Module - 1

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Electronic Circuits:

power supplies

A power supply is an electrical device that supplies electric power to an electrical load. The primary function of a power supply is to convert electric voltage from a source to the correct voltage and current to power the load.

The d.c power supply is one which supply correct d.c voltage and current to the load. The block diagram of a d.c power supply is show in fig. 1.

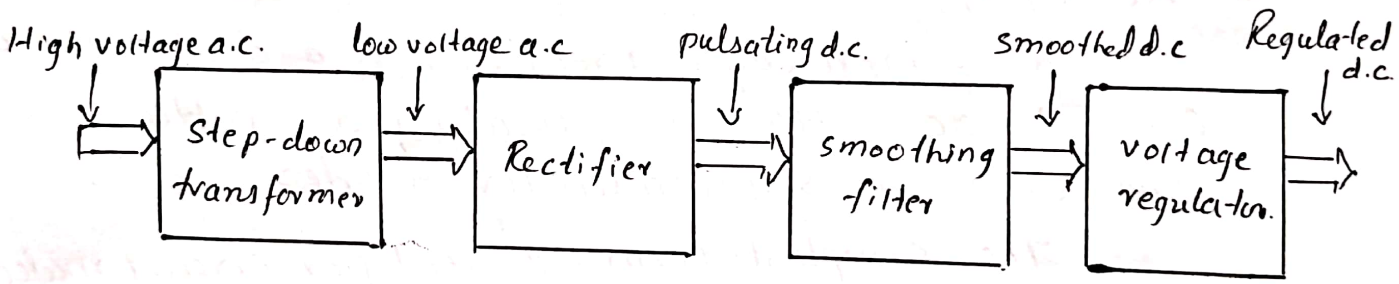

fig. 1 Block diagram of a d.c. power supply.

Since the mains input is at a relatively high voltage, a step-down transformer of appropriate turns ratio is used to convert this to a low voltage. The a.c output from the transformer secondary is then rectified using diodes to produce pulsating d.c. output. This is then smoothed or filtered before applying to voltage regulator circuit so that output voltage remains constant irrespective of variations in input voltage and load.

Fig 2. shows how some of the electronic components are used in the realization of the block diagram in fig.1

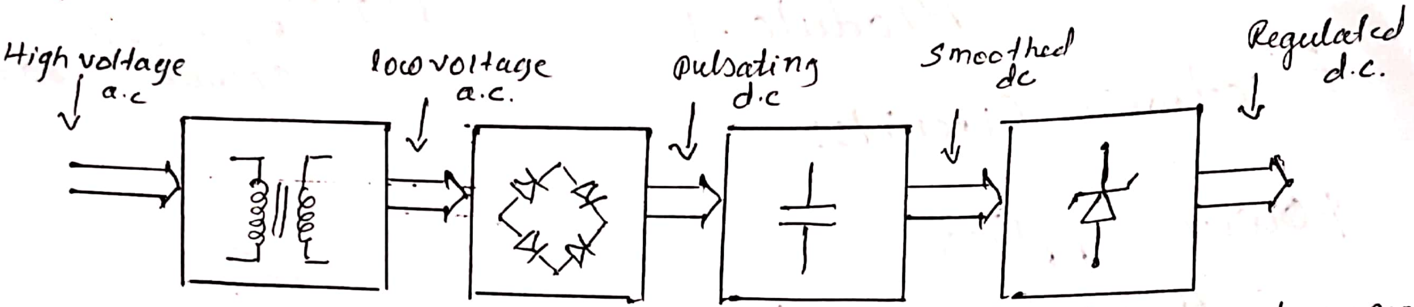

fig 2. d.c power supply showing principal components.

The iron-cored step-down transformer feeds a rectifier arrangement. The output of rectifier is then applied to a high value reservoir (filter) capacitor. The filter capacitor removes the pulsating dc components (a.c) present in the rectified output. finally a Zener diode voltage regulator (sometimes transistor or IC) is used to produce constant required dc voltage.

* Rectifiers

in a simple way, a rectifier is a device which converts ac voltage to pulsating dc voltage using one or more semiconductor diodes.

- The simplest form of rectifier circuit makes use of single diode is known as a half-wave rectifier. Fig 3. shows a simple half-wave rectifier (HWR).

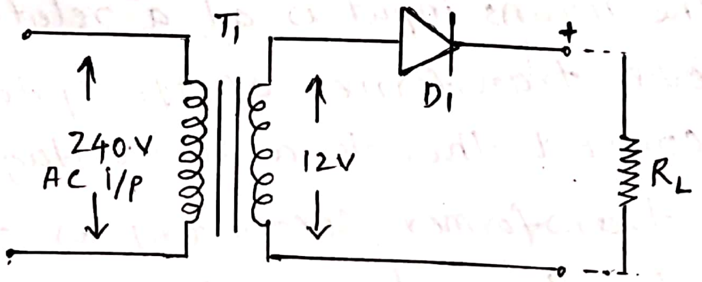

Fig 3. Half-wave Rectifier Circuit.

Mains voltage (220 to 240V) is applied to the primary of a step-down transformer T_1. The secondary of T_1 steps down the 240 V_{rms} to 12 V_{rms}. Thus the turns ratio of T_1 will be 240/12 or 20:1.

During the positive half cycle of secondary ac voltage, the diode D_1 is forward biased and the current flow in the clockwise direction as shown in fig. 4. The current will flow for almost full +ve half cycle. This current is also flowing through the load resistance R_L. During +ve half cycle diode D_1 behaves like a closed switch.

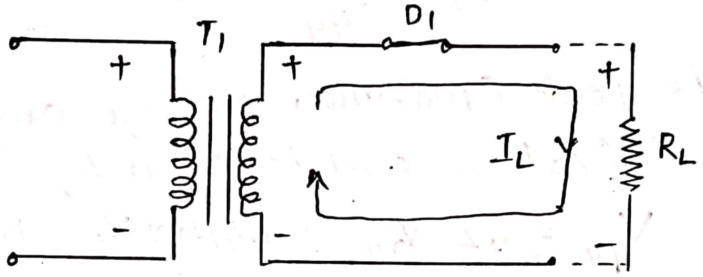

Fig 4. During forward bias.

During negative half cycle diode D_1 becomes reverse biased and acts like open switch. Hence no current flows in the circuit as shown in fig 5.

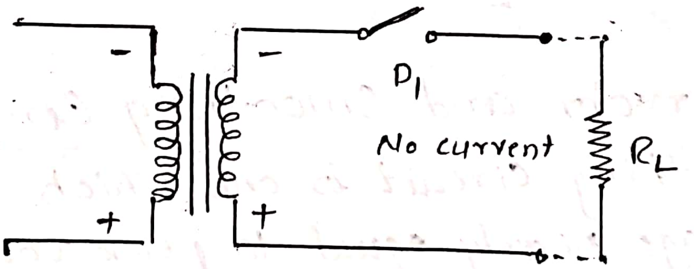

Fig 5. During reverse bias.

The switching action of D_1 results in a pulsating output voltage across R_L. 0.6 V to 0.7 V drop across D_1 during +ve half cycle called as threshold voltage for silicon diode.

For 12 V rms secondary voltage, It's peak voltage o/p of secondary will be given by.

$$V_{pk} = 1.414 \times V_{rms} = 1.414 \times 12V = 16.97\ V.$$

Ex: A mains transformer having a turns ratio of 44:1 is connected to a 220 V rms mains supply. If secondary output is applied to a half wave rectifier, determine the peak voltage that will appear across a load.

Soln: The rms secondary voltage will be given by.

$$V_s = V_P/44 = \frac{220}{44} = 5V \quad \because \frac{N_1}{N_2} = \frac{V_P}{V_S}$$

The peak (maximum) voltage developed after rectification will be given by

$$V_{pk} = \sqrt{2} \cdot V_{rms} = 1.414 \times V_s = 1.414 \times 5 = 7.07V$$

Assuming that the diode is silicon device with forward voltage drop of 0.6V, the actual peak voltage dropped across the load will be.

$$V_L = 7.07V - 0.6V = 6.47V \Leftarrow \text{Ans.}$$

* **Reservoir and smoothing circuits (Filter circuit)**

Smoothing circuit is one which mentains output voltage nearly equal to peak voltage when the diode is not conducting. This can be achieved by using capacitor in parallel with R_L as shown in fig. 6. The capacitor used is called reservoir capacitor.

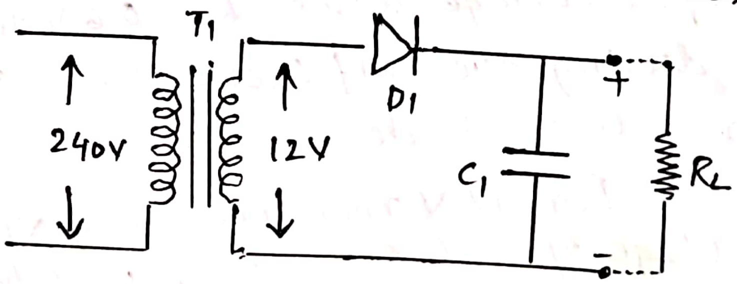

fig. 6. HWR with capacitor filter

During +ve half cycle of secondary voltage will charge C_1 to the peak value seen across R_L (16.3V). Because, C_1 and R_L are in parallel, the voltage across R_L will be the same as that across C_1. During -ve half cycle D_1 will be reverse biased and in non conducting state As a consequence, the only discharge path for C_1 is through R_L. C_1 is referred as reservoir capacitor. The discharge time constant is determined by the Capacitance value and the load resistance R_L.

Fig. 7 shows the secondary voltage waveform together with the voltage developed across R_L with and without C_1.

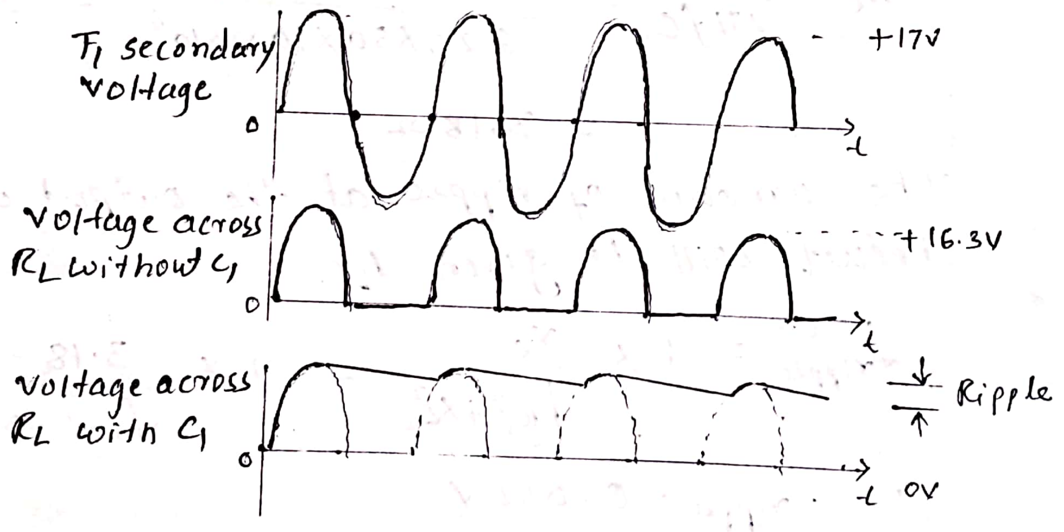

Fig. 7. voltage across R_L with and without C_1

Fig. 8 shows a further improvement in ripple voltage by using additional components R_1 and C_2, which act as filter to remove the ripple.

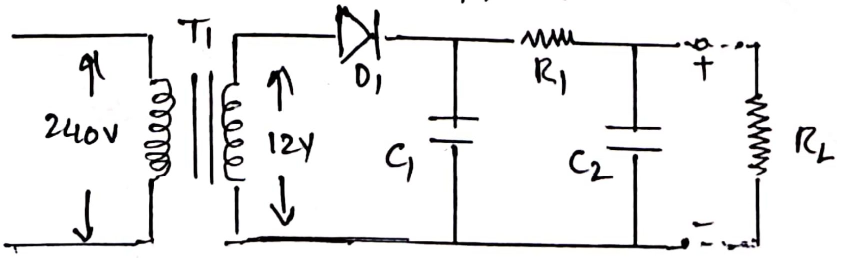

Fig. 8. HWR with RC filter (Smoothing filter)

In this R_1 and C_2 act like a potential divider. The amount of ripple voltage is reduced by a factor equal to

$$\frac{X_{C_2}}{\sqrt{R_1^2+X_{C_2}^2}}$$

Ex: The R-C smoothing filter in a 50 Hz mains operated halfwave rectifier circuit consists of $R_1 = 100\,\Omega$ and $C_2 = 1000\,\mu F$. If 1V of ripple appears at the input of the circuit, determine the amount of ripple appearing at the output.

Soln: First we must determine the reactance of the capacitor C_2 at the frequency 50 Hz.

$$X_{C_2} = \frac{1}{2\pi f C_2} = \frac{1}{6.28 \times 50 \times 1000 \times 10^{-6}} = \frac{1000}{314}$$

$$= 3.18\,\Omega$$

The amount of ripple at the output of the circuit will be given by.

$$V_{ripple} = 1 \times \frac{X_{C_2}}{\sqrt{R_1^2+X_{C_2}^2}} = 1 \times \frac{3.18}{\sqrt{100^2+3.18^2}}$$

$$\therefore V_{ripple} = 0.032\,V$$

$$= 32\,mV.$$

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Full-wave rectifiers.

Full-wave rectifier circuit converts both half cycles (+ve half cycle and -ve half cycle) in to pulsating dc. There are two basic forms of full-wave rectifier, the bi-phase type and the bridge rectifier type.

Bi-phase rectifier circuit.

Fig.9 shows a simple bi-phase rectifier circuit.

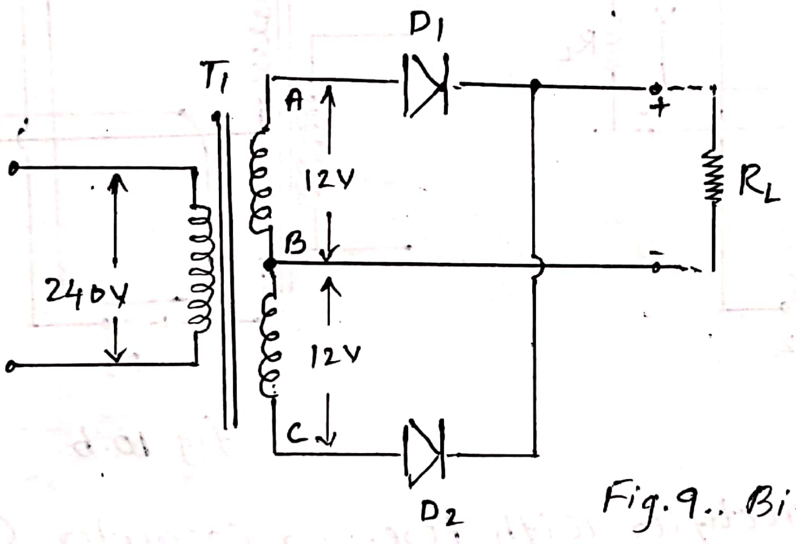


Fig.9.. Bi-phase rectifier circuit.

Mains voltage (240V) is applied to the primary of the step-down transformer (T_1) which has two identical secondary windings, each providing 12 V rms. The turns ratio of T_1 will be thus 240/12 or 20:1 for each secondary winding

Working of Bi-phase rectifier.

during +ve half cycle, point A will be positive with respect to point B. similarly point B will be positive with respect to point C. in this condition diode D_1 will conduct and diode D_2 will not conduct

on negative half cycles, point C will be positive with respect to point B. similarly, point B will be positive with respect to point A. In this condition diode D_2 will conduct and diode D_1 will not conduct. so during +ve half cycles, D_1 alone conducts and during -ve half cycles, D_2 alone conducts.

Fig.10 shows the bi-phase rectifier circuit with the diodes replaced by switches.

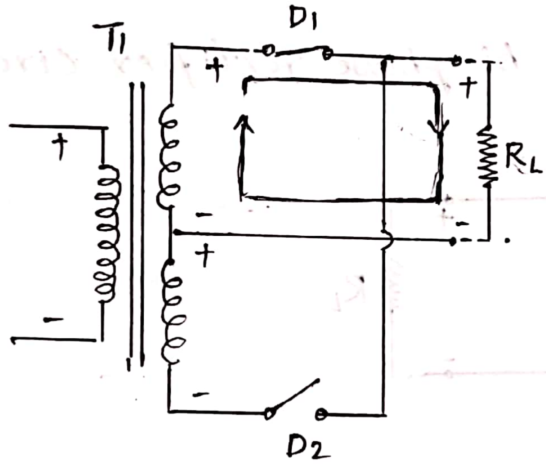


fig.10a

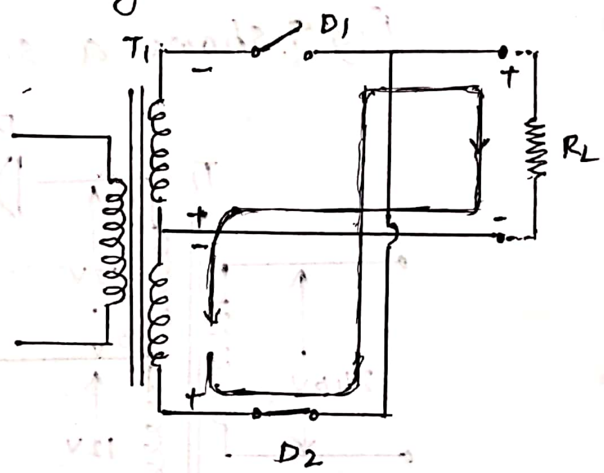


fig.10.b.

Full-wave rectifier with Reservoir Capacitor (filter ckt).

Fig. shows how a reservoir capacitor can be added to ensure smooth output even at diodes are not conducting.

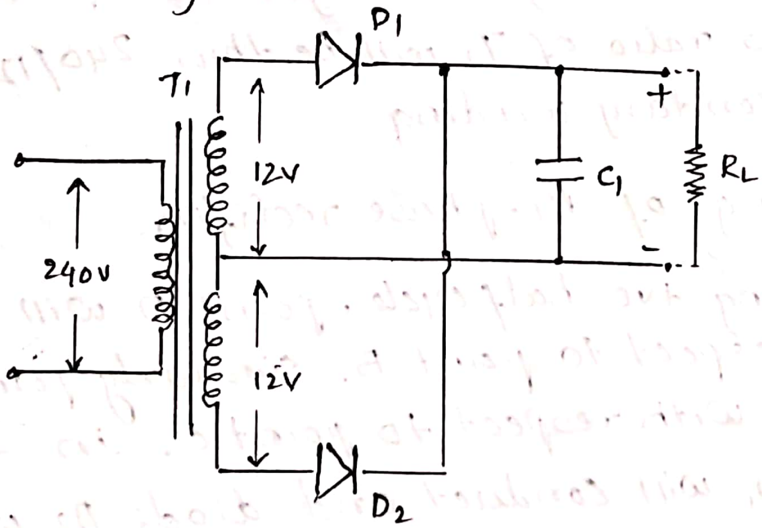


fig.11. Bi-phase rectifier with reservoir capacitor

The charging and discharge time of capacitor will be determined by time constant of the ckt. The R_L is large compared to secondary winding. so charge time is less and discharge time is more.

Fig.12 shows voltage waveforms for the bi-phase rectifier with and without C_1. The ripple frequency is twice that of halfwave rectifier.

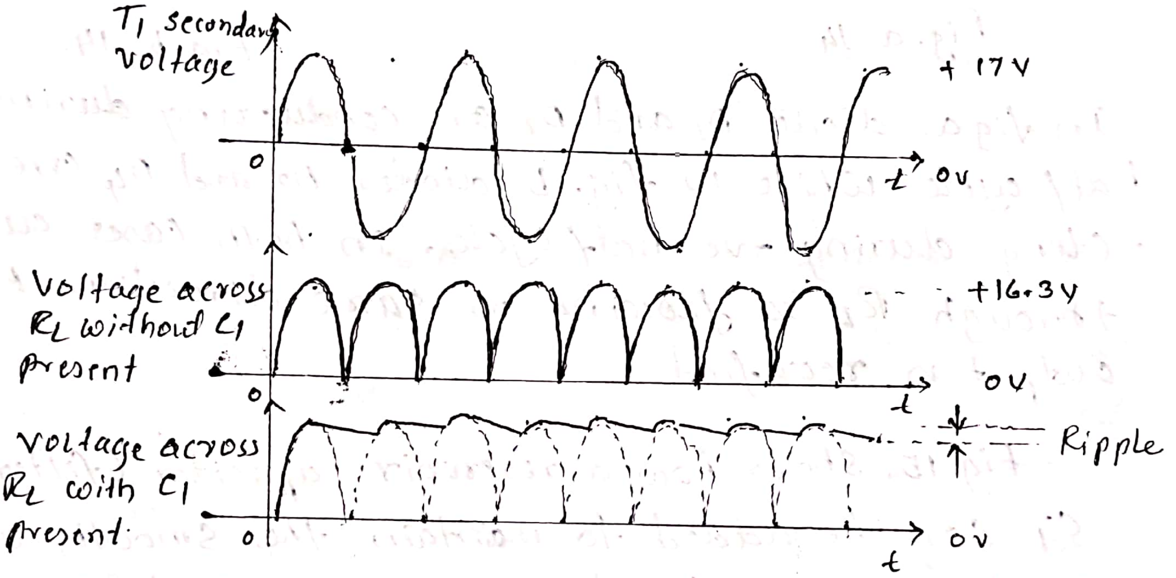


Fig.12. waveforms for Bi-phase rectifier.

* Bridge Rectifier Circuit.

In bridge fullwave rectifier four diodes are used in which two diodes are conducting in each half cycle. A bridge fullwave rectifier circuit is shown in fig.13

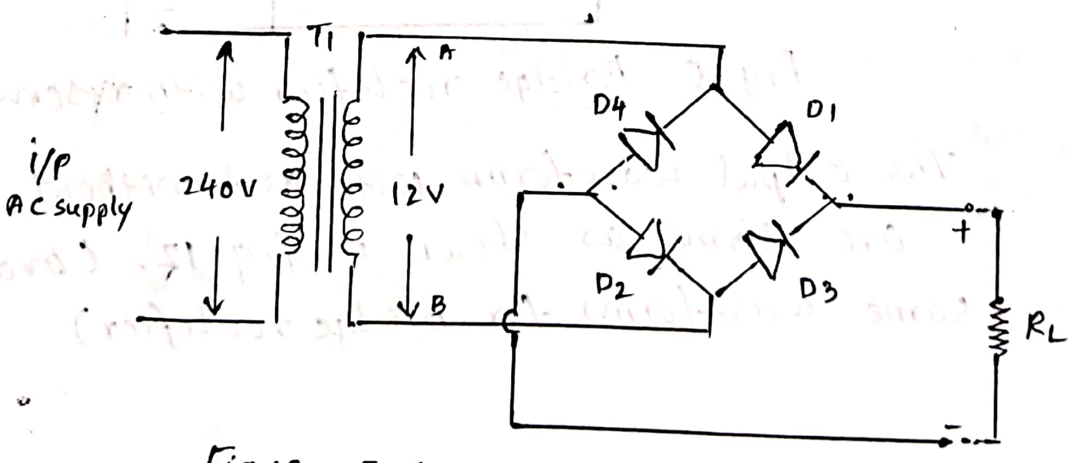


Fig.13. Fullwave Bridge rectifier circuit.

Fig. 14. shows bridge rectifier circuit with diodes replaced by four switches.

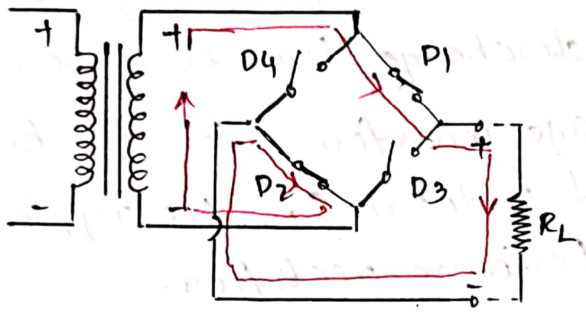


Fig. a 14.

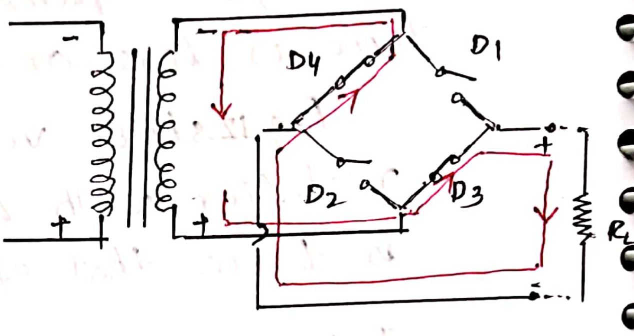


Fig. b. 14.

In fig a. diode D_1 and D_2 are conducting during +ve half cycle while in fig. b diodes D_3 and D_4 are conducting during -ve half cycle. In both cases current through R_L is flowing in same direction. Hence output is rectified.

Fig 15. Shows how a reservoir capacitor (filter capacitor) C_1 can be added to maintain the smooth output voltage when the diodes are not conducting.

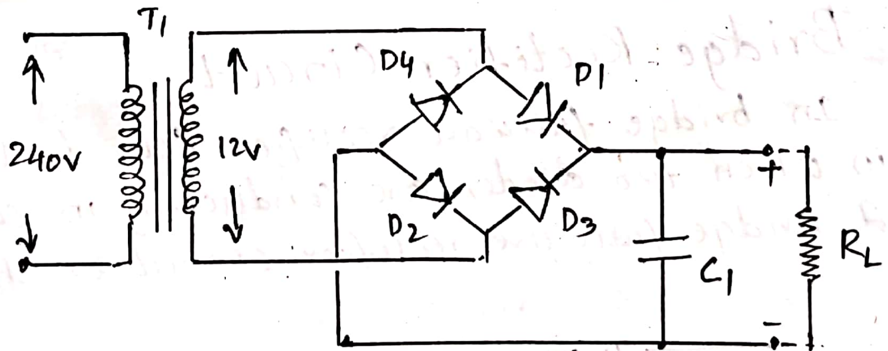


Fig 15. Bridge rectifier with reservoir capacitor

The output waveforms with and without capacitor C_1 are same as shown in fig. 12. (Draw the same waveforms for bridge rectifier).

Voltage Regulators:

A voltage regulator is a circuit that maintains a fixed output voltage irrespective of changes to the input voltage or load conditions.

A simple voltage regulator is shown in fig. 16.

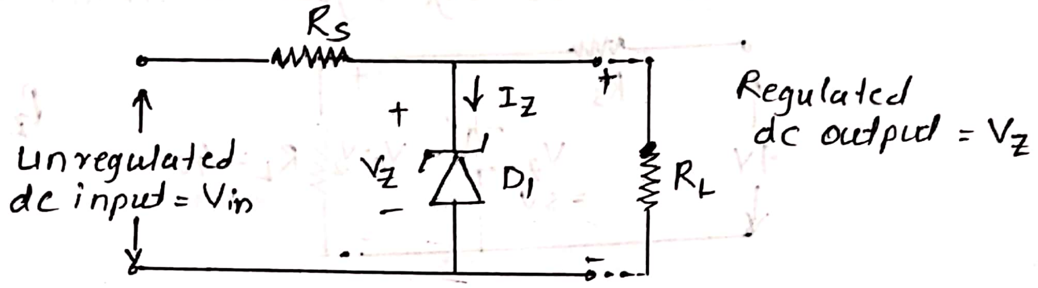


Fig. 16. A simple shunt Zener diode voltage regulator.

In fig. R_s is included to limit the zener current to a safe value when the load is disconnected. When a load (R_L) is connected, the zener current I_Z will fall as current is diverted in to the load resistance. The output voltage V_Z remain at the zener voltage.

From fig.

$$V_Z = V_{in} \times \frac{R_L}{R_L + R_s}$$

where V_{in} is the unregulated input voltage. Thus the maximum value of R_s can be calculated as.

$$R_{s\,max} = R_L\left(\frac{V_{in}}{V_Z} - 1\right)$$

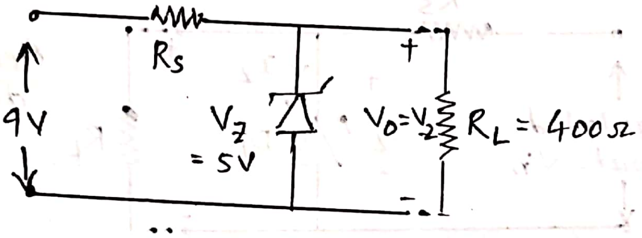
The power dissipated in zener diode will be given by. $P_Z = I_Z \times V_Z$, hence the minimum value for R_s can be determined from no-load condition.

$$R_{s\,min} = \frac{V_{in} - V_Z}{I_Z} = \frac{V_{in} - V_Z}{\left(\frac{P_{Z\,max}}{V_Z}\right)} = \frac{(V_{in} - V_Z) \times V_Z}{P_{Z\,max}}.$$

$$\therefore\ R_{s\,min} = \frac{V_{in}V_Z - V_Z^2}{P_{Z\,max}}$$

Ex: A 5V zener diode has a maximum rated power dissipation of 500mW. If the diode is to be used in a simple regulator circuit to supply a regulated 5V to a load having a resistance of 400 Ω. Determine a suitable value of series resistor R_s for operation in conjuction with a supply of 9V.

solution: we can draw voltage regulator circuit as follows.



$P_{Z\,max} = 500mW$

$$R_{s\,max} = R_L\left(\frac{V_{in}}{V_z} - 1\right) = 400\left(\frac{9}{5} - 1\right) = 400(1.8-1)$$

$$= 320 Ω$$

$$R_{min} = \frac{V_{in}V_z - V_z^2}{P_{z\,max}} = \frac{9\times5 - 5^2}{500\times10^{-3}} = \frac{45-25}{0.5}$$

$$= 40 Ω$$

Suitable value for R_s = 150 Ω.

* Output resistance and voltage regulation.

In a perfect power supply, the output voltage would remain constant regardless of the current taken by the load. In practice, the output voltage falls as the load current increases. This is because of internal resistance of the power supply. called output resistance. "Hence" it is defined as the change in output voltage divided by the corresponding change in output current."

$$R_{out} = \frac{\Delta V_{out}}{\Delta I_{out}}$$

- Voltage regulation of the power supply is given by.

$$\text{Regulation} = \frac{\text{Change in output voltage}}{\text{Change in input voltage}} \times 100\%$$

ideally, the value of regulation should be very small.

Ex: The following data were obtained during a test carried out on a d.c. power supply.

i) ~~Load test~~ Regulation test.

Output voltage (mains i/p, 220V) = 12 V

Output voltage (mains i/p, 200V) = 11.9V.

ii) ~~Regulation test~~ Load test.

Output voltage (no-load) = 12V

Output voltage (2A load current) = 11.5V

Determine the a) Regulation of the power supply

b) output resistance of the supply.

Soln: we know that.

a) $$\text{Regulation} = \frac{\text{Change in output voltage}}{\text{Change in input voltage}} \times 100\%$$

$$\text{Thus Regulation} = \frac{12-11.9}{220-200} \times 100\%$$

$$= \frac{0.1}{20} \times 100\% = 0.5\%$$

b) $$R_{out} = \frac{\text{Change in output voltage}}{\text{Change in output current}}$$

$$= \frac{12-11.5}{2-0} = 0.25\,\Omega$$

* Voltage multipliers.

Voltage doubler.

By adding a second diode and capacitor, the output of half wave rectifier is increased. A voltage doubler using this technique is shown in fig. 17.

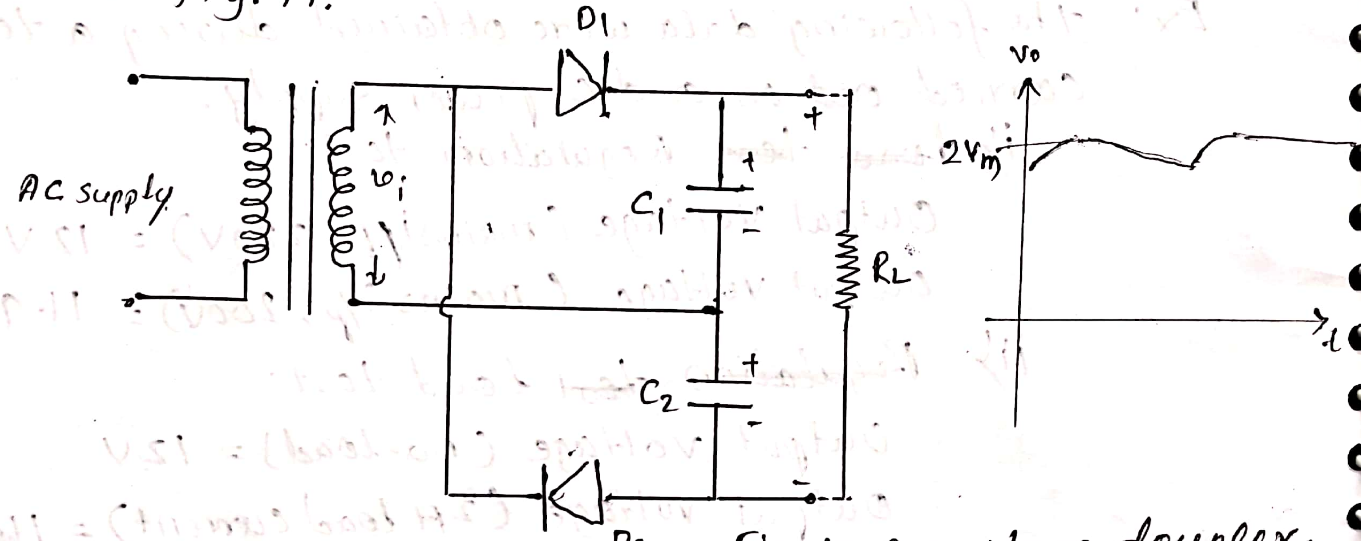


Fig. 17. A voltage doupler.

C_1 will charge to positive peak of secondary voltage and C_2 will charge to negative peak of secondary voltage. Since the output is taken from C_1 and C_2 connected in series the resulting output voltage is twice that produced by one diode alone.

Voltage tripler.

Voltage doubler can be extended to produce higher voltage using the cascade arrangement (voltage tripler) as shown in fig. 18. (next page)

C_1 charges to positive peak secondary voltage while C_2 and C_3 charges to twice the positive peak secondary voltage. The result is that the output voltage is the sum of the voltages across C_1 and C_3 which is 3-times the voltage that would be produced by a single diode.

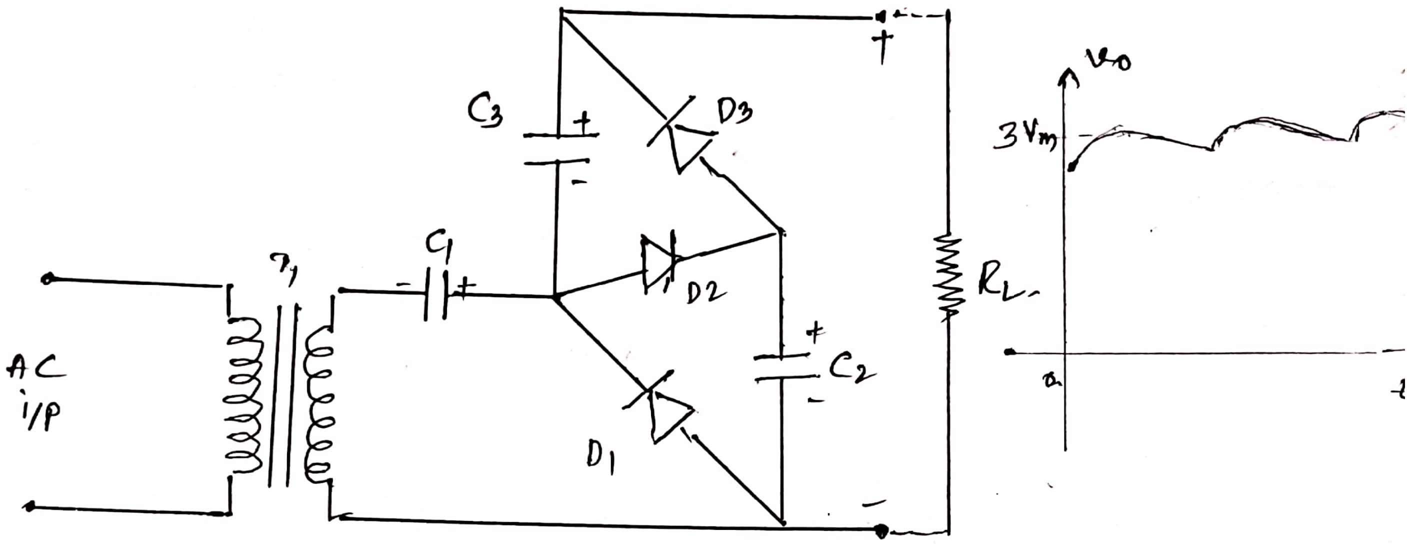


Fig 18. Voltage Tripler.

Voltage multiplier.

The voltage multiplier is an electronic Circuit that delivers the output voltage whose amplitude (peak value). is two, three or more times greater than the amplitude (peak value) of the input voltage.

Voltage Tripler (alternate circuit)