More Realistic Frequency Modeling of Op. Amps.
Final Project

Assessed Learning Objectives:

2. Apply various circuit laws and circuit analysis methods to determine current, voltage, power, energy, efficiency, and circuit element ratings in steady state and transient AC circuits.

5. Create and present problem solutions in various forms, and write lab reports that are clear and easy to follow by other engineers.

6. Use Python/MATLAB and interpret Python/MATLAB results based on your understanding of circuit behavior to assist in AC circuit problem solving (including but not limited to use of complex numbers, linear algebra, transfer functions, Bode diagrams).

Task:

Compare the modeled frequency behavior of four high-pass filters: one using the ideal model, and three using a more accurate transfer function. Report on your work, highlighting the differences identified and the implications when it comes to active filter design.

Background:

The circuit seen in Fig 1, is a more accurate model of the operational amplifier, where A is the Open-Loop Large-Signal Differential Voltage Amplification. In DC applications, this can be considered constant, but once we are studying the frequency behavior of the element, it becomes clear that it varies with frequency.

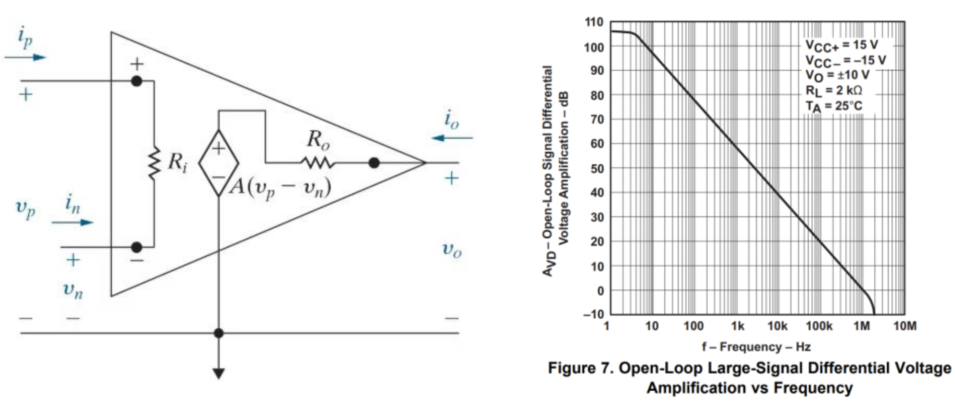

Figure 1 - Equivalent circuit model for an operational amplifier and Frequency behavior of A

We can estimate the A(s) transfer function, using our knowledge of sketching Bode magnitude plots by hand. See eq. 1, where Ao is the DC gain and τ is the inverse of the cut-off frequency ωc. From the datasheet we read: Ao ~ 200 000 and ωc = 25 rad/s.

$$A(s) = \frac{A_O}{\tau\, s+1} \qquad \text{Eq. 1}$$

Using this transfer function, and the dependent source circuit model, we can now build a circuit model for the filter that includes an op-amp. In this project, we are looking at the high pass filter, as I expect some interesting results in the higher frequency ranges. When doing this, feel free to simplify by assuming Ri is extremely large (infinite, essentially an open circuit) and Ro is extremely small (zero, negligible, essentially a short).

What is expected of you?

- Select an active high pass filter circuit topology, a gain, cut-off frequency, and passive components to realize your design. You may consider a specific application to help select amplification and cut off frequency, or not. Either way stay away from basic designs (i.e. everything is zero! Or everything is one!)
- Find datasheets for two more commonly used operational amplifiers and use the Open-Loop Large-Signal Differential Voltage Amplification vs. Frequency graph and estimate the op amps transfer function (as shown in class and in the Background section of this document)
- Derive the overall transfer functions of the active high pass filter the following four cases:
    - using the ideal op-amp model
    - using the LM 741 transfer function (derived in class and in Background section)
    - using the first of the two op-amps you found
    - using the second of the two op-amps you found
- Use Python or Matlab to graph the bode diagrams either on top of each other or separately, to be able to easily see the differences in frequency responses
- Study your graphs and identify differences, similarities, and the meaning for design applications
- PUSH YOURSELF: add an element to the project to make it yourself and closer related to your personal interests beyond circuits. Let’s chat about it during project time if you are unsure about what would make sense!
- Generative AI may not be used for any technical aspects of the work. It may be used for assistance with communicating your findings (if you need an infographic, help phasing something, or similar)
- This project is meant for one person to work on individually. No collaboration please!

Reproting ("Options")

Whatever reporting option you choose, you must include the following, in addition to what makes your chosen reporting option special:

- Sufficient context for January-you to be able to follow the flow of the paper
- diagram of your circuit
- transfer functions for each of the four cases
- discussion of differences observed between frequency behaviors (magnitude and angle) and implications for design decisions (this will be easier if you pick a specific application when designing your filter in the beginning)
- Recommendations on uses for different models and op-amps
- Python/Matlab script used for graphing in the appendix
- citations as applicable

Pick one of the following reporting options:

- An IEEE conference paper, using Overleaf IEEE Conference Template - Overleaf, Online LaTeX Editor or Word IEEE - Manuscript Templates for Conference Proceedings
- Have another idea? Let's chat!

Grading

40% - completeness of technical work as gleaned from your report
40% - correctness of technical work as gleaned from your report
5% - creativeness of the "Push Yourself" section
15% - in person Q&A on your work