EE3048D Project Report

Design and Control of Flyback Converters

SUBMITTED BY :

Vishnu Ajith   B170335EE

Yug Varshney B171034EE

DEPARTMENT OF ELECTRICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY CALICUT

NIT Campus P.O. Calicut - 673601, India

CONTENTS

ACKNOWLEDGEMENT

We are highly indebted to Dr.Kumaravel S for giving us guidance and constant supervision as well as for providing necessary information regarding the project.

We would like to express our special gratitude and thanks to industry persons at Bosch and Mathworks for giving us such attention and time.

Our sincere thanks and appreciation also goes to the college in giving the resources in developing the project and people who have willingly helped us out with their abilities.

INTRODUCTION

Derivation of the Flyback converter:

The flyback converter is based on the buck-boost converter. Its derivation is illustrated in Fig. 1. Figure 1(a) depicts the basic buck-boost converter, with the switch realized using a
MOSFET and diode. In Fig. 1(b), the inductor winding is constructed using two wires,with a 1:1 turns ratio. The basic function of the inductor is unchanged, and the parallel windings are equivalent to a single winding constructed of larger wire. In Fig. 1(c), the connections between the two windings are broken. One winding is used while the transistor Q1 conducts, while the other winding is used when diode D1 conducts. The total current in the two windings is unchanged from the circuit of Fig. 1(b); however, the

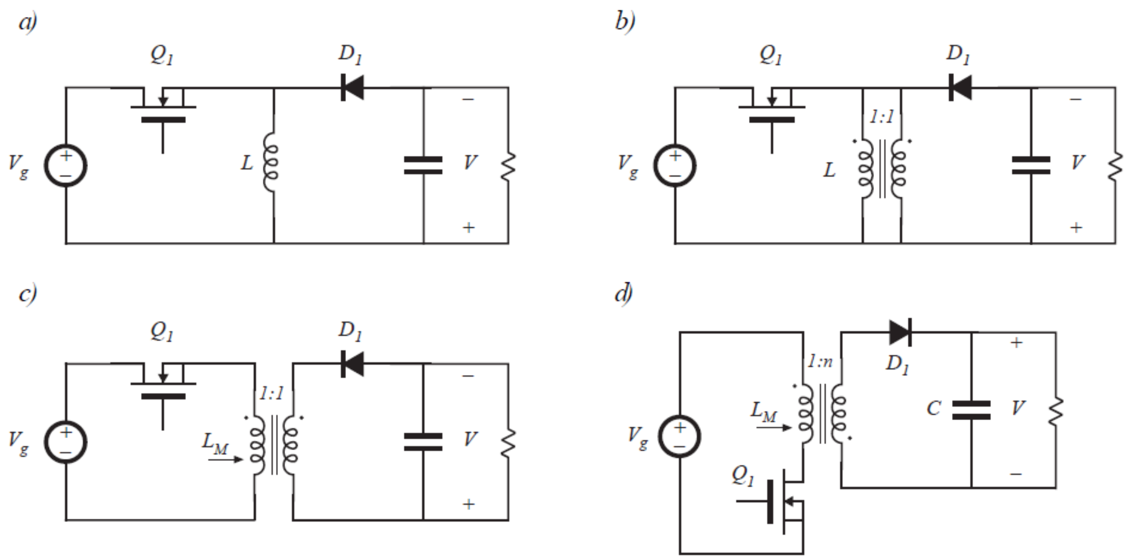


Fig. 1. Derivation of the flyback converter: (a) buck-boost converter, (b) inductor L is wound with two parallel wires, (c) inductor windings are isolated, leading to the flyback converter, (d) with a 1:n turns ratio and positive output.

current is now distributed between the windings differently. The magnetic fields inside the inductor in both cases are identical. Although the two-winding magnetic device is represented using the same symbol as the transformer, a more descriptive name is “two winding inductor”.

This device is sometimes also called a “flyback transformer”. Unlike the ideal transformer, current does not flow simultaneously in both windings of the flyback transformer. Figure 1(d) illustrates the usual configuration of the flyback converter. The MOSFET source is connected to the primary-side ground, simplifying the gate drive circuit. The transformer polarity marks are reversed, to obtain a positive output voltage. A 1: n turns ratio is introduced; this allows better converter optimization.

Advantages of Flyback Converter

1.The primary is isolated from the output.

2.Capable of supplying multiple output voltages, all isolated from the primary.

3.Ability to regulate the multiple output voltages with a single control.

4.Can operate on a wide range of input voltages

5.The Flyback converters use very few components compared to the other types of SMPSs.

Applications of Flyback Converter

1.Television sets which consume small amount of power of up to about 250W

2.Standby power supplies for computers

3.Cell phone and mobile device chargers

4.High-voltage supplies in TV and Monitor CRTs, Lasers, Xenon flashlights, copiers, etc

DESIGN PROCEDURE

The flyback convertor is designed as a 12V supply with power of 12W. The specification of the convertor is given below :

Specification:

Factors	Value
Input Voltage	24V
Output Voltage	12V
Duty Cycle	50%
Current Ripple	0.01A
Voltage Ripple	0.01V
Power Output	1A
Load Resistance	12ohm

To continue with the design we need to analyze the behaviour of the flyback converter with respect to the input from the gate driver.

Analysis of the Flyback converter :

The behavior of flyback converters with transformer-isolation are adequately understood by modeling the physical transformer with a simple equivalent circuit consisting of an ideal transformer in parallel with the magnetizing inductance or known as a *coupled inductor model*. The magnetizing inductance must then follow all of the usual rules for inductors thus volt-second balance must hold when the circuit operates in steady-state. This implies that the average voltage applied across every winding of the transformer must be zero. The Circuit model is given in Fig. 2.

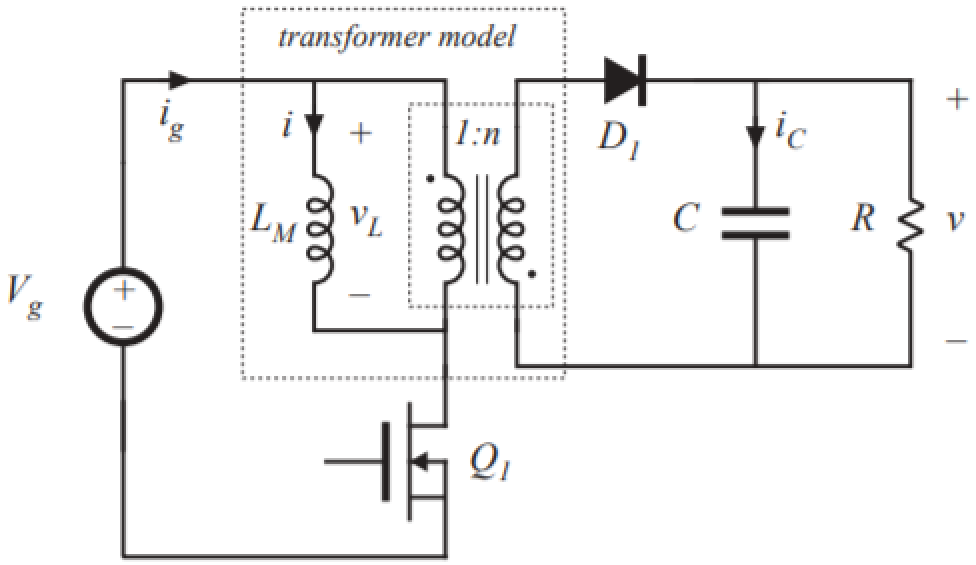
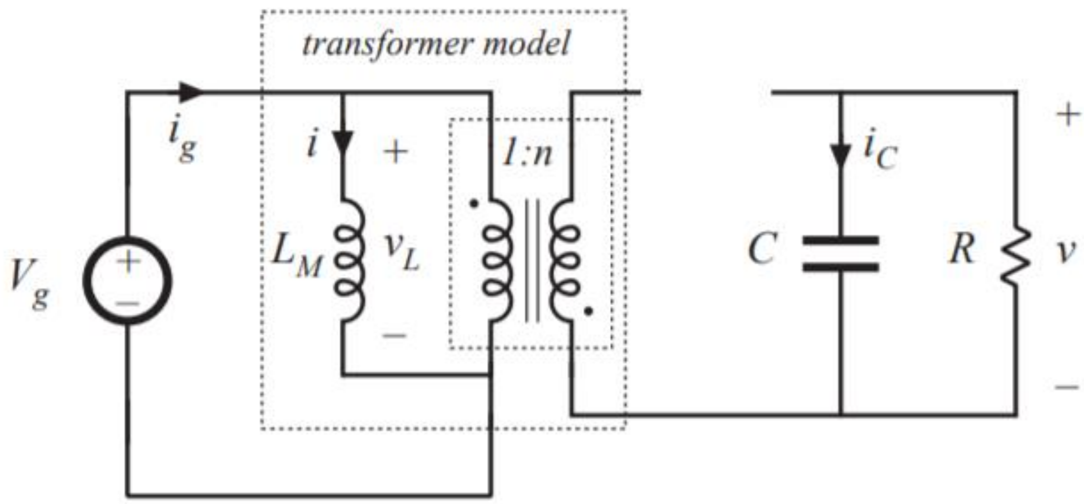


Fig.2

To analyse the circuit we split the time into two intervals ,subinterval 1 from 0 to DTs and subinterval 2 from DTs to Ts. Where the Ts is the Sampling time and, D the Duty Cycle of the PWM module.

Fig. 3



During **subinterval 1** , while transistor Q1 conducts, the converter circuit reduces to Fig. 3 .The inductor voltage vL, capacitor current i, and dc source current ig, are given by :

$$v_L = V_g$$
$$i_C = -\frac{v(t)}{R}$$
$$i_g = i(t)$$

Note here v_L is the Voltage across inductor, V_g is the Voltage of the input source. v(t) is the function of output voltage with time. i(t) is the function of output Current with time.

As there are more variables to solve in our model, we need to reduce the variable to constants to analyse the circuit in an easier manner with less loss of accuracy thus we make the Output voltage and output current as constants. This process is called Small signal approximation thus the new equations are:

$$v_L = V_g$$
$$i_C = -\frac{V}{R}$$
$$i_g = I$$

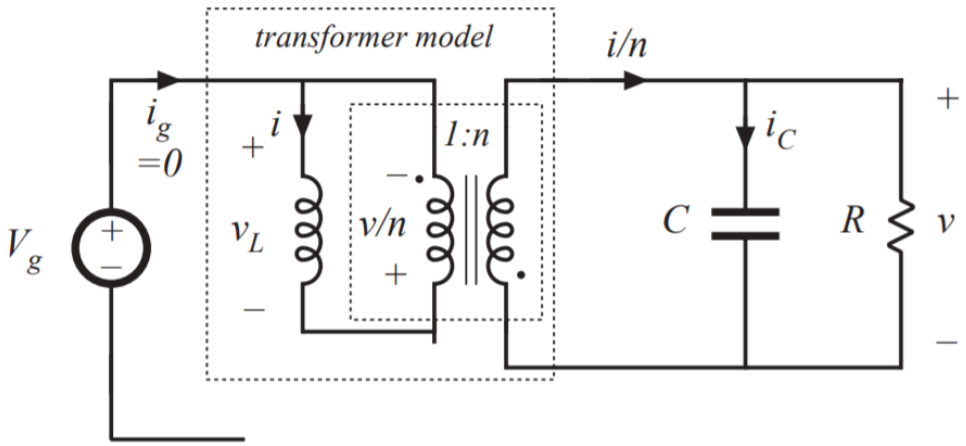


Fig 5

During the subinterval 2 , the transistor is in the off-state, and the diode conducts. The equivalent circuit of Fig. 5 is obtained. The primary-side magnetizing inductance voltage vL, the capacitor current iC, and the dc source current ig, for this subinterval are:

$$v_L = -\frac{v(t)}{n}$$
$$i_C = \frac{i(t)}{n} - \frac{v(t)}{R}$$
$$i_g = 0$$

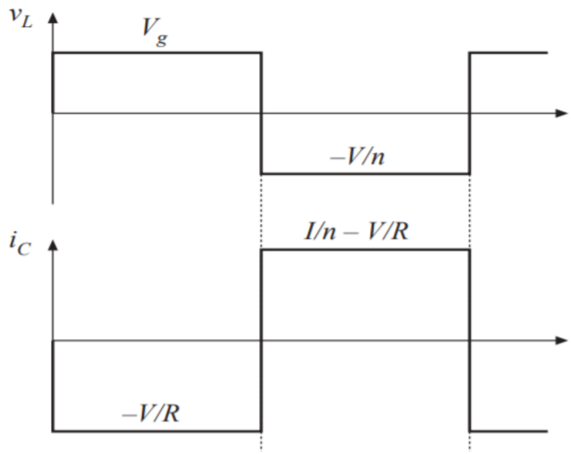
Applying Small Signal Approximation the new parameters are:

$$v_L = -\frac{V}{n}$$

$$i_C = \frac{I}{n} - \frac{V}{R}$$

$$i_g = 0$$

As a result of the analysis we can plot the variation of vL and iC with time as :



Application of the principle of volt-second balance to the primary-side magnetizing inductance yields :

$$< v_L > = \; D(Vg) + D'(-\frac{V}{n}) = 0$$

$$\Rightarrow V = \frac{n * Vg * D}{D'}$$

$$Substitute\ values :$$

$$\Rightarrow 12 = \frac{n * 24 * 0.5}{0.5}$$

$$\Rightarrow n \; = \; 0.5$$

Also we get the Conversion Ratio M(D) as :

$$M(D) = \frac{V}{Vg} = n * \frac{D}{D'} = 0.5$$

Application of the principle of Current-second balance to the primary-side magnetizing inductance yields :

$$i_C = D(-\frac{V}{R}) + D'(\frac{I}{n} - \frac{V}{R}) = 0$$
$$\Rightarrow I = \frac{n * V}{D'R} = \frac{0.5 * 12}{0.5 * R} = 1A$$
$$\Rightarrow R = 12\Omega$$

Ripple current analysis :

From Ripple in Inductor in Subinterva1 we can Write :
$$V_g = L\frac{dI}{dt}$$

Taking an average current I we can represent the equation as change in current as :

$$V_g = L\frac{2 * \Delta i}{DTs}$$

Setting the convertor frequency as F = 25KHz solving the above equation we get :

$$L = \frac{V_g * DTs}{2 * \Delta i} = \frac{24 * 0.5}{2 * 0.01 * 25 * 10^3} = 24mH$$

Ripple Voltage analysis :

Analyzing the voltage ripple in the capacitor we can write in Subinterval 1 :
$$I = C * \frac{dV}{dt} = \frac{V}{R}$$
Taking an average Voltage V and change delta V we can represent the equation as change in current as :

$$C * \frac{2\Delta v}{DT_s} = \frac{V}{R}$$

$$\Rightarrow C = \frac{V * DT_s}{2 * \Delta V * R} = \frac{12 * 0.5}{2 * 0.01 * 12 * 25 * 10^3} = 1mF$$

Summary of Design :

Factors	Value
n	0.5
L	24mH
C	2mF
F	25KHz

CONTROLLER DESIGN

As the controller for the Flyback converter the PI controller was used its Subsystem is given in the Fig. 6.

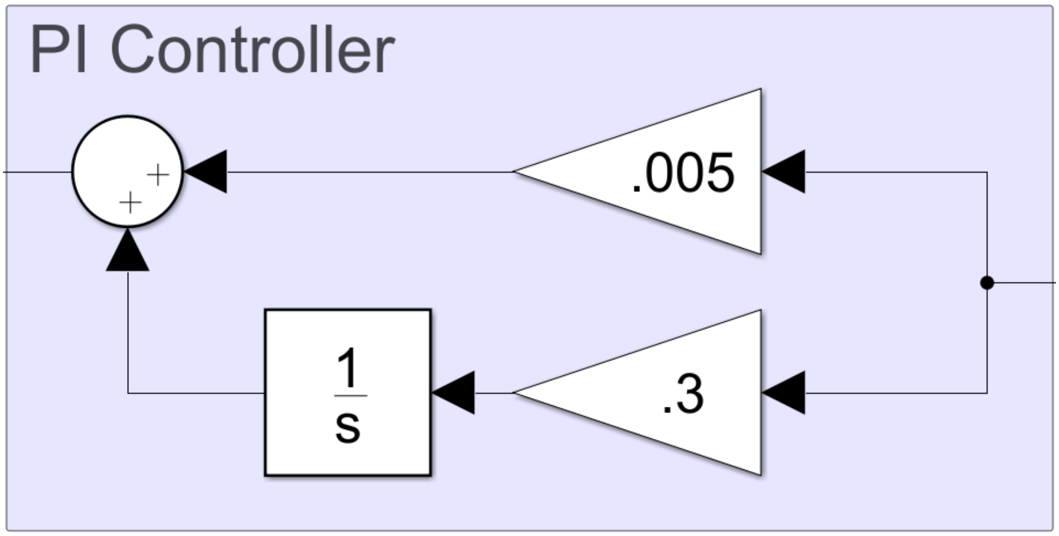


Fig 6

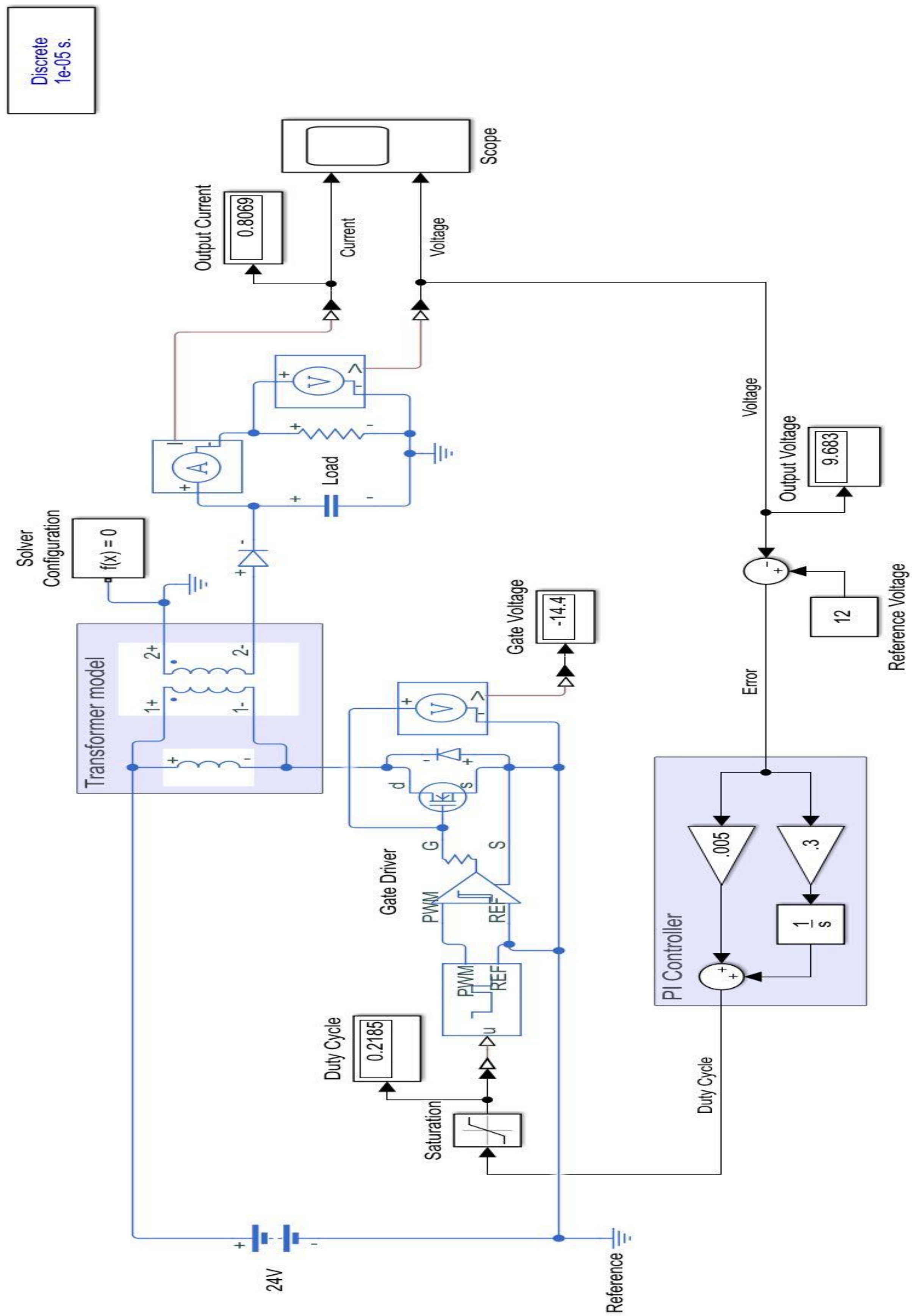
The tuning of the PI controller was done manually the system was reaching steady state in .3 seconds and no oscillations was observed with :

$$K_p = 0.05$$
$$K_I = 0.3$$

No overshoot was observed for a load of 12 W on the output.

SIMULATION RESULTS

Simulink Model :



Simulation Graphs:

Fig.8 Shows the Simulation of the model for 500ms for the output current and the output voltage.

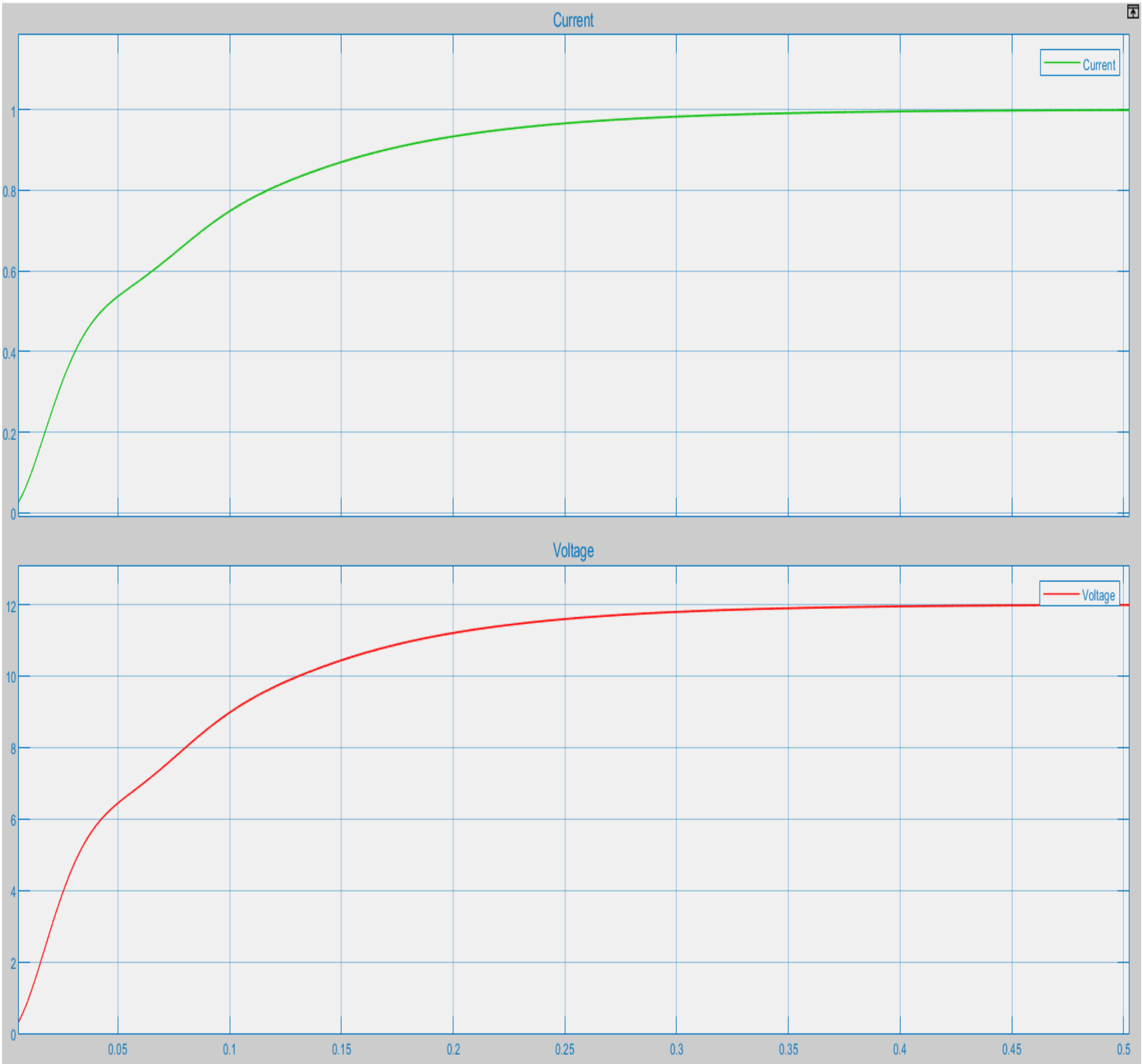


Fig.8

INFERENCE

The circuit can be used to power light loads in an EV and could be scaled to over 250W with changes in the design. The Flyback convertors have very low number of components thus is small in size and cheaper with respect to the size and power comparing to other convertors. The circuit was successfully simulated, and the parameters were verified. The PI controller was giving good performance in its operating region.

The magnetics of the circuit wasn't simulated as this was out of scope. The circuit was modelled using simscape models in discrete mode thus took subtle time for simulation.