# ACTIVE FILTER DESIGN : PROBLEM SET 6

In this assignment and the next, we will design a filter using the Gm-C technique. Different parts of these assignments will cover different aspects of the design. Implement the transfer function as a "cascade-of-biquads". Very carefully document your design. You will be using the transconductor in this design repeatedly over the next few assignments. So, it pays to do a good job of the design in this assignment - with careful and robust biasing, stable common-mode feedback etc.

## 1 Transfer Function

The filter to be designed is a third order Chebyshev low pass filter with a band edge frequency of 10 MHz. Find the transfer function and decompose it as a cascade of a first order filter and a biquadratic section. What is the bandwidth of the first order filter section ? What are the $\omega_p$ and $Q_p$ of the biquadratic section ? How will you order the two sections ?

## 2 Gm-C Macromodel Implementation

For this part use a single-ended macromodel for the transconductor, as you did for problem set 4. Assume that you have available only transconductors with $G_M = 250\,\mu S$.

a. Show the schematic of the filter, with the values of all capacitors marked. What is the spread in the capacitor values ?

b. Plot the frequency responses at all the nodes of the filter.

c. List the peak values of the frequency response at each node.

d. Plot the noise spectral density at the output of the filter. Find the RMS noise at the filter output. You may assume that the noise spectrum has negligible power beyond 50 MHz.

e. Now assume that you also have available transconductors with $G_M = 125\,\mu S$ in addition to the ones with $G_M = 250\,\mu S$. Which transconductors in the original design will you modify to get a "better scaled" filter ?

f. Now plot the noise spectral density at the filter output, and find the RMS output noise of the filter. Compare it with the value obtained previously. Comment on the results.

## 3 Transconductor Design

Now design a transconductor with $G_M = 125\,\mu S$. Use a degenerated differential pair and a folded cascode arrangement for the output as shown in Figure 1. Assume a power supply of 3.3 V. Ambient temperature may be assumed to be 300K. Design for the following constraints -

a. Transconductor DC gain must be greater than 100.

b. The lowest parasitic pole must occur at a frequency higher than 400 MHz.

c. The input and output common-mode voltages must be 1.6 V.

d. The distortion in the transconductor output differential current for a peak-to-peak input differential voltage of 1 V must be less than 1%.

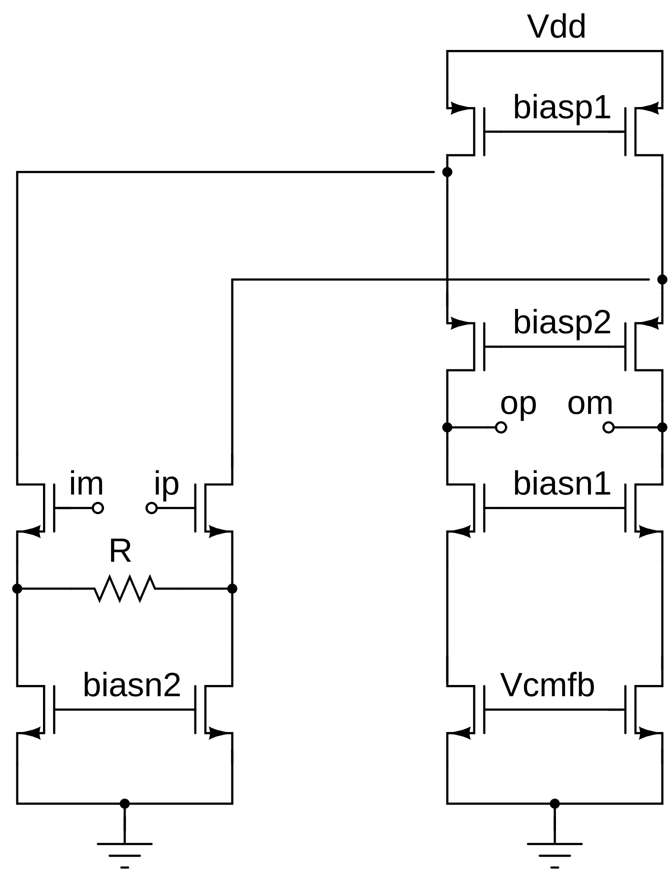


Figure 1: A folded cascode linearized transconductor.

1. Draw the complete schematic with all bias circuits and the common-mode feedback circuit. You may choose your favourite CM detector, servo amplifier etc. Mark the sizes of various devices and the value of the resistor R. Indicate how you got those values. I am interested in your line of thought. You are only allowed to use

one constant current source of $100\,\mu A$ and one voltage source of 1.6 V in the design (apart from the power supply, of course).

2. Simulate the AC transfer function of the transconductor. Plot the output differential voltage (in dB) as a function of frequency. The frequency axis should be on a log scale and should run from 100 KHz to 1 GHz.

3. Simulate the distortion performance of the transconductor. A test-bench for the simulation is shown in Figure 2. Simulate for amplitudes of 0.5 V and 1 V (peak-to-peak differential). Tabulate the third harmonic distortion levels at the two amplitudes. What do you notice ?

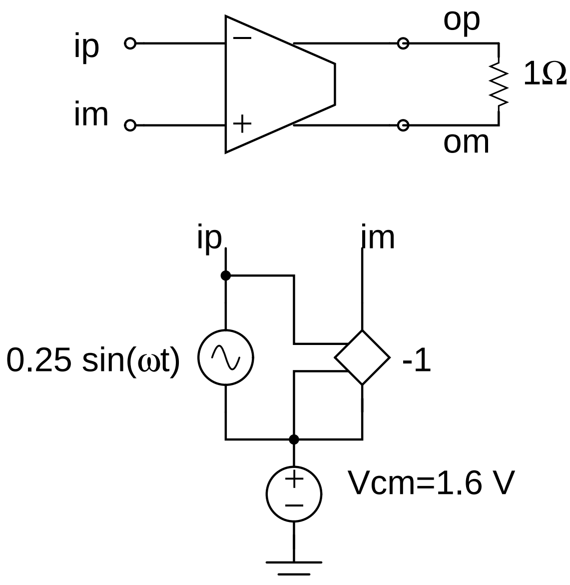


Figure 2: Suggested test-bench to measure distortion.

4. Simulate the common-mode stability of the transconductor using the test-bench of Figure 3. What can you deduce from the nature of the response at node vx ?

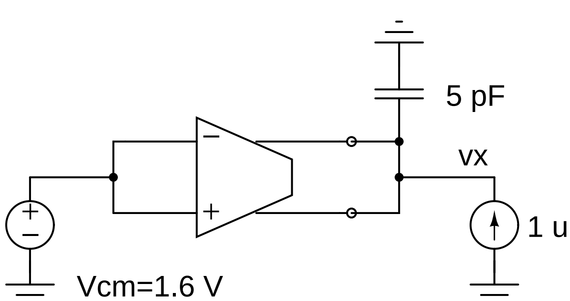


Figure 3: Suggested test-bench to measure common-mode stability.

5. Now that you have completed the design of a stable transconductor, hook up the entire filter, with capacitor values you determined for the "well-scaled" filter in Problem 2 of this assignment, but with the first order section using Gm's of $125\,\mu S$. A transconductor with $G_M = 250\,\mu S$ can be implemented as two $125\,\mu S$ $G'_m s$ in parallel. At this point do no worry about having many more common-mode feedback loops than are strictly necessary - you will fix all these small problems in the next Assignment ! Plot the frequency response of the filter. Why is there a deviation from what you designed for ? Readjust the capacitor values so that you get back the desired third order Chebyshev response.

6. Excite the filter with inputs of 1 V (pp differential) at frequencies of 1 MHz, 2 MHz, ..., 15 MHz. Tabulate the third order distortion obtained at the output and plot $HD_3$ (the ratio of the third harmonic to the fundamental) as a function of input frequency. What do you notice ?