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Half bridge Converter for Battery Charging Application

Sivaprasad.A*, K.Deepa,K.Mathew*****

*PG Student, ** Assistant Professor - Department of Electrical and Electronics Engineering , Amrita Vishwa Vidyapeetham University, Amrita School Of Engineering Bangalore, Karnataka

*** Assistant Professor - Department of Electronics and Communication Engineering , MA College Of Engineering, Kothamangalam, Kerala)

ABSTRACT

Integral part of modern day electric vehicle is power electronic circuits comprising of AC-DC converters and DC-DC converters. This project presents a charging circuit for batteries used in electric vehicle. The portion of DC-DC converters mainly handle the purpose of battery charging. The DC-DC converters include both isolated and non isolated ones. This project proposes isolated DC-DC converter for battery charging application with the concept of constant current charging. Here the current control strategy is mainly used for regulated current supply. In this paper a proto type of battery charger with half bridge converter is simulated in using matlab software and also the closed loop hardware implementation of proto type is described.

Keywords - **Battery charger, DC-DC converter,** Half bridge converter

I. INTRODUCTION

Recently the advancement in vehicular technology is indicated by the replacement of hydraulic, mechanical, or pneumatic systems by electrical systems, power electronic circuits, which have a high importance in these days.

The major part of an electric vehicle is its batteries. So the charging circuit for batteries is an integral part in the development of an electric vehicle. So the proper development of an efficient battery charging circuit is highly important in the manufacturing of an electric vehicle.

Many papers in the area of power electronics and drives proposes the use of different type of DC-DC converters especially isolated converters. The selection of these converters is strictly based on the area of application and power levels. Any way almost all power electronics papers encourages the use of isolated DC-DC converters because of safety considerations. Among these converters half bridge converter has significant role in power electronics and drives application. The converter can be proposed in different ways according to the area of application.

Single stage half bridge converter is proposed for dc voltage regulation and power factor correction. The performance of the converter is depends upon inductor operation mode, that is it depends on whether the inductor is operating on discontinuous conduction mode or continuous conduction mode. If the proposed converter is operating in discontinuous conduction mode it not only has high power factor but also avoids, use of bulk capacitor from high voltage stress at light loads[1]. So compared to two stage half bridge converter, single stage converter has the advantage of having one controller instead of two separate controllers as in two stage converter. Thus it has the advantages like reduced cost and less complexity [2].

The concept of power converter which is bi directional in nature for low power application is proposed. The proposed topology consists of half bridge converter on the primary side and push-pull on the secondary side of high frequency isolation transformer. Thus achieving bi directional power flow using the same power components provides a simple, efficient and isolated power converter topology, which can be used for many application especially battery charging purpose [3]. The hybrid combination of flyback and forward converter for single stage single switch isolated converter is proposed for buck mode of operation which can be operated at high input power factor with regulated dc voltage. This converter has both frequency and duty cycle control and it has the advantage of reduced voltage stress. But the main problem related with this topology is it can be used only for low input voltage application, for example 28V, 48Vetc [4].

The use of switch mode power supplies is widely increased in the modern industry in order to provide stable regulated output voltages. The conventional hard switching SMPS has large switching losses in the power switches such that total circuit efficiency is low. To achieve high efficiency circuit configuration, soft switching methods like zero voltage switching and zero current switching can be employed. Half bridge converter with ZVS operation was proposed to reduce the switching losses and the circuit cost compared with full bridge converter in medium and high power applications.

Then asymmetrical pulse width modulation is employed in the converter for output voltage regulation and to improve the duty cycle utilization [5].

There have been attempts to reduce the voltage stress across the switches of DC-DC converter for safety considerations and better performance. So the isolated DC-DC converter is proposed. There are various types of isolated DC-DC converters, among them proper converter is selected based on the voltage level and power. Several power converter topologies are proposed in high power applications like fuel cells, solar cells etc. These converters have the advantages like high voltage conversion ratio, high power capability, isolation between input side and output, avoids flux imbalance. But these converter topologies have the problem of transformer leakage inductance in output capacitors which leads to high voltage stresses and switching losses etc. So it is better to use snubber circuit to avoid these problem [6], so the concept of half bridge converter with PWM control is employed in order to get regulated output voltage for battery charging applications.

II. DC-DC CONVERTERS

1. ISOLATED CONVERTERS

An isolated DC-DC converter will have a high frequency transformer providing that barrier. This barrier can withstand anything from a few hundred volts to several thousand volts which is suitable for wide range of applications. One of the main features of isolated converter is, the output can be configured either positive or negative. Since it consists of a transformer it can produce an output of higher or lower voltage than the input by adjusting the turns ratio. For some topologies multiple windings can be placed on the transformer to produce multiple output voltages. Here half bridge converter is proposed for the purpose of battery charger.

2. HALF BRIDGE CONVERTER

Half bridge converter topology is an isolated dc-dc converter which is widely used in power electronics and drives application. This topology can be used for an output power capability up to 500W. One of the main features of half bridge converter is, it reduces the OFF-stage voltage requirement of the primary side switches to Vi apart from maintaining the bi-directional flux swing in the core. Thus the voltage stress and cost of the power switches is significantly reduced as compared to the push-pull topology. The secondary side of the half bridge converter is exactly same as the push-pull converter. In addition to battery charging application half bridge converter can be used for many other applications like UPS etc due to the reduced complexity of the converter.

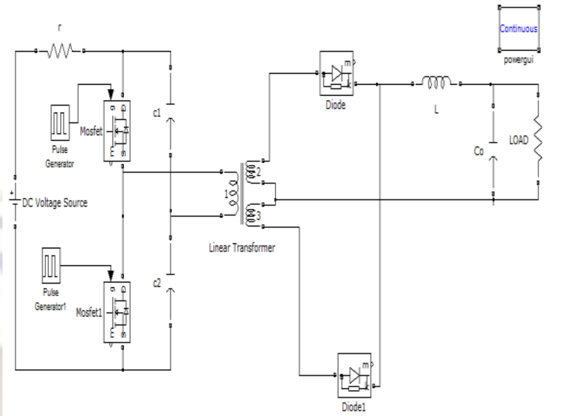

Fig.1. Circuit diagram of proposed half bridge converter.

2.1 MODES OF OPERATION

The operation of half bridge converter can br explained in two modes according to the switching ON of two switches T1 and T2.

2.1.1 MODE 1

Mode 1 starts when switch T1 is ON. This occurs during first *DTs* period. The input source voltage Vin is connected to one end of the primary winding through switch T1. The other end is at Vin/2. The voltage across the primary is Vin/2 with the dot end being positive with respect to the non dot end. The diode D1 is ON and D2 is OFF. The energy is supplied to charge up the inductor through the diode D1.

2.1.2 MODE 2

This mode starts when the switch T2 is ON. This occurs during the second *DTs* period. T1 and T2 will be ON during alternate *DTs* periods with *D* and *Ts* being defined with respect to the inductor current ripple. During this time, T2 is ON and the voltage across the primary winding is Vin/2., but the dot end is negative with respect to the non dot end. This will facilitate the core flux to swing in the negative direction. In secondary, D2 is ON and D1 is reverse biased. The inductor energy is flow through diode D2. When both T1 and T2 are OFF, the inductor current freewheels through both D1 and D2. The current flowing in the center tapped secondary are in directions that will cancel the flux in the core due to each other. This will leads to the voltage across all the transformer being zero.

III. PWM PULSE GENERATION

1. PWM CONTROLLER IC

One of the important process in the hard ware development of a DC-DC converter is pulse generation either by using analog method or digital method. In analog PWM pulse generation method analog IC's are mainly used for the development of PWM pulses. Here it is better to know the concept of PWM generation by both analog and digital method. One of the main advantages of PWM controller is, we can control the pulse width of the switches so that we can regulate output voltage and current. This is the main reason for the large scale advancement in the area of PWM generators (both analog and digital generators). Because compared to fixed pulse generation topologies variable pulse generation topologies have its own advantage.

One well known PWM controller IC is introduced for the generation of gate pulses, that IC is TL 494. The TL494 is a fixed frequency, pulse width modulation control circuit designed primarily for switch mode power supply control. The TL494 consists of 5V reference voltage circuit, two error amplifiers, flip flop, an output control circuit, a PWM comparator, a dead time comparator and an oscillator. This device can be operated in the switching frequency of 1 KHz to 300 KHz.

The TL494 is a fixed-frequency pulse-width-modulation (PWM) control circuit. Modulation of output pulses is accomplished by comparing the sawtooth waveform created by the internal oscillator on the timing capacitor (CT) to either of two control signals. The output stage is enabled during the time when the sawtooth voltage is greater than the voltage control signals. As the control signal increases, the time during which the sawtooth input is greater decreases; therefore, the output pulse duration decreases. A pulse-steering flip-flop alternately directs the modulated pulse to each of the two output transistors [7].

Design values

fs = 25 KHz

Ct = 0.01 Uf

Rt= 1/(2*fs*Ct) = 2 K =2.2 K as standard values.

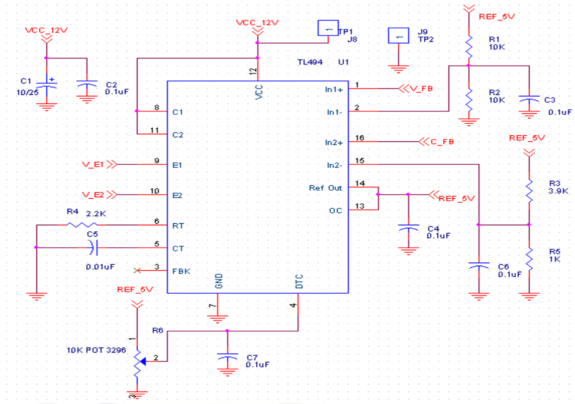

Fig.2. Orcad capture schematic of TL 494.

2. DRIVER CIRCUIT

The circuit which generates the duty-ratio or frequency signals to control the switches of a converter do not have the capability to drive the switches directly. Therefore, a driver stage is added after the duty-ratio/frequency stage. The driver stage is capable of supplying the voltages and currents needed to switch the devices of the converter. The driver circuit can also be designed to provide the isolation required between the high- and low-voltage sides of the converter.

In this paper IC TLP250 which has an inbuilt opto-coupler is used for driving.The TOSHIBA TLP250 consists of a GaAlAs light emitting diode and a integrated photodetector. This unit is 8−lead DIP package.TLP250 is suitable for gate driving circuit of IGBT or power MOSFET. Its features are Input threshold current A ceramic capacitor(0.1μF) should be connected from pin 8 to pin 5 to stabilize the operation of the high gain linear amplifier [8].

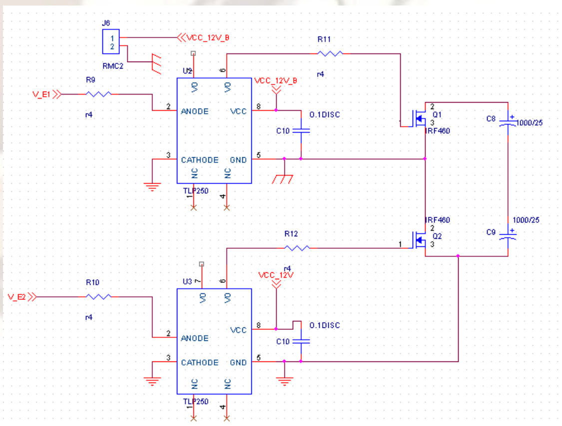

Fig.3. Orcad capture schematic of TLP 250 giving to swithes.

The typical driver IC's that used in general PWM generation methods are only intended for driving purposes. Because it carry out only the amplifying of the gate pulses that generates from the PWM controllers. But it is very important to provide the isolation for between the input side and output side of the PWM generators. So we have to use any of the isolation methods to provide the proper isolation. Generally we are using opto coupler IC's like MCT2E for such applications. Most of the driver IC's do not have opto isolation properties. For example if we are using IR 2110 driver IC for the driving circuit we have to include an opto coupler IC like MCT2E or any other type for isolation between input side and output side. But the main advantage of TLP 250 IC is it can be used for both driving and isolation purposes simultaneously.

IV. DESIGN

The design of half bridge converter mainly includes the design of centre tapped transformer, inductor, capacitor and power switches. Based on these designs only we can implement the half bridge converter in a proper manner. So among these process transformer design is important one. The proposed half bridge converter specification is given below.

Input voltage Vin =180V-270V

Switching frequency *fs* = 25 KHz

Output voltage Vo = 55 V

Output current = 1 A

Duty ratio = 0.45 (45%)

Inductor calculation

$$L_{min} = \frac{V_{in\ max}\, T_{off\ max}}{1.4\, I_{o\ max}} \quad (1)$$

L =1mH

Capacitance calculation

$$Co = \frac{I_{omax}\ T}{V_{ripple}} \quad (2)$$

C= 450 uF

Inductor core – E 25/13/7

Transformer core- E 42/21/20

No.of inductor winding turns =80

SWG for inductor = 24

Transformer primary winding turns N1=31

Secondary winding turns = 23

SWG for primary = 24SWG for secondary = 22

V. SIMULATION RESULTS

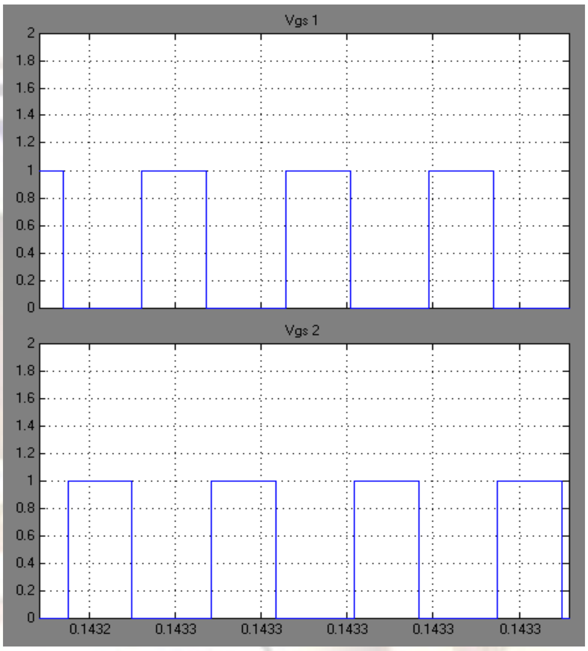

Fig.4. Wave forms of switching pulses

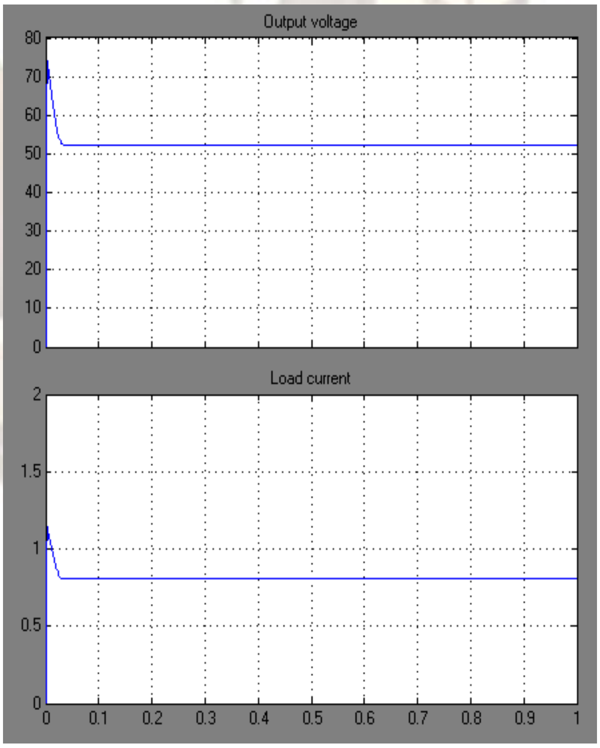

Fig.5. Wave forms of Output voltage and Load current

VI. HARDWARE RESULTS

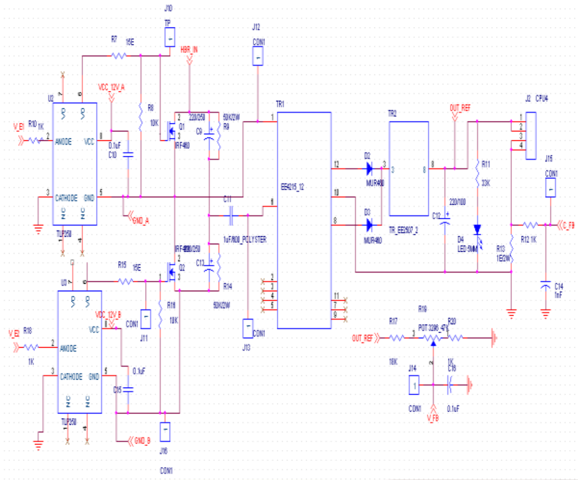

Fig.6. Orcad capture schematic of half bridge converter

1. RESULTS AND WAVEFORMS

Fig.7. Wave form of Switching pulse from TLP 250 for upper side switch.

Fig.8. Switching pulse from TLP 250 for lower side switch

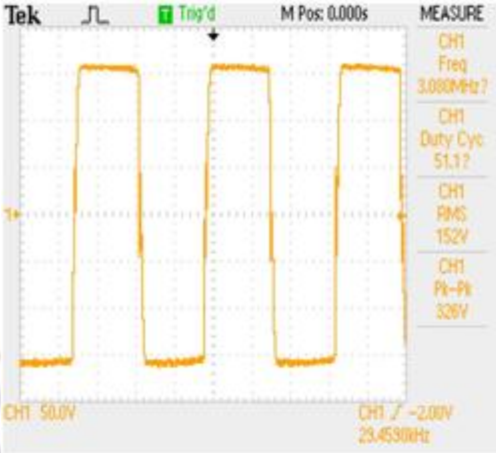

Fig.9. Transformer primary voltage

Fig.10. Upper side secondary voltage

Fig.11. Lower side secondary voltage

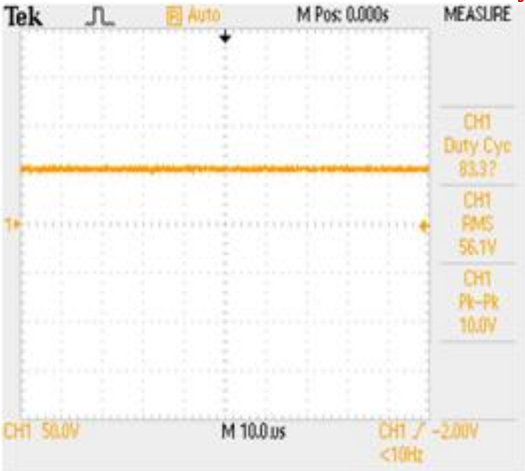

Fig.12. Output voltage across the load

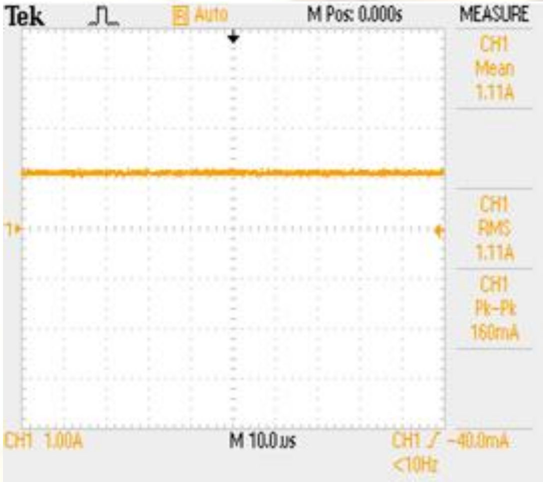

Fig.13. Load current

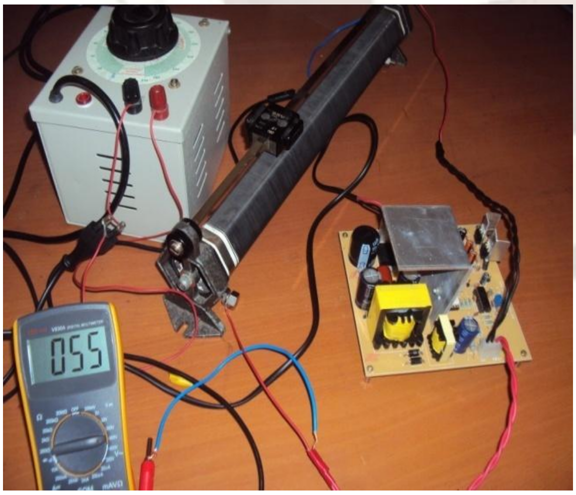

Fig.14.Total hardware implementation setup of proposed converter.

VII. CONCLUSION

The closed loop hard ware implementation and matlab simulation of the proposed half bridge converter with proposed rating is done with respective design values, including the design of transformer and inductor. Thus the implementation of the battery charger by the concept of half bridge converter with high voltage rating is finished. The problems that faced during the implementation process were analysed to find a proper solution for them.

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