

Design and Implementation of high frequency transformer for SMPS Based flyback DC-DC converter

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Abstract - 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. In this paper we have presented the design of transformer for variable DC input (18V to 60V) to 12V DC output. And observed the wave form across the switch, primary & secondary of the transformer.

Keywords: SMPS isolated DC-DC converters, flyback converters, transformer design.

I INTRODUCTION

According to efficiency and power density, SMPSs are more popular than linear power supplies [1]. Most of the advanced communications and computer systems require SMPSs which have high power density, high efficiency and constant operation frequency [2].

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 DC-DC converter, Flyback converters are the simplest isolated DC-DC 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 [5-6]. Because of these advantages, flyback converters become the most preferred DC-DC converter topology for switch mode power supplies [3].

Flyback 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 flyback 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 [8]. Input to the circuit is generally unregulated dc voltage obtained by rectifying the utility ac voltage followed by a simple capacitor filter. The circuit can offer single or multiple isolated output voltages & can operate over wide range of input voltage variation. In respect of energy-efficiency, flyback power supplies are inferior to many other SMPS circuits but it's simple topology & low cost makes it popular in low output power range [5].

Flyback converters are widely used in Low power SMPS applications: Cell phone charge unit, computer power sources (< 250W), To produce high voltage source for CRTs, To produce high voltage for Xenon flash lamps, lasers, photocopiers, Isolated driver circuits.

The commonly used flyback converter requires a single controllable switch like MOSFET & the usual switching frequency is in the range of 100 KHz. A two-switch exists that offer better energy efficiency & less voltage stress across the switches but cost more & the circuit complexity also increases slightly [9,10]. .

In this paper, we present, Basic flyback converter operation in part-II, Proposed flyback converter operation, Step By Step Design Procedure. Result & Discussion, in part-III, IV & V respectively.

II. FLYBACK CONVERTER

Converters can be classified as isolated and non-isolated. Flyback converter is one of the simple topology in isolated converters. Fig.1.1 shows the typical topology of flyback converters.

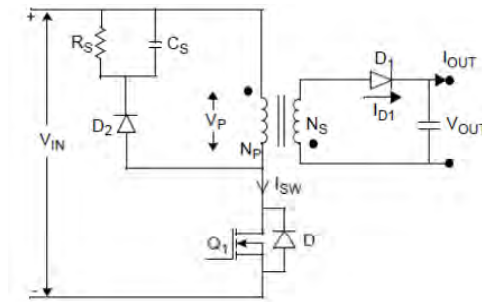


Figure 1.1: Basic flyback Topology.

Dot-ends of the inductors determine the operation of converter. Polarity of primary winding (L_p) and secondary (L_s) are not same. Operation of the converter is very simple; when the switch is turned-on, energy absorbed into the primary winding, then stored energy transferred to the secondary winding after switch turned-off [4,10]. This means there is no transformer action and L_p - L_s are only coupled- inductors. When switch Q is turned on, V_{dc} applied to primary winding. Because of constant V_{dc} , primary current I_p rise to peak value linearly [6]. At this interval, secondary winding is oppositely polarized to the primary inductor and consequently diode, D . Load current is supplied by capacitor, C . When switch Q is turned-off, stored energy at the air gap and magnetic core are transferred to secondary winding and load is fed by inductor L_s . I_s discharge linearly over resistive load. Stored energy at the air gap can be obtained from primary inductance and primary current by (1). Figure 1.2. Shows the waveforms of flyback converter topology.

$$E = \frac{1}{2} L_p I_p^2 \quad (1).$$

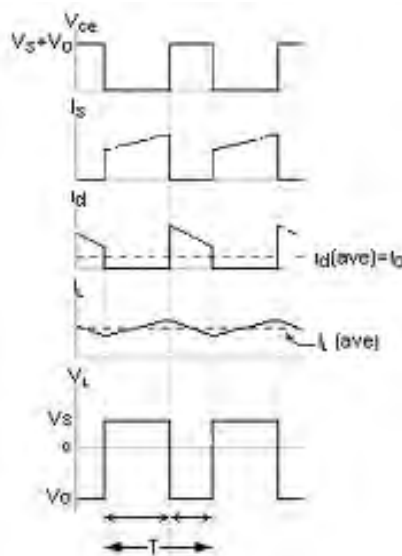


Figure 2: Waveforms of flyback converter topology.

III PROPOSED FLYBACK CONVERTER OPERATION:

The proposed circuit diagram of SMPS based flyback DC to DC converter is shown in figure3. This circuit takes the advantage to reduce cost & power supply size & to improve efficiency. The design delivers 30W at 12V. A nominal efficiency of 80% at full load is achieved using this topology.

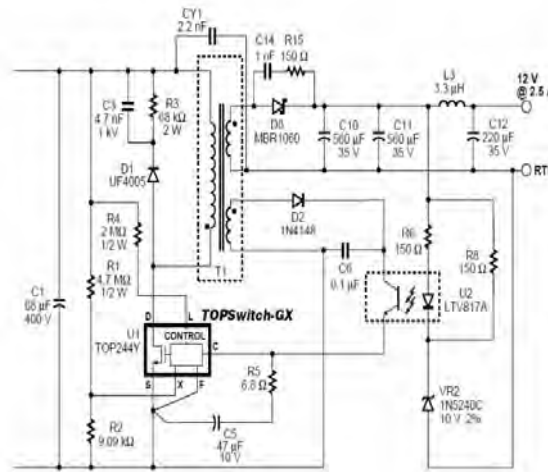


Figure 3: Proposed flyback converter circuit.

The current limit is externally set by resistors R1 and R2 to a value just above the low line operating peak DRAIN current of approximately 70% of the default current limit. This allows use of a smaller transformer core size and/or higher transformer primary inductance for a given output power, reducing MOSFET switch power dissipation, while at the same time avoiding transformer core saturation during startup and output transient conditions. The resistors R1 & R2 provide a signal that reduces the current limit with increasing line voltage, which in turn limits the maximum overload power at high input line voltage. This function in combination with the built-in soft-start feature of MOSFET IC, allows the use of a low cost RCD clamp (R3, C3 and D1) with a higher reflected voltage, by safely limiting the MOSFET drain voltage, with adequate margin under worst case conditions. Resistor R4 provides line sensing, setting UV at 100 VDC and OV at 450 VDC. The extended maximum duty cycle and the higher reflected voltage possible with the RCD clamp also permit the use of a higher primary to secondary turns ratio for T1 which reduces the peak reverse voltage experienced by the secondary rectifier D8. As a result a 60 V Schottky rectifier can be used for up to 15 V outputs, which greatly improves power supply efficiency.

Output regulation is achieved by using a simple Zener sense circuit for low cost. The output voltage is determined by the Zener diode (VR2) voltage and the voltage drops across the optocoupler (U2) LED and resistor R6. Resistor R8 provides bias current to Zener VR2 for typical regulation of +/- 5% at the 12 V output level, over line and load and component variations.

IV STEP BY STEP DESIGN PROCEDURE

The detailed system configuration of a flyback converter with optically isolated feedback loop is drawn in figure3. The circuit structure, analysis and design of transformer for the converter are described below.

Step 4.1. Determine system requirements:

$$V_{ACMAX} = 265V_{AC}$$

$$V_{ACMIN} = 85V_{AC}$$

$$f_L = 50\text{Hz}$$

$$f_S = 132\text{KHz}$$

$$V_O = 12V_{DC}$$

$$P_O = 12\text{W}$$

$$\eta = 80\% = 0.8$$

Loss allocation factor $Z = 0.5$.

Step 4.2. Determine maximum duty cycle at low line D_{MAX} using V_{OR} and V_{MIN} :

Once the V_{OR} and V_{MIN} are known, it is easy to calculate the D_{MAX} :

$$D_{MAX} = \frac{V_{OR}}{V_{OR} + (V_{MIN} - V_{DS})}$$

Step 4.3. Determine primary waveform parameters I_{AVG} , I_P , I_R and I_{RMS} :

The average DC current I_{AVG} at low line is simply the input power divided by V_{MIN} , where the input power is equal to the output power divided by the efficiency.

$$I_{AVG} = \frac{P_0}{\eta \times V_{MIN}}$$

With $K_{RP}=0.4$ and D_{MAX} already determined, the shape of the current waveform is known. Due to the simple geometry of the waveform, the Primary peak current I_p , ripple current I_R and RMS current I_{RMS} can be easily derived as a function of I_{AVG} :

$$I_p = \frac{I_{AVG}}{\left(1 - \frac{K_{RP}}{2}\right) \times D_{MAX}}$$

$$I_R = I_p \times K_{RP}$$

$$I_{RMS} = I_p \times \sqrt{D_{MAX} \times \left(\frac{K_{RP}^2}{3} - K_{RP} + 1\right)}$$

Step 4.4 Determine primary inductance L_p :

Because the energy transferred from primary to secondary each switching cycle is simply the difference between $1/2 \times L_p \times I_p^2$ and $1/2 \times L_p \times (I_p - I_R)^2$. The primary inductance L_p can be expressed as a function of I_p , D_{max} , and V_{min} :

$$L_p = \frac{D_{max} V_{min}}{I_p f}$$

After reviewing the core sizing information provided by the core manufacturer it was decided to use an EE core of size about 20mm. A Siemens N67 magnetic material is used, which corresponds to a Philips 3C85 or TDK PC40 material. The manufacturer recommends for that magnetic core a maximum operating flux density of:

$$B_{max}=0.2T$$

The cross-sectional area of the EE20 core is:

$$A_c = 33.5mm^2$$

Step 4.5. Calculate number of primary turn's n_p and secondary turns n_s :

The operating flux density is given by:

$$B_{max} = \frac{L_p I_p}{n_p A_c}$$

From the above equation one can obtain the equation for the number of turns of the primary winding:

$$n_p = \frac{L_p I_p}{B_{max} \times A_c}$$

The A_L factor (defines how many turns needed for a given inductance) is determined by:

$$A_L = \frac{L_p}{n_p^2} = \frac{L_p (B_{max} A_c)^2}{(L_p I_p)^2} = \frac{(B_{max} A_c)^2}{(L_p I_p^2)}$$

From the manufacturer catalogue recommendation, the core with an A_L of 100nHis selected. The desired number of turns of the primary winding is:

$$n_p = \sqrt{\frac{L_p}{A_L}}$$

The number of turns needed by the +12V secondary is (assuming an ultrafast rectifier is used);

$$n_s = \frac{(V_0 + V_{fwd})(1 - D_{max})n_p}{D_{max} V_{min}}$$

output power at minimum input line voltage, while meeting all specifications. Minor adjustments may be necessary to centre the output voltage.

V RESULTS AND DISCUSSION

The DC output voltage is noted for different DC input voltages and it is found to 12V DC voltage & 2.5A current for each case. The input & the flyback output relationship is shown in table 5.1. And DC output waveform is shown in figure 5.1.



Figure 5.1: DC output waveform for different in voltage of flyback converter.

Table5.1. Input Vs flyback output Relationship.

Input DC Voltage (V)	Flyback DC output Voltage(V)
18	12
20	12
24	12
28	12
30	12
45	12

The voltage across the primary winding of a transformer is shown in figure5.2. The voltage value measured for 24V DC input and it is found to be 24V with almost no spikes. This is due to the proper selection of RCD clamp circuit. The frequency of a waveform is about 132 kHz.



Figure5.2: waveform at the primary winding if the transformer.

The voltage across the secondary winding of a transformer is shown in figure5.3. The voltage value measured for 24V DC input and it is found to be 12V.



Figure5.3: Waveform across the secondary winding of a transformer.

The voltage across switch is also measured and it is found to be 48V for the 24V input. The voltage V_{DS} is two times that of the input voltage. The switch is operating at a frequency of 132 kHz and is shown in figure5.4.



Figure5.4: Voltage waveform across the switch (V_{DS}).

VI CONCLUSION

In this paper, analyze, design of transformer and implementation for flyback converters with desired parameters which is used in low power switch mode power supplies achieved. Implementation results are closely-matching with those obtained from the mathematical calculations. The results present that; proposed flyback converter is an excellent candidate for high-frequency, isolated DC-DC converters with low power applications.

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