PreLab 3 – Common Emitter Amplifier (Week of April 27th)

• GOAL

The overall goal of PreLab3 is to simulate some transistor amplifiers.

• GENERAL GUIDELINES

1) Each student must turn in his/her own PreLab assignment (include both schematics and waveforms).
2) Students are allowed (even encouraged) to work together. However, you must turn in your own work!
3) SAVE ALL SCHEMATIC AND WAVEFORM FILES – you will need them for your lab report.

• PART 1: LED DRIVER

A bipolar junction transistor (BJT) has current gain, making it extremely useful to drive indicators such as LEDs. A popular approach is to use the "common emitter" configuration shown to the right. The NPN transistor has a grounded emitter (hence the name "common emitter"). The voltage input is applied to the base, and the LED is connected to the collector.

TASK 1a: Simulate the transistor circuit in Figure 1.

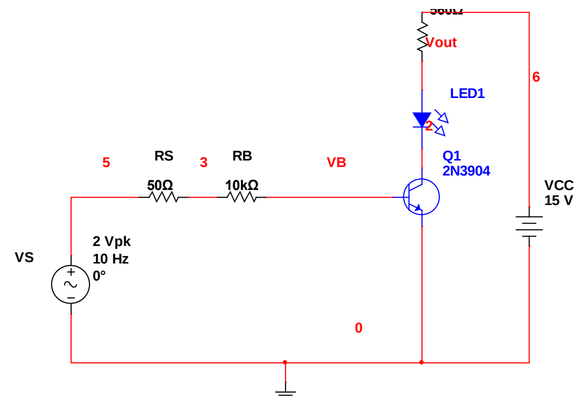

Figure 2: Transistor circuit to drive an LED.

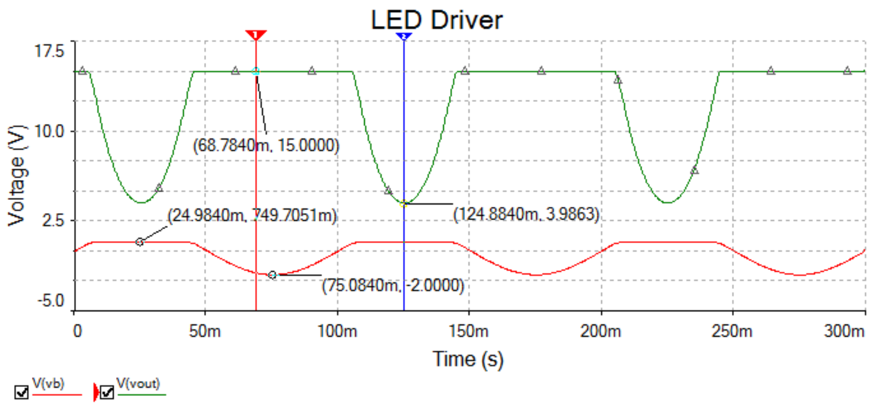

Fig. 1: Your voltage waveforms for Task 1a should look like this.

- Place a 2N3904 BJT transistor and use the RED LED model.
- Right click on the wire that goes between RB and the base of the 2N3904 click on properties and change the preferred name to VB (for base voltage). Do the same thing to change the name of the wire between RC and the LED to Vout. This will label the traces in the output graph as VB and Vout.
- The voltage source is a sine wave ($2V_P$, 10 Hz).
- Run your simulation.
- Measure the max voltage of V_{BASE}, min voltage of V_{OUT}, and add a legend box to the waveform graph.
- Save your circuit schematic and waveform by copying and pasting them to a WORD file.
- Turn in both the schematic and waveform with your lab report.

TASK 1b: Now let's measure the transistor current gain!

- Run another transient analysis but select @qq1[ib] (transistor base current) and @qq1[ic] (collector current).
- The base current is about 158 times smaller than the collector current. In order to display the base current so that it can be measured you will create a right t axis with a different scale from the left (to display the corrector current). Click on the base current trace and then Select Graph | Properties
- Fill out the Graph Properties form for the Right axis as in Figure 4 Below.

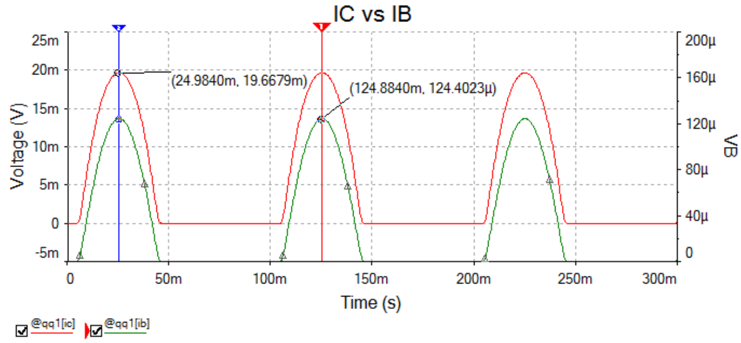

Figure 3: Your current waveforms for Task 1b should look like this.

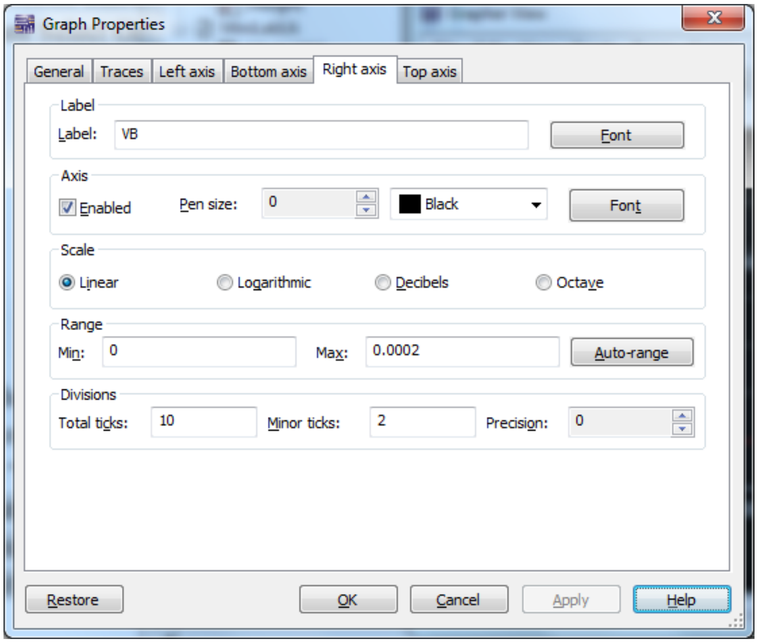

Figure 4

- You should get a graph like the one in Figure 3.
- Measure the peak current in both waveforms and add a title to your graph.
- Compute the current gain based on your measurements.
- Submit the current waveforms and computed current gain.

NOTE #1: You should find that the current gain is around 160. This means your voltage source (e.g. a sensor) only has to output around 120 uA in order to drive the LED with 20 mA!

NOTE #2: The base-emitter of the transistor acts like a diode, which is why the waveforms resemble half-wave rectifiers. Current only flows in one direction for a BJT (e.g. like water flowing out of a faucet)!

(see next page for Part 2)

PART 2: LOW GAIN VOLTAGE AMPLIFIER

As we discussed in lecture, a BJT amplifier needs to be biased for proper operation. A popular method is to use a voltage divider and coupling capacitors for the input and output signals.

TASK 2: Simulate the BJT amplifier shown in Fig. 5.

- Use a 2N3904 transistor.
- The signal source is a 20 mV_{PEAK} sine wave (2 kHz).
- Run a transient analysis with the output set to base voltage only. Then rerun the simulation for the collector voltage only. Copy the base voltage output graph to the same page as the collector voltage so that your graph looks like the one in figure 6.
- Compute the voltage gain A_0 based on the ratio of your peak-to-peak values.

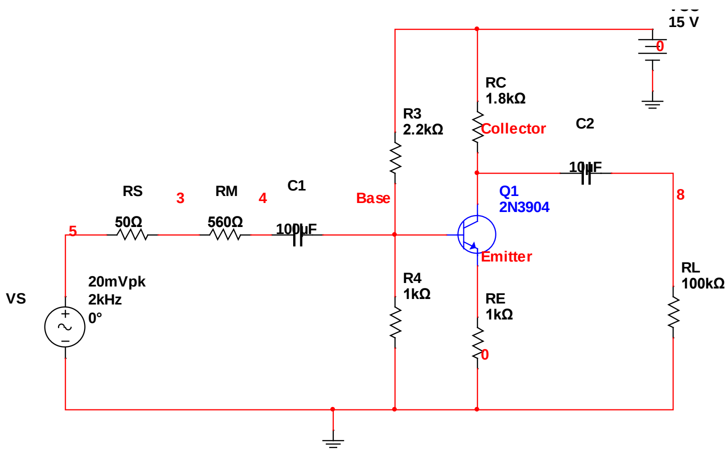

Figure 5: Voltage amplifier using a 2N3904 transistor.

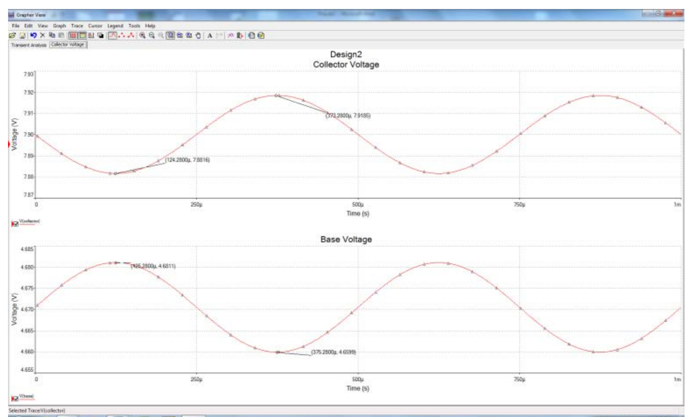

Figure 6: Your voltage waveforms should look like this.

- Run a DC operating point analysis and select I(Q1[IC]) (collector current),V(collector), and V(Base). You should get values like the ones in Figure 7 below.
- Submit the schematic, waveforms, quiescent voltages, and voltage gain.

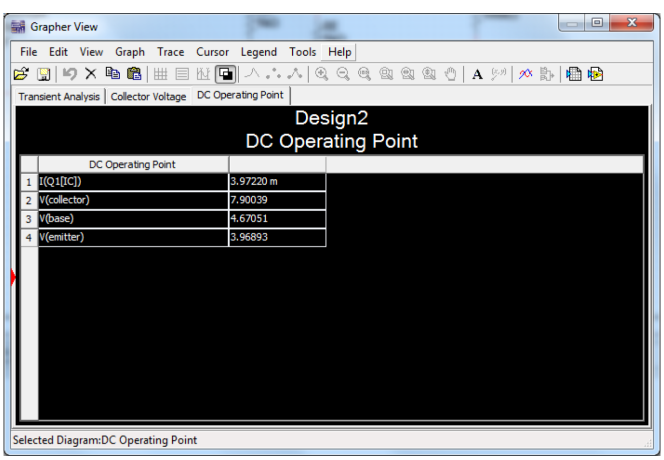

Figure 7

PART 3: HIGH GAIN VOLTAGE AMPLIFIER

We can crank up the amplifier gain by using a neat trick involving a bypass capacitor!

TASK 3: Add a 470 uF capacitor as shown in Fig. 8.

- Run both a transient analysis (on base and collector voltage) and a DC operating point analysis
- Compute the voltage gain A_0 – it should be MUCH higher than in Part 2!
- Submit only: the voltage waveforms, the DC operating point (collector current, base voltage, and emitter voltage), and voltage gain.

  NOTE: As we will discuss in Tuesday's lecture, the amplifier gain depends on the ratio of the AC collector resistance to the AC emitter resistance. The large 470 uF capacitor is basically a short circuit at AC signals. This means the AC emitter resistance is only due to r_e', which is very small – leading to a large voltage gain!

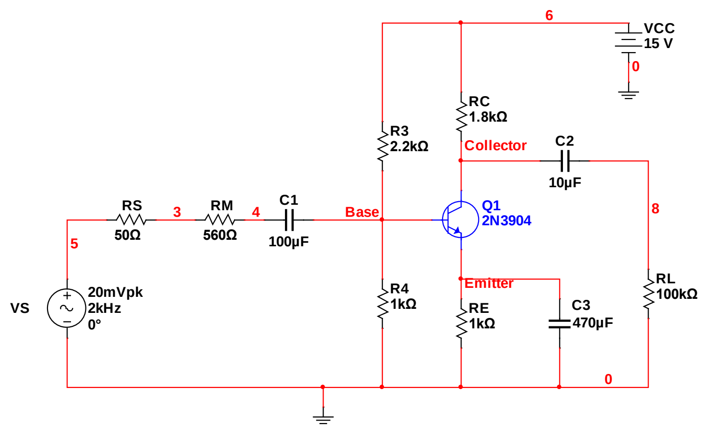

Figure 8: Add a 470 uF bypass capacitor to the emitter of the transistor.

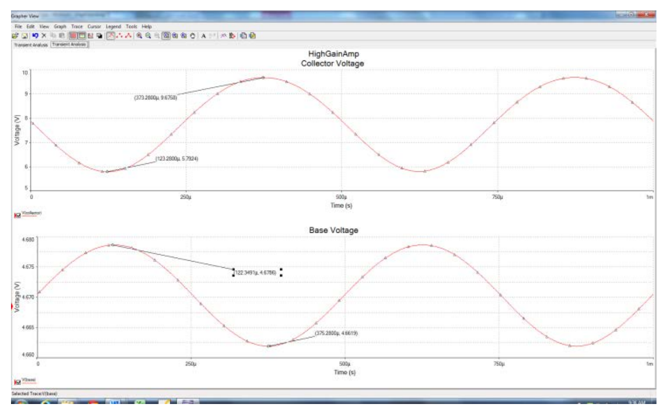

Figure 9: Your voltage waveforms should look like this.

PART 4: LOADED AMPLIFIER

Amplifier gain can be dragged down if the load resistance R_L is much lower than the output impedance of the amplifier (which is R_C). ☹

TASK 4: Replace the 100 kohm load resistor with a 100 ohm resistor.

- Use the same simulation time settings as Part 3.
- Measure the mean and peak-to-peak voltages at the transistor base and collector.
- Compute the voltage gain – it should be much lower than in Part 3!
- Submit only the voltage waveforms and voltage gain.