Lab 9

EE 352
April 11, 2020

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Experiment 1

In this experiment, the 2N3904 BJT was simulated in LTSPICE and the i_c-v_{CE} characteristic curves were obtained. From these curves, the current gain β was obtained at various collector-emitter voltages and base currents. The data is shown in Table 1. At $V_{CE} = 1$ V, the expected gain h_{FE} has a minimum of 70 (1 mA) and 100 (10 mA) and a maximum of 300. In the simulation, a current gain of just under 300 was calculated. At $V_{CE} = 10$ V, the gain exceeded 300, however an h_{FE} value was not listed for this voltage.

Table 1: Data collected from the i_c-v_{CE} curves and the current gains calculated.

V_{CE}	Approx. I_C (mA)	I_C (mA)	I_B (uA)	β (A/A)
1	3	2.9872372	10	298.72372
1	12	11.692551	40	292.313775
10	3	3.2552434	10	325.52434
10	12	12.741939	40	318.548475

For small AC signals, the gain was found to be $\beta = 320.7$. This was determined by fixing $V_{CE} = 10$ V and measuring the collector current I_C at the base currents of 10 and 20 mA,

$$\begin{aligned}\beta_{ac} &= \left.\frac{\Delta I_C}{\Delta I_B}\right|_{V_{CE}=10} \\ &= \frac{6.4623146 - 3.2552434\ \text{mA}}{10\ \text{uA}} = 320.71\end{aligned}$$

At the point $(V_{ce}, I_c) \approx (10\ \text{V}, 12\ \text{mA})$, the output resistance was determined using the slope,

$$\begin{aligned}\text{Slope} &= \frac{12.747768 - 12.736109\ \text{mA}}{10.05 - 9.95\ \text{V}} \\ r_o &= 8576.92\,\Omega\end{aligned}$$

The early voltage V_A was determined using this r_o,

$$\begin{aligned}V_A &= r_o I_c - V_{CE} \\ &= 8.577\,\text{k}\Omega \times 12.74\,\text{mA} - 10\,\text{V} \\ &= 99.28\,\text{V}\end{aligned}$$

Next, the collector-emitter terminals of the transistor were reversed and the reverse current gain β_r was calculated at $V_{CE} = 4$ V and at a base current $I_B = 10\,\mu\text{A}$,

$$\beta_r = \frac{39.77}{10} = 3.98$$

Experiment 2

The transistor was attached in a diode configuration, with the base and collector shorted together. Around a base current $I_B = 20\,\mu\text{A}$, the slope was measured using two data points and the resistance r_π was calculated,

$$\begin{aligned}\text{Slope} &= \frac{20.032921 - 19.958448\ \mu\text{A}}{702.5 - 702.4\ \text{mV}} = 0.000\,744\,731\ \text{A/V} \\ r_\pi &= 1342.77\,\Omega\end{aligned}$$