

EMBEDDED BOOST CONVERTER USING VOLTAGE FEEDBACK TECHNIQUE

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ABSTRACT

Renewable energy sources play an important role in electricity generation. This paper presents an approach to design a boost converter for infrared plastic solar cell using PIC microcontroller. This converter is designed to provide stable 24V output by stepping solar panel voltage without any storage element. The output voltage is controlled by microcontroller unit using voltage feedback technique. The output of the boost converter is measured continuously and the value is sent to the microcontroller unit to produce pulse width modulation signal. The PIC controller produces PWM signal using inbuilt CCP (compare, capture and PWM) module. The PWM signal which controls the switching of MOSFET. Thus by switching of MOSFET it would try to keep output as constant. Simulation and experimental results describe the performance of the proposed design. Microcontroller PIC16F877A is used to perform tasks in the proposed design.

KEYWORDS: DC-DC Boost Converter, Embedded Boost Converter, Microcontroller, Pulse-Width Modulation

INTRODUCTION

Electricity is a convenient form of energy for lightning, heating, cooling and also produces motive power for number of applications. The increased usage of electricity in the modern world which in turn increases the annual consumption of electricity. Many researchers have focused on renewable energy source based power quality improvement in the power distribution system. Power quality has caused a great concern to electric utilities with the growing use of electronic and computing equipment such as personal computers, uninterruptible power supplies, printers, etc. and other nonlinear loads such as fluorescent lighting, adjustable speed drives, heating and lighting control etc. People are finding the benefits of having their own renewable energy system more attractive than they ever had before. Specially, energy from the sun is the best option for electricity generation as it is available everywhere and is free to harness.

The merits of solar system are cleanness, relative lack of noise or movement, as well as their ease of installation and integration when compared to others. On an average the sunshine hour in India is about 6hrs annually also the sun shine shines in India for about 9 months in a year. Electricity from the sun can be generated through the (IRP) Infrared plastic solar cell The IRP comes in various power output to meet the load. However, the output power of a IRP panel is largely determined by the solar irradiation and the temperature of the panel.

At a certain weather condition, the output power of a plastic solar panel depends on the terminal voltage of the system. To maximize the power output of the plastic solar system, a high efficiency, low-cost DC/DC converter with a voltage feedback signal is commonly employed to control the terminal voltage of the solar system at optimal values in various solar radiation conditions.

DC-DC BOOST CONVERTER

The dc-dc boost converters are used to convert the unregulated dc input to a controlled dc output at a desired voltage level. They generally perform the conversion by applying a dc voltage across an inductor or transformer for a period of time (usually in the 20 kHz to 5 MHz range) which causes current to flow through it and store energy magnetically, then switching this voltage off and causing the stored energy to be transferred to the voltage output in a controlled manner. The output voltage is regulated by adjusting the ratio of on/off time.

The basic principle of step-up (boost) DC-DC converter is as follows. When switch SW is closed for the time t_1 , inductor current rises and energy is stored in inductor L. If switch is opened for time t_2 , energy stored in the inductor is transferred to load through diode D and the inductor current falls.

For a continuous current flow, waveform for the inductor current is as in figure. If large capacitor C is connected across the load, output voltage is continuous and becomes average value. Voltage across the load can be stepped up by varying duty cycle and the minimum output voltage is V_i when $k = 0$.

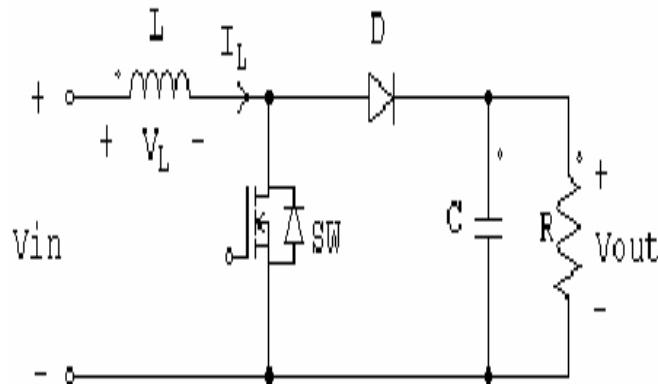


Figure 1: Boost Converter Circuit Diagram

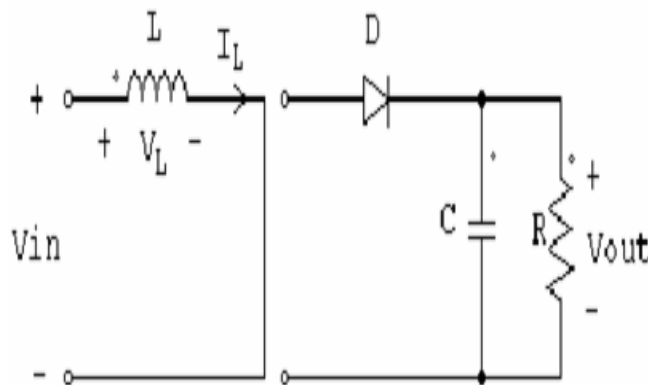


Figure 2: Mode 1

Mode-1: When the MOSFET switch is in ON state (closed), the whole circuit will be divided into two loops one at the output side and another at the input side. The closed loop at input consisting of inductor gets charged by the current flowing through the loop during this period. This current will increase linearly till the time the switch is in closed condition. In the same time interval, inductor voltage is also high as it is not delivered to any load but to itself. Diode is off during this mode.

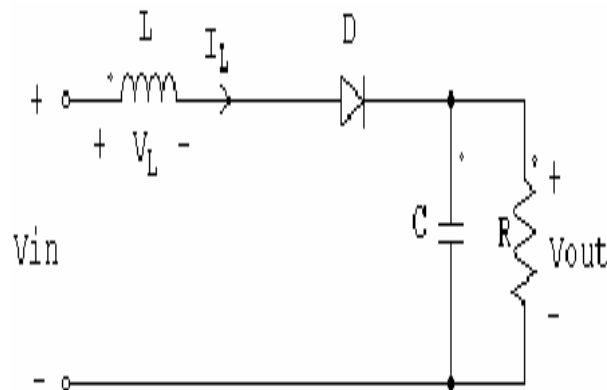


Figure 3: Mode 2

Mode-2: When the switch is in OFF state (Open), there will be a closed loop consisting of power source, inductor and RC load. The energy stored in the inductor during ON state is discharged to the RC load circuit through the diode. Thus inductor current is reducing linearly, charging the capacitor at the load side.

Thus for closed switch time inductor gets charged and capacitor is delivering the required power to the load, and for the opened switch time inductor will discharge supplying the full power to load and charging capacitor simultaneously.

EMBEDDED BOOST CONVERTER

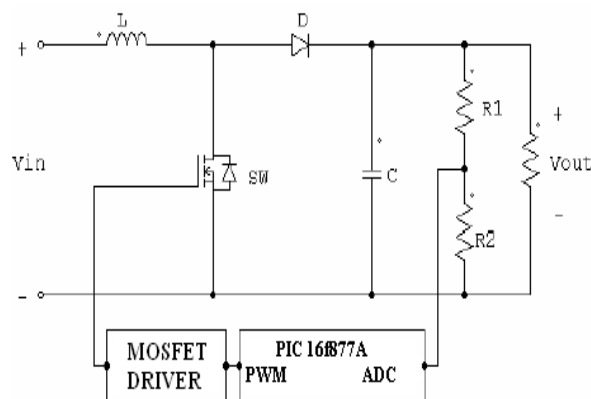


Figure 4: Embedded Boost Converter

The embedded boost converter consists of a PIC16F877A microcontroller with built-in analog-to-digital converter (ADC) and PWM module, a power MOSFET driver, and a voltage divider. Voltage divider resistors R1 and R2 will divide the output voltage to a suitable voltage range which is acceptable by the built-in ADC in the microcontroller. PIC16F877 will then perform calculation based on the control algorithm and produce a PWM signal with a set of duty cycle. The frequency of the PWM is programmable by PIC16F877. The PWM signal is then transmitted to power MOSFET in power stage through a power MOSFET driver to perform on and off state. The PIC16F877 microcontroller unit features an eight-bit, successive approximation ADC, used by the control program to measure signals required for the power flow control. The 10-bit resolution is adequate for the proposed design.

Also, it features two PWM outputs with program-controlled duty cycle and 208.3 kHz maximum frequency when driven by the 20 MHz clock of the unit. The first PWM output is used to control switch SW in boost converter while the second PWM output can be used to control switch in auxiliary circuit such as zero voltage switching circuit and

zero current switching circuit to reduce switching losses in boost converter. PIC16F877 microcontroller uses 5V as its reference voltage for the ADC. Therefore, the ADC should sense less than 5V from the voltage divider. The converter switching frequency and the inductance value is compromised between the converter's efficiency, cost, power capability and weight. For the control system, PIC16F877 microcontroller will produce a PWM signal pulse train with varying duty cycle in the range of 0 to 1.0. Practically, duty cycle for boost converter is only in the range of 0 to 0.75. This is due to instability of boost converter. Therefore, the range of the input voltage for the boost converter is in the range of 6V and 24V. If the voltage detected is not within the range, PIC16F877 microcontroller will put the whole system into sleep mode.

In order to control the duty cycle, voltage divider divides the output voltage of 24V to PIC reference voltage of 5V because ADC in PIC16F877 microcontroller is unable to operate under high voltage. The resistance of R1 and R2 should be high enough in order not to produce high power losses, I^2R and affect the overall converter performance.

Furthermore, as the reference voltage of PIC16F877 microcontroller is 5V, the PWM signal pulse train with the amplitude of 5V is unable to switch the power MOSFET on and off. Therefore, a current sink and source power MOSFET driver is needed to operate the power MOSFET as a switch working in the active region of its I-V characteristic.

PULSE WIDTH MODULATION

In PIC 16f877, In Pulse Width Modulation (PWM) mode, the CCPx pin produces up to a 10-bit resolution PWM output. Since the CCPx pin is multiplexed with the PORT data latch, the corresponding TRIS bit must be cleared to make the CCPx pin an output. A PWM output has a time-base (period) and a time that the output stays high (duty cycle). The frequency of the PWM is the inverse of the period ($1/\text{period}$).

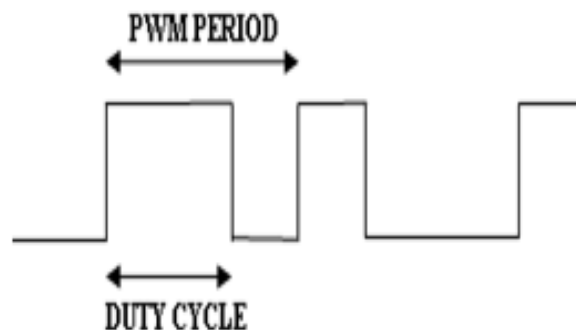


Figure 5: PWM Output

PWM Period

The PWM period is specified by writing to the PR2 register which is the period register. The formula for calculating PWM period.

$$\text{PWM period} = [(PR2) + 1] \cdot 4 \cdot TOSC \cdot (\text{TMR2 prescale value}), \text{ specified in units of time.}$$

PWM Duty Cycle

The PWM duty cycle is specified by writing to the CCPRxL register and to the DCxB1:DCxB0 (CCPxCON<5:4>) bits. Up to 10-bit resolution is available: the CCPRxL contains the eight MSBs and CCPxCON<5:4> contains the two LSbs. This 10-bit value is represented by CxB9:DCxB0. The formula for calculating the PWM duty cycle

$$\text{PWM duty cycle} = (\text{DCxB9:DCxB0 bits value}) \cdot TOSC \cdot (\text{TMR2 prescale value}), \text{ in units of time.}$$

The DCxB9:DCxB0 bits can be written to at any time, but the duty cycle value is not latched into CCPRxH until after a match between PR2 and TMR2 occurs (which is the end of the current period). In PWM mode, CCPRxH is a read-only register. The CCPRxH register and a 2-bit internal latch are used to double buffer the PWM duty cycle. This double buffering is essential for glitchless PWM operation. When CCPRxH and 2-bit latch match the value of TMR2 concatenated with the internal 2-bit Q clock (or two bits of the TMR2 prescaler), the CCPx pin is cleared. This is the end of the duty cycle.

CONCLUSIONS

In this paper, embedded boost converter has been proposed to produce constant output voltage without any storage device for solar cell using PIC microcontroller. It is very simple, light weight and smaller in size. It is designed based on microcontroller which permits easy modifications. In this design, inbuilt module of PIC microcontroller such as A/D converter and PWM module has been used which minimizes the size of the design and requirement of components for analog to digital conversion and pulse width modulation generation. The proposed boost converter solves the world's energy problem. The maximum percentage of radiant energy produced by the sun strikes the earth is utilized when compared to existing system.

This proposed system could be easily implemented with analog circuits instead of microcontroller, but the design above has the advantage of easy modification if additional renewable energy sources are used.

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