Simon Fraser University

Mechatronic Systems Engineering

Midterm Exam for ENSC 226: Electronic Circuits

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1 March 2011

Time: 110 minutes

Name: Solutions

Student number: ______________

Question	Mark
1	/ 30
2	/ 20
3	/ 20
4	/ 30
Total	/100

Question 1. [30 marks]

Circle the correct answer for each of the following problems.

1.a. [5 marks] During lab 1, you learned that the basic equation for the physical model of diodes needed to be modified. What was the additional parameter that was introduced? How was the equation for the small signal resistance of the diode modified?

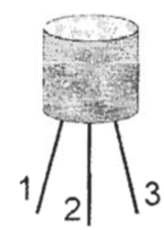
Additional parameter: n

$$r_d = \frac{nV_T}{I_D}$$

1.b. [5 marks] Assume that you are given a working BJT whose model number has been erased from its package. We want to use a multimeter similar to the one you used in the lab to determine the type (npn or pnp) and pins (base, collector, and emitter) of the transistor. Using the diode more on the multimeter, the following data is obtained:

Between pins 2&1: *0.5V*	Between pins 1&2: *OPEN*
Between pins 3&1: *0.7V*	Between pins 1&3: *OPEN*
Between pins 2&3: *OPEN*	Between pins 3&2: *OPEN*

where, for example, the measurement between pins 1&2 is taken by connecting the positive lead of the multimeter to pin 1 and its negative lead to pin 2. What are the type and pin arrangement of this transistor?



(a) npn; pin 1: Base, pin 2: Emitter, pin 3: Collector

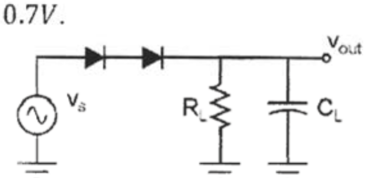
(b) npn; pin 1: Base, pin 2: Collector, pin 3: Emitter

(c) pnp; pin 1: Base, pin 2: Emitter, pin 3: Collector

(d) pnp; pin 1: Base, pin 2: Collector, pin 3: Emitter

(e) None of the above

1.c. [5 marks] What is the output ripple voltage of the circuit shown below? Assume $R_L = 1k\Omega$, $C_L = 100\mu F$, $v_{in} = 5.7 \sin 2\pi\, 100t$ and $V_{D,on} = 0.7V$.



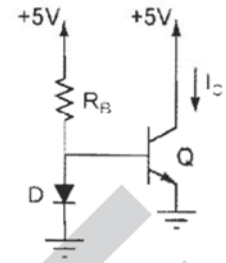
(a) 0.5V (b) 0.3V

(c) 0.36V (d) 0.43V

(e) None of the above

$$V_r = \frac{5.7 - 2\times 0.7}{100\times 10^{-4}\times 10^{3}} = \frac{4.3}{10} = 0.43V$$

1.d. [10 marks] Assume $I_{SD} = 1fA$, $I_{SQ} = 10fA$, $\beta = \infty$, and $V_A = \infty$. What is the collector current, I_C, if $R_B = 10k\Omega$?



$I_C =$ 4.35 mA

$$5 = \underbrace{I_D \times 10K + 0.025 \ln \frac{I_D}{10^{-15}}}_{A}$$ 5

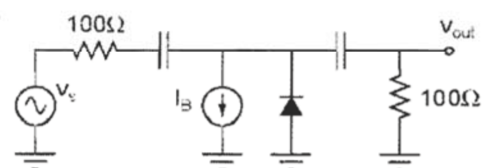
It ① $I_D = \frac{5-0.7}{10K} = 430\mu A \rightarrow A = 4.96V$

$I_D = 350\mu A \rightarrow A = 4.16$

$I_D = 435\mu A \rightarrow A = 5.02$ ✓ $\rightarrow I_D = 435\mu A$

$\rightarrow I_C = 10 I_D = 4.35 mA$ 5

1.e. [5 marks] Assume $I_B = 0.2mA$ and that the capacitors are short circuits for small signal operation. What is the small signal output voltage, v_{out}?



R_L

$v_{out} = v_S \times$ 0.36 2

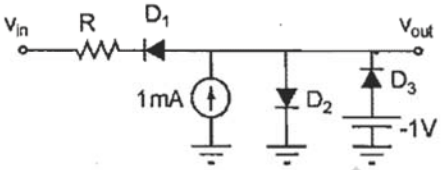
$r_d = \frac{V_T}{I_D} = \frac{25}{0.2} = 125\Omega$ 3

$R_L = 100 // 125 = 55.6$

$\rightarrow v_{out} = \frac{55.6}{155.6} v_s = 0.36 v_s$

Question 2. [20 marks]

Using the constant voltage drop model for the diodes, draw the input output characteristic curve for $-5V < v_{in} < +5V$ for the circuit shown. Label all important information on your graph.



$V_{in} \to -\infty \to D_1$: on, D_3: on, D_2: off

$V_{out} = -1.7v$

D_1 turns off at $I_{D1} = 0$ X will not happen before D_2 turns on

D_3 turns off if $I_{D3} = 0$: $I_{D3} + 1mA = I_{D1}$

$I_{D1} = \frac{-1.7 - 0.7 - V_{in}}{R}$ $I_{D3} = 0 \to \frac{-2.4 - V_{in}}{R} = 1mA \to V_{in} = -2.4 - R \times 1mA$

D_1: on, D_2: off, D_3: off $\to V_{out} = 0.7 + R \times 1mA + V_{in}$

D_2 turns on if $V_{out} = 0.7$ or $V_{in} = -R \times 1mA$

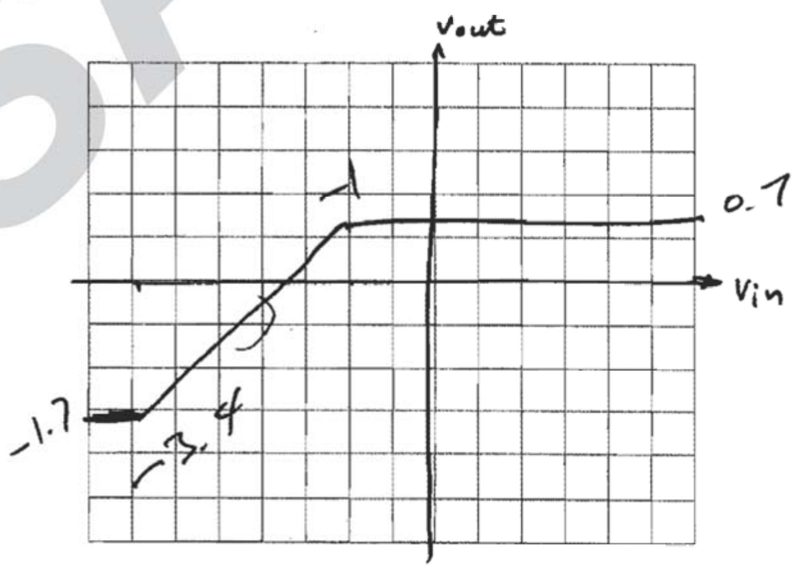
D_1 turns off if $I_{D1} = 0$ X

D_1: on, D_2: on, D_3: off

$V_{out} = +0.7$

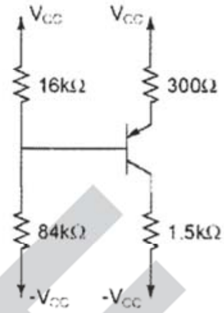
D_1 turns off if $I_{D1} = 0$ $\frac{V_{in}}{R} = 0 \to V_{in} = 0$ However, V_{out} does not change

$R = 1k\Omega$



Question 3. [20 marks]

What are I_C and V_{EC}? Assume $V_{CC} = +4V$, $\beta = 100$, and $V_A = \infty$. Justify any assumption you make.



$I_C =$ 1.33 mA (4) $V_{EC} =$ 5.6 V (6)

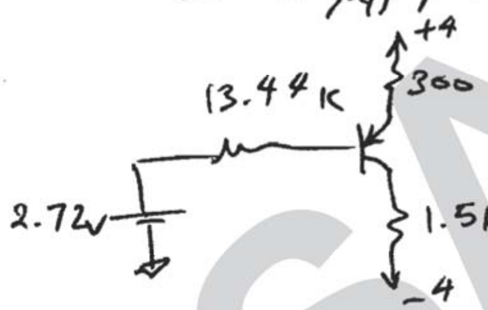
1.93 (6) 4.52 (4)

$I_B = 0 \to V_B = 0.84 \times 8 - 4 = 2.72V$ (6)

$\to V_E = 3.42 \to I_E \simeq I_C = 1.93mA \to$ ~~$V_{EC} = 3.42$~~

(a) $V_{EC} = 3.42 - \underbrace{(1.5 \times 1.93 - 4)}_{-1.1} \Rightarrow 4.52V$ (4) $\boxed{10}$

$I_B = 19.3\mu A$, $I_{BB} = 80\mu A \to I_B$ cannot be ignored. $\to$



$4 - 0.7 - 2.72 = I_B(13.44K + 300 \times 101)$

$\to I_B = 13.3\mu A \to I_C = 1.33mA$ (7)

(14)

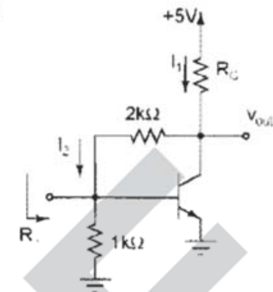
$\to V_C = 1.995 - 4 = -2V$

$\to V_{EC} = 4 - 300 \times 1.33 + 2 = 5.6V$ (3)

(6) without part (a)

Question 4. [30 marks]

The transistor shown in the circuit to the right is operating in its active region. Assume $R_C = 2k\Omega$, $\beta = 100$, and $V_A = \infty$.



4.a. Ignoring I_B, what is the collector voltage of the transistor?

$V_C = v_{out} =$ 2.1 V 3

$I_B = 0 \rightarrow I_2 = \frac{0.7}{1k\Omega} = 0.7mA \rightarrow V_{out} = 3K \times 0.7 = 2.1V$

4.b. What is the collector current of the transistor?

$I_C =$ 0.75 mA 3

$I_1 = \frac{5-2.1}{2k} = 1.45mA \rightarrow I_C = 0.75mA$

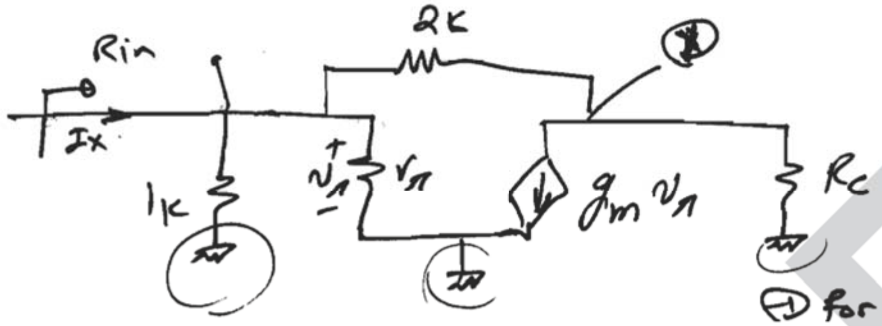
4.c. Calculate the small signal parameters g_m and r_π.

$g_m =$ 30 mS 2 $r_\pi =$ 3.3k Ω 2

$g_m = \frac{0.75}{25} = 30\ mS$

$r_\pi = \frac{100}{0.3 \times 10^{-3}} = 3.3k\Omega$

4.d. Draw the small signal equivalent of the circuit.



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−1 for each mistake

4.e. What is the input resistance of the circuit (R_{in} on the graph)?

R_{in} = 60.4 Ω

$$\frac{V_x}{1K} + \frac{V_x}{r_\pi} + \frac{V_x - V_y}{2K} = I_x$$

$$\frac{V_y}{R_C} + \frac{V_y - V_x}{2K} + g_m v_x = 0$$

$$V_y\left(\frac{1}{R_C} + \frac{1}{2K}\right) = V_x\left(\frac{1}{2K} - g_m\right)$$

10

$$V_y = -29.5\,V_x$$

$$i_x = v_x\left(\frac{1}{1K} + \frac{1}{3.3K} + \frac{30.5}{2K}\right)$$

$$R_{in} = \frac{v_x}{i_x} = 60.4\ \Omega$$

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