TIME & FREQUENCY DOMAIN REPRESENTATIONS

FT (Fourier Transform) IFT

SIGNALS

- V
- I
- Q

(Type)

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

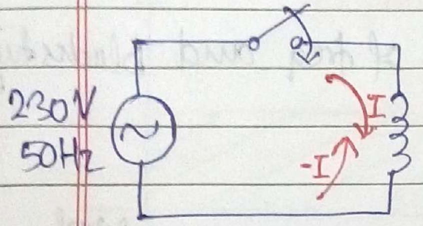
(Shape)

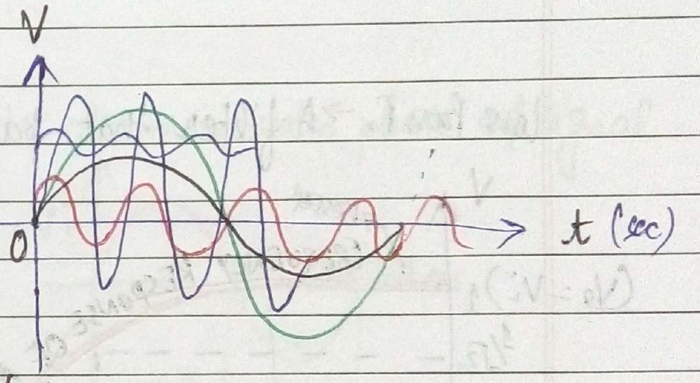
- Time domain
- Frequency domain

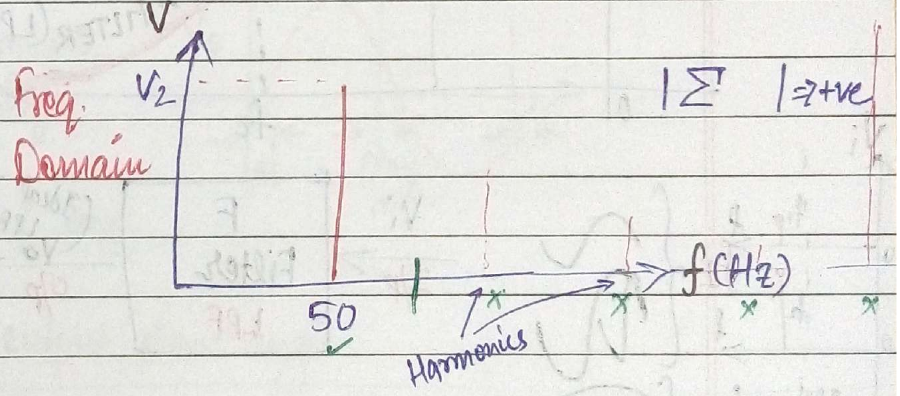
(Representation)

- Video
- Audio
- ....

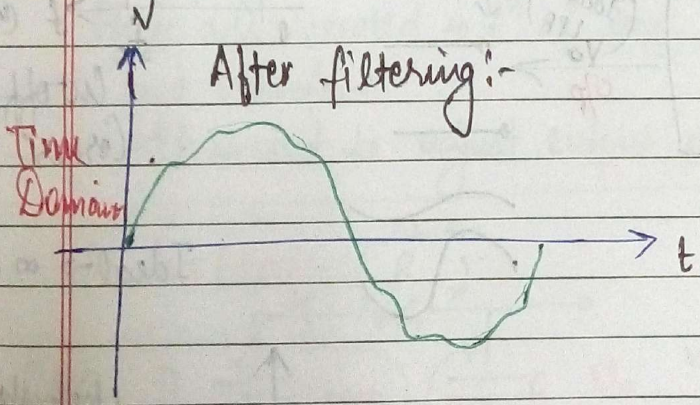
(Applications)







After filtering:-



FILTERS

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

FILTERS

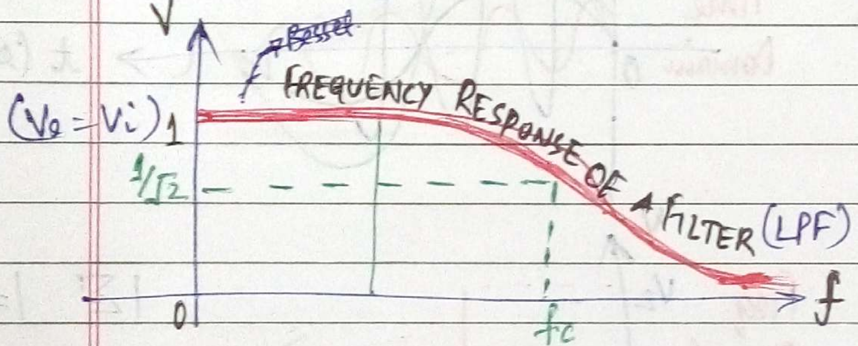
(Type)
- Low Pass
- High Pass
- Band Pass
- Band Stop
- All Pass

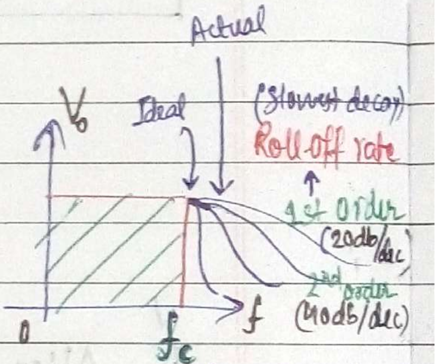
(Realization Components)
- RC
- RL
- RLC
- LC

(Response)
- Butterworth → A / P
- Chebyshev → A
- Bessel → Generally A

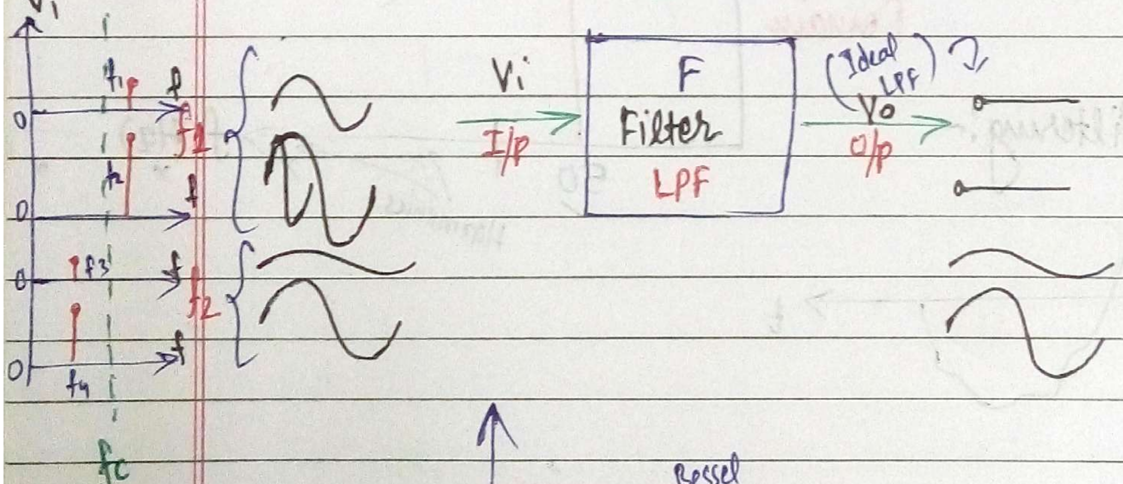
- Passive (If only R, L, C are used)
- Active → semiconductor devices

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

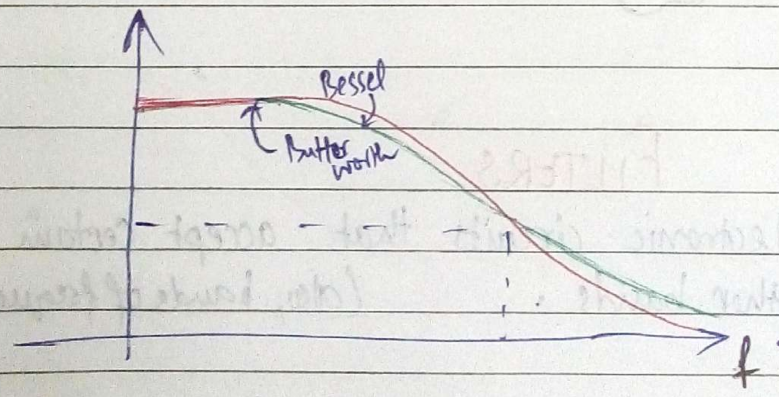


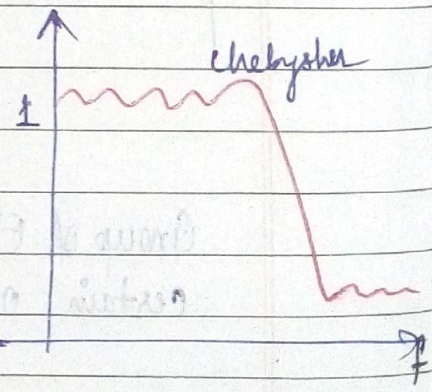


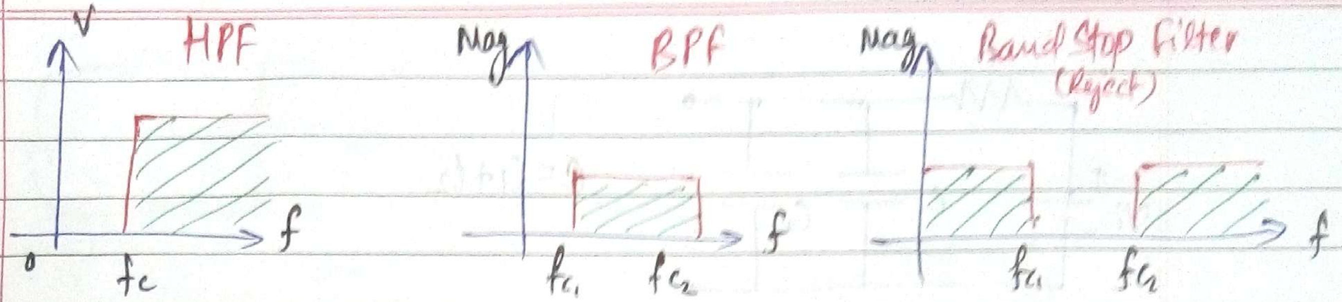
f_c Cutoff or Corner freq.

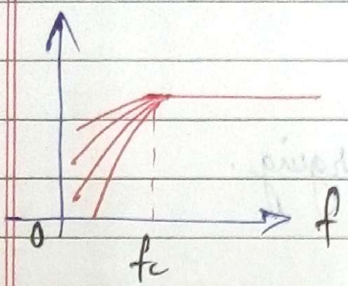


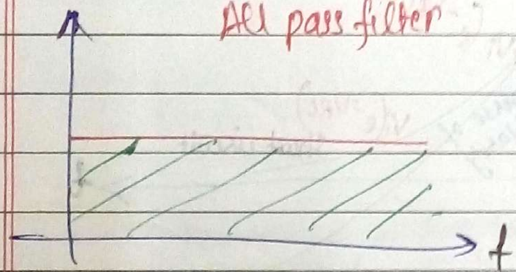
Ideal → ∞ db/dec



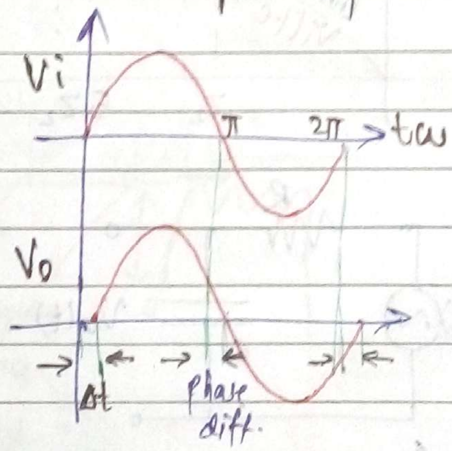








Filter also manipulates phase of signal

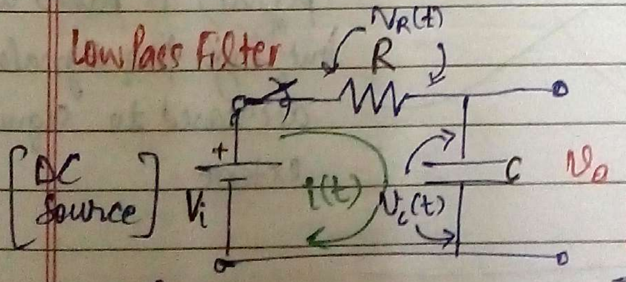


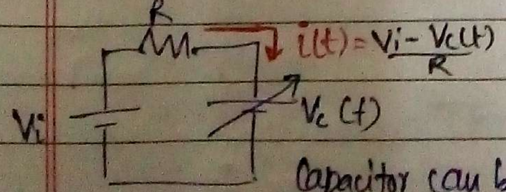
Phase diff can never become 0, hence, there is some phase shift.

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

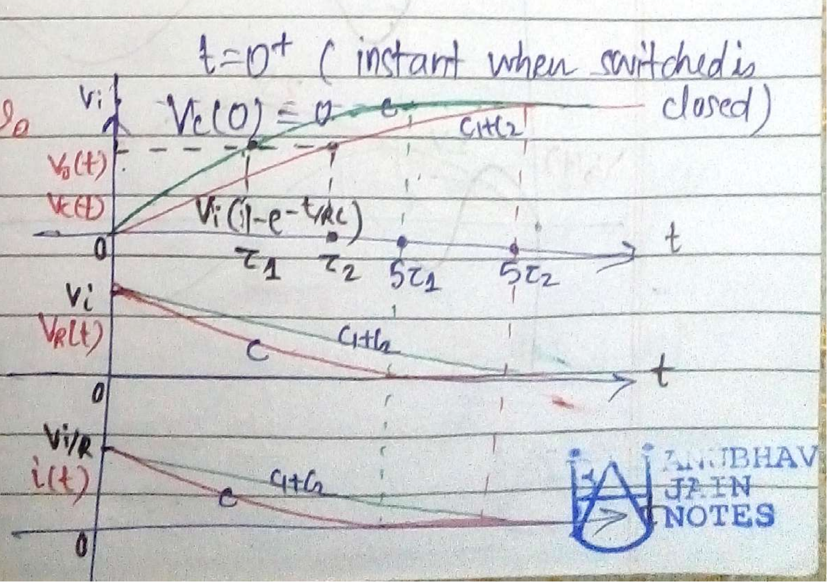
APF is used to adjust output phase angle.

Low Pass Filter

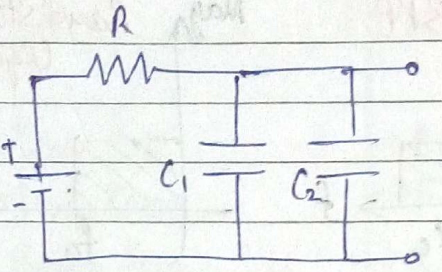




Capacitor can be assumed to be a battery.



* Super Capacitor

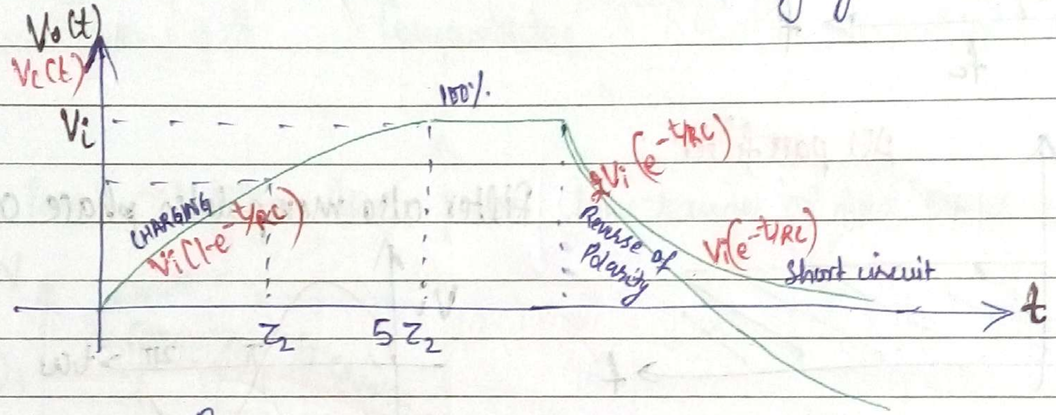


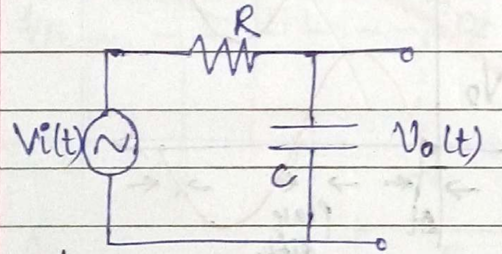
$C = C_1 + C_2$

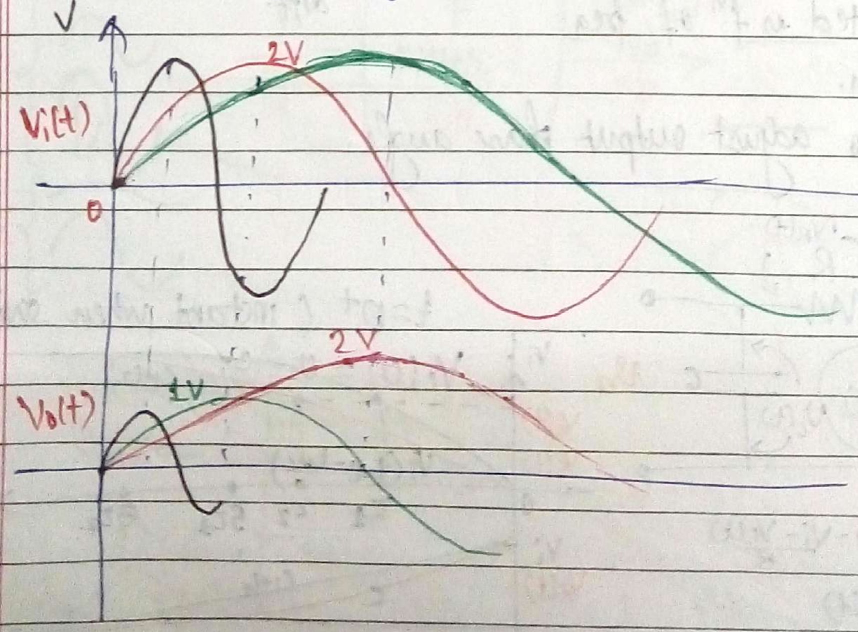
τ = Time Const.

$\tau = RC$ (sec)

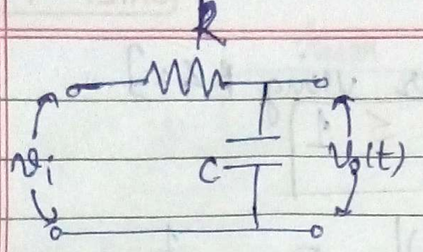
$5\tau \rightarrow 99.7\% \approx 100\%$ charging.

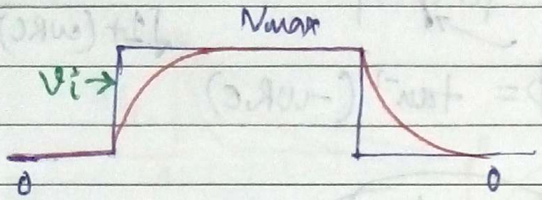


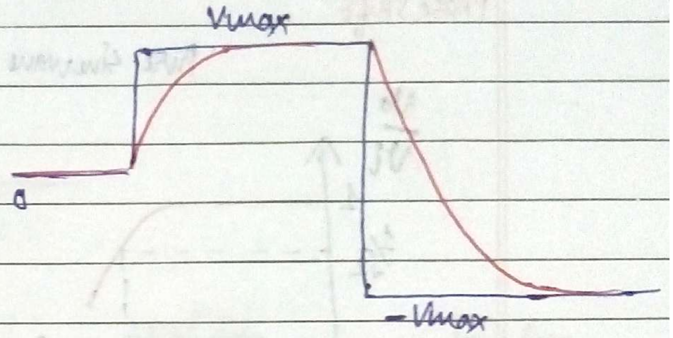




Working of LPF:- Amplitude of signals with low freq (high time period) is passed unchanged but of high freq signals is decreased to significant extent.







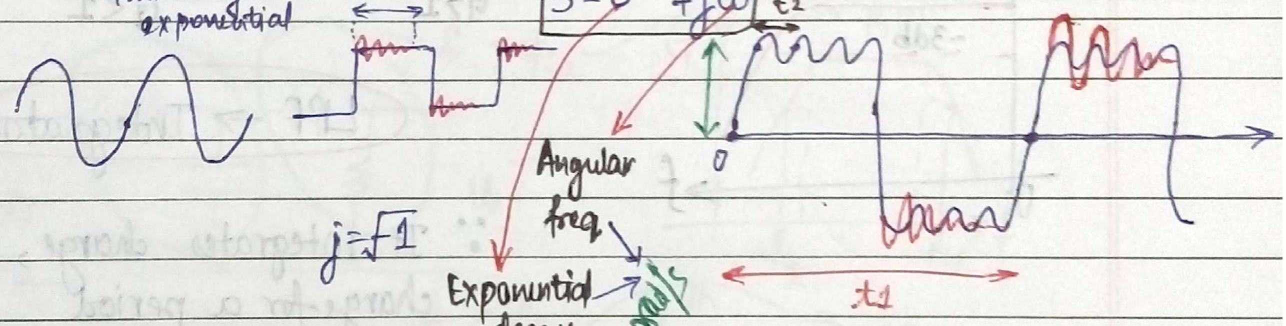
- TF = $\dfrac{\text{O/P Parameter}}{\text{I/P Param.}}$

↓
Transfer function

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

This decay is exponential ← decay time

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

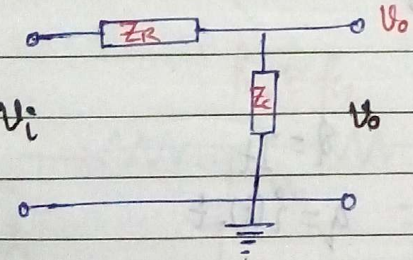


$j = \sqrt{-1}$

Angular freq

Exponential decay

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



$$v_o = \frac{Z_C}{Z_R + Z_C} v_i$$

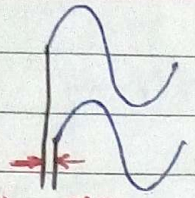
$$= \frac{\frac{1}{sC}}{R + \frac{1}{sC}} v_i = \left(\frac{1}{sRC + 1}\right) v_i$$

TF → $\boxed{H_C^{(s)} = \dfrac{v_o}{v_i} = \dfrac{1}{sRC+1}}$ ⇒ $\boxed{v_o \leq v_i}$

(σ = -ve in case of active filters)

ANUBHAV JAIN NOTES

[Passive low pass filter using R & C]



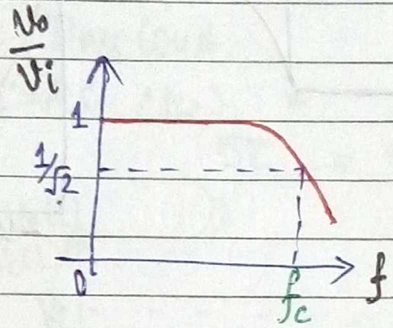
Phase Shift

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

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

Pure sinewave signal

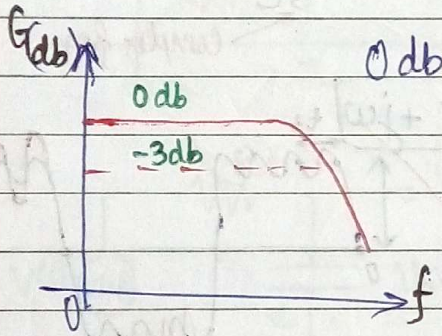
$$\phi = \tan^{-1}(-\omega RC)$$



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

* Gain is expressed in 'db'

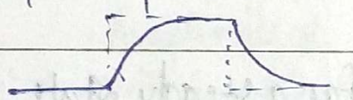
$$\boxed{G_{db} = 20\log_{10}\left(\frac{v_o}{v_i}\right)}$$



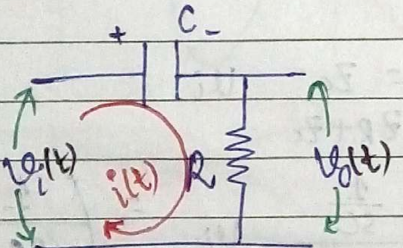
$0\,db$ = No $\underbrace{\text{amplification}}_{G>1}$, No $\underbrace{\text{attenuation}}_{G<1}$

LPF → Integrator

∵ It integrates charge, holds that charge for a period



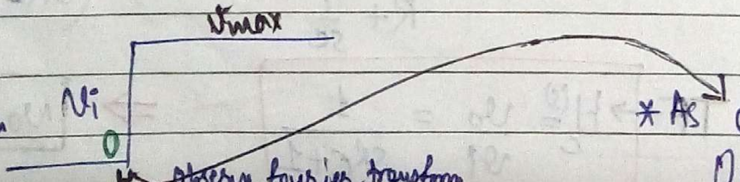
HIGH PASS FILTER (HPF → Differentiator)



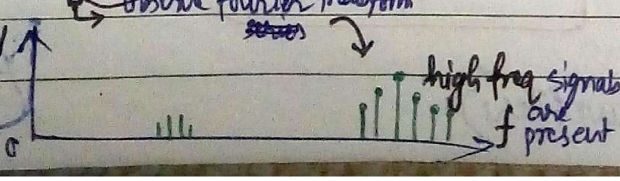
$q = It$

$q = i(t).t$

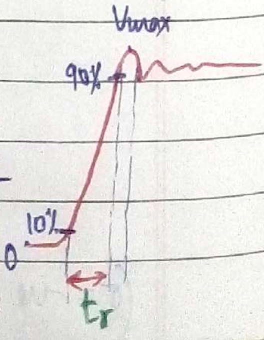
Time domain

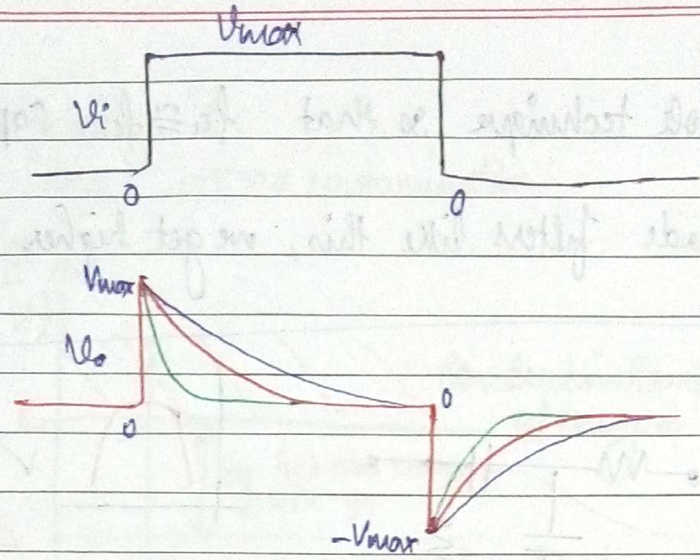


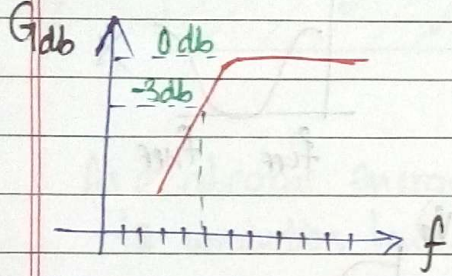
Freq. domain

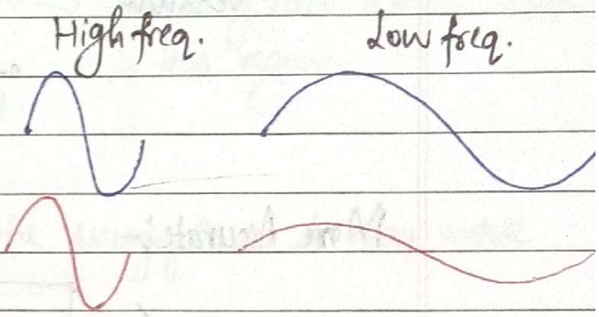


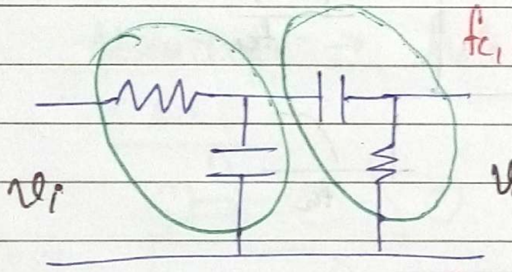
* As observed by Oscilloscope :-



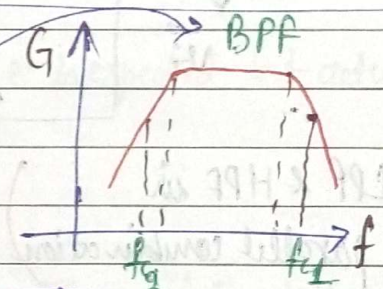




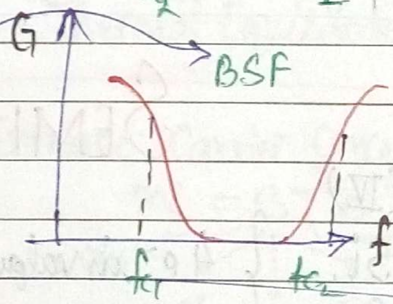




$f_{c_1} > f_{c_2}$

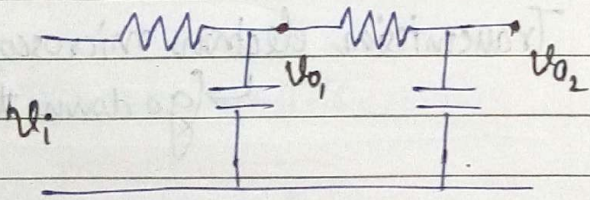


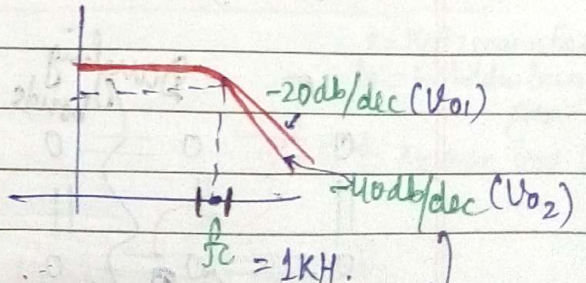
$f_{c_1} < f_{c_2}$



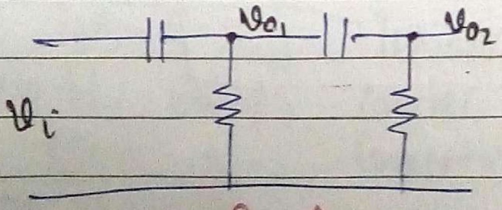
(Accurate version → PTO)

$f_{c_1} \cong f_{c_2}$





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



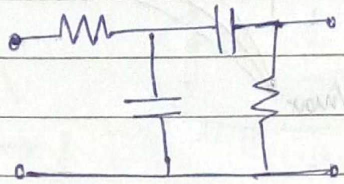
$f_{c_1} = f_{c_2}$

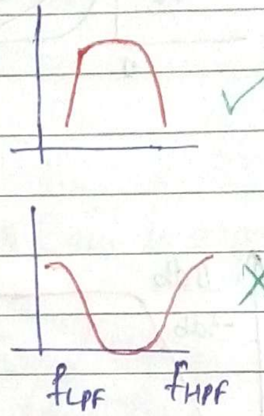
We use split pole technique so that $f_{c_1} \cong f_{c_2}$ (approx. equal)

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

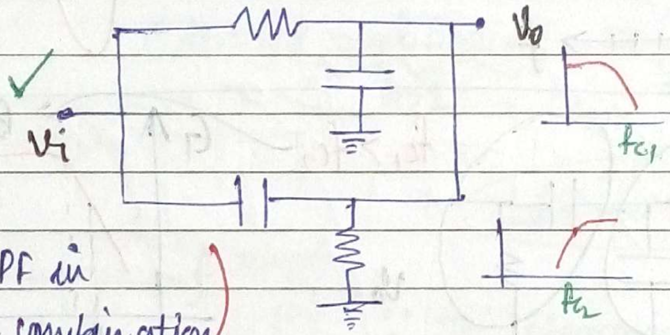
BSF.

Cascadic :- Version





More Accurate :-

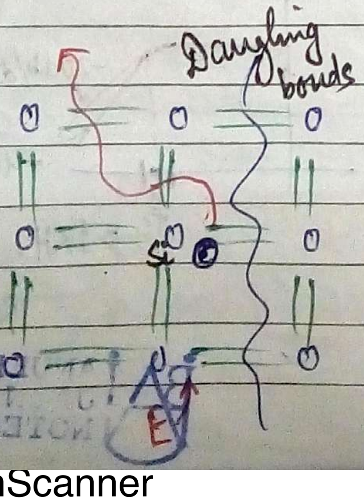


(LPF & HPF in parallel combination)

SEMICONDUCTORS

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

Transmission electron microscope
↳ (go down to Å level)



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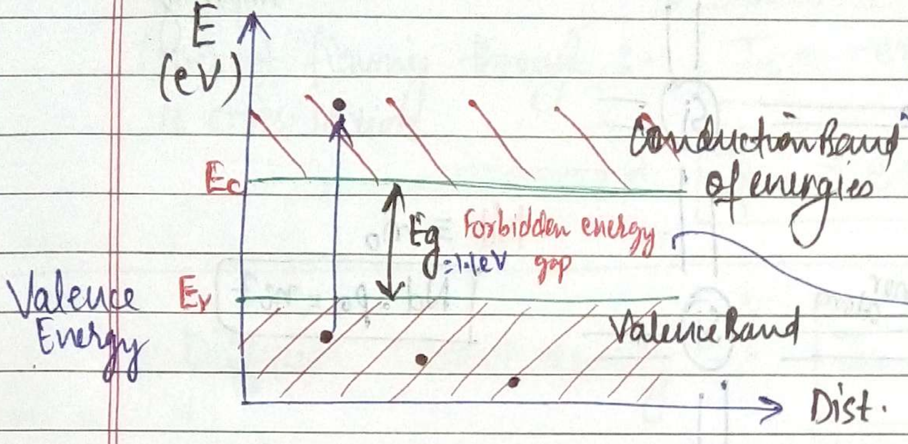
Intrinsic S-C

(Pure) → no contamination.

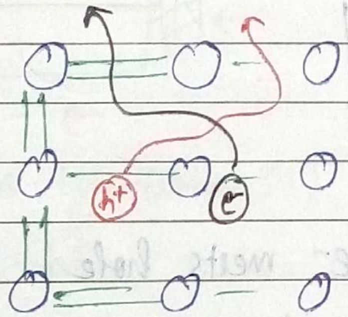


All e^- have diff energies.
Valence energy band → Collection of all energies of valence e^-.

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

As e^- absorbs 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

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

Const. → Si, Ge, C
Temp (K)

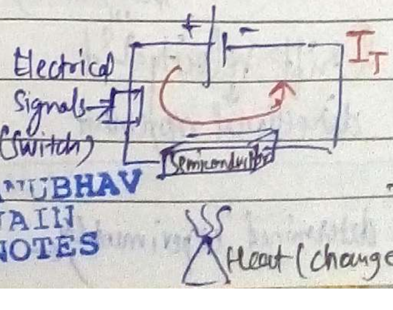
27/07/16

$T = 300K$. or $27°C$.

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

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

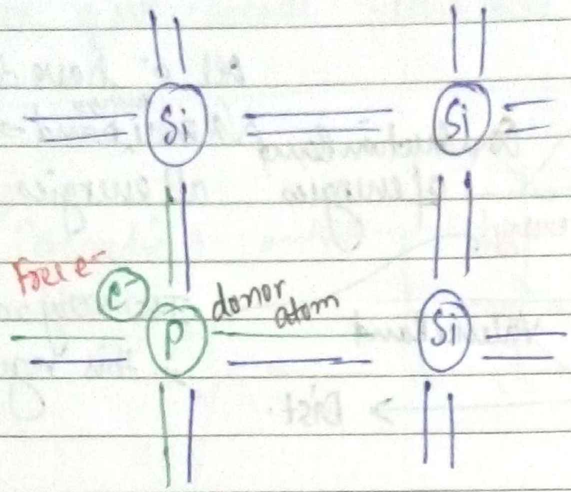
No. of e^- — No of h^+ — Intrinsic carrier Concentration



Current is f^n of Temp.

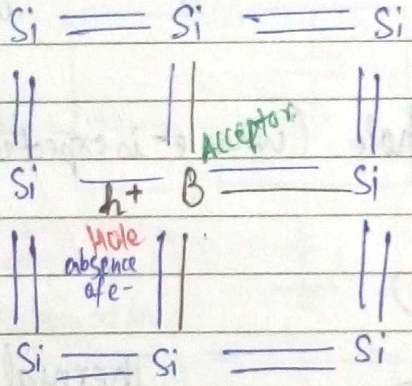
Extrinsic S-C
(Impure)

(S-C)
3 4 5
B (Boron) — Impurity — P (Phosphorus)



$N_d \equiv n_0$

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



$N_a \equiv p_0$

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

* 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)

Drift velocity → 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

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

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 :-

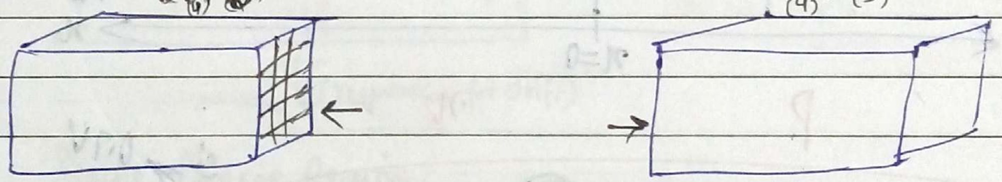
$$\boxed{J_n = \frac{dn}{dx} e D_n}$$

D_n → Diffusion const.

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

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

$Si_{(4)} + B_{(3)}$



n-type (Extrinsic S-C)

e^- Majority carriers (N_d)

h^+ Minority carriers (P_n)

+ve charge carriers in p type S-C

p-type (Ex-SC)

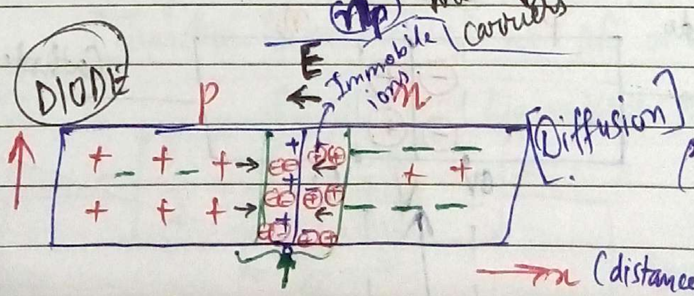
h^+ Majority carriers (N_a)

e^- Minority carriers (n_p)

DIODE

V=0

T=Const



(No Voltage applied, No Temp change)

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

→ $\mathcal{E}$

→ V_{bi} (Build-in potential)

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

Equilibrium Condition $\left(\begin{array}{l} \xrightarrow{\text{holes}} \text{Diffusion} \\ \xleftarrow{h^+} \text{Drift} \end{array} \right)$ E generated from n to p

(Drift = Diffusion)

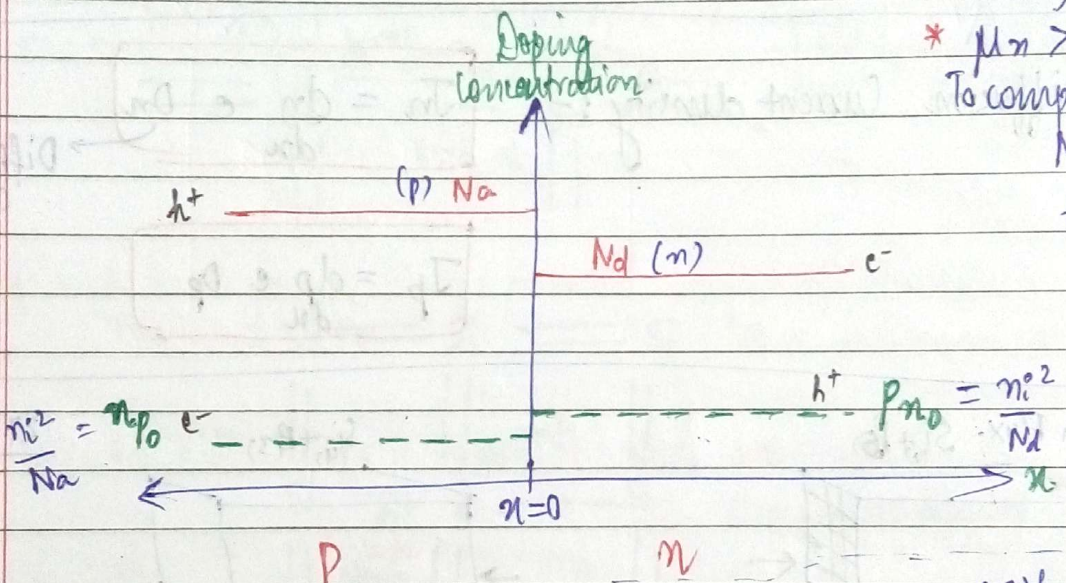
{No. of charge carriers moved by drift = diffusion}

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.



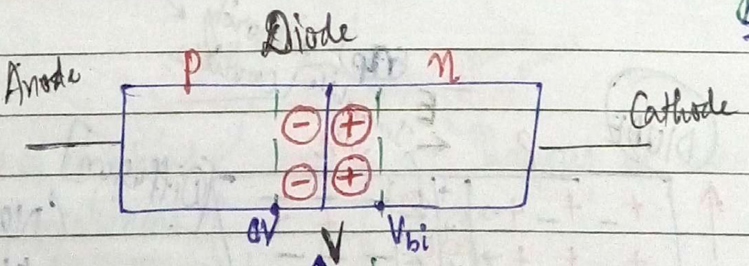
$$V_{bi} \text{ (Build-in Potential)} = \frac{KT}{q} \ln\left(\frac{N_a N_d}{n_i^2}\right)$$

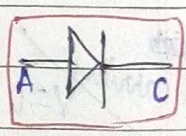
Si → 0.7V

Ge → 0.3V

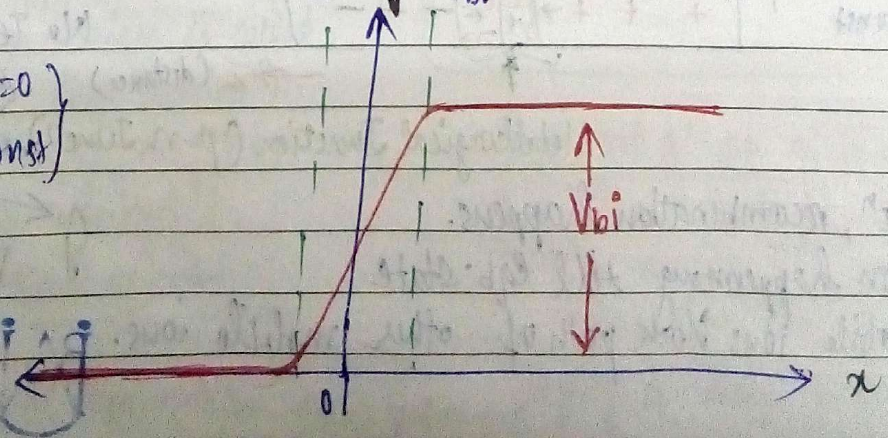
$\frac{KT}{q}$ → Thermal Voltage (V_T) $\simeq$ 26mV @ 300K.

Diode





{Vext = 0, T = const}



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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

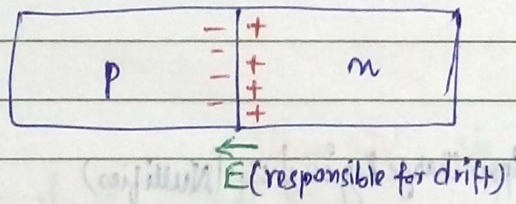
} Extrinsic

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

(I) (E)

$p_0 \rightarrow N_d$

$N_d \gg n_0$



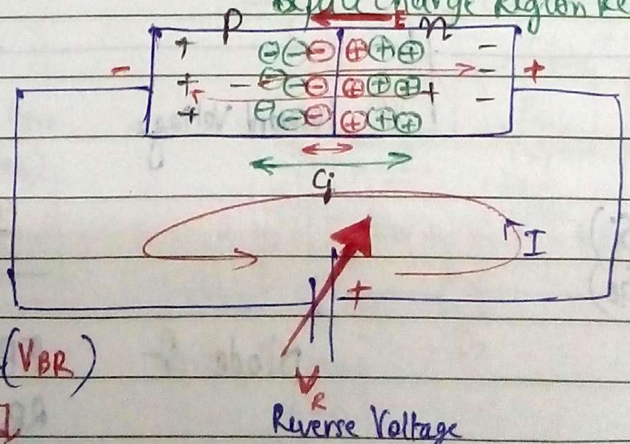
Space Charge Region
or
Depletion Region

V_{bi} (built-in potential)

C_j – Finite Value.
(Junction Capacitance) → (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)

ANUBHAV JAIN NOTES

Orion

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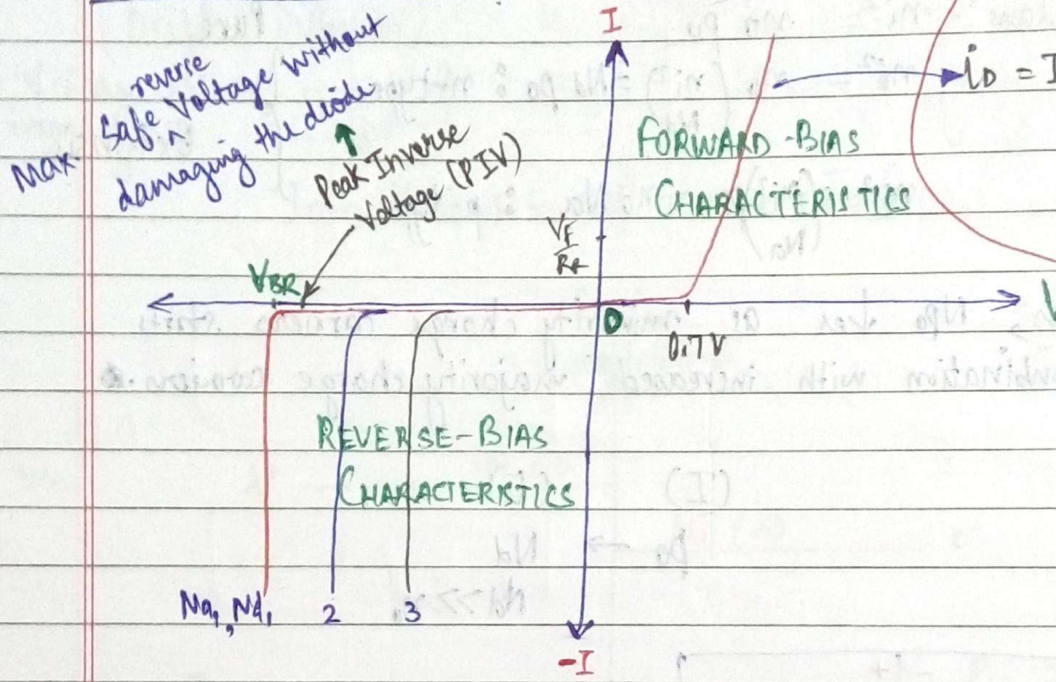
If $V_R < V_{BR}$ (After breakdown)

$\underbrace{fA - nA}$ $\longrightarrow \mu A - A$

($V_R \geq V_{BR}$)



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

I_S → Reverse Bias Saturation Current (fA-pA, 10^{-15} - 10^{-12})

v_D → Actual Voltage across diode

n → Const (Ideality factor)

V_T → Thermal Voltage

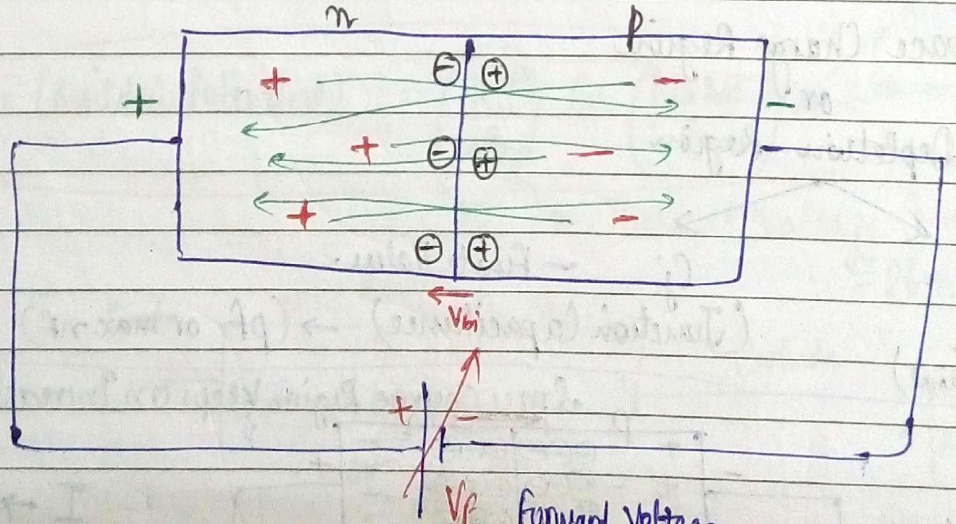
$n = 2$ (Low current)

$n = 1$ (High current)

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

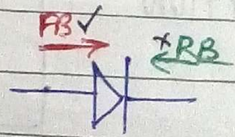
Space Charge Region ↓es. (Nullifies)

FORWARD BIAS CONDITION



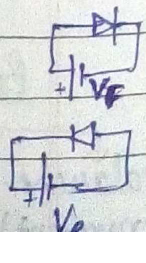
Forward Voltage

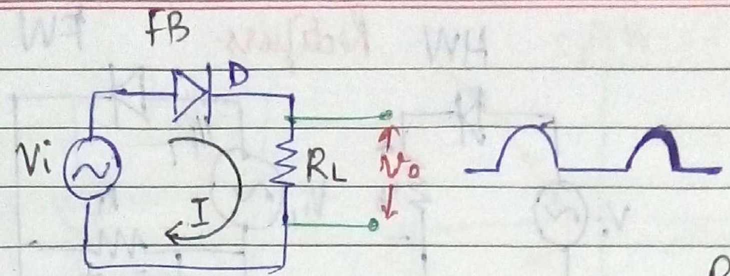
$$V_{bi} = \begin{cases} 0.7V & (Si) \\ 0.3V & (Ge) \end{cases}$$



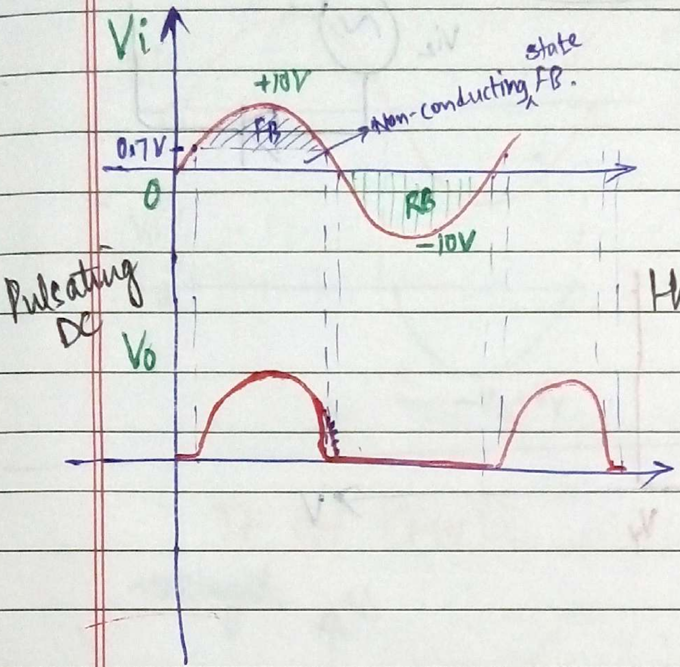
Diode :- FB - ON

RB - OFF

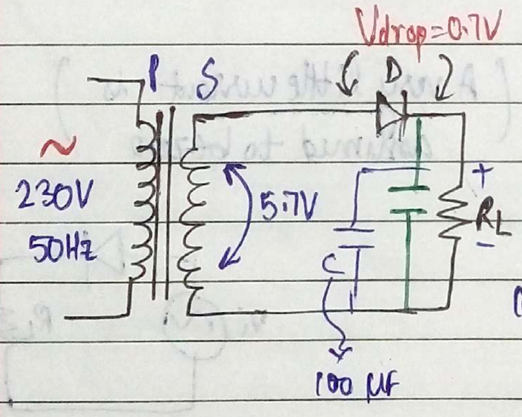


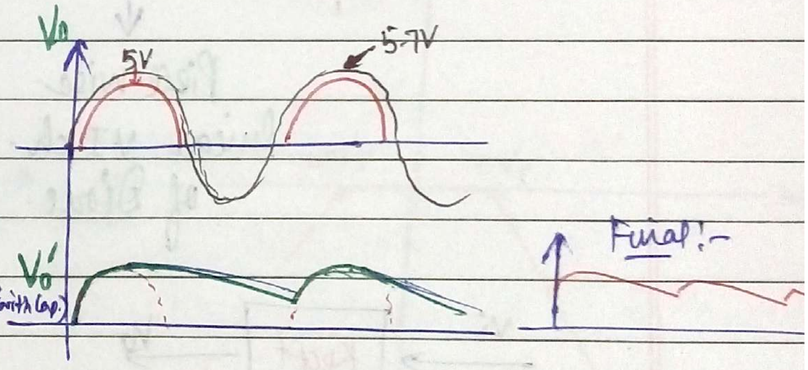


RECTIFICATION → AC→DC



HALF WAVE RECT^f

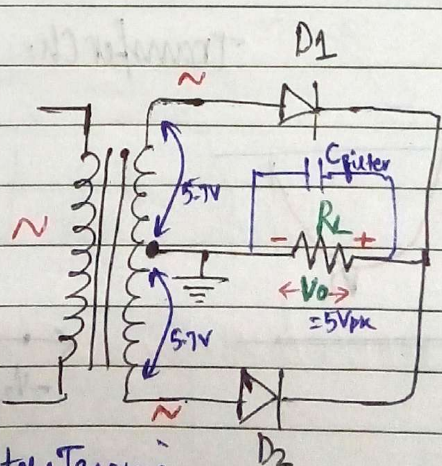


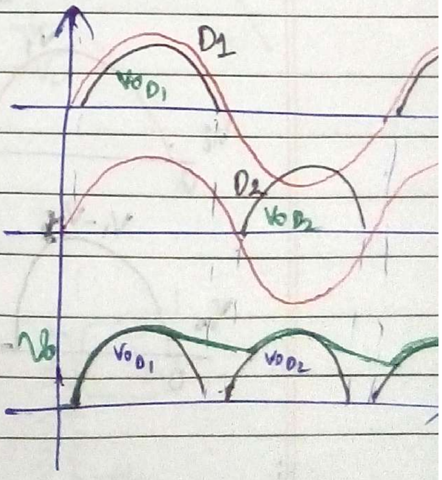


|| → Iron Core

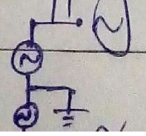
⁞⁞ → Ferride Core (High freq)

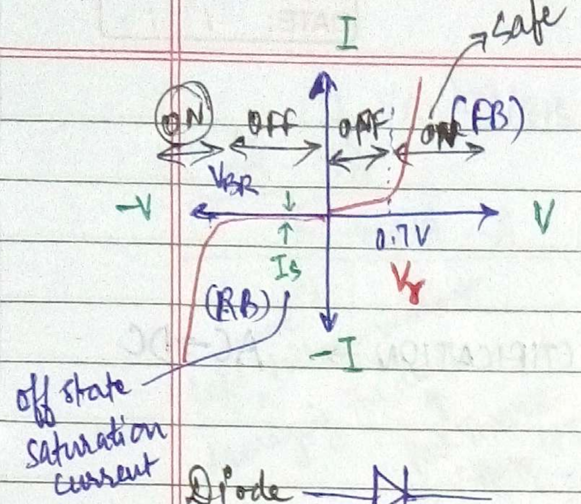
→ Air Core





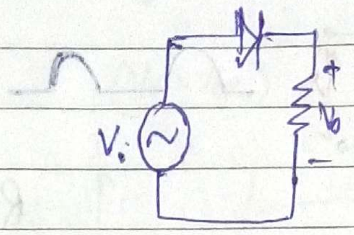
Centre Tapping



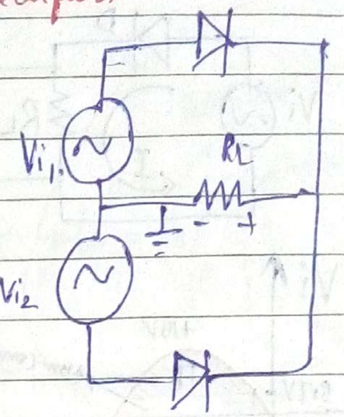


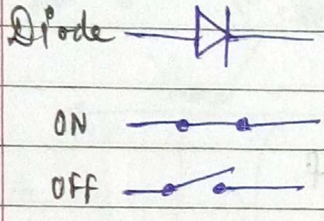
Rectifiers

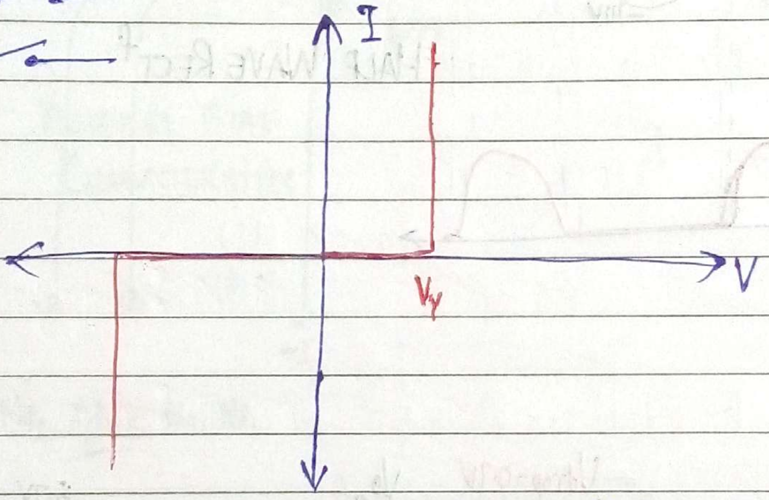
HW



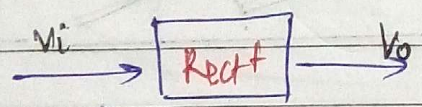
FW

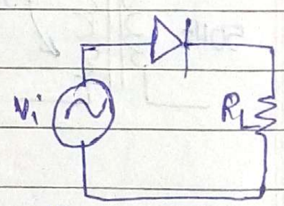


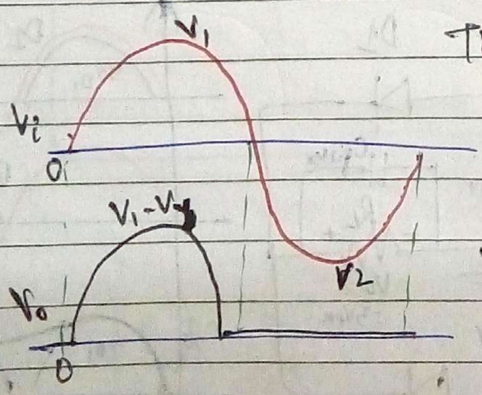




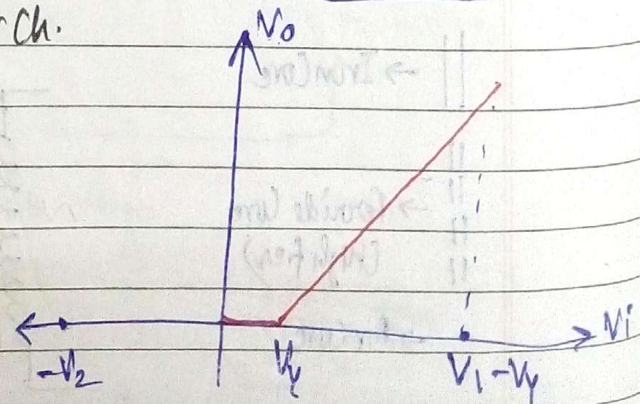
Piece-wise linear V-I ch. of Diode (A very little current is assumed to be zero)

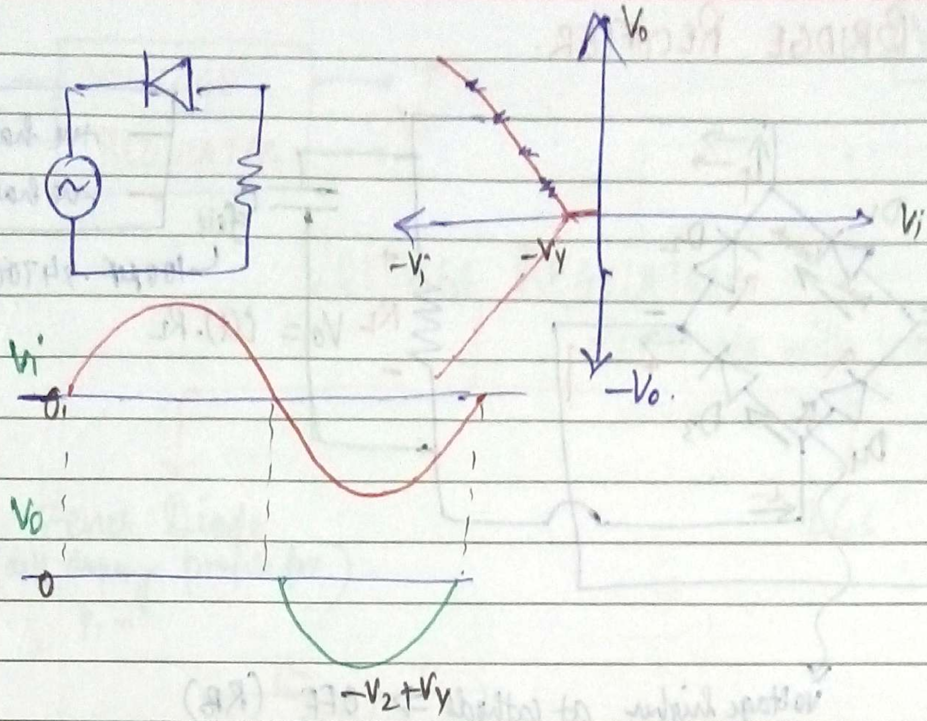






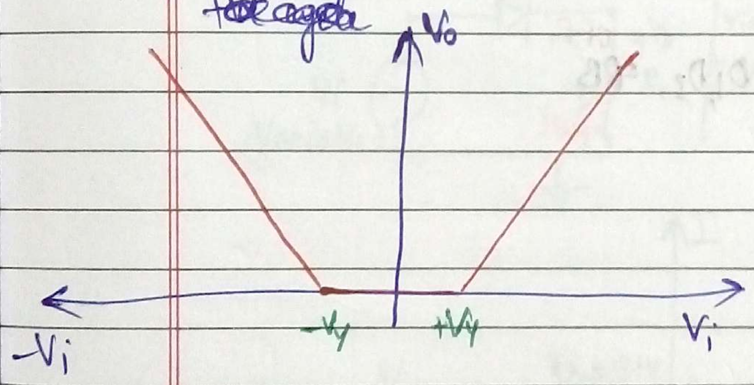
Transfer ch.



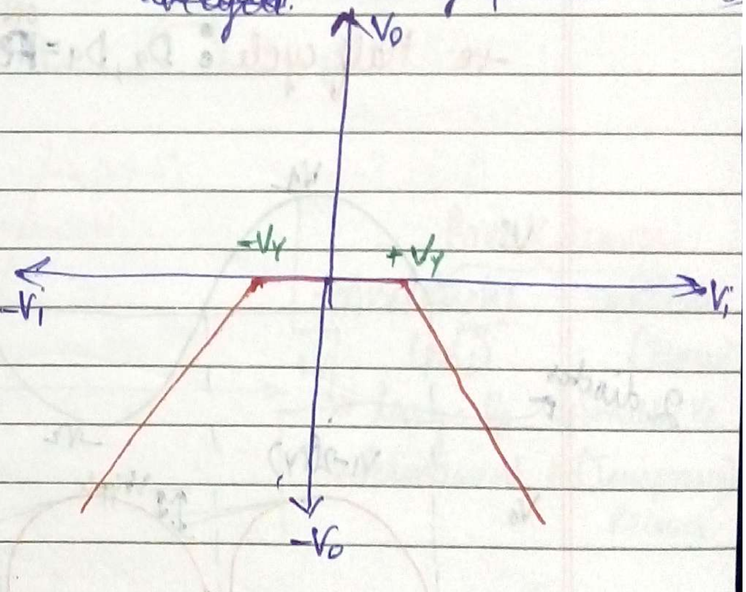


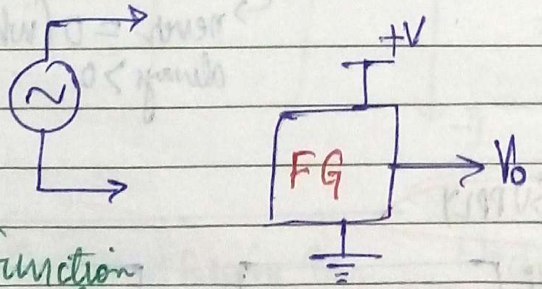
TF CH (CFW)

~~+ve cycle~~

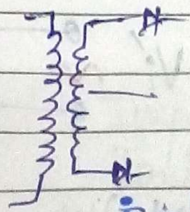


~~-ve cycle~~ (Polarity of diodes reversed)

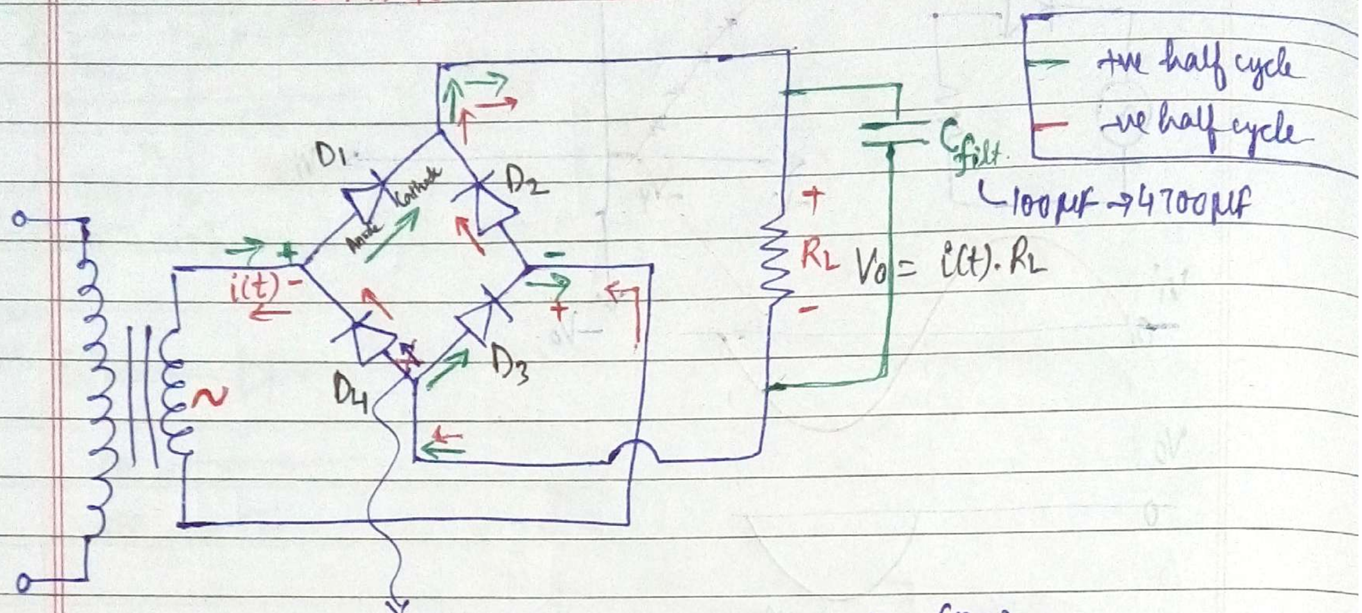




Function Generator
(No input, only output)



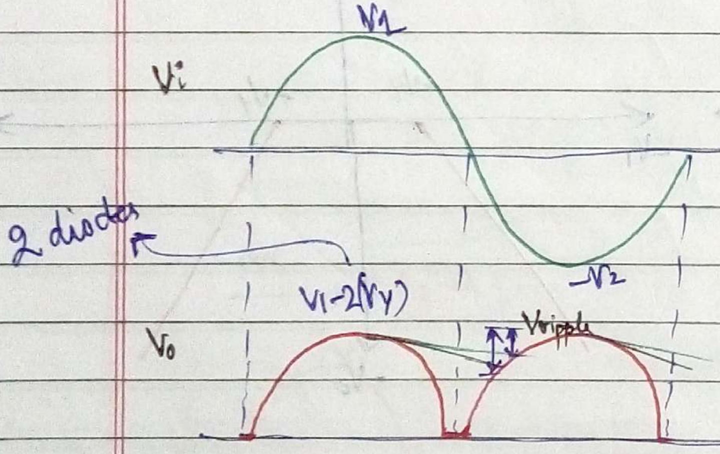
BRIDGE RECTIFIER.



voltage higher at cathode ⇒ OFF (RB)

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

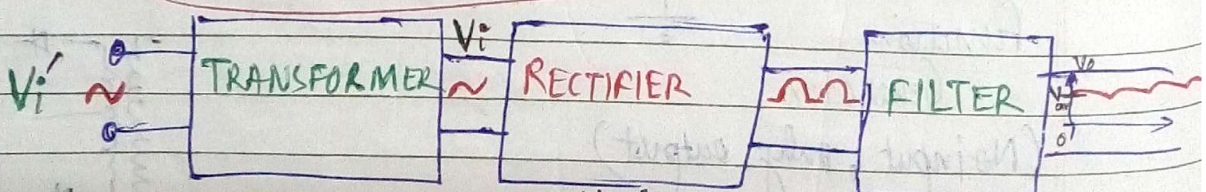
-ve Half cycle : D_2, D_4 = FB (ON), D_1, D_3 = RB (off)



V_{ripple} = Fluctuation in DC output

↳ never = 0 (when using 'C' only)
always > 0

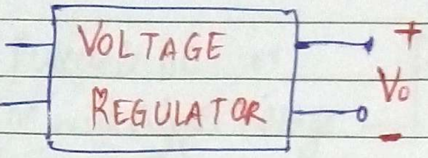
Linear DC POWER SUPPLY



HW
FW
BR

$(V_i' > V_0)$

$\boxed{V_i > V_o}$



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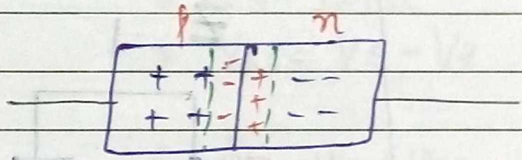
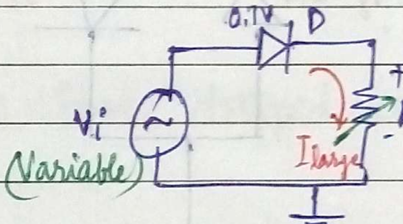
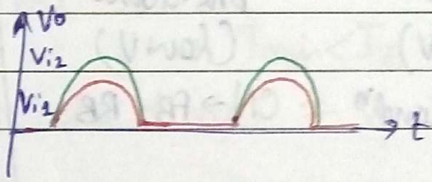
VOLTAGE REGULATORS

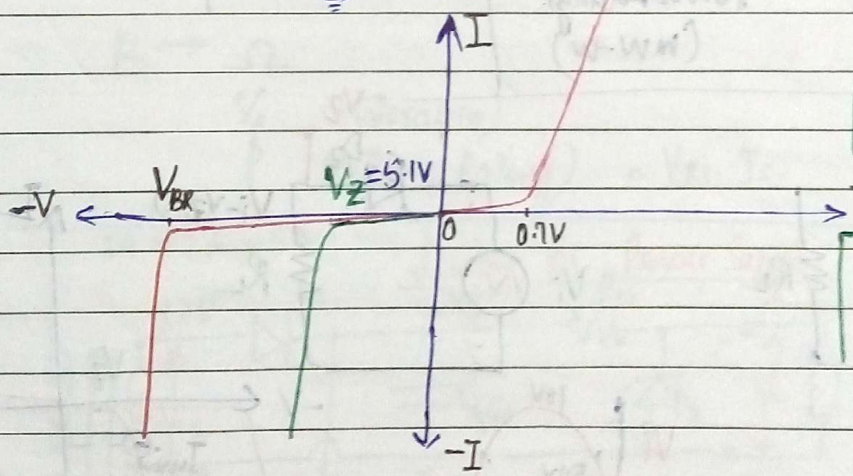
Const Vo with variable → Vi
↳ Z_L

- Zener Diode (diff doping profile for p, n)
- ICs



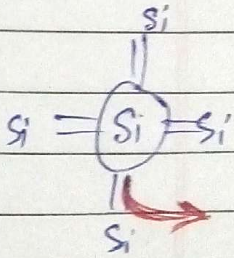




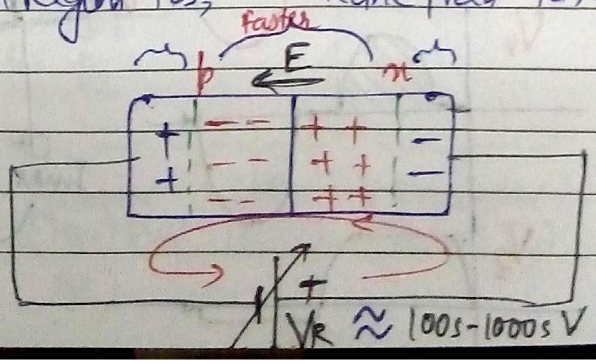


Breakdown

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



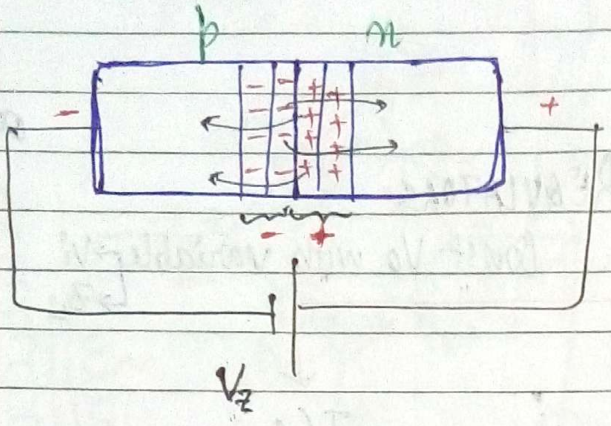
Depletion Region ↑es, Electric field ↑es.

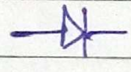
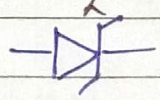


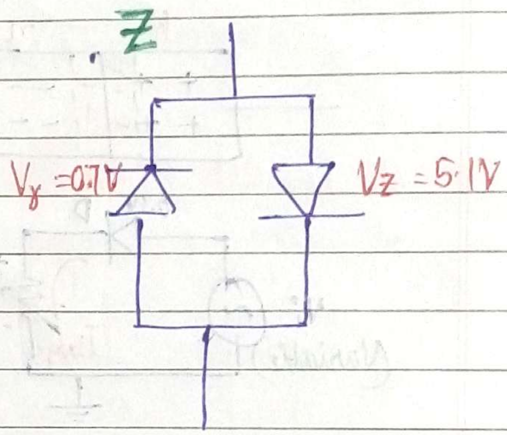
$V_R \approx$ 100s-1000s V (Normal diode)

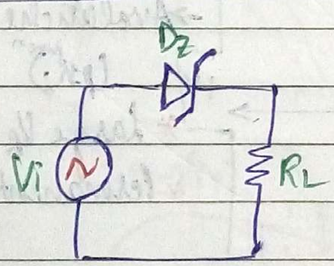
Impact Ionization
(Heavily accelerated beyond V_{BR})

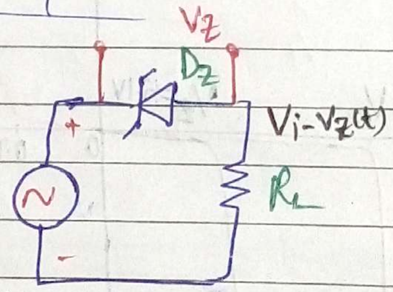
Zener

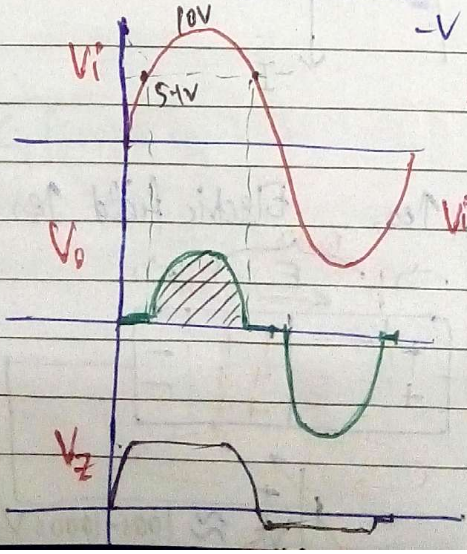


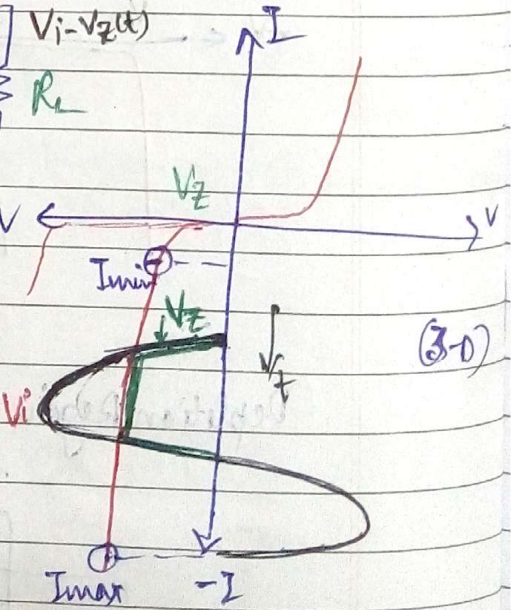
	PN	Z
1.		
2.	Avalance brk-down (High V)	Zener brk-down (Low V)
3.	ON → FB condⁿ OFF → RB	ON → FB, RB
4.	Power Ratings (mW - kW)	Power Ratings (mW - W)





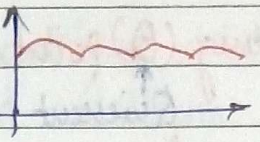




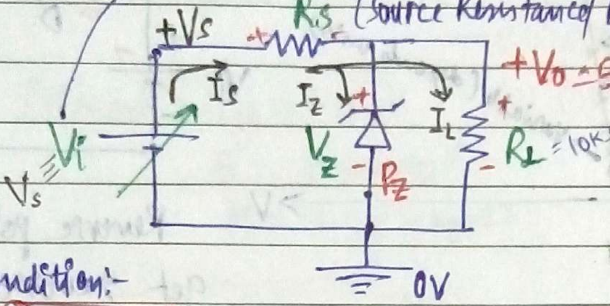


↳ for safely operating Zener diode

Pulsetile DC or
DC with Ripple Voltage →



R_s (Source Resistance / Dropout Resistance) → Protection Resistor / Supply Resistor.



$+V_0 = 5.1V$ → $5V \pm 10\%$ $(4.5V - 5.5V)$

theoritically $V_{max} = \infty$

V_1 to V_2

Practical limitation comes when we choose Rs.

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

$(V_0 = V_Z = 5.1V)$

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

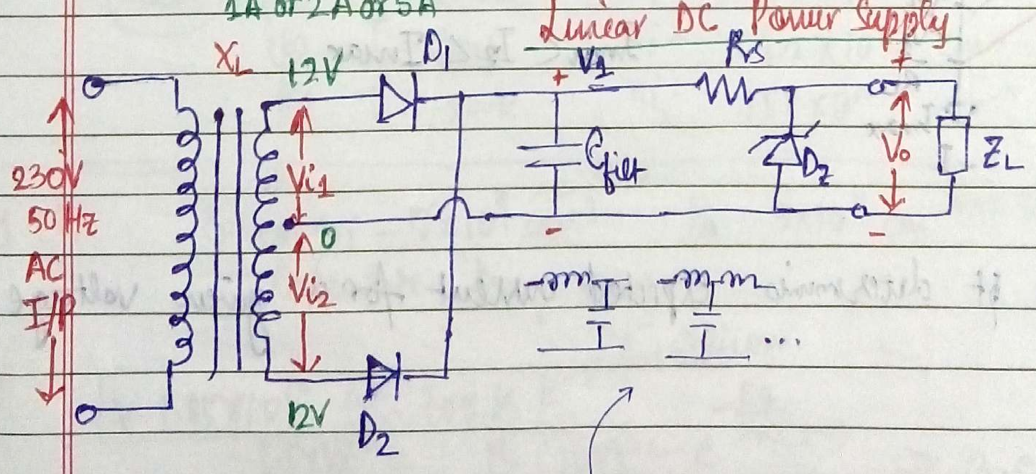
* $I_{min} < I_Z \leq I_{max}$

* P_Z = Power dropped across zener diode $= V_Z . I_Z$ (specified by manufactures)

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

Linear DC Power Supply

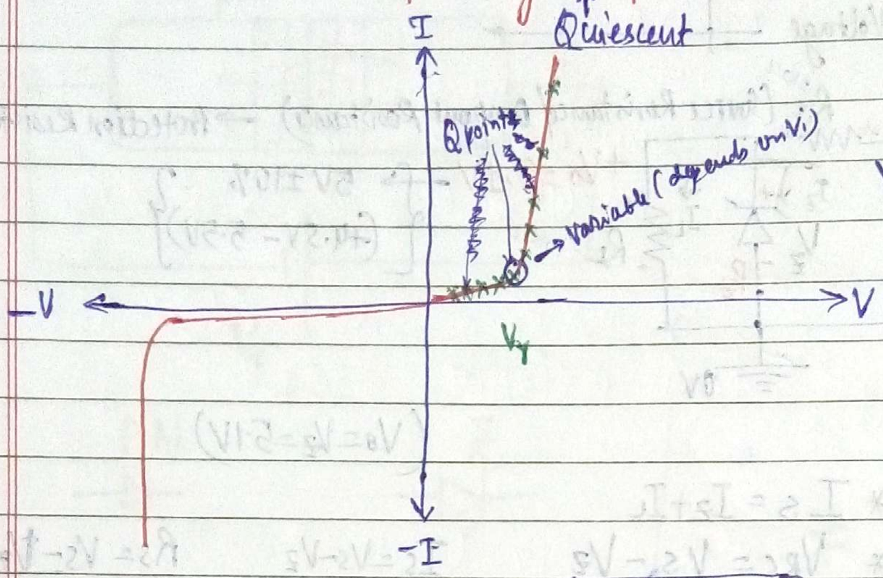
05/08/16

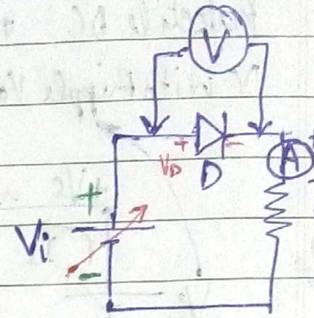


Transformer (Step up / dn) | Rectifier (HW / FW / BR) | Filter (C / LC) | V-Regulator (Zener / IC)

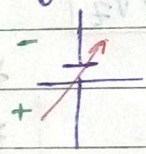
Load Line & Operating (Q) point

Quiescent





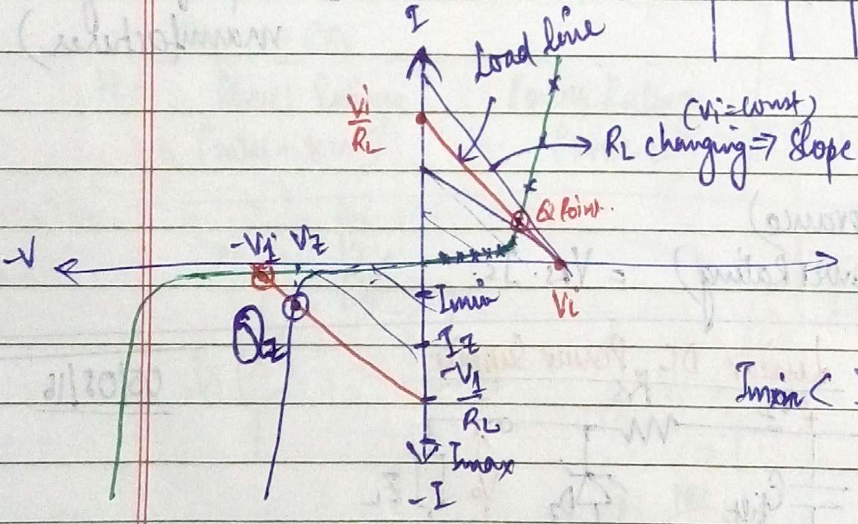
Reverse polarity to get reverse characteristic



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.

Orion

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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	$1.12eV$	$0.67eV$	$1.42eV$
B	5.23×10^{15}	1.66×10^{15}	2.1×10^{14}
k	1.38×10^{-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 calculation) | $n_i = 2.74\times10^{-10}\ cm^{-3}$

TRICK $E_g \rightarrow eV$. $k \rightarrow 8.6\times10^{-5} \equiv \frac{k}{e}$

(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 $n_i = 293\times10^{-19}\ cm^{-3}$
(b) T=300k $n_i = 122\times10^{6}\ cm^{-3}$
(c) T=500k $n_i = 158\times10^{11}\ cm^{-3}$.

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.

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

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

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

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

~~T = 290 K~~, $n_i = 4.57\times10^{9}\ cm^{-3}$.
T = 291 K, $n_i = 4.969\times10^{9}\ cm^{-3} \Rightarrow n_i \approx 5\times10^{9}\ cm^{-3}$

~~T = 350 K~~, $n_i = 2.85\times10^{11}\ cm^{-3}$
T = 360 K, $n_i = 4.98\times10^{11}\ cm^{-3} \Rightarrow n_i \approx 5\times10^{11}\ cm^{-3}$

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

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

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

at T = 300K, $n_i = 1.0177\times10^{10}\ cm^{-3}$
$\Rightarrow p_i = 2071.426\ cm^{-3}$.

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

at T = 350K, $n_i = 2.85\times10^{11}\ cm^{-3}$
$\Rightarrow p_i = 1624500\ cm^{-3}$.

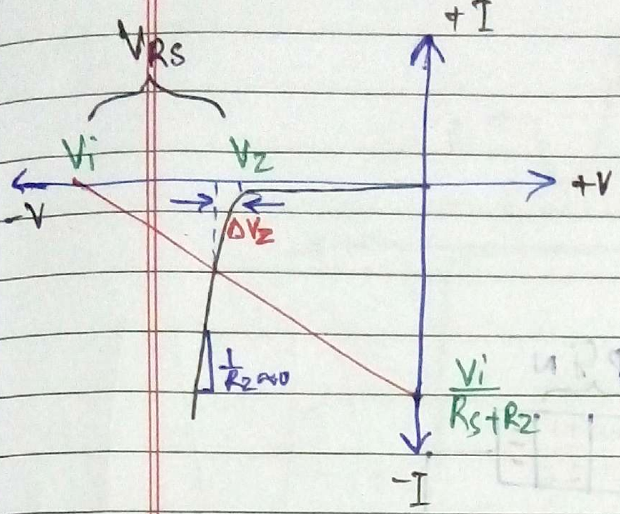
$1.61\times10^{6}\ cm^{-3}$

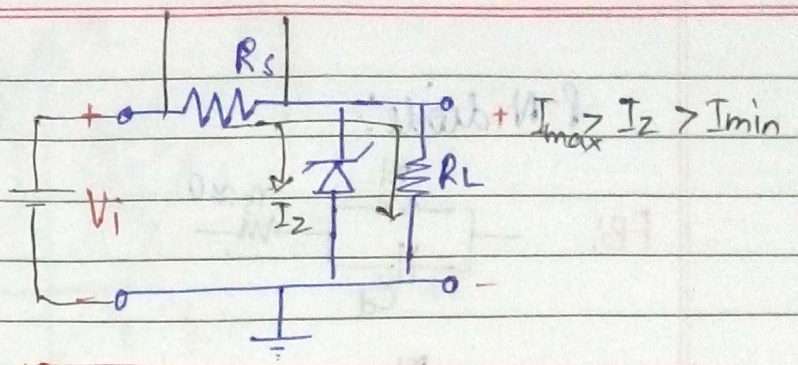
at 300K

	E_g	μ_n ($cm^2/V\text{-}s$)	μ_p
Si	1.12eV	1350	480
Ge	0.67eV	3900	1900
GaAs	1.42eV	8500	400

$$\frac{KT}{e} = \frac{D_n}{\mu_n} = \frac{D_p}{\mu_p} \rightarrow cm^2/s$$

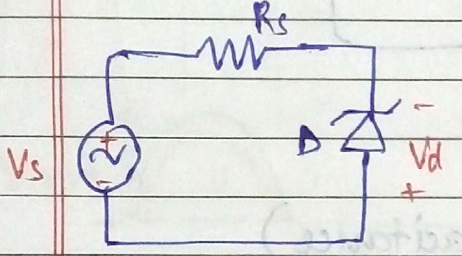
0.0259 V
(26mV)

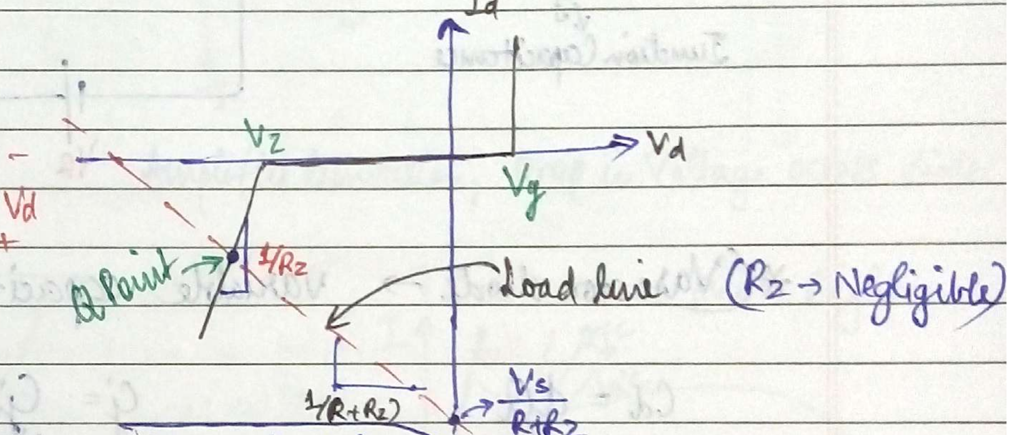




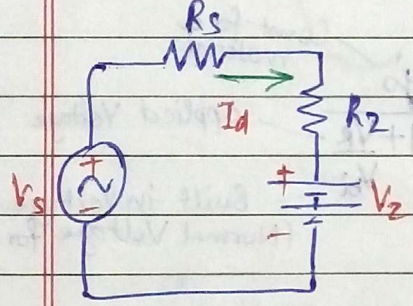
$I_{max} > I_Z > I_{min}$

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





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

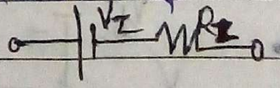
Quality of Regulation :-

1) Line / Source of Reg $= \frac{\Delta V_o}{\Delta V_i} \times 100\%$ (should be less than 5%)

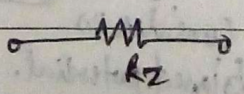
2) Load Reg. $= \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100\%$

Eq. Representation of Zener diode :-

* RB

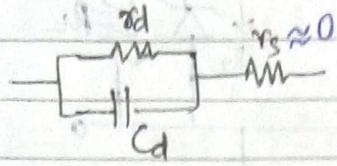


* FB

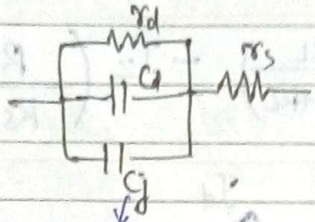


P-N diode :-

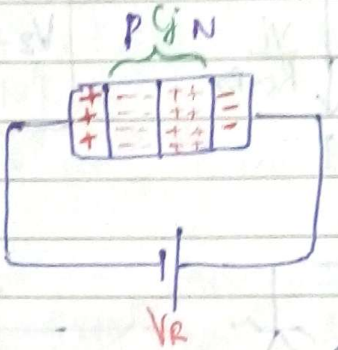
FB:



RB:



Junction Capacitance



*(Varector diode → variable capacitance)

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

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

C_{jo} — Const. for a material

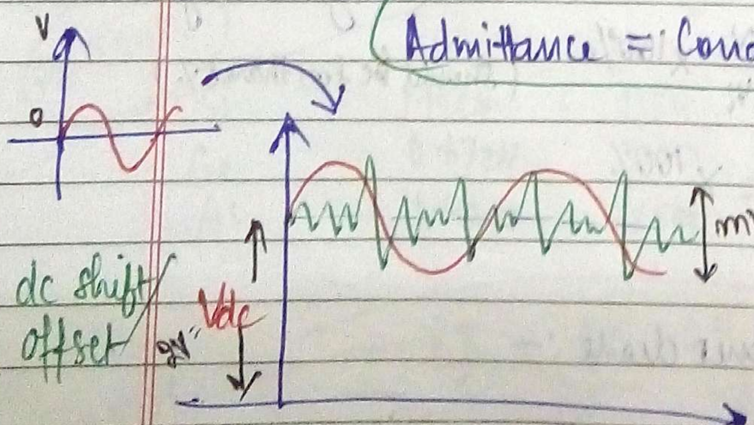
V_R — applied Voltage

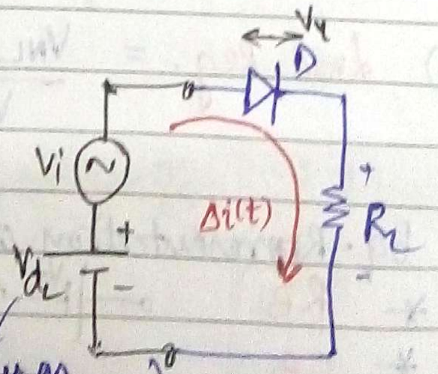
V_{bi} — Built in Voltage (Normal Voltage for Si - 0.7V)

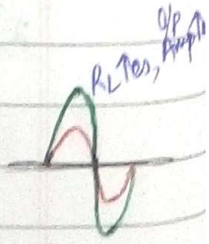
Conductance, (Inverse of Resistance) $g_m = \frac{1}{r_d}$

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

Admittance = Conductance + Susception



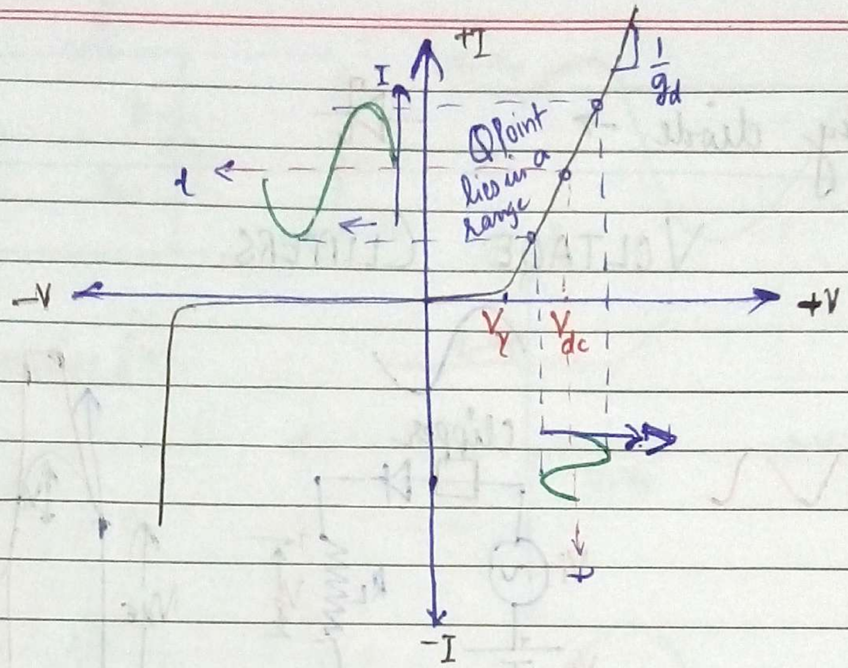


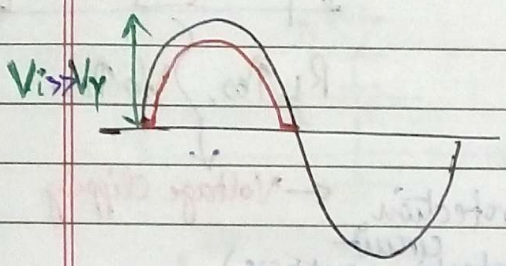


AMPLIFIER

Consider as biased potential.

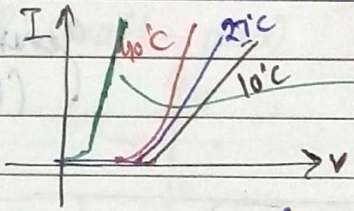
Input = AC + offset.





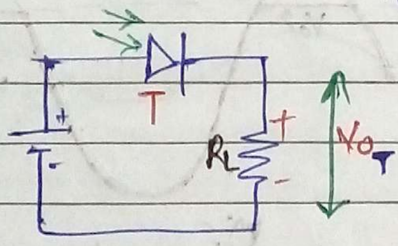
Amplifier limitation: Drop in Voltage across diode.

T ↑es → curve shifts Right.

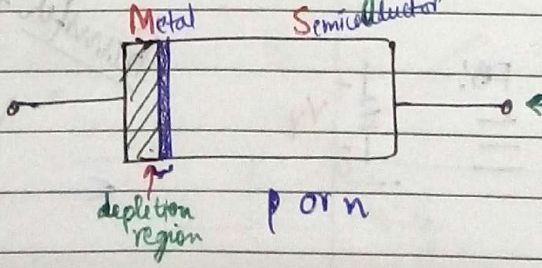


Diode can be used as a Temperature Sensor.

- Low Temp → low ^heat thermal energy → More energy is reqd. to turn it on.
- High Temp ≡ less energy reqd.



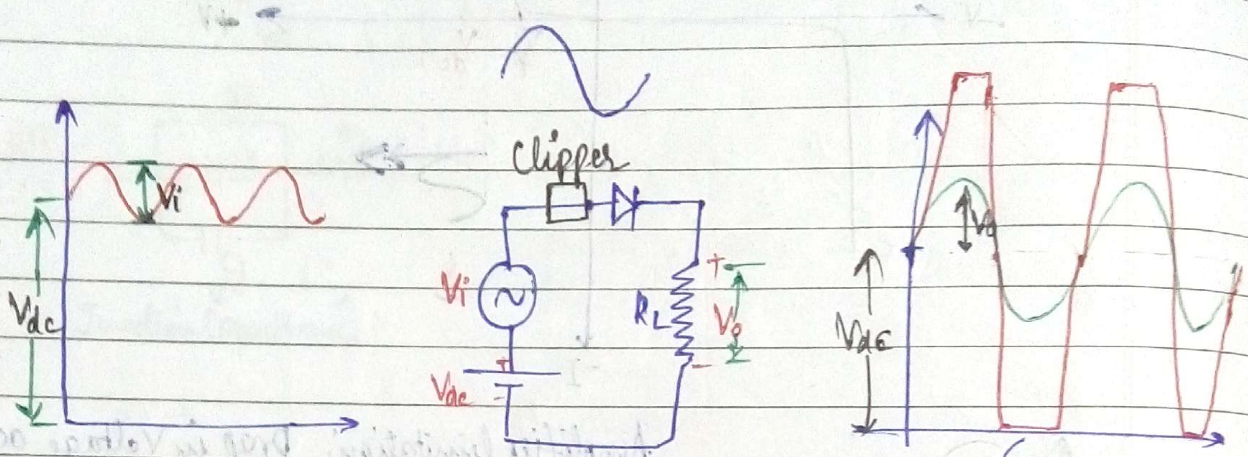
Schottky diodes



Metal- Semiconductor Junction → nanoscopic level accurate.

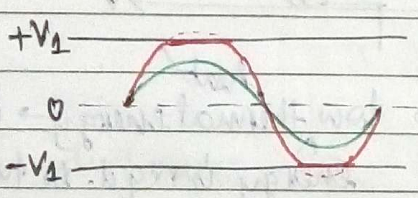
Schottky diode →

VOLTAGE CLIPPERS

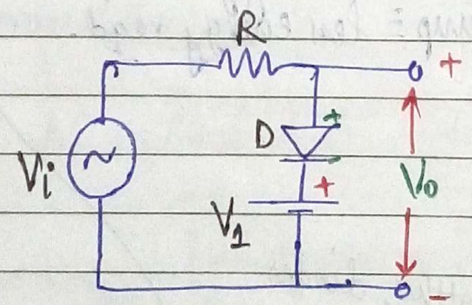


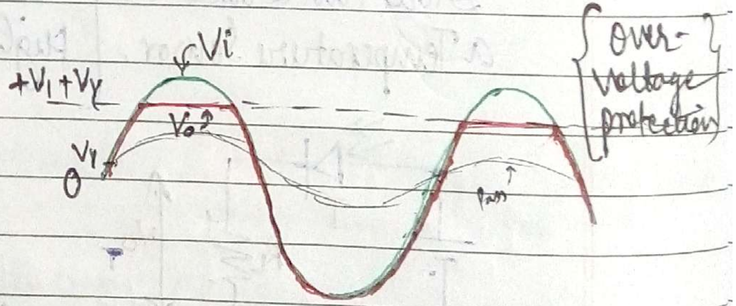
$R_L \uparrow$es, $V_0 \uparrow$es. → Voltage clipping

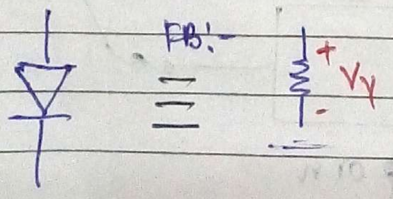
generally used for protection (over voltage protection circuit purpose)



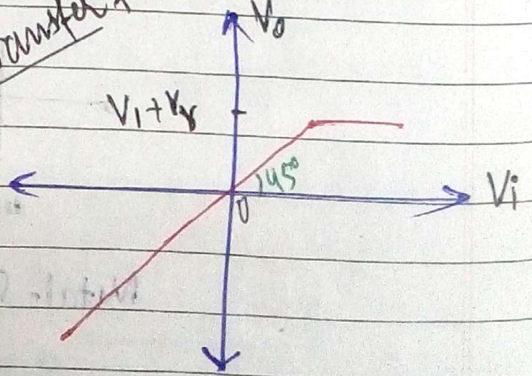
I



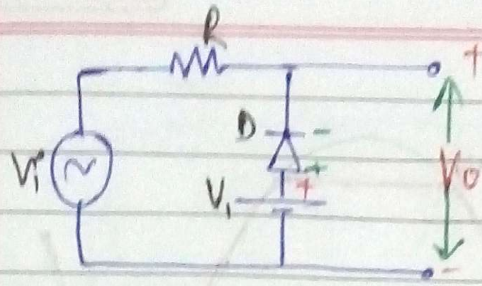


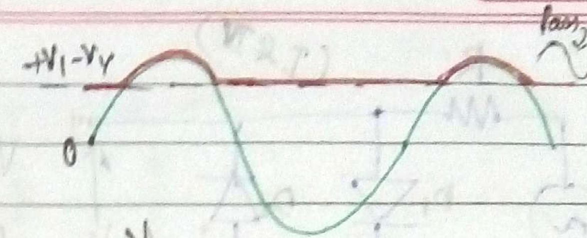


Transfer fn:-



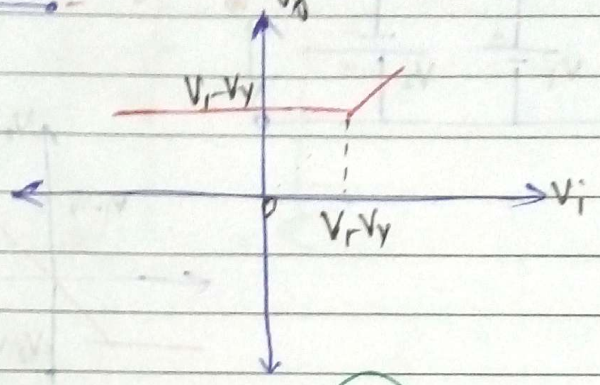
II



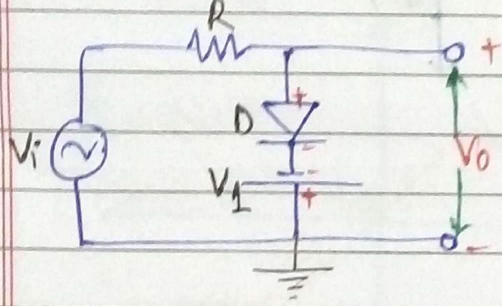


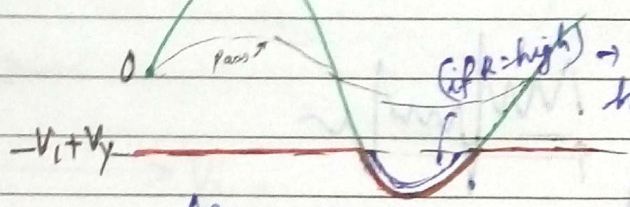
{Under-Voltage protection}

Transfer fn:-



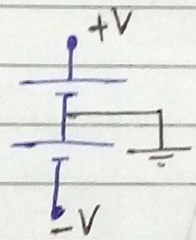
III



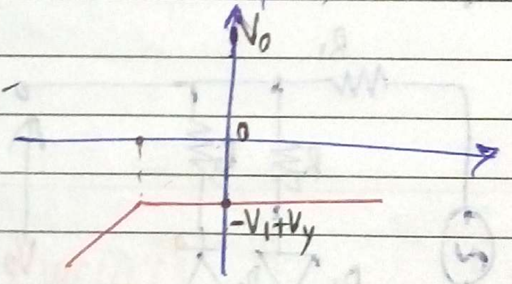


(if R=high) → V drop across R has to be considered

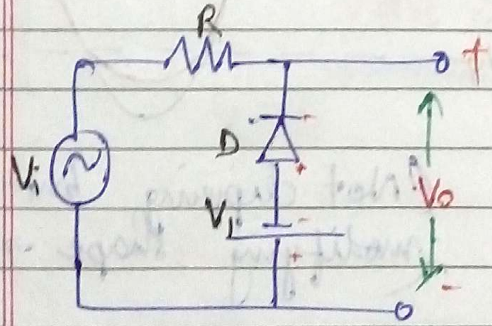
(R=small → peace)

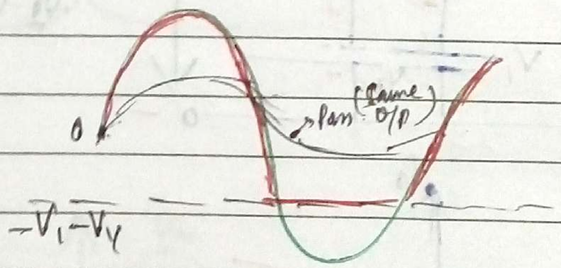


Tf:-

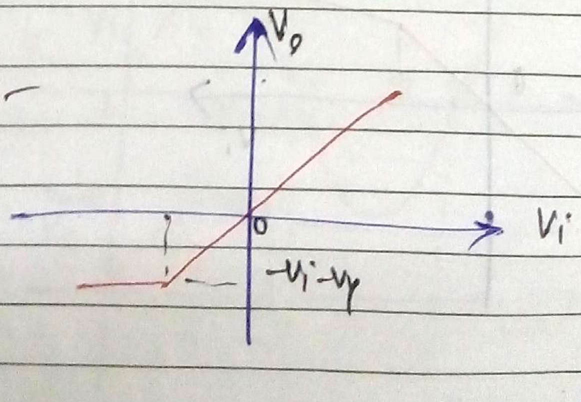


IV

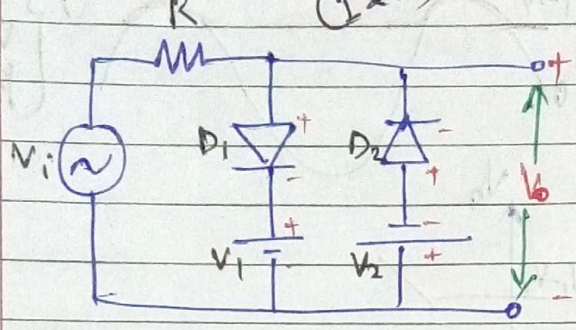


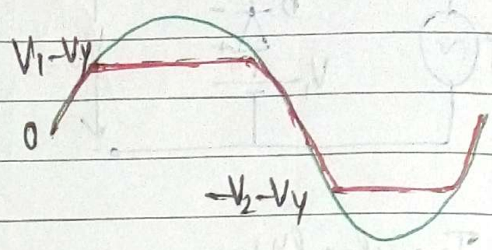


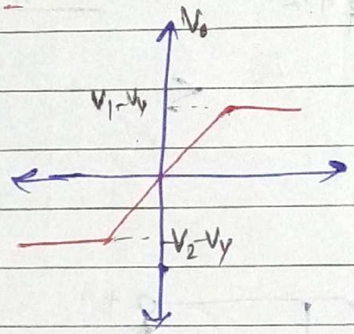
Tf. ch:-



(I & IV)

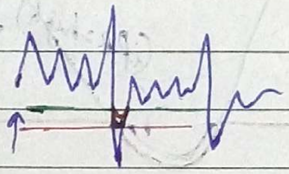


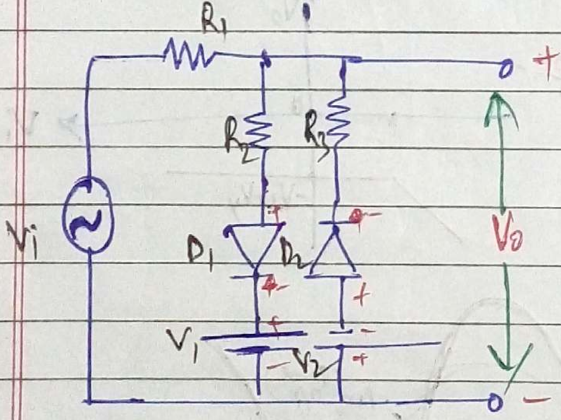


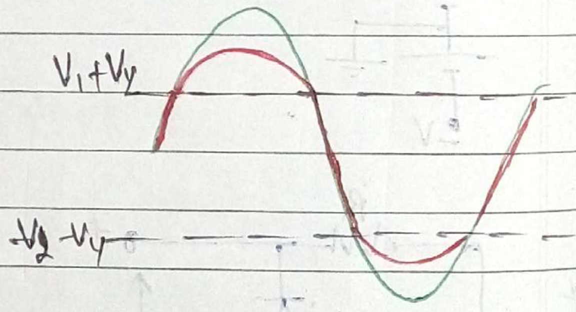


Decrease threshold

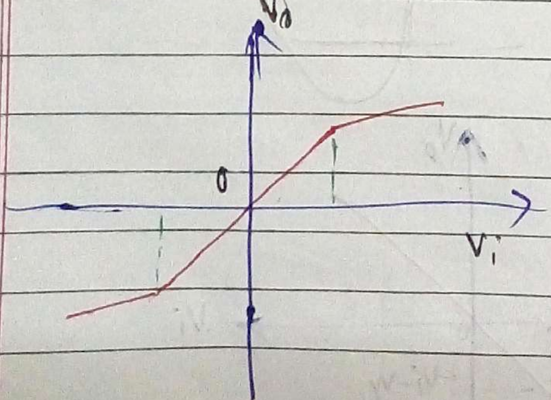
(for producing no sharp change

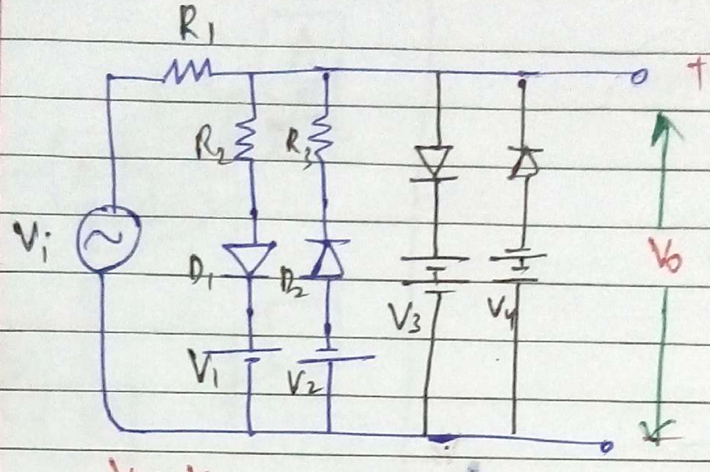






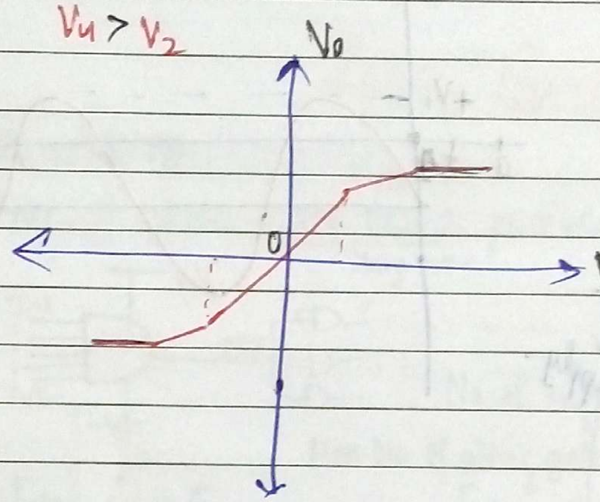
(Not clipping but modifying shape → Ver Amp)





$V_3 > V_1$

$V_4 > V_2$



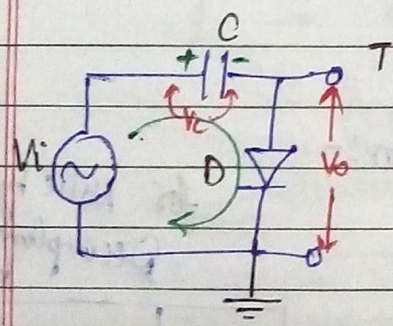
12/08/16

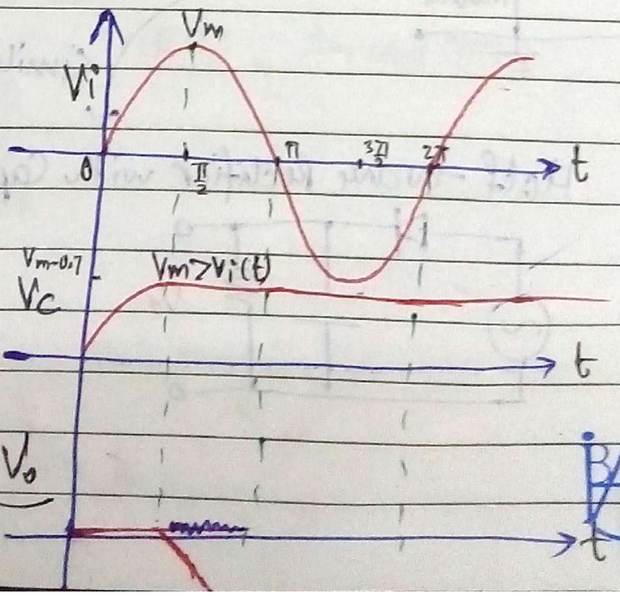
WAVE SHAPING CIRCUITS

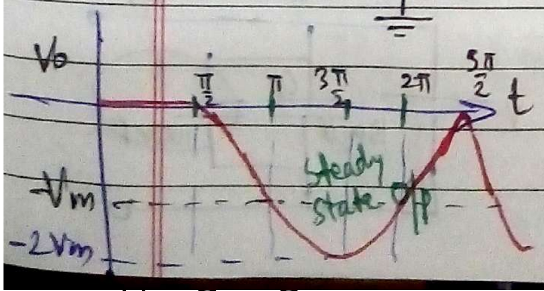
Clipper

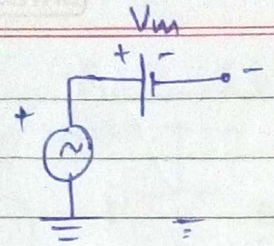
Clamper → DC shift

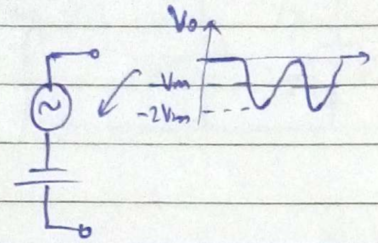
CLAMPER

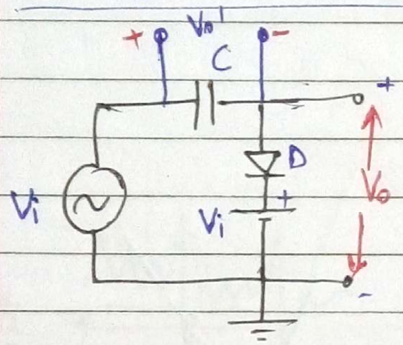


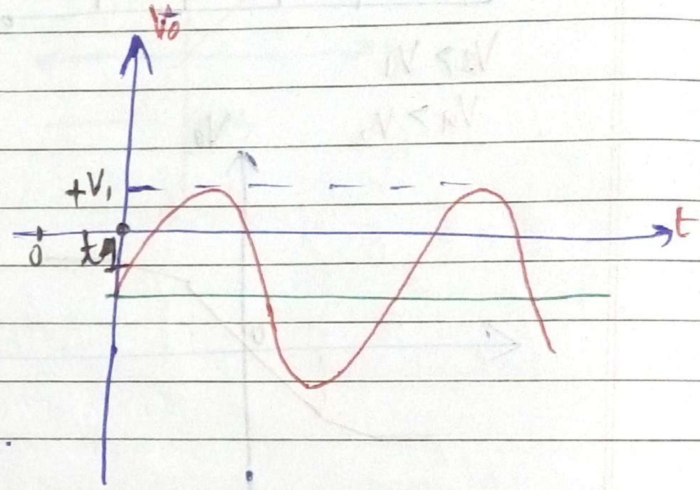




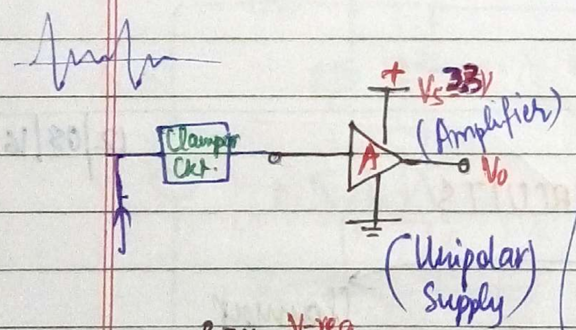


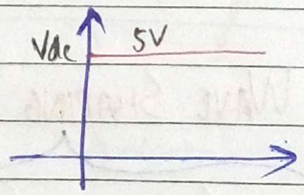


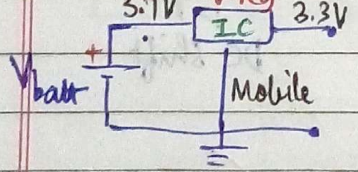




Clamping ckt as power supply.

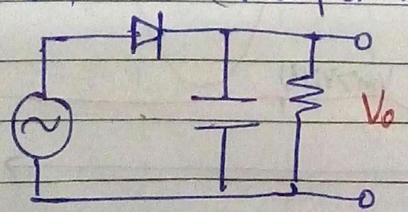




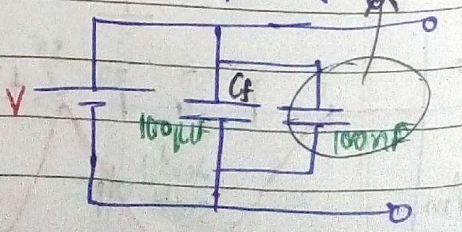


Similar.

Half-wave Rectifier with Capacitor:-



for Noise bypassing/ Decoupling



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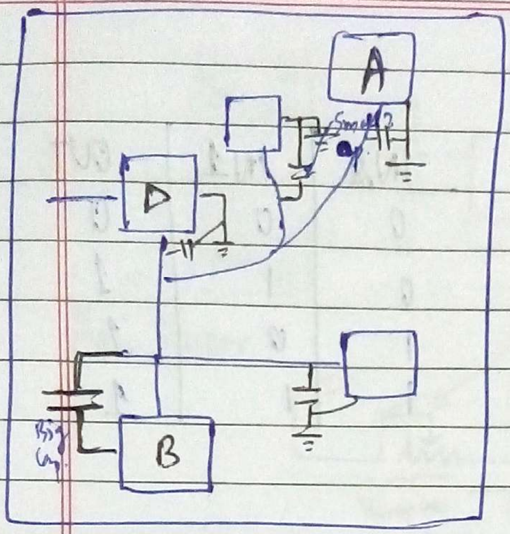
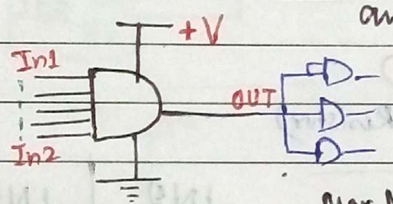


LOGIC GATES

NOT → 1 I/p

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



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

Max. No of other gate inputs that may be connected

Fan-in = 5 Fan-out = X

Emitter Coupled Logic

★ Logic family → TTL, DTL, ECL

Transistor Transistor Logic (+), Diode TL (+), (-)

* Noise Margin → 1, 0

TTL

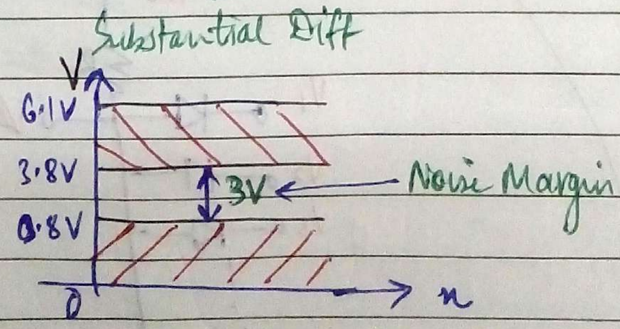
0 → 0V (0-0.8V)

1 → 5V, -5V (ECL), Any value (DTL)

(4.5-5.5)

(3.8-6.4V)

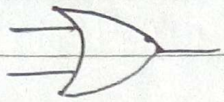
Substantial Diff

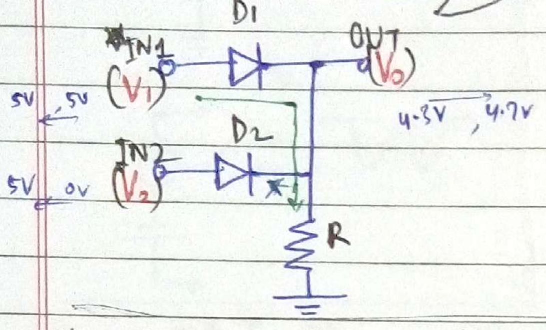


ANUBHAV JAIN NOTES

Scanned by CamScanner

OR GATE

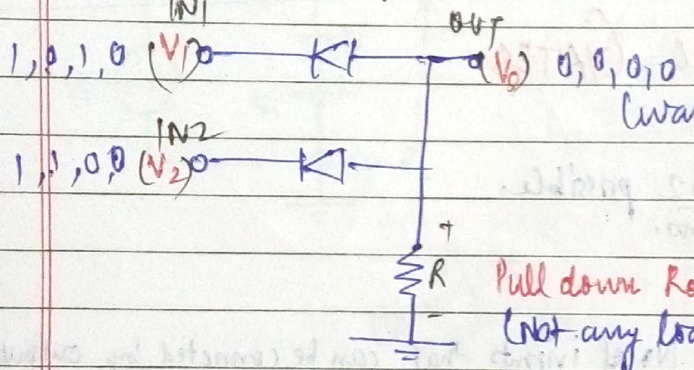




D2 → RB

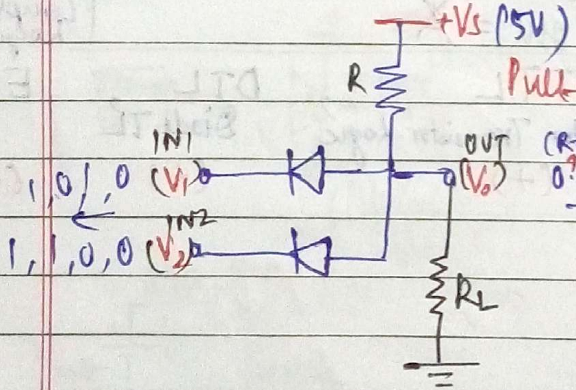
IN2	IN1	OUT
0	0	0
0	1	1
1	0	1
1	1	1

* Iterative Design Process.



(waste of time) → all o/p = 0.

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

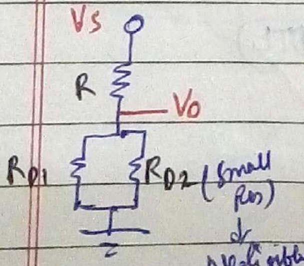


Pull-up Res (R)

(R R || → 2 diode parallel)

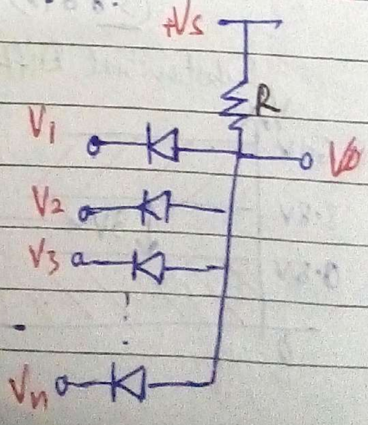
0.5V, 0.7V, 0.7V, 5V

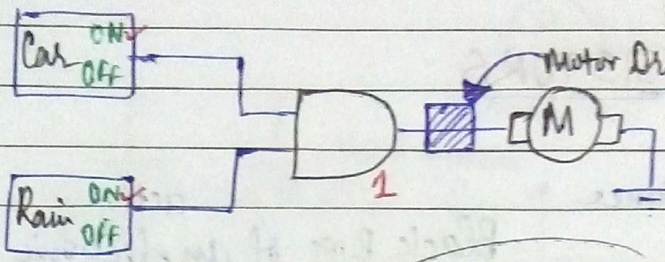
IN2	IN1	OUT
0	0	0
0	1	0
1	0	0
1	1	1



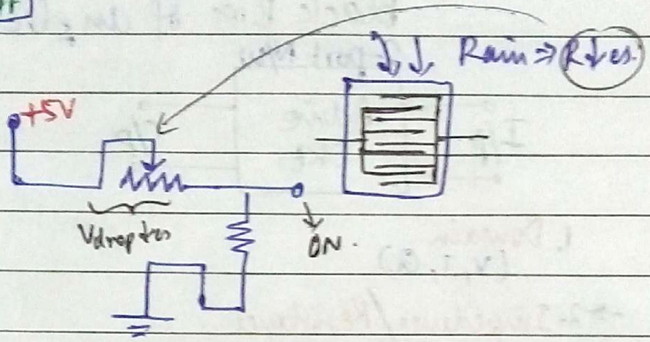
(Small Res) → Negligible V drop.

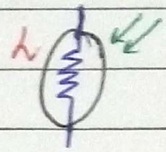
AND GATE: FAN-IN = n

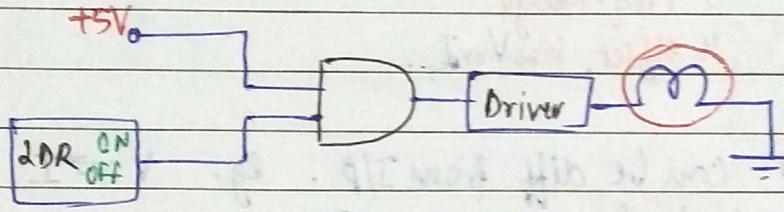


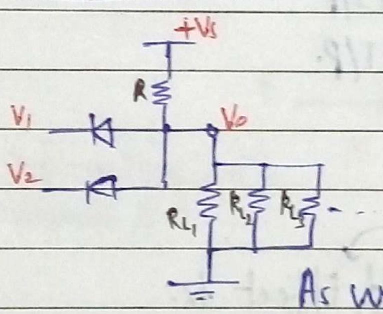


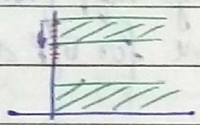
Rain Sensor.











As we add more load res, Vo ↓es.

R → large → Fan-out large

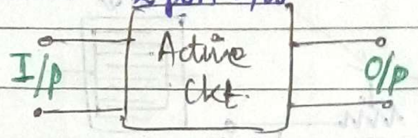
R → small → Fan-out low

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.

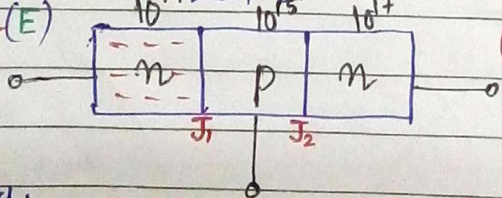
Transistors

Bipolar Junction tr. (BJT) | Field (E) Effect tr. (FET)

→ formed by extention of diode str.

(N_D or N_A) → Doping impurities per unit volume.

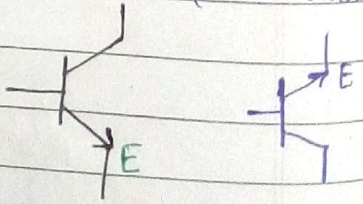
highest doping ⇓ Emit charge carriers. ← Emitter (E)



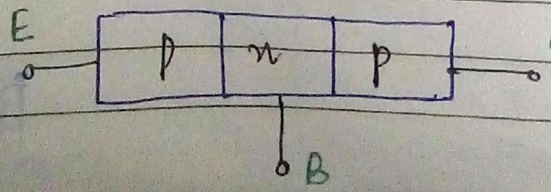
Collector (C)

Base (B) → lightly doped

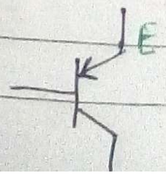
NPN tr. (arrow outside)

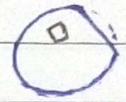


(Arrow ≡ E)



PNP tr. (arrow inside)



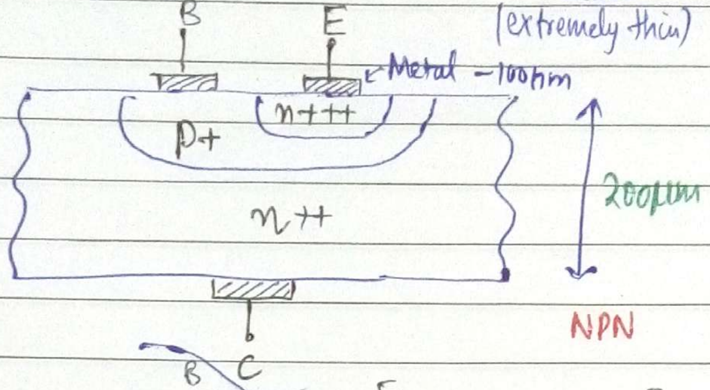


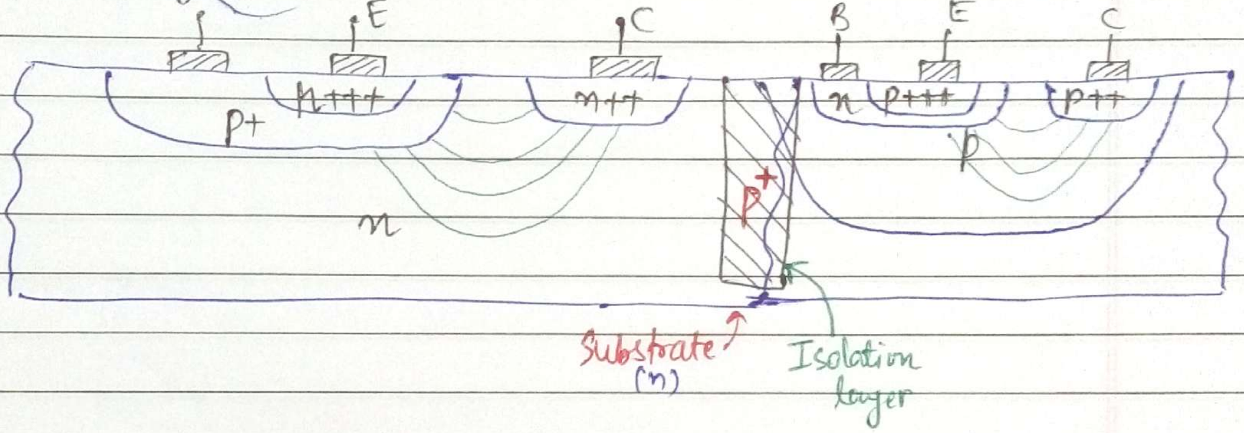
Wafer

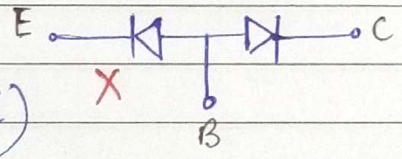
(extremely thin)

12", 8", 4", 2" → diameter

↑ industry ← lab





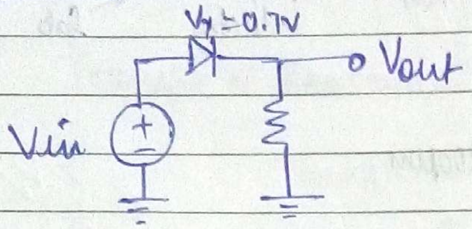


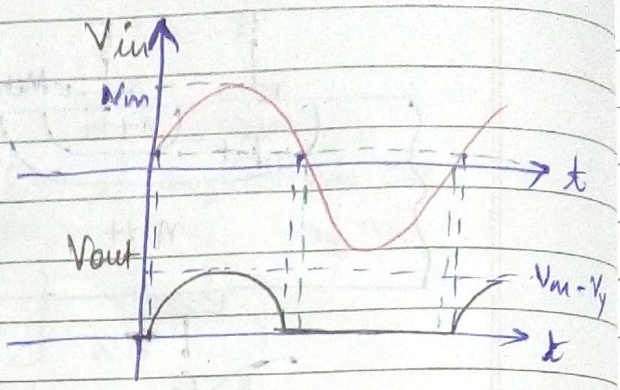
(Not a Realistic Model of tr.)

TUTORIAL

Rectified Circuits

Q1:

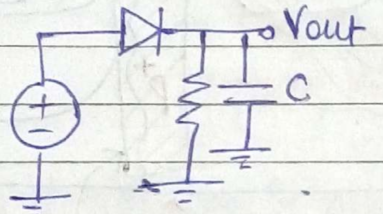


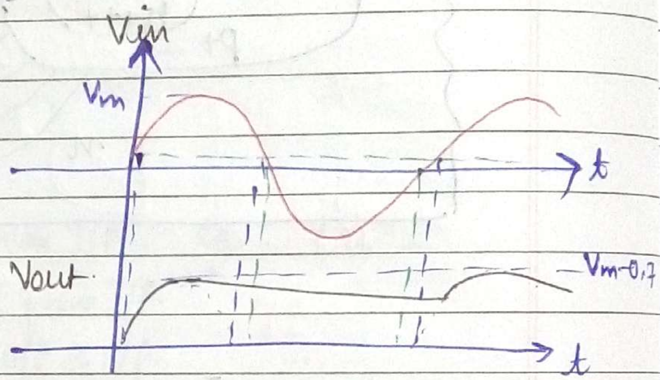


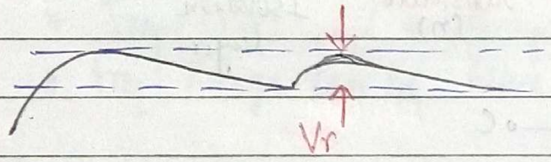
Max. $V_{out} = V_m - V_\gamma$

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

If





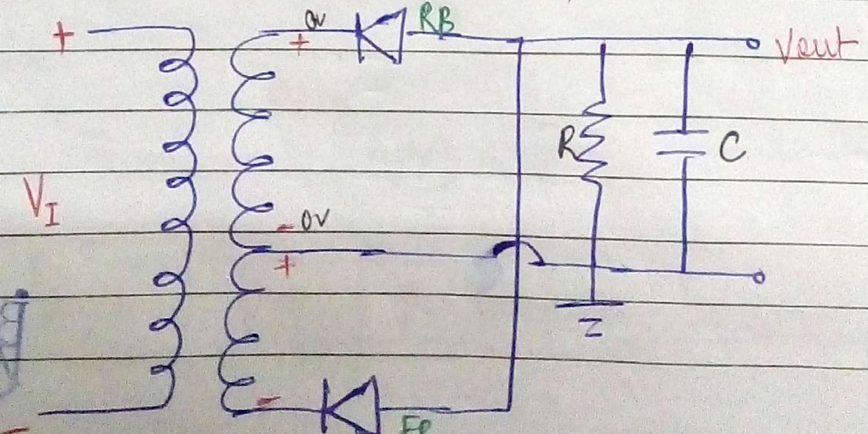


Full wave $V_r = \dfrac{V_m - 0.7}{2fRC}$

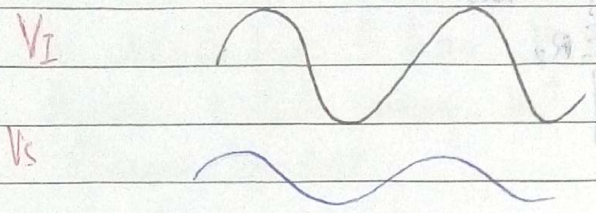
Halfwave $V_r = \dfrac{V_m - 0.7}{fRC}$

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

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



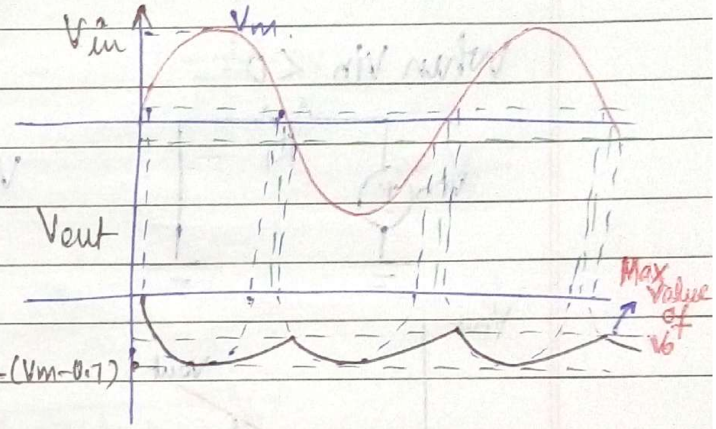
Centre tap transformer.



→ half of V_I.

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

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



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

$$V_m - 0.7 = 11.321\,V.$$

$$V_{o\,max} = -11.321 + 0.2298 = -11.091\,V.$$

$$V_r = \frac{11.321}{2\times 60\times 10\times 40\times 10^{-3}} = 0.2358 \cong 0.236\,V$$

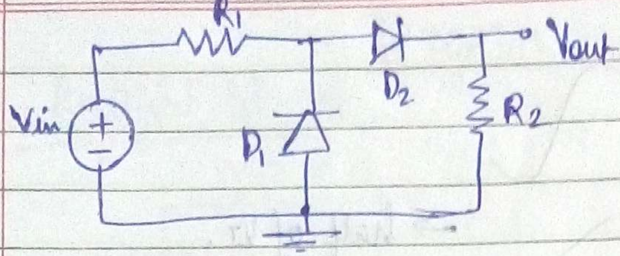
$$\therefore V_{o\,max} = -11.32 + 0.236 = -11.0851\,V$$

PIV: Peak Inverse Voltage :-

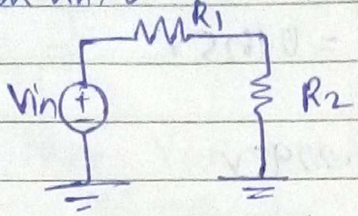
Max value of V_i − Min value of Vout will max. value of diode voltage.

$$\text{Max. PIV of diode} = 12.02 - (-11.32) = 23.34\,V.$$

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



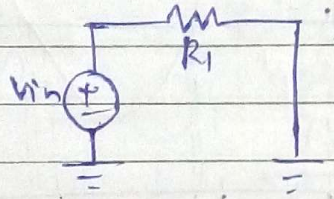
When $V_{in} > 0$



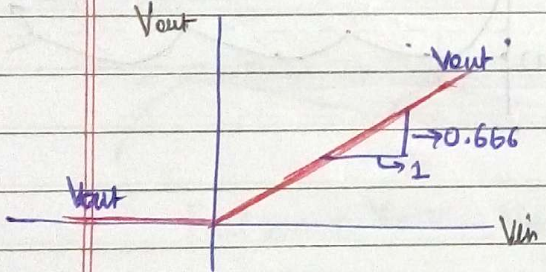
$$V_{out} = \frac{R_2}{R_1+R_2} V_{in} = \frac{2}{3} V_{in}$$

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

When $V_{in} < 0$

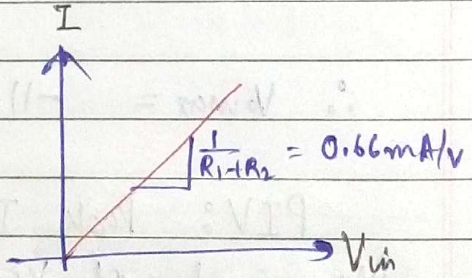


$V_{out} = 0$



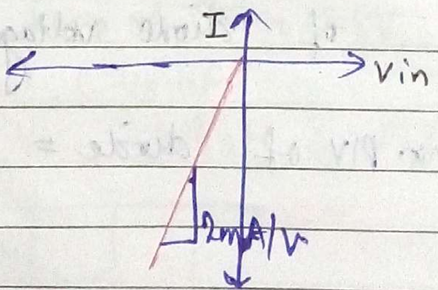
Current through R_1
when $V_i \geq 0$

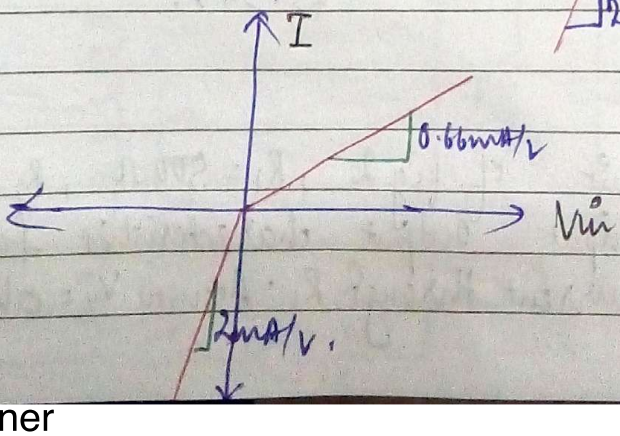
$$I = \frac{V_{in}}{R_1+R_2}$$



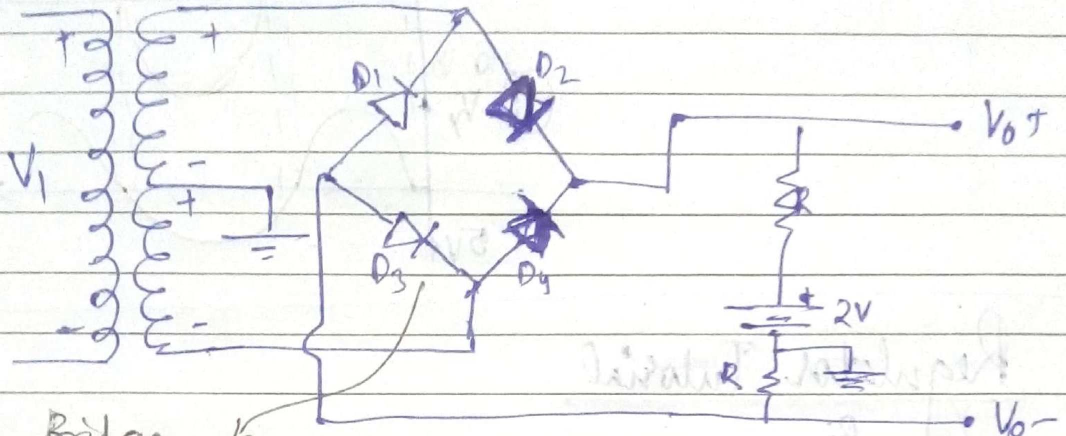
When $V_i < 0$

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



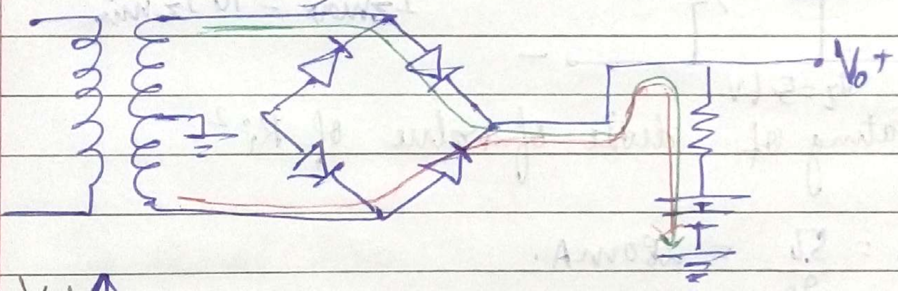


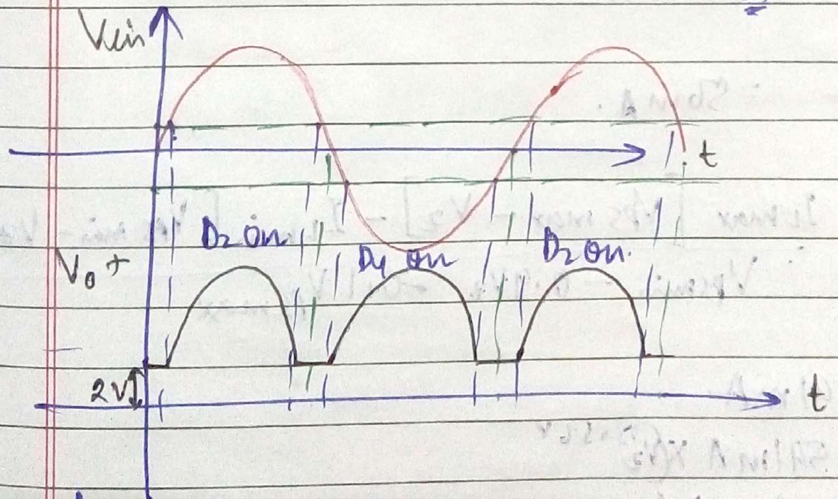
Q3. The ckt. in fig B has $V_s = 26 \sin(2\pi 60 t)$. Sketch output voltage V_0^+ and V_0^- v/s time.
Assume $V_\gamma = 0.7V$



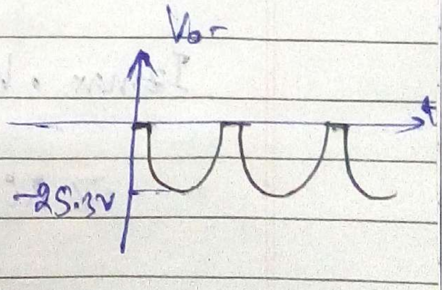
Bridge Rectifier

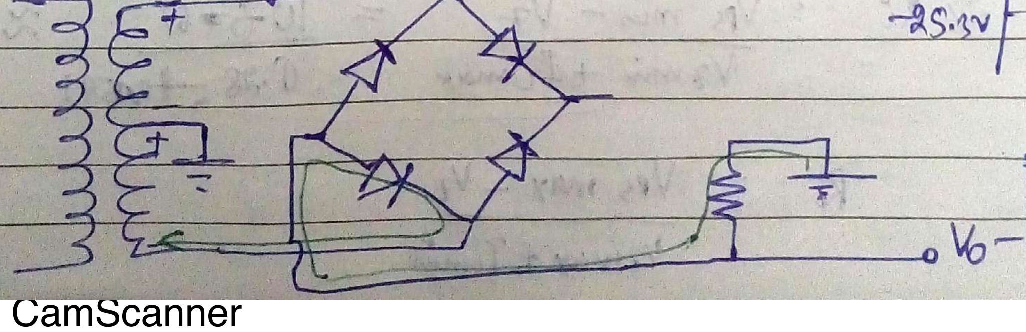
Consider V_0^+ only



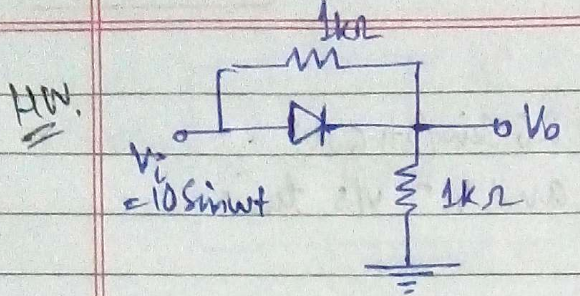


Now V_0^- only! -

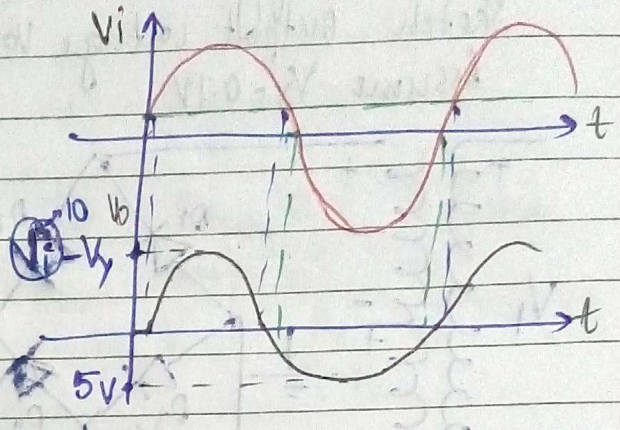




HW.

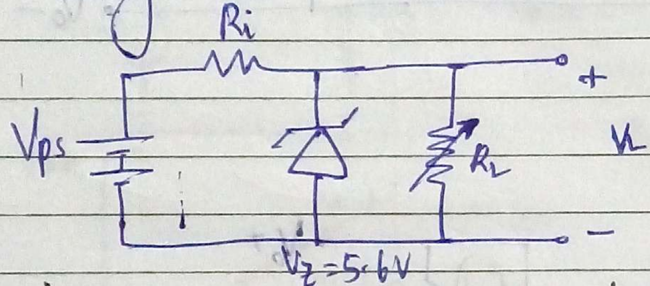


plot V_o v/s t.



Regulator Tutorial

Q1.



$20\Omega - 100\Omega$

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

Find power rating of diode of value of R_i?

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

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

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

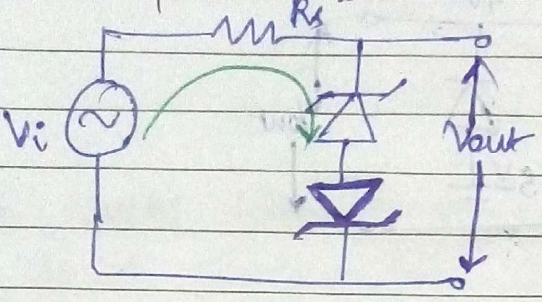
$$= 591mA$$

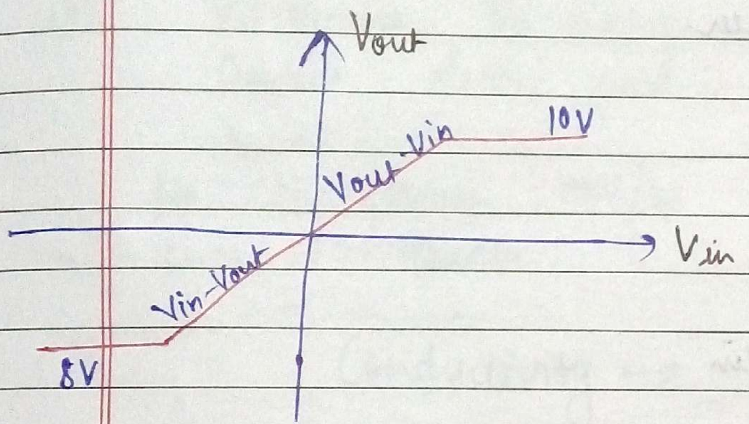
$$I_{zmax} \cdot V_z = 591mA \times V_z \; (5.6V)$$
$$= 3.31W$$

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

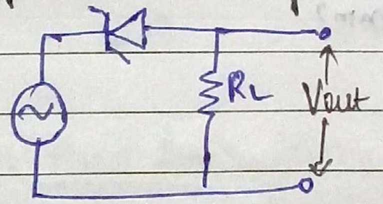
$$R_i = \frac{V_{ps\,max} - V_z}{I_{zmax} + I_{Lmin}}$$

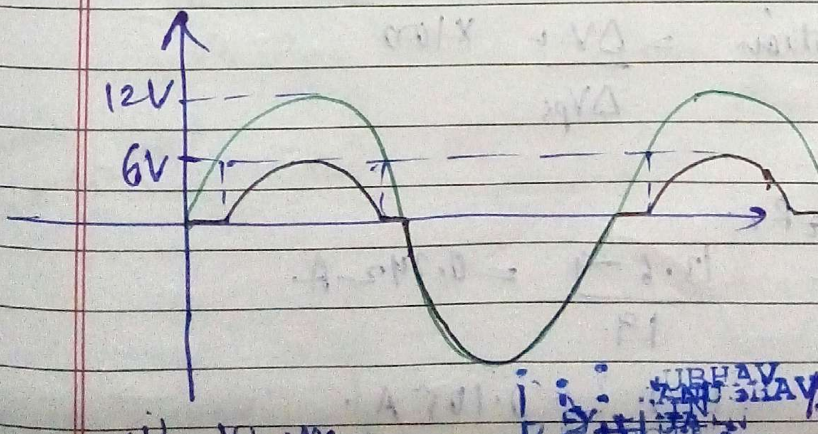
Q2. In the circuit shown diodes are ideal and have breakdown voltage of $V_{Z_1} = 10V$, $V_{Z_2} = 8V$. If input is 15V peak sinusoidal waveform then plot the output of transfer characteristics.

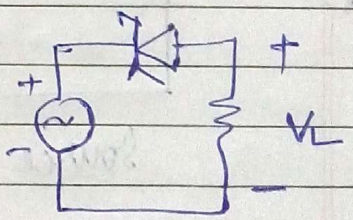


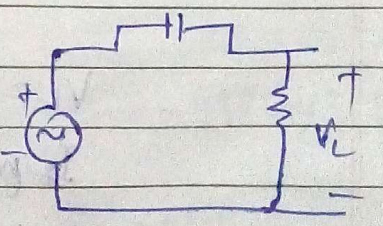


Q3. In circuit shown, zener diode is ideal and breakdown voltage is 6V, if the input voltage is 12V peak sinusoidal then plot the output waveform.









(i) Vin +ve

$V_s - 6 = V_L$

After breakdown, it const value = 6V.

Vin = +ve.

Orion

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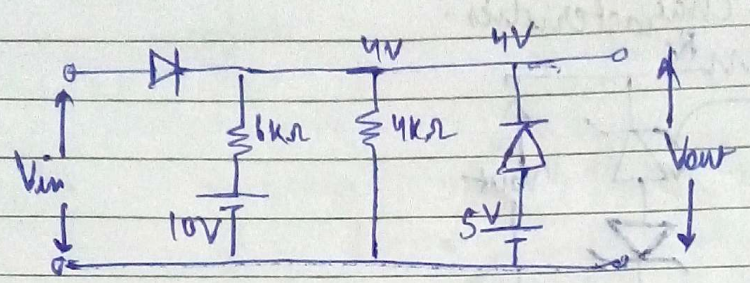
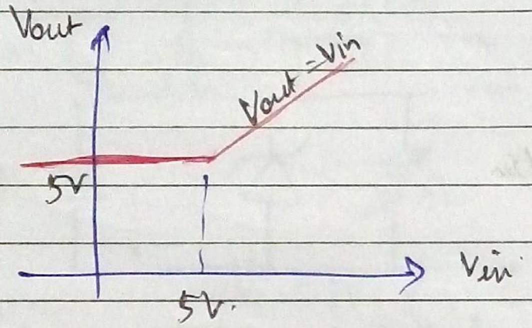
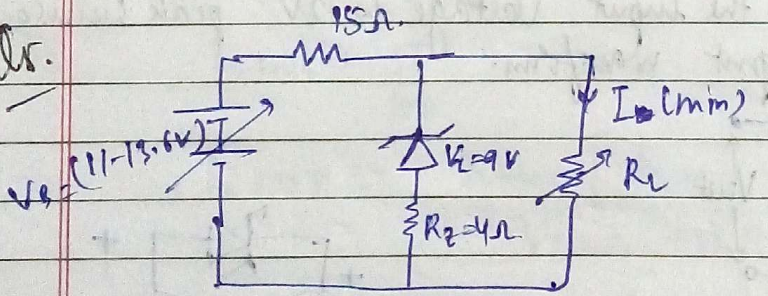
Q4. In the circuit shown, the diodes are ideal. Plot its char.



First assume both are open.



Q5.



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

$V_L = V_z + I_z R_z$.

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

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

Orion

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$V_{r max}, V_{r min}; \quad \Delta V_r = V_{r max} - V_{r min}$

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 $E = 0.1 V/cm$.

$\mu_p = 400\ cm^2/Vs$

$\mu_n = 8500$ "

(i) Conductivity $\rightarrow \sigma = e \mu_n N_d$.

$\sigma_{max} = 13600$

$\sigma_{min} = 1.36$

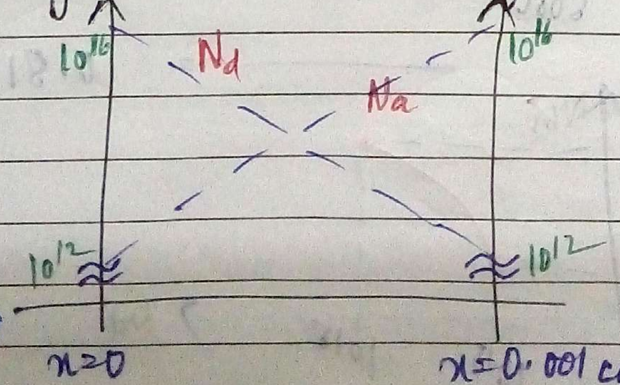
$\Rightarrow 1.36 < \sigma < 13600$

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

$\Rightarrow 0.136 < J < 1360$ $A\,cm^{-2}$

(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 → conc gradient



$\mu_n = 1250\ cm^2/Vs$

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

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

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

Scanned by CamScanner

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

$$J_n = eD_n \frac{dN_d}{dx}$$

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

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

$$J_p = -eD_p \frac{dN_a}{dx}$$

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

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

my → -70.4

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.

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

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

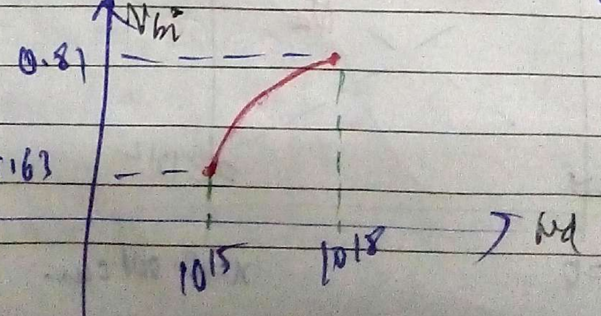
V_{bi} → Built in potential

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

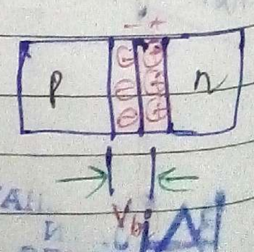
$$V_{bi} = \frac{(1.38\times10^{-23})(300)}{(1.6\times10^{-19})} \ln\left\{\frac{N_a\,(10^{16})}{(1.5\times10^{10})^2}\right\}$$

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

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



~~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.

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

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

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

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

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) $V_R = 5V$.

$$V_{bi} = \frac{kT}{e}\ln\left(\frac{N_a N_d}{n_i^2}\right) = 0.68\,V$$

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

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

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

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DATE: 25/08/16

Transistor.

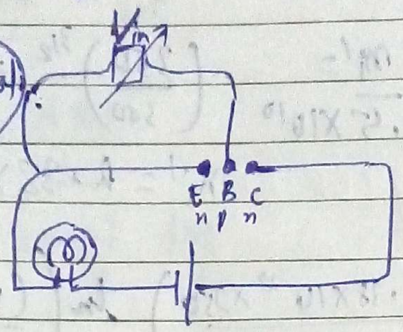
$\rightarrow 0\,\Omega$ Resistance
ON } Switch
OFF } Switch
$\hookrightarrow \infty\,\Omega$.

$\updownarrow$ Amplifier (somewhere in between 0 to $\infty\,\Omega$)

Ω
$K\Omega$
$M\Omega$

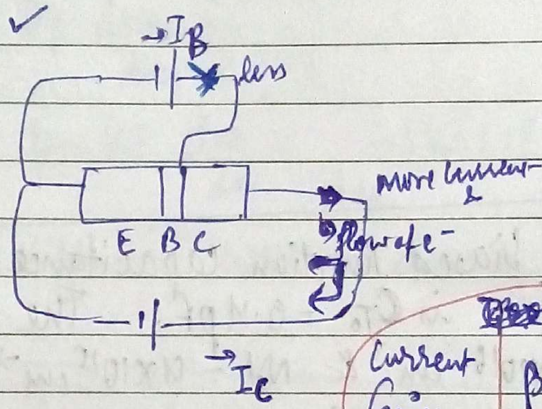
YouTube | Learn Engineering
Transistor – How does it work

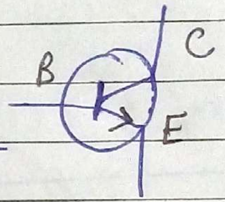
V_{in} not enough to overcome barrier potential $\Rightarrow$ OFF



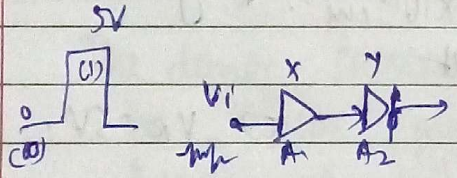
Silicon $\rightarrow$ ~~no use~~ alone

Silicon + Doping ✓

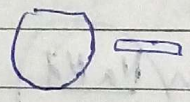




Current Gain $\beta = \dfrac{I_C}{I_B} > 1$



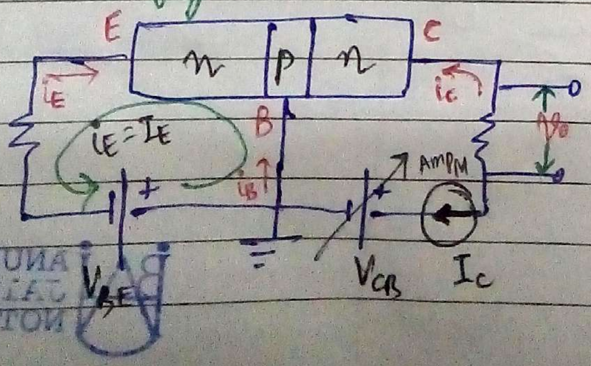
Gain = X·Y.



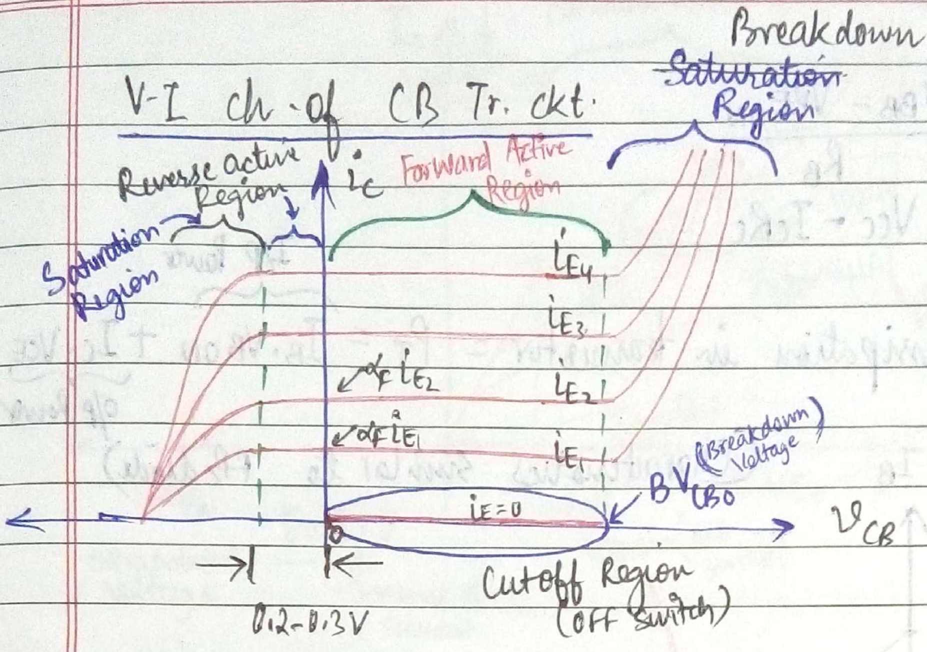
Transistor Ckts

- $\rightarrow$ Common Base config ✓
- $\rightarrow$ ——— E ——— ✓
- $\rightarrow$ ——— C ———

CB config.



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

Appl^n of CB conf:-

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

$$i_E = I_{E_0}\, e^{V_{BE}/V_T}$$

I_{E_0}: 10^{-12} to 10^{-15}; V_T: 26mV

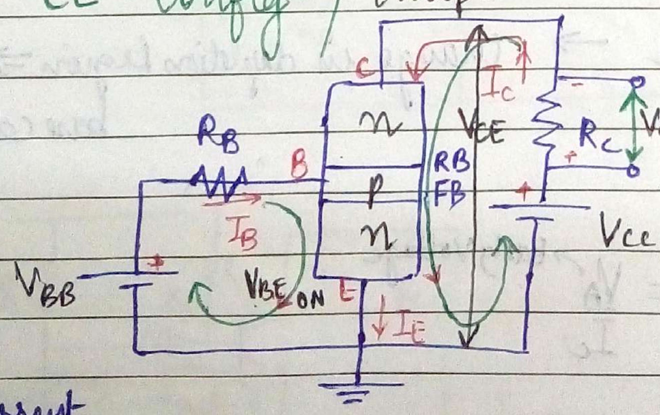
$$i_C = I_S\, e^{V_{BE}/V_T}$$

$$i_C = \alpha\, i_E \qquad I_S = \alpha I_{E0}$$

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

26/08/16

CE Config. / amp.



(α = CB current gain)

* β = CE current gain
(50-200)

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

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

Lab → $\beta = 100$

emitter current.

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

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

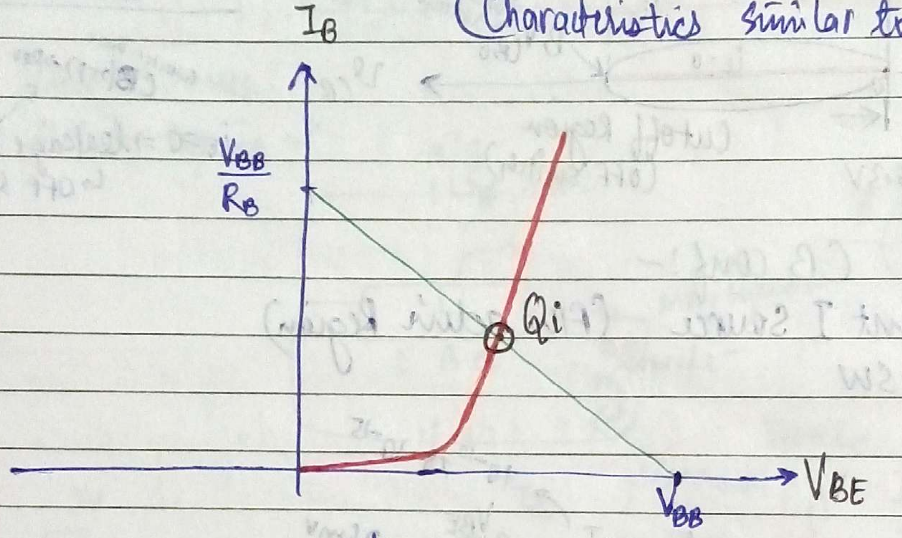
ANUBHAV JAIN NOTES

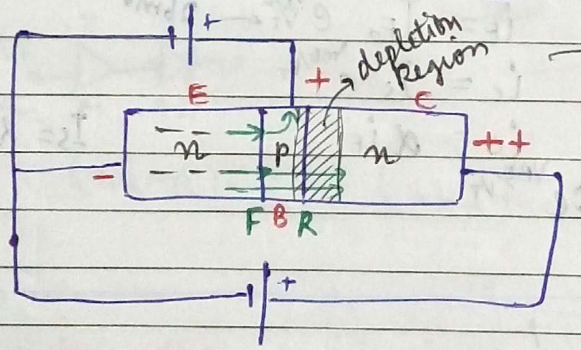
$$I_B = \frac{V_{BB} - V_{BE_{ON}}}{R_B}$$

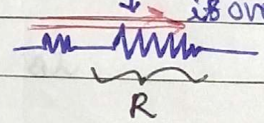
$$V_{CE} = V_{CC} - I_C R_C$$

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

(Characteristics similar to FB diode)







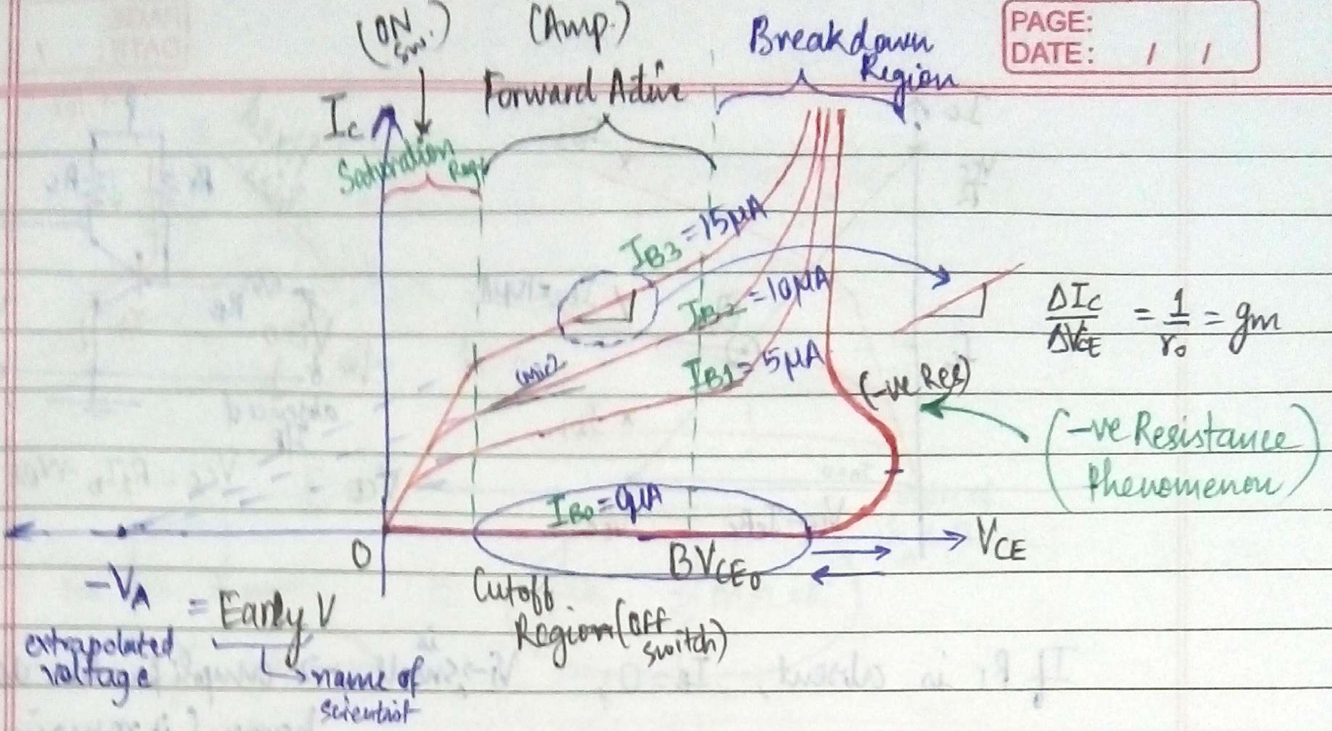
Providing big Resistance but is overcomed due to large Vcc.

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

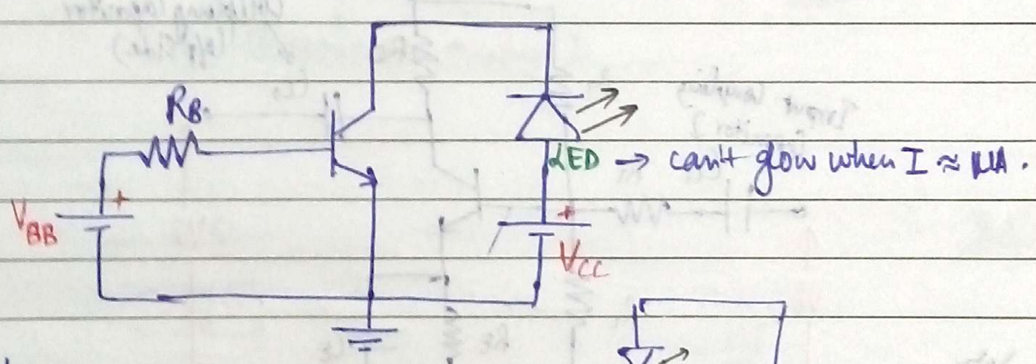
$$r_0 = \frac{V_A \xrightarrow{} \text{Early Voltage}}{I_C}$$

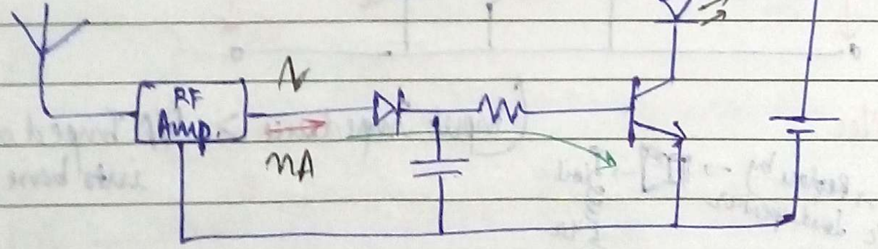
$$BV_{CE_0} = \frac{BV_{CB_0}}{\sqrt[n]{\beta}}$$

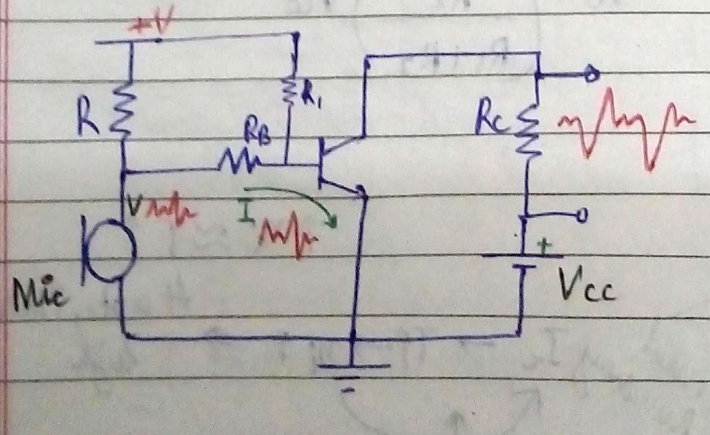
n → 3–6 (Given by manufacturer)

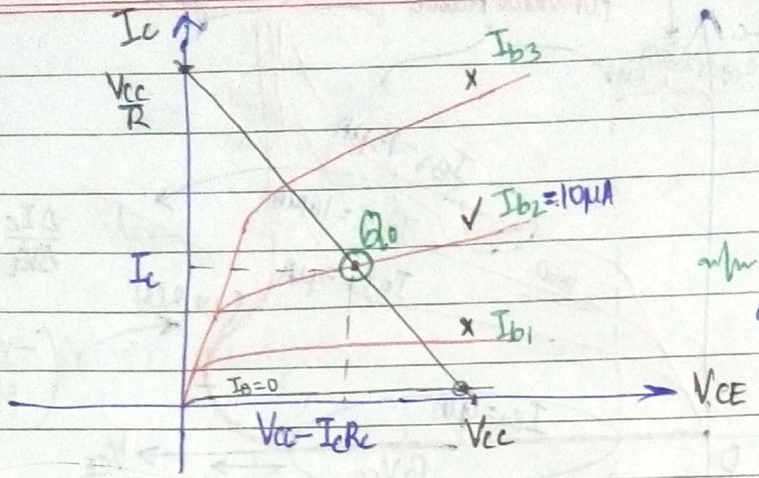


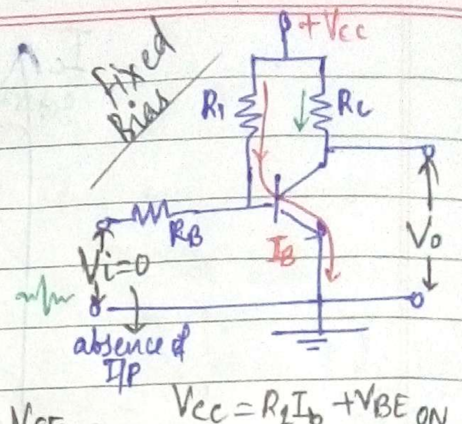
$I_C = \beta I_B$ } No longer valid after certain conditions.
V_{CE} = const.
↳ after $V_{CE} = BV_{CEo}$ → Not valid







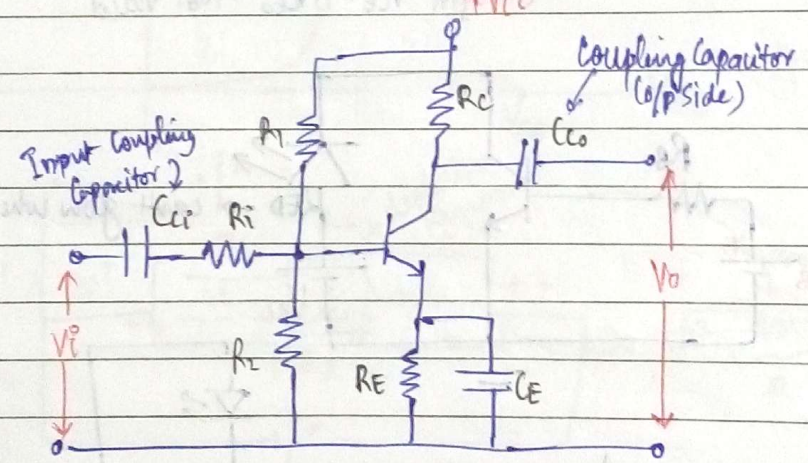




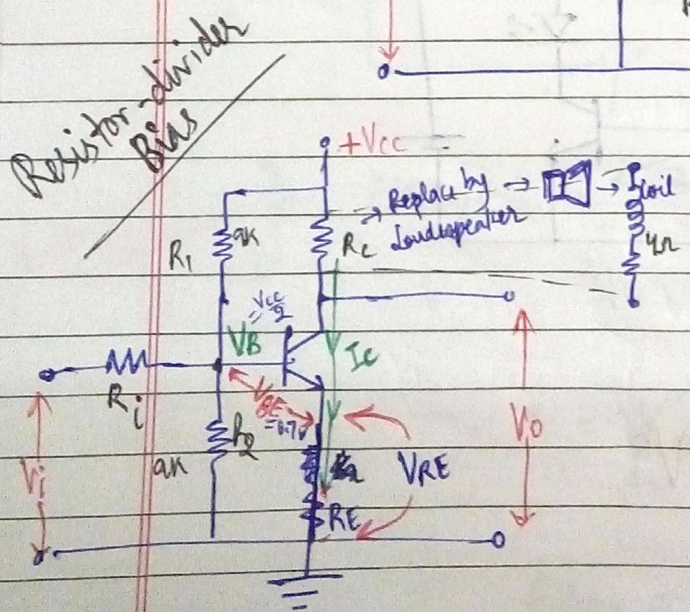
$V_{CC} = R_1 I_b + V_{BE\,ON}$

If R_1 is absent, $I_B = 0$, $V_i \to$ 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) $\Rightarrow$ Current into base is small.



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

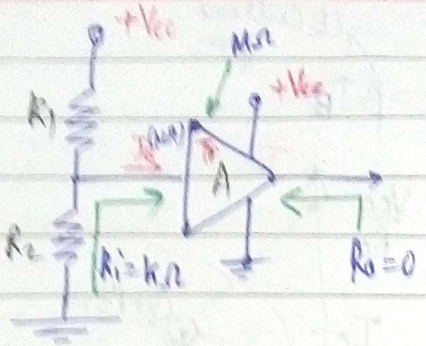
$\uparrow n_i \approx T \uparrow$

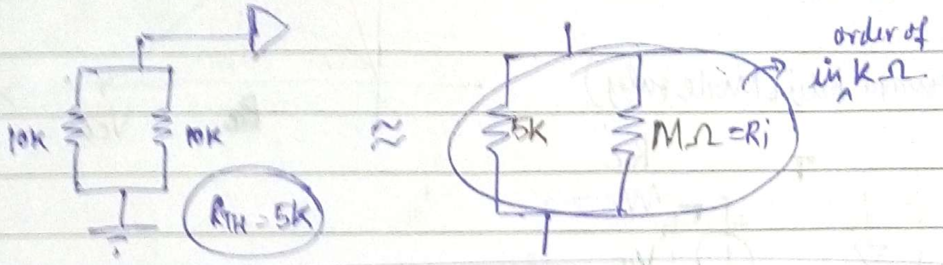
(RE is used to prevent Thermal Runaway)

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

Scanned by CamScanner

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





Role of R_E (in preventing Thermal Runaway) :-

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

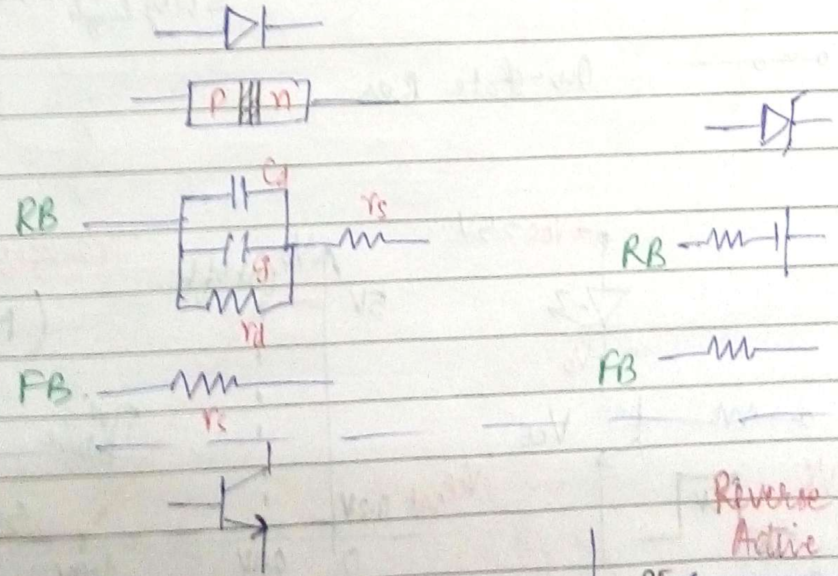
(V_B = fixed) $\quad$ ($I_C = \beta I_B$) β const.

−ve feedback

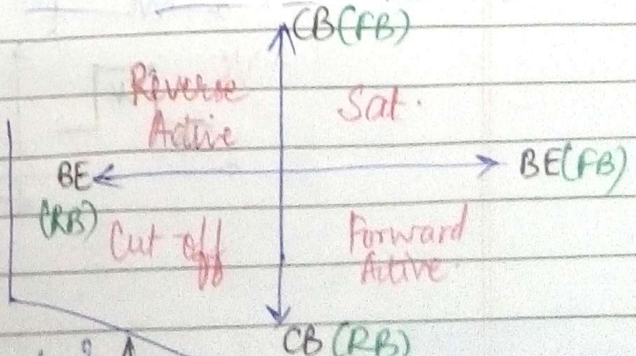
stabilises I_C.

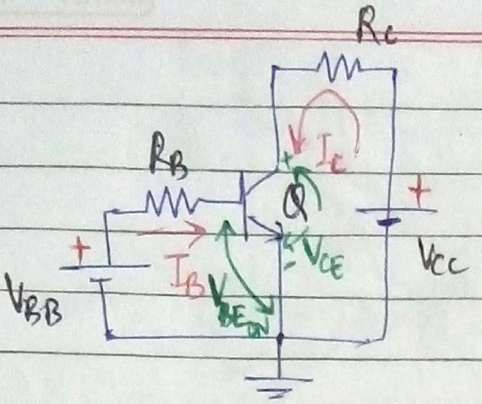
compensates ↑sing I_C

31/08/16



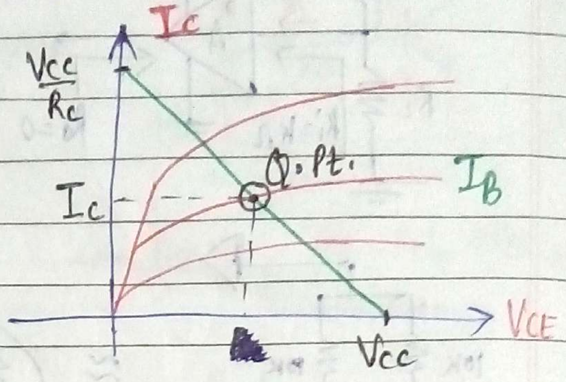
* Cut off
* Saturation } Switches
* Forward Active } Amp.
* Reverse / Inverse active Mode } Amp.



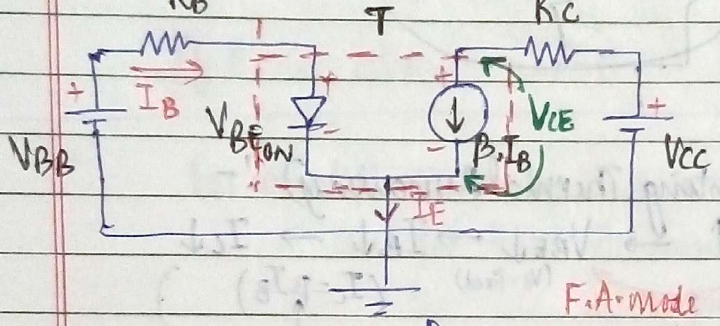


CE current gain

$I_C = \beta I_B$



(Eq. Ckt for Forward Active Mode only)

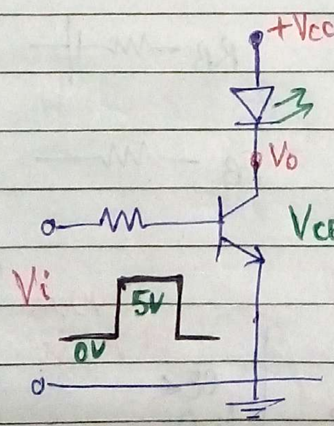


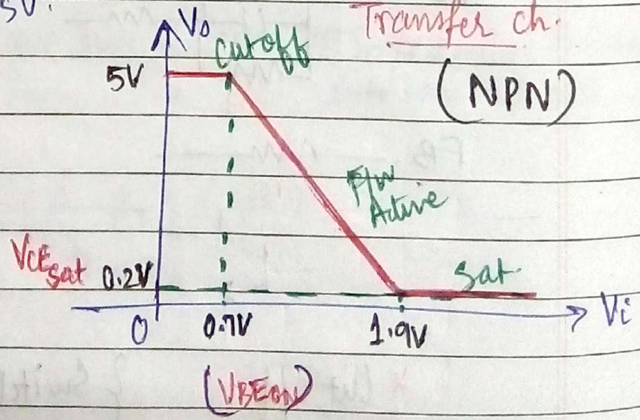
DC Equivalent ckt

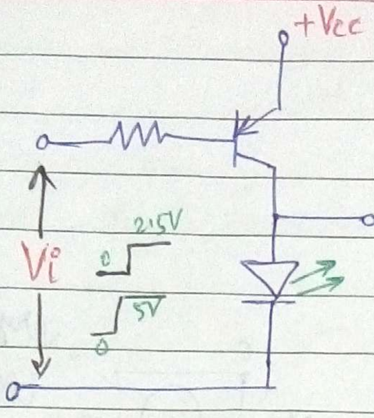
Hybrid π-model

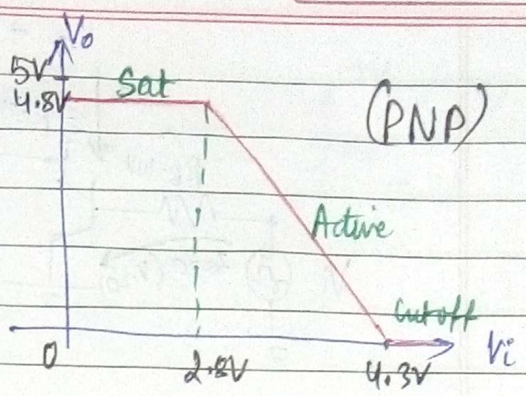
Open Switch — Off-state Resistor (Air, Moisture res.) → very high

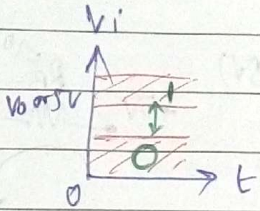
Closed Switch — On-state Res.







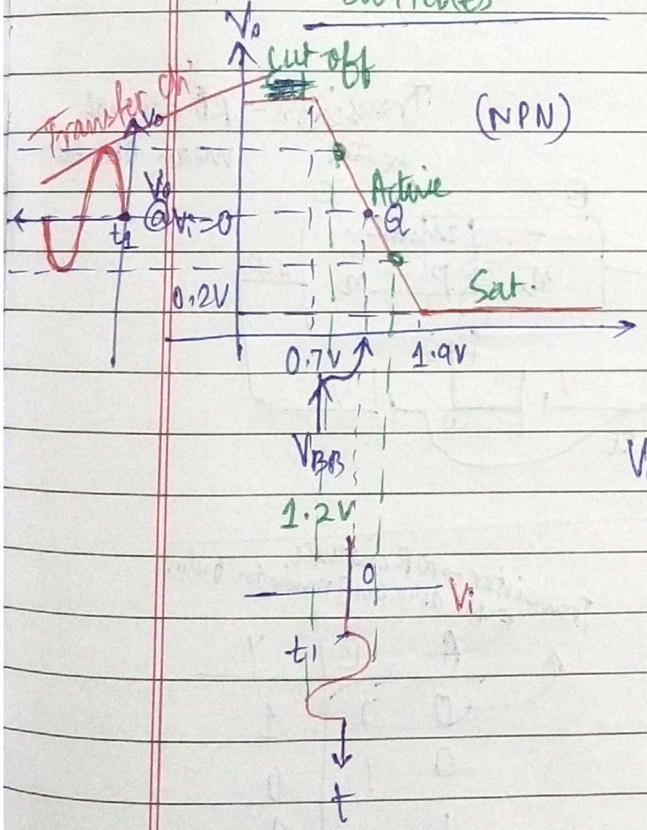


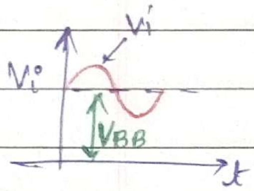


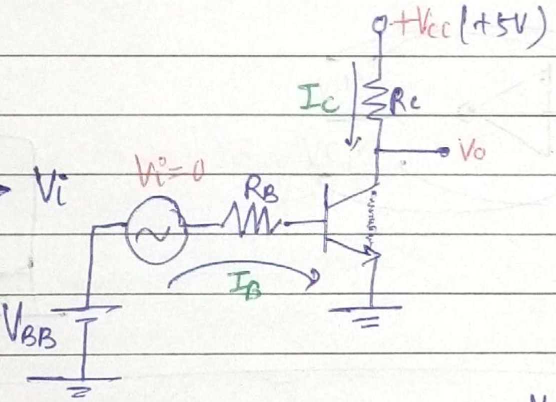
01/09/16.

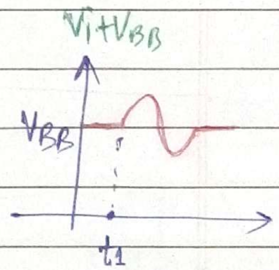
Transistor Circuits

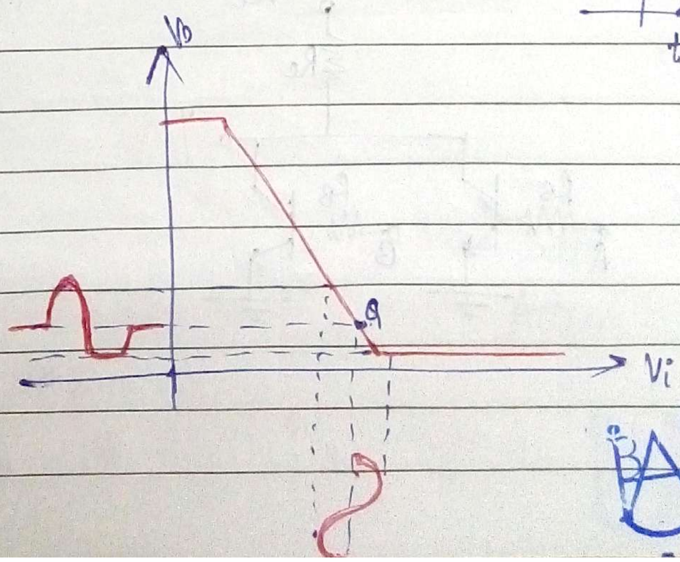
Switches — Amplifier

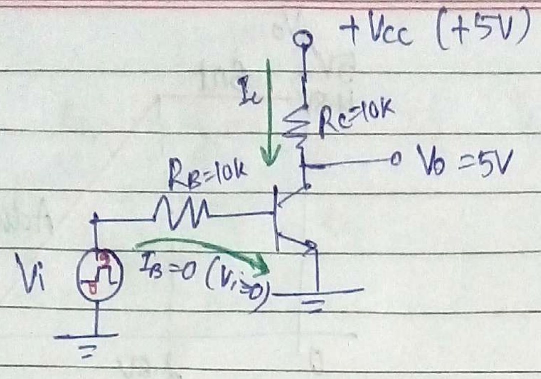


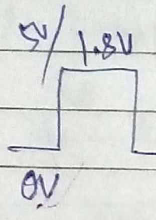


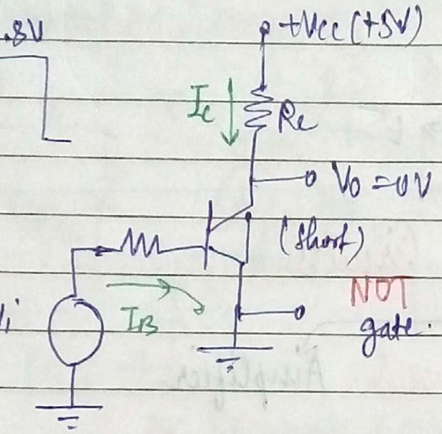


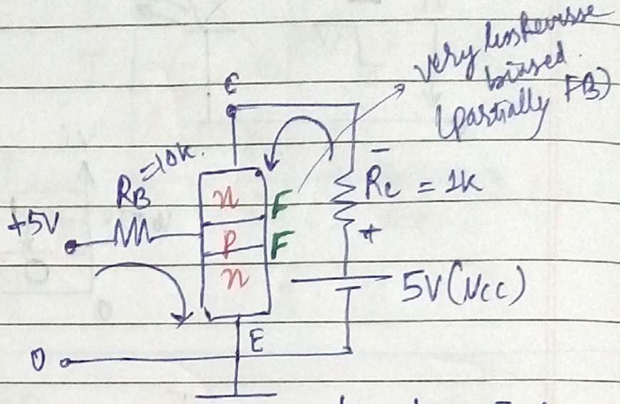






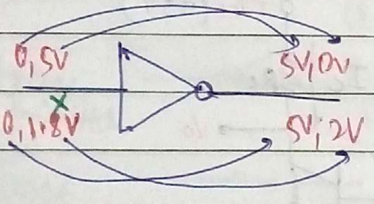




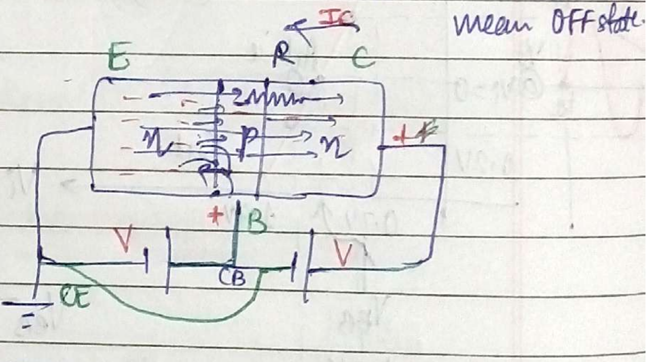


$V_{CE} = V_{CC} - I_C R_C$

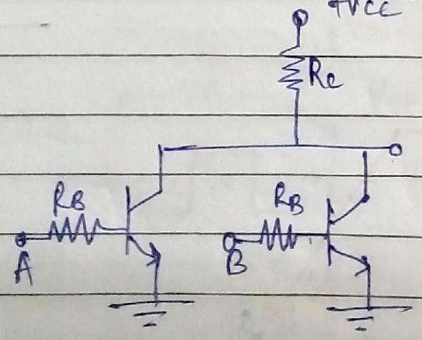
$V_{CE} < 5V.$



Transistor → RB does not mean OFF state.



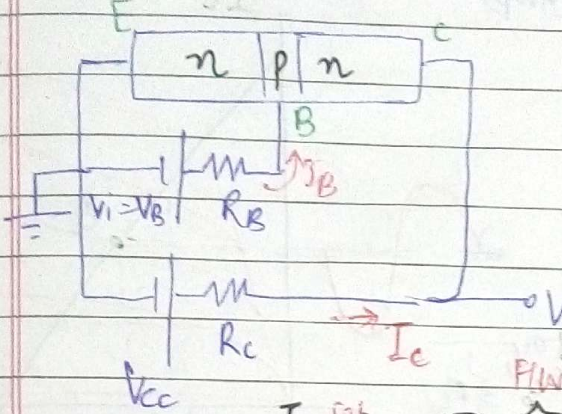
NOR

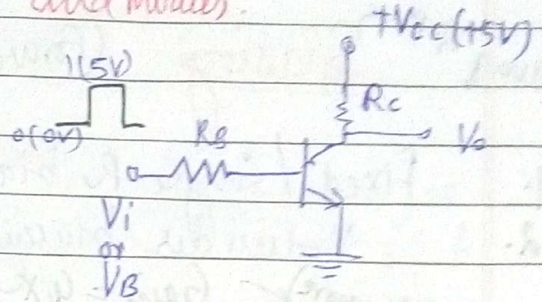


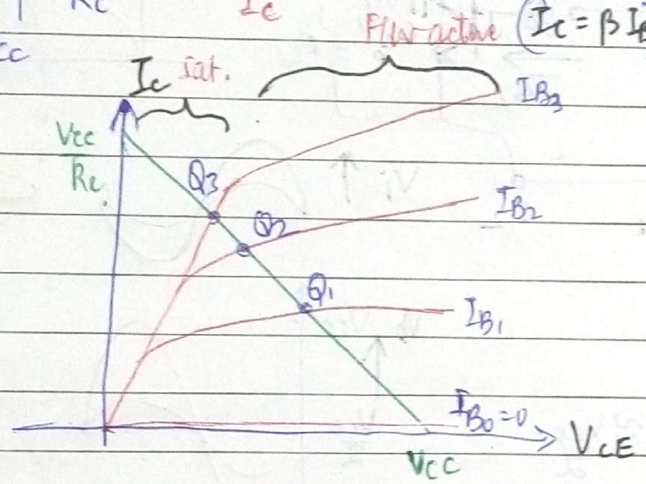
Transistor → ∞ Resistance
⇒ All drop on Transistor fully.

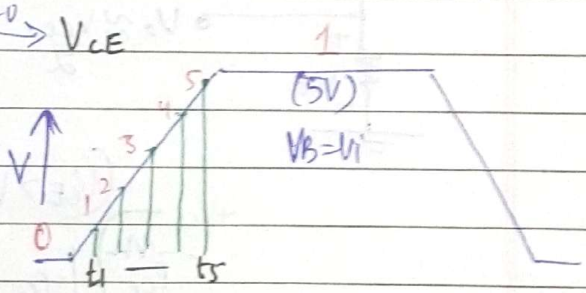
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

Transistor Circuits and Models





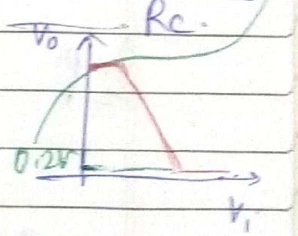




$$I_B = \frac{V_B - V_{BE}}{R_B}$$

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

0.2



Considerations:-

1. DC to RF / high freq.
2. Leakage (I_{E0}, I_{B0}, I_{C0})
3. V-range
4. Ri & Ro (ri) (ro)
5. β_{dc} and β_{ac}
6. Temp. Range

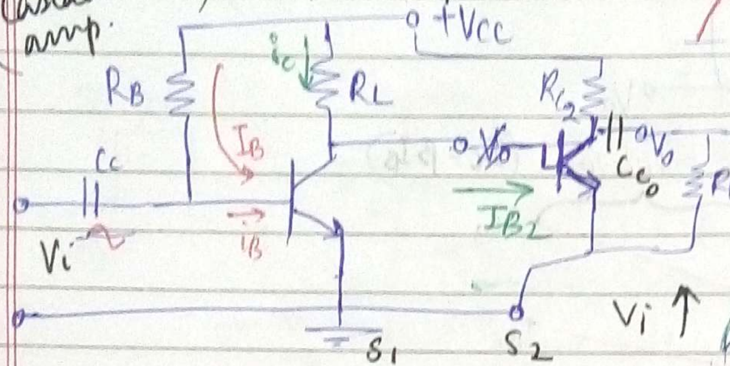
Sat: $V_{CE} < V_{BE}$

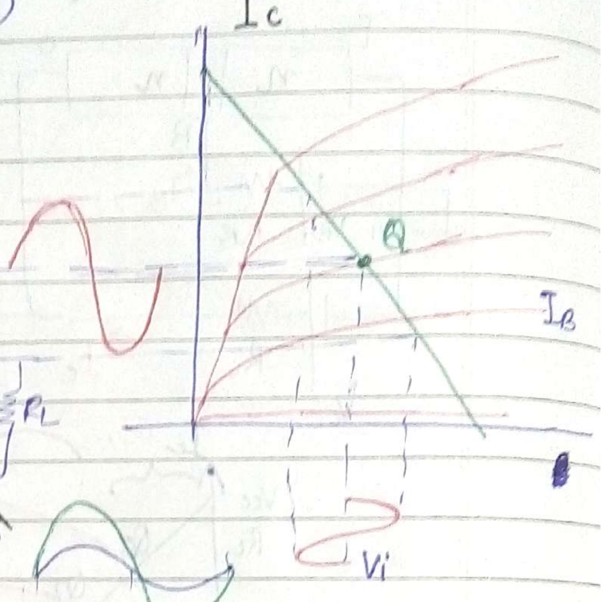
Active: $V_{CE} > V_{BE}$.

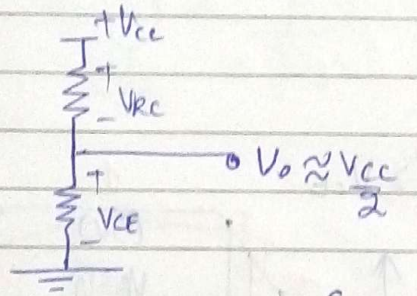
setting Q-Pt ← **Biasing** (Forward Active Mode) (Amp)

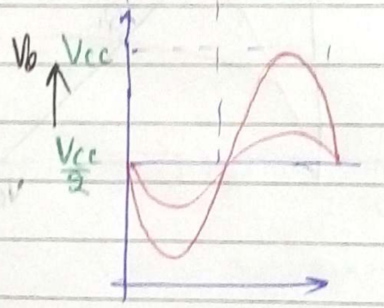
1. Fixed / Single R biasing
2. V-divider biasing

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

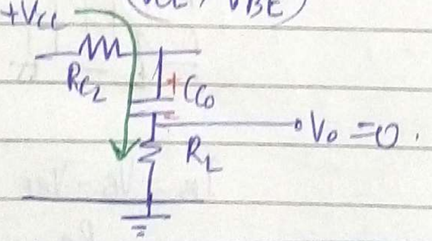




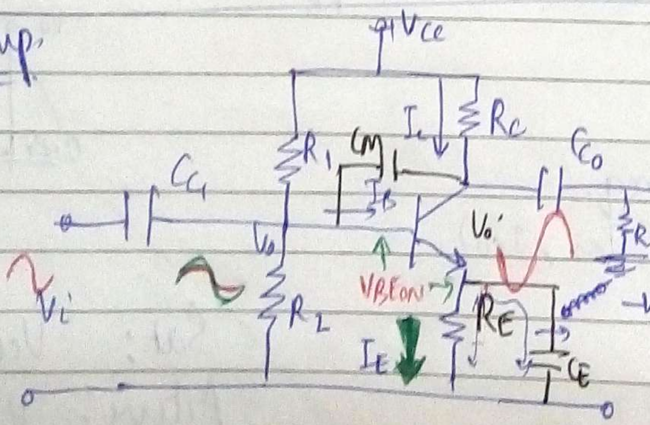




(VCE > VBE)



Amp.

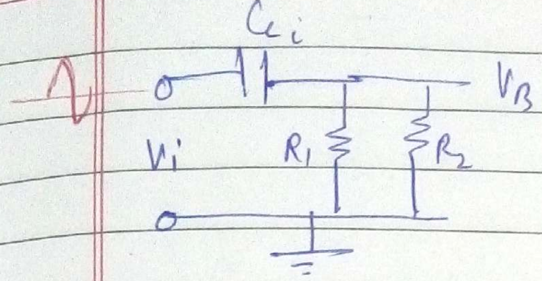


$I_E = I_C + I_B$

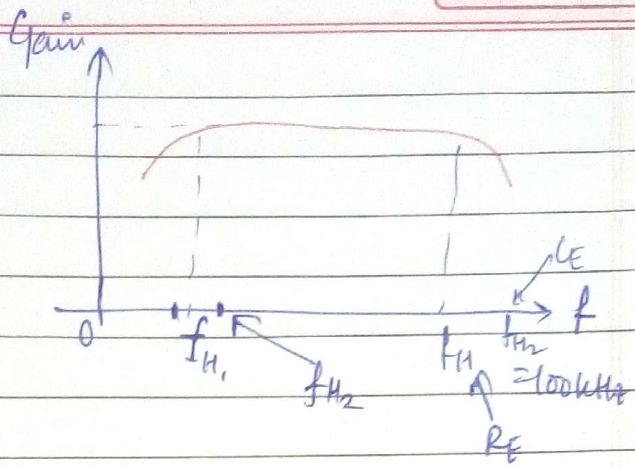
-ve feedback (f/b) against thermal runaway.

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

$\Rightarrow T\downarrow$



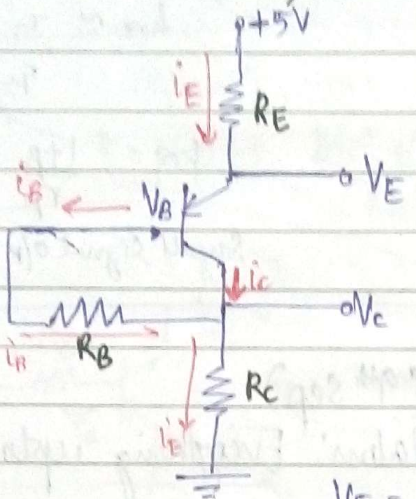
$$f_{H_1} = \frac{1}{2\pi (R_1 || R_2) C_{ci}}$$



VIVA:- 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 $|V_{BE}|_{ON} = 0.7V$.



$V_C = i_E R_C$

$V_B - V_C = i_B R_B$

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

$V_E - V_B = 0.7V$

$\therefore V_E = V_B + 0.7$

$V_E = i_E R_C + i_B R_B + 0.7$

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

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

$* \; i_E = i_C + i_B$

and $i_C = \beta i_B$

$\Rightarrow i_E = \beta i_B + i_B$

$= (\beta+1) i_B$

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

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

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

$= 0.35 \, mA$.

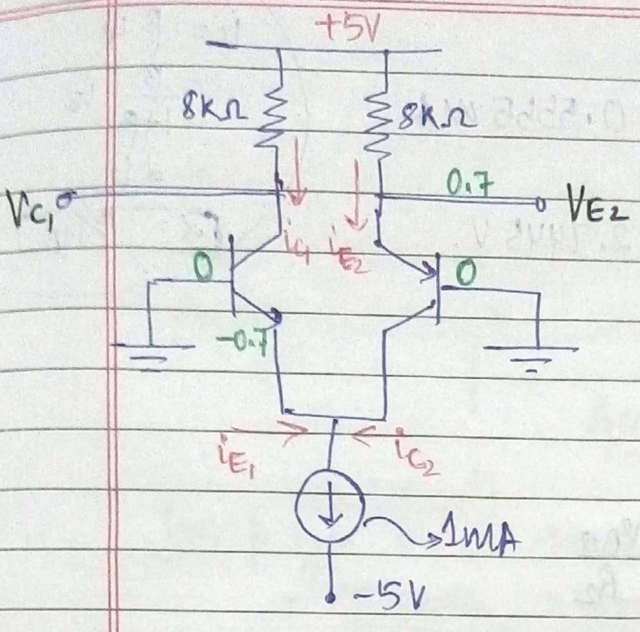
$i_B = \frac{i_E}{\beta+1} = \frac{0.35 \times 10^{-3} A}{76} = 4.614 \, \mu A$

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

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

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.



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

$i_E + i_C = 1mA$

$V_{E_2} = 0.7V$

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

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

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

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

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

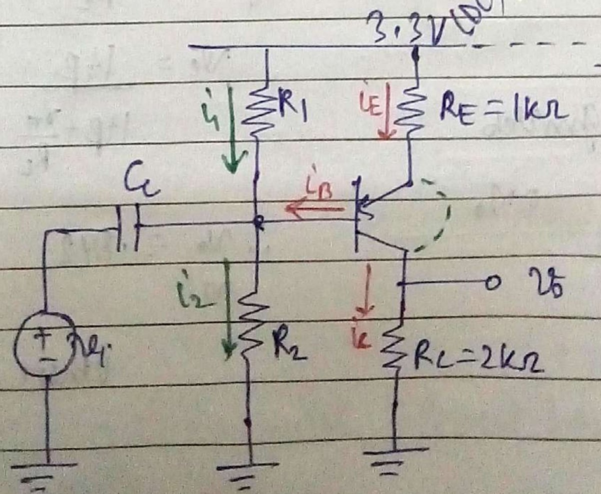
$\boxed{V_{C_1} = 1.297V}$

★ $|V_{BE}| = 0.7$ (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

$$i_c = \beta i_B = \frac{\beta}{1+\beta} i_E = \alpha i_E$$
$$\boxed{\alpha = \beta/(1+\beta)}$$

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

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

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

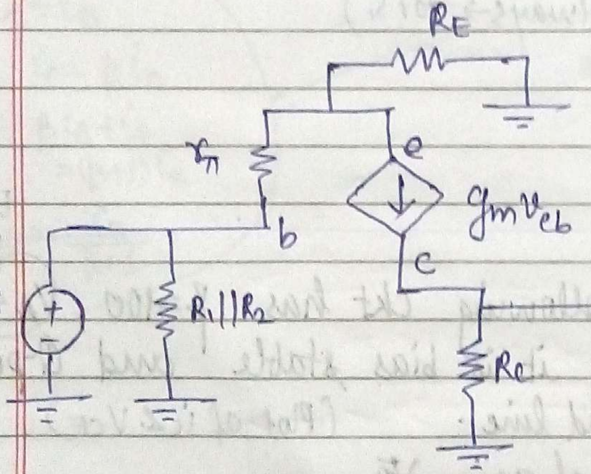
DC currents

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

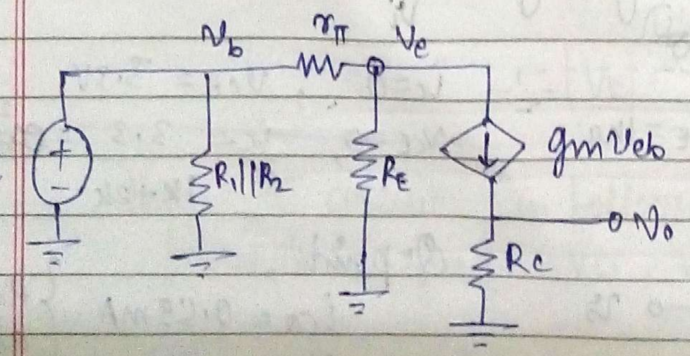
$$\frac{3.3 - v_{BQ}}{R_1} + 5.5\,\mu A = \frac{v_{BQ}}{R_2}$$

$$\Rightarrow R_2 = 50\,k\Omega \text{ (Assumed)}, \quad R_1 = 35.5\,k\Omega.$$

$\Rightarrow$ 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 $\beta = g_m r_\pi$

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

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

$V_T \rightarrow 26\,mV.$