"I hereby verify that I have read this work and in my opinion, this work fulfill the scope and quality to be graded Bachelor in Electrical Engineering (Industrial Power)."

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Date : 5/5/06

DEVELOPMENT OF BOOST CONVERTER FOR PHOTOVOLTAIC APPLICATION

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ACQUISITION

"It is hereby declared that all materials in this thesis are the effort of my own work and materials which are not the effort of my own work have been clearly acknowledged."

Signature :

Name : NUR ILYANI BINTI ADNAN

Date : 4 MAY 2006

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ABSTRACT

This project is about the development of a boost converter for the use in photovoltaic applications. The Boost converter changes the voltage level of a 12V dc voltage from supply to 24V dc output voltage. The designing of the boost converter requires basic elements such as an inductor, a capacitor, a diode, a switch and a load. All those elements have important roles in a boost converter. A gate drive is also needed to drive the switch, and UC3843 is chosen because of minimum external components and other beneficial characteristics can help in obtaining a better output. Simulation using OrCad Pspice shows the expected values and waveforms for the converter, and can be used as a guideline in hardware implementation.

ABSTRAK

Projek ini adalah mengenai pembangunan sebuah *boost converter* untuk kegunaan fotovoltan. *Boost converter* menukarkan aras voltan dari 12V arus terus bekalan ke 24V arus terus voltan keluaran. Rekabentuk *boost converter* memerlukan elemen asas seperti induktor, kapasitor, diode, suis dan beban. Kesemua elemen tersebut mempunyai peranan penting dalam sebuah *boost converter*. Sebuah *gate drive* diperlukan untuk memacu suis, dan UC3843 dipilih kerana bilangan komponen luaran yang minimum dan mempunyai ciri-ciri lain yang berguna untuk menghasilkan output yang lebih baik. Simulasi menggunakan OrCad Pspice menunjukkan nilai-nilai dan bentuk *waveform* yang bertindak sebagai panduan dalam membina *converter* ini.

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CHAPTER I

PROJECT OVERVIEW

1.1 INTRODUCTION

Photovoltaic (PV) means the change of light to electricity directly. Photovoltaic systems use energy from sunlight to power ordinary electrical equipment such as lighting. And this is where photovoltaic applications are. A PV cell consists of two or more thin layers of a semi-conducting material, which is silicone usually. When the material is hit by sunlight, electrical charges are generated. Electrical output that could be generated from a single cell is very small, so a lot of cells are connected together to form a panel or called PV array.

The advantages of PV applications is that it requires only a minimal maintenance, almost maintenance-free. This is because of no moving parts present. It operates silently. Typical PV modules have a rated output power of 75-120 Watts peak each. Most PV modules are able to deliver a direct current (DC) electricity at 12 volts. So a Boost converter is very useful to add up the voltage value for the use in many PV applications.

PV power is used in various applications. In lighting and small appliances, PV can be used to light homes, operate televisions and radios. Remote residential can benefit from PV since there may be no conventional electric grid.

1.2 PROJECT OBJECTIVES

The objectives of this project is;

a) To develop a Boost converter with an output value of 24V dc
b) To study the operation of a Boost converter and its requirements
c) To obtain a Boost converter that has minimum output ripple and preferably quite high in efficiency.

1.3 PROJECT SCOPE

The work scope of this project is to simulate the output waveforms using OrCad Pspice, and to build a Boost converter, that is dc to dc type and obtaining the values and possible waveforms of the Boost converter using function generator and oscilloscope.

1.3 PROBLEM STATEMENTS

The output voltage from a PV array is usually low in voltage, that is only 12V dc, so it is very important to have a converter that could increase the voltage level so it will become usable for any PV applications. The PV output is also high in ripple and unstable.

1.5 PROJECT METHODOLOGY

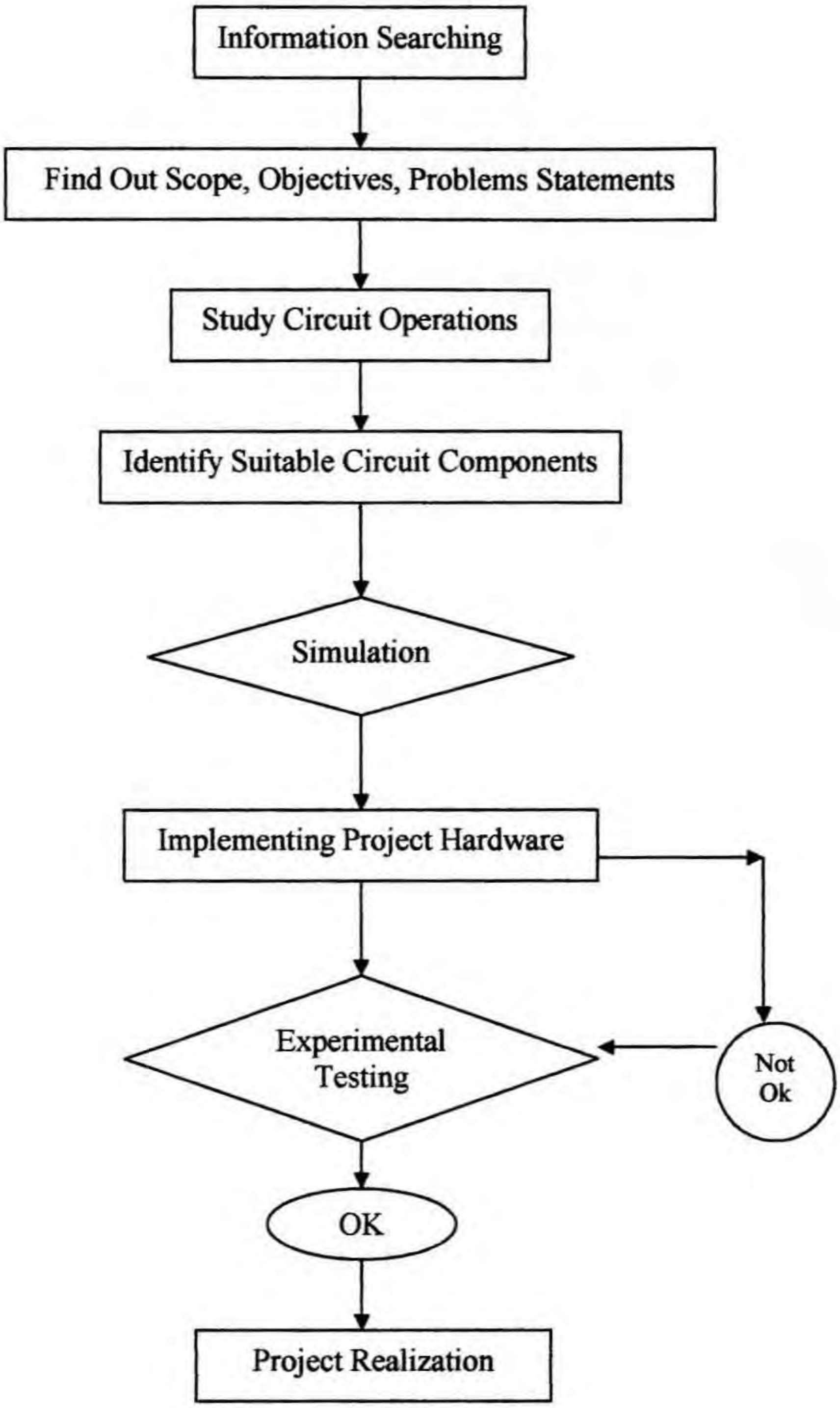

Figure 1.1: Flow Chart of Methodology

1.5.1 STEP OF PROGRESS

From Figure 1.1, each step in project methodology has a specific and fixed activities. The first step is information searching, the activities in this step is to find out the resources and references about the Boost converter circuit and what kind of photovoltaic applications can benefit from this project. The resources were found from different types such as website, books, the journal, project paper and previous thesis. The objective of this step is to collect all relevant information on the Boost converter and to develop the knowledge and get some idea about the topic of the project.

Step 2 is to find out scope, objectives, and problem statements this project. And to generate a flow chart based on these ideas. The activity in this step is to find the problems why the Boost converter needed to be developed.

Step 3 is studying circuit operations; this step is the activity to understand the concept and circuit operation. A Boost converter circuit has a switch and thus must also have a circuit for the switch's gate driver.

Step 4, identify the suitable circuit and component. In the step before, the circuit operation and the functions of component were known, so this step is to choose the best circuit and component to be used for the simulation in the next steps.

Step 5, simulation. This step uses the OrCad Pspice simulate the circuit identified in step 4. The OrCad Pspice can be used to approve the circuit design and ensure the components used can work properly. The output from simulation must come up to the expectation, but if it is not, the step 4 will be repeated until the set output is achieved.

Step 6, is implementing the hardware; the Boost converter circuit. This step is to produce the circuit on PCB layout with components on board.

Step 7, testing of the hardware. This step is to test the system operation whether it operate accordingly to achieve expected result. If the output is not satisfying, the Boost converter will be checked again.

Step 8, project realization. If the output of the circuit is within the expected result, that means the objective of this project is achieved.

1.6 PROJECT CONTRIBUTION

The development of boost converter for photovoltaic applications is a very useful project in terms of supplying input voltage of 24V DC with less ripple and high efficiency. As we know, PV power is one of alternatives energy source that can be exploited and commercialized, apart from the conventional and widely used electrical power. Since not all place have electrical supply, like in remote areas, PV power can be utilized for human benefits.

CHAPTER II

LITERATURE REVIEW

2.1 BOOST CONVERTER

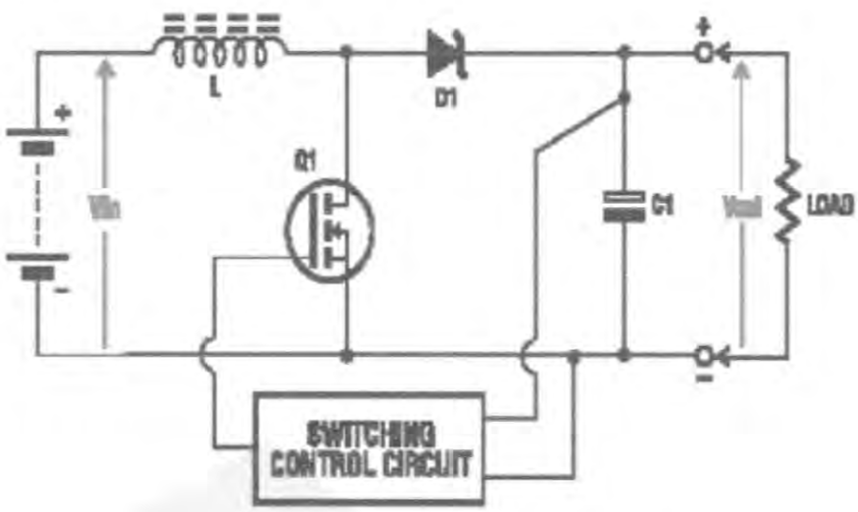

Figure 2.1: Basic design of a Boost converter

In a Boost converter, the output voltage is greater than the input voltage. The operation of a Boost converter consists of using a high speed switch, usually a power MOSFET, with output voltage is controlled by varying the switching duty cycle. The function of the Boost converter is to convert an AC voltage signal to DC signal, at the same time, boosting the voltage. This is accomplished by using an inductor controlling the time it conducts electrical current. Thus, an inductor that is connected and disconnected very quickly will charge and discharge the current very rapidly.

The Boost converter acts as a voltage step-up and also current step-down converter. The switching process produces a pulsating current and capacitor will filter and smoothes the pulsating current. Capacitor also provides a dc voltage to the load. The value of capacitor should be sufficient to maintain a minimum ripple output voltage at the load. The load is a resistor in parallel with the capacitor, and resistor has power losses when current flows through it.

The circuit operation of a boost converter is divided into two modes of continuous conduction. Under normal condition, the circuit is in continuous conduction, where the inductor current is not zero. Mode 1, transistor is switched on at t = 0, current flows from the input source through inductor L and transistor. Energy is stored in the inductor's magnetic coil. There is no current flow through the diode, capacitor or load.

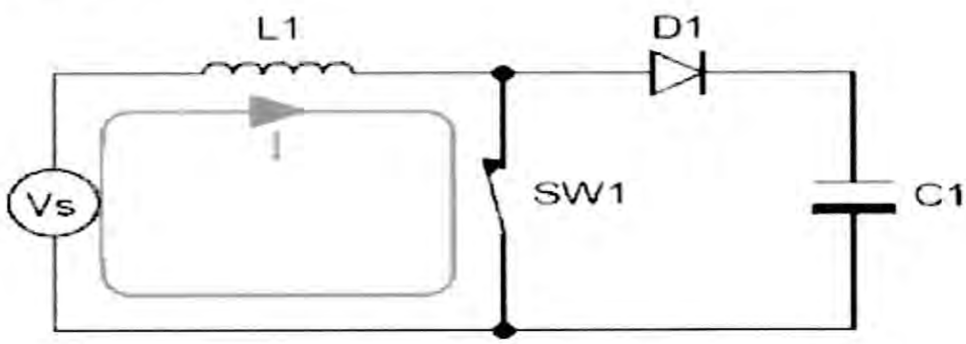

Figure 2.2: Mode 1 of boost converter

Mode 2 then begins when the transistor is switched off at $t = t_1$ and the current now flows through L, C, diode and load. The inductor current falls until the switch is turned on again in the next cycle. But it cannot change instantaneously, so it immediately reverses its EMF. Thus the inductor voltage adds to the source voltage. The energy that has been stored in the inductor is transferred to the load. The output voltage is therefore higher than the input voltage.

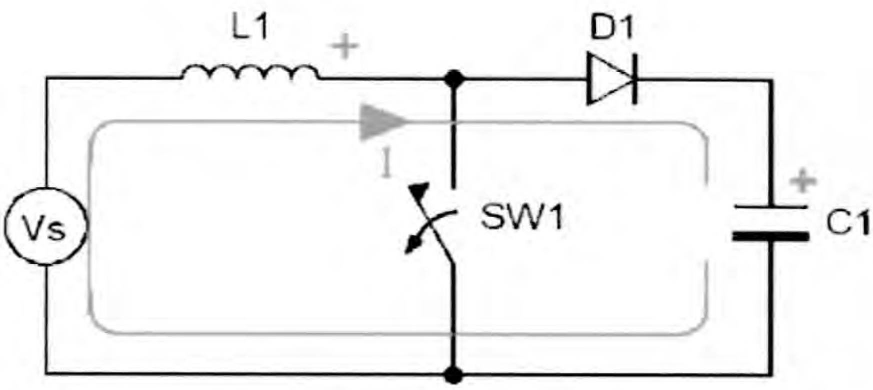

Figure 2.3: Mode 2 of Boost converter

Boost converter may slip into the discontinuous conduction mode at low load. This situation occurs when the current are near to zero. At that time, the capacitor tries to reverse i_L and "backfeed" the inductor, but the diode prevents current reversal. Thus the diode and switch open, until the switch closes again. All load power is provided by the capacitor. Once discontinuous, the voltage across the inductor is zero.

2.2 MICROCONTROLLER UC3843

UC3843 is a current-mode controller that has no slope compensation, so the duty ratio should be confined to [0, 0.5] for stable operation of boost converter. It also has a PWM controller, a trimmed oscillator for precise duty cycle control, a voltage reference of 5volt, an error amplifier, current sensing comparator and a high current totem pole output especially for driving the MOSFET gate. This chip can operate within 100% duty cycle.

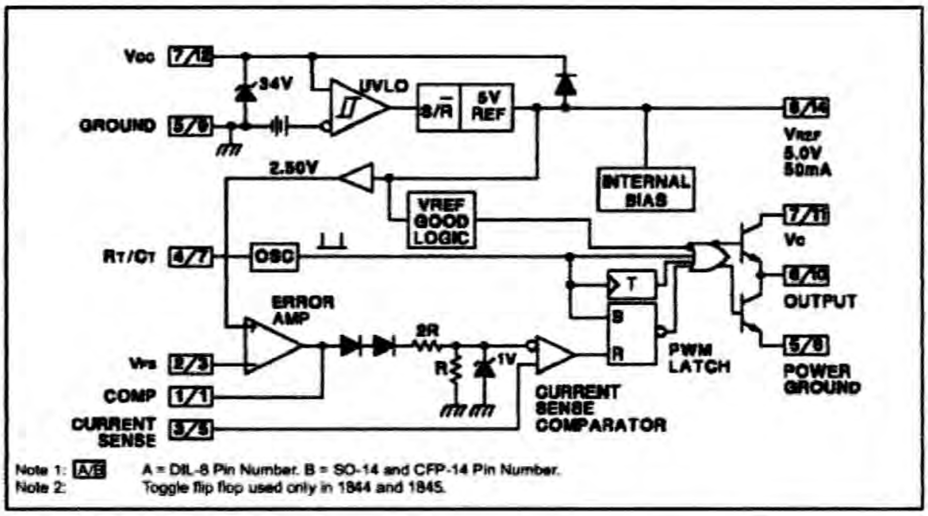

Figure 2.4: Internal Block Diagram of MOSFET's gate driver, UC3843.

The maximum supply voltage that it can accept through pin V_{cc} is 30V. So any supply given to the circuit must not exceed this value, or else it can damage the device .

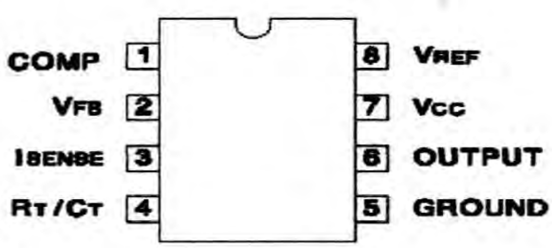

Figure 2.5: The pin connections of minidip UC3843

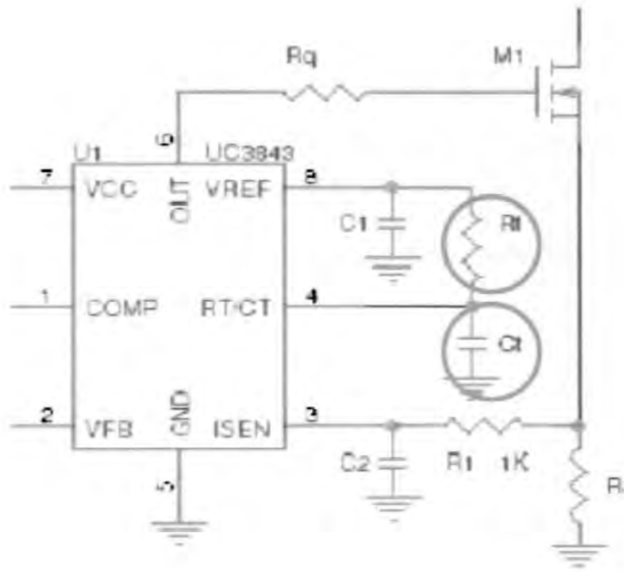

Figure 2.6: The values of C_t and R_t determines the switching frequency.

Switching frequency of the microcontroller is determined using f =1.8/(Ct*Rt), with Rt > 5k ohms [5].

2.3 PULSE WIDTH MODULATION

PWM is a method to control the amount of power to the load without power dissipation in the load driver. It provides a way to decrease the THD of a load current. The unfiltered PWM output has a relatively high THD, but the harmonics will be at mush higher than those for a square wave, and this makes filtering easier to do.

A ramp waveform is compared with a DC level produces the PWM waveform. The higher the DC level is (called the 'demand' signal'), the wider the PWM pulses are. The amplitude of the output voltage can be controlled with the modulating waveforms.

Control of the switches for sinusoidal PWM output requires:

a) a reference signal / modulating/ control signal
b) a carrier signal (a triangular wave that controls the switching frequency)

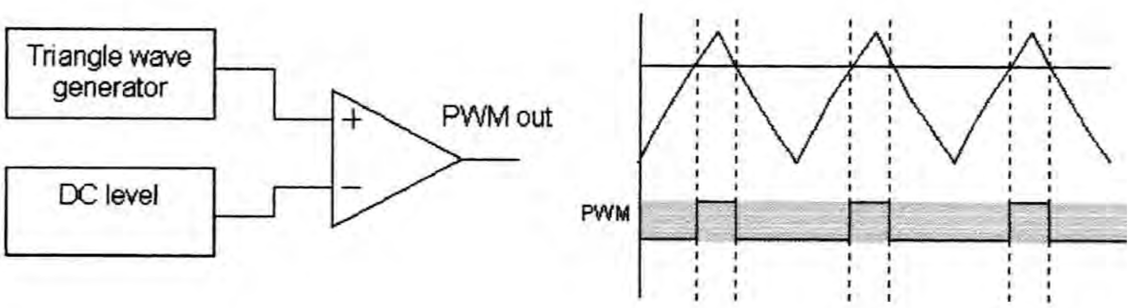

Figure 2.7: The output voltage waveform is the combination of a triangle wave with a sinewave.

Types

Three types of pulse-width modulation (PWM) are possible.

1. The pulse center may be fixed in the center of the time window and both edges of the pulse moved to compress or expand the width.
2. The lead edge can be held at the lead edge of the window and the tail edge modulated.

3. The tail edge can be fixed and the lead edge modulated.

Power delivery

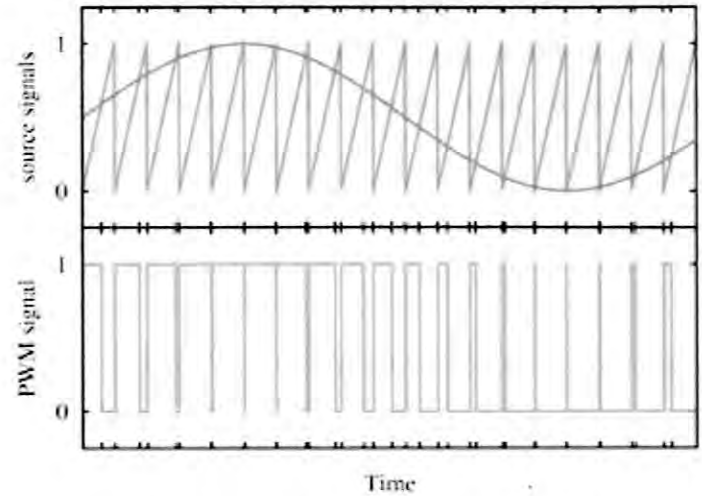

Figure 2.8 : The method to generate a PWM wave.

A simple method to generate the PWM pulse train corresponding to a given signal is the intersective PWM: the signal (here the green sinewave) is compared with a sawtooth waveform (blue). when the latter is less than the former, the PWM signal (magenta) is in high state (1). Otherwise it is in the low state (0).

PWM can be used to reduce the total amount of power delivered to a load without losses normally incurred when a power source is limited by resistive means. This is because the average power delivered is proportional to the modulation duty cycle. With a sufficiently high modulation rate, passive electronic filters can be used to smooth the pulse train and recover an average analogue waveform.

High frequency PWM power control systems are easily realisable with semiconductor switches. The discrete on/off states of the modulation are used to control the state of the switch(es) which corespondingly control the voltage across or current through the load. The major advantage of this system is the switches are either off and not conducting any current, or on and have (ideally) no voltage drop across them. The product of the current and the voltage at any given time defines the power dissipated by the switch, thus (ideally) no power is dissipated by the switch.