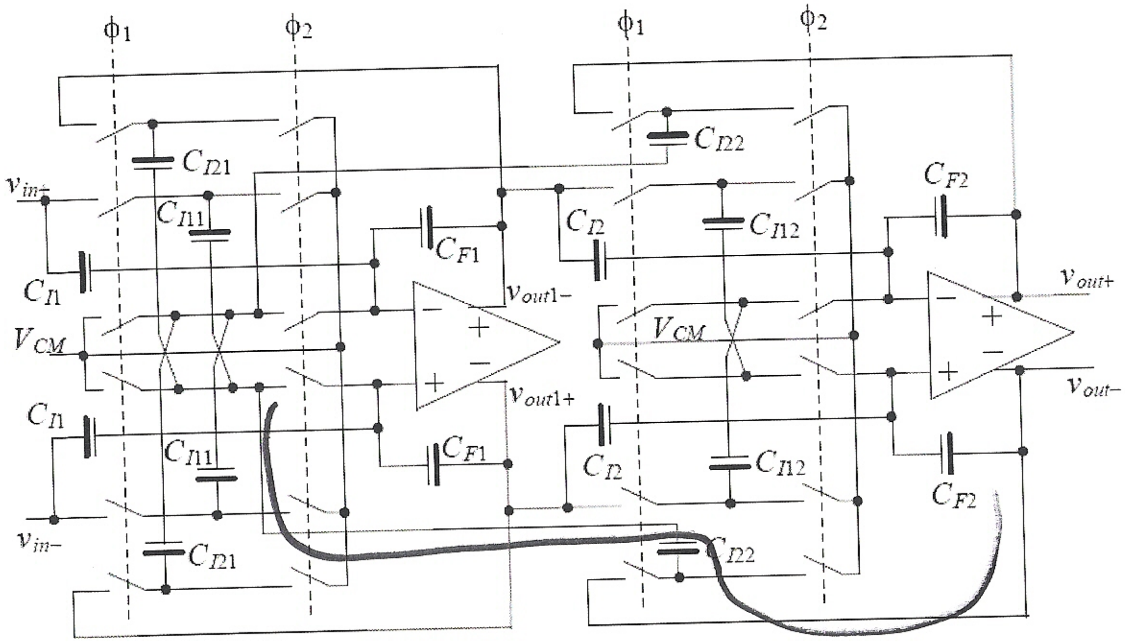
ECE 615 CMOS mixed-signal circuit design

BOISE STATE UNIVERSITY

Lecture 10 Sept. 27, 2010



$$G_1 = \frac{C_{I11}}{C_{F1}} \cdot f_s \quad G_2 = \frac{C_{I21}}{C_{I11}} \quad G_3 = \frac{C_{I1}}{C_{I11} \cdot f_s} \quad G_4 = \frac{C_{I12}}{C_{F2}} \cdot f_s \quad G_5 = \frac{C_{I22}}{C_{I11}} \quad G_6 = \frac{C_{I2}}{C_{I12} \cdot f_s}$$

Figure 3.43 Implementing a biquad filter using switched capacitors.

.707

.35

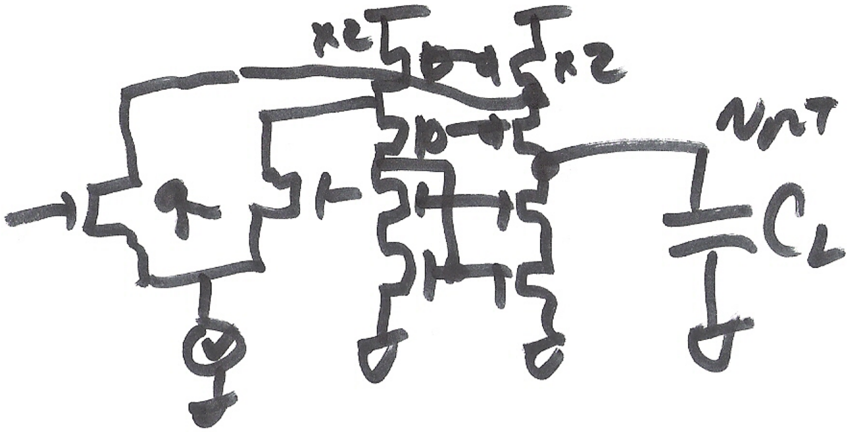
.85V

transconductor-C

fully-diff.

folded cascode

$$f_{un} = \frac{g_m}{2\pi C_L}$$



1)

EX. 3.12

Active-RC , $Q = 20$

$f_0 = 1.59\ \text{MHz}$

Bandpass

$$\frac{v_{out}}{v_{in}} = \frac{a_1 \cdot s}{s^2 + \left(\frac{2\pi f_0}{Q}\right)s + (2\pi f_0)^2}$$

$$= \frac{s^2 G_1 G_3 G_4 \cancel{G_6}_{\,0} + s\left(G_1 G_3 G_4 + G_1 G_4 \cancel{G_6}_{\,0}\right) + G_1 G_4}{s^2 + s\left(G_1 G_2 + G_1 G_4 G_5 \cancel{G_6}_{\,0}\right) + G_1 G_4 G_5}$$

$G_6 = 0$

1)

Ex. 3.12 cont'd

$$\frac{v_{OUT}}{v_{IN}} = \frac{a \cdot s}{s^2 + \left(\frac{2\pi f_0}{Q}\right)s + (2\pi f_0)^2} =$$

$$\frac{s \cdot G_1 G_3 G_4 + \cancel{G_1} G_4 \to 0}{s^2 + s G_1 G_2 + G_1 G_4 G_5}$$

$$G_1 = \frac{1}{\cancel{R_{I1}} C_{F1}} \quad R_{I1} \to \infty \qquad G_3 = R_{I1} \cdot C_{I1}$$

$$G_4 G_1 G_3 = \underline{\underline{\frac{C_{I1}}{C_{F1}} \cdot \frac{1}{R_{I2} C_{F2}}}}$$

$$G_4 = \frac{1}{R_{I2} C_{F2}}$$

3)

3.12 → Active RC

$C_{F1} = C_{F2} = 10pF$

$R_{I2} = R_{F2} = 10K$

$R_{F1} \Big| = 200K$ to get $Q = 20$

$$\frac{2\pi f_0}{Q} = \frac{1}{R_{F1} \cdot C_{F1}} = G_1 G_2$$

$f_0 = \text{const}$

$\boxed{Q \nearrow \rightarrow \frac{R_{F1} \nearrow}{\cancel{C_{F1}} \nearrow}}$

$$f_0 = \frac{1}{2\pi} \sqrt{\frac{1}{C_{F1} R_{I2} C_{F2} R_{F2}}}$$

$$G_2 = \frac{R_{I1}}{R_{F1}}$$

4)

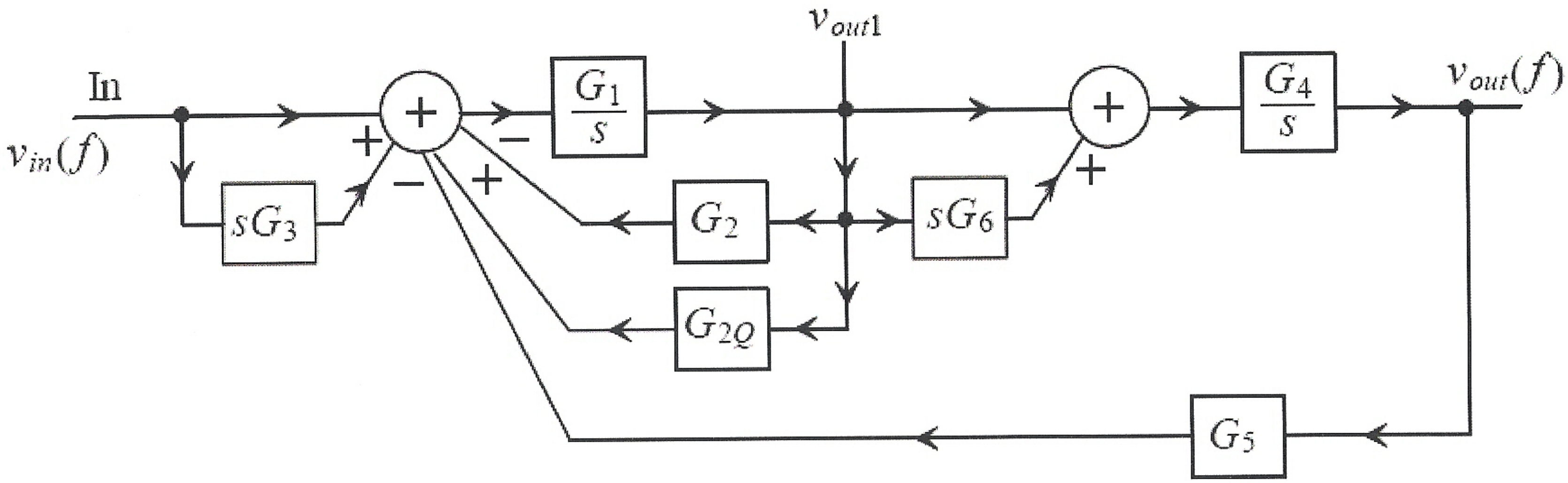
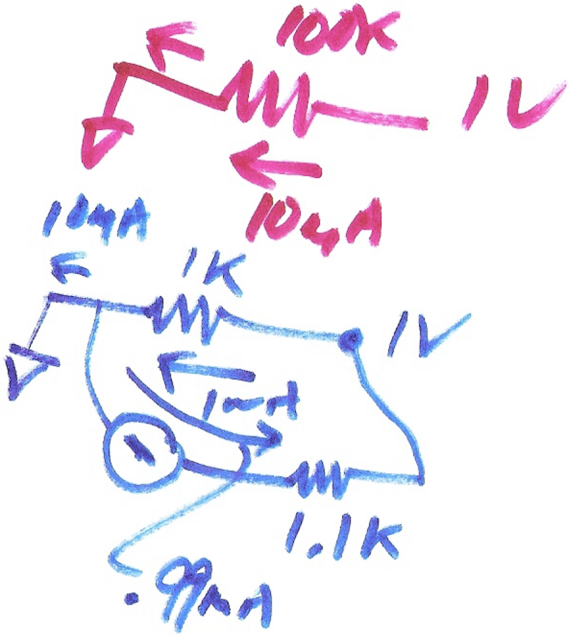


Figure 3.44 Implementation of a "high-Q" biquadratic transfer function.

$G_2 > G_{2Q}$

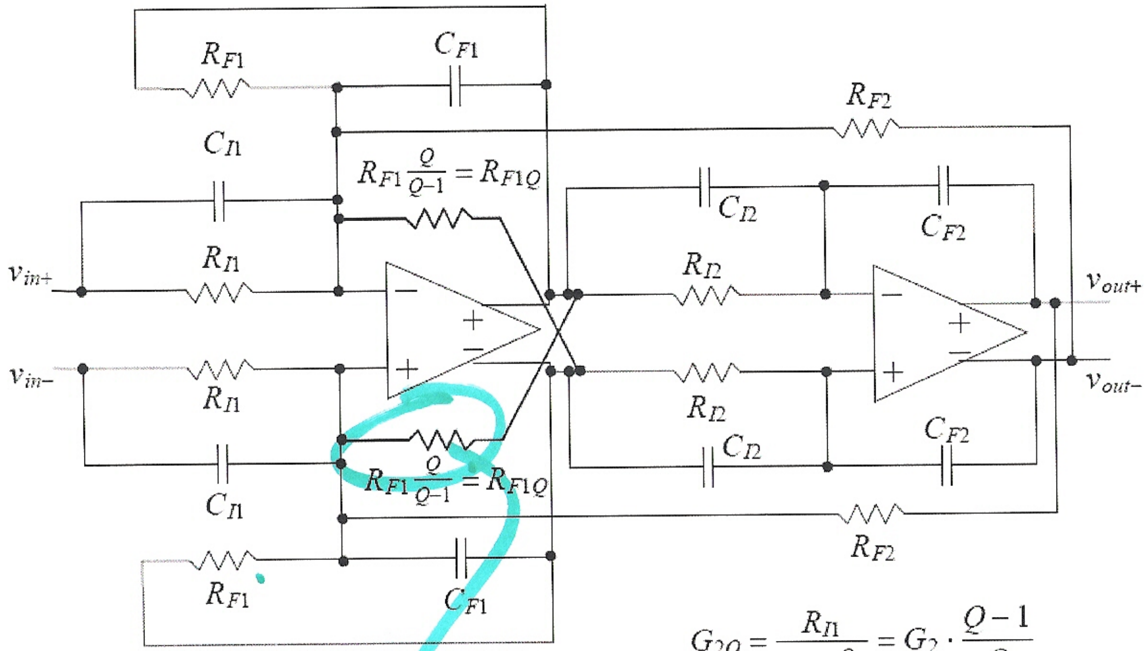
(3.79)

$$\frac{2\pi f_o}{Q} = G_1(G_2 - G_{2Q})$$



5)

Look at Ex 3.13



$$G_{2Q} = \frac{R_{I1}}{R_{F1}\frac{Q}{Q-1}} = G_2 \cdot \frac{Q-1}{Q}$$

Figure 3.45 Implementation of the "high-Q" active-RC biquadratic transfer function filter. The bold lines indicate the added components.

implement Hi-Q!

6)

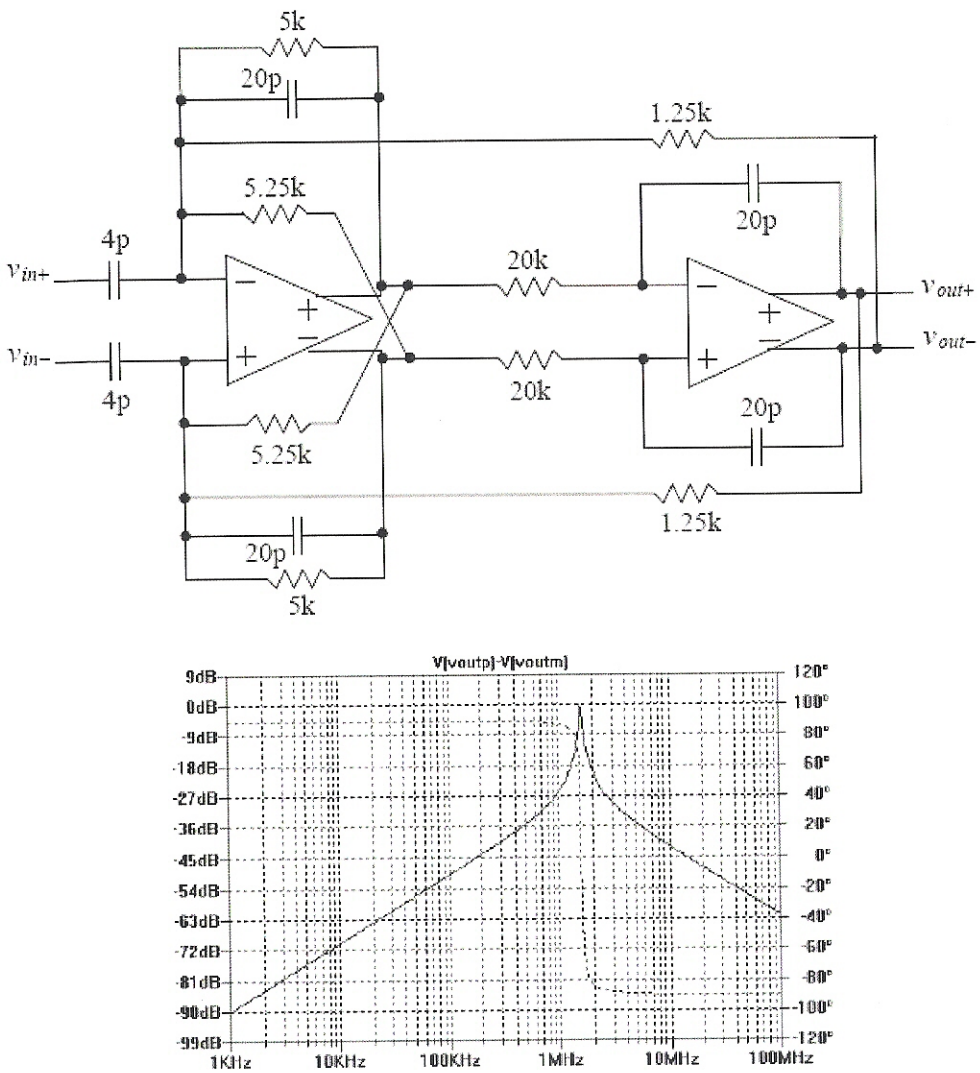
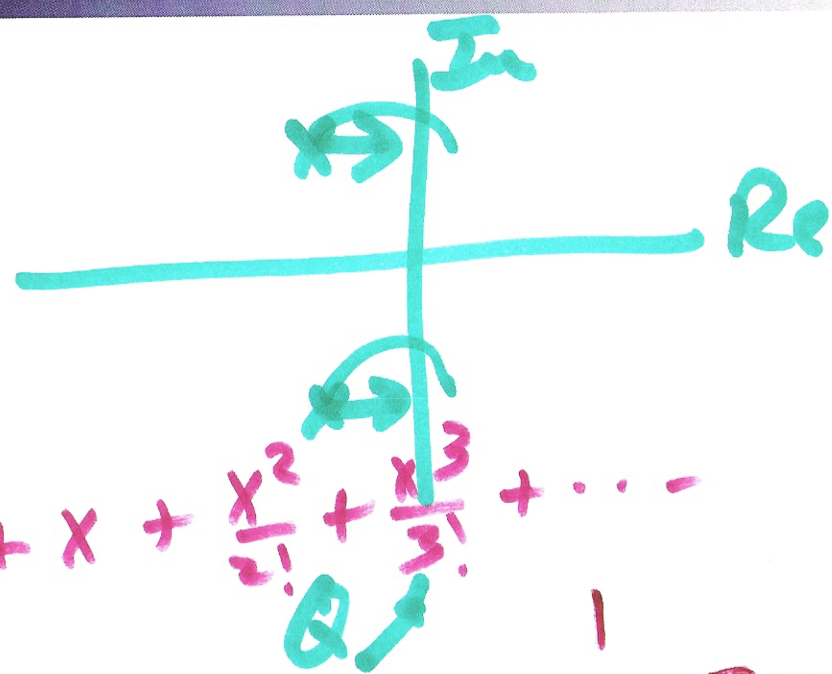


Figure 3.46 Bandpass filter discussed in Ex. 3.13.

Sim Results for Ex 3.13

7)

Hi-Q



Active-RC

↓

SC

$R = \frac{1}{fC}$

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \cdots$$

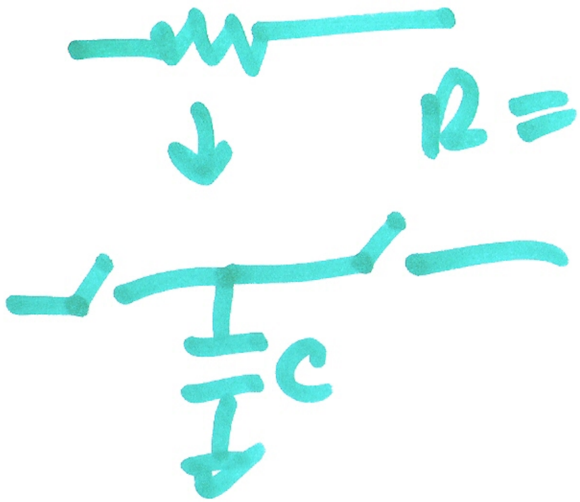
$$\frac{1}{z-1} = \frac{z^{-1}}{1-z^{-1}} = \frac{1}{s}$$

$$z \simeq 1 + j\frac{f}{f_s}\cdot 2\pi$$

$$z \simeq 1 + s$$

if valid

$\frac{1}{s}$



$R = \frac{1}{fC}$

8)

Q-peaking

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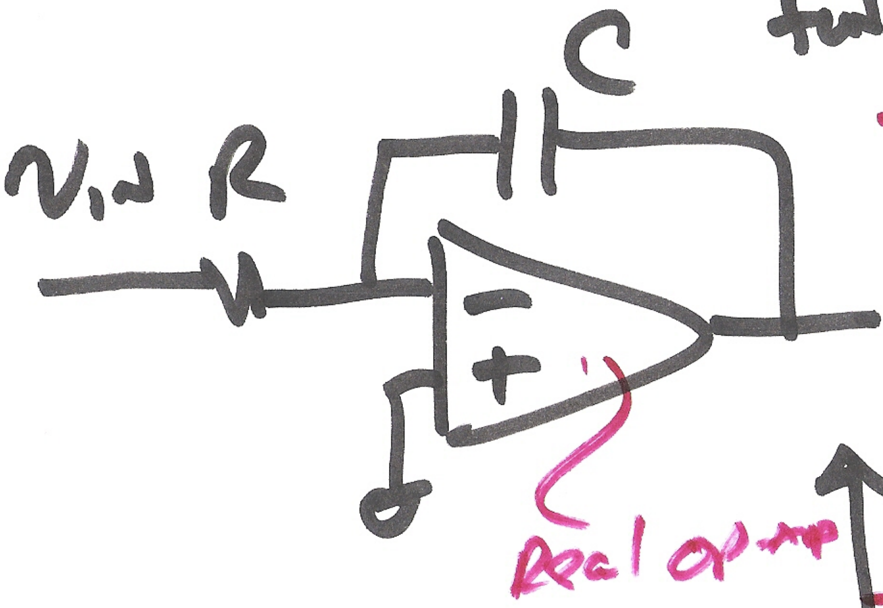
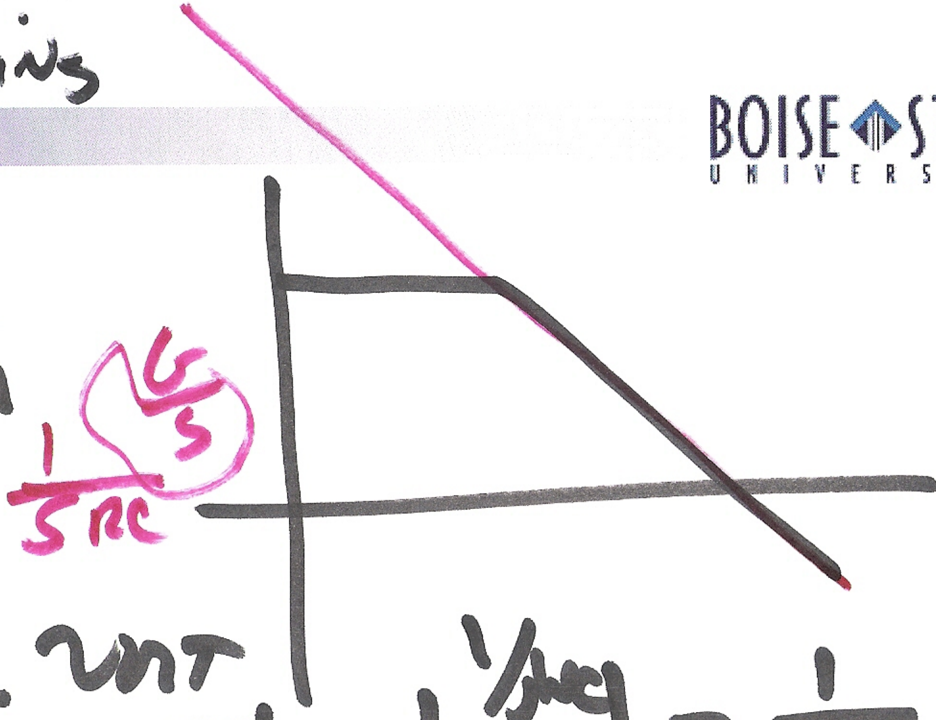
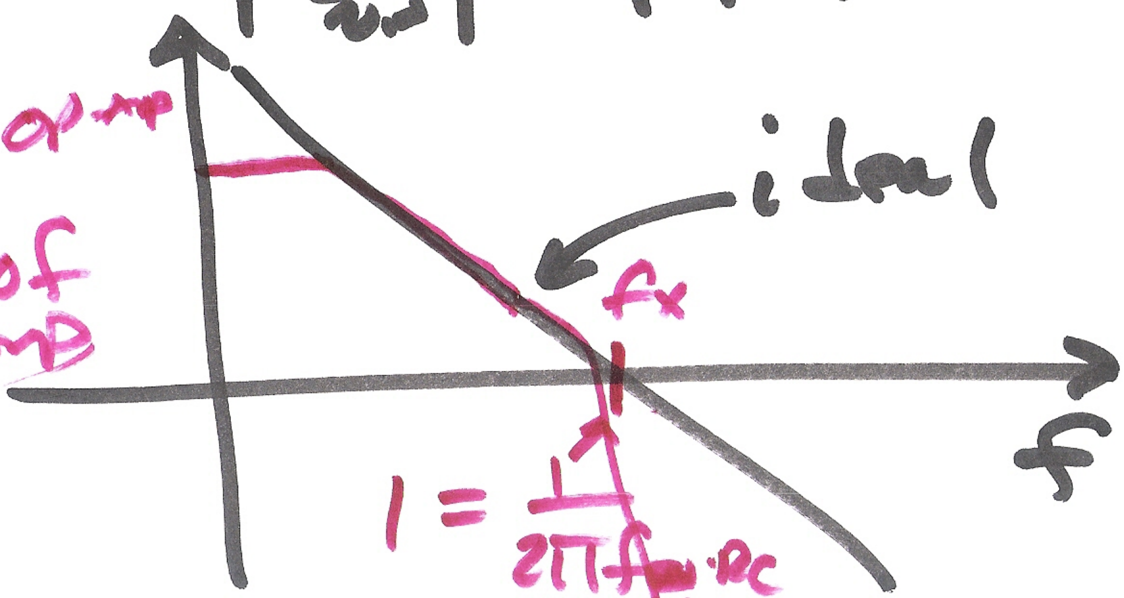
$A_{OL} \approx \dfrac{1}{j\frac{f}{f_{un}}}$





$$\left|\frac{v_{out}}{v_{in}}\right| = \left|\frac{1/j\omega C}{R}\right| = \frac{1}{2\pi f RC}$$



$f_x \ll f_{un}$ of op-amp

$$1 = \frac{1}{2\pi f_x \cdot RC}$$

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

$$\frac{1}{s} \rightarrow \frac{1}{s\left(1+\frac{s}{2\pi f_{un}}\right)}$$

op-amp

$$A_{OL} = \frac{A_{OLDC}}{1 + j\frac{f}{f_{3dB}}} = \frac{1}{\frac{1}{A_{OLDC}} + j\frac{f}{f_{un}}}$$

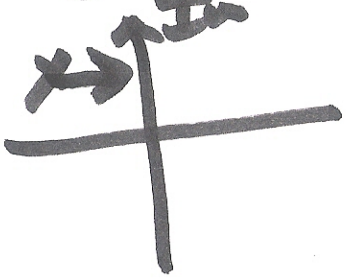
$$\frac{1}{1+\frac{s}{2\pi f_{un}}}$$

$$\frac{1}{s\left(1+\frac{s}{2\pi f_{un}}\right)+p_1} \cdot \frac{1}{s\left(1+\frac{s}{2\pi f_{un}}\right)+p_2}$$

EQ. 3.85

$$s + p_1 - \frac{(2\pi f)^2}{2\pi f_{un}}$$

$$s = -p_1 + \frac{(2\pi f)^2}{2\pi f_{un}}$$

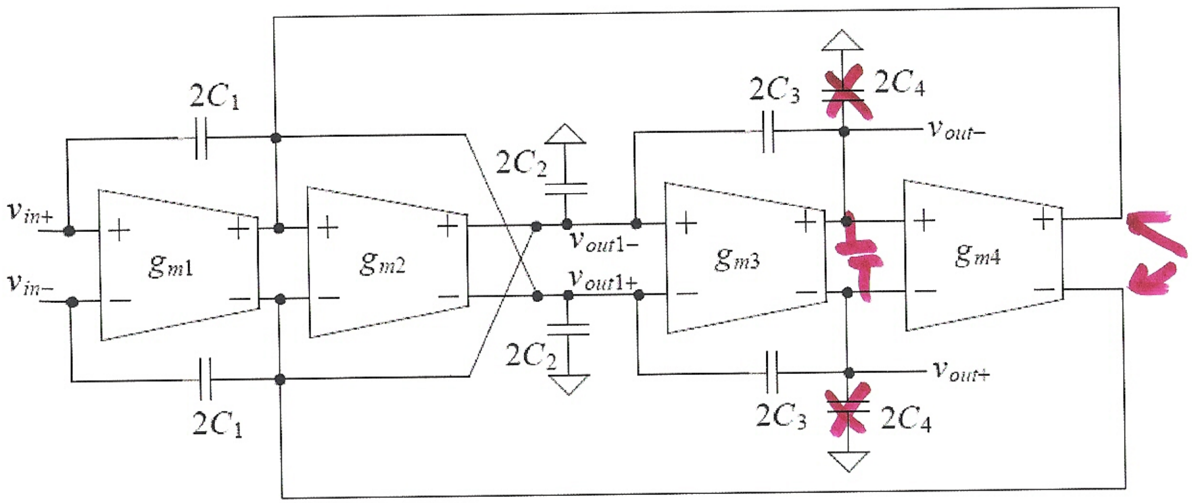


10)

Shift in Q

$$Q_{shift} = \frac{Q}{1 - Q \cdot \frac{2f_0}{f_{UW}}}$$

$$\frac{Q \cdot 2f_0}{f_{UW}} \ll 1$$



$$G_1 = g_{m1}/(C_1 + C_2) \quad G_2 = \frac{g_{m2}}{g_{m1}} \quad G_3 = \frac{C_1}{g_{m1}} \quad G_4 = g_{m3}/(C_3 + C_4) \quad G_5 = \frac{g_{m4}}{g_{m1}} \quad G_6 = \frac{C_3}{g_{m3}}$$

Figure 3.53 Implementing a biquadratic filter using transconductors.