LAB 3

Transistor Fundamentals

Reading: Malvino: Ch. 6 through Ch. 9.

You will study bipolar junction transistors (BJTs) in this lab. Most of the exercises will be done with the 2N3904 NPN transistor. The terminal connections are illustrated in Fig. 3.1 below.

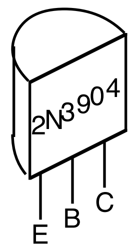

Fig 3.1

1. Using Transistor Curve Tracers to Measure Operating Characteristics

a) Determine the collector characteristics, I_C vs. V_{CE} with I_B as a parameter. The 571 curve tracer has a printer interface to let you make a hard copy of your curves. Save the curves in your lab book and keep the particular transistor belonging to those curves. Suggested settings for the curve tracer are listed below.

Function	Acquisition
NPN	
Vce max	20 V
Ic max	20 mA
Ib/step	10 μA
Steps	10
R load	100 Ohm
P max	2 Watt

The series resistor is to limit power dissipation. The maximum ratings are

V_{CE}	40 V
V_{CB}	60 V
V_{EB}	6 V
I_C	200 mA

The slope of the collector curves is a measure of how imperfectly the transistor acts as a current source. The parameter h_{oe} is called the output admittance. In the h-equivalent model of the transistor the collector-emitter output is modelled by an ideal current source in parallel with a resistance; h_{oe} is the inverse of this resistance. Measure h_{oe} from your curves. What is the accuracy and over what range of V_{CE} is this result valid?

b) Plot the transfer characteristics I_C vs I_B.

Use the cursor to read values of I_C for the ten I_B values at V_{CE} = 0, 5 and 15 V. Plot these values on a graph.

Calculate the dc current gain $h_{FE} = \beta_{dc}$ = at I_C = 1 mA, V_{CE} = 5 V.

Compare this value of β_{dc} with that measured by the multi-meter. At this point find another transistor with β_{dc} at least 20% different. Note the values of h_{FE} measured by the multi-meter for both transistors, label them and keep for later use.

c) Measure I_C vs. V_{BE}

Connect the base and collector of the first transistor together as shown in Fig. 3.2. Measure its diode characteristic curve using the method of Lab 2. This will give you I_C vs V_{BE} . The effective emitter resistance should be approximately $r_e' = (25\text{ mV})/I_C$. How closely does the transistor obey this relationship?

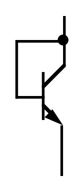

Fig 3.2

2. Transistor Biasing

a) Assume that is V_{BB} = 9V in the circuit of Fig 3.3. For homework you should calculate what values of R_B will

i) put V_C at 7.5 V,

ii) put V_C at 10 V

iii) put V_C at 1 V.

Note: Use the breadboard supply for V_{CC} and an external supply or a battery for V_{BB}

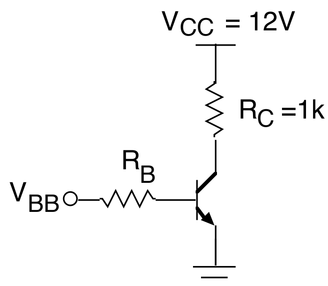

Fig 3.3

b) Find standard resistor values closest to those calculated in (a), build the circuit and measure V_C for each case. Make a table of calculated R_B, actual R_B and the expected and actual values of V_C. Mark any unexpected deviations from what was expected and hazard and explanation.

Now replace the transistor with the other one with a different β_{dc}. Compare V_C with that of the first transistor leaving R_B the same in both cases. Does the change match your predictions based on the measured values of β_{dc}?

c) Investigate how well the transistor circuit acts as a current source. Measure the current flowing through the collector resistor for R_C = 500 Ω and 2 kΩ. Model the response with a Norton equivalent circuit.

d) Design and build an emitter-biased LED driver to switch off and on with 0 and 5V.

e) Design a voltage divider biased circuit (Fig 3.4) with the following specifications: V_{CC} = 12 V, I_C= 2 mA, V_C = 7.5 V and V_E = 1 V. Build your circuit. Compare calculated and measured values V_{BB}, V_E and V_C for both of your transistors.

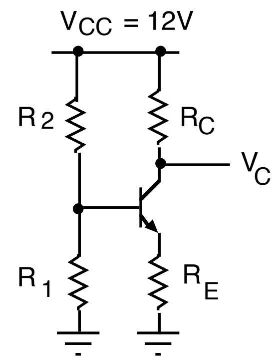

Fig 3.4

Homework Problems

1. Calculate the resistor values for part 2(a).

2. Design the voltage-divider bias circuit of part 2(e) and the write a computer program or make a spreadsheet that calculates the resistor values. Your input parameters are V_{CC}, I_C, V_C and V_{CE}.

3. Do the algebra you will need for part 2(c) to obtain the Norton equivalent circuit from the currents obtained using the two values of R_c; i.e., derive the equations for I_N and R_N in terms of the quantities you will measure.