Name:

Student ID Number:

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

Lecturer: Dr Jamaludin/Dr Azni Wati/Dr Jehana Ermy/Prof Md Zaini

Table Number:

UNIVERSITI TENAGA NASIONAL

The National Energy University

College of Engineering

Department of Electronics and Communication Engineering

Test 1

SEMESTER 2, ACADEMIC YEAR 2017/2018

Subject Code	:	**EEEB273**
Course Title	:	**Electronics Analysis & Design II**
Date	:	**18 November 2017**
Time Allowed	:	**2 hours**

<u>Instructions to the candidates:</u>

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.

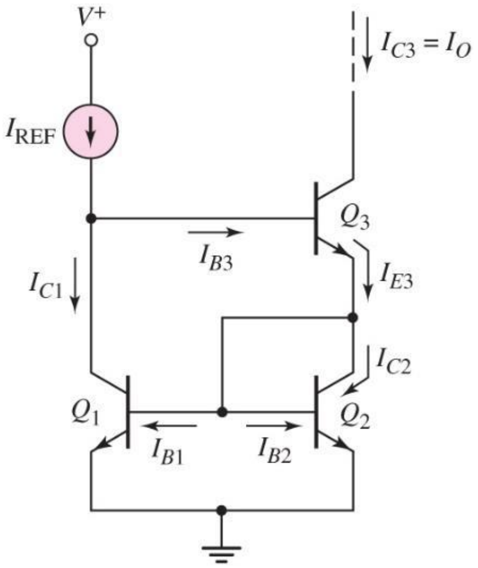
☺ **GOOD LUCK!** ☺

Question Number	Q1(a)	Q1(b)	Q2	Q3(a)	Q3(b)	Q4	Total
Marks							

<u>QUESTION 1 [35 marks]</u>

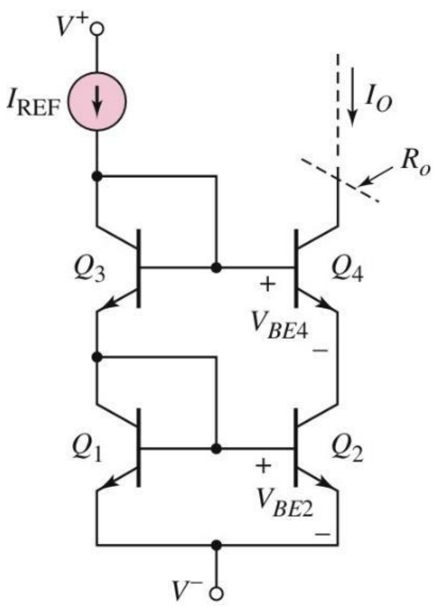
<u>Answers for Question 1</u>

(a) (i) BJT Wilson current source



Placements of Q1, Q2 and Q3 [2 marks]
IREF and IO labels [2 marks]
Power supplies labels [1 mark]

BJT Cascode current source



(a)

Placements of Q1, Q2, Q3 and Q4 [2 marks]
IREF and IO labels [2 marks]
Power supplies labels [1 mark]

(a)(ii)

At low ***β*** values, output current Io for Wilson is closer to Iref and more stable compared to Cascode,

i.e. $I_O = I_{REF}/\left[1+\frac{2}{\beta(1+\beta_3)}\right]$ for Wilson has better stability compared to $I_O = I_{REF}/\left[1+\frac{4}{\beta)}\right]$ for Cascode at low ***β*** values **[2.5 marks]**

At high ***β*** values, Io for Cascode is more stable due to its high output resistance Ro, where Ro for Cascode is given by ***β*** *ro*4 compared to Ro for Wilson that is given by **(*β*/2)** *ro*3. Bigger Ro means better Io stability **[2.5 marks]** (b)(i)

Summing the currents at *Q1*;

$I_{REF} = I_{C1} + I_{B3}$ … (1) **[2 marks]**

$I_{B1} = I_{B2}$ ➔ $I_{E3} = 2I_{B2}$ … (2) **[2 marks]**

And $I_{E3} = (1+\beta_3)I_{B3}$ … (3) **[2 marks]**

Combining the equations,

$I_{REF} = I_{C1} + \frac{I_{E3}}{(1+\beta_3)}$ → $I_{REF} = I_{C1} + \frac{2I_{B2}}{(1+\beta_3)}$ **[1 mark]**

Replacing I_{C1} with I_{C2} and $I_{B2} = I_{C2}/\beta$;

$I_{REF} = I_{C2} + \frac{2I_{C2}}{\beta(1+\beta_3)}$ **[2 marks]**

Therefore, $I_O = I_{REF}/\left[1 + \frac{2}{\beta(1+\beta_3)}\right]$ **[1 mark]**

$I_{C1} = I_{C2}; I_{B1} = I_{B2}$

$I_{C1} = \beta I_{B1} = \beta I_{B2}$

$I_{E3} = I_{B1} + I_{B2} = 2I_{B2}$

$I_{B3} = (2I_{B2})/(1+\beta_3)$

$I_{REF} = I_{C1} + I_{B3}$

$\rightarrow I_{REF} = (\beta + 2/(1+\beta_3))I_{B2}$

$$I_O = \beta I_{B2} = \frac{I_{REF}}{\left(1 + \frac{2}{\beta(1+\beta_3)}\right)}$$

(b)(ii)

For ***V*+ = 10 *V*** and ***V*- = 0 V**, design the circuit such that ***IO* = 0.7 mA**. The transistor parameters are: ***β* = 80**, ***β3*= 60, *VBE*(on) = 0.7 V** and ***VA* = ∞.**

Using the 3TCS equation, , $IREF=IO[1+2/(\beta(\beta 3+1))]$ [2 marks]

$IREF=(0.7m)[1+2/(80(60+1))]$ = **0.7003 mA** [2, 1 marks]

Using KVL,

$R1=(V+-vBE3- vBE1-V-)/IREF=(10-2(0.7)-0)/0.7003m$ = **12.28 kΩ** [2, 2 ,1 marks]

QUESTION 2 [20 marks]

Answers for Question 2

Using the formula,
$V_{DS2}(sat) = V_{GS2} - V_{TN}$ **[1]**

At 1 V, $V_{DS2}(\text{sat}) = V_{GS2} - V_{TN}$
→ $V_{GS2} = 1 + 0.5 =$ **1.5 V** **[2]**

Using the formula,

$$I_D = \left(\frac{k'_n}{2}\right)\left(\frac{W}{L}\right)_n (V_{GS} - V_{TN})^2 \quad ...(1)$$

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

Subs $I_O = 0.15$ mA, $0.15m = \left(\frac{0.08}{2}\right)\left(\frac{W}{L}\right)_2 (1.5 - 0.5)^2 \rightarrow \left(\frac{W}{L}\right)_2 = \mathbf{3.75}$ **[3]**

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

Subs $I_{REF} = 0.5$ mA, $0.5m = \left(\frac{0.08}{2}\right)\left(\frac{W}{L}\right)_1 (1.5 - 0.5)^2 \rightarrow \left(\frac{W}{L}\right)_1 = \mathbf{12.5}$ **[3]**

With KVL rule, $V_{GS1} + V_{GS3} = V^+ - V^-$
Thus, $V_{GS3} = 1.8 - (-1.8) - 1.5 = 2.1$ V **[2]**

So, $I_{REF} = \left(\frac{k'_n}{2}\right)\left(\frac{W}{L}\right)_3 (V_{GS3} - V_{TN})^2$ **[2]**

Subs $I_{REF} = 0.5$ mA, $0.5m = \left(\frac{0.08}{2}\right)\left(\frac{W}{L}\right)_3 (2.1 - 0.5)^2 \rightarrow \left(\frac{W}{L}\right)_3 = \mathbf{4.88}$ **[3]**

$$V_{GS2} = V_{DS2}(sat) + V_{TN} = 1 + 0.5 = 1.5 \text{ V}$$

$$I_O = \left(\frac{k'_n}{2}\right)\left(\frac{W}{L}\right)_2 (V_{GS2} - V_{TN})^2$$

$$0.15 = \left(\frac{0.08}{2}\right)\left(\frac{W}{L}\right)_2 (1.5 - 0.5)^2 \Rightarrow \left(\frac{W}{L}\right)_2 = 3.75$$

$$I_{REF} = 0.5 = \left(\frac{0.08}{2}\right)\left(\frac{W}{L}\right)_1 (1.5 - 0.5)^2 \Rightarrow \left(\frac{W}{L}\right)_1 = 12.5$$

$$V_{GS3} = (V^+ - V^-) - V_{GS1} = 1.8 - (-1.8) - 1.5 = 2.1 \text{ V}$$

$$I_{REF} = 0.5 = \left(\frac{0.08}{2}\right)\left(\frac{W}{L_3}\right)(2.1 - 0.5)^2 \Rightarrow \left(\frac{W}{L}\right)_3 = 4.88$$

QUESTION 3 [25 marks]

Answers for Question 3

(a)

$V_{CE4} = V^+ - I_{C4}R_C - V_E$ [2]

$I_{C4} = \frac{V^+ - V_{CE4} - V_E}{R_C} = \frac{5-(1.8)-(-0.7)}{5k} = 0.78\,mA$ [4]

$I_{E4} = \frac{1+\beta}{\beta} I_{C4} = \left(\frac{41}{40}\right)(0.78m) = 0.7995mA$ [3]

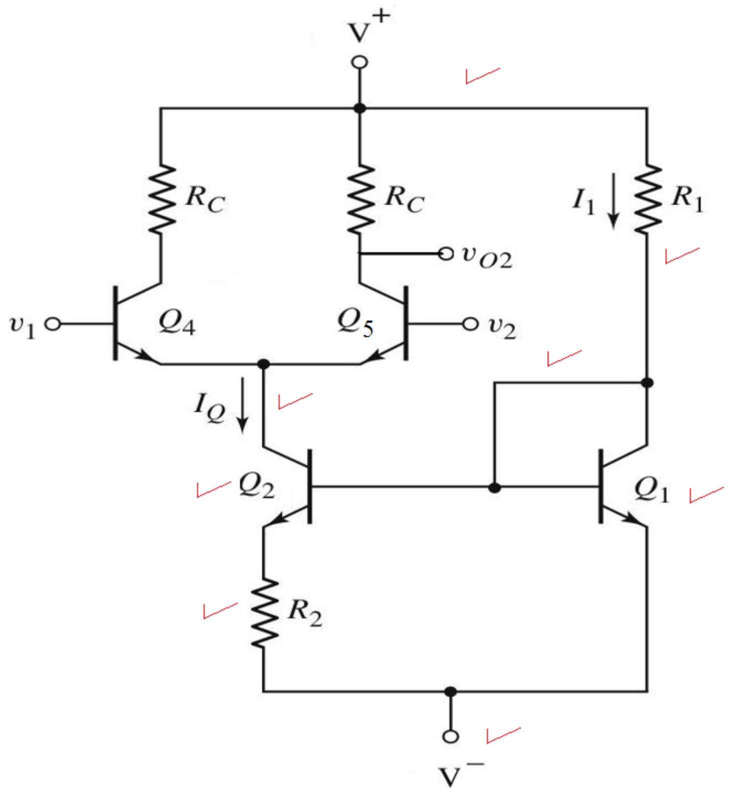
$I_{C2} = 2I_{E4} = 2(0.7995m) = 1.599mA$ [3]

$I_1 = \left(1 + \frac{2}{\beta(1+\beta)}\right)(I_{C2}) = \left(1 + \frac{2}{(40)(41)}\right)(1.599m) = 1.601mA$ [4]

$R_1 = \frac{V^+ - 2V_{BE} - V^-}{I_1} = \frac{5-2(0.6)+5}{1.601m} = 5497\Omega$ [4]

*Note: use β in current equations [1 mark each time]

(b)



Same diff-amp copied [1]
V- connection [1/2]
E4 and C2 connection [1]
Correct CS output components [1]
Correct Ref side with diode cooenection [1]
CS V+ connection [1/2]

QUESTION 4 [20 marks]

Answers for Question 4

Q4(a)

$I_{E2} = \frac{I_Q}{2} = 2mA$ [1]

$I_{C2} = \frac{\beta}{1+\beta} I_{E2} = 1.983mA$ [1]

$r_{\pi 2} = \beta \frac{V_T}{I_{C2}} = \frac{(120)(0.026)}{1.983m} = 1.573k\Omega$ [2]

$R_{id} = 2r_{\pi 2} = 2(1.573k) = 3.147k\Omega$ [2]

Q4(b)

$g_{m2} = \frac{I_{C2}}{V_T} = \frac{1.983m}{(0.026)} = 76.27mA/V$ [3]

$A_d = \frac{g_{m2}}{2} R_C = (76.27m)(5k) = 190.67$ [3]

Q4(c)

$v_d = v_1 - v_2 = 0.35m \sin wt$ [2]

$v_{cm} = \frac{v_1 + v_2}{2} = 1.075m \sin wt$ [2]

$v_o = A_d v_d + A_{cm} v_{cm}$ [2]

$= (190.67)(0.35m)\sin wt + (-0.09912)(1.075m)\sin wt$

$= (0.0667 - 0.10655m)\sin wt = 0.0666 \sin wt$ V [2]