Sri Lanka Institute of Information Technology

Faculty of Engineering

Analogue Electronics - EC2140

DC Power Supply Design
Assignment 01

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Index: EN21452970

Continuous Assessment Cover Sheet
Faculty of Engineering

Module Details			
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Program: SLIIT		Course: BSc engineering	
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Assessment details			
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Assignment 1: DC Power Supply Design

- **INTRODUCTION**

Due to economic considerations of electric power, electric power is generated, transmitted and distributed almost exclusively in AC form, but many electronic devices and circuits require DC supply to operate. Batteries and dry cells are suitable for this use. They are portable and have no ripple, but their voltages are low, they require frequent replacement, and they are more expensive than standard dc power supply. For this reason, DC power supplies is required to convert AC electricity into DC.

- Purpose

Set up the circuit and get an understanding of the circuit and to provide power to the amplifier circuit.

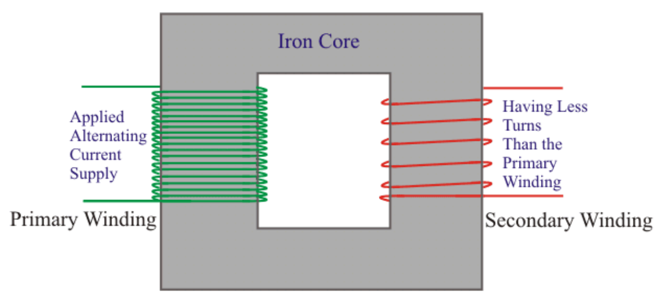
- Activity

Using the domestic supply voltage of 230 V, to create a power supply as the rated output voltage = 12V and the maximum output current = 500 mA and the ripple factor < 5%.

- The designing of the circuit was divided into 04 parts.
    1. Step Down Transformer
    2. Full Wave Bridge
    3. Capacitor
    4. Zener Regulator

1. Step Down Transformer

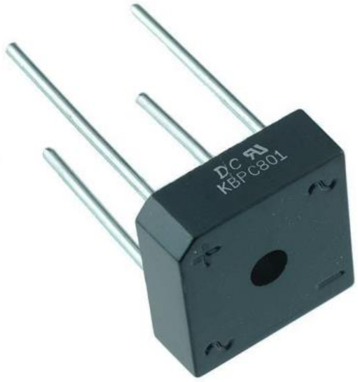
A step-down transformer is a transformer that changes the voltage at the primary and secondary windings from high to low. In terms of coil windings, the primary winding of a step-down transformer has more turns than the secondary winding. In this operation, a step-down transformer is used which reduces 230 V to 15 V.

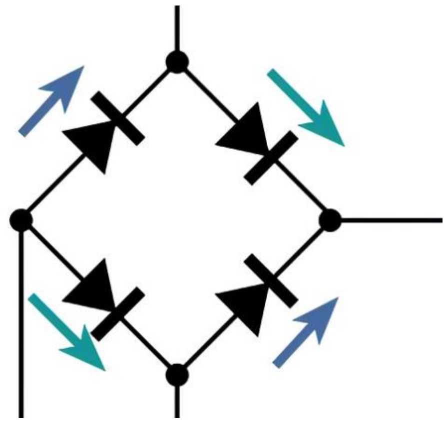


Step Down Transformer

2. Bridge rectifier

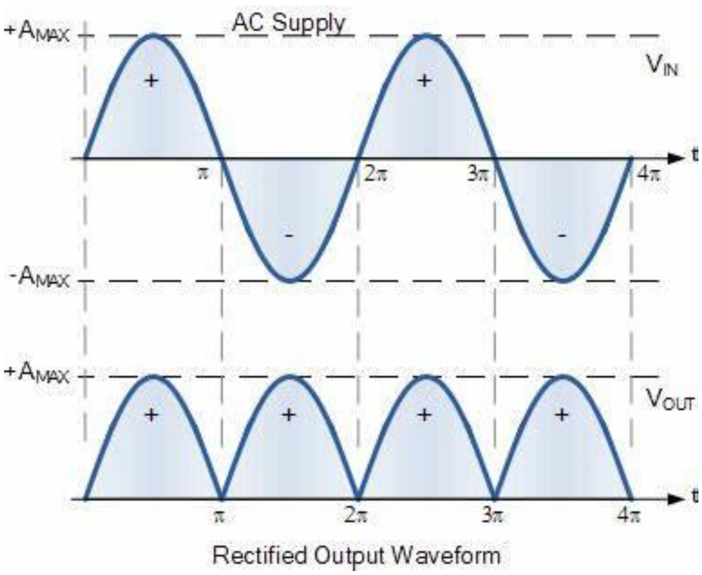
Bridge rectifiers are a specific kind of full-wave rectifier that effectively transforms AC current into DC current by employing four or more diodes in a bridge circuit design. In this activity, 4 1N4007 diodes have been used to create the bridge rectifier.





Bridge Rectifier Diode

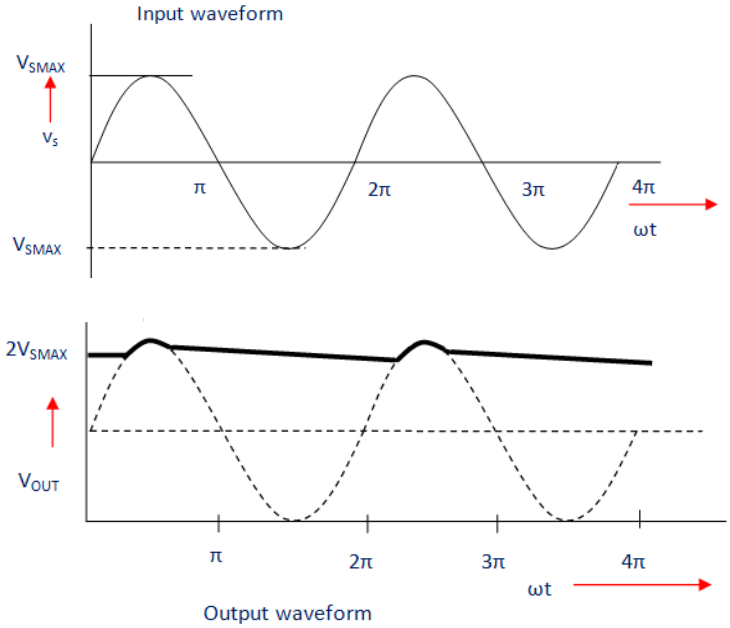
The output wave form can be observed as bellow after implementing bridge rectifier.



3. Capacitor

Capacitor is a device for storing electrical energy, consisting of two conductors in proximity and insulated from each other. capacitor is used to smooth the sine curve. Also, when the capacity of the capacitor increases, the smoothness of the sine curve increases. Then perfect DC current can be obtained. The capacitor used in this activity is a 4.7 mF capacitor.

The output wave form can be observed as bellow after capacitance.



4. Zener regulator

A Zener regulator is an electrical circuit that maintains a constant DC output voltage using a Zener diode. When the Zener diode receives a voltage higher than the breakdown voltage, the Zener diode reverses bios and causes current to flow through the diode, maintaining the potential gap on both sides of the Zener at a constant value. A 12 V zener diode has been used here.

- **DESIGN PROCEDURE**

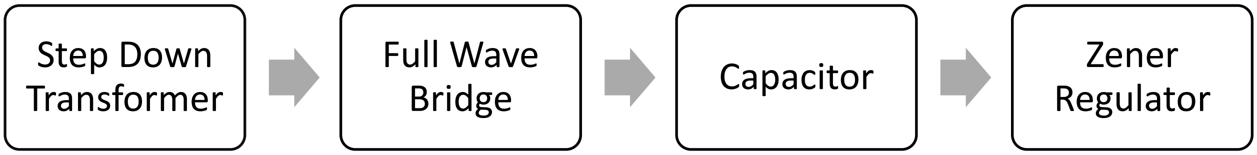
I. Design Specifications

- The input of the power supply is the domestic supply which is 230 V ± 5%.
- The parameter values of power supply are as given below.

Parameter	Expected Value/Range
Rated output voltage	12 V
Maximum output current	500 mA
Ripple factor	5% Maximum

The step-down transformer was used as first step to minimize domestic power voltage to 15 V. Then, using 4 1N4007 diodes as the full wave bridge that AC waveform was converted into the full wave form. After that, e capacitor was used to get a smooth waveform. Finally, the Zener regulator was used to keep the constant output value of 12 V voltage.

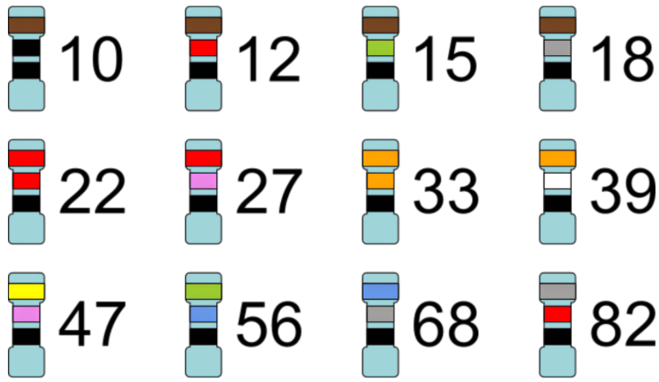
- Block diagram of the implemented circuit



II. Data References

- Resistor

  According to the E12 resistor series, 10 Ω and 22 Ω were chosen as the two resistors needed to set up this circuit.



- Capacitor

According to the standard capacitor values, 4.7 mF was chosen as the capacitor needed to set up this circuit.

These fixed capacitor values are the most commonly found										
pF	pF	pF	pF	µF	µF	µF	µF	µF	µF	µF
1.0	10	100	1000	0.01	0.1	1.0	10	100	1000	10,000
1.1	11	110	1100							
1.2	12	120	1200							
1.3	13	130	1300							
1.5	15	150	1500	0.015	0.15	1.5	15	150	1500	
1.6	16	160	1600							
1.8	18	180	1800							
2.0	20	200	2000							
2.2	22	220	2200	0.022	0.22	2.2	22	220	2200	
2.4	24	240	2400							
2.7	27	270	2700							
3.0	30	300	3000							
3.3	33	330	3300	0.033	0.33	3.3	33	330	3300	
3.6	36	360	3600							
3.9	39	390	3900							
4.3	43	430	4300							
4.7	47	470	4700	0.047	0.47	4.7	47	470	4700	
5.1	51	510	5100							
5.6	56	560	5600							
6.2	62	620	6200							
6.8	68	680	6800	0.068	0.68	6.8	68	680	6800	
7.5	75	750	7500							
8.2	82	820	8200							
9.1	91	910	9100							

- Diode

Here, used 4 1N4007 diodes.

- Zener

Suitable Zener diode was 12 V / 1W.

ELECTRICAL CHARACTERISTICS (T_{amb} = 25 °C, unless otherwise specified)								
PART NUMBER	**ZENER VOLTAGE RANGE** (1)	**TEST CURRENT**		**REVERSE LEAKAGE CURRENT**		**DYNAMIC RESISTANCE f = 1 kHz**		**TEMPERATURE COEFFICIENT**
	V_Z at I_{ZT1}	I_{ZT1}	I_{ZT2}	I_R at V_R		Z_Z at I_{ZT1} (1)	Z_{ZK} at I_{ZT2}	α_{VZ}
	V	**mA**		**μA**	**V**	**Ω**		**%/K**
	NOM.			**MAX.**		**MAX.**	**MAX.**	**TYP.**
1N5221	2.4	20	0.25	100	1	30	1200	- 0.085
1N5222	2.5	20	0.25	100	1	30	1250	- 0.085
1N5223	2.7	20	0.25	,75	1	30	1300	- 0.08
1N5224	2.8	20	0.25	75	1	30	1400	- 0.08
1N5225	3	20	0.25	50	1	29	1600	- 0.075
1N5226	3.3	20	0.25	25	1	28	1600	- 0.07
1N5227	3.6	20	0.25	15	1	24	1700	- 0.065
1N5228	3.9	20	0.25	10	1	23	1900	- 0.06
1N5229	4.3	20	0.25	5	1	22	2000	0.055
1N5230	4.7	20	0.25	5	2	19	1900	0.03
1N5231	5.1	20	0.25	5	2	17	1600	0.03
1N5232	5.6	20	0.25	5	3	11	1600	0.038
1N5233	6	20	0.25	5	3.5	7	1600	0.038
1N5234	6.2	20	0.25	5	4	7	1000	0.045
1N5235	6.8	20	0.25	3	5	5	750	0.05
1N5236	7.5	20	0.25	3	6	6	500	0.058
1N5237	8.2	20	0.25	3	6.5	8	500	0.062
1N5238	8.7	20	0.25	3	6.5	8	600	0.065
1N5239	9.1	20	0.25	3	7	10	600	0.068
1N5240	10	20	0.25	3	8	17	600	0.075
1N5241	11	20	0.25	2	8.4	22	600	0.076
1N5242	12	20	0.25	1	9.1	30	600	0.077
1N5243	13	9.5	0.25	0.5	9.9	13	600	0.079
1N5244	14	9	0.25	0.1	10	15	600	0.082
1N5245	15	8.5	0.25	0.1	11	16	600	0.082
1N5246	16	7.8	0.25	0.1	12	17	600	0.083
1N5247	17	7.4	0.25	0.1	13	19	600	0.084
1N5248	18	7	0.25	0.1	14	21	600	0.085
1N5249	19	6.6	0.25	0.1	14	23	600	0.086
1N5250	20	6.2	0.25	0.1	15	25	600	0.086
1N5251	22	5.6	0.25	0.1	17	29	600	0.087
1N5252	24	5.2	0.25	0.1	18	33	600	0.088
1N5253	25	5	0.25	0.1	19	35	600	0.089
1N5254	27	4.6	0.25	0.1	21	41	600	0.09
1N5255	28	4.5	0.25	0.1	21	44	600	0.091
1N5256	30	4.2	0.25	0.1	23	49	600	0.091
1N5257	33	3.8	0.25	0.1	25	58	700	0.092
1N5258	36	3.4	0.25	0.1	27	70	700	0.093
1N5259	39	3.2	0.25	0.1	30	80	800	0.094
1N5260	43	3	0.25	0.1	33	93	900	0.095
1N5261	47	2.7	0.25	0.1	36	105	1000	0.095
1N5262	51	2.5	0.25	0.1	39	125	1100	0.096
1N5263	56	2.2	0.25	0.1	43	150	1300	0.096
1N5264	60	2.1	0.25	0.1	46	170	1400	0.097
1N5265	62	2	0.25	0.1	47	185	1400	0.097
1N5266	68	1.8	0.25	0.1	52	230	1600	0.097
1N5267	75	1.7	0.25	0.1	56	270	1700	0.098

III. Analysis steps

- Domestic supply voltage is 230 V ± 5%. Voltage range is from 241.5 V to 218.5 V.

- Capacitor Value

$$\text{Ripple factor} = \frac{V_{r(rms)}}{V_D} \quad ; \quad V_{r(rms)} = \frac{V_{r(pk-pk)}}{2\sqrt{3}} \quad ;$$

$$V_{r(pk-pk)} = \frac{I_c}{f_c} = \frac{V_L}{R_{fc}}$$

$$\therefore \text{Ripple factor} = \frac{V_L}{R_{fc}} \times \frac{1}{V_{Dc}} \cdot \frac{1}{2\sqrt{3}}$$

Ripple factor should be $\leq 5\%$.

$$\frac{1}{22 \times 100 \times C \times 2\sqrt{3}} \leq 0.05$$

$$C \geq \frac{1}{22 \times 5 \times 2\sqrt{3}}$$

$$C \geq 2.6\ mF$$

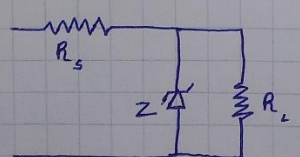
chose, $\underline{C = 3.3\ mF}$

- R_s resistor Value

$$V_{2,min} = V_{in,min} - 2V_r - V_{ripple,max} \quad ; \quad V_{ripple,max} = \frac{I_{max}}{fc}$$

$$= 15\sqrt{2} \times 0.95 - (0.7)2 - \frac{500 \times 10^{-3}}{100 \times 3.3 \times 10^{-3}}$$

$$\underline{V_{2,min} = 17.24\ V}$$



Removing zenor diode.

$$V_{out,min} = V_{2\,min} - I_{max} R_s \geq 12$$

$$17.24 - 500 \times 10^{-3} R_s \geq 12$$

$$R_s \leq 10.47\ \Omega$$

chose, $\underline{R_s = 10\ \Omega}$

-

- Zener power value

$$I_Z = I - I_L$$

$$I_{Z,max} = I_{max} - I_{L\,min}$$

$$= \frac{V_{in,max} - V_Z}{R_s} - \cancel{I_{L\,min}}^{=0} \quad ; \quad V_{in,max} = (15\sqrt{2} \times 1.05) - (0.7)2$$

$$= 20.87\,V$$

$$= \frac{20.87 - 12}{10}$$

$$I_{Z,max} = 0.89\,A$$

power rating of zener diode $= I_{Z,max} V_Z$

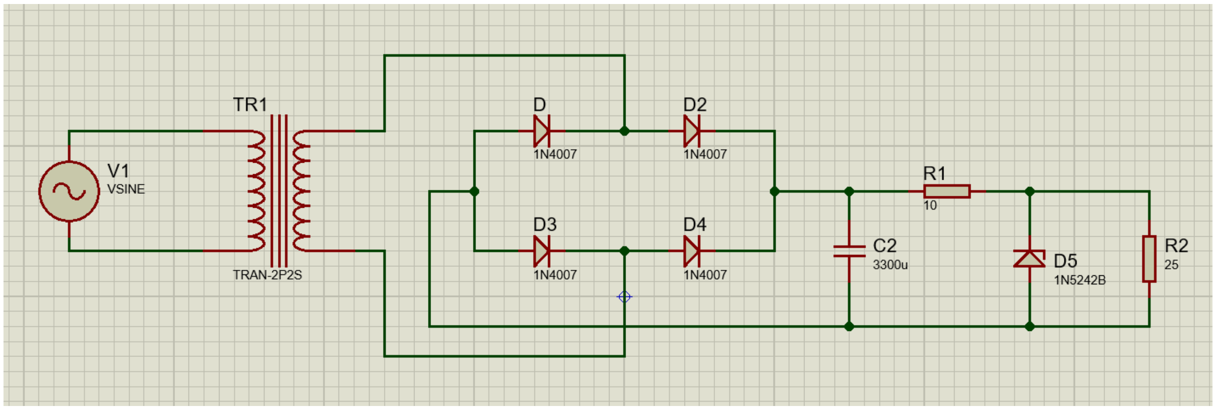
$$= 0.89 \times 12$$

$$P_Z = 10.68\,W$$

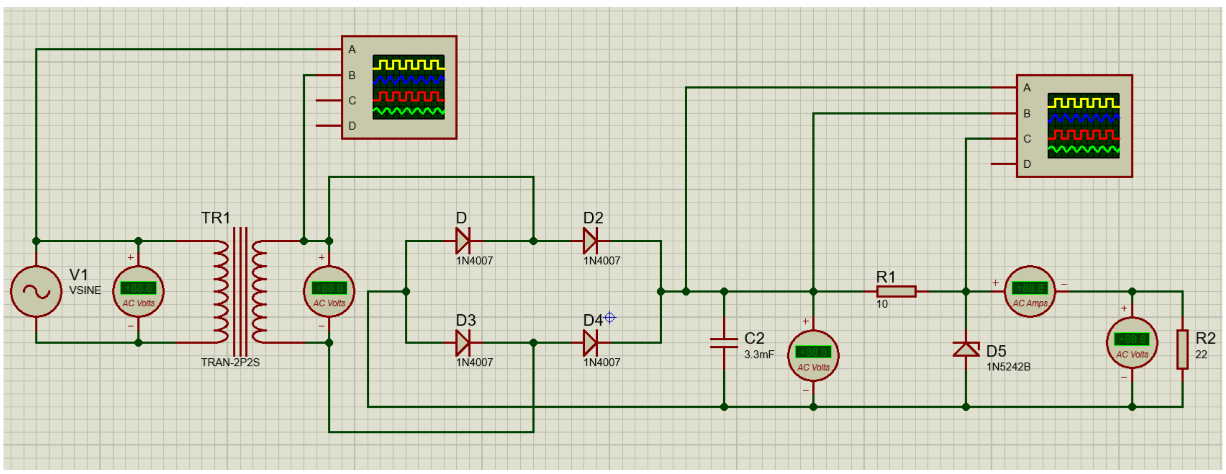
IV. Simulation results

➢ Schematic Design

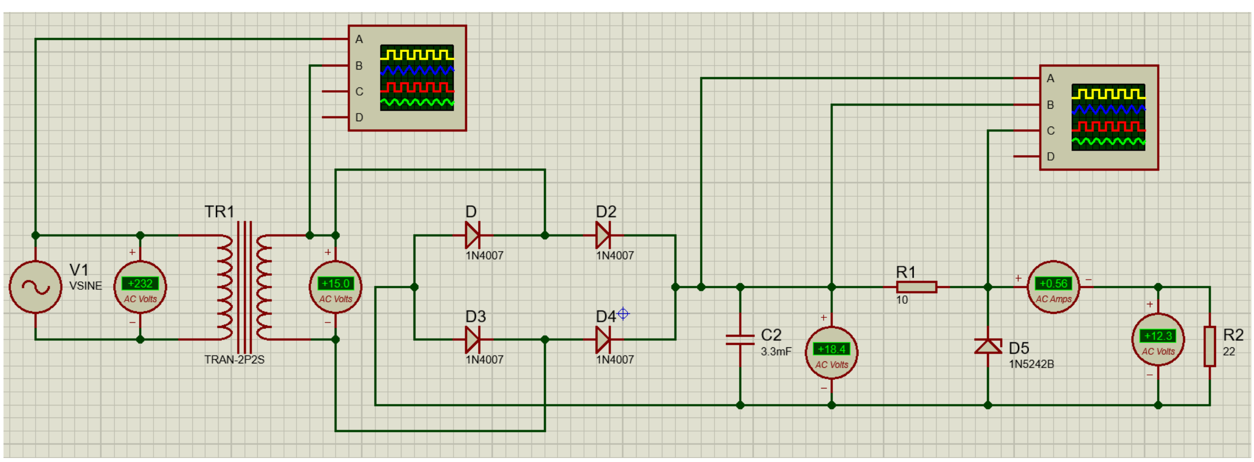
Schematic Design was done by Proteus' software. The components used for that were diode, capacitor, resistor, step down transformer, AC current source, Zener diode etc.



- To get the voltage measurements, voltmeters and Oscilloscopes was set upped.

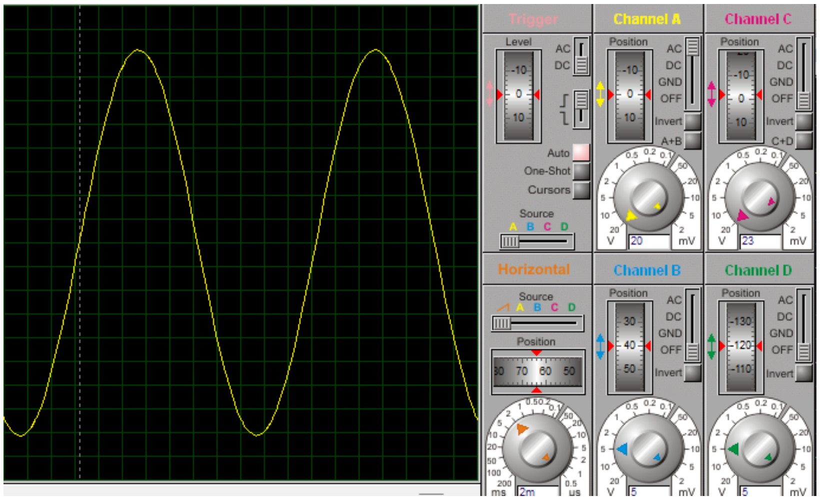


- Simulation results

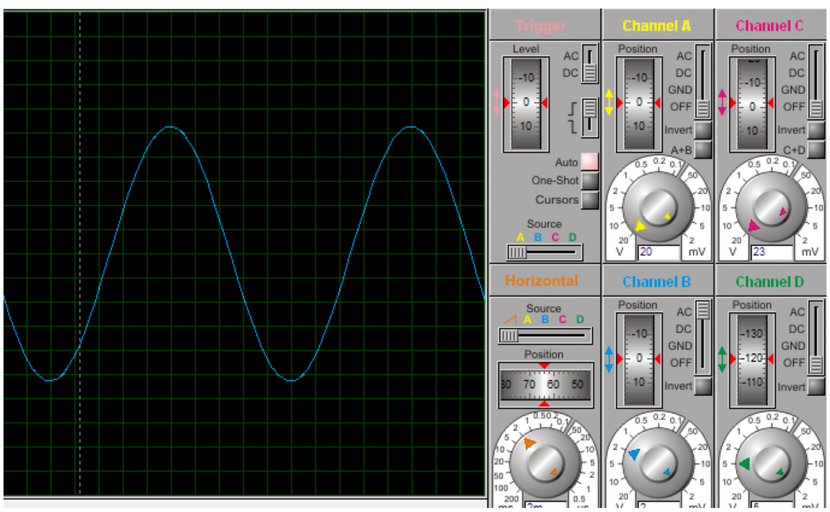


Input Voltage of Primary Side	232 V
Output Voltage of Secondary Side	15 V
Output Voltage	12.3 V
Voltage across Capacitor	18.4 V
Current across the Load	0.56 A

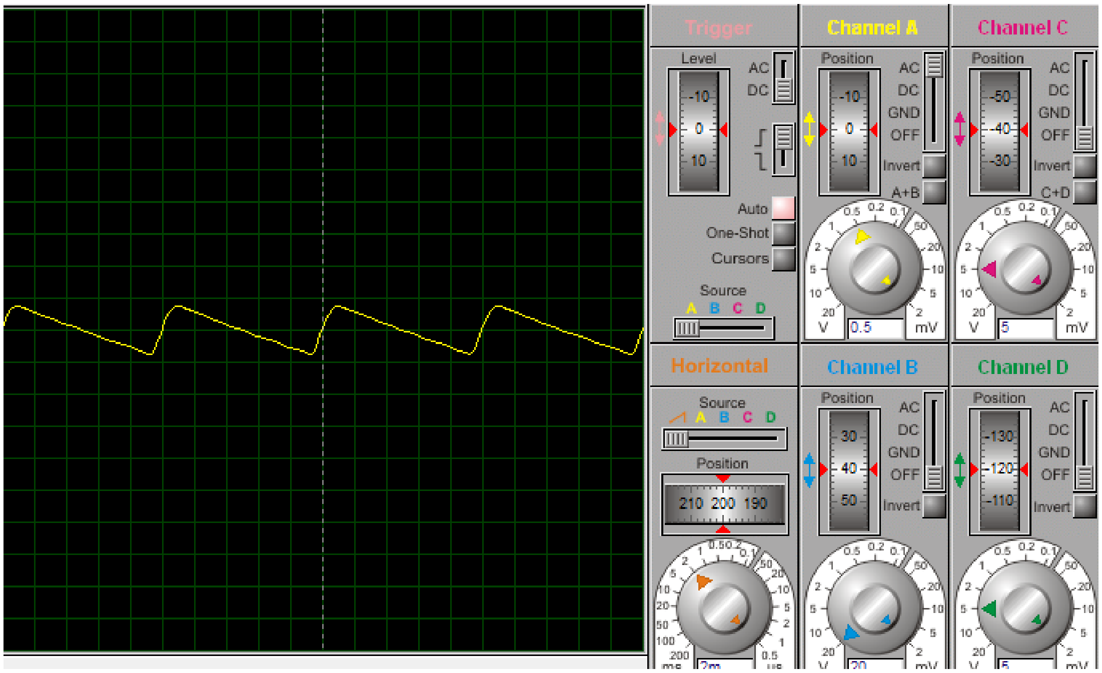
- Oscilloscope Waveforms



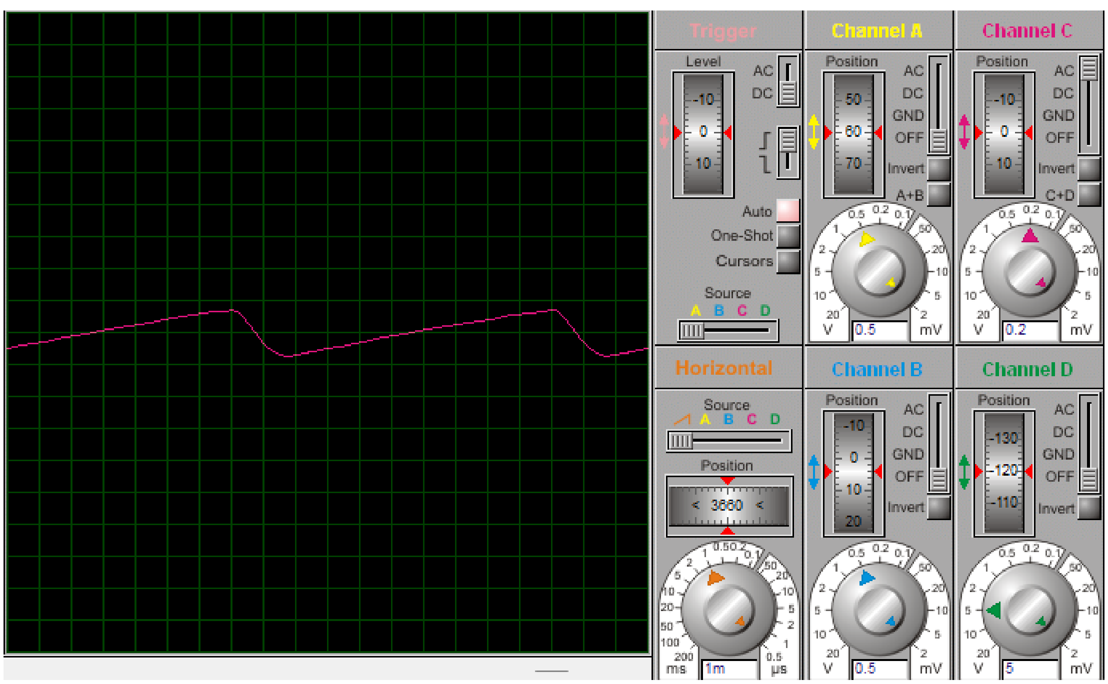
Input Waveform of Primary Side



Output Waveform of Secondary Side

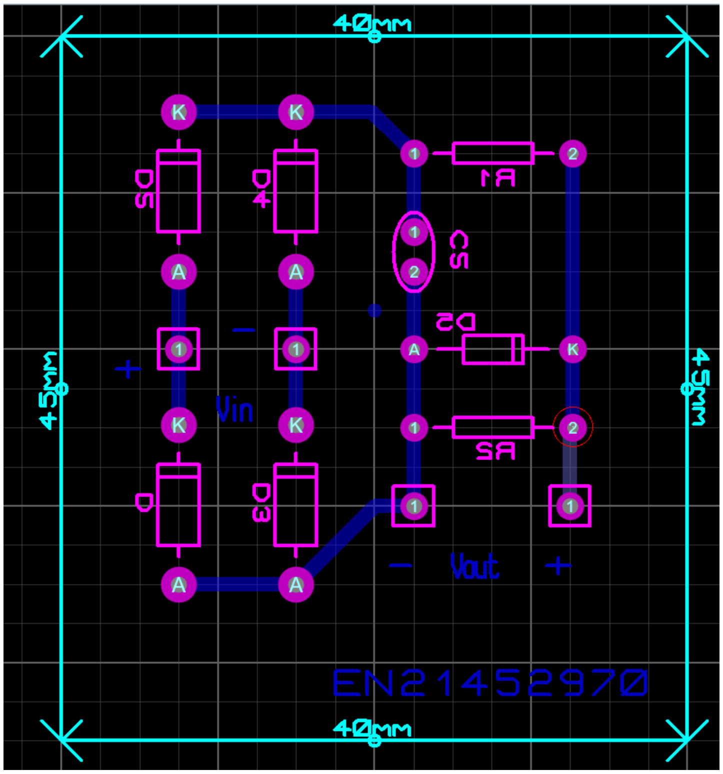


The Waveform after capacitance

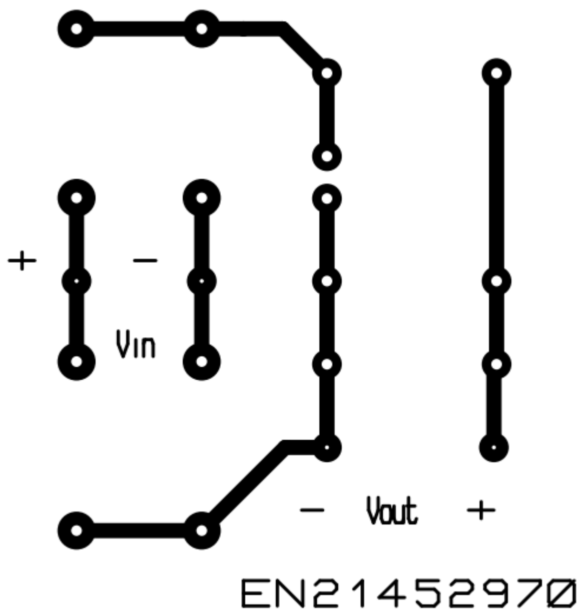


Output Waveform

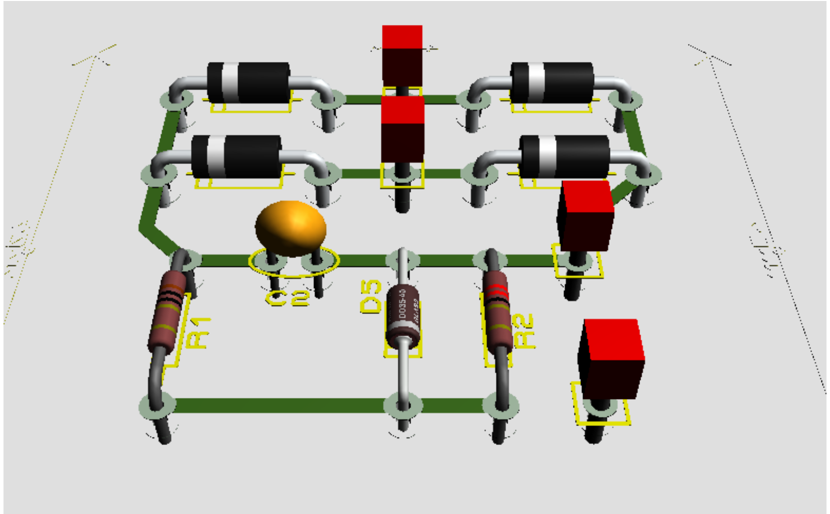
- **PCB Layout**



- PDF type format was taken to setup the PCB.

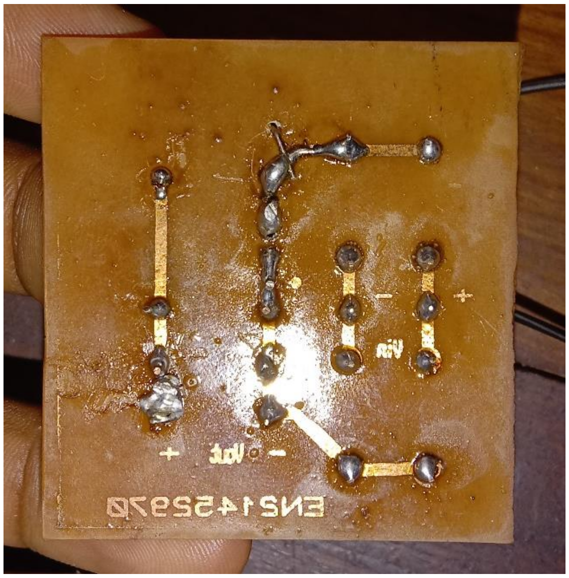


- 3D view of circuit



V. Test Results

Using the proteus software, I drew the PCB layout and made the PCB first. Then, the components were soldered to the relevant places on the PCB. Also, the two input terminals of the transformer were connected to the domestic supply and the output terminal of the transformer was connected to the PCB.

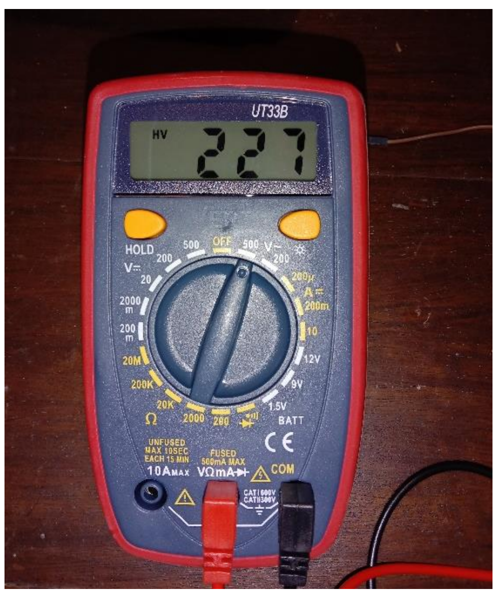


- Equipment and devices used for testing

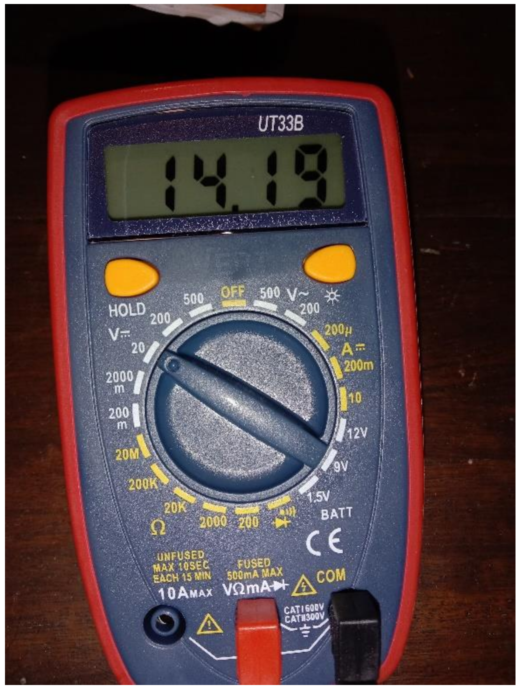
  1. Step down transformer (230V to 15V)
  2. Zener diode 12V, 1W
  3. 4 diodes of 1N4007
  4. 4.7mF capacitor
  5. 10Ω, 22Ω resisters
  6. Soldering iron
  7. Jumper wires
  8. PCB
  9. Multimeter

- Voltage Measurements

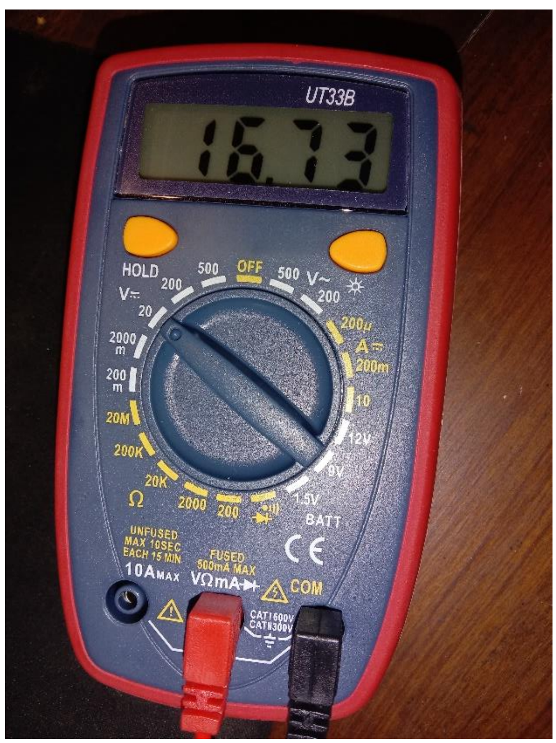
  - Input voltage of Transformer



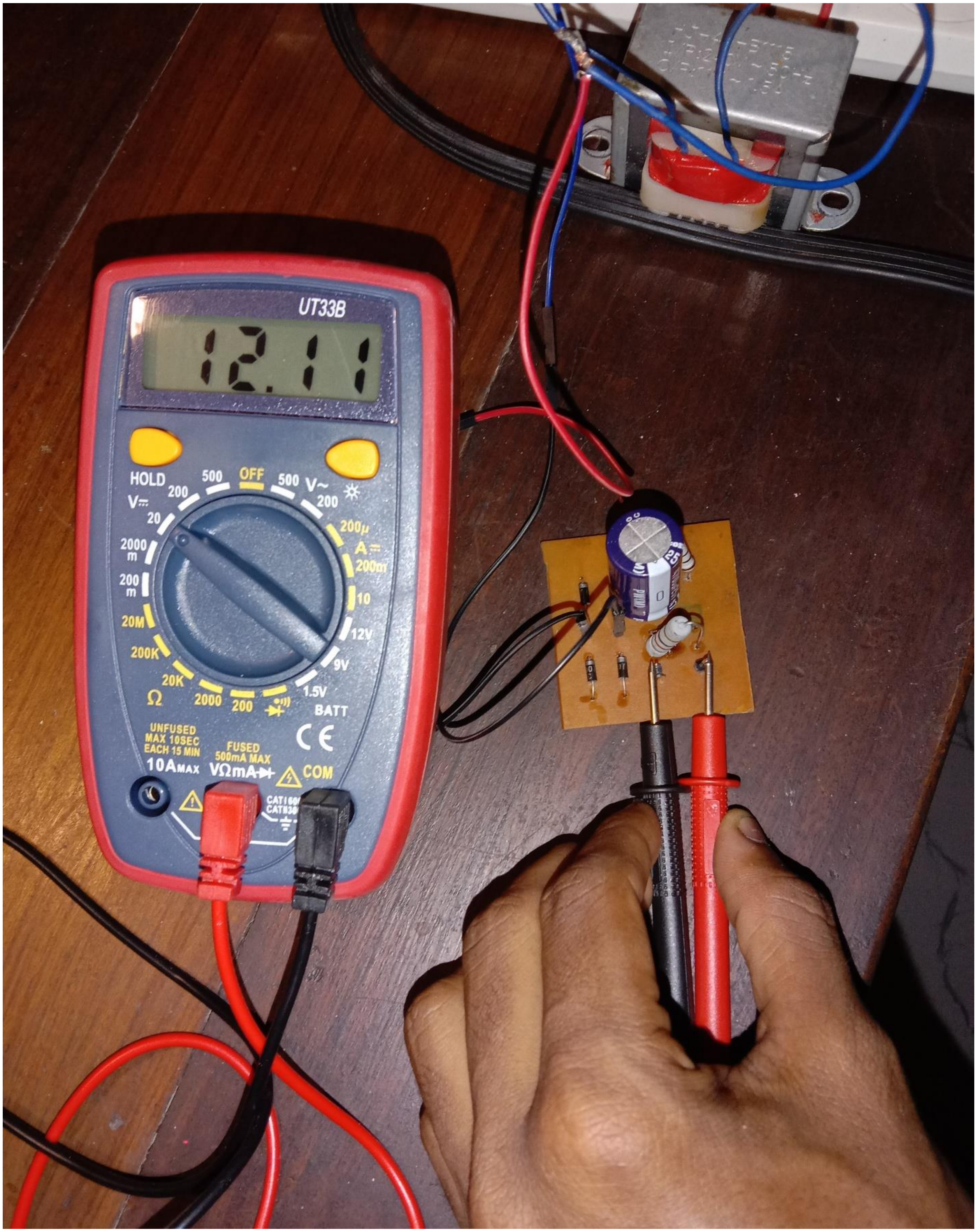
- Output voltage of Transformer



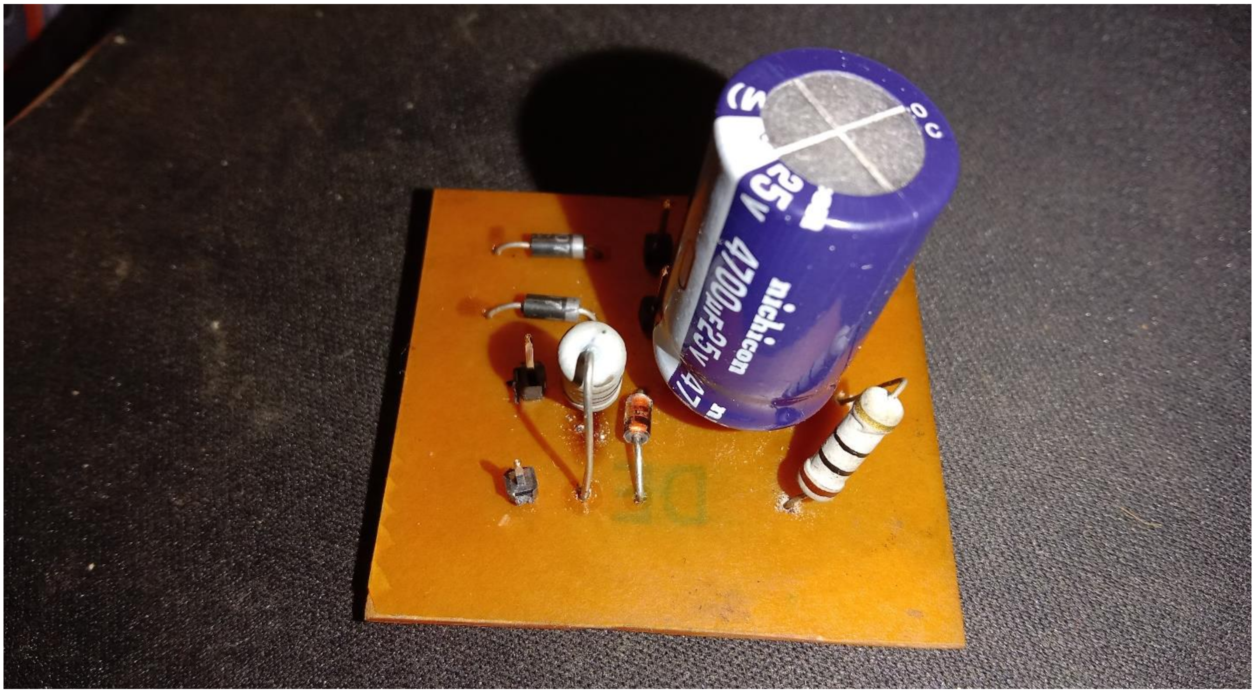
- Voltage across the capacitor

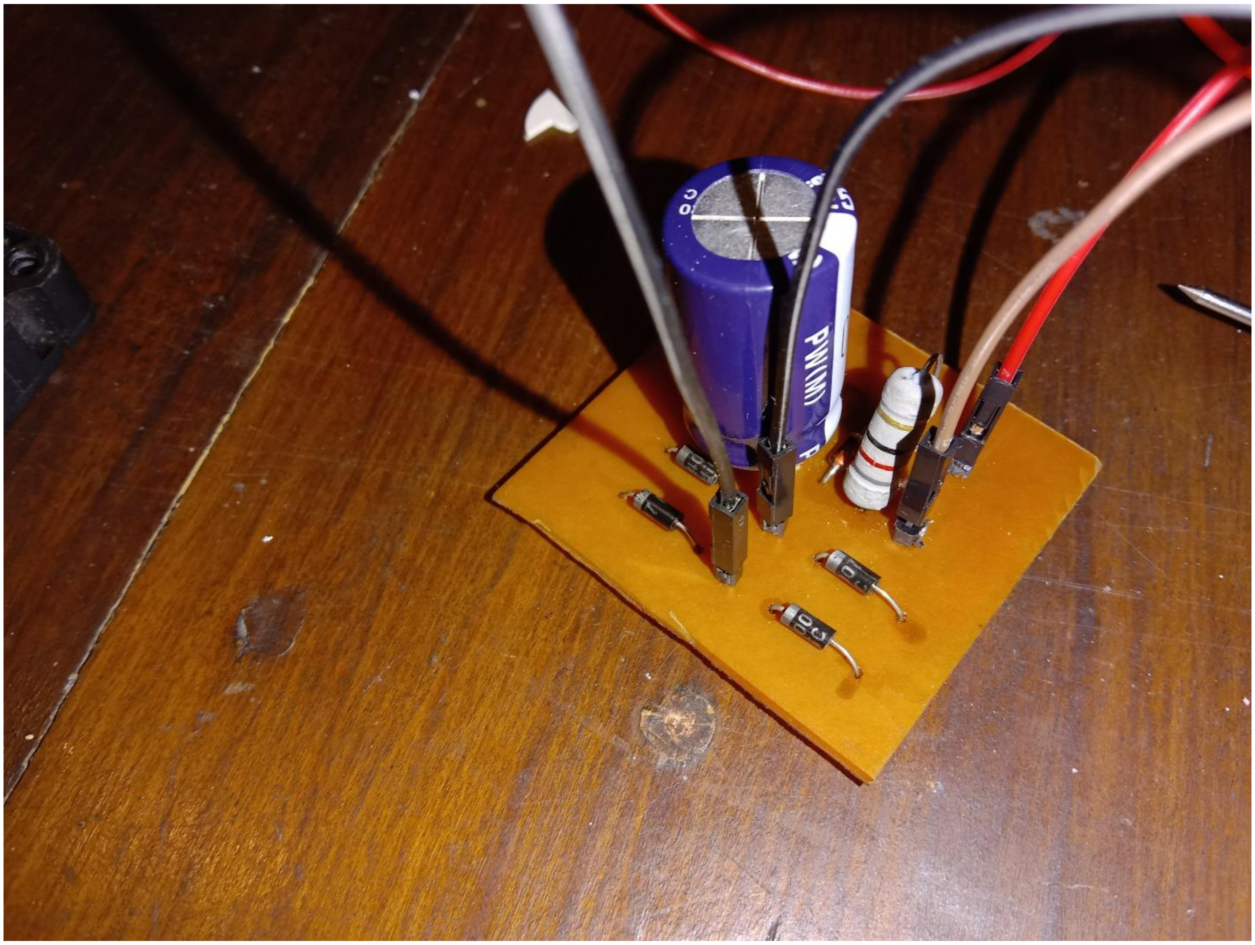


- Output Voltage



VI. The final design





- **Discussion and Conclusion**

I got to learn a lot by doing this assignment. Although these types of circuits have been designed before, this is the first time that a DC power supply has been designed. Also, it was necessary to create this circuit to do the next exam, so I created this circuit with good attention. Through this assignment, I was able to practice what I learned in class.

But many problems had to be faced while creating this. The biggest problem was to find the component related to the calculated values. It was possible to design the PCB easily. And then it was possible to solder the components related to the PCB. The next problem was that there was no transformer to supply 15V to the circuit. The solution I used for that problem was to take a 7.5V center tapped transformer and feed 15V from it to the circuit. But when the transformer was connected to the circuit and measurements were made, the desired results could not be obtained. The problem that arose while looking into it was that the transformer could not provide the amount of amperes the circuit demanded. When the circuit required more current than the related output current of the transformer, the output voltage of the transformer had dropped. Then I used a 500 mA output current transformer. Then when running the circuit everything was fine but there was one problem and that problem was that the Zener diode got a bit hot. The reason is that according to the calculations a 10W Zener diode is required, but I could find was an 1W Zener diode. But I was able to get all the desired results through this circuit.

But there were some minor differences between simulated values and practical values. In the simulated circuit, the output voltage was obtained as 12.3V. But after applying the practical circuit the value I got was 12.11 V. Although there was little difference from 12V I was very happy with this value. Because in lab3 exercise 2, when I had to get a 5V output voltage, the value I got was 5.43 V. Because this value is very close to 12V when compared to that value. A number of reasons can contribute to not being able to get 12V correctly. In the simulated circuit I gave 230V as the input voltage of the transformer but in the practical circuit I could give 227 as the transformer input voltage. Due to the same reason, the output voltage of the transformer could not be obtained as expected. It was 14.19 v. But I was able to reduce the ripple factor of the output waveform a lot. The reason for that was because I added a capacitor with a value of 4.7mF to the circuit even though the calculation indicated that a value of 3.3mF was required. So, I was able to get a much smoother DC output voltage.

And because I creatively drew the PCB layout, I was able to get a light little circuit.

I took all the results through the oscilloscope and photographed them, but due to some problem with my mobile phone, I lost all the data and lost that photos too. For this reason, I could not add the output waveform of the oscilloscope to the lab report. But I think I got everything right like the circuit and all the output values to be obtained from the circuit. So, I am happy about it and I gained a lot of experience through doing this assignment and I was very happy through this assignment.

- ## References

- Anon, (n.d.). *12Volt Transformerless power supply*. [online] Available at: https://www.elcircuit.com/2012/03/12volt-transformerless-power-supply.html [Accessed 26 Oct. 2022].

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