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Designing of DC-DC Converter

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***Abstract*— Today, human beings all around the globe are in need of automation. Electronic devices are needed in order to achieve automation and an efficient power supply is backbone of any electronic device and circuits. Without an efficient power supply one won't be able to do day to day work effectively. Therefore in order to make our live easier, power supply is needed. In this manuscript, designing of a DC-DC converter with particular performance specifications is done using analog circuitry. A DC-DC converter has been designed which converts 5V DC input to 250V DC output.**

***Index Terms*- Automation, power supply, DC-DC converter, analog circuitry**

I. Introduction

There are basically two categories of power supply-:

A. Linear Power supply

The voltage which is produced by an unregulated power supply will vary and will depend upon the load variations and the variations in the AC supply voltage [1], [4]. The voltage of a linear voltage regulator can be set to a precise value which is stable against any variation in load and input voltage for critical applications. The noise and ripple can also be greatly minimized in the output direct current by the use of a regulator. Also a safety feature against over current is provided by a regulator which limits the current to a safe value above which the attached circuitry might get damaged [5].

B. Switching Mode Power Supply

The input at the AC mains is directly rectified and then the rectified voltage is filtered to get the desired DC voltage in a switched-mode power supply. The DC voltage thus obtained is then switched on and off rapidly at a very high frequency by an electronic switching circuitry, which as a result produces an AC current which is capable of passing through a inductor or a high-frequency transformer. The switching frequency is very high (approximately 20KHz- 2MHz) as a result smaller cheaper and lighter transformers and filter capacitors can be used as compared to those which are found in linear power supply which are very expensive and bulky [1].

In this technical report, switched mode power supply has been used to design a DC-DC converter. Although a linear regulator is capable of providing a stable and desirable output voltage but it also dissipates excess amount of power in form of ohmic losses for example in losses that occur in CE region of a transistor during active mode of a transistor or ohmic losses in a transistor [3]. A linear voltage regulator is capable of regulating both output voltage and current but it dissipates a large amount of electric power in form of heat and thus its maximum power efficiency is quiet low. On the other hand switched mode power supply regulates both output voltage and current by switching all the ideal storage elements (capacitors and inductors) in and out of the electrical configuration. The ideal switching elements like transistor which are acting outside their active mode can theoretically operate at 100% efficiency as the have no resistance when they are in a closed circuit and they carry no current when they are in open circuit (i.e. no power is wasted at all and all the input power is transferred to the load) [6], [7].

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II. Switched-MODE POWER SUPPLY

A switched mode power supply is also referred as a switcher or simply called as SMPS. A switched mode power supply is capable of converting electrical energy efficiently by incorporating a switching regulator. Like all the other power supplies, the main function of an SMPS is the transfer of power from a source such as mains power supply to a load such as a television set while altering voltage and current characteristics [5]. A switched mode power supply is capable of providing a regulated output voltage efficiently, typically at a level which is different from the input voltage. There are basically two topologies of SMPS which are isolated and non-isolated. Non-isolated topologies make use of inductor to store energy and isolated topologies make use of transformer to store energy. SMPS are further classified in base of their configuration as flyback, ring choke converter, half-forward, forward, resonant forward, push-pull, half-bridge, full-bridge [1].

III. DESIGN SPECIFICATIONS

The aim is to design a power supply which is miniaturized, reliable, efficient, durable and also least expensive.
In this technical report designing has been done according to following specification:

- *Vin=5V (DC)*
- Vout =250V (DC)
- Output Power= 2 Watt
- Efficiency > 85%
- Topology Used = Flyback Converter

- Load Regulation
- Line Regulation
- Frequency = 240 KHz

In this technical report flyback topology has been used as it is best suited as per circuit requirement. It can be used for circuits having power ratings between 1 to 250 watts. It is relatively cost effective than other configurations. It has wide input range of 5V-500V. also its efficiency is greater than 85%.

IV. BLOCK DIAGRAM OF DC-DC CONVERTER

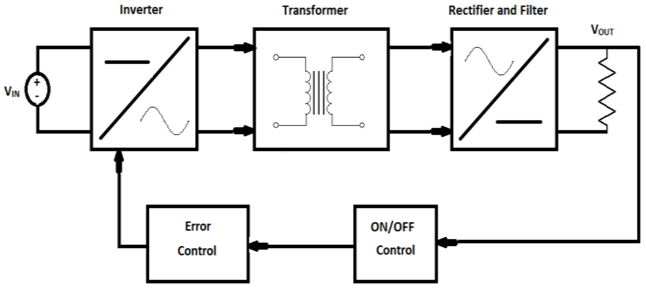


Figure no.1 Block Diagram of a DC-DC Converter

A. DC/AC Converter-:

A 5V DC power supply is used as the input to the circuit. It has to be converted into AC signal such that it could be fed into the transformer. For this purpose a PWM controller IC has been used. The main function of PWM controller IC is to convert the input DC signal into pulses of same amplitude. The IC has to be selected in such a way that it meet requirement of the circuit. For the purpose of this particular designing TPS 55340 IC has been used because it meets the required parameters of the project. Its input supply range is from 4.5V to 52V. It also has a very wide frequency range. Also it has a inbuilt mosfet and is very miniaturized in size [3].

B. Transformer-:

Transformer converts AC power from one voltage level to another voltage level. Transformers works only with AC and that is why mains electricity is AC. Step-up transformers tends to increase voltage level on the other hand step-down voltage tend to reduce voltage. The coil at the input of the transformer is called the primary coil and the coil at the output is called the secondary coil. There exists no physical connection between primary and secondary coil, instead there is an alternating magnetic field in soft-core of the transformer which couples the two cores. Transformer dissipate a very little power, so power in is almost equal to power out. The ratio of the number of turns on each coil, called the **turns ratio**, determines the ratio of the voltages. A step-down transformer has a large number of turns on its primary (input) coil which is connected to the high voltage mains supply, and a small number of turns on its secondary (output) coil to give a low output voltage.

Transformer calculations [2]:-

V_{in}=5V V_{out}=250V
I_{out}=10mA F=240 KHz
B_m=0.3 η=0.85

1. Calculation of output Power (P_o)

$$P_o = V_{out} \times I_{out}$$
$$=250 \times 10 \times 10^{-3}$$
$$P_o = 2.5\ W$$

2. Calculation of Apparent Power (P_t)

$$P_t = P_o\left(\frac{\sqrt{2}}{\eta} + \sqrt{2}\right)$$
$$P_t = 2.5\left(\frac{\sqrt{2}}{0.85} + \sqrt{2}\right)$$
$$P_t = 7.7\ Watt$$

3. Calculation of number of primary turns (N_P)

For POT 1408 $A_p = 0.0065\ cm^4$,
$A_c = 0.10\ cm^2$

$$N_p = \frac{V_p \times 10^4}{k_f \times B_m \times f \times A_c}\ turns$$
$$N_p = \frac{5 \times 10^4}{4 \times 0.3 \times 240000 \times 0.10}\ turns$$
$$N_p = \sim 2\ turns$$

4. Calculation of Primary current (I_P)

$$I_p = \frac{P_o}{\eta V_{in}}$$
$$I_p = \frac{2.5}{0.85 \times (5)}$$
$$I_p = 0.588\ A$$

5. Calculation of current density (J)

$$J = k_j \times (A_p)^y$$
$$J = 433 \times (0.0065)^{-0.17}$$
$$J = 1019.3\ A/cm^2$$

6. Calculation of bare wire size $A_{w(B)}$ for primary

$$A_{w(B)} = \frac{I_p}{J}\ cm^2$$
$$A_{w(B)} = \frac{0.588}{1019.3}\ cm^2$$
$$A_{w(B)} = 0.5768 \times 10^{-3}\ cm^2$$

7. Selection of wire size

From the AWG table select wire of size 29 AWG for

$$A_{w(B)} = 0.80 \times 10^{-3}\ cm^2$$

8. Calculation of number of secondary turns (N_s)

$$N_S = \frac{N_p \times V_S}{V_p}\ turns$$
$$N_S = \frac{2 \times 250}{5}\ turns$$

$$N_S = 100 \ turns$$

9. Calculation of bare size for secondary $A_{w(B)}$

$$A_{w(B)} = \frac{I_S}{J} \quad cm^2$$

$$A_{w(B)} = \frac{0.010}{1019.3} \quad cm^2$$

$$A_{w(B)} = 0.0098 \times 10^{-3} \quad cm^2$$

10. Calculation of secondary wire size
    From the AWG table select wire of size less than 44 AWG for secondary winding.

C. Rectifier-:

A rectifier circuit is used to convert ac signal to dc signal. In this circuit a single diode rectifier after the transformer stage has been used.

D. Feedback-:

The feedback circuit consists of on/off control and error control loop. A feedback signal is fed from output of the circuit to the PWM controller IC so as to provide line and load regulation. The feedback circuit provides stability to the output.

Calculations-:

1) R_{Freq}=57500×Freq$(khz)^{-1.03}$
   =57500×$(160)^{-1.03}$
   =390 kΩ
2) V_{out}=1.229× $(\frac{R_{SH}}{R_{SL}}$+1)

250 =1.229× $(\frac{R_{SH}}{R_{SL}}$+1) , $\frac{R_{SH}}{R_{SL}}$ = 202.41

V. DESCRIPTION OF COMPLETE CIRCUIT

The aim of this technical report is to amplify a 5V DC signal to a 250V DC regulated signal. For this purpose a regulated power supply as input source has been used. A 5V DC signal is fed into the primary winding of the transformer and also to the V_{in} and enable of the PWM controller IC (TPS 55340). The other end of the primary winding is connected to the mosfet switch of the IC. The pulse generated by the IC switches on and off the mosfet whose time duration depends upon the width of on pulse and off pulse [3]. When the pulse is switched off the energy is stored into the primary winding of the transformer. When the pulse is switched on the energy gets transferred to the secondary winding of the transformer. The signal gets amplified, whose magnitude depends upon the turns ratio of the transformer. The frequency of the pulse signal is decided by the resistor which is attached to the Freq pin of IC. This amplified signal which is AC in nature is fed into the rectifier circuit which is combination of a diode and a capacitor [4]. The rectifier circuit converts the AC signal to DC signal. The output of the complete circuit is decided by following equation:-

$$V_{out}=1.229\times \left(\frac{R_{SH}}{R_{SL}}+1\right)$$

In order to get line regulation and load regulation a feedback signal is fed from output of the IC The output of the circuit is regulated according to the given equation:-

$$V_{out}=V_{in}\times\frac{N_{sec}}{N_{prm}} \times \frac{T_{on}}{T_{off}}$$

V_{in} and transformer turn ratio is fixed by the designer. The varying duty cycle of the pulse generate by the PWM controller IC whose T_{on} and T_{off} duration depends upon feedback signal of circuit helps to provide regulation to the circuit [4]. Schematic design of complete circuit is given in figure no. 2 and final circuit glimpses are given in figure no.3.

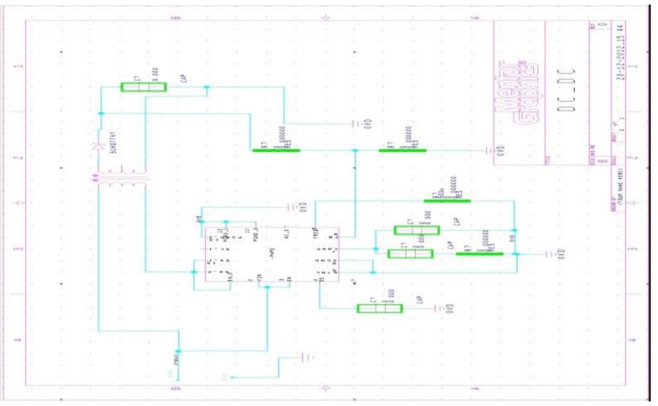
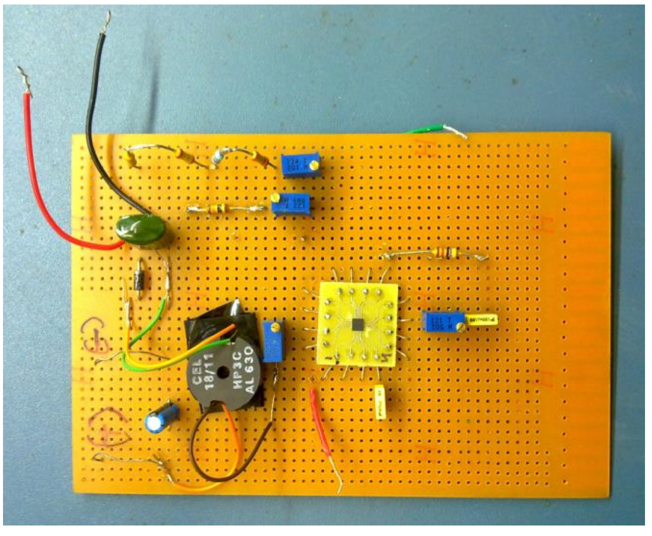


Figure no.2 Schematic diagram of complete circuit

Figure no. 3 Final circuit glimpses



VI. CONCLUSION

By using the above presented calculation, a DC-DC converter has been designed having following specifications:

1. V_{in} : 5V

2. V_{out} : 250V
3. Output Power : 2 Watt
4. Efficiency : 86 %
5. Topology used : Flyback topology
6. Frequency : 240 KHz

In this manuscript designing according to a particular set of design parameters has been done. Any desired configuration of DC-DC converter can be achieved by simply manipulating the values of resistance, wire size, transformer turns ratio by using the calculations explained in the earlier sections of this manuscript.

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REFERENCES

[1] .Digital Power Electronics and Applications by Muhammad Rashid
[2].Transformer and Inductor Design Handbook by Colonel.Wm.T.Mclyman
[3]. Data sheet of TPS 55340
[4]. Data sheet of UF 4007
[5] V. Vorperian, "Simplified Analysis of PWM Converters Using the Model of the PWM Switch: Parts I and II," *IEEE Transactions on Aerospace and Electronic Systems*, Mar. 1990, Vol. 26, No.2.
[6] H. Dean Venable, "Optimum Feedback Amplifier Design for Control Systems," Venable Technical Paper.
[7] H. Zhang, "PCB Layout Considerations for Non-Isolated Switching Power Supplies," Application Note 136, Linear Technology Corp., 2012.

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