

①

	$\phi_1$	$\phi_2$		$\phi_1$	$\phi_2$
A	$-v_1[n-1]$	0	C	0	$-v_2[n]$
B	$-v_2[n-1]$	$-v_2[n]$	D	$-v_1[n-1]$	$-v_1[n]$
F	0	$-v_2[n]$	E	$-v_2[n-1]$	$-v_2[n]$
I	$-v_1[n+1]$	0	G	$-v_1[n+1]$	0
J	0	$-v_1[n]$	H	0	$-v_1[n]$

$$B(v_2[n] - v_2[n-1]) + Fv_2[n] + A[-v_1[n-1]] + I[-v_1[n-1]] + Jv_1[n] =$$

$$D(v_1[n] - v_1[n+1]) + G(-v_1[n-1]) + Hv_1[n] + Cv_2[n] + E[v_2[n] - v_2[n-1]] =$$

$$D v_1(z)(1-z^{-1}) - G v_1(z) z^{-1} + H v_1(z) + C v_2(z) + E v_2(z)(1-z^{-1}) = 0 \quad (1)$$

$$B v_2(z)(1-z^{-1}) + F v_2(z) - A v_1(z) z^{-1} - I v_1(z) z^{-1} + J v_1(z) = 0 \quad (2)$$

$$\Rightarrow v_2(z) = \frac{A z^{-1} v_1(z) + I z^{-1} v_1(z) - I v_1(z)}{B + F - B z^{-1}} \quad \text{from (2)}$$

$$v_2(z) = \frac{-D(1-z^{-1}) v_1(z) - v_1(z)(H - G z^{-1})}{C + E(1-z^{-1})} \quad \text{from (1)}$$

equating (1) &amp; (2)

$$\frac{v_1(z)}{v_1(z)} = \frac{z^{-2} (EI - GB) + (HB + GB + Fz - IZ - IE - EJ) z^{-1} + (LJ + EJ - HB - H)}{(DB - AE) z^{-2} + (AC + EA - BD - DB - DF) + (DB + DF)}$$

2

$$H(s) = \frac{10 \frac{s}{10\omega_p}}{\left(\frac{s}{\omega_p}\right)^2 + \frac{s}{10\omega_p} + 1}$$

$$s = \frac{g}{T_s} \frac{1-z^{-1}}{1+z^{-1}}$$

$$H(z) = \frac{\frac{1}{\omega_p} \times \frac{g}{T_s} \frac{1-z^{-1}}{1+z^{-1}}}{\left(\frac{1}{\omega_p}\right)^2 \left(\frac{g}{T_s}\right)^2 \left(\frac{1-z^{-1}}{1+z^{-1}}\right)^2 + \frac{1}{10\omega_p} \times \frac{g}{T_s} \frac{1+z^{-1}}{1-z^{-1}} + 1}$$

$$\frac{1}{\omega_p T_s} = \frac{5}{g\pi}$$

$$= \frac{1.59 (1-z^{-2})}{3.369 z^2 - 3.05 z^{-1} + 3.687}$$

$$= \frac{0.47 - 0.471 z^{-2}}{z^{-2} - 0.908 z^{-1} + 1.094}$$

3

(a)  $E=0$  make  $H=0$   $B=D=1$ ,  $A=C$

$$\frac{V_1}{V_i} = \frac{-G_2 z^{-2} + \{G_2 + G_1 F - C I\} z^{-1} + C J}{z^{-2} + [C^2 - 2 - F] z^{-1} + F + 1}$$

$$\left. \begin{aligned} C^2 - 2 - F &= -0.908 & C^2 - F &= 1.09 \\ F + 1 &= 1.094 \end{aligned} \right\}$$

$$F = 0.0943 \quad A = C = 1.089$$

$$G_2 = 0.471$$

$$G_2 + G_1 F - C I = 0 \quad \Rightarrow \underline{I = 0.473}$$

$$C J = +0.47$$

$$J = 0.471$$

$$\frac{C_{\max}}{C_{\min}} = 11.54$$

(b)  $B=D=1$   $F=0$   $A=C$  Make  $H=0$

$$\left. \begin{aligned} DB - AE &= 0.9137 \\ C^2 - EA - G &= -0.83 \end{aligned} \right\} \begin{aligned} A=C &= 1.04 \\ E &= 0.083 \end{aligned}$$

$$-Bh + EI = -G + 0.083I = -0.432$$

$$Bh - IC - IE - EJ = 0$$

$$\Rightarrow G - 1.124I - 0.083J = 0$$

$$CJ + EJ = -0.43$$

$$J = 0.1382$$

$$I = 0.382$$

$$G = 0.4617$$

$$\frac{C_{\max}}{C_{\min}} = 75.8$$

(c)  $B=D=1$   $A=C$   $E=0$  Make  $I=0$

$$\frac{V_o}{V_i} = \frac{(AG)z^{-2} - (AH - DJ)z^{-1} - DJ}{(BD)z^2 - (GBD + FD - AC) + D(B+F)}$$

$$= \frac{AGz^{-2} - (HA - J)z^{-1} - J}{z^{-2} - (G + F - AC)z^{-1} + (HF)}$$

Compare to  $\frac{0.47 - 0.471z^{-2}}{z^{-2} - 0.908z^{-1} + 1.094}$

$$J = 0.47 \quad F = 0.0943$$

$$G + F - AC = 0.9017$$

$$AC = 1.192$$

$$A=C = 1.092$$

$$AG = 0.4719$$

$$G = 0.432$$

$$\frac{C_{\max}}{C_{\min}} = \frac{CA}{CF} = 11.54$$

$$(d) \quad A=C \quad F=0 \quad B=D=1 \quad \underline{\underline{\text{Maka } I=0}}$$

$$\frac{V_2}{V_1} = \frac{A_2 z^{-2} - (HA - J)z^{-1} - J}{z^2(1-AB) - (2-AB-AC)z^{-1} + (1+F)}$$

$$A_2 = 0.43 \quad \underline{\underline{J = 0.431}}$$

$$HA = J$$

$$4 - AE = 0.91 \quad AB = 0.086$$

$$2 - AB - AC = 0.83 \Rightarrow AC = 1.08 \Rightarrow \underline{\underline{A=C = 1.040}}$$

$$\therefore E = \underline{\underline{0.082}}$$

$$G = \underline{\underline{0.4141}}$$

$$H = \underline{\underline{0.414}}$$

$$\frac{C_{\max}}{C_{\min}} = 12.5 = \frac{CA}{CB}$$

4

$$H(s) = \frac{s}{Q\omega_p \left( \left( \frac{s}{\omega_p} \right)^2 + \left( \frac{s}{Q\omega_p} \right) + 1 \right)}$$

$$Q = 10$$
$$\omega_p = 2\pi \times 1M$$

$$\omega_p = \frac{1}{RC} = 2\pi \times 1M \text{ rad/s}$$

if  $R = 1k\Omega$   $C = 159.15 \mu F$

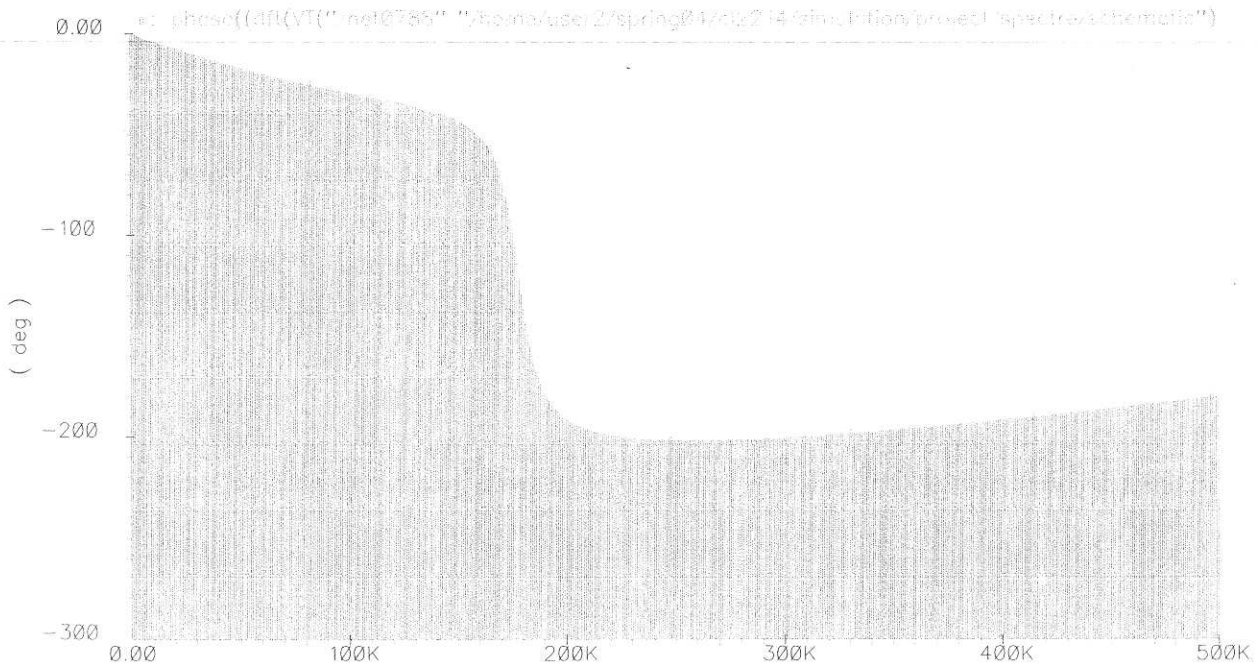
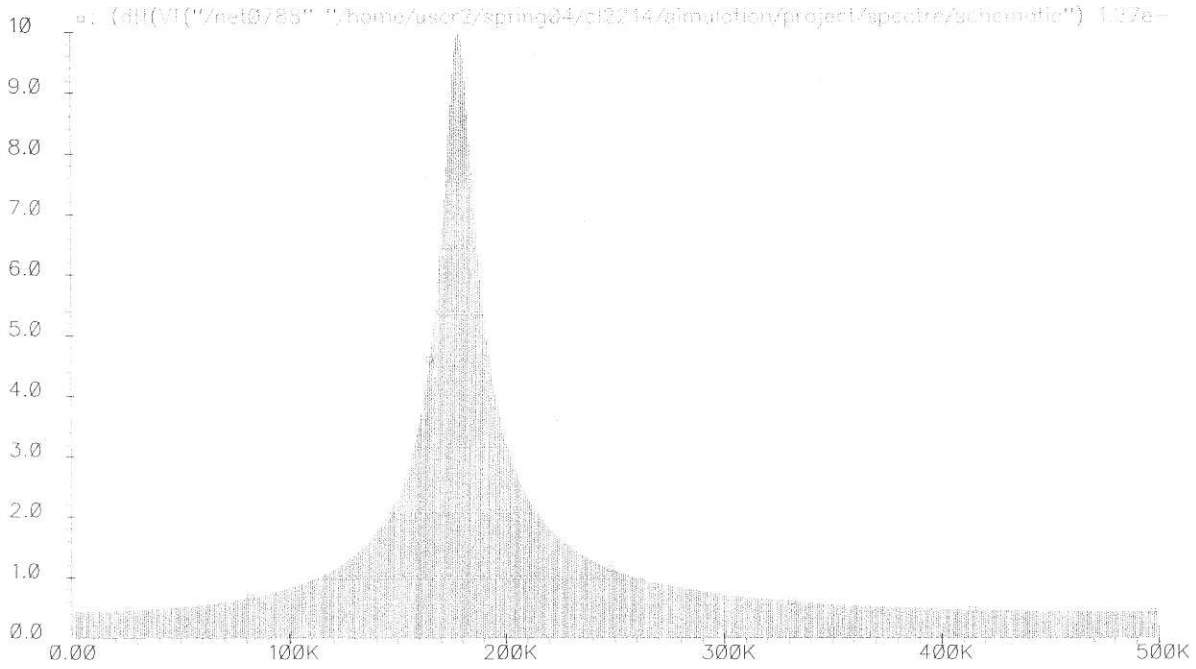
$$Q_{\text{actual}} = \frac{1}{\frac{1}{Q_{\text{design}}} + \frac{1}{A_0} + \frac{1}{A_0}}$$
$$\approx 8.33$$

[ one inverting  
and one non-inverting  
integrator ]

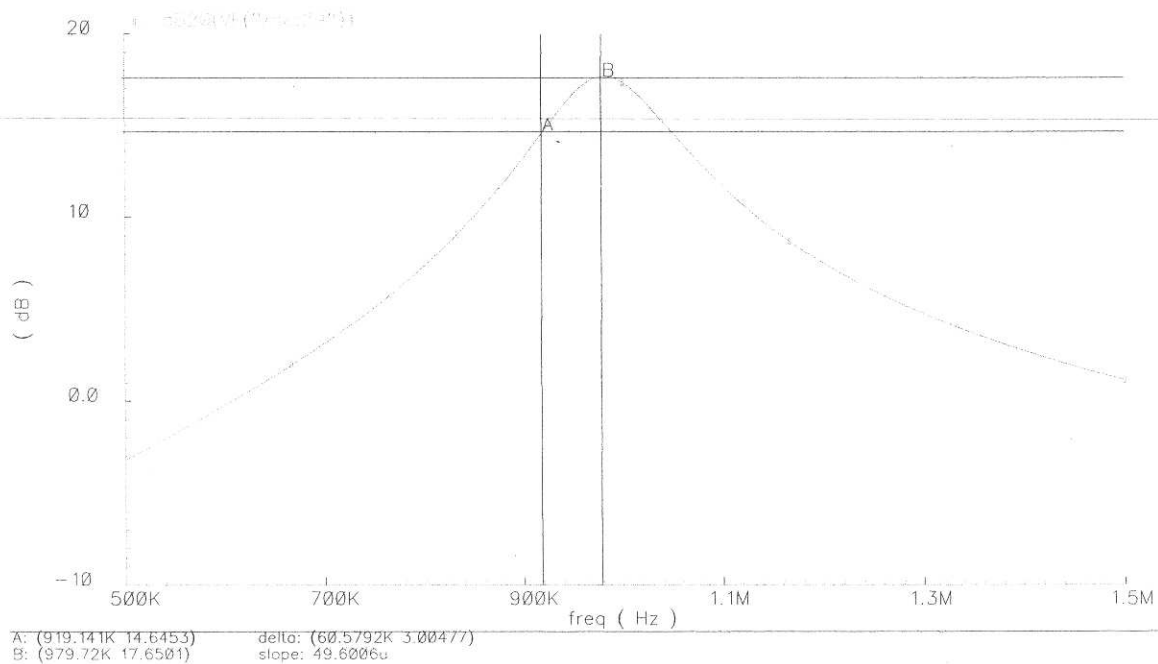
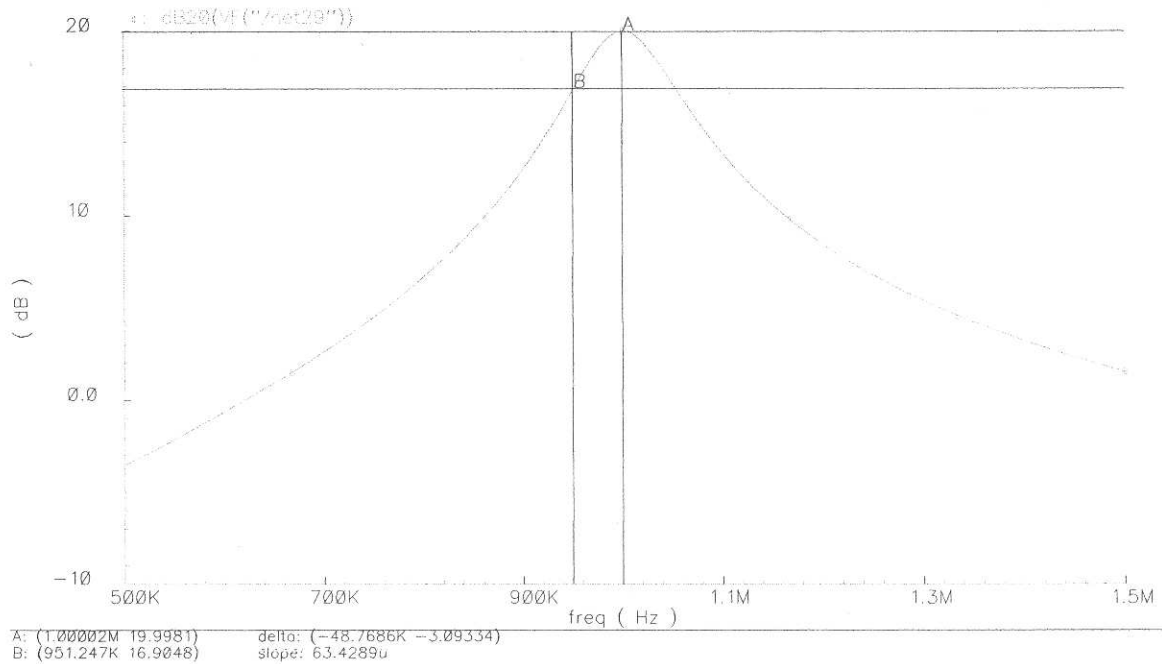
$$\text{error} = \frac{10 - 8.33}{10} \approx 16.67\%$$

Actual  $Q$  by simulation 8.17.

transfer response



3 (a)



Row 4