Dr. Charles Kim

ELECTRONICS I

Lab 5 Bipolar Junction Transistor (BJT) I

TRADITIONAL LAB

A. Experiment

Connect the common-emitter circuit configuration shown in Fig. 5.3. Note base current requires micro-amp meter and the collector current requires milli-amp meter.

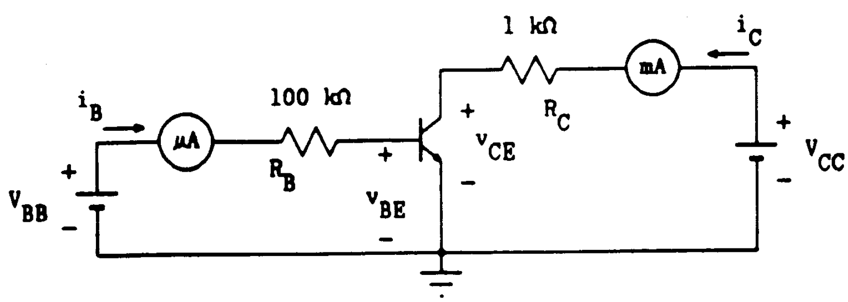


Fig. 5.3

1 . Obtain the collector characteristic.

Adjust V_{BB} to obtain base current of 9 μ-amp. Keep it there(i.e. fixed). Now vary V_{CC} according to the Table 1 below and record values at every step. Repeat the procedure with base currents of 6, 3, and 0 μ-amps.

Table 5.1 Collector characteristics

i_B = 9μA	V_{BB} =	V_{BE} =						
V_{CC} (volts)	0 –	0.5	1	2	4	8	12	15
V_{CE} (volts)								
i_C (mA)								
i_B = 6μA	V_{BB} =	V_{BE} =						
V_{CC} (volts)	0	0.5	1	2	4	8	12	15
V_{CE} (volts)								
i_C (mA)								
i_B = 3μA	V_{BB} =	V_{BE} =						
V_{CC} (volts)	0	0.5	1	2	4	8	12	15
V_{CE} (volts)								
i_C (mA)								
i_B=0(short)	V_{BB} = 0	V_{BE} =						
V_{CC} (volts)								
V_{CE} (volts)								
i_C (mA)								

(a) On the same graph plot i_C versus V_{CE} for fixed I_B's and hence obtain β beta graphically. Use a multimeter to measure β beta. Compare these two results with the manufacturer's data.

(b) Plot (On the same graph) the power dissipated P_D versus V_{CE} for each base current. Comment on your results.

2. Base characteristic

Using same circuit (short out 1 -kohm resistor). Fix V_{CE} for 4, 2, 0 volts each. For each value, vary base current and complete Table 5.2.

Table 5.2 **Base Characteristics**

V_{CE} = 4 volts

i_B μ-Amp	0	1	2	3	6	9	12	
V_{BE} volts								
V_{BB}								

V_{CE} = 2 volts

i_B μ-Amp	0	1	2	3	6	9	12	
V_{BE} volts								
V_{BB}								

V_{CE} = 0 volts (short circuit)

i_B μ-Amp	0	1	2	3	6	9	12	
V_{BE} volts								
V_{BB}								

On the same graph, for each V_{CE} setting plot V_{BE} versus i_B.
Comment on your results.

B. Statistical analysis.

1. Randomly select a minimum of ten similar npn BJTs measure beta of each one. Use the STAT-tutor program to find the mean, variance and standard deviation of β of the BJT.

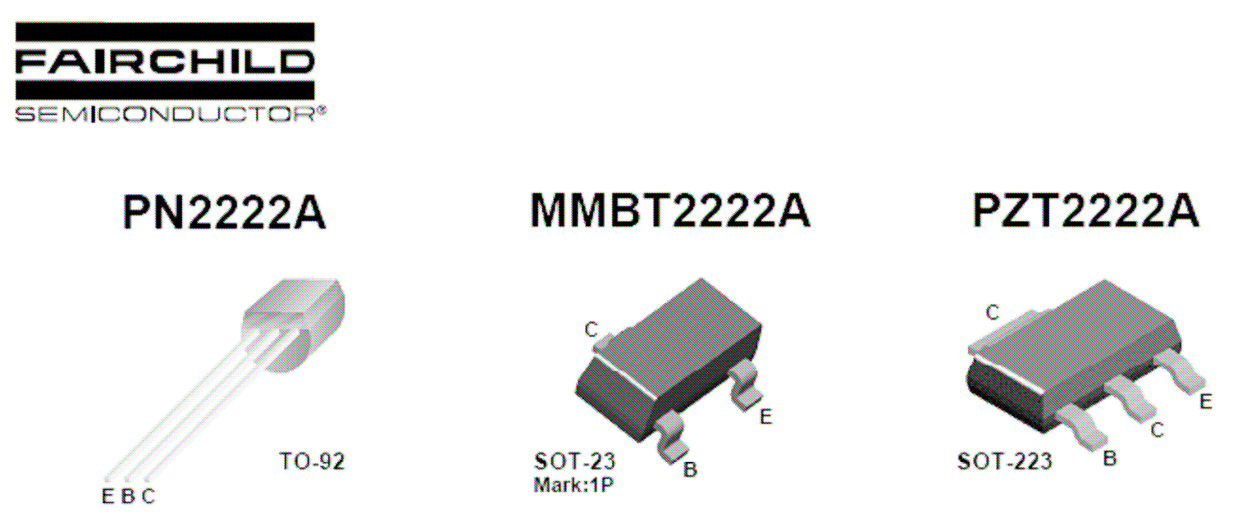
2. Get data from other groups, plot the frequenccy distribution for the range of beta and estimate its distribution density function.

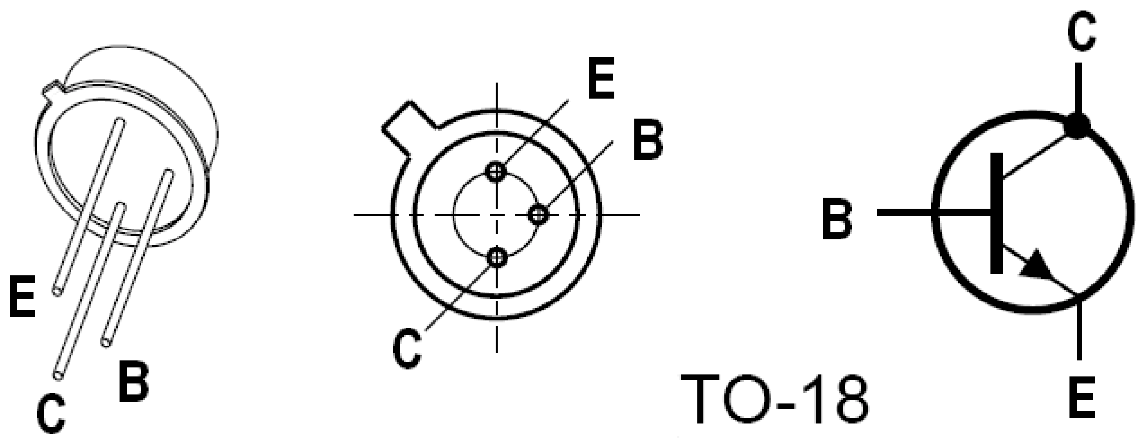
Note you will need the BJT parameters from this lab in order to proceed to the next lab (amplifier designs).

Comment and conclusion.

Before We Start

A transistor is a 3-terminal device available in two configurations, NPN and PNP. The transistor is one of the most important examples of an active component (Op Amp is another important active device as you already know) which amplifies and produces an output signal with more power than input signal. Of course, the additional power comes from the external power source we have to provide to the component. The most common, at least at the lab, NPN transistor is 2N2222. And there are two poplar types of packaging the transistor: TO-92 and TO-18.





The properties of NPN transistors meet the following rules[1]:

Rule 1: The Collector must be more positive than the Emitter.

Rule 2: The Base-Emitter and Base-Collector circuits behave like diodes.

Rule 3: There are maximum values of Collector current (I_C), Base current(I_B), Collector-Emitter voltage (V_{CE}), Base-Emitter voltage (V_{BE}) that cannot be exceeded.

Rule 4 (Simple Rule): When rules 1-3 are obeyed, Collector current (I_C) is roughly proportional to Base current (I_B)and can be written as: $I_C=\beta I_B$, where β is the current gain, typically about 100.

[1] Paul Horowitz and Winfield Hill, The Art of Electronics, Cambridge University Press, 1990.

Dr. Charles Kim

<u>Point</u> The Rule 4 says that a small current flowing into the Base controls a much larger current flowing into the Collector. The Rule 2 implies that an operating NPN transistor has $V_B=V_E+V_{BE}= V_E+0.6$ [V] relationship.

1. Experiment Overview

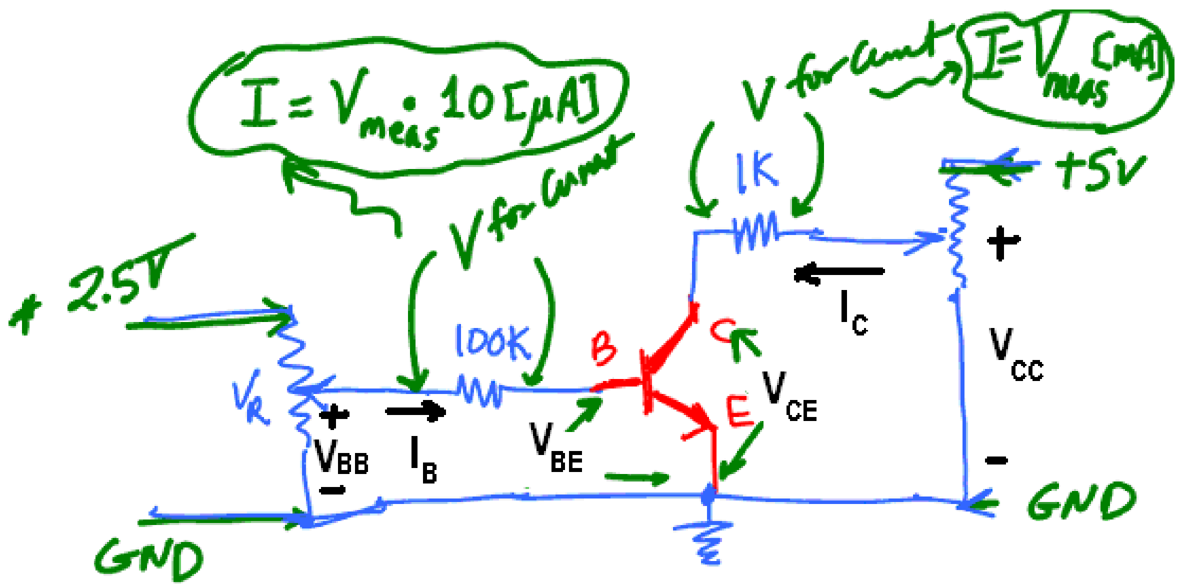
In the lab manual this experiment has two components:

1. Collector current characteristics, and
2. Base characteristics.

Specifically, the first one asks to connect I_C and V_{CE} with a given set of I_Bs. It again asks for connecting V_{CE} and P_D with the IBs, where P_D, power dissipated, is given by $P_D=I_BV_{BE}+ I_CV_{CE}$. On the other hand, the second one requires use to connect V_{BE} and I_B under different conditions of V_{CE}.

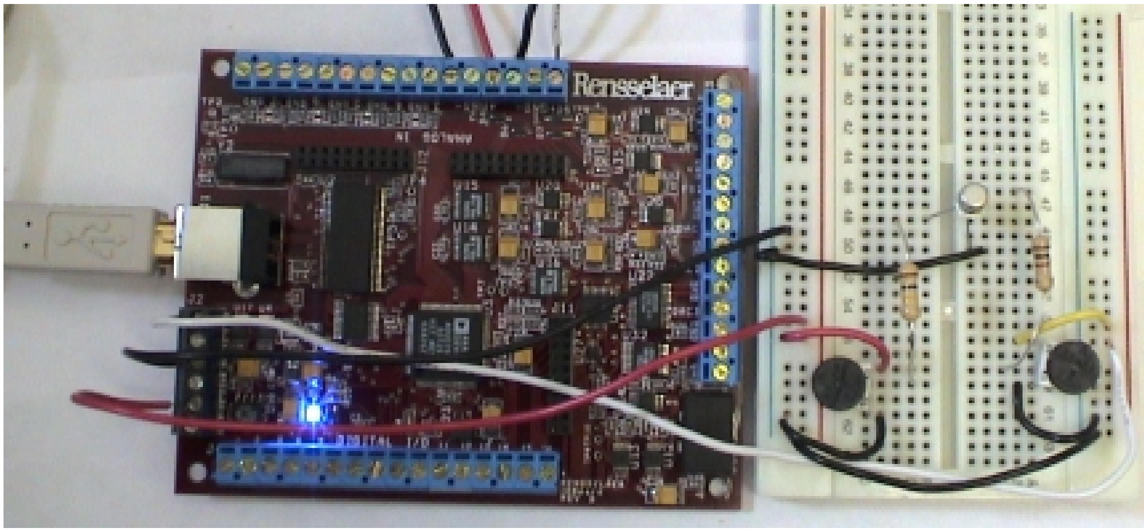
2. Implementation of the circuit for Mobile Studio Lab

As we discussed before, the current measurement in Mobile Studio Lab is performed by measuring voltage across the resistor through which the current is supposed to be measured. Also, the fixed voltage source from IOBoard must be fed via a variable resistor to provide variable voltage supply. So this is a sketch for the circuit implementation for the circuit.

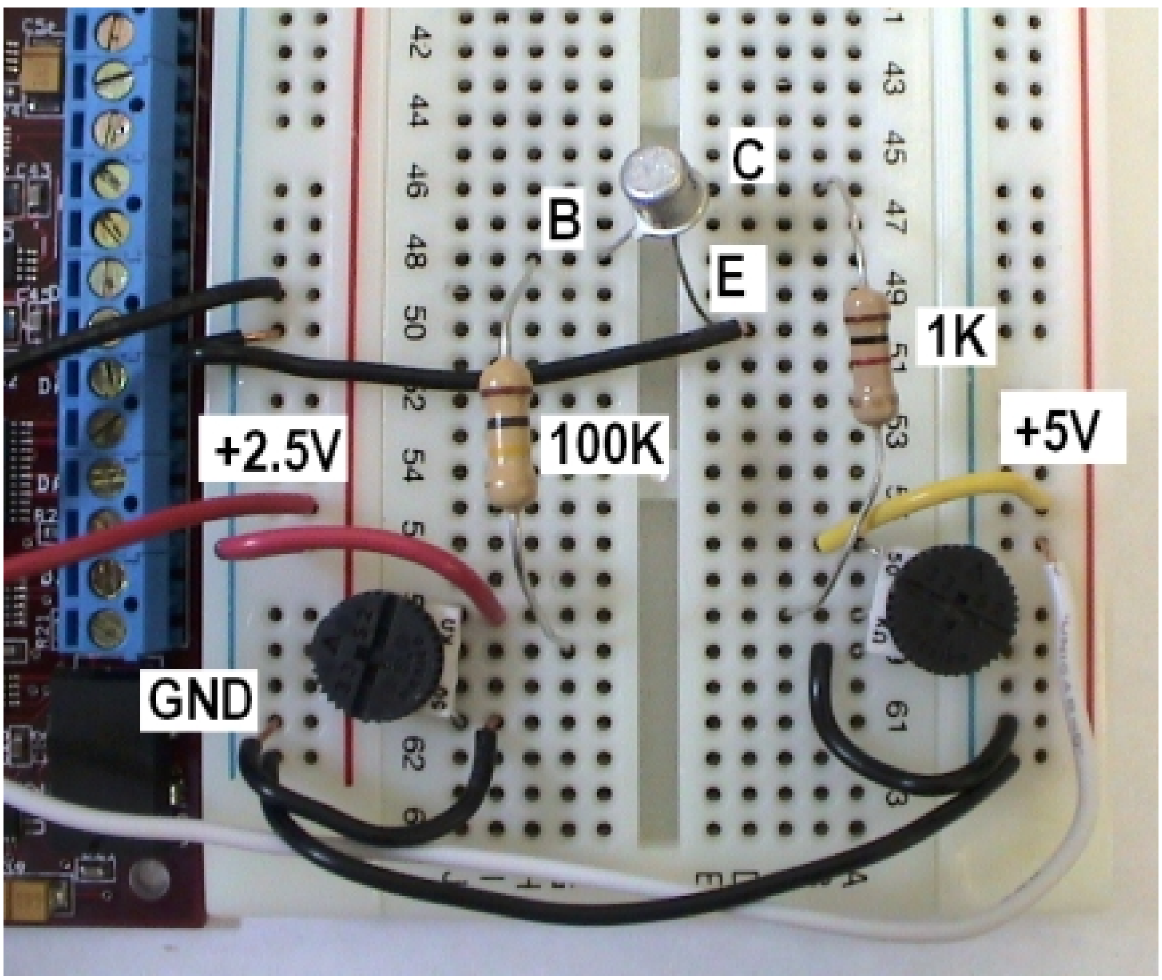


As you see in the above sketch, we connect +2.5V supply from the IOBoard to a variable resistor (left) for the current into the Base (B), and +5V supply from IOBoard to the other variable resistor for supplying into Collector (C). Emitter (E) is grounded. The Base current IB in [μA] into B is determined by multiplying the measured voltage across the 100K resistor in [V] by 10. On the other hand the Collector current IC in [mA] can be determined by the measured voltage across the 1K resistor.

Implementation Example: The NPN transistor use is 2N2222 with TO-18 package type.



Details of the circuit are shown below.



3. Collector Circuit Characteristics Experiment

From the Table 5.1 and succeeding question, we see that there are numerous quantities to measure. And some voltage level is apparent that we cannot supply using the IOBoard. So I changed the Table 5.1 to accommodate the IOBoard and Mobile Studio Lab. Let's hope that the next version of IOBoard can handle any request from us and from manual.

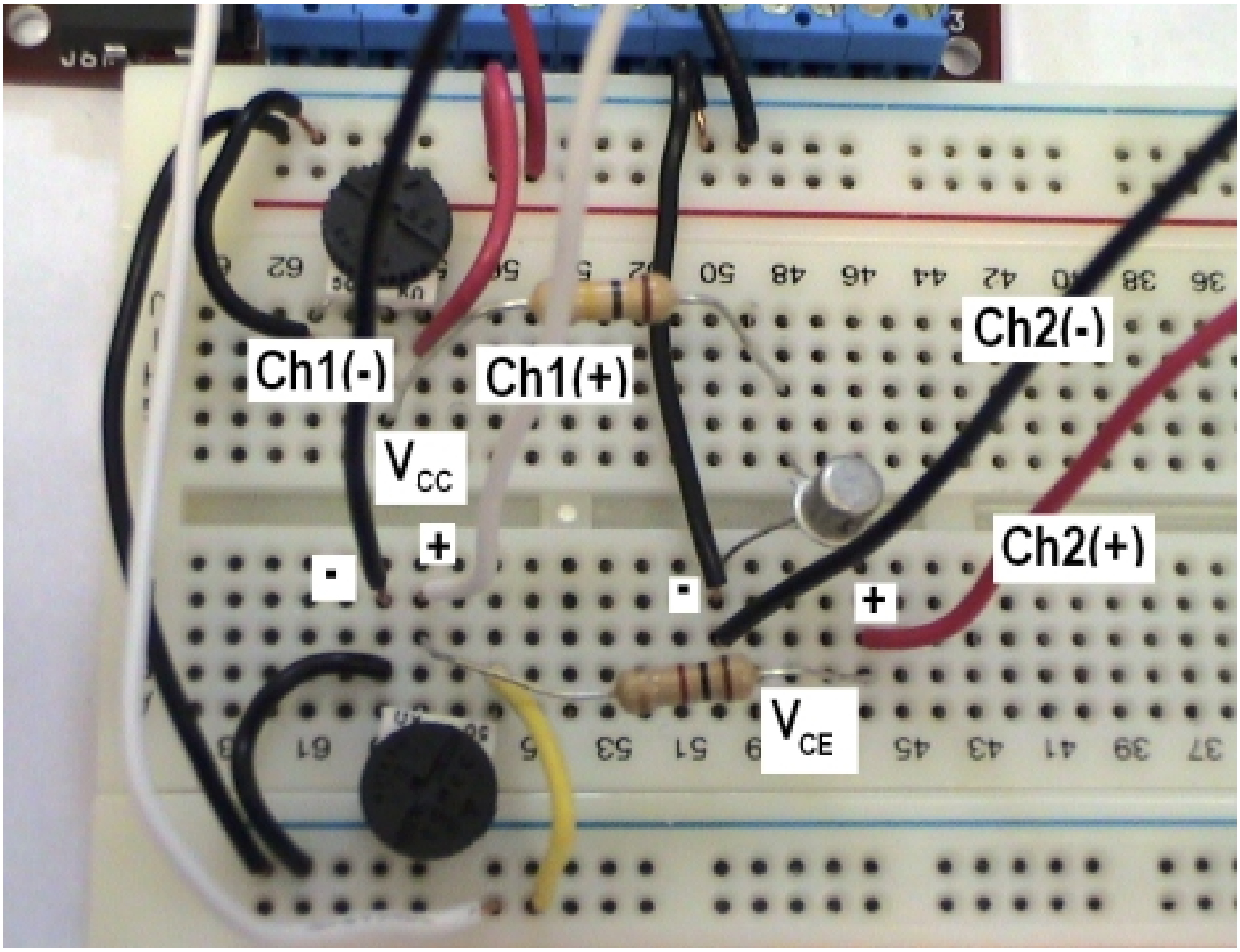
Collector Characteristics Table - I_C vs V_{CE} for different I_Bs.

I_B=9 μA		**V_{CC} [V]**						
		0	**0.5**	**1**	**2**	**3**	**4**	**5**
	V_{CE}							
V_{BE}=	**I_C**							
I_B=6 μA		**V_{CC} [V]**						
		0	**0.5**	**1**	**2**	**3**	**4**	**5**
	V_{CE}							
V_{BE}=	**I_C**							
I_B=3 μA		**V_{CC} [V]**						
		0	**0.5**	**1**	**2**	**3**	**4**	**5**
	V_{CE}							
V_{BE}=	**I_C**							
I_B=0 μA		**V_{CC} [V]**						
		0	**0.5**	**1**	**2**	**3**	**4**	**5**
	V_{CE}							
V_{BE}=	**I_C**							

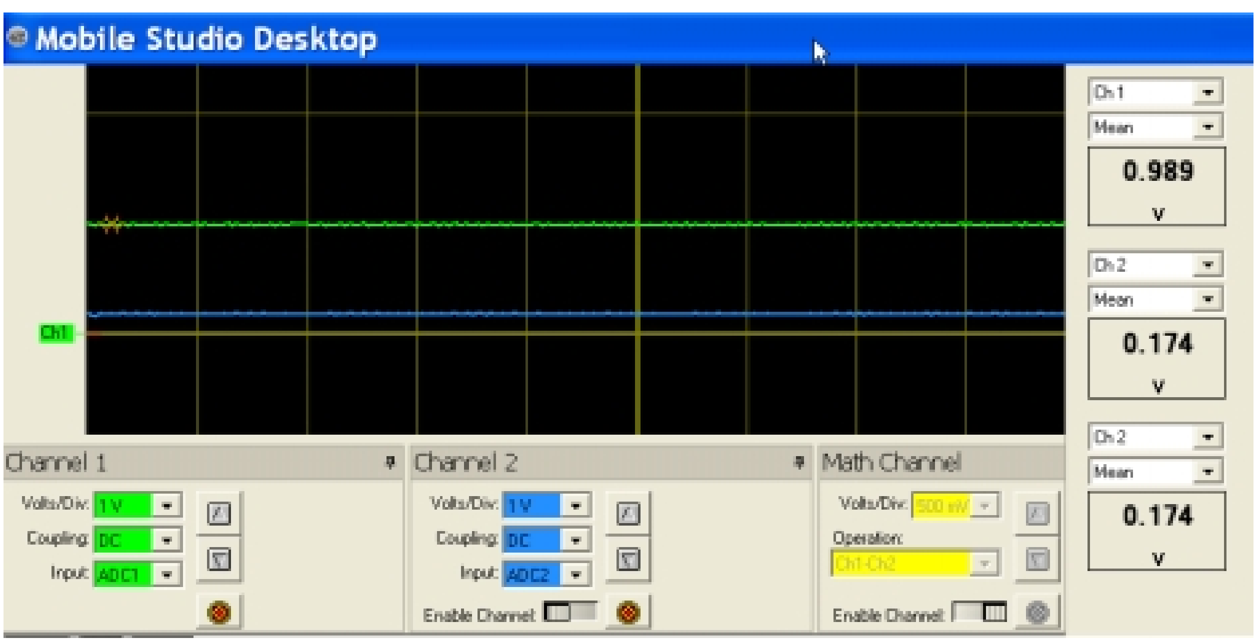
It's apparent that, to fill the table, we have to measure 5 items: I_B, V_{BE}, V_{CC}, V_{CE}, and I_C. Since we have only two channels in the scope function, we have to move our channel probes many different places in the breadboard. Here's my suggestion and sequence:

1. Use Channel 1 to measure I_B (i.e., voltage across 100K resistor) while move the wiper of the left variable resistor, and keep it when I_B is in the desired value. Don't change this for the entire measurement for a given I_B value.
2. Use Channel 1 to measure V_{BE}.
3. Now use Channel to measure V_{CC} and we will not move this setting. We dedicate Channel 1 for V_{CC} measurement.
4. Now move the wiper of the right variable resistor to have the desired value of V_{CC} on Channel 1.
    4.a. Use channel 2 to measure V_{CE}.
    4.b. Use channel 2 to measure I_C (which is the voltage across 1K resistor)
5. Do the steps 1 - 4 for all four different I_B values.
6. And draw a graph for I_V vs. V_{CE} for each of I_B.
7. Can you find your β?

The following photo is, after setting IB as 9μA, the measurement scheme for V_{CC} (using Channel 1) and V_{CE} (using Channel 2).



Next come the Mobile Studio Desktop screen shot for the above measurement scheme.



4. Base Characteristics Experiment

Since the 1K resistor now is shorted out and E is grounded, V_{CC} is the same as V_{CE}.

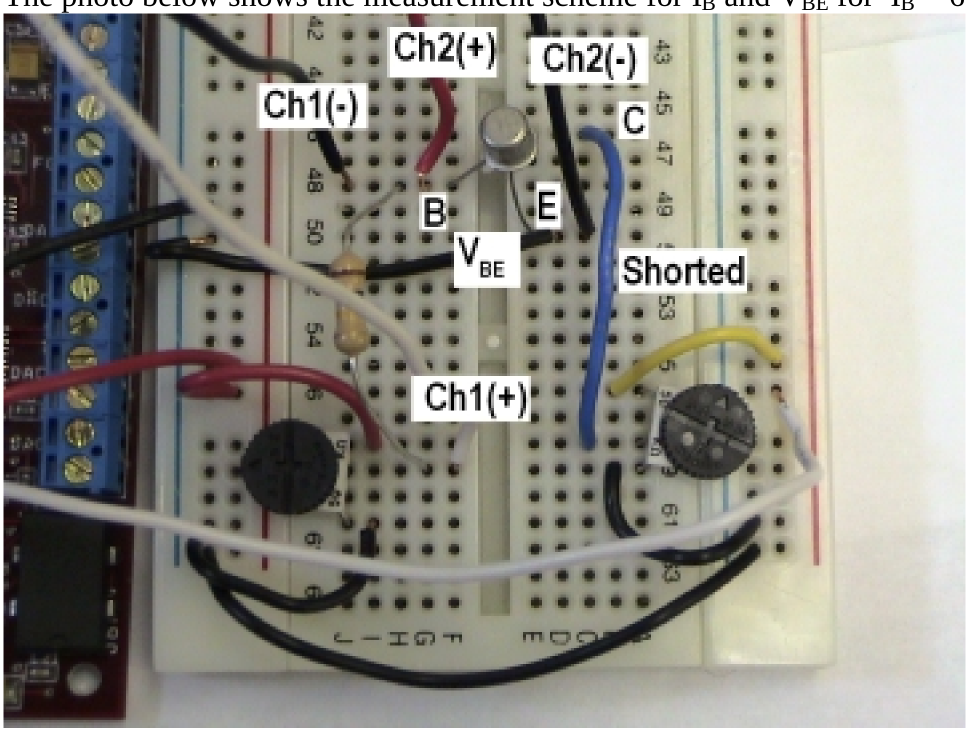
Base Characteristics Table - I_B vs V_{BE} for different V_{CE}s.

V_{CE}=4 V		**I_B [uA]**						
		0	**1**	**2**	**3**	**6**	**9**	**12**
	V_{BE}							
V_{CE}=2 V		**I_B [uA]**						
		0	**1**	**2**	**3**	**6**	**9**	**12**
	V_{BE}							
V_{CE}=0 V		**I_B [uA]**						
		0	**1**	**2**	**3**	**6**	**9**	**12**
	V_{BE}							

Here we have 3 quantities to measure. We dedicate our channel 1 for I_B measurement (i.e., voltage across 100k). Channel 2 will be used for both voltages:

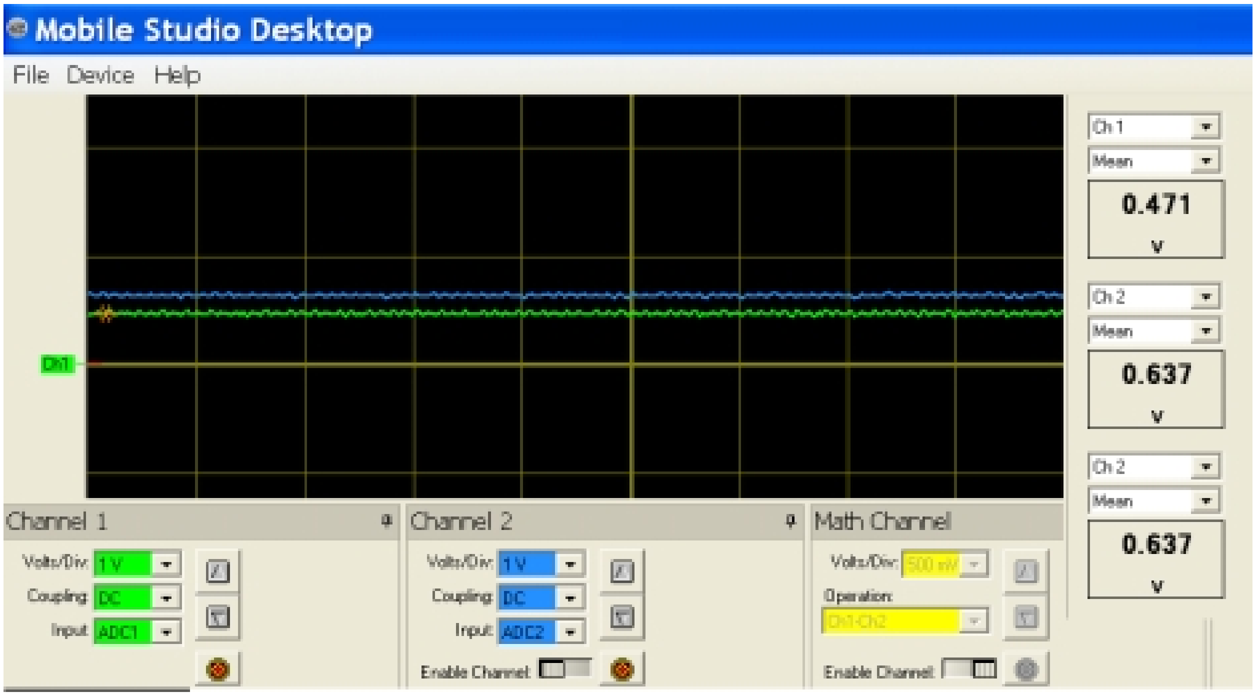
1. Use and fix channel 1 to measure the Base current.
2. Use channel 2 to measure V_{CC} (or V_{CE}) by adjusting the right variable resistor and set the desired value. At the same time, set the value of I_B by adjusting the left variable resistor for the desired value of I_B.
3. Move the channel 2 to measure the voltage V_{BE}.
4. Do the steps of 1-3 for other two values of V_{CE}.
5. And draw a graph for V_{BE} vs. I_B for each of V_{CE}.

The photo below shows the measurement scheme for I_B and V_{BE} for I_B = 6uA and V_{CE} = 4V.



In the photo above, channel 1 probes measure the voltage across 100K to indirectly measure the **current into B**, which is I_B.

Next shows the screen shot of the Mobile Studio Desktop of the scheme we use for Base characteristics.



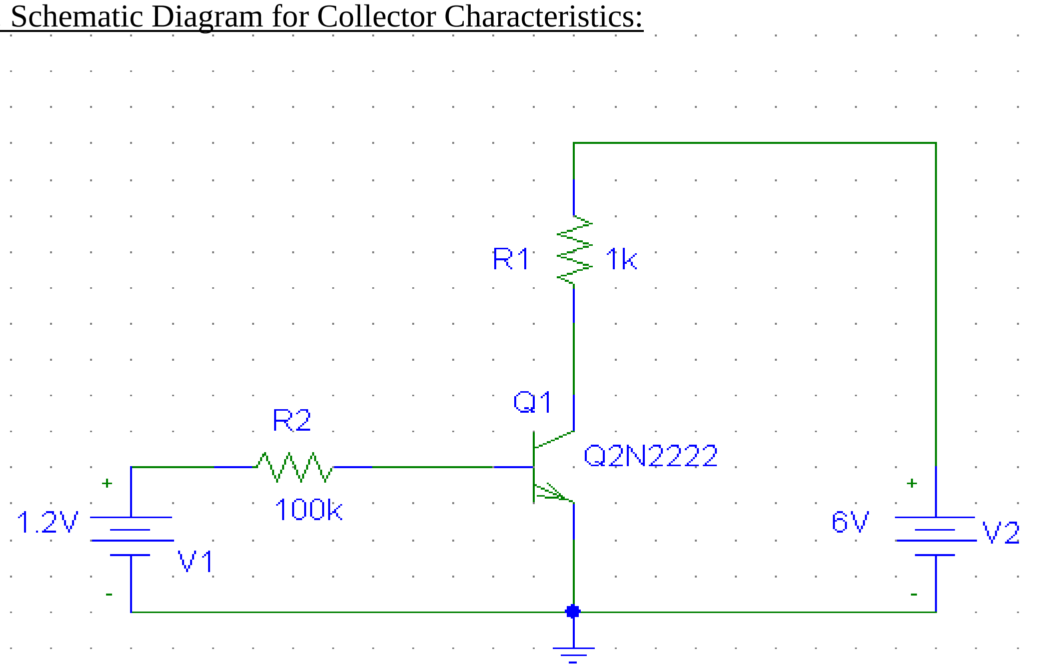
<Breadboard for above photo>

5. Part B- Statistical Analysis

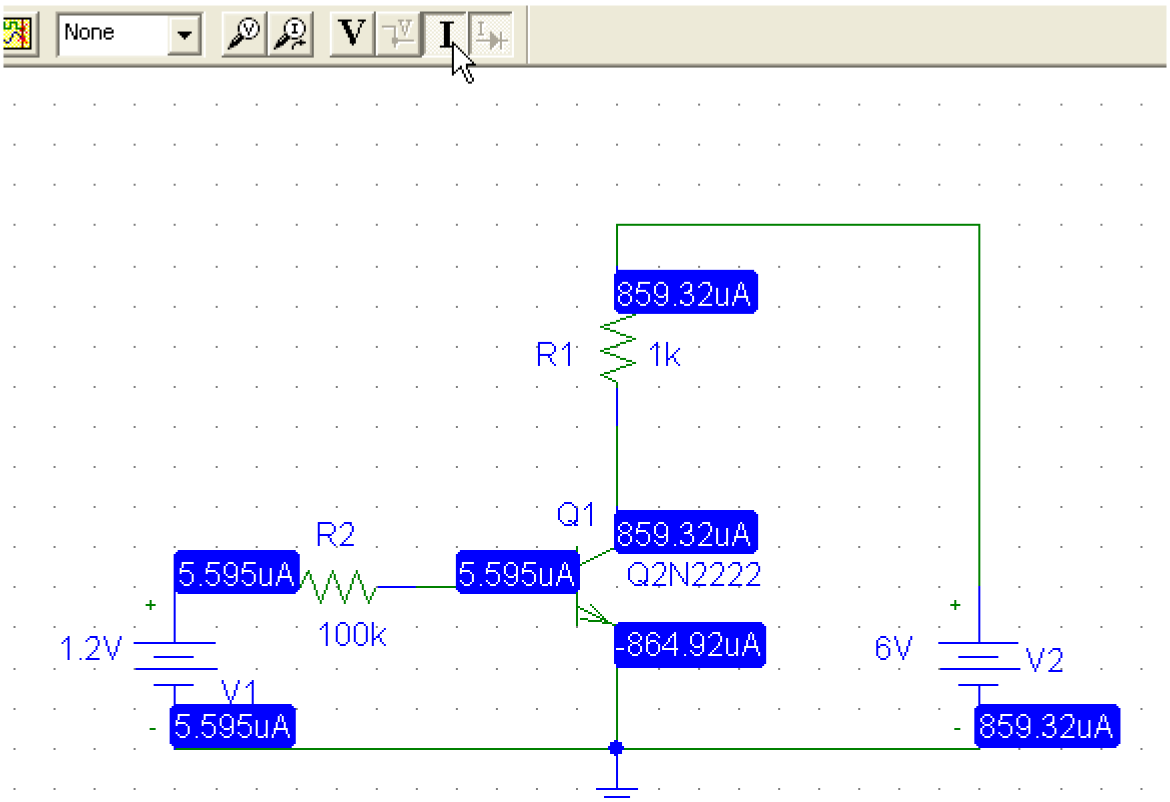
F'get about this!

6. PSpice Simulation

a. Schematic Diagram for Collector Characteristics:

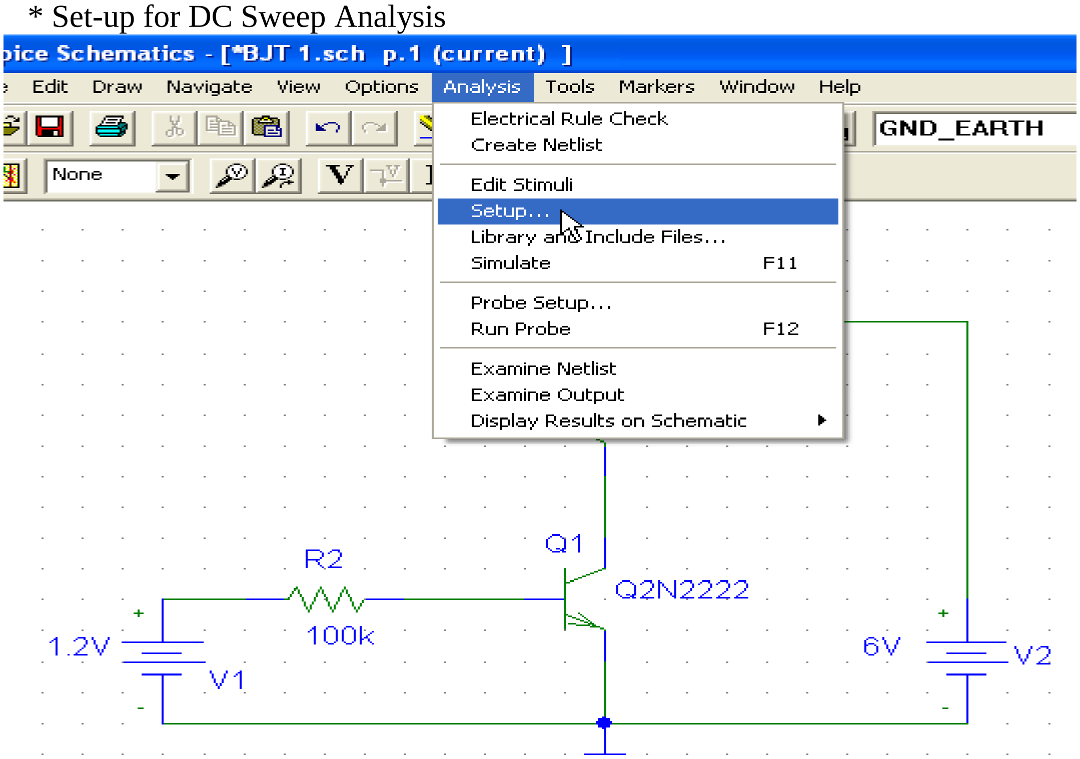


b. Simulation for Current

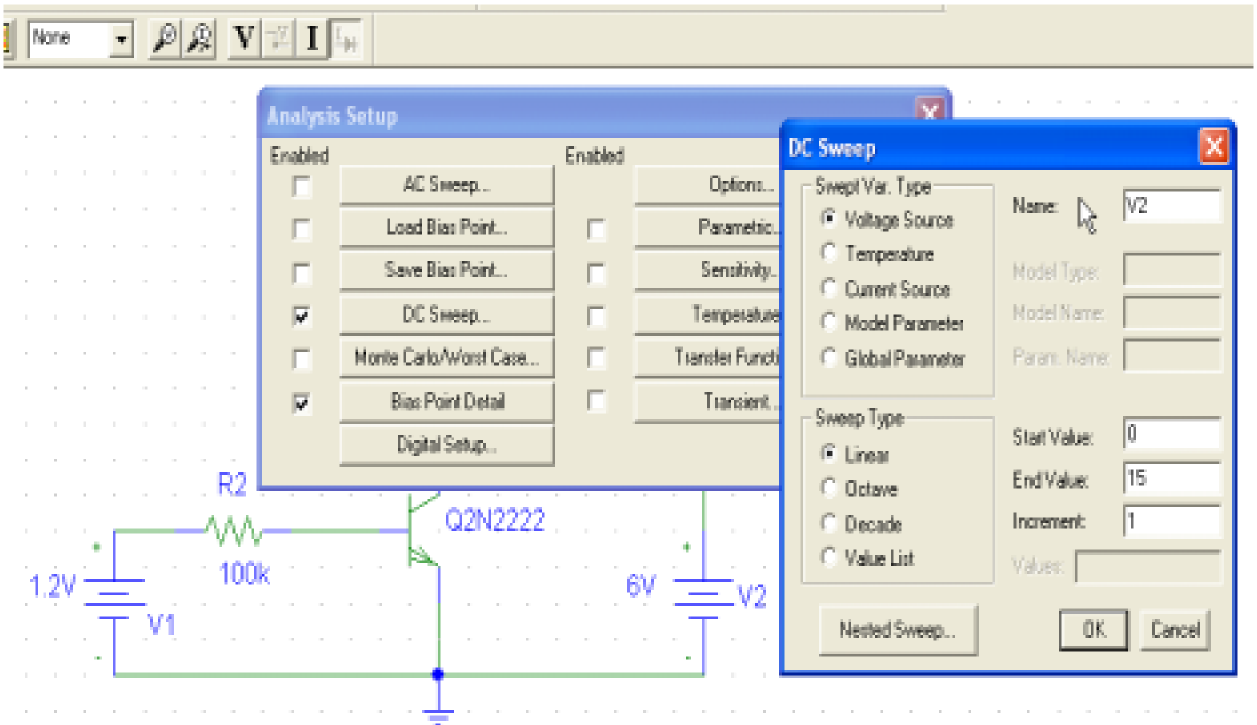


c. DC sweep analysis to find values while changing the voltage V2 from 0 to 15V

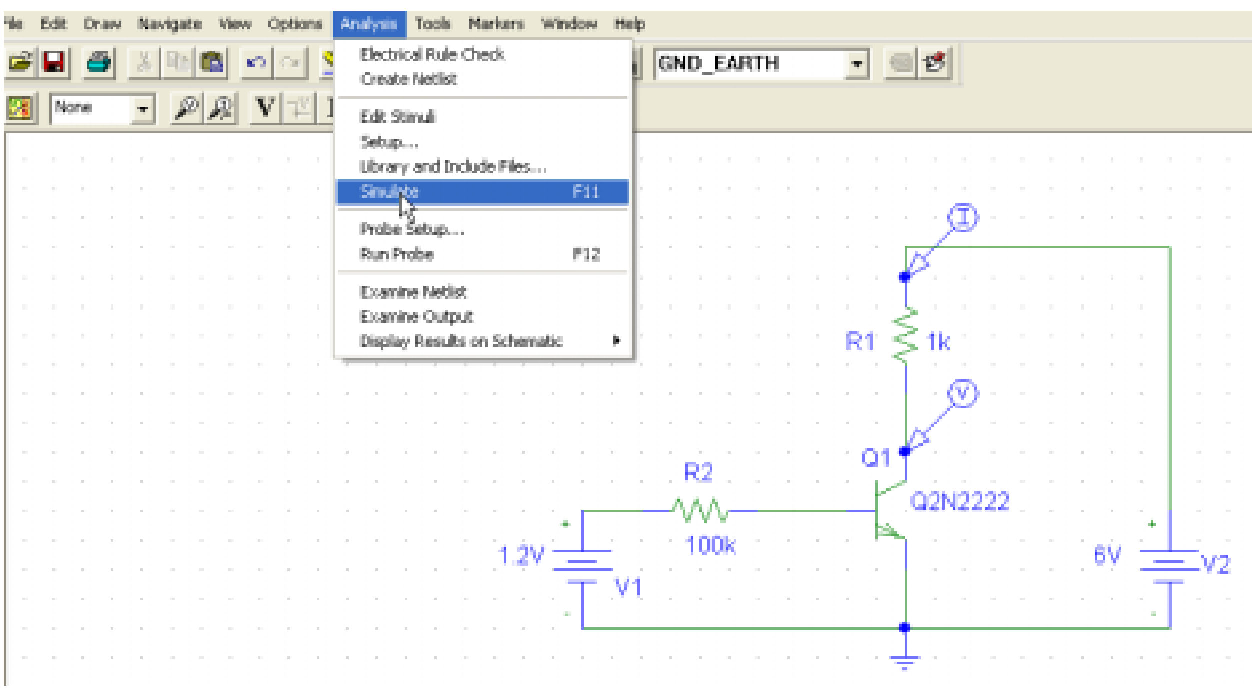
* Set-up for DC Sweep Analysis



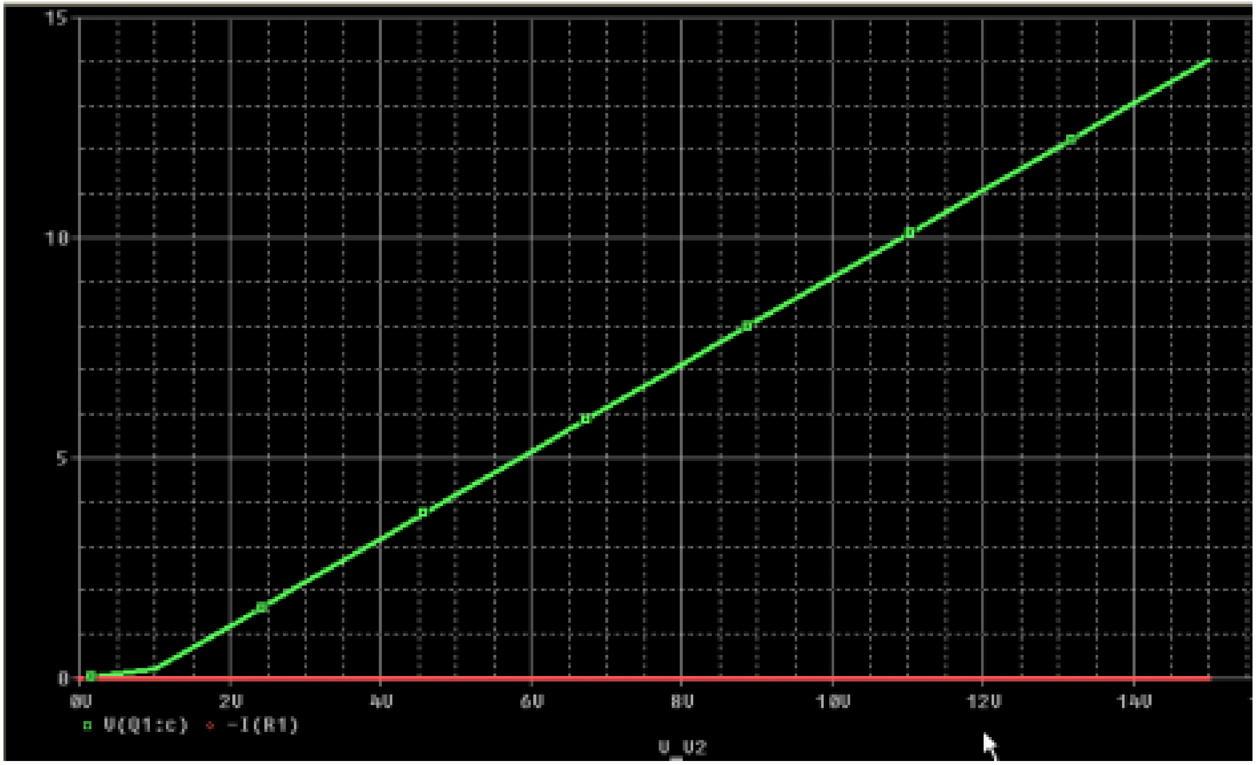
* DC Sweep Setting



<u>d. Run for I_C and V_{CE}.</u>



e. Result 1



f. Result 2 - Details of I_C.