Name:

Student ID Number:

Section Number: 01/02/03/04/05/06 A/B

Lecturer: Dr Azni Wati/ Dr Fazrena Azlee/ Dr Jehana Ermy/ Dr Jamaludin

Table Number:

UNIVERSITI TENAGA NASIONAL

College of Engineering
Department of Electronics and Communication Engineering

Test 1

SEMESTER 1, ACADEMIC YEAR 2017/2018

Subject Code	:	**EEEB273**
Course Title	:	**Electronics Analysis & Design II**
Date	:	**8 July 2017**
Time Allowed	:	**2 hours**

Instructions to the candidates:

1. Write your Name and Student ID Number. Indicate your Section Number and Lecturer's Name. Write also your Table Number.
2. **Write all your answers using pen**. **DO NOT USE PENCIL** except for the diagram.
3. **ANSWER ALL QUESTIONS. Show clearly** all your calculations. Every value **must** be written with its correct Unit.
4. **WRITE YOUR ANSWER ON THIS QUESTION PAPER.**

NOTE: DO NOT OPEN THE QUESTION PAPER UNTIL INSTRUCTED TO DO SO.

☺ **GOOD LUCK!** ☺

Question Number	Q1	Q2	Q3	Q4	Total
Marks					

QUESTION 1 [35 marks]

(a) Draw the BJT three-transistor and Wilson current sources with clear details of the transistors Q_1, Q_2 and Q_3 placements. [12 marks]

(b) What are the applications of the BJT three-transistor and Wilson current sources? [3 marks]

(c) **Figure 1** shows a Widlar current source. Derive an equation that gives the relationship between the reference current, I_{REF}, and the load current, I_O. [10 marks]

(d) Consider a Widlar current source with circuit parameters of $V^+ = 3$ **V**, $V^- = -3$ **V**, $V_{BE1}(on) = 0.6$ **V**, and $V_A = \infty$. Design the circuit such that $I_O = 20\ \mu A$ and $I_{REF} = 100\ \mu A$. Neglect the base currents. [10 marks]

Answers for Question 1

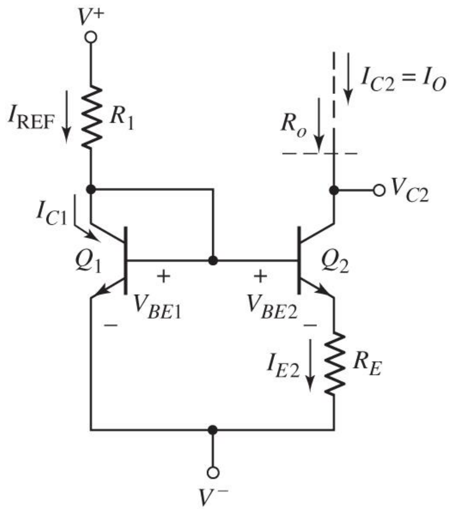

Figure 1

Answers for Question 1 (Continued)

QUESTION 2 [20 marks]

For a **MOSFET current source** shown in **Figure 2** the circuit parameters are: V^+ **= 3 V** and V^- **= –3 V**. Transistor parameters for **N-MOSFET** are: V_{TN} **= 0.5 V**, $½\mu_n C_{ox}$ **= 50** μ**A/V**^{2} and λ_n **= 0.02 V**$^{-1}$; and the transistor parameters for **P-MOSFET** are: V_{TP} **= -0.55 V**, $½\mu_p C_{ox}$ **= 20** μ**A/V**^{2} and λ_p **= 0.03 V**$^{-1}$. The transistor aspect ratios are: $(W/L)_1$ **= 20,** $(W/L)_2$ **= 35,** $(W/L)_3$ **= 5** and $(W/L)_4$ **= 10.**

(a) Find I_O, I_{REF} and the V_{GS} voltages for all transistors if the minimum voltage at the drain of transistor M_2, i.e. V_{D2} is **-2.1V**. [12 marks]

(b) Calculate the change in the output current, dI_o if V_{D2} varies from **-1.6V to 0.4V**. [5 marks]

(c) From the answer calculated in (b) find the output current, I_o in this condition when V_{D2} varies from **-1.6V to 0.4V**. [3 marks]

Answers for Question 2

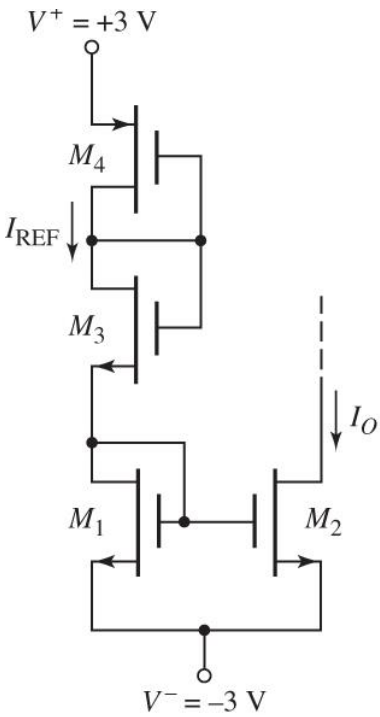

Figure 2

Answers for Question 2 (Continued)

<u>QUESTION 3 [25 marks]</u>

The BJT differential amplifier in Figure 3 is biased by a Cascode current source. Let the biasing current, I_Q, from the current source is 0.5 mA. The transistor parameters for the circuit shown are β **= 180**, V_{BE}**(on) = 0.7**, and $V_A = \infty$ for Q_1 and Q_2. The differential-mode voltage gain, A_d**, is 223** while the common-mode voltage gain A_{cm}**, is -10**.

(a) Redraw the circuit incorporating the Cascode current source. [5 marks]

(b) Design the differential amplifier such that $v_{o2} = 0.4$ **V for** $v_1 = v_2 = 0$. [6 marks]

(c) Calculate the differential-mode input voltage, v_d. [4 marks]

(d) Calculate the common-mode input voltage, v_{cm}. [4 marks]

(e) Calculate the output voltage, v_o, due to $v_1 = 250 \sin \omega t$ **μV** and $v_2 = 150 \sin \omega t$ **μV**. [6 marks]

<u>Answers for Question 3</u>

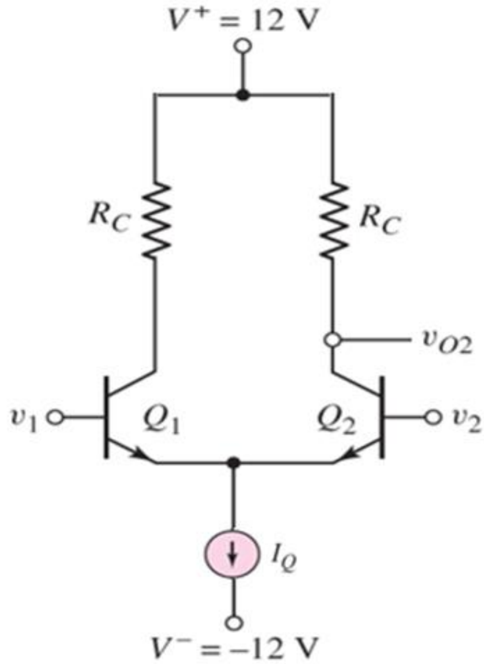

Figure 3

Answers for Question 3 (Continued)

QUESTION 4 [20 marks]

For a **BJT differential amplifier** in **Figure 4 (a)** we can use **Figure 4 (b)** to perform the small-signal circuit analysis.

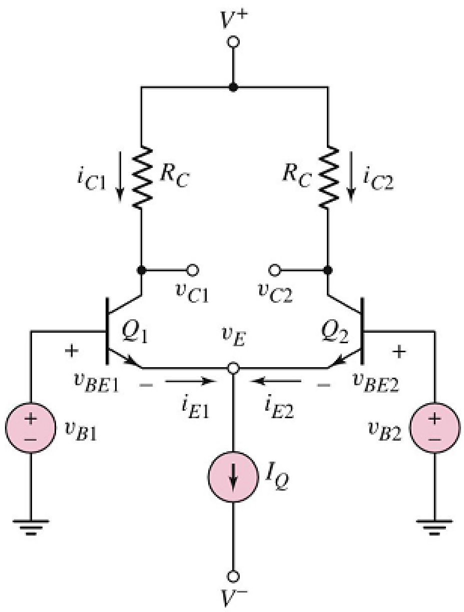

Figure 4 (a)

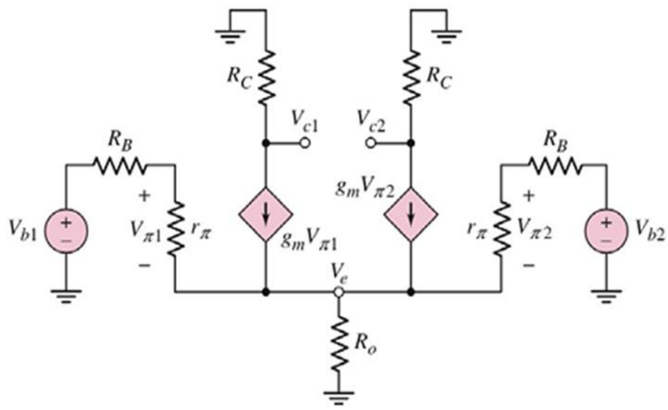

Figure 4 (b)

With small-signal circuit analysis, we can derive that **one-sided output voltage (*V_o*)** taken at ***V_{c2}*** is given by the following equation:

$$V_o = \frac{\beta R_C}{2(r_\pi + R_B)}.V_d - \frac{\beta R_C}{r_\pi + R_B + 2(1+\beta)R_o}.V_{cm}$$

where ***V_d*** is differential-mode input voltage, ***V_{cm}*** is common-mode input voltage, ***R_B*** is output resistance for input signals ***V_{b1}*** and ***V_{b2}***, and ***R_o*** is output resistance looking into the constant-current source that is biasing the diff-amp.

Consider the circuit in the **Figure 4 (a)** with parameters **V^+ = 10 V, V^- = -10V, I_Q = 0.8 mA**, and ***R_C*** = **12** kΩ. Transistor parameters are **β = 100** and **V_A** = ∞. Assume **R_o = 25 kΩ** and **R_B = 0.**

Calculate differential-mode gain (***A_d***), common-mode gain (***A_{cm}***), and the common-mode rejection ratio (***CMRR***) of the diff-amp. [20 marks]

Answers for Question 4

BASIC FORMULA FOR TRANSISTOR

BJT

$$i_C = I_S e^{v_{BE}/V_T} \text{; npn}$$

$$i_C = I_S e^{v_{EB}/V_T} \text{; pnp}$$

$$i_C = \alpha i_E = \beta i_B$$

$$i_E = i_B + i_C$$

$$\alpha = \frac{\beta}{\beta + 1}$$

;Small signal

$$\beta = g_m r_\pi$$

$$g_m = \frac{I_{CQ}}{V_T}$$

$$r_\pi = \frac{\beta V_T}{I_{CQ}}$$

$$r_o = \frac{V_A}{I_{CQ}}$$

$$V_T = 26\,\text{mV}$$

MOSFET

;N – MOSFET

$$v_{DS}(\text{sat}) = v_{GS} - V_{TN}$$

$$i_D = K_n[v_{GS} - V_{TN}]^2$$

$$K_n = \frac{k_n'}{2} \cdot \frac{W}{L}$$

;P – MOSFET

$$v_{SD}(\text{sat}) = v_{SG} + V_{TP}$$

$$i_D = K_p[v_{SG} + V_{TP}]^2$$

$$K_p = \frac{k_p'}{2} \cdot \frac{W}{L}$$

;Small signal

$$g_m = 2\sqrt{K_n I_{DQ}} \quad \text{; N - MOSFET}$$

$$g_m = 2\sqrt{K_p I_{DQ}} \quad \text{; P - MOSFET}$$

$$r_o \cong \frac{1}{\lambda I_{DQ}}$$

Quadratic formula :

$$Ax^2 + Bx + C = 0 \quad \rightarrow \quad x = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$