1. (4 pts.) Compute the transfer function $V_1/V_i$ in the Fleisher Laker biquad. Fig. 1. The output is defined at the end of $\phi_1$ and the input $V_i$ changes on the rising edge of $\phi_2$.

As the project deadline is close, the equations governing the charge balance at the virtual ground of each opamp at the $\phi_1$ to $\phi_2$ transition, and the transfer function $V_2/V_i$ is given below.

$$
D(V_1[n] - V_1[n-1]) + G(0 - V_1[n-1]) + 
H(V_i[n] - 0) + C(V_2[n] - 0) + E(V_2[n] - V_2[n-1]) = 0
$$

$$
B(V_2[n] - V_2[n-1]) + F(V_2[n] - 0) + A(0 - V_1[n-1]) + 
I(0 - V_i[n-1]) + J(V_i[n] - 0) = 0
$$

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