EE 435 Homework 3 Spring 2024

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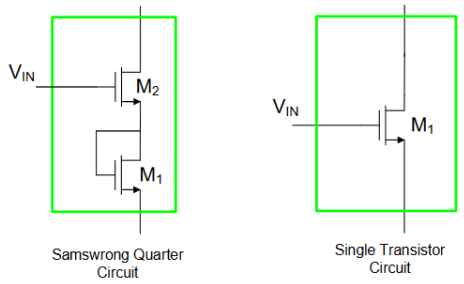
Assumptions

In the following problems, if reference to a semiconductor process is needed, assume processes with characteristics: CMOS Process – μ_nCOX=100μA/v2 , μ_npCOX=33μA/v2 , VTNO=0.5V, VTPO= -0.5V, COX=2fF/μ^2, μ_n= μ_p= 0.01V-1, and υ= 0.4 V-1/2

Problem 1

Consider the following quarter circuit. Assume an engineer from Samswrong has proposed this as the quarter circuit for building an operational amplifier with current-mirror connected counterpart circuits, n-channel inputs, and a tail current bias.



Problem 1a

Determine the two-port model of the Samswrong Quarter Circuit in terms of the small-signal model parameters

Problem 1b

Create the differential input operational amplifier described above and determine the differential voltage gain and the GB in terms of the small-signal parameters.small-

Problem 1c

Repeat part b) but express in terms of the practical design parameters

Problem 2

Consider again the amplifier in Problem 1. Assume the Samswrong engineer made the argument that the operational amplifier formed with the Samswrong quarter circuit is superior to that of the reference op amp (that was derived from the single-transistor quarter circuit). To draw this conclusion, the engineer designed both circuits with a 1 mW power budget and chose VEB1

and VEB2 for the Samswrong quarter circuit both be 150 mV and VEB1 for the reference op amp to be 500 mV. With these two designs, the engineer argued that the op amp derived from the Samswrong quarter circuit offered an improvement in both dc gain and GB.

Problem 2a

Are there improvements in both gain and GB actually achieved with the Samswrong op amp?

Problem 2b

Is the comparison of the two structures fair?

Problem 2c

Make your own comparison of the two operational amplifiers.

Problem 3

Consider an operational amplifier with differential inputs using the n- channel cascode structure for the quarter circuit and the Wilson Current Mirror (converted to p-channel devices) as an alternative counterpart circuit (the Modified Wilson Current Mirror was introduced in Lecture 6).

Problem 3a

Give the circuit schematic of the operational amplifier if it is biased with a tail current source.

Problem 3b

If a capacitive load of value CL is placed on the output, determine the differential voltage gain Ad(s) for this op amp.

Problem 3c

Determine the dc voltage gain and the GB for the op amp in terms of the small- signal model parameters.

Problem 3d

Make a comparison of the performance of this circuit with that of the telescopic cascode operational amplifier where the counterpart circuit of the telescopic cascode amplifier is connected as a current mirror.

Problem 4

Consider the folded-cascode operational amplifier with n-channel inputs, a tail current bias, and a current-mirror connected counterpart circuit. Assume it has been designed with a VDD=2V supply voltage, all devices were designed to have VEB=200 mV, the power dissipation was set at 10 mW, and the tail current of the differential pair at the input was 1/3 of the current coming out of VDD.

Problem 4a

Give the circuit schematic of this operational amplifier

Problem 4b

Give the device dimensions (W/L values) for all devices in the circuit.

Problem 4c

Numerically give the dc voltage gain and the GB for this op amp

Problem 5

In some processes, transistors with several different threshold voltages are available. Assume M1 and M2 in the circuit below have threshold voltages of VT1 and VT2 but all other model parameters are the same. Assume VT1=VDD/5 and VT2=VDD/10.

Problem 5a

Obtain the two-port model for this device.

Problem 5b

Identify a "practical" design parameter domain for this device

There is a practical parameter IQ which is the current flowing through the transistors at the quiescent point.

Problem 5c

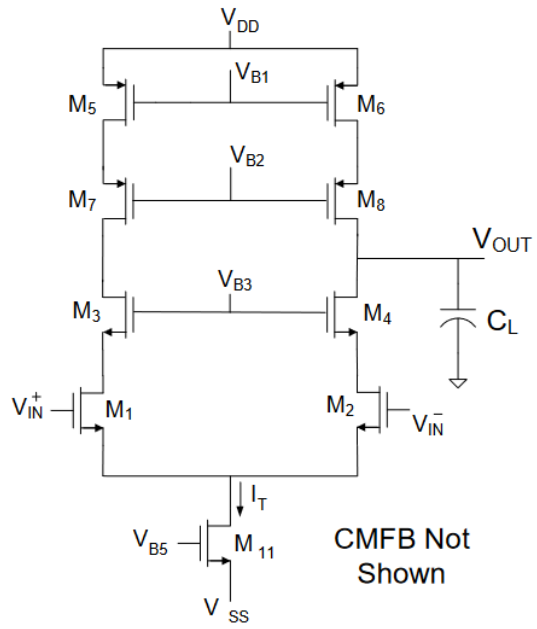
Give the schematic of a fully-differential operational amplifier with tail current bias if this is used as the "Quarter Circuit" for the op amp.

Problem 5d

What is the dc voltage gain and the GB of the operational amplifier of part c)? Assume a load capacitor of CL on both outputs.

Problem 6

The telescopic cascode op amp with n-channel inputs is shown below.



Problem 6a

Determine the common-mode gain of the telescopic cascode op amp if the tail current source is ideal.

Problem 6b

Give the circuit schematic for the telescopic cascode op amp with p-channel inputs

Problem 6c

Determine the positive and negative slew rates of the amplifer shown if the tail current source is ideal with a current of 100uA and the load capacitor is 2pF.

References

[1] Design and Analysis of Two-Stage CMOS Operational Amplifier for Fluorescence Signal Processing

[2] Operational Amplifier Basics

[3] TI Patent:Differential Amplifier Common Mode Voltage

[4] Wikipedia: Google File System