## Experiment No. 1

## HALFWAVE AND FULLWAVE RECTIFIERS

**AIM**: To study the characteristics of half wave, full wave and bridge rectifier with and without filter and calculate the ripple factor, rectification efficiency and % regulation.

**COMPONENTS AND EQUIPMENT REQUIRED**: Diodes, Resistor, Transformer, Voltmeter, Ammeter, Breadboard and CRO.

**THEORY:** Rectifier changes ac to dc and it is an essential part of power supply. The unique property of a diode, permitting the current to flow in one direction, is utilised in rectifiers.

### Half Wave Rectifier

Mains power supply is applied at the primary of the step-down transformer. All the positive half cycles of the stepped down ac supply pass through the diode and all the negative half cycles get eliminated. Peak value of the output voltage is less than the peak value of the input voltage by 0.6V because of the voltage drop across the diode.

For a half wave rectifier, $V_{rms} = V_m/2$ and $V_{dc} = V_m/\pi$: where $V_{rms}$ = rms value of input, $V_{dc}$ = Average value of input and $V_m$ = peak value of output.

Ripple factor r $=V_{r,rms}/V_{dc}$ where $V_{r,rms}$ is the rms value of the ac component. Since $V_{rms}^2 = V_{r,rms}^2 + V_{dc}^2$, ripple factor r $= \sqrt{(V_{rms}/V_{dc})^2 - 1} = 1.21$.

### Full Wave Rectifier

During the positive half cycle of the transformer secondary voltage, diode $D_1$ is forward biased and $D_2$ is reverse biased. So a current flows through the diode $D_1$, load resistor $R_L$ and upper half of the transformer winding. During the negative half cycle, diode $D_2$ becomes forward biased and $D_1$ becomes reverse biased. The current then flows through the diode $D_2$, load resistor $R_L$ and lower half of the transformer winding. Current flows through the load resistor in the same direction during both the half cycles. Peak value of the output voltage is less than the peak value of the input voltage by 0.6V because of the voltage drop across the diode.

For a full wave rectifier, $V_{rms} = V_m/\sqrt{2}, V_{dc} = 2V_m/\pi$

$$\text{Ripple factor r} = \sqrt{(V_{rms}/V_{dc})^2 - 1} = 0.48$$

**Bridge Rectifier**

During the positive half cycle of the secondary voltage, diodes $D_1$ and $D_2$ are forward biased and diodes $D_3$ and $D_4$ are reverse biased. Therefore, current flows through the secondary winding, diode $D_1$, load resistor $R_L$ and diode $D_2$. During the negative half cycle, $D_3$ and $D_4$ are forward biased and diodes $D_1$ and $D_2$ are reverse biased. Therefore, current flows through the secondary winding, diode $D_3$. Load resistor $R_L$ and $D_4$. During both the half cycles, the current flows through the load resistor in the same direction. Peak value of the output voltage is less than the peak value of the input voltage by 1.2V due to the voltage drop across two diodes. The ripple factor of the bridge rectifier is the same as that of full wave rectifier.

**Rectifiers with Filter**

All rectifier outputs contain considerable amount of ripple in addition to the DC component. In order to avoid AC components, a filter is connected at the output of the rectifier.

Capacitor input filter, choke input filter, RC, CRC, LC, and CLC filters are the usually used filters. Capacitor input filter is the simplest and cheapest. A high value capacitor C is connected in shunt with the load resistor $R_L$. Capacitor charges to peak voltage $V_m$ when the half cycle appears at the output. After the peak value is passed, the capacitor discharges through the load resistor slowly since the diode is reverse biased by the capacitor voltage. Before the capacitor voltage drops substantially, next output cycle arrives and the capacitor recharges to peak.

The rms value of the filtered output is calculated assuming that the wave as a triangular wave and it is $V_{r,rms} = V_{rpp}/2\sqrt{3}$, where $V_{rpp}$ is the peak to peak value of the ripple voltage.

$$V_{dc} = V_m - (V_{rpp}/2), \text{ Ripple factor r} = V_{r,rms}/V_{dc}$$

For a half wave rectifier the ripple factor is also expressed as a function of capacitance and load resistance, $r = 1/2\sqrt{3}fR_LC$. For a full wave rectifier, it is given by the expression, $r = 1/4\sqrt{3}fR_LC$. f is the mains supply frequency 50 Hz.

**Rectifier Efficiency**

Rectifier efficiency is defined as the ratio of DC output power to the input power from the AC supply. Even with ideal rectifiers with no losses, the efficiency is less than 100% because some of the output power is AC power rather than DC which manifests as ripple superimposed on the DC waveform.

$$\eta = \frac{V_{dc}{}^2}{V_{ac}{}^2}$$

PERCENTAGE REGULATION:

It is a measure of the variation of DC output voltage as a function of DC output current i.e. variation in load.

$$\% \text{ regulation} = \left(\frac{V_{NL} - V_{FL}}{V_{FL}}\right) * 100\%$$

$V_{NL}$= Voltage across load resistance when minimum current flows through it.

$V_{FL}$ = Voltage across load resistance when maximum current flows through it.

### 1.4. PROCEDURE:

1. Wire up the half wave rectifier circuit without capacitor after testing all the components.
2. Switch on the main supply. Observe the transformer secondary voltage waveform and output voltage waveform across the load resistor, simultaneously on the CRO screen. Note down $V_m$ and calculate $V_{rms}$ and $V_{dc}$.
3. Calculate the ripple factor, rectifier efficiency and % regulation using the expressions.
4. Connect the capacitor filter and observe the waveforms. Note down $V_m$ and $V_{rpp}$ and calculate ripple factor, rectifier efficiency and %regulation using the expressions. Repeat for different capacitor values.
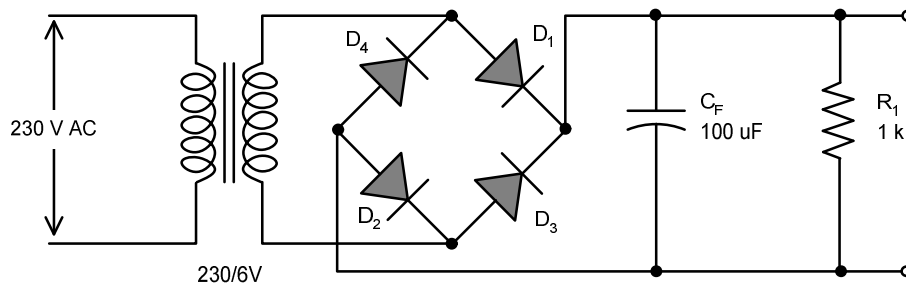5. Repeat the above steps for full wave and bridge rectifiers.

### CIRCUIT DIAGRAMS

Half wave rectifier with filter:
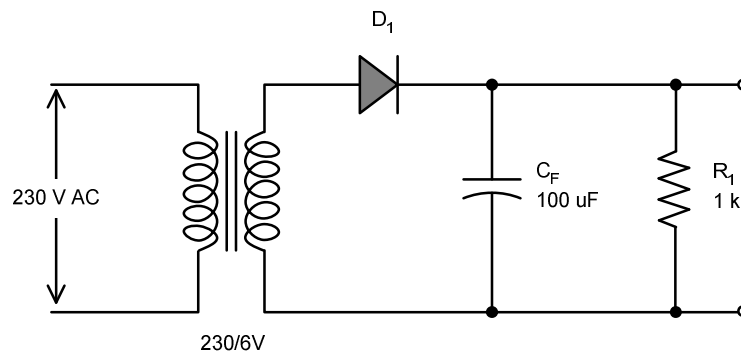
Full wave rectifier with filter:
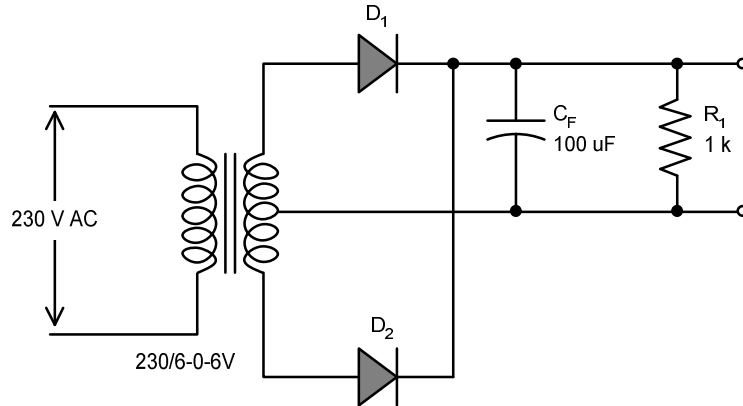


Bridge rectifier with filter:



**DESIGN**

Select 230V/6V-0-6V, 100 mA centre-tapped transformer and diodes 1N4001.

DESIGN OF LOAD RESISTOR $R_L$:

Load resistor $R_L$ should be high enough to make the capacitor discharge slowly. Same time it should limit the current through the diodes. Assume a current of 5 mA to flow through the diodes.

Then $R_L = \dfrac{6\sqrt{2}- 1.4}{0.005}\,\Omega = 920\Omega$. Because voltage drop across the two diodes together are 1.4V.

Select $R_L = 1k$.

DESIGN OF CAPACITANCE C:

The required ripple factor of capacitor input filter is 3%. Theoretical value of $r = 1/4\sqrt{3}fR_LC$.

Power supply frequency f = 50 Hz. Assume $R_L$ =1 k. Then C ≈ 100μF.

**TABULAR COLUMN**

Table 1: Rectifier without filter

| | $V_m$ | $V_{rms} = V_m/2$ | $V_{dc} = V_m/\pi$ | $r = \sqrt{(V_{rms}/V_{dc})^2 - 1}$ |
|---|---|---|---|---|
| **HWR** | | | | |
| | $V_m$ | $V_{rms} = V_m/\sqrt{2}$ | $V_{dc} = 2V_m/\pi$ | $r = \sqrt{(V_{rms}/V_{dc})^2 - 1}$ |
| **FWR** | | | | |
| | $V_m$ | $V_{rms} = V_m/\sqrt{2}$ | $V_{dc} = 2\,V_m/\pi$ | $r = \sqrt{(V_{rms}/V_{dc})^2 - 1}$ |
| **BR** | | | | |

Table 2: Rectifiers with capacitor filter

| Type | $V_m$ | $V_{rpp}$ | $V_{r,rms} = V_{rpp}/2\sqrt{3}$ | $V_{dc} = V_m - V_{rpp}/2$ | $r = V_{r,rms}/V_{dc}$ |
|---|---|---|---|---|---|
| **HWR** | | | | | |
| **FWR** | | | | | |
| **BR** | | | | | |

**WAVEFORMS**

Typical waveforms of half wave rectifier without filter and with filter are shown in the figure below