Bipolar Junction Transistor

Electronic Devices Lab : Experiment 6

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Think it. Make it. Prove it.

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

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Background Information (continued)

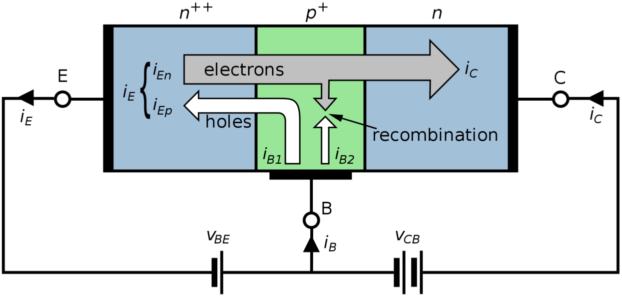

Figure: Current mechanisms in NPN BJT, Active Region

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.

$$\alpha_T = \frac{i_C}{i_E} \tag{1}$$

- Emitter Efficiency (γ) :

$$\gamma = \frac{i_{En}}{i_E} \tag{2}$$

- Common Emitter Current Gain (β):

$$\beta = \frac{i_C}{i_B} \tag{3}$$

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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.

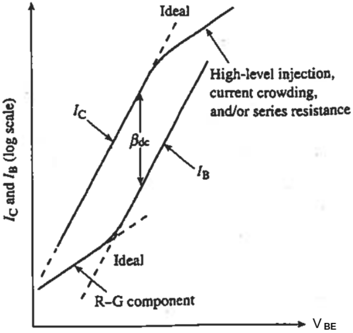

Figure: The Gummel Plot

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.

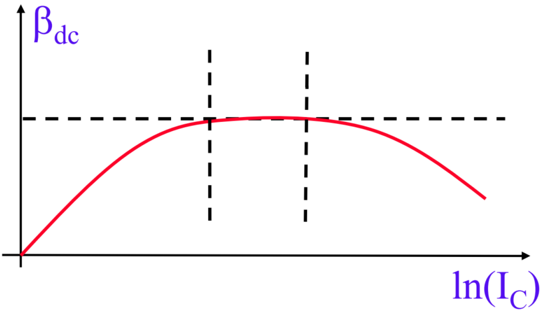

Figure: β_{DC} vs $\ln(I_C)$

r_π model

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

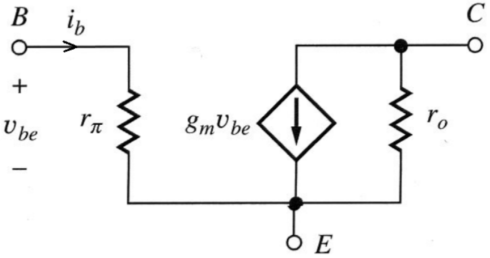

Figure: r_π model of BJT

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

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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.

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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

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BC547 BJT Pinout

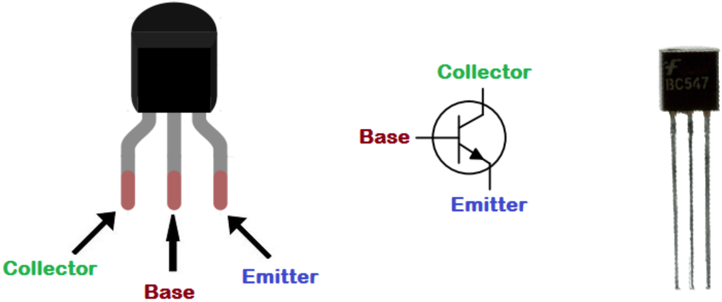

Figure: BC547 BJT Pinout

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 $\gamma = 1$.

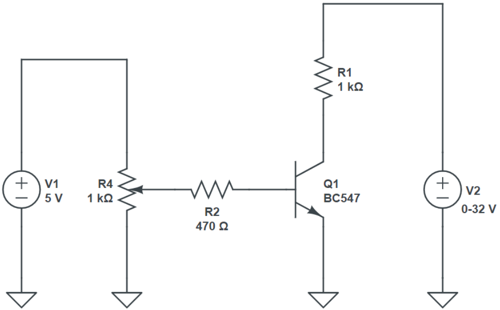

Figure: CE Circuit

Note : Take I_B from 100 μA to 400 μA in steps of 100 μA.
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)

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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 $\gamma = 1$.

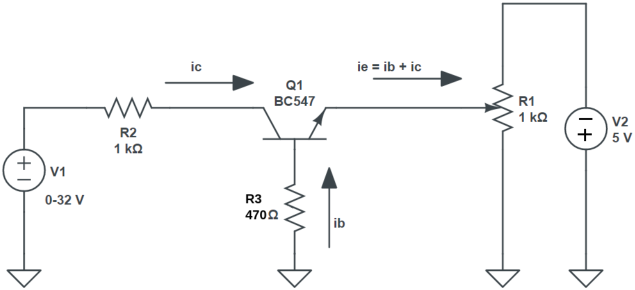

Figure: CB Circuit

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.

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- Use CE circuit for this part.
- Fix the DC bias operating point in Common Emitter circuit as: $V_{CE} = 5V$ and $I_C = 4.5\ mA$
- 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)

$$r_\pi = \beta g_m$$

$$r_o = V_A I_C$$