LAB#2b: HALF-WAVE RECTIFIER CIRCUIT WITHOUT AND WITH FILTER

Objectives:

1. To construct a half-wave rectifier circuit and analyze its output.
2. To analyze 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.

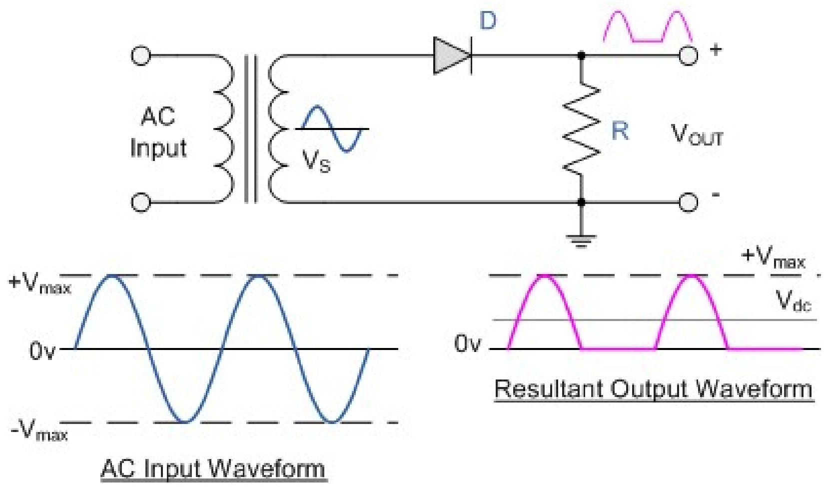

Fig.1: Half-wave rectifier circuit

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,

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

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

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

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.

$$\begin{aligned}\eta &= d.c.power\ delivered\ to\ load / a.c.power\ at\ input \\ &= V_{dc} I_{dc} / V_{ac}\, I_{ac} \\ &= \frac{I_{dc}^2 R}{I_{ac}{}^2 / (r_d + R)} = \frac{(0.318V_{\max})^2}{(0.5V_{\max})^2 \left(1 + \frac{r_d}{R}\right)} = \frac{0.405}{\left(1 + \frac{r_d}{R}\right)}\end{aligned}$$

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.

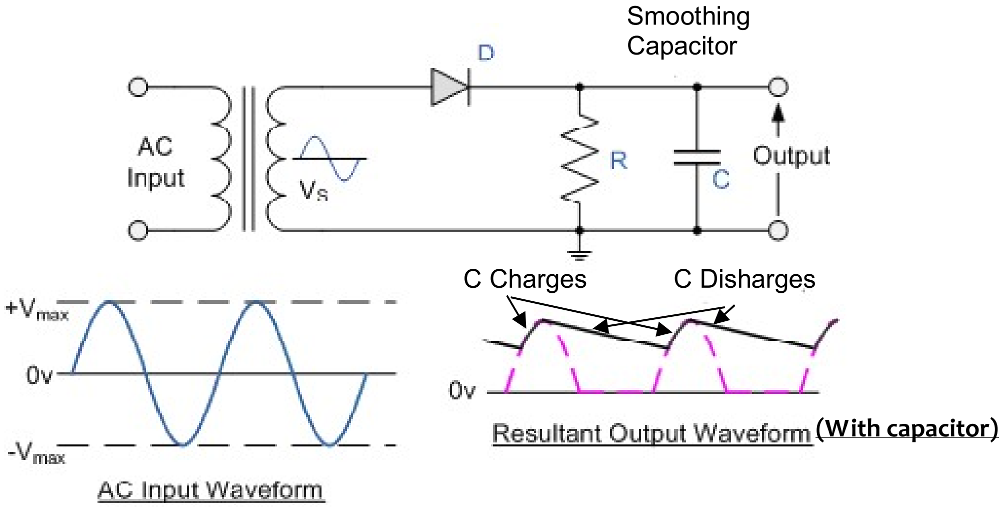

Fig.2: Half-wave rectifier circuit with capacitor filter

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/Equipments:

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

Circuit Diagram: (As shown in Figs. 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) Measure the input a.c. voltage (V_{ac}) and current (I_{ac}) and the output a.c. (V_{ac}), 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) Multiply the V_{ac} at the input by √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.

v) Feed the input and output (in DC coupling mode) to the two channels of oscilloscope. We will use oscilloscope here only to trace the output waveform. Save the data for each measurement using SAVE/LOAD or STORAGE button of the oscilloscope.

vi) Calculate the ripple factor and efficiency.

vii) Connect an electrolytic capacitor (with –ve terminal connected to ground) across the output for each load resistor and 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.

viii) Repeat the above measurement foe all values of capacitors and study the output.

Observations:

1. Code number of diode = ________
2. Input Voltage: V_{ac} = _________ Volt

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

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

Table(II): Half wave rectifier with filter (C = ____ μF) (Make separate tables for each capacitor)

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

(III) Input and output waveforms:

Waveforms without Filter:

R = ______ **Input** **Output**

(Paste data here)

Waveforms with Capacitor Filter: C = ______ μF

R = ______ **Input** **Output**

(Paste data here)

Discussions:

Precautions: