Group No:

Experiment-04

Study of Half-Wave and Full-Wave Rectifiers

CSE251 - Electronic Devices and Circuits Lab

Objective

1. To build a half-wave rectifier circuit and understand its operating principle.
2. To build a full-wave rectifier circuit and understand its operating principle.

Equipments

1. p-n junction diode (1N4007) x 4
2. Resistor (10kΩ) - $\times 1$
3. Capacitors (1μF, 4.7μF) – 1 each
4. Function Generator
5. Oscilloscope
6. Breadboard
7. Chords and Wires

Background Theory

Diodes are used to build rectifier circuits which convert 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.

Half-Wave (HW) Rectifier

The circuit of a half-wave rectifier is shown in the following figure:

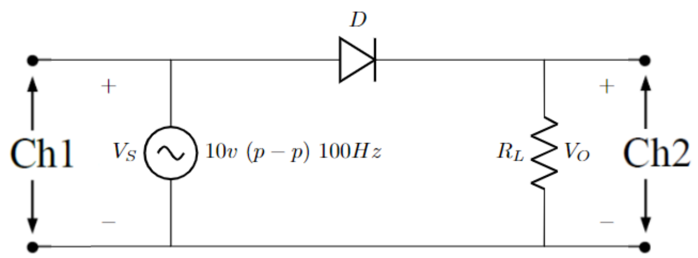


Figure 1: Half-Wave Rectifier

Assuming ideal diode model,

For the period, $t = 0 \rightarrow T/2$, $V_S > 0$, Diode is ON and $V_O = V_S$

For the period, $t = T/2 \rightarrow T$, $V_S < 0$, Diode is OFF and $V_O = 0$

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, $V_O = V_S - V_{D0}$. For, $V_S = V_m sin\omega t$, DC voltage and current of a half wave rectifier are:

$$V_{DC} = \frac{V_m}{\pi} - \frac{V_{D0}}{2} \quad \text{and} \quad I_{DC} = \frac{V_{DC}}{R} = \frac{V_m/\pi - V_{D0}/2}{R}$$

where, V_m = peak input voltage, $V_{D0} \approx 0.7v$ for Silicon diodes.

The following figures show the input and output wave shapes of a HW rectifier circuit:

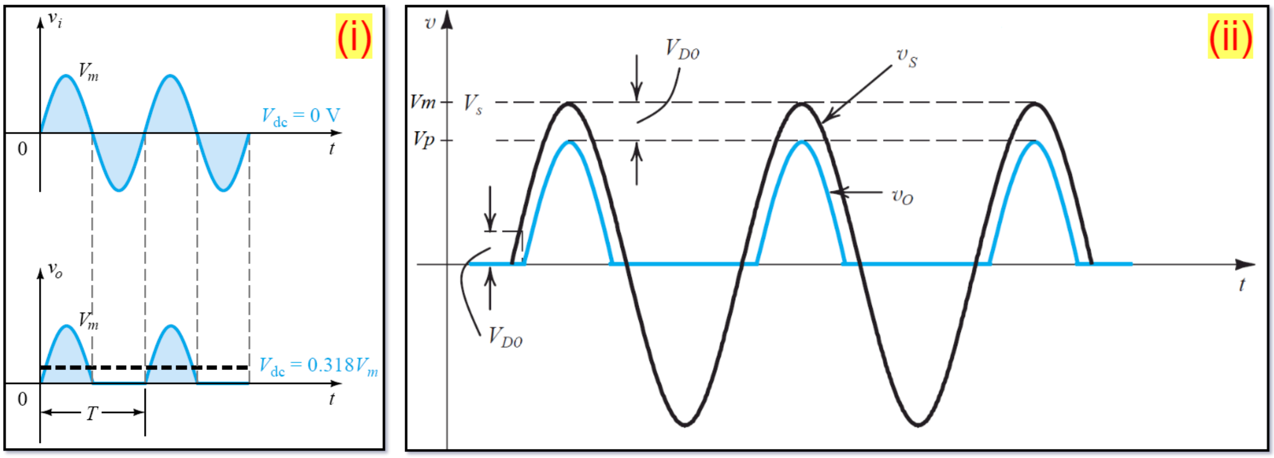


Figure 2: (i) Assuming Ideal Diode (ii) Assuming Real Diode (CVD Model)

HW Rectifier with Filter Capacitor

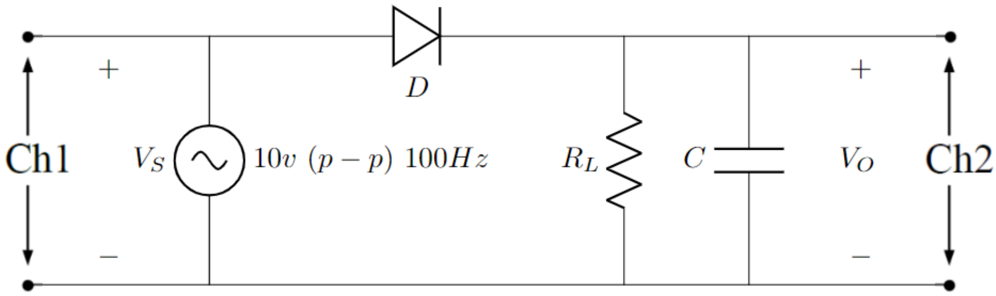


Figure 3: Half-Wave Rectifier with Filter Capacitor

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.

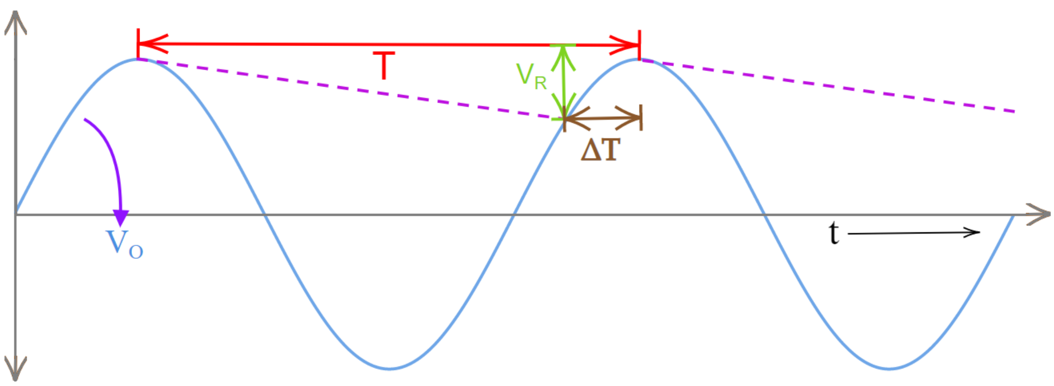


Figure 4: Vr or Vr(p-p) is the peak to peak ripple voltage.

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).

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

$$PIV = V_m$$

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,

$$V_{r(p-p)} = \frac{V_p}{fCR} = \frac{V_m - V_{D0}}{fCR}$$

Here, V_p = peak voltage of the rectified output, f = input frequency, and R is the resistance connected in parallel with C.

$$\text{Average value of the output wave, } V_{dc} = V_p - \frac{V_{r(p-p)}}{2}$$

$$\text{RMS value of the Ripple Voltage, } V_{r(rms)} = \frac{V_{r(p-p)}}{2\sqrt{3}}$$

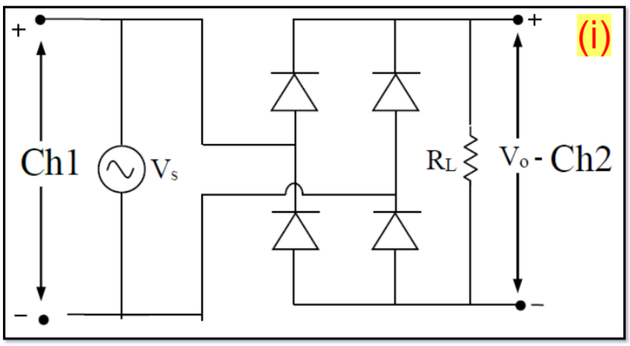
A measure of the fluctuating components is given by the ripple factor $\boldsymbol{r}$, which is defined as,

$$r = \frac{\text{rms value of alternating components of the output wave (multimeter in } AC\text{)}}{\text{average value of the output wave (multimeter in DC)}}$$

$$= \frac{V_{r-rms}}{V_{dc}}$$

Full-Wave (FW) Rectifier / Bridge Rectifier

The full-wave rectifier utilizes both halves of the input sinusoid. To provide a unipolar output,it inverts the negative halves of the sine wave. Figure-5 shows the circuit diagram, input and output waveform of Full-Wave Rectifier/Bridge Rectifier. In this case, constant voltage drop model was assumed. Peak inverse voltage across



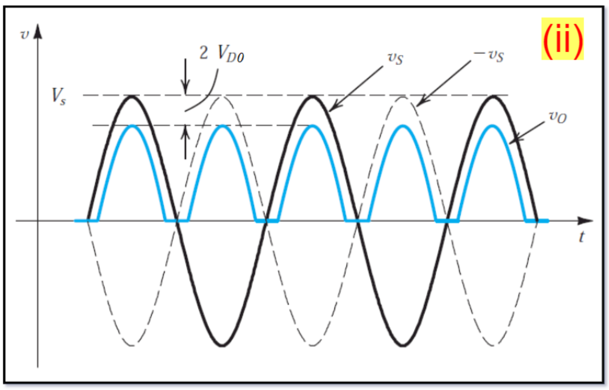


Figure 5: (i) Full-Wave Rectifier Circuit without Capacitor (ii) Input and Output Waveform

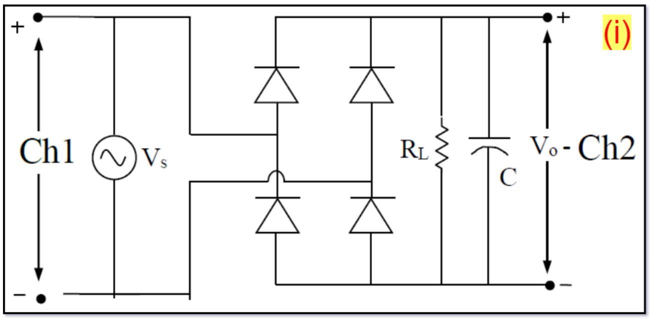
each diode and DC voltage in reverse-bias can be calculated using the following equations,

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

$$V_{DC} = \frac{2V_m}{\pi} - 2V_{D0}$$

Full-Wave (FW) Rectifier with Capacitor

The pulsating nature of the output voltage produced by the rectifier circuits discussed above makes it unsuitable as a dc supply for electronic circuits. A simple way to reduce the variation of the output voltage is to place a capacitor across the load resistor. Figure-6 shows the circuit diagram and output waveform of Full-Wave Rectifier with Capacitor.



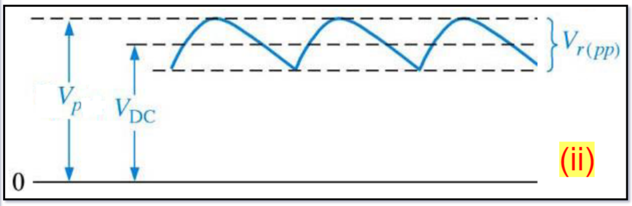


Figure 6: (i) Full-Wave Rectifier Circuit with Capacitor (ii) Output Waveform

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,

$$V_{r(p-p)} = \frac{V_p}{2fCR} = \frac{V_m - 2V_{D0}}{2fCR}, \text{ for a FW rectifier circuit}$$

Here, V_p = peak voltage of the rectified output, f = input frequency, and R is the resistance connected in parallel with C.

$$\text{Average value of the output wave, } V_{dc} = V_p - \frac{V_{r(p-p)}}{2}$$

$$\text{RMS value of the Ripple Voltage, } V_{r-rms} = \frac{V_{r(p-p)}}{2\sqrt{3}}$$

A measure of the fluctuating components is given by the ripple factor $\boldsymbol{r}$, which is defined as

$$r = \frac{\text{rms value of alternating components of the output wave (multimeter in } AC)}{\text{average value of the output wave (multimeter in DC)}}$$
$$= \frac{V_{r-rms}}{V_{dc}}$$

Task-01: HW Rectifier

Procedure

1. Construct circuit of Figure 1. Observe V_s and V_o simultaneously on Channel 1 and Channel 2 of the oscilloscope respectively.
2. Capture the image of the input and output waveforms using your mobile camera.
3. Measure V_o with a multimeter in dc and ac mode to take data for the Data Sheet.
4. Connect 1μF capacitor across the resistor, $R_L = 10k\Omega$ (***Be careful*** about the polarity of the capacitor).
5. Capture the image of the input and output waveforms using your mobile camera.
6. Measure the peak voltage of the output, V_p and peak-to-peak ripple voltage $V_{r(p-p)}$ from the oscilloscope. To measure the peak and the ripple voltages, go to the "measure" tab of the oscilloscope or switch on the cursors of the oscilloscope. This allows you to level your cursor horizontally with the peak or the ripple voltage and measure the values.
7. Again, measure V_o with a multimeter in dc and ac mode to take data for the Data Sheet. Calculate the ripple factor.
8. Replace 1μF Capacitor with 4.7μF and repeat steps 4-7.

Task-02: FW Rectifier

Procedure

1. Construct circuit of Figure 6 without the capacitor. Observe V_s and V_o separately on the oscilloscope [i.e use only one channel].
2. Capture the image of the input and output waveforms using your mobile camera.
3. Measure V_o with a multimeter in dc and ac mode to take data for the Data Sheet.
4. Connect 1μF capacitor across the resistor, $R_L = 10k\Omega$ (***Be careful*** about the polarity of the capacitor).
5. Capture the image of the input and output waveforms using your mobile camera.
6. Measure the peak voltage of the output, V_p and peak-to-peak ripple voltage $V_{r(p-p)}$ from the oscilloscope. To measure the peak and the ripple voltages, go to the "measure" tab of the oscilloscope or switch on the cursors of the oscilloscope. This allows you to level your cursor horizontally with the peak or the ripple voltage and measure the values.
7. Again, measure V_o with a multimeter in dc and ac mode and calculate the ripple factor.
8. Replace 1μF Capacitor with 4.7μF and repeat steps 4-7.

Task-03: Report

1. Cover page [include course code, course title, name, student ID, group, semester, date of performance, date of submission]
2. Attach all the captured images.
3. Attach the signed Data Sheet.
4. Add a brief **Discussion** at the end of the report. **Discussion** should contain the answers of the following questions:
   - Which capacitor acts as a better filter? Explain your answer.
   - Which of the two rectifiers is better? Explain why.
   - Why can't you see the input and output using 2 channels of oscilloscope simultaneously?
   - What challenges did you face during the experiment?

Data Sheet

Experimental Observation: HW Rectifier

1. **HW Rectifier without Capacitor:**
   Peak output voltage, V_p (oscilloscope) =
   Average or DC output voltage, V_{dc} (multimeter in DC mode) =
   RMS or AC output voltage, V_{r-rms} (multimeter in AC mode) =

2. **HW Rectifier with 1μF Capacitor:**
   Peak output voltage, V_p (oscilloscope) =
   Peak to peak ripple voltage, $V_{r(p-p)}$ (oscilloscope) =
   Average or DC value of the ripple voltage, V_{dc} (multimeter in DC mode) =
   RMS or AC value of the ripple voltage, V_{r-rms} (multimeter in AC mode) =
   Ripple factor, $r = V_{r-rms}/V_{dc}$ =

3. **HW Rectifier with 4.7μF Capacitor:**
   Peak output voltage, V_p (oscilloscope) =
   Peak to peak ripple voltage, $V_{r(p-p)}$ (oscilloscope) =
   Average or DC value of the ripple voltage, V_{dc} (multimeter in DC mode) =
   RMS or AC value of the ripple voltage, V_{r-rms} (multimeter in AC mode) =
   Ripple factor, $r = V_{r-rms}/V_{dc}$ =

Theoretical Calculation: HW Rectifier

1. **HW Rectifier Without Capacitor:**
   Peak output voltage, V_p (see the experimental observation) =
   Peak input voltage, V_m =
   Diode voltage, $V_{D0} = 0.7$ V
   DC output voltage of the rectifier, $V_{dc} = \frac{V_m}{\pi} - \frac{V_{DO}}{2}$ =
   RMS or AC output voltage, $V_{r-rms} = \frac{V_p}{2}$ =

2. **HW Rectifier With 1μF Capacitor:**
   Peak output voltage, V_p (see the experimental observation) =
   Peak to peak ripple voltage, $V_{r(p-p)}$ (see the experimental observation)=
   DC value of the ripple voltage, $V_{dc} = V_p - \frac{V_{r(p-p)}}{2}$ =
   RMS value of the ripple voltage, $V_{r-rms} = \frac{V_{r(p-p)}}{2\sqrt{3}}$ =
   Ripple factor, $r = V_{r-rms}/V_{dc}$ =

3. **HW Rectifier with 4.7μF Capacitor:**
   Peak output voltage, V_p (see the experimental observation) =
   Peak to peak ripple voltage, $V_{r(p-p)}$ (see the experimental observation) =
   DC value of the ripple voltage, $V_{dc} = V_p - \frac{V_{r(p-p)}}{2}$ =
   RMS value of the ripple voltage, $V_{r-rms} = \frac{V_{r(p-p)}}{2\sqrt{3}}$ =
   Ripple factor, $r = V_{r-rms}/V_{dc}$ =

Experimental Observation: FW Rectifier

1. **FW Rectifier without Capacitor:**
   Peak output voltage, V_p (oscilloscope) =
   Average or DC output voltage, V_{dc} (multimeter in DC mode) =
   RMS or AC output voltage, V_{r-rms} (multimeter in AC mode) =

2. **FW Rectifier with 1μF Capacitor:**
   Peak output voltage, V_p (oscilloscope) =
   Peak to peak ripple voltage, $V_{r(p-p)}$ (oscilloscope) =
   Average or DC value of the ripple voltage, V_{dc} (multimeter in DC mode) =
   RMS or AC value of the ripple voltage, V_{r-rms} (multimeter in AC mode) =
   Ripple factor, $r = V_{r-rms}/V_{dc}$ =

3. **FW Rectifier with 4.7μF Capacitor:**
   Peak output voltage, V_p (oscilloscope) =

Peak to peak ripple voltage, $\mathrm{V_{r(p-p)}}$ (oscilloscope) =
Average or DC value of the ripple voltage, V_{dc} (multimeter in DC mode) =
RMS or AC value of the ripple voltage, $\mathrm{V_{r-rms}}$ (multimeter in AC mode) =
Ripple factor, $r = V_{\mathrm{r-rms}}/\mathrm{V_{dc}}$ =

Theoretical Calculation: FW Rectifier

1. **FW Rectifier without Capacitor:**
   Peak output voltage, $\mathrm{V_p}$ (see the experimental observation) =
   Peak input voltage, $\mathrm{V_m}$ =
   Diode voltage, $\mathrm{V_{D0}} = 0.7$ V
   DC output voltage of the rectifier, $V_{\mathrm{dc}} = \frac{2\ \mathrm{V_m}}{\pi} - 2\ \mathrm{V_{D0}}$ =
   RMS or AC output voltage, $\mathrm{V_{r-rms}} = \frac{\mathrm{V_p}}{\sqrt{2}}$ =

2. **FW Rectifier with 1μF Capacitor:**
   Peak output voltage, $\mathrm{V_p}$ (see the experimental observation) =
   Peak to peak ripple voltage, $\mathrm{V_{r(p-p)}}$ (see the experimental observation) =
   DC value of the ripple voltage, $V_{\mathrm{dc}} = \mathrm{V_p} - \frac{\mathrm{V_{r(p-p)}}}{2}$ =
   RMS value of the ripple voltage, $\mathrm{V_{r-rms}} = \frac{\mathrm{V_{r(p-p)}}}{2\sqrt{3}}$ =
   Ripple factor, $r = V_{r-rms}/V_{\mathrm{dc}}$ =

3. **FW Rectifier with 4.7μF Capacitor:**
   Peak output voltage, $\mathrm{V_p}$ (see the experimental observation) =
   Peak to peak ripple voltage, $\mathrm{V_p}$ (see the experimental observation) =
   DC value of the ripple voltage, $V_{\mathrm{dc}} = \mathrm{V_p} - \frac{\mathrm{V_{r(p-p)}}}{2}$ =
   RMS value of the ripple voltage, $\mathrm{V_{r-rms}} = \frac{\mathrm{V_{r(p-p)}}}{2\sqrt{3}}$ =
   Ripple factor, $\mathrm{r = V_{r-rms}/V_{dc}}$ =

Table for Comparison

Use the experimental and theoretical data for comparison.

		Experimental Observation			Theoretical Calculation		
	C(uF)	Vr-rms (V)	Vdc (V)	Ripple Factor	Vr-rms (V)	Vdc (V)	Ripple Factor
HW	1						
	4.7						
FW	1						
	4.7						