Name:
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Section: **01/02/03 A/B**
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UNIVERSITI TENAGA NASIONAL

College of Engineering

Department of Electronics and Communication Engineering

Test 1 - MODEL ANSWERS

SEMESTER 2, ACADEMIC YEAR 2013/2014

Subject Code	:	**EEEB273**
Course Title	:	**Electronics Analysis & Design II**
Date	:	**14 November 2013**
Time Allowed	:	**1 hour 15 minutes**

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.**
5. For BJT, use V_T **= 26 mV** where appropriate.
6. Use at least **4 significant numbers** in all calculations.

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

☺ **GOOD LUCK!** ☺

Question No.	1	2	Total
Marks			

FORMULA FOR TRANSISTORS

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

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

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

Question 1 **[65 marks]**

You are assigned to analyze the following BJT current sources: **Three-transistor current source, Wilson current source, and Cascode current source**. All **NPN transistors** in the given current sources are matched. The transistor parameters are: $\beta = 50$, $V_{BE}(on) = 0.6$ V, and $V_A = 150$ V. The circuit parameters for the current sources are: $V^+ = 12$ V, $V^- = -12$ V, and $R_1 = 30$ kΩ.

(a) **Calculate** reference current (I_{REF}), output current (I_O), and output resistance (R_O) for every BJT current source given above. **Show clearly all calculations** and **do not forget** to put proper **Units** for I_{REF}, I_O, and R_O. [45 marks]

(b) Based on the value of R_O, **which current source** has the most stable I_O? **Give a reason** for your answer. [5 marks]

(c) **What is the percent change in** I_O as the output voltage of a particular current source changes by **+3 V**? [15 marks]

Answers for Question 1

Q1(a)

Three-transistor current source	Wilson current source	Cascode current source
$I_{REF} = (V^+ - 2V_{BE} - V^-)/R_1$ = (12 – 2x0.6 – (-12))/(30k) = 0.76 mA [2, 2, 1]	$I_{REF} = (V^+ - 2V_{BE} - V^-)/R_1$ = (12 – 2x0.6 – (-12))/(30k) = 0.76 mA [2, 2, 1]	$I_{REF} = (V^+ - 2V_{BE} - V^-)/R_1$ = (12 – 2x0.6 – (-12))/(30k) = 0.76 mA [2, 2, 1]
$I_O = I_{REF}/(1 + 2/(\beta(1+\beta)))$ = (0.76m)/(1+2/(50x51)) = 0.7594 mA [2, 2, 1]	$I_O = I_{REF}/(1 + 2/(\beta(2+\beta)))$ = (0.76m)/(1+2/(50x52)) = 0.7594 mA [2, 2, 1]	$I_O = I_{REF}/(1 + 4/\beta)$ = (0.76m)/(1+4/50) = 0.7037 mA [2, 2, 1]
$r_{O2} = V_A / I_O$ = 150/(0.7594m) = 197.524 kΩ $R_O = r_{O2}$ = 197.524 kΩ [1, 1, 1, 1, 1]	$r_{O3} = V_A / I_O$ = 150/(0.7594m) = 197.524 kΩ $R_O = (\beta r_{O3})/2$ = (50 x 197.524k)/2 = 4.9381 MΩ [1, 1, 1, 1, 1]	$r_{O4} = V_A / I_O$ = 150/(0.7037m) = 213.159 kΩ $R_O = \beta r_{O4}$ = 50x206.89k = 10.6579 MΩ [1, 1, 1, 1, 1]

[5 marks each box, Total 45 marks]

Answers for Question 1 (Cont.)

Q1(b)

Cascode current source. [3]
Because with highest value for *Ro* makes change in *Io* to be smallest and *Io* most stable. [2]

Q1(c)

Three-transistor current source	Wilson current source	Cascode current source
$R_O = \Delta V_O / \Delta I_O$ $\Delta I_O = \Delta V_O / R_O$ = (3)/(197.524k) = 15.188 uA $\%\Delta I_O = (\Delta I_O / I_O)$x100% = (15.188u/0.7594m)x100% = 2 % [1, 1, 1, 1, 1]	$R_O = \Delta V_O / \Delta I_O$ $\Delta I_O = \Delta V_O / R_O$ = (3)/(4.9381M) = 0.6075 uA $\%\Delta I_O = (\Delta I_O / I_O)$x100% = (0.6075u/0.7594m)x100% = 0.0799 % [1, 1, 1, 1, 1]	$R_O = \Delta V_O / \Delta I_O$ $\Delta I_O = \Delta V_O / R_O$ = (3)/(10.6579M) = 0.2814 uA $\%\Delta I_O = (\Delta I_O / I_O)$x100% = (0.2814u/0.7037m)x100% = 0.0399 % [1, 1, 1, 1, 1]

Question 2 **[35 marks]**

For a **MOSFET current source** circuit shown in **Figure 1**, transistor parameters are $\boldsymbol{V_{TN} = 0.7}$ **V**, $\boldsymbol{k'_n = 70\ \mu A/V^2}$, and $\boldsymbol{\lambda = 0.015\ V^{-1}}$. The transistor aspect ratios are $\boldsymbol{(W/L)_1 = 20}$**,** $\boldsymbol{(W/L)_2 = 12.5}$**,** and $\boldsymbol{(W/L)_3 = 3}$.

(a) Determine V_{GS1}, V_{GS3}, I_{REF}, I_O, and V_{DS2} [25 marks]

(b) Find I_O at $V_{DS2} = 2.5$ V [10 marks]

Answers for Question 2

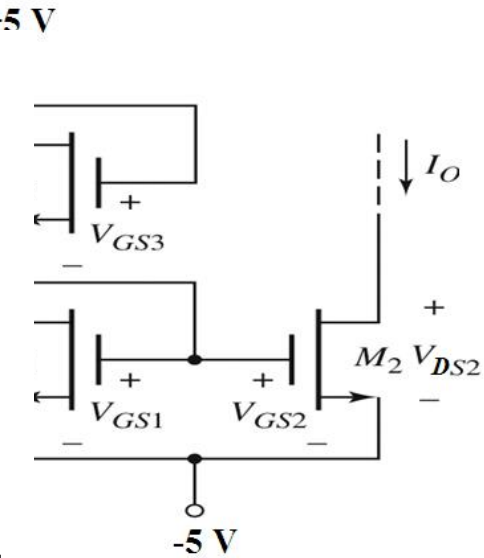

Figure 1

(a)

$$I_{REF} = I_{D1} = \frac{k_n'}{2}\left(\frac{W}{L}\right)_1 (V_{GS1} - V_{TN})^2 \quad [2]$$

$$I_{REF} = \frac{70\mu}{2}(20)(V_{GS1} - 0.7)^2 \quad [1]$$

$$I_{REF} = I_{D3} = \frac{k_n'}{2}\left(\frac{W}{L}\right)_3 (V_{GS3} - V_{TN})^2 \quad [2]$$

$$I_{REF} = \frac{70\mu}{2}(3)(V_{GS3} - 0.7)^2 \quad [1]$$

$$V_{GS1} + V_{GS3} = V^+ - V^- = 5 - (-5) = 10\text{ V} \quad [2]$$

$$V_{GS3} = 10 - V_{GS1} \quad [1]$$

$$20(V_{GS1} - 0.7)^2 = 3(10 - V_{GS1} - 0.7)^2 \quad [1]$$

Solve the equation clearly to find

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

$$V_{GS3} = 10 - V_{GS1} = 10 - 3.1 = 6.9\text{ V} \quad [1]$$

$$I_{REF} = I_{D1} = \frac{70\mu}{2}(20)(3.1 - 0.7)^2 = 4.032\text{ mA} \quad [3]$$

$$V_{GS2} = V_{GS1} = 3.1\text{ V} \quad [2]$$

$$I_O = I_{D2} = \frac{k_n'}{2}\left(\frac{W}{L}\right)_2 (V_{GS2} - V_{TN})^2 \quad [2]$$

$$I_O = \frac{70\mu}{2}(12.5)(3.1 - 0.7)^2 = 2.520\text{ mA} \quad [3]$$

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

Answers for Question 2 (Cont.)

(b)

From part (a)

I_O **= 2.520 mA** at V_{DS2} **= 3.1 V** **[1]**

$R_O = 1/(\lambda\, I_O) = 1/(0.015 \times 2.520\text{m}) = 26.455\ \text{k}\Omega$ **[2, 1, 1]**

At V_{DS2} **= 2.5 V,**

$\Delta\, I_O = V_{DS2}/R_O = (2.5 - 3.1)/R_O = -0.0226\ \text{mA}$ **[1, 1, 1]**

➔ $I_O = 2.520\text{m} + (-0.0226\text{m}) = 2.4974\ \text{mA}$ **[2]**