

ELEC 361 Measurement and Analysis

Lab 5. Differential Amplifier

This lab investigates the transistor differential amplifier that is a basic building block in all op-amps, audio amplifiers, comparators, etc. The challenge question asks you to configure the differential amplifier as a trans-conductance multiplier and use it to produce Dalek speech. (https://www.youtube.com/watch?v=mxD-5z_xHBU)

This is a 2-week lab.

Pre-Lab Homework

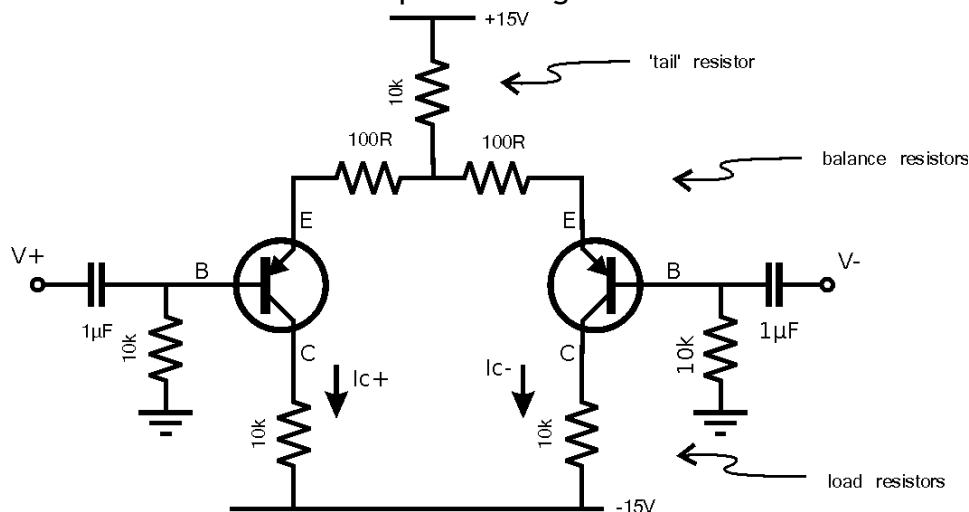
1. Assigned reading:

- Read section 2.18 in The Art of Electronics - Horowitz and Hill.

Background

We first look at the basic configuration of the differencing ‘long tailed pair’, and then go on to characterize and include an improved current source and current mirror. Both these improvements give big increases in the common mode rejection ratio that is an important property of any system with differential inputs. A general understanding of the differential amplifier, in basic form and with improvements, can be found in The Art of Electronics by Horowitz and Hill, section 2.18.

The basic circuit for a differential amplifier using PNP transistors is:



Lab tasks

1. Calculate the d.c. operating voltages and currents
2. Build the circuit and measure all the d.c. operating voltages and currents, and compare with your calculated values.
3. Do the balancing resistors help in making the measured values symmetrical?

The *differential* input voltage is $V_{\text{diff}} = V_+ - V_-$.

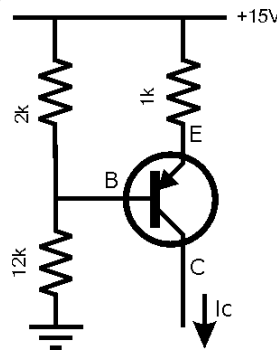
The *common-mode* input voltage is $V_{\text{cm}} = V_+ + V_-$

4. Measure the collector currents as a function of the differential input, and plot the two I_c -vs- V_{diff} curves on a single graph. Make sure the maximum and minimum collector currents are displayed. *Important: make sure the balancing resistors are in place for this measurement, otherwise you will kill the transistors.*
5. Identify the linear region of operation.
6. Measure the collector currents as a function of common-mode input.
7. Calculate the common-mode rejection ratio (CMRR)

$$CMRR = \frac{\text{differential gain}}{\text{common - mode gain}}$$

Current Source

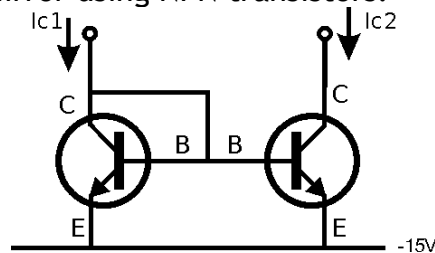
Build the following current source:



8. Set the resistor values so that this current source produces the same current as the 'tail' resistor in the basic circuit.
9. Measure the small-signal impedance of the current source.
10. Replace the 'tail' resistor with this current source, measure the new differential gain and common-mode gain.
11. Is the CMRR improved?

Current Mirror

Build the following current mirror using NPN transistors:



12. Predict the relationship between the two collector currents.
13. Measure to confirm.
14. Replace the collector resistors with this current source; are the d.c. operating points changed?
15. Put a current-to-voltage converter (either a resistor, or a common-emitter BJT stage) at the output; how is the gain and CMRR affected?

Challenge (optional)

Modulate the current source by applying a (a.c. coupled) voltage. The output voltage is the product of this voltage and V_{diff} . Use this to make your voice sound like a Dalek.