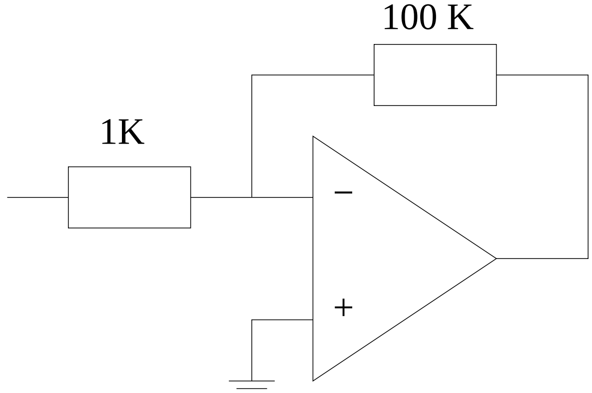
EE 321 Analog Electronics, Fall 2011
Exam 4 December 12, 2011
Solution

Rules: This is a closed-book exam. You may use only your brain, a calculator and pen/paper. Each numbered question counts equally toward your grade.

Note: The questions are designed to test your conceptual understanding, not your ability to do many pages of math. If you find yourself doing long calculations there is a high probability that you are doing something wrong.

Operational amplifier

1. **Draw a inverting amplifier with input resistance $1\,\mathrm{k}\Omega$ and gain of -100.**

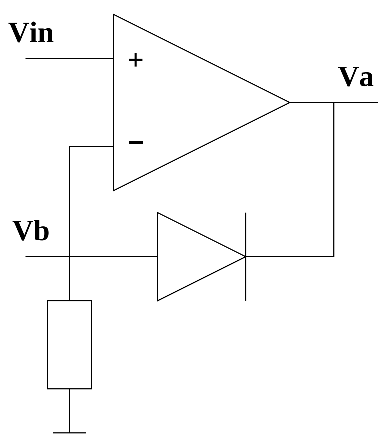


2. **Compute the output voltage due to a input offset voltage of $1\,\mathrm{mV}$.**

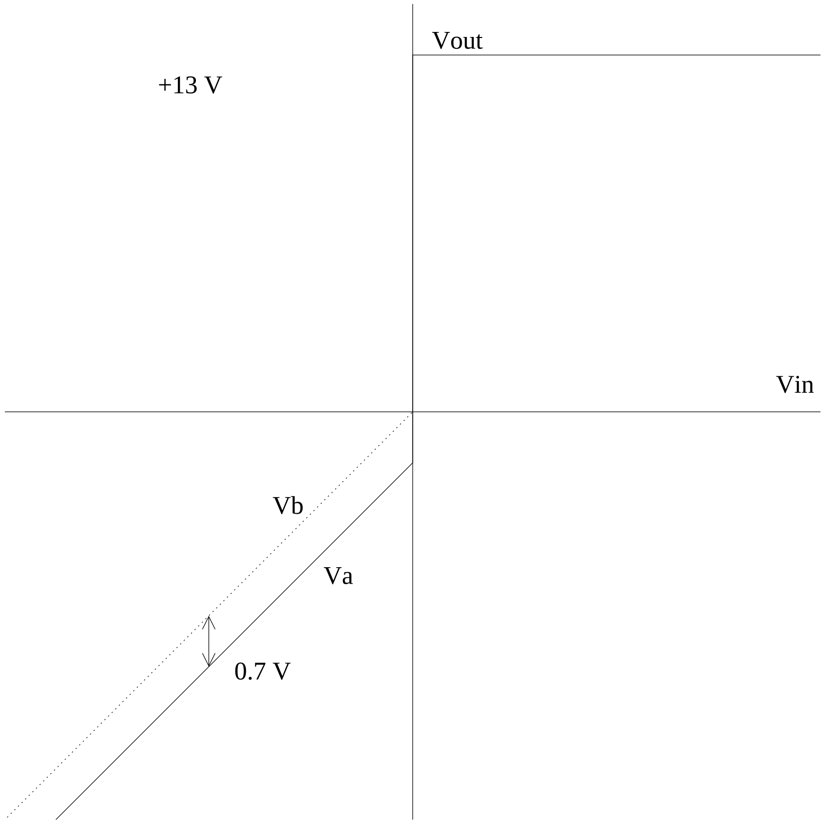
   The offset voltage is amplified by the non-inverting gain, so

$$V_{\text{out}} = \left(1 + \frac{R_2}{R-1}\right) V_{OS} = 101 \times 1\,\mathrm{mV} = 0.101\,\mathrm{V}$$

Diode

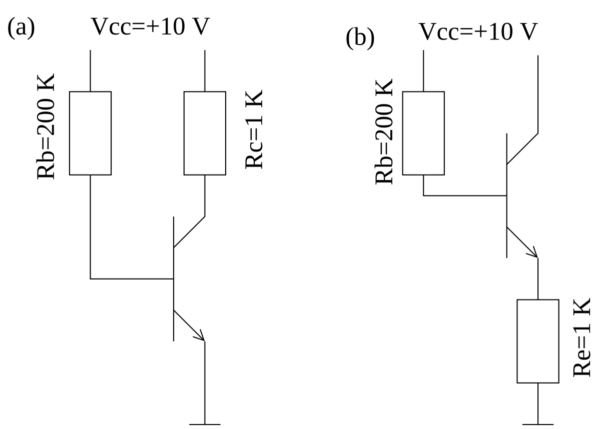


3. **Carefully plot the labeled voltages V_A and V_B as a function of V_{in} between -5 and +5 V. The saturation voltage levels of the op-amp are $\pm 13\,\text{V}$. For the diode assume the fixed voltage drop model with $V_D = 0.7\,\text{V}$.**



BJT

4. **Find all voltages and currents in these two circuits (assume $\beta = 100$)**



(a) Assume active mode operation

$$V_{CC} = i_B R_B + V_{BE}$$

$$i_B = \frac{V_{CC} - V_{BE}}{R_B} = \frac{10 - 0.7}{200} = 46.5\,\mu\text{A}$$

$$i_C = \beta i_B = 4.65\,\text{mA}$$

$$v_C = V_{CC} - i_C R_C = 10 - 4.65 \times 1 = 5.35\,\text{V}$$

$$v_B = V_{BE} = 0.7\,\text{V}$$

active mode confirmed

$$v_E = 0$$

$$i_E = (\beta + 1)\, i_B = 4.70\,\text{mA}$$

(b) This BJT is obviously in active mode

$$V_{CC} = i_B R_B + V_{BE} + i_E R_E = i_B \left[R_B + (\beta + 1)\, R_E\right] + V_{BE}$$

$$i_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta + 1)\, R_E} = \frac{10 - 0.7}{200 + 101 \times 1} = 30.9\,\mu\text{A}$$

$$v_B = V_{CC} - i_B R_B = 10 - 30.9 \times 200 = 3.82\,\text{V}$$

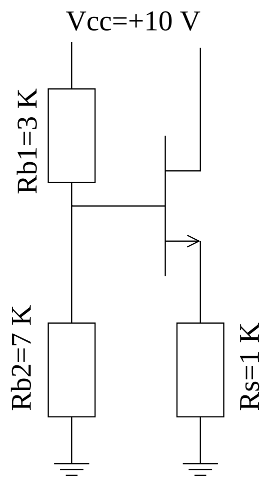
$$i_C = \beta i_B = 100 \times 30.9 \times 10^{-6} = 3.09\,\text{mA}$$

$$v_C = V_{CC} = 10\,\text{V}$$

$$i_E = (\beta + 1)\, i_B = 101 \times 30.9 \times 10^{-6} = 3.12\,\text{mA}$$

$$v_E = i_E R_E = 3.12 \times 1 = 3.12\,\text{V}$$

MOSFET



5. **Compute the voltages and currents for this circuit. Use $V_t = 2\,\mathrm{V}$ and $k_n' \frac{W}{L} = 1\,\frac{\mathrm{mA}}{\mathrm{V}^2}$**

First we see that $V_G = 7\,\mathrm{V}$. We also know that $I_G = 0$. The MOSFET is in saturation mode so that

$$i_D = \frac{k_n'}{2}\frac{W}{L}\left(v_{GS} - V_t\right)^2$$

$$v_{GS} = V_G - i_D R_S$$

$$i_D = \frac{k_n'}{2}\frac{W}{L}\left(V_G - i_D R_S - V_t\right)^2$$

$$i_D = \frac{k_n'}{2}\frac{W}{L}\left[i_D^2 R_S^2 + \left(V_G - V_t\right)^2 - 2 i_D R_S \left(V_G - V_t\right)\right]$$

$$\frac{k_n'}{2}\frac{W}{L} R_S^2 i_D^2 - 2\frac{k_n'}{2}\frac{W}{L} i_D R_S \left(V_G - V_t\right) - i_D + \left(V_G - V_t\right)^2 = 0$$

$$i_D^2 - 13 i_D + 36 = 0$$

$$i_D = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A} = \frac{13 \pm 5}{2} = 4\,\mathrm{mA} \text{ or } 9\,\mathrm{mA}$$

$i_D = 4\,\mathrm{mA}$ is the only answer that is consistent with saturation mode.