HALF-WAVE RECTIFIER CIRCUIT WITHOUT AND WITH FILTER

Objectives:

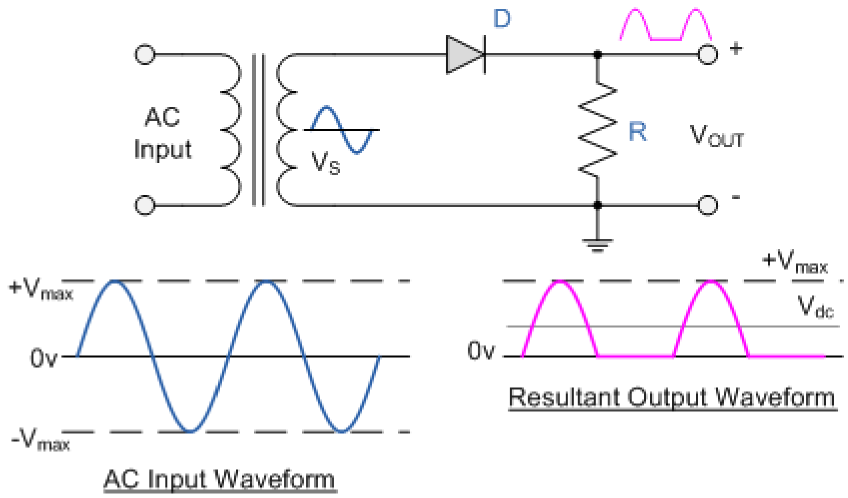
iii) To construct a half-wave rectifier circuit and analyse its output.

iv) To analyse the rectifier output using a capacitor in shunt as a filter.

Overview:

The process of converting an alternating current into direct current is known as rectification. The unidirectional conduction property of semiconductor diodes (junction diodes) is used for rectification. Rectifiers are of two types: (a) Half wave rectifier and (b) Full wave rectifier. In a half-wave rectifier circuit (Fig. 1), during the positive half-cycle of the input, the diode is forward biased and conducts. Current flows through the load and a voltage is developed across it. During the negative half-cycle, it is reverse bias and does not conduct. Therefore, in the negative half cycle of the supply, no current flows in the load resistor as no voltage appears across it. Thus the dc voltage across the load is sinusoidal for the first half cycle only and a pure a.c. input signal is converted into a unidirectional pulsating output signal.

Fig.1: Half-wave rectifier circuit



Since the diode conducts only in one half-cycle (0-π), it can be verified that the d.c. component in the output is V_{max}/π, where V_{max} is the peak value of the voltage. Thus,

$$V_{dc} = \frac{V_{\max}}{\pi} = 0.318 V_{\max}$$

The current flowing through the resistor, $I_{dc} = \frac{V_{dc}}{R}$ and power consumed by the load, $P = I_{dc}^2 R$.

Ripple factor:

As the voltage across the load resistor is only present during the positive half of the cycle, the resultant voltage is "ON" and "OFF" during every cycle resulting in a low average dc value. This variation on the rectified waveform is called "**Ripple**" and is an undesirable feature. The ripple factor is a measure of purity of the d.c. output of a rectifier and is defined as

$$r = \frac{V_{ac}(output)}{V_{dc}(output)} = \sqrt{\frac{V_{rms}^2 - V_{dc}^2}{V_{dc}^2}} = \sqrt{\frac{V_{rms}^2}{V_{dc}^2} - 1} = \sqrt{\left(\frac{0.5}{0.318}\right)^2 - 1} = 1.21$$

In case of a half-wave rectifier $V_{rms} = V_{max}/2 = 0.5V_{max}$. (How?)

Rectification Efficiency:

Rectification efficiency, η, is a measure of the percentage of total a.c. power input converted to useful d.c. power output.

$$\eta = d.c.\ power\ delivered\ to\ load \,|\, a.c.\ power\ at\ input$$

$$= \frac{V_{dc}^2 / R_L}{V_s^2 / (r_d + R_L)} = \frac{(0.318 V_{\max})^2}{(0.5 V_{\max})^2 \left(1 + \frac{r_d}{R_L}\right)} = \frac{0.405}{\left(1 + \frac{r_d}{R_L}\right)}$$

Here r_d is the forward resistance of diode. Under the assumption of no diode loss (r_d<<), the rectification efficiency in case of a half-wave rectifier is approximately 40.5%.

Filters:

The output of a rectifier gives a pulsating d.c. signal (Fig.1) because of presence of some a.c. components whose frequency is equal to that of the a.c. supply frequency. Very often when rectifying an alternating voltage we wish to produce a "steady" direct voltage free from any voltage variations or ripple. Filter circuits are used to smoothen the output. Various filter circuits are available such as shunt capacitor, series inductor, choke input LC filter and π-filter etc. Here we will use a simple **shunt capacitor** filter circuit (Fig. 2). Since a capacitor is open to d.c. and offers low impedance path to a.c. current, putting a capacitor across the output will make the d.c. component to pass through the load resulting in small ripple voltage.

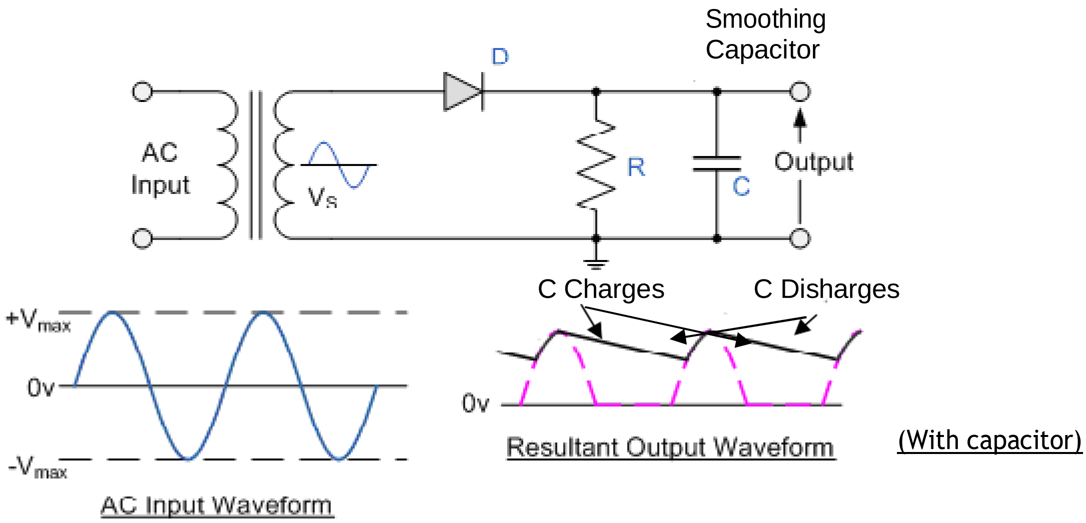


Fig.2: Half-wave rectifier circuit with capacitor filter

The working of the capacitor can be understood in the following manner. When the rectifier output voltage is increasing, the capacitor charges to the peak voltage V_m. Just past the positive peak the rectifier output voltage tries to fall. As the source voltage decreases below V_m , the capacitor will try to send the current back to diode making it reverse biased. Thus the diode separates/disconnects the source from the load and hence the capacitor will discharge through the load until the source voltage becomes more than the capacitor voltage. The diode again starts conducting and the capacitor is again charged to the peak value V_m and the process continues. Although in the output waveform the discharging of capacitor is shown as a straight line for simplicity, the decay is actually the normal exponential decay of any capacitor discharging through a load resistor. The extent to which the capacitor voltage drops depends on the capacitance and the amount of current drawn by the load; these two factors effectively form the RC time constant for voltage decay. A proper combination of large capacitance and small load resistance can give out a steady output.

Circuit components:

(ii) A step-down transformer, (ii) A junction diode, (iii) 3 Load resistors, (iv) Capacitor, (v) Oscilloscope, (vi) Multimeter, (vii) Connecting wires, (viii) Breadboard.

Circuit Diagram: (As shown in Fig. 1 and 2)

Procedure:

i) Configure the half-wave rectifier circuit as shown in the circuit diagram. Note down all the values of the components being used.

ii) Connect the primary side of the transformer to the a.c. Mains and secondary to the input of the circuit.

iii) Feed the input and output to the two channels of oscilloscope (we will use oscilloscope here only to trace the output waveform) and save the data for each measurement.

iv) Measure the input a.c. voltage and the output a.c. and d.c. voltages using multimeter for at least 3 values of load resistor (Be careful to choose proper settings of multimeter for ac and dc measurement).

v) Multiply the V_{ac} at the input by $\sqrt{2}$**?** to get the peak value and calculate V_{dc} Using the formula $V_{dc} = V_{max}/\pi$. Compare this value with the measured V_{dc} at the output.

vi) Calculate the ripple factor and efficiency.

vii) Connect the capacitor across the output for each load resistor and measure the output a.c. and d.c. voltages once again and calculate the ripple factor. (If time permits you could also use different values of capacitors and study the output)

Observations:

iv) Code number of diode = _________

v) Input Voltage: V_{ac} =___________Volt

Table(I): Half wave rectifier w/o filter

Sl. No	Load R_L (kΩ)	Output Voltage			Ripple Factor r	Efficiency η (%)
		V_{ac} (Volt)	V_{dc} (Volt)	V_{max}/π (Volt)		
1						
2						
3						

Table(II): Half wave rectifier with filter (C = _____μF)

Sl. No	Load R_L (kΩ)	Output Voltage		Ripple Factor r
		V_{ac} (Volt)	V_{dc} (Volt)	
1				
2				
3				

(III) Input and output waveforms:

Waveforms without Filter:

R_L = _______ **Input** **Output**

(Paste data here)

Waveforms with Capacitor Filter:

R_L = _______ **Input** **Output**

(Paste data here)

Discussions:

Precautions:

FULL WAVE RECTIFIER CIRCUIT WITHOUT AND WITH FILTER

Objectives:

v) To construct a full-wave bridge rectifier circuit and analyze its output.

vi) To analyze the rectifier output using a capacitor in shunt as a filter.

Overview:

As you have seen already a half-wave rectifier circuit is unsuitable to applications which need a "steady and smooth" dc supply voltage. One method to improve on this is to use every half-cycle of the input voltage instead of every other half-cycle. The circuit which

allows us to do this is called a Full-wave Rectifier. Here, unidirectional current flows in the output for both the cycles of input signal and rectifies it. The rectification can be done either by a center tap full wave rectifier (using two diodes) or a full wave bridge rectifier (using four diodes). In this experiment we will study a full wave bridge rectifier.

The Full-wave Bridge Rectifier

Another type of circuit that produces the same output as a full-wave rectifier is that of the Bridge Rectifier (Fig. 1). This type of single phase rectifier uses 4 individual rectifying diodes connected in a "bridged" configuration to produce the desired output but does not

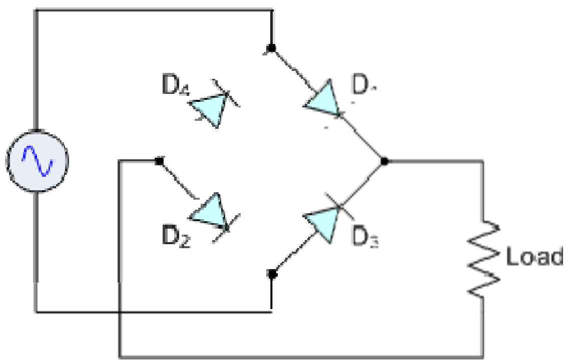


Fig. 1: Full-wave Bridge Rectifier

require a special centre tapped transformer, thereby reducing its size and cost. The single secondary winding is connected to one side of the diode bridge network and the load to the other side as shown in figure. The 4 diodes labeled D_1 to D_4 are arranged in "series pairs" with only two diodes conducting current during each half cycle. During the positive half cycle of the supply, diodes D1 and D2 conduct in series while diodes D3 and D4 are reverse biased and the current flows through the load as shown below (Fig. 2). During the negative half cycle of the supply, diodes D3 and D4 conduct in series, but diodes D1 and D2 switch of as they are now reverse biased. The current flowing through the load is the same direction as before.

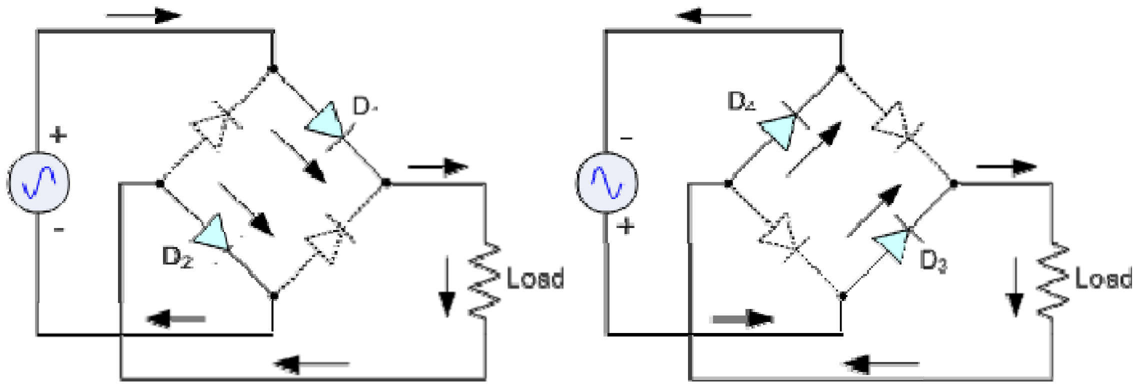


Fig. 2: Working of Full-wave bridge rectifier

As the current flowing through the load is unidirectional, so the voltage developed across the load is also unidirectional during both the half cycles. Thus, the average dc output voltage across the load resistor is double that of a half-wave rectifier circuit, assuming no losses.

$$V_{dc} = \frac{2V_{\max}}{\pi} = 0.637V_{\max}$$

Ripple factor:

As mentioned in the previous lab the ripple factor is a measure of purity of the d.c. output of a rectifier and is defined as

$$r = \frac{V_{ac}(output)}{V_{dc}(output)} = \sqrt{\frac{V_{rms}^2 - V_{dc}^2}{V_{dc}^2}} = \sqrt{\frac{V_{rms}^2}{V_{dc}^2} - 1} = \sqrt{\left(\frac{0.707}{0.637}\right)^2 - 1} = 0.48$$

In case of a full-wave rectifier $V_{rms} = V_{max}/\sqrt{2} = 0.707V_{max}$. The ripple frequency is now twice the supply frequency (e.g. 100Hz for a 50Hz supply).

Rectification Efficiency:

Rectification efficiency, η, is given by

$$\eta = d.c.\, power\, delivered\, to\, load \,|\, a.c.\, power\, at\, input$$

$$= V_{dc}I_{dc} \,|\, V_{ac}I_{ac} = \frac{V_{dc}^2 \,|\, R_L}{V_s^2 \,|\, (r_d + R_L)} = \frac{(0.637V_{\max})^2}{(0.707V_{\max})^2\left(1 + \frac{r_d}{R_L}\right)} = \frac{0.811}{\left(1 + \frac{r_d}{R_L}\right)}$$

$$\max \left(\quad R_L \right) \quad \left(\quad R_L \right)$$

where r_d is the forward resistance of diode. Under the assumption of no diode loss (r_d<<), the rectification efficiency in case of a full-wave rectifier is approximately 81.1%, which is twice the value for a half-wave rectifier.

Filter:

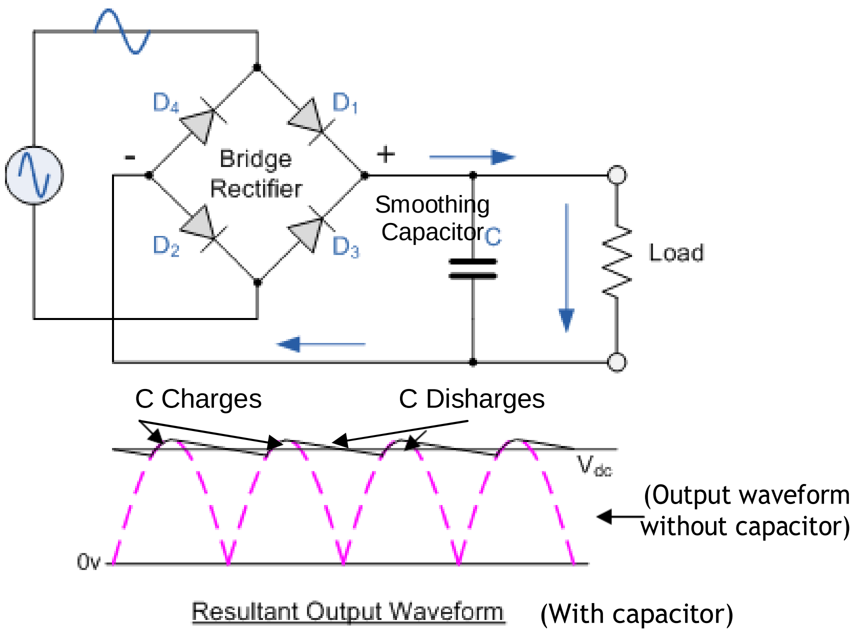


Fig.3: Full-wave rectifier circuit with capacitor filter

The full-wave rectifier circuit with capacitor filter is shown in Fig. 3. The smoothing capacitor converts the full-wave rippled output of the rectifier into a smooth dc output voltage. The detailed description of its filtering action is already explained in half-wave rectifier handout. Two important parameters to consider when choosing a suitable a capacitor are its *working voltage*, which must be higher than the no-load output value of the rectifier and its *capacitance value*, which determines the amount of ripple that will appear superimposed on top of the dc voltage.

Apart from rectification efficiency, the main advantages of a full-wave bridge rectifier is that it has a smaller ac ripple value for a given load and a smaller smoothing capacitor than an equivalent half-wave rectifier. The amount of ripple voltage that is superimposed on top of the dc supply voltage by the diodes can be virtually eliminated by adding other improved filters such as a pi-filter.

Circuit components/Equipments:

(i) A step-down transformer, (ii) 4 junction diodes, (iii) 3 Load resistors, (iv) Capacitor, (v) Oscilloscope, (vi) Multimeters, (vii) Connecting wires, (viii) Breadboard.

Circuit Diagram: (As shown in Fig. 1 and 3)

Procedure:

i) Configure the full-wave rectifier circuit as shown in the circuit diagram. Note down all the values of the components being used.

ii) Connect the primary side of the transformer to the a.c. Mains and secondary to the input of the circuit.

iii) Measure the input a.c. voltage (V_{ac}) and current (I_{ac}) and the output a.c. (V_{ac}) and d.c. (V_{dc}) voltages using multimeter for at least 3 values of load resistor (Be careful to choose proper settings of multimeter for ac and dc measurement).

iv) Feed the input and output to the oscilloscope (we will use oscilloscope here only to trace the output waveform) and save the data for each measurement. BE CAREFUL NOT TO MEASURE THE INPUT AND OUTPUT VOLTAGES SIMULTANEOUSLY.

v) Multiply the V_{ac} at the input by $\sqrt{2}$ to get the peak value and calculate V_{dc} Using the formula $V_{dc} = 2V_{max}/\pi$. Compare this value with the measured V_{dc} at the output.

vi) Calculate the ripple factor and efficiency.

vii) Connect the capacitor across the output for each load resistor. Measure the output a.c. and d.c. voltages once again and calculate the ripple factor. Trace the input and output waveforms in oscilloscope and notice the change. (If time permits you could also use different values of capacitors and study the output)

Observations:

vi) Code number of diode = _________

vii) Input Voltage: V_{ac} =__________Volt

Table(I): Full-wave rectifier w/o filter

Sl. No	Load R_L (kΩ)	Input Current I_{ac} (mA)	Output Voltage			Ripple Factor *r*	Efficiency η $(V_{dc}^2/R_L)/V_{ac}I_{ac}$ (%)
			V_{ac} (Volt)	V_{dc} (Volt)	$2V_{max}/\pi$ (Volt)		
1							
2							
3							

Table(II): Full-wave rectifier with filter (C =_____μF)

Sl. No	Load R_L (kΩ)	Output Voltage		Ripple Factor r
		V_{ac} (Volt)	V_{dc} (Volt)	
1				
2				
3				

(III) Input and output waveforms:

Waveforms without Filter:

R_L = _______

Input **Output**

(Paste data here)

Waveforms with Capacitor Filter:

R_L = _______

Input **Output** (Paste data here)

Discussions:

Precautions: