EEE — Date: 3/4/2016

1(D)-Day

Referenced Books:

1. Electronic device and Circuit – Boylestad
2. Principle of Electronics – V.K. Mehta
3. Op-Amp and Linear integrated circuit – Gayakward

1(E)-Day Date: 4/4/2016

Analog Electronics

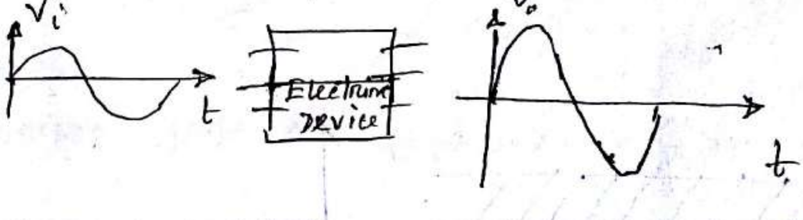
Electronics:

Conduction through vacume, gas, semiconductor (without conductor) is discussed in Electronics.

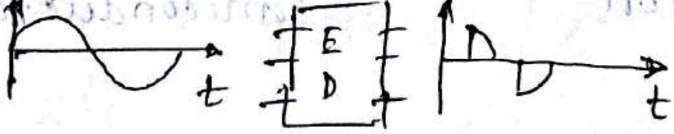
Importance:

1. Rectification (AC to DC)

2. Amplification



3. DC → AC converter
4. Voltage to light converter
5. control



6. Light to voltage converter (Solar cell)

Atomic Structure:

$2n^2$ electron at nth energy shell of an atom

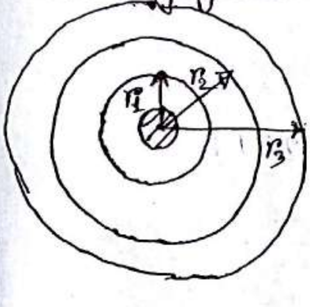
Valence electron:

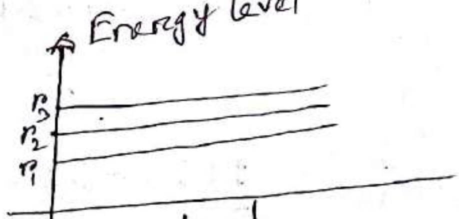
Generally, $<4 \rightarrow$ metal / conductor

$>4 \rightarrow$ non-metal / insulator

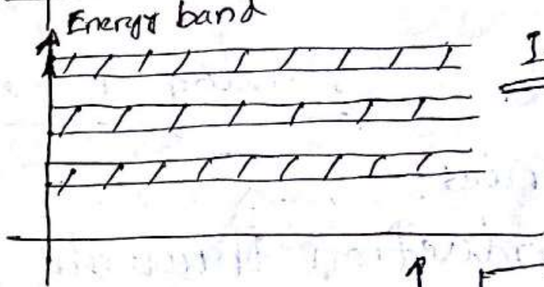
$=4 \rightarrow$ Semi-conductor $C_{(6)}$, $Si_{(14)}$, $Ge_{(32)}$.

Energy level:





One atom



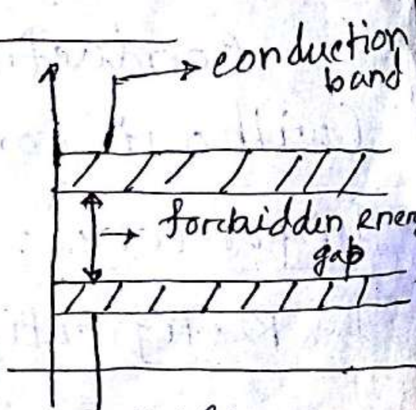
In a metal

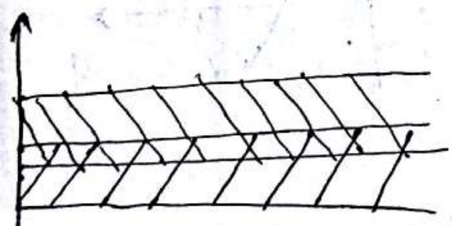
Valence band:

Energy band of valence electron

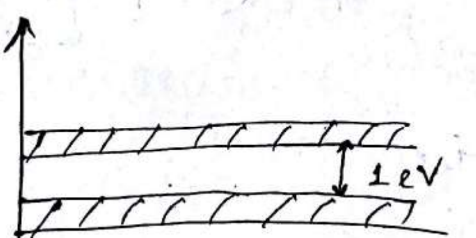
Conduction band:

Energy band of free electron

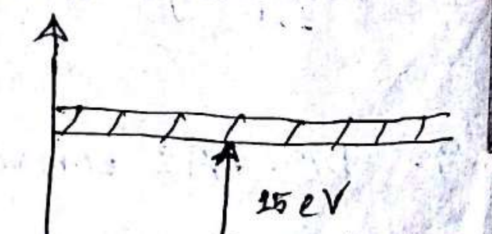




Conductor



Semiconductor



Insulator

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2(B)-Day

Date: 6/4/2016

Semiconductor

Ge, Si

→ valence band → almost full
conduction " → partially full

The energy of forbidden gap ~~of~~ between valence and conduction band

for Ge → 0.7 eV
Si → 1.0 eV

Gallium Arsenide → flow of e^- higher

		Mobility
Si	→	1500
Ge	→	3900
GaAs	→	8500

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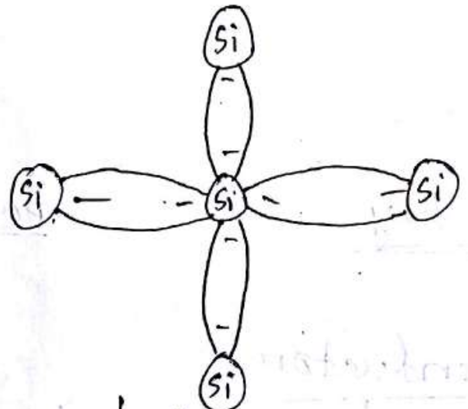
Conductor → temperature co-efficient (+ve)

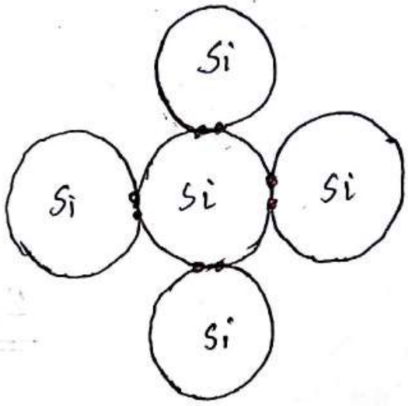
→ temperature ↑ , resistance ↑ then (+ve)

" ↑ , " ↓ then (−ve)

Semiconductor → temperature co-efficient (−ve)

Bonds in Semiconductor:





Difference between Ge and Si.

Intrinsic Semiconductor: (pure semiconductor)

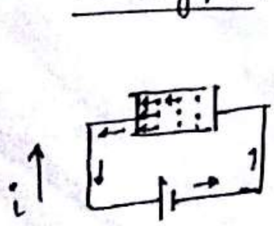
Only Si or only Ge. | Cond band এ যতগুলো e^-
valence " এ ততগুলো hole

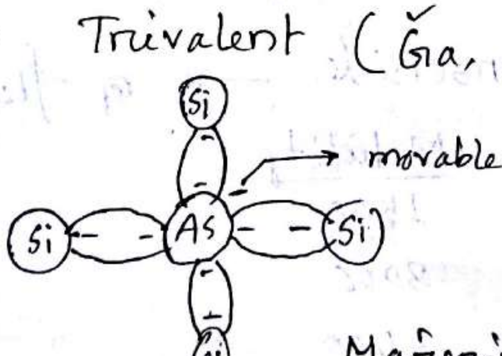
Extrinsic semiconductor: (Dopping) → n-type

→ Pentavalent (As, Sb, P) | Sb = antimony

→ Trivalent (Ga, Al) → P-type

n-type:





Majority carriers → electron
Minority " → hole

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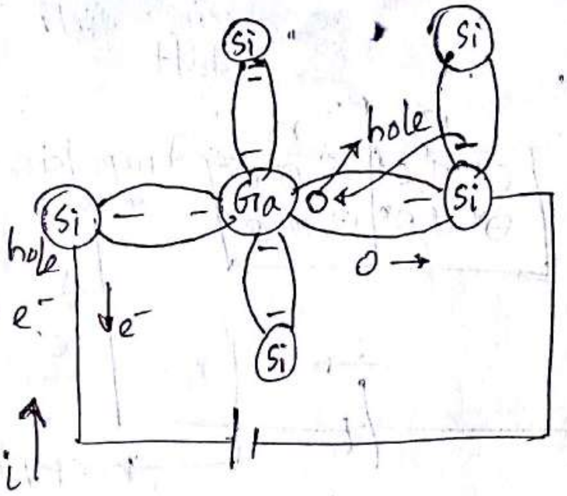
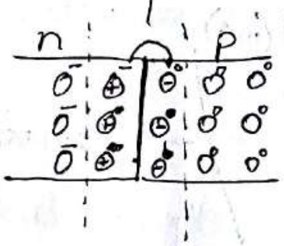
p-type

majority carrier → hole
minority " → e^-

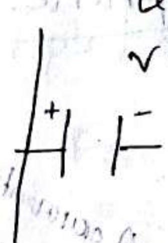


Hole current ?

Deplesion
~~Depression~~ region (No carrier)



Like capacitor
$V = \frac{Q}{C}$

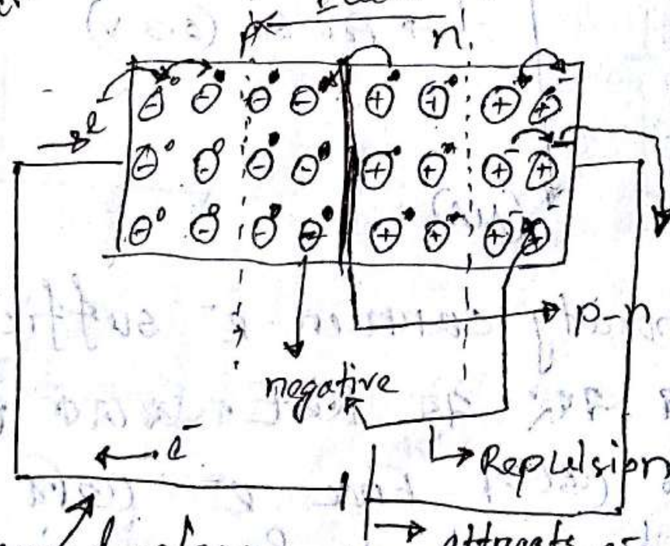


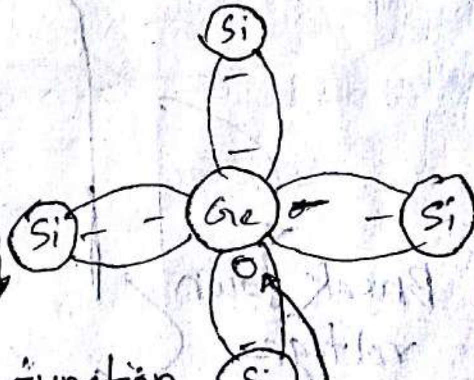
2 (D) - Day

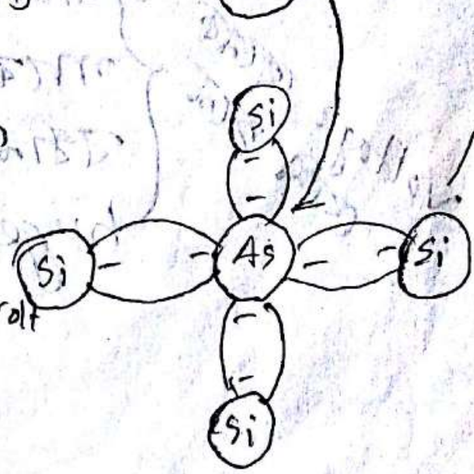
Date - 10/4/2016

Deplesion region will increase

no current flow

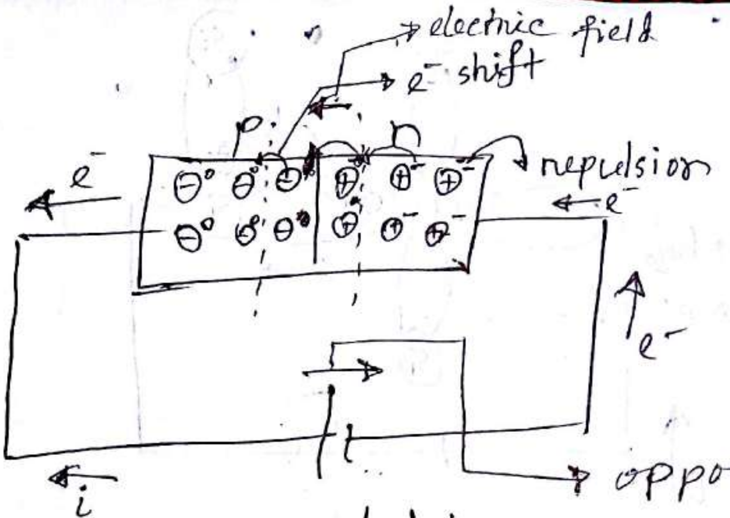


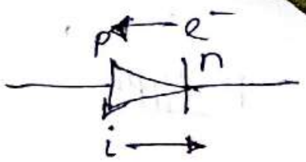




For semiconductor,
voltage drop → 0.7 volt

Reverse bias

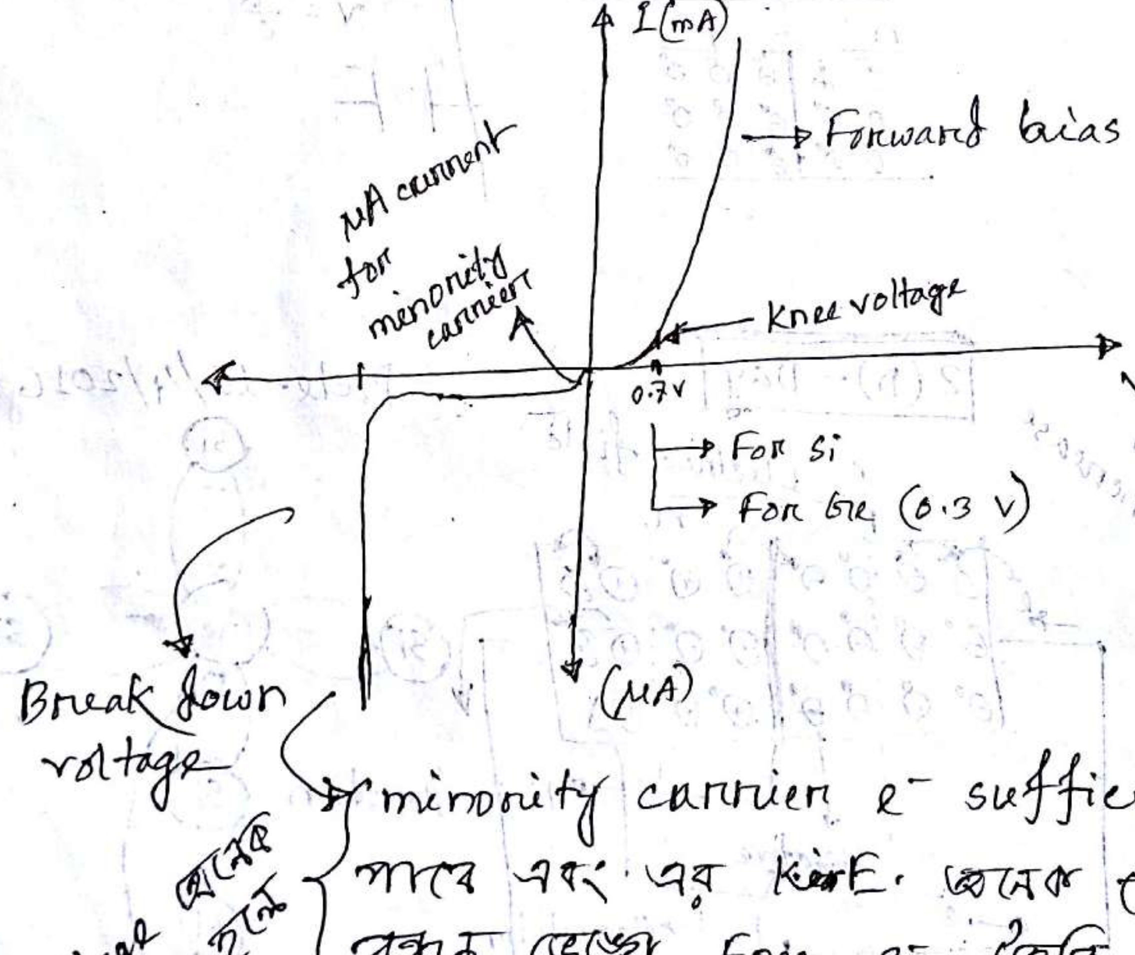




depletion region decreases

Forward bias

Volt-amphere characteristics:

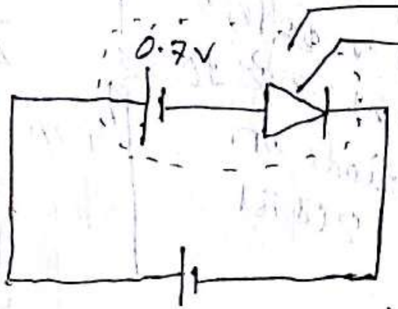


Voltage অনেক বেশি হলে
- minority carrier e⁻ sufficient energy পাবে এবং এর K.E. অনেক বেশি হবে এবং বন্ধন ভেঙে Free e⁻ তৈরি হবে এবং huge current flow করবে।

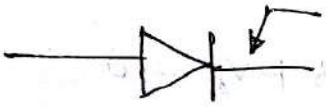
2(E) - Day

Date: 11/4/2016

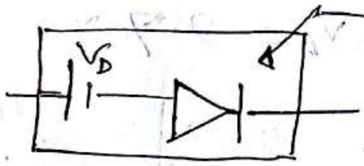
practical > 0.7 V → current flow
ideal > 0 V → current flow



↳ supply voltage < 0.7 V → Reverse bias
> 0.7 V → forward "



← ideal equivalent circuit

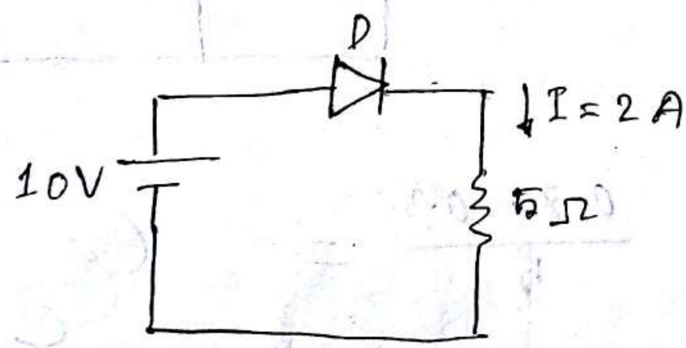


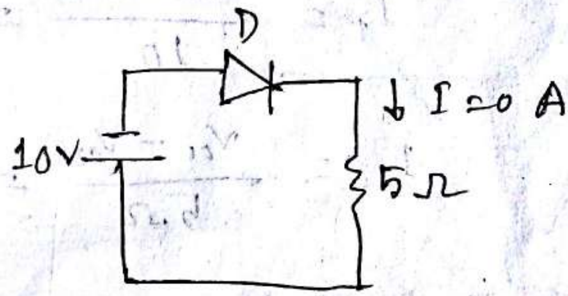
← simplified equivalent circuit.

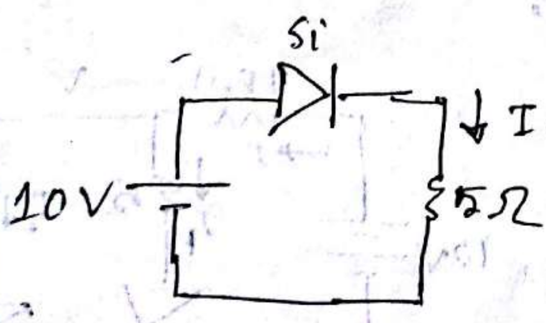
For Si, $V_D = 0.7$ V
" Ge, $V_D = 0.3$ V

D → ideal diode

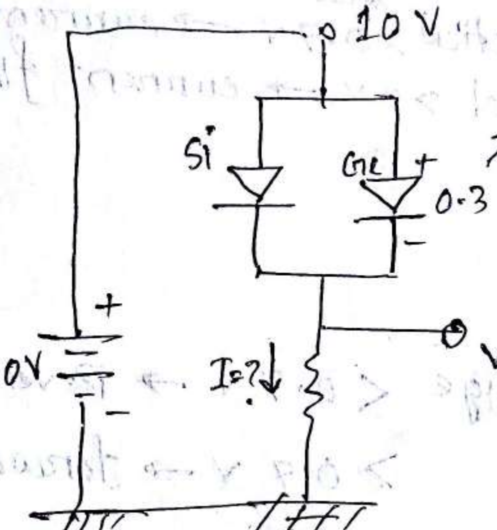
Si / Ge → Si / Ge diode [Voltage drop 2(?)]



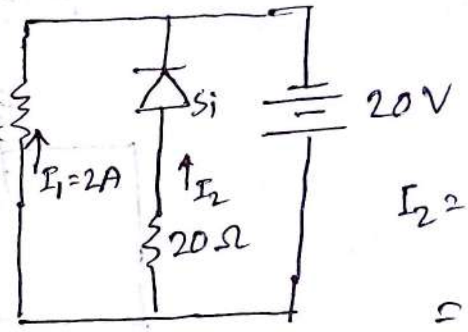




$I = \frac{10-0.7}{5}$ A



আগেই হয়ে যায় তাই 0.7 V প্রয়োজন হবে না। তাই si diode on হবে না



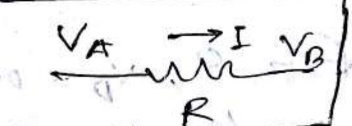
$I_2 = \frac{(20-0.7)}{20\,\Omega}$

$= \quad A$

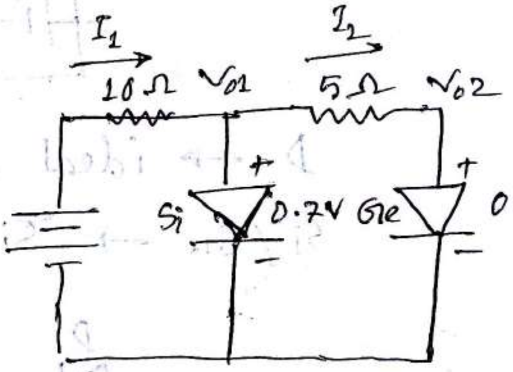
$V_0 = (10-0.3)\,V = 9.7\ V$

$-10+0.3+V_0 = 0$

$\Rightarrow V_0 = 9.7\ V$



$I = \frac{V_A - V_B}{R}$

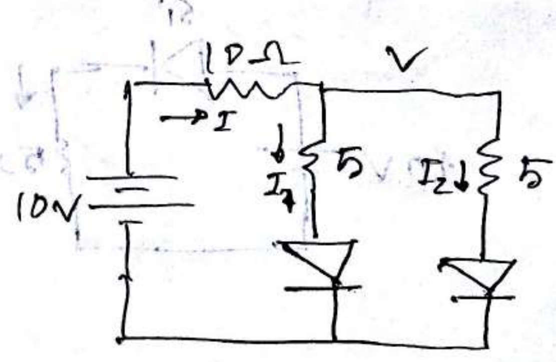


$I_1 = \frac{E - V_{01}}{10\,\Omega}$

$I_1 = \frac{10-0.7}{10} =$

$I_2 = \frac{V_{01}-V_{02}}{5\,\Omega} = \frac{0.7-0.3}{5} =$

~~Half wave rectifier circuit~~:

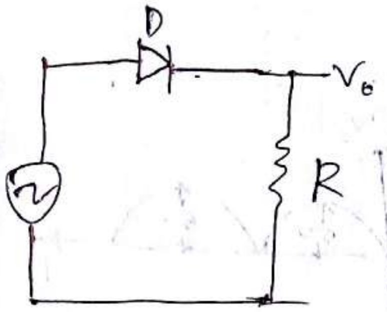


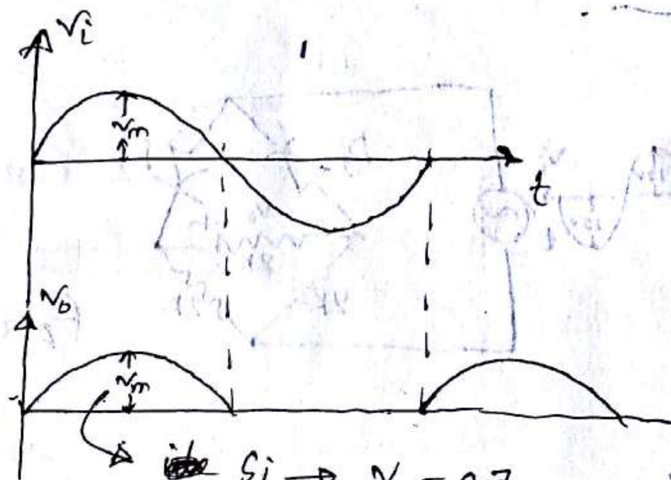
$I = I_1 + I_2$

$\Rightarrow \frac{10-V}{10} = \frac{V-0.3}{5} + \frac{V-0.7}{5}$

$V = ?$

Half wave rectifier circuit:





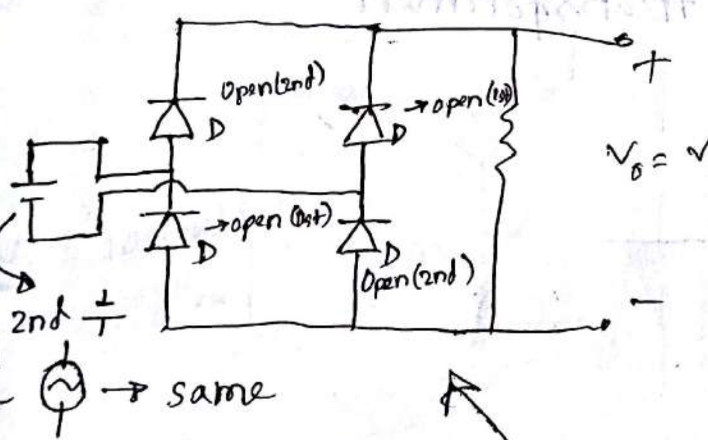
Si → $V_m - 0.7$

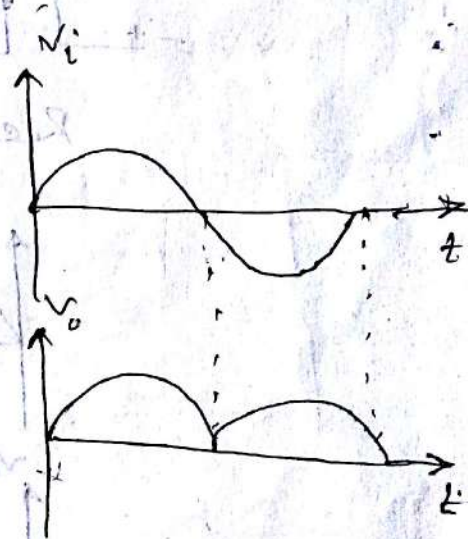
Ge → $V_m - 0.3$

$$V_o(av) = \frac{1}{T}\int_0^T V_m \sin\omega t \, dt$$

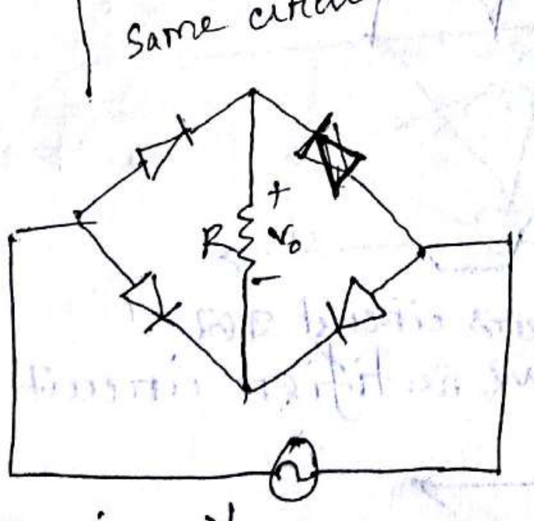
$$= \frac{1}{T}\int_0^{T/2} V_m \sin\omega t \, dt$$

Full wave rectifier circuit:





Same circuit

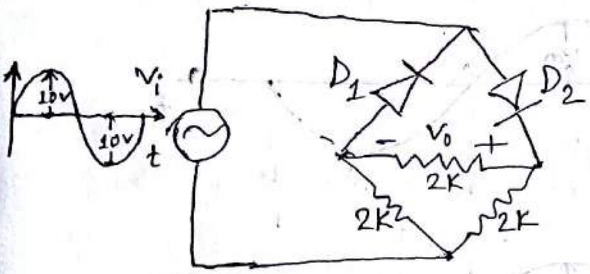


→ From book

Bridge-rectifier circuit

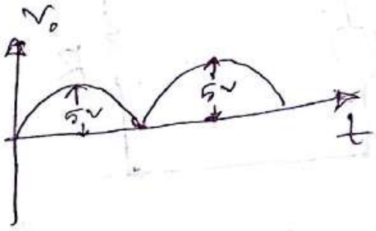
3(B)-Day

Date: 13/4/2016

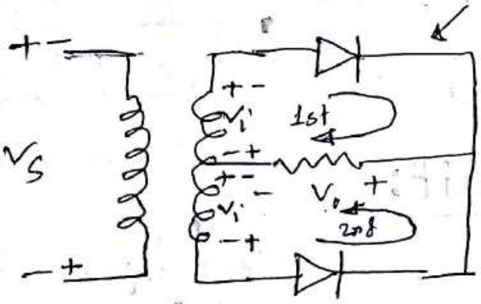


For +ve cycle, $V_o = 5$ V

For -ve cycle $V_o = 5$ V



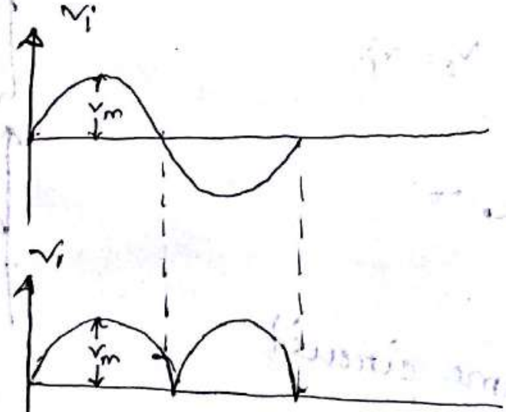
$v_i = v_o$ হয়



$V \propto \frac{d\phi}{dt}$ → rate of change of flux

voltage

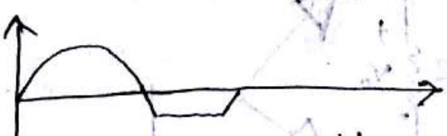
Rectifier using transformer



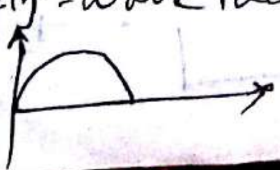
→ ছিন্ন করে/ কেটে দেয়

Clippers:

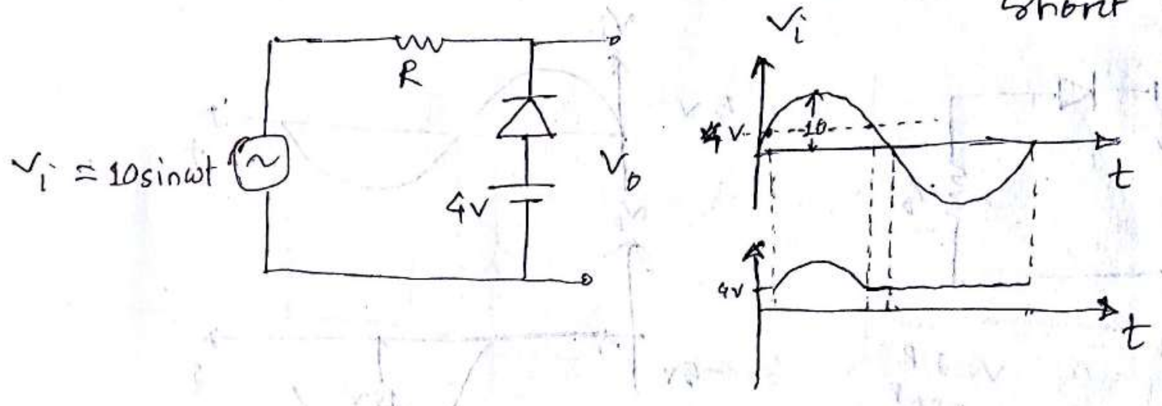
যে circuit input কে distort না করে কিছু অংশ কেটে দেয়, তাকে clippers circuit বলে।

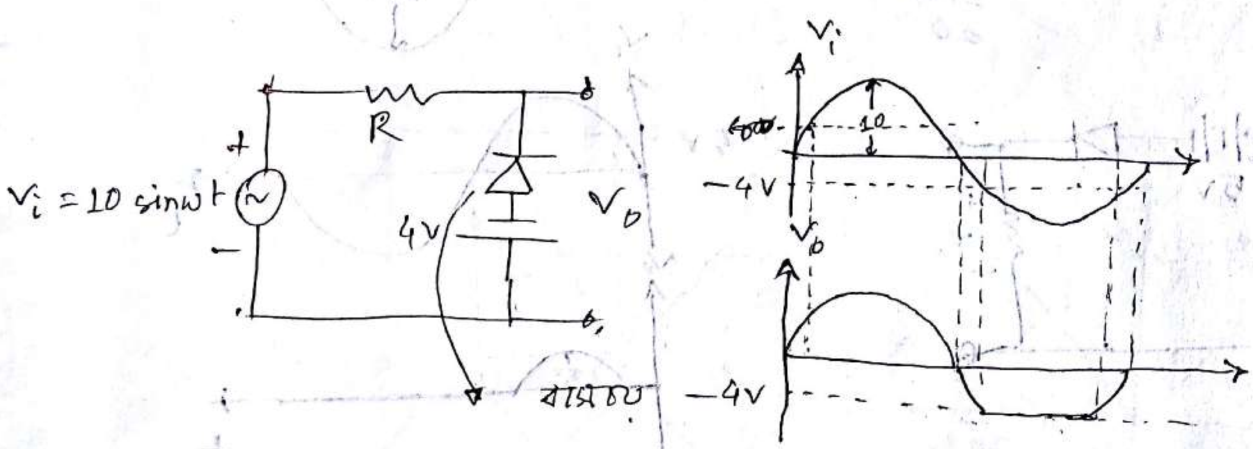


Example: Half-wave rectifier circuit

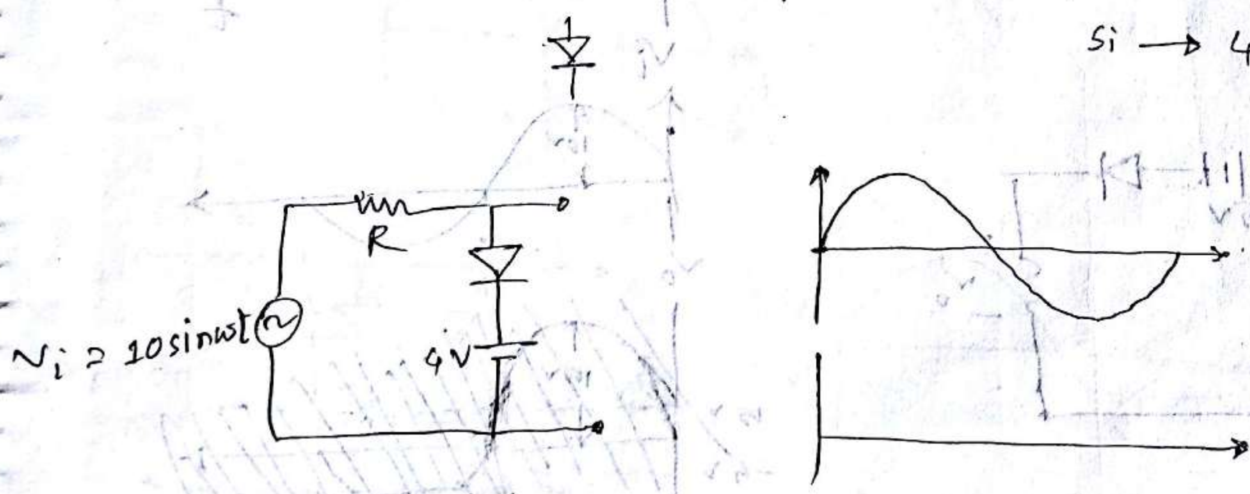


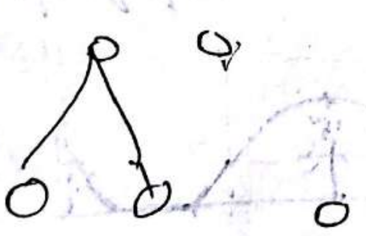
Open হলে Output = input
short ০ 4V

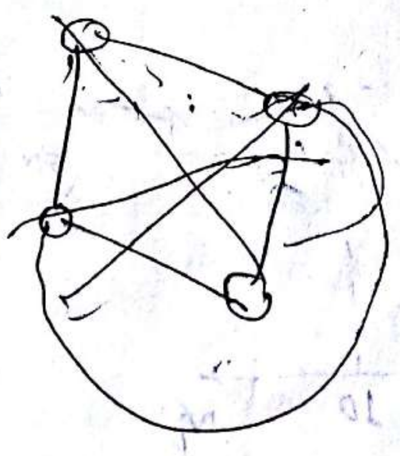




Si → 4.7 V

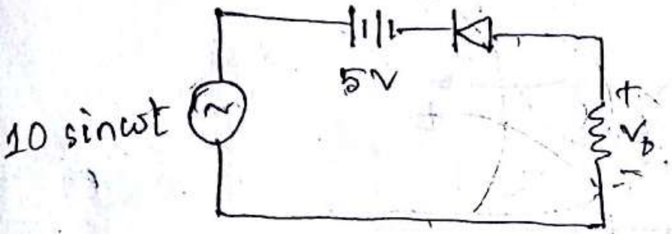


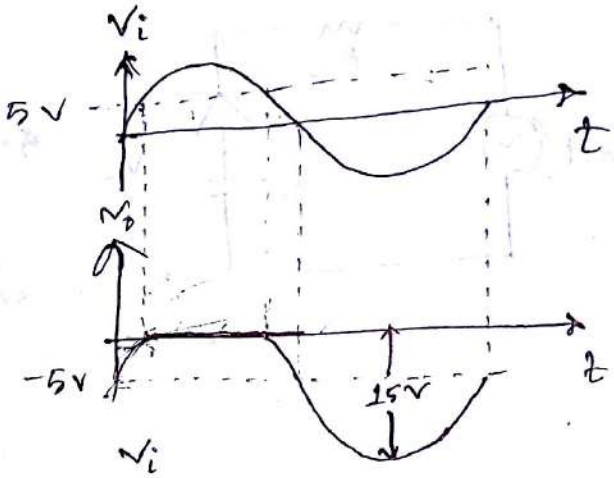




3(D)-Day

Date 17/4/2016





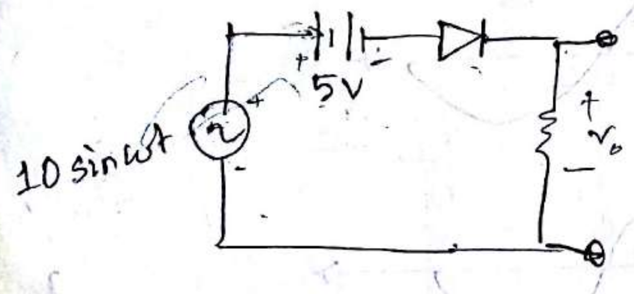
$5 - 0 + V_o = 0$

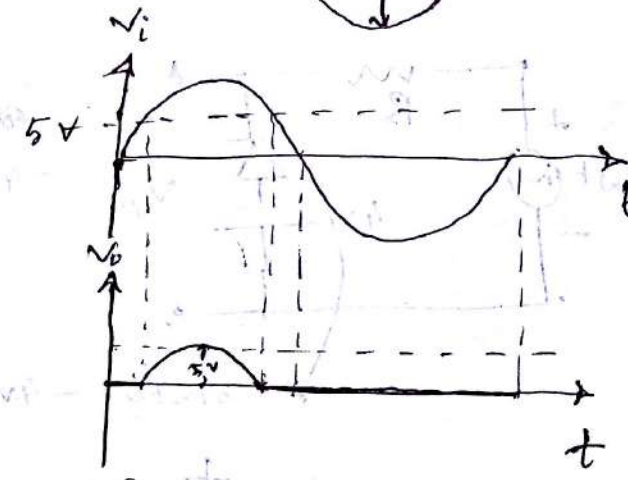
$V_o = -5$

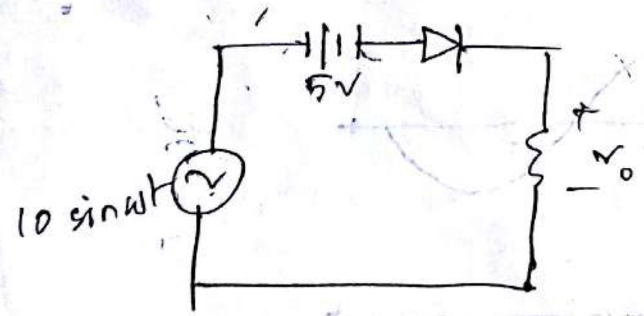
$V = IR$

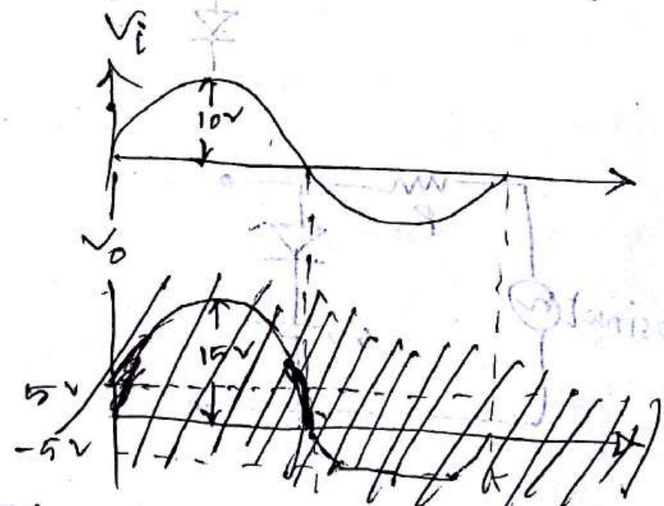
$= 20 \times R$

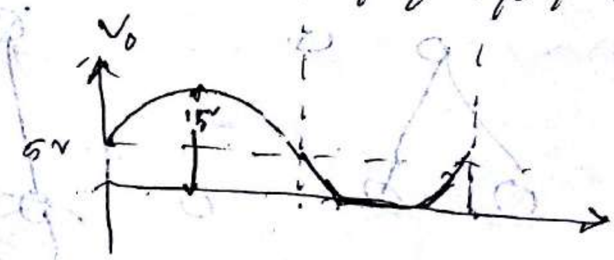
20

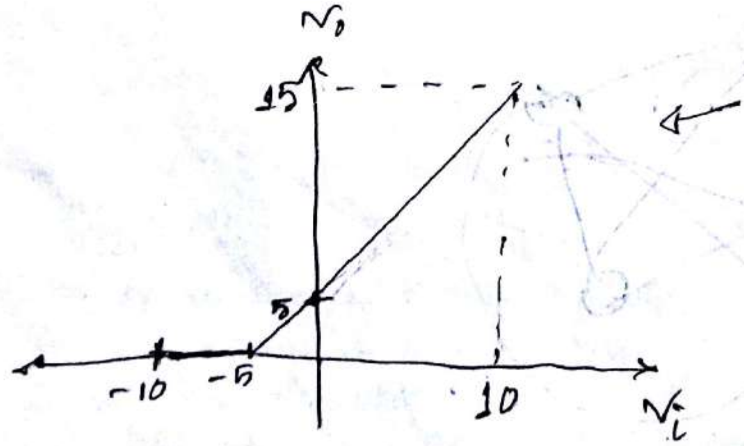




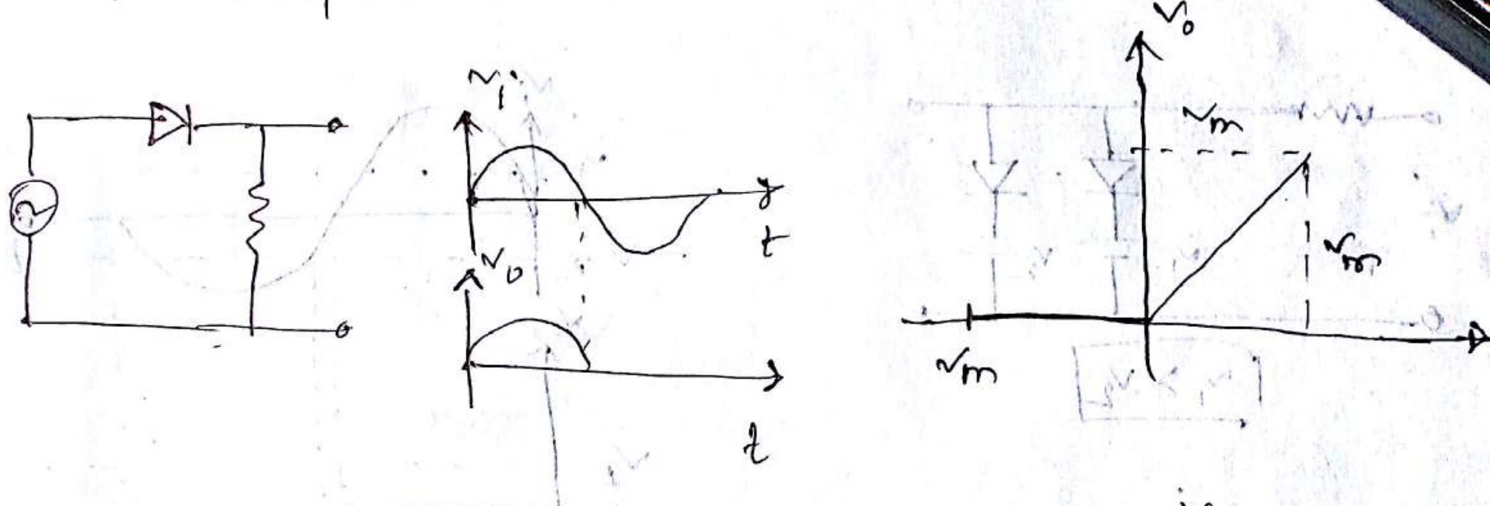


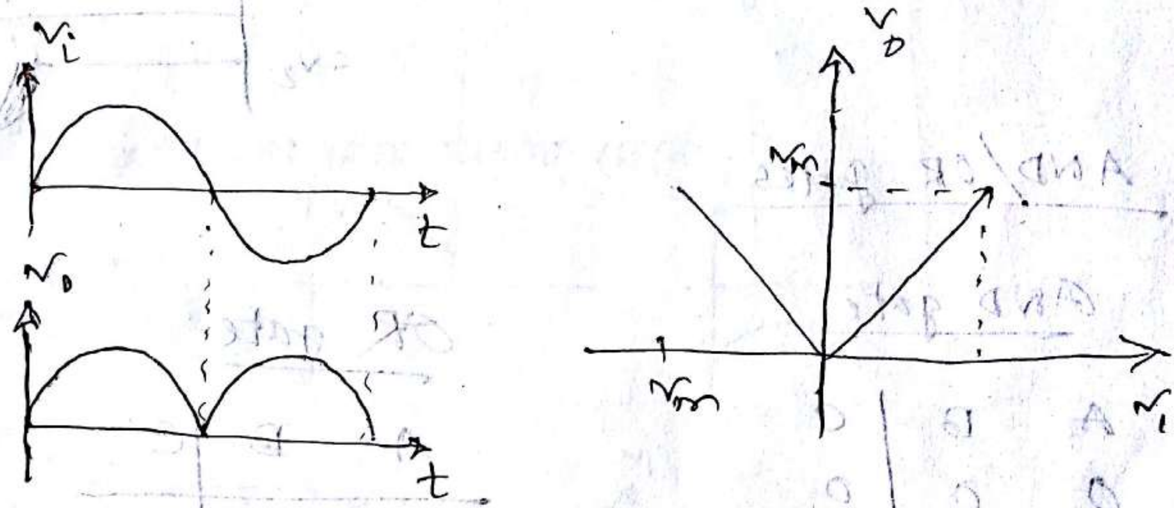


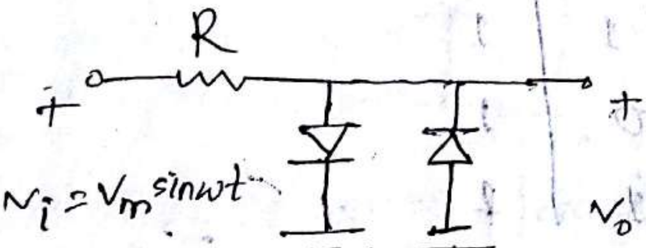


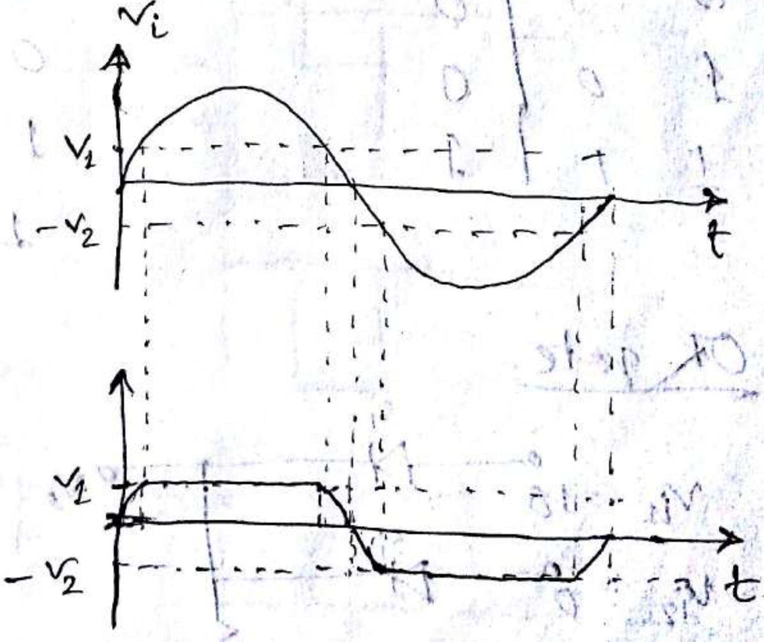


Input-output characteristic curve:







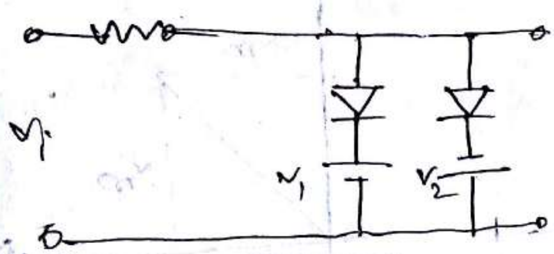


$|V_m| > |v_1|$

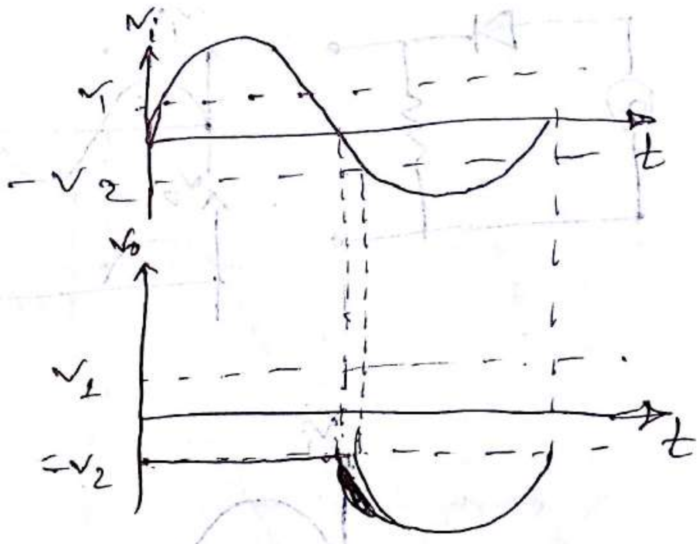
$|V_m| > |V_2|$

3(E) - Day

Date: 18/4/2016



$\boxed{V_1 > V_2}$



AND/OR gates

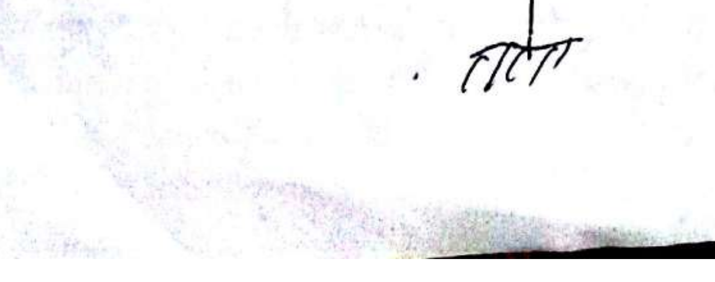
AND gate

A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

OR gate

A	B	C
0	0	0
0	1	1
1	0	1
1	1	1

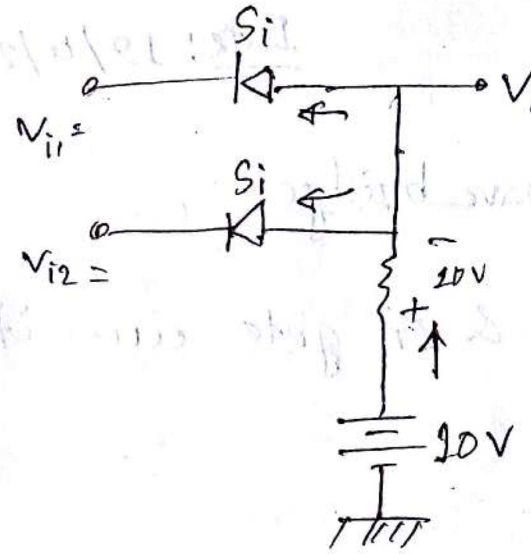
OR gate



$V_o = 9.3$ volt

V_{i1}	V_{i2}
0	10
10	10

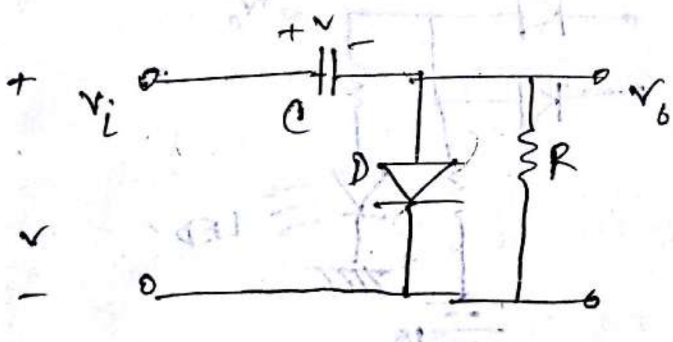
same

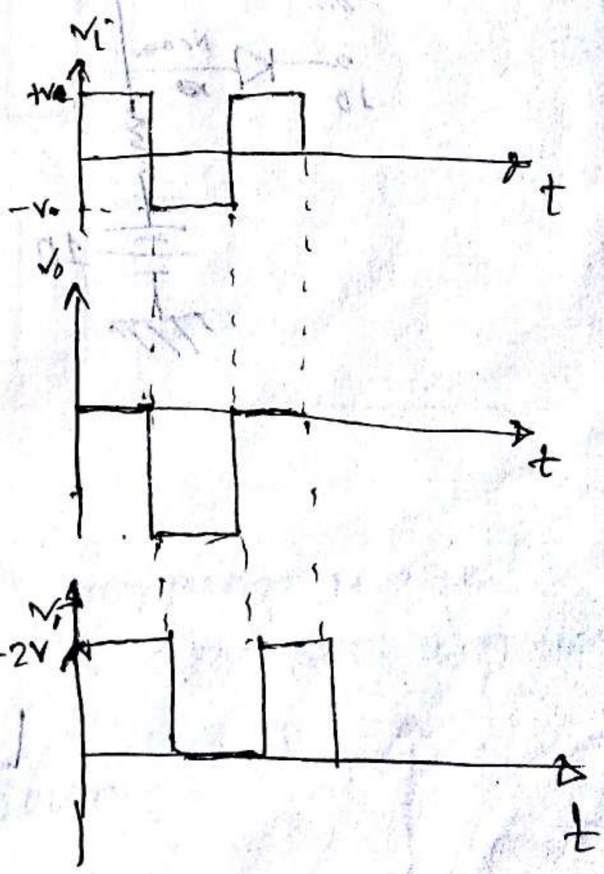


V_{i1}	V_{i2}	V_o
0	0	0
10	0	0
0	10	0
10	10	10

Clampers:

DC level উপরে বা নিচে সরিয়ে দেবে।





* Diode কে প্রথমে forward bias এ নিয়ে কাজ করতে হবে।

4(A)-Day

LAB

Date: 19/4/2016

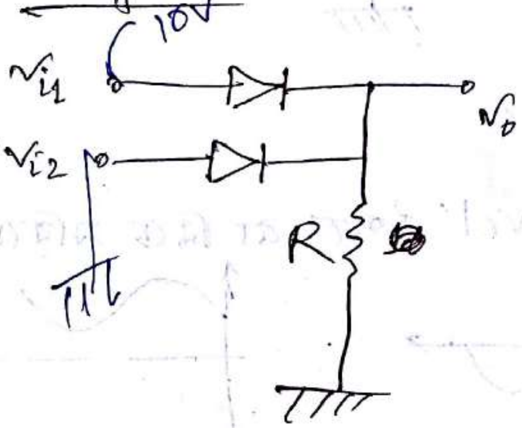
~~Experiment 2: Study of a full wave bridge~~

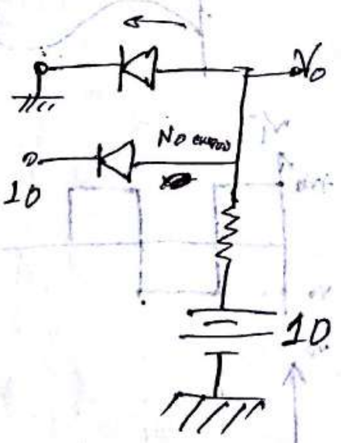
Exp: 2: Study of AND gate & OR gate circuit.

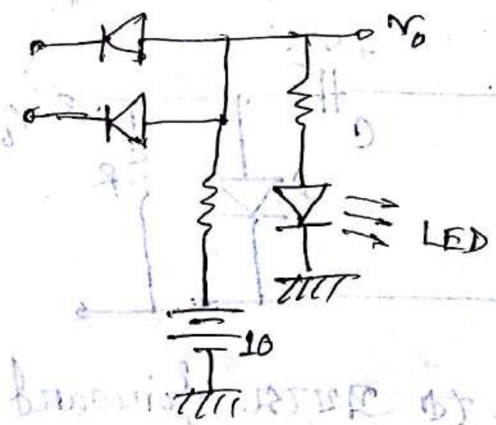
AND gate

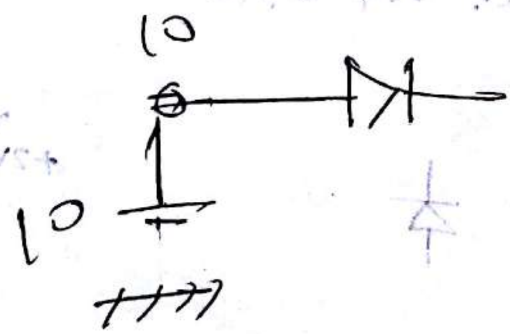
V_{i1}	V_{i2}	
0	0	0
0	1	0
1	0	0
1	1	1

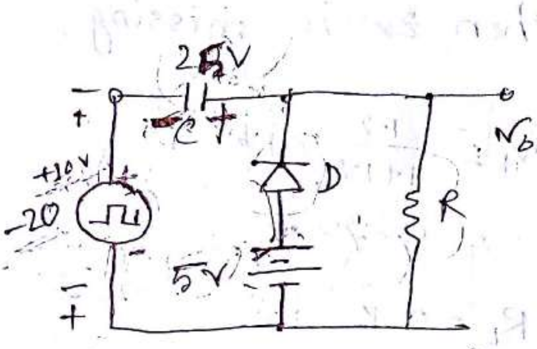
OR gate





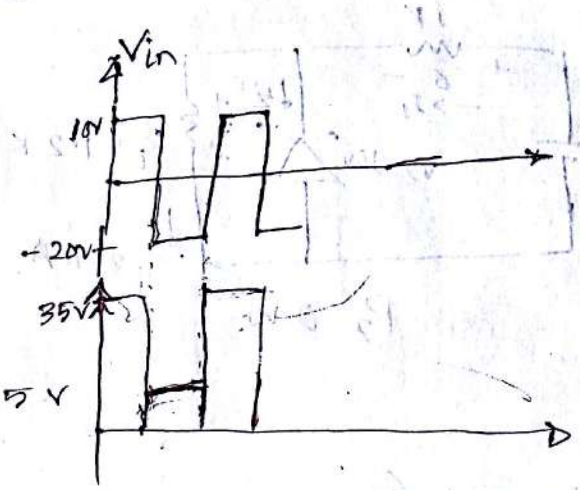


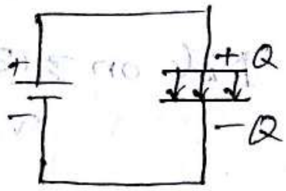




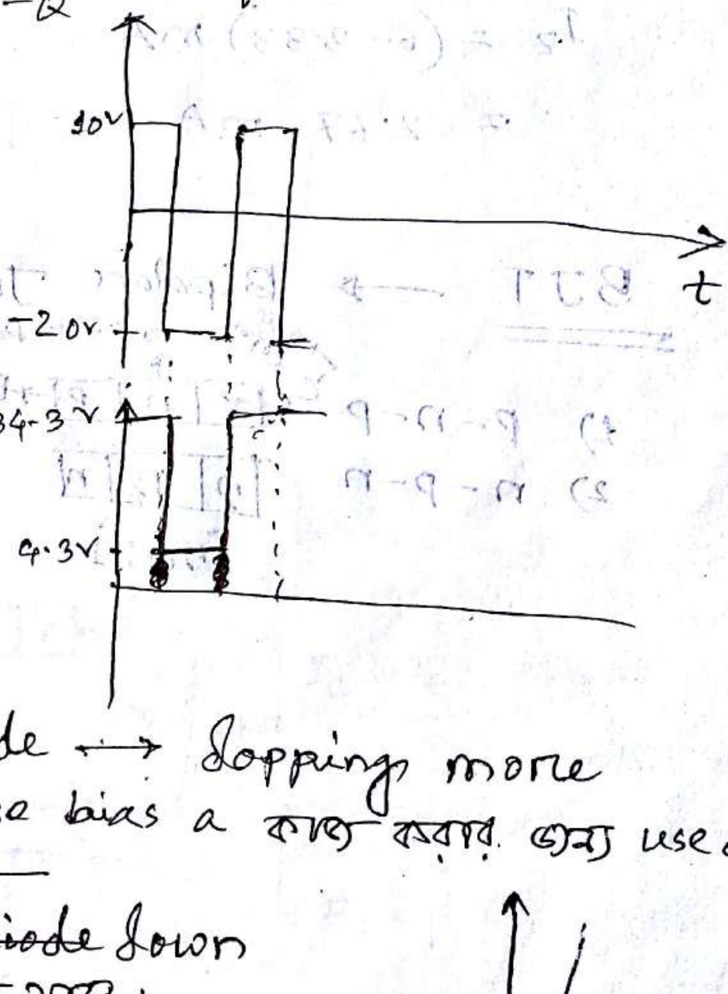
$+5 - 20\,v + v = 0$

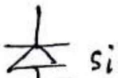
$v = -15\,V$





$v \propto q$





$(-20 - 5 + 0.7)\,V = -24.3\,V$

$(10 + 24.3)\,V = 34.3\,V$

Zener diode

Sepecial type of diode → Dopping more

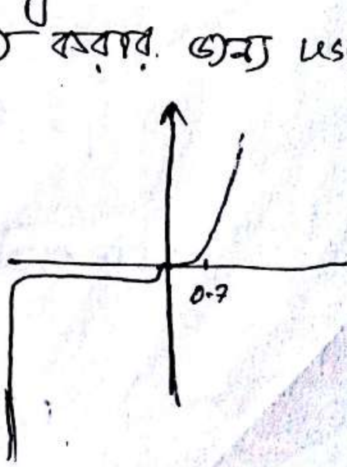
Zener diode reverse bias a কাজ করার জন্য use করা হয়

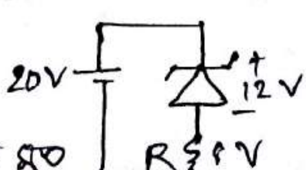
Normal diode ~~a~~ break ~~diode~~ down voltage এ আসার আগেই পুড়ে যাবে।

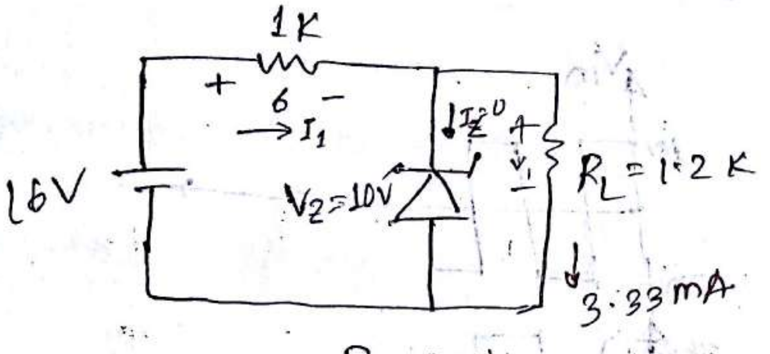
But, zener diode পুড়ে যাবে না।

একটা Fixed voltage output এ দিবে।

Forward bias এ Normal diode এর মত







$P_Z = 0\,W$

When Z_0 is missing.

$V_1 = \frac{1.2}{1+1.2} \times 16$

$= 8.73\,V$

if $R_L = 3\,K$

$V_1 = \frac{3}{1+3} \times 16$

$= 12\,V$

Diode on হলে , So,

$V_1 = 10\,V \mid \neq 12\,V$

$I_1 = \frac{6}{1K}$

$= 6\,mA$

$I_Z = (6 - 3.33)\,mA$

$= 2.67\,mA$

BJT → Bipolar Junction Transistor

Area বেশি — Base → Dopping সবচেয়ে কম

1) p-n-p C ← | p | n | p | → E → Dopping বেশি

└→ Resistivity কম

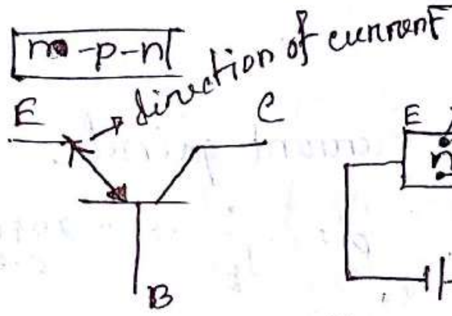
2) n-p-n | n | p | n |

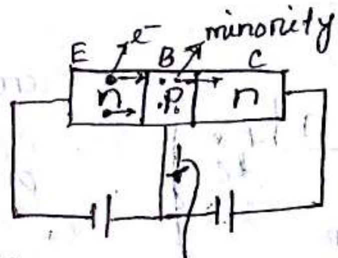
150 : 1

4(D)-Day

Date - 24/4/2016

$\boxed{n-p-n}$



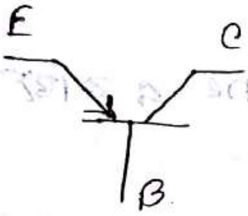


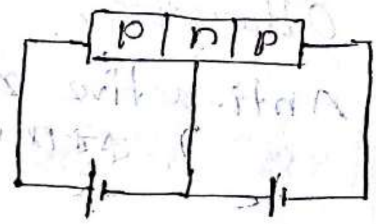
Base to collector এ minority carrier এর জন্য current flow হবে।

Base এর Resistivity বেশি থাকার কারণে এই পথে e খুব কম flow হবে।

$$\boxed{I_E = I_C + I_B}$$

$\boxed{p-n-p}$



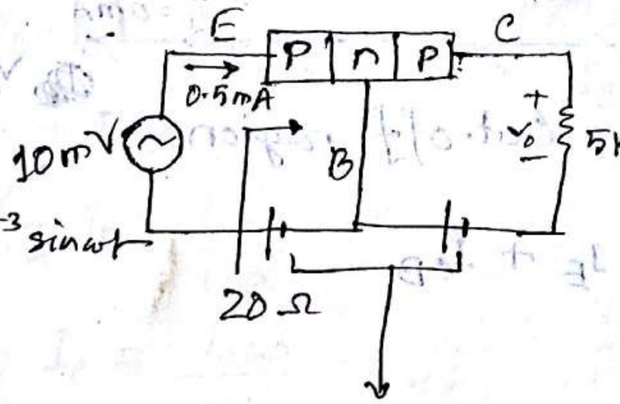


Emitter এবং Collector এর current প্রায় same হয়। Base এর মধ্য দিয়ে খুব কম পরিমাণ current flow হয়।

E - B $\longrightarrow$ Forward bias

B - C $\longrightarrow$ Reverse bias

Transistor Amplifying Action:



$$I_C = I_E = 0.5\ mA$$

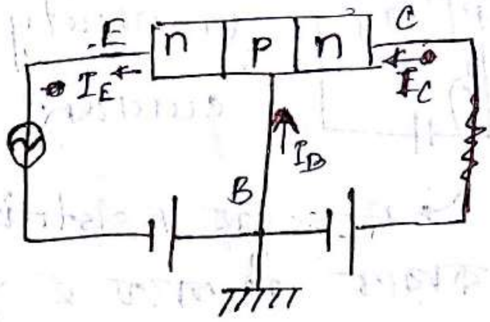
$$V_o = 5\times10^3 \times 0.5\ mA$$
$$= 2.5\ V$$

First এ DC supply দিতে হবে।

1. Common Base configuration
2. " Emitter "
3. " Collector "

Scanned by CamScanner

Common Base Configuration:



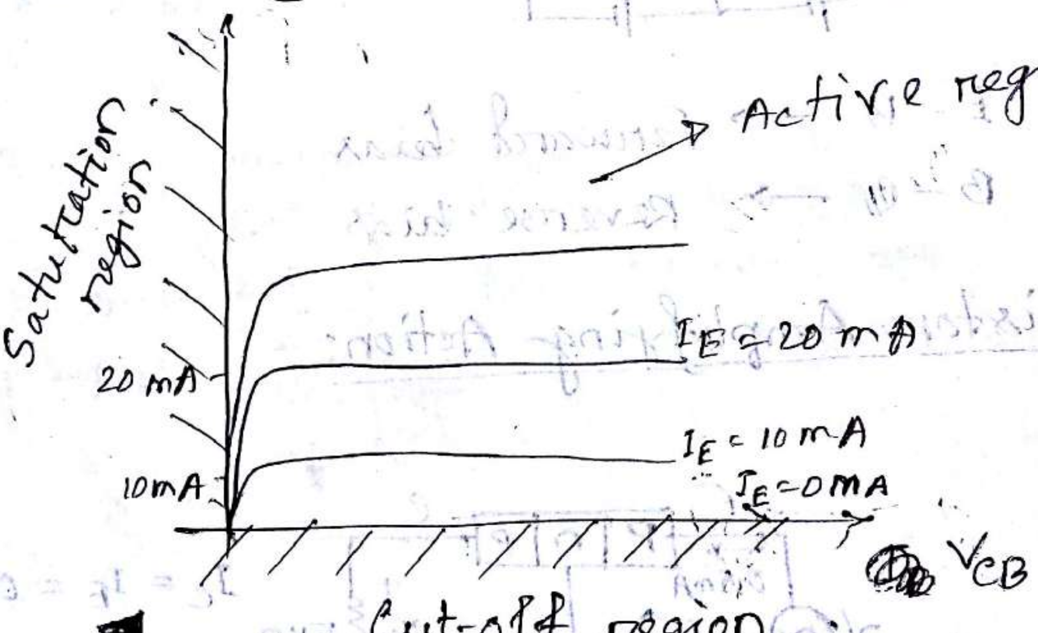
Current gained

$$\alpha = \frac{I_C}{I_E} \approx 0.99 \text{ to } 0.994$$

E–B → Forward
B–C → Reverse

} Active ~~reason~~ region এ থাকবে।

Otherwise,
Anti-active zone এ থাকবে।



$$I_C = \alpha \cdot I_E + I_{CB}$$

4(E)-Day

Date : 25/4/2016

Collector এর current দুই ভাবে Flow হতে পারে।

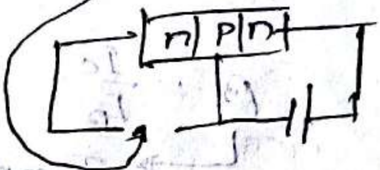
→ Emitter এর Free e^- এর জন্য (n-p-n)

→ Collector এর নিজের minority carrier এর জন্য

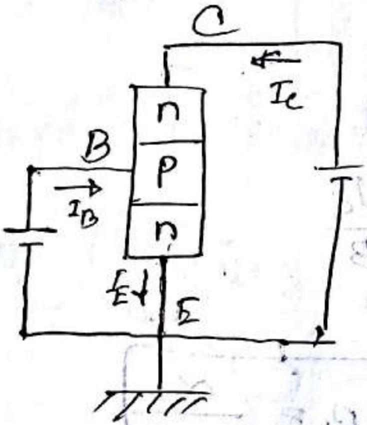
$I_C = \alpha I_E + I_{CBO}$ → Base current open

$I_E = 0$

$I_C = I_{CBO}$



Common emitter configuration:-



Current gained,

$$\boxed{\beta = \frac{I_C}{I_B}}$$

$I_C = \alpha \cdot I_E + I_{CBO}$

$= \alpha (I_B + I_C) + I_{CBO}$

$(1-\alpha) I_C = \alpha I_B + I_{CBO}$

$\Rightarrow I_C = \frac{\alpha}{1-\alpha} I_B + \frac{I_{CBO}}{1-\alpha}$

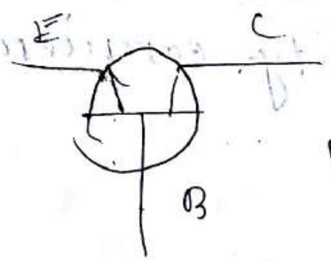
$I_B = 0$, $I_C = \frac{I_{CBO}}{1-\alpha}$ → শুধু minority carrier এর জন্য current flow হয়।

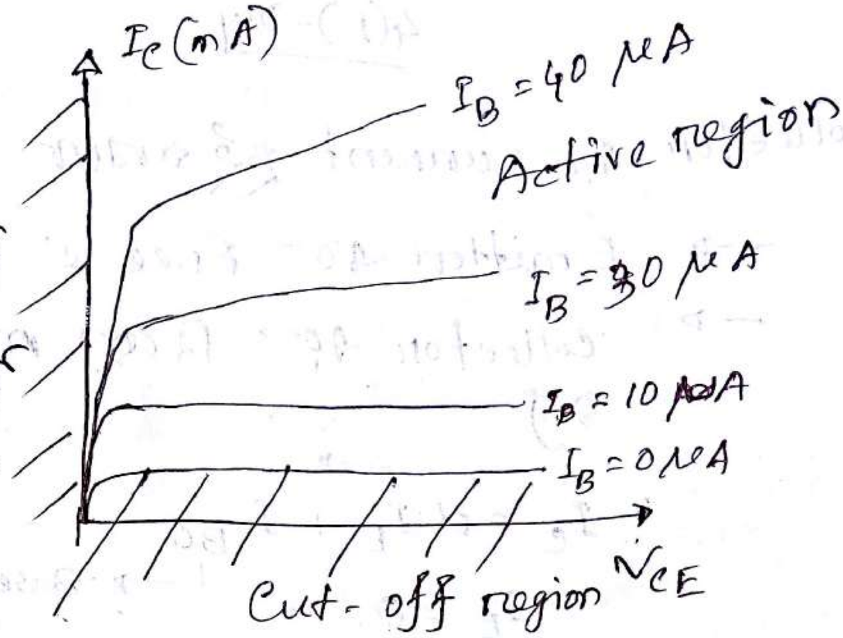
$I_C = \frac{I_{CBO}}{1-\alpha} = I_{CEO}$

$I_{CBO} = 1\ \mu A$ $[I_B = 0]$

$I_C = \frac{1\ \mu A}{1-0.99}$

$= 0.1\ mA$





$$\boxed{\beta = \frac{I_C}{I_B}}$$

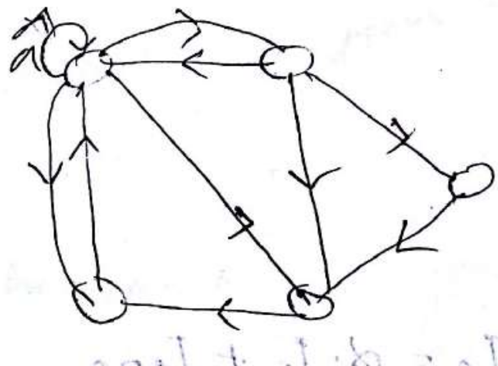
$\longrightarrow$ Temperature dependent

$$I_E = I_C + I_B$$

$$\Rightarrow \frac{I_C}{\alpha} = I_C + \frac{I_C}{\beta}$$

$$\Rightarrow \frac{1}{\alpha} = 1 + \frac{1}{\beta}$$

$$\boxed{\alpha = \frac{\beta}{\beta+1}, \quad \beta = \frac{\alpha}{1-\alpha}}$$



ā(2)

$I_{C max} = 50\ mA$

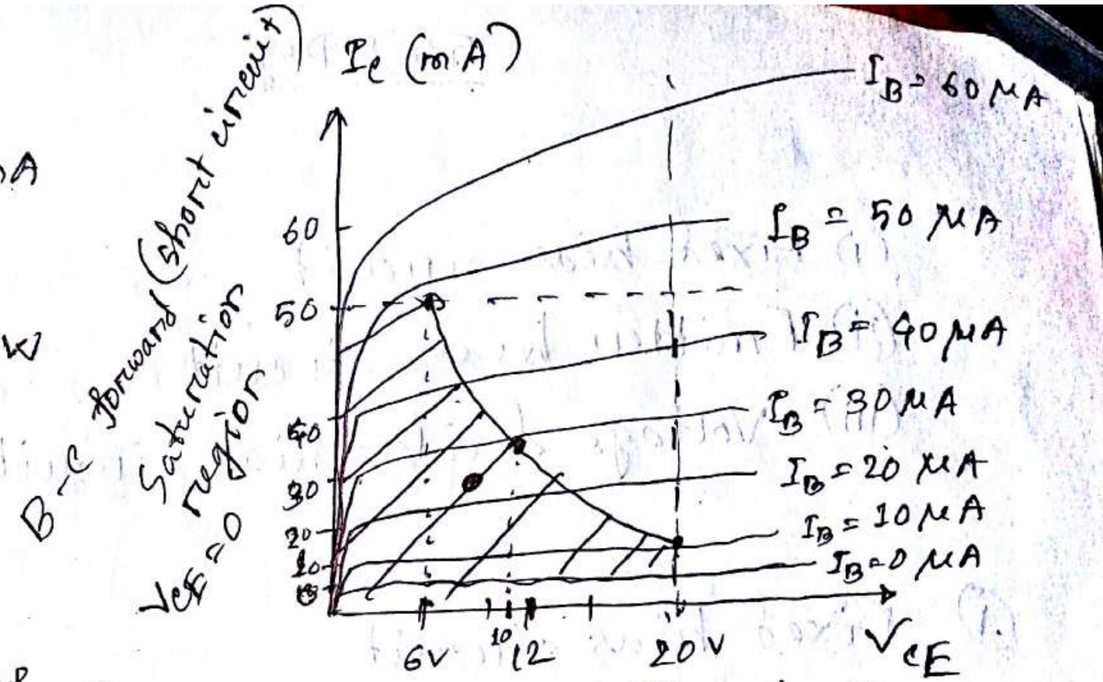
$V_{CE max} = 20\ V$

$P_{max} = 300\ mW$

$P = I_c \cdot V_{CE}$

$= 50 \times 6$

$= 300\ mW$



if $I_c = 50\ mA$

$V_{CE} = 6V$

if $V_{CE} = 20\ V$

$I_c = 15\ mA$

Cutoff region (open circuit)

if $V_{CE} = 10\ V$

$I_c = 30\ mA$

$\boxed{I_c = \beta I_B}$

* DC is mainly used for selecting operating point.

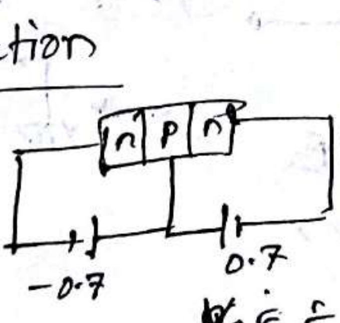
$I_E = I_B + I_C = (1+\beta) I_B$

$= \beta I_B$

$I_c = I_E$

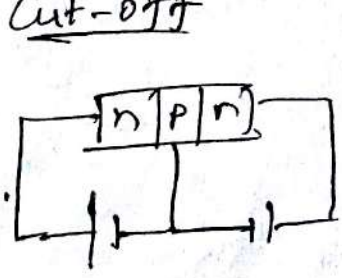
$\boxed{V_{BE} = 0.7\ V}$

Saturation



$V_{CE} = 0\ V$

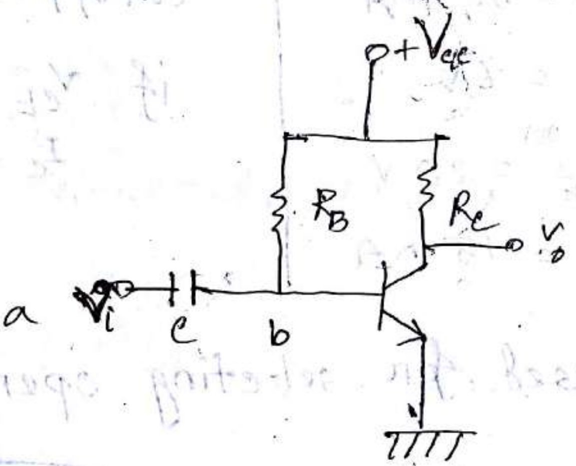
Cut-off



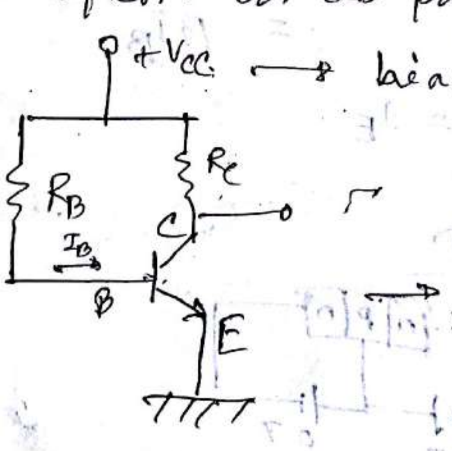
7(B)-Day Date : 27/4/2016

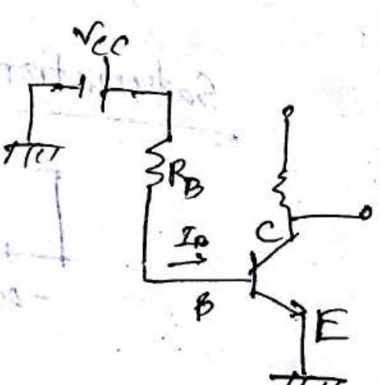
(i) Fixed bias circuit ↓ stability
(ii) Emitter bias circuit
(iii) Voltage divider bias circuit ↓ more stable

① Fixed bias circuit



DC ⇒ capacitor open. So, ab part is missing.



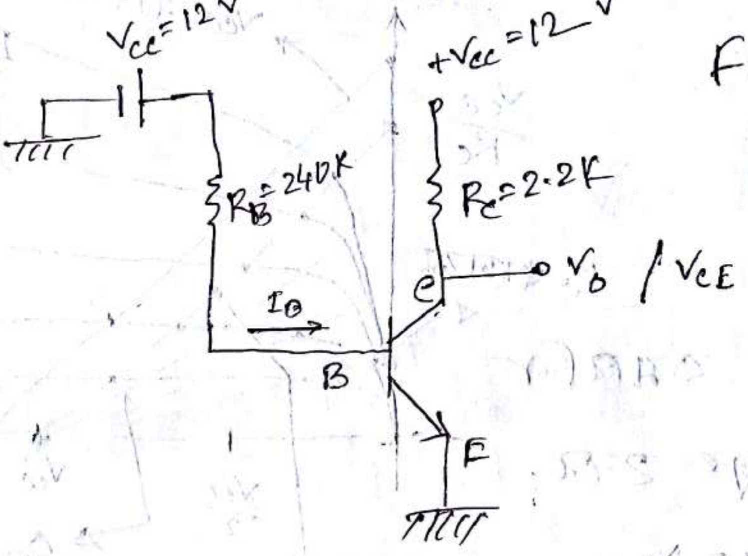


$$-V_{CC} + I_B R_B + V_{BE} = 0$$
$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

$$I_C = \beta I_B$$

$$-V_{CC} + I_C R_C + V_{CE} = 0$$
$$\Rightarrow V_{CE} = V_{CC} - I_C R_C$$

H.W



Find the operating point.

$V_o = V_{CC}$

$I_B = 0$

$I_C = \beta I_B = 0$

$$-V_{CC} + I_B R_B + V_{BE} = 0$$

$$\Rightarrow I_B = \frac{V_{CC} - \cancel{0.7V}\ V_{BE}}{R_B}$$

$$= \frac{12 - 0.7}{240K}$$

$$= 47.08\ \mu A$$

I_B তে β এর Effect নেই.

So, $\beta = 50$ or $\beta = 100$ এ I_B same.

Temp ↑ β ↑

when $\beta = 50$

$I_C = \beta I_B = 2.35$ mA

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

$= 12 - I_C \times 2.2K$

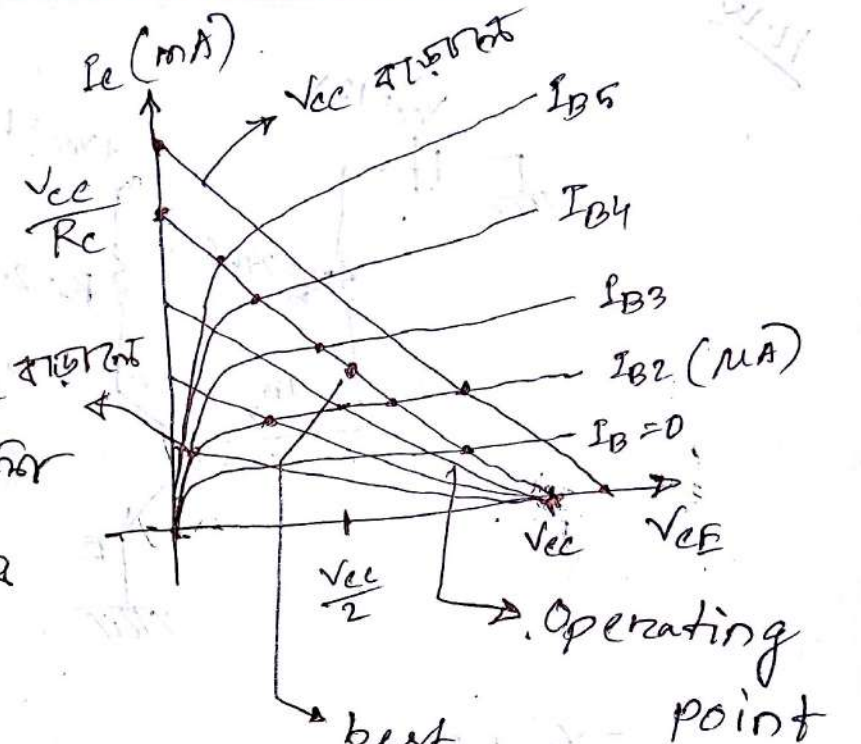
$= 6.83$ V

$\beta = 100$

$I_C = 4.71$ mA

$V_{CE} = 1.64$ V

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



R_B এর value কমিয়ে দিয়ে I_B change হবে

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

হলে, $\frac{V_{CC}}{2}$ আসা থাকবে

$I_B = 15\ \mu A$ হলে

$\frac{V_{CC}}{2}$ পাওয়া যাবে।

CT ⟶ Clippers - Clampers পর্যন্ত

* Emitter bias নিজে করে নিতে হবে

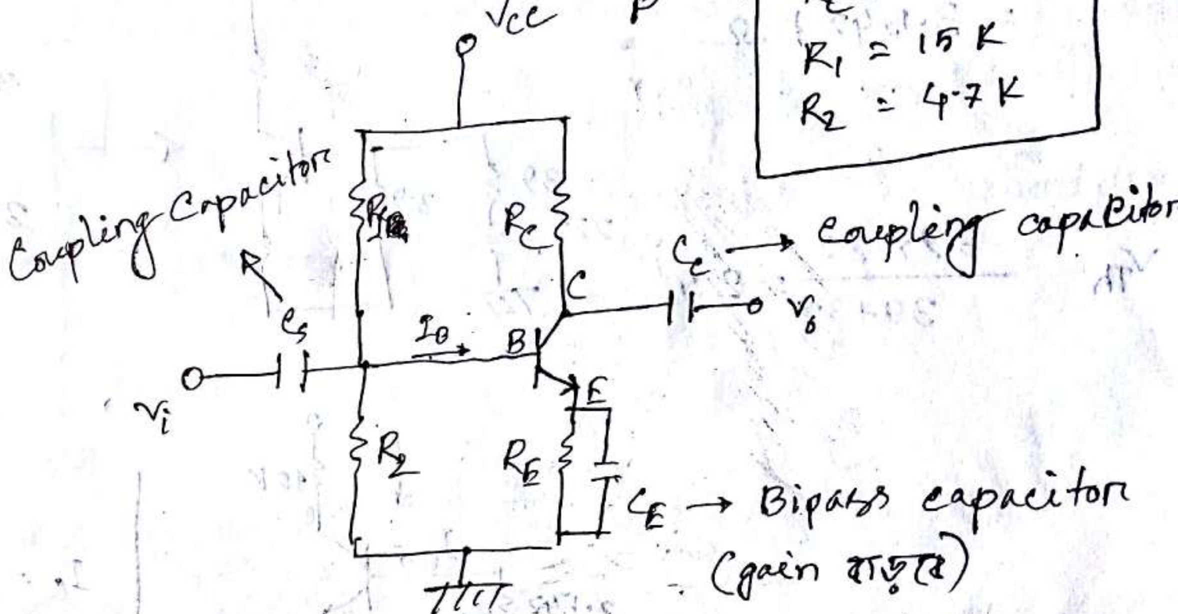
5(E) - Day

Date 3/5/2016

Voltage divider bias

$\beta = 50$? $\beta = 100$?

$$\boxed{\begin{aligned} V_{cc} &= +12\text{ V} \\ R_E &= 1\text{K} \\ R_C &= 2.2\text{K} \\ R_1 &= 15\text{K} \\ R_2 &= 4.7\text{K} \end{aligned}}$$



$I_B = ?$

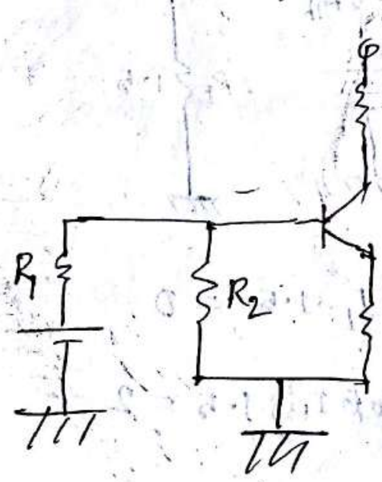
$I_C = ?$

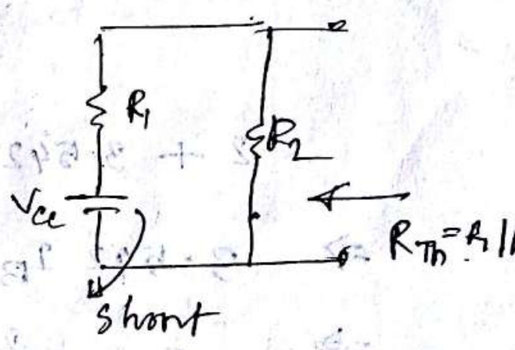
$V_{CE} = ?$

$I_E \approx I_C$

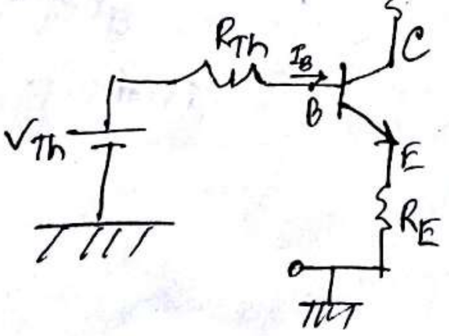
$V_{CE} = V_{cc} - I_C R_C - I_C R_E$

$= V_{cc} - I_C (R_C + R_E)$





$$V_{Th} = \frac{R_2}{R_1 + R_2} \times V_{cc}$$



$$\boxed{\begin{aligned} I_C &= \beta I_B \\ I_E &= I_C + I_B \\ &= (1+\beta) I_B \end{aligned}}$$

Using KVL,

$-V_{Th} + I_B R_{Th} + V_{BE} + I_E R_E = 0$

$\Rightarrow I_B R_{Th} + I_E R_E = V_{Th} - V_{BE}$

$\Rightarrow I_B R_{Th} + (1+\beta) I_B R_E = V_{Th} - V_{BE}$

$\Rightarrow I_B = \dfrac{V_{Th} - V_{BE}}{R_{Th} + (1+\beta) R_E}$

$I_C = \beta I_B$

$-V_{cc} + I_C R_C + V_{CE} + I_E R_E = 0$

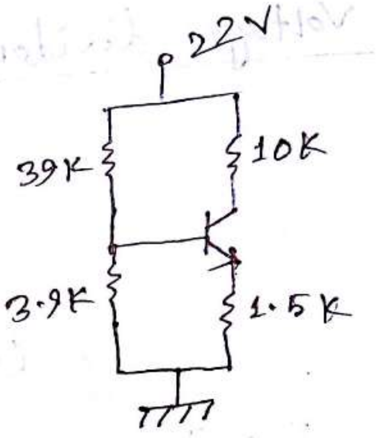
$\therefore V_{CE} = -I_C R_C + V_{cc} - I_E R_E$

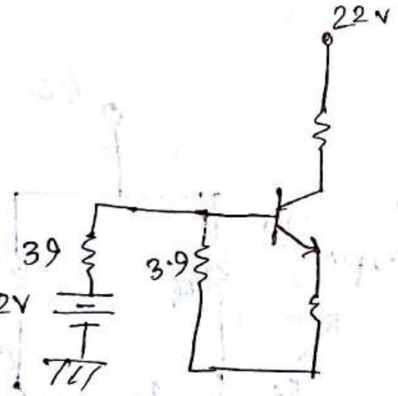
6(B)-Day

Date: 7/5/2016

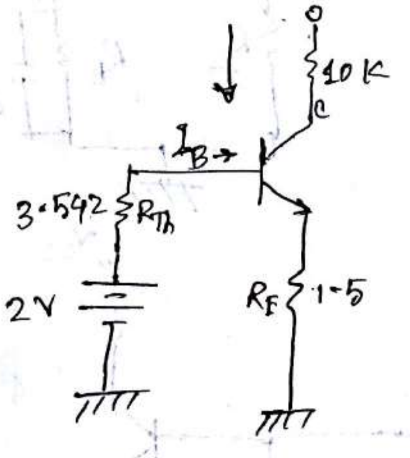
$R_{Th} = 3.9K \| 39K$

$= 3.542 \, K\Omega$





$V_{Th} \quad \frac{3.9 \times 22}{39+3.9} = 2V$



$-2 + 3.542 \, I_B + I_E \cdot 1.5 = 0$

$\Rightarrow \quad 3.542 \, I_B + \beta I_B) \times 1.5 = 2$

$\Rightarrow \quad I_B = \frac{2-0.7}{(3.542+50\times 1.5)10^3}$

$= 16.24 \, \mu A$

$I_C = \beta I_B = 50 \times I_B$

$= 0.812 \, mA$

$10K \times I_C - 22 + V_{CE} + 1.5K I_E = 0$

$\Rightarrow V_{CE} = 22 - (10+1.5)\times 10^3 I_C$

$= 12.66V$

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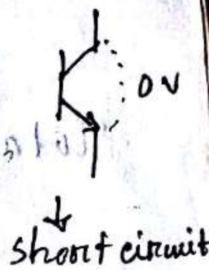
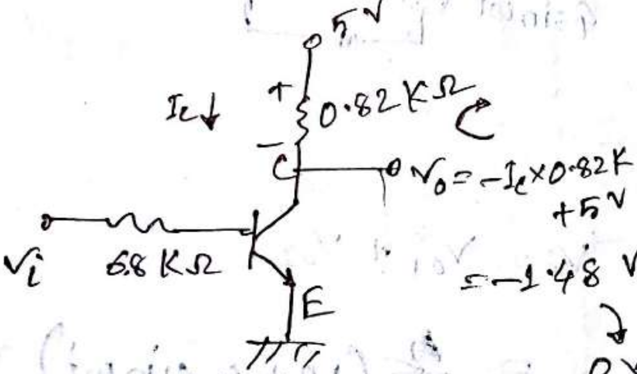
Transistor switching network:

Saturation region $\longrightarrow$ short circuit

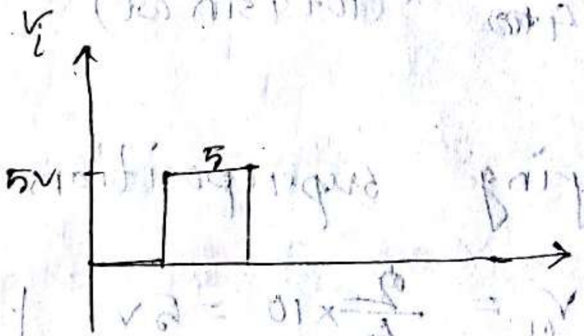
$V_{CE} \approx 0$



Cut-off region $\longrightarrow$ open circuit



0 এর কাছাকাছি 'Equivalently short circuit'.



$V_i = 0$, $I_B = 0$, $V_{BE} = 0$

That means short circuit

$V_i = 5$, $\beta = 125$

$-5 + 6.8K \times I_B + 0.7 = 0$

$\Rightarrow I_B = 63.23\ \mu A$

$I_C = \beta I_B$

$= 7.9\ mA$

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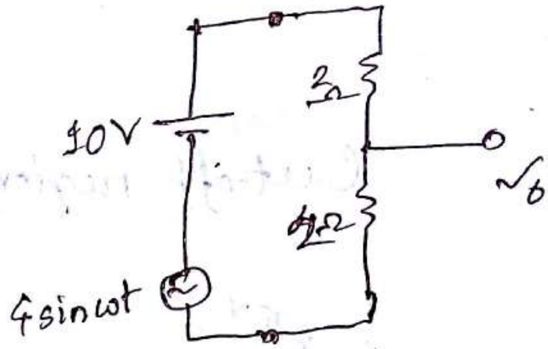
BJT AC Analysis:

Bipolar $\longrightarrow$ hole and electrons both are carriers.

Total input voltage

$10 + 4\sin\omega t$



$$V_o = \frac{2}{4} \times (10 + 4\sin\omega t)$$

Or,

Applying superposition

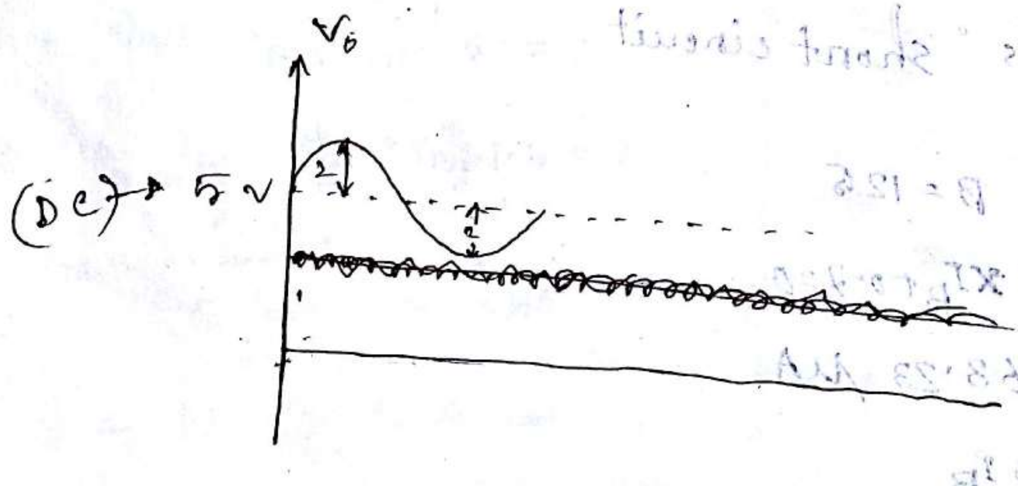
② inactive, $V_{o1} = \frac{2}{4} \times 10 = 5V$

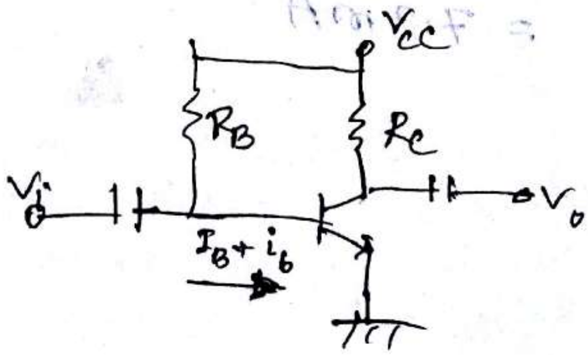
⏚ inactive, $V_{o2} = \frac{2}{4} \times 4\sin\omega t$

$a = 2$

$V_o = V_{o1} + V_{o2}$

$= \frac{2}{4}(10 + 4\sin\omega t)$





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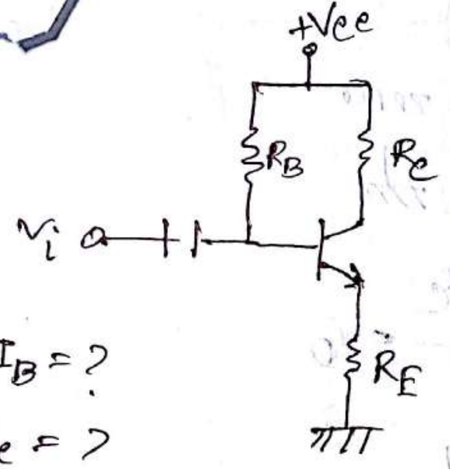
6(D)-Day

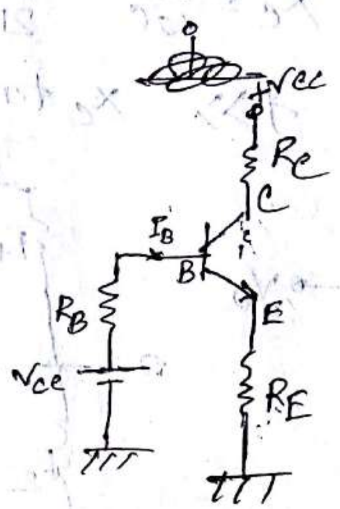
Date: 9/5/2016

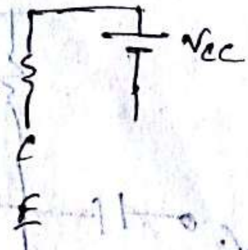


$I_B = ?$

$I_C = ?$

$V_{CE} = ?$





$$-V_{cc} + I_B R_B + V_{BE} + I_E R_E = 0$$

$$\Rightarrow -V_{cc} + I_B R_B + \beta I_B R_E + V_{BE} = 0$$

$$\Rightarrow \cancel{I_B = \frac{V_{cc} - V_{BE} - \beta I_B R_E}{R_B}}$$

$$\Rightarrow I_B (R_B + \beta R_E) = V_{cc} - V_{BE}$$

$$\therefore \boxed{I_B = \frac{V_{cc} - V_{BE}}{R_B + \beta R_E}}$$

$$I_C = \beta I_B$$

$$= \beta \frac{V_{cc} - V_{BE}}{R_B + \beta R_E}$$

$$+I_E R_E - V_{cc} + I_C R_C + V_{CE} = 0$$

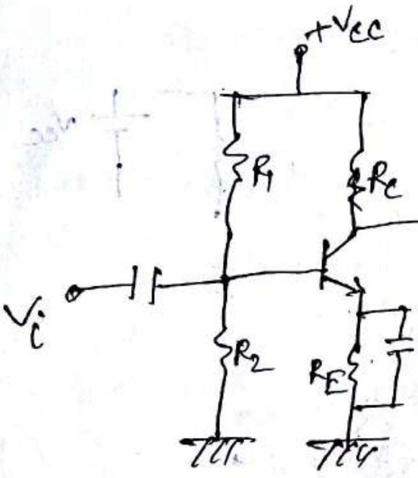
$$V_{CE} = V_{cc} - I_C R_C - R_E I_C \qquad I_E \approx I_C$$

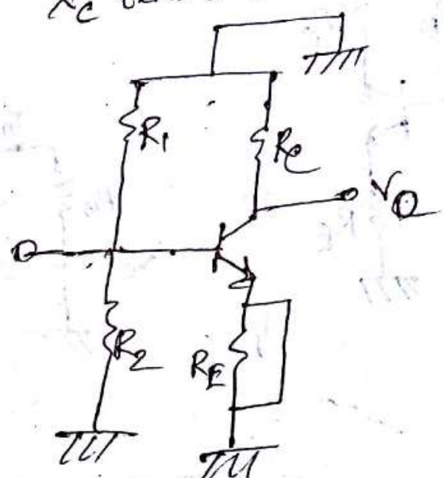
$$= V_{cc} - I_C (R_C + R_E)$$

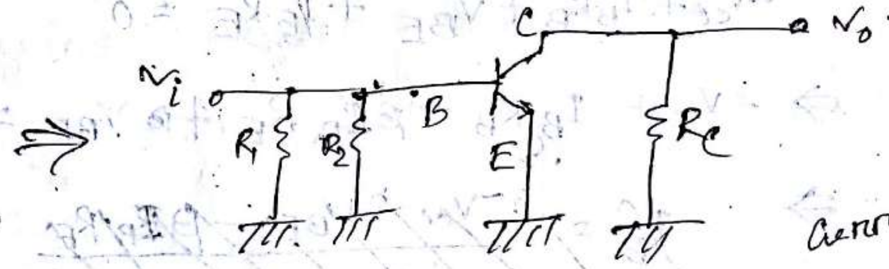
AC Analysis:

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$

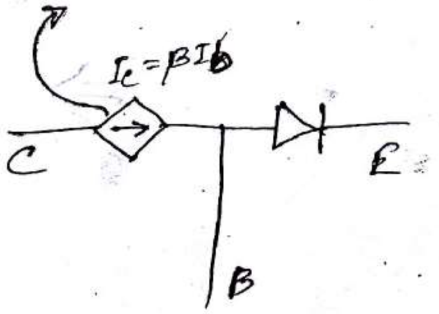
$f \gg$ X_C tends to zero





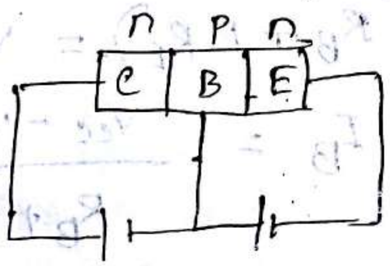


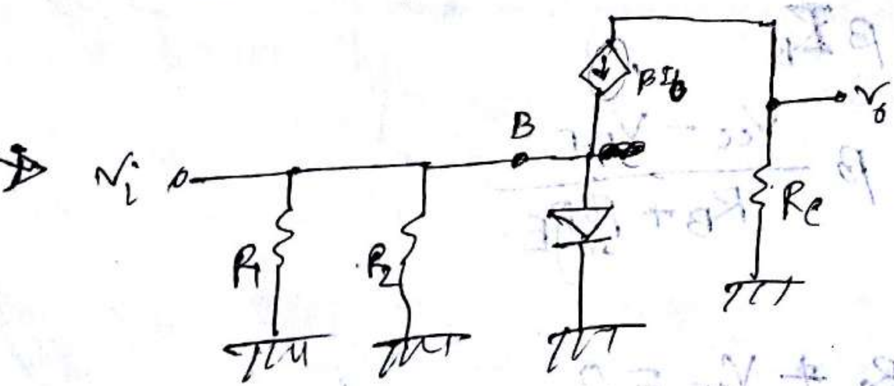
Current dependent current source



$I_C \propto I_B$

$\Rightarrow I_c = \beta I_B$

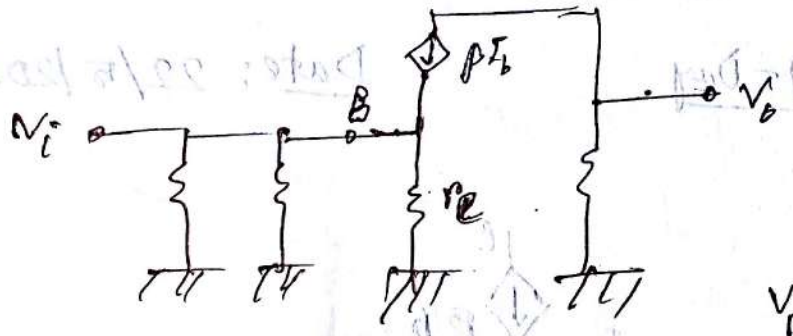


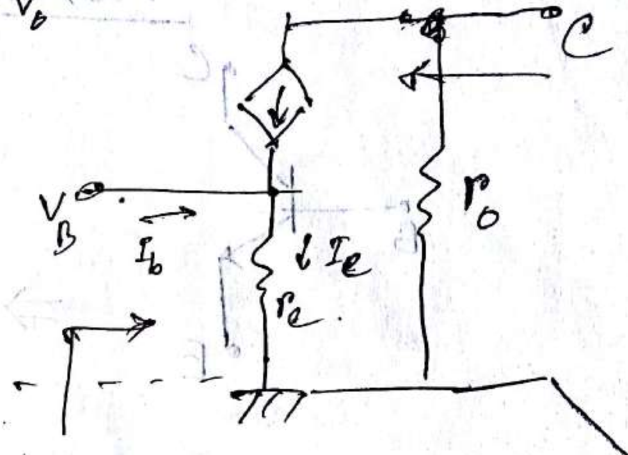


1.5 AC resistance of a diode $r_e \approx \frac{26\ mV}{I_E}$

$I_E \rightarrow$ DC biasing এর

DC Analysis $\longleftrightarrow$ থেকে Emitter current

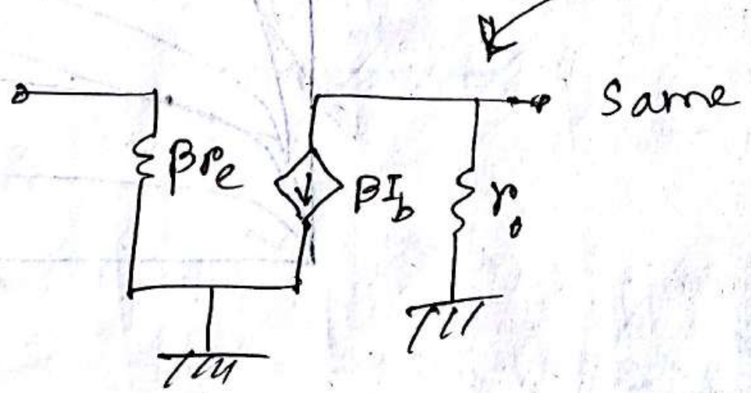




input impedence $Z_i = \frac{V_B}{I_b} = \frac{r_e I_e}{I_b} = \frac{r_e \beta I_b}{I_b}$

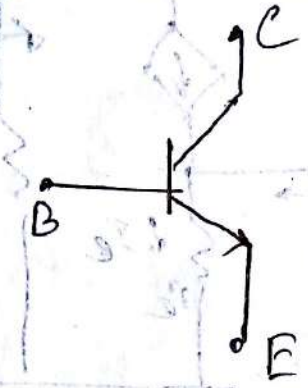
$= \beta r_e$

Output impedence, $Z_o = r_o$

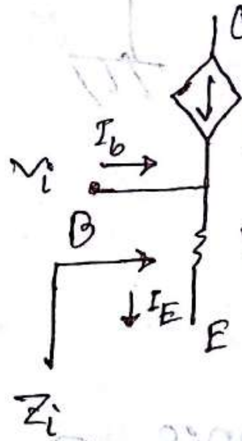


7(B) - Day

Date: 22/5/2016



$\Rightarrow$



$r_e = \frac{26\,mV}{I_E}$

$V_i = r_e(\beta I_b + I_b)$

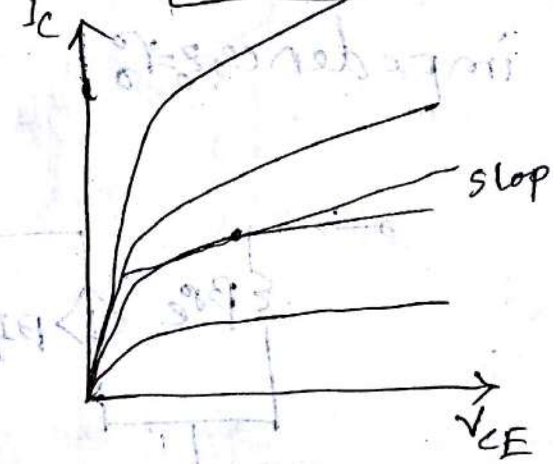
$= r_e(\beta+1)I_b$

$= r_e \beta I_b$

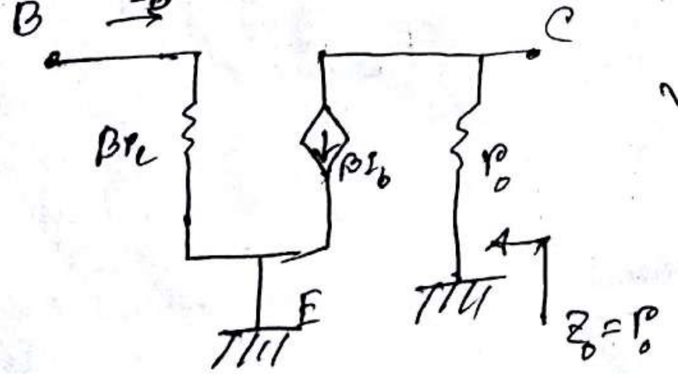
$\boxed{Z_i = \frac{V_i}{I_b} = \beta r_e}$

output impedance

$\boxed{Z_o = \frac{V_{CE}}{I_c} = r_o}$



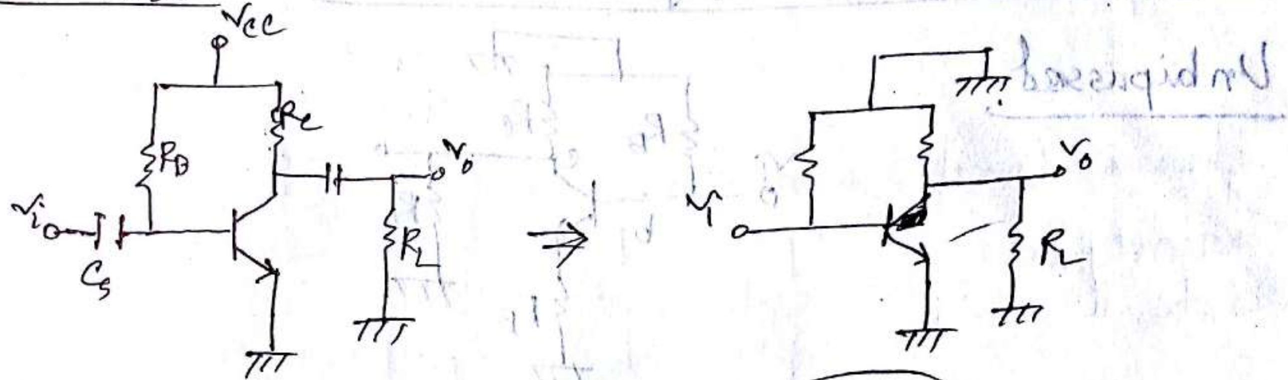
slope $= \frac{\Delta I_c}{\Delta V_{CE}}$

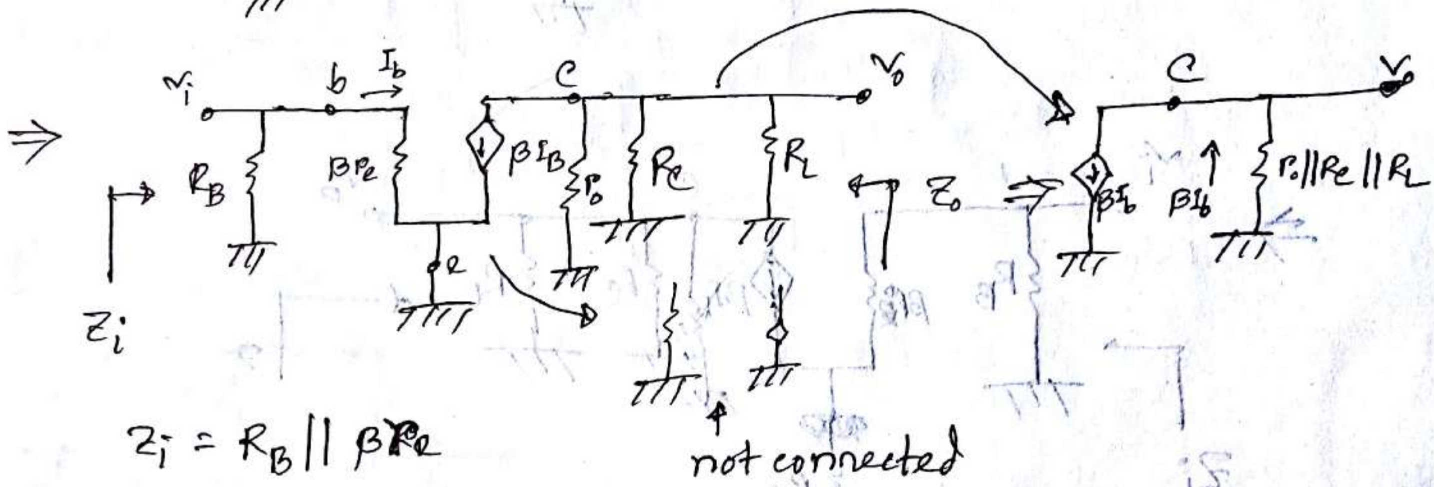


$V_i = \beta r_e I_b$

$Z_i = \frac{V_i}{I_b} = \beta r_e$

Fixed bias





$Z_i = R_B \,||\, \beta r_e$

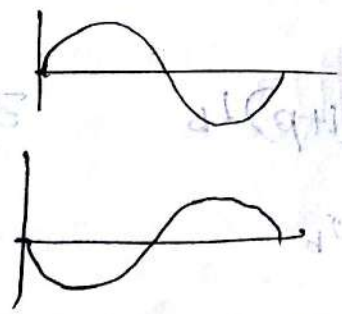
$Z_o = r_o \,||\, R_C \,||\, R_L$

Gain, $A_V = \dfrac{V_o}{V_i}$

$= -\dfrac{r_o || R_C || R_L}{r_e}$

$V_i = \beta r_e I_b$

$V_o = -\beta I_b \,(r_o || R_C || R_L)$

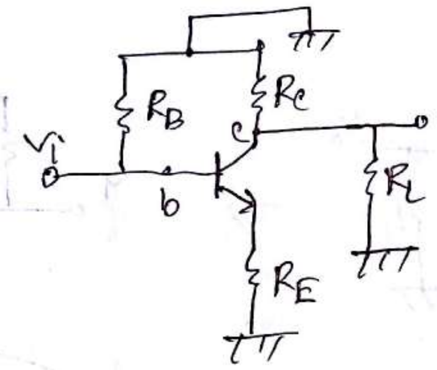


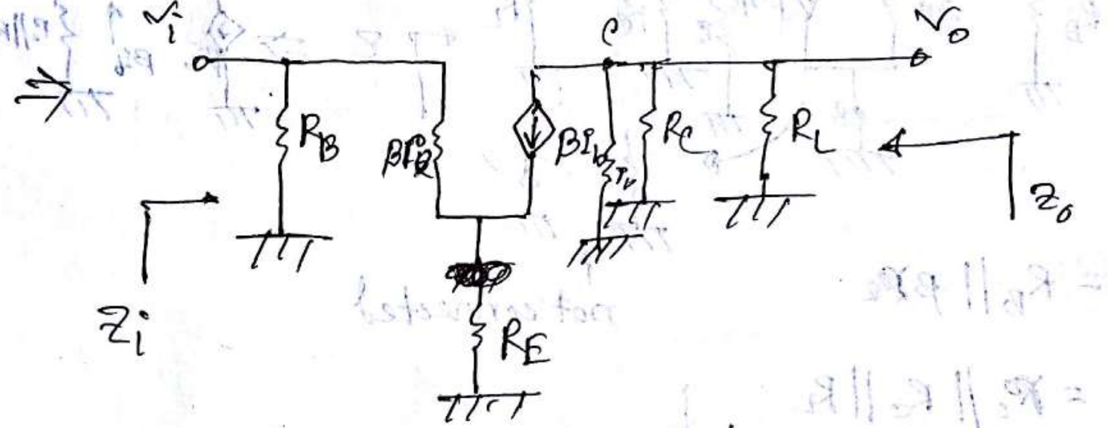
if $r_o = \infty$

Then, $A_V = -\dfrac{R_C || R_L}{r_e}$

Common Emitter configuration bias: → বেশি stable

Unbipassed





$Z_i = R_B || [(r_e + R_E)\beta]$

$Z_o = r_o || R_C || R_L$

$v_i = \beta r_e I_b + R_E (1+\beta) I_b$

$= \beta r_e I_b + \beta R_E I_b$

$v_o = -\beta I_b (r_o || R_C || R_L)$

$$\frac{v_o}{v_i} = -\frac{r_o || R_C || R_L}{r_e + R_E}$$

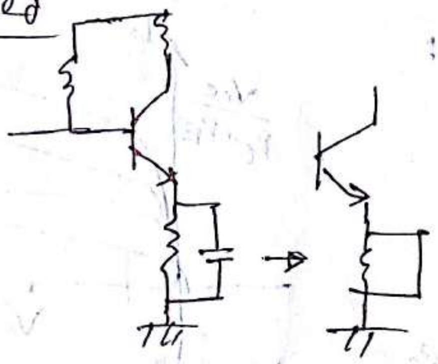
$v_i = \beta r_e I_b + R_E (I_b + \beta I_b)$

$= \beta r_e I_b + R_E \beta I_b$

$= \beta (r_e + R_E) I_b$

$Z_b = \frac{v_i}{I_b} = \beta (r_e + R_B)$

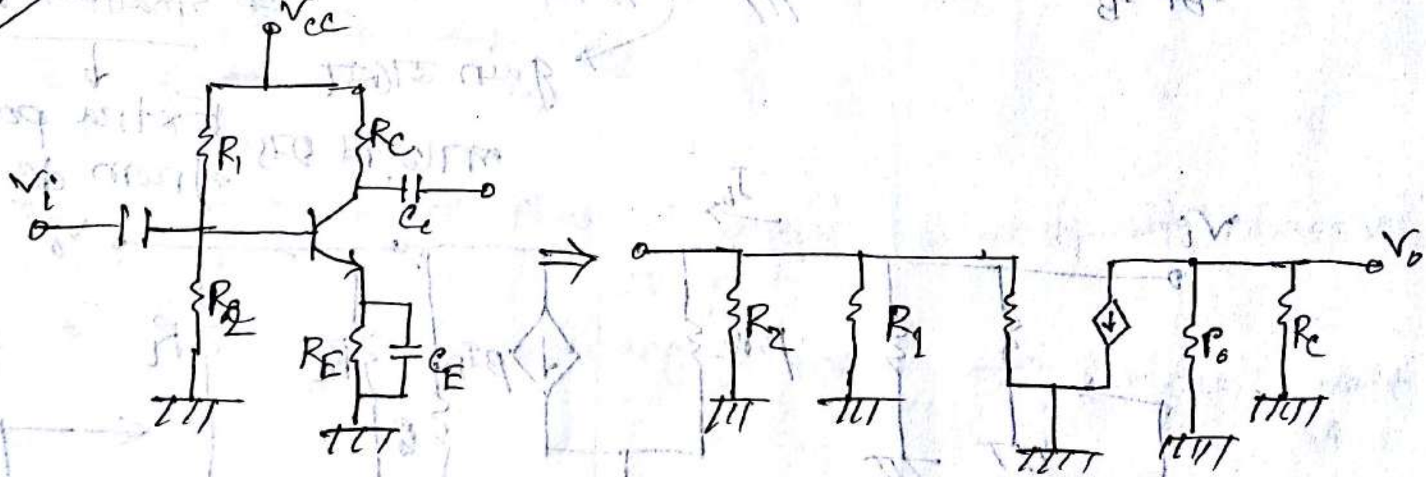
Bipassed



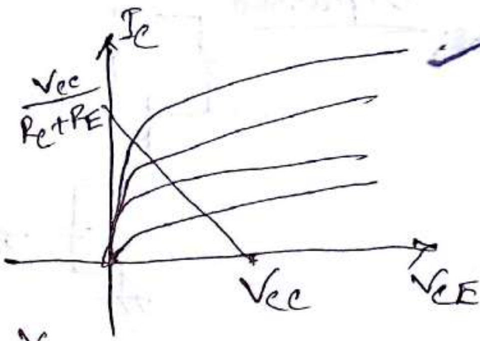
→ Same as fixed biased but more stable

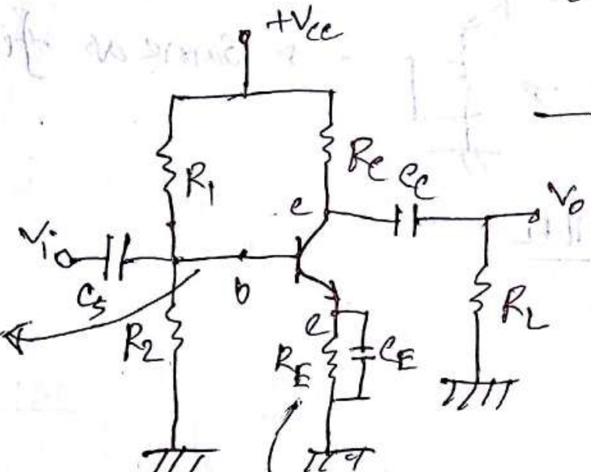
$$A_v = -\frac{r_o \| R_C \| R_L}{r_e}$$

H.W



Voltage divider bias circuit:
R_E model



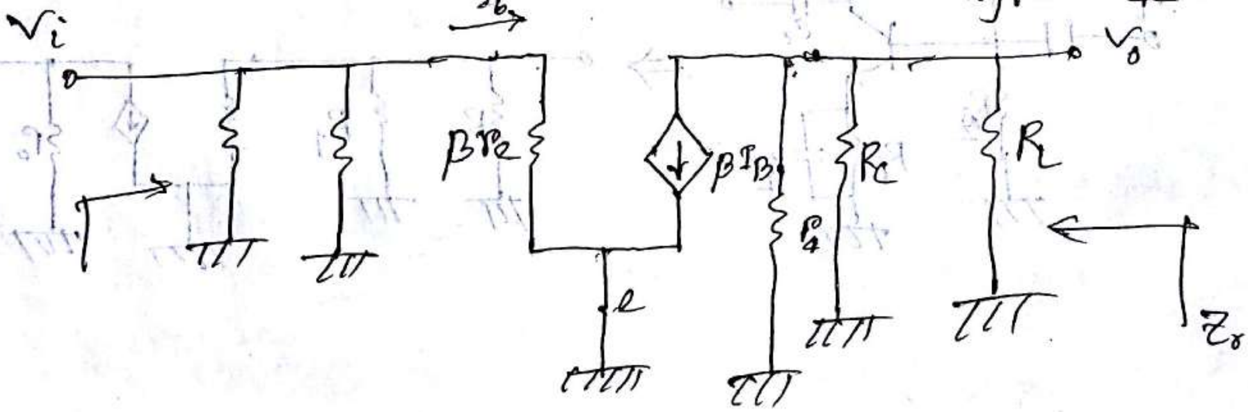


When AC and DC both active → $I_b + I_B$

Max amplify → $\frac{V_{cc}}{2}$

Small → big
↓
Extra power from dc source

gain ভালো পাওয়ার জন্য



$$Z_i = R_1 \| R_2 \| \beta r_e$$

$$Z_o = r_o \| R_c \| R_L$$

$$V_i = I_b \beta r_e$$

$$V_o = -\beta I_b (r_o \| R_c \| R_L)$$

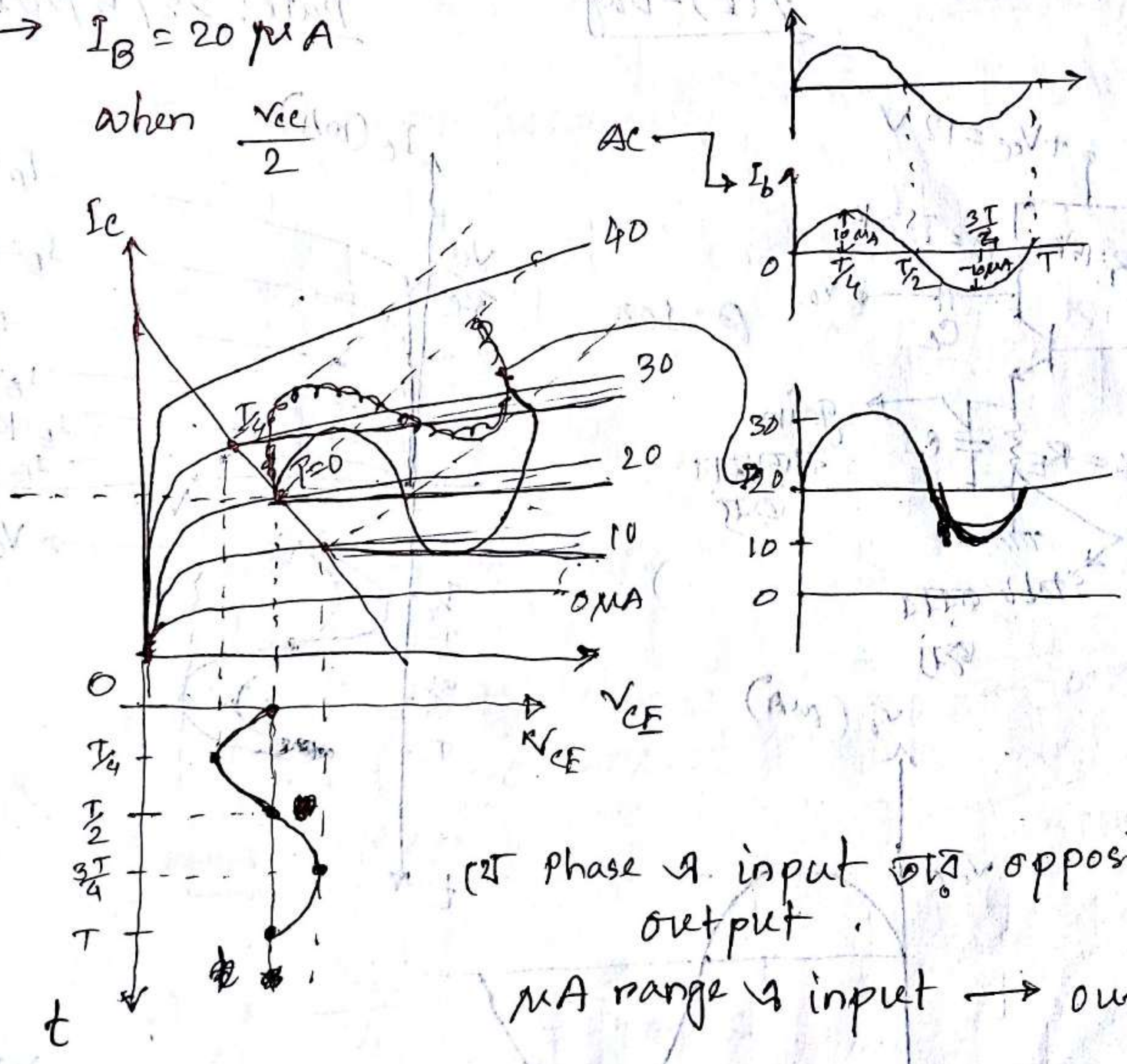
$$A = \frac{V_o}{V_i} = -\frac{r_o \| R_c \| R_L}{r_e}$$

$$r_e = \frac{26\text{ mV}}{I_e}$$

I_e → at the time of DC analysis

DC
↳ $I_B = 20\ \mu A$

when $\frac{V_{CC}}{2}$

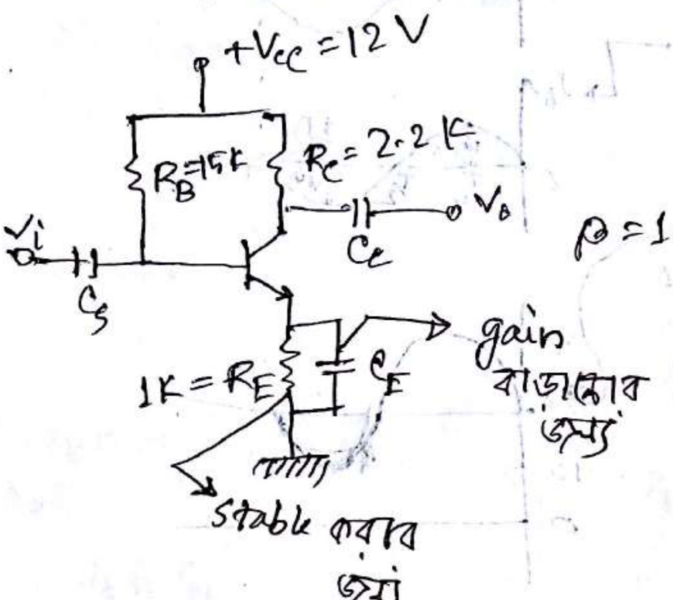


যে Phase এ input তার opposite phase এ output.

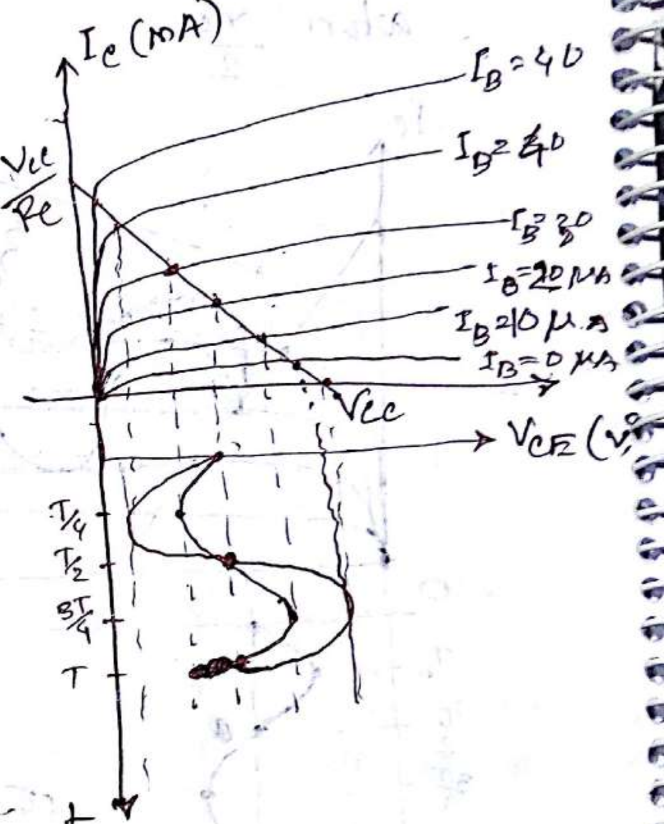
μA range এ input → output Volt এ

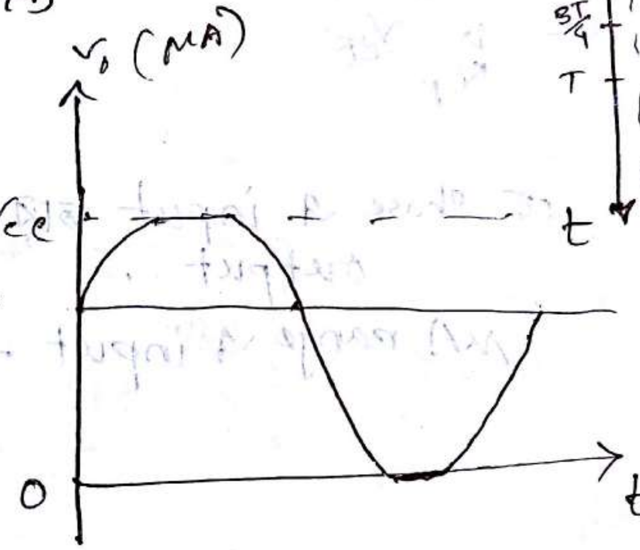
7(E)-Day

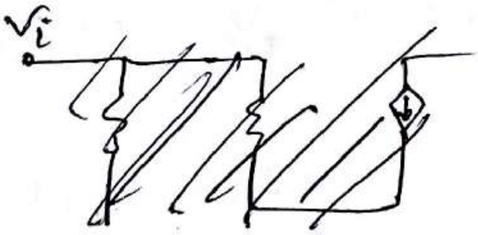
Date: 28/5/2016



$\beta = 100$







V

$$A_v = \frac{V_o}{V_i} = -\frac{R_C}{r_e}$$

output, input এর উল্টো

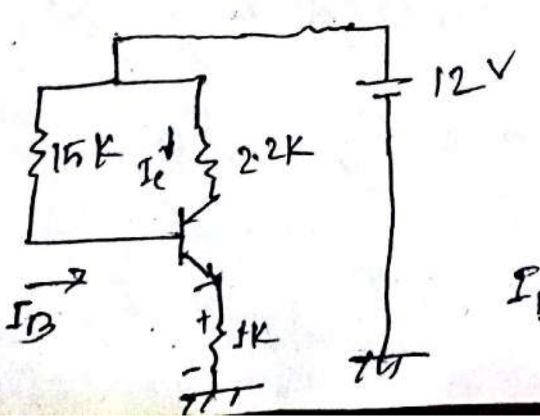
$$= -\frac{R_C \times I_E}{26\text{ mV}}$$

$$= -\frac{2.2 \times 9.826}{26}$$

$$= -0.83$$

$$I_B = \frac{12 - 0.7}{15K + 100 \times 1K} = \cancel{0.7533\text{ mA}}\ 98.261\,\mu A$$

~~$I_C \cdot 2.2 + I_E \cdot 1 = 12$~~



$$I_E = \beta I_B = 100 \times 98.261$$

$$= 9.826\text{ mA}$$

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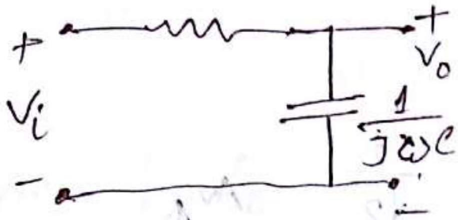
8(B)-Day

Date: 30/5/

Chapter-9

~~BJT frequency Response~~:

Filter:



$\frac{1}{j\omega C} = -jX_c$

$$V_o = \frac{-jX_c}{R - jX_c} \times V_i$$

$$= \frac{\frac{1}{j\omega C}}{R + \frac{1}{j\omega C}}$$

$$= \frac{V_i}{1 + j\omega RC}$$

$$= \frac{V_i}{1 + j2\pi f RC}$$

f যত বাড়বে V_o তত কমবে

if $f = \alpha$

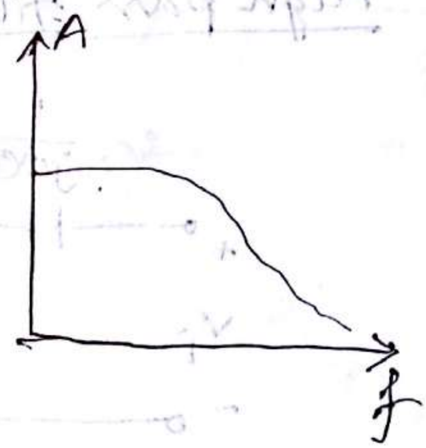
then equivalently short circuit

$V_o = 0$

$\boxed{\text{Low pass filter}}$

$$A_v = \frac{V_o}{V_i} = \frac{1}{1 + j2\pi f RC}$$

$$|A_v| = \frac{1}{\sqrt{1^2 + (2\pi f RC)^2}}$$



Cut-off frequency

→ অর্ধেক power transmit হবে output এ

~~$-\frac{R_c \| R_L}{r_e}$~~

~~$r_e = \frac{26mV}{I_E}$~~

$$P = \frac{V^2}{R}$$

$$P_{\frac{1}{2}} = \frac{1}{2}\frac{V^2}{R} = \frac{\left(\frac{V}{\sqrt{2}}\right)^2}{R} = \frac{(0.707V)^2}{R}$$

V এর value 70.7% হলে half power transmit হবে।

$$|A_v| = \frac{1}{\sqrt{1^2 + (2\pi f RC)^2}}$$

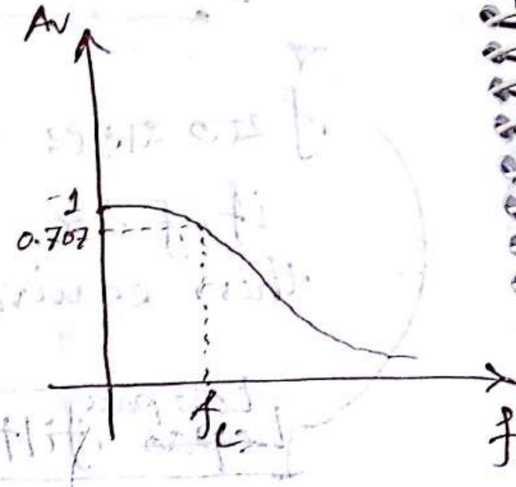
At cut-off frequency, $f = f_c$

$$|A_v| = \frac{1}{\sqrt{1^2 + (2\pi f_c RC)^2}} = \frac{1}{\sqrt{2}}$$

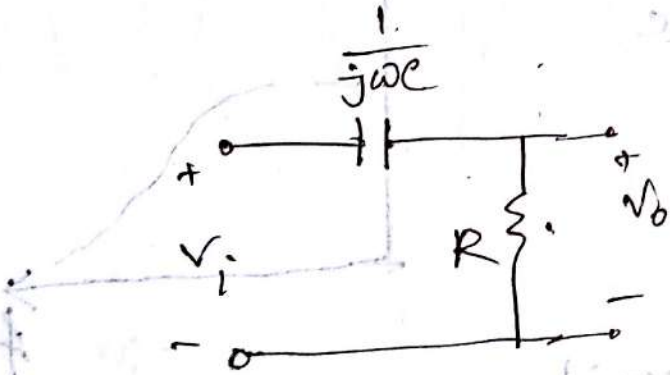
$$\Rightarrow \frac{1}{1^2 + (2\pi f_c RC)^2} = \frac{1}{2}$$

$$\Rightarrow 1^2 + (2\pi f_c RC)^2 = 2$$

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



High pass Filter



$$V_0 = \frac{R}{R + \frac{1}{j\omega C}} \times V_i$$

$$= \frac{j\omega RC}{1 + j\omega RC} v_i$$

DC এর জন্য gain zero

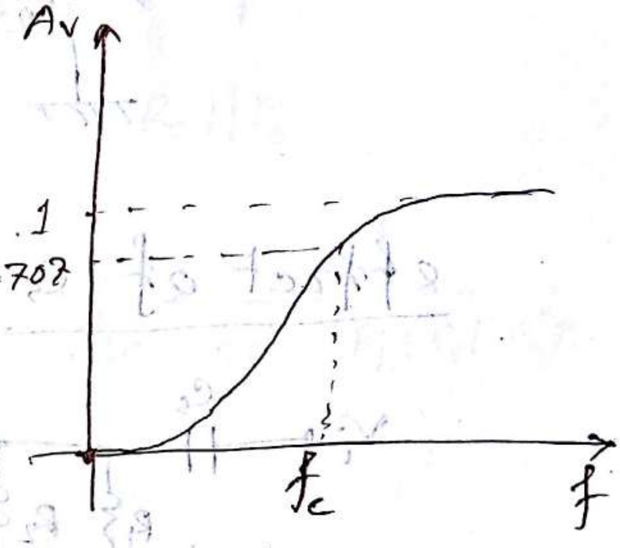
$f = \infty$

$V_0 = v_i$

$$A_V = \frac{V_o}{V_i} = \frac{j\omega RC}{1 + j\omega RC}$$

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

At $f = f_c$, $|A_v| = \frac{1}{\sqrt{2}}$ [voltage gain]



$$\frac{2\pi f_c RC}{\sqrt{1+(2\pi f_c RC)^2}} = \frac{1}{\sqrt{2}}$$

$$\therefore \frac{4\pi^2 f_c^2 R^2 C^2}{1+(2\pi f_c RC)^2} = \frac{1}{2}$$

$$\Rightarrow 2\cdot(2\pi f_c RC)^2 = 1+(2\pi f_c RC)^2$$

$$\Rightarrow (2\pi f_c RC)^2 = 1$$

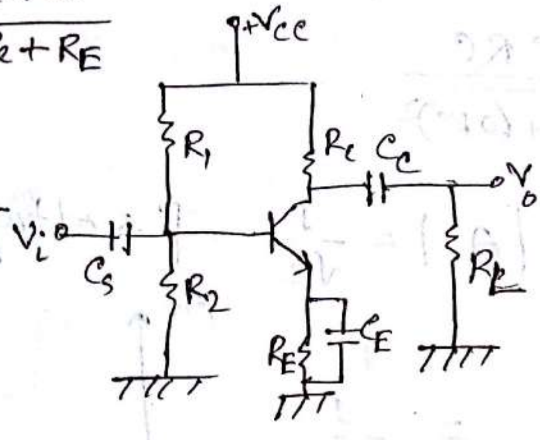
$$\therefore f_c = \frac{1}{2\pi RC}$$

Note: যে frequency out-put voltage 70.7% তা cutoff frequency

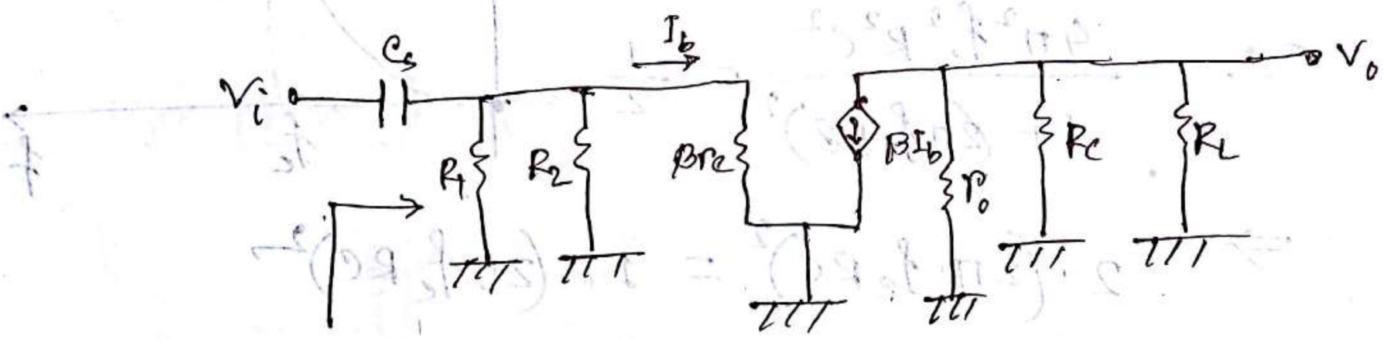
Low frequency response of BJT amplifier:

$$A_v = -\frac{R_C \| R_L}{r_e + R_E}$$

DC

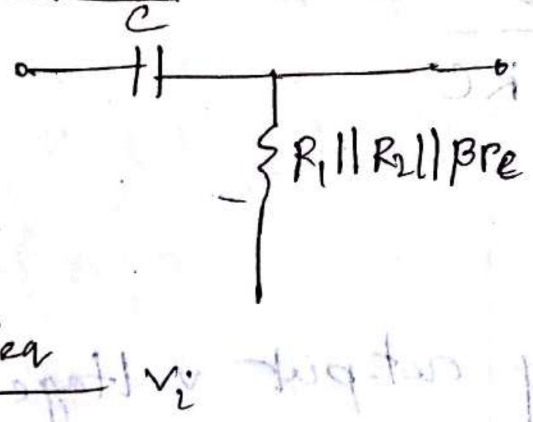


effect of C_S (C_C and C_E short)



$$R_{eq} = Z_i = R_1 \| R_2 \| \beta r_e$$

High pass filter



Cut-off frequency

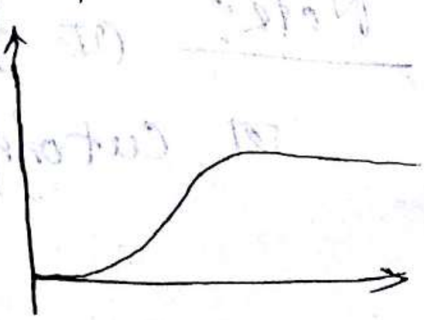
$$f_{L_S} = \frac{1}{2\pi (R_1 \| R_2 \| \beta r_e) C_S}$$

Lower

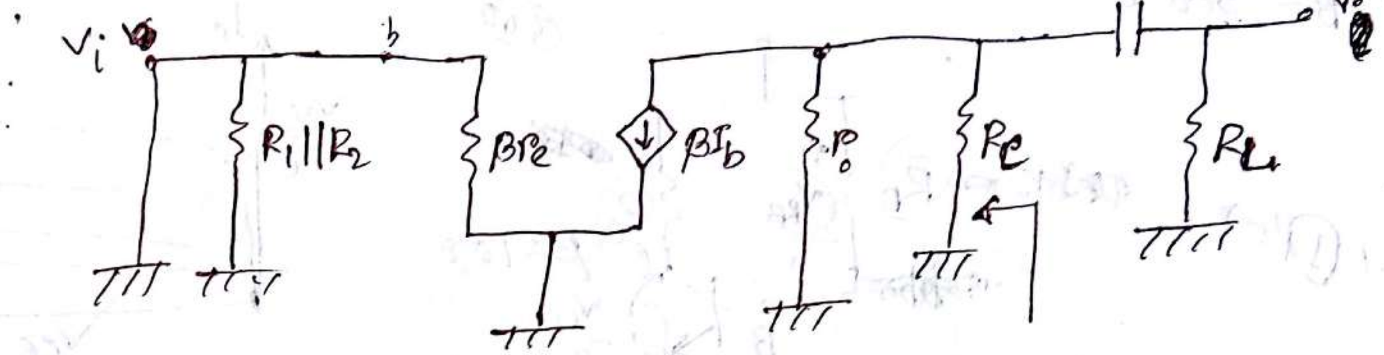
C_S

$$V_o = \frac{R_{eq}}{R_{eq} + X_C} V_i$$

$V_o = V_i$ when $f = \infty$



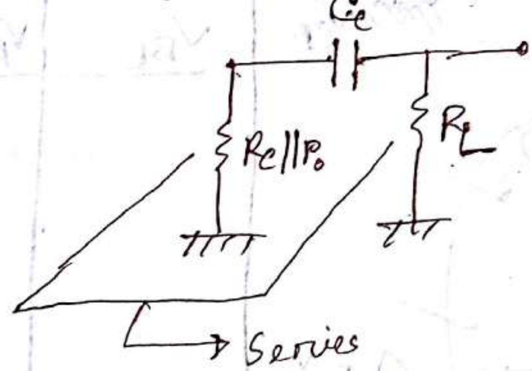
effect of C_c (C_s and C_E short):



$I_b = 0$ [No potential diff.]

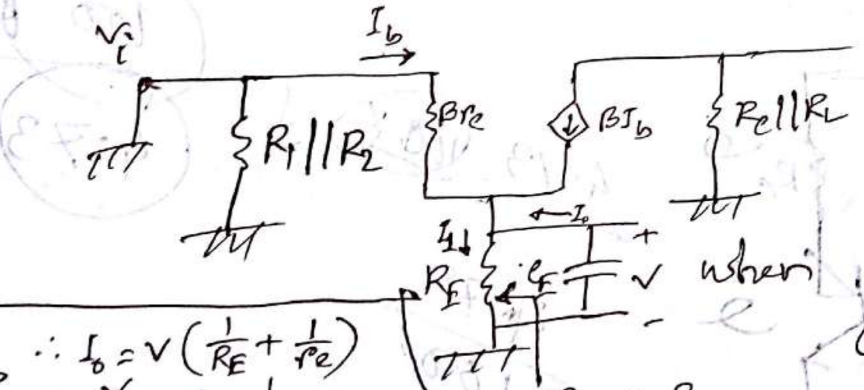
$\beta I_b = 0$

$R_c || r_o$



$$f_{LC} = \frac{1}{2\pi (R_L + R_c||r_o) C_c}$$

effect of C_E (C_s and C_c short)



$$X_{CE} = \frac{1}{2\pi f C_E}$$

$$f_{LE} = \frac{1}{2\pi (R_E || r_e) C_E}$$

when $f = \infty$

$C_E = 0$

$\therefore Z_{eq} = 0$

So, gain maximum.

$R_{eq} = ?$

$\therefore I_o = V\left(\frac{1}{R_E} + \frac{1}{r_e}\right)$

$\Rightarrow \frac{V}{I_o} = \frac{1}{\frac{1}{R_E} + \frac{1}{r_e}}$

$R_{eq} = \frac{V}{I_o}$

$\therefore \frac{V}{I_o} = R_E || r_e$

$\therefore I_1 = I_o + I_b + \beta I_b$

$\Rightarrow \frac{V}{R_E} = I_o + \beta I_b$ [$\because \beta + 1 \approx \beta$]

$= I_o - \frac{V}{r_e}$

$V = -I_b \beta r_e$

$I_b = -\frac{V}{\beta r_e}$

$R_1 || R_2$ থাকবে না

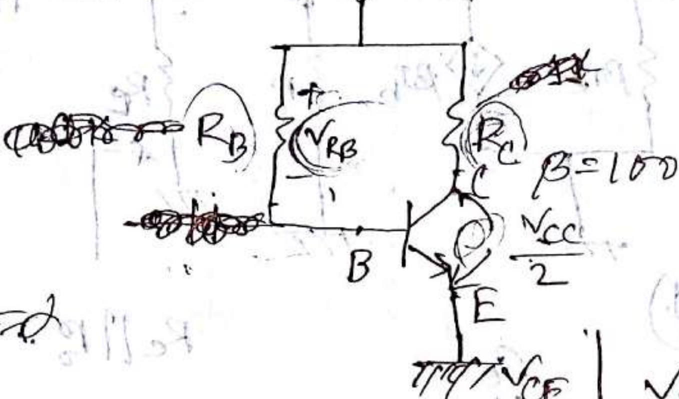
P same

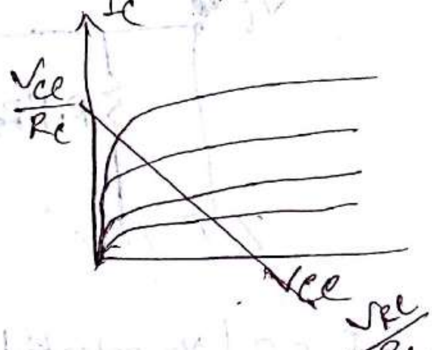
8(C)-Day

Date: 31/5/2016

$R_C = 500\,\Omega$ (1K||1K) Lab

$R_B = 300$ K





V_{CE}	V_{BE}	V_{RB}	$I_B = \frac{V_{RB}}{R_B}$	$I_C = \frac{V_{RC}}{R_C}$	β

V_{RB}

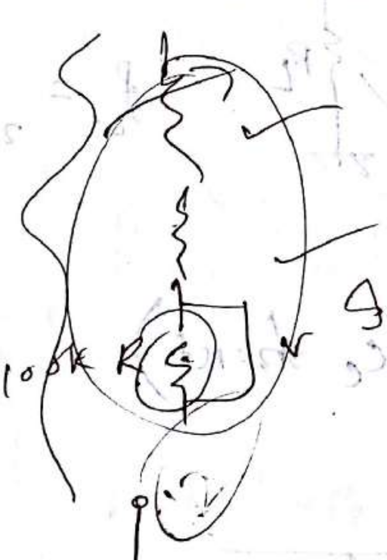
$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

$$= \frac{12 - 0.7}{100\text{K}}$$

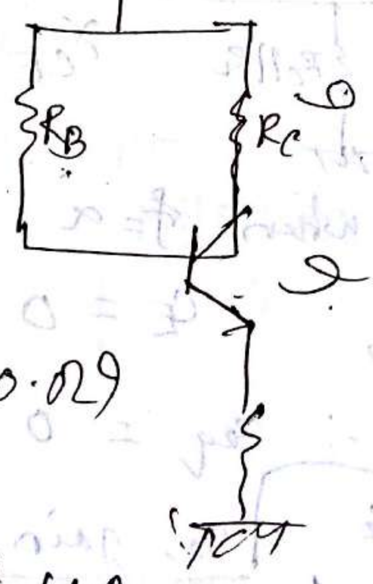
$=$

$I_C = \beta I_B$

$=$



$I = \frac{V}{R}$



0.33 K

4.14 0.029

20.7 μA

$\frac{4.73}{100\text{K}}$

100

4.73

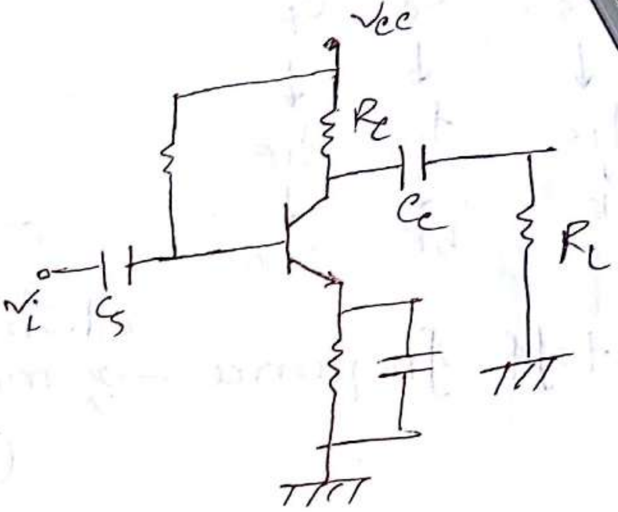
$\frac{4.73}{100}$

0.0473 mA

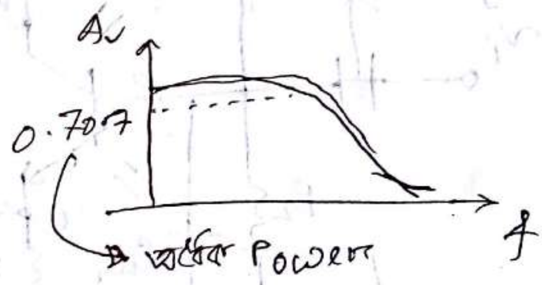
47.3 μA

8(D)-Day

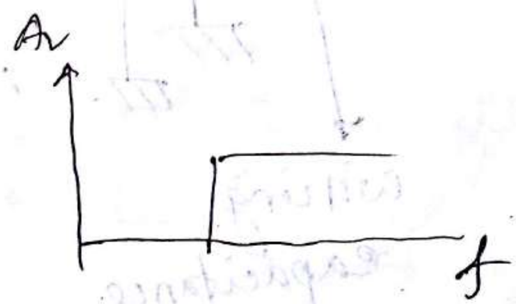
Frequency Response

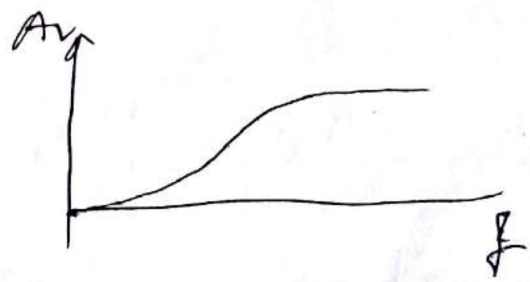


Low-pass filter

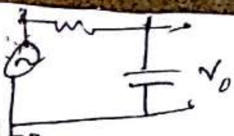


High-pass filter





Note:

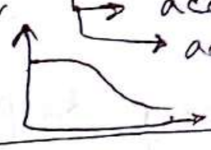


Resistor
$V_o = \frac{R}{R+jX_c} V_i$

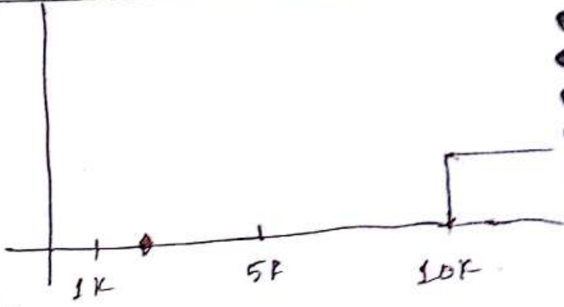
Capacitor
$V_o = \frac{jX_c}{R+jX_c} \times V_i$

[8(E)-Day] 12/7/14

Output
Av → across capacitor → Low pass filter
→ across resistance → high pass filter

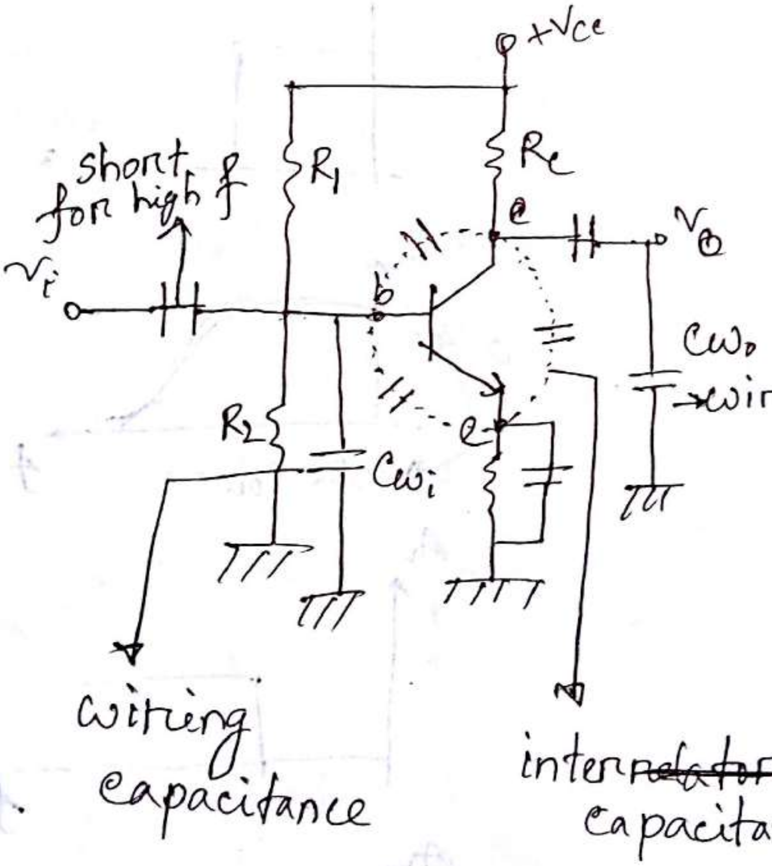


C_S, C_C, C_E
↓ ↓ ↓
f_{LS} f_{LC} f_{LE}
↓ ↓ ↓
1K 5K 10K



Lower cutoff frequence → which is maximum
(Here, 10 K)

High frequency response:



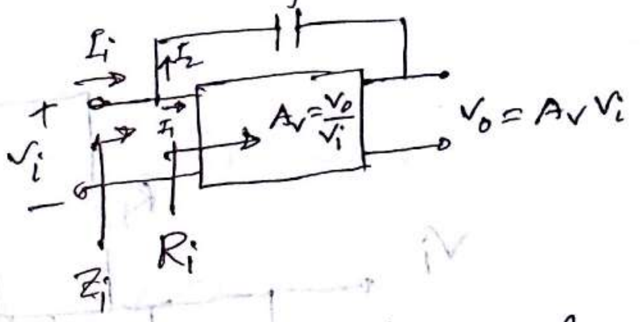
for Low frequency

$C = \frac{\epsilon A}{d}$

C is very small

$X_C = \infty$
$= \frac{1}{2\pi f C}$

$C_f \rightarrow$ inter electrode



$\hookrightarrow$ total input impedance

$$I_i = I_1 + I_2$$

$$\Rightarrow \frac{V_i}{Z_i} = \frac{V_i}{R_i} + \frac{V_i - V_o}{jX_{cf}}$$

$$\Rightarrow \frac{V_i}{Z_i} = \frac{V_i}{R_i} + \frac{V_i - A_v V_i}{jX_{cf}}$$

$$\Rightarrow \frac{1}{Z_i} = \frac{1}{R_i} + \frac{1 - A_v}{jX_{cf}}$$

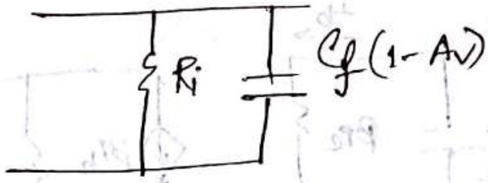
$$\Rightarrow \frac{1}{Z_i} = \frac{1}{R_i} + \frac{1}{\frac{jX_{cf}}{1-A_v}}$$

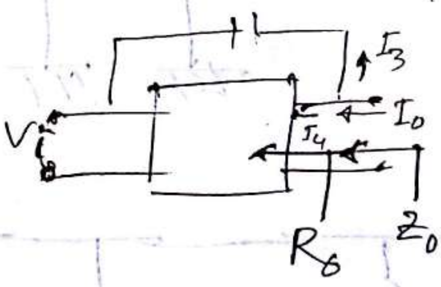
$$\therefore Z_i = R_i \,||\, \frac{jX_{cf}}{1-A_v}$$

$$\frac{jX_{cf}}{1-A_v} = \frac{j\frac{1}{\omega C_f}}{1-A_v} = \frac{j}{\omega C_f(1-A_v)}$$

$$C_{Mi} = C_f(1-A_v)$$

Equivalent circuit:





$$V_i = \frac{V_o}{A_v}$$

$$I_o = I_3 + I_4$$

$$\Rightarrow \frac{V_o}{Z_o} = \frac{V_o - V_i}{jX_{cf}} + \frac{V_o}{R_o}$$

$$\Rightarrow \frac{V_o}{Z_o} = \frac{V_o - \frac{V_o}{A_v}}{jX_{cf}} + \frac{V_o}{R_o}$$

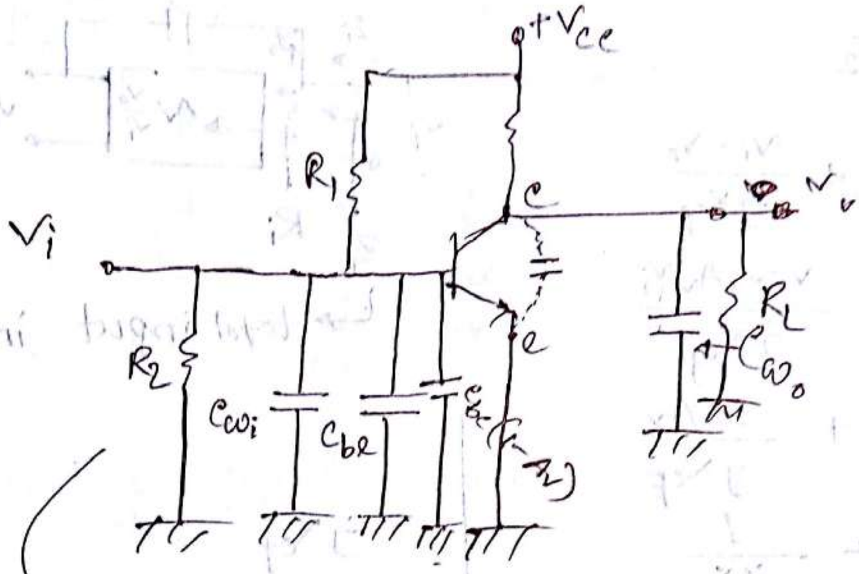
$$\Rightarrow \frac{1}{Z_o} = \frac{1}{\frac{jX_{cf}}{\frac{A_v - 1}{A_v}}} + \frac{1}{R_o}$$

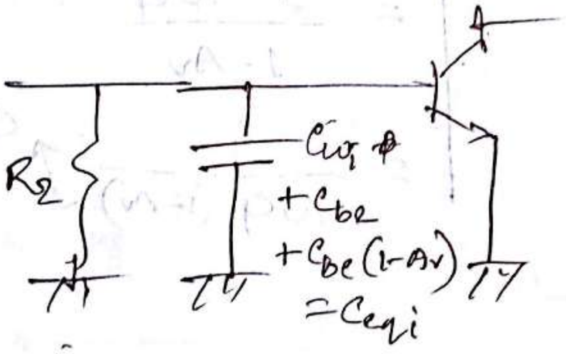
$$\therefore Z_o = R_o \,||\, \frac{jX_{cf}A_v}{A_v - 1}$$

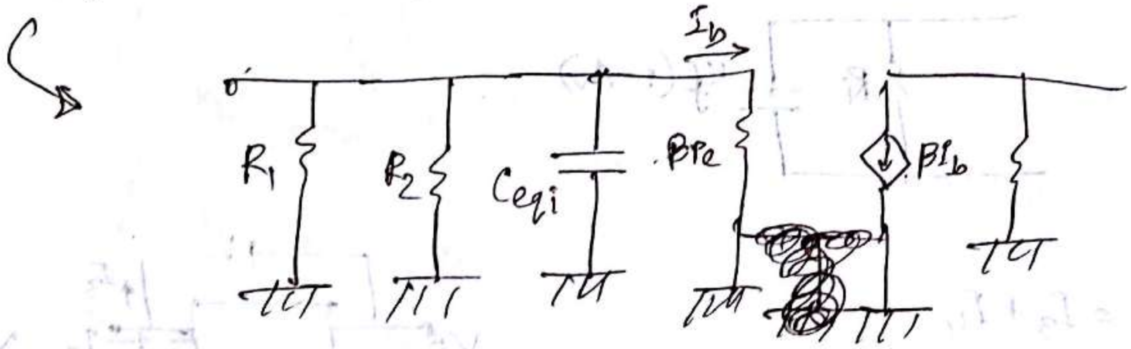
$$= R_o \,||\, \frac{jA_v}{\omega C_f(A_v - 1)}$$ [Reactance]

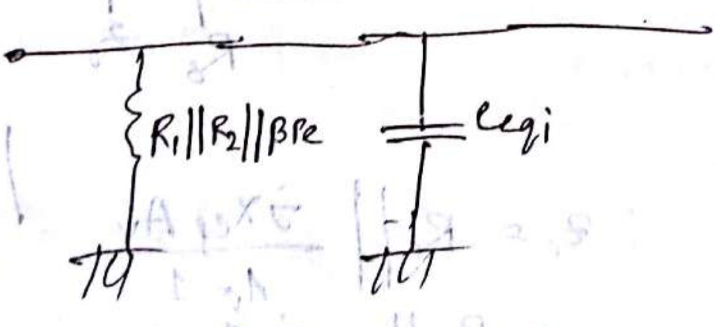
$$C_{Mo} = \frac{C_f(A_v - 1)}{A_v}$$

& Capacitance

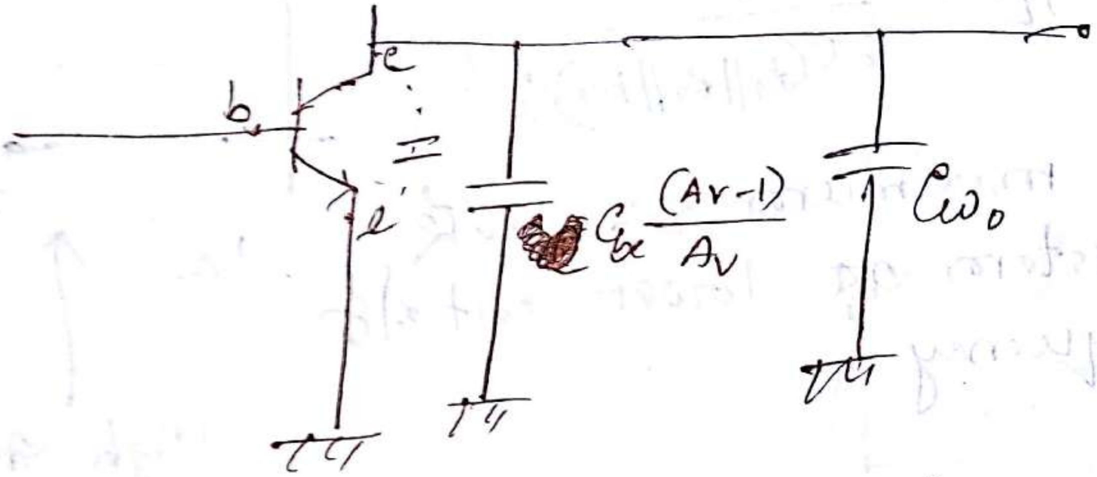




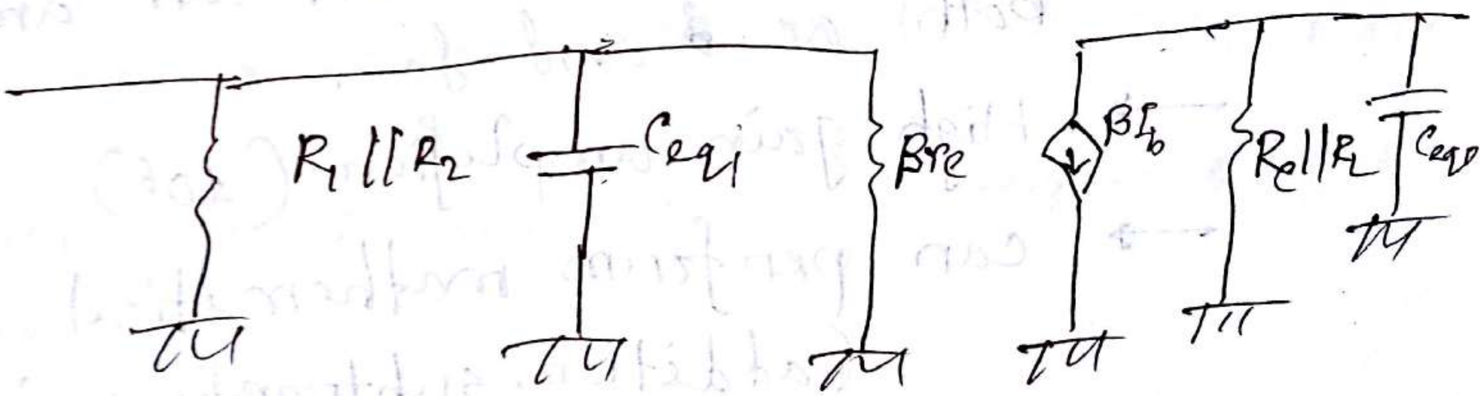




$$f_{H_i} = \frac{1}{2\pi (R_1 || R_2 || \beta r_e) C_{eqi}}$$



$$C_{w_o} + C_{ce} + C_{bc}\left(\frac{A_v - 1}{A_v}\right)$$

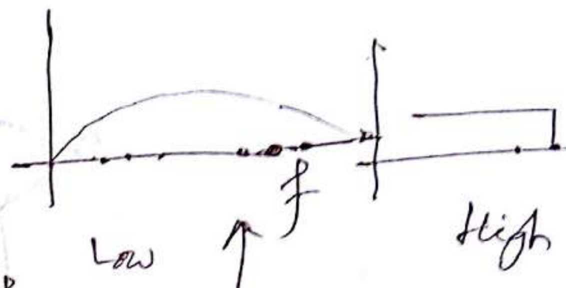


9(B)-Day

Date- 16/7/2016

$$f_L = \frac{1}{2\pi (R_1 || R_2 || \beta R_E) C_S}$$

যেটা maximum হবে সেটাই এ system এর lower cut off frequency.



High এবং Low frequency কে Pass করতে দেয় না। Band pass filter

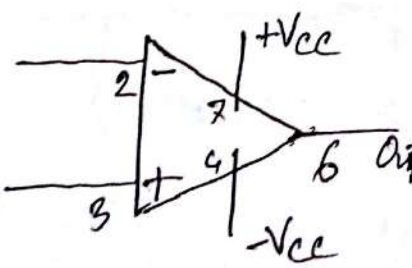
Op-Amp: (Operational Amplifier / differential amplifier)

→ versatile device which can amplify both ac and dc.

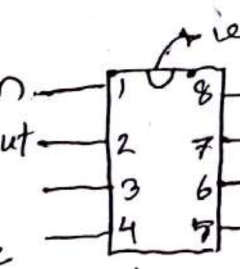
→ High gain amplifier (10^6)

→ can perform mathematical operation. (addition, subtraction, integration, differentiation)

That's why it's called operational amplifier.



Symbol



balance pin — 1 | 8 — No connection

inverting input — 2 | 7 — +Vcc

non- " " — 3 | 6 — Output. $V_0 = A(V_3 - V_2) = AV_d$ (A → gain)

−Vcc — 4 | 5 — balance pin

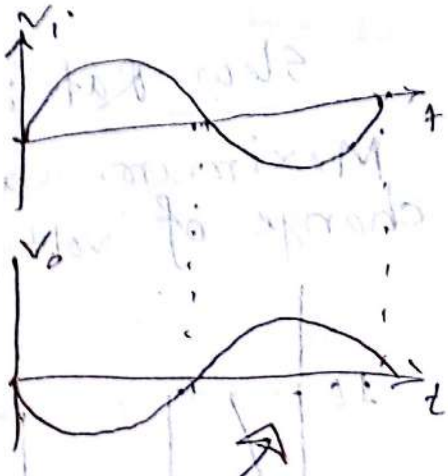
pin configuration

→ negative biasing voltage যেটা লাগে

Scanned by CamScanner

differential amplifier:

2 এবং 3 নং এ অবস্থিত voltage এর difference কে amplify করে।



inverting

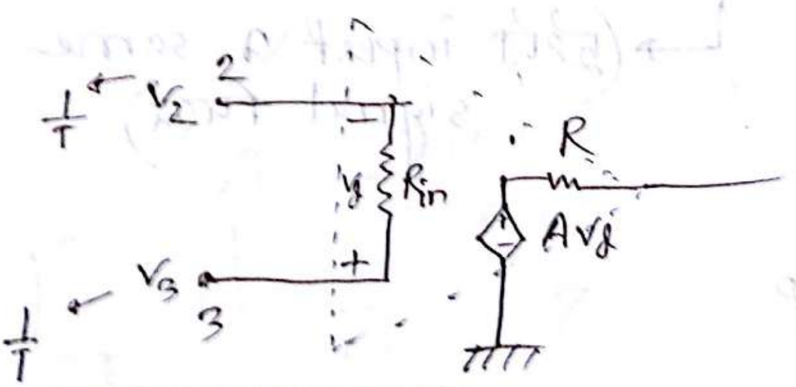
Ideal Characteristics

1) Input impedence infinite. $Z_{in} = \alpha$.
2) Ouput impedence zero. $Z_o = 0$.
3) Open loop gain $= \alpha$.
4) slew rate $= \alpha$.
5) CMRR $= \infty$.

CMRR $\rightarrow$ Common Mode Rejection Ratio

* দুইটা Pin এ noise সমান হওয়ায় Output এ noise amplified হবে না।

AC equivalent circuit:



At ideal case $\rightarrow$

$R_{in} = \alpha$
so open

$R = 0$
so short

$$\boxed{\begin{aligned} -V_3 + V_d + V_2 &= 0 \\ \therefore V_d &= V_3 - V_2 \end{aligned}}$$

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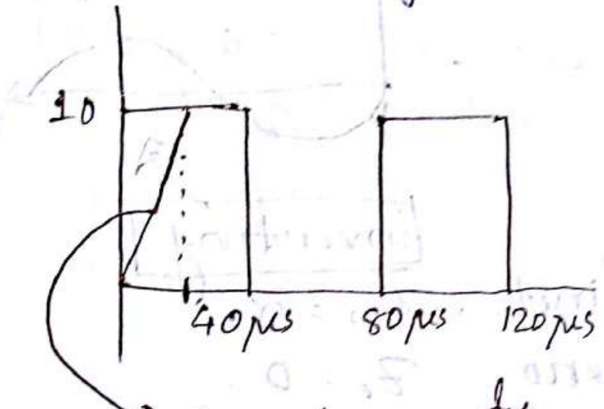
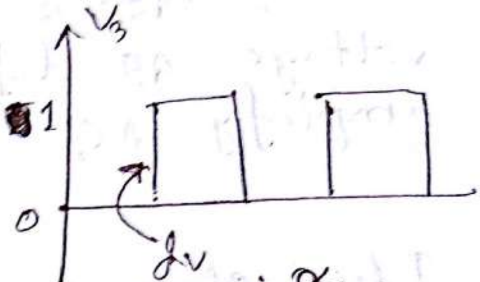
Slew Rate:

Maximum ability of ~~of~~ changing rate of change of voltage



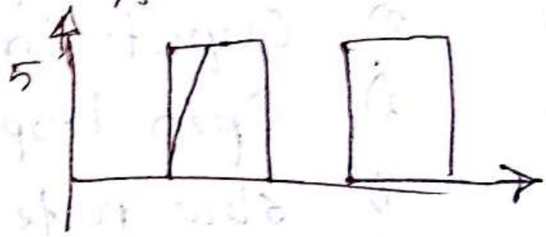


$\rightarrow 0.5\ V/\mu s = \frac{dy}{dx} = \frac{10\ V}{20\ \mu s}$

$= 0.5\ V/\mu s$

$\hookrightarrow$ slew rate

A = 5



0.5 V/μs

যদি 1 μs এ 0.5 V change করতে পারে।

CMRR:

$$CMRR = \frac{A_d}{A_c}$$

$A_d \rightarrow$ differential gain (open loop)

$A_c \rightarrow$ Common mode gain

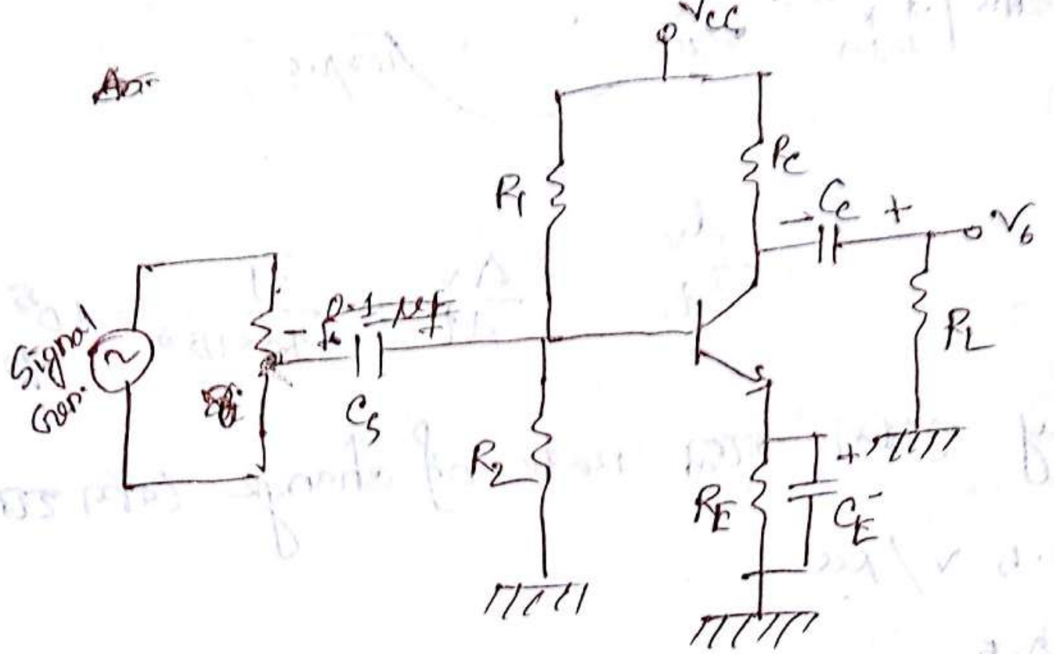
$\hookrightarrow$ (দুইটা input এ same signal দিলে)

Gayakward $\rightarrow$ Op-Amp

Date: 17/7/2016.

EEE Lab

Exp: Study of voltage divider biased BJT circuit as an amplifier.



$R_L = 2.2K$

$V_{CC} = 12V$

$R_C = 2.2K$

$R_1 = 15K$

$R_2 = 4.7K$

$R_E = 1K$

without load

$$A = -\frac{R_C}{r_e}$$

with Load

$$A = -\frac{R_C \| R_L}{r_e}$$

$$r_e = \frac{26\,mV}{I_E}$$

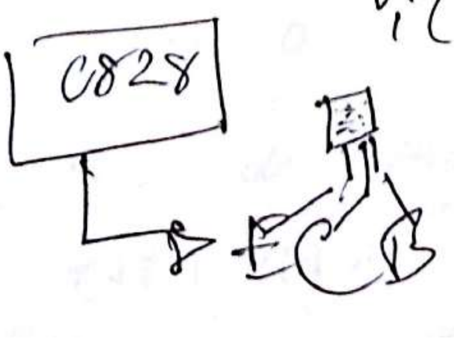
$C_S = C_C = C_E = 1\,\mu F$

$v_i \approx 50\,mV$ এর নিচে

$v_i\ (p-p) = ?$

$v_o\ (p-p) = ?$

$$A = \frac{v_o\,(p-p)}{v_i\,(p-p)}$$



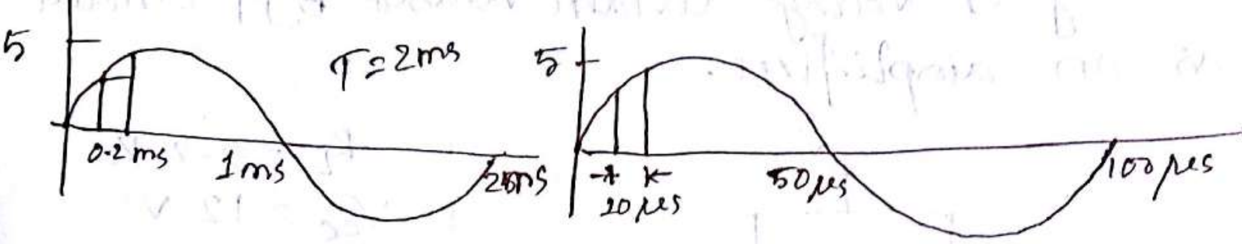
$x + y + 2z = 0$

$2x\ 3z = 0$

$6z = 0$

9(D)-Day

Date: 18/7/2016



$\frac{dv}{dt} = \frac{1}{0.2\times10^{-3}}$

$= 5000$ v/s

$\frac{dv}{dt} = \frac{\Delta v}{\Delta t} = \frac{1}{10\times10^{-6}} = 10^5$ v/s

frequency বাড়লে হলে rate of change বেশি হবে

$SR = 0.5$ V/μs

$= \frac{0.5}{10^{-6}}$

$= 5\times10^5$ v/s

rate of change of voltage 5×10^5 v/s এর বেশি হওয়া যাবেনা।

$v = 5\sin\theta$

$\frac{dv}{dt} = 5\cos\theta$

$\theta = 0$ হলে $\frac{dv}{dt} = 5$

$$v = V_m \sin \omega t$$

$$\frac{dv}{dt} = V_m \omega \cos \omega t$$

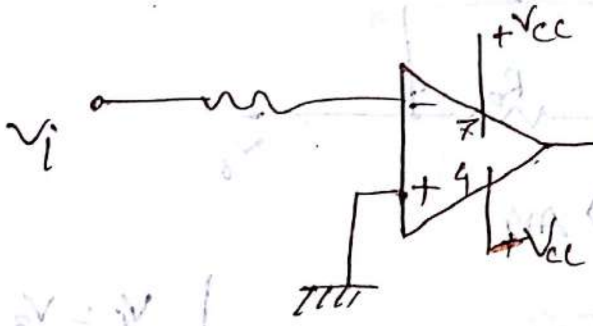
$$\left.\frac{dv}{dt}\right|_{max} = V_m \omega = V_m \times 2\pi f$$

frequency ↑ rate of change of voltage ↑

$$\boxed{V_m \omega \leq SR}$$

$$\boxed{f \leq \frac{SR}{2\pi V_m}}$$

হতে হবে। না হলে signal distoret হয়ে যাবে। [sinusoidal থেকে triangular হয়ে যাবে]



$$V_o = A\,v_d = A(v_3 - v_2)$$

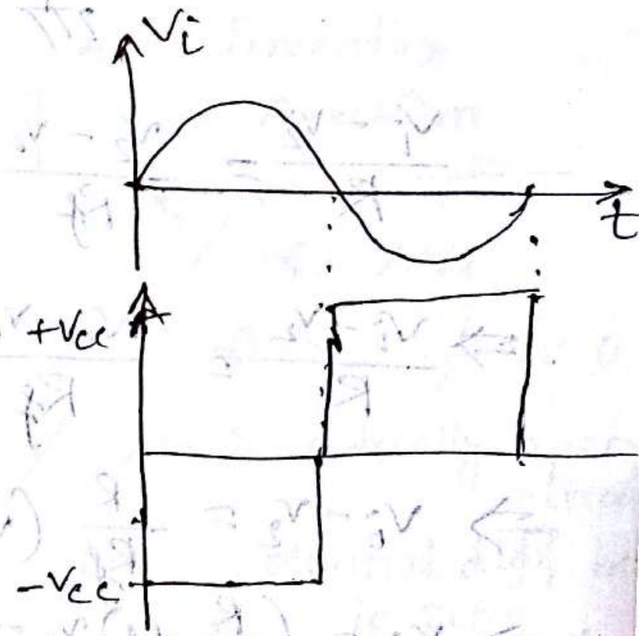
(+)ve half cycle

$$V_d = -V_i$$

$$v_2 = V_i$$

$$v_3 = 0$$

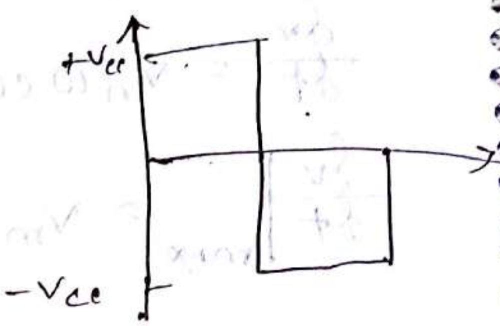
$V_o = -\alpha$, কিন্তু $-V_{cc}$ এর বেশি হবে না।

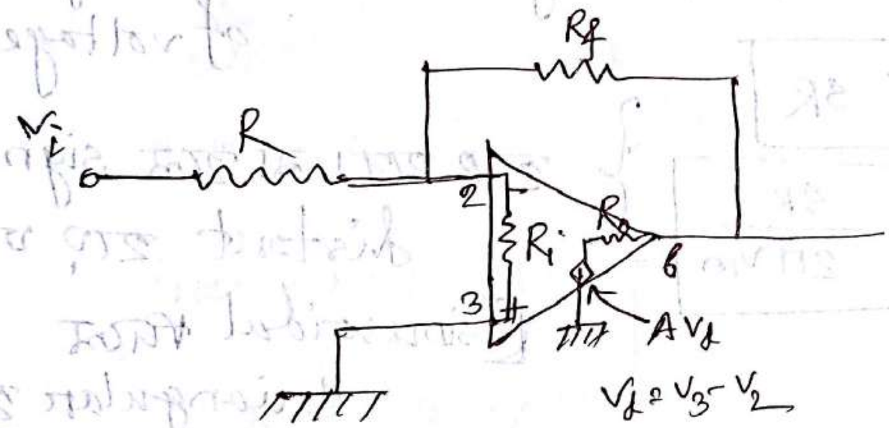


(-)ve half cycle:

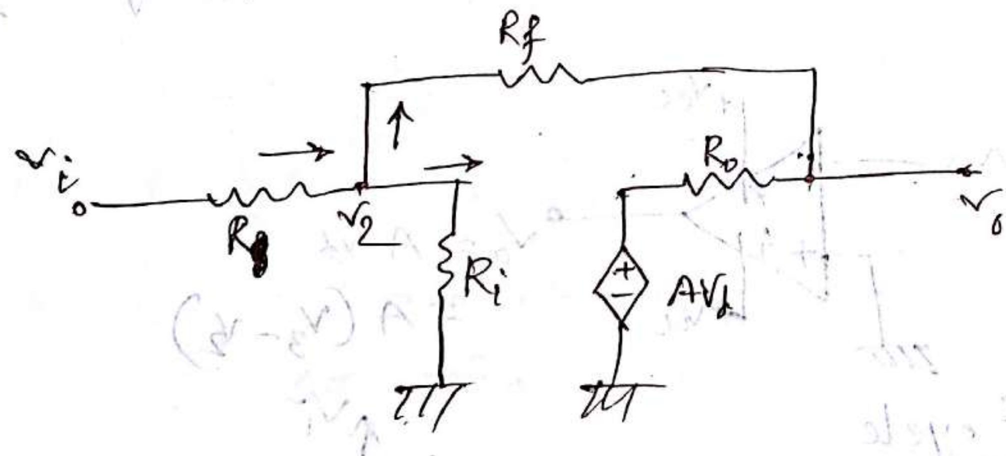
$V_2 = -v_i$ $\quad V_d = v_i$

$V_3 = 0$ $\quad \therefore V_o = \alpha$





$V_d = V_3 - V_2$



$V_d = V_3 - V_2$
$= -V_2$

$$\frac{V_i - V_2}{R} = \frac{V_2 - V_o}{R_f} + \frac{V_2}{R_i}$$

$$\Rightarrow \frac{V_i - V_2}{R} = \frac{V_2 - V_o}{R_f} \quad \text{when } R_i = \alpha$$

$$\Rightarrow V_i - V_2 = \frac{R}{R_f}(V_2 - V_o)$$

$$\Rightarrow V_i = \left(\frac{R}{R_f} + 1\right) V_2 - \frac{R}{R_f} V_o \quad \text{--- (1)}$$

$V_o = A V_d = -A V_2$

$\Rightarrow V_2 = -\frac{V_o}{A} = 0 \quad |_{A=\alpha}$

$$v_i = -\frac{R}{R_f} v_o \quad [\text{From (i)}]$$

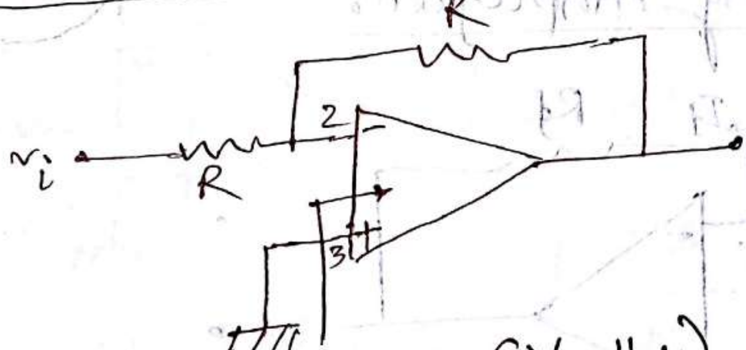
$$\Rightarrow V_o = -\frac{R_f}{R} v_i$$

$$\therefore A = -\frac{R_f}{R}$$

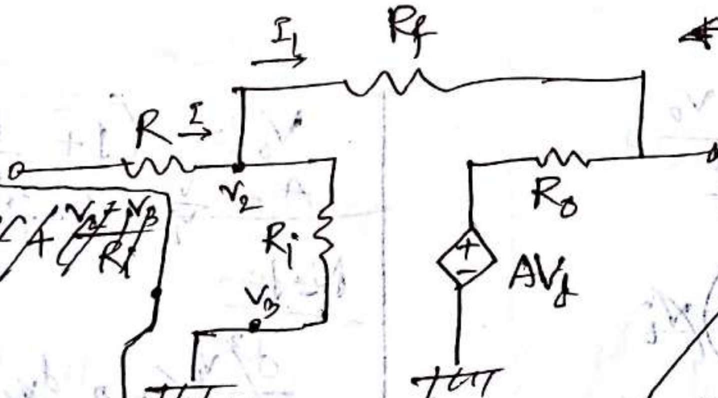
Date : 19/7/2016

9 (E) - Day

Virtual Ground:



$R_i = \alpha$ (ideally)



← Inverting Amplifier

~~$\frac{V_i - V_2}{R} = \frac{V_2 - V_o}{R_f} + A \frac{V_2 - V_3}{R_i}$~~

$v_o = AV_d$

$\Rightarrow V_d = \frac{V_o}{A} \approx 0$

$V_d = V_3 - V_2$

$V_o = AV_d$
$= A(V_3 - V_2)$
$= -AV_2 \quad [V_3 = 0]$
$\therefore V_2 = -\frac{V_o}{A} \approx 0$ (Ideally $A = \alpha$)

2 ↔ 3 Actually open circuit

But potential diff between 2 and 3 is zero

3 → 0 V ∴ 2 → 0 V so, 2 virtually ground

~~[Alexander]~~

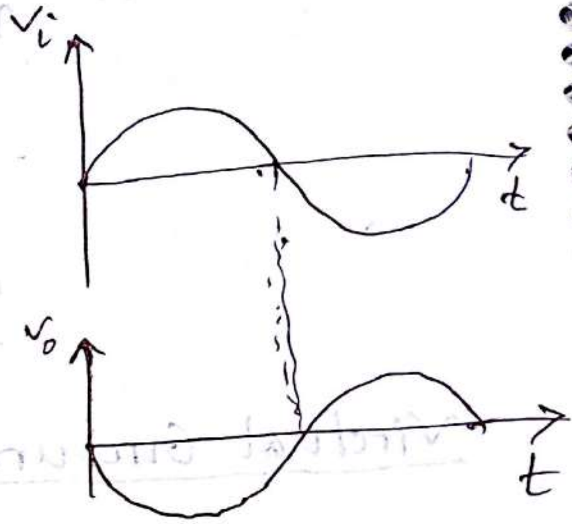
$2 \leftrightarrow 3 \longrightarrow R_i = \alpha$

$$I = I_1$$

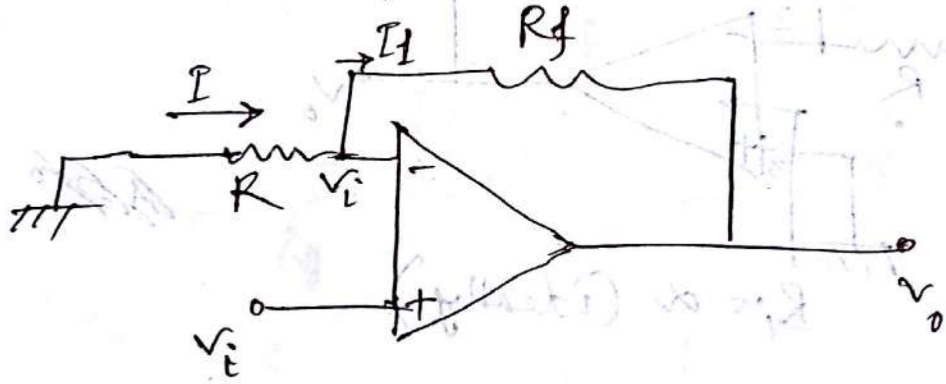
$$\Rightarrow \frac{v_i - 0}{R} = \frac{0 - V_0}{R_f}$$

$$\Rightarrow V_0 = -\frac{R_f}{R} v_i$$

$$\Rightarrow A = \frac{V_0}{V_i} = -\frac{R_f}{R}$$



Non-inverting Amplifier:



$$\frac{0 - V_i}{R} = \frac{V_i - V_0}{R_f}$$

$$\cancel{V_0 = \left(1 + \frac{R_f}{R}\right) V_i}$$

$$\Rightarrow -\frac{V_i}{R} = \frac{V_i}{R_f} - \frac{V_0}{R_f}$$

$$\Rightarrow \frac{V_0}{R_f} = \frac{V_i}{R_f} + \frac{V_i}{R}$$

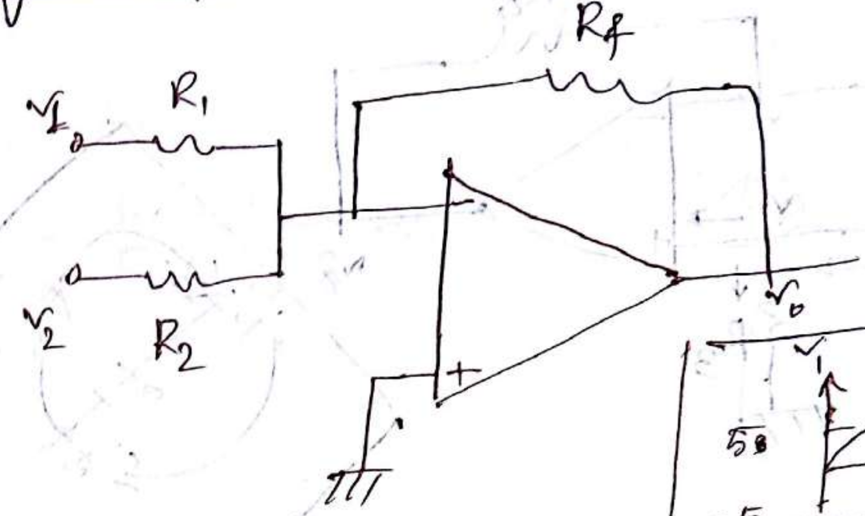
$$V_0 = \left(1 + \frac{R_f}{R}\right) V_i$$

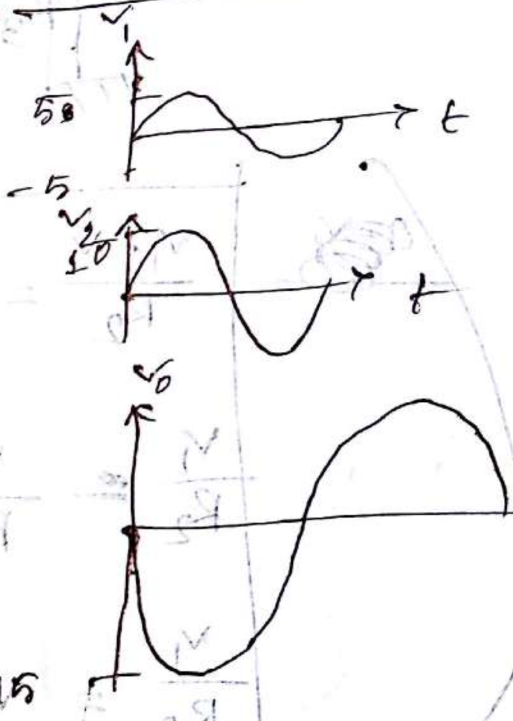
$$A = \frac{V_0}{V_i} = 1 + \frac{R_f}{R}$$

Note

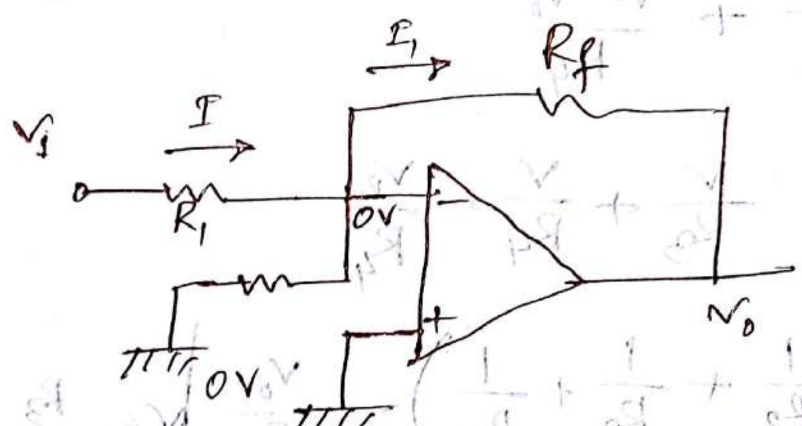
$$\frac{d^2 V_0}{dt^2} + 2\frac{dV_0}{dt} -$$

Summing Amplifier:





V_1 active, V_2 inactive



$$V_{01} = -\frac{R_f}{R_1} V_i \quad \text{[like inverting Amplifier]}$$

$$\frac{V_1 - 0}{R} = \frac{0 - V_{01}}{R_f}$$

$$\therefore V_{01} = -\frac{R_f}{R_1} V_1$$

Similarly,

$$V_{02} = -\frac{R_f}{R_2} V_2$$

$$V_0 = V_{01} + V_{02}$$

$$= -\frac{R_f}{R_1} V_1 - \frac{R_f}{R_2} V_2$$

if $R_1 = R_2 = R$

$$V_0 = -\frac{R_f}{R}(V_1 + V_2)$$

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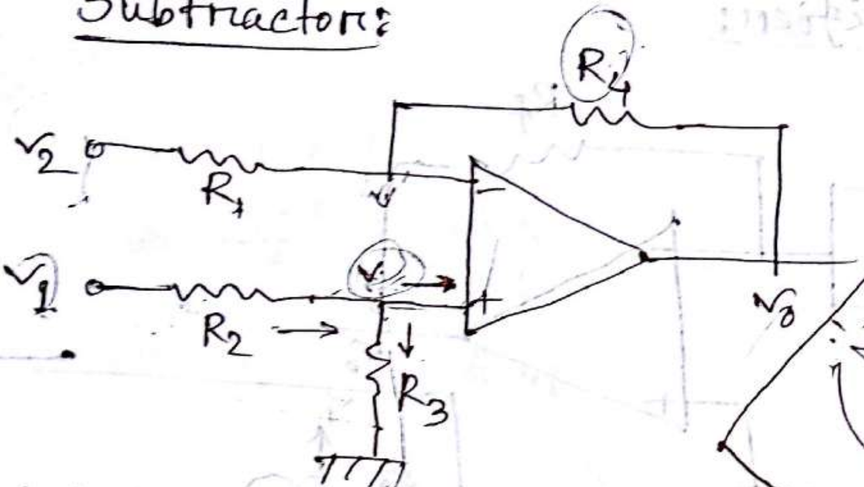
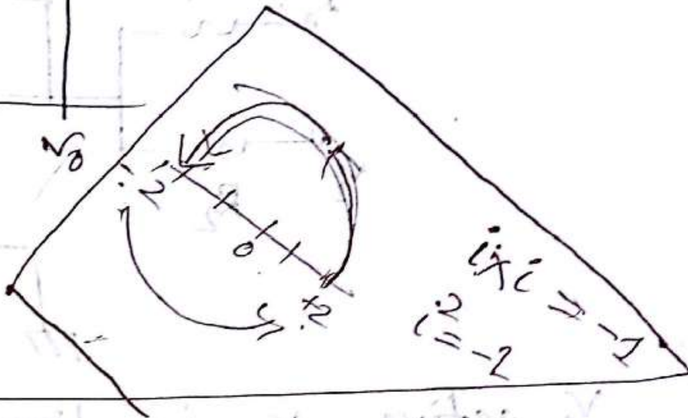
Subtractor:





$$\frac{v_1 - v}{R_2} = \frac{v - 0}{R_3} + \frac{v - v_0}{R_4}$$

$$\frac{v_1}{R_2} - \frac{v}{R_2} = \frac{v}{R_3} + \frac{v}{R_4} - \frac{v_0}{R_4}$$

$$\frac{v_1}{R_2} = v\left(\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right) - \frac{v_0}{R_4}$$

$$v = \frac{R_3}{R_2 + R_3} v_1$$

$$v_{o1} = \left(1 + \frac{R_4}{R_1}\right) v$$ [like non inverting Amplifier]

$$= \left(1 + \frac{R_4}{R_1}\right) \frac{R_3}{R_2 + R_3} v_1$$

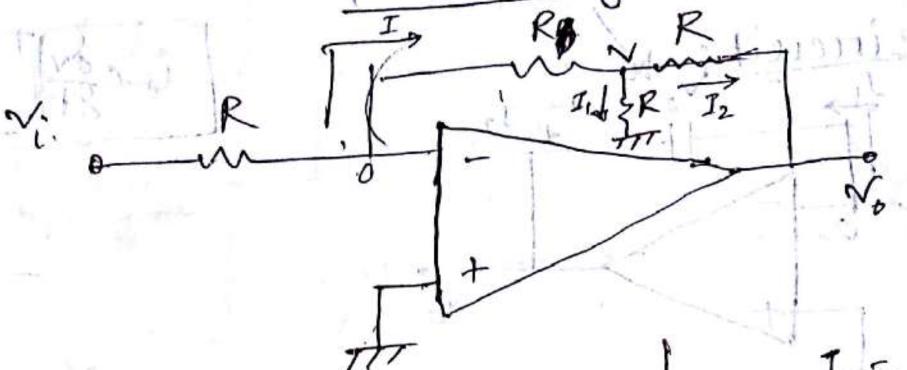
$$v_{o2} = -\frac{R_4}{R_1} v_1$$ [like inverting Amplifier]

$$V_0 = V_{o1} + V_{o2}$$

$$= \left(1 + \frac{R_4}{R_1}\right)\frac{R_3}{R_2 + R_3} V_1 - \frac{R_4}{R_1} V_1$$

Date: 25/7/2016

10(D)-Day



$$\frac{V_i - 0}{R} = \frac{0 - V_o}{R}$$

$$\Rightarrow V = -V_i$$

$$I = I_1 + I_2$$

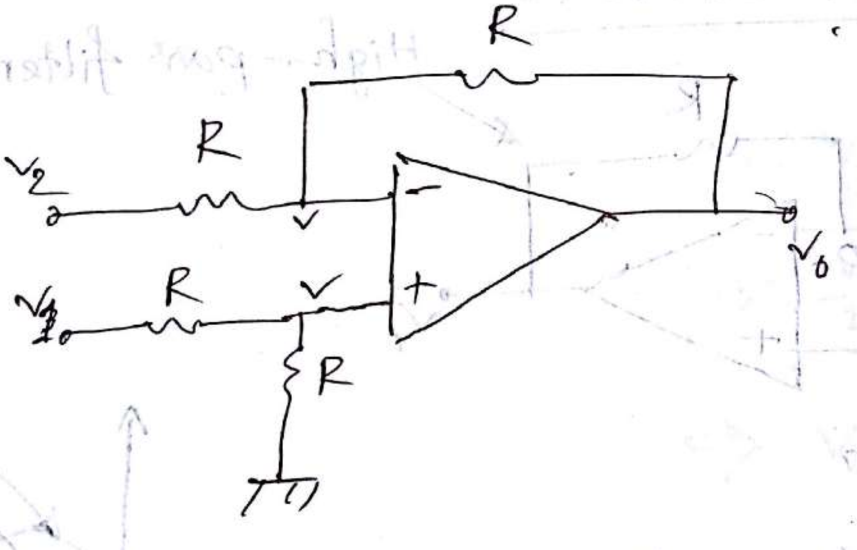
$$\frac{0 - V}{R} = \frac{V}{R} + \frac{V - V_o}{R}$$

$$\Rightarrow -V = V + V - V_o$$

$$\Rightarrow 3V = V_o$$

$$\Rightarrow -3V_i = V_o$$

$$\therefore V_o = -3V_i$$



$$\frac{V_2 - V}{R} = \frac{V - V_o}{R}$$

$$\Rightarrow V_2 - V = V - V_o$$

$$\Rightarrow 2V = V_2 + V_o$$

$$\frac{V_1 - V}{R} = \frac{V}{R}$$

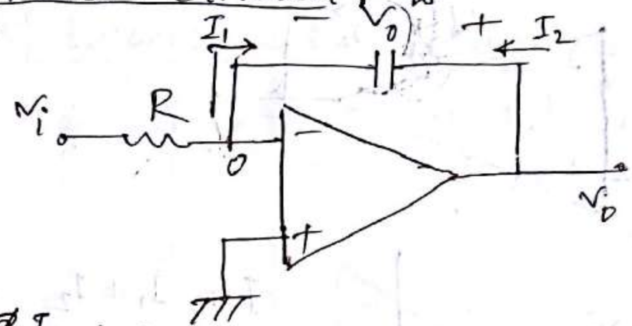
$$\Rightarrow V_1 = 2V = V_2 + V_o$$

$$\Rightarrow V_1 - V_2 = V_o$$

$$\therefore V_o = V_1 - V_2$$

Low-pass filter

Integrator circuit:



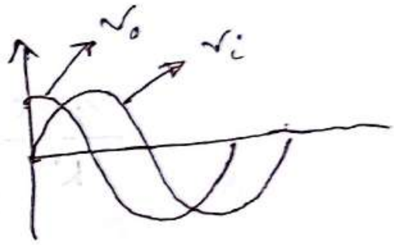
$\boxed{i_c = C\frac{dv}{dt}}$

$I_1 + I_2 = 0$

$$\frac{V_i}{R} = -C\frac{dv_o}{dt}$$

$$\Rightarrow \frac{dv_o}{dt} = -\frac{1}{RC}V_i$$

$$\Rightarrow V_o = -\frac{1}{RC}\int V_i\,dt$$

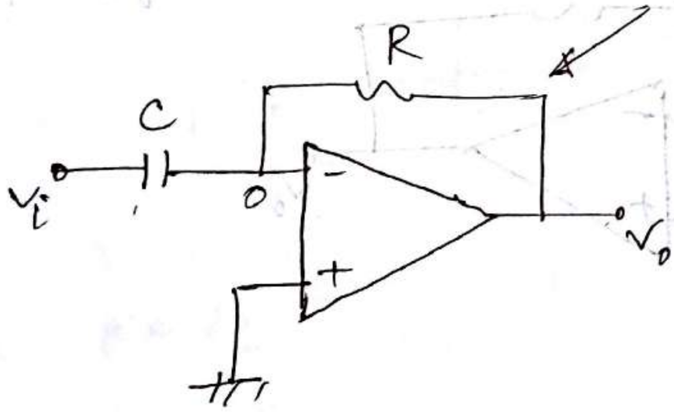


$\int \sin x = -\cos x$

এক্ষেত্রে - এ + হবে,
$+\cos x$ হবে

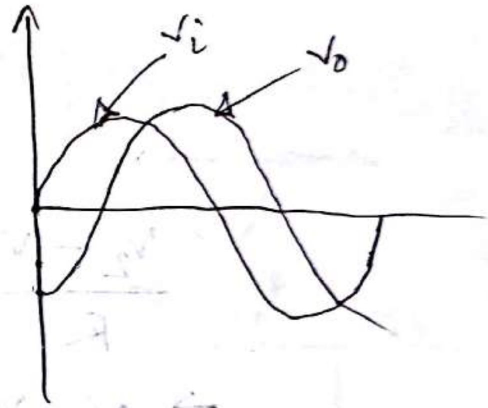
Differential circuit:

High-pass filter



$$C\frac{dV_i}{dt} = \frac{0 - V_o}{R}$$

$$\Rightarrow V_o = -RC\frac{dv_i}{dt}$$



$$\frac{d}{dx}\sin x = \cos x$$

এক্ষেত্রে - এ $-\cos x$ হবে।

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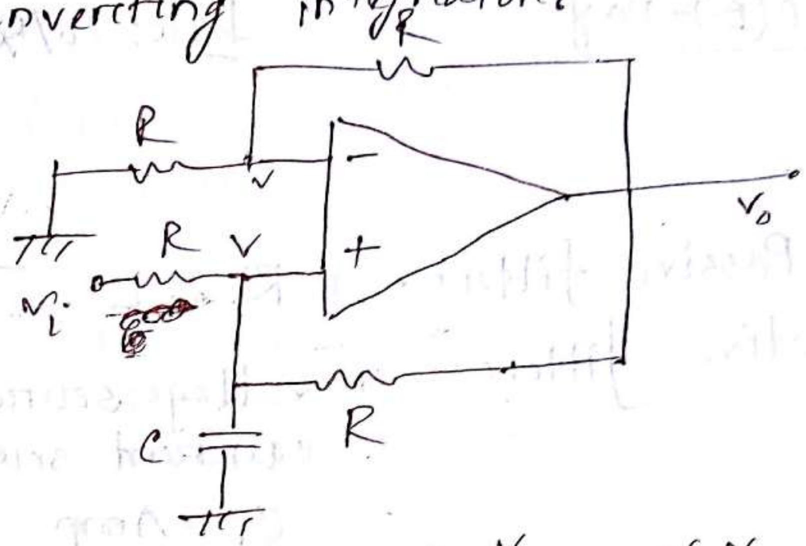
Non-inverting integrator:



$$\frac{0-v}{R} = \frac{v-v_o}{R}$$

$$\Rightarrow -v = v - v_o$$

$$\Rightarrow v_o = 2v$$

$$\frac{v_i - v}{R} = C\frac{dv}{dt} + \frac{v-v_o}{R}$$

$$\Rightarrow v_i - v = RC\frac{dv}{dt} + v - v_o$$

$$\Rightarrow v_i = RC\frac{dv}{dt} + 2v - v_o$$

$$= RC\frac{dv}{dt} + v_o - v_o$$

$$\therefore v_i = RC\frac{dv}{dt}$$

$$\therefore v = \frac{1}{RC}\int v_i\,dt$$

$$\Rightarrow \frac{v_o}{2} = \frac{1}{RC}\int v_i\,dt$$

$$\Rightarrow v_o = \frac{2}{RC}\int v_i\,dt$$

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10(E)-Day

Date: 26/7/2016

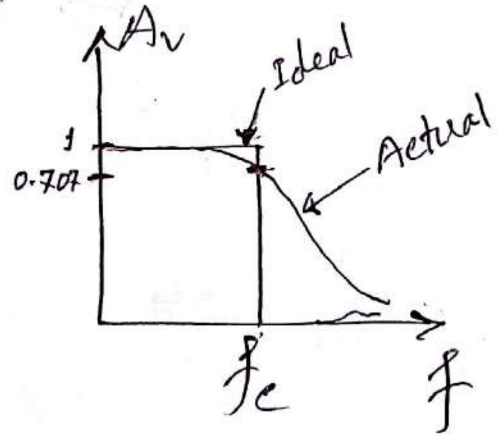
Filter:

- ~~Active~~ (i) Passive filter → R, C, L
- (ii) Active filter → voltage source, current source, OP-Amp

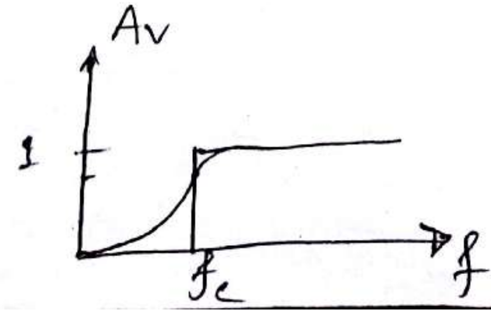
(i) Low-pass
(ii) High pass
(iii) Band pass
(iv) Band reject
(v) All pass

Active → active + passive
Passive → only passive

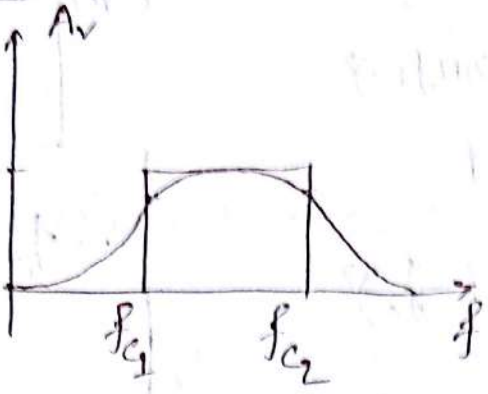
Low pass



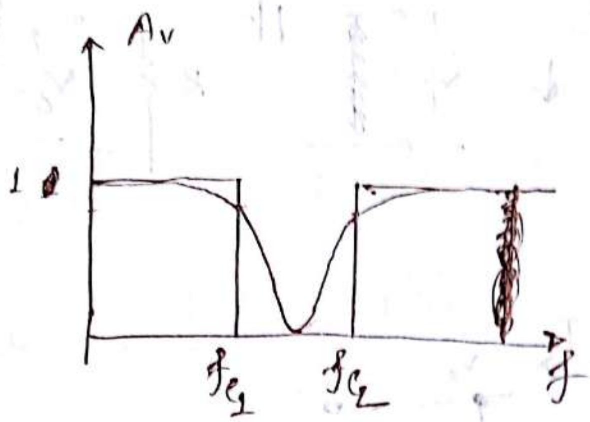
High pass



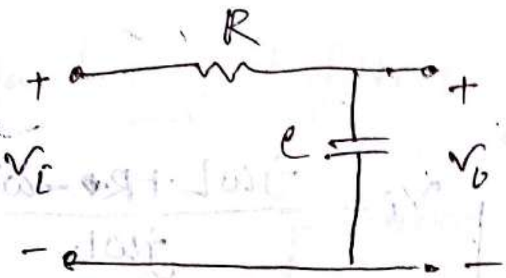
Band pass:



Band reject:



Low pass (passive)



$$V_o = \frac{\frac{1}{j\omega C}}{R + \frac{1}{j\omega C}} \times V_i$$

$$\frac{V_o}{V_i} = \frac{1}{1 + j\omega RC}$$

$$A_v = \left|\frac{V_o}{V_i}\right| = \frac{1}{\sqrt{1 + (\omega RC)^2}}$$

at, $f = f_c$,

$$A_v = \frac{1}{\sqrt{2}}$$

$$\Rightarrow \frac{1}{\sqrt{1 + (\omega RC)^2}} = \frac{1}{\sqrt{2}}$$

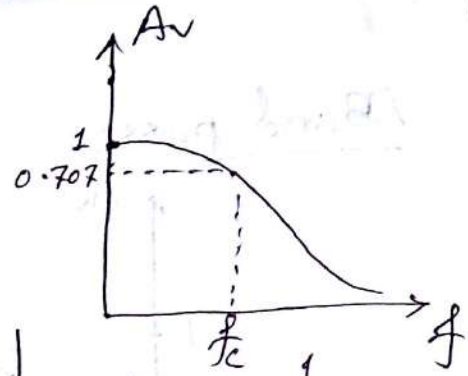
$$\Rightarrow \frac{1}{1 + (2\pi f_c RC)^2} = \frac{1}{2}$$

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

$$A_v = \frac{1}{\sqrt{1+(2\pi f RC)^2}}$$

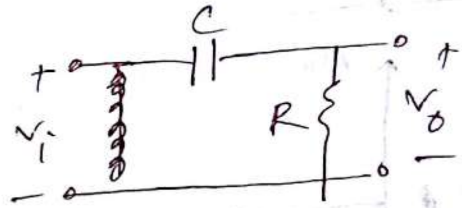
$$= \frac{1}{\sqrt{1+\left(\frac{f}{f_c}\right)^2}}$$

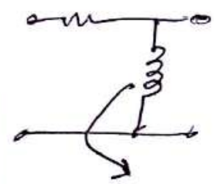
$\because f_c = \frac{1}{2\pi RC}$



High pass

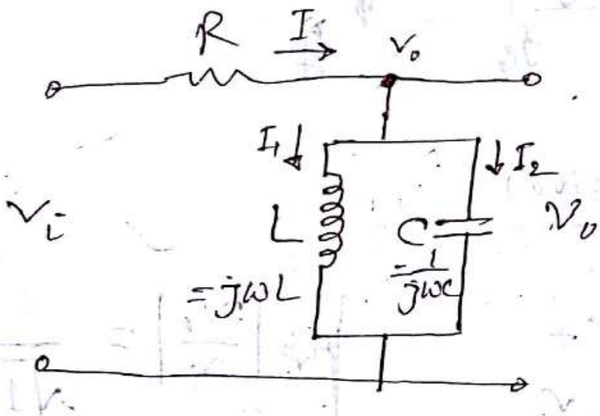
previous class





if, f=0
↳ short

Band pass (Passive):



$I = I_1 + I_2$

$$\Rightarrow \frac{v_i - v_o}{R} = \frac{v_o}{j\omega L} + \frac{v_o}{\frac{1}{j\omega C}}$$

$$\Rightarrow v_i - v_o = \frac{R}{j\omega L} v_o + j\omega RC\, v_o$$

$$\Rightarrow v_i = \left(1 + \frac{R}{j\omega L} + j\omega RC\right) v_o$$

$$v_i = \frac{j\omega L + R - \omega^2 LRC}{j\omega L} \times v_o$$

$$\Rightarrow \frac{v_o}{v_i} = \frac{j\omega L}{j\omega L + R - \omega^2 RLC}$$

$$|A_v| = \frac{\omega L}{\sqrt{(R - \omega^2 RLC)^2 + (\omega L)^2}}$$

at $f = f_c$, $A_v = \frac{1}{\sqrt{2}}$
$\omega = \omega_c$

$$\frac{\omega_c L}{\sqrt{(R-\omega_c^2 RLC)^2 + (\omega_c L)^2}} = \frac{1}{\sqrt{2}}$$

$$\Rightarrow 2(\omega_c L)^2 = (R-\omega_c^2 RLC)^2 + (\omega_c L)^2$$

$$\Rightarrow (R-\omega_c^2 RLC)^2 = (\omega_c L)^2$$

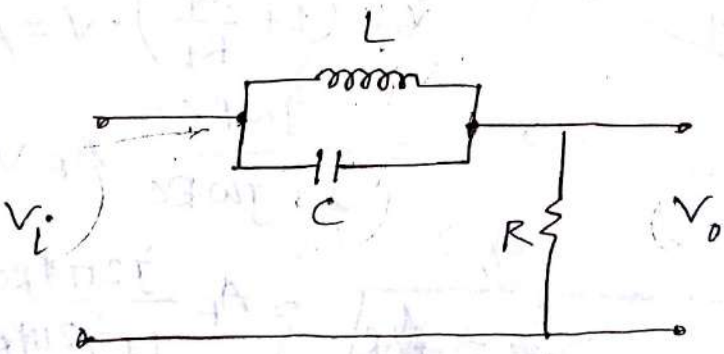
$$\Rightarrow R-\omega_c^2 RLC = \omega_c L$$

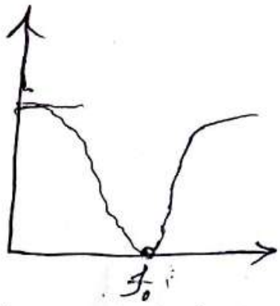
$$\Rightarrow \omega_c^2 RLC + \omega_c L - R = 0 \qquad \text{[Quadratic equation]}$$

$$\Rightarrow \omega_c = \frac{-L \pm \sqrt{L^2 + 4R^2 LC}}{2RLC}$$

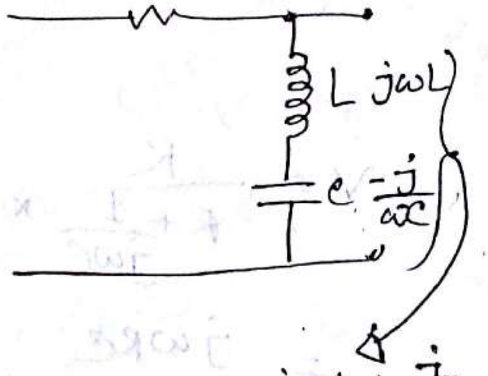
$$\Rightarrow \omega_c = -\frac{L}{2RC} \pm \sqrt{\left(\frac{1}{2RC}\right)^2 + \frac{1}{LC}}$$

Band reject filter:





or,



$$\omega L = \frac{1}{\omega C}$$

$$\Rightarrow f_0 = \frac{1}{2\pi\sqrt{LC}}$$

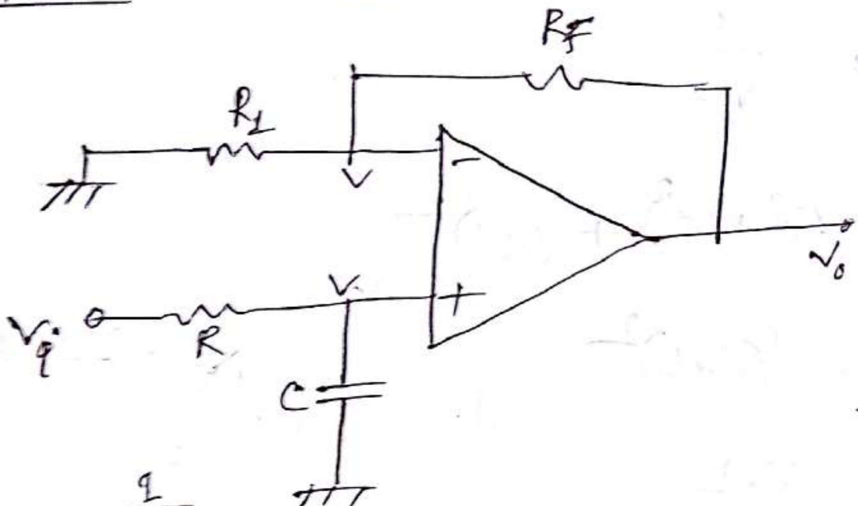
$j\omega L - \frac{j}{\omega C}$

At specific f_0, $j\omega L - \frac{j}{\omega C} = 0$, $V_0 = 0$

Active filter:

Op-Amp, R, C (No inductor)

Low pass



$$V_0 = \left(1+\frac{R_F}{R_1}\right)V$$

$$= A_F \times \frac{1}{1+j\omega RC} \times V_i$$

$$V = \frac{\frac{1}{j\omega C}}{R+\frac{1}{j\omega C}} \times V_i$$

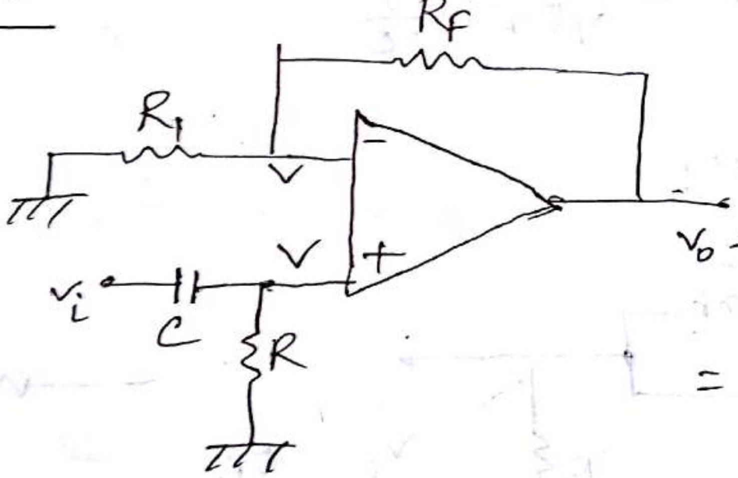
$$V = \frac{1}{1+j\omega CR} \times V_i$$

$$V_0 = \frac{1}{1+j2\pi fRC} \times V_i \times A_F$$

$$= \frac{1}{1+j\frac{f}{f_c}} \times V_i \times A_F$$

$$= \frac{A_F}{\sqrt{1+\left(\frac{f}{f_c}\right)^2}} \times V_i$$

High pass



feedback gain

$$V_0 = \left(1+\frac{R_F}{R_1}\right) \times V = A_F V$$

$$= \frac{j\omega RC}{1+j\omega RC} A_F V_i$$

$$= A_F \frac{j2\pi fRC}{1+j2\pi fRC} \times V_i$$

$$= A_F \frac{j(f/f_c)}{1+j(f/f_c)} \times V_i$$

$$V = \frac{R}{R+\frac{1}{j\omega C}} \times V_i$$

$$= \frac{j\omega RC}{1+j\omega RC} \times V_i$$

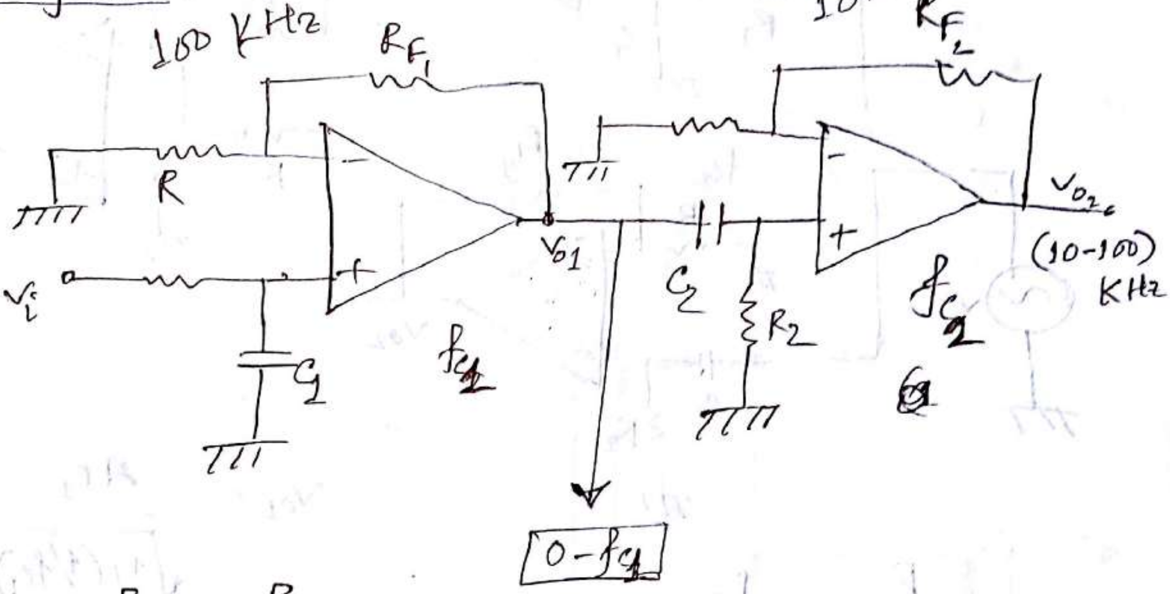
$$\boxed{\frac{1}{\omega C} = R \Rightarrow \frac{1}{2\pi f_c C} = R \Rightarrow f_c = \frac{1}{2\pi RC}}$$

$$\frac{V_o}{V_i} = \frac{j(f/f_c)}{1+j(f/f_c)} A_F$$

$$\left|\frac{V_o}{V_i}\right| = \frac{f/f_c}{\sqrt{1+(f/f_c)^2}} A_F$$

1 KHz cutoff frequency and gain 2 → circuit design

Band-pass filter:



if $f_{c_1} < f_{c_2}$, then no output.

$$V_{o1} = \frac{AF_1}{\sqrt{1+(f/f_{c_1})^2}} \times V_i$$

$$V_{o2} = \frac{AF_2 \; f/f_{c_2}}{\sqrt{1+(f/f_{c_2})^2}} V_{o1}$$

$$V_o = \frac{AF_1 \times AF_2 \; (f/f_{c_2})}{\sqrt{(1+(f/f_{c_1})^2)(1+(f/f_{c_2})^2)}} \times V_i$$

$$= \frac{AF_T \; (f/f_{c_2})}{\sqrt{(1+(f/f_{c_1})^2)(1+(f/f_{c_2})^2)}} V_i$$

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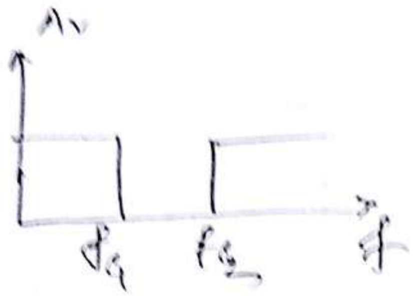
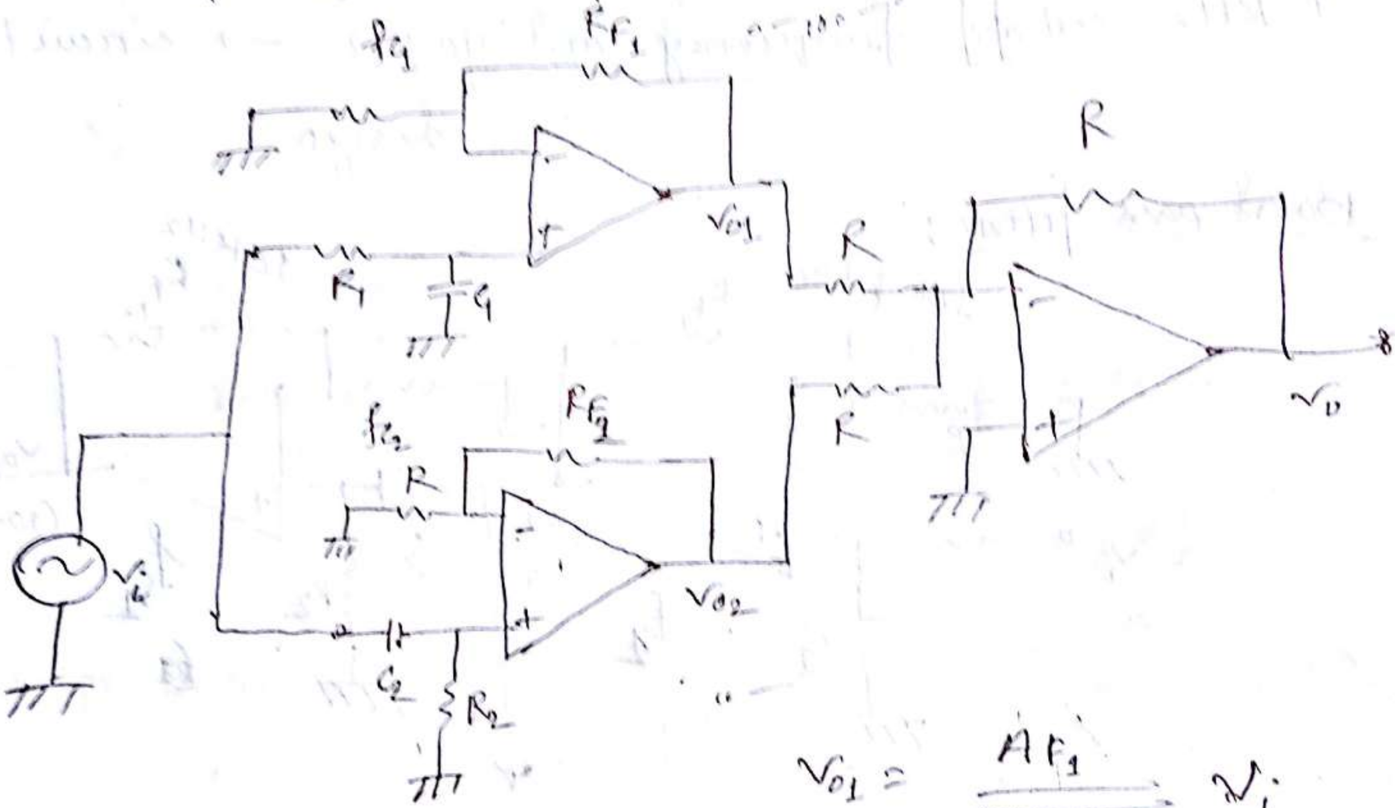
Band Reject filter :





$$V_{o1} = \frac{A_{F_1}}{\sqrt{1+(f/f_{c_1})^2}} V_i$$

$f_{c_1} < f_{c_2}$

$(f_{c_1} - f_{c_2})$ blocked

$$V_{o2} = \frac{A_{f_2}\,(f/f_{c_2})}{\sqrt{1+(f/f_{c_2})^2}} V_i$$

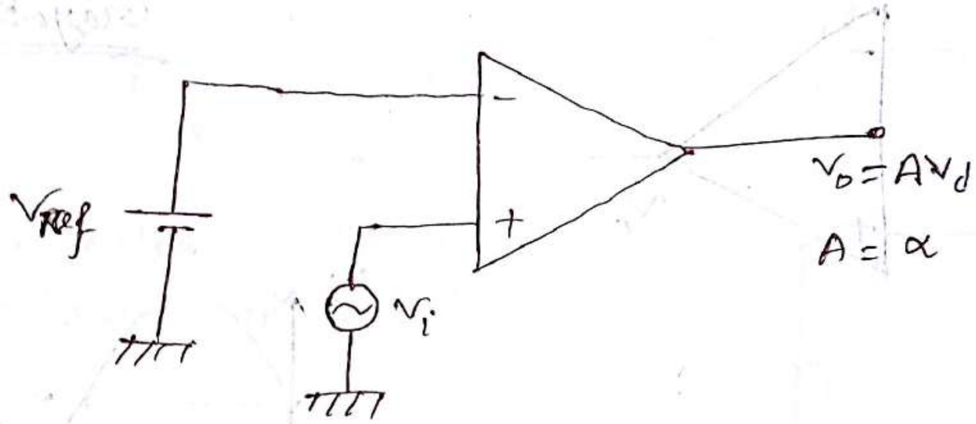
$V_o = V_{o1} + V_{o2}$

$=$

11(D)-Day

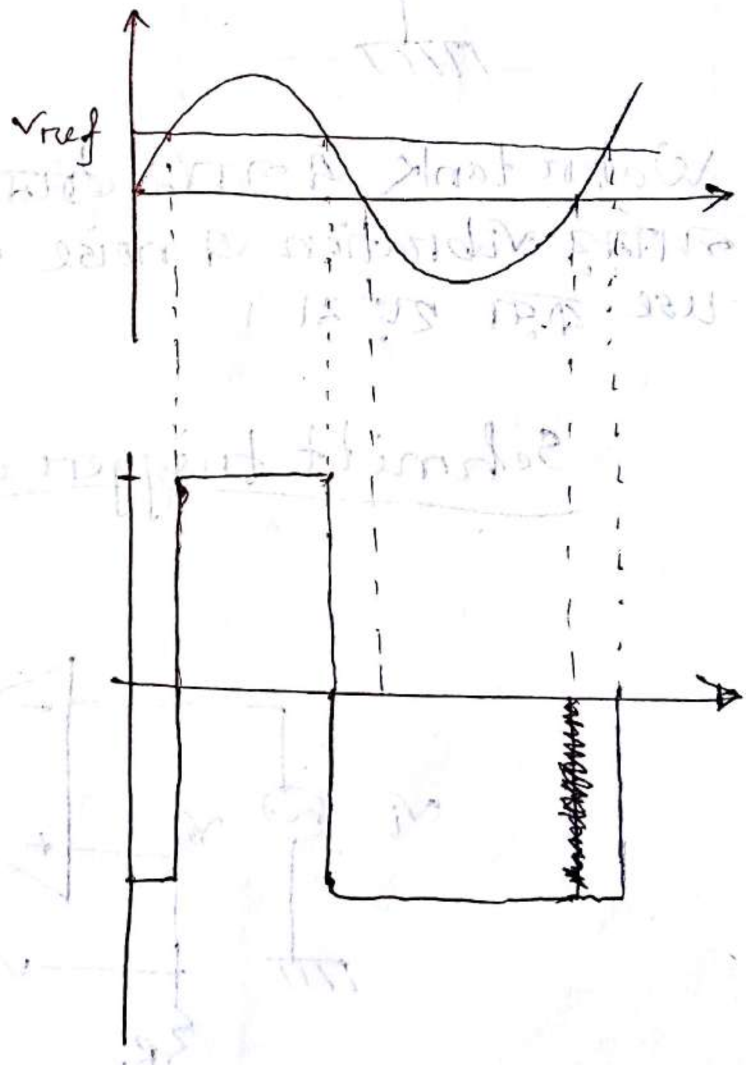
Date: 01/8/2016

Comparator Circuit:



$V_d = V_3 - V_2$

$= V_i - V_{ref}$

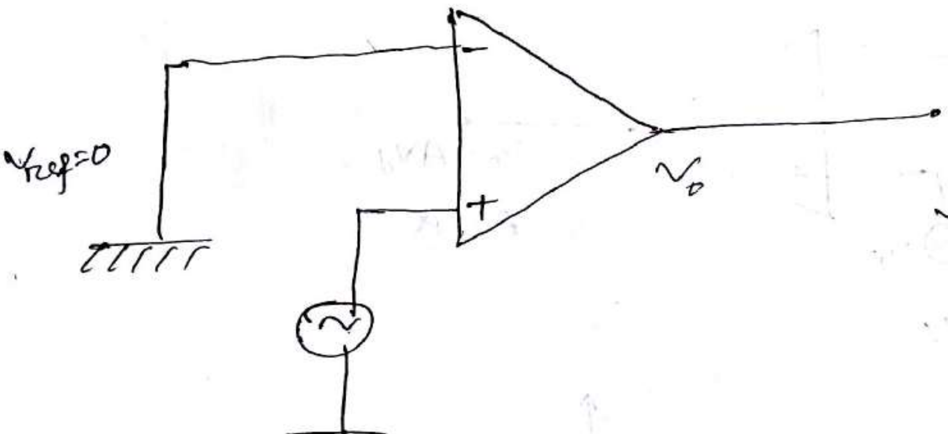


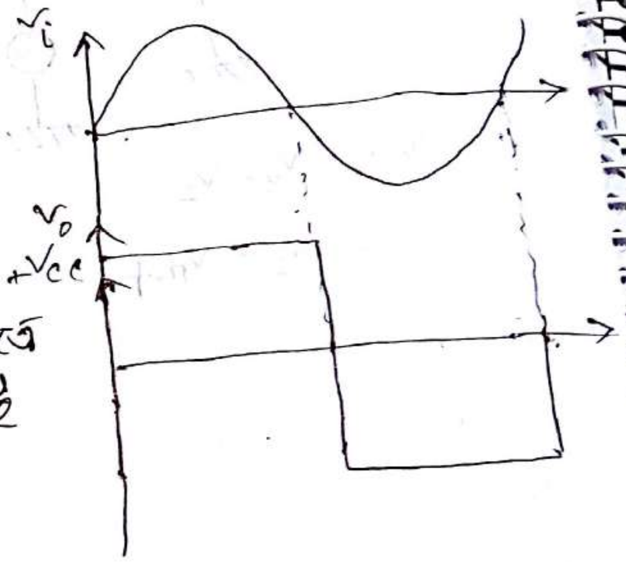
Zero crossing detector:

~~Schmitt trigger circuit:~~

Chapter-8

Gayakwad

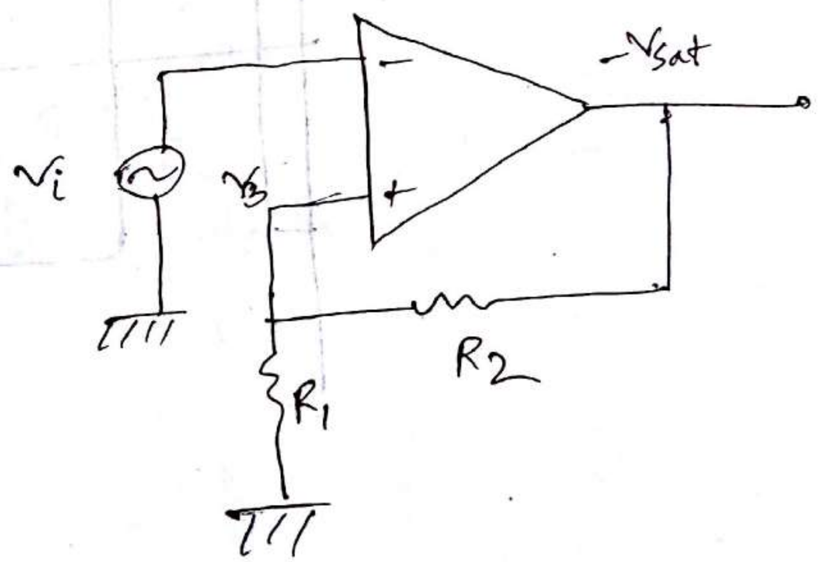




Water tank এ পানির লেভেলের ক্ষেত্রে পানির vibration এ noise হয়, তাই use করা হয় না।

Schmitt trigger circuit:

Sat → saturation



$V_d = V_3 - V_2$

when, $V_2 < V_3$

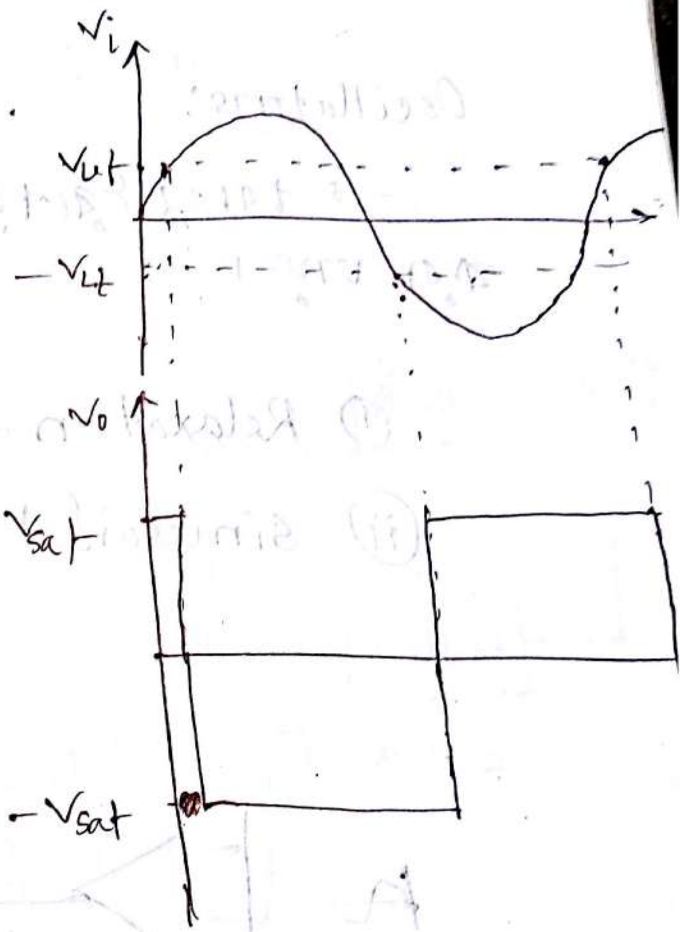
$$-V_{Lt} = V_3 = \frac{R_1}{R_1+R_2}(-V_{sat})$$

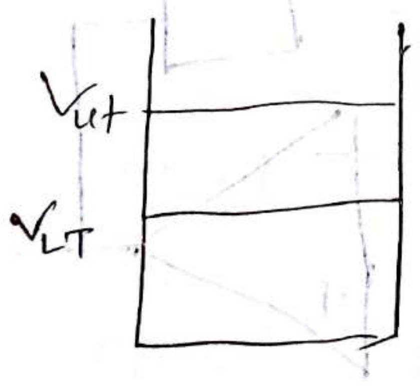
when, $V_2 > V_3$

$$V_{ut} = \frac{R_1}{R_1+R_2}(+V_{sat})$$

ut → upper threshold

Lt → Lower threshold





11 (E)-Day

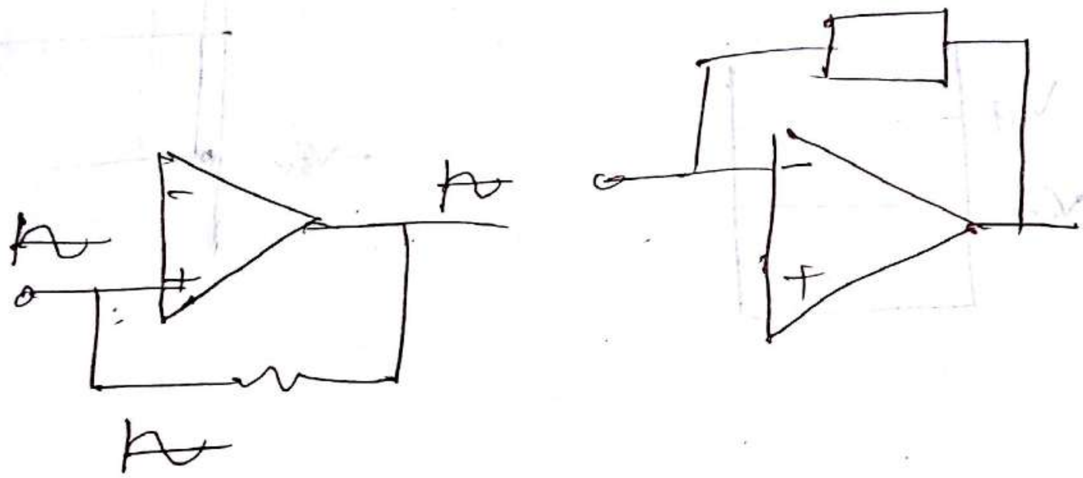
Date: 02/8/2016

Oscillators:

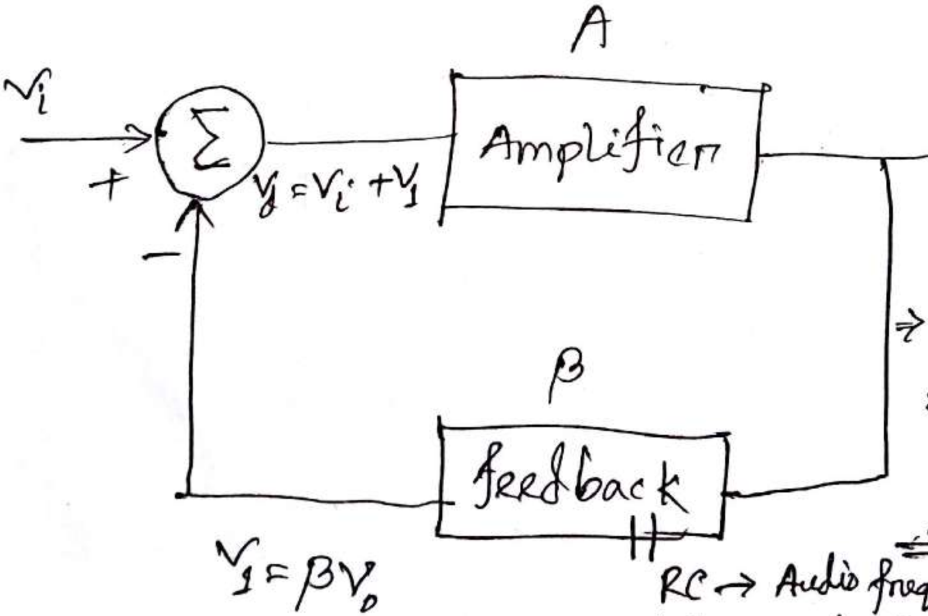
→ বিভিন্ন ধরনের Periodic waveform generate করা যায়।

① Relaxation → Square, triangular

(ii) Sinusoidal



Audio freq → 20 — 20,000 Hz



$$V_o = A(V_i + V_1)$$
$$= A(V_i + \beta V_o)$$
$$\Rightarrow (1 - A\beta)V_o = AV_i$$
$$\Rightarrow \frac{V_o}{V_i} = \frac{A}{1 - A\beta}$$
$$\Rightarrow \frac{V_o}{V_i} = \frac{A}{1-1}$$
$$\frac{V_o}{V_i} = \frac{A}{0}$$

RC → Audio freq

LC → Radio freq

Oscillator circuit এ কোন input দিতে হয় না।

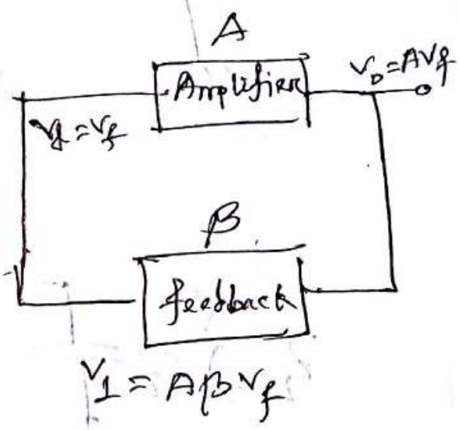
Power এর Amplifier এর biasing voltage থেকে

Barkhausen condition for oscillation:

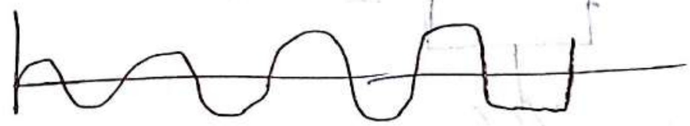
$$A\beta = 1\angle 0^\circ = 1\angle 360^\circ$$

$v_g = v_f \qquad v_o = A v_f$

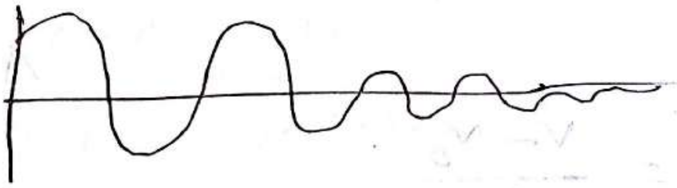
$v_1 = A\beta v_f$



$A\beta > 1$



$A\beta < 1$



* Initially oscillation শুরু করার জন্য $A\beta > 1$ রাখতে হবে। পরে var. resistance এর সাহায্যে gain এর value 1 করতে হবে।

* Signal আসে noise থেকে।

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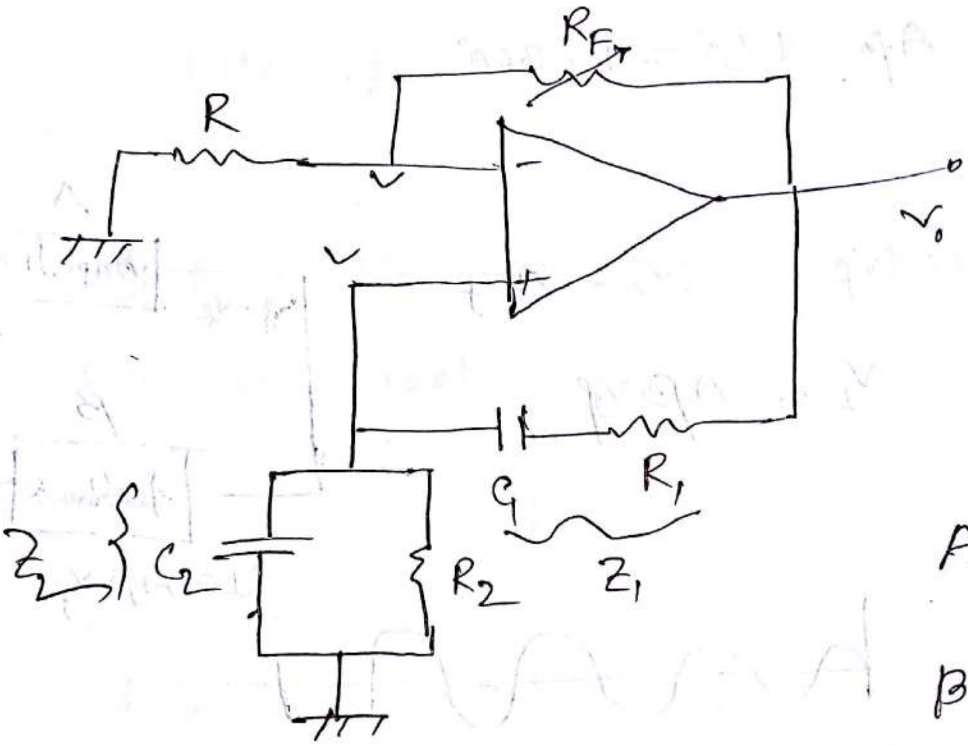
Wein bridge Oscillator:



$$A = 1 + \frac{R_F}{R}$$

$$\beta = \frac{1}{A}$$

$$A\beta = 1 \angle 0^\circ$$

$$\frac{0 - v}{R} = \frac{v - v_0}{R_F}$$

$$\Rightarrow v = -\frac{R}{R_F}(v - v_0)$$

$$\Rightarrow \left(1 + \frac{R}{R_F}\right)v = \frac{R}{R_F} v_0$$

$$v_0 = \left(1 + \frac{R_F}{R}\right) v_i$$ [Directly লিখে দাও]

$$Z_1 = R_1 + \frac{1}{j\omega C_1} = \frac{1 + j\omega R_1 C_1}{j\omega C_1}$$

$$Z_2 = R_2 \,||\, \frac{1}{j\omega C_2} = \frac{R_2 \times \frac{1}{j\omega C_2}}{R_2 + \frac{1}{j\omega C_2}}$$

$$= \frac{R_2}{1 + j\omega R_2 C_2}$$

$$V = \frac{Z_2}{Z_1 + Z_2} \times V_0$$

$$\frac{V}{V_0} = \frac{\frac{R_2}{1 + j\omega R_2 C_2}}{\frac{1 + j\omega R_1 C_1}{j\omega C_1} + \frac{R_2}{1 + j\omega R_2 C_2}}$$

$$\frac{V}{V_0} = \frac{\frac{R_2}{1 + j\omega R_2 C_2}}{\frac{(1 + j\omega R_1 C_1)(1 + j\omega R_2 C_2) + j\omega R_2 C_1}{j\omega C_1 (1 + j\omega R_2 C_2)}}$$

$$\frac{V}{V_0} = \frac{j\omega R_2 C_1}{(1 + j\omega R_1 C_1)(1 + j\omega R_2 C_2) + j\omega R_2 C_1}$$

$$\frac{V}{V_0} = \frac{j\omega R_2 C_1}{1 + j\omega R_1 C_1 + j\omega R_2 C_2 - \omega^2 R_1 R_2 C_1 C_2 + j\omega R_2 C_1}$$

$$\frac{V}{V_0} = \frac{1}{\frac{R_1}{R_2} + \frac{C_2}{C_1} + 1 + \overset{\cancel{\omega R}}{j\omega R_1 C_2} + \frac{1}{j\omega R_2 C_1}}$$

$$\frac{V}{V_0} = \frac{1}{\frac{R_1}{R_2} + \frac{C_2}{C_1} + 1 + j\left(\omega R_1 C_2 - \frac{1}{\omega R_2 C_1}\right)}$$

when,

$$\omega R_1 C_2 - \frac{1}{\omega R_2 C_1} = 0$$

then, gain maximum $\qquad \frac{1}{R+jX} = \frac{1}{\sqrt{R^2+X^2}}$

$$\omega R_1 C_2 = \frac{1}{\omega R_2 C_1}$$

$$\Rightarrow \omega^2 = \frac{1}{R_1 R_2 C_1 C_2}$$

$$\therefore \omega = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}}$$

$$\therefore f = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}}$$

f frequency-তে এবং gain maximum.

Then,

$$\beta = \frac{1}{\frac{R_1}{R_2} + \frac{C_2}{C_1} + 1}$$

$\cancel{R_1 = R_2}$

when, $R_1 = R_2$, $C_1 = C_2$, then $f = \frac{1}{2\pi RC}$

$$\beta = \frac{1}{1+1+1} = \frac{1}{3}$$

$$A\beta = 1$$

$$A = \frac{1}{\beta} = 3$$

$$\Rightarrow 1 + \frac{R_F}{R} = 3$$

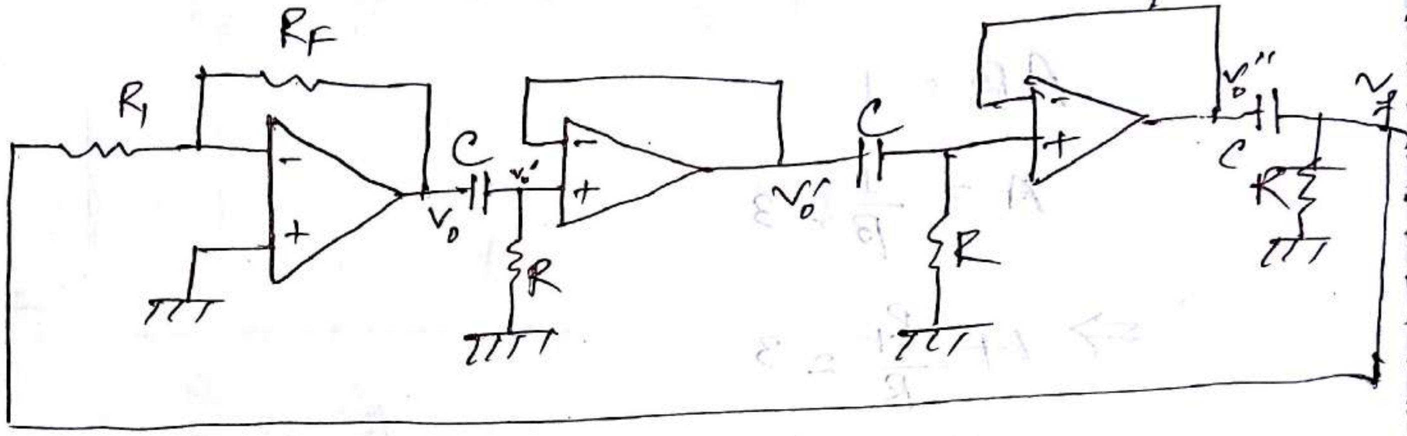
$$\Rightarrow \frac{R_F}{R} = 2$$

$$\Rightarrow R_F = 2R$$

12(D)-Day Date : 8/8/2016

Phase-shif Oscillator (Buffered)

Impedance matching का use होता है।



$$A = -\frac{R_F}{R_1}$$

$$V_o' = \frac{R}{R + \frac{1}{j\omega C}} V_o$$

$$= \frac{j\omega RC}{1 + j\omega RC} \times V_o$$

$$V_o'' = \frac{j\omega RC}{1 + j\omega RC} \times V_o'$$

$$V_f = \frac{j\omega RC}{1 + j\omega RC} V_o''$$

$$= \frac{(j\omega RC)^3}{(1 + j\omega RC)^3} V_o$$

$$\frac{V_f}{V_o} = \frac{-j\omega^3R^3C^3}{1 + j3\omega RC - 3\omega^2R^2C^2 - j\omega^3R^3C^3}$$

$$\therefore \frac{V_f}{V_o} = \frac{-\omega^2R^2C^2}{\frac{1}{j\omega RC} + 3 - \frac{3\omega RC}{j} - \omega^2R^2C^2}$$

$$\frac{3\omega RC}{j} \rightarrow = +j3\omega RC$$

$$= \frac{-\omega^2R^2C^2}{3 - \omega^2R^2C^2 + j\left(3\omega RC - \frac{1}{\omega RC}\right)}$$

$$3\omega RC = \frac{1}{\omega RC}$$

$$\Rightarrow \omega^2 = \frac{1}{3R^2C^2}$$

$$\Rightarrow f = \frac{1}{2\pi\sqrt{3}\,RC}$$ [At this frequency, gain is maximum]

$$\therefore \beta = -\frac{\omega^2R^2C^2}{3-\omega^2R^2C^2}$$

$$= -\frac{\frac{1}{3}}{3-\frac{1}{3}}$$

$$= -\frac{1}{8}$$

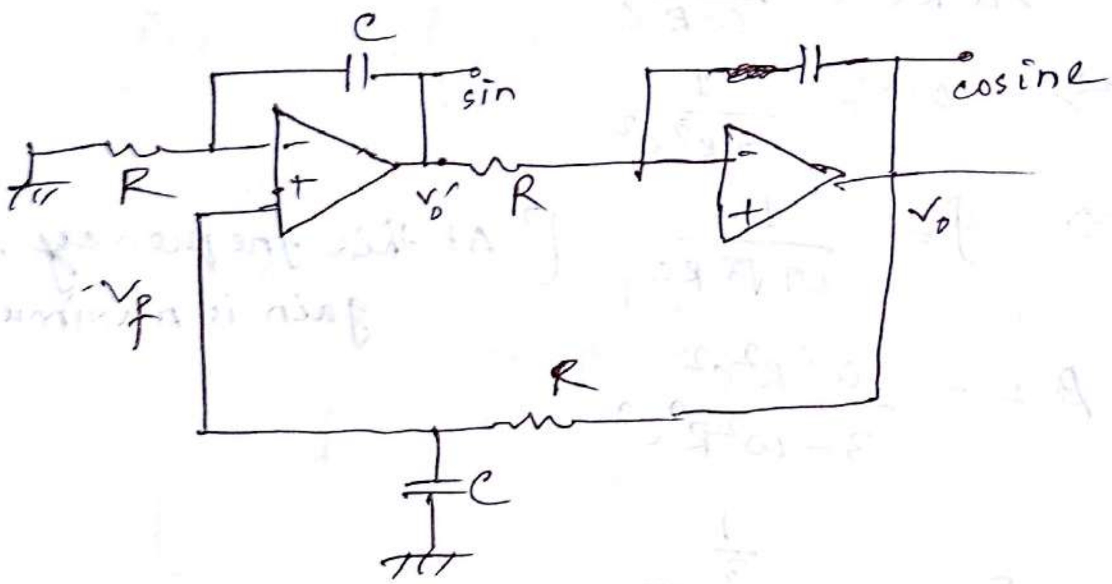
$$A\beta = 1$$

$$\Rightarrow \frac{R_F}{R_1} \times \frac{1}{8} = 1$$

$$\Rightarrow \frac{R_F}{R_1} = 8$$

$$\therefore R_F = 8R_1$$

Quadrature Oscillator:



$$v_o' = \left(1 + \frac{\frac{1}{j\omega C}}{R}\right) v_f$$

$$= \frac{1 + j\omega RC}{j\omega RC} v_f$$

$$v_o = -\frac{\frac{1}{j\omega C}}{R} v_o'$$

$$= -\frac{1}{j\omega RC} \times \frac{1 + j\omega RC}{j\omega RC} \times v_f$$

$$A = -\frac{1 + j\omega RC}{(j\omega RC)^2}$$

$$v_f = \frac{\frac{1}{j\omega C}}{R + \frac{1}{j\omega C}} v_o = \frac{1}{1 + j\omega RC} v_o$$

$\therefore \beta = \dfrac{1}{1+j\omega RC}$

$$A\beta = -\frac{1+j\omega RC}{(1+j\omega RC)^2} \times \frac{1}{1+j\omega RC}$$

$$= \frac{-1}{-\omega^2R^2C^2}$$

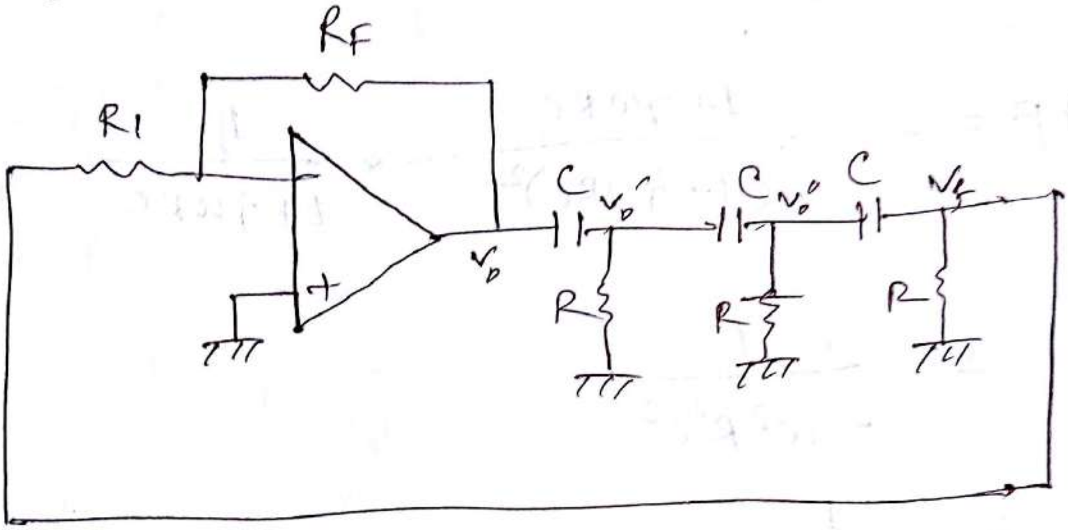
$$= \frac{1}{\omega^2R^2C^2}$$

$$\frac{1}{\omega^2R^2C^2} = 1\angle 0^\circ$$

$\Rightarrow \omega^2R^2C^2 = 1$

$\Rightarrow f = \dfrac{1}{2\pi RC}$ [Frequency of oscillation]

Phase-shift oscillator (not buffered):



$$\frac{V_o - V_o'}{\frac{1}{sC}} = \frac{V_o'}{R} + \frac{V_o' - V_o''}{1/sC} \qquad \Bigg| \; s = j\omega$$

$$\Rightarrow sRC(V_o - V_o') = V_o' + sRC(V_o' - V_o'')$$

$$\frac{V_o' - V_o''}{1/sC} = \frac{V_o''}{R} + \frac{V_o'' - V_f}{1/sC}$$

$$\Rightarrow SRC(V_o' - V_o'') = V_o'' + SRC(V_o'' - V_f)$$

$$\frac{V_o'' - V_f}{1/SC} = \frac{V_f}{R}$$

[R_1 এর value অনেক বেশি]

$$\Rightarrow SRC(V_o'' - V_f) = V_f$$

$$\boxed{\frac{V_f}{V_o} = \frac{s^3R^3C^3}{s^3R^3C^3 + 6s^2R^2C^2 + 5sRC + 1}}$$

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$$\frac{V_f}{V_o} = \frac{s^3R^3C^3}{s^3R^3C^3+6s^2R^2C^2+5sRC+1}$$

$$= \frac{-j\omega^3R^3C^3}{-j\omega^3R^3C^3-6\omega^2R^2C^2+j5\omega RC+1}$$

$$= \frac{-\omega^2R^2C^2}{-\omega^2R^2C^2-\frac{6\omega RC}{j}+5+\frac{1}{j\omega RC}}$$

$$= \frac{-\omega^2R^2C^2}{5-\omega^2R^2C^2+j\left(6\omega RC-\frac{1}{\omega RC}\right)}$$

$$6\omega RC = \frac{1}{\omega RC}$$

$$\Rightarrow \omega^2 = \frac{1}{6R^2C^2}$$

$$\Rightarrow \omega = \frac{1}{\sqrt{6}RC}$$

$$\therefore f = \frac{1}{2\pi\sqrt{6}RC}$$

$$\beta = -\frac{\frac{1}{6}}{5-\frac{1}{6}} = -\frac{1}{29}$$

$$A = -\frac{R_F}{R_1} \quad \Bigg| \quad A\beta = 1 \Rightarrow \frac{R_F}{R_1} = 29$$

12(E)-Day Date: 9/8/2016

555-timer:

→ waveform can be generated

→ Astable multivibrator

→ Monostable "

Ground	1	8	$+V_{cc}$
trigger	2	7	Discharge
Output	3	6	Threshold
Reset	4	5	Control voltage

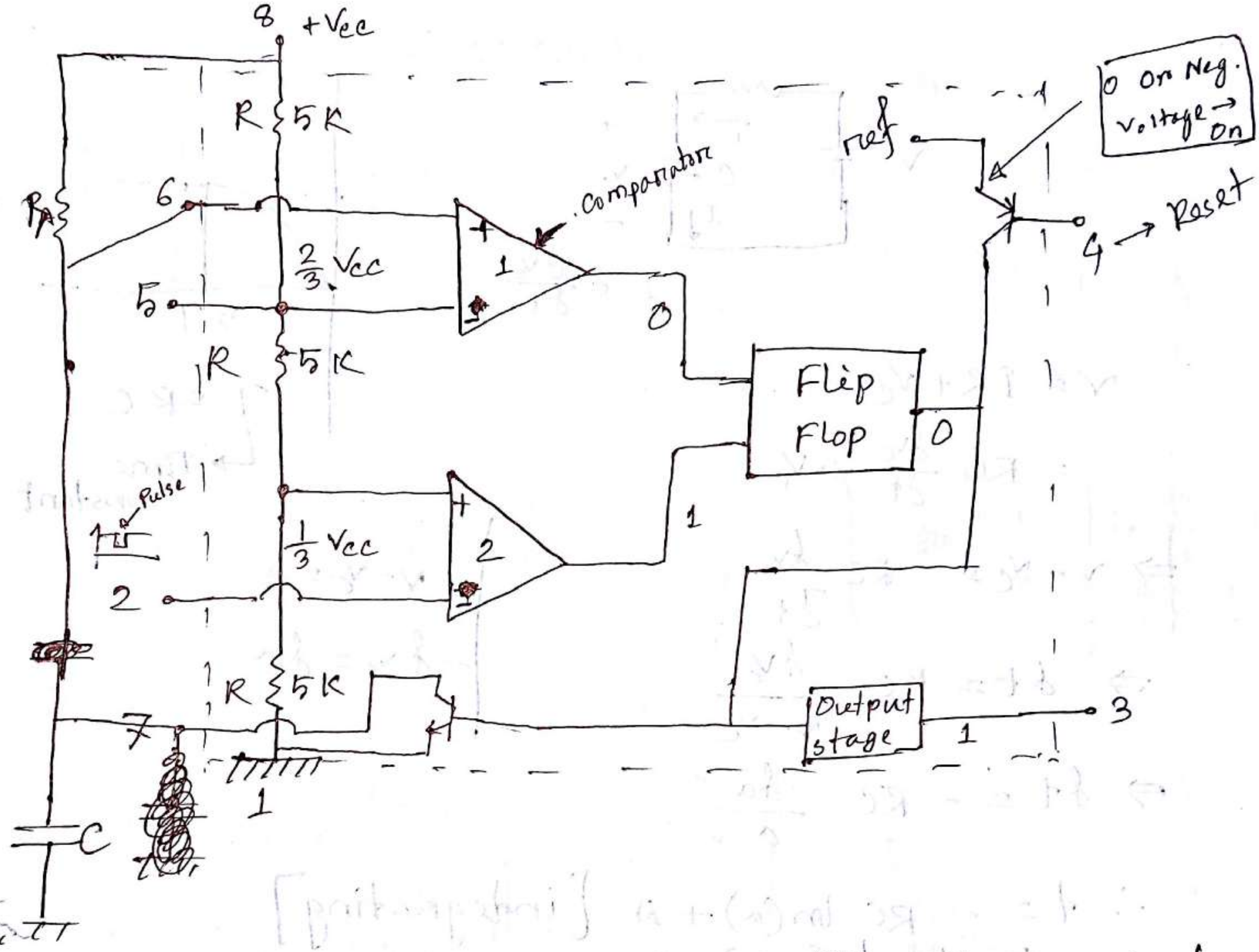
Fig.: Pin Configuration

* Comparator circuit is used here

→ 4 No. pin ground করলে সব আগের মত হবে

→ 6 No pin এ comparator থাকে। এখানে যে voltage দেয়া হয় তা Threshold voltage

→ 7 No. pin এ capacitor use করা হয়।



Flip-Flop

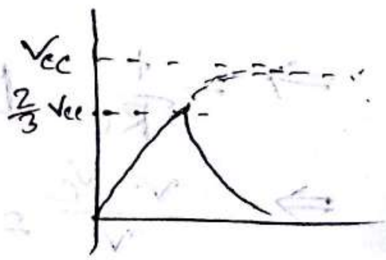
No. change

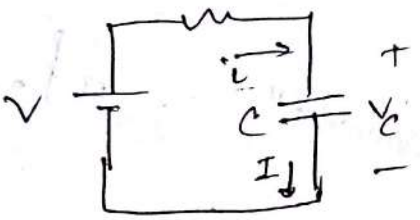
J	K	Output
0	0	NC
1	0	1
0	1	0
1	1	Q

$V_{LT} = \frac{1}{3} V_{cc}$

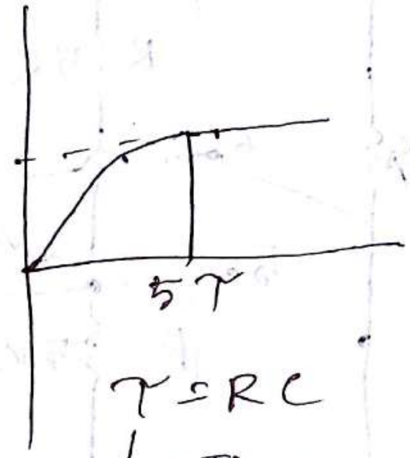
$V_{UT} = \frac{2}{3} V_{cc}$

Pin (2)	Pin (6)	Output (3)	Discharge (7)
$< V_{LT}$	$< V_{UT}$	High	Open
$< V_{LT}$	$> V_{UT}$	High	Open
$> V_{LT}$	$< V_{UT}$	Remember last state	
$> V_{LT}$	$> V_{UT}$	Low	ground





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



$\tau = RC$

↳ Time constant

$$V = IR + V_c$$
$$= RC\frac{dV_c}{dt} + V_c$$
$$\Rightarrow V - V_c = RC\frac{dV_c}{dt}$$
$$\Rightarrow dt = RC\frac{dV_c}{V - V_c}$$

$V - V_c = a$

$-dV_c = da$

$$\Rightarrow dt = -RC\frac{da}{a}$$
$$\therefore t = -RC\ln(a) + A \quad \text{[integrating]}$$
$$= -RC\ln(V - V_c) + A$$

$t = 0,\ V_c = 0$

$$0 = -RC\ln(V) + A$$
$$\therefore A = RC\ln(V)$$
$$t = -RC\ln(V - V_c) + RC\ln(V)$$
$$\Rightarrow t = RC\ln\frac{V}{V - V_c}$$
$$\Rightarrow -\frac{t}{RC}\ln\frac{V - V_c}{V}$$
$$\Rightarrow \frac{V - V_c}{V} = e^{-t/RC}$$

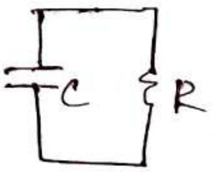
$V - V_c = Ve^{-t/RC}$

$\therefore V_c = V(1 - e^{-t/RC})$

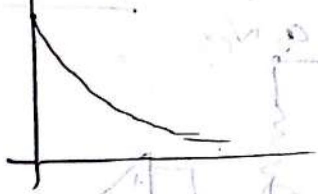
$t = 5\tau = 5RC$ 2ms

$V_c = V$.

discharge এর সময়,



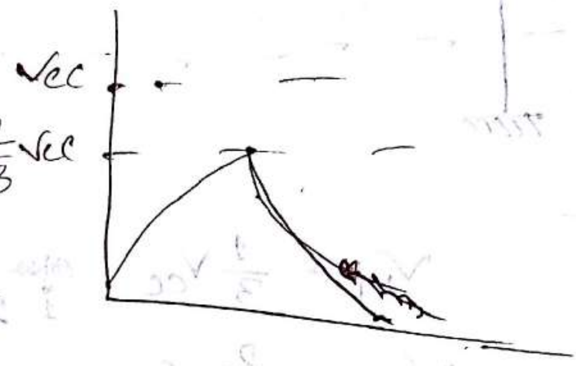
$$V_c = V_e^{-t/RC}$$



$$RC = \frac{V}{I} \times i\,\frac{dt}{dv}$$

$$i = C\,\frac{dv}{dt}$$

$$\therefore C = i\,\frac{dt}{dv}$$



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

$$\frac{2}{3}V_{cc} = V_{cc}\left(1 - e^{-t/RC}\right)$$

$$\Rightarrow e^{-t/RC} = \frac{1}{3}$$

$$\Rightarrow -\frac{t}{RC} = \ln\left(\frac{1}{3}\right)$$

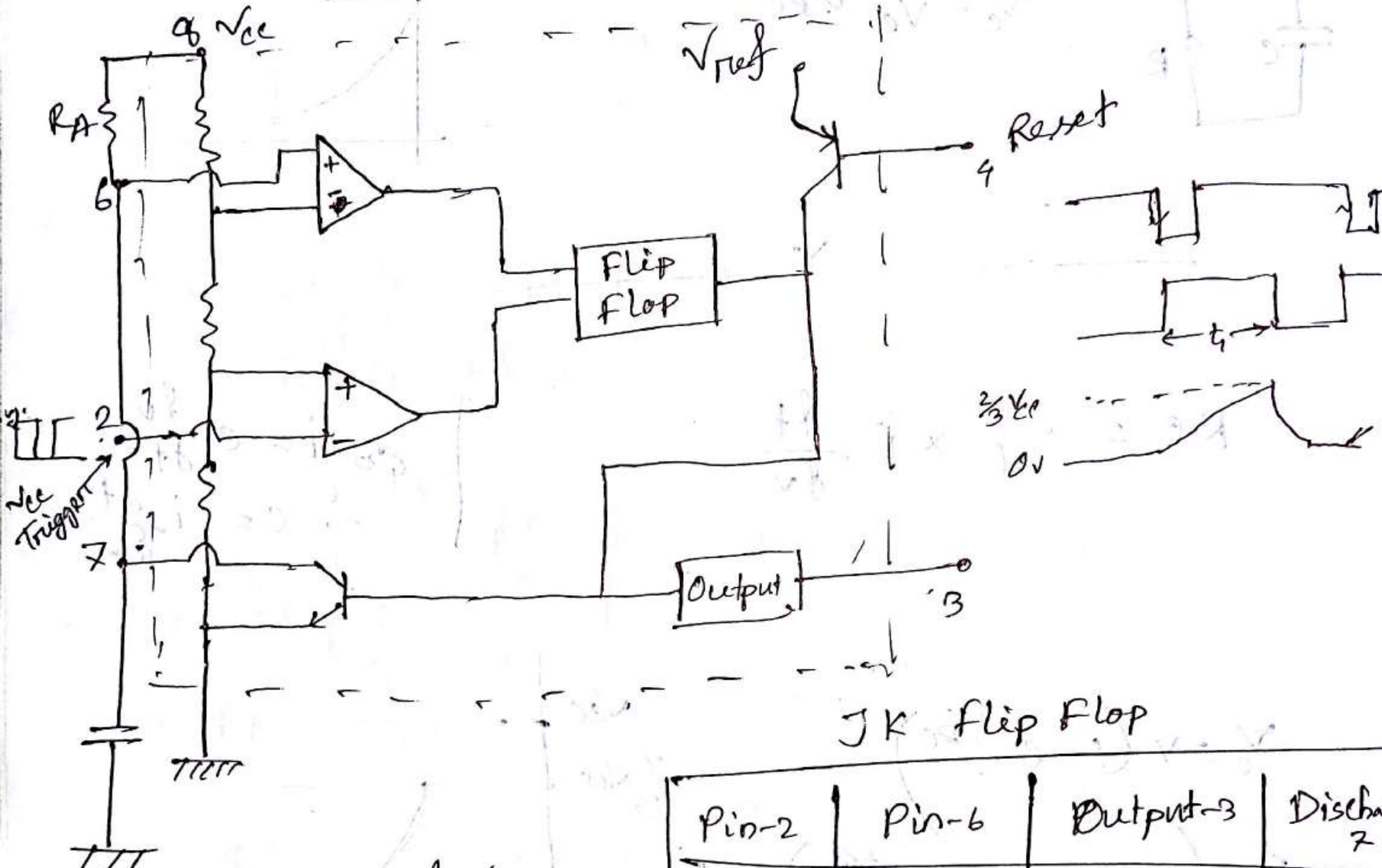
$$\Rightarrow \frac{t}{RC} = \ln(3)$$

$$\Rightarrow t = 1.1\ RC$$

13(B)-Day

Date: 13/8/2016

Monostable



JK Flip Flop

$V_{LT} = \frac{1}{3} V_{CC}$

$V_{UT} = \frac{2}{3} V_{CC}$

	Pin-2	Pin-6	Output-3	Discharge 7
Astable 1 2	$< V_{LT}$	$< V_{UT}$	High	Open
	$< V_{LT}$	$> V_{UT}$	High	Open
2 1	$> V_{LT}$	$< V_{UT}$	Remember	Last state
3	$> V_{LT}$	$> V_{UT}$	Low	discharge

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$$V_c = V_{cc}\left(1 - e^{-t/RC}\right)$$

After t_1 time, $V_c = \frac{2}{3} V_{cc}$

$$\frac{2}{3} V_{cc} = V_{cc}\left(1 - e^{-t_1/RC}\right)$$

$$\Rightarrow e^{-t_1/RC} = 1 - \frac{2}{3}$$

$$\Rightarrow -t_1/RC = \ln\left(\frac{1}{3}\right)$$

$$\Rightarrow \frac{t_1}{RC} = \ln(3)$$

$$\Rightarrow t_1 = 1.1 R_A \cdot C$$

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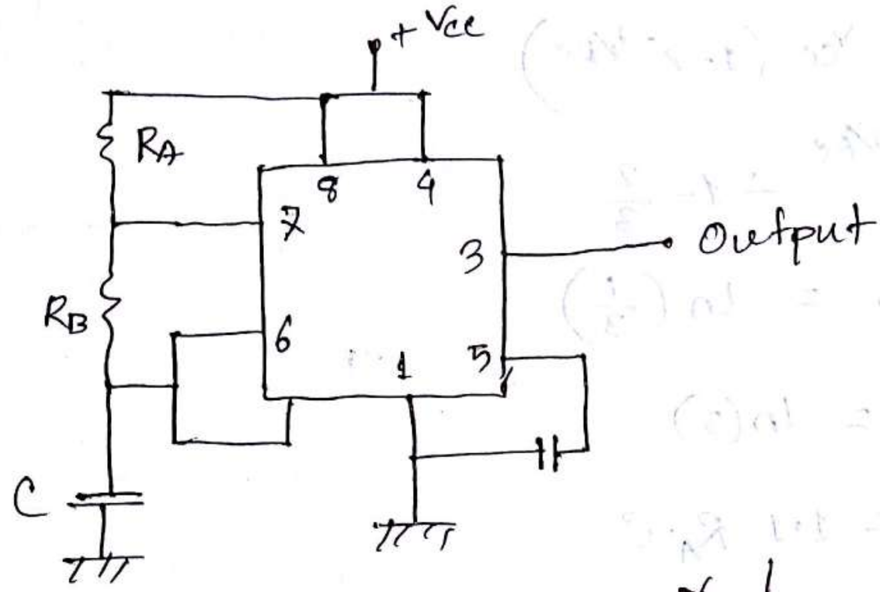
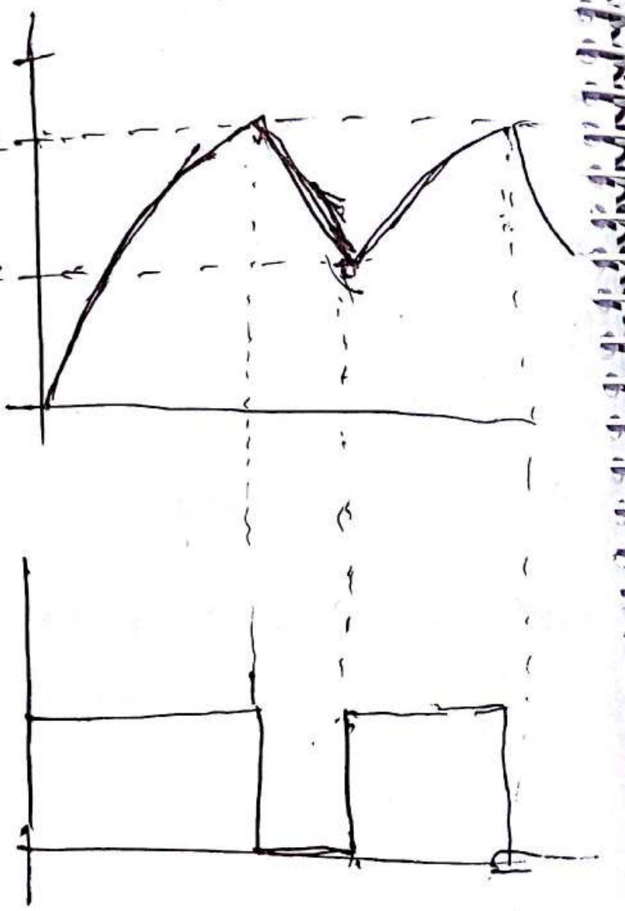
Astable Operation:

→ Relaxation wave design করা যায়।





$$\frac{1}{3} V_{cc} = V_{cc}\left(1 - e^{-t_2/RC}\right)$$

$$\Rightarrow e^{-t_2/RC} = 1 - \frac{1}{3}$$

$$\Rightarrow \frac{t_2}{RC} = \ln\left(\frac{3}{2}\right)$$

$$\Rightarrow t_2 = 0.41\, RC$$

From $\frac{1}{3} V_{cc}$ to $\frac{2}{3} V_{cc}$

$$t_1 - t_2 = 1.1\, RC - 0.41\, RC$$

$$= 0.69\, RC$$

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$\therefore t_{on} = 0.69 (R_A + R_B) C$

$t_{off} = 0.69 \, R_B C$

duty cycle $= \dfrac{t_{on}}{T}$ | $T = T_{on} + T_{off}$

$= \dfrac{\cancel{0.69} \; R_A + R_B}{R_A + 2R_B}$

→ What is 555-timer

→ Diagram

→