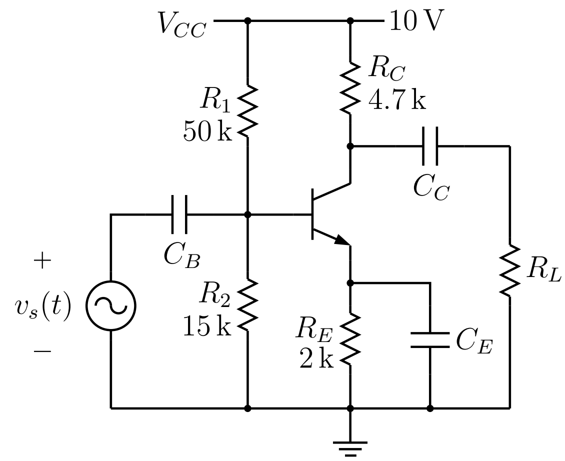
EE 112 End-Sem Exam (MBP)

(April 25, 2017)

Note: (a) As far as possible, work in terms of symbols (like R_1, R_2, V_T), and substitute numbers at the end. This will make it easier for you to get partial credit. (b) Do not write numerical answers as fractions. For example, write 0.24 and not 6/25. You will lose some marks if the decimal format is not followed. (c) Use $V_T = kT/q = 26$ mV.

1. Assume that the amplifier shown in the figure is operating in the mid-band region.



(a) What are the bias values of I_C and V_{CE}? (You can assume β to be large for this calculation.)

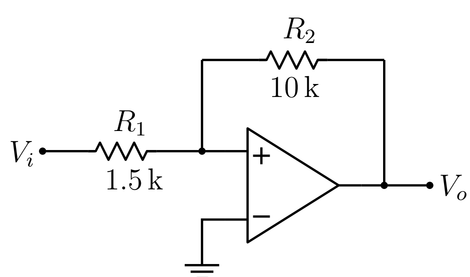
(b) Calculate g_m and r_π (take $\beta = 120$).

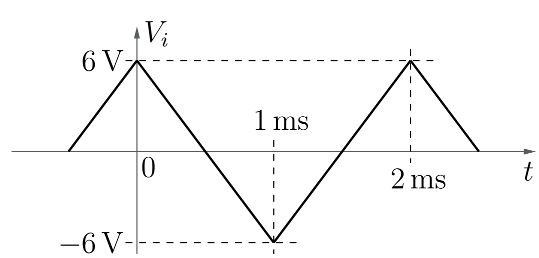
(c) Draw the small-signal equivalent circuit of the amplifier.

(d) Compute the amplifier gain with (i) $R_L \to \infty$, (ii) $R_L = 2$ k.

(e) With $v_s(t) = (2\,\text{mV})\,\sin\omega t$ and $R_L = 2$ k, write equations for $i_C(t)$, $v_C(t)$, $v_E(t)$ (the total instantaneous quantities). [5]

2. For the Schmitt trigger circuit shown in the figure, let $V_{\text{sat}} = 12$ V.



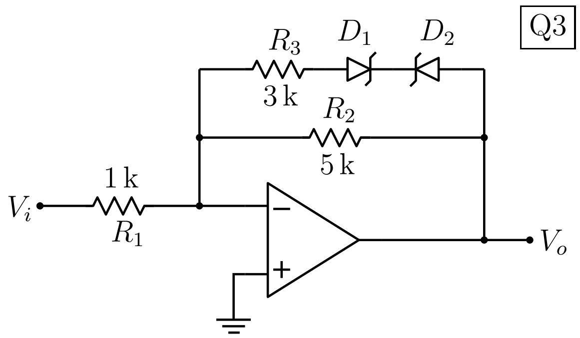


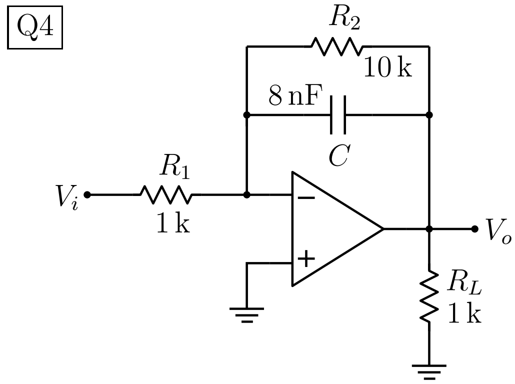
(a) Compute V_{TH} and V_{TL}.

(b) Plot V_o versus V_i.

(c) Plot the output waveform (for $0 < t < 2$ ms) for the triangular input waveform shown in the figure. Compute the time points at which V_o changes from $+V_{\text{sat}}$ to $-V_{\text{sat}}$ (and *vice versa*), and show them clearly in your plot. [6]

3. In the circuit shown in the figure, assume that the op-amp has $V_{sat} = 14\,\text{V}$. Let $V_Z = 5\,\text{V}$ and $V_{on} = 0.7\,\text{V}$ for the diodes. Plot V_o versus V_i for $-3\,\text{V} < V_i < 3\,\text{V}$, marking clearly the break points and slopes. [5]





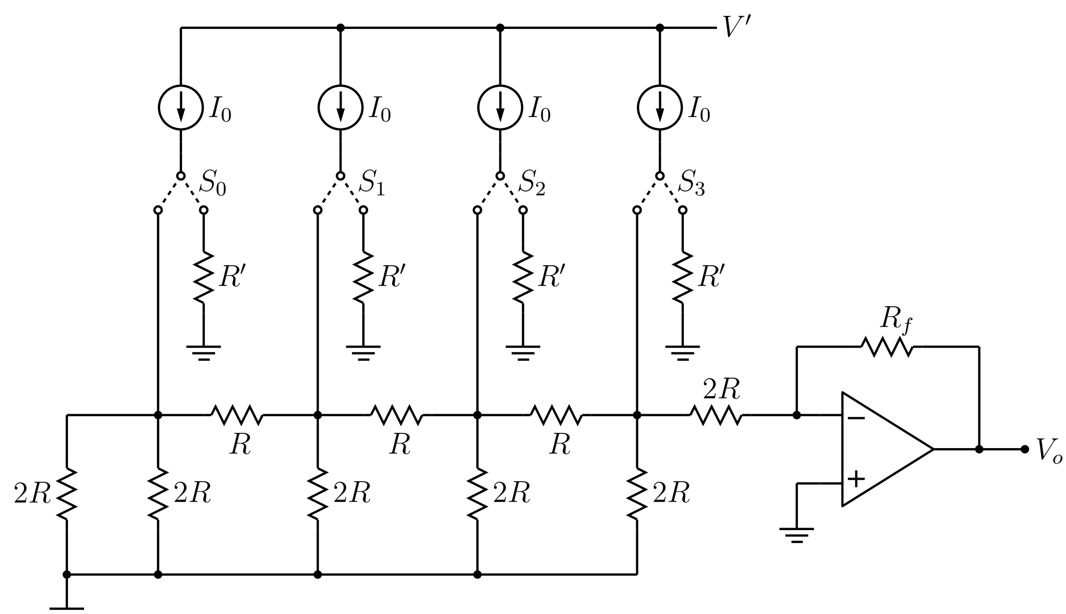
4. For the op-amp filter shown in the figure,

   (a) Derive an expression for $H(j\omega) = \dfrac{V_o(j\omega)}{V_i(j\omega)}$. (Do not substitute component values.)

   (b) What is $H_0 \equiv |H(j\omega)|$ as $\omega \to 0$? Compute its numerical value. What is the physical reason for your answer?

   (c) Compute the frequency (both in rad/s and in Hz) at which $|H| = H_0/\sqrt{2}$. [6]

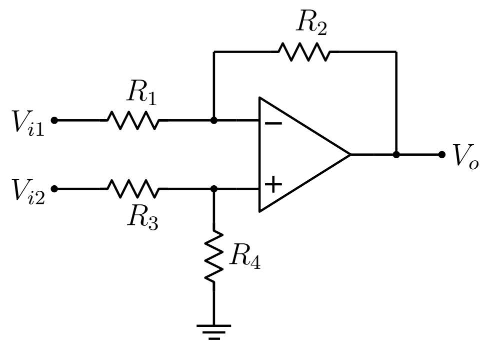
5. Shown in the figure is a current-driven DAC. If $S_k = 1$, the corresponding current (I_0) flows through the R-$2R$ network; else, it gets diverted to the corresponding R'. Find an expression for V_o for the following cases. (Hint: Note that $V_- \approx V_+ = 0\,\text{V}$.)



(a) $S_3 = 1$, all others are 0. (b) $S_2 = 1$, all others are 0.
(c) $S_1 = 1$, all others are 0. (d) $S_0 = 1$, all others are 0.

Using the above results, write a general expression for V_a in terms of S_0, S_1, S_2, S_3. [6]

6. In the difference amplifier shown in the figure, $R_3 = R_1 = 4.7\,\text{k}$, and $R_4 = R_2 = 47\,\text{k}$. The input voltages are $V_{i1} = 8.02\,\text{V}$ and $V_{i2} = 7.98\,\text{V}$. Assume that the op-amp is ideal.



(a) If the resistance values are exactly matched, what is V_o?

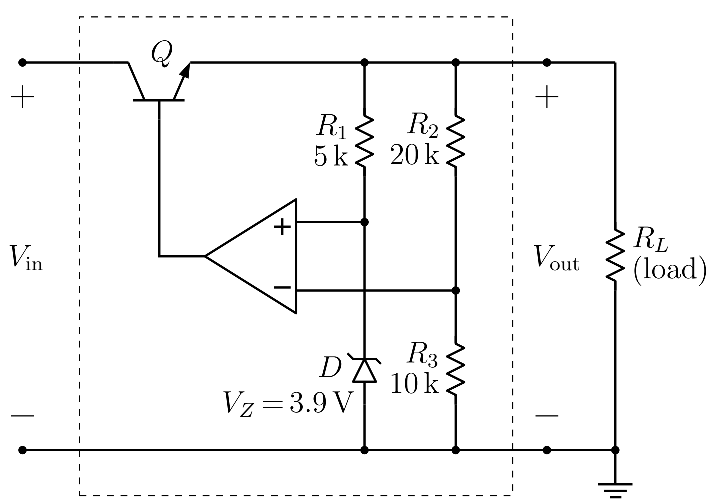
(b) If R_3 is larger than R_1 by 2 % (all other resistances being equal to their nominal values),

(i) Find the common-mode gain A_c.

(ii) Find the differential-mode gain A_d.

(iii) Find V_o using (i) and (ii) (not by any other means). [6]

7. Shown in the figure is a "voltage regulator" circuit. The objective is to provide a constant voltage V_{out} even if the input voltage V_{in} or load R_L changes. The circuit employs negative feedback, the op-amp operates in its linear region, and the BJT operates in the active mode. The Zener diode operates in the reverse breakdown mode, and R_1 controls the diode current. We will assume that the above conditions are valid for all parts of this problem. Consider $V_{\text{in}} = 18\,\text{V}$ first.



(a) Find V_{out} and V_{CE} for the BJT.

(b) If $R_L = 50\,\Omega$, estimate the power dissipated in Q.

(c) If the BJT has $\beta = 50$, how much current does the op-amp need to supply?

(d) Repeat (a), (b), (c) for $V_{\text{in}} = 21\,\text{V}$. [6]