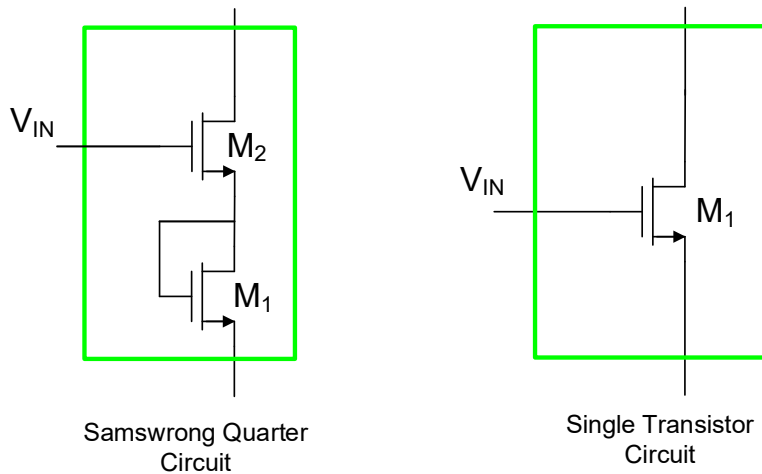


EE 435
Homework 3
Spring 2024

Due Wednesday Feb 14

In the following problems, if reference to a semiconductor process is needed, assume processes with characteristics: CMOS Process -- $\mu_n C_{OX}=100\mu A/v^2$, $\mu_p C_{OX}=33\mu A/v^2$, $V_{TNO}=0.5V$, $V_{TPO}= - 0.5V$, $C_{OX}=2fF/\mu^2$, $\lambda_n=\lambda_p= 0.01V^{-1}$, and $\gamma = 0.4V^{-1/2}$.

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.



- a) Determine the two-port model of the Samswrong Quarter Circuit in terms of the small-signal model parameters
- b) Create the differential input operational amplifier described above and determine the differential voltage gain and the GB in terms of the small-signal parameters.
- c) 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 V_{EB1} and V_{EB2} for the Samswrong quarter circuit both be 150 mV and V_{EB1} 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.

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

- b) Is the comparison of the two structures fair?
- c) 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).

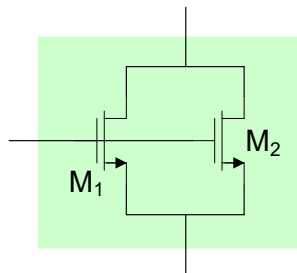
- a) Give the circuit schematic of the operational amplifier if it is biased with a tail current source.
- b) If a capacitive load of value C_L is placed on the output, determine the differential voltage gain $A_d(s)$ for this op amp.
- c) Determine the dc voltage gain and the GB for the op amp in terms of the small-signal model parameters.
- d) 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 $V_{DD}=2V$ supply voltage, all devices were designed to have $V_{EB}=200\text{ mV}$, 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 V_{DD} .

- a) Give the circuit schematic of this operational amplifier
- b) Give the device dimensions (W/L values) for all devices in the circuit.
- c) 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 M_1 and M_2 in the circuit below have threshold voltages of V_{T1} and V_{T2} but all other model parameters are the same. Assume $V_{T1}=V_{DD}/5$ and $V_{T2}=V_{DD}/10$.

- a) Obtain the two-port model for this device.
- b) Identify a “practical” design parameter domain for this device
- c) 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.
- d) What is the dc voltage gain and the GB of the operational amplifier of part c)? Assume a load capacitor of C_L on both outputs.



Problem 6 The telescopic cascode op amp with n-channel inputs is shown below.

- Determine the common-mode gain of the telescopic cascode op amp if the tail current source is ideal.
- Give the circuit schematic for the telescopic cascode op amp with p-channel inputs
- Determine the positive and negative slew rates of the amplifier shown if the tail current source is ideal with a current of 100uA and the load capacitor is 2pF.

