PWM CONTROLLED DC-DC BOOST CONVERTER DESIGN AND IMPLEMENTATION

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ABSTRACT: In this study DC-DC boost converter circuit was designed and implemented. The converter input voltage range determined as 9V-30V DC and output voltage of boost converter is created as 48V DC. This converter has potential uses 48V compatible applications. In this circuit design, the implementation of a PWM DC/DC boost converter contains two subsystems – a conventional PWM boost converter and a control circuit. A PIC microcontroller is used to send the gating signals to a driver which drives the Metal-Oxide-Semiconductor Field Effect Transistors (MOSFET), allowing the converter's output to be kept steady at 48V and 220 W through pulse width modulation, even with a fluctuating input voltage. A switching frequency of 100 kHz was achieved, and PWM control method was used for switching. The use of a PWM boost converter allows for a variable input and constant output. The output is regulated by the control circuit which adjusts the duty cycle of the gating pulse to maintain a constant output.

Keywords: PWM, Microcontroller, Boost, Converter

INTRODUCTION

Increasing need for energy in today's world, limited existing energy sources and contamination of environment has made research lead to new and clean energy sources. Since increase of solar energy which is used as clean energy source, wind power and these kind of renewable sources increased the need for energy conversion, the use of DC-DC energy converters become widespread day by day.
In power sources such as solar panels energy obtained from energy resources at specific voltage value. Converters are used for to handle desired voltage value. With the inclining of energy markets to more environmental sources, practice of DC-DC voltage boost convertor type circuit has increased. In industrial practices, DC-DC boost convertors are used commonly. Most of researches which are about DC-DC

convertors have focused on putting forward the best switching method. In recent years, numerical control in power electronics has been used really intensively. Applying numerical control circuits to the power convertor circuits has increased circuit performance and the cost has decreased at the same time. Some typical practices of these types of convertors can be seen at auxiliary power sources practices of hybrid vehicles with fuel cells or practices involving sun panels. Electrical cars with the energy of fuel cell need energy storing devices for the first starting time. Under voltage battery packs are preferable for energy storing transaction .That's why, DC-DC converters are needed as an interface connecting under voltage battery packs and high voltage fuel cell systems.

When the literature is considering there can be seen studies which are related with DC-DC boost converter design. Çoruh N., Erfidan T., Ürgün S.(2008) are presented microcontroller boost convertor. Materialized power and controlled circuit at high switching frequency is worked for different charge situations and duty cycle rates. In the studies of Demirtaş M., Sefa İ., Irmak E., Çolak İ. (2008), a micro controlled based DA/DA boost convertor design and practice for solar energy systems is realized. A needed switching signal for the system to work is produced by microcontroller. In the practice in which sun panels are used to convert the energy taken from the sun to the electric energy, in order to make the system to work more efficiently, a micro controlled DA/DA boost convertor design and practice at 2600 W power is performed. Sathya P., Natarajan R. (2013) did a low cost, high performance and closed cycle DC-DC boost type convertor practice in their studies. HBLED led lamps are linked as charge to the converter output by making the input power to work as sun panel. All system is simulated by multisim program and fertility rate is 98,33%.System fertility is 95% when the same system is tested in laboratory. Thomas L., Midhun S., Mini P K, Thomas J.A., Krishnapriya M N (2014) did DC-DC voltage boost type converter practice circuit in their studies. The converter circuit that has the input voltage between 3V and 12V is designed as having 25V at the output. Şahin Y., Aksoy İ, Tınğ N. S (2015) presented a developed ZCZVT PWB DC DC boost convertor that has active compression cell.

A developed ZCZVT PWB DC DC convertor that has the capacity of gathering wanted features of resonance and overcoming unwanted features is presented by PWM study. Fathah A. (2013) did voltage boost voltage type circuit design whose input voltage 5V and output voltage 15V in his thesis paper. The converter yield is 94.16% in this practice by using MATLAP and PSPICE programs. Muthukrishnan P. and Dhanasekaran R. (2014) did DC-DC voltage boost circuit design which is formed by double inductors for sun panel practices in their studies. They did voltage gain by increasing the coiling number of the inductor they used. In the study, a converter whose input voltage is 60V, output voltage is 600V and power is 900W by using PSIM program. Hassan F. A. and Lanin V. L. (2012) did a dissipation less voltage boost type DC-DC converter for under voltage photovoltaic sun panels in their studies. The most significant advantage of this circuit topology is the low voltage tension at switching elements and high voltage rate is realized with low size and cost. Input voltage of circuit is 15V and output voltage of it is 130V.Fertility rate is between 90% and 94% in 30kHz switching situation. Demirtaş M. and Şerefoğlu Ş. (2014) did ds-PIC controlled voltage boost type DC-DC converter practice for wind turbine system. In this practice, almost 35% efficiency increase is detected with the use of converter in the system. Tyagi P., Kotak V. C., Singh V. D. did from 30 to 50 high efficiency voltage boost type simulation circuit design with multiple coiling inductor with PSIM program. Especially it can be used to increase sun panels' under output voltage. Input voltage is 12V and output voltage is 360V which is fixed by PI controller.

In this study DC-DC voltage boost type circuit was designed and implemented. PWM controlled DC-DC converter design is made. Input voltage of the designed DC-DC voltage convertor circuit can change between 9V and 30V. Output voltage is fixed 48V. PWM signals are produced by 18f2550 PIC microcontroller. The converter output is fixed at 48V-240W by the produced PWM signals, even though there is fluctuation at the input.

METODOLOGY

Voltage boost type circuit having input voltage which is between 9-30V and output voltage which is fixed at 48V was designed. The maximum power of the circuit is designed as 240W. Circuit system mainly consists of two parts: power and control circuit. Firstly, control circuit will be designed and then design of power circuit starts. Since the circuit which will be designed is PWM controlled voltage convertor, PWM signal is necessary. PWM signal is formed by PC18f2550 microprocessor. Because of the features of microprocessor which will be used, PWM signals which are at different frequency values and duty cycles rates can be taken from metal pin. Additionally, since output voltage of voltage boost type circuit has to be at fixed 48V, output voltage of circuit will be applied to analog entrance of PIC18f2550 microprocessor. In this way, feedback can be provided and output voltage will be fixed at 48V in software. In software, output voltage will be fixed by increasing and decreasing duty cycle rate of PWM signal and adjusting it with the value taken from output of circuit. MikroC will be used as software language. After designing control card and getting right PWM signal, the design of power card starts and material choice according to the intended power value. Basically, voltage boost type circuit topology which will be applied is shown in Figure 1. According to this circuit topology, necessary elements will be chosen. MOSFET transistor will be used as switching element.

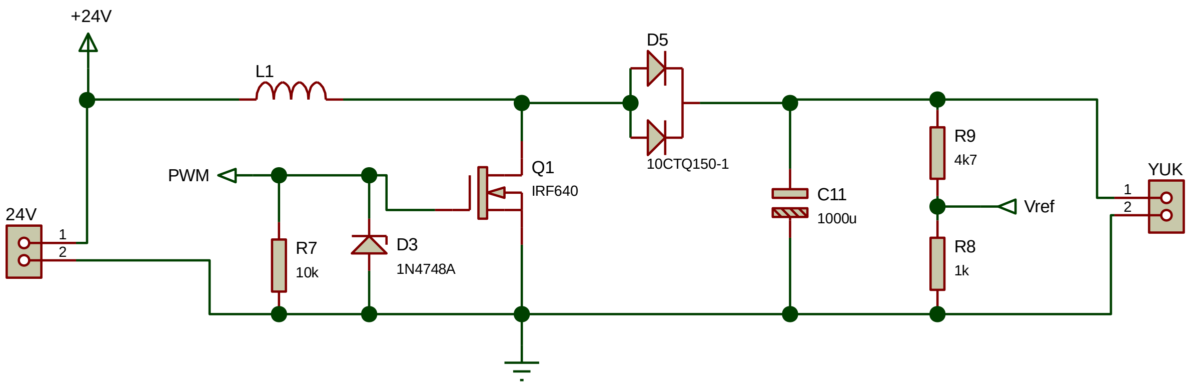


Figure 1: Conventional PWM Boost Converter

The components used for the boost converter, as shown in Figure 1, are as follows:

Power MOSFET Q1: STNF75NF

Schottkey Diode D5: MBL10100

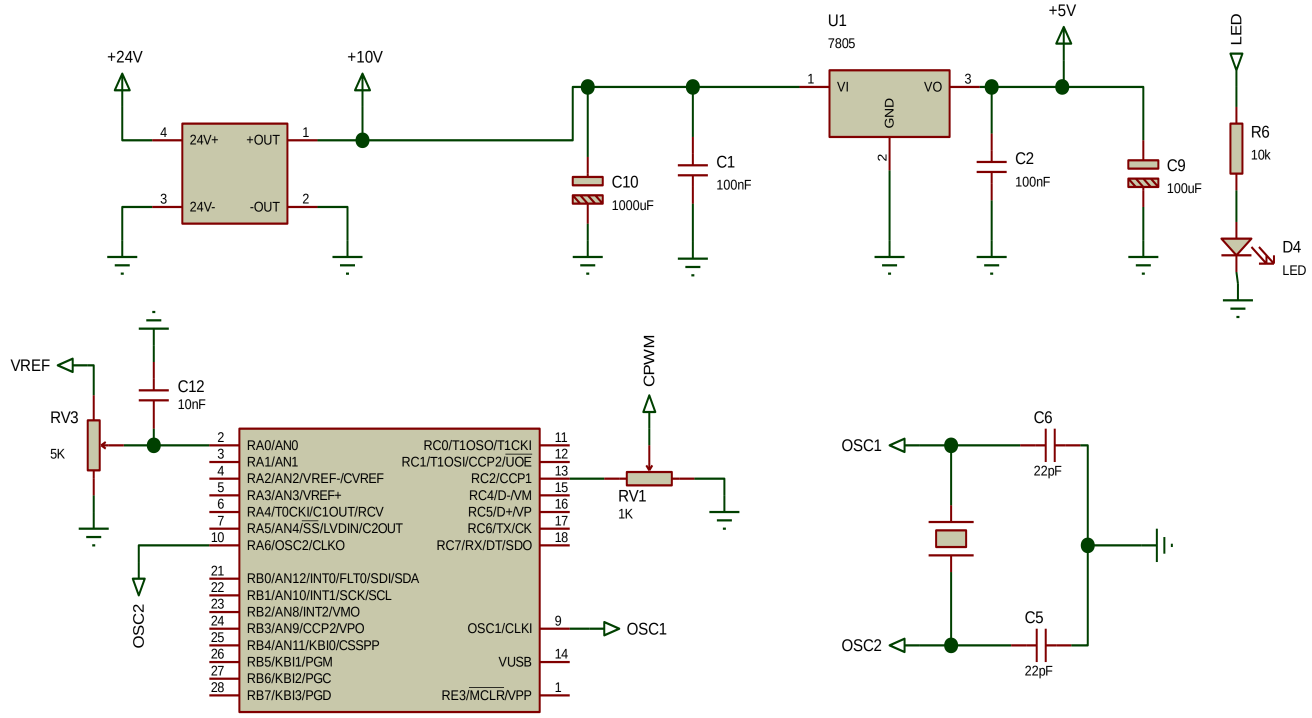
Zener Diode D3

Caps/Resistors – values as shown on circuit diagram

Inductor L1– Wound with 3 turns using a core of material ETD 59/31/22.

The purpose of the control circuit is to provide to the MOSFET with gating pulses. The main components of the control circuit are the microprocessor, the optocoupler and the Mosfet drivers. The microprocessor used was the PIC18f2550.

The schematic of the control circuit can be seen below in Figure 2.



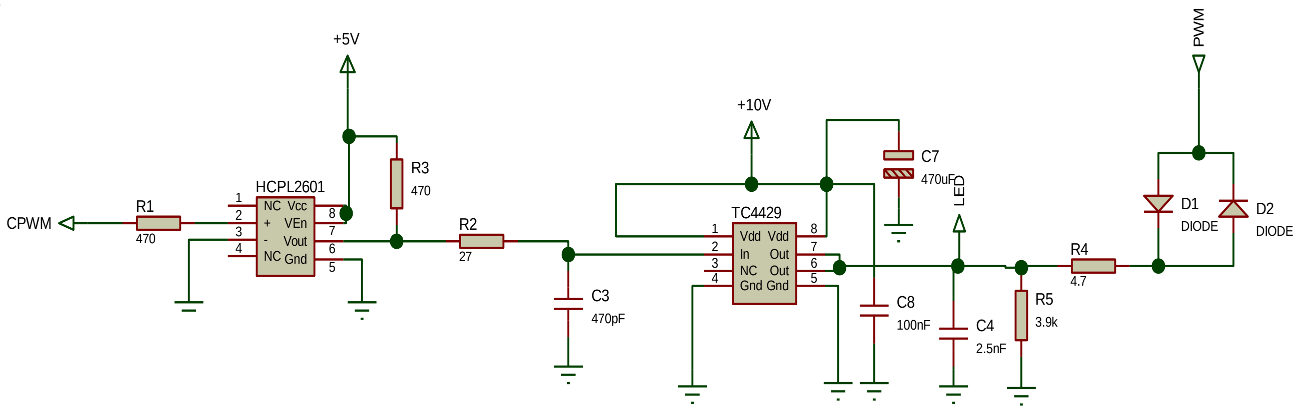


Figure 2: Control Circuit

The microprocessor was programmed to output two gating pulses. The circuit was tested effectively with a switching frequency of 100 kHz. Pulse is sent at a frequency of 100 kHz with an initial duty cycle of the Mosfet set to 50%.

A feedback loop is implemented to ensure a constant 48V is obtained at the output for 24VDC input voltage. The microprocessor is programmed to automatically adjust the duty cycle according to a comparison made between a reference voltage of 4.2V and a feedback signal from a voltage divider at the output. This comparison makes use of the 18f2550 analog to digital converter. The voltage divider (shown in Figure 1 as R8 and R9) is designed such that at the desired output of 48V the feedback signal is 4.2V and no adjustment of the duty cycle is made. If the output voltage is greater than 48V the duty cycle is decreased until the desired output voltage is obtained. If the output voltage is less than 48V the duty cycle is increased until the desired output is obtained. The microprocessor continuously loops through this code adjusting the output voltage according to the variance in the input voltage. After each loop the reference is checked again to ensure the output voltage is maintained.

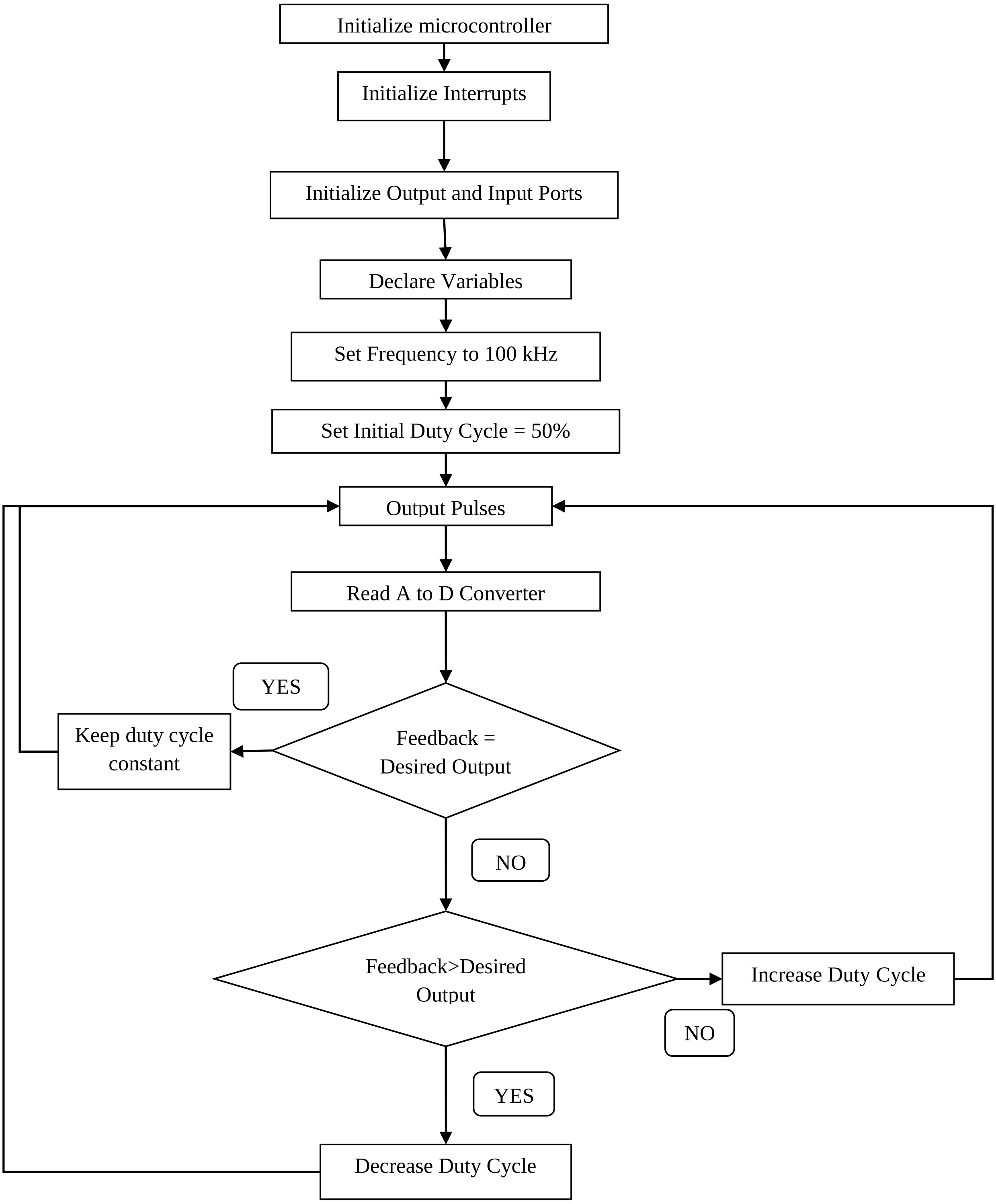


Figure 3: Microcontroller Flow Diagram

Experimental Results

The PWM DC/DC Boost Converter was built in the laboratory and the actual product resulted in the following specifications:
Input Voltage Range: 18-24VDC
Output Voltage: 48VDC

Output Power: 220W
Switching Frequency: 100kHz
Efficiency, η, of the PWM DC/DC Boost Converter can be determined as follows:

$$\eta = \frac{P_{out}}{P_{in}} = \frac{V_{out} I_{out}}{V_{in} I_{in}} \quad (1)$$

where V_{out}, V_{in}, I_{out} & I_{in} can all be measured in the laboratory.
Table 1 below details the Voltage and Current measurements taken in the laboratory at resistive loads, and the resulting efficiency calculations: Designed converter can be seen at Figure 4.

Table 1: Voltage and Current Measurements and Resulting Efficiency and Various Resistive Loads

V_{in} (V)	I_{in} (A)	V_{out} (V)	I_{out} (A)	η (%)
24	8	48.00	2.8	70.00
24	10	48.00	4.6	91.60

Figure 4:Designed Boost Converter

Figure 5. TC4429 and HCPL2601 PWM Output Signals

At Figure 5 there can be seen PWM signals. TC4429 was used as a MOSFET driver and HCPL2601 was used as an optocoupler. These PWM signals belong to respectively TC4429 and HCPL2601 ICs. As a result of these IC PWM signal is not corrupted while 100 kHz signal applied.

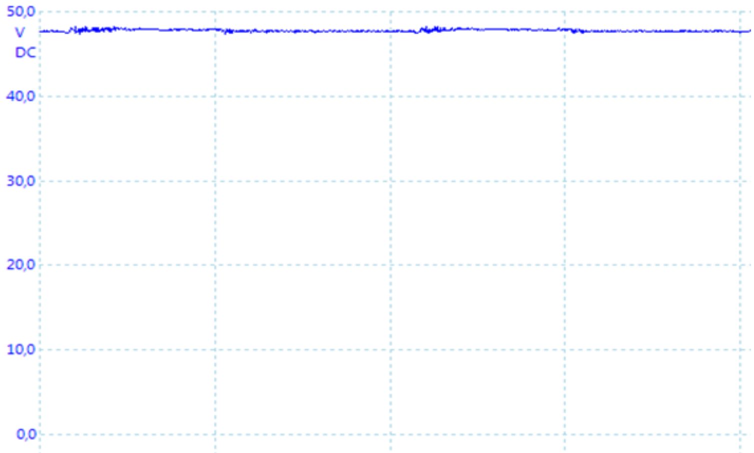


Figure 6 Boost Converter Output Voltage at DC Mode (5 µs)

According to Figure 6 the converter DC output value can be seen as 48 V. Figure 6 was taken from DC mode. And at Figure 7 boost converter output voltage is investigated at AC mode. And it is seen nearly 0.2-0.3 ripple voltage value at Figure 7.

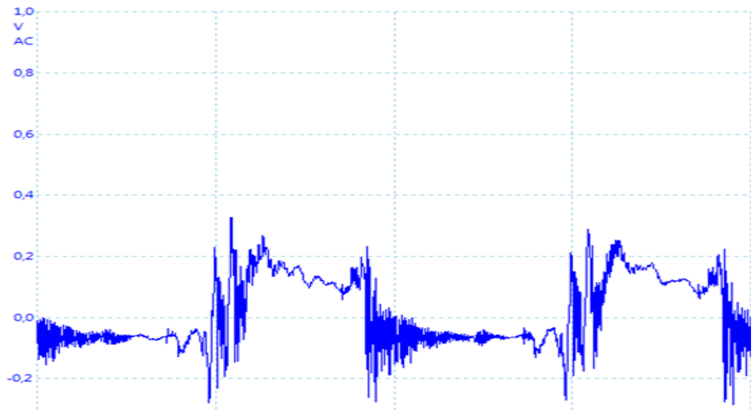


Figure 7 Boost Converter Output Voltage at AC Mode (5 µs)

Costs

The costs associated with the design and implementation of the PWM DC/DC boost converter were relatively low given the simple design of both the conventional boost converter. The per unit costs are detailed below in Table 2:

Table 2: Per Unit Costs for the PWM DC/DC Boost Converter

Component	Part Number	Unit Price (TL)	Quantity	Total Cost
FET Driver	AC419	8	1	8
Optoisolator	ICPL 2601	10	1	10
Power MOSFET	NF75NF	5	2	10
Schottkey Diode	BR10100	10	1	10
5V Regulator	LM7805C	3	1	3

Microcontroller	PIC18f2550	15	1	15
4 MHz Crystal Oscillator	4.0000M-C	5	1	5
PCB Board		20	1	20
Miscellaneous Parts	Capacitors/Resistors etc.			10
MOSFET Heatsink		20	1	20
Ferrit Core	ETD 59/31/22	20	1	20
	Total Per Unit Cost:			111 TL

CONCLUSION

The two subsystems of the PWM DC/DC Boost Converter – the conventional PWM boost converter and the control circuit were constructed and tested in the laboratory. The PWM boost converter proposed for this project was tested at a switching frequency of 100 kHz. This switching frequency is equal the project goal of 100 kHz. Theoretical calculations were made and used to select components for each of the subsystems. First each subsystem was test individually and then the subsystems were implemented and tested together.

The circuit was tested with resistive load and the circuit was confirmed to be functional at a minimum of 50W, and a maximum of 220W. The overall efficiency of the PWM DC/DC Boost converter was calculated though measurements taken in the laboratory to be %91.6. With this high efficiency and relative low per unit cost of 111 TL, this PWM DC/DC boost converter is suitable for applications such as solar battery storage systems or fuel-cell powered electric vehicles where a fixed out of 48VDC is required.

In future studies the PWM DC/DC converter can be implemented with digital programmable logic device such as an FPGA for a higher switching frequency with using a different type of Mosfet which Rds value lower than used in this article. Also soft switching techniques can be implemented to Mosfets for increasing circuit power and efficiency rate.

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