

Lab 3: Common Emitter Amplifier (week of April 4th)

GOAL

To implement a voltage amplifier using a bipolar junction transistor (BJT).

OBJECTIVES

To build, test, simulate, and understand BJT amplifiers based on the following circuits:

- 1) LED driver
- 2) Biased common emitter amplifier with bypassed emitter resistor.

GENERAL GUIDELINES

- 1) Each student must build, test, and demo all circuits.
- 2) During the lab session, students must share test stations.
- 3) Students are allowed (even encouraged) to help each other. Of course, Professor Hedrick will be around to provide assistance as well. Use neat wiring for your circuits! A messy circuit will cost you 10 points from your lab demo grade.
- 4) Do not worry if you need lots of help during the lab. Just make sure you know your stuff for the exams. **In addition to the written exams, there will be two laboratory exams where each student is tested on basic skills in circuit construction and simulation.**
- 5) Ask questions! The more questions you ask, the more you learn (assuming Professor Hedrick can provide adequate answers ☺).
- 6) Build your circuits with neat wiring! Messy circuits will result in a 10 point deduction from your lab demo grade.
- 7) Please keep your lab kit and work area organized.

PARTS AND MATERIALS

- Lab kit, scope, two scope probes, coaxial cable
- Function generator, coaxial cable with alligator clips, benchtop power supply
- Transistors: 2N3904 (2)
- Resistors:

100 Ω	(brown/black/brown)	(1)
560 Ω	(green/blue/brown)	(2)
1.0 k Ω	(brown/black/red)	(2)
1.8 k Ω	(brown/gray/red)	(1)
2.2 k Ω	(red/red/red)	(1)
10 k Ω	(brown/black/orange)	(1)
100 k Ω	(brown/black/yellow)	(1)
- Capacitors:

10 μ F	(1)
100 μ F	(1)
470 μ F	(1)
- Red LED

PART 1: LED DRIVER

- Step 1a: Build the LED driver shown in Fig. 1.
 - Wire up the benchtop power supply!
 - The (+) output should go to your board's RED terminal.
 - The (-) output should go to your board's GREEN terminal.
 - Use red wires for VCC and black for common. Use the ground and VCC busses on the protoboard.
 - The pin diagram for the 2N3904 is in the data sheet on the course website.
 - The LED cathode is the FLAT side of the LED "rim".
 - The input signal V_IN comes from the function generator.
 - Use the coaxial cable with alligator clips to apply V_IN.
 - Set the function generator to "High Z" output, and configure it to output a $4V_{pp}$ sine wave at 10 Hz.
 - Your circuit works when the LED is blinking.

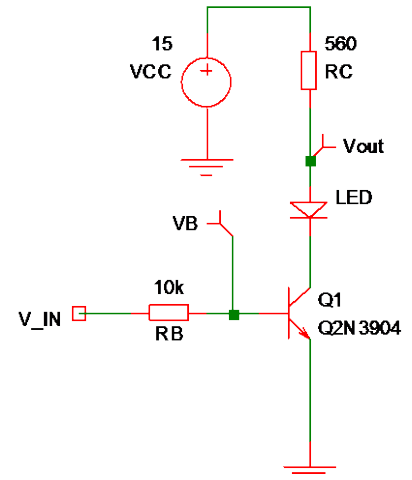


Fig. 1: LED driver using a 2N3904 transistor.

- Step 1b: Configure the scope trigger.
 - Press the "Default" button on the scope. This resets the scope.
 - Change the scope's "Trigger Source" to be "EXT" instead of "CH 1".
 - Use a coaxial cable to connect the function generator's SYNC output to the "EXT" input of the scope.
 - Adjust the trigger level to be +1V.
 - Why do this?
 - In this lab, some of your scope signals will be very weak.
 - It is a bad idea to trigger the scope with a weak signal, because the lack of a reliable rising edge will cause the scope trace to be very unstable. ☹
 - Fortunately, the function generator produces a SYNC output (a TTL signal) with the same frequency as the output sine wave.
 - This SYNC output provides a nice rising edge to trigger the scope in a reliable fashion.
- Step 1c: Measure 6 cycles of "Vout" and "VB".
 - Use CH1 of the scope to measure the voltage just above the LED ("Vout" in Fig. 1).
 - Use CH2 of the scope to measure the base voltage of the transistor ("VB" in Fig. 1).
 - Adjust the CH1 and CH2 probe settings to be 1X
 - Make sure your actual scope probes are also set to 1X!
 - Adjust the scope settings to display 6 cycles of both Vout and VB.
 - Measure and write down the minimum value of Vout and the maximum value of VB .
 - Record snapshots of Vout and VB for your lab report.
 - Based on your measured "min Vout" and "max VB", compute the peak I_C , peak I_B , and current gain β of your transistor. Hopefully it is in reasonable agreement with your PreLab3 result!

DO NOT DISASSEMBLE THIS CIRCUIT!

PART 2: LOW GAIN VOLTAGE AMPLIFIER

The intended application of this circuit is to be a microphone preamplifier. For this lab, the “microphone” is approximated with the function generator (50 ohm output impedance) in series with a 560 ohm resistor. This leads to a source impedance of $R_{SOURCE} = 610$ ohm, which is fairly typical of “low impedance” microphones.

- Step 2a: Build the biased common emitter amplifier shown in Fig. 2.

- Build this circuit on a different part of your breadboard.
- Pay attention to the location of the “minus” side of the electrolytic capacitors.
- V_{SIG} comes from the function generator.
- Adjust the function generator to output a 40 mV_{pp} sine wave at 2 kHz.

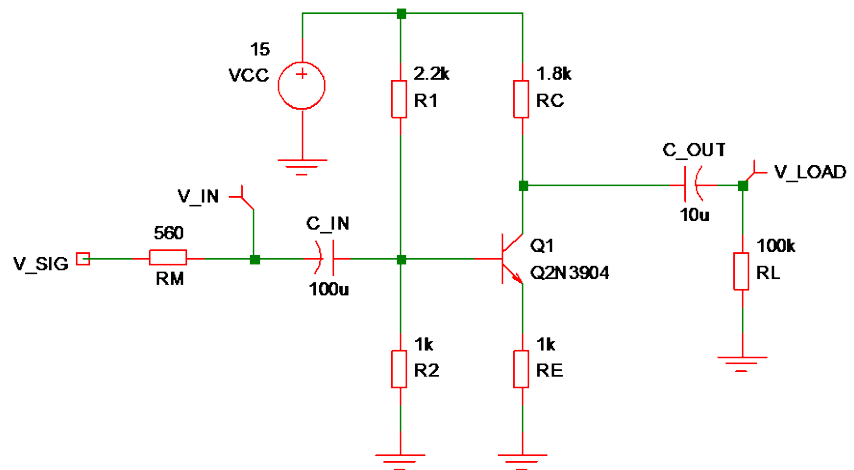


Fig. 2: Common emitter amplifier with the 2N3904 transistor.

- Step 2b: Measure quiescent voltages.

- Turn off the output of the function generator.
- Use the digital multimeter to measure the DC voltage at the base, emitter, and collector of the transistor.
- Record these values of V_{BB} , V_{EQ} , and V_{CQ} for your lab report. Hopefully your V_{BB} and V_{CQ} are in reasonable agreement with your PreLab3 (Part 2) simulation.

- Step 2c: Measure 4 cycles of V_{IN} and V_{LOAD} .

- Turn on the function generator.
- Adjust the CH1 and CH2 input coupling to AC.
- Measure V_{LOAD} with CH1 and V_{IN} with CH2 (see Fig. 2).
- Adjust the scope settings to show 4 cycles of V_{LOAD} and V_{IN} .
- Use the cursors to measure the peak-to-peak values of V_{LOAD} and V_{IN} .

NOTE: The tiny sine waves will be pretty noisy, so the “Measure” function on the scope will produce erroneous results. Adjust each cursor line to be near the middle of the “fuzziness” in each signal.

- Compute the voltage gain of your amplifier. Hopefully it is similar to your PreLab3 (Part 2) simulation.
- You do NOT need to record any scope traces.

- Step 2d: Compute some amplifier parameters based on your measurements.

- Based on your experimental V_{EQ} , compute the bias current I_{EQ} and the AC emitter resistance r_e' .

- Assuming $\alpha = 0.99$, compute the theoretical voltage gain based on the formula $A = -\alpha (R_C // R_L) / (r_e' + R_E)$.

PART 3: HIGH GAIN VOLTAGE AMPLIFIER

We can crank up the amplifier gain by using a neat trick involving a bypass capacitor! This capacitor shorts out R_E for AC signals, leading to a much higher gain.

- Step 3a: Add a 470 uF capacitor to the emitter of the transistor (see Fig. 3).
- Step 3b: Measure 4 cycles of V_{LOAD} and V_{IN} .
 - Adjust the CH1 setting to view the very large V_{LOAD} signal.
 - Use the cursors to measure the peak-to-peak values of V_{LOAD} and V_{IN} .
 - Record snapshots of the V_{LOAD} and V_{IN} scope traces for your lab report.
 - Compute the voltage gain of your amplifier. Hopefully it is similar to your PreLab3 (Part 3) simulation.
- Step 3c: Compute some amplifier parameters.
 - Assuming $\alpha = 0.99$ and using your value of r_e' from Step 2d, compute the theoretical voltage gain based on the formula $A = -\alpha (R_C // R_L) / r_e'$.
 - Based on your experimental peak-to-peak value of V_{IN} , what is the input impedance of your amplifier?

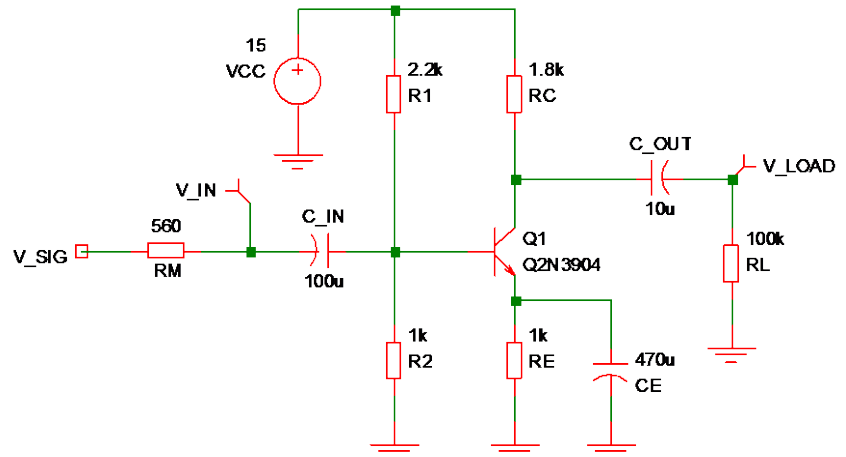


Fig. 3: Common emitter amplifier with 470 uF emitter bypass capacitor.

Hint: $V_{IN} = V_{SOURCE} * R_{IN} / (R_{IN} + R_{SOURCE})$, where $V_{SOURCE} = 40 \text{ mV}_{PP}$ and $R_{SOURCE} = 610 \text{ ohm}$.

(see next page for Part 4)

PART 4: LOADED VOLTAGE AMPLIFIER

The common emitter amplifier gain can be dragged down if the load resistance R_L is much lower than R_C . ☹

- Step 4a: Replace the 100 kohm resistor with a 100 ohm resistor (see Fig. 4).
- Step 4b: Measure 4 cycles of V_LOAD and V_IN.
 - Adjust the scope settings (vertical and horizontal) to show 4 cycles of V_LOAD and V_IN.
 - Use the cursors to measure the peak-to-peak values of V_LOAD and V_IN.
 - Record a snapshot of only V_LOAD for your lab report.
 - Compute the voltage gain of your amplifier. Hopefully it is similar to your PreLab3 (Part 4) simulation.
- Step 4c: Compute the theoretical voltage gain.
 - Assuming $\alpha = 0.99$ and using your value of r_e' from Step 2d, compute the theoretical voltage gain based on the formula $A = -\alpha (R_C // R_L) / r_e'$.

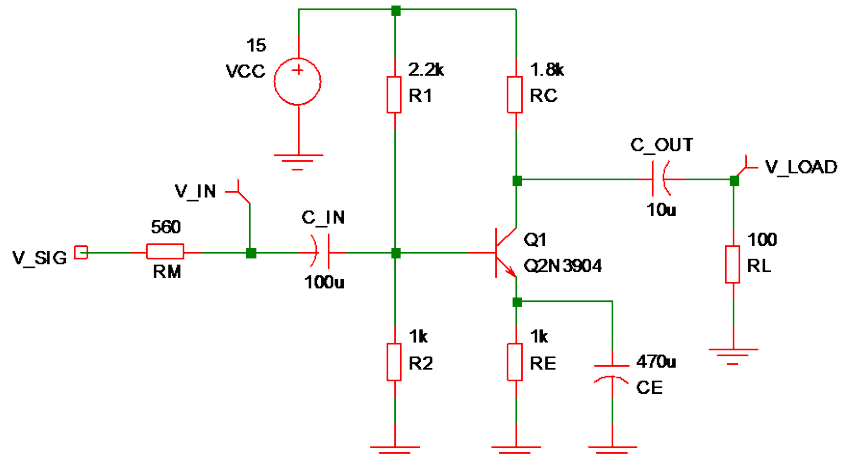


Fig. 4: Common emitter amplifier with 100 ohm load.

(see next page for Part 5)

PART 5: CIRCUIT DEMO

Professor Hedrick will reset the scope and function generator.

- LED driver (10 pts of lab demo grade)
 - Function generator settings:
 - High Z output and 4 V_{PP} sine wave at 10 Hz
 - CH1 measures V_{out}
 - CH2 measures V_B
 - Scope settings:
 - Trigger source = EXT
 - CH1 probe = 1X
 - CH2 probe = 1X
 - Adjust the scope to show 5 cycles of V_{out} and V_B at the same time.

- Voltage amplifier with 100 kohm load and 470 uF emitter bypass capacitor (20 pts of lab demo grade)
 - Function generator settings:
 - High Z output and 40 mV_{PP} sine wave at 2 kHz
 - CH1 measures V_{LOAD}
 - CH2 measures V_{IN}
 - Scope settings:
 - Adjust the scope to show 4 cycles of V_{LOAD} and V_{IN} at the same time.
 - Use the cursors to measure the peak-to-peak voltage of V_{LOAD}.

NOTE: When you demo your circuits, Professor Hedrick will ask you to operate the scope WITHOUT USING THE AUTOSCALE BUTTON. Professor Hedrick will deduct 600 pts from your lab grade if you press Autoscale!

(End of Lab 3)