EXPERIMENT 3

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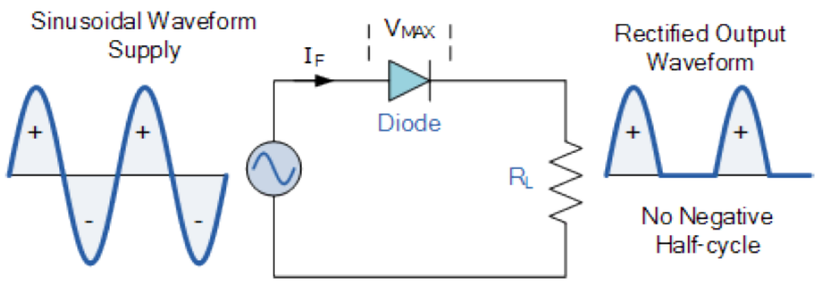
Half-Wave Rectification

1. **Aim of the experiment:**
   - Explaining Half-Wave Rectification for both positive and negative half cycles of an input waveform and to show that Ripple factor remains constant even when input voltage amplitude is changed.

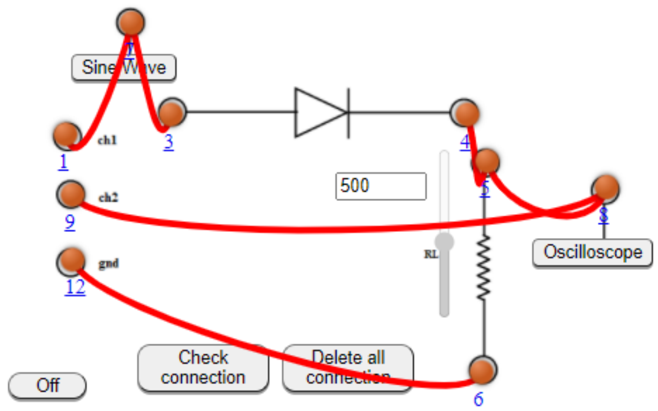
2. **Tools used:**
   - P-N junction diode
   - AC voltage source
   - Resistor
   - Connecting Wires
   - Oscilloscope

3. **Background knowledge:**
   - A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. Half wave rectifier (HWR) is the first type in the rectifiers which rectifies the full wave input AC signal in to half wave pulsating DC signal. That's why this is called half wave rectifier.
   - The diode is the first component used in rectifiers which is a uni-directional device i.e. it allows the signal in one direction and blocks the signal flow in opposite direction. In HWR, the diode is placed in series with the input AC sinusoidal signal which consists of positive and negative peaks.
   - If the diode is placed in the normal direction then it rectifies the negative peak and produces positive peak as output. If it placed in reverse direction then it acts as positive clipper and produces negative HW output. Thus half-wave rectifier only allows one half cycle of the input to pass through, and blocks the other half.
   - When the input voltage is greater than diode cut-in voltage then it starts conducting and the input signal is produced at the output. i.e. until the diode is conducting state the output will be same as input. During the negative pulse, once again when the input voltage is less than cut in voltage, the diode is reverse biased and stops conducting which blocks the input signal. So the resultant output during this period will be zero.



   - RMS Load Voltage : $V_{rms} = I_{rms} \times R = V_m/2$
   - Average Voltage is : $V_m/\pi = 0.318V_m$
   - Form Factor is the ratio of RMS load voltage and average load voltage. For a half wave rectifier, it is equal to 1.57.
   - Ripple factor is given by the ratio between the RMS value of the AC voltage (on the input side) and the DC voltage (on the output side). For a half wave rectifier, it is equal to 1.21.
   - The efficiency of a half-wave rectifier the ratio of dc power available at the load to the input ac power.

4. **Circuit / Oscilloscope(hand drawn/image):**



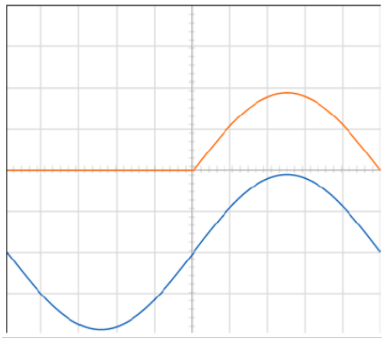
5. **Measurement Table:**

- Resistance= 500 Ohm, Frequency = 1000Hz.

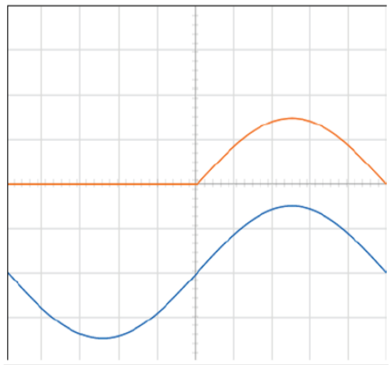
Peak Input Voltage	Peak Observed Current
2 V	2.599 A
1.5 V	1.599 A

6. **Graph (Image)/Screenshots**

- Blue color represents the input waveform, the output waveform is represented by Orange color.
- 1 unit on Y axis represents 1V
- Reading 1 : Input Voltage Amplitude = 2V, Frequency= 1000Hz, Resistance =500 Ohms



- Reading 2 : Input Voltage Amplitude = 1.5V, Frequency= 1000Hz, Resistance =500 Ohms



7. <u>**Conclusion:**</u>

- We have observed and concluded that a Half-Wave rectifier rectifies an AC Signal into a pulsating DC Voltage by blocking one half cycle and allowing the other half cycle to pass.
- Considering V_m as the peak input voltage, then

$$V_{rms}=V_m/2,\ V_{dc}=V_m/\pi$$
$$V_{ac}= (V_{rms}\text{^}2 - V_{dc}\text{^}2)\text{^}0.5$$
$$\text{Ripple Factor}=V_{ac}/V_{dc}$$

- For reading 1,
  - V_m=2V
  - V_{dc}=0.6366V
  - V_{ac}=0.7712
  - Ripple factor= V_{ac}/V_{dc}=1.211
- For reading 2,
  - V_m=1.5V
  - V_{dc}=0.4775V
  - V_{ac}=0.5784V
  - Ripple factor= V_{ac}/V_{dc}=1.211
- **We observe that Ripple factor is 1.211 in both cases.** Hence, the **ripple factor for a half-wave rectifier circuit is constant** and does not depend with variation of amplitude of input voltage signal.

8. <u>**Discussions:**</u>

- **Significance of the Ripple Factor:**
  - Ripple factor, denoted by γ, is used to measure the amount of ripples present in the output pulsating DC signal. A lower ripple factor indicates a more pure DC output with higher smoothness in the output signal. Hence for a good rectifier, the ripple factor should be as close to 0 as possible.
  - The ripple factor is equal to 1.21 for a half-wave rectifier. Therefore unwanted ripple present in the output along with the DC voltage is 121% of the DC magnitude. This indicates that the half wave rectifier is not an efficient AC to DC converter. The high ripples in the half wave rectifier can be reduced by using filters like capacitors.
- The **peak current** observed from the experiment as shown in the simulation is **slightly less** than the ideal case (V_m/R). This proves that the diodes used in the circuit have some **built-in knee voltage and are not ideal diodes**.
- **Disadvantages of Half-Wave rectifier**
  - Half of the applied voltage is wasted as only one half (positive) of the signal is allowed to pass through and the rest is blocked. Thus, there is power loss. It produces low output voltage.
  - The DC output signal obtained is not ideal DC and hence is not smooth.
- **Advantage of Half-Wave rectifier**
  - It is easy to build and cheap, because it involves minimum components to build the circuit.
- **Applications of Half-Wave Rectifier:**
  - Power rectification: One of the most obvious ways for a half wave diode rectifier to be used is within a power rectifier. A line or mains power input normally passes through a transformer to transform the voltage to the required level.
  - Signal demodulation: A simple half wave diode rectifier can be used for signal demodulation of amplitude modulated signals. The rectification process enables the amplitude modulation to be recovered.
  - Signal peak detector: The simple half wave diode detector can be used as a peak detector, detecting the peak of an incoming waveform.

<u>**Full-Wave Rectification**</u>

9. Aim of the experiment:

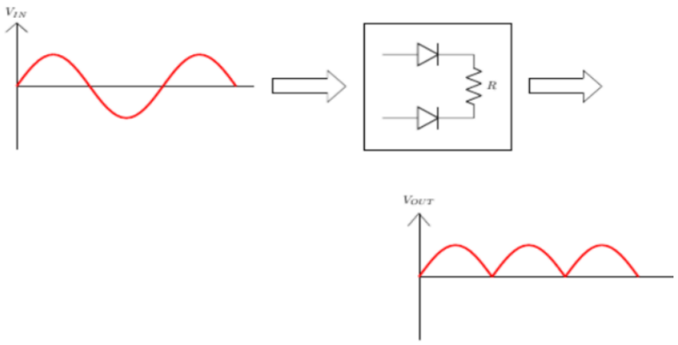
- Explain Rectification
- Explain Centre Tapped Full Wave Rectification
- Explain Bridge Full Wave Rectification
- Show that ripple factor remains constant even when input voltage amplitude is changed

10. Tools used:

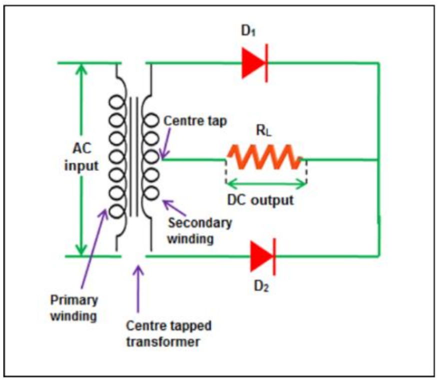
- AC Voltage Source
- 4 P-N junction diodes
- Load resistance (500 ohm)
- Oscilloscope
- Connecting wires

11. Background knowledge:

- Rectifier is a device which converts input AC Signal to a DC Signal output.
- Full wave rectifier, allows uni-directional current through the current during the entire sinusoidal cycle (as opposed to half cycle for half-wave rectifier). It converts both the positive and negative half cycles of the input AC waveform into a DC pulsating output signal.

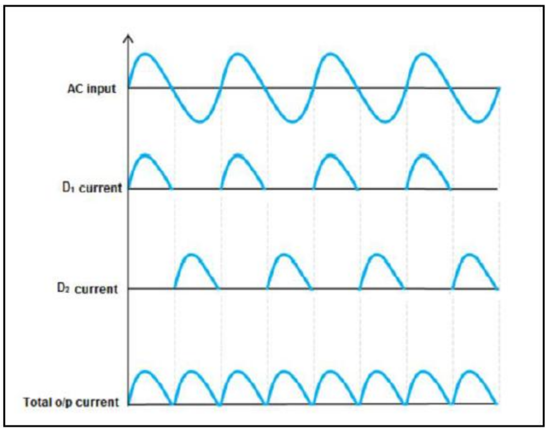


- There are two types of full wave rectifier: center-tapped full wave rectifier and bridge rectifier.
- **Centre-tapped Full Wave Rectifier**
    - A Full-Wave Rectifier can be constructed using Centre -Tapped transformer – which give us two shifted sinusoids so that exactly one of the waveforms is positive at one time and two diodes. It is a transformer in which an additional wire is connected across the center of the secondary winding. The wire is called the center tap. The AC sinusoidal voltage source is connected to the primary winding of the transformer.
    - The center tap connected at the center of the secondary winding always remains at 0 volts and divides the input voltage into two parts. The upper part of secondary winding is connected to diode D1 and the lower part to D2. The diodes are connected to load resistance RL.4

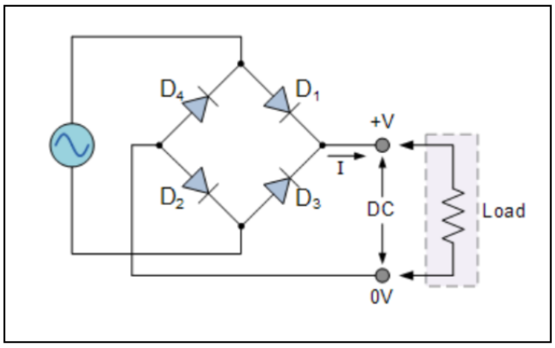


    - During the positive half cycle of AC input, diode D1 is switched on because the voltage across it (due to the center tap transformer) makes it forward biased. At the same time, D2 is in reverse bias, so it stays off. So, current only flows through diode D1 and current is blocked by diode D2.Thus, D1 supplies DC voltage at the load resistance RL. DC current flows through the load RL.

- During the negative half cycle, diode D2 turns on because it is in forward bias condition. Diode D1 is off, because it is in reverse bias condition. This is achieved by the voltage division by center tap transformer. Thus, D1 does not allow current to flow through it, but D2 allows current to flow through it. DC voltage is supplied to the load resistance RL and current flows in RL in the same direction as before. Thus, both half cycles are allowed to pass and an output waveform is created, which follows the input waveform except the polarity of output voltage does not change sign, and current flows only in one direction through the load.



- **Full-wave bridge rectifier**
  - In a full wave bridge rectifier, there are four diodes (D1 to D4) which are arranged such that in each half cycle, two diodes conduct current and two diodes don't conduct current. During the positive half cycle, diodes D1 and D2 are forward biased (ON) and D3 and D4 are reverse biased (OFF). Current flows through D1 and D2 and a DC output voltage is obtained across the load resistor RL. During the negative half cycle, diodes D3 and D4 are forward biased (ON) and D1 and D2 are reverse biased (OFF). Current flows through D3 and D4 and a DC output voltage is obtained across the load resistor RL. The output voltages obtained in the two half cycles have the same polarity across load resistor RL because current flows in the same direction in both cases. Thus, we obtain a rectified DC signal from both half-cycles of the AC input.



- The **average DC Load Voltage** is given by:

$$V_{av} = V_{dc} = \frac{2 \times V_m}{\pi}$$

- The **average Load Current** is given by:

$$I_{av} = \frac{2 \times I_m}{R}$$

- The **RMS Load Current** is given by:

$$I_{rms} = \frac{I_m}{\sqrt{2}}$$

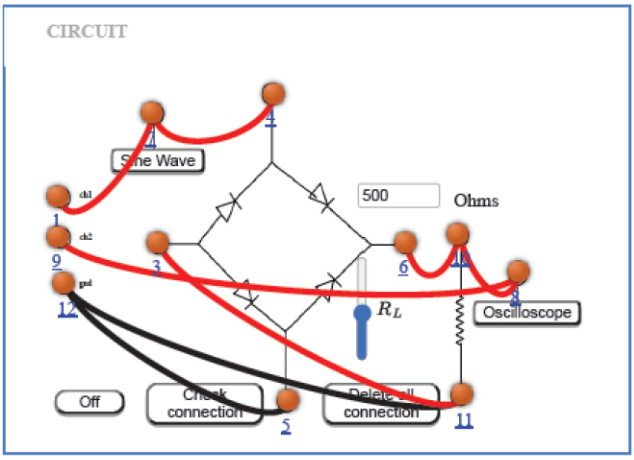
- The **RMS Load Voltage** is given by:

$$V_{rms} = \frac{V_m}{\sqrt{2}}$$

- The **Form factor** is given by the ratio of RMS Load Voltage to average Load Voltage. Its value is 1.1 for a full wave rectifier.
- The **Ripple factor** is given by the ratio of RMS value of AC component to the average value of DC component. Its value is 0.48 for a full wave rectifier.
- **Efficiency** is given as the ratio of DC power at load to the AC power of input signal.

$$n\% = \frac{I_{dc}^2 \times R}{I_{rms}^2 \times R} \times 100\%$$

12. Circuit / Oscilloscope(hand drawn/image):



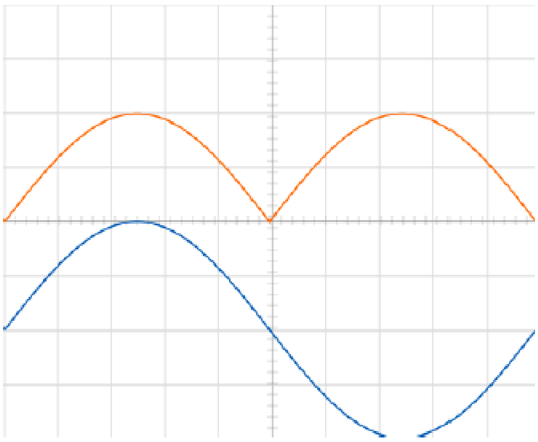
13. Measurement Table:

- Resistance= 500 Ohm, Frequency = 1000Hz.

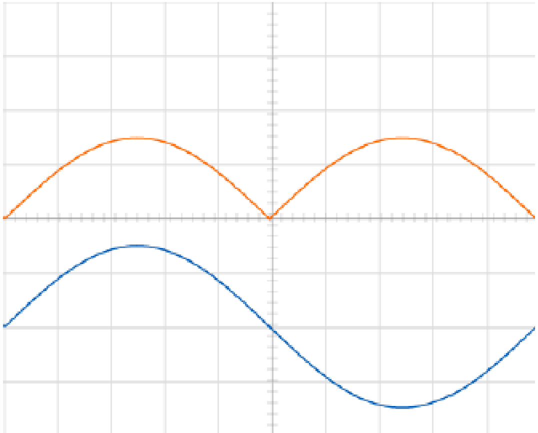
Peak Input Voltage	Peak Observed Current
2 V	2.599 A
1.5 V	1.599 A

14. Graph (Image)/Screenshots

- Blue color represents the input waveform, the output waveform is represented by Orange color.
- 1 unit on Y axis represents 1V
- **Reading Set 1**
  Input Voltage Amplitude = 2V, Frequency= 1000Hz, Resistance =500 Ohms



- **Reading Set 2**
  Input Voltage Amplitude = 1.5V, Frequency= 1000Hz, Resistance =500 Ohms



15. Conclusion:

- We have observed and concluded that a Full-Wave rectifier rectifies an AC Signal into a pulsating DC Voltage by allowing both cycles to pass.
- Considering V_m as the peak input voltage, then

$$V_{rms}=V_m/\text{root } 2,\ V_{dc}=2V_m/\pi$$
$$V_{ac}= (V_{rms}\text{^}2 - V_{dc}\text{^}2)\text{^}0.5$$
$$\text{Ripple Factor}=V_{ac}/V_{dc}$$

- **For reading Set 1,**
  - V_m=2V
  - Vdc=1.2732 V
  - Vac=0.6156 V
  - Ripple factor= Vac/Vdc= 0.48
- **For Reading Set 2,**
  - V_m=1.5V
  - Vdc=0.954805V
  - Vac=0.46189V
  - Ripple factor= Vac/Vdc=0.48
- **We observe that Ripple factor is 0.48 for all cases.** Hence, the ripple factor for a full-wave rectifier circuit is constant and does not depend with variation of amplitude of input voltage signal.

16. Discussions:

- **Significance of the Ripple Factor:**
  - Ripple factor, denoted by γ, is used to measure the amount of ripples present in the output pulsating DC signal. A lower ripple factor indicates a more pure DC output with higher smoothness in the output signal. Hence for a good rectifier, the ripple factor should be as close to 0 as possible.
  - The ripple factor is equal to 0.48 for a full-wave rectifier. Therefore unwanted ripple present in the output along with the DC voltage is 48% of the DC magnitude. This indicates that the full wave rectifier is not a highly efficient AC to DC converter.
- The **peak current** observed from the experiment as shown in the simulation is **slightly less** than the ideal case (V_m/R). This proves that the diodes used in the circuit have some **built-in knee voltage and are not ideal diodes**.
- **Advantages of full wave rectifier with center tapped transformer:**
  - **High rectifier efficiency:** Full wave rectifier has high rectifier efficiency than the half wave rectifier. That means the full wave rectifier converts AC to DC more efficiently than the half wave rectifier.
  - **Low power loss:** In a half wave rectifier, only half cycle (positive or negative half cycle) is allowed and the remaining half cycle is blocked. As a result, more than half of the voltage is wasted. But in full wave rectifier, both half cycles (positive and negative half cycles) are allowed at the same time. So, no signal is wasted in a full wave rectifier.

    - **Low ripples:** The output DC signal in full wave rectifier has fewer ripples than the half wave rectifier.
- **Advantages of bridge rectifier:**
    - **Low ripples in the output DC signal:** The DC output signal of the bridge rectifier is smoother than the half wave rectifier. In other words, the bridge rectifier has fewer ripples as compared to the half wave rectifier. However, the ripple factor of the bridge rectifier is same as the center tapped full wave rectifier.
    - **High rectifier efficiency:** The rectifier efficiency of the bridge rectifier is very high as compared to the half wave rectifier. However, the rectifier efficiency of bridge rectifier and center tapped full wave rectifier is same.
    - **Low power loss:** In half wave rectifier only one-half cycle of the input AC signal is allowed and the remaining half cycle of the input AC signal is blocked. As a result, nearly half of the applied input power is wasted. However, in the bridge rectifier, the electric current is allowed during both positive and negative half cycles of the input AC signal. So, the output DC power is almost equal to the input AC power.

- **Disadvantages of Full wave rectifiers:**
    - **Full wave rectifier with centre tapped transformer:** The full wave rectifier with centre tapped transformer has high cost of construction as it uses two diodes. The increase in number of secondary transformer windings required for the construction of this rectifier also increases its cost as compared to the half wave rectifier.
    - **Bridge Rectifier:** This Full wave rectifier also has the same disadvantage, i.e. increase in cost of construction as four diodes are required in its construction.

Capacitive Rectification

1. Aim of the experiment:

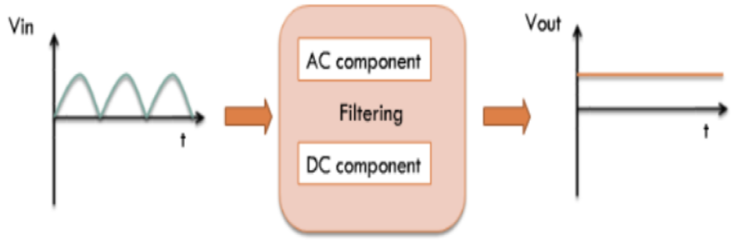
- Learn Filtering of Rectified Signals
- Ripple Voltage and Ripple factor
- Learn Capacitive Filtering

2. Tools used:

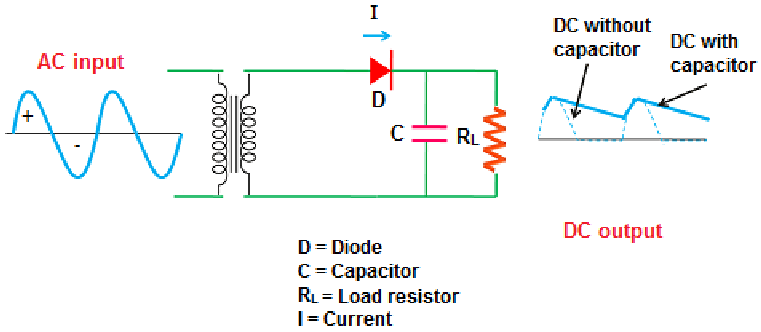
- AC Voltage Source
- Capacitor
- Resistor
- Diode for Half-wave rectifier and Bridge Rectifier
- Oscilloscope
- Connecting wires

3. Background knowledge:

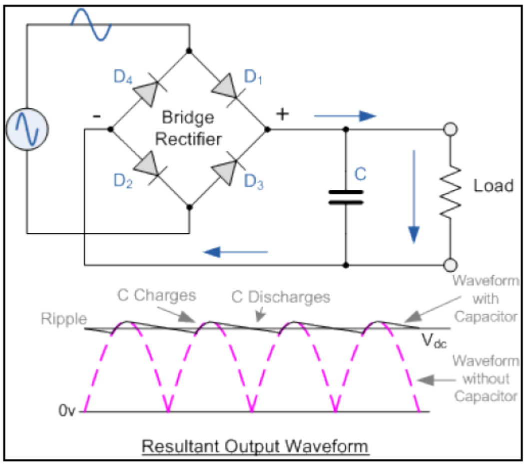
- **Rectifier**
  There are 2 types of rectifiers i.e half wave rectifier and full wave rectifier. A full-wave rectifier is exactly the same as the half-wave, but allows unidirectional current through the load during the entire sinusoidal cycle (as opposed to only half the cycle in the half-wave). A full-wave rectifier converts the whole of the input waveform to one of constant polarity (positive or negative) at its output. When we use a rectifier, we obtain a pulsating output DC Signal.
- **Filter**
  To smoothen the pulsating output signal, a capacitive filter is used. The filter works by splitting the input waveform into AC (high frequency) and the DC components (very low frequency) and then 'rejects' the high frequency components.



- **Full Wave Rectification + Filtering**
  A reservoir capacitor is placed across the output of the rectifier in parallel with the load. The capacitor charges up when the voltage from the rectifier increases above that of the capacitor. The capacitor keeps getting charges till peak value of rectifier voltage is reached (corresponding to peak input voltage), and then as the rectifier voltage falls, the capacitor provides the required current from its stored charge. The only discharge current path is through the resistor. The diode becomes 'off' in this situation. Thus, the capacitor is able to provide charge when current is not available from the rectifier, and the voltage also varies considerably less than if the capacitor were not present. Thus, with the help of a capacitive filter, we can make the output waveform look closer to a DC signal.
- **Ripple Voltage and Ripple Factor**
  There will be some variation in the output voltage obtained from a filter. The charging and discharging of the capacitor **causes ripple voltage** in the output. Larger capacitance value (or the load resistor value) results in slower discharge and "flat" output giving rise to less ripple content. The higher the value of the capacitor, the greater will be the smoothing effect of the filter. This is because, the time constant of the circuit will be much greater and discharging of the capacitor will occur slowly.



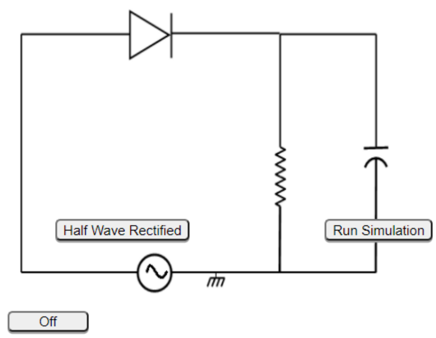
Half wave rectifier with capacitor filter



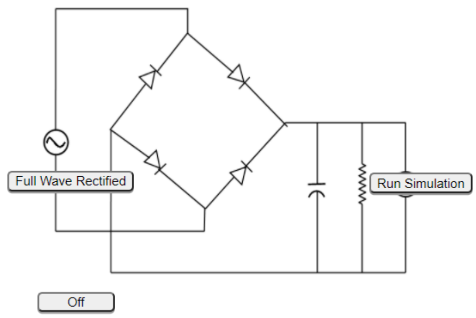
Ripple factor is a measure of effectiveness of a rectifier circuit. It is defined as the ratio of RMS value of the AC component (ripple component) in the output waveform to the DC component in the output waveform.

4. **Circuit / Oscilloscope(hand drawn/image):**

- **Capacitive Rectification for half-wave rectifier:**

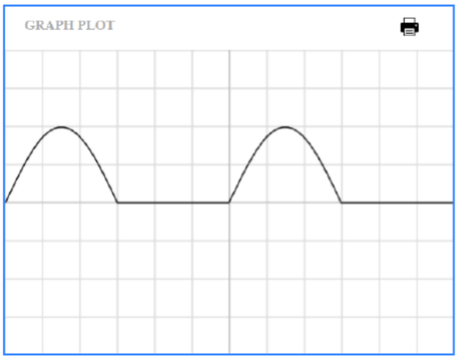


- **Capacitive Rectification for Full wave Rectifier:**

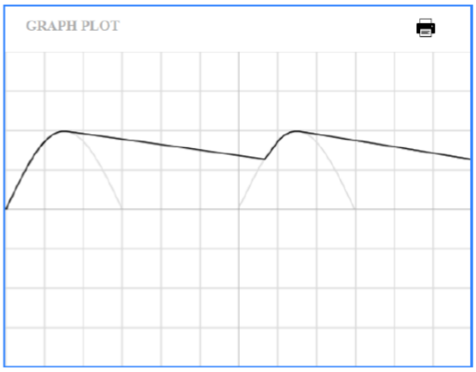


5. Graph (Image)/Screenshots

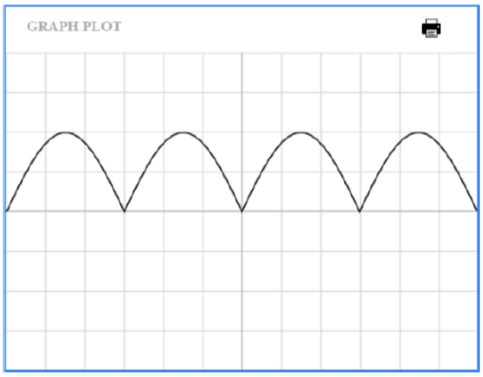
- **Capacitive Rectification for Half Wave Rectifier**
  - Waveform of output without capacitor filter



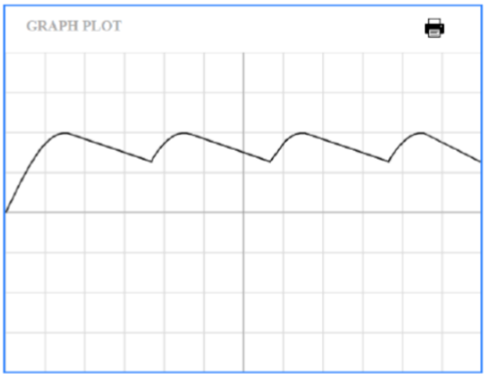
  - Waveform of output with capacitor filter



- **Capacitive Rectification for Full Wave Rectifier**
  - Waveform of output without capacitor filter



○ Waveform of output with capacitor filter



6. Conclusion:

- For a half-wave rectifier with capacitor filter, ripple factor is given by:

$$\gamma_H = \frac{1}{2\sqrt{3} \times fR_LC}$$

- For a full wave rectifier with capacitor filter, ripple factor is given by:

$$\gamma_F = \frac{1}{4\sqrt{3} \times fR_LC}$$

- We can see that Ripple factor depends on the input frequency, load resistance and capacitance value. It is independent of the amplitude of input signal.
- The output that is obtained from a rectifier is pulsating in nature, which basically means that it has certain amount of AC component called as ripple. These ripple components are very much unwanted and undesirable in a rectifier circuit as they reduce the efficiency of AC to DC conversion. So, in order to remove these components, filters are used.
- Thus, Ripple Factor can be changed by changing the capacitance of the capacitor filter. The ripple caused in a rectifier circuit can actually be smoothened by using a capacitive filter.
- **We can thus conclude that using a capacitive filter with a rectifier circuit makes the output signal smoother.**

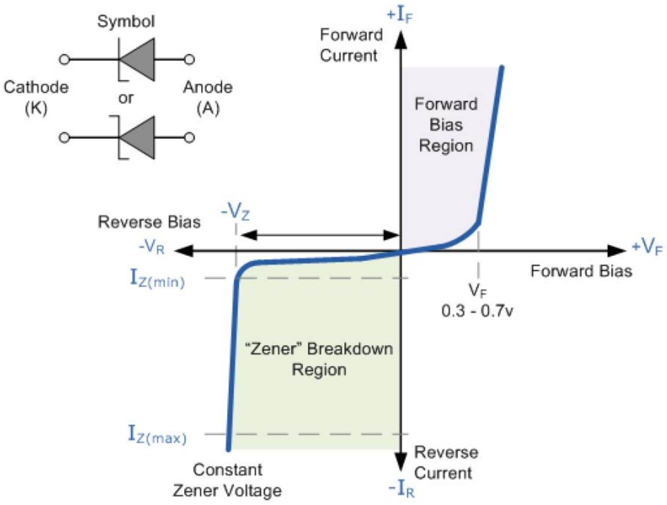
7. Discussions:

- The Ripple factor for a full-wave rectifier with capacitor is half the value of that of a half-wave rectifier with capacitor, for the same values of frequency, capacitance and resistance. This shows that a full wave rectifier is a better choice while converting AC input signal to DC signal because it causes less ripples in the obtained DC output signal. This causes less noise and error. This happens because, in a full wave rectifier, both half cycles are rectified so in the output waveform, the peaks are located closer. So, the capacitor can more effectively reduce ripple when the time between peaks is shorter.
- Most sophisticated electronic systems need pure DC supply to drive, or power them. To construct a good power supply which gives pure DC output, we need to remove or filter out the AC component from the output of rectifiers.
- The output from these rectifiers with Ripple components, is fed to filter circuits so that the output from the filter is pure DC.
- Most commonly used filter types are:
    - ○ Capacitor filter
    - ○ Series inductor filter
    - ○ Choke input filter
    - ○ π-filter
    - ○ RC filter.

Zener Diode – Voltage Regulator

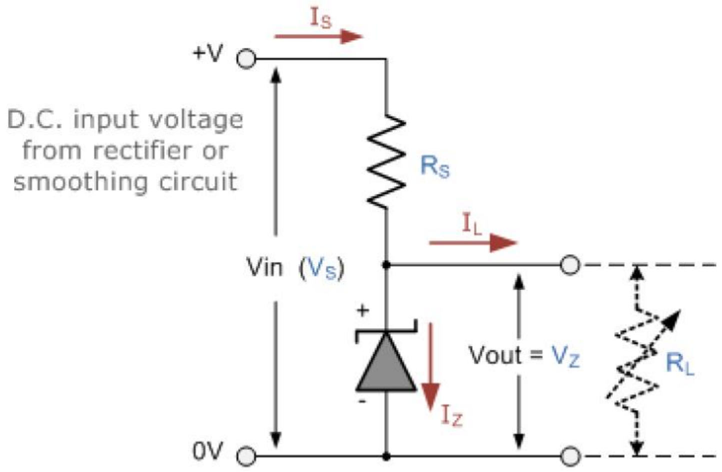
1. **Aim of the experiment:**
    - To understand the function of Zener diode.
    - Explain the function of Zener diode as a voltage regulator
2. **Tools used:**
    - Zener Diode
    - Variable voltage source
    - Voltmeters
    - Ammeters
    - Connecting wires
    - Rheostat
3. **Background knowledge:**
    - **Zener Diode and Functioning**

      The Zener diode also known as "breakdown diode", is similar to a p-n junction diode, but it is specifically designed to be used in reverse biased mode. Zener diode behaves as a normal diode in forward biased mode, however when it is reverse biased, its functioning slightly differs. Unlike a conventional diode that blocks any flow of current through itself when it is reverse biased, as soon as the applied reverse voltage reaches a fixed value, the Zener diode begins to conduct in the reverse direction and when this happens, the current through the Zener diode in rises sharply but the voltage across it remains constant, which is called as the Zener Voltage. This characteristic feature of Zener diode is used in voltage regulation.

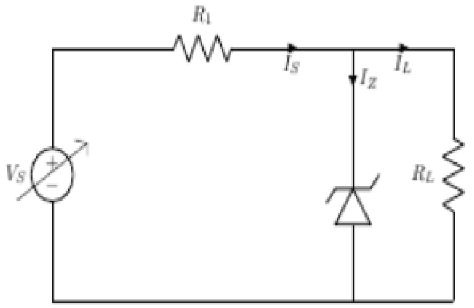


    - **Voltage Regulation**

      The Zener diode is specially used to produce a stabilised voltage output, under varying load conditions. When a Zener diode is connected to a circuit specially for this purpose, it is connected in reverse biased conditions, the diode is connected across a load resistance and in series with a current limiting resistor. The voltage applied is kept in such a way that it is greater than its reverse biased breakdown voltage. There is a minimum Zener current for which the stabilisation of the voltage is effective and the Zener current must stay above this value, while operating within its breakdown region at all times. The upper limit of current is dependent upon the power rating of the device. While the Zener diode is operating in the breakdown region, the output voltage across the Zener diode remains constant at Zener breakdown voltage (stable voltage), for whatever value of reverse biased current that may be flowing through it. However, this current value must stay within the operating range.

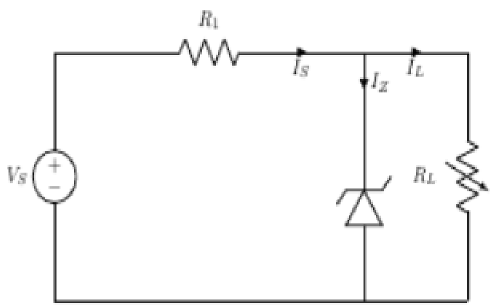


- There are two types of voltage regulations:
  - **Line Regulation:** In this scenario, the values of the series and the load resistances are fixed, and only the value input voltage changes. Output voltage remains the same as long as input voltage value is kept above some minimum value. The minimum value is given by V_{Imin} below.



$$V_{Imin} = \frac{V_Z \times (R_S + R_L)}{R_L}$$

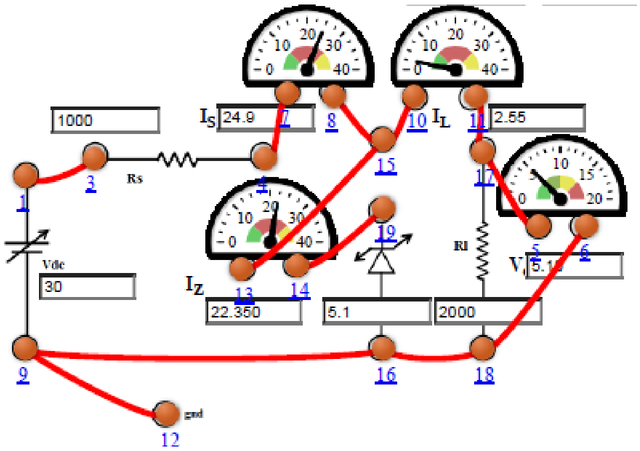
  - **Load Regulation:** In this regulation, the value of the input voltage is constant and the load resistance value is varying. Output voltage value remains same, as long as load resistance value is kept above some minimum value. The minimum value is given by RLmin below.



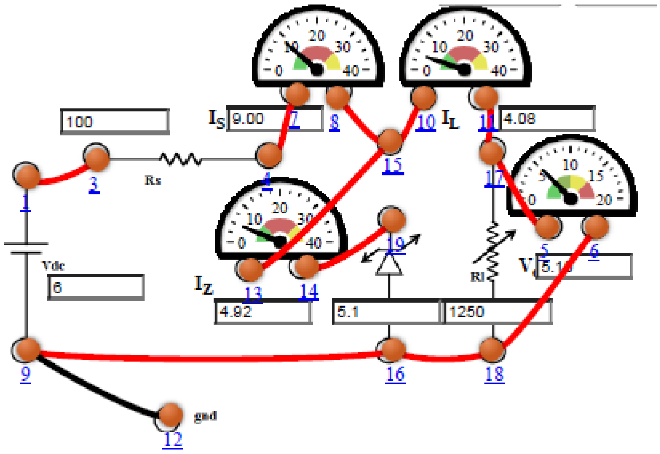
$$R_{Lmin} = \frac{V_Z \times R_S}{V_I - V_Z}$$

4. <u>Circuit / Oscilloscope(hand drawn/image):</u>

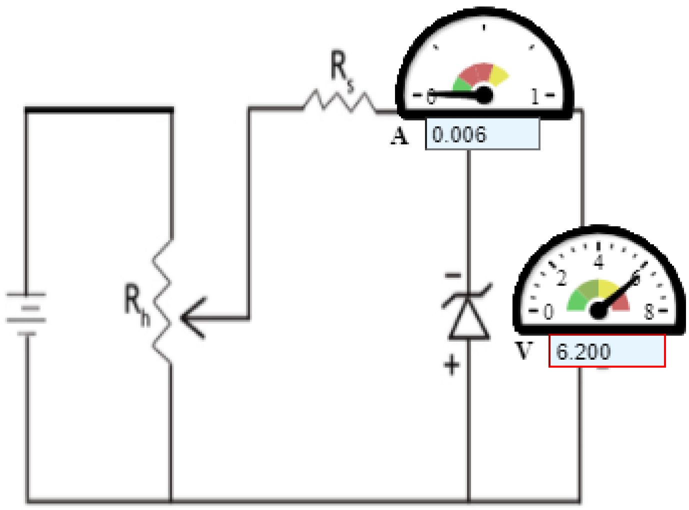
- **Line Regulation**



- **Load Regulation**



- **Zener Characteristics**



5. Measurement Table:

- Line Regulation:

EXPERIMENTAL TABLE

Zener Voltage(V_Z): 5.1 V
Series Resistance(R_S): 1 KΩ
Load Resistance (R_L): 2 KΩ

Serial No.	Unregulated supply voltage(V_S) V	Load Current(I_L) mAmp	Zener Current(I_Z) mAmp	Regulated Output Voltage(V_O) V	% Voltage Regulation
1	1.2	2.55	0	1.2	100
2	3.8	2.55	0	3.8	100
3	5	2.55	0	5	100
4	5.2	2.55	-2.450	5.10	100
5	18	2.55	10.350	5.10	27.8
6	30	2.55	22.350	5.10	16.7

- Load Regulation:

EXPERIMENTAL TABLE

DC Voltage (V_{DC}): 6 V Zener Voltage(V_Z): 5.1 V

Series Resistance(R_S): 0.1 KΩ

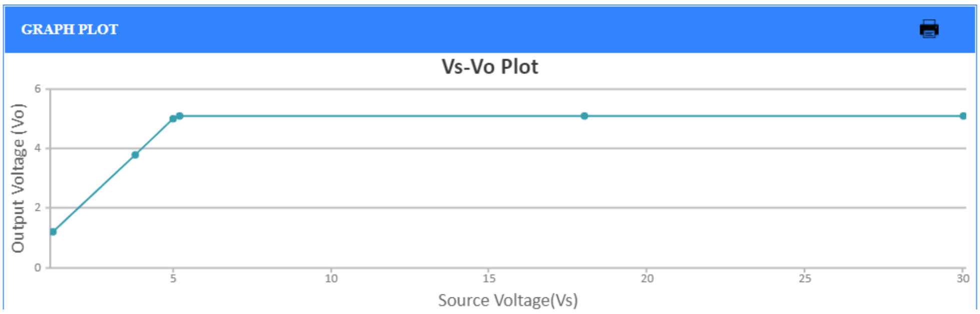
Serial No.	Load Resistance(R_L) Ohm	Load Current(I_L) mAmp	Zener Current(I_Z) mAmp	Regulated Output Voltage(V_O) V	% Voltage Regulation
1	194	26.3	0	6	34.0
2	308	16.6	0	6	24.5
3	569	8.96	0.0369	5.10	14.9
4	838	6.09	2.91	5.10	10.7
5	1041	4.90	4.10	5.10	8.76
6	1250	4.08	4.92	5.10	7.41

- Zener Characteristics:

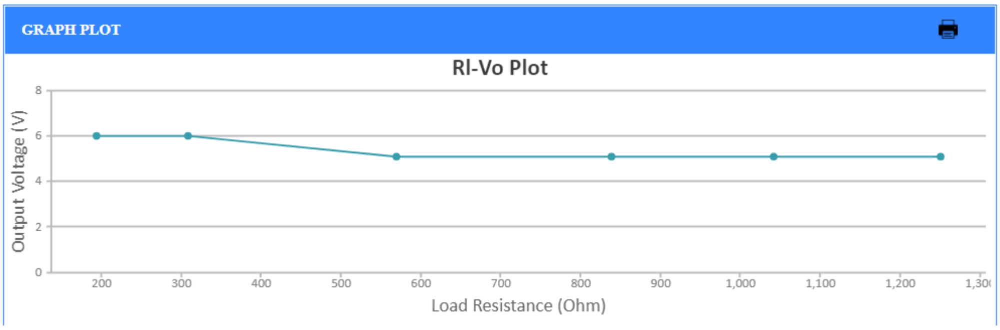
Sl.No	Voltage(v)	Current(mAmp)
1	0.120	0.000
2	1.877	0.000
3	2.953	0.001
4	3.475	0.001
5	3.991	0.002
6	4.503	0.002
7	5.013	0.003
8	5.520	0.003
9	6.200	0.003

6. Graph (Image)/Screenshots

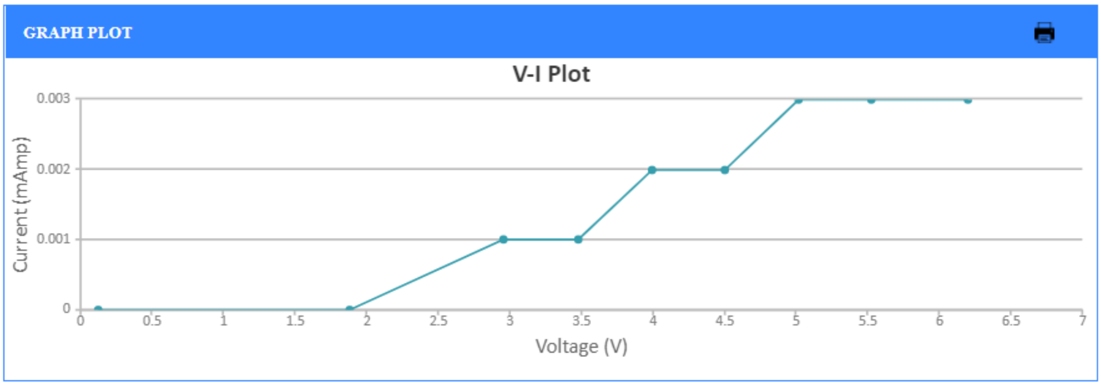
- **Line Regulation:**



- **Load Regulation:**



- **Zener Characteristics:**



7. Conclusion:

- **Line Regulation**:
  Comparison of the theoretically obtained and experimentally obtained value for the minimum input voltage Vi for the Zener diode to function as a voltage regulator:

  Formula used:

$$V_{Imin} = \frac{V_Z \times (R_S + R_L)}{R_L}$$

  Vz=5.1 V
  Rs=1 Kohms
  RL=2 Kohms
  Therefore, Vi(min)= 7.65 V (Using the above formula)
  From the graph, approximately Vi(min)= 5.2 V (Approximately, Experimentally)
  Since the two values are close to each other, we can conclude and verify that Zener diode works as a voltage regulator when input voltage varies.

- **Load Regulation**:
  Comparison of the theoretically obtained and experimentally obtained value for the minimum load resistance value RL for the Zener diode to function as a voltage regulator.

  Formula used:

  $$R_{Lmin} = \frac{V_Z \times R_S}{V_I - V_Z}$$

  Vz=5.1 V
  Rs=0.1 Kohms
  Vl=6 V
  Therefore, RL(min)= 0.567 Kohms (Theoretically)
  From the graph, approximately RL(min)= 0.57 Kohms (Approximately, Experimentally)
  Since the two values are close to each other, we can conclude and verify that Zener diode works as a voltage regulator when load resistor value varies.
  Hence we can finally conclude that a Zener diode can efficiently act as a voltage regulator in applications with load regulation and line regulation.
- **Zener Characteristics**:
  Diode used :ZD5234A
  Zener Voltage (Vz) : 3V
  From the graph we can see that the diode starts conducting electricity when the voltage drop about it is 2.9V (approx.) which is very close to the Zener Voltage (Vz) for this diode.
  Hence we can conclude that the Zener Diode conducts electricity only when the voltage drop around it is greater than its break-down voltage and thus it acts as a voltage regulator.

8. <u>Discussions:</u>

- Voltage regulation percent output in line regulation using a Zener diode, can be given by the formula: V(output)/V(in) x 100%
- As evident from the observation table we can see as V(in) increases and V(output) remains same because of constant Zener voltage, the voltage regulation percent output keeps decreasing.
- The IV characteristics of a non-ideal Zener diode is not exactly vertical in the breakdown region, hence for small changes in current, small changes in the voltage that appears across the diode are also observed. The voltage change for a given change in current is the internal resistance of the diode.
- The Zener voltage specification of the Zener diode is termed as Vz and it is defined as the breakdown voltage at which the diode acts as a voltage regulator. The current, Iz, of the diode represents the maximum current that flows through a Zener diode at the diode rated voltage Vz. Generally, there is also a minimum current requirement so that the diode is in operating mode. It is advisable that the Zener diode is operated above the minimum value. Zener diodes have a particular power rating that must not be exceeded. This defines the maximum power that can be dissipated across the diode, and it is represented by the product of the voltage across the diode and the current flowing through the Zener diode.

  $$I_{max} = \frac{Power}{Zener\ voltage}$$

- Applications and Uses of Zener Diode can be seen in the following:
  - As a voltage regulator
  - Protects from over voltage
  - Used in clipping circuits
  - Used to shift voltage
  - Due to the voltage drop across the diode remains constant over a wide range of voltages, Zener diode is suitable for voltage regulation.