UNIVERSITY OF SWAZILAND

MAIN EXAMINATION FIRST SEMESTER 2007/8

FACULTY OF SCIENCE

DEPARTMENT OF ELECTRONIC ENGINEERING

TITLE OF PAPER: ANALOGUE ELECTRONICS III

COURSE NUMBER: E511

TIME ALLOWED: THREE HOURS

INSTRUCTIONS:

1. **Answer any <u>FOUR</u> (4) of the following five questions.**
2. **Each question carries 25 marks.**
4. **If you think not enough data has been given in any question you may assume reasonable values.**
5. **A sheet containing some useful equations and other data is attached at the end of the examination paper.**

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) Three matched diodes and a resistor R are connected in series to a 9 V d.c. power supply. The diodes are specified as having $V_D = 0.7$ V at $I_D = 1$ mA. Find the value of R necessary to get a total voltage of 2.22 V across the string of diodes.

(5 marks)

(b) A diode with $n = 2$ is found to have a voltage V_{D1} at I_{D1} and V_{D2} at I_{D2}. Show that

$V_{D2} = V_{D1} + \Delta V \log_{10}\left(\frac{I_{D2}}{I_{D1}}\right)$ and evaluate ΔV. *(5 marks)*

(c) A diode specified as having $V_D = 0.7$ V at $I_D = 1$ mA and $n = 2$ is connected in series with a 500 Ω resistor to a 3 V d.c. power supply. Use an iteration procedure with 4 decimal places accuracy to evaluate the actual diode current. *(15 marks)*

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

An NMOS inverter circuit is shown in Fig. Q2. Both transistors have

$k_n' \frac{W}{L} = 30\ \mu A/V^2$ and $V_t = 1$ V.

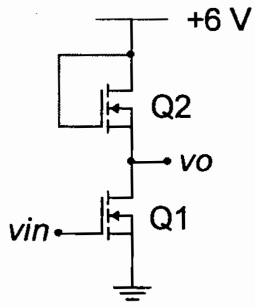


Fig. Q2

(a) Show that Q2 can operate in two modes while Q1 can operate in 3 modes. You must establish the signal conditions for each mode of operation. *(10 marks)*

(b) Find the transfer relationships between v_o and v_{in} for each mode of operation and by picking a few points on the transfer characteristic sketch the transfer characteristic. *(15 marks)*

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

(a) The MOSFETs in Figure Q3a have

$$V_t = 0.8\ \text{V},\ \mu_n C_{ox} = 180\ \mu\text{A/V}^2,\ \frac{W_1}{L_1} = 10\ \text{and}\ \lambda = 0$$

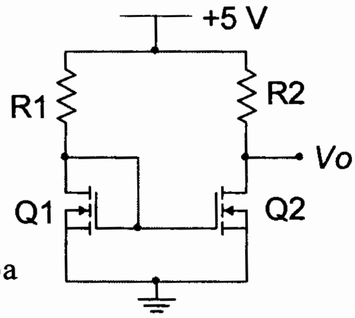


Fig. Q3a

(i) Find R_1 for $I_{D1} = 0.1$ mA. *(5 marks)*

(ii) Find $\frac{W_2}{L_2}$ and R_2 for $I_{D2} = 0.8$ mA with a drain voltage of 1.2 V. *(5 marks)*

(b) The transistor in Fig. 3b has $V_t = 0.7$ V, $V_A = 60$ V and $V_{DS} = 3$ V. Assume that the current source is ideal.

(i) Find the voltage gain v_o/v_{in} of the circuit. *(7 marks)*

(ii) If I is increased to 1.5 mA what will be the new gain? *(8 marks)*

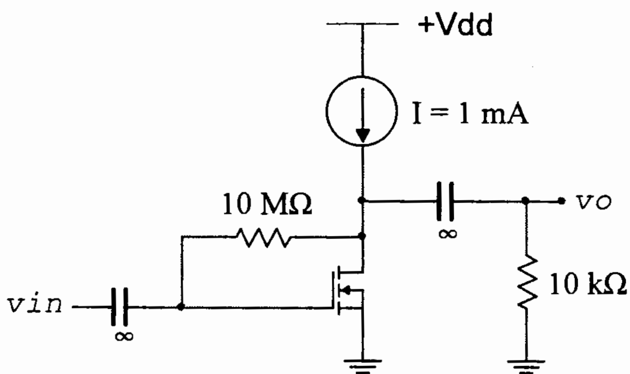


Fig. Q3b

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

(a) For a MOSFET in saturation

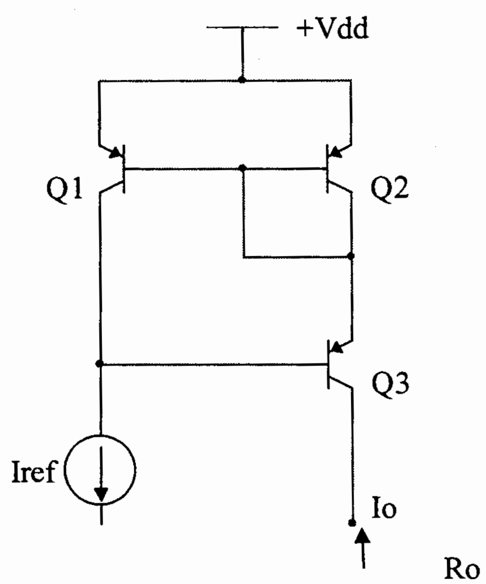
(i) Show that the transconductance g_m is proportional to the square root of the drain current. *(5 marks)*

(ii) Obtain a relationship between the transconductance g_m, the overdrive voltage and the drain current. *(3 marks)*

(b) Sketch a CMOS implementation of the logic expression $F = \left(\overline{C} + A\overline{B}\right)\overline{D} + E$.

(5 marks)

(c) A Wilson current mirror which can be used as an active load is shown in Fig. Q5c. Assume that all transistors are matched. Show that the output impedance of the current source is given by $R_o \approx (\beta/2)r_o$. *(12 marks)*



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

(a) For the circuit in Fig. 5a assume that $|V_{BE}| = 0.7$ V, $\beta >> 1$ and R = 5 kΩ. Find the voltage V_o.

(7 marks)

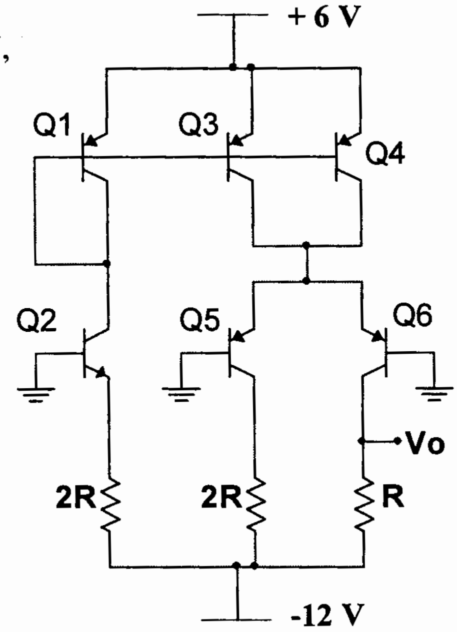


Fig. Q5a

(b) In a BJT differential amplifier the collector resistors are R_C = 100 kΩ and the bias current source (tail current) is I = 200 μA. Assume that the transistors are matched with $\beta = 150$.

(i) What is the differential voltage gain? *(3 marks)*

(ii) What is the common mode gain? *(2 marks)*

(iii) If the bias source is reduced to 100 μA and resistors are added to the emitter circuit to increase the input resistance to 500 kΩ, what the values of the emitter resistors added? *(3 marks)*

(c) Consider the circuit shown in Fig. Q5c. Assume that all MOSFETS are matched and that the BJT has V_{BE} = 0.7 V at I_c =1 mA.

(i) Show that $IR = V_T \ln\left(\frac{I}{I_S}\right)$ *(4 marks)*

(ii) Calculate the value of R necessary to make I = 10 μA. *(6 marks)*

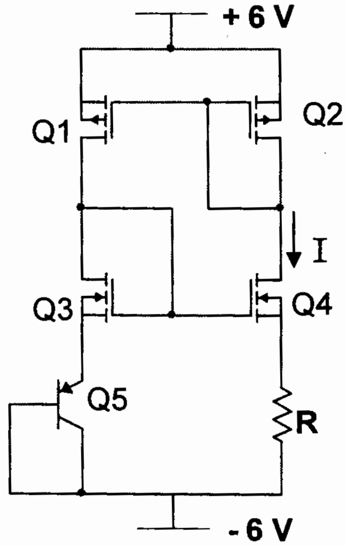


Fig. Q.5c

===== END OF EXAMINATION PAPER, ATTACHMENT FOLLOWS =====

1. **SOME USEFUL MOSFET EQUATIONS**

$$i_D = k_n' \frac{W}{L}\left[(v_{GS} - V_t)v_{DS} - \frac{1}{2}v_{DS}^2\right] \text{ in triode region}$$

$$i_D = \frac{1}{2}k_n' \frac{W}{L}(v_{GS} - V_t)^2 \text{ in saturation region}$$

$$i_D = \frac{1}{2}k_n' \frac{W}{L}(v_{GS} - V_t)^2(1 + \lambda v_{DS}) \text{ in saturation region with Channel Modulation effect}$$

2. **BJT EBERS-MOLL EQUATIONS**

$$i_E = \frac{I_s}{\alpha_F}\left(e^{v_{BE}/V_T} - 1\right) - I_s\left(e^{v_{BC}/V_T} - 1\right)$$

$$i_C = I_s\left(e^{v_{BE}/V_T} - 1\right) - \frac{I_s}{\alpha_R}\left(e^{v_{BC}/V_T} - 1\right)$$

$$i_B = \frac{I_s}{\beta_F}\left(e^{v_{BE}/V_T} - 1\right) + \frac{I_s}{\beta_R}\left(e^{v_{BC}/V_T} - 1\right)$$

3. **Unless otherwise stated, $V_{BE(ON)}$ = 0.7 V and V_T = 0.025 V.**