BJT Small-Signal Parameters

Objectives: To obtain some small signal parameters of Bipolar Junction Transistors (BJTs).

Background: One of the most important applications of BJTs is in amplifiers, where a small input signal is amplified into a large output signal. For such applications, the small-signal (linear) parameters of a transistor are more important than the DC I-V characteristics which were measured in Experiment No.6. To analyze a BJT amplifier circuit, it is convenient to replace the transistor when it is in the *linear* region by its "small-signal equivalent circuit". There are many equivalent circuits in use for BJTs, and one of the most common is the (common-emitter) hybrid -π equivalent circuit. In its full form, this is shown in fig 1(a). At low frequencies, and because $r_{b'c}$ is very large, the equivalent circuit of Fig 1 (b) is often used.

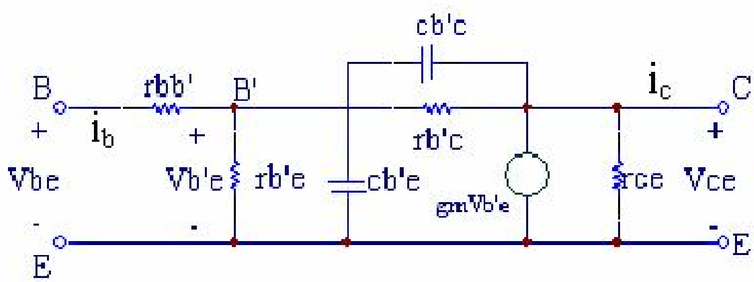

Fig 1(a)

Fig 1(b)

In the circuit of Fig 1 (b), $r_{bb'}$ and $r_{b'e}$ together constitute the input resistance (r_{bb}' is a constant base spreading resistance, whereas $r_{b'e}$ is the resistance of the B-E junction and goes as $r_{b'e}= \frac{kT}{qI_B}$). The transconductance g_m represents the gain of the transistor and r_{ce} is the output resistance. Sometimes the current source $g_m.\upsilon_{b'e}$ is drawn as β i_b with the current gain $\beta = g_m.r_{b'e}$ (show that this is the case).

Experiment: The resistances $r_{bb'}$ and $r_{b'e}$ can be measured by measuring the small-signal (ac) input resistance as a function of the DC base current I_B when the output is AC-short-circuited. A possible set up to use is shown in Fig. 2.

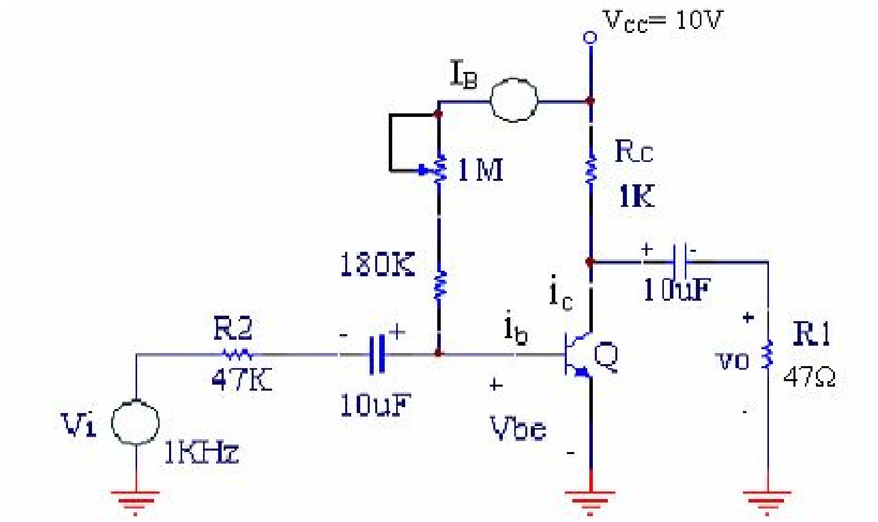

Fig 2

Use an appropriate value of υ_i, such that υ_{be} is about 20-30 mV peak-to-peak.

Ensure that the transistor is in the active region (V_{CE} should be in the range 1-9 V). The ac input resistance is given by

$$r_i = r_{bb'} + r_{b'e} = r_{bb'} + \frac{kT}{qI_B} = \frac{v_{be}}{i_b} \approx \frac{v_{be}}{\frac{v_i - v_{be}}{R_2}}$$

(Note: Measure all voltages on the scope, to ensure that they are good sine waves) Measure r_i for different values of I_B (in the range approximately 6-50μA) which will enable r_{bb}' and $r_{b'e}$ to be extracted. While measuring r_i, you can also measure the small signal β of the transistor which is given by,

$$\beta = \frac{i_c}{i_b} \approx \frac{v_o / R_1}{i_b}$$

A knowledge of β and $r_{b'e}$ (both as functions of I_B) enables you to find out g_m.

To find r_{ce}, the circuit shown in fig.3 can be used. (Note that f=10 KHz in this circuit. Change the value of R_0 till the output voltage becomes half the open-circuit output voltage. Then, $r_{ce} \approx R_0$. Measure r_{ce} as a function of I_C.

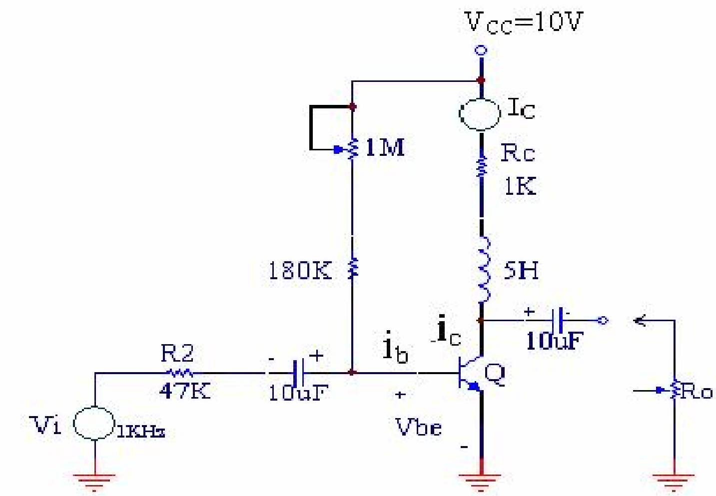

Figure 3