Laboratory #3

DC Characteristics of Bipolar Junction Transistors

I. Pre-Laboratory Assignments

1. Assuming $\beta = 100$, compute the voltages V_C, V_B, and V_E for the circuit shown in Fig. 3. Also determine the currents I_C, I_E, and I_B.
2. For the circuit shown in Fig. 4, compute and plot V_{CE} and V_{BC} versus V_I for V_I between 0 and 12 V. Assume $\beta = 100$. In your plot, identify the active, saturation, and cutoff regions of operation for the transistor. Verify your plot using Keysight's *Advanced Design System* (*ADS*) first with generic transistor with $\beta = 100$ and then with a device model for a 2N2222A.
3. If the output of the circuit shown in Fig. 4 is taken as V_{CE}, this circuit is called an "inverter." Explain why.
4. For the circuit shown in Fig. 6, compute and plot V_{EC} and V_{CB} versus V_I for V_I between 0 and 12 V. Assume $\beta = 100$. In your plot, identify the active, saturation, and cutoff regions of operation for the transistor. Verify your plot using *ADS* first with a generic transistor with $\beta = 100$ and then with a device model for a 2N2907.

II. Laboratory Experiments

An *npn* bipolar junction transistor

1. A simple model for an *npn* BJT is shown in Fig. 1. The two *pn* junctions in the transistor are shown as back-to-back diodes. While this simple model has little practical use, it can be useful when deciphering if the "magic smoke" is still inside the package (i.e., if the transistor has not been catastrophically electrically damaged).

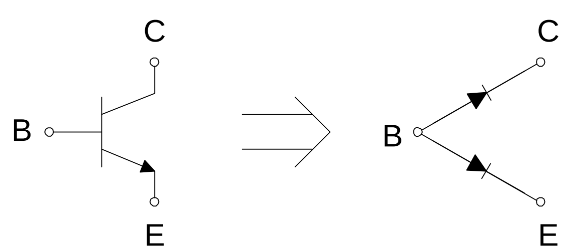

Figure 1 Simple model of an *npn* BJT useful for diagnostic purposes.

   (a) Attach a DMM to various combinations of leads from the 2N2222A BJT and measure the resistances R_{BC} and R_{CB}; R_{BE} and R_{EB}; R_{CE} and R_{EC}. The pin out of the TO-92 package is shown in Fig. 2 below. Explain why these resistance measurements are consistent with your expectations for these two *pn* junctions.

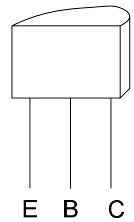

Figure 2 Pin out for the BJT in a TO-92 package (<u>both</u> *npn* and *pnp*).

(b) Construct the circuit shown in Fig. 3. Measure V_C, V_B, and V_E as well as the resistances R_C, R_B, and R_E.

(c) From your measurements in part 1(b), calculate V_{BE}, I_E, I_C, I_B, α, and β. Compare β with that reported in the data sheet for the device. (Note that $\beta = h_{FE}$ in some data sheets.)

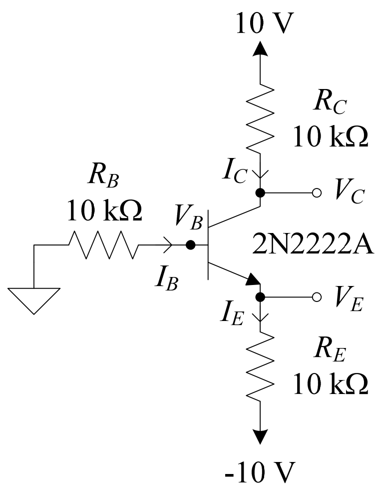

Figure 3 DC biased *npn* BJT circuit.

An *npn* BJT inverter

2. Construct the *npn* BJT inverter circuit shown in Fig. 4.
   (a) Vary V_I between 0 and 12 V and record V_C, V_B, and V_E.
   (b) Using your data from part 2(a), plot V_{CE} versus V_I. In your sketch identify the active, saturation, and cutoff regions of operation for the transistor.
   (c) Adjust V_I to 18 V, which should be far into the saturation region for the BJT. Accurately measure I_C and I_E and deduce β. Compare with your measurements in part 1(c). They should be very different. Explain why.
   (d) From your data in part 2(a), plot V_{BC} versus V_I. Identify the active, saturation, and cutoff regions on this plot.

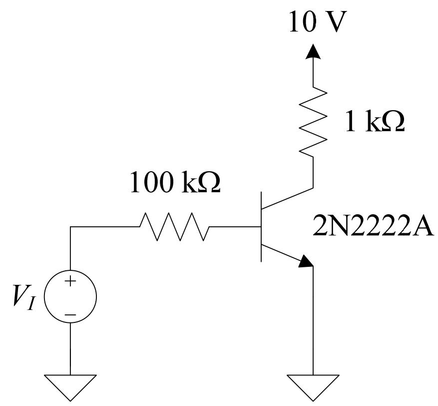

Figure 4 An *npn* BJT inverter circuit.

A *pnp* BJT inverter

3. In this section we will repeat portions of parts 1 and 2 of the Laboratory Experiments, but for a *pnp* BJT.
   (a) Repeat part 1(a), but using the supplied 2N2907 *pnp* transistor. The simple back-to-back diode model for this type of transistor is shown below in Fig. 5. The pin out of this transistor is the same as that shown in Fig. 2.

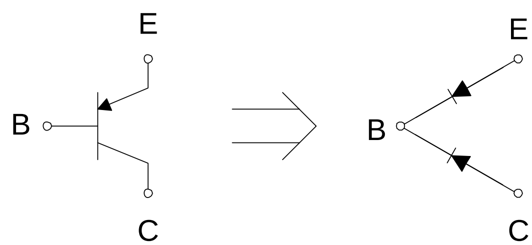

Figure 5 Simple model of a *pnp* BJT useful for diagnostic purposes.

   (b) With the following modifications, repeat all the measurements and plots in part 2, but using a *pnp* transistor as shown in Fig. 6 below (note the polarity of V_I). For part (b), plot V_{EC} versus V_I; for part (d), plot V_{CB} versus V_I. Otherwise, follow the same instructions in part 2.

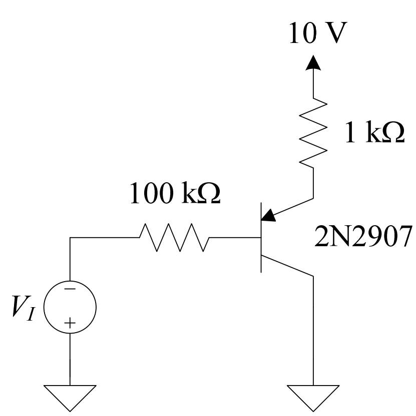

Figure 6 A *pnp* BJT inverter circuit.