



ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF ELECTRICAL AND COMPUTER ENGINEERING

# APPLIED ELECTRONICS I: Project 1

TITLE: REGULATED DC POWER SUPPLY DESIGN

December 27, 2023

## GROUP MEMBERS |

1. NAOL ABOMA	UGR/9692/14
2. NATAN SAMUEL	UGR/8778/14
3. GELETOM WORKINEH	UGR/3740/14

## ID No.

APPLIED ELECTRONICS I

INSTRUCTOR SOSINA ABIYOT

## **INTRODUCTION**

In most electricity generation stations, the predominant form of power produced is alternating current (AC) due to its affordability and widespread use in industrial applications. However, common household devices such as televisions, computers, and radios require a steady supply of direct current (DC) to function properly. Since generating DC voltage on a large scale can be prohibitively expensive, an ingenious solution was devised to convert the supplied AC voltage into regulated DC voltage and seamlessly integrate it into these devices' circuitry.

To achieve this conversion, a power module is included within the packaging of these devices. This power module is specifically designed to efficiently convert the AC voltage to the required DC voltage, ensuring a reliable and stable power supply. The power module offers flexibility by providing different levels of DC voltage to meet the specific needs of various electronic devices.

In essence, the incorporation of this power module allows our everyday electronics to operate smoothly by bridging the gap between the readily available AC power and the essential DC power they require.

This important process usually involves the following sequential steps:

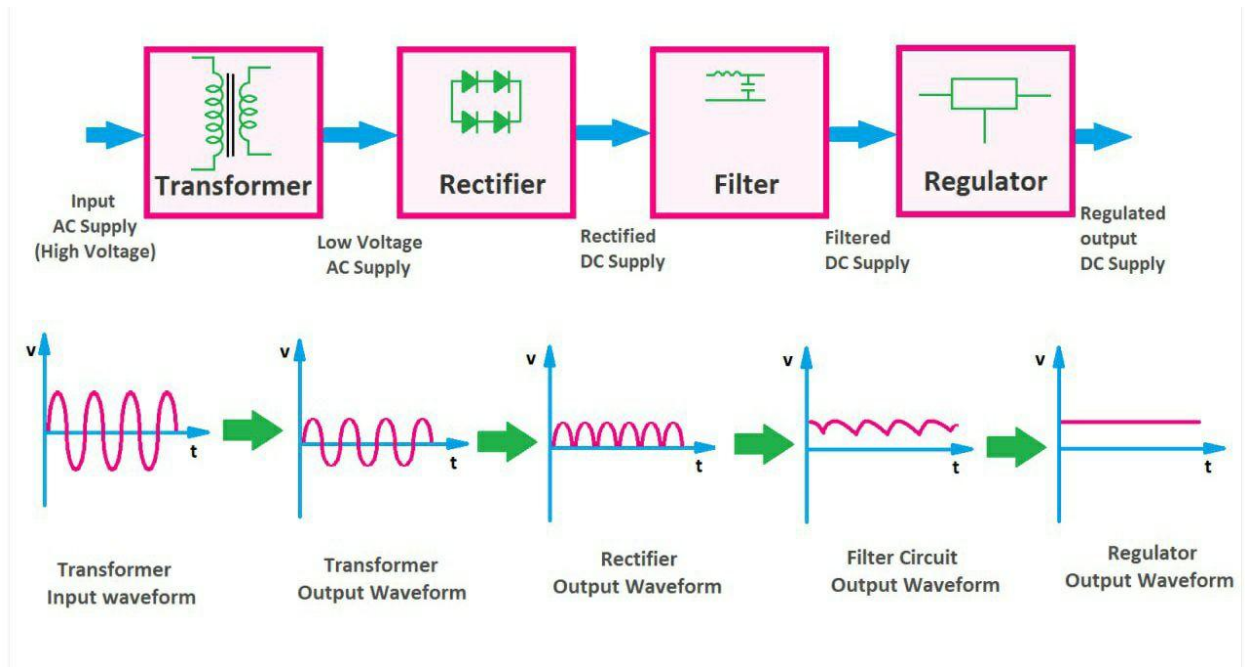
Input AC waveform → Rectification → Filtering → Regulation → Output DC

## **OBJECTIVES**

1. Ensuring a reliable power source for circuits and devices by delivering a consistent voltage within specified limits.
2. Safeguarding sensitive equipment by effectively separating high voltage AC input from low voltage DC input, while also mitigating any unwanted noise that may affect the output voltage.
3. Providing precision and stability in voltage output to meet the demands of electronic and electric devices.

## PROCEDURES

A typical regulated DC power supply design proceeds according to the following steps.



### Regulated DC power supply block diagram

The above diagram illustrates a regulated DC power supply circuit consisting of four primary sub-blocks. Initially, the input to the regulated DC power supply circuit is a sinusoidal signal. By utilizing the provided information of  $V_{rms} = 220V$  and a frequency of 50 Hz, we can determine  $V_{max}$  using the following formula.

$$V_{rms} = V_{max}/(2)^{1/2}$$

$$\begin{aligned} V_{max} &= V_{rms} * (2)^{1/2} \\ &= 220V * (2)^{1/2} \end{aligned}$$

$$\underline{V_{max} = 311.13V}$$

Then the input signal in the form of sinusoidal signal is

$$V(t) = 311.13 \sin(2\pi 50t) \text{ V}$$

As we stated above we have 4 main sub-blocks

## 1. The Transformer

The primary function of the mentioned transformer in the regulated DC power supply circuit is to step down the high-amplitude AC voltage and produce an AC voltage with a smaller amplitude. In order to achieve this, the transformer is modeled using coupled inductors.

To model the transformer, each winding is represented as an inductor. The primary winding is denoted as L1, and the secondary winding is denoted as L2. The coupling of the windings is simulated using a spice directive called the case statement (k), where the mutual coefficient is set to 1 to represent perfect coupling with no leakage.

The transformer obeys the relationship:

$$n = (L2/L1)^{(1/2)} = N2/N1 = V2/V1$$

To obtain an output voltage of  $V_{cc} = 20V$ , the turn ratio of the transformer is set to 121:1. Since  $N1 > N2$ , the transformer performs a step-down operation. As a result of this transformation process, the stepped-down voltage becomes 27V.

## 2. The rectifier

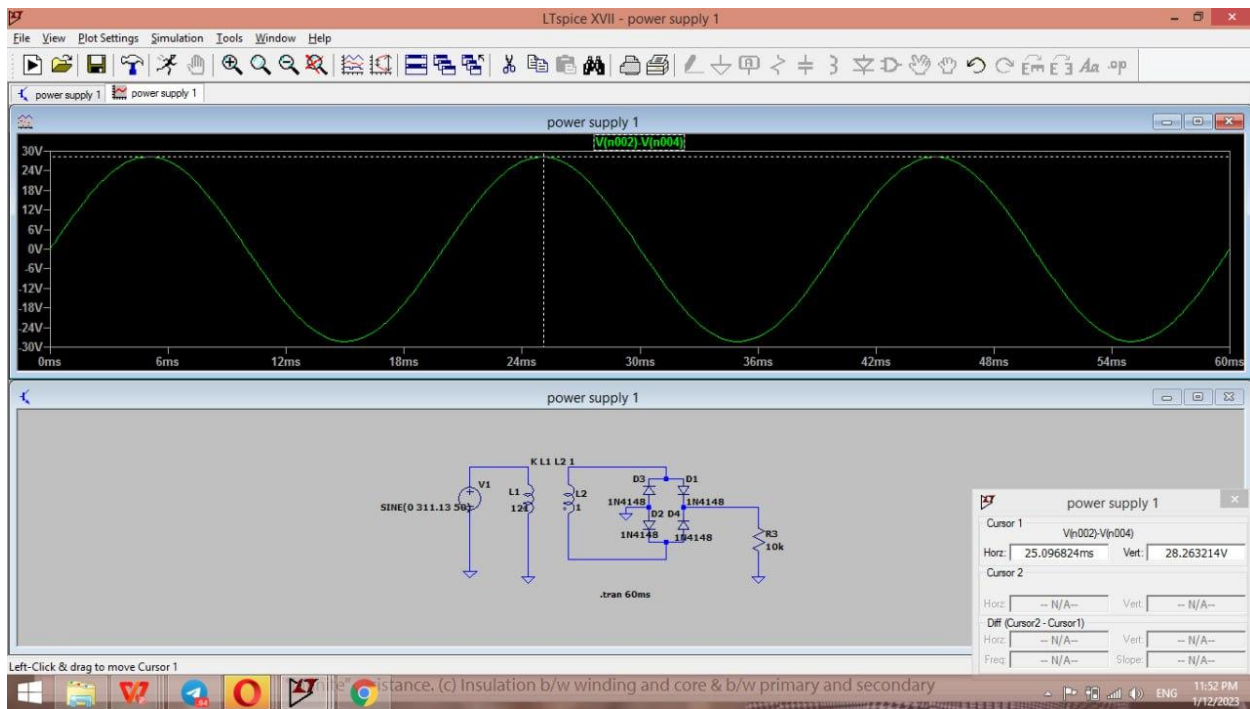
In the rectification process of the regulated DC power supply circuit, a bridge rectifier is utilized to convert AC voltage into pulsating DC voltage. The commonly used rectifier diode model, 1N4148, is employed in the bridge circuit.

The diode bridge rectifier takes the sinusoidal waveform from the secondary side of the transformer as its input and generates a full-wave rectified voltage at its output. It achieves this by allowing current flow in only one direction through the diodes.

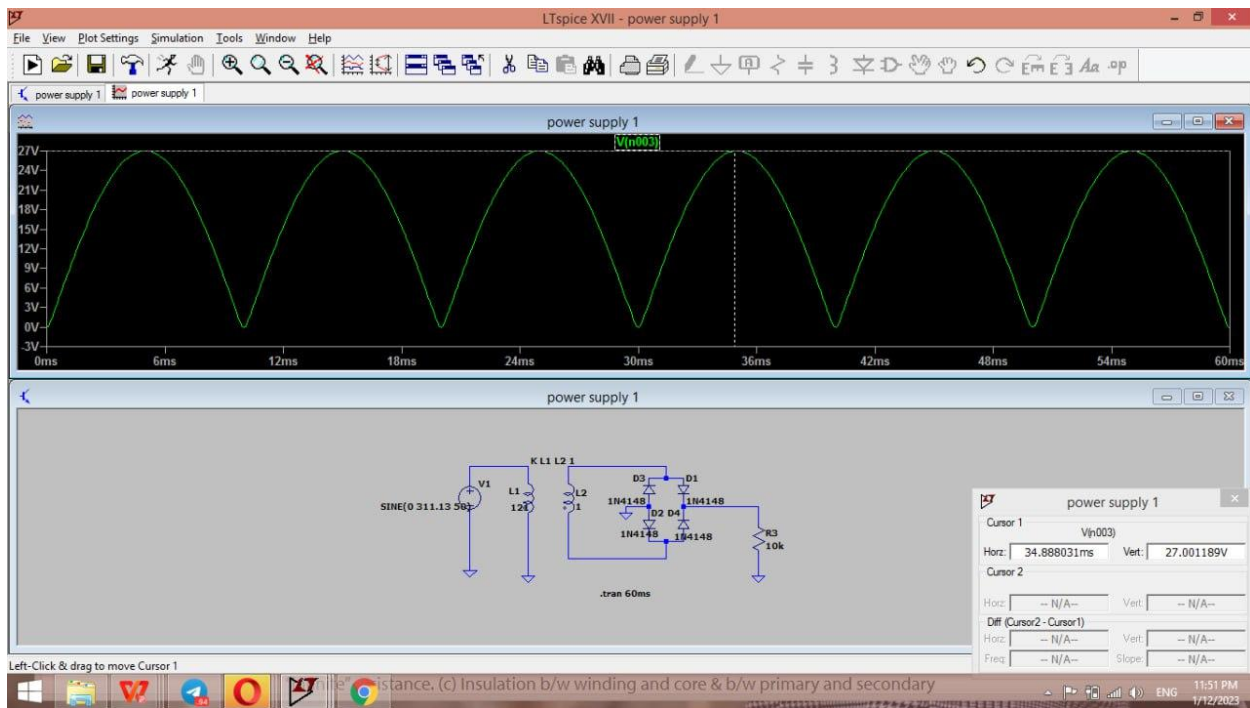
At the output of the bridge rectifier, the peak value of the rectified output voltage can be determined by subtracting the voltage drops across two diodes from the peak value of the input voltage. This subtraction accounts for the forward voltage drop across each diode during the rectification process.

It's important to note that the specific voltage drops across diodes may vary depending on the diode model used. However, in this case, the mentioned rectifier diode model, 1N4148, is commonly known to have a typical forward voltage drop of around 0.7 to 0.8 volts.

By considering these diode voltage drops, the peak value of the rectified output voltage can be calculated as the difference between the peak value of the input voltage and twice the diode voltage drop. This calculation enables accurate determination of the resulting DC voltage after rectification.



**INPUT VOLTAGE  $V_i(p)$**



**Fig of OUTPUT VOLTAGE  $V_o(p)$**

$$V_o(p) = V_i(p) - 1.4$$

$$27 \approx 28.3 - 1.4$$

### 3. The Smoothing filter

In the filter circuit of the regulated DC power supply, a low pass filter, such as a capacitor filter, is commonly employed. The capacitor filter is created by connecting a capacitor in parallel with the load resistor.

The purpose of the capacitor filter is to convert the pulsating DC input from the rectifier into a smoother DC output with reduced ripple. The capacitor acts as a storage element, charging up during the peaks of the input waveform and discharging during the troughs, thereby smoothing out the variations.

To characterize the output of the capacitor filter, a theoretical formula is commonly used. This formula is as follows:

$$V_o(DC) = V_o(p) - 1/2 * V_{rpp}$$

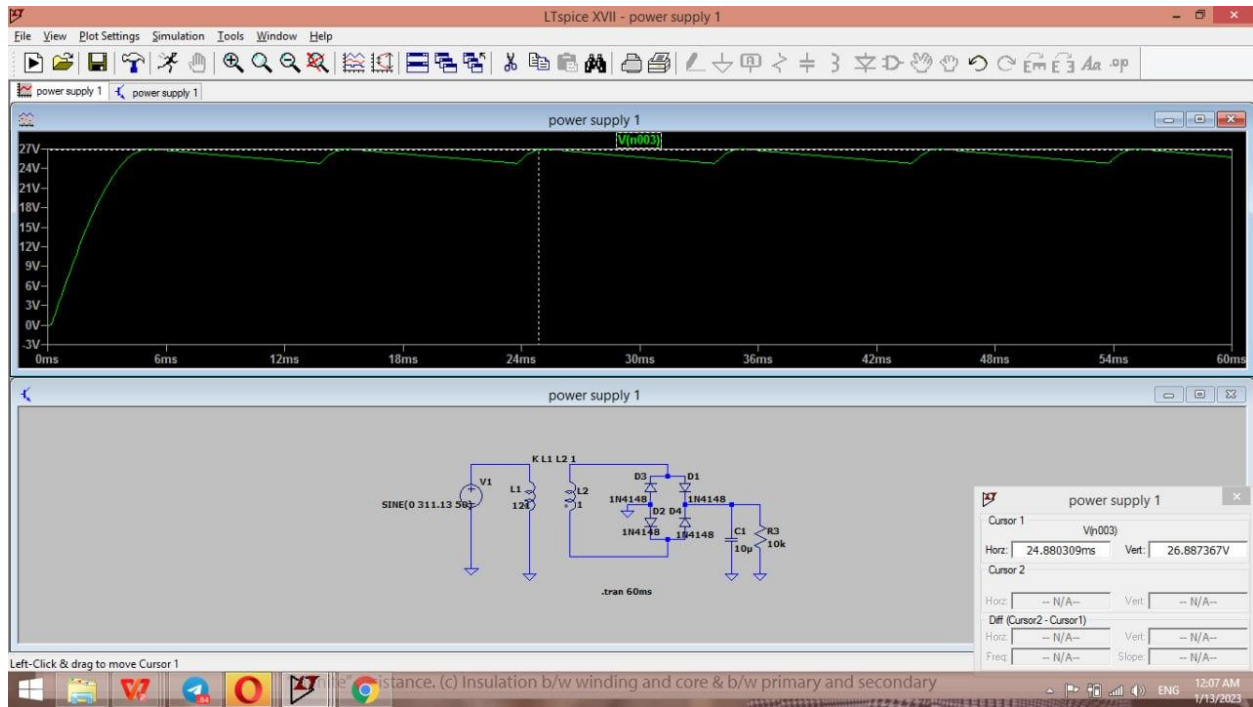
Here,  $V_o(DC)$  represents the DC component of the output voltage,  $V_o(p)$  represents the peak value of the output voltage, and  $V_{rpp}$  represents the ripple voltage.

The ripple voltage,  $V_{rpp}$ , is calculated using the following formula:

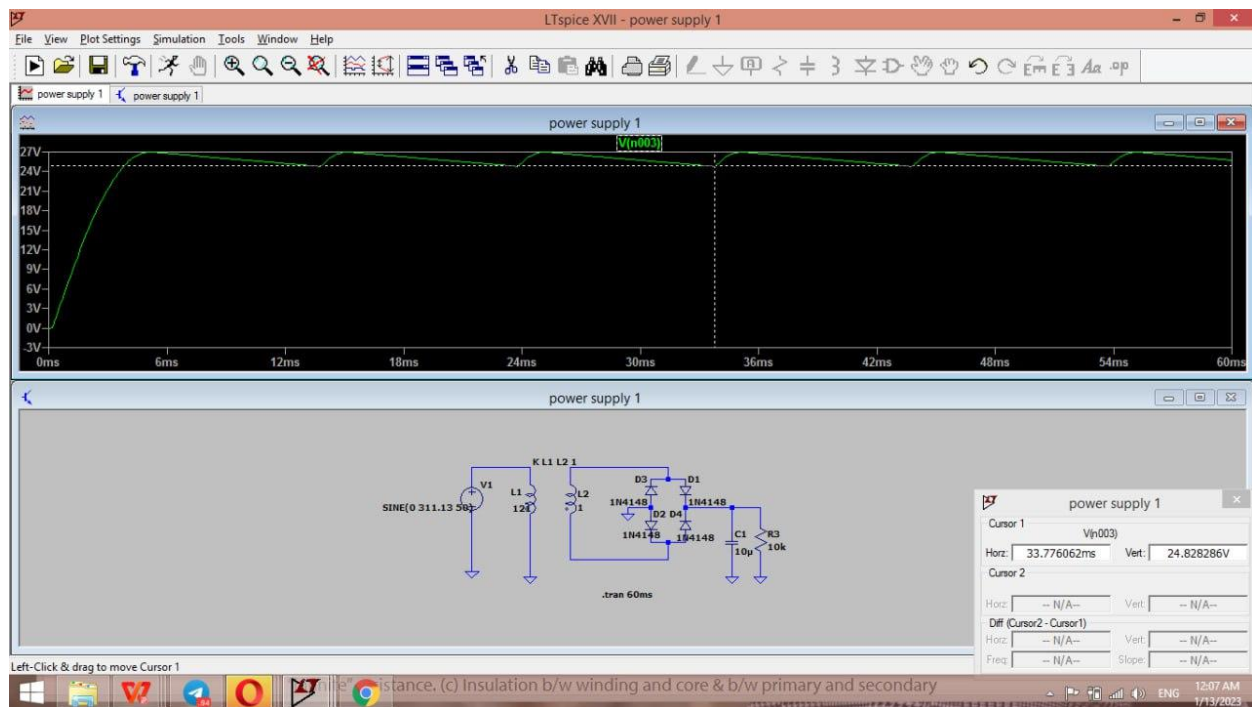
$$V_{rpp} = V_o - 2 * V_{Don} / (2 * R * C * f_{in})$$

In this equation,  $V_o$  represents the average output voltage,  $V_{Don}$  represents the forward voltage drop across the diodes,  $R$  represents the load resistor,  $C$  represents the capacitance of the capacitor, and  $f_{in}$  represents the input frequency.

By using these formulas, the output characteristics of the capacitor filter can be determined, allowing for the analysis and design of a smoother and more stable DC output voltage.



**Fig of: UPPER PEAK VOLTAGE**



**Fig of : LOWER PEAK VOLTAGE**

As we can from the given above figures  $V_{rpp}$  approximately two.

Also from the above formula

$$V_{rpp} = 27/2(10k\Omega)(50Hz)(10\mu C)$$

$$V_{rpp} \approx 2$$

So our assumption holds true.

#### **4. The regulator**

To regulate the output voltage in the regulated DC power supply circuit, a zener regulator is utilized to convert the smooth DC voltage from the capacitor filter into a constant DC voltage.

A zener regulator circuit achieves this by employing a zener diode, specifically the EDZV20B model with a zener voltage ( $V_{zm}$ ) of 20.4V.

The zener diode operates when the input voltage, which consists of the DC value of the filter output ( $V_{cDC}$ ) plus its ripple voltage ( $V_{ripple}$ ), exceeds the zener voltage.

To ensure that the desired output voltage is obtained and to accommodate the ripple voltage, an additional capacitor is added to the circuit.

Given the values mentioned:

$$V_{cDC} = 26.8V$$

$$V_{ripple} = 2V$$

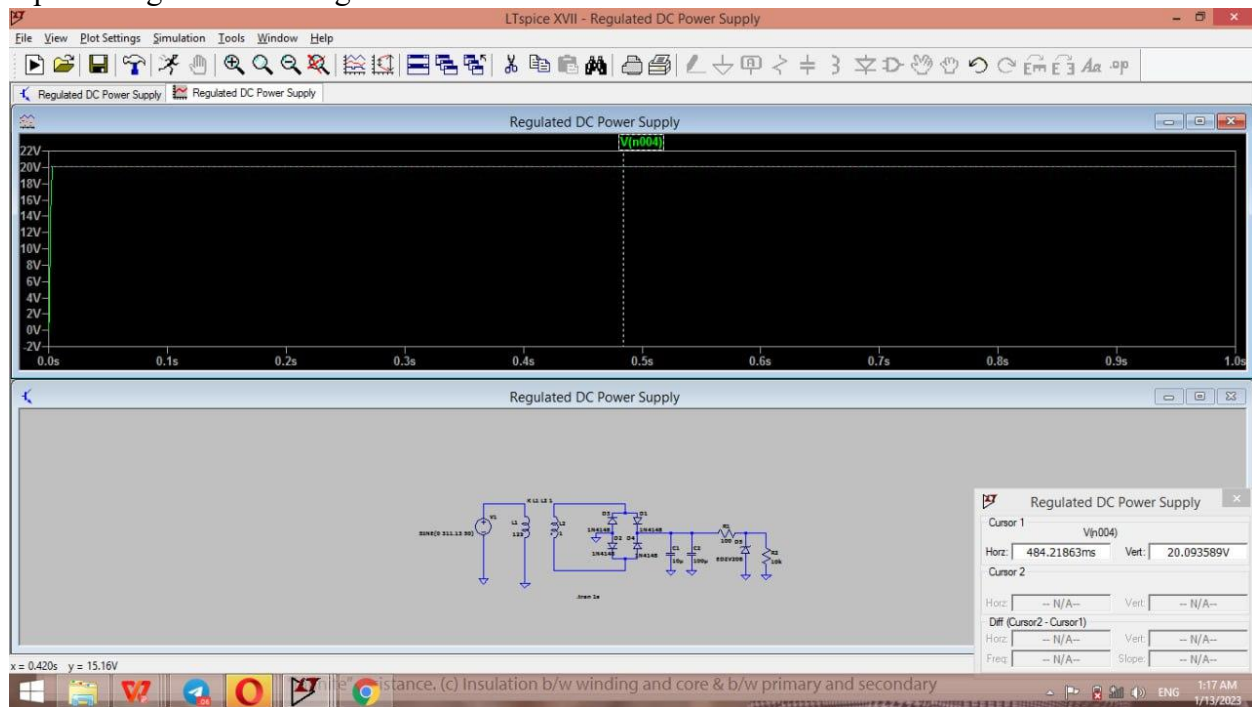
$$V_{cDC} + V_{ripple} > V_{zm}$$

In this case, the sum of the DC voltage and the ripple voltage ( $26.8V + 2V$ ) is indeed greater than the zener voltage (20.4V). This condition ensures that the zener diode operates within its desired voltage range, allowing for the regulation of the output voltage.

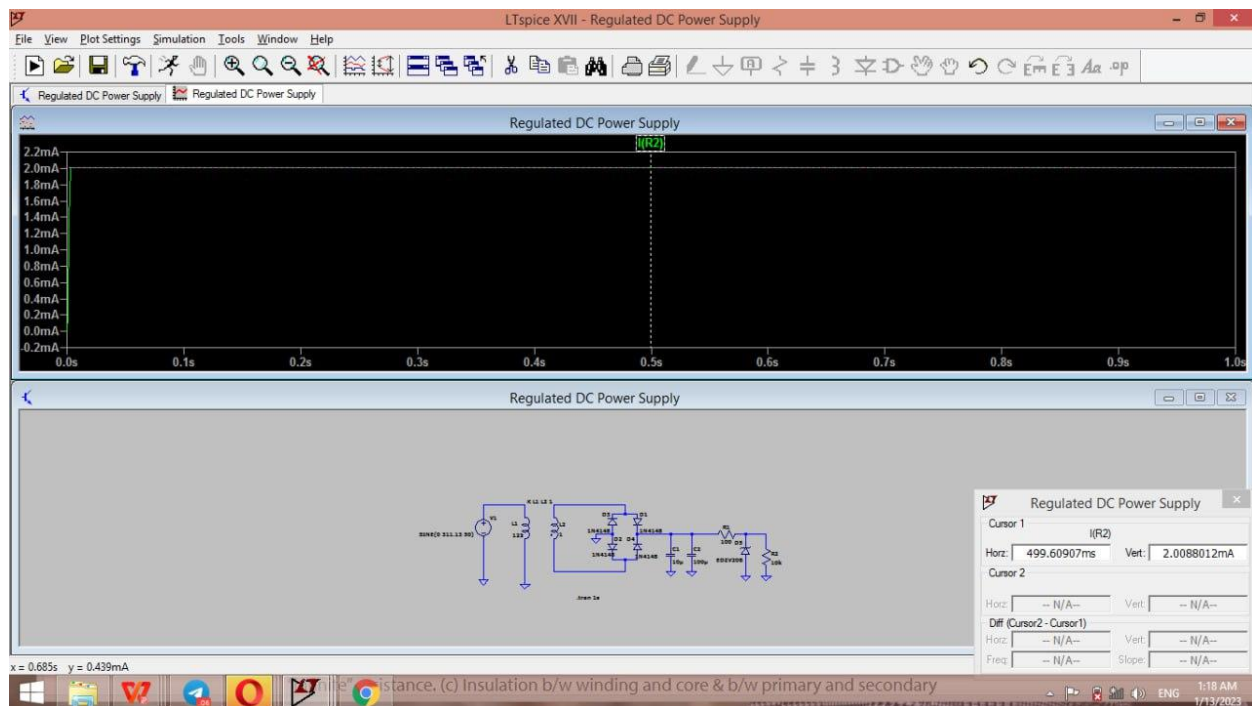
By satisfying this requirement, the zener regulator can effectively maintain a constant output voltage, compensating for any variations and fluctuations in the input voltage. We are sure the



input voltage is in the range to make the diode on.



**Fig of : output voltage( $V_L = 20V$ )**



**Fig of : ouput current ( $I_L = 2mA$ )**

Or we can calculate the current from the output voltage,  $V_{cc}=20V$

$$I_L = V_{cc}/R_L = 20V/10k\Omega = 2mA$$

## CONCLUSION

In conclusion, the inclusion of a Zener diode in a regulator circuit is essential for maintaining a consistent and unvarying output voltage. By utilizing the unique properties of the Zener diode, such as its ability to maintain a constant voltage across its terminals, the regulator circuit ensures a stable output voltage, regardless of variations in the input voltage or changes in the load.

Furthermore, the capacitors connected in parallel with load resistors play a crucial role in filtering out fluctuations in the DC voltage. By acting as energy storage devices, these capacitors help smooth out the output voltage by charging during periods of higher voltage and discharging during periods of lower voltage. This effectively reduces the ripple or variations in the output voltage, ensuring a more stable and reliable power supply.

By accurately implementing the four main sub-blocks of the regulated DC power supply circuit, namely the transformer, rectifier, filter, and voltage regulator, we can achieve the desired output values that match the specified requirements. Each sub-block performs its designated function, with the transformer stepping down the voltage, the rectifier converting AC to DC, the filter reducing ripple, and the voltage regulator maintaining a constant output voltage. By ensuring the accuracy and effectiveness of each sub-block, we can confidently conclude that the output values at the regulator step align with the expected specifications.

Overall, the Zener diode, capacitors, and the successful execution of the sub-blocks collectively contribute to a regulated DC power supply that delivers a constant, filtered, and reliable output voltage, meeting the desired requirements of electronic devices and systems.