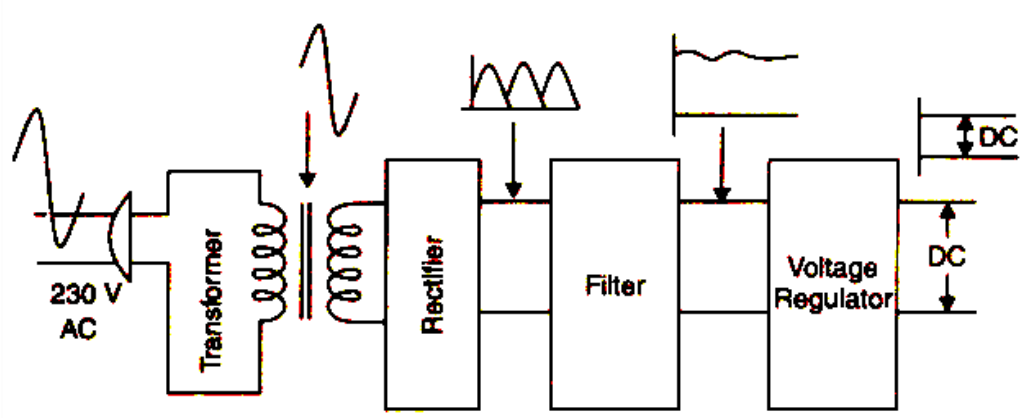
REGULATED POWER SUPPLY

With the help of block diagram, explain regulated power supply.

Block Diagram of Regulated Power Supply –

The regulated power supply contains following main blocks as

1. Transformer
2. Rectifier
3. Filter
4. Voltage Regulator



1. ***Transformer*** – A transformer changes the A.C. mains voltage into required or desired A.C. voltage. It is used to step the voltage up or down. It also provides the isolation between primary and secondary windings due to this power supply becomes shock proof.
2. ***Rectifier*** – The process of converting bidirectional A.C. into unidirectional D.C. is known as rectification and the device used for this purpose is called rectifier. Three circuits are commonly used for the rectification these are half wave rectifier, centre tapped full wave rectifier and full wave bridge rectifier. The output of rectifier is pulsating D.C. and not smooth D.C.
3. ***Filter*** – Filter is an electronic circuit which blocks unwanted ac signal and bypasses D.C. signal Different types of filter used for this purpose such as Capacitor filter, Inductor filter, L-C filter or π type filter.
4. ***Voltage Regulator*** – A voltage regulator is necessary to maintain the output voltage constant irrespective of A.C. mains and load variation. Zener regulator, transistorized regulator or three terminal IC regulator or SMPS can be used for this purpose.

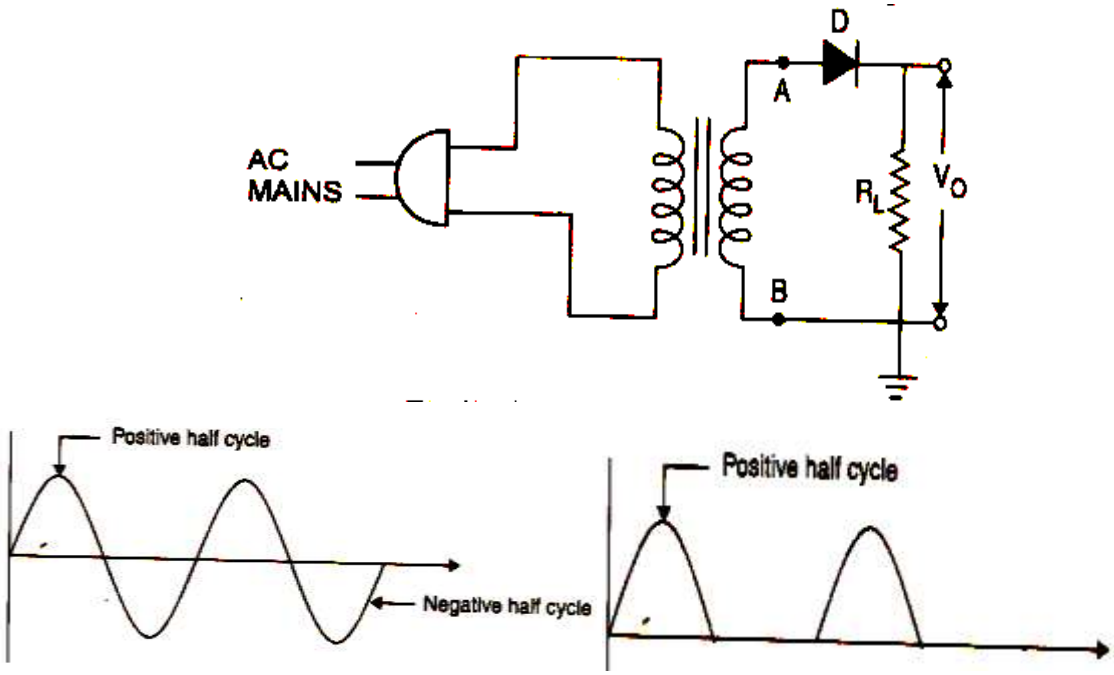
Rectifier – The process of converting bidirectional A.C. into unidirectional D.C. is known as rectification and the device used for this purpose is called rectifier.

Types of rectifier

1. Half wave rectifier
2. centre tapped full wave rectifier
3. full wave bridge rectifier

1. **Half wave rectifier –**

The A.C. supply to be rectified is applied in series with diode D and load resistance. The rectifier conducts current only during positive half cycle and negative half cycle of ac are suppressed.



Operation- During the positive half cycle of input ac voltage end A becomes positive with respect to end B. This makes diode forward biased and hence it conducts current. During the negative half cycle of input ac voltage end A becomes negative with respect to end B. This makes diode reverse biased and hence it conducts no current. Therefore current flows through diode during positive half cycle only through load R_L. It may be noted that output across load is pulsating D.C.

Advantages-

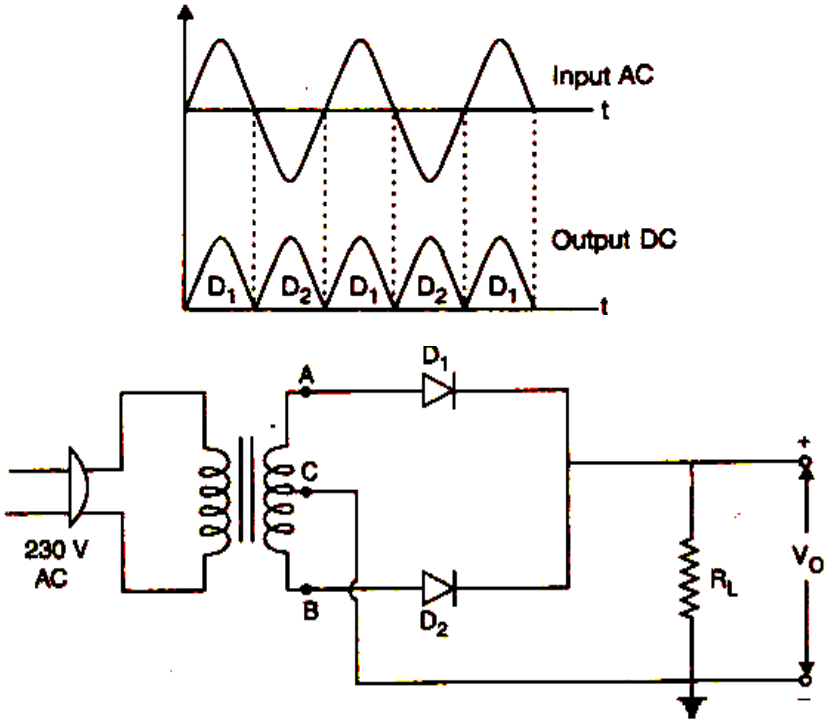
1. Only one diode and normal transformer is used.
2. Transformer is not essential for high voltage.
3. Circuit is simple and low cost.
4. PIV is only $V_{P.}$

Disadvantages –

1. The output of half wave rectifier is less since only half cycle is appears at output, it is $V_{DC} = V_P / \pi$.
2. Poor quality of DC is obtained.
3. Ripple frequency is low, it is $f_{in.}$
4. Low efficiency, it is 40.6 %.
5. Ripple factor is 1.21.

2. Center tapped Full wave rectifier –

The circuit employs two diodes D_1 and D_2 as shown in figure. A center tapped secondary winding is used with two diodes connected so that each uses one half cycle of input ac voltage.



Operation – During the positive half cycle of input ac voltage, end A becomes positive with respect to end B. This makes diode D_1 forward biased and diode D_2 reverse biased. Therefore diode D_1 conducts and D_2 does not. During the negative half cycle of input ac voltage, end A becomes negative with respect to end B. This makes diode D_2 forward biased and diode D_1 reverse biased. Therefore diode D_2 conducts and D_1does not. It may be seen that current in the load R_L is in same direction for both half cycles of input ac voltage. It may be noted that output across load is pulsating D.C.

Advantages-

1. More DC voltage than half wave rectifier
2. The ripple frequency is doubled because two cycles are developed, it is $2f_{in}$
3. Only two diodes are used.
4. Low ripple factor is 0.48.
5. High efficiency, it is 81.2 %.

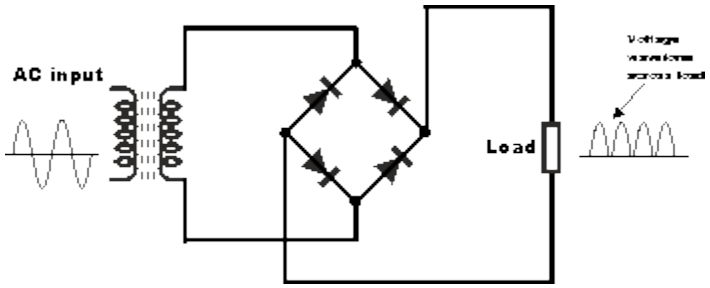
Disadvantages –

1. Diode used must have high PIV, it is $2V_P$.
2. Center tapped transformer is essential which increases the cost.
3. It is difficult to locate the center tap on secondary winding.

4. Full wave bridge rectifier –

The need for center tapped transformer is eliminated in the bridge rectifier. It contains four diodes D1, D2, D3, D4 connected to form a bridge. The ac to be rectified is applied to the

diagonally opposite ends of the bridge through the transformer. Between the two opposite ends of the bridge, the load resistance RL is connected.



Operation - During the positive half cycle of input ac voltage, end A becomes positive with respect to end B. This makes diode D_1 and D_3 forward biased and diode D_2 and D_4 reverse biased. Therefore diode D_1 and D_3 conducts and D_2 and D_4 does not. During the negative half cycle of input ac voltage, end A becomes negative with respect to end B. This makes diode D_2 and D_4 forward biased and diode D_1 and D_3 reverse biased. Therefore diode D_2 and D_4 conducts and D_1 and D_3 does not. It may be seen that current in the load R_L is in same direction for both half cycles of input ac voltage. It may be noted that output across load is pulsating D.C.

Advantages-

1. No need of center tapped transformer.
2. The output is twice that of center tapped circuit.
3. PIV is V_P that is half of the center tap circuit.
4. More DC output voltage, it is $V_{DC} = 2V_P / \pi$
5. Ripple frequency is $2f_{in.}$
6. Low ripple factor is 0.48.
7. High efficiency, it is 81.2 %.

Disadvantages –

1. It requires four diodes.
2. As two diodes conducts at a time it reduces the output voltage. It is significant in low voltage power supply.

Filter Circuit –

A filter circuit is a device which removes the ac component of rectifier output but allows the dc components to reach the load.

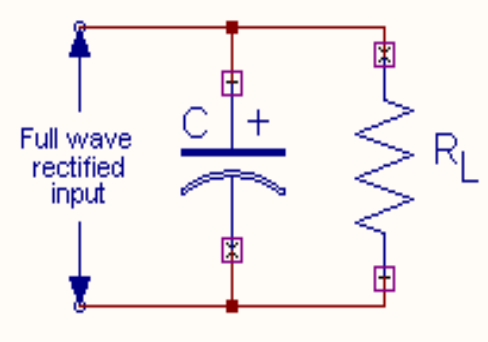
A filter circuit should be installed between rectifier and load. A filter circuit is a combination of inductor (L) and capacitor (C). A capacitor passes ac readily but does not pass dc at all. An inductor opposes ac but allows dc to pass through it. Different types of filter circuits used for this purpose such as,

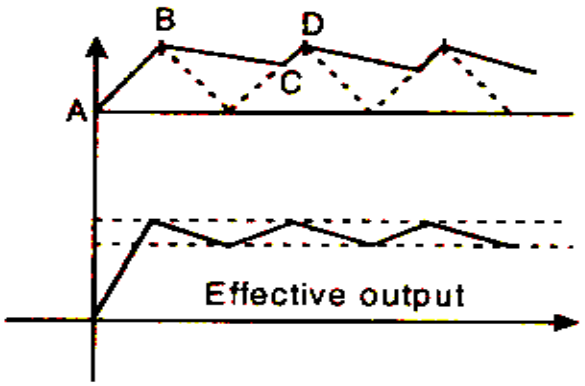
1. Capacitor filter
2. Inductor filter (Choke input filter)
3. L-C filter (π filter)

1. **Capacitor Filter –** The capacitor is connected in parallel with rectifier output and load resistance R_L. The pulsating direct voltage is applied to capacitor. As rectifier voltage increases,

the capacitor C charges. At the quarter cycle the capacitor is charged to peak value of rectifier output. Now the rectifier voltage is start to decreases, as this occurs the capacitor discharges through the load and voltage across this decrease. The voltage across load decreases slightly because immediately the next voltage peak comes and recharges the capacitor. This process is repeated again and again and output voltage is higher as it remains substantially near the peak value of rectifier output voltage.

When ac component arrives at capacitor it bypasses the ac component to the ground and will supply the dc component to the load.





Advantages –

1. It reduces the % ripple from 48% to 5%
2. This filter is suitable for low current and high voltage circuits
3. Low cost and small size as compared to inductor filter.

Disadvantages –

1. Not suitable for heavy load current because ripple increases for heavy load current.

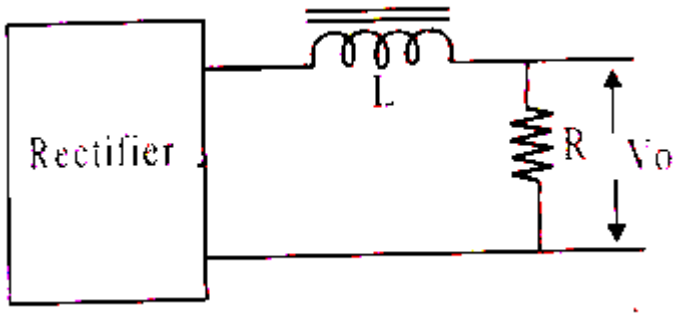
Inductor filter (Choke input filter) –

It consists of inductor connected in series with the rectifier output. The pulsating output of rectifier contains both ac and dc components. The inductor offers high opposition to the passage of ac components but negligible opposition to the dc components. The result is that most of ac components appear across choke while dc components pass through choke on its way to load.

The action can explain by mathematical equation of inductive reactance $X_L = 2\pi f L$

For DC frequency is zero, therefore $X_L = 2\pi f L = 2\pi \times 0 \times L = 0$ Thus it will pass DC

For AC, $X_L = 2\pi f L$, its opposition is high it will drop AC across it.



Advantages –

1. % ripple is minimizing for heavy load current. It reduces the % ripple from 48% to 5%
2. Output is almost smooth DC.

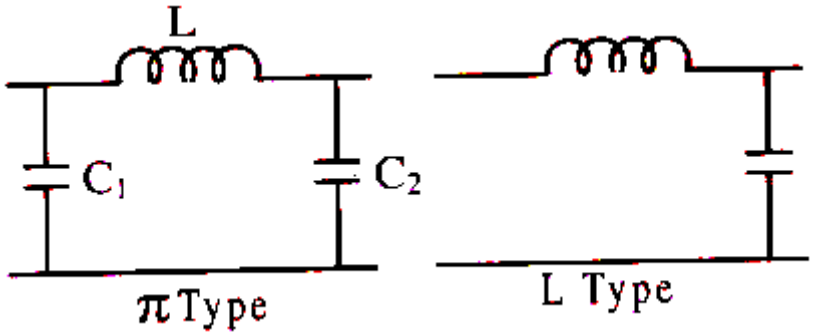
Disadvantages –

1. Circuit is not suitable for high voltage and low load current.
2. High cost and big size as compared to capacitor filter.
3. It cannot be used in half wave rectifier.

L type or π type filter –

Figure shows LC filter. It consists of choke connected in series with rectifier output and capacitor C across the load.

The choke offers high opposition to pass ac components while negligible opposition to the dc components the result is most of the ac components is blocked and the remaining ac components which are not blocked by choke , the capacitor offers bypasses the ac components while high opposition to the dc components which passes towards load. Thus, only dc components reach the load removing the ac components.



Characteristics of power supply –

1. Load regulation
2. Line regulation
3. Output impedance (Z_o)
4. Ripple Rejection (RR)

1. **Load Regulation –** A load regulation is defined as the change in output voltage

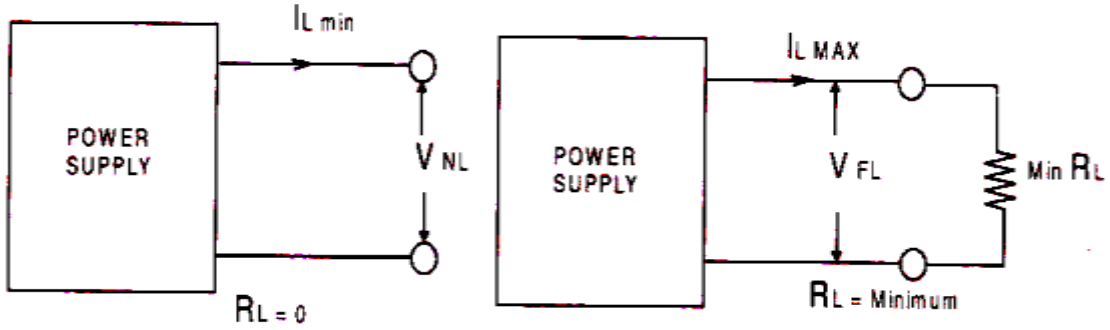
when load current changes from minimum to maximum value.

$$\% \text{ Load regulation} = \frac{V_{NL}-V_{FL}}{V_{NL}} x\ 100\ \%$$

V_{NL} = output voltage with no load or minimum load current

V_{FL} = output voltage with full load or maximum load current

For good power supply % load regulation must be very small.



2. **Line Regulation (Source Regulation) –** A line regulation is defined as the change in output voltage for the specified range of line or source voltage. This characteristic is due to variation of mains line voltage. As the source voltage changes output voltage is also changes, for better regulation line regulation must be low. It is expressed in terms of percentage.

$$\% SR = \frac{\text{Source regulation}}{\text{Nominal voltage}} \text{ x } 100$$

$$\text{S. R.}_{max} = V_{0max} - V_{0min}$$

3. **Output Impedance –** The output impedance of power supply must be minimum so that more power is delivered towards the load and power supply becomes effective for this purpose emitter follower circuit is used.
4. **Ripple Rejection –** The unwanted ac components are present at the output stage of power supply called as RR and measured in terms of dB which are reduced at output. 80dB means 10,000 times ripples are reduced. 40 dB means 100 times ripples are reduced. 20 dB means 1000 times ripples are reduced.

   Regulator Circuit –To get better performance the output of power supply must remain constant even though there is variation in load or line voltage for this purpose regulator circuit is used.

   There are four types of regulator circuits,

   1. Zener regulator
   2. Transistorized regulator
   3. Integrated Circuit regulator
   4. Switch Mode Power Supply (SMPS)

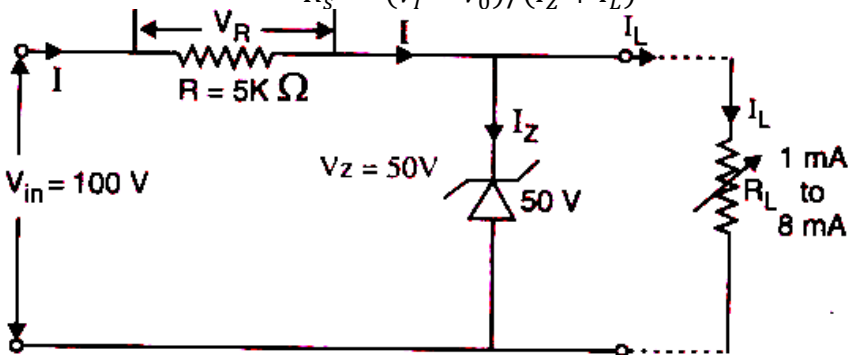
1. **Zener regulator (Shunt Regulator) -** A Zener diode can be used as a voltage regulator to provide constant voltage. The Zener diode is reverse connected across the load; the series resistance absorbs the output voltage fluctuation so as to maintain the constant voltage across the load. For operation of this circuit the voltage across input must be greater than voltage across output. i.e. $V_i > V_o$

The circuit should satisfy the following conditions,

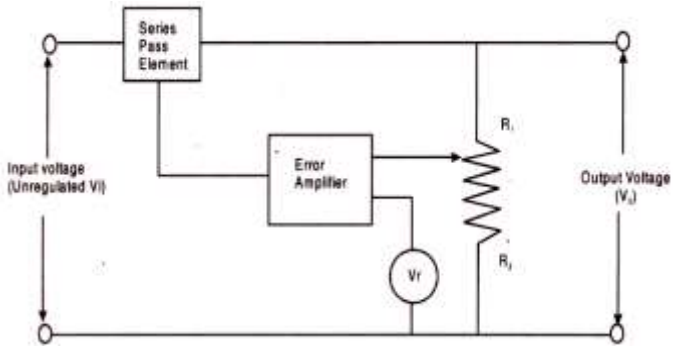
1. Zener diode must be used in reverse bias
2. It must be sufficient power rating
3. Current through zener should be above knee point and below I_{max}.
4. Input voltage should be greater than zener breakdown voltage.

Zener diode acts as bypass valve through which less or more amount of current can pass and maintain the output voltage constant. The total current is passes through load and Zener Regulator.

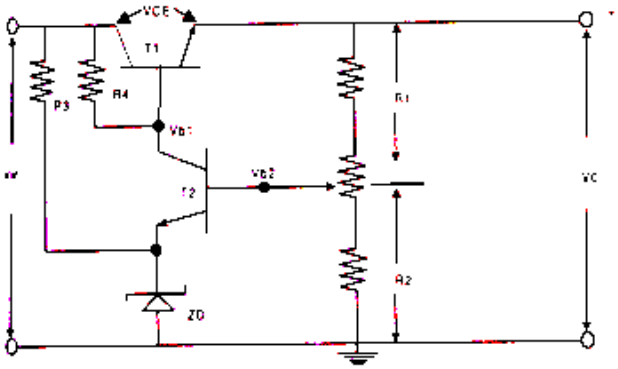
$$I = I_z + I_L$$
$$V_0 = V_z$$
$$V_i = VR + V_0$$
$$= V_0 + IR_S$$
$$R_s = (V_I - V_0)/(I_Z + I_L)$$



2. Transistorized Regulator – The transistorized regulator consist of series pass transistor which is connected in series with both input and output, transistor T_2 acts as error amplifier gives feedback voltage through voltage divider arrangement to take sample voltage from output and Zener diode provides reference voltage.



The transistor T_1 is connected in series with both input and output known as series pass transistor because it drops voltage to make required change in output.



Working –

By Kirchhoff's law,

$$V_0 = V_{in} - V_{CE} \quad \ldots\ldots(1)$$

Case 1 – When input voltage increases, it increases the voltage across R_2. Since it is coupled with base of T_2 it increases base voltage of $T_2$and collector voltage of T_2 decreases, ultimately it reduces base voltage of T_1. When V_{b1} decreases its collector voltage increases. According to equation (1), when V_{CE} increases the output voltage decreases.

$$V_0 \uparrow V_{b2} \uparrow V_{c2} \downarrow V_{b1} \downarrow V_{CE} \uparrow therefore\, V_0 \downarrow$$

Case 2 – When input voltage decreases, it decreases the voltage across R_2. Since it is coupled with base of T_2 it decreases base voltage of $T_2$and collector voltage of T_2 increases, ultimately it increases base voltage of T_1. When V_{b1} increases its collector voltage decreases. According to equation (1), when V_{CE} decreases the output voltage increases.

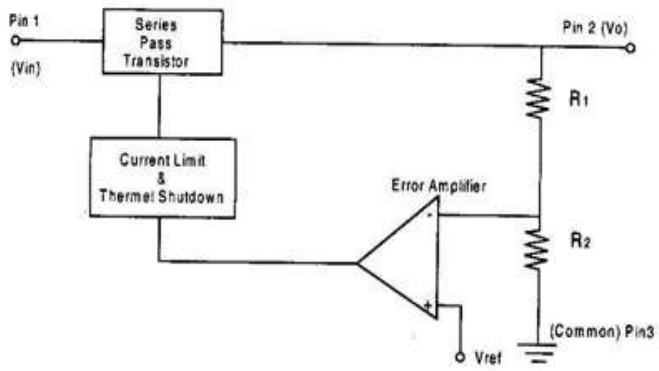
$$V_0 \downarrow V_{b2} \downarrow V_{c2} \uparrow V_{b1} \uparrow V_{CE} \downarrow therefore\, V_0 \uparrow$$

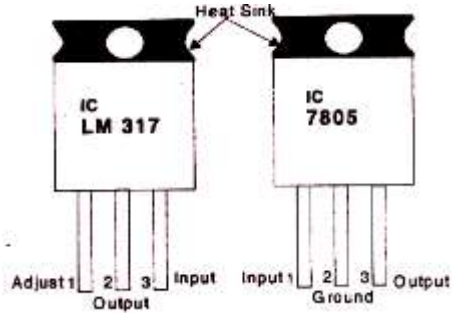
Three terminal IC regulators –

The regulator circuit has common principle to regulate output voltage and it is,

1. Take the sample voltage from output by means of voltage divider.
2. Compare it with reference voltage by means of error amplifier.
3. Drop appropriate voltage by means of series pass transistor.

This IC has internal series pass transistor that handle specific load current. Normally heat sink is provided with the package itself to avoid damage of internal transistor due to excess heating. It also includes thermal shut down and current limit circuit, which provides protection from excessive power dissipation.





Advantages –

1. Minimum size and needs only three pins.
2. Available in plastic and metal package with standard pin configuration.
3. Easy to use because no external components required.
4. Available in different voltage configuration.
5. Can be used for fixed and variable voltage power supply.
6. Provide positive as well as negative output voltage.
7. It is possible to construct dual power supply.
8. Supply load current from 100 mA to about 5 Amp.

LM 340 series – It is a standard voltage regulator having standard blocks inside with built in reference voltage and internal voltage divider is used to develop output voltage of 5 V, 6 V, 8 V, 10V etc. For example LM 340 – 5 has regulated output voltage of 5 V, LM 340 – 18 have regulated output voltage of 18 V and so on. This series gives ***fixed positive*** output with sufficient load current capacity about 1.5 Amp.

LM 320 series – It is a standard voltage regulator having standard blocks inside with built in reference voltage and internal voltage divider is used to develop output voltage of 5 V, 6 V, 8 V, 10V etc. For example LM 320 – 5 has regulated output voltage of 5 V, LM 320 – 18 have regulated output voltage of 18 V and so on. This series gives ***fixed negative*** output with sufficient load current capacity about 1.5 Amp.

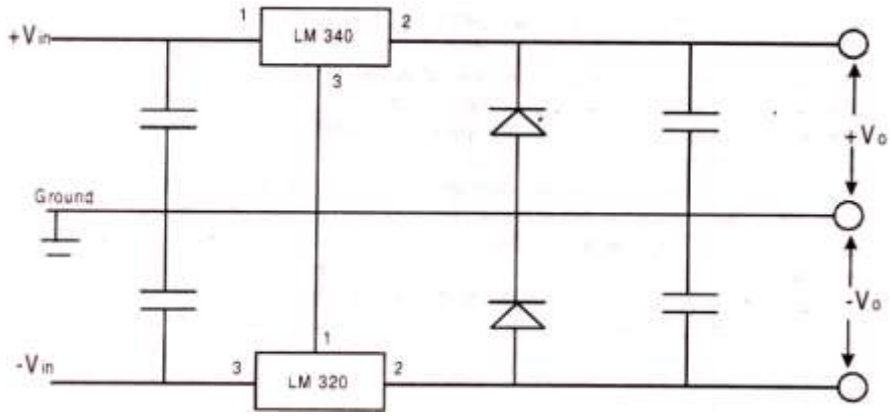
LM 317 regulator – It is an adjustable regulator IC, can produce variable regulated output voltage with better load and line regulation as well as better ripple rejection. This regulator can be used without filter.

The main features of this regulator are

1. Adjustable +ve output with range of 1.25 V to 37 V.
2. Maximum load current 1.5 A.
3. Line regulation only 0.01 %
4. Load regulation is 0.1 %.
5. Ripple rejection is 80 dB.

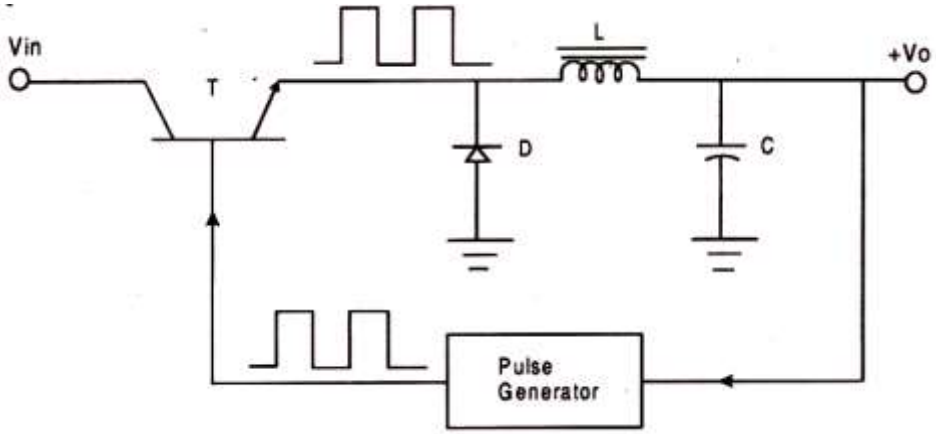
$$V_0 = 1.25\left(1 + \frac{R_2}{R_1}\right)$$

Dual power supply -



4. Switch Mode Power Supply (SMPS) –

In SMPS instead of making series pass transistor conducting continuously a transistor is operated in switching mode that acts as rapidly opening and closing switch. Practically when transistor is operated as switch it dissipates very low power.



SMPS circuit produces regulated output by adjusting the duty cycle of square wave. The output is fed back to a pulse generator in order to control duty cycle, ultimately the switching time of transistor.

$$V_{out} = D \; x \; V_{in}$$

Duty cycle is defined as the ratio of ON time to the total period of square wave.

Working –

Case 1 – Suppose output voltage increases due to load or line variation, since it is fed back to the pulse generator it will reduce duty cycle. It will make transistor ON for short period. Due to which voltage decreases to desired level.

Case 1 – Suppose output voltage decreases due to load or line variation, since it is fed back to the pulse generator it will increase duty cycle. It will make transistor ON for long period. Due to which voltage increases to desired level.