 11.6743 | 4.814 |

Table 29 contents were measured using a digital oscilloscope.

TABLE 30 EXPERIMENT 8.3: Buck boost Converter

| TRIAL | Average Vin(max)Vdc Boost Mode | Average Vin(max)Vdc Buck Mode | Average Vout(max)Vdc Boost Mode | Average Vout(max)Vdc Buck Mode |
|---|---|---|---|---|
| 1-30 | 4.8675 | 11.7985 | 11.721 | 4.774 |

Table 30 contents were measured using the prototype.

$$\frac{4.8675 \ - 4.7557}{4.7557} \times 100\% = 2.3509\% \; error \; in \; terms \; of \; Average \; Vin(max)Vdc \; Boost \; Mode$$

$$\frac{11.7985 - 11.8477}{11.8477} \times 100\%$$

$$= 0.4153\% \; error \; in \; terms \; of \; Average \; Vin(max)Vdc \; Buck \; Mode$$

$$\frac{11.721 - 11.6743}{11.6743} \times 100\% = 0.4\% \; error \; in \; terms \; Average \; Vout(max)Vdc \; Boost \; Mode$$

$$\frac{4.774 - 4.814}{4.814} \times 100\% = 0.8309\% \; error \; in \; terms \; of \; Average \; Vout(max)Vdc \; Buck \; Mode$$

TABLE 31 EXPERIMENT 9: Power Conditioning and UPS

| USING OSCILLOSCOPE | | | | | | |
|---|---|---|---|---|---|---|
| SUPPLY/LINE OUTPUT VOLTAGES | | | | BATTERY OUTUT VOLTAGES | | |
| TRIAL | Vmax | Vmin | Vpp | Vmax | Vmin | Vpp |
| 1 | 12.6 | 12.588 | 0 | 12.616 | 12.616 | 0 |

Table 31 contents were measured using a digital oscilloscope.

TABLE 32 EXPERIMENT 9: Power Conditioning and UPS

| USING ANDROID APP | | | | | | |
|---|---|---|---|---|---|---|
| SUPPLY/LINE OUTPUT VOLTAGES | | | | BATTERY OUTUT VOLTAGES | | |
| TRIAL | Vmax | Vmin | Vpp | Vmax | Vmin | Vpp |
| 1 | 12.6248 | 12.6248 | 0 | 12.6054 | 12.6054 | 0 |

Table 32 contents were measured using the prototype.

The proponent had compared the developed prototype of Advance Power Supply Trainer with the existing similar trainers available in market by using cost benefit analysis.

TABLE 33: Summary of Percentage Errors

| Experiment Number | Experiment Average Error Percentage |
|---|---|
| EXPERIMENT 1.1 | 1.457966667 |
| EXPERIMENT 1.2 | 1.8246 |
| EXPERIMENT 2.1 | 0.698966667 |
| EXPERIMENT 2.2 | 1.9739 |
| EXPERIMENT 4.1 | 0.115033333 |
| EXPERIMENT 4.2 | 0.390766667 |
| EXPERIMENT 5.1 | 0.41335 |
| EXPERIMENT 5.2 | 0.2186 |
| EXPERIMENT 5.3 | 0.5383 |
| EXPERIMENT 6 | 0.21555 |
| EXPERIMENT 7.1 | 1.079975 |
| EXPERIMENT 7.2 | 1.5333 |

| | |
|---|---|
| EXPERIMENT 8.1 | 1.2528 |
| EXPERIMENT 8.2 | 1.01285 |
| EXPERIMENT 8.3 | 0.999275 |
| **OVERALL AVERAGE ERROR** | **0.915015556** |

Table 33 shows the overall average error which is 0.92% on all experiment modules made for the developed trainer in compliance with the CHED Memorandum #101 series of 2017 specifically for the subject Advanced Power Supply Systems.

TABLE 34: COST BENEFIT ANALYSIS

| | **Alternative 1** | **Alternative 2** | **Prototype** |
|---|---|---|---|
| **Total Cost of Development (Php):** | 22666.67 | 4080.31 | 14682 |
| **Total Cost of Benefits (Php):** | 33596 | 5716.47 | 29564 |
| **Mark-Up Investment (%):** | 50% | 50% | 50% |
| **Cost benefit ratio:** | 1.482 | 1.401 | 2 |

The table above shows the cost benefit analysis of the trainer with the two existing alternatives (see table (N)). It is clearly shown in the table the cost benefit ratio of the developed prototype is higher than the ratio of the two alternatives. The proponent assumed of 50% mark-up investment to each in order to have a fair adjustment and disregarded the inflation rate and discount rate to make the analysis ideal.

The formula to get the cost benefit ratio is:

**Benefit Ratio** = $\frac{Total\ Cost\ of\ Benefits}{Total\ Cost\ of\ Development}$

**TCD =** Total Cost of development

**TCB =** Total Cost of benefits

**Alternative 1:**

**TCD =** PHP 22666.67 **Benefit Ratio** = $\frac{Total\ Cost\ of\ Benefits}{Total\ Cost\ of\ Development}$

**TCB =** PHP 33596 **Benefit Ratio** = $\frac{\text{PHP 33596}}{\text{PHP 22666.67}}$

**Benefit Ratio** = 1.482

**Alternative 2:**

**TCD =** PHP 4080.31 **Benefit Ratio** = $\frac{Total\ Cost\ of\ Benefits}{Total\ Cost\ of\ Development}$

**TCB =** PHP 5716.47 **Benefit Ratio** = $\frac{\text{PHP 5716.47}}{\text{PHP 4080.31}}$

**Benefit Ratio** = 1.401

**Prototype:**

**TCD =** PHP 14682 **Benefit Ratio** = $\frac{Total\ Cost\ of\ Benefits}{Total\ Cost\ of\ Development}$

**TCB =** PHP 29564 **Benefit Ratio** = $\frac{\text{PHP PHP 14682}}{\text{PHP PHP 29564}}$

**Benefit Ratio** = 2

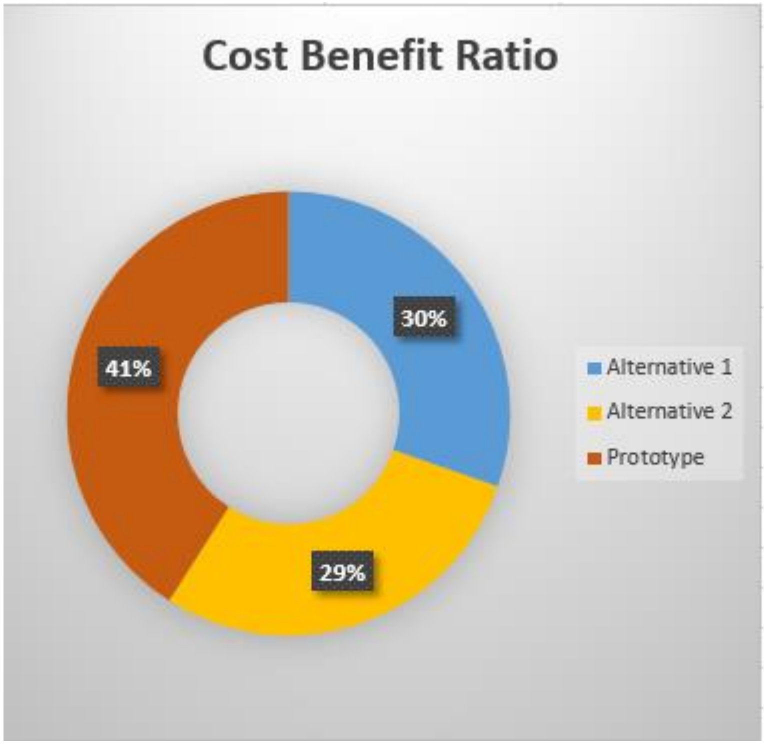


**Figure 12. Chart for the Cost Benefit Ratio**

Comparing the chart above, the percentage ratio for the benefit analysis of the two alternatives and the developed prototype. The developed prototype gained 41%, 11% higher than the Alternative 1 and 12% higher than

Alternative 2. This noticeably explain that among the three, the developed low-cost prototype by the proponent is more practical and beneficial.

TABLE 35: User Acceptance Testing Summary

| | Description of Testing | Average | Verbal Interpretation |
|---|---|---|---|
| Functional Stability | Is the training kit appropriate and compatible in learning the subject? | 3.8 | Strongly Agree |
| | Does the android app provide user manual and experiment manual? | 3.4 | Strongly Agree |
| | Are all fonts, colours, shading and toolbars consistent of the android app? | 3.8 | Strongly Agree |
| | Do the waveform graphics appear clearly and display correctly? | 3.2 | Agree |
| **Functional Stability Average** | | **3.55** | **Strongly Agree** |
| Performance Efficiency | Does the signal generator and waveform display meet the required output parameter? | 3.8 | Strongly Agree |
| | Does the android application is fully functional when connected to the trainer and does not experience malfunction? | 3.4 | Strongly Agree |
| **Performance Efficiency Average** | | **3.6** | **Strongly Agree** |
| Compatibility | Does the trainer and the android app perform its required function efficiently while sharing without detrimental impact between each other? | 3.4 | Strongly Agree |
| | Does the phone can connect the android application into the trainer? | 3.6 | Strongly Agree |
| | Is the android program compatible to the Android Pie, Oreo, Nougat, and Android Marshmallow? | 3.8 | Strongly Agree |
| **Compatibility Average** | | **3.6** | **Strongly Agree** |
| Usability | Is the android application easy to understand and to interact? | 3 | Agree |
| | Is the system can be used for a long time? | 3.4 | Strongly Agree |
| **Usability Average** | | **3.2** | **Agree** |

| | | | |
|---|---|---|---|
| Reliability | Does the android app can be used despite the presence of hardware faults? | 3.5 | Strongly Agree |
| | Does the output parameters from the android application is the same with the parameters measured from the oscilloscope? | 3.4 | Strongly Agree |
| | Do the system program and the trainer meet its use? | 3.4 | Strongly Agree |
| **Reliability Average** | | **3.43** | **Strongly Agree** |
| Maintainability | Is the android application works fine and not lagging when using it? | 3 | Agree |
| **Maintainability Average** | | **3** | **Agree** |
| Portability | Is the system not bulky? | 3.6 | Strongly Agree |
| | Can the training kit adapt to the continuous growth of terminology | 3.4 | Strongly Agree |
| **Portability Average** | | **3.5** | **Strongly Agree** |
| Usability in use | Are you satisfied with the result of the use? | 3.5 | Strongly Agree |
| | Does the training kit help you to understand the topics under Advanced Power Supply System? | 3.6 | Strongly Agree |
| **Usability in use Average** | | **3.55** | **Strongly Agree** |
| **Overall Average** | | **3.48** | **Strongly Agree** |

The table shows the summary of data gathered from the user acceptance testing in the following categories, functional stability, performance efficiency, compatibility, usability, reliability, maintainability, portability, and usability. The individuals selected for the user acceptance testing involved those from the electronics industry and academe. The table uses a 4-point Likert scale, 4 being the highest and 1 being the lowest, wherein 4 – strongly agree, 3 – agree, 2 – disagree, and 1 – strongly disagree. As shown in the table the trainer has an overall average of 3.48 in scores with verbal interpretation of strongly agree.

## Chapter 5

## SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

This Chapter presents the Summary of Findings, Conclusions and Recommendations of the study based on the analysis on Chapter 4 duly supported by the observations and experimentations made for the study.

The Summary of Findings contains the brief discussion about the answer to stated problems governing the study. The Conclusion states the wrapped-up end result of the study responding to each specific research problems. Recommendations were given to open a door for future improvement of this research.

### Summary of Findings

1. As required by the CHED memorandum order no. 101 series of 2017 under the subject advanced power supply systems 9 topics the following experiments where provided:
    - 1.1. Semiconductor switches – Experiment 1: Operation of Semiconductor Switches & Experiment 2: AC triggering of Semiconductor Switches
    - 1.2. Passive components for electronic power supply: Experiment 3 Passive Components for electronics power supply
    - 1.3. Rectifiers - Experiment 4: Half wave rectifier and full wave rectifier
    - 1.4. Phase controlled rectifiers and converters - Experiment 5: Phase Controlled Rectifier
    - 1.5. Switch-Mode Power Supply - Experiment 6: Switch Mode Power Supply
    - 1.6. Inverters – Experiment7: Single phase inverters
    - 1.7. Resonant Converters – Experiment 8: Resonant converter
    - 1.8. Power Conditioners and UPS - Experiment 9: Power Conditioning and UPS

1.9. Power supply design and applications in DC motor drives, synchronous motor drives, step motor drives, servo motor system, variable frequency motor control, harmonics and electromagnetic interference - Experiment 10: Application

2. An android application was developed that is able to show the output waveform of a measures signal wirelessly with a percentage error of 0.92% as compared to a standard bench top oscilloscope.
3. The overall system as assessed by the user acceptance testing with an overall average of 3.48 in scores with verbal interpretation of strongly agree. With an average of 3.55 (strongly agree) in functional stability, 3.6 (strongly agree) performance efficiency, 3.6 (strongly agree) compatibility, 3.2 (agree) usability, 3.43 (strongly agree) reliability, 3 (agree) maintainability, 3.5 (strongly agree) portability, and 3.55 (strongly agree) usability in individual categories using ISO 25010 to meet the requirements needed of the prototype and the program.

**Conclusions**

1. Trainer was developed both hardware and system requirements satisfied as all topics where covered as dictated in the CHED memorandum order no. 101 series of 2017 under the subject advanced power supply systems through the fabricated trainer alongside all necessary hardware such as the modules, power supply and function generator and for the software requirement an android application is provided as to provide the waveform display.
2. The system proves to be achievable and productive after the development. With the help of series of test and analysis, data showed that there is no significant difference on the measurement from the system with the measurement from certified measuring device such digital oscilloscope used by the proponent on testing stages. The accuracy of the

system that is greater than 95.5% passed the standards based on the Engineering Standard (ES-002) Instrument Error Calculation and Setpoint Determination.

3. The device and system were proven to be accepted as reflected on the user acceptance testing.

## Recommendations

1. Further development of the android application as to add features found on a standard bench top oscilloscope.
2. The body of the trainer should be change to a firmer material such as metal that are earthed for rigid and safe body. Solidified body can make the lifespan of the trainer longer than on hollowed cases.

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