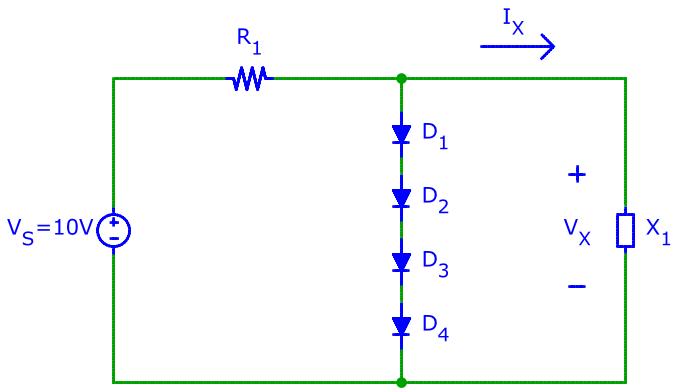
- Open-book, one 8.5 by 11 inch page of handwritten notes (two sided)
- No calculators (or other electronic devices)
- Write all your work and answers on the exam sheet
- Clearly mark results with a box around them
- Show your work (large and small-signal circuit diagrams, design equations)
- Cross out incorrect answers. If you present two or more inconsistent answers we invariably grade the wrong one.
- All problems have equal weight.

1. In the circuit below, gizmo X_1 (e.g. a smart phone) draws $I_X = 0 \ldots 90\,\text{mA}$ depending on operating mode. Find the maximum value of resistor R_1 that results in no more than 10 % variation of the voltage $V_X \approx 2.4\,\text{V}$. Devices $D_1 \ldots D_4$ are silicon diodes at room temperature.

   Briefly (!) explain how you arrived at your result.

   Hint: how much does the diode current change when V_X changes by 10 %?

   Note: A value of R_1 that is within 5 % of the ideal (optimal) value is appropriate here. This allows you to make assumptions that significantly simpify calculations.

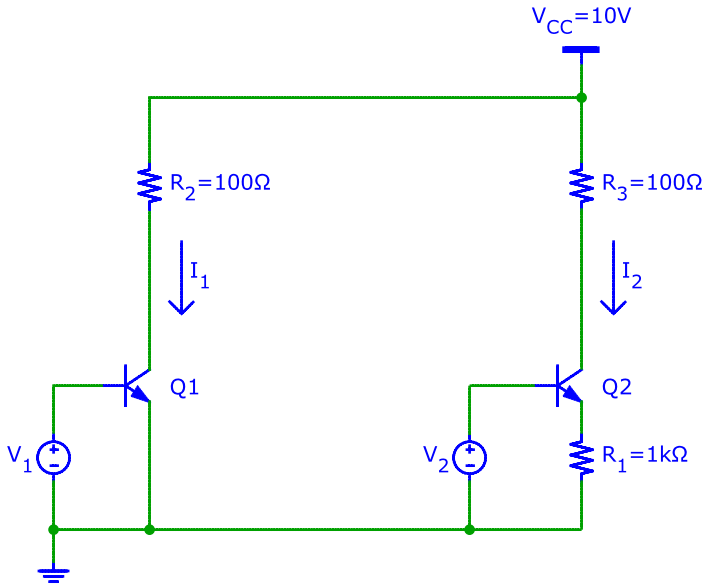


2. In circuit below V_1 and V_2 are adjusted such that $I_1 = I_2 = I_o = 1\,\text{mA}$. Calculate the fractional change of I_1 and I_2 (i.e. $I_1/I_o - 1$ and $I_2/I_o - 1$) in percent for the following circuit modifications:

   a) The values of R_2 and R_3 are doubled.
   b) The values of V_1 and V_2 are increased by 60 mV.

   Transistor parameters: $I_s = 10\,\text{fA}$, $\beta \to \infty$, $V_A \to \infty$.

   State the final numerical results with 10 % accuracy (you do not need a slide rule).

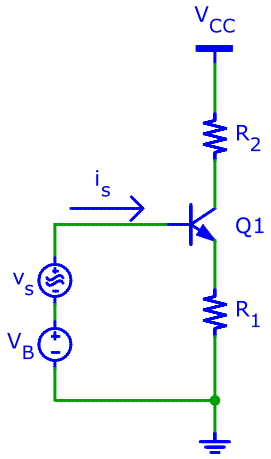


3. Derive an algebraic expression for the small-signal input resistance $r_i = v_s / i_s$ as a function of circuit parameters R_1, R_2, V_{CC}, I_{C1} and β.

   I have verified for you that the transistor is operating in the forward active region. You can thank me after the exam. Use $V_A \to \infty$.

   Suggestion: draw the small-signal circuit model and do all your calculations in terms of small-signal parameters. Separately state the equations relating small-signal parameters to circuit parameters.

   After the exam when you have a quiet minute reflect on the potential uses of this circuit. There are many!



4. Design a circuit (i.e. draw the large signal circuit diagram) such that the small-signal gain $v_o/v_s = -50$.

   Available components: Transistors with $I_s = 10\,\text{fA}$, $\beta = 100$, $V_A = \rightarrow \infty$ and resitors. You may adjust bias V_B to an appropriate value (no need to calculate it).

   Specify the value of all resistors, collector currents of transistors, and the large-signal output voltage V_O.

   You may assume that the circuit operates at room temperature, but you need to check other assumptions yourself, such as the region of operation of all transistors. Don't blame me if assumptions are not met—it's your design not mine!