# EE 3310L/5310L · Electronic Devices and Circuits Laboratory

## Lab 9: CMOS Differential Amplifier

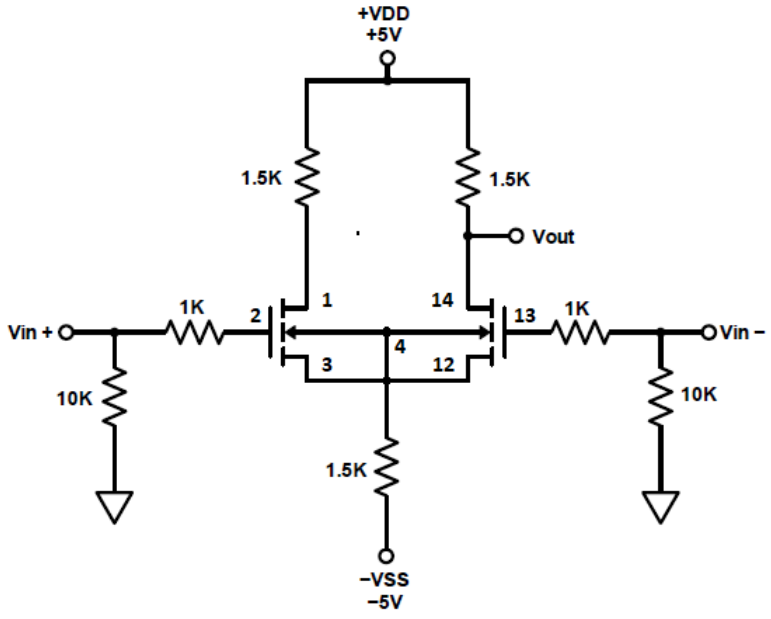
**Purpose**

The purpose of this lab is to construct and test a CMOS differential amplifier in three configurations: 1) resistive drain loads and sink; 2) resistive drain loads with electronic current-mirror sink; and 3) active current-mirror drain load and sink. We will use the Advanced Linear Devices ALD1103 monolithic I.C., which contains two matched pairs of enhancement-mode MOSFETs in one 14-pin DIP package; one *n*-channel pair and one *p*-channel pair. As with discrete MOSFETs, **these are static-sensitive devices; use a dissipative anti-static work surface and wrist strap connected to ground when handling these ICs. Use caution and try not to touch the pins.**

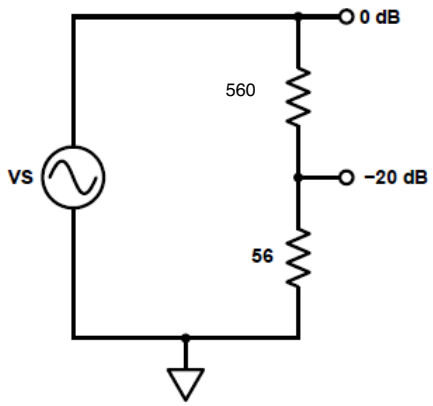
We will measure the gains from each of the two inputs to determine the differential gain ($A_{dm}$) and balance, and the gain with inputs connected together to determine the common-mode gain ($A_{cm}$) and common-mode rejection ratio (CMRR). All measurements will be performed at 1 kHz. Note that all of these circuits are undecoupled at DC (i.e., no blocking capacitors); therefore, we will use AC coupling on the oscilloscope for all measurements.

**Configuration #1: resistive drain loads and sink**

Build the following circuit. **Before connecting the ±$V_{DD}$ power supplies, preset the output voltages to ±5V to avoid damaging the ALD1103 IC**; it is only rated for ± 10V maximum. Measure and record all transistor DC voltages before applying an AC signal and verify that the drains are resting at approximately 3V with respect to ground; this indicates approximately 1.25 mA drain current per MOSFET. Observe the pins indicated on the schematic and build the circuit carefully. Note that the substrate of the IC is not internally connected to the source terminals of the MOSFETs and must be done so externally via pin 4.



Connect your function generator to a 20-dB pad as shown and leave it on your breadboard such that you can select between the full and attenuated generator voltages as needed.




1) Apply a 1 kHz 100mV peak-to-peak signal to $V_{in}$+ via the 20-dB pad. Measure the peak-to-peak voltage at $V_{in}$+ with Channel 1 of the oscilloscope and $V_{out}$ with Channel 2. Determine the positive-input gain $A_{Vin+} = V_{out}/V_{in}$+.

2) Now connect the generator to $V_{in}$- via the 20-dB pad. Measure the peak-to-peak voltage at $V_{in}$- with Channel 1 of the oscilloscope and $V_{out}$ with Channel 2. Determine the negative-input gain $A_{Vin-} = V_{out}/V_{in}$-. Verify that the polarity of the output is inverted with respect to the input and don't forget the negative sign in your calculation.

3) Determine the differential-mode gain $A_{dm} = A_{Vin+} - A_{Vin-}$. Also determine $A_{dm}$(dB). Again, don't forget the negative sign in your computation.

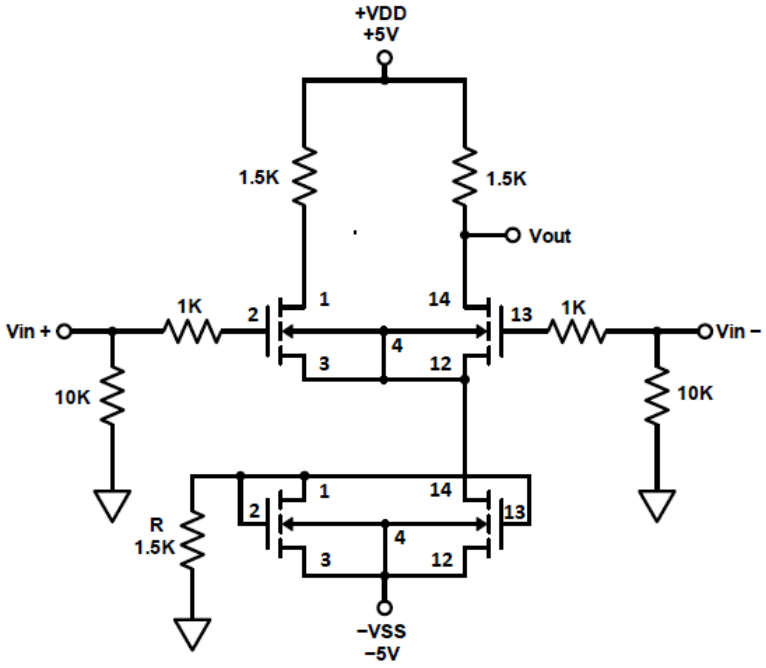
4) Compute the differential imbalance $A_i = |A_{Vin+} / A_{Vin-}|$. Also determine $A_i$(dB).

5) Now connect the signal generator without pad to **both** inputs simultaneously. Measure the peak-to-peak voltage at $V_{in}$+ = $V_{in}$- with Channel 1 of the oscilloscope and $V_{out}$ with Channel 2.

6) Determine the common-mode gain $A_{cm} = V_{out}/V_{in}$. If the circuit is built correctly, this should be a <u>fractional</u> value. Also determine $A_{cm}$(dB).

**Configuration #2: resistive drain loads with electronic current-mirror sink**

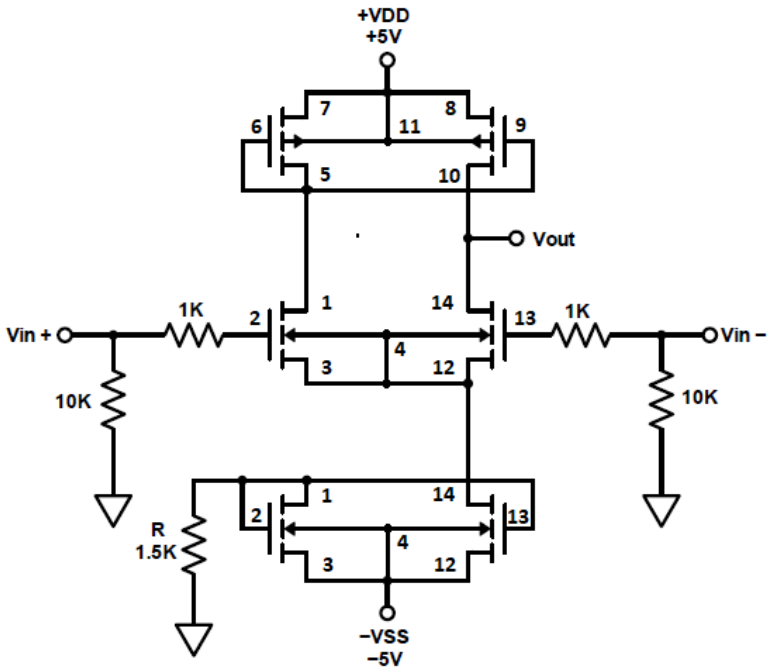
Turn off the power supply, remove the 1.5-kΩ source resistor, and build a MOSFET current mirror using a second ALD1103 IC. **Again, use the grounded wrist strap when handling this component.** Before applying any AC signals, verify that DC drain voltages are approximately 3V with the power supply energized; if not, adjust the current-programming resistor in the current mirror.




Repeat steps 1-6 with this configuration. Differential imbalance should be much better with the current source, as should CMRR.

**Configuration #3: active current-mirror drain load and sink**

Turn off the power supply, remove the 1.5-kΩ drain resistors, and build a MOSFET current-mirror active drain load using the *p*-channel MOSFETs in one of the ALD1103s currently being used. Note that the substrate of the IC is not internally connected to the source terminals of the *p*-channel pair and this is done so externally via pin 11. Repeat steps 1-6 with this configuration. Differential-mode gain should be much greater due to the active drain load.




**Postlab**

Include all measurements, computations, and comments in your lab report. **Specifically address how this lab fosters an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.**