Lab 2: Current Mirrors

Introduction

A current mirror is used to copy or multiply the input current. It is often used as a bias circuit that provides a known current to an analog circuit like a common-source amplifier with an active load. A current mirror in CMOS relies on the property that ideal transistors of the same size (W/L) with the same V_{GS} have the same drain current (I_D) regardless of V_{DS} as long as both are in saturation. A simple NMOS current mirror is shown in Figure 1(a).

With real transistors, however, I_D changes slightly with V_{DS} because of the channel-length modulation. In small signal, this effect appears as a finite output impedance (as opposed to the inifinite output impedance of an ideal current mirror). A cascode transistor can be stacked on top of the current-mirror transistor to improve the output impedance of a current mirror as shown in Figure 1(b).

A current mirror can be also used as an active load of a common-source amplifier as shown in Figure 2. A very high small-signal gain is achievable with an active load because of its high output impedance.

In this lab, you will measure I_{D2} versus V_o of a current mirror without and with a cascode transistor to determine their output impedance and output swing. A common-source amplifier with a current mirror as an active load will also be tested.

Preparation

1. Current mirrors

Do the following for both of the current mirrors in Figure 1. Use $I_{D1} = 1$ mA and $V_{DD} = 5$ V. For the cascoded current mirror, set V_{B2} wisely to maximize the output swing while keeping the transistors in saturation.

1. Perform a hand analysis to find the numerical value of the output impedance. Do not expect good matching between hand calculation and simulation as the output resistance of the actual transistor and thus the model depends on V_{DS} This effect is not captured by the square law you use in hand analysis.

2. Run a DC sweep to plot I_{D2} versus V_o. You need to connect a DC voltage source to the output of the current mirror to provide V_o and sweep it.

3. Show the output swing and output impedance of the current mirror on the plot in the previous step.
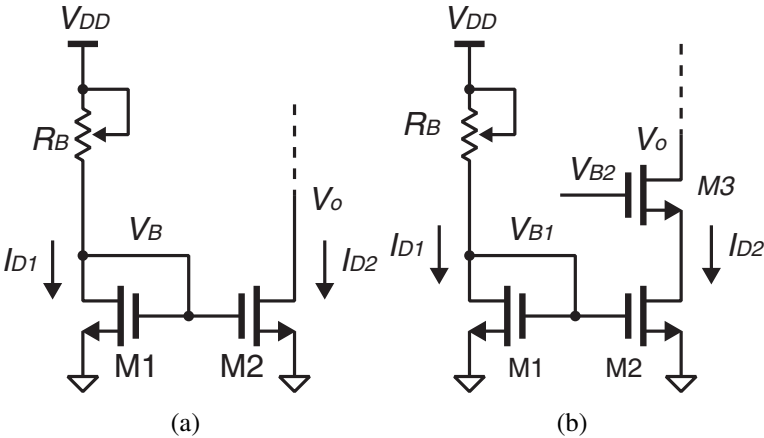
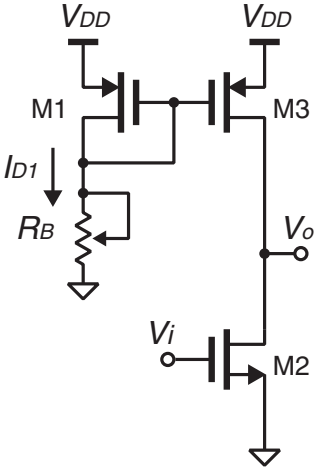Figure 1: An NMOS current mirror (a) without and (b) with a cascode transistor.

Figure 2: An NMOS common-source amplifier with a PMOS current mirror as an active load.

Table 1: Minimum parts list

Part	Description	Quantity
ALD1101	NMOS transistor pair	1
ALD1102	PMOS transistor pair	1
-	10-kΩ multi-turn potentiometer	2

4. Organize the results for presentation to your TA.

2. Common-source amplifier with an active load

Do the following for the common-source amplifier with an active load shown in Figure 2. Use $I_{D1} = 1$ mA and $V_{DD} = 5$ V.

1. Perform a hand analysis to find the expression and numerical value of the small-signal gain.

2. Run a DC sweep to plot V_o and $A_v = dV_o/dV_i$ versus V_i. Determine the input bias point for maximum singnal swing.

3. Run a transient analysis for 10 ms with a 10-mV$_{pp}$ 1-kHz sinusoidal input biased at the voltage found in the previous step. Plot V_o and verify the small-signal gain found in the previous step.

4. Organize the results for presentation to your TA.

Lab

A minimum parts list for this lab is shown in Table 1. This is the absolute minimum. You may bring more parts for your convenience and backup.

1. Current mirrors

Repeat the following for the normal current mirror and cascoded current mirror.

1. Assemble the current mirror on the bread board and connect a power supply to provide V_{DD}.

2. Adjust the potentiometer (R_B) for $I_{D1} = 1$ mA.

3. Connect another power supply and a multimeter to the output side of the current mirror for providing V_o and measuring I_D. Remember that the multimeter has a separate port for current measurement and it has to be inserted in series with the circuit unlike voltage measurement. Connect another multimeter to measure V_D accurately as the power supply doesn't provide accurate voltage reading.

4. Vary V_o from 0 V to 5 V and measure I_D to plot an I_D versus V_D curve.

5. Label and comment on the plot as necessary to clearly show the output impedance and swing of the current mirror.

6. Organize the results for presentation to your TA.

2. Common-source amplifier with a current-mirror load

1. Assemble the common-source amplifier with an active load on the breadboard. The input should be biased with a potentiometer and capacitor for fine tuning of the input bias voltage (same as Lab 1).

2. Adjust the potentiometer (R_B) for $I_{D1} = 1$ mA.

3. Adjust the potentiometer for input biasing for maximum output swing.

4. Apply a 1-kHz 10-mV$_{pp}$ sinusoid and find the small-signal gain of the amplifier.

5. Change the amplitude of the input to determine the output swing of the amplifier.

6. Organize the results for presentation to your TA.