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Implementation of PIC Microcontroller Based Boost Converter for Solar Panel without Battery Backup

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ABSTRACT

Solar energy is radiant light and heat from the sun harness. A solar cell is a device that converts photons from the sun (solar light) into electricity. This works implements Converter which is used to step up solar panel voltage to a stable voltage without storage element such as battery. This converter is designed to provide stable 24V constant output. 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 inbuilt A/D converter module of microcontroller unit to convert into digital data and sent to the PWM module 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.
Keywords: Plastic solar cell, Practical Boost converter, Voltage divider, PIC Microcontroller, MOSFET driver,

I. INTRODUCTION

Solar irradiance is a measure of the irradiance produced by the Sun in the form of electromagnetic radiation, which is perceived by humans as sunlight. Irradiance is a measurement of solar power and is defined as the rate at which solar energy falls onto a surface. The irradiance falling on a surface can and does vary from moment to moment which is why it is important to remember that irradiance is a measure of power - the rate that energy is falling, not the total amount of energy. The total amount of solar energy that falls over a given time is called the insolation. Light shining on the solar cell produces both a current and a voltage to generate electric power. This process requires firstly, a material in which the absorption of light raises an electron to a higher energy state, and secondly, the movement of this higher energy electron from the solar cell into an external circuit. The electron then dissipates its energy in the external circuit and returns to the solar cell. A variety of materials and processes can potentially satisfy the requirements for photovoltaic energy conversion, but in practice nearly all photovoltaic energy conversion uses semiconductor materials in the form of a p-n junction. Newly developed solar cell called plastic solar cell that can turn the suns power into electric energy even during cloudy days. Additionally, Microcontroller based boost converter is used to produce stable voltage without any storage element.

II. METHODS AND MATERIAL

1. Block Diagram of the System

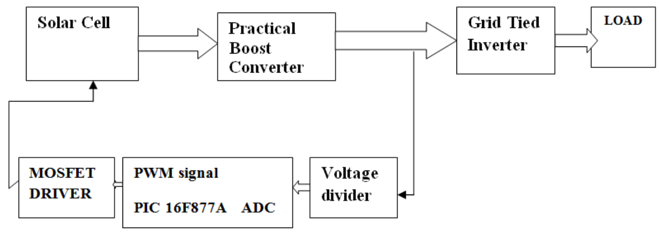
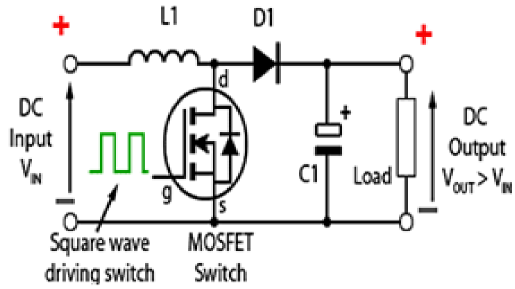


Figure 1: Block diagram of the proposed system

2. Practical Boost Converter

Figure 2: Practical Boost Converter



N channel power MOSFET is used for designing practical boost converter circuit. A boost converter (step-up converter) is a DC-to-DC power converter with an output voltage greater than its input voltage. In Figure 2, the gate terminal of the MOSFET is controlled by square wave. During high period of the high frequency square wave, the current flows between positive and negative supply terminal through L1 which stores energy in its magnetic field . no current flowing in the remainder of the circuit(D1, C1 and load). During low period of the switching square wave, MOSFET turned off the sudden drop in current causes L1 to produce a back e.m.f. in the opposite polarity to the voltage across L1 during the ON period, to keep current flowing .Two voltages are supply voltage Vin and back e.m.f(v2) across L1 in series with each other Higher voltage (Vin +Vl) which forward bias D1(MOSFET-off). The resulting current through D1 charges up C1 to Vin+Vl minus small forward drop across D1 and supplies the load.

During MOSFET on periods after the initial start up. Each time the MOSFET conducts, the cathode of D1 is more positive than anode due to the charges on C1. Diode is turned off. So output isolated from input load continues to be supplied with Vin + Vl from the charge on C1. C1 is recharged each time the MOSFET switches off, so maintaining an almost steady output voltage across the load[8][5].

Theoretical DC output voltage = Input /1- duty cycle of the switching waveform Example: if switching square wave 10µs with the input voltage 9v. The ON period of the square wave is one half of the periodic time (5µs).

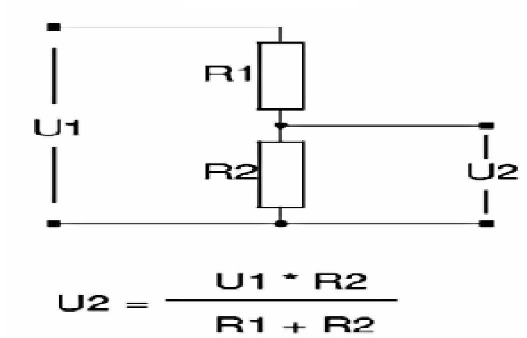
Duty cycle = ON/ON+OFF. =5/10 = 0.5

Vout = 9/0.5 = 18V (minus output diode voltage drop). Output dependent on duty cycle[1].

3. Voltage Divider Circuit

R1 and R2 should be high enough in order to avoid high power losses which affect converter performance Voltage divider divides output voltage of 24v to PIC microcontroller reference voltage of 5v. 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.

Figure 3: Voltage Divider Circuit



If R1=10KΩ and R2= 2631.58 ohms. Then using formula, In the figure 3, the output voltage of the voltage divider is 5v

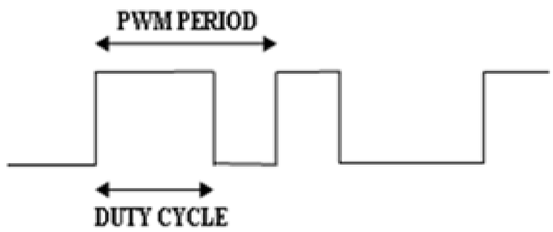
$$= \frac{2631.58}{10000+2631.58} \times 24V$$

$$= 5V$$

4. PIC 16F877AMICROCONTROLLER

It is a microcontroller with the maximum operating speed of 20MHz and 40 pin IC. It has inbuilt A/D converter and PWM module. The conversion of A/D converter output is a 10 bit digital number. It has internal reference voltage that is software selectable. The A/D converter module can be configured by using two control registers ADCON0 and ADCON1. The output of the module stored in A/D result register. The output of the A/D converter module is used to control the duty cycle of the PWM module. PWM module produces 10 bit resolution output which has the time base called period and a time that output stays high called duty cycle. The frequency of the PWM is the inverse of the time period(1/ period)[6].

Figure 4: PWM output



PWM PERIOD

In figure 4, the PWM period is specified by writing to the PR2 register. The PWM period can be calculated using the following formula:

PWM Period = [(PR2) + 1] • 4 • TOSC•(TMR2 Prescale Value)

Timer2 is an 8-bit timer with a prescaler and a postscaler. It can be used as the PWM time base for the PWM mode of the CCP module(s). The input clock (FOSC/4) has a prescale option of 1:1, 1:4 or 1:16, selected by control bits T2CKPS1:T2CKPS0 (T2CON<1:0>).

The Timer2 module has an 8-bit period register, PR2.Timer2 increments from 00h until it matches PR2 and then resets to 00h on the next increment cycle. PR2 is a readable and writable register. The PR2 register is initialized to FFh upon Reset.The PWM duty cycle is specified by writing to the CCPR1L register and to the CP1CON<5:4> bits. Upto 10-bit resolution is available. The CCPR1L contains the eight MSbs and the CCP1CON<5:4> contains the two LSbs. This 10-bit value is represented byCCPR1L:CCP1CON<5:4>. The following equation is used to calculate the PWM duty cycle in time:

PWM Duty Cycle:

= (CCPR1L:CCP1CON<5:4>)• TOSC• (TMR2 Prescale Value)

CCPR1L and CCP1CON<5:4> can be written to at any time, but the duty cycle value is not latched into CCPR1H until after a match between PR2 and TMR2 occurs (i.e., the period is complete)[4].

5. Mosfet Driver

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. Half bridge N channel Power MOSFET driver is used for switching the MOSFET. Its operating voltage is 5v to 30v. In order to conserve power, the gate drivers only provide turn-on current for up to 2µs, set by internal one-shot circuits. Each LT1158 driver can deliver 500mA for 2µs, or 1000nC of gate charge more than enough to turn on multiple MOSFETs in parallel. Once turned on, each gate is held high by a DC gate sustaining current: the bottom gate by a 100µA current source, and the top gate by an on-chip charge pump running at approximately 500kHz.The floating supply for the top side driver is provided by a bootstrap capacitor between the boost pin 16 and top source pin 13. This capacitor is recharged each time pin 13 goes low in PWM operation, and is maintained by the charge pump when the top MOSFET is on DC. A regulated boost driver at pin 1 employs a source-referenced 15V clamp that prevents the bootstrap capacitor from overcharging regardless of V+ output transients[9].

III. CONCLUSION

Embedded boost converter has been implemented to produce constant output voltage without any storage device for solar cell using PIC microcontroller. This is implemented using voltage feedback technique by PIC microcontroller which has in built A/D converter and PWM module 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. The nanorods used in the plastic solar cell are compact, consume more power from solar panel and delivers to the load. 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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