2.4. The Basic DC Power Supply

All active electronic devices require a source of constant DC that can be supplied by a battery or a DC power supply. The **DC power supply** converts the standard 220 V, 50 Hz AC voltage available at wall outlets into a constant dc voltage. The DC power supply is one of the most common circuits you will find, so it is important to understand how it works. The basic block diagram of the complete power supply is shown in the following figure.

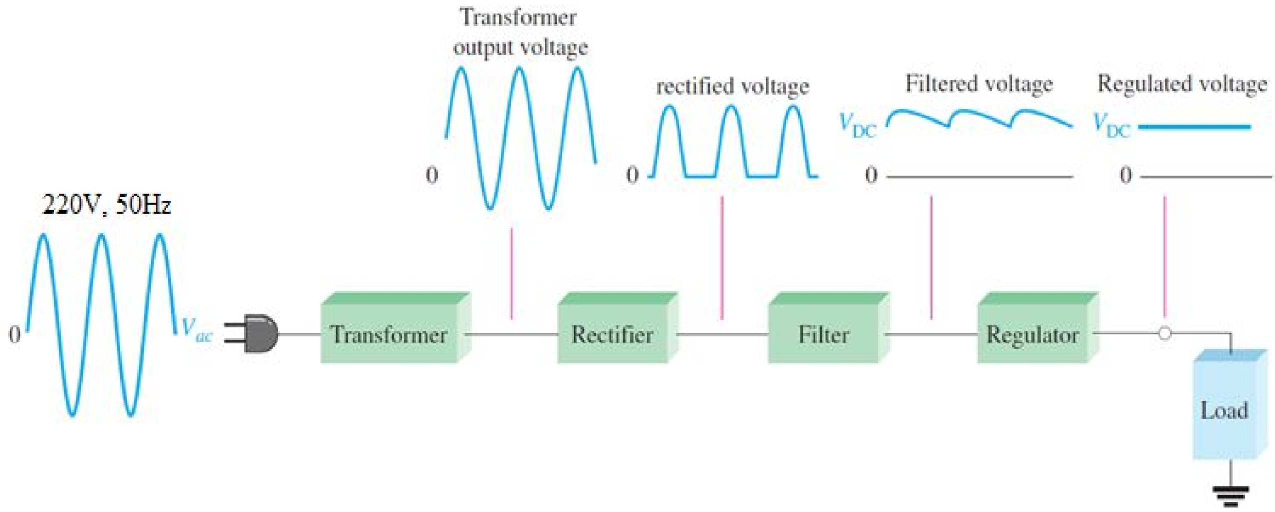


Fig.2.9. The Basic DC Power Supply

1) Generally the AC input line voltage is stepped down to a lower ac voltage with a **transformer** (a **transformer** changes ac voltages based on the turn ratio between the primary and secondary).

2) The **Rectifier** can be either a half-wave rectifier or a full-wave rectifier (covered in the previous part).

3) The **Filter** eliminates the fluctuations in the rectified voltage and produces a relatively smooth dc voltage.

4) The **Regulator** is a circuit that maintains a constant DC voltage for variations in the input line voltage or in the load. Regulators vary from a single semiconductor device to more complex integrated circuits.

5) The **load** is a circuit or device connected to the output of the power supply and operates from the power supply voltage and current.

Before going into the details of a filter circuit we have to take in consideration the following notes:

- ✓ The output of the rectifier is not pure DC but it also contains some AC components. The AC component is called as ripple.
- ✓ When we measure the output voltage of a rectifier (or rectifier +filter) circuit, using a DC voltmeter and an AC (RMS) voltmeter, the DC voltmeter will read only the average or DC level of the output voltage. The AC (RMS) meter will read only the RMS value of the AC component of the output voltage.

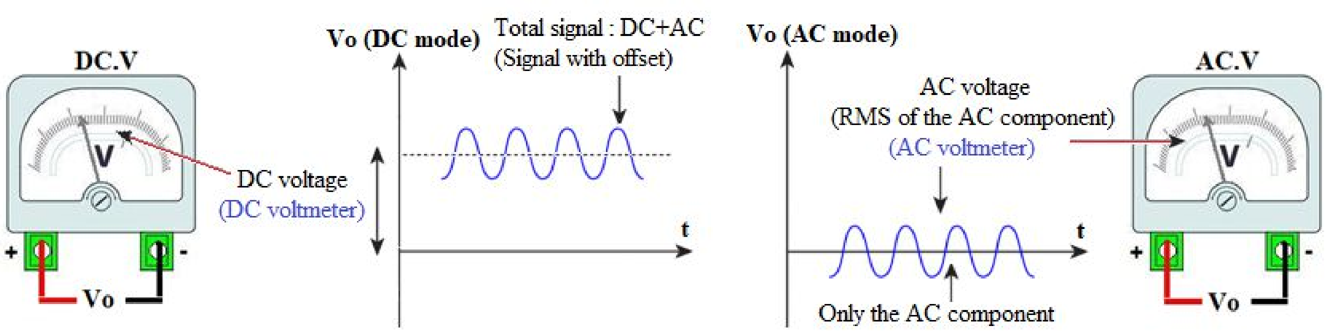
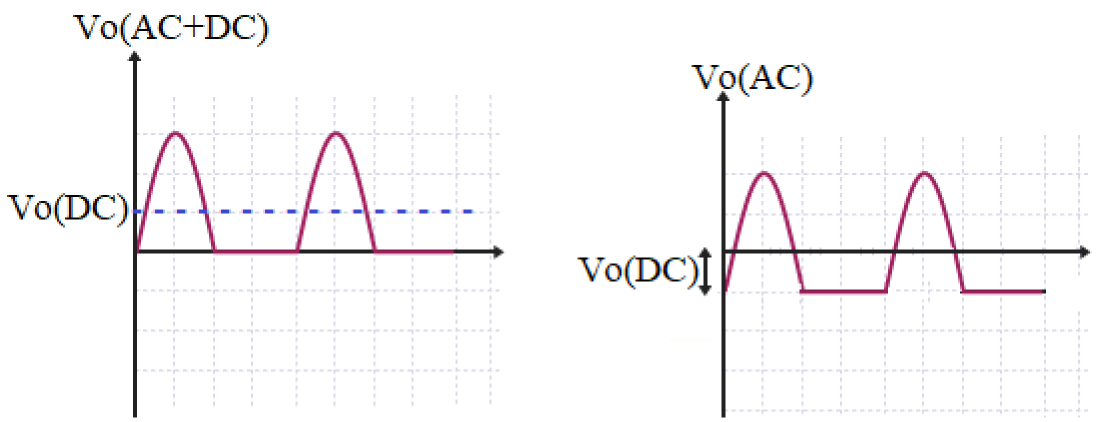


Fig.2.10. The measured output voltage

Example: Half wave rectifier (When we use the oscilloscope).



Vo (Total signal) Vo (only the ripple signal)

- ***Ripple factor:***

The ripple factor is defined as the ratio of the RMS of the AC component (ripple voltage Vr) to the DC component in the output.

$$r = \frac{\text{RMS value of AC component}}{\text{DC component}} = \frac{Vr\ (RMS)}{Vo(DC)}$$

$$r\% = \frac{Vr\ (RMS)}{Vo(DC)} x\ 100\%$$

- ✓ The ripple factor indicates magnitude of AC component in the output.
- ✓ Higher value of ripple factor means higher AC component in the output of the rectifier.
- ✓ Smaller value of ripple factor means effective rectification.

The RMS of the ripple voltage Vr:

$Vo = Vr + Vo(DC)$ (Vo is the total output signal)

$$Vr = Vo - Vo(DC)$$

$$\mathrm{Vr(RMS)}^2 = \frac{1}{T}\int_0^T (Vo - Vo(DC)\ )^2\ dt$$

$$\mathrm{Vr(RMS)}^2 = \frac{1}{2\pi}\int_0^{2\pi} Vo^2\ d\omega t + \frac{1}{2\pi}\int_0^{2\pi} Vo(DC)^2\ d\omega t - \frac{2}{2\pi}\int_0^{2\pi} Vo * Vo(DC)\ d\omega t$$

$$\mathrm{Vr(RMS)}^2 = \mathrm{Vo(RMS)}^2 + Vo(DC)^2 - 2Vo(DC) * \frac{1}{2\pi}\int_0^{2\pi} Vo * d\omega t$$

$$\mathrm{Vr(RMS)}^2 = \mathrm{Vo(RMS)}^2 + Vo(DC)^2 - 2Vo(DC) * Vo(DC)$$

$$\mathrm{Vr(RMS)}^2 = \mathrm{Vo(RMS)}^2 - Vo(DC)^2$$

$$\boxed{\mathrm{Vr(RMS)} = \sqrt{\mathrm{Vo(RMS)}^2 - Vo(DC)^2}}$$

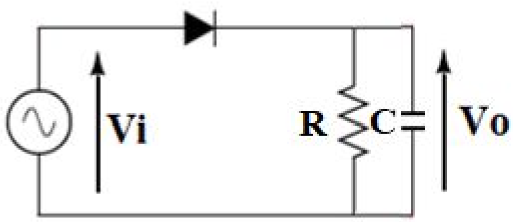
The ripple factor:

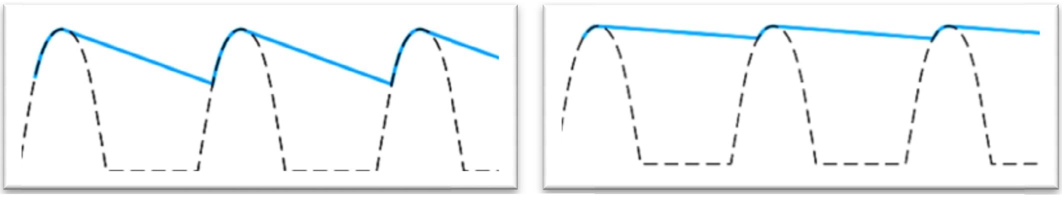
$$\boxed{r = \frac{Vr\ (RMS)}{Vo(DC)} = \sqrt{\frac{\mathrm{Vo(RMS)}^2}{Vo(DC)^2} - 1}}$$

Rectification	Half wave rectifier	Full wave rectifier
Vo(RMS)	Vop/2	Vop/√2
Vo(DC)	Vop/π	2Vop/π
Ripple factor “r”	1.21	0.48

2.5. Rectifier circuit with a filter capacitor

The DC voltage derived from an AC source signal by rectifying and filtering will have some AC variation (the ripple voltage Vr). The smaller the AC variation with respect to the DC level, the better the filter circuit’s operation.





Vo (with Large ripple) Vo (with small ripple)

Fig.2.11.1. Rectifier circuit with a filter capacitor

- ***The ripple voltage (peak to peak value)***

The voltage across the capacitor:
Vop : is the peak output voltage
Vo: is the total output voltage ⇒ **$V_o(t)= V_{op}\, e^{-t'/\tau}$** (With : τ =RC)
T' : is the discharging time.
VoL: is The minimum output voltage ⇒ **$V_{oL}= V_{op}\, e^{-T'/RC}$**
Vo(DC) : is the average of the output voltage
Vr(p-p): is the peak to peak ripple voltage.

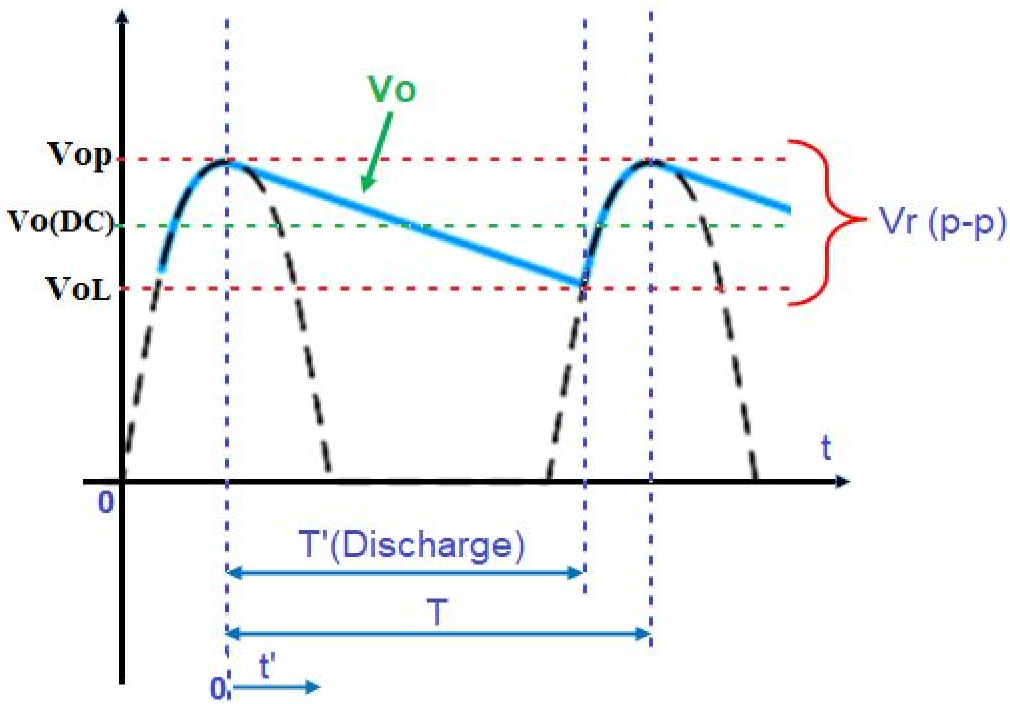


Fig.2.11.2. Voltage across the capacitor

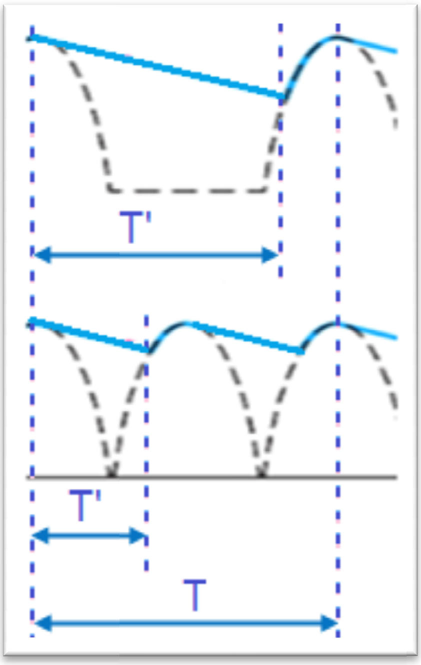
Vr(p-p)=Vop-VoL =Vop $(1 - e^{-T'/RC})$.........................(1)

For small ripple (RC>>T) :

$e^{-T'/RC} \approx 1 - \frac{T'}{RC}$ ....(2)

(2) in (1)

Vr(p-p)= $\frac{Vop\,T'}{RC}$ .... (3)



T' ≈ T for Half wave rectification.
Vr(p-p)= $\frac{\boldsymbol{Vop\,T}}{\boldsymbol{RC}} = \frac{\boldsymbol{Vop}}{\boldsymbol{RCf}}$

T' ≈ T/2 for Full wave rectification.
Vr(p-p)= $\frac{\boldsymbol{Vop\,T}}{\boldsymbol{2RC}} = \frac{\boldsymbol{Vop}}{\boldsymbol{2RCf}}$

Note: To get good and effective filtering: RC ≥10 T

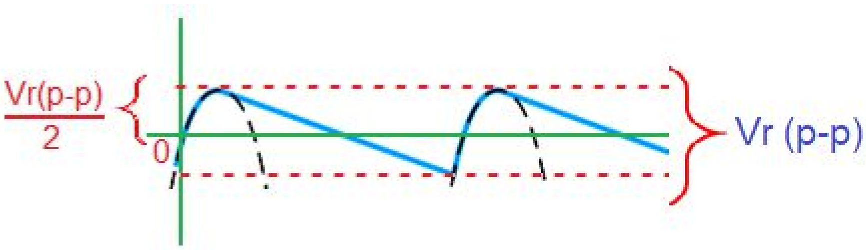
- ***The RMS of the ripple voltage (Vr(RMS))***

When we select the AC mode (on the oscilloscope) as a result we will get a pure AC signal (ripple signal).
To find the RMS of this ripple we have to go to the nearest approximation of this signal which is the triangular signal.

Vr(RMS) = $\frac{\mathbf{Vr(p-p)/2}}{\sqrt{\mathbf{3}}} = \frac{\mathbf{Vr(p\text{-}p)}}{\mathbf{2\sqrt{3}}}$

From **Fig.5.2** :

Vo(DC) = $\boldsymbol{Vop} - \frac{\mathbf{Vr(p\text{-}p)}}{\mathbf{2}}$



***For Half wave rectification*:**

$$\mathbf{Vr(RMS)} = \frac{Vop}{2\sqrt{3}RCf}$$

$$\mathbf{Vo(DC)} = Vop\left(1 - \frac{1}{2RCf}\right)$$

$$\mathbf{r} = \frac{\mathrm{Vr(RMS)}}{\mathrm{Vo(DC)}}$$

***For Full wave rectification*:**

$$\mathbf{Vr(RMS)} = \frac{Vop}{4\sqrt{3}RCf}$$

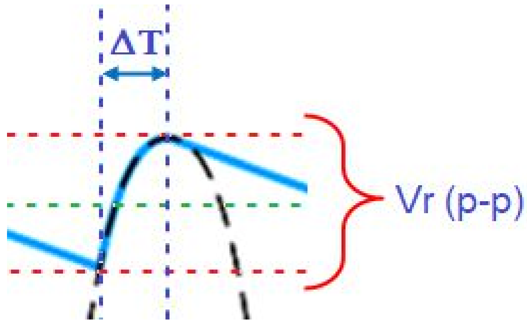
$$\mathbf{Vo(DC)} = Vop\left(1 - \frac{1}{4RCf}\right)$$

$$\mathbf{r} = \frac{\mathrm{Vr(RMS)}}{\mathrm{Vo(DC)}}$$

- ***Conduction angle:***

During this interval the diode conducts.

$$\Delta T\omega \approx \sqrt{\frac{2Vr(\text{p-p})}{Vop}}$$



- ***Conduction time interval:***

$$\Delta T \approx \frac{1}{2\pi f}\sqrt{\frac{2Vr(\text{p-p})}{Vop}}$$

- ***Average current during diode conduction: (i_D (av))***

Q lost ⇒ Qc= C Vr(p-p) ....(*)

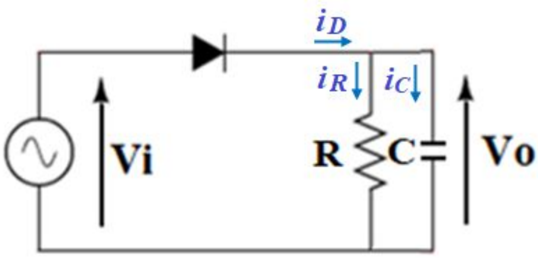
Q supplied ⇒ Qc= ic(av) . ΔT..............................(**)

(*) = (**)

C Vr(p-p)= ic(av) . ΔT

$\boldsymbol{i}$**c(av) = C Vr(p-p)/ ΔT**

$\boldsymbol{i}$**R(av) = Vo(DC)/R**



$\boldsymbol{i}$**D(av) =** $\boldsymbol{i}$**c(av) +** $\boldsymbol{i}$**R(av)**