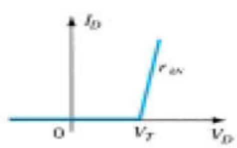
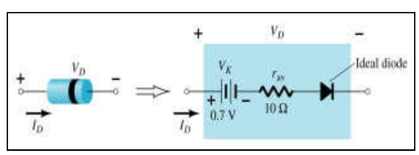
Diode Circuit Analysis

Diode Circuit Analysis

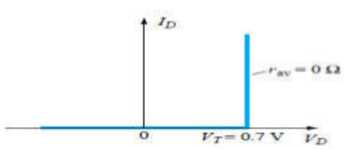
Diode Equivalent Circuit

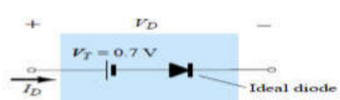
1. Piecewise linear equivalent circuits:



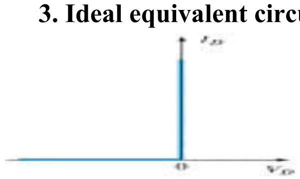


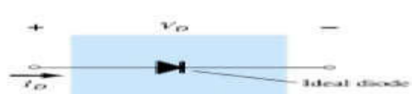
2. Simplified equivalent circuits:





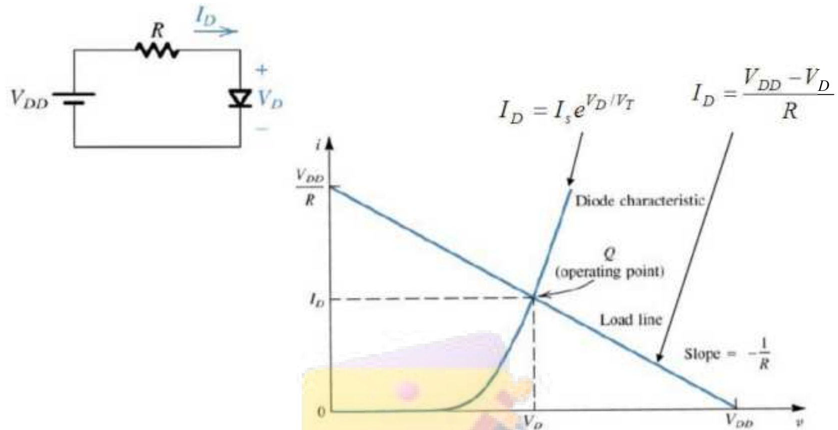
3. Ideal equivalent circuits:





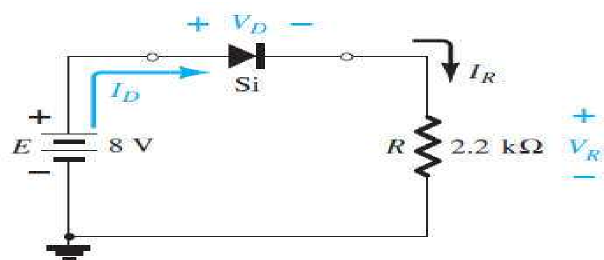
Diode Circuits

•Look at the simple diode circuit below. We can write two equations:



Examples from Text Book

Example: 4 For the series diode configuration shown in fig. determine V_D, V_R and I_D.



Solution:

Since the applied voltage establishes a current in the clockwise direction to match the arrow of the symbol and the diode is in the "on" state,

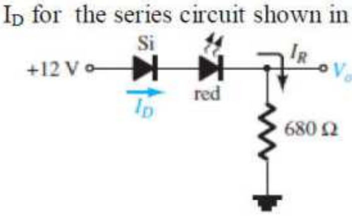
$$V_D = \mathbf{0.7\ V}$$

$$V_R = E - V_D = 8\text{ V} - 0.7\text{ V} = \mathbf{7.3\ V}$$

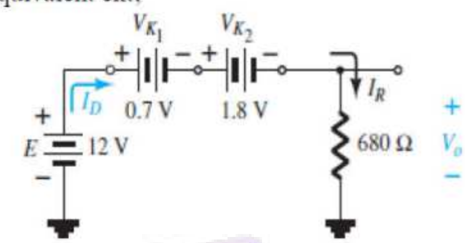
$$I_D = I_R = \frac{V_R}{R} = \frac{7.3\text{ V}}{2.2\text{ k}\Omega} \cong \mathbf{3.32\ mA}$$

Examples

Example: 5 Determine V_o and I_D for the series circuit shown in fig.



Solution: First drawing equivalent ckt;

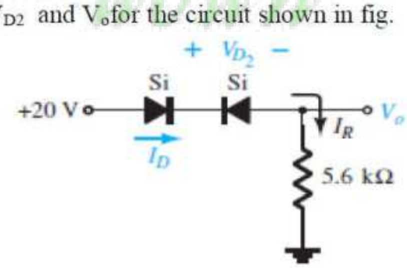


$$V_o = E - V_{K_1} - V_{K_2} = 12\text{ V} - 2.5\text{ V} = 9.5\text{ V}$$

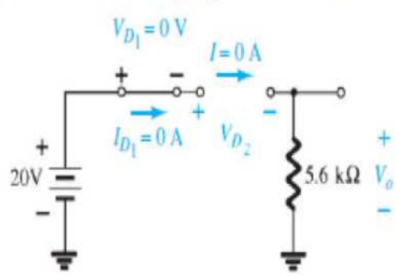
and $$I_D = I_R = \frac{V_R}{R} = \frac{V_o}{R} = \frac{9.5\text{ V}}{680\ \Omega} = 13.97\text{ mA}$$

Examples

Example: 6 Determine I_D, V_{D2} and V_o for the circuit shown in fig.



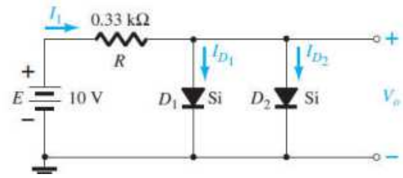
Solution: First drawing equivalent ckt and then analysing ckt;



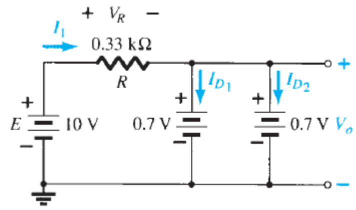
$$V_o = I_R R = I_D R = (0\text{ A})R = 0\text{ V}$$
$$V_{D_2} = V_{\text{open circuit}} = E = 20\text{ V}$$

Examples

Example: 7 Determine V_o, I_1, I_{D1} and I_{D2} for the parallel diode configuration shown in fig.



Solution :



The current

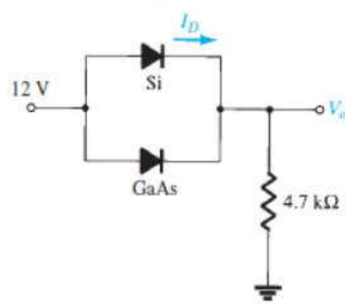
$$I_1 = \frac{V_R}{R} = \frac{E - V_D}{R} = \frac{10\ \text{V} - 0.7\ \text{V}}{0.33\ \text{k}\Omega} = \mathbf{28.18\ mA}$$

Assuming diodes of similar characteristics, we have

$$I_{D_1} = I_{D_2} = \frac{I_1}{2} = \frac{28.18\ \text{mA}}{2} = \mathbf{14.09\ mA}$$

Examples

Example: 8 Determine the current I_D for the network.



Solution: Si diode is conducting and GaAs diode is non-conducting because barrier or knee voltage os Si is less than GaAs.

Therfore Current;

$$I_D = \frac{12 - 0.7}{4.7 \times 10^3} = 2.40425\ mA$$

RECAP

- There are three types of Diode Equivalent Circuit:
  1. Piecewise linear equivalent circuits
  2. Simplified equivalent circuits
  3. Ideal equivalent circuits

- If diode is FB, then practically voltage drop across the Si & Ge diodes are 0.6-0.7 V & 0.2-0.3 V respectively and ideally it should be zero.
- If diode is RB, then voltage drop across the Si & Ge diodes are equal to applied external supply voltage.
- Use **KVL** or **KCL** carefully.

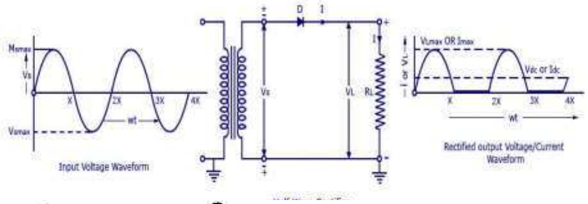
Diodes Rectifier Circuits:

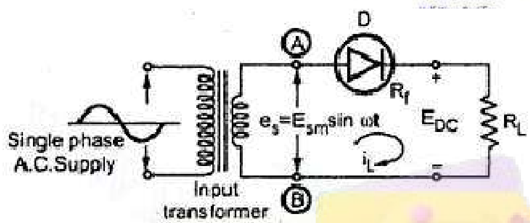
1. **Half wave rectifier**
2. **Full wave rectifier**

Rectifiers convert AC voltage to pulsating DC voltage.

Diodes – Rectifier Circuits

1. Half-Wave Rectifier: This conducts only during positive half cycles of input ac supply.



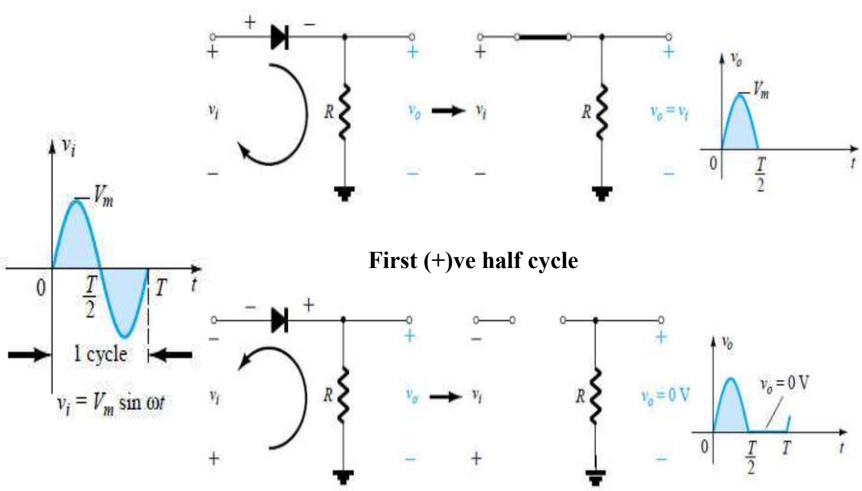


$N_2/N_1 = E_{sm}/E_{pm}$

$E_s = E_{sm} \sin (\alpha t)$

Diodes – Rectifier Circuits

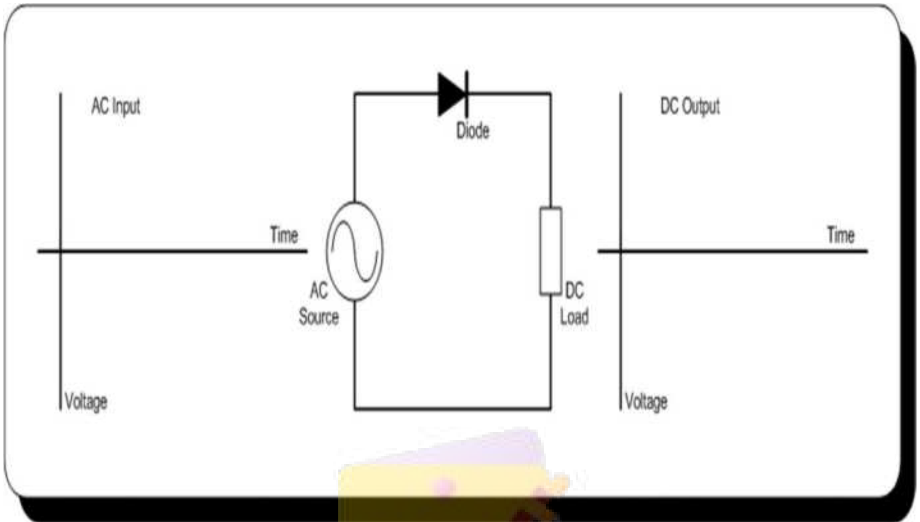
Working of Half-Wave Rectifier:

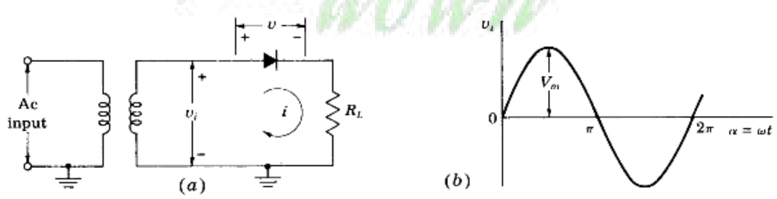


First (-)ve half cycle

Diodes – Rectifier Circuits

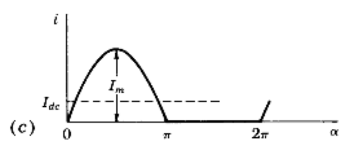
Working of Half-Wave Rectifier (ANIMATION)





$$i = I_m \sin \alpha \qquad \text{if } 0 \leq \alpha \leq \pi$$

$$i = 0 \qquad \text{if } \pi \leq \alpha \leq 2\pi$$

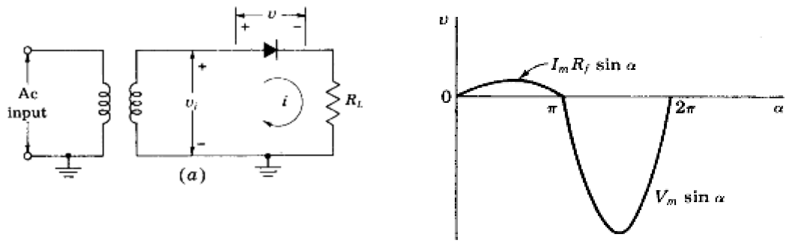


where $\alpha \equiv \omega t$ and

$$I_m \equiv \frac{V_m}{R_f + R_L} \qquad I_{dc} = \frac{1}{2\pi}\int_0^{2\pi} i \, d\alpha$$

$$V_{dc} = I_{dc}R_L = \frac{I_m R_L}{\pi} \qquad I_{dc} = \frac{1}{2\pi}\int_0^{\pi} I_m \sin \alpha \, d\alpha = \frac{I_m}{\pi}$$

$$I_m = \frac{V_m}{R_f + R_L + R_s} \qquad R_s = \text{resistance of secondary of transformer}$$



$$V'_{dc} = \frac{1}{2\pi}\left(\int_0^{\pi} I_m R_f \sin \alpha \, d\alpha + \int_{\pi}^{2\pi} V_m \sin \alpha \, d\alpha\right)$$

$$= \frac{1}{\pi}(I_m R_f - V_m) = \frac{1}{\pi}[I_m R_f - I_m(R_f + R_L)]$$

$$V'_{dc} = -\frac{I_m R_L}{\pi}$$

$$I_{rms} = \left(\frac{1}{2\pi}\int_0^{2\pi} i^2 \, d\alpha\right)^{\frac{1}{2}}$$

$i = I_m \sin \alpha$ if $0 \le \alpha \le \pi$

$i = 0$ if $\pi \le \alpha \le 2\pi$

where $\alpha \equiv \omega t$ and

$$I_{rms} = \left(\frac{1}{2\pi}\int_0^{\pi} I_m^2 \sin^2 \alpha \, d\alpha\right)^{\frac{1}{2}} = \frac{I_m}{2}$$

$$I_m \equiv \frac{V_m}{R_f + R_L}$$

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

$$I_m = \frac{V_m}{R_f + R_L + R_s}$$

$$\% \text{ regulation} \equiv \frac{V_{\text{no load}} - V_{\text{load}}}{V_{\text{load}}} \times 100\%$$

$$I_{dc} = \frac{I_m}{\pi} = \frac{V_m/\pi}{R_f + R_L}$$

$$V_{dc} = \frac{V_m}{\pi} - I_{dc} R_f$$

RMS value of load voltage

$$\therefore \quad \boxed{E_{L\,(RMS)} = I_{RMS} R_L = \frac{I_m}{2} R_L}$$

$$\therefore \quad E_{L\,(RMS)} = \frac{E_{sm}}{2(R_f + R_L + R_s)} \times R_L = \frac{E_{sm}}{2\left[1 + \frac{R_f + R_s}{R_L}\right]}$$

Now $R_L >> R_f + R_s$ hence $\frac{R_f + R_s}{R_L} << 1$

$$\therefore \quad E_{L\,(RMS)} \approx \frac{E_{sm}}{2}$$

DC Power Output

$$\therefore \quad \boxed{P_{DC} = E_{DC} I_{DC} = I_{DC}^2 R_L}$$

$$\text{D.C. Power output} = I_{DC}^2 R_L = \left[\frac{I_m}{\pi}\right]^2 R_L = \frac{I_m^{\,2}}{\pi^2} R_L$$

$$\therefore \quad P_{DC} = \frac{I_m^{\,2}}{\pi^2} R_L$$

where $I_m = \frac{E_{sm}}{R_f + R_L + R_s}$

$$\therefore \quad \boxed{P_{DC} = \frac{E_{sm}^{\,2} R_L}{\pi^2 [R_f + R_L + R_s]^2}}$$

AC Power Input

$$\boxed{P_{AC} = I_{RMS}^2 [R_L + R_f + R_s]}$$

but $I_{RMS} = \frac{I_m}{2}$ for half wave,

$$\therefore \quad \boxed{P_{AC} = \frac{I_m^2}{4} [R_L + R_f + R_s]}$$

Efficiency

$$\eta = \frac{\text{D.C. output power}}{\text{A.C. input power}} = \frac{P_{DC}}{P_{AC}}$$

$$\eta = \frac{\frac{I_m^2}{\pi^2} R_L}{\frac{I_m^2}{4}[R_f + R_L + R_s]} = \frac{(4/\pi^2)R_L}{(R_f + R_L + R_s)}$$

$$\boxed{\eta = \frac{0.406}{1 + \left(\frac{R_f + R_s}{R_L}\right)}}$$

$$\boxed{\%\eta_{max} = 0.406 \times 100 = 40.6\ \%}$$

Ripple Factor

$$\boxed{\text{Ripple factor } \gamma = \frac{\text{R.M.S. value of a.c. component of output}}{\text{Average or d.c. component of output}}}$$

I_{ac} = r.m.s. value of a. c. component present in output

I_{DC} = d.c. component present in output

I_{RMS} = R.M.S. value of total output current

$$I_{RMS} = \sqrt{I_{ac}^2 + I_{DC}^2}$$

$$I_{ac} = \sqrt{I_{RMS}^2 - I_{DC}^2}$$

$$\boxed{\text{Ripple factor} = \frac{I_{ac}}{I_{DC}}}$$

$$\gamma = \frac{\sqrt{I_{RMS}^2 - I_{DC}^2}}{I_{DC}}$$

$$\boxed{\gamma = \sqrt{\left(\frac{I_{RMS}}{I_{DC}}\right)^2 - 1}}$$

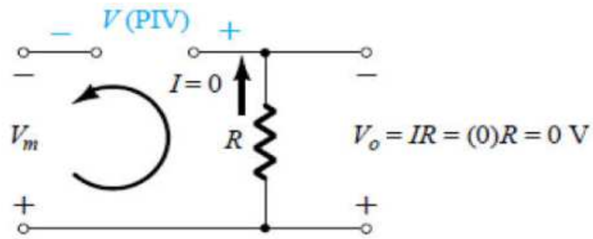
$I_{RMS} = \frac{I_m}{2}$ while $I_{DC} = \frac{I_m}{\pi}$

$$\gamma = \sqrt{\left[\frac{\left(\frac{I_m}{2}\right)}{\left(\frac{I_m}{\pi}\right)}\right]^2 - 1} = \sqrt{\frac{\pi^2}{4} - 1} = \sqrt{1.4674}$$

$\boxed{\gamma = 1.211}$ .. Half wave

Diodes – Rectifier Circuits

Peak Inverse Voltage (PIV) of HWR: PIV is the maximum voltage that appears across the diode when non-conducting or off state.



Using KVL;

$$-V_m + PIV = 0$$

$$\mathbf{PIV = V_m}$$

Transformer Utilization Factor (TUF)

The T.U.F. is defined as the ratio of d.c. power delivered to the load to the a.c power rating of the transformer. While calculating the a.c. power rating, it is necessary to consider r.m.s. value of a.c. voltage and current.

$$\text{A.C. power rating of transformer} = E_{RMS} I_{RMS} = \frac{E_{sm}}{\sqrt{2}} \cdot \frac{I_m}{2} = \frac{E_{sm} I_m}{2\sqrt{2}}$$

$$\text{D.C. power delivered to the load} = I_{DC}^2 R_L = \left(\frac{I_m}{\pi}\right)^2 R_L$$

$$\boxed{\text{T.U.F.} = \frac{\text{D.C. Power delivered to the load}}{\text{A.C. Power rating of the transformer}}}$$

$$\text{T.U.F.} = \frac{\left(\frac{I_m}{\pi}\right)^2 R_L}{\left(\frac{E_{sm} I_m}{2\sqrt{2}}\right)}$$

$$E_{sm} = I_m R_L$$

$$\text{T.U.F} = \frac{I_m^2}{\pi^2} \cdot \frac{R_L . 2\sqrt{2}}{I_m^2 R_L} = \frac{2\sqrt{2}}{\pi^2} = 0.287$$

Voltage Regulation

If $(V_{dc})_{NL}$ = D.C. voltage on no load

$(V_{dc})_{FL}$ = D.C. voltage on full load

then voltage regulation is defined as,

$$\boxed{\text{Voltage regulation} = \frac{(V_{dc})_{NL} - (V_{dc})_{FL}}{(V_{dc})_{FL}}}$$

$$(V_{dc})_{NL} = \frac{E_{sm}}{\pi}$$

While $$(V_{dc})_{FL} = I_{DC}\, R_L = \frac{I_m}{\pi} R_L = \frac{E_{sm}}{\pi[R_f + R_s + R_L]} \times R_L$$

$$\therefore \quad \% R = \frac{\frac{E_{sm}}{\pi} - \frac{E_{sm}}{\pi} \cdot \frac{R_L}{[R_f + R_s + R_L]}}{\frac{E_{sm}}{\pi} \cdot \frac{R_L}{R_f + R_s + R_L}} \times 100$$

$$= \frac{1 - \frac{R_L}{R_f + R_s + R_L}}{\frac{R_L}{R_f + R_s + R_L}} \times 100 = \frac{R_f + R_s}{R_L} \times 100$$

$$\boxed{\% R \approx \frac{R_f}{R_L} \times 100}$$

where R_f = Diode forward resistance

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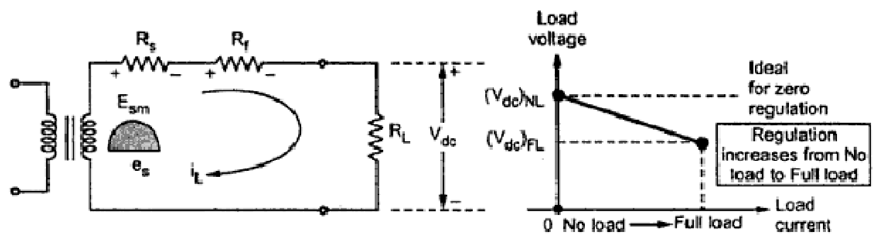
Voltage Regulation variation



(a) Equivalent circuit (b) Regulation characteristics

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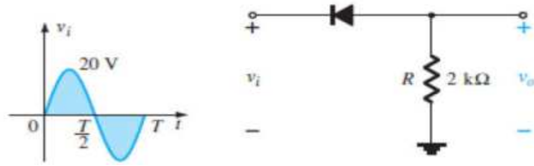
Examples

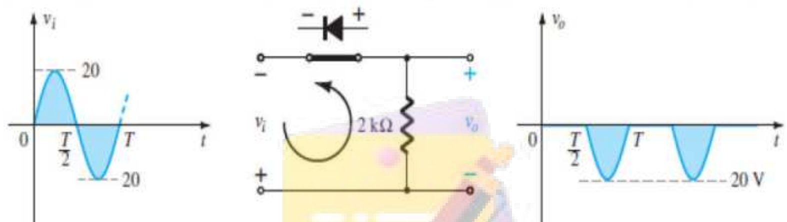
Example: 9 (a) Sketch the output V_o and determine the dc level for the network.
(b) Repeat part (a) if the ideal diode is replaced by silicon (Si) diode.



Solution: (a) In this network diode will conduct during negative half cycle only and V_o will appear as shown in the same figure (because we consider ideal diode in rectifier if diode material is not specified i.e. either Si or Ge)). For the full period, the dc level is

$$V_{dc} = -0.318V_m = -0.318(20\text{ V}) = -6.36\text{ V}$$

The negative sign indicates that the polarity of the output is opposite to the defined polarity.

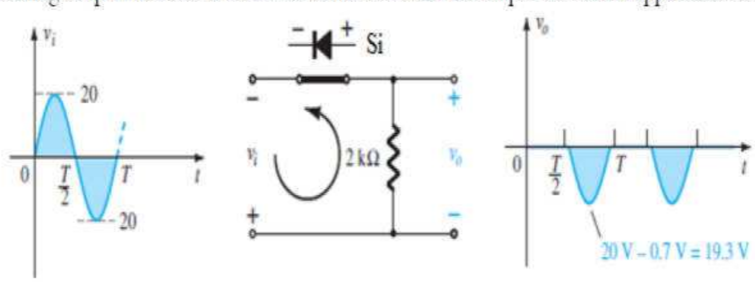


Examples

(b) For the silicon diode, dc level is

$$V_{dc} \cong -0.318(V_m - 0.7\text{ V}) = -0.318(19.3\text{ V}) \cong -6.14\text{ V}$$

The resulting drop in dc level is 0.22V or about 3.5% and the output waveform appearance is:



QUIZ

- RMS load current of HWR is…………………
  ($I_m/2$)
- The average load voltage of HWR is ……….
  (V_m/ π)
- The ripple factor of HWR is…………………
  (1.21)

RECAP

- Rectifiers convert AC voltage to pulsating DC voltage.
- There are two types of rectifiers:
  1. Half Wave Rectifier (HWR)
  2. Full Wave Rectifier (FWR)
- FWR again divide into two parts
  1. Center-Tapped (CT) Full-Wave Rectifier **2.** Full-Wave Bridge Rectifier
- HWR conducts only during positive half cycles of input ac supply.
- Peak Inverse Voltage (PIV) is the maximum voltage appears across the diode during non-conducting or off state.
- For HWR, PIV is Vm.
- For HWR, efficiency is 41%.
- Ripple Factor measures the percentage of ac component in the rectified output.
- For HWR, Ripple Factor (γ) 121%.

Diodes Rectifier Circuits:

1. **Half wave rectifier**
2. **Full wave rectifier**

Full-Wave Rectifier Circuits

(a) Center-Tapped (CT) Full-Wave Rectifier **(b)** Full-Wave Bridge Rectifier

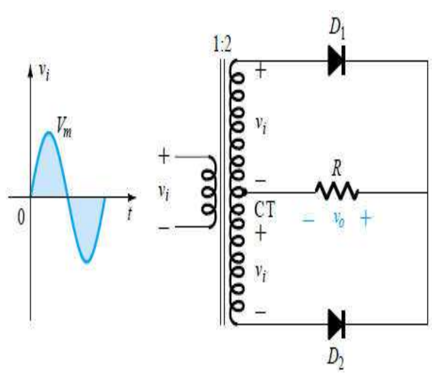


Fig. (a) Center-Tapped (CT) Full-Wave Rectifier

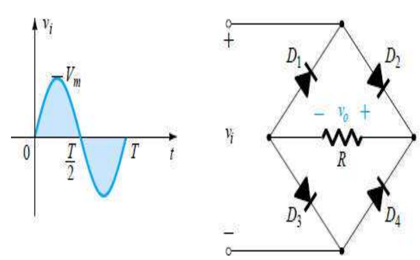
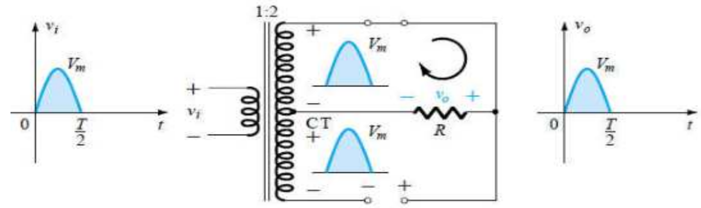


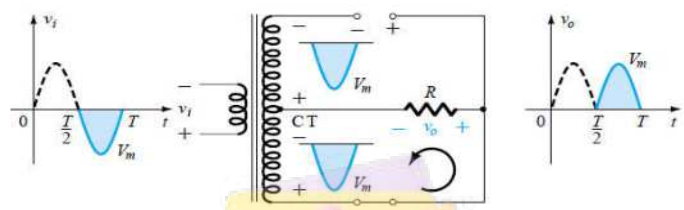
Fig. (b) Full-Wave Bridge Rectifier

Full-Wave Rectifier Circuits

Working of Center-Tapped Full-Wave Rectifier



First (+)ve half cycle



First (-)ve half cycle

Maximum Load Current

R_f = forward resistance of diodes

R_s = winding resistance of each half of secondary

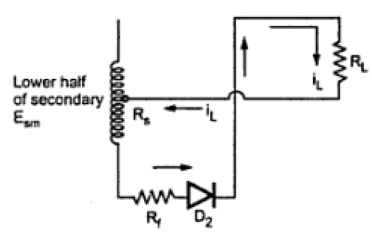
R_L = load resistance

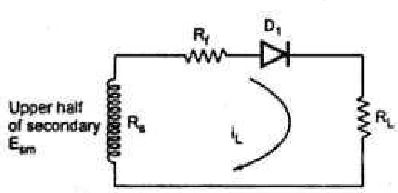
e_s = instantaneous a.c. voltage across each half of secondary

$$\boxed{e_s = E_{sm} \sin \omega t}$$

$\omega = 2\pi f$

E_{sm} = maximum value of a.c. input voltage across each half of secondary winding

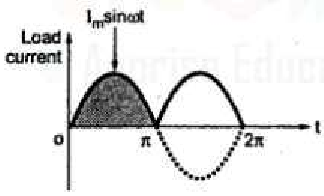




$$\boxed{I_m = \frac{E_{sm}}{R_s + R_f + R_L}}$$

I_m = maximum value of load current i_L

Average DC Load current



Consider one cycle of the load current i_L from 0 to π to obtain the average value which is d.c. value of load current.

$$i_L = I_m \sin\omega t \qquad 0 \le \omega t \le \pi$$

$$I_{av} = I_{DC} = \frac{1}{\pi}\int_0^{\pi} i_L \, d(\omega t) = \frac{1}{\pi}\int_0^{\pi} I_m \sin\omega t \, d(\omega t)$$

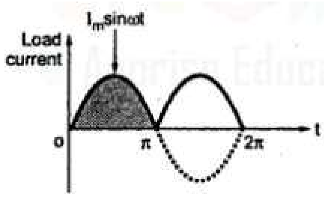
$$= \frac{I_m}{\pi}\left[(-\cos\omega t)_0^{\pi}\right]$$

$$= \frac{I_m}{\pi}[-\cos\pi - (-\cos 0)] \qquad \cos\pi = -1$$

$$= \frac{I_m}{\pi}(+1-(-1))$$

$$\boxed{I_{DC} = \frac{2I_m}{\pi}}$$

Average DC Load Voltage



$$E_{DC} = I_{DC}R_L = \frac{2I_m R_L}{\pi}$$

$$E_{DC} = \frac{2E_{sm} R_L}{\pi[R_f + R_s + R_L]} = \frac{2E_{sm}}{\pi\left[1 + \frac{R_f + R_s}{R_L}\right]} \qquad \frac{R_f + R_s}{R_L} << 1$$

$$\boxed{E_{DC} = \frac{2E_{sm}}{\pi}}$$

RMS Load Current (I_{RMS}) & Load Voltage

$$I_{RMS} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} i_L^2 d(\omega t)}$$

Since two half wave rectifiers are similar in operation, we can write:

$$I_{RMS} = \sqrt{\frac{2}{2\pi}\int_0^{\pi} [I_m \sin \omega t]^2 d(\omega t)}$$

$$= I_m \sqrt{\frac{1}{\pi}\int_0^{\pi}\left[\frac{1-\cos 2\omega t}{2}\right] d(\omega t)} \qquad \text{as } \sin^2 \omega t = \frac{1-\cos 2\omega t}{2}$$

$$I_{RMS} = I_m \sqrt{\frac{1}{2\pi}\left[[\omega t]_0^{\pi} - \left(\frac{\sin 2\omega t}{2}\right)_0^{\pi}\right]} = I_m \sqrt{\frac{1}{2\pi}[\pi - 0]}$$

$$= I_m \sqrt{\frac{1}{2\pi}(\pi)} \qquad \text{as } \sin(2\pi) = \sin(0) = 0$$

$$\boxed{I_{RMS} = \frac{I_m}{\sqrt{2}}}$$

Since the load is resistive, the r.m.s. value of the load voltage is given by:

$$\boxed{E_{L\,(RMS)} = I_{RMS} R_L = \frac{I_m}{\sqrt{2}} R_L}$$

DC Power Output (P_{DC})

$$\text{D.C. Power output} = E_{DC} I_{DC} = I_{DC}^2 R_L$$

$$P_{DC} = I_{DC}^2 R_L = \left(\frac{2I_m}{\pi}\right)^2 R_L$$

$$P_{DC} = \frac{4}{\pi^2} I_m^2 R_L$$

$$\boxed{P_{DC} = \frac{4}{\pi^2} \frac{E_{sm}^2}{(R_s + R_f + R_L)^2} \times R_L}$$

AC Power Input (P_{AC})

$$\boxed{P_{AC} = I_{RMS}^2 (R_f + R_s + R_L) = \left(\frac{I_m}{\sqrt{2}}\right)^2 (R_f + R_s + R_L)}$$

$$P_{AC} = \frac{I_m^2 (R_f + R_s + R_L)}{2}$$

$$P_{AC} = \frac{E_{sm}^2}{(R_f + R_s + R_L)^2} \times \frac{1}{2} \times (R_f + R_s + R_L)$$

$$\boxed{P_{AC} = \frac{E_{sm}^2}{2(R_f + R_s + R_L)}}$$

Rectifier efficiency

$$\boxed{\eta = \frac{P_{DC}\ \text{output}}{P_{AC}\ \text{input}}}$$

$$\eta = \frac{\frac{4}{\pi^2} I_m^2 R_L}{\frac{I_m^2 (R_f + R_s + R_L)}{2}}$$

$$\eta = \frac{8\ R_L}{\pi^2 (R_f + R_s + R_L)}$$

But if $R_f + R_s << R_L$, neglecting it from denominator

$$\eta = \frac{8\ R_L}{\pi^2 (R_L)} = \frac{8}{\pi^2}$$

$$\boxed{\%\ \eta_{max} = \frac{8}{\pi^2} \times 100 = 81.2\ \%}$$

Ripple factor

$$\text{Ripple factor} = \sqrt{\left[\frac{I_{RMS}}{I_{DC}}\right]^2 - 1}$$

For full wave $I_{RMS} = I_m / \sqrt{2}$ and $I_{DC} = 2I_m / \pi$ so, substituting in the above equation,

$$\text{Ripple factor} = \sqrt{\left[\frac{I_m / \sqrt{2}}{2I_m / \pi}\right]^2 - 1} = \sqrt{\frac{\pi^2}{8} - 1}$$

$$\boxed{\text{Ripple factor} = \gamma = 0.48}$$

Load current (i_L)

The Fourier series for the load current is obtained by taking the sum of the series for the individual rectifier current. The two diodes conduct in alternate half cycles, i.e. there is a phase difference of π radian between two diode currents

$$i_{d_1} = I_m\left[\frac{1}{\pi}+\frac{1}{2}\sin\omega t-\frac{2}{3\pi}\cos 2\omega t-\frac{2}{15\pi}\cos 4\omega t\ldots\right]$$

$$i_{d_2} = i_{d_1} \text{ with } \omega t \text{ replaced by } (\omega t+\pi)$$

$$i_{d_2} = I_m\left[\frac{1}{\pi}+\frac{1}{2}\sin(\omega t+\pi)-\frac{2}{3\pi}\cos 2(\omega t+\pi)-\frac{2}{15\pi}\cos 4(\omega t+\pi)\ldots\right]$$

$$= I_m\left[\frac{1}{\pi}-\frac{1}{2}\sin\omega t-\frac{2}{3\pi}\cos(2\omega t+2\pi)-\frac{2}{15\pi}\cos(4\omega t+4\pi)\ldots\right]$$

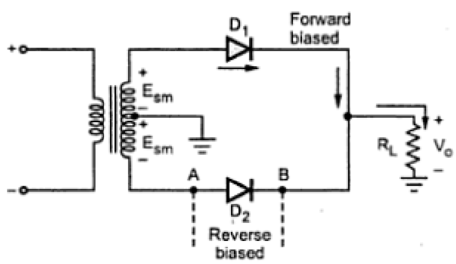
$$= I_m\left[\frac{1}{\pi}-\frac{1}{2}\sin\omega t-\frac{2}{3\pi}\cos 2\omega t-\frac{2}{15\pi}\cos 4\omega t\ldots\right]$$

$$i_L = i_{d_1}+i_{d_2} = I_m\left[\frac{2}{\pi}-\frac{4}{3\pi}\cos 2\omega t-\frac{4}{15\pi}\cos 4\omega t\cdots\right]$$

$$\boxed{i_{sec} = i_{d_1}-i_{d_2}} \qquad i_{sec} = I_m \sin\omega t$$

First term represents the average or DC value, while the remaining terms represent "ripple". Lowest frequency to the ripple is $2f$. Individual diode currents flow in the opposite directions through two halves of secondary winding. Secondary current is difference of individual diode currents.

Peak Inverse Voltage (PIV)



When D_2 is reverse biased, point A is at $-E_{sm}$ w.r.t. ground while point B is at $+E_{sm}$ w.r.t. ground, neglecting diode drop. The total peak voltage across D_2 is 2 E_{sm}.

$$\boxed{\text{PIV of diode} = 2\,E_{sm} = \pi E_{DC}\big|_{I_{DC}=0}}$$

$$\boxed{\text{PIV of diode} = 2E_{sm} - 0.7}$$

Transformer Utilization Factor (TUF)

$$\text{Secondary T.U.F} = \frac{\text{D.C. power to the load}}{\text{A.C. power rating of secondary}}$$

$$= \frac{I_{DC}^2 R_L}{E_{RMS}\, I_{rms}} = \frac{\left(\frac{2}{\pi} I_m\right)^2 R_L}{\frac{E_{sm}}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}}}$$

Neglecting forward resistance R_f of diode, $E_{sm} \approx I_m R_L$.

$$\text{Secondary T.U.F.} = \frac{\frac{4}{\pi^2} \times I_m{}^2 R_L}{\frac{I_m{}^2 R_L}{2}} = \frac{8}{\pi^2} = 0.812$$

$$\text{T.U.F. for primary winding} = 2 \times \text{T.U.F. of half wave circuit}$$

$$= 2 \times 0.287 = 0.574.$$

$$\text{Average T.U.F. for full wave rectifier circuit} = \frac{\text{T.U.F of primary} + \text{T.U.F of secondary}}{2}$$

$$= \frac{0.574 + 0.812}{2} = 0.693$$

In Secondary of transformer, current flows through each half separately in every half cycle. While primary carries current continuously. TUF of primary & secondary calculated separately.

Primary is feeding two half wave rectifiers separately which seems to work independently but feed to a common load.

Voltage Regulation

$$(V_{dc})_{NL} = \frac{2E_{sm}}{\pi}$$

$$(V_{dc})_{FL} = I_{DC} R_L$$

$$\% R = \frac{(V_{dc})_{NL} - (V_{dc})_{FL}}{(V_{dc})_{FL}} \times 100$$

$$\boxed{\% R = \frac{\frac{2E_{sm}}{\pi} - I_{DC} R_L}{I_{DC} R_L} \times 100}$$

$$I_m = \frac{E_{sm}}{R_f + R_L + R_s}$$

$$E_{sm} = I_m (R_f + R_L + R_s)$$

$$I_{DC} = \frac{2I_m}{\pi}$$

$$\% R = \frac{\frac{2I_m}{\pi}[R_f + R_L + R_s] - \frac{2I_m}{\pi} R_L}{\frac{2I_m}{\pi} R_L} \times 100$$

$$= \frac{R_f + R_L + R_s - R_L}{R_L} \times 100$$

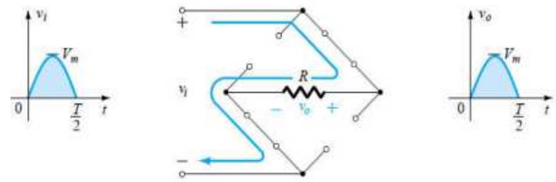
$$\boxed{\% R = \frac{R_f + R_s}{R_L} \times 100}$$

Neglecting winding resistance R_s, regulation is given by:

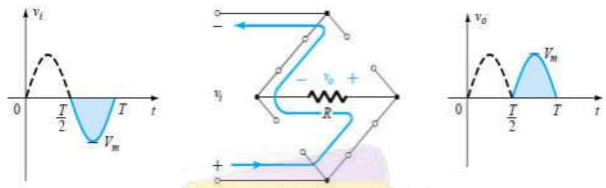
$$\boxed{\% R \approx \frac{R_f}{R_L} \times 100}$$

Full-Wave Rectifier Circuits

Working of Full-Wave Bridge Rectifier



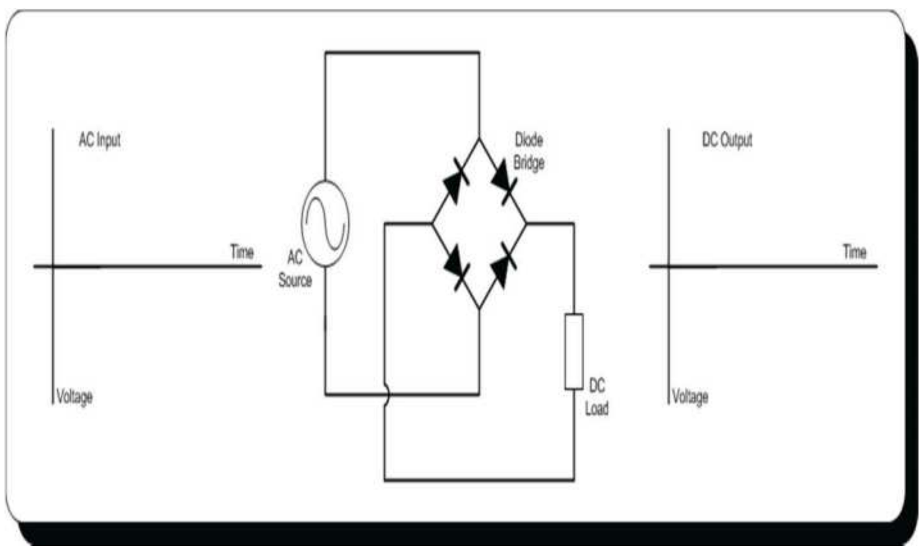
First (+)ve half cycle



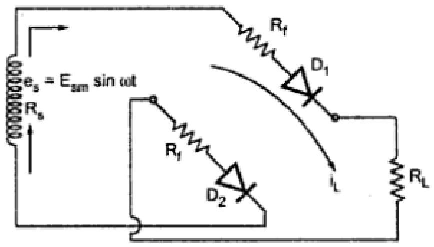
First (-)ve half cycle

Full-Wave Rectifier Circuits

Working of Full-Wave Bridge Rectifier (ANIMATION)



Expression for various parameters



$$I_{DC} = \frac{2I_m}{\pi} \quad \text{and} \quad I_{RMS} = \frac{I_m}{\sqrt{2}}$$

$$I_m = \frac{E_{sm}}{R_s + 2R_f + R_L}$$

Inplace of R_f, the term $2R_f$ appears in the denominator !

$$E_{DC} = I_{DC} R_L = \frac{2E_{sm}}{\pi}$$

$$P_{DC} = I_{DC}^2 R_L = \frac{4}{\pi^2} I_m^2 R_L$$

$$P_{AC} = I_{RMS}^2 (R_s + 2R_f + R_L) = \frac{I_m^2 (2R_f + R_s + R_L)}{2}$$

$$\eta = \frac{8R_L}{\pi^2 (R_s + 2R_f + R_L)}, \ \% \eta_{max} = 81.2\%$$

$$\gamma = 0.48$$

As current flows through the entire secondary of the transformer for all the time, TUF is 0.812 !

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Full-Wave Rectifier Circuits

PIV for Full wave Center-Tapped (CT) and Full wave Bridge rectifier:

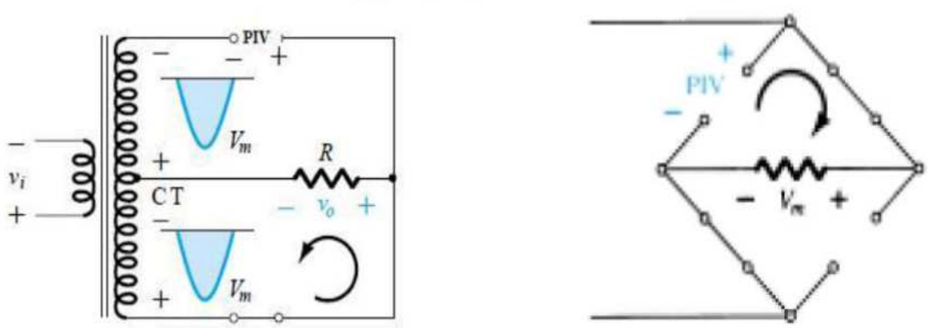

Fig. 1.27 Determining the required PIV Rating for Full wave **(a)** CT rectifier **(b)** Bridge rectifier

Using KVL;

$PIV = V_{secondary} + V_R$ $\qquad$ $-V_m + PIV = 0$

$PIV = V_m + V_m = \mathbf{2\ V_m}$ $\qquad$ $\mathbf{PIV = V_m}$

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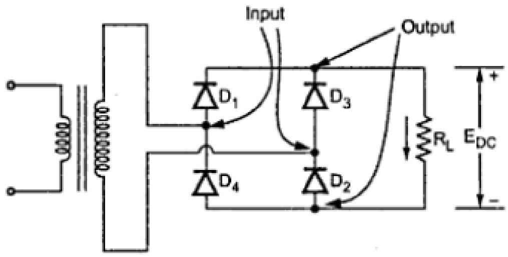
What happens if Input and Output Terminals are Reversed ?



If the input and output terminals in bridge rectifier are reversed without any change in the diodes, then it will not work. Since, for one cycle, supply will get shorted through the forward biased diodes across the supply while for other cycle the circuit will be open circuit. The output will be zero.

Comparison between HWR & FWR

S.No.	Parameters	Half Wave Rectifier	Full Wave	
			Center-Tapped Rectifier	Bridge Rectifier
1	Operation	Conducts during positive half cycles.	Conducts during both the half cycles	Conducts during both the half cycles
2	Number of diodes	1	2	4
3	The average (dc) load voltage	V_m/π.	$2V_m/\pi$.	$2V_m/\pi$.
4	RMS load current	$I_m/2$.	$I_m/\sqrt{2}$.	$I_m/\sqrt{2}$.
5	Ripple Factor	1.21	0.48	0.48
6	Efficiency	41%.	81.2%.	81.2%.
7	PIV	V_m	$2V_m$	V_m
8	TUF (Transformer Utilization Factor)	0.287	0.69	0.81

Quiz

- RMS load current of FWR is…………..

  $I_m/\sqrt{2}$

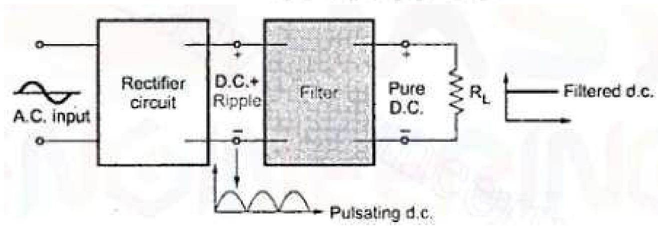
- The average load voltage of FWR is …………

  ($2V_m/\pi$)

- The ripple factor of FWR is ……………………

  (0.48)

Filter Circuits

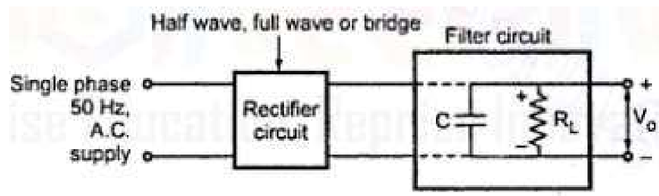


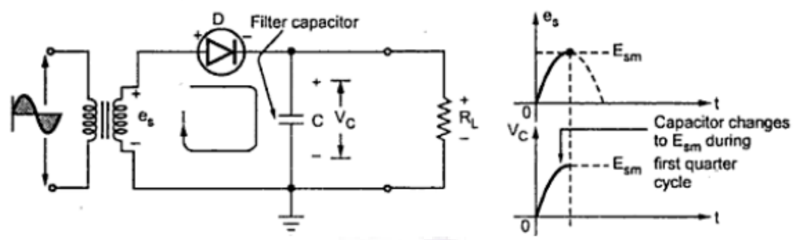
- **Inductance acts as a short circuit for DC, but has a large impedance for AC. Inductance acts as short circuit for DC, it can not be placed in shunt arm across the load. Inductance used in filter circuits are called "choke".**

- **Capacitor acts as open circuit for DC and almost short for AC (if the capacitance is sufficiently large enough). Capacitance is open for DC, it blocks DC, hence it can not be connected in series with the load.**

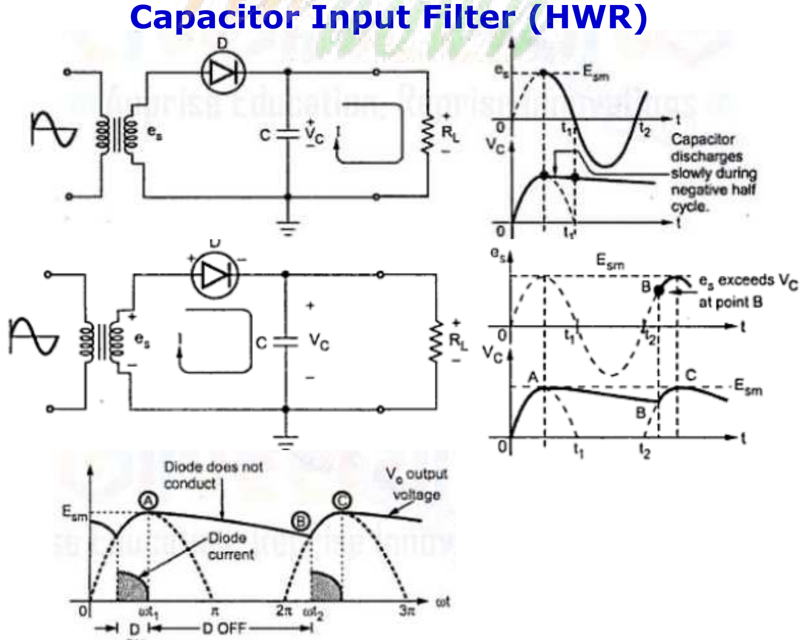
Two types of Filter circuits:
(i) Capacitor input filter and (ii) choke input filter

Capacitor Input Filter (HWR)

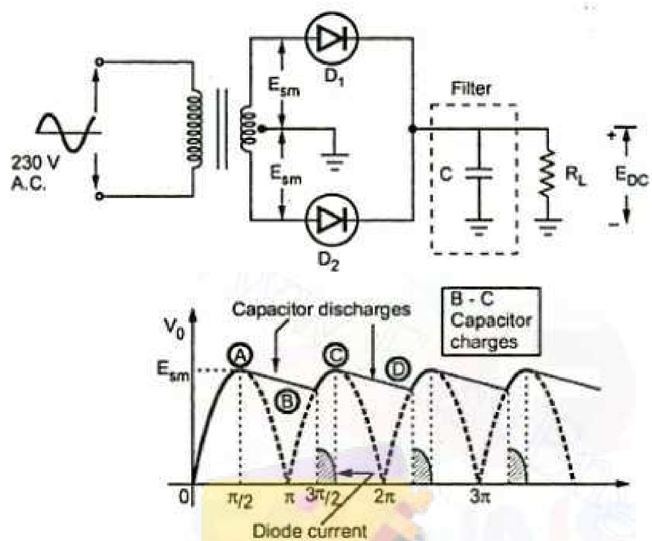




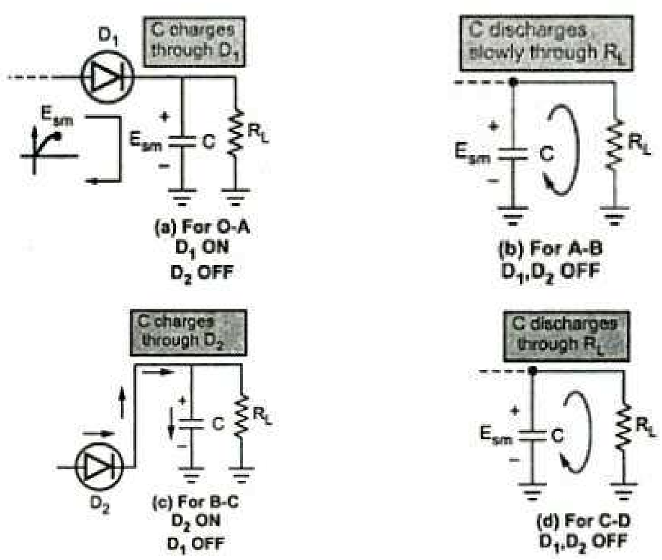
Capacitor Input Filter (HWR)



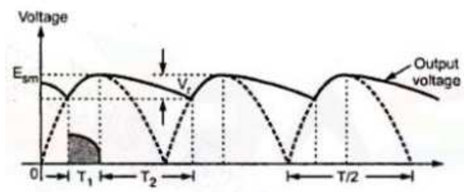
Capacitor Input Filter (FWR)

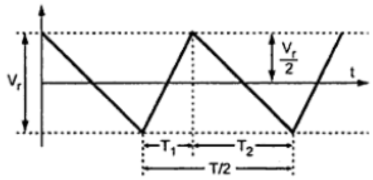


Operation of Capacitor Input Filter (FWR)



Approximate Analysis of CIF





$$\boxed{V_{rms} = \frac{V_r}{2\sqrt{3}}}$$

$$Q = CV_r$$

$$i = \frac{dQ}{dt}$$

$$Q = \int_0^{T_2} i\,dt = I_{DC}\,T_2$$

During T_2, capacitor C discharges through load resistance R_L.

Integration gives average or DC value.

$$I_{DC}\,T_2 = CV_r$$

$$V_r = \frac{I_{DC}\,T_2}{C}$$

$$T_1 + T_2 = \frac{T}{2}$$

Normally, $T_2 >> T_1$

$$T_1 + T_2 \approx T_2 = \frac{T}{2}$$

where $T = \frac{1}{f}$

$$V_r = \frac{I_{DC}}{C}\left[\frac{T}{2}\right] = \frac{I_{DC} \times T}{2C} = \frac{I_{DC}}{2fC}$$

$$I_{DC} = \frac{E_{DC}}{R_L}$$

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Approximate Analysis of CIF

$$\boxed{V_r = \frac{E_{DC}}{2fCR_L} = \text{peak to peak ripple voltage}}$$

$$\text{Ripple factor} = \frac{V_{rms}}{E_{DC}} = \frac{\frac{E_{DC}}{2fCR_L}}{2\sqrt{3}} \times \frac{1}{E_{DC}}, \text{ Since } V_{rms} = \frac{V_r}{2\sqrt{3}}$$

CR_L is the time constant of the filter circuit.

$$\boxed{\text{Ripple factor} = \frac{1}{4\sqrt{3}\,fCR_L} \quad \text{for full wave}}$$

$$\boxed{\text{Ripple factor} = \frac{1}{2\sqrt{3}\,fCR_L} \quad \text{for half wave}}$$

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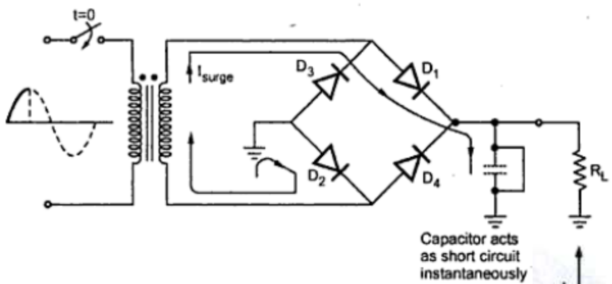
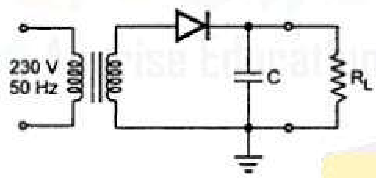
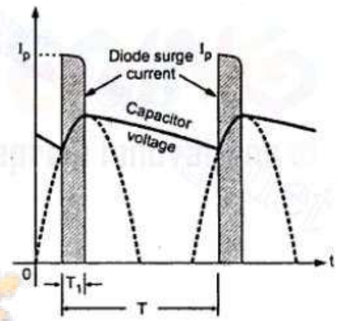
Surge current in CIF



Initially, capacitor acts as short circuit, and hence momentarily it does not offer any resistance to the input current.





Surge current in CIF

Assume current pulse to be rectangular and peak surge current flows for the entire conduction period of diode which is T_1.

I_{DC} = average d.c. current

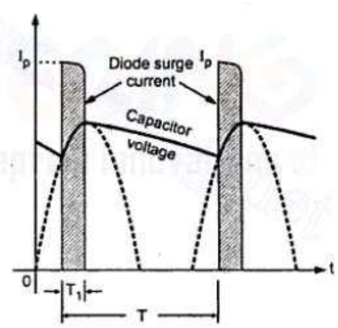
$I_{p\,(surge)}$ = peak value of the surge current

$$Q\text{ (discharge)} = Q\text{ (charge)}$$

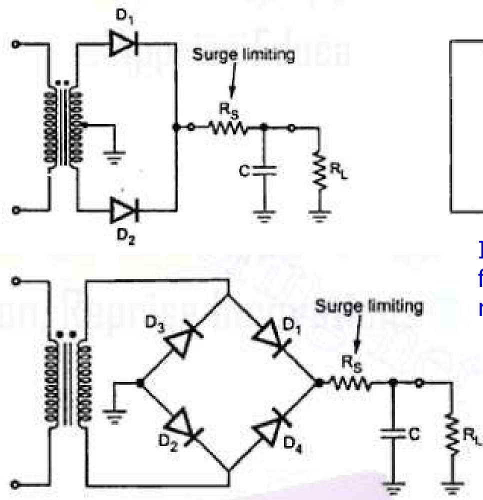
$$I_{DC}T = I_{p(surge)}\,T_1$$

$$\boxed{I_{p(surge)} = I_{DC}\left(\frac{T}{T_1}\right)} \qquad T_1 << T,$$

Since, $T_1 << T$, $I_{p(surge)}$ can be many times larger than the avarage DC current supplied to the load !



Limiting the Surge current in CIF



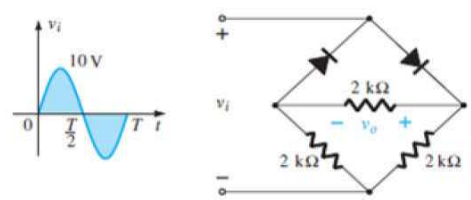
$$R_S = \frac{E_{sm} - 1.4}{I_{FSM}}$$

$$R_S = \frac{E_{sm} - 0.7}{I_{FSM}}$$

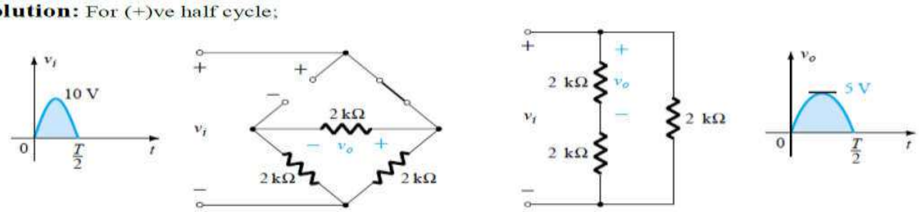
I_{FSM} is the maximum forward surge current rating of diode.

Example

Example: 10 Determine the output waveform for the network and calculate the output dc level and required PIV of each diode.



Solution: For (+)ve half cycle;



Using voltage divider rule;

$$v_o = \frac{2}{2+2} \times 10 = 5V$$

The effect of removing two diodes from the bridge configuration was therefore to reduce the available dc level to the following:

$$V_{dc} = 0.635(V_m) = 0.635(5V) = 3.18V$$

$$\text{and PIV} = v_o = V_m = 5V$$

RECAP

- In Full Wave Rectifier (FWR) circuit current flows through the load line in the same direction for both half cycles (full wave) of input ac voltage.
- There are two types of FWR:
  1. FWR with Centre Tapped Transformer
  2. Full Wave Bridge Rectifier
- In Centre Tapped FWR there are two diodes.
- In Full Wave Bridge Rectifier there are four diodes.
- PIV for Centre Tapped FWR is 2Vm.
- PIV for Full Wave Bridge Rectifier is V_m.
- For FWR, Ripple Factor (γ) 48%.
- TUF for Centre Tapped FWR is 69%.
- TUF for Full Wave Bridge Rectifier is 81%.

Diodes - Zener diode as Voltage regulator

Zener-Diode Voltage-Regulator Circuits

Zener-Diode Voltage-Regulator Circuits Zener produces constant output voltage while operating from a variable supply voltage. Such circuits are called voltage regulator.

- The Zener diode has a breakdown voltage equal to the desired output voltage.
- The resistor limits the diode current to a safe value so that Zener diode does not overheat.

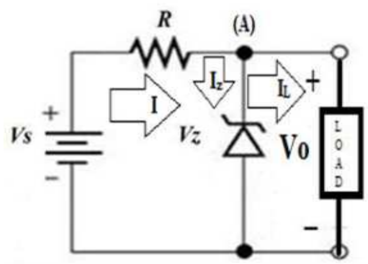


Fig. Zener Diode Voltage- Regulator Circuit

Using **KVL;** $V_s = I.R + V_z$

on solving we get

$$I = \frac{V_s - V_z}{R}$$

Now, using **KCL** at node (A); $\mathbf{I = I_z + I_L}$

Where; $\mathbf{I_z}$ = current across zener diode

$\mathbf{I_L}$ = current across load resistance

Zener-Diode Voltage-Regulator Circuits

Case I: Regulation with Varying Input Voltage (V_{in}):

V_{in} increases ➔	$I = I_L + I_Z$ increases ➔	I_L is constant (V_Z/R_L) ➔	So I_Z increases ($I_Z = I - I_L$) ➔	As long $I_Z < I_{Zmax}$, V_Z is constant i.e. output voltage is constant
V_{in} decreases ➔	$I = I_L + I_Z$ decreases ➔	I_L is constant (V_Z/R_L) ➔	So I_Z decreases ($I_Z = I - I_L$) ➔	As long $I_Z > I_{Zmin}$, V_Z is constant i.e. output voltage is constant

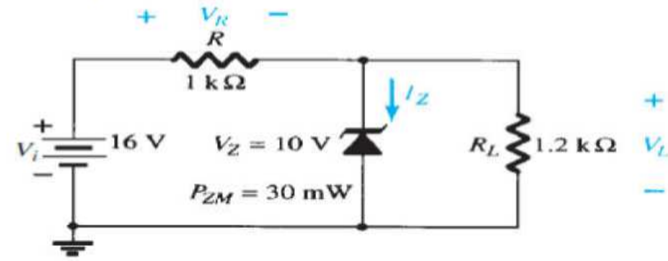
Case II: Regulation with Varying Load (R_L):

R_L increases I_L decreases ➔	$I = \frac{V_{in} - V_Z}{R}$ constant ➔	$I_Z = I - I_L$ increases ➔	As long $I_Z < I_{Zmax}$, V_Z is constant i.e. output voltage is constant
R_L decreases I_L increases ➔	$I = \frac{V_{in} - V_Z}{R}$ constant ➔	$I_Z = I - I_L$ decreases ➔	As long $I_Z > I_{Zmin}$, V_Z is constant i.e. output voltage is constant

Examples

Example: 11 (a) For the Zener diode network, determine V_L, V_R, I_Z and P_Z

(b) Repeat part (a) with R_L= 3 kΩ

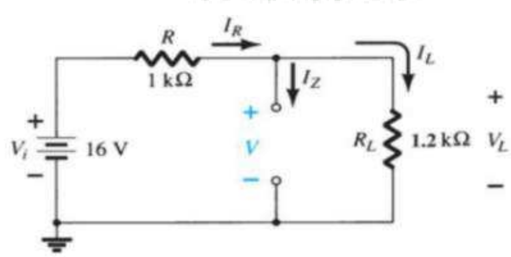


Solution: **(a) Note:** First we check wheather Zener is **ON** or **OFF**. If **V ≥ VZ**, then Zener is **ON** otherwise it is **OFF.** Now;

$$V = \frac{R_L V_i}{R + R_L} = \frac{1.2\ \text{k}\Omega(16\ \text{V})}{1\ \text{k}\Omega\ +\ 1.2\ \text{k}\Omega} = 8.73\ \text{V}$$

Here; **$V < V_Z$** i.e. 8.73 V < 10 V, So Zener is **OFF** means not conducting. Now we can redraw the given network as:

Examples



Hence; V_L = V = **8.73 V**, V_R = V_i - V_L = 16 – 8.73 = **7.27 V**, I_Z **= 0 A**, P_Z = $V_Z I_Z$ = 10 (0) = **0 W**

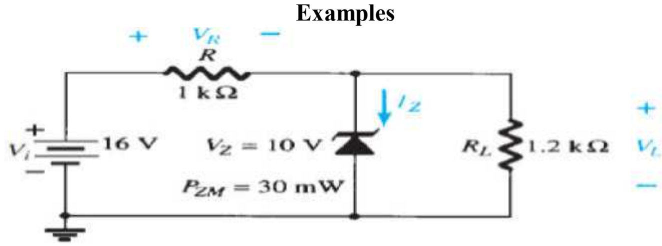
(b) Now; R_L= 3 kΩ

Again here we check whether Zener is **ON** or **OFF**. For this we calculate **V** across Zener i.e.

$$V = \frac{R_L V_i}{R + R_L} = \frac{3\ \text{k}\Omega(16\ \text{V})}{1\ \text{k}\Omega\ +\ 3\ \text{k}\Omega} = 12\ \text{V}$$

Here; **$V > V_Z$** i.e. 12 V > 10 V, So Zener is **ON** means conducting.

Examples



Hence; $V_L = V_Z = 10$ V. $V_R = V_i - V_L = 16 - 10 = 6$ V.

$$I_L = \frac{V_L}{R_L} = \frac{10\text{ V}}{3\text{ k}\Omega} = 3.33\text{ mA}$$

$$I_R = \frac{V_R}{R} = \frac{6\text{ V}}{1\text{ k}\Omega} = 6\text{ mA}$$

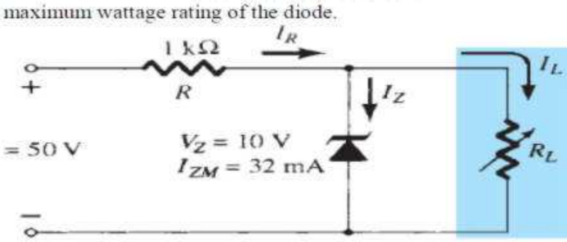
$$I_Z = I_R - I_L\ [\text{Eq. (2.18)}]$$
$$= 6\text{ mA} - 3.33\text{ mA}$$
$$= \mathbf{2.67\text{ mA}}$$

The power dissipated is

$$P_Z = V_Z I_Z = (10\text{ V})(2.67\text{ mA}) = \mathbf{26.7\text{ mW}}$$

which is less than the specified $P_{ZM} = 30$ mW.

Example: 12 (a) For the network, determine the range of R_L and I_L that will result in V_{RL} being maintained at 10 V.
(b) Determine the maximum wattage rating of the diode.



Solution: (a) In these type of Zener numericals Zener is always in ON condition.

$$V = \frac{R_L}{R_L + R} \times V_i;\ OR\ V = V_Z = \frac{R_L\,(\text{min})}{R_L\,(\text{min}) + R} \times V_i$$

$$R_{L_{\min}} = \frac{RV_Z}{V_i - V_Z} = \frac{(1\text{ k}\Omega)(10\text{ V})}{50\text{ V} - 10\text{ V}} = \frac{10\text{ k}\Omega}{40} = \mathbf{250\ \Omega}$$

The voltage across the resistor R is then determined by

$$V_R = V_i - V_Z = 50\text{ V} - 10\text{ V} = \mathbf{40\text{ V}}$$

the magnitude of I_R:

$$I_R = \frac{V_R}{R} = \frac{40\text{ V}}{1\text{ k}\Omega} = \mathbf{40\text{ mA}}$$

The minimum level of I_L is then determined by

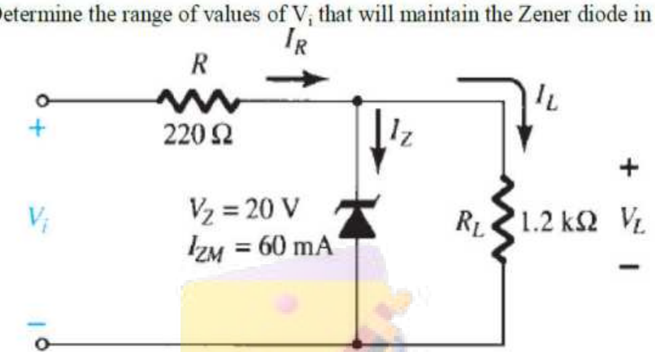
$$I_{L_{min}} = I_R - I_{ZM} = 40 \text{ mA} - 32 \text{ mA} = \mathbf{8 \text{ mA}}$$

the maximum value of R_L

$$R_{L_{max}} = \frac{V_Z}{I_{L_{min}}} = \frac{10 \text{ V}}{8 \text{ mA}} = \mathbf{1.25 \text{ k}\Omega}$$

(b) $P_{ZMAX} = V_Z * I_{ZM} = (10 \text{ V})(32\text{mA}) = \mathbf{320 \text{ mW}}$

Example: 13 Determine the range of values of V_i that will maintain the Zener diode in the ON state.



Examples

Solution: In these type of Zener numericals Zener is always in ON condition.

$$V = \frac{R_L}{R_L + R} \times V_i; \quad OR \quad V = V_Z = \frac{R_L}{R_L + R} \times V_i(\text{min})$$

$$V_{i_{min}} = \frac{(R_L + R)V_Z}{R_L} = \frac{(1200\ \Omega + 220\ \Omega)(20 \text{ V})}{1200\ \Omega} = \mathbf{23.67 \text{ V}}$$

$$I_L = \frac{V_L}{R_L} = \frac{V_Z}{R_L} = \frac{20 \text{ V}}{1.2 \text{ k}\Omega} = 16.67 \text{ mA}$$

$$I_{R_{max}} = I_{ZM} + I_L = 60 \text{ mA} + 16.67 \text{ mA}$$
$$= 76.67 \text{ mA}$$

$$V_{i_{max}} = I_{R_{max}}R + V_Z$$
$$= (76.67 \text{ mA})(0.22 \text{ k}\Omega) + 20 \text{ V}$$
$$= 16.87 \text{ V} + 20 \text{ V}$$
$$= \mathbf{36.87 \text{ V}}$$

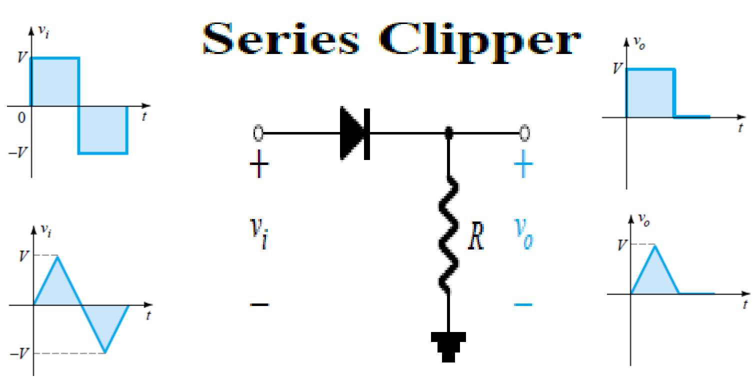
Diodes – Wave-Shaping Circuits
Clippers

Diodes – Wave-Shaping Circuits

Clipper Circuits: Clipper or Limiter circuit is used to cut off or eliminate an unwanted section of a waveform.

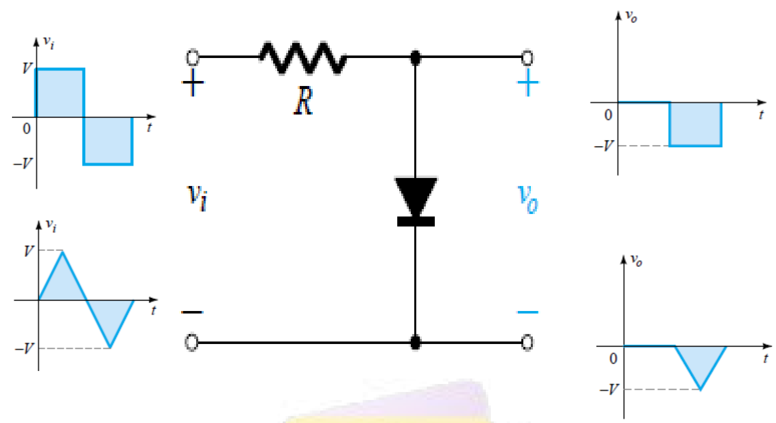
Note: Clipper circuits are the combination of **DR** or **RD** or **RDR**; where **D** and **R** stand for **DIODE** and **RESISTANCE** respectively.

- There are two types of clippers:



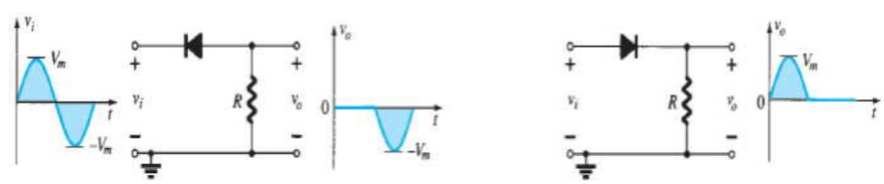
Diodes – Wave-Shaping Circuits

Shunt Clipper

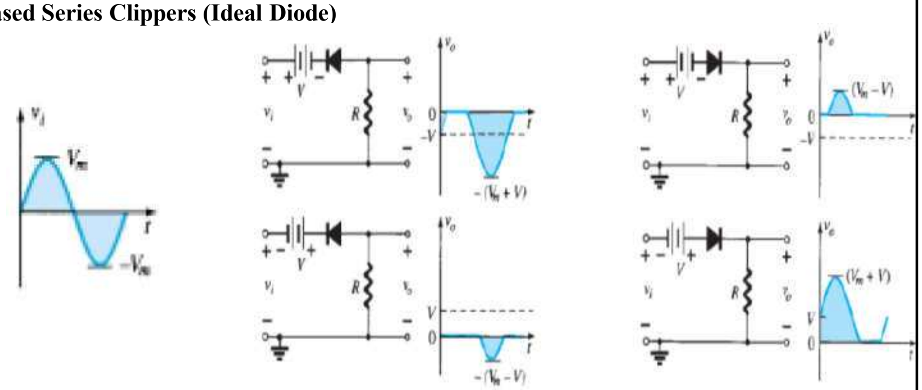


Diodes – Wave-Shaping Circuits

Simple Series Clippers (Ideal Diodes)

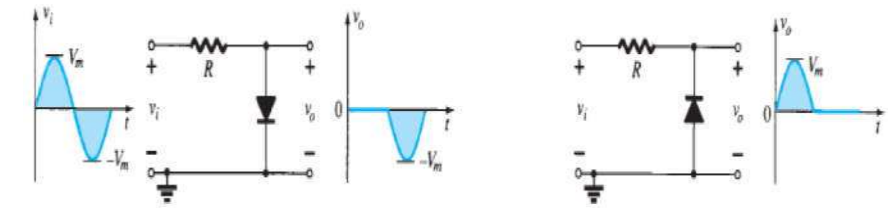


Biased Series Clippers (Ideal Diode)

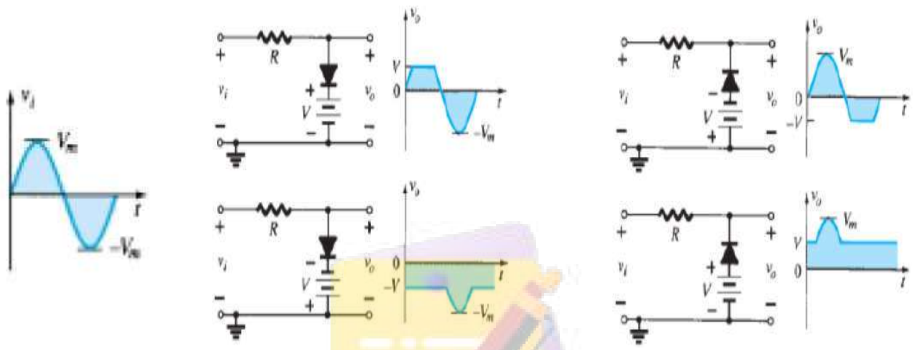


Diodes – Wave-Shaping Circuits

Simple Parallel (Shunt) Clippers (Ideal Diodes)

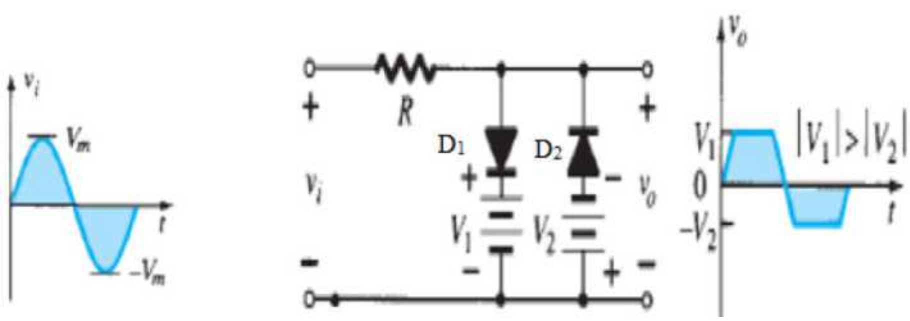


Biased Parallel (Shunt) Clippers (Ideal Diode)



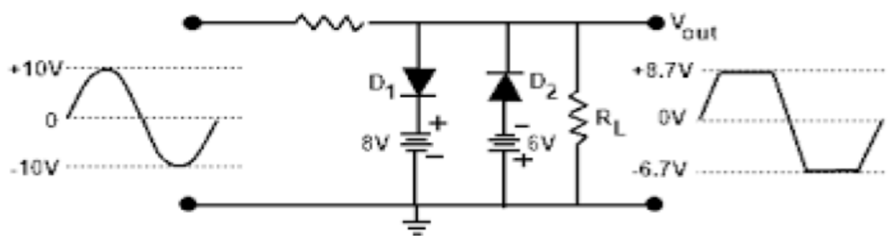
Diodes – Wave-Shaping Circuits

- **Combination clipper circuit** is the combination of two clipper circuits.
- In this clipper circuits diode D_1 conducts during (+)ve half cycle, only when applied voltage is greater than or equal to V_1.
- When D_1 is forward biased then it maintains voltage V_1 across it which appears at the output as shown in figure.
- Similarly, diode D_2 conducts during (-)ve half cycle, only when applied voltage is greater than or equal to V_2.
- When D_2 is forward biased then it maintains voltage V_2 across it which appears at the output as shown in figure.

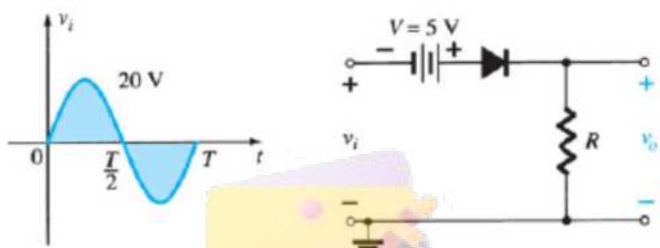


Examples

Solved Example: 14 Sketch the output.

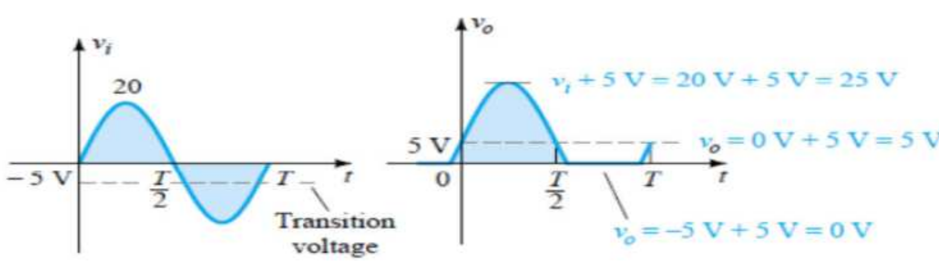


Example: 15 Determine the output waveform for the network.

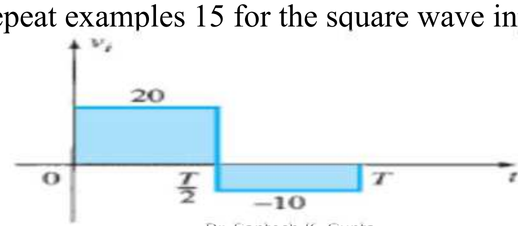


Examples

Solution: The diode will be in the ON state for positive half cycle.
Here diode is forward biased by V = 5 V.
So for v_i = + 20 V output waveform should be start from +5 V to +25 V and ; for v_i = - 20 V output waveform should be start from +5 V to 0 V.

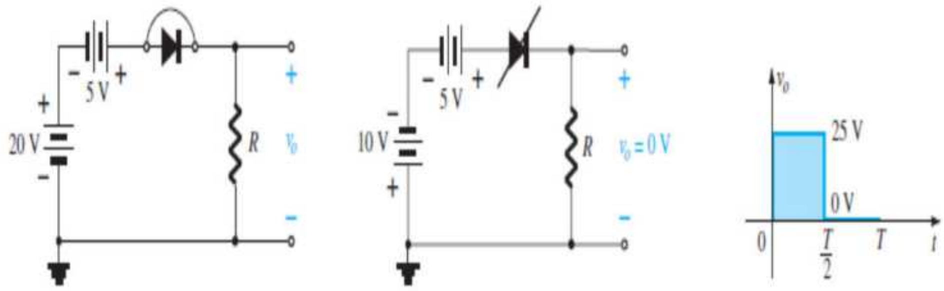


Example: 16 Repeat examples 15 for the square wave input.



Examples

Solution: For v_i = 20V (0 to T/2) the diode is in short circuit (ON) state and v_o = 20 + 5 = 25 V.
For v_i = - 10V the diode is in open circuit (OFF) state
and v_o = $i_R R$ = (0) R = 0 V.

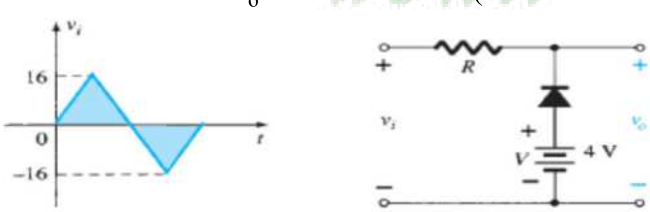


V_o at v_i = +20 V. V_o at v_i = −10 V. Sketching v_o for Example

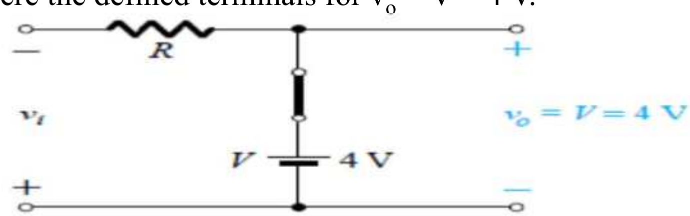
Note: In example no.15 that the clipper not only clipped off 5 V from the total swing but raised the dc level of the signal by 5 V.

Examples

Example: 17 Determine v_o for the network (consider diode is ideal).

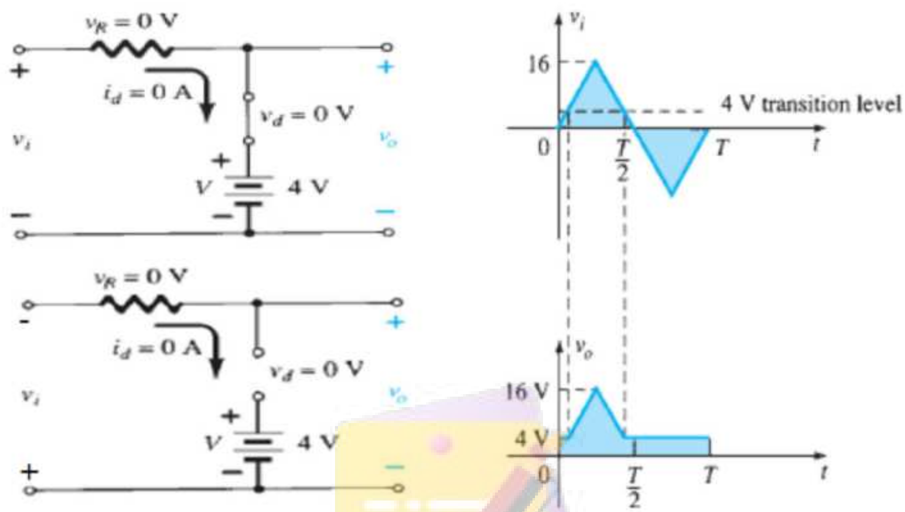


Solution: The polarity of the dc supply and direction of the diode strongly suggest that the diode will be in the ON state for a good portion of the negative region of the input signal.
For this region (For (-)ve cycle) the network will appear as shown in figure, where the defined terminals for v_o = V = 4 V.



Examples

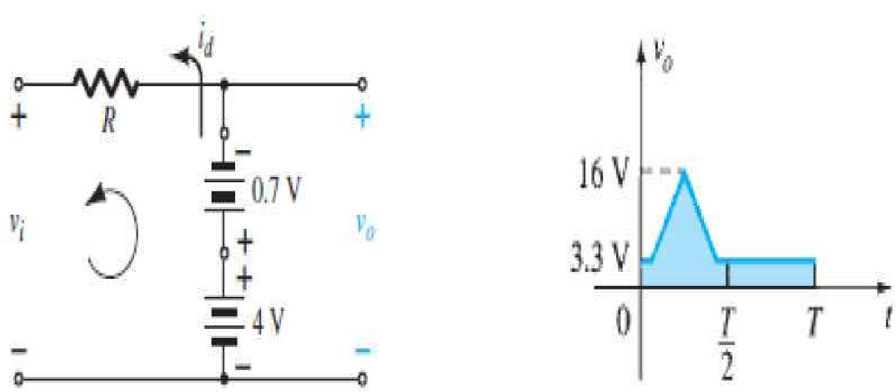
•For (+)ve cycle, when the input voltage greater than 4 V the diode will be in OFF state. But for any input voltage less than 4 V will result in a short circuited diode (ON state).



Examples

Example: 18 Repeat example 17 for $V_T = 0.7$ V (means for Si diode).

Solution: Here; when the input voltage greater than 3.3 V the diode will be in OFF state. But for any input voltage less than 3.3 V will result in a short circuited diode (ON state).



QUIZ

- The clipper circuit are used for……… some portion of input signal.
  (Clip-off)
- A positive clipper clips off ……..portion of the input waveform.
  (Positive)
- In a series clipper , for a clipping region, the diode must be in ……………….condition.
  (Reverse biased)

Home Work (no submission)

1. Sketch i_R and V_0 of Fig. 1 for the input shown and draw the V_o waveform for the Fig. 2 circuit.

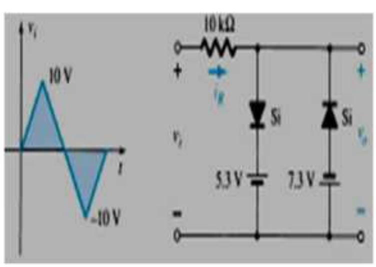


Fig. 1

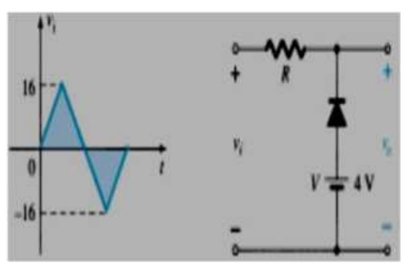


Fig. 2

RECAP

- Clipper or Limiter circuit is used to cut off or eliminate an unwanted section of a waveform.
- There are two types of clipper circuits:

  1. Series Clipper
  2. Shunt or Parallel Clipper

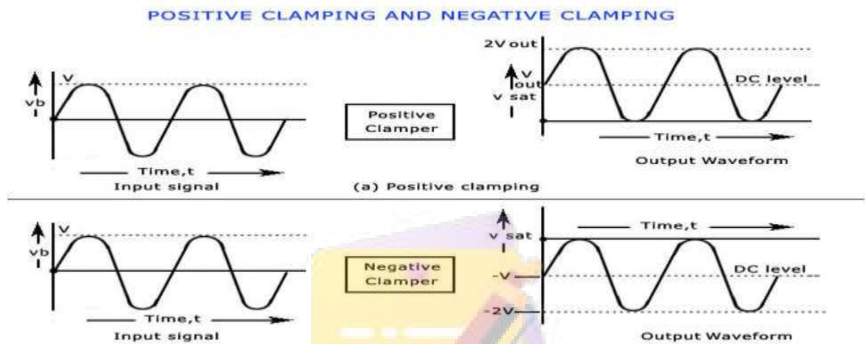
- In Series clipper diode is connected in series with load.
- In Shunt or parallel clipper diode is connected in parallel with load.
- If the diode is biased then clipper circuits are known as biased clipper otherwise it is known as unbiased clipper circuits.

Diodes – Wave-Shaping Circuits Clampers

Diodes – Wave-Shaping Circuits

Clamper Circuits: Clamper circuits are used to add a dc level to an ac input waveform.
Note: Clamper circuits are the combination of **CDR**; where **C**, **D** and **R** stand for **CAPACITANCE**, **DIODE** and **RESISTANCE** respectively.

- 1n numerical, if diode material is not specified then consider it as ideal diode always.
- On the basis of dc shift (positive or negative) clampers circuits of two types:
- Positive Clamper Circuit **(DIODE in upward direction)**
- Negative Clamper Circuit **(DIODE in downward direction)**
- If the diode is biased then clamper circuits are known as biased clamper otherwise it is known as simple clamper circuits (Unbiased).

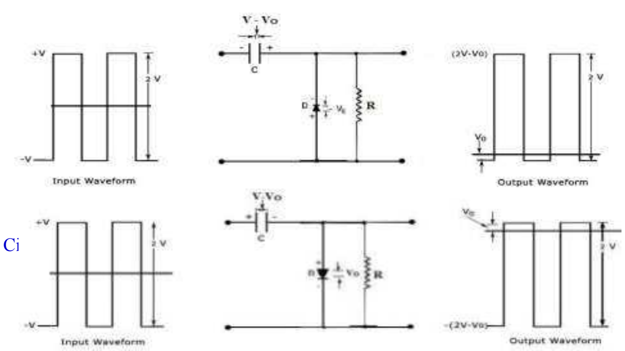


Diodes – Wave-Shaping Circuits

Steps for analysis of a clamper circuit:

- First charge the capacitor by choosing appropriate input cycle so that diode is conducting.
- Now calculate the output voltage as $\mathbf{v_o = v_i + V_c}$ (for positive clamper)
  and $\mathbf{v_o = v_i - V_c}$ (for negative clamper)
- Check output swing is equal to input swing i.e. $2V_m$ OR 2V.

Working of Clamper Circuits



1. Positive Clamper Ci
2. Negative Clamper Circuit

Diodes – Wave-Shaping Circuits
Working of Negative Clamper Circuit

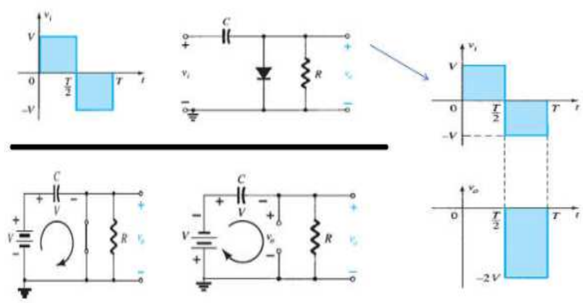
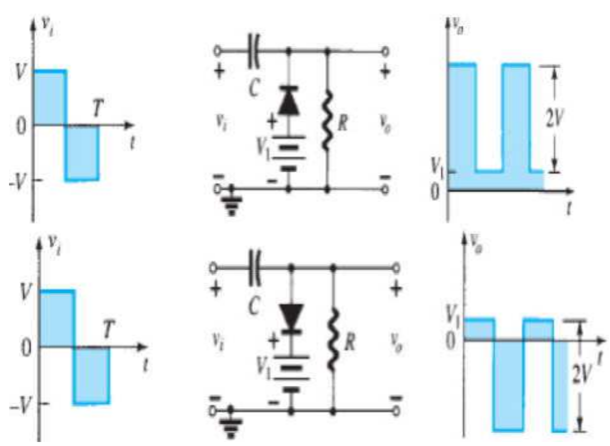


Fig. 1.42 (a) Diode is ON and capacitor is charging

Fig. 1.42 (b) Diode is OFF and $-V - V - v_o = 0$ i.e. $v_o = -2$ V

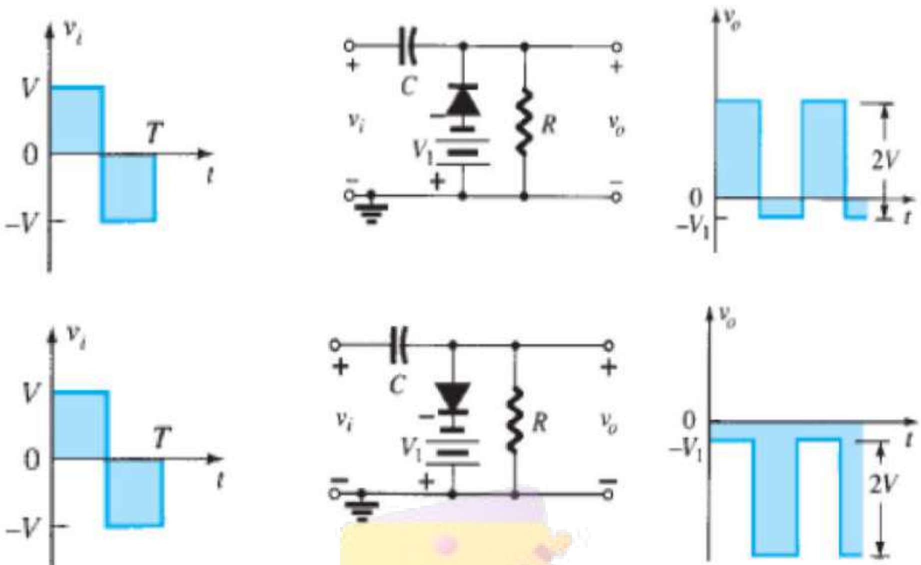
Diodes – Wave-Shaping Circuits
Biased Clamper Circuits

- When a dc supply is used in the clamper circuits then they are known as:



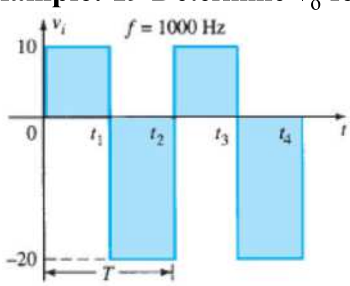
2. Biased Negative Clamper Circuit

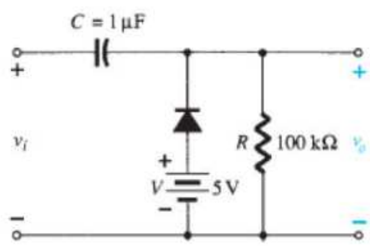
Diodes – Wave-Shaping Circuits (Clamping)



Examples

Example: 19 Determine v_o for the network and sketch the waveform.

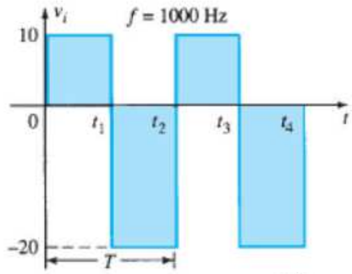


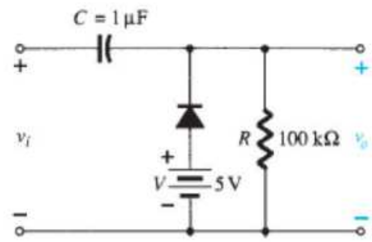


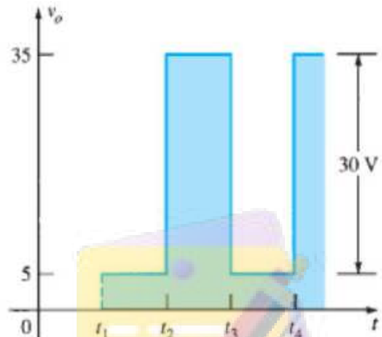
Solution: This is biased positive clamper circuit.
For capacitor charging we have to take negative half cycle of period t_1 to t_2.
Also we can observe that diode is forward biased by 5 V battery so total voltage across the capacitor is appear as $V_C = 20 + 5 = 25$ V.
Since frequency is 1000 Hz the time period will be 1 mS.
Now the output voltage for positive clamper is given as $v_o = v_i + V_C$
For positive cycle $v_o = 10 + 25 = 35$ V
For negative cycle $v_o = -20 + 25 = 5$ V

Examples

Hence final waveform is as follows:



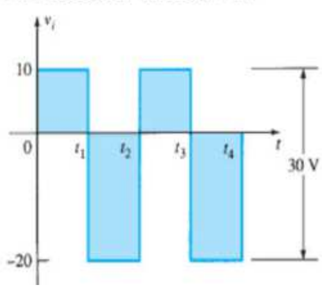


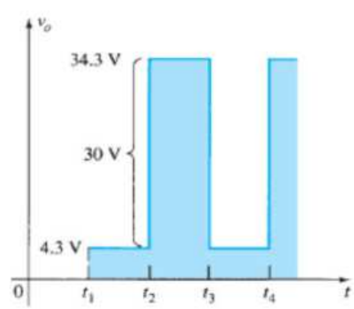


Examples

Example: 20 Repeat examples 19 if diode is not ideal.

Solution: This is biased positive clamper circuit. But in this numerical diode is not ideal. So we consider it as practical (Si) diode with barrier potential 0.7 V.
Now, for capacitor charging we have to take negative half cycle of period t_1 to t_2.
Also we can observe that diode is forward biased by **5 V – 0.7V = 4.3 V** battery so total voltage across the capacitor is appear as $V_C = 20 + 5 – 0.7 = 24.3$ V.
Since frequency is 1000 Hz the time period will be 1 mS.
Now the output voltage for positive clamper is given as $v_o = v_i + V_C$
For positive cycle $v_o = 10 + 24.3 = 34.3$ V
For negative cycle $v_o = - 20 + 24.3 = 4.3$ V
Hence final waveform is as follows:





QUIZ

- Clamper circuit are used for………… …………level of the input signal.
  (Shift DC)

- In a clamper , the analysis must start considering that part of the input which…………….
  (Forward biases the diode)

- In a ………………clamper, the capacitor gets charged during first quarter of the negative cycle of the input.
  (Positive)

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RECAP

- Clamper circuits are used to add a dc level to an ac input waveform.
- On the basis of dc shift (positive or negative) clampers circuits of two types:

  1. Positive Clamper Circuit

  2. Negative Clamper Circuit

- If the diode is biased then clamper circuits are known as biased clamper otherwise it is known as simple clamper circuits.

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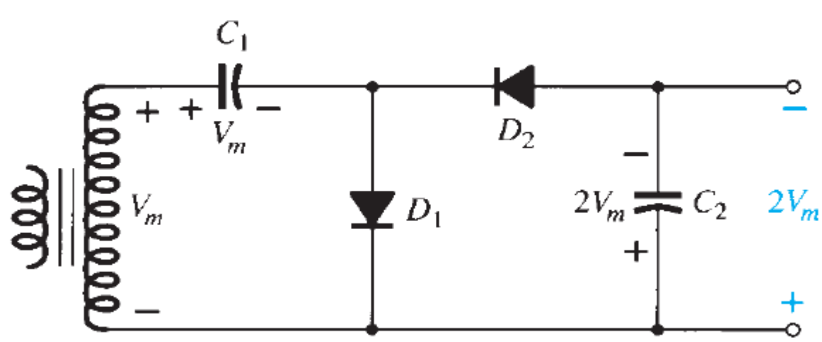
Diodes - Voltage Multipliers Circuits

Diodes – Wave-Shaping Circuits

Voltage Multiplier Circuits and its type

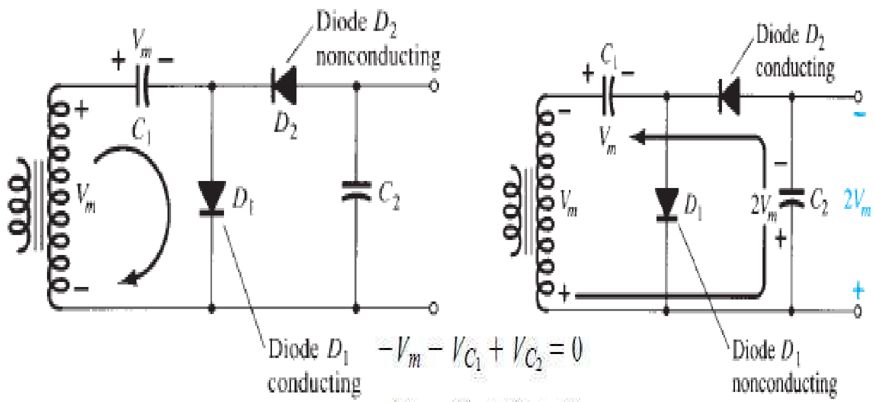
- Voltage - multiplier circuits produce a dc output voltage that is some multiple of the peak ac input voltage to this circuit.
- On the basis of multiplying factor, voltage multiplier circuit can be classified as:

1. Half wave Voltage Doubler Circuit



Diodes – Wave-Shaping Circuits (voltage multiplier)

1. Half wave Voltage Doubler Circuit



$$-V_m - V_{C_1} + V_{C_2} = 0$$

$$-V_m - V_m + V_{C_2} = 0$$

First (+)ve half cycle

First (-)ve half cycle

$$V_{C_2} = 2V_m$$

Voltage Multiplier Circuits

2. Full wave Voltage Doubler Circuit

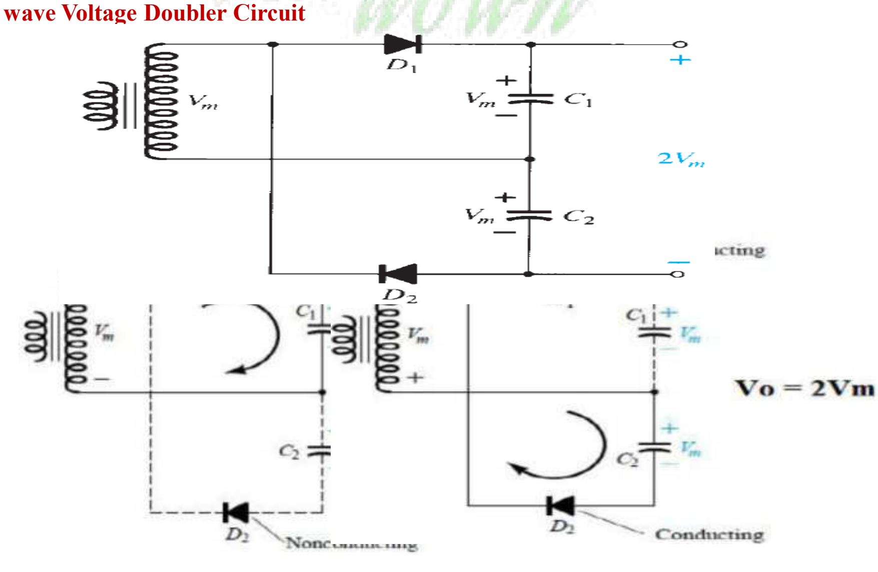


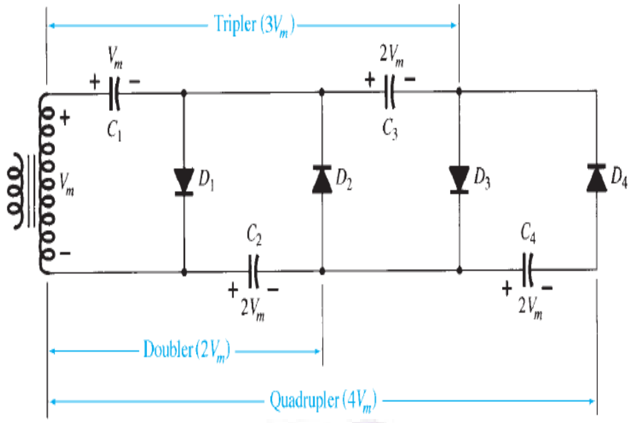
Fig. (a) (+)ve half cycle

Fig. (b) (–)ve half cycle

Diodes – Wave-Shaping Circuits

Voltage Multiplier Circuits

3. Extension of Voltage Doubler as Voltage Tripler and Quadrupler Circuits



QUIZ

- In a voltage …….., the output is twice the peak value of the input voltage.
  (Doubler)

- In Voltage multipliers, the diode and capacitors get connected in ………fashion.
  (Ladder)

- In a Voltage tripler there are …………diodes and capacitors.
  (3)