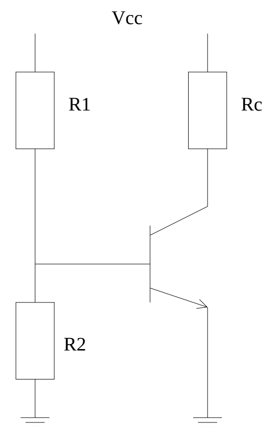
EE 321 Analog Electronics, Fall 2009
Exam 4 December 9, 2009

Rules: This is a open book test. You may use the textbook as well as your notes. The exam will last 50 minutes. Each problem counts equally toward your grade. None of the problems require long calculations.



1. **For $V_{CC} = 10\,\text{V}$, $R_1 = R_2 = 500\,\text{k}\Omega$, and $R_C = 100\,\text{k}\Omega$, what is the operating mode of this circuit, V_B, V_C, I_C, and I_B? Since you will find it is in saturation, what is β_{forced}? Ignore the Early effect.**

   Replace the input network with $R_B = R_1||R_2 = 250\,\text{k}\Omega$, $V_{BB} = \frac{R_2}{R_1+R_2}V_{CC} = 5\,\text{V}$. Then we see the BE junction is on, so $V_B = V_{BE} = 0.7\,\text{V}$. Then the base current is

$$I_B = \frac{V_{BB} - V_B}{R_B} = \frac{5 - 0.7}{250} = 0.0172\,\text{mA}$$

   Next assume saturation, so we get $V_C = V_{CE} = 0.2\,\text{V}$. Then

$$I_C = \frac{V_{CC} - V_C}{R_C} = \frac{10 - 0.2}{100} = 0.098\,\text{mA}$$

   Then, $\beta_{\text{forced}} = \frac{I_C}{I_B} = \frac{0.098}{0.0172} = 5.7$. Thus $\beta_{\text{forced}} < \beta = 100$, so saturation mode is confirmed.

2. **Now make $R_C = 1\,\text{k}\Omega$. The circuit is now in active mode. What is the transconductance and the raw voltage gain, $\frac{v_c}{v_{be}}$?**

   If it is in active mode then $I_C = \beta I_B = 0.017 \times 100 = 1.17\,\text{mA}$. In that case, the tranconductance is

$$g_m = \frac{I_C}{V_T} = \frac{1.72}{25} = 0.0688\,\Omega^{-1}$$

   The raw voltage gain is

$$\frac{v_c}{v_{be}} = -g_m R_C = 0.0468 \times 10^3 = -68.8$$

3. If the active mode circuit is attached to a signal generator with output resistance $R_{\text{sig}} = 10\,\text{k}\Omega$, and a load with resistance $R_L = 1\,\text{k}\Omega$, what is the overall gain, $\frac{v_c}{v_{\text{sig}}}$?

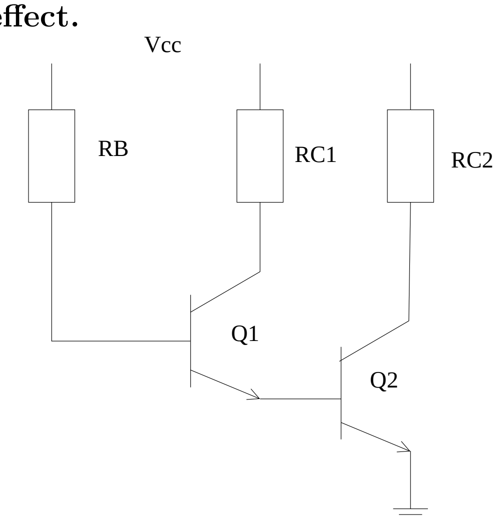
This is a common emitter circuit. In the book we look up the formula for the overall voltage gain,

$$\frac{v_o}{v_{\text{sig}}} = G_v = -\frac{R_B||r_\pi}{R_B||r_\pi + R_{\text{sig}}} g_m \left(r_o||R_C||R_L\right)$$

with $r_o = \infty$ and $r_\pi = \frac{\beta}{g_m} = 1453\,\Omega$,

$$G_v = -\frac{250 \times 10^3||1453}{250 \times 10^3||1453 + 10 \times 10^3} \times 0.0688 \times \left(10^3||10^3\right) = -4.34$$

4. For the following circuit perform a simple DC analysis. For each transistor determine the operating mode, the base voltage, and the collector voltage. Assume $\beta = 100$, $V_{CC} = 15\,\text{V}$, $R_B = 1\,\text{M}\Omega$, $R_{C1} = 5\,\text{k}\Omega$, and $R_{C2} = 1\,\text{k}\Omega$. Ignore the Early effect.



We see immediately that both transistors are on, so $V_{B2} = 0.7\,\text{V}$, and $V_{B1} = 1.4\,\text{V}$. Next find I_{B1},

$$I_{B1} = \frac{V_{CC} - V_{B1}}{R_B} = \frac{15 - 1.4}{10^6} = 13.6\,\mu\text{A}$$

Next assume active mode for transistor 1, we get $I_{C1} = \beta I_{B1} = 1.36\,\text{mA}$. And then $V_{C1} = V_{CC} - I_{C1}R_{C1} = 15 - 1.36 \times 5 = 8.2\,\text{V}$. Since this is greater than the base voltage active mode is confirmed.

For the second transitor I will assume saturation mode (because the base current is very large). We then get $V_{C2} = 0.2\,\mathrm{V}$. In that case, $I_{C2} = \frac{V_{CC} - V_{C2}}{R_{C2}} = \frac{15-0.2}{1} = 14.8\,\mathrm{mA}$. Since this is only slightly more than 10 times $I_{B2} = I_{E1}$, saturation mode is confirmed.