Bipolar Junction Transistor

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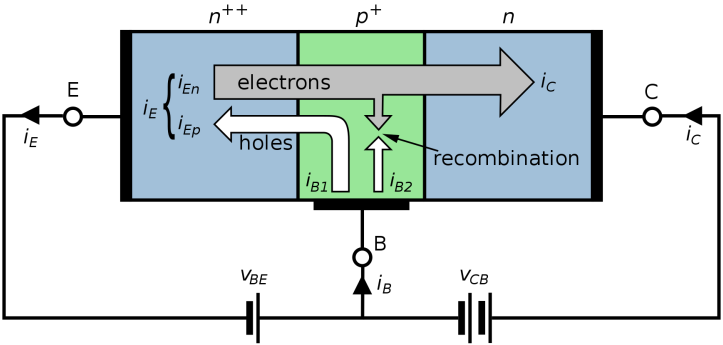
Background Information

* BJT is another type of transistor that is used in high frequency applications (such as RF circuits).
* It has three terminals- Base (B), Collector (C) and Emitter (E).
* A BJT allows a small current injected at its Base to control a much larger current flowing between the Emitter and Collector terminals, making the device capable of amplification and switching.
* Regions of Operation of BJT (npn)

B-E Junction	B-C Junction	Region
Reverse	Reverse	Cut-off
Forward	Reverse	Active
Reverse	Forward	Inverse-active
Forward	Forward	Saturation

Current mechanisms of NPN BJT in Active Region



Note that in NPN BJT, electrons are majority carriers and holes are minority carriers.

Background Information (cont'd...)

DC parameters of BJT:

* Base Transport Factor (α_T) : The fraction of the minority carriers injected into the base that successfully diffuse across the width of the base and enter the collector.

$$\alpha_T = \frac{I_C}{I_E}$$

* Emitter Efficiency (γ) :

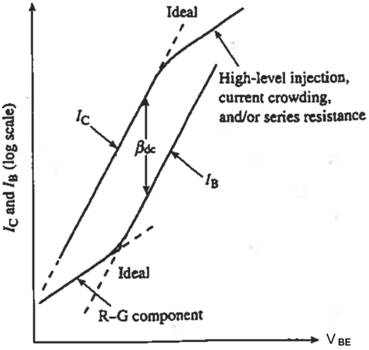
$$\gamma = \frac{I_{En}}{I_E}$$

* Common Emitter Current Gain (β) :

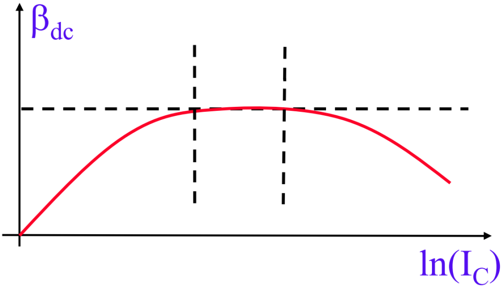
$$\beta = \frac{I_C}{I_B}$$

Gummel Plot

The Gummel plot is the combined plot of the base and collector electric currents I_C and I_B of a BJT v/s base-emitter voltage V_{BE} on a semi-logarithmic scale. This plot is very useful in device characterization because it reflects on the quality of the emitter–base junction while the base–collector bias V_{CE} is kept constant.

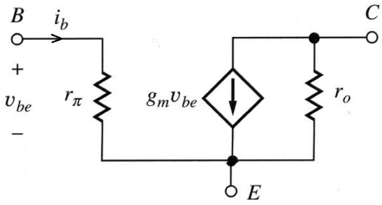


beta dc vs collector current



r_π model

r_π model is a small signal model of BJT that is biased in linear region.



r_π is the input resistance, g_m is the trans-conductance and r_o is the output resistance.

The Problem Statement

In this experiment, we will do the following:

* Measure the forward active and reverse active parameters in common base and common emitter configurations.
* Plot the output DC characteristics in CB and CE configurations.
* Plot the combined I_C and I_B vs V_{BE} of a BJT on a semi-log scale (also called Gummel plot).
* Plot the β_{DC} v/s I_C characteristics for constant V_{BC}.
* Calculate pi model small signal parameters (r_π, g_m and r_o).
* Analyse performance of BJT inverter at different frequencies.

What You Will Need

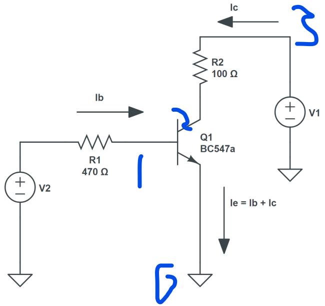
You have been provided with the following model files.

* Q1 - 2N3904c.
* Q3 - BC547a.
* D - BAT54.

Experiment-1 : Part 1) BJT Parameters in CE configuration

Aim of the experiment:

- To plot the output characteristics of CE configuration (I_C v/s V_{CE})
- To determine the parameters α, β, Reverse β (RB) and Early Voltage (V_A) [assume $\gamma = 1$]

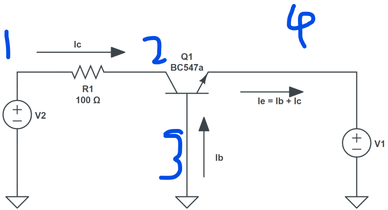


Note : Take I_B from 0 to 1 mA in steps of 0.1 mA.

Experiment-1 : Part 2) BJT Parameters in CB configuration

Aim of the experiment:

- To plot the output characteristics of CB configurations (I_C v/s V_{CB})
- To determine the parameters α and β and Reverse β (RB) assume $\gamma = 1$



Note : Also plot the characteristics for higher voltages.(V $\approx 100V$)
Note : Take I_E from 0 to 10 mA in steps of 1 mA.

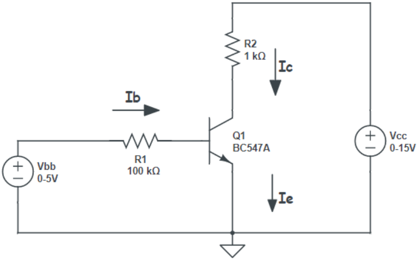
Experiment-2 : Gummel Plot

Procedure:

- Plot collector and base currents against base emitter voltage at a fixed collector to base bias voltage.
- Plot β_{DC} vs I_C.

Explain the reason for β_{DC} modification with collector current (for low and high value of collector current) using Gummel plot.

Experiment-3 : Small Signal Parameters



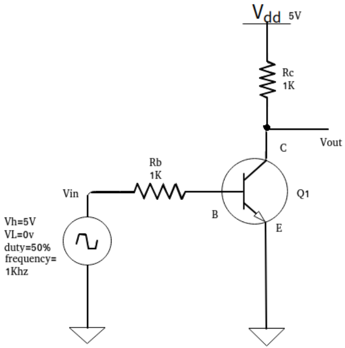
1. Fix the DC bias operating point in Common Emitter circuit as: $V_{CE} = 5\ V$ and $I_C = 4.5\ mA$
2. Calculate the small signal parameters g_m, r_π and r_o.

$$g_m = \frac{I_C}{V_t} \qquad r_\pi = \frac{\beta}{g_m} \qquad r_o = \frac{V_A}{I_C}$$

(here $V_t = 26\ mV$)

Experiment-4 : Switching behaviour

In this section you will simulate the behavior of BJT inverter at different frequencies. Consider the circuit shown below. Write it's netlist and find the turnoff time of BJT?. Use BC547a for this part.



Switching behaviour (cont'd...)

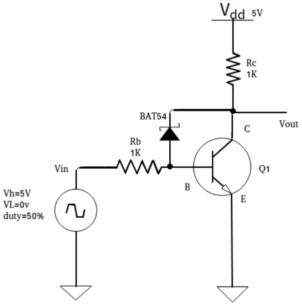
Repeat the above simulation after increasing the frequency of the input square wave to a) 100KHz b) 1MHz. What did you observe?

Now, keep the frequency fixed at 100KHz and replace BC547a with 2N3904c, and find the turnoff time? Which transistor is worst in terms of its switching performance at higher frequencies?

What guesses can you make to explain this behaviour?

Switching behaviour (cont'd...)

You can improve the previous circuit by adding a Schottky diode from base to collector. See the figure given below. Why is it done?



Simulate this circuit using the worst performing transistor (ie, one with largest turnoff time). Write down your observation.