Transistors II

Physics 251

Fall 2022

This is a transistor amplifier lab. You will be building and evaluating at least one common emitter transistor amplifier. There are several characteristics of amplifiers which you will try to measure for your circuit. These are

- All DC voltages (the values with no signal applied to the amplifier) The nominal small signal gain
- The gain as a function of frequency
- The output impedance
- The input impedance

You may wish to measure other things as well, such as the total power the power supply must deliver to the amplifier, or the way the circuit amplifies triangle or square wave signals.

Part 1: Measuring the output impedance of the function generator.

This step will serve as practice for a procedure you will need to do later. The objective is to measure the Thevenin equivalent resistance (which is frequently referred to as "output impedance") of the function generator. To make the measurement, set the function generator to a convenient frequency (like 5 or 10 kHz) and its output to a convenient smallish value (like 1 or 2 volts peak to peak) when no load is connected to it. Next arrange things so you can connect various resistors across the generator output while observing the voltage on the scope. When you place a load resistance across the generator output, the observed voltage will decrease. Keep trying different resistors until the voltage drops to one-half its no-load value. When this happens, the resistor you have connected is equal to the output impedance of the generator. (You can verify this by using Thevenin's theorem and what you know about voltage dividers.) Most commercial equipment has either a 50 or a 600 ohm output impedance, so start by trying a resistor with one of these values.

Part 2: Common emitter amplifier.

Make the amplifier shown in Figure 1 using a 2N3904, a 2N4401, a 2N2222 or similar small signal npn transistor. Connect the 15 volt supply from your protoboard at V_{cc} as shown. If nothing seems to be getting hot, use your digital meter to measure the DC voltages at the collector, the base and the emitter. If things are OK, you should have $V_C > V_B > V_E$. The base should be pretty close to 0.6 volts higher than the emitter, and the collector should be several volts

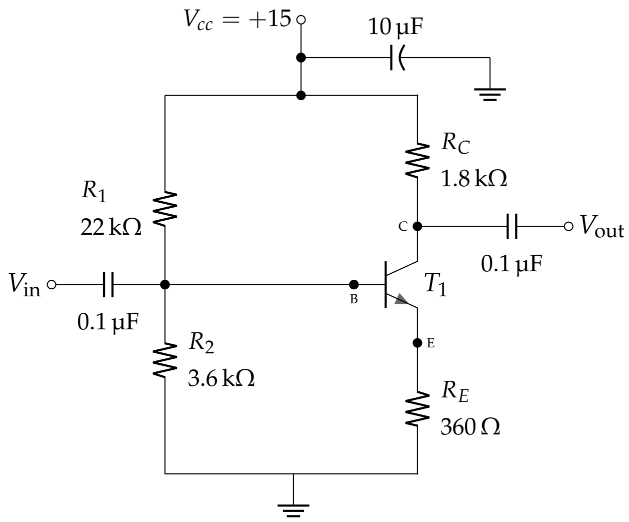

Figure 1: The common emitter amplifier circuit you will build. The transistor T_1 should be either a 2N3904, a 2N4401, or a 2N2222 npn transistor.

higher than the base and several volts below V_{cc}. Record the actual DC voltages.

Next, connect the function generator to the input, and the scope to the output. With the function generator set for a volt or two peak to peak and a frequency of 5 or 10 kHz, you should be able to see the amplifier output on the scope. Verify that the amplifier is working (that the output voltage is larger than the input) and measure the voltage gain. Record the actual gain, and the gain in dB. You may find it useful to display both the input and output voltage on your scope at the same time. To do this connect one to channel 1 and the other to channel 2 (using scope probes). You may need to experiment with triggering to get a good display. If displaying both signals introduces unwanted complexity, first look at the output and adjust function generator amplitude until you get a nice looking medium sized signal at the output — say 5 or 6 volts peak to peak. Then move the scope probe to the input and measure the input voltage.

Next, measure and record the output impedance of your amplifier. Use the same procedure you used for the function generator. After measuring Z_{out}, the input impedance must also be measured. This can be more difficult, but if it is high compared to the output impedance of the function generator, the following procedure can be used. First note the amplifier's output voltage, and make sure you do not change the function generator's output until you are done with this part of the procedure. Next, set things up so you can put various resistors in series between the function generator and the input to the amplifier. Try various resistors until the amplifier's output falls to half its original value. When this happens, you have just inserted a resistor equal to the amplifier's input impedance. (Why does this work?) Be sure to remove this resistor and connect the generator back to the amplifier's input before proceeding to the next step.

Now, it's time to measure the gain as a function of frequency.

Make measurements which will allow you to plot the gain (in dB) as a function of log(f). (As in a previous labs, label the f axis in Hz rather than using the value of the log.) Using the function generator at your lab station, measure from about 100 Hz to it's maximum frequency. Hint: Start by increasing the frequency by factors of 10. If nothing much is happening in a particular frequency range, you do not need a lot of points.

Part 3: Optional further investigation: More gain!

The gain of the above amplifier is just the ratio R_C/R_E which you can easily verify to be about 14 dB for the resistors given. Your measurements should have given about this value as well. To get more gain, the resistance ratio could be changed, but this would have ramifications on the DC voltages and currents which might make the amplifier not work at all.

1. Instead of changing resistors, try putting a "bypass" capacitor in parallel with the $360\,\Omega$ emitter resistor. For high frequency, the capacitor acts like a low resistance thereby increasing the gain. A $1\mu F$ electrolytic (watch polarity!) should have an impressive effect on the gain. Try it - maybe even to the point of getting a dB gain vs log(f) plot.
2. A second optional investigation is to try to redesign the amplifier to get a gain of twice the 14 dB value (that would be 17dB). This will take more work. You could do the calculations before you get to lab, and then just try it at the end of lab. When checking "the gain," signal frequency can be important. You should pick a frequency that makes sense. A 1 kHz or 10Khz signal is probably a good starting point.