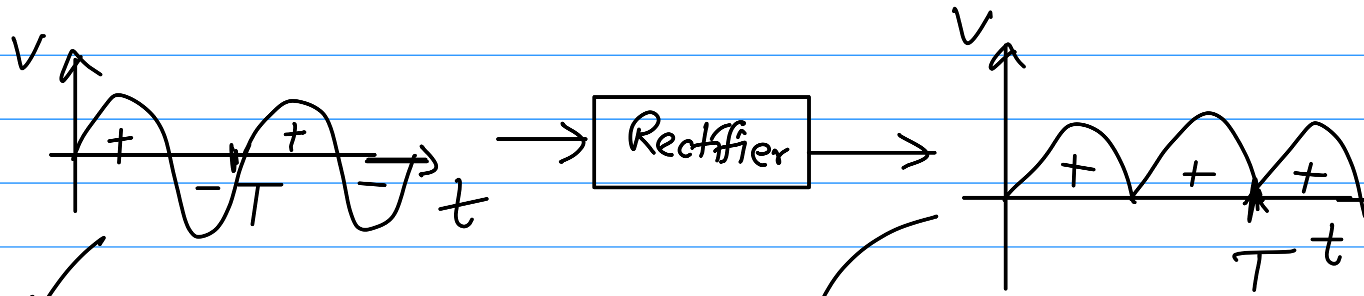
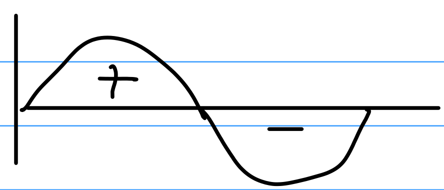
→ Rectifiers –



In ac signal
avg. vol. = 0

$$\boxed{V_{avg} = \frac{1}{T}\underbrace{\int_0^T V(t)\,dt}_{\text{area under vol. curve}}}$$

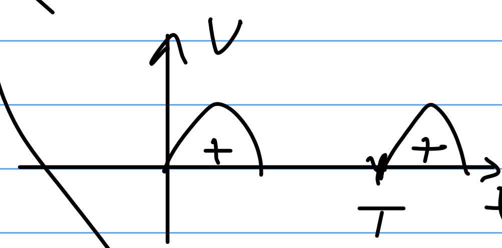
$\left(+ve \text{ area} + (-ve) \text{ area}\right)$



So, total area = 0

So, $\boxed{V_{avg} = 0}$

(or)



$V_{avg} = +ve$

$\because$ +ve area + 0

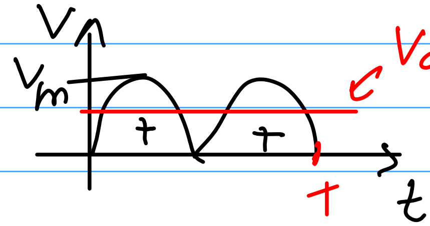
or +ve area + (+ve) area

* So, Rectifier is used to get +ve avg vol. or current from a zero avg vol. or current signal (Symmetric ac)

* (Or) rectifier increases the avg vol. or current in a signal.

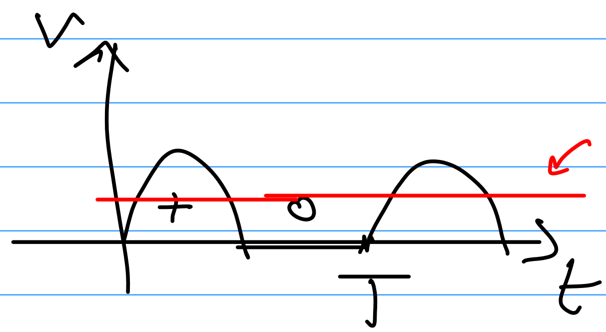
* Avg vol can also be called 'dc' vol.

(FWR)



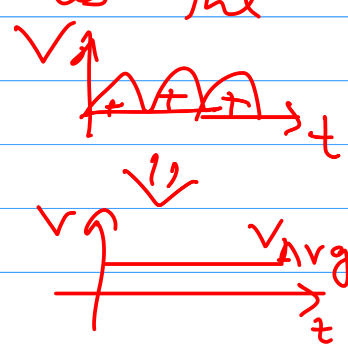
$V_{avg} = \frac{2V_m}{\pi}$ = DC vol.

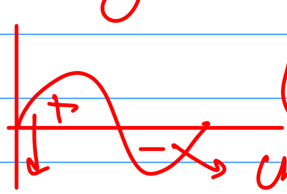
(HWR)



$V_{Avg} = \frac{V_m}{\pi}$

* Avg vol. is that DC vol which if applied to a resistance will cause same amount of charge transfer as the original non constant signal



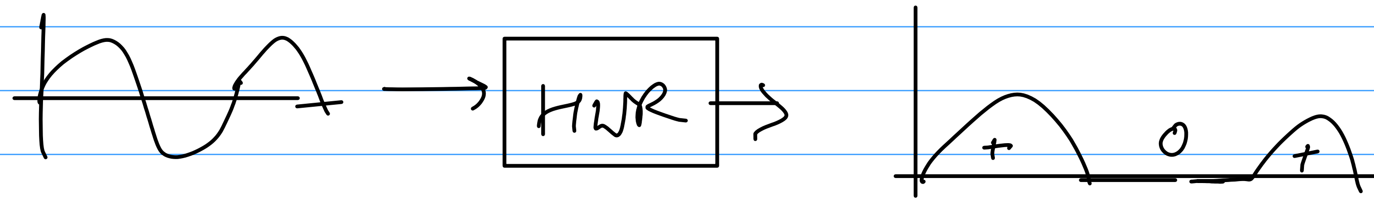


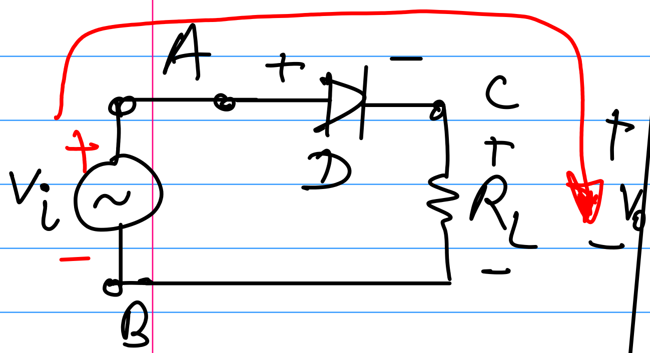
So total = 0 charge Xfer

+ Charge in one dir

in opp dir.

→ Half wave Rectifier (HWR) –

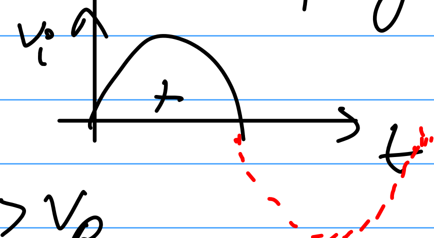




HWR

$$\boxed{V_0 = V_{CB} = V_C - V_B}$$

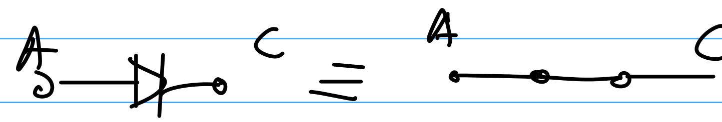
(i) for +ve half cycle of V_i



$V_A > V_B$

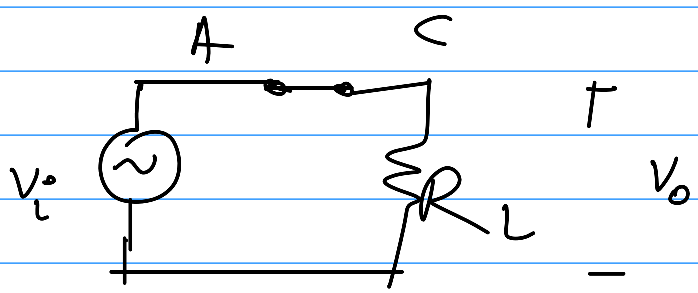
$V_A > V_C > V_B$

So, Diode D is F.B.

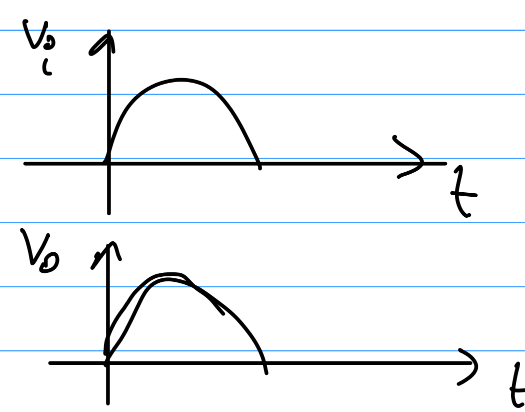


(assuming ideal diode)

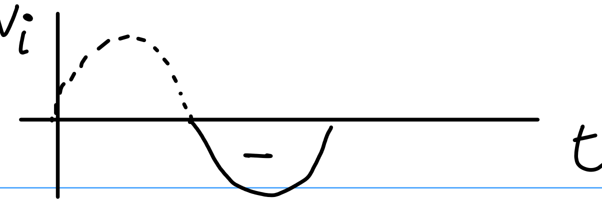
So ckt (for +ve half cycle)

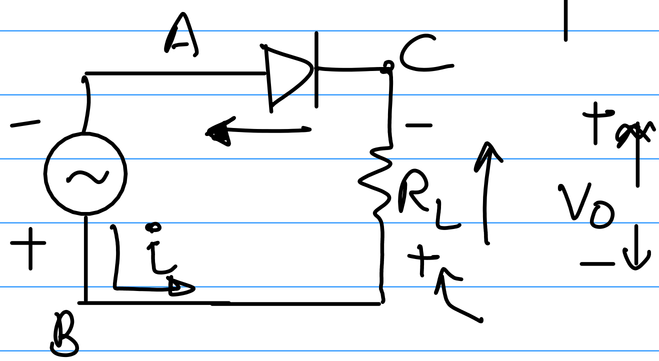


By KVL, $V_i = V_0$

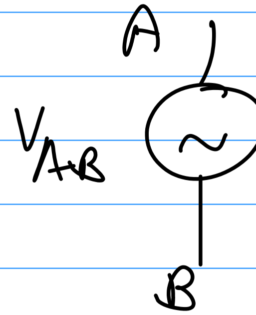


(ii) -ve half cycle -





$V_B > V_C$ (it seems)
if there is
current (anti-
clockwise)



$= V_A - V_B$

$V_{AB} < 0$

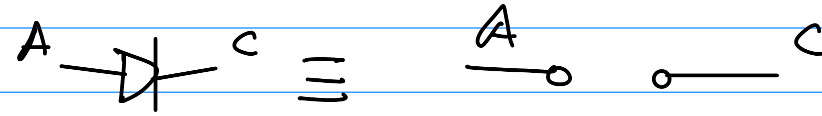
$V_A < V_B$

$V_B > V_A$

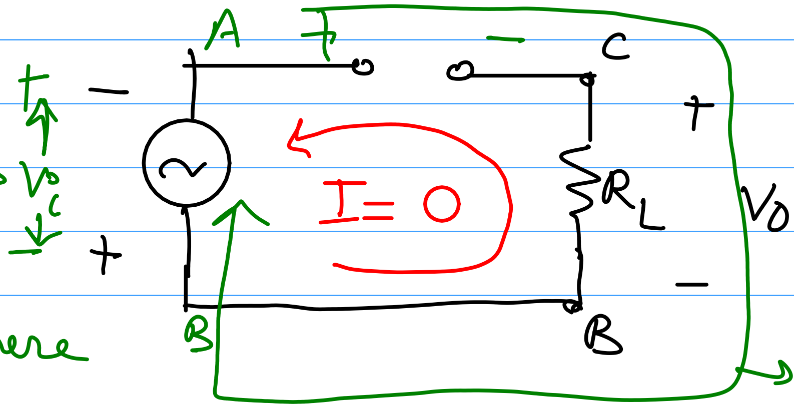
For anticlockwise current, Diode current is from N to P (Reverse Bias)

(or) $V_A < V_C$

For R.B.,



So, ckt becomes



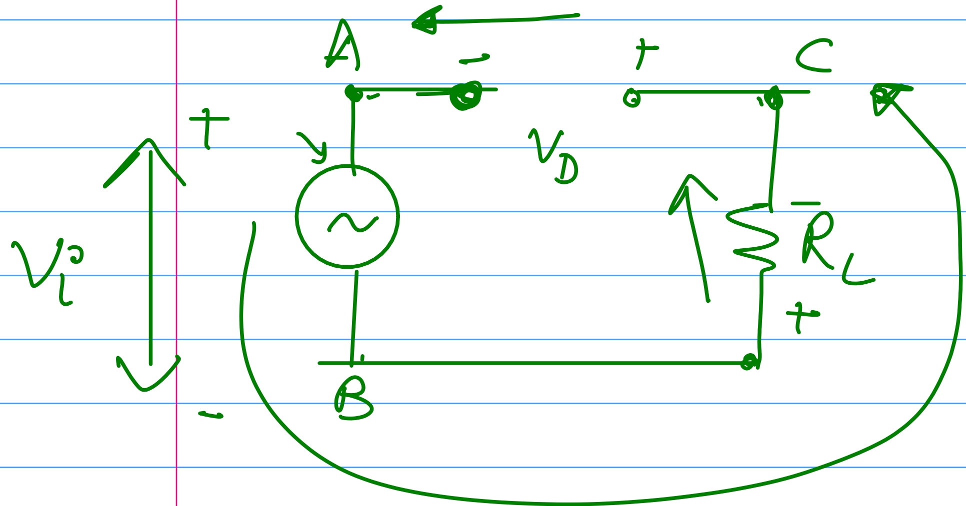
$V_i = V_{AB}$
$= V_A - V_B$
$= -ve$ here

$V_0 = V_{CB} = V_C - V_B$

$\because$ o.c. , $I = 0$, Using KVL,

$+V_i - V_{AC} - V_0 = 0 \Rightarrow V_i = V_{AC} = V_{AB}$

also, $V_0 = -I \cdot R_L = 0 \quad (\because I = 0)$



(-ve value)

$V_i = V_{AB}$

$= V_A - V_B$

(by def.)

$-V_i - V_{R_L} - V_D = 0$

$V_{RL} = I \cdot R_L = 0 \quad (\because I = 0)$

$-V_i - V_D = 0 \Rightarrow V_D = -V_i$

(Where $V_D = V_C - V_A = V_{CA}$)

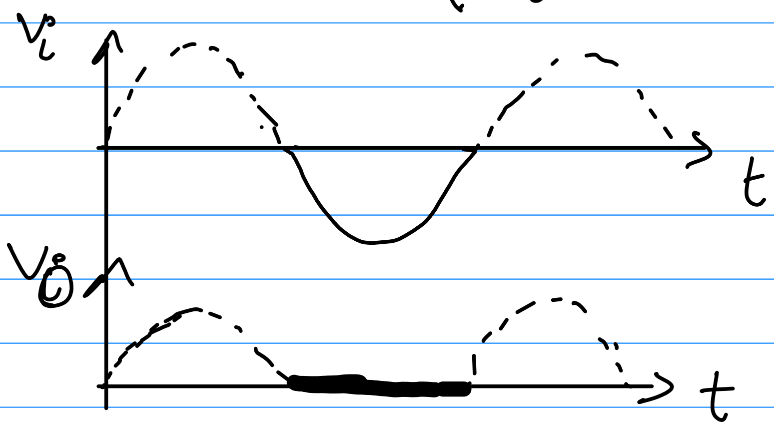
$V_{CA} = -V_i$ (or) $V_{AC} = V_i = V_{AB}$

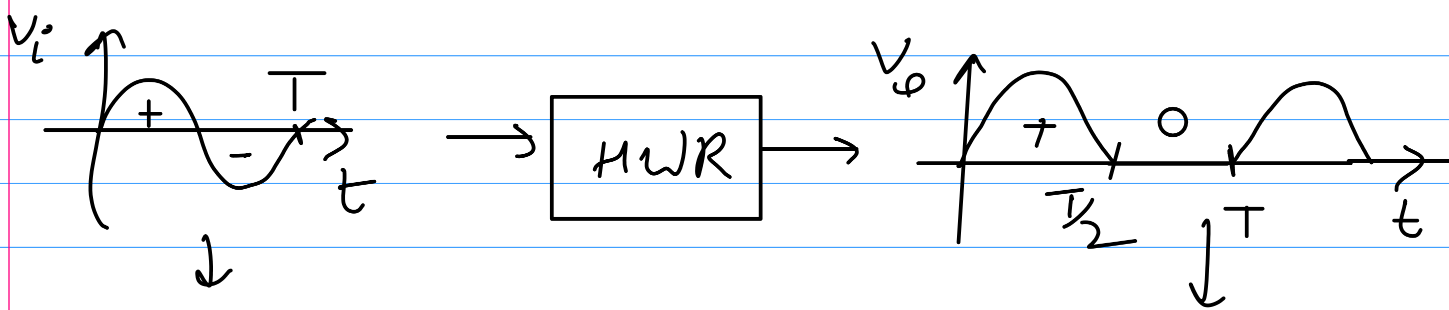
$V_B = V_C \quad (\because V_{BC} = V_{R_L} = 0)$

So, $V_D = V_{CB} = 0$

& $V_{AC} = V_i = -ve$ (So, diode is actually R.B)

P N (−ve half cycle)





$V_{Avg} = V_{dc} = 0$

$V_{avg} = V_{dc} = +ve$

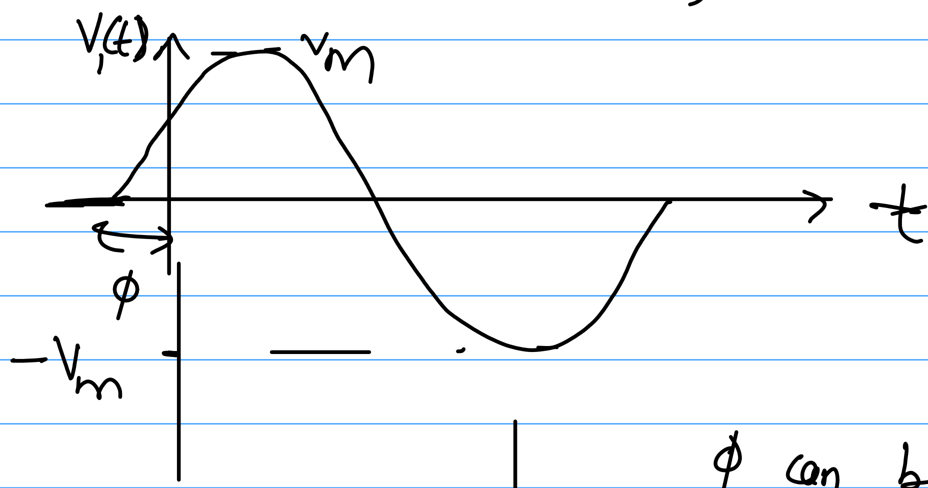
* $$\boxed{V_{avg} = \frac{1}{T}\int_0^T v(t)\,dt}$$ for any $v(t)$

→ **Definitions** - let's have a vol. signal $v(t)$

1. **V_{RMS}** — (root of mean of square) → (avg)

$$\boxed{V_{rms} = \sqrt{\frac{1}{T}\int_0^T v^2(t)\, dt}}$$

let $v_1(t) = V_m \sin(\omega t + \phi)$

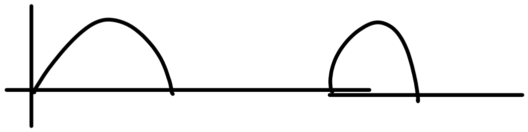


$$V_{1rms} = \frac{V_m}{\sqrt{2}}$$

ϕ can be anything,
ω can be anything,

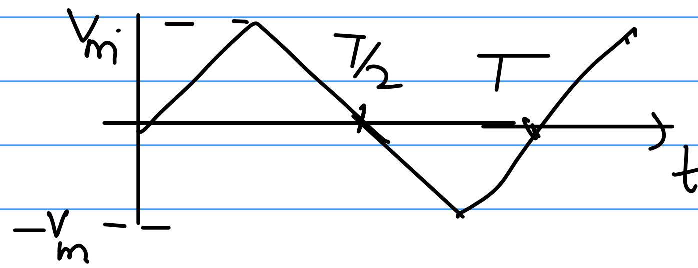
* RMS value is independent of freq & phase of a signal. It only depends on the shape.

ex2) $v_2(t)$



$$V_{2rms} = \frac{1}{\sqrt{2}} \frac{V_m}{\sqrt{2}} = \frac{V_m}{2}$$

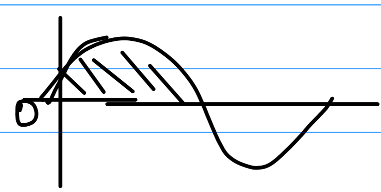
$v_3(t)$



$$V_{3rms} = \frac{V_m}{\sqrt{3}}$$

(2) $$V_{avg} = V_{dc} = \frac{1}{T} \int_0^T v(t)\, dt$$

$v_1(t)$

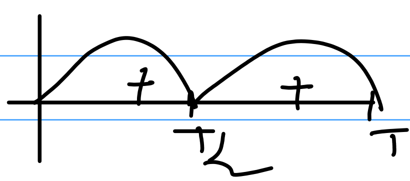


if Avg is taken over 1 period (T)

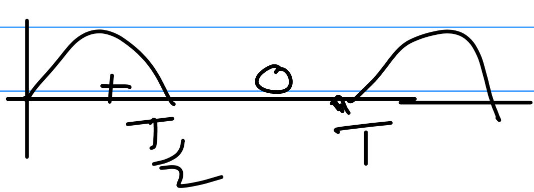
$V_{avg} = 0$

But for sinusoidals (or osc. signals), avg is taken over $\frac{1}{2}T$.

$$V_{avg} = \frac{2V_m}{\pi}$$



$\rightarrow$ $V_{avg} = \frac{2V_m}{\pi}$ (over T)

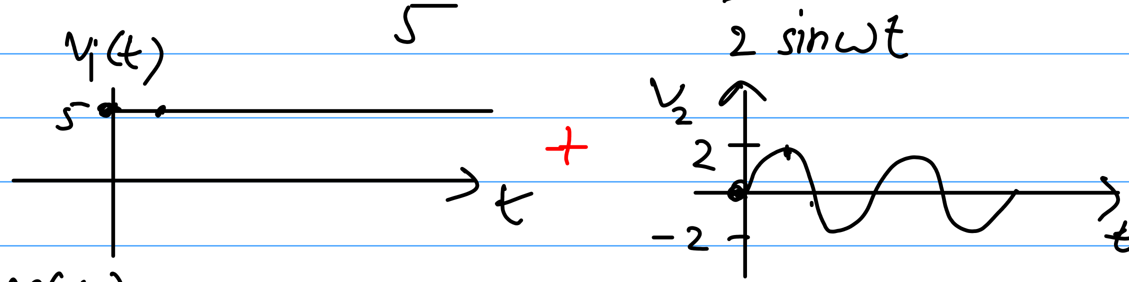


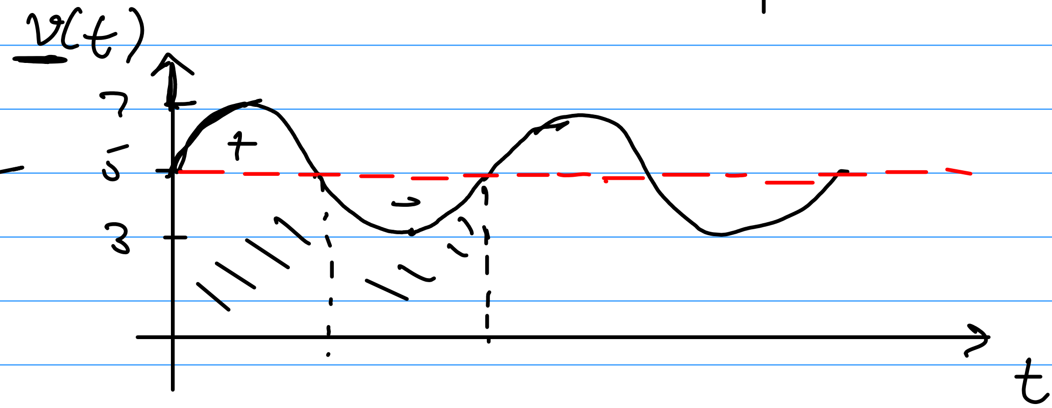
$V_{avg} = \frac{V_m}{\pi}$ (over T)

3) <u>Ripple vol.</u> - assume $v(t) = 5 + 2\sin\omega t$

Plot it $\quad v(t) = v_1(t) + v_2(t)$

$v_1(t) \to 5 \qquad v_2(t) \to 2\sin\omega t$





has 2 parts → DC part (avg) constant
→ ac part (osc. about the avg value)

avg or dc value = 5

$V_{dc} = 5$

other part is called the ac vol.

$V_{ac} = 2\sin\omega t \quad \& \quad V(t) = V_{dc} + V_{ac}$

Now the max deviation of $v(t)$ from avg value V_{dc} is called the "Ripple vol." (V_r)

* Ripple vol, is amplitude of the osc. part.

$$v(t) = 5 + 2\sin\omega t$$

V_{rms} ?

$$V = V_1 + V_2$$

$$\downarrow$$

$$V_{Rms} = \sqrt{V_{1\,rms}^2 + V_{2\,rms}^2}$$

(comes from power)

$$\text{Power} = I^2 R = I_{rms}^2 R = \frac{V_{rms}^2}{R}$$

$$\left(\because V_{rms} = I_{rms} R\right)$$

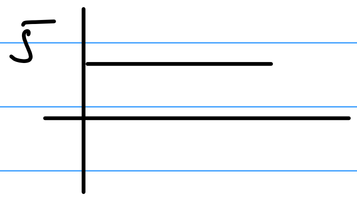
$$\text{Power due to } V = \text{Power}_{V_1} + \text{Power}_{V_2}$$

$$\frac{V_{rms}^2}{\cancel{R}} = \frac{V_{1\,rms}^2}{\cancel{R}} + \frac{V_{2\,rms}^2}{\cancel{R}}$$

$$V_{rms} = \sqrt{V_{1\,rms}^2 + V_{2\,rms}^2}$$

$V(t) = 5 + 2\sin\omega t$

for V_{dc}, RMS value is same as V_{dc}



$\rightarrow$ $\underline{\underline{Rms = 5}}$

$$V_{rms} = \sqrt{5^2 + \left(\frac{2}{\sqrt{2}}\right)^2}$$

$V_{ac\,rms}$

$$\boxed{V_{rms} = \sqrt{V_{dc}^2 + (V_{ac\,rms})^2}}$$

$$\boxed{V_{ac\,rms} = \sqrt{V_{rms}^2 - V_{dc}^2}}$$

$$V_{ac\,rms} = V_{dc}\sqrt{\left(\frac{V_{rms}}{V_{dc}}\right)^2 - 1}$$

4) Ripple factor – $\boxed{\gamma = \frac{V_{ac\,rms}}{V_{dc}}} = \frac{\sqrt{V_{rms}^2 - V_{dc}^2}}{V_{dc}}$

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

5) <u>Form factor</u> –

$$F = \frac{V_{rms}}{V_{dc}}$$

So, $$\boxed{\gamma = \sqrt{F^2 - 1}}$$

* For Rectifiers, O/p should as DC as possible so, ripple factor γ should be as low as possible

$$\boxed{\text{Ideally } \gamma = 0 \text{ \& } F = 1}$$

6) Crest factor $= C = \dfrac{\text{Peak vol.}}{\text{rms vol.}}$

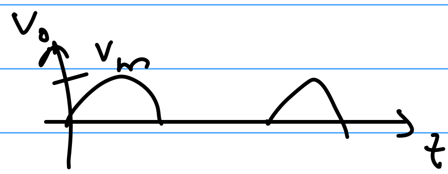
7) Rectifier efficiency,

$$\eta = \frac{\text{o/p dc power}}{\text{i/p ac power}} \times 100\%$$

[* $V_i = V_m \sin(\omega t)$]

for HWR –

(I) $V_{o\,rms}$ or $V_{rms} = \dfrac{V_m}{2}$



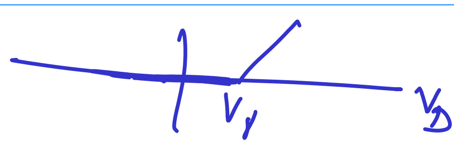
(II) V_{avg} or $V_{dc} = \dfrac{V_m}{\pi}$ (o/p)

(III) Form factor – $F = \dfrac{V_{rms}}{V_{dc}} = \dfrac{V_m/2}{V_m/\pi} = \dfrac{\pi}{2}$

$F = 1.58$

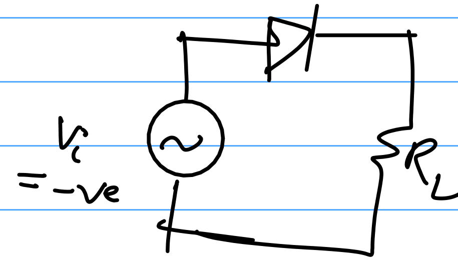
(V) Ripple factor – $\gamma = \sqrt{F^2 - 1} = 1.21$

(VI) Crest factor – $\dfrac{\text{peak}}{\text{rms}} = C = \dfrac{V_m}{V_m/2} = 2$



(VII) PIV – (Peak inverse vol) –

during –ve $\frac{1}{2}$ cycle

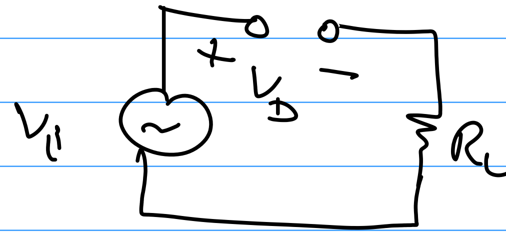


(∵ diode is OC)

$V_D = V_i = -ve$

(R.B.)

|||



$V_i\Big|_{max} = V_m$

$V_{D\,max}$ (R.B) $= -V_m$

$\boxed{PIV = -V_m}$ for HWR

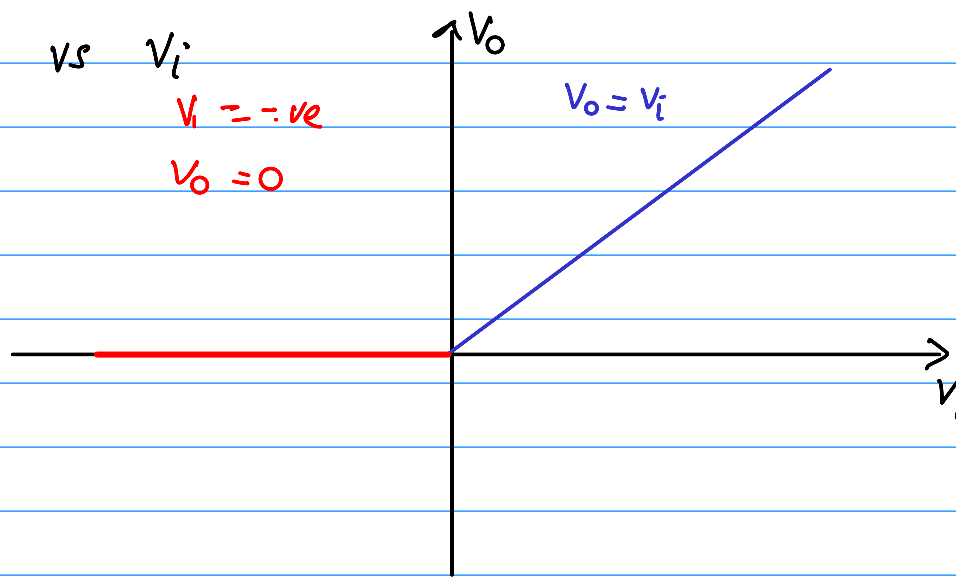
* PIV for any ckt should be as low as possible.

* Transfer Characteristics of HWR –

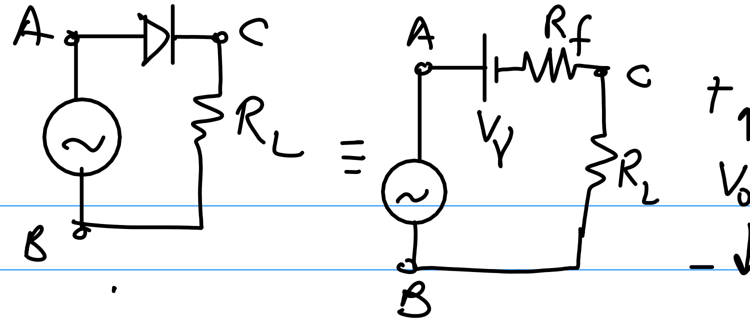
(ideal diode)**

V_i	V_o
(i) +ve	V_i
(ii) –ve	0

V_o vs V_i



for practical diode –



(i) $V_i > V_\gamma$

$(V_i = V_{AB} = V_A - V_B)$

By KVL, $V_o = V_i - V_\gamma - I R_f$

$$R_L I = V_o$$

$$V_o = V_i - V_\gamma - \frac{V_o}{R_L} \cdot R_f$$

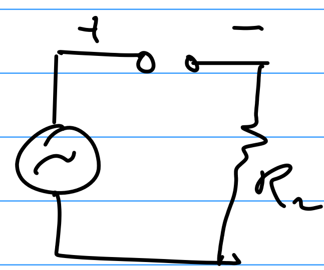
$$V_o \left[1 + \frac{R_f}{R_L} \right] = V_i - V_\gamma$$

$$\boxed{V_o = \frac{R_L}{R_L + R_f} (V_i - V_\gamma)}$$

$$\Rightarrow V_o = \left(\frac{R_L}{R_L + R_f} \right) \cdot V_i - \left(\frac{R_L}{R_L + R_f} \right) V_\gamma$$

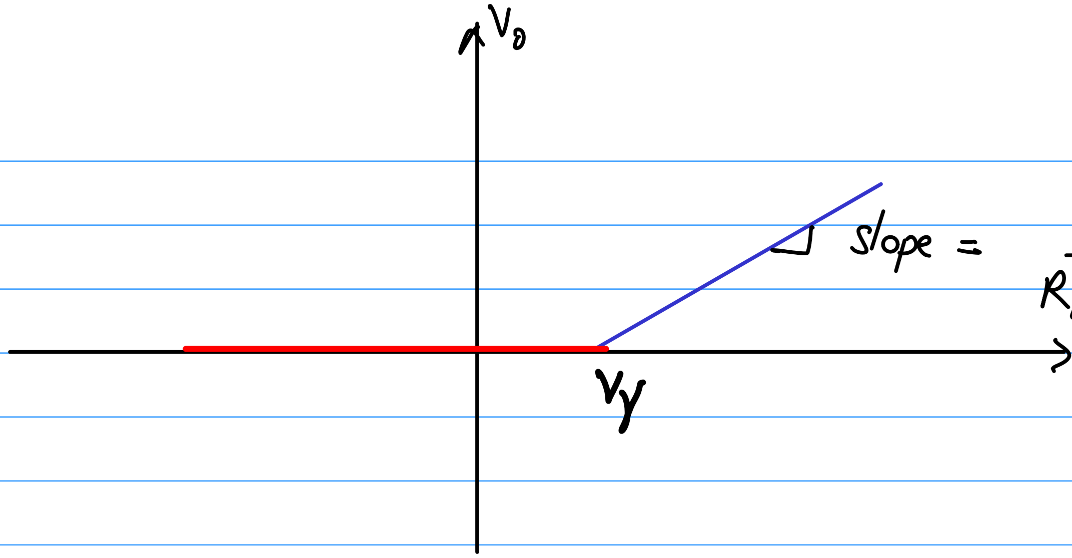
$$y = mx + c$$

(ii) $V_i < V_\gamma$ Diode → R.B. →

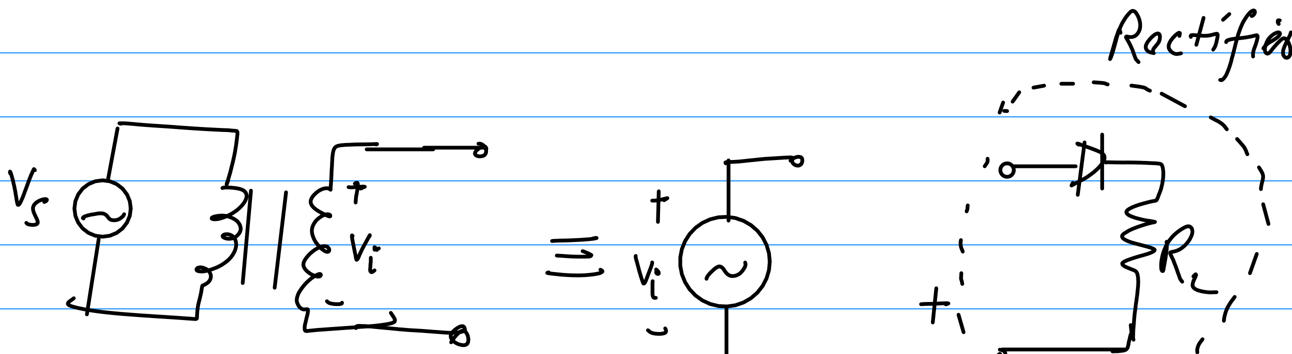


$V_o = 0$

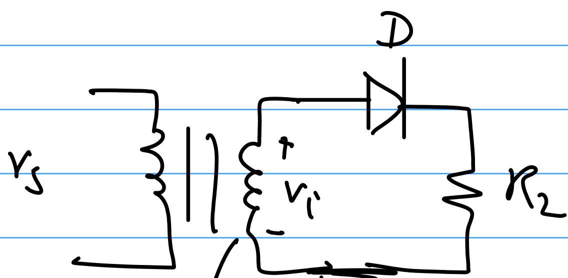
(by KVL)



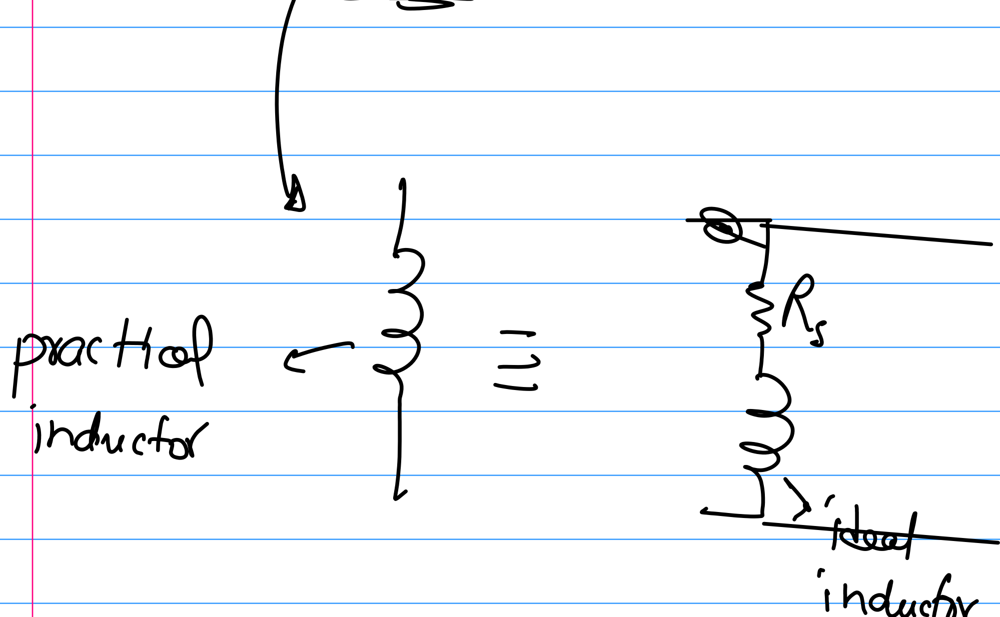
slope $= \dfrac{R_L}{R_L+R_f}$

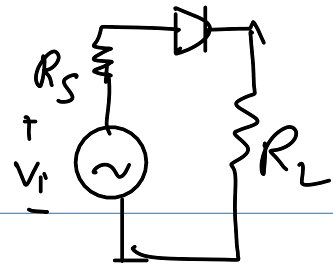


$N_1 > N_2$



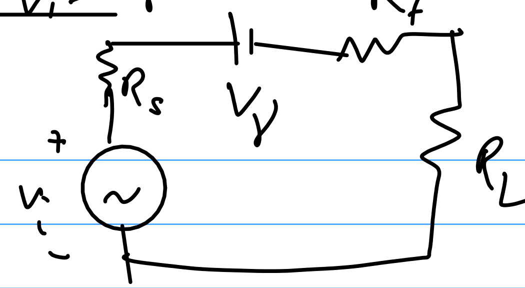
$v_i = V_m \sin \omega t$
(same analysis)



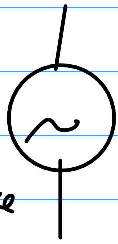


$\rightarrow$

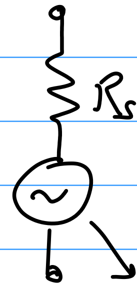
$\underline{V_i > V_\gamma}$



Practical Vol source

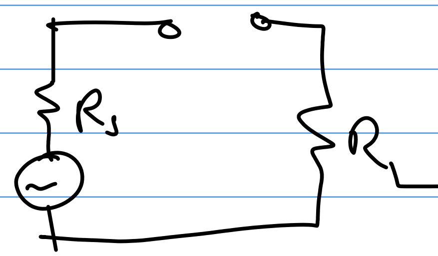


$\equiv$

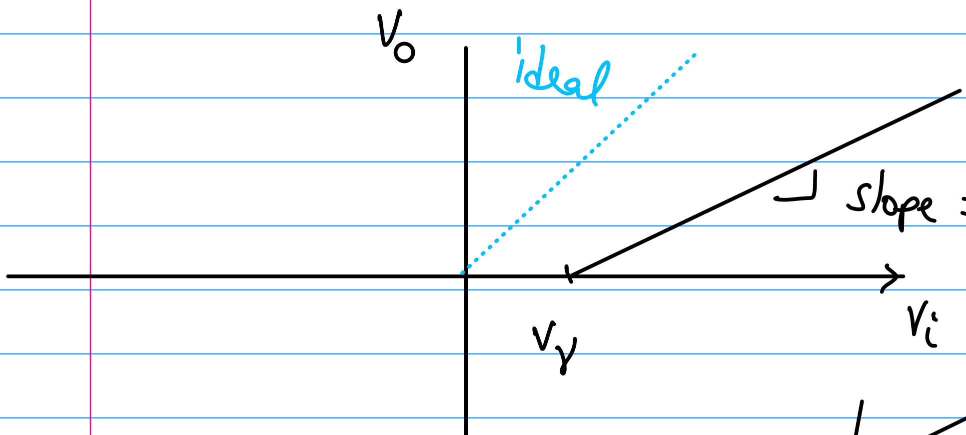


ideal vol. source

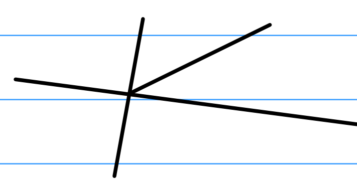
$\underline{V_i < V_\gamma}$



for $V_i > V_\gamma$, $V_o = \left(\dfrac{R_L}{R_s + R_f + R_L}\right) V_i - \left(\dfrac{R_L}{R_s + R_f + R_L}\right) V_\gamma$



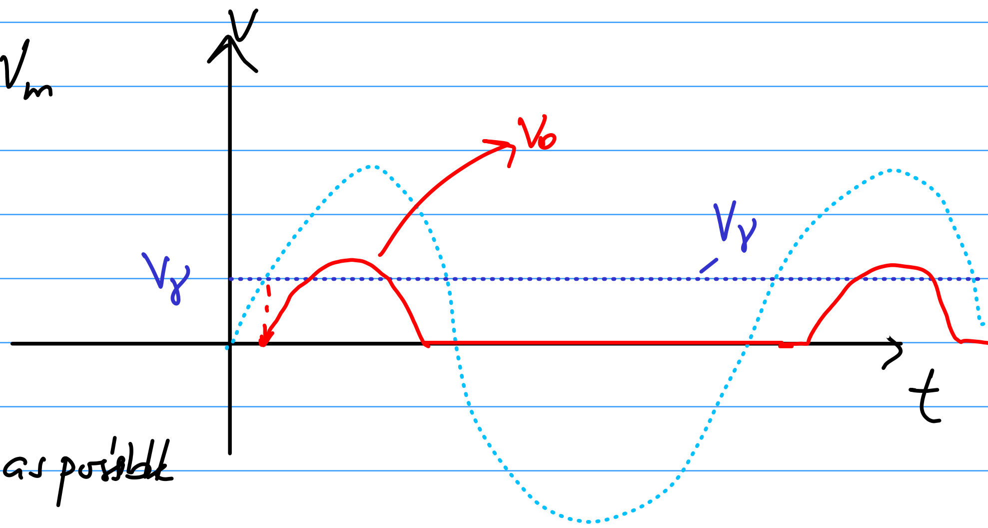
slope $= \dfrac{R_L}{R_s + R_f + R_L}$



when $v_i = V_m$

$$V_o = \left(\frac{R_L}{R_s + R_f + R_L}\right) V_m - \left(\frac{R_L}{R_s + R_f + R_L}\right) V_\gamma$$

$V_o < V_m$



make as small as possible

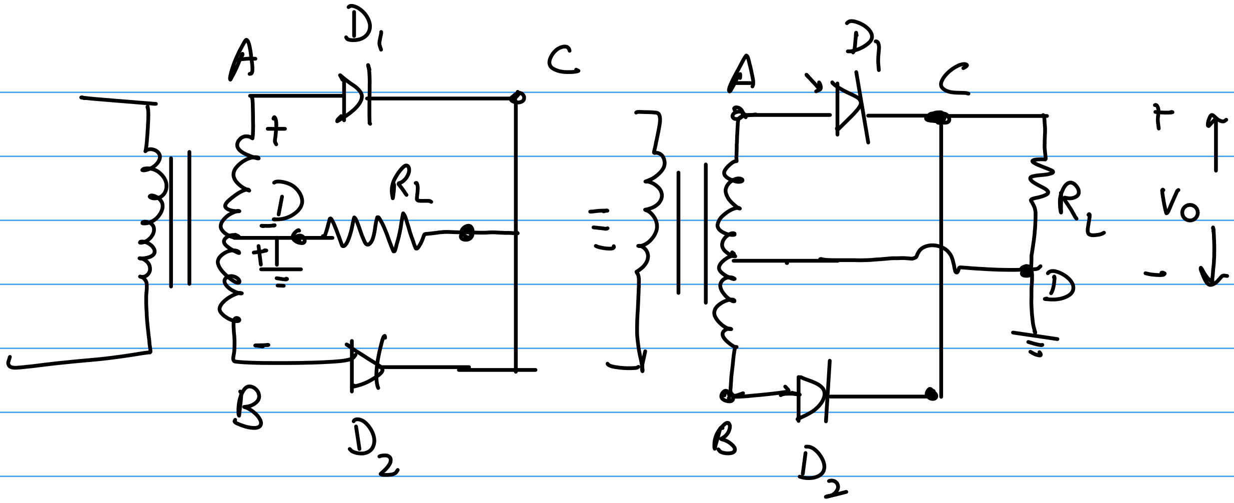
if $(R_s + R_f) << R_L$

then $\frac{R_L}{(R_s + R_f) + R_L} \simeq \frac{\cancel{R_L}}{\cancel{R_L}} = 1$

$(R_s + R_f)$ neglected

2) FWR — 1. Centre tapped
2. Bridge

2.1) Centre Tapped Xformer FWR –



in +ve $\frac{1}{2}$ cycle of i/p,

$$V_{AD} = V_m \sin\omega t \quad (+ve)$$

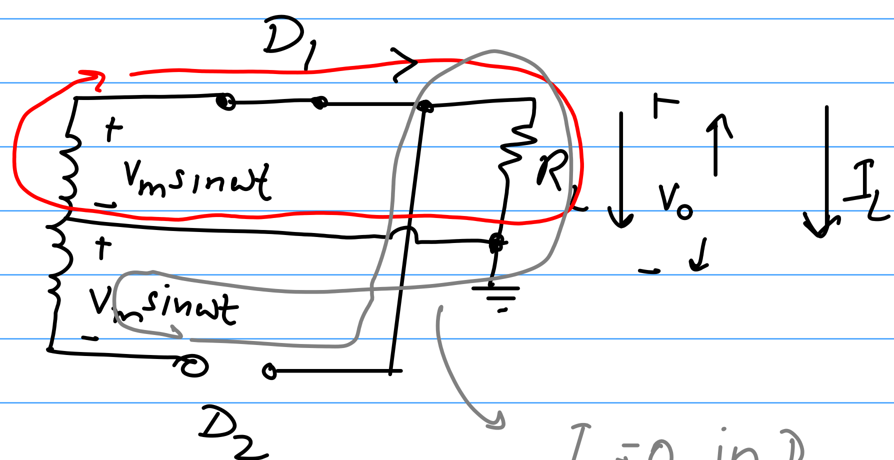
$$V_{DB} = V_D - V_B = V_m \sin\omega t \quad (+ve)$$

$$V_{BD} = -ve$$

$D_1 \rightarrow$ F.B. $(V_A > V_C)$

$D_2 \rightarrow$ R.B. $(V_B < V_C)$

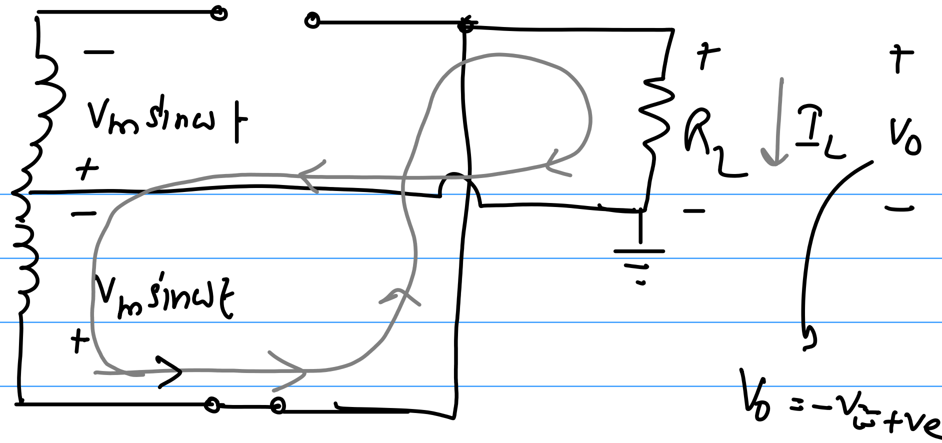
(ideal diodes)



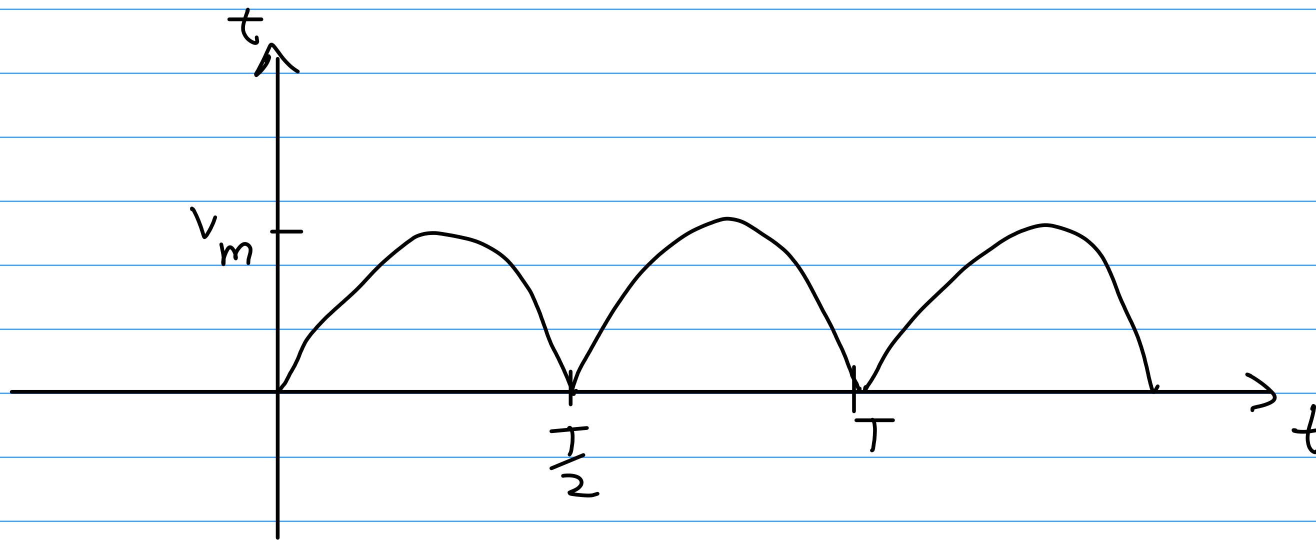
I = 0 in D_2

KVL → $V_o = V_m \sin\omega t$

$-ve \frac{1}{2}$ cycle —

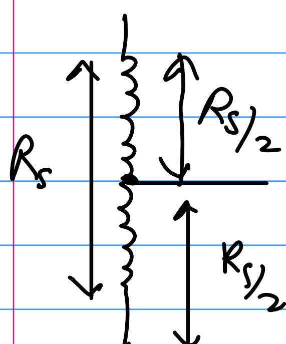


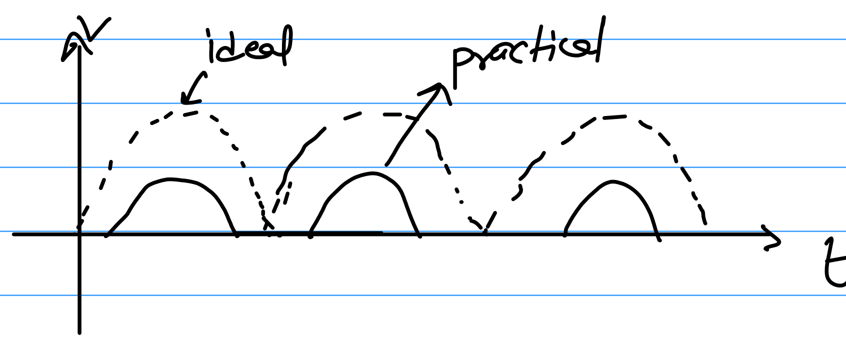
$V_o = -v_i = +ve$



* Using practical diodes (& practical windings in Xformer)

$$v_o = \left(\frac{R_L}{R_f + \frac{R_s}{2} + R_L}\right) v_i - \left(\frac{R_L}{R_f + \frac{R_s}{2} + R_L}\right) v_\gamma$$





* <u>Rectifier Efficiency</u>, $\eta = \dfrac{o/p \text{ dc power}}{i/p \text{ ac power}} \times 100\%$

<u>o/p dc power</u> – dc power consumed by load (R_L)

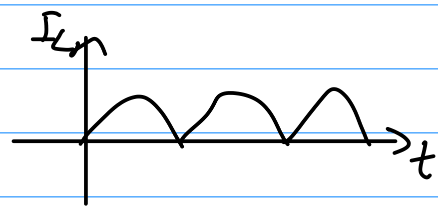
$$= I_{L_{dc}}^2 R_L$$

$I_{L_{dc}} = ?$

$$I_L = \begin{cases} I_m \sin\omega t & \text{for } 0<t<\frac{T}{2} \\ -I_m \sin\omega t & \text{for } \frac{T}{2}<t<T \end{cases}$$

+ve

+ve



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

$$I_{avg} = I_{L_{dc}} = \frac{2I_m}{\pi}$$

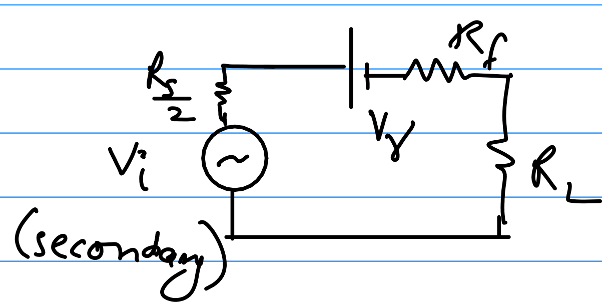
<u>i/p ac power</u> – $V_{i_{rms}} \cdot i_{i_{rms}}$

input vol

current from the i/p vol source

(at secondary windings)

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



[for one half cycle]

(Let's ignore the effect of V_γ)

write KVL ($V_\gamma = 0$ assumption),

$$V_i = I_i \left(\frac{R_s}{2} + R_f + R_L\right) \rightarrow \frac{V_m \sin\omega t}{\left(\frac{R_s}{2} + R_f + R_L\right)} = I_i$$

$$V_{i_{rms}} = I_{i_{rms}} \left(\frac{R_s}{2} + R_f + R_L\right)$$

$$\boxed{\begin{aligned} \text{ac i/p power} &= V_{i_{rms}} \cdot I_{i_{rms}} \\ &= I_{i_{rms}}^2 \left(\frac{R_s}{2} + R_f + R_L\right) \end{aligned}}$$

$$I_{i_{rms}} = I_{L_{rms}}$$

($\because$ in series ckt, same current flows everywhere)

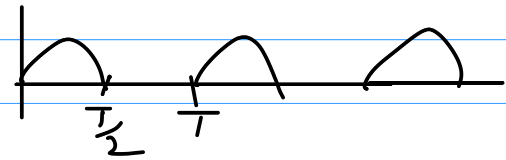
$$= \frac{I_m}{\sqrt{2}}$$

where $I_m = \dfrac{V_m}{R_L}$

$$\eta = \frac{I_{dc}^2 R_L}{I_{rms}^2 \left(\frac{R_s}{2} + R_f + R_L\right)} \times 100\% = \frac{\left(\frac{2 I_m}{\pi}\right)^2 R_L}{\left(\frac{I_m}{\sqrt{2}}\right)^2 \left(\frac{R_s}{2} + R_f + R_L\right)}$$

$$\boxed{\eta = \left(\frac{8}{\pi^2}\right)\left(\frac{R_L}{\frac{R_s}{2} + R_f + R_L}\right) \times 100\%}$$

* for HWR, $\eta_{HWR} = \dfrac{I_{dc}^2 R_L}{I_{rms}^2 (R_s + R_f + R_L)} \times 100\%$ $\because$ no centre tapping

$I_{dc\,(HWR)} = \dfrac{I_m}{\pi}$ ($\because$ )

$I_{rms\,(HWR)} = \dfrac{I_m}{2}$

So, $\eta = \dfrac{\left(\dfrac{I_m}{\pi}\right)^2 R_L}{\left(\dfrac{I_m}{2}\right)^2 (R_s + R_f + R_L)} \times 100\%$

$$\boxed{\eta_{HWR} = \frac{4}{\pi^2}\left(\frac{R_L}{R_s + R_f + R_L}\right) \times 100\%}$$

$$\boxed{\eta_{max\,(HWR)} = \frac{4}{\pi^2} \times 100\% \simeq 40.6\%}$$

(when $(R_s + R_f) << R_L$)

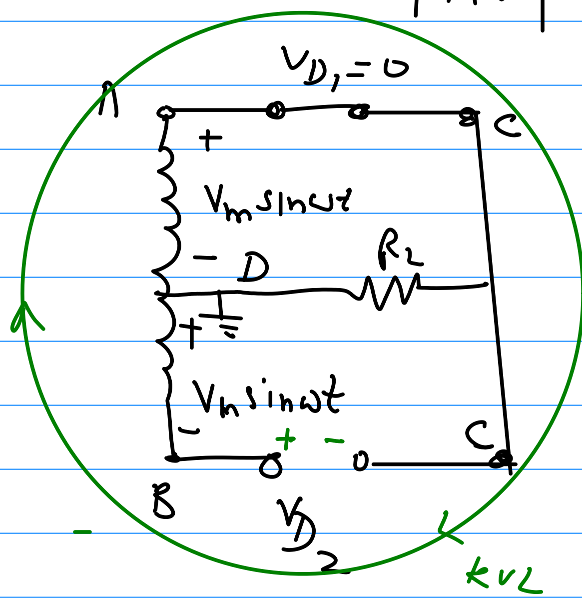
$$\boxed{\eta_{max\,(FWR)} = \frac{8}{\pi^2} \times 100\% = 81.2\%}$$

when $\dfrac{R_s}{2} + R_f << R_L$

* CT FWR has higher efficiency (double) than HWR
* But CT FWR need a x'former (bulky)

* another disad. of CTFWR is PIV

$$|PIV| = 2V_m$$



$V_{D_2} = ?$ $V_{D_2} = V_{BC}$

KVL −

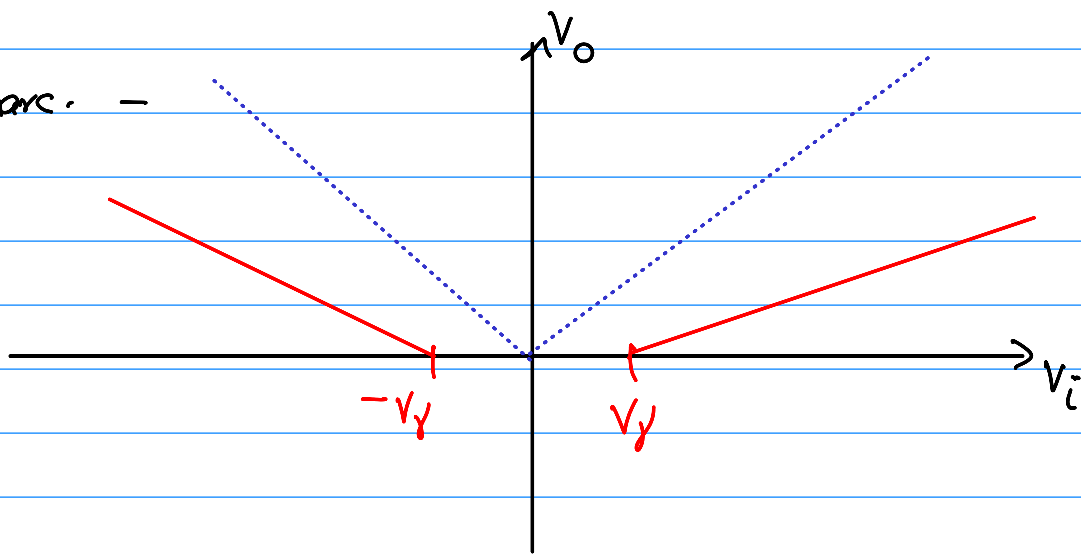
$$+V_{DB} + V_{AD} + \cancel{V_{D_1}} + V_{D_2} = 0$$

$$V_m \sin\omega t + V_m \sin\omega t + V_{D_2} = 0$$

$$V_{D_2} = -2V_m \sin\omega t$$

$$|V_{D_2}|_{max} = 2V_m \quad (R.B) = PIV$$

* Transfer char. −



* $V_{dc} = \frac{2V_m}{\pi}$ (o/p)

* $V_{rms} = \frac{V_m}{\sqrt{2}}$ (o/p)

* $F = \frac{rms}{dc} = \frac{V_m/\sqrt{2}}{2V_m/\pi} \Rightarrow \boxed{F = 1.11}$

* $\gamma_{(FWR)} = \sqrt{F^2 - 1} = \sqrt{1.11^2 - 1} = 0.48$

$\gamma_{HWR} = 1.21$

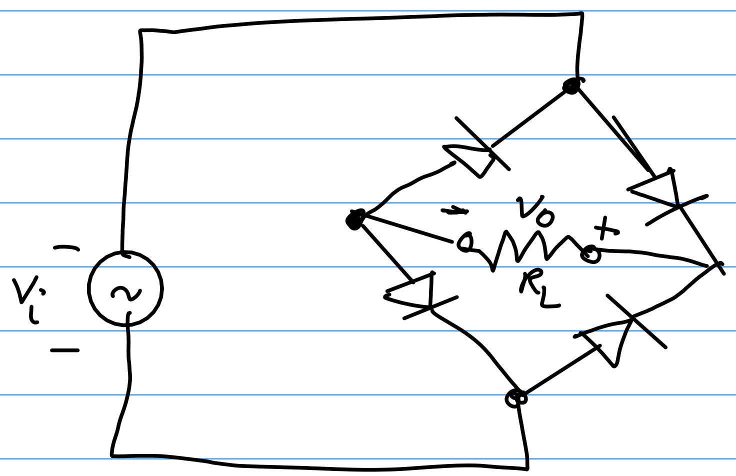
$\gamma_{FWR} < \gamma_{HWR}$

$\downarrow$

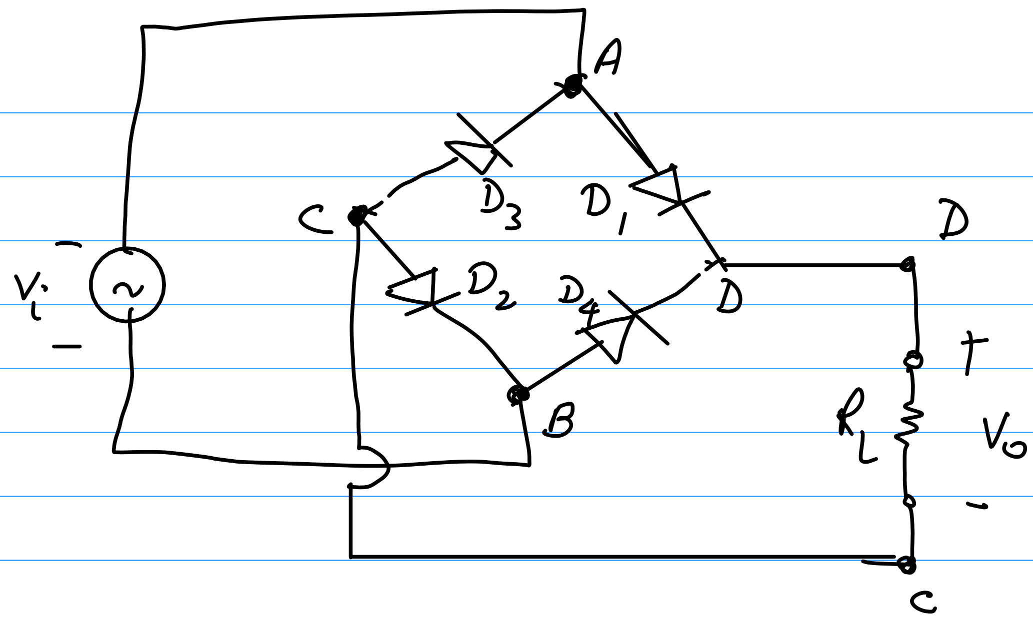
better

* Crest factor, (o/p) $C = \frac{peak}{rms} = \frac{V_m}{V_m/\sqrt{2}} = \sqrt{2}$

2.2) Bridge Rectifier -



FWR



* $\underline{+ve\ \tfrac{1}{2}\ cycle}$ — $V_i = V_{AB} = +ve$

A → highest vol $V_C < V_A$

B → lowest vol $V_D > V_B$

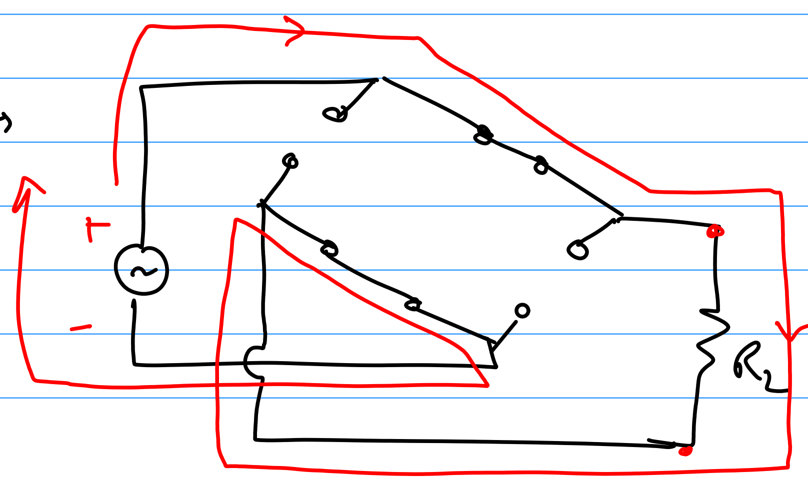
So, D_1 → F.B (on) ∵ $V_A > V_D$

D_2 → F.B (on) ∵ $V_C > V_B$

D_3 & D_4 → R.B (off) ∵ $V_C < V_A$

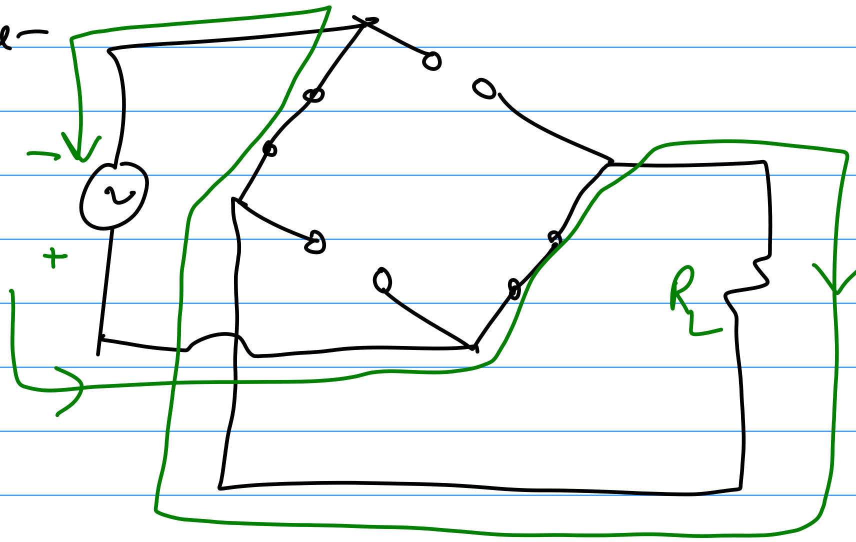
& $V_B < V_D$

Eql. ckt →



By KVL, $V_o = V_i = V_m \sin\omega t$ (ideal diodes)

× $-\frac{1}{2}$ cycle-

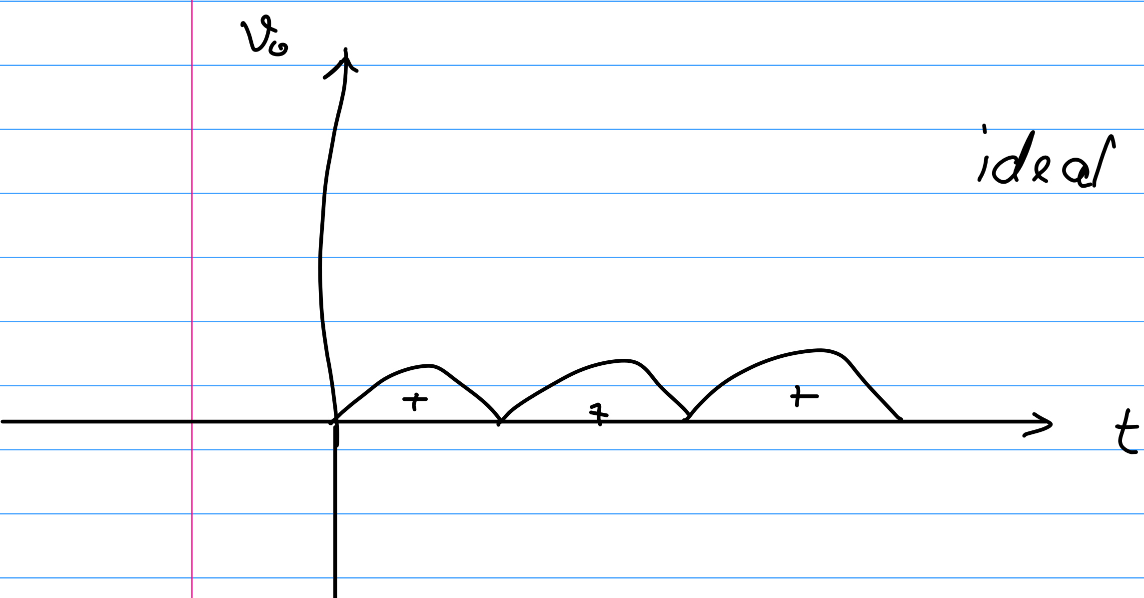


T

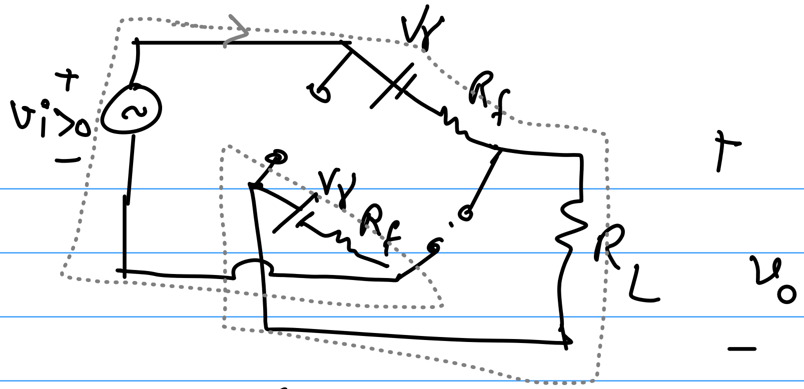
V_o = +ve

$$V_o = -V_i = -V_m \sin\omega t = +ve$$

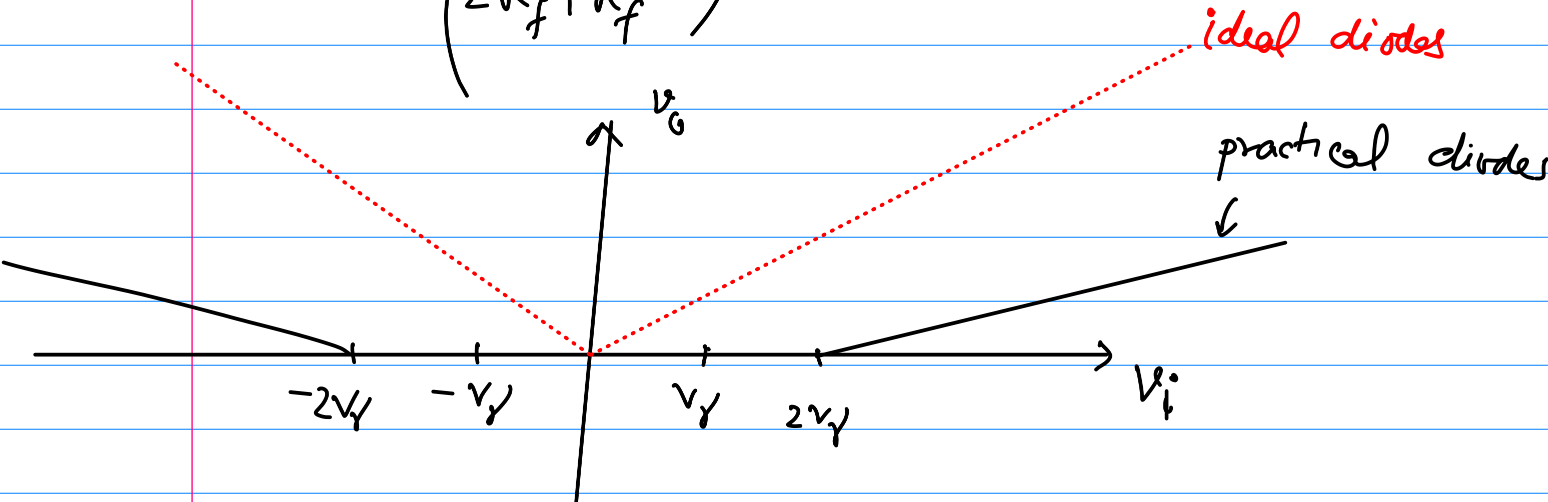
$$\because \frac{T}{2} \leq t < T$$



ideal diodes



$$v_o = \left(\frac{R_L}{2R_f + R_f}\right)(v_i - 2V_\gamma)$$



for ideal diodes –

* $V_{rms} = \dfrac{V_m}{\sqrt{2}}$ * $V_{dc} = \dfrac{2V_m}{\pi}$

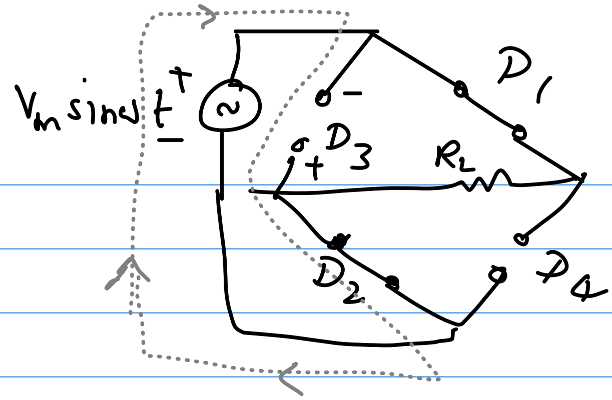
* $F = \dfrac{rms}{dc} = \dfrac{\pi}{2\sqrt{2}}$

* $r = \sqrt{F^2 - 1} \simeq 0.48$

* Efficiency $= \eta = 0.806 \times \left(\dfrac{R_L}{2R_f + R_L}\right) \times 100\,\%$

$\eta_{max} = 80.6\,\%$ when $2R_f \ll R_L$

* PIV →



KVL −

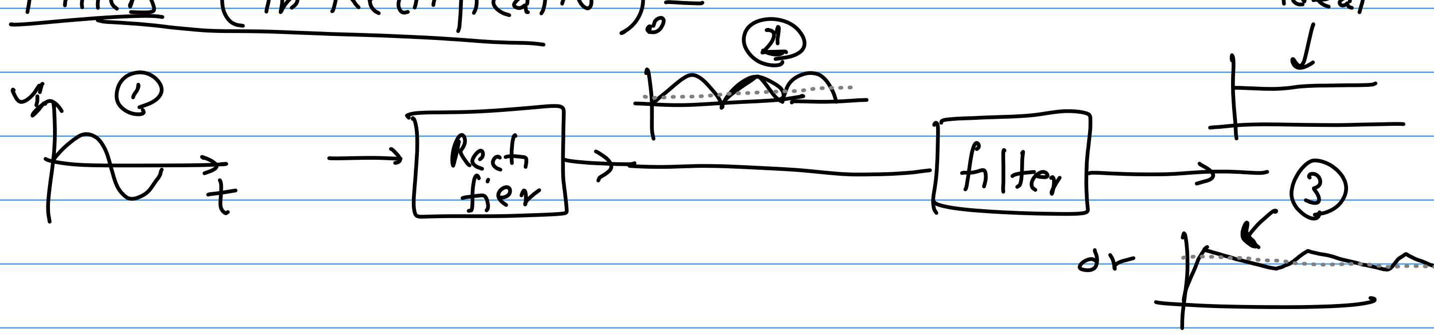
$$+V_m \sin\omega t + V_{D_3} = 0$$

so, $V_{D_3} = -V_m \sin\omega t$ (where $\sin\omega t = +ve$ ∵ $+\frac{1}{2}$ cycle)

So $|V_{D_3}|_{max} = V_m$
(R.B)

$$\boxed{PIV = V_m}$$

→ Filters (in Rectification):-



Compare (2) & (3)

$V_{dc_{(3)}} > V_{dc_{(2)}}$ $\gamma_{(3)} < \gamma_{(2)}$

filtering reduces the ripple factor (so makes pure dc ideally)

Inductor -

L

$V_L = L\frac{dI}{dt}$

Ohm's law for inductor

* Inductor opposes change in current flowing through it.

* $V_L = L\frac{dI}{dt}$ if I is constant with time (steady state, dc source), then $\frac{dI}{dt} = 0$

So, $\boxed{V_L = 0}$ i.e., inductor behaves as a short ckt for dc sources under steady state.

* Inductor does not allow sudden change in current. [if there is any resistance in series]

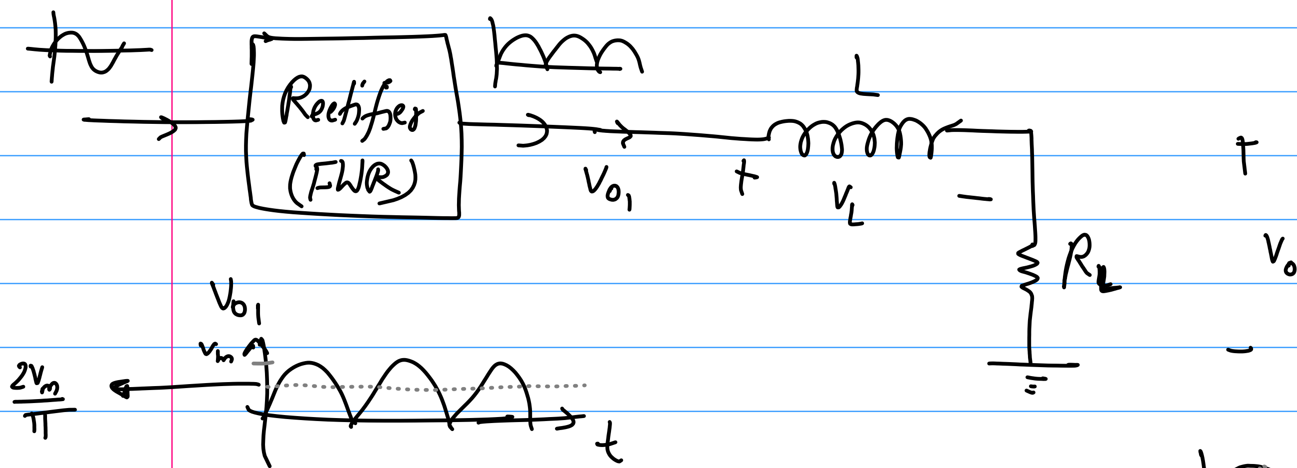
sudden change - $dt \to 0$, $dI \to$ finite non zero

$L\frac{dI}{dt} \to \frac{\text{finite}}{0} = \infty$ So, $V_L \to \infty$ (impossible)

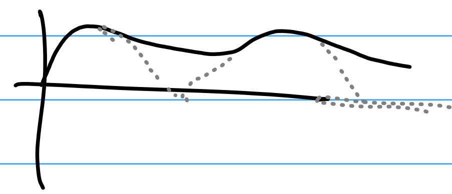
* Inductor acts as short ckt (v.v. low vol. drop (V_L)) for low frequency input sources (e.g. dc) in steady state

* Inductor can be assumed to be open ckt for v. high frequcies.

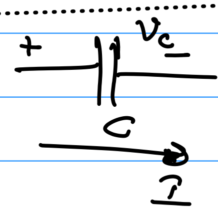
* So, inductor passes low frequencies (like dc) & blocks high frequency signals (like ac).



$$\boxed{V_{dc_1} = \frac{2V_m}{\pi}}$$



→ Capacitor -



$$\boxed{I = C\frac{dV_c}{dt}}$$

↓

Ohm's law for Cap.

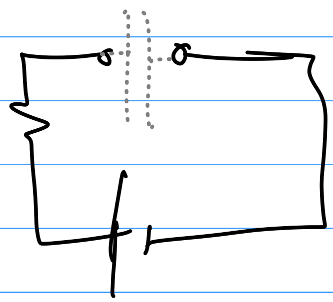
* Cap. opposes change in vol. across it.

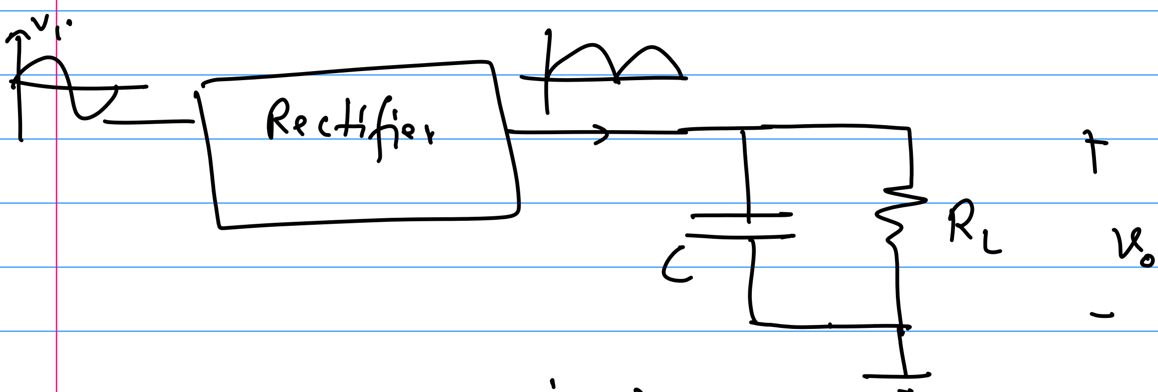
* Cap. doesnot allow sudden change in vol. across it

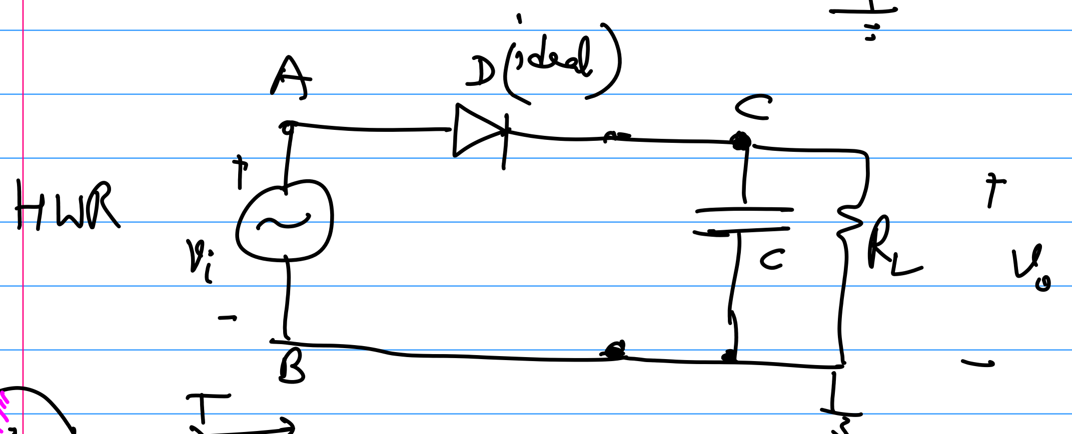
$$\because \frac{dV_c}{dt \to 0} \to \infty \quad \Rightarrow \quad I = \infty$$

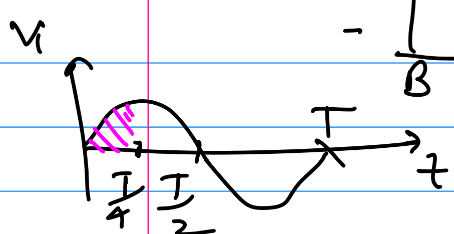
* ∞ current is needed to change v_C suddenly.
* v_C can change suddenly only if there is no series resistance in the ckt.

* Cap. acts as O.C. for low freq. (like dc) in steady state & S.C for v. high freq.







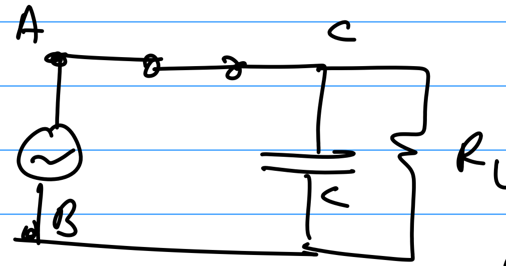


$[v_C = 0 \text{ at } t=0]$

for $0 < t \leq \frac{T}{4}$ → D is 'ON'

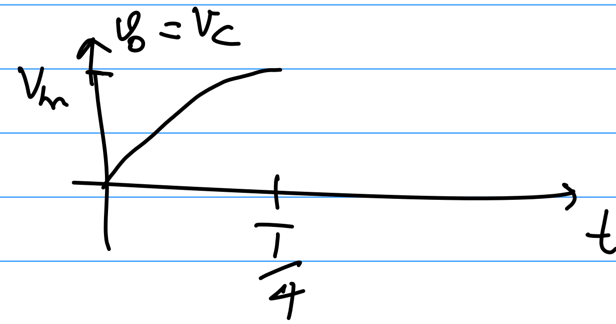
∴ $V_A = +ve$, $V_C = 0$

So,



(by KVL)

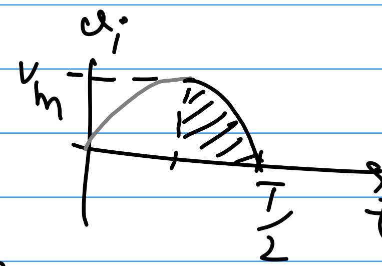
$V_C = V_i = V_0$



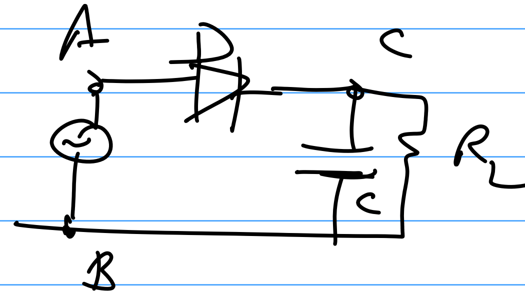
(ii) for $\frac{T}{4} < t < \frac{T}{2}$ →

at $t = \frac{T}{4}$, $V_C = V_m$

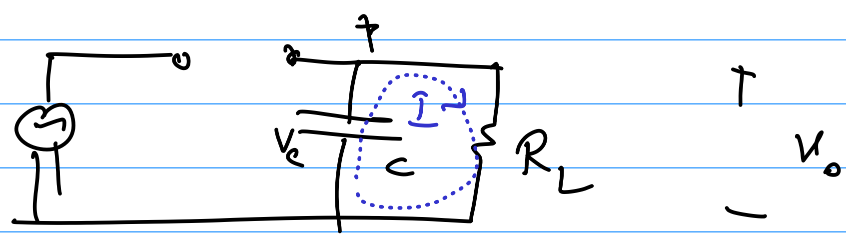
but $v_i < V_m$ for $t > \frac{T}{4}$



So, $V_A < V_C$



So D = off



$V_C = V_m$ (at $t = T/4$)

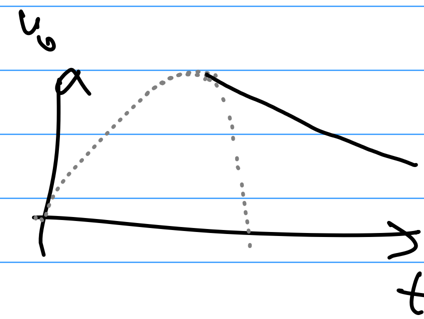
$v_o = v_c$

& $I = -C \dfrac{dv_o}{dt}$

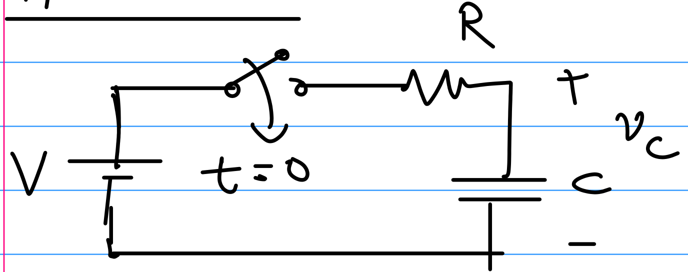
also, $IR_L = v_o$

$\dfrac{v_o}{R_L} = -C \dfrac{dv_o}{dt}$

$$\boxed{v_o = V_m e^{-t/CR_L}}$$



* <u>Time constant</u> -



Capacitor charging

<u>for $t>0$</u> —

$V - IR - v_c = 0$

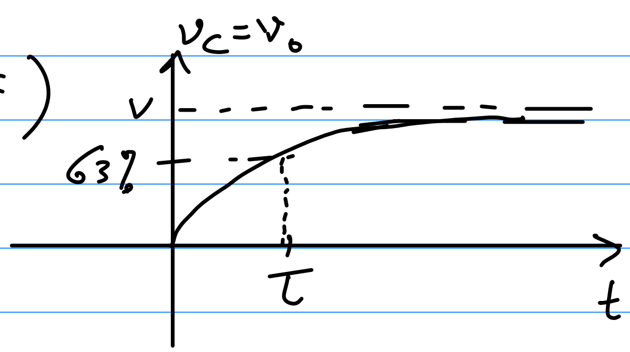
$I = C \dfrac{dv_c}{dt}$

$V - CR \dfrac{dv_c}{dt} - v_c = 0$

$$\boxed{\dfrac{dv_c}{dt} + \dfrac{v_c}{RC} = V}$$

<u>Solution</u> -

$v_c(t) = V\left(1 - e^{-t/RC}\right)$



$e^{-t/\tau}$

$\boxed{\tau = RC}$ *

τ (or time constant) is the time where rising o/p reaches ~63% of max value

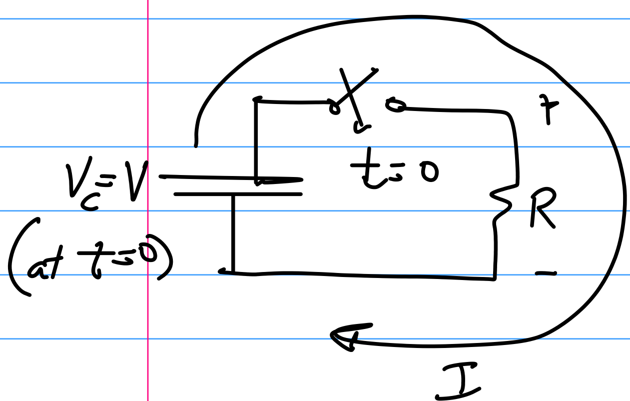
at $t = 2\tau$, $v_c = ?$

$t = 3\tau$, $v_c = ?$ (95% of V)

$t = 4\tau$ $\quad V_c \simeq 98\%$ of V

$t = 5\tau$ $\quad v_c > 99\%$ of V

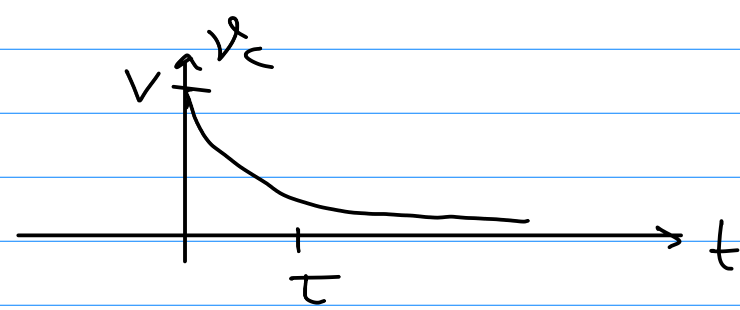
steady state → o/p doesn't change (if i/p is constant)



$$C\frac{dv_c}{dt} \cdot R = v_c$$

$$\boxed{v_c(t) = Ve^{-t/RC} = Ve^{-t/\tau}}$$

$$\boxed{\tau = RC}$$

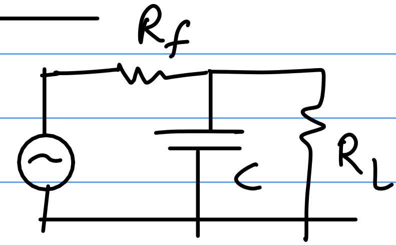


at $t = \tau$, $v_c = v_0 \cong 37\%$ of V

* if τ is large, C takes a long time to change its vol.
* If τ is small, v_C changes quickly

<u>for HWR with C-filter</u> —

(1) during $+\frac{1}{2}$ cycle,



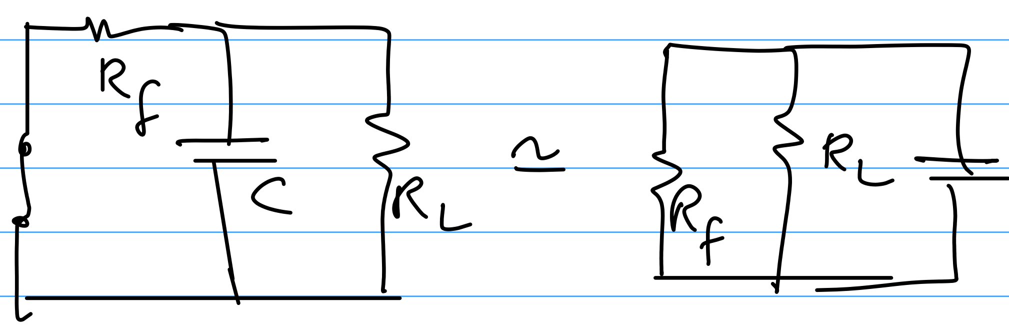
<u>How to find τ ?</u>

(i) - Replace all ideal vol sources by S.C.
- & all ideal current sources by O.C.

(Replace any source by its internal resistance)

(ii) Across the 2 nodes of concern, find Equivalent resistance R_{eq} & C_{eq}

(iii) $\tau = R_{eq} \cdot C_{eq}$



$R_{eq} = R_f \parallel R_L \simeq R_f \quad \because \quad R_f << R_L$

$C_{eq} = C$

$\tau = R_f C$ = v.v. small

$\because R_f \to 0$

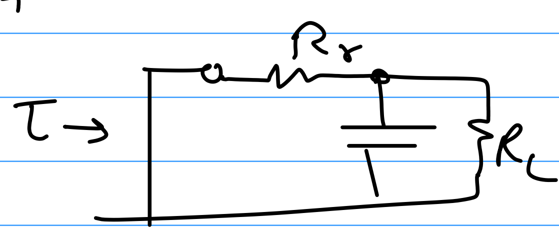
So, during $0 < t < T/4$, cap charges

to follow v_i v. quickly

by KVL $v_c = v_i - V_D \simeq v_i$

$\because V_D = 0$ (ON)

for $t > T/4$ – D = off



$R_{eq} = R_r \parallel R_L$

$\simeq R_L$

$\because R_r >> R_L$

$C_{eq} = C$

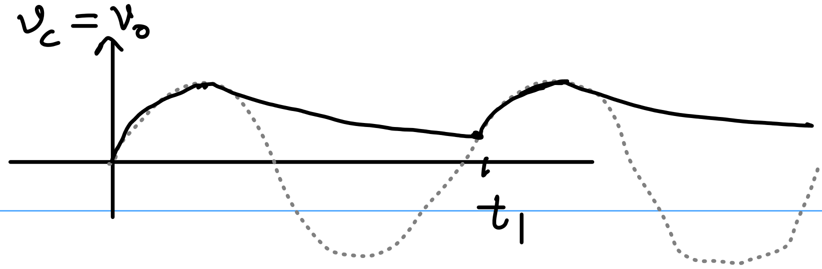
$\boxed{\tau = R_L C}$ → can be designed

so that

$\boxed{R_L C > T}$

time period of i/p

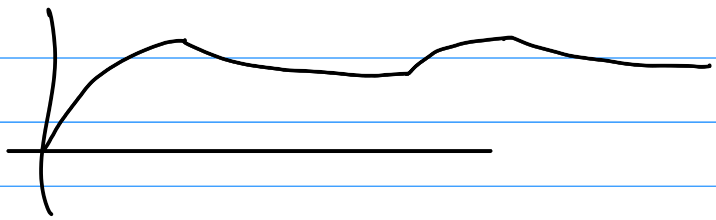
the Cap discharges through R_L 'slowly' as compared to T.



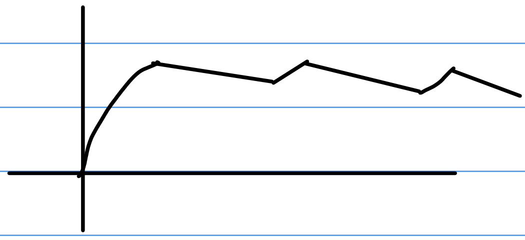
at $t = t_1^+$, $v_i > v_c$

so, $D \to ON$, $\tau \to R_L C \simeq 0$

so cap follows v_i again (quickly)



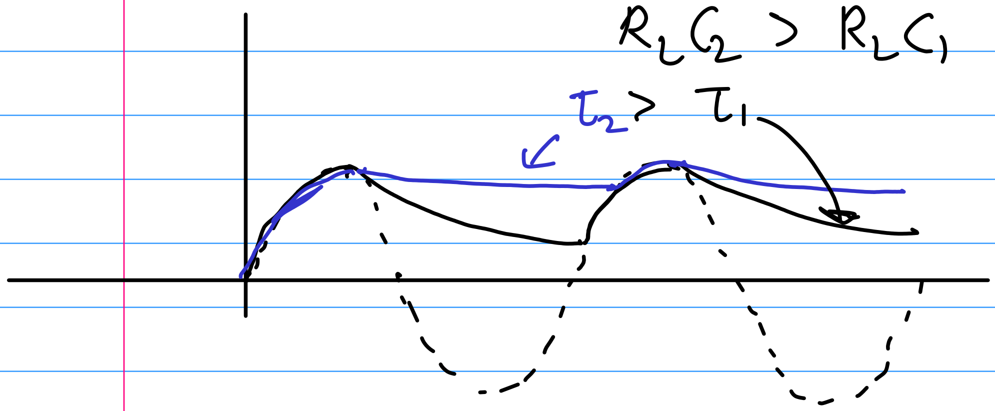
$\equiv$



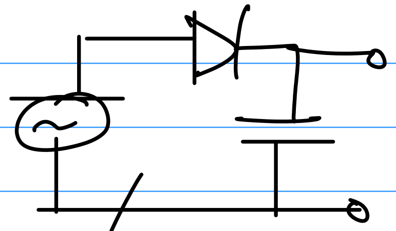
approximation

if $\tau \uparrow$ $(R_L C)$ then discharge time $\uparrow$

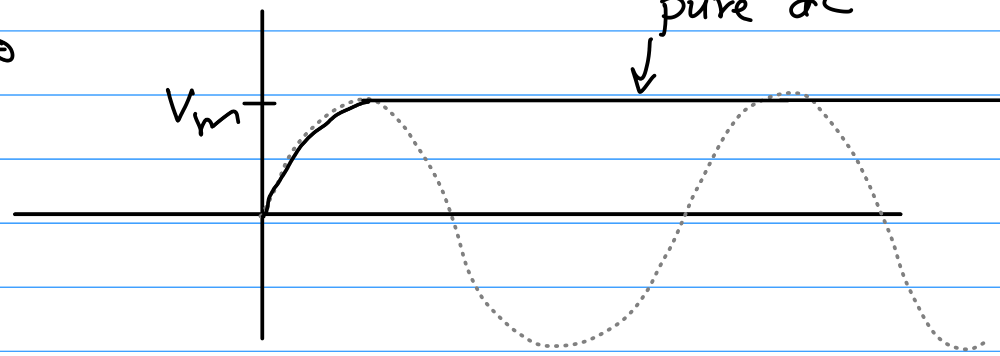
$R_L C_2 > R_L C_1$



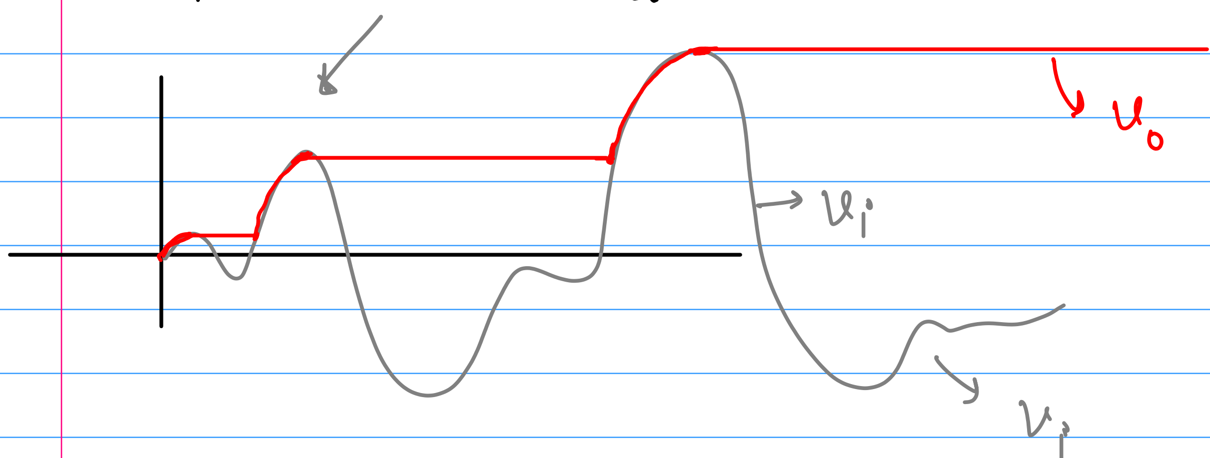
$R_L C \to \infty$ (by using $R_L = \infty$) or O.C.

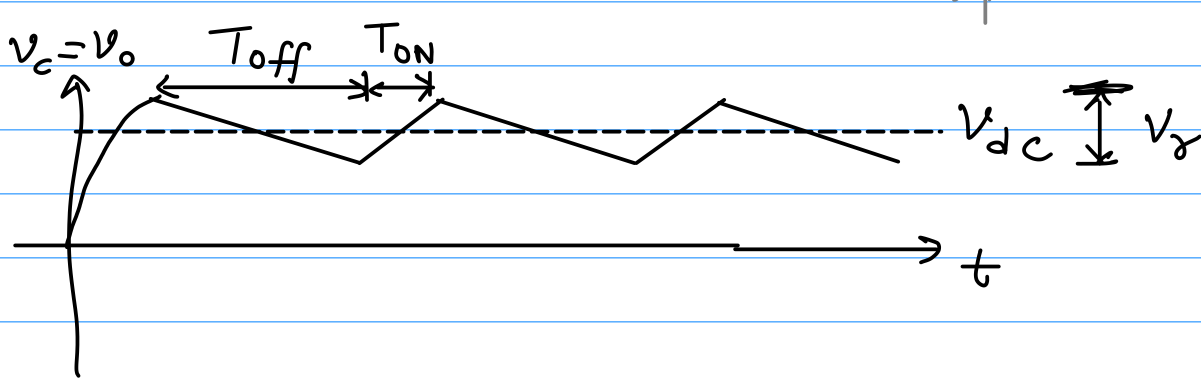


Cap never discharges



" Peak Detector ckt "





$$v_o = v_{dc} + v_r$$

v_r → ac part

$T_{off} \to$ D off

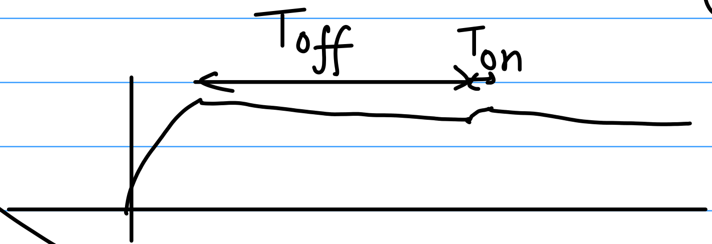
$T_{ON} \Rightarrow D = on$

$T_{off} + T_{ON} = T = \frac{1}{f}$ (time period of i/p)

f → 'i/p freq.'

if $R_L C \gg T$ the cap almost never discharge

(v. little discharge)



→ $T_{off} \gg T_{on}$ So, $\boxed{T_{off} \simeq T}$

$V_r = \Delta V_o =$ change in o/p vol.

$Q = CV$ or $\boxed{\Delta Q = C \Delta V}$

$\Delta Q = \frac{I_{dc}}{f}$ & $\Delta V = V_r$

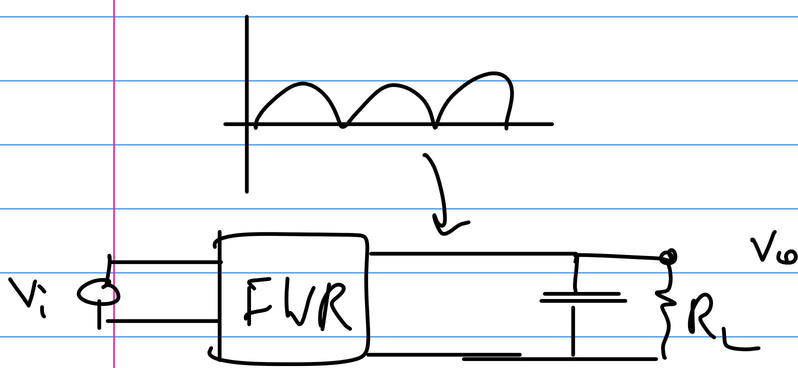
So, $\boxed{V_r \cong \frac{I_{dc}}{fC}}$ * approximation

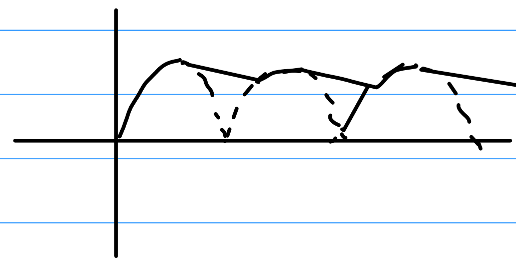
Now $\boxed{V_{dc} \simeq V_m - \frac{V_r}{2}}$

$$\boxed{\gamma = \frac{1}{2\sqrt{3} f R_L C}}$$ for HWR with C-filter

$$\boxed{\gamma \propto \frac{1}{L}}$$ $\gamma \propto \frac{1}{R_L C}$

for FWR with C-filter —





$$\boxed{V_r = \frac{I_{dc}}{2fC}}$$ [2f ∵ FWR o/p has a freq 2f]

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

C - filter

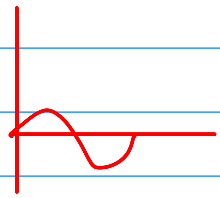
HWR	Centre tapped	Bridge
PIV = $2V_m$ (gets bad)	PIV = $2V_m$ (same)	PIV = V_m (same)

HW

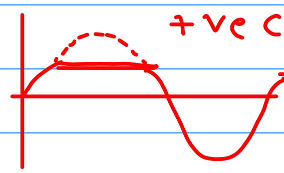
HW → 1) Clipper ckts

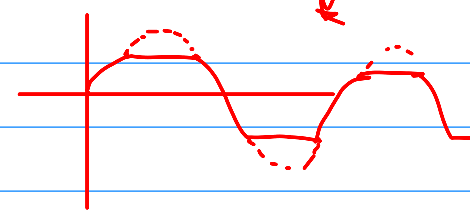
- series
  - +ve
  - −ve
- shunt
  - +ve
  - −ve
- 2 level clipper

KVL & Ohm's law



+ve clipper

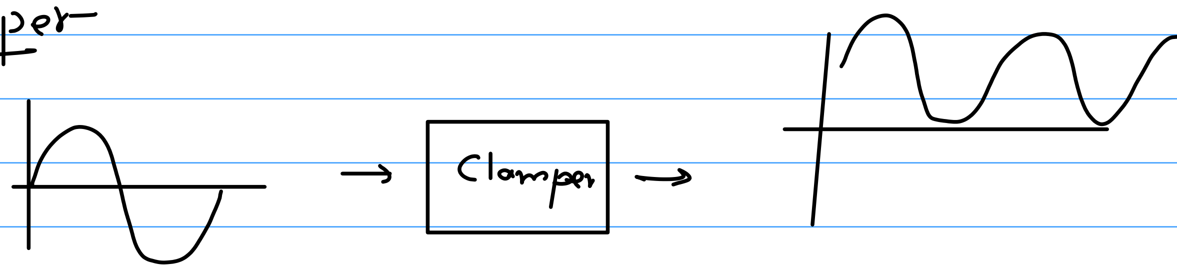




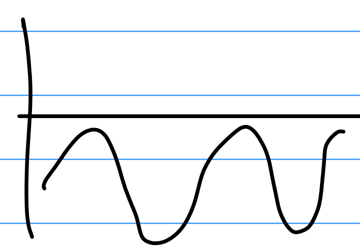
2) Zener diode vol. regulators

Problem from "Sedra & Smith"

→ Clamper

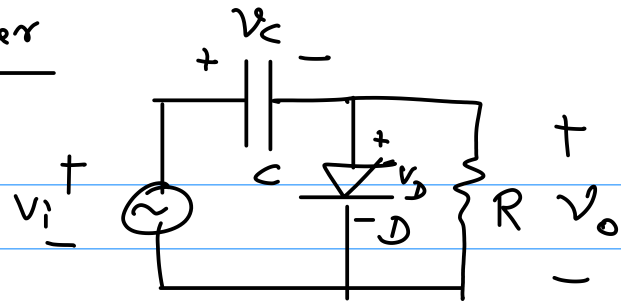


or



{ * Adds or subtracts a dc vol from i/p }

1) <u>-ve clamper</u>

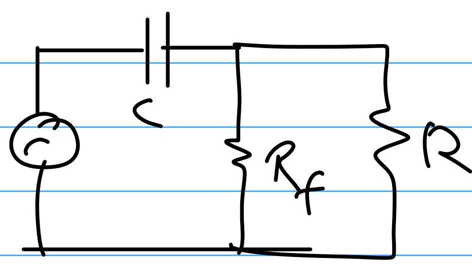


$v_C(t=0^-)=0$

<u>+½ cycle -</u>

$v_i - \cancel{v_C}^{\,0} = v_D = v_o$ (KVL)

$v_i = v_D = +ve$ <u>'D = ON'</u>



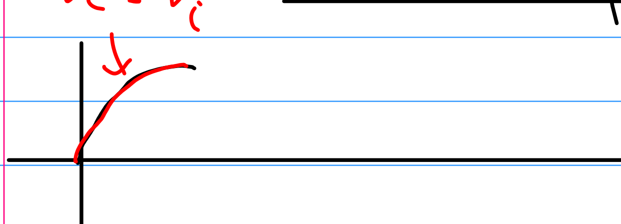
($V_{cut-in} = 0$)

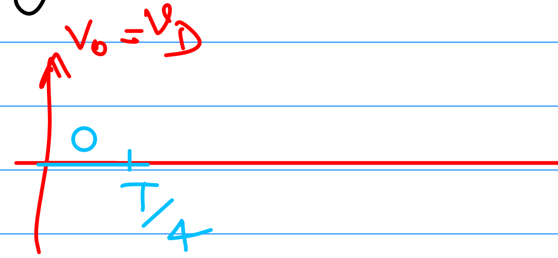
time constant $\boxed{\tau = R_f C}$ $\because R_f \ll R$

small τ so, cap charges quickly to follow v_i

→ $v_D \simeq 0$ (S.C. D = ON)

$\boxed{v_i = v_c}$ (by KVL)





for $t > \frac{T}{4} \rightarrow$ at $t = T/4$, $\boxed{v_c = v_i = V_m}$

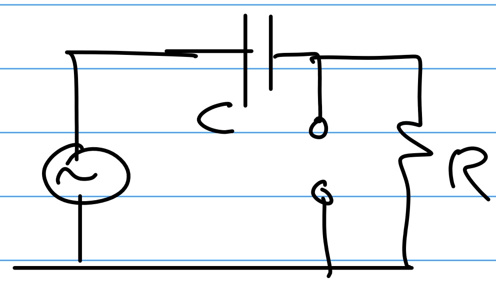
for $t > \frac{T}{4}$ (or $t = \frac{T}{4}^{+}$),

$v_i < V_m$ $\quad v_D = v_i - V_c$ (from KVL)

$= -ve$

$D = R.B. = \text{off}$

So, $\tau = RC$



Let $RC >> T$

then C doesn't discharge

$v_c = v_m$ (constant)

$v_o = v_D = v_i - v_c$

$$\boxed{v_o = v_i - V_m}$$

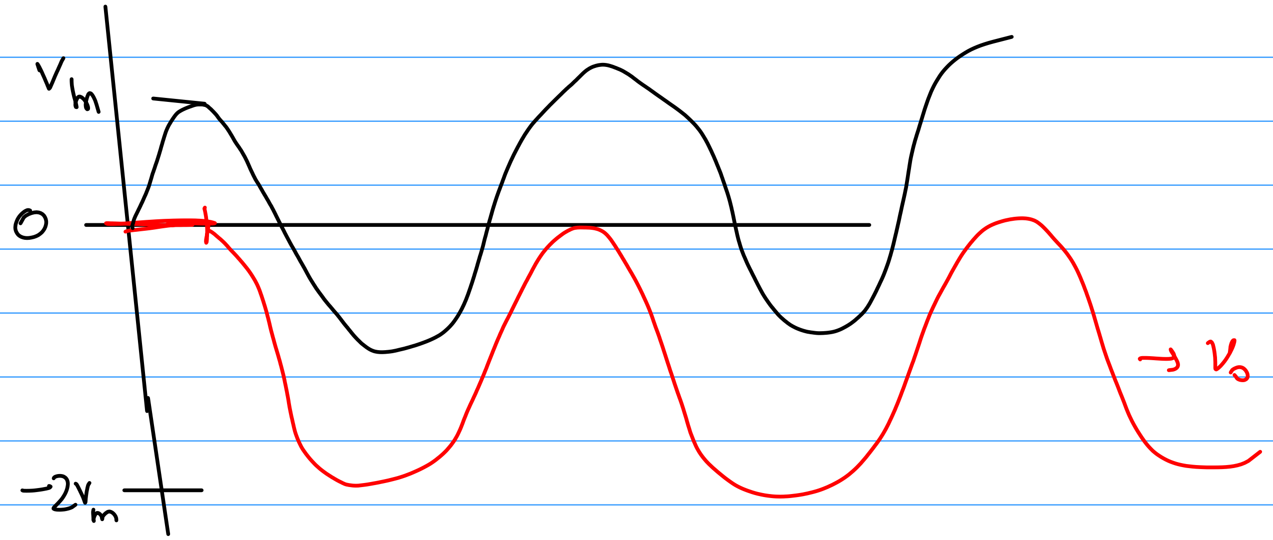
if $v_i = 0$ $\quad v_o = -V_m$

if $v_i = -V_m$ $\quad v_o = -V_m - V_m = -2V_m$

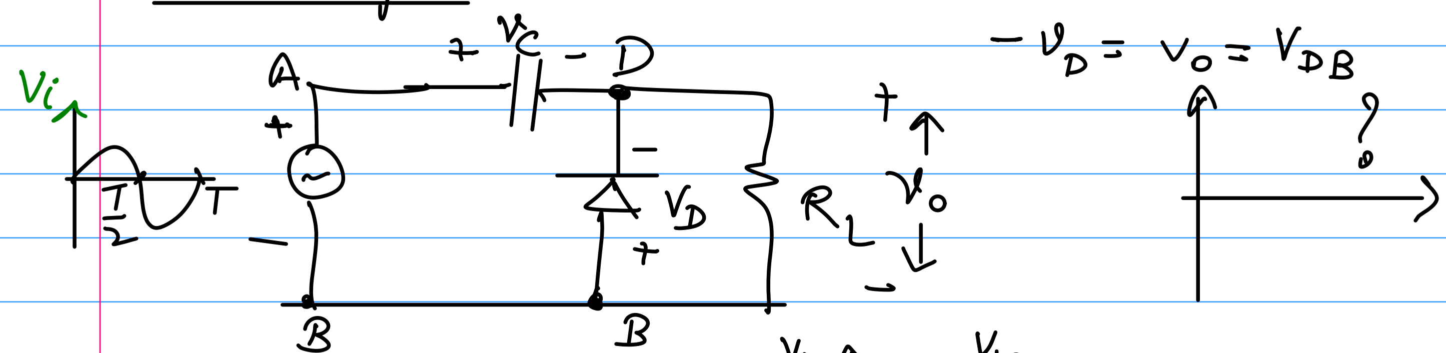
if $v_i = +V_m$, $\quad v_o = V_m - V_m = 0$

Diode vol

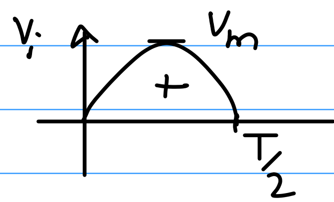
"(for $t > T/4$, Diode Never turns ON again)"



(ii) <u>+ve clamper</u> —



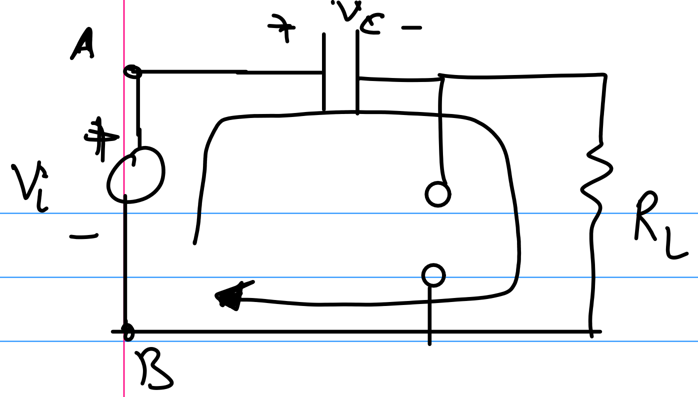
<u>$+\frac{1}{2}$ cycle, $0 < t < \frac{T}{2}$</u> $\to$



<u>Assumption</u> — $\underline{V_c(t=0) = 0 = V_{AD}}$

$+v_i - \cancel{V_c} + V_D = 0$
(+ve) $\quad V_c \to 0$ (initially, $t=0$)

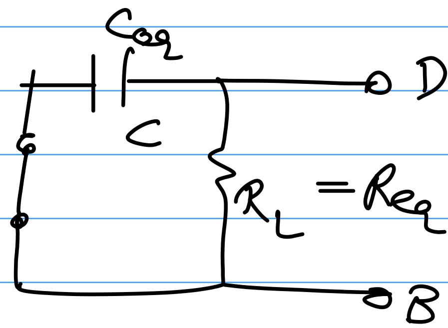
$\Rightarrow v_D = -v_i = -ve$
$\downarrow$
<u>R.B.</u> $\quad (t \sim 0^+)$



V_B = lowest pot in the ckt

($+\frac{1}{2}$ cycle)

$\tau = R_L C$



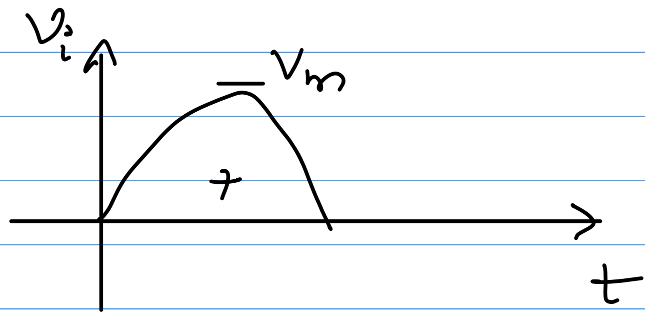
if $\underline{R_L C >> T}$ (which usually is the case)

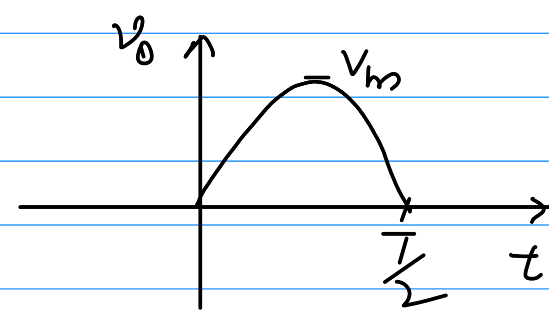
So, cap. charges v.v. slowly as comp. to 'T'.

So, during $+\frac{1}{2}$ cycle, we can assume that C doesn't charge, $v_c = 0$ $(0 \leq t \leq \frac{T}{2})$

By $\underline{KVL \rightarrow}$ $v_i - \underbrace{v_c}_{0} - v_o = 0$

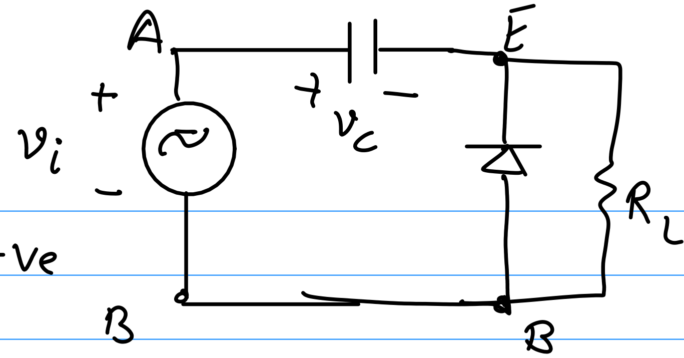
$\Rightarrow v_o = v_i$ (for $0 \leq t \leq \frac{T}{2}$)





$\left\{ \begin{array}{l} * \text{ Diode} = RB. \\ * \ C = \text{doesn't charge} \end{array} \right\}$

— ½ cycle —



$v_i = -ve$

$\because$ $v_c \simeq 0$ (at $t = \frac{T}{2}$) ; v_i is the only source

V_B = highest pot. in the ckt ($\because$ $v_i = -ve$)

by KVL, $V_A - \underbrace{V_c}_{\sim 0} = V_E$ (at $t = \frac{T}{2}$)

$V_E \simeq V_A$ $V_D = V_B - V_E = V_B - V_A$

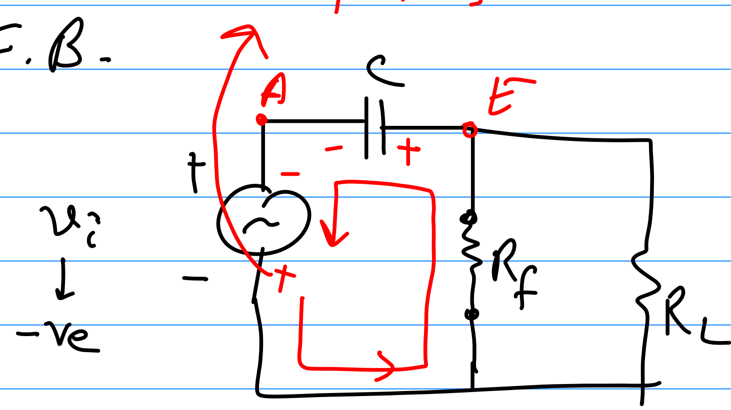
$= -v_i$

$= (+ve)$

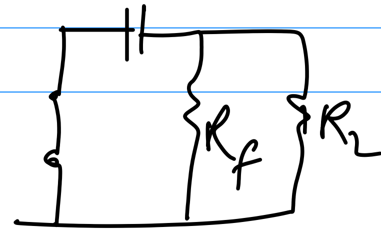
So, D = F.B.

for $t > \frac{T}{2}$ →

real polarities



time constant →



$R_{eq} = R_f \| R_L$

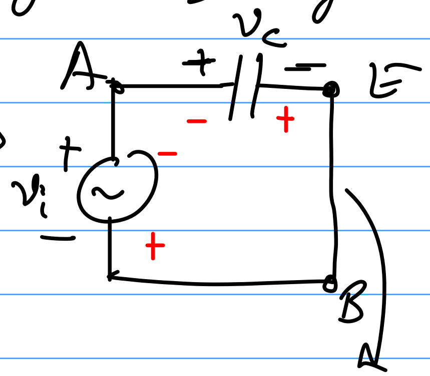
Since $R_f \ll R_L$ So, $R_f \| R_L \simeq R_f$

So, $\tau_{(t > T/2)} \simeq R_f C$ = v.v. small

So, C charges quickly

Red = Real polarities

approximation →



neglected R_f

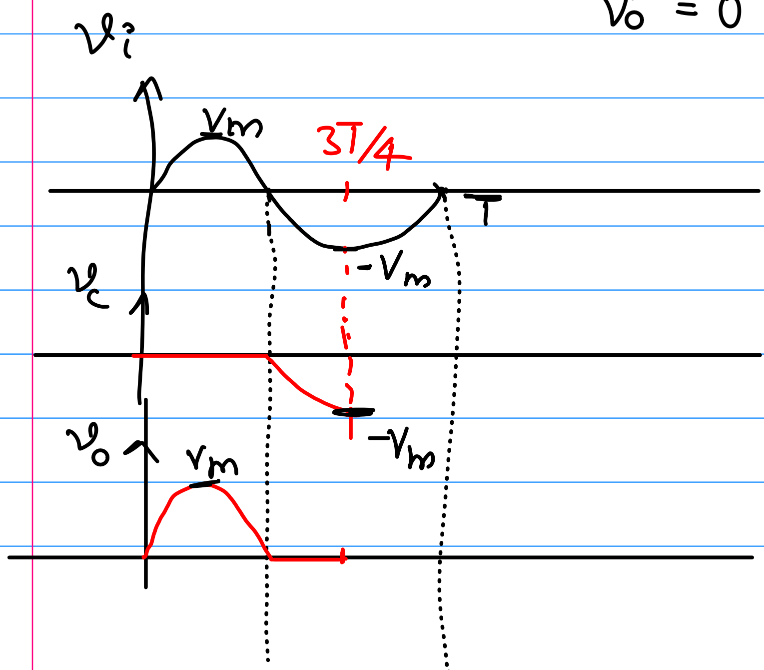
KVL → $v_i - v_c = 0$

$\Rightarrow v_c \simeq v_i = -ve$

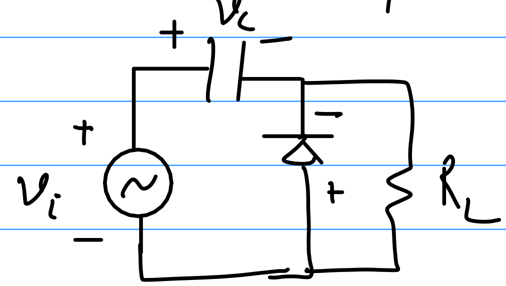
$v_{EB} = v_o \simeq \underline{\underline{0}}$ $\left(\text{for } \frac{T}{2} < t < \frac{3T}{4} \right)$

at $t = \frac{3T}{4}$; $\underline{v_i = -V_m} = v_c$

$v_o = 0$



for $t = \frac{3T}{4}^+$



$v_i - v_c + v_D = 0 \Rightarrow v_D = v_c - v_i$

$v_c = -V_m$ $|v_i| < V_m$

$v_i > -V_m$

$\underline{v_D = -V_m - v_i} = -ve \Rightarrow \underline{\underline{D = R.B}}$

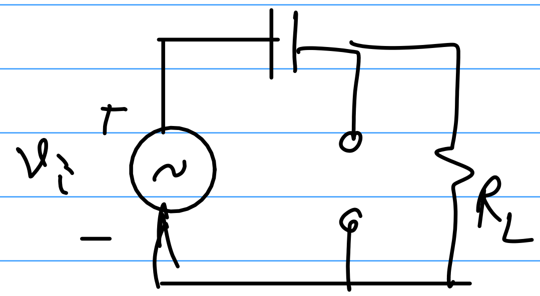
$v_i > -V_m$

Since KVL is valid always,

& $\underline{v_i \geq -V_m}$ always

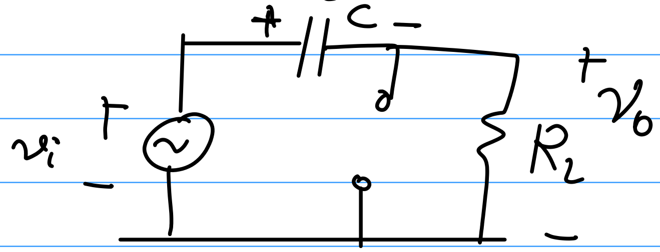
$\tau = \underline{\underline{R_L C}} = \underline{\underline{\text{v. high}}}$

(cap vol. doesn't change)



So, D stays R.B. forever

So, for $\underline{t > \frac{3T}{4} \quad \& \quad t < \infty} \rightarrow$



$R_L C >> T$

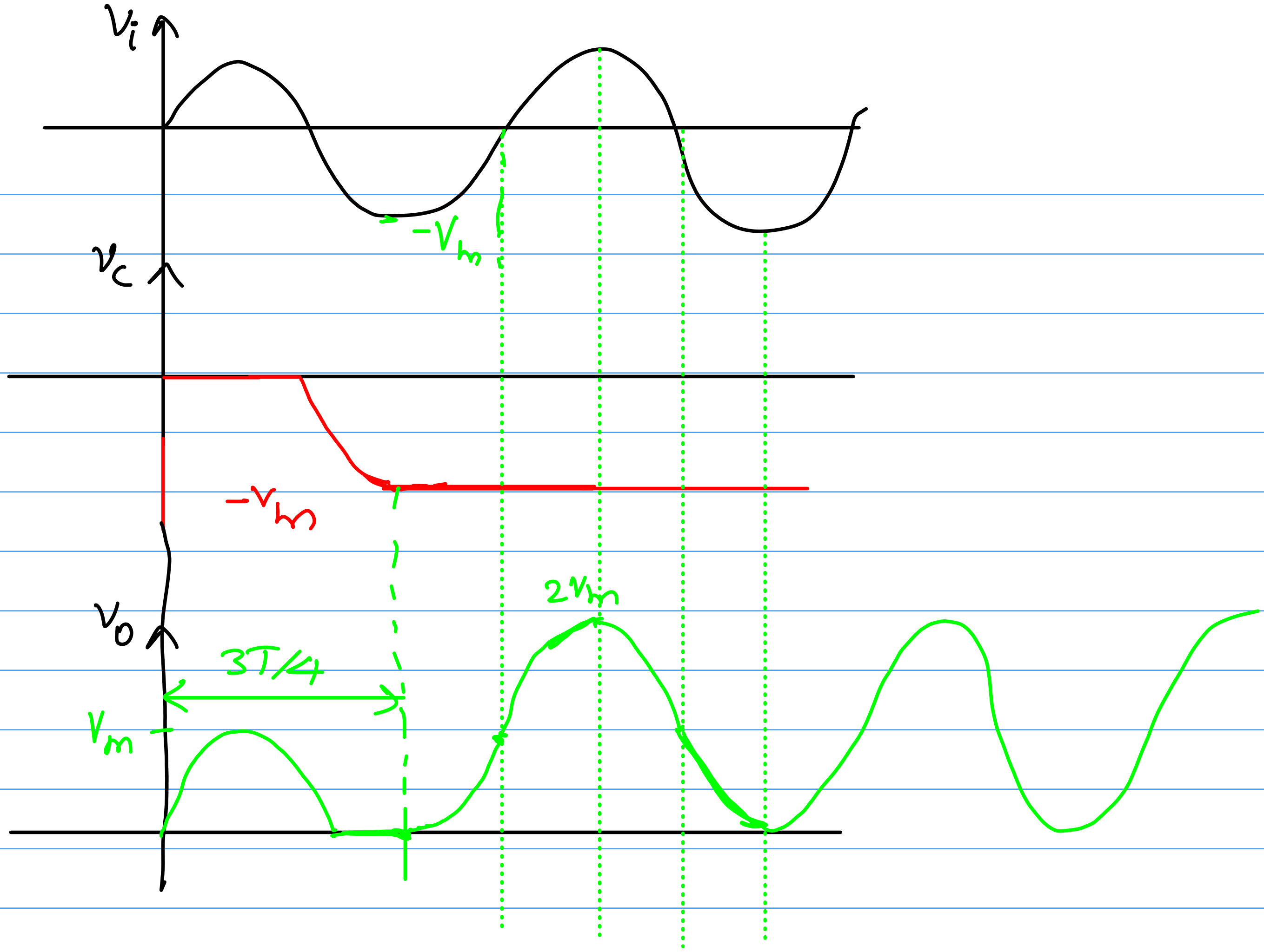
So, $v_c = -V_m$ (always)

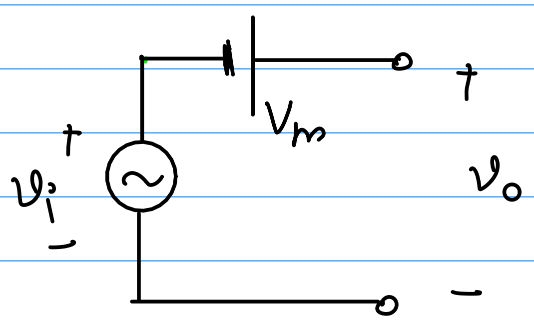
& $v_o = v_i - v_c$ (by KVL)

$v_o = v_i - (-V_m)$

$$\Rightarrow \boxed{v_o = v_i + V_m} \; * \quad \text{for } \frac{3T}{4} < t < \infty$$

Shiram 427

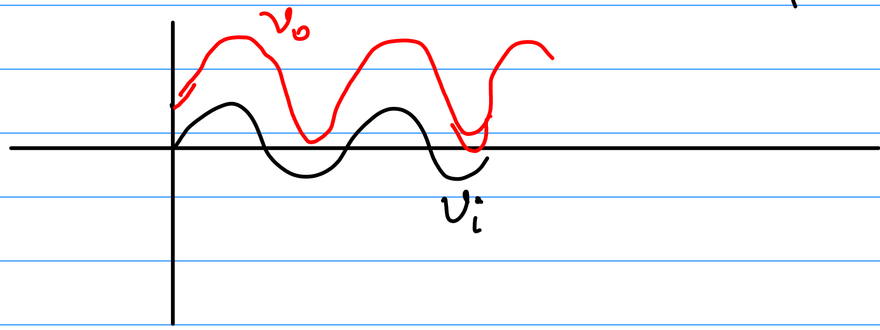




KVL →

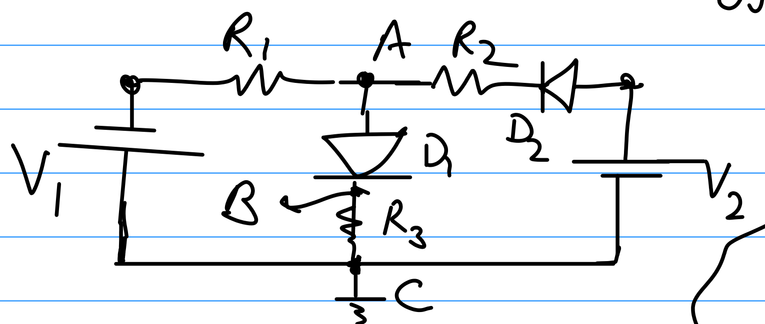
$$v_i + v_m - v_o = 0$$

$$\Rightarrow \boxed{v_o = v_i + V_m}$$



tips - (Diode ckts)

(i) When in doubt, Assume all diodes to be off (R.B)



$V_{AB} = V_{D_1} = +ve$

$V_A > V_B$

(can D_1 be off)

(ii) Name all the nodes

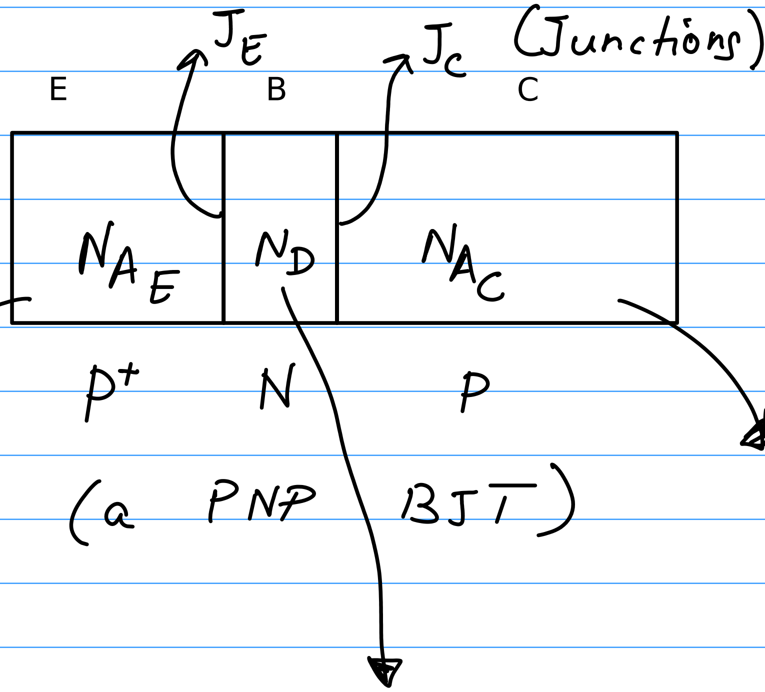
(iii) use KVL → to find Diode vol.

if $v_{D1} = +ve$ → D_1 assumption wrong (D_1 is ON)

$v_{D_2} = -ve$ → D_2 assumption is right (D_2 → off)

(iv) finally re-analyse the ckt (again find all the vol.) now with the correct diode states (on or off)

Bipolar Junction transistor



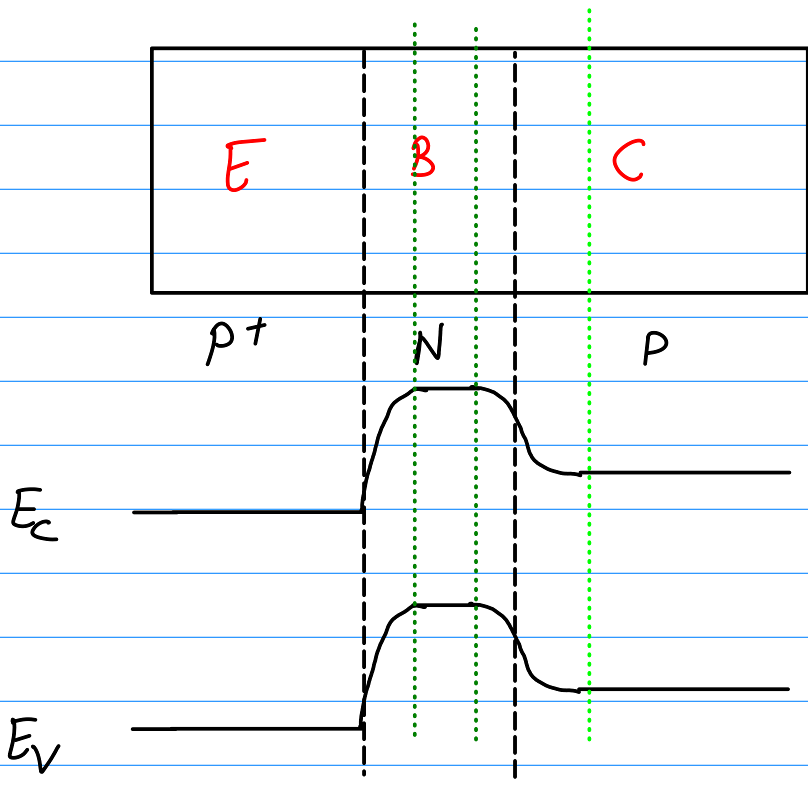
Dopings –
$N_{A_E} > N_D > N_{A_C}$

Area
$C > E > B$

(Source of Charge carriers)

(Sink)

Electrical Isolation Between E & C



MODES OF OPERATION

	Mode	J_E	J_C	APPLICATION
1)	Forward Active	F.B.	R.C.	Amplification
2)	Saturation	F.B.	F.B.	Switching (Digital - ON/OFF 1/0)
3)	Cut-off	R.B.	R.B.	Switching (Digital - ON/OFF 1/0)
4)	Reverse Active	R.B.	F.B.	Rarely used for Amp.

OPERATION (ACTIVE MODE)