Middle East Technical University

EE464 Power Electronics

"Turning Coffee into Electricity"

Project 2 Report

June 8, 2018

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To be submitted to

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Contents

1 Introduction

As Fiero Converters, we manufacture 230 V AC to 9 V DC, 10 W Flyback Converters. This documents shows the detailed pre-manufacturing process of designing, simulating of the converter and the controller of the product. The design to be used in the simulations is provided in figure 1.

2 Isolated Converter Simulation

The design is made using []. There is snubber in order to reduce the current and voltage stress the MOSFET endures during operation. The resultant effect of the snubber is clearly observed in the simulations as well. The simulations were done synchronously with the implementation and hence the design parameters for the switch, diode and the transformer are taken from the implemented products.

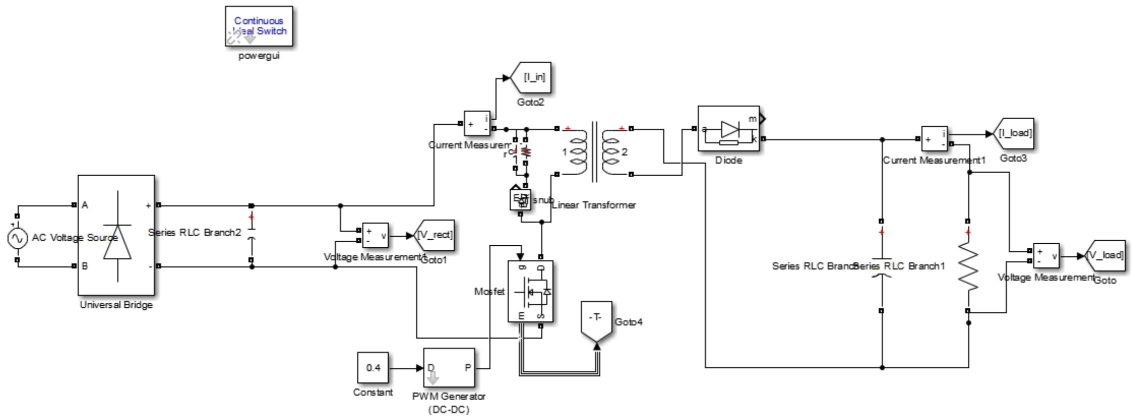

Figure 1: Flyback Design

2.1 Part I. Steady State Operation of the Converter

The figures 2, 3, 4, 5 show the simulation waveforms and the resultant voltage, current and power outputs for the calculated values of maximum duty cycle, turns ratio, reasonable capacitor values and resistance for the ideal case.

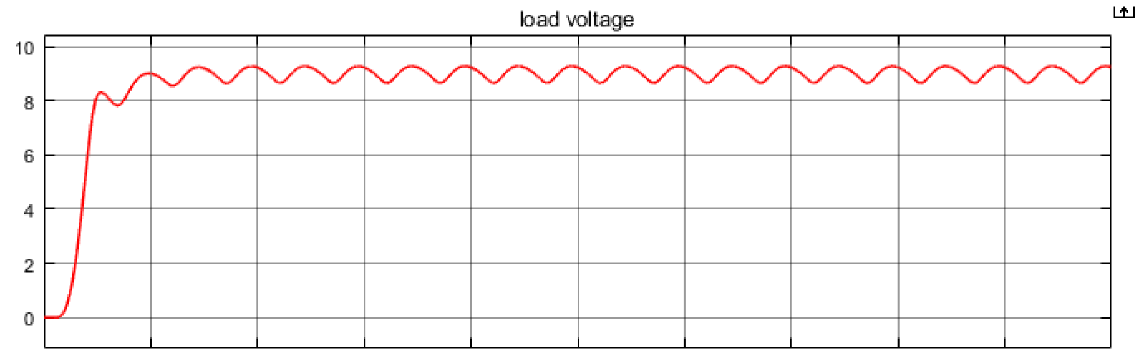

Figure 2: Load Steady State Voltage

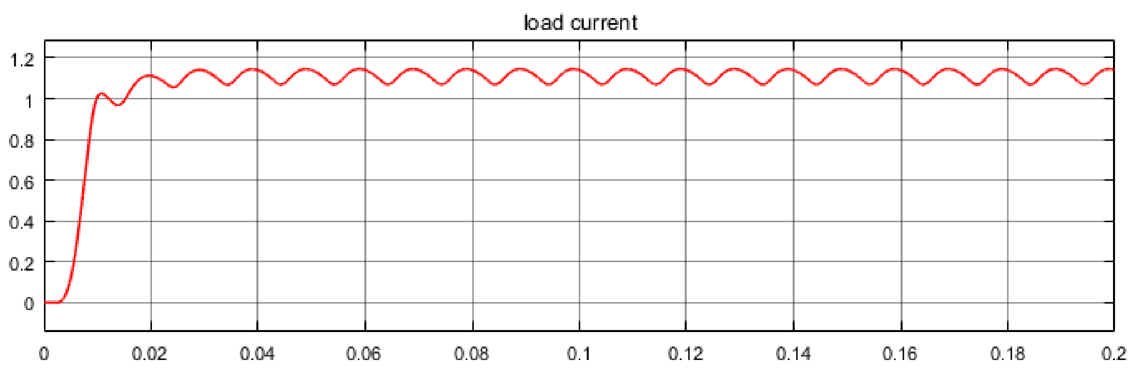

Figure 3: Load Steady State Current

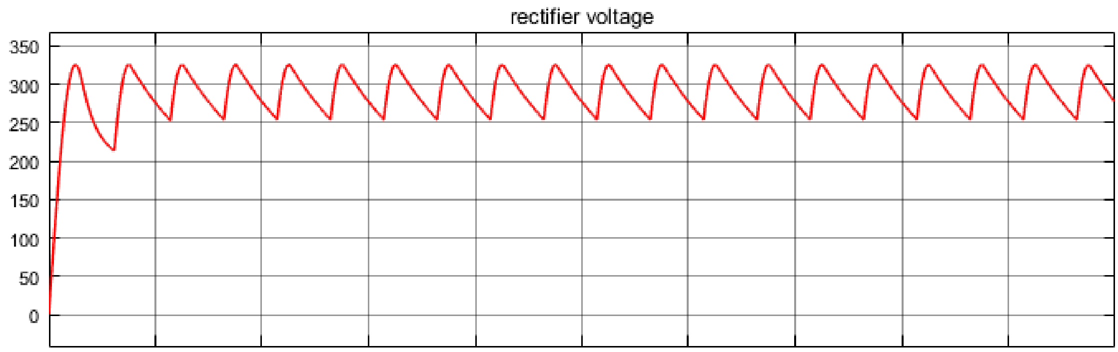

Figure 4: Rectifier Output Voltage at Steady State

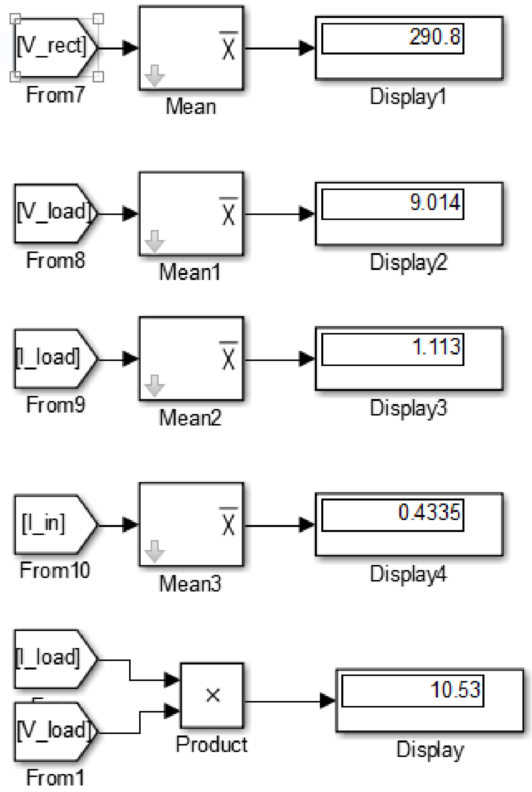

Figure 5: All voltage current display values

Moreover, we have also checked that the switch voltage and current remains in the tolarable range. As expected, the voltage across the switch will be twice the input voltage when it turns off. This can be seen in figure6.

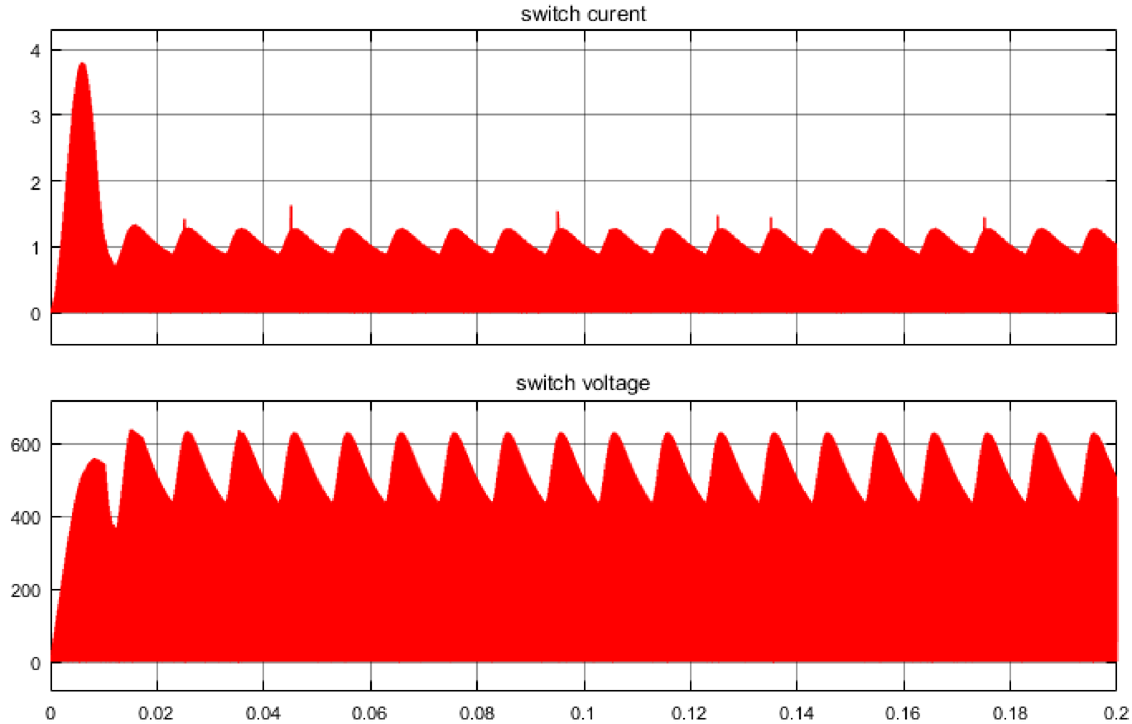

Figure 6: Current and voltage of the MOSFET during operation

2.2 Transformer Design

For flyback topology design, there are many different considerations like loss, area, saturation etc. We started the topology knowing that the duty cycle can not exceed 0.5. Following the steps in [?], we started by putting a safety margin to the duty cycle and selecting it to be 0.4. Once we have decided on this, using the flyback input output relation $N_{sec}/Nprim \cdot D/(1-D) \cdot V_{in} = V_{out}$,since flyback is a buck boost topology, we found the turns ratio to be 19. Following this, we need the primary and secondary rms and average currents in order to decide on the core inductance and the exact turns ratio. We know that ideally we need around 1.2 A in secondary and .....

3 Controller Design

This part contains the desired control design for our flyback converter. The controller is chosen to be type 2 controller with a schematic shown in figure 9.

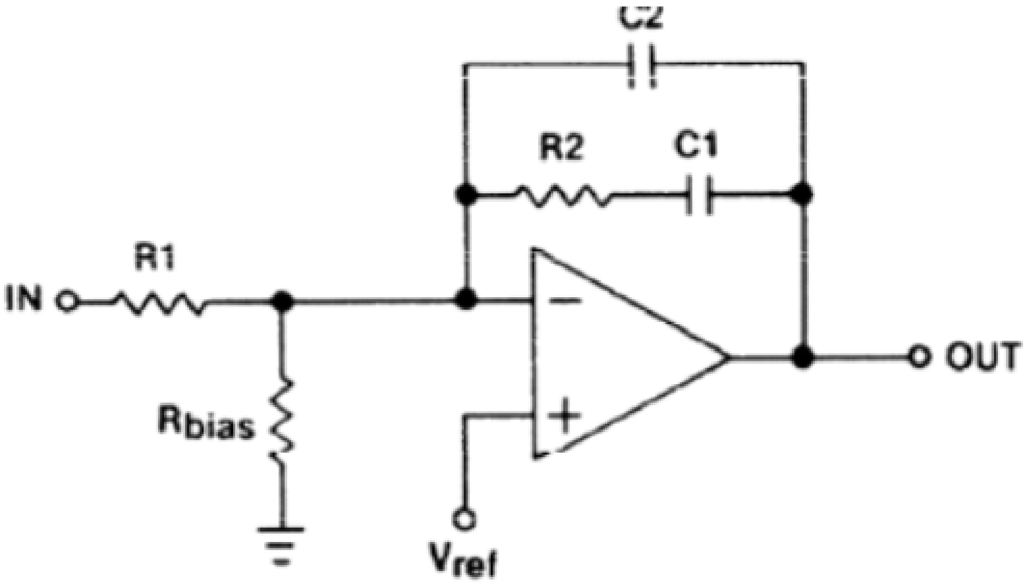

Figure 7: Type 2 Controller

3.1 Part 1. Controller Transfer Function

The transfer function for the controller is:

$$\tilde{v}_c/\tilde{v}_o = Z_{feedback}/Z_{input}$$

COnsider that the input and output voltages contain DC and ACcomponents, while the reference is DC. In order to derive the transfer function, consider the AC components:

$$Z_{feedback} = 1/sC_2//(R_2 + 1/sC_1)$$

$$Z_{input} = R_1 R_{bias}/(R_1 + R_{bias})$$

This yield the following transfer function:

$$T_c(s) = \frac{R_1 + R_{bias}}{R_1 R_{bias}} \cdot \frac{1}{C_2} \cdot \frac{s + 1/(R_1 C_1)}{s(s + (C_1 + C_2)/R_2 C_1 C_2)}$$

Here, we observe that the controller is a compensator function. It is in our control to make it either a lead or lag compensator. For stability, we need an increase in the phase margin of our close loop system. Hence, we desire the controller to add a phase lead (boost). Therefore, we need to place a zero before a pole so that first an incline in the phase occurs. The general bode plot for the controller transfer function is provided controllerd

Figure 9: Controller designed for the plant

in figure 8, we see that the zero is placed before the pole.

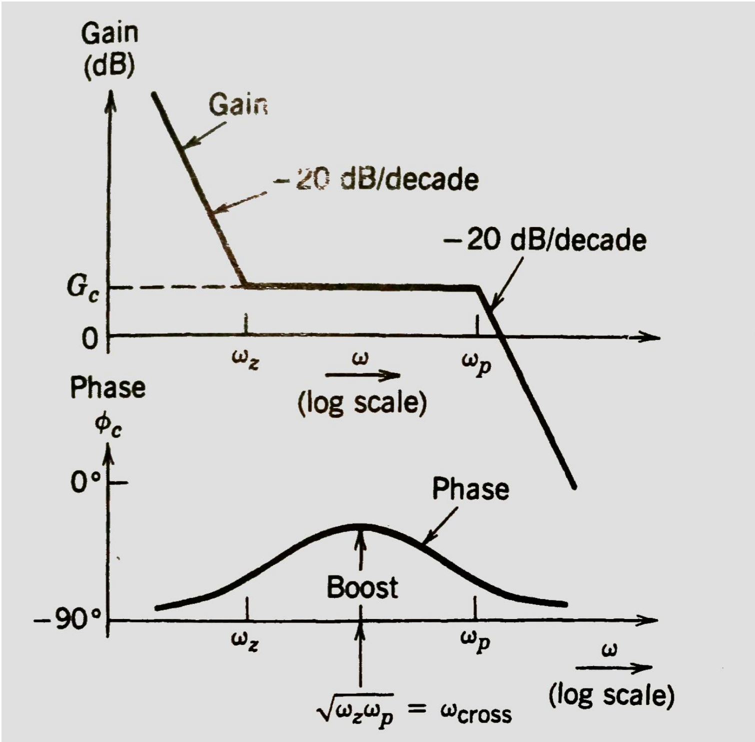

Figure 8: Type 2 Controller Bode Plot

3.2 Controller Computer Simulation -b and c-

The bode plot for type 2 controller is simulated as seen in figure9

This controller was designed for the flyback converter. Since the transfer function for a flyback isa nonlinear one, first a system identification is applied on the converter. Then, not being sure whether this system is fine, literature is researched and an application noteof texas instruments(http://www.ti.com/lit/an/slua086/slua086.pdf) is found explaining in detail of how to select the necessary parameters.

The rightmost zero (the one closer to the unstable region) is found from:

$$\omega_{rhz} = \frac{NV_{in}^2}{R_{out}L_p(V_{in} + NV_{out})} \tag{1}$$

Using the measured inductance of our core, this yields a zero around 0.510^{-4} and according to the document, this zero determines the maximum crossover frequency. Taking this value as our crossover frequency, one zero and one pole is selected. $\omega_z = 0.0001 and \omega_p = 0.001$.

Once again the document suggests that for compensation, high gain at low frequencies is needed. Hence,the gain is selected as 10. For very low frequencies, the gain contribution of the controller is 1.

The closed loop control works fine and the system settles at the very desired point. The results are shown in 10 and 11.

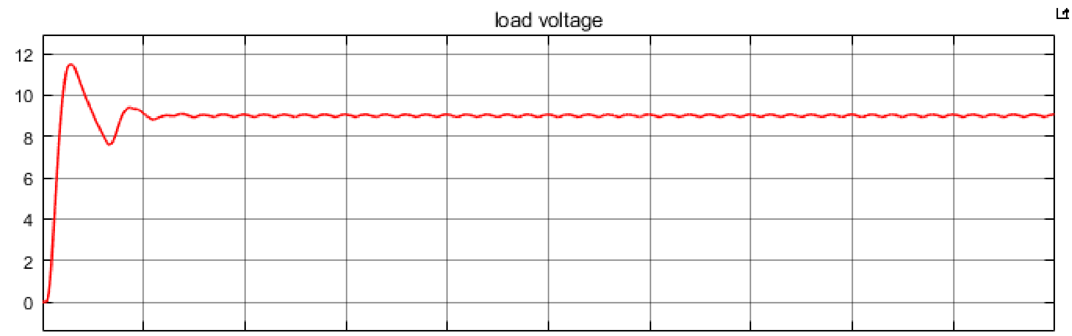

Figure 10: Controller output voltage

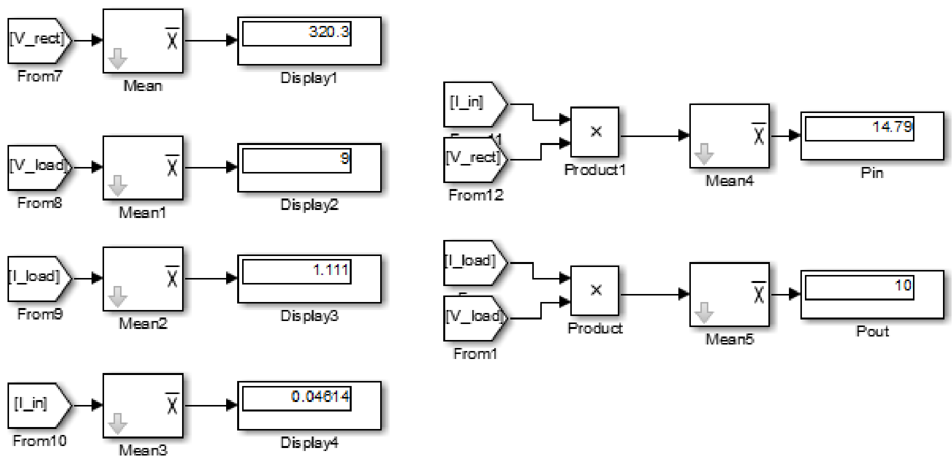

Figure 11: Controller output values

4 Load and input Change Adaptation

The controller behaves very quick and compensated to the load changes as seen in 14 and 15.

Figure 12: Controller output voltage for load increase

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Figure 16: Frequency response of the flyback from system identification

Figure 13: Controller output values for load increase

And when the Ac voltage input is decreased by 10 percent from its nominal value, the controller is still able to keep the output at 9 V.

Figure 14: Controller output voltage for input decrease 200V AC

Figure 15: Controller output values for input decrease 200V AC

5 Discussion

This controller performs very quick and the output oscillation is acceptable. At the very beginning it has an overshoot but this overshoot settles quickly. The controller is capable of adjusting to both input and output changes.

Looking at the frequency response **??** and the crossover frequency we have calculated from the document base equation 1, we see that the derived and simulated values do fit. And we observe that the controller works nice.