EE 435

Experiment 4

Spring 2022

Two Stage Op Amp Design

1 Introduction

In many applications of operational amplifiers, the gain of a single-stage amplifier is not adequate. Operational amplifier architectures that use two or more gain stages are widely used when higher gains are needed. Additional phase shift is invariably introduced when multiple gain stages are cascaded and compensation of these structures is invariably required to maintain acceptable magnitude response or time-domain response of feedback circuits that use the multiple-stage architectures. Of the multiple-stage architectures that are used, two-stage configurations are the most popular because primarily of the challenges associated with compensating three or more stages. In this experiment, a two-stage op amp using the basic architecture shown in Fig. 1 will be designed. Though shown with n-channel inputs on the first stage and p-channel inputs on the second stage, you may use either n-channel or p-channel inputs. After the initial two-stage design is completed, the right half-plane zero will be removed.

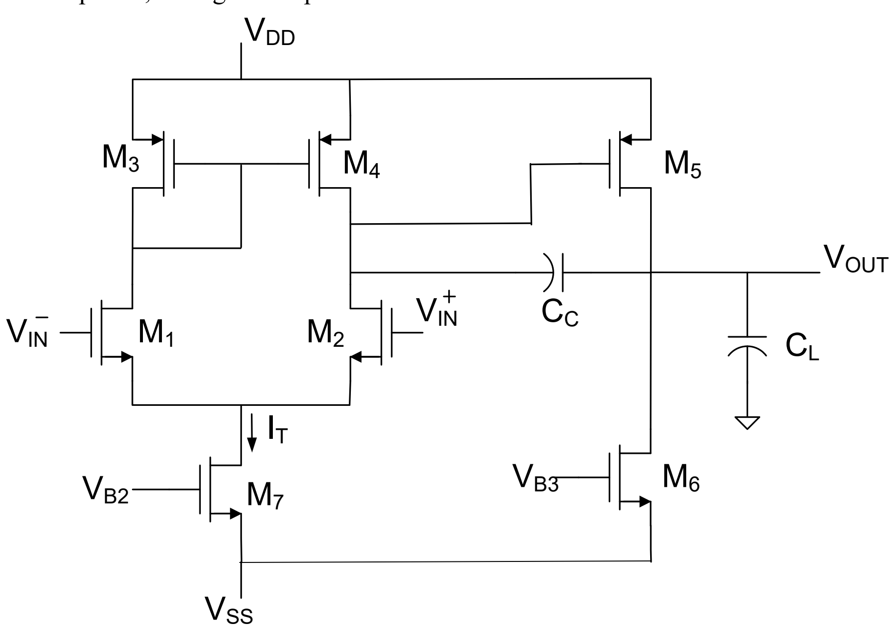

Fig. 1 Basic Two Stage Amplifier

Part 1: Design a two-stage operational amplifier using the architecture of Fig. 1 that meets the following specifications while keeping the power as small as possible:

1 - DC gain in excess of 60 dB.
2 - GB in excess of 2.5 MHz.
3 - Phase margin between 45 and 60 degrees with unity-gain feedback (β=1) when C_L= 20pF
4 - 2.5 V power supply.
5 - Systematic offset voltage of at most 20mV.
6.- ON 0.5µ CMOS process

Give the poles of your open-loop amplifier and determine the pole Q of the FB amplifier when connected as a unity-gain feed amplifier. Identify key performance parameters for an operational amplifier and summarize the analytical formulation of your design in a spreadsheet. Include a clear description of the design variables you use in your design, the number of degrees of freedom in your design, and an assessment of how power was split between the first and second stages.

Although not a design requirement, specify the common-mode input range and the output range you selected for your amplifier and compare with simulated results.

The design should include a complete circuit schematic and SPICE simulation results that compare analytical performance with simulated results. A layout of the circuit is not necessary.

Test your circuit in two configurations: unity gain and unity-gain inverting. Use very large resistors in your feedback network when testing the feedback amplifier. This test should include the step response and the gain magnitude response of the closed-loop amplifier.

Part 2: **Design of a two-stage operational amplifier using the architecture of Fig. 1 modified to remove the RHP zero**

In this design, simply remove the RHP zero of the previous design and change the compensation capacitor to meet the original phase margin requirements. Compare the performance of the modified op amp with that of the original op amp. You may remove the RHP zero by placing it at infinity or by moving it into the LHP and placing it at a critical location. You may remove it in any way you choose but specify how you decided to do it and what benefits in performance you expect to derive.

Test your circuit in two configurations: unity gain and unity-gain inverting. Use very large resistors in your feedback network when testing the feedback amplifier. This test should include the step response and the gain magnitude response of the closed-loop amplifier.

Part 3: **Comparison of operational amplifiers with RHP and no RHP zeros**

Make a comparison of the performance of the two amplifiers designed in the previous two parts of this experiment. This comparison should be analytical and supported with simulation results.

Report Requirements

Include a discussion of how you approached the design including the design flow that you established, a discussion of how many degrees of freedom that are available, the variables you used in the design and how each one was used. Also include your spreadsheet that you used to explore the design space and compare the performance requirements you predicted with the spreadsheet with what you actually verified with simulations. Your report should include complete circuit schematics.