Adwait Naravane

19MS151

PH3104

~~Electric~~

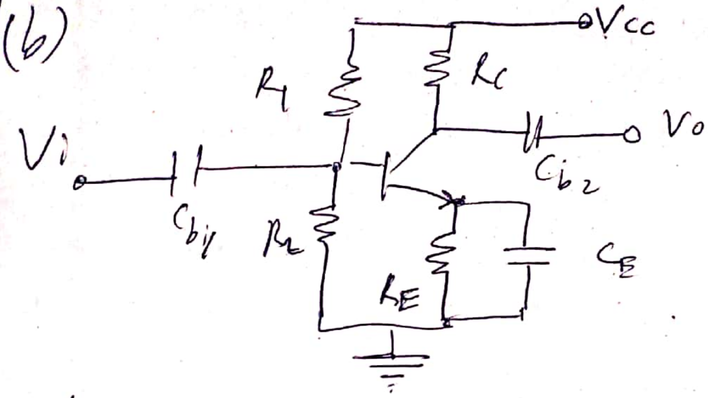
Circuit Analysis

Q1

(a)

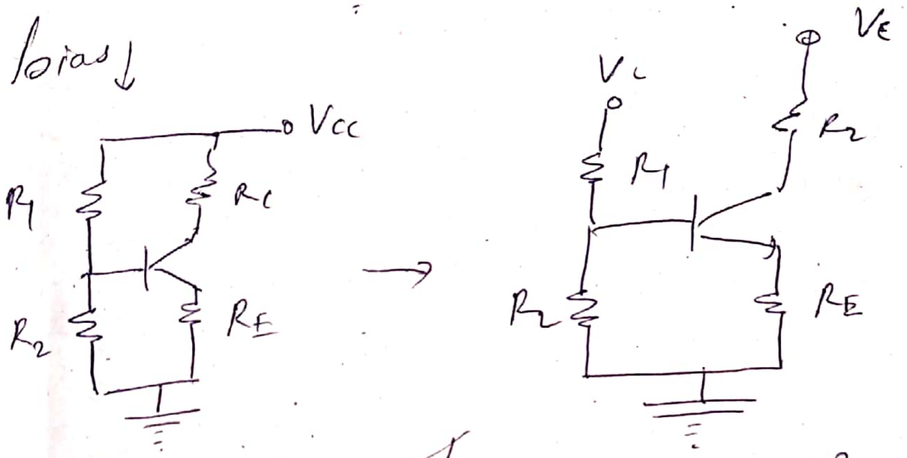
Scanned with CamScanner

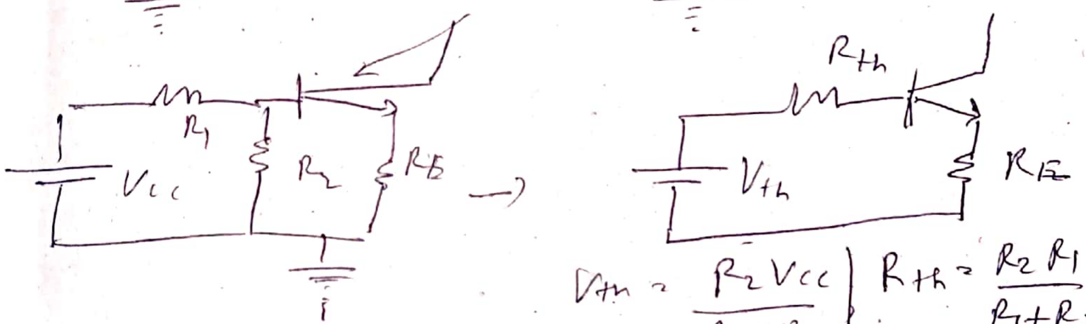
Q1 (b)



$R_1 = 20k,\ R_2 = 10k,$
$R_C = R_E = 4k$

bias ↓





$$V_{th} = \frac{R_2 V_{cc}}{R_1+R_2} = \frac{V_{cc}}{3} \qquad R_{th} = \frac{R_2 R_1}{R_1+R_2} = \frac{20}{3}k.$$

$$V_{th} - I_B R_{th} - V_{BE} - I_E R_2 = 0$$

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

$$I_B = \frac{V_{th} - V_{BE}}{R_{th} + (1+\beta)R_E} = \frac{\frac{V_{cc}}{3} - 0.7}{\frac{20}{3} + 101} = \frac{V_{cc} - 2.1}{323}\ mA.$$

$$I_C = \beta I_B = \frac{100(V_{cc} - 2.1)}{323}\ mA.$$

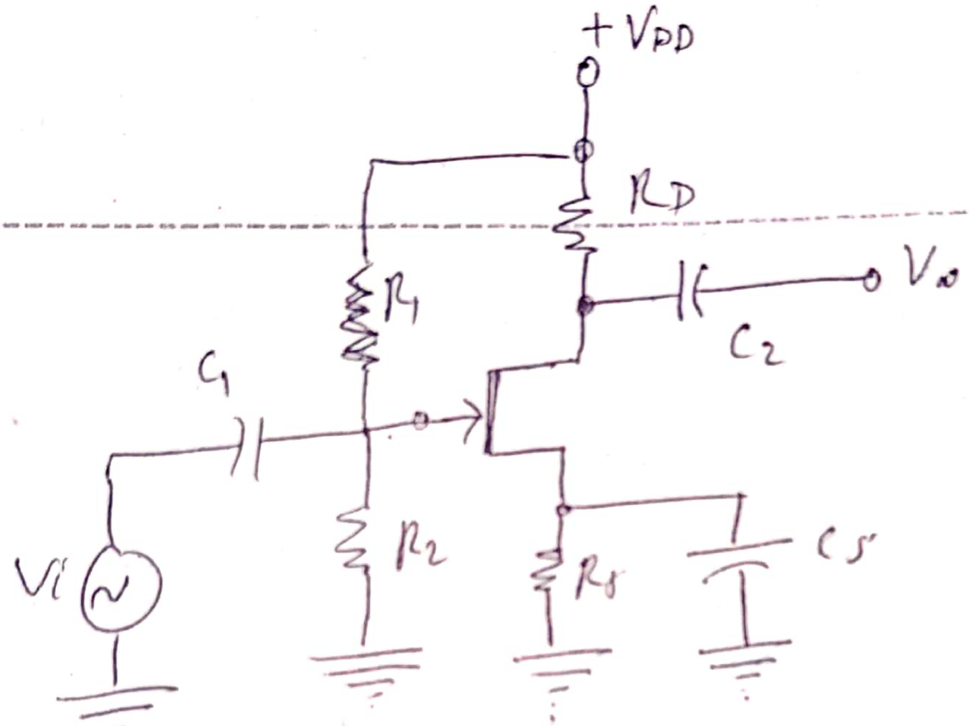
$$I_E = (\beta+1) I_B = \frac{101(V_{cc} - 2.1)}{323}\ mA.$$

$$V_{CE} = V_{cc} - I_c(R_c + R_E) = V_{cc} - 200\frac{(V_{cc} - 2.1)}{323}$$

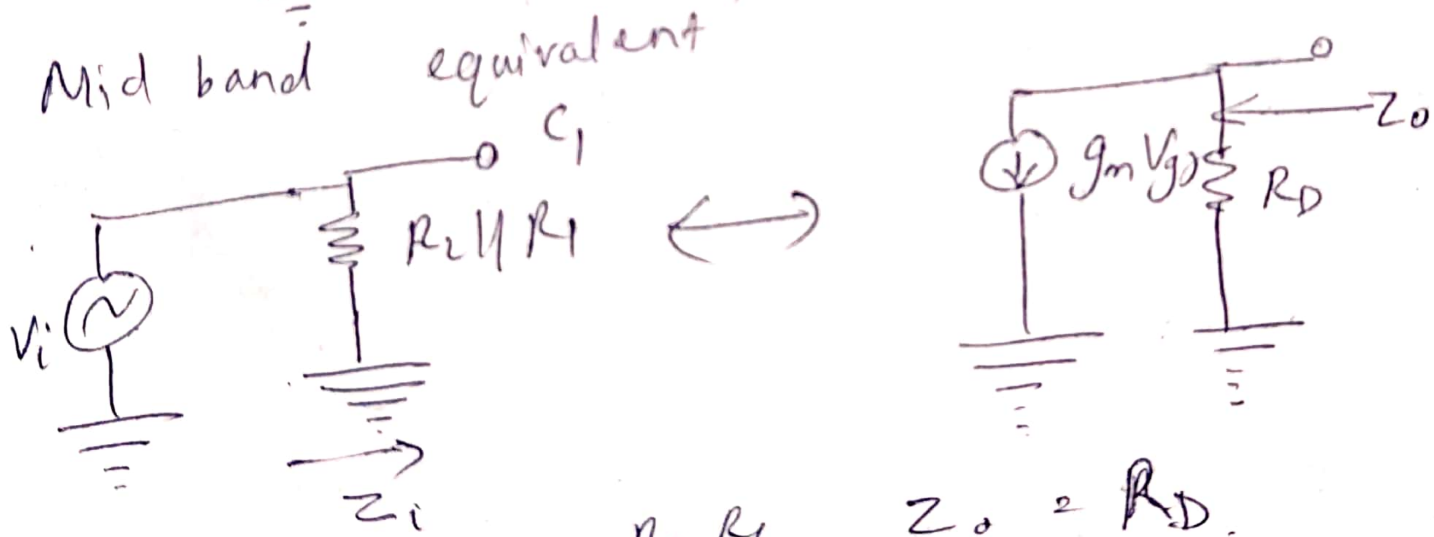
$$\Rightarrow V_{CE} = \frac{123V_{cc} - 420}{323}$$

Q2

(a)



Mid band equivalent



$Z_o = R_D$.

(b) $Z_i = R_2 \| R_1 = \frac{R_2 R_1}{R_2 + R_1}$,

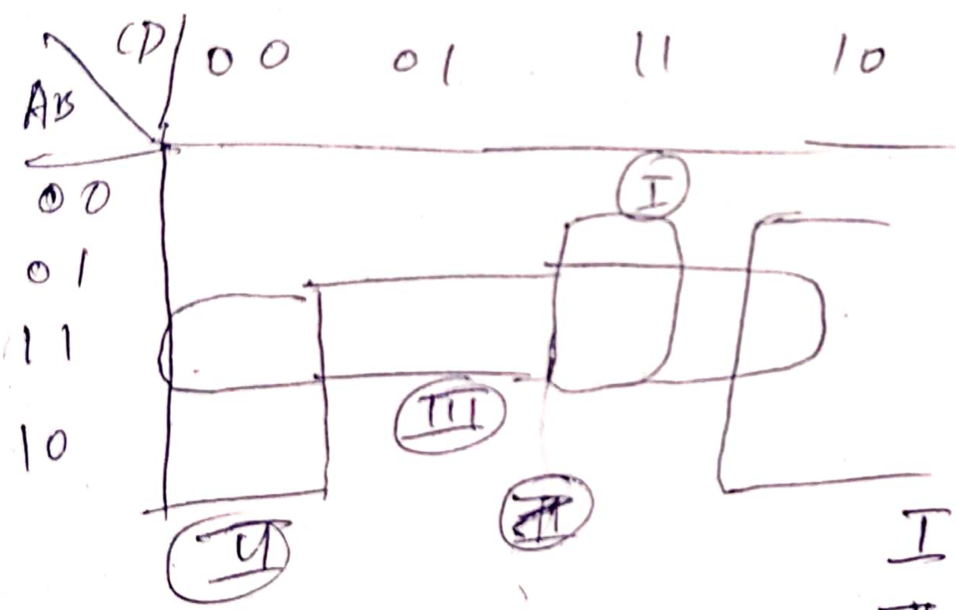
$V_G = V_i$, $V_s = 0 \Rightarrow V_o = g_m V_{gs} R_D$

$\Rightarrow \frac{V_o}{V_{gs}} = \frac{V_o}{V_i} = g_m R_D$

5) a

AB \ CD	00	01	11	10
00	0	0	0	X = 0
01	0	0	1	0
11	X = 1	1	X = 1	1
10	1	0	0	1

↓



I ⇒ BCD

II ⇒ $A\bar{D}$

III ⇒ AB.

$Y = \cancel{BCD + A\bar{D} + AB}$

$+ AB + (AB + \bar{A}B)CD$

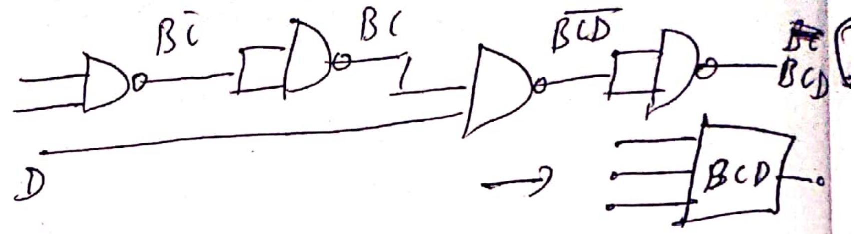
$Y = (AB + A\bar{B})(\bar{C}\bar{D} + C\bar{D}) + AB + BCD$

$= \cancel{AB}\ A(\bar{C}\bar{D} + C\bar{D}) + AB + BCD$

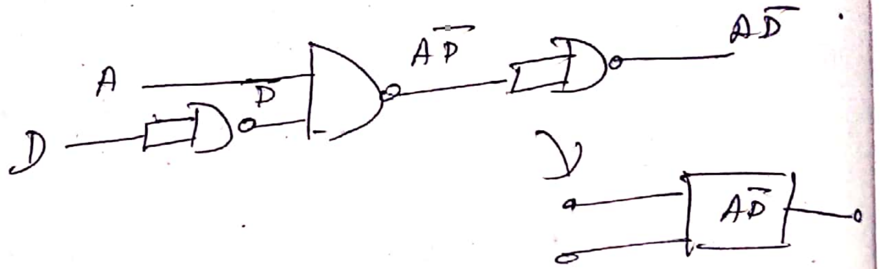
$= A\bar{D} + AB + BCD$

Q5 (b)

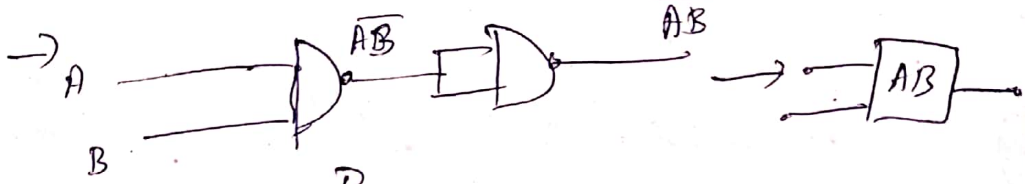
BCD →

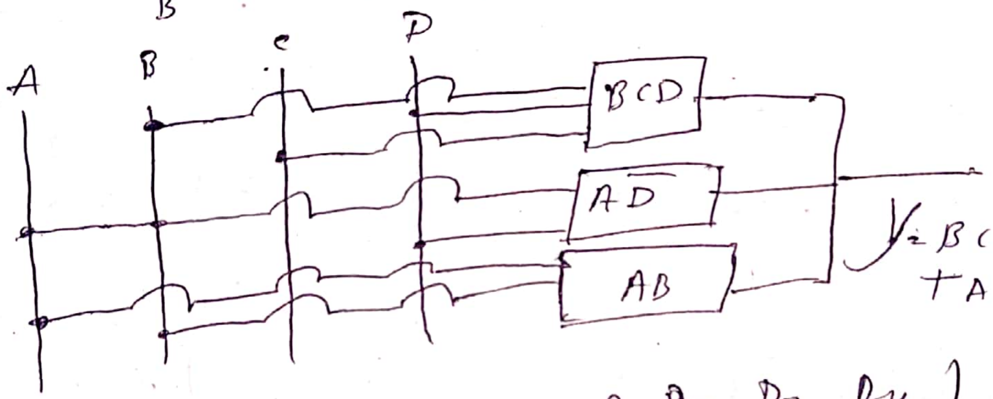


AD →



AB





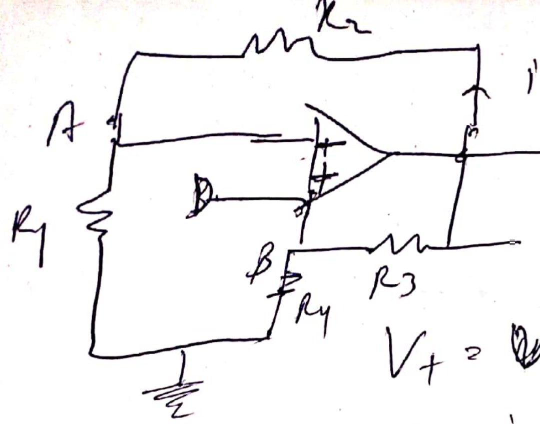
$Y = BCD + A\bar{D} + AB$

(c)

A_0	A_1	A_2	A_3	D_0	D_1	D_2	D_3	D_4
0	0	0	0	0	0	1	0	1
1	0	0	0	1	0	0	1	1
0	1	0	0	0	0	0	0	0
1	1	0	0	1	0	0	0	1
0	0	1	0	0	0	1	1	0
1	0	1	0	0	1	0	1	0
0	0	1	0	0	0	0	0	1
1	1	1	0	1	0	0	1	0
1	0	0	1	0	0	1	0	0

combination logic circuit like this can be used in signal processing, controlling systems through input (control theory?) .. etc.

Q3



* Negligible current through op-amp.

$V_+ = V$

$i_2 = i + i_1$

$i_2 R_4 = V_B = V$

$(i + i_1) = \frac{V_B}{R_4}$

$i_3 = \frac{V_o}{R_2 + R_3} = \frac{V_A}{R_1}$

$V_B = V_+ = V_0 \Rightarrow V_A = V_- = V$

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

$$\boxed{\frac{V_o}{V_i} = 1 + \frac{R_2}{R_1}}$$

2) $i_1 R_3 + i_2 R_4 = V_o$

$i_1 R_3 + (i + i_1) R_4 = V_o$

$i R_4 = V_o - i_1 (R_4 + R_3)$

$i = \frac{V_o}{R_4} - i_1 \frac{(R_4 + R_3)}{R_4}$

2) (a). $R_1 = R_4 = R_3 = 1k, \; R_2 = 10k.$

$V_o = \left(1 + \frac{R_2}{R_1}\right) V = 11V.$

$|V_o| = V_{saturation}$

$i_1 (\frac{R_4 + R_3}{R_4}) = V_o - 2i_1$

~~KVL~~ 1: , $i = \frac{V_o}{R_4} - $

$i_1 = \frac{V_o - V}{R_3}$

$i_1 = \frac{V_0 - V}{R_3}$

$i = \frac{V_0 - 2(V_0 - V)}{R_3} = 2V - V_0$

$\frac{V_0}{V} = \left(1 + \frac{R_2}{R_1}\right) = \cancel{11V}$

$V_0 = \left(1 + \frac{R_2}{R_1}\right)V = 11V$

$i = 2V - 11 = -9V$

$\Rightarrow \underline{i = -9V}$

if $|V| \geq 1$, $\underline{|V_0| = |V_{sat}| = 11V.}$

if $V > 1$, $V_0 = +11V \Rightarrow \underline{i = 2V - 11}$

if $V < 1$, $V_0 = -11V \Rightarrow \underline{i = 2V + 11}$

$|V| \geq 1$.

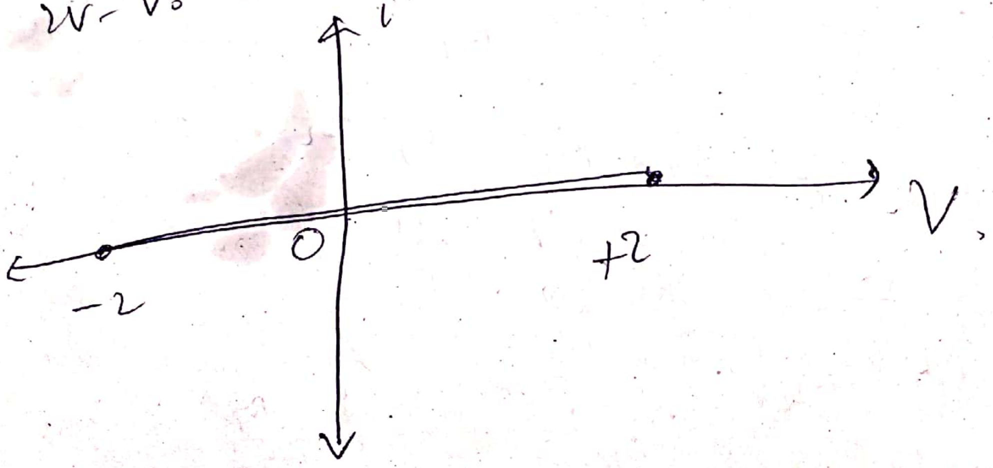
b) $R_1 = R_2 = R_3 = R_4 = 1k$;

$V_0 = \left(1 + \frac{R_2}{R_3}\right)V = 2V.$

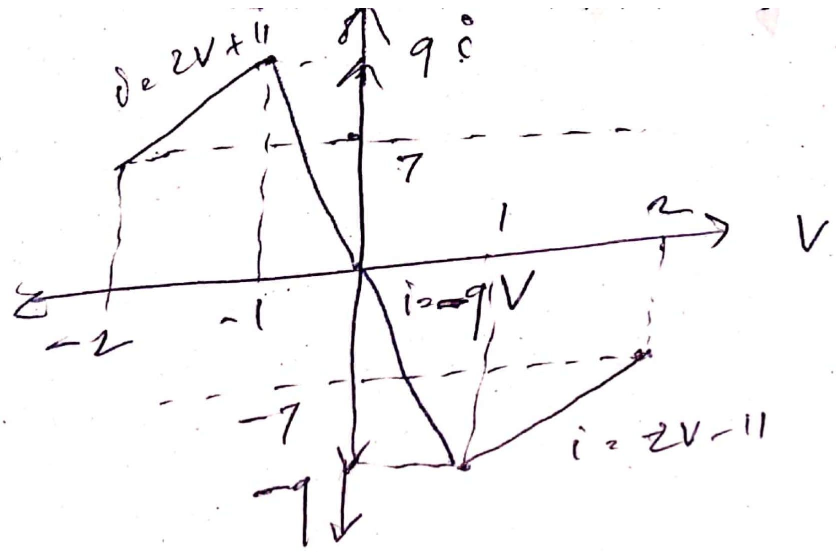
$|V_0| \leq 4$ if $|V| \leq 2$.

$\Rightarrow$ V_0 cannot reach saturation.

$i = 2V - V_0 = 2V - 2V = 0.$

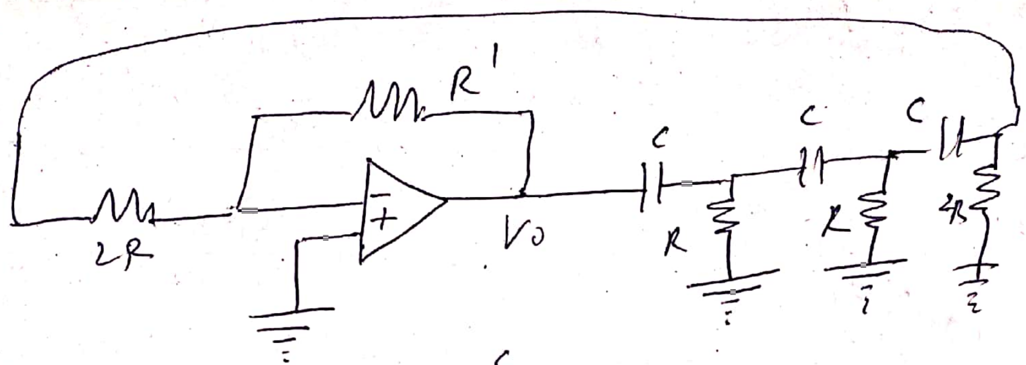


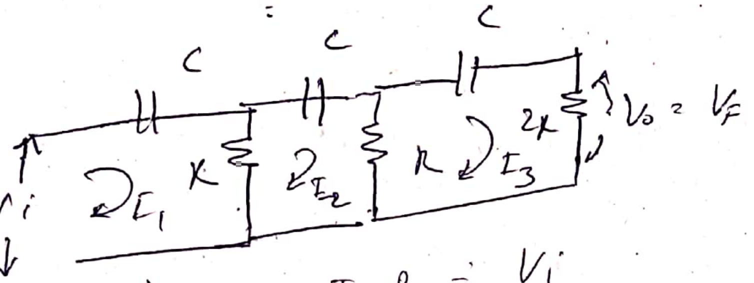
(a)



Q4

(a)





$$I_1\left(R+\frac{1}{j\omega C}\right) - I_2R = V_i$$

$$-I_1R + I_2\left(2R+\frac{1}{j\omega C}\right) - I_3R = 0.$$

$$-I_2R + I_3\left(3R+\frac{1}{j\omega C}\right) = 0.$$

$$R\text{ matix} = \begin{pmatrix} R+\frac{1}{jC\omega} & -R & 0 \\ -R & 2R+\frac{1}{jC\omega} & -R \\ 0 & -R & 3R+\frac{1}{j\omega C} \end{pmatrix}$$

$$RI = V = \begin{pmatrix} V_i \\ 0 \\ 0 \end{pmatrix}$$

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

$$= 5R^3 + \frac{5R^2}{Cj\omega} + \frac{R}{(j\omega)^2C^2} + \frac{5R^2}{j\omega C} + \frac{5R}{(j\omega)^2C^2} + \frac{1}{(j\omega C)^3} - 3R^3 - \frac{R^2}{j\omega C}$$

$$\det R = \frac{1 + 6Rj\omega C + 9R^2j^2\omega^2C^2 + 2R^3j^3\omega^3C^3}{j^3\omega^3C^3}$$

$$R_3 = \begin{bmatrix} \frac{1+j\omega RC}{j\omega C} & -R & V_i \\ -R & \frac{1+2j\omega RC}{j\omega C} & 0 \\ 0 & -R & 0 \end{bmatrix}$$

$$\Rightarrow I_3 = \frac{\det R_3}{\det R} = \frac{R^2V_ij^3\omega^3C^3}{1+6Rj\omega C+9R^2j^2\omega^2C^2+2R^3j^3\omega^3C^3}$$

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$V_o = V_f = I_3 R = \dfrac{R^3 j^3 \omega^3 c^3 \quad V_i}{1 + 6Rj\omega C + 9R^2 j^2 \omega^2 c^2 + 2R^3 j^3 \omega^3 c^3}$

$\beta = \dfrac{V_f}{V_i} = \dfrac{R^3 j^3 \omega^3 c^3}{1 + 6Rj\omega C + 9R^2 j^2 \omega^2 c^2 + 2R^3 j^3 \omega^3 c^3}$

define $\alpha = \dfrac{1}{\omega R C}$

$\Rightarrow \beta = \dfrac{1}{(1 - 6\alpha^2) + j\alpha(9 - 2\alpha^2)}$

b) $\pi = 180°$ phase shift
Minima. ∴ imaginary part

$\alpha(9 - 2\alpha^2) = 0$

$\Rightarrow \alpha = \pm 3/\sqrt{2}$

$\Rightarrow \omega = \dfrac{\sqrt{2}}{3RC} \Rightarrow f = \dfrac{\omega}{2\pi} = \dfrac{\sqrt{2}}{6\pi RC}$ ∴ frequency

gain $A \Rightarrow A = \dfrac{R'}{2R}$

$A\beta \geq 1 \Rightarrow \dfrac{R'}{2R} \cdot \dfrac{1}{26} \geq 1$

$\left[\beta = \dfrac{1}{1 - 6\left(\frac{3}{\sqrt{2}}\right)^2} = -\dfrac{1}{26} \right.$

$R' \geq \cancel{106R}\ 52R.$