Al-Mustaqbal University
Department Prosthetics & Orthotics Engineering
Class 2nd
Subject: Electronic circuits Practical Part
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2ndterm – Lec 2

Experiment No.2: Rectifiers and Filters

OBJECTIVES:

After performing this experiment, you should be able to:

- **Understand rectification and filtering techniques** to convert AC to DC
- **Develop circuit analysis and design skills** using simulation and lab tools.
- **Apply concepts in medical devices** such as power supplies for prosthetics and biomedical equipment.

SUMMARY OF THEORY:

The most popular application of the diode is the rectification. Rectification is simply defined as: the conversion of alternating current (AC) to direct current (DC). This almost always involves the use of some devices that conduct in only one direction, so one polarity of an AC signal, which has zero average (DC) level, can be eliminated resulting in net DC component. As we have seen in the previous experiment, this is exactly what a semiconductor diode does. This process can be used to make power supplies, peak detectors, and amplitude modulators.

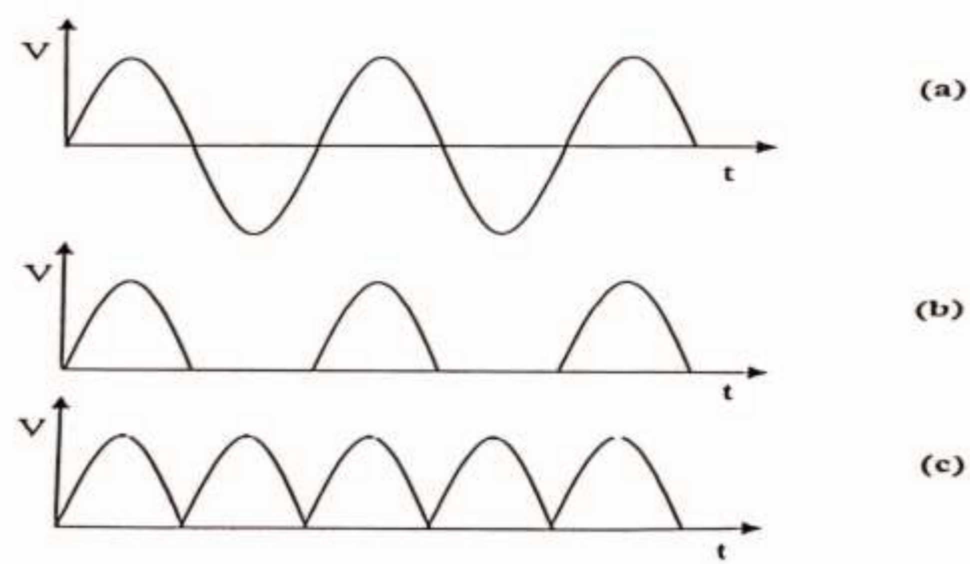

Fig. 1: (a) Input Waveform, (b) Half-Wave Rectified Waveform and (c) Full-Wave Rectified Waveform

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The three basie rectifier configurations are the half-wave, full-wave, and bridge rectifiers. The output of a positive half-wave rectifier is shown in Figure (b). figure(c) shows the output of a positive full-wave, or bridge rectifier. In any case of rectification the amount of AC voltage mixed with the rectifier's DC output is called ripple voltage. In most cases, since "pure" DC is the desired goal, ripple voltage is undesirable or unwanted. If the power levels are not too great, filtering networks that are composed of suitably connected capacitors and inductors may be employed to reduce the amount of ripple in the output voltage. We will be discussing and using only the simple capacitor filter. A measure of the effectiveness of a filter is given by ripple factor (r), which is defined as the ratio of the peak-peak value of the AC component to the DC or average value. That is

$$r = \frac{V\,r}{V\,avg} \qquad \dots.(1)$$

It is desirable and important to make ripple factor as small as possible.

The capacitor filter is the simplest filter circuit with a capacitor in parallel to the load resistor R. The capacitor is charged to the peak value of the rectified voltage V, and begins to discharge through load resistance R_l after the rectified voltage decreases from the peak value. The rate of decrease in the capacitor voltage between charging pulses depends upon the relative values of time constant RC and the period of the input voltage. The large time constant results in slower decrease and hence smaller ripple component. The concept of capacitor filter is illustrated in Figure 2. The disadvantages of the capacitor filter lies in: (a) poor regulation and (b) increased ripple at large loads.

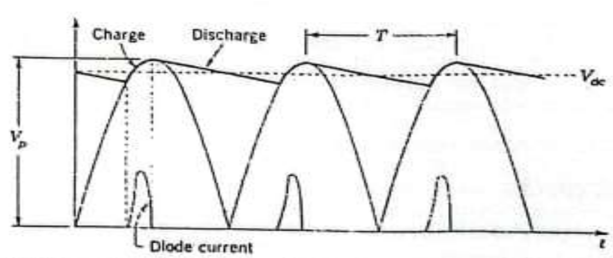

Fig. 2: Output Voltage Capacitor Filter is a DC Voltage and Small Triangular Ripple Voltage.

For most power applications, half-wave rectification is insufficient for the task. The harmonic content of the rectifier's output waveform is very large and consequently difficult to filter. Furthermore, AC power source only works to supply power to the load once every half-cycle, meaning that much of its capacity is unused. Half-wave rectification is, however, a very simple way to reduce power to the resistive load.

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The half-wave voltage signal of Figure 3(a) normally established by a network with a single diode has an average or equivalent DC voltage level equal to 31.8% of the peak voltage Vp.

That is,

$$v_{avg} = \frac{v_p}{\pi} = 0.318\, v_{peak} \quad \textbf{Volt} \mid \textbf{Half-wave} \qquad (2)$$

The full-wave rectified signal of Figure 3(b) has twice the average or DC level of the half-way signal, or 63:6% of the peak value Vp.

That is,

$$v_{avg} = \frac{2v_p}{\pi} = 0.636\, v_{peak} \quad \textbf{Volt} \mid \textbf{Full-wave} \qquad (3)$$

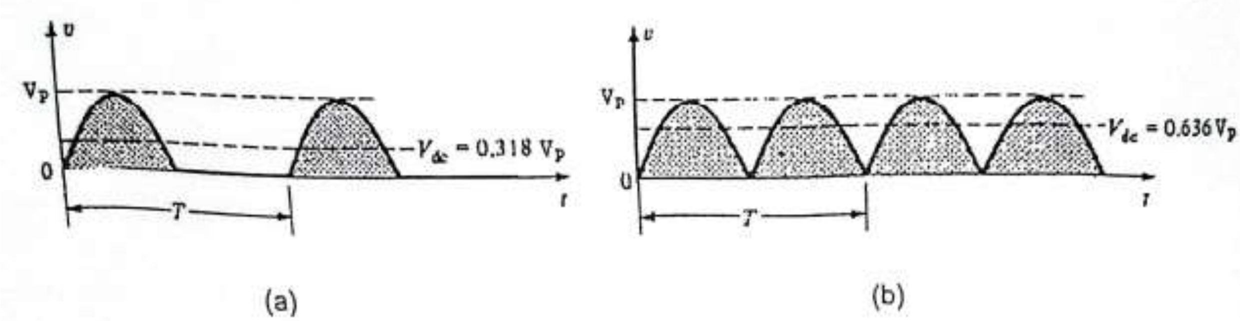

Fig.3: (a) Half-Wave Rectifier (b) Full-Wave Rectifier.

In rectification systems the peak inverse voltage (PIV) or Zener breakdown voltage parameter must be considered carefully. The PIV voltage is the maximum reverse- bias voltage that a diode voltage can handle before entering the Zener breakdown region. For ideal single-diode half-wave rectification systems, the required PIV level is equal to the peak value of the applied sinusoidal signal. For the four-diode full- wave bridge rectification system, the required PIV level is again the peak value, but for a two-diode center- tapped configuration, it is twice the peak value of the applied signal.

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Procedures

In this simulation, we will create three different circuits to analyze the effect of rectification and filtering:

1. Half-Wave Rectification
2. Full-Wave Rectification (Bridge Configuration)
3. Adding a Filter Capacitor to Study Its Effect on the Output

◈ Step 1: Setting Up the Work Environment in Multisim

1. Open Multisim and create a new project: File → New.
2. Ensure the correct measurement unit is selected (AC Voltage).

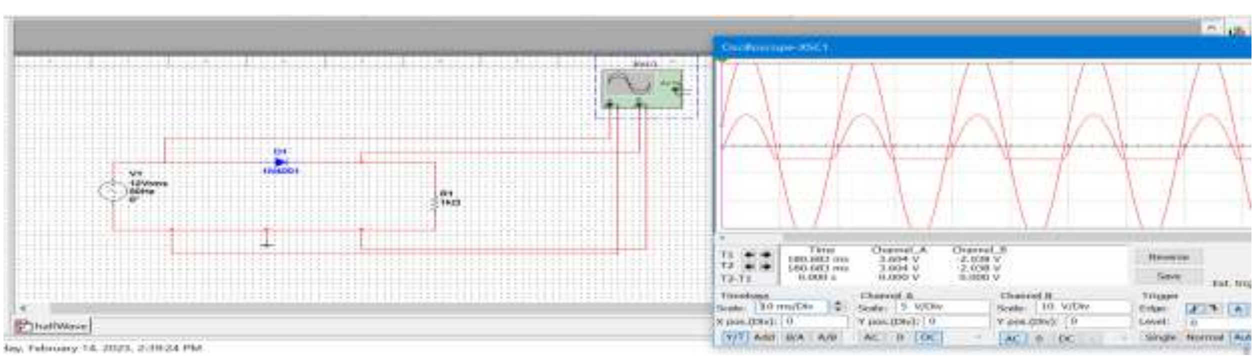
◈ Step 2: Creating a Half-Wave Rectifier Circuit

- **AC Voltage Source**
- **1N4001 Rectifier Diode**
- **Resistor (1kΩ)**
- **Oscilloscope (to monitor the waveform before and after rectification)**

Connection Steps:

1. Place the AC voltage source in the workspace and set its value to 12V RMS at 50Hz.
2. Add the diode (1N4001) with its anode connected to the source and cathode to the resistor.
3. Connect the resistor to the ground to complete the circuit.
4. Add the oscilloscope, ensuring:
   - **Channel A** is connected to the input voltage (before the diode).
   - **Channel B** is connected to the output voltage (after rectification).
5. Run the simulation and observe the output waveform.

Observation: The negative half of the waveform disappears, indicating that only the positive half is being transmitted.



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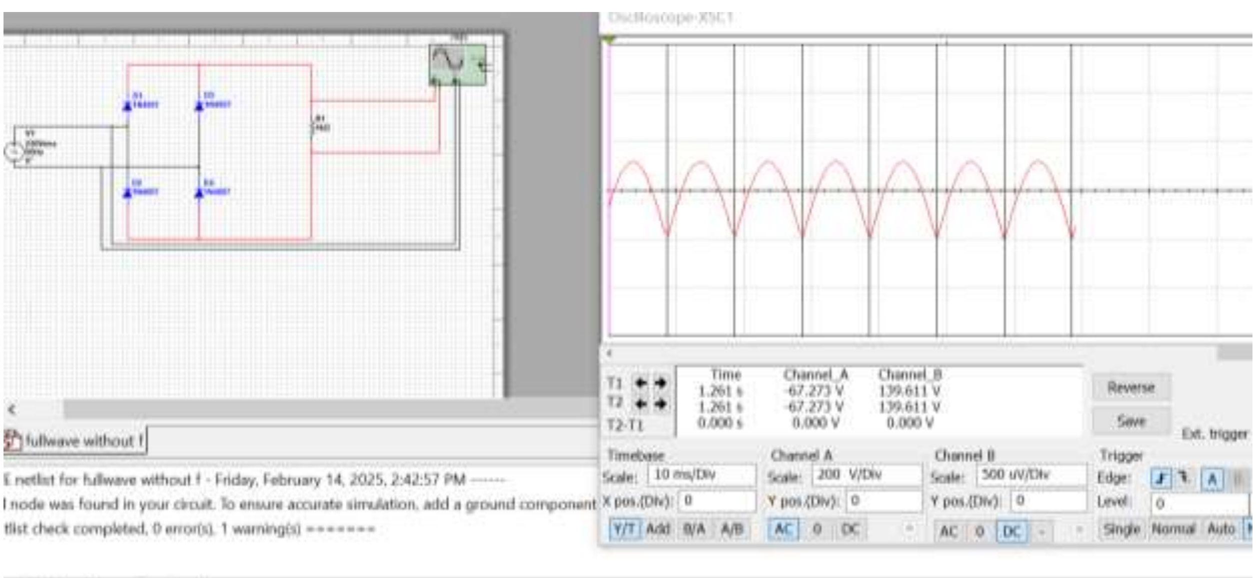
◈ Step 3: Creating a Full-Wave Rectifier Circuit (Bridge Configuration)

- AC Voltage Source
- 4 × 1N4001 Diodes (to form a bridge rectifier)
- Resistor (1kΩ)
- Dual-Trace Oscilloscope

Connection Steps:

1. Add the AC source with the same settings as before.
2. Arrange four diodes to form a bridge rectifier as follows:
   - The AC source terminals are connected to the top two points of the bridge.
   - The positive DC output is taken from the junction of the cathodes.
   - The negative DC output (ground) is taken from the junction of the anodes.
3. Connect a 1kΩ resistor between the output and ground.
4. Connect the oscilloscope as follows:
   - **Channel A** at the input (before the bridge).
   - **Channel B** at the output (after rectification).
5. Run the simulation.

Observation: The output waveform is entirely positive without interruptions, indicating that both halves of the AC wave are being rectified.



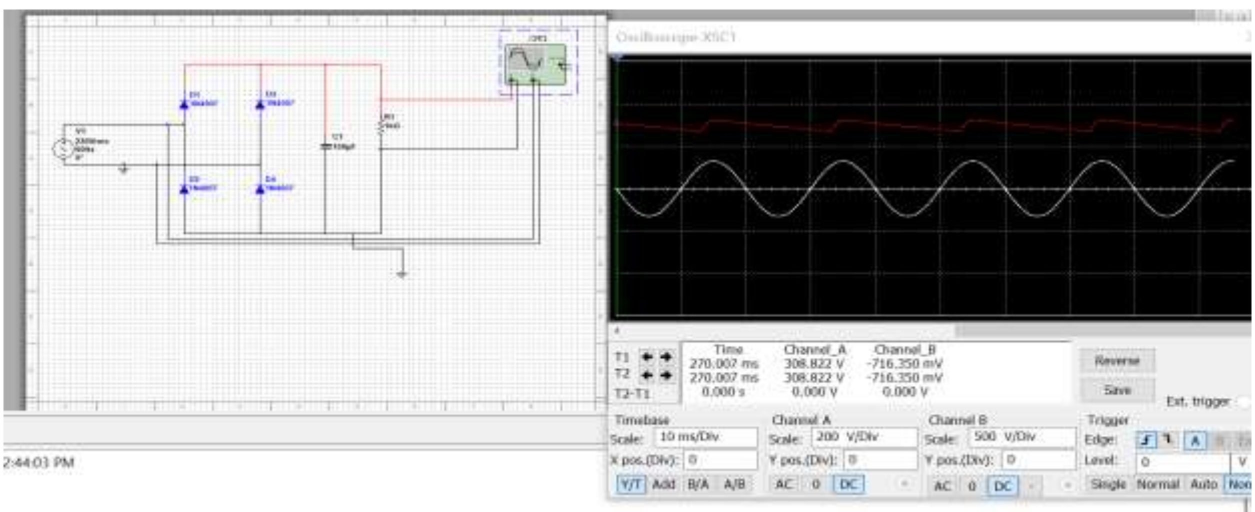
◈ Step 4: Adding a Filter Capacitor to Improve Output Stability

- Same components as the full-wave rectifier
- Capacitor (100µF – 470µF)

Connection Steps:

1. Add a filter capacitor in parallel with the load resistor:
   - The positive terminal of the capacitor connects to the rectifier output.
   - The negative terminal connects to the ground.
2. Connect the oscilloscope as before.
3. Run the simulation.

Observation: The waveform becomes smoother with reduced ripple, as the capacitor stores and releases charge to stabilize the voltage closer to DC.



- ❖ **Half-wave rectification is inefficient since half of the energy is lost.**
- ❖ **Full-wave rectification is more efficient as it utilizes the entire AC waveform.**
- ❖ **Adding a filter capacitor significantly reduces ripples, providing a more stable DC voltage.**

Questions

1. How does the ripple factor affect the performance of rectifiers, and what techniques can be used to minimize it in practical circuits?

2. What are the advantages and disadvantages of using a capacitor filter in rectifier circuits, and how does its capacitance value impact the output voltage stability?

3. Why is full-wave rectification considered more efficient than half-wave rectification, and in what practical applications would a half-wave rectifier still be preferable?

4. How does the Peak Inverse Voltage (PIV) requirement differ among half-wave, full-wave, and bridge rectifier configurations, and why is it a critical design consideration?

5. In what ways can rectifier and filter circuits be optimized for medical applications, such as prosthetic devices or biomedical sensors?

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