EEAP 243　　Lab Work:
Lab 10　　Questions Due:

EMITTER FOLLOWER AMPLIFIERS

READING ASSIGNMENT: Horowitz, pgs.53-58.

Abstract:

In this experiment you will study the emitter follower amplifier, its input impedance, its output impedance, and its ability to drive a load. You will also learn how to operate the lab's curve tracer which allows you to display a transistor's output characteristics.

NOTE: You will need to use the same transistor for the whole experiment, so be careful with your alligator clips and test leads. Accidental short circuits can easily destroy your transistor.

The input and output impedances of an "active" circuit must be measured under "active" conditions. For example, you do not measure DC parameters with the DC power supplies turned on and the signal generator tuned off, nor do you measure AC parameters with the DC power supplies turned off and the signal generator turned on. In part 2 you will try several flawed methods for measuring input and output impedance. These flawed methods will produce erroneous or inconclusive results. This is done to
(a) demonstrate that the methods are invalid and
(b) to emphasize the right way of doing things. All of your measurements in part 2 will be made with the DMM. Use several DMM ranges when making the flawed measurements.

Part 1 - Transistor Characterization

The transistor curve tracer can be used to quickly and accurately measure your transistor's β_o. This can be done any time during the lab period, so don't waste time by standing in line. The instrument room attendant can help you if you have any problems.

(1) Set the transistor curve tracer to the default positions listed in Figure 1.
(2) Move switch 24 to the left to display the reference transistor's characteristics in order to verify that everything is set properly.
(3) Move switch 24 to the right to display your transistor's characteristics.
(4) The exact center of the display corresponds to $I_c = 10$ mA and $V_{ce} = 10$ V which is approximately the operating point for your circuits.
(5) You can adjust switch 17 to change the base current per step to change the spacing between the displayed curves. Changing switch 12 (I_c per vertical cm) or switch 15 (V_{ce} per horizontal cm) will change the position of the operating point on the display.
(6) Measure the vertical distance between the curves above and below the display's center, and multiply by the β per division (lowest readout) to get β_o in the vicinity of your operating point.

add a Figure to record characteristics make it 10X10

explain in class.

also can calculate based upon $\frac{I_c}{I_B}$

CONTROL	DEFAULT SETTING	DESCRIPTION
2	on	main power
7	5 o'clock	graticule (grid) illumination
8	3 o'clock	readout illumination
10	1 o'clock	display intensity
11	1 o'clock	display focus
19	in (steps)	continuous curves
22	in (rep)	draw curves repetitively
21	in (norm)	normal curve repetition rate
4	norm	normal display mode
14	out	display not inverted
13	*	- set so display starts at point labeled 9
5	NPN	transistor type
23	step generator base term	test configuration
24	center	disconnect both transistors right to test your transistor left to display reference transistor
3	140 (black arrow)	collector resistance
6	15 (white arrow)	maximum collector voltage
1	100	percent of maximum collector voltage
12	2 mA	I_C - collector current per vertical cm.
15	2 ~~collector~~ volts	V_{CE} - col~~l~~lector voltage per horiz. cm.
16	10	number of base current steps
20	out	base current polarity not inverted
18	in (zero)	no base current offset
17	10µA	I_B - base current increment per step

NOTE: Any unlabeled switches are in the OUT position.

Figure 1(a) Default settings for testing an NPN transistor

TEST SET-UP CHART TYPE 576

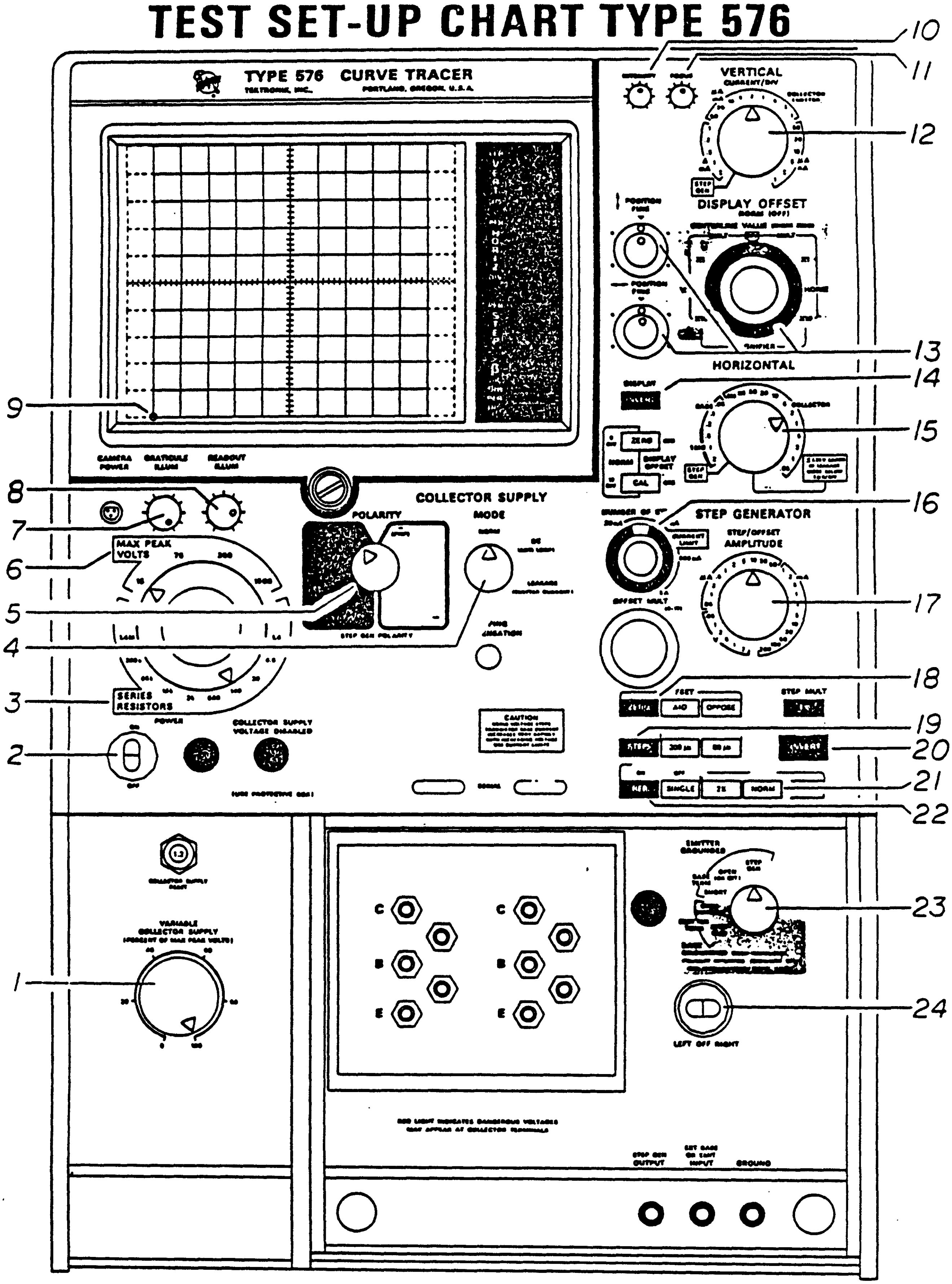

Figure 1(b) - Front Panel of Curve Tracer

Part 2 - Input and Output Impedance

Before you can try to measure input and output impedances, you must first build the circuit and bias it correctly.

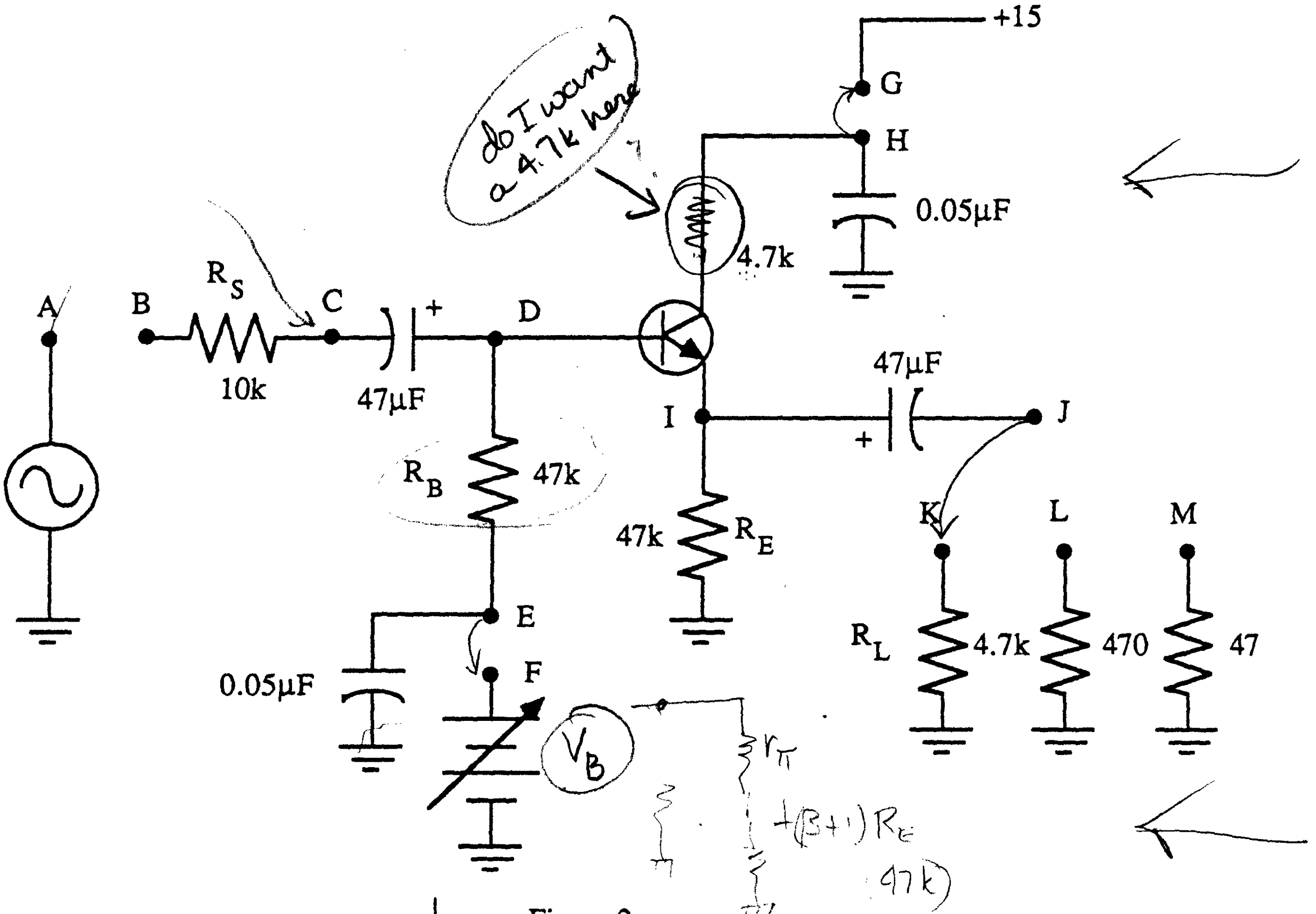

Figure 2

(1) Build the circuit of Fig.2 exactly as it is shown. Connect the scope CH1 input to point A and CH2 input to point F. (You will keep these connections for this ENTIRE part.)
(2) Set the signal at point A to a 2 KHz sine wave at approximately 100 mV RMS with zero DC offset. Set the voltage at point F to approximately 7 V DC.
(3) Connect A to C, E to F, G to H, and J to K. If you observe high frequency oscillation, connect a 100 pF capacitor from D to H. (If you need this capacitor, it must stay in place for the ENTIRE lab.)
(4) Adjust the variable supply so that point I is at approximately 5 V DC.

1 The first flawed method of measuring Z_i and Z_o that you will try is that of simply using the DMM. ~~Your meter~~ measures resistance by using the unknown resistance in a voltage divider with a known resistance and a known DC voltage. This method is clearly useless when trying to measure AC impedances in an active circuit.

(5) Set the DMM to OHMS and (try to) measure the resistance to ground at points C, D, I, and J. Record your results (if any) in Table 10.2.
(6) Disconnect E from F and G from H so that you don't short circuit your power supplies. Connect E and H to ground.
(7) Repeat step 5.

② The second flawed method of measuring Z_i and Z_o that you will try is that of applying a known AC voltage source at the input and the output and measuring the current that flows. This doesn't work for Z_i because the current is too small to be accurately measured. It doesn't work for Z_o because the transistor does not appreciate trying to force current into its output. The resistances of the ammeter and signal generator don't help, either.

(8) Restore the circuit to that of Fig.2. Connect E to F, G to H, and J to K.
(9) Set the DMM to AC AMPS, connect its mA input to A, and connect its COM input to C.
(10) Measure (or try to) the AC current flowing into the amplifier's input. Record any results in Table 10.3.
(11) Restore the circuit to that of Fig.2. Connect E to F and G to H.
(12) Set the DMM to AC AMPS, connect its mA input to A, and connect its COM input to J.
(13) Measure (or try to) the AC current flowing through the amplifier's output. Record any results in Table 10.3.

③ The third flawed method of measuring Z_o that you will try is that of measuring the AC short circuit current at the output. This doesn't work because the transistor becomes nonlinear with small load resistances and because the ammeter does not provide a true short circuit.

(14) Restore the circuit to that of Fig.2. Connect A to C, E to F, and G to H.
(15) Set the DMM to AC AMPS, connect its mA input to J, and connect its COM input to ground.
(16) Measure (or try to) the AC short circuit current at the output. Observe the signal at J on your scope. RECORD ANY RESULTS IN TABLE 10.4.

The proper way to measure Z_i is to use a voltage divider with a series source resistance. This method works best when Z_i and the series resistance are comparable. The resultant loss in input voltage can be used to calculate Z_i. If the input voltage is small, the resultant loss in output voltage can be used instead. The correct way to measure Z_o is to use it in a voltage divider with a load resistance. This method works best when the load is larger than Z_o because amplifiers often become nonlinear when small load resistances are used. Again, the resultant loss in output voltage can be usedto calculate Zo.

(17) Restore the circuit to that of Fig.2. Connect A to C, E to F, and G to H.
(18) Adjust the generator so that point A is at approximately 100 mV RMS. Adjust the variable supply so that point I is at approximately 5 V DC.
(19) Measure the exact DC voltages at D, E, H, and I. Record your measurements in Table 10.5.
(20) Measure the exact AC RMS voltages at A, D, and J. Record your measurements in ~~Table 10.5.~~
(21) Repeat step 20 for J connected to K, J connected to L, and J connected to M.
(22) Disconnect J from M to remove the load. Disconnect A from C and connect A to B.
(23) Repeat steps 20 and 21.

PLEASE CALL A TEACHING ASSISTANT TO CHECK YOUR DATA BEFORE CONTINUING.

Part 3 - Emitter Follower Cutoff

The emitter follower amplifier is often capacitively coupled to its load. If the load resistance is too small and the signal's voltage swing is too large, it is possible to reverse bias the transistor's base-emitter junction. This results in clipping of the lower portion of the output waveform. ?

(1) Restore the circuit to that of Fig.2. Connect A to C, E to F, and G to H.
(2) Connect the scope CH2 input to point I. DC couple both scope channels.
(3) Set the signal generator to a triangle wave and set its amplitude so that the lower peaks of the waveform at I are SLIGHTLY flattened.
(4) Record the DC voltage difference between ground and the flattened portion of the waveform at I.
(5) Connect the scope CH2 input to point J and record the DC voltage difference between ground and the flattened portion of the waveform at J.
(6) Repeat steps 2 to 5 for J connected to K, J connected to L, and J connected to M.

PLEASE CALL A TEACHING ASSISTANT TO CHECK YOUR DATA BEFORE LEAVING.

this is not 10.6 mA in reality it really $\frac{3V}{47K} \approx 0.1mA$

Questions:

1. Consider the circuit of Fig. [redacted] 2 and assume connections from A to C, E to F, and G to H. Use your measured b_o, $I_c = 10.6$ mA and $r_\pi = .026\, b_o/I_c$ (not your data from subsequent parts) in the following calculations.

   Calculate Z_i looking to the RIGHT from point C for
   (a) no load,
   (b) the 4.7 K load,
   (c) the 470 ohm load, and
   (d) the 47 ohm load.
   (e) Calculate Z_o looking to the LEFT from point J.

   Calculate the gain (J/C) for
   (f) no load,
   (g) the 4.7 K load,
   (h) the 470 ohm load, and
   (i) the 47 ohm load.

2. ~~In the following calculations, use the experimental data which will yield the "best" calculations.~~

   ~~Calculate Z_i looking to the RIGHT of point C for~~
   ~~(a) no load,~~
   ~~(b) the 4.7 K load,~~
   ~~(c) the 470 ohm load, and~~
   ~~(d) the 47 ohm load.~~

   ~~(e) Calculate Z_o looking to the LEFT of point J.~~

   ~~Calculate the gain (J/C) for~~
   ~~(f) no load,~~
   ~~(g) the 4.7 K load,~~
   ~~(h) the 470 ohm load, and~~
   ~~(i) the 47 ohm load.~~

   Calculate
   (j) r_π and
   (k) b_o. data

3. (a) Compare your r_p and b_o values from Questions 1 and 2. Which do you feel is the most accurate?
   (b) Did you need to use the 100 pF capacitor?
   (c) Do any of the [redacted] 4 methods yield Z_i [redacted] values close to those found in Ques. [redacted] 1?

4. For each of the four cases tested, calculate the instantaneous current through the emitter, emitter resistor, and load resistor during the flattened portion of the waveform.

5. Write an equation which defines the maximum undistorted AC output voltage in terms of the operating point, emitter resistance, and load resistance.

EEAP 243 LAB 10 EVALUATION

NAME (print)____________________________ CHECKPOINT #1 ___ DATE _____
GRADE _____/_____ CHECKPOINT #2 ___ DATE _____

With respect to the course material, this lab was: (pick one)
___ highly relevant ___ relevant ___ not relevant ___ completely irrelevant

This lab was: (pick one)
___ too long ___ long ___ just right ___ short ___ too short

This lab was: (pick one)
___ too hard ___ hard ___ just right ___ easy ___ too easy

The background material in the lab assignment was: (pick one)
___ too detailed ___ just right ___ sufficient ___ insufficient ___ totally inadequate

The step by step procedures in the lab assignment were: (pick one)
___ too detailed ___ just right ___ sufficient ___ insufficient ___ totally inadequate

Describe any mistakes made in the lab assignment.

Describe anything that just didn't work right.

Describe how this lab could be made better.

QUIZ

NOTE: THE TEACHING ASSISTANT IS TO SELECT BOTH QUESTIONS FROM THE UNDERLINED OPTIONS AT THE SECOND CHECKPOINT

Question #1

In Fig. 10.1 assume connections from F to J and from E to N. What will happen to the gain from point D to point L if we increase/decrease the resistance of $R_4/R_6/R_8/R_9/R_{10}/R_{11}/R_{12}$?

It will increase / decrease / stay the same.

Question #2

In Fig. 10.1 assume connections from F to J and from E to N. What will happen to the gain from point D to point L if we increase/decrease the resistance of R_{13}/R_5 ?

It will increase / decrease / stay the same.

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NAMES: ____

Lab 10 Data

		E/H grounded.
C	____________	____________
D	____________	____________
I	____________	____________
J	____________	____________

Table 10.2 Measuring Z with an ohmmeter

AC INPUT CURRENT: ____________

AC OUTPUT CURRENT: ____________

Table 10.3 Measuring Z using source current

AC OUTPUT CURRENT: ____________

Table 10.4 Measuring Z using short circuit current

	----- V DC -----	------------------------ V AC (rms) ------------------------			
		no load	4.7k	470	47
A		__________	__________	__________	__________
D	____________	__________	__________	__________	__________
E	____________				
H	____________				
I	____________				
J		__________	__________	__________	__________

/e

Table 10.5 DC and AC Measurments of emitter follower

	point I	point J
DC VOLTAGE DIFFERENCE (J open):	______________	______________
DC VOLTAGE DIFFERENCE (J-K):	______________	______________
DC VOLTAGE DIFFERENCE (J-L):	______________	______________
DC VOLTAGE DIFFERENCE (J-M):	______________	______________

Table 10.6 - Emitter follower cutoff