

ORDRE DES INGÉNIEURS DU QUÉBEC

NOVEMBER 2008 SESSION

Open-book examination
Calculators : only authorized models
Duration : 3 hours

98-Phys-A5 Semiconductors Devices and Circuits

Question 1 (20 points)

In a p-n junction diode, the minority carrier doping in the depletion zone is given by $n_{p0} = p_{n0} = 10^5/\text{cm}^3$. A forward biased voltage $v_D = 0.6\text{V}$ is applied across the junction. Calculate the resulting values of hole concentration on the n-type side of the depletion zone as well as the electron concentration on the p-type side of the depletion zone. Describe quantitatively what happens to these carrier concentrations when the temperature (in Kelvin) is doubled.

Question 2 (20 points)

A circuit includes a resistance $R = 10\text{k}\Omega$ in series with a capacitor $C = 22\mu\text{F}$ (see figure 1 below). If the voltage v_i suddenly changes from 0V to 5V, what is the response of the circuit as measured at v_o ?

Question 3 (20 points)

- Sketch in a realistic manner and with all quantitative values possible the characteristic curves $I_C - V_{CE}$ for a npn bipolar transistor with $\beta=50$.
- This transistor is biased as illustrated in figure 2, with $R_B = 10\text{k}\Omega$, $R_C = 1\text{k}\Omega$. A voltage $V_{BB} = 1.5\text{V}$ is applied, while $V_{CC} = 10\text{V}$. Calculate the value of I_B . Using the graphic from part a) of this question (for which you might have to adjust the range of values to cover the correct value of I_B), calculate the operating point of the device using the load line method.

Question 4 (20 points)

a) For the circuit of figure 3, $R_1 = R_2 = 10\text{k}\Omega$. We assume that the operational amplifier operates in its linear region. Find the values of v_o for the following cases:

- $v_1 = 0\text{V}$; $v_2 = 1\text{V}$;
- $v_1 = 1\text{V}$; $v_2 = 0\text{V}$;
- $v_1 = 2\text{V}$; $v_2 = 1\text{V}$.

b) Indicate in what manner this circuit can be modified so that v_o becomes directly proportional to the difference between v_1 and v_2 .

Question 5 (20 points)

Draw the circuit diagram of a simple 8 bits digital-analog converter using a single operational amplifier and a reference voltage source. Indicate the relative values of all resistors used in the circuit. If the operational amplifier is powered by voltage sources of +10 V and -10V, and that the reference voltage of the circuit is +3V, find the possible values of the resistors for this circuit and show by calculations that your solution respects the limits imposed on this circuit.

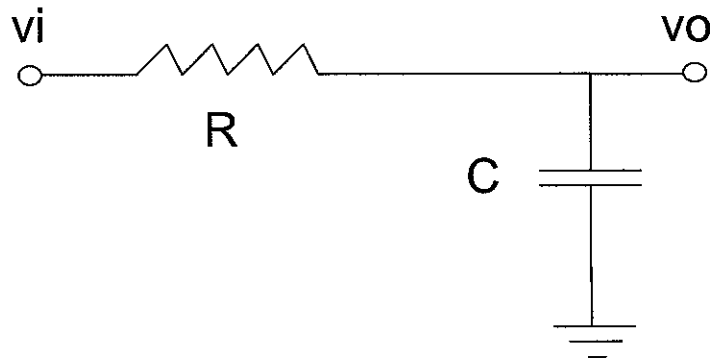


Figure 1

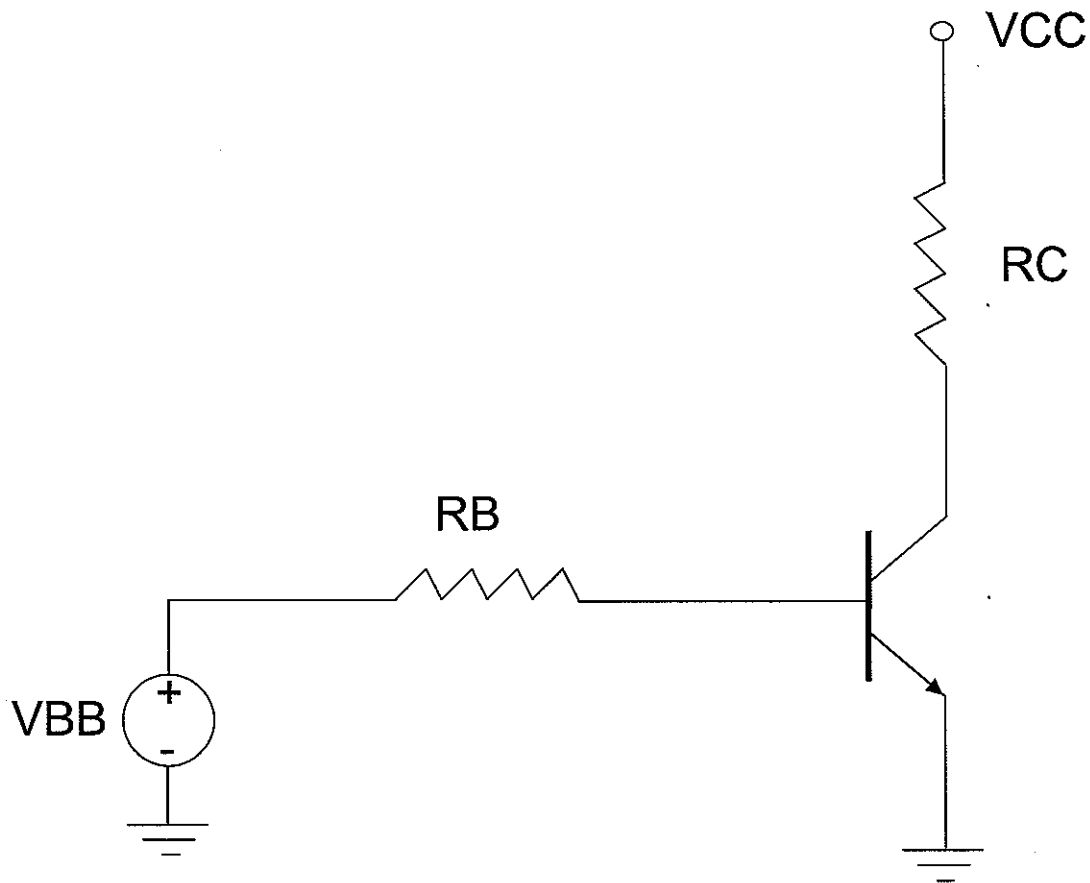


Figure 2

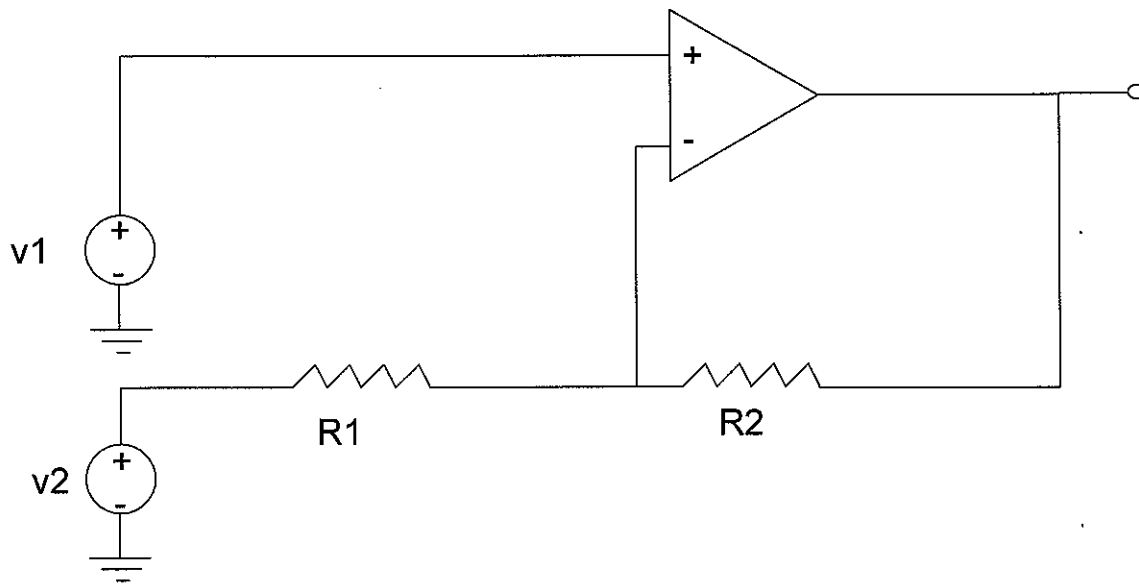


Figure 3