American International University- Bangladesh
Faculty of Engineering (FE)
Department of Electrical and Electronic Engineering (EEE)
EEE 2104: Electronic Devices Lab

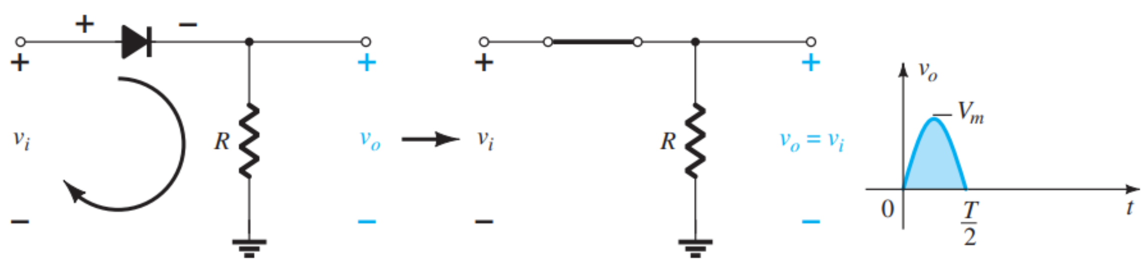
Title of the Experiment: Study of Diode Rectifiers.

Objectives:
The objectives of this experiment are to
1. Study half-wave and full-wave rectifier circuits using semiconductor diodes.
2. Find the different parameter values of half-wave and full-wave rectifier circuits.

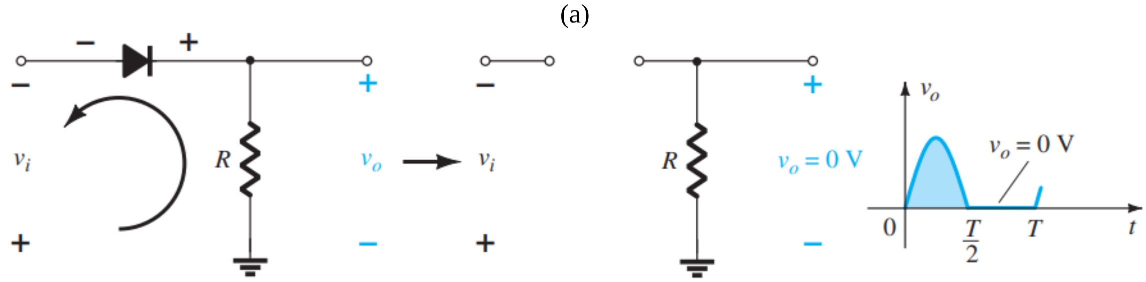
Theory:
A diode rectifies an AC voltage so that it can be smoothed and converted into a DC voltage. A rectifier, however, can produce a constant or variable DC voltage. A diode rectifier can produce a fixed DC voltage whereas an SCR can produce a variable DC voltage. Diode rectifiers are of the following types:
1. Half-wave rectifier.
2. Full-wave bridge rectifier.
3. Center-tapped Full-wave rectifier.

A rectifier, however, cannot produce a smooth DC voltage. So, the rectification block that makes the output DC voltage a smooth one follows a filter circuit. In this case, the capacitor acts as a smoothing filter so that the output is nearly a DC voltage. The filtering is not perfect; there will be a remaining voltage fluctuation known as a ripple, on the output voltage.
The half-wave voltage signal is normally established by a network with a single diode that has an average or equivalent DC voltage level equal to 31.8% of the peak voltage, whereas the full-wave rectified signal has twice the average or DC level of the half-wave signal, or 63.6% of the peak value.

Working Principle of Half-Wave Rectifier:
In a half-wave rectifier, only half a cycle of applied AC voltage is used. Another half cycle of AC voltage (negative cycle) is not used. Only one diode is used which conducts during the positive cycle. The circuit diagram of a half-wave rectifier without a capacitor is shown in Fig. 1.



(a)



(b)

Figure 1: Half-Wave Rectification: (a) conduction in the positive half-cycle from 0 to $T/2$; (b) no conduction in the negative half-cycle from $T/2$ to T.

During the positive half cycle of the input voltage anode of the diode is positive compared with the cathode. The diode is in forward bias and current passes through the diode and a positive cycle develops across the load resistance R as shown in Fig. 1 (a). During the negative half cycle of input voltage, the anode is negative with respect to the cathode and the diode is in reverse bias. No current passes through the diode and hence the output voltage is zero across the load resistance R as shown in Fig. 1 (b). The complete wave shape for two cycles is shown in Fig. 2. The average value of the half-wave rectified voltage signal over a full period (T) is given by

$$V_{dc} = 0.318V_m$$

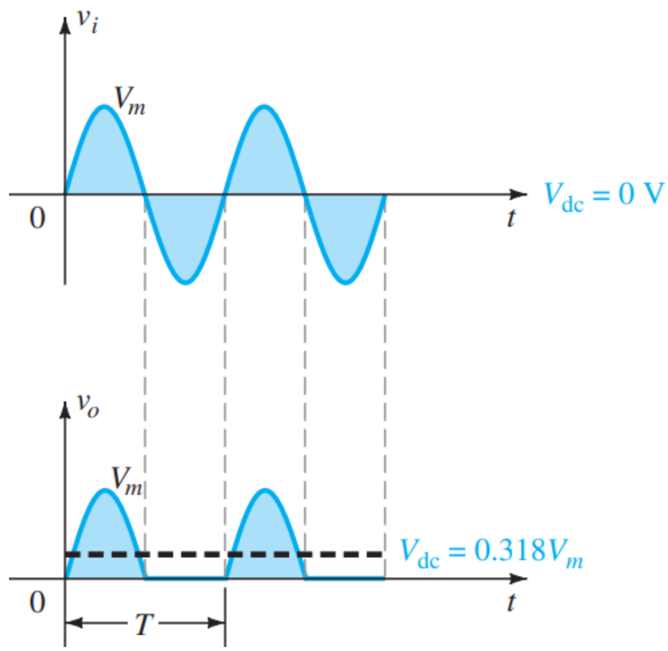


Figure 2: Half-wave rectified signal for two cycles.

Working Principle of Full-Wave Rectifier:

The DC level obtained from a sinusoidal input can be improved by 100% using a process called full-wave rectification. The bridge rectifier is a circuit that converts an AC voltage to a DC voltage using both half cycles of the input AC voltage. The most familiar network for performing such a function is a bridge rectifier as shown in Fig. 3 with its four diodes in a bridge configuration. The AC input voltage is applied to the diagonally opposite ends of the bridge. The load resistance is connected between the other two ends of the bridge.

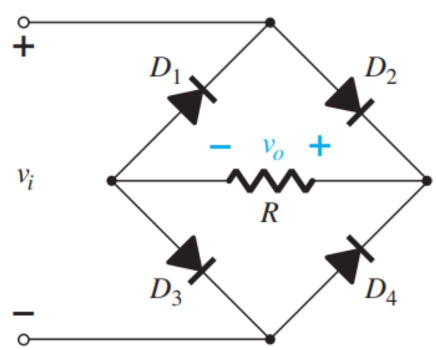


Figure 3: Full-wave bridge rectifier.

During the period t = 0 to T/2, that is, in the positive half-cycle, the polarity of the input is shown in Fig. 4. The resulting polarities across the ideal diodes are also shown in Fig. 4 to reveal that D2 and D3 are conducting, whereas D1 and D4 are in the "off" state. The net result is the configuration of Fig. 4, with its indicated current and polarity across the load resistance, R. Since the diodes are ideal, the load voltage is $v_o = v_i$, as shown in the same figure. The bridge rectifier circuit is shown in Fig. 3.

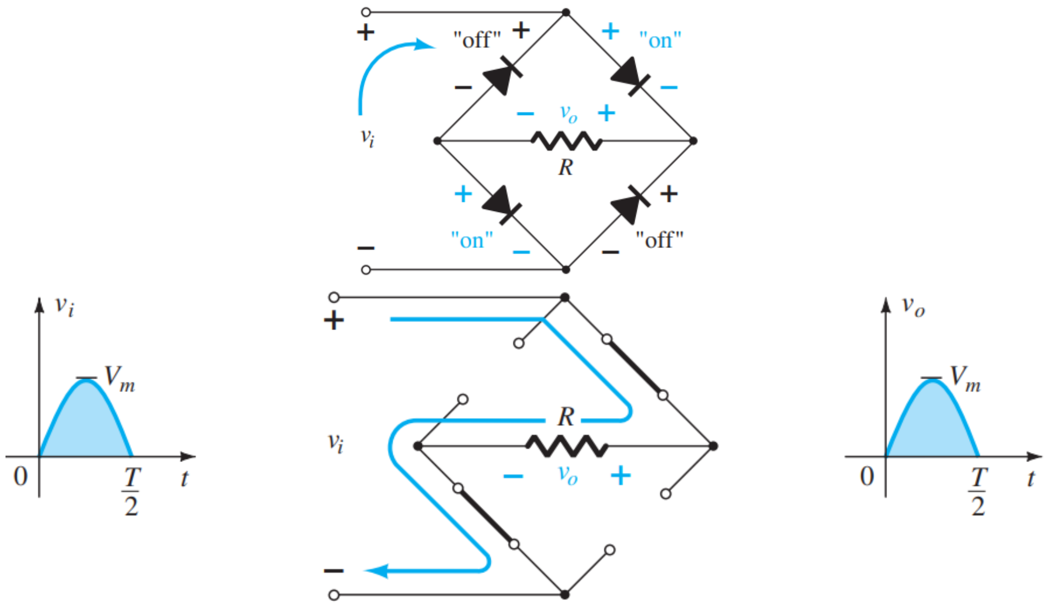


Figure 4: During the positive half-cycle of the input signal, D2 and D3 diodes are forward-biased and conduct current, while D1 and D4 diodes are reverse-biased and hence conduct no current.

For the negative half-cycle of the input, the conducting diodes are D1 and D4, resulting in the configuration of Fig. 5. The important result is that the polarity across the load resistor, *R*, is the same as in Fig. 5, establishing a second positive pulse, as shown in Fig. 5.

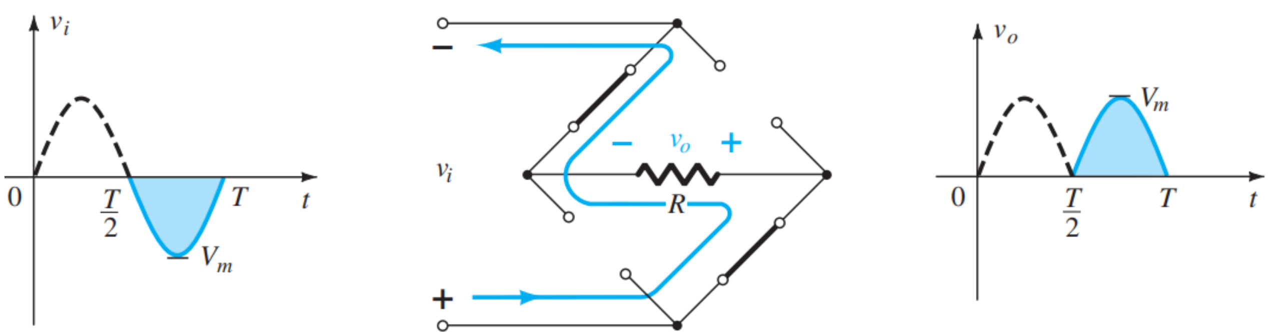


Figure 5: During the negative half-cycle of the input signal, D1 and D4 diodes are forward-biased and conduct current, while D2 and D3 diodes are reverse-biased and hence conduct no current.

Over one full cycle, the input and output voltages will appear as shown in Fig. 6. The average value of the full-wave rectified voltage signal over a full period (T) is given by

$$V_{dc} = 2 \times 0.318V_m = 0.636V_m$$

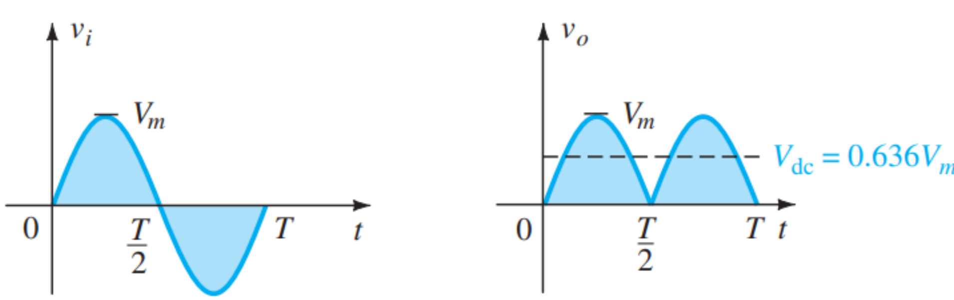


Figure 5: Input and output waveforms for a full-wave rectifier.

Working Principle of Center-Trapped Full-Wave Rectifier:
A second popular full-wave rectifier is a center-tapped rectifier. It is a type of full-wave rectifier that uses two diodes connected to the secondary of a center-tapped transformer, as shown in Fig. 6. The input voltage is coupled through the transformer to the center-tapped secondary. Half of the total secondary voltage appears between the center tap and each end of the secondary winding as shown in Fig. 6 with only two diodes but requiring a center-tapped (CT) transformer to establish the input signal across each section of the secondary of the transformer.

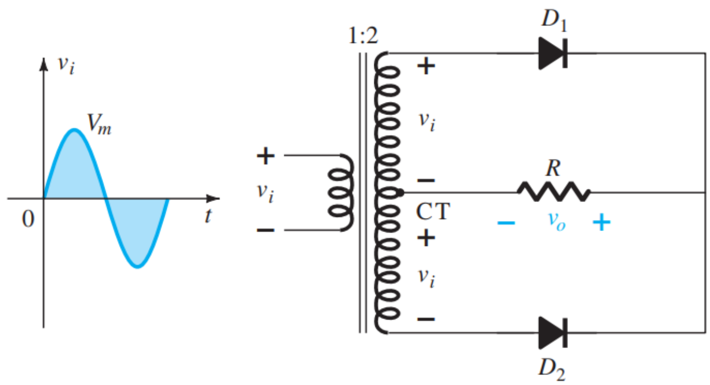


Figure 6: Center-tapped transformer full-wave rectifier.

During the positive half-cycle of v_i applied to the primary of the transformer, the network will appear as shown in Fig. 7 with a positive pulse across each section of the secondary coil. D1 assumes the short-circuit equivalent and D2 the open-circuit equivalent, as determined by the secondary voltages and the resulting current directions. The output voltage appears as shown in Fig. 7.

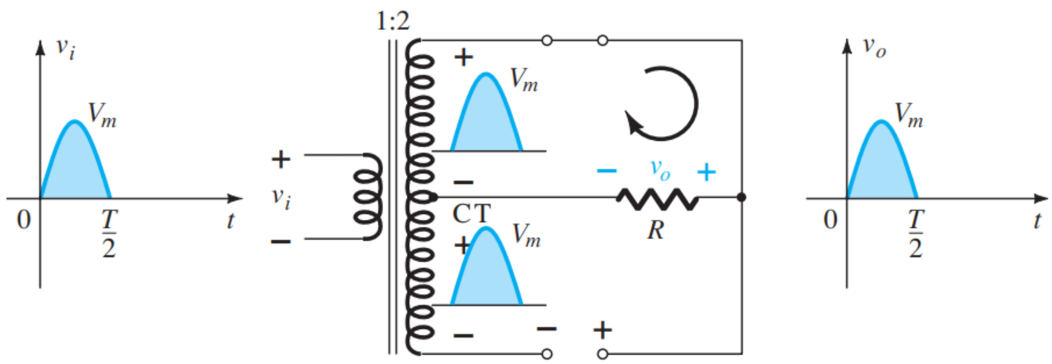


Figure 7: Network conditions for the positive region of v_i.

During the negative half-cycle of v_i applied to the primary of the transformer, the network will appear as shown in Fig. 8 with a positive pulse across each section of the secondary coil. D2 assumes the short-circuit equivalent and D1 the open-circuit equivalent, as determined by the secondary voltages and the resulting current directions. The output voltage appears as shown in Fig. 8.

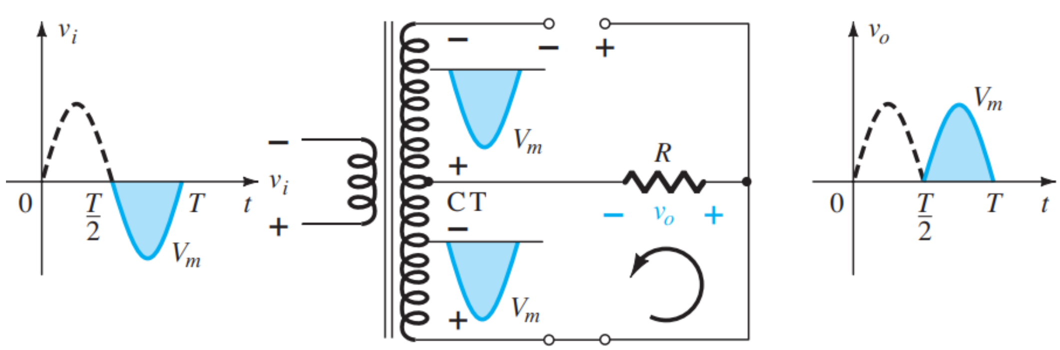


Figure 8: Network conditions for the negative region of v_i.

Pre-Lab Homework:
Students will be provided with the upcoming lab manuals, and they will be asked to prepare the theoretical (operations/working principle) information on the topic from the textbook.
Besides, they must implement the circuit (as given in Figures 1, 3, and 6) using a MultiSIM simulator. Observe the input-output wave shapes and fill up Tables 1, 2, and 3 using the simulation tool. Measure the values of different parameters and fill up the tables (Tables 1, 2, and 3) using the simulation tool.

Apparatus:

SL#	Apparatus	Quantity
1	Diode	1
2	Resistance (1 kΩ)	1
3	Capacitors (47 and 100 μF)	1 each
4	Transformer (220V/12V/9V/6V)	1
5	Project Board	1
6	Function Generator	1
7	Oscilloscope	1
8	Multimeter	1
9	Connecting Leads	10

Precaution!
The following is a list of some of the special safety precautions that should be taken into consideration when working with diodes:

1. **Never remove or insert a diode into a circuit with voltage applied.**
2. **Ensure a replacement diode into a circuit is in the correct direction.**
3. **Make sure the correct connection of the transformer.**
4. **When testing a diode, ensure that the test voltage does not exceed the diode's-**
   a. **Maximum allowable voltage.**
   b. **Ensure a replacement diode into a circuit is in the correct direction.**

Experimental Procedures:

1. Measure the actual value of the 1 kΩ resistor.
2. Connect the circuit as shown in Figure 1 without any capacitors.
3. Turn on the AC power supply (function generator) with the voltage control nob at 0 V.
4. Rotate the amplitude control nob from 0 V to 10 V (maximum voltage) gradually.
5. Select the sinusoidal waveform and set the frequency to 100 Hz.
6. Connect the oscilloscope to observe the wave shapes of the input and output voltages in the dual channel mode of the oscilloscope with no capacitor connected across the load resistance, *R*.
7. Measure the peak AC voltage from the oscilloscope screen.
8. Measure the output voltage by a multimeter (DC and AC modes) and compare it to that obtained from the oscilloscope screen.
9. Record the measured data in Table 1.
10. Turn off the power supply and connect 47 μF and 100 μF capacitors across the load. Observe the output voltage and measure it using the oscilloscope and multimeter and then compare them.
11. Turn off the power supply and record the measured data in Table 1.
12. Connect the circuit as shown in Figures 3 and 6 without any capacitors. Then repeat steps 3-11, but record data in Tables 2 and 3, respectively.

Table 1 Data Table for the Circuit of Figure 1

Capacitance (μF)	Output Voltage, V_o (V) (By Oscilloscope)	Output Voltage, V_o (V) (By Multimeter)	
		DC Mode (V_{DC}, V)	AC Mode (V_{rms}, V)
0			
47			
100			

Table 2 Data Table for the Circuit of Figure 3

Capacitance (μF)	Output Voltage, V_o (V) (By Oscilloscope)	Output Voltage, V_o (V) (By Multimeter)	
		DC Mode (V_{DC}, V)	AC Mode (V_{rms}, V)
0			
47			
100			

Table 3 Data Table for the Circuit of Figure 6

Capacitance (μF)	Output Voltage, V_o (V) (By Oscilloscope)	Output Voltage, V_o (V) (By Multimeter)	
		DC Mode (V_{DC}, V)	AC Mode (V_{rms}, V)
0			
47			
100			

Questions:

1. Show the difference between your simulated and measured values. Comment on the results.
2. Take the images from the oscilloscope screen and present them in the lab report.
3. What are the effects and significance of using filter capacitance?
4. What is the minimum PIV for the diodes used in circuits 3 and 6?
5. Why circuit in Fig. 6 is better than that in Fig. 3?
6. Discuss the overall aspects of the experiment. Did your results match the expected ones? If not, explain.

References:

[1] Robert L. Boylestad, Louis Nashelsky, Electronic Devices and Circuit Theory, 9th Edition, 2007-2008

[2] Adel S. Sedra, Kenneth C. Smith, Microelectronic Circuits, Saunders College Publishing, 3rd ed., ISBN: 0-03-051648-X, 1991.

[3] American International University–Bangladesh (AIUB) Electronic Devices Lab Manual.

[4] David J. Comer, Donald T. Comer, Fundamentals of Electronic Circuit Design, John Wiley & Sons Canada, Ltd., ISBN: 0471410160, 2002.

[5] Resistor values: *https://www.eleccircuit.com/how-to-basic-use-resistor/*, accessed on 20 September 2023.

List the references that you have used to answer the "Discussion" section.

Appendix A:

Ripple Factor:

The ripple factor is a measure of the fluctuating component in the output voltage and is defined as:

$$r = \frac{\text{rms value of alternative component of the wave}}{\text{Average value of the wave}} = \frac{I_{rms} V_{rms}}{I_{dc} V_{dc}} = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1}$$