Name:

Student ID Number:

Section Number: 01/02/03 A/B

Lecturer: Dr Fazrena Azlee/ Dr Jamaludin/ Dr Ahmad Wafi

Table Number:

UNIVERSITI TENAGA NASIONAL

The National Energy University

College of Engineering

Department of Electrical and Electronics Engineering

Test 1 – MODEL ANSWERS

SEMESTER 1, ACADEMIC YEAR 2019/2020

Subject Code	:	**EEEB2014/EEEB273**
Course Title	:	**Electronics Analysis & Design II**
Date	:	**13 July 2019**
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 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! ☺

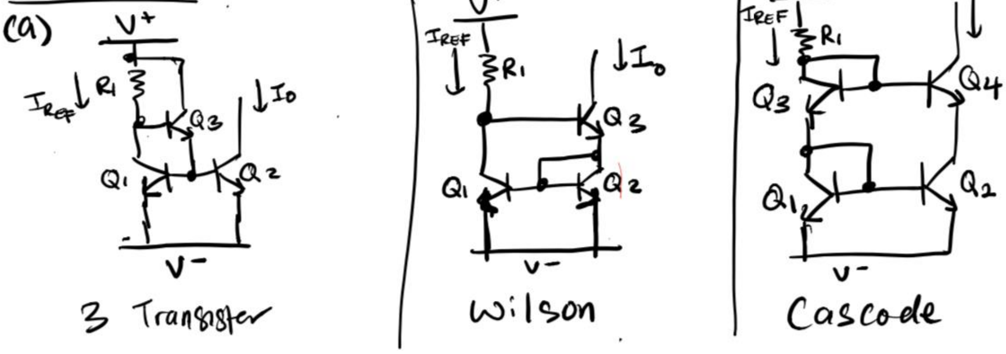
Question Number	Q1(a)	Q1(b-d)	Q2(a)	Q2(b)	Q3(a)	Q3(b,c)	Total
Marks							

QUESTION 1 [35 marks]

Answers for Question 1

Question 1

(a)



- 3 mark each for correct drawing (total 9 mark.).
- 1 mark extra for correct labelling

b) **3T**

$$R_1 = \frac{V^+ - 2V_{BE} - V^-}{I_{REF}} = \frac{20 - 2(0.7)}{1m} = 18.6\,k\Omega \text{ – 3m}$$

Wilson

$$R_1 = \frac{V^+ - 2V_{BE} - V^-}{I_{REF}} = 18.6\,k\Omega \text{ – 3m}$$

c) **3T Current Source**

$$I_O = I_{REF} \times \frac{1}{1 + \frac{2}{\beta(1+\beta)}} \text{ – 1m}$$

$$= 0.992\,mA$$

– 3 m for correct equation & answer

$$R_O = r_{o2} = \frac{V_A}{I_O} = 150\,k\Omega$$

– 3 m for correct equation & answer

Wilson

$$I_O = I_{REF} \times \frac{1}{1 + \frac{2}{\beta(2+\beta)}}$$

$$= 0.992\,mA$$

– 3 m for correct equation & answer

$$R_O = \frac{\beta}{2} r_{o3} = \frac{\beta}{2}\left(\frac{V_A}{I_O}\right) = 3.75\,M\Omega.$$

– 3 m for correct equation & answer.

Answers for Question 1 (Continued)

d) $dV_o = 6 - 1 = 5V$ — 1m

<u>3T</u>

$dI_o = \frac{1}{R_o} \times dV_o$

$= 33\mu A$ — 3m

<u>wilson</u>

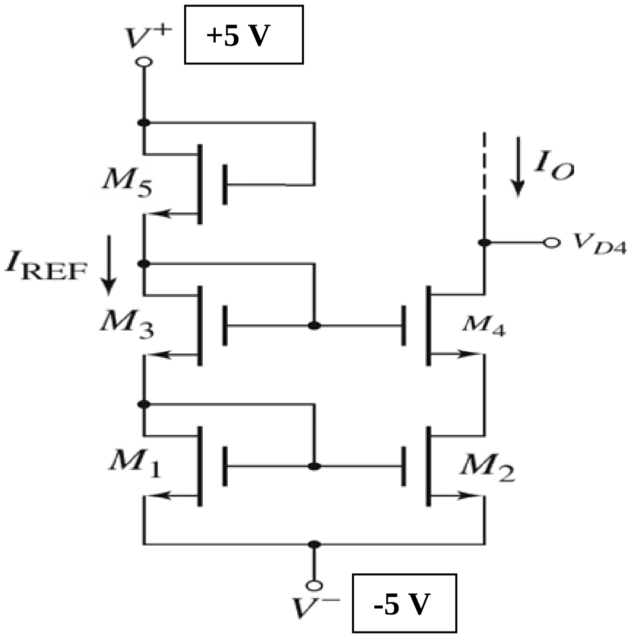
$dI_o = \frac{1}{R_o} \times dV_o$

$= 1.33\mu A$ — 3m

QUESTION 2 [30 marks]

Answers for Question 2

Q2a [5 marks]



Power supplies **+5 V** and **-5 V** labelling: **[1]**
Correct polarity & connection for M_1 to M_4: **[2]**
Correct polarity & connection for M_5: **[1]**
Correct labelling and arrow for I_{REF} and I_O: **[1]**

Answers for Question 2 (Continued)

Q2b(i) [17 marks]

$I_{REF} = I_{D1} = I_{D3}$ [2]
$I_{REF} = \left(\frac{k_p'}{2}\right)\left(\frac{W}{L}\right)_1 (V_{SG1} + V_{TP})^2 = \left(\frac{k_p'}{2}\right)\left(\frac{W}{L}\right)_3 (V_{SG3} + V_{TP})^2$ [2]
$V_{SG3} = 5 - V_{SG1}$ [2]

$\left(\frac{60\mu}{2}\right)(25)(V_{SG1} - 0.4)^2 = \left(\frac{60\mu}{2}\right)(5)(V_{SG3} - 0.4)^2$ [1]
$\left(\frac{60\mu}{2}\right)(25)(V_{SG1} - 0.4)^2 = \left(\frac{60\mu}{2}\right)(5)(5 - V_{SG1} - 0.4)^2$ [1]

$\sqrt{25/5}(V_{SG1} - 0.4) = (4.6 - V_{SG1})$
$2.236(V_{SG1} - 0.4) = (4.6 - V_{SG1})$
$3.236V_{SG1} = 5.4944 \rightarrow V_{SG1} = 1.698\ V$ [2]

$V_{SG3} = 5 - 1.698 = 3.302\ V$ [1]

$I_{REF} = I_{D1} = \left(\frac{k_p'}{2}\right)\left(\frac{W}{L}\right)_1 (V_{SG1} + V_{TP})^2 = \left(\frac{60\mu}{2}\right)(25)(1.698 - 0.4)^2 = 1.2636\ mA$ [2]

$V_{SG2} = V_{SG1} = 1.698\ V$ [2]
$I_O = I_{D2} = \left(\frac{k_p'}{2}\right)\left(\frac{W}{L}\right)_2 (V_{SG2} + V_{TP})^2 = \left(\frac{60\mu}{2}\right)(15)(1.698 - 0.4)^2 = 0.75816\ mA$ [2]

Q2b(ii) [8 marks]

Maximum value of V_{D2} is when $V_{SD2} = V_{SD2}(\text{min}) = V_{SD2}(\text{sat})$:

$V_{D2} = V^+ - V_{SD2}$ [1]
$V_{D2}(max) = V^+ - \boldsymbol{V_{SD2}(min)} = V^+ - \boldsymbol{V_{SD2}(sat)}$ [2]
$V_{SD2}(sat) = V_{SG2} + V_{TP} = 1.698 - 0.4 = 1.298\ V$ [1]
$\rightarrow \boldsymbol{V_{D2}(max)} = V^+ - \boldsymbol{V_{SD2}(sat)} = 5 - 1.298 = \mathbf{3.702\ V}$ [1]

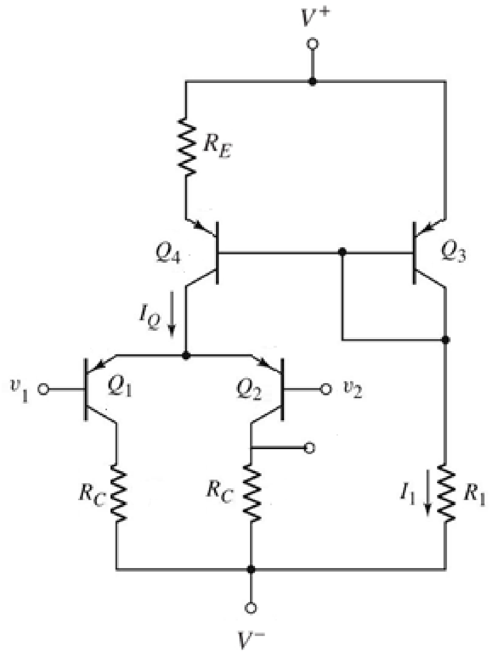
Largest value of R is at $V_{D2}(\text{max})$:

$$R(max) = \frac{V_{D2}(max) - 0}{I_O} = \frac{3.702}{0.75816m} = 4.88\ k\Omega$$ [3]

QUESTION 3 [35 marks]

Answers for Question 3

Q3(a) [10 marks]



Correct differential amplifier with Rc and inputs	[2]
Correct IQ current source C4 to E1/E2 connection	[1]
V+ and V-	[1]
Correct **Widlar** current source connection	[2]
Correct I_1 (Iref) side with diode connection	[2]

Widlar is better than 2 transistor c.s. since it has higher output resistance (Ro) compared to 2 transistor c.s [2]

Or (choose either answer)

Widlar is used to provide a current source with lower output current [2]

Q3(b)(i) [6 marks]

1 1

$$i_{C1} = I_S e^{v_{BE1}/V_T}, i_{C2} = I_S e^{v_{BE2}/V_T}$$

$$I_Q = i_{C1} + i_{C2} = I_S\left[e^{v_{BE1}/V_T} + e^{v_{BE2}/V_T}\right]$$ 1

$$\frac{i_{C1}}{I_Q} = \frac{I_S e^{v_{BE1}/V_T}}{I_S\left[e^{v_{BE1}/V_T} + e^{v_{BE2}/V_T}\right]} = \frac{I_S(e^{v_{BE1}/V_T})/e^{v_{BE1}/V_T}}{I_S\left[e^{v_{BE1}/V_T} + e^{v_{BE2}/V_T}\right]/e^{v_{BE1}/V_T}} = \frac{1}{1+e^{(v_{BE2}-v_{BE1})/V_T}}$$ 1

$$\frac{i_{C2}}{I_Q} = \frac{I_S e^{v_{BE2}/V_T}}{I_S\left[e^{v_{BE1}/V_T} + e^{v_{BE2}/V_T}\right]} = \frac{I_S(e^{v_{BE2}/V_T})/e^{v_{BE2}/V_T}}{I_S\left[e^{v_{BE1}/V_T} + e^{v_{BE2}/V_T}\right]/e^{v_{BE2}/V_T}} = \frac{1}{1+e^{-(v_{BE2}-v_{BE1})/V_T}}$$ 1

$$v_{BE1} - v_{BE2} = v_d$$

$$\rightarrow i_{C1} = \frac{I_Q}{1+e^{(v_{BE2}-v_{BE1})/V_T}} = \frac{I_Q}{1+e^{-vd/V_T}}$$ 0.5

$$\rightarrow i_{C2} = \frac{I_Q}{1+e^{-(v_{BE2}-v_{BE1})/V_T}} = \frac{I_Q}{1+e^{+vd/V_T}}$$ 0.5

Q3(b)(ii) [4 marks]

$$i_{C1} = \frac{I_Q}{1+e^{-v_d/V_T}} = \frac{I_Q}{1+e^{-0/V_T}} = \frac{I_Q}{1+1} = \frac{I_Q}{2}$$ 1

$$i_{C2} = \frac{I_Q}{1+e^{+v_d/V_T}} = \frac{I_Q}{1+e^{0/V_T}} = \frac{I_Q}{1+1} = \frac{I_Q}{2}$$ 1

When $v_d = 0$, $i_{C1} = i_{C2} = I_Q/2$ 1

current I_Q splits evenly between i_{C1} and i_{C2} 1

Q3(c)(i) [5 marks]

$A_d = \frac{g_{m1}R_C}{2}$ [1]

$g_{m1} = \frac{I_{C1}}{V_T}, I_{C1} = I_{C2} = 1m$ [1]

$g_{m1} = \frac{1m}{26m} = 38.48\ mA/V$ [1]

$A_d = \frac{(38.46m)(15k)}{2} = 288.45\ V/V$ [2]

Q3(c)(ii) [6 marks]

$R_{id} = 2r_{\pi 1}$ [1]

$r_{\pi 1} = \frac{\beta V_T}{I_{C1}} = \frac{(100)(0.026)}{1m} = 2.6\ k\Omega$ [0.5]

So $R_{id} = 2(2.6k) = 5.2\ k\Omega$ [0.5]

$R_{icm} = (1+\beta)\left[R_O || \frac{r_{O1}}{2}\right]$ [1]

Ro = βr_{o4} [0.5]

ro4 = VA/IQ = 200/2m = 100kΩ [0.5]

Ro = (100)(100kΩ) = 10MΩ [0.5]

ro1 = VA/Ic1 = 200/1m = 200kΩ [0.5]

Ricm = (1+100)(10M||(200k/2)) = 10 MΩ [1]

Q3(c)(iii) [4marks]

Vo = AdVd + AcmVcm [1]

Vd = v1 – v2

= 200 x 10^{-6} sin ωt V – (-200 x 10^{-6} sin ωt V) = 400 x 10^{-6} sin ωt V [1]

Vcm = ½ (v1+v2) = ½ (200 x 10^{-6} sin ωt V + (-200 x 10^{-6} sin ωt V)) = 0 [1]

Vo = AdVd + 0

= (288.45)(400 x 10^{-6} sin ωt V) = 115.38 x 10^{-3} sin ωt V [1]