EICoM
ELECTRICAL COMPUTER MECHATRONICS

الكترونيات ١

م.زهرة غانم

للطالبة المبدعة

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إرادة - ثقة - تغيير

DATE: 14th/Jul NO: ece1 chapter „1"

Semiconductors:-
* 4th group of periodic table

Conductors:-
* 1st, 2nd, 3rd groups of periodic table

Insulators:-
* 5th, 6th, 7th groups of periodic table.

conduction band
$C_B \rightarrow E_c$

E_g gap

E_g:- Energy gap

velence band
$V_B \rightarrow E_v$

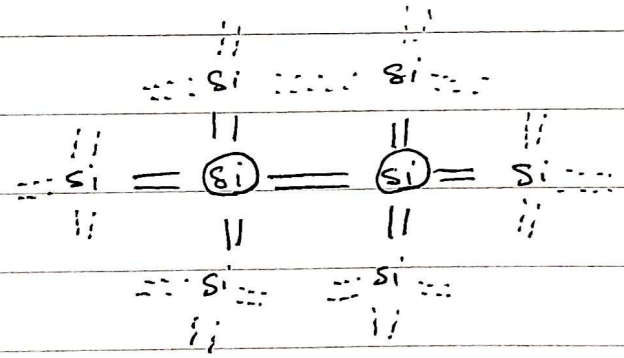
$E_c = E_v + E_g$

ex of sc :- Si, Ge
$E_{g_{Si}} = 1.16\,ev$ $E_{g_{Ge}} = 0.6\,ev$

$E_g = 0\,ev$
$E_c = E_v$

$E_g = (2 \rightarrow 6)\,ev$

⇒ Covalent Band :-



pure semiconductor intrinsic

n_i = number of electrons in pure sc.

$n_i = BT^{3/2} e^{-E_g/2KT}$

T :- Temp in Kelven.

holes :- positive charge (gap)

P_i = number of holes

$n_i = P_i$ ⇝ in pure sc.

Concentration # of carriers in pure sc is low.

DATE : NO :

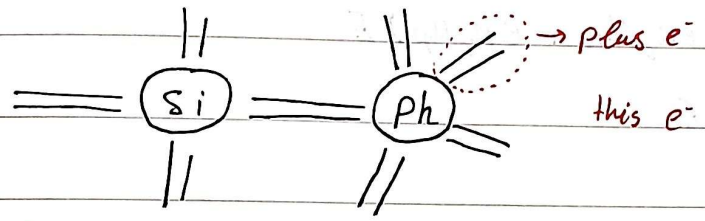
⇒ Impurity :-

use 3rd & 5th groups of periodic table.

$3^{rd} \rightarrow B$ $5^{th} \rightarrow Ph / Ar$

Doners :-

5th group of periodic table. Ph / Ar



this e⁻ go to the conduction band.

* Add free electrons: $n > n_i$ $n > P_i$

* Conelation of dopant : N_d $N_d > P_i$

$$N_i^* = \underbrace{N_i}_{\text{exists from the beginning.}} + N_d$$

* حركة التيار عكس الجمال

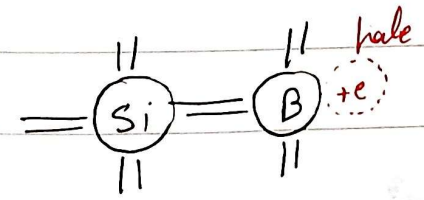
تيار اصطلاحي

$\rightsquigarrow n_o P_o = (n_i)^2$

* If we add doners :- $N_d >> n_o$ $P_o = \frac{n_i^2}{n_o}$ so this n-type

Acceptor :-

3rd group of periodic table. B



Acceptor :- number of holes.

$P_o = N_a$ $n_o = \frac{n_i^2}{n_a}$

DATE : 15th/Jul NO : Lec 2

Drift current.

drift current density (J_n) = $e \cdot n \cdot \mu_n \cdot E$.

e :- charge n :- concentration

μ_n :-

$$J_p = e \cdot n \mu_p \cdot E$$

μ_p :-

$$J = J_n + J_p = (en\mu_n + en\mu_p) E \quad (A/cm^2)$$

$$= \sigma \cdot E = \frac{1}{\rho} E$$

σ :- Con

ρ :-

$$I = J \cdot A = \sigma \cdot E \cdot A \quad (A)$$

A :- cross section area (cm^2)

ex :- find J for si with Arsenic atoms with concentration $9 * 10^{16}$ cm^3 with E = 100 V/cm (μ_n = 1355, μ_p = 480)

$n_i = 1.5 * 10^{10}$ $A = 0.01\ cm^2$

n-type

$$p_0 = \frac{n_i^2}{N_d} = \frac{1.5 * 10^{10}}{9 * 10^{16}} = 2.5 * 10^3$$

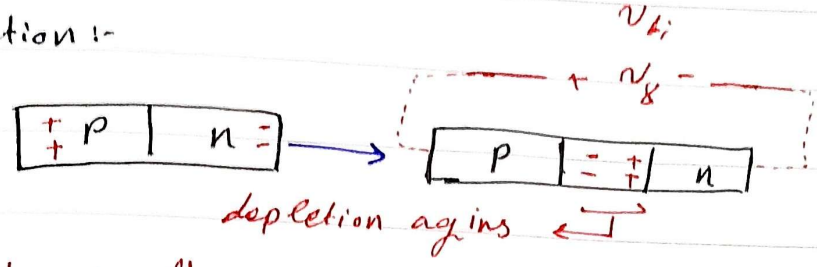
$$J = J_n + J_p = J_n = en\mu_n E$$

$$= 1944\ A/cm^3$$

$$I = J \cdot A = 1944 * 0.01 = 19.44\ A$$

DATE : NO :

Pn - Junction :-



V_{bi} :- built - in voltage = V_γ

for si $V_{bi} = 0.8 - 0.7\ V$

fo Ge $V_{bi} = 0.2 - 0.3\ V$

$$I_D = I_S\left[e^{\frac{V_D}{nV_T}} - 1\right]$$

V_T = Thermal voltage

= 26 mV

n = 1, high current level

$$V_{bi} = \frac{kT}{q} \ln \frac{N_a N_d}{n_i^2} = V_T \ln \frac{N_a N_d}{n_i^2}$$

n = 2, low current level

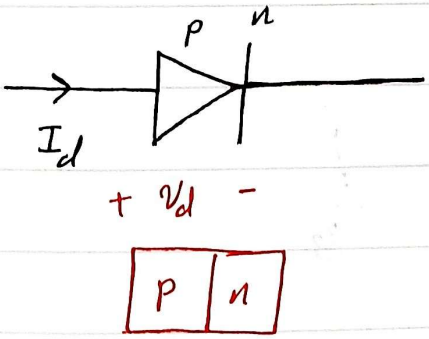
T :- temp in Kelven

$V_T = \frac{kT}{q} = 26\ mV$ at room temp $T = 300\ mK$

↳ Thermal voltage

Diode :-

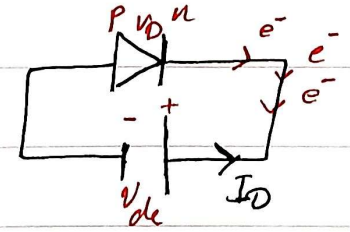
is an electronic elemnts from pn



Diode Biasing :-

Add DC Source to the bias diode.

1- Reverse-biased (R.B)



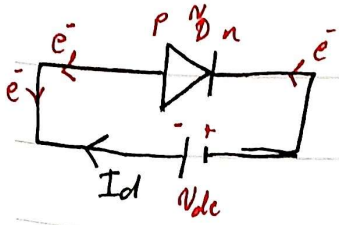
→ R.B → $I \approx 0$

I_S = saturation current = $1 * 10^{-19}$

↳ diode of → o.c

$V_D = -V_{dc}$

2- forward. biased (F.B)



F.B → Pn → Act as short circuits diode or

for ideal → $V_D = 0$

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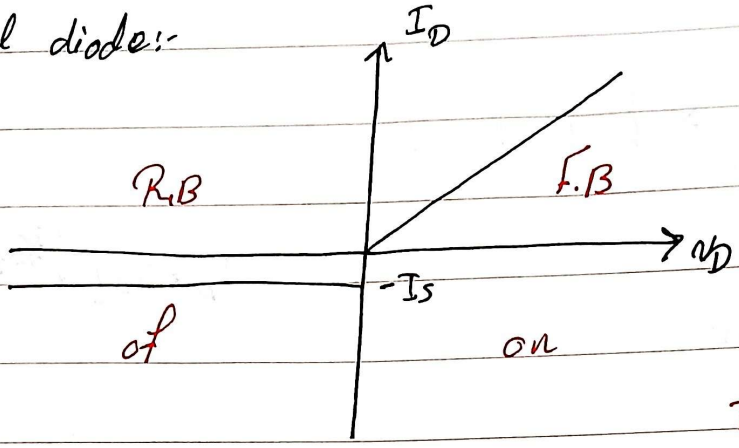
for ideal diode:-

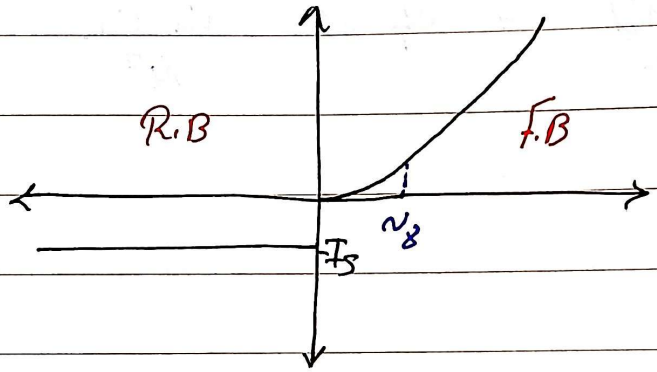


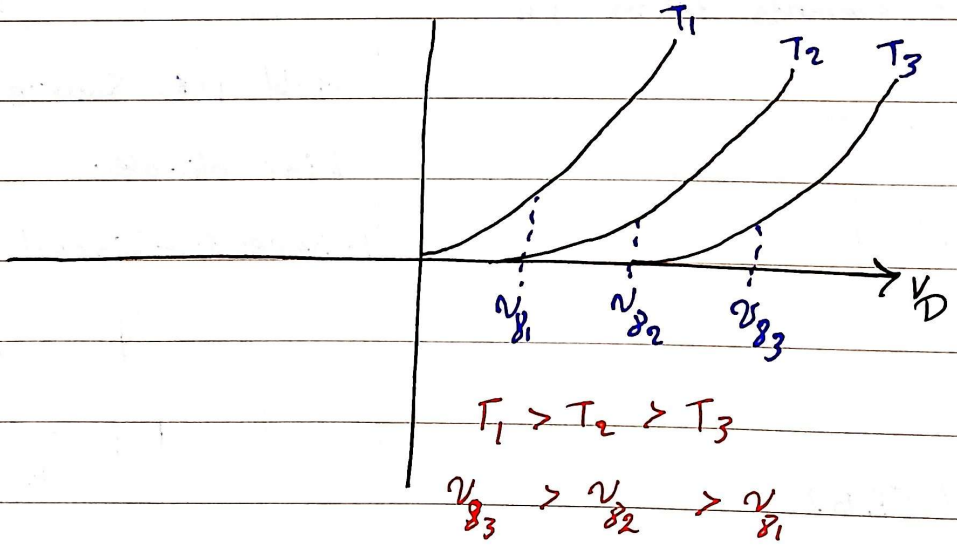
of on

* I_S depend on temp

$T \propto I_S \propto \frac{1}{V_D}$

for non ideal diode:-





$T_1 > T_2 > T_3$

$V_{\gamma_3} > V_{\gamma_2} > V_{\gamma_1}$

DATE : NO :

example:- pn-Junction , $I_S = 10^{-14} A$, $n = 1$, $V_T = 26mV$

find I_d,

1- $V_D = 0.7V$ → diode on

$$I_D = I_S \left[e^{\frac{V_D}{nV_T}} - 1 \right] = 5mA$$

2- if $V_D = -0.7V$ d pn-Reversed biased

Diode off → o.c

$I_D \approx -I_S$

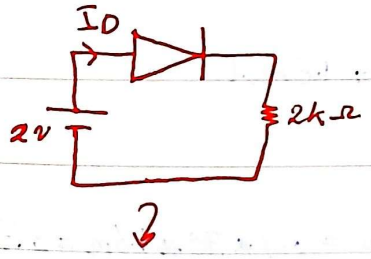
DC for diode circuits:-

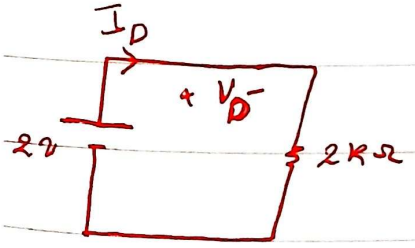
Piece wise method :-

*Ideal diode

1. F.B → Diode on → S.C

$V_D = 0$ $I_D > 0$

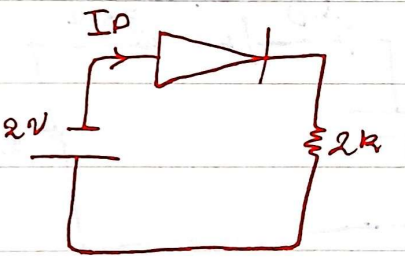


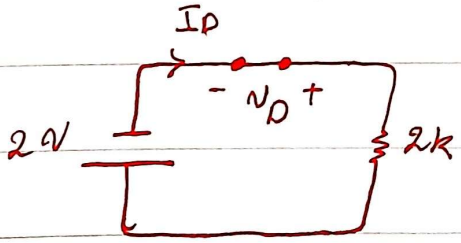


$$I = \frac{V}{R} = \frac{2}{2k} = 1mA$$

2. R.B → Diode off → o.c

$I_D = 0$ $V_D < 0$



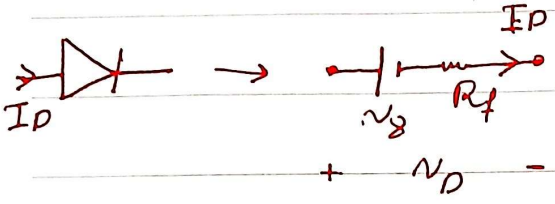


$V_D + 2 = 0 \Rightarrow V_D = -2V$

DATE : NO :

*non-Ideal diode

1. F.B → Diode on



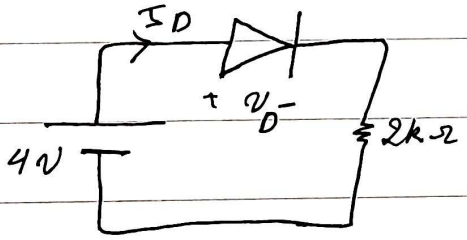
$V_D = V_\gamma + I_D R_f$

2. R.B → Diode off

$V_D < 0$

$I_D \approx -I_S$

Example:-



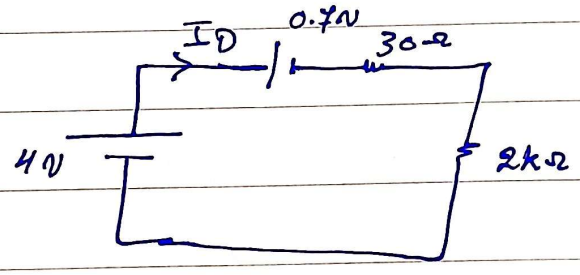
1- Ideal diode.

F.B → diode on → S.C

$V_D = 0$ $I_D = \frac{V}{R} = \frac{4}{2k} = 2mA$

$P = V_D I_D = 0$ watt

2- Non-Ideal diode. $V_\gamma = 0.7V$ $r_f = 30\Omega$

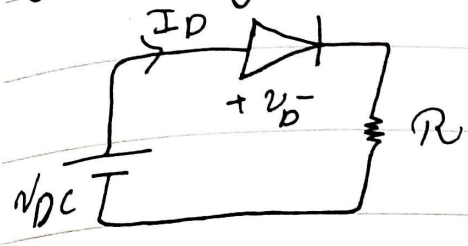


$I_D = \frac{4 - 0.7}{30 + 2k} = 1.6mA$

$V_D = V_\gamma + I_D r_f = 0.7 + 30 * 1.6m = 0.75V$

$P = V_D I_D = 0.7 * 1.6m = 1.12m$ watt

Graphically

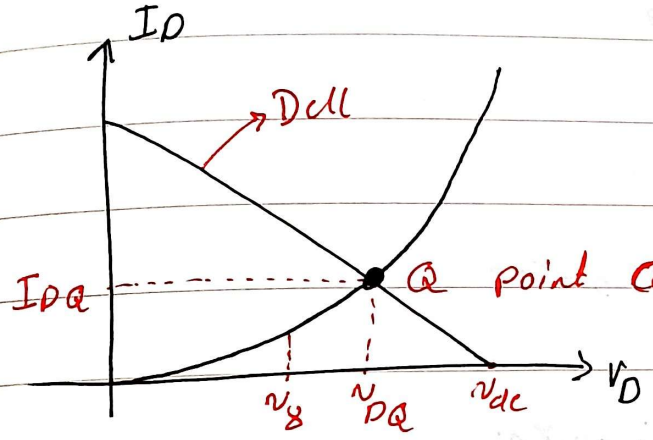


$v_D + RI_D - v_{dc} = 0$

$v_{dc} = v_D + RI_D$

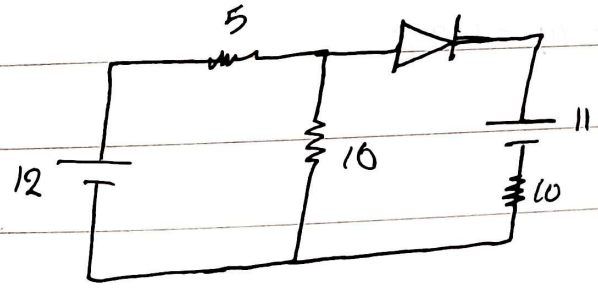
if $I_D = 0 \rightarrow v_D = v_{dc}$ (x)

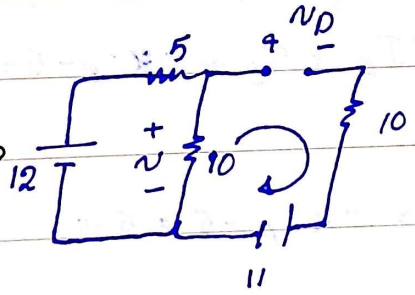
if $v_D = 0 \rightarrow I_D = \frac{v_{dc}}{R}$ (y)



Dc load line . $v_D \propto I_D$

ex:-





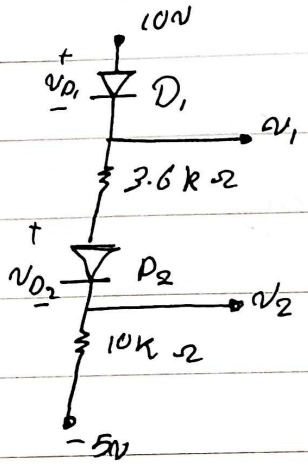
$v_D + 11 - v = 0$ $\qquad v = \frac{10}{10+5} * 12 = 8v$

$v_D = -3$

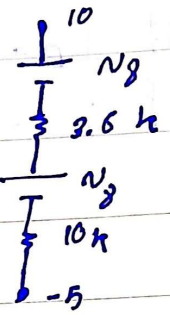
$v_D < 0 \rightarrow$ diode off $\rightarrow$ o.c

DATE : NO :

ex:- $V_\gamma = 0.7\,V$



Suppose diode on ⇒ S.C



$$-10 + V_\gamma + 3.6\,k I_D + V_\gamma + 10\,k I_D - 5 = 0$$

$$I_D = 1\,mA$$

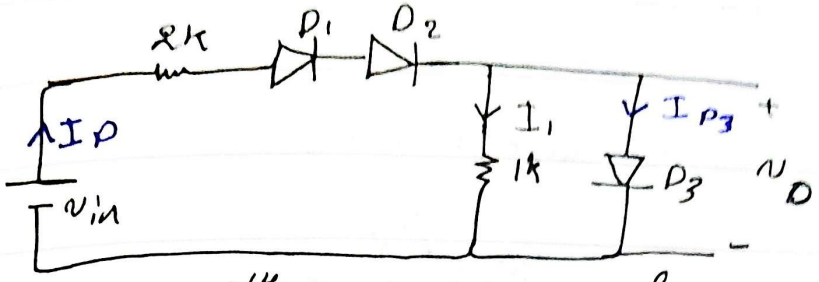
$$-10 + 2V_\gamma + 13.6 - 5 = 0 \Rightarrow V_\gamma = 0.7\,V$$

$$-10 + V_\gamma + v_1 = 0 \Rightarrow v_1 = 9.3\,V$$

$$3.6 I_D + V_\gamma + 10 k I_D - 5 = v_1 \Rightarrow v_1 = 9.3\,V$$

$$v_2 = 10\,k I_D - 5 = 5\,V$$

Ex:-



If $I_S = 10^{-14} A$ $\quad v_o = 0.6$ $\quad$ find v_i , I_1

$$I_{D_3} = I_S \, e^{\frac{v_D}{V_T}} = v_o = 0.6$$

$$I_{D3} = 0.1 \, mA$$

$$I_1 = \frac{v_{D3}}{1k} = \frac{0.6}{1k} = 0.6 \, mA$$

$$I_D = I_1 + I_{D3} = 0.7 \, mA$$

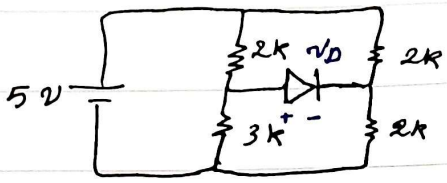
$$I_{D_1} = I_{D_2} = I_S \, e^{\frac{v_{D_1}}{V_T}} = 0.64 V = I_D$$

$$-v_{in} + 2k I_D + v_{D1} + v_{D2} + v_o = 0$$

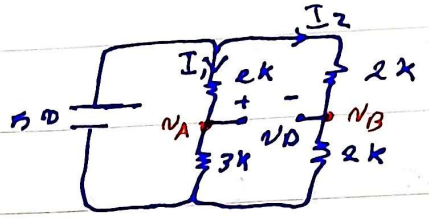
$$v_{in} = 3.3 \, v.$$

DATE : NO :

ex: $V_\gamma = 0.6\,V$, find I_D , V_D



suppose diode off → O.C



$$I_1 = \frac{5}{(2+3)k} = 1\,m$$

$$I_2 = \frac{5}{4k} = 1.25\,m$$

$V_D = V_A - V_B \rightarrow V_A = I_1 * 3k = 3\,V$ $\quad V_B = I_2 * 2k = 2.5\,V$

$V_D = 3 - 2.5 = 0.5\,V$

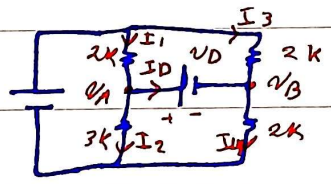
$V_D < V_\gamma \rightarrow$ diode off → O.C

so $V_D = 0.5\,V$ $\quad I_D \approx 0$

if $V_\gamma = 0.3\,V$

$V_D = 0.5 > V_\gamma = 0.3 \rightarrow$ diode on → S.C

$V_D = V_\gamma = 0.3$



$I_1 = I_D + I_2$, $I_3 = I_D + I_4$

$$\frac{5 - V_A}{2k} = I_D + \frac{V_A}{2k} \quad \ldots\ldots ①$$

$V_A - V_B = V_D = 0.3\,V \ldots ③$ $\quad \frac{5 - V_B}{2k} + I_D = \frac{V_B}{2k} \quad \ldots\ldots ②$

$V_A = 2.2\,V$, $V_B = 2.6\,V$, $I_D = 0.1\,mA$

chapter „2" :- Diodes Applications. DATE : NO :

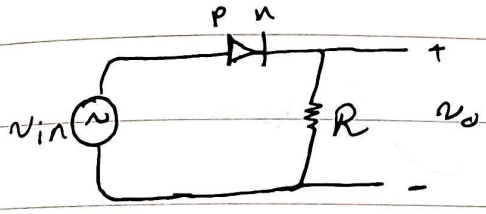
⇒ Diodes Applications :-

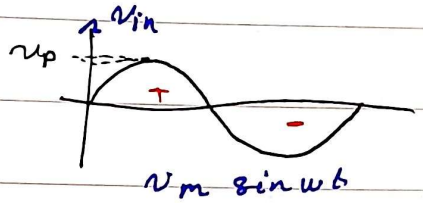
1. HWR 2. FWR 3. clipper 4. power supply.

Rectifier :- convert AC signal voltage to DC voltage

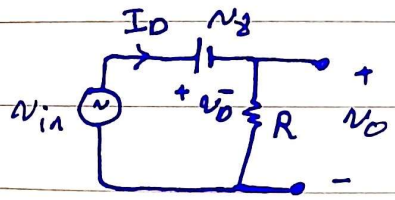
type rectifier : 1. half wave 2. full wave

HWR (Half wave rectifier) :-





⊕ cycle of v_{in} ($v_{in} > 0$) ($v_{in} > v_\gamma$) → D on → S.C



$v_D = v_\gamma$ const

$v_o = v_{in} - v_D = v_{in} - v_\gamma$

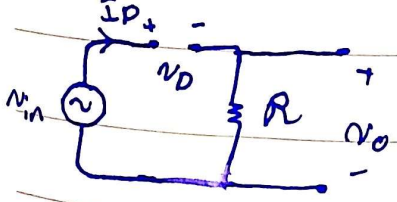
$v_{o\,max} = v_{in\,max} - v_\gamma = v_{max}$

$$I_D = \frac{v_{in} - v_\gamma}{R}$$

$$I_{D\,max} = \frac{v_{in\,max} - v_\gamma}{R} = \frac{v_{o\,max}}{R} = I_{max}$$

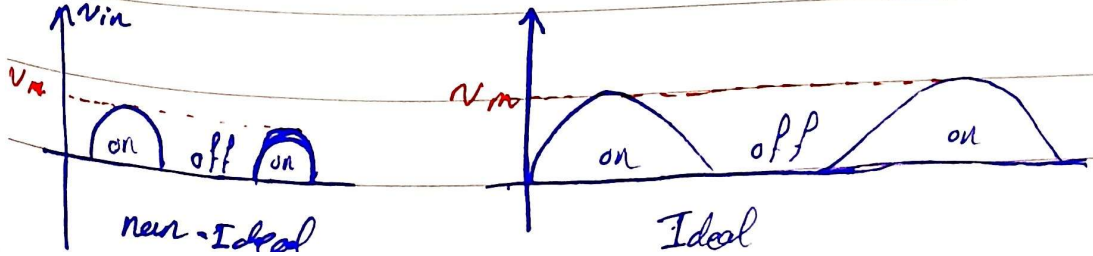
PIV = positive

⊖ cycle of v_{in} ($v_{in} < 0$) ($v_{in} < v_\gamma$) → D off → O.S



$v_D = v_{in}$ ✱ $I_D = 0$

$v_o = 0$



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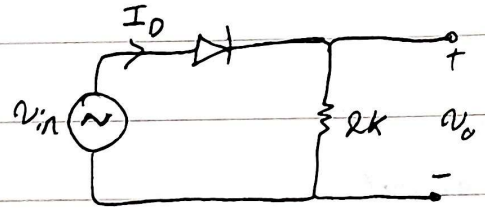
$$V_{avg} = \frac{1}{T}\int_0^T v(t) \qquad V_{o\,avg} = \frac{V_m}{\pi} = \frac{V_{o\,max}}{\pi}$$

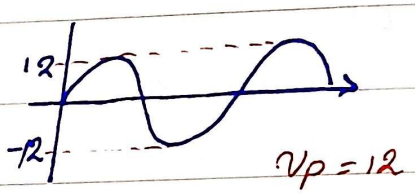
$$I_{o\,avg} = \frac{I_m}{\pi} = \frac{I_{D\,max}}{\pi}$$

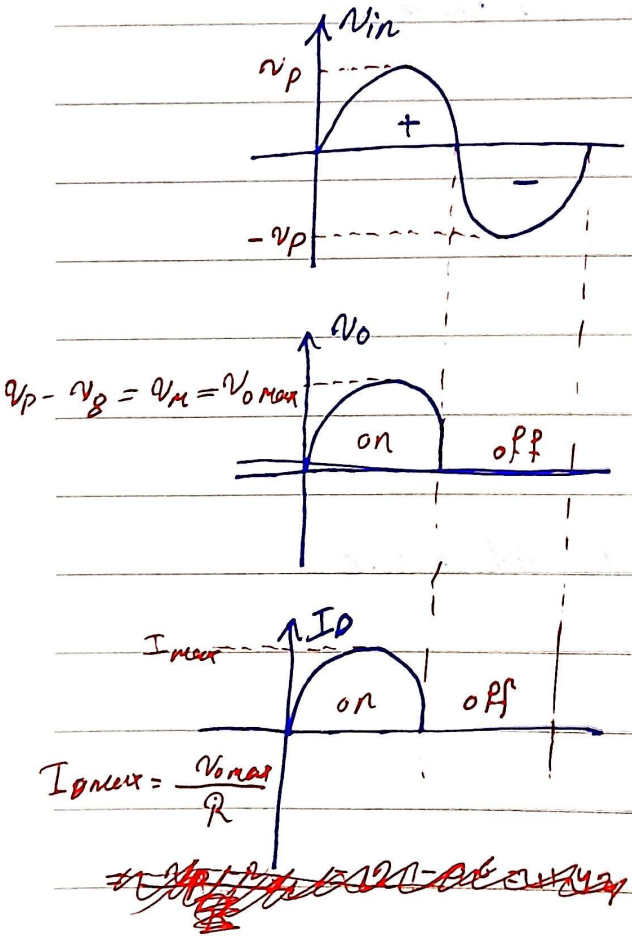
PIV :- peak inverse voltage , max reverse voltage — diode

$$V_{D\,off} \rightarrow PIV = V_o$$

ex:- $v_{in} = 12\sin\omega t$ $\quad V_\gamma = 0.6\ V$







$$I_D = \frac{v_{in} - v_\gamma}{R}$$

$$I_{D\,max} = I_m$$

$$I_m = \frac{V_p - V_\gamma}{R} = \frac{12 - 0.6}{R} = 5.7\,mA$$

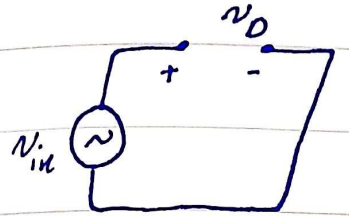
$$I_{D\,avg} = \frac{I_m}{\pi} = 1.8\,mA$$

$$V_m = 12 - 0.6 = 11.4\ V$$

$$P_{D\,avg} = I_{avg} * V_\gamma = 1.1\,mA$$

DATE : NO :

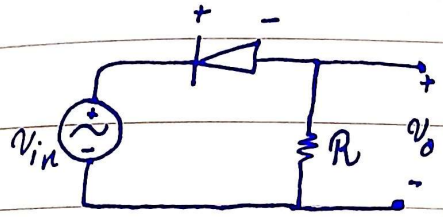
O.C

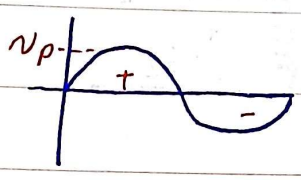


$v_{o\,off} = v_{in} = v_p$

$PIV = v_{in} =$

another half wave rectifier circuit





⊕ cycle → diode off → o.c

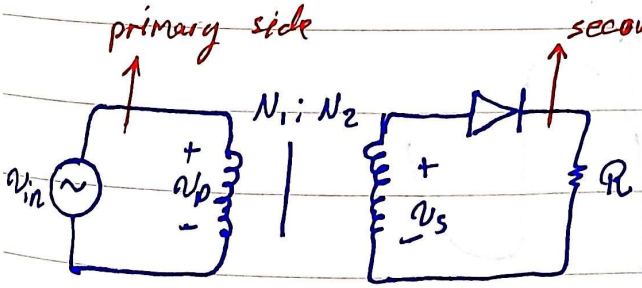
$v_o = 0$, $v_D = -v_{in}$ → $I_D = 0$.

⊖ cycle → diode on → s.c

$v_o = v_{in} + v_\gamma$ $\quad v_{o\,max} = v_m = v_{in\,max} + v_\gamma$ $\quad I_D = \frac{v_o}{R} = \frac{v_{o\,max}}{R}$

$v_{o\,avg} = -v_m/\pi$. $\quad I_{D\,avg} = \frac{I_{D\,max}}{R}$

Sometimes a transformer used at the input of rectifier

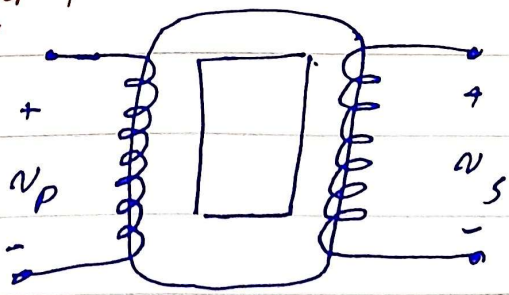


$v_{o\,max} = v_m = v_{s\,max} - v_\gamma$

$\frac{v_p}{v_s} = \frac{N_1}{N_2} = a$ → $v_p = \frac{N_1}{N_2} \cdot v_s$ → step up

step down

a :- transformation ratio

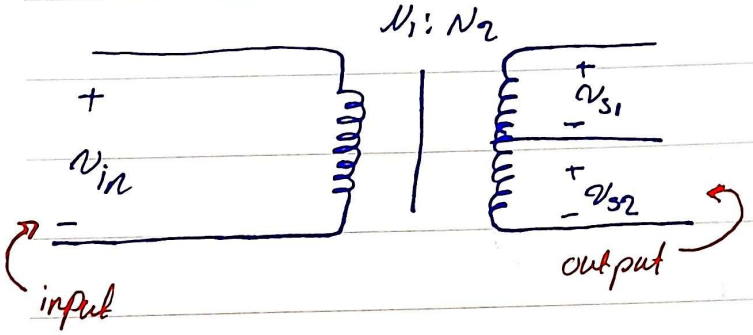


DATE : NO :

(FWR) full wave rectifier

type fwR :- 1. center tapped transformer 2. Bridge rectifi

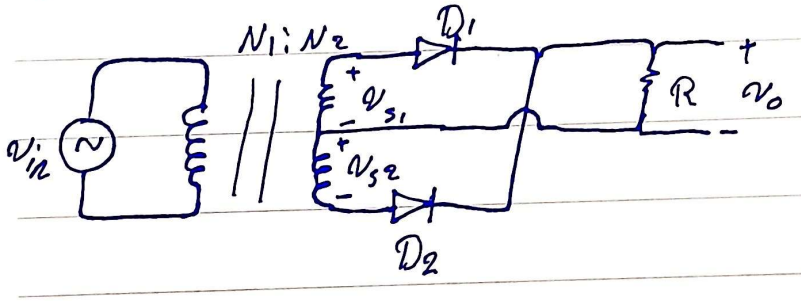
⇒ Centertapped transformes.



$v_s = \frac{N_2}{N_1} v_{in}$, $\phi = 180$

$N_{s1} = -v_{s2}$

$N_s = v_{s1} + v_{s2}$

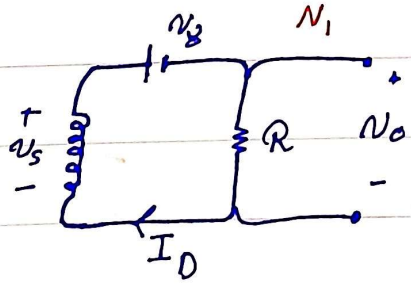


$v_{s1} = v_{s2}$

$v_{s1} = \frac{N_2}{N_1} v_{in}$

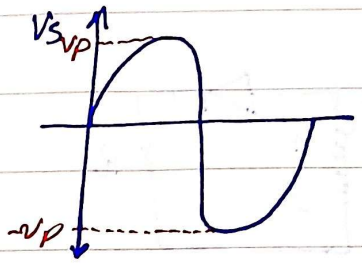
⊕ cycle of $v_{in} \rightarrow (v_s)$

$D_1 \rightarrow$ on s.c , $D_2 \rightarrow$ off o.c



$v_o = v_s - v_\gamma$

$v_{o max} = v_{s max} - v_\gamma = v_m$



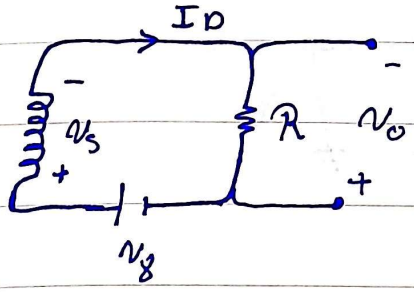
$I_D = \frac{v_o}{R}$, $I_{D avg} = \frac{v_{o max}}{R}$

DATE : NO :

⊖ cycle of $v_{in} \Rightarrow v_{s1}$ ⊖ , v_{s2} ⊕

D_1 → off , D_2 → on

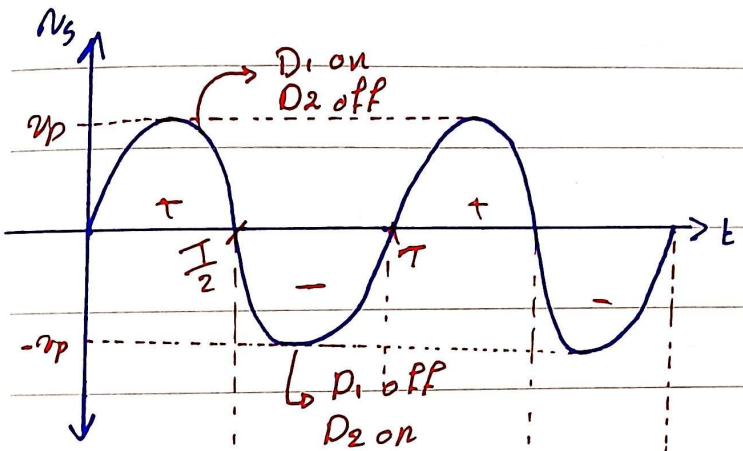
o.c s.c



$v_o = v_s - v_\gamma$

$v_{o\,max} = v_{s\,max} - v_\gamma$

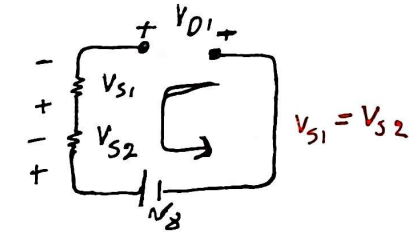
$I_{D_{max}} = \frac{v_{o\,max}}{R} = I_m$



v_s avg = 0

$f_o = \frac{1}{T}$

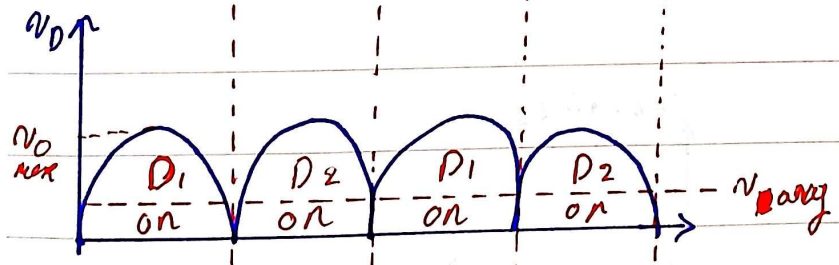
PIV for D_1 = PIV for D_2



$-V_{D_1} - V_{s1} - V_{s2} + V_\gamma = 0$

$V_{D1} = -2V_s + V_\gamma$

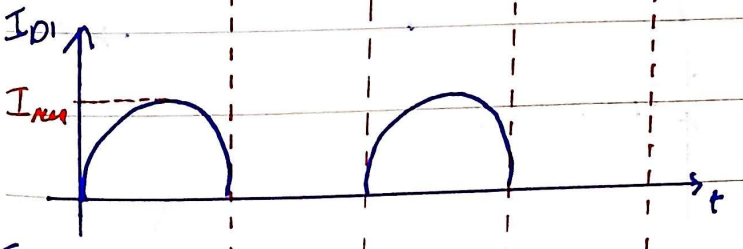
$PIV = 2V_s - V_\gamma$



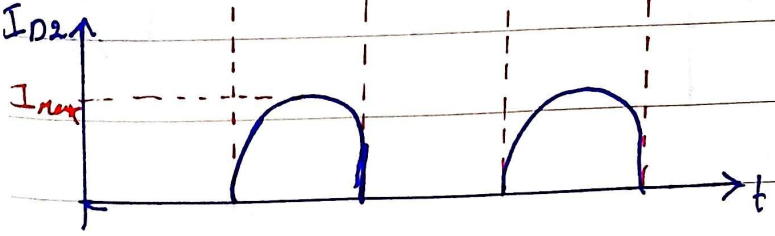
$v_{o\,max} = v_{s\,max} - v_\gamma = v_m = v_p$

$v_{o\,avg} = \frac{2 v_{o\,max}}{\pi}$

$f = \frac{2}{T}$



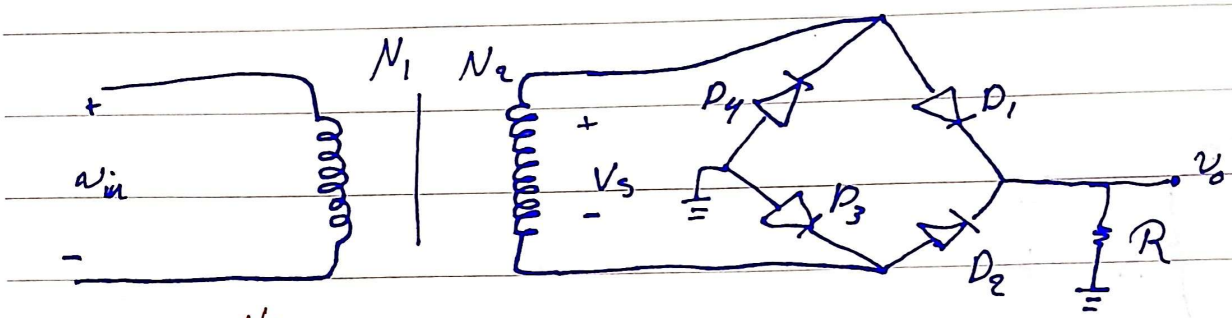
$I_{avg} = \frac{I_{max}}{\pi}$, $f = 2f_o$



$PIV = 2V_s - V_\gamma$

DATE : NO :

⇒ Bridge rectifier :-

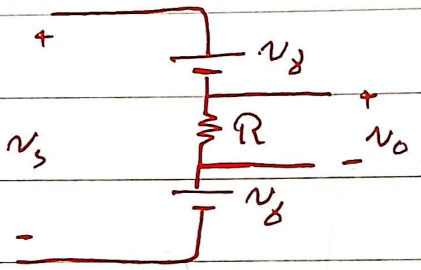


$$v_s = \frac{N_2}{N_1} v_{in}$$

⊕ cycle of v_{in}

$D_1, D_3 \rightarrow$ on $\rightarrow$ s.c

$D_2, D_4 \rightarrow$ off $\rightarrow$ o.c



$$v_o = v_s - 2v_\gamma$$

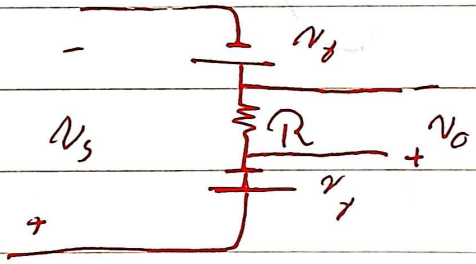
$$v_{o\,max} = v_{s\,max} - 2v_\gamma$$

$$PIV = v_s - v_\gamma$$

⊖ cycle of v_{in}

$D_1, D_3 \rightarrow$ off $\rightarrow$ o.c

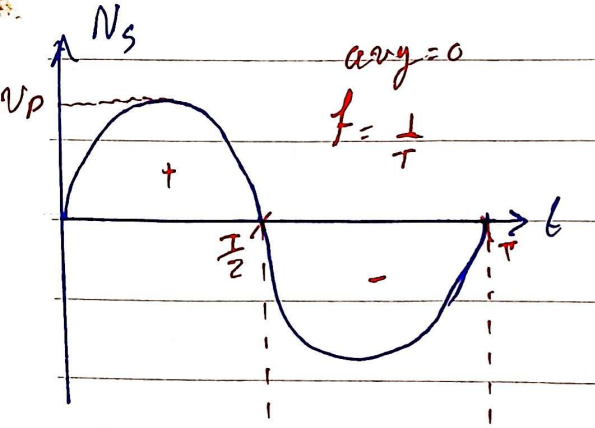
$D_2, D_4 \rightarrow$ on $\rightarrow$ s.c

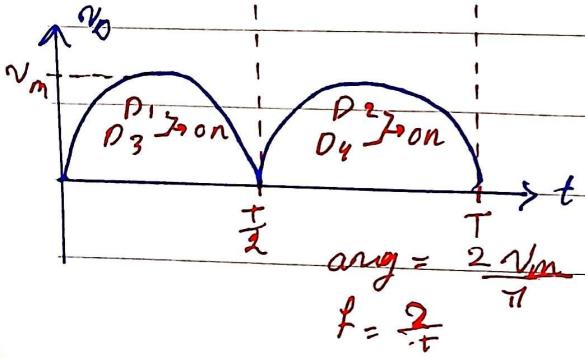


$$v_o = v_s - 2v_\gamma$$

$$v_m = v_{o\,max} = v_{s\,max} - 2v_\gamma$$

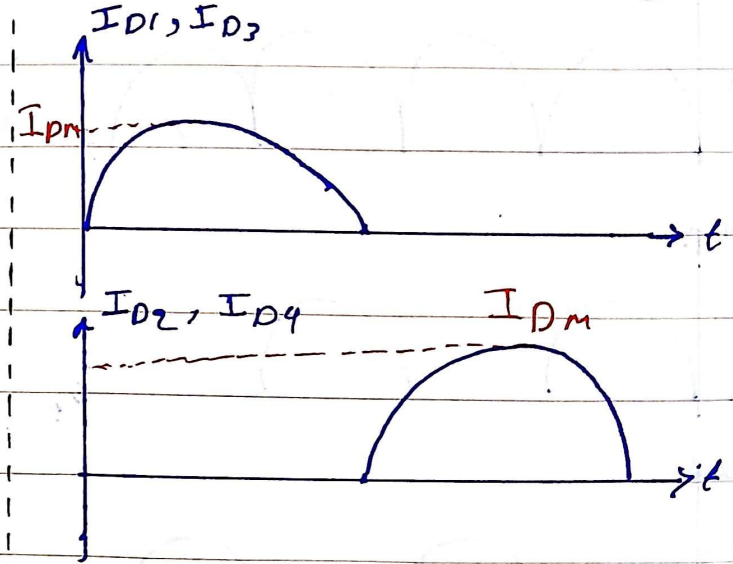
$$PIV = v_s - v_\gamma$$





$$avg = \frac{2v_m}{\pi}$$

$$f = \frac{2}{T}$$



$$avg = \frac{I_{DMax}}{\pi} = \frac{I_m}{\pi}$$

DATE : NO :

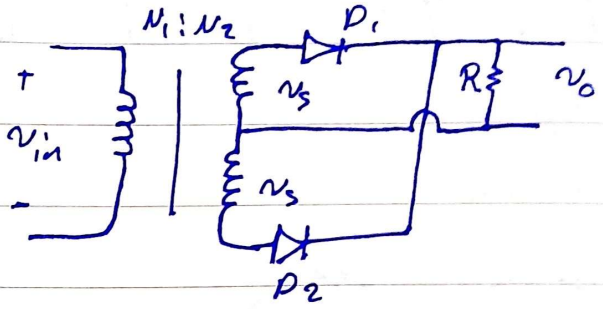
ex:- Design a FWR , $V_p = V_{omax} = 15\ V$

$V_{in} = 120\ V_{rms}$ $R = 100\ \Omega$ $V_\gamma = 0.7\ V$ using FWRB and center tapped.

1. center tapped:-

$V_{om} = 15 = V_s - V_\gamma \Rightarrow V_s = 15.7\ V$

$\frac{V_s}{V_{in}} = \frac{N_2}{N_1} = \frac{15.7}{120\sqrt{2}} = 10.8$



$PIV = 2V_s - V_\gamma = 30.7\ V$

$I_m = \frac{V_{omax}}{R} = \frac{15}{100} = 150\ mA$

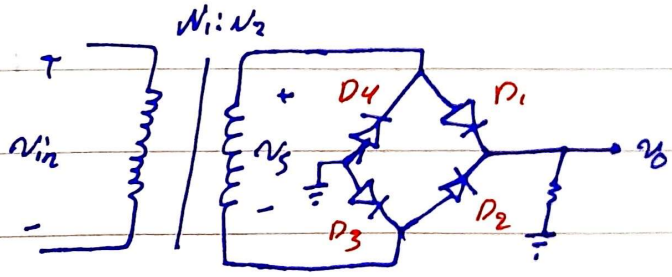
$P_{avg} = I_{aavg} \cdot V_\gamma = 33.4\ mW$

$I_{avg} = \frac{I_m}{\pi} = \frac{150}{\pi}\ m$

2. FWRB:-

$V_{omax} = V_s - 2V_\gamma \Rightarrow V_s = 16.4\ V$

$a = \frac{V_{in}}{V_s} = \frac{120\sqrt{2}}{16.4} = 10.31$



$PIV = V_s - V_\gamma = 15.7\ V$

$I_{Dmax} = \frac{V_m}{R} = \frac{150}{\pi}\ mA$

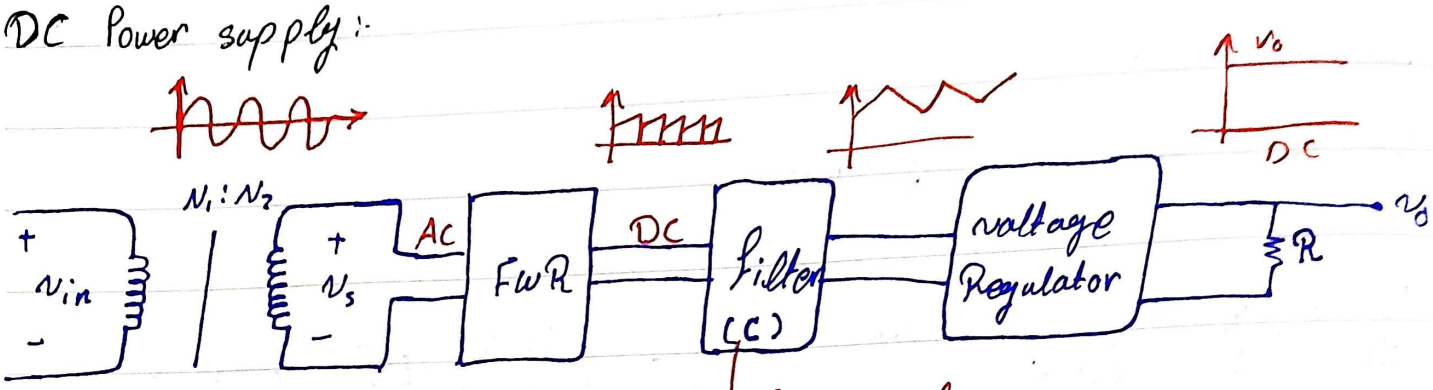
$I_{av} = \frac{I_m}{\pi} = \frac{150}{\pi}\ mA$

note that PIV less than center tapped.

$P_{avg} = I_{avg} * V_\gamma = 33.4\ mW$

DATE : NO :

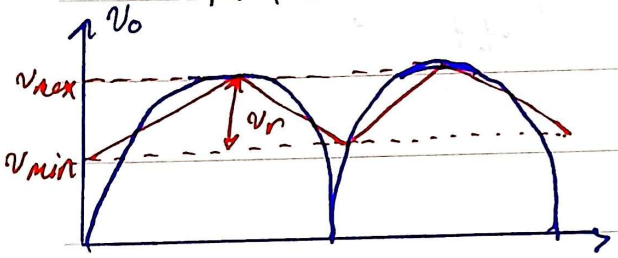
DC Power supply :



step down

Low pass filter

→ FWR

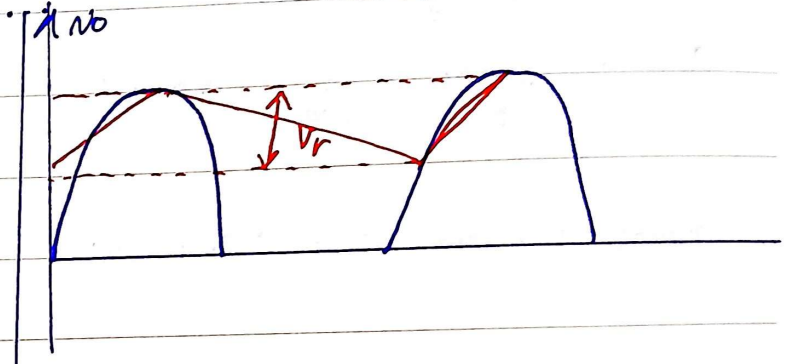


$V_r = V_{o\,max} - V_{o\,min}$

$V_r = \frac{V_{o\,max}}{2RfC}$

$V_{r\,HWR} > V_{r\,FWR}$

→ HWR



$V_r = V_{o\,max} - V_{o\,min}$

$V_r = \frac{V_{o\,max}}{fRC}$

$V_{r\,FWR} = \frac{1}{2} V_{r\,HWR}$

$C_{FWR} = \frac{1}{2} C_{HWR}$

DATE : NO :

ex:- Design FWBR $v_{o\,max} = 15\,v$, $f = 50\,Hz$, $R = 100\,\Omega$
$v_\gamma = 0.6\,v$, Ripple 5% , $v_{in} = 120\,v\,rms$.

$$v_{o\,max} = v_s - 2v_\gamma \Rightarrow v_s = 15.2\,v$$

$$\frac{N_1}{N_2} = \frac{v_{in}}{v_s} = \frac{120/\sqrt{2}}{15} = 10.5$$

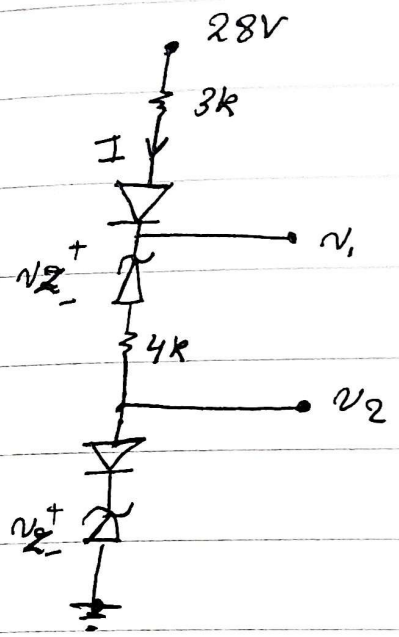
$$v_r = 5\% * v_{o\,max} = \frac{5 \times 15}{100} = 0.75\,v$$

$$v_r = v_{max} - v_{min} \Rightarrow v_{min} = 14.25\,v$$

$$v_r = \frac{v_{o\,max}}{2fRC} \Rightarrow C = \frac{v_{o\,max}}{2fRv_r} = 2000\,\mu f$$

$$PIV = v_s - v_\gamma = 15.6\,v$$

ex:-



$v_\gamma = 0.7\,V \qquad v_Z = 6.3\,V$

suppose diode on → S.C → $I_D > 0$

diode off → O.C → $v_D < 0$

$$-28 + 3I + v_\gamma + v_Z + 4I + v_\gamma + v_Z = 0$$

$I = 2mA = I_D > 0$ → diode on → S.C

$$-28 + 3I + v_\gamma + v_1 = 0 \rightarrow v_1 = 21.3\,V$$

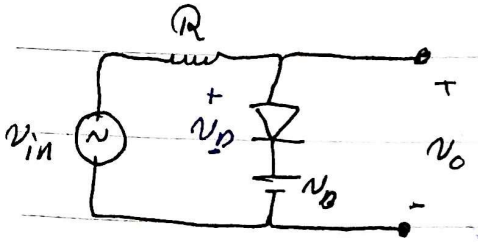
$$v_2 = v_\gamma + v_Z = 7\,V$$

3. Clipper Limiter

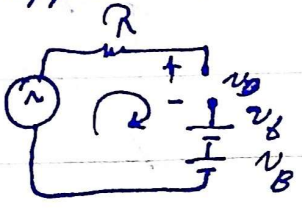
* Cutting a portion of AC input voltage.



Clipping value:- 1. value of battery. 2. direction of battery (polarity



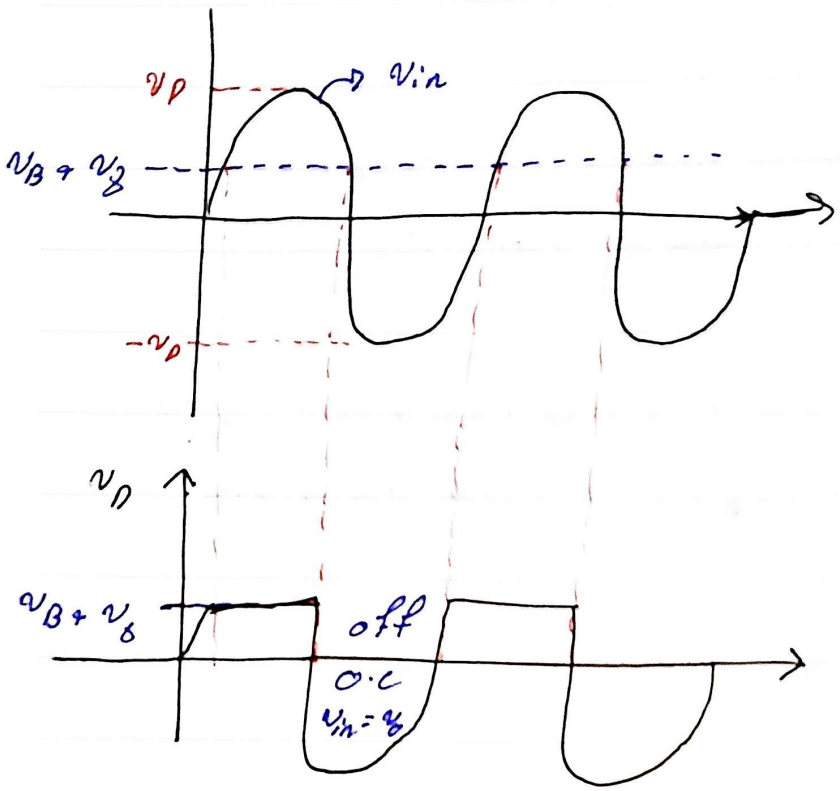
suppuse diode off → O.C



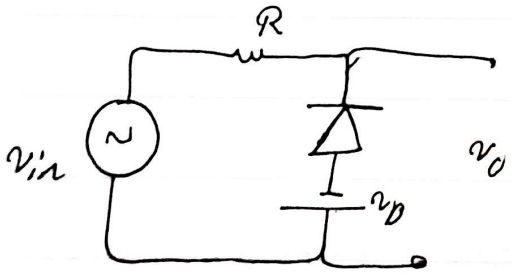
$$v_D = v_{in} - (v_B + v_\gamma) > 0$$

diode on if $v_D > 0 \rightarrow v_{in} > v_B + v_\gamma$, $v_o = v_B + v_\gamma$, $I_D = \frac{v_D}{R}$

if $v_D < 0 \rightarrow v_{in} < v_B + v_\gamma$, $v_o = v_{in}$, $I_D = 0$



⊕ clipper

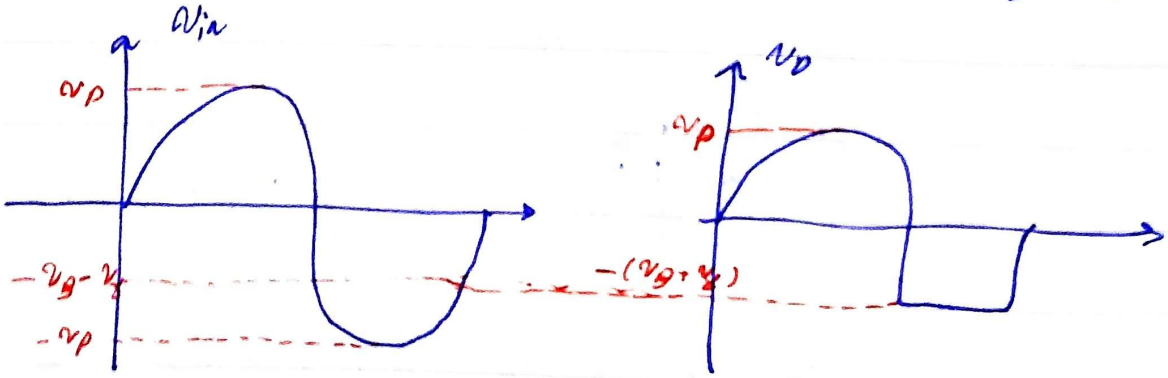


suppose diode off

$v_D = -v_{in} - (v_\gamma + v_B) > 0$

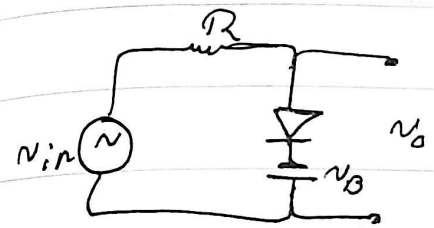
$v_D > 0 \Rightarrow v_{in} < -v_\gamma - v_B \Rightarrow v_o = -v_B - v_\gamma$

$v_D < 0 \Rightarrow v_{in} > -v_\gamma - v_B \Rightarrow v_{in} = v_o$



⊖ clipper

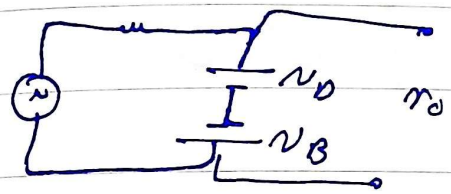
DATE : NO :



$-v_B + v_\gamma$

$v_{in} > v_\gamma - v_B \Rightarrow$ diode on

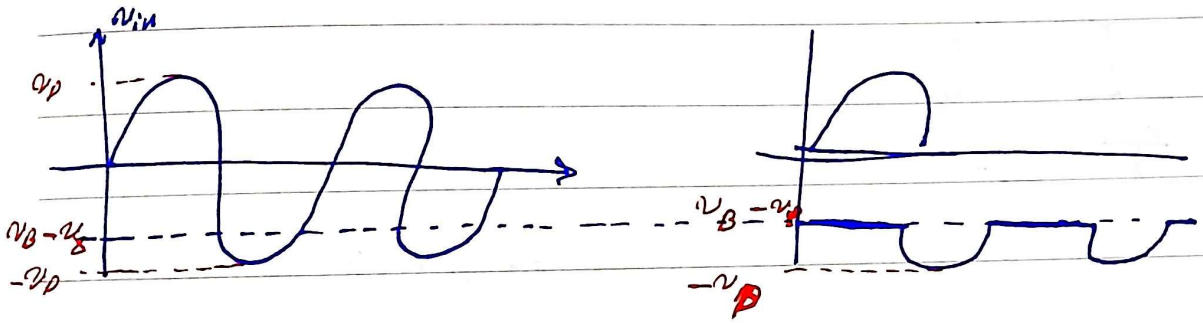
S.C $\Rightarrow v_o = -v_B - v_\gamma$



diode of

$v_{in} < v_\gamma - v_B$

$v_o = v_{in} \rightarrow$ O.C



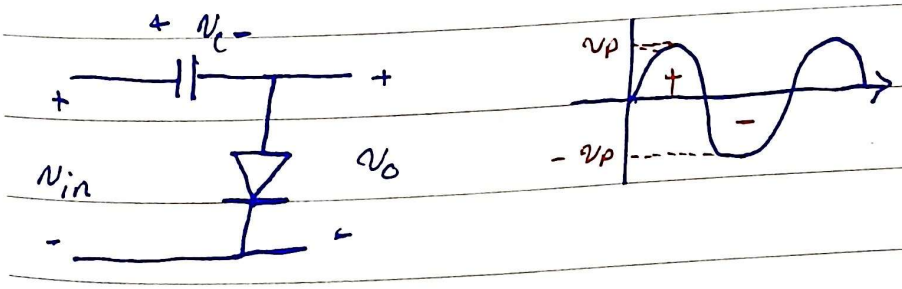
4. Clamper:

*change DC level for (v_{in}) shift

levels of clamper: 1. battery value 2. polarity

* capacitor to shift voltage.

* direction of diode → shift up or shift down.



@battery

@ cycle → diode on → S.C

capacitor charge

$v_c = v_p$

$(v_c = v_{in} - v_\gamma = v_p - v_\gamma)$

DATE : NO :

in blue non-ideal

in red ideal

⊖ cycle → diode off → o.c

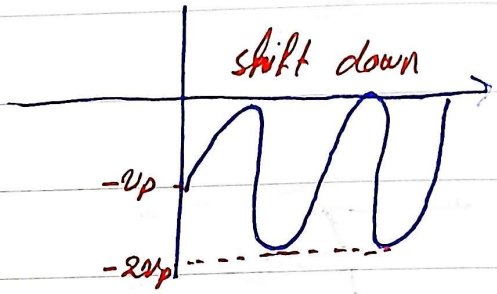
$v_o = v_{in} - v_C = v_{in} - v_p$

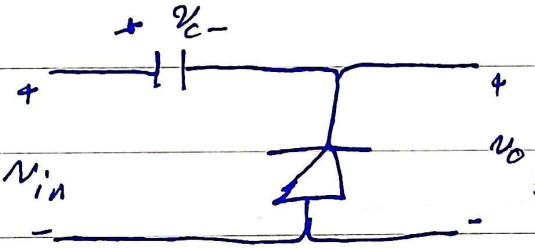
$v_o = v_{in} - v_p + v_\gamma$

$v_{in} = 0 \rightarrow v_o = -v_p \quad (-v_p + v_\gamma)$

$v_{in} = v_p \Rightarrow v_o = 0 \quad (v_\gamma)$

$v_{in} = -v_p \rightarrow v_o = -2v_p \quad (-2v_p + v_\gamma)$





capacitor charge → diode on (s.c)

⊖ cycle → diode on → s.c

$v_C = -v_p$

$v_C = -v_p + v_\gamma$

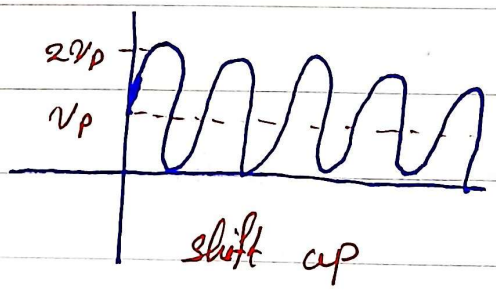
$v_o = v_{in} - v_C = v_{in} + v_p$

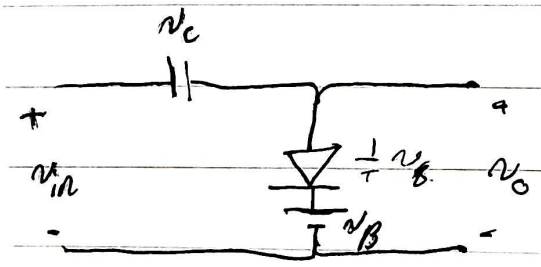
$v_o = v_{in} + v_p - v_\gamma$

$v_{in} = 0 \rightarrow \quad v_o = v_p$

$v_{in} = v_p \rightarrow v_o = 2v_p$

$v_{in} = -v_p \rightarrow v_o = 0$





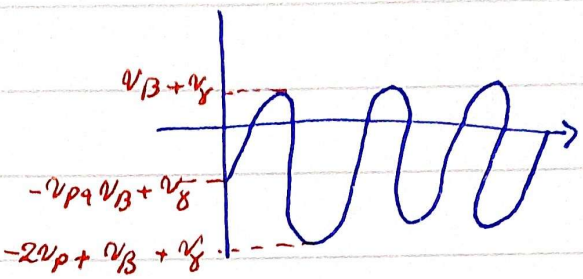
⊕ cycle → diode short

$v_C = v_{in} - (v_\gamma + v_B)$

$v_C = v_p - (v_\gamma + v_p)$

⊖ cycle → 0.C

$v_o = v_{in} - v_C = v_{in} - v_p + (v_\gamma + v_B)$

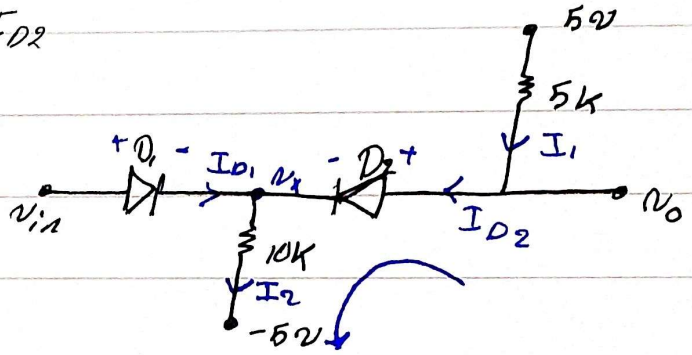


$v_{in} = 0 \rightarrow v_o = -v_p + (v_\gamma + v_B)$

$v_{in} = v_p \rightarrow v_o = v_B + v_\gamma$

$v_{in} = -v_p \rightarrow v_o = -2v_p + v_B + v_\gamma$

ex: $v_C = 0.7$ V find $v_{D1}, I_{D1}, v_{D2}, I_{D2}$



if $v_{in} = 4$

suppose diode on → S.C

$I_D > 0$

$-v_{in} + v_\gamma - v_\gamma + v_o = 0$

$v_{in} = v_o = 4$ V

$I_1 = \frac{5-4}{5k} = 0.2\,mA = I_{D2} > 0$ D_2 on S.C

$v_x = 10k\,I_2 - 5$

$-v_o + v_\gamma + v_x = 0$ $v_x = v_o - v_\gamma = 4 - 0.7 = 3.3$ V

$I_2 = 0.83\,mA$

$v_{D1} = 0.7 = v_\gamma$

$I_{D1} + I_{D2} = I_2 \rightarrow I_{D1} = 0.03\,mA > 0$

$v_{D2} = 0.7 = v_\gamma$

diode on S.C.