TIME & FREQUENCY DOMAIN REPRESENTATIONS

FT (Fourier Transform)
IFT

SIGNALS

- V
- I
- Q

(Type)

- Sine wave
- Square "
- Ramp
- . . .

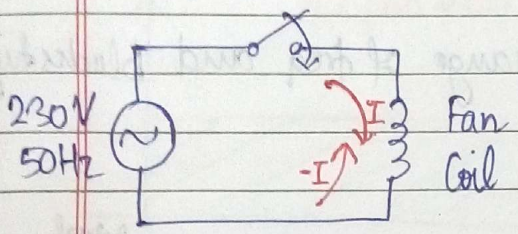
(Shape)

- Time domain
- Frequency domain

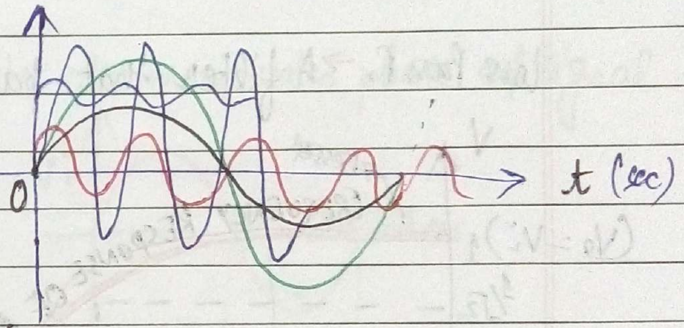
(Representation)

- Video
- Audio
- . . . .

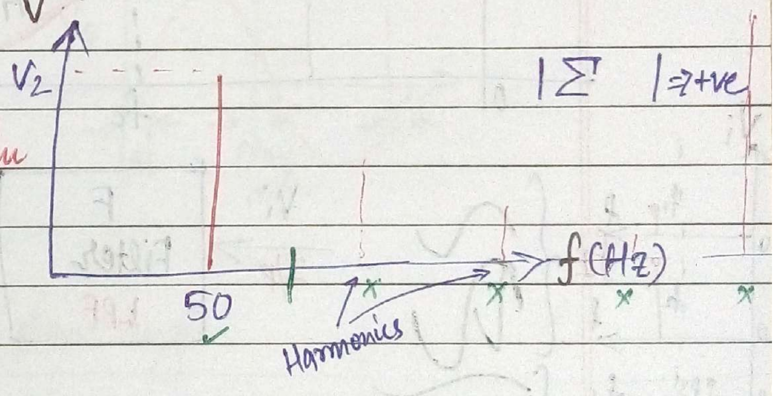
(Applications)



Time Domain

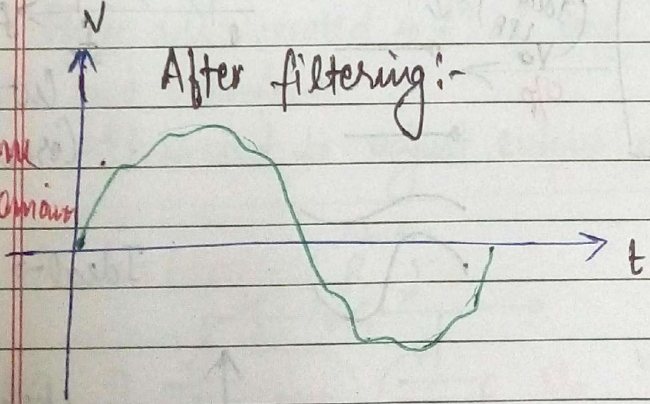


Freq. Domain



After filtering:-

Time Domain



FILTERS

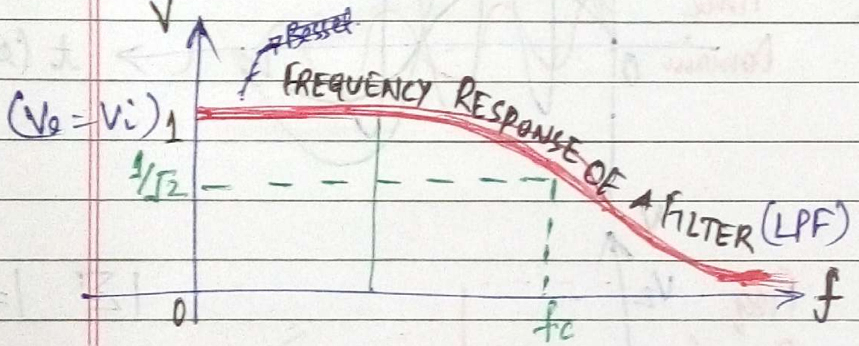
Group of Electronic circuits that accept certain band & reject certain other bands. (also, bands of frequency)

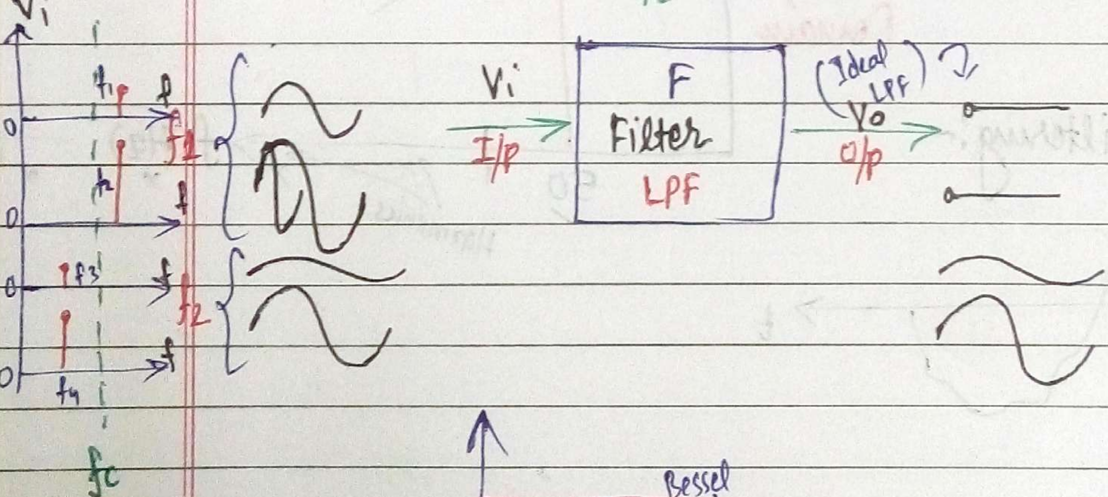
(If only R,L,C are used)

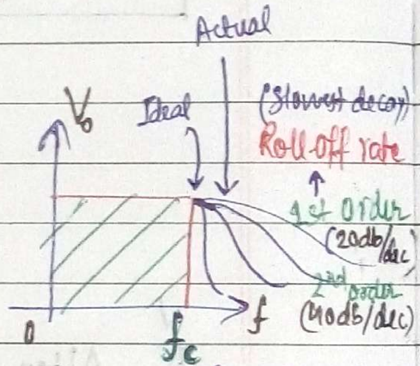
FILTERS

- **(Type)**
  - Low Pass
  - High Pass
  - Band Pass
  - Band Stop
  - All Pass
- **(Realization Components)**
  - RC
  - RL
  - RLC
  - LC
- **(Response)**
  - Butterworth → A, P
  - Chebyshev → A
  - Bessel → Generally A
- Passive
- Active → Semiconductor devices

Low Pass F. → A filter that passes low range of freq and blocks high freq.

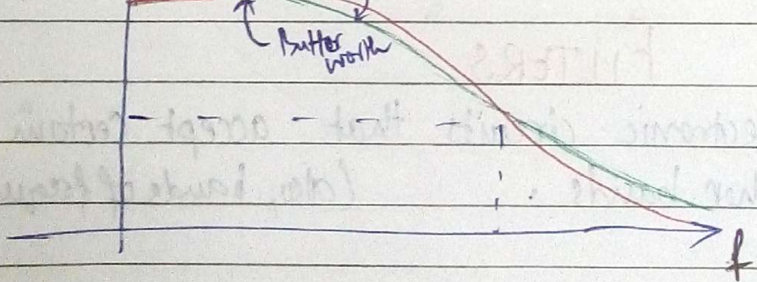


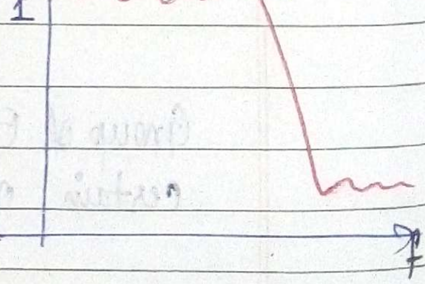


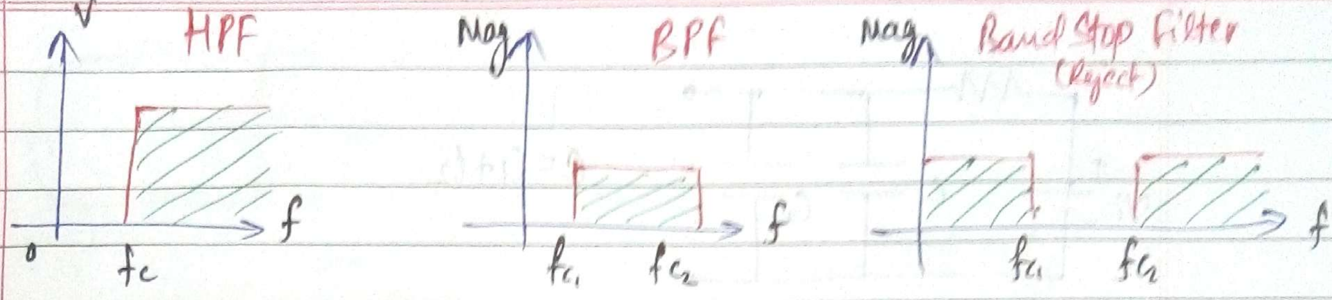


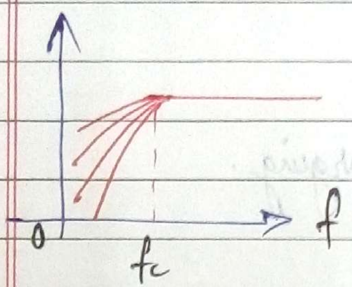
Cutoff or Corner freq.

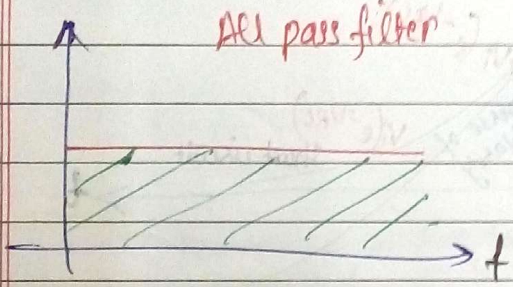
Ideal → ∞ db/dec



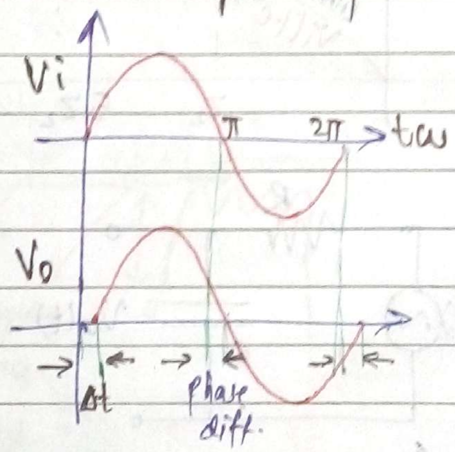








Filter also manipulates phase of signal

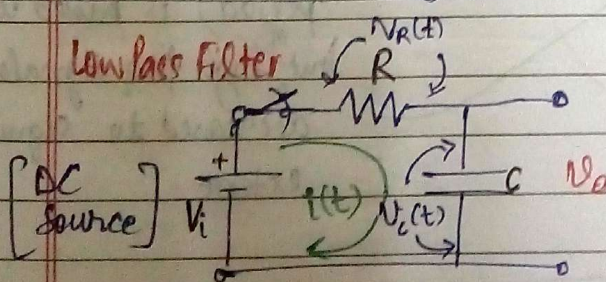


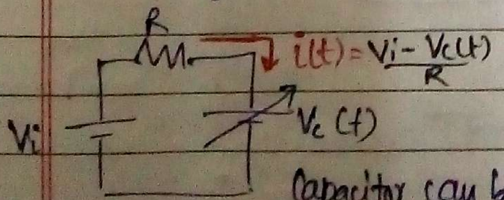
Phase diff can never become 0, hence, there is some phase shift.

Phase diff. created is f^n of freq and waveform.

APF is used to adjust output phase angle.

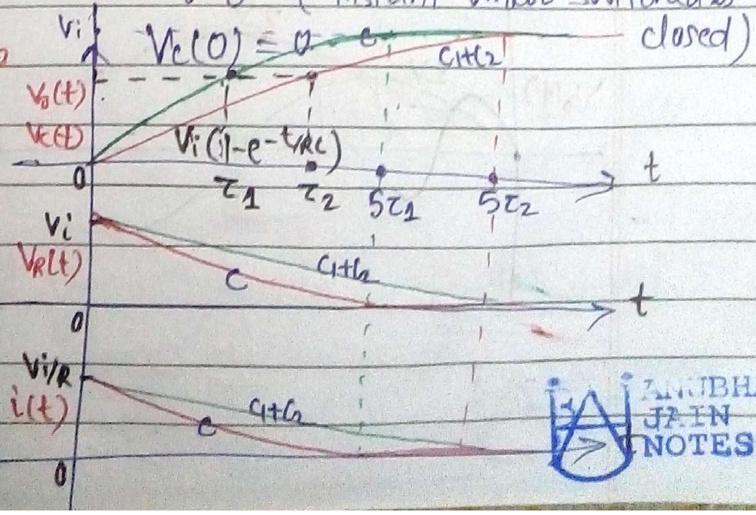
Low Pass Filter



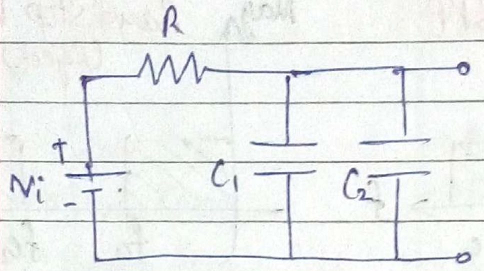


Capacitor can be assumed to be a battery.

$t = 0^+$ (instant when switched is closed)



* Super Capacitor

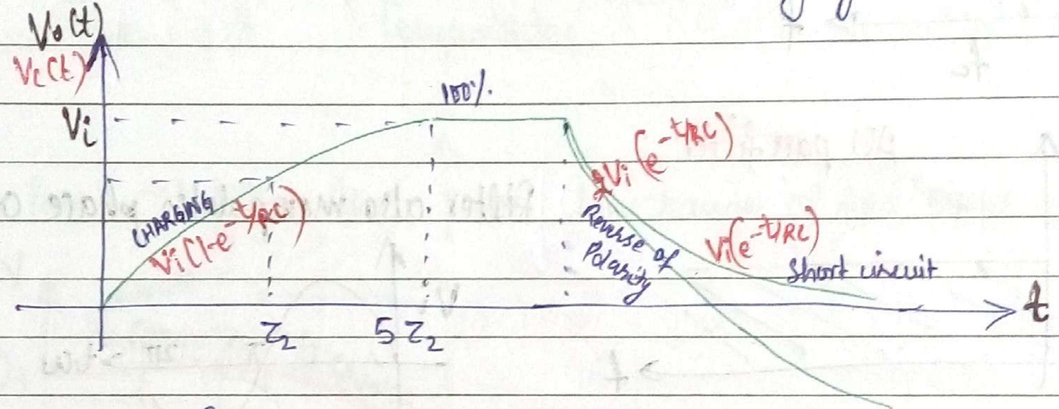


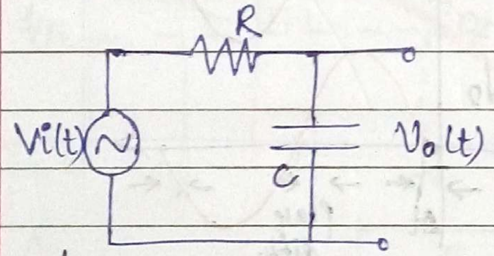
$C = C_1 + C_2$

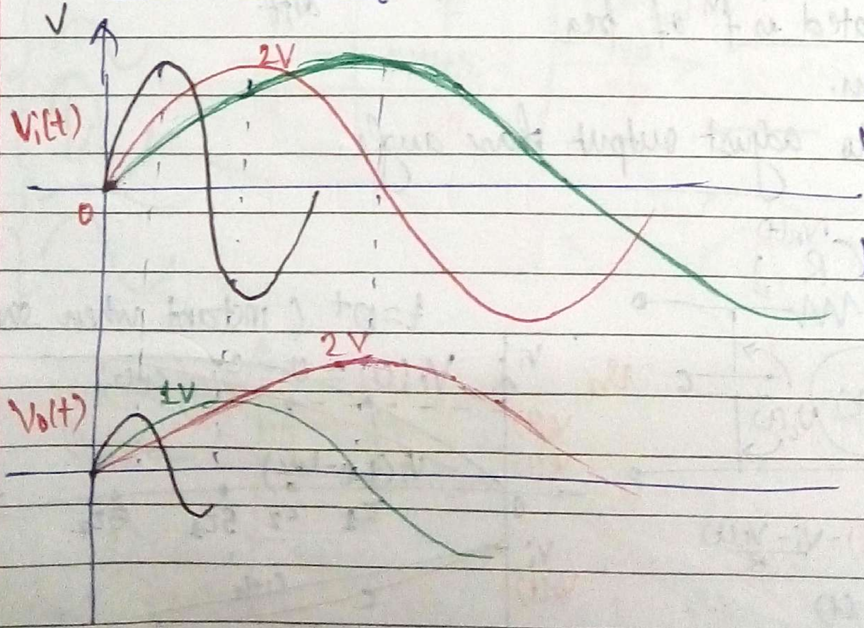
τ = Time Const.

$\tau = RC$ (sec)

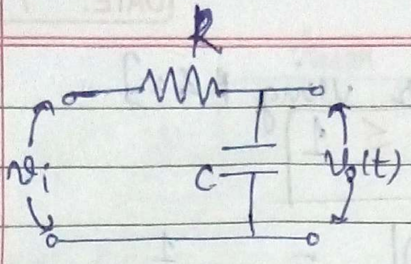
$5\tau \rightarrow 99.7\% \approx 100\%$ charging.

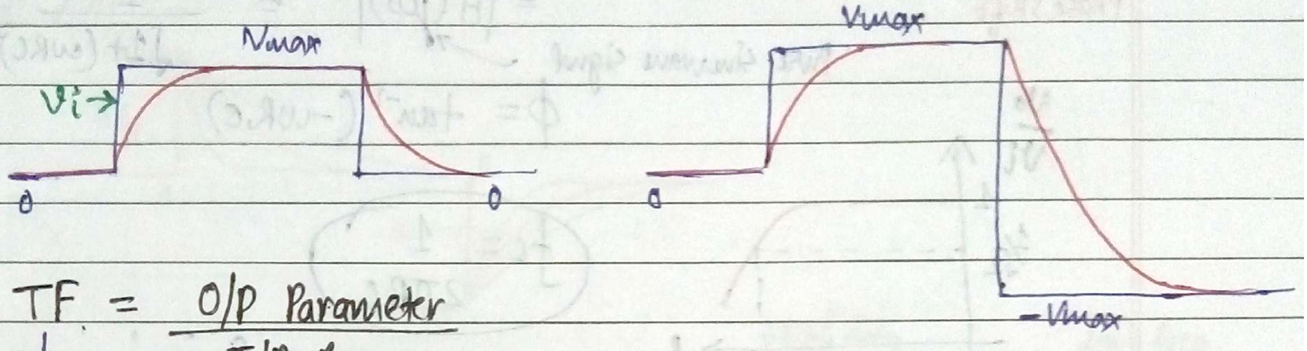






Working of LPF:-
Amplitude of signals with low freq (high time period) is passed unchanged but of high freq signals is decreased to significant extent.





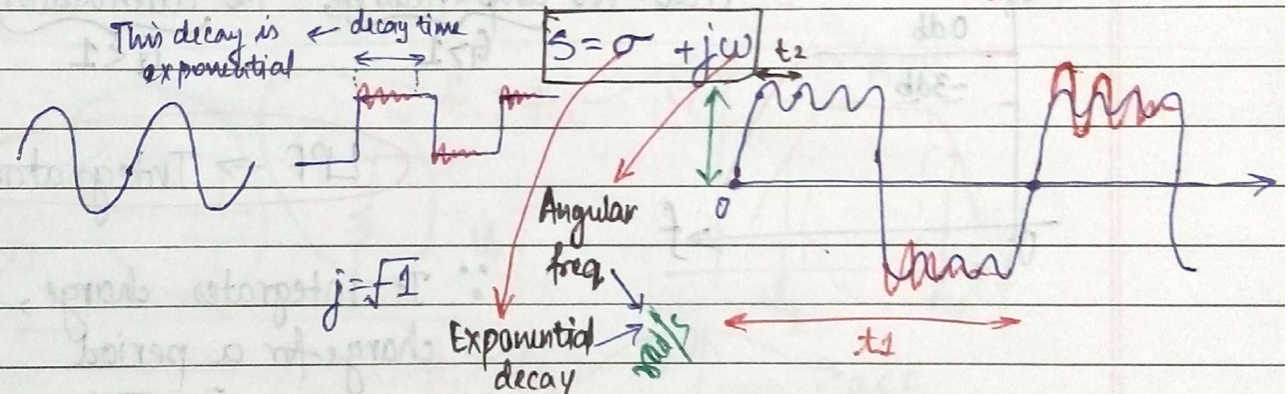
- TF = $\dfrac{\text{O/P Parameter}}{\text{I/P Param.}}$

Transfer function

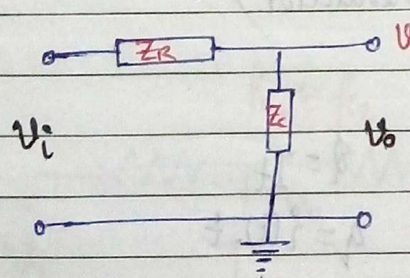
(Impedance of Resistor) $Z_R = R$ (Imp. of capacitor) $Z_C = \dfrac{1}{sC}$ — complex freq

$\boxed{s = \sigma + j\omega}$

$j = \sqrt{-1}$



* For a steady state sine wave, $\sigma = 0 \Rightarrow s = j\omega$

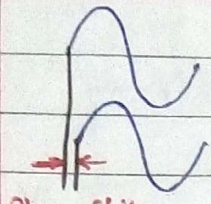


$$V_o = \frac{Z_c}{Z_R + Z_c} V_i$$

$$= \frac{\frac{1}{sC}}{R + \frac{1}{sC}} V_i = \left(\frac{1}{sRC+1}\right) V_i$$

$$\text{TF} \rightarrow \boxed{H_c(s) = \frac{V_o}{V_i} = \frac{1}{sRC+1}} \Rightarrow \boxed{V_o \le V_i}$$

(σ = -ve in case of active filters)



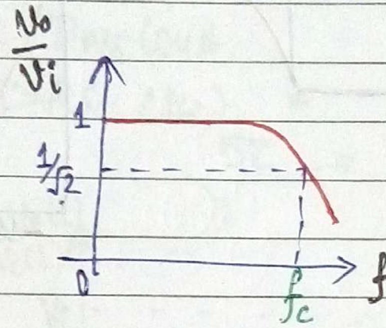
[Passive low pass filter using R & C]

$$\boxed{\text{Gain} = G = |H_c(s)| \leq 1}$$

$$= |H(j\omega)| = \frac{1}{\sqrt{1+(\omega RC)^2}}$$

Pure sinewave signal

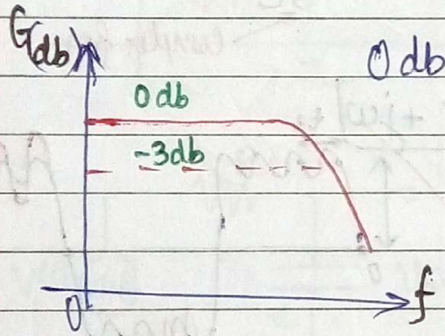
$$\phi = \tan^{-1}(-\omega RC)$$



$$f_c = \frac{1}{2\pi RC}$$

* Gain is expressed in 'db'

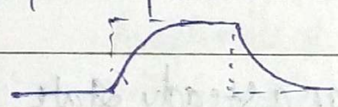
$$\boxed{G_{db} = 20\log_{10}\left(\frac{v_o}{v_i}\right)}$$



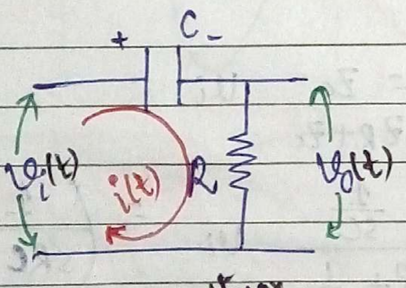
0 db = No $\underbrace{\text{amplification}}_{G>1}$, No $\underbrace{\text{attenuation}}_{G<1}$

LPF → Integrator

∴ It integrates charge, holds that charge for a period

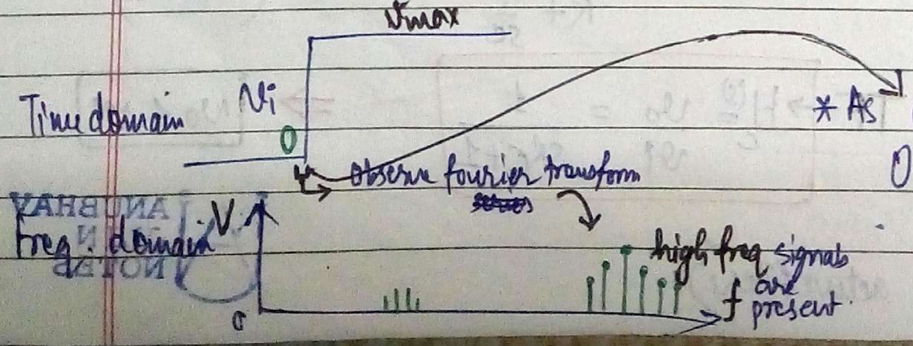


HIGH PASS FILTER (HPF → Differentiator)

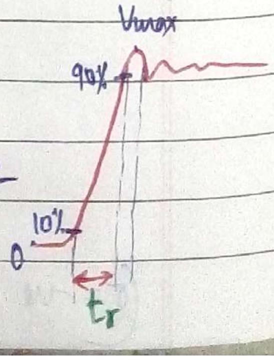


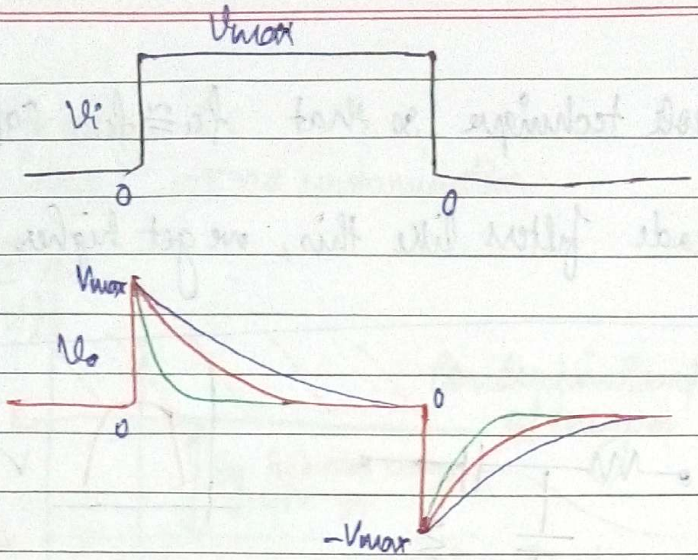
$q = It$

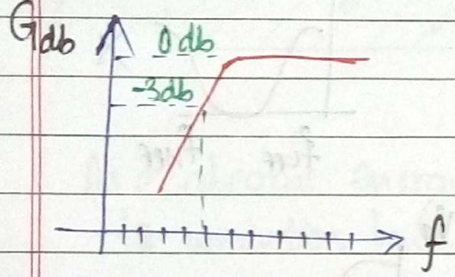
$q = i(t).t$

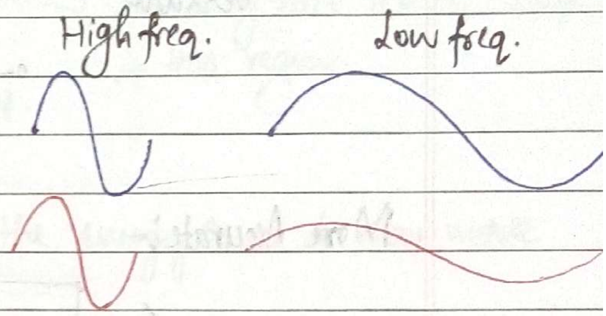


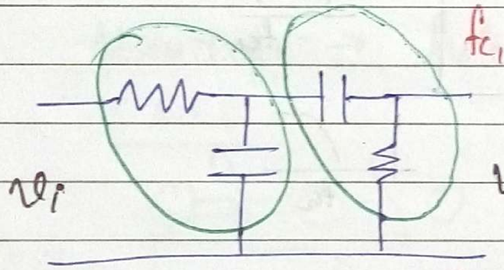
* As observed by Oscilloscope :-



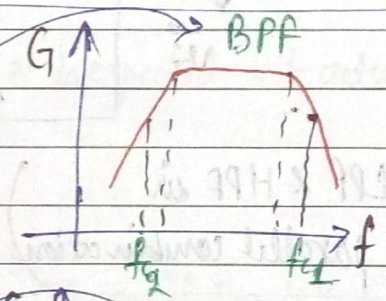




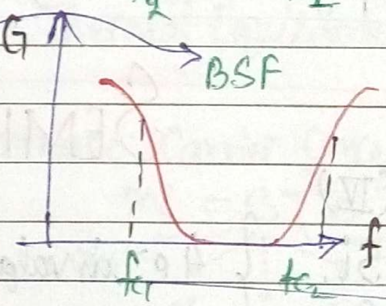




$f_{c_1} > f_{c_2}$

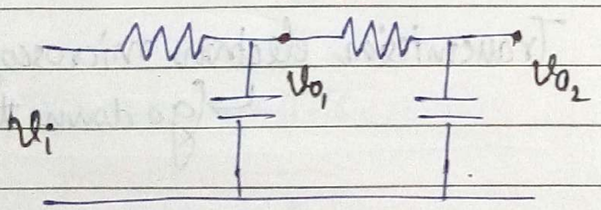


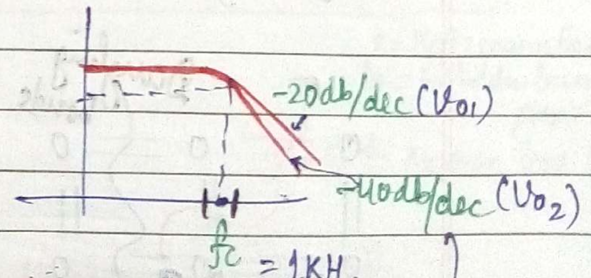
$f_{c_1} < f_{c_2}$



(Accurate version → PTO)

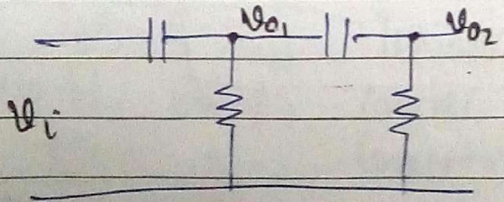
$f_{c_1} \simeq f_{c_2}$





$f_c = 1KH.$

Rate of decrease doubles as $f_{c_1} = f_{c_2}$



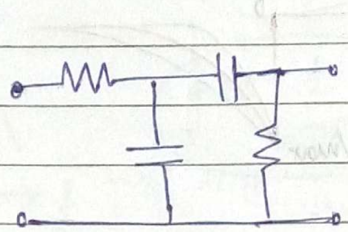
$f_{c_1} = f_{c_2}$

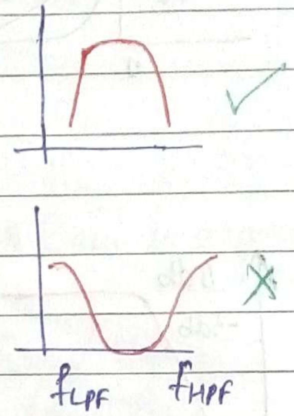
We use split pole technique so that $f_{c1} \cong f_{c2}$ (approx. equal)

Hence, if we cascade filters like this, we get higher rate filters.

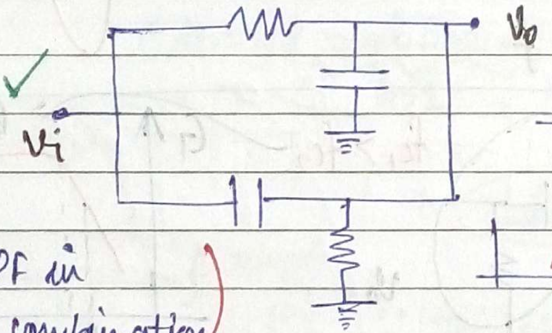
BSF.

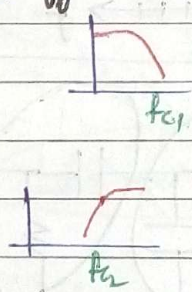
Cascadic Version :-





More Accurate :-



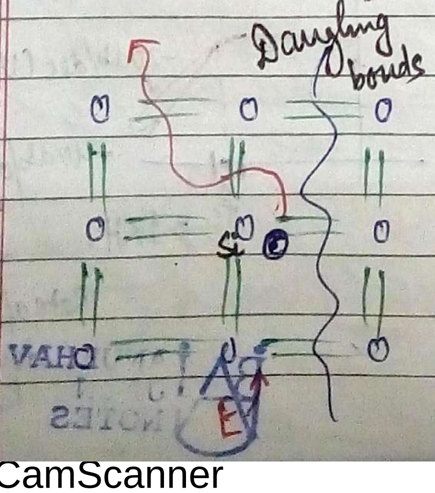


(LPF & HPF in parallel combination)

SEMICONDUCTORS

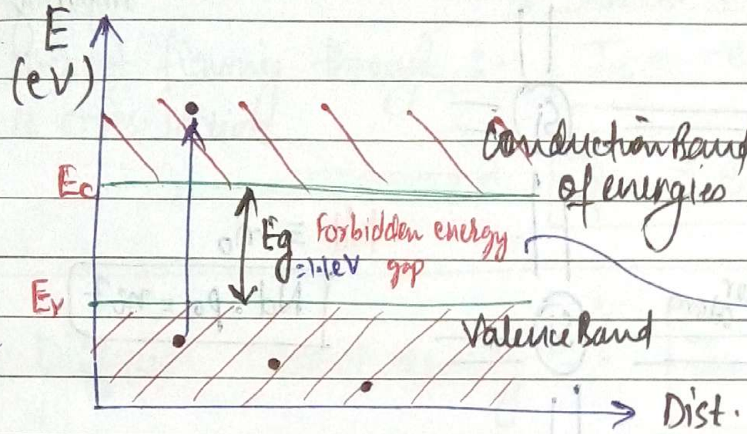
(IV)
Si } $4e^-$ in valance shell. → Lattice Structure
Ge }

Transmission electron microscope
↳ (go down to Å level)



Intrinsic S-C

(Pure) → no contamination.



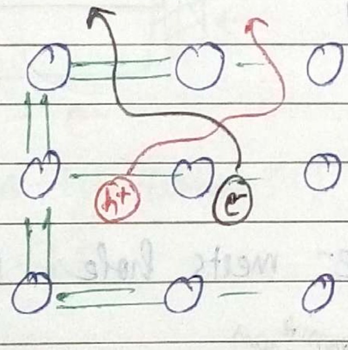
All e^- have diff energies.

Valence energy band → Collection of all energies of valence e^-.

It's very rare that e^- stays in this region.

As e^- abrorbs energy, it rises up the energy level & may move to conduction band.

Absence of e^- → hole (when e^- is expected but actually not present)



Thermal Equilibrium

Intrinsic Carrier Concentration

$$n_i = BT^{3/2} e^{(-Eg/2KT)}$$

Const. — Si, Ge, C — Temp (K)

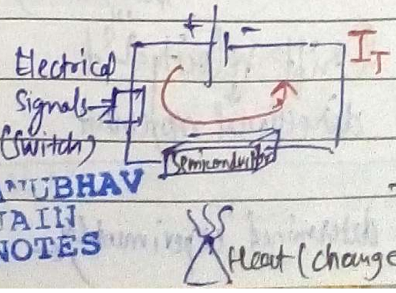
K = Boltzmann Const
Eg = Forbidden Energy gap.
T = Absolute Temp (K)

27/07/16

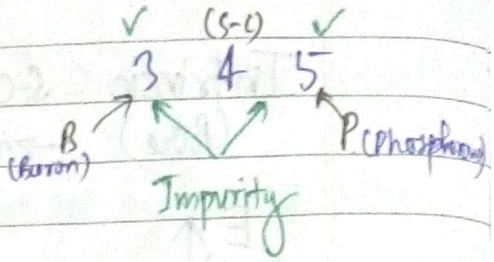
T = 300K. or 27°C.

$$\boxed{n_0 p_0 = n_i^2}$$

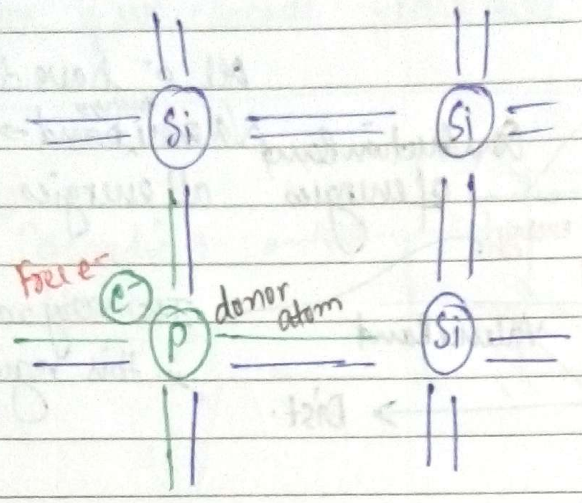
No. of e^- — No of h^+ — Intrinsic carrier Concentration



Current is f^n of Temp.

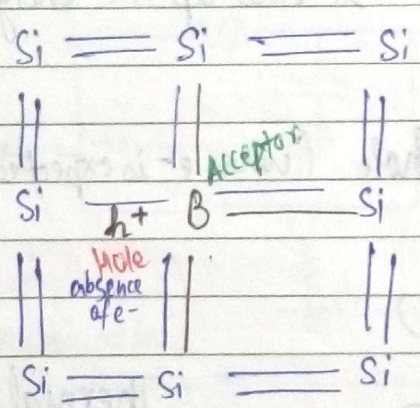


Extrinsic S-C
(Impure)



$N_d \equiv n_0$

$\boxed{N_d \cdot p_0 = n_i^2}$



$N_a \equiv p_0$

$\boxed{n_0 . N_a = n_i^2}$

* Recombination :- free e⁻ meets hole (e⁻-hole pair)

DRIFT & DIFFUSION

DRIFT → active process
DIFFUSION → passive process

In presence of any kind of energy, movement of charge carriers is called drift (eg. stirring).

Diffusion: happens in absence of ext. energy.

Drift velocity = V_d (speed of stirring)
↓
directional movement

Drift vel. of an e⁻ in any extrinsic S-C

$\boxed{V_{dn} = -\mu_n E}$

μ_n → Mobility: Agility of charge particle → const value → determined experimentally

E → Elec. field

Orion

PAGE:
DATE: / /

$$\boxed{v_{dp} = +\mu_p \cdot E}$$

Mobility : $\frac{cm^2}{V\text{-}s}$ $\mu_n \to 1350$ $\mu_p \to 480$

Drift Current Density :

Current flowing through :- a cross section

$$\boxed{J_n = -e n v_{dn}}$$

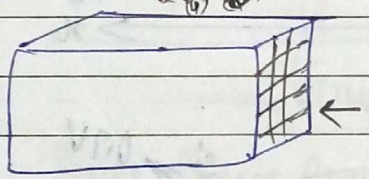
$$\boxed{J_p = +e p v_{dp}}$$

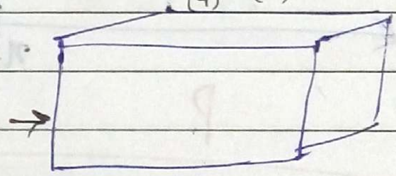
Diffusion Current density :-

$$\boxed{J_n = \frac{dn}{dx} e D_n}$$ → Diffusion Const.

$$\boxed{J_p = \frac{dp}{dx} e D_p}$$

Silicon Flux. $Si_{(4)} + P_{(5)}$ $Si_{(4)} + B_{(3)}$ 27/07/16.





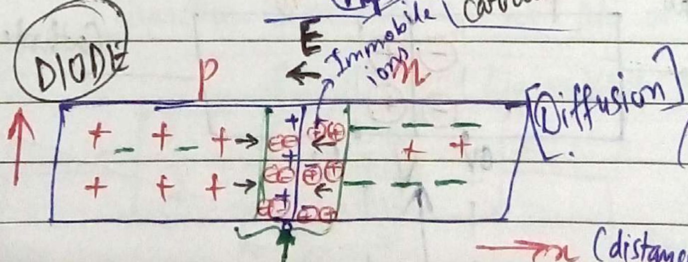
e^- Majority carriers (N_d) n-type (Extrinsic S-C)

h^+ Minority carriers (P_n) → +ve charge carrier in p type S-C.

h^+ Majority carriers (N_a) p-type (Ex. SC)

e^- Minority carriers (n_p)

DIODE



V = 0
T = Const

(No Voltage applied, No Temp change)

→ x (distance)

Metallurgical Junction (p-n Junc^n) → Space Charge Region (width is inversely proportional to N_a & N_d)

→ ε

→ V_{bi} (Build-in potential)

At junc^n, recombination happens.
Keeps on happening till eq^b state
Immobile ions block path of other mobile ions.

ANUBHAV JAIN NOTES

Equilibrium Condition $\left(\xrightarrow{\text{holes}} \text{Diffusion} ,\ \xleftarrow{h^+} \text{Drift} \right)$ → 'E' generated from n to p

(Drift = Diffusion)

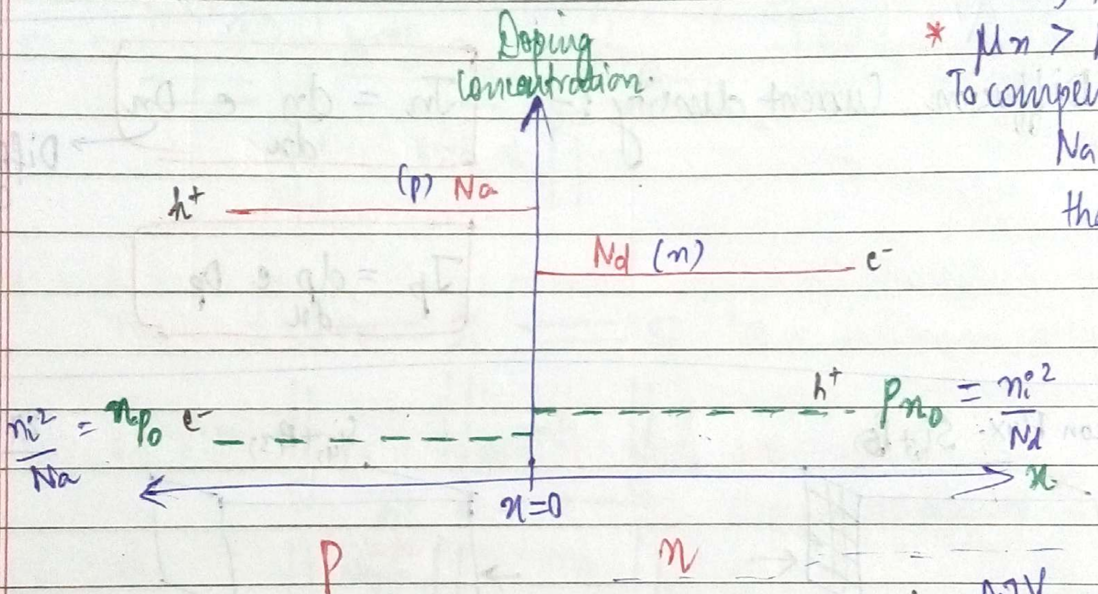
{No. of charge carriers moved by drift = ― diffusion}

Immobile ions ⇒ Net movement is zero.

Mobility of e^- is higher

* $\mu_n > \mu_p$

To compensate that, N_a is kept greater than N_d.



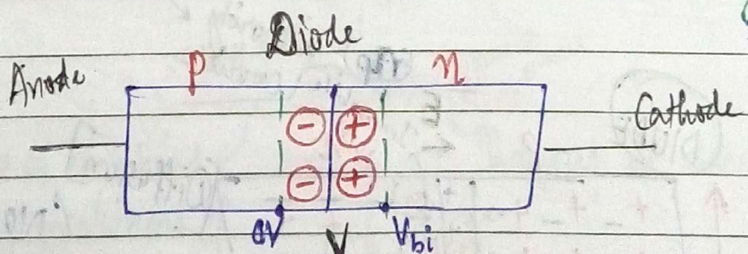
$$V_{bi}\ (\text{Build-in Potential}) = \frac{KT}{e^- q} \ln\left(\frac{N_a N_d}{n_i^2}\right)$$

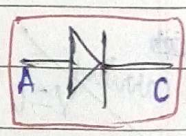
Si → 0.7V

Ge → 0.3V

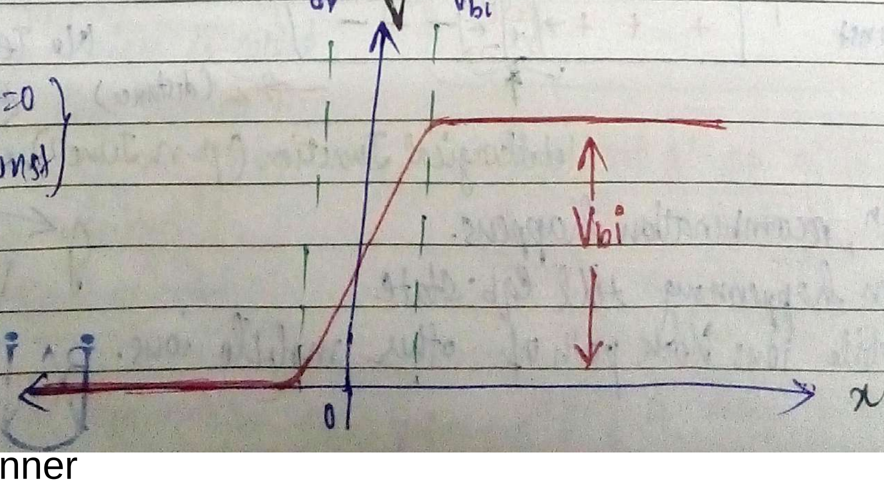
$\frac{KT}{q}$ → Thermal Voltage (V_T) ≃ 26mV @ 300 K.

Diode





{Vext = 0, T = const}



Doping: Addition of impurities.

Mass action Law :- $n_i^2 = n_0 p_0$ — Pure

$n_i^2 = n_0 \left(\frac{n_i^2}{N_d}\right) = N_d p_0$: n-type

$n_i^2 = \left(\frac{n_i^2}{N_a}\right) p_0 = n_0 N_a$: p-type

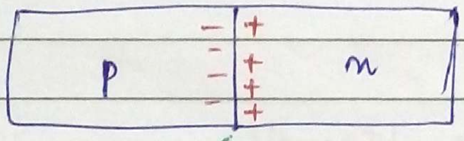
} Extrinsic

If N_a ↑es, N_{p_0} ↓es as minority charge carriers starts recombination with increased majority charge carriers.

(I) (E)

$p_0 \rightarrow N_d$

$N_d >> n_0$



E (responsible for drift)

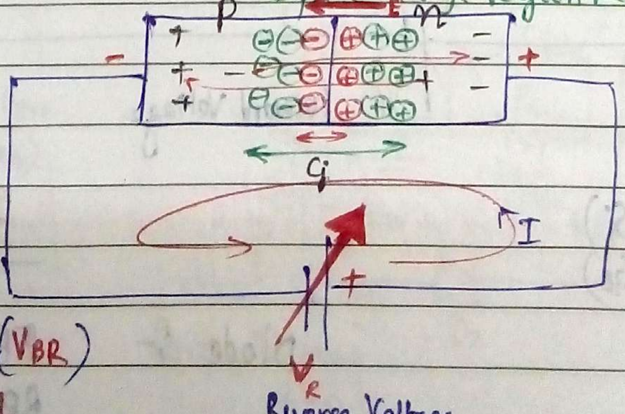
Space Charge Region
or
Depletion Region

V_{bi} (built-in potential)

C_j (Junction Capacitance) — Finite Value. → (pF or max. nF)

Space Charge Region keeps on Increasing as V_R ↑es.

REVERSE BIAS CONDITION :-



I → very low

Range (fA → nA)

nanometre nm or μm → Depletion Region

Breakdown (V_{BR})

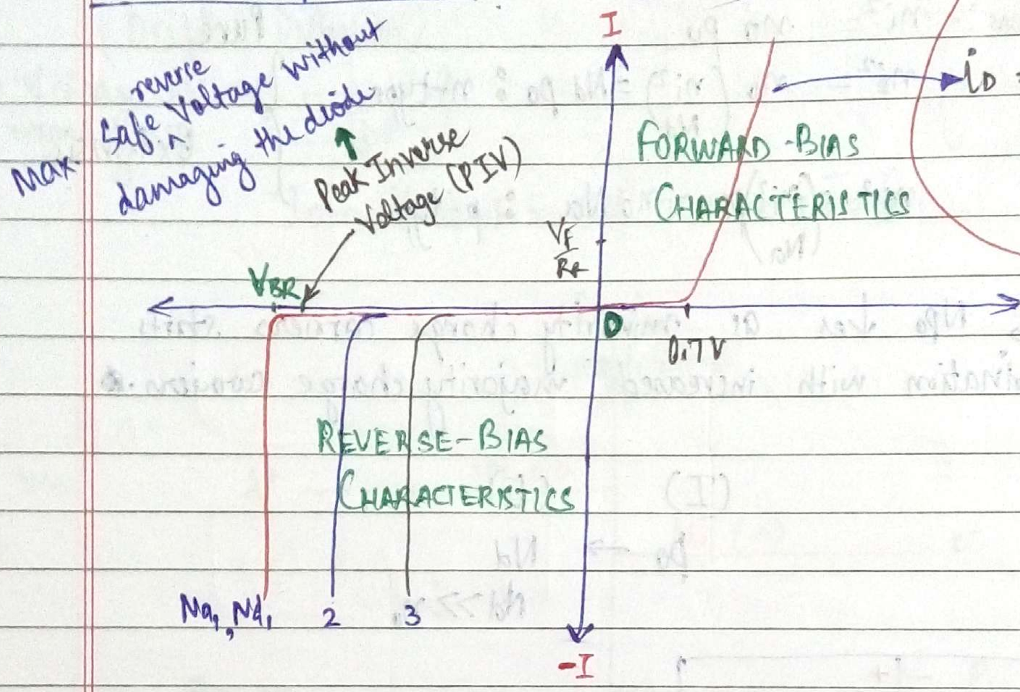
Avalanche (Permanent)

Zener (Recoverable)

If $V_R < V_{BR}$ (After breakdown)

$\underbrace{fA - nA}$ → $\mu A - A$

($V_R \geq V_{BR}$)



$$i_D = I_s\left(e^{\frac{v_D}{nV_T}} - 1\right)$$

I_s: Reverse Bias Saturation Current (fA-pA) (10^{-15} - 10^{-12})

v_D: Actual Voltage across diode

V_T: Thermal Voltage

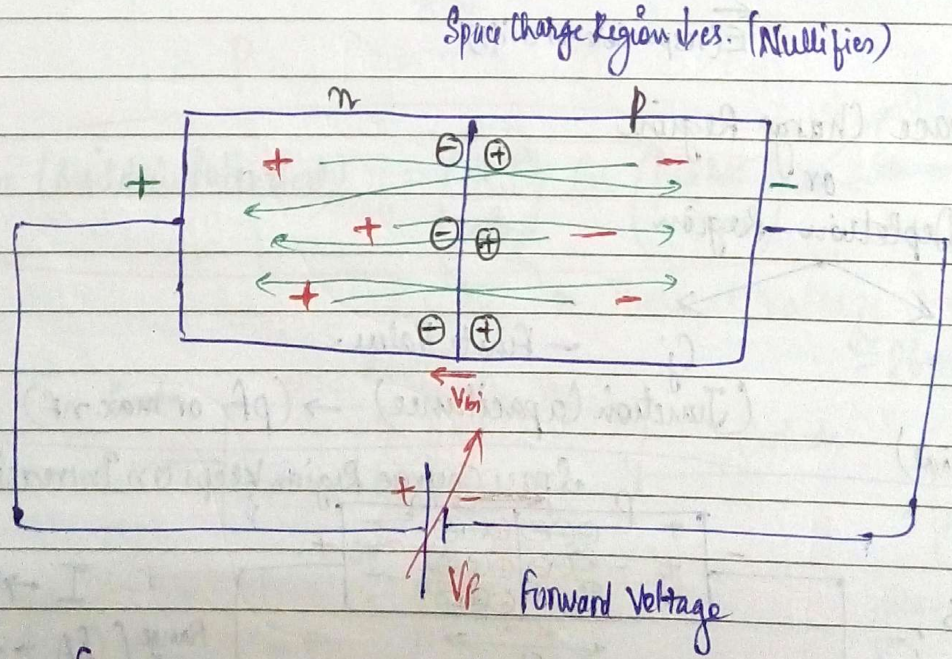
n: Const (Ideality factor)

$n = 2$ (Low Current)

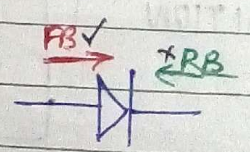
$n = 1$ (High Current)

$Na_3, Nd_3 > Na_2, Nd_2 > Na_1, Nd_1$

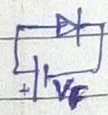
FORWARD BIAS CONDITION



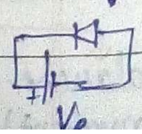
$$V_{bi} = \begin{cases} 0.7V & (Si) \\ 0.3V & (Ge) \end{cases}$$

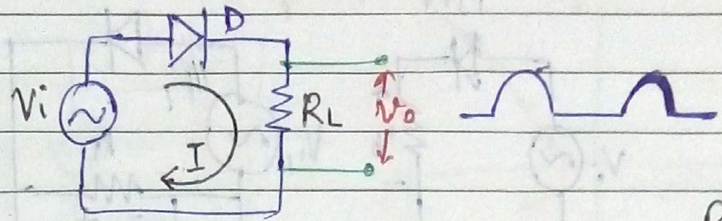


Diode :- FB – ON

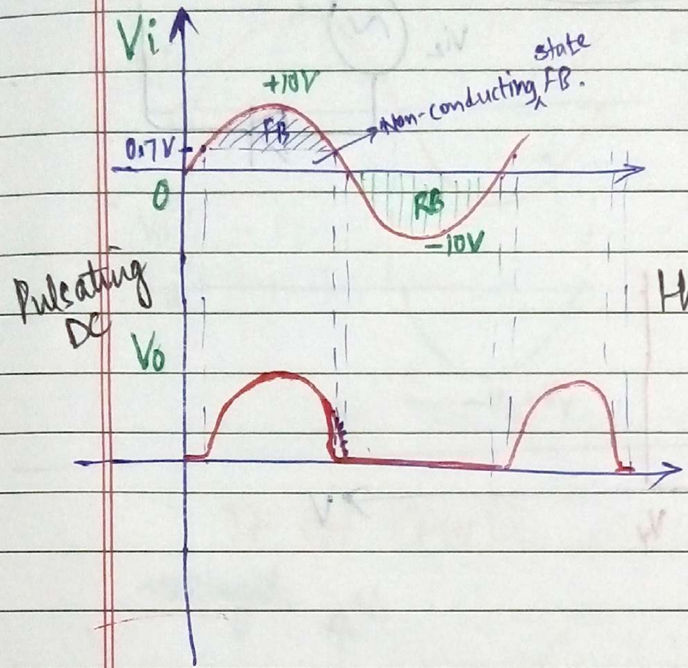


RB – OFF

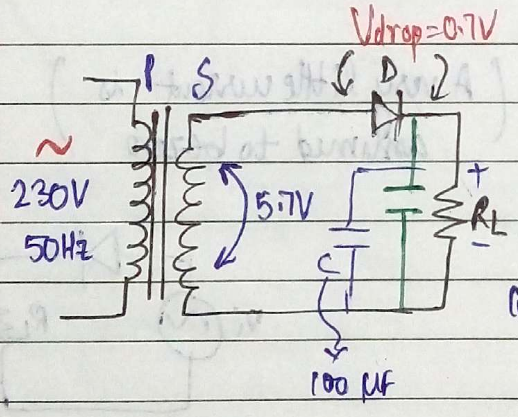


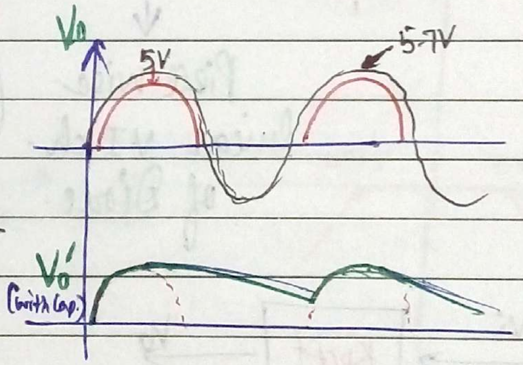


RECTIFICATION → AC→DC

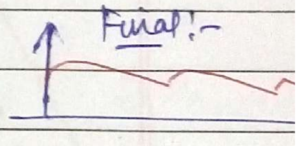


HALF WAVE RECT^{f}





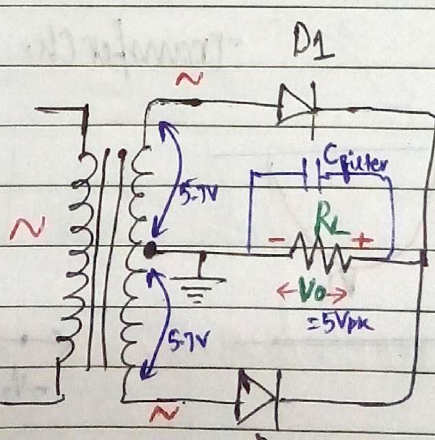
Final:-

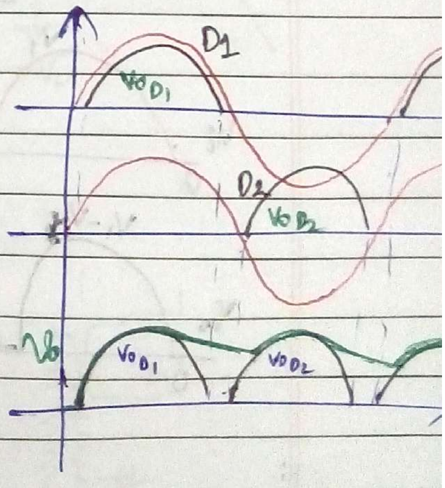


|| → Iron Core

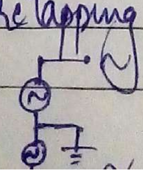
¦¦ → Ferride Core (High freq)

→ Air Core

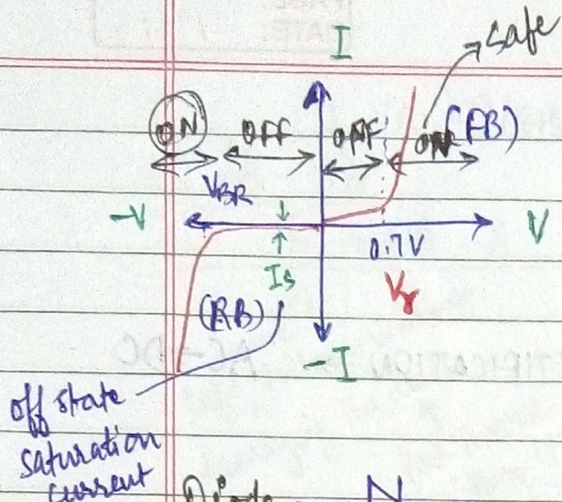




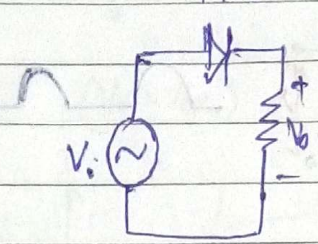
Centre Tapping



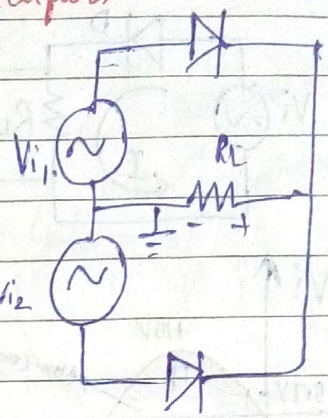
Rectifiers

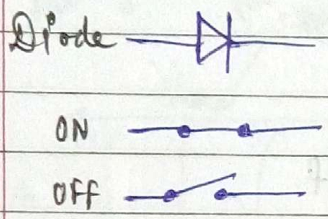


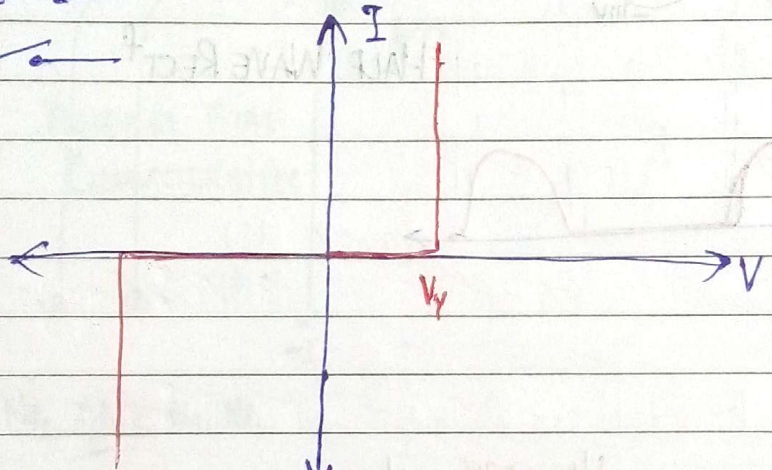
HW



FW

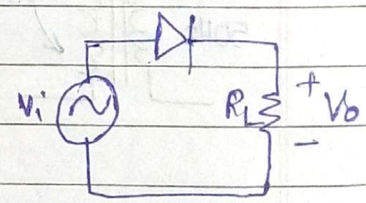


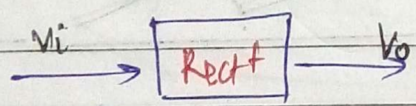


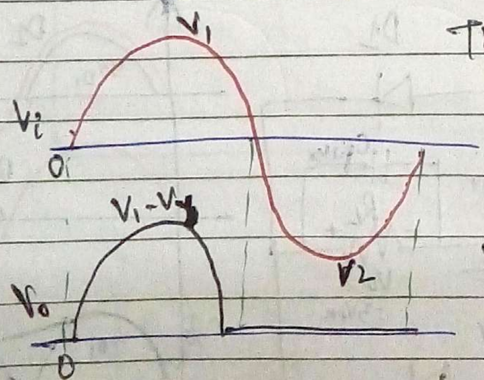


Piece-wise linear V-I ch. of Diode

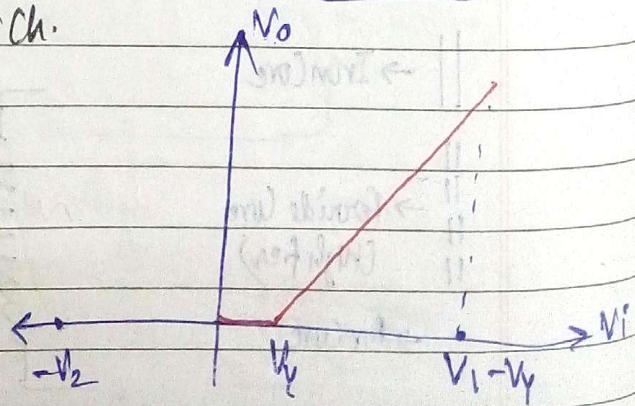
(A very little current is assumed to be zero)

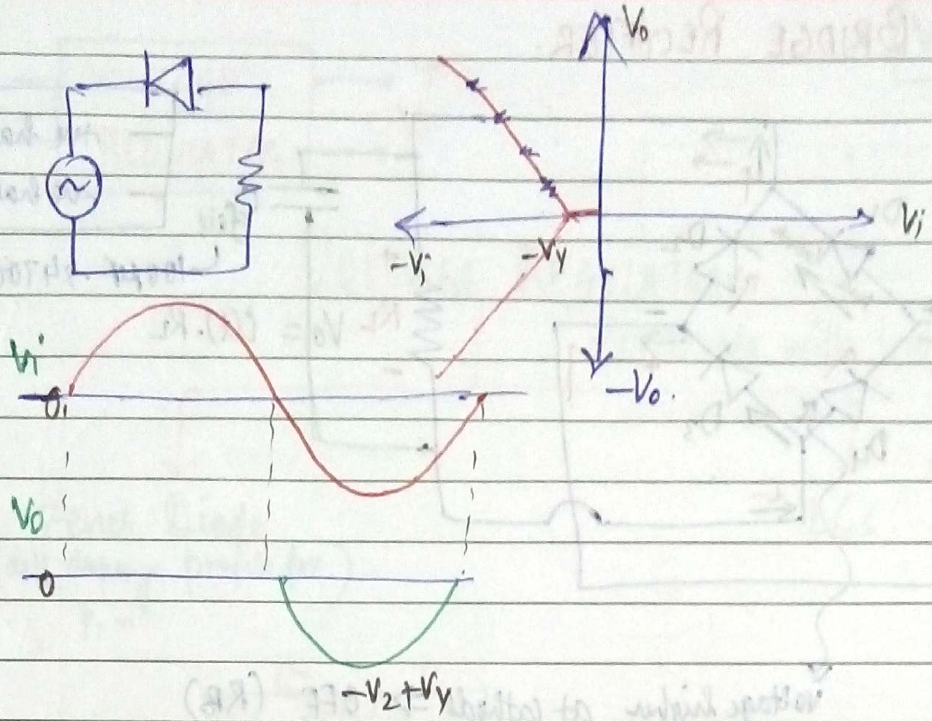






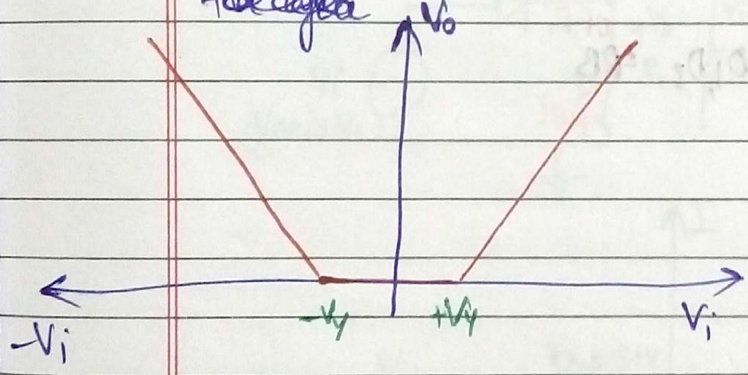
Transfer Ch.



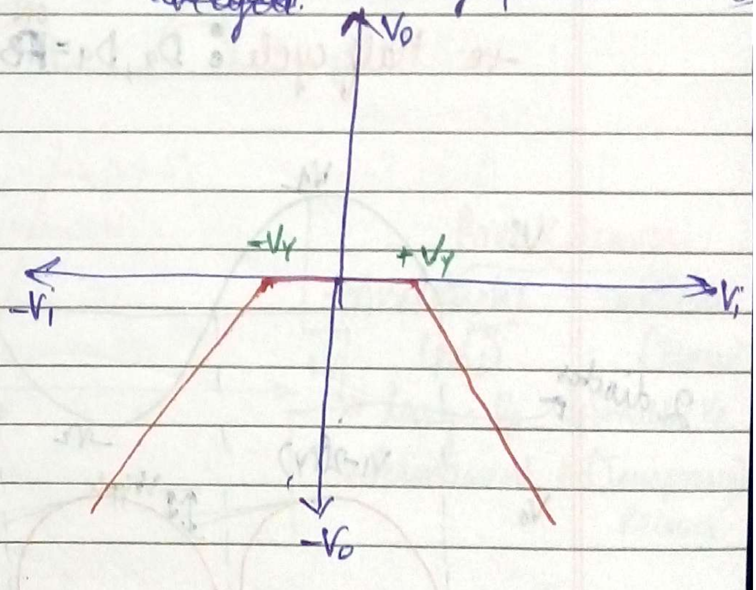


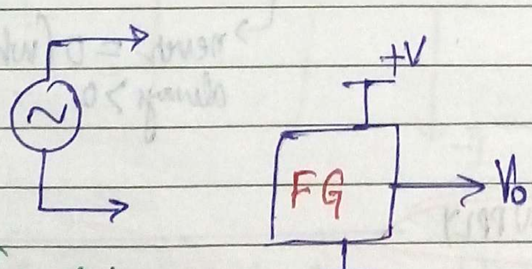
TF CH (FW)

~~+ve cycle~~

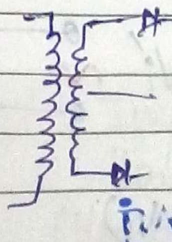


~~-ve cycle~~ (Polarity of diodes reversed)

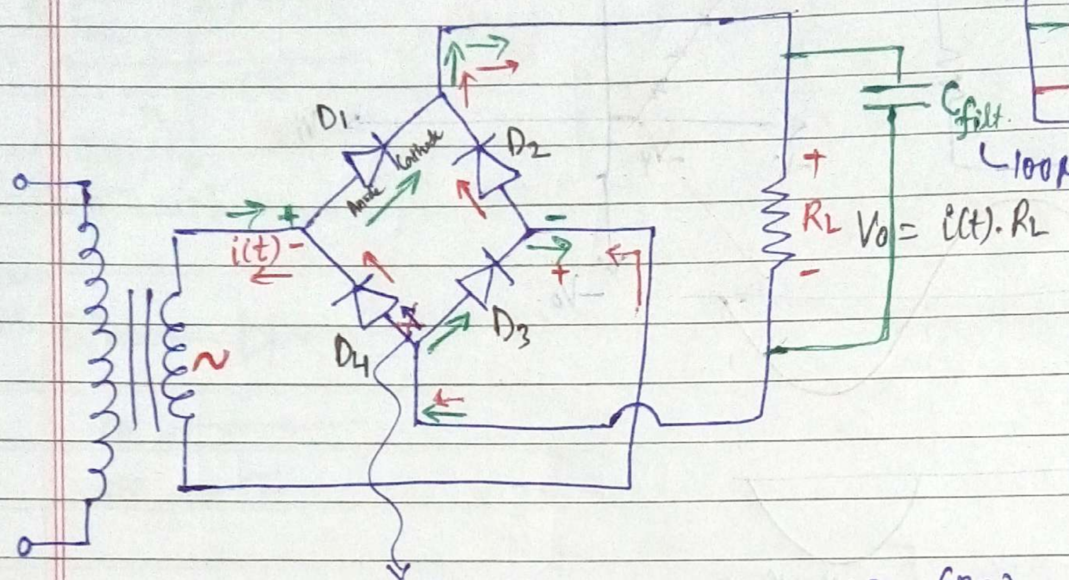


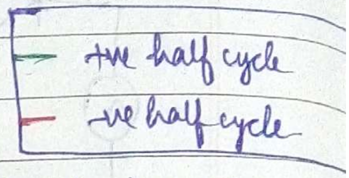


Function Generator
(No input, only output)



BRIDGE RECTIFIER





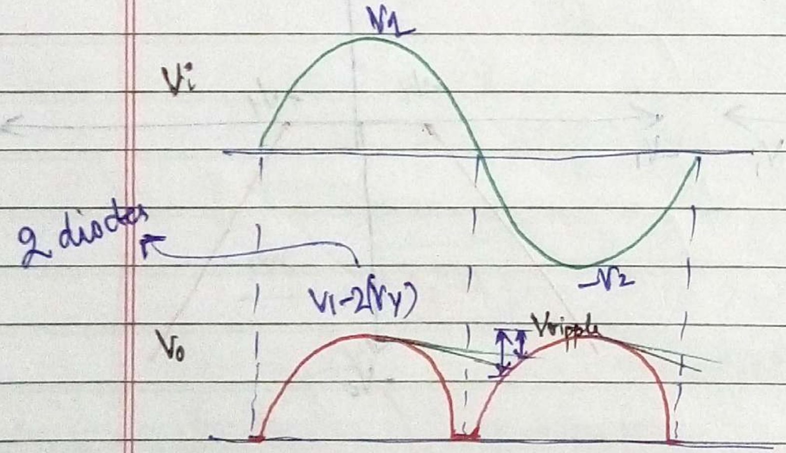
C_{filt} → 100 μF → 4700 μF

$V_0 = i(t) \cdot R_L$

voltage higher at cathode ⇒ OFF (RB)

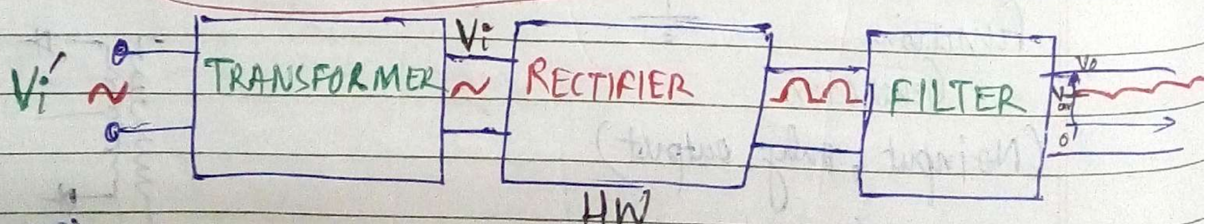
+ve Half cycle : D_1, D_3 = FB (ON), D_2, D_4 = RB (off)

-ve Half cycle : D_2, D_4 = FB (ON), D_1, D_3 = RB (off)



V_{ripple} = Fluctuation in DC output
→ never = 0 (when using 'C' only)
always > 0

Linear DC POWER SUPPLY



HW
FW
BR

(Vi' > Vo)

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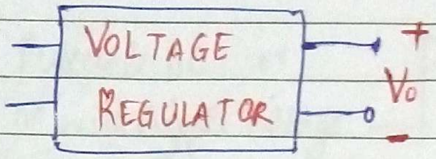
$\boxed{V_i > V_o}$



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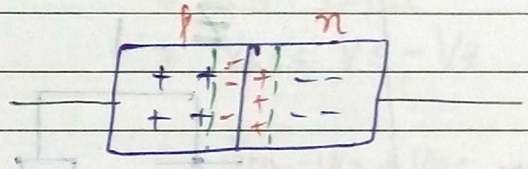
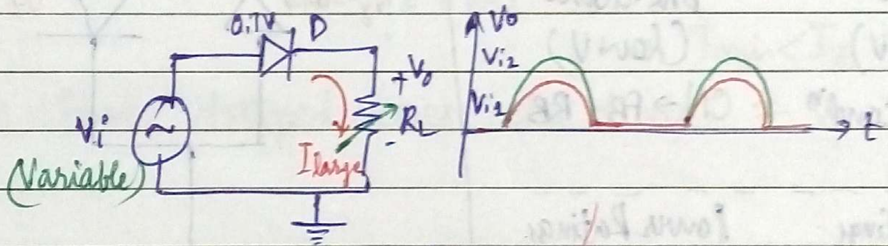
VOLTAGE REGULATORS

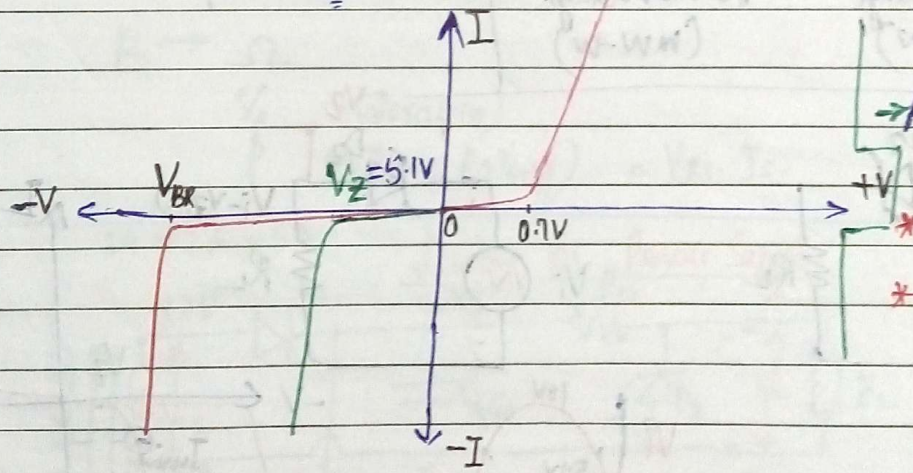
Const Vo with variable → Vi
↳ Z_L

Zener Diode (diff doping profile for p, n)

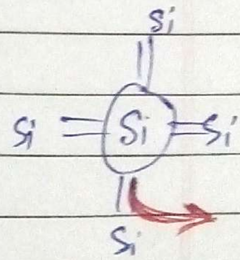
ICs



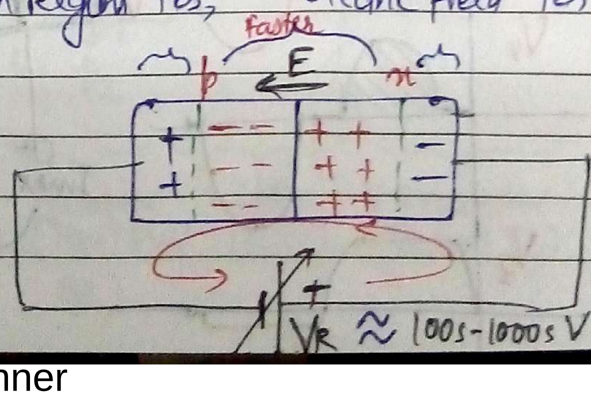




Breakdown
→ Avalanche (pn) → Zener (Zener)
* Large V_R * Smaller V_R
* Permanent * (Temporary) Recover.



Depletion Region ↑es, Electric field ↑es.



$V_R \approx$ 100s-1000s V (Normal diode)

Impact Ionization
(Heavily accelerated beyond V_{BR})

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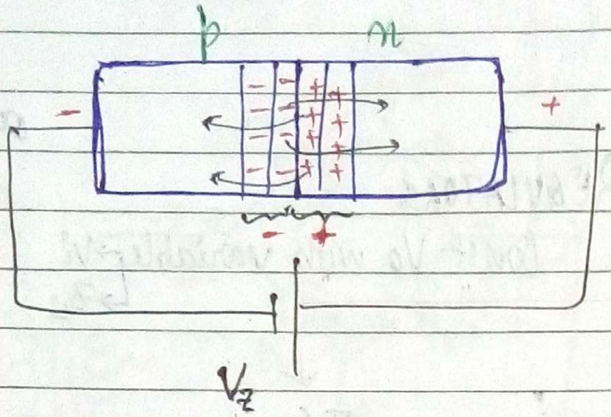
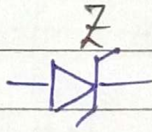
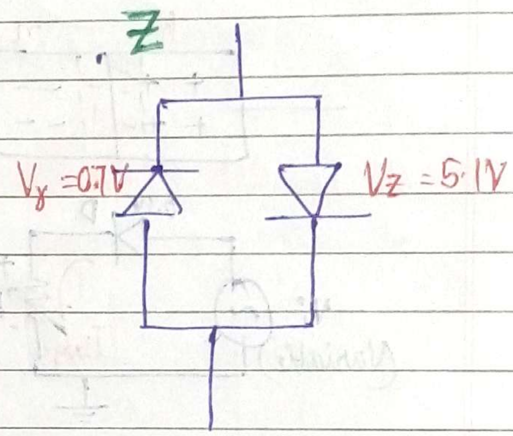
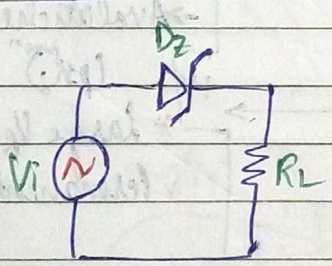
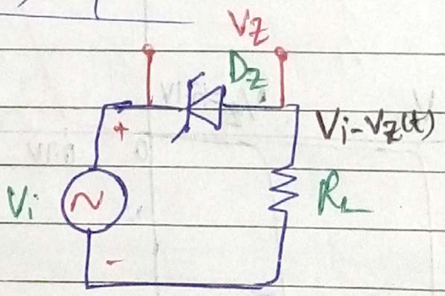
Zener

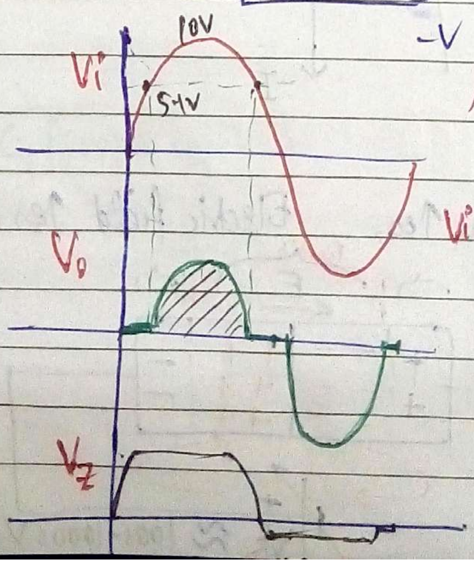


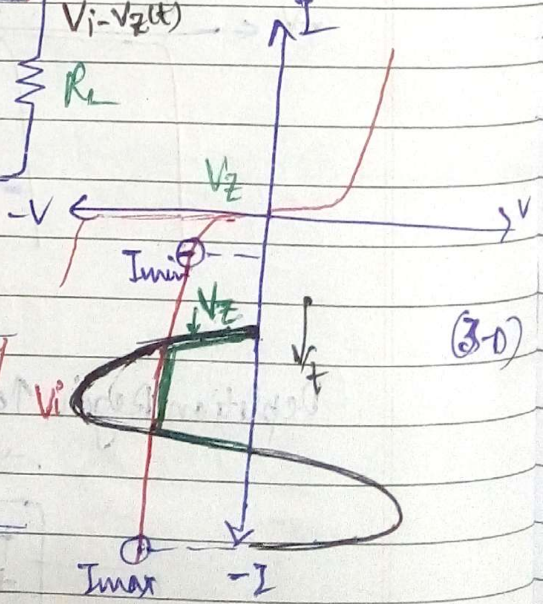
	PN	Z
1.		
2.	Avalance brk.down (High V)	Zener brk.down (Low V)
3.	ON → FB cond^n OFF → RB	ON → FB, RB
4.	Power Ratings (mW - kW)	Power Ratings (mW - W)





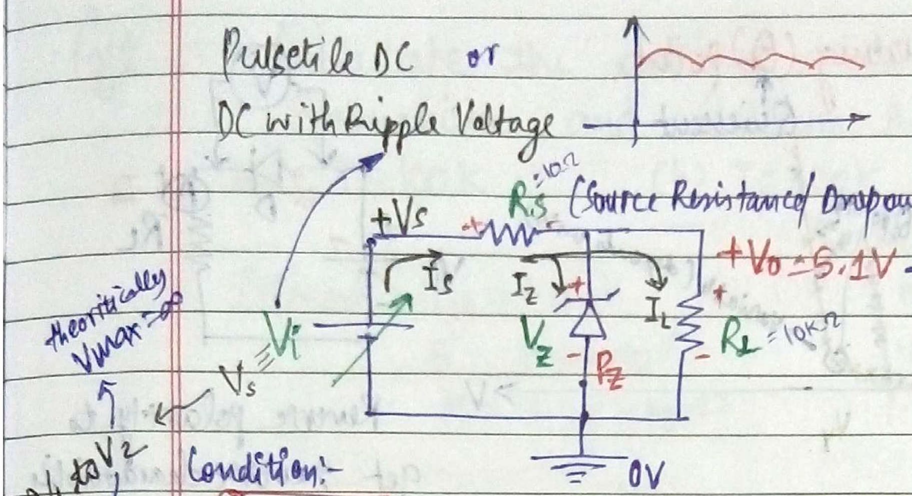






↳ for safely operating Zener diode

Pulsetile DC or
DC with Ripple Voltage



+V₀ = 5.1V → { 5V ±10% (+4.5V – 5.5V) }

Condition:-
$\boxed{V_i > V_Z}$

$(V_0 = V_Z = 5.1V)$

* $I_S = I_Z + I_L$
* $V_{RS} = V_S - V_Z$ $\quad I_S = \frac{V_S - V_Z}{R_S}$ $\quad R_S = \frac{V_S - V_Z}{I_S}$
* $V_S = V_Z + V_{RS}$

* $I_{min} < I_Z \leq I_{max}$

* P_Z = Power dropped across zener diode $= V_Z \cdot I_Z$ (specified by manufacturer)

R → Ω
% (Tolerance)
P (Power Rating) $= V_{RS} \cdot I_S$

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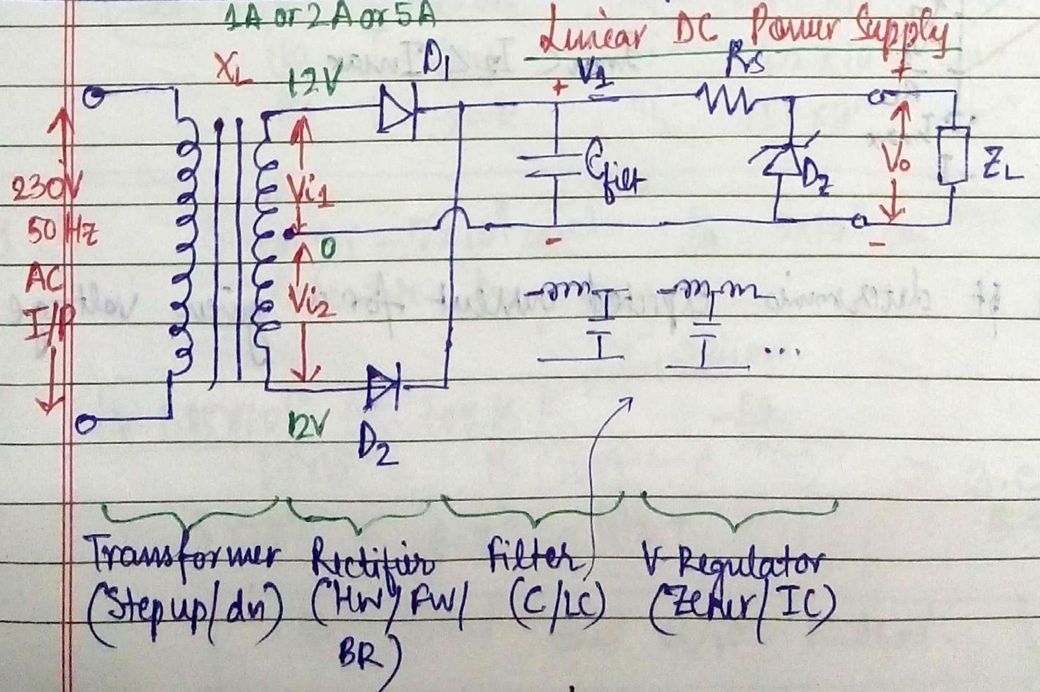
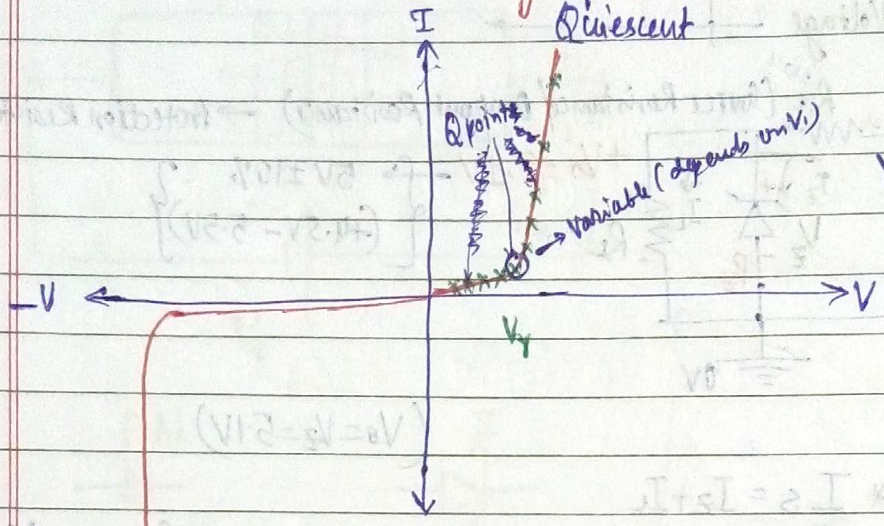
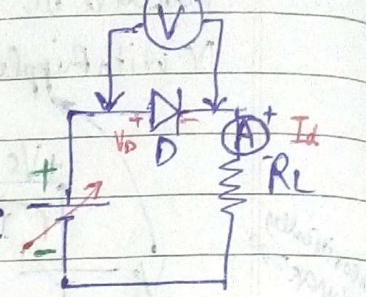
Linear DC Power Supply



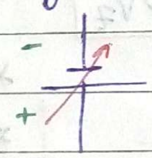
Load Line & Operating (Q) point

Q → Quiescent





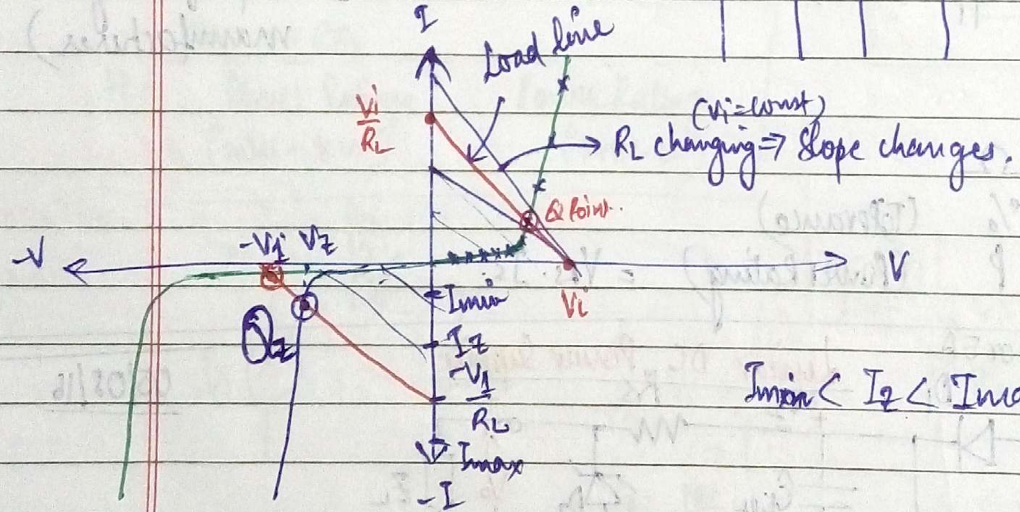
Reverse polarity to get reverse characteristic



Vi	Vd	Id
0	-	-
0.1	-	-

$I_S = I_Z + I_L$

$I_S = I_Z + \frac{V_0}{R_L}$



$I_{min} < I_Z < I_{max}$

Q pt determines expected current for a given voltage.

Q1. Calculate the intrinsic carrier conc of Silicon, Germanium and Gallium Arsenide at
(a) T = 100K (b) T = 300K (c) 500K.

	Silicon	Germanium	GaAs
E_g	$= 1.12\,eV$	$0.67\,eV$	$1.42\,eV$
B	$= 5.23\times10^{15}$	1.66×10^{15}	2.1×10^{14}
K	$= 1.38\times10^{-23}$	1.38×10^{-23}	1.38×10^{-23}

Ans. $n_i = BT^{3/2}\, e^{-E_g/2KT}$

(a) Si, T = 100K $n_i = 3.317\times10^{-10}\ cm^{-3}$ (normal calculations) | $n_i = 2.74\times10^{-10}\ cm^{-3}$

TRICK : $E_g \to eV$. $K \to 8.6\times10^{-5} \equiv \frac{K}{e}$

(b) T = 300K $n_i = 1.0177\times10^{10}$
(c) T = 500K $n_i = 1.29\times10^{14}$.

Ge (a) T = 100K $n_i = 20.08\ cm^{-3}$.
(b) T = 300K $n_i = 1.98\times10^{13}\ cm^{-3}$
(c) T = 500K $n_i = 7.67\times10^{15}\ cm^{-3}$

GaAs (a) T = 100K $n_i = 2.93\times10^{-19}\ cm^{-3}$
(b) T = 300K $n_i = 1.22\times10^{6}\ cm^{-3}$
(c) T = 500K $n_i = 1.58\times10^{11}\ cm^{-3}$.

Q1 (i) Given $n_i = 5\times10^{9}\ cm^{-3}$ ($= 291K$) to $5\times10^{11}\ cm^{-3}$ ($= 360K$)
Calculate temp range.

$\boxed{*\ 1.5\times10^{10} \text{ at } 300K}$ → for Silicon.

$1.5\times10^{10} = B(300)^{3/2}\, e^{-\frac{E_g}{2K(300)}}$ ⇒ $B.e^{-\frac{E_g}{2K(300)}} = 2886751.346$

$5\times10^{9} = BT^{3/2}\, e^{-E_g/2KT}$

$\boxed{\text{Use Trial and error method.}}$

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$$\frac{n_i}{B} = T^{3/2}\cdot \exp\left(\frac{-E_g}{2k}\cdot\frac{1}{T}\right) = T^{3/2}\cdot \exp\left(\frac{-K_2}{T}\right)$$

~~T=290K~~, $n_i = 4.57\times10^{9}\ cm^{-3}$.

T=291K, $n_i = 4.969\times10^{9}\ cm^{-3} \Rightarrow n_i \approx 5\times10^{9}\ cm^{-3}$.

~~T=350K~~, $n_i = 2.85\times10^{11}\ cm^{-3}$

T=360K, $n_i = 4.98\times10^{11}\ cm^{-3} \Rightarrow n_i \approx 5\times10^{11}\ cm^{-3}$

(iii) Silicon is doped with $5\times10^{16}\ cm^{-3}$ Arsenic atoms. Calculate the electron and hole conc. at 300K and 350K.

Ans $N_d = 5\times10^{16}\ cm^{-3}$ $p_i = \frac{n_i^2}{N_d}$

$n_i = 1.5\times10^{10}$ at 300K

at T=300K, $n_i = 1.0177\times10^{10}\ cm^{-3}$

$\Rightarrow p_i = 2071.426\ cm^{-3}$.

Si's Ans. $4500\ cm^{-3}$

at T=350K, $n_i = 2.85\times10^{11}\ cm^{-3}$

$\Rightarrow p_i = 1624500\ cm^{-3}$.

$1.61\times10^{6}\ cm^{-3}$

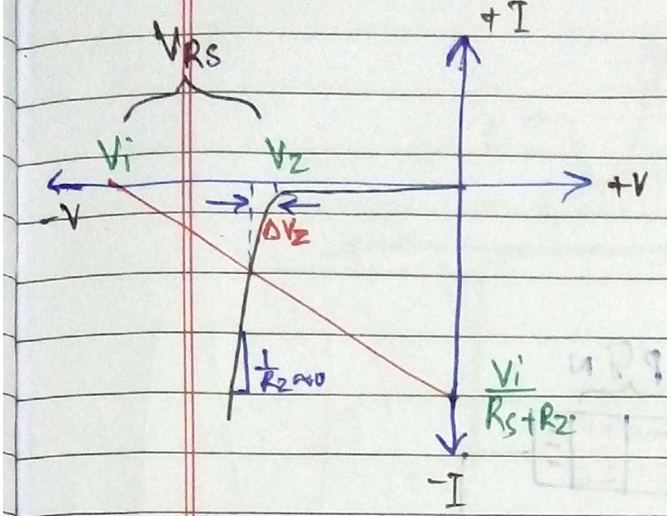
at 300K

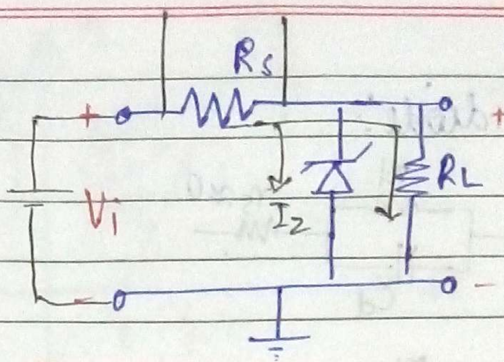
	E_g	μ_n	μ_p
		(cm²/V-s)	
Si	1.12eV	1350	480
Ge	0.67eV	3900	1900
GaAs	1.42eV	8500	400

$$\frac{kT}{e} = \frac{D_n}{\mu_n} = \frac{D_p}{\mu_p}$$

cm^2/s

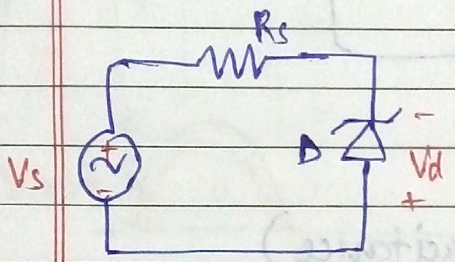
0.0259 eV

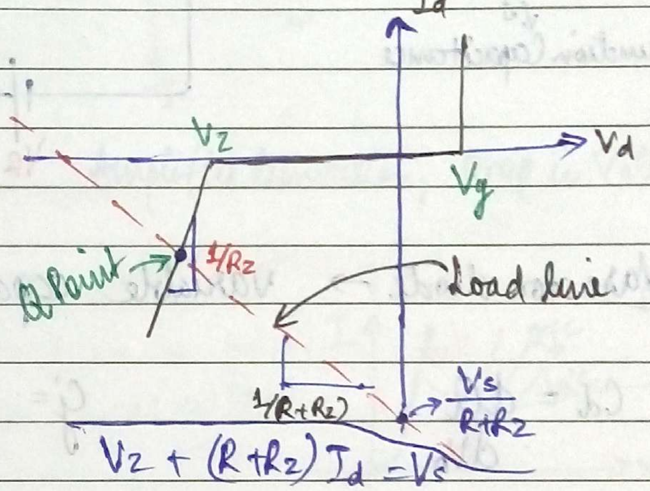




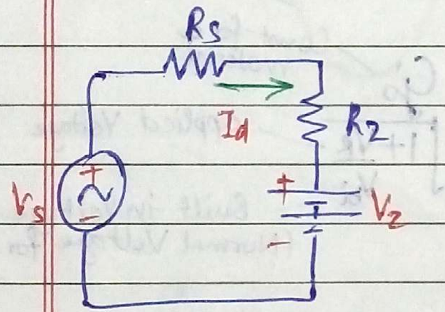
$I_{max} > I_Z > I_{min}$

$$\boxed{V_Z = V_i\left(\frac{R_L}{R_S+R_L}\right) - I_Z\left(\frac{R_S \cdot R_L}{R_S+R_L}\right)}$$





Load line ($R_Z \to$ Negligible)



$$V_Z + (R+R_Z)\,I_d = V_s$$

$$I_d = \frac{-V_Z}{R+R_Z} + \frac{V_s}{R+R_Z}$$

($R_Z > 0 \to$ finite slope, little change in V_Z causes high change in I)

Input Voltage, Regulation accuracy

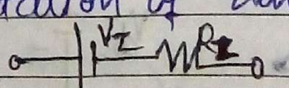
Quality of Regulation :-

1) Line / Source of Reg $= \frac{\Delta V_o}{\Delta V_i} \times 100\%$ (should be less than 8%)

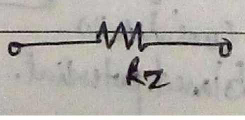
2) Load Reg. $= \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100\%$

Eq. Representation of Zener diode :-

* RB

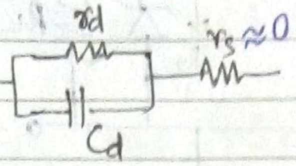


* FB

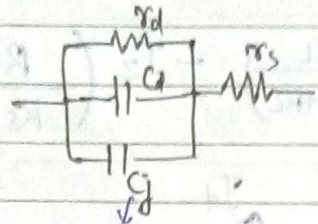


P-N diode :-

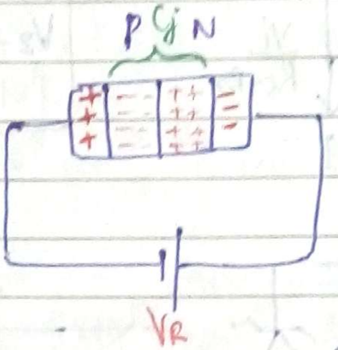
FB:



RB:



Junction Capacitance



*(Varactor diode → variable capacitance)

$$C_d = \frac{dQ}{dV_D}$$

$$C_j = \frac{C_{j0}}{\sqrt{1+\frac{V_R}{V_{bi}}}}$$

C_{j0} — Const for a material

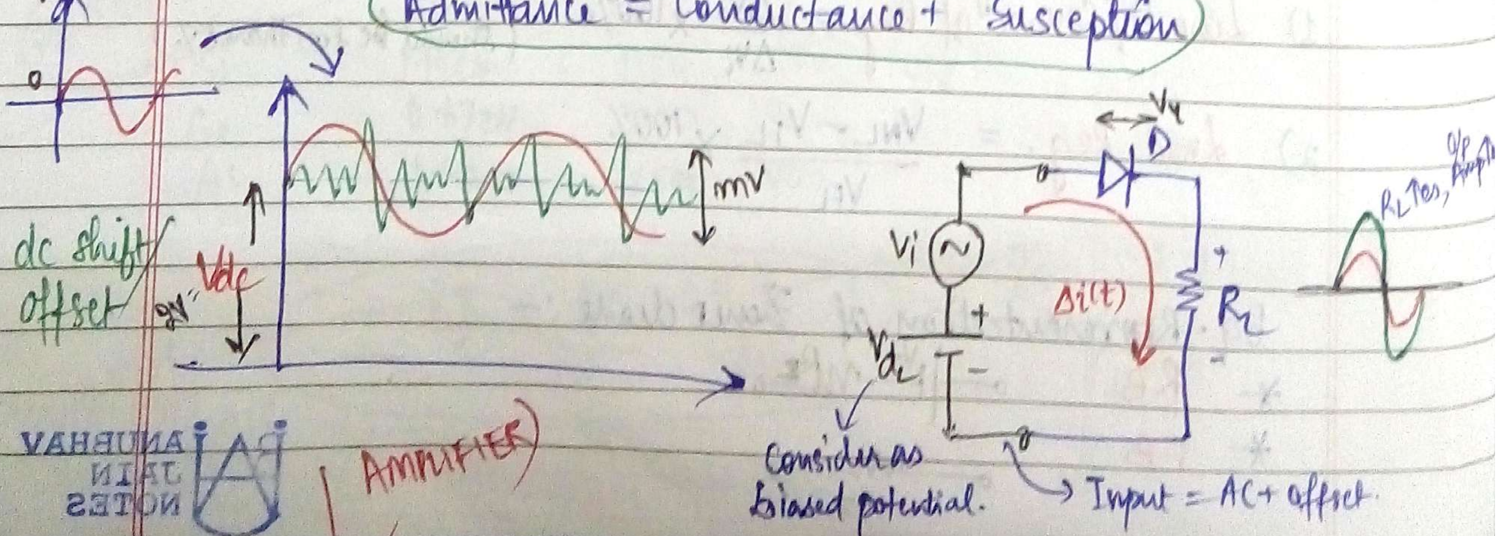
V_R — applied Voltage

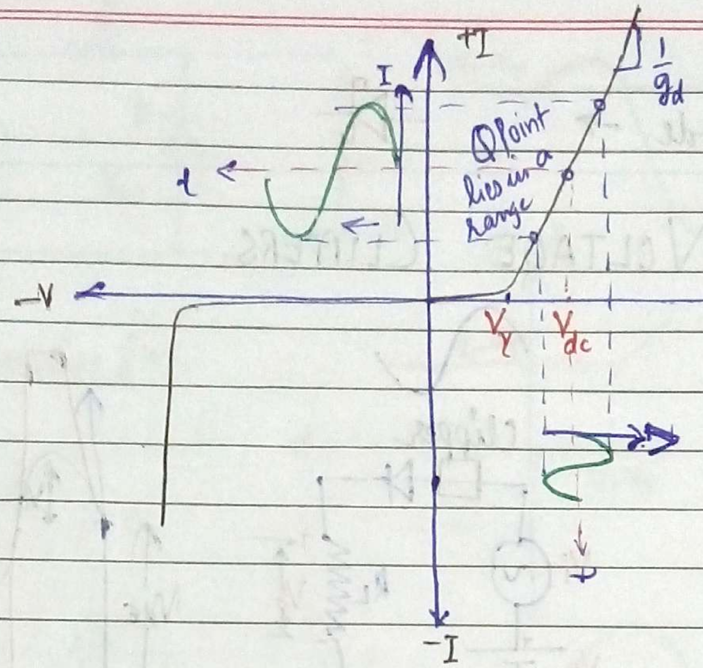
V_{bi} — Built in Voltage (Normal Voltage for Si - 0.7V)

Conductance, $g_m = \frac{1}{r_d}$
(Inverse of Resistance)

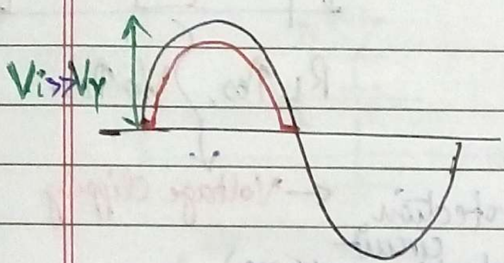
AC equivalent of conductance → Admittance, $Y = g_m + j\omega C_d$

Admittance = Conductance + Susception

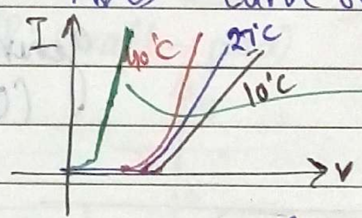




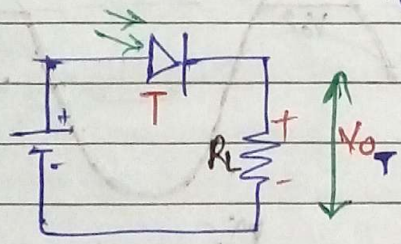
Amplifier limitation: Drop in Voltage across diode.



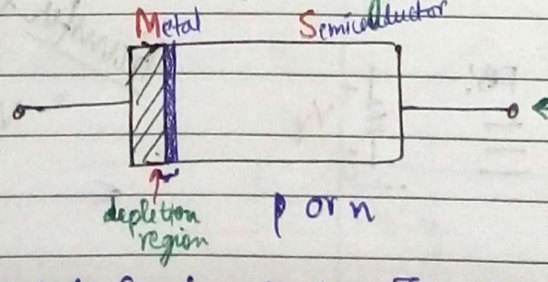
T ↑es → curve shifts Right.



Diode can be used as a Temperature Sensor.
- Low Temp → low thermal (heat) energy → More energy is reqd. to turn it on.
- High Temp ≡ less energy reqd.

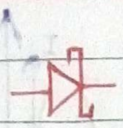


Schottky diodes

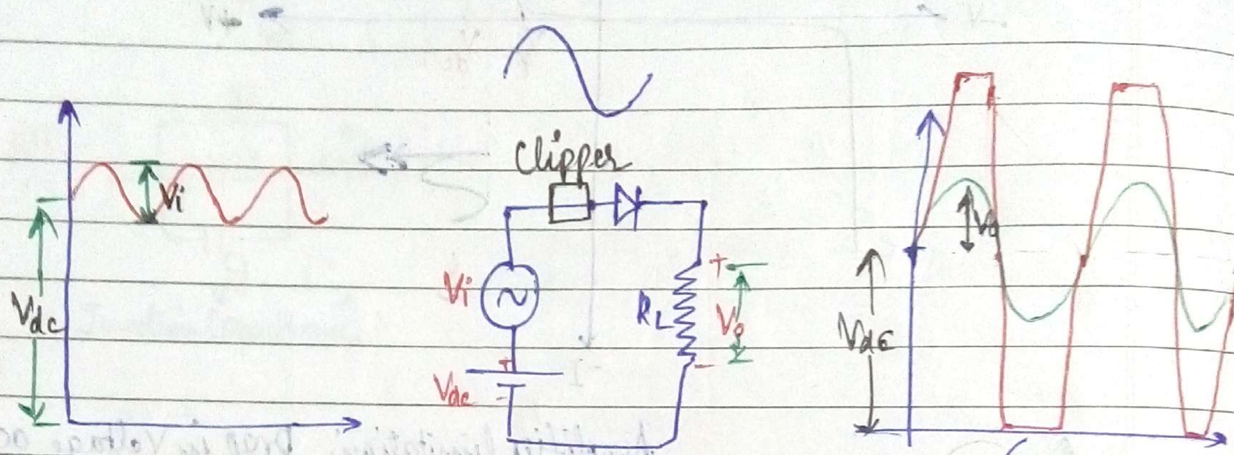


Metal-Semiconductor Junction → nanoscopic level accurate.

Schottky diode →

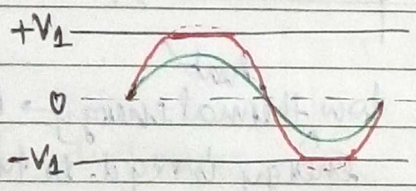


VOLTAGE CLIPPERS

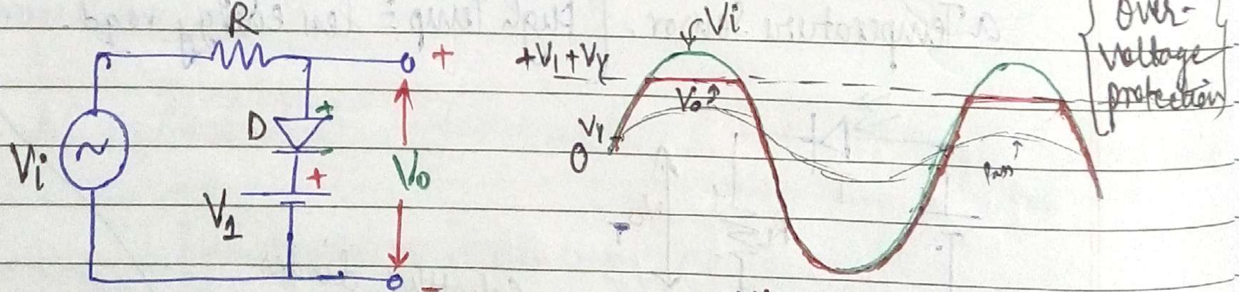


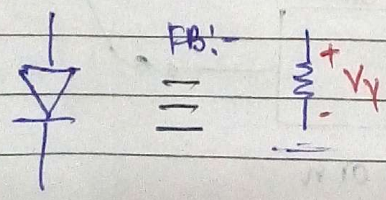
$R_L \uparrow$ es, Vo $\uparrow$ es. → Voltage clipping

generally used for protection circuit ← Voltage clipping
(over voltage protection purpose)

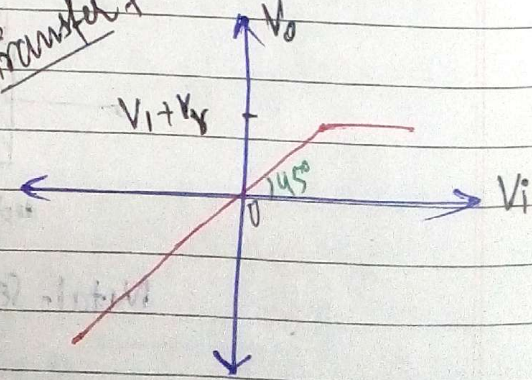


I





Transfer fn:-



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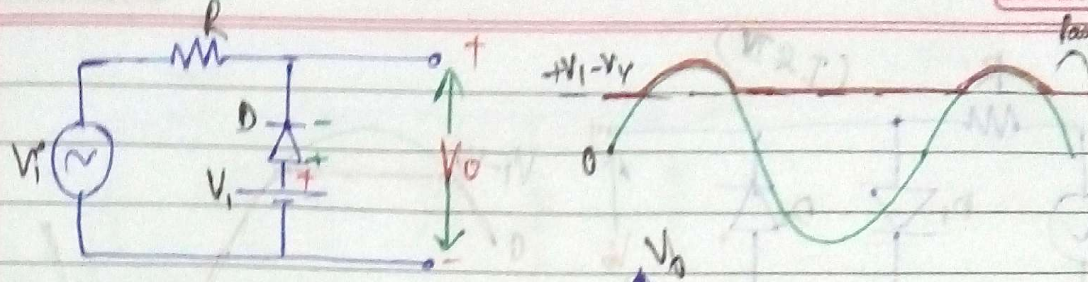
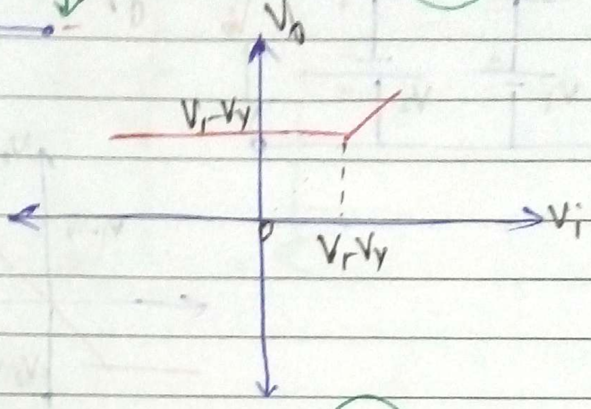
II

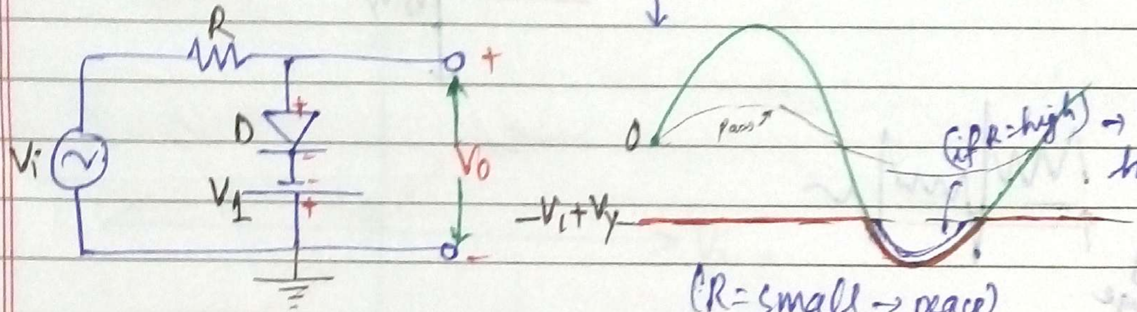


{ Under-Voltage protection }

Transfer fn:-

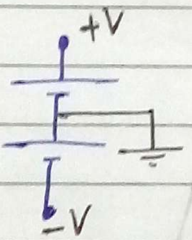


III

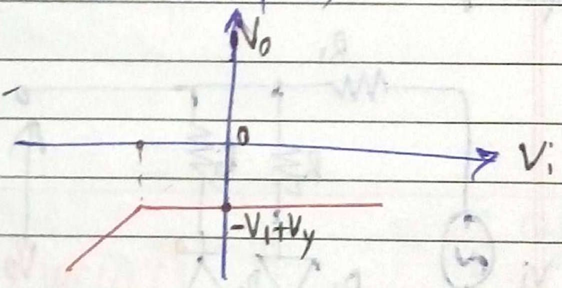


(if R = high) → V drop across R has to be considered

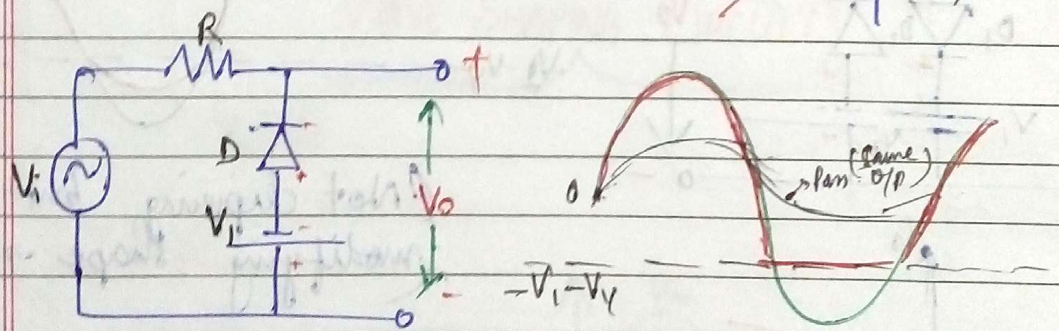
(R = small → peace)



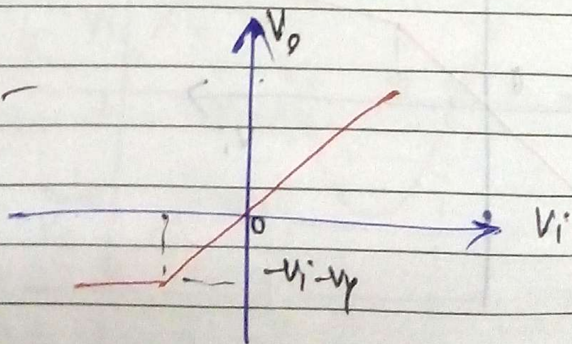
Tf:-

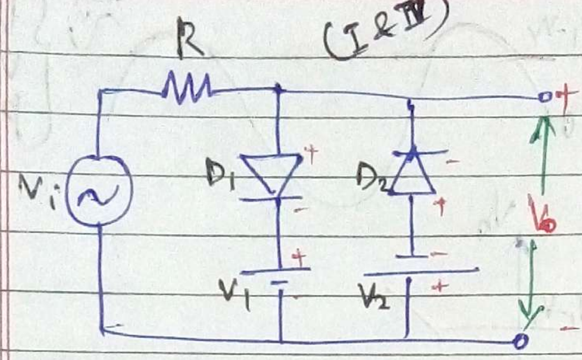


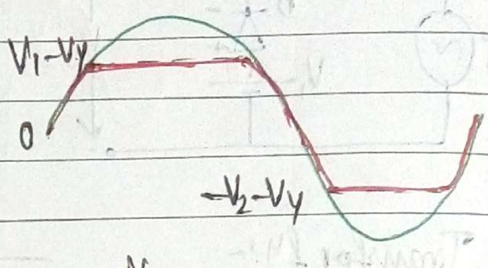
IV

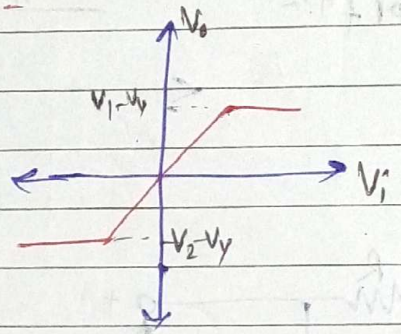


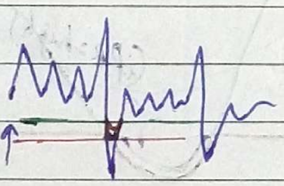
Tf. ch:-





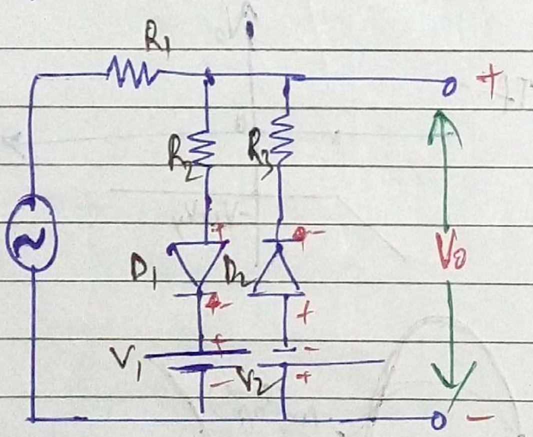


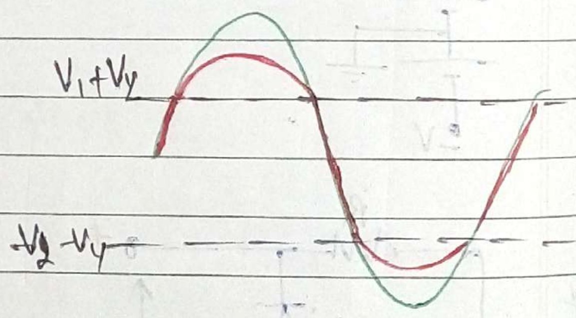




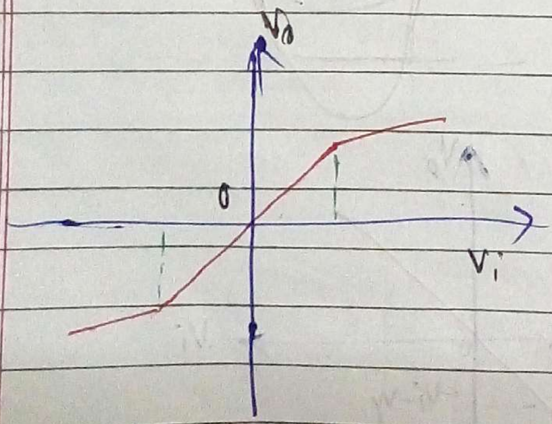
Decrease threshold

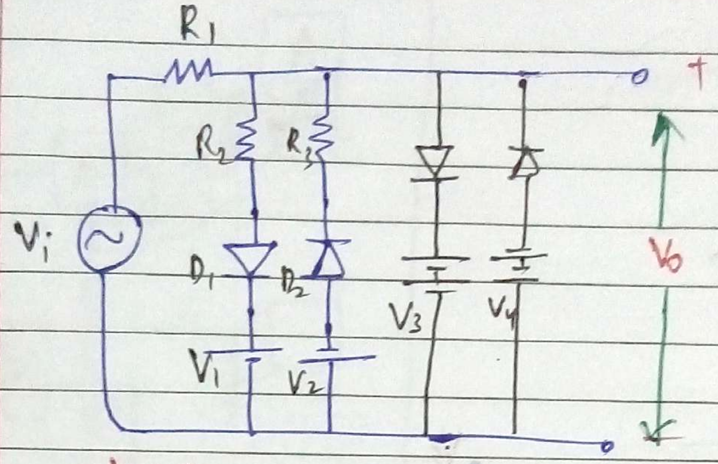
(for producing no sharp change





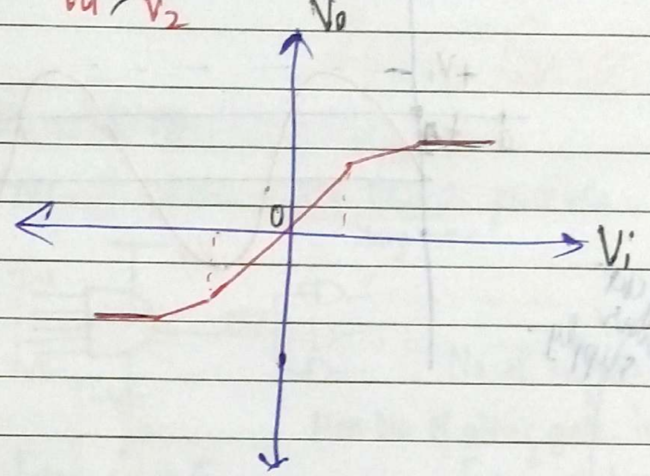
(Not clipping but modifying shape → Vers Amp)





$V_3 > V_1$

$V_4 > V_2$

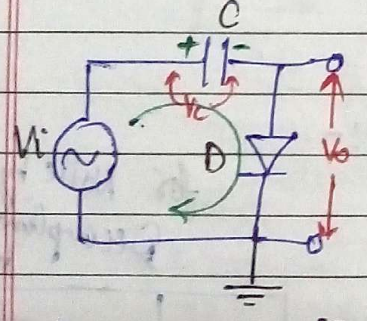


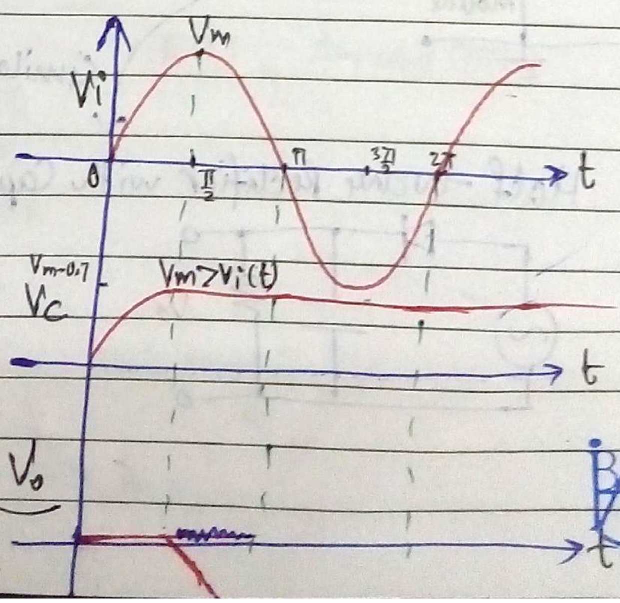
12/08/16

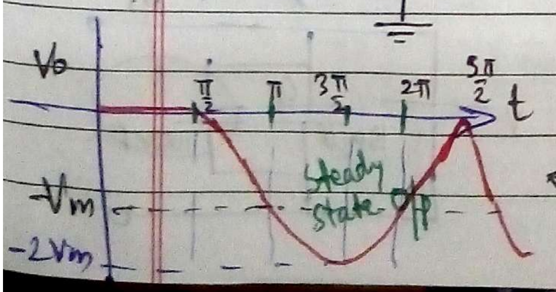
Wave Shaping Circuits

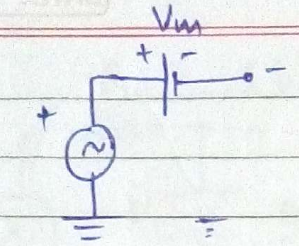
- Clipper
- Clamper → DC shift

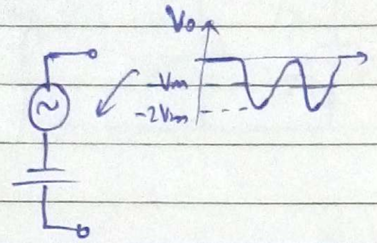
Clamper

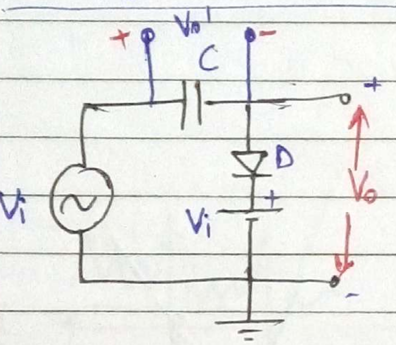


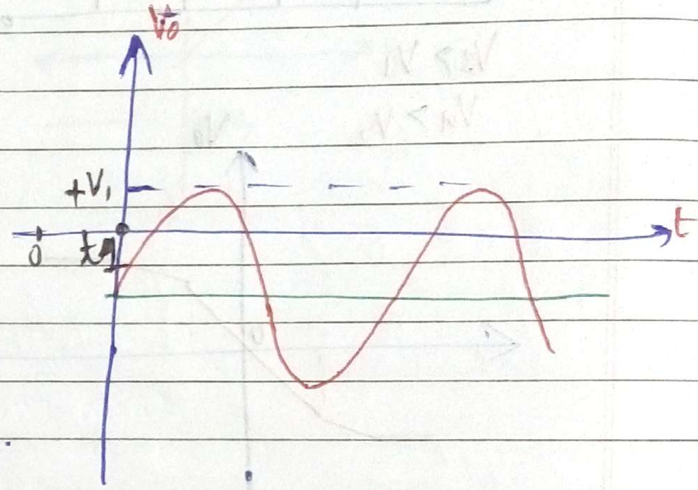




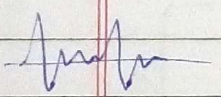


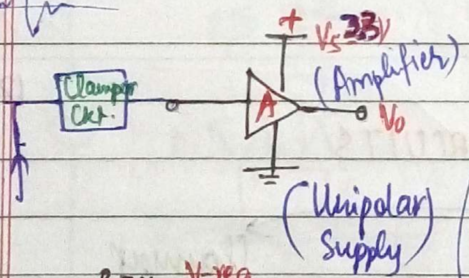


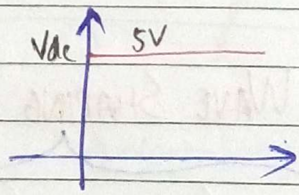


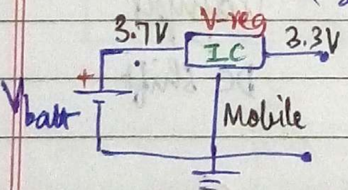


Clamping ckt as power supply.



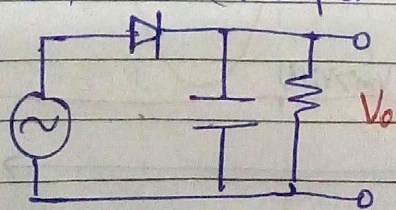




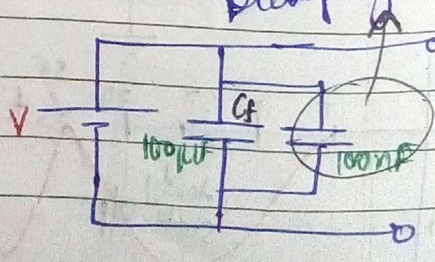


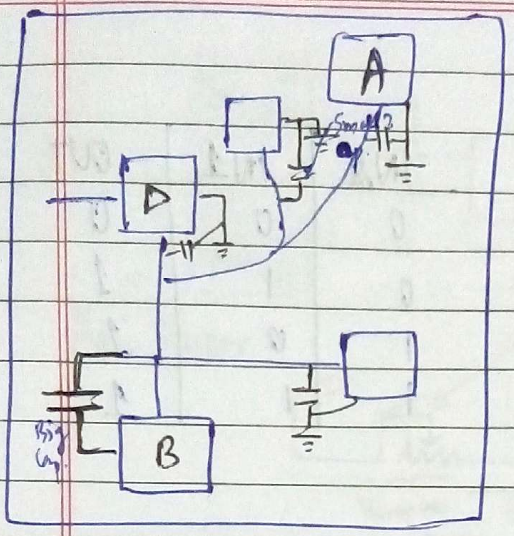
Similar.

Half-wave Rectifier with Capacitor:-



for Noise bypassing/ Decoupling

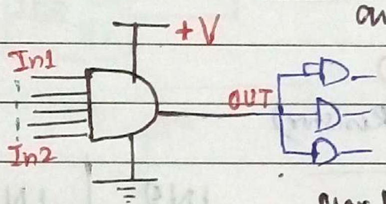




LOGIC GATES

NOT → 1 I/p

Other → 2 or More than 2 possible.
any no.



No. of inputs that can be conneted by output → Limited

Max. No of other gate inputs that may be connected

Fan-in = 5   Fan-out = ~~X~~

* Logic family → TTL, DTL, ECL

TTL: Transistor Transistor Logic (+)

DTL: Diode TL (+)

ECL: Emitter Coupled Logic (−)

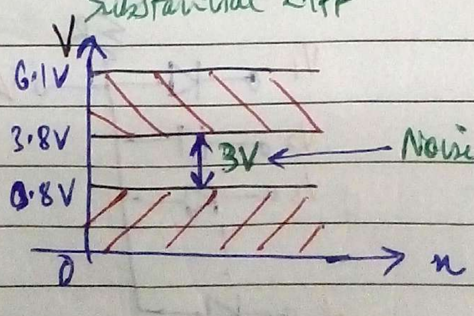
* Noise Margin → 1, 0

TTL

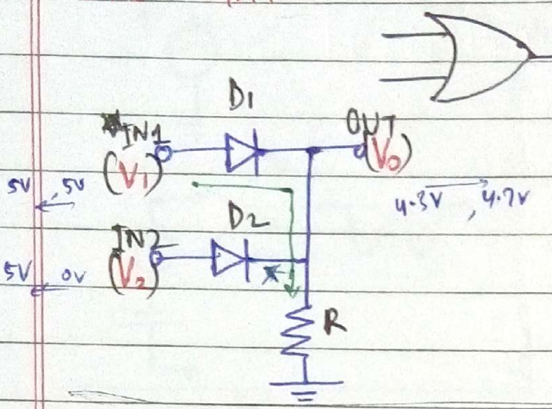
0 → 0V (0–0.8V)

1 → 5V, −5V (ECL), Any value (DTL)
(4.5–5.5)
(3.8–6.4V)

Substantial Diff



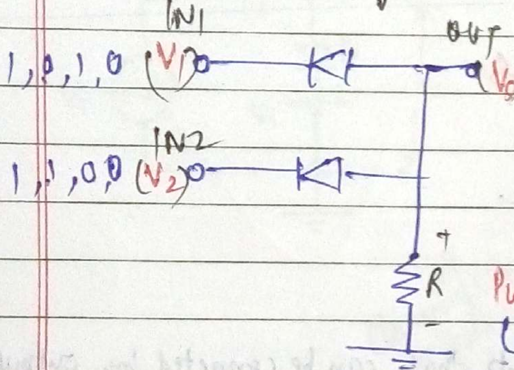
OR GATE



$D_2 \rightarrow RB$

IN2	IN1	OUT
0	0	0
0	1	1
1	0	1
1	1	1

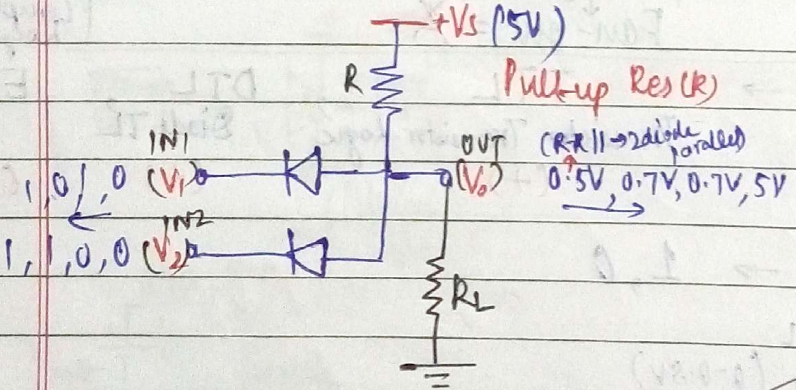
* Iterative Design Process.



(waste of time) → all o/p = 0.

Pull down Res(R)
(Not any Load Resistor)

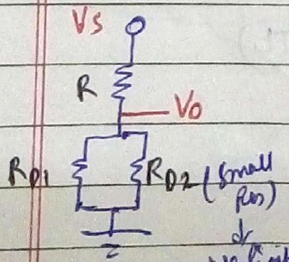
*



Pull-up Res(R)

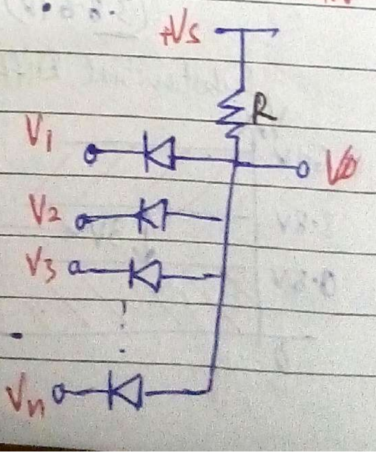
(R‖R → 2 diode parallel)
0.5V, 0.7V, 0.7V, 5V

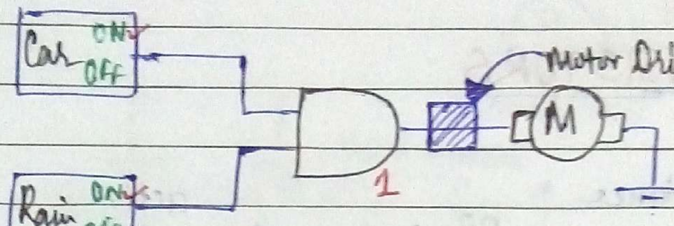
IN2	IN1	OUT
0	0	0
0	1	0
1	0	0
1	1	1



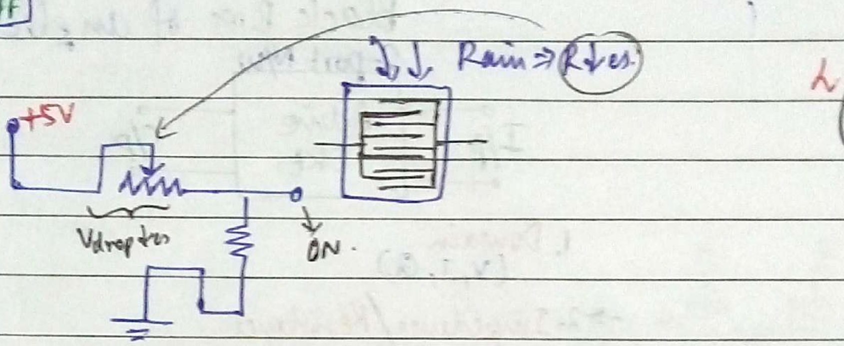
(Small Res)
↓
Negligible V drop.

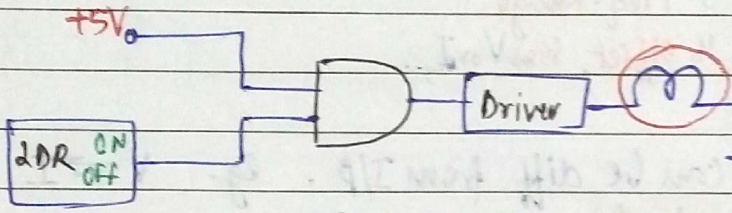
AND GATE: FAN-IN = n

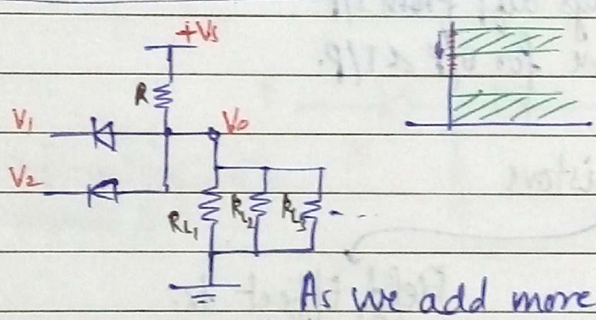




Rain Sensor.







As we add more load res, Vo ↓es.

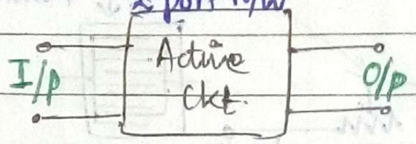
R → large → Fan-out large
R → small → Fan-out low.

TRANSISTORS

Transfer of Resistance

Black Box of an active electronic ckt.

2-port N/W



1. Domain (V, I, Q)
2. Impedence / Resistance
3. Freq. Range
4. Offset, bias V or I, ...

* Domain of O/P can be diff from I/P. eg. $V \rightarrow I$
* Impedence O/P is always diff from I/P.
* Freq. Range can be same for O/P & I/P.

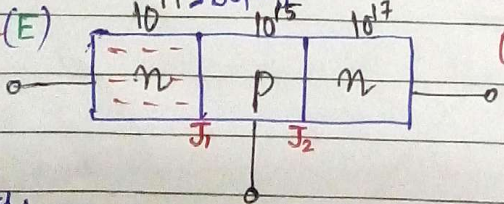
Transistors

Bipolar Junction tr. (BJT) — Field Effect tr. (FET)

→ formed by extention of diode str.

(N_D or N_A) 10^{19} → Doping impurities per unit volume.

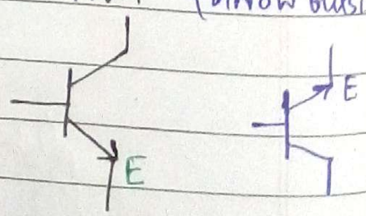
Emitter (E) — highest doping ⇓ Emit charge carriers.



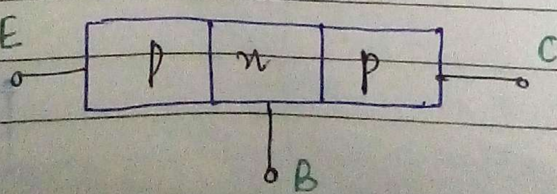
Collector (C)

Base (B) → lightly doped

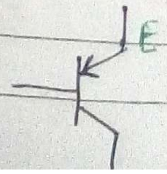
NPN tr. (arrow outside)

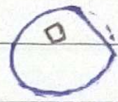


(Arrow ≡ E)



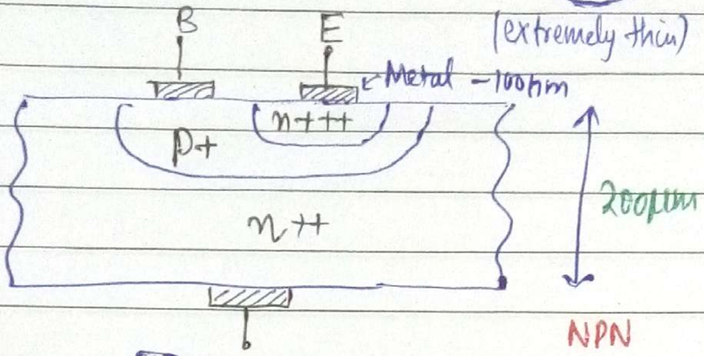
PNP tr. (arrow inside)



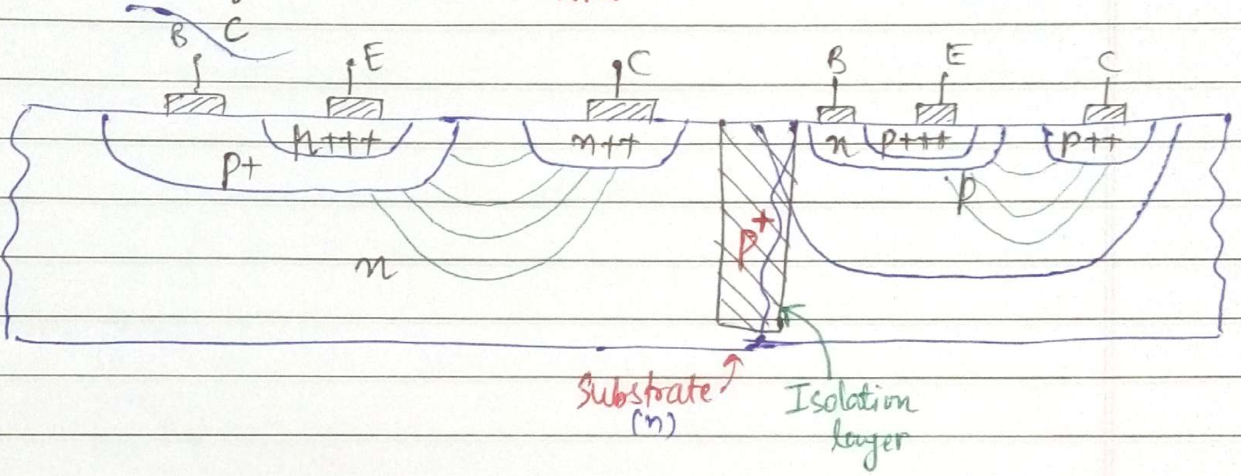


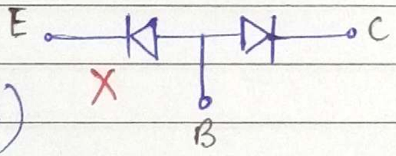
Wafer
(extremely thin)

12", 8", 4", 2" → diameter
industry, lab



NPN



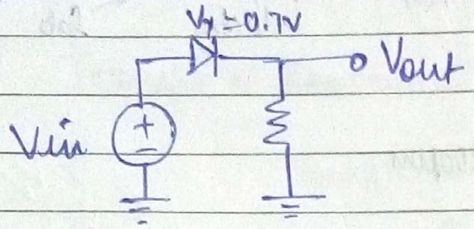


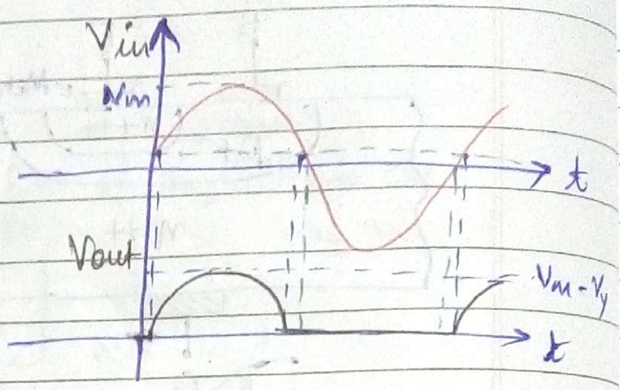
(Not a Realistic Model of tr.)

TUTORIAL

Rectified Circuits

Q1.

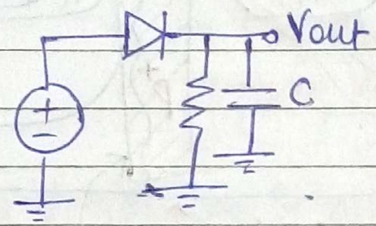


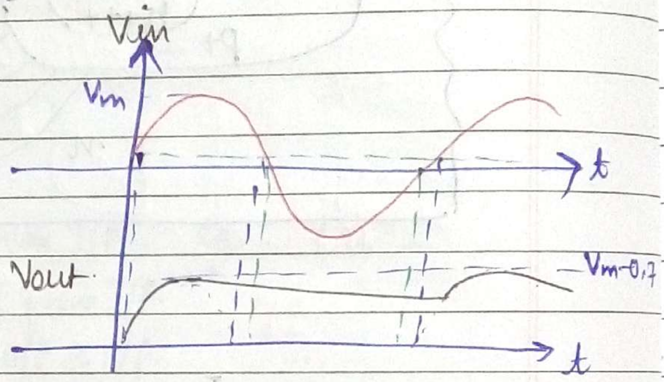


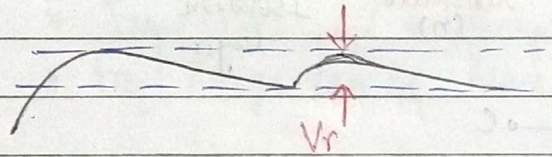
Max. $V_{out} = V_m - V_\gamma$

$V_{in} = V_m \sin(\omega t)$

If





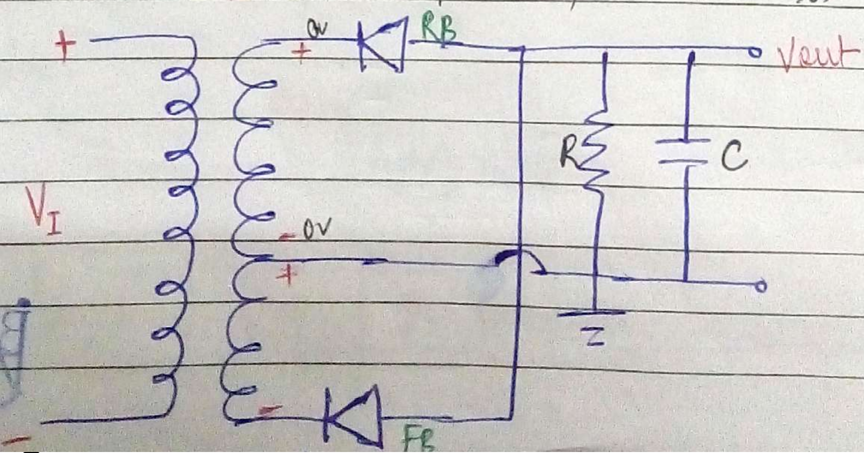


Full wave $V_r = \dfrac{V_m - 0.7}{2fRC}$

Halfwave $V_r = \dfrac{V_m - 0.7}{fRC}$

Q1. The rectifier circuit shown in Fig 1 has an input signal value of freq 60 Hz. Rms of $V_s = 8.5V$. Cut-in voltage of diodes $= 0.7V$, $R = 10\Omega$, $C = 40mF$

Find max. value of V_0, What is PIV of each diode?



Centre tap transformer.

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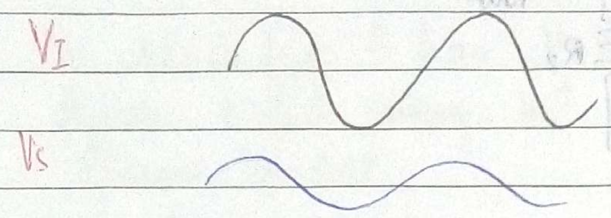
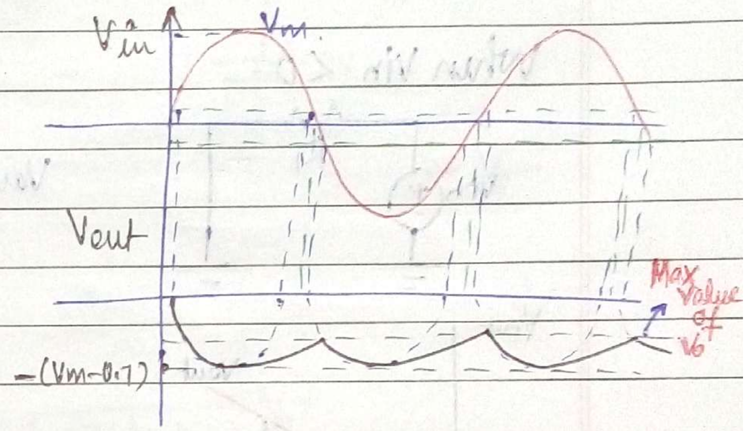


→ half of V_I.

$$V_{o_{rms}} = \frac{8.5-0.7}{2\times 60\times 10\times 40\times 10^{-3}} = \frac{13}{80} = 0.1625\,V$$

$$V_{o_p} = V_{o_{rms}}(\sqrt{2}) = 0.2298\,V.$$



$V_m = 8.5\sqrt{2} = 12.021\,V$

$V_m - 0.7 = 11.321\,V.$

$V_{o\,max} = -11.321 + 0.2298$

$= -11.091\,V.$

$$V_r = \frac{11.321}{2\times 60\times 10\times 40\times 10^{-3}}$$

$= 0.2358 \cong 0.236\,V$

$\therefore V_{o\,max} = -11.32 + 0.236 = -11.0851\,V$

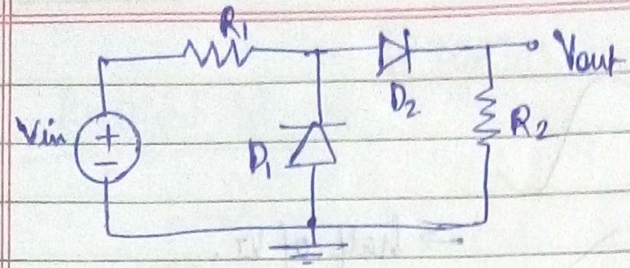
PIV: Peak Inverse Voltage :-

Max value of V_i - Min value of Vout will max. value of diode voltage.

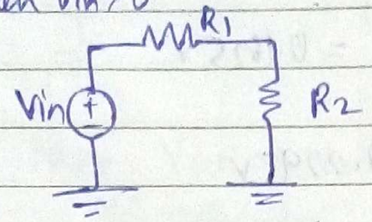
Max. PIV of diode $= 12.02 - (-11.32)$

$= 23.34\,V.$

Q2. In the circuit of fig 2, $R_1 = 500\,\Omega$, $R_2 = 1\,k\Omega$. Sketch the input output characteristics for Vout v/s Vin. Also plot the current through R_1. Assume $V_\gamma = 0\,V$.



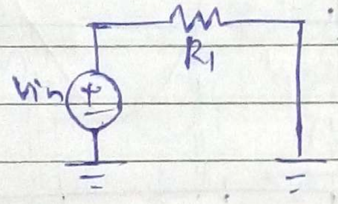
When $V_{in} > 0$



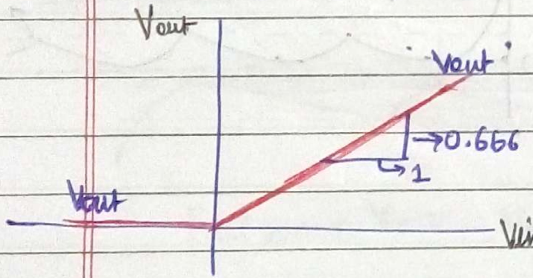
$$V_{out} = \frac{R_2}{R_1+R_2} V_{in} = \frac{2}{3} V_{in}$$

$$= V - \frac{R_1}{R_1+R_2} V$$

When $V_{in} < 0$



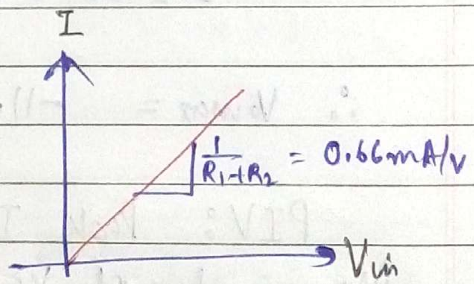
$V_{out} = 0$



Current through R_1

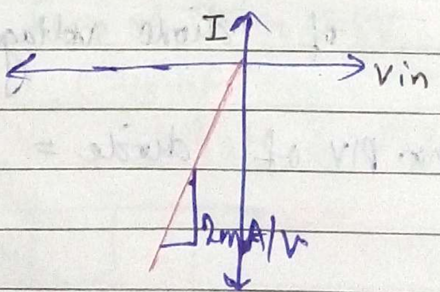
When $V_i \geq 0$

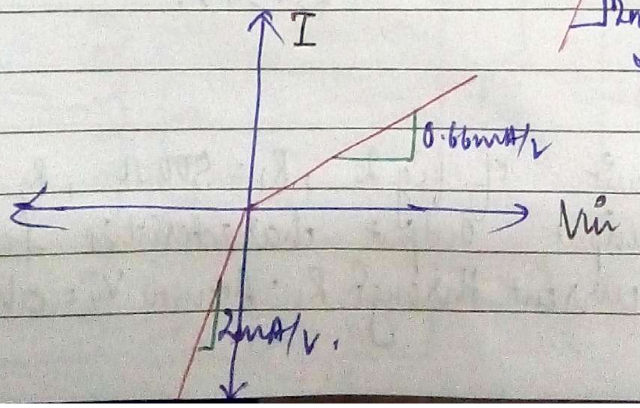
$$I = \frac{V_{in}}{R_1+R_2}$$



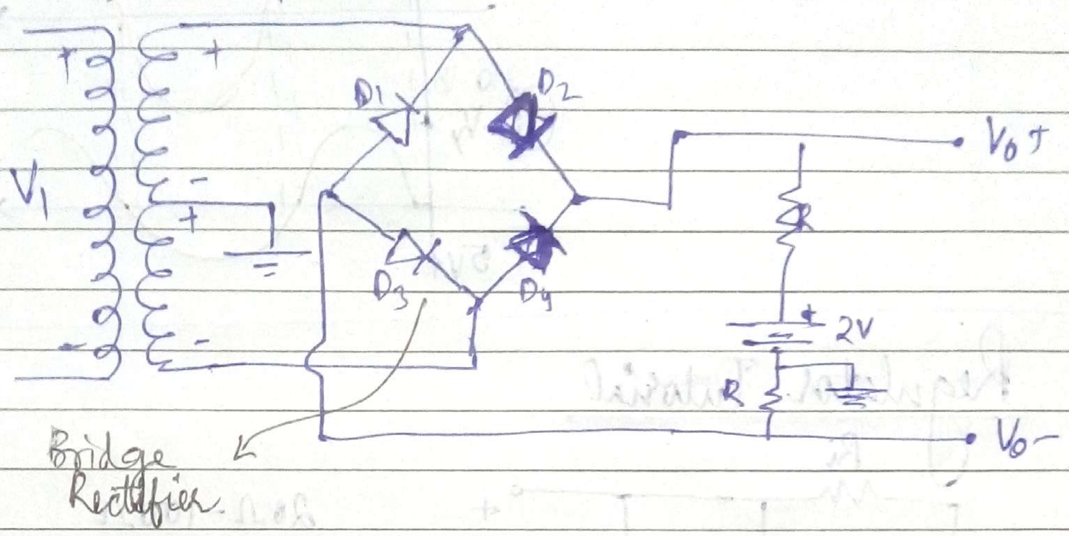
When $V_i < 0$

$$I = \frac{V_{in}}{R_1}$$

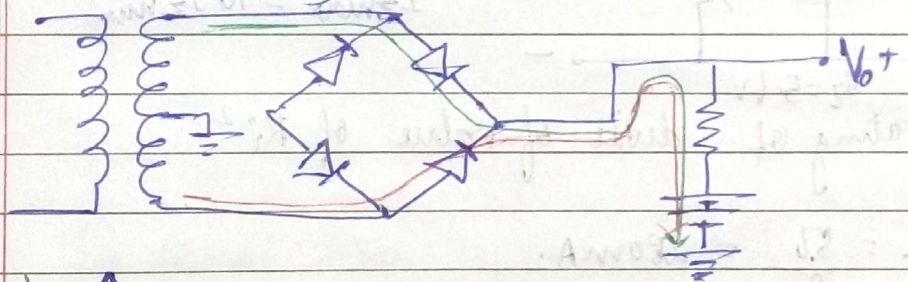


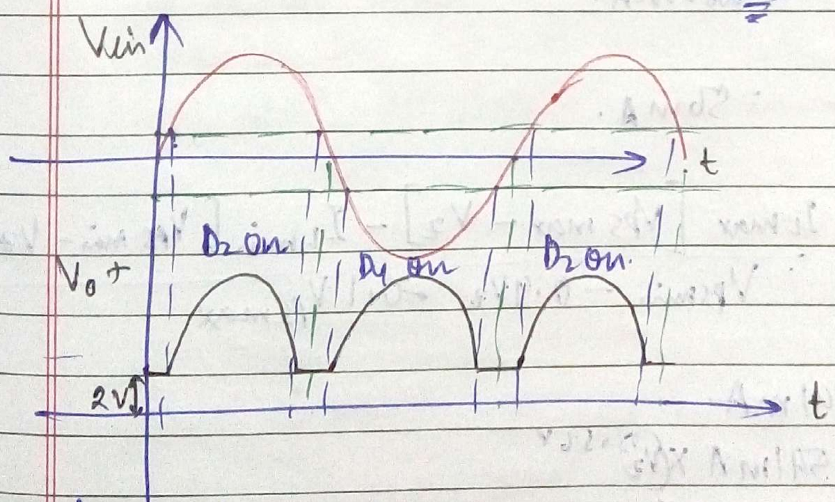


Q3. The ckt. in fig B has $V_s = 26\sin(2\pi 60 t)$. Sketch output voltage V_o^+ and V_o^- v/s time. Assume $V_\gamma = 0.7V$

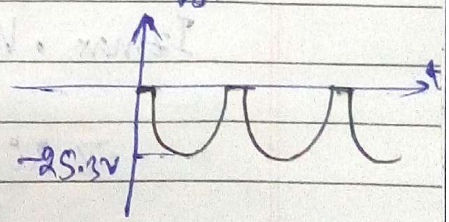


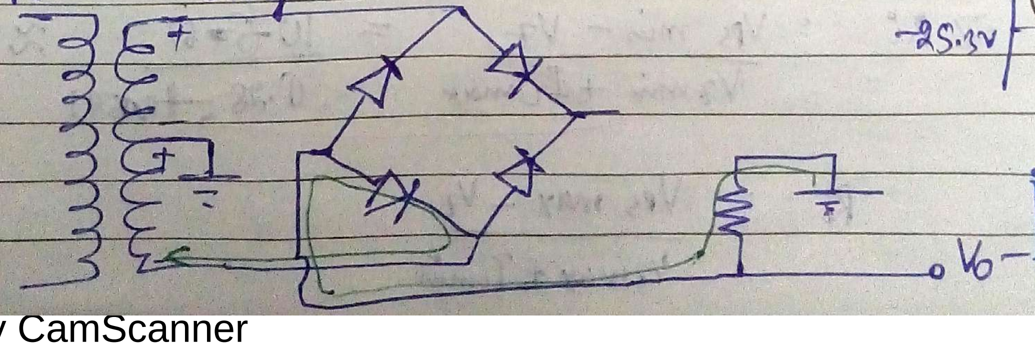
Considen V_o^+ only





Now V_o^- only:-





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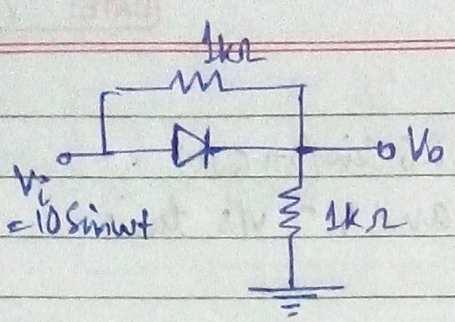
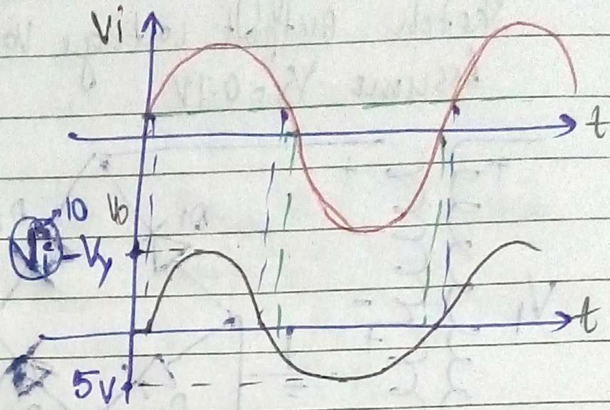
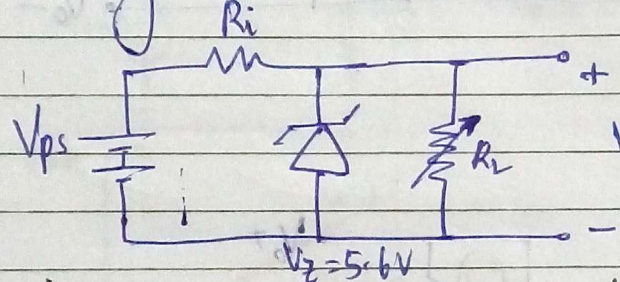


Plot V_o v/s t.



Regulator Tutorial

Q1.



$20\Omega - 100\Omega$

$I_{zmax} = 10\, I_{zmin}$

Find power rating of diode of value of R_i?

$$I_{Lmax} = \frac{5.6}{20} = 280mA.$$

$$I_{Lmin} = \frac{5.6}{100} = 56mA.$$

$$I_{zmax} = \frac{I_{Lmax}[V_{ps\,max} - V_z] - I_{Lmin}[V_{ps\,min} - V_z]}{V_{ps\,min} - 0.9V_z - 0.1\,V_{ps\,max}}$$

$$= 591mA.$$

$$I_{zmax} \cdot V_z = 591mA \times V_z \;(5.6V)$$
$$= 3.31W.$$

$$\Rightarrow R_i = \frac{V_{ps\,min} - V_z}{I_{zmin} + I_{Lmax}} = \frac{10 - 5.6}{0.28 + 0.0591} \approx 13\Omega$$

$$R_i = \frac{V_{ps\,max} - V_z}{I_{zmax} + I_{Lmin}}$$

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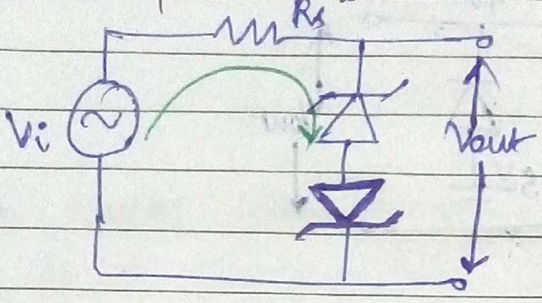
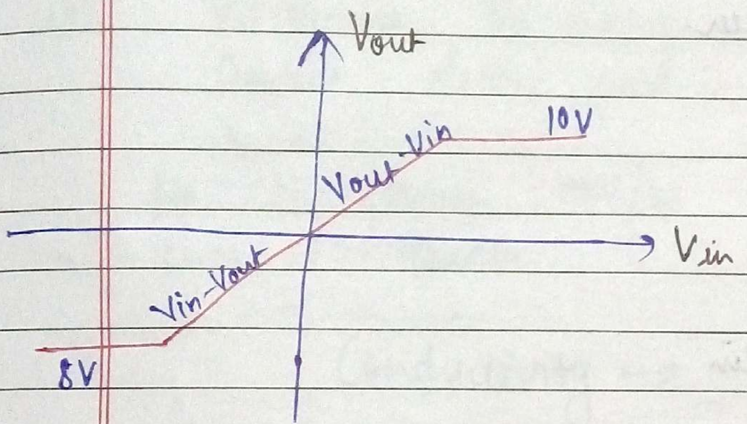
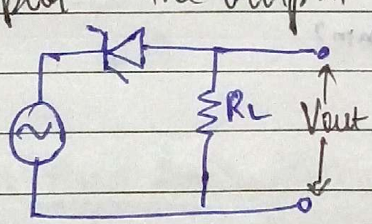
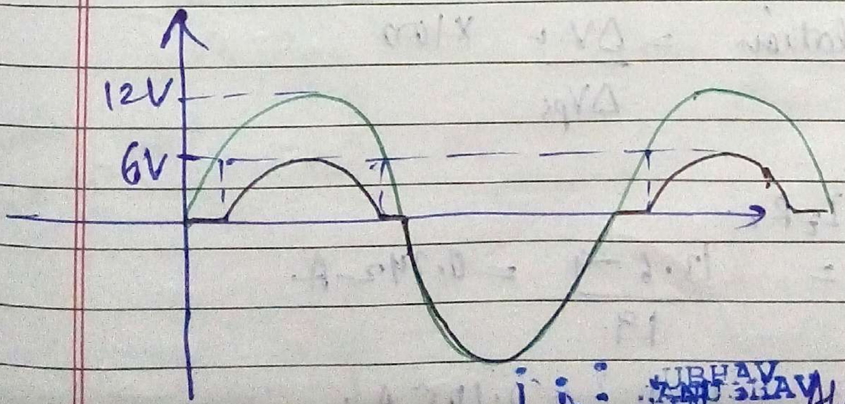
Q2. In the circuit shown diodes are ideal and have breakdown voltage of $V_{Z_1} = 10V$, $V_{Z_2} = 8V$. If input is 15V peak sinusoidal waveform then plot the output of transfer characteristics.

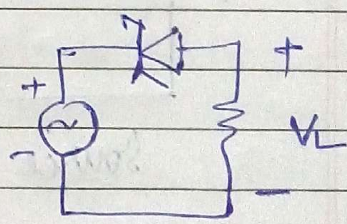


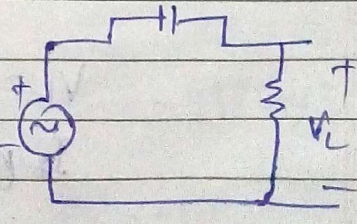


Q3. In circuit shown, zener diode is ideal and breakdown voltage is 6V, if the input voltage is 12V peak sinusoidal then plot the output waveform.





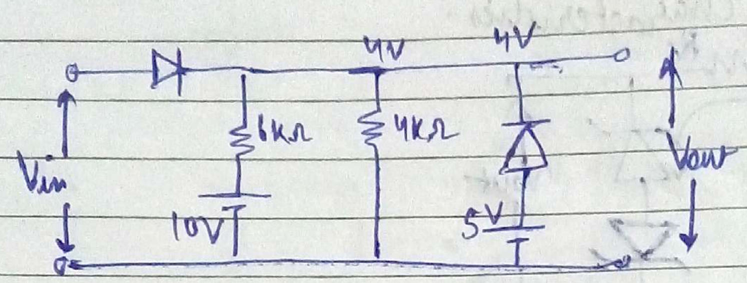




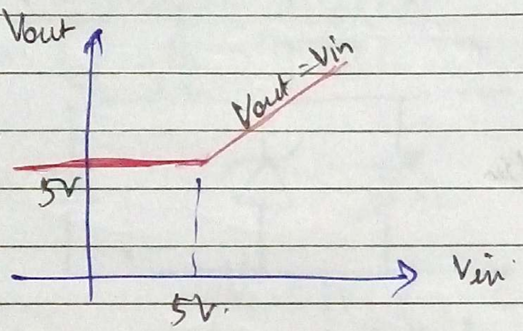
(i) Vin+ve

After breakdown, $V_{in} - 6 = V_L$, It const value $= 6V$.
Vin = +ve.

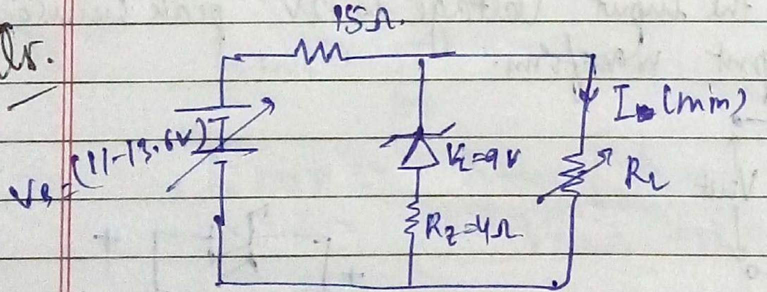
Q4. In the circuit shown, the diodes are ideal. Plot its char.



First assume both are open.



Q5.



Source Regulation $= \frac{\Delta V_L}{\Delta V_{PS}} \times 100$

$V_L = V_Z + I_Z R_Z$.

I_Z (max) $= \frac{13.6 - 9}{19} = 0.242$ A

I_Z min $= \frac{11-9}{19} = 0.105$ A.

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V_{rmax}, V_{rmin} ; $\Delta V_r = V_{rmax} - V_{rmin}$

TUTORIAL

24/08/16.

Q2(i) In GaAs determine the range of conductivity for a range in donor concentration of $10^{15} \le N_d \le 10^{19}$ cm^{-3}

(ii) Determine the range of direct current density if the applied electric field is $E = 0.1$ V/cm.

$\mu_p = 400$ ~~[illegible]~~ cm^2/Vs

$\mu_n = 8500$ ~~[illegible]~~ "

(i) Conductivity $\rightarrow$ $\sigma = e\,\mu_n N_d$. Ω^{-1}cm^{-1}

$$\sigma_{max} = 13600$$

$$\sigma_{min} = 1.36$$

$$\Rightarrow \quad 1.36 < \sigma < 13600$$

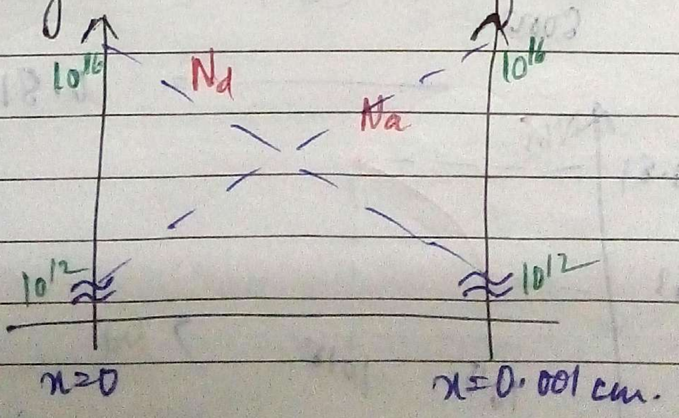
(ii) $J_n = \sigma E = 0.1\,\sigma$

$$\Rightarrow \quad 0.136 < J < 1360$$

$\hookrightarrow$ A cm^{-2}

(iii) Electron and hole conc in a sample of silicon are shown in fig. Determine the total diffusion current density versus distance for $0 \le x \le 0.001$ cm

diffusion $\rightarrow$ conc gradient



$\mu_n = 1250$ cm^2/Vs

$\mu_p = 450$ cm^2/Vs.

$$\frac{dn}{dx} = \frac{-(10^{16} - 10^{12})}{0.001 - 0} = -9.999 \times 10^{18}$$

$$\frac{dp}{dx} = -\frac{dn}{dx} = +9.999 \times 10^{18}$$

$$\boxed{\frac{KT}{e} = \frac{D_n}{\mu_n} = \frac{D_p}{\mu_p}}$$

$$J_n = e D_n \frac{dN_d}{dx}$$

$$= \cancel{e}\, \mu_n \frac{kT}{\cancel{e}} \frac{dN_d}{dx} = -51.767 \ \cancel{\times 10^{4}} \times 10^{2} \cancel{\times 10^{9}} \ A\,cm^{-2}.$$

$$= 5176.7 \ A\,cm^{-2}.$$

$$J_p = -e D_p \frac{dN_a}{dx}$$

$$= -\mu_n KT \frac{dN_a}{dx} = -18.62,8137 \times 10^{2} \ A\,cm^{-2}$$

Total diffusion current density $= -70.72 \ A/cm^2$.

my $\to$ -70.7

Q3 (i) The donor concentration at a silicon p-n Junction is $N_d = 10^{16}\ cm^{-3}$ plot the V_{bi} versus N_a over the range of $10^{15} \le N_a \le 10^{18}\ cm^{-3}$ at 300k.

$n_i = 1.5 \times 10^{10}\ cm^{-3}$

$N_d = 10^{16} cm^{-3}$

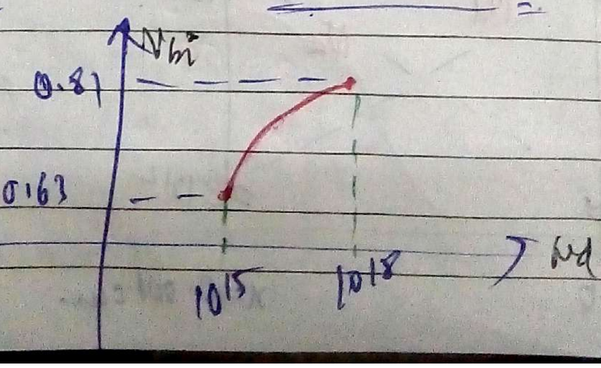
$V_{bi} \rightarrow$ Built in potential

$$= \frac{KT}{q} \ln\left(\frac{N_a N_d}{n_i^2}\right)$$

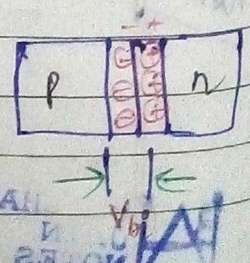
$$V_{bi} = \frac{(1.38\times10^{-23})(300)}{(1.6\times10^{-19})} \ln\left\{\frac{N_a\,(10^{16})}{(1.5\times10^{10})^2}\right\}$$

$$V_{bi}\ min = \frac{207}{8000} \ln\left(\frac{-}{-}\right) = 0.6344\,V$$

$$V_{bi}\ \cancel{max} = \text{———} = 0.8131\,V.$$



~~0.7401~~
350K
~~0.9486~~



$C_j = C_{j0}\left(1+\frac{V_R}{V_{bi}}\right)^{-1/2}$

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On changing Temp, n_i also changes.

$n_i \propto T^{3/2}$

$$\frac{n_i'}{1.5\times10^{10}} = \left(\frac{350}{300}\right)^{3/2} = 1.588.$$

$$\therefore n_i' = 2.38\times10^{10}$$

$$V_{bi\,max} = \left(\frac{1.38\times10^{-23}\times350}{1.6\times10^{-19}}\right)\ln\left(\frac{(10^{18})(10^{16})}{(2.38\times10^{10})^2}\right) = 0.92.$$

Q4. The zero biased Junction capacitance of a Silicon p-n junction is $C_{j0} = 0.4\,pF$. The doping conc are $N_a = 1.5\times10^{16}\,cm^{-3}$ & $N_d = 4\times10^{15}\,cm^{-3}$.

Determine the junction cap at

(a) $V_R = 1V$ (b) $V_R = 3V$ (c) $V_R = 5V$.

$$V_{bi} = \frac{kT}{e}\ln\frac{N_a N_d}{n_i^2} = 0.68\,V.$$

(a) $C_j = (0.4\,pF)\left(1+\frac{01}{0.68}\right)^{-1/2} = 0.254\,pf.$

(b) $C_j = (0.4\,pf)\left(1+\frac{3}{0.68}\right)^{-1/2} = 0.172\,pf.$

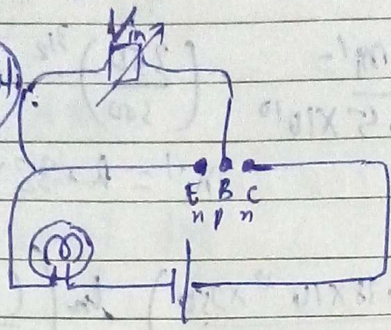
(c) $C_j = (0.4\,pf)\left(1+\frac{5}{0.68}\right)^{-1/2} = 0.138\,pf.$

ANUBHAV JAIN NOTES

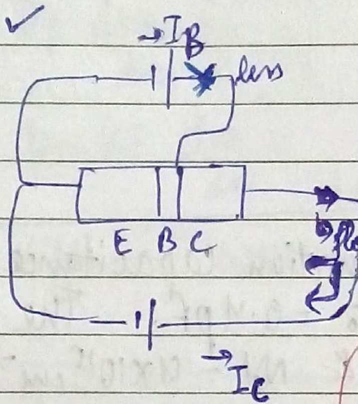
Transistor. ON → 0Ω Resistance } Switch | Amplifier (somewhere in between 0 to ∞Ω) Ω kΩ MΩ
OFF → ∞Ω.

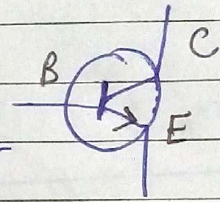
YouTube | LearnEngineering
Transistor – How does it work

Vin not enough to overcome barrier potential ∴ OFF

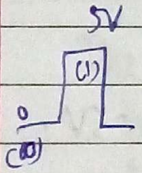


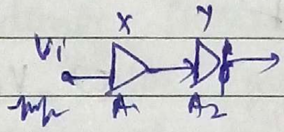
Silicon alone → no use
Silicon + Doping ✓



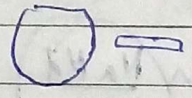


Current Gain | $\beta = \frac{I_C}{I_B} > 1$





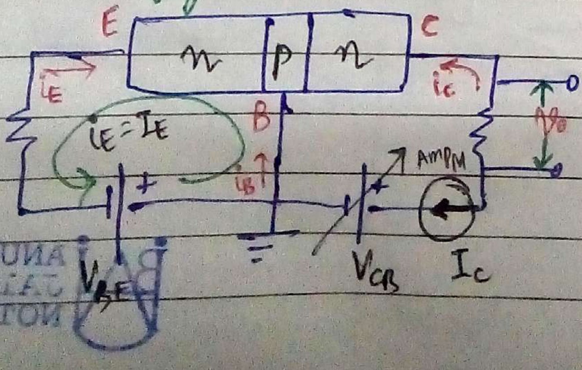
Gain = X·Y.



Transistor Ckts

- → Common Base config. ✓
- → ——— E ——— ✓
- → ——— C ———

CB config.



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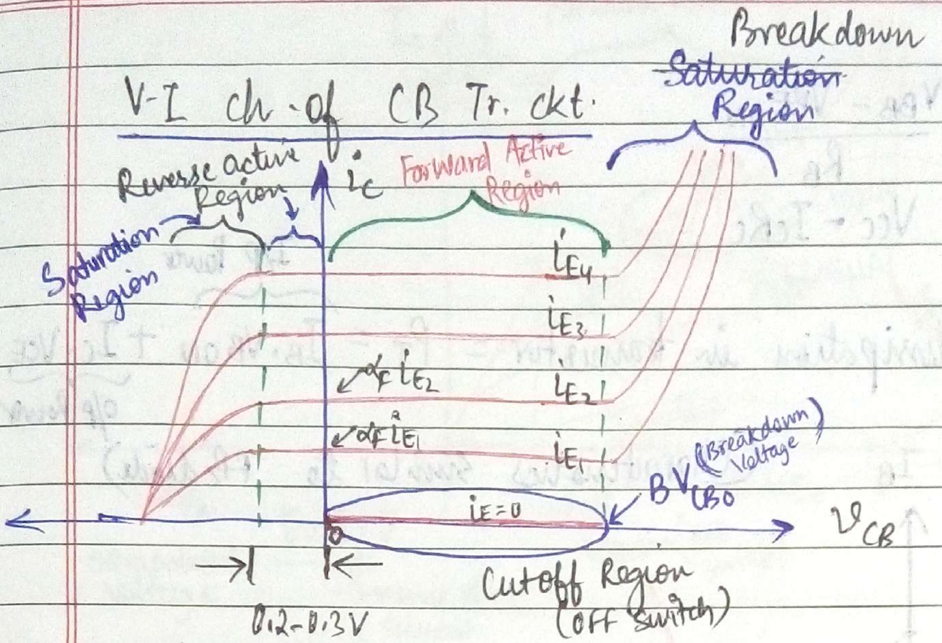
V-I ch. of CB Tr. ckt.



$\alpha_F \rightarrow$ CB current gain (never zero) (≤ 1) Specified by manufacturer in datasheet.

Collector Base CB (n-p) ⇒ Rev. biased

$i_E = 0 \Rightarrow$ leakage current flows (negligible) ↳ OFF SW cond^n.

Appl^n of CB conf:-

1. Constant I Source (F/W active Region)
2. OFF SW
3. Amp.

$$i_E = I_{E_0}\, e^{V_{BE}/V_T} \qquad I_{E_0}: 10^{-12} \text{ to } 10^{-15},\quad V_T = 26\,mV$$

$$i_C = I_S\, e^{V_{BE}/V_T}$$

$$i_C = \alpha\, i_E \qquad I_S = \alpha I_{E_0}$$

$$i_B \propto e^{V_{BE}/V_T}$$

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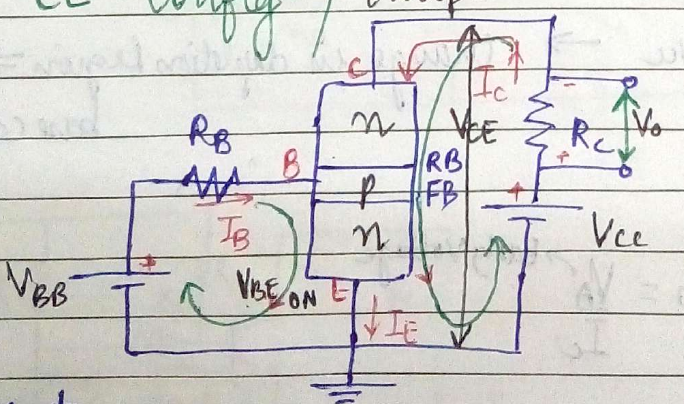
CE Config. / amp.



(α = CB current gain)

* β = CE current gain (50-200)

$(\alpha \leq 1 \ll \beta)$

* $\alpha = \dfrac{\beta}{1+\beta}$ * $\beta = \dfrac{\alpha}{1-\alpha}$

Lab → $\beta = 100$

emitter current.

- $I_E = I_C + I_B$
- $\boxed{I_C = \beta I_B}$ ↳ V_{CE} = const (cond^n) ⇒ $\boxed{I_C > I_B}$

$\boxed{V_{CC} > V_{BB}}$

ANUBHAV JAIN NOTES

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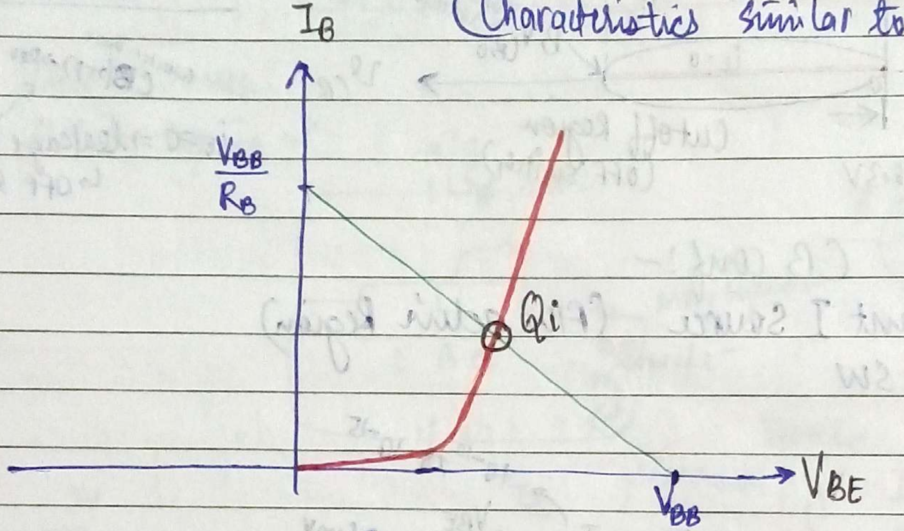
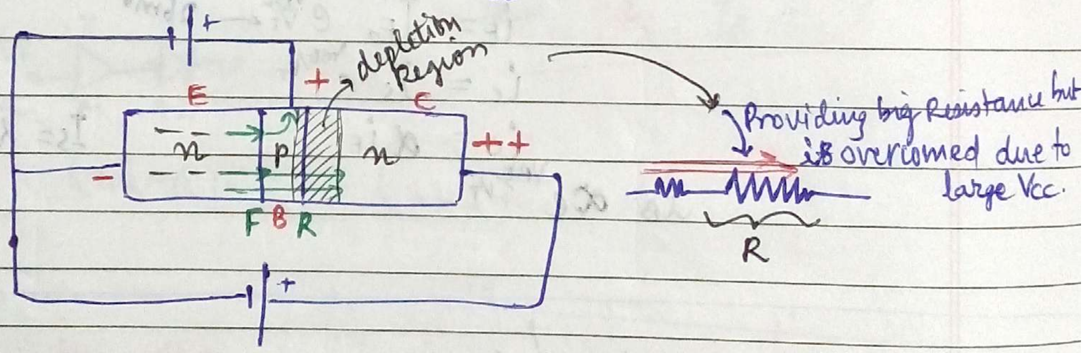
$$I_B = \frac{V_{BB} - V_{BE_{ON}}}{R_B}$$

$$V_{CE} = V_{CC} - I_C R_C$$

Total power dissipation in transistor $= P_T = \underbrace{I_B \cdot V_{BON}}_{\text{I/P Power}} + \underbrace{I_C \cdot V_{CE}}_{\text{O/P Power}}$

(Characteristics similar to FB diode)





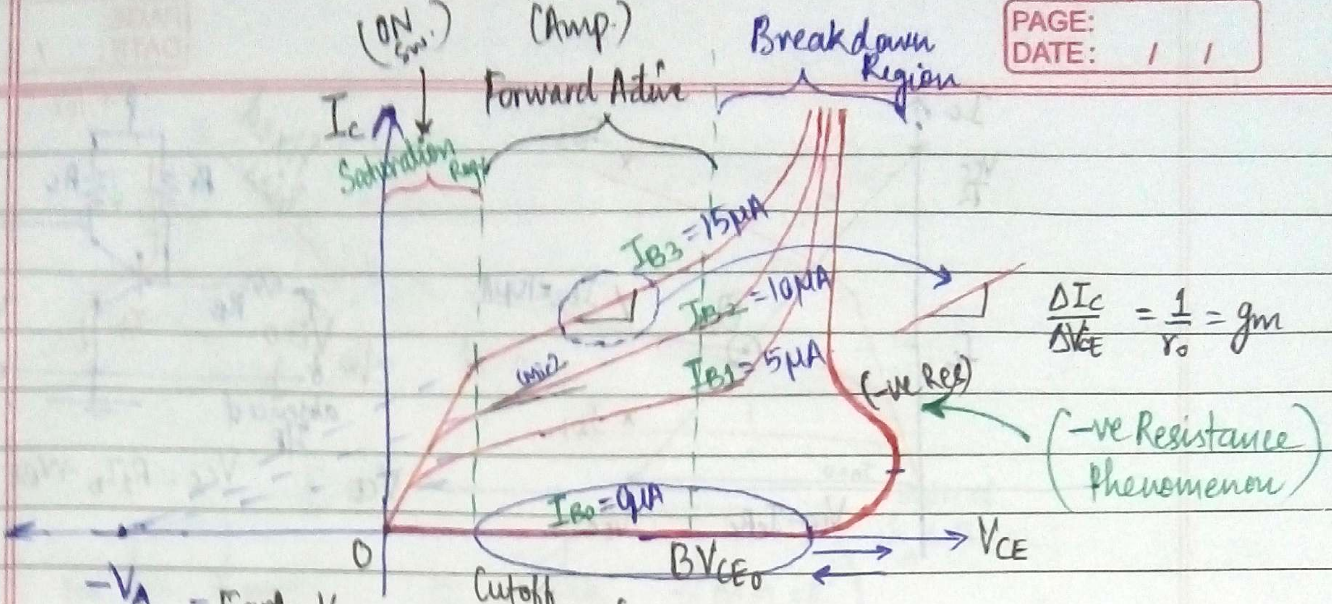
Base width modulation } Change in Vcc → Change in depletion Region ⇒ width of base can be modified

$$r_0 = \frac{V_A}{I_C}$$ V_A → Early Voltage

$$BV_{CE_0} = \frac{BV_{CBO}}{\sqrt[n]{\beta}}$$

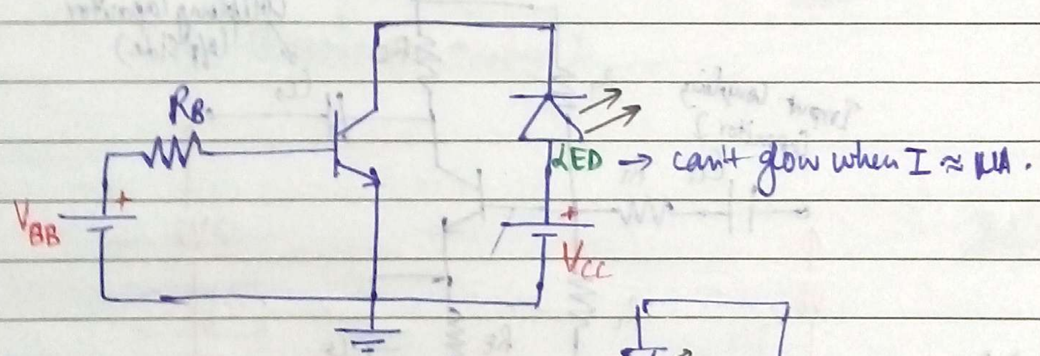
n = 3–6 (Given by manufacturer)

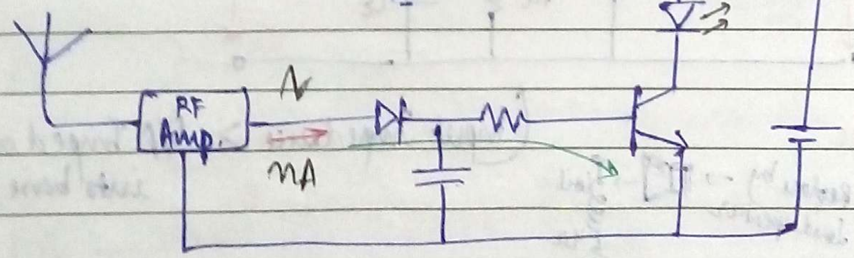
ANUBHAV JAIN NOTES

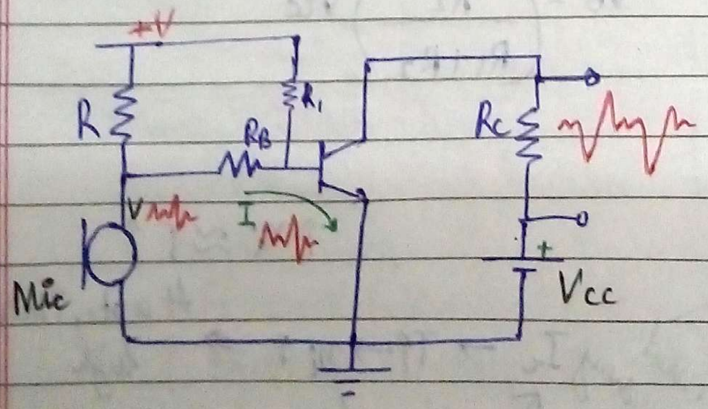


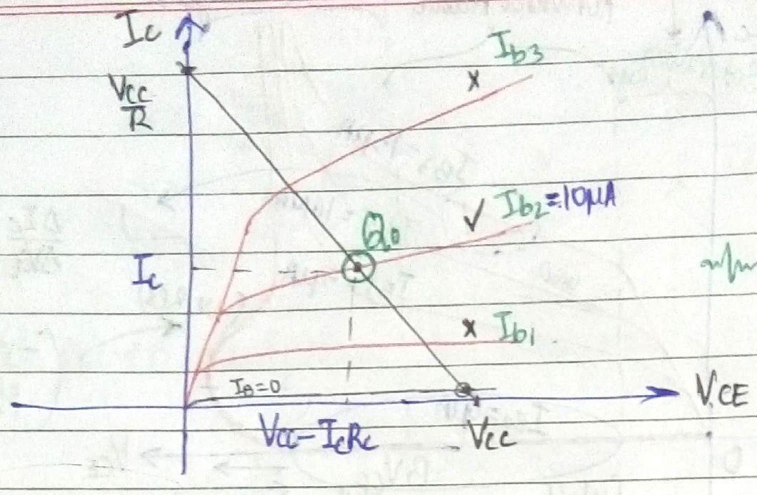
$-V_A$ = Early V
extrapolated voltage
name of scientist

$I_c = \beta I_B$ } No longer valid after certain conditions.
$V_{CE} = $ const
after $V_{CE} = BV_{CE_0} \to$ Not valid

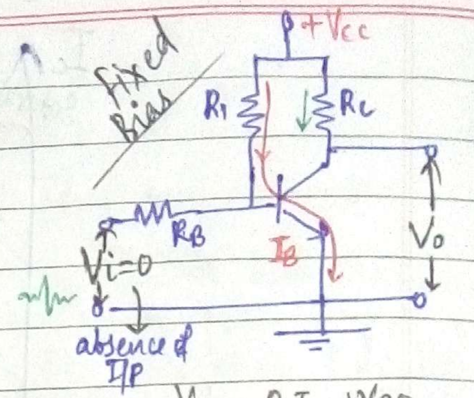








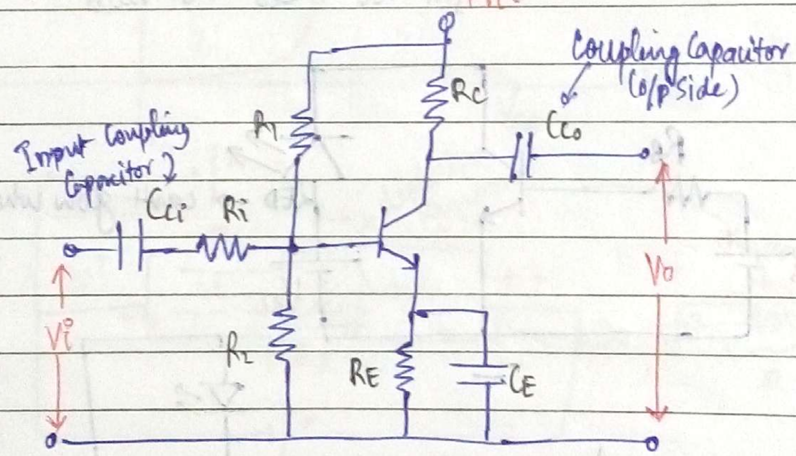
Fixed Bias



$V_{CC} = R_1 I_b + V_{BE\,ON}$

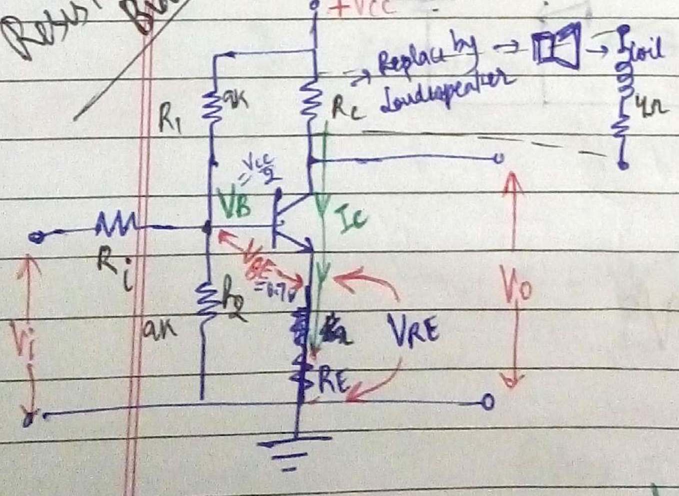
If R_1 is absent, $I_B = 0$, $V_i \rightarrow$ is small $\rightarrow$ amplification does not happen (it remains close to zero)

For amplification, big I_C is required and for that, R_1 should be there & $I_B > 0$



(Input Impedence > O/P Impedence) ⇒ Current into base is small.

Resistor-divider Bias



$$V_B = \left(\frac{R_2}{R_1 + R_2}\right) V_{CC}$$

$\uparrow n_i \approx T \uparrow$

Thermal Runaway $I_C \rightarrow T\uparrow \rightarrow n_i \uparrow \Rightarrow$ At a pt., T becomes very high.

(R_E is used to prevent Thermal Runaway)

FP Code → CS → 77
CT → Ckt Dia, Formula, Charac (Qualitative)

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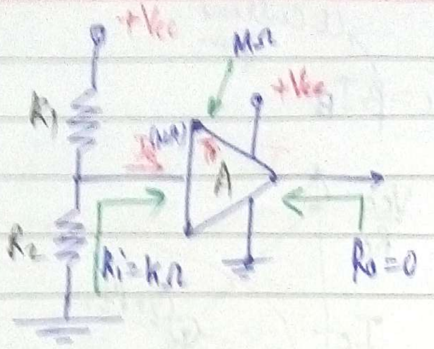
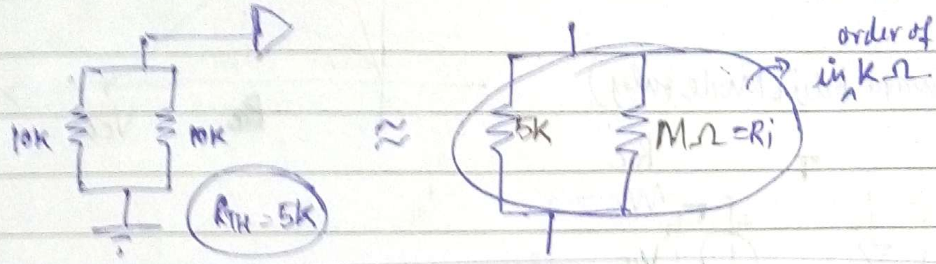




Role of RE (in preventing Thermal Runaway) :-

$I_C\uparrow \Rightarrow V_{RE}\uparrow \rightarrow V_{BE}\downarrow \rightarrow I_B\downarrow \rightarrow I_C\downarrow$

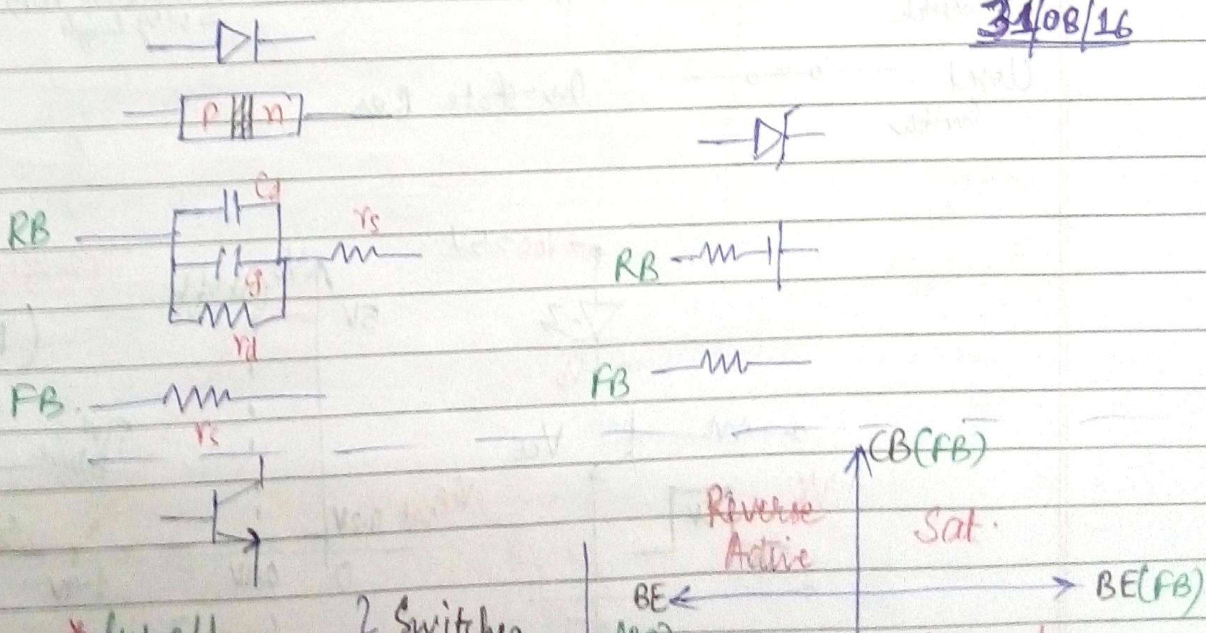
(V_B = fixed) ($I_C = \beta I_B$)

-ve feedback   const.

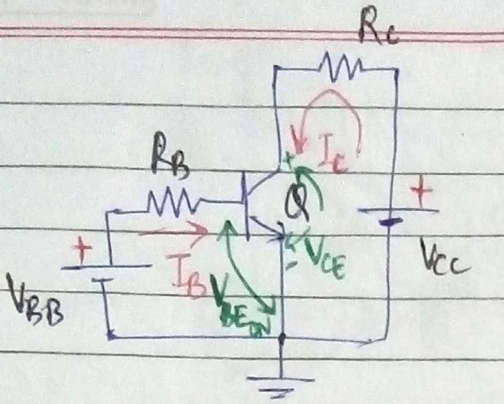
stabilises I_C

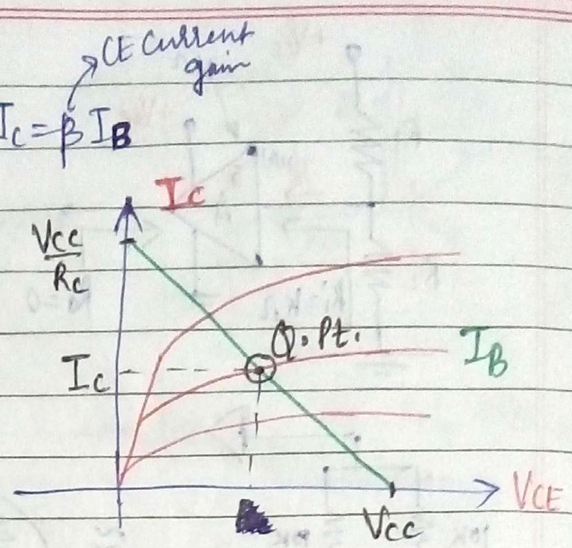
compensates ↑ sing I_C

31/08/16

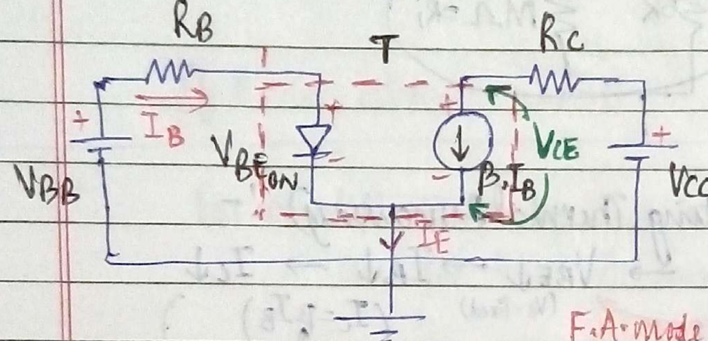


* Cut off } Switches
* Saturation
* Forward Active } Amp.
* Reverse / Inverse active Mode } Amp.





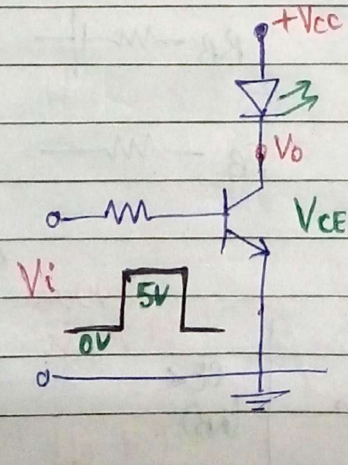
(Eq. Ckt for Forward Active Mode only)

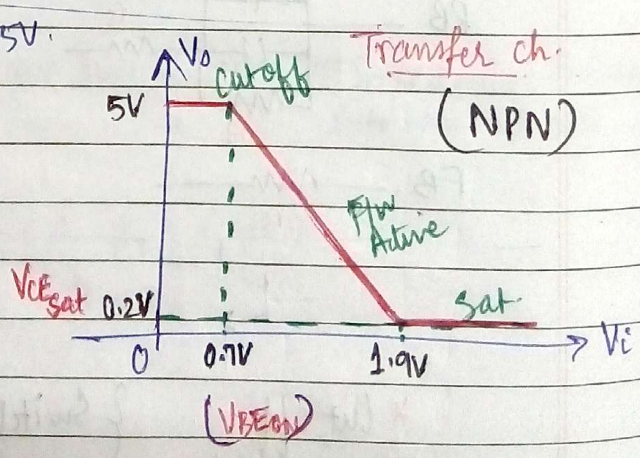


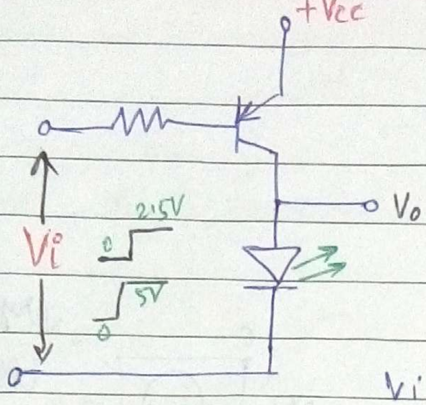
DC Equivalent ckt
Hybrid π-model

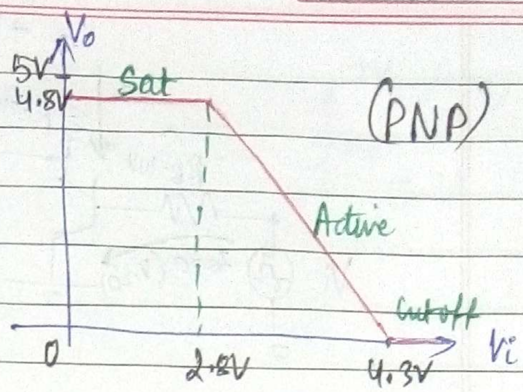
Open Switch —o~~o— Off-state Resistor (Air, Moisture res.) → very high.

Closed Switch —o—o— On-state Res.

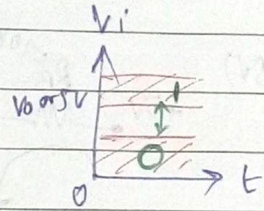








(PNP)



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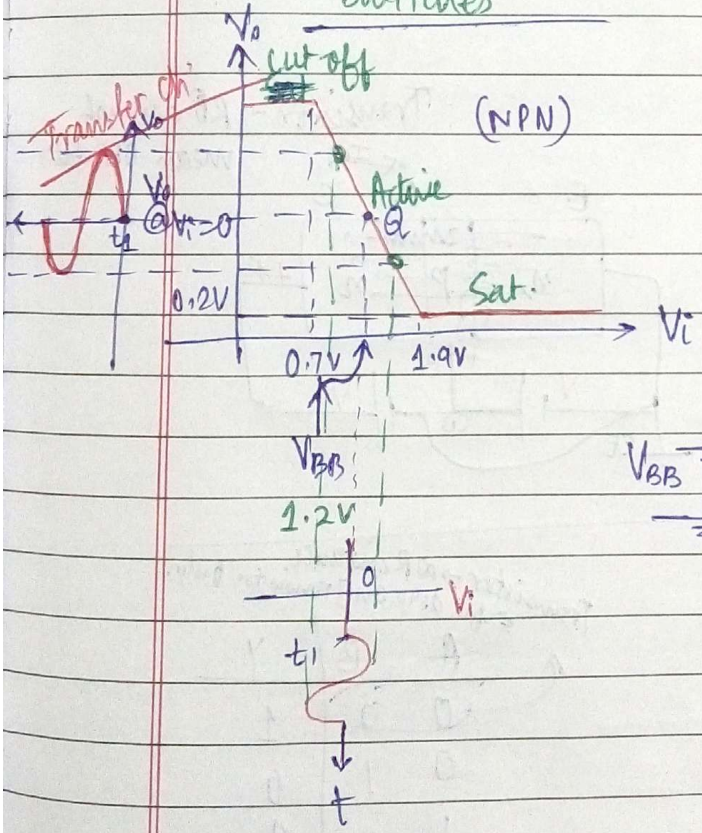
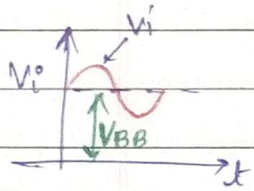
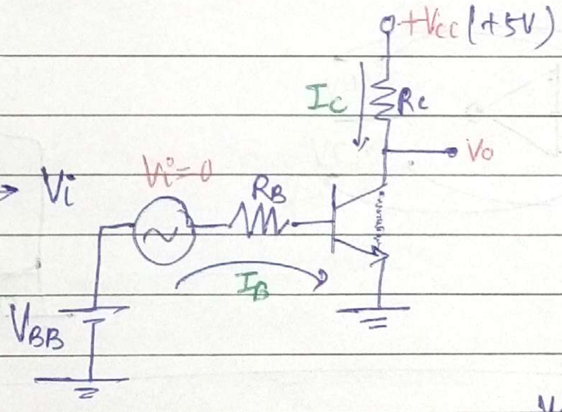
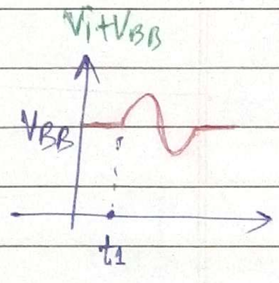
Transistor Circuits

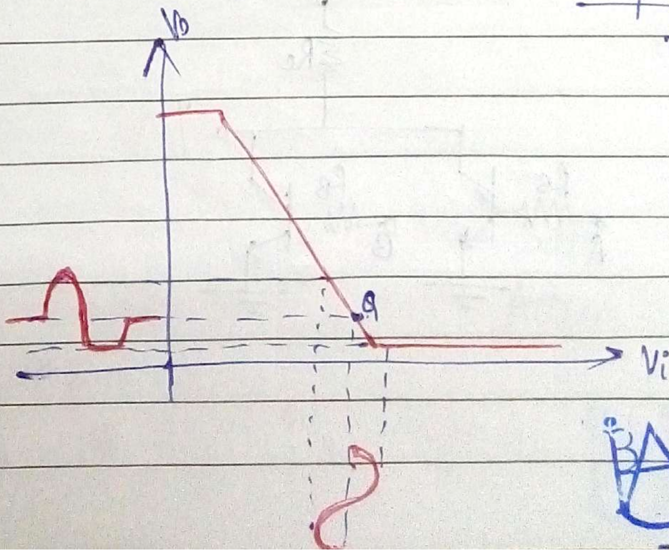
Switches — Amplifier

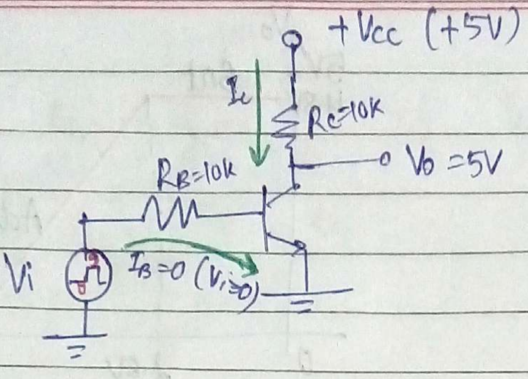


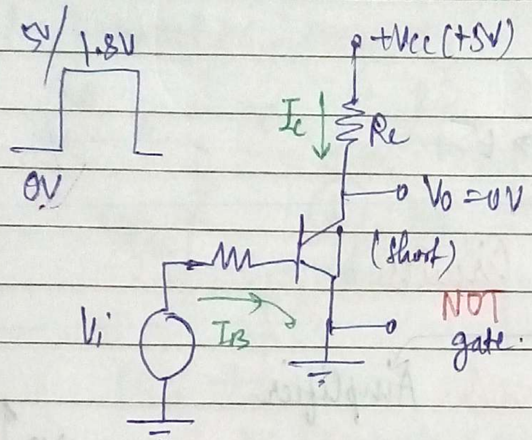


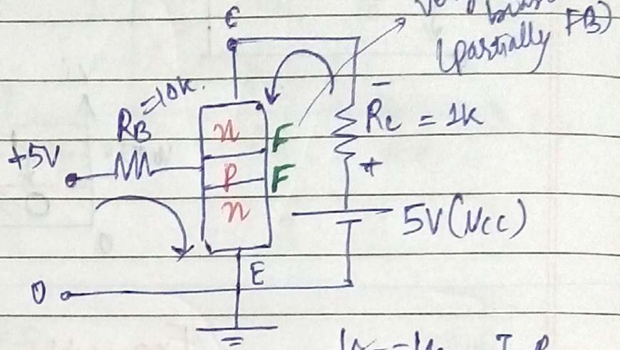






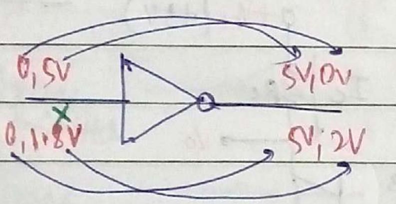




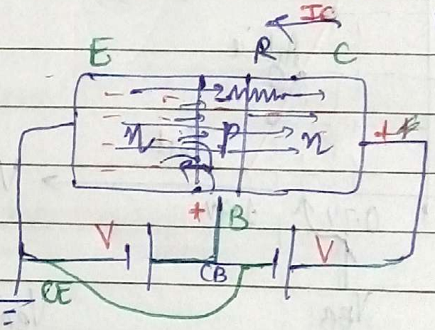


$V_{CE} = V_{CC} - I_C R_C$

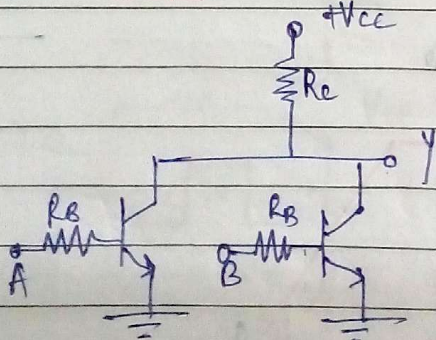
$V_{CE} < 5V.$



Transistor → RB does not mean OFF state.



NOR



Transistor → ∞ Resistance
⇒ All drop on Transistor Only.

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

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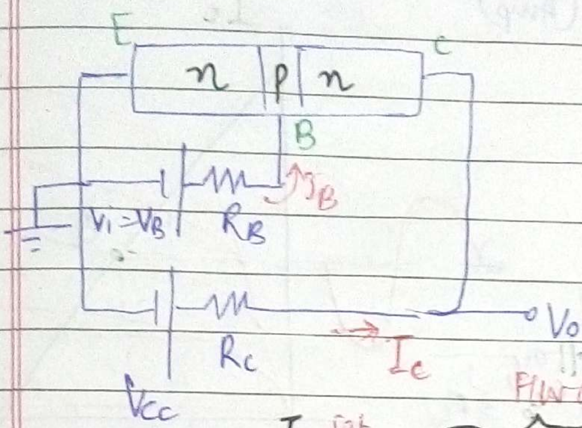
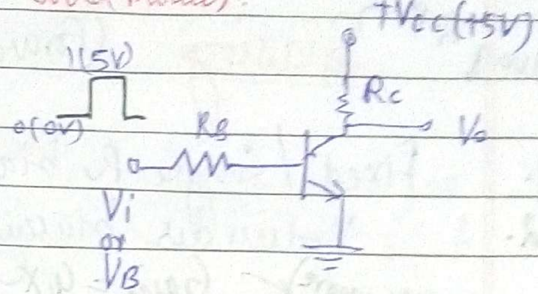
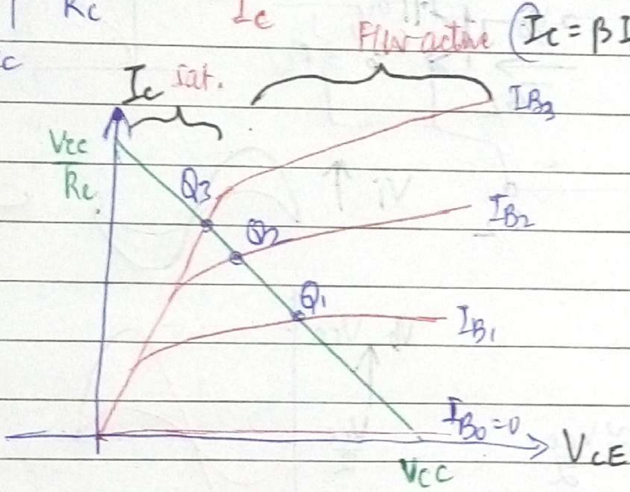
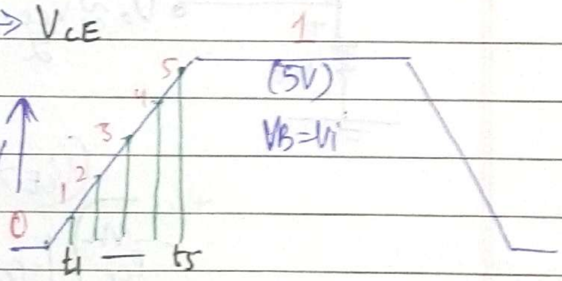
Transistor Circuits and Models



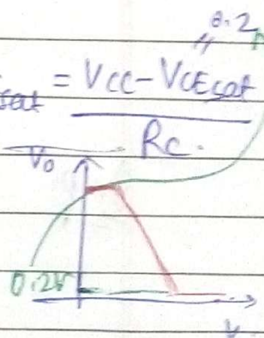






$$I_B = \frac{V_B - V_{BE}}{R_B}$$

$$I_{C_{sat}} = \frac{V_{CC} - V_{CE_{sat}}}{R_C}$$



Considerations:-

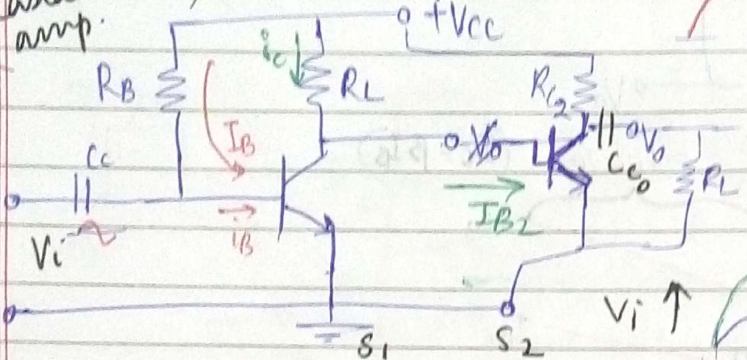
1. DC to RF/high freq.
2. Leakage (I_{EO}, I_{BO}, I_{CO})
3. V-range
4. R_i & R_o (r_i) (r_o)
5. β_{dc} and β_{ac}
6. Temp Range

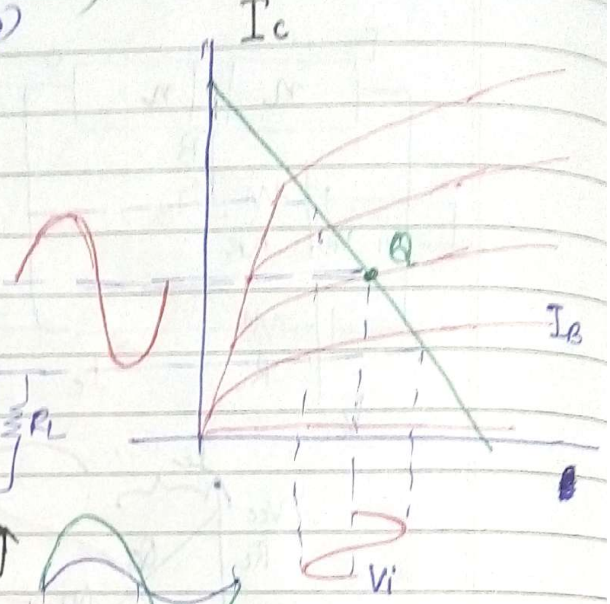
Sat: $V_{CE} < V_{BE}$
Active: $V_{CE} > V_{BE}$

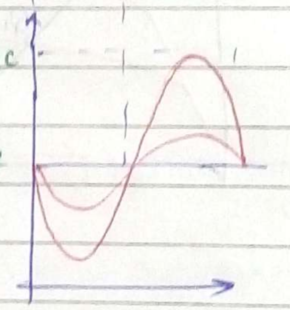
setting Q-Pt ← **Biasing** (Forward Active Mode) (Amp)

1. Fixed / Single R biasing
2. V-divider biasing.

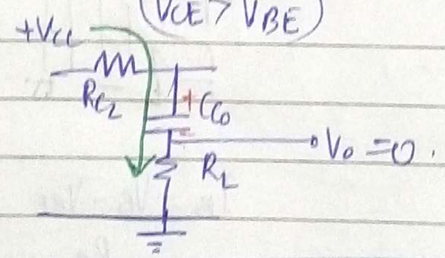
(Cascade more amp.) ← Gain $= G_1 \times G_2$.





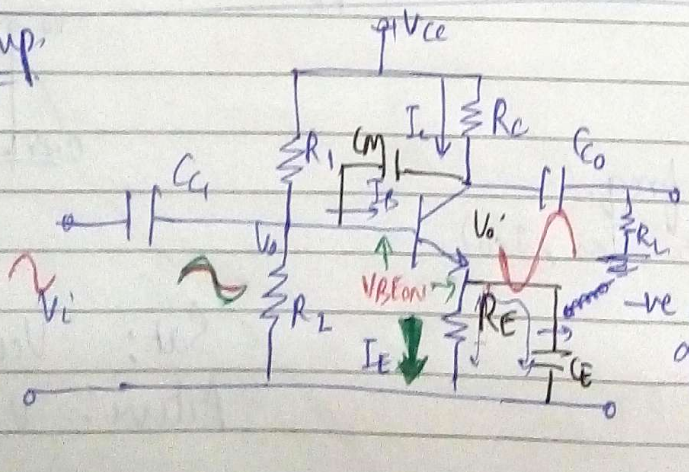


($V_{CE} > V_{BE}$)



Amp.

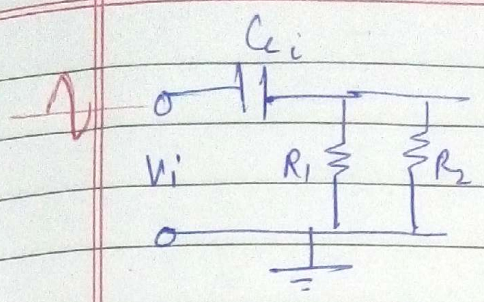
$I_E = I_c + I_B$

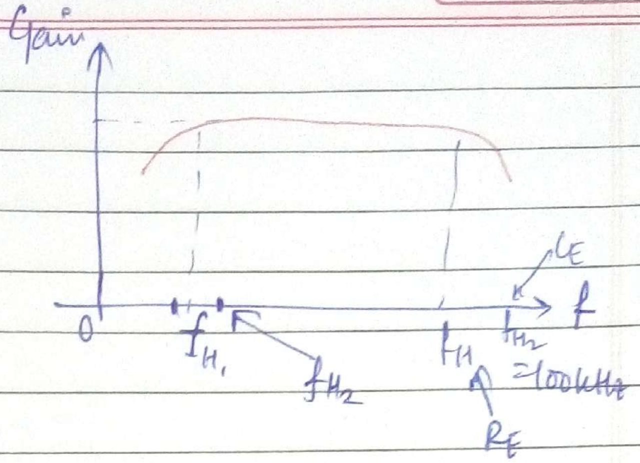


–ve feedback (f/b) against thermal runaway.

$T \uparrow \quad I_c \uparrow \quad I_E \uparrow \quad V_{RE} \uparrow \quad V_{BE} \downarrow \quad I_B \downarrow \quad I_c \downarrow$

$\Rightarrow T \downarrow$



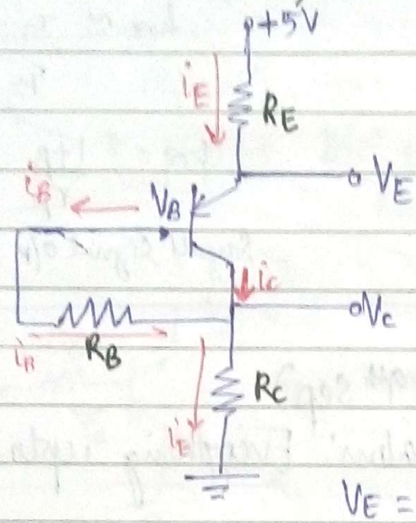


$$f_{H_1} = \frac{1}{2\pi (R_1 \| R_2) C_{Ci}}$$

VIVA 2 - Features & Purpose of components.

Tutorial

Q1. For the transistor circuit in following figure, $\beta = 75$. Find the values of labeled voltages and currents. $R_E = 10k\Omega$, $R_C = 2k\Omega$, $R_B = 20k\Omega$, Consider $|V_{BE}|_{ON} = 0.7V$.



$V_C = i_E R_C$

$V_B - V_C = i_B R_B$

$V_B = V_C + i_B R_B = i_E R_C + i_B R_B$.

$V_E - V_B = 0.7V$

$\therefore V_E = V_B + 0.7$

$V_E = i_E R_C + i_B R_B + 0.7$

$V_E = 5 - i_E R_E = i_E R_C + i_B R_B + 0.7$

$5 - i_E R_E = i_E R_C + \dfrac{i_E}{\beta+1} R_B + 0.7$

$* \; i_E = i_C + i_B$

and $i_C = \beta i_B$

$\Rightarrow i_E = \beta i_B + i_B$

$= (\beta+1) i_B$

$\Rightarrow i_B = \dfrac{i_E}{\beta+1}$

or $\quad i_E \left(R_C + \dfrac{R_B}{\beta+1} + R_E \right) = 5 - 0.7$

$$i_E = \frac{4.3}{2K + \frac{20k}{76} + 10k}$$

$= 0.35\, mA$.

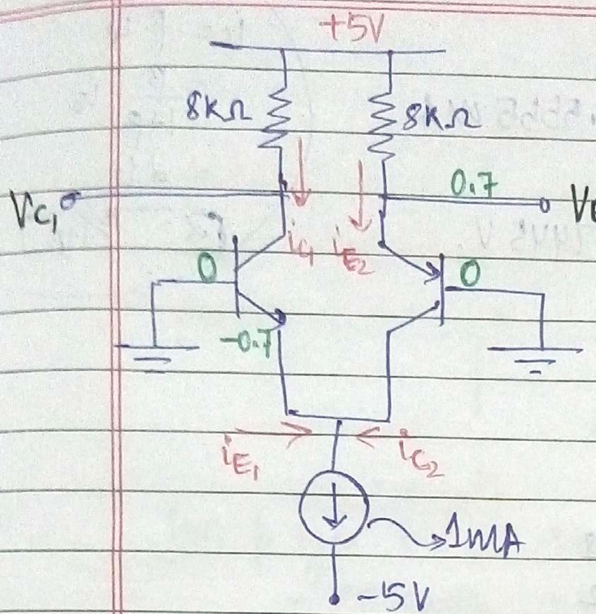
$$i_B = \frac{i_E}{\beta+1} = \frac{0.35 \times 10^{-3} A}{76} = 4.614\,\mu A.$$

$\boxed{V_C} = i_E R_C = \boxed{0.7012\ V}$

$\boxed{V_E} = 5 - i_E R_E = \boxed{1.494\ V}$

Q2. For the circuit in following fig., $\beta = 200$ for each transistor, find V_{C1}, V_{E2}, i_{E1} and i_{C2}.

Assumed Transistors → Active Mode.



• $V_{B_2} = 0$ • $V_{BE} = V_{E_2} = 0.7V$.

$i_E + i_C = 1mA$

$V_{E_2} = 0.7V$

$i_{E_2} = \frac{5-0.7}{8k} = 0.5375mA$

• $i_{C_2} = \frac{\beta}{\beta+1} i_{E_2} = 0.5348mA$

• $i_{E_1} = 1mA - 0.5348mA$
$= 0.4652mA$.

$i_{C_1} = \frac{\beta}{\beta+1} = 0.4628mA$.

$V_{C_1} = 5 - (8k)i_{C_1} = 5 - (8k)(0.4628m)$

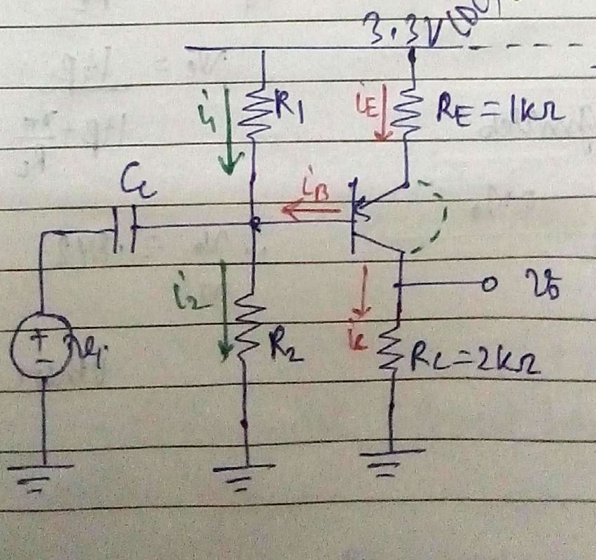
$\boxed{V_{C_1} = 1.297V}$

★ $|V_{BE}| = 0.7$ (Always → for Si)

pnp: $-V_{BE} = 0.7$

npn: $V_{BE} = 0.7$

Q3. The transistor for the following ckt has $\beta = 100$, $V_A = \infty$ (Early voltage).
Find R_1 and R_2 such that it is bias stable and Q-point is near the centre of load line. (Plot of i_c & V_{CE})
Also find the small signal gain $\frac{V_o}{V_i}$



$i_c = 0$, $V_{CE} = 3.3V$

$V_{CE} = 0$, $i_c = \frac{3.3}{1k+2k} = 1.1 mA$.

Q-point,

$i_{CQ} = 0.55mA$.

$V_{CE_Q} = 1.65V$.

Half of above values & we get mid point

$i_C = \beta i_B$
$= \frac{\beta}{1+\beta} i_E$
$= \alpha i_E$
$\boxed{\alpha = \beta/1+\beta}$

$i_{EQ} = \frac{i_{CQ}}{\alpha} = \frac{0.55\,mA}{(100/101)} = 0.5555\,mA$

$v_{EQ} = 3.3 - i_{EQ} \times R_E = 2.7445\,V.$

$v_{BQ} = v_{EQ} - 0.7$
$= 2.0445V$

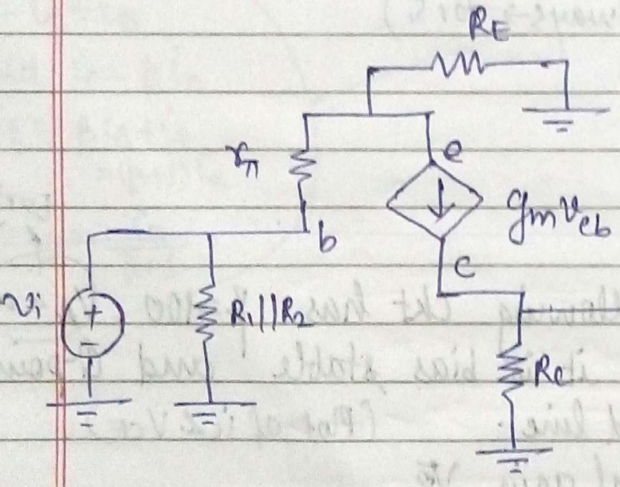
DC currents

$i_{BQ} = \frac{i_{CQ}}{\beta} = 5.5\,\mu A.$

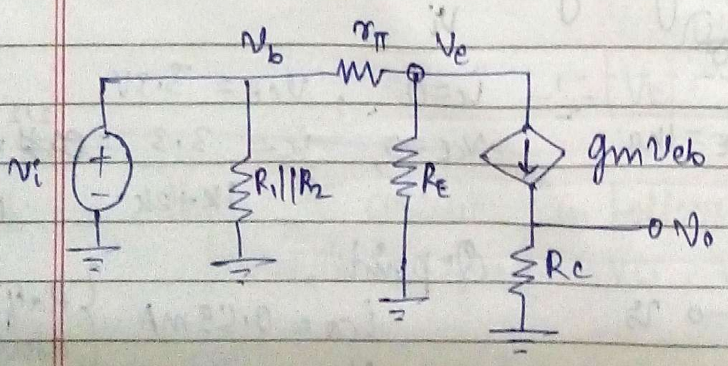
$\frac{3.3 - v_{BQ}}{R_1} + 5.5\,\mu A = \frac{v_{BQ}}{R_2}$

$\Rightarrow R_2 = 50k\Omega$ (Assumed), $R_1 = 35.5k\Omega.$

$\Rightarrow$ No current in Capacitor branch $\Rightarrow i_1 + i_B = i_2.$



$v_{eb} = v_e - v_i$
$v_o = g_m v_{eb} R_C$
$= g_m R_C (v_e - v_i)$
$= \frac{g_m R_C}{(1+\beta)\frac{R_E}{r_\pi} + 1} v_i$



$\frac{v_i - v_e}{r_\pi} = \frac{v_e}{R_E} + g_m(v_e - v_i)$

$v_e = \frac{1+\beta}{1+\beta+\frac{r_\pi}{R_E}} v_i$

$\therefore \frac{v_o}{v_i} = 1.892$

where $\beta = g_m r_\pi$

$r_\pi = \frac{\beta}{g_m} = 4.727\,k\Omega$

$g_m = \frac{I_C}{V_T} = 21.154\,mA/V$

$V_T \rightarrow 26mV.$