Spring 2004; E4215: Analog Filter Synthesis and Design; HW9

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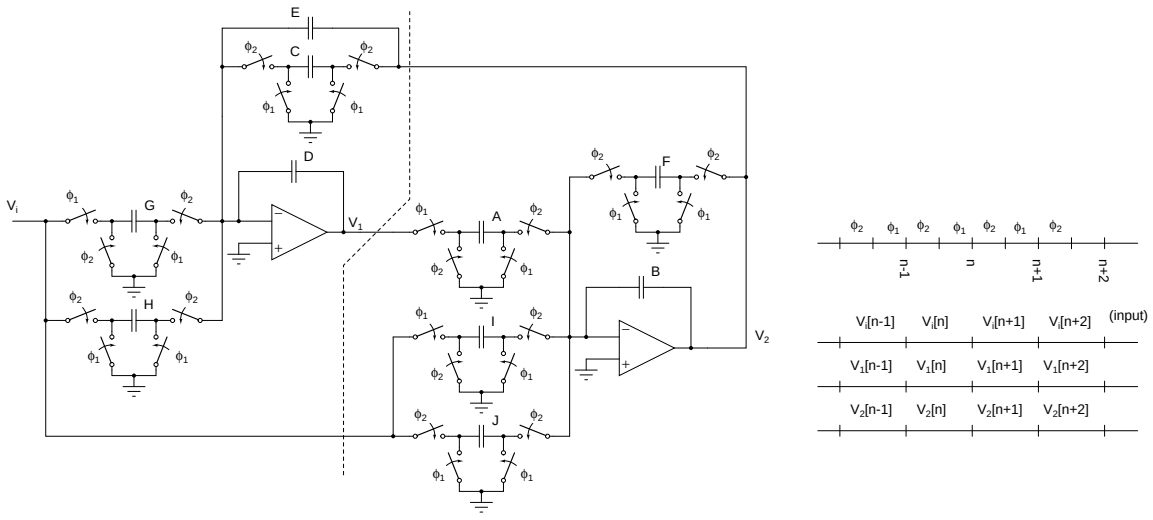

Figure 1:

1. (4 pts.) Compute the transfer function V_1/V_i in the Fleischer Laker biquad. Fig. 1. The output is defined at the end of ϕ_1 and the input V_i changes on the rising edge of ϕ_2.

   As the project deadline is close, the equations governing the charge balance at the virtual ground of each opamp at the ϕ_1 to ϕ_2 transition, and the transfer function V_2/V_i is given below.

$$\begin{aligned} D(V_1[n]-V_1[n-1])+G(0-V_i[n-1])+ & \\ H(V_i[n]-0)+C(V_2[n]-0)+E(V_2[n]-V_2[n-1]) &= 0 \\ B(V_2[n]-V_2[n-1])+F(V_2[n]-0)+A(0-V_1[n-1])+ & \\ I(0-V_i[n-1])+J(V_i[n]-0) &= 0 \end{aligned}$$

$$\frac{V_2}{V_{in}} = \frac{-DJ+(ID+DJ-HA)z^{-1}+(GA-ID)z^{-2}}{D(B+F)+(-2BD-DF+AC+AE)z^{-1}+(BD-AE)z^{-2}}$$

2. (2 pts.) Transform a second order CT (continuous time) bandpass filter into a DT(discrete time) bandpass filter using bilinear transformation. The gain at center frequency and the quality factor of the CT prototype are both 10. The resonant frequency f_p (in Hz) is 20% of the sampling frequency f_s (in Hz).

3. (8 pts) Compute the values of the capacitors in the Fleischer-Laker biquad to realize the above filter. Assume $B = D = 1$ and $A = C$. Also, usually, you can set one of G, H, I, J to zero. Try each of the following cases

   (a) V_1 as output; F circuit ($E = 0$)

   (b) V_1 as output; E circuit ($F = 0$)

   (c) V_2 as output; F circuit ($E = 0$)

   (d) V_2 as output; E circuit ($F = 0$)

   What is the spread in capacitor values (The ratio of the largest to the smallest capacitor) in each case?

   (2 pts.) Simulate the magnitude and phase responses of the first case above in Cadence.

4. (2 pts.) Design a continuous-time Tow-Thomas bandpass filter[1] with V_1 as the output. Design it for $Q = 10$ and a center frequency of 1 MHz. What would be the error in the quality factor if the opamps had a gain of 100?

   (2 pts.) Simulate it with opamps with gain of 10^6 and 100. Measure the quality factor from the magnitude response (the quality factor is the ratio of the center frequency to the bandwidth). Make sure you simulate enough points in the ac response so that you can measure the 3 dB bandwidth and the center frequency accurately.

[1] From the handout on "transfer functions in a biquad"