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Design of Cost Effective Flyback Converter with Wide Input Voltage Range

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ABSTRACT: Nowadays we see that new innovations and technologies are growing in field of electronics. For any designer the cost, size or efficiency is the consideration for implementing the design. Power supply forms an integral part of any technology. Power supply can be classified into linear and switch mode power supplies. Switch mode power supplies are widely used in many applications due to its high efficiency and thermal stability. One such converter is a Flyback converter which is isolated dc-dc converter. It finds its use in various application because of its simplicity, low cost design, ability to provide multiple output and isolation between input and output. In this paper, the cost effective design of Flyback converter is discussed and its working is proved via simulation study. The simulation was carried out using LT Spice.

KEYWORDS: Flyback, SMPS, Isolated, PSR, DCM, Simulation.

I. INTRODUCTION

The field of power electronics has contributed a lot to the research and development sector. One such contribution is SMPS. SMPS are popular due to its efficient working compared to linear mode power supplies. SMPS can be further divided into isolated and non-isolated converters. Non-isolated dc-dc converters are efficient, cost effective but they do not provide any isolation between input and output side. Isolated converters find their suitability where isolation is required between input and output. One of the isolated converter which finds its use in many applications due to its simplistic design and isolation needs is flyback converter. It is used in low power applications for power range from few watts to 100W.[1]

Flyback converter finds its place in array of applications. It is used in industrial, commercial, automotive and medical applications etc. As far as efficiency is considered flyback is inferior to other SMPS circuits. But due to its isolation provision, low cost design and multiple output derivation it is extensively used. Flyback converters are operated at high switching frequencies. Flyback converter can operate smoothly over a wide input voltage range by controlling duty cycle through feedback sensing mechanism.[2]

The designer has to develop a design for specific application based on following approaches:

- High efficiency
- Low cost
- Less space
- Balanced

The paper is organised into five sections. Section I gives introduction. Section II gives outlook to flyback converter topology working and its principle. The detailed design approach for flyback converter with input specifications is given in Section III. Section IV presents simulation results showing analysis and waveforms of the design proposed. Finally the section V gives conclusion of the results obtained.

II. LITERATURE SURVEY

Flyback converters are isolated dc-dc converters which have galvanic isolation achieved by transformer. As we are using transformer it can also generate multiple outputs as we can connect N no. of windings in the transformer. Fig 1

shows the flyback converter equivalent circuit. It consists of coupled inductor, switch, capacitor and diode. Supply may be unregulated dc supply. The switching frequency is in kHz. Hence mostly MOSFET is preferred as switch for high switching frequency. The coupled inductor with gapped core is used in flyback converter. The transformer operation in flyback converter is bit different from other topologies. Here it acts like split or coupled inductor and core stores the energy when primary switch is in ON state and then transfers it to secondary side when switch is made OFF. This is due to connection of inductors. The inductors phase dot are reversed. Hence when primary switch is ON rectifying diode at secondary is reverse biased. Hence in this condition output capacitor supplies energy to the load. The gapped core stores the energy in this mode. Whenever switch becomes OFF the stored energy in the core is transferred to secondary side as the secondary diode is now forward biased. In this mode energy is supplied by secondary inductor. The switch is controlled by driver circuit which controls the duty cycle as per load requirements and input variations.[3]

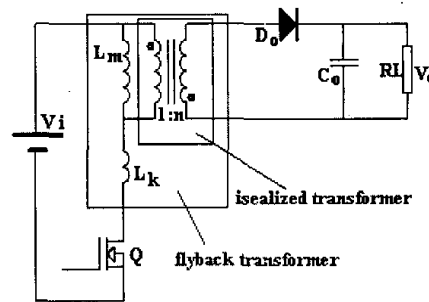


Fig 1 Flyback Converter[4]

Flyback converter can be operated into three types of conduction modes namely CCM, BCM and DCM. CCM is continuous conduction mode, BCM is boundary conduction mode and DCM is discontinuous conduction mode. Every mode has its own advantages and drawbacks. The mode is chosen as per design requirements for the specific application.

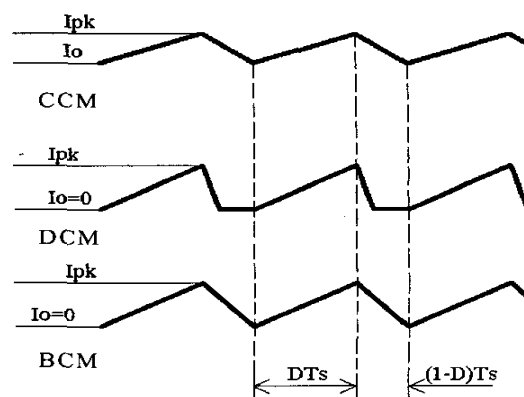


Fig 2 CCM, DCM and BCM mode flyback converter waveforms[4]

Fig 2 shows the CCM, DCM and BCM mode waveforms. In CCM mode of operation the energy stored in transformer core is not completely transferred to the secondary side. The current (primary and secondary inductor) does not reach zero level. Whereas in DCM the energy stored in the core is transferred to secondary completely before the start of the next switching cycle. Here the current reaches zero level. While in case of BCM the energy is transferred from core to secondary just on the boundary of completion of the cycle. It is also called as critical conduction mode.[5]

Primary Side Regulation (PSR) and Secondary Side Regulation (SSR) are two methods used for regulating the output voltage. As the name suggests PSR uses the feedback network from primary side and SSR uses feedback from secondary side. Fig 3 shows us the PSR method for flyback converter and fig 4 shows the SSR method.

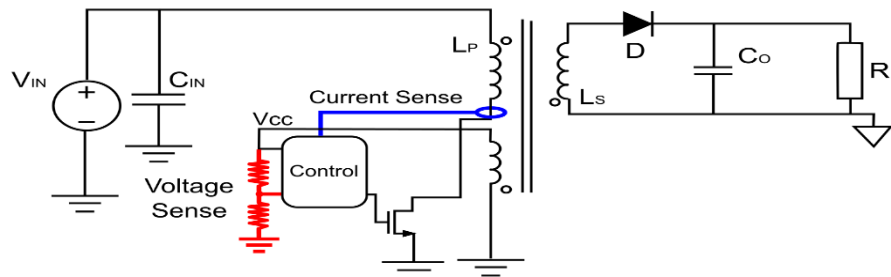


Fig 3 Primary Side Regulation[6]

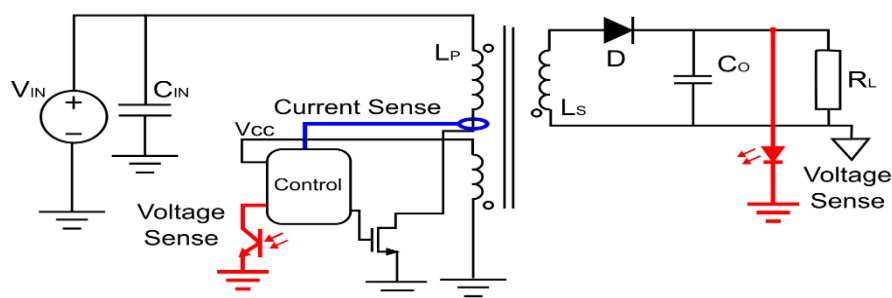


Fig 4 Secondary Side Regulation[6]

In SSR method the feedback is sensed through the secondary side. It requires opto-coupler for feedback circuit as primary and secondary are to be kept isolated. SSR method is more accurate even for multiple output due to its better cross regulation. But it requires more components and also opto-isolator degrades over the time.

The cost related drawback of SSR can be overcome by the PSR method which indirectly senses the output. This method uses turns ratio of the transformer as a factor for feedback circuit. This reduces the overall cost of the converter as less components are required. It has less accuracy and slow transient response whenever multiple outputs are connected. The further cost reduction can be achieved by eliminating the third or bias winding in PSR method.[6][7]

III. DESIGN OF FLYBACK CONVERTER

The design of flyback converter for the given input and output specifications is designed as follows.

Input Voltage	18-24V DC
Output Voltage	12V DC
Output Power	6W
Switching Frequency	66 kHz
Mode	DCM

Table 1 Input and Output Specifications

Flyback converter design is iterative in nature. We have to make certain assumptions while picking up components and then verify it in later analysis. Like we assume D_{max} and then design the inductance but value of inductance selected might be different which causes change in D_{max} of the circuit. Also we need to verify if the selected components are adequately capable of handling the stress at worst cases. We can follow certain flow of design steps while designing a flyback converter.

The design steps are as follows:[8]

1. Select a controller IC
2. Switching frequency selection
3. Selecting mode of operation
4. Using input voltage range to select D_{max} goal

5. Determining the maximum power and picking up a switch
6. Primary inductance design
7. Designing winding ratio of the transformer
8. Verifying the switch is capable
9. Design output capacitor based on ripple voltage
10. Ancillary IC components design

Based on the above design flow and for the given specifications LT3573 IC was chosen. It is designed for the isolated flyback topology. No additional winding or opto-isolator is required for regulation. It senses the isolated output voltage directly from the primary-side flyback. It has integrated switch with 1.25A, 60V rating along with all control logic. It operates with input supply voltage range from 3V to 40V, and can deliver output power up to 7W with no external power devices requirement.[9]

The switching frequency is 66 kHz. Mode of operation is DCM. Assume secondary diode forward voltage drop as 0.8V. Let us calculate first reflected voltage V_r which is reflected on primary side.

$$D_{max} = 0.48 = \frac{V_r}{V_{inmin} + V_r} = \frac{V_r}{18 + V_r}$$

$$V_r = 16.62 \text{ V}$$

Now the maximum switch voltage is

$$V_{swmax} = V_{inmax} + V_r = 24 + 16.62 = 40.62 \text{ V}$$

$$40.62 < 50$$

As the maximum stress voltage should be less than 50V (considering safety margin) our design assumption are correct. Let us assume converter efficiency to be 80%.

$$\text{So input power } P_{in} = \frac{P_{out}}{\eta} = \frac{6}{0.8} = 7.5 \text{ W}$$

$$\text{Average input current } = I_{av} = \frac{7.5}{18} = 416.7 \text{ mA}$$

$$\text{Peak input current } = I_{pk} = I_{pk} = \frac{0.4167}{0.5 \times 0.48} = 1.7363 \text{ A}$$

$$\text{Primary inductance } L_p = \frac{V \Delta t}{\Delta I} = \frac{18 \times (0.48)}{(66000) \times 1.7363} = 75.39 \mu\text{H}$$

$$\text{Transformer ratio } N = \frac{V_r}{V_{out} + V_f} = \frac{16.62}{12.8} = 1.3$$

$$\text{Secondary inductance } L_s = \frac{L_p}{N^2} = \frac{75.39}{1.3^2} = 44.61 \mu\text{H}$$

The Transformer Design and core selection:

Core selected: EE16/8/5 Ferroxcube/TDK

$$A_e = 20.1 \text{ mm}^2$$

Core material: 3C90/Ferroxcube

$$\text{No. of Primary turns } N_p = \frac{L_{pri} \times I_{pri}}{B_{max} \times A_e} \approx 22$$

$$\text{No. of Secondary turns } N_s = \frac{N_p}{n} = \frac{14}{1.3} \approx 17$$



$$\text{Primary RMS current } I_{prms} = I_p \times \sqrt{\frac{D_{max}}{3}} = 0.7A$$

$$I_{spk} = \frac{12.8 \times (0.52)}{66000 \times 44.61 \times 10^{-6}} = 2.26 A$$

$$\text{Secondary RMS current} = I_{srms} = I_s \times \sqrt{\frac{1-D_{max}}{3}} = 0.95A$$

For primary AWG 26 and for secondary AWG 24 wire can be used.

$$\text{The PRV for diode is } V_{prv} = \frac{24}{1.3} = 18.46V$$

So we need $18.46 \times 1.5 = 27.69V$ minimum rating of diode.

The selected diode is 40V, 3A rated.

The output capacitor selection. Let us assign 67% of ripple voltage to ESR and 33% to AC impedance. Let us assume 100mV of ripple voltage.

$$ESR = \frac{0.67 \times 100}{2.13} = 31.46 m\Omega$$

$$X_c = \frac{0.33 \times 100}{2.13} = 15.49 m\Omega$$

$$C = \frac{1}{2\pi \times 66 \times 15.49} = 155.68 \mu F$$

The selected capacitance is 180 μ F, 25V

The clamp circuit consists of zener diode and schottky diode.

The breakdown voltage rating of zener

$$V_z = V_r \times 1.4 = 23.26V$$

The selected zener is with breakdown voltage of 24V.

The schottky diode should be of minimum rating $24 \times 1.5 = 36V$. So the selected is with 40V and current of 2A

The overall design contains IC LT3573, transformer, 2 schottky diodes, 1 zener diode, resistors and capacitors. So total component count is decreased. Also no third winding is included in this design. Hence transformer cost is also less.

IV. SIMULATION RESULTS

The simulation was carried out in LT Spice simulation software. LT Spice is used to produce ideal as well as real world simulation analysis using ideal or real world components available in the component library. It has waveform viewer to view the designed schematic output. This platform was used to carry out and validate the design.

The schematic of the design is shown in fig5 which shows the designed flyback converter with real world components.

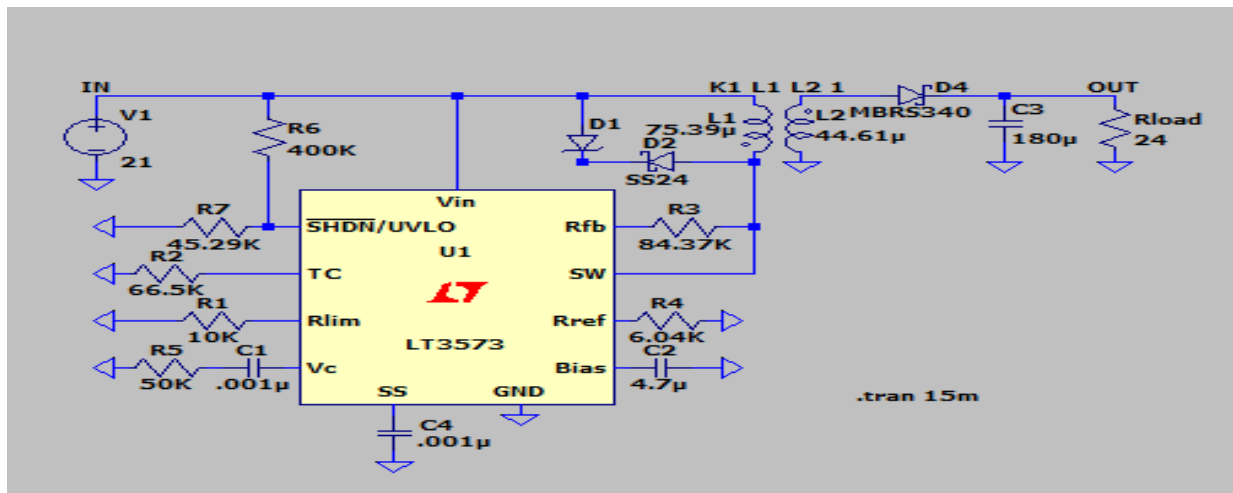


Fig5 Simulation schematic of NO-Opto Flyback converter on LT Spice.

The fig 6 shows waveforms of steady state output voltage (red coloured) for variation in input voltage from 18-24V (blue coloured). The input voltage is ramped up from 18-24V. For variation in input voltage within specified range it was seen that the design produced constant 12V at output. This validates our design that would work for specified input voltage range.

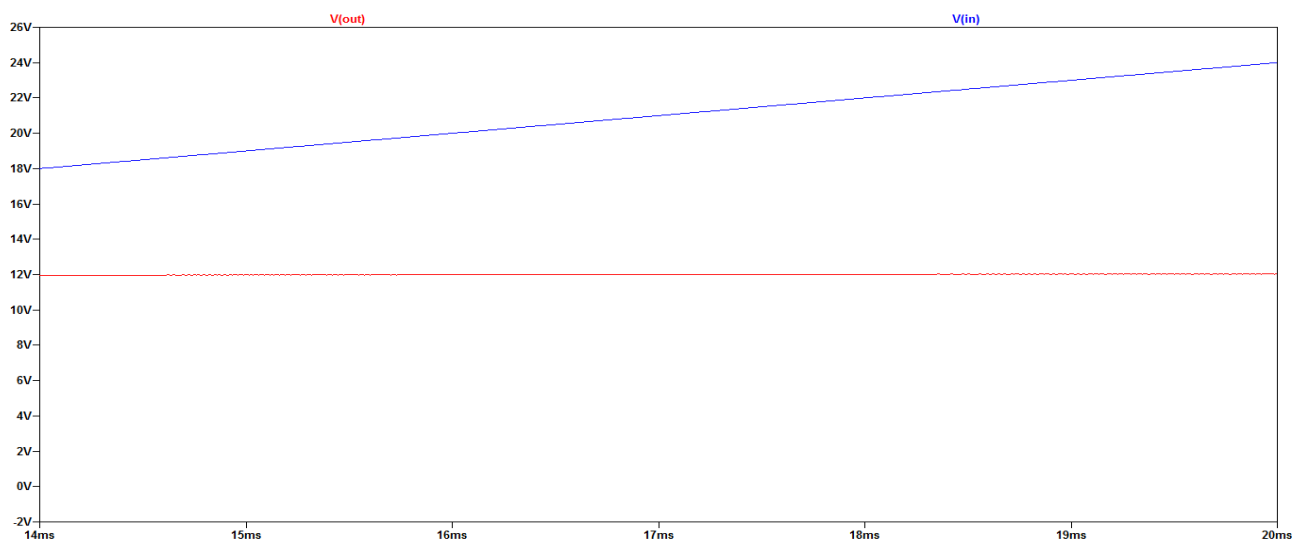


Fig 6 Steady State output voltage waveform with input voltage variations

Fig 7 shows input inductor current (red coloured) at 18V input voltage. It was observed that peak input inductor current is 1.6A at minimum input voltage. Duty cycle is 0.48. Hence average current can be calculated as $1.6 \times 0.48 \times 0.5 = 0.384A$.

This average current is lesser than what was calculated. This shows that our minimum efficiency assumption was correct. The actual efficiency is better than what was assumed.

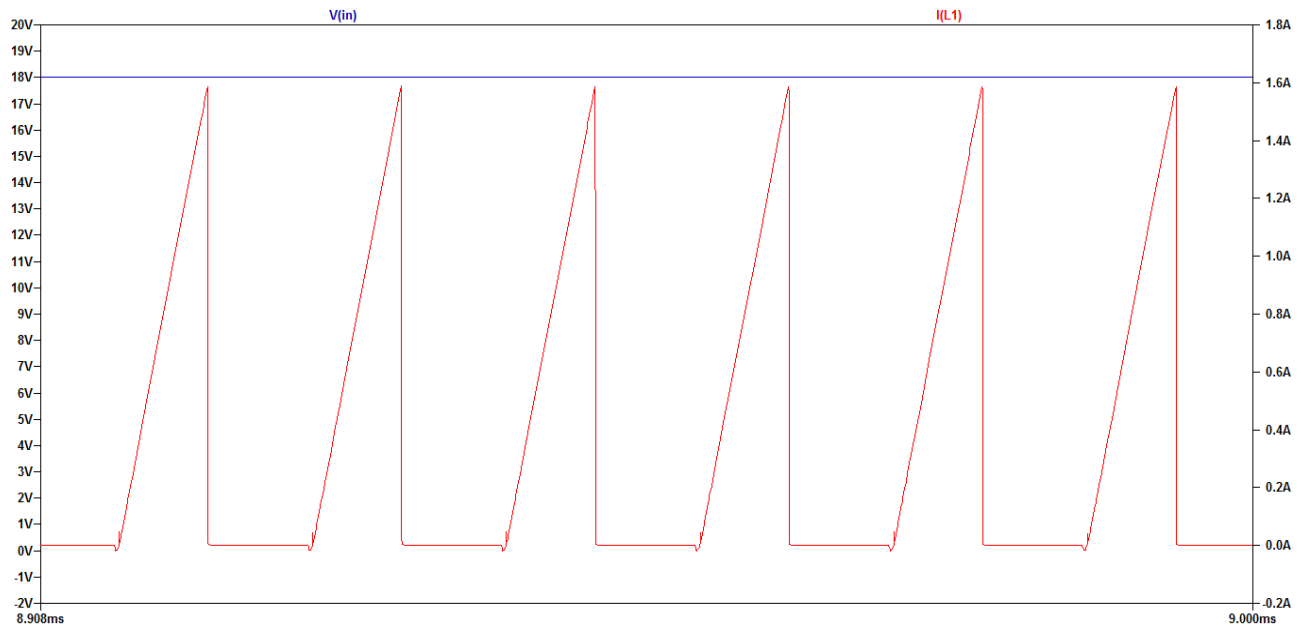


Fig 7 Input inductor current at 24V input

INPUT VOLTAGE (V)	OUTPUT VOLTAGE (V)	EXPECTED VOLTAGE (V)	ERROR (%)
18	12.04	12	0.33%
21	12.04	12	0.33%
24	12.04	12	0.33%

Table 2 Error% between simulated output and expected

The table 2 gives us the idea of how much is the deviation in the output voltage of the designed converter from the expected. It was observed that there was 0.33% of deviation between expected and actual readings of the output voltages tested at various input voltages 18V, 21V and 24V.

Efficiency calculation at rated load: $\text{Efficiency} = \frac{P_{out}}{P_{in}} = \frac{6}{0.384 \times 18} = 86.81\%$. So the efficiency of the converter is greater than what was assumed during calculation.

V. CONCLUSION

The cost effective flyback converter with wide input voltage range was designed. The converter was designed using LT3573 with No-Opto isolation which gives regulation from primary side. The design was simulated on LT Spice software. The simulation results were analysed for various input voltages and the results were found matching with the calculations. The converter was tested by ramping up the voltage from 18-24V and it was observed that it provided constant 12V output. The error report for actual to expected was seen to be in range. The converter was found to have typical efficiency of about 86%. The design was created using No-Opto isolation technique and no third winding Primary Side Regulation method. The component count was reduced and hence cost reduction was achieved.

REFERENCES

[1] . S. Kunkolkar and V. N. Shet, "Flyback Converter Design and Simulation," International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol. 6, no. 5, p. 4077, 2017.



- [2] . S. Desai, P. Bhatkar, A. Bhise, k. Todankar and N. N. Kasar, "Design and Implementation of Isolated Multi-Output Flyback Converter," International Research Journal of Engineering and Technology (IRJET), vol. 5, no. 10, p. 1714, 2018.
- [3] . V. and A. R. B., "Design of Fly Back Converter for Solar Energy," Journal of Emerging Technologies and Innovative Research (JETIR), vol. 7, no. 7, pp. 243-245, 2020.
- [4] . X. Zhang and D. Xu, "Analysis and Design of the Flyback Transformer," in ResearchGate, 2003.
- [5] . N. Coruh, U. Satilmis and T. Erfidan, "Design and Implementation of Flyback Converters," in IEEE Conference on Industrial Electronics and Applications, 2010.
- [6]. Tomas Hudson, "monolithicpower," 27 May 2022. [Online]. Available: <https://www.monolithicpower.com/en/primary-side-vs-secondary-side-regulation>. [Accessed 26 July 2022].
- [7] . Sean Chen, Eric Ian and Lawrence Lin, "EETimes," 5 March 2011. [Online]. Available: <https://www.eetimes.com/implementation-of-the-primary-side-regulation-in-flyback-converters-part-1-of-2/>. [Accessed 26 July 2022].
- [8] . M. Brown, N. Kularatna, M. J. Raymond A and S. Maniktala, Power Source and Supplies World class Design, Newnes an imprint of Elsevier, 2010.
- [9] . "LT3573 - Isolated Flyback Converter without an Opto-Coupler," Linear Technology, [Online]. Available: <https://www.analog.com/media/en/technical-documentation/data-sheets/3573fd.pdf>. [Accessed 26 July 2022].



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