

Performance Analysis of a Flyback Converter

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ABSTRACT: DC-DC converters are power electronics devices which convert a dc voltage to a different dc voltage level as per the requirement. In this paper, an analysis on open and closed loop control of DC-DC flyback converter is done. The main objective of this paper is to achieve the voltage mode control in a closed loop model using a PID controller by which the efficiency is increased by 9%. A flyback transformer has been designed for the same parameters. The design models of the open and closed loop flyback converter are verified using a MATLAB simulation software.

KEYWORDS: PID Controller, Pulse Generator, MOSFET, Relational Operator.

I. INTRODUCTION

DC-DC isolated converters are widely used in industrial applications, SMPS, telecommunication devices, etc. In recent years, DC-DC conversion techniques have been developed and are in great demand. There are various DC-DC converters which are used based on their power rating, input voltage and output voltage rating and also based on the need of electrical (galvanic) isolation. These DC-DC converters are divided into two categories based on electrical isolation and are classified as isolated and non-isolated converter. Out of which flyback converter is best suited for high switching frequency and SMPS applications as it has many advantages like simple to control, components required is less, reduced complexity, low cost, etc. The proposed flyback converter operates in open loop configuration but the resulting output shows much deviation from the required value and has much ripple content, hence a closed loop configured model is designed to reduce the ripple and achieve the required output values and it shows that the efficiency of the converter is increased by 9%. The converter design details, simulation models are included in the following sections.

II. WORKING PRINCIPLE OF FLYBACK CONVERTER

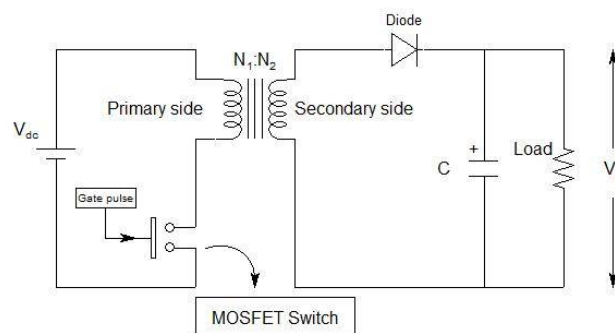


Figure 1: circuit diagram of a DC-DC Flyback Converter

The principle of flyback converter is same as that of buck-boost converters with the inductor split to form a transformer. During ON state when the MOSFET switch is closed the primary of the inductor-transformer is directly connected to the input voltage source [6]. The primary current and magnetic flux in the transformer increases, storing energy in the

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primary winding. The voltage induced in the secondary winding is negative, so the diode is reversed-biased. The output capacitor supplies energy to the output load.

During OFF state when the switch is opened the primary current and magnetic flux drops. The secondary voltage is positive, forward-biasing the diode, allowing current to flow from the secondary winding. The energy from the secondary winding recharges the capacitor and supplies to the load. And again the cycle is repeated.

III. MODES OF OPERATION

The operation of flyback converter can be explained by two modes Continuous conduction mode and Discontinuous conduction mode and are explained as follows[6]:

MODE -1 CONTINUOUS CONDUCTION MODE

Under this mode the input supply voltage appears across the primary winding inductance and the primary current rises linearly. This current rise in primary winding is expressed as:

$$E_{ds} = L_{pri} * \frac{d}{dt} I_{pri} \quad (1)$$

In this case the transformer core is not reset to zero before the next cyclic turning ON of switch. Since some flux is already present before Switch is turned on is shown by continuous lines in figure 2, the primary winding current abruptly rises to a finite value as the switch is turned on. At the end of switch conduction, the energy is stored in the primary winding of flyback inductor-transformer. As the secondary winding does not conduct during this mode, the load connected to the output capacitor gets uninterrupted supply due to previously stored charges on the capacitor

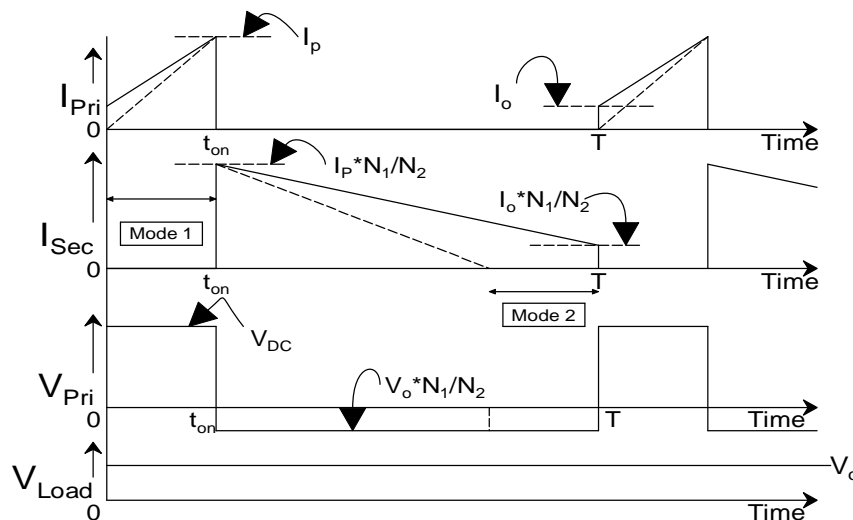


Figure 2: Waveforms for CCM and DCM

MODE-2 DIS-CONTINUOUS CONDUCTION MODE

If the OFF period of the switch is kept large, the secondary current gets sufficient time to decay to zero which is shown by discontinuous lines in figure 2 and magnetic field energy is completely transferred to the output capacitor and load. Flux linked by the windings remain zero until the next turn-on of the switch, and the circuit is under discontinuous flux mode of operation

IV. MATLAB SIMULATION MODELS OF FLYBACK CONVERTER

OPEN LOOP FLYBACK SIMULATION MODEL

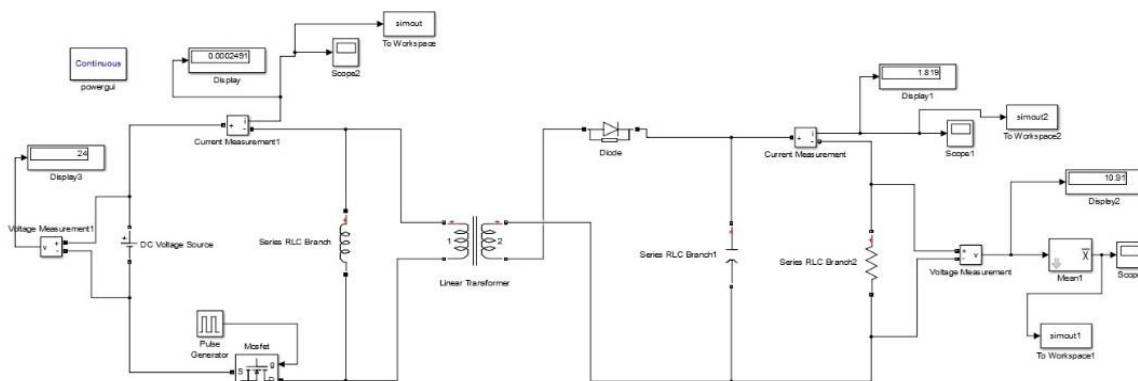


Figure. 3: Open Loop Flyback Converter

A Matlab Simulink model of open loop flyback converter is shown in the figure 3. A DC voltage source of 24V is connected to the primary winding through the magnetizing inductance. It is observed that the peak input current during Ton period is 4.5A and similarly the linear rise in the secondary current reaches a peak of 1.85A as shown in figure 6. The output voltage waveform of open loop converter has ripple content which is shown in the figure 7.

CLOSED LOOP FLYBACK SIMULATION MODEL

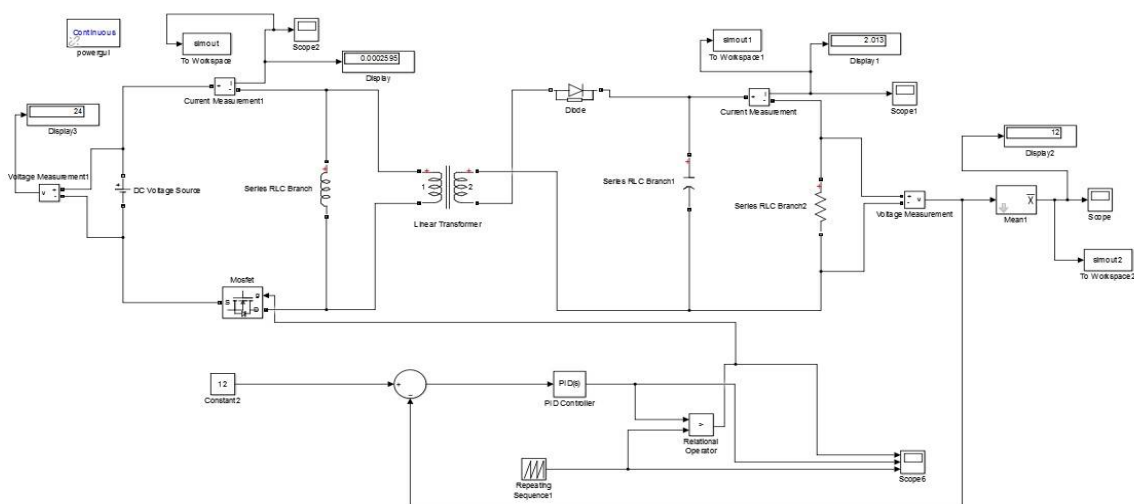


Figure. 4: Closed loop flyback converter

A Matlab Simulink model of closed loop flyback converter is shown in the figure 4. The modelling is same as the open loop and for the same parameters. The feedback loop used in closed loop model consists of a relational comparator which is fed from PID controller and repeating sequence block, through which the pulses are generated which is then fed to the gate terminal of the mosfet and thus the circuit works in closed loop. It is observed that the output current is

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1.94A which is much closer to design value and the output voltage is 11.94 whose waveforms are shown in the figure 8 and 9.

DESIGN SPECIFICATIONS

Input voltage, $V_{dc} = 24V \pm 10V$

Output voltage, $V_o = 12V$

Switching Frequency, $f_s = 20 \text{ KHz}$

Duty cycle, $D = 0.4$

Efficiency, $\eta = 100\%$ (for simulation model)

The above specified values of a flyback converter are used to design the open as well as closed loop MATLAB simulation models. A flyback transformer has been designed for the same values is shown in figure 5 and the calculated values of various parameters involved in flyback transformer calculation are shown in Table 1 below:

Table 1: Details of Designed Parameters of Flyback Transformer.

Sl. No.	Parameters	Values Obtained
1	Output Power	$P_{out} = 40.5W$
2	Turns Ratio	0.764
3	Core Selection	E42/21/15 Area product is $A_p = 46590 \text{ mm}^4$ Cross section area is $A_c = 182 \text{ mm}^2$ Window area is $A_w = 256 \text{ mm}^2$
4	No of Turns	$N_1=29 \text{ turns}, N_2=23 \text{ turns}$
5	Wire gauge selection	$I_1= 2.444A, I_2=2.98A$ Therefore SWG 18 is best choice.
6	Cross check	$A_w k_w = 102.4 \text{ mm}^2$ $\sum_{i=1}^n a_i N_i = 60.684 \text{ mm}^2$ Hence inequality is satisfied
7	Primary inductance	$L_1 = 106.02 \mu H$
8	Air Gap Length	$l_g = 1.814 \text{ mm}$

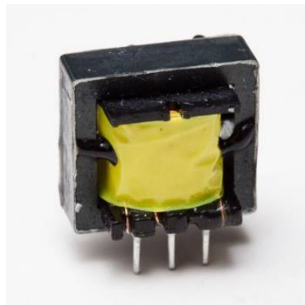


Figure 5: Practical Designed Model of a Flyback Transformer

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V. RESULTS AND DISCUSSIONS

The open loop and closed loop flyback converter has been designed for the buck operation of flyback converter using a MATLAB Simulink software. A high frequency flyback transformer and its parameters has been designed. The output waveforms of voltage and current have been plotted for both open and closed loop flyback converter and are shown below. It is observed that the proposed closed loop flyback converter has a 10% voltage tolerance and hence can work in voltage controlled mode.

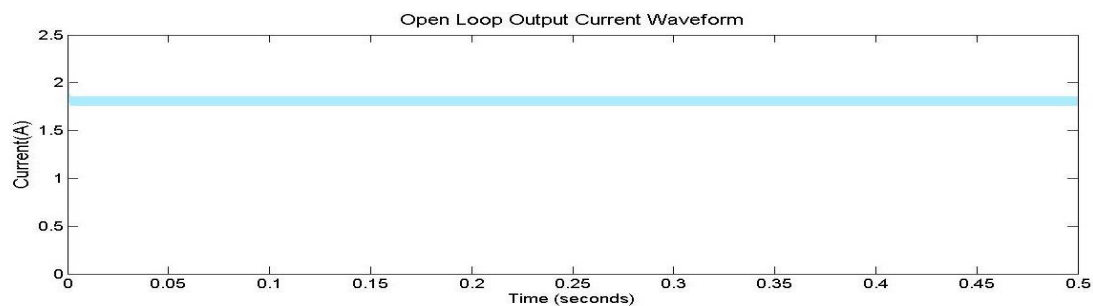


Figure 6: Output Current Waveform of Open Loop Flyback Converter

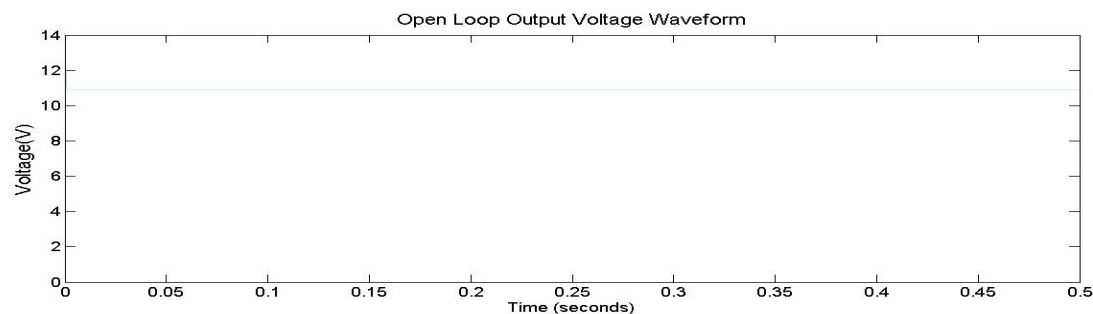


Figure 7: Output Voltage Waveform of Open Loop Flyback Converter

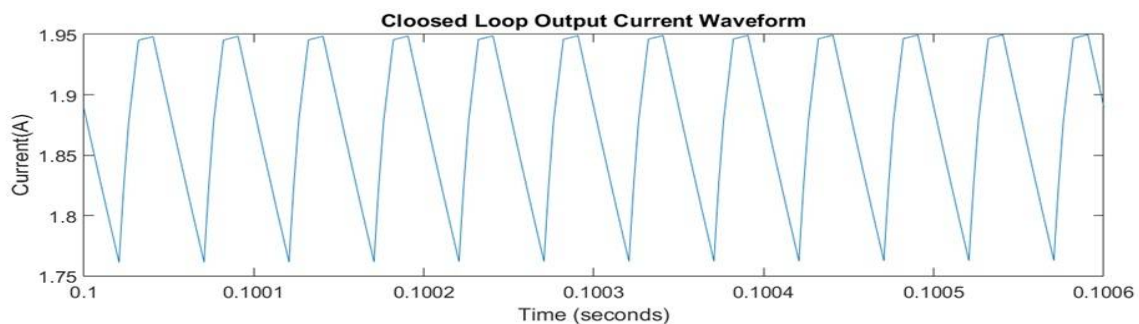


Figure 8: Output Current Waveform of Closed Loop Flyback Converter

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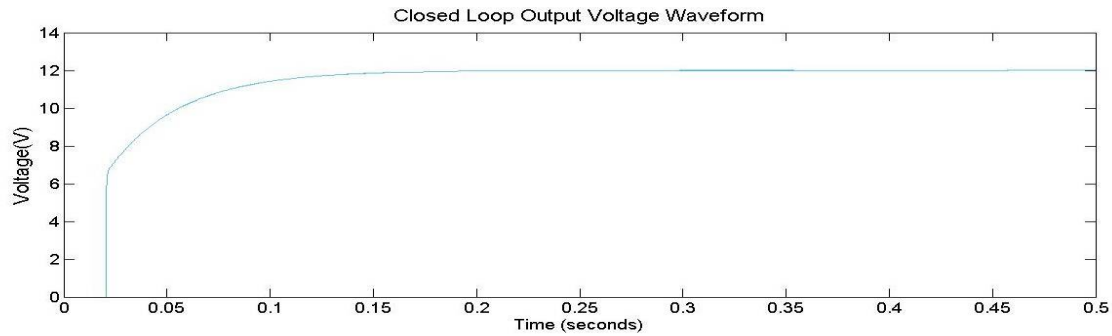


Figure 9: Output Voltage Waveform of Closed Loop Flyback Converter

VI. CONCLUSION

A Performance analysis on open loop and close loop dc-dc flyback converter model has been done and simulation models are obtained using Matlab Simulink software. A high frequency flyback transformer have been designed for same parameters. Using Matlab Simulink model results for the output current and voltage waveforms of a buck type flyback converter have been plotted. Comparing the resultant values of open loop converter voltage to be 10.95V and closed loop converter to be 11.98V for various loads, it shows that close loop model has more accurate and close to design values. Hence the efficiency of closed type of converter is more than the open type by 9%.

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