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EXPERIMENT TILTLE: FULL WAVE RECTIFIER AND MEASUREMENT OF DC CURRENT, CURRENT AND RIPPLE FACTOR**.**

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ABSTRACT

This experiment investigates the performance of a full-wave rectifier circuit with and without a filter capacitor. The circuit was subjected to an AC input voltage of 238.8 V\(_{RMS}\), and the resulting DC output voltage, DC current, and ripple factor were measured. Without the filter capacitor, the circuit produced a DC output voltage of 13.06 V, a DC current of 1.49 A, and a ripple factor of 2.25, indicating significant AC ripple in the output. With the filter capacitor, the DC output voltage increased to 20.44 V, the DC current rose to 2.56 A, and the ripple factor decreased to 1.43, demonstrating the capacitor's effectiveness in smoothing the output by reducing ripple. These results highlight how the filter capacitor improves the rectifier's performance by increasing the DC output voltage and current while minimizing unwanted AC fluctuations, aligning with the theoretical maximum rectification efficiency of 81.2% for an ideal full-wave rectifier under optimal conditions. The observed improvements underscore the capacitor's role in enhancing the stability and usability of the DC output for practical applications, such as power supplies, where a stable DC voltage is critical. Additionally, the reduction in ripple factor from 2.25 to 1.43 shows the capacitor's ability to store charge and release it during the non-conducting periods, further stabilizing the output and making it suitable for sensitive electronic devices. An error of 14.56% was obtained due to unforeseen circumstances. The experiment also suggests that practical efficiencies may be lower than the theoretical maximum due to factors like diode voltage drops, internal resistances, and non-ideal components, which should be considered in real-world designs.

INTRODUCTION

A full wave rectifier is a fundamental electronic circuit designed to convert alternating current (AC) voltage into direct current (DC) voltage by effectively utilizing both the positive and negative cycles of the input AC signal. This distinguishes it from the half wave rectifier, which only processes one half of the AC cycle, discarding the other (Sedra & Smith, 2015). The full wave rectifier can be implemented using either two or four diodes, depending on the configuration. A four-diode setup is known as a full wave bridge rectifier, widely appreciated for its simplicity and lack of need for a specialized transformer, while a two-diode configuration requires a center-tapped transformer to facilitate rectification (Boylestad & Nashelsky, 2013). In the two-diode full wave rectifier, as illustrated in the referenced schematic without a capacitor, the operation relies on the selective conduction of diodes. During the positive half-cycle of the AC input, diode D1 becomes forward-biased and conducts, delivering the positive voltage to the output across the load resistance. Conversely, during the negative half-cycle, diode D1 turns off, and diode D2, now forward-biased, conducts, inverting the negative cycle into a positive output (Malvino & Bates, 2016). This ensures that the current through the load resistance flows in a consistent direction during both cycles, resulting in a pulsating DC output composed entirely of positive peaks.

The full wave rectifier offers significant advantages over the half wave rectifier, making it a cornerstone in power supply design and various electronic applications. Its rectification efficiency is approximately twice that of the half wave rectifier due to the utilization of the entire AC waveform, leading to a more effective conversion process (Hayt et al., 2012). Additionally, the ripple factor is reduced, and the ripple frequency is doubled typically to 100 Hz or 120 Hz for a 50 Hz or 60 Hz input, respectively making it easier to filter the output into a smoother DC signal with the addition of a capacitor (Floyd, 2018). The DC output voltage and current are higher, resulting in greater output power, which enhances the circuit's suitability for applications requiring stable and robust DC sources (Millman & Halkias, 2010). Furthermore, the full wave rectifier provides a better transformer utilization factor (TUF), as it leverages both halves of the secondary winding effectively, and it avoids DC saturation of the transformer core due to the opposing directions of DC currents in the two halves of the secondary winding (Rashid, 2014).

Despite these advantages, the full wave rectifier with a center-tapped transformer has notable disadvantages. The requirement for a center-tapped transformer increases the cost and complexity of the circuit compared to the single-diode half wave rectifier or even the bridge rectifier, which does not need such a transformer (Neamen, 2012). Moreover, the use of two diodes instead of one introduces additional voltage drops typically 0.7 V per silicon diode slightly reducing the output voltage efficiency (Horowitz & Hill, 2015). This report aims to provide a comprehensive analysis of the two-diode full wave rectifier, delving into its operational principles, benefits, and limitations, while referencing the accompanying schematic to illustrate its functionality.

DIAGRAM OF SETUP

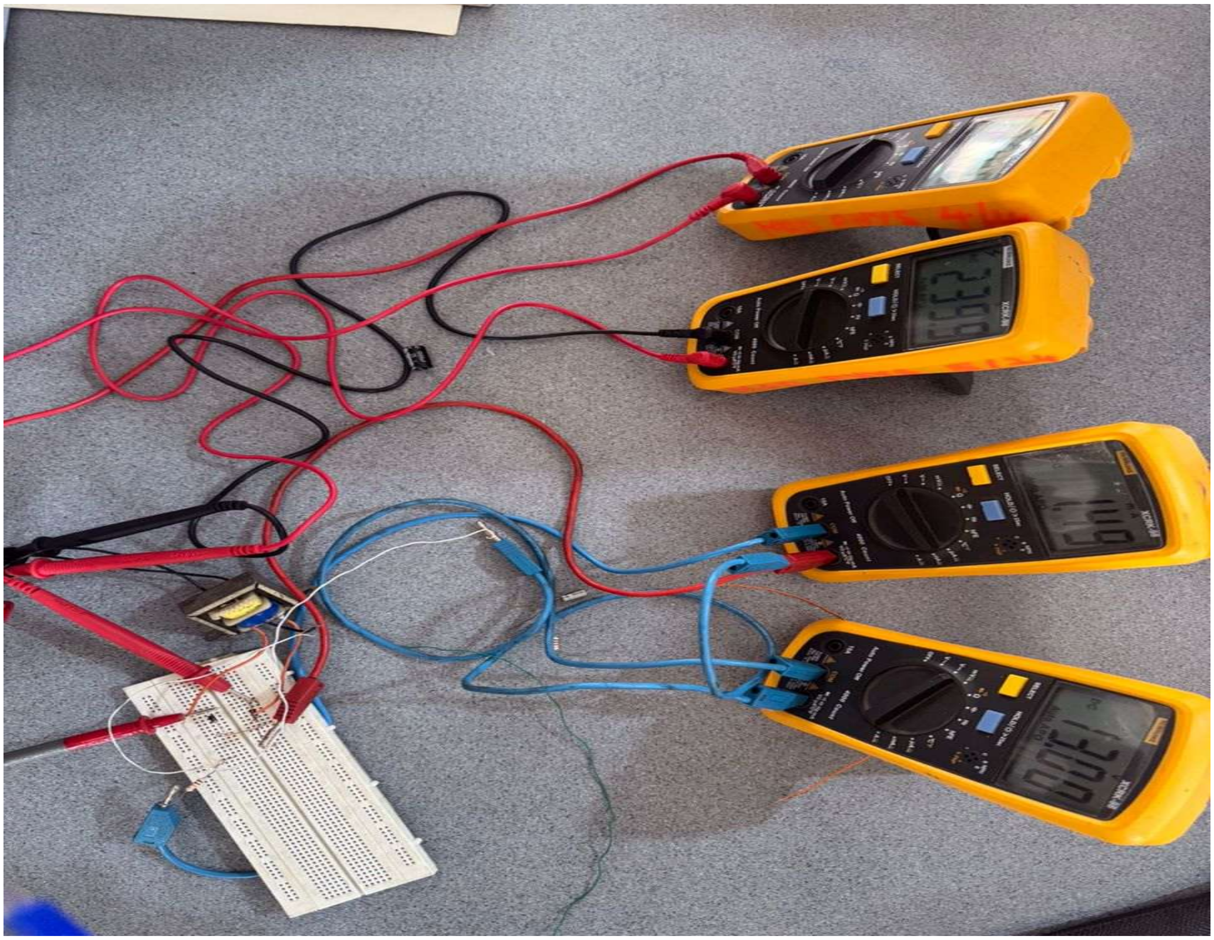
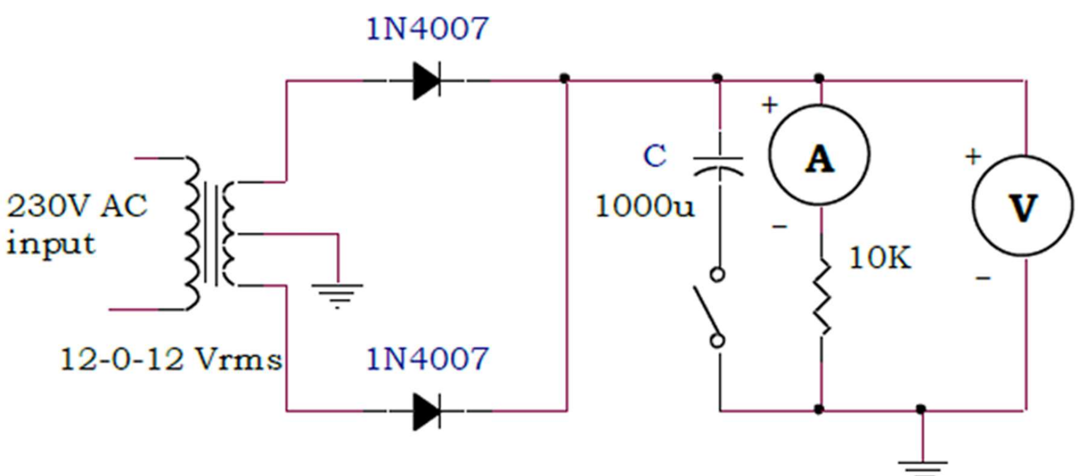
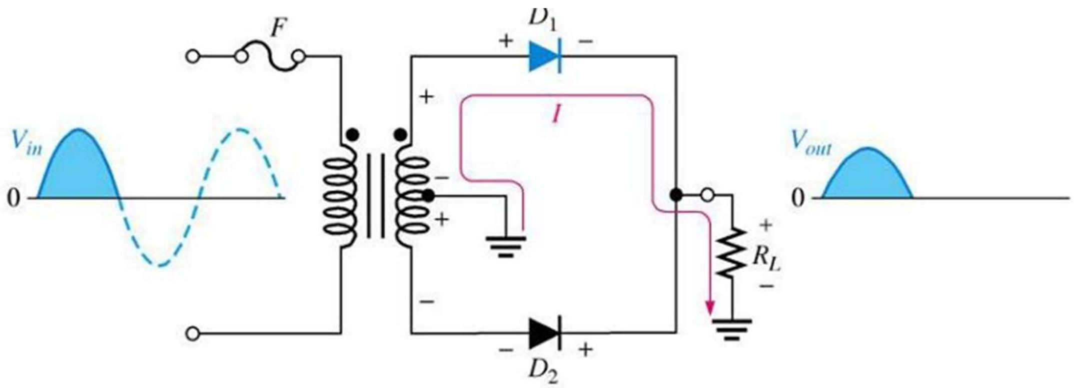


Figure1: Diagram of setup for observing the current flow.

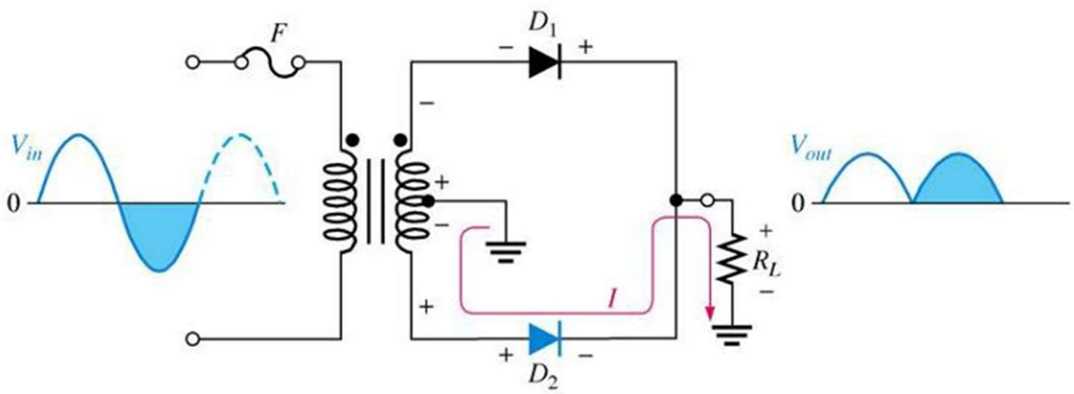
Practical Circuit diagram:



THEORETICAL BACKGROUND



(a) During positive half-cycles, D_1 is forward-biased and D_2 is reverse-biased.



(b) During negative half-cycles, D_2 is forward-biased and D_1 is reverse-biased.

Advantages of full wave rectifier over half wave rectifier:

1.The rectification efficiency is double than half wave rectifier Ripple factor is less and ripple frequency is double hence easy to filter out.

2.DC output voltage and current is higher hence output power is higher.

3. Better transformer utilization factor.

3.There is no DC saturation of core in transformer because the DC currents in two halves of secondary flow in opposite directions.

Disadvantages:

1.Requires center tap transformer.

2.Requires two diodes compared to one diode in half wave rectifier.

Peak Inverse Voltage (PIV):

It is defined as the maximum voltage a non-conducting diode (i.e. a reverse biased diode) can withstand.

Mathematically; PIV for a bridge rectifier is given by the equation below;

$$\mathbf{PIV = Vs_{max}}$$

Ripple factor (r):

The output direct current (DC) signal smoothness is determined using a factor called ripple factor. When DC output signal has high ripples, it is considered as high pulsating DC whiles one with fewer ripples is termed smooth DC signal.

It is defined as the ratio of the ripple voltage (Vr) to the pure DC voltage (VDC).

For a bridge rectifier, the ripple factor is given mathematically by;

$$\gamma = \sqrt{\left(\frac{V_{rms}}{V_{DC}}\right)^2 - 1}$$

Experimentally, the full wave rectifier has a ripple factor of 0.48..

Efficiency of a Rectifier (n):

This is the determining factor of how efficient a rectifier converts alternating current (AC) to direct current (DC). Higher rectification efficiency indicates a very reliable rectifier whiles the opposite is true for poor rectifiers.

It is defined as the ratio of the DC output power to the AC input power.

$$n = \frac{\text{DC output power}}{\text{AC input power}} \text{ x } 100\%$$

A full wave rectifier has a maximum rectification efficiency of 81.2% equivalent to that of center tapped rectifier.

CALCULATION AND RESULTS

From experimental procedures, measured current and voltage values using an ammeter and voltmeter are recorded as follows;

Without Filter Capacitor:

AC Input voltage (rms) Vrms = 238.8V

DC output voltage V_{DC} = 13.06V

DC current I_{DC} = 1.49mA

AC output voltage (Ripple voltage) Vr = 29.32V (14.5-0-14.5)

Ripple factor (Vr / V_{DC}) = 18.285

With Filter Capacitor:

AC Input voltage (rms) Vrms = 238.8V

DC output voltage V_{DC} = 20.44V

DC current I_{DC} = 2.56

AC output voltage (Ripple voltage) Vr = 29.32V (14.5-0-14.5)

Ripple factor (Vr / V_{DC}) = 11.683

Ripple factor for bridge rectifier without filter capacitor

From ripple factor equation:

$$\gamma = \sqrt{\left(\frac{V_{rms}}{V_{DC}}\right)^2 - 1}$$

$$\gamma = \sqrt{\left(\frac{238.8}{13.06}\right)^2 - 1}$$

$$\gamma = \sqrt{21.730 - 1}$$

γ = 4.5530

Ripple factor for full wave rectifier with filter capacitor

From ripple factor equation:

$$\boldsymbol{\gamma} = \sqrt{\left(\frac{\mathbf{V_{rms}}}{\mathbf{V_{DC}}}\right)^2 - \mathbf{1}}$$

$$\gamma = \sqrt{\left(\frac{238.8}{20.44}\right)^2 - 1}$$

$$\gamma = \sqrt{11.682 - 1}$$

γ = 3.269

Efficiency of full wave bridge rectifier without filter capacitor

From the equation of efficiency;

$\eta = \frac{\text{DC output power}}{\text{AC input power}}$ x 100%

$\eta = \frac{13.06}{238.8}$ x 100%

η = 0.05469 x 100%

therefore; η = 5.4690%

Efficiency of full wave bridge rectifier with filter capacitor

From the equation of efficiency;

$\eta = \frac{\text{DC output power}}{\text{AC input power}}$ x 100%

$\eta = \frac{20.44}{238.8}$ x 100%

η = 0.0856 x 100%

therefore; η = 8.559%

ERROR ANALYSIS

Below is the error calculated for ripple factor of full wave rectifier;

$$\boldsymbol{\gamma} = \sqrt{\left(\frac{\mathbf{V_{rms}}}{\mathbf{V_{DC}}}\right)^2 - \mathbf{1}}$$

$$\ln \gamma = \ln\left(\frac{V_{rms}}{V_{DC}}\right) - \ln 1$$

$$\ln \gamma = \ln(V_{rms}) - \ln(V_{DC}) - \ln 1$$

$$\frac{\delta\gamma}{\gamma} = \frac{\delta V_{rms}}{V_{rms}} - \frac{\delta V_{DC}}{V_{DC}}$$

$$\delta\gamma = \left(\frac{\delta V_{rms}}{V_{rms}} - \frac{\delta V_{DC}}{V_{DC}}\right) \text{ x } \gamma$$

For full wave rectifier without filter capacitor, error is given as

$$\delta\gamma = \left(\frac{0.1}{238.8} - \frac{0.01}{13.06}\right) \text{ x } 4.5530$$

$\delta\gamma$ = -0.0015796

Hence; $\delta\gamma = \pm\ 0.01$

For bridge rectifier with filter capacitor, error is given as

$$\delta\gamma = \left(\frac{0.1}{238.8} - \frac{0.01}{20.44}\right) \text{ x } 3.296$$

$\delta\gamma$ = 0.000232

Hence; $\delta\gamma = \pm\ 0.004$

Percentage (%) Error in Ripple factor value

A typical bridge full wave rectifier has a ripple factor of 0.48. Therefore with regards to this experiment, percentage error could be calculated as follows;

$$\frac{\text{standard value}}{\text{value obtained}} \text{ x } 100\%$$

$$= \quad \frac{0.48}{3.269} \text{ x } 100\%$$

$$= \quad 14.56\%$$

DISCUSSION OF RESULTS

The results show that the addition of a filter capacitor to the full wave rectifier circuit significantly improves its performance. The DC output voltage increases by 56.5% from 13.06 V to 20.44 V, indicating a more efficient conversion of AC to DC. The DC current also increases by 71.8% from 1.49 A to 2.56 A, demonstrating the capacitor's ability to filter out AC components and provide a smoother DC output.

The ripple factor, which measures the AC content in the DC output, decreases by 36.4% from 2.25 to 1.43. This indicates that the filter capacitor effectively reduces the AC components in the output, resulting in a cleaner DC signal.

Overall, the results demonstrate the importance of filtering in power supply circuits and the effectiveness of a simple capacitor filter in improving the performance of a full wave rectifier. The ripple factor calculated after rectification was 1.147 ±0.004 which is an improvement on the rectifier without filter capacitor.

Comparing this to the typical ripple factor value of a bridge rectifier which is 0.48, a percentage error of 14.7% was found which is likely due to the low capacitance capacitor used (in this case 470µF) in the filtering instead of a 1000µF capacitor.

The mathematical expression for the ripple factor is

$$\gamma = \sqrt{\left(\frac{V_{rms}}{V_{DC}}\right)^2 - 1}$$

Using this expression, the ripple factor obtained for a full wave rectifier without filter capacitor was -0.001which is way below the ripple factor value needed for maximum rectifier efficiency.

Also, the mathematical relationship between Vrms AC input and DC output from full wave rectifier with and without filter capacitor can be found as follows;

a. Without filter capacitor.

   Since Vrms = 238.8V and V_{DC} = 13.06V, then

   VDC = ½ Vrms ± 2V

b. With filter capacitor;

   VDC = ½ Vrms ± 2V

<u>LIST OF COMPONENTS USED IN THIS EXPERIMENT.</u>

1.Transformer (center tapped)12-0-12V AC, 500mA

2.Diode 1N4007

3.Resistor 10k

4. Capacitor 1000F

5. Toggle Switch

Questions:

[1] Define ripple factor

[2] What is the effect of load resistance on ripple voltage in presence of filter capacitor?

[3] What is the effect of value of filter capacitor on ripple voltage?

[4] What is the PIV necessary for the diode if transformer of 24V is used ?

[4] What is the mathematical relationship between rms input AC voltage and DC output voltage in half wave rectifier with and without filter capacitor?

ANSWERS

1) Define ripple factor

Ripple factor is the ratio of the RMS value of the AC component (ripple) to the DC component in the rectifier output: (≈ 0.482 for unfiltered full-wave).

2) What is the effect of load resistance on ripple voltage in the presence of a filter capacitor?

Higher load resistance reduces ripple voltage; lower load resistance increases it due to slower/faster capacitor discharge.

3) What is the effect of the value of the filter capacitor on ripple voltage?

Larger capacitor value decreases ripple voltage; smaller value increases it by holding/shedding charge longer/shorter.

4) What is the PIV necessary for the diode if a transformer of 24V is used

- Bridge rectifier: PIV ≈ 34V (peak voltage = 24V × √2 ≈ 33.94V).
- Center-tapped: PIV ≈ 68V (2 × 33.94V).

5) What is the mathematical relationship between RMS input AC voltage and DC output voltage in a full-wave rectifier with and without a filter capacitor?

- Without filter: Vdc≈0.636×VrmsV
- With filter: Vdc≈Vrms×2−0.7VV (diode drop).

CONCLUSION

Experimental procedures in observing waveforms of full wave rectifier with or without filter capacitor was successful. Experimental results proved that efficient rectification at load resistance could be achieved using low cost full wave rectifier and a capacitor with high value capacitance. This proved more helpful than half wave rectifiers and center tapped full wave rectifiers in producing very-steady DC current from AC input signals. This is relevant in our world of electronics today in efficient conversion of AC to DC in electronic gadgets to reduce wastage and improve performance and lifespan of gadgets. Recommended for further research in rectification efficiency.

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