International Journal of Research in Advent Technology, Vol.2, No.11, November2014
E-ISSN: 2321-9637

High Efficient Buck Converter DC Drive for Battery Charger

A.Mohandoss[1], S.Ashwinkarthik[2], R.Sivaramachandran[3]
Department of EEE[1, 2, 3], R.V.S. College of Engineering and Technology[1, 2, 3]
Email: mohandass321@gmail.com[1], ksrchandran5@gmail.com[3]

Abstract- In recent years all portable electronic devices are operating at low dc power supply. Most of the DC-DC converters such as IC regulators, SMPS, chopper are used to supply these devices. But they have the limitation that they work at switching frequency only. This paper is for portable electronic devices which need high switching frequencies. In this paper we are using power supply, PIC16F877A microcontroller, MOSFET IRF250, opt coupler, capacitors and inductors. Microcontroller is used for providing gate signal to the MOSFET switch .MOSFET switch plays a main role here that it converts high voltage DC into lower level associated with capacitors and inductors. Opto coupler provides electrical isolation between main circuit board to driver circuit. The current stress is lower than that of traditional converter. The voltage across all semiconductor devices can be regulated by adjusting the turn ratio of the coupled inductors, the switching losses can be minimized. Additionally, a high step down conversion ratio can also be obtained. The performance of the proposed converter is confirmed by the experimental results of prototype converters with 48V input and 24V as output of this buck converter drive.

Index Terms- Bridge rectifiers, Microcontroller (PIC16F877A), MOSFET switch, capacitor, Opto-coupler.

1. INTRODUCTION

This project presents a design of Buck converter with constant DC output for DC drive battery charging applications. This buck converter consists of power MOSFET (IRF 840), diodes, ferrite core inductors and capacitors. In dual battery structure established vehicles, the bidirectional dc–dc converter proceeds merit of this technique three-to-five paralleled buck legs are used for persistent dc output. This paper proposes a much higher number of phases in parallel together with digital control in this circuit for buck drive. This approach opens new possibilities since changes in the technology are possible. In this buck drive two 1000-W prototypes have been designed using surface mount technology devices (SO-8 transistors). An important feature of this proposed buck drive is that due to the accuracy of the digital device [field-programmable gate array (FPGA)] used here; current loops in this circuit have been eliminated, and also greatly simplifying the implementation of the control stage of this proposed converter drive.

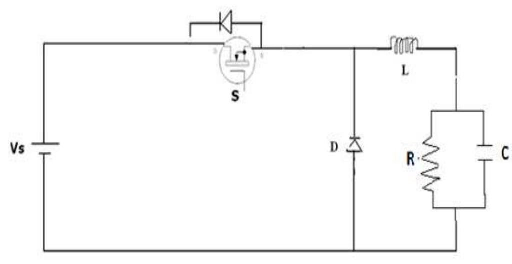
2. DC-DC CONVERTERS

2.1. *Converter topologies*

DC to DC converter is a circuit which converts a DC voltage from one level of input to another level as output using power electronic switch. It is a class of power converter circuit. Hard Switching converters comprise of those converters which obeys the traditional switching phenomenon. While the switch

Is turned ON, the voltage across the switch tends to decrease and the current across the switch tends to increase. This may results in some switching losses. Alike to turning ON, when the switch is turned OFF, the current through the switch tends to decrease and the voltage across its terminals tends to increase. This too results in switching losses. There are many converter topologies of these traditional hard switching converters of which we discuss mainly five types of converters:

1). Buck Converter
2). Boost Converter
3). Buck – Boost Converter
4). Cuk Converter
5). SEPIC Converter



2.2. *Buck converter*

Buck Converter is also known as Step-down Converter. When the MOSFET switch is ON, then the

Fig.1. Schematic Diagram of Buck Converter

Voltage across the load is Vs. The current passing through the load is similar as shown in the diagram. When the MOSFET switch is turned off, the Current through the load is in the same direction as mentioned but the voltage across the load is zero. The power is Flowing from source to load. The average voltage across the load is less than the source voltage, which is determined by the duty cycle of the pulse provided to the MOSFET switch. The inductor is used to smoothen the load current and make it a DC current and the capacitor is used to reduce the ripples of the output voltage and supply a steady output voltage of the buck converter drive.

3. EXISTING CONVERTER SYSTEM

3.1. *Switched mode conversion*

Electronic switch-mode DC to DC converters are available to convert one DC voltage level to another level as output. These circuits, very alike to a switched mode power supply, Usually do the conversion by applying a DC voltage across an inductor or transformer for a period of time (usually in the 100 kHz to 5 MHz range) which causes current to flow through it and store energy magnetically, and then switching off this voltage and causing the stored energy to be transferred to the voltage output in a controlled manner. By adjusting the mosfet switch on/off time ratio, the output voltage can be regulated even as the current demand changes. This conversion method is high efficient (often 80% to 95%) than linear voltage conversion which must dissipate unwanted power in the circuit. This efficiency is beneficial to increasing the running time of battery operated system devices. The main drawback to switching converters is the electronic noise generated at high frequencies, which must be filtered by using proper filter circuit.

3.2. *Chopper*

Chopper is also a DC to DC converter which converts fixed DC voltage into variable DC voltage. These types of circuits are mainly used in traction purpose. Like that of other converters chopper also uses thyristors as a switch to convert fixed DC into variable DC voltages. But it requires many computing components. The control is so complex. It also operates at limited switching frequencies only. To avoid this instability following converters are classified into

(1) Buck
(2) Boost
(3) Buck-Boost

The term "DC to DC converter" almost always refers to one of these switching converters. Switching DC to DC converters are available in a wide variety of input and fixed or adjustable output voltages. DC to DC converters are now available as integrated circuits needing minimal extra components to build a complete converter. DC to DC converters are also available as complete hybrid circuits, ready for use within an electronic device. This AC supply is converted to a DC voltage by using a diode bridge rectifier circuit. Here we can use the electrolytic capacitor which provides the filter operation. The output obtained from the rectifier unit having some harmonic contents, so as to provide the filter circuit. This filter circuit is used to minimize the harmonics.

3.3. *Proposed converter system*

DC to DC converters are widely used in regulated switch mode DC applications and in DC motor drive applications. Moreover the input to these converters is an unregulated voltage DC Voltage, which is obtained by rectifying the line voltage and therefore fluctuations, occurs due to changes in the line voltage magnitude. Switch mode, DC-DC converters are used to convert the unregulated DC Input into controlled DC at a desired voltage level. It is a converter in which the output voltage is less than the input voltage. It is like a step-down converter. In Fig 4.1 Va< Vs. The circuit diagram of Buck Converter using a power BJT is as follows:-

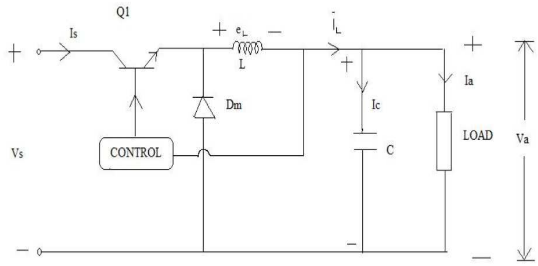


Fig.2. Circuit Diagram of Buck Converter

4. PROPOSED BUCK CONVERTER

It is seen from the above equation the magnetic energy storage requirements when two interleaved converters are employed is 50% for the single buck converter. Fig shows the circuit configuration of the proposed buck converter. The structure is similar to a conventional buck converter except two active switches in series and a coupling capacitor employed in the power path. Referring to the simulation output, it can be seen that switches *Q*1 and *Q*2 are driven with the phase shift angle of 180◦. In order to illustrate the

operation of the proposed converter, some assumptions are made as follows:
1) The output capacitor (C_O*) range should be* more enough to be considered as V_s;
2) The two inductors L_1 and L_2 in this circuit are used with the same inductance L;
3) All power semiconductors in this circuit are ideal;
4) The circuit capacitor C_B for coupling in this buck drive circuit is large enough to be considered as V_s.

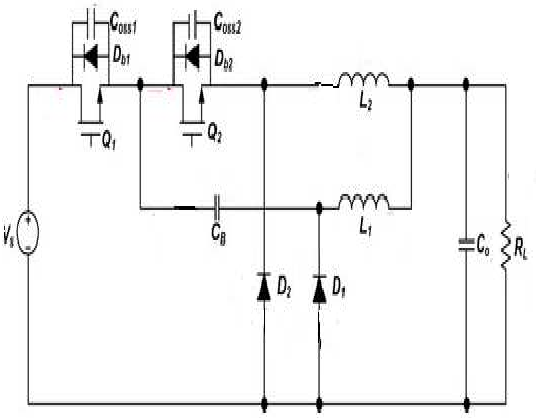


Fig.3. Two Phase Buck Converter without Inductor Coupling

4.1. *Modes of operation*

Mode 1 operation of BC:
Mode 1 begins when Q1 is turned ON. Then the current of L1 (iL1) flows through Q1, Cb and L1 and the voltage of the coupling capacitor Vcb is charged. The current of L_2 (iL2) freewheels through D2. During mode1 the voltage across L1 (VL1) is the difference of the input voltage Vs. The voltage across the circuit capacitor Vcb, and the voltage at output Vo, and its level is positive. Hence, the current iL_1 increases linearly from the initial value. The voltage across L_2(VL_2) is the negative output voltage. Hence,iL_2 decreases linearly from the initial value. The voltage across Q_2(VQ2) becomes the input voltage and the voltage across D1(VD1) the difference of Vs and Vcb.

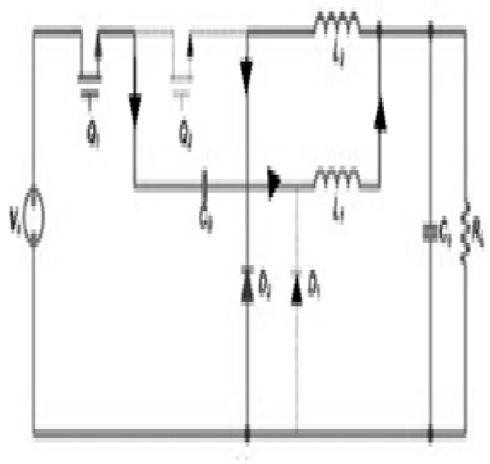


Fig.4. Mode 1 operation of proposed BC

$$V_{L1} = V_s - V_{cb} - V_0$$
$$V_{L2} = -V_0$$
$$V_{Q2=V_s}$$

Mode 2 or mode 4 operation of BC:

Mode 2 begins when Q1 is turned OFF. Then the current of L1(iL1) and L2(iL2)freewheels through diode D1 and D2 respectively. Both VL1 and VL2 become the negative VO. And hence iL1 and 2 iL2 gradually decrease. During this mode the voltage across the switch Q1 (VQ1) is equal to the difference of source VS and linking capacitor voltage Vcb. And VQ2 becomes Vcb.

$$V_{L1=}V_{L2=-}V_0$$
$$V_{Q1=}V_s - V_{cb}$$
$$V_{Q2=}V_{cb}$$

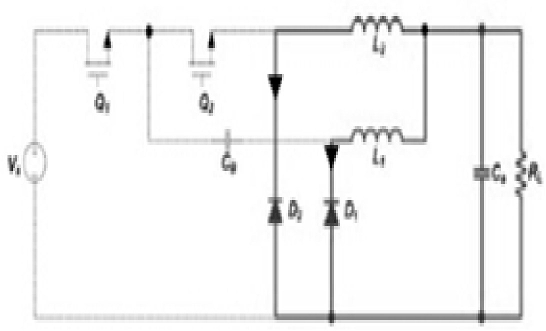


Fig.5. Mode 2&4 operation of proposed BC

Mode 3 operation of BC:

Mode3 begins when Q2 is turned ON. Then The current of L1(iL1) freewheels through D1 and the current of L2(iL2) flows through D1,CB,Q2 and L2.Thus the Vcb is discharged. During this mode, VL2 is equal to the difference of Vcb and Vo and its level is positive. Here iL2 increases linearly and iL2 decreases linearly. Hence the VL1 is the negative Vo.

$$V_{L1} = -V_o$$

$$V_{L2} = V_{cb} - V_o$$

$$V_{Q1} = V_s - V_{cb}$$

$$V_{Q2} = V_{cb}$$

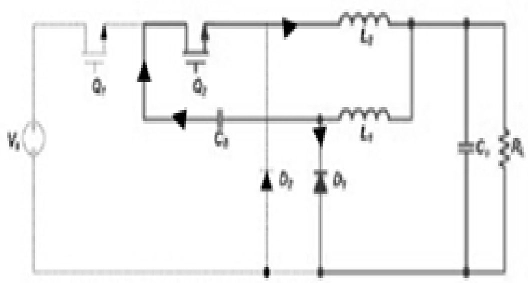


Fig.6. Mode 3 operation of proposed IBC

5. SIMULATION RESULTS

MATLAB provides an intuitive language and flexible environment for technical computations which integrates mathematical computing visualization tools for data analysis and development of algorithms and applications. This program system currently features more mathematical, statistical and engineering functions. Its open architecture and companion products allow users to explore, develop, share and modify data sets, algorithms and custom tools, there by achieving a fairly fast updating, improving and expanding of MATLAB environment.

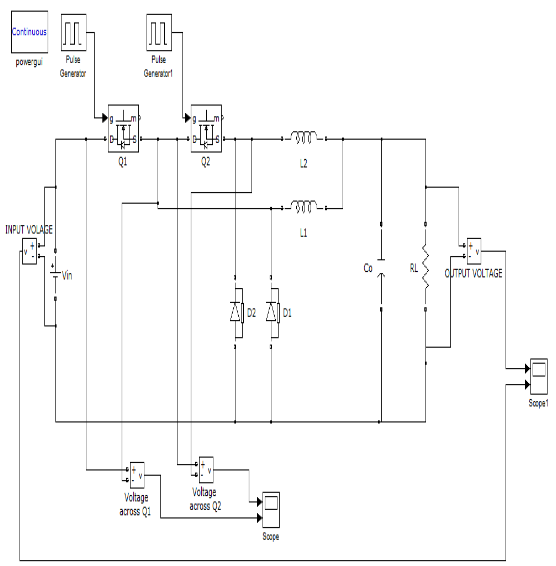


Fig.7. proposed converter Circuit Mat lab model

5.1. *Input and output waveforms*

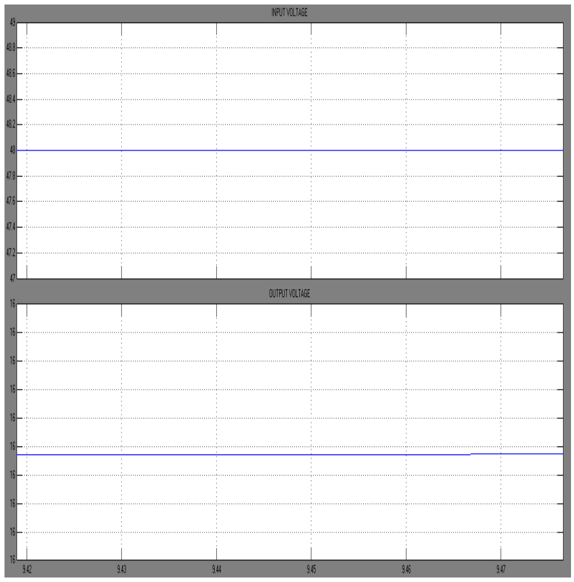


Fig.8. Input & Output Waveform

□

5.2. *Output across switches*

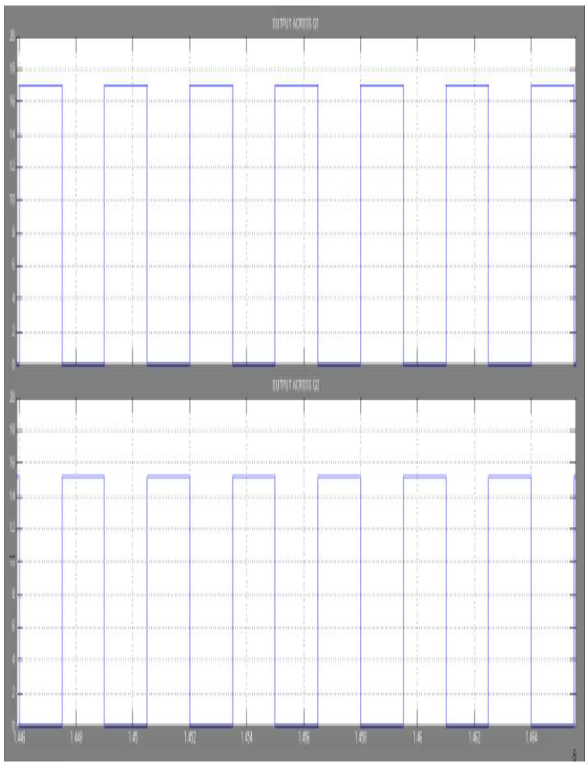


Fig.9. Output waveform across the switches

6. CONCLUSION

The high efficiency buck converter is designed and is simulated in MATLAB Simulink environment to know the characteristics of the converter. Moreover, the comparative study is made between conventional DC to DC converters and the proposed Buck Converter in terms of efficiency improvement; as a result, the overall system is highly portable and cost effective.

7. FUTURE ENHANCEMENT

The converter designed in this project operates at 20 KHz. However, for faster response at higher frequencies with easily customizable control, FPGA implementation can be made and can be integrated with micro controller control for more stability in output at various conditions. Such low cost systems with less error due to digital operation can be used to operate low power high current devices and also the isolated house power can be managed with these microcontroller based systems which has an added advantage of flexibility and ability to interact with other devices. Thus the freedom to get electricity anywhere and the adaptability of micro controllers to suit many conditions easily can be exploited to make such portable systems in an effective manner.

REFERENCES

[1] J. H. Lee, H. S. Bae, and B. H. Cho, “Resistive control for a photovoltaic battery charging system using a microcontroller,” IEEE Trans. Ind. Electron., vol. 55, no. 7.

[2] Y.C. Chuang, “High-efficiency ZCS buck converter for rechargeable batteries,” IEEE Trans. Ind. Electron., vol. 57, no. 7.

[3] R. L. Lin, C. C. Hsu, and S. K. Changchien, “Interleaved four-phase buck-based current source with isolated energy-recovery scheme for electrical discharge machine,” IEEE Trans. Power Electron., vol. 24, no. 7.

[4] C. Garcia, P. Zumel, A.D. Castro, and J. A. Cobos, “Automotive DC–DC bidirectional converter made with many interleaved buck stages,” IEEE Trans. Power Electron., vol. 21, no. 21.

[5] P.L. Wong, P. Xu, B. Yang, and F. C. Lee, “Performance improvements of interleaving VRMs with coupling inductors,” IEEE Trans. Power Electron., vol. 168, no. 4.

[6] X. Du and H. M. Tai, “Double-frequency buck converter,” IEEE Trans. Ind. Electron., vol. 56, no. 54.

[7] K. Jin and X. Ruan, “Zero-voltage-switching multi resonant three-level converters,” IEEE Trans. Ind. Electron., vol. 54, no. 3.O. Yung, “Synthetic structure of industrial plastics,” in *Plastics*, 2nd ed. vol. 3, J. Peters, Ed. New York: McGraw-Hill, 1964, pp. 15-64.

[8] J. P. Rodrigues, S. A. Mussa, M. L. Heldwein, and A. J. Perin, “Three level ZVS active clamping PWM for the DC–DC buck converter,” IEEE Trans. Power Electron., vol. 24 no. 10.,

[9] W. D. Doyle, “Magnetization reversal in films with biaxial anisotropy,” in *Proc. 1987 INTERMAG Conf.*, 1987, pp. 2.2-1-2.2-6.

[10] G. W. Juette and L. E. Zeffanella, “Radio noise currents n short sections on bundle conductors,” presented at the IEEE Summer Power Meeting, Dallas, TX, June 22-27, 1990.

[11] J. Williams, “Narrow-band analyzer,” Ph.D. dissertation, Dept. Elect. Eng., Harvard Univ., Cambridge, MA, 1993.

[12] N. Kawasaki, “Parametric study of thermal and chemical non equilibrium nozzle flow,” M.S. thesis, Dept. Electron. Eng., Osaka Univ., Osaka, Japan, 1993.

[13] X. He and W. Li(2011), “Review of non-isolated high-step-up dc/dc converters in photovoltaic grid-connected applications,”IEEE Trans. Ind. Electron., vol. 58, no. 4, pp. 1239–1250.

[14] E. H. Kim, B. H. Kwon, J. M. Kwon, and K. H. Nam(2009), “High-efficiency fuel cell power conditioning system with input current ripple reduction,” IEEE Trans. Ind. Electron., vol. 56, no. 3, pp. 826–834.

[15] M. W. Ellis, D. J. Nelson, and M. R. Von Spakovsky(2001), “Fuel cell systems: Efficient, flexible energy conversion for the 21st century,”Proc. IEEE, vol. 89, no. 12, pp. 1808–1817.

[16] J. F. Chen, T. J. Liang and L. S. Yang(2009), “Transformer less dc-dc converters with high step-up voltage gain,”IEEE Trans. Ind. Electron., vol. 56, no. 8, pp. 3144–3152.

[17] Q. Chen, Y. Cho, J.-S. Lai, M. Xu and Z. Zhao(2010), “Derivation of boost-buck converter based high-efficiency robust PV inverter,” in Proc. IEEE Energy Convers. Cong. Expos.,Sep.12–16, 2010, pp.1479–1484.

[18] B. K. Bose(2000), “Energy, environment, and advances in power electronics,” IEEE Trans. Power Electron., vol. 15, no. 4, pp. 688–701.

[19] W. D. Doyle, “Magnetization reversal in films with biaxial anisotropy,” in *Proc. 1987 INTERMAG Conf.*, 1987, pp. 2.2-1-2.2-6.

[20] P. Y. Huang ,C. S. Leu and M. H. Li(2011), “A novel dual-inductor boost converter with ripple cancellation for high-voltage-gain applications,”IEEE Trans. Ind. Electron., vol. 58, no. 4, pp. 1268–1273.