UNIVERSITY OF CALIFORNIA
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EE 105 Prof. Pister
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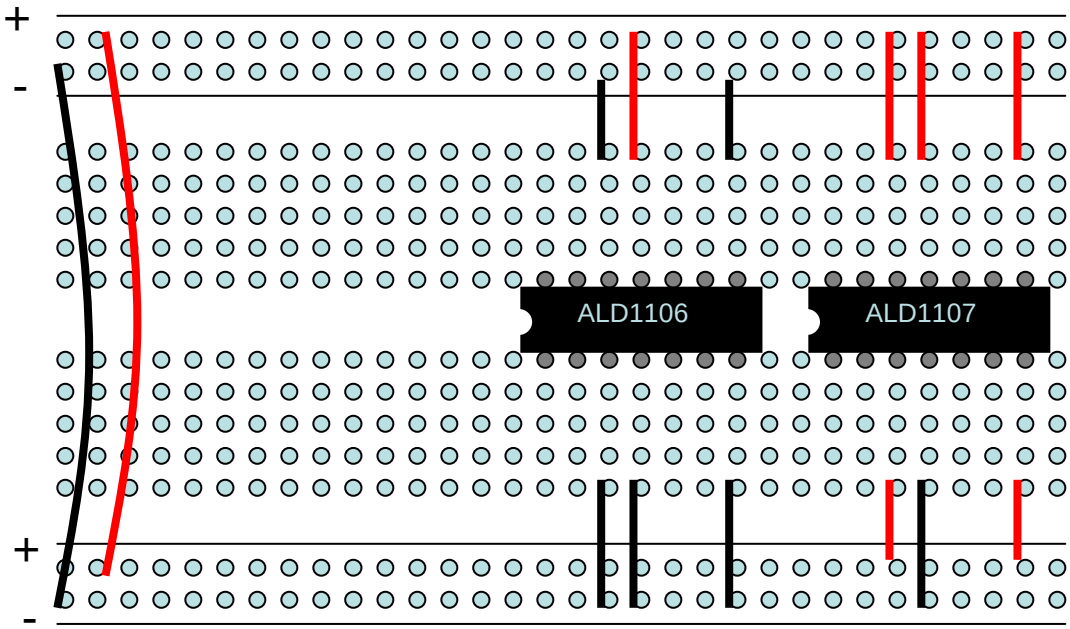
Lab 9 – CMOS Inverter, Ring Oscillator, Amplifier

The goal of this lab for you to build some CMOS inverters, use them as analog amplifiers, and see how feedback can be used to make a ring oscillator, or to bias a high-gain amplifier. You'll have six transistors in your final circuit. If you don't use some discipline in wiring, your circuit will be impossible to debug. So here are some tips on wiring up your circuit:

1) keep your wires short whenever possible. Big loopy wires make it difficult to trace out circuits.
2) Use the +/- rails on the top and the bottom of your circuit board for power and ground.
3) Wire up the power and ground lines with short, straight wires.
4) All of our MOSFETS in this lab will have their sources tied to the power supply (NMOS to ground, PMOS to Vdd), so do that first.

If you orient the chips as shown below then all transistor terminals are oriented Drain Gate Source, left to right.



PART 0 Transistor Check
Now that you've got the substrate and all the sources wired up, do a quick check to make sure that all of your transistors are working ok. One good way to do that is to diode-connect the transistor (drain and gate shorted) and then push a few microamps through it and make sure that it gives you roughly a threshold voltage. Plug a 100k Ohm resistor into Vdd, and then use two wires on the other side of the resistor to probe each NMOS transistor in turn (one wire on drain, one on gate) and make sure that the voltage reads just over the threshold voltage. Do the same thing for the PMOS transistors, but use the resistor to ground.

PART 1 DC transfer function
The goal for part 1 is for you to make a CMOS digital inverter, measure the DC transfer function, use it as an analog amplifier. Look at the Lab9part1 simulation in LTspice.
Use the spice deck to see what the circuit and DC transfer should look like, then measure it using a low-frequency triangle wave input from 0 to 5V. Label your plot to show the different regions of operation: NMOS OFF; NMOS saturated and PMOS linear; NMOS and PMOS saturated; NMOS linear and PMOS saturated; PMOS off.
Estimate the input bias necessary to get the output to be 2.5V, and record that value to use it in part 2.

PART 2 AC transfer function
Apply a small sine wave to the input of the circuit, with a DC bias such that the output is roughly at mid-rail. Measure the frequency response and make a Bode plot, showing clearly the response near the pole and unity gain frequencies. Compare to spice.

PART3 3 Stage gain

Build the 3 stage amplifier (add another 2 stages to your existing amplifier), measure the response to a 100mV input sine wave. Use a DC offset that gives the first stage a decent gain. Estimate the gain to out1, out2, and out3.

PART 4 Ring oscillator

Remove the input voltage source. Short the output to the input through a 10k resistor, R_F, with C_3 on the input side (see lab9part4 spice deck for a schematic). If the output doesn't oscillator, decrease the resistance until it does. Measure the frequency of oscillation vs. load capacitance for a few different load capacitances.

PART 5 Accurate voltage amplifier

Add 1uF to C3. Change RF to 100k. Add a 100mV input sine wave through a 10k input resistor. Bias the sine wave so that the output DC offset is roughly 2.5V. Measure the frequency response and draw a Bode plot. Compare