

ECE-205 Lab 4

System Linearity

Overview

For many engineering systems, we can model the system as linear only over a specified region of operation. In this lab you will be constructing the simple common emitter BJT amplifier shown in Figure 1 below, and determining the range of input signals for which we can model the circuit as having linear behavior. Note that this is not a well designed amplifier, but is easy for us to build and learn from.

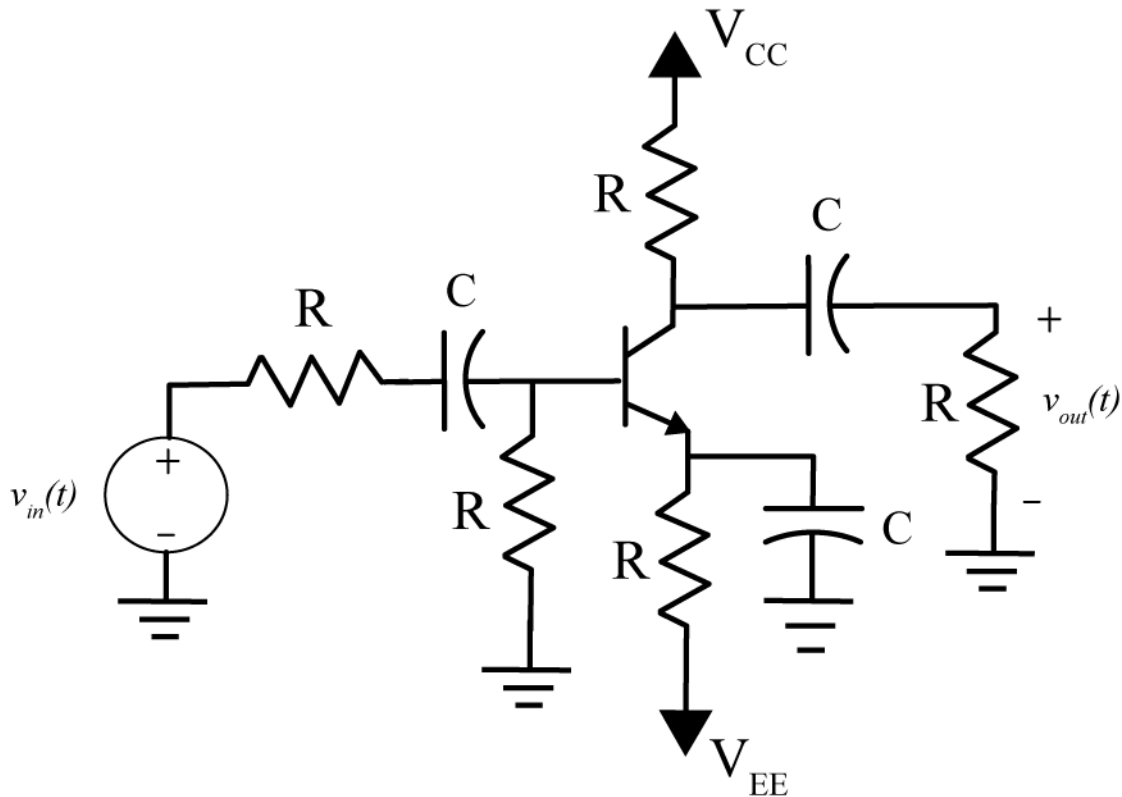


Figure 1: Simple common emitter amplifier.

PART I : Building the Circuit

We will be building the circuit in two stages, do not try to build this all at once. All of the resistors are $1\text{ k}\Omega$ resistors, all capacitors are electrolytic $100\mu\text{f}$ capacitors and the BJT is a 2N-2222A-836. You will need to get the capacitors and the BJT. The electrolytic capacitors *must be connected with the correct polarity*, so be careful and read the instructions.

1) We will first set up our bread board. We need both a positive and a negative supply, as well as ground. It is probably most convenient to set the top red rail on the breadboard to +6.4 volts (red wire on the battery supply), the bottom red rail to -6.4 volts (the green wire on the battery supply), and the top and bottom blue rails to ground (the black wire on the batter supply). It is important that both the top and bottom blue (common) rails are connected together.

2) The npn BJT is represented by the symbol shown in figure 2, and it has three terminals. If you hold the BJT with the flat part to the your right, then the collector is on top, the base is in the middle, and the emitter is on the bottom.

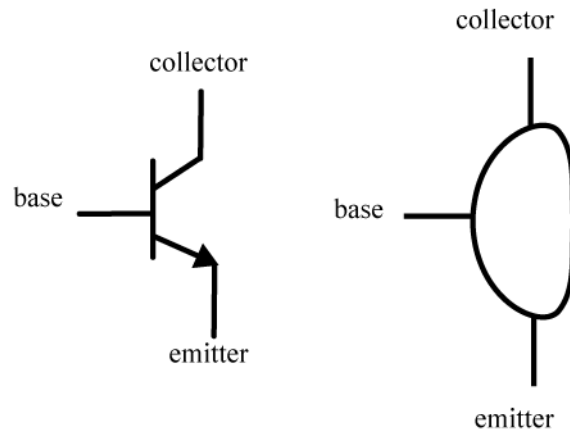


Figure 2. Circuit symbol for an npn BJT (left) and physical device (right).

3) Now we will build the circuit subsystem shown in Figure 3. Note that the collector is connected to the +6.4 volt source V_{CC} , the emitter is connected to the -6 volt source V_{EE} , the base is connected though a resistor to ground, and the collector is also connected through an electrolytic capacitor (note the negative sign!) in series with a resistor to ground.

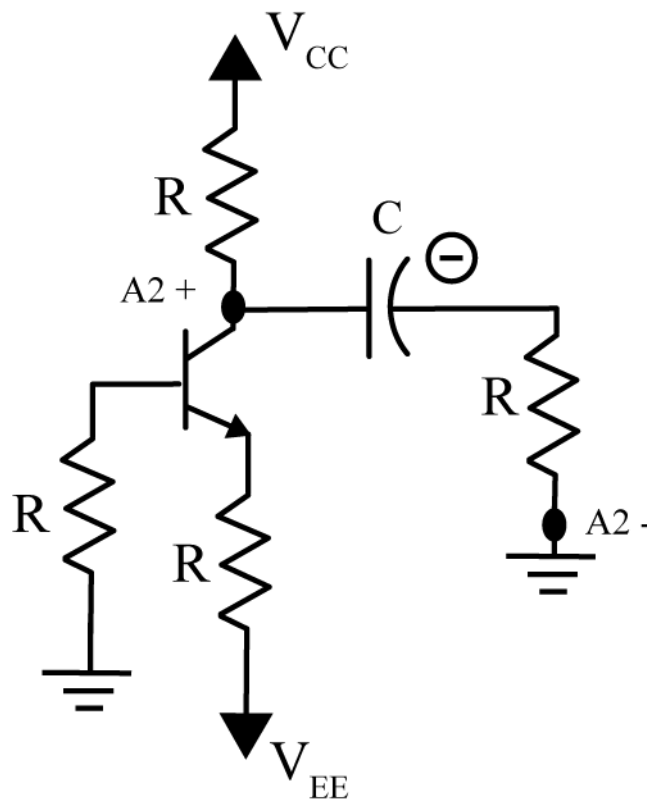
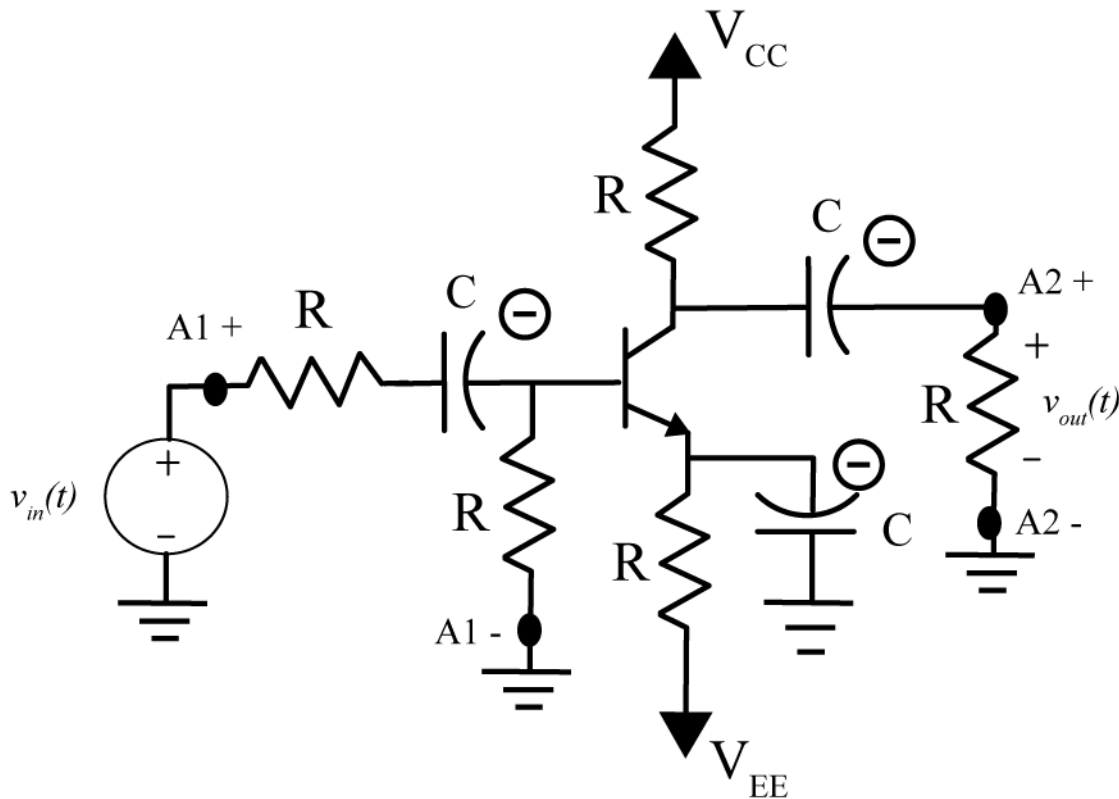


Figure 3: Biasing the transistor circuit.

4) Connect probes A2+ and A2- as shown in Figure 3. Start Mobile Studio, and set the function generator to channel one, a sine wave with a frequency of 100 Hz and 2 volts peak to peak (*note that we are not connecting this to the circuit yet!*). Set channel one of the oscilloscope for 500 mV/div, **AC coupling**, input AGW1, and

channel two for 1 volt/div, **DC coupling**, and input A2 DIFF. The triggering should be off of channel one (it is hard to trigger off of a DC signal), and set the horizontal scale to 2 ms/div. If you have done everything correctly, you should read channel two as somewhere between 1.5 and 1.8 volts DC. Do not go on until you get this correct!

5) Now finish building the circuit as shown in Figure 4. Note that the polarity of all of the capacitors, and that everything we are now connecting is connected to ground (not one of the voltage sources). Also note where we are connecting our probes.



6) Change the input (function generator) signal to 1 volt peak to peak and connect the function generator to the circuit as the input voltage $v_{in}(t)$. Be sure to change channel one so you are reading A1 DIFF rather than believing the function generator and set the coupling to AC (for channel one only) and DC (for channel two only).

7) Use the cursors to measure the *peak positive amplitude* of the input and output signals (**do not** measure peak-to-peak!). The ratio of the output magnitude to the input magnitude is the gain, and it should be between 2 and 4. If it is not, check your circuit and then ask for help. *Be sure to move A2+ so you are measuring the voltage across the load resistor.*

Now we are ready to make our measurements.

PART II : Measuring and Plotting the Input and Output Amplitudes

Our circuit can only be modeled as a linear system for a limited range of input signals. We will measure the input and output amplitudes as the input amplitude changes. We will assume the input signal is a sine wave with a frequency of 100 Hz for all of the following measurements.

1) Starting with an input amplitude of 50 mV, up through an input amplitude of 2.5 volts (by increments of 100 mV) measure the amplitude of the input and output signals. The input voltage should be centered at zero (*have a zero offset*). Be sure to measure only the *peak positive amplitudes* of the output signal, **do not** measure peak-to-peak amplitudes. You will need to enter your measurements into Matlab (see step 3 below) so you may want to do that as you are measuring. *Change the size of the oscilloscope view screen as necessary to get as much of each signal in the window (while still seeing the entire signal).*

2) Start Matlab and open a new m-file

3) Enter the input amplitudes and output amplitudes into two arrays in Matlab, and plot the output versus the input amplitudes. To enter values in an array in Matlab, type something like

```
Vin = [1.0 2.0 3.0 4.0]; % not the array used to make the plot below  
Vout = [5.5 6.6 7.7 8.8]; % this creates a row vector
```

You should put a space between array entries. To plot the arrays type

```
plot(Vin, Vout, 'o');
```

Your graph should look something like that shown in Figure 5 below:

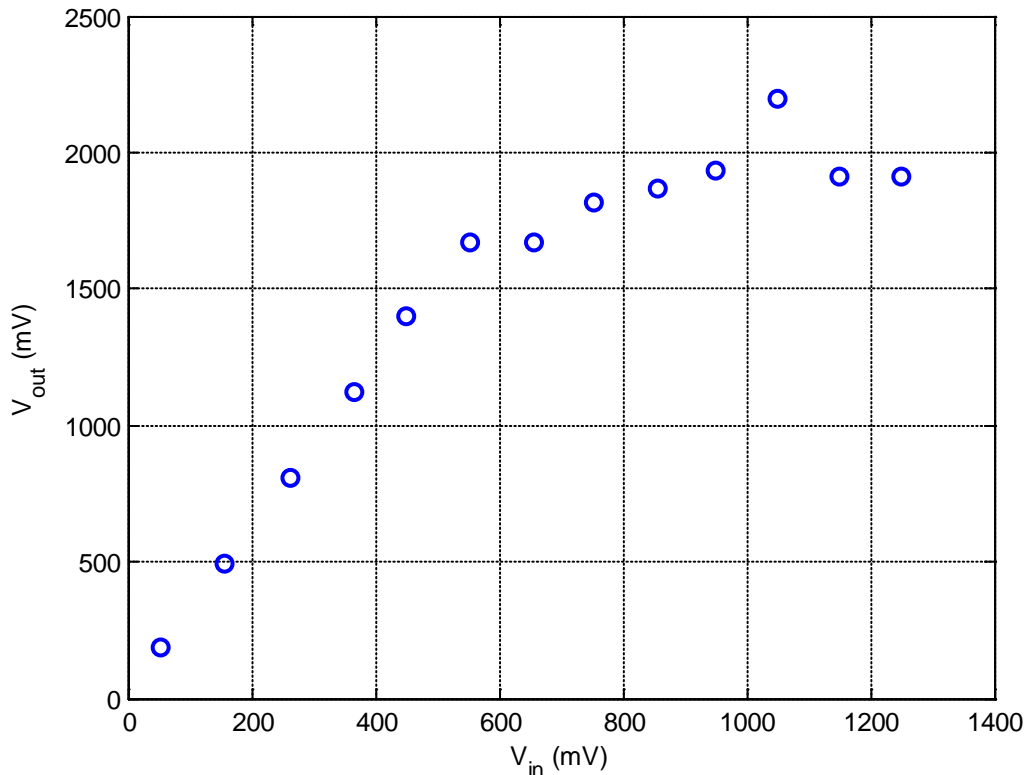


Figure 5. Measured input/output data.

4) We want to fit a least squares straight line between the points that show a linear input/output relationship. We can use the Matlab command **polyfit** to do this. Let's assume we have arrays **Vin** and **Vout** that contain the input and corresponding output measurements. Then if we want a least squares line that fits the first **N data** points we will type the following into Matlab:

```
N = 5; % just a guess, yours may be different
p = polyfit(Vin(1:N),Vout(1:N),1);
m = p(1); b = p(2);
est_output = m*Vin+b;
```

Enter these commands into Matlab and generate a plot like the one shown in figure 6. Vary the parameter **N** to include as many points as you think reasonably fit a straight line. ***Include this plot in your memo.*** Be sure to use the Matlab **Copy Figure** command (click on **Edit**, do not copy the entire window, only the figure). Be sure to include a figure number and caption.

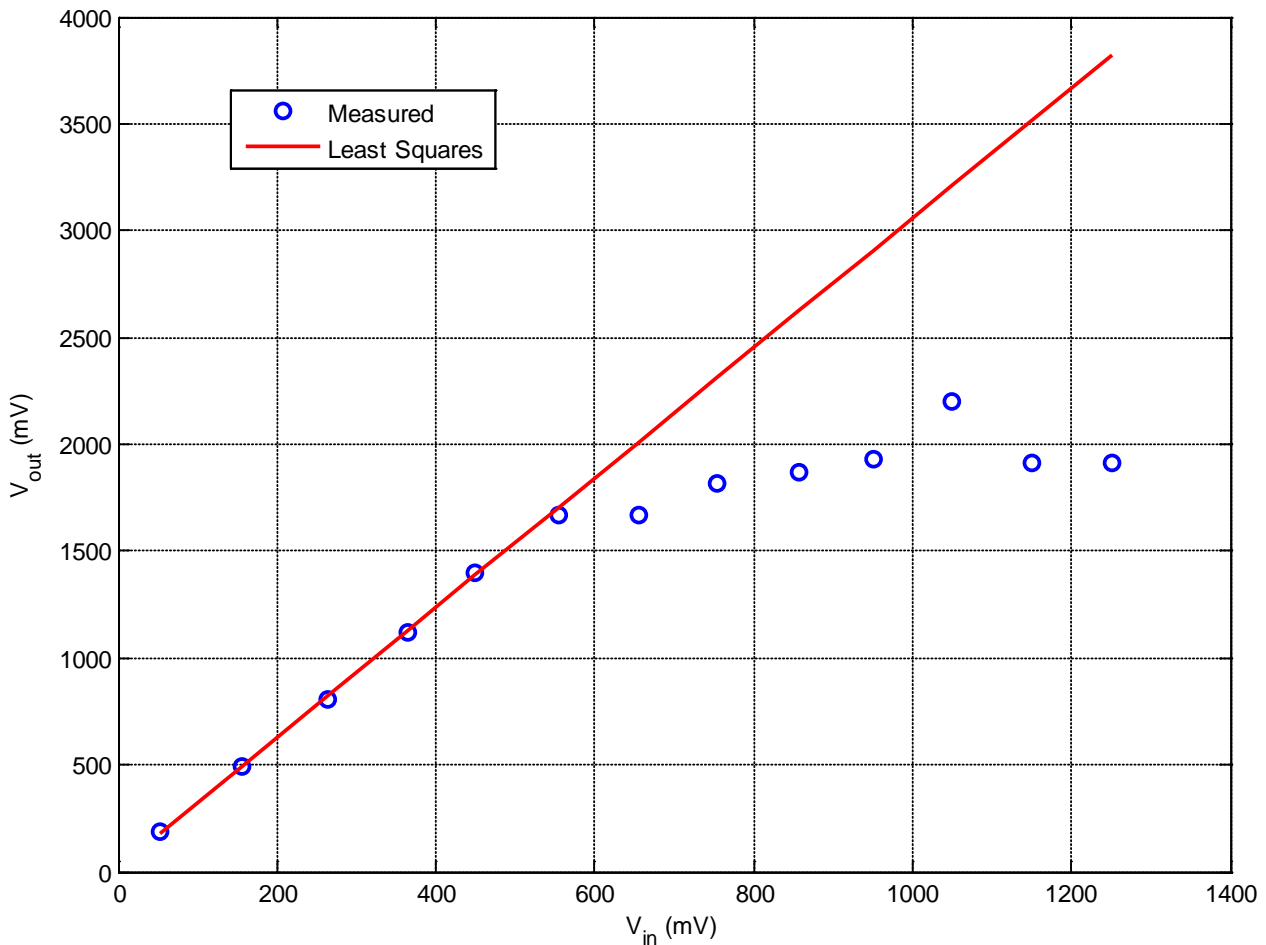


Figure 6: Measured data and least squares fit.

6) Save one screenshot showing a linear behavior of the system, and one screenshot showing nonlinear behavior of the system. ***Include these figures in your memo.*** Use a black background and use the screenshot command, do not copy the entire window. Be sure to include figure numbers and captions.

7) Copy your m-file as an appendix to your memo since this contains your data.

8) e-mail me your memo, and you are done. Be sure to try and make your memo look like a memo. It should be very short, and include and suggestions for improvement.

Your memo should contain 3 graphs: one Matlab graph and two screen captures. You should e-mail your memo to me. Your e-mail should also include your Matlab m-file as an attachment.