DEVELOPMENT OF TIME DELAY VOLTAGE CONTROL FOR LEAD ACID BATTERY USING ARDUINO

NURUL NADIA BINTI MOHAMMAD

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Faculty of Electrical and Electronic Engineering
Universiti Tun Hussein Onn Malaysia

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ABSTRACT

A time delay controller with voltage control technique is designed and developed in this project. In order to control the output voltage, a DC-DC buckboost converter has been development. The buckboost circuit with mosfet as a switching component has been drives by using gate driver as a medium between buckboost circuit and the ARDUINO that generates the PWM signals. The several of input voltage range which is from 10V for minimum voltage until 18V for maximum voltage has been tested in this project to determine the effectiveness of the output results for charging a battery. Finally, the control performance was evaluated through both simulations by using MATLAB software and also the experimental hardware. The results are observed in three conditions which are simulation, open loop control and close loop control. The simulation and experimental hardware results indicate that this control method shows successful for charging a battery.

ABSTRAK

Sebuah pengawal penangguh masa dengan teknik kawalan voltan direka dan dilaksanakan dalam projek ini. Dalam usaha untuk mengawal voltan keluaran, litar buckboost arus terus telah direka dan dilaksanakan. Litar buckboost dengan MOSFET sebagai komponen pensuisan telah digunakan sebagai perantaraan diantara litar buckboost dan juga peranti papan Arduino yang menghasilkan isyarat PWM. Beberapa rangkaian input voltan iaitu daripada 10V untuk mimima voltan kepada 18V untuk maksima voltan telah diuji di dalam projek ini untuk menentukan keberkesanan keputusan dalam mengecas bateri. Akhirnya, kawalan dinilai melalui simulasi dengan menggunakan perisian MATLAB dan juga perkakasan eksperimen. Keputusan diperhatikan di dalam tiga keadaan iaitu simulasi, kawalan gelung terbuka dan kawalan gelung rapat. Keputusan simulasi dan perkakasan eksperimen menunjukkan bahawa kaedah kawalan ini berjaya untuk mengecas bateri.

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LIST OF SYMBOLS AND ABBREVIATIONS

PID - *Proportional Integral Derivative;*

PWM - *Pulse Width Modulation*

FLC - *Fuzzy Logic Controller*

ADC - *Analog to Digital Converter*

DAC - *Digital to Analog Converter*

DSP - *Digital signal Processing*

K_p - *Proportional gain*

K_i - *Integral gain*

K_d - *Derivative gain*

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CHAPTER 1

INTRODUCTION

1.1 Project background

A battery, which is actually an electric cell, is a device that produces electricity from a chemical reaction and therefore the battery is an essential component of almost in various applications in electrical systems such as electric vehicle and others. Batteries are also extensively adopted in various applications, such as telecommunication power supply, uninterruptible power supplies, photovoltaic systems and many of portable electronics products [1]. For example, a portable device requires a battery as its power source when an AC adapter is not available [2]. Normally, batteries are used to start engines and auxiliary power units, to provide emergency backup power for essential avionics equipment. Many of these functions are mission critical, so the performance and reliability of the battery is considerable importance such as rapid recharge capability. This is because the charging mode of the battery normally takes several hours to complete the charging. The battery acts very an important role in the system performance such as system run-time and system stability [2]. So, some factor must be taking into consideration for example rapidly charging in term of to maintain the battery performance and the time for the battery to fully charging.

DC-DC converters are very famous electronic devices used whenever to change the DC electrical power efficiently from one voltage level to another. For example, DC power converters are extensively used in various applications like power supplies, dc motor drives, front-end converters in adjustable-speed ac drives, HVDC transmission, SMPS, utility interface with non-conventional energy sources,

in process technology like welding, power supplies for telecommunications systems, aerospace, military environment and so on [3]. In general, converter has several topologies such as boost, buck, buck–boost and multi-level converters. The selection of the converter depends on the different applications that have been approached. There are five commonly used in DC-DC conversion topologies that suitable for battery operated systems which are buck, boost, non-inverting buck-boost, charge pump and flyback converters [2]. So, here the buck boost topology has been introduced as a converter to convert the voltage from the power supply to the battery.

In junction to control the charging process, the controller is an important element to achieve desired process charging in term of time. There are many controllers that have been developed such as proportional-integral-derivative (PID), fuzzy logic, P-resonant, neural network and others. However, time delay controller is been introduced as this controller have their advantages such as dynamic, simple structure compared to others controller. In recent years, time delay control schemes have been suggested as an effective way for a control of systems with unknown dynamics and uncertainties since these schemes require little knowledge of the dynamics of the system [4]. The development of time delay controller can control the battery with the used of voltage control technique. The voltage control method will control the instantaneous voltage waveform and also in term of accuracy. Therefore, this technique was normally used as the industry-standard to control the battery charging.

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. The typical uses of this software are includes math and computation, algorithm development, modeling, simulation, and prototyping, data analysis, application development, including Graphical User Interface building. Model-based design on other hand has many advantages compared to manual coding and is easy even for novice designers using MATLAB and Simulink as an integral part of modern power electronic and also control system design [5]. So, MATLAB have been approached as a medium to control the controller by using ARDUINO as a signal processing to interface with the system. ARDUINO is best known for its hardware and the combination enables to create projects that sense and control the physical world and also the software is free, open source, and cross-platform [6].

1.2   Problem statement

Batteries are widely used in various applications such as telecommunication power supply, electric vehicles and portable electronics products, for example lead-acid battery. As they are inexpensive compared to newer technologies, lead-acid batteries are widely used even when surge current is not important and other designs could provide higher energy densities. Lead-acid battery is an electrical storage device that uses a reversible chemical reaction to store energy. It has a capacity up to six or more volts. However, this battery has its own capacity charging mode that influent how long the battery will fully charging. The charge mode significantly influences the battery life and capacity [1]. Battery charging is related to the time taken to recharge any battery that dependent on the voltage and current applied. Normally, the used of batteries are depend on the application or works that have been applied. If the application or works used more capacity of the battery, therefore the capacity of the battery will reduce rapidly. If the charge current or voltage is too low, then the recharge time will be relatively long and if the current or voltage is high then the recharge time will be short. Here, the recharge capability has been approached to complete the charging and the time delay controller with voltage source technique is applied to resolve the battery charging making better replacement.

1.3   Project objectives

The objectives of this project are listed as follows:
1. To develop a time delay control as a controller in this system.
2. To develop the hardware for buck-boost circuit to control DC power supply.
3. To develop the gate driver as a medium connection between ARDUINO and the buck-boost circuit.
4. To investigate the communication between ARDUINO and MATLAB software as they are medium to the system.

1.4 **Scope project**

In this project the scope of work will be undertaken in the following four developmental stages:

- The type of the battery that has been used is lead-acid battery and the rating voltage is 12V and with 7Ah.
- The buck-boost circuit that been construct to control the input power supply and the battery that have the rating maximum output is about 14V and the value of the inductance and capacitance must be determined.
- The gate driver that been develop in order to connect the ARDUINO software and buck-boost circuit.
- The MATLAB software must be interconnected with the ARDUINO board as a signal processing to control the system.

CHAPTER 2

LITERATURE REVIEW

2.1   Battery

Battery is a device that consists of one or more electrochemical cells that convert stored chemical energy into electrical energy. Each battery consists of a negative electrode material, a positive electrode material, an electrolyte that allows ions to move between the electrodes, and terminals that allow current to flow out of the battery to perform a work. They are two types of battery which is primary battery and secondary primary. The primary battery is not rechargeable and must be replaced once the reactants are depleted. Common examples for primary include carbon-zinc (Leclanche or dry cell), alkaline-manganese, mercury-zinc, silver-zinc, and lithium cells The secondary battery can be discharged and recharged multiple times whereas the original composition of the electrodes can be restored by reverse current. Common examples of secondary battery include the lead-acid batteries used in vehicles and lithium ion batteries used for portable electronics. Batteries operate by converting chemical energy into electrical energy through electrochemical discharge reactions.

Batteries are rated in terms of their nominal voltage and ampere-hour capacity. The voltage rating is based on the number of cells connected in series and the nominal voltage of each cell (2.0 V for lead-acid and 1.2 V for nickel-cadmium) [7]. The ampere-hour (Ah) capacity available from a fully charged battery depends on its temperature, rate of discharge, and age [7].

2.1.1   Rechargeable battery

A rechargeable battery, storage battery, or accumulator is a type of electrical battery. It comprises one or more electrochemical cells. It is known as a secondary cell because its electrochemical reactions are electrically reversible. Rechargeable batteries come in many different shapes and sizes, ranging from button cells to megawatt systems connected to stabilize an electrical distribution network. Several different combinations of chemicals that are commonly used including lead-acid, nickel cadmium(NiCd), nickel metalhydride(NiMH), lithium ion(Li-ion), and lithium ion polymer(Li-ion polymer). The most popular types of rechargeable batteries nowadays, are the Sealed-Lead-Acid(SLA), Nickel-Cadmium(NiCd), Nickel-Metal-Hydride(NiMH), and Lithium-Ion(Li-Ion) [8]. Normally, the rechargeable battery serves the important functions. The function is to provide power supply to the appliances and another function is to be able to replace the battery if the need arises. The size of the chargers is very important to the life and service of the battery [9]. The rechargeable battery must have enough capacity to easily gas the battery under charging conditions. The Figure 2.1 illustrates a generalized battery charging circuit [8]. The battery is charged with a constant current until fully charged. The voltage developed across the resistor is used to maintain the constant current. The voltage is continuously monitored, and the entire operation is under the control of a microcontroller which may even have an on-chip A/D converter.
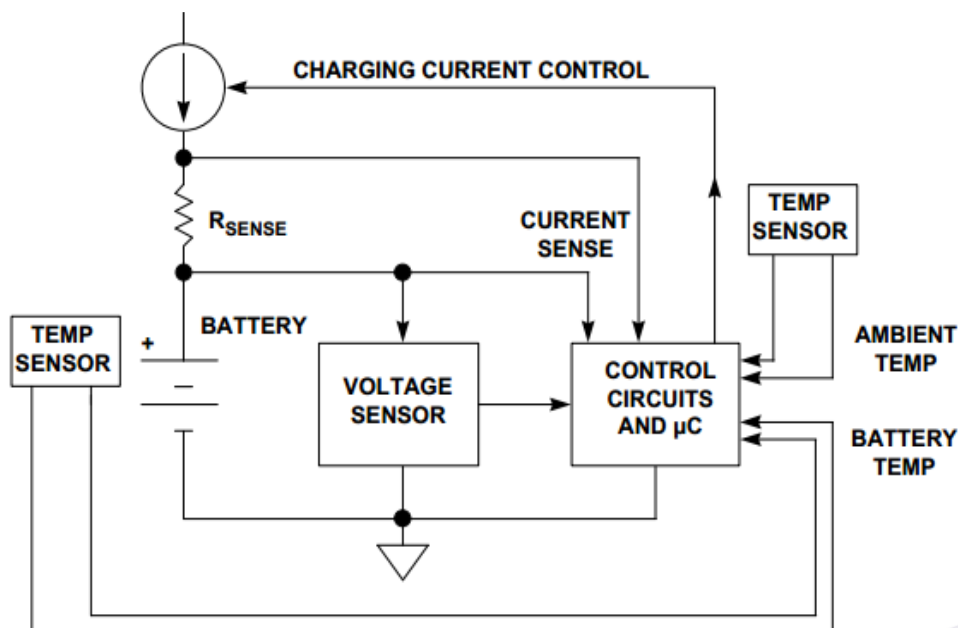
Figure 2.1 Generalized battery charging circuit

2.2   Converter (DC to DC)

DC to DC converters are important in portable electronic devices such as cellular phones and laptop computers. Most DC to DC converters also regulate the output voltage. A DC-to-DC converter also converts a source of direct current (DC) from one voltage level to another. It is a class of power converter. DC-DC converter was very useful for portable applications in general or any application which uses rechargeable batteries [10]. Dc converters widely used for traction motor in electric automobiles, trolley cars, marine hoists, and forklift trucks. They provide smooth acceleration control, high efficiency, and fast dynamic response. The basic DC-DC converters use a pair of switches, usually one controlled example MOSFET and one uncontrolled example diode to achieve unidirectional power flow from input to output. The converters also use one capacitor and one inductor to store and transfer energy from input to output and buck converter also filter or give smooth voltage and current. There are many types of DC-DC convertor which is buck (step down) converter, boost (step-up) converter, buck-boost (step up- step-down) convertor [11].

The functions of DC-DC converters are stated as below:

i. Convert a DC input voltage Vs into a DC output voltage Vo.

ii. Regulate the DC output voltage against load and line variations.

iii. Reduce the AC voltage ripple on the DC output voltage below the required level.

iv. Provide isolation between the input source and the load (if required).

2.2.1 Buck Converter
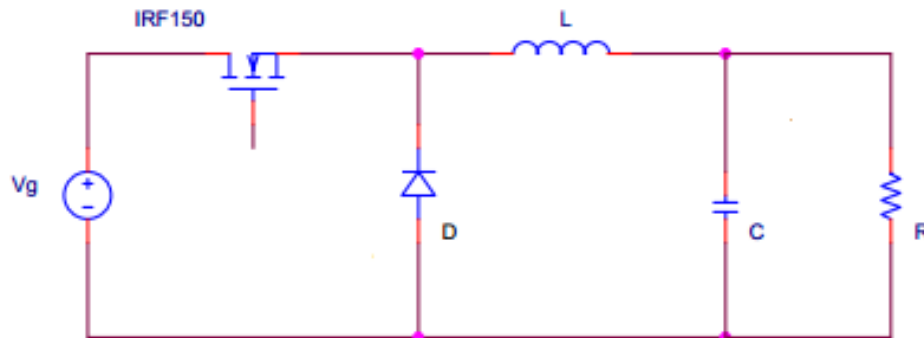
Figure 2.2: General buck converter circuit

The buck converter is used to generate a lower output voltage from a higher DC input voltage. Stepdown as refer to buck converters are integral to modern electronics. Stepdown converters transfer small packets of energy using a switch, a diode, an inductor and several capacitors. Though substantially larger and noisier than their linear-regulator counterparts, buck converters offer higher efficiency in most cases. The Figure 2.2 depicts the general buck converter circuit.

2.2.2 Boost Converter
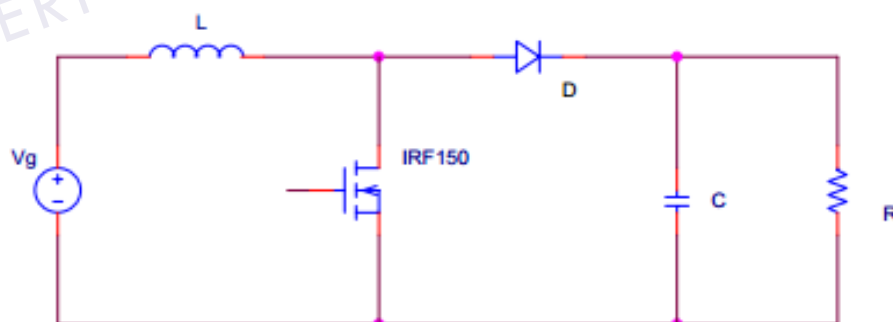
Figure 2.3: General boost converter circuit

Power for the boost converter can come from any suitable DC sources, such as batteries, solar panels, rectifiers and DC generators. A boost converter is a DC to DC converter with an output voltage greater than the source voltage. A boost

converter is sometimes called a step-up converter since it steps up the source voltage. The Figure 2.3 depicts the general boost converter circuit.

2.2.3 Buck-boost Converter
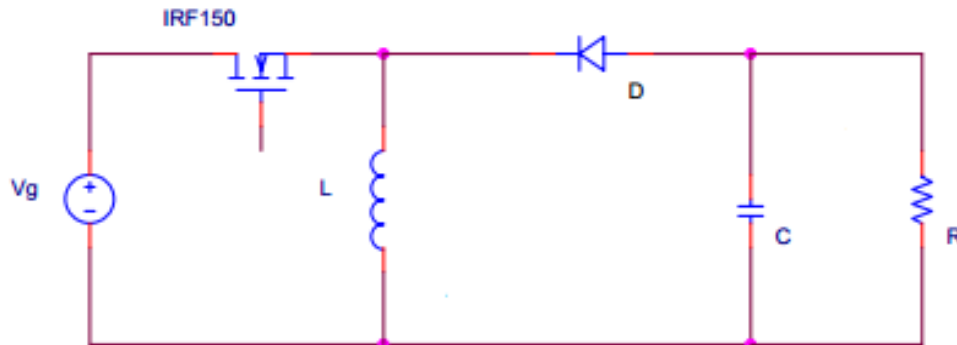
Figure 2.4: General buck boost converter circuit

DC-DC converters have a wide range of uses today and are becoming increasingly more important in daily use. DC power supplies are probably the largest use of the converters and are much more compact and efficient than the old method of conversion with transformers. These converters can have an output of any range; for instance, one can run logic gates or large dc motor drives with a simple converter. The buck–boost converter is a type of DC-to-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. The two different topologies are called buck–boost converter. Both of them can produce a range of output voltages, from an output voltage much larger (in absolute magnitude) than the input voltage, down to almost zero. Both buck (step-down) and boost (step-up) converters are widely used in power management circuits, little attention has been given to integrated buck-boost converters for portable applications [12]. Figure 2.4 shows the general buck-boost converter circuit.

2.3 Controller

A controller is a device, possibly in the form of a chip, analogue electronics, or computer, which monitors and physically alters the operating conditions of a given dynamical system. Many controllers have been developed, that can be divided into two classifications, passive and adaptive power controller. The example for

passive power controller is hysteresis, relay and sliding mode control and for adaptive power controller is PID, fuzzy, and P-resonant controller. Each of them has their own advantages, such as simple structure and low maintenance cost.

2.3.1 Adaptive controller

Adaptive controller is a controller that can modify its behavior in response to changes in the dynamics of the process and the disturbances. A great number of industrial control loops are under adaptive control. These include a wide range of applications in aerospace, process control, ship steering, robotics and other industrial control systems. Because of the ability of the adaptive controller, there are the reasons for using adaptive control such as variations in process dynamics, variations in the character of the disturbances and engineering efficiency [13]. The model reference adaptive system of [14,15] assumed to be represented by a transfer function as in eqn (2.1):

$$\widehat{W}_p(s) = K_p \frac{\hat{n}_p(s)}{\hat{d}_p(s)} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2.1)$$

Where $\hat{n}_p$ and $\hat{d}_p$ are relatively prime monic polynomials of degree m and n respectively and K_p is a scalar.

Battery is receiving a vast amount of attention as the most important energy storage device in electric vehicles. Due to the battery dynamics, an adaptive and nonlinear methods, such as an extended Kalman filter and a sliding-mode observer are deployed [16]. The methodology has been applied to improve the energy and power density of the batteries.

In paper [17] explains a novel multiple model adaptive controller for a class of nonlinear system in parameter-strict-feedback form is proposed. It not only improves the transient performance significantly, but also guarantees the stability of all the states of the closed-loop system. A simulation example is proposed to illustrate the effectiveness of the developed multiple model adaptive controller.

2.3.1.1 PID controller
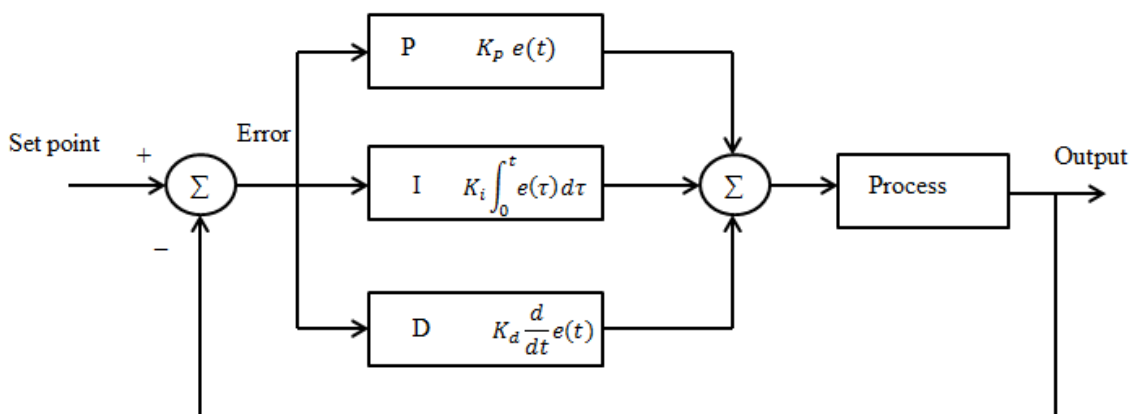
Figure 2.5: PID controller

The PID controller (proportional integral derivative controller) is widely used in industrial control system as shown in Figure 2.5. A PID controller calculates an "error" value as the difference between the measured process variable and the desired set point. The PID controller calculation involves three separate constants and is accordingly sometimes called three-term control which the proportional, the integral and derivative values are denoted by P, I and d respectively. The proportional, integral, and derivative terms are summed to calculate the output of the PID controller. Defining $u(t)$ as the controller output, the final form of the PID algorithm is in eqn (2.2):

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau)\, d\tau + K_d \frac{d}{dt} e(t) \quad \cdots\cdots\cdots\cdots\cdots\cdots (2.2)$$

Where:

K_p: Proportional gain, a tuning parameter

K_i: Integral gain, a tuning parameter

K_d: Derivative gain, a tuning parameter

e: Error

t: Time or instantaneous time (the present)

τ: Variable of integration; takes on values from time 0 to the present t

The proportional component depends only on the difference between the set point and the process variable. This difference is referred to as the Error term.

The proportional gain determines the ratio of output response to the error signal. In general, increasing the proportional gain will increase the speed of the control system response. The integral component sums the error term over time. The result is that even a small error term will cause the integral component to increase slowly. The derivative component causes the output to decrease if the process variable is increasing rapidly. The derivative response is proportional to the rate of change of the process variable. Increasing the derivative time parameter will cause the control system to react more strongly to changes in the error term and will increase the speed of the overall control system response.

In the paper [18] explains a proposed method of computing Proportional, Integral and Derivative (PID) parameters controller for positive buck-boost converter with mode-select circuit and with wide range of input voltages. By employing PID controller the converter operates effectively and improves the output voltage, when the supply voltage changes[18]. Therefore, the proposed converter can improve its transient response when the supply voltage changes.

In the paper [19] explains a proposed of a PID controlled buck-boost DC-DC converter for battery load system. The complete converter-load system has been developed, analyzed, and validated by the simulation. Simulation results show robustness of the proposed method to system parameters variations.

2.3.1.2 Fuzzy controller

A fuzzy control system is a control system based on fuzzy logic. Fuzzy means uncertainty, fuzzy computes uncertainty by assigning values between 0 and 1 compared to conventional computation 0 or 1. This fuzzy logic involves computing using knowledge base and rule base. Fuzzy sets theory was first invented by Professor Lotfi Zadeh in 1973 and seeks to realize artificial intelligence and automation by formalizing sophisticated human thought and quantitative methods of judgment and then incorporating these in a automated control system [20]. Fuzzy logic controllers have been reported to be successfully used for a number of complex and nonlinear processes [21]. Therefore, the classical control algorithms such as PID, PI and others are difficult to implement due to non-linear current-time relationships of rechargeable batteries [20]. So, fuzzy logic controller is one of the demanding

controllers that can be implemented for charging battery. The Figure 2.6 illustrates the functional block diagram of fuzzy logic controller.
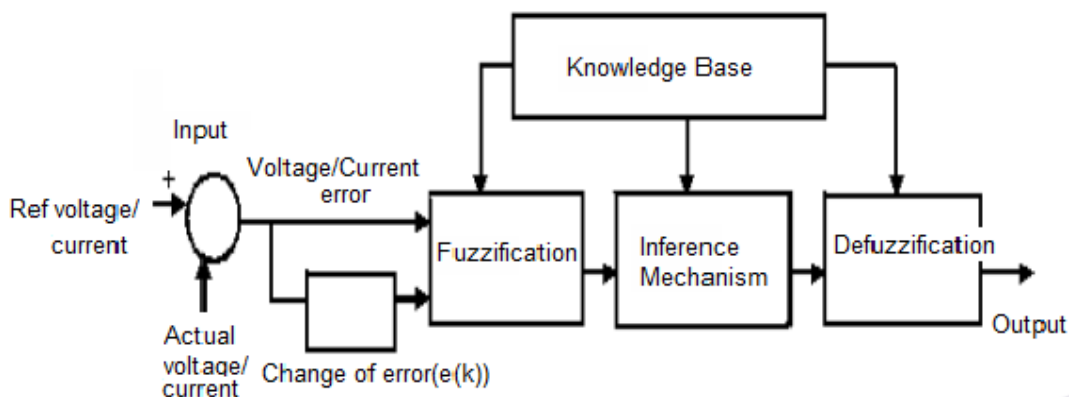
Figure 2.6 Functional block diagram of fuzzy logic controller

The paper [22] explains a proposed of a Fuzzy Logic Controlled (FLC) buck-boost DC-DC converter for solar energy-battery systems. For the controller FLC, PI, and FLC+PI controllers are used and the simulation results are compared. The result can be seen that there is no big overshoot in output voltage and no need for any change in parameters to stable the system. It can be noted that it is possible to use a fuzzy logic controller for power electronics applications and also practical to simulate the designed circuits in MATLAB or Simulink [22].

2.4   Proposed controller

Time delays control are common in a variety of systems, often caused by communication lags, material transport, delayed sensing and others. The time delay controller has been chosen because the time delay controller is suitable and simple controller for this application. In recent years, time delay control schemes have been suggested as an effective way for a control of systems with unknown dynamics and uncertainties since these schemes require little a priori knowledge of the dynamics of the system [23]. The basic idea is to approximate a disturbance or uncertainty with the time-delayed value of control inputs and derivatives of state variables at the previous time step. This algorithm does not require an explicit dynamic model nor does it depend on the estimation of specific parameters. Instead, it uses information

in the past to directly estimate the unknown dynamics or uncertainties at any given instant through the time delay [23]. Moreover, time delay control is depends on estimation of specific parameters, discontinuous control, nor repetitive actions [24].

Normally, time delay control is suitable for nonlinear system that varying with the time. A time delay controller has been suggested as an effective control technique for nonlinear time-varying systems with uncertain dynamics and for unpredictable disturbances [25]. Time delay in the structure of a controller may improve its performance [26]. Therefore the used of time delay as a controller in the system may enhance and gives better performance. The time delay controller normally involved delay component which is used to predict the future path. Essentially, the time delay controller proposed includes a delay element in a positive feedback and a reference model in the forward path [26].
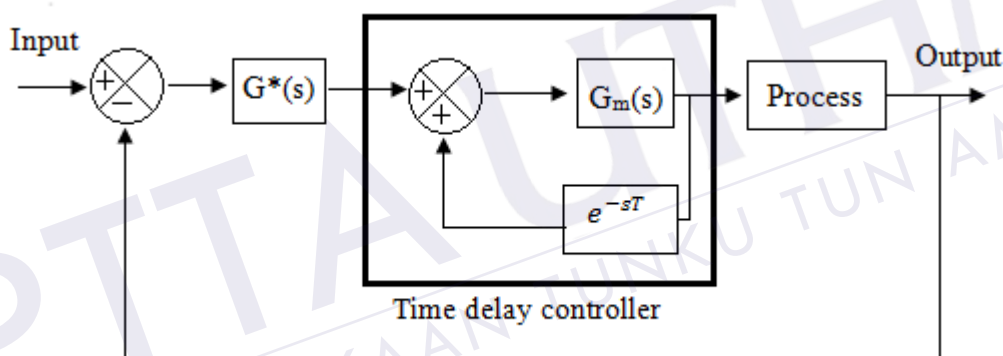
Figure 2.7: Basic time delay controller

Figure 2.7 illustrates basic time-delay controller where G(s) includes only the rational part of the transfer function and where Gm(s) is a rational transfer function that selected by the user. Suppose that the closed-loop reference model is represented by eqn (2.3).

$$e^{-st} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2.3)$$

Where t is the value of the time delay that is appropriate with the system.
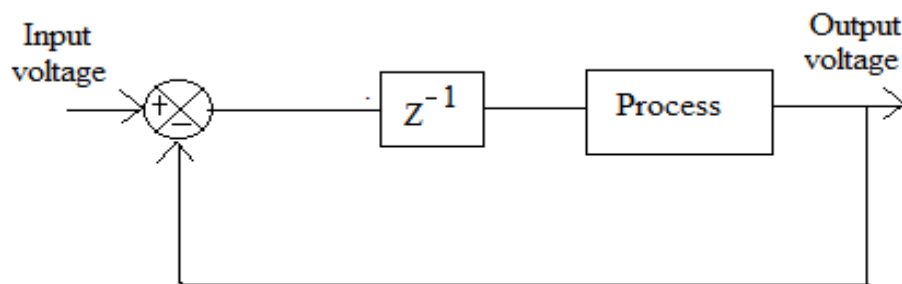
Figure 2.8: Time delay controller

This project proposed a time delay controller to control the voltage of the charging battery as depicts in Figure 2.7. The time delay control scheme is one of the simple controllers of the primary goal in this project to apply knowledge and technically on how to control a charging battery. Therefore, faster output that is in term of time is required for the battery charging system. Here, the controller which is time delay will control the charging of the battery. The main contribution in this project is the algorithm of the time delay controller.

$$Z^{-1} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2.4)$$

The eqn (2.4) has been implemented as the time delay controller algorithm. The main task of the control scheme in a voltage source is to obtain the voltage that is similar to the reference voltage signals although the input voltage is varied.

2.5   Arduino

ARDUINO is a single board microcontroller designed to make the process of using electronics in multidisciplinary projects more accessible that illustrates in Figure 2.8. The hardware consists of a simple open source hardware board designed around an 8-bit Atmel AVR microcontroller, though a new model has been designed around a 32-bit Atmel ARM. The software consists of a standard programming language compiler and a boot loader that executes on the microcontroller. The ARDUINO project is a fork of the open source wiring platform and is programmed using a wiring-based language (syntax and libraries), similar to C++ with some slight simplifications and modifications, and a Processing-based integrated development environment (IDE). The ARDUINO integrated development environment (IDE) is

a cross-platform application written in Java, and is derived from the IDE for the Processing programming language and the wiring projects.

Moreover, ARDUINO is used to create prototypes, its underlying hardware works at the same level of sophistication that engineers employ to build embedded devices[6]. ARDUINO is the best known neither for its hardware nor software. Both the hardware and the software are using ARDUINO. The combination enables to create projects that sense and control the physical world.

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation such as matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C and Simulink that adds graphical multi-domain simulation and Model-Based Design for dynamic and embedded systems. An additional package MATLAB Support Package for ARDUINO enables to use MATLAB or Simulink to communicate with the ARDUINO board over a USB cable. This package is based on a server program running on the board, which listens to commands arriving via serial port, executes the commands, and, if needed, returns a result.

Figure 2.9: Arduino board

CHAPTER 3

METHODOLOGY

The work includes stages such as designing, simulation, implementation and verification. The designing part involves using PROTEUS software for buckboost and gate driver design. The simulation part is conducted using MATLAB/Simulink software for controller design, download and implemented on the ARDUINO in the implementation stages. The verification stage involves the testing of the controller design using a hardware development to verify its correctness.

3.1 Block diagram of project
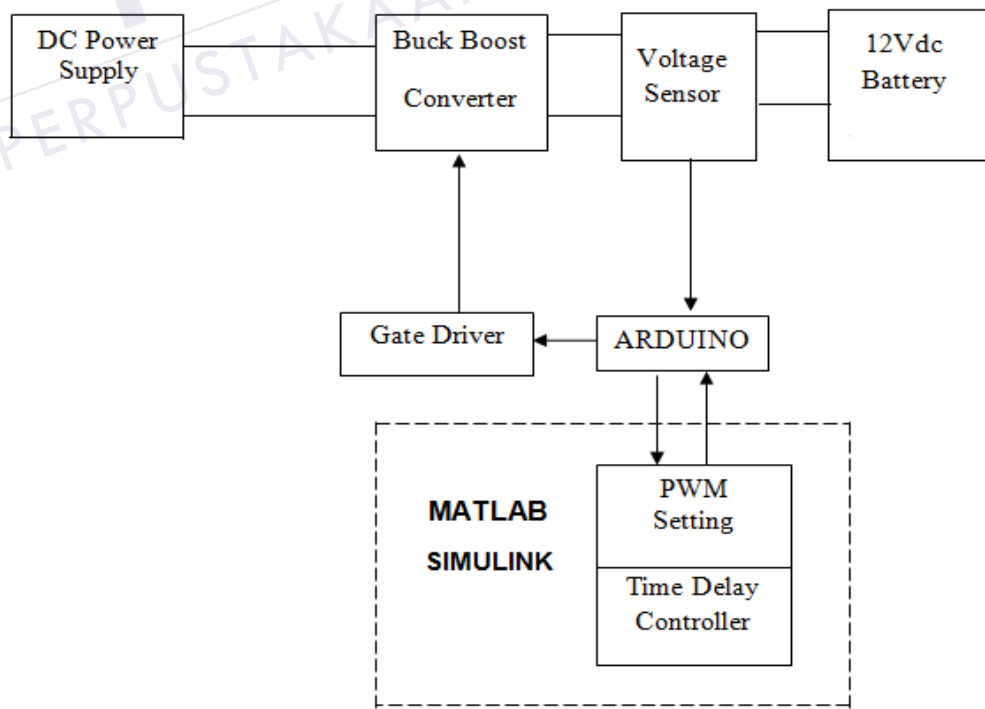
Figure 3.1: Block diagram of the project

In this project, it consists of the main component which is a battery where the charging process occurs in this system. Figure 3.1 illustrates the overall of the block diagram of the project. Firstly, the DC source will supply the voltage and current in order to supply voltage to the battery. Here, the buck-boost converter is needed because to control the power supply flow from the source to the battery. Here the voltage sensor will sense the actual voltage and will be compared to the reference voltage. The result of the comparison voltage between reference and actual will produce the difference voltage. The difference voltage will send to the ARDUINO board and simultaneously the signal will be adjusted together with the time delay controller algorithm by using MATLAB Simulink. Then, the time delay controller will control the Pulse Width Modulation (PWM) signal. PWM is the most widely used method for controlling the output voltage [27]. Then the PWM signal will send back the signal to the ARDUINO board and here the gate driver is needed to give switching control to the buck-boost converter and send the output of voltage to the battery charging process.

3.2   Flow chart of system
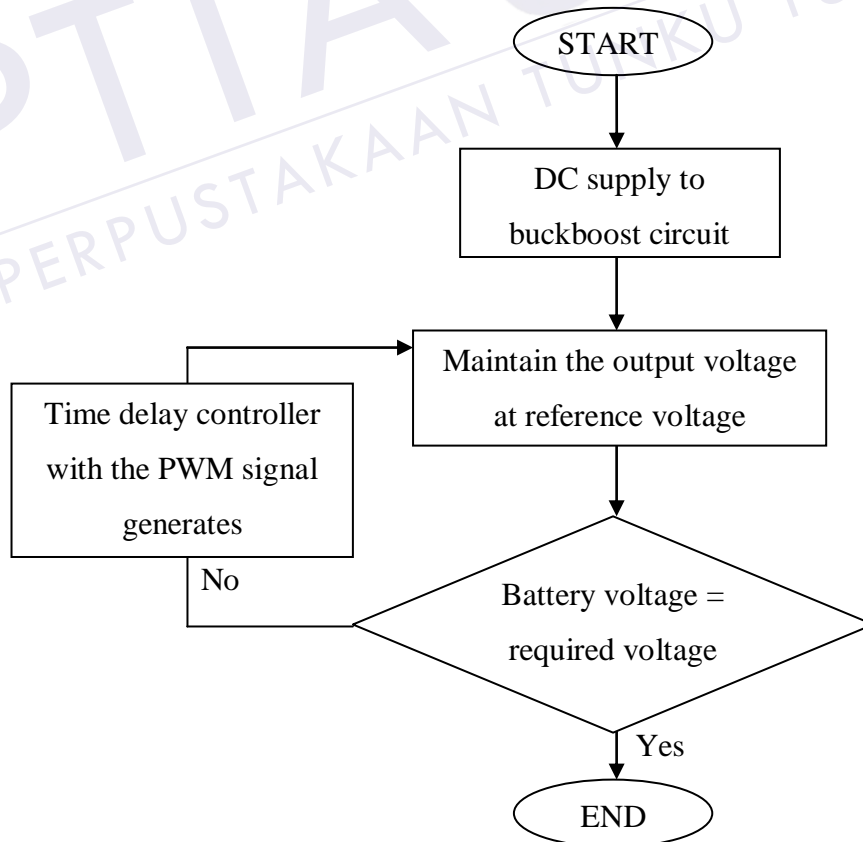
Figure 3.2: Flow chart of system

Figure 3.2 depicts the flowchart of the system for this project. Firstly, the DC supply will supply the voltage and current in order to charge a battery. The DC supply will supply the source to the buckboost circuit with the help of gate driver and the ARDUINO that generates the PWM signal so that the buckboost circuit can be drove. The reference voltage has been set based on the specification of the battery's nominal voltage that is 14V. Here, the output voltage of the buckboost circuit must be maintained at the reference voltage whenever any of the input voltage been applied. When the battery voltage not achieved the required voltage, therefore, the PWM signal will generate and time delay controller that acts as a controller for this system will adjust and send the signal to be corrected. The battery will successfully charging when the output voltage is maintained at the reference voltage.

3.3   Flow chart of project

```
                        ┌───────────┐
                        │   Start   │
                        └─────┬─────┘
          ┌───────────────────┴───────────────────┐
          ▼                                        ▼
┌───────────────────┐                  ┌───────────────────────┐
│   Hardware part   │                  │ Software part (MATLAB │
│                   │                  │      simulink)        │
└─────────┬─────────┘                  └───────────┬───────────┘
          ▼                                        ▼
┌───────────────────┐                  ┌───────────────────────┐
│ Study the buckboost│  ─────────────▶ │  Study the structure  │
│     circuit       │                  │  of buckboost converter│
└─────────┬─────────┘                  └───────────┬───────────┘
          ▼                                        ▼
┌───────────────────┐                  ┌───────────────────────┐
│ Study the gate    │                  │ Time delay control    │
│     driver        │                  │      design           │
└─────────┬─────────┘                  └───────────┬───────────┘
          ▼                                        ▼
┌───────────────────┐               No        ◇─────────────◇
│  Hardware setup   │           ◀────────     ◇ Voltage meet ◇
│                   │                         ◇ requirement  ◇
└─────────┬─────────┘                         ◇─────────────◇
          │                                        │ Yes
          │                              ┌───────────────────────┐
          │                              │  Upload to ARDUINO    │
          │                              └───────────┬───────────┘
          └───────────────┬───────────────────────┘
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              │ Observe performance   │
              │   of the project      │
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                          ▼
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              │     Write thesis      │
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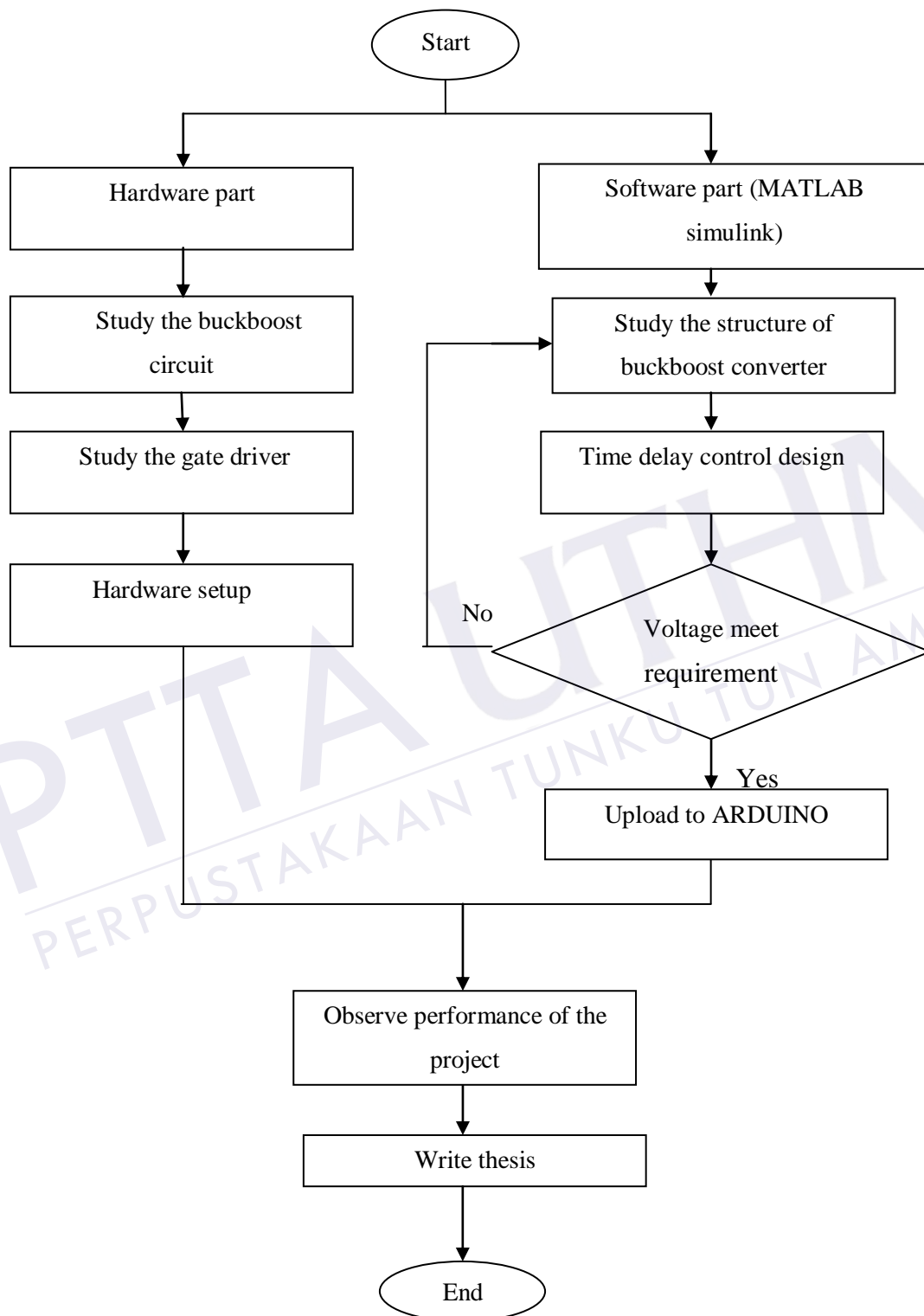
Figure 3.3: Flowchart of project development

The Figure 3.3 illustrated the flowchart of the project development. This project consists of two parts that must be conducted which are software part and hardware part. For software part, this project using MATLAB Simulink with ARDUINO support package. Firstly, the design of the buckboost circuit is constructed in the MATLAB software to verify whether the output voltage is maintained as a required voltage. Then, the time delay controller that acts as a controller is design to control the system. Here, any input that is in the range of 10V to 18V has been tested and applied. When the result of output voltage is maintained at the reference voltage meaning that the software part are successfully been designed and developed.

For the hardware part, there two circuits that must be developed which are the buckboost circuit and the gate driver. The buckoost circuit is design based on the battery specification for charging which is 14V. Here, the value of inductor and capacitor of the buckboost circuit must be determined by using calculation theory of the buck and boost circuit. In order to run the buckboost circuit, the switching frequency of the buckboost circuit must take into consideration. So, the duty cycle and the frequency of the ARDUINO are important in dealing with buckboost circuit for switching. Same goes to the gate driver, the gate driver is use in this project is 2 inputs and 4 outputs. The inputs come from the ARDUINO that produces the PWM signal with 5V and the output of the gate driver generates the output voltage that is +15v and -15V to drive the buckboost circuit. After the hardware part completes, the experimental hardware is setup. Then, the performance of the project was observed and recorded. After overall results have got and collected, finally, the thesis is being prepared.

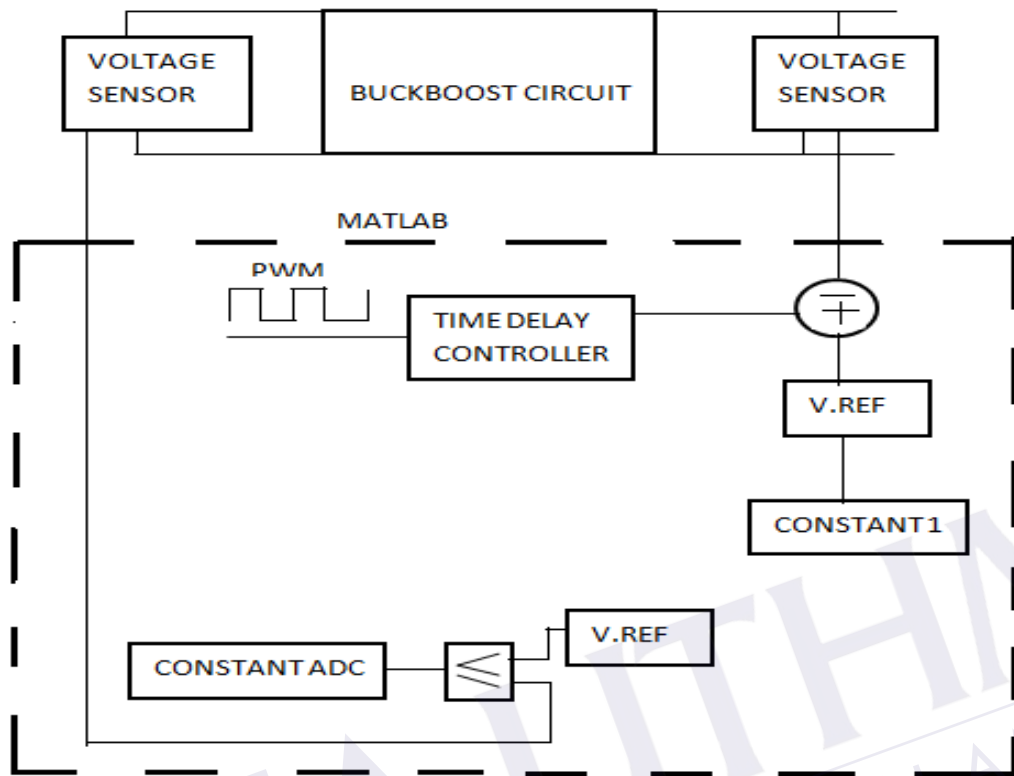**3.4   Overall closed loop system of the project**

Figure 3.4: Overall closed loop system of the project

This project consists of two parts which are hardware part and software part. For the hardware part, it consists of main circuit which is the buckboost circuit. The other circuits are gate driver, ARDUINO board and voltage sensor. For the software part, MATLAB has been implemented. Firstly, the buckboost circuit has been designed by using MATLAB Simulink software. Here, the control switching also must be designed whether the circuit will became buck or boost situation based on input that have been applied. In controlling the switching, the duty cycle and period play the important role in order to determine the operations whether buck or boost condition. So, to make appropriate control switching, the AND gate and OR gate has been implemented where the AND gate for buck condition and OR gate for boost condition. After completing designed the circuit and control switching, then the program has been downloaded through the ARDUINO board to generate the PWM signals. Then, the gate driver received the PWM signals and gave the switching output about 15V to drive the buckboost circuit. The time delay was used as a controller to get better output result. In maintaining and controlling the voltage, the

voltage sensors have been replaced at the output and input of the buckboost circuit. On the other hands, it been used as an interfacing which is ADC converter and once making the closed loop system that illustrated in Figure 3.4.

3.5 Hardware Development

There are three parts that involve in hardware development which are the buckboost circuit, gate driver and ARDUINO board. This hardware development is very important to ensure the process is sufficient and successful.

3.5.1 Implement buckboost circuit

First of all, in preparing and designing the buckboost circuit, the value of the duty cycle, capacitor and inductor must be determined. Duty cycle is defined as the ratio of switch on time to reciprocal of the switching frequency [27]. Besides that, control switching of the MOSFET also important to drive the buckboost circuit.
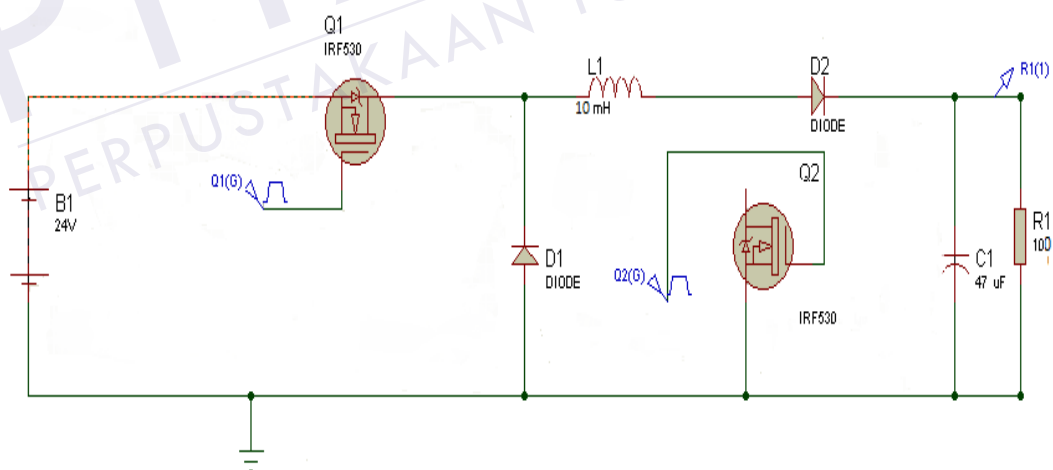
3.5.1.1 Buckboost circuit

Figure 3.5: Modified buck-boost converter circuit

The buck–boost converter is a type of DC-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. For this project, the aim of buckboost circuit is to convert the DC voltage to the fixed DC voltage. The Figure 3.5 illustrates the modified buckboost converter circuit that

has been designed in this project by using Proteus software and Figure 3.6 illustrates the hardware of buckboost circuit. Table 3.1 had shown the list of component that has been used.
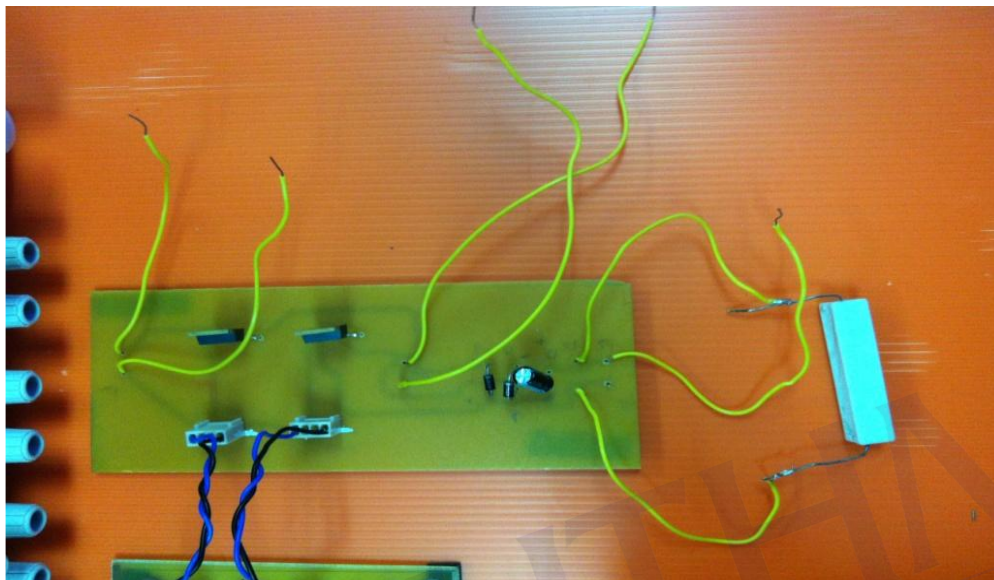

Figure 3.6: Hardware development of buckboost circuit

Table 3.1: List of component for buckboost circuit

NO	COMPONENT	UNIT
1	Switches IRF 540	2
2	Inductance 10mH	1
3	Capacitance 47uF	1
4	Diode 1N4148	2
5	Resistor 100Ω, 10W	1

3.5.1.2 Calculation theory of buckboost circuit

In preparing and designing the buckboost circuit, the value of the duty cycle, capacitor and inductor must be determined. Table 3.2 had shown the calculation theory of the buckboost circuit.

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