11 LOW FREQUENCY HYBRID – PI MODEL

INSTRUCTIONAL OBJECTIVES

Given a 2N3704 transistor and circuit diagram for a test circuit, you should be able to:

a. construct the test circuit;

b. construct resistor combination to form R_C to obtain the specified values of I_C.

c. measure the data required to compute β_{dc}, β_o, r_π, and g_m at $V_{CE} = 2V$;

d. obtain and interpret natural and log-log plot of the parameters.

1.0 PRELAB ACTIVITIES

1.1 The basis for this experiment is shown by beginning with the formal definition of β_o, adding the small-signal equivalent, and ending with the ratio of small measurable quantities:

$$\beta_o = h_{fe} = \left.\frac{\partial I_C}{\partial I_B}\right|_{V_{CE} = \text{constant}} = \left.\frac{i_C}{i_B}\right|_{V_{CE} = 0} \approx \left.\frac{\Delta I_C}{\Delta I_B}\right|_{\Delta V_{CE} \approx 0}$$

Write similar equations for r_π, and g_m.

1.2 Give two reasons why the parameters determined by this experiment are approximate. (The first reason: Measurement error)

1.3 Data sheets for the 2N3702 and 2N3704 are given at the end of Experiment 9B. (Pages 9-12).
Which maximum free-air specification for the 2N3704 might be violated when working with the circuit?
(Collector-Base Voltage, Collector-Emitter Voltage, Emitter-Base Voltage, etc.)

2.0 INVESTIGATION OF A 2N3704: β_{dc}, β_o, r_π, and g_m vs. I_C at V_{CE}=2V

The circuit shown in Figure 2-1 is designed to safely test a 2N3704 at V_{CE} = 2 Volts. The worst case power dissipation occurs when testing for I_C = 30 mA. I_C = 15 mA, V_{CE} = 2.5 V can occur during that test to produce 37.5 mW. Voltages and currents are well below maximum specifications.

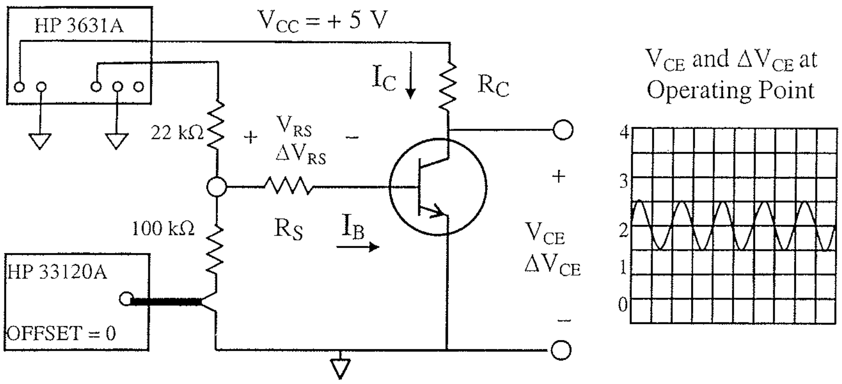


Fig. 2.1. Test Circuit and Monitor Display

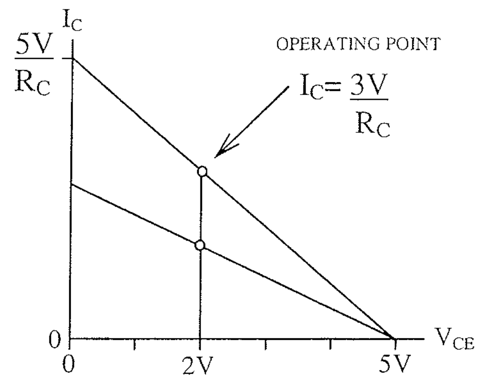


Fig. 2.2. Two Load Lines for the Test Circuit

The goal of the circuit is to measure the low frequency small signal parameters of a 2N3704 transistor as a function of I_C at = V_{CE} = 2 volts. Available equipment yields reasonably accurate results for 1mA $\leq I_C \leq$ 30 mA. A different circuit is required for $I_C \leq$ 1mA.

The strategy is based on holding V_{CC} constant at 5 volts, choosing an appropriate I_C, choosing R_C for the correct load line, adjusting I_B to obtain the desired operating point, and measuring six voltages to obtain the data needed to compute the small signal parameters at that operating point.

An oscilloscope is used as an aid in adjusting $V_{CE} \approx$ 2 V and adjusting ΔV_{CE} to approximately 1 volt peak-to-peak at each operating point. The scope also monitors V_{CE} and ΔV_{CE} during the test. The voltage measurements (three dc and three ac) are made with a DMM.

The nominal values of I_C shown in Table 3-1 are chosen to cover a wide range and facilitate comparison with the h_{FE} vs. I_C curve given in the data sheet for the 2N3704. The equation given in Figure 2.2., I_C = 3V / R_C, is used to compute the nominal values of R_C. All resistor values needed to construct R_C are in the CK-1 kit.
(3kΩ = 1.5 kΩ + 1.5 kΩ, 600 Ω = 1 kΩ || 1.5 kΩ, etc)

PROCEDURE:

(1) Measure $R_S \approx$ 33.0 kΩ and adjust $V_{CC} \approx$ 5.00V. Record this data in Table 3-1.
(2) Construct R_C for the nominal I_C. Measure R_C. Record R_C in Table 3-1. Install R_C.
(3) Observing the scope, adjust the E3631A +25V supply to obtain the operating point and the 33120A amplitude to obtain a display similar to Figure 2.1.
   Set V_{CE} at slightly less than 2 volts. (Allows measurement with 4 digit precision)
   Set ΔV_{CE} at about 1 volt peak-to-peak.
(4) Using the DMM (dc), measure and record V_{CE}, V_{RS}, and V_{BE} in Table 3-1.
(5) Using the DMM (ac-rms),measure and record ΔV_{CE},ΔV_{RS}, and ΔV_{BE} in Table 3-1.
(6) Go to (2)

3.0 EXERCISES

Table 3-1. Measurements

NOMINAL		DMM MEASUREMENT								
		DC			DC			AC		
I_C (mA)	R_C (Ω)	V_{CC} (Vdc)	R_S (Ω)	R_C (Ω)	V_{CE} (Vdc)	V_{RS} (Vdc)	V_{BE} (Vdc)	ΔV_{CE} (Vrms)	ΔV_{RS} (Vrms)	ΔV_{BE} (Vrms)
0.5	6000									
1.0	3000									
2.0	1500									
5.0	600									
10.0	300									
30.0	100									

Table 3-2. Calculations

I_C (mA)	I_B (µA)	β_{dc}	ΔI_C (mA)	ΔI_B (µA)	β_o	r_π (Ω)	g_m (mmho)
$\frac{V_{CC} - V_{CE}}{R_C}$	$\frac{V_{RS}}{R_S}$	$\frac{I_C}{I_B}$	$\frac{\Delta V_{CE}}{R_C}$	$\frac{\Delta V_{RS}}{R_S}$	$\frac{\Delta I_C}{\Delta I_B}$	$\frac{\Delta V_{BE}}{\Delta I_B}$	$\frac{\beta_o}{r_\pi}$

3.1 Construct the circuit of Figure 2-1. Be sure to set $V_{CC} \approx 5.00$ V and don't change it! Follow the procedure given in Section 2.0 to obtain the data for Table 3-1.

*3.2 Compute the values for Table 3-2 using the data in Table 3-1.

*3.3 Plot β_{dc} and β_o vs. I_C (on the same graph) using a natural scale.
Plot β_{dc} and β_o vs. I_C (on the same graph) using a log-log scale.

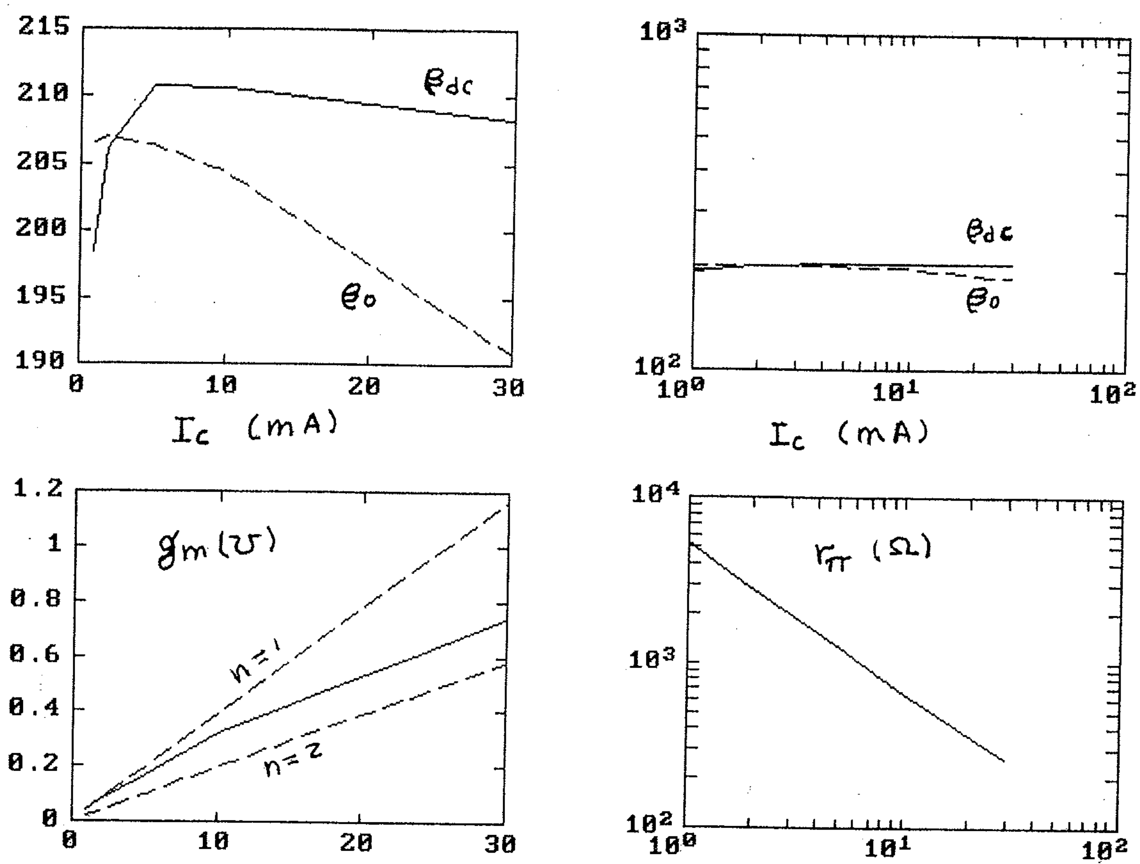
*3.4 Plot r_π vs. I_C using a log-log scale.

*3.5 Plot g_m vs. I_C using a natural scale.

3.6 Discuss the β_{dc} and β_o vs. I_C plots. How do β_{dc} and β_o vary with I_C in the region above 10 mA? How does the maximum value of β_o in this region compare with the value of β_{dc} at 30 mA ? How does the h_{FE} vs. I_C plot on the data sheet resemble the β_{dc} vs. IC log-log plot ?

3.7 Discuss the r_π vs. I_C and g_m vs. I_C plots. Do these parameters vary as expected

* The measurement can be accomplished in an hour. The computations can be done manually in about 20 minutes, the plots will take longer. See program for Student Matlab (DOS) on next page.

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% DOS Student Matlab Program to Plot Hybrid-Pi Parameters
clear;
clg;
load data;            % Filename for data = data.mat.
                      % All units in volts or ohms.
                      % Format for each row of data.mat:
                      % VCC, RS, RC, VCE, VRS, VBE, vce, vrs, vbe
                      %
[N,M]=size(data);     % Automatic sense # rows = N,  M = 9 or error.
for J= 1:1:N,                                      % For Data Row J
    Ic(J,1)=(data(J,1)-data(J,4))/data(J,3);       % Ic vector
    Ib(J,1)=data(J,5)/data(J,2);                   % Ib vector
    Bdc(J,1)=Ic(J,1)/Ib(J,1);                      % BETAdc vector
    ic(J,1)=data(J,7)/data(J,3);                   % ic vector
    ib(J,1)=data(J,8)/data(J,2);                   % ib vector
    Bo(J,1)=ic(J,1)/ib(J,1);                       % BETAo vector
    rpi(J,1)=data(J,9)/ib(J,1);                    % rpi vector
    gm(J,1)=Bo(J,1)/rpi(J,1);                      % gm vector
    Vbe(J,1)=data(J,6);                            % Vbe vector
end;
IC = 1000 * Ic;                                    % scale to mA
subplot(221), plot(IC,Bdc,IC,Bo,'--');
subplot(222), loglog(IC,Bdc,IC,Bo,'--');
subplot(223), plot(IC,gm,IC,38.9*Ic,'--',IC,19.45*Ic,'--');
subplot(224), loglog(IC,rpi);
end;
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