Orkun İbrahim Kök 22003656

EE419/519 Homework Assignment #1

"I completed this homework assignment independently."

Introduction:

The aim of this homework is to design an old-fashioned linear power supply. The input voltages are 230Vrms±15% 50Hz. The output voltage should be adjusted to +3.3V or +5V accordingly and maximum output current should be 0.5A at most and the output ripple should be less than 25mV.

Methodology:

In order to maximize the efficiency of the design, the calculations are done for the worst case which is V_{in}=195.5V rms 50Hz and R_{Load}=10Ω with V_{out}=+5V. The peak value of 195.5V rms is 276.5V. Considering the leakage in the transformer (K=0.92), I choose to get a voltage around +10V (Fig. 1.a) at the secondary winding of the transformer (Eqn. 1). In order to maximize the efficiency for the worst condition, the bottom corner of the ripple voltage of the filtering capacitor should be greater than output voltage (5V) + voltage regulator's dropout voltage (300mV) (Eqn. 2). Fig 1.b shows the voltage waveform of the filtering capacitor.

$$\frac{V_{primary}}{V_{secondary}} = \sqrt{\frac{L_1}{L_2}} \qquad \text{Eqn. 1}$$

$$\frac{274.5}{10} = 27.45$$

$$L_2 = L_1 \times (27.45)^2 = 16mH$$

$$V(C) \geq 5 + 0.3 \qquad \text{(Eqn. 2)}$$

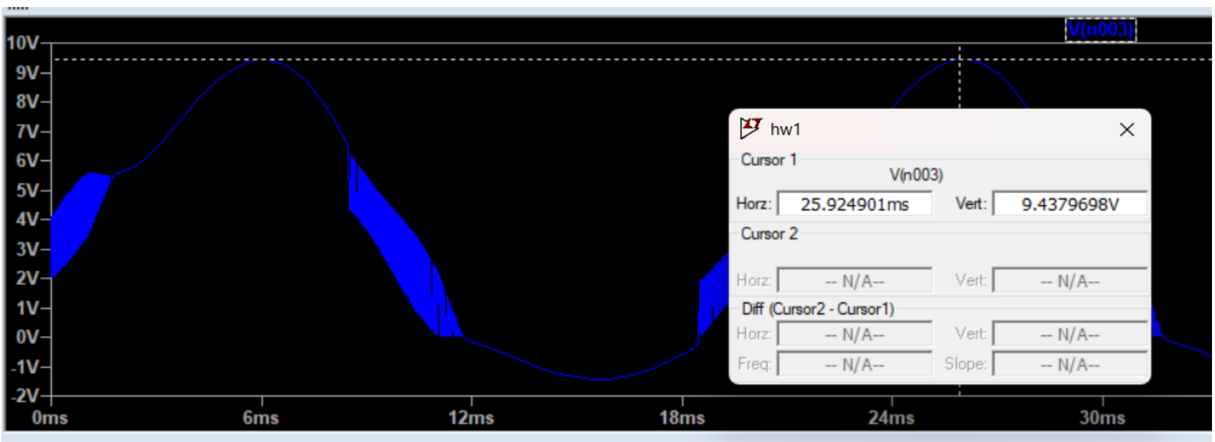

Fig. 1.a: Secondary winding voltage

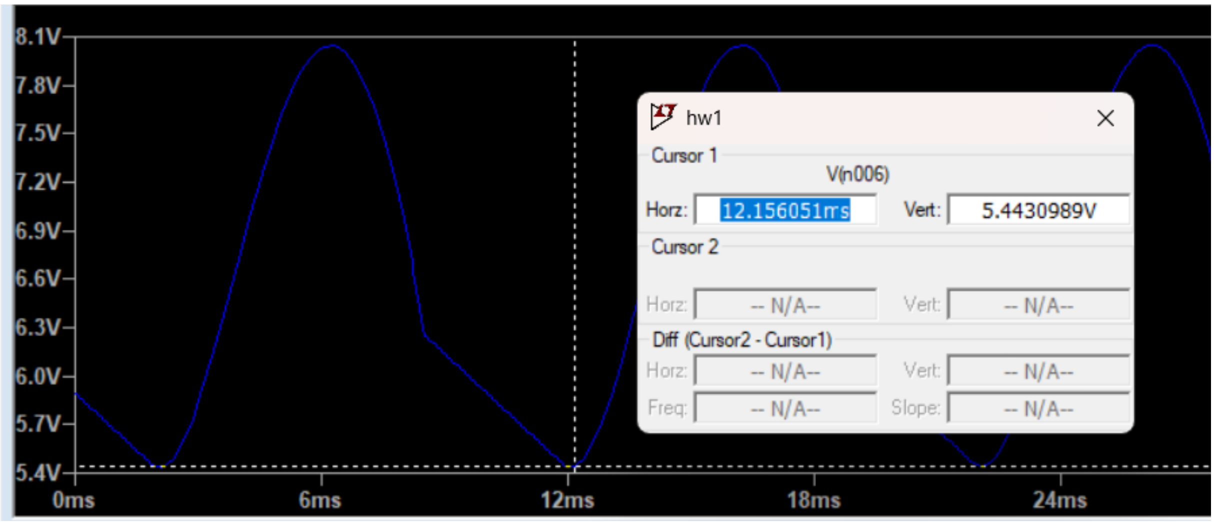

Fig. 1.b: Filtering capacitor voltage

Looking at the Fig. 2, the average input current is measured a value close to zero. Therefore it can be said that the simulation is in the steady state.

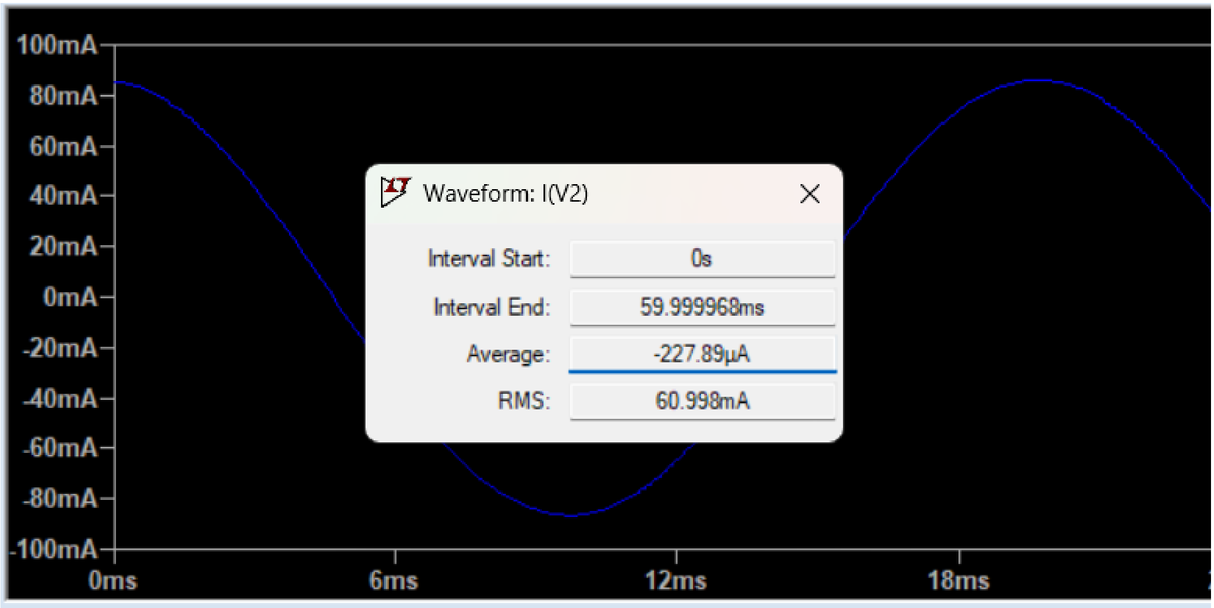

Fig. 2: Average input current in steady state

After simulating the circuit, a small adjustment was made and inductor of the secondary winding was chosen as 19mH, and output voltage 9.43V (Fig. 1.a). After the secondary winding of the transformer, a full-wave bridge rectifier is added in order to convert the AC voltage to DC voltage. In this bridge rectifier, 4 Schottky diodes were used in order to minimize the energy dissipation and maximize the efficiency of the circuit. Then, for filtering purpose, a 2200µF electrolytic capacitor is added to the circuit. This filtering capacitor gets rid of the ripple before the voltage is inputted to the LDO voltage regulator. For LDO voltage regulator, LT1763 is chosen for this design. This voltage regulator has 300mV dropout voltage, 500mA output current and it is also adjustable. Fig. 3 shows the equation for the resistors for LT1763 in order to get desired output voltages.

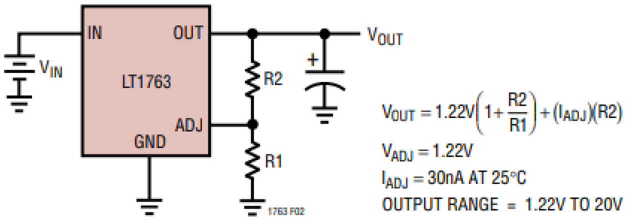

Fig. 3: Adjustable Operation

To get +5V, R1 values is set to 1KΩ and R2 value is calculated as 3.13KΩ. For +3.3V, R1 value again set to 1KΩ and R2 value is calculated as 1.72KΩ.

Fig. 4 shows the circuit schematic.

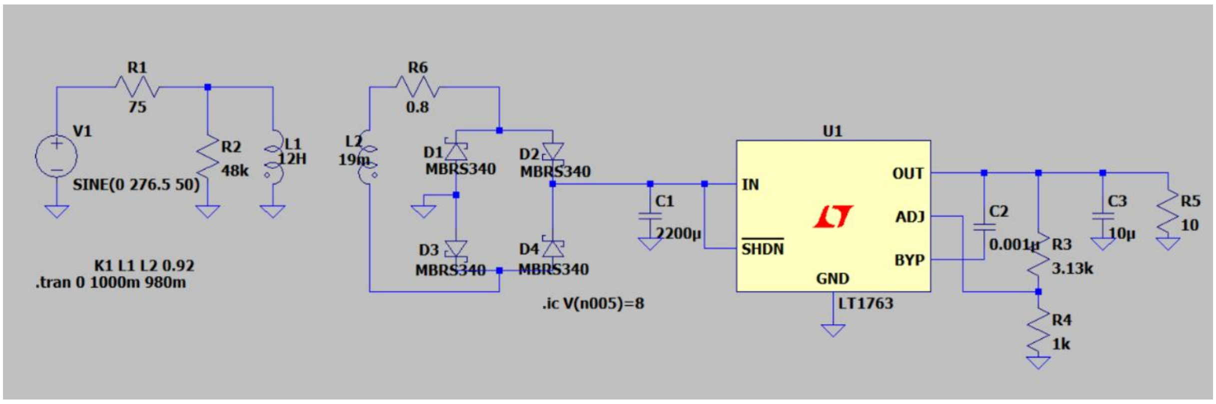

Fig. 4: Circuit Schematic

The 0.001µF capacitor is added to the circuit in order to minimize the output noise as written in the datasheet. The 10µF capacitor is again present for minimizing the ripple. Additionally, I added 1.6Ω resistors in series with capacitors larger than 100µF and 0.2Ω resistors in series with capacitors smaller than 10µF as ESR values.

Design Specifications: (All three circuit schematics and output voltage waveforms can be seen in Appendix)

Specification b. (Vin=195.5V rms RL=10ohm Vout=5V)

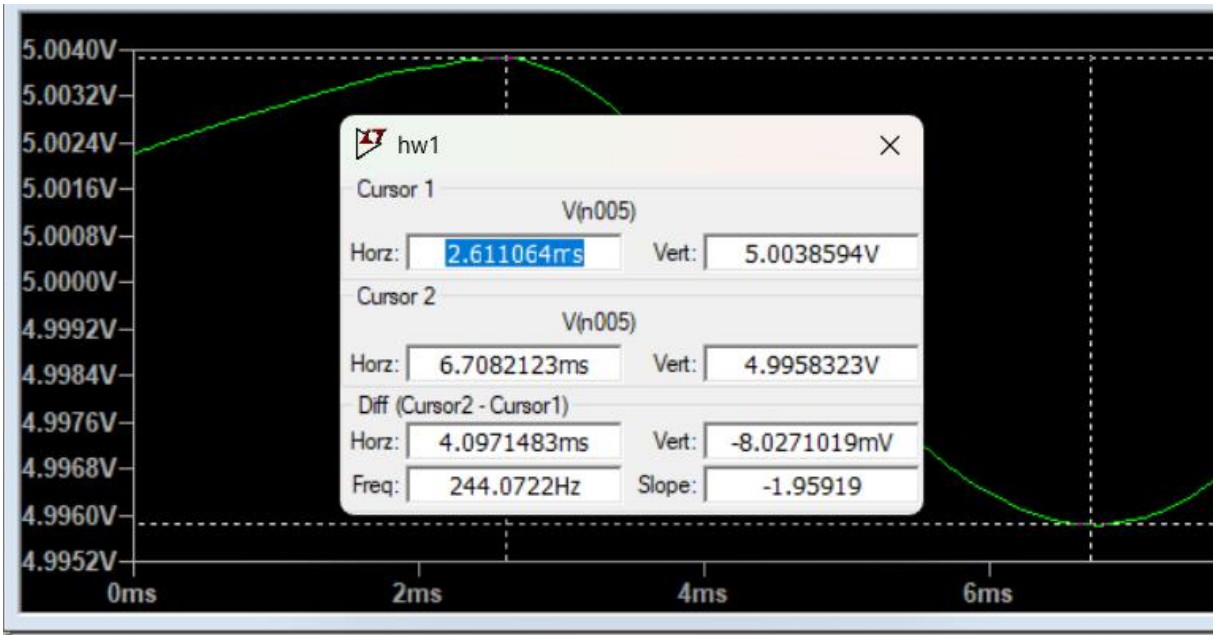

Fig. 5: Output Voltage ripple

Fig. 5 shows the measured output voltage is +5V and the output voltage ripple is measured 8mV, which is smaller than 25mV. The input voltage is 276.5V p-p (195.5V rms).

The instantaneous input power (average) value is measured as 5.76W (Fig. 6). The instantaneous output power (average) value is measured as 2.5W (Fig. 7).

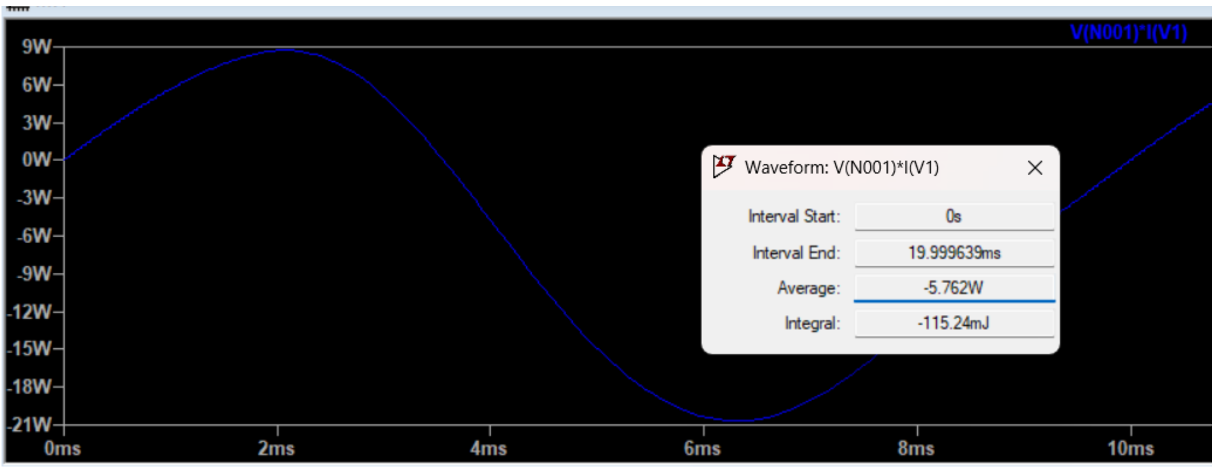

Fig. 6: Instantaneous Input Power

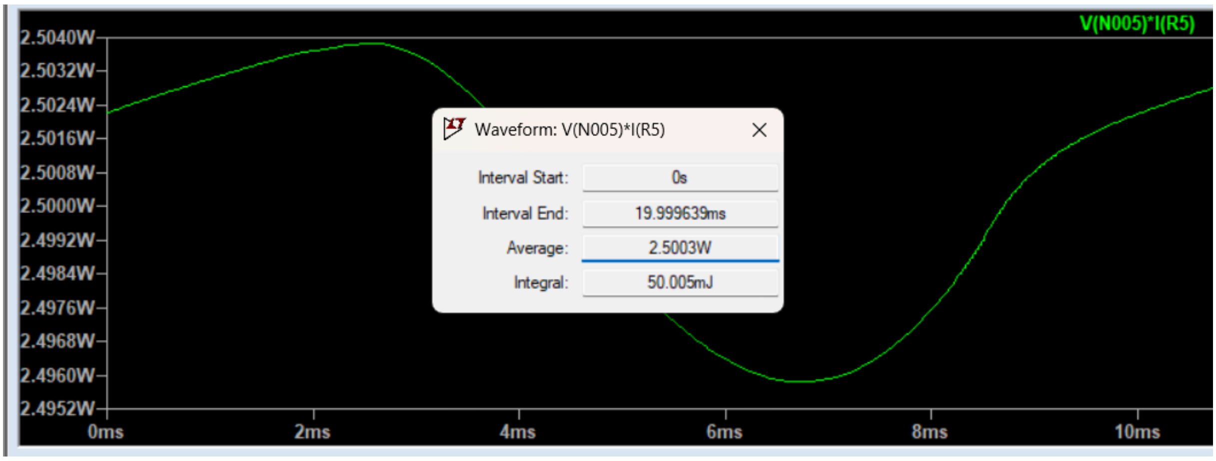

Fig. 7: Instantaneous Output Power

The efficiency of this circuit is calculated as

$$\frac{P_{out}}{P_{in}} \times 100 = \frac{2.5}{5.76} \times 100 = 43.4\% \qquad \text{(Eqn. 2)}$$

Specification c. (Vin=264.5V rms RL=6.6ohm Vout=3.3V)

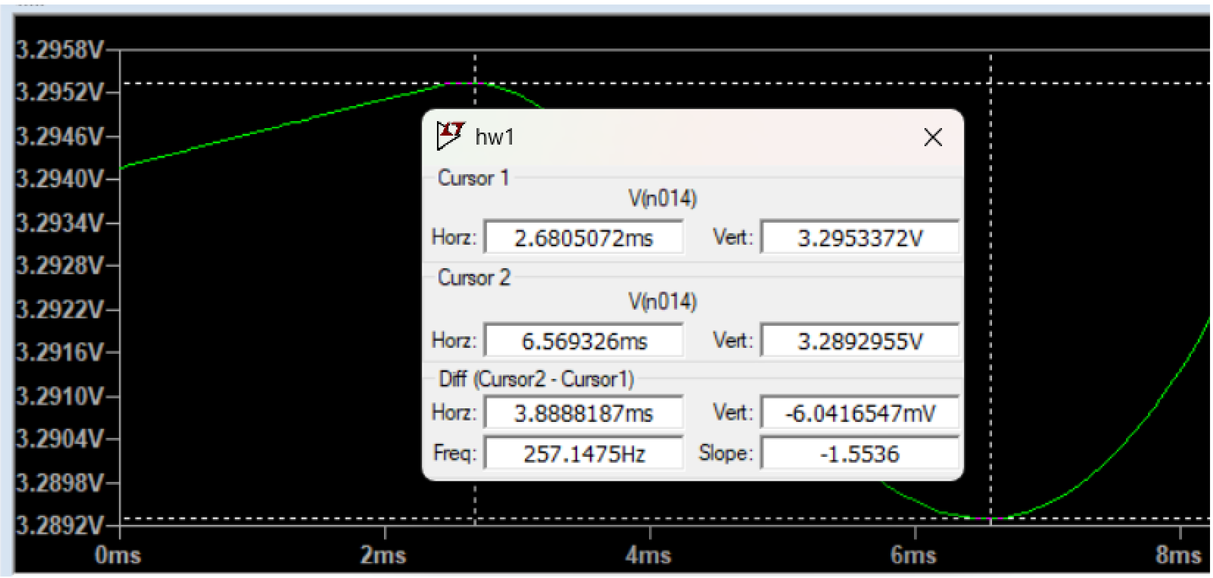

Fig. 8: Output Voltage Ripple

For this specification, the output voltage is measured as 3.3V and the ripple is measured 6mV (Fig. 8), which is again less than 25mV. The input voltage is 374V p-p (264.5V rms).

The instantaneous input power (average) value is measured as 8.35W (Fig. 9). The instantaneous output power (average) value is measured as 1.64W (Fig. 10).

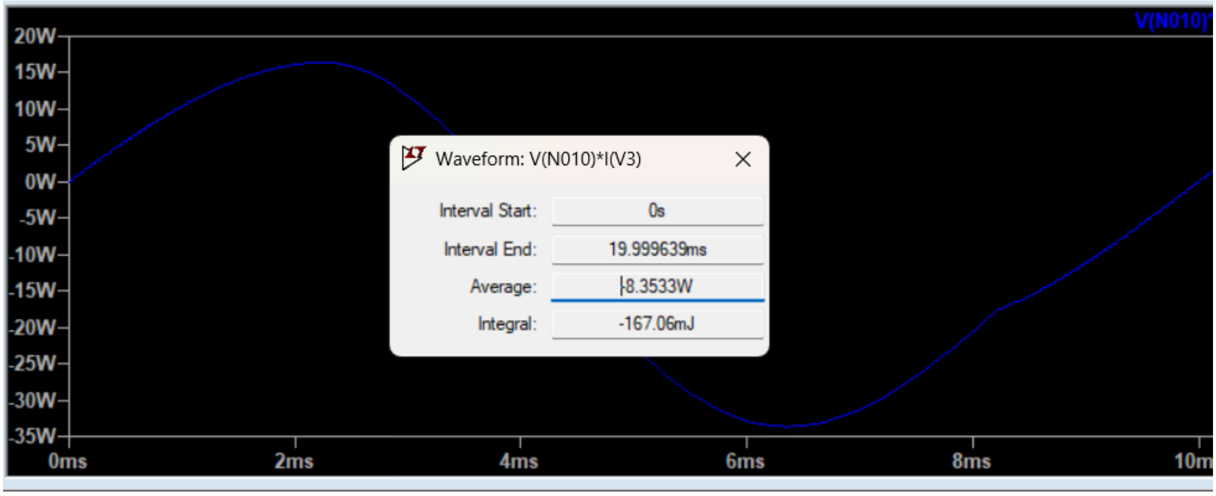

Fig.9: Instantaneous Input Power

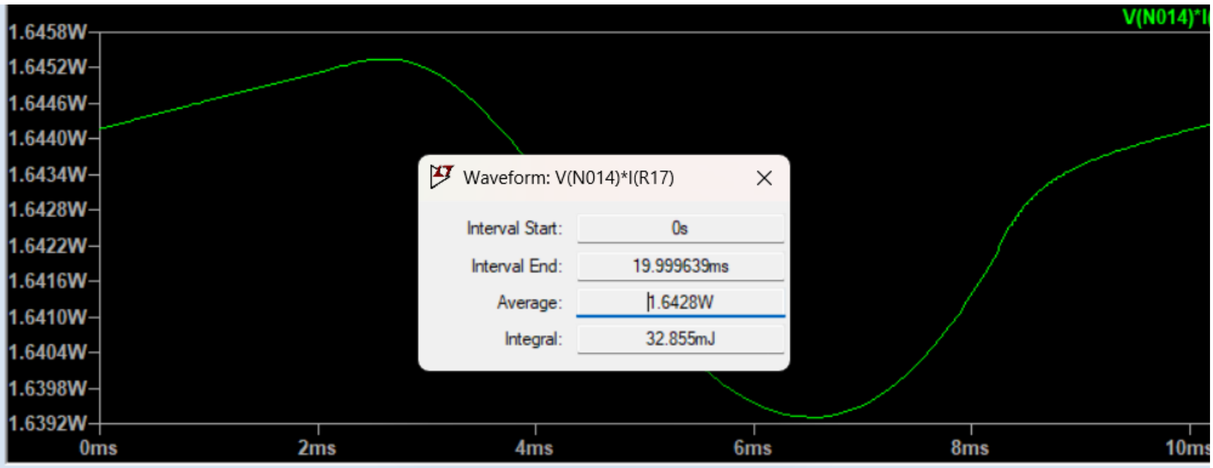

Fig.10: Instantaneous Output Power

Efficiency of this system is calculated as 19.6%. The efficiency value is nearly halved compared to 195.5V rms input voltage. However in this case, the interval between input voltage and output voltage is too wide. Therefore the efficiency value is reasonable for this circuit.

Specification d. (Vin=230V rms RL=no load Vout=3.3V)

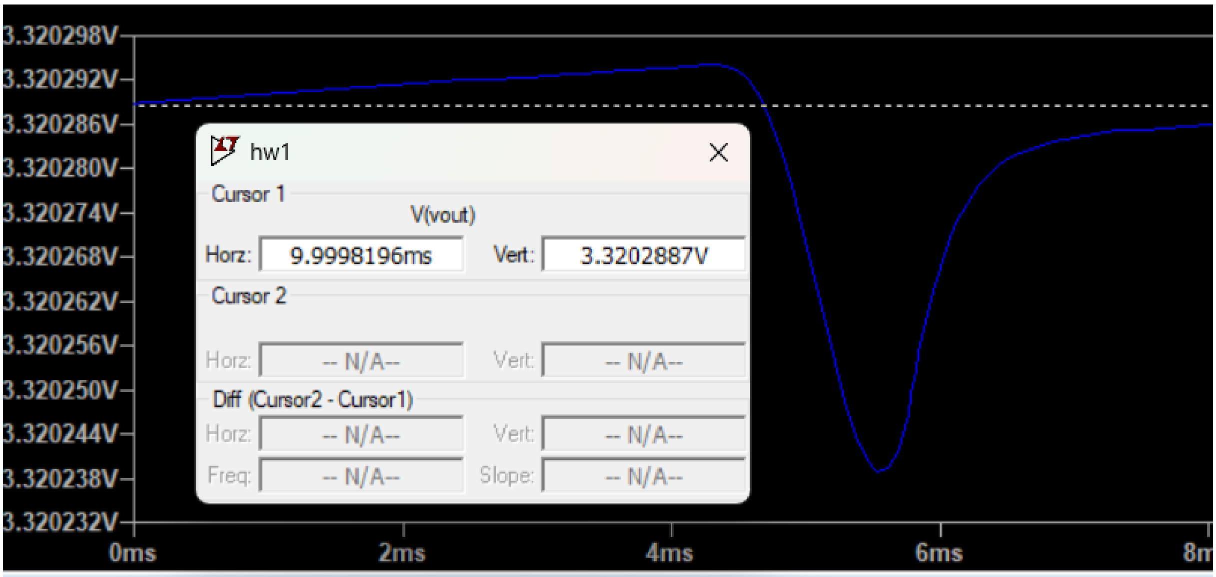

Fig.11: Output Voltage Ripple

Again in this specification, output voltage is measured as +3.3V.

The instantaneous input power (average) of this system is measured as 1.39W (Fig. 12).

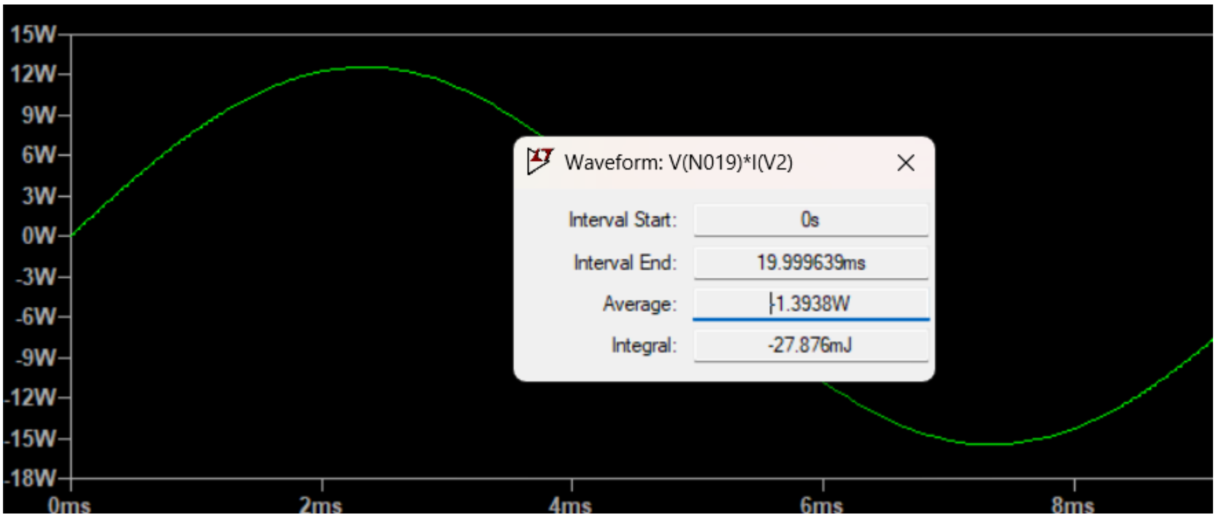

Fig. 12: Instantaneous Input power

Appendix

Vin=195.5V rms RL=10ohm Vout=5V

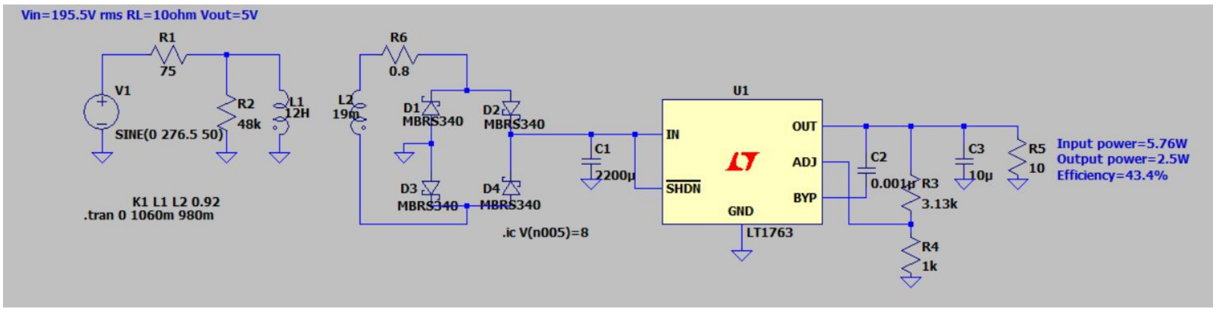

Fig. 13: Spec. b. Circuit Schematic

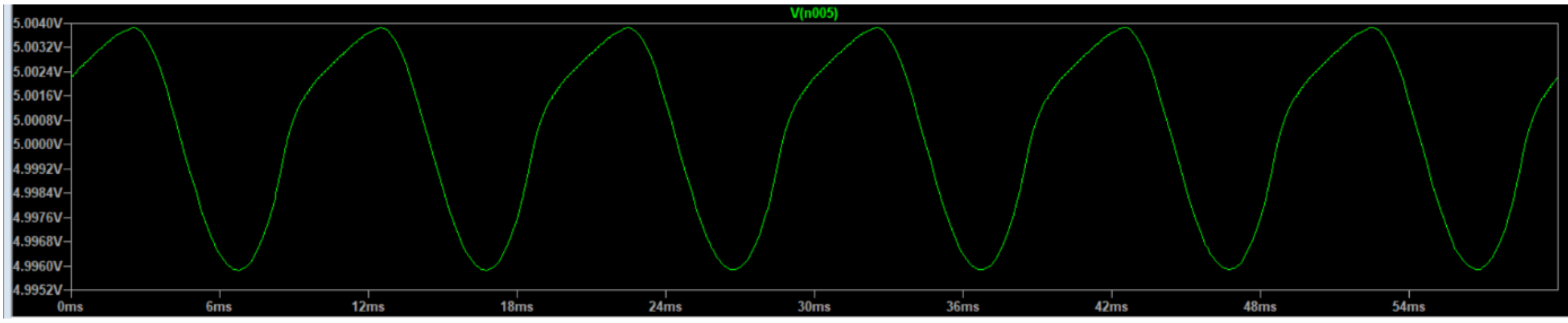

Fig. 14: Spec. b. Output voltage

Vin=264.5V rms RL=6.6ohm Vout=3.3V

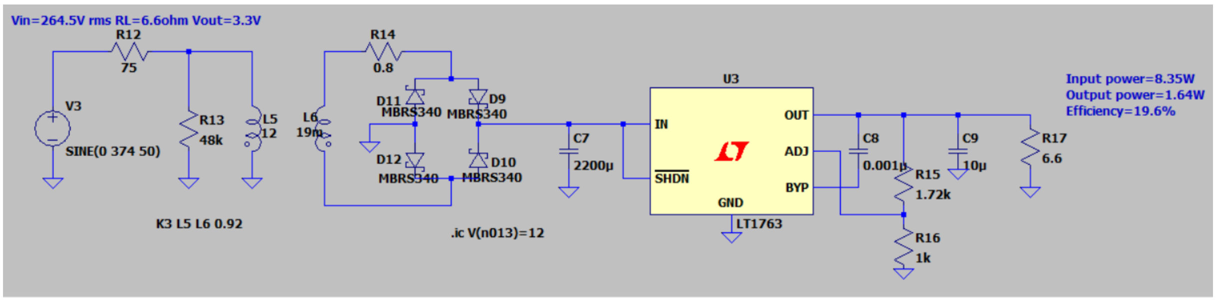

Fig. 15: Spec. c. Circuit Schematic

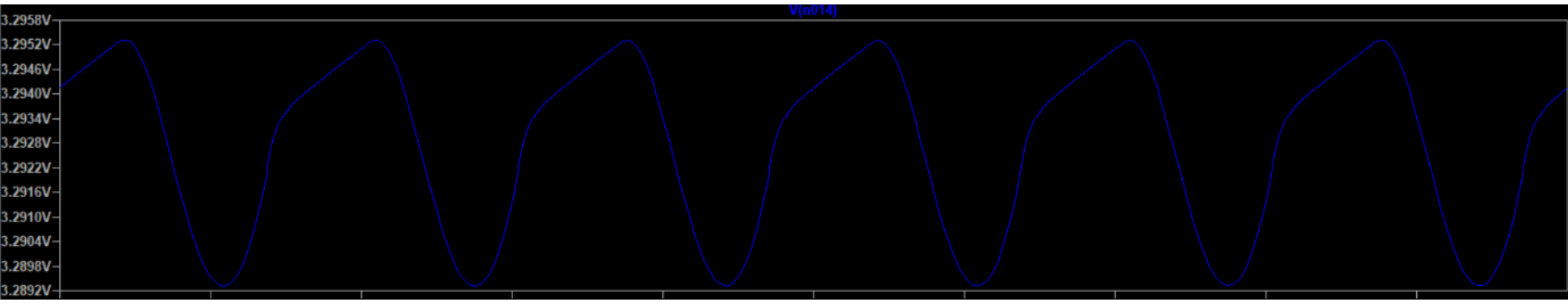

Fig. 16: Spec. c. Output voltage

Vin=230V rms RL=no load Vout=3.3V

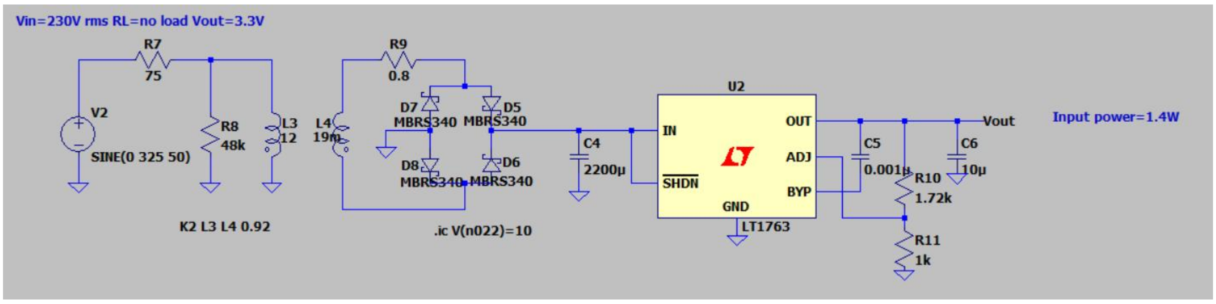

Fig. 17: Spec. d. Circuit Schematic

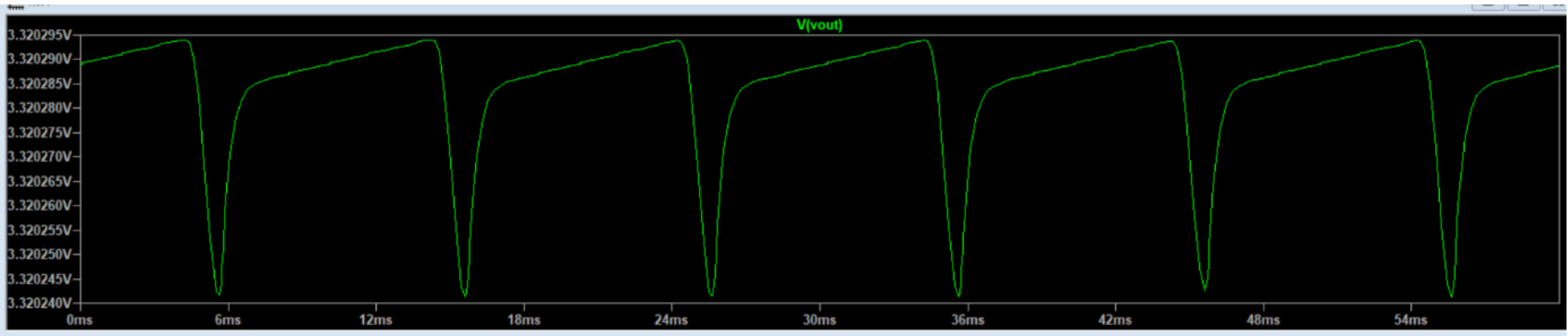

Fig. 18: Spec. d. Output voltage