MICROCONTROLLER BASED SMPS PROTECTION

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This thesis is submitted as partial fulfillment of the requirements for the award of the Bachelor of Electrical Engineering (Hons.) (Power System)

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Date : 17 NOVEMBER 2008

To my beloved mother and father,

And my friend,

“I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor Degree of Electrical Engineering (Power Systems)”

Signature : ______________________________

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Date : 17 NOVEMBER 2008

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ABSTRACT

This project have 3 main objectives to achieve, first the project should be able to protect DC load equipment from over voltage from their maximum voltage value or lower voltage from their minimum value. Second it should be able to protect DC load equipment from over current form their maximum current value or lower current from their minimum value. Third the voltage and current protection value are free to set by user. Simple methodology for this project is when the protection circuit detects any high or low voltage and current from power supply output that supplied to the load, it will stop the Pulse-width modulation (PWM) signal output. Sensing circuit will detect any voltage and current alteration output from power supply. Using the PIC microcontroller (PIC 18F4550), it will control the PWM signal output. The PWM output signal can be use for the power supply switching circuit. If the PWM signal stops, the operation for the power supply also will stop. Controlling the PWM signal will ensure that we can control the power supply whether want to turn it on or off.

ABSTRAK

Projek ini mempunyai 3 objektif utama yang perlu dicapai iaitu, pertama projek ni seharusnya dapat berupaya melindungi beban kelengkapan litar terus daripada voltan lebih atau kurang daripada julat voltan yang sesuai. Kedua litar ini berupaya untuk melindungi kelengkapan daripada arus lebih atau kurang daripada julat arus yang sesuai dan ketiga nilai voltan dan arus perlindungan adalah bebas untuk dipiih oleh pengguna. Kaedah mudah untuk projek ini ialah apabila litar pelindung mengesan voltan tinggi atau rendah dan arus tinggi atau rendah daripada pengeluaran bekalan kuasa, ia akan memberhentikan pengeluaran modulasi nadi lebar (PWM). Litar pengesan voltan dan arus akan mengesan sebarang perubahan voltan dan arus keluaran daripada bekalan kuasa. Menggunakan mikropengawal (PIC 18F4550), ia akan menguasai PWM yang berupaya untuk digunakan sebagai litar pensuisan bekalan kuasa. Jika pengeluaran isyarat PWM diberhentikan maka operasi untuk bekalan kuasa juga akan berhenti. Mengawal isyarat PWM akan memastikan bahawa kita boleh mengawal bekalan kuasa jika hendak menjalankan ataupun memberhentikan operasinya.

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LIST OF SYMBOLS

s	=	Second
V	=	Voltage
GND	=	Ground
Ω	=	Ohm
F	=	Farad
A	=	Ampere

LIST OF ABBREVIATIONS

LCD	=	Liquid Crystal Display
I/O	=	Input or Output
ADC	=	Analog-To-Digital Converter
OSC	=	Oscillator
PWM	=	Pulse Width Modulation
DC	=	Direct Current
LED	=	Light-Emitting Diode
IC	=	Integrated Circuit

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In new technology today, we already have many innovation and research to afford any benefit to human life. Most of task or problems are easy to solve because we already have various technology equipment to help people in their life. Main objective the equipment designed is to make sure all of matter can be solve efficient and perfect. Some of the design and innovation also can be made people life more easy and fast.

With the increasing use of sophisticated electronic equipment, users have become more aware of common problems caused by the imperfection of main power supply. These problems include over voltage, spikes, over current and even complete main failure, some or all of which can cause the malfunctioning of on line electronics equipment.

In some situation, if over voltage or over current occur, the internal fuse that already built in the equipment will blow and need to be replace. For the worst case, some part in the electronic equipment will burn or damage.

This project is to design and implement microcontroller based system protection for the dc equipment supplied by DC-DC converter power supply like electronic equipment or others DC equipments from over voltage and over current by using the PIC microcontroller based. This design will sense the output voltage and current supply from the power supply and make sure that the output voltage and current do not exceed the user setting.

1.2 Objective of Project

The overall of this project is to sense the output voltage and current that supply from the DC power supply and to ensure that the output voltage and current are not exceed from the user setting limit depend the program upload to the PIC microcontroller. This circuit is acting as the voltage and current protection circuit for load. The objective of this project is to;

i. The project should be able to protect DC load equipment from over voltage from their maximum voltage range.
ii. Should be able to protect DC load equipment from over current form their maximum current range.
iii. The voltage and current protection value are free to set by user.

1.3 Scope of Project

They are several scopes that need to be proposed for the project;

i. This project will design the protection system from over voltage and over current circuit based on microcontroller.
ii. This protection circuit will detect the over current and voltage from user setting limit depend the program upload to the PIC microcontroller.
iii. This project do not include the DC-DC converter power supply design but this protection circuit can be attached to the others DC-DC converter power supply. This protection circuit will control the Pulse-width modulation (PWM) switching from the existing DC-DC converter power supply.

1.4 Summary of Project

This project is to design and implement microcontroller (PIC 18F4550) based system for protection the dc equipment supplied by switch mode power supply (SMPS) or variable DC-DC converter. Once it attached to the SMPS, it will protect and ensure the voltage or current supply to the dc equipment is not exceeding the maximum value or lowers the minimum value. The sensing circuit is used to sense the output voltage and current value that supplied to the equipment. The shunt resister with low resistance is used to sense the current and voltage divider is use to sense the voltage. The 8-bit PIC 18F4550 analog-to-digital converter (ADC) used to read the value from sensing circuit by converting the sensing value from analog to digital. The reference values voltage and current for protection set by PIC. Based on the reference values, PIC compares the measured voltage and current flow to the equipment. If the measured voltage or current exceeding or lower from the reference values, the PIC will disable the PWM signal, at the same time the buzzer will trigger.

PIC will enable back the PWM signal and buzzer stop trigger if the value is back to the normal range. The PIC is used as a central controller to display the measured voltage and current on a 16 x 2 character LCD, control the buzzer, LED and 7 segment as the indicator to alert the user if voltage or current value out of range from normal value.

CHAPTER 2

THEORY AND LITERATUE REVIEW

2.1 Introduction

It is a common requirement for electronic circuits to have to withstand some degree of overvoltage and over current from the power-supply lines. Any overvoltage protection circuit will be required to do some basic things. The first is to prevent voltages greater than the maximum allowable. A trip voltage value (the power-supply voltage above which the protection circuit will activate) is therefore required that will allow the system to function with normal power-supply voltages. The second task is for the protection circuit not to intrude on the normal function of the circuit. At the present, types of circuit existing in various kind and method protection from over voltage and current. Below is some example device that we already used as the protection device.

2.1.1 Fuse (electrical)

In electronics and electrical engineering a fuse (short for *fusible link*), is a type of over current protection device. Its essential component is a metal wire or strip that melts when too much current flows, which breaks the circuit in which it is connected, thus protecting the circuit's other components from damage due to excessive current.

A practical fuse was one of the essential features of Thomas Edison's electrical power distribution system. An early fuse was said to have successfully protected an Edison installation from tampering by a rival gas-lighting concern. Fuses (and other over current devices) are an essential part of a power distribution system to prevent fire or damage. When too much current flows through a wire, it may overheat and be damaged or even start a fire. Wiring regulations give the maximum rating of a fuse for protection of a particular circuit. Local authorities will incorporate national wiring regulations as part of law. Fuses are selected to allow passage of normal currents, but to quickly interrupt a short circuit or overload condition. [7]

Fuses are often characterized as "fast-blow", "slow-blow" or "time-delay", according to the time they take to respond to an over current condition. The selection of the characteristic depends on what equipment is being protected. Semiconductor devices may need a fast or ultrafast fuse for protection since semiconductors may have little capacity to withstand even a momentary overload. Fuses applied on motor circuits may have a time-delay characteristic, since the surge of current required at motor start soon decreases and is harmless to wiring and the motor.

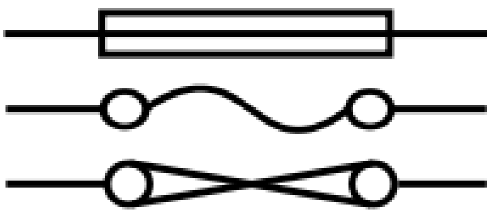


Figure 2.1 Electronic symbols for a fuse

2.1.2 Circuit breaker

A circuit breaker is an automatically-operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit. Unlike a fuse, which operates once and then has to be replaced, a circuit breaker can be reset (either manually or automatically) to resume normal operation. Circuit breakers are made in varying sizes, from small devices that protect an individual household appliance up to large switchgear designed to protect high voltage circuits feeding an entire city.

All circuit breakers have common features in their operation, although details vary substantially depending on the voltage class, current rating and type of the circuit breaker. The circuit breaker must detect a fault condition; in low-voltage circuit breakers this is usually done within the breaker enclosure. Large high-voltage circuit breakers have separate devices to sense an over current or other faults. Once a fault is detected, contacts within the circuit breaker must open to interrupt the circuit; some mechanically stored energy within the breaker is used to separate the contacts, although some of the energy required may be obtained from the fault current itself. When a current is interrupted, an arc is generated - this arc must be contained, cooled, and extinguished in a controlled way, so that the gap between the contacts can again withstand the voltage in the circuit. Finally, once the fault condition has been cleared, the contacts must again be reclosed to restore power to the interrupted circuit.

Figure 2.2 Photo of inside of a circuit breaker

2.1.3 Overvoltage Protection IC

Now, some of the big manufacture IC company already design their IC acted as the over voltage protection. For example, MAXIM Company designs the MAX4864L/MAX4865L/MAX4866L/MAX4867/MAX4865/MAX4866 overvoltage protection controller IC. These IC controllers will protect low-voltage systems against high-voltage faults up to +28V, and negative voltages down to -28V. These devices drive a low-cost complementary MOSFET. If the input voltage exceeds the overvoltage threshold, these devices turn off the n-channel MOSFET to prevent damage to the protected components. If the input voltage drops below ground, the devices turn off the p-channel MOSFET to prevent damage to the protected components. An internal charge pump eliminates the need for external capacitors and drives the MOSFET GATEN for a simple, robust solution. [8]

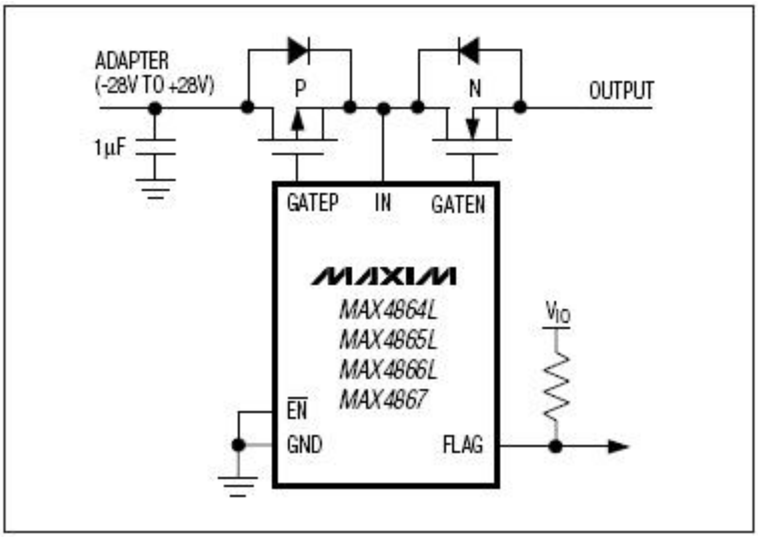


Figure 2.3 MAXIM IC

2.2 Switched-mode power supply (SMPS)

A switched-mode power supply, switching-mode power supply or SMPS, is an electronic power supply unit (PSU) that incorporates a switching regulator. While a linear regulator maintains the desired output voltage by dissipating excess power in a "pass" power transistor, the SMPS rapidly switches a power transistor between saturation (full on) and cutoff (completely off) with a variable duty cycle whose average is the desired output voltage. The resulting rectangular waveform is low-pass filtered with an inductor and capacitor. The main advantage of this method is greater efficiency because the switching transistor dissipates little power in the saturated state and the off state compared to the semiconducting state (active region). Other advantages include smaller size and lighter weight (from the elimination of low frequency transformers which have a high weight) and lower heat generation from the higher efficiency. Disadvantages include greater complexity, the generation of high amplitude, high frequency energy that the low-pass filter must block to avoid EMI, and a ripple voltage at the switching frequency and the harmonic frequencies thereof.

SMPS can be classified into four types according to the input and output waveforms, as follows.

- AC in, DC out: rectifier, off-line converter input stage.
- DC in, DC out: voltage converter, or current converter, or DC to DC converter
- AC in, AC out: frequency changer, cycloconverter.
- DC in, AC out: inverter

2.2.1 SMPS and Linear Power Supply comparison

Table 2.1 SMPS and Linear Power Supply comparison

	Linear power supply	**Switching power supply**
Size and weight	Huge due to low operating frequency (mains power frequency is at 50 or 60 Hz)	Smaller due to higher operating frequency (typically 50 kHz - 1 MHz)
Output voltage	Output can only produce a positive/negative voltage which varies depending on loading.	Output is able to produce a voltage lower, higher or even negative to the input voltage with superior regulation.
Efficiency, heat, and power dissipation	Output voltage is regulated by expending excess power as heat, which is inefficient.	Output is regulated using duty cycle control, which draws only the power required by the load. In all SMPS topologies, the transistors are always switched fully on or fully off.
Complexity	Consists of a voltage regulating IC or discrete circuit and a noise filtering capacitor.	Consists of a controller IC, one or several power transistors and diodes as well as a power transformer, inductors, and filter capacitors.
Radio frequency interference	No interference produced, except possibility of mains hum induction into unshielded cables.	EMI/RFI produced due to the current being switched on and off sharply. Therefore, EMI filters and RF shielding are needed to reduce the disruptive interference.
Electronic noise at the output terminals	Unregulated PSUs may have a small amount of AC "riding on" the DC component at twice the main frequency (100-120	Noisier due to the switching frequency of the SMPS. An unfiltered output may cause glitches in digital circuits or

	Hz). This can cause an audible mains hum in audio equipment or unexpected brightness ripples or other banded distortions in analog security cameras.	noise in audio circuits.
Electronic noise at the input terminals	Causes harmonic distortion to the input AC, but no high frequency noise.	Very low cost SMPS may couple electrical switching noise back onto the mains power line, causing interference with A/V equipment connected to the same phase. Non power-factor-corrected SMPSs also cause harmonic distortion.
Acoustic noise	Faint, usually inaudible mains hum, usually due to vibration of windings in the transformer and/or magnetostriction.	Inaudible to humans, unless they have a fan or are unloaded/malfunctioning.
Power factor	Low because current is drawn from the mains at the peaks of the voltage sinusoid.	Ranging from low to medium since a simple SMPS without PFC draws current spikes at the peaks of the AC sinusoid.
Risk of electric shock	Limited to either the full mains voltage or the secondary terminals in contact with the body.	Common rail of equipment (including casing) is energised to half mains voltage unless equipment is earthed/grounded or doesn't contain EMI/RFI filtering at the input terminals.
Risk of equipment destruction	Very low, unless a short occurs between the primary and secondary windings or the regulator fails by shorting	Capable of destroying input stages in amplifiers due to the floating voltage being above the base-emitter breakdown voltage

	internally.	of the transistor, causing the transistor's gain to drop and noise levels to increase.

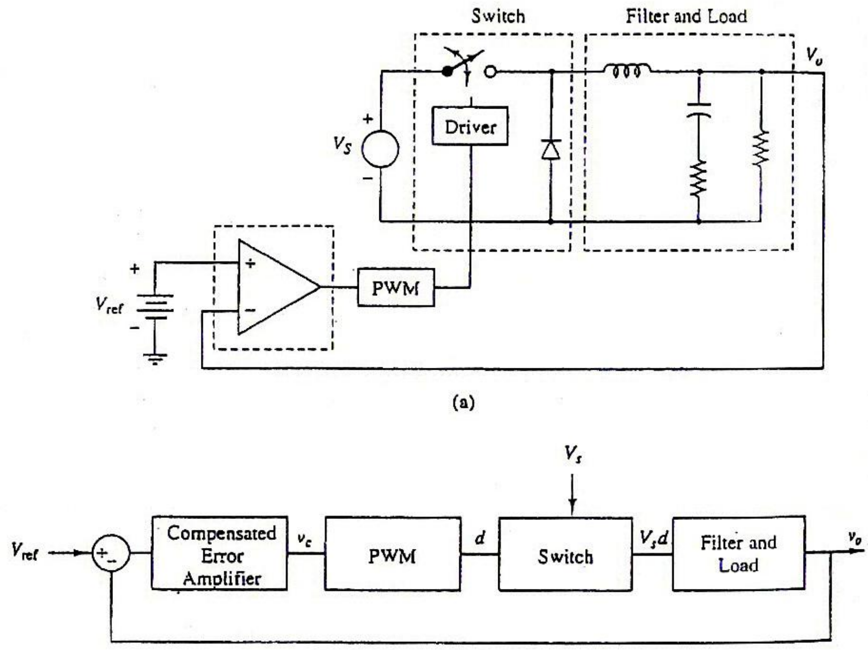
[9]

2.2.2 Power Supply Control

In switching DC-DC converter, the output voltage is a function of the input voltage and duty ratio. In real circuit with non ideal components, the output is also a function of the load current. A power supply output is regulated by modulating the duty ratio to compensate for variations in the input or load. A feedback control system for power supply control compares output voltage to a reference and converts the error to a duty ratio.

The buck converter operating in the continuous-current mode is used to illustrate the basics of power supply control. Figure shows the converter and feedback loop consisting of

- The switch, including the diode and drive circuit
- The output filter
- A compensated error amplifier
- A pulse-width modulating circuit, which convert the output of the compensated error amplifier to a duty ratio to drive the switch.



b)

Figure 2.4 a) Buck converter with feedback b) Control representation

2.3 Operational Amplifier (Op-Amp)

An operational amplifier or Op-Amp is a very high gain differential amplifier with high input impedance and low output impedance. Typical uses of the operational amplifier are to provide voltage amplitude changes (amplitude and polarity), oscillator, filter circuit, and many types of instrument circuit. An Op-Amp contains number of different amplifier stages to achieve a very high gain voltage gain. [10]

Figure below show the basic op-amp with two and one output as would result using a differential amplifier input stage. Each input result in either the same or an opposite polarity (or phase) output, depending on whether the signal is applied to the plus (+) or the minus (-) input, resistively. [10]