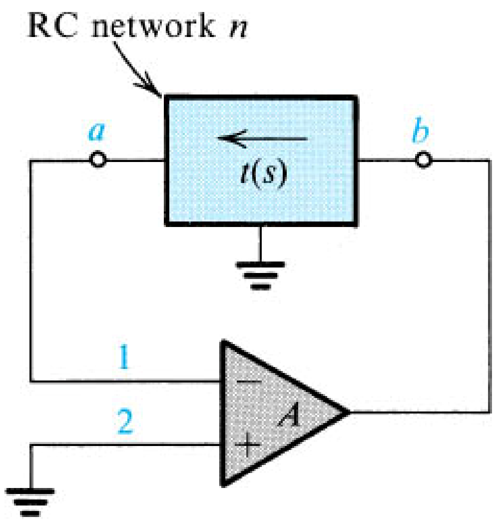
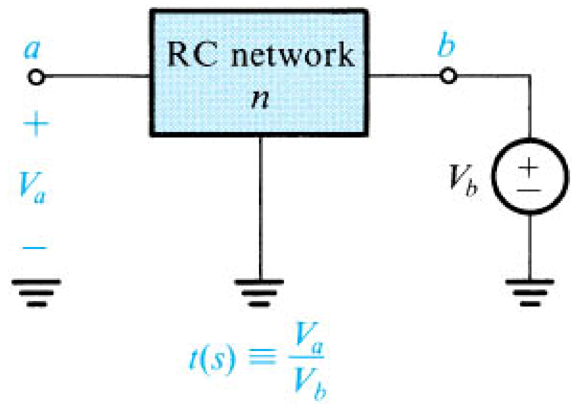
Single-Amplifier Biquadratic Active Filters

- Op-amp RC biquadratic circuits provide good performance. They are versatile, and are easy to design and tune after final assembly.
- However, they are not economic in their use of op amps, requiring three or more amplifiers per second-order section.
- This can be a problem, especially in applications where power supply current is to be conserved.
- In this lecture we will study a class of second-order filter circuits that requires only one op amp per biquad.
- This realization, however, suffer a greater dependence on the limited gain and bandwidth of the op amp and are more sensitive to the unavoidable tolerances in the values of resistors and capacitors.
- Accordingly, the single-amplifier biquads (SABs) are therefore limited to the less stringent filter specifications, pole Q factors less than about 10.

Feedback loop obtained by placing a two-port RC network *n* in the feedback path of an op amp.

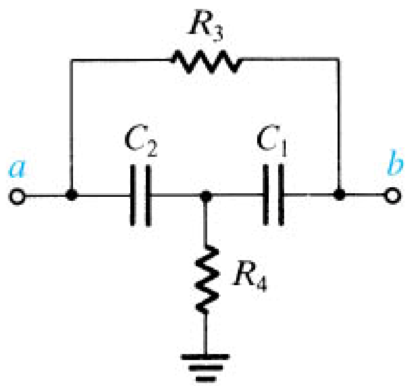


(a)



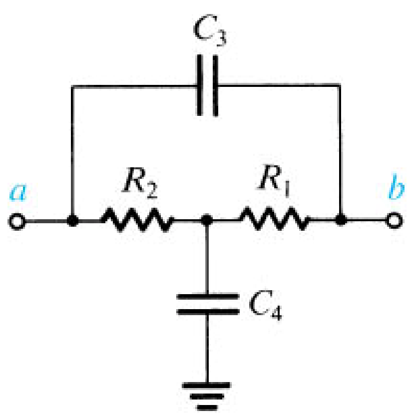
(b)

Two RC networks (called bridged-T networks)



$$t(s) = \frac{s^2 + s\left(\frac{1}{C_1} + \frac{1}{C_2}\right)\frac{1}{R_3} + \frac{1}{C_1 C_2 R_3 R_4}}{s^2 + s\left(\frac{1}{C_1 R_3} + \frac{1}{C_2 R_3} + \frac{1}{C_1 R_4}\right) + \frac{1}{C_1 C_2 R_3 R_4}}$$

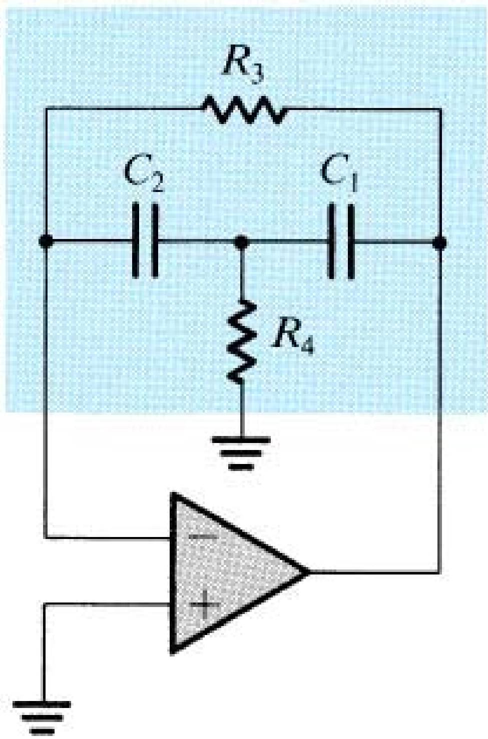
(a)



$$t(s) = \frac{s^2 + s\left(\frac{1}{R_1} + \frac{1}{R_2}\right)\frac{1}{C_4} + \frac{1}{C_3 C_4 R_1 R_2}}{s^2 + s\left(\frac{1}{C_4 R_1} + \frac{1}{C_4 R_2} + \frac{1}{C_3 R_2}\right) + \frac{1}{C_3 C_4 R_1 R_2}}$$

(b)

An active-filter feedback loop generated using the bridged-T network



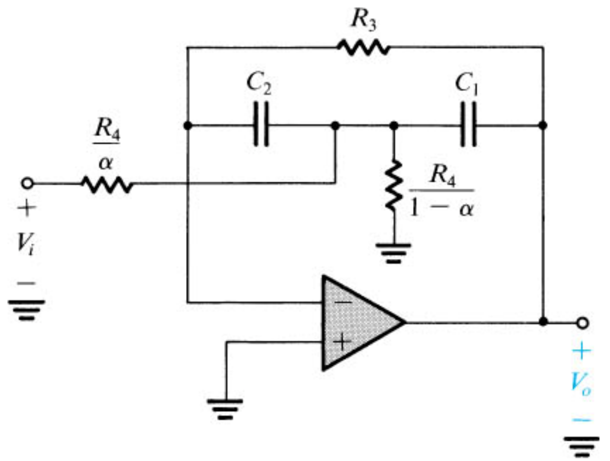
$$s^2 + s\frac{\omega_o}{Q} + \omega_o^2 = s2 + s\left(\frac{1}{C_1} + \frac{1}{C_2}\right)\frac{1}{R_3} + \frac{1}{C_1 C_2 R_3 R_4}$$

$$\omega_o = \frac{1}{\sqrt{C_1 C_2 R_3 R_4}}$$

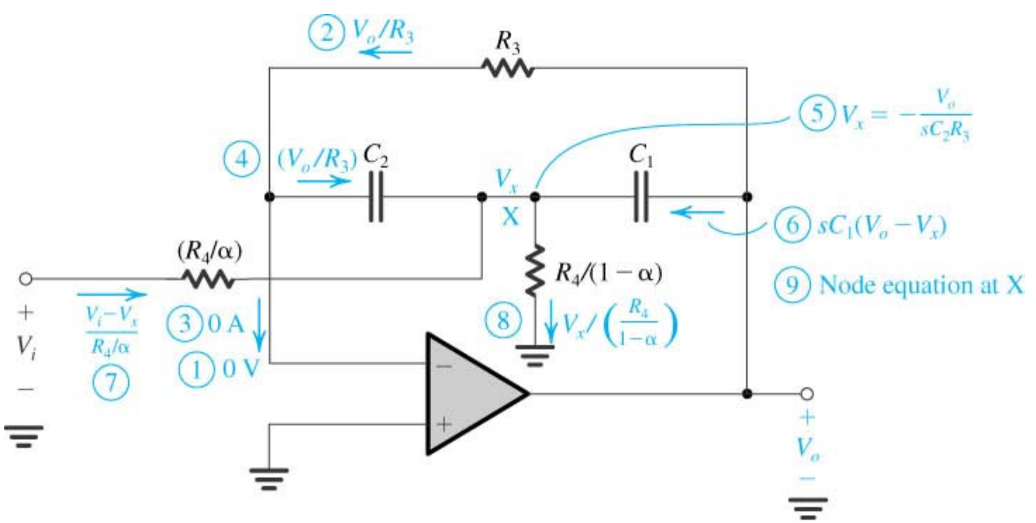
$$Q = \left[\frac{\sqrt{C_1 C_2 R_3 R_4}}{R_3}\left(\frac{1}{C_1} + \frac{1}{C_2}\right)\right]^{-1}$$

$$C_1 = C_2 = C;\, R_3 = R;\, R_4 = R/m;\, m = 4Q^2\,;\, CR = \frac{2Q}{\omega_o}$$

Injecting the Input Signal

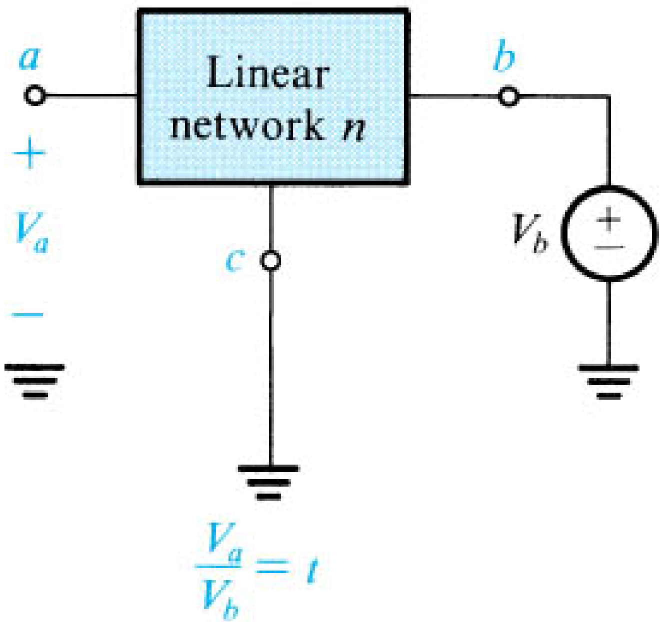


(a)

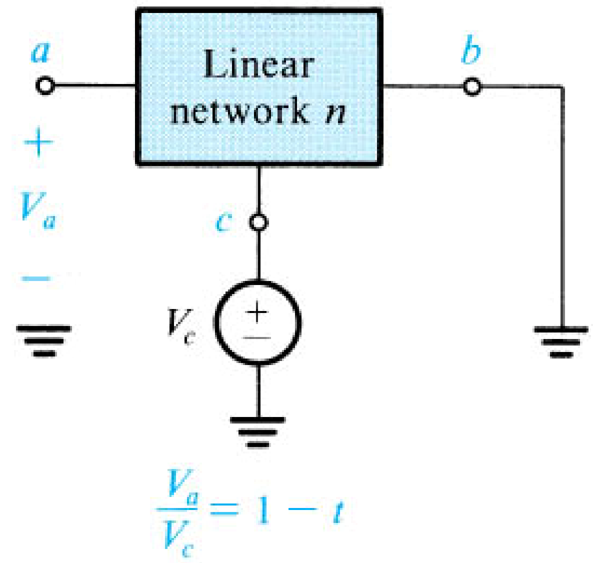


(b)

Generation of Equivalent Feedback Loops

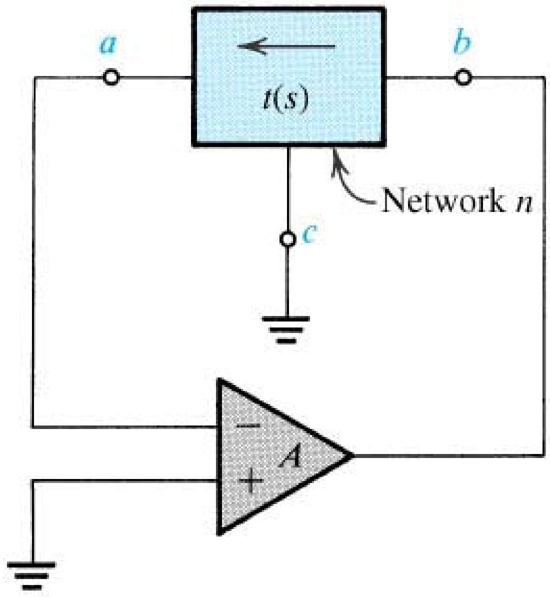


(a)

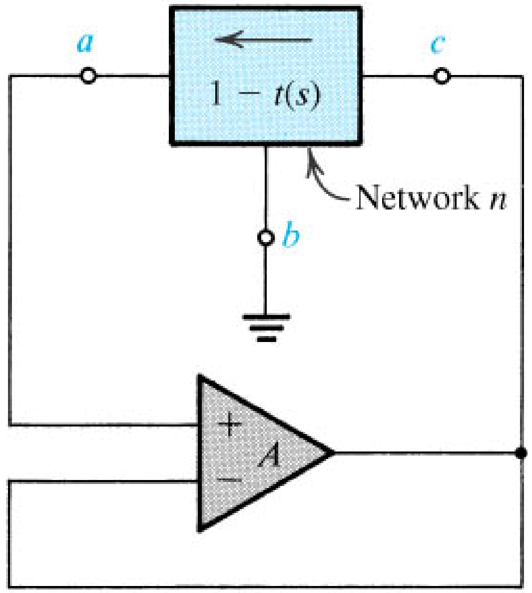


(b)

Application of the complementary transformation to the feedback loop

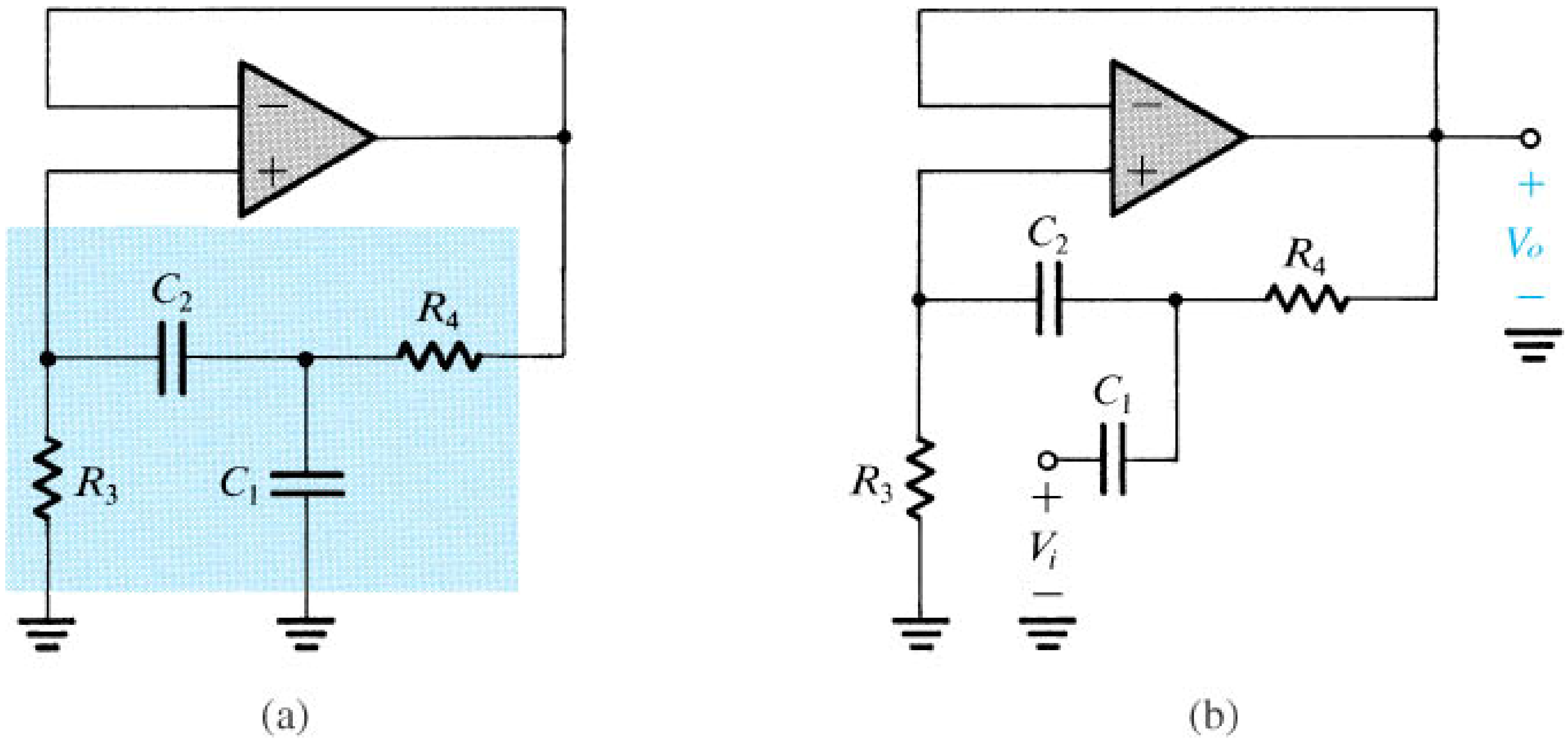


(a)

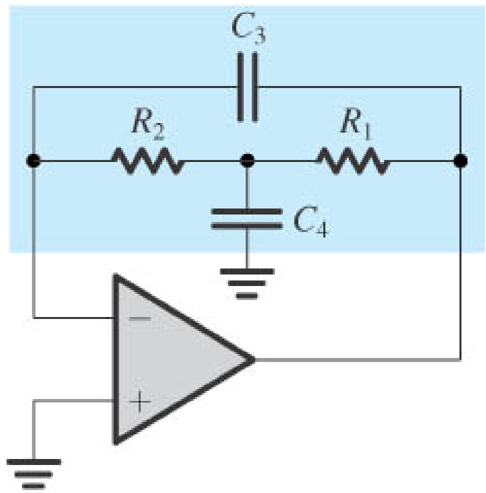


(b)

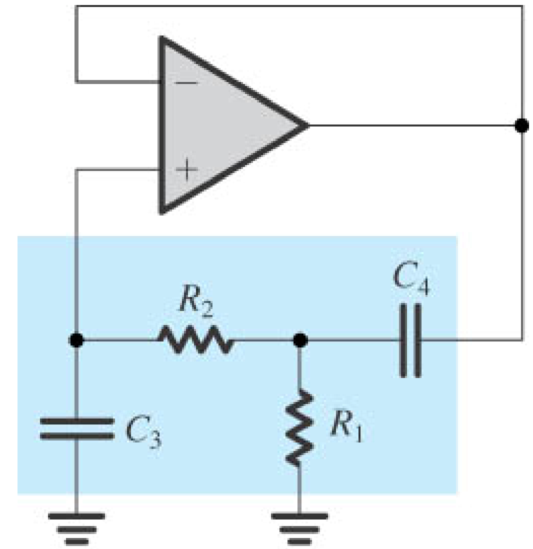
Feedback loop obtained by applying the complementary transformation to the loop



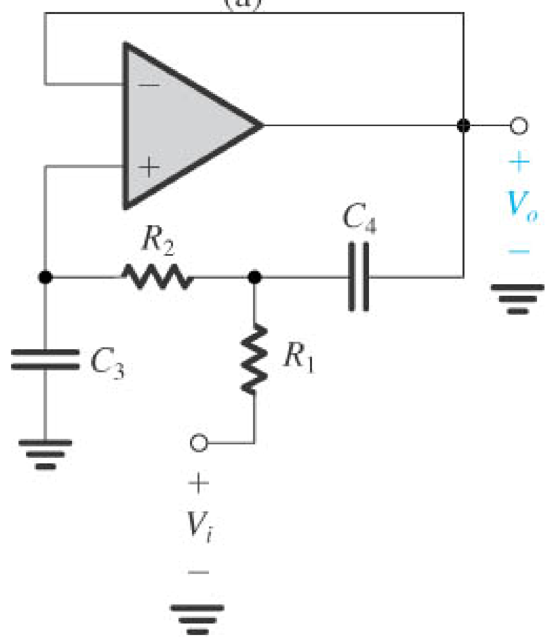
Feedback loop obtained by placing the bridged T-network



(a)



(b)



(c)

$$\omega_o = \frac{1}{\sqrt{C_3 C_4 R_1 R_2}}$$

$$Q = \left[\frac{\sqrt{C_3 C_4 R_1 R_2}}{C_4} \left(\frac{1}{R_1} + \frac{1}{R_2} \right) \right]$$

$$R_1 = R_2 = R; C_4 = C; C_3 = C / m$$

$$m = 4Q^2$$

$$CR = 2Q / \omega_o$$