

Design of Low Cost DC-DC Flyback Converter

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Abstract— The fly-back converter is used in both AC/DC and DC/DC conversion with galvanic isolation between the input and outputs. More precisely, the fly-back converter is a buck boost converter with the inductor split to form a transformer, so that the voltage ratios are multiplied with an additional advantage of isolation. In the on-state the energy is transferred from the input voltage source to the transformer while the output capacitor supplies energy to the output load. In the off-state, the energy is transferred from the transformer to the output load and the output capacitor. By controlling the duty ratio of switch used in the primary of transformer a DC supply of zero to a desired maximum value is obtained. A fly-back transformer is designed to meet the output requirement. In this project the aim is to design a pure DC supply that can be used to obtain the output of 48V.

Keywords—Flyback converter , IC UC3843, MOSFET,Transformer core.

I. INTRODUCTION

In switch mode power supplies (SMPS), flyback converters are very popular because of, design simplicity, low cost, multiple isolated outputs, high output voltages and high efficiency. They are preferred especially for low power applications. According to efficiency and power density, SMPSs are more popular than linear power supplies. Most of the advanced communications and computer systems require SMPS switch have high power density, high efficiency and constant operation frequency [1].

At the last decade, a lot of converter topology has been proposed for switch mode power supplies. Among the currently existing transformer coupled switching mode converter, Fly-back converters are the simplest isolated converter topology because of absence of inductor at the output filter, only one semiconductor switch and only one magnetic component transformer or coupled inductor. Besides, obtaining up to 5000V output voltage and having multiple outputs are the superiorities. Because of these advantages, fly-back converters become the most preferred converter topology for switch mode power supplies.

Fly-back converters are popular for its, simple in design for low power applications, Low cost because of less component requirement, Blocking voltage not occurred on the output diode, thus diode cost reduced, There is no additional inductor at the output circuit This simplifies the usage of multiple outputs, Transient response is fast because of output inductor absence. Flyback converters are preferred mostly for low power applications for low output power applications where the output voltage needs to be isolated from the input main supply. The output power of fly-back type SMPS circuits may vary from few watts to less than 100 watts. The overall circuit topology of this converter is considerably

simpler than other SMPS circuits. Input to the circuit is generally unregulated dc voltage obtained by rectifying the utility ac voltage followed by a simple capacitor filter. Direct DC supply can also be used. The circuit can offer single or multiple isolated output voltages & can operate over wide range of input voltage variation [2].

II. METHADODOLOGY

AC input is rectified to DC by a full bridge rectifier so the voltage applied across the primary of the fly-back transformer is DC. A MOSFET switch is connected in series with the primary of the fly-back transformer. The voltage pulse needed to control the switch is generated by IC UC3843. IC generates a pulse whose duty ratio can be varied from 0 to 100%. When the duty ratio varies from zero to hundred percent the average value of voltage induced in primary of transformer varies. So output varies from zero to desired volts. The controller circuit and power circuit is isolated using opto coupler. Various protection units were also employed to ensure proper working. The output is taken across a resistive load. The basic block diagram is shown in Figure1

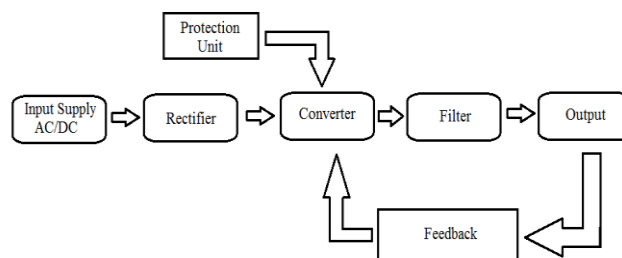


Figure 1:- Block Diagram of Flyback Converter

The flyback converter is used in both AC/DC and DC/DC conversion with galvanic isolation between the input and any outputs. The flyback converter is a buck-boost converter with the inductor split to form a transformer, so that the voltage ratios are multiplied with an additional advantage of isolation. When driving for example a plasma lamp or a voltage multiplier the rectifying diode of the boost converter is left out and the device is called a flyback transformer[3]. The schematic of a flyback converter can be seen in figure below. It is equivalent to that of a buck-boost converter, with the inductor split to form a transformer.

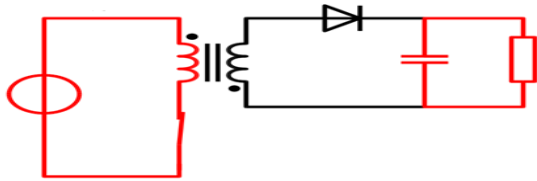


Figure2:- Operation of Flyback converter during ON state

When the switch is closed shown in Figure 2, the primary of the transformer is directly connected to the input voltage source. The primary current and magnetic flux in the transformer increases, storing energy in the transformer. The voltage induced in the secondary winding is negative, so the diode is reverse-biased (i.e., blocked). The output capacitor supplies energy to the output load.

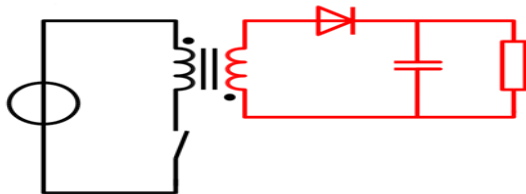


Figure 3:- Operation of Flyback converter during OFF state
When the switch is opened shown in Figure 3, the primary current and magnetic flux drops. The secondary voltage is positive, forward-biasing the diode, allowing current to flow from the transformer. The energy from the transformer core recharges the capacitor and supplies the load.

III. BASIC OPERATION

The input can be AC or DC as per requirement. A fuse in series and a MOV in parallel is connected to the circuit of protection. A full bridge rectifier is used to rectify the input, if it is AC. A capacitor is used to avoid ripples in rectified output. When the gate pulse is high, switch is on and the transformers to restore energy. The output diode will be reverse biased. The energy stored in output capacitor discharges to load. When gate pulse is low, switch is off and output diode is forward biased and so output capacitor stores energy and dissipates in load. First of all, when the MOSFET turns on, given that the polarity of the transformer

is reversed, a current flows to the primary winding of the transformer, where energy is stored. At this time, the diode is off. Next, when the MOSFET turns off, the stored energy is output through the diode from the secondary winding of the transformer, and after undergoing rectification and smoothing, it generates a DC voltage.

When the MOSFET turns on, a current flows to the primary winding of the transformer, where energy is stored. During this time, the diode remains off. When the MOSFET turns off, the stored energy is output through the diode from the secondary winding of the transformer. The Figure 4 below illustrates this operation and the voltage and current waveforms at major nodes:

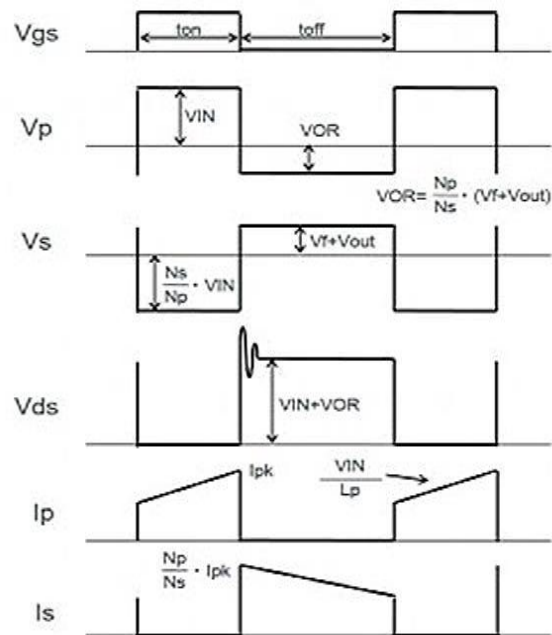


Figure 4:- Voltage and current waveforms at major nodes

IV. CONVERTER DESIGN

Transformer Design:

The following steps are carried out for the design of transformer

Step 1:- Find area product of the transformer

$$A_p = \frac{P_o \left(1 + \frac{1}{n}\right)}{1.41 \times kw \times j \times fs \times B_m}$$

$$A_p = 30,780 \text{mm}^2$$

Step 2:- Select a core having a greater area product.

E42/21/15 is suitable for our design having a area product of 31,700. And the parameters are shown in table below

| SYMBOLS | PARAMETERS | VALUES | UNITS |
|---------|----------------|--------|-----------------|
| Ap | Area Product | 31,700 | mm ⁴ |
| Ae | Effective Area | 178 | mm ² |
| Aw | Window Area | 178 | mm ² |
| M | Mass of core | 44 | grams |

Step 3:- Calculate the primary number of turns.

$$N_p = \frac{V_p}{4 \times A_c \times B_m \times f_s}$$

$$N_p = 357.43 \approx 58 \text{ turns}$$

Step 4 :- Calculate the secondary turns.

$$N_s = N_p \times n$$

$$N_s = 15.06 \approx 15 \text{ turns}$$

Step 5:- Calculate the auxiliary turns.

$$N_a = \frac{V_{sec}}{(V_{aux} + V_d)}$$

$$N_{aus} = 3 \text{ turns}$$

Step 6:- Calculate wire gauge.

$$d = 3.14 \times a_2 / 4$$

Therefore,

$$a_p = 0.610 \text{ mm}^2 \text{ (SWG = 23)}$$

$$a_s = 1.42 \text{ mm}^2 \text{ (SWG = 17)}$$

$$a_x = 0.529 \text{ mm}^2 \text{ (SWG = 24)}$$

Step 7:- Calculate the required window area.

$$N_p \times a_p + N_s \times a_s + N_{aux} \times a_x < K_w \times A_w$$

$$58 \times 0.61 + 15 \times 1.42 + 3 \times 0.52 < 0.4 \times 178$$

$$58.24 < 71.2$$

- Hence the windings will get fit into the available window area shown in Figure 5.

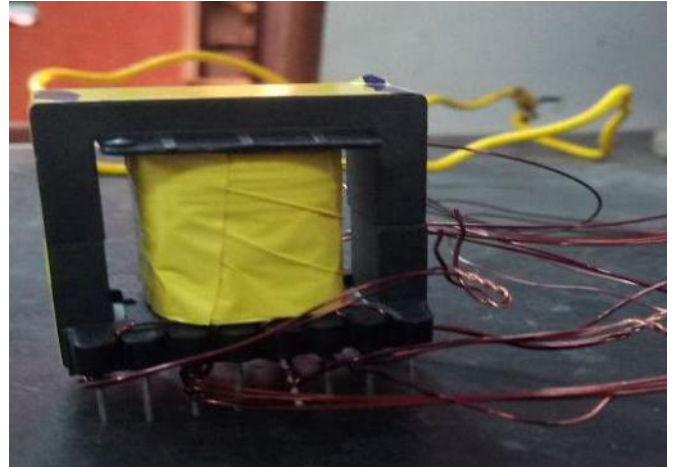


Figure 5:- Actual Transformer

Inductor Design:

When output passes through the inductor, it offers a high resistance to the AC components and no resistance to the DC components. Therefore AC components are blocked and only the DC component reaches to the load. Calculations are shown as follows.

Step 1:- Calculate Output Inductance

$$L_{out} = \frac{(V_{in_{max}} - V_{out}) \times T_{off}}{1.4 \times I_{out}}$$

$$L_{out} = 12.14 \mu H$$

Step 2:- Calculate area product

$$E = \frac{L \times I_m}{2} = 0.1673 \times 10^{-3}$$

$$A_p = \frac{2E}{k_w \times j \times B_m} = 0.00927 \text{ cm}^4$$

Step 3:- Calculate the number of turns

$$N = \frac{L \times I_m}{A_c \times B_m} = 31.55 \approx 32 \text{ turns}$$

Capacitor Design

Capacitors are used for filtering of undesirable frequencies. They are common in electrical and electronic equipment, and cover a number of applications. The value of input capacitor and output capacitor are calculated as $C_{in} = 375 \mu F$ and $C_{out} = 416 \mu F$ respectively [1].

Snubber Circuit Design

When the MOSFET turns off, a high-voltage spike occurs on the drain pin because of a resonance between the leakage inductor (L_{lk}) of the main transformer and the output capacitor (COSS) of the MOSFET. The excessive voltage on the drain pin may lead to an avalanche breakdown and

eventually damage the MOSFET. Therefore, it is necessary to add an additional circuit to clamp the voltage. The basic snubber circuit for converter is shown in Figure 6.

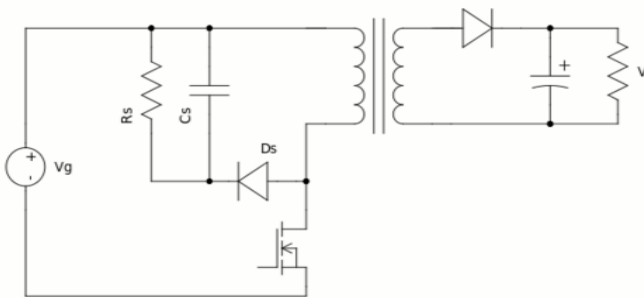


Figure 6:- Snubber circuit

The value of snubber resistor and capacitor are calculated as $R_{sn} = 16344.03\Omega$ and $C_{sn} = 31.815 \text{ nf}$ respectively. Fast operation is required of the diode, and so a fast-recovery diode is used. Hence BR107 diode is used.

Feedback Circuit Design

The converter contains a feedback loop shown in Figure 7. The task of this loop is to measure the output voltage (or current), compare it to a desired value and use the error between them to adjust the switching pattern of the switch, until the error becomes zero or close enough to zero. It helps to keep the output voltage (or current) constant, even with a variable load, input voltage, temperature, etc[1].

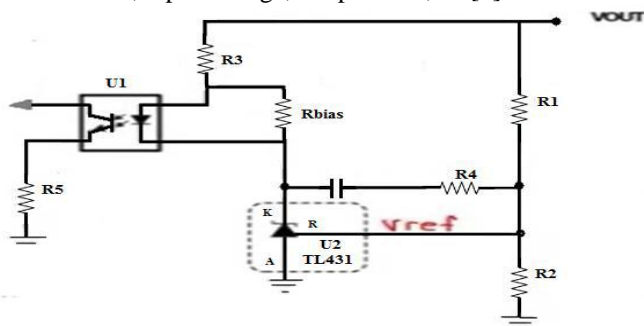


Figure 7:- Feedback circuit

Control circuit design

The UCx84x series of control integrated circuits provide the features that are necessary to implement off-line or DC-to-DC fixed-frequency current-mode control schemes, with a minimum number of external components. The internally implemented circuits include an under voltage lockout (UVLO), featuring a start-up current of less than 1 mA, and a precision reference trimmed for accuracy at the error amplifier input. Other internal circuits include logic to ensure latched operation, a pulse-width modulation (PWM) comparator that also provides current-limit control and a totem-pole output stage that is designed to source or sink high-peak current. The output stage, suitable for driving N-channel MOSFETs, is low when it is in the off state. The UCx84x family offers a variety of package options,

temperature range options, choice of maximum duty cycle, and choice of turn on and turn off thresholds and hysteresis ranges. The UC184x devices are specified for operation from -55°C to 125°C , the UC284x series is specified for operation from -40°C to 85°C , and the UC384x series is specified for operation from 0°C to 70°C .

V. RESULTS AND DISCUSSION

Experimental results obtained from the converter are presented to confirm the feasibility of the proposed AC-DC flyback converter. The converter used in the experimental studies was implemented based on the specifications and design example presented above. Typical experimental waveforms such as primary and secondary waveform of transformer, output waveform are presented in this chapter and the converter’s performance is evaluated at two input line voltage. Figure 8 shows schematic of the circuit hardware in this the schematic consist of a control circuit on the primary side and feedback compensation circuit on the secondary side. Figure 9 and 10 shows primary, secondary waveform of the transformer while Figure 11 shows the output waveform at the 48V according to the design.

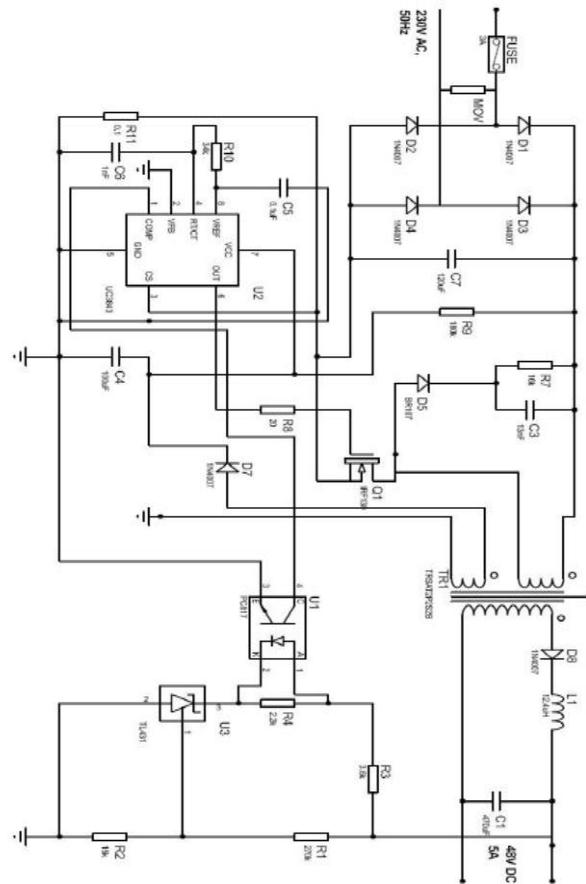


Figure 8:- Schematic of Flyback Dc-Dc converter

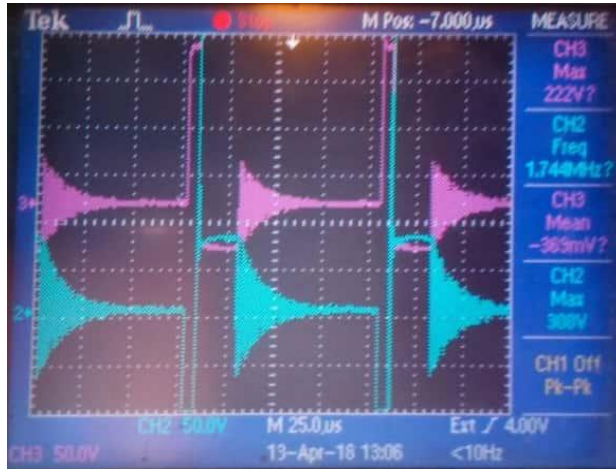


Figure 9:- Primary & Secondary waveform

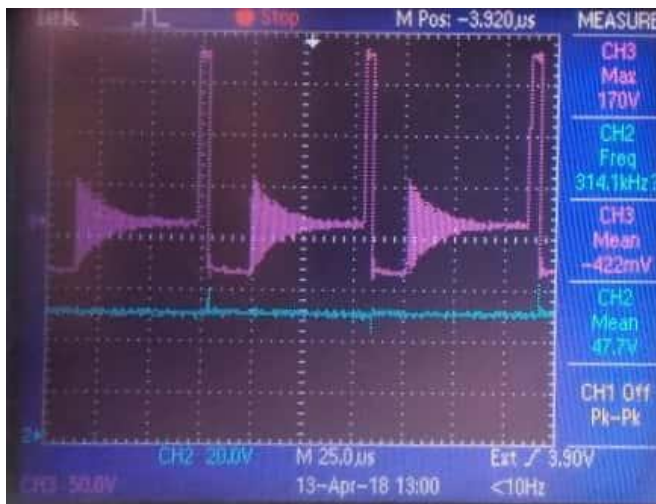


Figure 10:- Output & Secondary waveform

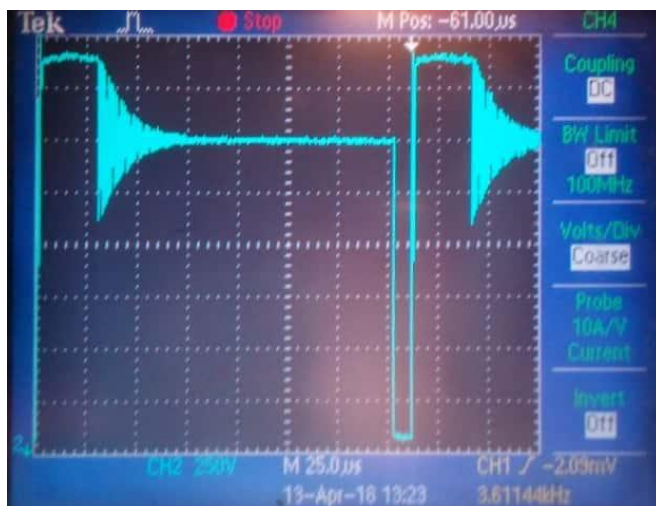


Figure 11:- Vds waveform

VI. CONCLUSION

A fixed DC power supply is designed using flyback principle. Here for a input of 230V a fixed DC output of 48V is obtained. This is a model of designing a power supply. Depending on the application and input conditions, any power supply can be designed. Flyback transformer can be designed for any required output and rectangular pulses of desired frequency and duty cycle can be generated using IC UC3843.

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Authors Profile

Rashmi Sharma received her B.E. Degree in Electrical Engineering from Oriental Institute of Technology, RGPV, Bhopal and subsequently completed her M.Tech. in Electrical Engineering from Nirma University, Ahmedabad in year 2010. Presently she is working as an Assistant Professor in Electrical and Electronics Engineering Department at Indus University. She has 8 years of teaching experience and 1 years of Research Experience.

