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UNIVERSITI TENAGA NASIONAL

College of Engineering

Department of Electronics and Communication Engineering

Test 1 – MODEL ANSWERS

SEMESTER 2, ACADEMIC YEAR 2012/2013

Subject Code	:	**EEEB273**
Course Title	:	**Electronics Analysis & Design II**
Date	:	**2 November 2012**
Time Allowed	:	**1½ hours**

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.**

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

☺ **GOOD LUCK!** ☺

Question 1 **[30 marks]**

For all **BJT current sources** given in **Table 1**, all transistors are matched and have same parameters. The transistor parameters are: β **= 50**, V_{BE}**(on) = 0.6 V**, and V_A **= 150 V**. The circuit parameters for the current sources are: V^+ **= 10 V**, V^- **= -10 V,** and R_1 **= 24 kΩ**.

(a) **Calculate** reference current (I_{REF}), output current (I_O), and output resistance (R_O) for every BJT current source given in the **Table 1** and fill in the **Table 1** with your answers. **Show all calculations** in the area provided after the **Table 1** and **do not forget** to put proper **Units** for I_{REF}, I_O, and R_O in the **Table 1**. [9 marks]

Table 1

BJT current source	Reference current, I_{REF}	Output current, I_O	Output resistance, R_O
1) **Three-transistor** current source	**0.783 mA**	**0.783 mA**	**191.57 kΩ**
2) **Wilson** current source	**0.783 mA**	**0.783 mA**	**4.789 MΩ**
3) **Cascode** current source	**0.783 mA**	**0.725 mA**	**10.3445 MΩ**

[1 mark each box, Total 9 marks]

(b) Based on the value of R_O, **which current source** has the most stable I_O? [3 marks]

Cascode **[3]**

(c) **Show all your calculations** for I_{REF}, I_O, and R_O for every BJT current source given in the **Table 1** in the following space: [18 marks]

Three-transistor current source	**Wilson current source**	**Cascode current source**
$I_{REF} = (V^+ - 2\,V_{BE} - V^-)/R_1$ = (10 – 2x0.6 – (-10))/(24k) = 0.783 mA -- same for all CS		
$I_O = I_{REF}/(1 + 2/(\beta(1+\beta)))$ = (0.783m)/(1+2/(50x51)) = 0.783 mA	$I_O = I_{REF}/(1 + 2/(\beta(2+\beta)))$ = (0.783m)/(1+2/(50x52)) = 0.783 mA	$I_O = I_{REF}/(1 + 4/\beta)$ = (0.783m)/(1+4/(50)) = 0.725 mA
$r_{O2} = V_A / I_O$ = 150/(0.783m) = 191.57 kΩ $R_O = r_{O2}$ = 191.57 kΩ	$r_{O3} = V_A / I_O$ = 150/(0.783m) = 191.57 kΩ $R_O = (\beta\, r_{O3})/2$ = (50 x 191.57k)/2 = 4.789 MΩ	$r_{O4} = V_A / I_O$ = 150/(0.725m) = 206.89 kΩ $R_O = \beta\, r_{O4}$ = 50x206.89k = 10.3445 MΩ

[2 mark each box, Total 18 marks]

Answer for Question 1

Question 2 **[30 marks]**

For a MOSFET current source circuit shown in **Figure 2**, the transistor parameters are $\boldsymbol{V_{TN} = 0.7}$ **V**, $\boldsymbol{k'_n = 60}$ **μA/V²**, and $\boldsymbol{\lambda = 0.015}$ **V⁻¹**. The transistor aspect ratios are $\boldsymbol{(W/L)_1 = 20}$, $\boldsymbol{(W/L)_2 = 12}$, and $\boldsymbol{(W/L)_3 = 3}$.

(a) Determine V_{GS1}, I_{REF}, I_O, and V_{DS2} [20 marks]

(b) Find V_{GS3} [5 marks]

(c) Find I_O at $V_{DS2} = 3.0$ V [5 marks]

Answer for Question 2

(a)

$$I_{REF} = \frac{k_n'}{2}\left(\frac{W}{L}\right)_1 (V_{GS1} - V_{TN})^2$$

$$I_{REF} = \frac{60\mu}{2}(20)(V_{GS1} - 0.7)^2 \quad [2]$$

$$I_{REF} = \frac{k_n'}{2}\left(\frac{W}{L}\right)_3 (V_{GS3} - V_{TN})^2$$

$$I_{REF} = \frac{60\mu}{2}(3)(V_{GS3} - 0.7)^2 \quad [2]$$

$$V_{GS1} + V_{GS3} = V^+ - V^- = 10$$

$$V_{GS3} = 10 - V_{GS1} \quad [2]$$

$$20(V_{GS1} - 0.7)^2 = 3(10 - V_{GS1} - 0.7)^2$$

$$V_{GS1} = 3.1\text{ V} \quad [2]$$

$$I_{REF} = \frac{60\mu}{2}(20)(3.1 - 0.7)^2 = 3.456\text{ mA} \quad [2]$$

$$V_{GS2} = V_{GS1} = 3.1\text{ V} \quad [3]$$

$$I_O = \frac{k_n'}{2}\left(\frac{W}{L}\right)_2 (V_{GS2} - V_{TN})^2 \quad [2]$$

$$I_O = \frac{60\mu}{2}(12)(3.1 - 0.7)^2 = 2.073\text{ mA} \quad [3]$$

$$V_{DS2} = V_{DS1} = V_{GS1} = 3.1\text{ V} \quad [2]$$

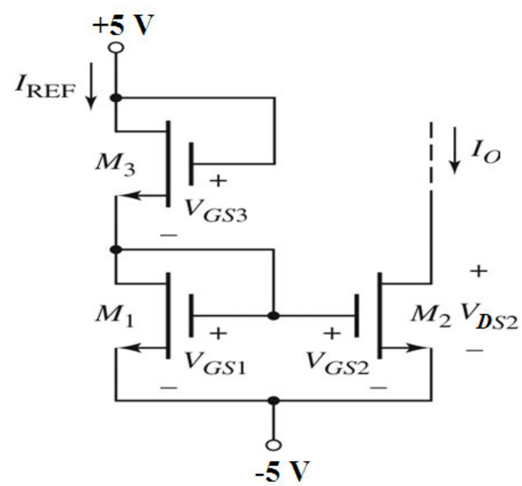


Figure 2

Answer for Question 2

(b) **$V_{GS3} = 10 - V_{GS1} = 6.9$ V** **[5]**

(c) **$I_O = 2.073$ mA** at **$V_{DS2} = 3.1$ V** **[1]**

$R_O = 1/(\lambda I_O) = 1/(0.015 \times 2.073m) = 32.159$ kΩ **[1]**

At **$V_{DS2} = 3.0$ V,**
$\Delta I_O = (3.0 - 3.1)/R_O = -0.003$ mA **[2]**

➔ **$I_O = 2.073m + (-0.003m) = 2.070$ mA** **[1]**

Question 3 [40 marks]

(a) **Figure 3a** shows a circuit diagram for a BJT differential amplifier (**diff-amp**). Study the circuit diagram carefully. Transistor parameters are: $\beta = \infty$ (neglect base current), $V_A = \infty$, and V_{BE}(on) = 0.7 V. For the circuit also, voltages measured at v_{C1} and v_{C2} are **4.5 V**.

(i) What are the values for v_{cm} and v_d? Show clearly your calculations. [5 marks]

(ii) Find I_Q [10 marks]

(iii) Find v_{CE2} [5 marks]

Answer for Question 3a

(a)

(i)

From Figure 3a:

$v_{B1} = v_{B2} = 0$ V [1]

→ $v_{cm} = (v_{B1} + v_{B2})/2 = 0$ V [2]

→ $v_d = v_{B1} - v_{B2} = 0$ V [2]

(ii)

Given: $v_{C1} = v_{C2} = 4.5$ V

$10 - I_{C1}R_C = v_{C1} = 4.5$ V [4]

→ $I_{C1} = 0.55$ mA $= I_{C2}$ [3]

→ $I_Q = I_{C1} + I_{C2} = 1.1$ mA [3]

(iii)

Given: $v_{C2} = 4.5$ V

$v_{CE2} = v_{C2} - v_E$ [2]

$v_E = v_{B2} - V_{BE}(\text{on}) = 0 - 0.7 = -0.7$ V [2]

→ $v_{CE2} = v_{C2} - v_E = 4.5 - (-0.7) = 5.2$ V [1]

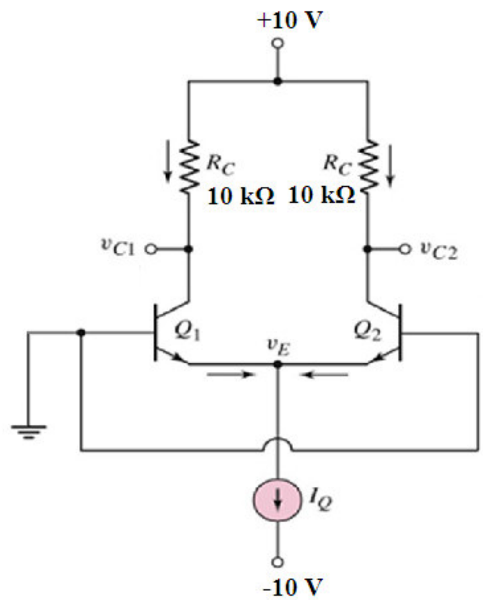
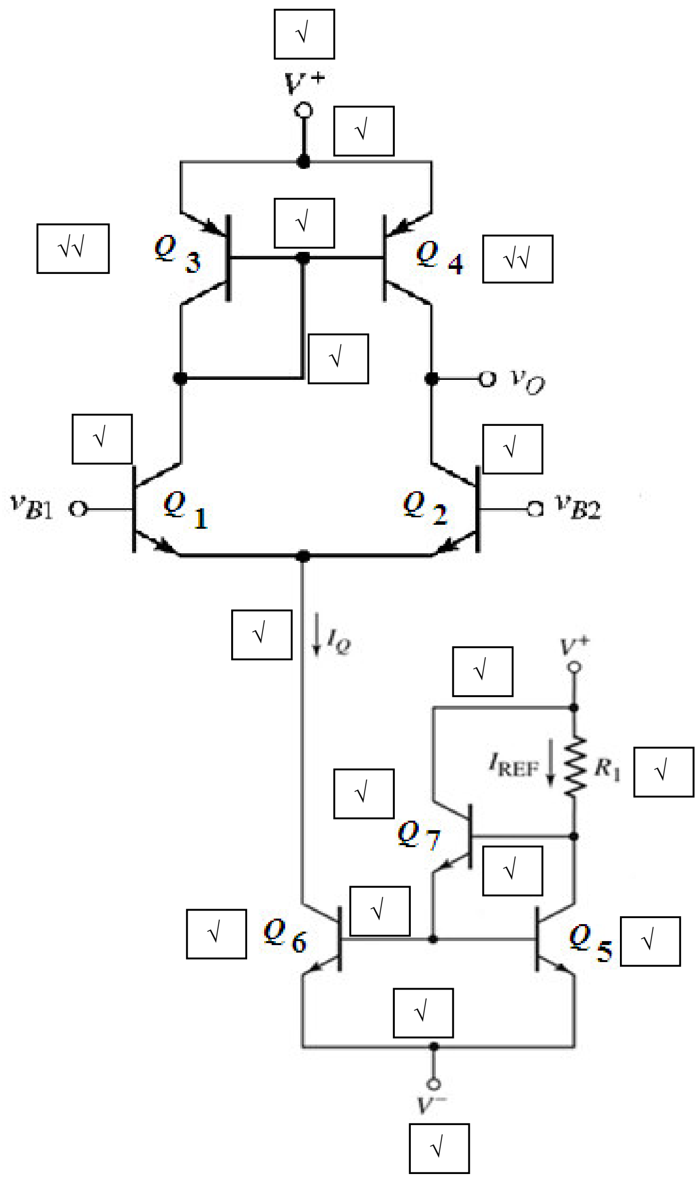


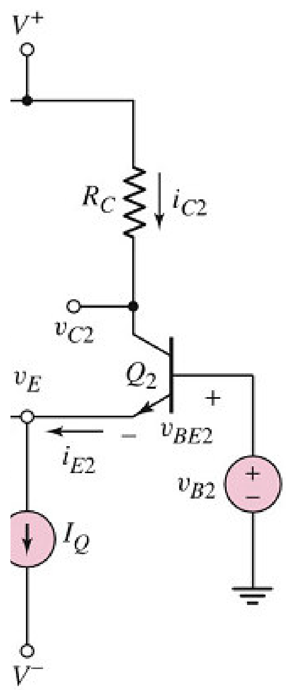
Figure 3a

(b) The differential amplifier in **Figure 3b** is modified to have a two-transistor current source using **pnp transistors** as **an active load** to replace the passive load resistors $\boldsymbol{R_C}$. A three-transistor current source using **npn transistors** is also incorporated in the circuit to establish the bias current, $\boldsymbol{I_Q}$. **Draw** the complete **NEW circuit** after the circuit in the **Figure 3b** is modified to have the active load and also incorporating the bias circuit mentioned above.

[20 marks]

Answer for Question 3b





'igure 3b

APPENDIX

BASIC FORMULA

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

$$\beta = g_m r_\pi$$

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

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

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

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

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

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