EE091
ELECTRONICS DEVICES LAB

LAB 3

BJT BIASING

Full name:
Nguyễn Minh Đức - ITITIU21045………………………...
Nguyễn Quang Tâm - ITITIU21304………………………..
Tôn Long Thuận - ITITIU21322………………………...

I. OBJECTIVES

The purpose of this lab is to measure some characteristics of a transistor (a bipolar junction transistor, or BJT) in two useful circuit configurations, the emitter follower amplifier and the common emitter amplifier.

II. MATERIAL AND EQUIPMENT

1. Oscilloscope
2. Power Supply
3. Multimeter
4. 2N3904
5. Assorted Resistors

III. BACKGROUND

The bipolar junction transistor (BJT) can be modeled as a current controlled current source. The circuit symbol and the pin out for the actual device can be seen in Figure 1.

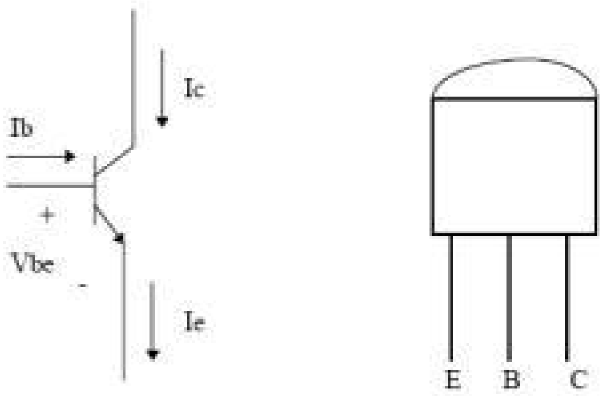


Figure 1: The bipolar junction transistor.

In order to analyze a BJT circuit the following simplified equations can be used:

$$I_c \approx I_c \approx \beta I_b$$
$$V_{be} \approx .7V$$

These equations assume the device is operating in the active region (typical for amplifier applications). From these equations we see that the current through the collector of the device is controlled by the input current to the base. Thus if we change the current into the base, we get a proportional change in the collector current. The constant of proportionality is called β, or sometimes *hfe*. β is typically on the order of 20 - 500.

In order to characterize the operation of a particular transistor, a complete set of characteristic equations is needed. Typically, these curves look like those in Figure 2. These curves show that in the active region of operation, the collector current is constant and depends on the base current.

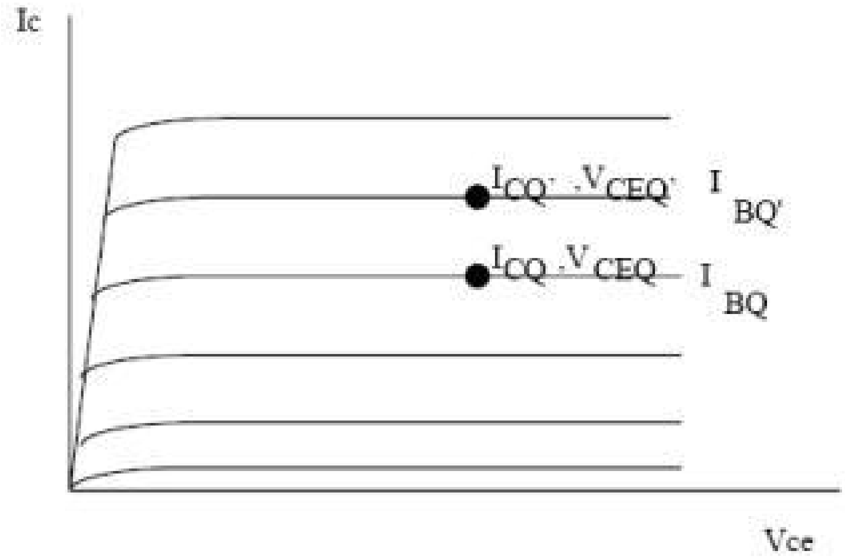


Figure 2: Characteristic curves for the BJT transistor.

These curves can be used to calculate the large signal current gain, βDC (or hFE) and the small signal current gain, βAC (or hfe). These values are in general calculated for a given bias point ICQ, VCEQ using the following equations:

$$\beta_{DC} = \frac{I_{CQ}}{I_{BQ}}$$

$$\beta_{AC} = \left| \frac{I_{CQ} - I_{CQ'}}{I_{BQ} - I_{BQ'}} \right|$$

From this, one can see that the large signal gain depends only on the Q point and the small signal gain depends only on small deviations around the Q point.

In order to use a transistor in an amplifying circuit it has to be biased. In other words, a Q point has to be set in order to place the device in the active region of operation. There are several methods which can be used bias a transistor. Figures 3 and 4 demonstrate two possibilities.

The first scheme (Figure 3) is called a fixed bias scheme. In a fixed biasing the base current is set through a base resistor and the emitter of the transistor is grounded. This scheme is not used in practice since the Q point depends very strongly on β.

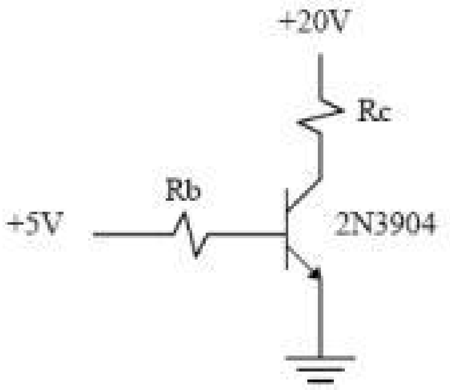


Figure 3: Fixed biasing scheme.

A second possibility, which is commonly used, is the self-biasing scheme. Here the base voltage is set through a voltage divider and the emitter is tied to ground through a resistor. If designed correctly, this scheme is relatively independent of β.

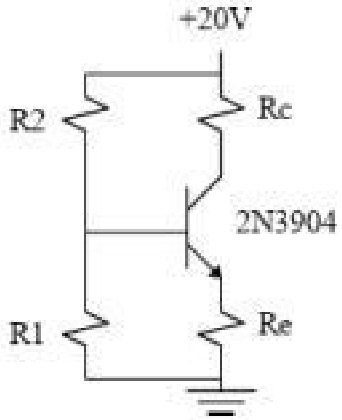


Figure 4: Self-biasing voltage divider scheme.

IV. PROCEDURE

1. FIXED BASE BIASING (Simulation)

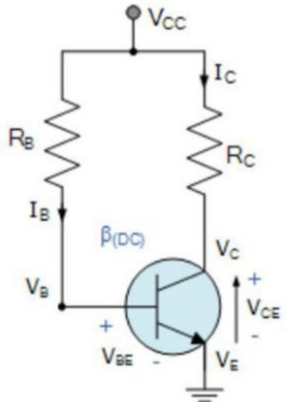
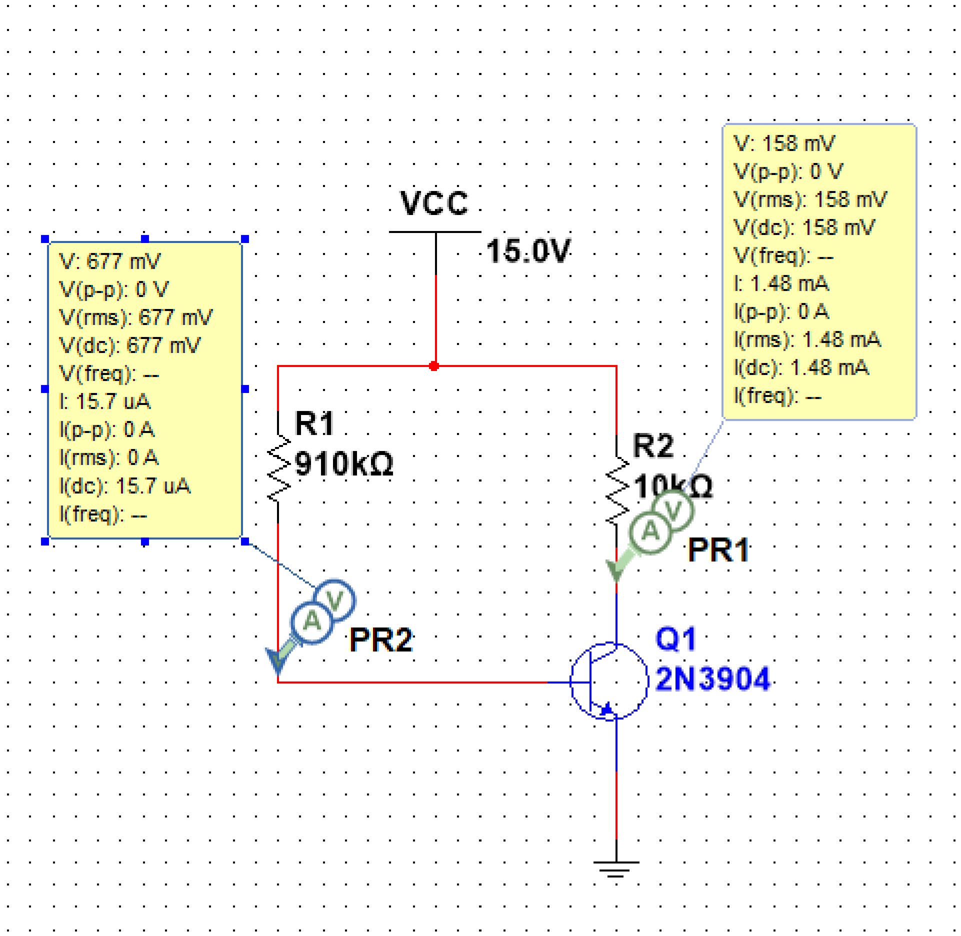


Figure 5: Fixed biasing circuit,

In this exercise, you will examine the values of the DC biasing process in a fixed biasing circuit. Assuming $Vcc = 15V$, $RB = 910k\Omega$, $RC = 10k\Omega$, β = 100. Fill in the below table.



	V_B	V_E	V_C	V_{BE}	I_B	I_E	I_C	β
Calculation	700 mV	0	100 mV	700 mV	15.7 uA	1.85 mA	1.57 mA	100
Simulation	677 mV	0	158 mV	677 mV	15.7 uA	1.5 mA	1.48 mA	97.1

2. COLLECTOR FEEDBACK BIASING (Simulation)

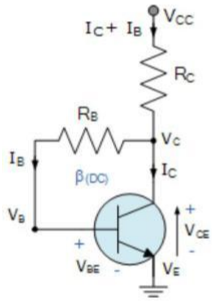
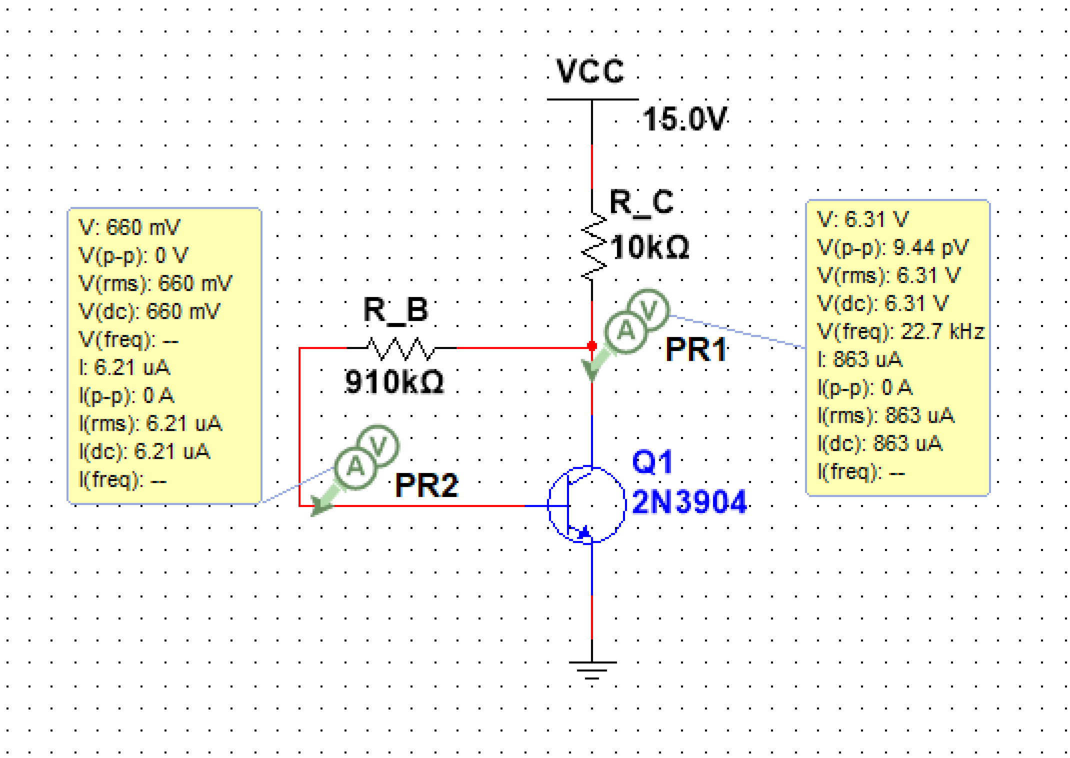


Figure 6: Fixed biasing circuit,

In this exercise, you will examine the values of the DC biasing process in a fixed biasing circuit. Assuming $Vcc = 15V$, $RB = 470k\Omega$, $RC = 4.7k\Omega$, β = 100. Fill in the bellow table.



	V_B	V_E	V_C	V_{BE}	I_B	I_E	I_C	β
Calculation	700 mV	0	7.88	700 mV	15.14 uA	1.53 mA	1.51 mA	100
Simulation	660 mV	0	6.31	660 mV	6.21 uA	269 uA	863 uA	98.4

3. EMITTER FOLLOWER (COMMON COLLECTOR) AMPLIFIER

In this exercise, you will see what the transistor does in an emitter follower circuit and what the entire circuit does. Construct the emitter follower circuit shown in figure 7.

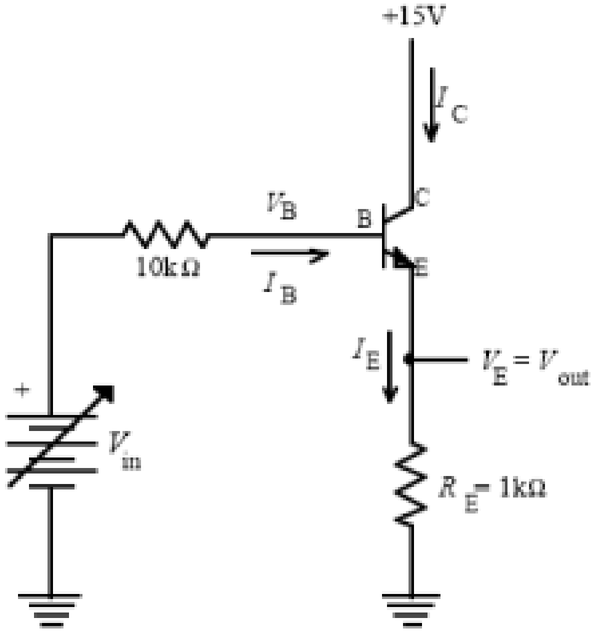
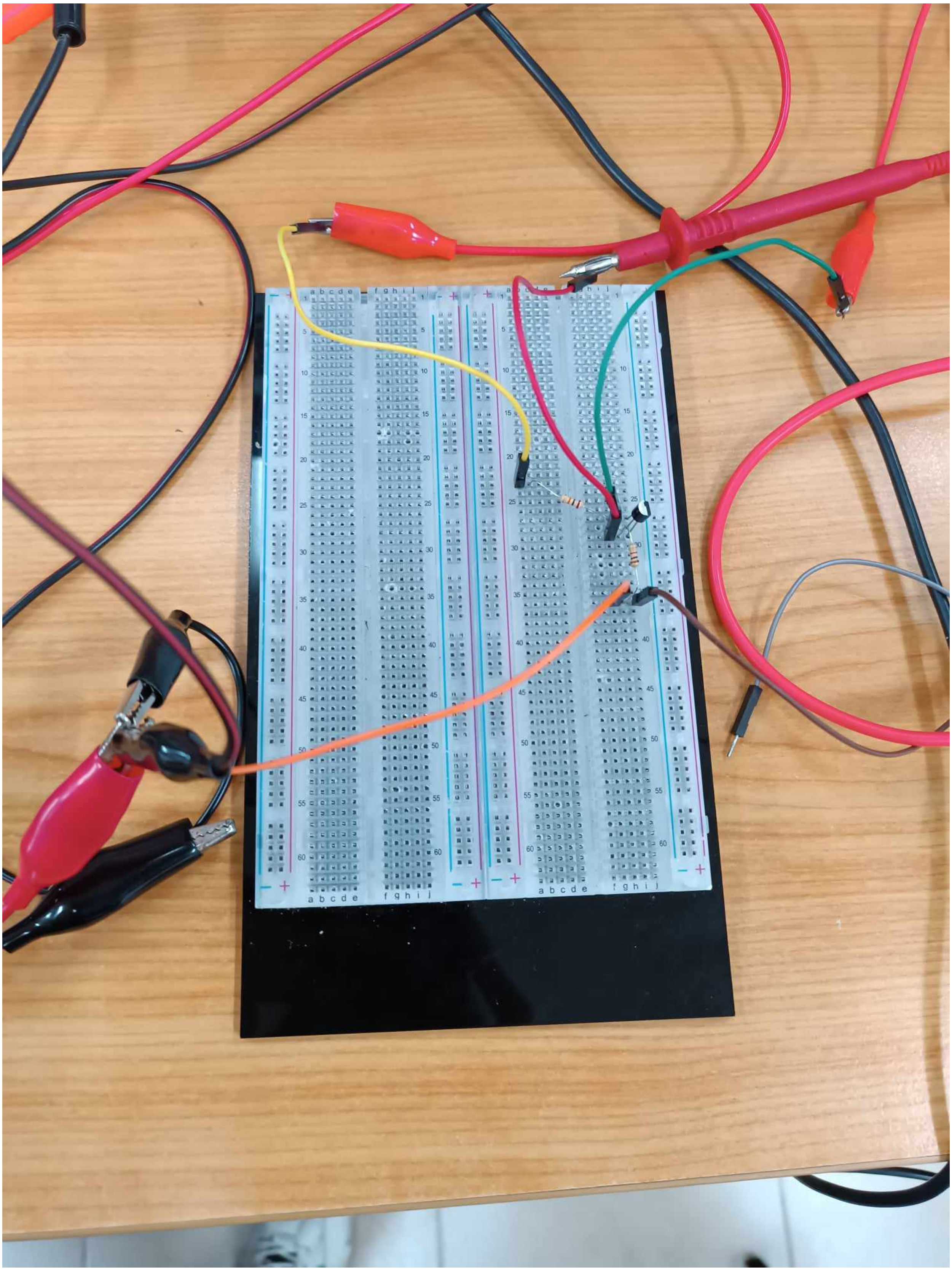
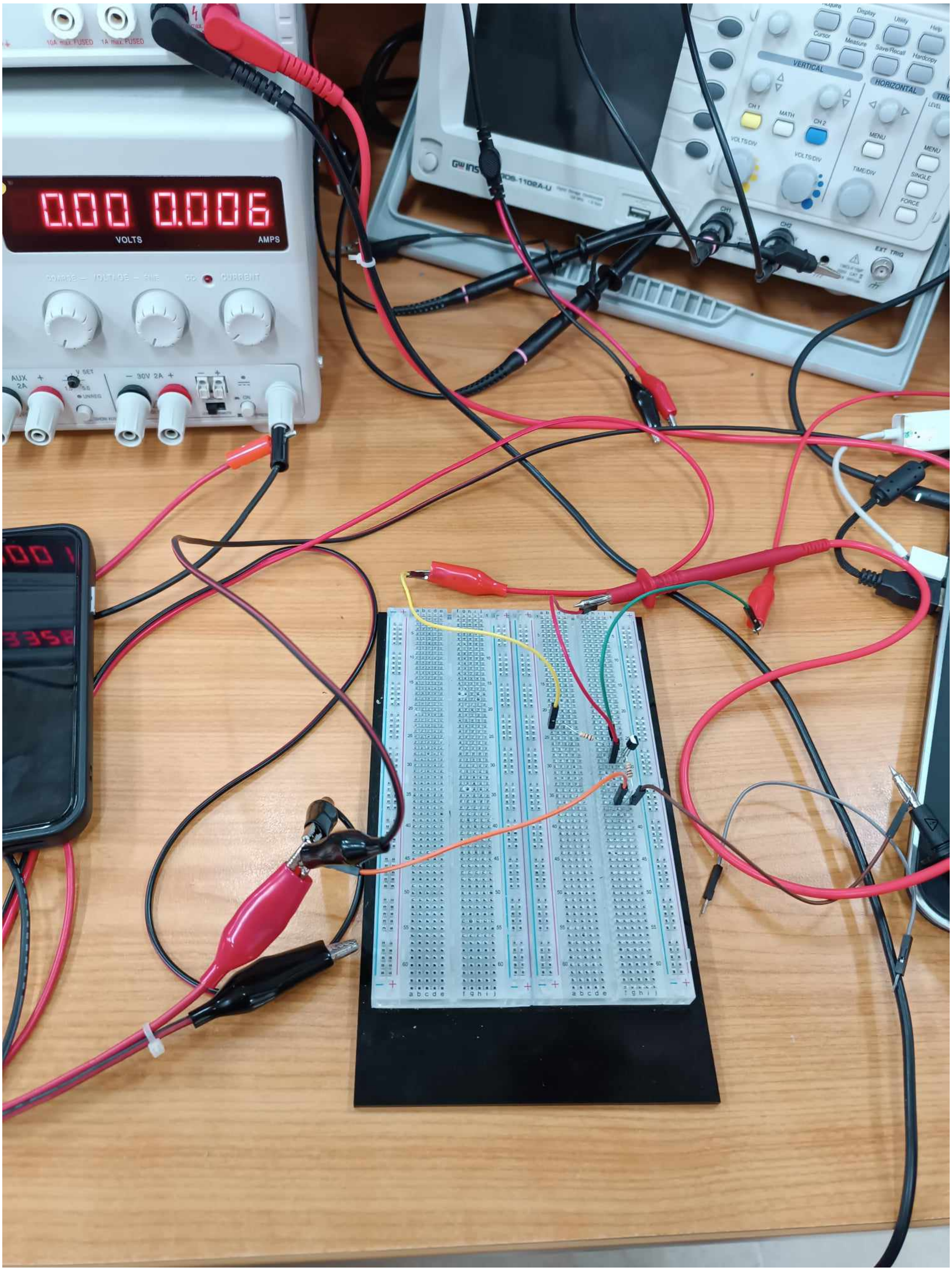


Figure 7: Emitter follower amplifier.

First, examine the behavior of the transistor. Set V_B to approximately 2,4,6,8,10,12, and 14 volts and for each V_B measure V_{in}, V_B (accurately), and V_E. From this, calculate $V_{BE} = V_B - V_E$, I_B and I_E from Ohm's law, $I_C = I_E - I_B$, and $hfe = \beta = I_C / I_B$. Put all of this in one data table.





V_B	V_E	V_C	V_{BE}	I_B (mA)	I_E (mA)	I_C (mA)	β
2	2.1	1.45	0.65	0.2	2.1	1.9	9.5
4	4.05	3.38	0.67	0.4	4.05	3.65	9.125
6	5.9	5.412	0.488	0.6	5.9	5.3	8.83
8	8.16	7.112	1.048	0.8	8.16	7.36	9.2

10	10.5	9.296	1.204	1	10.5	9.5	9.5
12	12.8	10.833	1.967	1.2	12.8	10.7	8.9167
14	14.44	13.3	1.14	1.4	14.44	13.04	9.3143

To analyze this data, plot I_B vs. V_{BE}. This will look like a nearly vertical line, but since the base-emitter junction is a forward biased diode, it is actually part of diode exponential curve. On the same graph, plot a calculated diode curve that approximately fits your data. Comment how a straight line can fit these data points fairly well.

Now, looking at the data and the graph, answer these questions:

1. What is the range of V_{BE}? **From 0.65 to 1.14**
2. Does V_{BE} stay at approximately 0.7V? **No, it doesn't. It fluctuates due to error in laboratory**
3. What does it mean for a transistor to be in its "active region"? **The active region is defined region in which the emitter-base junction is forward bias while the collector-base junction is reverse bias**
4. Does the transistor stay in its active region? **Yes, it does according to the given data,**
5. Is $I_C \approx I_E$? **Yes, usually in a bipolar junction transistor (BJT), we see that the collector current (IC) is approximately equal to the emitter current (IE) under ideal conditions.**

4. COMMON EMITTER AMPLIFIER

In this section, you will analyze the bias characteristic of a common emitter amplifier, a popular transistor amplifier circuit.

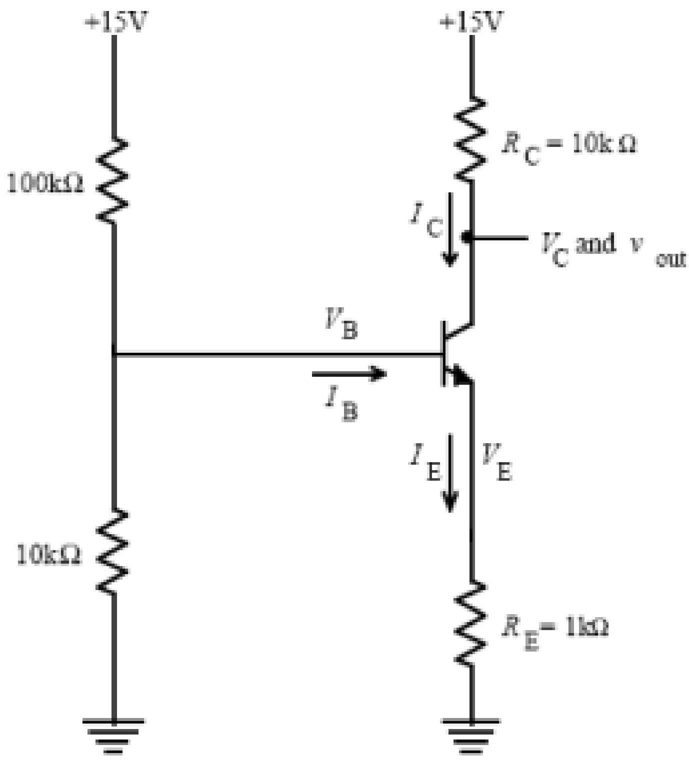
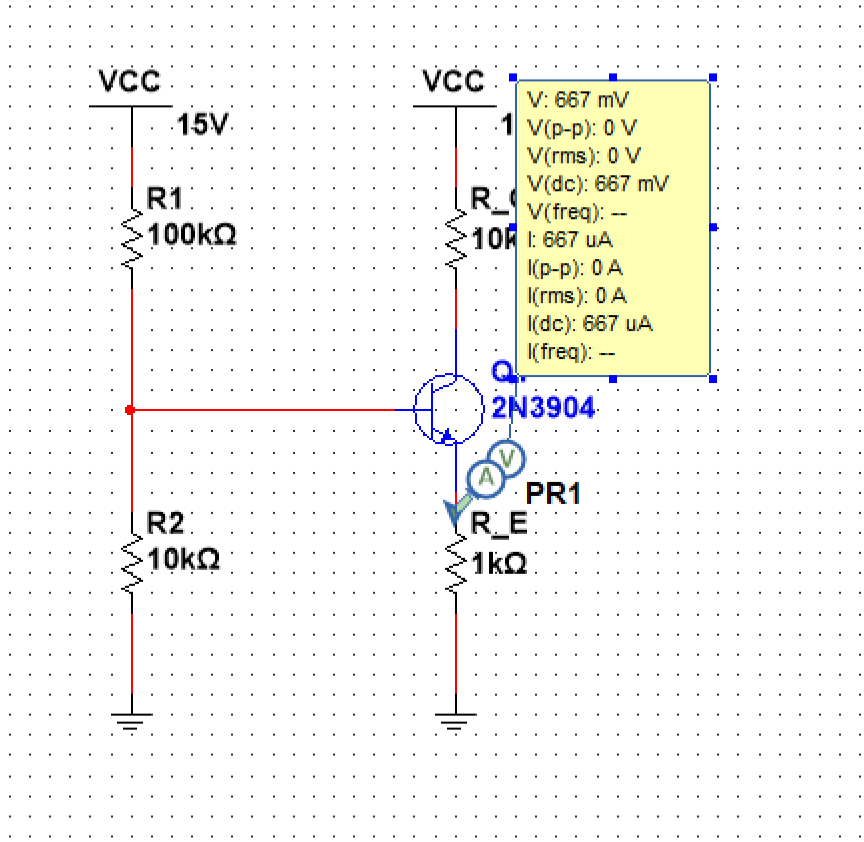


Figure 8: Common emitter amplifier.

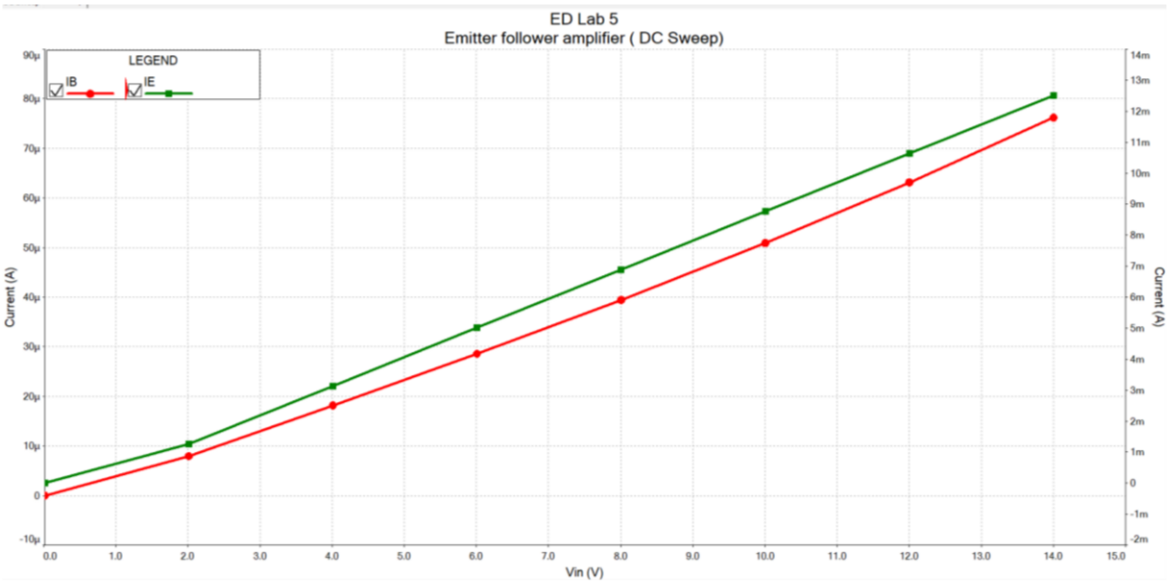
.

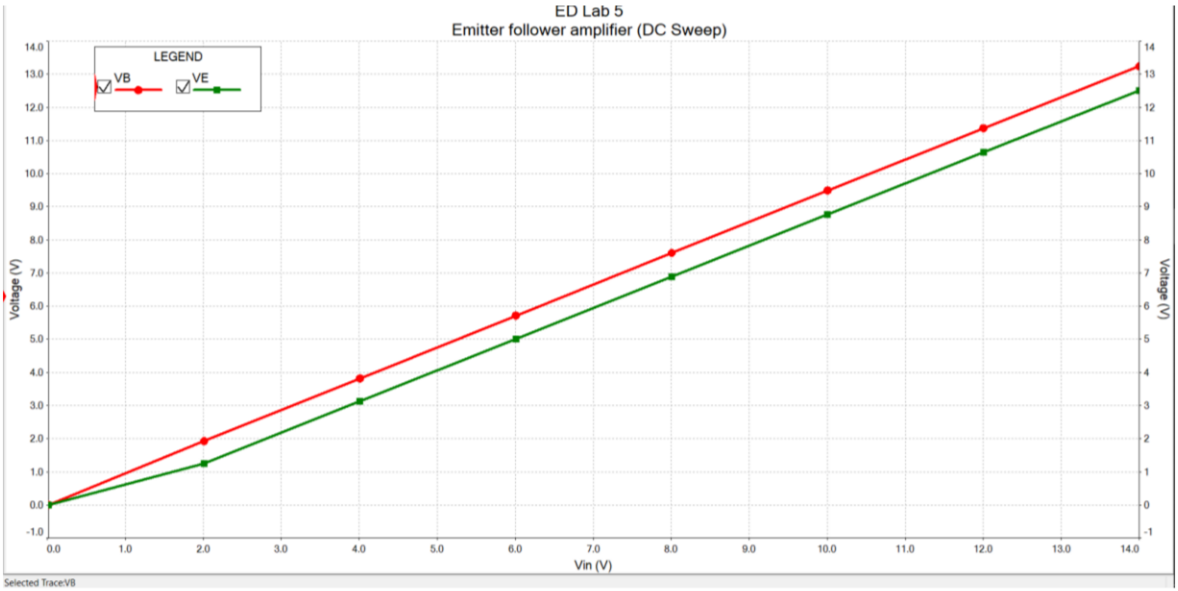
Find the bias conditions of the transistor. That is, find the voltages and currents in the circuit with no input signal. This is also called the "quiescent point", the "operating point", or the "DC" conditions for the circuit. To do this, first using theory to calculate V_B, V_E, and V_C, I_E, I_C, I_B and V_{BE}. Is the transistor in its active region now? Then measure V_B, V_E, and V_C, use Ohm's law to calculate I_E and I_C, calculate $I_B = I_C / \beta$ using the β you found in section 1, and calculate V_{BE}.

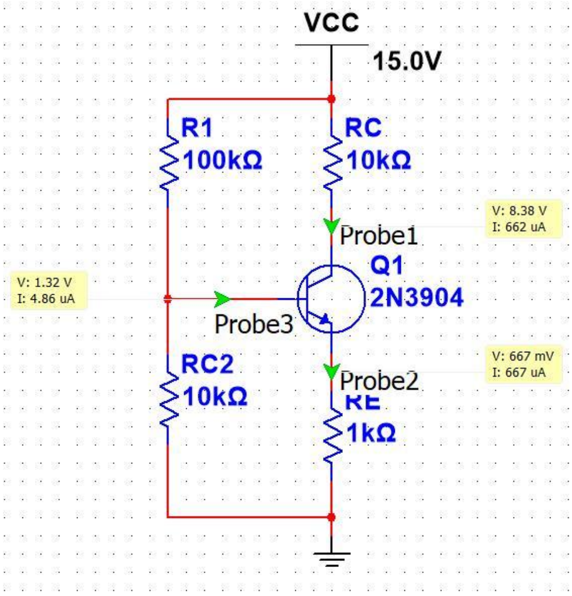


	V_B	V_E	V_C	V_{BE}	I_B	I_E	I_C	β
Calculation	1.36	0.66	8.36	0.65	6.63 uA	663 uA	663 uA	100
Simulation	1.32	667 mV	8.38	0.653	4.86 uA	667 uA	662 uA	115.4
Measurement	1.3411	705 mV	1.9345	0.6221	148 uA	0.7192	0.5712	5.5

Put all this data to one table. Compare the error between calculating and measuring.


ED Lab 5
Emitter follower amplifier (DC Sweep)
LEGEND
IB
IE
Current (A)
Vin (V)


ED Lab 5
Emitter follower amplifier (DC Sweep)
LEGEND
VB
VE
Voltage (V)
Vin (V)
Selected Trace:VB


VCC
15.0V
R1
100kΩ
RC
10kΩ
V: 8.38 V
I: 662 uA
Probe1
Q1
2N3904
V: 1.32 V
I: 4.86 uA
Probe3
RC2
10kΩ
V: 667 mV
I: 667 uA
Probe2
RE
1kΩ