University of Utah
Electrical & Computer Engineering Department
ECE 2100
Experiment No. 8

Common-Collector Amplifier

A. Stolp, 3/7/00
rev, 3/4/03

Minimum required points = 48 Grade base, 100% = 67 points
Recommend parts = 67 points (100%, ALL parts are recommended this time)

Objectives

1.) Observe the problem of a high output impedance source connected to a low impedance load.
2.) Build a common-collector amplifier to insert between source and load and measure its characteristics.
3.) Look at similarities and differences between the common-collector and common-emitter amplifiers.

Check out from stockroom:

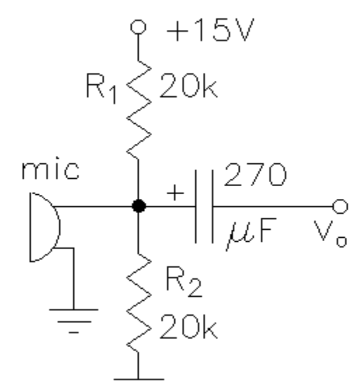
- Wire kit & Two 10x scope probes
- Possibly one speaker

Parts:

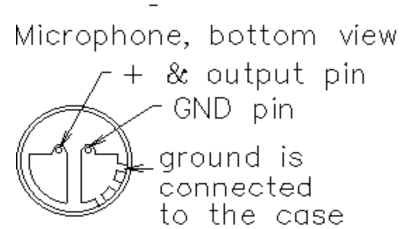
- 10, 100, 10 k, & two 20 kΩ resistors
- one 1 - 10 µF & one 270 - 470 µF capacitor
- 2N3904 transistor
- microphone and speaker (you may have to check the speaker out)

Experiment 1, Common-Collector (pts, Recommended)

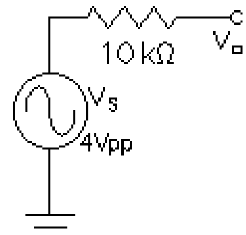
Last week you measured the β of your 2N3904 transistor with a circuit that was essentially a common-collector amplifier (the collector is connected to a DC voltage source, which looks like a signal ground, or common). At that time you simply measured the DC (bias) voltages and currents. We used this circuit because it's very easy to bias and very stable. Today you'll use this circuit with AC signals and see that although this circuit only has a signal voltage gain of about 1 (which explains its stability), it is still a very useful circuit. First let's take a look at the problem that this circuit will solve.



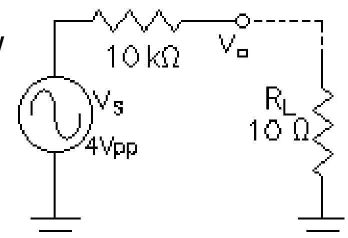
Impedance mismatch of a microphone and a speaker:
Hook up your microphone as shown. The two 20 kΩ resistors simply provide the microphone with some DC voltage that it needs to operate. Most electret microphones need some external DC voltage. (These mics are also called condenser mics because the actual microphone is a capacitor and the old-fashioned name for a capacitor is a condenser.) Hook the scope up to v_o and confirm that the microphone is working.



Hook up your speaker to v_o. (The other speaker wire goes to ground, of course. In future, I won't mention the ground connection specifically. I'll assume that you can figure that part out on your own.) Does the scope still show a signal at v_o? If yes, is it anywhere near as large as it was before the speaker was connected? Can you hear anything at the speaker? (Possibly the best way to test this is to hold the speaker right to your ear and blow on the microphone, but frankly, I don't think a hurricane would make enough noise that you'd hear it though this setup.) The mic has a large output resistance (called output impedance in more general terms) and the speaker is a low impedance load (has a low input impedance). Even if the output voltage from the mic were sufficient to operate the speaker, it can't supply enough current. Comment in your lab notebook concerning how the mismatched impedances effects operation of this circuit.



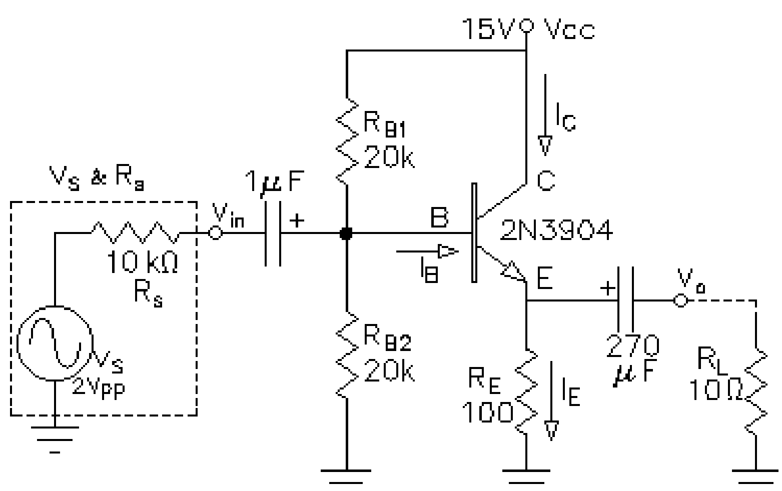
Artificial Impedance mismatch:
Because the output impedance of the microphone is difficult to measure, we're going to switch to an artificial signal source and artificially make it's output impedance about as large as that of the mic. Set the bench function generator output to about 4 V_{pp} (2 V_{pp} on the HP) at 1 kHz. Add a 10 kΩ resistor in series as shown. The function generator and the 10 kΩ resistor together model a source with a 10 kΩ output resistance. (Actually 10,050 Ω, but we'll ignore the 50 Ω output resistance of the generator itself.) I'll call this "V_S & R_S" from now on and you'll use it throughout this section of the lab.



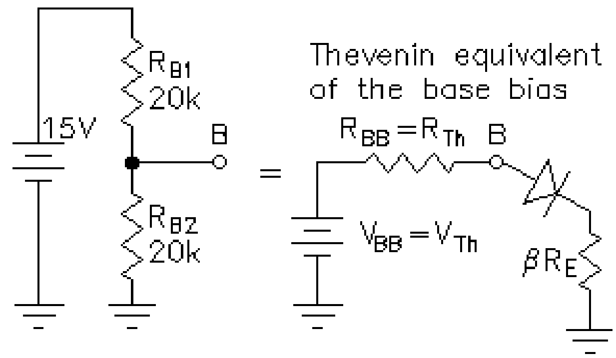
Measure the output voltage of "V_S & R_S" with no load resistor. Now add the 10 Ω load resistor (R_L) as shown and measure the output voltage again. See how this mimics the microphone-speaker problem? Why is the output of "V_S & R_S" so much lower than before? Record the measurements so you can see the improvement later. (If the signal across R_L is too small to measure accurately, state that in your notebook in lieu of a measurement.) Try the speaker in place of the 10 Ω resistor. Can you hear anything from the speaker?

In the next section you'll build an amplifier circuit to insert between the source, "V_S & R_S" and the load, R_L.

Common-Collector: Build the common-collector transistor circuit shown. Leave off the source ("V_S & R_S") and the load resistor (R_L) for now. Notice that instead of using a separate voltage supply for the base bias (like the circuit from last lab), this circuit uses a voltage divider between Vcc (15V) and ground.



Bias: Calculate the Thévenin equivalent of the base bias circuit (Vcc, R_{B1}, and R_{B2}) to find V_{BB} and R_{BB} and show that this is very close to a separate 7.5 V supply with a series 10 kΩ resistor.



Measure and record the DC bias voltages of the common-collector circuit (measure V_B and V_E with a DC voltmeter). Make a reasonable assumption for β (look back at the last lab) and calculate these voltages. (If we're not yet that far in class, look at the circuit I've drawn with a diode and a resistor that's β times bigger than R_E. Use that circuit model to calculate V_B and V_E.) Compare your measurements and calculations.

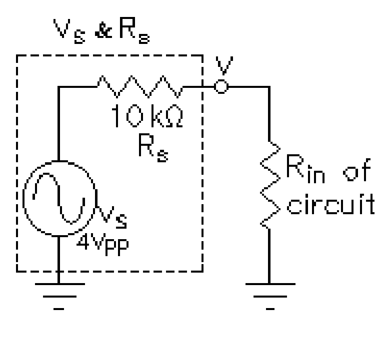
Signals: Connect "V_S & R_S" to the input of this circuit, as shown before.

Set both channels of the scope to 1 V/div, DC coupling and adjust both ground levels to the bottom of the screen. This way you'll be able to observe both the AC an DC characteristics of both v_B and v_E at the same time. **Don't press the "auto" button** or you'll mess things up. Connect the scope probes to the base and to the emitter. Find V_{AVE} (DC) for both signals. These should be the same as the DC bias voltages that you measured earlier. Notice that the signals swing above and below these bias levels. This is classic AC + DC superposition and you'll see this many more times in this class. Make a sketch of these voltages in your notebook, showing AC signals "riding on" the DC average voltages.

Note: Leave the scope set this way so that you can see both signals on the same scale along with the DC biases.

0.7 V difference: What is the difference between the two voltages? Is the difference constant? Notice that v_E simple tracks or *follows* v_B, just 0.7 V under. The AC signal voltages are the same for both (signal voltage gain ≈ 1), just the DC is different. The common-collector circuit is also known as an *emitter follower* because the emitter voltage *follows* the base voltage.

Loaded: Add the load resistor (R_L=10 Ω). Measure the signal voltage across the load. It's still not very big, but that's because the load is so small. (Remember, we were trying to mimic the mismatch between a microphone and a speaker, which is an outrageously bad mismatch.) Contrast the load voltage you measure now to what you measured when this load was connected directly to "V_S & R_S". Try the speaker in place of the 10 Ω resistor. Can you hear something from the speaker now? You see that the current gain of the emitter follower circuit does help, even though it has no voltage gain. It begins to fix the mismatch between the source and the load resistances (or source and the load impedances).



Input resistance: From the standpoint of the signal source ("V_S & R_S") the rest of this circuit can be modeled as a single resistor hooked to ground (R_{in}). Remember the general models of amplifiers from chapter 1 of your textbook. Devise a way to measure R_{in}. (No, you can't just use an ohmmeter to find this.) You may have to add another part to your circuit. Remember that you cannot move the ground of your scope to some point other than the ground from the signal generator. (They are both connected to bench-ground and if you hook then to different points in the circuit, those two points will be shorted together.) Make whatever measurements you need in order to find the signal input resistance of this amplifier. Consider this a little design problem. If you can't figure out a way to find R_{in}, then look in the appendix for the answer. However, if you do have to look in the appendix then you ought to ask yourself why you can't engineer a solution to this simple problem after nearly two years in electrical engineering.

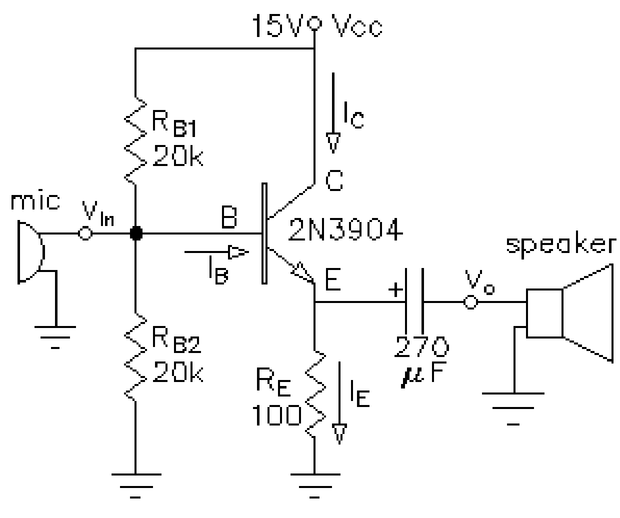
Remove R_L from the common-collector circuit and find the circuit's input resistance (R_{in}) again.

Assume a reasonable β and calculate the theoretical input resistance of the common-collector circuit in each case (with and without R_L). Compare these to what you found from measurements, above. (If we're not yet that far in class you may leave these calculations and comparisons until later.)

Output resistance: Devise a method to find the signal output resistance of this amplifier. Make whatever measurements and changes as necessary so you can calculate R_o from your measurements. Again, if you can't figure this out, look in the appendix, but do ask yourself why you can't figure this out.

Assuming a reasonable β, calculate the expected output resistance and compare.

Back to the microphone and speaker:
Change your circuit to the one shown at right. Notice that input coupling capacitor is gone. That's because I'm doing something a little tricky-slimy in this circuit. I'm borrowing the DC voltage necessary to operate the microphone from the DC bias circuit for the transistor.

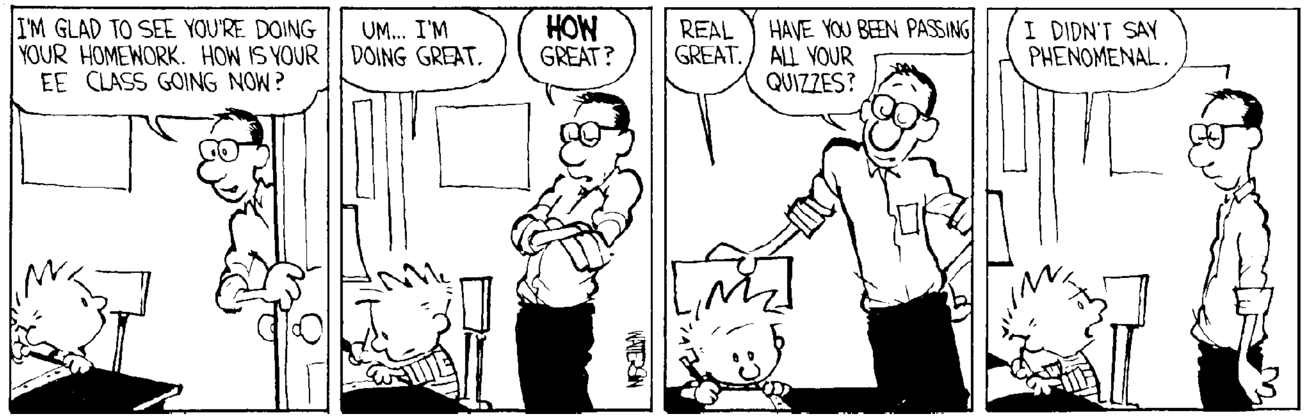


Can you measure an audio signal at v_o now? Can you hear anything at the speaker if you hold the speaker right to your ear and blow on the microphone? Admittedly this isn't a P.A. system yet, but is a phenomenal improvement for just one lousy little transistor.

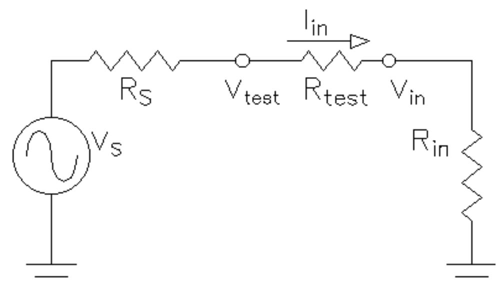
Main points of the common-collector: (hints for a conclusion)
1) Emitter voltage tracks or follows the base voltage, just 0.7 V DC less. Signal voltage gain ≈ 1 not counting losses due to input and output resistances.
2) Emitter follower R_{in} >> R_o (which also means that it has current gain).

3) R_{in} is [(R_E || R_L)•β] || R_{B1} || R_{B2} which is usually much greater than R_o and hopefully R_L too.
4) R_o is R_E||[(R_S || R_{B1} || R_{B2})/β] which is usually much less than R_{in} and hopefully less than R_S.

Next lab: Leave this circuit intact for the next lab. Next time you'll look at the CE amplifier.

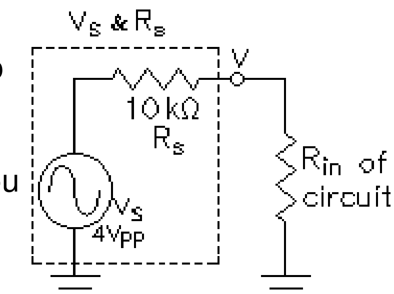


Appendix



To Measure Input resistance: Add a resistor (R_{test}) between the source and the circuit input. Measure to ac signal voltage on both sides of R_{test} using the scope (peak-to-peak is alright).

$$I_{in} = \frac{v_{test} - v_{in}}{R_{test}} \qquad R_{in} = \frac{v_{in}}{I_{in}}$$



Alternatively, if you know the value of R_s, then you don't have to add an R_{test}. Measure the voltage V with the circuit connected and then again without the circuit connected (with and then without R_{in}). From those measurements and the value of R_S, you can calculate I_{in} & then R_{in}. Be sure to measure AC signal voltages (peak-to-peak is alright).

To Measure Output resistance: Measure the signal voltage output without R_L. This is the *open-circuit* output (v_{nL}). Remember that the open circuit voltage relates directly to the Thévenin voltage of a Thévenin equivalent circuit. Reconnect R_L and measure the loaded output (v_L). Use these two measurements to calculate the output resistance (R_o) of this amplifier. Be sure to measure AC signal voltages (peak-to-peak is alright).

$$R_O = \frac{v_{nL} - v_L}{v_L} R_L$$