EE1025-Independent Project
BIPOLAR JUNCTION TRANSISTOR

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Abstract

This report illustrates some typical characteristics of Bipolar Junction Transistor.Indeed a semiconductor device which can be used for switching or amplification.It's combination of the two words Transfer- Varistor which is used widely in different modes(common-collector,common-base,common-emitter).Operating in different modes produces various and significant voltage,current,power gains!

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Contents

1 Aim

Understanding the following explicitly considering various parameters and conditions of BJT:-

- NPN and PNP constructions
- COMMON-base,collector,emitter configurations
- The current gain or current transfer ratio for all the configurations .
- Three different regions of transistor (Linear, saturation and cutoff).

2 Introduction

The fusion of these two diodes produces a three layer, two junction, three terminal device forming the basis of a Bipolar Junction Transistor.
The transistors ability to change between these two states enables it to have two basic functions: switching (digital electronics) or amplification (analogue electronics).

Bipolar Transistors are current regulating devices that control the amount of current flowing through them from the Emitter to the Collector terminals in proportion to the amount of biasing voltage applied to their base terminal, thus acting like a current-controlled switch. As a small current flowing into the base terminal controls a much larger collector current forming the basis of transistor action.

NPN and PNP:-
In an NPN transistor, a thin and lightly doped P-type base is sandwiched between a heavily doped N-type emitter and another N-type collector; while in a PNP transistor, a thin and lightly doped N-type base is sandwiched between a heavily doped P-type emitter and another P-type collector.
The principle of operation of the two transistor types PNP and NPN, is exactly the same the only difference being in their biasing and the polarity of the power supply for each type.

COMMON-base,collector,emitter configurations:- In short, the which ever terminal is common i.e is connected two the rest and grounded.
Common Base (CB) Configuration: no current gain but voltage gain
Common Collector (CC) Configuration: current gain but no voltage gain
Common Emitter (CE) Configuration: current gain and voltage gain.

Different regions of transistor Active Region the transistor operates as an amplifier and Ic =
Saturation the transistor is Fully-ON operating as a switch and Ic = I(saturation)
Cut-off the transistor is Fully-OFF operating as a switch and Ic = 0

3 Appartus

These experiments are conducted on an open-source LT-spice with mostly resistors of kΩ $range\ andResistors\ much\ greater\ than\ 1M\Omega$
$cause\ excessive\ thermal\ noise\ and\ make\ the\ circuit\ operation\ susceptible\ to\ significant\ errors\ due\ to\ bias\ or\ leakage\ currents.$
$Transistor(NPN) : -2N3904; (PNP) : -2N3906$
$Voltagesourceswithintherange 0 - 30V.$

4 Theoretical Background

4.1 Common-Base

:-

- The input signal is applied between the transistors base and the emitter terminals, while the corresponding output signal is taken from between the base and the collector terminals.

- The input current flowing into the emitter is quite large as its the sum of both the base current and collector current respectively therefore, the collector current output is less than the emitter current input resulting in a current gain for this type of circuit of 1 (unity) or less.

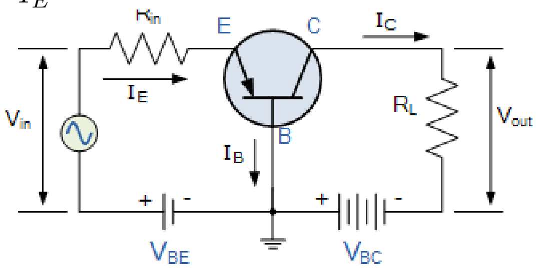
- This type of amplifier configuration is a non-inverting voltage amplifier circuit, in that the signal voltages Vin and Vout are in-phase.

- It's mainly used for photo-diode.

The voltage gain is given as:-

$$A_V = \frac{V_{OUT}}{V_{IN}} = \frac{I_C R_L}{I_E R_{IN}} \tag{1}$$

The α *parameter as the current transfer ratio typically which is less than one* $: -$
$\alpha = \frac{I_C}{I_E}(2)$



4.2 Common-Emitter

:-

- The input signal is applied between the base and the emitter, while the output is taken from between the collector and the emitter.

- The common emitter amplifier configuration produces the highest current and power gain of all the three bipolar transistor configurations. This is mainly because the input impedance is LOW as it is connected to a forward biased PN-junction, while the output impedance is HIGH as it is taken from a reverse biased PN-junction.

- It's mainly used for transistor amplification.

By KCL:-

$$I_E = I_C + I_B \tag{3}$$

α *parameter*

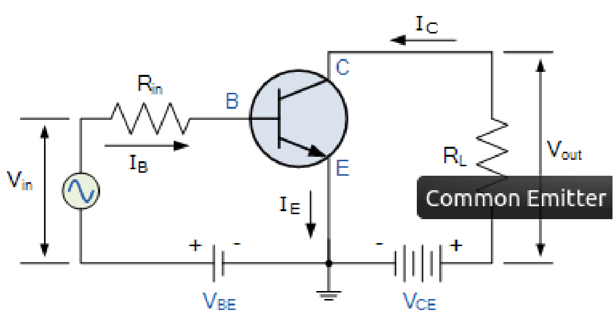
$\alpha = \dfrac{I_C}{I_E}(4)$

β *parameter*

$\alpha = \dfrac{I_C}{I_B}(5)$

Relationship between $\alpha and \beta$.

$\beta = \dfrac{\alpha}{1-\alpha}(6)$



4.3 Common-Collector

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- This configuration is also known as emitter follower configuration because the emitter voltage follows the base voltage.The input signal is applied between the base-collector region and the output is taken from the emitter-collector region.

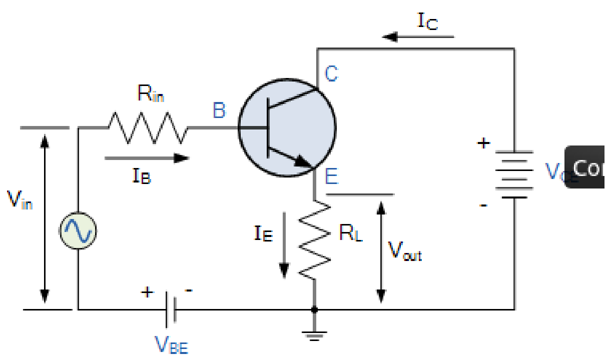
- The voltage gain for this circuit is less than unity but it has large current gain because the load resistor in this circuit receives both the collector and base currents.

- It's mainly used for impedance matching applications because of their high input impedance and in buffers too.

The Gain in this mode is:-

$$A = \frac{I_C + I_B}{I_B} \tag{7}$$

Therefore A $= \beta + 1$.



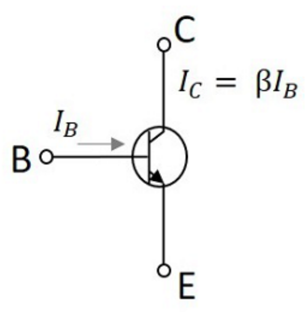
4.4 Regions of Transistor

:-

Active region:- This is the region in which transistors have many applications. This is also called as linear region. A transistor while in this region, acts better as an Amplifier.This region lies between saturation and cutoff. The transistor operates in active region when the emitter junction is forward biased and collector junction is reverse biased. In the active state, collector current is times the base current, i.e.,

$$I_c = \beta I_b$$

(8)

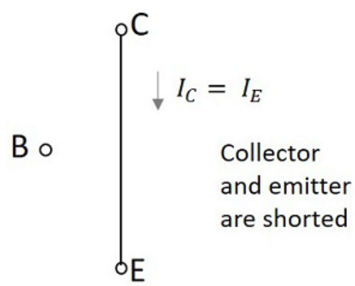


In Active region

Saturation region :- This is the region in which transistor tends to behave as a closed switch. The transistor has the effect of its collector and Emitter being shorted. The collector and Emitter currents are maximum in this mode of operation.The transistor operates in saturation region when both the emitter and collector junctions are forward biased. As it is understood that, in the saturation region the transistor tends to behave as a closed switch, we can say that,

$$I_c = I_e$$

(9)

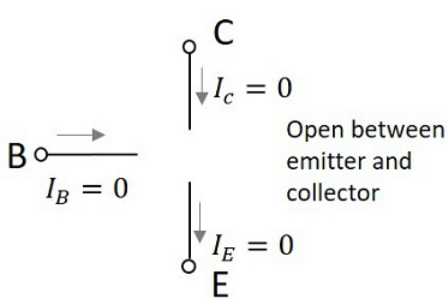


In Saturated region

Cut-off region:- This is the region in which transistor tends to behave as an open switch. The transistor has the effect of its collector and base being opened. The collector, emitter and base currents are all zero in this mode of operation. The transistor operates in cutoff region when both the emitter and collector junctions are reverse biased. As in cutoff region, the collector current, emitter current and base currents are nil, we can write as

$$I_c = I_e = I_b = 0$$

(10)



In Cutoff region

5 Experimentation

5.1 TASK 1 :NPN-COMMON EMITTER

Step-1:-Input resistor with relativley low impedance (1k) compared to load resistance (50k).

Step-2:-Voltage sources are connected with transistor as shown below.

Step-3: For input characteristics ,excite Vbe source with a dc sweep from 0 to 1 V in 0.01 step size.

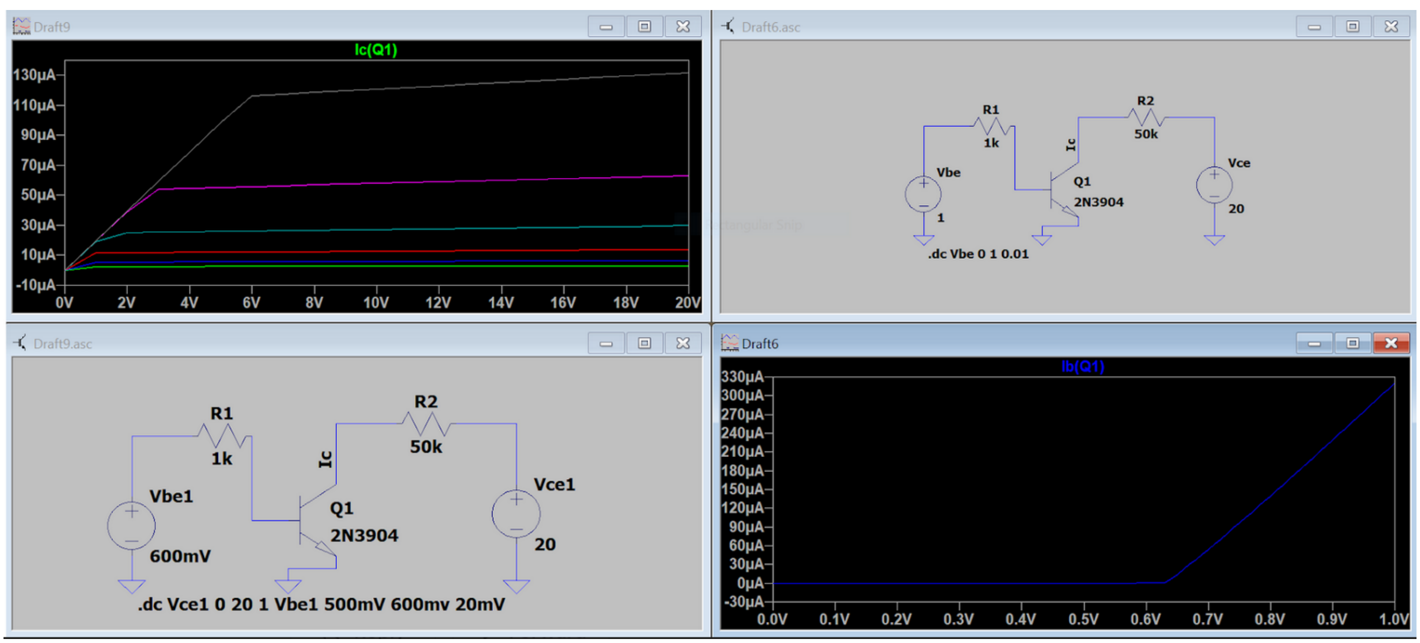
We obtain the input characteristic $I_B\ in\ uA\ range.$

Step-4 : $-For\ output\ characteristics\ ,excite\ Vce\ source\ with\ a\ dc\ sweep\ from\ 0\ to\ 20V\ in\ 1step\ size\ and$

$We\ obtain\ the\ output\ characteristic\ I_C\ in\ uA\ range.$

$At\ 0.6V\ we\ obtain\ I_B\ as\ 0.36uA\ and\ I_C\ as\ 120uA.$

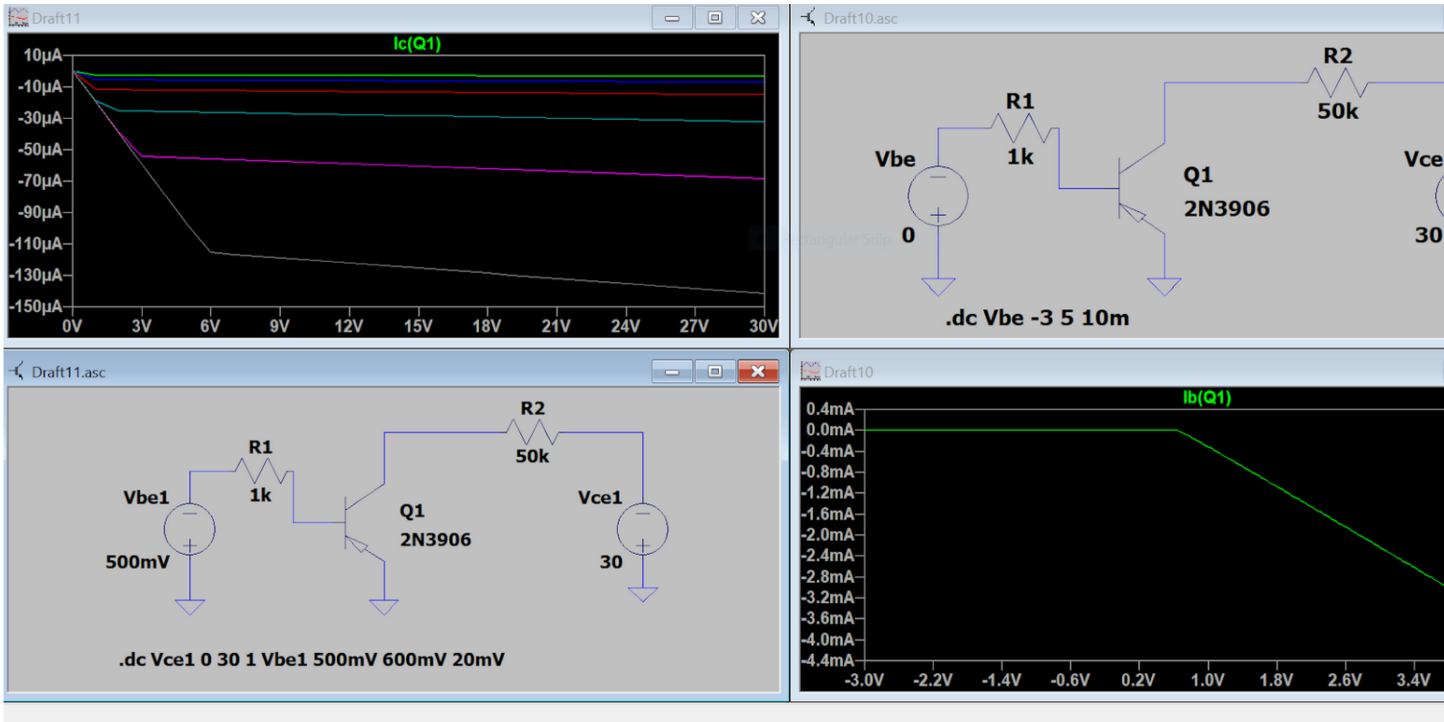
$GAIN = 333.33(\frac{I_C}{I_B})$



5.2 TASK 2:PNP-COMMON EMITTER

Similar input values are given with voltage polarities reversed.
Almost same output values are obtained with 180 degrees rotation in the graph about x-axis.
At 0.6V we obtain $I_B\ as\ -0.33uA\ and\ I_C\ as\ -121uA.$

$GAIN = 366.67(\frac{I_C}{I_B})$



5.3 TASK 3: NPN-COMMON BASE

Step-1:-Input resistor with medium impedance (100) compared to load resistance (2k).

Step-2:-Voltage sources are connected with transistor as shown below.

Step-3: For input characteristics ,excite Veb source with a dc sweep from 0 to 2 V in 0.01 step size.

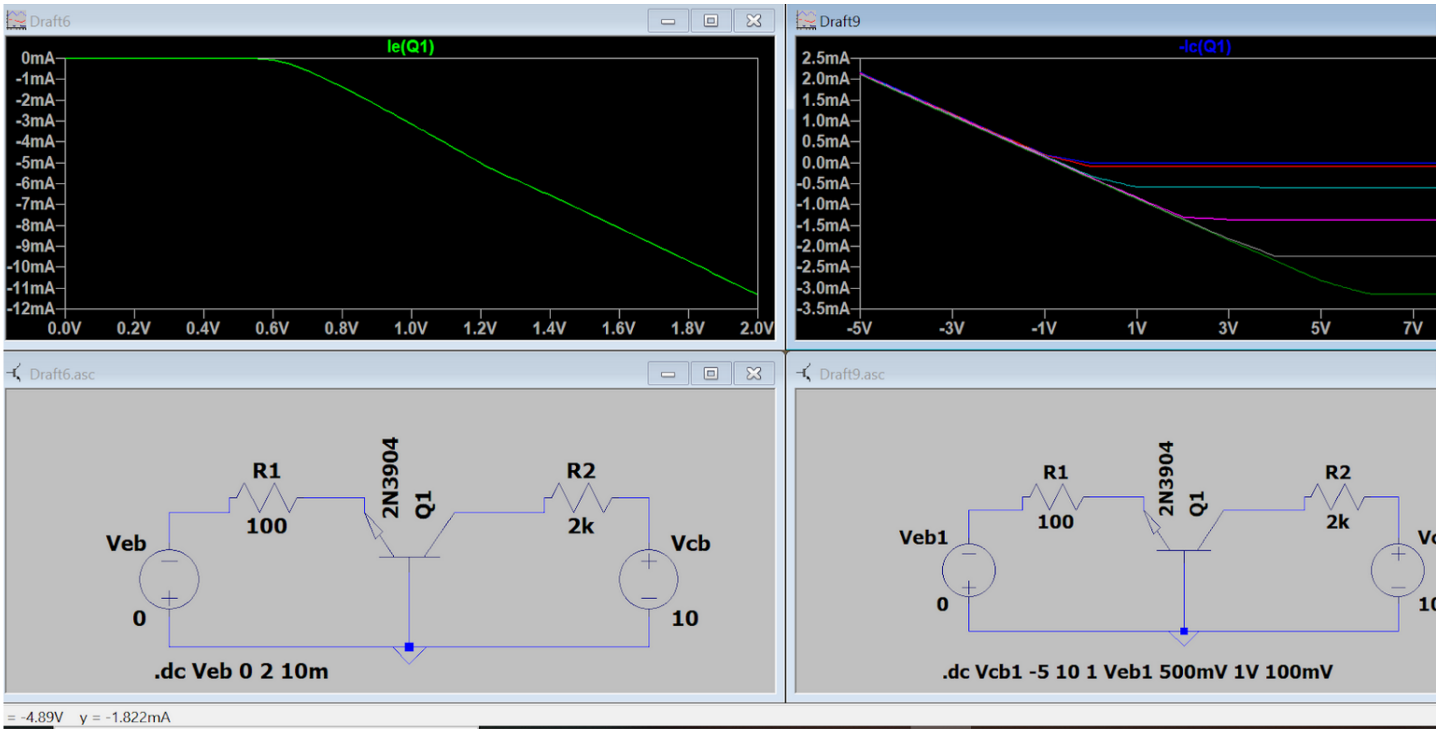
We obtain the input characteristic I_E *in mA range.*

Step-4 : $-$*For output characteristics ,excite Vcb source with a dc sweep from* -5 *to* $10V$ *in* 1*step size and the Veb source with a dc sweep from* $500mV$ *to* $1V$ *in* $100mV$ *step size.*

We obtain the output characteristic I_C *in mA range.*

At $1V$ *we obtain* I_E *as* $-3.2mA$ *and* I_C *as* $-3mA$.

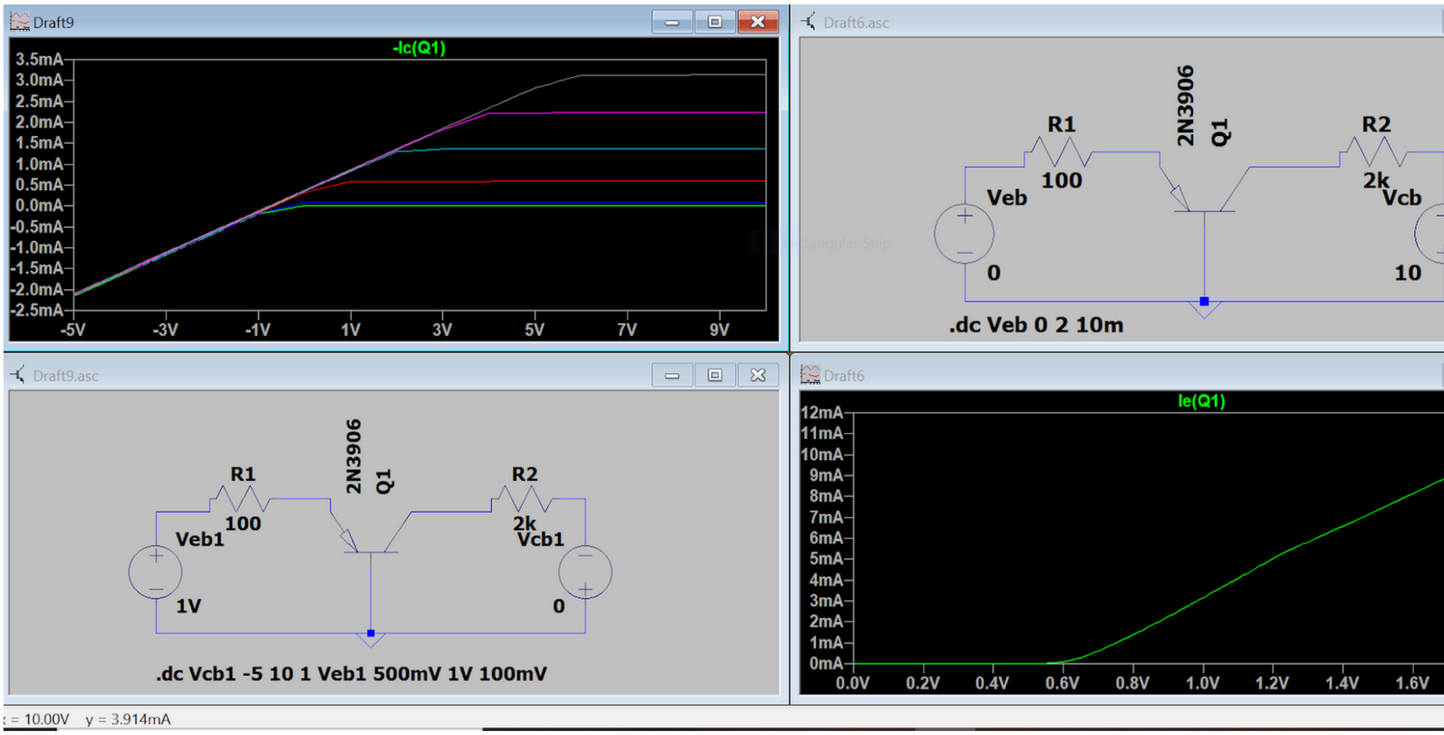
$GAIN = 0.9375(\frac{I_C}{I_E})$



5.4 TASK 4: PNP-COMMON BASE

Similar input values are given with voltage polarities reversed.
Almost same output values are obtained with 180 degrees rotation in the graph about x-axis.
At 1V we obtain I_E $as\ 3.18mA\ and\ I_C\ as\ 3mA.$

$GAIN = 0.9433(\frac{I_C}{I_E})$



5.5 TASK 5:NPN-COMMON COLLECTOR

Step-1:-Input resistor with relativley high impedance (220k) compared to load resistance (2k).

Step-2:-Voltage sources are connected with transistor as shown below.

Step-3: For input characteristics ,excite Vbe source with a dc sweep from 0 to 5V in 0.01 step size.

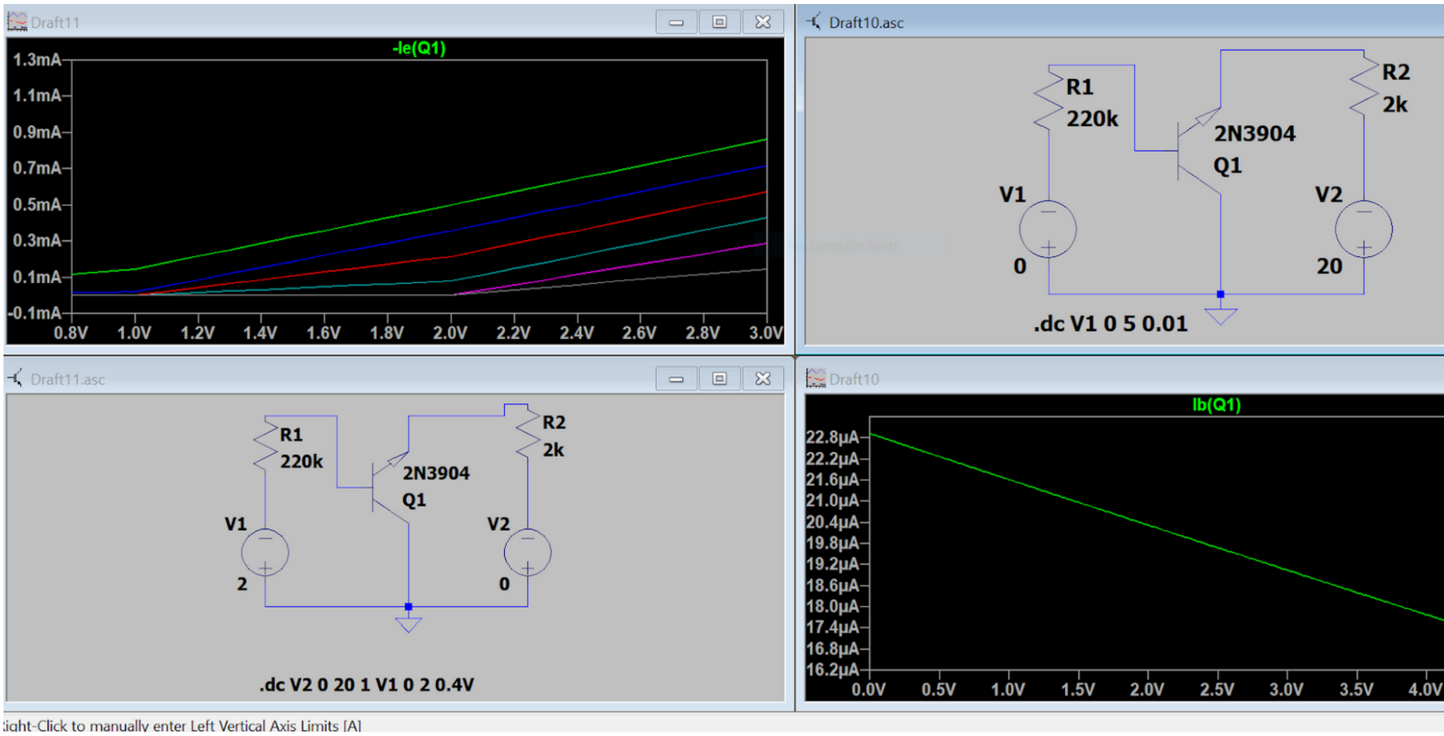
We obtain the input characteristic I_B *in uA range.*

Step-4 : $-For\ output\ characteristics\ , excite\ Vce\ source\ with\ a\ dc\ sweep\ from\ 0\ to\ 20V\ in\ 1 step\ size\ and$

$We\ obtain\ the\ output\ characteristic\ I_E\ in\ mA\ range.$

$At\ 2V\ we\ obtain\ I_B\ as\ 20.108uA\ and\ I_E\ as\ 0.45mA.$

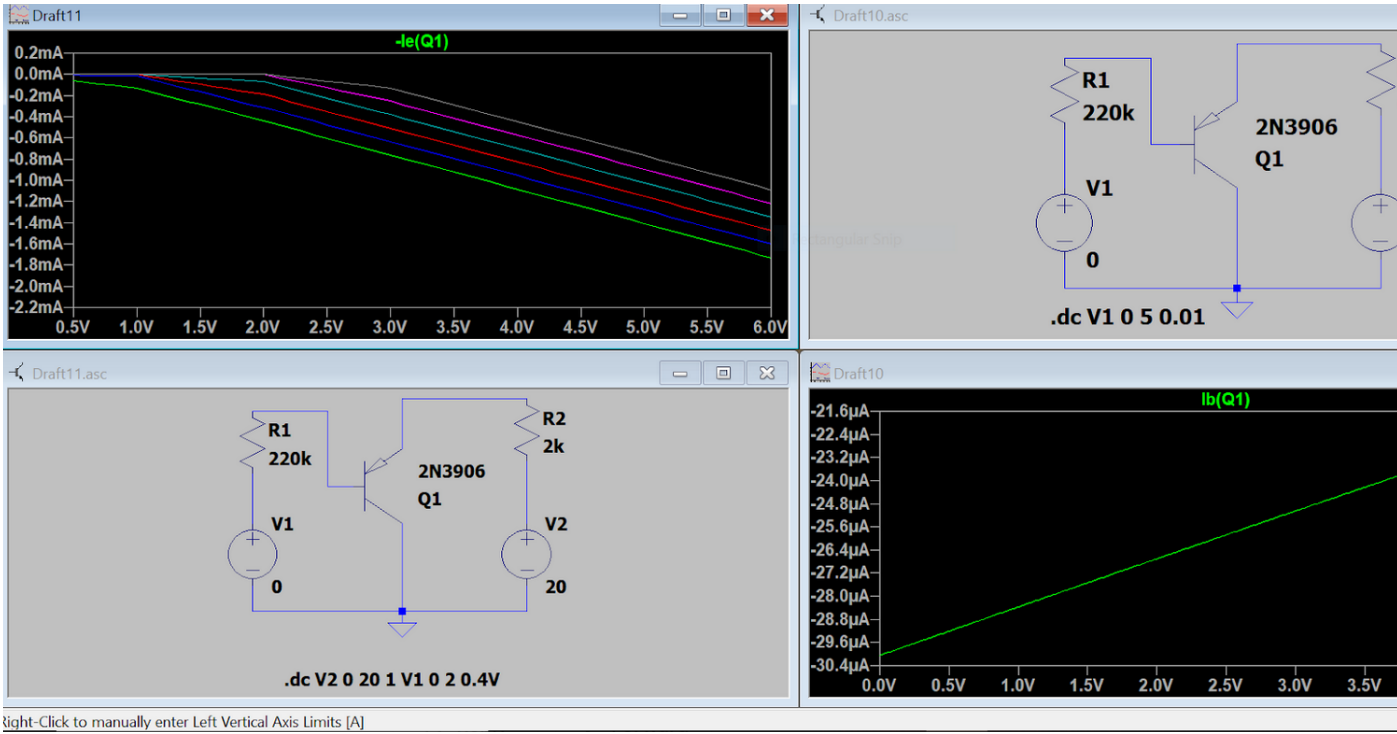
$GAIN = 22.379\frac{I_E}{I_B})$



5.6 TASK 6 :PNP-COMMON COLLECTOR

Similar input values are given with voltage polarities reversed.
Almost same output values are obtained with 180 degrees rotation in the graph about x-axis.
At 2V we obtain I_B $as\ -26.868uA\ and\ I_E\ as\ -0.463mA$.

$GAIN = 17.232(\frac{I_E}{I_B})$



6 Conclusions

- To get approriate current transfers, resistors values should be choosen carefully.

- Generally,NPN Transistor as being normally OFF but a small input current and a small positive voltage at its Base (B) relative to its Emitter (E) will turn it ON allowing a much large Collector-Emitter current to flow.
(switching)

- Small changes in input can lead to large changes in output .(amplification)

Characteristic	Common Base	Common Emitter	Common Collector
Input Impedance	Low	Medium	High
Output Impedance	Very High	High	Low
Phase Shift	0^{o}	180^{o}	0^{o}
Voltage Gain	High	Medium	Low
Current Gain	Low	Medium	High
Power Gain	Low	Very High	Medium

7 References

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