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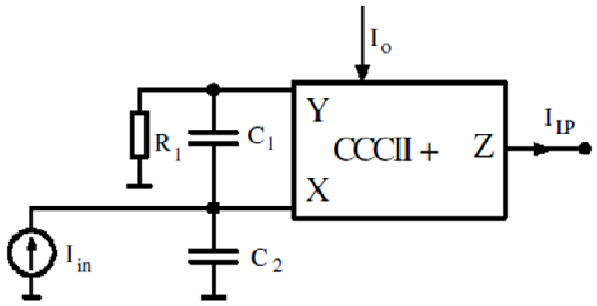
ELE509E
Current-Mode Analog Circuit Design
Final Project

Design a current-mode sixth-order Butterworth LP filter with a cut-off frequency of 3 MHz. Use the second order CCCII+ based filter topology illustrated in Figure 1. The overall filter can be obtained by cascading these second-order sections, as shown in Figure 2.

a) Choose a suitable CCCII+ realization topology (BJT or CMOS). Specify the supply voltages.
b) Determine the biasing currents, resistance and capacitance values.

Using SPICE simulation results

a) draw the frequency and phase responses of the filter for ideal and actual cases, determine the actual cut-off frequency,
b) compare the simulated frequency and phase responses with the theoretical results.
c) Investigate the large signal behaviour of the filter by applying a sinusoidal input current in the pass band of the filter and observing the total harmonic distortion THD at the output for different input levels; draw the plot of THD against i_{in},
d) investigate the dependence of the output voltage upon the load resistance R_L keeping the input level constant, observe the harmonic distortion THD at the output for each load resistance value; draw the plots of THD against R_L and V_O against R_L.
e) Investigate the tunability of the realized filter.
f) Give a detailed evaluation of your results.



$$\frac{I_{LP}}{I_{in}} = -\frac{\frac{1}{R_1 R_x C_1 C_2}}{s^2 + \frac{(C_1 + C_2)}{R_1 C_1 C_2} s + \frac{1}{R_1 R_x C_1 C_2}}$$

Figure 1. CCCII+ based second-order LP filter topology

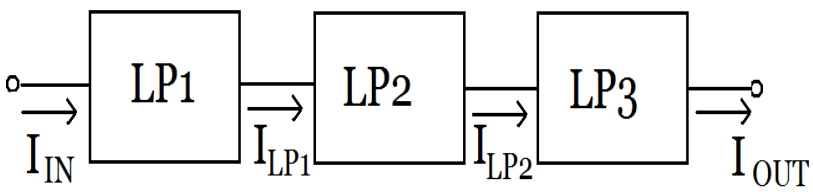


Figure 2. 6th order LP filter obtained by cascading second-order sections.

References:

- Minaei S., Çiçekoğlu, O, Kuntman, H., and Türköz, S., 2001. "High Output Impedance Current-Mode Low pass, Band pass and High pass Filters Using Current Controlled Conveyors". *International Journal of Electronics*. 88 (8), 915-922.

Normalized Butterworth polynominals

n	*Factors of polynomial* $P_n(s)$
1	$(s + 1)$
2	$(s^2 + 1.414s + 1)$
3	$(s + 1)(s^2 + s + 1)$
4	$(s^2 + 0.765s + 1)(s^2 + 1.848s + 1)$
5	$(s + 1)(s^2 + 0.618s + 1)(s^2 + 1.618s + 1)$
6	$(s^2 + 0.518s + 1)(s^2 + 1.414s + 1)(s^2 + 1.932s + 1)$
7	$(s + 1)(s^2 + 0.445s + 1)(s^2 + 1.247s + 1)(s^2 + 1.802s + 1)$
8	$(s^2 + 0.390s + 1)(s^2 + 1.111s + 1)(s^2 + 1.663s + 1)(s^2 + 1.962s + 1)$