Name:

Student ID Number:

Section: **01/02/03/04 A/B**

Lecturer: **Dr Jamaludin /Dr Azni Wati /Dr Fazrena**

UNIVERSITI TENAGA NASIONAL

College of Engineering

Department of Electronics and Communication Engineering

Test 1 – Model Answer

SEMESTER 1, ACADEMIC YEAR 2013/2014

Subject Code	:	**EEEB273**
Course Title	:	**Electronics Analysis & Design II**
Date	:	**27 June 2013**
Time Allowed	:	**1 hour**

Instructions to the candidates:

1. Write your Name and Student ID number. Circle your section number.
2. Write all your answers using pen. **DO NOT USE PENCIL** except for the diagram.
3. **ANSWER ALL QUESTIONS.**
4. **WRITE YOUR ANSWER ON THIS QUESTION PAPER.** Use both sides of the question paper to write your answers.
5. For all calculations, assume that V_T = **26 mV**.

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

☺ **GOOD LUCK!** ☺

FORMULA FOR TRANSISTORS

BJT

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

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

$i_C = \alpha i_E = \beta i_B$

$i_E = i_B + i_C$

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

;Small signal

$\beta = g_m r_\pi$

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

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

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

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

$g_m = 2\sqrt{K_? I_{DQ}}$

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

Question 1 [60 marks]

(a) Consider a **modified three-transistor BJT current source** as in **Figure 1(a)**. Transistor parameters are V_{BE}**(on) = 0.7 V**, $V_A = \infty$, and $\beta = 80$. *Hint: Please take note of the current directions given in the* **Figure 1(a)**.

(i) **Show** that

$$I_{REF} - \frac{V_{BE}}{(1+\beta)R_2} = I_O\left(1 + \frac{2}{\beta(1+\beta)}\right)$$ [20 marks]

(ii) For R_2 **= 10 kΩ**, V^+ **= 10 V**, and I_O **= 0.70 mA**, **find** I_{REF} and R_1. [20 marks]

Answers for Question 1(a)

(i)

$I_{B1} = I_{B2}$ [2]

$I_O = \beta I_{B2} \rightarrow I_{B2} = I_O / \beta$ [2]

$I_{C1} = \beta I_{B2} \rightarrow I_{C1} = I_O$ [2]

$I_{E3} = 2 I_{B2} + V_{BE} / R_2$ [2]

$I_{B3} = I_{E3} / (1 + \beta)$ [2]

$= (2 I_{B2})/(1 + \beta) + (V_{BE})/(1 + \beta)(R_2)$

$= (2 I_O)/(\beta(1 + \beta)) + (V_{BE})/((1 + \beta)R_2)$ [2]

$I_{REF} = I_{C1} + I_{B3}$ [2]

$= I_O + (2 I_O)/(\beta(1 + \beta)) + (V_{BE})/((1 + \beta)R_2)$ [2]

$I_{REF} - (V_{BE})/((1 + \beta)R_2) = I_O + (2 I_O)/(\beta(1 + \beta))$ [2]

$= I_O [1 + 2/(\beta(1 + \beta))]$

$$I_{REF} - \frac{V_{BE}}{(1+\beta)R_2} = I_O\left(1 + \frac{2}{\beta(1+\beta)}\right)$$ [2]

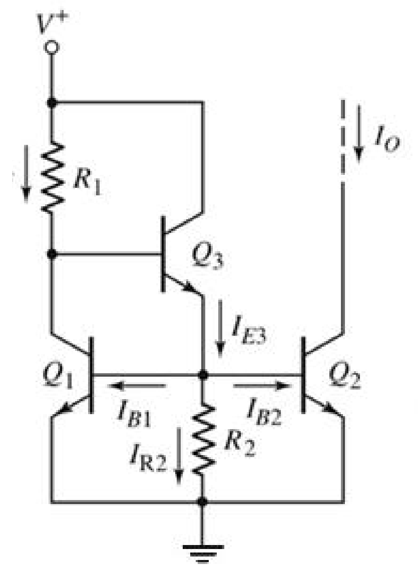


Figure 1(a)

(ii)

$I_{REF} = I_O (1 + 2/(\beta(1 + \beta))) + (V_{BE})/((1 + \beta)R_2)$ [4]

$= (0.70m)(1+2/(80x81)) + (0.7)/(81x10k)$ [4]

$= 0.700216m + 0.000864m$

$= 0.7011$ mA [2]

$R_1 = (V^+ - 2V_{BE}(on) - 0) / I_{REF}$ [4]

$= (10 - 2(0.7)) / (0.7011m)$ [4]

$= 12.27$ kΩ [2]

(b) For a MOSFET current source circuit in **Figure 1(b)** the transistor parameters are V_{TN} **= 0.5 V**, k'_n **= 80 µA/V²**, and $\lambda = 0$. **Design** the circuit such that V_{DS2}**(sat) = 0.3 V**, I_{REF} **= 50 µA**, and the load current is I_O **= 100 µA**.

[20 marks]

Answers for Question 1(b)

$V_{DS2}(\text{sat}) = V_{GS} - V_{TN}$ **[2]**

$V_{GS} = V_{DS2}(\text{sat}) + V_{TN}$
$= 0.3 + 0.5 = 0.8$ V **[2]**

$I_{REF} = (V^+ - V_{GS} - 0) / R_1$ **[2]**

$R_1 = (V^+ - V_{GS} - 0) / I_{REF}$
$= (2 - 0.8) / (50\mu) = 24$ kΩ **[2]**

$I_{REF} = (k'_n / 2)\,(W/L)_1\,[V_{GS} - V_{TN}]^2$ **[2]**

$(W/L)_1 = I_{REF} \;/\; \{(k'_n / 2)\,[V_{GS} - V_{TN}]^2\}$ **[2]**
$= (50\mu) / \{(80\mu/2)\,[0.8 - 0.5]^2\}$
$= 13.889$ **[2]**

$I_O = (k'_n / 2)\,(W/L)_2\,[V_{GS} - V_{TN}]^2$ **[2]**

$(W/L)_2 = I_O / \{(k'_n / 2)\,[V_{GS} - V_{TN}]^2\}$ **[2]**
$= (100\mu) / \{(80\mu/2)\,[0.8 - 0.5]^2\}$
$= 27.778$ **[2]**

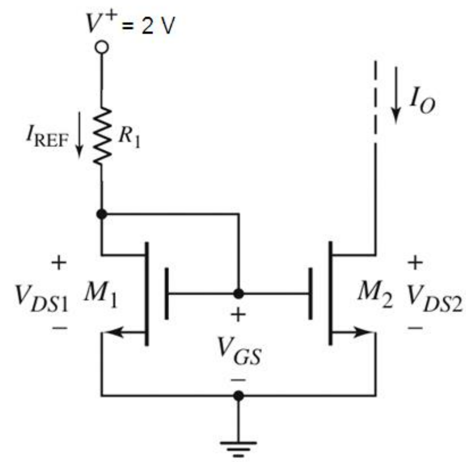
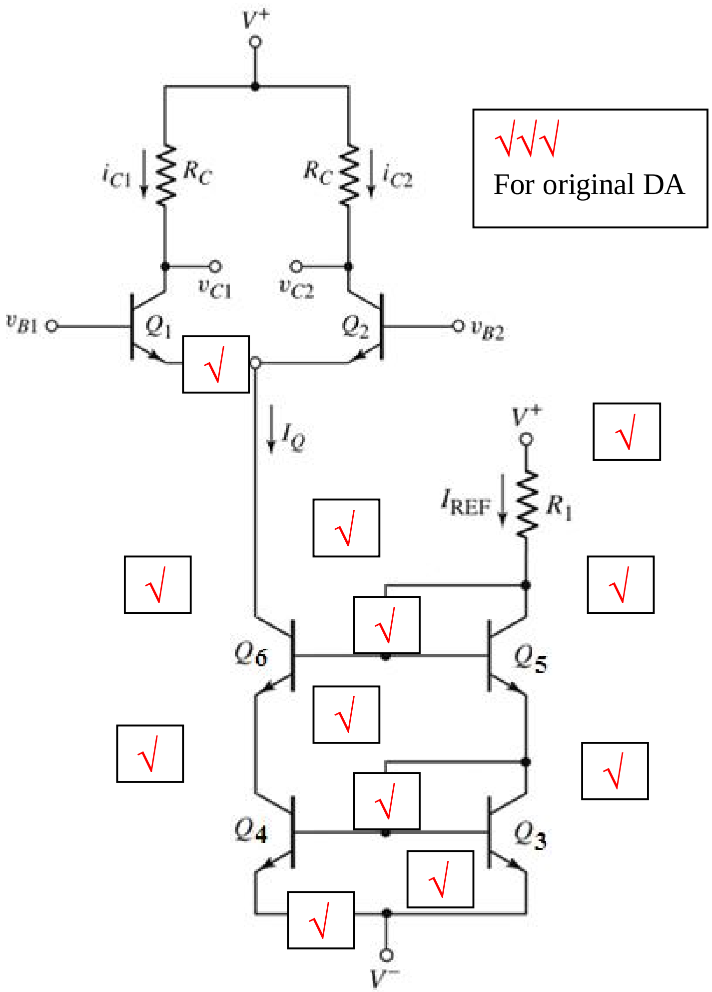


Figure 1(b)

Answers:

Question 2

(i)



√ = 1 mark

Question 2 **[40 marks]**

The basic BJT differential pair is shown in **Figure 2**. The circuit parameter values are: $V^+ = +10$ **V**, $V^- = -10$ **V**, $I_Q = 1$ **mA**, and $R_C = 10$ **kΩ**. The transistor parameters in the differential pair are $\beta = \infty$ (neglect base currents), $V_A = \infty$, and V_{BE} (on) = **0.7 V**. The constant current source in **Figure 2** that is providing the current I_Q is implemented using the **cascode current source**.

(i) **Sketch the whole differential pair circuit** to include the circuit for the constant current source circuit. [15 marks]

(ii) For all transistors in cascode current source, $V_A = 120$ **V** and $\beta = 100$. **What** is the value of the **output resistance** (R_O) looking into the constant current source? [5 marks]

(iii) **Determine** i_{C1} and v_{CE1} for common-mode voltages $v_{B1} = v_{B2} = v_{CM} = -5$ **V**. [10 marks]

(iv) It is given that the input voltages for the differential amplifier are $v_{B1} = 210 \times 10^{-6} \sin \omega t$ **V** and $v_{B2} = 190 \times 10^{-6} \sin \omega t$ **V**. **Calculate** differential-mode input voltage (v_d) and common-mode input voltage (v_{cm}) of the differential amplifier. [10 marks]

Answers for Question 2

(ii)

$\beta = 100$, $I_Q = 1$ mA

For cascode current source

$R_O = (\beta\, r_{O6})$ [2]

$r_{O6} = V_A / I_Q$ [1]

$= (120)/(1\text{m}) = 120$ kΩ [1]

$R_O = (\beta\, r_{O6}) = 100 \times 120\text{k}$

$= 12$ MΩ [1]

(iii)

$\beta = \infty$

$i_{C1} = i_{E1} = I_Q / 2 = 0.5$ mA [3]

$v_{C1} = V^+ - i_{C1} R_C$ [1]

$= 10 - (0.5\text{m})(10\text{k}) = 5$ V [1]

For $v_{CM} = -5$ V

$v_E = v_{CM} - V_{BE}\,(\text{on}) v_E$ [1]

$= -5 - 0.7 = -5.7$ V [1]

$v_{CE1} = v_{C1} - v_E$ [2]

$= 5 - (-5.7) = 10.7$ V [1]

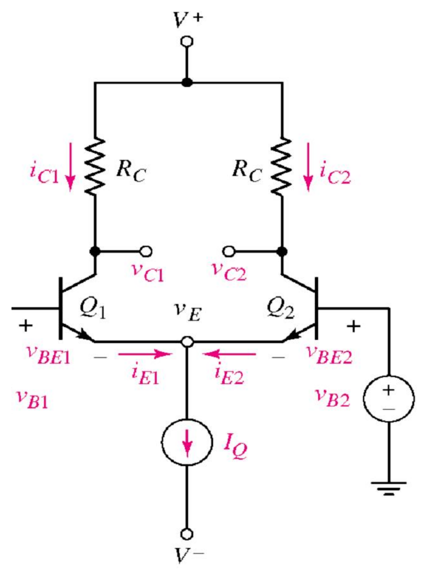


Figure 2

Answers:

(iv)

v_d	$= v_{B1} - v_{B2}$	**[2]**
	$= 210\text{x}10^{-6} \sin \omega t - 190\text{x}10^{-6} \sin \omega t$	**[2]**
	$= 20\text{x}10^{-6} \sin \omega t$	**[1]**
v_{cm}	$= (v_{B1} + v_{B2}) / 2$	**[2]**
	$= (210\text{x}10^{-6} \sin \omega t + 190\text{x}10^{-6} \sin \omega t)/2$	**[2]**
	$= 200\text{x}10^{-6} \sin \omega t$	**[1]**