UNIVERSITI TEKNIKAL MALAYSIA MELAKA

FACULTY OF ELECTRICAL ENGINEERING

REPORT FINAL YEAR PROJECT 2

DESIGN OF DC BOOST CONVERTER IN CONTINUOUS CURRENT MODE

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A report submitted in partial fulfilment of the requirement for the Degree of Electrical Engineering

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2018

APPROVAL

I hereby declare that I have read through this report entitled “Design of DC Boost Converter in Continuous Current Mode” and found that it complies the fulfilment for awarding the degree of Bachelor of Electrical Engineering.

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Date : ________________________________

DECLARATION

I declare that this report entitled "Design of DC Boost Converter in Continuous Current Mode" is the result of my own research expect as cited in the reference. This report has not been accepted for any degree and is not concurrently in candidature of any other degree.

Signature : ____________________

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Date : ____________________

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious and the Most Merciful

Alhamdulillah, all praises to Allah for the strength and HIS blessing in completing my Final Year Project (FYP) report. Special appreciation goes to my supervisor, En Ahmad Aizan bin Zulkefle for his supervision and unconditional support. His invaluable help of constructive comment and suggestion throughout the period have contributed to the success. Not forgotten, to all my lecturers that had me throughout my study which help me a lot in completing this report.

I would like to express my appreciation to the Dean of Electrical Engineering Faculty Ir. Dr Md Nazri bin Othman for their support and help towards undergraduate affairs. My acknowledgement also goes to all technicians and office staff of Faculty of Electrical Engineering for their co-operations.

My greatest acknowledgement I dedicated to my parents, Puan Rosnah and Encik Md Aziz for their endless love, support, prays, and cheers. Surely, without the passion and affection from both of you, I will not go this far. Not forgotten to all my family and friends, thank you very much for your support and pray.

To those who indirectly contributed in this report, your kindness means a lot to me. Thank you very much.

ABSTRACT

DC-DC converters are widely used in regulated switch mode DC power supplies. The input of these converters is an unregulated DC voltage and therefore it will fluctuate due to the disturbances in the system. This project presents a design and analysis of DC-DC boost converter for continuous current mode (CCM). This system has a non-linear dynamic behaviour, as it work in switch-mode. Moreover, it is exposed to significant variations which may take this system away from nominal conditions, due to changes on the load or the line voltage at the input. DC-DC boost converter is developed and simulated using MATLAB Simulink software. MATLAB Simulink tool environment is used for plotting the waveforms and implementing mathematical equations. In this project, the equations of a boost converter are analyzed and a design of components and simulation of DC-DC boost converter are proposed. Other than that, the changes of duty cycle (D) for boost converter affect the whole operation of the system and analyze an output waveform of simulation part and hardware part.

ABSTRAK

Penukar DC-DC digunakan secara meluas dalam mod suis terkawal bekalan kuasa DC. Masukan dari penukar ini adalah voltan DC yang tidak dikawal dan oleh itu ia akan berubah-ubah disebabkan oleh gangguan dalam sistem. Projek ini membentangkan reka bentuk dan analisis simulasi DC-DC boost converter untuk mod semasa berterusan (CCM). Sistem ini mempunyai kelakuan dinamik yang tidak setara, kerana ia berfungsi dalam mod suis. Selain itu, ia terdedah kepada variasi ketara yang mungkin mengambil sistem ini dari keadaan nominal, disebabkan oleh perubahan beban atau voltan garisan pada input. DC-DC boost converter dibangunkan dan disimulasikan menggunakan perisian MATLAB Simulink. Persekitaran alat MATLAB Simulink digunakan untuk merancang bentuk gelombang dan melaksanakan persamaan matematik. Dalam projek ini, persamaan rangsangan penukar dianalisis dan reka bentuk komponen dan simulasi penaik rangsangan DC-DC dicadangkan. Selain daripada itu, perubahan kitaran duti (D) bagi penukar rangsang menjejaskan keseluruhan operasi sistem dan menganalisis bentuk gelombang keluaran.

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CHAPTER 1

INTRODUCTION

This chapter will describe the project background, problem statement, project objective, and project scope. In this project background, it will briefly the description of the "Design of DC Boost Converter in Continuous Current Mode" and study the waveform in continuous current mode (CCM) as well as the project objective and scope.

1.1: Project background

DC – DC converter are power electronic circuit that convert a dc voltage to a different dc voltage level. It important component in many applications and power capability demands. It may applicable in electric vehicle, uninterruptable power supply (UPS), photovoltaic (PV) system, and fuel cell system. The DC – DC converter can be divided into two categories which are non-isolated and isolated converter. This report is focus on the boost converter is one type of non-isolated converter. It can raise low input voltage and current to higher output voltage and current. The circuit diagram of boost converter is shown as in Figure 1.1.

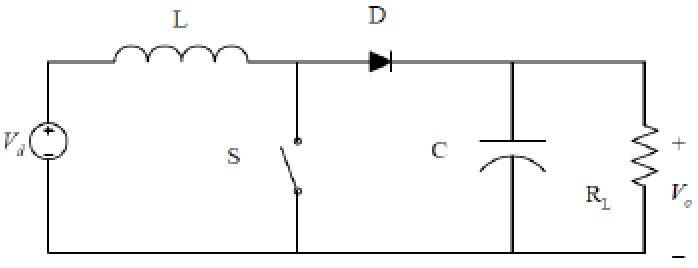

Figure 1.1: Circuit boost converter

The principle thought of this report is to design a boost converter and analyse a waveform in continuous current mode. The simulation of the circuit will be finished by utilizing in MATLAB software. Also the hardware prototype will be do and to compare and analysis the result from simulation and hardware.

1.2: Motivation

A boost converter is used in renewable energy system to step up an unregulated DC voltage to a higher constant output voltage that required by load and batteries. The design and development of boost converter is mainly concern of its output voltage, current ripple and ease of design. Renewable energy such as solar system and wind uses boost converter as a medium of power transmission to perform energy absorption to load and batteries. For conventional DC –DC boost converter has a higher current ripple. In this project the current ripple is main important to reduce with selecting the best value of parameter.

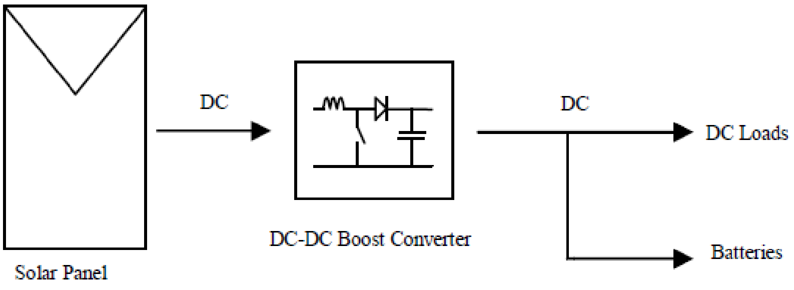

Figure 1.2: Block diagram of solar system

1.3: Problem statement

Nowadays, the DC-DC boost converter is the common step up power converter used in many applications because it can convert from low input voltage to high output voltage by controlling the duty cycle of the power switch. But for the conventional boost DC-DC converter, it produce large output current ripple and input current ripple. For an ideal circuit, the ripple must be avoided so that any application can perform at its optimum performance. The ripple can reduce efficiency and thus reduce the performance itself. Therefore to overcome this problem, the selected value of capacitor and inductor is very important to make sure the ripple will reduce. This research is analyzing the waveform boost converter in continuous current mode. The main challenge faced by this study is to design a boost converter from a data in calculation and simulation.

1.4: Objective

The objectives of this project are:-

1. To design and obtain a boost converter circuit with the correct value of parameter.
2. To perform simulation of boost converter by using a MATLAB software.
3. To develop hardware prototype of the DC – DC boost converter.
4. To analyze an output waveform of simulation and hardware part.

1.5: Scope project

This project primarily focuses on designing the DC – DC converter circuit, examining the circuit, analyzing the output and comparing the result of boost converter in continuous current mode. The circuit are design and simulate by using MATLAB / SIMULINK software. The pulse width for the switching controller is generated by using programming developed by Infineon XMC4500. The hardware implementation of the DC-DC switching boost converter is based on the simulation done in MATLAB software. This project will cover the fundamental knowledge of DC – DC converter topic only.

CHAPTER 2

LITERATURE REVIEW

2.1: Introduction

This chapter review the existing project created to get an idea about the boost converter by following conception, specification and any information that related to the project. In later of this chapter, some review about the proposed design of boost converter to fulfil this project will be reported.

2.2: Converter

Converter is defined as a electronic circuit that convert one type or level of voltage to another level voltage waveform. It serves as the connector between power source and load. [1]

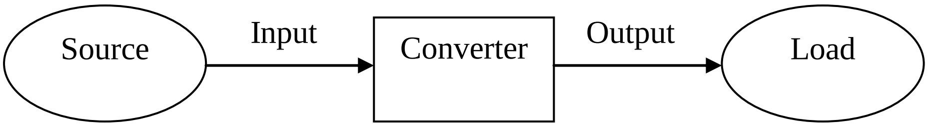

Figure 2.1: Basic converter operation

Converters are classified into four types by the relationship between input and output:

Table 2.1: Classification of converter

Type of converter	**Functions**
AC input/DC output	The AC/DC converter that produces a DC output from an AC input. It classified as a rectifier.
DC input/AC output	The DC/AC converter that produces a DC output from a DC input. It classified as a inverter.
DC input/DC output	The DC/DC converter that produces a DC output from a DC input. It classified as a regulator.
AC input/AC output	The AC/DC converter that produces a DC output from an AC input. It used to change the level and/or frequency of an AC signal.

2.3: DC - DC Converter

A dc - dc converter can be defined as a power electronic circuit that convert a dc voltage to a different dc voltage level. It often provided a regulated output [2]. DC - DC converter is required because it operation not similar like AC which the DC cannot be step-up or step-down using a transformer. DC converter is an equivalent to a transformer [3].

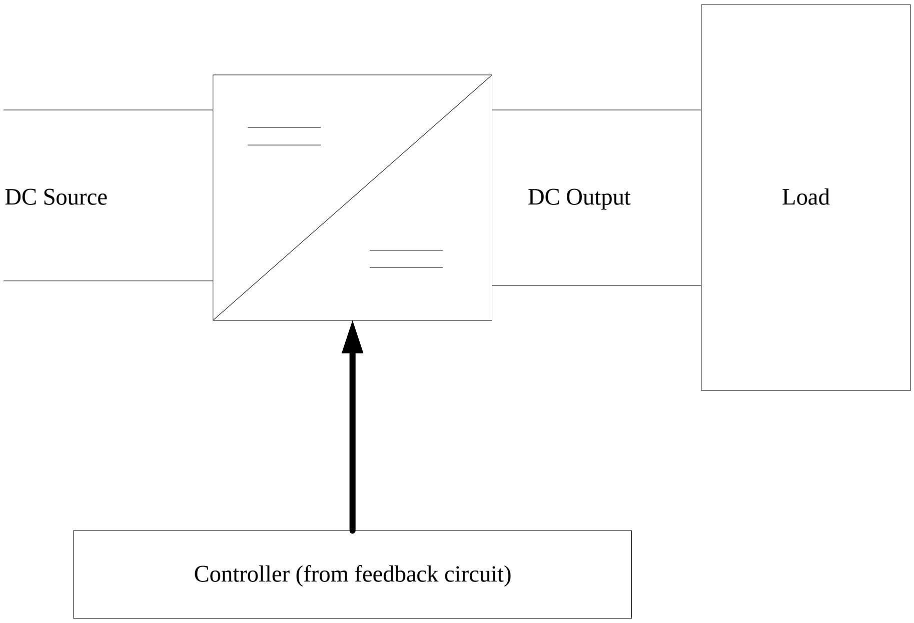

Figure 2.2: General DC – DC converter block diagram

DC-DC converters include buck converters, boost converters, buck-boost converters, Ćuk converters and full-bridge converters. Switched DC-DC converters offer a method to increase or decrease an output voltage depend on application or system. DC-DC converters operated in two modes according to the inductor current. The inductor current fluctuates but never goes down to zero is called Continuous Conduction Mode (CCM) and Discontinuous Conduction Mode (DCM) happen when the inductor current fluctuates and goes down to zero at or before the end of each cycle.

Energy is periodically stored into and released from a magnetic field in an inductor. This is applied to control the output voltage so that the output remains constant even though the input voltages keep changing. There are two categories of DC-DC converters that are non-isolated DC-DC converter (Buck, Boost and Buck-Boost) and isolated DC-DC converter (Flyback, Forward, Push-Pull, Full-Bridge and Half-Bridge).

Non-isolated DC-DC converter is used when the input of converter is often an unregulated Dc voltage, which is obtained by rectifying the line voltage. Therefore, it will vary due to the changes in the line voltage magnitude. Switched-mode DC-DC converters are used to convert the unregulated DC input to a controlled DC output at a desired voltage level.

Isolated DC-DC converter, full-bridge converter and half-bridge converter are derived from the step-down converter. Flyback converter is derived from the buck-boost converter. Forward converter and push-pull converter are derived from the step-down converter with isolation.

2.3.1: DC – DC converter switching

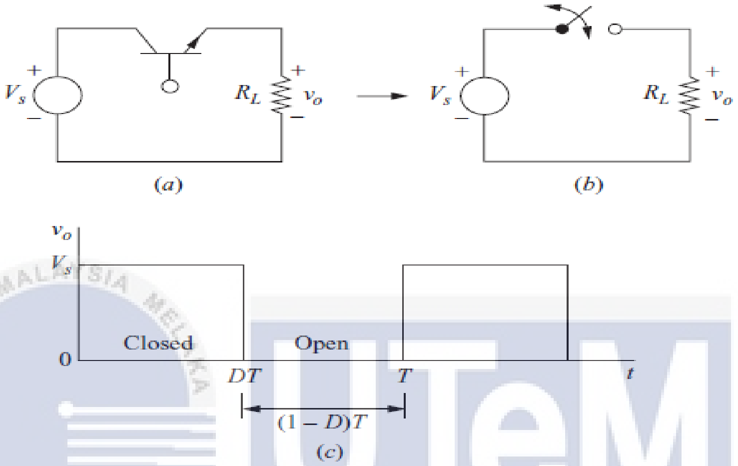

Figure 2.3: (a) Basic dc-dc switching converter; (b) Switching equivalent; (c) Output voltage

Figure 2.3 shown a basic switching converter and the switch is ideal. The output voltage is comparable to the input voltage when the switch is on and the output voltage is zero when the switch is off. This condition will produced waveform as in Figure 2.2(c). The DC component of the output voltage is regulated by varying the duty ratio *D*, which is the division of the switching period when the switch is off. The DC component of the output voltage will be lower than or same to the input voltage for the circuit.[1]

2.4: Study of DC – DC Converter

2.4.1: Boost Converter

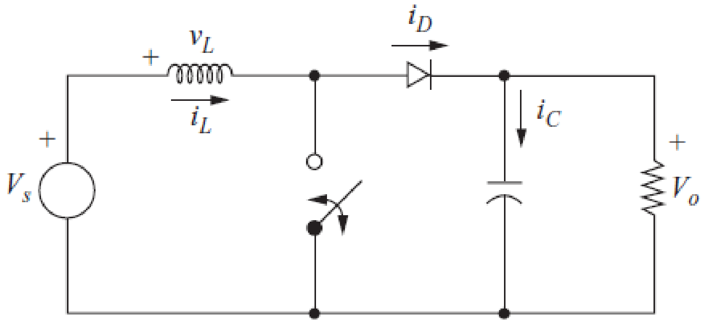

Figure 2.4: Boost converter circuit

The boost converter is shown in figure above and as well known as the output voltage is larger than the input voltage.

To analyze boost converter, following characteristics is being assumed:

1. Steady-state conditions exist.
2. T is the switching period and the switch is closed at time DT and open at time $(1\text{-}D)T$.
3. The inductor current always positive and it is continuous.
4. The capacitor value is very large and the output voltage is held constant at voltage Vo.
5. The components are ideal.

The inductor current and voltage are analyzed during switch is closed and switch is opened. When the switch is closed (OFF), the diode operates in reverse-biased.

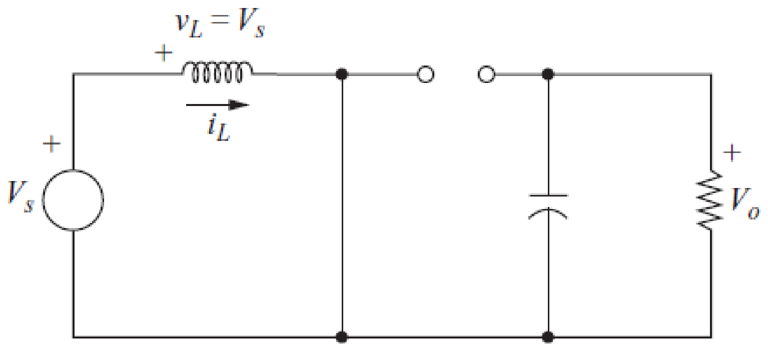

Figure 2.5: Boost converter circuit for switch closed (OFF)

Therefore, the Kirchhoff voltage law for the circuit in figure 2.11,

$$v_L = V_S = L\frac{di_L}{dt} \tag{2.1}$$

Rearranging,

$$\frac{di_L}{dt} = \frac{V_S}{L}$$

$$\frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{DT} = \frac{V_S}{L}$$

$$(\Delta i_L)closed = \frac{V_S DT}{L} \tag{2.2}$$

Next, when switch is opened (ON), the diode become a forward biased and the current will flow to the load from an inductor current.

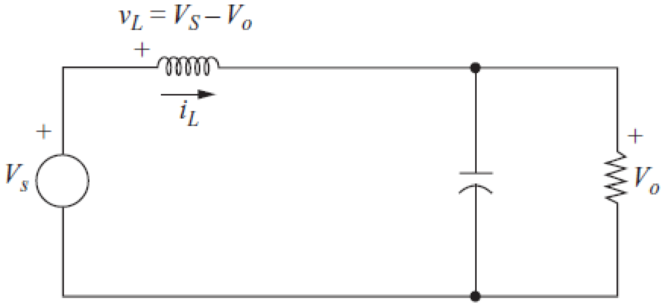

Figure 2.6: Boost converter circuit for switch opened (ON)

The output voltage is assumed constant, therefore the voltage across inductor (output voltage) is:

$$v_L = V_S - V_O = L\frac{di_L}{dt}$$

$$\frac{di_L}{dt} = \frac{V_S - V_O}{L}$$

Note that, the rate of change of inductor is constant. Therefore, the current need to change linearly. The change in inductor current when the switch is open:

$$\frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{(1-D)T} = \frac{V_S - V_O}{L}$$

$$(\Delta i_L)open = \frac{(V_S - V_O)(1-D)T}{L} \tag{2.3}$$

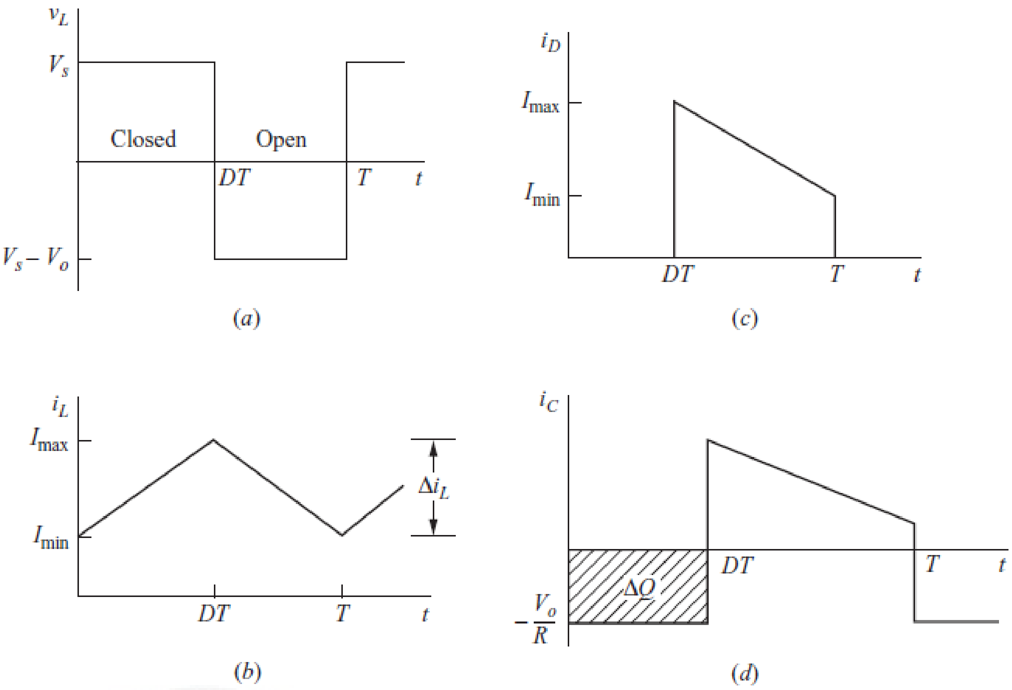

Figure 2.7: Waveform boost converter; (a) inductor voltage; (b) inductor current; (c) diode current; (d) capacitor current

As for steady-state operation, the change in inductor current needs to be null. Using (2.2) and (2.3):

$$(\Delta i_L)closed + (\Delta i_L)open = 0$$

$$\frac{V_S DT}{L} + \frac{(V_S - V_O)(1-D)T}{L} = 0$$

Therefore,

$$V_O = \frac{V_S}{1-D} \tag{2.4}$$

From Equation (2.4), if the switch is always open (OFF) and D is zero, the output voltage value is as same as the input voltage. The higher the duty ratio D value, the smaller the denominator of Equation (2.4), which results in larger output voltage. The boost converter produces an output voltage larger than or same to the input voltage.

To obtain the average current, the average power supplied by the source need to be equal to average power absorbed by the load resistor.

Output power,

$$P_{out} = P_{in}$$

$$P_O = \frac{Vo^2}{R} = V_O I_O$$

$$P_{in} = V_S I_S = V_S I_L$$

$$V_S I_L = \frac{Vo^2}{R}$$

Substitute Equation (2.4) into the output power equation,

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

$$I_L = \frac{V_S}{(1-D)^2 R} = \frac{V_O I_O}{V_S} \tag{2.5}$$

The maximum and minimum inductor current can be obtained by using the average value from Equation (2.2) and the change in current from Equation (2.5).

$$I_{Lmax} = I_L + \frac{\Delta i_L}{2} = \frac{V_S}{(1-D)^2 R} + \frac{V_S DT}{2L} \tag{2.6}$$

$$I_{Lmin} = I_L - \frac{\Delta i_L}{2} = \frac{V_S}{(1-D)^2 R} - \frac{V_S DT}{2L} \tag{2.7}$$

For continuous current mode (CCM), Equation (2.5) was developed with the assumption that the inductor current, thus it always positive it is essential for inductor current I_{min} to be positive for inductor currents. Therefore, the boundary between continuous and discontinuous inductor current is determined from

$$I_{Lmin} = 0 = \frac{V_S}{(1-D)^2 R} - \frac{V_S DT}{2L}$$

$$\frac{V_S}{(1-D)^2 R} = \frac{V_S DT}{2L} = \frac{V_S D}{2Lf}$$

The minimum value of combination of induction and switching frequency for continuous current

$$(Lf)_{min} = \frac{D(1-D)^2 R}{2} \tag{2.8}$$

$$L_{min} = \frac{D(1-D)^2 R}{2f} \tag{2.9}$$

A boost converter designed for continuous-current operation will have an inductor value greater than Lmin. From a design perspective, it is useful to express L in terms of a desired Δi_L,

$$L = \frac{V_S DT}{\Delta i_L} = \frac{V_S DT}{\Delta i_L f} \tag{2.10}$$

The peak-to-peak output voltage ripple can be determined by calculating the capacitor current waveform as shown in Figure 2.7(d). Therefore,

$$|\Delta Q| = \left(\frac{V_O}{R}\right) DT = C\Delta V_O$$

$$\Delta V_O = \frac{V_O DT}{RC} = \frac{V_O D}{RCf}$$

$$\frac{\Delta V_O}{V_O} = \frac{D}{RCf} \tag{2.11}$$

Where *f* is the switching frequency, the capacitance C can be obtained from Equation (2.11)

$$C = \frac{D}{R\left(\frac{\Delta V_O}{V_O}\right) f} \tag{2.24}$$

The boost converter also operated for discontinuous current mode (DCM) when the selected value of inductor below than L_{min} . The inductor and diode current have the basic waveform as shown in figure 2.8. When the switch is closed (ON), the voltage across the inductor is Vs. When switch is opened (OFF), the inductor current is positive and the inductor voltage is Vs – Vo. Inductor current will decreases until it reaches zero and is prevented from going negative by diode. When the switch and diode same OFF, the inductor current is zero.

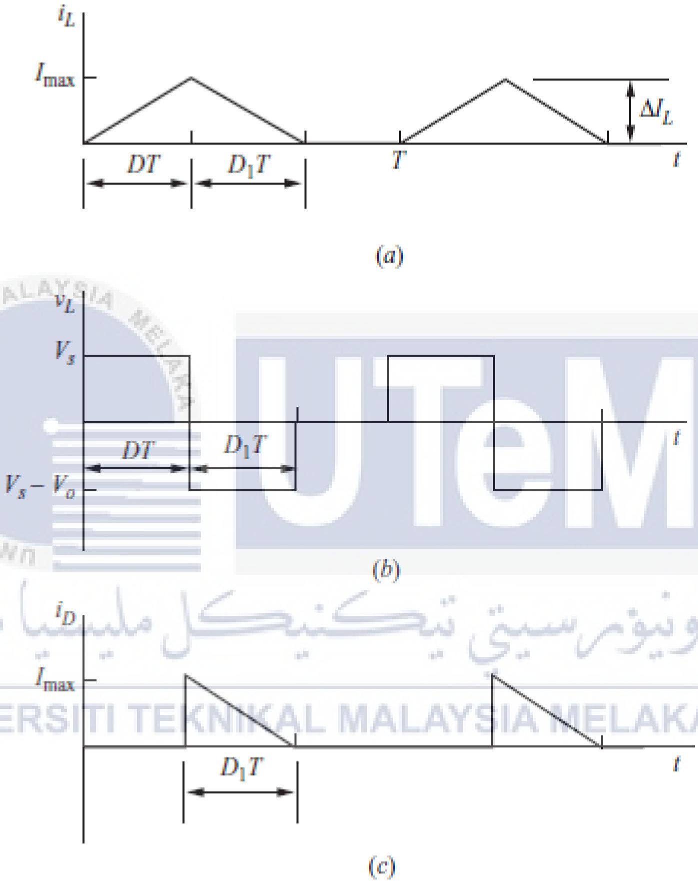

Figure 2.8: Discontinuous current in boost converter.

(a) Inductor current; (b) Inductor voltage; (c) Diode current.

2.5: Interleaved Converter

Interleaving also called as multiphasing is a technique which is useful for reducing the size of filter component [1]. In a interleaved circuit there will more than one power switch. The phase difference for two switches is 180º. Interleaving technique is a strategic interconnection of multiple switching cells that will increase the effective pulse frequency by synchronizing several smaller sources and operating them with relative phase shift. [1]

Interleaved method is used in order to improve converter performance in the aspects of efficiency, size, and conducted electromagnetic emission. Interleaved also has benefits such as high power capability, modularity, and improved reliability. But, having interleaved may cost on additional inductors, power switching devices, and output rectifiers. When the size of inductor increases, the power loss in a magnetic component will decrease although both the low power loss and small volume are required [11].

In the power electronics, application of interleaving technique can be found back to early days especially in high power application. The voltage and current stress can easily go beyond the range that power device can handle in high power application. One solution to this problem is by connecting multiple power devices in parallel or in series. But, instead of paralleling power devices, it is better to parallel the power converters. By paralleling the power converters, the interleaving technique will comes naturally. Interleaving can cancel the harmonics, increase the efficiency, better thermal performance and the high power density can be obtained [12].

2.6: MATLAB Simulink

The simulation software used in this project is MATLAB Simulink by MathWork as shown in figure 2.9 below. MATLAB Simulink is used for the boost converter simulation in order to model and to analyze the DC-DC boost converter. Based on [11], the software allows user to analyze and to obtain results for further investigation, as it helps to identify trends and uncertainty as well as to test hypothesis. The boost converter circuit is drawn in the work place and is simulated. The results are obtained by tapping a scope to wherever output desired.

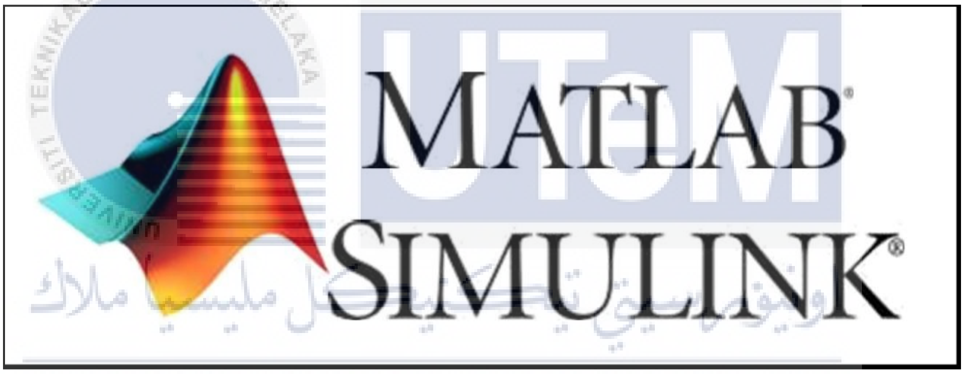

Figure 2.9: MATLAB Simulink

2.7: Chapter summary

In summary, chapter 2 includes the general overview on parameters, criteria’s or components involved throughout the project. The literature review done is based on research and findings of previous researchers as cited above.

CHAPTER 3

METHODOLOGY

3.1: Introduction

This chapter review the methodology where the calculation for design DC – DC boost converter circuit and the simulation tool is used to design and analyze the DC-DC boost converter by using MATLAB. Thus, flowchart will be used to assist the procedure of designing and the step taken to analyse the result of this project.

3.2: Project Methodology

Upon the completion of this research, several processes had been designed according to the sequence. All the procedures conducted throughout the project are discussed in detail with the help of flowchart and Gantt chart.

3.2.1: Flowchart

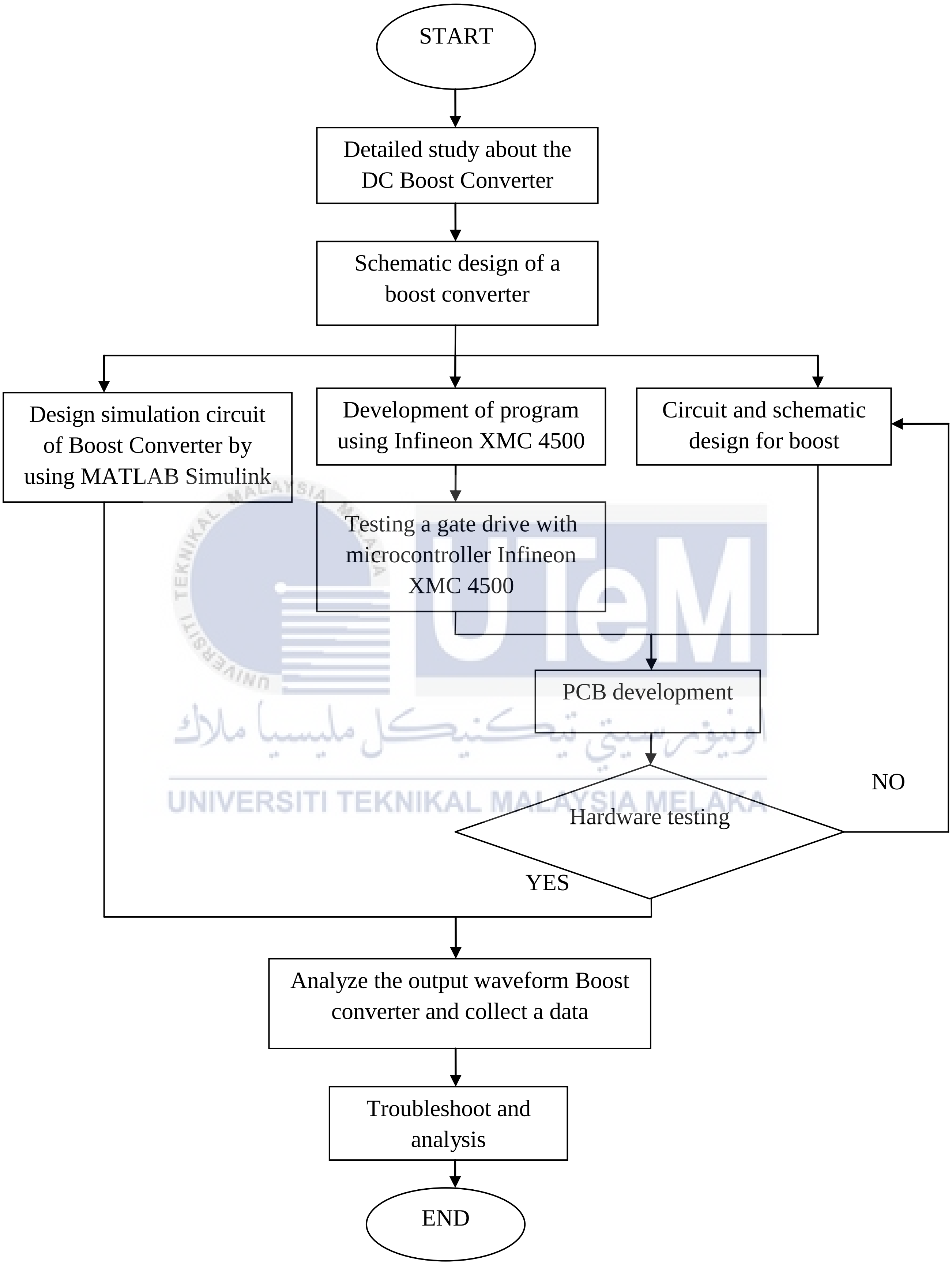

Figure 3.1: Flowchart

Figure 3.1 shows a process sequence of this project. Firstly, all the data and information are gathered and synthesized to ease the progress of the project. Next, the calculation analysis is done to estimate the important values of parameter involve in the circuit design of DC – DC boost converter. The project is then continued to simulate the boost converter circuit by using MATLAB Simulink software. The Infineon XMC 4500 is using to develop a program to generate a pulse for gate drive and testing the circuit. Then, collect a data from a hardware testing. Lastly, the project report is written and compiled. All the results and analysis of the data gathered and presented in the report.

3.3: Calculation Analysis

3.3.1: Design calculation

This section will shown a step to calculate a value of parameter for DC – DC boost converter. The parameter of the designed DC – DC boost converter circuit are shown in Table 3.2.

Table 3.1: The parameter of DC – DC boost converter

Parameter	**Rating**
Input voltage, Vs	6V
Output voltage, Vo	15V
Rated output power, P	10W
Switching frequency, f	20kHz
Output voltage ripple, $\Delta V_o/V_o$	1%

First find the value of duty ratio D by using (2.16)

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

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

$$D = 1 - \frac{6V}{15V} = 0.6$$

Next, determine the output load resistor R.

$$P = \frac{{V_o}^2}{R}$$

$$R = \frac{V_o^2}{P} = \frac{15V^2}{10W} = 22.5\Omega$$

The value of inductor Lmin can be determined by using (2.21)

$$L_{min} = \frac{D(1-D)^2R}{2f} = \frac{(0.6)(1-0.6)^2(22.5)}{2(20k)} = 58\mu H$$

For continuous current mode (CCM) the value of inductor must bigger than value of Lmin, so that for this project value of inductor is calculated ten times from Lmin. Therefore,

$$L = L_{min} \times 10$$

$$L = 58\mu \times 10$$

$$L = 0.58mH$$

Choose CCM value of inductor, $L \approx 1mH$

The capacitor value was determine using (2.24) to limit the output voltage ripple 1%,

$$C = \frac{D}{Rf(\frac{\Delta V_o}{V_o})} = \frac{0.6}{(22.5)(20k)(0.01)} = 133\mu F$$

For hardware design, this project choose a capacitor $100\mu F$

3.4: MATLAB Simulink

For simulation process, the simulation of the DC –DC boost converter circuit is done in the MATLAB simulink. The component want to build the boost converter circuit is obtained in simulink library at the command window. After construct the circuit, it must be saved. If any error or warnings appear at the command window, the error and command are solved according to the system recommendation.

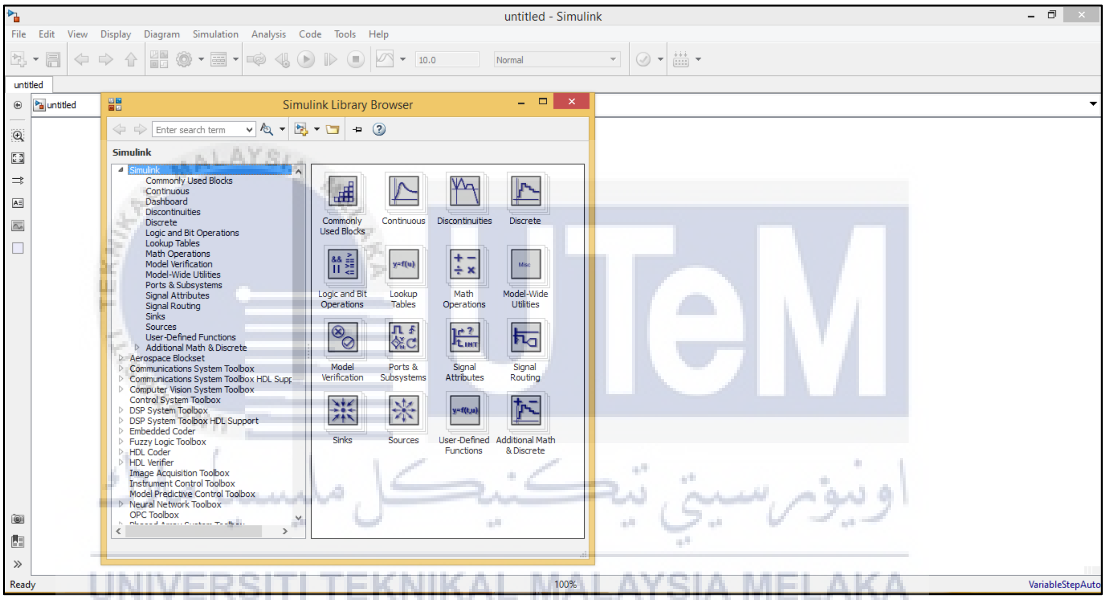

Figure 3.2: MATLAB simulink

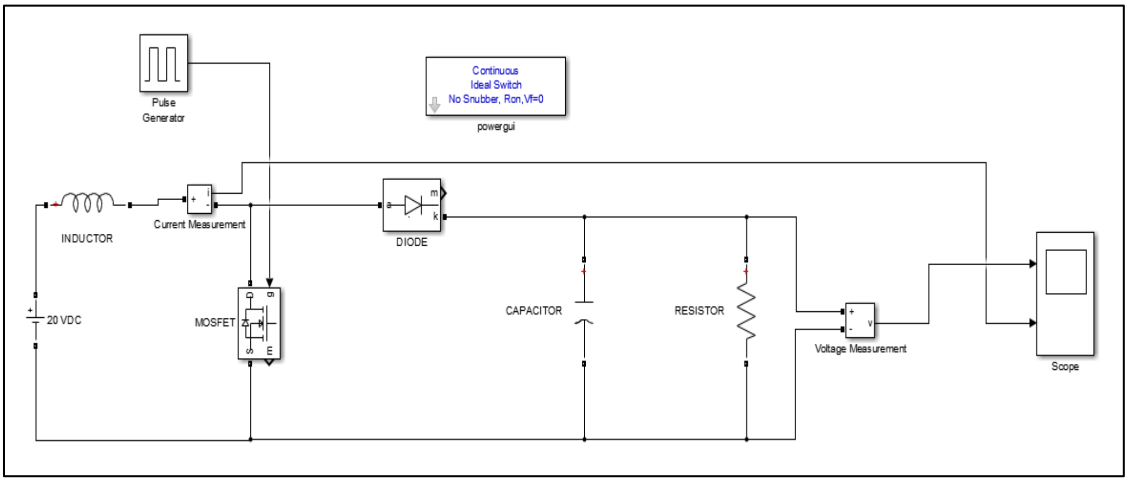

Figure 3.3: MATLAB simulation for boost converter circuit design

3.5: Hardware design

3.5.1: Infineon XMC 4500 microcontroller

Infineon XMC 4500 is an electronic component of microcontroller which will produce pulse signal. This pulse signal can be design using the MATLAB Simulink block diagram as shown in Figure 3.5 below. The XMC 4500 is easy to understand and control.

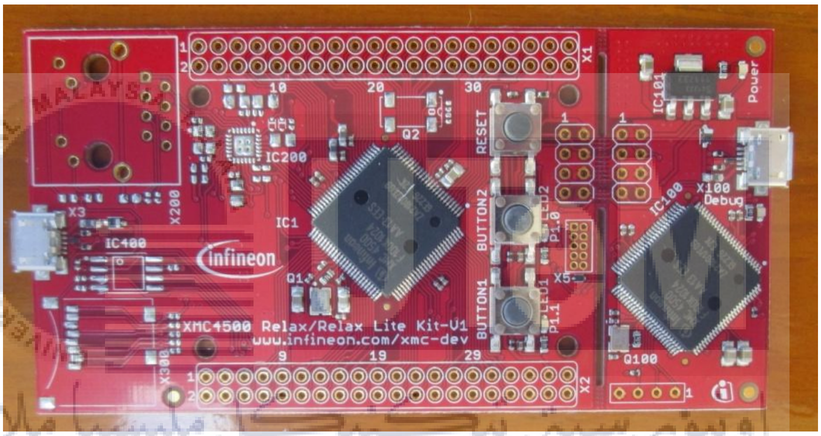

Figure 3.4: Infineon XMC 4500

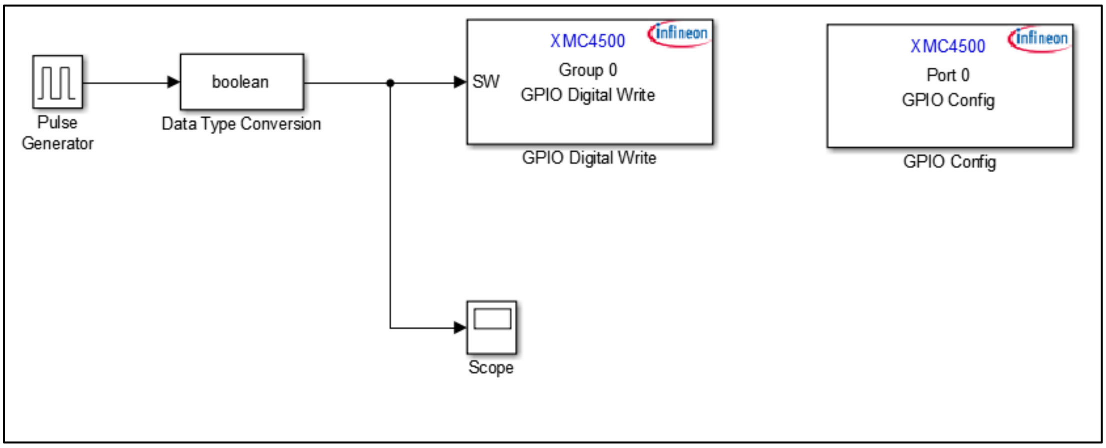

Figure 3.5: MATLAB Simulink design generated pulse for XMC 4500

3.5.2: Gate Drive Circuit

The main purpose of used the gate drive circuit in this project is to isolate signal from microcontroller and switching devices. The PWM signal will generate from the microcontroller. The signal 5V from microcontroller is not capable to switch ON the MOSFET/IGBT power switch which need 15V. The additional 15V supply is connected to the gate drive as a desired voltage to turn ON the MOSFET/IGBT.

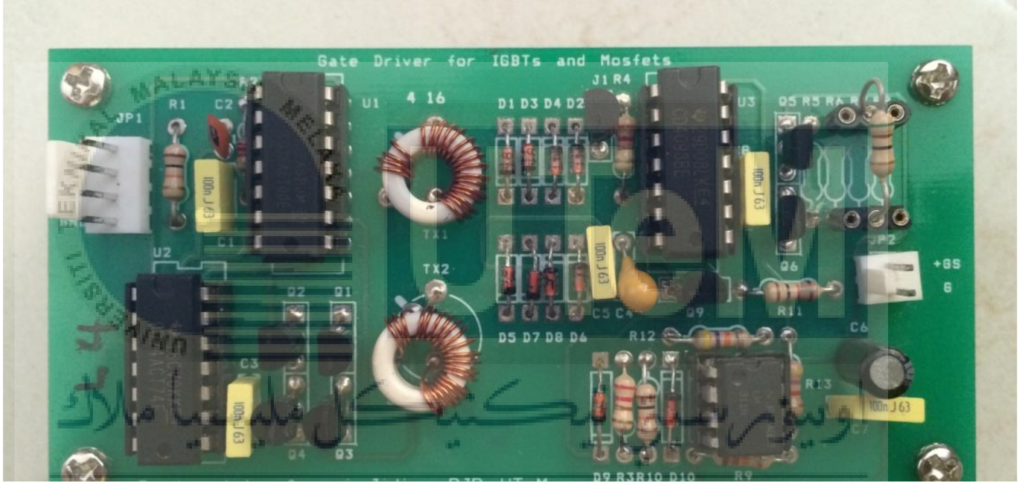

Figure 3.6: Gate drive circuit

3.5.3: Schematic design using Proteus 8 software

Proteus 8 professional is used to design the schematic and layout for the gate drive circuit and boost circuit as illustrated in figure 3.5 Proteus 8 professional below. ISIS schematic capture is used to draw the circuit desired and it is then opened using the ARES PCB layout. In the ARES PCB layout, components are placed according to desired design and the routes are placed accordingly.

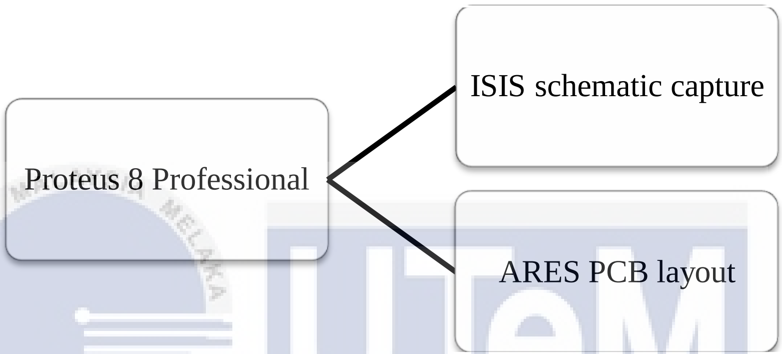

Figure 3.7: Proteus 8 Professional

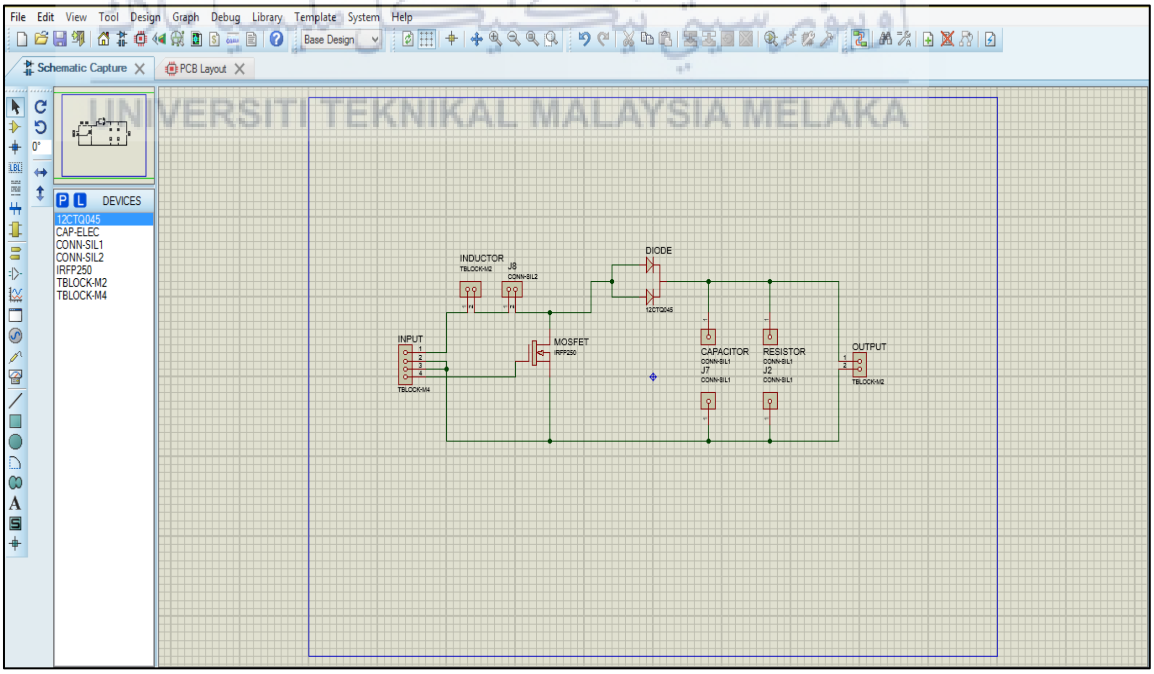

Figure 3.8: ISIS schematic capture

The circuit needs to be developed in order to create the boost converter which includes component is IGBT's, inductor and capacitor where an input pulse (obtained from the output of the XMC4500) with a minimum of 15V is required to drive the IGBT at the boost circuit. As illustrated in figure 3.8: Isis schematic capture above, the components are obtained from the "place component" tab and if the component is not inside the library of the system, it can be created by manually creating the block of the component. The pins to the block are then assigned accordingly as required. The completed schematic design is opened using ARES PCB layout where the components are placed as desired and the route are connected accordingly. The layout created is single layer as can be shown in figure 3.9: ARES PCB layout below. The schematic of the boost converter and layout is attached in Appendix D.

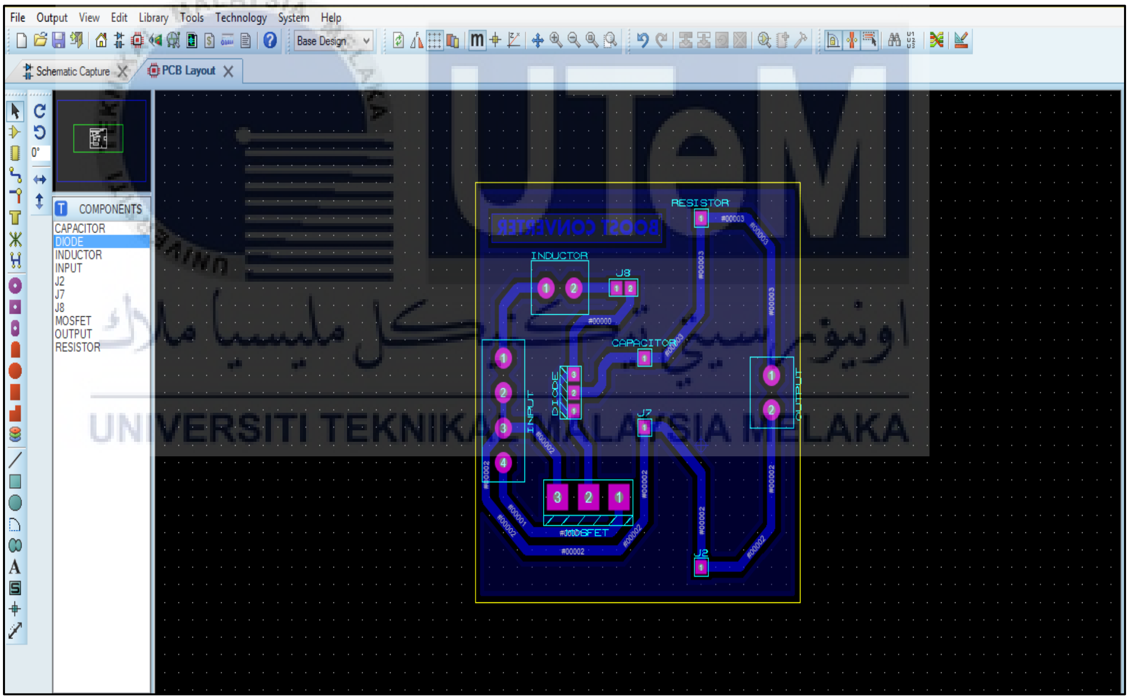

Figure 3.9: ARES PCB layout

3.5.4: Hardware Experimental Setup

The final part is to test the hardware to see either it is functioning or not. The output is checked through the multimeter and oscilloscope and is compared to the results obtained from the simulation and hardware.

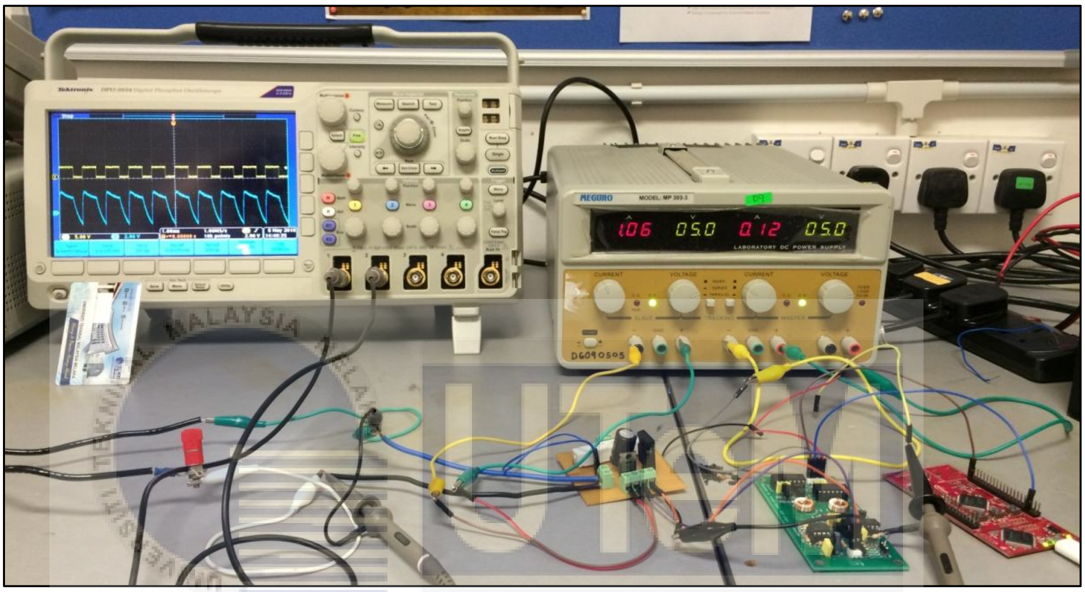

Figure 3.10: Hardware setup

CHAPTER 4

RESULT AND DISCUSSION

4.1: Introduction

This chapter will discuss the simulation results for DC-DC boost converter circuit design. The discussion will focus on the performance analysis of the boost converter output waveform for continuous current mode (CCM) when duty cycle (D) is varied.

4.2: Simulation result

4.2.1: Result output voltage and inductor current of boost converter

The simulation of boost converter is designed to verify the response of the converter. The voltage input is 20 V. The DC-DC converter has been simulated under CCM operating condition and the parameters involved are V_s = 6 V, R = 50Ω, D = 10% - 90%, fs = 10 kHz, L = 10 mH and C = 100 μF. The output voltage, V_o and the inductor current, I_L are generated as shown in below.

As shown in figure 4.1 below is the waveform of output voltage and inductor current. The parameters used for the circuit is refer to table 3.3. The MATLAB simulation of boost converter circuit is output voltage when D=0.1 is Vo =6.671V.

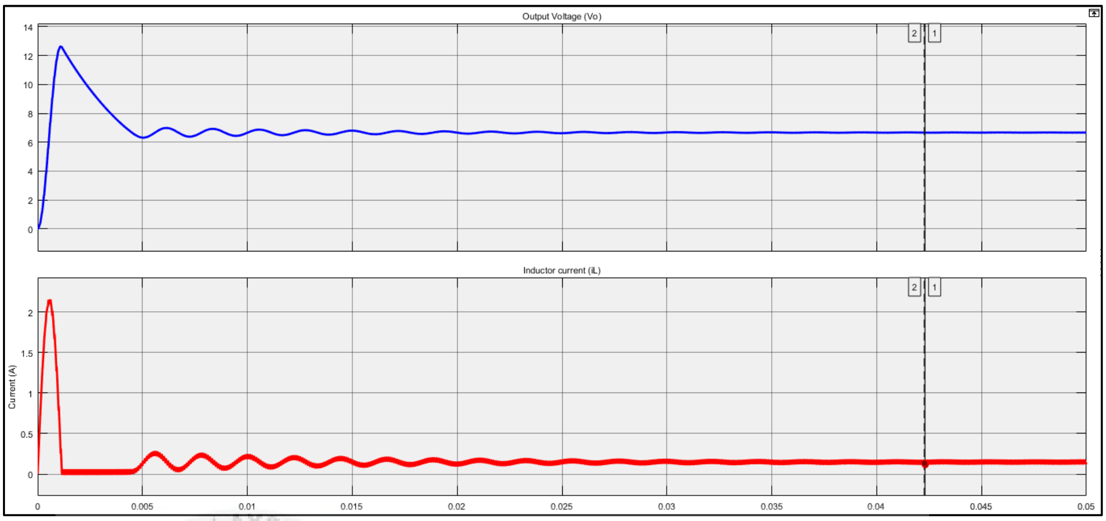

Figure 4.1: Output voltage and inductor current waveform when D=0.1

The MATLAB simulation of boost converter circuit is output voltage when D=0.2 is Vo =7.505V. The output voltage will increases as shown in figure 4.2 below when the value of duty cycle is varied increase.

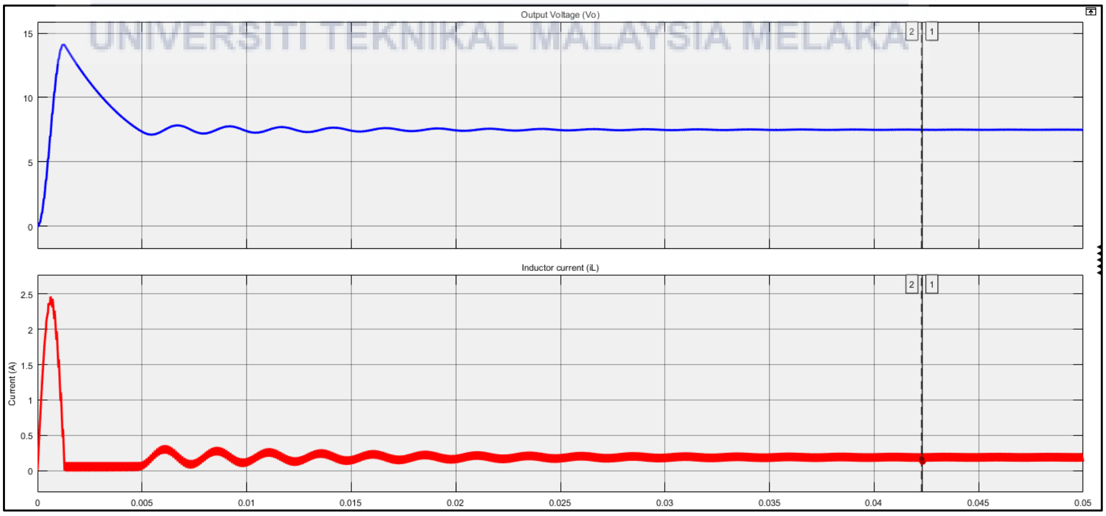

Figure 4.2: Output voltage and inductor current waveform when D=0.2

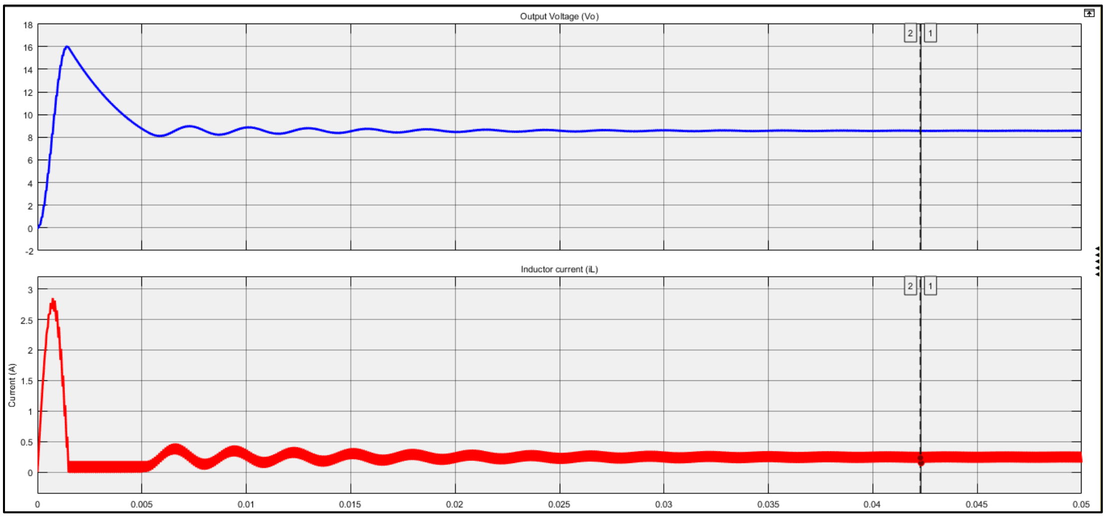

Figure 4.3: Output voltage and inductor current waveform when D=0.3

For figure 4.4 as shown below is the MATLAB simulation result of output voltage Vo=10.020V when the value of duty cycle is varied to D=0.4.

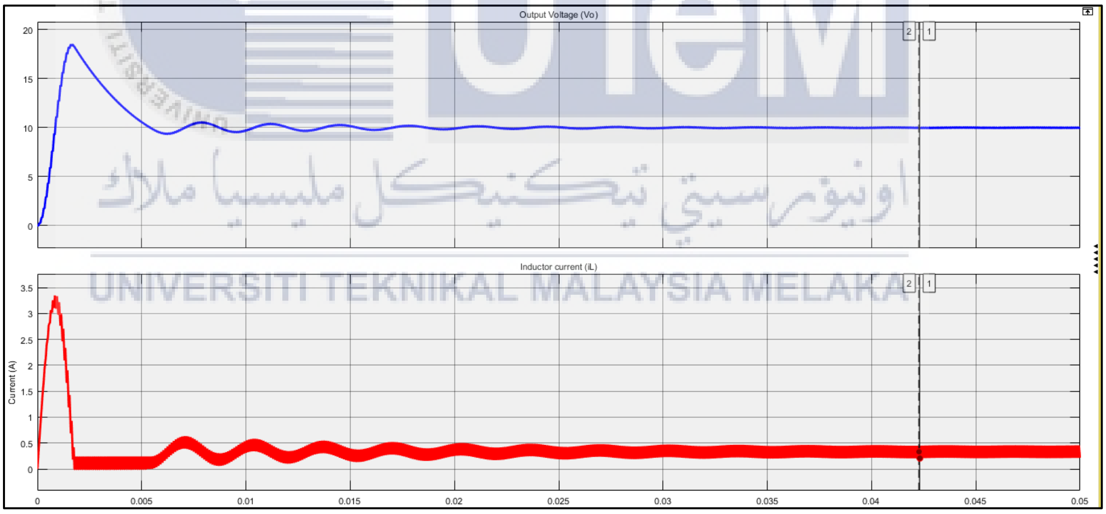

Figure 4.4: Output voltage and inductor current waveform when D=0.4

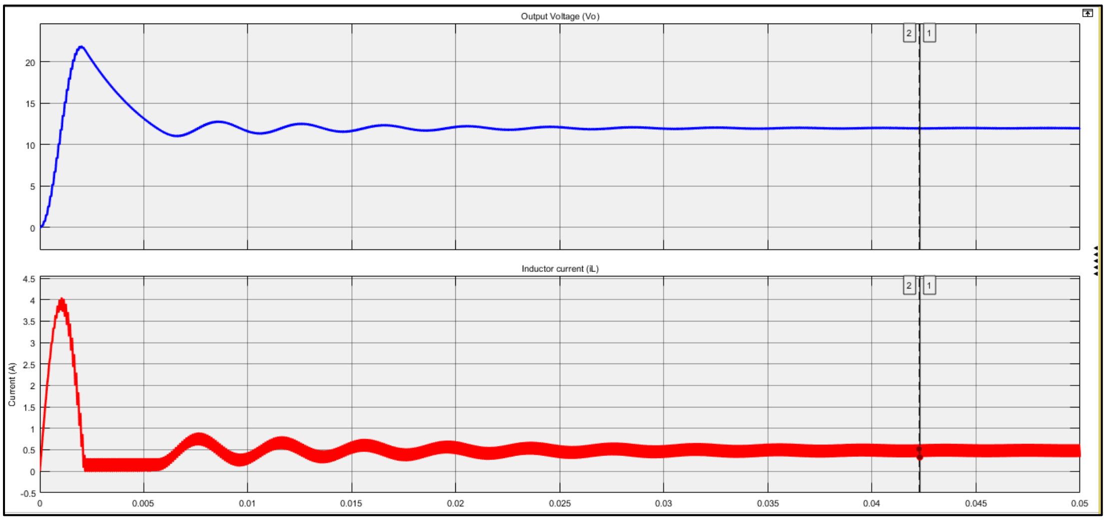

Figure 4.5: Output voltage and inductor current waveform when D=0.5

For duty cycle D=0.6, the output voltage is achieved the boost converter circuit design for this project Vo=15.100V.

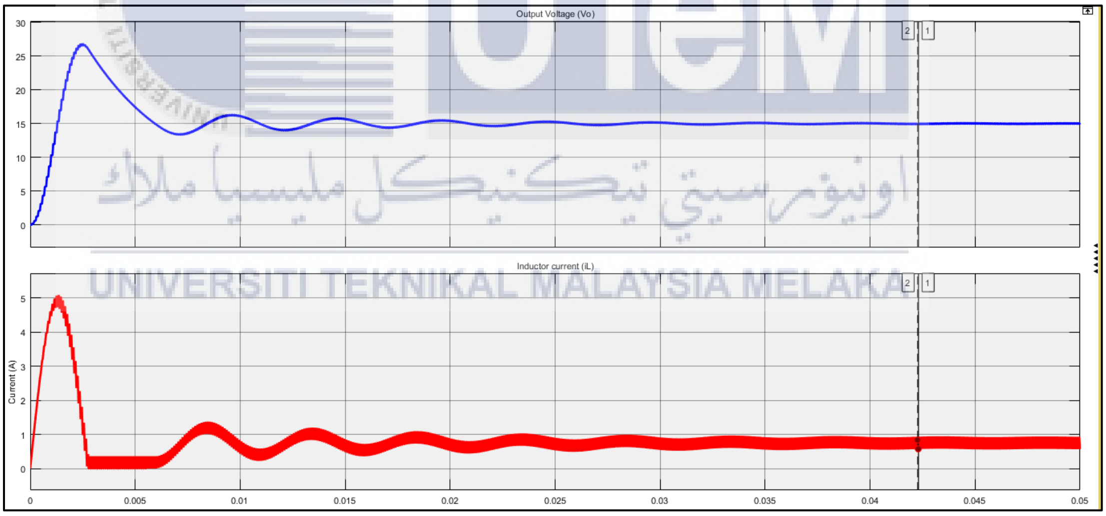

Figure 4.6: Output voltage and inductor current waveform when D=0.6

Figure 4.7 and 4.8 below shown an output voltage waveform is faster to steady state when the duty cycle is increases D=0.7 and 0.8. This is because the time of switching is higher, so the current charging to the inductor longer and it can affect the output voltage at load.

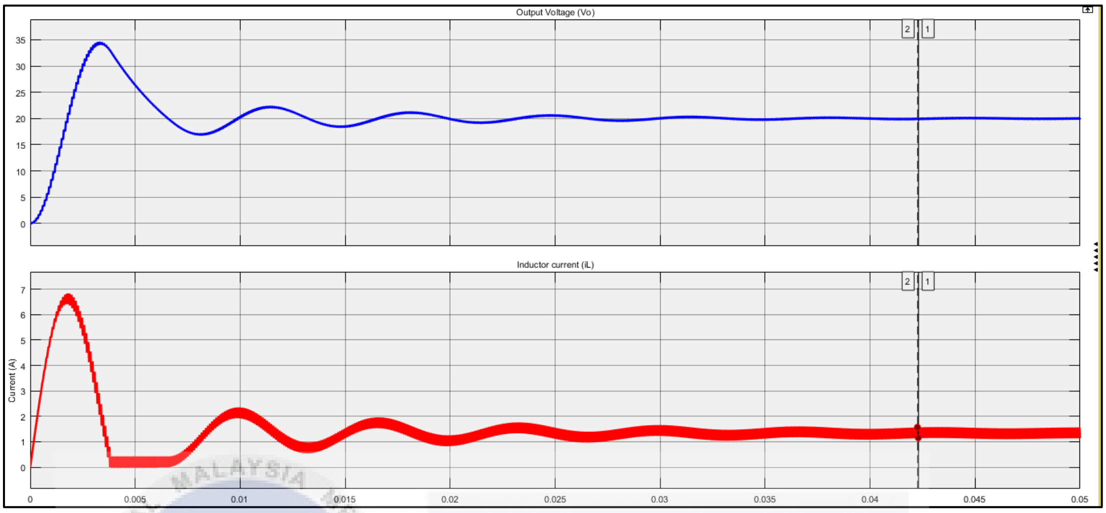

Figure 4.7: Output voltage and inductor current waveform when D=0.7

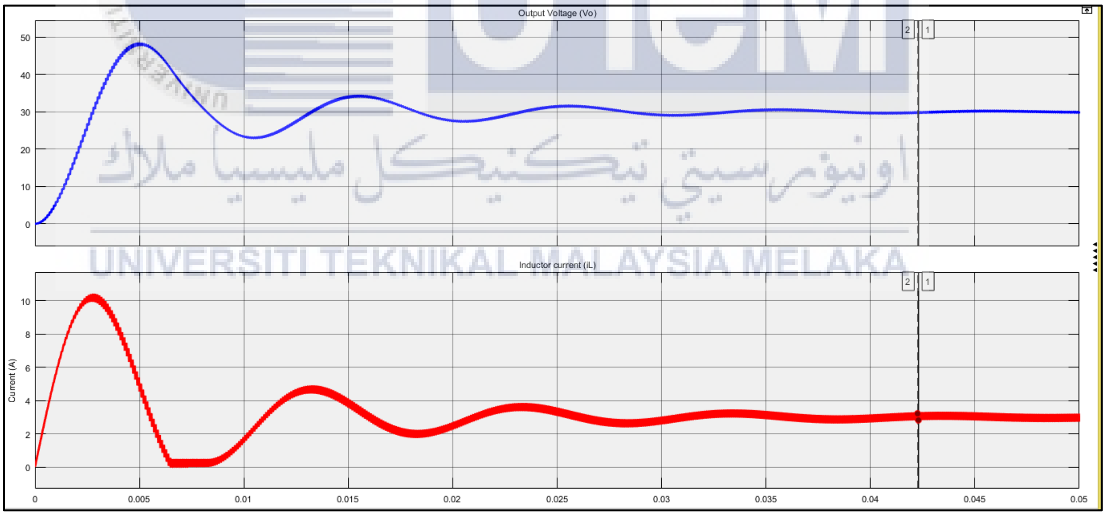

Figure 4.8: Output voltage and inductor current waveform when D=0.8

As shown in figure 4.9 below, the output voltage waveform is more to steady state when value of D=0.9. Also the inductor current always in CCM condition and the boost converter circuit operate in good condition.

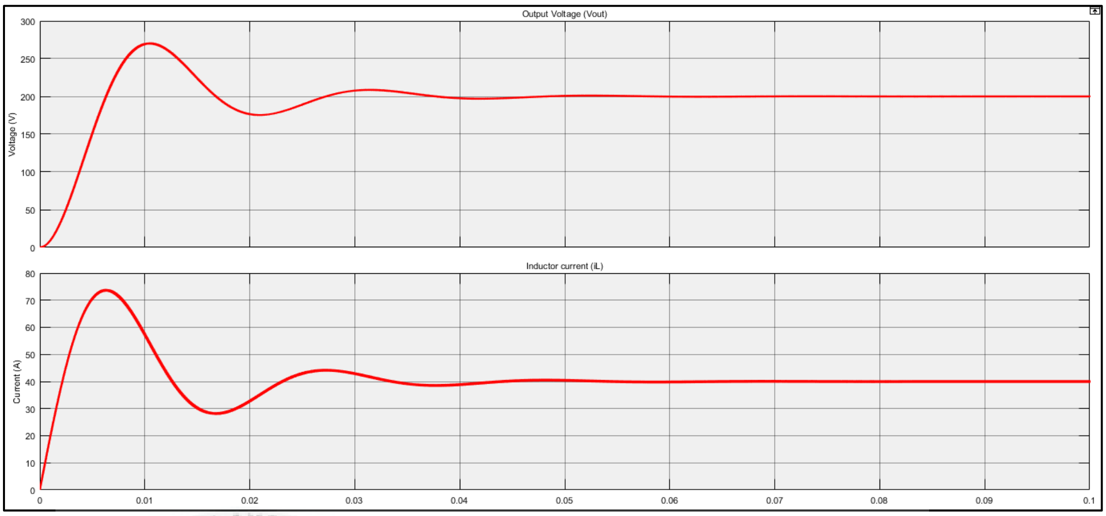

Figure 4.9: Output voltage and inductor current waveform when D=0.9

4.2.2: The effect toward current ripple when the value of duty cycle (D) is varied

This case is to see the effect of varying the duty cycle D form 0.1 to 0.9 towards the current ripple Δi_L boost converter.. In this figure 4.10 below, the graph of pulse with a duty cycle D=0.1 and the time ON of the pulse generated to charge current in inductor is short period and the time OFF of the pulse is to discharge current form inductor at in long period. The current ripple Δi_L as shown in figure 4.11 below is Δi_L= 0.1161A when the duty cycle is varied to D=0.2

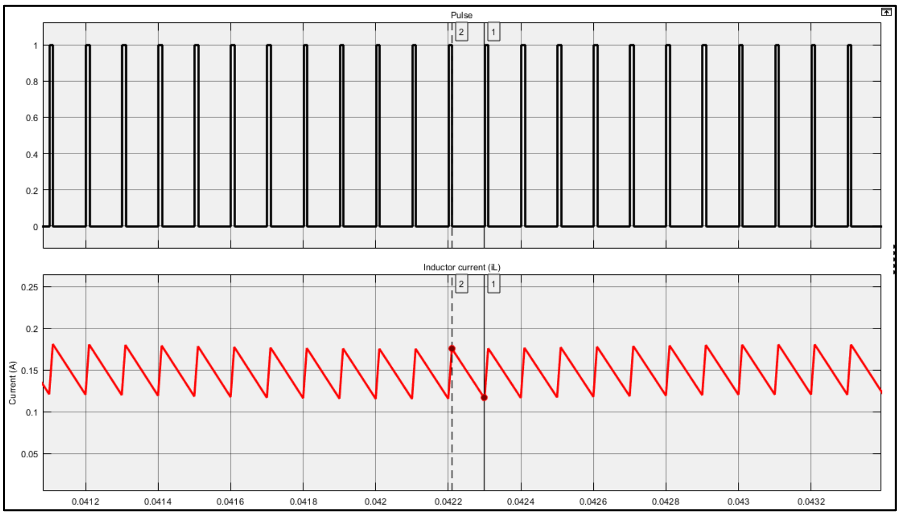

Figure 4.10: Graph of pulse when duty cycle D=0.1 and the current ripple Δi_L

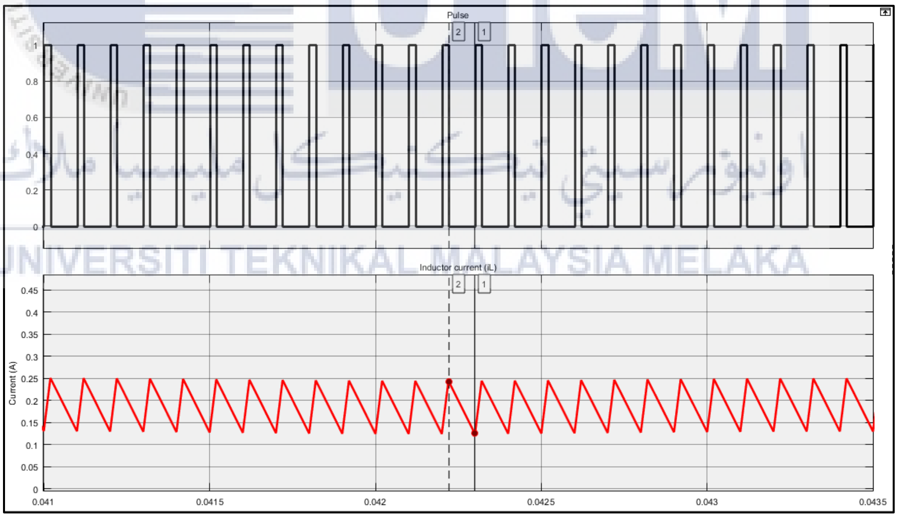

Figure 4.11: Pulse waveform when duty cycle D=0.2 and current ripple Δi_L at inductor

For a duty cycle D=0.3, the current ripple in the inductor based on simulation done in the MATLAB software as shown in figure 4.12 below. The result for current ripple is Δi_L= 0.1773A. As for duty cycle D=0.4, the current ripple is Δi_L= 0.2358A as shown in figure 4.13 below.

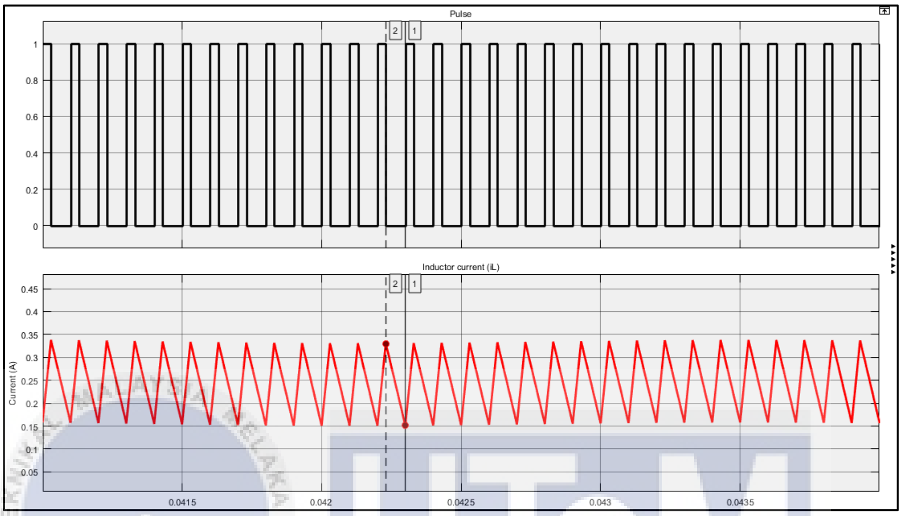

Figure 4.12: Graph of pulse when duty cycle D=0.3 and the current ripple Δi_L

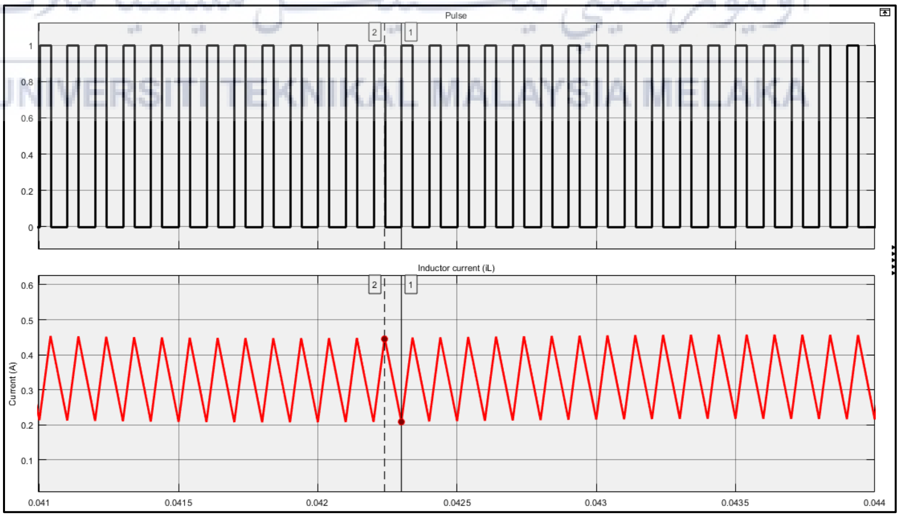

Figure 4.13: Graph of pulse when duty cycle D=0.4 and the current ripple Δi_L

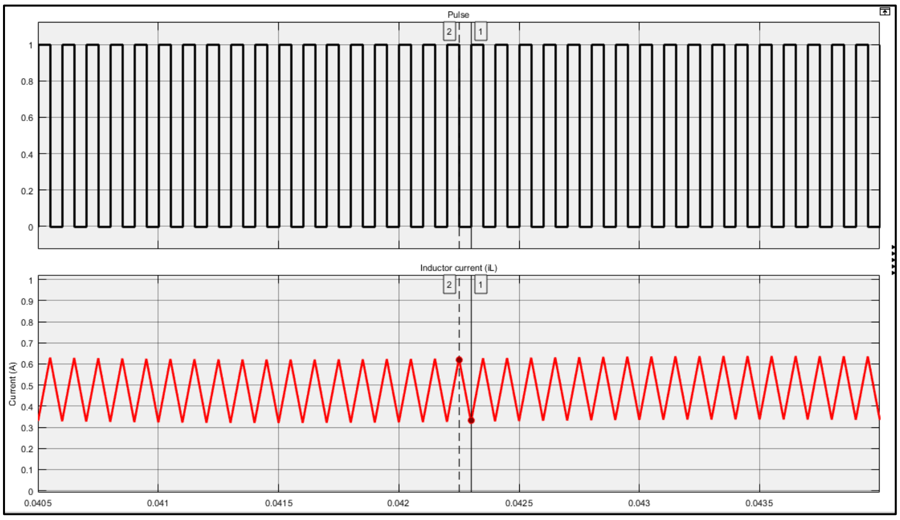

Figure 4.14: Graph of pulse when duty cycle D=0.5 and the current ripple Δi_L

As shown in figure 4.14 above, since the duty cycle D=0.5, the time ON and time OFF of pulse generator is same for current charging and discharging at inductor. For figure 4.15 below, the duty cycle D=0.6 and the OFF is longer than the time ON for pulse switching.

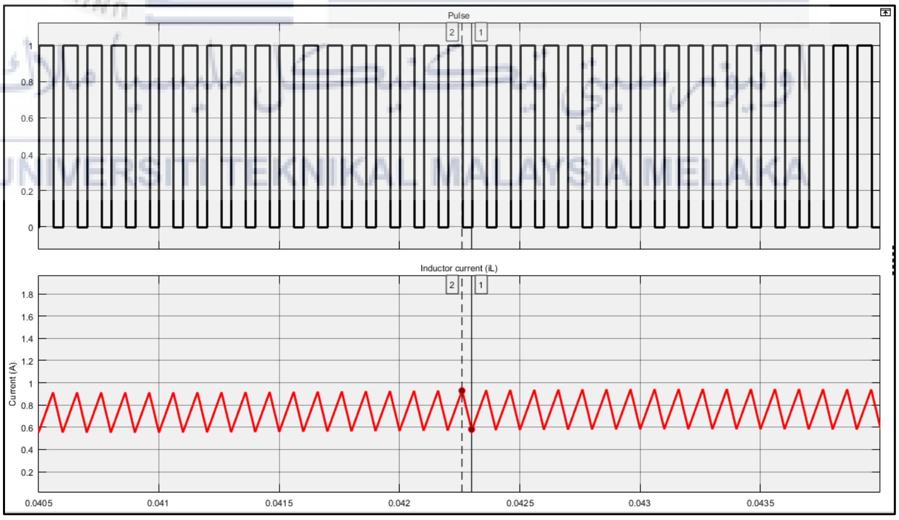

Figure 4.15: Graph of pulse when duty cycle D=0.6 and the current ripple Δi_L

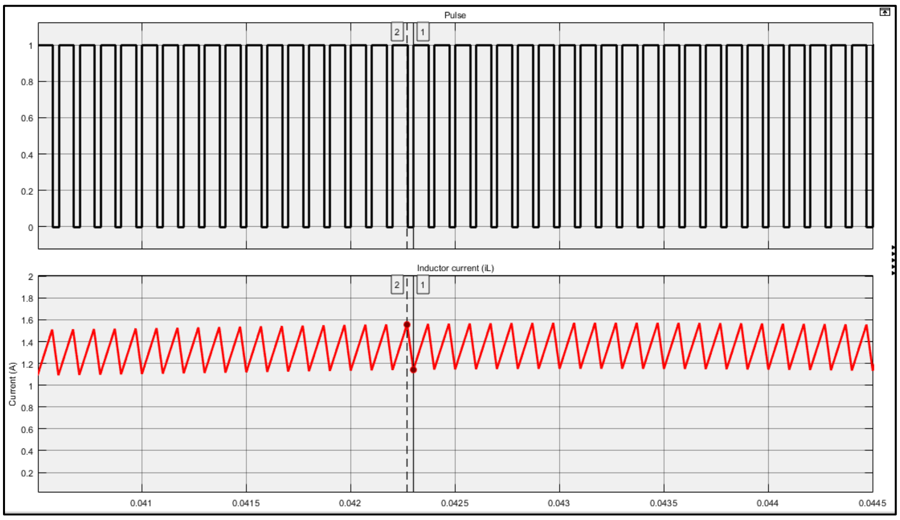

Figure 4.16: Graph of pulse when duty cycle D=0.7 and the current ripple Δi_L

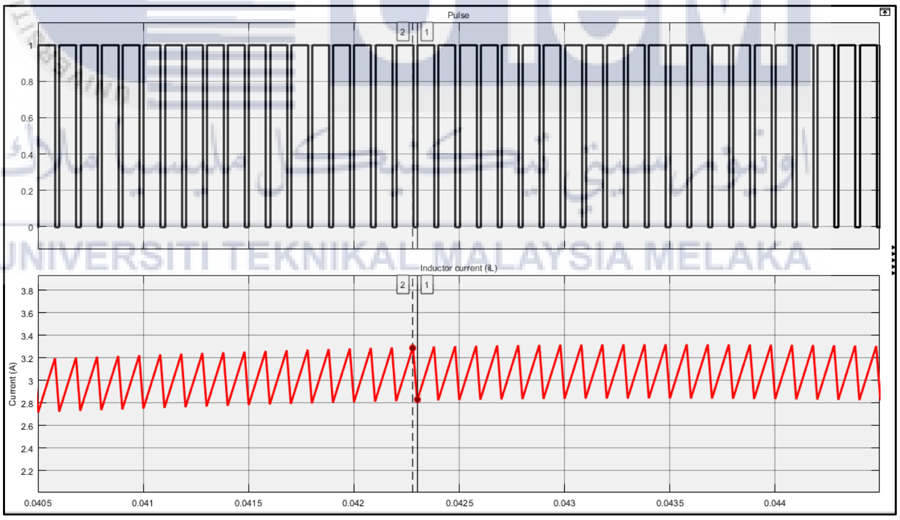

Figure 4.17: Graph of pulse when duty cycle D=0.8 and the current ripple Δi_L

For the last parameter for the response of the current ripple towards the change of duty cycle is shown in figure 4.18 below. The figure 4.18 below shows that the time off for the switching is too brief. The same parameter will be tested in the experimental part to discover either does the experimental and simulation part differs.

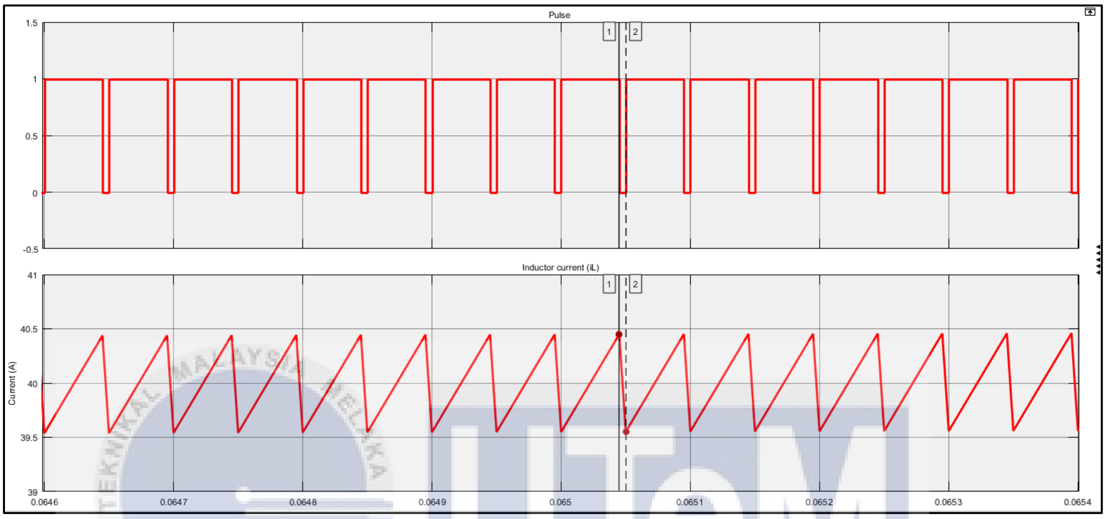

Figure 4.18: Graph of pulse when duty cycle D=0.9 and the current ripple Δi_L

4.3: Hardware result

For hardware design, this project use a value of component same like simulation because to compare the result.

4.3.1: Output voltage

This result is show how the hardware circuit functionally. When the MOSFET is turn ON the current flow to inductor and the current will charging. After that, when MOSFET is turn OFF, the current from inductor will discharging and go to load to complete the circuit. The operation will continuously operate.

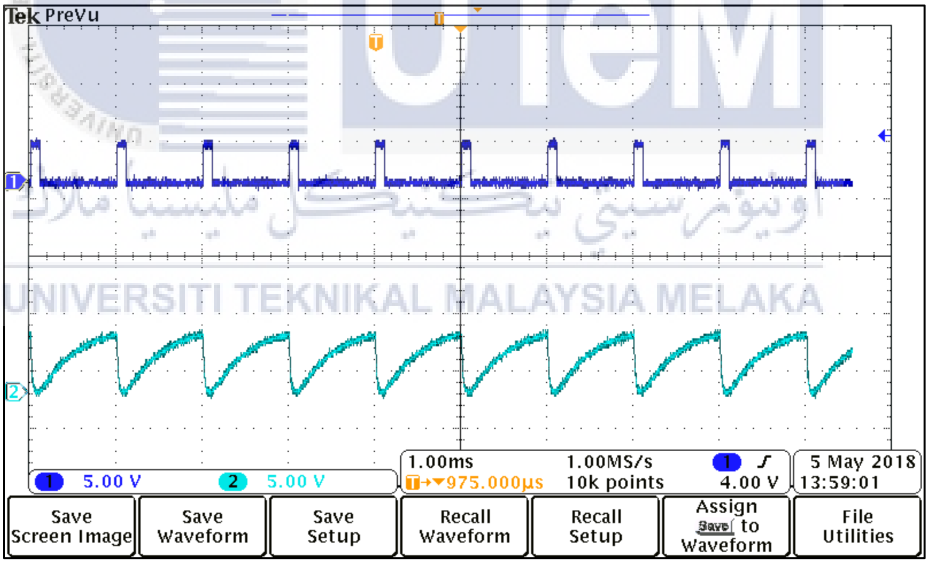

Figure 4.19: Output voltage when D=10%

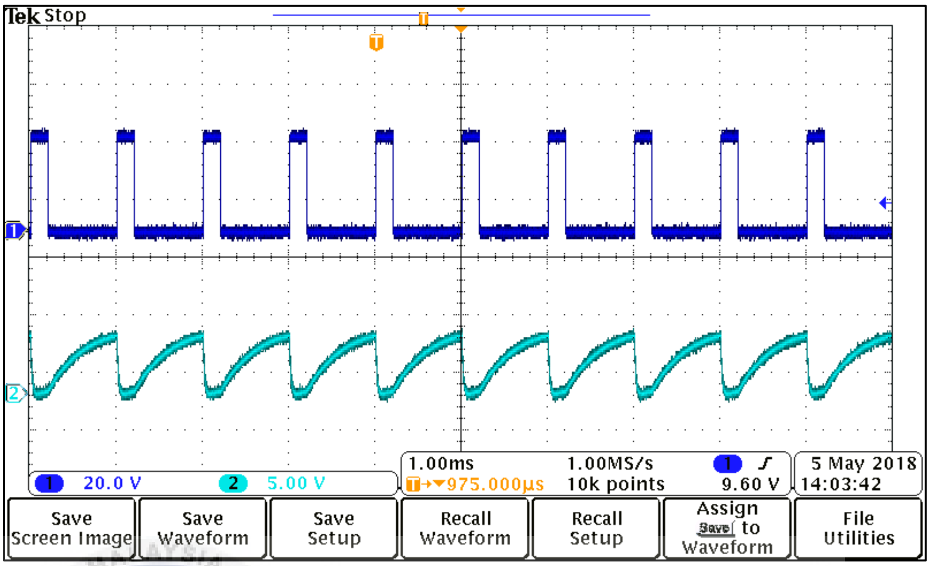

Figure 4.20: Output voltage when D=20%

For figure 4.21 below shown a output voltage when the duty cycle 30%, the time current charging to inductor is longer than time current discharging.

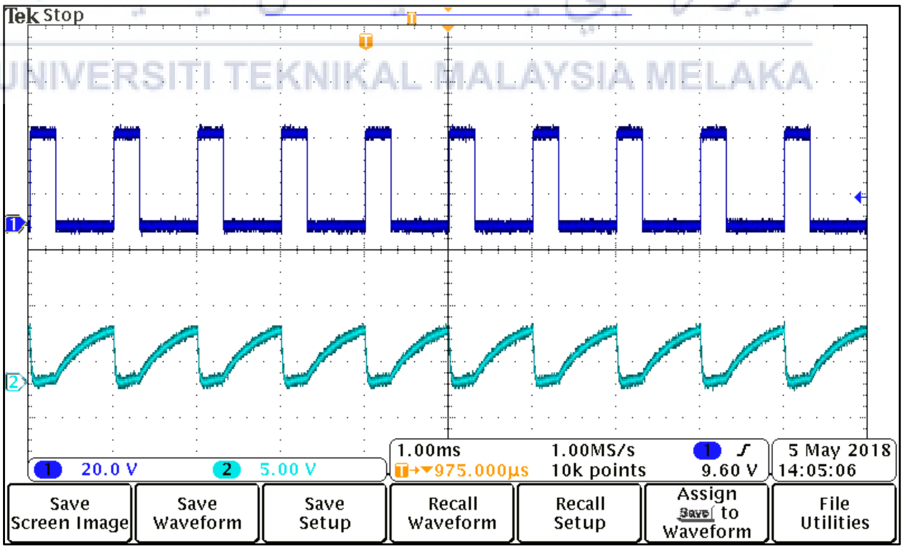

Figure 4.21: Output voltage when D=30%

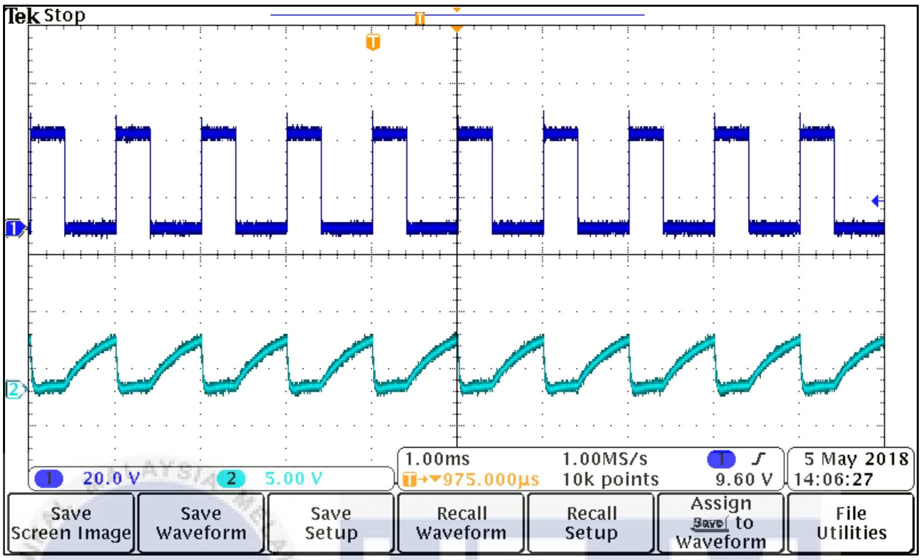

Figure 4.22: Output voltage when D=40%

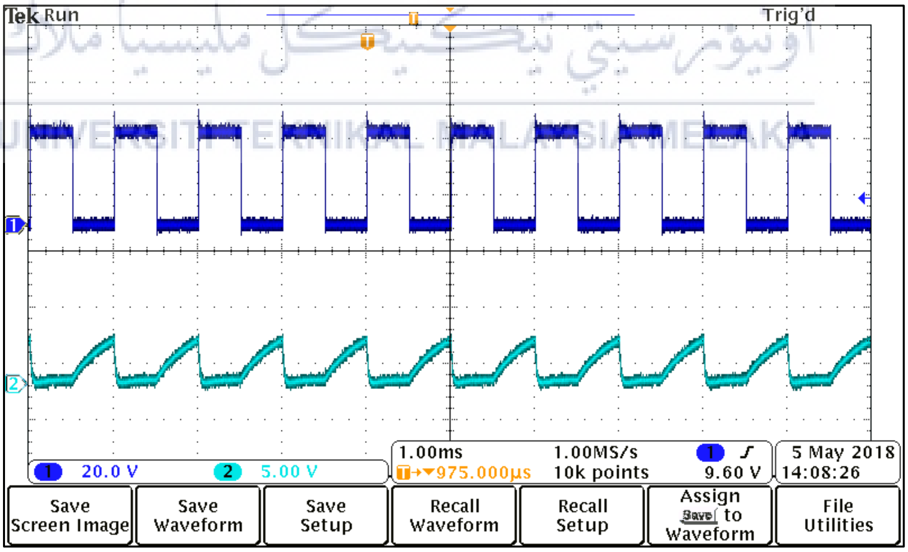

Figure 4.23: Output voltage when D=50%

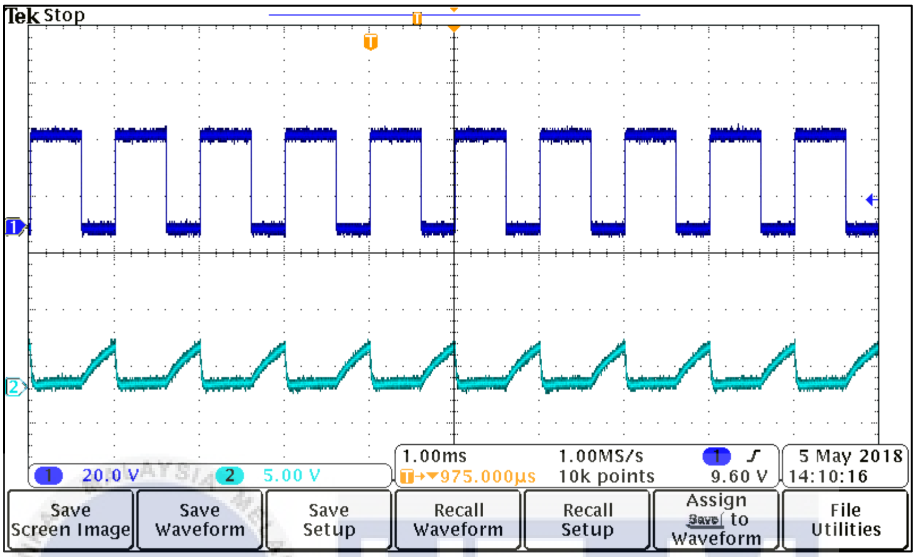

Figure 4.24: Output voltage when D=60%

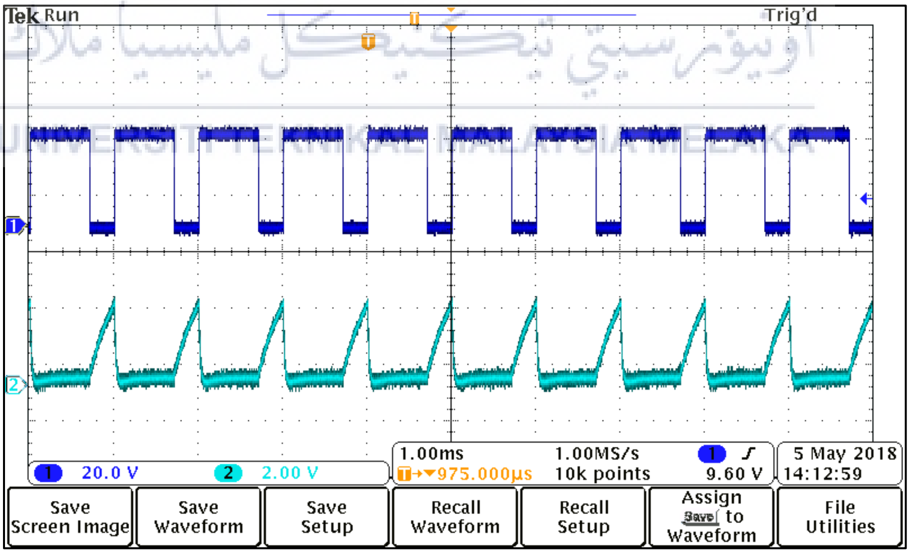

Figure 4.25: Output voltage when D=70%

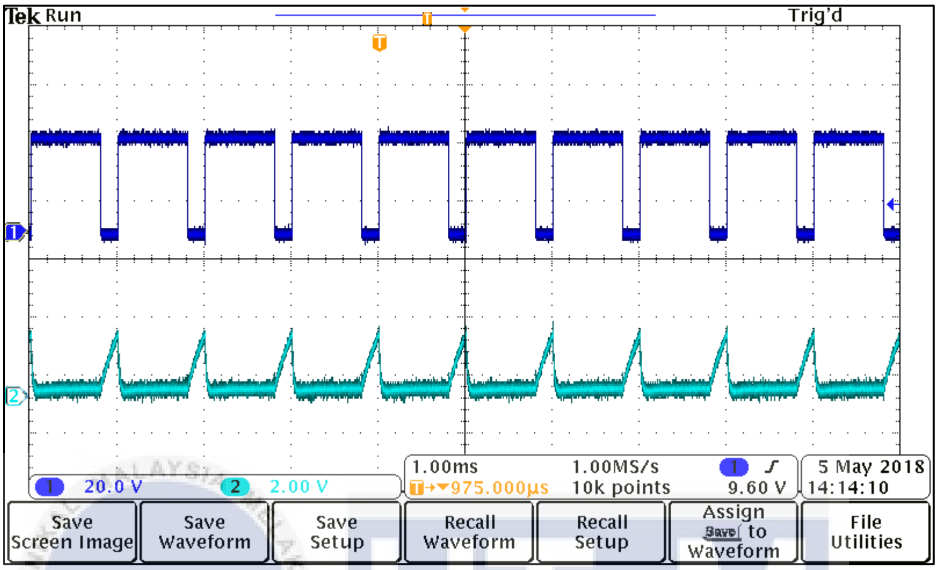

Figure 4.25: Output voltage when D=80%

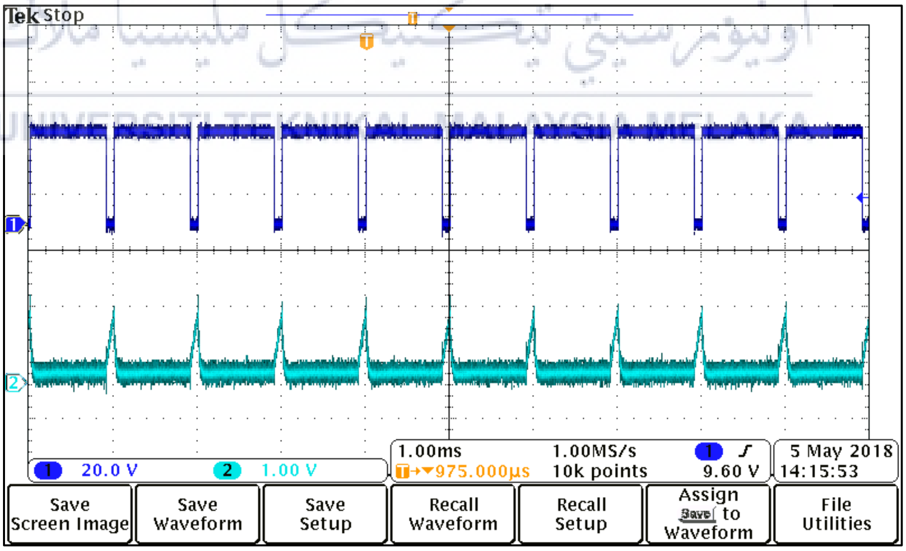

Figure 4.26: Output voltage when D=90%

4.3.2: The effect toward current ripple when the value of duty cycle (D) is varied

As can be seen in figure 4.27, with a duty cycle of 10%, the turn on state is only for a brief second while the turn off state is longer. The current ripple is with a ΔiL of 0.048 A. Figure 4.28 below shows a pulse with a duty cycle, D of 20% and the current ripple, iL at the inductor is ΔiL=0.095 A.

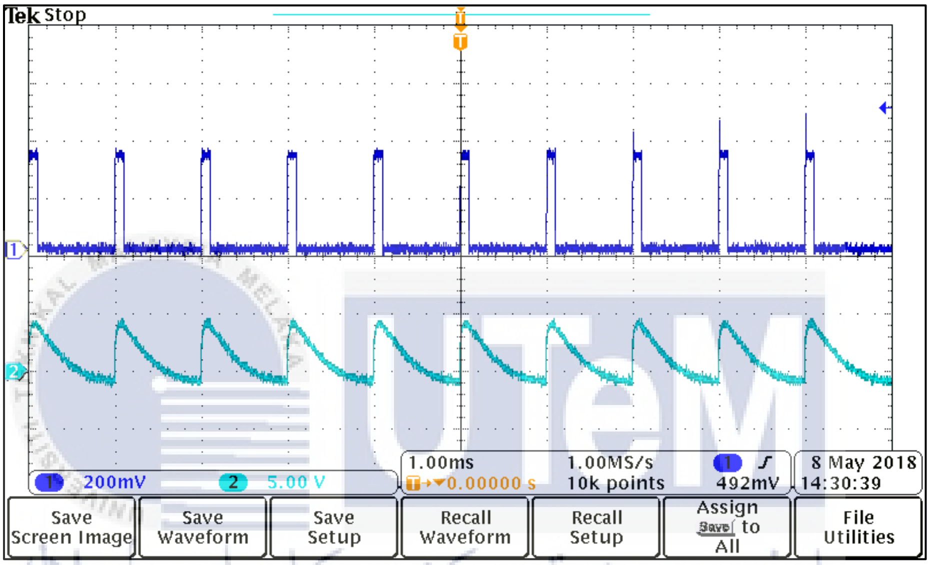

Figure 4.27: Pulse with duty cycle (D) 10% and ripple current

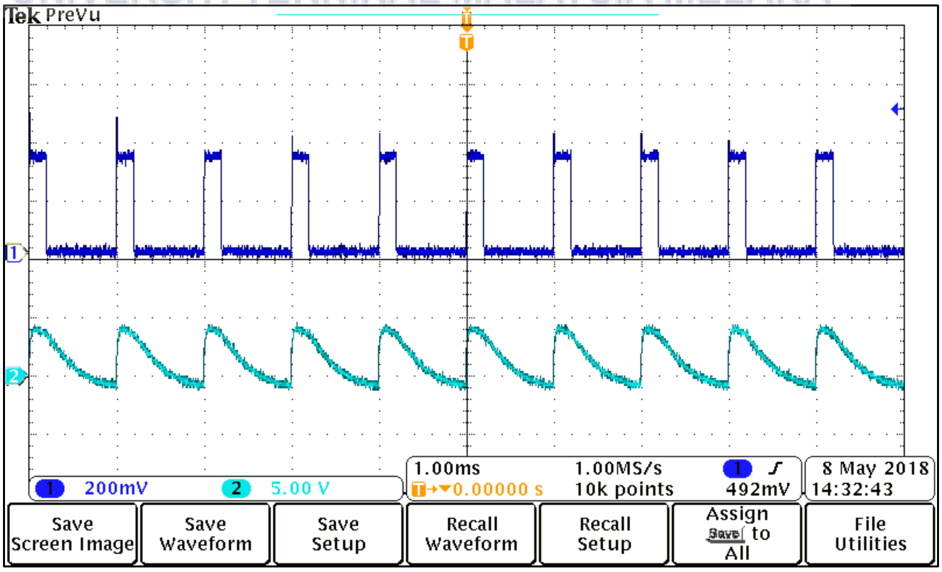

Figure 4.28: Pulse with duty cycle (D) 20% and ripple current

Figure 4.29 below shows the effect of current ripple when the duty cycle is 30%. The current ripple is ΔiL= 0.14A.

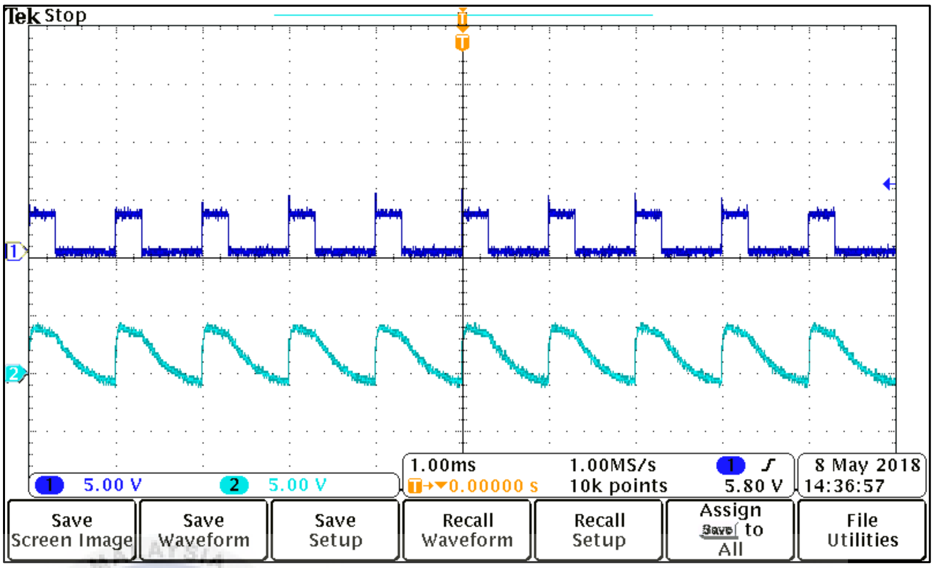

Figure 4.29: Pulse with duty cycle (D) 30% and current ripple

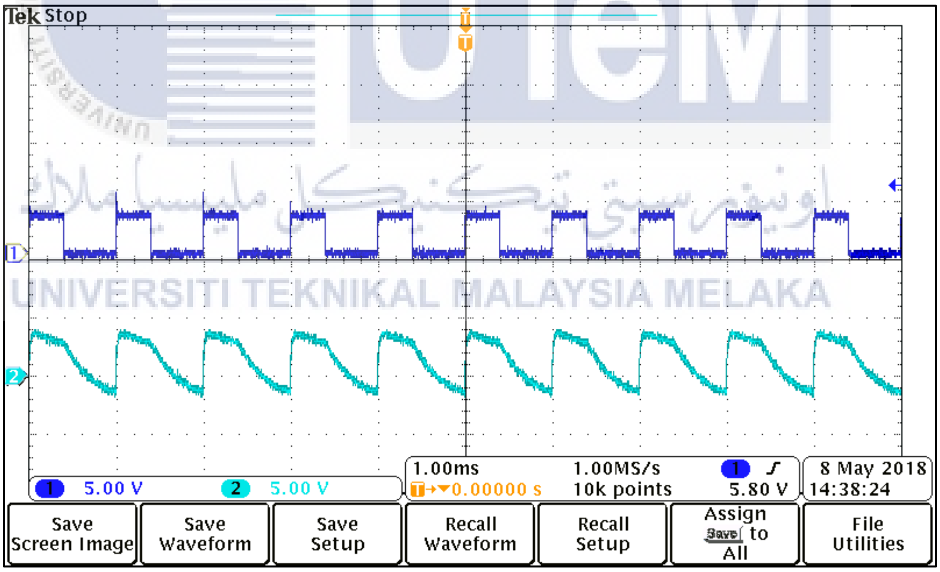

Figure 4.30: Pulse with duty cycle (D) 40% and current ripple

As the duty cycle increases (40%), the on state also increases. The charging of the current during the on state increases linearly. The current ripple ΔiL= 0.18A.

As for a duty cycle for 50% as illustrated in figure 4.31 below, the current ripple also increase. The current ripple ΔiL for a duty cycle of 50% is 0.23 A.

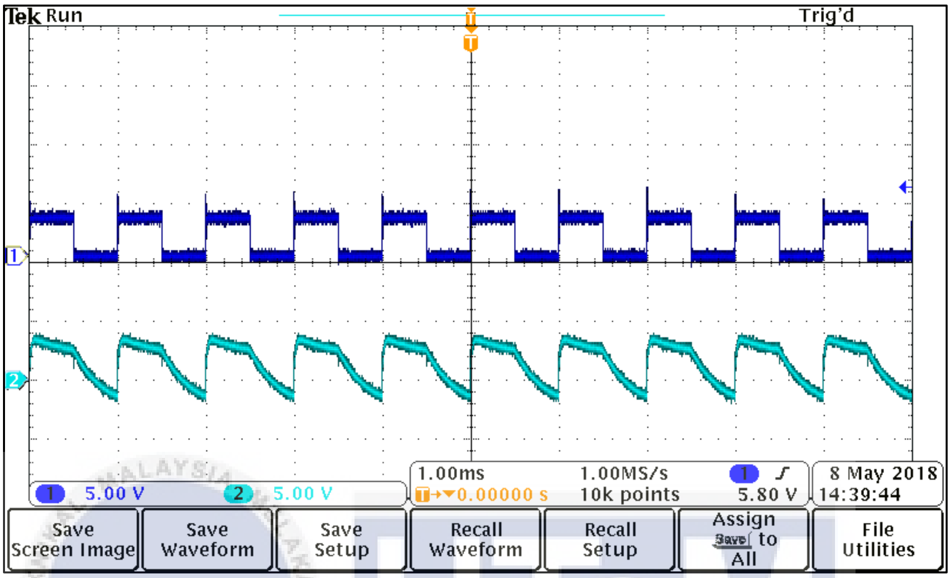

Figure 4.31: Pulse with duty cycle (D) 50% and current ripple

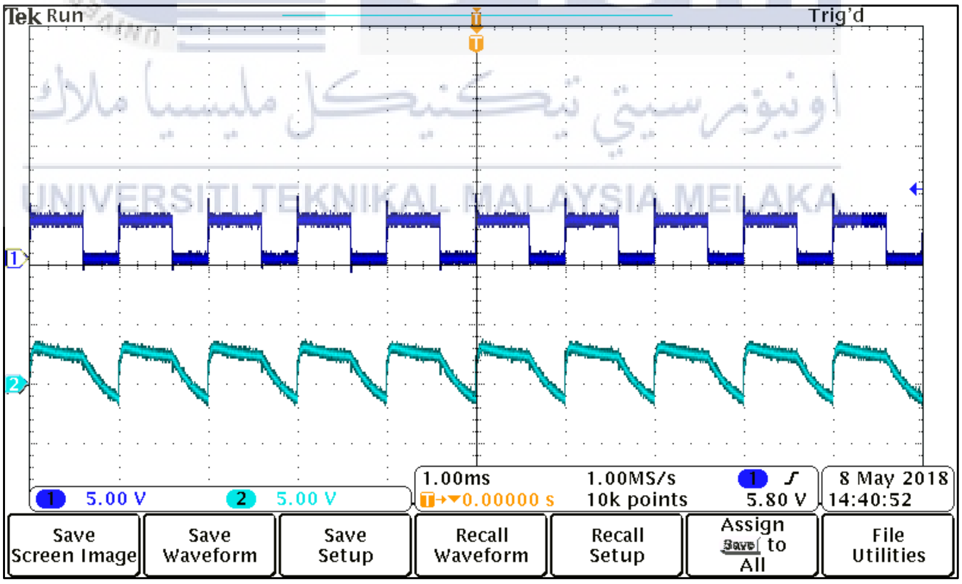

Figure 4.32: Pulse with duty cycle (D) 60% and current ripple

Another 10% of duty cycle is increased as in figure 4.32 causing the duty cycle to be 60% of the input voltage. The current ripple ΔiL for 60% duty cycle is 0.31A. Figure 4.33 and figure 4.34 with a duty cycle of 70% and 80% the ΔiL with a duty cycle of 70% is 0.5A and the ΔiL for a duty cycle of 80% is 0.39A. as the duty cycle increases, so does the current ripple.

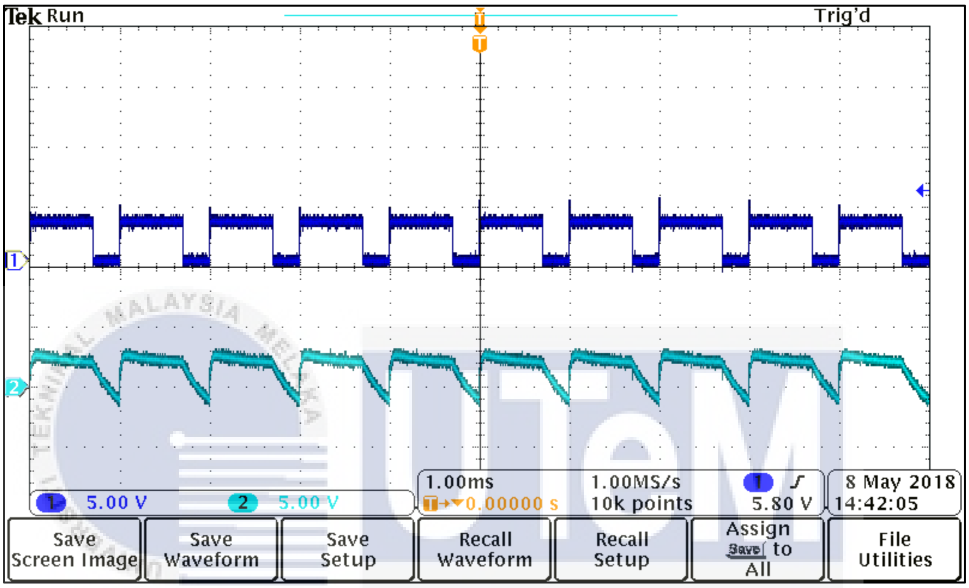

Figure 4.33: Pulse with duty cycle (D) 70% and current ripple

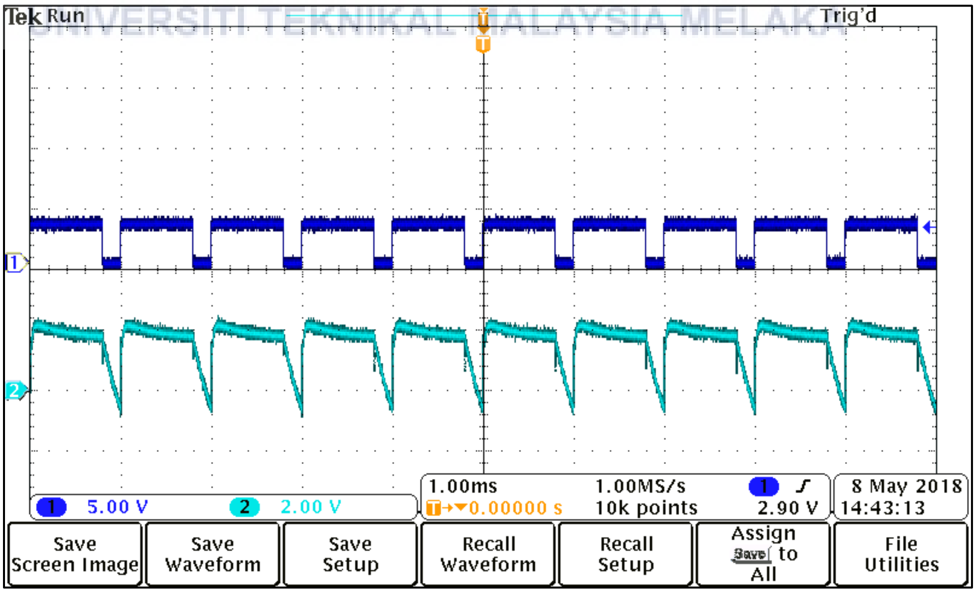

Figure 4.34: Pulse with duty cycle (D) 80% and current ripple

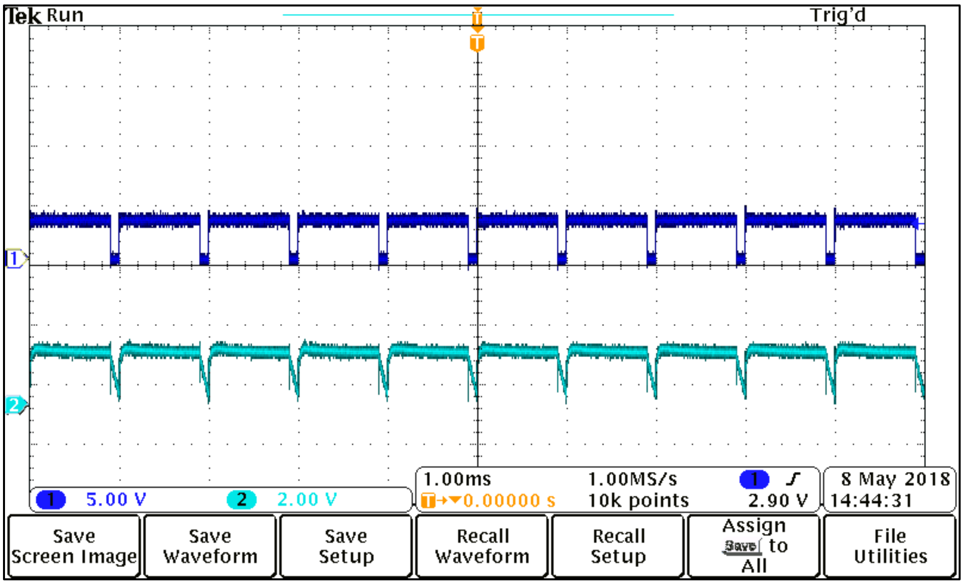

Figure 4.35: Pulse with duty cycle (D) 90% and current ripple

4.4: Analysis

4.4.1: Analysis on the effect towards the current ripple when varying the value of duty cycle (D)

The case is to see the different effects of the duty cycle towards the current ripple. The parameters remain the same as the simulation section. Table 4.1 below shows the ripple current at the inductor, ΔiL (A) for calculations, simulations and experiments for duty cycles between 10% and 90%. The task cycle is different by changing the duration of the ON instruction on the watch tab to 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80% and 90% while maintaining the frequency being 10 kHz. All data are listed as shown in Table 4.1.

Table 4.1: Result analysis

Duty cycle (D)	**Calculation**		**Simulation**		**Experimental**	
	ΔiL (A)	**Vout (V)**	**ΔiL (A)**	**Vout (V)**	**ΔiL (A)**	**Vout (V)**
0.1	0.05878	6.671	0.05878	6.671	0.048	6.137
0.2	0.1161	7.505	0.1161	7.505	0.095	7.190
0.3	0.1773	8.593	0.1773	8.593	0.140	8.286
0.4	0.2358	10.020	0.2358	10.020	0.180	9.853
0.5	0.2848	12.040	0.2848	12.040	0.230	11.833
0.6	0.3491	15.100	0.3491	15.100	0.320	14.921
0.7	0.4131	20.140	0.4131	20.140	0.500	19.154
0.8	0.4588	30.120	0.4588	30.120	0.390	13.645
0.9	0.5146	60.760	0.5146	60.760	0.180	7.089

In the simulation section, all data is obtained from the 10% duty cycle up to 90%. For a 10% duty cycle, the generated pulse time is only 10% of the total time or duration of the pulse which causes a short-run current and release over a longer period of time.

In the hardware part is also with a scale of 5V/div=5A which is equivalent to 1: 5, it can be seen that when the duty cycle is 10% of the input voltage, the output voltage increases up to 6.137V from a 6V input. This is related to the equation (2.4). The output voltage is directly proportional the amount of duty cycle that is set; therefore the larger the duty cycle, the bigger the output voltage and the larger the duty cycle, the current ripple would enhance as well. In the experimental part, when the duty cycle is increased up to 70% the output voltage increases up to 19.154V from an input of 12V. The current ripple also increases up to 0.5A. Another 10% is increased to the duty cycle which results to a duty cycle of 80%. The output voltage and the current ripple starts to drop to 22.65V and 0.39A. This event is possible due to the switching itself. The time off of the pulse is too short that no switching is likely to happen as 2 pulses occur for every 0.001s.

This condition continues as the duty cycle is set to 90% of the input voltage causing the output voltage to drop to 11.09V and a current ripple of 0.18A. When the duty cycle is 90%, the inductor would reach a saturation point whereby would act almost to have the characteristic of a DC. The inductor would act like a short circuit to the DC causing the voltage and current to drop. This case only apply to the experimental part this is because, in calculation and simulation, both are based on ideal cases unlike the experimental part where real time application is applied whereby the losses and voltage drop as well as the components used may affect the performance of the circuit itself.

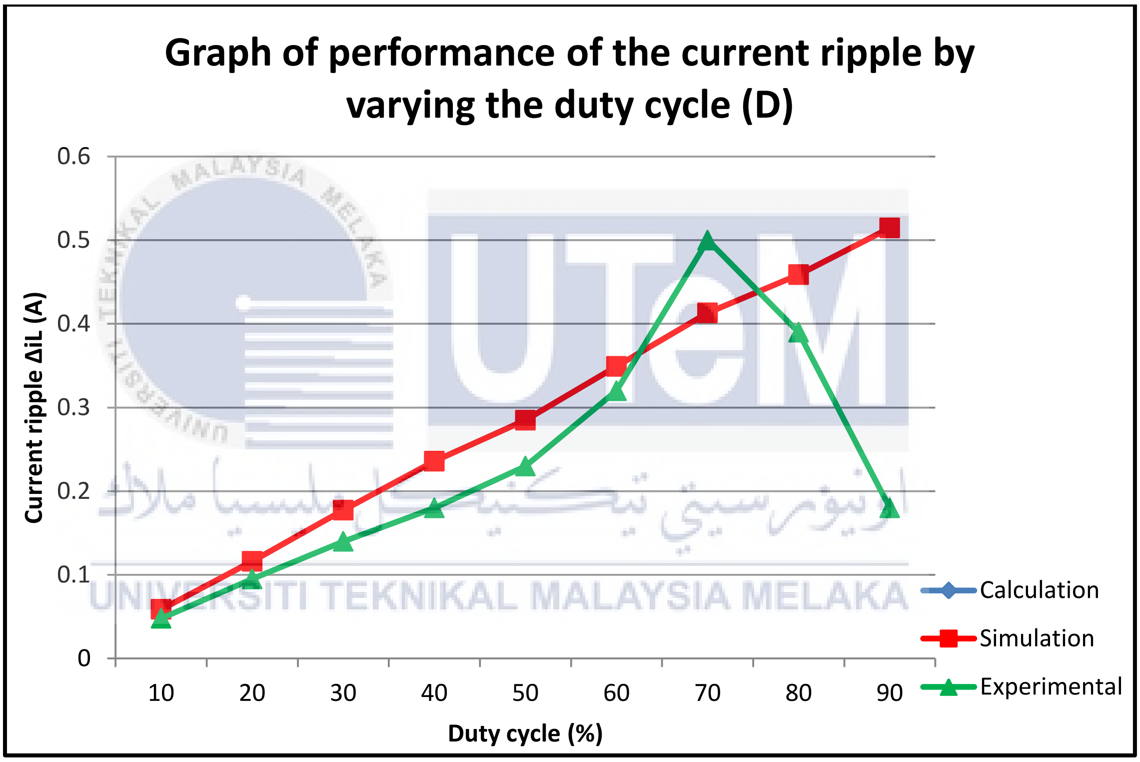

Figure 4.36: Graph performance of current ripple by varying duty cycle (D)

As illustrated in the graph of performance of the current ripple by varying the value of duty cycle, D in figure 4.36 above, the calculation and simulation matches as the higher the duty cycle which results in a longer time on and a shorter period of time off, the current ripple increases. As shown in the figure 4.36 above, the hardware result differs a when the duty cycle reaches 80%. When the duty cycle reaches 80% the current ripple starts to decrease.

This is because the output voltage also decreases since the switching has reached a peak where the time off of the pulse is too brief. When the time off per cycle is too brief, the switching is most likely unable to switch (making switch close all the time) this would cause the voltage to drop as illustrated in figure 4.37 below. Therefore, it can be stated that the minimum duty cycle is 10% and the maximum duty cycle available for the parameters used are only up 70%.

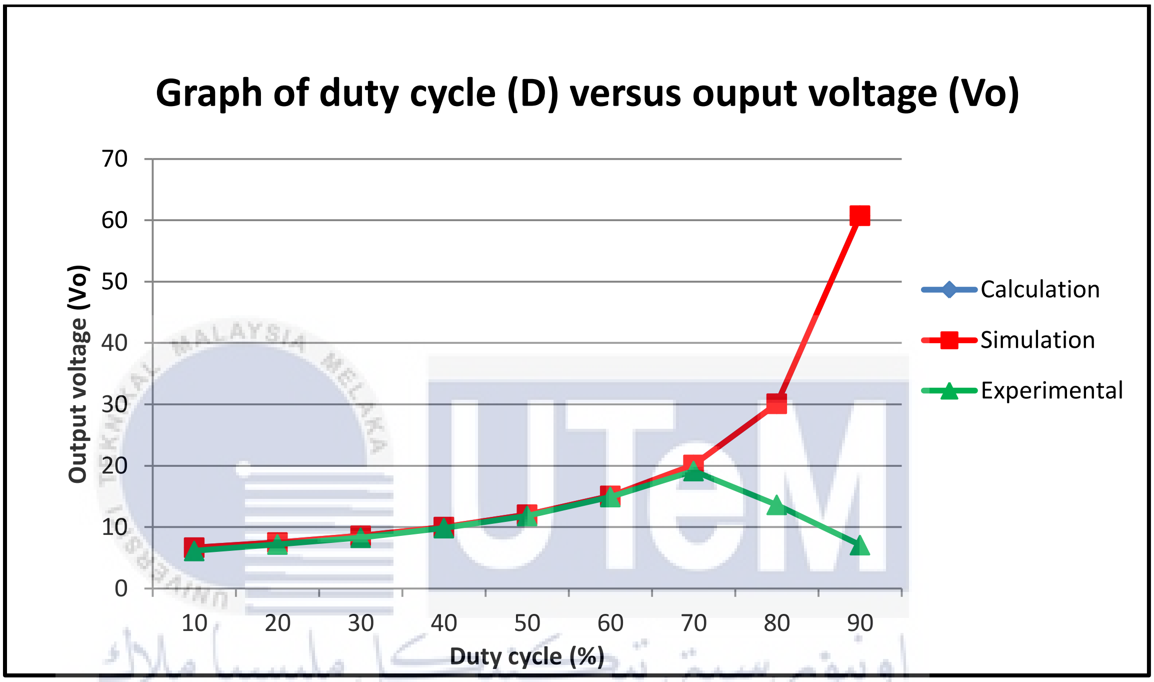

Figure 4.37: Graph of duty cycle (D) versus output voltage (Vo)

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1: Conclusion

In this project, a boost converter is designed, developed and implemented for continuous current mode. The converter topology is selected after doing several calculations and estimations of various parameters. The designed circuit is modelled and simulated using MATLAB simulink. The simulation results of these systems are compared for the analysis. The result for varied duty cycle has an advantage to reduce a current ripple. The selective value is important to get a best performance for boost converter circuit.

5.2: Recommendation

The switching topology using the Infineon XMC 4500 is definite reliable way to control the switching of the pulse as the switching can be edited at will by directly re uploading the program from MATLAB into the XMC 4500. As the switching process continues, the high current switching would generate noise as well as voltage spike during the turn off and turn on state of the switching process. In this project implemented, only a basic boost circuit is developed. In order to overcome the downsides of the switching phenomenon, special measures like filtering, shielding of components is recommended. The boost converter developed is bulky in size. For future development, it is recommended to build a boost converter that is small in size but with high performance.

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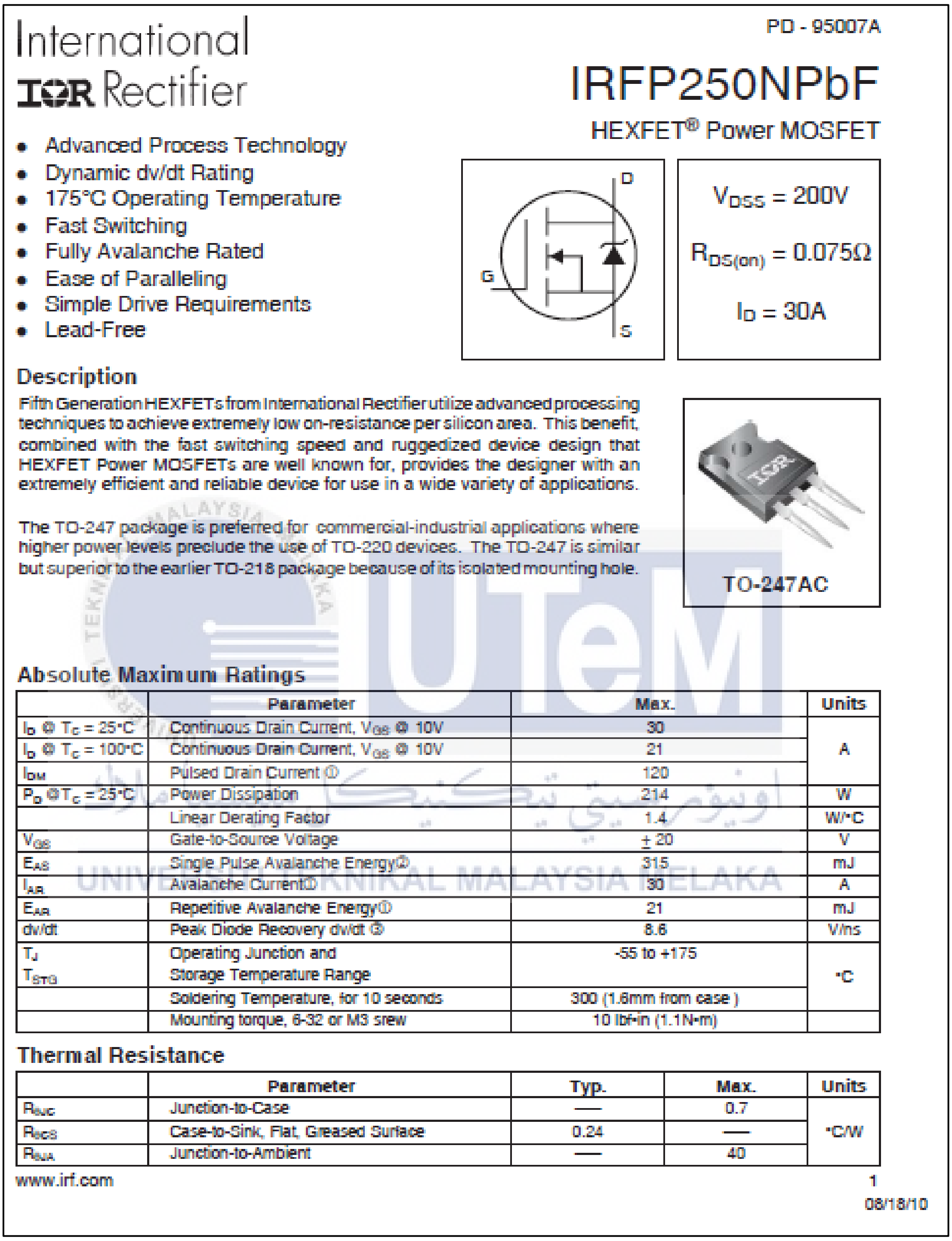
APPENDIX A

Gantt chart

Activities of project	**Final year project 2**													
	2018													
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
FYP 2 briefing	■													
Title registration		■												
Finding and researching component DC-DC boost converter			■	■	■	■								
Circuit design and hardware design					■	■	■							
Testing hardware circuit						■	■	■	■	■				
Troubleshoot the circuit						■	■	■						
Collecting data and result								■	■	■	■			
Analyzing data										■	■	■	■	
Report writing					■	■	■	■	■	■	■	■	■	
FYP 2 presentation														■
Full Report submission														■

APPENDIX B



International
IOR Rectifier

PD - 95007A

IRFP250NPbF

HEXFET® Power MOSFET

- Advanced Process Technology
- Dynamic dv/dt Rating
- 175°C Operating Temperature
- Fast Switching
- Fully Avalanche Rated
- Ease of Paralleling
- Simple Drive Requirements
- Lead-Free

$V_{DSS} = 200V$

$R_{DS(on)} = 0.075\Omega$

$I_D = 30A$

Description

Fifth Generation HEXFETs from International Rectifier utilize advanced processing techniques to achieve extremely low on-resistance per silicon area. This benefit, combined with the fast switching speed and ruggedized device design that HEXFET Power MOSFETs are well known for, provides the designer with an extremely efficient and reliable device for use in a wide variety of applications.

The TO-247 package is preferred for commercial-industrial applications where higher power levels preclude the use of TO-220 devices. The TO-247 is similar but superior to the earlier TO-218 package because of its isolated mounting hole.

TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
I_D @ T_C = 25°C	Continuous Drain Current, V_{GS} @ 10V	30	A
I_D @ T_C = 100°C	Continuous Drain Current, V_{GS} @ 10V	21	
I_{DM}	Pulsed Drain Current ①	120	
P_D @T_C = 25°C	Power Dissipation	214	W
	Linear Derating Factor	1.4	W/°C
V_{GS}	Gate-to-Source Voltage	± 20	V
E_{AS}	Single Pulse Avalanche Energy②	315	mJ
I_{AR}	Avalanche Current①	30	A
E_{AR}	Repetitive Avalanche Energy①	21	mJ
dv/dt	Peak Diode Recovery dv/dt ③	8.6	V/ns
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +175	°C
	Soldering Temperature, for 10 seconds	300 (1.6mm from case)	
	Mounting torque, 6-32 or M3 srew	10 lbf•in (1.1N•m)	

Thermal Resistance

	Parameter	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	——	0.7	°C/W
$R_{\theta CS}$	Case-to-Sink, Flat, Greased Surface	0.24	——	
$R_{\theta JA}$	Junction-to-Ambient	——	40	

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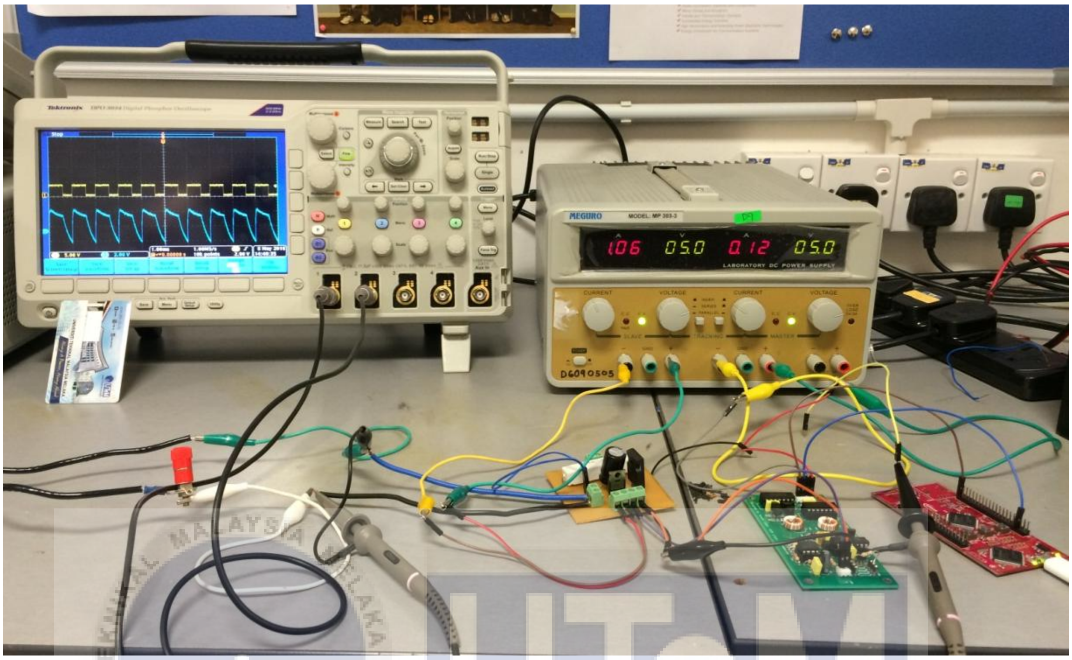
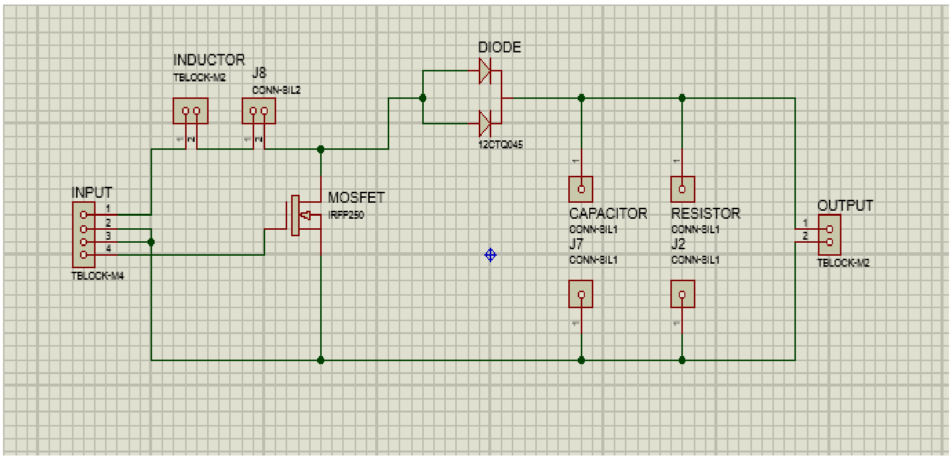
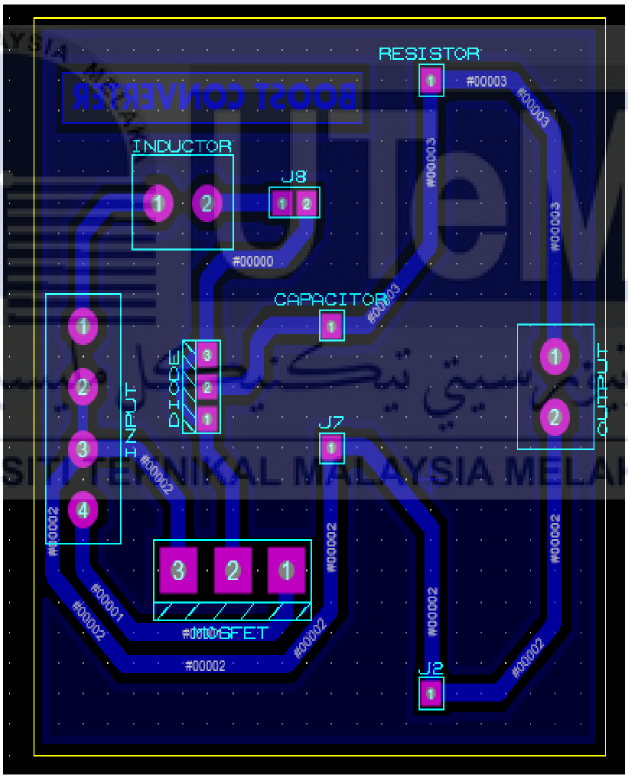
APPENDIX C



APPENDIX D


DIODE
INDUCTOR
TBLOCK-M2
J8
CONN-SIL2
12CTQ045
INPUT
1
2
3
4
TBLOCK-M4
MOSFET
IRFP250
CAPACITOR
CONN-SIL1
J7
CONN-SIL1
RESISTOR
CONN-SIL1
J2
CONN-SIL1
OUTPUT
1
2
TBLOCK-M2


BOOST CONVERTER
RESISTOR
#00003
INDUCTOR
J8
#00000
CAPACITOR
INPUT
DIODE
J7
OUTPUT
#00002
#00001
MOSFET
J2

APPENDIX E