Experiment No. - 01

Half wave rectifier and Full wave rectifier

Object :-

Study the wave shapes of half and full wave rectifier by CRO and determine the ripple factor of half and full wave rectifier.

Appratus required :-

1) Half wave and Full wave Rectifier Kit.
2) Connecting Probes (Leads), CRO Connecting Probe.
3) Cathode Ray Oscilloscope (CRO)
4) Power Supply

Principle :-

1) Alternating current (AC)

Alternating current (AC) describes the flow of charges direction periodically. As a result, the voltage level also reverses along with the current. AC is used to deliver power to houses, office buildings, etc. The AC voltage of a periodic waveform may be written as

$$V(t) = V_m \sin(\omega t). \quad \text{----(1)}$$

where $\omega = 2\pi/T$ is the angular frequency of the waveform or voltage and T is the time period of the voltage.

Average voltage over the time period

The average value of V(t) over the time period T is defined as

$$\boxed{\bar{V} = \frac{1}{T}\int_0^T V(t)\,dt} \quad \text{.....}(2)$$

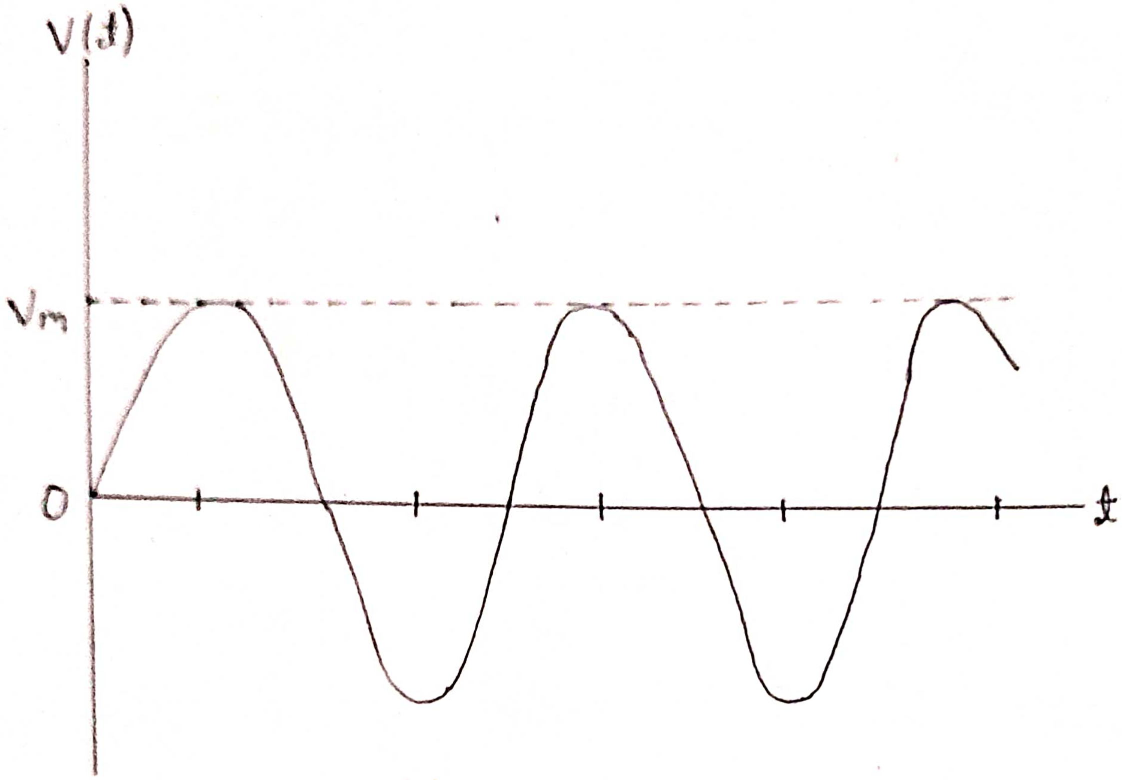

fig. :- AC voltage V(t)

Hence

$$\bar{V} = \frac{V_m}{T}\int_0^T \sin(\omega t)\,dt$$

$$= \frac{V_m}{T}\left[-\frac{\cos(\omega t)}{\omega}\right]_0^T$$

$$= \frac{V_m}{\omega T}\left[-\cos(\omega T) + \cos 0\right]$$

$$= \frac{V_m}{2\pi}\left[-\cos(2\pi) + \cos 0\right]$$

$$\bar{V} = \frac{V_m}{2\pi}(-1+1)$$

$$\bar{V} = 0. \quad \text{.....(3)}$$

Therefor, the average value of an AC valtage over the time period of the oscillation is zero.

Average voltage over half of the time period

Since the average value of the AC valtage over the time period is zero, we may calculate the average value over the half of the time period using a similar definition as (2) Therefore:

$$V_{avg} = \frac{1}{T/2}\int_0^{T/2} V(t)\,dt$$

$$= \frac{2V_m}{T}\int_0^{T/2} \sin(\omega t)\,dt$$

$$= \frac{2V_m}{T}\left[-\frac{\cos(\omega t)}{\omega}\right]_0^{T/2}$$

$$V_{avg} = \frac{2V_m}{\omega T}\left[-\cos(\omega T/2) + \cos 0\right]$$

$$= \frac{2V_m}{2\pi}\left[-\cos(\pi) + \cos 0\right]$$

$$= \frac{V_m}{\pi}(+1+1)$$

$$= \frac{2}{\pi} V_m$$

$$\approx 0.637\, V_m \quad \text{-----(4)}$$

The RMS value of the AC voltage

$$V_{rms}^2 = \frac{V_m^2}{2} \quad \text{-----(5)}$$

Therefore ,

$$V_{rms} = \frac{V_m}{\sqrt{2}}$$

$$\approx 0.707\, V_m \quad \text{-----(6)}$$

2) Half wave rectifier :-

A half wave rectifier is a type of rectifier that only allows one half - cycle of an AC voltage waveform to pass. blocking the other half - cycle. Half - wave rectifiers are used to convert AC voltage to DC voltage. and only require a single diode to construct. A half wave rectifier is the simplest form of rectifier available.

Fig 2 shows the input AC voltage waveform, the circuit diagram and the final output voltage waveform of a half wave rectifier. During the positive half cycle, the diode is forward biased making the current flow through the load resistor. while during the Negative half cycle the diode is reverse biased so it stops the current flow through the the load resistor. Since current can not flow through the load during the negative half cycles, the output voltage is equal to zero.

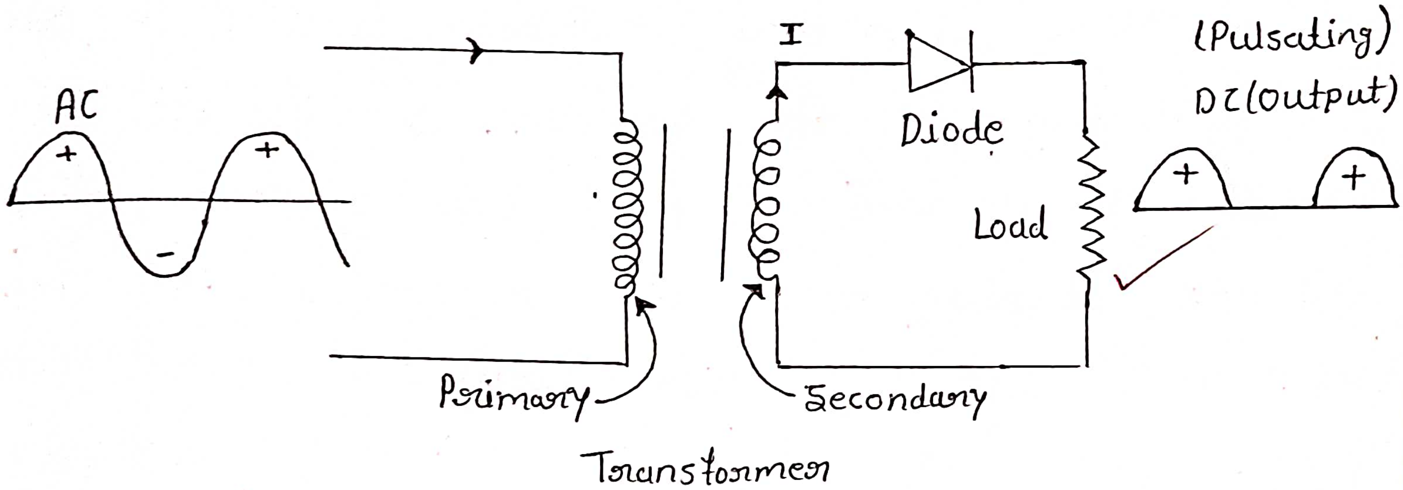

fig :- Half wave rectifier circuit diagram and waveform

Therefor, for an AC voltage given by (1) the output Voltage of a half wave rectifier will be (for an ideal diode)

$$V_o(t) = \begin{cases} V_m \sin(\omega t), & 0 \leq t \leq T/2 \\ 0, & T/2 \leq t \leq T \end{cases}$$

RMS value of the output voltage of a ~~ful~~ half wave rectifier:-

$$\boxed{V_{rms} = \frac{V_m}{2}} \quad ---(7)$$

Ripple factor of half wave rectifier :-

Ripple is the unwanted AC component remaining when converting the AC voltage waveform into a DC waveform. Even though we try out best to remove all AC components, there is still some small amount left on the output side which pulsates the DC waveform. This undesirable AC component is called ripple.

To quantify how well the half wave rectifier can convert the AC voltage into DC voltage, we use what is known as the ripple factor (represented by γ). The ripple factor is the ratio between the RMS value of the AC voltage and the DC voltage of the rectifier.

$$\gamma = \frac{\text{RMS value of the AC component}}{\text{Value of DC component}} = \frac{V_{r(rms)}}{V_{dc}}$$

Note that the RMS value of the AC component of the signal is $V_{r(rms)}$ and V_{rms} is the RMS value of the whole voltage signal.

o calculate $V_{r(rms)}$, the RMS value of the AC omponent present in the output of the half wave rectifier we write the output voltage as.

$$V_o(t) = V_{ac} + V_{dc},$$

where V_{ac} is the AC component remaining when onverting the AC voltage waveform into a DC waveform. The RMS value of the AC component present in the output of the half wave rectifier is given by

$$V_{r(rms)} = \left[\frac{1}{T}\int_0^T V_{ac}^2\, dt\right]^{1/2}$$

Therefore,

$$V^2_{r(rms)} = \frac{1}{T}\int_0^T (V_0 - V_{dc})^2\, dt$$

$$= \frac{1}{T}\int_0^T (V_0^2 - 2V_0V_{dc} + V_{dc}^2)\, dt$$

$$= \frac{1}{T}\int_0^T V_0^2\, dt - \frac{2V_{dc}}{T}\int_0^T V_0\, dt + V_{dc}^2$$

$$= V^2_{rms} - 2V^2_{dc} + V^2_{dc}$$

$$= V^2_{rms} - V^2_{dc}$$

Hence the formula to calculate the ripple factor can be written as

$$\gamma = \frac{V_{r(rms)}}{V_{dc}} = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1}$$

Using the values of V_{dc} and V_{rms} given in (7) respectively for the half wave rectifier we find the ripple factor as

$$\gamma = \sqrt{\left(\frac{V_m}{2} \times \frac{\pi}{V_m}\right)^2 - 1}$$

$$\gamma = \sqrt{\left(\frac{\pi}{2}\right)^2 - 1}$$

$$\boxed{\gamma \approx 1.21}$$

Note that to construct a good rectifier, one should keep the ripple factor as low as possible. This is why capacitors and inductors as filters are used to reduce the ripples in the circuit.

Observation table :-

S.N.	Eac Measured by mm	Edc Measured by mm
1.	3.42	2.70

$$\frac{E_{ac}}{E_{dc}} = \frac{3.42}{2.70} = 1.26$$

Advantages of half wave rectifier

The main advantage of half-wave rectifiers is in their simplicity. As they do not require as many components, they are simpler and cheaper to setup and construct. As such, the main advantages of half-wave rectifiers are.

- Simple (lower number of components)

- Cheaper up front cost (as their is less equipment. Although there is a higher cost over time due to increased power losses).

Disadvantages of half wave rectifier

The disadvantages of half-wave rectifiers are:

- They only allow a half-cycle through per sinewave, and the other half-cycle is wasted. This leads to power loss.

- They produces a low output voltage.

- The output current we obtain is not purely DC, and it still contains a lot of ripple (i.e. it has a high ripple factor)

3) Full wave rectifier :-

A full wave rectifier converts both halves of each cycle of an alternating wave (AC signal) into pulsating DC signal. Figure shows the input AC voltage waveform, the circuit diagram and the final output voltage waveform of a center tapped full wave rectifier.

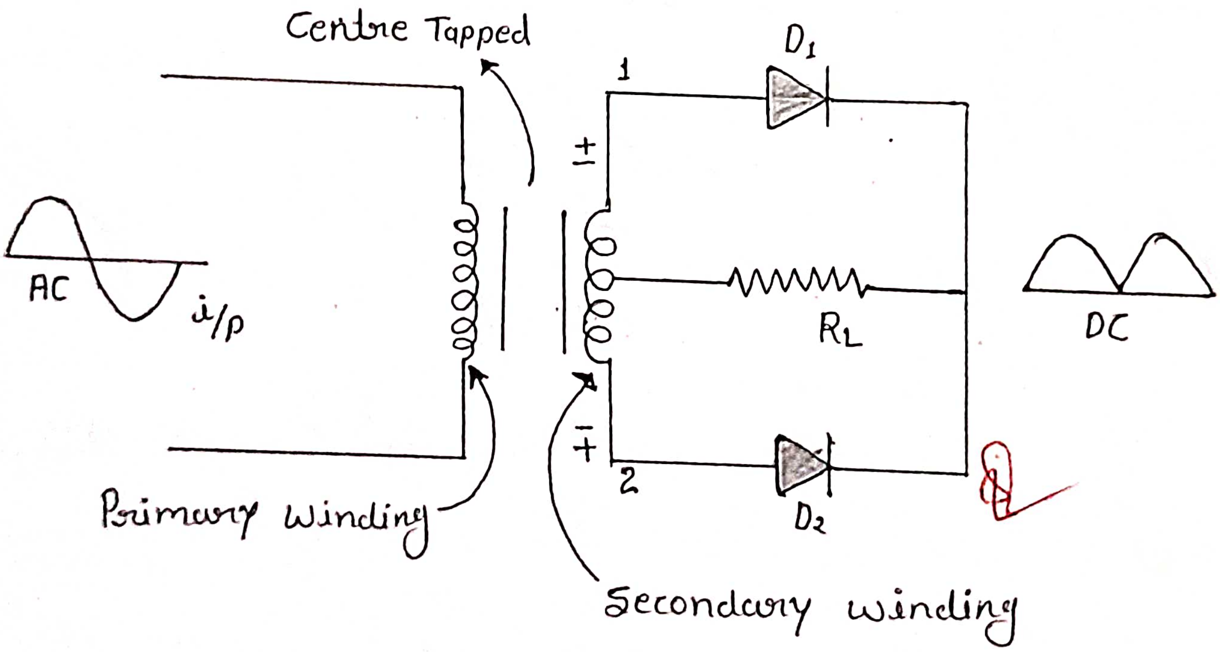

fig :- Center tapped full wave rectifier circuit diagram and waveform

For an AC voltage given by the waveform of the output voltage of a full wave rectifier can be written as (for an ideal diode)

$$V_o(t) = \begin{cases} V_m \sin(\omega t), & 0 \le t \le T/2 \\ V_m \sin(\omega t - \pi), & T/2 \le t \le T \end{cases}$$

Ripple factor of full wave rectifier

$$\gamma = \sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1}$$

$$= \sqrt{\left(\frac{\pi}{2\sqrt{2}}\right)^2 - 1}$$

$$\approx 0.48$$

Observation table :-

S.N.	Eac Measured by MM	Edc Measured by mm
1.	2.78	5.45

$$\frac{E_{ac}}{E_{dc}} = \frac{2.78}{5.45}$$

$$= 0.51$$

Efficiency of full wave rectifier

$$\eta = \frac{P_{dc}}{P_{dc}}$$

$$= \left(\frac{V_{dc}}{V_{rms}}\right)^2 \times \left(1 + \frac{r_f}{R_L}\right)$$

$$\approx 0.8106 \left(1 + \frac{r_f}{R_L}\right)$$

In reality r_f is much smaller then R_L. If we neglect r_f compare to R_L then the efficiency of the rectifier is maximum. Therefore,

$$\eta_{max} \approx 0.8106 = 81.06\%$$

Advantages of full wave rectifier

- Full wave rectifiers have higher rectifying efficiency than half-wave rectifiers. This means that they convert AC to DC more efficiently.

- They have low power loss because no voltage signal is wasted in the rectification process.

- The output voltage of center tapped full wave rectifier has lower ripples than a half wave rectifiers.

Disadvantages of full wave rectifier

- The center tapped rectifier is more expensive than half-wave rectifier and tends to occupy a lot of space.

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