Name:
Student ID Number:
Section Number: 01/02/03/04 A/B
Lecturer: Dr Jamaludin/Dr Fazrena Azlee
Table Number:

UNIVERSITI TENAGA NASIONAL
The National Energy University

College of Engineering
Department of Electronics and Communication Engineering

Test 1

SEMESTER 2, ACADEMIC YEAR 2018/2019

Subject Code	:	**EEEB273/EEEB2014**
Course Title	:	**Electronics Analysis & Design II**
Date	:	**1 December 2018**
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 all calculations clearly**. Every value or parameter **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 (a-d)	Q2 (a)	Q2 (b)	Q3 (a)	Q3 (b)	Q4 (a-b)	Total
Marks							

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 :

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

This is extra page for answers. Please indicate question number clearly.

QUESTION 1 [30 marks]

For all **BJT current sources mentioned** in **this Question 1**, all transistors are matched and have same parameters. The transistor parameters are: $\boldsymbol{\beta}$ **= 40**, $\boldsymbol{V_{BE}}$**(on) = 0.7 V**, and $\boldsymbol{V_A}$ **= 120 V**. The circuit parameters for the current sources are: $\boldsymbol{V^+}$ **= 12 V** and $\boldsymbol{V^-}$ **= -12 V.**

(a) **Design** a **Two-transistor** current source, a **Three-transistor** current source, and a **Wilson** current source such that $\boldsymbol{I_{REF}}$ **= 1.2 mA**. **[7.5 marks]**

(b) **Calculate** values of **output current (**$\boldsymbol{I_O}$**)** and **output resistance (**$\boldsymbol{R_O}$**)** for all the BJT current sources given in **part (a)**. **[13.5 marks]**

(c) **Find** the **change in the output current (**$\boldsymbol{dI_O}$**)** as the **output voltage** for all the BJT current sources given in **part (a)** had **changed by +2.3 V**. **[6 marks]**

(d) Based on your calculations in **part (b)** and **part (c)**, **which current source** has the most stable $\boldsymbol{I_O}$, **which current source** has the medium stable $\boldsymbol{I_O}$, and **which current source** has the least stable $\boldsymbol{I_O}$ from all the BJT current sources given in **part (a)**? **Explain** clearly your answers. **[3 marks]**

Answers for Question 1

Answers for Question 1 (Continued)

QUESTION 2 [30 marks]

(a) It is required that a **PMOS current mirror** circuit is implemented using transistors $\boldsymbol{M_1}$ and $\boldsymbol{M_2}$, and a resistor $\boldsymbol{R_1}$.

(i) **Sketch** the PMOS current mirror. **Indicate** the currents $\boldsymbol{I_{REF}}$ and $\boldsymbol{I_O}$. **[6 marks]**

(ii) **Show** that the current relationships are as is **Equation 1**. **[4 marks]**

$$I_O = \frac{(W/L)_2}{(W/L)_1} . I_{REF} \qquad \textbf{Equation 1}$$

Answers for Question 2(a)

(b) An **NMOS cascode current source** is shown in **Figure 1**. The currents are $\boldsymbol{I_{REF}}$ **= 2mA** and $\boldsymbol{I_O}$ **= 40 µA**. It is given that $\boldsymbol{K_{n1} = K_{n3} = K_{n4}}$ **= 25 mA/V²**. The transistor parameters are $\boldsymbol{k_n'}$ = **0.5m A/V²**, $\boldsymbol{V_{TN}}$ **= 0.9 V** and $\boldsymbol{\lambda}$ **= 0.02 V⁻¹**.

(i) **Find** all V_{GS} voltages for the circuit. **[5 marks]**

(ii) **Design** the current source to produce $\boldsymbol{I_{REF}}$ **= 2 mA** and $\boldsymbol{I_O}$ **= 40µA**. **[5 marks]**

(iii) **Find** output impedance ($\boldsymbol{R_O}$) of the **cascode current source**. **[4 marks]**

(iv) **Calculate** percent change in output current $\boldsymbol{I_O}$ if $\boldsymbol{V_{D4}}$ changes by **2.5 V**. **[4 marks]**

(v) If a **2-transistor current source** is used instead, will the percent change in $\boldsymbol{I_O}$ increase or decrease? **Justify** your answer. **[2 marks]**

<u>Answers for Question 2(b)</u>

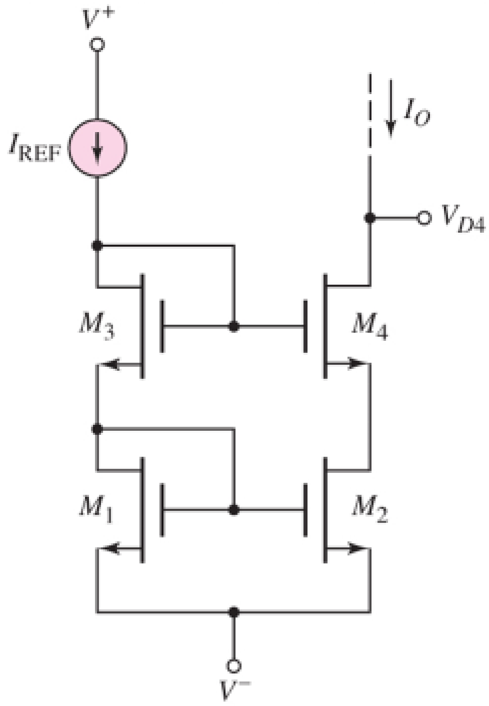

Figure 1

QUESTION 3 [20 marks]

(a) **Draw** a complete circuit diagram for a **PNP** differential amplifier with resistive load biased by a **cascode** current source. Transistors $\boldsymbol{Q_1}$ and $\boldsymbol{Q_2}$ are used in the differential amplifier while transistors $\boldsymbol{Q_3}$ until $\boldsymbol{Q_6}$ are used in the **cascode** current source. **Label the diagram clearly**, showing all necessary currents, resistors, and **PNP** BJTs used in the circuit.

[5 marks]

Answers for Question 3(a)

(b) **Figure 2** has the transistor parameters of $\boldsymbol{\beta} = \mathbf{120}$, $\boldsymbol{V_{BE}}\mathbf{(on) = 0.7\ V}$, $\boldsymbol{V_A} = \infty$ for $\boldsymbol{Q_1}$ and $\boldsymbol{Q_2}$, and $\boldsymbol{V_A} = \mathbf{100\ V}$ for $\boldsymbol{Q_3}$ and $\boldsymbol{Q_4}$. Given $\boldsymbol{R_C} = \mathbf{5\ k\Omega}$.

(i) **Calculate** $\boldsymbol{R_1}$ such that $\boldsymbol{I_Q} = \mathbf{4\ mA}$. **[5 marks]**

(ii) **Determine** output of the differential amplifier, $\boldsymbol{V_{O2}}$, if $\boldsymbol{v_1} = \boldsymbol{v_2} = \boldsymbol{v_{cm}} = \mathbf{0}$.

[5 marks]

(iii) **Determine** $\boldsymbol{V_{CE4}}$ for $\boldsymbol{v_1} = \boldsymbol{v_2} = \boldsymbol{v_{cm}} = \mathbf{0}$. **[5 marks]**

<u>Answers for Question 3(b)</u>

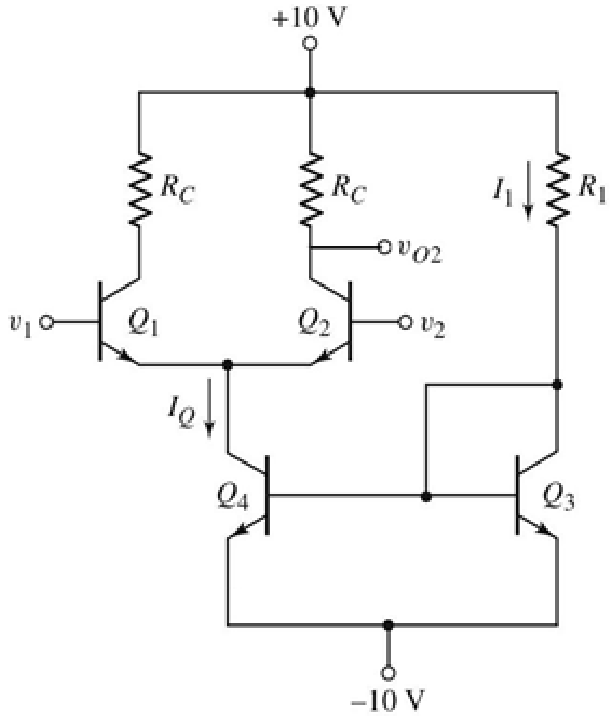

Figure 2

QUESTION 4 [20 marks]

Please refer to a **BJT** differential amplifier circuit in **Figure 3**. From small-signal analysis the expression of the output voltage at V_{C2} is shown in **Equation 2**. It is given that for the transistors V_{BE}**(on) = 0.7 V,** β **= 250,** V_A for Q_1 and Q_2 is **infinity**, while for Q_3 and Q_4, V_A **= 100 V**. For the circuit R_1 **= 37 kΩ,** R_C **= 30 kΩ,** and R_B **= 500 Ω**. For the differential amplifier, **neglect the base currents**.

$$v_O = \frac{\beta R_C}{2(r_\pi + R_B)} \cdot v_d - \frac{g_m R_C}{1 + \frac{2(1+\beta)R_O}{r_\pi + R_B}} \cdot v_{cm} \qquad \textbf{Equation 2}$$

(a) **Find** the **differential gain (**A_d**), the common mode gain (**A_{cm}**), and the common mode rejection ratio** ***CMRR*** **(dB)** of the circuit. **[13 marks]**

(b) It is given for the inputs, v_1 **= 210 x 10**$^{-6}$ **sin ωt V** and v_2 **= 190 x 10**$^{-6}$ **sin ωt V**. **Calculate** the output voltage V_o. **[7 marks]**

Answers for Question 4

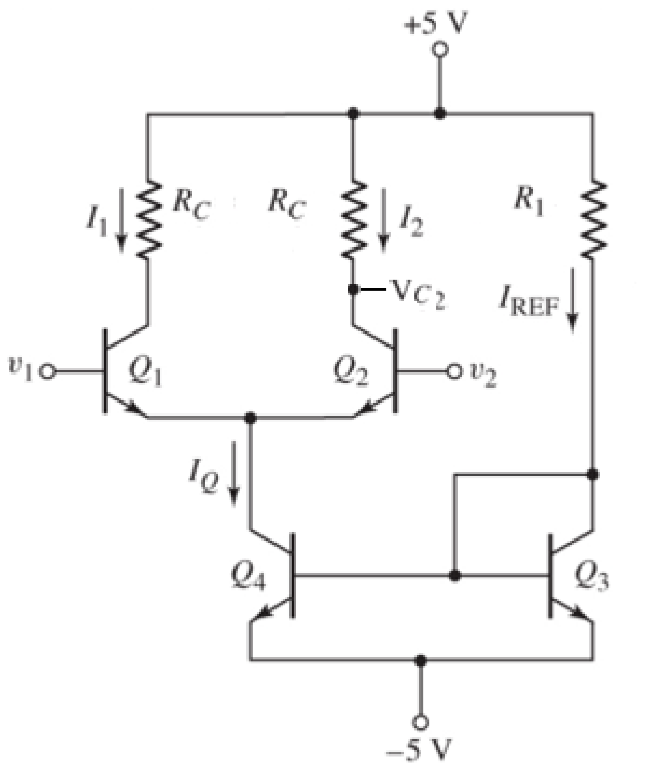

Figure 3

Answers for Question 4 (Continued)

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