LABORATORY #3
THE DIFFERENTIAL AMPLIFIER

Equipment

2 matching 2N5458 JFET's
2N5210 bipolar transistor
TL081 OpAmp
various resistors

Introduction

A perfect differential amplifier has equal gains of opposite sign at the two inputs, and thus can cancel any common mode signal. In this experiment, we evolve the design of a differential amplifier from a simple circuit with two transistors to more complex designs which provide successively better common mode rejection and approach the complexity of a commercial operational amplifier. The design improvements are in the form of successively better current sources.

Select the JFET's

To begin, we want well matched transistors. Set up a circuit on your proto-board in which you can plug in each of your 2N5458's successively to measure its drain current with identical bias conditions. You could use the circuit of lab #2, for example, or you could even do it with the circuit below. Try several JFETs to find a best match. Select the two most closely matched and construct the circuit of figure 1. Chose $R_{dA} = R_{dB}$ so as to make V_{oa} and V_{oa} about 6 or 8 volts with V_{dd} at 12 volts, V_{ss} at -12 volts, and the drain current in each JFET 1.5 mA. The drain currents (about 1.5 ma) should be nearly equal, or the output voltage range will be limited. All resistors should end up around 4kΩ.

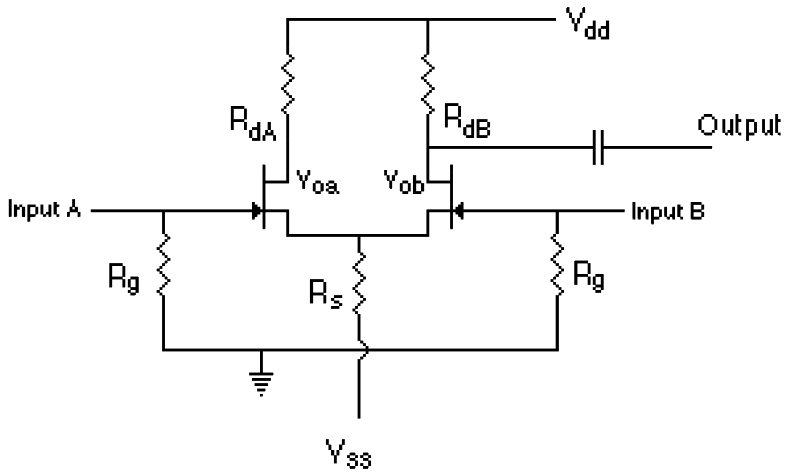


Figure 1

Check the operating point

Make certain that there is a common ground connection between the function generator ground, the scope ground, the circuit ground and the power supply ground. Each power supply voltage should be bypassed to ground at the differential amplifier. Measure the voltage drop across the (equal- select them to make it so at the 1-2% level) drain resistors to check that the drain currents are nearly equal (10-20%) and about 1.5 ma. Connect the same, single ended (one side is ground) signal from the function generator to both inputs. Use a sine wave at 10 kHz and 50 mV pp(peak to peak). Attach each of the output voltages of your differential amplifier to its own channel on the scope and display the trace for both channels. In an ideal differential amplifier, the JFET sources are connected to a constant current source. If the input signals to each side are identical and the total source current for both sides is constant, then there should be no change in drain voltage on either side. However, with finite R_s the source current is not constant so that there will be a finite common mode signal at either the A or B output of your amplifier.

Measure the gain and common mode rejection ratio(CMRR)

The gain from either input to either drain output should be the same except for sign. With the same 50mv pp input signal applied to each input in turn, measure the four gains (A-A, A-B, B-B, B-A).
Now apply the same input signal to both inputs at the same time and measure the output at either drain. The CMRR is calculated from this data as
CMRR= 20 $\log_{10}$((output amplitude with one driven input)/(output amplitude with both inputs driven))
The common mode rejection ratio is a pure number; as given above, the units are in db(decibels). Repeat this process for each of the following circuits. In each case, compare your result with the theoretical expectation. You should find substantial improvement as the current source is improved. With the regulated current source(s), the common mode signal will be so small that you will need to use a large input(1 or 2 volts) and then scale the output linearly to insert in the above formula.

Add a constant current source

A simple improvement to the circuit is to use a transistor as a constant current source in the open collector configuration of figure 2.

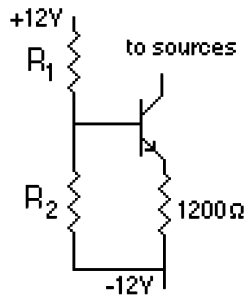
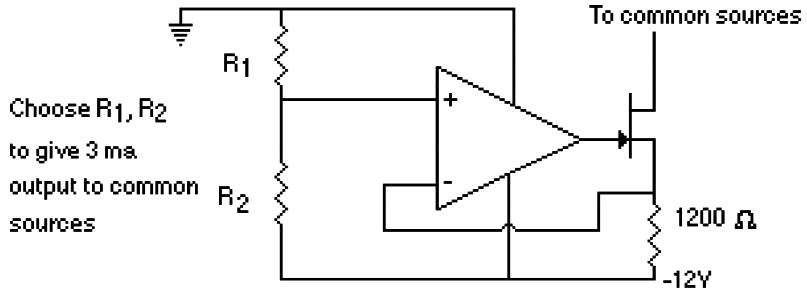


Figure 2

R_1 = 30 k and R_2 = 6.8 k should yield about the right base bias voltage. Explain what criteria are used to determine these resistors. Use the small signal model to show that this should provide a constant current source. If you place a scope probe on the emitter of figure 2 you should be able to determine by how much the "constant current" source is actually changing(should be below one millivolt). If you can see variations, discuss why and what could be done to improve it.

Still better constant current sources are described in chapter 7 of the text. Commercial OpAmps use the current mirror described in section 7.8 (page 268) of the text . A better option for a constant current source was discussed in class and is given below. A JFET is a better choice for the transistor than a bipolar transistor. Why? You are unlikely to be able to be careful enough to see the theoretical result.



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