

Bipolar Junction Transistor

Electronic Devices Lab : Experiment 6

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Background Information

BJT is a 3-terminal 2-junction 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

Background Information (continued)

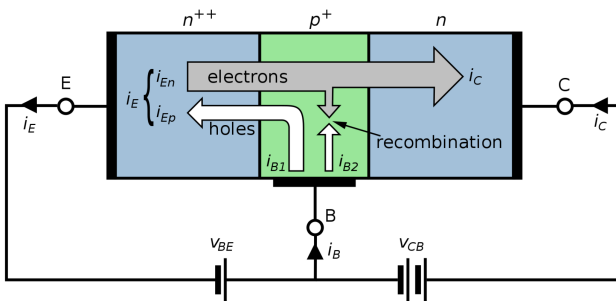


Figure: Current mechanisms in NPN BJT, Active Region

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

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.

$$\alpha_T = \frac{i_C}{i_E} \quad (1)$$

- Emitter Efficiency (γ) :

$$\gamma = \frac{i_{En}}{i_E} \quad (2)$$

- Common Emitter Current Gain (β):

$$\beta = \frac{i_C}{i_B} \quad (3)$$

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_{CB} is kept constant.

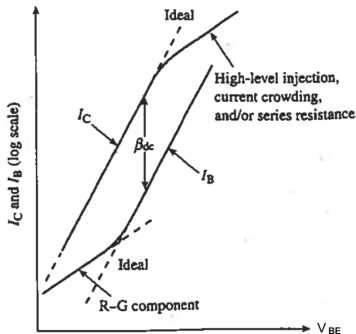


Figure: The Gummel Plot

Extension of Gummel Plot : β_{DC} vs $\ln(I_C)$

It can be seen in the Gummel plot that β_{DC} is high in the middle region where I_C is significantly higher than I_B , whereas β_{DC} is lower at both lower and higher values.

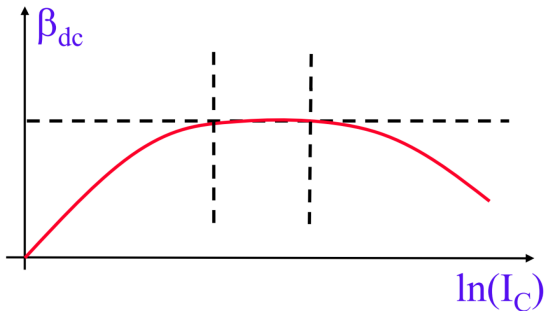


Figure: β_{DC} vs $\ln(I_C)$

r_π model

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

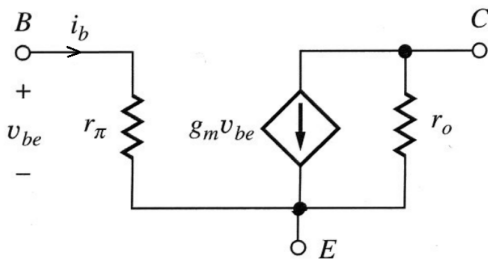


Figure: r_π model of BJT

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

Aim of the experiment

In this experiment, the following tasks are to be done:

- Measure the forward active and reverse active parameters in common base and common emitter configurations.
- Plot the output DC characteristics in CE configuration.
- Plot combined I_C and I_B vs V_{BE} of a BJT on a semi-log scale (also called Gummel plot).
- Plot β_{DC} vs I_C characteristics for constant V_{BC} .
- Calculate r_π model small signal parameters.

Components Necessary

The following components are needed in order to perform the experiment.

- BC547 Discrete BJT
- Resistors : $1k\Omega$, 470Ω
- Potentiometer : $1k\Omega$
- Variable and fixed power supplies, multi-meters
- Breadboard and connecting wires

BC547 BJT Pinout

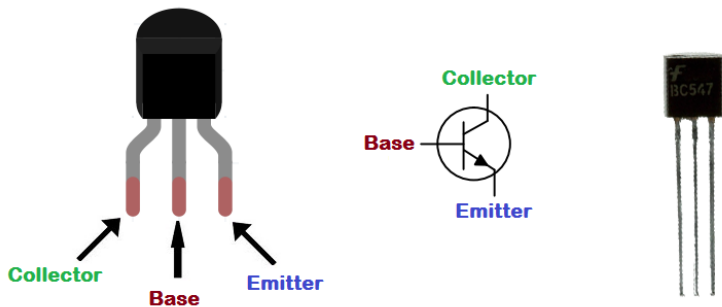


Figure: BC547 BJT Pinout

Part 1) BJT Parameters in CE configuration

- Plot output characteristics of CE configuration (I_C vs V_{CE} for different I_B).
- Determine the parameters α , β and Early Voltage (V_A), assuming $\gamma = 1$.

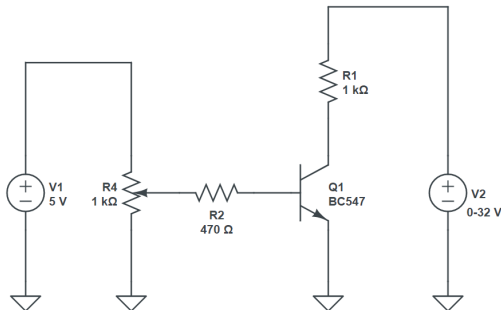


Figure: CE Circuit

Note : Take I_B from $100 \mu A$ to $400 \mu A$ in steps of $100 \mu A$.
CE circuit will be useful for part 4, so better not remove it.

Part 1) BJT Parameters in CE configuration

Important points to remember before performing the experiment.

- You will need 3 multi-meters. One to measure I_B , one to measure V_{CE} and one to measure I_C .
- As you change V_{CE} , the current I_B will change. Hence, you need to use the potentiometer to reset I_B to the required value for each reading.

(Similar care needs to be taken care of for the next part as well)

Part 2) BJT Parameters in CB configuration

- Plot output characteristics of CB configuration (I_C vs V_{CB} for different I_E).
- Determine the parameters α and β assuming $\gamma = 1$.

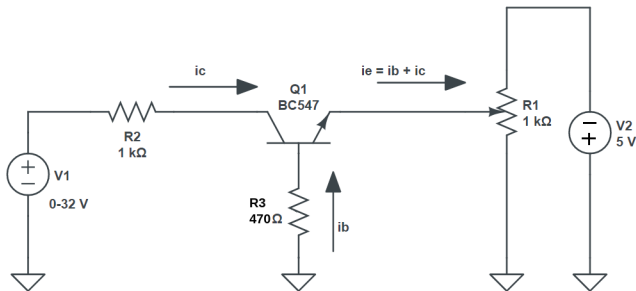


Figure: CB Circuit

Note : Take I_E from 1 mA to 10 mA in steps of 3 mA.

Part 3) Gummel Plot

- Use CB circuit for this part.
- Plot collector and base currents (I_C and I_B) against varying base emitter (V_{BE}) voltage at a fixed collector to base bias voltage (V_{CB}).
- You can fix V_{CB} at 4-5V, but make sure it stays at the same value throughout the experiment. Vary V_{BE} from 0 to 7-8V in order to properly get the Gummel plot..
- Calculate β_{DC} from the above data. Plot β_{DC} v/s I_C .
Explain the reason for the modification of β_{DC} with collector current (for low and high value of collector current) using Gummel the plot.

Part 4) Small Signal Parameters

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

$$g_m = I_C V_t$$

(here V_t is the thermal voltage, which is 26 mV at room temperature)

$$r_\pi = \beta g_m$$

$$r_o = V_A I_C$$