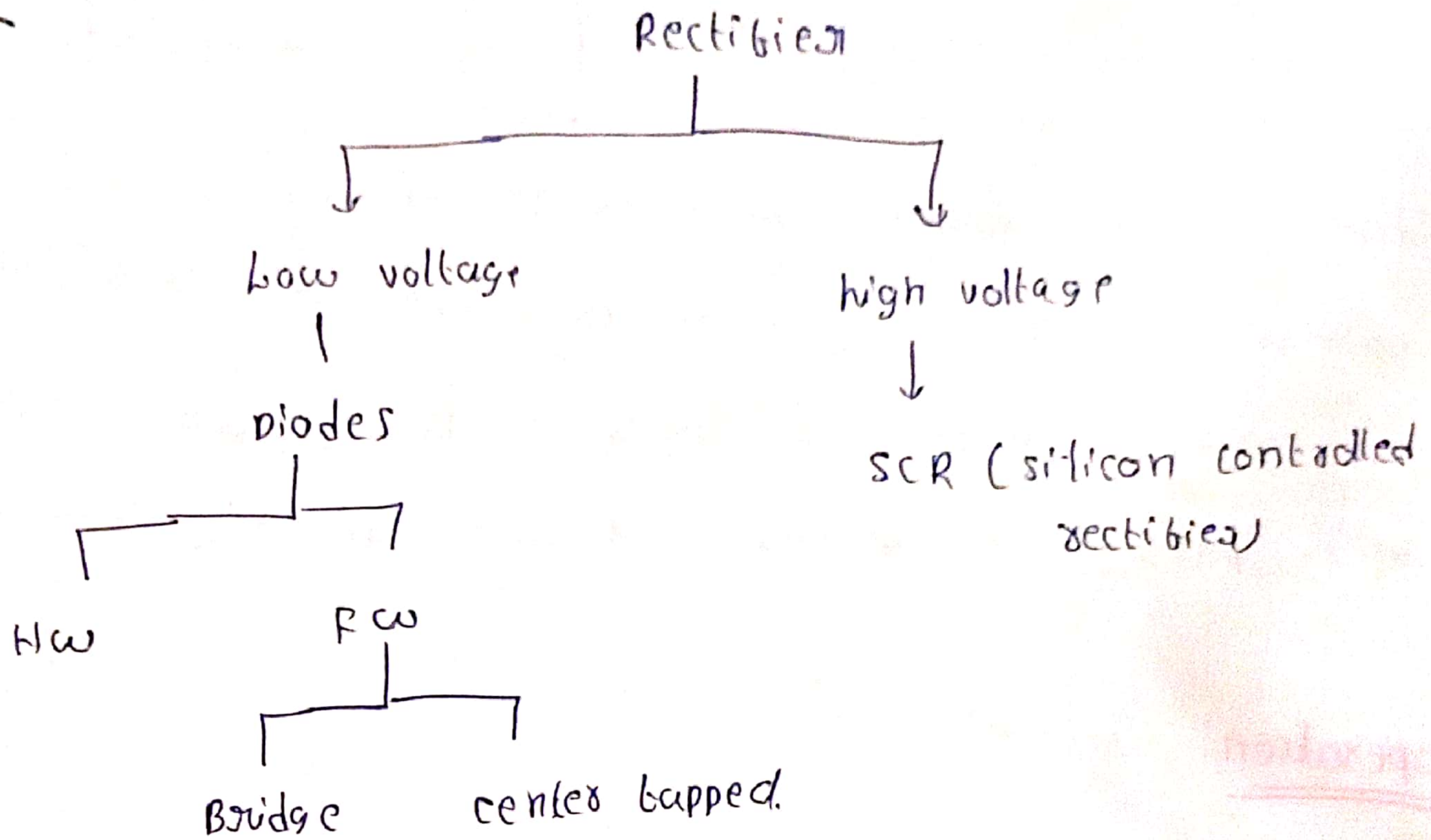


RECTIFIERS

P. Siva Bharthi (1)
Asst. prof (ECE)

A circuit which convert pure A.C signal into pulsating D.C.

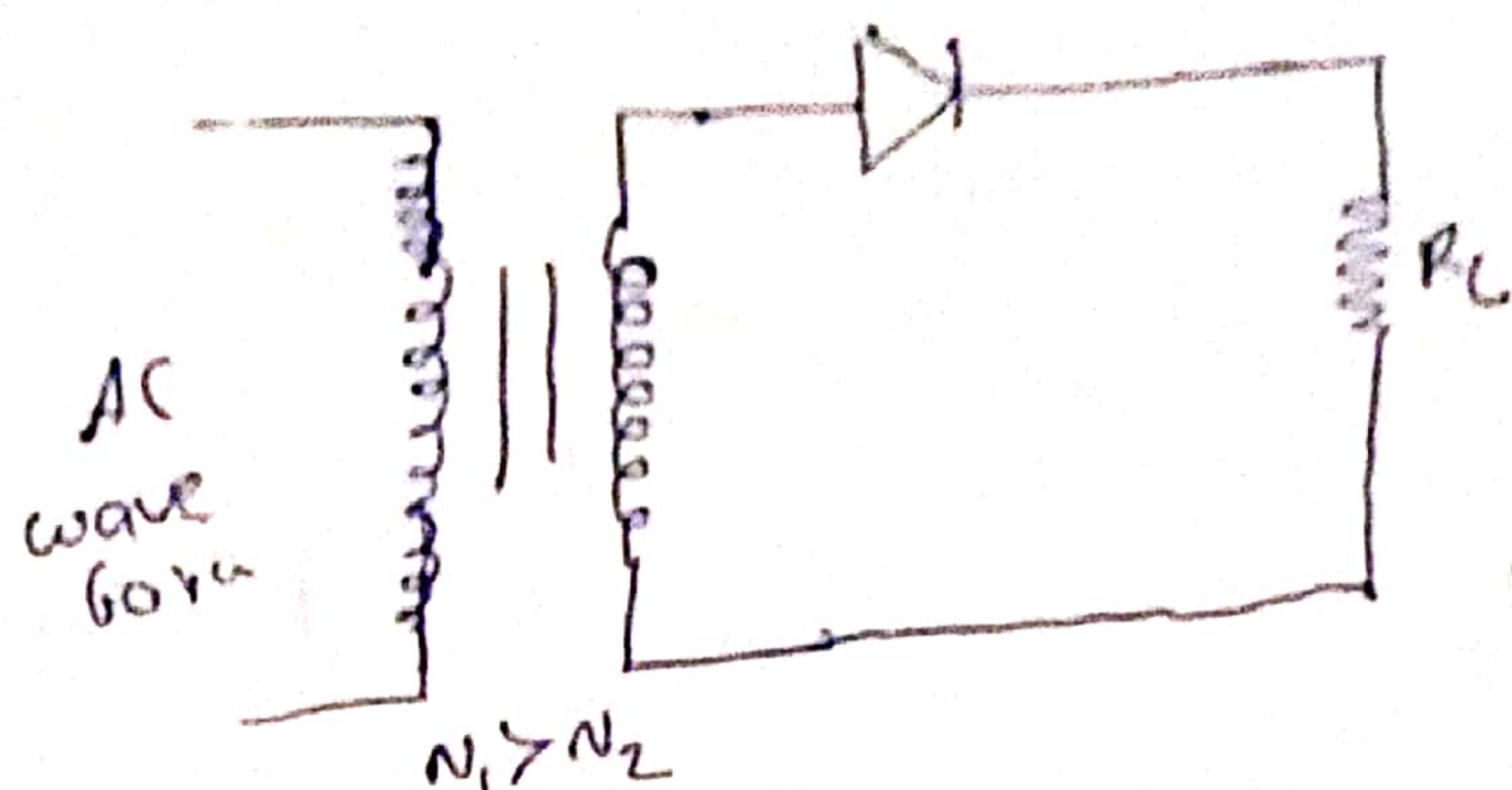


In low voltage rectifiers stepdown transformer is used which reduces the strength of A.C signal.

stepdown transformer is necessary becoz.

- 1) To obtain low DC voltage from rectifier.
- 2) To protect the diode which has smaller break down voltage.

Half wave rectifier:

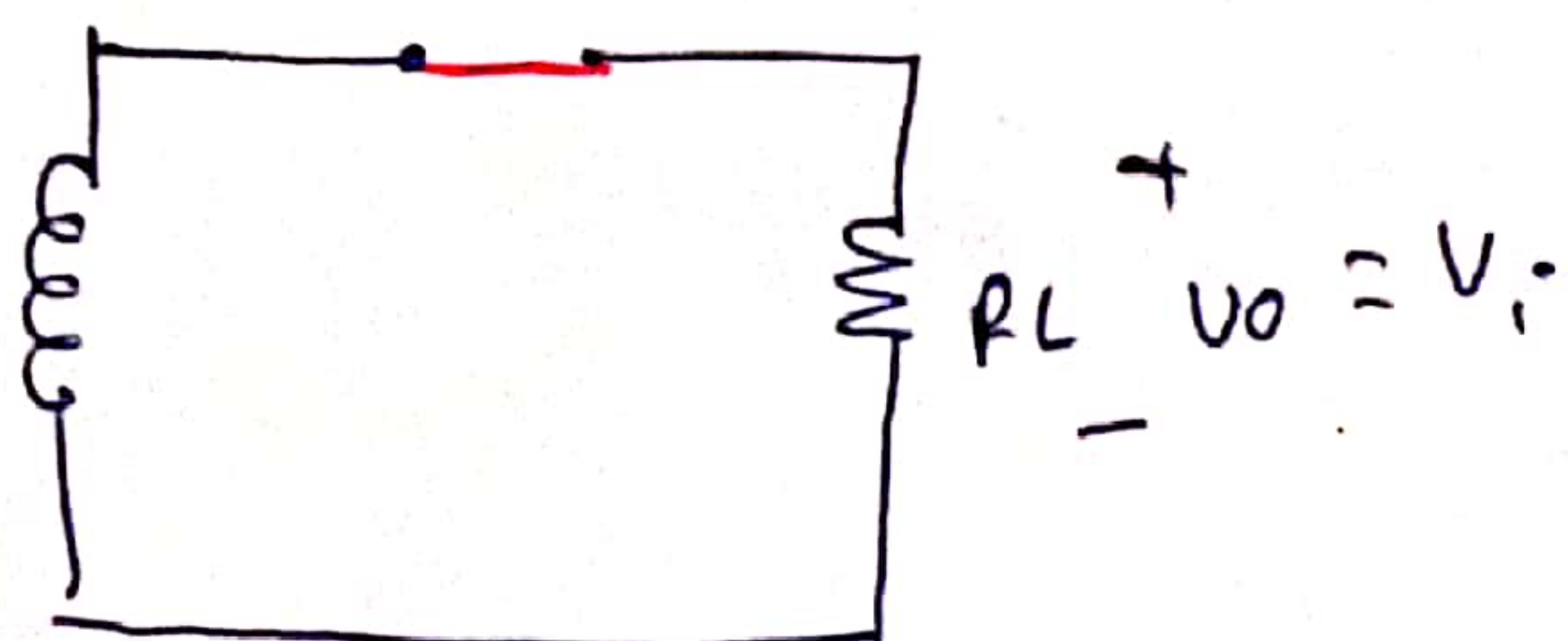


- stepdown transformer has greater no. of turns in primary windings greater than the secondary windings
- It converts pure AC voltage having large RMS value into pure A.C. voltage having smaller RMS value

operation:

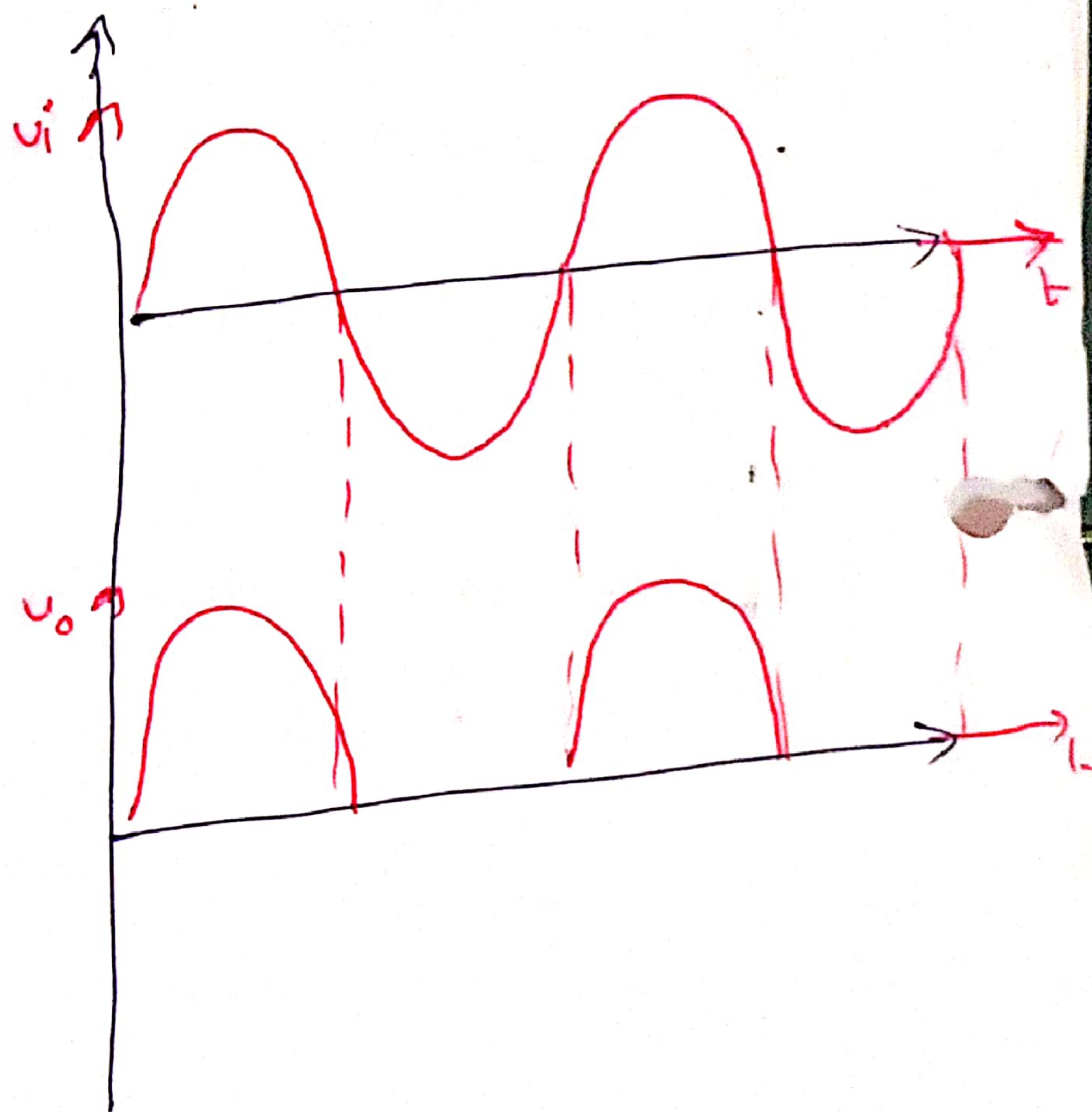
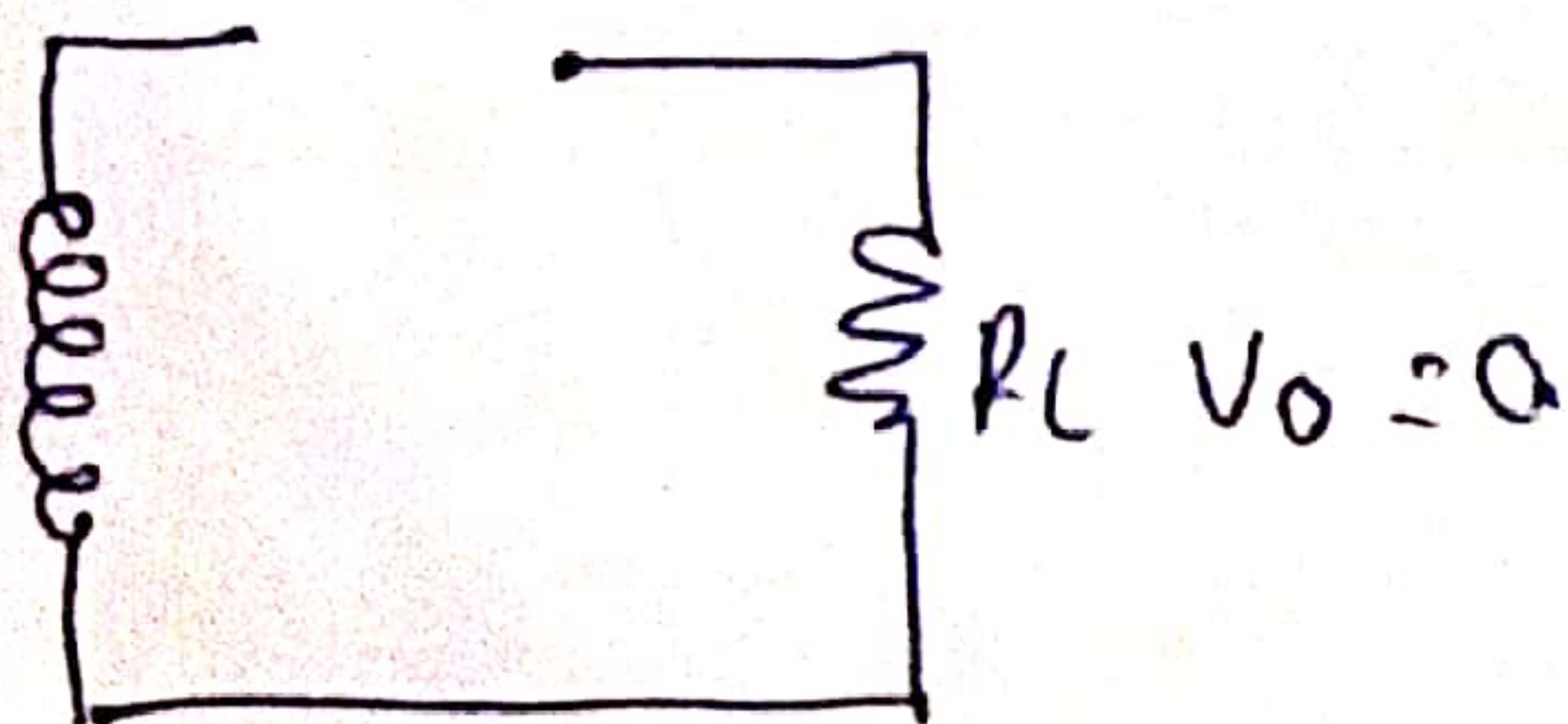
case ①: v_i is +ve ($0 < \alpha < \pi$)

Diode operates in F.B. = s/c.



case 2: v_i is -ve ($\pi < \alpha < 2\pi$)

Diode operates in R.B. = o/c.



- I/p voltage full appears across the diode which is acting as open circuit. hence voltage across resistor is zero

Analysis of half wave rectifier!

1) instantaneous o/p current (i)

$0 < \alpha < \pi$: diode is in F.B $\rightarrow$ resistance $\rightarrow R_F$

$$V_i = i(R_F + R_L)$$

$$i = \frac{V_i}{R_F + R_L} = \frac{V_m \sin \alpha}{R_F + R_L}$$

$$\therefore i = I_m \sin \alpha, \text{ where } I_m = \frac{V_m}{R_F + R_L} //$$

$\pi < \alpha < 2\pi$:

Diode is in R.B = o/c $\Rightarrow i = 0 //$

$\rightarrow$ Reverse current is in nano amps for silicon diode and
micro amps for Ge diode.

$\rightarrow$ silicon diode is preferred in rectified ckt because it
has much smaller reverse current

$$\therefore i = \begin{cases} I_m \sin \alpha ; & 0 < \alpha < \pi \\ = 0 ; & \pi < \alpha < 2\pi \end{cases} \rightarrow \text{instantaneous o/p current}$$

2) DC o/p current!

$$I_{DC} = I_{avg} = \text{avg value of 'i'}$$

$$= \frac{1}{T} \int_0^T i \cdot dt$$

$$= \frac{1}{2\pi} \int_0^{2\pi} i(\alpha) \cdot d\alpha$$

$$= \frac{1}{2\pi} \left[\int_0^{\pi} I_m \sin \alpha \cdot d\alpha + \int_{\pi}^{2\pi} 0 \cdot d\alpha \right]$$

$$= \frac{1}{2\pi} \left[-I_m \cos \alpha \right]_0^{\pi}$$

$$= \frac{1}{2\pi} \left[-I_m \cos \pi + I_m \cos 0 \right]$$

I_{rms} : rms value of i

(3)

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

$$\therefore I_{DC} = I_{avg} = \frac{I_m}{\pi}$$

RMS o/p current: (I_{rms})

$$I_{rms} = \sqrt{\frac{1}{T} \int_0^T i^2 dt}$$

$$= \sqrt{\frac{1}{2\pi} \int_0^{2\pi} (I_m \sin \alpha)^2 d\alpha}$$

$$= \sqrt{\frac{1}{2\pi} I_m^2 \int_0^{2\pi} \sin^2 \alpha d\alpha}$$

$$= \sqrt{\frac{I_m^2}{2\pi} \int_0^{2\pi} \left(\frac{1 - \cos 2\alpha}{2} \right) d\alpha}$$

$$= \sqrt{\frac{I_m^2}{4\pi} \left(\alpha - \frac{\sin 2\alpha}{2} \right)_0^{2\pi}}$$

$$= \sqrt{\frac{I_m^2}{4\pi} \cdot \pi} = \frac{I_m}{2}$$

$$\therefore I_{rms} = \frac{I_m}{2}$$

RMS AC o/p current:

pulsating DC o/p current of a rectifier is a combination of DC & AC o/p currents

i.e. i : DC component + AC component

$$i = I_{DC} + i'$$

$$i' = i - I_{DC} = \text{AC o/p current}$$

I_{rms} : rms value of i

I'_{rms} : rms value of A.C. current

$$I'_{rms} = \sqrt{\frac{1}{2\pi} \int_0^{2\pi} i'^2 d\alpha}$$

$$= \sqrt{\frac{1}{2\pi} \int_0^{2\pi} (i - I_{DC})^2 d\alpha}$$

$$I'^2_{rms} = \frac{1}{2\pi} \int_0^{2\pi} (i^2 + I_{DC}^2 - 2iI_{DC}) d\alpha$$

$$I'^2_{rms} = \frac{1}{2\pi} \left[\int_0^{2\pi} i^2 d\alpha + I_{DC}^2 \int_0^{2\pi} d\alpha - 2I_{DC} \int_0^{2\pi} i d\alpha \right]$$

$$= \frac{1}{2\pi} \int_0^{2\pi} i^2 d\alpha + I_{DC}^2 \cdot \frac{1}{2\pi} \int_0^{2\pi} d\alpha - 2I_{DC} \times \frac{1}{2\pi} \int_0^{2\pi} i d\alpha$$

$$= I_{rms}^2 + I_{DC}^2 - 2I_{DC}^2$$

$$I'^2_{rms} = I_{rms}^2 - I_{DC}^2$$

An AC ammeter connected in series with RL records I'_{rms}

Ripple factor:-

PP

The unwanted AC component present in the o/p of a rectifier is known as "ripple".

Ripple factor is a measure of the amount of AC-component or ripples

Higher ripple factor indicates greater A.C. component

Ripple factor : $\frac{\text{RMS of AC component}}{\text{DC component}}$

$$\gamma = \frac{I'_{rms}}{I_{DC}} \quad \text{or} \quad \frac{V'_{rms}}{V_{DC}}$$

$$\gamma = \frac{I'_{rms}}{I_{DC}} = \frac{\sqrt{I_{rms}^2 - I_{DC}^2}}{I_{DC}}$$

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

$$= \sqrt{\left(\frac{I_{m/2}}{I_{m/\sqrt{2}}}\right)^2 - 1}$$

$$\gamma = 1.21 \%$$

RMS AC component is stronger than DC component in a/p of HWR

6) Input power:-

It is the avg. value of product of instantaneous voltage across secondary windings & instantaneous current through secondary windings.

P_i = avg. value of $V \times i$.

$$P_i = \frac{1}{2\pi} \int_0^{2\pi} v i d\alpha$$

$$= \frac{1}{2\pi} \int_0^{2\pi} i (R_F + R_L) \times i \cdot d\alpha$$

8)

$$P_i = (R_F + R_L) \times \frac{1}{2\pi} \int_0^{2\pi} i^2 d\alpha$$

4

$$P_i = I_{rms}^2 (R_F + R_L)$$

efficiency or rectification ratio PP

It is a measure of the ability of a rectifier to convert I/P power into DC power

$$\eta = \frac{\text{DC o/p power}}{\text{I/P power}}$$

$$= \frac{P_{DC}}{P_i} \times 100$$

$$= \frac{I_{DC}^2 R_L}{I_{rms}^2 (R_F + R_L)} \times 100$$

$$= \frac{\left(\frac{I_m}{\sqrt{2}}\right)^2 (R_L)}{\left(\frac{I_m}{2}\right)^2 (R_F + R_L)} \times 100$$

$$\eta\% = 40.5 \times \frac{R_L}{R_F + R_L}$$

If diode is ideal, i.e., $R_F = 0$, A HWR has a maximum efficiency of 40.5%.

$$59.5\% \text{ of AC will remain in HWR}$$

V_{dc} diode voltage ($V_{diode, dc}$)

It is the Avg value of instantaneous diode voltage.

V_{diode} : Inst. Diode voltage.

$0 < \alpha < \pi$, Diode is in F.B.

$$V_{diode} : I \cdot R_F = 0, \quad (\because R_F \text{ is very small})$$

$\pi < \alpha < 2\pi$, Diode is in R.B.

$$V_{diode} : V_i : V_m \sin \alpha,$$

→ Full r.p voltage appears across the diode because it is acting as o/c.

$$\text{then } V_{diode} : 0, \quad 0 < \alpha < \pi \\ = V_m \sin \alpha, \quad \pi < \alpha < 2\pi.$$

$V_{diode, dc}$ = Avg. value of dc V_{diode}

$$= \frac{1}{2\pi} \int_0^{2\pi} V_{diode} d\alpha$$

$$= \frac{1}{2\pi} \int_{\pi}^{2\pi} V_m \sin \alpha d\alpha$$

$$= \frac{V_m}{2\pi} [-2]$$

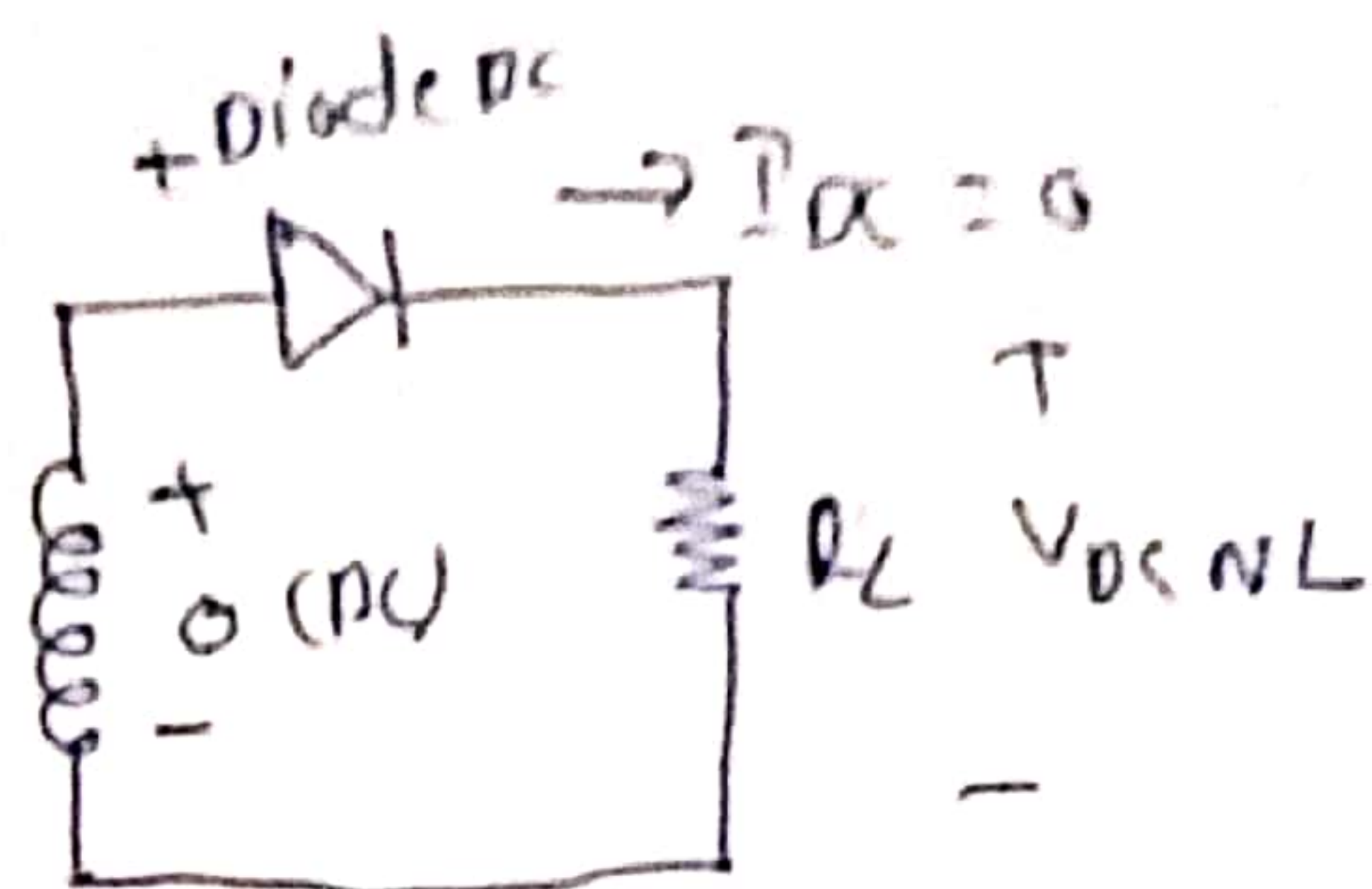
$$= \frac{-V_m}{\pi}.$$

$\therefore V_{diode, dc}$ is recorded by dc voltmeter connected across diode

5) a) No load DC o/p voltage (V_{DCNL})

→ It is the DC o/p voltage of a rectifier when load current I_{DC} is zero.

$$V_{DCNL} = V_{DC} / \text{at } I_{DC} = 0.$$



KVL in loop.

$$-0 + V_{Diode, DC} + V_{DCNL} = 0$$

$$V_{Diode, DC} = -V_{DCNL}$$

$$\therefore V_{DCNL} = \frac{V_m}{\pi}$$

V_{DC} no load represent max DC o/p voltage.

b) Full load DC o/p (V_{DCFL})

→ It is the DC o/p voltage of a rectifier, when load current is not zero.

$$V_{DCFL} = V_{DC} / \text{at } I_{DC} \neq 0.$$

when load current flows, voltage drop occurs secondary windings & across diode.

$$\therefore V_{DCFL} = V_{DCNL} - \text{Internal DC voltage drop}$$

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

when $R = R_s + R_f$

V_{DCFL} can also be calculated as $V_{DCFL} = I_{DC} \cdot R_L$

11) Regulation factor:-

PP

It is a measure of change in o/p voltage due to changes load current

$$\therefore \% \text{ Regulation} = \frac{V_{DCFL} - V_{DCNL}}{V_{DCFL}}$$

$$= \frac{V_{DCNL} - V_{DCFL}}{V_{DCFL}} \times 100$$

$$= \frac{\frac{V_m}{\pi} - \left(\frac{V_m}{\pi} - I_{DC} R_F \right)}{I_{DC} R_L} \times 100$$

$$\therefore \% R = \frac{R_F}{R_L} \times 100.$$

ideally $R \rightarrow$ is zero

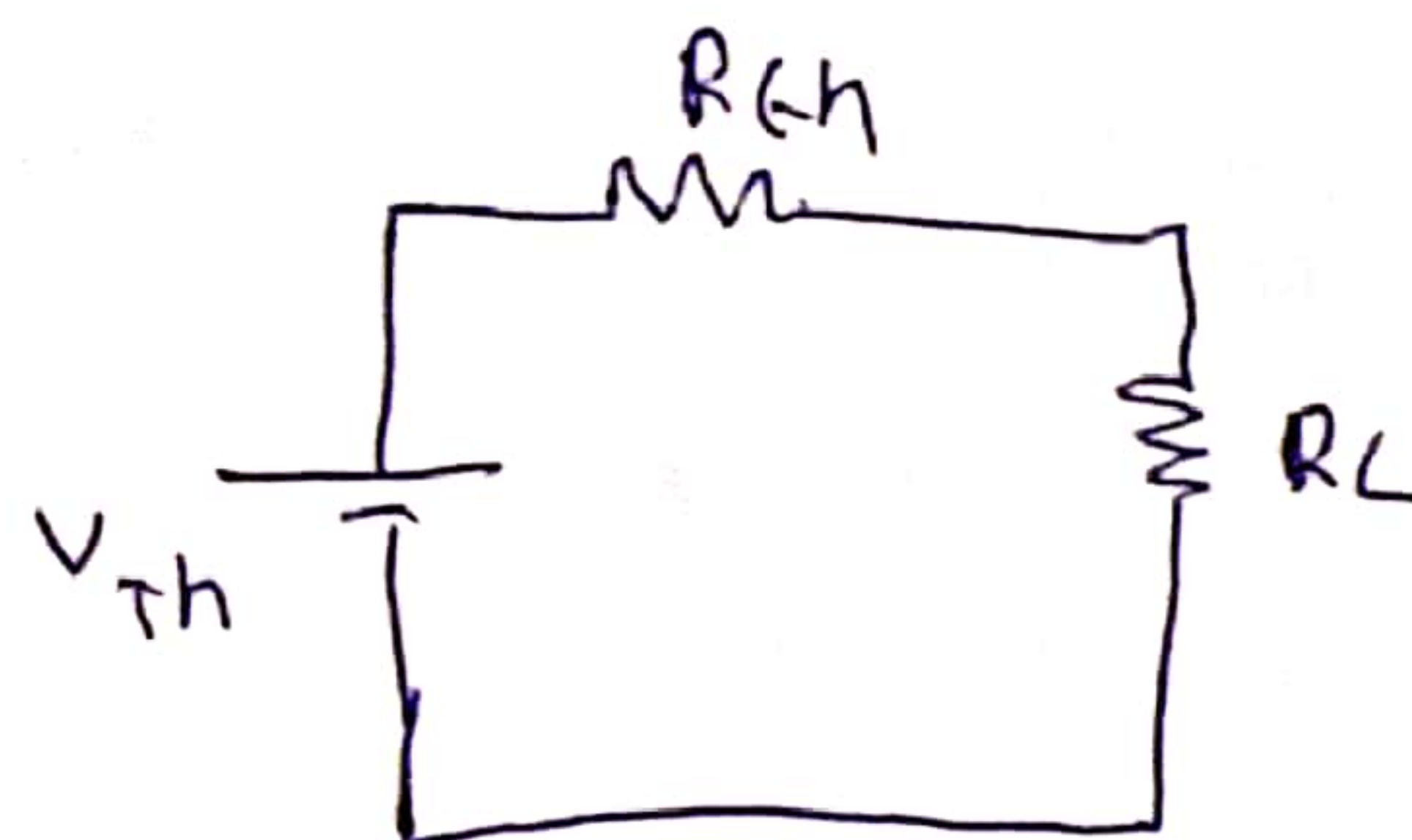
for a power supply ideal regulation factor is 0

12) Thevenins equivalent ckt:-

$$V_{DCFL} = \frac{V_m}{\pi} - I_{DC} R$$

$$\therefore \frac{V_m}{\pi} = V_{Th}$$

$$R = R_{Th}$$



13) Peak inverse voltage:- It is the max voltage which appears across a diode in R.B.

$$PIV = |V_{diode}|_{max} \text{ when diode is R.B.}$$

$$= |V_m \sin \omega t|_{max}$$

$$\boxed{PIV = V_m}$$

for safe operation of diode, PIV must be less than break down voltage of diode.

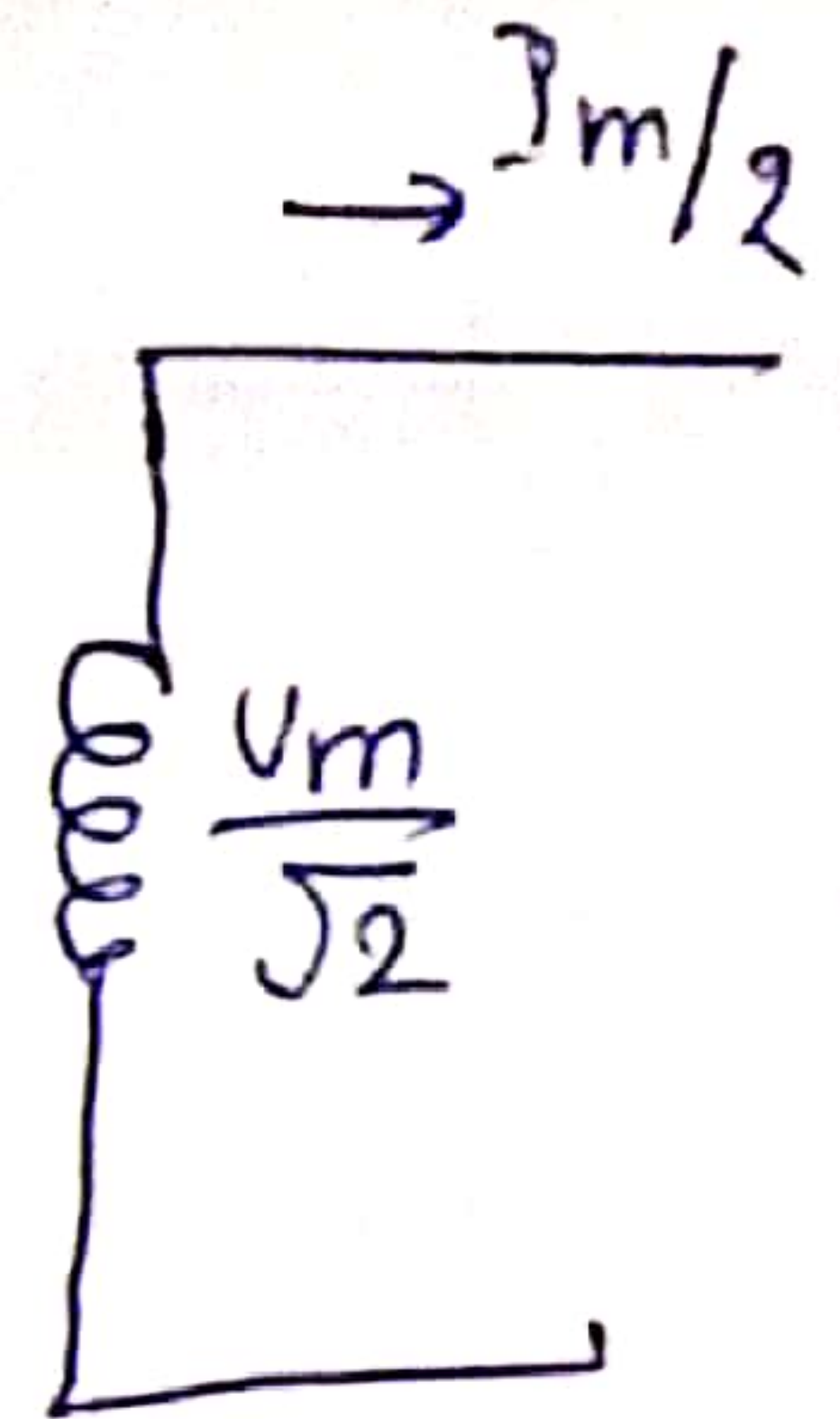
PIV is used in selection of diode in rectifiers.

14) Transformer utilization factor:-

① → It is the ratio of DC o/p power & AC rating of ~~sec~~ secondary winding.

→ AC rating of winding is product of RMS voltage across winding & RMS current through the winding.

$$TUF = \frac{\text{DC o/p power}}{\text{AC rating of secondary winding}}$$



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

$$= \frac{\left(\frac{I_m}{\pi}\right)^2 R_L}{\frac{I_m^2}{2\sqrt{2}} (R_F + R_L)}$$

$$TUF = 0.286 \times \frac{R_L}{R_F + R_L}$$

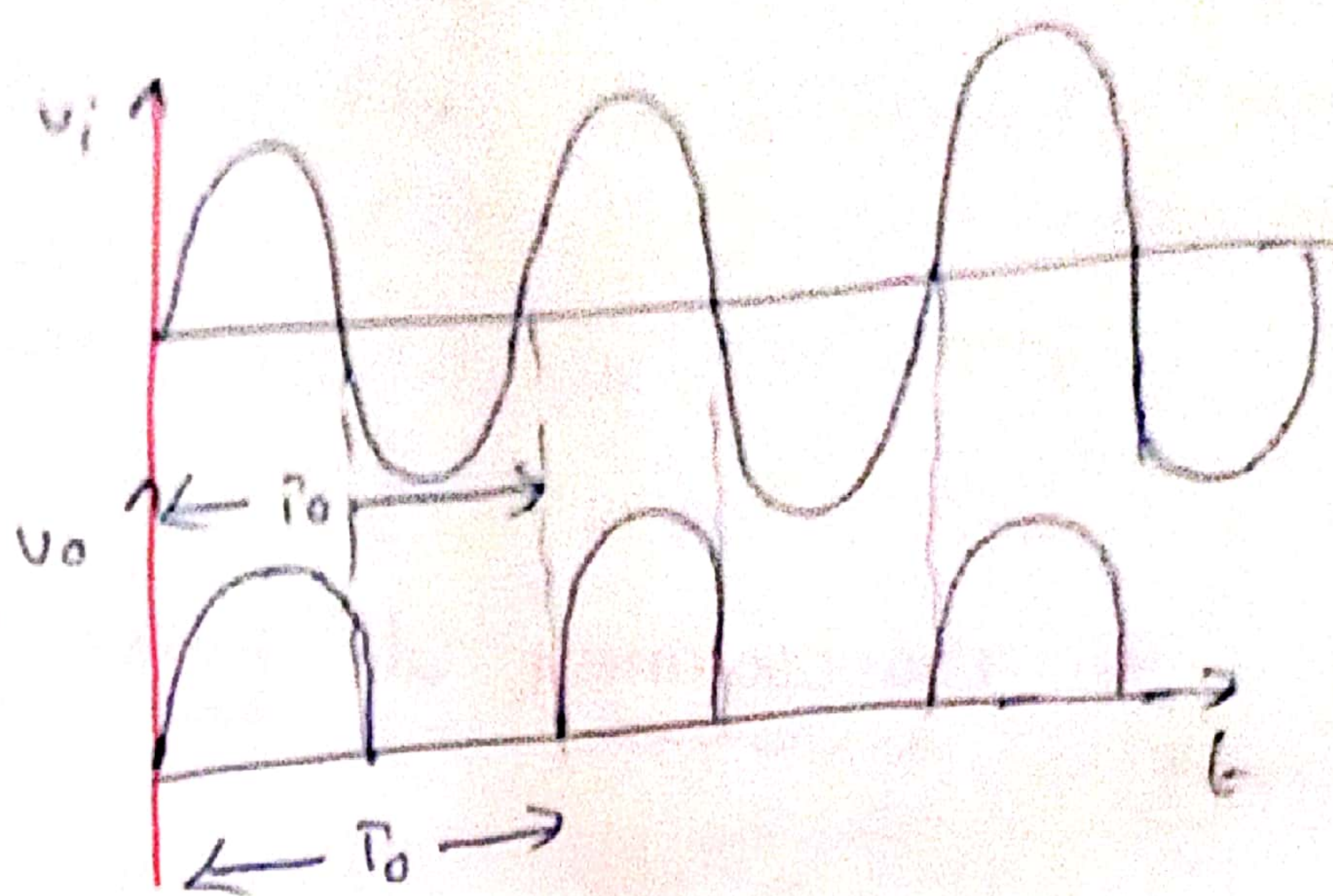
$$\text{max } TUF = 0.286$$

$$P_{DC} = TUF \times \text{AC rating in 2nd winding.}$$

→ Highest the TUF highest the DC power.

in frequency of i/p or ripple frequency.

Since i/p and o/p waveforms has equal time period, their frequency will be equal.



$\therefore$ Ripple frequency = S_o

where $S_o \rightarrow$ is line frequency

As o/p waveform is non sinusoidal, it will consist of harmonic frequencies also. These frequencies can be obtained from trigonometric F.S of V_o

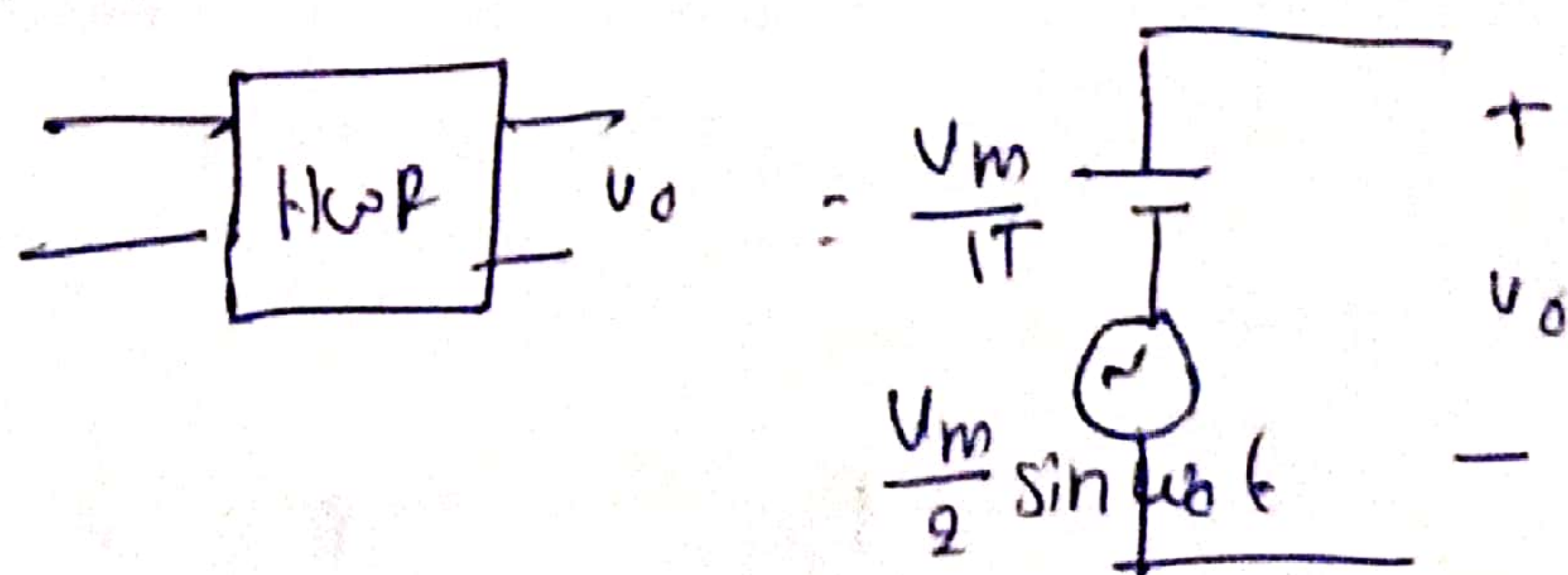
$$\therefore V_o = \underbrace{\frac{V_m}{\pi}}_{\text{DC component}} + \underbrace{\frac{V_m}{2} \sin \omega_o t - \frac{2V_m}{\pi} \sum_{k=\text{even}} \frac{\cos k \omega_o t}{(k+1)(k-1)}}_{\text{AC component}}$$

$\rightarrow$ AC component has fundamental freq. ω_o & even harmonics $2\omega_o, 4\omega_o, \dots$

If higher frequencies are neglected,

$$V_o = \frac{V_m}{\pi} + \frac{V_m}{2} \sin \omega_o t$$

$\rightarrow$ HWR is equivalent to series connect of DC source $\frac{V_m}{\pi}$ & AC source $\frac{V_m}{2} \sin \omega_o t$.



①

Form factor:

$$F = \frac{I_{rms}}{I_{oc}} = \frac{I_m/2}{I_m/\pi}$$

$$= 1.57.$$

→ HWR

peak factor:

$$P = \frac{I_{peak}}{I_{rms}} = \frac{I_m}{I_m/2}$$

$$= 2$$

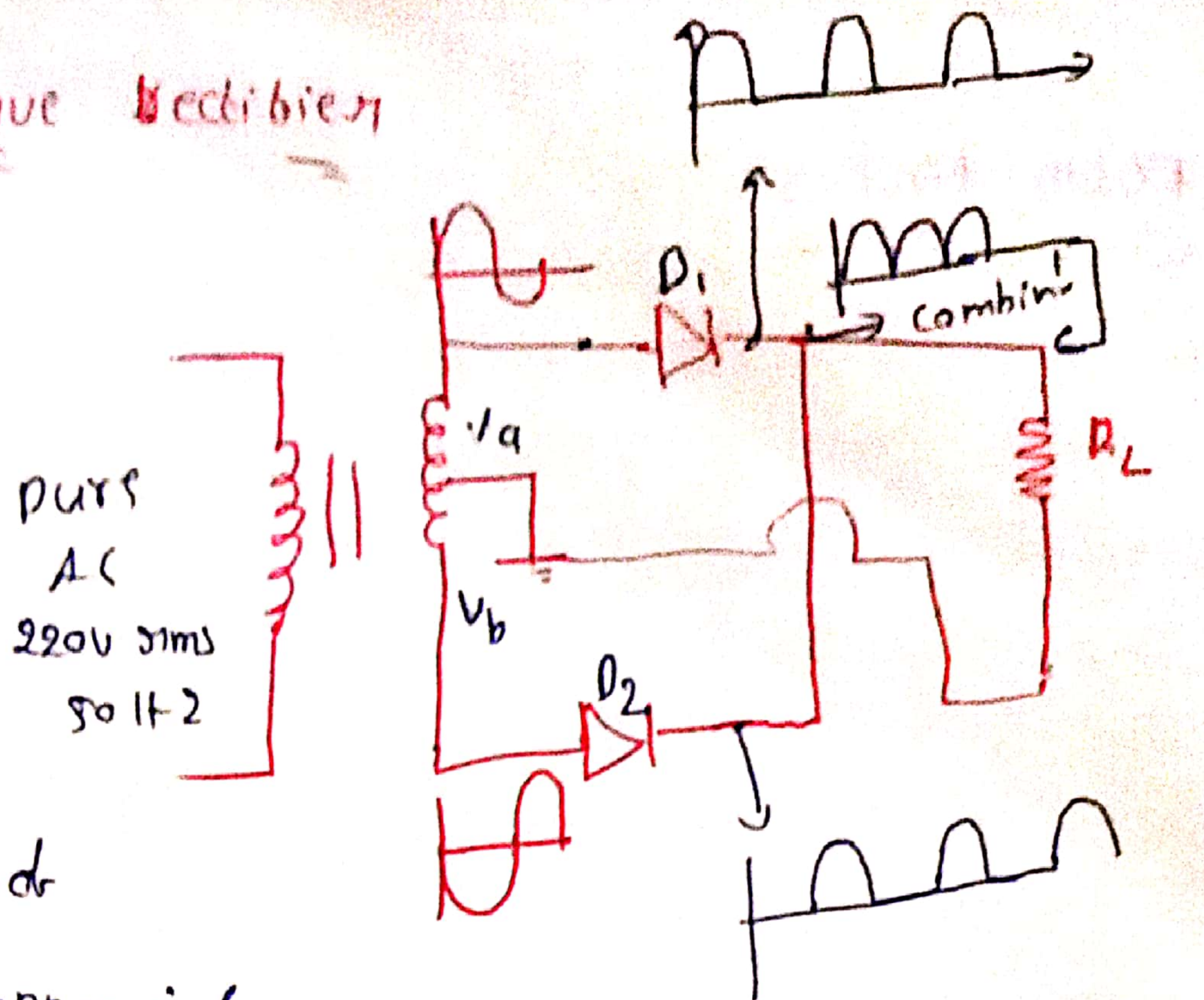
FWF

$$F.F = \frac{I_{rms}}{I_{oc}} = \frac{I_m/\sqrt{2}}{\frac{2I_m}{\pi}}$$

$$= \frac{\pi}{2\sqrt{2}} = 1.11$$

$$P.F = \frac{I_{peak}}{I_{rms}} = \frac{I_m}{I_m/\sqrt{2}} = 1.414.$$

center-tapped full wave rectifier



Secondary winding of

Transformer center-tapped i.e.

Secondary winding is divided into two halves each half has N_2 turns.

→ If center terminal is grounded. Then instantaneous voltages at nodes a & b equal in magnitude & opposite in sign i.e. $V_a = -V_b$.

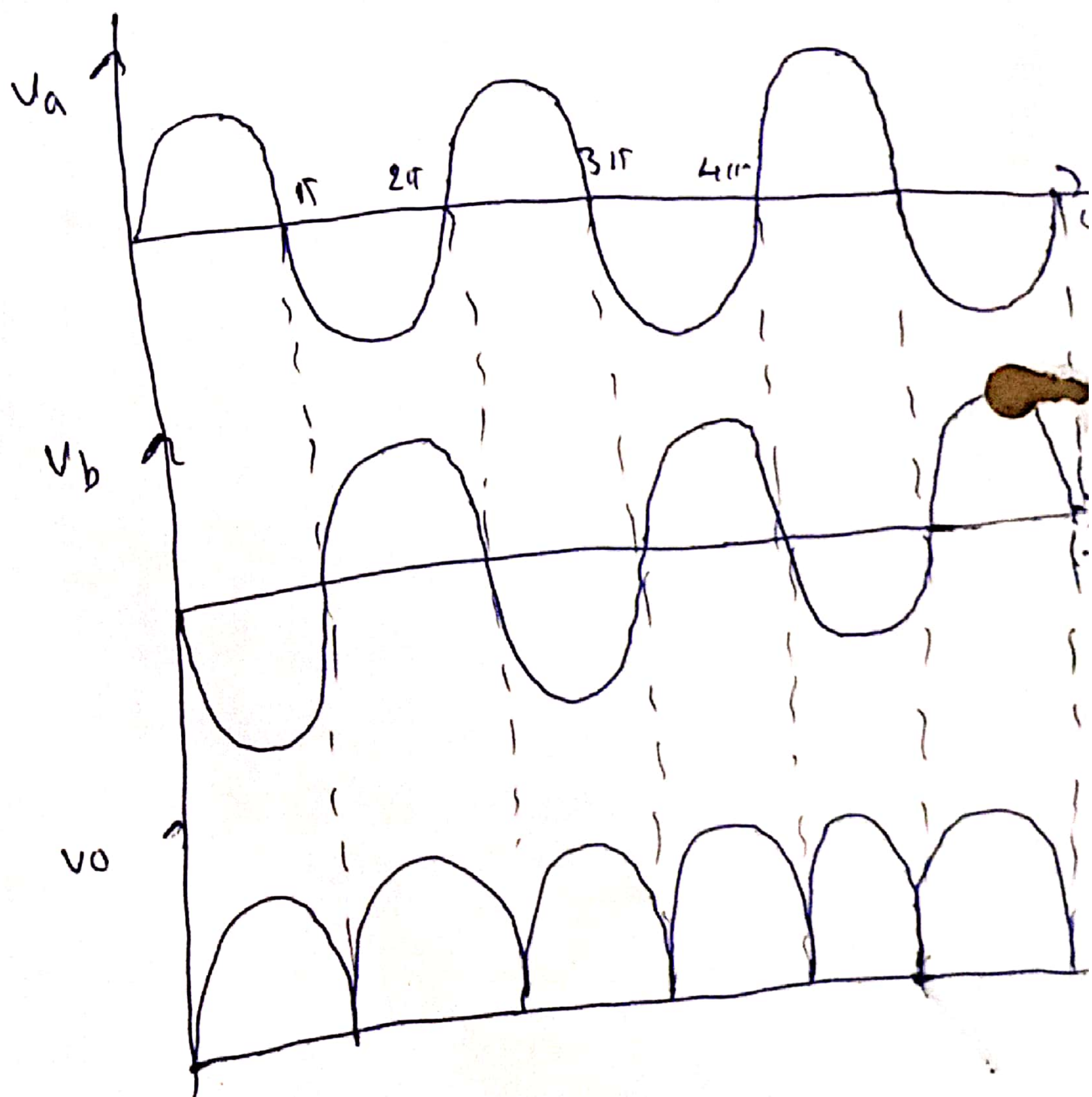
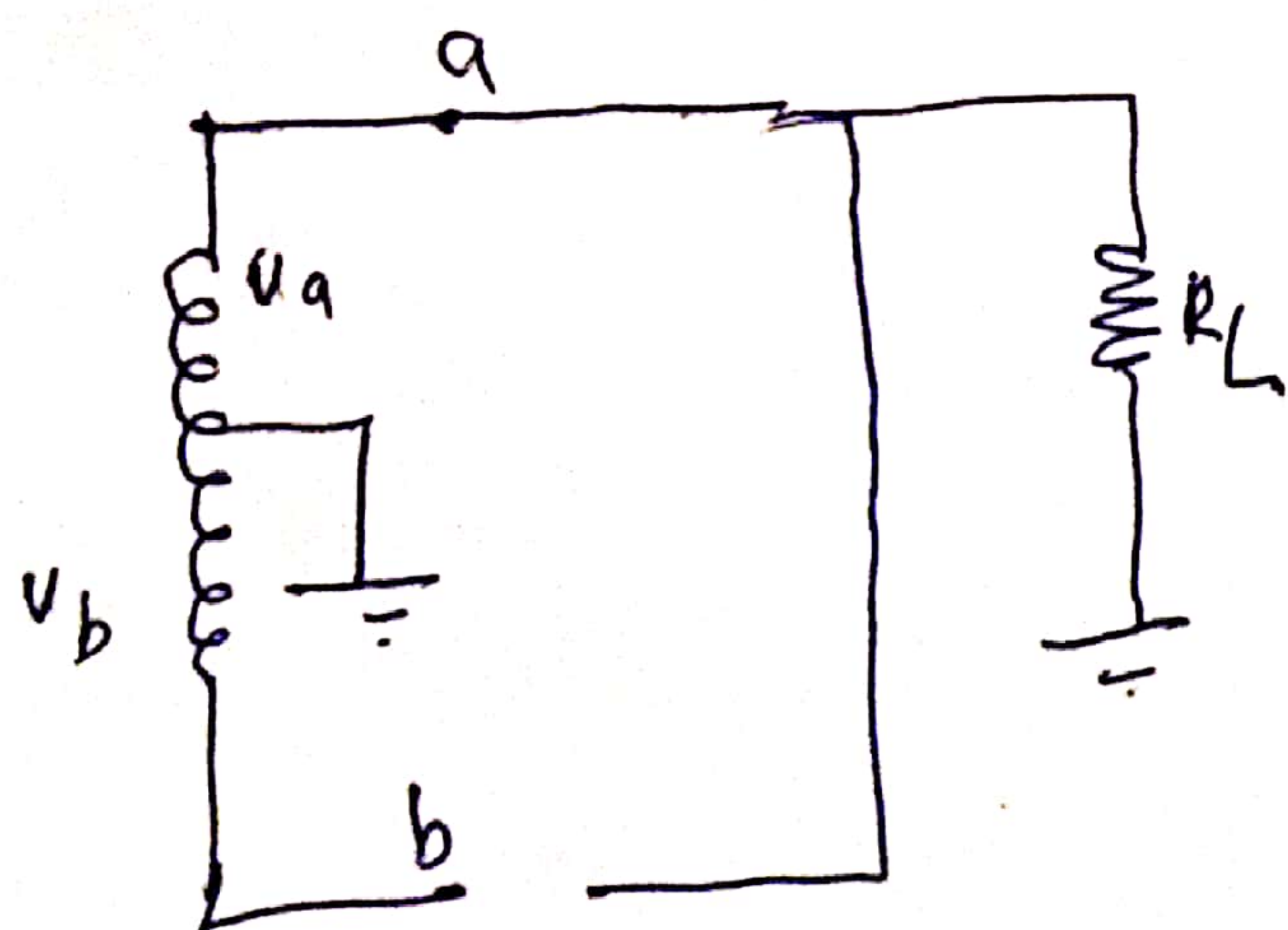
$$\text{If } V_a = V_m \sin \omega t, \quad V_b = -V_m \sin \omega t.$$

operation:

$$1) \quad 0 < \alpha < \pi.$$

V_a is +ve, D_1 in F.B $\rightarrow$ s/c

V_b is -ve, D_2 in R.B $\rightarrow$ o/c



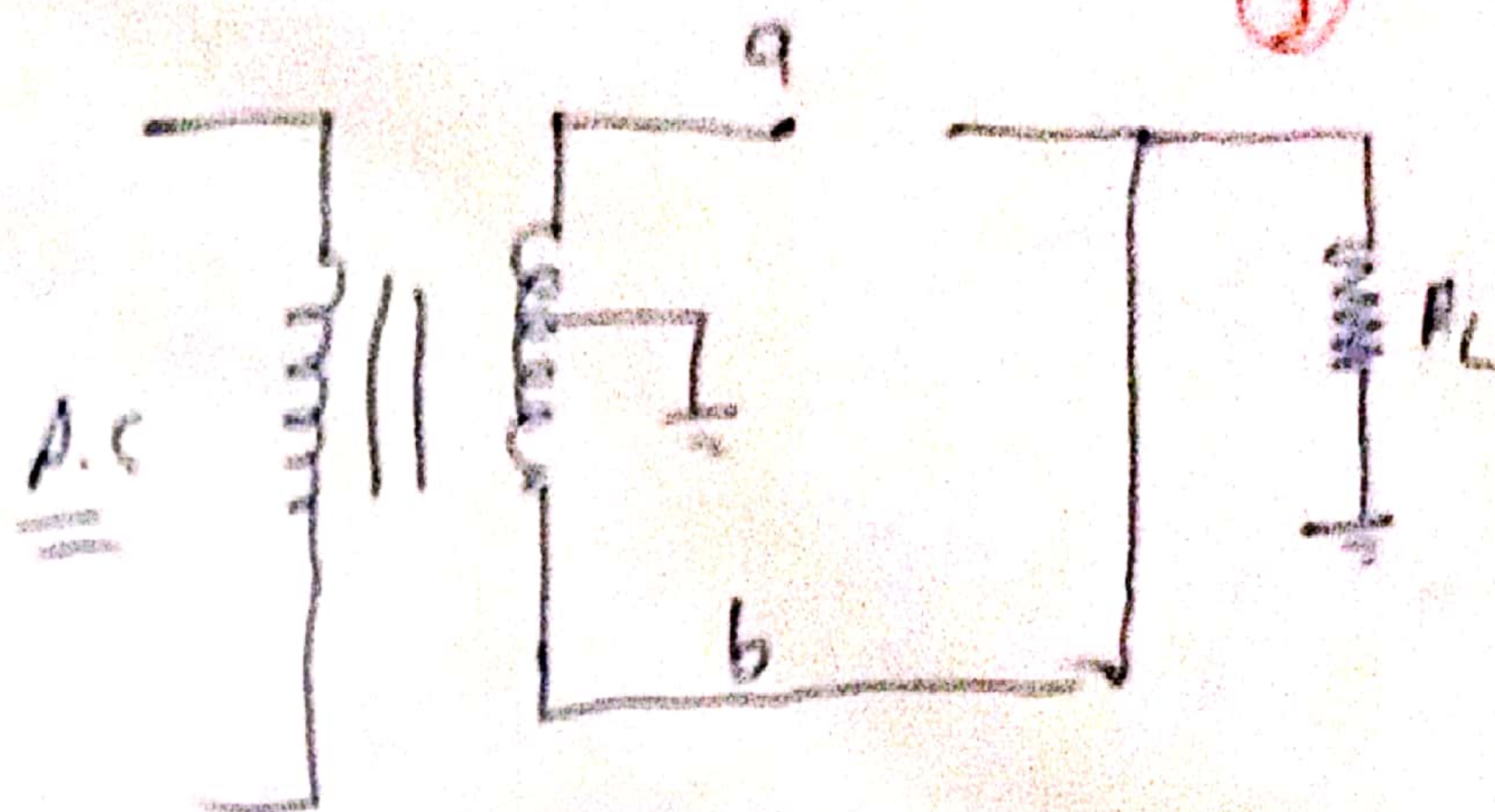
Since node a gets s/c to R_L V_a appears across R_L .

$$\therefore V_o = V_a.$$

$$2) \pi < \alpha < 2\pi$$

V_a is -ve, D_1 is F.B $\rightarrow$ o/c

V_b is +ve, D_2 is F.B $\rightarrow$ s/c



As node b is s/c to R_L ,

V_b app appears across R_L

$$\text{i.e., } V_o = V_b$$

FWR is functionally equivalent to two HWR.

Analysis of FWR

1) Instantaneous o/p current (i)

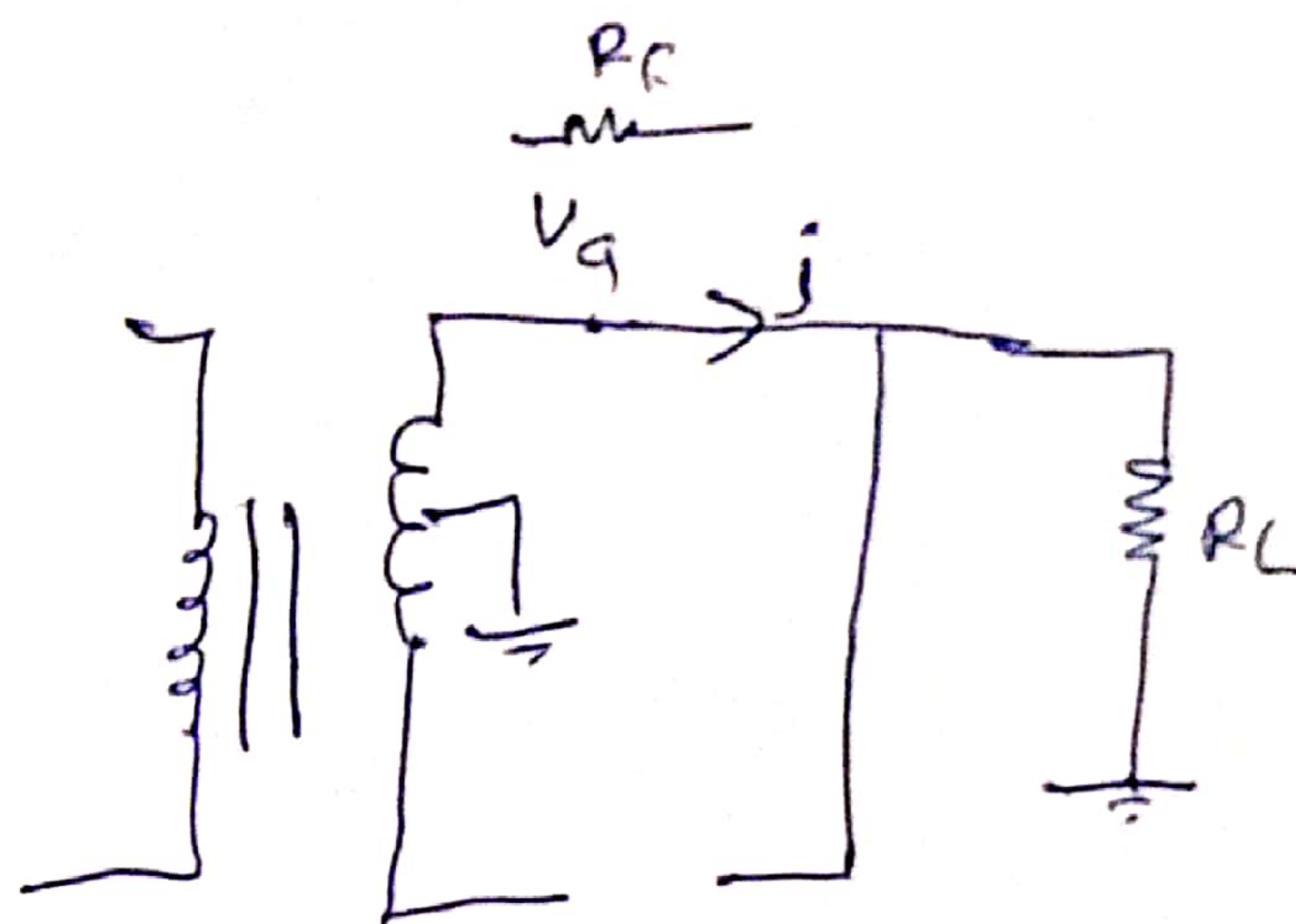
1) $0 < \alpha < \pi$, D_1 is in F.B. = R.F.

KVL in loop 1,

$$-V_a + iR_F + iR_L = 0$$

$$i = \frac{V_a}{R_F + R_L} = \frac{V_m \sin \alpha}{R_F + R_L}$$

$$i = I_m \sin \alpha, \text{ where } I_m = \frac{V_m}{R_F + R_L}$$



2) $\pi < \alpha < 2\pi$

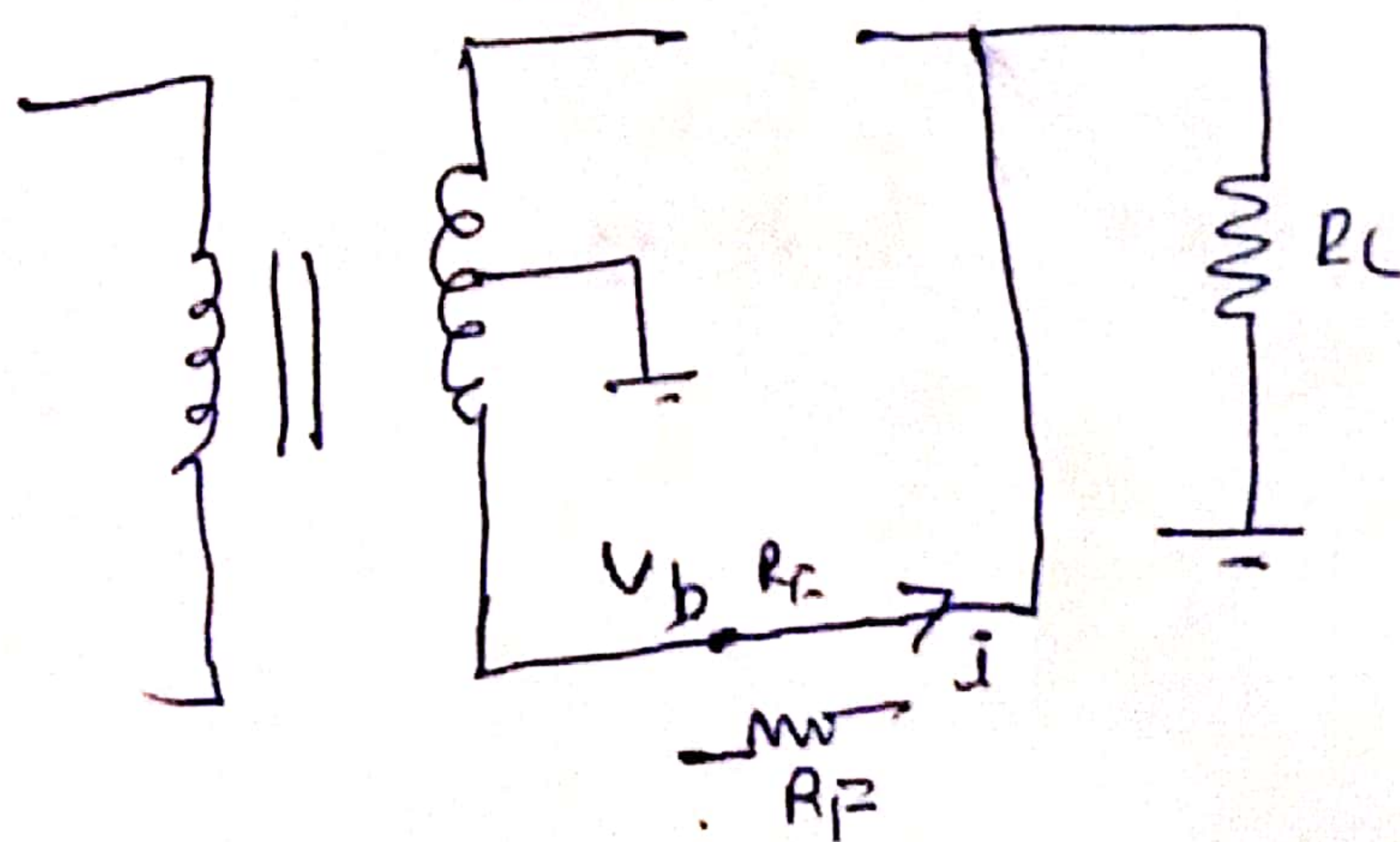
KVL in loop.

$$V_b = i(R_F + R_L)$$

$$i = \frac{V_b}{R_F + R_L}$$

$$i = \frac{-V_m \sin \alpha}{R_F + R_L}$$

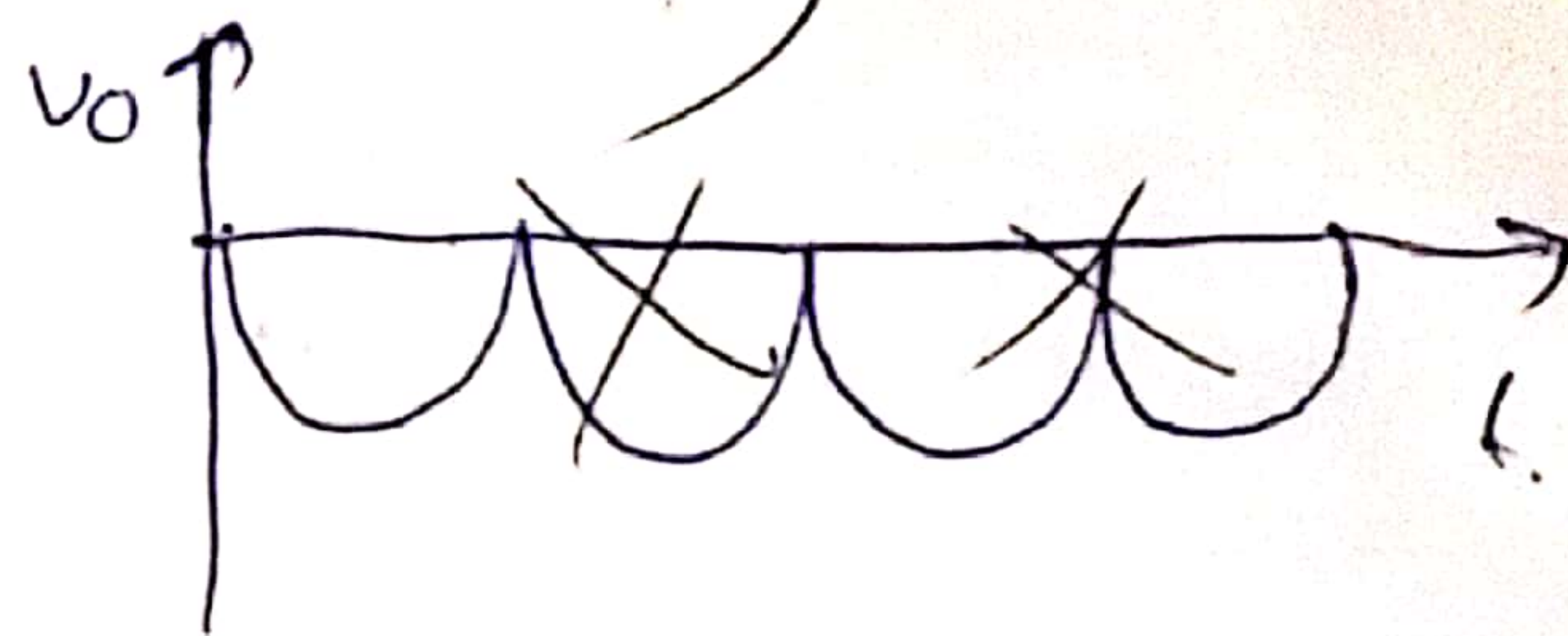
$$i = -I_m \sin \alpha$$



In above ckt, current through R_L flows in down direction.

hence it is a unidirectional current.

→ ~~(I_b diode connections are inverted, current through R_L flows always in upward direction.)~~



2) DC o/p current: (I_{DC})

$$I_{DC} = I_{avg}$$

$$= \frac{1}{2\pi} \int_0^{2\pi} i \cdot d\omega$$

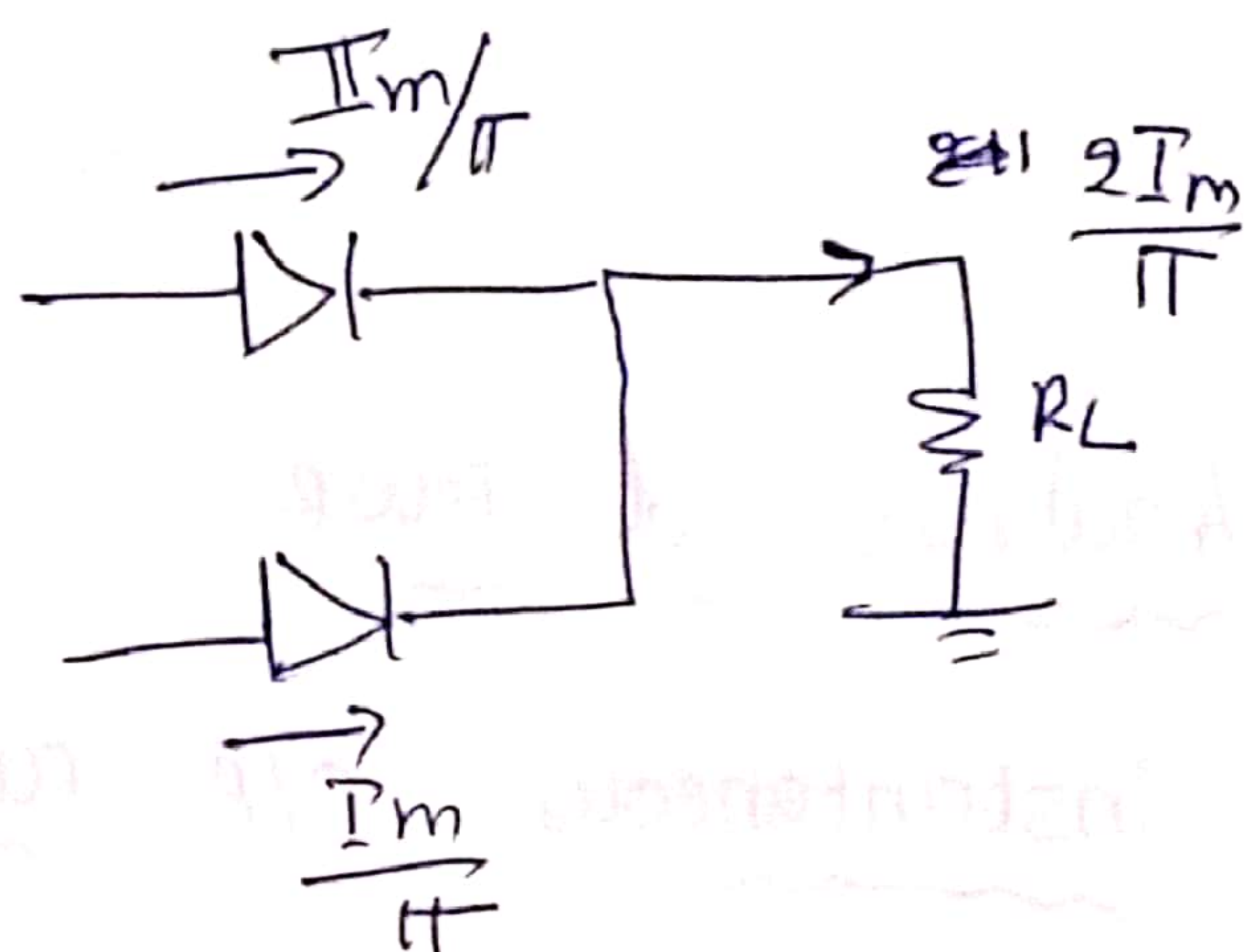
$$= \frac{1}{2\pi} \int_0^{\pi} I_m \sin \omega \cdot d\omega + \int_{\pi}^{2\pi} -I_m \sin \omega \cdot d\omega$$

$$= \frac{I_m}{2\pi} \left[-\cos \omega \right]_0^{\pi} - \left[-\cos \omega \right]_{\pi}^{2\pi}$$

$$= \frac{I_m}{2\pi} \left[-\cos \pi + \cos 0 \right] - \left[-\cos 2\pi + \cos \pi \right]$$

$$= \frac{I_m}{2\pi} \left[+1 + 1 - (-1 + (-1)) \right]$$

$$= \frac{I_m}{2\pi} \left[2 - (-2) \right] = \frac{I_m}{2\pi} \times 4 = \frac{2I_m}{\pi} //$$



Avg current through each diode is $\frac{I_m}{\pi}$ but DC current through R_L is $\frac{2I_m}{\pi} //$

RMS o/p current! (I_{rms})

(9)

$$I_{rms} = \sqrt{\frac{1}{T} \int_0^T i^2 dt}$$

$$= \sqrt{\frac{1}{2\pi} \int_0^{2\pi} (I_m \sin \alpha)^2 d\alpha}$$

$$= \sqrt{\frac{I_m^2}{2\pi} \int_0^{2\pi} \sin^2 \alpha d\alpha}$$

$$= \sqrt{\frac{I_m^2}{2\pi} \int_0^{2\pi} \left(\frac{1 - \cos 2\alpha}{2} \right) d\alpha}$$

$$= \sqrt{\frac{I_m^2}{4\pi} \left(\alpha - \frac{\sin 2\alpha}{2} \right)_0^{2\pi}} = \sqrt{\frac{I_m^2}{4\pi} \times 2\pi}$$

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

RMS A.C o/p current! (I'_{rms})

$$I'_{rms} = \sqrt{I_{rms}^2 - I_{DC}^2}$$

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

Ripple factor!

$$\gamma = \frac{I'_{rms}}{I_{DC}} \quad \underline{\underline{PV}}$$

$$\frac{I'_{rms}}{I_{DC}} = \frac{\sqrt{I_{rms}^2 - I_{DC}^2}}{I_{DC}}$$

$$\gamma = \sqrt{\left(\frac{I_{rms}}{I_{DC}} \right)^2 - 1} = \sqrt{\frac{\left(\frac{I_m}{\sqrt{2}} \right)^2}{\left(\frac{2I_m}{\pi} \right)^2} - 1}$$

$$\gamma = 0.483$$

RMS AC component is weaker than DC component in o/p of FWR.

6) IIP power (P_i) instantaneous.

P_i is obtained from upper half of secondary winding from 0 to π . Lower half secondary winding from π to 2π .

$$\begin{aligned}\therefore \text{IIP power} = P_i &= \frac{1}{2\pi} \left[\int_0^\pi v_o \cdot i \cdot d\omega + \int_\pi^{2\pi} v_o \cdot i \cdot d\omega \right] \\ &= \frac{1}{2\pi} \left[\int_0^\pi i^2 (R_F + R_L) d\omega + \int_\pi^{2\pi} i^2 (R_F + R_L) d\omega \right] \\ &= \frac{(R_F + R_L)}{2\pi} \cdot \int_0^{2\pi} i^2 d\omega \\ &= I_{rms}^2 (R_F + R_L)\end{aligned}$$

$$\therefore P_i = I_{rms}^2 (R_F + R_L)$$

7) efficiency: $\eta = \frac{\text{DC O/P power}}{\text{IIP power}} = \frac{P_{OL}}{P_i} \times 100$ PP

$$= \frac{I_{DC}^2 \cdot R_L}{I_{rms}^2 (R_F + R_L)} \times 100$$

$$= \frac{\frac{4I_m^2}{\pi^2} \cdot R_L}{\frac{I_m^2}{2} (R_F + R_L)} \times 100$$

$$= \frac{800}{\pi^2} \times \frac{R_L}{R_L + R_F}$$

$$= 81 \times \frac{R_L}{R_L + R_F}$$

$\therefore$ max efficiency is $\eta = 81\%$ is achieved when
 $R_{L/R} (\text{W}) = 600 \text{ W} (40.5\% + 40.5\%) =$

8) Dc diode voltage:

10

consider diode D_1

V_{diode} - instantaneous voltage across D_1

$0 < \alpha < \pi$, D_1 is in F.B.

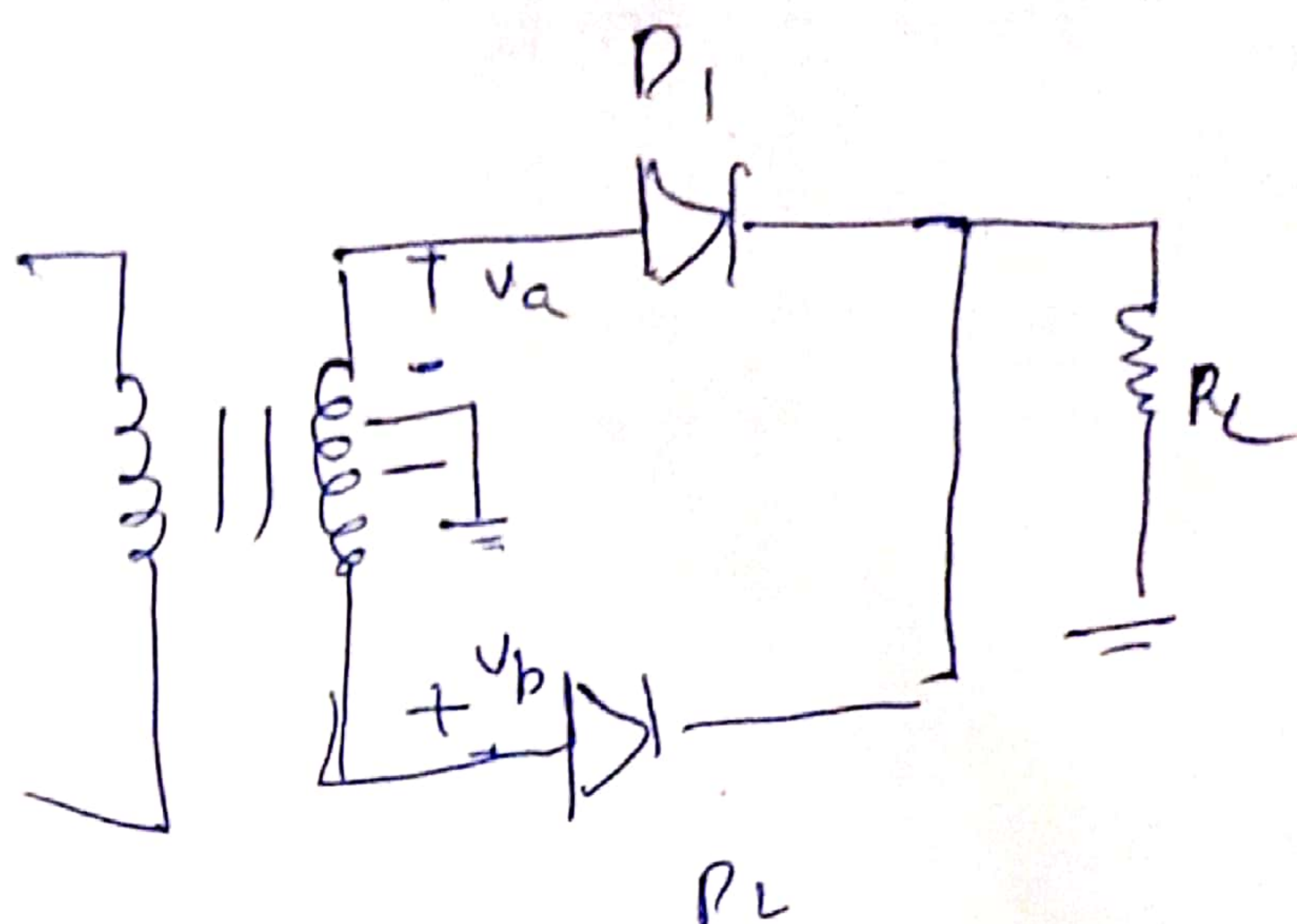
$$V_{diode} = i R_f \approx 0$$

$\pi < \alpha < 2\pi$, D_1 is R.B.

$$V_b - V_a + V_{D1} = 0 \Rightarrow$$

$$V_{diode} = V_a - V_b = 2V_m \sin \alpha$$

$$V_{diode} = \begin{cases} 0 & 0 < \alpha < \pi \\ 2V_m \sin \alpha & \pi < \alpha < 2\pi \end{cases}$$



$$V_{diode} = \begin{cases} -2V_m \sin \alpha & 0 < \alpha < \pi \\ 0 & \pi < \alpha < 2\pi \end{cases}$$

$V_{diode, DC}$: Avg value of V_{diode}

$$= \frac{1}{2\pi} \int_0^{2\pi} V_{diode} d\alpha$$

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

9) no load dc o/p voltage:

$$V_{DCNL} = V_{DC} \text{ at } I_{DC} = 0.$$

$$-0 + V_{diode, DC} + V_{DCNL} = 0.$$

$$V_{DCNL} = -V_{diode, DC}$$

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

10) Full load dc o/p voltage

$$V_{DCFL} = V_{DNL} - I_{DC} R$$

$$R = \frac{R_{sw}}{2} + R_L$$

11) Regulation factor:

$$\frac{V_{DNL} - V_{DCFL}}{V_{DCFL}} \times 100$$

$$= \frac{\frac{2V_m}{\pi} - \frac{2V_m}{\pi} + I_{DC} R}{I_{DC} + R_L} \times 100$$

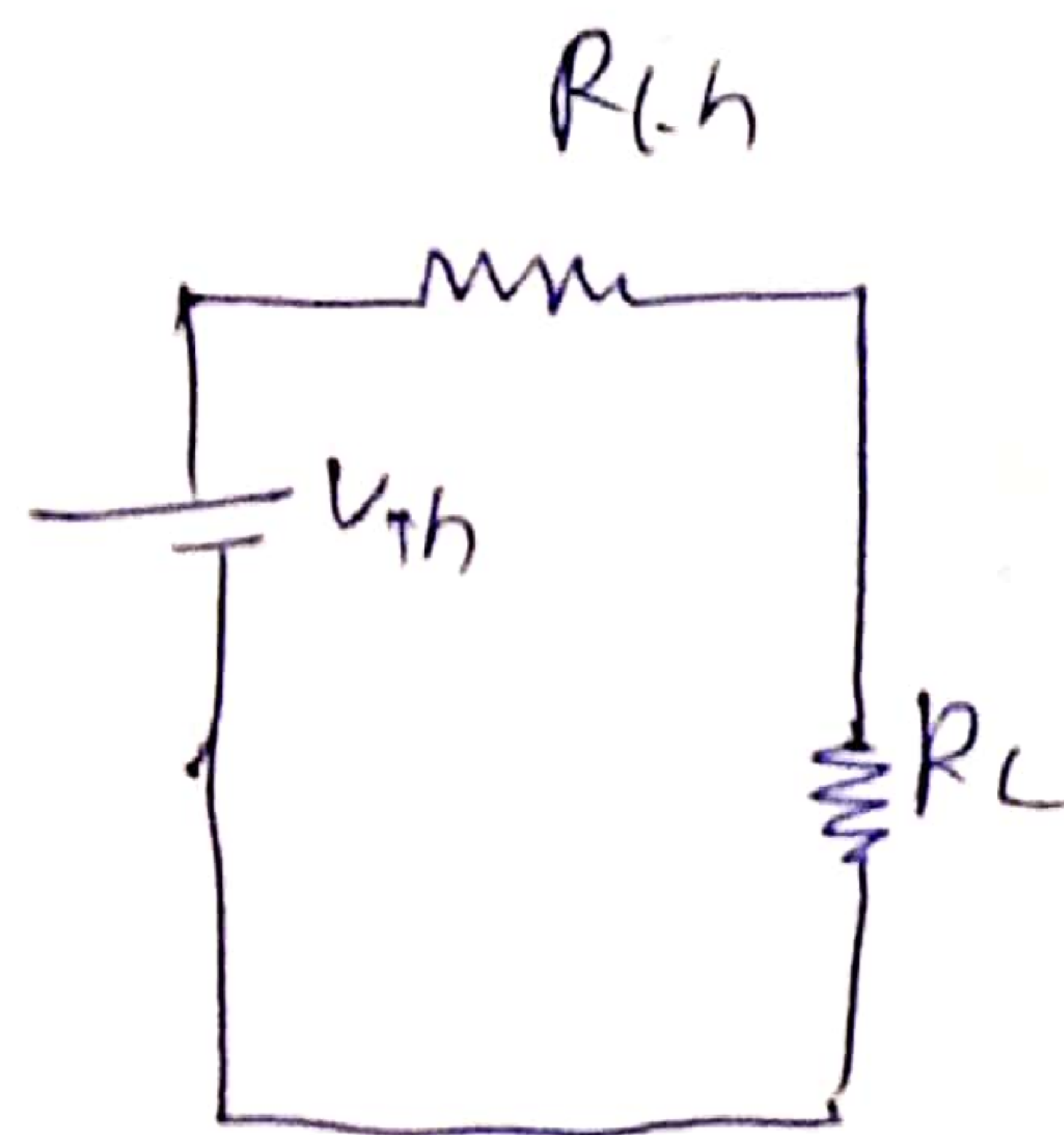
$$\therefore R = \frac{R}{R_L} \times 100$$

12) Thevenin's eq. circ.

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

$$R_{th} = \frac{R_{sw}}{2} + R_L$$

$$V_{DCFL} = \frac{2V_m}{\pi} - I_{DC} R$$



13) PDU:-

$$PDU = \left(\frac{2V_m}{\pi} \right)_{max}$$

$$= 2V_m$$

Higher PDU is undesired because it requires diodes having breakdown voltage which are costlier and bigger in size

14) TUF (Transformer utilization factor):

(17)

A FWR is a combination of 2 HWR. The value of TUF w.r.t 2nd secondary winding will be twice the TUF of HWR.

$$[TUF]_{sec} = 2 \times 0.286 = 0.57$$

TUF w.r.t primary winding is defined as

$$[TUF]_{pw} = \frac{\text{DC o/p power}}{\text{AC rating of primary winding}}$$

$$= \frac{I_{dc}^2 \cdot R_L}{\frac{V_{m1}}{\sqrt{2}} \cdot \frac{I_{m1}}{\sqrt{2}}}$$

$$= \frac{\left(\frac{2 I_m}{\pi}\right)^2 \cdot R_L}{(R_F + R_L) \frac{I_m^2}{2}}$$

$$= 0.81 \times \frac{R_L}{R_L + R_F}$$

$$\text{max } TUF_{pw} = 0.81$$

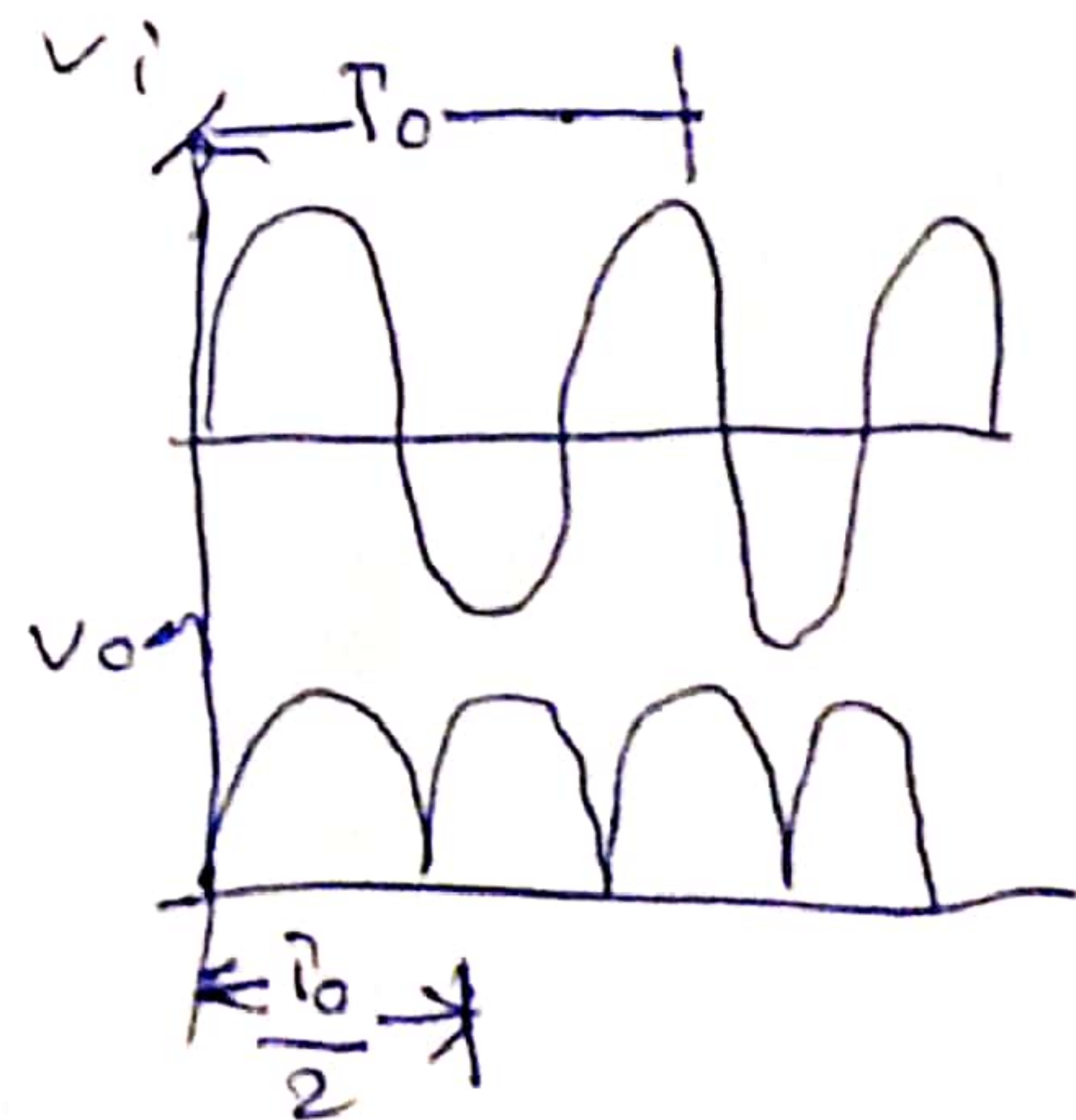
$$\text{Avg. TUF} = \frac{TUF_{prim} + TUF_{sec}}{2} = \frac{0.81 + 0.57}{2} = 0.69$$

15) Frequency of o/p (or) ripple frequency

Since o/p waveform has a Time period $\frac{T_0}{2}$

→ Then frequency of o/p will be two times of i/p frequency

, ripple frequency = 2f



$$\text{F.S of } V_o : \frac{2V_m}{\pi} - \frac{4V_m}{\pi} \sum_{k=\text{even}} \frac{\cos k\omega_0 t}{(k+1)(k-1)}$$

$\downarrow$ D.C $\downarrow$ A.C

→ A.C component consists of even harmonics $2\omega_0, 4\omega_0, \dots$

→ fundamental freq. ω_0 is not present in o/p of FWR. Due

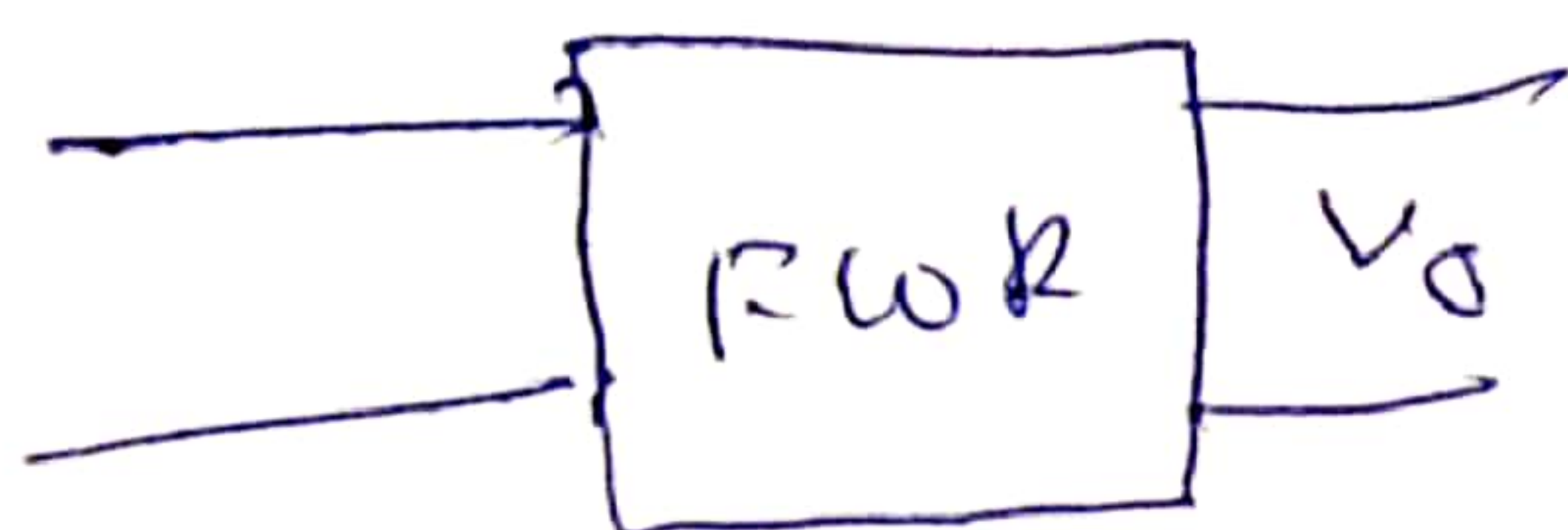
to this filtering of A.C component is becomes very

easier in FWR.

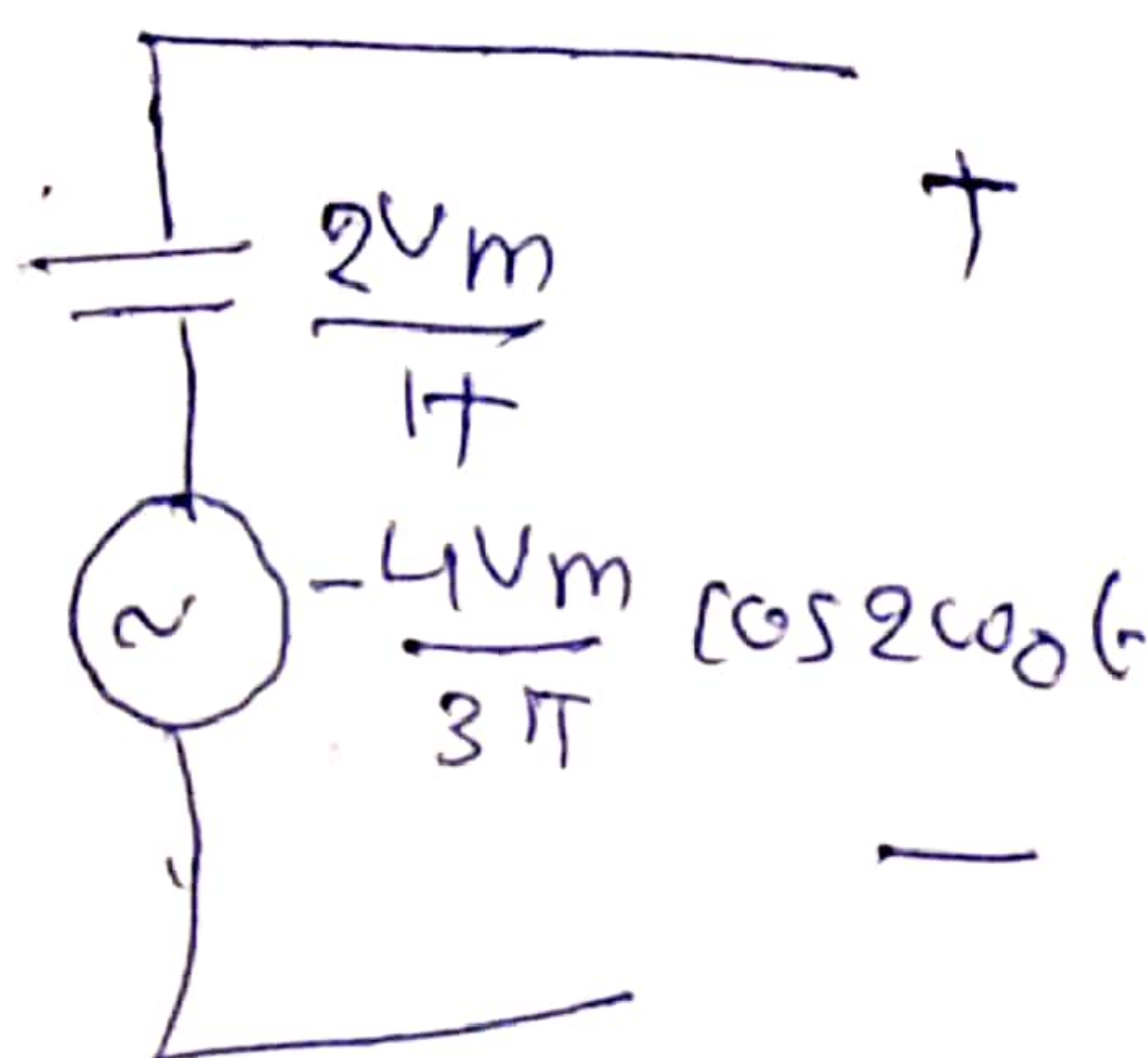
∴ If highest harmonics are neglected

$$V_o : \frac{2V_m}{\pi} - \frac{4V_m}{3\pi} \cos 2\omega_0 t$$

$\downarrow$ D.C $\downarrow$ A.C



$\approx$



Bridge rectifier

Bridge rectifier uses a normal stepdown transformer

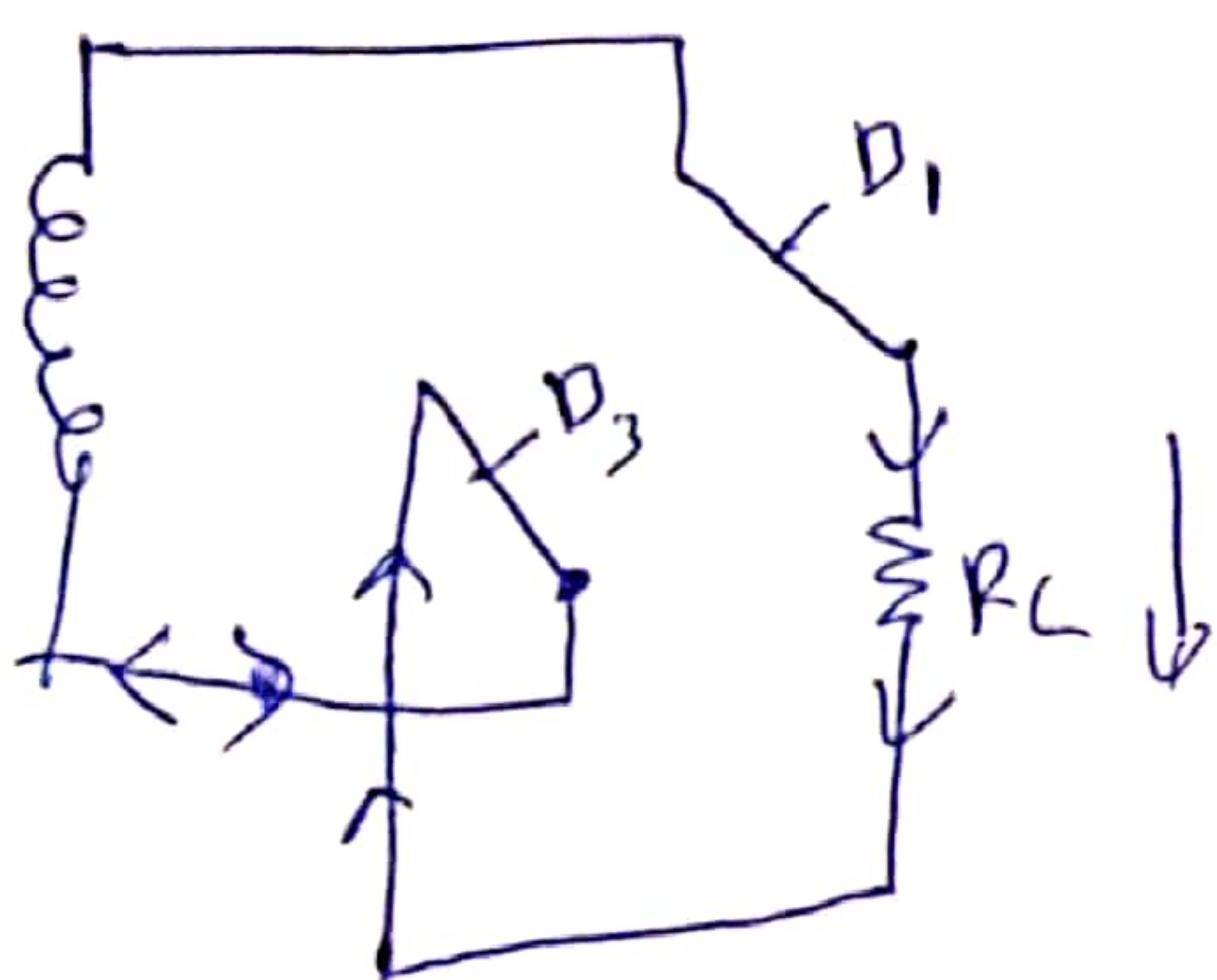
$$V_i = V_m \sin \alpha$$

operation:

1) $0 < \alpha < \pi$. (V_i is +ve)

node a is +ve so D_1 is on
node b is -ve so D_3 is on
 D_2 and D_4 are in R.B

current flow takes place
in a loop D_1, R_L, D_3
& secondary winding



→ current through secondary winding
where as current through R_L is
DC current

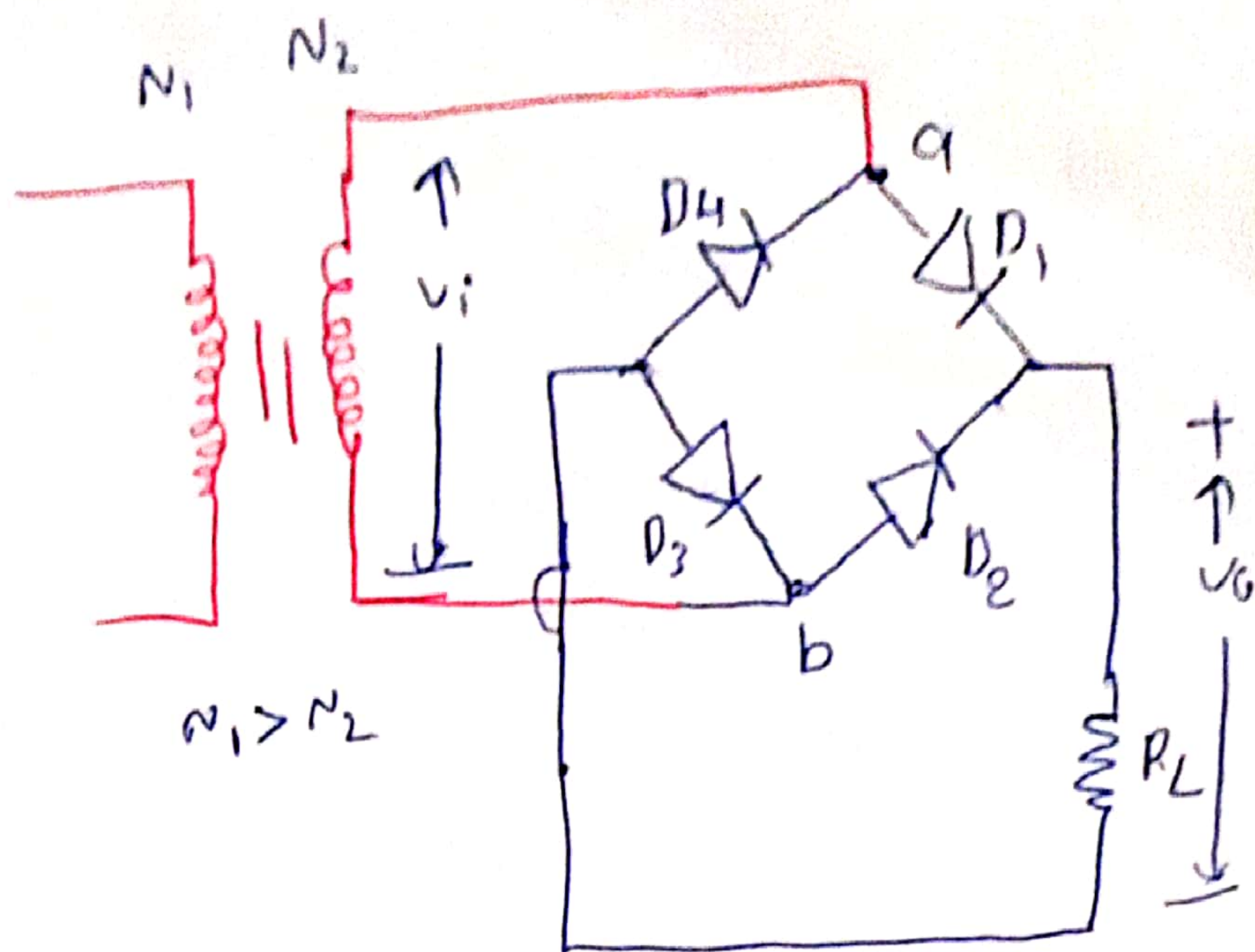
winding is bidirectional (or) AC current
 R_L is unidirectional (or) pulsating

Analysis of bridge rectifier

1) instantaneous o/p current

$$i = I_m \sin \alpha \quad 0 < \alpha < \pi$$

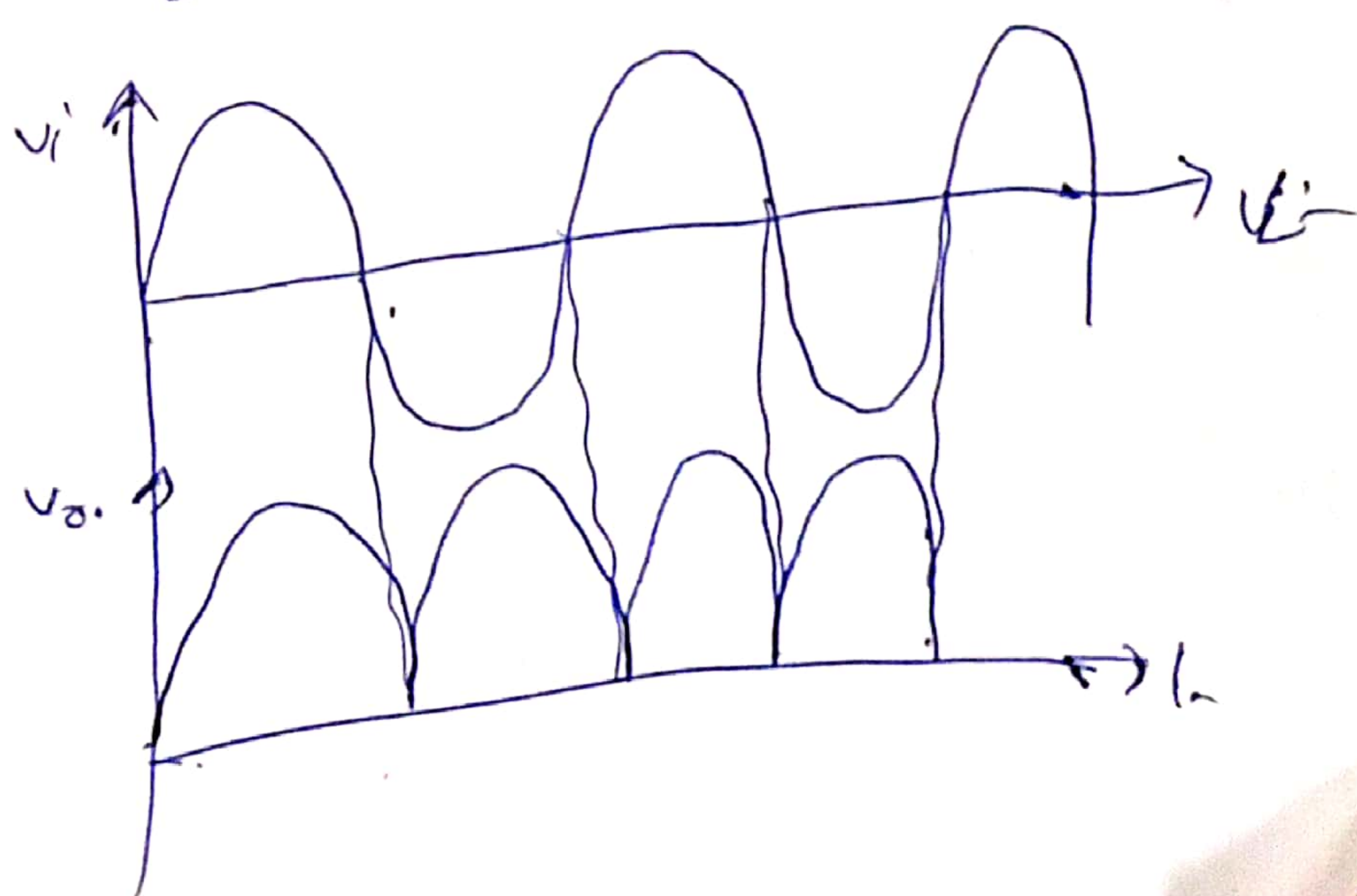
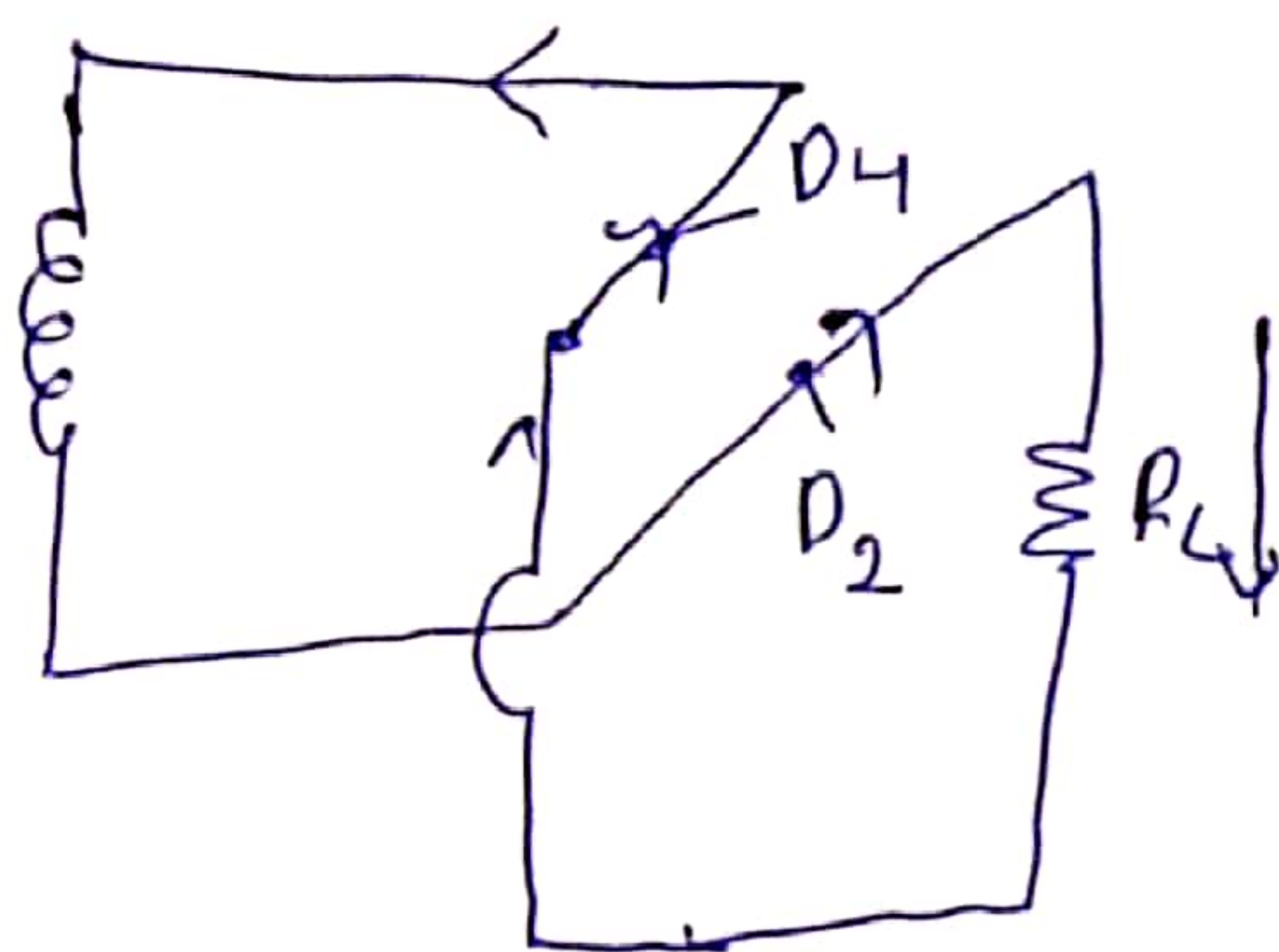
$$= -I_m \sin \alpha \quad \pi < \alpha < 2\pi$$



2) Let V_i is -ve ($\pi < \alpha < 2\pi$)

node a is -ve, node b is +ve
(D_1 & D_3 in R.B.)
(D_2 & D_4 in F.P.)

current flow in a loop D_2, R_L, D_4
& secondary winding



where $I_m = \frac{V_m}{2R_F + R_L}$

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

6) $P_i = I_{rms}^2 (2R_F + R_L)$

3) $I_{rms} = I_m / \sqrt{2}$

7) $\eta\% = 81 \times \frac{R_L}{2R_F + R_L}$

4) $I'_{rms} = \sqrt{I_{rms}^2 - I_{DC}^2}$

5) $\gamma = 0.483$

8) DC diode voltage:

consider diode D_1

$0 < \alpha < \pi$

D_1 is F.B.

$V_{Diode} = 0 //$

$\pi < \alpha < 2\pi$

Diode is in R.B.

$\therefore V_{Diode} = V_i$
 $= V_m \sin \alpha$

$V_{Diode} = 0 ; 0 < \alpha < \pi$

$= V_m \sin \alpha ; \pi < \alpha < 2\pi$

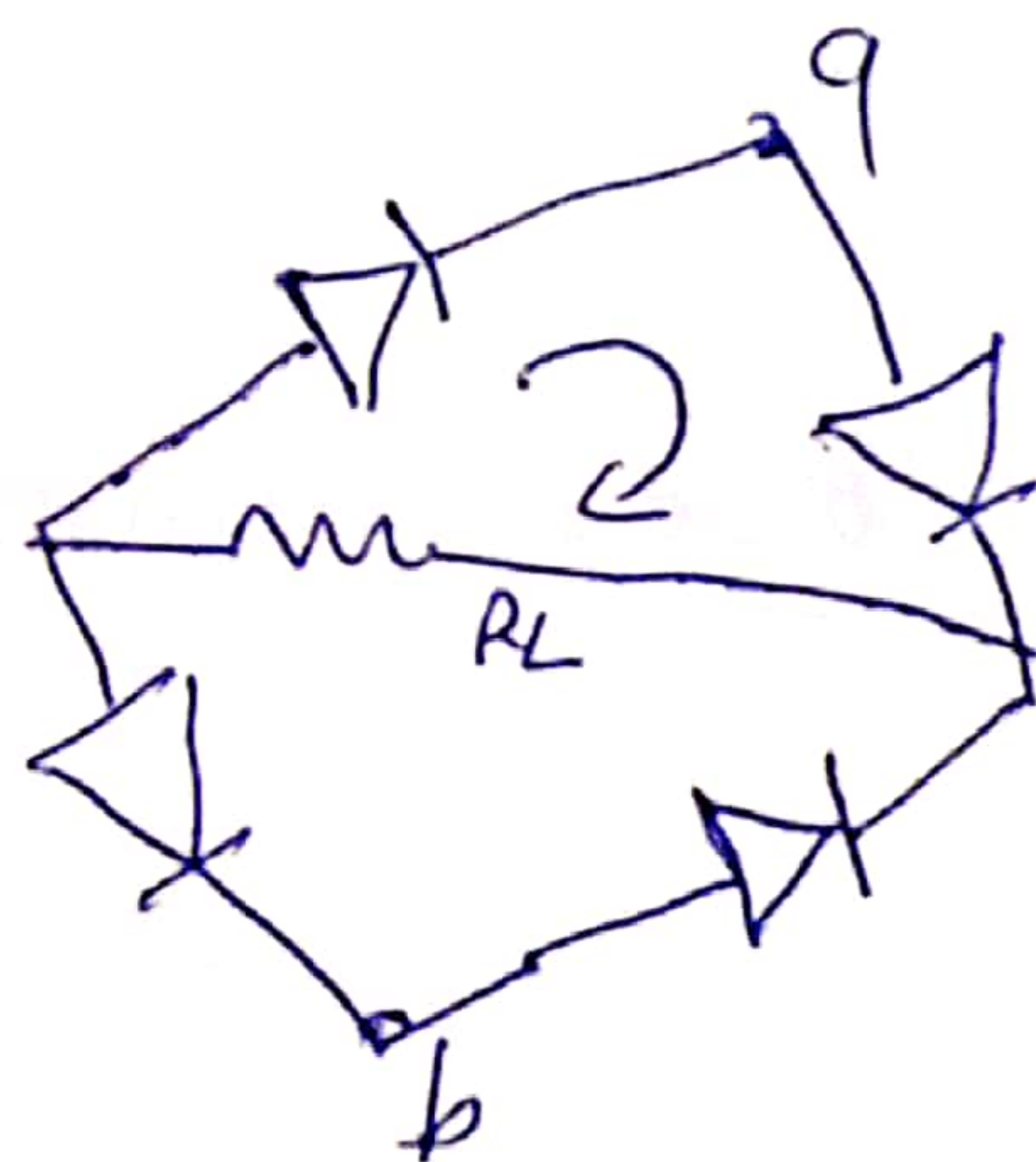
$V_{Diode DC} = \frac{1}{2\pi} \int_0^{2\pi} V_{Diode} d\alpha$

$V_{Diode DC} = \frac{-V_m}{\pi} //$

9) V_{DCNL} (no load DC voltage)

$V_{DCNL} = V_{DC} / \text{at } I_{DC} = 0$

$V_{DCNL} = \frac{2V_m}{\pi} //$



10) $V_{DCFL} = I_{DC} R_L$

(or) $\frac{2V_m}{\pi} = 2I_{DC} R_F R$

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

where $R = 2R_F + R_{sw}$

11) % Regulation = $\frac{V_{DCNL} - V_{DCFL}}{V_{DCFL}} \times 100$

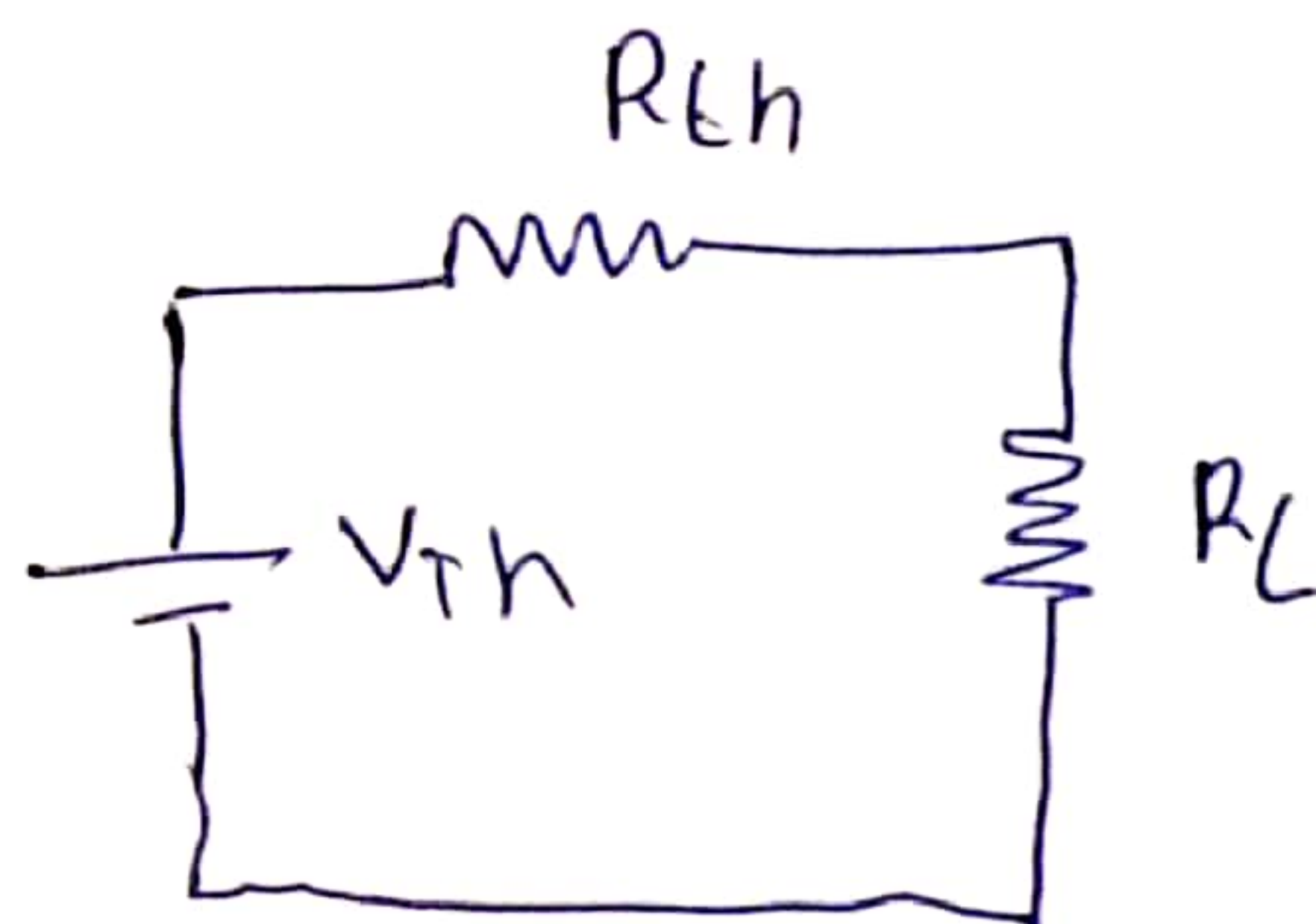
= $\frac{\frac{2V_m}{\pi} - \frac{2V_m}{\pi} + I_{DC} R}{I_{DC} R_L}$

%R = $\frac{R}{R_L} \times 100$

12) Thevenin's eq. ckt:-

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

$R_{th} = R_{sw} + 2R_F$



13) Peak inverse voltage:-

$P.I.V. = (V_{diode})_{max} \text{ in R.B.}$

= $(V_m \sin \alpha)_{max}$

$P.I.V. = V_m$

14) T.O.F:-

= $\frac{\text{DC o/p power}}{\text{Ac ratings of sec. winding}}$

$$= \frac{I_m^2 R_L}{\frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}}}$$

$$= \frac{\frac{L I_m^2}{\pi^2} \times R_L}{\frac{I_m^2}{2} (2R_F + R_L)} = \frac{8}{\pi^2} \times \frac{R_L}{2R_F + R_L}$$

$$TUF = 0.81 \times \frac{R_L}{2R_F + R_L}$$

$$\therefore \max TUF = 0.81 //$$

15) Ripple frequency = $2f_o$.

Advantages of bridge rectifier over center tapped FWR:

- 1) Smaller PIV
- 2) Doesnot require center tapped Transformer.
- 3) Greater TUF

(3)

Advantages of FWR (center tapped) over HWB

- 1) High TUF
- 2) High efficiency
- 3) low ripple factor
- 2) high dc o/p voltage.

Advantages of HWB over FWR (center tapped)

- 1) peak inverse voltage is less for HWB when compared with FWR (with center tapped)

parameter	HWR	FWR (center tapped)	FWR (bridge)
1) V_{dc} (or) V_{avg}	$\frac{V_m}{\pi}$	$\frac{2V_m}{\pi}$	$\frac{2V_m}{\pi}$
2) V_{rms} (o/p)	$\frac{V_m}{2}$	$\frac{V_m}{\sqrt{2}}$	$\frac{V_m}{\sqrt{2}}$
3) I_{dc} (or) I_{avg}	$\frac{I_m}{\pi}$	$\frac{2I_m}{\pi}$	$\frac{2I_m}{\pi}$
4) I_{rms}	$\frac{I_m}{2}$	$\frac{I_m}{\sqrt{2}}$	$\frac{I_m}{\sqrt{2}}$
5) TUF	0.287	0.69	0.81
6) Efficiency	40.5%	81%	81%
7) $V_{diode, dc}$	$-\frac{V_m}{\pi}$	$-\frac{2V_m}{\pi}$	$-\frac{V_m}{\pi}$
8) V_{dc} no load	$\frac{V_m}{\pi}$	$\frac{2V_m}{\pi}$	$\frac{2V_m}{\pi}$
9) PIV	V_m	$2V_m$	V_m
10) Ripple factor	1.21	0.48	0.48
11) ripple frequency	f_o	$2f_o$	$2f_o$
12) V_{rms} (i/p)	$\frac{V_m}{\sqrt{2}}$	$\frac{V_m}{\sqrt{2}}$	$\frac{V_m}{\sqrt{2}}$

Filter:

→ It is a selective w/w which can transmit desired range of frequencies & stop unwanted frequencies

→ filter is used, in order to eliminate the AC component present in o/p of rectifier.

→ AC component has frequencies $\omega_0, 2\omega_0, 4\omega_0, \dots$ etc. in half wave rectifier, $2\omega_0, 4\omega_0, \dots$ etc. in FWR & bridge rectifier. These frequencies can be removed by using filter.

→ filter consists of reactive elements. i.e. inductor & capacitor.

	$\omega = 0$	$\omega = \infty$
$X_L = j\omega L$	0	High
$X_C = \frac{1}{j\omega C}$	High (∞)	0 (low)

→ For A.C component, inductor offers high reactance & capacitor offers low reactance

→ For D.C component capacitor offers high reactance & inductor offers low reactance

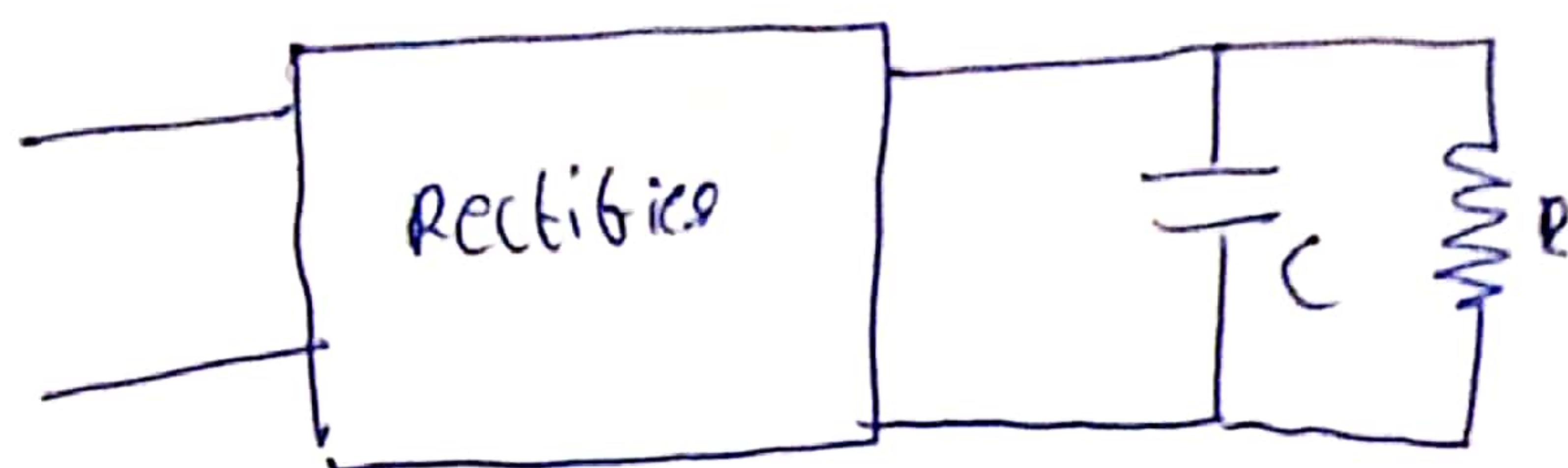
→ It means, capacitor blocks D.C, & allows A.C
inductor blocks A.C & allows D.C

→ Filters used in power supply are

- 1) capacitor
- 2) inductor
- 3) LC
- 4) CLC

capacitor filter

A large capacitor connected in parallel with load resistance can eliminate the AC component



capacitor should be selected if reactance is much smaller than R_L .

$$|X_C| \ll R$$

$$\frac{1}{\omega C} \ll R \rightarrow H \omega R, \quad \frac{1}{2\omega C} \ll R \rightarrow F \cdot \omega R$$

→ capacitor and R_L form current divider w/ ω

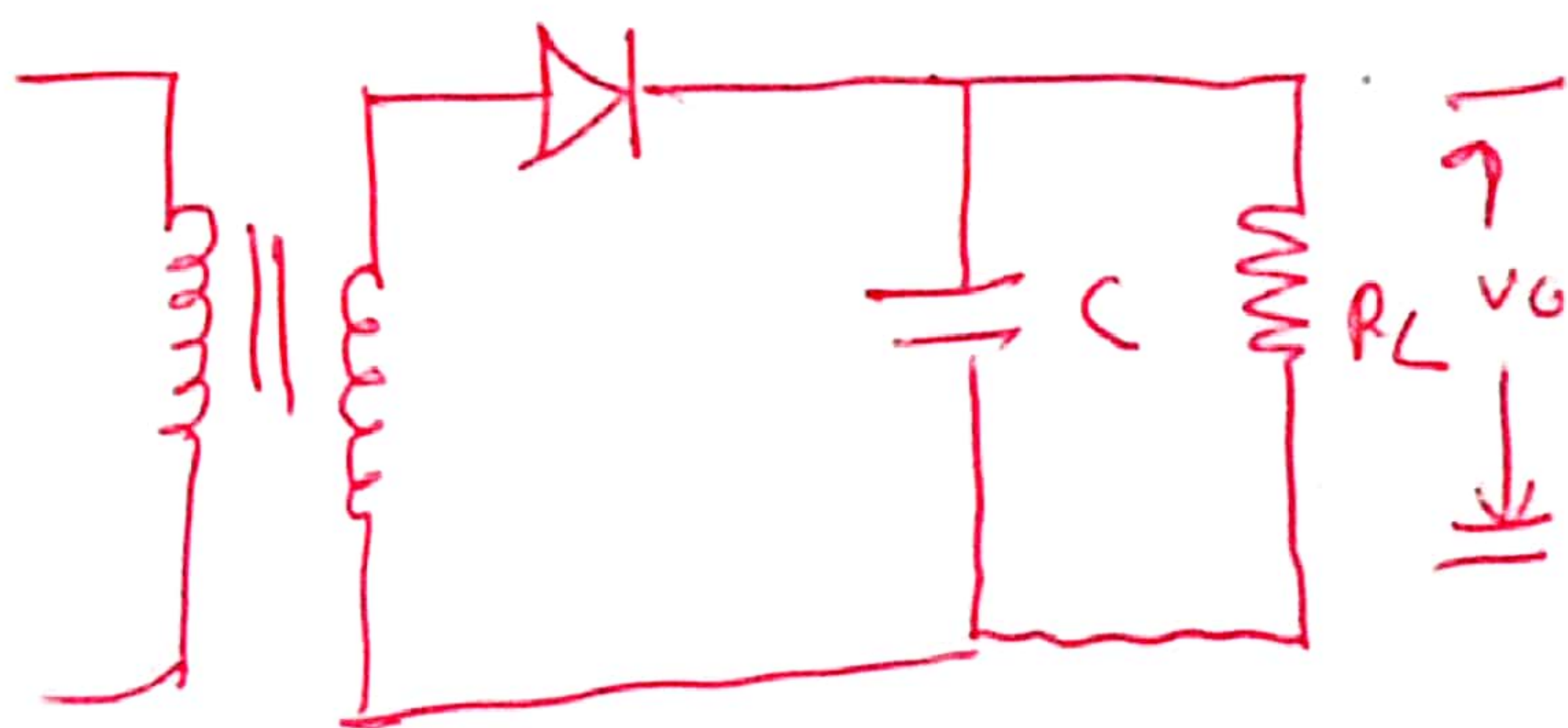
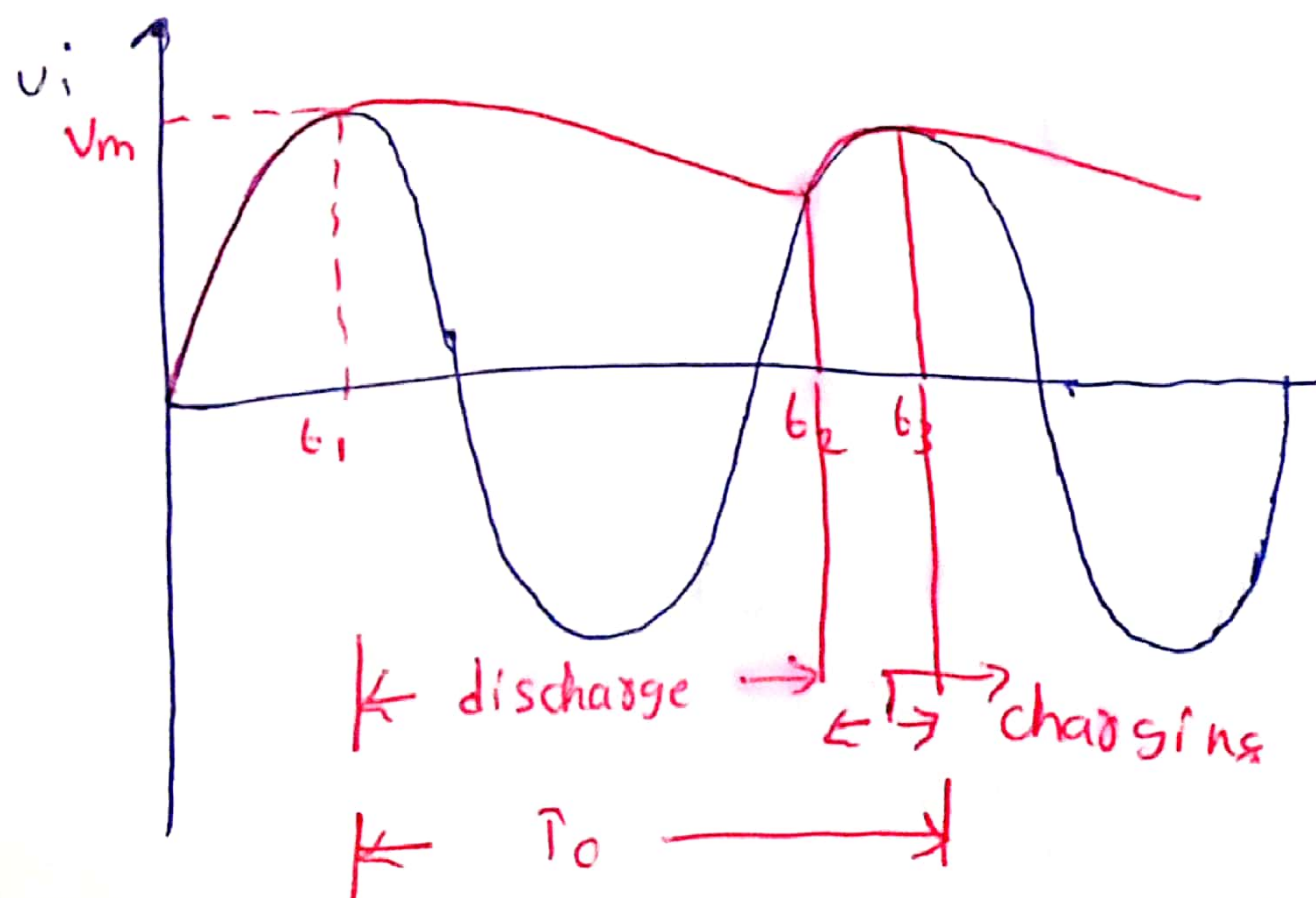
→ The o/p current of rectifier is a combination of AC & DC.

→ AC current flows almost through the capacitor & negligible AC current flows through R_L .

→ DC current flows through R_L .

Analysis of capacitive filter

1) consider HWR with 'C' filter



②

For $t > 0$:- Diode begins conduction, capacitor charges through diode, V_c keeps increasing

→ If diode is ideal, it behaves as s/c

∴ V_c increases at a rate at which V_i ↑.

→ charging process continues till $t = t_1$ at which both V_i & V_c becomes V_m .

for $t > t_1$:-

capacitor starts discharging through R_L

→ since discharging time constant is very large.

Discharging process will be very slow.

→ capacitor continues discharging till $t = t_2$

→ Diode remains off b/w t_1 & t_2

for $t > t_2$:-

Diode starts conduction & capacitor charges, which continues upto $t = t_3$

Thus above process of charging & discharging through diode & discharging through R_L keeps repeating.

$$T_{\text{disch}} + T_{\text{charge}} = T_0$$

If $R_L C$ is very large, discharge process will be very slow.

$$\therefore T_{\text{discharge}} \gg T_{\text{charge}}$$

$$\therefore T_{\text{discharge}} \approx T_0$$

→ capacitor loses charge during discharge interval
 → The amount of charge lost by capacitor during discharge interval is given by $\Delta Q_1 = C \cdot \Delta V$.

where ΔV = decrease in capacitor voltage b/w t_1 & t_2

$$\therefore \Delta Q_1 = CV_r$$

→ when capacitor discharges, it supplies charge to load resistance.

→ The amount of charge supplied to R_L during discharge interval.

$$\Delta Q_2 = \text{Avg. output flow} \times T_{\text{discharge}}$$

$$= I_{DC} \times T_r$$

$$\therefore \Delta Q_2 = \frac{I_{DC}}{f_0}$$

using charge conservation principle $\Delta Q_1 = \Delta Q_2$

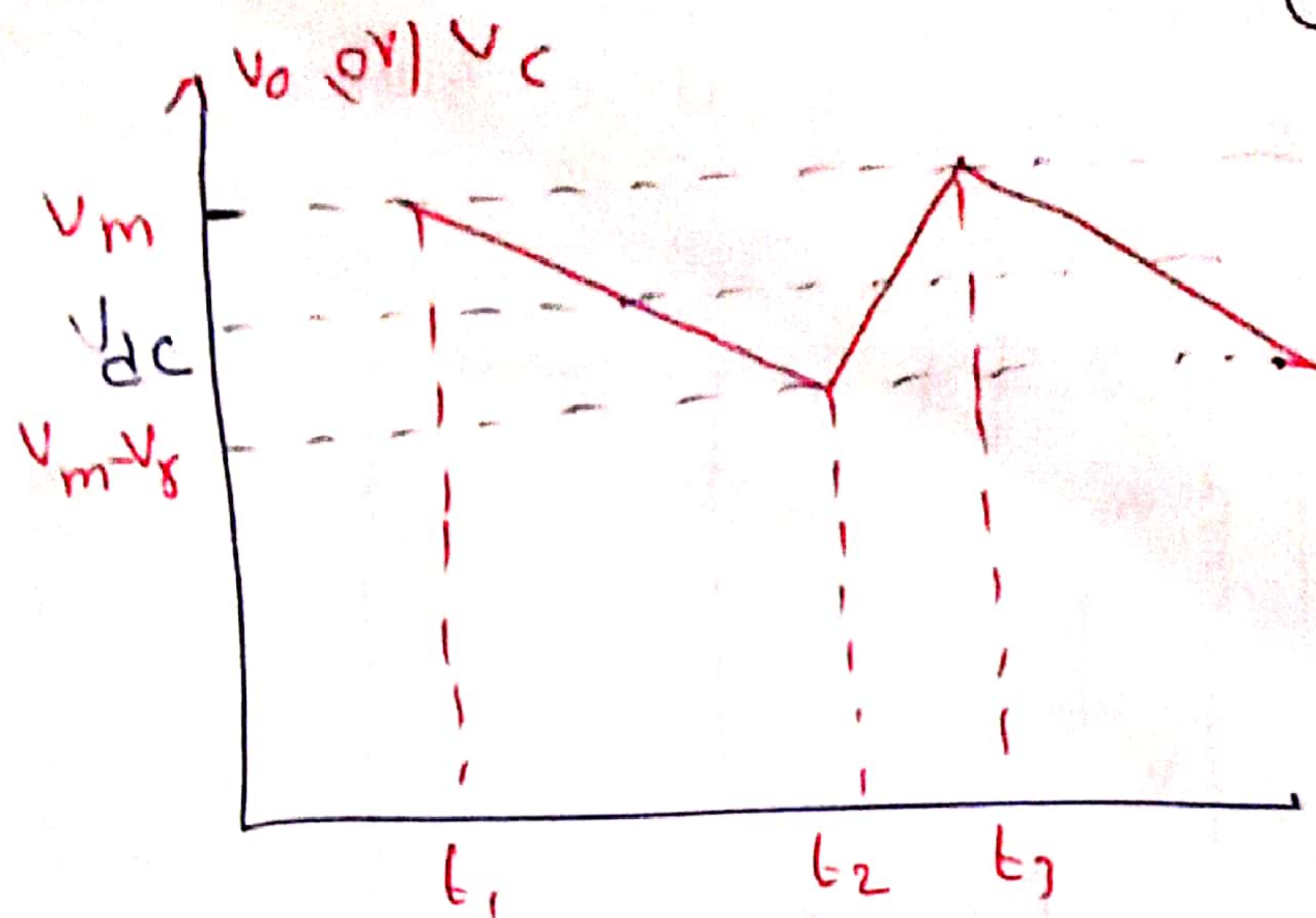
$$CV_r = \frac{I_{DC}}{f_0}$$

$$\boxed{V_r = \frac{I_{DC}}{f_0 C}} = \text{peak to peak ripple voltage}$$

$$\text{peak ripple voltage} = \frac{V_r}{2}$$

Rms value of
triangular

$$\text{wave is} = \frac{V_m}{\sqrt{3}}$$



$$\text{Rms ripple voltage} = \frac{V_r/2}{\sqrt{3}} = \frac{V_r}{2\sqrt{3}}$$

$$V'_{rms} = \text{Rms ripple voltage} \times$$

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

$$V'_{rms} = \frac{I_{DC}}{50 C 2\sqrt{3}}$$

$$V'_{rms} = \frac{I_{DC}}{2\sqrt{3} 50 C R_L}$$

$$V'_{rms} = \frac{V_{DC}}{2\sqrt{3} 50 C R_L}$$

$$\gamma = \frac{V'_{rms}}{V_{DC}} = \frac{1}{2\sqrt{3} 50 C R_L}$$

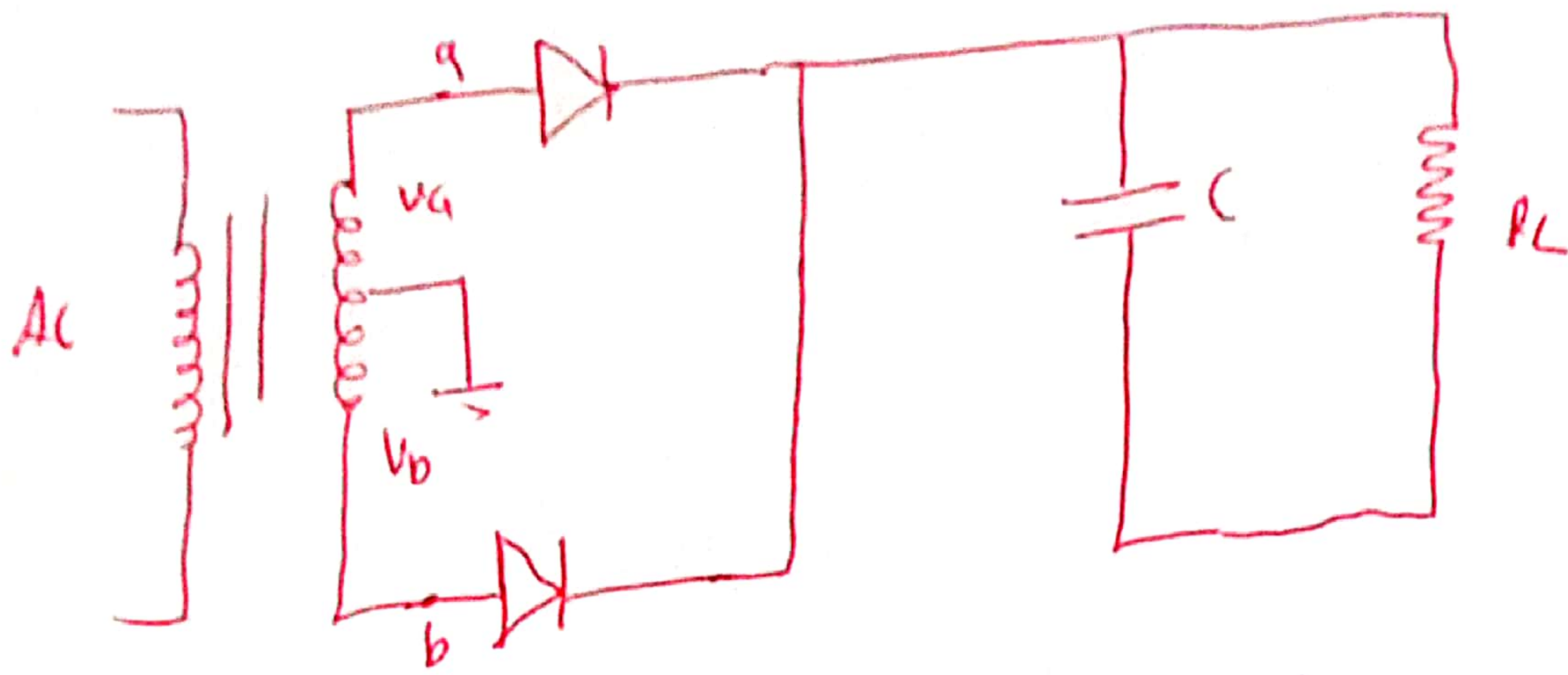
To achieve smaller ripple factor, capacitor filter should be used when R_L is very large.

from o/p wave form

$$V_{DC} = V_m - \frac{V_r}{2}$$

$$V_{DC} = V_m - \frac{I_{DC}}{250 C}$$

FWR with capacitive filter



$0 < t < t_1$

capacitor charges through D_1 & v_c follows v_a .

$t_1 < t < t_2$

capacitor slowly discharges through R_L and v_c reduces upto $V_m - V_r$

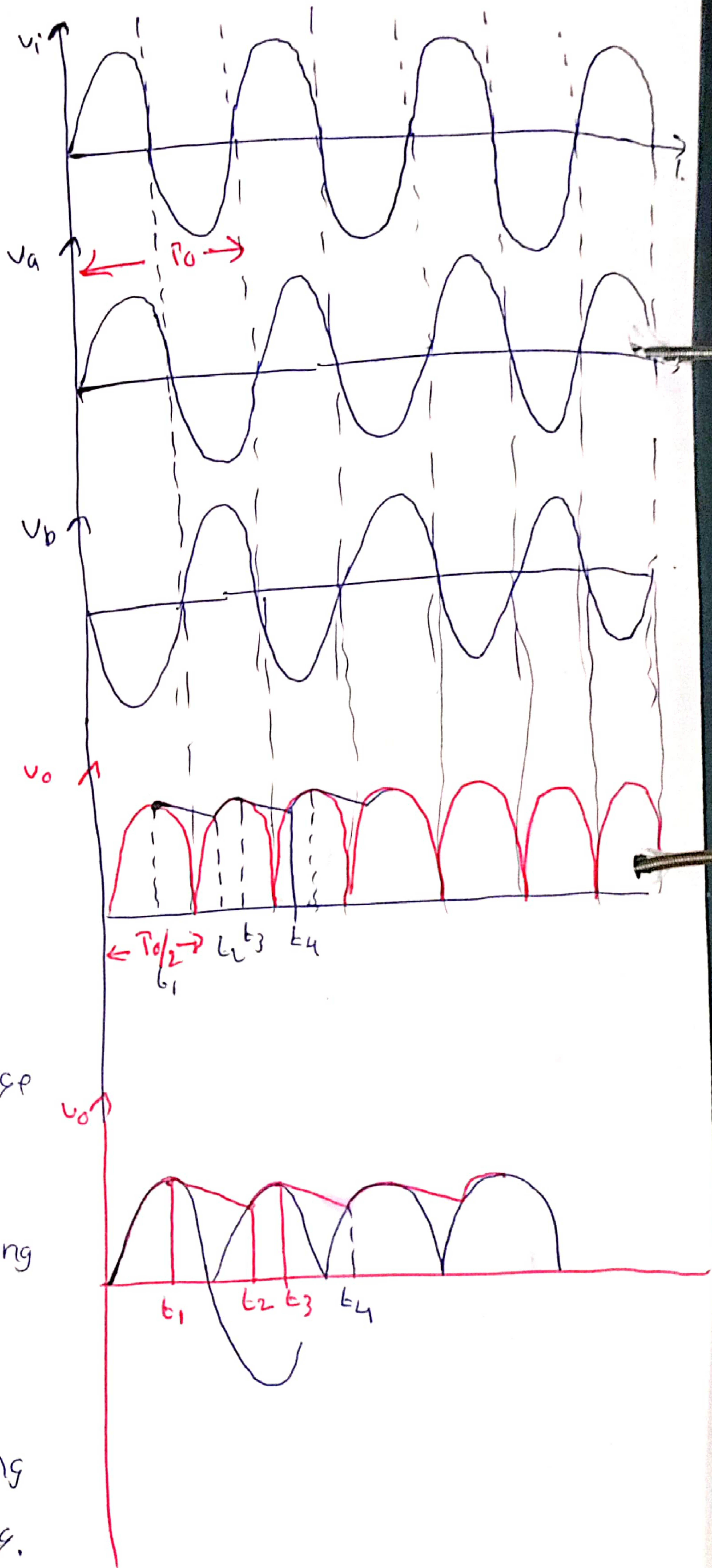
$t_2 < t < t_3$

capacitor charges through D_2 & v_c follows v_b

$t_3 < t < t_4$

capacitor has slow discharge through R_L .

Thus above process, charging through D_1 & discharging through R_L , charging through D_2 & discharging through R_L keeps repeating.



$$t_2 - t_1 = T_{\text{discharge}}$$

$$t_3 - t_2 = T_{\text{charge}}$$

$$T_{\text{discharge}} + T_{\text{charge}} = \frac{T_0}{2}$$

$$\text{since } T_{\text{discharge}} \gg T_{\text{charge}}$$

$$T_{\text{discharge}} = \frac{T_0}{2}$$

$$\text{charge lost} = \text{charge gained}$$

$$\begin{aligned} \Delta Q_1 &= C \Delta V, & \Delta Q_2 &= I_{DC} \times \frac{T_0}{2} \\ &= C V_r \end{aligned}$$

$$C V_r = I_{DC} \frac{T_0}{2}$$

$$V_r = \frac{I_{DC} T_0}{2C} = \frac{I_{DC}}{250C}$$

$$\text{peak ripple} = \frac{V_r}{2}$$

$$V_{rm} = \frac{V_m}{\sqrt{3}} = \frac{V_r}{2\sqrt{3}}$$

$$V_{rms} = \frac{I_{DC}}{4\sqrt{3}50C}$$

$$= \frac{V_{DC}}{4\sqrt{3}50C R_L}$$

$$\boxed{\gamma = \frac{V_{rms}}{V_{DC}} = \frac{1}{4\sqrt{3}50C R_L}}$$

$$V_{DC} = V_m - \frac{V_r}{2}$$

$$V_{DC} = V_m - \frac{I_{DC}}{450C}$$