UNIVERSITI TEKNIKAL MALAYSIA MELAKA

1.5V to 24V Adjustable DC Power Supply Design based on Bang – Bang Control of Buck Converter

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electrical Engineering Technology (Industrial Power) with Honours.

by

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BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **1.5V TO 24V ADJUSTABLE DC POWER SUPPLY DESIGN BASED ON BANG-BANG CONTROL OF BYCK CONVERTER**

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Date : **02 JANUARY 2017**

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering Technology (Industrial Automation & Robotics) with Honors. The member of the supervisory is as follow:

……

(Dr. Mohd Badril Bin Nor Shah)

ABSTRAK

Project ini mengenai pembangunan peranti bekalan kuasa arus terus (AT) boleh laras. Ia direka berdasarkan penukar Buck gelung tertutup dimana masukan litar tersebut diambil dari bekalan kuasa 240V dari soket kuasa. Algarithm pengawal buka-tutup dipilih sebagai pengawal gelung tertutup kerana ia mudah direka bentuk dan teguh pada gangguan dan ketidaktentuan parameter, seterusnya membentuk keluaran boleh laras 1.5V hingga 24V penukar Buck. Kerja simulasi dilakukan menggunakan perisian Matlab/Simscape dan prototaip litar juga telah dibina untuk mengesahkan prestasi sebenar. Pada akhir projek ini, peranti yang boleh menghasilakan kekuasaan boleh laras 1.5V hingga 24V berjaya dihasilkan untuk menghidupkan kebanyakan peralatan elektrik berkuasa rendah.

ABSTRACT

This project addresses the development of adjustable output of DC power supply device. It is designed based on closed – loop control of buck converter where the input of the circuit is taken from 240V of power socket outlet. Bang – bang control algorithm is chosen as a closed – loop control since it is easy to design and robust to disturbances and parameter uncertainties, thus forming 1.5V – 24V adjustable output of buck converter. Safety circuit also will be designed as prevention of electrocution. The simulation work is performed by using Matlab/Simscape and a hardware prototypes also will be developed to verify the real – time performance. In the end of this project, the device that is able to produce 1.5V – 24V adjustable DC output is successful developed to power up most low voltage electronic equipment

DEDICATION

To my beloved parents, I acknowledge my sincere indebtedness and gratitude to them for their love, dream and sacrifice throughout my life. Their sacrifice had inspired me from the day I learned how to read and write until what I have become now. I cannot find the appropriate words that could properly describe my appreciation for their devotion, support and faith in my ability to achieve my dreams.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

VB	-	Visual Basic
MPPT	-	Maximum Power Point Tracking
IDE	-	Integrated Development Environment
VC	-	Automatic Voltage regulator
AVR	-	Automatic Voltage Regulator
SMPS	-	Switch-Mode Power Supply
AC	-	Alternating Current
DC	-	Direct Current
BCDMOS	-	Buried Collector Double Metal Oxide semiconductor
PWM	-	Pulse Width Modulation
SAR	-	Specific Absorption Rate
VREF	-	Voltage Reference
VOUT	-	Output Voltage

CHAPTER 1
INTRODUCTION

1.0 Project Background

Most compact and portable electric appliances such as toys, mobile phone, clocks, radio, to name a few, are powered by DC source. A DC source can be obtained either from batteries or rectified AC source. For instant, batteries perform electrochemical reaction which result in electrical difference between anode and cathode terminals. A rectified AC source produces DC voltage by converting AC voltage to clean DC voltage by using rectifier and filter circuit.

DC source also can be obtained from the output of buck converter circuit. Buck converter is a switching-based circuit to step down DC voltage to the desired voltage. A basic buck converter circuit is consists of inductance, capacitor, diode and transistor. The magnitude of the output voltage of buck converter is depends on the duty cycle of PWM signal.

Bang-bang controller is also known as on-off controller. It is the simplest and basic form of controller and used in many applications such as temperature and power supply control. The advantage of this controller are ease to design and also robust to disturbance and parameter uncertainties.

With pulse width modulation (PWM) signal, buck converter itself is not capable to provide constant output voltage under different leads. Hence it need to be combined with control algorithm in such a way it is not at desired level.

1.1 Problem Statement

Most electric equipment is operate in range 1.5V to 24V and it can be powered from batteries. However for certain equipment, e.g. radio, modem, router, batteries, is not favorably powered by batteries since it consume a lot of current. Hence power supply adapter always been used to power these equipments.

Most universal power supply adapter device is designed by using step-down transformers, rectifier and filter circuit. It does not provide closed-loop control, thus a desired constant voltage output cannot be supplied under different load. Figure 1.1 shows the example of universal power supply that is commonly sold at the market.

Figure 1.1: Common universal power supply adapter

1.2 Objective

The objectives of this project are:

a) To design DC power supply circuit based on Buck Converter where the input is taken from 240V of power socket outlet.
b) To design a closed-loop control of buck converter by using bang-bang control algorithm to form 1.5V to 24V adjustable DC power supply circuit.
c) To analyse the efficiency of the designed power supply circuit through simulation using MATLAB/Simscape.
d) To develop a hardware prototype of the designed power supply circuit.

1.3 Project Scope

The scope of this project are:

a) **Circuit design**

The fundamental theory of buck and bang – bang control will be used to design a closed – loop control of buck converter thus forming an adjustable output of power supply circuit. A rectifier circuit to convert AC to DC voltage also will be designed which serve an input of buck converter. A simple safety circuit will be provided as a protection from electrocution.

b) **Simulation**

The simulation of the designed power supply circuit will be performed by using Matlab / Simscape.

c) **Hardware**

A microcontroller based circuit will be used combined with the designed buck converter, and other interfacing device to form a prototype of this project.

1.4 Thesis Outline

This thesis consists of five chapters and are organized as the following. Chapter 2 provide a literature review on buck converter, bang-bang controller and the preview of related work.

Chapter 3 discusses the methodology of this project that covers circuit design and hardware development.

Chapter 4 explains the result of the designed bang-bang control of Buck Converter. The analysis of the circuit performance is also discussed in details.

Chapter 5 is the conclusion. Recommendation for future works is also included in this chapter.

CHAPTER 2
LITERATURE REVIEW

2.0 Introduction

Literature review is first step to understand the ideas to develop the project of 1.5V to 24V adjustable DC power supply design based on Bang-bang Control of Buck Converter. In this chapter, detail summaries of the project ideas from previous researchers are determined.

2.1 Buck Converter

Buck converter is DC-DC converter that is used to step down voltage to meet the requirement of load. There are four main components in the buck converter which we need to design in order obtain the desired output voltage.

a) Inductor
b) Capacitor
c) Diode
d) Resistor

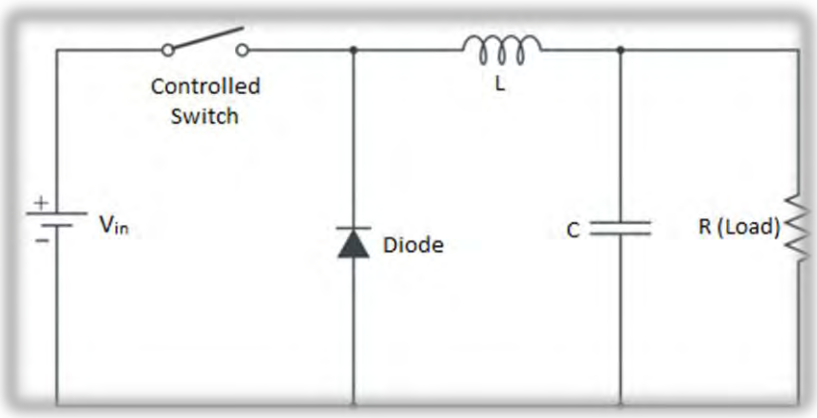

Figure 2.1a: Buck converter circuit

2.1.1 Pulse Width Modulation

The input of buck converter is duty cycle where it can be generate from PWM signal. PWM signals can be generated as a digital signal, using counters or digital output line(s), or as an analog signal, using for instance, an arbitrary waveform generator or an RF signal generator. Figure 2.1.2 shows the example of magnitude for duty cycle.

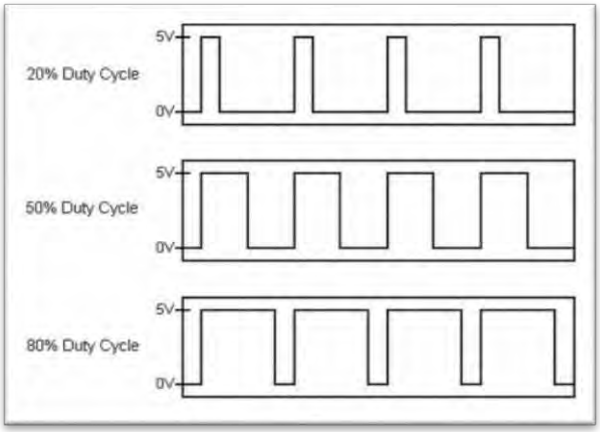

Figure 2.1b: Output duty cycle

2.2 Bang-bang Controller Design

A bang-bang controller is a controller which outputs only two discrete commands. The output signal is for on / off controller.

Figure 2.2: Bang-bang controller

The mathematical equation for bang-bang controller is described by:

$$u = \text{sgn}(e)$$
$$= \begin{cases} u = 1 & if\ e > 0 \\ u = 0 & if\ e = 0 \\ u = -1 & if\ e < 0 \end{cases} \quad (2.1)$$

2.2.1 Bang-bang Controller

For an ideal control issue, a standout amongst the most widely recognized sorts of control capacity is the piecewise-steady capacity by which a succession of steady inputs is utilized to control a given framework with reasonable exchanging times. Furthermore, when the control is limited, a normally experienced kind of piecewise constant control is bang-bang, which switches between the upper what's more, lower limits of the control information. The ideal control issue is to minimize a cost utilitarian, characterized on the state direction, as an element of the exchanging parameters. Such ideal control issues emerge in different application spaces, counting workman, mechanical autonomy, power converters, generation control and so forth. In exchanging power converter control the controller yield has one of two states: "on" or "off". These applications are not well

suited to standard direct control plan techniques. An exchanging procedure including hysteresis is ordinarily utilized for these sorts of force converters.

In control theory, a bang–bang controller (on–off controller), otherwise called a hysteresis controller, is a feedback controller that switches unexpectedly between two states. These controllers might be acknowledged regarding any component that gives hysteresis. They are frequently used to control a plant that acknowledges a twofold contribution, for instance a heater that is either totally on or totally off. Most basic private indoor regulators are bang–bang controllers. The Heaviside step capacity in its discrete structure is a case of a bang–bang control signal. Because of the discontinuous control signal, frameworks that incorporate bang–bang controllers are variable structure frameworks, and bang–bang controllers are hence variable structure controllers.

2.3 Buck Converter Design

This section explains the review of the electrical hardware components that is used in this project. The fundamental components for buck converter which are inductor, capacitor, diode and resistor are discussed in the following subtopic.

2.3.1 Inductor

An inductor is a passive component intended to store vitality in its magnetic field. An inductor will oppose the adjustment in current coursing through it. The current through inductor can't change quickly. A perfect inductor does not dissipate energy. The energy put away in it can be recovered at a later time. The inductor takes power from the circuit while putting away vitality and conveys energy to the circuit while returning

beforehand put away vitality. A practical non ideal inductor has a critical resistive part. This is because of the way that the inductor is made of a conducting material, for example, copper, which has some resistance. This resistance is known as the winding resistance, and it shows up in series with the inductance of the inductor. The nearness of winding resistance makes it both an energy stockpiling gadget and an energy dissipation gadget. Since the winding resistance is typically little, it is disregarded as a rule. The non-ideal inductor additionally has a twisting capacitance because of the capacitive coupling between the leading coils. Winding capacitance is little and can be disregarded much of the time, aside from at high frequencies.

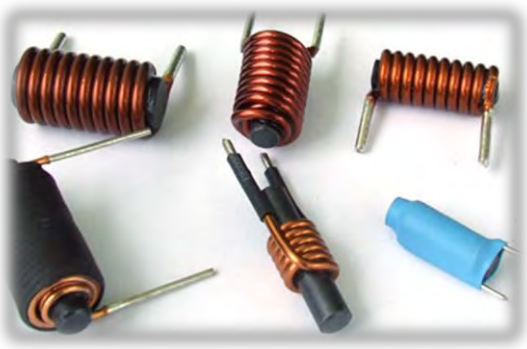

Figure 2.3a: Inductor

2.3.2 Capacitor

A capacitor is a detached component intended to store vitality in its electric field. The capacitor opposes an unexpected change in the voltage crosswise over it. The voltage on a capacitor can't change suddenly. The perfect capacitor does not disseminate vitality. It takes power from the circuit while putting away vitality in its field and returns already put away vitality when conveying energy to the circuit. A genuine, noni deal capacitor has a parallel-model spillage resistance. The spillage resistance might be as high as 100 MQ and can be disregarded for most reasonable applications.

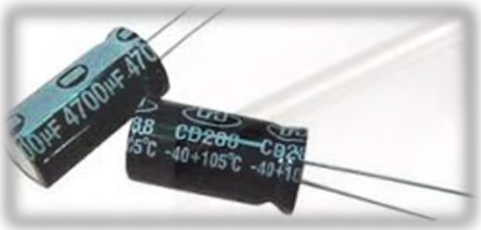

Figure 2.3b: Capacitor

2.3.3 Diode

Since the current in the inductor can't change momentarily, a way should exist for the inductor current when the switch is off (open). This way is given by the freewheeling diode (or catch diode). The motivation behind this diode is not to correct, but rather to direct current stream in the circuit and to guarantee that there is dependably a way for the current to stream into the inductor. It is likewise vital that this diode ought to have the capacity to kill generally quickly. In this way the diode empowers the converter to change over put away vitality in the inductor to the load.

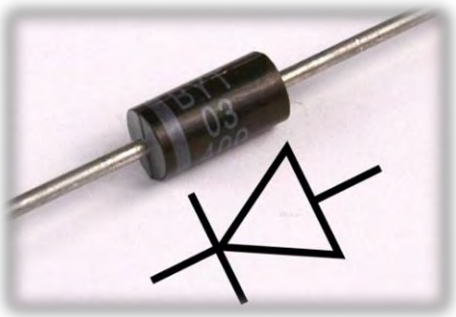

Figure 2.3c: Diode