ECE311 Electronic Circuit HW3
Due: **Jun 10th 11:59 a.m.**

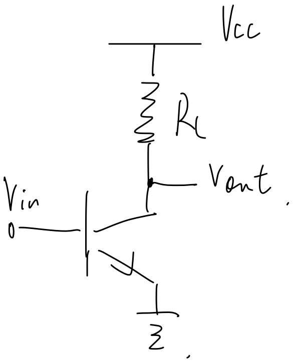
Note

1. Please use A4 size paper or page.
2. Please clearly state your final result for each question.
3. Please state and verify the operating region (cutoff, FAR/active, or saturation) of each BJT.

Mike is very interested in the field of integrated circuit. However, he knows nearly nothing about the common components appeared in integrated circuit and their features. Thus, Mike decides to first take a look on a single npn transistor to see the simple relationship between the magnitude of current at each node under the circumstance of FAR.

Problem 1

An npn transistor of a type whose β is specified to range from 50 to 300 is connected in a circuit with emitter grounded, collector at +10 V, and a current of 10 μA injected into the base. Calculate the range of collector and emitter currents that can result. What is the maximum power dissipated in the transistor?
(Note: Perhaps you can see why this is a bad way to establish the operating current in the collector of a BJT.)



$I_C = \beta I_B \in [5\times10^{-4}A, 3\times10^{-3}A]$.

$I_E = I_C + I_B \in [5.1\times10^{-4}A, 3.01\times10^{-3}A]$.

$P_{max} = V_{CC}\cdot I_{Cmax} = 3\times10^{-3}\times10\ W = 3\times10^{-2}\ W$.

After performing tests and some calculations on an npn transisor, Mike gets familiar with the basic characteristics of the transisor. Then he decides to build a circuit based on single transistor to see how npn transistor behaves in a simple circuit.

Problem 2

A very simple circuit for measuring β of an npn transistor is shown in Fig 1. In a particular design, V_{DD} is provided by a 9-V battery; M is a current meter with a 50-μA full scale and relatively low resistance that you can neglect for our purposes here. Assuming that the transistor has V_{BE}=0.7 V at I_E=1mA, what value of R_C would establish a resistor current of 1 mA? Now, to what value of β does a meter reading of full scale correspond? What is β if the meter reading is 1/5 of full scale? 1/10 of full scale?

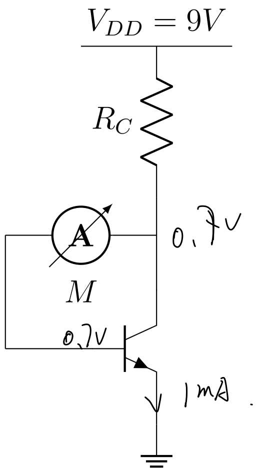


Figure 1: circuit for problem 2

$$R_C = \frac{9-0.7}{1\times10^{-3}} = 8.3\times10^{3}\,\Omega.$$

$$\beta_1 = \frac{I_C}{I_B} = \frac{1\times10^{-3}-50\times10^{-6}}{50\times10^{-6}} = 19.$$

$$\beta_2 = \frac{I_C}{I_B} = \frac{1\times10^{-3}-10\times10^{-6}}{10\times10^{-6}} = 99.$$

$$\beta_3 = \frac{I_C}{I_B} = \frac{1\times10^{-3}-5\times10^{-6}}{5\times10^{-6}} = 199.$$

After successfully building up the circuit and analysing the result, Mike decides to challenge himself. So he decides to build a brand-new circuit using both npn and pnp resistors to see how the two transistors behave and react with each other and how the affect the whole circuit under different given voltage.

Problem 3

For the circuit in Fig 2, find V_B and V_E for v_I = 0V, +2V,–2.5V, and –5V. The BJTs have β=50.

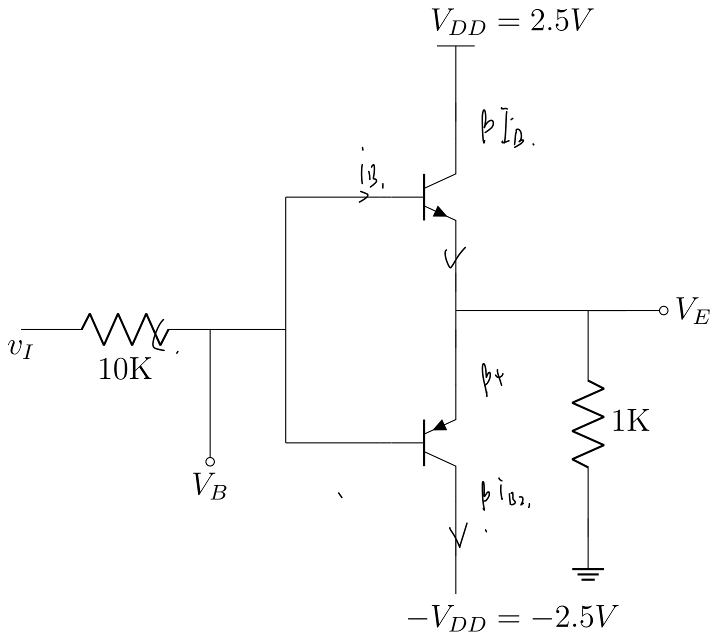


Figure 2: circuit for problem 3

when $V_I = 0V$,

Assume BJT 1 is on.

$$\begin{cases} i_B = \frac{-V_B}{10\times10^3}, \\ V_B - V_E = 0.7V. \\ i_B(\beta+1) = \frac{V_E}{10^3}, \end{cases}$$

$V_B = 0.115 > 0$

Therefore, BJT 1 is off.

Assume BJT 2 is on.

$$\begin{cases} i_B = \frac{V_B}{10\times10^3}. \\ V_E - V_B = 0.7V \\ i_B(\beta+1) = \frac{-V_E}{10^3}. \end{cases}$$

$V_B = -0.115 < 0$

Therefore, BJT 2 is off.

Therefore, $\boxed{V_B = V_I = 0V, \quad V_E = V_{Ground} = 0V}$.

when $V_I = 2V$.

Assume BJT 1 is on.

$$\begin{cases} i_B = \frac{2 - V_B}{10\times10^3} \\ V_B - V_E = 0.7V, \\ i_B(\beta+1) = \frac{V_E}{10^3}, \end{cases}$$

$\boxed{V_B = 1.79V < 2V. \quad V_E = V_B - 0.7 = 1.09V}$

when $V_I = -2.5V$,

Assume BJT 2 is on

$$\begin{cases} i_B = \frac{V_B + 2.5}{10\times10^3}. \\ V_E - V_B = 0.7V \\ i_B(\beta+1) = -\frac{V_E}{10^3}. \end{cases}$$

$\boxed{V_B = -2.2V > 2.5V. \; V_E = V_B + 0.7V = -1.5V}$

when $V_I = -5V$.

Assume BJT 2 is on.

$$\begin{cases} i_B = \frac{V_B + 5}{10\times10^3} \\ V_E - V_B = 0.7V, \\ i_B(\beta+1) = -\frac{V_E}{10^3}. \end{cases}$$

$\boxed{V_B = -4.3V > -5V. \quad V_E = V_B + 0.7V = -3.6V.}$

Aftering building up the circuit, Mike thinks it is still not enough. Thus he upgrades his circuits. He tries to measure the voltage at every node to see how the transistors behave and what region they are. Moreover, he also wants to know how different assumptions will affect the circuit behavior. However, he encounters some difficulties when dealing with the circuit when trying to first analyze the complex circuit.

Problem 4

For the circuit shown in Fig. 3, find the labeled node voltages for:
(a) $\beta = \infty$;
(b) $\beta = 100$;

Mike successfully handles the complex circuit composed of BJT. He feels proud of himself and decides to dig further into integrated circuit.

(a) $\beta = \infty$.

$i_B \to 0$,

$V_1 = 0$.

$V_2 = V_1 + 0.7V = 0.7V$.

$$\frac{V_3+3}{9.1\times10^3} = \frac{3-V_2}{9.1\times10^3}.$$

$V_3 = -0.7V$.

$V_3 - V_4 = 0.7V$,

$V_4 = -1.4V$.

$$\frac{3-V_5}{5.1\times10^3} = \frac{V_4+3}{4.3\times10^3}.$$

$V_5 = 1.1V$

Therefore $\begin{cases} V_0 = 0\ V \\ V_2 = 0.7V \\ V_3 = -0.7V, \\ V_4 = -1.4V, \\ V_5 = 1.1V. \end{cases}$

(b)

$$\begin{cases} \dfrac{3-V_2}{9.1\times10^3} = 101 \cdot \dfrac{V_1}{10\times10^3}. \\ \dfrac{V_3+3}{9.1\times10^3} = 100 \cdot \dfrac{V_1}{10\times10^3} \\ V_2 - V_1 = 0.7. \\ V_3 - V_4 = 0.7V. \\ \dfrac{3-V_5}{5.1\times10^3} = \dfrac{V_4+3}{4.3\times10^3}. \end{cases}$$

$$\begin{cases} V_1 = 0.025\ V. \\ V_2 = 0.725\ V \\ V_3 = -0.747\ V \\ V_4 = -1.45\ V. \\ V_5 = 1.16\ V. \end{cases}$$

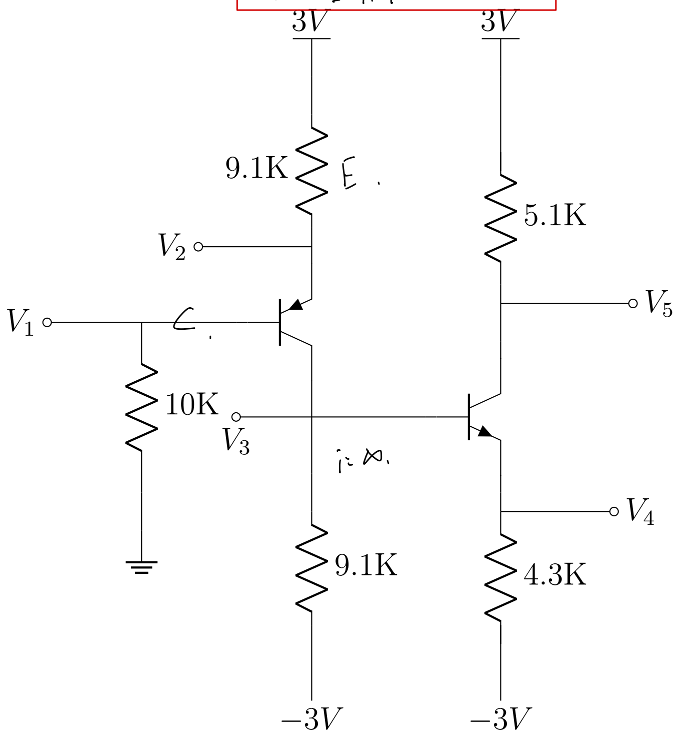


Figure 3: circuit for problem 4