UNIVERSITY OF DHAKA
ELECTRONIC DEVICE AND CIRCUITS LAB

Exp. 2: STUDY OF DIODE RECTIFIER CIRCUITS

OBJECTIVE

To build different diode rectifier circuits and understand their operation principle.

COMPONENTS REQUIRED

Resistor 10kΩ
Capacitor 1μF, 47μF
Diode 4 pieces

THEORY

The diode rectifier converts the input sinusoidal voltage V_s to a unipolar output V_o. There are two types of rectifier circuits: (i) Half-wave rectifier and (ii) Full-wave rectifier.

(i) *Half-wave (HW) rectifier*

The circuit of a half-wave rectifier is shown in Fig. 1.

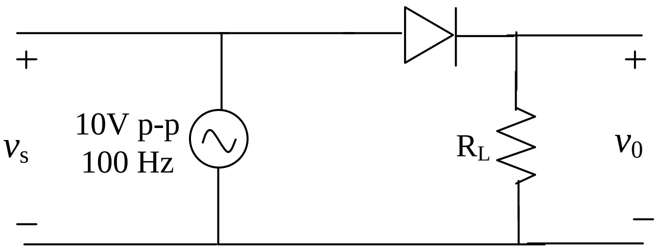


Figure. 1

Assuming ideal diode model

For the period $\boldsymbol{t = 0 \rightarrow T/2}$, $\boldsymbol{v_s > 0}$, Diode is ON, and $\boldsymbol{v_0 = v_s}$

For the period $\boldsymbol{t = T/2 \rightarrow T}$, $\boldsymbol{v_s < 0}$, Diode is OFF, and $\boldsymbol{v_0 = 0}$

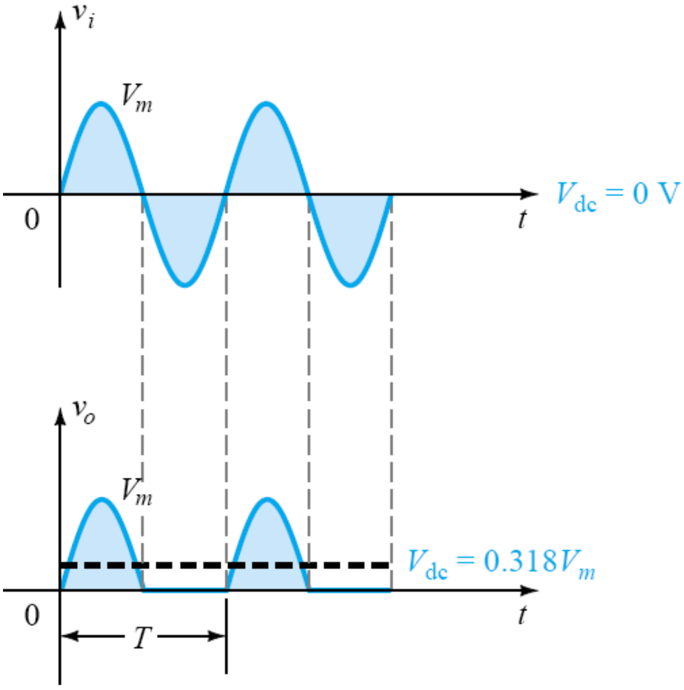
As only positive half cycle appears at the output and the negative half is blocked, the AC input voltage changes into a unidirectional DC voltage at the output. The process of removing half of the input signal to establish a dc level is aptly called half-wave rectification. Due to diode voltage drop, the actual output voltage will be approximately, $\boldsymbol{v_0 = v_s - V_{D0}}$.

For $V_s = V_m \sin\omega t$, DC voltage and current of a half wave rectifier are as follows

$$\boldsymbol{V_{DC} = V_m/\pi - V_{DO}/2}$$

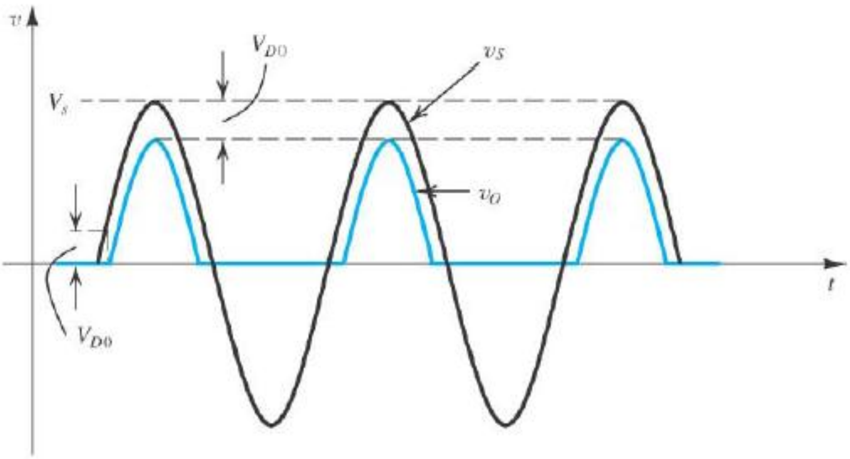
$$\boldsymbol{I_{DC} = (V_m/\pi - V_{DO}/2)/R}$$

where, $\boldsymbol{V_{DO} \approx 0.7}$ **V**, for Si.



Input and output wave shapes of a HW rectifier circuit assuming an **ideal diode model**.

Figure. 2



Input and output wave shapes of a HW rectifier circuit assuming **constant voltage drop model.**

Figure. 3

HW rectifier with a Filter Capacitor

Although the rectification stage makes the sine wave voltage to be positive, the rectifier's result is not as "flat" a DC value as we would like to have from a reliable voltage source, as you will measure in the lab. The capacitor is included to help smooth out the ripples that result in the output from the rectification stage.

Recall that the voltage across a capacitor cannot change instantaneously, but rather it requires a certain amount of time before it is fully charged. Initially, as the input voltage rises, diode turns on, and the capacitor starts charging. After the input voltage reaches its peak value, the capacitor gets charged to the peak input voltage. As the input voltage now starts decreasing below the peak value, the diode turns off, since the n-side is more positive than the p-side due to the voltage across the capacitor which does not change instantaneously. The stored charges on the capacitor will be released through R_L.

For $R_LC >> T$, it will take long time for the capacitor to discharge and the output terminal will maintain almost a dc voltage. Thus large capacitance values help suppress the quickly changing voltage from the rectifier and result in a flatter DC value being supplied to the load. Typical power supply designs use relatively large capacitor values (greater than 1000 µF).

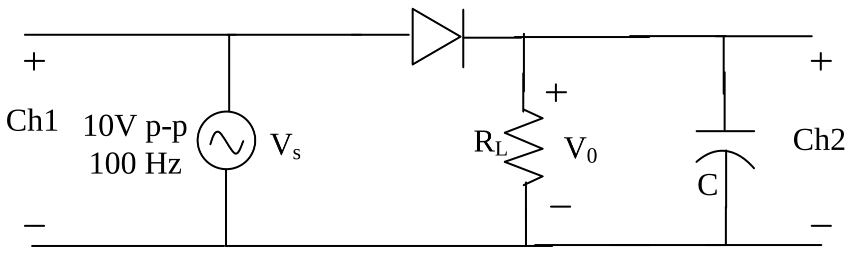
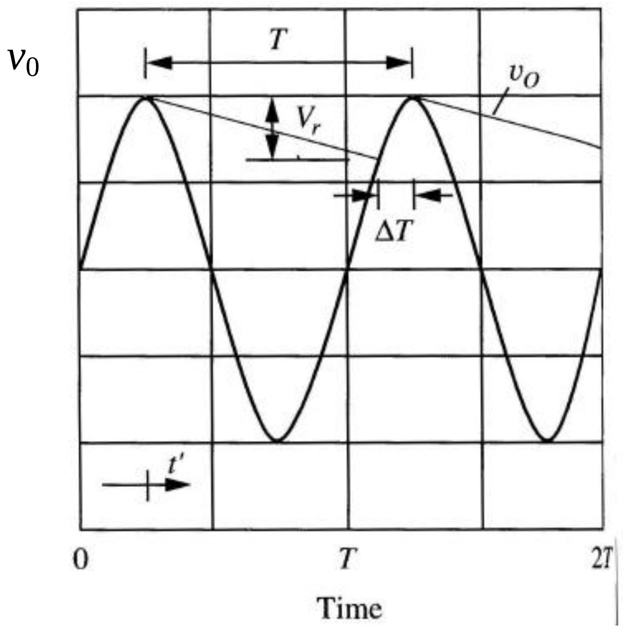


Figure. 4

Circuit diagram for half wave rectifier with the filter capacitor.



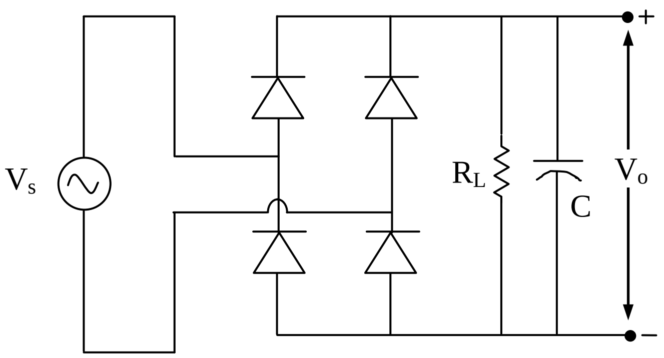
V_r is the ripple voltage. A small ripple voltage is required in most supply design.

Figure. 5

PIV (Peak Inverse Voltage): PIV is the maximum voltage that appears across the diode when it is reverse-biased.

$$\text{PIV} = V_m$$

(ii) *Full-wave (FW) Bridge Rectifier*



Circuit diagram for the bridge rectifier.

Figure. 6

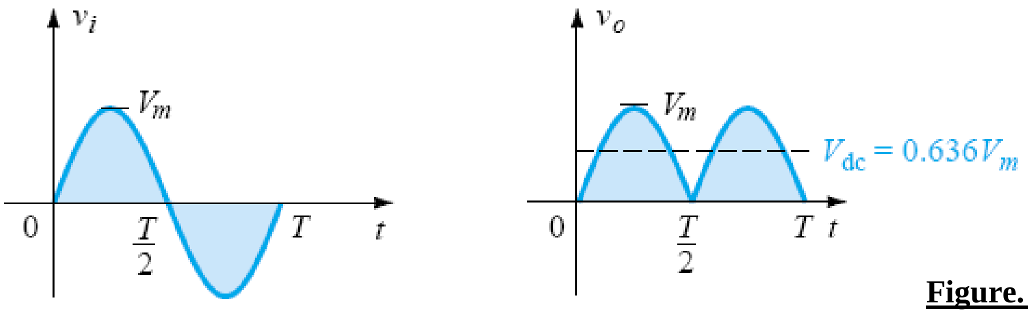


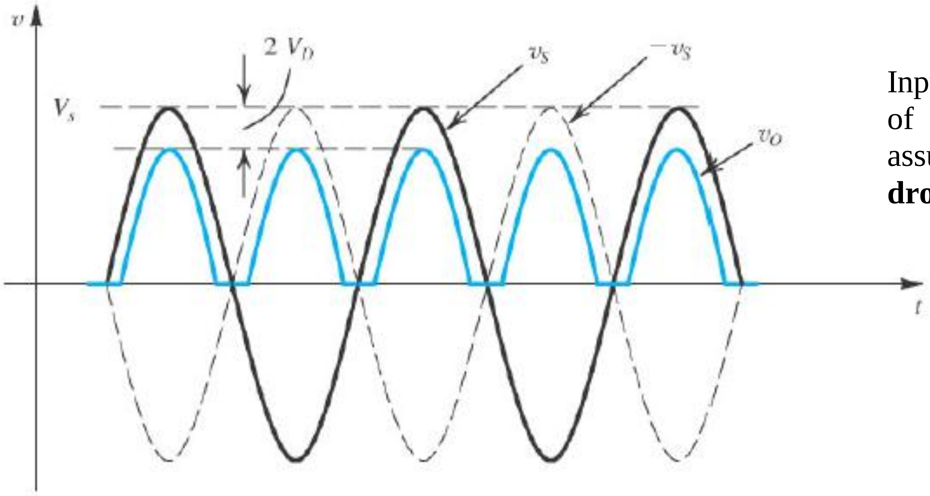
Figure. 7

Input and output wave shapes of a FW rectifier circuit without the filter capacitor, assuming an **ideal diode model**.

Fig. 8 shows the output voltage of a FW rectifier as a function of time assuming constant voltage drop model. Peak voltage across each diode when it is reverse-biased is

$$\mathbf{PIV = V_m - V_{DO}}$$

DC voltage, $\mathbf{V_{DC} = 2V_m/\pi - 2V_{DO}}$



Input and output wave shapes of a FW rectifier circuit assuming **constant voltage drop model.**

Figure. 8

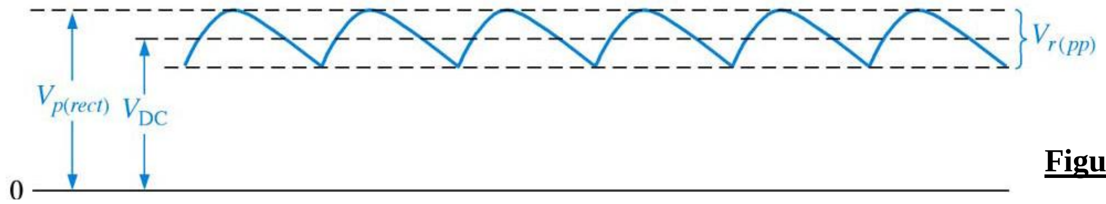


Figure. 9

Output voltage wave shape of a FW rectifier circuit with the filter capacitor.

Ripple voltage and ripple factor

The output of a rectifier though unidirectional, contains periodically fluctuating components. The theoretical value for the peak-to-peak ripple voltage is given by,

$\mathbf{V_r = Vp/(fCR),}$ for a HW rectifier circuit

$\mathbf{V_r = Vp/(2fCR),}$ for a FW rectifier circuit

Here *f* is the ripple frequency, and *R* is the resistance connected in parallel with *C*.

A measure of the fluctuating components is given by the ripple factor ***r***, which is defined as

$$\boldsymbol{r} = \frac{\text{rms value of alternating components of wave}}{\text{average value of wave}}$$

$$= I'_{rms}/I_{dc} = V'_{rms}/V_{dc}$$

where, I'_{rms} and V'_{rms} denote the rms value of the ac components of the current and voltage, respectively.

PROCEDURE

1. Construct circuit of Fig. 1 without the capacitor. Observe V_s and V_o simultaneously on the oscilloscope.

2. Sketch input and output waveforms. Note down the voltage levels. Also measure V_o with a multimeter in dc and ac mode.

3. Connect 1μF capacitor across the load resistor, R_L (**BE CAREFUL** about the polarity of the capacitor).

4. Measure the dc load voltage V_0 (DC) and peak-to-peak ripple voltage $V_{r(pp)}$ as shown in the figure (To measure the ripple voltages, switch the oscilloscope to AC coupling. This slows you how to magnify the small ac ripple voltage without including the much larger dc level).

5. Measure the ripple frequency at which the waveform repeats. Sketch input and output waveforms. Also measure V_o with a multimeter.

6. Replace 1μF Capacitor with 47μF and repeat steps 4 and 5.

7. Construct the circuit of Fig. 6 without the capacitor. Observe and sketch V_s and V_o (**DO NOT** observe them simultaneously). Repeat step 2.

8. Connect 1μF capacitor as shown in Fig.6 and repeat steps 4 and 5.

9. Replace 1 μF capacitor by 47 μF for Fig. 6 and repeat steps 4 and 5.

10. Perform PSpice simulation of the circuits in Figs. 1 and 2 and repeat the steps above.

REPORT

1. Calculate the average and effective values of the load voltages in circuits of Fig.1 and Fig. 2 without capacitor. Compare these values with those obtained with the multimeter.

2. Comment on PIV of the diodes for both the HW and FW rectifier.

3. Calculate the ripple factor for both the HW and FW rectifiers and complete the following table. Compare your results with the calculated values.

4. Which capacitor acts as a better filter? Explain your answer.
5. Which of the two rectifiers is better? Explain why.
6. Compare the PSpice results with those obtained experimentally.
7. The output still contains ripple even after using filter capacitor. What do you suggest?

		Experimental				Theoretical		
	C (μF)	**V_r(rms) (V)**	**V_{dc} (V)**	**Ripple Factor**	**Ripple Frequency, f (Hz)**	**V_r (V)**	**V_{dc} (V)**	**Ripple Factor**
HW	**1**							
	47							
FW	**1**							
	47							