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ELG3336
Electronics for Mechanical Engineering

MIDTERM EXAMINATION

Length of Examination: 90 minutes **October, 2016**

Professor: Riadh Habash **Page 1 of 7**

Family Name: ____

Other Names: ____

Student Number: ___________

Signature ___________________________

Closed book.

If you do not understand a question, clearly state an assumption and proceed.

At the end of the exam, when time is up:
- Stop working and turn your exam upside down.
- Remain silent.
- Do not move or speak until <u>all</u> exams have been picked up, and a TA or the Professor gives the go-ahead to leave.

QUESTION 1 (5 marks):
Follow the procedure of solution, answer questions, identify mistakes (circle) and correct them, if any!

Consider the small-signal amplifier shown in Figure 1. Assume V_{CC} = 24 V, R_S = 1.5 kΩ, R_1 = 8.6 kΩ, R_2 = 200 kΩ, R_C = 5 kΩ, R_L = 2 kΩ, β = 75, and π = 750 Ω.

- Draw the DC bias circuit and prove that the BJT operates in the active region.
- Draw the small-signal equivalent circuit and find the voltage gain of the amplifier.

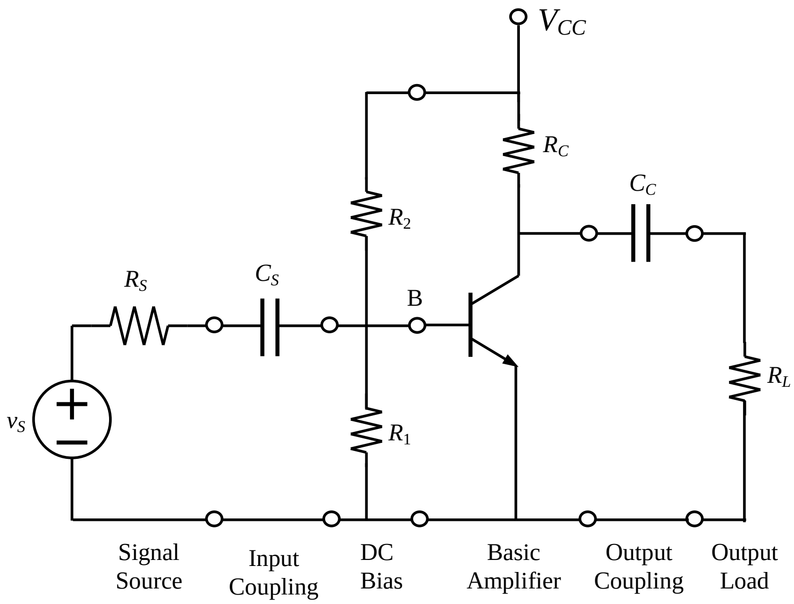

Figure 1 A stage of an amplifier circuit.

Solution:

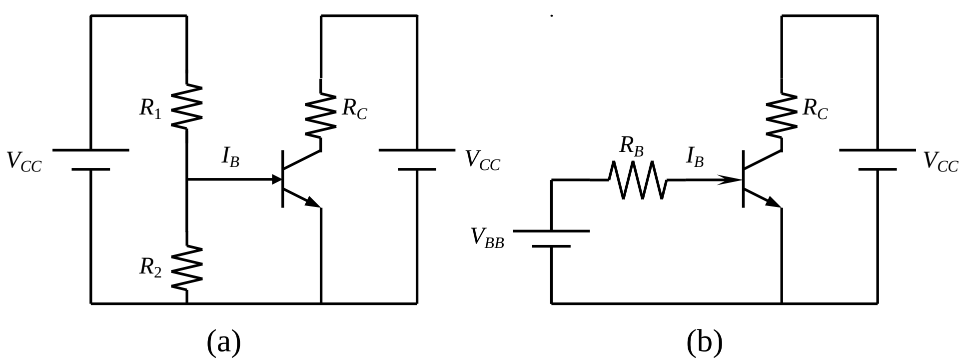

Figure 2 (a) DC bias circuit. (b) Equivalent of the input portion.

Step One: The DC analysis

The open-circuit base DC bias voltage is

	$V_{BB} = 24 \times \dfrac{8.6}{8.6 + 200} = \text{-}1.99\,\text{V}$

The DC output impedance of the bias network is

	$R_B = 8.6 // 200 = 8.25\,\text{k}\Omega$	

A silicon transistor requires a threshold voltage of V_{BE} = 0.7 V to turn ON the base-emitter junction, therefore

	$I_B = \frac{V_{BB} - 0.7}{R_B} = \frac{0.99 - 0.7}{8.25\,\text{k}\Omega} = 35.1\text{A}$ $I_C = \beta I_B = 75 \times 35.1 \times 10^{-6} = 2.63\,\text{A}$	

Now consider the closed loop path in the output circuit of the amplifier and apply KVL in order to find the collector-emitter voltage V_{CE}.

	$-V_{CC} + I_C R_C + V_{CE} = 0$ $V_{CE} = 24 - 5 \times 2.63 = 10.8\,\text{V}$	

Therefore, the BJT is operating in the saturation region.

Step Two: AC Analysis

Draw the Small-signal circuit of the BJT amplifier (1 mark).

Figure 4 Small-signal circuit of the BJT amplifier.

Consider the circuit in stage one, first.

- Let us find the equivalent resistance of the four resistors: 1.5, 200, 8.6, and 0.75

$$\frac{1}{R_T} = \frac{1}{1.5} + \frac{1}{200} + \frac{1}{8.6} + \frac{1}{0.75}$$
$$R_T = 0.472\,\Omega$$

Stage one circuit will turn into the following circuit

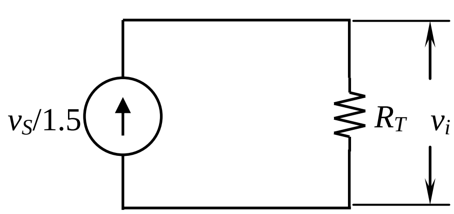

Figure 4: Equivalent circuit of stage-one circuit.

$$v_i = \frac{v_S}{1.5} \times R_T = 0.314\, v_S$$

This value of v_i is same across each element in the circuit of Figure 3. Now, apply ohm's law to find i_b

$$i_b = \frac{v_i}{r_\pi} = \frac{0.314\, v_S}{0.75} = 0.416\, v_S$$

Now, consider stage two circuit

$$v_{out} = -75\; i_b \times (2//5) = -75 \times 0.416\, v_S \times 1.42 = 446\, v_S$$

Accordingly, the gain is v_{out} / v_S = 446.

QUESTION 2 (2 marks)

A safety system shown has three inputs. If two or more of these are 1 at the same time, an alarm should sound. Draw a figure for the system; give its truth table; give its Boolean function; simplify the results; and draw the logic circuit to perform the alarm using NAND gates only.

QUESTION 3 (3 marks)

Design and draw a DC power supply that provides a nominal DC voltage of 5 V and be able to supply a load current I_{load} as large as 25 mA; that is R_{load} can be as low as 200 Ω. The power supply is fed from a 120-V (rms) 60 Hz AC line. Assume the availability of a 5.1-V zener diode having $r_z = 10\ \Omega$ at $I_z = 20$ mA (and use $V_{zo} = 4.9$ V), and that the required minimum current through the zener diode is $I_{\text{zmin}} = 5$ mA.