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Hardware Development of Flyback Converter for Hybrid Electric Vehicles

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***Abstract*—Hybrid electric vehicle is a need of the today's world because of the fact that it is pollution free and has more fuels efficiency. Flyback converter plays important role in hybrid electric vehicles because it is an isolated DC-DC boost converter. The objective of this paper is to design an isolated DC- DC converter for HEVs which convert low power to high power & saves energy &mitigates pollution. In the proposed work simulation of flyback converter has been done in the SIMULINK tool of MATLAB and voltage and current waveforms are obtained .The results of simulations matches the theoretical calculations and which led to the development of hardware model of Flyback converter.**

***Index Terms*— Hybrid Electric Vehicles, Fly back Converter, buck-boost converter, PMOSFET.**

I. INTRODUCTION

In the modern world lots of attention has been given in hybrid electric vehicles. Many companies like Toyota, Honda are coming forward to manufacture hybrid electric vehicles because its fuel efficiency is very high and mitigates pollution [1], [2], [3], [4], [5].

Power electronics plays vital role for design of converter for hybrid electric vehicles. We have chosen the PMOSFET for the design of hybrid electric vehicles because its switching is smooth and it has positive temperature of coefficient so there is no second breakdown as in case of Power MOSFET. Moreover paralleling of Power MOSFET is very easy [6], [7].

Flyback converter is an isolated buck-boost converter. It has one very big advantage over dc-dc converter because it is difficult to obtain large input–output voltage ratio with a dc-dc converter, because D may not reach a very small values. For the same reason it is difficult to obtain output voltage that is adjustable in large range. Because of this fact it increases the input voltage of voltage-source inverter and reduces the size of batteries [8], [9],

The paper has been organized as follows. An elaboration of various topologies of hybrid electric vehicles is given in section II. Third section deals with theoretical aspects of flyback converter.Simulation of flyback converter and forward converter have been discussed in section IV. Fifth section is the overall conclusion.

II. CLASSIFICATION OF HYBRID ELECTRIC VEHICLES

HEVs are categorized into following types.

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a. Series hybrid
b.Parallel hybrid
c. Series- parallel hybrid
d. Complex hybrid

Figures 1,2,3,4 are the block diagrams of various types of hybrid electric vehicles (HEV) in which the bidirectional link is Electrical, the unidirectional link is hydraulic and the mechanical link (clutches and gears) is also bidirectional.

A. Series Hybrid Electric Vehicles

The series hybrid has very simple construction. The mechanical output that we are getting from ICE is converted into electricity using a generator. The converted electricity is either used to charges the battery or it can directly used to propel the wheels via the same electric motor and mechanical transmission. Due to the absence of clutches throughout the mechanical link, it has the certain advantage of flexibility locating the ICE-generator set.

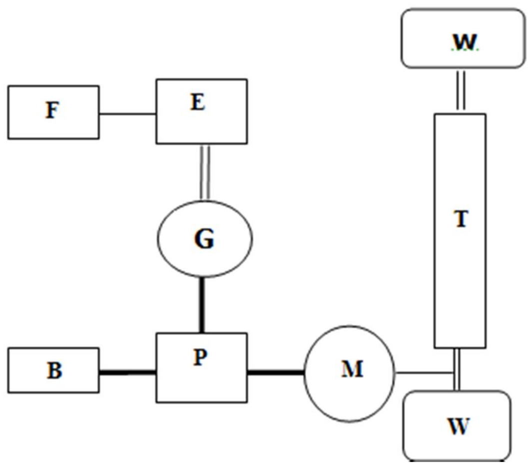


Figure 1: Topology of series hybrid electric vehicles

B. Parallel Hybrid Electric Vehicles

The parallel HEV allows both the ICE and electric motor to deliver power in parallel to drive the wheels. Since both the ICE and electric motor are generally coupled to the drive shaft of the wheels via two clutches, the propulsion power may be supplied by the ICE alone by the electric motor or by both.

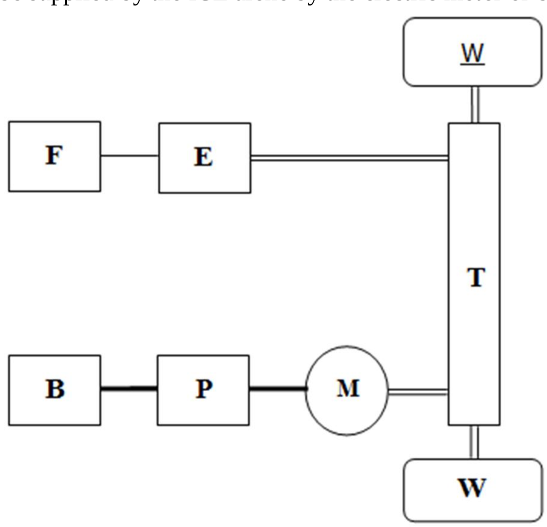


Figure 2: Topology of parallel hybrid electric vehicles

C. Series-Parallel Hybrid Electric Vehicles

There are features of both series and parallel hybrids in series-parallel HEV. Apart from this it has also an added advantage over series hybrid that it has a supplementary mechanical link, and also a supplementary generator than the parallel hybrid. Its construction is comparatively more complicated and also it is more costly.

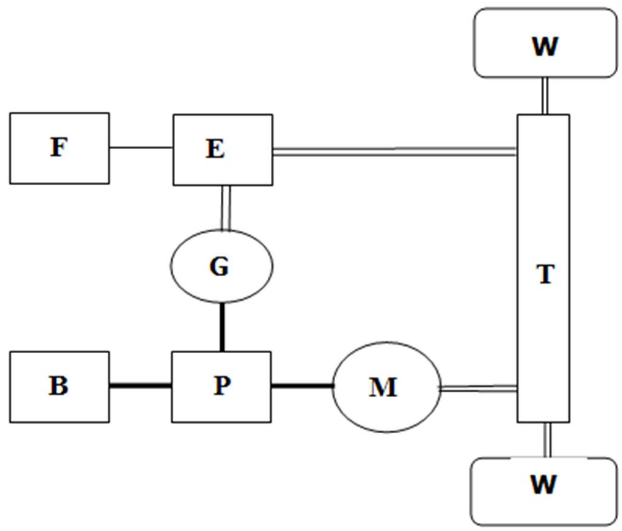


Figure 3: Topology of series-parallel hybrid electric vehicles

D. Complex hybrid electric vehicles

As its name reflects it involve more complex construction as compare to other HEVs stated above. As shown in figure4 4 the construction of complex HEVs is very close to series-parallel HEVs. But there is an important difference between two. In the complex HEVs, the bidirectional power flow of the electric motor and in the series-parallel hybrid unidirectional power flow of the generator. This bidirectional power can add many advantages on complex hybrid, especially the three propulsion power (due to the ICE and two electric motors) operating modes which cannot be in the series-parallel hybrid. But the complex hybrid also suffers from complex construction and high cost.

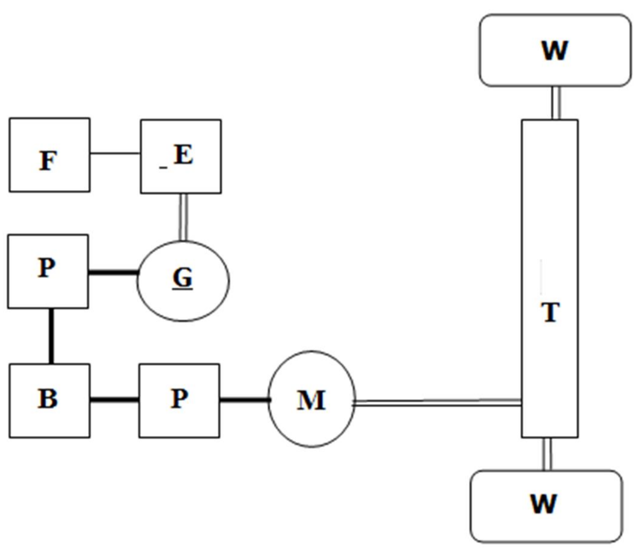


Figure 4: Topology of complex hybrid electric vehicles

Flyback converter is a isolated buck boost converter which has many features. It is of smaller in size, lighter in weight possess of higher efficiency because of its higher frequency operation. It is less sensitive to input voltage variation. It is low cost multiple output power supplies. It is used for high voltage generation and used as a gate drive circuit. In dc-to-dc converter it is difficult to obtain large input output voltage ratio. In dc-to-dc converter if there is large input output voltage ratio duty ratio may reach very small value. So it is difficult to obtain large range of output voltage. Flyback converter is overcome this limitation by performing a voltage ratio $\frac{d^2}{1-d}$ in the best operating mode.

III. THE FUNDAMENTAL OF FLYBACK CONVERTER & FORWARD CONVERTER

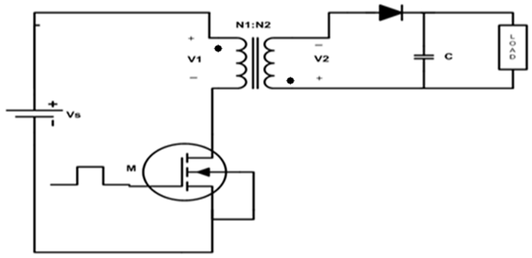


Figure 5: Power Circuit of Flyback Converter

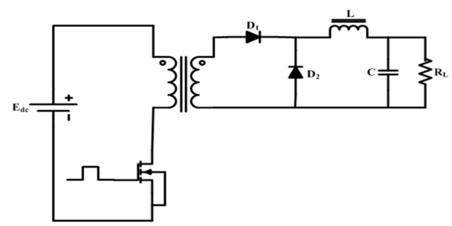


Figure 6: Power Circuit of Forward Converter

It consists of a power MOSFET M_1, transformer for isolation purposes, diode D, capacitor C and load shown un figure 5. Here, the magnetic component of coupling inductor is used for energy conversion
When PMOSFET M_1 is turned on, voltage across the primary

$$V_1 = V_S \quad (1)$$

Since transformer winding have 180^o phase polarity, so V_2 appears across the secondary with the polarity shown in figure.

$$\frac{V_s}{V_2} = \frac{N_1}{N_2} \quad (2)$$

Since,

$$V_2 = -V_0 \quad (3)$$

$$V_s = \frac{-V_o \ N_2}{N_1} \quad (4)$$

During turn-on, magnetic component of coupling inductor is used for energy conversion. As V_2 reverses bias the diode D, so secondary circuit is open circuited. As filter capacitor C is large enough to smoothen the output. Transformer core is not demagnetized completely at the end of periodic time but having some positive value I_0. I_1 is input current. So during turn-on of PMOSFET.

$$I(t) = I_1(t) = I_0(t) + \frac{V_s}{L}t \quad (5)$$

As PMOSFET is turned off, emf induced in the primary and secondary are reversed which forward bias the diode and diode starts conducting. As current starts flowing in secondary, some current charges the capacitor and some current go to the output.

$$V_2 = V_0 \quad (6)$$

The voltage when referred to primary.

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} \quad (7)$$

$$V_1 = -V_s \quad (8)$$

$$V_s = -\frac{V_0}{N_2} N_1 \qquad (9)$$

The fall of current during turn-off can be expressed as

$$I(t) = I_1 - \frac{V_0}{N_2} N_1 \frac{1}{L}(T - T_{on}) \qquad (10)$$

Putting the value of I_1 from equation

$$I(t) = I_0 + \frac{V_s}{L}.T_{on} - \frac{V_0}{N_2} N_1 \frac{1}{L}(T - T_{on}) \qquad (11)$$

Since,

$$I(0) = I(T) \qquad (12)$$

We get,

$$V_0 = \frac{a.V_s.k}{1-k} \qquad (13)$$

$a = \frac{N_2}{N_1}$, $k = \frac{T_{on}}{T}$

Forward converter is another switch mode power supply, it is more efficient than flyback converter but uses more number of components as compare to flyback converter. Figure 6 shows the basic circuit diagram of a single ended isolated forward converter. However there are some distinct differences between the two circuits: The dot polarities are on the same side of the transformer. This means that the two windings are wound in the same sense and hence carry the current simultaneously. Thus, the transformer of the forward converter is a pure transformer.

IV. SIMULATION RESULTS

Flyback converter has been simulated in simulink tool of MATLAB available in power electronics laboratory. From figures 7 to 18. Figures 8 and 9 show primary and secondary voltage of isolated transformer, they are in same phase and this is the importance of isolated transformer in flyback converter. Similarly figures 10 and 11 shows primary and secondary currents of isolated transformer. It is a magnetizing current so there is exponential rise and exponential decay of current. Since T_{on} and T_{off} are very small so figures show linear increase and decrease of currents. As there is voltage spikes which can be reduced using suitable capacitor in parallel with load. Figure 17 and 18 shows the primary and secondary voltage of forward converter. Figures 15 and 16 shows the exponential rise and decays of primary and secondary currents of forward converter. Figure 12 shows the voltage spike during turning off PMOSFET.

A. Simulation of Flyback Converter

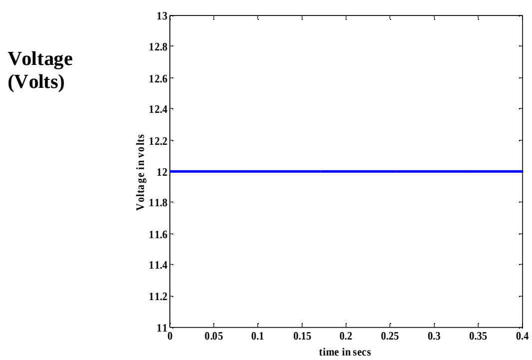


Figure 7: Input voltage of flyback

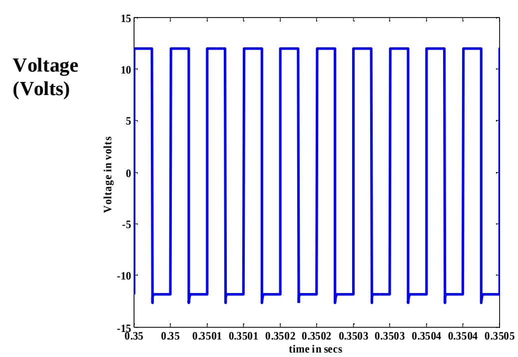
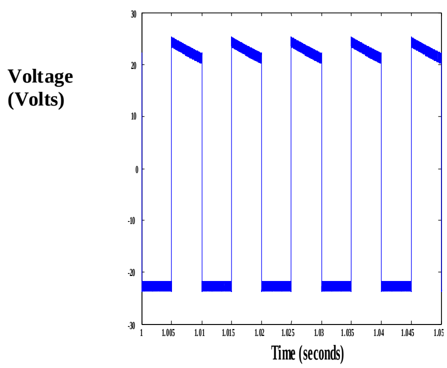


Figure8: Primary voltage of flyback converter



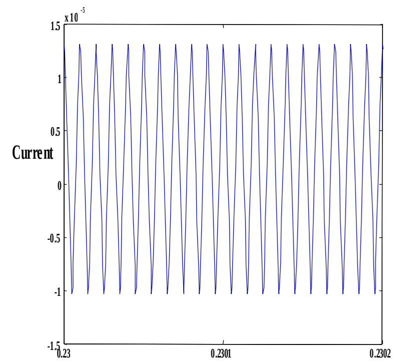
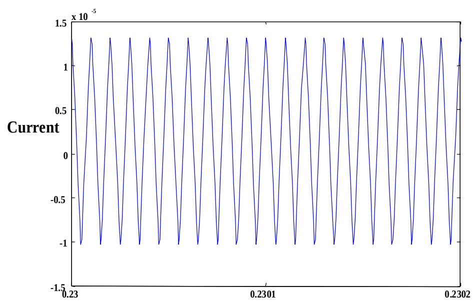


Figure 9: Secondary voltage of flyback converter

Figure 10: Primary current of flyback converter



Time in secs

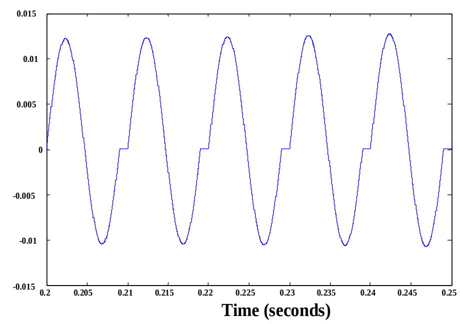
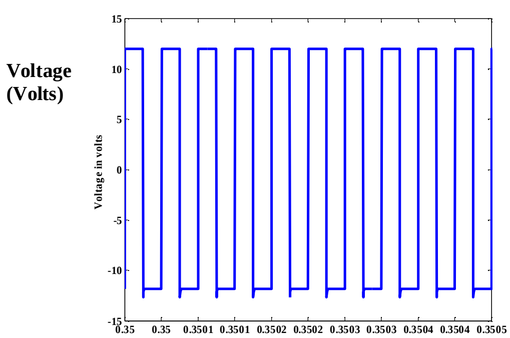
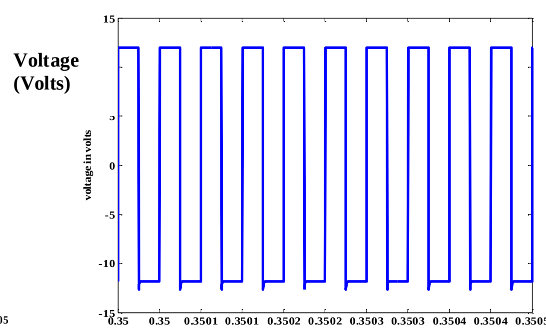


Figure15: Primary current of forward converter

Figure 16: Secondary current of forward converter





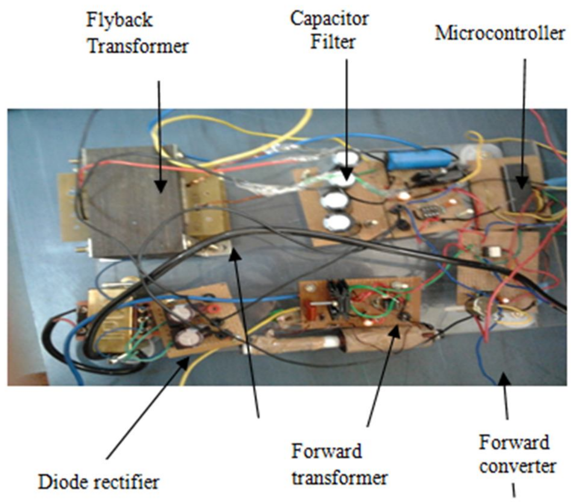
Time in secs

Figure 17: Primary voltage of forward converter

Figure 18: Secondary voltage of forward converter

V. EXPERIMENTAL RESULTS

The figure shows the experimental setup of flyback converter and forward converter. The set-up consists of power circuit of flyback converter & forward converter using IRFP460 PMOSFET. The firing pulse provided both by 555 timer and microcontroller. The above set-up consists of ATMEGA16 microcontroller, KA 7805 DC voltage regulator, TLP 250 optocoupler, 555 timers, and 2000 uF filter capacitor in flyback converter and IN4997 diode.



VI. RESULTS AND ANALYSIS

A. Gate pulse generated using ATMEGA16 microcontroller and 555 timers:

Gate pulse is generated both by 555 timer and microcontroller with 7.5ms on period and 7ms off period. PMOSFET conduct for 7.5ms as shown in the figure. We can vary the width of pulse by 555 timer but not by microcontroller. So generally we prefer 555 timer for firing PMOSFET.

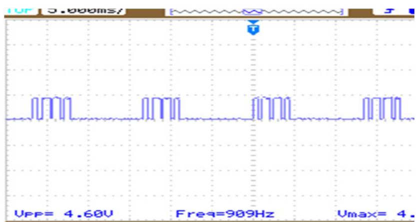


Figure 19: Firing pulse varied by using Microcontroller

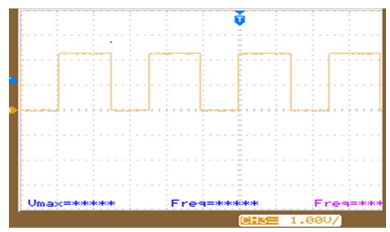


Figure 20: Firing pulse to PMOSFET by using 555 timer

Figure 21: Firing pulse varied by using potentiometer

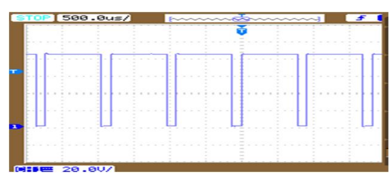


Figure 22: Amplified pulse using TLP250

Figure 23: Primary Voltage of Flyback converter

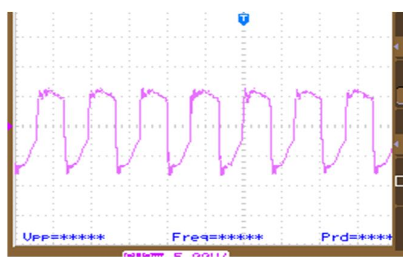


Figure 24: Secondary voltage across PMOSFET

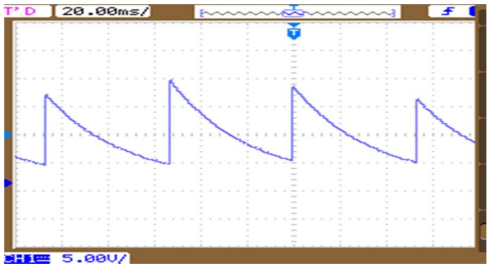


Figure 25: Charging and discharging voltage of capacitor of flyback converter capacitor

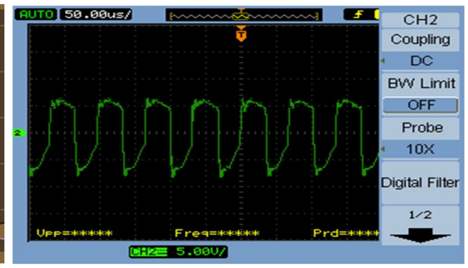


Figure 26: Primary voltage of forward converter

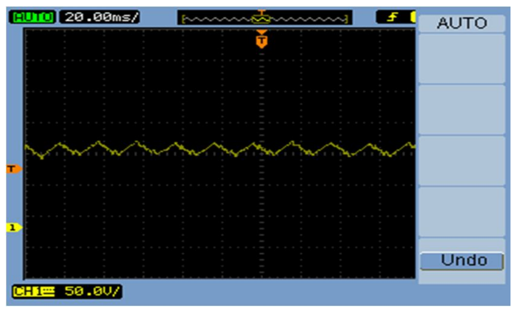


Figure 25: Charging and discharging of capacitor of forward converter capacitor

VII. Conclusions

Hybrid Electric vehicle is the emerging technology for present and future generation. Converters plays vital role in HEVs. Flyback converter is an isolated dc-dc buck-boost converter; it plays a vital role in design an operation of hybrid electric vehicles. It is a reflection of the fact that it increases the load voltage which is the input of the voltage source inverter. Thereby it reduces the weight caused by batteries in vehicles. In the proposed work a simulation has been done on isolated flyback converter.

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