SMART BOOST CONVERTER FOR DC ENERGY SOURCE APPLICATION

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“I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelro Degree of Eletrical Engineering (Power System)”

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Date : 23 NOVEMBER 2009

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Name : MUNIRAH BT AYUB

Date : 23 NOVEMBER 2009

Specially dedicated to my parents, siblings, lecturers, friends and anybody were involved in this project

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May Allah reward His peace and blessings to all of you, and may this work brings benefits to mankind.

ABSTRACT

Basically this project is about the operation of step-up dc-dc boost converter for DC energy source application. The objective of this project is to practice the application of boost converter and DC source energy. It also have it's purpose in producing a simple control method for maximum power protection by employing a step-up dc-dc boost converter voltage to a certain value and set the limit voltage for the overvoltage protection system application and load protection. The DC source energy application can be obtain from voltage multiplier as power supply circuit. By using the basic principle, we will build the model and get the simulation for the circuit. In other way to generally explain the operation is the boost converter has functioning switch which had to produce the step-up voltage according to the correct design, the voltage will be the input for the overvoltage protection circuit which is used to protect the load. This circuit has variable voltage setting which can be set as the cut-off voltage to stop the excess voltage from damaging the load or equipment. LED power saving are implement as the load for the DC source energy and also have economical purposes in saving power consumption.

ABSTRAK

Projek ini merangkumi operasi penaikan voltan terus dalam aplikasi sumber tenaga voltan terus.Tujuan projek ini adalah pengaplikasian penukar arus terus dan punca tenaga arus terus. Ia juga merupakan salah satu cara menghasilkan satu kawalan ringkas untuk melindungi litar dari kesan operasi kuasa maksimum dengan menetapkan voltan 'boost converter' pada nilai voltan tertentu dan voltan tersebut ditetapkan pada satu nilai supaya dapat dikesan oleh aplikasi alat perlindungan voltan tinggi untuk melindungi beban elektrik tertentu.Secara ringkasnya, litar penaikkan voltan yg akan menaikkan voltan pada suatu nilai yg telah ditetapkan dengan menggunakan litar rekaan yg betul.Voltan keluar dari litar tadi akan menjadi punca kepada litar perlindungan voltan tinggi dan akan memastikan operasi pengeluaran voltan tidak melebihi voltan yang sepatutnya.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICIES

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICIES

APPENDIX	TITLE	PAGE

CHAPTER 1

INTRODUCTION

1.1 Background

A boost converter (step-up converter) is a power converter with an output DC voltage greater than its input DC voltage. It is a class of switching-mode power supply (SMPS) containing at least two semiconductor switches, a diode and a transistor and at least one energy storage element. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple. Power can also come from DC sources such as batteries, solar panels, rectifiers, and DC generators. A process that changes one DC voltage to a different DC voltage is called DC to DC conversion.

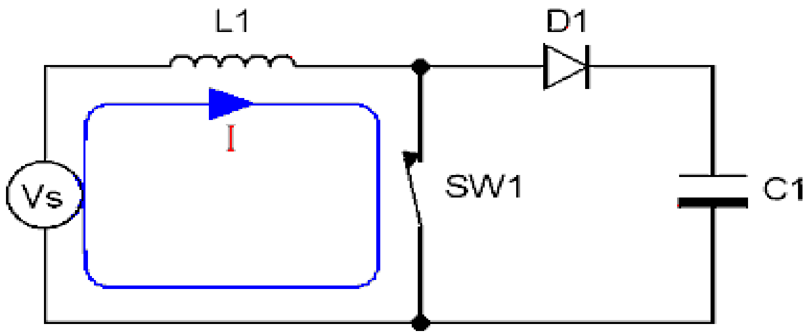

Figure 1.0: The boost converter circuit when the switch is close

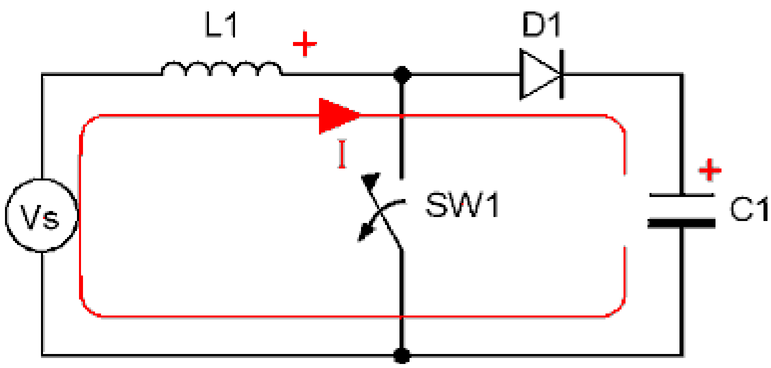

Figure 1.1: The boost converter circuit when the switch is open

The main part that drives the boost converter is the tendency of an inductor to resist changes in current. When being charged it acts as a load and absorbs energy somewhat like a resistor, when being discharged, it acts as an energy source like a battery. The voltage it produces during the discharge phase is related to the rate of change of current, and not to the original charging voltage, thus allowing different input and output voltages. The basic principle of a Boost converter consists in 2 distinct states (see figure 1.4):

- In the On-state, the switch S (see figure 1.3) is closed, resulting in an increase in the inductor current;

- In the Off-state, the switch is open and the only path offered to inductor current is through the flyback diode D, the capacitor C and the load R. This result in transferring the energy accumulated during the On-state into the capacitor.

- The input current is the same as the inductor current as can be seen in figure 2. So it is not discontinuous as in the buck converter and the requirements on the input filter are relaxed compared to a buck converter.

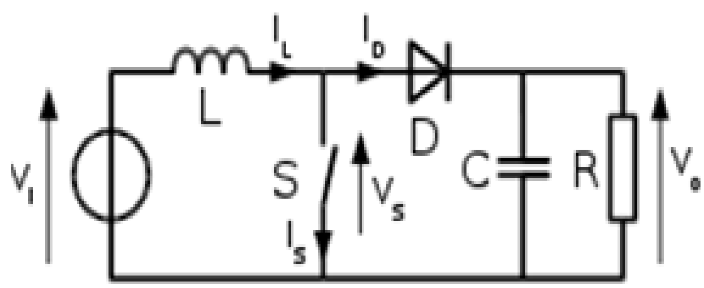

Figure 1.2: The schematic of current and voltage for boost converter

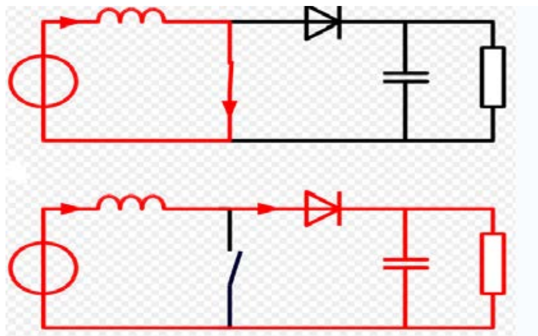

Figure 1.3: The two configurations of a boost converter, depending on the state of the switch S.

Boost converter already been used widely either in electronic for small component with small scale of step-up voltage or mechanical and automotive engineering for its' specialty of converting the voltage to a larger voltage, for example, the Toyota Prius HEV contains a motor which utilizes voltages of approximately 500 V. Without a boost converter, the Prius would need nearly 417 cells to power the motor. However, a Prius actually uses only 168 cells and boosts the battery voltage from 202 V to 500 V.

1.2 Voltage multiplier

A voltage multiplier is an electrical circuit that converts AC electrical power from a lower voltage to a higher DC voltage by means of capacitors and diodes combined into a network.

Voltage multipliers can be used to generate bias voltages of a few volts or tens of volts or millions of volts for purposes such as high-energy physics experiments and lightning safety testing. The most common type of voltage multiplier is the half-wave and full wave series multiplier, also called the Villard cascade (but actually invented by Heinrich Greinacher). Such a circuit is shown opposite.

Voltage multipliers may be classified as voltage doublers, triplers, or quadruplers. The classification depends on the ratio of the output voltage to the input voltage. For example, a voltage multiplier that increases the peak input voltage twice is called a voltage doubler. Voltage multipliers increase voltages through the use of series-aiding voltage sources. This can be compared to the connection of dry cells (batteries) in series. The input could be directly from the power source or line voltage. This, of course, does not isolate the equipment from the line and creates a potentially hazardous condition. Most military equipments use transformers to minimize this hazard.

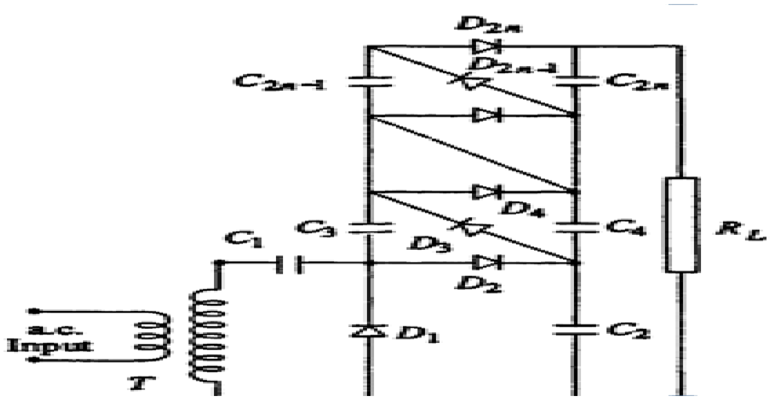

Figure 1.4: Example Cockcroft-walton voltage multiplier circuit

1.3 LED Power Saving

LEDs are based on the semiconductor diode. When the diode is forward biased in switched on state, electrons are able to recombine with holes and energy is released in the form of light. This effect is called electroluminescence and the color of the light is determined by the energy gap of the semiconductor. The LED is usually small in area (less than 1 mm^2) with integrated optical components to shape its radiation pattern and assist in reflection.

LEDs present many advantages over traditional light sources including lower energy consumption, longer lifetime, improved robustness, smaller size and faster switching. However, they are relatively expensive and require more precise current and heat management than traditional light sources.

Applications of LEDs are diverse. They are used as low-energy indicators but also for replacements for traditional light sources in general lighting, automotive lighting and traffic signals. The compact size of LEDs has allowed new text and video displays and sensors to be developed, while their high switching rates are useful in communications technology.

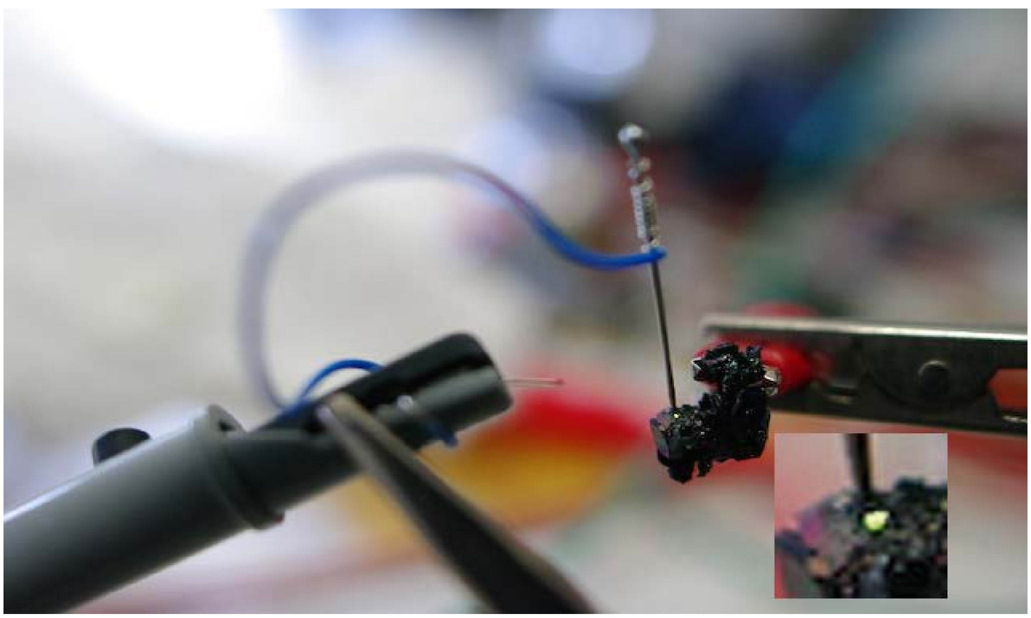

Figure 1.5 : Green electroluminescence from a point contact on a crystal of SiC recreates H. J. Round's original experiment from 1907.

1.4 Objective of Project

The objective of this project is to:

i. Build a voltage multiplier that capable to step-up DC-DC input voltage into multiple range of output that supply by the DC power supply

ii. Apply the LED power saving at boost converter output to prove economical power consumption

iii. Compare the complexity of voltage multiplier and boost converter as the source of LED power saving

1.5 Scope of Project

In this project, I want to build a boost converter which will interface with the PIC controller that controls the driver circuit that generate the pulse for the boost converter. There are specifications that need to consider for the boost converter such as:

Voltage multiplier Input	: 240 VAC
Voltage multiplier Output	: 9VDC, 15VDC, 24VDC, 105VDC
Boost converter input voltage	: 15V
Boost converter output voltage	: 28VDC-30VDC
LED power supply source	: 12VDC

1.6 Summary of the Project

The flow of the project can be summarized by the block diagram and flow chart respectively from figure 1.41 and figure 1.42. Both of the diagram and chart can summarize all the work progress that has been implemented in first and second semester.

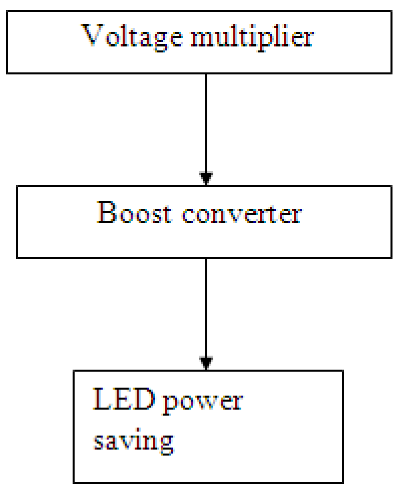

Figure 1.6: The block diagram

Description:

Boost converter circuit was sketched based on the basic boost converter circuit. Boost converter part and component has been studied and identified. At first the boost converter specification are listed to ensure the required calculation for the component such as inductor, capacitor and resistor value. It is important especially for the inductor since the value for inductor cannot be found in the market; it has to be made by using conventional way.

The circuit has been designed in the PSPICE to ensure that the result of the boost converter certified with the output voltage specification. It is important to know whether the boost converter successfully step-up the voltage to the calculation value of output voltage.

The voltage regulator are needed to get desired voltage regulated from the source voltage for the boost converter while the capacitor are needed as the filters to get clean Vdc output for any lamp or other applications.

Description:

The voltage multipliers are use in this project as the source for the boost converter and other application even for the LED power saving and motor. The input for the voltage multipliers is 240 Vac, therefore the rectifier is needed to produce Vdc and filter to produce clean Vdc output. The casing of voltage multiplier not just measured voltage for the load, but also measured current used for the load. The boost converter circuit can also been compared with the voltage multiplier circuit and advantages and disadvantages are study. Instead of using number of lab power supply, we can simplify the source in one casing of multiple voltage supply.

Description:

LED lamps are used for both general lighting and special purpose lighting. Where colored light is required, LEDs come in multiple colors, which are produced without the need for filters. This improves the energy efficiency over a white light source that generates all colors of light then discards some of the visible energy in a filter.

White-light light-emitting diode lamps have the characteristics of long life expectancy and relatively low energy consumption. The LED sources are compact, which gives flexibility in designing lighting fixtures and good control over the distribution of light with small reflectors or lenses. LED lamps have no glass tubes to break, and their internal parts are rigidly supported, making them resistant to vibration and impact. With proper driver electronics design, an LED lamp can be made dimmable over a wide range; there is no minimum current needed to sustain lamp operation. LEDs using the color-mixing principle can produce a wide range of colors by changing the proportions of light generated in each primary color. This allows full color mixing in lamps with LEDs of different colors. LED lamps contain no mercury.

The application of LED in this project is in term of LED bulb and LED lamp which are already been modify to suitable shape so that it can be join in the casing of voltage multipliers circuit. White color LED are choose for this application because of it's luminance and similarity to the color of fluorescents or other bulb that being used nowadays.

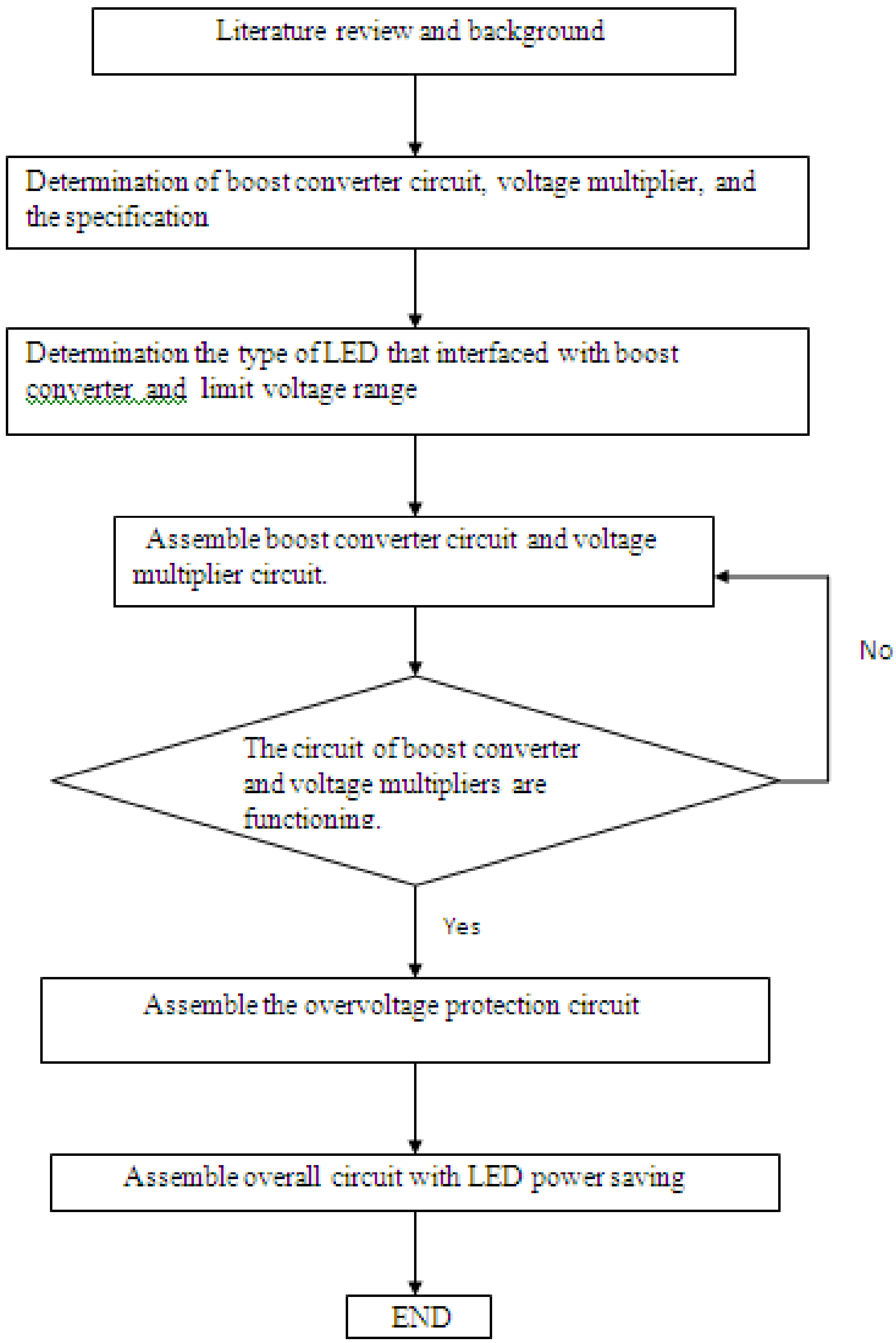

Figure 1.9: Flow chart of development

Description:

The literature review and research on theories related to the projects begin after the title of the project was decided. These involve the application theories of boost converter and the protection system that should be included in the circuit for the project. Most of the information was obtained from the internet and a few reference books. A boost converter circuit with voltage multiplier was chosen to be developed in this project because it was relevant with the objective and the purpose of the project.

The project is divided into two parts which are hardware and simulation. Firstly, the circuit of the boost converter needs to be built inside the PSPICE software to see the output voltage result and after that need to be tested to ensure the output is 20 V from the input voltage of 15V.

The output of boost converter which already been step-up to 30V but the input voltage for LED is 28 volt. Therefore the overvoltage protection circuit will ensure that the input voltage from the boost converter to LED power saving will not exceed the limit of 28V to protect the LED from overvoltage and damage the LED.

CHAPTER 2

THEORY AND LITERATURE RIVIEW

2.1 Introduction

This chapter includes the study of boost converter and its system. It also touches on microcontroller and other relevant hardware used in this project.

2.2 Boost converter

The Function of boost converter as power converter with an output DC voltage greater than its input DC voltage are widely use and starting to be popular around 1960's when this converter are being the most popular topic for doctorate student to pursue their carrier in power electronic and electronic devices. It is a class of switching-mode power supply (SMPS) which contain at least two semiconductor switches (a diode and a transistor) and at least one energy storage element. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple. For high efficiency, the SMPS switch must turn on and off quickly and have low losses. The advent of a commercial semiconductor switch in the 1950's represented a major milestone that made SMPSs such as the boost converter possible. Semiconductor switches turned on and off more quickly and lasted longer than other switches such as vacuum tubes and electromechanical relays.

The major DC to DC converters were developed in the early-1960s when semiconductor switches had become available. The aerospace industry's need for small, lightweight, and efficient power converters led to the converter's rapid development. Switched systems such as SMPS are a challenge to design since its model depends on whether a switch is opened or closed. R.D. Middlebrook from Caltech in 1977 published the models for DC to DC converters used today. Middlebrook averaged the circuit configurations for each switch state in a technique called state-space averaging. This simplification reduced two systems into one. The new model led to insightful design equations which helped SMPS growth. Take the simple boost converter as an example, the transistor switch is turned on and off periodically resulting in a sequence of linear circuits being toggled in a supposedly orderly manner. The objective is to achieve some power conversion function which is, in this case, a regulated output voltage. Obviously, control is necessary in the form of feedback. The usual implementation is to vary the relative durations of the turn on and turn-off intervals of the transistor switch according to a control signal derivable from the output voltage. This constitutes the required feedback loop for continuous adjustment of the duty cycle (defined as the fractional turn-on period of the transistor switch) so as to maintain a fixed output voltage.

The operating frequency of boost converter can be anywhere between 50-250kHz so the diode and switch must be capable of fast, efficient switching. A standard rectifier diode and bipolar transistor would not be the ideal components in this regard, although the circuit should still function at lower frequencies.

The current waveform in the inductor will depend on the nature of the load to which it is connected. A capacitor load behaves very much like a constant voltage on the timescale of a storage/delivery cycle so the current ramps down more or less linearly during each delivery phase. As the capacitor voltage increases the delivery phase current ramps down faster due to the larger inductor induced voltage. Note that as well as the inductor's stored energy, the source (Vs) also supplies energy during the deliver phase. This energy is the time integral of the source power output during this phase, and it decreases as the load voltage increases (the current ramps down faster so the time that the source delivers power also decreases).In this project I will insert a low pass filter after the voltage input

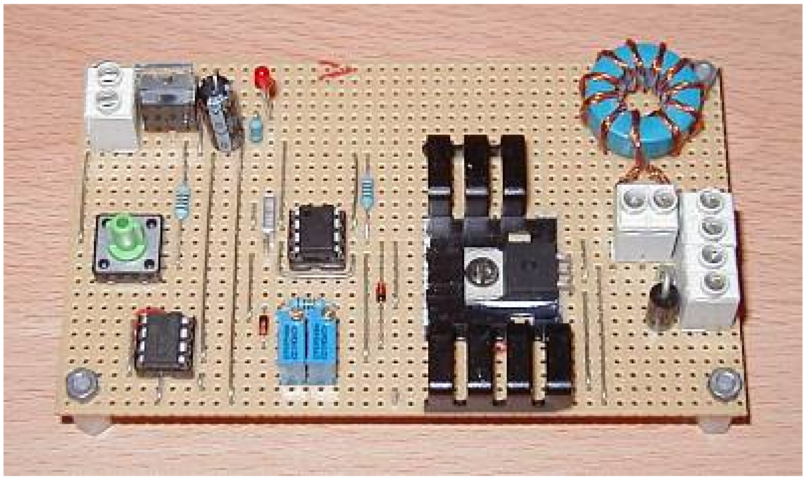

Figure 2.0: boost converter evaluation board

2.3 The Boost Converter Pitfall

There are some pitfalls in dealing with boost converter. One of the major shortcomings of a boost converter is that they do not have true shutdown. Now, another name for true shutdown is output disconnects. In the case where you disable the switcher, there's a direct path from Vin to Vout through the inductor and diode. So when you disable the switcher, the output voltage drops down to Vin less a diode drop. Now, if an IC does include true shutdown, they will brag about it on the datasheet and that's something to look for in the fine print. It does not have true shutdown so you'll have to either add an extra switch either in series with the input or the output. If it's in series with the input, it could be as simple as an on/off switch.

One of the other important limitations of a boost converter is that there is no current limit on the output. So if you short the output, there's an uncontrolled path from Vin to Vout flowing through the inductor and diode. It doesn't matter if the IC is in shutdown when you do this. The output short is passed through to the input. There are cases where even if you momentarily short the output voltage, you can cause damage to the switch because you cause an escalating current in the inductor and when you release this short, the energy in that inductor charges the output capacitor past the switch voltage reading. So it's very easy to damage boost converters if you slip with a test lead so be very cautious with that. There's an intermediate condition. Let's suppose you've overloaded a boost converter and you've muscled the output voltage down below Vin through a low impedance path. The switch converter may still be operating so while you have this escalating current through the inductor, every time the switch turns on, it is attempting to shunt this high current through the switch to ground. This can cause overheating in the boost converter and it may, in fact, cause damage.

Another important point is that as the input voltage surges, that this will be passed through to the output. So as Vin rises up past the regulated Voutput voltage level, the switcher stops switching and Vin passes through the inductor and the diode to Vout. So at that particular part, you can cause damage to your load circuitry if there's an input surge occurring. Another shortcoming is that there's no isolation between input and output. This is a three terminal connection. Circuitry input and output grounds are common. If you need an isolated converter where there's no DC continuity between input and output grounds, take a look at the flyback converter using opto-isolated feedback.

2.4 Boost Converter Improvement

The improvement that has been made is improved boost converter with coupled inductors and buck-boost type of active-clamp feature, PWM control and zero-voltage switching in both main and auxiliary switches. In the converter, the active-clamp circuit is used to eliminate voltage spike induced from the leakage inductor of the coupled inductors. The active switch of the converter can still sustain a proper duty cycle when it operates with a high step-up voltage ratio, reducing voltage stress significantly. A set of passive-clamping circuit is adopted to eliminate undesired resonance between leakage inductor of the coupled inductors and stray capacitor of the boost diode, recovering trapped energy. Thus, conversion efficiency can be improved significantly. A 200 W prototype of the proposed boost converter was built from which experimental results have shown that efficiency can reach as high as 92% and surge can be suppressed effectively. In a boost converter with coupled inductors, the active switch can sustain proper duty cycle while operated with high step-up voltage ratio, reducing voltage stress significantly.

However, leakage inductor of the coupled inductors would induce voltage spike which results in high component stress, low conversion efficiency and high noise level. A resistor capacitor- diode snubber can alleviate voltage stress of the switch, but the energy trapped in the leakage inductor is dissipated. A boost converter with active clamp and pulse width modulated (PWM) control can result in zero-voltage switching (ZVS) in both main and auxiliary switches, which makes the converter more viable. Additionally, leakage inductor of the coupled inductors can limit the decreasing rate of the boost-diode current, reducing diode reverse-recovery loss.

Due to the resonance between leakage inductor of the coupled inductors and junction capacitor of the boost diode, it is necessary to add a proper resistor-capacitor snubber to suppress voltage ringing across the boost diode. Since the trapped energy in the leakage inductor is dissipated and conversion efficiency of the converter has not been optimized yet, several methods were proposed in to relieve this drawback.

2.5 Overvoltage Protection Circuit

Normally circuits that using TTL ICs the supply voltage is a great concern and a slight increase in supply from the rated 5V may damage the IC. Using fuses alone does not solve the problem because a fuse may take several milliseconds to blow off and that's enough time for the IC to get damaged.

Here is the circuit diagram of an adjustable voltage regulator using IC L200. L200 is a monolithic integrated adjustable voltage regulator IC having features like current limiting, thermal shut down, power limiting, input over voltage protection etc. Here the regulator is designed to produce an output adjustable supply between 2.85V to 15V at 1A.The resistors R1 and R2 determines the output voltage. The resistor R3 determines the limiting value of output current, here 1A. Capacitors C1 and C2 does filtering.

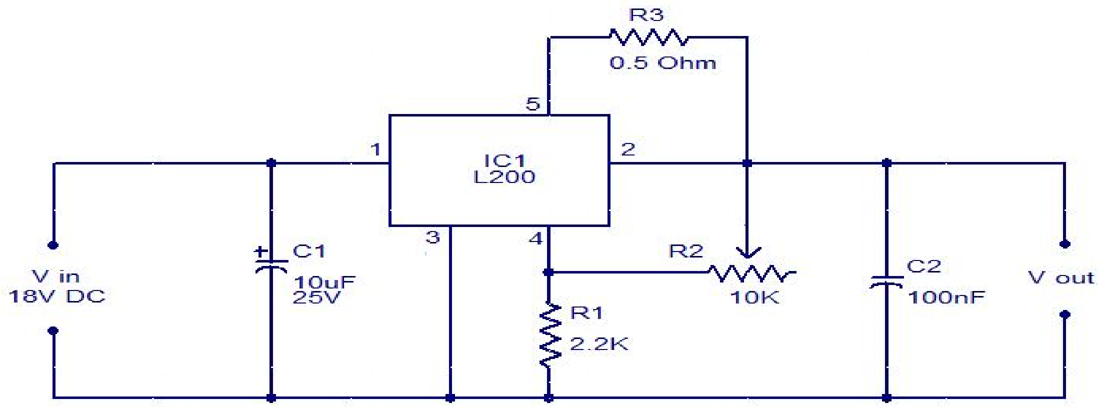

Figure2.1: Example of overvoltage protection circuit for the power

2.6 LED Power Saving

LEDs (Light Emitting Diodes) are solid light bulbs which are extremely energy-efficient. Until recently, LEDs were limited to single-bulb use in applications such as instrument panels, electronics, pen lights and, more recently, strings of indoor and outdoor Christmas lights. Manufacturers have expanded the application of LEDs by "clustering" the small bulbs. The first clustered bulbs were used for battery powered items such as flashlights and headlamps. Today, LED bulbs are made using as many as 180 bulbs per cluster, and encased in diffuser lenses which spread the light in wider beams.

The high cost of producing LEDs has been a roadblock to widespread use. However, researchers at Purdue University have recently developed a process for using inexpensive silicon wafers to replace the expensive sapphire-based technology. This promises to bring LEDs into competitive pricing with CFLs and incandescents. LEDs may soon become the standard for most lighting needs..

Electroluminescence was discovered in 1907 by the British experimenter H. J. Round of Marconi Labs, using a crystal of silicon carbide and a cat's-whisker detector. Russian Oleg Vladimirovich Losev independently reported on the creation of a LED in 1927. His research was distributed in Russian, German and British scientific journals, but no practical use was made of the discovery for several decades. Rubin Braunstein of the Radio Corporation of America reported on infrared emission from gallium arsenide (GaAs) and other semiconductor alloys in 1955. Braunstein observed infrared emission generated by simple diode structures using gallium antimonide (GaSb), GaAs, indium phosphide (InP), and silicon-germanium (SiGe) alloys at room temperature and at 77 kelvin. In 1961, experimenters Robert Biard and Gary Pittman working at Texas Instruments, found that GaAs emitted infrared radiation when electric current was applied and received the patent for the infrared LED.

The first practical visible-spectrum (red) LED was developed in 1962 by Nick Holonyak Jr., while working at General Electric Company. Holonyak is seen as the "father of the light-emitting diode" M. George Craford, a former graduate student of Holonyak, invented the first yellow LED and improved the brightness of red and red-orange LEDs by a factor of ten in 1972. In 1976, T.P. Pearsall created the first high-brightness, high efficiency LEDs for optical fiber telecommunications by inventing new semiconductor materials specifically adapted to optical fiber transmission wavelengths.

Up to 1968 visible and infrared LEDs were extremely costly, on the order of US $200 per unit, and so had little practical application. The Monsanto Company was the first organization to mass-produce visible LEDs, using gallium arsenide phosphide in 1968 to produce red LEDs suitable for indicators. Hewlett Packard (HP) introduced LEDs in 1968, initially using GaAsP supplied by Monsanto. The technology proved to have major applications for alphanumeric displays and was integrated into HP's early handheld calculators.

Figure 2.2: LED Power Saving

2.7 Voltage Multipliers

The voltage multiplier can be used to produce thousands of volts of output, the individual components do not need to be rated to withstand the entire voltage range. Each component only needs to be concerned with the relative voltage differences directly across its own terminals and of the components immediately adjacent to it. Typically a voltage multiplier will be physically arranged like a ladder, so that the progressively increasing voltage potential is not given the opportunity to arc across to the much lower potential sections of the circuit.

Note that some safety margin is needed across the relative range of voltage differences in the multiplier, so that the ladder can survive the shorted failure of at least one diode or capacitor component. Otherwise a single-point shorting failure could successively over-voltage and destroys each next component in the multiplier, potentially destroying the entire multiplier chain.

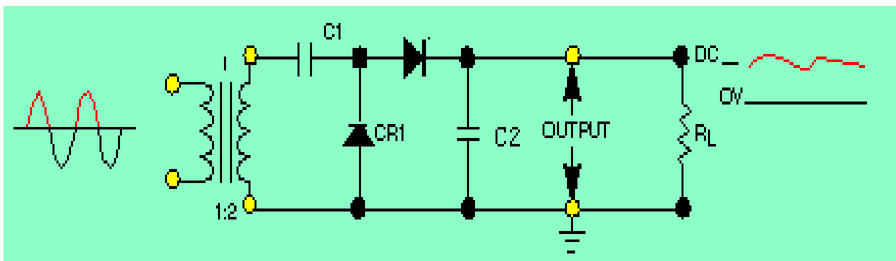

Figure 2.3: Half-wave voltage doubler.

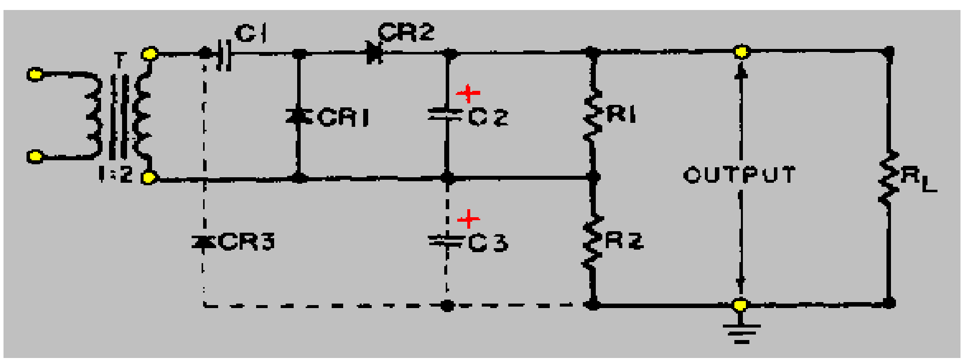

Figure 2.4: Half-wave voltage Tripler

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this project, the work methodology can be shown by block diagram below:

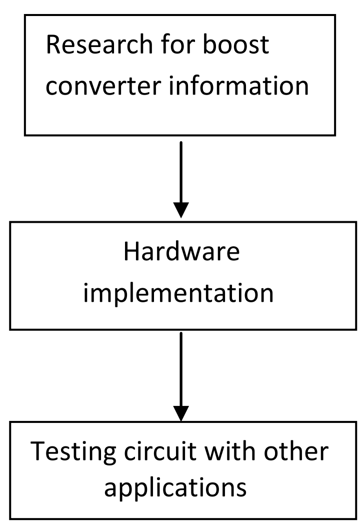

Figure 3.0: Methodology block diagram

3.2 Research for boost converter

3.2.1 Books

There are many books about boost converter with many languages in many difference perceptions. Almost the books are about the research on the potential and renovation of boost converter. Some of the books are obtained from the internet in certain journal as the reference. These are 2 books that I use as my reference in this project that elaborate more detail about boost converter.

"Electronic Devices and Circuit theory" by Robert L. Boylestad gives more focus on how the MOSFET operates. There are detail explanations on function and the related information that must be used in MOSFET operation. It also complete with pictures and any related figures such as voltage graph, pin function, guide figures that contain MOSFET specification and some example of MOSFET model. It also explains on some important calculation that need to be done before the circuit can be built.

"Introduction to Power Electronics" by Daniel W. Hart also guide on how to design the boost converter. This book also shows which MOSFET has the most suitable specification to provide the signal for boost switch, some important calculation for the boost converter component such as inductor value, capacitor value and some explanation about PWM signal.

3.2.2 Internet

There are many website that we can get the information of boost converter and PIC, timer circuit, flip-flop IC and some other PWM IC that involve in the search for boost converter component. Voltage Multiplier circuit are provided from websites and the information and references are collected from 'Electronic Today' websites. Some are invention articles, some are research article, and some are basic information of boost converter. The overvoltage protection circuits is obtain from forum about how to develop a circuit by using adjustable IC regulator and produce certain range of output voltage. The difference between internet and books are they are worldwide and more information for just a click. Those are really helped for this project and more information has been gathered. Also we can use it as reference for advanced the project.

3.3 Hardware Implementation

3.3.1 Boost converter

The boost converter was built base on sketched circuit and the component was taken from the lab through component form that already been authorized. It was newly build based on the sketched circuit and the component was not taken from any other electrical equipment spare part. PIC18F4550 was ordered and taken from the lab. The figure are shown as below.

The other component that included after proper calculation and experiment value was done are shown below:

Figure 3.1: Capacitors

Figure 3.2: Diode 1N4148

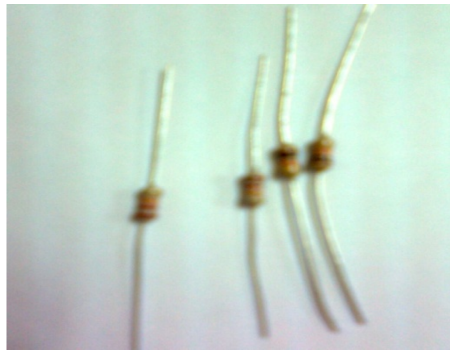

Figure 3.3: Resistors

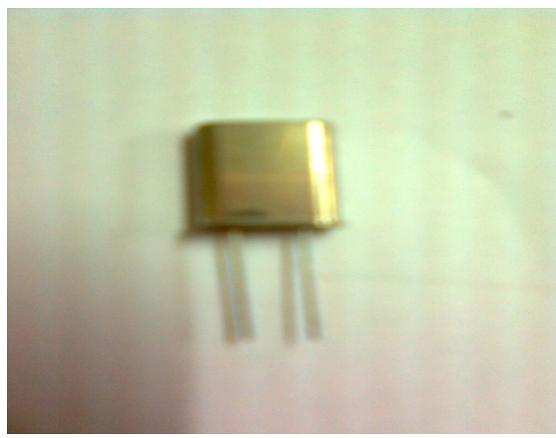

Figure 3.4: Crystal 20Mhz

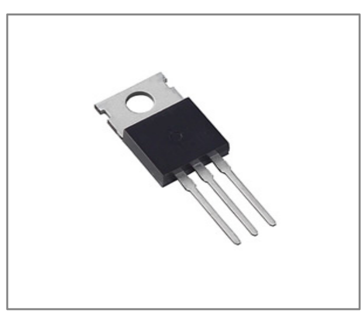

Figure 3.5: Voltage regulator LM7809

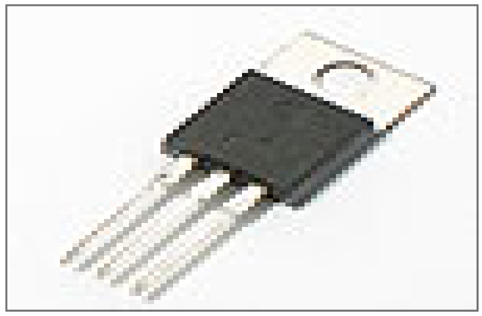

Figure 3.6: MOSFET IRF740

Figure 3.7: Voltage regulator LM7815

Figure 3.8: Inductor 60uH

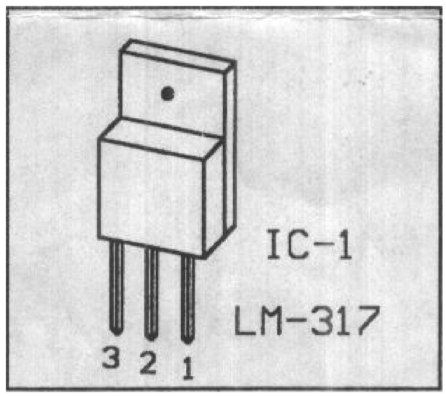

Figure 3.9: Regulator LM317

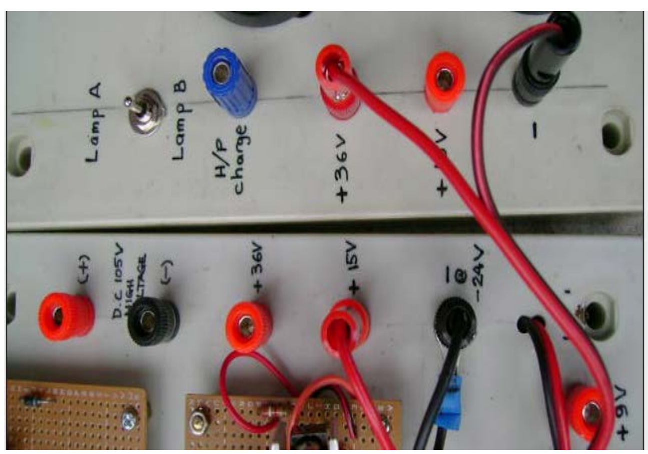

Figure 3.10: Voltage Binder

Figure 3.11: LED lamp

Figure 3.12: LED bulb

Figure 3.13: Meter reading

3.3.2 Boost Converter Circuit

Boost converter is additional circuits in this project. Basic boost converter consists of inductor as the energy storage device, MOSFET as a power switch, diode, and capacitor is used to limit the output ripple and output resistor as show in figure 3.13. The design of boost converter need to be consider the Continuous Current Mode (CCM), input and output voltage, current, output ripple and component rating. There is an additional part of low pass filter to filter out the noise from the power supply to get pure and smooth supply voltage for the boost circuit. Basic design starts with a detail calculation on every value of component need to be used to produce a desired output. Select a suitable frequency range and find a component according to all value collected in the calculation.

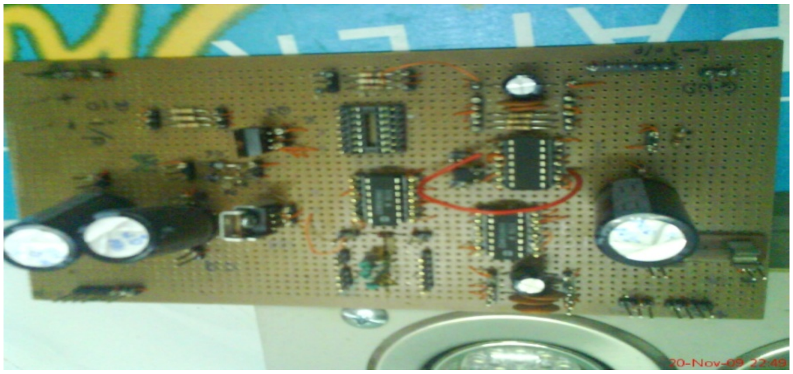

Figure 3.14: Boost Converter Circuit

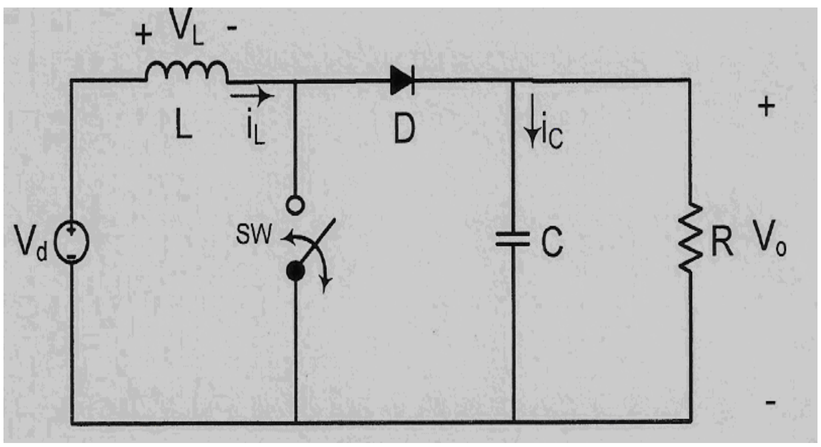

Figure 3.15: Basic circuit of boost converter

3.3.3 Boost Converter Calculation

Vin = 15Vdc

Vout = 30Vdc

Assuming ripple voltage, Vr = 2%

Load resistance, R = 1000 Ω

Duty Cycle, D:

$$D = 1 - \frac{V_i}{V_o}$$

$$= 1 - \frac{15}{30}$$

$$= 0.5$$

To find frequency range, f:

Using MOSFET driver IRF740

$t_r = 150ns$ $t_{on(\min)} = 750ns$ $D_{\max} = 90\%$

$t_f = 50ns$ $t_{off(\min)} = 200ns$ $D_{\min} = 10\%$

$$\frac{4(1-D_{\max})}{3(t_r+t_f)+4t_{off\,(\min)}} \le f \le \frac{4D_{\min}}{t_r+t_f+4t_{on(\min)}}$$

$$\frac{4(1-0.5)}{3(150\times10^{-9}+50\times10^{-9})+4(200\times10^{-9})} \le f \le \frac{4(0.5)}{(150\times10^{-9})+(50\times10^{-9})+4(750\times10^{-9})}$$

$$1.43MHz \le f \le 625kHz$$

Frequency choose, f = 1MHz

Minimum inductor value, L:

$$L_{\min} = \frac{D(1-D)^2 R}{2f}$$

$$L_{\min} = \frac{0.5(1-0.5)^2(1000)}{2(1\times10^6)}$$

$$L_{\min} = 62.5\mu H$$

Standard inductor value, L= μH

Inductor current, IL:

$$T = \frac{1}{f}$$

$$T = \frac{1}{1\times10^6}$$

$$T = 1\mu s$$

$$I_L = \frac{V_{in}}{(1-D)^2 R}$$

$$I_L = \frac{14}{(1-0.5)^2 (1000)}$$

$$I_L = 0.056A$$

$$\frac{\Delta i}{2} = \frac{V_i DT}{2L}$$

$$\frac{\Delta i}{2} = \frac{15(0.5)(1\times10^{-6})}{2(62.5\times10^{-6})}$$

$$\frac{\Delta i}{2} = 0.0566A$$

Capacitor value, C:

$$C = \frac{D}{RfV_r}$$

$$C = \frac{0.5}{(1000)(1\times10^{6})(0.02)}$$

$$C = 25000\,pF$$

Standard value of capacitor, C = 22000 *pF*

3.3.4 Voltage Multipliers

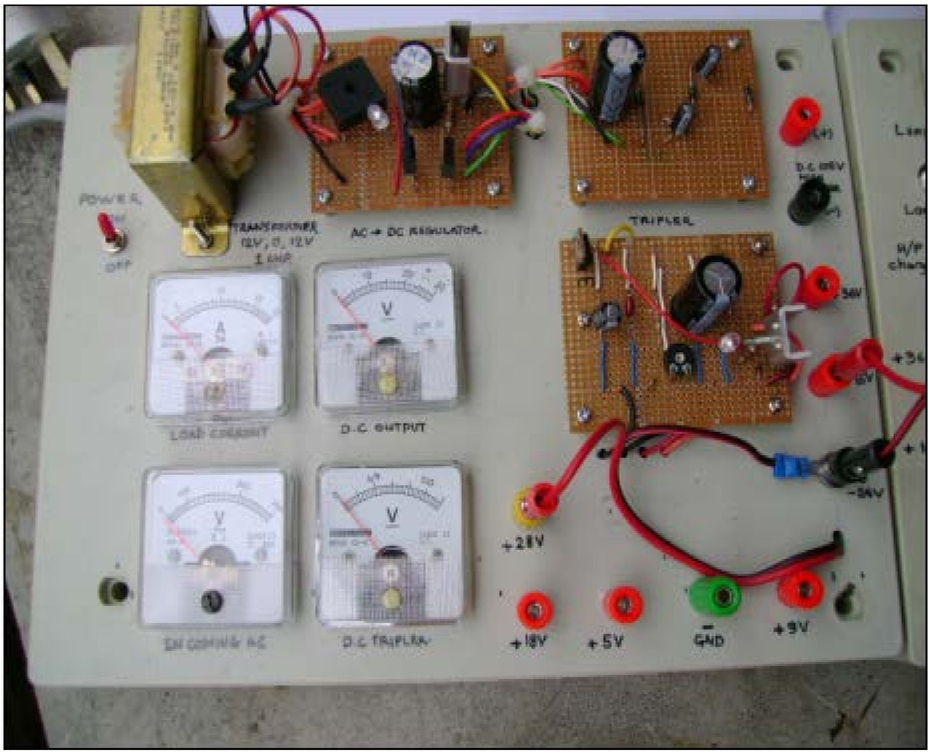

Figure 3.16: Voltage Multiplier circuit

Voltage multipliers are used primarily to develop high voltages where low current is required. Voltage multipliers may also be used as primary power supplies where a 177 volt-ac input is rectified to pulsating dc. This dc output voltage may be increased (through use of a voltage multiplier) to as much as 1000 volts dc. This voltage is generally used as the plate or screen grid voltage for electron tubes.

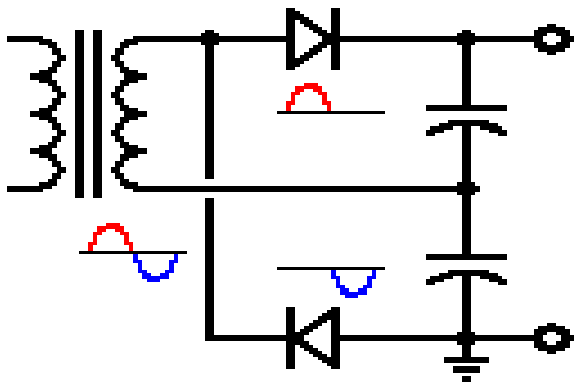

Figure 3.17: A Full-Wave Voltage Doubler

The circuit diagram is simply use the negative output as our ground reference, and takes the positive output voltage as our only output from the power supply. Since each capacitor charges to the peak secondary voltage, the output voltage from this circuit will be the sum of the two capacitor voltages, or twice the peak voltage of the secondary winding.

This circuit, then, operates in such a way as to produce an output voltage that is twice the transformer secondary voltage. Therefore, it is known as a voltage doubler. More accurately, it is a full-wave voltage doubler, because it uses both half-cycles of the incoming ac wave.

Each capacitor is charged individually from its rectifier, but they appear in series to the output. Therefore, the available output current is only half the current that would be available from a half-wave rectifier by itself.

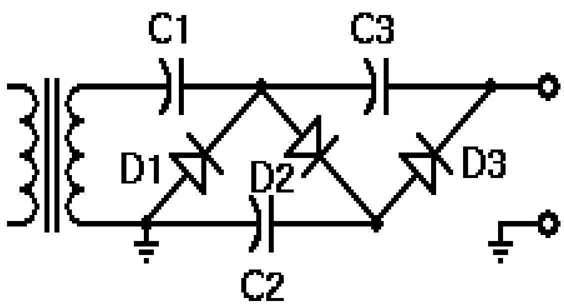

Figure 3.18: A Full-Wave Voltage Tripler

The first two sections, consisting of C1-D1 and C2-D2, still operate as a voltage doubler exactly as described above. With the addition of C3-D3 on the negative half-cycles, when D1 is forward biased, D3 is also forward biased by the voltage on C2. Therefore C2 and C3 are effectively connected in parallel by D1 and D3, while D2 remains reverse biased and therefore does not conduct. As a consequence of this parallel connection, C2 shares its charge with C3 and both capacitors get charged towards a voltage of $+2v_p$. On the positive half-cycles, D1 and D3 are off, and D2 is on. This allows C2 to recharge from C1, but it also connects C1 and C3 in series, thus increasing the output voltage even more than the voltage doubler circuit.

The output voltage from this circuit will fluctuate on alternate half-cycles so that a considerable amount of filtering will be required to produce a smooth dc output. Once all capacitors are fully charged under no-load conditions, this output will vary from $+2v_p$ on negative half-cycles to $+4v_p$ on positive half-cycles. The average output voltage will be $+3v_p$, so this circuit is a voltage tripler.

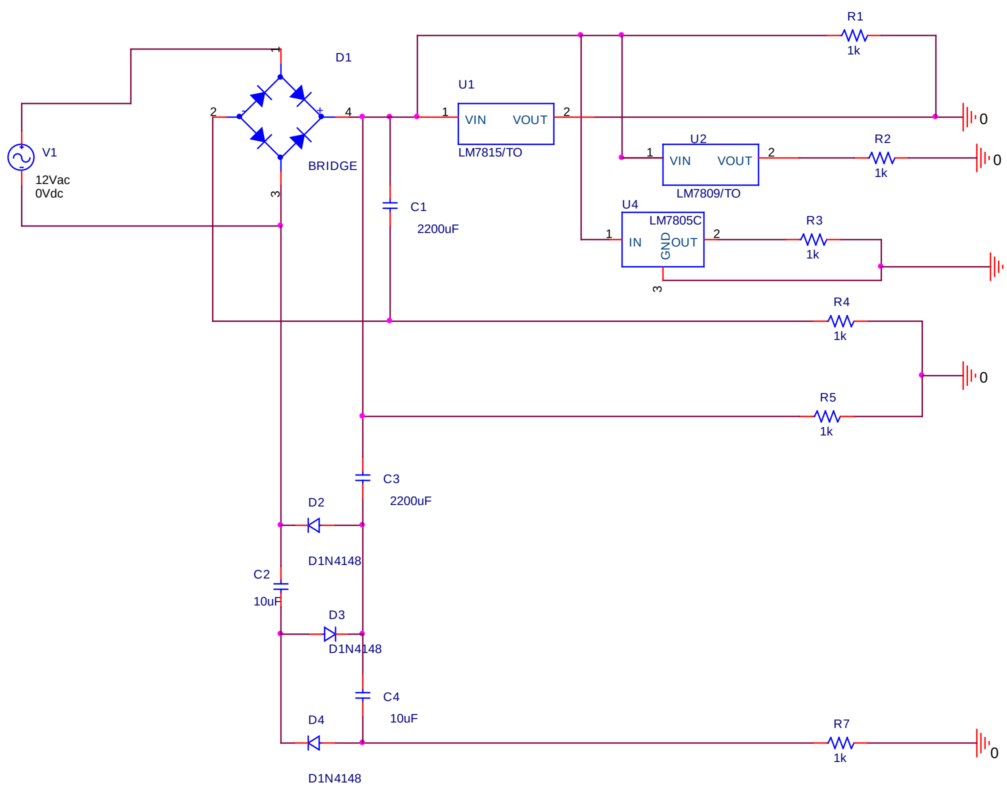

Figure 3.19: The combination of Voltage doubler and voltage tripler

3.3.5 Voltage regulator

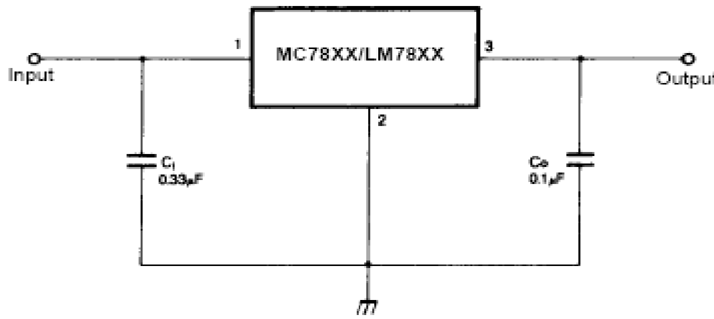

Figure 3.20: Voltage Regulator Circuit

The circuit in Figure 3.15 above shows the basic component in voltage regulator. Where the circuit consists of input power, input capacitor (Ci), voltage regulator IC (LM7805/LM7809/LM7815), and output capacitor (Co). The IC used in this circuit is a Fixed Regulator ICs where the output voltage produce is smaller than the input voltage. The voltage different between the input and output appears as heat and dissipated through head sink. The capacitor attached at the input and output is used to remove an unwanted noise and spike.

3.3.6 Overvoltage Protection Circuit

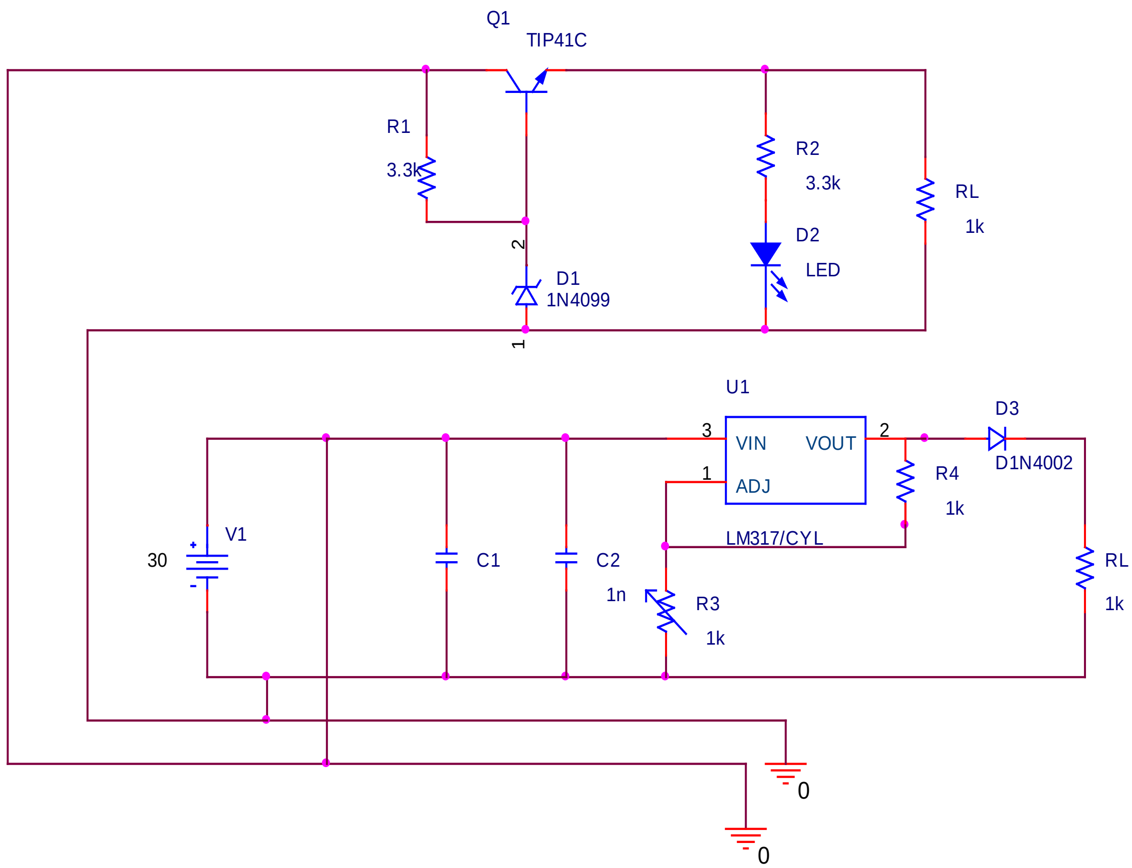

Figure 3.21: Overvoltage protection circuit

This circuit contain of voltage regulator using IC LM317 and several capacitor, resistor, LED and diode. The function of this overvoltage protection circuit is to maintain the power supply at fix value and to protect the LED power saving from overvoltage. The regulator capable to produce an output between 0V to 30V at .The resistors R1 and R2 determines the output voltage. The resistor R3 determines the limiting value of output current. Capacitors C1 and C2 does filtering.

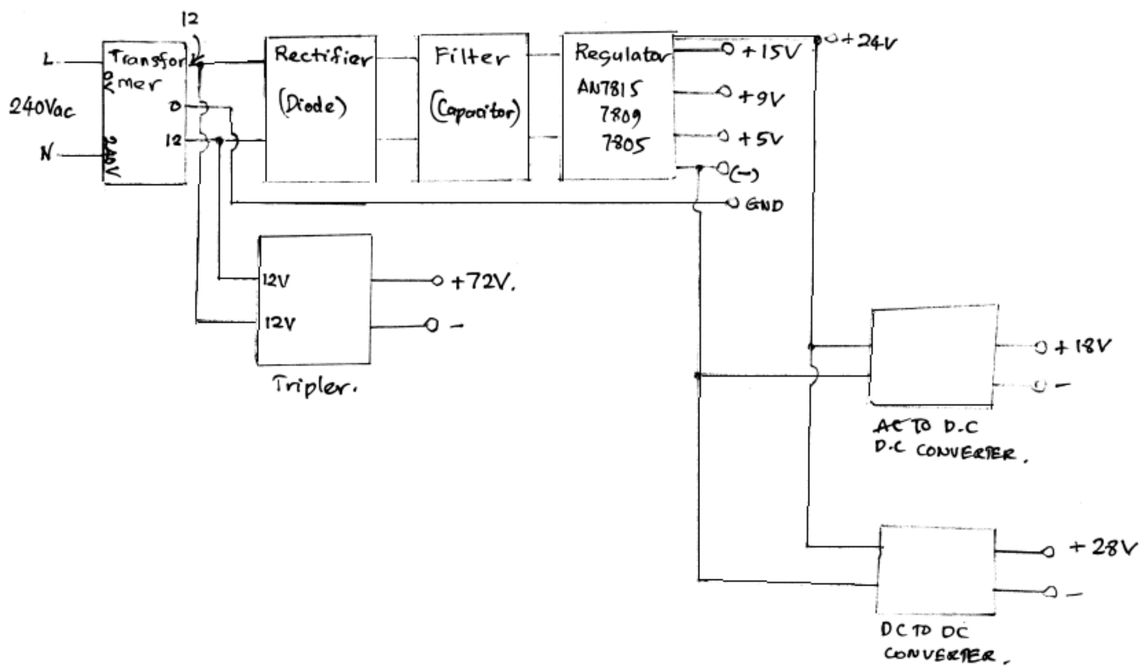

Figure 3.22 : The combination flow of the overall circuit

CHAPTER 4

RESULT AND ANALYSIS

4.1 Introduction

This project has been successfully work for the PWM generation for the switch of the boost converter from the program that has been burn in the PIC18F4550 but unfortunately, the result has not been recorded and the driver of the MOSFET is already damage because of non-constant voltage. Therefore the exact result cannot be shown in the. Below are the finish circuit and the sketch circuit that already been soldered and tested:

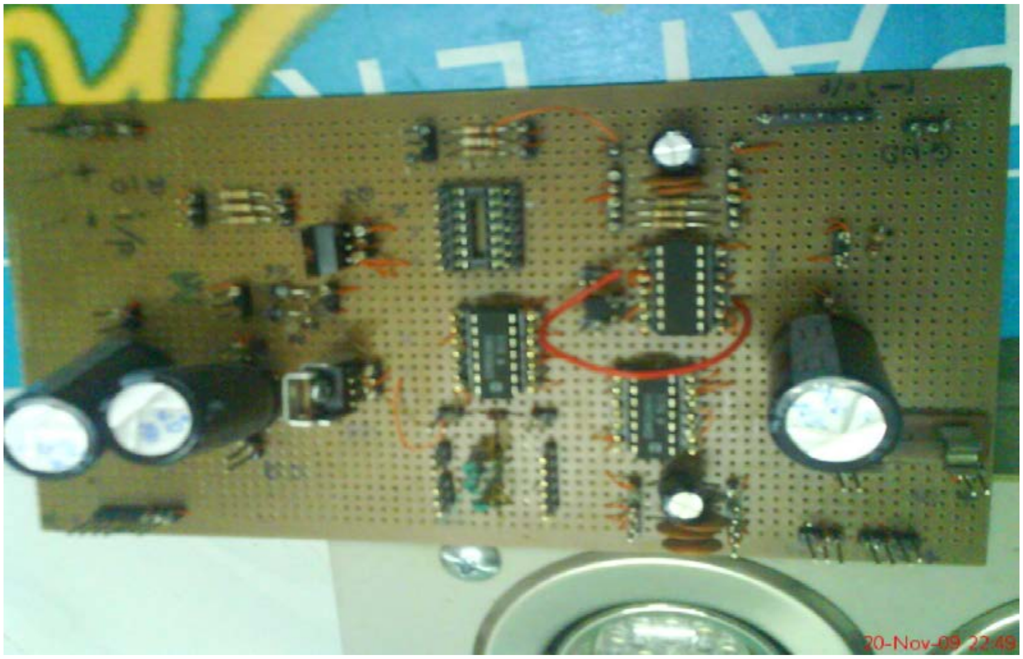

Figure 4.0: boost converter circuit

4.2 The voltage regulator result

The voltage regulator of LM 7815 will regulate the input voltage from the power supply which is 24V to regulated voltage of 15V. The second voltage regulator which is LM7805 will produce the output voltage of 5V by taking the output voltage of LM7815 as the input voltage and regulate the voltage to 5V.below is the result shown for the regulated voltage for both voltage regulator of LM 7815 and LM 7805.

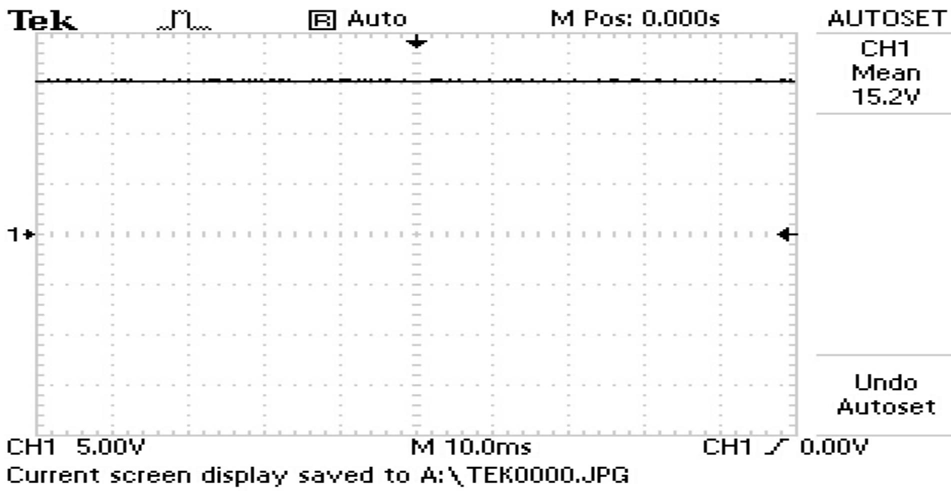

FIGURE 4.1: RESULT FROM OSCILLOSCOPE FOR VOLTAGE REGULATOR LM 7815 TAKEN AT 12.23PM , 20/10/09

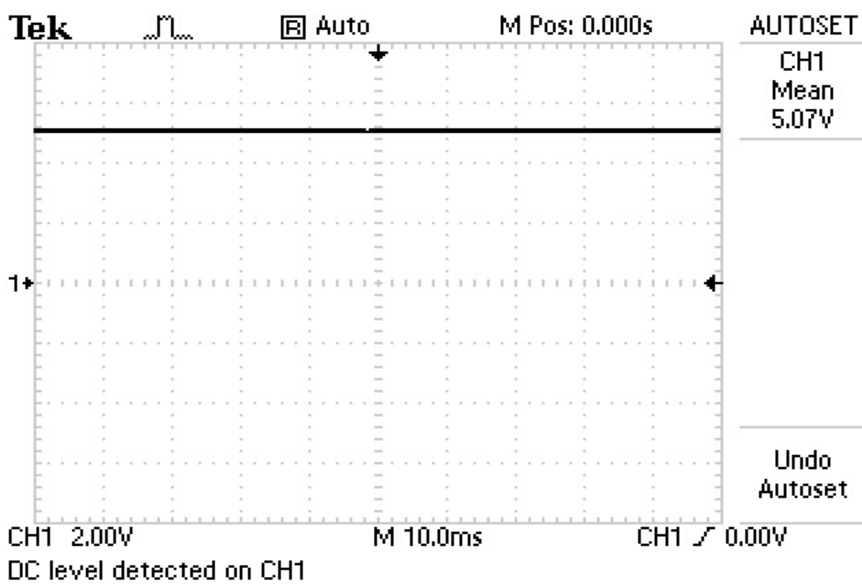

FIGURE 4.2: RESULT FROM OSCILLOSCOPE FOR VOLTAGE REGULATOR LM 7805 TAKEN AT 12.30PM, 20/10/09

4.3 LED power saving results

FIGURE 4.3: LED Power Saving is in ON state state and the meter are showing the voltage and current reading

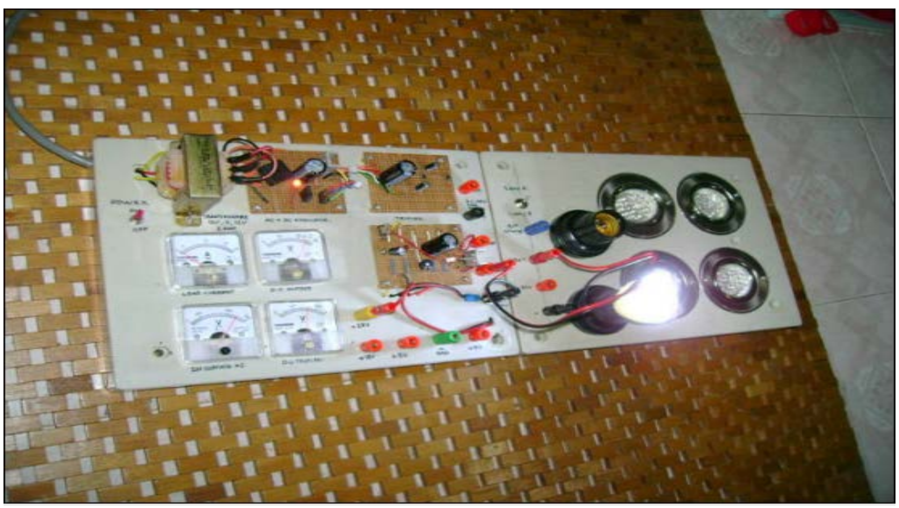

FIGURE 4.4: LED Bulb is in ON state and the meter are showing the voltage and current reading

4.4 PSPICE Simulation Result

PSPICE are use for the circuit development and simulation graph. The PSICE simulation views contain result for the overvoltage protection, voltage multiplier and the PWM signal for boost converter. The circuit has been separately built and simulate according to figures shown.

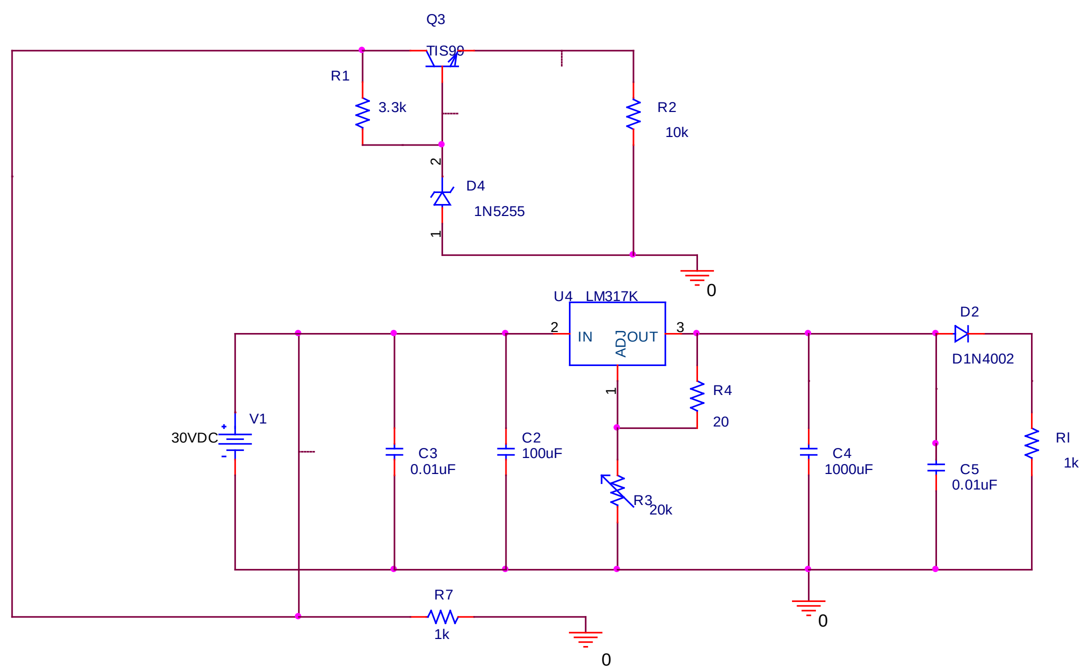

FIGURE 4.5: Overvoltage Protection PSPICE circuit

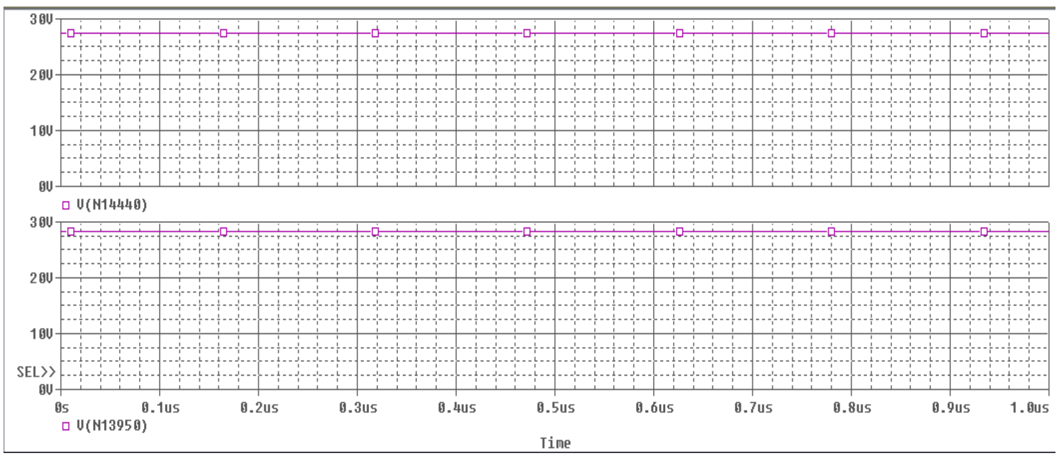

FIGURE 4.6: Simulation result

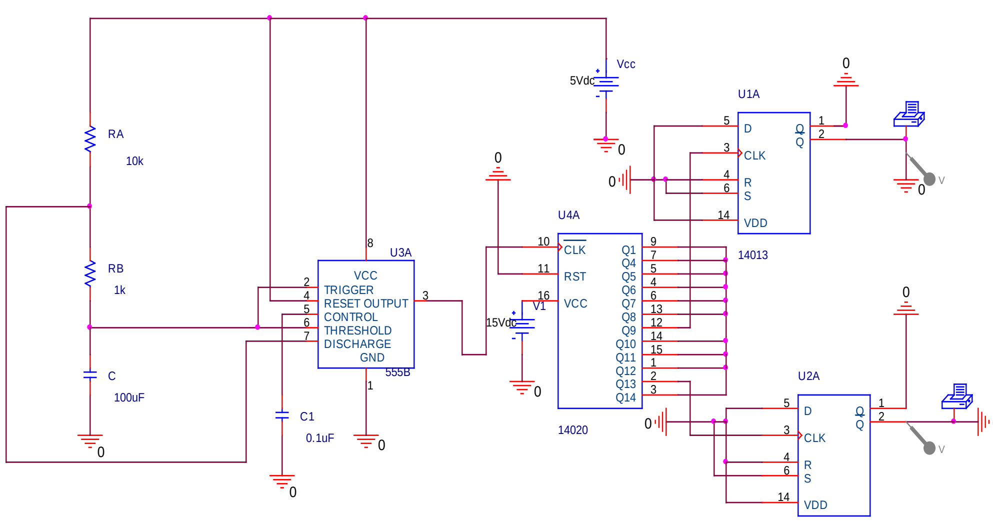

FIGURE 4.7: Timer and IC flip-flop circuit

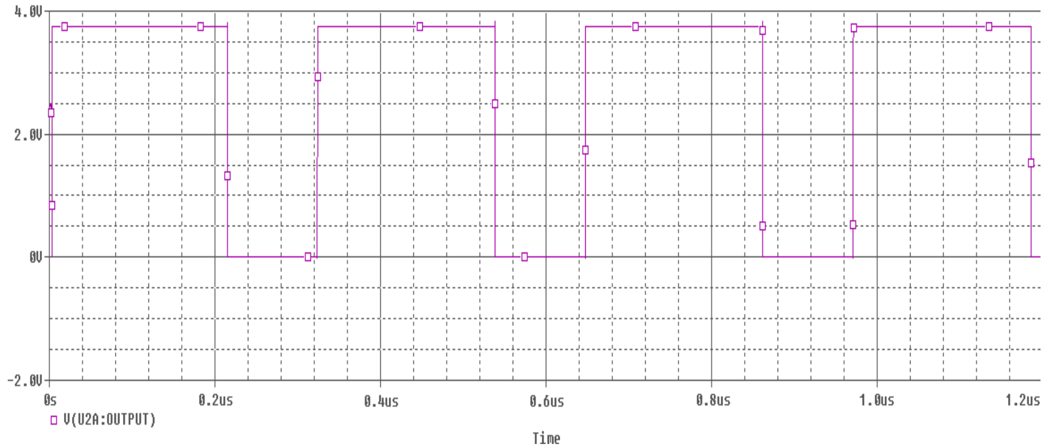

FIGURE 4.8: Output voltage for timer

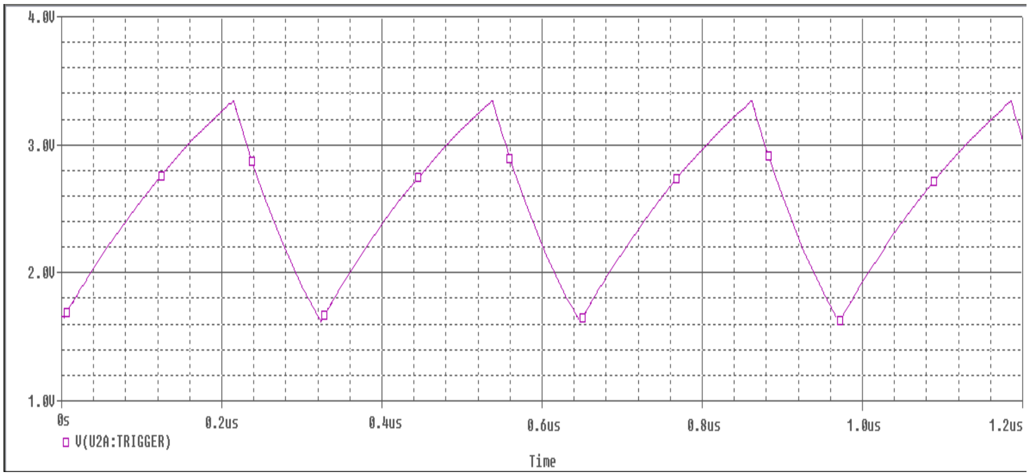

FIGURE 4.9: Trigger voltage for timer

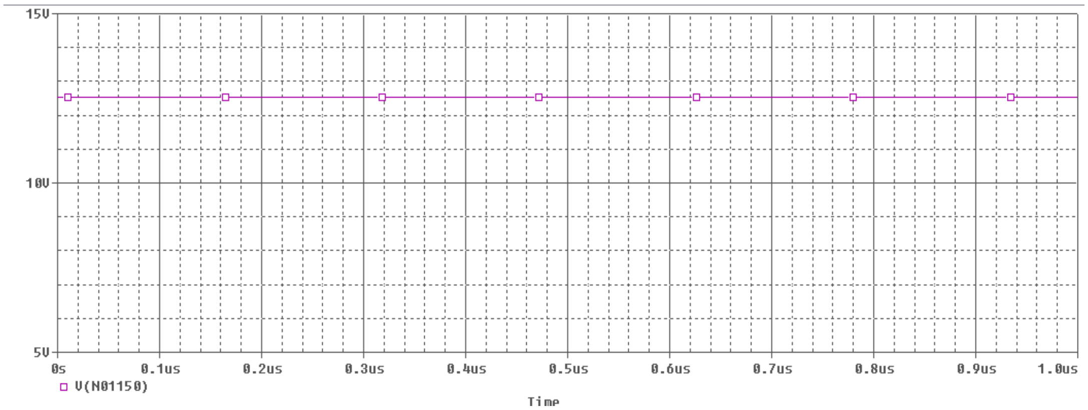

FIGURE 4.10 : Simulation result for the LM 7815of voltage multiplier

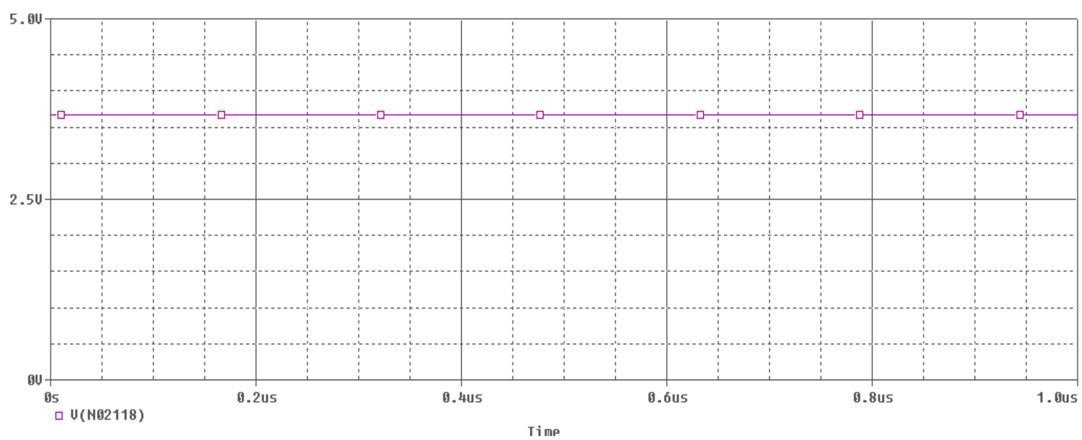

FIGURE 4.11 : Simulation result for the LM 7805 of voltage multiplier

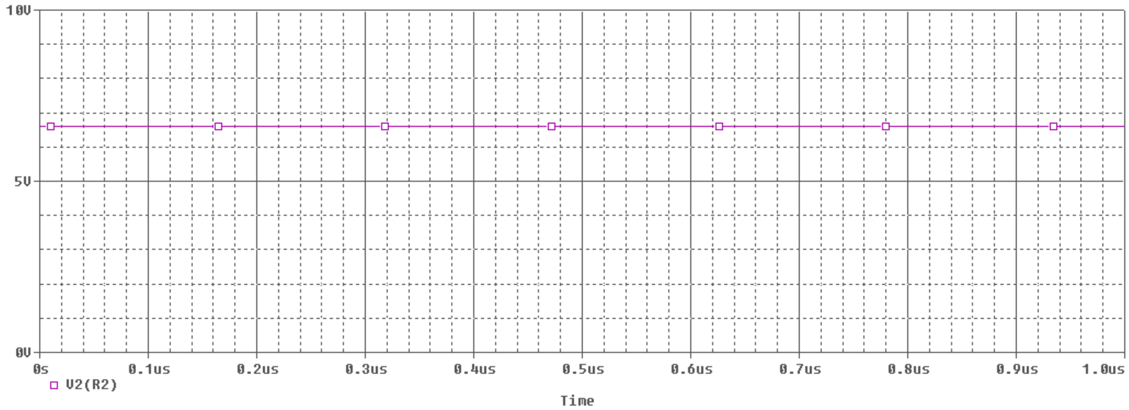

FIGURE 4.12 : Simulation result for the LM 7809 of voltage multiplier

4.5 LED Power Saving current result

LED current results are obtained from the multimeter where as shown in figure below. The current are tested for both LED lamp and LED bulb.

TABLE 4.5.1: LED current reading

LED	**Current reading(A)**
LED lamp	**0.42**
LED bulb	**0.32**

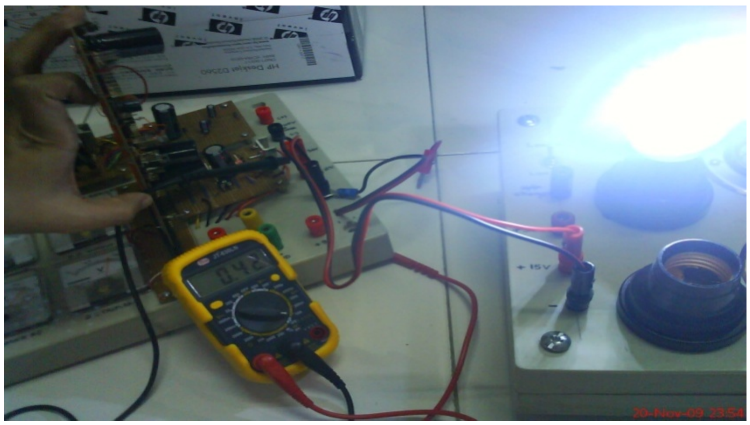

FIGURE 4.13:LED bulb current reading

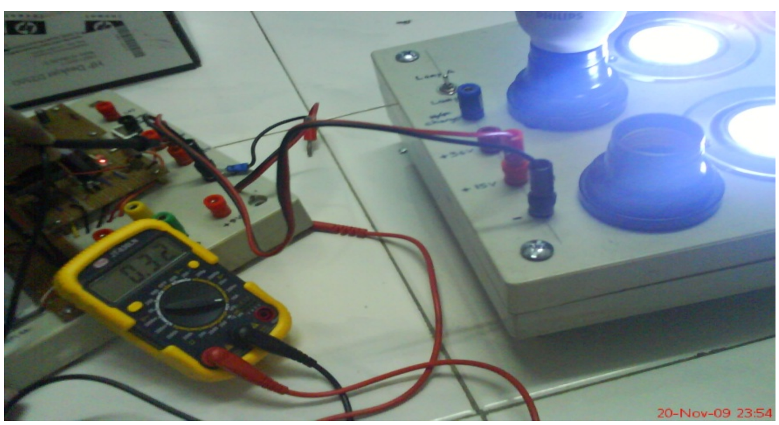

FIGURE 4.14: LED lamp current reading

4.6 Result comparison

TABLE 4.15: result compare for voltage multiplier

Voltage regulator	Set value	Simulation value	Actual value
LM 7805	5V	4.OV	4.0V
LM 7809	9V	6.74V	6.80V
LM 7815	15V	12.45V	14.70V

TABLE 4.16: result compare for boost converter voltage regulator

Voltage regulator	Set Value	Actual value
LM7805	5V	5.07V
LM7815	15V	15.2V

TABLE 4.17: result compare for boost converter input and output

Boost converter	Input voltage	Output voltage
Calculated value	15V	28V/30V
Actual value	14.7V	25.4V

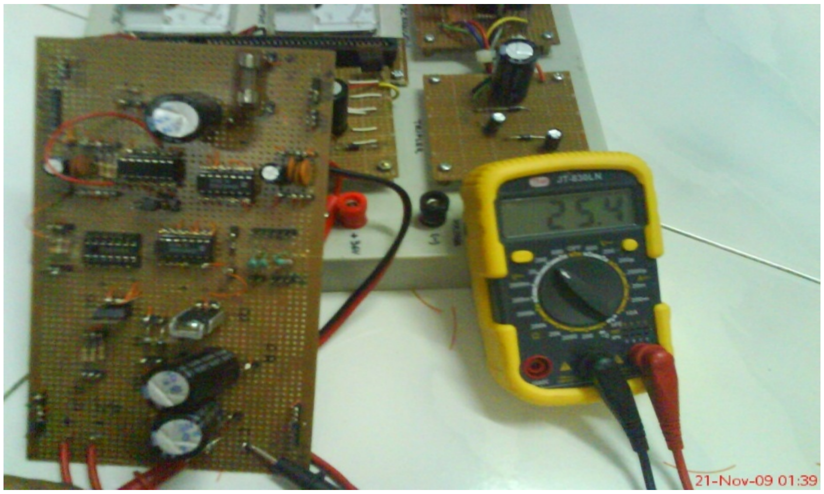

FIGURE 4.18: Boost converter result

TABLE 4.19: result compare for voltage multiplier voltage value

Set Value	Actual value
9V	6.8V
15V	14.9
28V	27
36V	37.2V
110V	105V

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Nowadays, boost converter are already been used widely and the application as a DC-DC converter are already well-known. As we can see in this project, boost converter can still be used even apart of the project was changed according to the desired design. This shows that boost converter can be and apply in any way and user-friendly since the size of the circuit is small and it is portable. The modern applications of boost converter are often seen in car’s engine, motors, generator and power equipment. As in this project, the boost converter was being applied with two different system which are PIC and overvoltage protection circuit.

Problems

The typical problem that are facing during this project is to create the program of the PIC to stop the PWM since the previous purpose of this program is to stop the generation of PWM by using the PIC program. The program that already been created contain error and the lack of expertise knowledge in programming made it more difficult and hard to achieve the target of the project. Even if the PIC is only use to generate PWM, the other circuit such as driver circuit and MOSFET component which consider as fragile and sensitive component are easily damage by the non-constant voltage. While the tools to test is limited to the power supply and the oscilloscope which located at the lab, therefore it is also time consuming to fulfill the requirements of this project.

Boost converter can be considered as a good electronic device to overcome the big number of motor and transformer that should be use in equipment of vehicles, but since electronic devices are sensitive to high voltage and high current, the application are limited to only medium voltage and the effect of this limitation to other part of the mechanical equipment will reduces the reliability and the efficiency of the performance of the equipment.

Voltage multiplier has the voltage drop for every voltage terminal when the circuit has been build in real practices. Most of the value of PSPICE simulation, actual and set value are already been compare and the voltage is higher for small voltage regulator.

Therefore the implementation of PIC auto-off cannot be imply in this circuit because of the varied voltage drop and regulation. Some of the PSPICE simulation cannot provide the true value because of the circuit configuration and software error.

LED power saving drawbacks is the voltage limitation. The LED can only accept maximum voltage of 12V and because of the expensive cost of circuit implementation, it is not really well known like fluorescent and bulb lamp for common electrical appliances.

5.3 Recommendation

It is to be advised that the circuit should be tested under low voltage and current before increase the voltage for desired output. In the circuit, instead of using programming to generate the PWM for the switch of boost, we can also use other devices such as timer, flip-flop and PWM integrated to overcome the programming problem and error encountered.

In stead of using the overvoltage protection circuit, we can also use overload protection circuit but the circuit will be much complex compared to overvoltage protection because it will involved the load demanding requirement and will be harder to design.

As for the step-up voltage, the design and circuit of boost converter in the voltage multiplier are as the back up supply in case the voltage multiplier terminal are damage for certain value of voltage, the boost converter can be use as the replacement.

5.4 Costing and Commercialization

The cost to develop one unit of this project is summarized in the table shown:

Table 4.20: Overall cost for one set of boost converter , voltage multiplier and Overvoltage protection circuit

Boost converter & Voltage Multiplier	IC LTC1696	2	3.50	7.00
	MC14020	2	5.00	10.00
	MC14013	2	5.00	10.00
	LM7805	2	2.00	2.00
	LM7815	2	2.50	2.50
	LM7809	2	2.00	2.00
	Heat sink	2	1.50	3.00
	IRF740	1	5.00	5.00
	8-pin IC holder	1	0.70	0.70
	Inductor 60uH	2	18.90	18.90

	Independent board	1	2.00	2.00
	IN4148	4	0.50	2.00
	Resistor 1kΩ	3	0.10	0.30
	Resistor 2kΩ	3	0.10	0.10
	Resistor 4.6kΩ	2	0.70	0.70
	Capacitor 22pF	4	0.20	0.80
	Capacitor 0.33µF	2	0.10	0.10
	Capacitor	1	0.10	0.10
	Capacitor 0.1µF	4	0.10	0.40
	Zener diode 5V	2	0.80	0.80
	LED bulb	1	7.00	14.00
	Transfomer 240Vac	1	20.00	20.00
	Bridge Rectifier	1	0.70	0.70
	voltmeter	1	5.00	5.00
	Ammerter		5.00	5.00
	LED lamp	2	8.50	17.00
Overvoltage Protection circuit	Capacitor 0.01uF	2	0.20	0.40
	Capacitor 4700uF	1	0.50	0.50
	Capacitor 100uF	1	0.50	0.50
	Variable resistor 91M	2	0.50	1.00
	Resistor 3.3k	2	1.00	2.00

	IC LM317	2	3.50	7.00
	D 4002	1	0.30	0.30
TOTAL				141.80

This project can be commercialized LED light power saving for small appliances. It is suitable to be used electrical appliances and home appliances .The production cost for this project is considered high because the materials used in this project are quite expensive from some of the component those are hardly to get and need to be ordered through internet and mails. The costs above also include the sinking cost for the damage boost converter and component. The prospect of this project is to build a multiple choice in voltage for power supply, varied the distribution of boost converter and also for education purposes.

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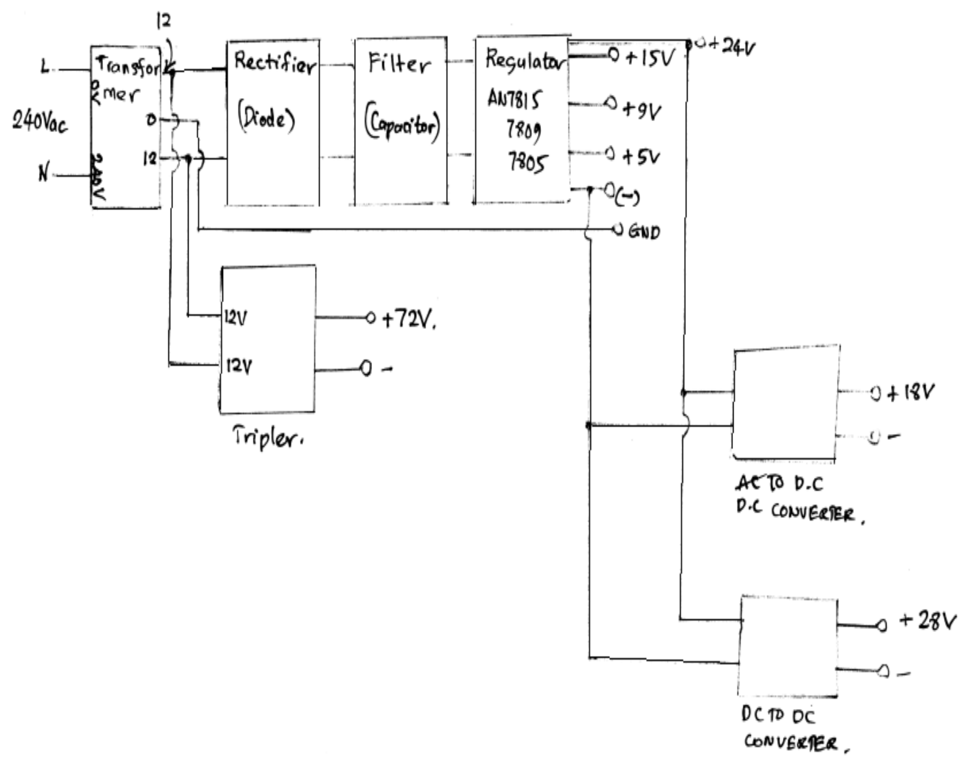
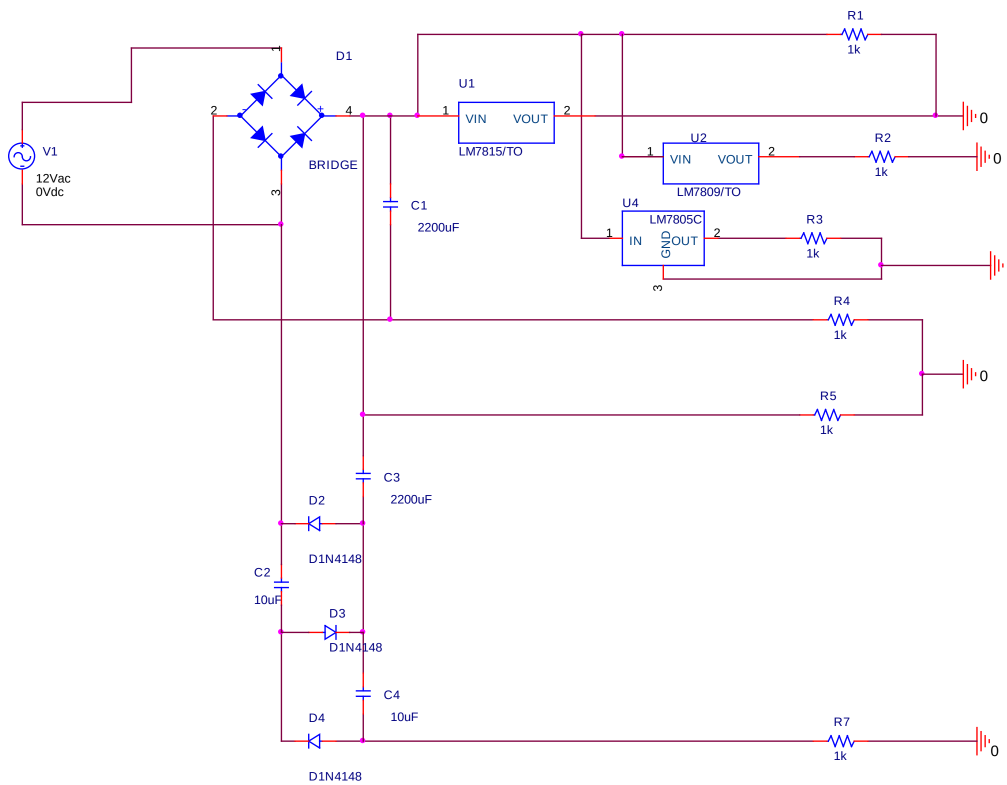
APPENDIX A



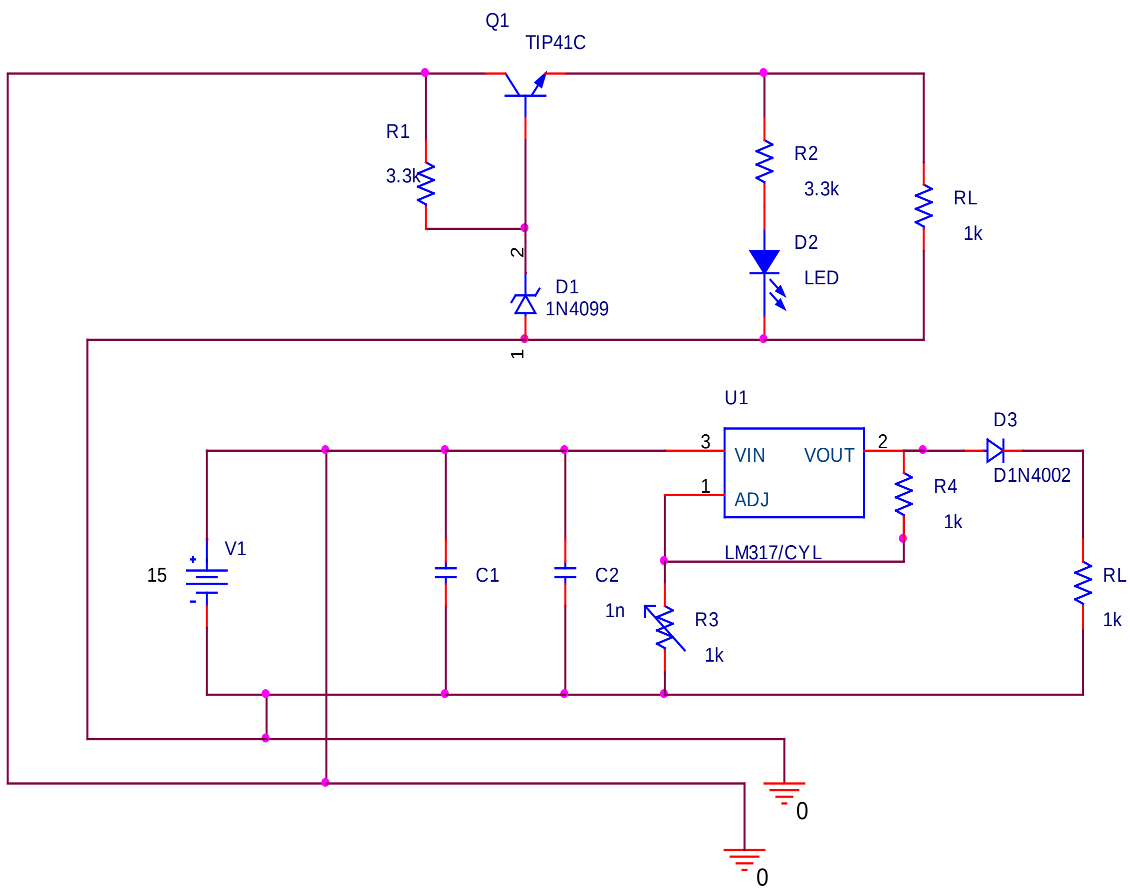
Voltage Multiplier sketch

APPENDIX B



Voltage Multiplier Circuit

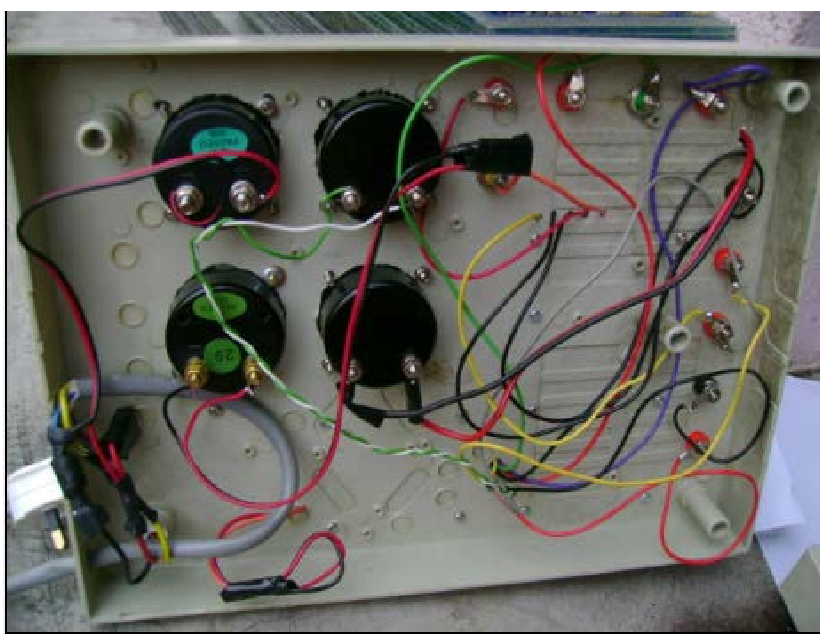
APPENDIX C

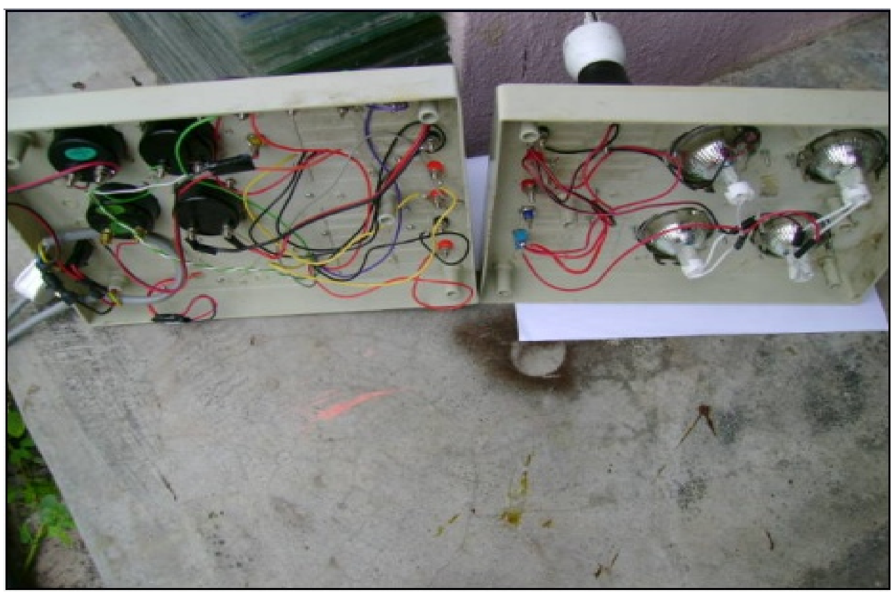


Overvoltage Protection Circuit

APPENDIX D

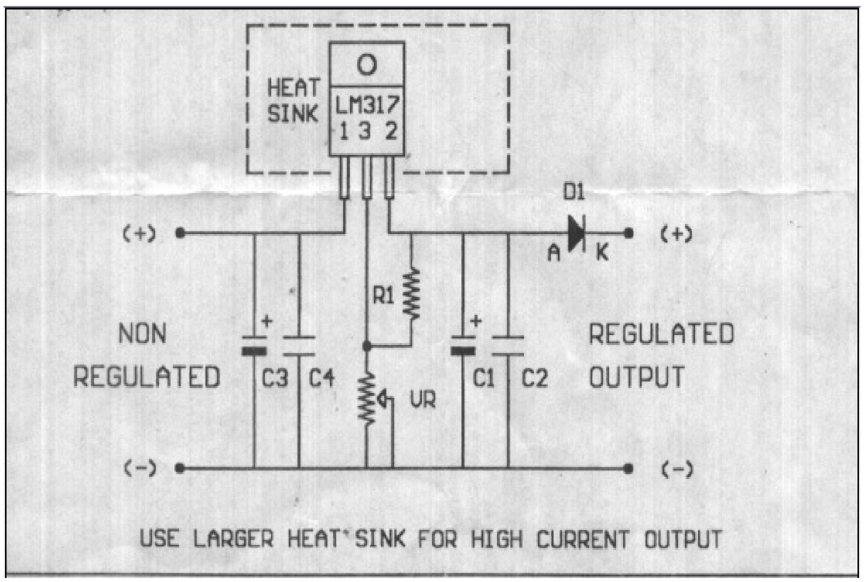
Project Pictures

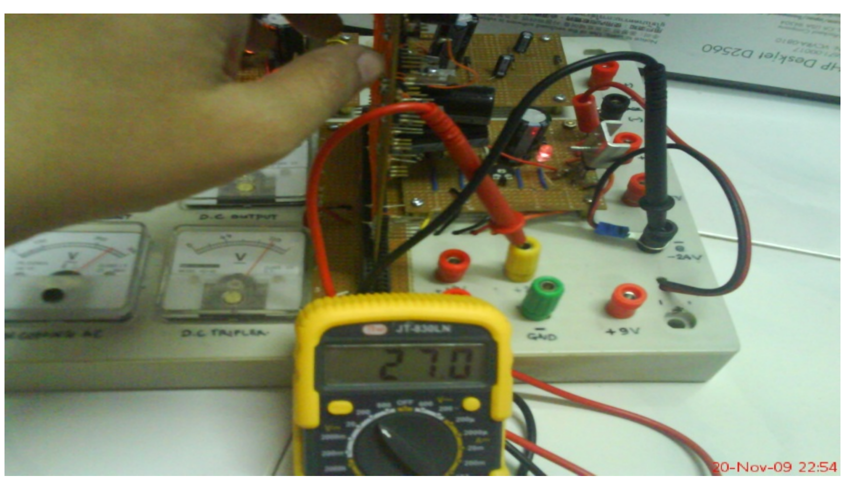


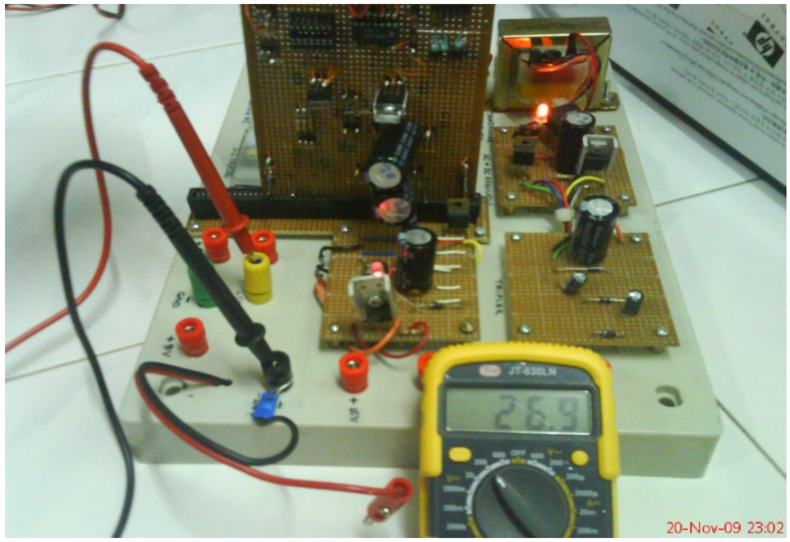


APPENDIX E

Result Pictures

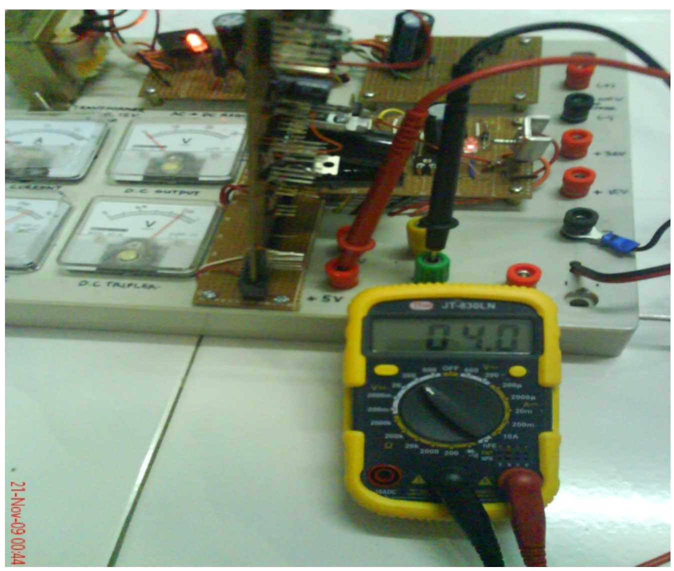





JT-830LN
26.9
20-Nov-09 23:02


21-Nov-09 00:43


JT-830LN
14.7
D.C output
D.C TRIPLEX
+5V
21-Nov-09 00:43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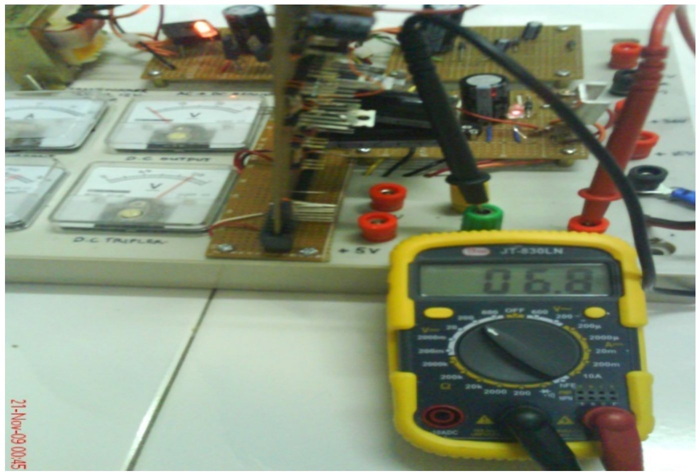
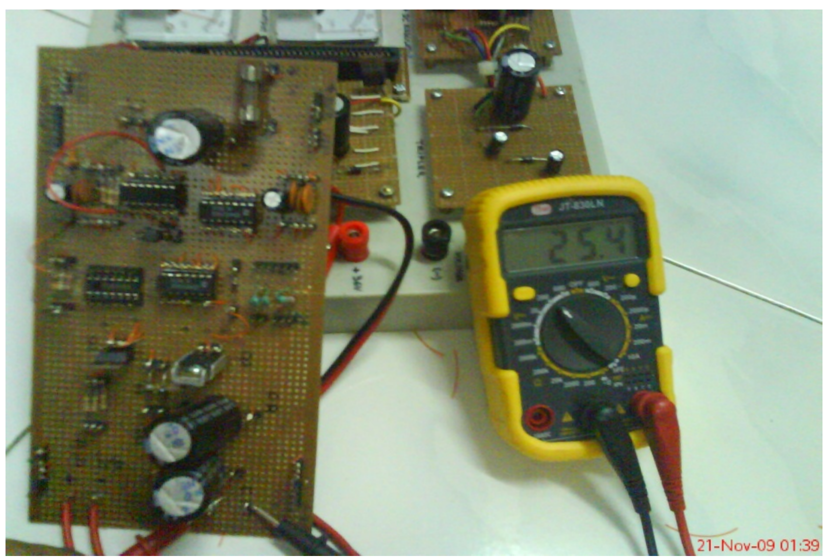
04.0
D.C output
D.C TRIPLEX
+5V
21-Nov-09 00:44


+5V
JT-830LN
06.8


25.4
21-Nov-09 01:39

APPENDIX F

DATASHEETS

REFERRENCES

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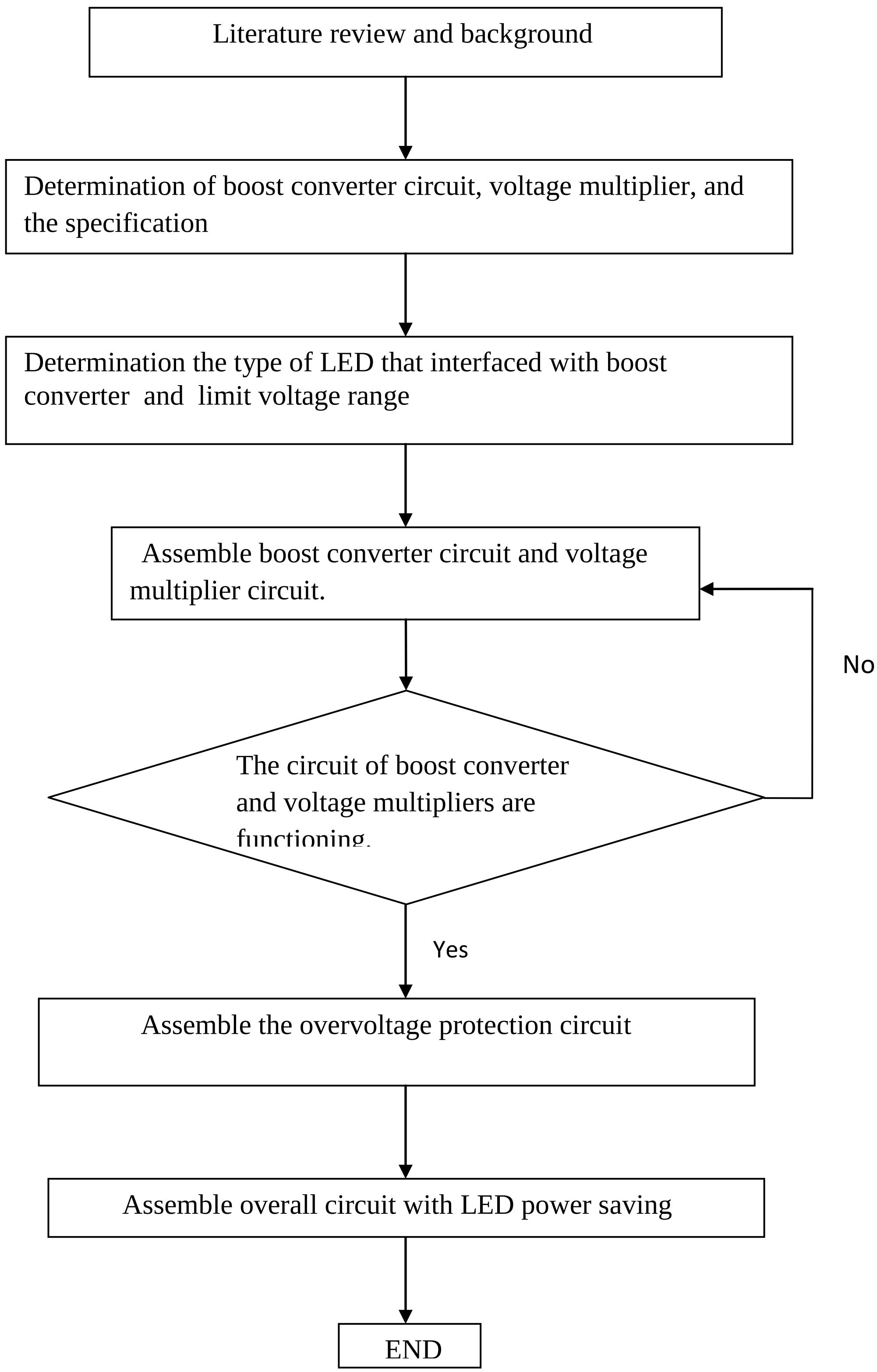
Literature review and background
Determination of boost converter circuit, voltage multiplier, and the specification
Determination the type of LED that interfaced with boost converter and limit voltage range
Assemble boost converter circuit and voltage multiplier circuit.
No
The circuit of boost converter and voltage multipliers are functioning.
Yes
Assemble the overvoltage protection circuit
Assemble overall circuit with LED power saving
END

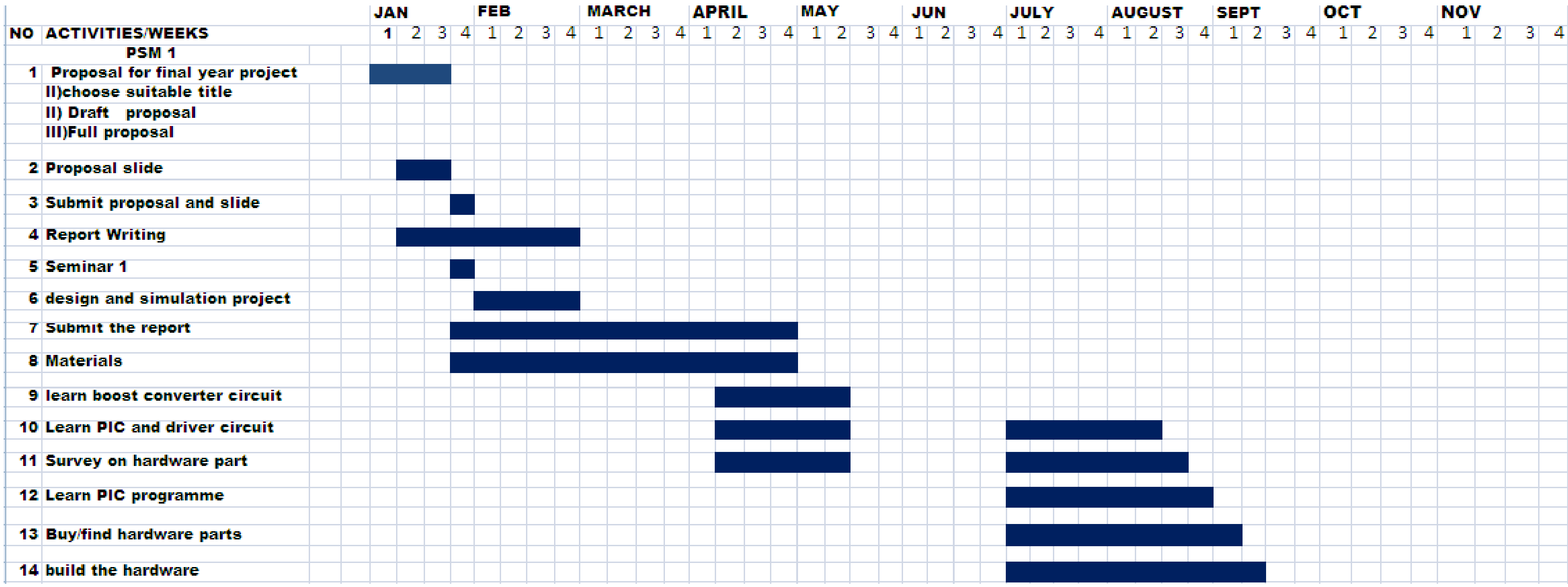

Figure 1.7: Gantt Chart of the project schedule for Semester 1

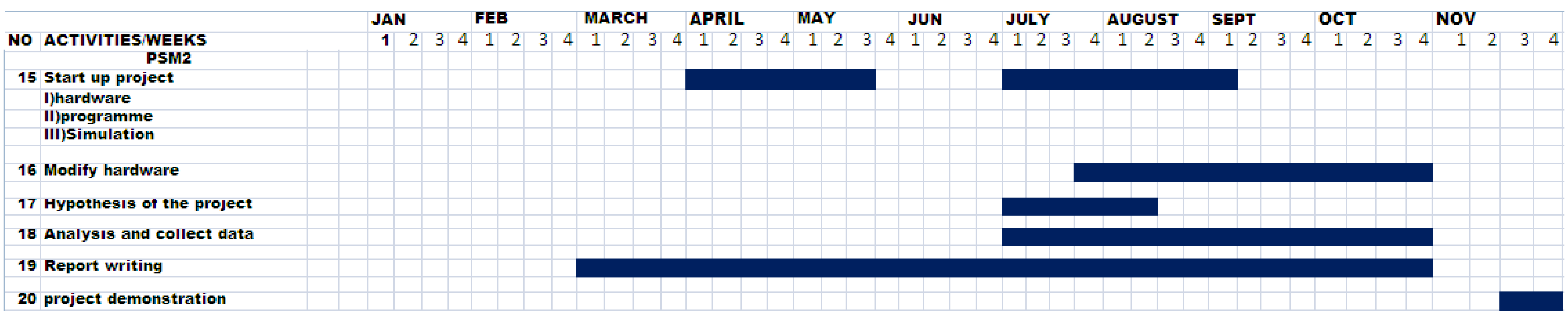

Figure 1.8: Gantt Chart of the project schedule for Semester 2