MASSACHUSETTS INSTITUTE OF TECHNOLOGY

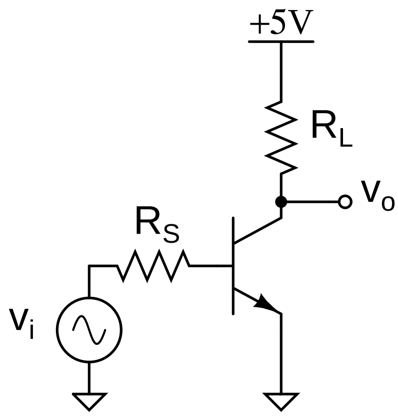
Department of Electrical Engineering and Computer Science

6.301 Solid State Circuits

Spring Term 2003 — Issued : February 7, 2003

Problem Set 2 — Due : Friday, February 14, 2003

Problem 1: For the common-emitter amplifier shown below:



(a) Find the small signal voltage gain v_o/v_i as a function of R_S, R_L, β, V_A, and collector current I_C. Do not ignore r_o in this problem.

(b) Find the small signal input resistance and output resistance. Do not include R_S in calculating the input resistance. Include R_L, however, in calculating the output resistance.

Problem 2: In this problem, we examine the effect of temperature on the bias stability. It is found that the I_S of the npn transistor shown below has a temperature coefficient $(\frac{1}{I_S}\frac{dI_S}{dT})$ of 3300 ppm/°C near 300 K. Also, $\beta_F = 200$ at 300 K, and has a temperature coefficient $(\frac{1}{\beta_F}\frac{d\beta_F}{dT})$ of 2000 ppm/°C. You are given that $I_S = 10^{-15}$A at 300 K. Assume that the values of V_{BB}, R_B and R_C are independent of temperature.

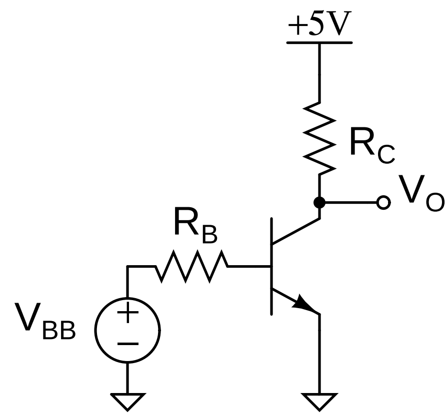
To simplify some of the math, you may assume that

$$\frac{\partial(\log I_C)}{\partial T} \approx 0$$

(a) Find the values of R_B and R_C to make $I_C = 500\mu$A and $V_O = 2.5$V at 300 K.

(b) Derive the temperature coefficient of the collector current $(\frac{1}{I_C}\frac{dI_C}{dT})$ at $T = 300$ K.

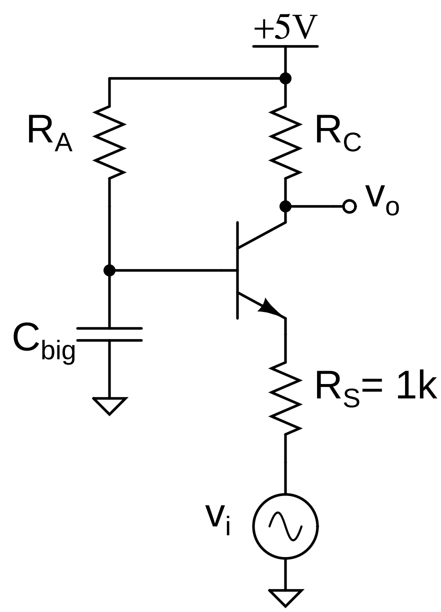
(c) Compute the temperature dependence of the quiescent output voltage $(\frac{dV_O}{dT})$ in V/°C at $T = 300$ K.



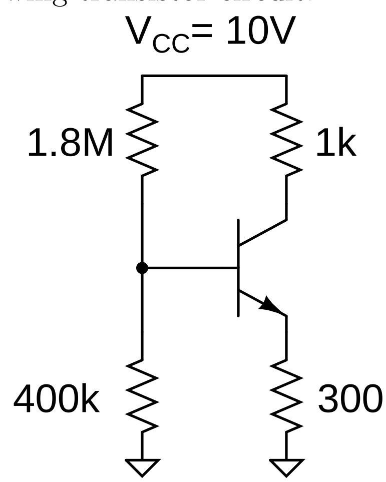
Problem 3: For the common-base amplifier circuit illustrated below:

(a) Determine the values of R_A and R_C so that $I_C = 500\mu\text{A}$ and the small signal voltage gain $v_o/v_i = 5$. Assume that $I_S = 10^{-15}\text{A}$ and $\beta_F = \beta_o = 200$. Be sure to make reasonable approximations in your calculations.

(b) Assuming that the temperature coefficient of V_{BE} is $-2\text{mV}/°\text{C}$, compute the temperature coefficient of I_C. Assume that $(1 + \beta_F)R_S \gg R_A$. Express your answer as a function of the voltage drop V_S across R_S. What V_S do you need to reduce the temperature coefficient of I_C to 500 ppm/ °C?



Problem 4: Consider the following transistor circuit.



(a) With $V_{BE} = 0.7$ V and $\beta = 400$, calculate the transistor operating point (find I_C and V_{CE}).

(b) Due to a manufacturing mix-up, some of your transistors have $\beta = 100$. Find I_C for the new transistors.

(c) Find new values for the base-biasing resistors so that I_C only changes by 10% when β falls from 400 to 100.

(d) Refer again to the circuit in part (a). Due to temperature fluctuations in your operating enviroment, V_{BE} sometimes drops as low as 0.5V. Find I_C under this condition.

(e) How should the transistor be biased so that I_C only changes by 10% if V_{BE} falls from 0.7V to 0.5V?

Problem 5: An EFCB (emitter-follower common-base) connection is illustrated below. Determine the overall small signal voltage gain v_o/v_i, input resistance, and output resistance. Assume $\beta = 200$. You may neglect r_o for this problem.