UNIVERSITY OF SWAZILAND

SUPPLIMENTERY EXAMINATION, SECOND SEMESTER

JULY 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.**
3. **Some useful formulas are given in the last page.**

THIS PAPER SHOULD NOT BE OPENED UNTIL PERMISSION HAS BEEN GIVEN BY THE INVIGILATOR

THIS PAPER CONTAINS SEVEN (7) PAGES INCLUDING THIS PAGE

QUESTION ONE (*25 marks*)

A circuit of a BJT differential amplifier is shown in Figure-Q1. Assume $V_{BE} = 0.6V$ in general.

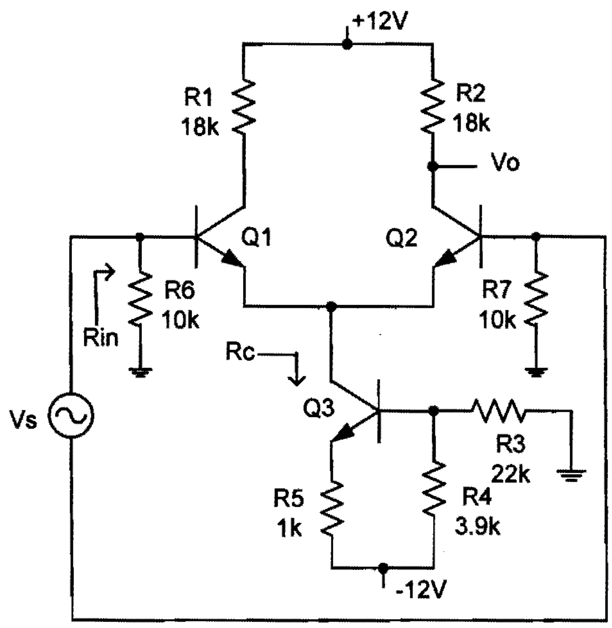

Figure-Q1

(a) Assuming the transistors are of high gain type, find the following at quiescent conditions.

(i) Voltage at the collectors and emitters of all transistors.

(ii) Collector current in each transistor.

(6 marks)

(b) Draw the differential half circuit and calculate the voltage gain $\frac{V_o}{V_S}$.

(8 marks)

(c) Assuming $R_C = 500k$, draw the common mode half circuit and calculate the common mode gain and CMRR.

(8 marks)

(d) If the gain of Q_1 and Q_2 is 100, find the differential input resistance R_{in}.

(3 marks)

QUESTION TWO *(25 marks)*

(a) Consider the current source shown in Figure-Q2(a). The transistors Q1 and Q2 are matched and of high gain type.

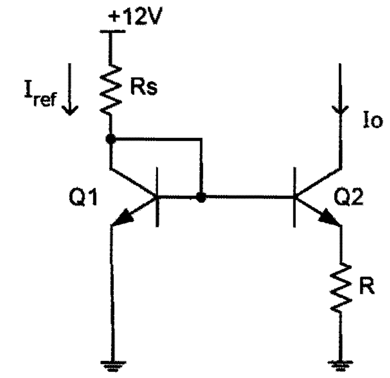

Figure-Q2 (a)

(i) Derive an relationship between I_o and I_{ref}. (7 marks)

(ii) If the output current of the current source is $120\mu A$, find the values of R_S and R. Assume $I_{ref} = 1.15mA$. (5 marks)

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

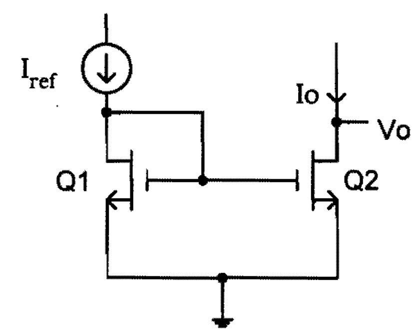

Figure-Q2 (b)

You may assume the following device parameters.

$L_1 = L_2 = 6\mu m$ $\quad w_1 = 18\mu m$ $\quad w_2 = 60\mu m$ $\quad v_t = 1V$ $\quad \mu C_{ox} = 40\frac{\mu A}{V^2}$

(i) If $I_o = 150\mu A$, calculate the value of V_{GS}. (5 marks)

(ii) Calculate the value of I_{ref} to have $I_o = 150\mu A$. (6 marks)

(iii) What is the value of V_o which gives $I_o = 150\mu A$, for the value of I_{ref} found in (ii)? (2 marks)

QUESTION THREE *(25 marks)*

(a) A BJT amplifier is shown in Figure-Q3(a) where Q2 and Q3 are matched. Assume that the transistors in the circuit are of high gain type.

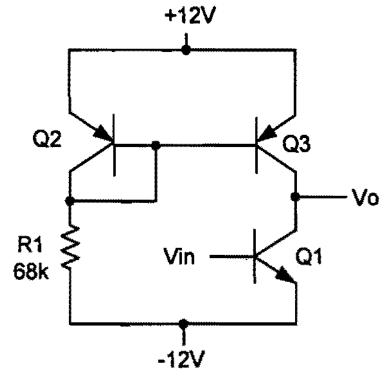

Figure-Q3(a)

(i) Find the collector current of Q1 at the quiescent conditions. (5 marks)

(ii) Derive an expression for the voltage gain $\frac{V_o}{V_{in}}$ and find its value. You may assume $V_A = 100V$. (7 marks)

(b) The circuit shown in Figure-Q3(b) uses enhancement type NMOS devices.

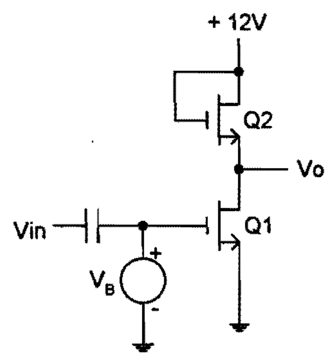

Figure-Q3 (b)

Some useful process parameters of the devices are given below.

$W_1 = 160\mu m$ $W_2 = 12\mu m$ $L_1 = 10\mu m$ $L_2 = 50\mu m$

$V_t = 3V$ $\mu C_{ox} = 100\frac{\mu A}{V^2}$

(i) Find the value of V_B to have $V_o = 6V$ at no signal. (5 marks)

(ii) Draw the small signal equivalent circuit and calculate the voltage gain $\frac{V_o}{V_{in}}$.

(8 marks)

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

A BJT cascode amplifier is shown in Figure-Q4.

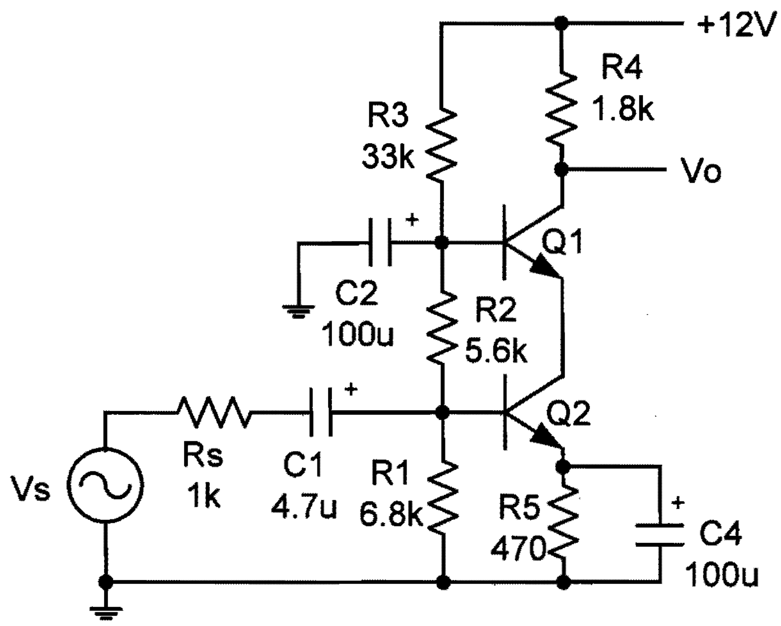

Figure-Q4

(i) Assuming that the transistors are identical and of high gain type, calculate the voltages at the collector and emitter of each transistor at no signal.

(12 marks)

(ii) Find an expression for the mid-band gain $\frac{v_o}{v_s}$ and calculate its value. Neglect the effect of r_o in both transistors while $\beta = 100$.

(13 marks)

QUESTION FIVE (25 *marks*)

A circuit of a dc regulator is shown in Figure-Q5.

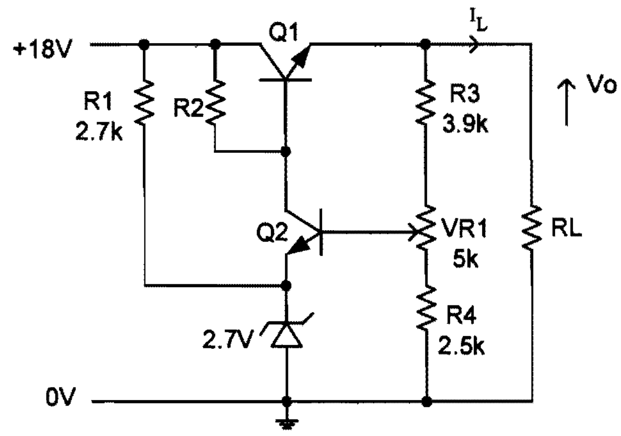

Figure-Q5

(i) Calculate the maximum and minimum value of V_o.

(5 marks)

(ii) If the maximum power dissipation of Q1 is $15W$, find the maximum load current I_L of the regulator.

(5 marks)

(iii) Show the implementation of an active current limit for the protection of Q1 and give the related component values with power rating.

(5 marks)

(iv) If the minimum collector current of Q2 is $10mA$, find the value of $R2$ and its maximum power dissipation. Assume that the $\beta_1 = 25$.

(5 marks)

(v) Find the maximum power dissipation of the zener diode.

(5 marks)

1. SOME USEFUL MOSFET EQUATIONS

$i_D = \mu_n C_{ox} \frac{W}{L}\left[(v_{GS} - v_t)v_{DS} - \frac{1}{2}v_{DS}^2\right]$ in triode region

$i_D = \frac{1}{2}\mu_n C_{ox} \frac{W}{L}(v_{GS} - v_t)^2$ in saturation region

$i_D = \frac{1}{2}\mu_n C_{ox} \frac{W}{L}(v_{GS} - v_t)^2(1 + \lambda v_{DS})$ in saturation region with Channel Modulation effect

$V_A = \frac{1}{\lambda}$

2. Unless otherwise stated $V_{BE(ON)} = 0.6V$ and $V_T = 0.025V$.