MINI PROJECT 1

MATHEMATICAL AND COMPUTER TOOLS

Objectives — To investigate the accuracy and usefulness of Miller's theorem and the method of open-circuit and short-circuit time constants and to become familiar with computer based circuit simulation tools.

Introduction — In this project, we study the application of two mathematical tools, Miller's theorem and the method of open-circuit (OC) and short-circuit (SC) time constants, and verify their usefulness using very accurate SPICE (Simulation Program with Integrated Circuit Emphasis) simulations. Both Miller's theorem and the method of OC and SC time constants have been covered in the class notes.

Project — You will model the three circuits shown in Figures 1.1, 1.2, and 1.3 using your chosen circuit simulation software — you are required to model all three circuits. You will first calculate (by hand, using the methods learned in class) the frequency response of each circuit and then compare your calculated and simulated results.

References

1. ELEC 301 Course Notes.
2. A. Sedra and K. Smith, "Microelectronic Circuits," 5th (or higher) Ed., Oxford University Press, New York.
3. CircuitMaker™ (or other circuit simulator) User's Manual.
4. Notes on CONNECT.

Part I — The circuit shown in Figure 1.1 is a three-pole low-pass filter. It is to have the following transfer function:

$$T(s) = \frac{V_o(s)}{V_s(s)} = 0.125 \times \frac{10^5/\text{sec}}{s + 10^5/\text{sec}} \times \frac{10^6/\text{sec}}{s + 10^6/\text{sec}} \times \frac{10^7/\text{sec}}{s + 10^7/\text{sec}}$$

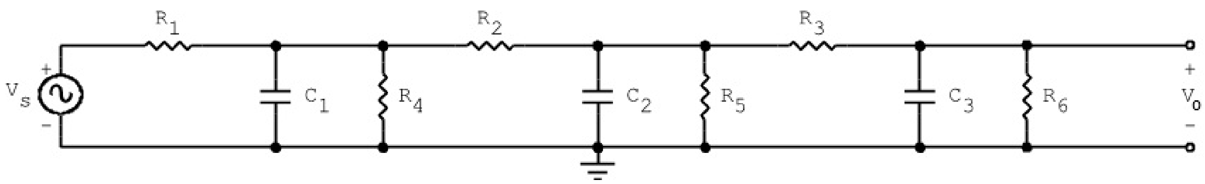
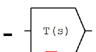


Figure 1.1.

Do the following:

A. Using the method of open circuit/short circuit time constants, design your circuit to give the desired frequency response. Given that $C_1 > C_2 > C_3$, you should design your circuit using four 1kΩ and two 2kΩ resistors. Run an AC simulation on your circuit and plot the Bode plots, both magnitude and phase.

B. Using s-domain function components (e.g., sxfer blocks in Circuitmaker - ) create a circuit with the exact transfer function given above, simulate it, and plot the Bode plots, both magnitude and phase, for it. Compare these Bode plots with those obtained in part A above.

Part II — Figure 1.2 shows a simple four-pole RC filter. With proper selection of the values of R_1, R_2, R_3, R_4, C_1, C_2, C_3, and C_4, this circuit becomes a band pass filter. We will use the method of OC and SC time constants to find the transfer function of such a filter.

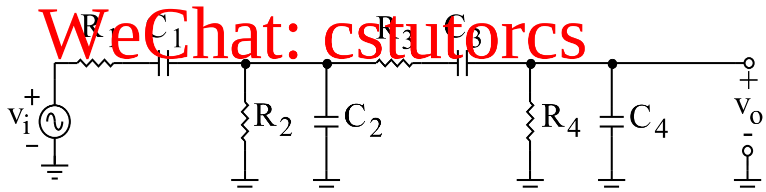


Figure 1.2. Four-Pole RC Filter.

Table 1.1. Initial Component Values for the Circuit Shown in Figure 1.2.

R_1	R_2	R_3	R_4	C_1	C_2	C_3	C_4
50 Ω	1 kΩ	1 kΩ	1 kΩ	20 μF	100 pF	500 nF	100 pF

For the circuit shown in Figure 1.2, start by using the component values shown in Table 1.1. and do the following:

A. Run an AC simulation on the circuit over a frequency range from at least 3 decades below the low frequency 3-dB point to at least 3-decades above the high frequency 3-dB point. Plot the Bode plots, both magnitude and phase, for the circuit. Graphically identify and record the locations of each of the poles of the transfer function.

B. Increase the value of C_3 to 1 µF, 2 µF, 5 µF, and 10 µF and rerun the AC simulation recording the effect on the low frequency poles for each C_3 value. Calculate the percent error in the calculated low-frequency 3-dB point (calculated using the method of OC and SC time constants) as compared to those obtained from the simulation for each value of C_3 value (including C_3 = 500 nF).

Part III — Figure 1.3 shows a basic transconductance amplifier. It has been designed with R_1 = 50 Ω, R_2 = 1kΩ, R_3 = R_4 = 2kΩ, C_1 = 4µF, C_2 = 10pF, C_3 = 2pF, C_4 = 1µF and G = 0.1℧

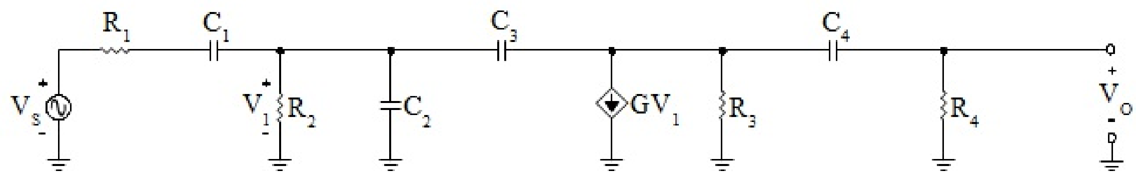


Figure 1.3. Basic Transconductance Amplifier.

For the circuit shown in Figure 1.3, use the component values given above to do the following:

A. Calculate the mid band gain and the locations of all of the poles (and any zeros) of the circuit shown in Figure 1.3 using Miller's theorem and the method of OC and SC time constants.

B. Run an AC simulation on the circuit over a frequency range from at least 3 decades below the low frequency 3-dB point to at least 3-decades above the high frequency 3-dB point. Plot the Bode plots, both magnitude and phase, for the circuit. Identify and record the location of each pole (and any zeros) of the transfer function using the magnitude plot and compare these with the values calculated in part A, above. Also, calculate the percent error in the estimated 3-dB points (calculated using the values of the pole locations obtained in part A, above) as compared to those obtained from the simulation.

Report — The report for this project should document the circuits that have been modelled and tested, i.e., provide printouts of the circuits used (for the circuit shown in Figure 1.2 a single plot of the circuit with C_3 = 1 µF is sufficient). Also, a discussion comparing the calculated and the simulated responses should be provided. Attach copies (printouts) of your Bode plots for both circuits showing how you determined the locations of all of the poles. Provide tables of your calculated pole locations and 3-dB points.

