



Regulated power supply using Proteus

Project synopsis submitted in partial fulfillment

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CERTIFICATION OF COMPLETION

in

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by

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CHAPTER 1

DESIGNING A REGULATED POWER SUPPLY USING PROTEUS

To design, simulate, and analyse a regulated DC power supply using Proteus software, with the aim of converting an AC input into a stable and constant DC output voltage. The project will involve the use of essential power electronics components such as a transformer, rectifier, filter, and load resistor, Zener diode. The simulation will verify the performance, stability, voltage regulation, ripple reduction and efficiency of the power supply circuit under various load conditions.

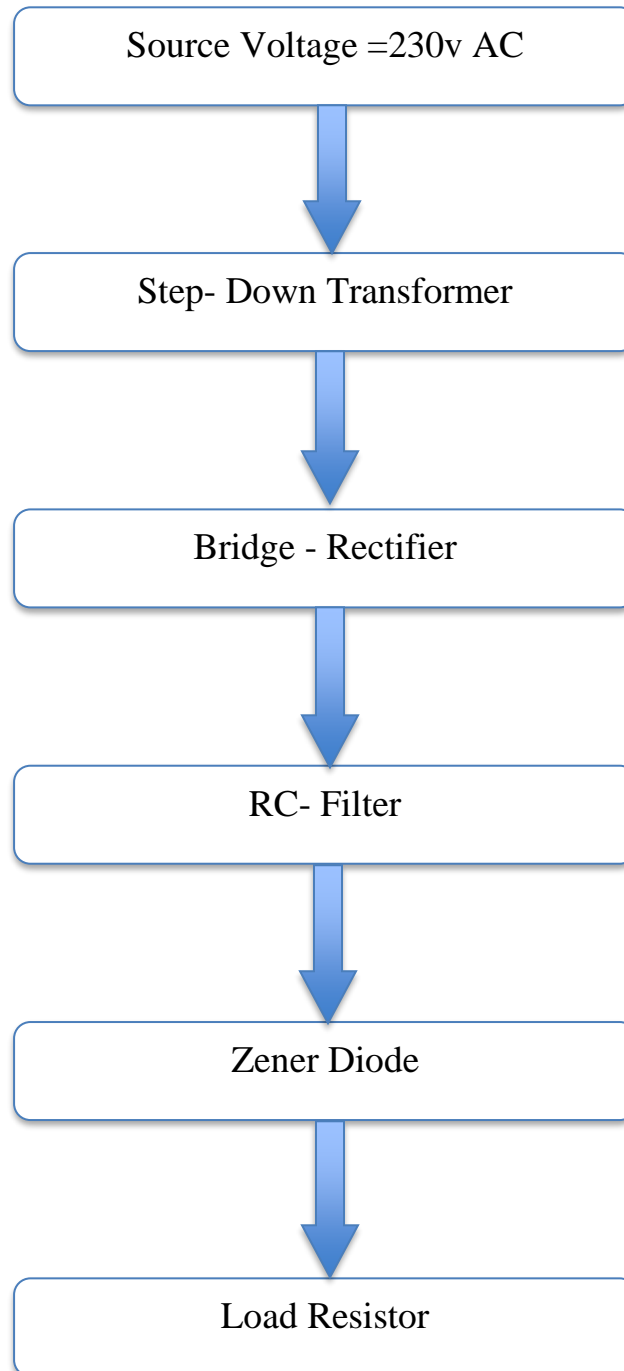
Objectives:

- Understand the hardware design and virtual prototyping.
- Design a regulated power supply that provides a constant +5 V DC output.
- Understand the role of the Zener diode in regulating the output voltage.
- Investigate the function of the filter capacitor in smoothing the output voltage.

CHAPTER 2

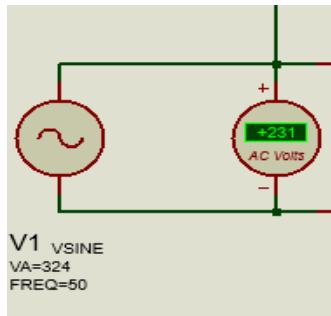
PROJECT DESCRIPTION

Block Diagram:

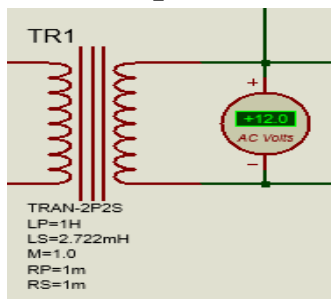


CIRCUIT DIAGRAM COMPONENTS:

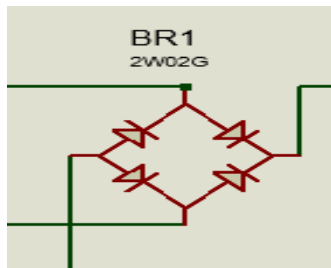
- 1) **230 V AC Supply:** Represents the Sinusoidal AC Input Power Source.



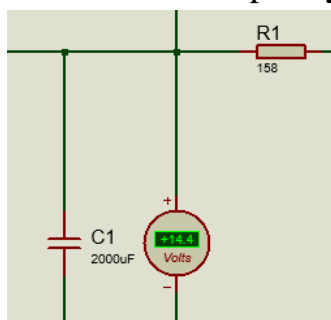
- 2) **Step-down Transformer:** To step down the 230V AC to a lower voltage.



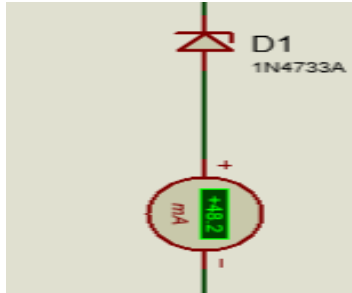
- 3) **Bridge Rectifier:** A full bridge rectifier to convert AC to DC (pulsating).



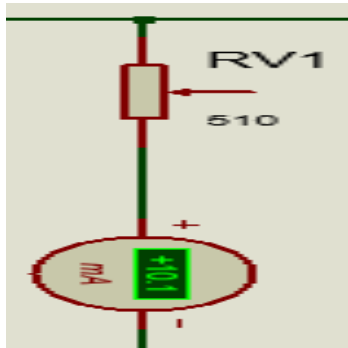
- 4) **RC-Filter:** Consisting of a Series Resistor and a capacitor, to smooth out the rectified DC output by reducing ripples.



- 5) **Zener Diode:** To regulate/ limit the DC current output voltage up to a constant 5 V.



6) **Load Resistor/Potentiometer:** To represent the range of load resistances.



CHAPTER 3

REQUIRED INPUT PARAMETERS AND CALCULATIONS

1) TRANSFORMER (TR1):

Purpose of Transformer:

1. **Step down** the high AC mains voltage (typically 230V RMS in many regions) to a lower AC voltage suitable for rectification and regulation.
2. **Provide isolation** between the high-voltage mains and the low-voltage electronics for safety.

Transformer Voltage Selection:

We need a regulated **5.1V DC output** using a **Zener diode**. The voltage available before the Zener diode must be a bit higher to account for:

- Voltage drop across the **series resistor** (used for Zener regulation),
- Ripple voltage,
- Forward drop of rectifier diodes.

Target DC Peak Voltage Before Regulation:

Let's say we need around **14.4V peak DC** before the Zener + series resistor. Then we work backwards to find the required **RMS AC voltage** from the transformer.

Relationship Between AC RMS and DC Peak:

For a sine wave: $V_{\text{peak}} = 1.414 \times V_{\text{RMS}}$

To get 14.4V peak: $V_{\text{RMS}} = 14.4/1.414 \approx 10.1\text{V}$

Since 10V is not a standard transformer value, we choose the **nearest standard value: 12V RMS**. This gives:

$$V_{\text{Peak}} = 1.414 \times 12 \approx 16.97\text{V}$$

After accounting for diode drops and ripple, this will still provide enough headroom for a 5.1V Zener regulator.

A 12V RMS transformer is standard, which works well.

So,

$$VAC \text{ (secondary)} = 12 \text{ V RMS}$$

$$VAC \text{ (primary)} = 230 \text{ V (mains)}$$

If

$$L(\text{primary}) = 1 \text{ H}$$

$$L(\text{secondary}) = L(\text{primary}) / (VAC \text{ (primary)} / VAC \text{ (secondary)})^2 = 2.722 \text{ mH.}$$

As per calculation component TRANS-2P2S can select.

2) BRIDGE RECTIFIER (BR1)

Purpose:

- Converts the AC voltage from the transformer into pulsating DC.

Selection:

- Diode Peak Inverse Voltage (PIV):

Each diode must withstand the peak voltage from the transformer secondary:

$$V(\text{PIV}) = 2 \times VDC \text{ (peak).}$$

$$\text{For } VDC \text{ (peak)} = 14.4V$$

$$VPIV \geq 2 \times 14.3 = 28.8V.$$

Diode selected with a total PIV of 200V.

- Forward Current Rating: The diodes must handle the maximum load current.

$$I_{\text{forward}} = I_{\text{total}} = 100\text{mA (Assume).}$$

selected diodes are rated of 2A for reliability. **As per calculation BR1 2W02G is selected.**

3) FILTER CAPACITOR

Purpose:

- Smooths the rectified DC voltage and reduces ripple.

Selection:

- Capacitance:

Formula for Calculating Capacitance:

$$C = I / (f * V_r)$$

Where,

- C = Capacitance in Farads
- I = Load current in Amps
- f = Ripple frequency (Hz) → For full-wave: $2 \times$ mains frequency
- V_r = Acceptable ripple voltage (Volts)

Calculation:

Assume:

- Load current $I = 100 \text{ mA} = 0.10 \text{ A}$
- Mains frequency = $50 \text{ Hz} \Rightarrow f = 100 \text{ Hz}$
- Allowable ripple $V_r = 0.6 \text{ V}$ (reasonable for Zener-regulated circuits)

Now plug into the formula:

$$C = 0.100 / (100 * 0.6)$$

$$C = 0.001666 \text{ F} = 1666 \mu\text{F}$$

As per calculation for safety reason, 2000 μF electrolytic capacitor is selected.

This value:

- Is large enough to reduce ripple to acceptable levels.
- Ensures the Zener regulator receives a reasonably stable voltage.
- Is a common, readily available capacitor size in power supply circuits.

4) SERIES RESISTOR (R1)

Purpose:

- Limits current through the Zener diode and regulates the voltage.

Selection:

- Use Ohm's Law to calculate R1:

$$R1 = \{ V (\text{rectifier}) - V (\text{zener}) / I (\text{load}) + I (\text{zener}) \}$$

Substituting:

$$\text{➤ } V(\text{rectifier}) = 14.4\text{V}$$

$$\text{➤ } V (\text{zener}) = 5.1\text{V (Assume)}$$

$$\text{➤ } I (\text{load}) = 0.01\text{A (Assume) or } I (\text{max}) = 0.05\text{A (safety consideration)}$$

$$\text{➤ } I (\text{zener}) = 0.049\text{A}$$

$$R1 = (14.4 - 5.1) / (0.01 + 0.049) = 158 \, \Omega$$

OR

$$R1 = (14.4 - 5.1) / (0.05 + 0.049) = 94 \, \Omega$$

As per calculation Series Resistor is 94Ω or 158Ω (a higher resistance reduces Zener power dissipation).

5) ZENER DIODE (D1)

Purpose:

- Provides regulated output voltage.

Selection:

- Zener Voltage: The Zener voltage should match the desired regulated output voltage

$$V_{Zener} = 5.1V.$$

- Power Rating: The Zener diode must dissipate power:

$$P_{Zener} = V_{Zener} \times I_{Zener}.$$

Substituting:

$$P_{Zener} = 5.1 \times 0.049 = 0.2499W = 249.9mW$$

As per calculation Zener diode is not dissipating power more than 500mW.

So, 1N4733A Zener Diode is selected.

6) LOAD RESISTOR (RV1)

Purpose:

- Simulates various loads and adjusts the current.

Selection:

- Resistance Range: For a 5.1V output, the minimum resistance should ensure the desired load current:

$$R_{max} = V_{Zener} / I_{load(assume)}$$

$$I_{load(assume)} = 0.01A$$

$$R_{max} = 5.1 / 0.01 = 510 \Omega$$

And

$$R_{min} = V_{Zener} / I_{load(max)}$$

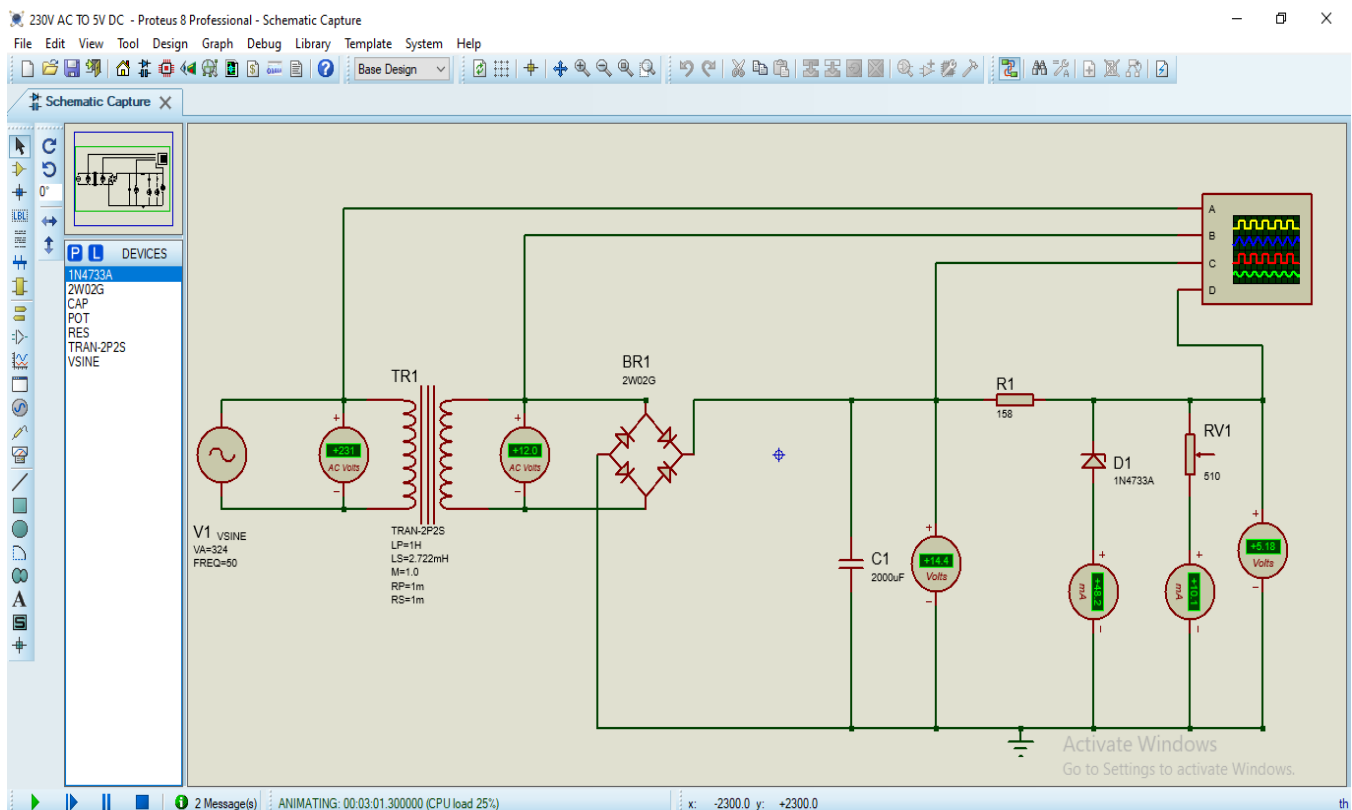
$$I_{load(max)} = 0.05A$$

$$R_{min} = 5.1 / 0.05 = 102 \Omega$$

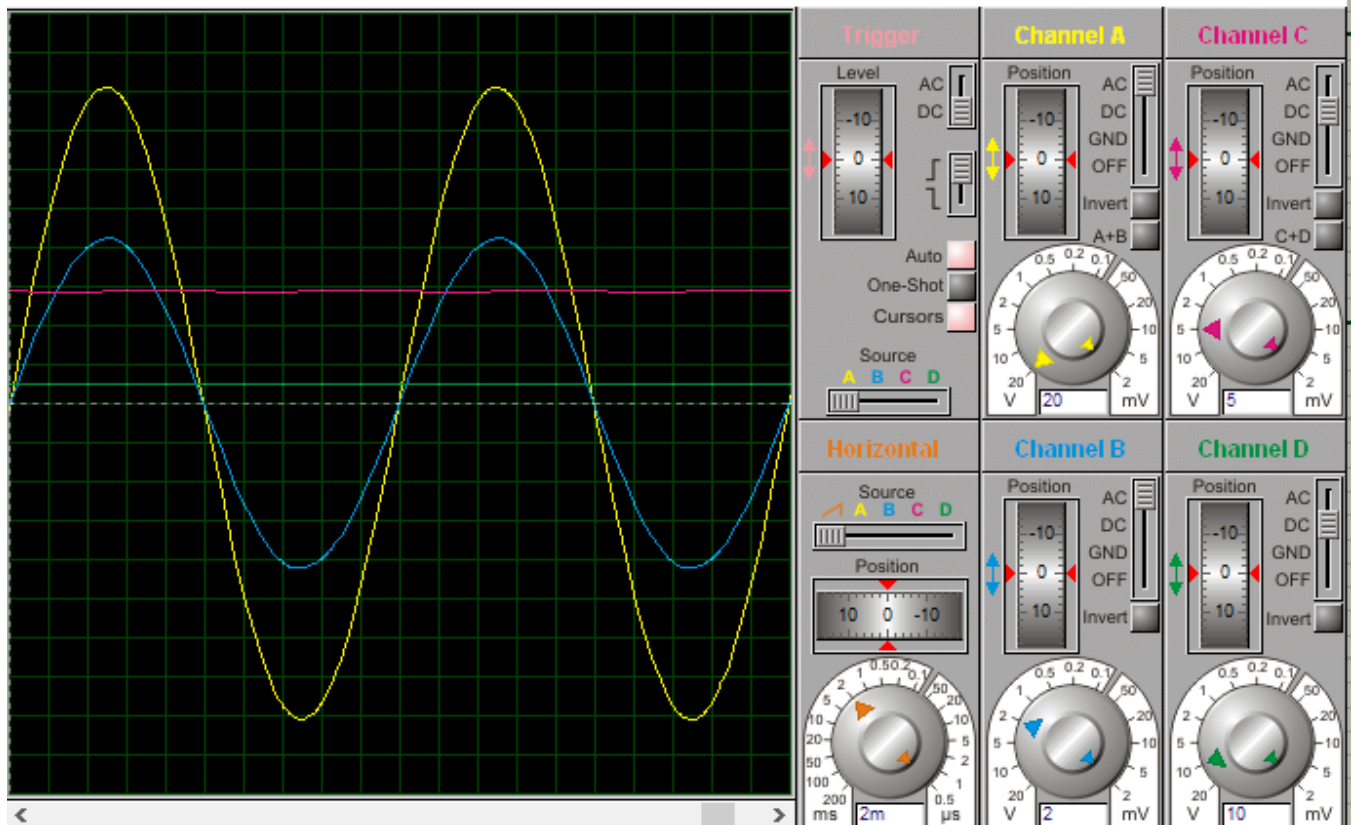
Select a variable resistor (potentiometer) with a range of 50Ω to 550Ω.

Summary of Component Values:

Component	Value	Rating
Transformer (TR1)	12V RMS	2P2S
Diode (BR1)	PIV = 200V, 2A	4 nos of 2W02G
Capacitor (C1)	2000uF	
Series Resistor (R1)	94 Ω and 158 Ω	
Zener Diode (D1)	5.1V, 49mA	1N4733A
Load Resistor (RV1)	50 Ω to 550 Ω	



Digital Oscilloscope



$V_{ac} = 230v$ (Pulsating Yellow Line)

$V_{dc} = 5v$ (Straight Green Line)

CHAPTER 4

RESULTS

With the use of capacitor:

Case 1:

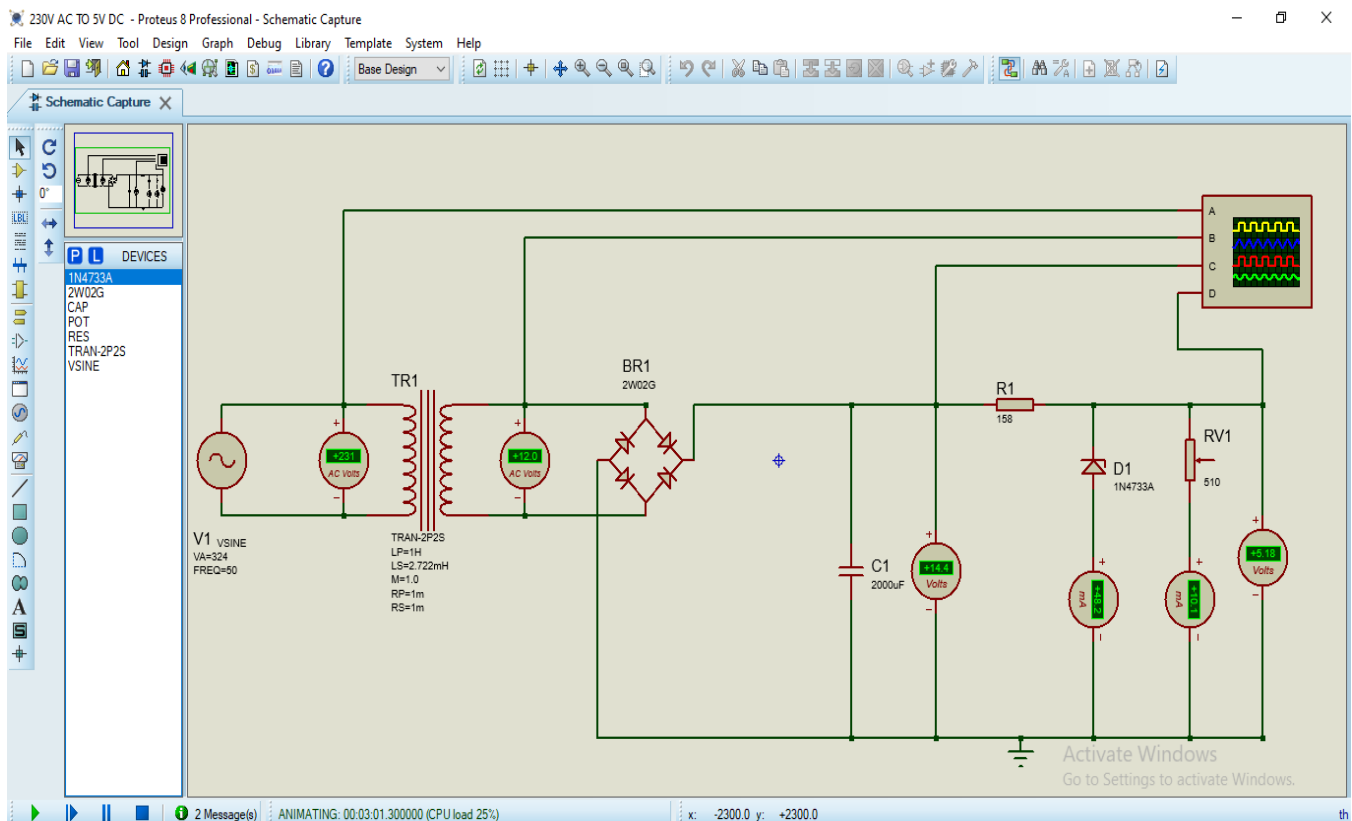
VAC (primary) = 230 V (mains), VAC (secondary) = 12 V

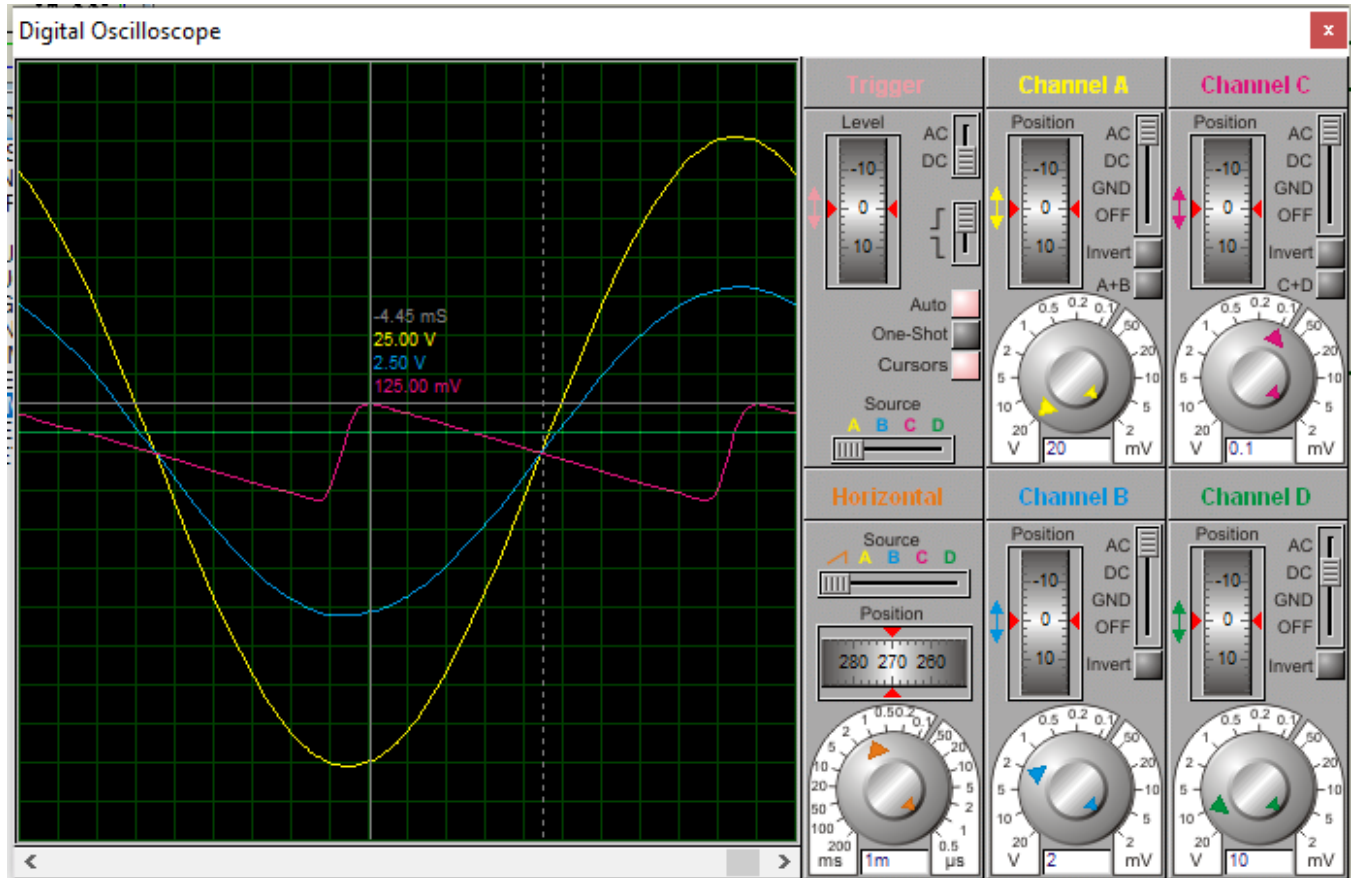
L(primary) = 1 H, L(secondary) = 2.722 mH

C = 2000 μ F

VZener = 5.1V

R1 = 158 Ω , Rload = 510 Ω





VDC = 5.18 V (with capacitor)

Vripple = 250 mV (peak to peak)

Case 2:

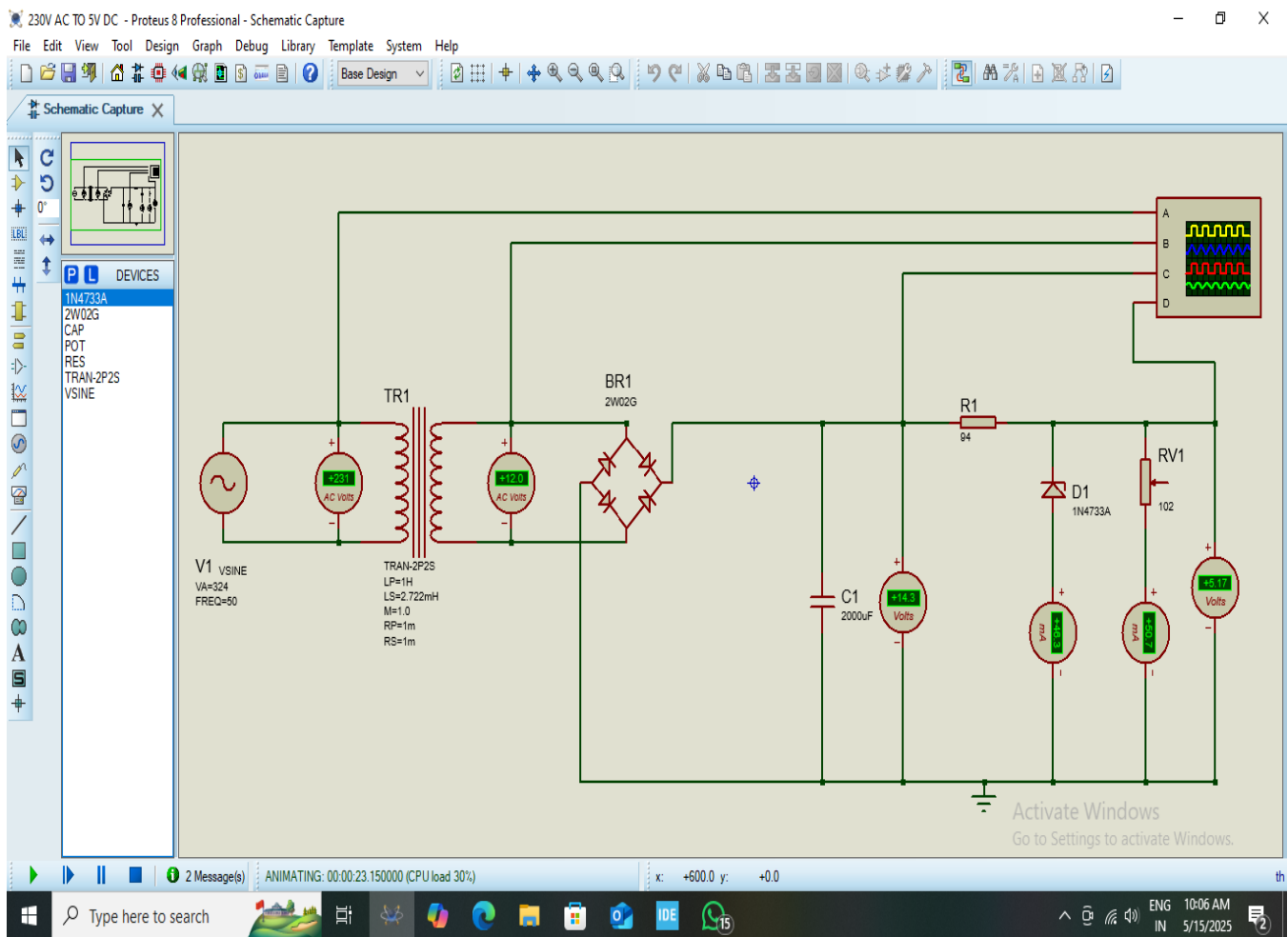
VAC (primary) = 230 V (mains), VAC (secondary) = 12 V

L(primary) = 1 H, L(secondary) = 2.722 mH

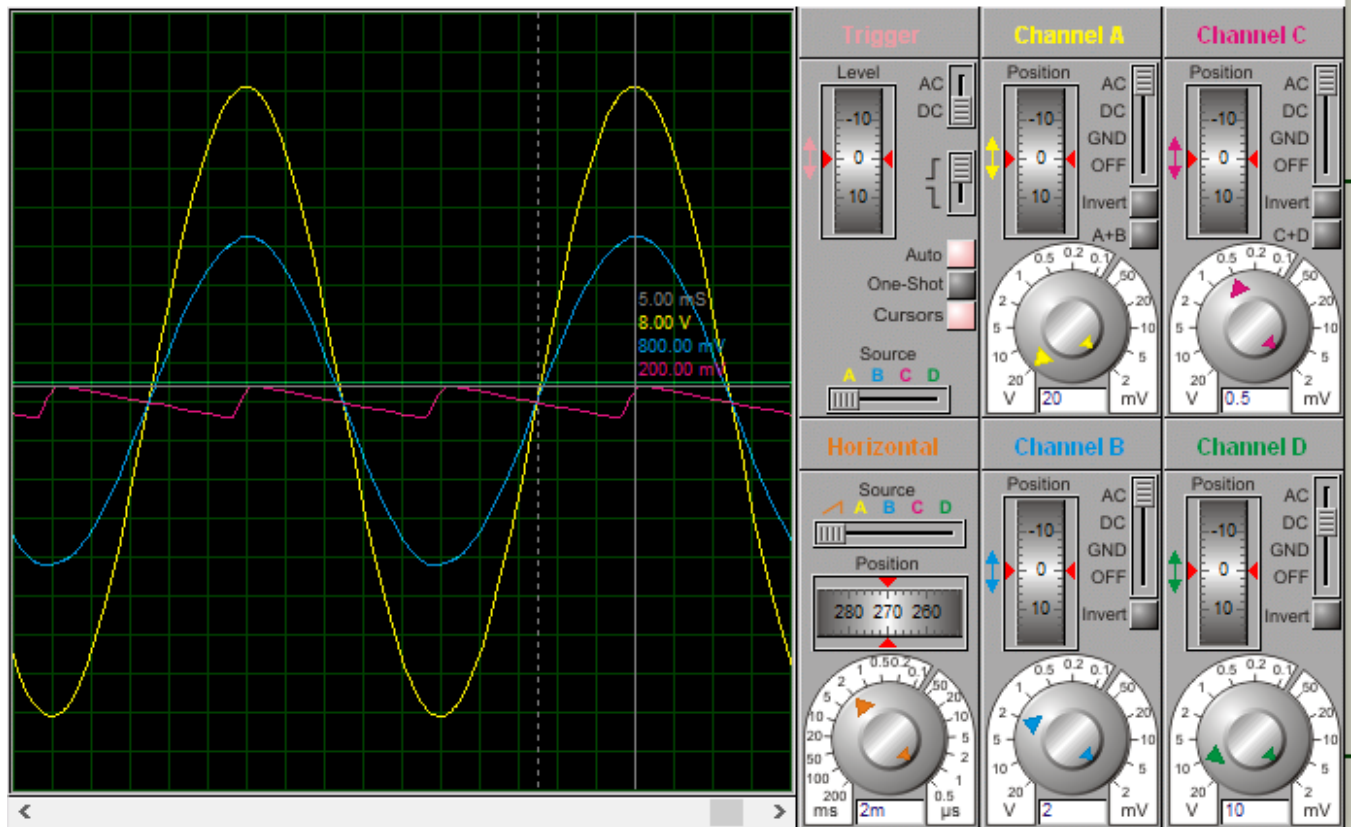
C = 2000 μ F

VZener = 5.1V

R1 = 94 Ω , Rload = 102 Ω



Digital Oscilloscope



VDC = 5.17 V (with capacitor)

Vripple = 400 mV (peak to peak)

Without using a capacitor:

Case 1:

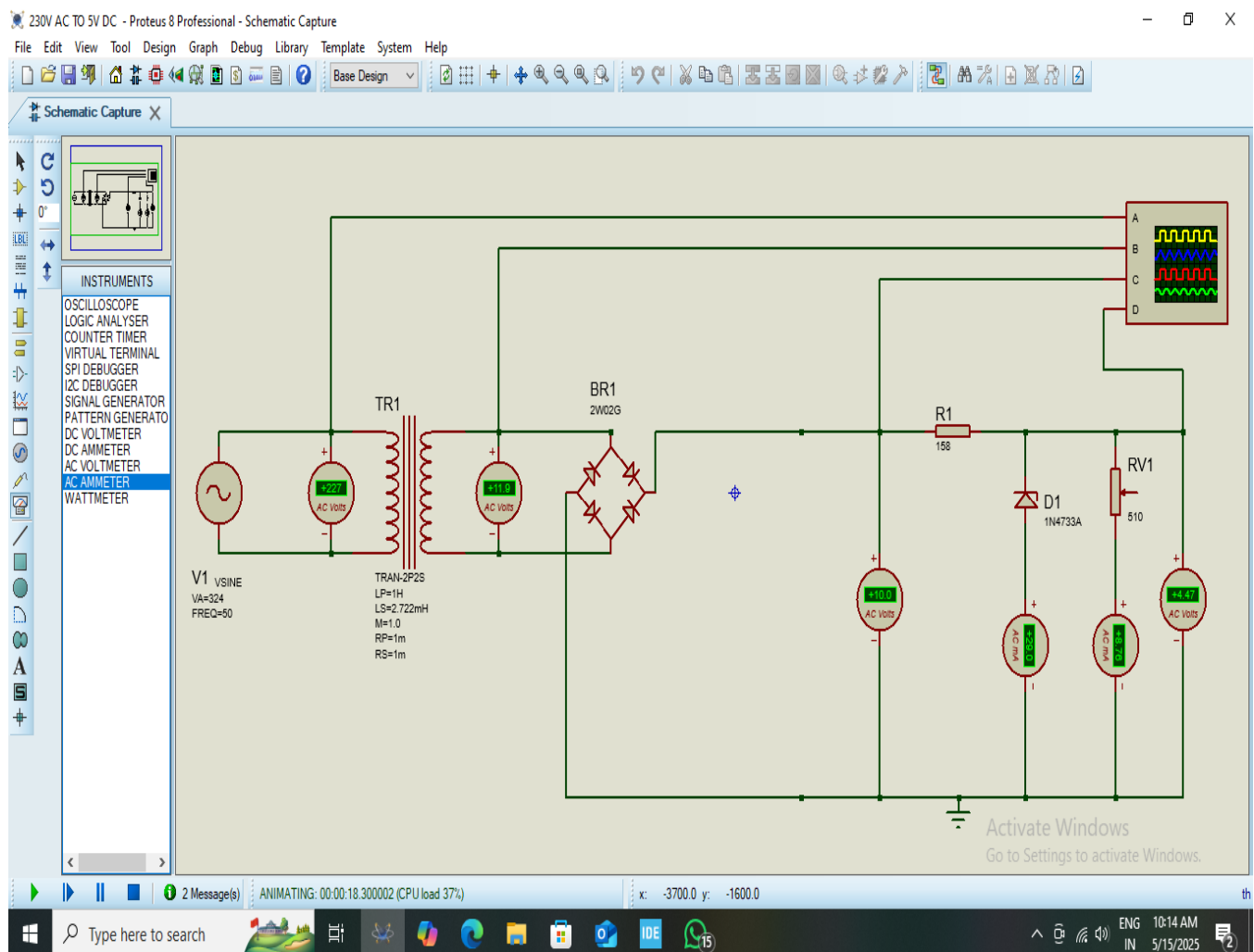
VAC (primary) = 230 V (mains), VAC (secondary) = 12 V

L(primary) = 1 H, L(secondary) = 2.722 mH

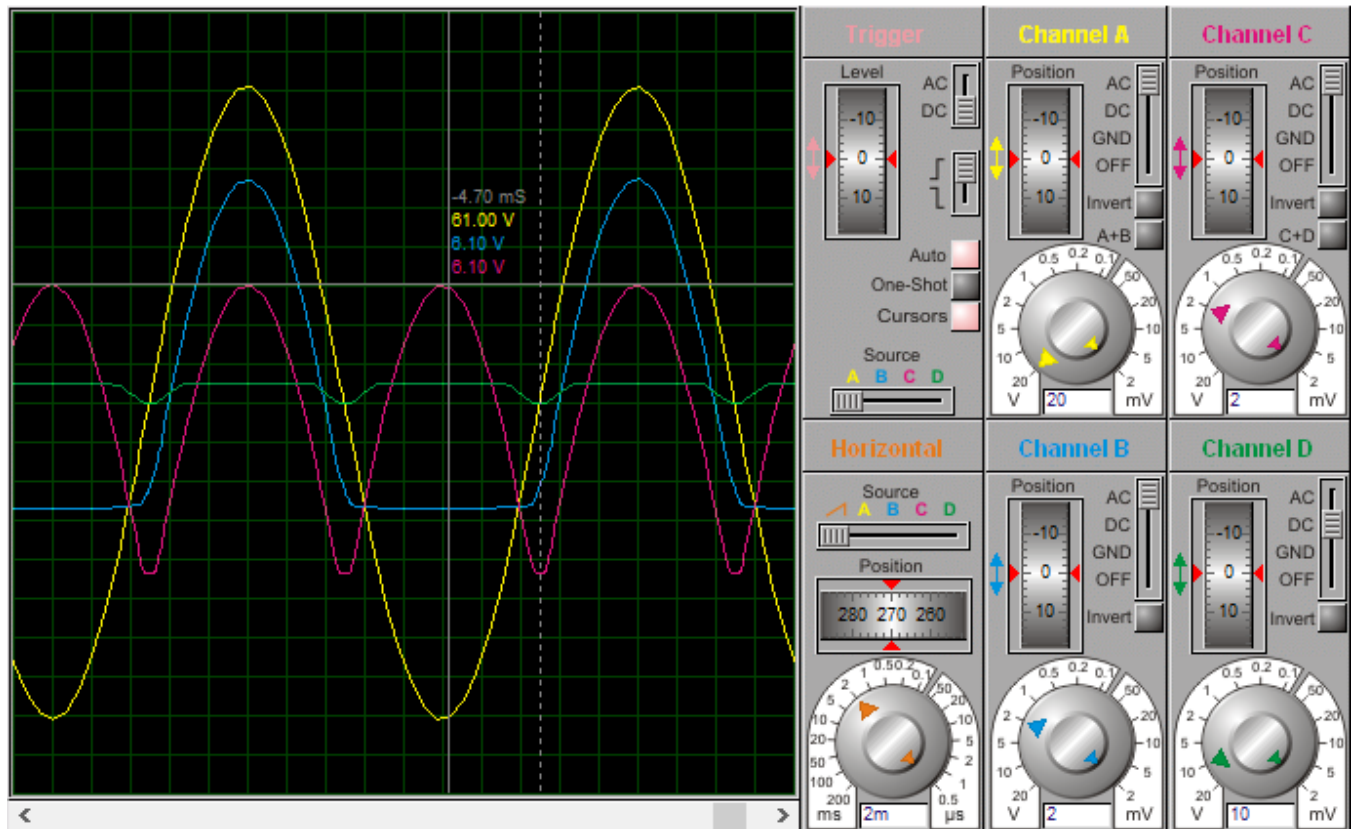
C = 0 μ F

VZener = 5.1V

R1 = 158 Ω , Rload = 510 Ω



Digital Oscilloscope



VDC = 4.47 V (alternating, without capacitor)

Vripple = 12.20 V (peak to peak)

Case 2:

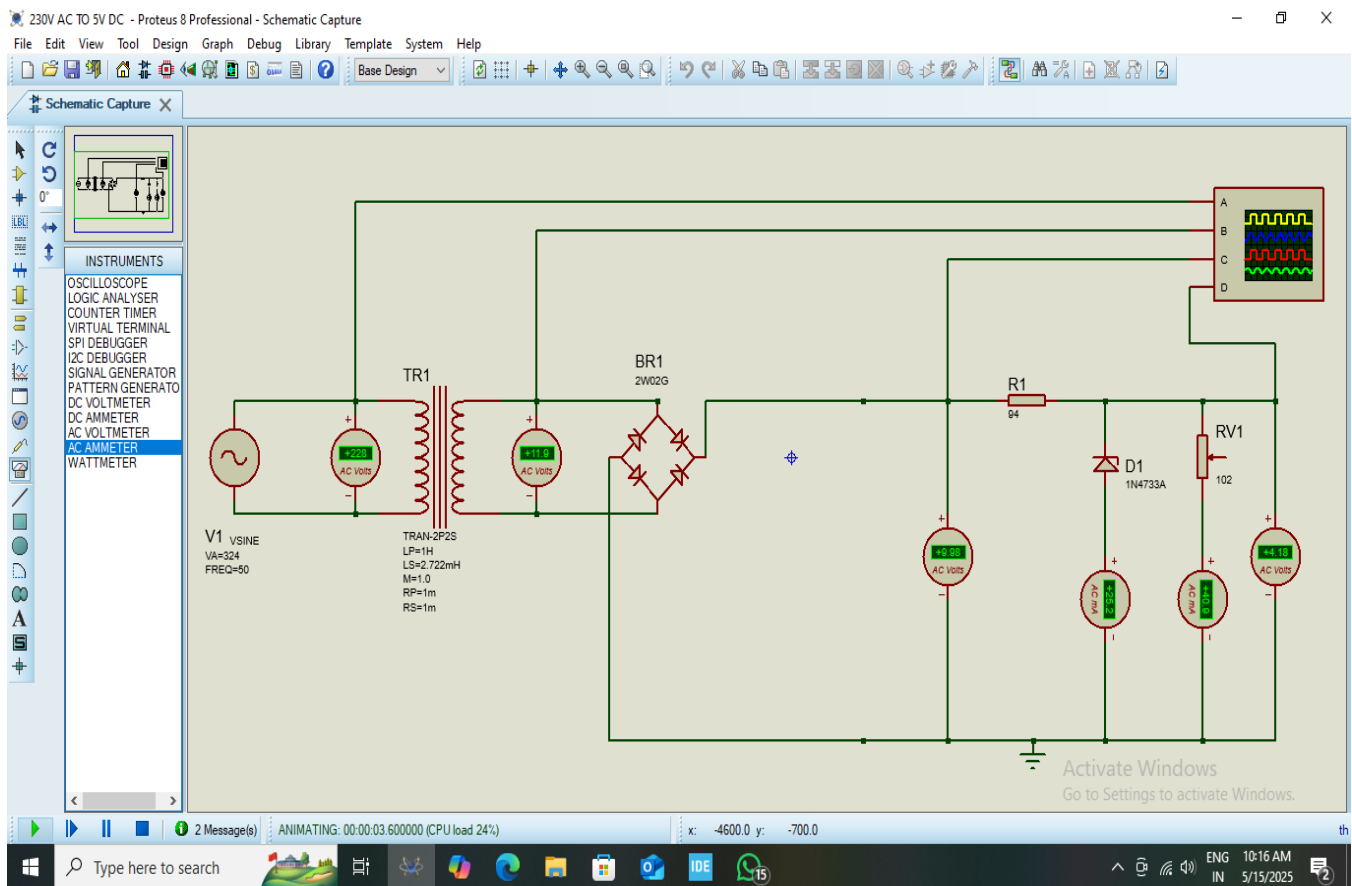
VAC (primary) = 230 V (mains), VAC (secondary) = 12 V

L(primary) = 1 H, L(secondary) = 2.722 mH

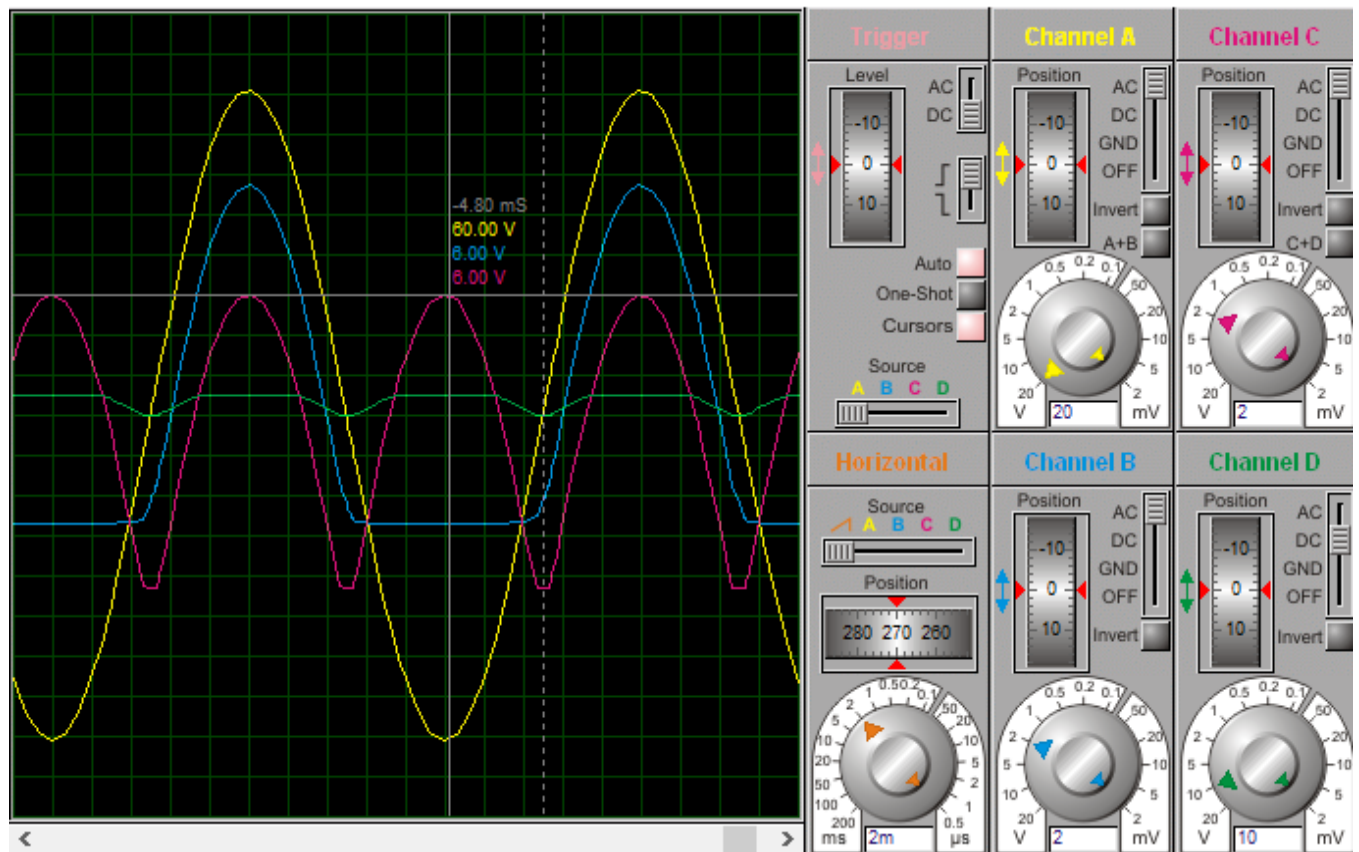
C = 0 μ F

VZener = 5.1V

R1 = 94 Ω , Rload = 102 Ω



Digital Oscilloscope



VDC = 4.18 V (alternating, without capacitor)

Vripple = 12 V (peak to peak)

CHAPTER 5

OBSERVATION

With the use of capacitor							
Case	Capacitor	R1 (Ω)	Rload (Ω)	Vdc (output)	V ripple	Output	comments
1	2000uF	158	510	5.18	250mv	Smooth DC	Low Vripple, Stable DC
2	2000uF	94	102	5.17	400mV	Smooth DC	Slightly increase in Vripple due to increase in load current.
Without using a capacitor							
Case	Capacitor	R1 (Ω)	Rload (Ω)	Vdc (output)	V ripple	Output	comments
1	0uF	158	510	4.47	12.20V	Pulsating DC	Absence of capacitor cause high Vripple,
2	0uF	94	102	4.18	12V	Pulsating DC	Absence of capacitor and low load resistance cause worse Vripple

Key observations:

- 1) Presence of capacitance show significantly reduced in ripple voltage and smooth DC output.
- 2) Lower load resistance (R_{load}) value increase current demand, leading to higher ripple voltage and slightly lower output stability.
- 3) Lower series resistance (R_1) allows more current, resulting in increased ripple.

CHAPTER 6

ANALYSIS AND CONCLUSION

Functionality Analysis:

With the use of Capacitor:

- **Ripple Reduction:** The presence of a filter capacitor ($C=2000\ \mu\text{F}$) significantly reduces the ripple voltage to manageable levels (0.25–0.4 V), ensuring a smooth DC output. This is crucial for applications that require stable DC voltage, such as powering sensitive electronics.
- **Stable Output Voltage:** The Zener diode successfully regulates the output voltage near 5.1 V, matching its breakdown voltage. This indicates the circuit is functioning correctly as a regulated power supply.
- **Load Dependency:** The increased ripple in (400 mV) compared to (250 mV) demonstrates the impact of a lower load resistance ($R_{\text{load}}=158\ \Omega$) and a lower series resistance ($R_1=94\ \Omega$). Higher current demands increase ripple and reduce overall efficiency, but the circuit still maintains a reliable DC output.

Without capacitor:

- **High Ripple Voltage:** The absence of a filter capacitor leads to extremely high ripple voltage (12.20V) resulting in a pulsating DC output. Such high ripple is unsuitable for most practical applications and could damage connected devices.
- **Unstable Output:** Without a capacitor, the Zener diode cannot regulate the voltage effectively. The output fluctuates between 0 V and the peak rectified voltage (pulsating DC). This makes the circuit unreliable for powering sensitive loads.
- **Increased Load Effect:**

The lower $R_{\text{load}}=102\ \Omega$ results in higher current draw, exacerbating ripple and further degrading output stability. This highlights the critical role of the capacitor in smoothing the output.

Reliability Analysis:

With the use of Capacitor:

- **High Reliability:** The circuit is reliable for low to moderate current loads. The capacitor minimizes ripple and ensures stable output voltage. This makes the circuit suitable for powering devices that require consistent voltage.
- **Load Limitations:** Higher current loads increase ripple, which may affect performance in high-demand scenarios. However, increasing the capacitor value could mitigate this issue, enhancing reliability for larger loads.

Without the use of Capacitor:

- **Low Reliability:** The circuit becomes highly unreliable without a capacitor. The pulsating output and high ripple make it unsuitable for most applications. Connected devices may experience erratic behavior or even damage due to the lack of voltage stability.
- **Component Stress:** High ripple voltage places significant stress on the Zener diode and other components, potentially reducing their lifespan and increasing the likelihood of failure.

Implications for Design Improvements:

- **Capacitor Necessity:** A filter capacitor is essential for ensuring smooth and stable DC output. Larger capacitor values (e.g., $C > 2000 \mu\text{F}$) could further reduce ripple for high current loads.
- **Load Adaptation:** Lowering the load resistance (R_{load}) increases ripple and decreases stability. This implies the circuit's reliability is limited by its current-handling capability. Careful design adjustments, such as improving the power supply rating or adding better regulation techniques, could address this.

• **Circuit Optimization:**

For higher reliability:

- Use a capacitor with appropriate value for the load.
- Add an additional stage of regulation (e.g. an integrated voltage regulator) to improve ripple rejection.
- Use a higher-rated transformer or rectifier to handle larger loads effectively.

Role of the Zener Diode:

- The Zener diode effectively regulated the output voltage to approximately 5.18 V, matching its breakdown voltage.
- It maintained a stable DC output under varying load conditions as long as a filter capacitor was present.
- Without the capacitor, the Zener diode struggled to regulate the voltage due to the high ripple voltage in the unfiltered pulsating DC.

Key Insight: The Zener diode ensures voltage regulation but depends on a relatively smooth DC input to operate reliably. A filter capacitor is necessary to enable its functionality.

Role of the Filter Capacitor:

- The filter capacitor significantly reduced ripple voltage, resulting in smooth DC output.
 - Case 1: Ripple reduced to 0.25 V.
 - Case 2: Ripple increased to 0.4 V due to higher load current.
- Without the capacitor, ripple voltage was extremely high (12.2V), leading to an unreliable pulsating DC output.

Key Insight: The capacitor's presence is essential for smoothing the rectified voltage, enabling stable operation of the Zener diode and ensuring reliability for sensitive loads.

Power Supply Design Insights:

1) Transformer Selection: A 12V RMS step-down transformer provided sufficient headroom for rectification, ripple reduction, and regulation.

2) Ripple Reduction: The filter capacitor and load resistance (R_{load}) directly influenced ripple voltage and output stability.

- ❖ Larger capacitance values reduce ripple more effectively.
- ❖ Higher R_{load} values reduce current demand, minimizing ripple.

3) Load Handling: Lower load resistances and higher current draw increased ripple but remained within acceptable limits.

4) Series Resistance (R_1) Optimization: The series resistor limited current through the Zener diode, protecting it from excessive dissipation.

Project Objectives Met:

- The circuit demonstrated the ability to convert 230v AC voltage to a regulated 5v DC voltage.
- Ripple voltage was reduced to acceptable levels in designs with the filter capacitor, ensuring a smooth and stable DC output.
- The Zener diode performed as expected, maintaining a regulated output voltage under varying conditions.

CONCLUDING REMARKS:

The project highlights the importance of proper component selection in power supply design. The interplay between the Zener diode, filter capacitor, load resistance, and series resistor determine the circuit's functionality and reliability. By analyzing the results, it is evident that:

- a) **A filter capacitor is indispensable for ripple reduction.**
- b) **The Zener diode provides effective voltage regulation with a smooth input.**
- c) **Optimizing resistor and load values is crucial for efficiency and reliability.**

These insights are foundational for designing power supplies in various electronic applications, including electric vehicles (EVs), where reliable DC voltage is critical.

