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Reduction of Power Loss in Boost Converter using Capacitor Switching Method

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Abstract: In the current century, the requirement of dc power plays a vital role in industrial areas. Most of the application needs variable dc power supply for the operation. The efficient dc power is able to control the electrical equipment appropriately. A microcontroller based DC-DC Buck-boost converter is designed and presented in this project. The variable dc voltage obtained from the converter circuit which is controlled by signal representing from microcontroller. In order to control the output voltage of the buck-boost converter, the controller is designed to change the duty cycle of the converter. The simulation circuit is developed using MATLAB simulation program. An experimental set up is developed to verify the simulation results. The buck-boost converter circuit with MOSFET as a switching component is developed. The microcontroller is used to generate duty cycle of PWM signal is programmed. The simulation and experimental results show that the output voltage of the buck-boost converter can be controlled according to the value of duty cycle.

Key words: Controller circuit, Driver circuit, Duty cycle, Boost converter, Matlab

INTRODUCTION

The general idea of a dc-dc converter is to convert a fixed voltage dc source into a variable voltage dc source. The output voltage of the dc-dc converter can be higher or lower than the input. Dc-Dc converter is widely used for traction motor in electric automobiles, trolley cars, marine hoists, and forklift trucks. The converter provides smooth acceleration control, high efficiency, and fast dynamic response and high reliability. The Dc-Dc converter can be used in regenerative braking of dc motor to return energy bake into the supply, and this feature results in energy saving for transportation system with frequent stop and also are used, in dc voltage regulation. There are many types of dc-dc converter which is buck (step down converter), boost (step-up) converter, and buck-boost (step up- step-down) convertor [1].

Buck-Boost converter is an intriguing subject from the control point of view, due to its intrinsic non-linearity. This project controls the dc output voltage based the load connected at the output terminal. The output voltage can be controlled in the range of 6 V to 90 V by using this Buck-Boost topology. The voltage monitoring circuit connected at the output as a feedback circuit to monitoring the output voltage. The duty cycles will be varied based on the requirement of load voltages. Microcontroller is used to produce the PWM pulses which in turn control the output voltage. The lamp load which have different power ratings where used to test the output voltages.

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The buck boost converter designed in MATLAB for the analysis purpose. The PI and PID controller introduced and implemented in this project.

PROBLEM STATEMENT

The buck - boost converters are needed for increasing low voltage dc to high voltage dc. The conventional buck-boost converters has high voltage duty ratio and it causes severe losses in power devices and high voltage stress across the switching devices. This produces the conduction losses in the converter circuit [2]. This project is designed to eliminate the conduction losses occur at the switching devices by using capacitor switching method. But when the capacitor is used, more current pulses passing through the devices, thus damage the device. A small inductor is used in the circuit to avoid the sudden rise of current. Overall the efficiency of the buck-boost converter can be increased using this method.

BACKGROUND OF STUDY

A dc to dc converter is an electronic circuit which converts a source of direct current from one voltage level to another voltage level. A dc to dc converter is more important in high powerand portable electrical and electronics circuits such as HVDC system, traction control, mobile phones and computers, which are supplied with power from dc power supply or batteries primarily. Such circuits often contain several sub-circuits, each with its own voltage level requirement different from that supplied by the battery or an external supply. Most DC to DC converters also regulate the output voltage. A many number of dc-dc converter circuits are known that can increase or decrease the magnitudeof the dc voltage.The below Figures illustrates several commonly used dc-dc convertercircuits, along with their respective conversion ratios. In each circuit, the switch is grasped using a power MOSFET and diode. Other semiconductor switches such as thyristors,IGBTs or BJTs can be substituted if preferred.

The Figure 2.1 shows the buck converter, which reduces the dc voltage and has conversion ratio of
M (D) = D.
The conversion ratio is defined as the ratio of output voltage to input voltage.

M (D) = $\frac{Vo}{Vs}$(2.1)

Where, D is the duty ratio or cycle.
Vo,is the output voltage
Vs. is the supply voltage

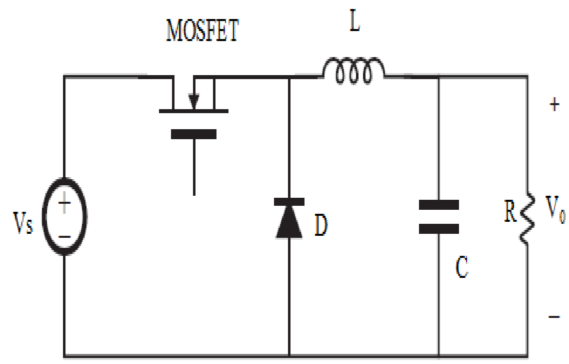

Figure 2.1: Buck converter

Figure 2.1 shows a similar topology known as the boost converter, the positions of the MOSFET switch and inductor areinterchanged. This boost converter produces an output voltage V_0that is greater in magnitude than the input supply voltage *V*s. The conversion ratio of boost converter is

M(D) = 1/(1 – D). (2.2)

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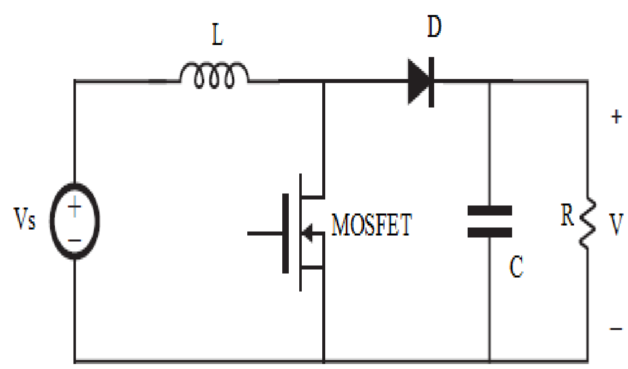


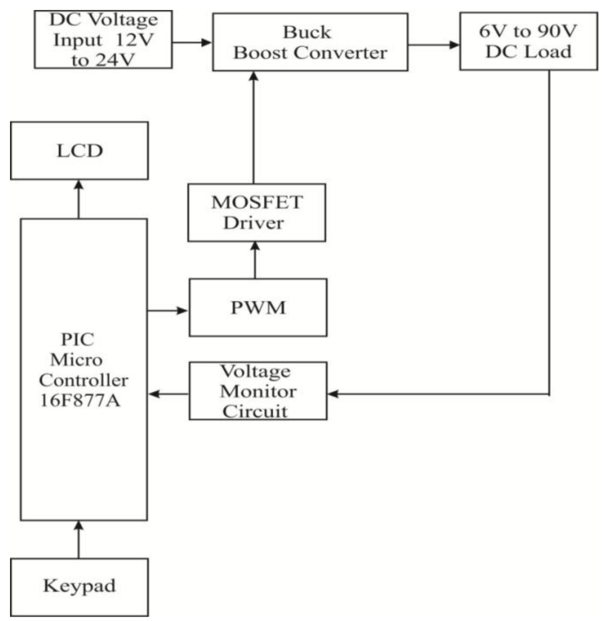
Figure 2.2: Boost converter

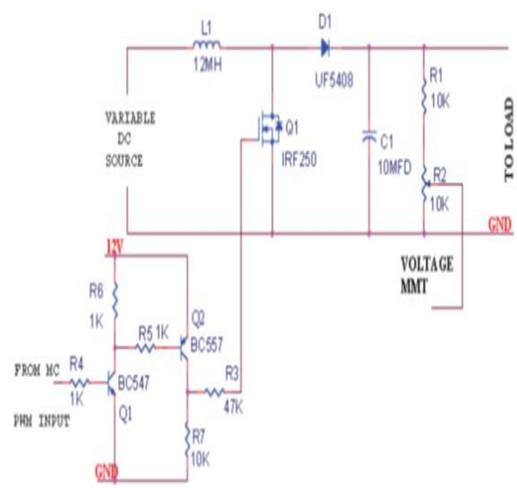
Pulse-Width Modulation (PWM)

Pulse-Width Modulation (PWM) technique is used for controlling the analog circuitswith a processors digital output signal. In this project the gate of the power MOSFET can be controlled with the help of PWM pulse generated by the microcontroller unit. PWM uses a square wave pulse whose duty cycle is modulated resulting in the variation of the average output voltage value of the waveform [3]. PWM generally can be used to reduce the total amount of power delivered to a load without losses. This is because the average power delivered to the load is proportional to the modulation duty cycle.

The high frequency PWM power control systems are easily realizable with semiconductor switch. The on/off states of the pulse modulation are used to control the state of the switch which correspondingly controls the voltage across or current through the load. The main advantage of this system is, the switch 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 gives the power dissipated by the switch [4]. This project involves the modulation technique to produce the required pulse necessary for the operation of the power MOSFET. The pulse width can be controlled or adjusted based on the reference voltage set by the user. Because of the inductor and capacitor in the circuit proper switching is necessary to reduce the power losses.

SYSTEM DESIGN





MOSFET DRIVER CIRCUIT

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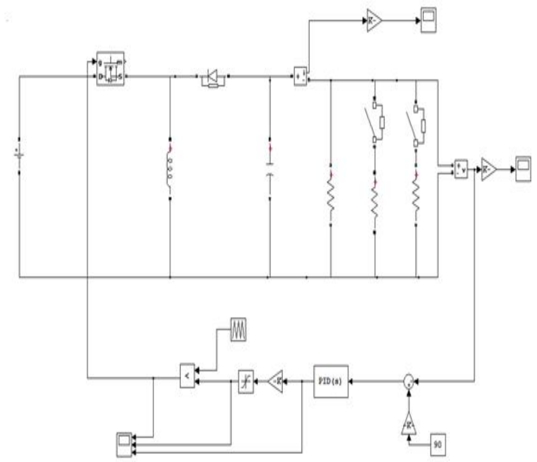
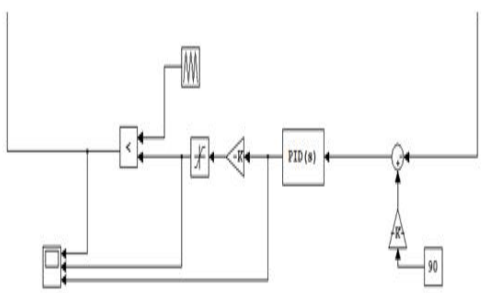
VOLTAGE MONITORING CIRCUIT

In this circuit we provide to measure the voltage level by using the potential divider output voltage using R1 and R2 resister formation. The output voltage is given to the ADC terminal. This circuit is mainly used to generate the PWM pulse output for MOSFET switching [5].





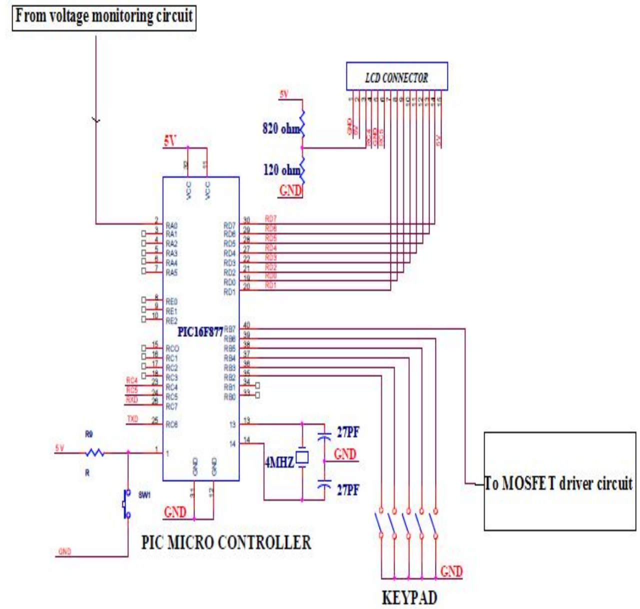


Table 5.1: Overall readings from the proposed project

Input DC Voltage (v)	DC Supply Current (A)	Reference voltage (V)	Output voltage (V)
24	3.37	90	89
24	1.71	60	60
24	0.63	30	31
24	0.16	12	11
20	3.68	80	79
20	1.16	40	39
20	0.22	12	12
15	2.97	60	60
15	1.12	30	31
15	0.28	12	11
12	3.6	50	49
12	1.56	30	31
12	0.75	20	19

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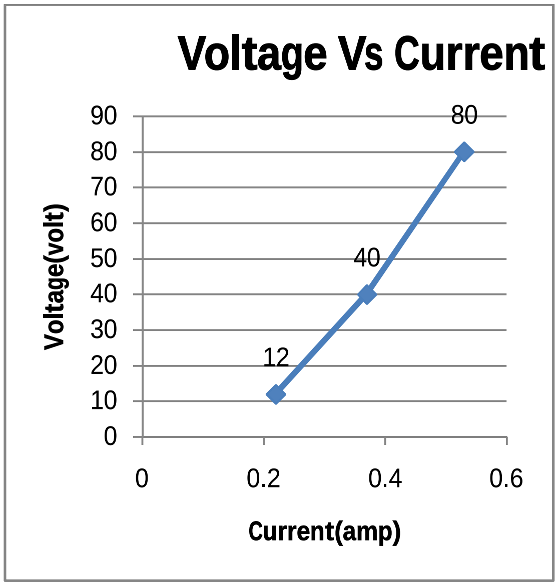
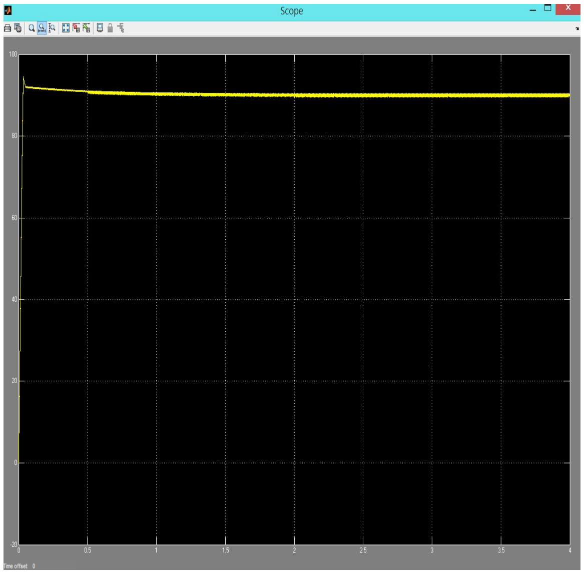
Current in load 1 "60W' (A)	Current in load 2 "100W' (A)	Current in load 3 "60W' (A)	Total current (A)
0.14	0.26	0.14	0.54
0.11	0.21	0.11	0.43
0.08	0.15	0.08	0.31
0.06	0.10	0.06	0.22
0.14	0.25	0.14	0.53
0.10	0.17	0.10	0.37
0.06	0.10	0.06	0.22
0.12	0.21	0.12	0.45
0.09	0.15	0.09	0.33
0.06	0.10	0.06	0.22
0.11	0.19	0.11	0.41
0.09	0.15	0.09	0.33
0.07	0.13	0.07	0.27





DISCUSSION OF THE PROJECT

The expected results were obtained from the proposed project. The readings were taken for various input supply voltage. The input supply voltage was set at different level. The buck boost converter, boost the maximum voltage of 90 V. So the reference voltage was set at 90 V. Form the Table 5.2 the input supply voltage to the buck boost converter was 24 V and the maximum load voltage was 90 V. Form the efficiency calculation for the 24 V dc supply, the efficiency was 59.4 %. But when the voltage boosted at lower voltage than 90 V, the efficiency of the converter was increased. This seems that, when the buck boost converter produces high output voltage compared to input voltage the efficiency of the buck boost converter is decreased. This happened for all other different value of input dc voltage with various reference voltages. The wave form obtained from the MATLAB compared with the hardware results. The maximum load voltage was 100 V from the 24 V when the circuit was simulated in MATLAB, but in the actual hardware the output voltage was 90 V dc.

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CONCLUSION

This chapter mainly focuses on conclusion and future recommendation of the project. The proposed buck boost converter was designed and implemented. The theoretical information was reviewed based on the research made. Aim and objective was set to solve the problem identified in this project. The circuit was developed based on the problem identified. The proposed circuit was buck boost converter. The circuit was designed in MATLAB initially to analyze the operation of the converter. The PID controller circuit was designed to produce the PWM pulses necessary for the operation of the power MOSFET. The circuit was designed with input voltage of 24 V dc and the maximum voltage boosting by the converter was 100 V. The duty cycle values were calculated from the waveform.

The hardware circuit was developed to verify the results. Power supply circuit (5 V and 12 V) was developed for microcontroller and driver circuit. The buck boost converter designed and developed to get variable dc output voltage. The power MOSFET in the converter circuit was driven by the microcontroller based PWM circuit.

The microcontroller program were written and compiled for the generation of PWM. Driver circuit was designed to isolate and amplify the PWM pulse. The circuit was connected with three lamp loads at different power rating. The circuit was tested with different level of input voltages. When the input voltage was set at 24 V dc, the circuit boosts the maximum voltage to 90 V. The efficiency of the converter for this 24 V is 59.4 % at a duty ratio of 30 %. From the problem statement, when the duty ratio is more power loss also will be increasing this decrease the efficiency of the converter. But the designed project was giving 59.4 % efficiency at duty ratio of 30 %. The main factor needs to consider that, when the circuits boost more (high) voltage the efficiency will be decrease. The tabular readings were shown for the performance of the buck boost converter.

FUTURE RECOMMENDATION

From the above conclusion the efficiency of the converter is depend upon the boosting voltage and also depend upon the circuit elements. The future recommendation for this project is to design the appropriate value of circuit elements (capacitor and inductor) and technique to improve the duty cycle of the converter without the power loss. Special type of capacitor and inductor can be designed to improve the efficiency more than 80 %.

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