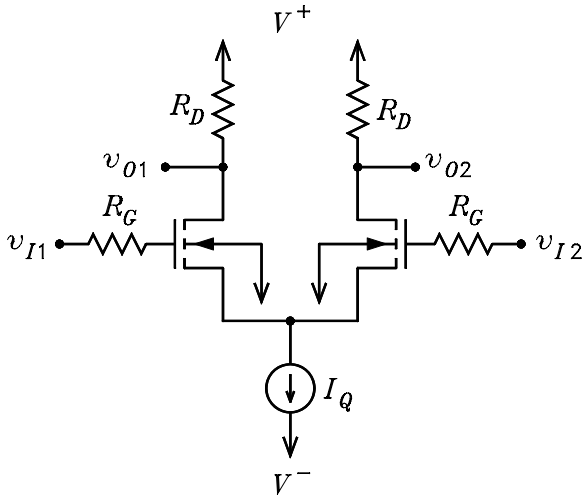
ECE3040 – Assignment 6

1. The figure shows a MOSFET differential amplifier. It is given that $K = 0.001\,\text{A/V}^2$, $V_{TH} = 2\,\text{V}$, $\lambda = 0$, $V^+ = 18\,\text{V}$, $V^- = -18\,\text{V}$, $I_Q = 3\,\text{mA}$, $R_D = 6.2\,\text{k}\Omega$, and $R_G = 100\,\text{k}\Omega$.



   (a) Show that $V_{GS} = 3.225\,\text{V}$ and $V_{DS} = 11.93\,\text{V}$.

   (b) For an ac small-signal analysis, show that

$$v_{o1} = -v_{o2} = -7.593\,(v_{i1} - v_{i2})$$

   (c) Use the pi or T model of the MOSFETs to investigate whether the body effect cancels out if a resistor R_S is placed in series with the source lead of each MOSFET.

2. For the BJT, show that the base-to-collector current gain can be written

$$\beta = \frac{I_C - I_{CBO}}{I_B + I_{CBO}}$$

3. Calculate the values of β and I_S for the transistor shown if $V_{CB} = V_{BE} = 0.7\,\text{V}$, $I_B = 0.2\,\text{mA}$, and $I_E = 10\,\text{mA}$. [$\beta = 49$, $I_S = 6.78 \times 10^{-15}\,\text{A}$]

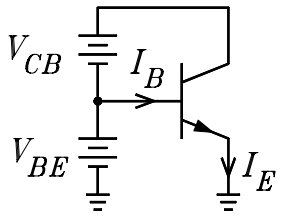
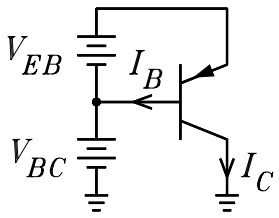
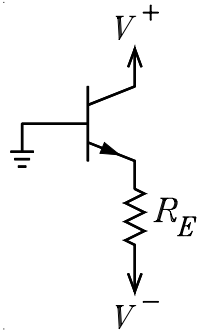


Figure 1:

4. Calculate the values of β and I_S for the transistor shown if $V_{EB} = V_{BC} = 0.7\,\text{V}$, $I_B = 50\,\mu\text{A}$, and $I_C = 2.5\,\text{mA}$. [$\beta = 50$, $I_S = 1.73 \times 10^{-15}\,\text{A}$]



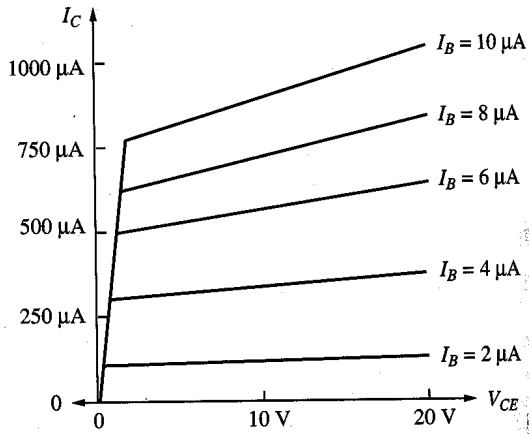
5. Calculate the collector, emitter, and base currents if $V^+ = 3.3\,\text{V}$, $V_{EE} = -3.3\,\text{V}$, $V_{BE} = 0.7\,\text{V}$, $R_E = 47\,\text{k}\Omega$, and $\beta = 90$. [$I_E = 55.3\,\mu\text{A}$, $I_B = 0.608\,\mu\text{A}$, $I_C = 54.7\,\mu\text{A}$]



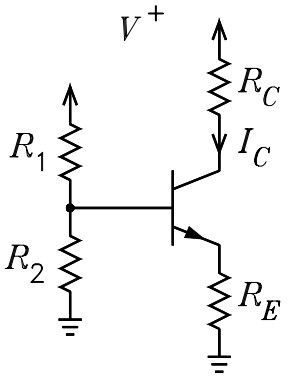
6. An npn transistor is operated in the active mode with a base current of $3\,\mu\text{A}$. It is found that $I_C = 240\,\mu\text{A}$ for $V_{CE} = 5\,\text{V}$ and $I_C = 265\,\mu\text{A}$ for $V_{CE} = 10\,\text{V}$. What are the values of β_0 and V_A for this transistor? [$\beta_0 = 71.7$, $V_A = 43.1\,\text{V}$]

7. A BJT has the parameters $\beta_0 = 75$, $V_A = 100\,\text{V}$, and $V_{CE} = 10\,\text{V}$. Show that $\alpha = 0.9880$.

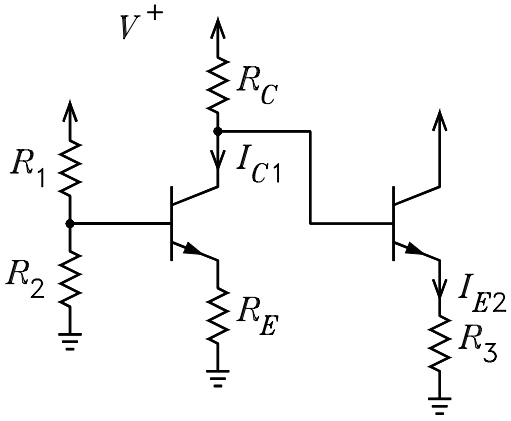
8. The output characteristics of a BJT are shown. (a) What are the values of β and β_0 at $I_B = 4\,\mu\text{A}$ and $V_{CE} = 10\,\text{V}$? [$\beta = 90$, $\beta_0 = 120$] (b) What are the values of β and β_0 at $I_B = 8\,\mu\text{A}$ and $V_{CE} = 10\,\text{V}$? [$\beta = 95$, $\beta_0 = 75$]



9. Solve for I_C and V_{CB} for the values $V^+ = 18\,\text{V}$, $R_E = 1\,\text{k}\Omega$, $R_1 = 130\,\text{k}\Omega$, $R_2 = 36\,\text{k}\Omega$, $R_C = 2.4\,\text{k}\Omega$, $V_{BE} = 0.7\,\text{V}$, and $\beta = 99$. Is the BJT biased in the active mode? [$I_C = 2.474\,\text{mA}$, $V_{CB} = 8.863\,\text{V}$]



10. Add a second npn transistor to the circuit of problem 9 as shown with $R_3 = 1\,\text{k}\Omega$. Assume the same V_{BE} and β. Solve for I_{E2}. Solve for V_{CB} for both transistors and verify they are in the active mode. [$I_{E2} = 11.10\,\text{mA}$, $V_{CB2} = 6.204\,\text{V}$, $V_{CB1} = 8.597\,\text{V}$]



11. For $R_1 = 10\,\text{k}\Omega$, $R_2 = 47\,\text{k}\Omega$, $R_C = 1.5\,\text{k}\Omega$, $R_E = 2\,\text{k}\Omega$, and $V^+ = 9\,\text{V}$, solve for I_C and V_{CB} for $\beta = 99$ and $\beta = \infty$. Verify that the BJT is biased in the active mode. Assume $V_{BE} = 0.7\,\text{V}$ for each case. [$I_C = 1.968\,\text{mA}$, $V_{CB} = 1.212\,\text{V}$, $I_C = 2.038\,\text{mA}$, $V_{CB} = 1.016\,\text{V}$]