LABORATORY 4

PHYSICS 117 (Winter 2017)
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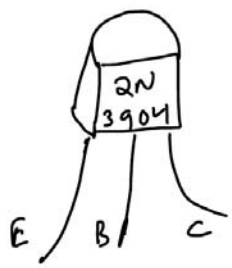
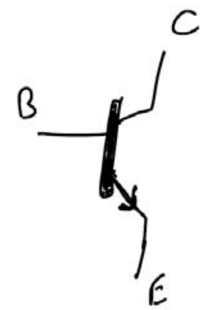
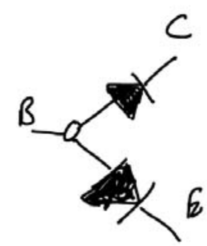
Reading: Sherz & Monk: sections 4.3, 2.32

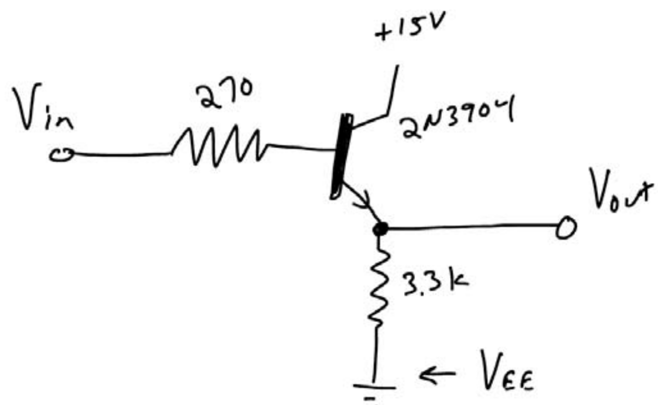
a) Transistor Junctions:
Use the DMM on the "diode test" function to measure the voltage drop across a diode for the test current (a few milliamps). A transistor is much more than two diodes stuck together, but that model is at least a useful way of checking if a transistor has been damaged. Using an NPN resistor (eg, 2N3904), measure the voltages across the BC and BE junctions using the DMM's diode test function.







b) Emitter-follower:
Wire up an NPN transistor as an emitter-follower as below:



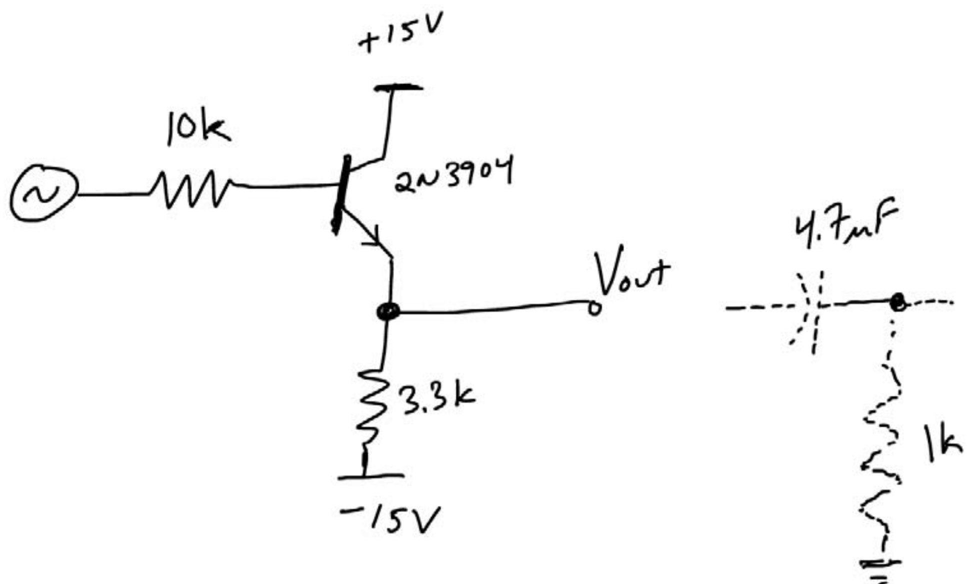
(If you find the output is noisy (due to high frequency oscillations) try a larger input resistor, e.g. 3kΩ.)

Drive the input with a sine wave with no DC offset and amplitude of a few volts. Look at the input and output simultaneously. Notice the poor replica that comes out. Turn up the waveform amplitude and you will see bumps that appear below ground. What is going on? (Hint check the data sheet for "breakdown" of the 2N3904).

Now change the voltage at V_{EE} to be -15V instead of ground. (Your power-supply knob does not go below zero. How will you make a negative voltage?) Do you see an improvement?

c) Measure V_{CE} with a DMM and explain why it is not just two diode drops (ie, not ~1.2V)

d) Drive the emitter-follower circuit below (part in solid lines) with a signal amplitude of a few volts.

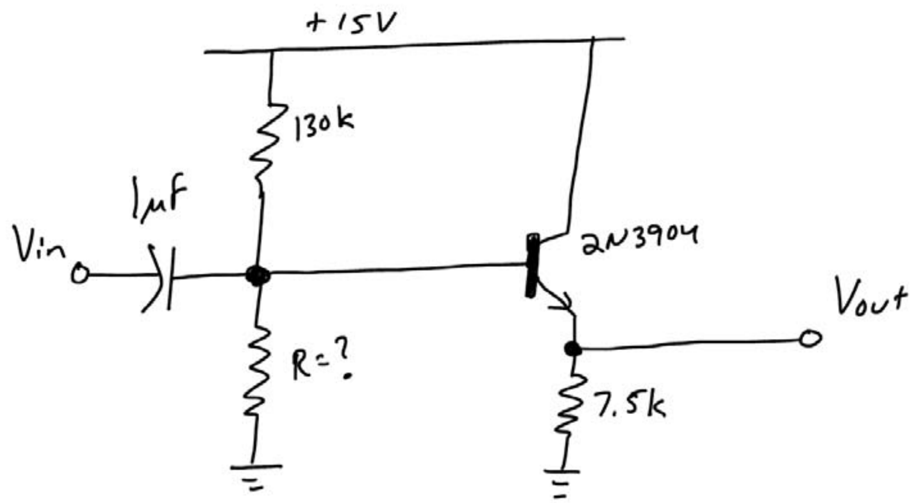


Measure Z_{in} and Z_{out} . Hint #1: to find Z_{out}, you can't just short the output to ground, but you can use a well-chosen resistor value to determine it. Hint #2: You will probably want to use a blocking capacitor on the output to remove the DC offset which can be confusing. The dashed lines show parts you will be adding to the circuit to make measurements.

Using Z_{in} and Z_{out} , calculate your transistor's β.
Measure V_{CE} again and notice it is large.

Hint: You can't measure I_{SS} or even go much lower than about 500Ω for the output load before drawing too much current from the circuit and causing it to go nuts. So you have to do it with a larger resistor, make a careful measurement, and calculate Z_{out}.

e) Single-supply emitter-follower:
The emitter follower can be made using one voltage supply, as long as you build in the voltage offset on the input, as shown below:



This input DC offset is called the "bias". The output voltage corresponding to this bias is the "quiescent point". Assuming V_{BE} is 0.6V, what value of *R* should you use so the output voltage has a quiescent point at 7.5V, thus giving you the most range before the signal hits the maximum allowed upper or lower voltage (beyond which, it suffers what is called "clipping")? Build the circuit above with your calculated *R*. (Note that it may not clip symmetrically, and rather the transistor pushes the average voltage lower.)

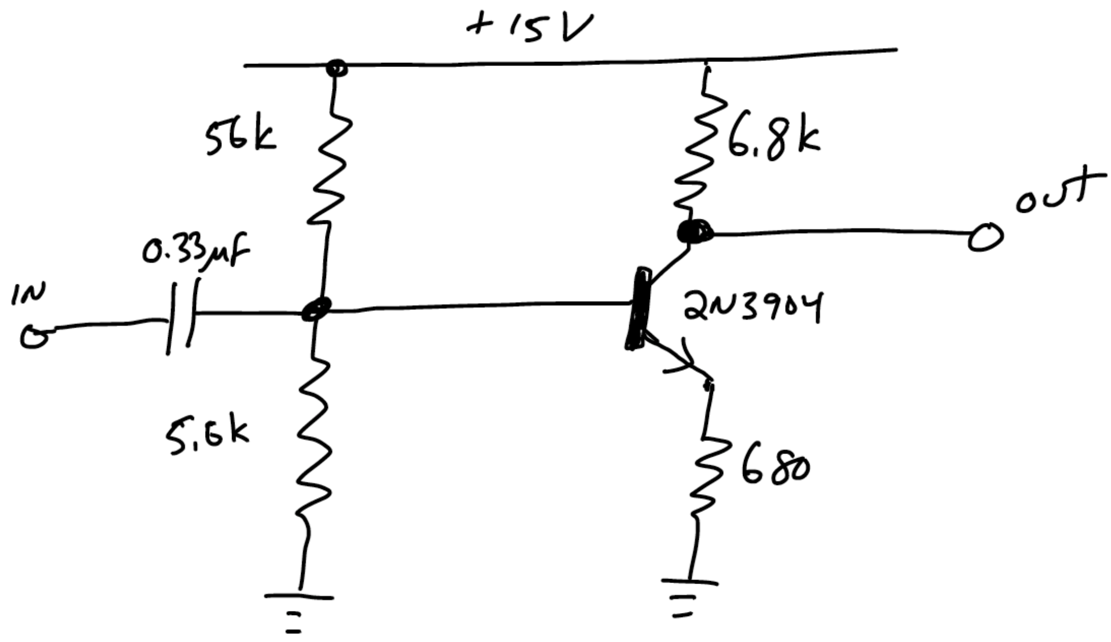
f) Drive the circuit at an easy-to-hear frequency and put its output into a 100Ω speaker. What happens to the tone once you start clipping? Why might this be bad for the speaker?

Measure V_{CE} again and observe that it is large.

g) Measuring β:
Build a circuit to measure the current gain (the ratio of I_C to I_B) of the 2N3904 while watching V_{CE}. You can use various currents from microamps to milliamps. Beyond a few milliamps, you should see the gain start to "saturate" and V_{CE} decrease. You might want to use the "1% tolerance" resistors we have in the lab to get nice event steps.

How could this circuit be used to provide a constant current source to a load? (Draw it.)

h) Common-Emitter Amplifier   Build this amplifier circuit:



Drive it with 5kHz sine wave.

What should its voltage gain be? Is it?

What is the purpose of the capacitor?

Explain why you needed to connect V_{OUT} to the collector instead of the emitter in to get voltage gain.

What happens to the phase of the output relative to the input?

What is the quiescent point of the output?

What should the output impedance be? Check it with a similar sized resistor.

i) Set the function generator to about 5 kHz.   First, hook up one of the 100Ω speaker to the input of your circuit (the other side of the speaker should be connected to ground) to verify the speaker is working. Then, hook up the speaker to the output of the amplifier. Even though the voltage is amplified, you can barely hear it. Why?

Now, put an emitter follower between the output of the amplifier and the input of the speaker. You should hear the tone is louder even though that second stage has no voltage gain. Why did this work?