UNIVERSITY OF SWAZILAND
MAIN EXAMINATION, FIRST SEMESTER DECEMBER 2012

FACULTY OF SCIENCE

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

TITLE OF PAPER: ANALOGUE DESIGN III
COURSE CODE: EE421

TIME ALLOWED: THREE HOURS

INSTRUCTIONS:

1. There are five questions in this paper. Answer any FOUR questions. Each question carries 25 marks.

2. If you think not enough data has been given in any question you may assume any reasonable values.

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THIS PAPER CONTAINS EIGHT (8) PAGES INCLUDING THIS PAGE

**QUESTION ONE (*25 marks*)**

A differential amplifier implemented with MOS devices is shown in Figure-Q1.

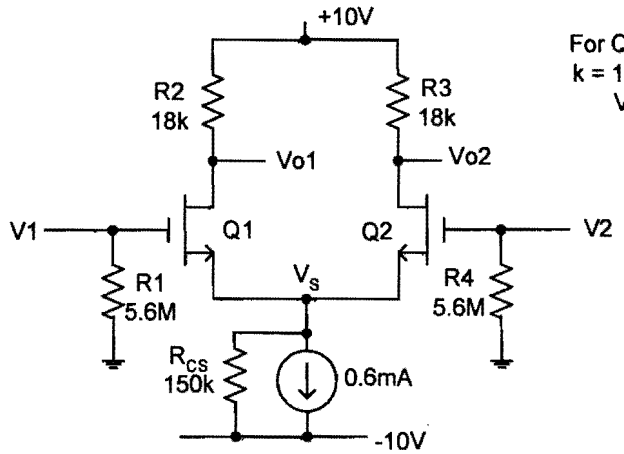


Figure-Q1

(a) Calculate the transconductance $g_m$ of the devices under the shown operating conditions. (4 marks)

(b) If $V_1 = 100mV$ and $V_2$ = -100mV , calculate the drain currents and drain voltages of the transistors. (5 marks)

(c) A differential signal $v_d$ is applied to the inputs($ie,\ v_d = v_1 - v_2$ ).

(i) Draw the differential half circuit for ac signals.

(ii) Calculate the voltage gains $\frac{v_{o2}}{v_d}$ and $\frac{v_{o2}-v_{o1}}{v_d}$ .

(8 marks)

(d) If a common mode signal $v_{cm}$ is applied to the inputs,

(i) Draw the common mode half circuit for the ac signals and find the common mode gain at the output $v_{o2}$.

(ii) Calculate CMRR in $dB$.

(8 marks)

**QUESTION TWO *(25 marks)***

(a) A circuit of a BJT current source is shown in Figure-Q2(a). You may assume that the transistors are matched.

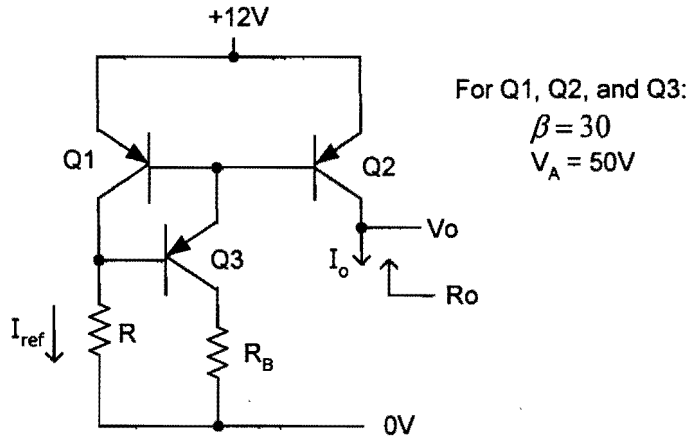


Figure-Q2(a)

(i) Find an expression for the current $I_o$ in terms of $I_{ref}$ and $\beta$, where $\beta$ is the current gain of the transistors. ( 5 marks)

(ii) Find suitable values for $R$ and $R_B$ to have $I_o = 1mA$. ( 4 marks)

(iii) Find the output resistance $R_o$. If $V_o$ = 5V, what is the output current $I_o$?

( 5 marks)

(b) A current mirror implemented with NMOS transistors in an integrated circuit is shown in Figure-Q2(b).

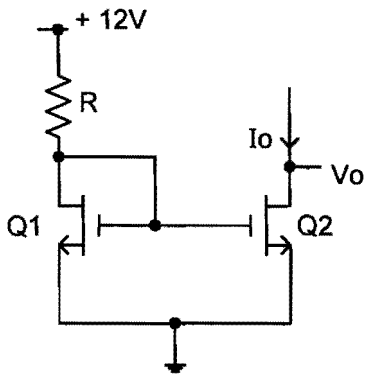


Figure-Q2 (b)

Following are the some of device parameters for Q1 and Q2.

$L_1 = L_2 = 10\mu m$ $W_1 = 30\mu m$ $W_2 = 60\mu m$ $V_t = 1V$ $\mu C_{ox} = 50\frac{\mu A}{V^2}$

The output current $I_o = 100\mu A$.

(i) What is the value of $V_{GS}$ ? ( 3 marks)

(ii) Calculate the value of $R$. ( 3 marks)

(iii) When $V_o$ is raised to 8 volts, $I_o$ becomes $110\mu A$. Estimate the output resistance of the mirror and the Early voltage of the devices. ( 5 marks)

**QUESTION THREE *(25 marks)***

(a) In the circuit shown in Figure-Q3(a), the transistors $Q_1$and $Q_2$are matched and of high gain type. For all transistors, $V_A = 100V$ and for $Q_3$, $\beta$ = 100.

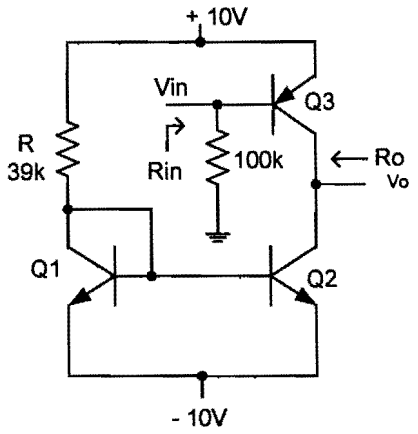


Figure - Q3(a)

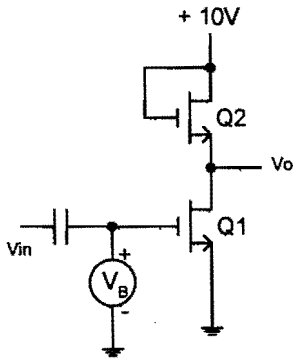


Figure-Q3 (b)

(i) Calculate the collector current of $Q_3$ at no signal. (3 marks)

(ii) Derive an expression for the voltage gain $\left(\frac{v_o}{v_{in}}\right)$ and find its value.

( 4 marks)

(iii) Find the input and output impedance of the circuit. ( 4 marks)

(b) An enhancement type NMOS amplifier is shown In Figure-Q3(b). You may use the following device parameters.

$$W_1 = 150\mu m \quad W_2 = 10\mu m \quad V_t = 2V \quad \mu C_{ox} = 100\frac{\mu A}{V^2}$$

$$L_1 = 10\mu m \quad L_2 = 50\mu m$$

(i) Calculate the bias voltage $V_B$ required to keep $V_o = 5V$ at no signal.

( 6 marks)

(ii) Draw the small signal equivalent circuit. Hence derive the voltage gain $\frac{v_o}{v_{in}}$ and find its value.

( 8 marks)

**QUESTION FOUR (*25 marks*)**

(a) A circuit of a cascode amplifier is shown in Figure-Q4.

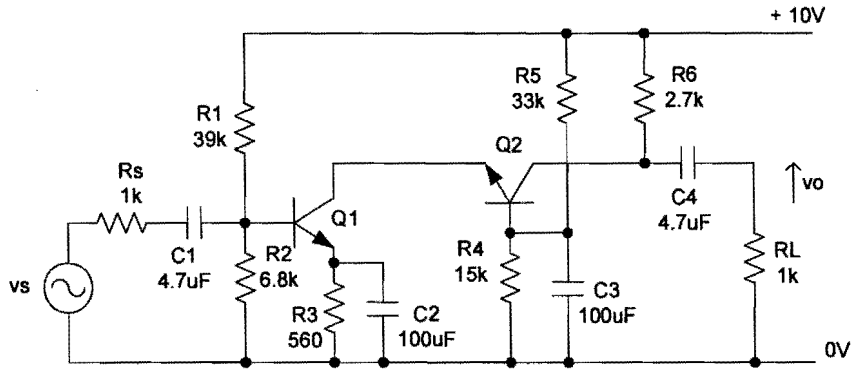


Figure - Q4

Assume that the transistors are of high gain type.

(i) Show that the collector currents of the transistors are 1.58mA. Hence calculate the collector voltages under quiescent conditions.

(6 marks)

(ii) Derive an expression for the mid-band gain and calculate its value. Assume that the $\beta = 100$ and $I_{c1} = I_{c2} = 1.58mA$.

(8 marks)

(iii) Find the values of the three pole frequencies and hence determine the high frequency 3dB bandwidth.

$C_\pi = 15pF$ $C_\mu = 3pF$

(11 marks)

**QUESTION FIVE (25 *marks*)**

A dc voltage regulator circuit is shown in Figure-Q5.

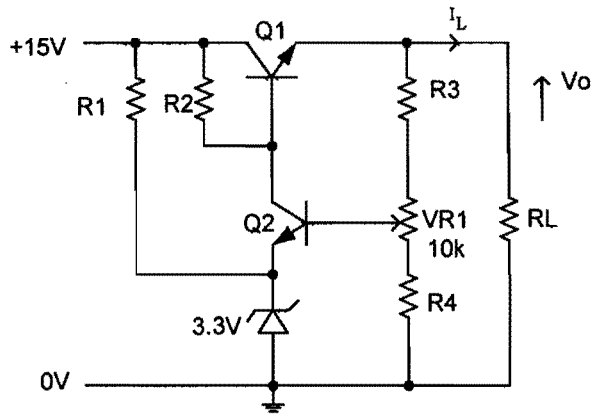


Figure-Q5

(i) Calculate the values of $R_3$ and $R_4$ in order to have maximum and minimum output voltages of 12V and 4V respectively. (6 marks)

(ii) If the maximum load current $I_L = 1.5A$, find the maximum power dissipation requirement of $Q_1$. (4 marks)

(iii) Show the implementation of an active current limit protection for $Q_1$ and find the related component values with power rating. (5 marks)

(iv) Assuming a minimum collector current of 5mA for $Q_2$, find the value of $R_2$ and its power rating. The $\beta$ *of* $Q_1 = 25$. (5 marks)

(v) What is the power rating of the zener diode? If the zener diode requires a minimum current of 10mA, find the value of $R_1$. (5 marks)

**USEFUL FORMULAE:**

$$I_D = \frac{I}{2} \pm \sqrt{2KI}\left(\frac{V_{id}}{2}\right)\sqrt{1 - \frac{\left(v_{id}^2/4\right)}{I/2k}}$$