JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

MATHEMATICAL MODELING, DESIGN AND ANALYSIS OF FLYBACK CONVERTER

Open loop and closed loop Flyback converters

Srividya.N.S, Dr.Venkatesha.K,
M.Tech Student, Professor,
Department of Electrical and Electronics Engineering,
BNMIT, Bengaluru, India

Abstract: The proposed work focuses on the Design and Simulation of a Flyback Converter. In recent days electric energy is one of the basic requirements for most of the purposes (defense and space applications) which also require conversion of power according to the load requirement like the appliances which uses DC or AC loads. This paper briefs the design of flyback converter in open loop and closed loop mode with R and RL load. Performance parameters such as power, power factor, and efficiency of the converter are analyzed in open loop and closed loop mode. The load regulation is achieved by closed loop system with the help of PID controller and the desired voltage supplied by the user in conformation with the simulation results obtained from the converter.

***Index Terms*-Flyback converter, voltage conversion, design, MOSFET switch, DC loads.**

I. INTRODUCTION

Power Flyback converter topology is well known among other Switch Mode Power Supplying power converters because of isolation provided between the input voltage and the output voltage. Whereas its input may be from a source of rectified DC voltage from AC mains supply or a direct DC input source of voltage. The output power range can change from 1W to a maximal range of 10KW. Hence flyback converter is used because of its simple circuit model and high efficiency with lower range power outputs. Its usage has widely increased in the areas which needs regulated low DC power outputs.

II. PRINCIPLE AND WORKING OF FLYBACK CONVERTER

The circuit diagram of flyback converter is shown in Figure.1, the isolation between input and output is provided by the DC-DC converter. The transformer model includes the magnetizing inductance L_m. The basic operation of this converter is similar to that of buck-boost converter. When the switch is closed energy stored in L_m, and is transferred to load when the switch is open. To determine the relationship between input and output, the circuit is analyzed for both switch positions.

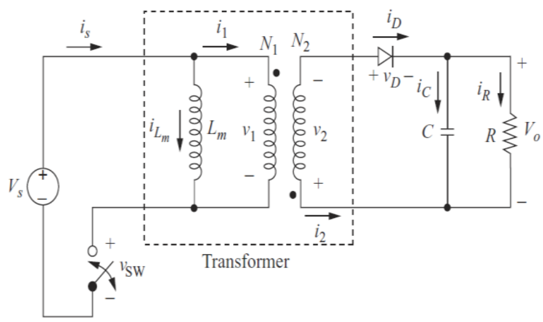

Figure.1: Basic Topology of Flyback Converter

The current flows alternately through the primary and the secondary windings depending on the switch operation.

A. *When the switch is closed*

When the switch is closed (Figure.3), there is a return path for current at the primary side of the transformer. The primary side inductor gets energized linearly. But due to the reverse biased diode the secondary side inductor cannot be energized. So, the current through it will be zero.

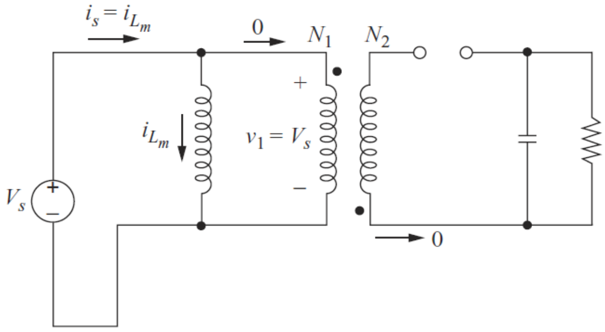

Figure.2: Circuit for switch closed

B. *When the switch is open*

When the switch is opened (Figure.3), the current in the inductance *Lm* cannot change instantaneously, so the conduction path must be through the primary turns of the transformer.

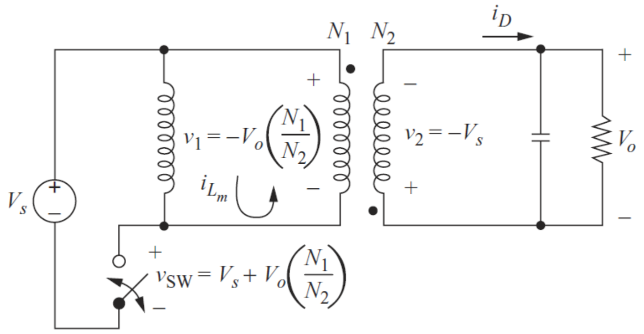

Figure.3: Circuit for switch open

The current i_{Lm} enters the undotted terminal of the primary and must exist at the undotted terminal of the secondary. This is acceptable since the diode current is positive. Considering that the output voltage remains constant at *VO*, the transformer secondary voltage v_2 becomes $-V_o$. The secondary voltage transforms back to the primary, creating the voltage across L_m at v_1.

III. MATHEMATICAL MODELING OF THE BASIC FLYBACK CONVERTER

DESIGN

The flyback converter is to be designed for the requirements as tabulated below:
Input Voltage, Vs=24V
Output Voltage, Vo = 5 V

$\frac{N_2}{N_1}$=1/3

R=5Ω

C=200µF

F=5 KHz

Lm=500µH

$$Vo = Vs\frac{D}{(1-D)}\frac{N_2}{N_1}$$

$$D=\frac{1}{\left(\frac{Vo}{Vs}\right)\left(\frac{N_2}{N_1}\right)+1}=0.385$$

$$I_{L_m} = \frac{V_o^2}{VsDR}=540mA$$

$$\Delta I_{L_m}=\frac{V_s D}{Lmf}=3.696A=3700mA$$

$$I_{L_{m,max}} = I_{L_m}+\frac{\Delta i_{L_m}}{2} = 2390mA = 2.39A$$

$$I_{L_{m,min}} = I_{L_m} - \frac{\Delta i_{L_m}}{2} = 1.31A$$

$$\frac{\Delta Vo}{Vo} = \frac{D}{RCf} = 0.077\%$$

$$Lm=\frac{V_s D}{\Delta i_{L_m} f}=500\mu H$$

Table 1: Design specifications of the Basic Flyback converter

Parameters	**Specifications**
Input Voltage	24V
Output Voltage	5V
Output Power	5W
Frequency	5kHz
Capacitance	2000 µF
Resistance	5Ω
Inductance	119.3µH

MATLAB SIMULATION BLOCK OF BASIC FLYBACK CONVERTER WITH RL LOAD

DESIGN OF INDUCTANCE

R= 5Ω, f= 5000Hz

We know that,

$\text{Cos}\emptyset = \frac{R}{Z}$

$Z = \frac{R}{\text{Cos}\emptyset} = \frac{5}{0.8} = 6.25$

$Z^2 = R^2 + X_L^2$

$X_L = \sqrt{(Z^2 - R^2)} = \sqrt{(6.25^2 - 5^5)} = 3.75\Omega$

$X_L = 2\pi fL$

$L = \frac{XL}{2\pi f} = \frac{3.75}{2\pi * 5000} = 119.3\mu H$

3.1 SIMULATION OF BASIC FLYBACK CONVERTER WITH RL LOAD

3.1.1 MATLAB SIMULATION BLOCK OF BASIC FLYBACK CONVERTER WITH RL LOAD

The proposed Simulink model of the basic flyback converter with RL load is shown in Figure.6; the DC power supply from the source is stepped down to lower voltage levels using the flyback converter.

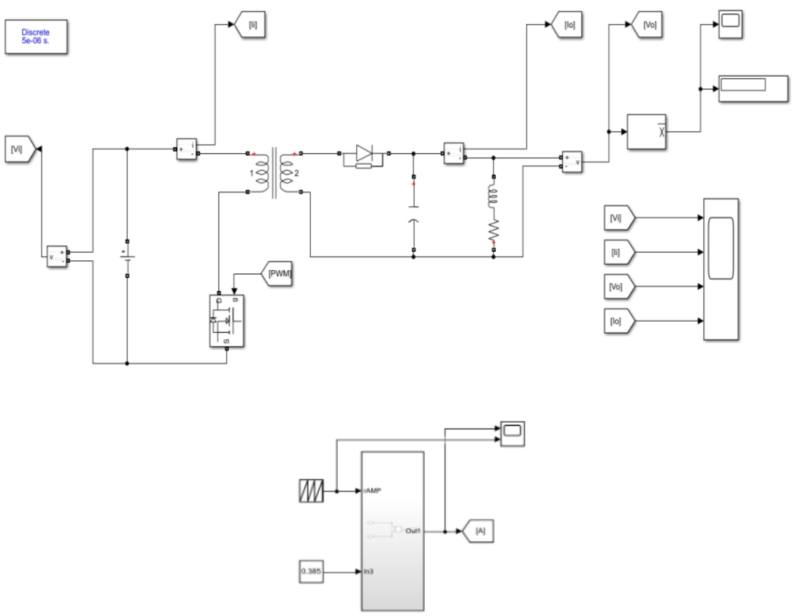

Fig.6: Simulation block of Flyback converter (with RL load)

3.1.2 SIMULATION RESULTS OF FLYBACK CONVERTER WITH RL LOAD

SIMULATION OUTPUT VOLTAGE VALUE VARIATION WITH RESPECT TO CHANGE IN DUTY RATIO AND TURNS RATIO IN COMPARISON WITH THEORETICALLY CALCULATED VALUE OF OUTPUT VOLTAGE

(i) When $N_1 : N_2$ = 1:1 (V_1=24V)

Duty ratio	Theoretical values Vo (volts)	Simulation values Vo (volts)
0.9	216	224.3
0.8	96	97.57
0.7	56	58.77
0.6	36	41.62
0.5	24	30.87
0.4	16	23.35
0.3	10.28	16.62
0.2	6	10.84
0.1	2.66	5.452

(ii) When $N_1 : N_2$ = 1:2 (V_1=24V)

Duty ratio	Theoretical values Vo (volts)	Simulation values Vo (volts)
0.9	432	434
0.8	192	197.1
0.7	112	114.2
0.6	72	74.19
0.5	48	49.43
0.4	32	35.03
0.3	20.57	24.03
0.2	12	15.42
0.1	5.33	7.676

IV. SIMULATION OF OPEN LOOP AND CLOSED LOOP FLYBACK CONVERTER CIRCUIT

This chapter includes simulation model of open loop and closed loop flyback converter and their respective results. The simulation was carried out in MATLAB Simulink. The open loop flyback and closed loop converters with R and RL load is also designed for input voltage of V_1=24V, output voltage of V_2=40V, output power of 40 W with operating frequency of 10KHz.

The open loop schematic is similar to that of the basic flyback converter. Here the power calculation block is made additional. Flyback converter with closed loop mechanism is considered where the error in output voltage is given as the feedback through PID controller after comparing with desired output voltage in order to generate PWM pulses for the switches. The output voltage obtained in the closed loop system conforms to the desired output voltage supplied by the user.

The flyback converter is to be designed for the requirements as tabulated below.

DESIGN

The open loop and closed loop flyback converters are to be designed for the requirements as tabulated below:

Table 1: Design specifications of the open loop and closed loop flyback converter

Parameters	Specifications
Input Voltage	24V
Output Voltage	40V
Output Power	40W
Frequency	10kHz
Capacitance	17.85µF
Resistance	10Ω
Inductance	477.464µH

Matlab simulation block of basic flyback converter with RL load

DESIGN OF INDUCTANCE

R= 40Ω, f=1 0000Hz

We know that,

$\text{Cos}\emptyset = \frac{R}{Z}$

$Z = \frac{R}{\text{Cos}\emptyset} = \frac{40}{0.8} = 50$

$Z^2 = R^2 + X_L^2$

$X_L = \sqrt{(Z^2 - R^2)} = \sqrt{(50^2 - 40^5)} = 30\Omega$

$X_L = 2\pi fL$

$L = \frac{XL}{2\pi f} = \frac{30}{2\pi * 10000} = 477.464\mu H$

4.1Simulation of open loop flyback converter with RL load

4.1.1 Matlab simulation block of open flyback converter with RL load

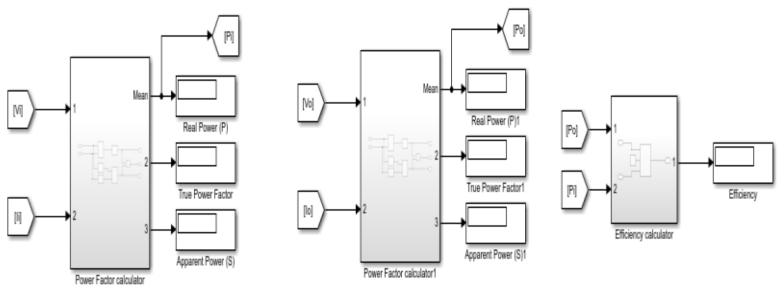

Fig.10: Simulation power calculation block of Open loop flyback converter (with RL load)

4.1.2SIMULATION RESULTS OF OPEN LOOP FLYBACK CONVERTER WITH RL LOAD

VARIATION OF OUTPUT VOLTAGE, POWER FACTOR AND EFFICIENCY WITH RESPECT TO DUTY RATIO IN SIMULINK OF OPEN LOOP FLYBACK CONVERTER WITH RL LOAD.

Duty ratio	Output Voltage (volts)	Power factor (input side)	Power factor (output side)	Po (watts)	Pi (watts)	Efficiency (%)
0.9	38.86	0.947	1	37.83	38.93	97.18
0.8	38.8	0.8897	1	37.75	38.89	97.08
0.7	38.71	0.8288	1	37.65	38.84	96.96
0.6	38.62	0.7628	1	37.53	38.77	96.79
0.5	38.51	0.6904	1	37.35	38.68	96.57
0.4	38.36	0.6198	1	37.1	38.55	96.25
0.3	38.11	0.5393	1	36.68	38.33	95.7
0.2	37.66	0.4433	1	35.86	37.9	94.62
0.1	36.4	0.3153	1	33.56	36.67	91.54

VARIATION OF OUTPUT VOLTAGE, POWER FACTOR AND EFFICIENCY WITH RESPECT TO VARIATION OF TRANSFORMER SECONDARY WINDING VOLTAGE IN SIMULINK OF OPEN LOOP FLYBACK CONVERTER WITH RL LOAD.

D=0.3571

V1 (volts)	V2 (volts)	Output voltage	Power factor (input side)	Power factor (output side)	Po (watts)	Pi (watts)	Efficiency (%)
24	20	18.98	0.5373	1	9.105	9.568	95.16
24	40	38.27	0.5866	1	36.95	38.47	96.05
24	60	56.45	0.5954	1	80.4	85.09	94.49
24	80	73.14	0.5969	1	135	147	91.83

Tables above shows the Variation of output voltage, power factor input power, output power and efficiency with respect to duty ratio in Simulink of open loop flyback converter. Here the high frequency transformer voltage is set to V_1=24V, V_2=40V with RL load and duty ratio is varied from 0.9 to 0.1 at each step respective values of output voltage, power factor input power, output power and efficiency are tabulated. And the open loop flyback converter with RL load is found to be performing with efficiency above 90% at all the duty ratio

And above tables. shows the Variation of output voltage, power factor and efficiency with respect to variation of transformer secondary winding voltage in Simulink of open loop flyback converter. Here the high frequency transformer voltage is set to V_1=24V, V_2 is varied at each step and duty ratio is set to 0.3571 and respective values of output voltage, power factor input power, output power and efficiency are tabulated.

4.2Simulation of closed loop flyback converter with RL load

4.2.1 MATLAB SIMULATION BLOCK OF CLOSED LOOP FLYBACK CONVERTER WITH RL LOAD

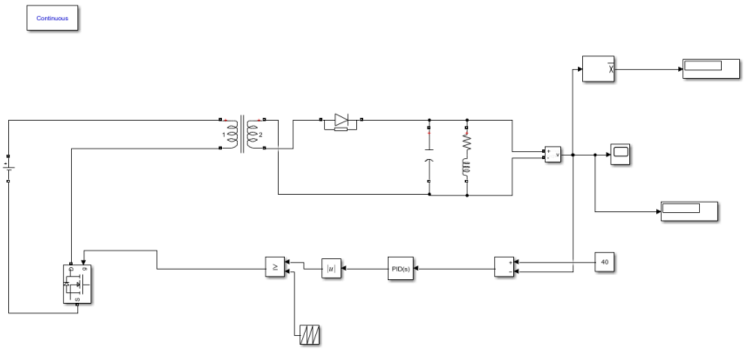

Fig.14: Simulation block of closed loop flyback converter (with RL load)

4.2.3Simulation results of closed loop flyback converter with RL load

VARIATION OF OUTPUT VOLTAGE WITH RESPECT TO CHANGE IN DESIRED OUTPUT VOLTAGE VALUE IN SIMULINK

Desired output voltage (volts)	Output voltage(volts)	Error (%)
20	19.8	1
30	30.23	-0.766
40	40.88	-2.2
50	51.57	-3.14
60	62.28	-3.8
70	72.9	-414

Section 4.2.3shows the Variation of output voltage with respect to change in desired output voltage value in Simulink for closed loop flyback converter with R load. Here the desired output voltage value is set at each step and its respective Simulation Output voltage is noted and error is calculated and tabulated for the same.

$$\%error=\left(\frac{\text{Desired output voltage}-\text{Simulation Output voltage}}{\text{Desired output voltage}}\right)*10$$

V. CONCLUSION AND FUTURE ENHANCEMENT

CONCLUSION

The basic working of the flyback converter in Open loop and closed loop mode with R load and RL load is carried out by designing the circuit components with the help of mathematical modeling of the converter. The simulation of these converters is carried out using MATLAB Simulink software package. The parameters such as input voltage, input power, output voltage, output power, efficiency, input power factor, and output power factor are considered as performance parameters of the circuit. The theoretical results obtained are in conformation with the simulation results obtained. This flyback converter is mainly purposed to be used in electronic gadgets, space application, battery chargers, and Electric vehicle technology and in defense applications.

In this project, the basic flyback converter with R and RL load is designed for input voltage of V_1=24V, output voltage of V_2=5V, power output of 5 W with operating frequency of 5 kHz. The open loop flyback converter with R and RL load is also designed for input voltage of V_1=24V, output voltage of V_2=40V, output power of 40 W with operating frequency of 10KHz. Flyback converter operation is simulated for various duty ratios and different turns ratios of high frequency transformer and the respective results are obtained with efficiency more than 90% for all the cases.

Flyback converter with closed loop mechanism is considered where the error in output voltage is given as the feedback through PID controller after comparing with desired output voltage in order to generate PWM pulses for the switches. The output voltage obtained in the closed loop system conforms to the desired output voltage supplied by the user.

FUTURE SCOPE OF THE WORK

This project presents analysis of Flyback converter and its working in different modes of operation by carrying out simulation in MATLAB. Further work can be carried out to implement the hardware design of the same.