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Design and Construction of Switch Mode Power Supply (SMPS)

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ABSTRACT

There are two types of DC power supply can be found in the market, Switch-Mode Power Supply (SMPS) and linear power supply. However, many customers prefer to choose SMPS than linear power supply because for same power rating, SMPS is smaller, cheaper and lighter than linear power supply especially transformer. The high frequency switching transformer that is used in SMPS is smaller and lighter than the transformer that is used in linear power supply. SMPS also have better efficiency than linear power supply. This project is focusing on developing SMPS using flyback converter topology. This flyback converter topology is chosen because it affords to carry power till 150 watts and few components are used to construct the circuit. There is high frequency switching transformer at the middle of flyback circuit that is used to isolate and step-down the high DC voltage and low DC voltage.

Keywords: Switch Mode Power Supply (SMPS), Through hole PCB, Power Transformers.

I. INTRODUCTION

Switched mode power supply converts the available unregulated ac or dc input voltage to a regulated dc output voltage. However in case of SMPS with input supply drawn from the ac mains, the input voltage is first rectified and filtered using a capacitor at the rectifier output. The unregulated dc voltage across the capacitor is then fed to a high frequency dc-to-dc converter.

Most of the dc-to-dc converters used in SMPS circuits have an intermediate high frequency ac conversion stage to facilitate the use of a high frequency transformer for voltage scaling and isolation. In contrast, in linear power supplies with input voltage drawn from ac mains, the mains voltage is first stepped down (and isolated) to the desired magnitude using a mains frequency transformer, followed by rectification and filtering. The high frequency transformer used in a SMPS circuit is much smaller in size and weight compared to the low frequency transformer of the linear power supply circuit. The 'Switched Mode Power Supply' owes its name to the dc-to-dc switching converter for conversion from unregulated dc input voltage to regulated dc output voltage.

SMPS are rapidly replacing linear regulated power supplies in most of the consumer electronic applications due to their advantages like higher efficiency, better output voltage regulation, compact size. In this paper the 25W SMPS has been designed by using a flyback isolating transformer.

The main components used in the design of SMPS are as follows

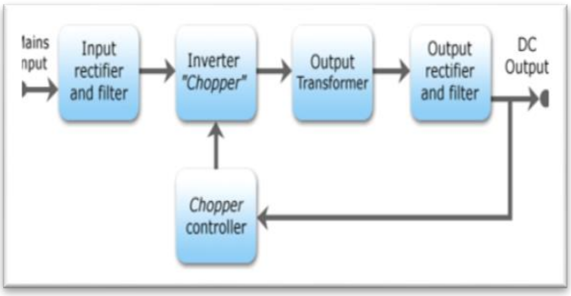
- Kbl10 (Bridge Rectifier)

- Mov Capacitor
- Resistor
- Capacitors
- Top Switch 258 With Heat Sink
- Smps Transformer
- Mbr30100(Schottky Diode)
- Ka431 (Shunt Regulator)
- Pc817(Opto Coupler)
- Diodes
- Throuh Hole Pcb Board

II. METHODOLOGY

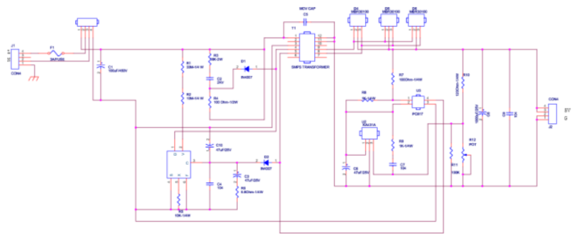
The SMPS can be made of different voltage and current ratings based the output requirements. The design of SMPS worked in this paper is basically 5V, 5A, 25W SMPS.

The basic block diagram of SMPS is as follows



The input supply drawn from the ac mains, the input voltage is first rectified and filtered using a capacitor at the rectifier output. The unregulated dc voltage across the capacitor is then fed to a high frequency dc-to-dc converter. The dc-to-dc converters used in SMPS circuits have an intermediate high frequency ac conversion stage to facilitate the use of a high frequency transformer for voltage scaling and isolation. The high frequency transformer used in a SMPS circuit is much smaller in size and weight. Then the output of the transformer is connected to the output rectifier and filter then the output is being fed to the output.

III. DESIGN AND CONSTRUCTION OF SMPS



Schematic diagram of SMPS

The components and type of topology are selected based on the specifications. For the converter AC input voltage varying from Vin_min 80V and Vin_max 285V, corresponding bridge rectifier DC voltage and hence DC input to flyback converter varies from VDC_min 72 V to V DC_max 400V. The nominal switching frequency is 132 kHz and the Switching frequency of converter topology ranges between 30 kHz to 150 kHz according to the variation of load and input voltage, and expressed by equation (3.1)

$$F_{SW} = \frac{1}{I_{pri_{pk}} * L_{pri}\left(\frac{1}{V_{in}}+\frac{1}{V_R}\right)+\pi\sqrt{L_{pri}(C_D)}} \quad \text{.....3.1}$$

Where

F_{SW}: Switching frequency

V_{in} : AC input voltage

V_R : Reflection voltage

L_{pri}: Primary inductance of transformer

C_D : Capacitance of drain

$I_{pri_{pk}}$: Primary peak current of transformer

T_{on} : ON time period of switch

T_{off}: OFF time period of switch

The variation in the duty cycle with respect to switching frequency is presented by equation

$$D = \frac{T_{on}}{T_{on} + T_{off}}$$

Considering efficiency of the converter is η as 85%.

Where

D: Duty cycle

T_{on}: ON time period of switch

T_{off} : OFF time period of switch

Total output power

P_{out}=$V_{out} * I_{out}$

3.1 DESIGN OF SMPS TRANSFORMER(DCM FLYBACK)

The design of flyback transformer is shown in below steps

STEP 1: System Specifications and Requirements:

Table 2. Flyback Transformer System Specifications

Parameter	Value	Name
Vac Maximum	265V	Maximum input AC voltage
Vac Minimum	85V	Minimum input AC voltage
Fsw	132KHz	Switching Frequency
Eff	75%	Efficiency
Pout	30W	Output power (maximum)
Vout	5V	Output Voltage
Fline	60Hz	Line Frequency

STEP 2: Determining Input Capacitor Cin and the DC input voltage range:

Maximum input power: $PinMax = \frac{Pout}{n}$

Using 1uF per watt of input power, the required DC capacitor

C_{in} is:

C_{in}=40uF

Use the standard capacitance value of 40uF/400V

With the input capacitor chosen the minimum DC input voltage (DC link capacitor voltage) is obtained by:

$$VDCmin = \sqrt{2Vac^2 - \frac{Pinmax * (1 - d_{Charge})}{Cin * Fline}}$$

STEP 3: Flyback reflected voltage (VR) and the Max VDS MOSFET voltage stress, VR is chosen at 75V. Assuming 30% leakage spike the expected maximum VDS is equal to:

V_{DSmax}=V_{DCmax}+V_R+30% of V_{spike}

STEP 4: Determining D_{max} based on $V_{reflected}$ and V_{inmin}:

$$D_{max} = \frac{V_R}{V_R + V_{DCmin}}$$

STEP 5: Calculate primary inductance and primary peak current: The primary peak current can be found by

$$P_{inmax} = \frac{P_{outmax}}{n}$$

$$I_{pri} = \frac{2 * P_{inmax}}{V_{dcmin} * D_{max}}$$

The primary inductance should then be design within the limit of maximum duty cycle;

$$L_{primax} = \frac{V_{dcmin} * V_{dcmax}}{I_{pri} * f_{sw}}$$

STEP 6: Choosing the proper core type and size: we can use EE20/10/6 ferriite core for this 25W power level

Core: EE20/10/6 Ferroxcube/TDK

Cross Sectionl Area, Ae=32mm^2

Core Material: 3C96/Ferroxcube, TP4A/TDK

Bobbin: E20/10/6 coil former, 8 pins

STEP 7: Determining minimum primary turns:

$$N_p = \frac{L_{pri} * I_{pri}}{B_{max} * A_e}$$

It is important that operating B_{max} should not exceed the saturating flux density (B_{sat}) given on the core's data sheet. B_{sat} of ferrite core varies depending on the core material and temperature but most of them has a B_{sat} rating closed to 400mT. If there is no further reference data used B_{max}= 300mT. Higher B_{max} allows for lower number of primary turns for lower conduction loss but with higher core loss. For optimized design the sum of both the core loss and the copper loss should be mutually minimized. This usually happened near the point where core loss is equal to the copper loss.

STEP 8: Determine the number of turns for the secondary main output (Ns) and other auxiliary turns (N_{aux}):

$$n = \frac{V_R}{V_{out} + V_d}$$

$$N_s = \frac{N_p}{n}$$

An auxiliary winding N_{aux}, on the primary is needed for the VCC supply

$$\frac{N_{aux}}{N_s} = \frac{V_{auxmax} + V_f}{V_{out} + V_f}$$

STEP 9: Determining the wire size for each output windings: The RMS current on each winding is calculated: Primary winding RMS current:

$$I_{prms} = I_p * \sqrt{\frac{D_{max}}{3}}$$

Secondary Winding RMS current:

$$I_{secpk} = I_p * \frac{N_p}{N_s}$$

$$I_{secrms} = I_{secpk} * \sqrt{\frac{1 - D_{max}}{3}}$$

STEP 10: Calculation of the wired size

$$A_{wpri} = \frac{I_{prms}}{J_{max}}$$

Where, A_{wpri} =Size of the primary wire in mm^2

$J_{max=}$Current density in A/mm^2

$$A_{waux} = \frac{I_{auxrms}}{J_{max}}$$

A_{waux} =Size of the auxillary wire in mm^2

$$A_{wsec} = \frac{I_{srms}}{J_{max}}$$

A_{wsec} =Size of the secondary wire in mm^2.

Output diode selection

The selection of output diode is governed by the output voltage and output capacitor voltage twice of these voltage the ratings of diode is selected. The maximum voltage across the diode is 24V and maximum current is 5A. Hence by considering the factor of safety,

MBR30100 Diode of 100V, Vf =0.15V and 20A rating is selected.

Power loss in output diode is

P_D= Vf*Iout (3.34)

= 0.75 W.

Output capacitor selection:

The output capacitor is selected on the basis of permissible ripples ΔVo = 80mV in the output and is determined by equation.

$$C_{out} = I_{out} * (1 - D_{min}) * T_s \Delta V_o$$

= 0.9mF

Thus, 1capacitor of 1000uF value each are selected.

Prototype model of an SMPS

IV. CONCLUSION

In this paper a 5V, 5A SMPS has been implemented.

- ✓ It has high efficiency and low cost and small weight and size.
- ✓ The operation of flyback transformer has been studied and a flyback transformer is being implemented.
- ✓ The losses will be minimum and only the switching losses are present.
- ✓ The current rating is medium.
- ✓ The high frequency transformer used in a SMPS.

In addition to the proposed SMPS, the SMPS can also be implemented to multiple outputs using DC-DC converters.

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