MIDDLE EAST TECHNICAL UNIVERSITY

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

EE464 Simulation Project #2

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Student 1: Mert KARAÇELEBİ - 2030930
Student 2: Tuna YILDIZ - 2031656
Student 3: Göksenin Hande BAYAZIT - 2093441

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1 Introduction

For EE464 (Static Power Conversion II) course hardware project has been announced. Our group "EMI Monster" selects flyback converter design with specified conditions given in Table 1.

Table 1: My caption

Project No	Vin (V)	Vout (V)	Pout (W)	Topology
9	230 AC	15	15	Flyback

We choose this project because flyback topology is more feasible to apply because of it does not require additional output inductance and third transformer winding to discharge magnetizing current. Moreover, our project needs to deal with high voltages but our load power is smaller than other projects therefore, overall design should require smaller components. In this report we have explained our design guide for project and simulation results for different cases.

2 Isolated Converter Design

2.1 Steady State Operation

In part a we were asked to implement the converter which converts 230 V_{rms} to 15 V output DC voltage. For this purpose, we implemented flyback converter. In flyback converter we used transformer and we adjusted the turns ratios of the transformer in order to have low voltage at the secondary side of the transformer. After that, by adjusting the duty cycle we obtained the 15 V output DC voltage. The circuit schematic of the flyback is in figure 1.

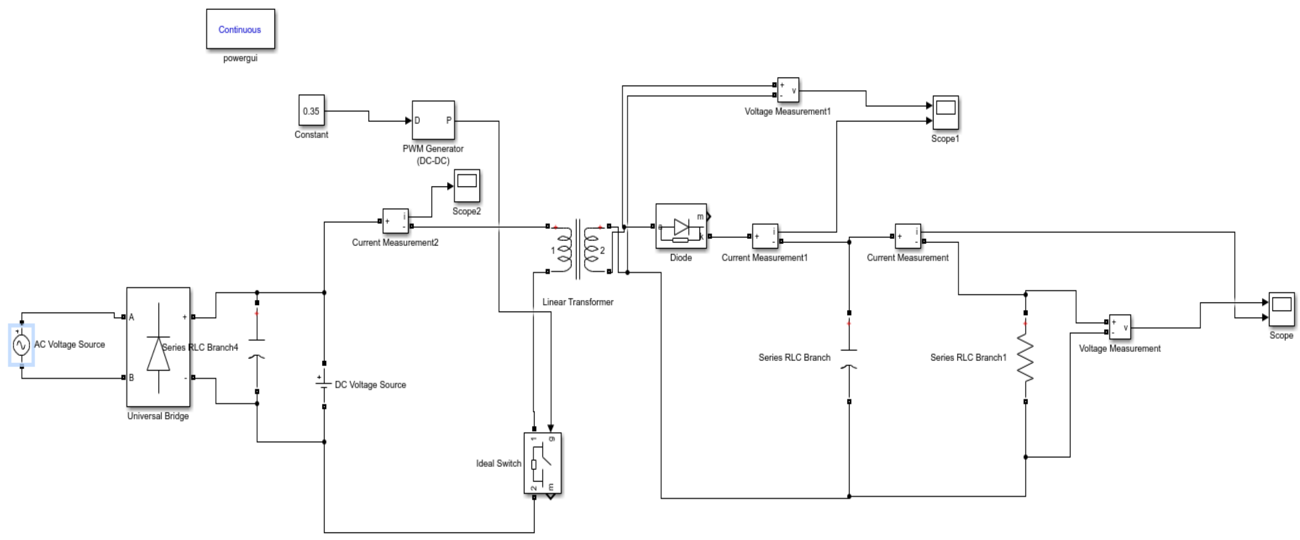

Figure 1: Flyback Converter Circuit Schematic

In flyback converter, in order to have an small magnetizing inductance value of the transformer for staying in continues conduction mode at normal operation, we decided the frequency of switch as 80 kHz. In other words, size of the transformer decreases as switching frequency increases. Moreover, with increasing switching frequency, all components such as filters, capacitors and inductors. However, when the switching frequency increases the switching loss increases as well.

In order to obtain the proper duty cycle value we used the formula 1

$$[H]V_o = V_{in} \times \frac{N_s}{N_p} \times \frac{D}{1-D} \tag{1}$$

By using this formula we calculated the D value as 0.35. While calculating the duty cycle we used the turns ratio of the transformer as calculated in the section 2.2.

Moreover, we are using the full bridge rectifier and DC link capacitor in order to have the DC voltage at the input of the flyback converter. For this purpose we calculated the input voltage of the flyback converter by using the formula 2.

$$V_{dc} = 0.9 \times V_{rms} \tag{2}$$

By using the formula 2 the V_{in} voltage of the flyback converter is calculated as the 207 V.

The output voltage and output current graph of the flyback converter that we designed in the project is in figure 2.

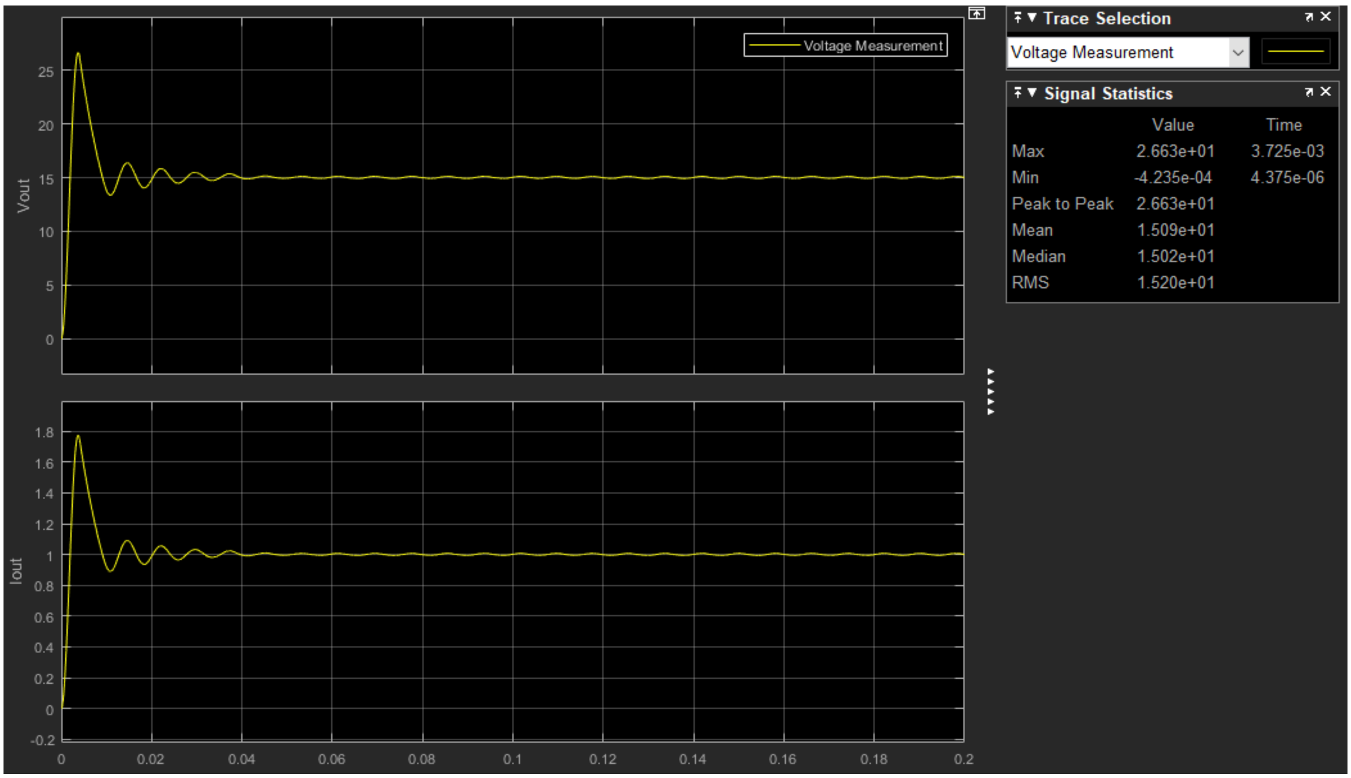

Figure 2: Output voltage and current graphs of the flyback converter.

2.2 Transformer Design

2.3 Discontinuous Mode Calculations

Discontinuous mode is defined for flyback converter as; magnetizing current of transformer drops to zero in one cycle period. This condition is directly related to duty cycle of switching and inductance of the magnetizing branch. Magnetizing inductance can be found from the number of turns in the primary winding. This magnetizing inductance is calculated in 5.

$$Lmin = \frac{(1-D)^2 \times R}{2 \times f} . \frac{N1}{N2}^2 \tag{3}$$

We have designed our converter to operate at continuous mode when loading is 50%. Our nominal load is 15 Ohm. In our minimum magnetizing inductance calculation we calculated with 30 Ohm. As stated before our turns ratio is 7 (N1/N2), duty cycle is 0.35 (D) and switching frequency is 80 kHz (f).

$$Lmin = \frac{(0.65)^2 \times 30}{2 \times 80000} . \frac{7}{1}^2 = 2.14mH \tag{4}$$

We expect to observe discontinuous mode of operation at higher resistances/ lower load currents than %50 loading case. Minimum current of magnetizing branch can be calculated in equation . Naturally at the edge of discontinuous minimum magnetizing current should be zero.

$$Imin = I_{lm} - \frac{\Delta Ilm}{2} \tag{5}$$

$$Imin = \frac{V_s \times D}{(1-D)^2 \times R} \times (\frac{N1}{N2})^2 - \frac{V_s \times D \times T_s}{2 \times L_m} \tag{6}$$

Using equation 6 we calculated the R value as:

$$R = \frac{2 \times L_m}{(1-D)^2 \times Ts} \times (\frac{N1}{N2})^2 = 29.98\Omega \tag{7}$$

This resulted is expected. In figure 3 one can find the simulation results for 30 Ohm load in secondary side of the transformer. In 30 Ohm load our minimum current for continuous operation is 0.5 A . In figure 4 shows the load current and voltage.

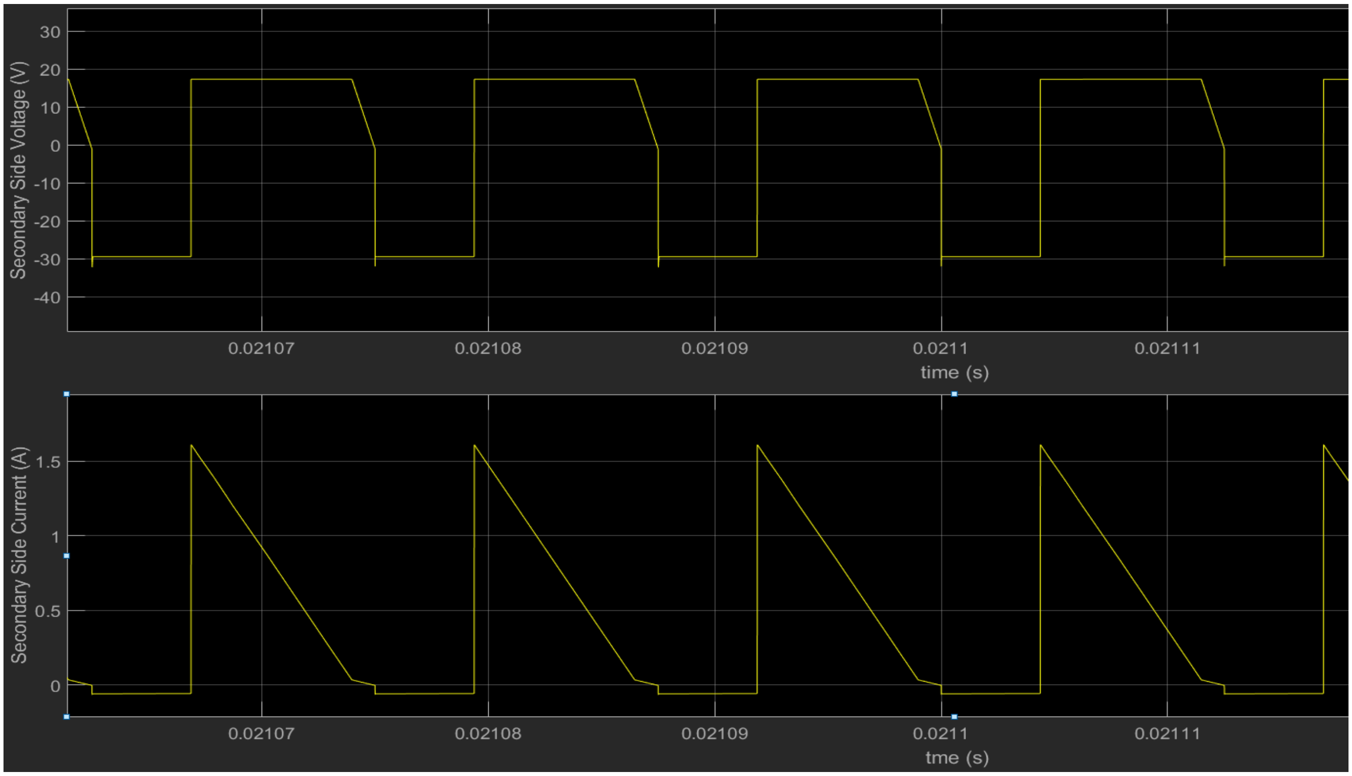

Figure 3: Transformer Secondary Side Voltage and Current Waveform

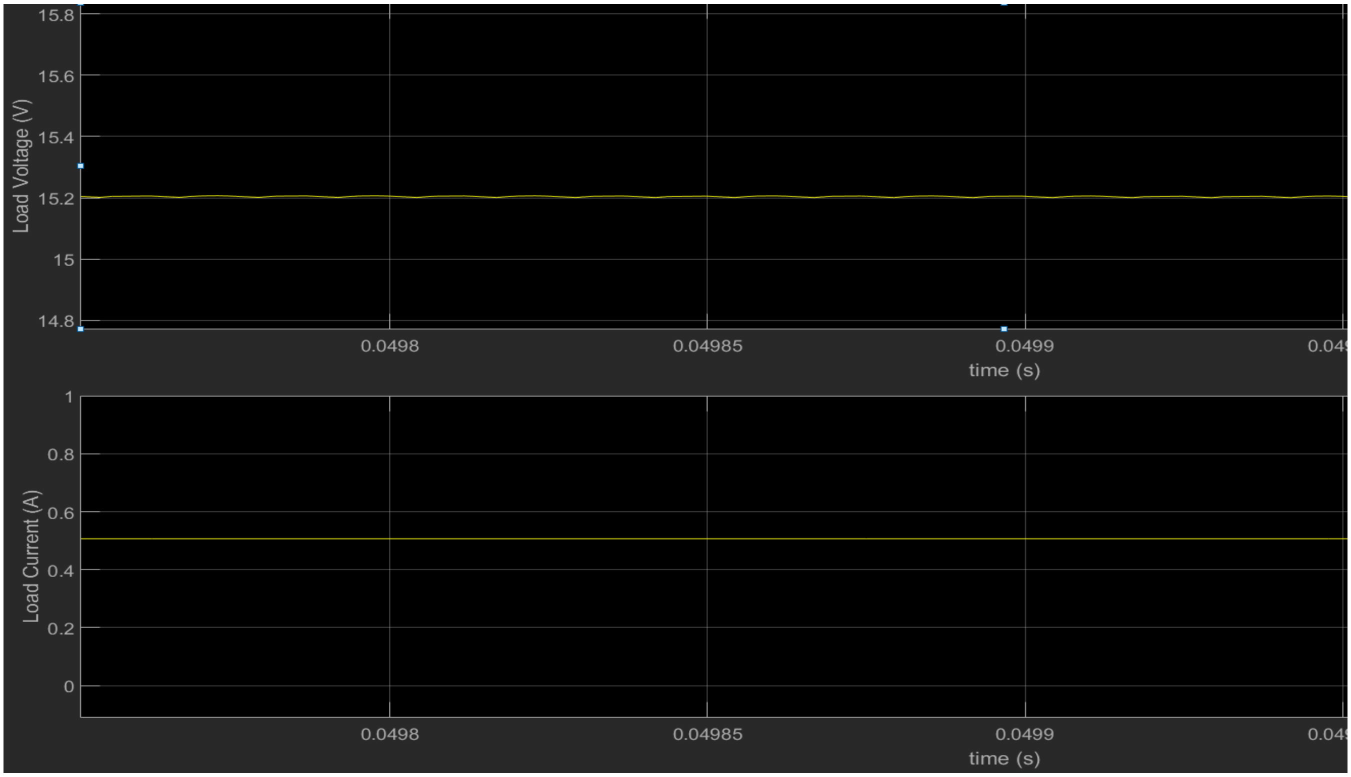

Figure 4: Load Voltage and Current Waveform at the Edge of Discontinuous

Our normal operation is shown in section 2.1. When we increased the load resistance 1 Ohm more we observed sudden voltage drop at the secondary terminals while switch is still operating at off condition. This kind of operation is not desired using a controller can solve this issue since our design is capable to compensate the increment in duty cycle up to 0.5 approximately.

2.4 Non Ideal Simulation

In this circuit we were asked to implement the same flyback converter with using the non ideal switches. The circuit schematic is in figure 5.

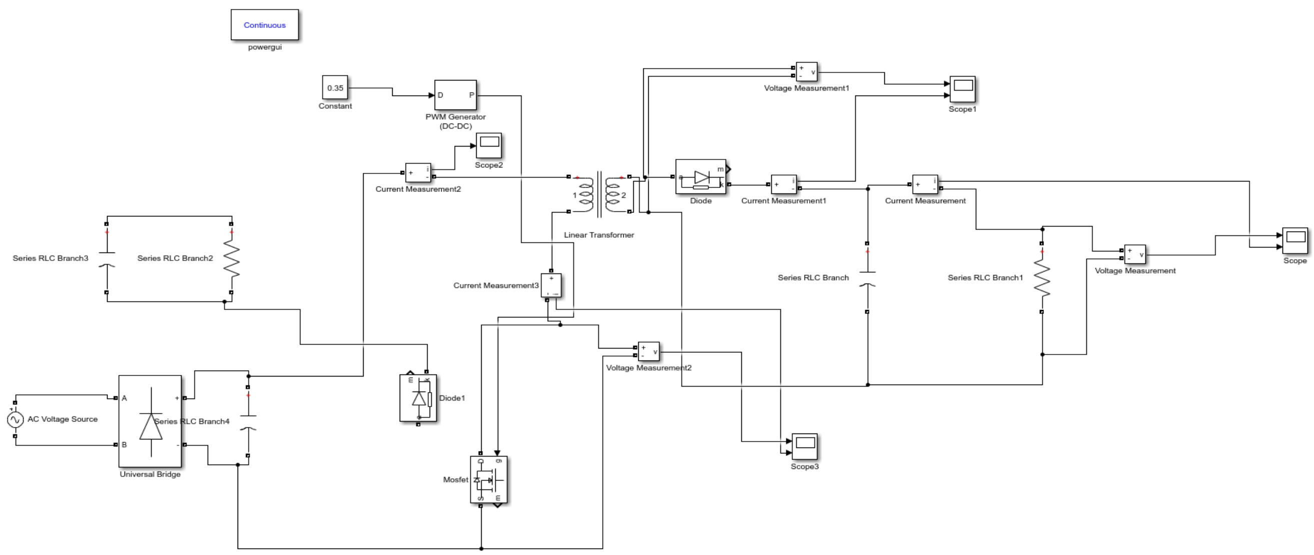

Figure 5: The circuit schematic with non ideal switches and without snubber circuit.

The switch voltage and current graph is in figure 6.

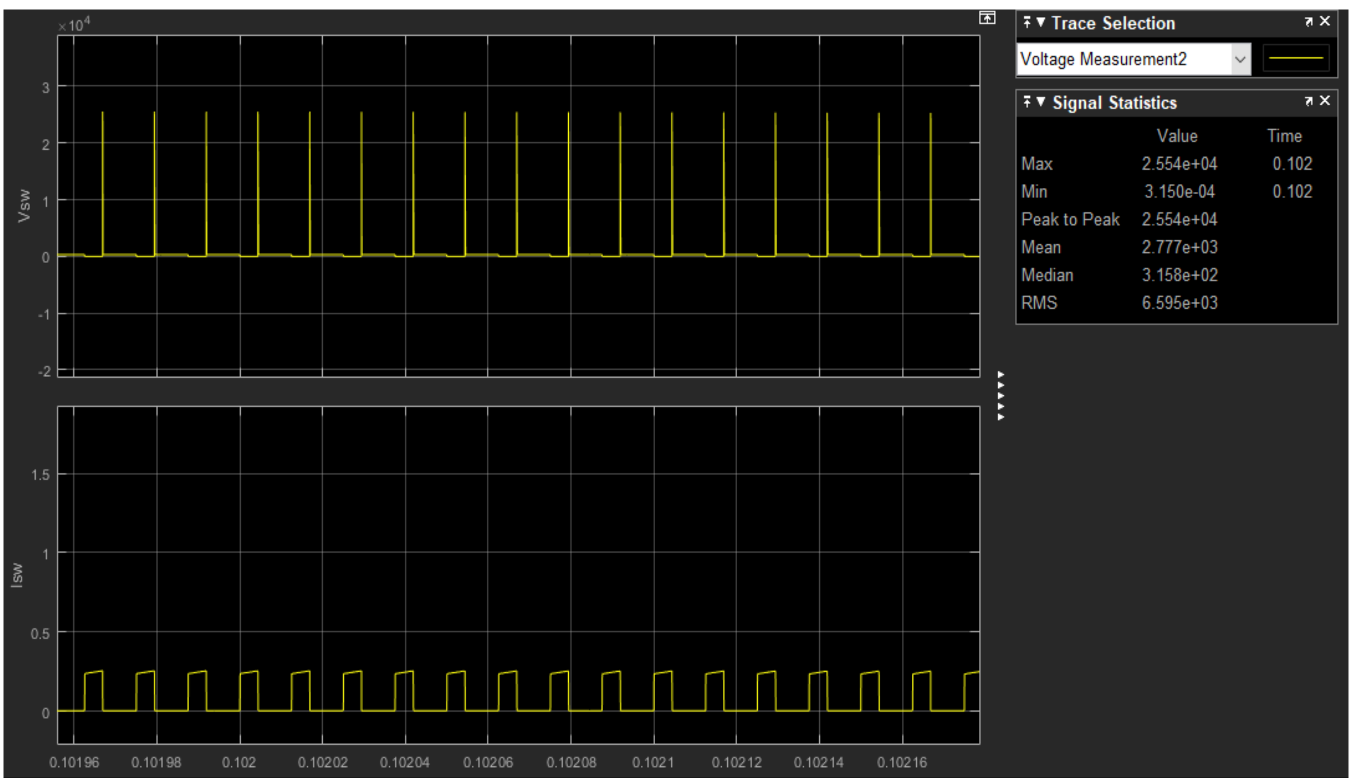

Figure 6: The switch voltage and switch current graph of the flyback converter.

As it seen from the figure 6 when we use the non ideal switch and not using the snubber circuit, voltage is increasing to $2.5444 * e + 04$. It is serious problem for the switch component since it sees very high voltage when the switch is off. Therefore, we need the snubber circuit for protect the switch from high voltages.

The flyback converter with the snubber circuit is in figure 7.

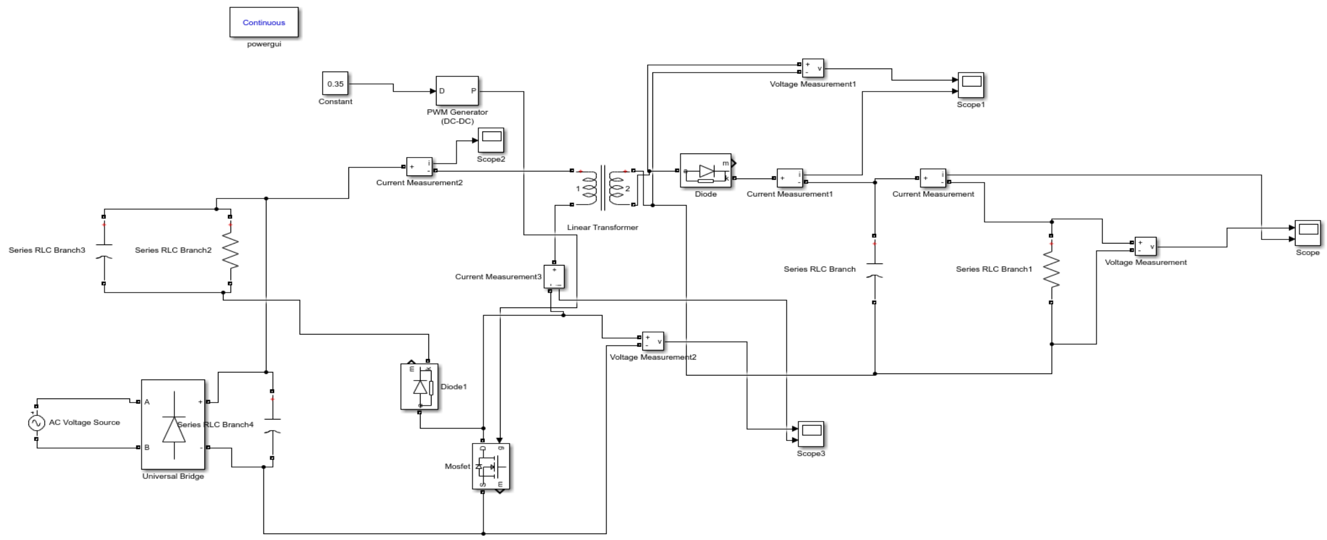

Figure 7: The flyback converter with snubber circuit.

The voltage and current of the switch graph is in figure 8.

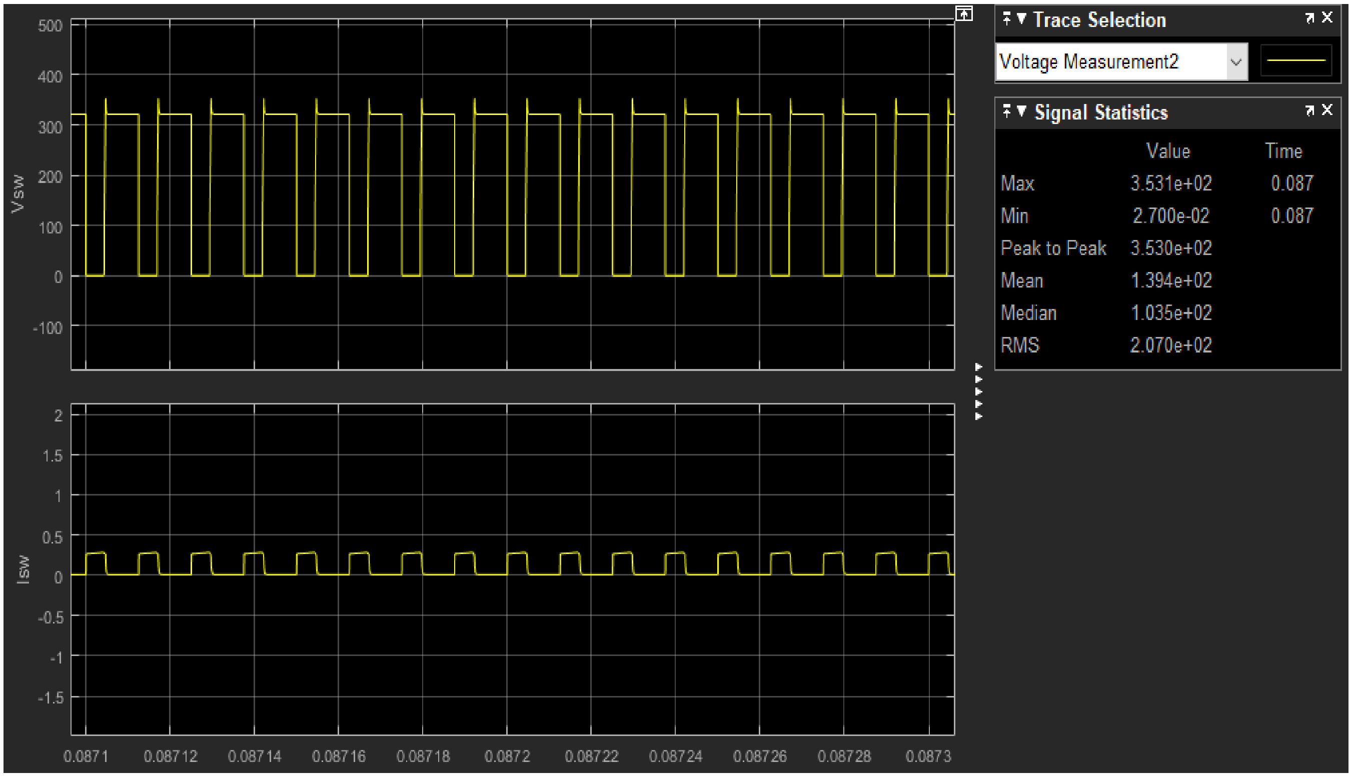

Figure 8: The voltage and current graph of the switch.

As is seen from the figure 6 and 8 there is quite difference for voltage being seen at the switch. Therefore, we built a snubber circuit for reducing the overshoots for switch voltages. In order to have a proper snubber circuit we used some equations which are 8, 9.

$$C > \frac{V_{clamp}}{V_{ripple} \times f_{sw} \times R} \tag{8}$$

$$R < 2 \times V_{clamp} \times \frac{V_{clamp} - V_{OR}}{L_{leak} \times I_p^2 \times f_{sw}} \tag{9}$$

By using these 8 and 9 formulas we obtained the resistance value as 75 $k\Omega$ and capacitance value as 330 pF.

2.5 Efficiency

2.6 Component Selection

For this project we add every component a safety margin with all those margins our component list has been found at table **??** . All of these components have already been bought, on the other hand if unexpected situations are encountered we could change our components during the implemantation part of the project.

3 Controller Design

3.1 Analytic Transfer Function Calculations

3.2 Simulations

3.3 Type II Controller

3.4 Performance Analysis

3.5 Comments

4 Conclusion