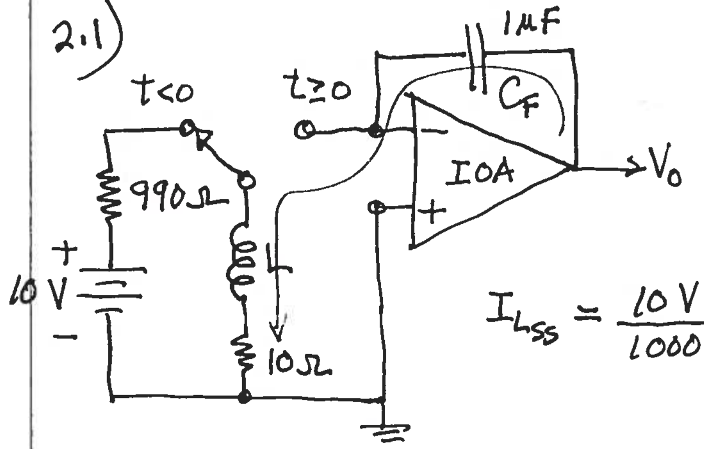
CHAPTER 2 H.P. SOLUTIONS:

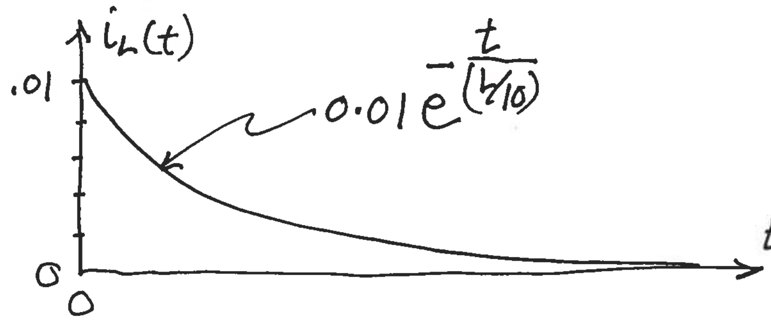
2.1)



A)

$$I_{L_{ss}} = \frac{10\,V}{1000\,\Omega} = 0.010A$$

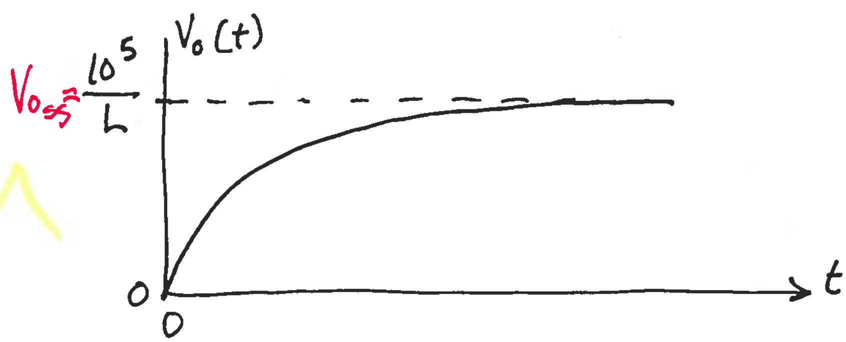
A)



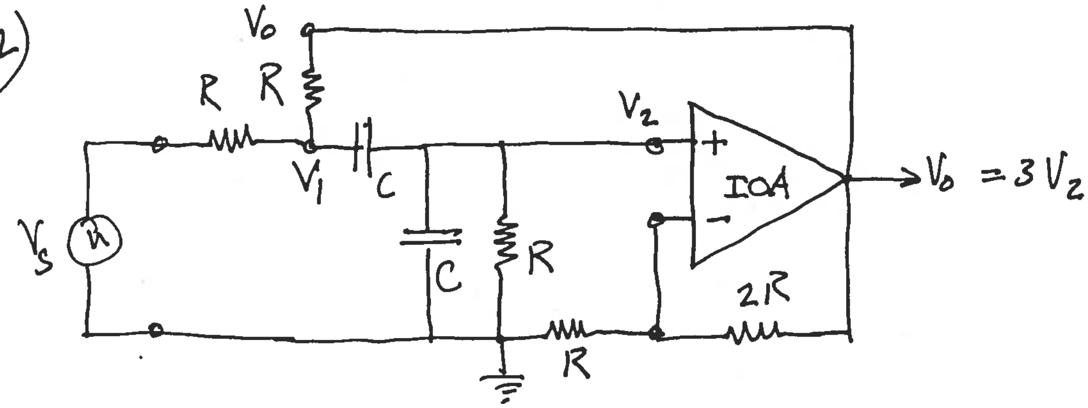
$$\int e^u du = e^u$$

B) $$V_{o_{ss}} = V_{c_{ss}} = \frac{1}{C}\int_0^\infty i_L(t)\,dt = \frac{0.01}{10^{-6}F}\int_0^\infty e^{-\frac{t10}{L}}\,dt$$

$$V_{oss} = 10^4\left(\frac{-10}{L}\right)\left[0 - 1\right] = \frac{10^5}{L}$$



2.2)



A) FIND $\frac{V_o}{V_s}(s)$: WRITE 2 NODE EQUATIONS:

USE CRAMER'S RULE

$$\begin{cases} V_1[2G + sC] - 3\overset{V_o}{V_2}G - V_2 sC = V_s G \\ -V_1 sC + V_2[G + 2sC] = 0 \end{cases}$$

$$\Delta = \begin{vmatrix} [2G + sC] & -[3G + sC] \\ -sC & [G + 2sC] \end{vmatrix} = 2G^2 + s2GC + s^2C^2$$

$$\Delta V_2 = \begin{vmatrix} (2G + sC) & V_s G \\ -sC & 0 \end{vmatrix} = V_s sCG, \therefore$$

A)

$$\boxed{\frac{V_o}{V_s}(s) = \frac{s\frac{3CR}{2}}{\left(s^2\frac{R^2C^2}{2} + sRC + 1\right)}}$$

B) $\omega_n = \frac{\sqrt{2}}{RC}$ r/s, $\frac{2\zeta}{\omega_n} = RC \rightarrow \zeta = \frac{\omega_n RC}{2} = \frac{\sqrt{2}\cancel{RC}}{\cancel{RC}\,2} = \frac{\sqrt{2}}{2} = \underline{\underline{.7071}}$

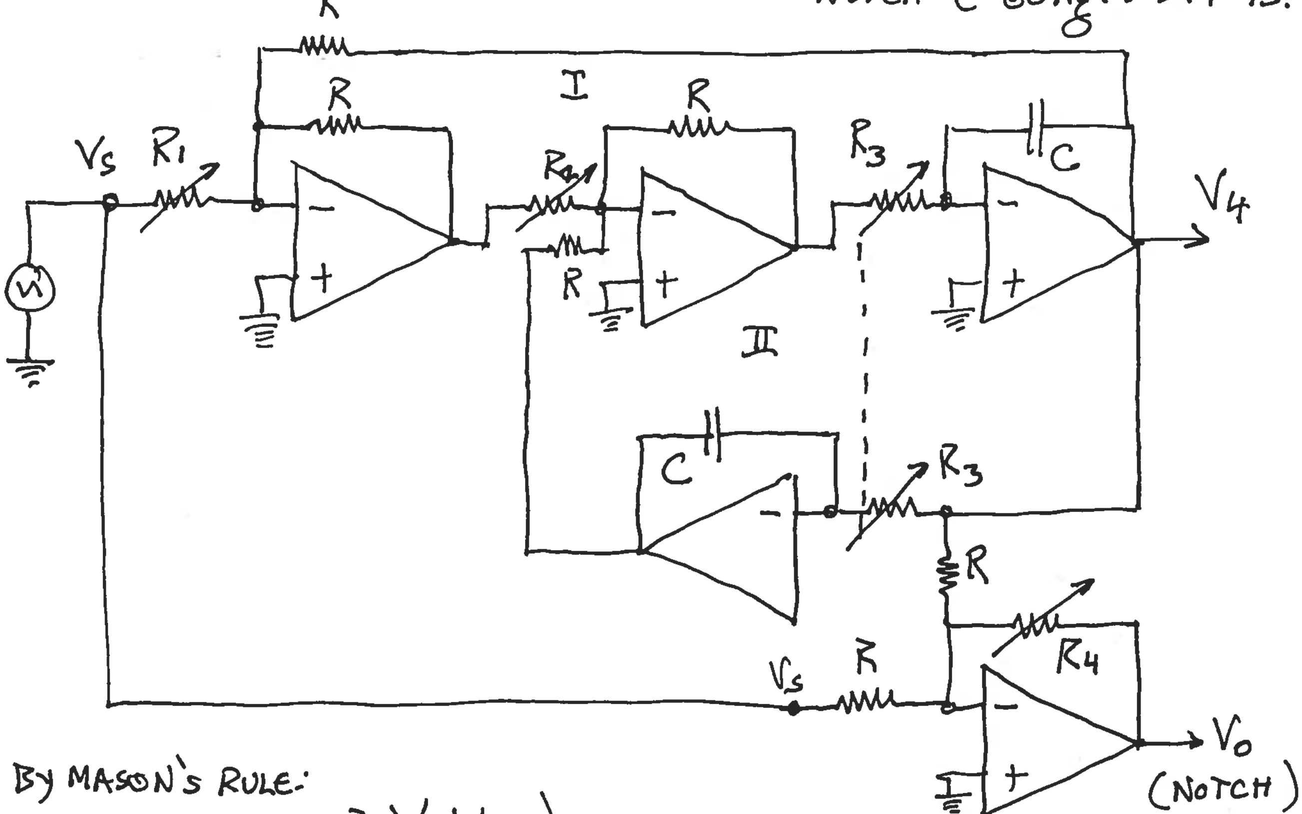
& PK GAIN @ $\omega = \omega_n$

$$\frac{V_o}{V_s}(j\omega_n) = \frac{\cancel{j\omega_n}\frac{3\cancel{CR}}{2}}{\cancel{j\omega_n}\cancel{RC}} = \frac{3}{2} = \underline{\underline{1.5}}$$

2.3) 2-LOOP, BIQUAD NOTCH FILTER: HAS $Q = 50$, $A_{v_0} = 20\,dB$ or $\times 10$

$f_b \doteq > 100\ kHz$

NOTCH @ $60\,Hz \to 377\ r/s$.



BY MASON'S RULE:

$$\frac{V_4}{V_s} = \frac{\left(\frac{-R}{R_1}\right)\left(\frac{+R}{R_2}\right)\left(\frac{+1}{sR_3C}\right)}{1 + \Big[\underbrace{(+1)\left(\frac{+R}{R_2}\right)\left(\frac{+1}{sR_3C}\right)}_{\text{LOOP I}} + \underbrace{(+1)\left(\frac{+1}{sR_3C}\right)\left(\frac{+1}{sR_3C}\right)}_{\text{LOOP II}}\Big] + 0}$$

(NO NONTOUCHING LOOPS)

$$= \frac{-sR_3CR^2/R_1R_2}{s^2(R_3C)^2 + s(R_3C)\frac{R}{R_2} + 1} \quad (\text{BPF}) \quad \omega_n = \frac{1}{R_3C}\ r/s$$

$$\frac{2\zeta}{\omega_n} = \frac{R_3CR}{R_2} = \frac{1}{Q\,\omega_n}$$

$$\therefore \downarrow Q = \frac{R_2}{R} \doteq 50, \quad \therefore R_2 = 50R$$

$$V_o = \left(\frac{-R_4}{R}\right)\left[V_s + V_4\right]$$

$\downarrow$

$$\frac{V_o}{V_s}(s) = \left(\frac{-R_4}{R}\right)\left\{1 - \frac{s\frac{R^2}{R_1R_2}R_3C}{\left[s^2(C_3R) + sR_3C\frac{R}{R_2} + 1\right]}\right\} \longrightarrow$$

2.3) CONT'D.

$$\frac{V_o}{V_s}(s) = -\frac{R_4}{R}\left\{\frac{s^2(C_3R)^2 + s(R_3C)\frac{R}{R_2} + 1 - \frac{R^2}{R_1R_2}s(R_3C)}{s^2(C_3R)^2 + s\frac{R}{R_2}C_3R + 1}\right\}$$

* TO MAKE NUMERATOR s^1 TERM VANISH

$$1\frac{R}{\cancel{R_2}} = \frac{R^{\cancel{2}}}{R_1\cancel{R_2}} \longrightarrow \text{MAKE } R = R_1$$

NOW:

$$\frac{V_o}{V_s}(s) = \frac{\left(s^2(R_3C)^2 + 1\right)}{\left(s^2(R_3C)^2 + s(R_3C)\frac{R}{R_2} + 1\right)}$$

* DESIGN:

* SET $C = 1\mu F = 10^{-6} F$ $\qquad \omega_n = \frac{1}{R_3 \times 10^{-6}} = 2\pi 60 = 377$

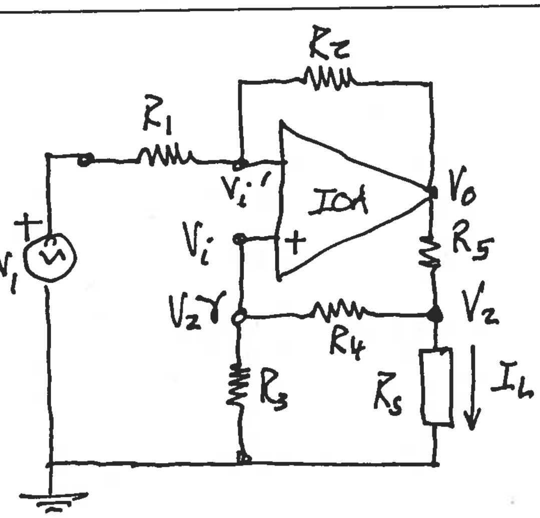
$R_3 = 2.653E3\,\Omega$ FOR 60Hz NOTCH

* SET $R = 1K\Omega$

$\therefore \quad R_1 = 1K\Omega, \quad R_2 = 50K\Omega., \quad R_3 = 2.653K\Omega$

* NOW DO SIM.

2.4)



$\alpha \equiv \frac{R_2}{R_1 + R_2}, \beta \doteq \frac{R_1}{R_1 + R_2}$

$\gamma \equiv \frac{R_3}{R_3 + R_4}$

FIND:

* $G_M = \frac{I_L}{V_1}$

* CONDITIONS ON CKT SO I_L INDEPENDENT OF R_s

* AS IOA: $V_i' = V_1\alpha + V_o\beta = V_2\gamma$

* DO KCL ON V_2 NODE: $V_2\left[G_s + G_5 + \frac{1}{R_3 + R_4}\right] = V_oG_5 \Longrightarrow$

2.4) CONT'D: NOW $V_0 = \frac{\gamma V_2 - V_1 \alpha}{\beta}$, SO

$$V_2\left[G_S + G_5 + \frac{1}{R_3+R_4}\right] = G_5\left[\frac{\gamma V_2 - \alpha V_1}{\beta}\right]$$

$\downarrow$ (ALG)

$$V_2\left[G_S R_5 + \left(1 + \frac{R_5}{R_3+R_4} - \frac{\gamma}{\beta}\right)\right] = -V_1 \frac{\alpha}{\beta}$$

MAKE $\to 0$

$$\frac{R_2}{R_1} = \frac{\alpha}{\beta}$$

$$V_2\left[G_S R_5\right] = -V_1 \frac{\alpha}{\beta} \longrightarrow V_2 = \frac{-V_1\, \alpha/\beta}{G_S R_5}$$

NOW $\boxed{I_L = \frac{V_2}{R_S} = \frac{-V_1\, \alpha/\beta}{\cancel{R_S G_S} R_5} = -V_1 \frac{R_2}{R_1 R_5} \quad , \therefore G_M = -\frac{R_2}{R_1 R_5}\ S}$

TO MAKE $(*) \to 0$;

$$\frac{R_5 R_3}{R_3(R_3+R_4)} = \frac{\gamma}{\beta} - 1 = \frac{\overset{\gamma}{\frac{R_3}{R_3+R_4}}}{\underset{\beta}{\frac{R_1}{R_1+R_2}}} - 1 \to 0$$

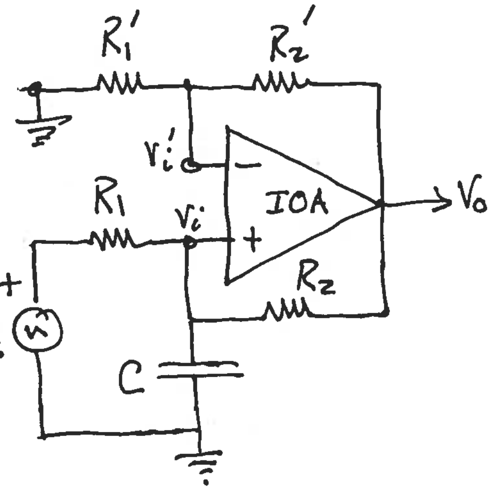
* AFTER MUCH ALGEBRA:

1. MAKE: $\gamma > \beta$
2. MAKE: $R_2 R_3 - R_1 R_4 = R_1 R_5$

FOR $\boxed{\frac{I_L}{V_1} = -\frac{\alpha}{\beta} G_5}$

2.5) DEBOO NON-INVERTING INTEGRATOR: OA ≡ IDEAL, $R_1 \equiv R_1'$, $R_2 \equiv R_2'$.

A) $\frac{V_o}{V_s}(s)$



$$\beta \equiv \frac{R_1}{R_1 + R_2}$$

$$V_i' = V_o \frac{R_1'}{R_1' + R_2'} = V_i$$

BY KCL: $V_i\left[G_1 + G_2 + sC\right] - G_2 V_o - V_s G_1 = 0$

$$\downarrow$$

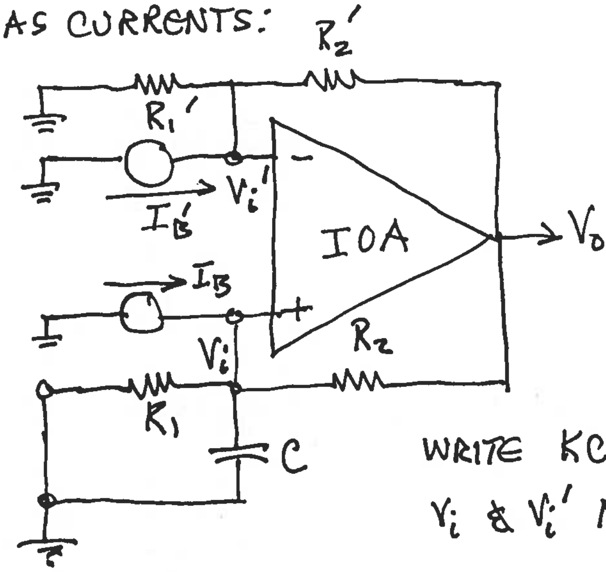
$$V_o\beta\left[G_1 + G_2 + sC\right] - V_o G_2 = V_s G_1$$

$$\downarrow$$

$$\frac{V_o}{V_s} = \frac{G_1}{\beta\left[\frac{R_2 + R_1}{R_1 R_2} + sC\right] - G_2} = \frac{G_1}{\beta\left[\frac{G_2}{\beta} + sC\right] - G_2}$$

$$\therefore \boxed{\frac{V_o}{V_s} = \frac{G_1}{sC\beta} = \frac{1}{sCR_1\beta}}$$

B) CONSIDER BIAS CURRENTS:



$V_s \equiv 0$

WRITE KCL NODE EQS FOR V_i & V_i' NODES:

2.5) CONT'D

B) $V_i'\left[G_1 + G_2\right] - V_o G_2 = I_B'$

$$V_i\left[sC + G_1 + G_2\right] - V_o G_2 = I_B, \qquad V_i' = \frac{I_B' + V_o G_2}{G_1 + G_2}$$

$$\therefore \frac{I_B' + V_o G_2}{(G_1 + G_2)}\left[sC + (G_1 + G_2)\right] - V_o G_2 = I_B$$

AFTER SOME ALGEBRA:

$$V_o = (I_B - I_B')\frac{R_1 + R_2}{sCR_1} = (I_B - I_B')\frac{1}{sC\beta} - I_B' R_2$$

OFFSET CURRENT, I_{os} *

LET $I_B(t) = I_B\, u(t)$ & $I_B' = I_B'\, u(t)$
STEP

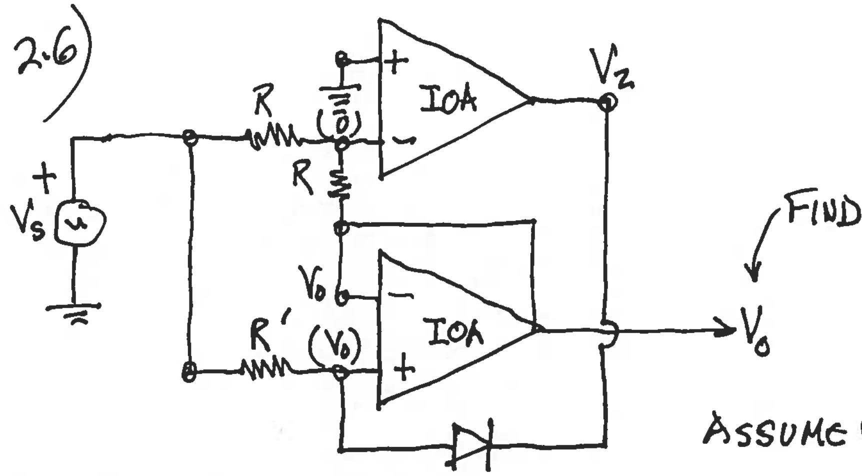
$$\therefore I_B(s) = \frac{I_B}{s}, \quad I_B'(s) = \frac{I_B'}{s}$$

$$\therefore V_o(s) = \frac{I_B - I_B'}{s}\,\frac{1}{sC\beta} - \frac{I_B'}{s} R_2$$

$\downarrow \mathcal{L}^{-1}$

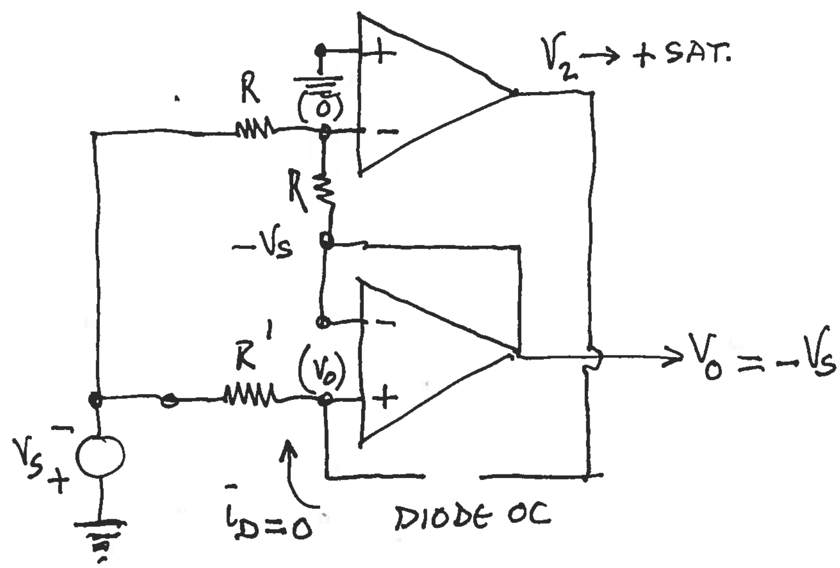
$$\boxed{v_o(t) = I_{os}\frac{t}{C\beta} - I_B' R_2\, u(t), \quad t \geq 0}$$

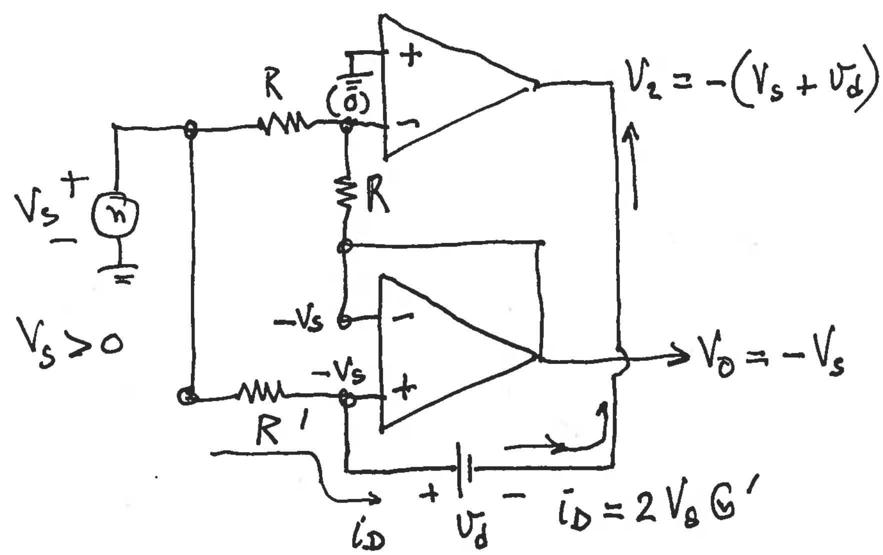
2.6)

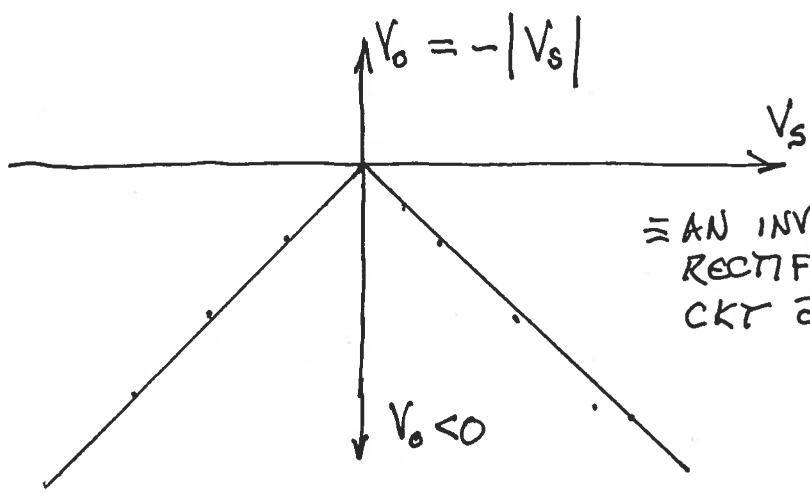


ASSUME DIODE IS IDEAL: $\Rightarrow$

2.6) CONT'D. $V_S < 0$:







≡ AN INVERTING FULL-WAVE RECTIFIER (OR ABSVAL) CKT c̄ UNIT GAIN.

2.7) DESIGN 60Hz NOTCH FILTER: $\alpha \equiv \frac{R_2}{R_1+R_2}$

* CLEARLY, $V_2 = -3V_S$, $V_3 = -3V_S \frac{R_2}{R_1+R_2} = -3V_S\alpha$

* USING SUPERPOSITION ON IOA-2:

$$V_o(s) = -3V_S\left[\frac{-sCR_3}{(1+sCR_3)^2}\right] + -3V_S\alpha\left[1 + \frac{\frac{1}{G_3+sC}}{\frac{1}{sC}+R_3}\right]$$

ALGEBRA

SET $\alpha \equiv \frac{1}{3}$

$$\boxed{\frac{V_o}{V_S}(s) = \frac{-\left[s^2(R_3C)^2+1\right]}{\left[s^2(R_3C)^2+s2R_3C+1\right]}}$$

B)

NOTCH

$\zeta = 1$, $Q = \frac{1}{2}$

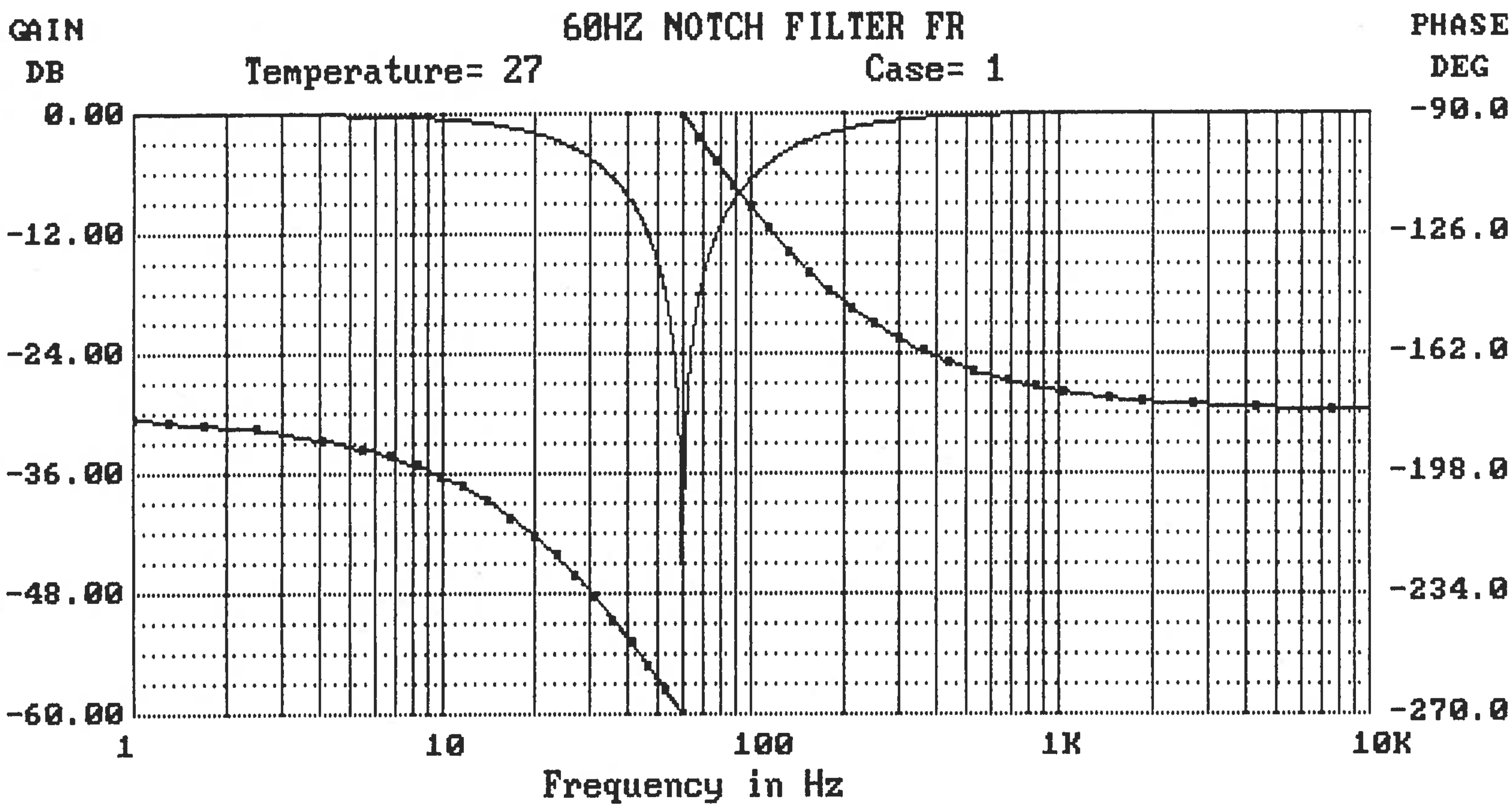
DESIGN: $R_1 \equiv 1K$, $R_2 \equiv 2K$, $\therefore \alpha = \frac{1}{3}$, $R_3 \equiv 10K$

$\therefore C = \frac{1}{\underbrace{2\pi 60}_{=(377)} \times 10^4} = \underline{\underline{2.653\ E-7}}\ F$

* DEEPEST NOTCH CA. -80 dB USING FIXED-STEP INTEG. @ 0.05% ACC., $Q = \frac{\Delta f}{f_o} \cong \frac{60}{60} = 1$

* SEE NEXT PAGE FOR PLOT: OP-37 OA'S WERE USED $\bar{c}$ MICROCAP SIM.

2.7) BODE PLOT



Frequency	=	100.00000E+02 Hz	Gain	=	-.009 Db
Phase angle	=	-179.349 Degrees	Group delay	=	0.00000E+00
Gain slope	=	115.82310E-05 Db/Oct	Peak gain	=	-.009Db/F= 100.00000E+02

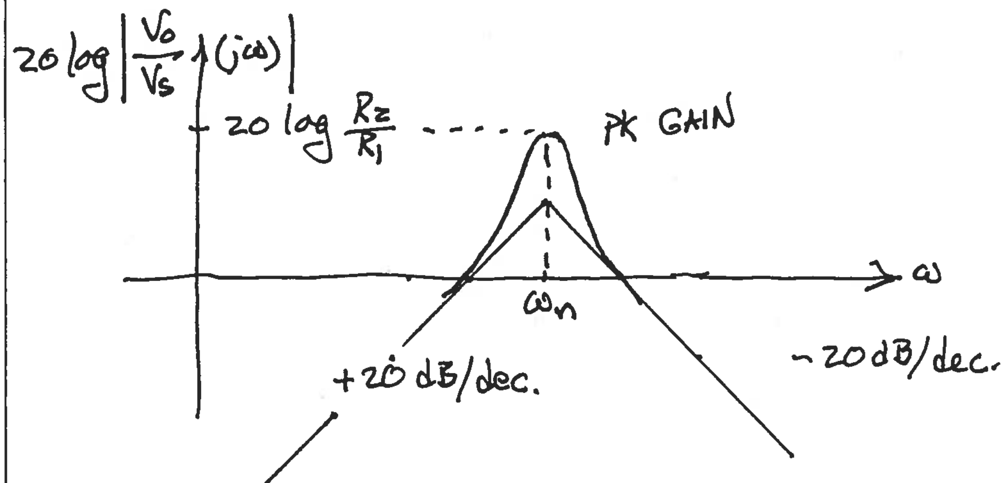
2.8) SINGLE-LOOP BIQUAD: (SEE FIG. P2.8)

A) $\frac{V_o}{V_S}(s)$ IN TC FORM: USING MASON'S RULE:

$$\frac{V_o}{V_S}(s) = \frac{-\left(\dfrac{\frac{1}{sC+G_2}}{R_1}\right)}{1+\left[(+1)\left(\dfrac{+1}{sR_3C}\right)\left(+\dfrac{\frac{1}{sC+G_2}}{R_3}\right)\right]}$$

$\downarrow$

$$\frac{V_o}{V_S}(s) = \frac{-sCR_3\left(\frac{R_3}{R_1}\right)}{s^2(CR_3)^2+sCR_3\left(\frac{R_3}{R_2}\right)+1} \quad \text{(T.C. FORM)}$$



B) $\omega_n = \frac{1}{CR_3}$ r/s, $\frac{2\zeta}{\omega_n} = R_3C\frac{R_3}{R_2} \rightarrow \zeta = \frac{R_3}{2R_2}$, $Q = \frac{1}{2\zeta} = \frac{R_2}{R_3}$

THERE IS MUCH INTERACTION BETWEEN R's: pk GAIN @ $\omega = \omega_n$ $= -\frac{R_2}{R_1}$

DESIGN: 1) PICK ω_n, C, FIND REASONABLE R_3 $(1K \leq R_3 \leq 1M)$;

2) PICK ζ (OR Q). R_2 SETS Q; R_1 SETS GAIN.

2.9) (SEE FIG P2.9)

A) $V_o = -I_1 R_F$

B) SYSTEM WILL BE UNSTABLE:

IF OA K_{V_o} IS FINITE, $\beta K_{V_o} < 1$

SO $\beta < \frac{1}{K_{V_o}}$. $V_o \cong V_1 \frac{1}{\beta}$

C) $V_o = \frac{-1}{sC} I_1$

D) $$\frac{V_o}{V_1}(s) = \frac{-\frac{1}{(G_2 + sC_2)}}{\left(R_1 + \frac{1}{sC_1}\right)} = \frac{-sC_1R_2}{(sC_2R_2+1)(sC_1R_1+1)}$$

AMID $= -\frac{C_1}{C_2}$

E) $$V_o(s) = -V_1(s)\frac{R_2 + \frac{1}{sC_2}}{R_1} \rightarrow \frac{V_o}{V_1}(s) = \frac{-(sC_2R_2+1)}{sC_2R_1}$$

F) $$\frac{V_o}{V_1}(s) = -\frac{(sC_1R_1+1)}{sC_2R_1}$$

G) $$\frac{V_o}{V_1}(s) = -\frac{sC_1R_2}{(sC_1R_1+1)}$$

2.10) LINEARIZED WHEATSTONE BRIDGE: (SEE FIG P2.10)

FIND V_o: N.B: $V_2 = V_3 \cong 0$ AS IOA.

$$\begin{cases} \cancel{V_2\left[G_3 + \frac{1}{R+\Delta R}\right]}^{\to 0} - \frac{V_1}{R+\Delta R} = V_s G_3 \\ \cancel{V_3\left[G_3 + G + G_2\right]}^{\to 0} - V_1 G - V_o G_2 = V_s G_3 \end{cases}$$

$\Downarrow$

1) $-\frac{V_1}{R+\Delta R} = V_s G_3$; 2) $-V_1 G - G_2 V_o = V_s G_3$ $\Rightarrow$

2.10) CONT'D:

$$V_1 = -V_s G_3 (R + \Delta R) \xrightarrow{\text{SUB.}} -V_1 G - V_o G_2 = V_s G_3$$

$$\downarrow \text{ALG}$$

$$\boxed{V_o = \left(\frac{\Delta R}{R}\right) \frac{R_2}{R_3}}$$

2.11) RE: CMRR

$$\text{CMRR} @ 60\,Hz \equiv 120\,dB \rightarrow 10^6 \text{(NUMERIC)}$$

$$\text{CMRR} \equiv \frac{A_D}{A_C} = 10^6 \qquad V_o = A_D V_{id} + A_C V_{ic} \quad \text{(D.A. OUTPUT)}$$

$$v_{id} = \frac{.004 + 0}{2} = 0.002\,V\,pk, \quad v_{ic} = \frac{.004 + 0}{2} = 0.002\,V\,pk.$$

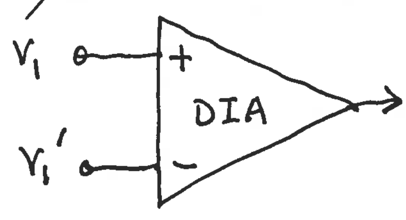
$$1.414_{PK} = .002 A_D + 0.002 A_C$$

$$\therefore A_D + A_C = \frac{1.414}{.002} = 707.1$$

$$\downarrow$$

$$\left(10^6 A_C + \cancel{A_C}\right) \cong 707.1 \rightarrow \left.\begin{array}{l} A_C \cong 7.071E-4 \\ \therefore A_D \cong 707.1 \end{array}\right\}$$

2.12)



$$\rightarrow V_o = \underset{\uparrow \atop 10^3}{A_D} V_{id} + \underset{\uparrow \atop 10^{-2}}{A_C} V_{ic}$$

A) $\text{CMRR}_{dB} = 20 \log\left(\frac{10^3}{10^{-2}}\right) = \underline{\underline{100\,dB}}$ →

2.12 B) $\begin{cases} V_1(t) \equiv 0.002 \sin(2\pi 400t) \\ V_1'(t) = -0.002 \sin(2\pi 400 t) + 2\sin(377t) \end{cases}$ 60 Hz HUM

$$v_{1d} = \frac{v_1 - v_1'}{2} = 0.002 \sin(2\pi 400t) - 1\sin(377t)$$

$$v_{1C} = \frac{v_1 + v_1'}{2} = +1 \sin(377t)$$

X

$$\therefore V_o(t) = 2\sin(2\pi 400t) - 10^3 \sin(377t) + 10^{-2} \times 1 \sin(377t)$$

* BECAUSE OF HIGH DM HUM COMPONENT, OP AMP SATURATES DUE TO HUM, GET SQ WAVE OUT! IS USELESS.

2.13) A WIEN BRIDGE NOTCH FILTER: (SEE FIG. P 2.13)

$$V_o = (V_3 - V_2), \quad V_1 = K_D(V_o - V_s) = K_D(V_3 - V_2 - V_s)$$

BUT $V_2 = V_1 \dfrac{R}{R+2R} = \dfrac{V_1}{3}$, $\therefore V_1 = K_D\left[V_3 - \dfrac{V_1}{3} - V_s\right]$

$$V_1\left[1 + \frac{K_D}{3}\right] = K_D(V_3 - V_s)$$

NOW $V_3 = V_1 \dfrac{\dfrac{1}{sC+G}}{\dfrac{1}{sC+G} + R + \dfrac{1}{sC}}$

$$V_3 = V_1 \frac{sRC}{s(RC)^2 + s3RC + 1}$$

$\Rightarrow$

2.13 A) $V_0 = V_3 - V_2 = V_1\left[\dfrac{sRC}{s^2(RC)^2 + s3RC + 1} - \dfrac{1}{3}\right]$

$\downarrow$

$$V_0 = -K_D\left[V_0 - V_s\right]\left[\frac{s^2(RC)^2 + 1}{s^2(RC)^2 + s3RC + 1}\right]$$

$\downarrow$ MORE ALG!

A) $$\frac{V_0}{V_s}(j\omega) = \frac{K_D}{K_D+1}\,\frac{(j\omega)^2(RC)^2 + 1}{\left\{(j\omega)^2(RC)^2 + \frac{3RC}{K_D+1}j\omega + 1\right\}}$$

B) $f_n = \dfrac{\omega_n}{2\pi} = \dfrac{1}{2\pi RC}$

LET $C = 10^{-6}F$ ($1\mu F$), $\therefore R = \dfrac{1}{377\times10^{-6}} \simeq \underline{\underline{2.653E3\,\Omega}}$

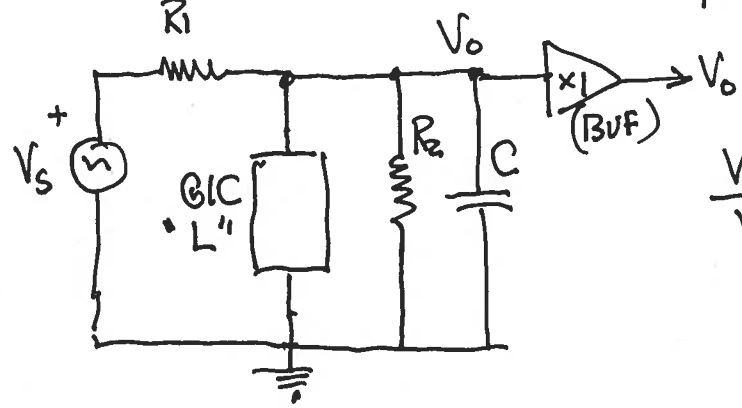
C) DC GAIN: ω_n:

$A_{V_0} = \dfrac{K_D}{K_D+1}$, $\omega_n = \dfrac{1}{RC}$ r/s, $\dfrac{2\xi}{\omega_n} = \dfrac{3RC}{K_D+1} \rightarrow 2\xi = \dfrac{3}{K_D+1}$

$\therefore Q = \dfrac{1}{2\xi} = \dfrac{K_D+1}{3}$

2.14) DESIGN A QUADRATIC BPF $\bar{c}$ GIC CKT:

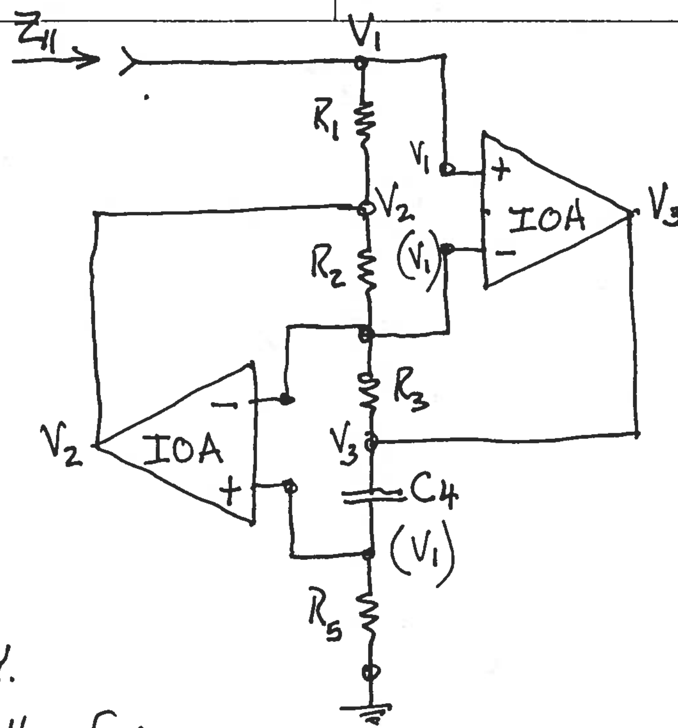
$f_n = 1\,Hz$, $Q = 10$, ALL R's: $10^3 - 1.0M$; ALL C's: $3pF - 1\mu F$



$$\frac{V_0}{V_s}(s) = \frac{\dfrac{1}{sC + G_2 + 1/sL}}{R_1}$$

$$= \frac{sL/R_1}{s^2LC + sLG_2 + 1}$$

2.14) GIC "L":



$$\vec{Z}_{11} = \frac{\bar{Z}_1 \bar{Z}_3 \bar{Z}_5}{\bar{Z}_2 \bar{Z}_4}$$

$$\vec{Z}_{11} = \frac{R_1 R_3 R_5}{R_2 \frac{1}{j\omega C_4}}$$

$$\vec{Z}_{11} = j\omega\left[C_4 \frac{R_1 R_3 R_5}{R_2}\right]$$

$\therefore L_{eq} = C_4 R_1 R_3 R_5 / R_2$ HY.

*NEED HUGE L_{eq} FOR 1 Hz f_n:

$$L_{eq} = 10^3 \text{ HY} = \underset{C_4}{10^{-6}} \frac{10^4 \times 10^4 \times 10^4}{\underset{R_2}{10^3}} = 10^{-6} \times 10^{+9} = 10^3 \text{ HY}$$

$$Q = \frac{1}{L G_2 \omega_n} = \frac{\sqrt{LC}}{L G_2} \cong 10 \qquad \omega_n = \frac{1}{\sqrt{LC}} \text{ r/s}$$

$$100 = \frac{\cancel{L} C}{L^{\cancel{2}} G_2^2} \rightarrow G_2^2 = \frac{C}{L}\frac{1}{100} \rightarrow G_2 = \sqrt{\frac{C}{L}}\frac{1}{10}, \therefore R_2 = 10\sqrt{\frac{L}{C}}$$

$$f_n^2 = 1 = \frac{1}{(2\pi\, 1)^2 LC} \longrightarrow C = \frac{1}{(2\pi 1)^2 L} = 2.533E-5 = 25.33 \mu F$$

$$\therefore R_2 = 10\sqrt{\frac{10^3}{10^{-6} \times 25.33}} = 6.283E4\,\Omega \quad \text{FOR } Q \cong 10$$

*FOR UNITY GAIN, LET $R_1 = R_2$

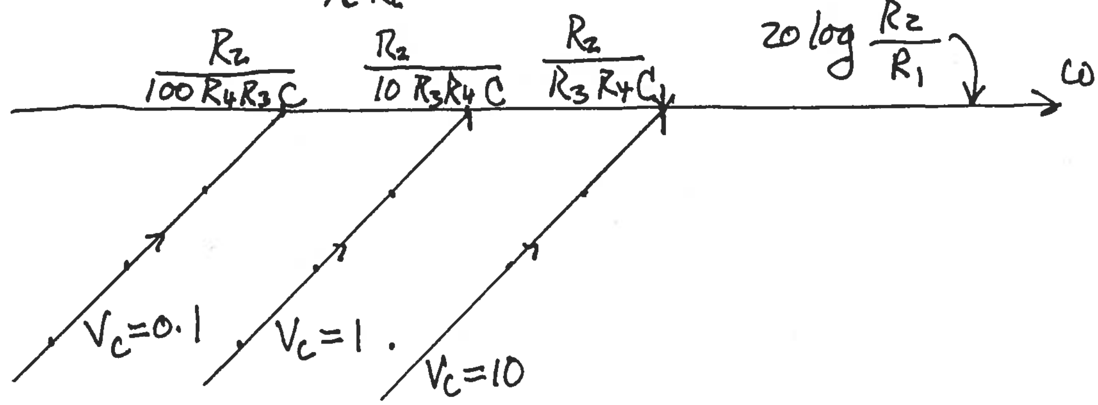
2.15) (SEE FIG. P 2.15)

A) $$\frac{V_o}{V_1}(s) = \frac{-\frac{R_2}{R_1}}{1+\left[\left(+\frac{R_2}{R_3}\right)\left(+\frac{V_c}{10}\right)\left(\frac{+1}{sR_4C}\right)\right]} = \frac{-s\frac{R_2}{R_1}}{\left(s+\frac{R_2}{R_3}\frac{V_c}{10}\frac{1}{R_4C}\right)}$$

IN TC FORM: $$\frac{V_o}{V_1}(s) = \frac{-s\left(\frac{10R_3R_4C}{R_1V_c}\right)}{\left[s\left(\frac{10R_3R_4C}{V_cR_2}\right)+1\right]}$$

B) HI-F. GAIN:

$$\frac{V_o}{V_1}(HI) = \frac{-\frac{\cancel{10R_3R_4C}}{R_1\cancel{V_c}}}{\frac{\cancel{10R_3R_4C}}{\cancel{V_c}R_2}} = -\frac{R_2}{R_1}$$



2.16) $V_3 = \frac{V_1}{2}$

BY KCL: $\boxed{V_2[G+s2C]-V_osC = V_1\left[G+s\frac{C}{2}\right]}$

AT THE SJ: $V_i'\left[\frac{G}{4}+sC\right]-V_o\frac{G}{4}-V_2sC=0$

BUT $V_i' = V_i = \frac{V_1}{2}$

$$\boxed{-V_2sC-V_o\frac{G}{4} = -\frac{V_1}{2}\left[sC+\frac{G}{4}\right]}$$

SOLVE BY CRAMER'S RULE:

⇒

2.16) FIND:

$$\frac{V_o}{V_i}(s) = \frac{\frac{1}{2}\left[1 - s2RC + s^2(2RC)^2\right]}{\left[1 + s2RC + s^2(2RC)^2\right]}, \quad \omega_n = \frac{1}{2RC} \text{ r/s}$$

$$\frac{2\xi}{\omega_n} = 2RC \rightarrow \xi = \frac{2RC}{2}\frac{1}{2RC} = \frac{1}{2}$$

* THIS IS AN ALL-PASS FILTER.

2.17) @ S.J. OF IOA-1:

$$\cancel{V_i'\left[G_1 + G_1 + G_2\right]} - G_1\frac{V_2^2}{\cancel{10}} - G_1\frac{V_1^2}{\cancel{10}} - G_2\left(\frac{-V_o^2}{\cancel{10}}\right) = 0$$

$$G_1\left(V_2^2 + V_1^2\right) = G_2 V_o^2$$

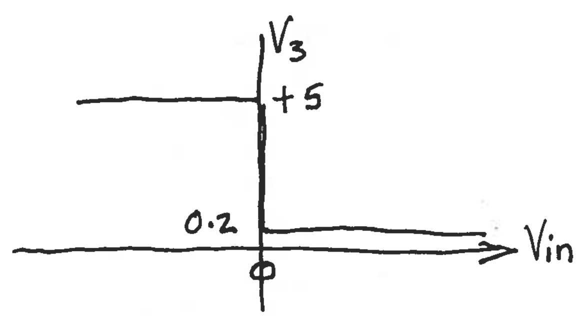
$$V_o^2 = \frac{G_1}{G_2}\left(V_2^2 + V_1^2\right)$$

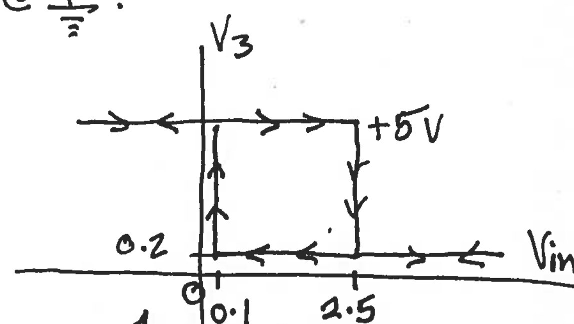
{NEED INVERTER TO SUM Is CORRECTLY @ IOA-1 S.J.}

$$\boxed{V_o = \sqrt{\frac{R_2}{R_1}}\sqrt{V_2^2 + V_1^2}}$$

2.18) A) $V_3 = f(V_{in}, R_1, R_2)$? $V_B \equiv 0$

WITH NO R_1, R_2 FEEDBACK: & V_2 @ ⏚.





WITH FEEDBACK, GET HYSTERISIS:

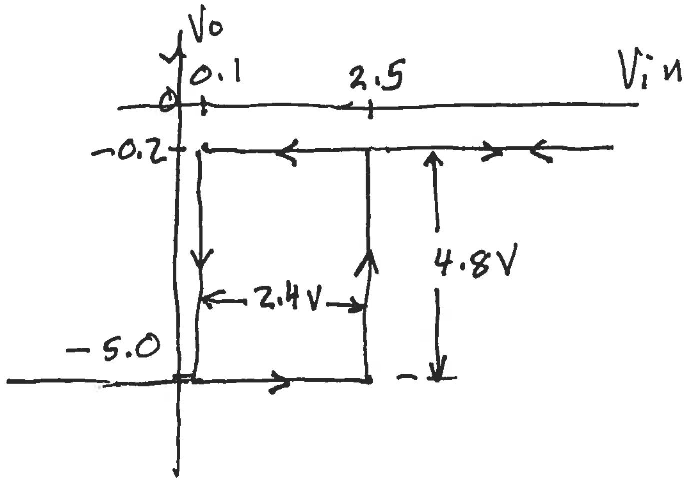
KCL @ V_2 NODE: $V_2\left[G_1 + G_2\right] - V_3 G_2 = 0 \rightarrow V_2 = \frac{V_3 R_1}{R_1 + R_2}$ ⇒

2.18) For V_3 to go LO; $V_1 = \dfrac{5R_1}{R_1+R_3} = \dfrac{5\times 100K}{200K} = 2.5 = V_{in}$

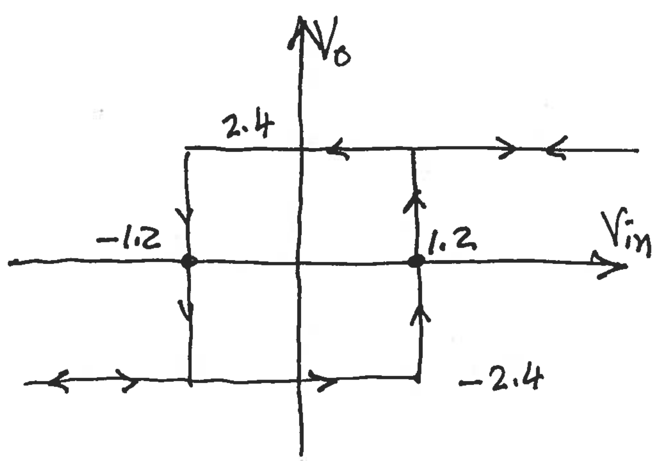
For V_3 to go HI; $V_1 \le \dfrac{0.2\times 100k}{200K} = 0.1V. = V_{in}$

B) THE IOA INVERTS V_3:

i.e, $V_o = -V_3$



C) TO MAKE HYST. LOOP CENTERED ON 0,0:



ADD +2.6V TO RAISE:

$\therefore V_C = -2.6$

$V_B + 2.5 = 1.2$

$\therefore V_B = -1.3$