Lab 5

Junction Transistor, Part II

REFERENCE: Horowitz and Hill Sections 2.07, 2.12 (common-emitter amp)
Section 2.18 (differential amp)

INTRODUCTION

We continue the bi-polar transistor experiments begun in the preceding experiment.

In the common emitter and differential amplifier experiments, you will learn techniques and terminology that are valuable not only in building circuits, but also in the use of commercially-made amplifiers.

EQUIPMENT

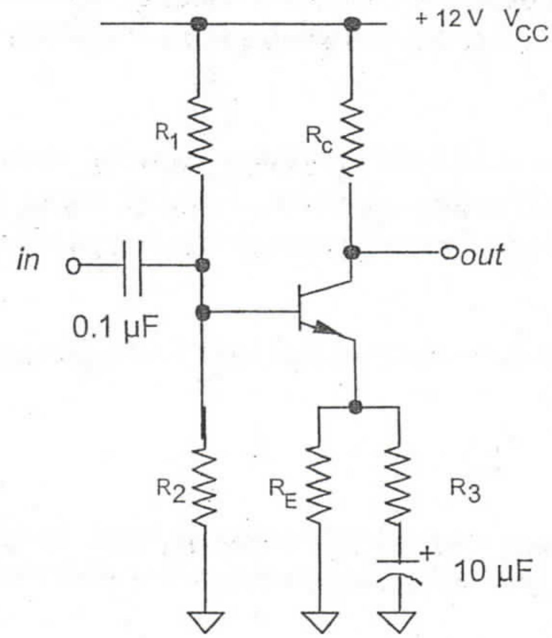
Prototyping board		
Oscilloscope		
Function generator		
Digital multimeter		
NPN Silicon Transistor (3)	2N3904	
Resistors	220, 1 k, 6.8 k, 12k, 82 k	[for CE amp]
	100 (2), 680, 1k, 2.7 k	[for diff. amp]
	5.6 k, 7.5 k, 10 k (3)	[for diff. amp]
Decade Box		
Capacitors	1 μF (2)	[for diff. amp]
	0.1 μF, 10 μF electrolytic	[for CE amp]
Potentiometer	1k trimpot*	[for CE amp]

* alternatively, you may use a pot with wires soldered on

PROCEDURE

1. Common Emitter Amplifier

The common-emitter amplifier shown below is based on Figure 2.37 in the **text**, with changes to accommodate V_{CC} = 12 V instead of 15 V in the power supply. The purpose of resistor R_3 is to reduce the gain to avoid excessive high frequency noise.



common-emitter amplifier

Use the following resistor values:

$R1$	= 82 k	RC	=	6.8 k
$R2$	= 12 k	RE	=	1 k
$R3$	= 220 Ω			

(a) Calculations

☛ ✍ Measure your component values. If your multimeter has a beta-measurement feature, use it to measure h_{fe}.

☛ ✍ Compute the following quantities:

(i) dc base bias and the emitter potential, assuming an 0.6V B–E drop.

(ii) dc collector current and the dc bias on the output. Note that the output dc bias is about ½ V_{CC}. Why is this bias value desirable for this circuit?

(iii) the impedance Z_{eb} of the emitter bypass, i.e., the parallel sub-circuit consisting of the emitter resistor & capacitor, for the following frequencies: 0, 100 Hz, 5 kHz, ∞ .

" Recall that $Z_s = R_e + Z_C$ for a resistor and capacitor in series, where $Z_C = j / \omega C$ is the impedance of a capacitor at frequency $\omega = 2\pi f$, and $1 / Z_{eb} = 1 / R_e + 1 / Z_s$ for Z_s in parallel with R_e. Also recall $|Z_{eb}| = [Z_{eb}{}^2]^{1/2}$.

(iv) the input impedance at 5 kHz (if you didn't measure h_{fe}, assume it is 100). Note that resistors R_1 and R_2 appear to be in parallel with h_{fe} times the emitter bypass. Use the 5 kHz result (see above) for the emitter bypass impedance.

(v) the theoretical gain $A_V = - R_C / (r_e + Z_{eb})$ at $f = 5$ kHz, assuming $r_e = 25 / I_C$ (mA).

(b) Operating point

☞ Connect the circuit shown above using a prototyping board. In wiring it up, it may be easiest if you use three of the long thin rails on the prototyping board for +12 V, GND, and-12 V.

☞ ✍ Measure and compare to the calculations above:
(i) the dc base bias and the emitter potential.
(ii) the collector current (use Ohm's Law and a measurement of the potential across the collector resistor to determine this).

(c) Voltage gain

(i) with emitter bypass capacitor

☞ Set up the function generator to produce a 5 kHz sine wave with a low output amplitude. (Use the LOW or -20 dB output if there is one on your function generator.) Set up the oscilloscope to make a dual-trace measurement of the input and output of the amplifier.

☞ Connect the SYNC output of the function generator to the EXT TRIGGER input on the scope, and use external triggering. Make sure that the grounds of the oscilloscope, the prototyping board, and the function generator are all somehow connected.

Sync output of function generator

☛ Adjust the function generator amplitude to produce a good sine wave on the output of your amplifier. If the output waveform is saturated or clipped, reduce the input amplitude from your function generator. If it is necessary to reduce the input amplitude further, wire up a 1 k potentiometer as an adjustable voltage divider and connect it between the output of the function generator and the input of the amplifier.

☛ ✍ Measure the input and output amplitudes using the oscilloscope.

☛ ✍ Compute the gain, and compare to the theoretical value, using measured component values, from above. Is this an inverting amplifier?

(ii) without emitter bypass capacitor

☛ ✍ Repeat these steps with the bypass capacitor disconnected.

(d) Input impedance

☛ ✍ Measure the ac input impedance using the procedure from Lab 4. Compare to the theoretical value from above.

(e) Output impedance

☛ ✍ Measure the ac output impedance using the procedure from Lab 4.

2. Differential Amplifier

“ A differential amplifier has two inputs. The term “common mode” refers to a signal that is present on both inputs, while the “difference mode” is a signal that is not the same for both inputs.

Often a common mode is undesirable noise while the differential mode is a desirable signal. One uses a differential amplifier to reduce the common mode, in comparison to the difference mode.

A differential amplifier is rated by its common-mode-rejection ratio, CMRR = differential mode gain / common mode gain.

The common mode gain is $A_C = v_{out} / v_{in}$, where the same v_{in} is applied to both inputs.

The differential mode gain is $A_D = v_{out} / (v_{in1} - v_{in2})$.

(a) Operating point

☞ Using the prototyping board, connect the circuit shown in the schematic. It may be easiest later on if you lay out the circuit so that the left and right sides are symmetric, as they are shown in the schematic.

(i) quiescent current

“ Using Ohm's law, the DC current through the tail resistor should be

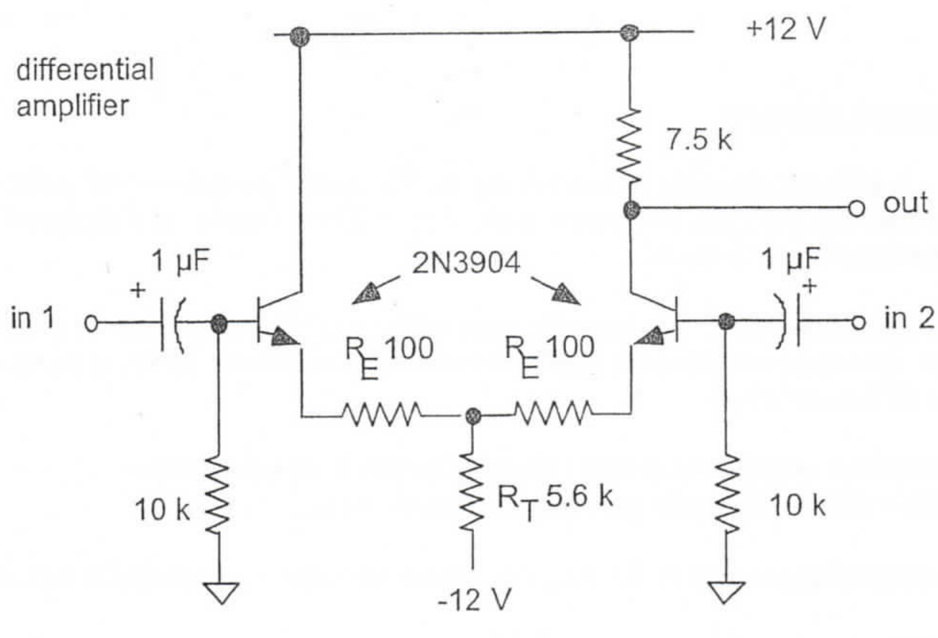
$$I_t = [V_e - (-12\ V)] / (R_T + R_E)$$
$$\approx [V_e - (-12\ V)] / R_T$$

where $V_e \approx -0.7$ V, since the bases are tied to ground by the 10 k resistors.

☞ ✍ Measure the potential across the tail resistor and use Ohm's law to determine the quiescent current through the tail resistor, I_t. Compare to the predicted value (see above).

(ii) DC output voltage

☞ ✍ Measure the DC output voltage. (The differential and common mode outputs will swing around this voltage.)



(Note to instructor:
It is possible to use smaller input capacitors ≈ 0.1 μF, if necessary.)

(b) AC Amplification

☞ Set up the function generator to produce a sine wave at 1 kHz. Make sure that the ground on the prototyping board is connected somehow to ground on the oscilloscope. Use the oscilloscope with dual-trace inputs and BNC-to-banana connectors on the oscilloscope inputs.

(i) measurement

☞✍ Measure the common mode gain A_C and the differential mode gain A_d for several AC input amplitudes. For the common mode gain, apply the same signal to the two inputs. For the differential mode gain, connect one input to ground and apply the signal to the other input.

(ii) comparisons to theory

✍ Compare your results for A_D and A_C to the theoretical gains:

$$A_D = \frac{R_c}{2\,(r_e + R_e)}$$

7.5 k

just one

100 ...... $r_e = \frac{25}{I_e} =$ just one

$$A_C = \frac{R_c}{r_e + R_e + 2R_t}$$

$$r_e = 25\,/\,I_e\ (\text{mA})$$

(iii) AC common-mode rejection ratio (CMRR)

✍ Compute the actual and theoretical CMRR of this amplifier. (Write your value where you can find it again in Lab 7, when you will compare it to an op-amp differential amplifier.)

(c) Improving the common-mode-rejection

[Optional, depending on time remaining. TA should announce whether to perform this part.]

☞ ✍ Replace the 5.6 k "tail" resistor with a 2 mA current source as shown below. This change should make the common-mode amplification negligible; what do you find for the common mode gain and the CMRR?

2 mA

current source