Lab 7
BJT IV Characteristics and common-emitter amplifier

Pre-Lab

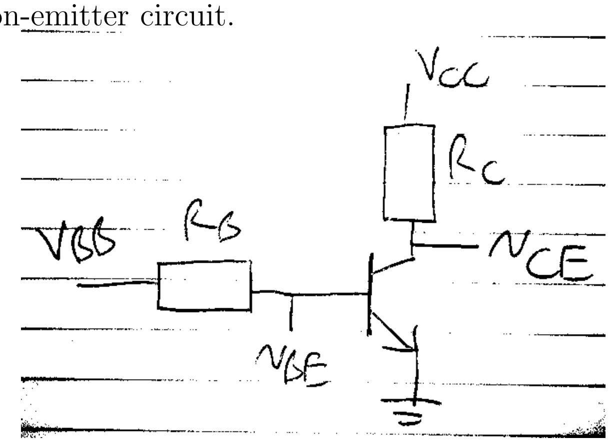
1. Find the data sheets for the 2N3904 and 2N3906 BJT transistors. What is the maximum power dissipation that this component can tolerate? Write an expression for the power dissipation in terms of I_C, v_{CE}, and β. Note that h_{FE} on the data sheet is what we call β in class.
2. Compute the value of R_C in step 3.
3. For step 6 prepare some values for I_B that you will try (larger and smaller than 0.1 mA), estimate corresponding I_C, pick values for R_C, and verify the power dissipation.
4. Estimate the value of V_{BB} in step 10.
5. Compute the theoretically expected small-signal gain in step 12.
6. Produce a tentative answer to the question in step 16.
7. Compute a rough estimate of the value for R_B in step 17, and the size of C and the frequency f in step 18.

In this lab we will look at the IV characteristics of BJTs and build and characterize a simple voltage amplifier.

BJT common-emitter characteristics

In this section we will look at the IV characteristic of a BJT.

1. Build the common-emitter circuit.



2. Choose R_B such that the maximum base current is approximately 0.1 mA when $V_{BB} = 10\,\text{V}$. What is, approximately, the maximum corresponding value of I_C?

3. Next, attach 10 V to V_{BB} and to V_{CC}. Pick a value R_C for which you expect $V_{CE} = 5\,\text{V}$.

4. What are the actual values of I_B and I_C? What is β? Compare with the data sheet. What is the power dissipation in the BJT?

5. Next, map out the i_C versus v_{CE} characteristic for several representative values of I_B in the following way. Use the power supply to control I_B by varying V_{BB}, and attach the function generator to V_{CC} to supply a low-frequency triangular wave ranging between 0 V and 20 V. Attach one probe to v_{CE} and the other to V_{CC}. i_C is now proportional to the difference between probe voltages.

6. For several (3-5 total depending on how fast you progress) values of I_B, both smaller and larger than 0.1 mA (you may need to pick a different R_B), do the following: Estimate the maximum value of I_C (when in active mode, using the β you found previously). Pick R_C such that most of V_{CC} falls across v_{CE}. IMPORTANT: Before turning on your circuit verify that the maximum power dissipation, $(v_{CE} \times i_C)_{\text{MAX}}$ does not exceed the maximum power dissipation of the BJT. You can increase R_C, or reduce the peak of V_{CC}, either of which reduce the maximum value of v_{CE}.

7. Plot $i_C \sim V_{CC} - v_{CE}$ as a function of v_{CE}. Label saturation and active regions. Do you notice the slop of i_C as a function of v_{CE}? If so, use that to estimate the Early voltage.

8. Verify that if you reduce V_{BB} enough the BJT enters cutoff mode where $i_C \approx 0$ and $v_{CE} \approx V_{CC}$. At what value of V_{BE} is cutoff mode reached? Is this what you expect? If you have time, connect the triangular wave to V_{BB} and a fixed voltage to V_{CC} and plot v_{CE} as a function of V_{BB}. Is it as you expect?

The common-emitter amplifier

In this section you will experiment with the common-emitter amplifier.

9. Keeping the circuit from before, make $R_B = 10\,\text{k}\Omega$, $R_C = 1\,\text{k}\Omega$, connect $V_{CC} = 10\,\text{V}$, and connect the function generator to V_{BB}.

10. What value of V_{BB} do you expect will produce $i_C = 5\,\text{mA}$? Set V_{BB} to that value and measure i_C. What value of β does this imply?

11. Now with the function generator signal set to its minimum amplitude adjust the function generator offset to get close to $I_C = 5\,\text{mA}$. Find β again. It should be the same as before, or at least very close.

12. Connect AC coupled probes to the input, v_B, and the output, v_C. Plot the AC input, v_b, and output, v_c, together. What is the small-signal voltage gain? Compare with a theoretical prediction.

13. Increase the amplitude of the input as much as possible until the output begins to clip, then back off, and measure the gain again. Plot input and output in XY mode. How linear is the relationship?

14. Increase the amplitude again such that clipping is present approximately 25-50% of the time, and adjust the offset to produce equal amount of clipping at the top and bottom.

15. Without moving the probe AC coupled to v_C, plot v_{BE} and v_{CE} (DC coupled) together with v_c (AC coupled).

16. Use the preceding plots to explain what causes the clipping at both the top and the bottom of the output.

Capacitive coupling in the common-emitter amplifier

In this section we will bias the amplifier and then capacitively couple the input signal.

17. In the same circuit, connect V_{BB} to V_{CC}, and resize R_B to preserve $I_C = 5\,\text{mA}$.

18. Now couple a signal, v_s, from a function generator to the base through a large capacitor. The capacitor should be large enough such that $R_B C \ll \frac{1}{f}$.

19. Notice that at this point the input signal is controlling i_b not v_{be}. Since there is a linear relationship between i_b and i_c, we would thus expect a better linear relationship between v_s and v_c.

20. Plot input and output signals together as a function of time and in XY mode. Do you see an improvement in the linearity?