Laboratory 12 : Differential Amplifier

Concept

Operational amplifiers are differential amplifiers, that is, $V_{out} = G(V_+ - V_-)$. The input stage or front end of a simple op amp such as the 741 is based upon a differential amplifier made with bipolar junction transistors. The concept is to fix the sum of the currents through the transistors using a constant current device, and then use the fact that if the collector current in one transistor increases the current in the other must decrease. If the base currents are the same in both transistors, then there should be no change in the current through either collector.

The constant current device is a current mirror. The concept for this device is that the current through the transistor connected to the circuit of interest is controlled by adjusting the current through a transistor not connected to the circuit of interest.

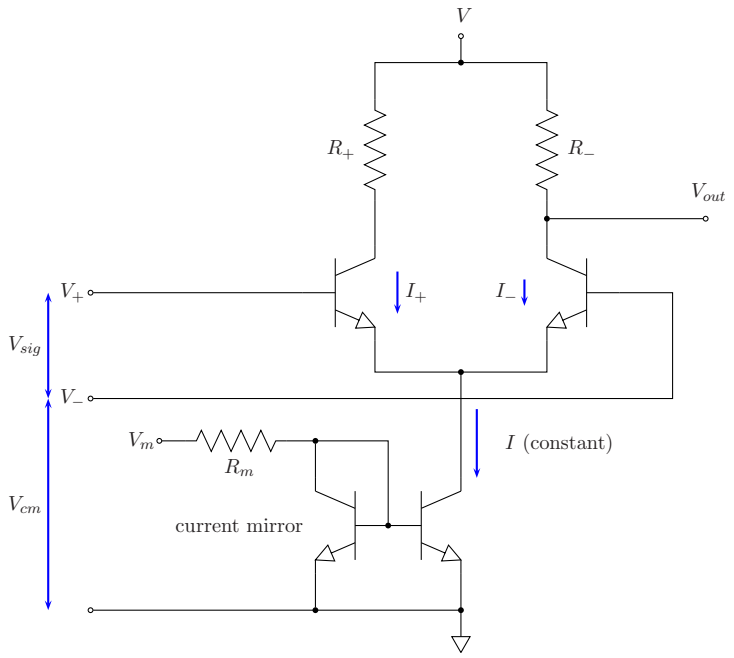

Figure 1: General concept of a differential amplifier. The total current through the differential pair of transistors is determined by the current mirror. The inverting and noninverting inputs of the amplifier are the bases of the differential pair transistors.

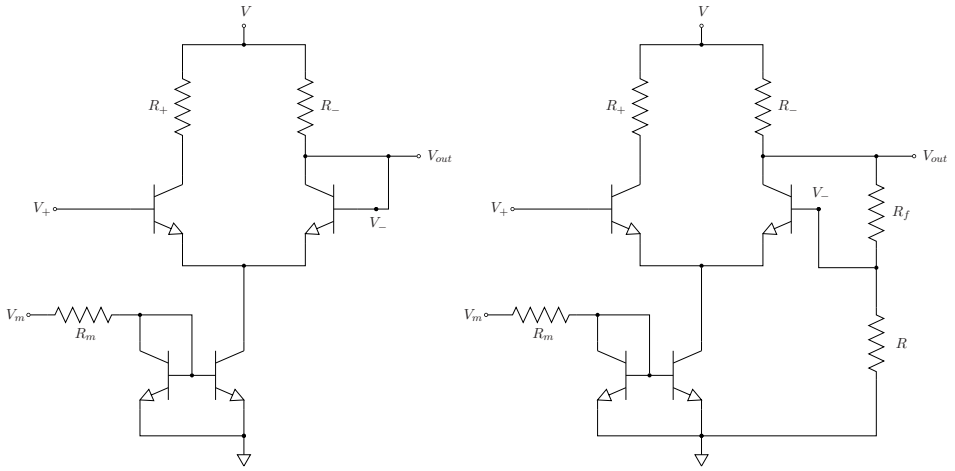

Figure 2: Two examples of feedback in a differential amplifier circuit. On the left, similar to an operational amplifier, unity negative feedback yields a unity gain amplifier. On the right, the gain is determined by the negative feedback fraction.

Experimental Instructions

1. Analysis of the Current Mirror

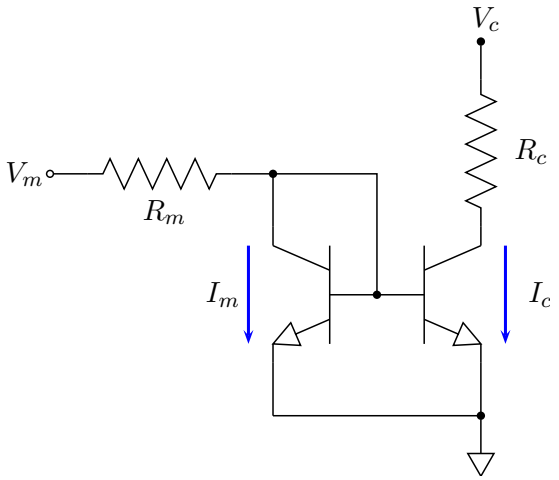

Figure 3: Current mirror.

a. Using two 2N4123 npn transistors, build a current mirror such that $I = 1$ to 10 mA. For example, if $V_m = 10$ V and $R_m = 10\text{k}\Omega$ then $I_m \approxeq 1$ mA. Measure the currents through R_m and R_c using unity gain difference amplifiers connected across the resistors. The signals on the two oscilloscope channels will then be $V_m = I_m R_m$ and $V_c = IcR_c$. Using a unipolar positive ramp output of the function generator for V_m, acquire $V_m(t)$ and $V_c(t)$ from the oscilloscope, plot I_c versus I_m and measure the deviation from exact linearity. Be careful not to draw too much current through the transistors. R_m

will have a minimum value given the maximum value of V_m. For the transistor on the right, R_c and V_c must be chosen to support the maximum value of I.

2. Differential Amplifier with BJTs

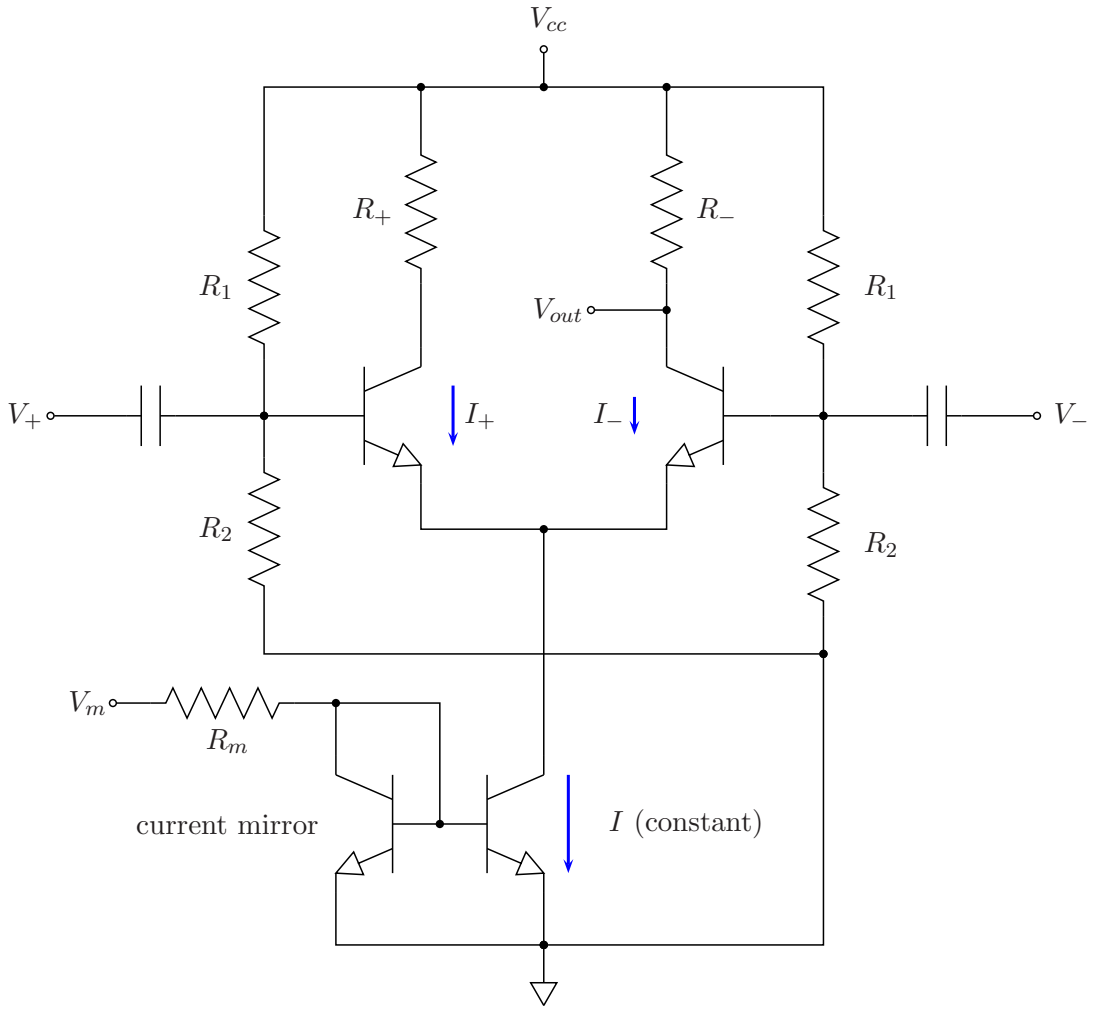

Figure 4: Differential amplifier using an npn transistor and the necessary bias.

a. Construct this circuit meeting the criterion that the current mirror current is 1 mA. Choose bias resistors R_1 such that with no input signals, $I_- = I_+ \approxeq 0.5$ mA. Set $R_2 = \infty$ to achieve a high input impedance. Choose $R_+ = R_-$ such that $V_{out} = V_{cc}/2$.

b. With equal input signals $V_+(t)$ and $V_-(t)$ (capacitively-coupled), the output signals should be zero. Test that assumption by applying the same small bipolar sine wave signal to both inputs.

c. Using V_- and V_+ with different amplitudes, measure the AC potential gain, and verify that $V_{out} = A(V_+ - V_-)$.

d. Measure the very small common mode gain $A_{cm} = V_{out}/V_+ = V_{out}/V_-$ when $V_+ = V_-$, and calculate the *common mode rejection ratio* $CMRR = 20 \log A/A_{cm}$ in dB.