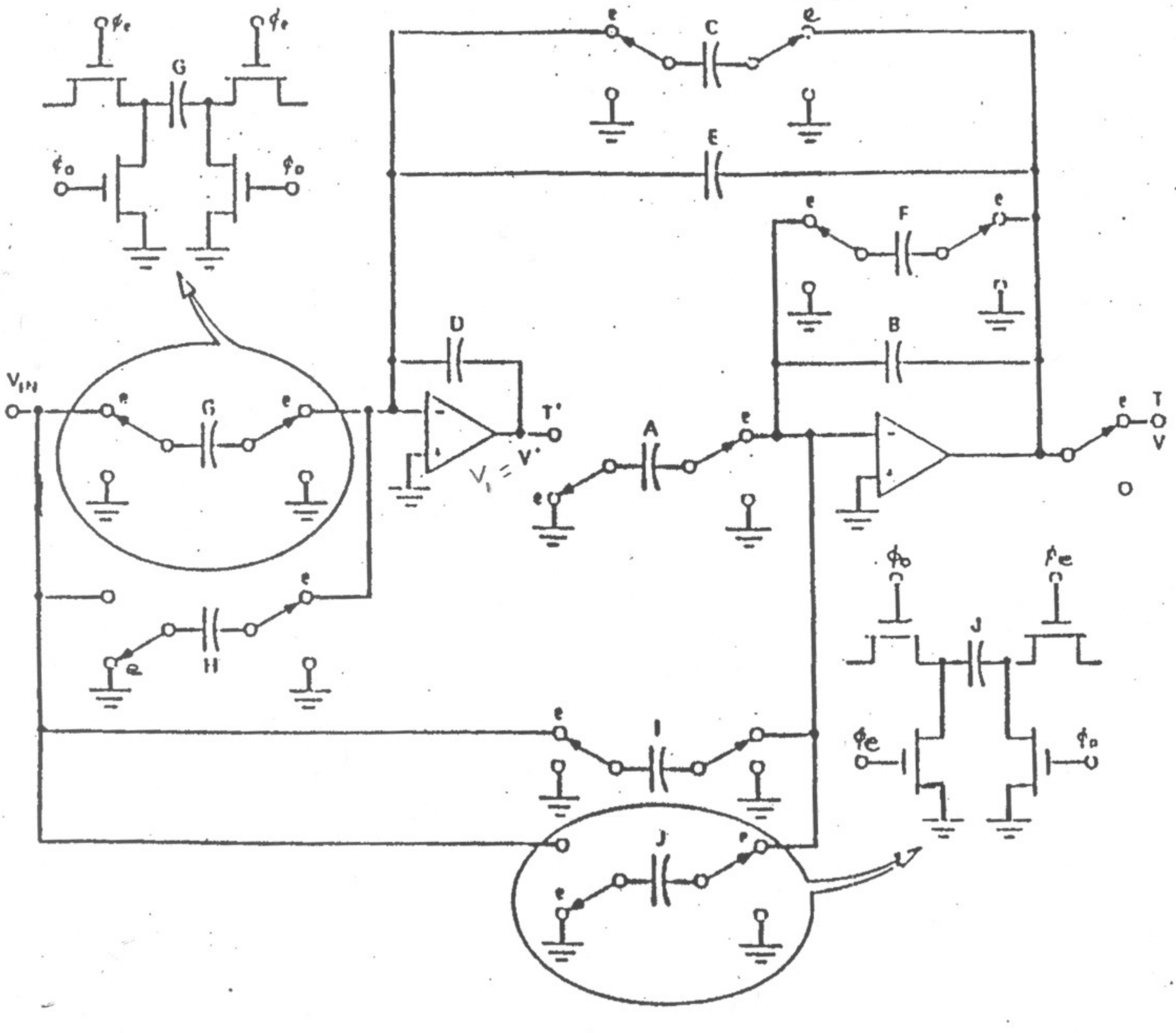
General Switched-Capacitor Biquad



$$T' \triangleq \frac{V'}{V_{in}} = -\frac{DI + (AG - DI - DJ)z^{-1} + (DJ - AH)z^{-2}}{D(F + B) + (AC + AE - DF - 2DB)z^{-1} + (DB - AE)z^{-2}}$$

$$= -\frac{\frac{I}{B} + \left(\frac{A}{B}\frac{G}{D} - \frac{I}{B} - \frac{J}{B}\right)z^{-1} + \left(\frac{J}{B} - \frac{A}{B}\frac{H}{D}\right)z^{-2}}{\left(\frac{F}{B}+1\right) + \left(\frac{A}{B}\frac{C}{D} - \frac{F}{B} - 2\right)z^{-1} + z^{-2}}$$

let $E = 0$

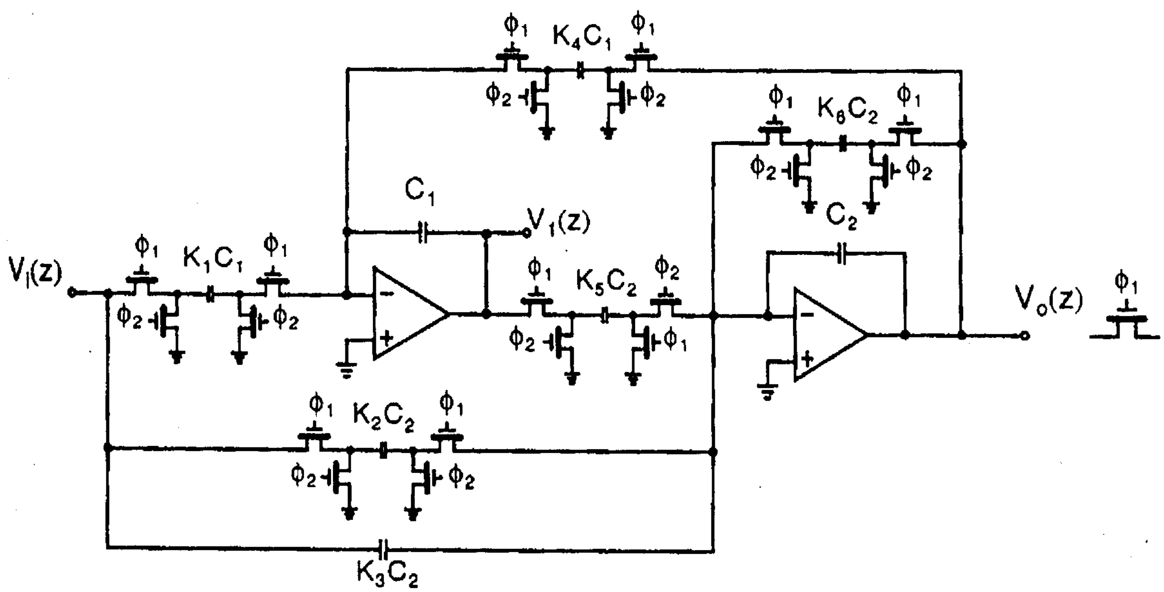


Fig. ~~10.21~~ A low-Q switched-capacitor biquad filter (without switch sharing).

Fig. 14.24 $Q \leq 3$

$$H(z) \equiv \frac{V_o(z)}{V_i(z)} = -\frac{(K_2 + K_3)z^2 + (K_1K_5 - K_2 - 2K_3)z + K_3}{(1 + K_6)z^2 + (K_4K_5 - K_6 - 2)z + 1} \qquad \cancel{(10.49)} \quad (14.53)$$

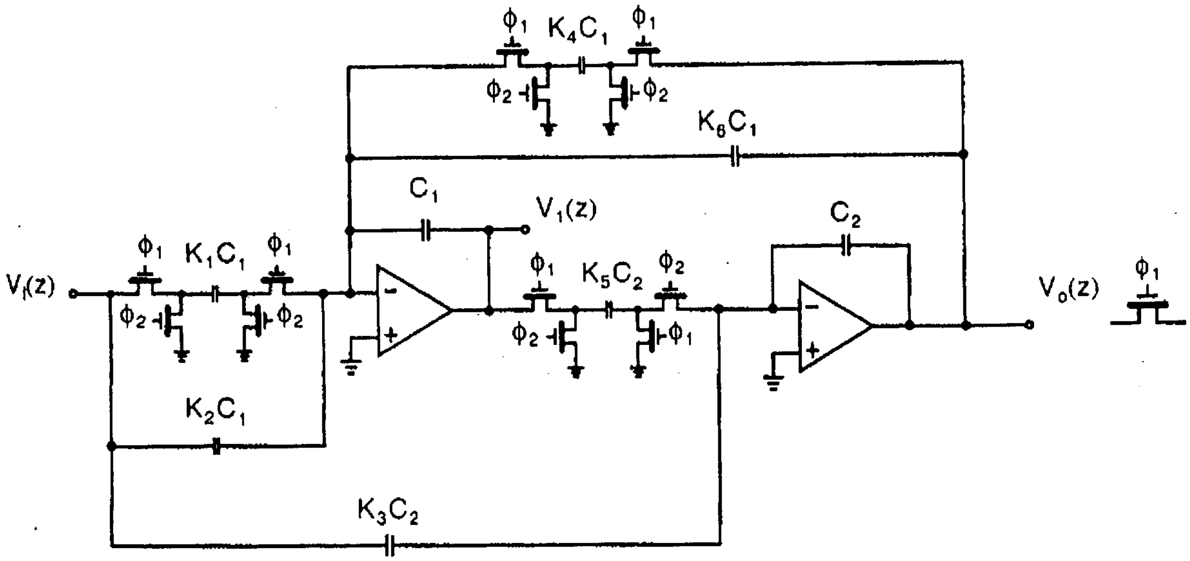


Fig. ~~10.25~~ A high-Q switched-capacitor biquad filter (without switch sharing).
Fig. 14.28

The input capacitor K_1C_1 is the major signal path when realizing low-pass filters, the input capacitor K_2C_2 is the major signal path when realizing bandpass filters, and the input capacitor K_3C_2 is the major signal path when realizing high-pass filters. Other possibilities for realizing different types of functions exist. For example, a non-delayed switched capacitor going from the input to the second integrator could also be used to realize an inverting bandpass function. If the phases on the input switches of such a switched capacitor were interchanged, then a noninverting bandpass function would result, but with an additional period delay.

Using the signal-flow-graph approach described in Section 10.2, the transfer function for this circuit is found to be given by

$$H(z) \equiv \frac{V_o(z)}{V_i(z)} = -\frac{K_3z^2 + (K_1K_5 + K_2K_5 - 2K_3)z + (K_3 - K_2K_5)}{z^2 + (K_4K_5 + K_5K_6 - 2)z + (1 - K_5K_6)} \qquad \cancel{(10.67)}\ (14.71)$$

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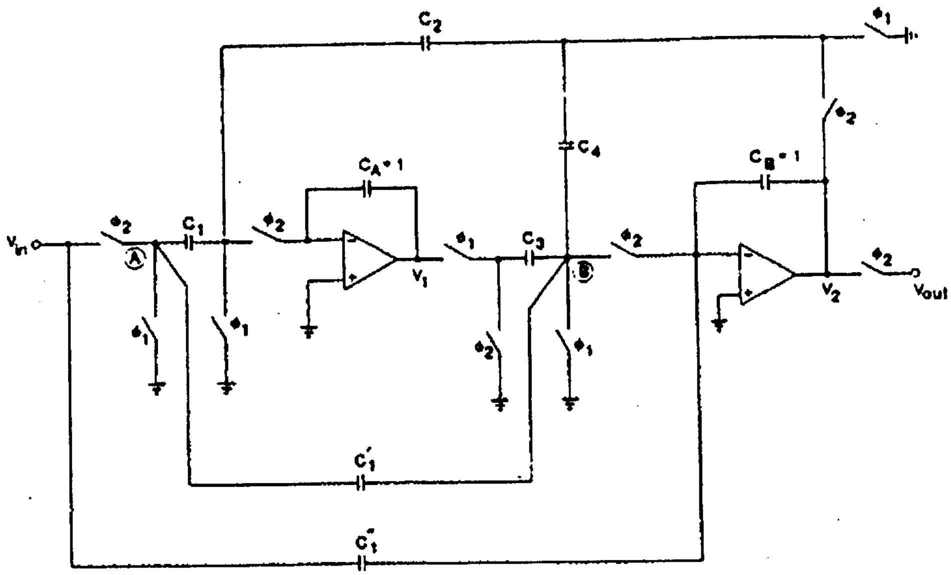
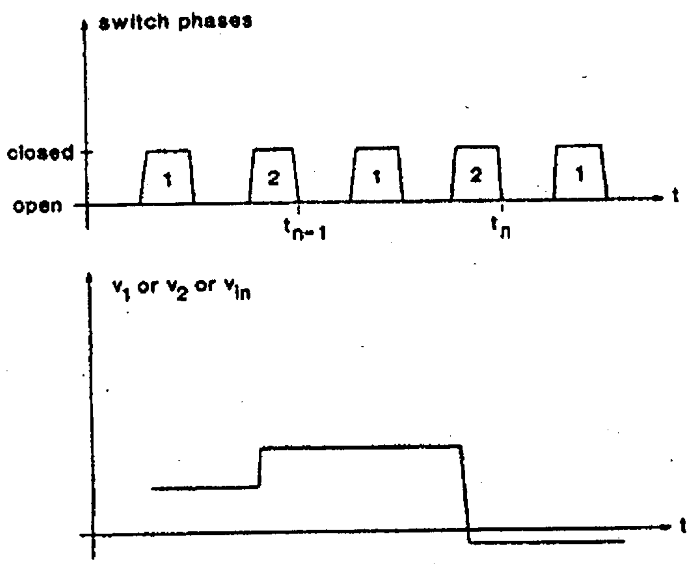


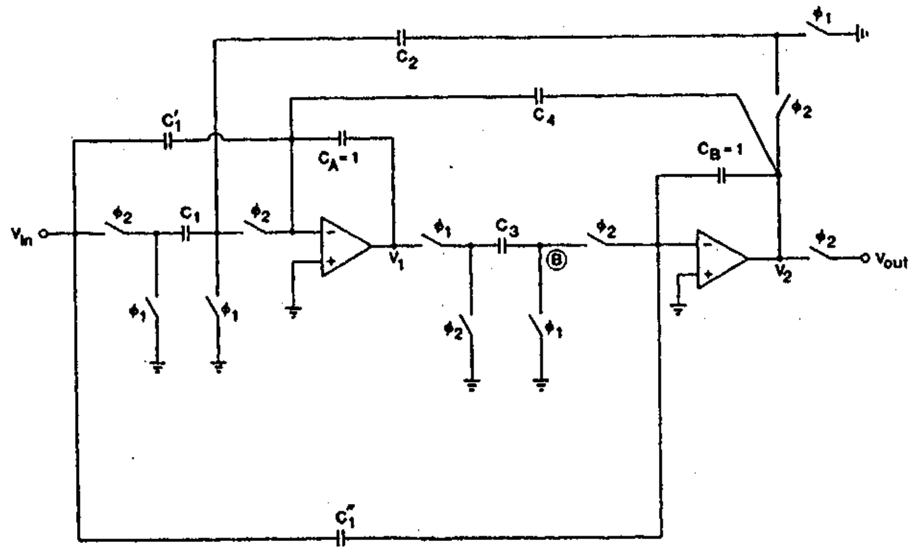
(c)



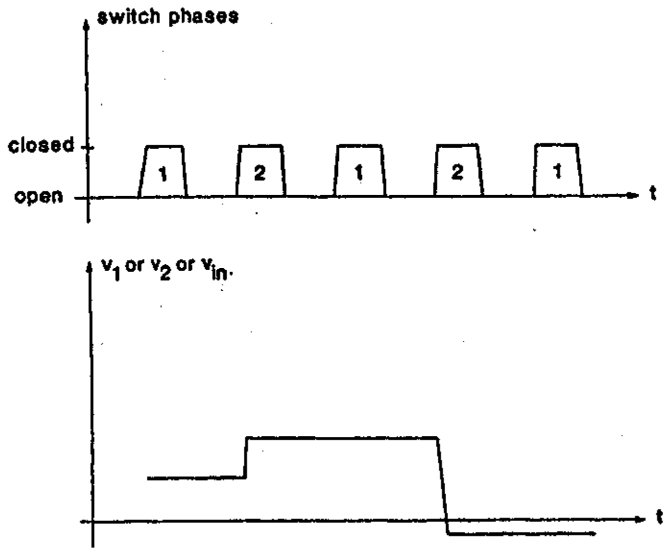
(d)

FIGURE 5.10. continued.

$$H(z) = \frac{V_{out}(z)}{V_{in}(z)} = -\frac{(C_1' + C_1'')z^2 + (C_1C_3 - C_1' - 2C_1'')z + C_1''}{(1 + C_4)z^2 + (C_2C_3 - C_4 - 2)z + 1}. \quad (5.40)$$



(c)



(d)

FIGURE 5.13. continued.

For $Q > 1$, the capacitance spread is once again $C_A/C_2 \cong 1/\omega_0 T$.

The exact transfer function $H(z)$ can be found using the waveform diagram of Fig. 5.13*d*, and the block diagram of Fig. 5.14. The result is (Problem 5.8)

$$H(z) = \frac{V_{out}(z)}{V_{in}(z)} = -\frac{C_1'' z^2 + (C_1 C_3 + C_1' C_3 - 2C_1'')z + (C_1'' - C_1' C_3)}{z^2 + (C_2 C_3 + C_3 C_4 - 2)z + (1 - C_3 C_4)}. \tag{5.46}$$