

Unit 3 :-

Diode Applications : HWR, FW & Bridge Rectifier (their operation, Performance calculations), with Filters (RC, LC, RLC), Ripple factor calculations, Clipper (two level) Transfer characteristic, Clampers, Diode as a switch, Diode as a analog gate, Voltage Multiplier (Doubler & tripler).

- The diodes used in rectifier circuits where the power line ac signal is converted into the dc signal are called large signal diodes (or) rectifier diode (1N4001). These diodes are basically silicon pn-juncⁿ diodes with larger junction area $\Rightarrow$ high transition capacitance as well as higher power rating. ($>0.5W$) of the diode.
 $\downarrow$ best better at lower power line freq.
- If the processing of the signals takes place at much higher freqs. then small signal diodes (0A79) which have much lower capacitance as well as power rating as compared to rectifier diodes are used.
- * The rectifier ckt. are used to convert the ac i/p of the normal available power supply into a dc o/p.
- * The dc source of power is an important requirement in almost all electronic systems eg:- TV, stereos & Computers.
- * However the o/p rectifier ckt. always contains some ac components that we can remove using some filtering techniques and typical characteristic of breakdown diode.
- * Other applications of diodes are clamper, Clipper, envelope detector, peak-to-peak detector, Voltage multiplier & Variable tuning using varactor diode.

Rectifier :- A rectifier is a ckt. which converts bidirectional voltage to unidirectional voltage.

* The elements used to get dc regulated power supply are

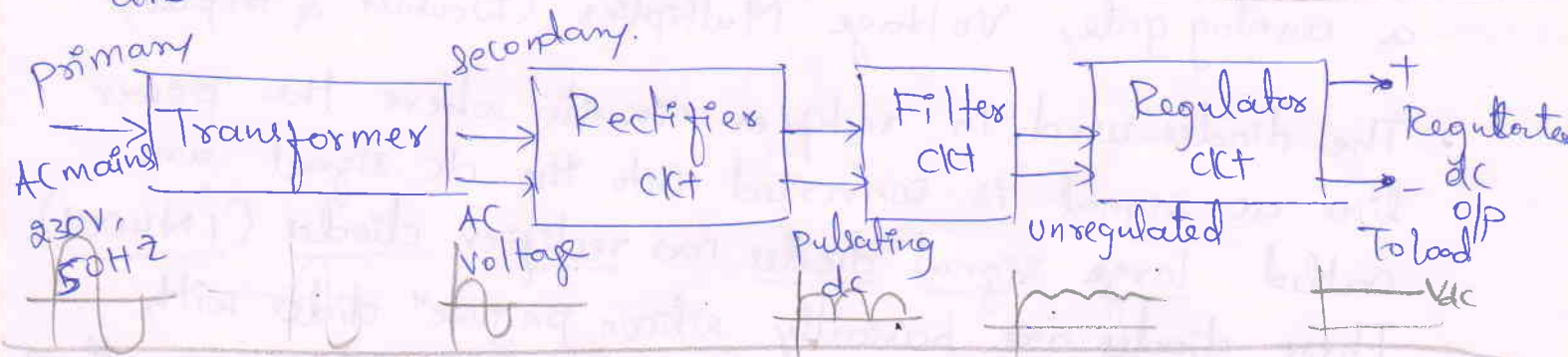


fig:- Blk. diag. of Regulated DC Power Supply.

* Transformer is a device that transfers the energy from primary winding to secondary winding through the mutual induction principle without changing the freq.

- Primary winding of transformer is connected to AC mains. & the load of transformer is connected to Secondary winding.

Let N_1 & N_2 be no^r of turns on pri & sec. windings of transformer then voltages induced on pri & sec. are

$$\frac{N_2}{N_1} = \frac{V_{sm}}{V_{pm}} \rightarrow \begin{array}{l} \text{Voltage across sec. winding} \\ \text{" " " primary} \end{array}$$

• Different types of transformers

① Stepup transformer $\rightarrow V_{sm} > V_{pm}$

② Step down " $\rightarrow V_{sm} < V_{pm} \rightarrow$ used in Rectifiers

③ Centre-tapped transformer.

2.

• Voltage transformation ratio : $\frac{V_2}{V_1} = \frac{N_2}{N_1}$

• Current transformation ratio : $\frac{I_2}{I_1} = \frac{N_1}{N_2}$

• Impedance transformation ratio : $\frac{Z_L}{Z_{in}} = \left(\frac{N_2}{N_1}\right)^2$

* Rectifiers

Half wave Rectifier (HWR)

Full Wave Rectifier (FWR)

1) Centre tap FWR

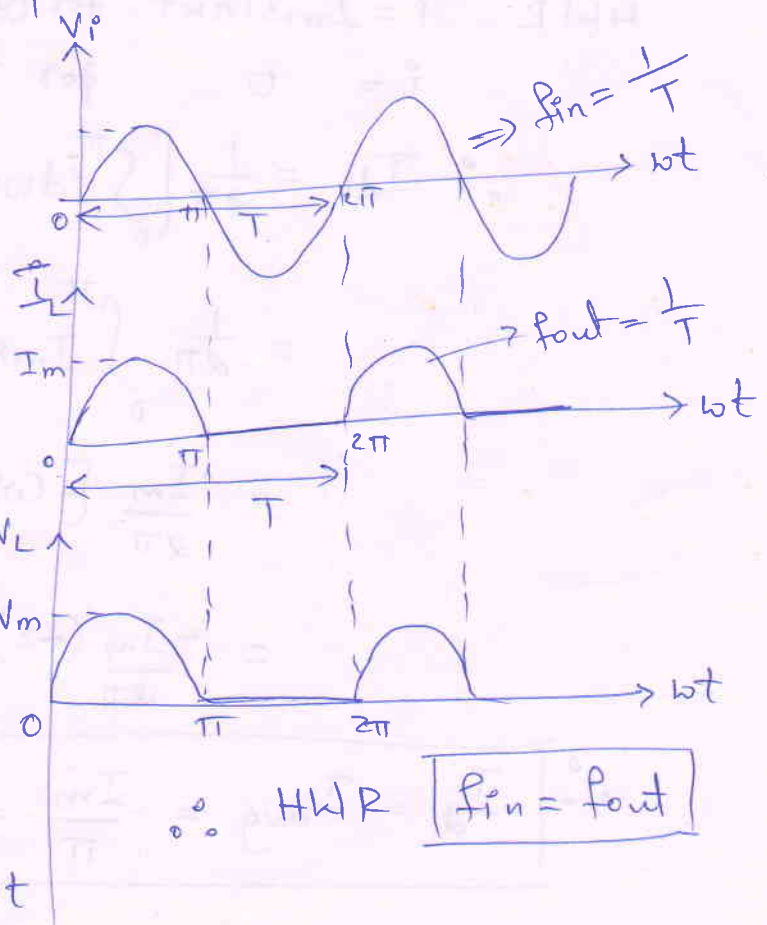
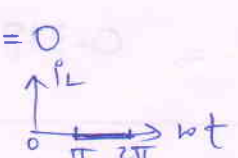
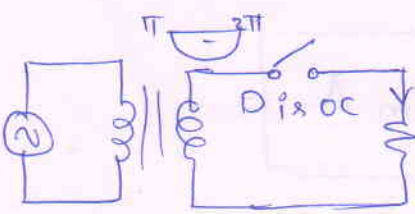
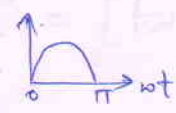
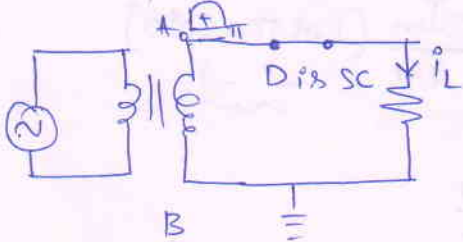
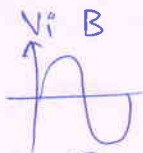
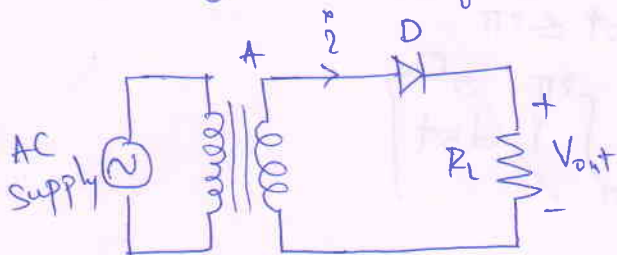
2) Bridge Rectifier

* HWR :

• The process of removing one-half the i/p signal to establish a dc level is called half-wave rectification.

• In HWR, the rectifier conducts current during positive half cycle of input ac signal only

• Negative half cycle is suppressed.



Explanation: AC Voltage across secondary terminals AB changes its polarity after each half cycle.

- During negative half cycle terminal A is -ve so diode is RB & conduct no current. So current flows through diode during positive half cycle only.
- In this way current flows through load R_L in one direction.

* Analysis for HWR circuit:

① Average (or) DC load current I_{DC} :

I_{DC} is obtained by integration of alternating current i.e. Avg. current is defined as the area of one cycle of the curve divided by the base.

$$I_{DC} = \frac{1}{2\pi} \int_0^{2\pi} i \, d(\omega t)$$

base means

↳ upper limit - lower limit
 2π to 0 ~~to~~ 2π

where $i = I_m \sin \omega t$

HWR $i = I_m \sin \omega t$ for $0 \leq \omega t \leq \pi$

$i = 0$ for $\pi \leq \omega t \leq 2\pi$

$$\therefore I_{DC} = \frac{1}{2\pi} \left[\int_0^{\pi} i \, d\omega t + \int_{\pi}^{2\pi} i \, d\omega t \right]$$

$$= \frac{1}{2\pi} \int_0^{\pi} I_m \sin \omega t \, d\omega t$$

$$= \frac{I_m}{2\pi} \left[-\cos \omega t \right]_0^{\pi} = \frac{-I_m}{2\pi} (\underbrace{\cos \pi}_{-1} - \underbrace{\cos 0}_{-1})$$

$$= \frac{-I_m}{2\pi} (-2) = \frac{I_m}{\pi}$$

$$\therefore \boxed{I_{DC} = I_{avg} = \frac{I_m}{\pi} = 0.318 I_m \text{ A}}$$

Note:- if diode consider is having some forward resistance R_f then $I_m = \frac{V_m}{R_f + R_L}$

$$\therefore I_{dc} = \frac{V_m}{\pi(R_f + R_L)} \quad \& \text{ if } R_L \gg R_f, R_L \text{ ignore}$$

$$I_{dc} = \frac{V_m}{\pi R_L} \Rightarrow \boxed{0.318 \frac{V_m}{R_L}}$$

② Avg. or dc o/p voltage.

$$V_{dc} = I_{dc} \times R_L = \frac{I_m}{\pi} \times R_L = \frac{V_m R_L}{\pi(R_f + R_L)}$$

$$\therefore V_{dc} = \frac{V_m R_L}{\pi(R_f + R_L)}$$

$$\text{if } R_L \gg R_f \text{ then } V_{dc} = \frac{V_m}{\pi} = 0.318 I_m$$

$$\therefore \boxed{V_{dc} = \frac{V_m}{\pi} = 0.318 V_m}$$

③ Root Mean Square (RMS) Value of o/p Current:-
RMS value is nothing but dc equivalent value for ac signal.

$$I_{rms} = \left(\frac{1}{2\pi} \int_0^{2\pi} i^2 d\omega t \right)^{1/2}$$

$$\text{where } i = \begin{cases} I_m \sin \omega t & \text{for } 0 \leq \omega t \leq \pi \\ 0 & \text{for } \pi \leq \omega t \leq 2\pi \end{cases}$$

$$\therefore I_{rms} = \left[\frac{1}{2\pi} \int_0^{\pi} I_m^2 \sin^2 \omega t \, d\omega t + \frac{1}{2\pi} \int_{\pi}^{2\pi} 0 \, d\omega t \right]^{1/2}$$

$$I_{rms} = \left[\frac{I_m^2}{2\pi} \int_0^{\pi} \left(\frac{1 - \cos 2\omega t}{2} \right) d\omega t \right]^{1/2}$$

$$= \left[\frac{I_m^2}{4\pi} \left(\omega t - \frac{1}{2} \sin 2\omega t \right) \right]_0^{\pi}^{1/2}$$

$$= \left[\frac{I_m^2}{4\pi} \left(\pi - 0 - \frac{\sin 2\pi}{2} + \sin 0 \right) \right]^{1/2}$$

$$= \left(\frac{I_m^2}{4} \right)^{1/2} \Rightarrow \frac{I_m}{2}$$

$$\Rightarrow \boxed{I_{rms} = 0.5 I_m} \quad (\text{or}) \quad \boxed{I_{rms} = \frac{I_m}{2}}$$

if diode has R_f .

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

$$\text{then } \boxed{I_{rms} = \frac{V_m}{2(R_f + R_L)}}$$

④ RMS o/p Voltage:

$$V_{rms} = I_{rms} \times R_L$$

$$= \frac{I_m}{2} \times R_L$$

$$V_{rms} = \frac{V_m}{2(R_f + R_L)} \times R_L$$

if $R_L \gg R_f$, ignore R_f

$$\text{then } \frac{V_m R_L}{2 R_L} = \frac{V_m}{2}$$

$$\therefore \boxed{V_{rms} = V_m/2}$$

(4)

⑤ Rectifier Efficiency (η) :- Represents that how well the rectifier ckt. converts ac to dc.

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{\text{Dc o/p Power}}{\text{Ac i/p Power}}$$

WKT $P_{dc} = V_{dc} \times I_{dc} = I_{dc}^2 R_L$

$$P_{ac} = V_{ac} \times I_{ac} = I_{ac}^2 (R_L + R_f)$$

Note: when we see o/p it is across only (or) through only R_L .
but i/p is for both R_L & R_f

$$\therefore \eta = \frac{I_{dc}^2 R_L}{I_{ac}^2 (R_L + R_f)} ; \text{ If } R_f \ll R_L \text{ then}$$

$$\eta = \frac{I_{dc}^2 R_L}{I_{ac}^2 R_L} = \frac{I_{dc}^2}{I_{ac}^2} = \frac{(I_m/\pi)^2}{(I_m/2)^2} = \frac{4}{\pi^2} = 40.6\%$$

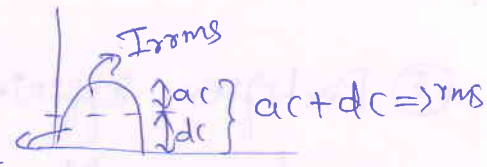
$$\Rightarrow \boxed{\eta = 40.6\%} \Rightarrow \text{in HWR } 40.6\% \text{ of ac power gets converted into}$$

DC power across the load & remaining is ripple.

i.e., η is more means ripple is less.

⑥ Ripple factor :- It is observed that the o/p of HWR is not pure dc it is pulsating dc $\therefore$ The o/p contains pulsating components called "ripples". The measure of such ripples present in the o/p by a mathematical factor called "Ripple factor" (γ). It tells how smooth the o/p is.

$$\gamma = \frac{\text{RMS value of AC component}}{\text{Avg. value of DC component } I_{dc}}$$



$$= \frac{V_{rms}}{V_{dc}} (\cos) \frac{I_{rms}}{I_{dc}}$$

$$= \frac{\sqrt{I_{rms}^2 - I_{dc}^2}}{I_{dc}}$$

Note : $I_{rms} = I_{ac} + I_{dc}$

$I_{ac} = I_{rms}$

$\therefore I_{rms} = \sqrt{I_{dc}^2 + I_{rms}^2}$

$\therefore I_{rms}^2 = I_{rms}^2 - I_{dc}^2$

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

For HWR. $I_{rms} = \frac{I_m}{2}$, $I_{dc} = \frac{I_m}{\pi}$

$\therefore \gamma = \sqrt{\left(\frac{I_m/2}{I_m/\pi}\right)^2 - 1} \Rightarrow \sqrt{\frac{\pi^2}{4} - 1}$

$= \sqrt{1.4674} = 1.211$

$\therefore \boxed{\gamma = 1.211}$

This indicates the ripple contents in the o/p is 1.21.
The ripple factor is minimized using filter ckts along with Rectifiers.

⑦ Transformer Utilization Factor (TUF) :- The dc power to be delivered to the load in a rectifier ckt. decides the rating of the transformer used in the ckt. i.e,

$$TUF = \frac{P_{dc}}{P_{ac(rated)}}$$

TUF :- How much transformer power is utilized.

• The ac power rating of transformer = $V_{rms} \cdot I_{rms}$.

• The rms value of sinusoidal signal is $\frac{1}{\sqrt{2}}$ times of its I_{max} . The secondary voltage of purely sinusoidal is $\frac{1}{\sqrt{2}} V_m$.

• The diode conducts only for half cycle $\therefore$ rms value is $\frac{1}{2}$ of the maximum.

$$\therefore P_{ac(rated)} = V_{ac} \times I_{ac} = \frac{V_m}{\sqrt{2}} \times \frac{I_m}{2} = \frac{V_m I_m}{2\sqrt{2}}$$

The dc power delivered to the load = $I_{dc}^2 R_L = \left(\frac{I_m}{\pi}\right)^2 R_L$

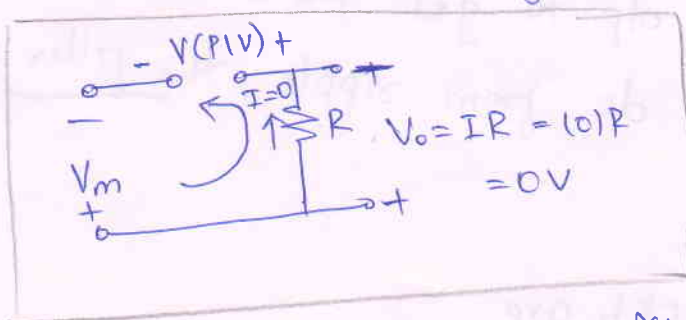
$$\therefore TUF = \frac{P_{dc}}{P_{ac(rated)}} = \frac{2\sqrt{2}}{\pi^2} = 0.287$$

$$\therefore \boxed{TUF = 0.287 \Rightarrow 28.7\%} \Rightarrow \text{transformer is}$$

not fully utilized.

⑧ Peak Inverse Voltage (PIV) :- It is the voltage rating

(or) Peak Reverse Voltage (PRV) :- that must not exceed in the reverse-bias region or the diode will enter the Zener avalanche region. To find PIV Apply KVL to ckt of HWR under RB mode.



$$\Rightarrow \boxed{PIV \geq V_m} \quad \text{HWR}$$

⑨ Form factor (F) :- $F = \frac{\text{rms value (V or I)}}{\text{Avg. value (V or I)}} = \frac{I_{rms}}{I_{dc}} = \frac{I_m/2}{I_m/\pi}$

$$\Rightarrow \boxed{F = \pi/2 = 1.57}$$

⑥ Peak factor (P) :-

$$P = \frac{\text{Peak Value}}{\text{RMS Value}} = \frac{V_m}{V_m/2}$$

$$\Rightarrow \boxed{P=2}$$

⑦ Regulation :- It is defined as the variation in dc voltage with change in dc load current.

$$\% \text{ age Regulation} = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100$$

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

$$V_{NL} \Rightarrow I=0 \Rightarrow R=0$$

$$V_{FL} \Rightarrow I \neq 0 \Rightarrow R \neq 0$$

$R_f \rightarrow$ forward resistance of diode

$R_s \rightarrow$ Series resistance

$R_L \rightarrow$ load $\rightarrow$ —

Disadvantages of HWR :-

① Ripple factor is high $\rightarrow 1.21$

② Efficiency is low $\rightarrow 40.6\%$

③ Low TUF ④ Poor Regulation.

Advantages of HWR :- ① Requires 1 diode ② Cost is low ③ Simple ckt

HWR with Filter :- The op of the Rectifier contains both ac component as well as dc component, the amount of ac present in the Rectifier op is called Ripple factor. so it is very important to remove the ac component from the dc compo. Rectifier op to get pure dc. Hence in order to separate dc from ripple, the filter ckt should be used.

Two components of filter ckt. are

① Inductor (L) $\rightarrow \omega L = X_L$ (or) $\frac{1}{\omega L} = Z_L$

② Capacitor (C) $\rightarrow \frac{1}{\omega C} = X_C$ (or) $\frac{1}{\omega C} = Z_C$

(6)

where $\omega = \frac{1}{2\pi f}$ $\omega = 2\pi f$

Ideally the inductor acts as a short ckt. for dc.
 ||ly the capacitor acts as a open ckt for dc.

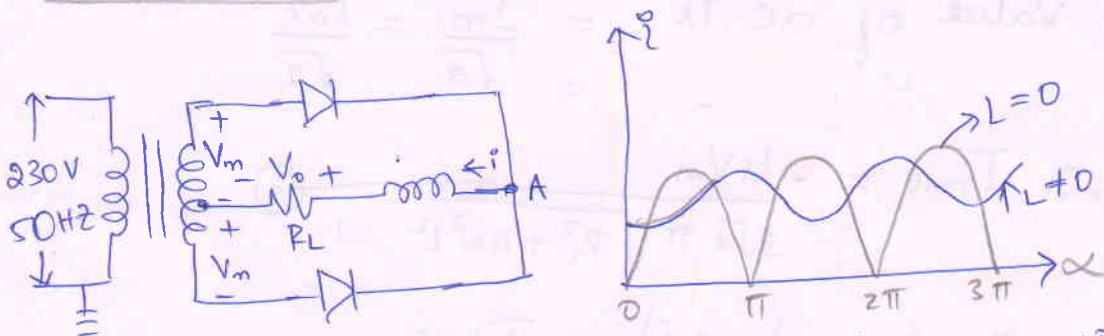
Hence in a filter ckt., inductance is always connected in series with the load, and the capacitance is connected in || with the load.

Filter :- Converts pulsating dc to Pure dc.

Types of Filters

- ① Inductor filter
- ② Capacitor filter
- ③ LC (or) L-Section Filter
- ④ CLC (or) π -section filter.

* Full Wave Rectifier with Inductor filter :-



→ The equation of the o/p current of FWR is

$$i = I_m \left[\frac{2}{\pi} - \frac{4}{\pi} \sum_{\substack{k=2,4,6 \\ k \neq 0}} \frac{\cos k\omega t}{(k+1)(k-1)} \right]$$

$$i = \frac{2I_m}{\pi} - \frac{4I_m}{3\pi} \cos 2\omega t - \frac{4I_m}{5\pi} \cos 4\omega t - \frac{4I_m}{35\pi} \cos 6\omega t \rightarrow \textcircled{1}$$

if we neglect all the higher order freq. terms.

$$i = \frac{2I_m}{\pi} - \frac{4I_m}{3\pi} \cos 2\omega t \quad \text{--- (2)}$$

Here $I_{dc} = \frac{2I_m}{\pi}$, $I_{ac} = \frac{4I_m}{3\pi} \cos 2\omega t$

if R_f, R_s neglected $I_m = \frac{V_m}{R_L}$, $\left[I_m = \frac{V_m}{R_f + R_L + R_s} \right]$

→ From the ckt. $Z = R_L + X_L$

$$Z = R_L + j\omega L$$

$$Z = \sqrt{R_L^2 + 4\omega^2 L^2} \quad \theta = \tan^{-1} \left(\frac{2\omega L}{R_L} \right)$$

If we replace I_m with V_m in eqⁿ (2)

$$i = \frac{2V_m}{\pi R_L} - \frac{4V_m}{3\pi} \frac{\cos(2\omega t - \theta)}{\sqrt{R_L^2 + 4\omega^2 L^2}}$$

Here $I_{dc} = \frac{2V_m}{\pi R_L}$ $I_{ac} = \frac{4V_m}{3\pi \sqrt{R_L^2 + 4\omega^2 L^2}}$ → magⁿ

Here $I_m = I_{ac}$

→ rms value of ac is $= \frac{I_m}{\sqrt{2}} = \frac{I_{ac}}{\sqrt{2}}$

$$\therefore I_{rms} = \frac{4V_m}{3\sqrt{2} \pi \sqrt{R_L^2 + 4\omega^2 L^2}} \quad \text{--- (3)}$$

$$\therefore \text{Ripple factor}(\gamma) = \frac{I_{rms}}{I_{dc}}$$

$$\gamma = \frac{\frac{4V_m}{3\sqrt{2} \pi \sqrt{R_L^2 + 4\omega^2 L^2}}}{\frac{2V_m}{\pi R_L}}$$

(7)

$$r = \frac{4V_m}{3\sqrt{2}\pi\sqrt{R_L^2 + 4\omega^2 L^2}} \cdot \frac{\pi R_L}{2V_m}$$

$$r = \frac{2}{3\sqrt{2}\sqrt{\frac{R_L^2 + 4\omega^2 L^2}{R_L^2}}}$$

$$\text{Ripple factor} = \frac{2}{3\sqrt{2}} \frac{1}{\sqrt{1 + \frac{4\omega^2 L^2}{R_L^2}}} \rightarrow (4)$$

Case (i) if $\frac{4\omega^2 L^2}{R_L^2} \gg 1$ so neglect '1' from above eqⁿ

$$R.F = \frac{2}{3\sqrt{2}} \frac{1}{\sqrt{\frac{4\omega^2 L^2}{R_L^2}}} = \frac{2}{3\sqrt{2}} \times \frac{R_L}{2\omega L}$$

$$R.F = \frac{R_L}{3\sqrt{2}\omega L}$$

Case (ii) if $R_L \xrightarrow{\text{tends to}} \infty$ then $\frac{1}{R_L^2} = 0$ in eqⁿ (4)

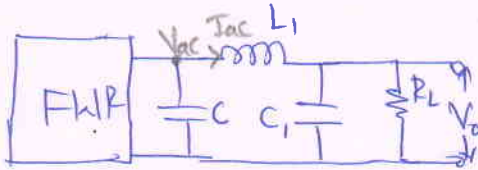
$$r = \frac{2}{3\sqrt{2}} \frac{1}{\sqrt{1+0}} = \frac{2}{3\sqrt{2}} = 0.47$$

R.F of FWR with inductor filter is "0.47"

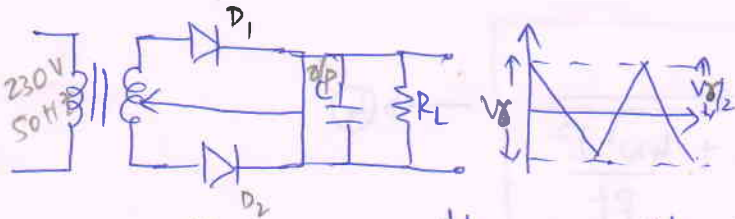
$$\therefore \boxed{r = 0.47}$$

CLC (cos) π -section filter

π -section filter



Fourier Analysis of capacitor filter for FWR



The voltage across the capacitor is

$$V_c = V_{dc} - \frac{V_r}{\pi} \left[\sin 2\omega t - \frac{\sin 4\omega t}{2} + \frac{\sin 6\omega t}{3} + \dots \right]$$

$$V_c = V_{dc} - \frac{V_r}{\pi} \sin 2\omega t - \frac{V_r}{\pi} \frac{\sin 4\omega t}{2} + \dots$$

From the above eqⁿ

dc component = V_{dc}

$$\text{ac} \text{ --- } = \frac{V_r}{\pi} \left(\frac{V_r}{2} = \frac{I_{dc}}{2fc} \right)$$

$$V_{ac} = \frac{V_r}{\pi}$$

$$I_{ac} = \frac{V_{ac}}{X_{L1}} = \frac{V_r}{\pi X_{L1}} = \frac{I_{dc}}{2\pi fc} \cdot \frac{1}{X_{L1}}$$

$$I_{rms} = \frac{I_{ac}}{\sqrt{2}} = \frac{I_{dc}}{2\sqrt{2}\pi fc} \cdot \frac{1}{X_{L1}}$$

The voltage across capacitor C_1

$$V_{rms} = I_{rms} \cdot X_{C1}$$

$$V_{rms} = \frac{I_{dc}}{2\sqrt{2}\pi fc} \cdot \frac{X_{C1}}{X_{L1}}$$

$$V_{rms} = I_{rms} \cdot X_{C1}$$

$$V_{rms} = \frac{V_{dc}}{R_L} \cdot \frac{1}{2\sqrt{2}\pi fc} \cdot \frac{X_{C1}}{X_{L1}}$$

$$\gamma = \frac{V_{rms}}{V_{dc}} = \frac{\frac{V_{dc}}{R_L} \cdot \frac{1}{2\sqrt{2}\pi fc} \cdot \frac{X_{C1}}{X_{L1}}}{V_{dc}}$$

$$\gamma = \frac{1}{2\sqrt{2}\pi fc R_L} \cdot \frac{1}{2\omega C_1} \cdot \frac{1}{2\omega L_1}$$

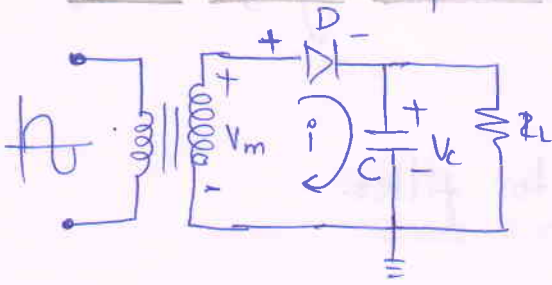
$$\gamma = \frac{1}{8\sqrt{2}\pi fc R_L} \cdot \frac{1}{\omega^2 L_1 C_1}$$

$$\gamma = \frac{1}{8\sqrt{2}\pi fc (2\pi f)^2 R_L C_1 L_1}$$

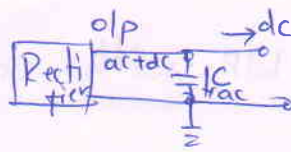
$$\gamma = \frac{1}{32\sqrt{2}\pi^3 f^3 C} \cdot \frac{1}{R_L C_1 L_1}$$

* Half wave, Full wave Rectifier with Capacitor filter:-

① HWR with Capacitor filter (Shunt Capacitor filter)

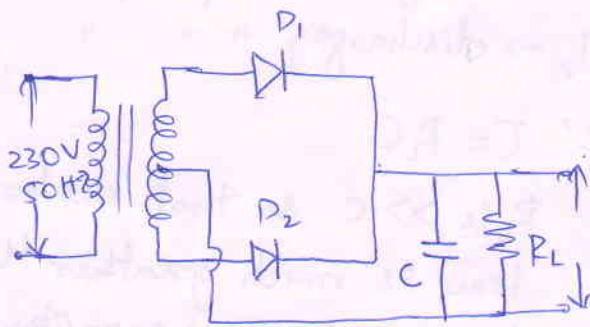


The capacitor used in filter ckt. here is connected in || with load bcoz

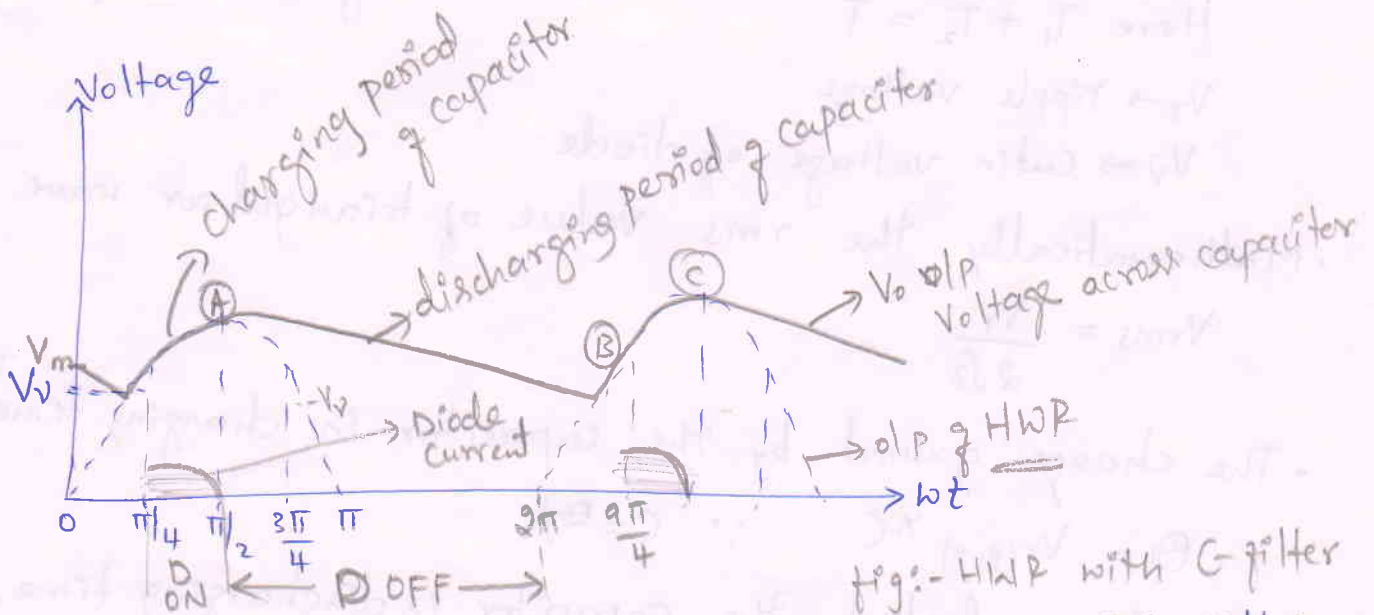


Capacitor will allow ac so ac component passes through C & 'C' is grounded

② FWR with Capacitor filter



dc will choose another path bcoz 'C' will not allow (block) dc. so o/p across load will be only dc component.



WKT diode conducts only when i/p voltage = Cut in Voltage

i.e. $V_i = V_V = \text{Cut in Voltage}$

for an 'ac' sig. V_i varies w.r.t wt .

let at $\pi/4$ the V_i value is V_V ∴ before $\pi/4$ the

$V_i < V_V$ ∴ Diode is (OFF) ∴ no capacitor charging

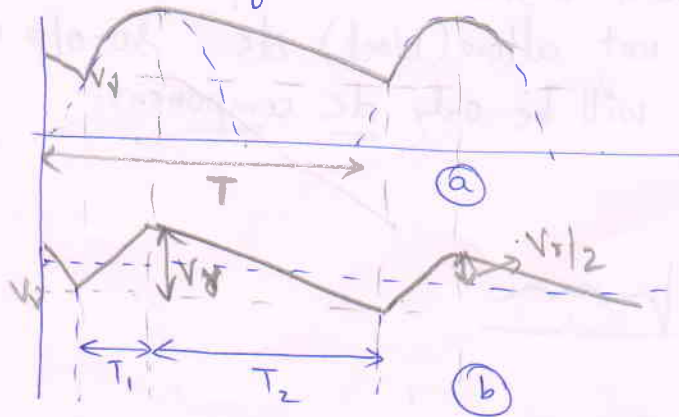
$V_i \geq V_V$ ∴ Diode is (ON) ∴ Capacitor charges to V_c

∴ from $\pi/4$ to $\pi/2$, it is the max. voltage above V_V of diode
from $\pi/2$ to π , the V_i is $\downarrow$ ing the diode goes into OFF state.

∴ diode acts as open ckt. ∴ no current will flow in the ckt. but due to the presence of capacitor, now capacitor will acts as the supply & starts discharging through load R_L .

* Ripple factor for HWR with capacitor filter.

→ The o/p wvg obtained across capacitor in HWR ckt is.



T_1 → charging time of capacitor

T_2 → discharging " " "

$$\therefore T = RC$$

R_L is $\gg C$ so that discharging time is much greater than charging time of capacitor.

$$\text{Here } T_1 + T_2 = T$$

V_r → ripple voltage

V_D → cutin voltage of diode

• Mathematically the rms value of triangular wave is

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

• The charge gained by the capacitor in charging time T_1 is

$$Q_1 = V_r(p-p) \times C \quad \therefore C = Q_1/V$$

• The charge lost by the capacitor is discharging time, T_2 is

$$Q = I_{dc} \times T_2 \quad \therefore I = dQ/dt \Rightarrow dQ = I \cdot dt$$

$$(or) \int dQ = \int I \cdot dt$$

• Charge gained by capacitor = charge lost

$$V_r(p-p) = I_{dc} \times T_2 \rightarrow (1)$$

$$\text{from fig (b)} \quad T_1 + T_2 = T$$

$$\text{but } T_1 \ll T_2 \text{ if } R_L \gg C$$

$$\therefore T_2 \approx T \rightarrow (2)$$

(81)

Sub. ② in ①

$$V_o(p-p) C = I_{dc} T$$

$$V_o(p-p) = \frac{I_{dc}}{fC}$$

$$\text{but } V_{rms} = \frac{V_o(p-p)}{2\sqrt{3}}$$

$$V_{rms} = \frac{I_{dc}}{2fC} \times \frac{1}{2\sqrt{3}}$$

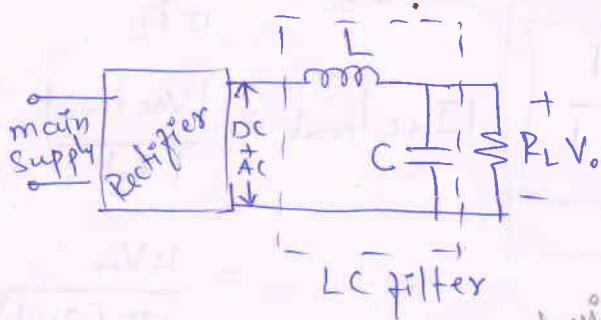
$$\gamma = \frac{V_{rms}}{V_{dc}} = \frac{I_{dc} / 2\sqrt{3} fC}{V_{dc}}$$

$$\gamma = \frac{V_{dc}}{\frac{R_L 2\sqrt{3} fC}{V_{dc}}}$$

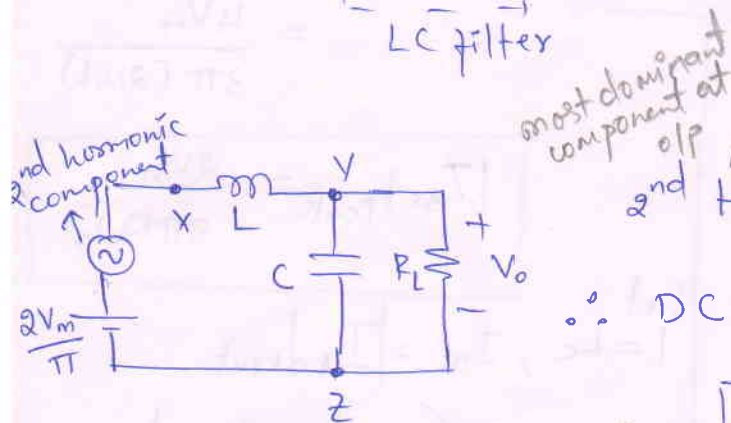
$$\therefore I_{dc} \times R_L = V_{dc}$$

$$\gamma = \frac{1}{2\sqrt{3} fC R_L}$$

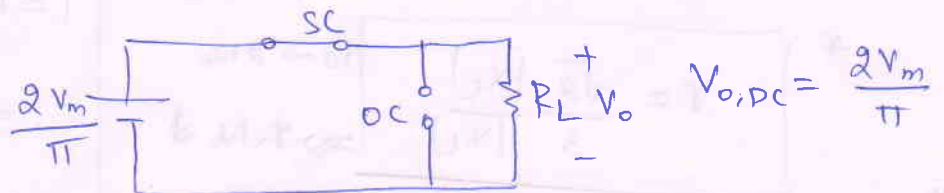
* LC Filter :- (or) L-section filter



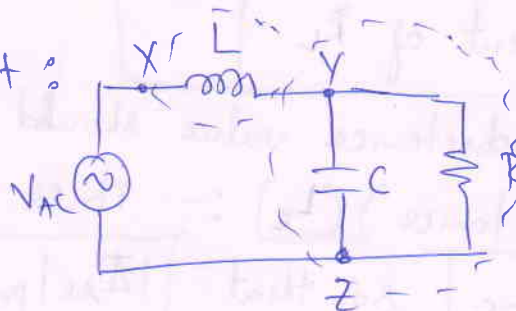
The rectifier o/p contains both AC & DC signal, & the AC component we consider here is 2nd harmonic component & higher order components are neglected. & avg. value of FWR o/p is $V_{dc} = 2V_m/\pi$



$\therefore$ DC equivalent ckt $L \rightarrow s.c$ $C \rightarrow o.c$



||| AC equivalent ckt :



We can Apply VDR to find V_o

$$V_o = \frac{Z_{YZ}}{Z_{XY} + Z_{YZ}} V_{AC}$$

$$Z_{xy} = j\omega L$$

$$Z_{yz} = (X_C \parallel R_L)$$

$$\text{if } Z_{xy} \gg Z_{yz}$$

i.e., if inductive

reactance is larger than the Z_{yz} reactance, then most of the ac signal will drop (or) blocked due to 'L'

$$\Rightarrow Z_{xy} + Z_{yz} = Z_{xy}$$

$$\text{also } X_C \ll R_L$$

$$X_C \parallel R_L \approx X_C$$

$$\therefore V_{o,AC} = \frac{Z_{yz}}{Z_{xy}} V_{AC}$$

$$X_L \gg (X_C \parallel R_L)$$

$$X_C \ll R_L$$

assume

$$V_{o,AC} = \frac{X_C}{X_L} V_{AC}$$

$$|V_{o,AC}|_{\text{peak}} = \frac{|X_C|}{|X_L|} |V_{AC}|_{\text{peak}}$$

$$|V_{o,AC}|_{\text{peak}} = \frac{|X_C|}{|X_L|} \frac{4V_m}{3\pi} \rightarrow \text{This is required to find rms Ac. o/p}$$

$$V'_{\text{rms}} = \frac{|V_{o,AC}|_{\text{peak}}}{\sqrt{2}} = \frac{4V_m}{3\sqrt{2}\pi} \frac{|X_C|}{|X_L|}$$

$$V_{o,DC} = \frac{2V_m}{\pi}$$

$$\therefore \gamma = \frac{V'_{\text{rms}}}{V_{o,DC}} = \frac{\frac{4V_m}{3\sqrt{2}\pi} \frac{|X_C|}{|X_L|}}{\frac{2V_m}{\pi}}$$

$$\gamma = \frac{\sqrt{2}}{3} \frac{|X_C|}{|X_L|} \quad \omega \rightarrow 2\omega_0 \Rightarrow \gamma \text{ is } \propto$$

R.F is independent of R_L

$$I_{DC} = \frac{2V_m}{\pi R_L}$$

$$|I_{AC}|_{\text{peak}} = \frac{|V_{AC}|_{\text{peak}}}{|X_L|}$$

$$= \frac{4V_m}{3\pi (2\omega_0 L)}$$

$$|I_{AC}|_{\text{peak}} = \frac{2V_m}{3\pi \omega_0 L}$$

$$\text{let } L = L_c, I_{DC} = |I_{AC}|_{\text{peak}}$$

$$\Rightarrow \frac{2V_m}{\pi R_L} = \frac{2V_m}{3\pi \omega_0 L} \quad | L = L_c$$

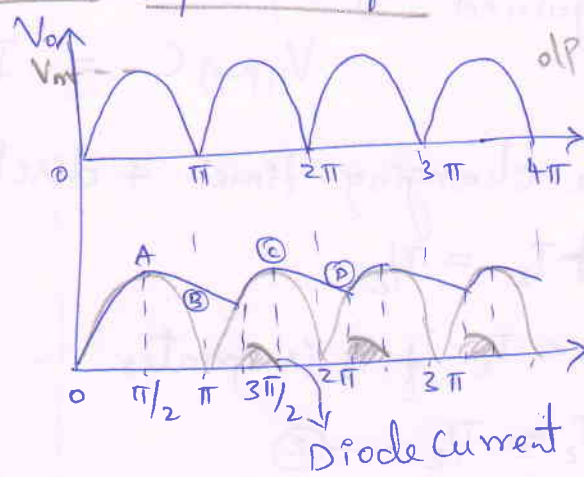
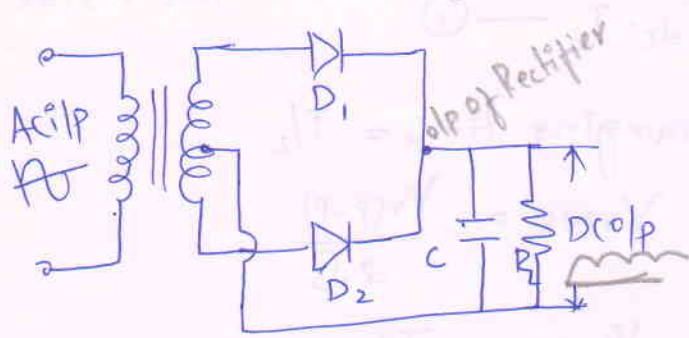
$$L_c = \frac{R_L}{3\omega_0}$$

* The minimum inductance value should be

(Critical Inductance) (L_c) :- it is very important to make sure that $L > L_c$ so that $|I_{AC}|_{\text{peak}} < I_{DC}$

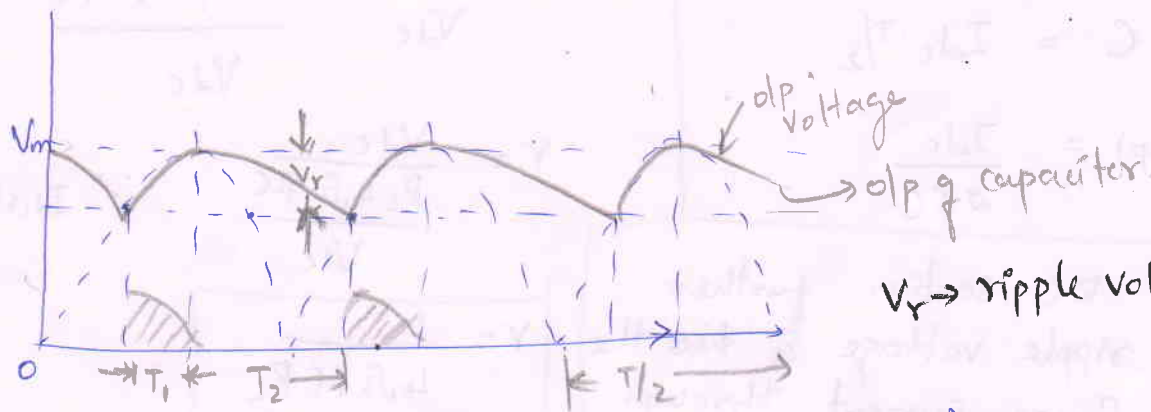
For better filtering, the inductance used in LC filter should be greater than L_c (critical inductance)

* Ripple factor of FWR with capacitor filter



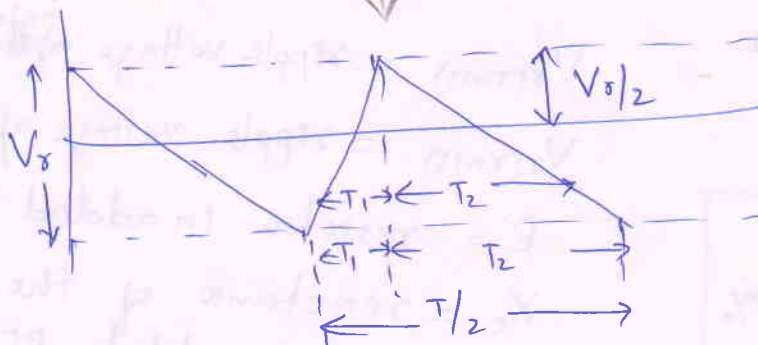
A to B $\rightarrow$ C
discharge
C to D $\rightarrow$ C
charges

• Expression for Ripple factor



$T_1 \rightarrow$ charging time of capacitor } as R_L large $\therefore T = R_L C$
 $T_2 \rightarrow$ discharging time of capacitor } T_2 Very large.

$$T_1 + T_2 = T/2$$



• Mathematically the rms value of triangular wave is

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

• The charge gained by the capacitor in charging time is $\therefore C = Q/V$

$$Q = V_r(p-p) \times C$$

$$Q = CV$$

• The charge lost by the capacitor in discharging time $Q =$

$$Q = I_{dc} \cdot T_2$$

$$\therefore I = dQ/dt$$

charge gained by capacitor = charge lost

$$V_{r(p-p)} C = I_{dc} \cdot T_2 \quad \text{--- (1)}$$

$$d\theta = i dt$$

$$\int d\theta = \int i dt$$

let the charging time + discharging time = $T/2$

$$T_1 + T_2 = T/2$$

$T_1 \ll T_2$ if R_L is greater

$$T_2 \approx T/2 \quad \text{--- (2)}$$

sub. (2) in (1)

$$V_{r(p-p)} C = I_{dc} \cdot T/2$$

$$V_{r(p-p)} = \frac{I_{dc}}{2 f C}$$

$$V_{rms} = \frac{V_{r(p-p)}}{2\sqrt{3}}$$

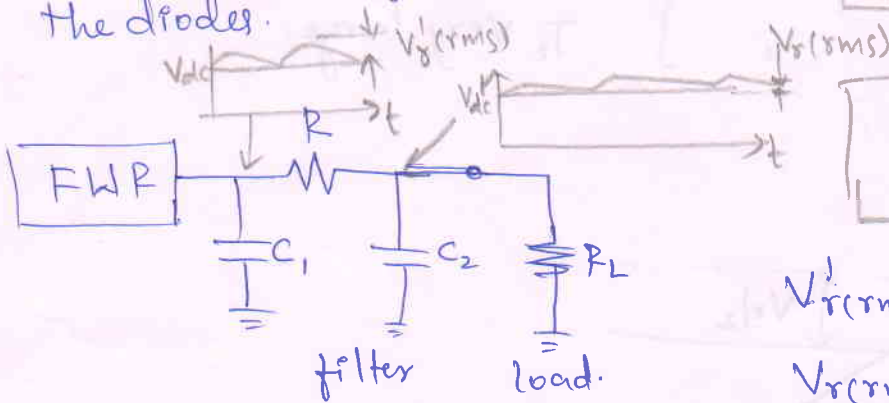
$$V_{rms} = \frac{I_{dc}}{2 f C} \times \frac{1}{2\sqrt{3}}$$

$$\gamma = \frac{V_{rms}}{V_{dc}} = \frac{I_{dc}}{4\sqrt{3} f C V_{dc}}$$

$$\gamma = \frac{V_{dc}}{R_L 4\sqrt{3} f C V_{dc}}$$

$$\because I_{dc} \times R_L = V_{dc}$$

* Adding an RC section further reduces the ripple voltage & less the ripple volt Surge current through the diodes.



$$\gamma = \frac{1}{4\sqrt{3} f C R_L}$$

$$V_g(rms) \approx \frac{X_c}{R} V_r(rms)$$

$V_r(rms)$ = ripple voltage ^{before} RC filter

$V_r(rms)$ = ripple voltage after RC filter

R = resistor in added RC filter

X_c = reactance of the capacitor in the added RC filter

$$\% V_R = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100\%$$

V_{NL} = no-load Voltage

V_{FL} = Full-load " "

* Problems on Rectifiers with Filter.

Formulae

1. FWR with capacitor filter Ripple factor $= \frac{1}{4\sqrt{3}fCR_L}$

2. FWR with Inductor filter Ripple factor $= \frac{R_L}{3\sqrt{2}\omega L}$

3. FWR with L-section or LC filter

$$\text{Ripple factor} = \frac{1}{6\sqrt{2}\omega^2 LC} = \frac{1.194}{LC} \text{ at } f=50\text{Hz}$$

$C = \mu\text{F}$

4. FWR with CLC or π -filter

$$\text{Ripple factor} = \frac{\sqrt{2}}{8\omega^2 L C_1 C_2 R_L}$$

Q1) A 15-0-15V(rms) 50Hz ideal transformer is used with FWR ckt with diodes having forward drop of 1V. The load is a resistance of 100 Ω & capacitor of 10,000 μF is used as a filter across the load resistance then calculate the dc load current & voltage

Solⁿ Given: transformer secondary voltage = 15-0-15V(rms)
 $R_L = 100\Omega$, $C = 10,000\mu\text{F}$

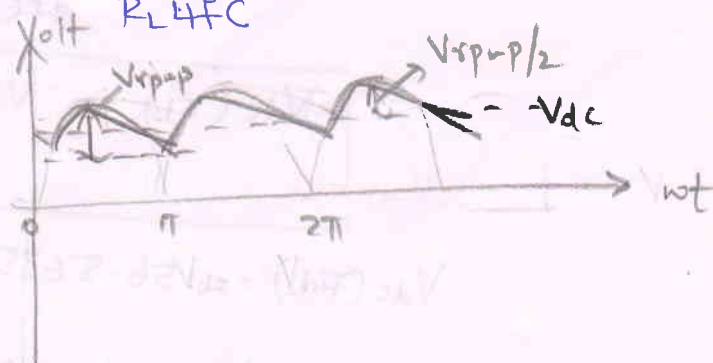
WKT $V_{dc} = V_m - \frac{V_{sp-p}}{2}$

$$V_{dc} = V_m - \frac{I_{dc}}{4fc} = V_m - \frac{V_{dc}}{R_L 4fc}$$

$$V_{dc} = \frac{V_m}{\frac{4R_L fc + 1}{4R_L fc}}$$

$$V_{dc} = \left[\frac{4R_L fc}{1 + 4R_L fc} \right] V_m$$

$$V_m = \sqrt{2} V_{rms} = 15\sqrt{2}$$



$$V_{dc} = \left[\frac{4 \times 50 \times 100 \times 10000 \times 10^{-6}}{1 + 4 \times 50 \times 100 \times 10000 \times 10^{-6}} \right] 15\sqrt{2}$$

$$V_{dc} = 21.105V$$

if we consider diode voltage drop

$$\text{then } V_{dc} = 21.105 - 1 = 20.105V$$

$$\rightarrow I_{dc} = \frac{V_{dc}}{R_L} = \frac{20.105}{100} = 0.20105A$$

Q2) A bridge rectifier with capacitor filter is fed from 220V to 40V stepdown transformer. if average dc current in load is 1A & capacitor filter of 800μF. Calculate the load regulation, ripple factor.

Assume power line freq = 50Hz, neglect diode forward resistance & dc resistance of transformer.

Sol^y Given : $V_{rms(sec)} = 40V$

$$I_{dc} = 1A, C = 800\mu F \text{ \& } f = 50Hz$$

$$V_m = \sqrt{2} V_{rms} = \sqrt{2} \times 40 = 56.5685V$$

$$I_{dc} \neq 0 \rightarrow V_{dc}(\text{full load}) = V_m - \frac{V_r(p-p)}{2}$$

$$V_m = V_{dc} + V_{ac}$$

$$V_r(p-p) = \frac{I_{dc}}{2fc}$$

$$V_{dc}(FL) = V_m - \frac{I_{dc}}{4fc}$$

$$V_{dc}(FL) = 56.5685 - \frac{1}{4 \times 50 \times 800 \times 10^{-6}}$$

$$V_{dc}(FL) = 50.3185V$$

$$\rightarrow V_{dc}(\text{no load}) = V_m = 56.5685$$

$$\uparrow \\ I_{dc} = 0$$

$$\text{Percentage Regulation} = \frac{V_{dc}(NL) - V_{dc}(FL)}{V_{dc}(NL)} \quad (2)$$

$$= \frac{56.5685 - 50.3185}{50.3185} \times 100$$

$$= 12.42\%$$

$$R_L = \frac{V_{dc}}{I_{dc}} = \frac{50.3185}{1} = 50.3185 \Omega$$

$$\text{Ripple factor} = \Gamma = \frac{1}{4\sqrt{3}fCR_L} = \frac{1}{4\sqrt{3} \times 50 \times 800 \times 10^{-6} \times 50.3185}$$

$$\Gamma = 0.0717 = 7.17\%$$

Q3) Determine the R.F of a L-type choke i/p filter comprising a 10H choke and 84F capacitor used with FWR. Compare with a simple 84F capacitor i/p filter at a load current 50mA & also at 150mA. Assume dc voltage is 50V

Solⁿ Given: $V_{dc} = 50V$, $L = 10H$, $C = 84F$ assume $f = 50Hz$

$$\omega = 2\pi f = 2\pi \times 50 = 100\pi \text{ rad/sec.}$$

for an LC filter ripple factor is

$$\Gamma = \frac{1}{6\sqrt{2}\omega^2 LC}$$

$$= \frac{1}{6\sqrt{2}(100\pi)^2 \times 10 \times 8 \times 10^{-6}}$$

$$\text{Ripple factor} = \Gamma = 0.01492 \Rightarrow 1.492\% \quad \text{--- (1)}$$

→ For simple capacitor filter 84F at $I_L = 50mA$

$$R_L = \frac{V_{dc}}{I_L} = \frac{50}{50 \times 10^{-3}} = 1000 \Omega$$

$$\therefore R.F = \Gamma = \frac{1}{4\sqrt{3}fCR_L} = \frac{1}{4\sqrt{3} \times 50 \times 8 \times 10^{-6} \times 1000}$$

$$\boxed{\Gamma = 0.3608 = 36.08\%} \quad \text{--- (2)}$$

at $I_L = 150 \text{ mA}$

$$R_L = \frac{V_{dc}}{I_L} = \frac{50}{150 \times 10^{-3}} = 333.3 \Omega$$

$$R.F = \frac{1}{4\sqrt{3}fCR_L} = \frac{1}{4\sqrt{3} \times 50 \times 8 \times 10^{-6} \times 333.3}$$

$$\boxed{R.F = \Gamma = 1.082 = 108.2\%} \quad \text{--- (3)}$$

from ①, ② & ③ $\Rightarrow$ L-section filter is more effective if we compare with Capacitor filter.

Q4) Design a filter for FWR with LC filter to provide an o/p voltage of 10V with load current of 200mA & the ripple is limited to 2%. Assume $f = 50 \text{ Hz}$

84%
Given: $V_{dc} = 10 \text{ V}$, $I_L = 200 \text{ mA}$, % ripple = 2% $\therefore \Gamma = 0.02$

• load resistance $R_L = \frac{V_{dc}}{I_L} = \frac{10}{200 \times 10^{-3}} = 50 \Omega$

• Ripple factor $\Gamma = \frac{1}{6\sqrt{2}\omega^2 LC} = \frac{1.194}{LC}$

$$0.02 = \frac{1.194}{LC} \Rightarrow LC = \frac{1.194}{0.02}$$

$$\therefore \boxed{LC = 59.7}$$

critical value of L is $L_c = \frac{R_L}{3\omega} = \frac{50}{3 \times 2\pi \times 50}$

$$\Rightarrow \boxed{L_c = 53 \text{ mH}}$$

Now consider inductor value is 20% higher than the

L_c i.e., $= 60 \text{ mH} \Rightarrow LC = 59.7 \Rightarrow \boxed{C = \frac{59.7}{60 \text{ m}} \approx 100 \mu\text{F}}$

Q5) An LC filter is to be used to provide a dc o/p with 1% ripple from a FWR operating at 50 Hz, Assume $V_c = 0.01$, determine L & C.

Sol Given ripple is 1% $\Rightarrow \Gamma = 0.01$
 $f = 50 \text{ Hz} \Rightarrow V_c = 0.01$

Wkt for $f = 50 \text{ Hz}$ & $C = \sim \mu\text{F}$ then

$$\Gamma = \frac{1.194}{LC} \Rightarrow 0.01 = \frac{1.194}{LC}$$

$$LC = \frac{1.194}{0.01} \quad \text{--- (1)}$$

$$\text{Given } V_c = 0.01 \quad \text{--- (2)}$$

$$\text{(1)} \times \text{(2)} \Rightarrow LC \cdot \frac{L}{C} = \frac{1.194}{0.01} \times 0.01 = 1.194$$

$$\text{(or)} L^2 = 1.194 \text{ (or)} \boxed{L = \sqrt{1.194} = 1.09}$$

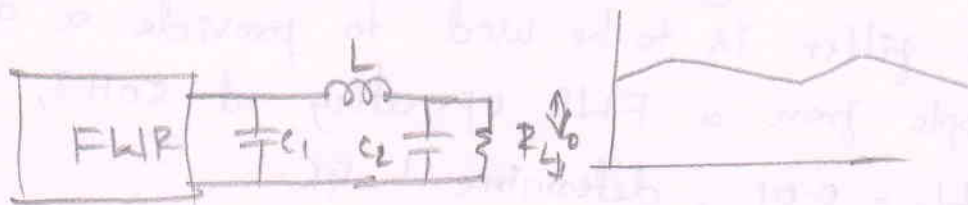
$$\frac{L}{C} = 0.01$$

$$C = L/0.01 = \frac{1.09}{0.01} = 109 \mu\text{F}$$

$$\therefore \boxed{L = 1.09 \text{ H} \text{ \& } C = 109 \mu\text{F}}$$

Q6) A FWR employs a π -Section filter consisting of two $4 \mu\text{F}$ capacitors & a 20 H choke. The transformer voltage to the centre tap is 300 V rms . The load current is 500 mA . Calculate the dc o/p voltage & ripple voltage. The resistance of choke is 200Ω .

Soln



Given that $\Rightarrow C_1 = C_2 = 4 \mu F$ & $L = 20 \text{ mH}$

$I_{dc} = 500 \text{ mA}$, $R_x = 200 \Omega$
(choke resistance)

$$V_s = 300 \text{ V}_{rms}$$

$$V_m = \sqrt{2} V_{rms} = \sqrt{2} \times 300 = 424.2 \text{ V}$$

$$\text{Ripple voltage } V_r = \frac{I_{dc}}{2fC} = \frac{500 \text{ m}}{2 \times 50 \times 4 \times 10^{-6}}$$

$$V_r = 1.25 \text{ mV}$$

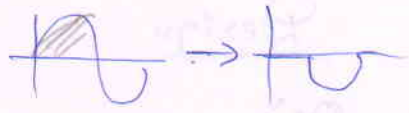
$$V_{dc} = V_m - \frac{V_r}{2} - I_{dc} R_x$$

$$= 424.2 - \frac{1.25 \times 10^{-3}}{2} - 500 \times 10^{-3} \times 200$$

$$V_{dc} = 324.19 \text{ V}$$

$$\text{Ripple factor} = \frac{\sqrt{2}}{8\omega^2 L C_1 C_2 R_L}$$

$$R_L = \frac{V_{dc}}{I_{dc}} =$$

* Clippers : Removing part from wave Eg:- 

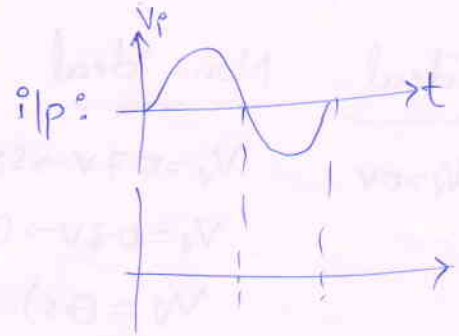
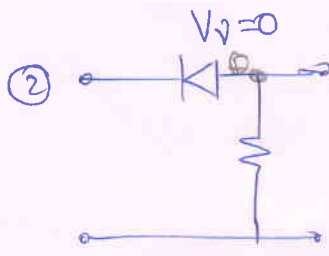
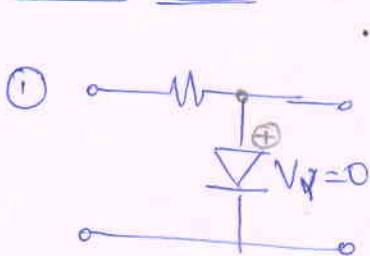
Types of Clippers :
 - Series
 - Parallel
 - Double Ended

Types of Sums :
 - Analysis
 - Design

How to solve Clipper Sums by trick method :

- ① Sign of diode towards node $\rightarrow$ decides which part to clip
- ② 1st sign of voltage in clockwise direction $\rightarrow$ gives axis.

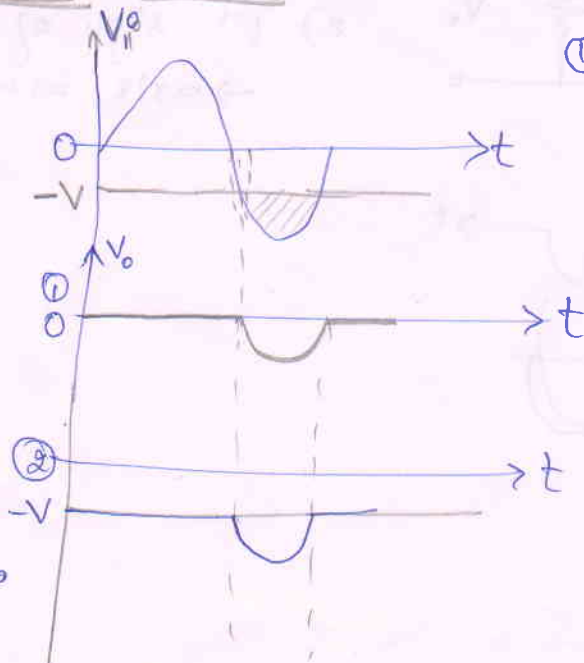
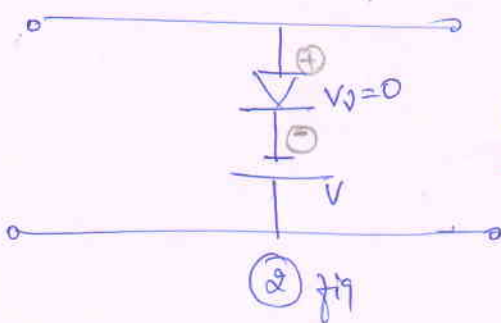
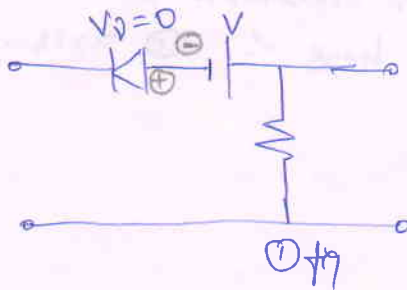
Basic Sums



positive parallel clipper positive series clipper

$\therefore$ Anode of diode i.e., + is towards the node $\therefore$ it clips +ve cycle

* Difference in || & Series Clipper :



① Diode '+' is towards node & 1st sign of V is -ve in ckt. wire dirⁿ $\Rightarrow$ -ve axis.

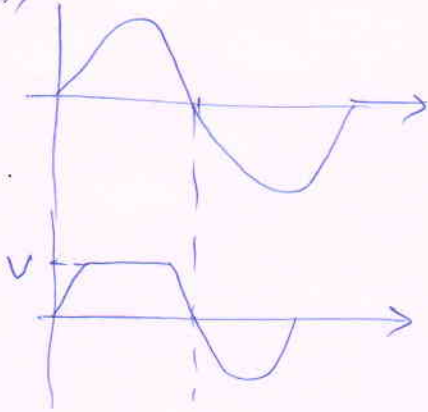
① If $D = \text{OFF}$
 $V_o = 0$

② If $D = \text{OFF}$
 $V_o = V_{in}$

$V_o \neq 0$ in || clipper.

Design

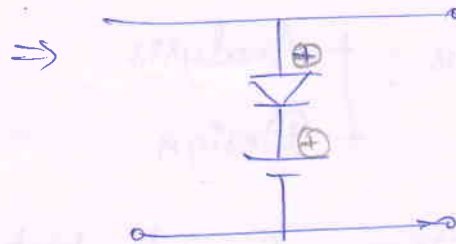
Q: >



Solⁿ: Observe 1) $V_0 \neq 0 \Rightarrow$ 1st clipper

2) +ve part is clipper

3) Axis is +V



Diode



Ideal

Non-ideal

$$V_f = 0V$$

$$V_f = 0.7V \rightarrow Si$$

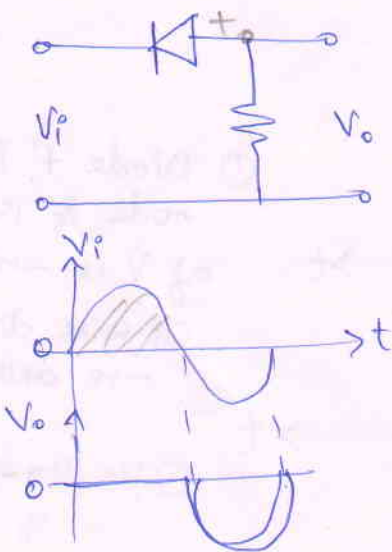
$$V_f = 0.3V \rightarrow Ge$$

$$V_f = 0V$$

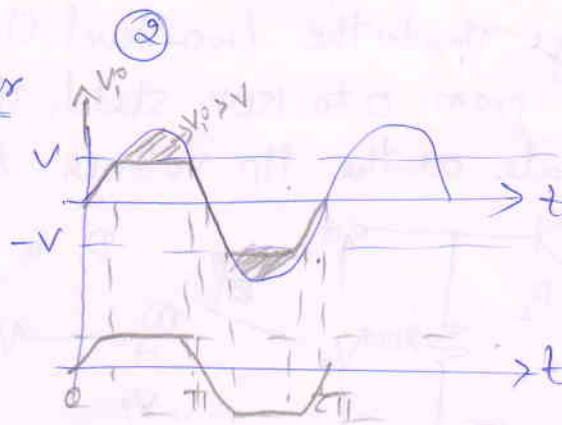
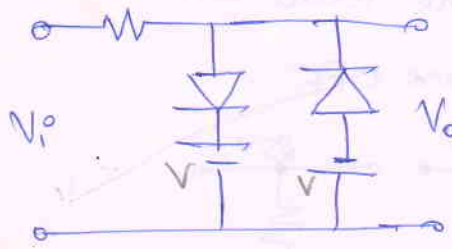
① Series positive clipper:

1) Sign of diode toward node is +ve $\Rightarrow$ +ve voltage (+ve part) is clipped

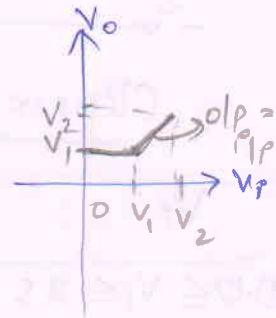
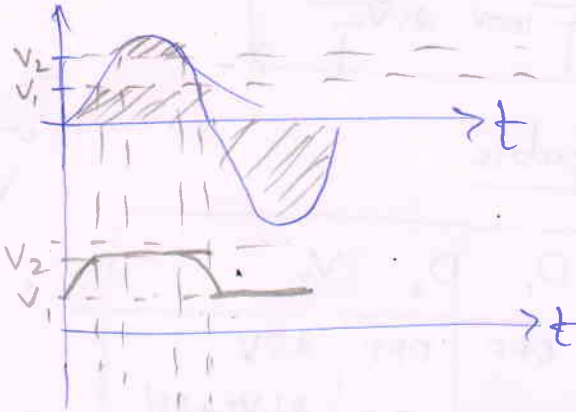
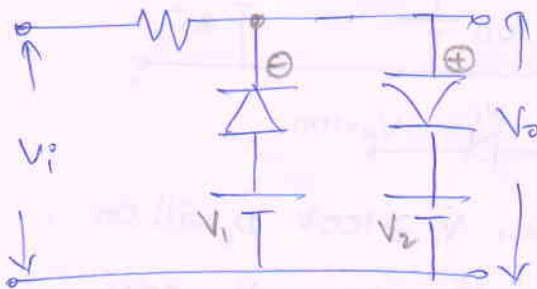
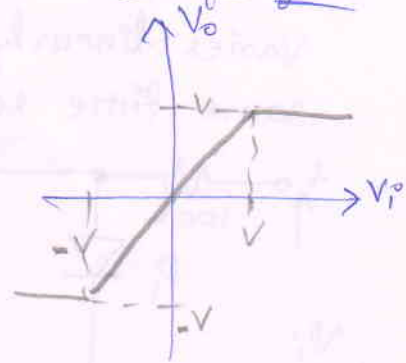
2) 1st sign of V in clockwise direction $\rightarrow$ axis. $\Rightarrow$ no V here $\because$ ~~no~~ axis.



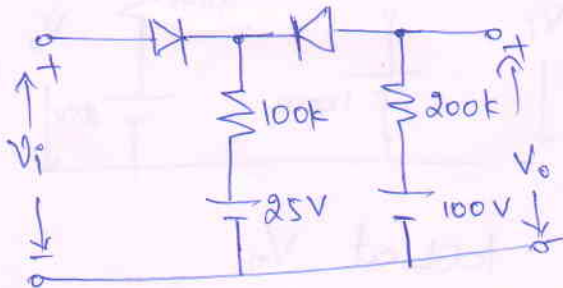
Double Ended Clipper



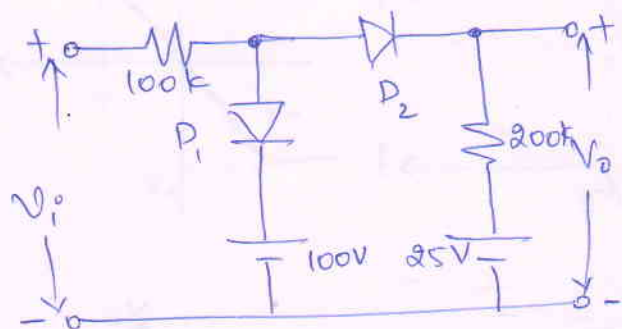
transfer funcⁿ.



Q) The i/p voltage V_i to the two-level clipper shown in figure varies linearly from 0 to 150V. sketch the o/p voltage V_o to the same time scale as the i/p voltage. Assume ideal diodes.



Q) The i/p voltage V_i to the two-level clipper shown in figure varies linearly from 0 to 150V. Sketch the o/p voltage V_o to the same time scale as the i/p voltage. Assume ideal diodes.

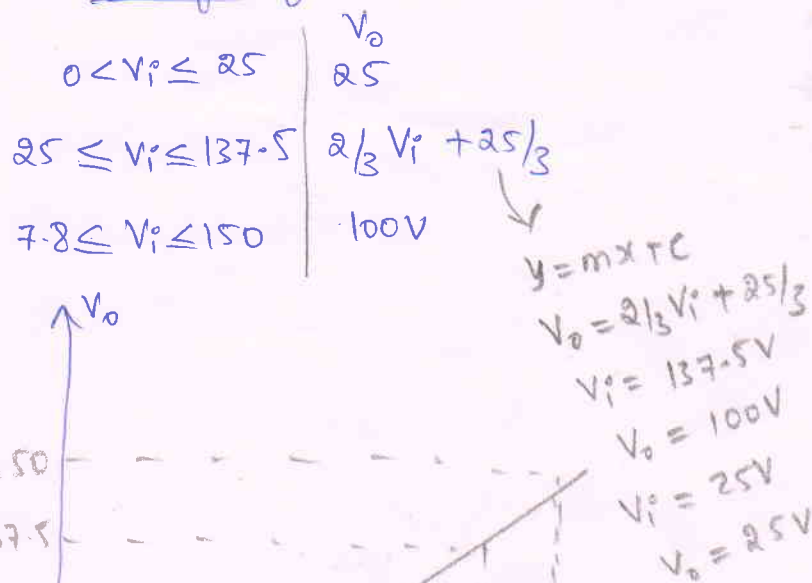


Clipper table

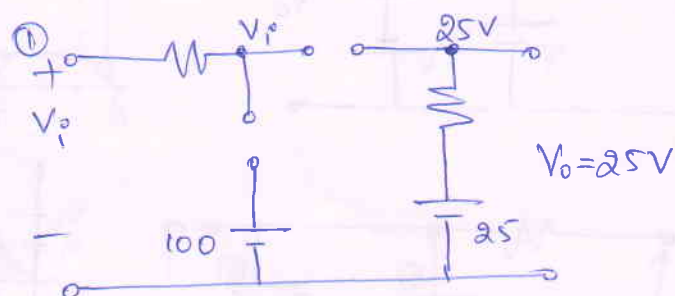
V_i	D_1	D_2	V_o
① $0 \leq V_i \leq 25$	OFF	OFF	25V
② $25 \leq V_i \leq 137.5$	OFF	ON	$\frac{2}{3}V_i + \frac{25}{3}$
③ $137.5 \leq V_i \leq 150$	ON	ON	100V

∴ Max. value of o/p is 25 to 100V.

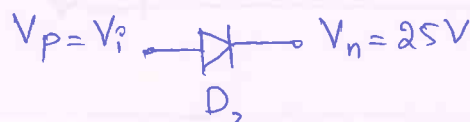
transfer function V_o vs V_i



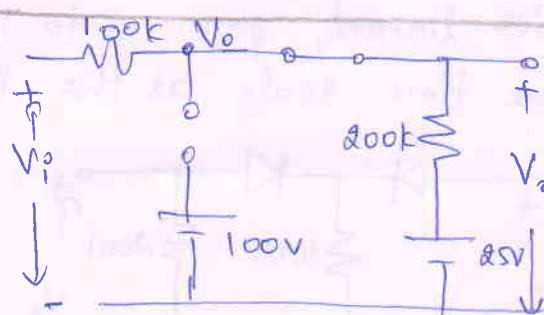
D_1 & D_2 are OFF



• when $V_i \geq 100V$ D_1 will ON



• when $V_i \geq 25V$ D_2 will ON



KCL at V_o

$$\frac{V_o - V_i}{100} + \frac{V_o - 25}{200} = 0$$

$$2V_o - 2V_i + V_o - 25 = 0$$

$$3V_o = 2V_i + 25$$

$$\boxed{V_o = \frac{2}{3}V_i + \frac{25}{3}}$$



$V_{P1} = V_o$ D_1 will ON

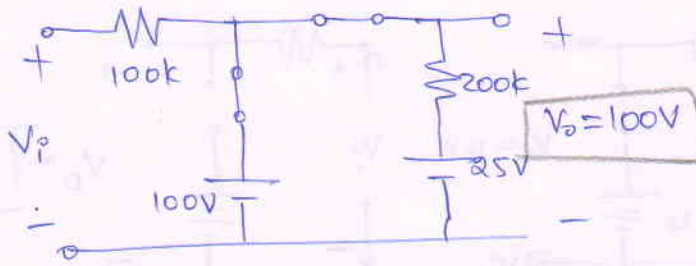
$V_o \geq 100V$ D_1 will ON

$$\frac{2}{3}V_i + \frac{25}{3} \geq 100$$

$$V_i \geq \frac{300 - 25}{2} \geq \frac{275}{2} \geq 137.5$$

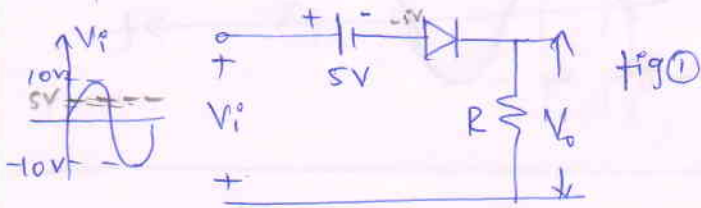
③ D_1 & D_2 both are ON

③.



$$I = \frac{100 - 25}{200} = \frac{75}{200} = 3/8 \text{ mA.}$$

Q) Plot the op w/f for the given ckt.



$V_i = 0$, Diode R.B

Case (i): $V_i > 5V$, Diode F.B. acts as S.C

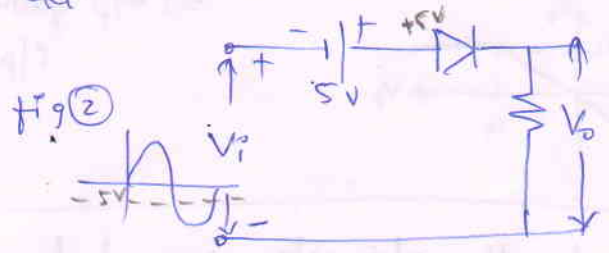
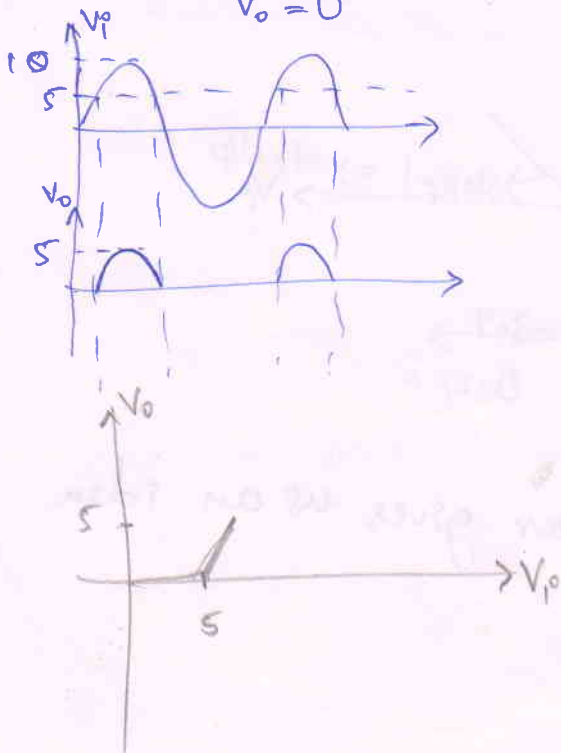


$$-V_i + 5 + V_o = 0$$

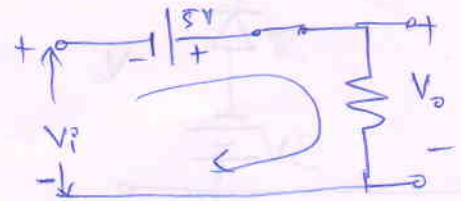
$$V_o = V_i - 5$$

Case (ii): $V_i < 5V$, Diode R.B. acts as O.C

$$V_o = 0$$



Case (i): $V_i > -5V$, diode F.B. acts as S.C

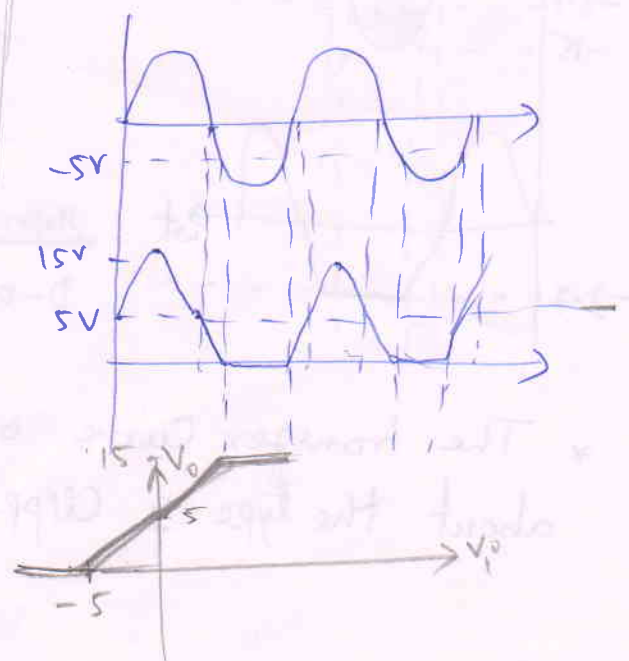


$$-V_i + 5 + V_o = 0$$

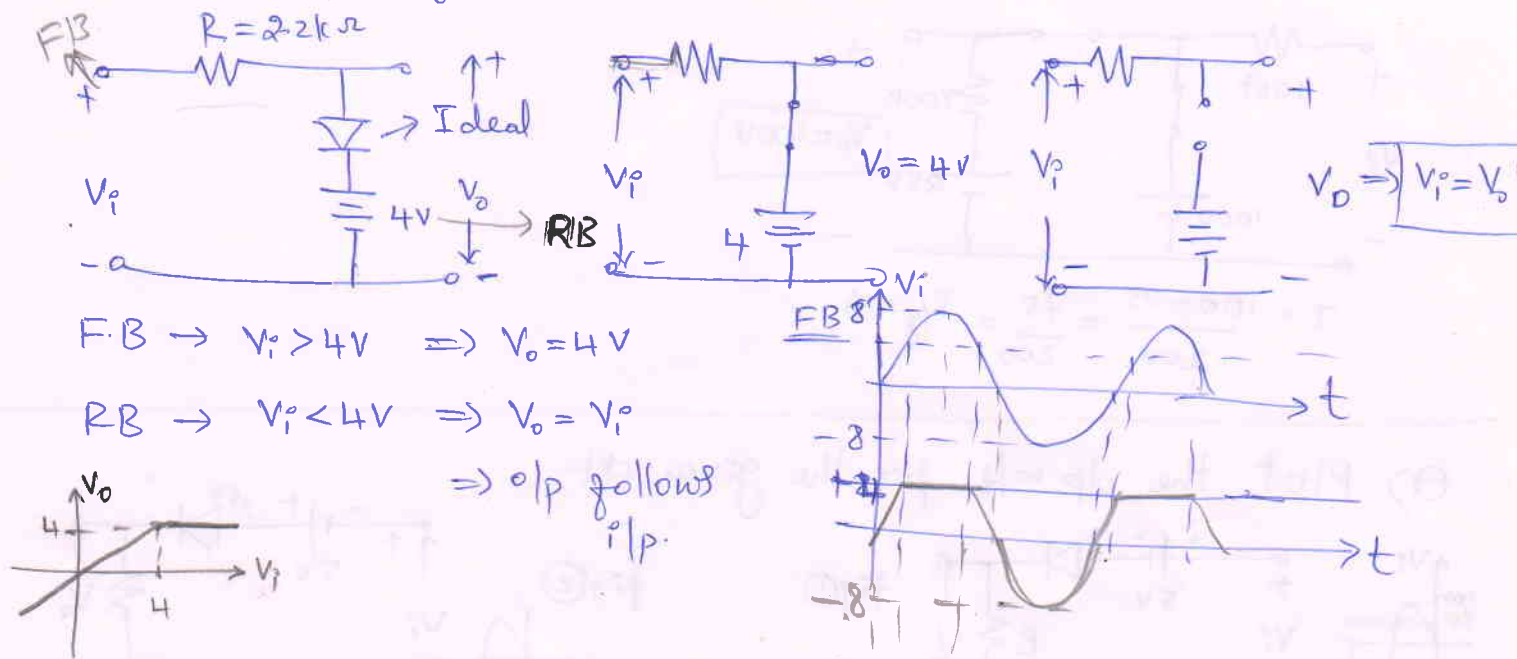
$$V_o = V_i + 5$$

Case (ii): $V_i < -5V$, Diode R.B. acts as O.C

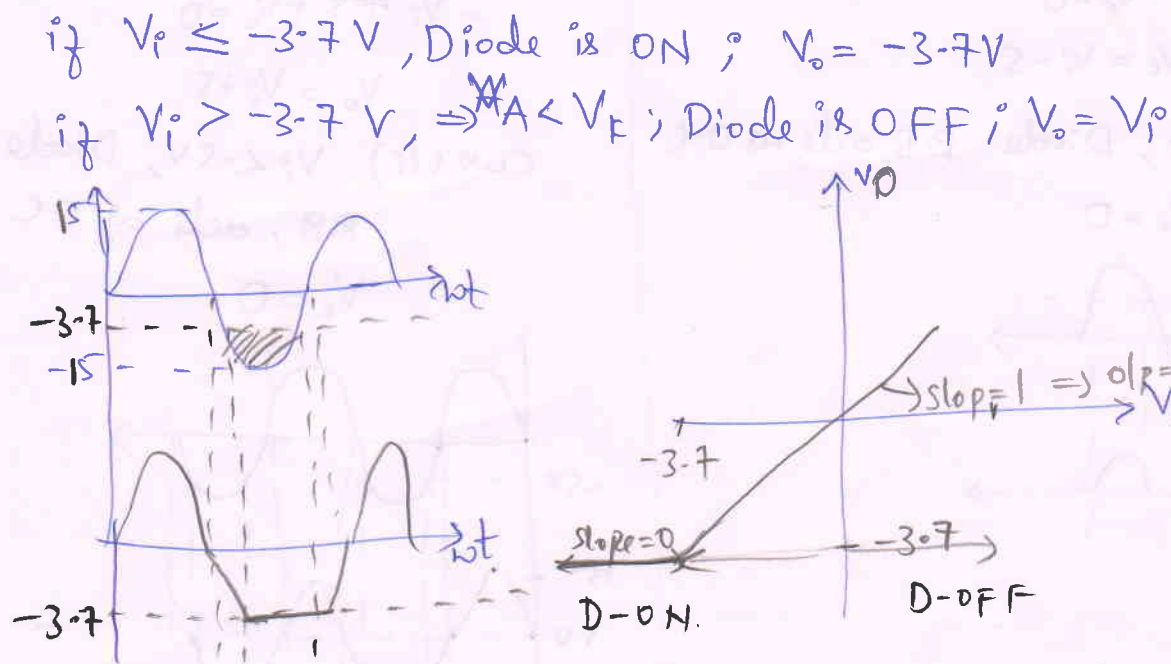
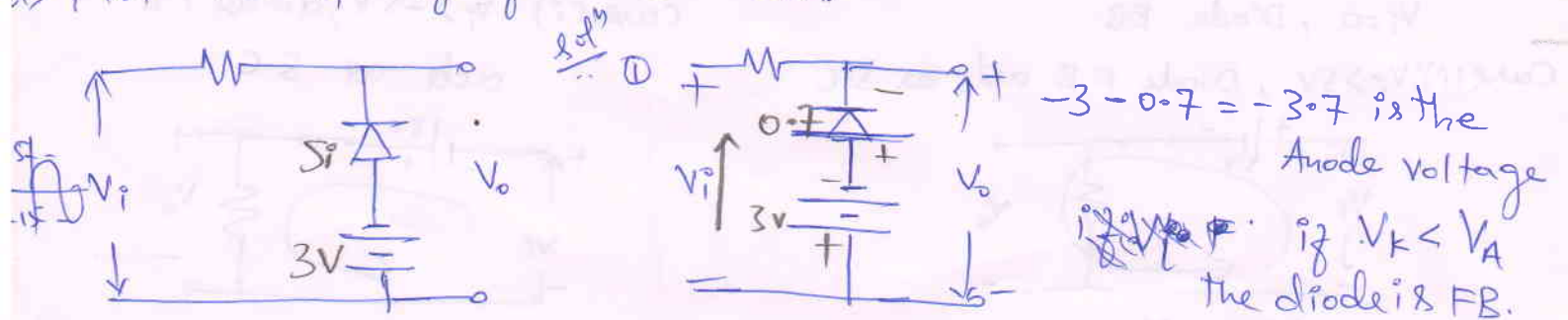
$$V_o = 0$$



a) sketch the op wlg for below ckt



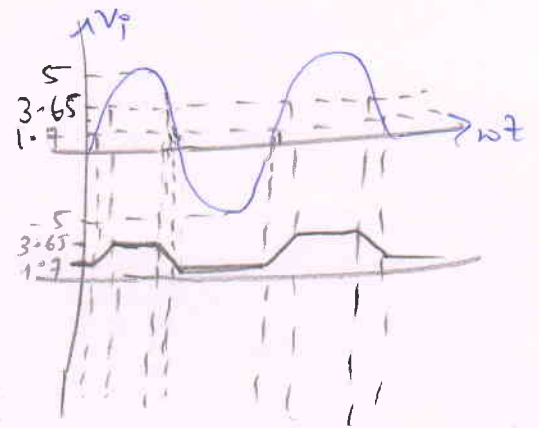
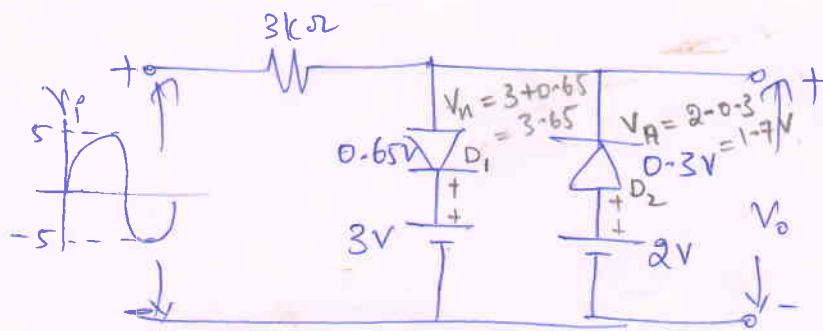
b) Plot the op wlg for below ckt:



* The transfer curve of a Clipper gives us an idea about the type of Clipper.

(4)

a) sketch the o/p w/ g for below ckt:

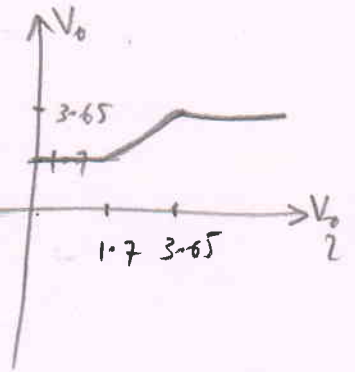


For D_1 to ON $V_i \geq 3.65$; $V_o = 3.65V$

For D_2 to ON $V_i \leq 1.7V$; $V_o = 1.7V$

if $1.7 \leq V_i < 3.65$ both D_1 & D_2 are OFF,

$$V_o = V_i$$



* Diode as a gate

①
 digital gate
 Analog gate.

positive logic

SV logic 1

0V logic 0

OR

$$C = A + B$$

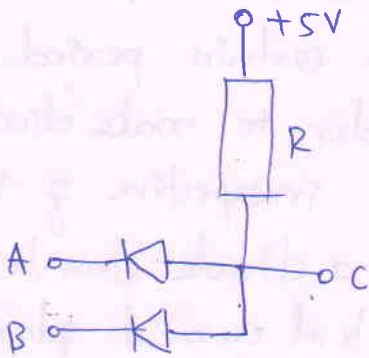
AND

$$C = A \cdot B$$

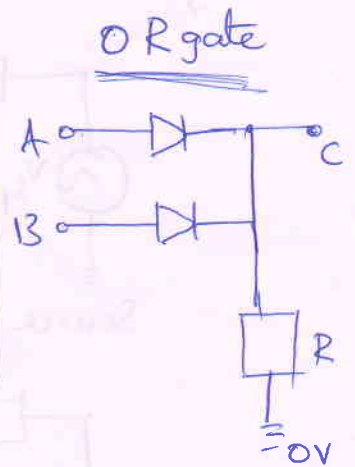
Truth table

A	B	C
0	0	0
0	1	1
1	0	1
1	1	1

A	B	C
0	0	0
0	1	0
1	0	0
1	1	1



AND gate



OR gate

a) Design a diode logic gate for the following function.

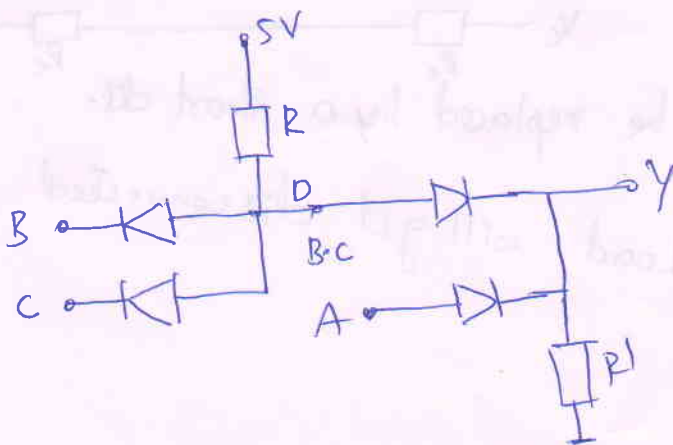
$$D = A \cdot B \cdot C$$

a) Design a diode logic gate for the following function

$$Y = A + B + C$$

a) Design a diode logic gate to the following Boolean function.

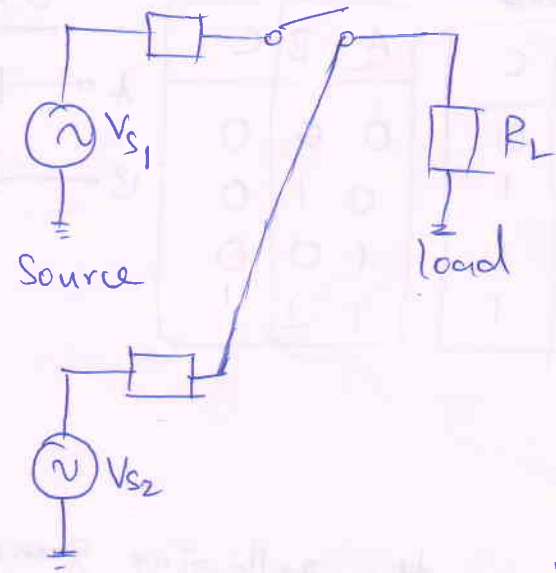
$$Y = A + \underbrace{B \cdot C}_D$$



* Analog multiplexer (or) Analog gate Pg:-101 Millman

It is a device used to select one of many i/p signals and connect that selected input to a single o/p.

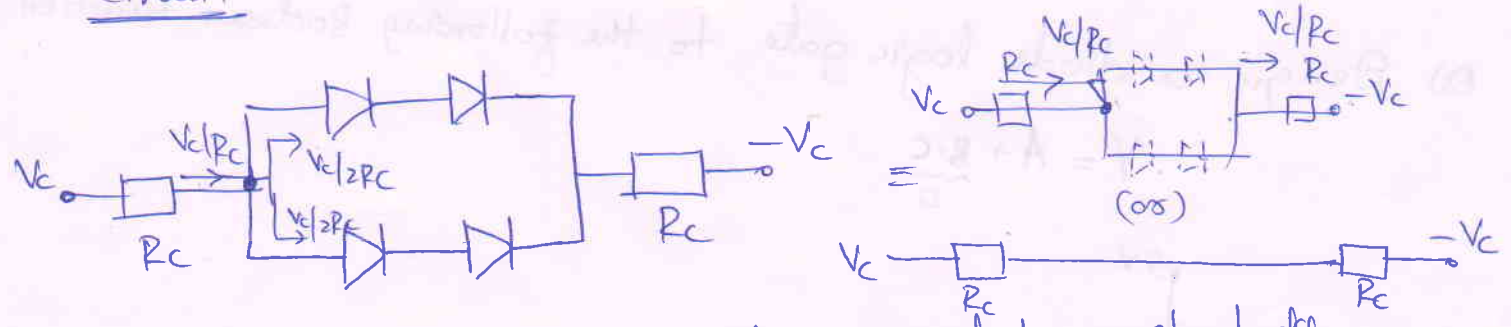
Eg:- when ~~single~~^{two} sources are present



Using 'ac' source we can make diode to conduct only for a certain period. but in order to make diode conduct irrespective of input ac, a diode can be biased & control current flows to cause the diode to conduct

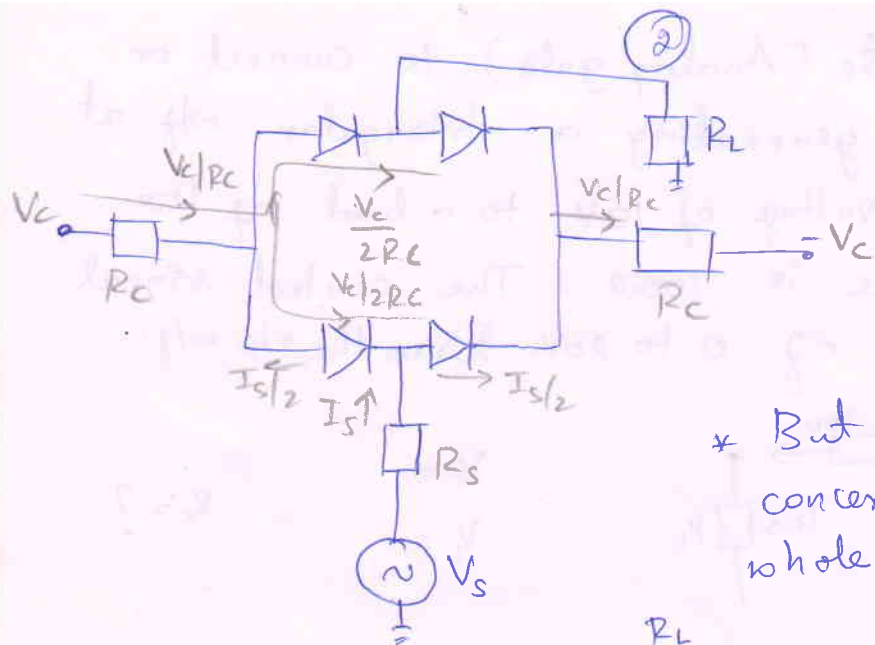
* diode is biased in such a manner as not to conduct $\rightarrow$ by applying a reverse bias voltage

Circuit



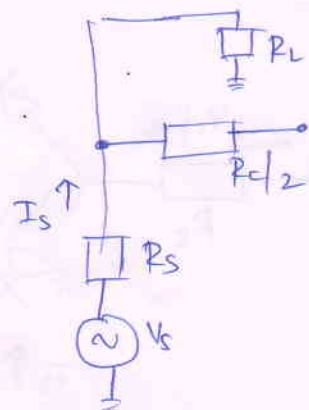
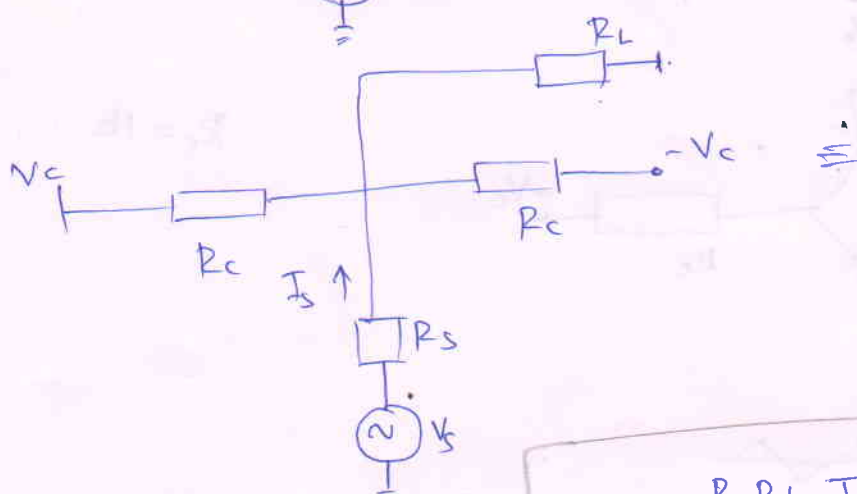
all the diodes get FB & can be replaced by a short ckt.

* If $|V_s| < V_c$ then Load will get disconnected from the signal.



As long as control current is greater than the signal current, all the diodes can be conducting

* But as for an analysis is concerned we can replace the whole ckt. by a short like below.



$$V_o = \frac{R_L R_{d2} I_s}{R_L + R_{d2}} = \frac{V_s \left(\frac{R_L R_{d2}}{R_L + R_{d2}} \right)}{R_s + \frac{R_L (R_{d2})}{R_L + R_{d2}}}$$

if $R_s \ll (R_L || R_{d2})$

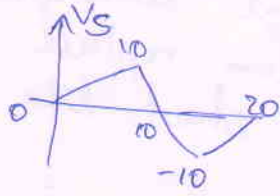
$V_o \approx V_s \Rightarrow$ the signal is

connected to R_L fully (or) completely

$$\frac{I_s}{2} = \frac{V_s}{2 \left[R_s + \frac{R_L (R_{d2})}{R_L + R_{d2}} \right]}$$

This ckt. will function as Analog gate and connects signal completely to load as long as $\frac{V_c}{2 R_c} > I_s/2$

- a) Design a diode gate (Analog gate) to connect or disconnect a source generating a triangular w/f at 50 Hz with peak voltage of 10V to a load of $1k\Omega$. The source resistance is 100Ω . The control signal has a time period of 0 to 20V. Draw the o/p w/g.

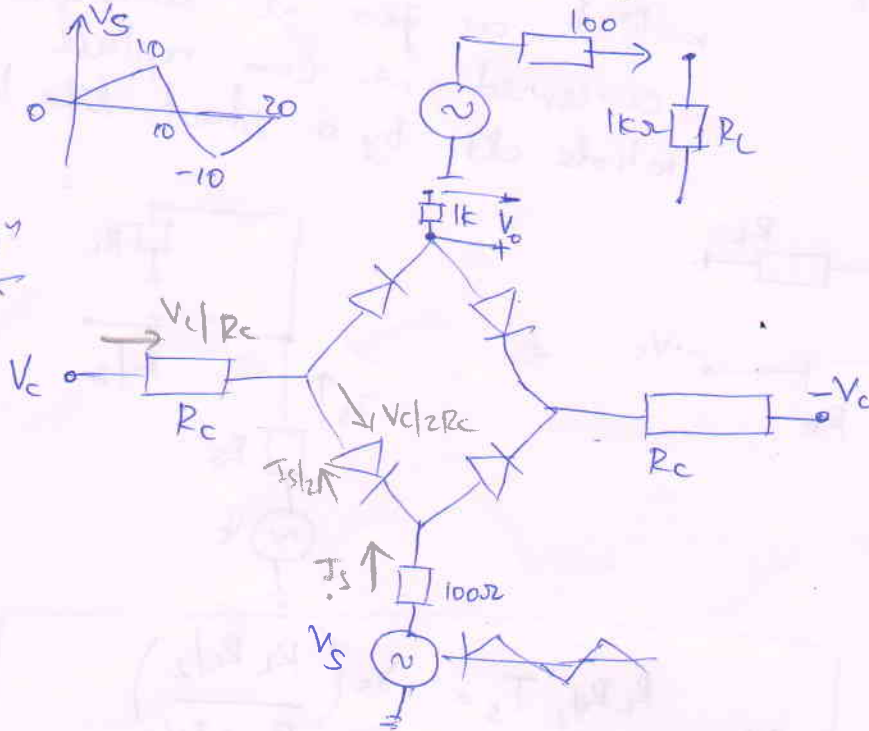


$$V_c =$$

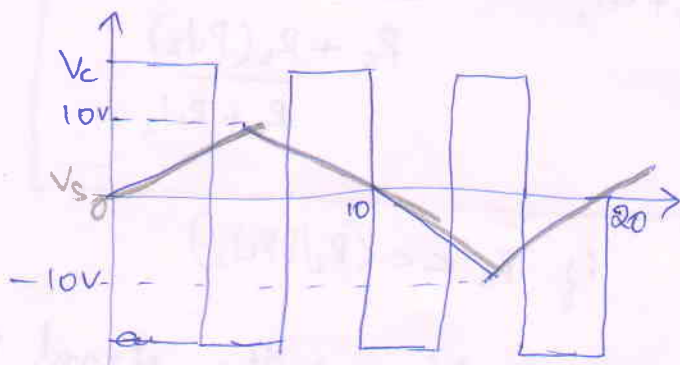
$$V_s =$$

$$R_c = ?$$

solⁿ



$$R_c = 1k$$



$$V_c > V_s \rightarrow \text{D are ON } \therefore$$

$$V_o \neq 0 \text{ \& } V_o = V_s$$

There will be some attenuation factor that depends on values of R_c

when all diodes are conducting, we know that we can replace the whole ckt. by a short ckt. $\therefore$

condⁿ to keep diodes conducting is

$$\frac{V_c}{2R_c} > \frac{V_s}{2(100 + \frac{1000}{3})}$$

$$V_{s\max} = 10V$$

(3)

$$V_c > \left[\frac{2 \times 1000}{2 \left(100 + \frac{1000}{3} \right)} \right] 10$$

$$V_c > \left(\frac{3000}{1300} \right) 10$$

$$V_c > \frac{300}{13}$$

$$\text{if } R_c = 1k$$

$$V_s > 10V$$

$$V_o = \left[\frac{1000/3}{100 + \frac{1000}{3}} \right] \times V_s$$

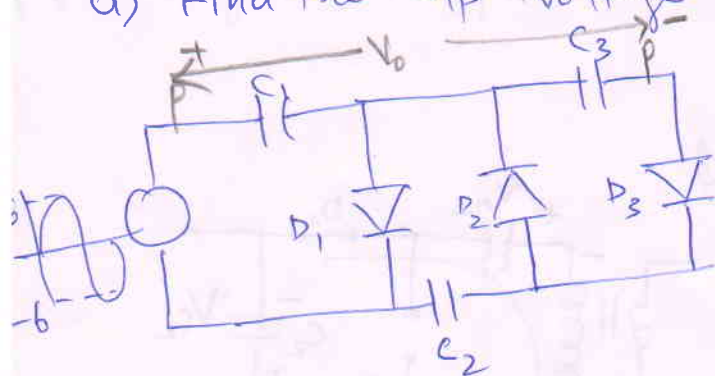
$$= \frac{1000}{1300} \times V_s$$

$$V_o = \frac{10}{13} V_s \Rightarrow \text{o/p is getting attenuated to}$$

some extent but V_s keep connected to o/p depending upon control signal.

across the terminals shown in fig.

a) Find the o/p voltage



* Voltage Multipliers. (Voltage doubler & Voltage tripler)

Voltage multiplier ckt are used to maintain relatively low transformer peak voltage by stepping up the peak output voltage to two, three, four or more times the peak rectified voltage

Voltage Multiplier ckt

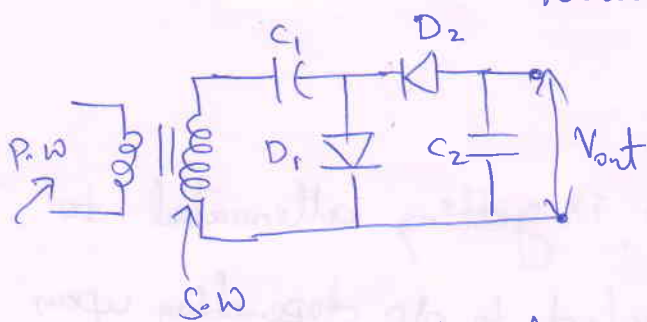
$2V_m \rightarrow$ Voltage doubler

$3V_m$
Voltage tripler &

Quadrupler
 $\rightarrow 4V_m$

Half wave voltage doubler

Full wave voltage Doubler



During positive half cycle of i/p signal

D_2 is RB & D_1 is FB.

$D_1, D_2 \rightarrow$ Ideal diodes.

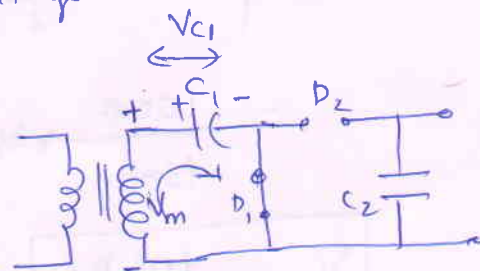
$V_o > 0 \therefore D_1 \rightarrow S.C \text{ \& } D_2 \rightarrow O.C$

During -ve half cycle of i/p signal

D_1 is RB & D_2 is FB.

D_1 is O.C D_2 is S.C

Capacitor C_2 gets charging.

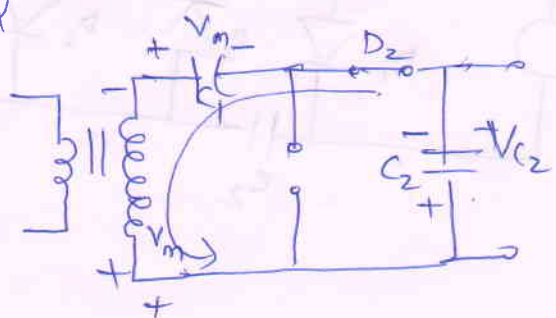


KVL:

$$V_m - V_{C1} = 0$$

$$V_{C1} = V_m$$

Capacitor C_1 gets charging



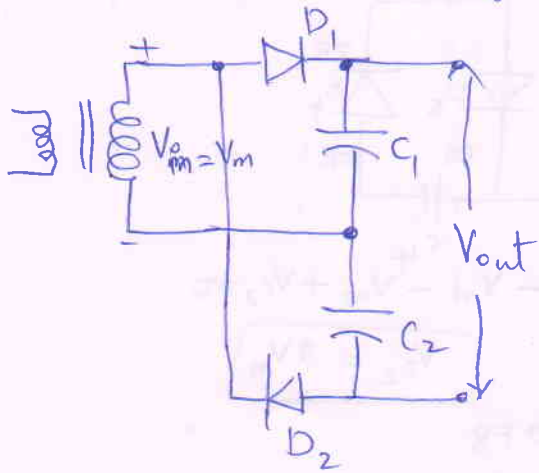
KVL:

$$-V_m - V_m + V_{C2} = 0$$

$$V_{C2} = 2V_m$$

(4)

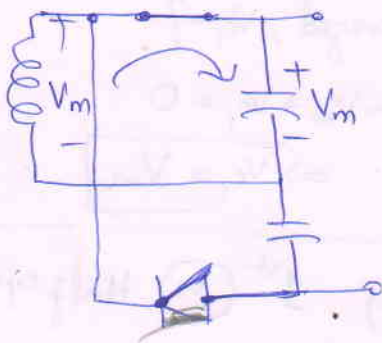
* Full wave Voltage doubler:



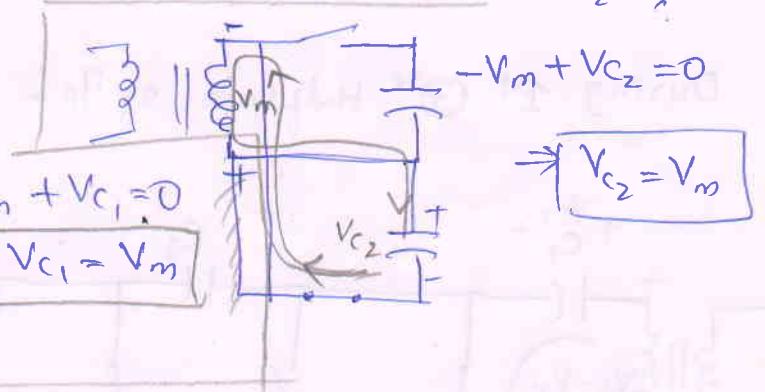
Assumptions: C_1 & C_2 are initially discharged

⊕^{ve} $\frac{1}{2}$ cycle: $D_1 = F \cdot B$
 $D_2 = R \cdot B$
 $V_{C1} = ?$

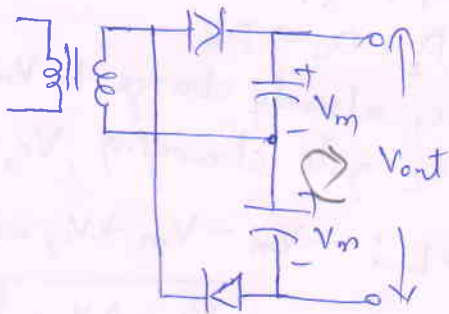
⊖^{ve} $\frac{1}{2}$ cycle
 $D_1 = R \cdot B$
 $D_2 = F \cdot B$
 $V_{C2} = ?$



KVL: $-V_m + V_{C1} = 0$
 $\Rightarrow V_{C1} = V_m$

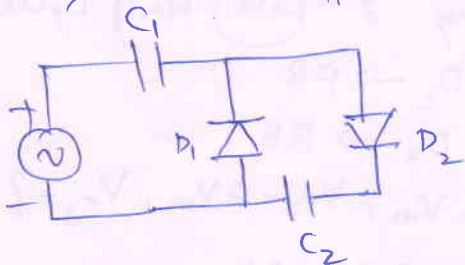


∴ Both the capacitors are charged.



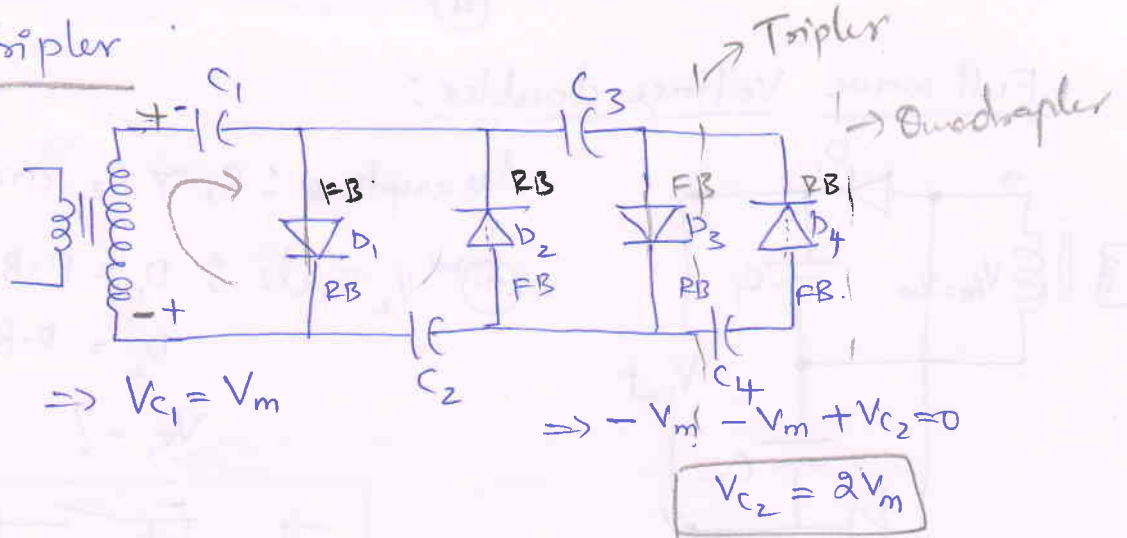
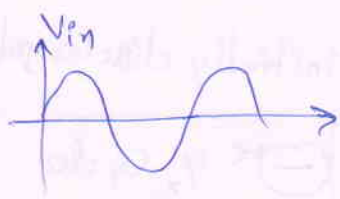
$V_m + V_m = V_{out}$
 $V_{out} = 2V_m$

Q) Find o/p voltage across C_2 if i/p is 6V_{p-p} value.



Note:- The discharging time constant $R_L C_2$ of the half-wave dtr is larger than time constant $RL \left(\frac{C_1 C_2}{C_1 + C_2} \right)$ of FW circuit. Since higher discharging time constant results in low ripple voltage, the ripple voltage in FW voltage doubler is thus larger than the half-wave dtr. for the same load resistance R_L .

* Voltage Tripler



During 1st (+ve) Half cycle of i/p:

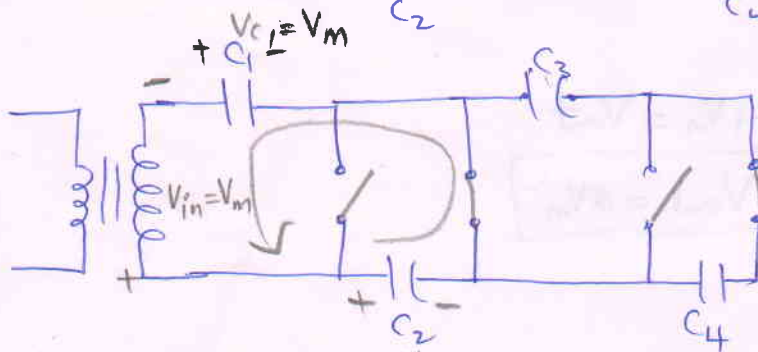
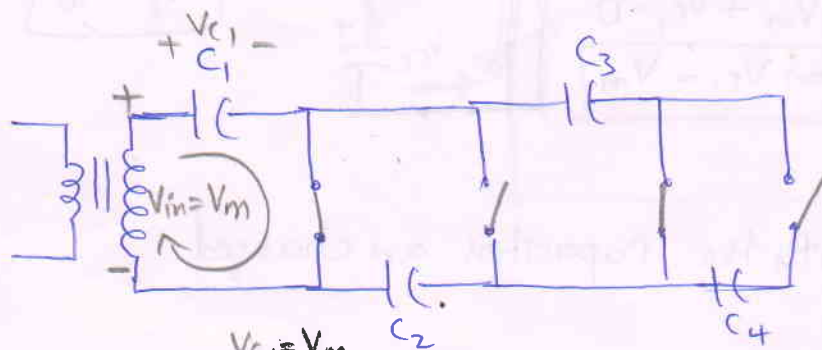
$D_1, D_3 \rightarrow FB$

$D_2, D_4 \rightarrow RB$

C_1 gets charged, $V_{C1} = ?$

KVL: $-V_m + V_{C1} = 0$

$\Rightarrow V_{C1} = V_m$



During 1st (-ve) Half cycle

$D_1, D_3 \rightarrow RB$

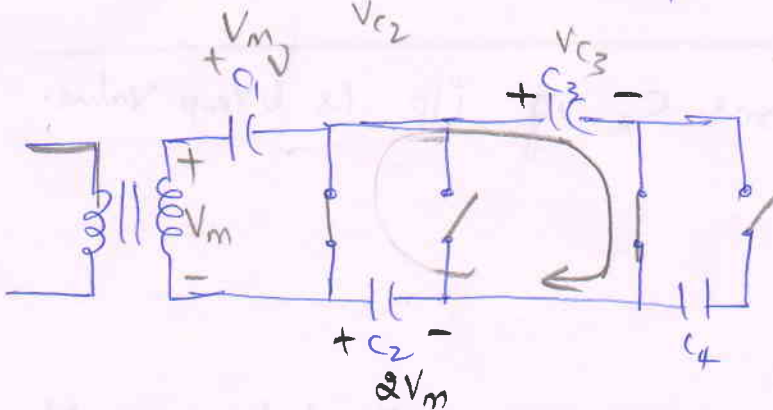
$D_2, D_4 \rightarrow FB$

C_1 already charge to V_m ,

C_2 gets charging, $V_{C2} = ?$

KVL: $-V_m - V_m + V_{C2} = 0$

$\Rightarrow V_{C2} = 2V_m$



During 2nd (+ve) Half cycle

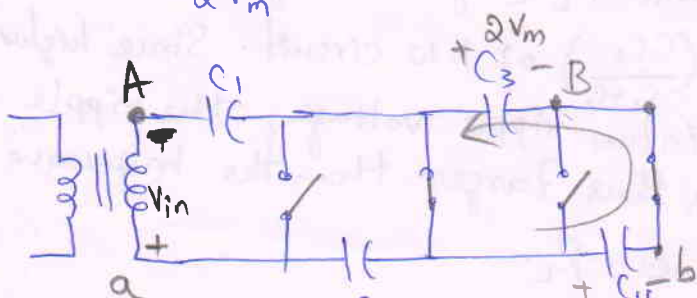
$D_1, D_3 \rightarrow FB$

$D_2, D_4 \rightarrow RB$

$V_{C1} = V_m, V_{C2} = 2V_m, V_{C3} = ?$

KVL: $-2V_m + V_{C3} = 0$

$\Rightarrow V_{C3} = 2V_m$



During 2nd (-ve) Half cycle

$D_1, D_3 \rightarrow RB, D_2, D_4 \rightarrow FB$

$\therefore V_{C4} = ?$

KVL: $-2V_m + V_{C4} = 0 \Rightarrow V_{C4} = 2V_m$

Voltage measured across node $V_{C4} AB = 3V_m$
 $ab = 4V_m$