Name:

Student ID Number:

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

Lecturer: Dr Jamaludin/Dr Fazrena Azlee/

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 – Model Answers

SEMESTER 1, ACADEMIC YEAR 2018/2019

Subject Code	:	**EEEB273**
Course Title	:	**Electronics Analysis & Design II**
Date	:	**7 July 2018**
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)	Q2 (a)	Q2 (b)	Q3 (a)	Q3 (b)	Q4 (a-c)	Q4 (d)	Total
Marks									

QUESTION 1 [35 marks]

Answers for Question 1

Answers for Question 1(a)

(i) Better approximation of $\boldsymbol{I_O}$ to $\boldsymbol{I_{REF}}$ for circuit using same transistors **[2]**

(ii) Higher output resistance by a factor of $\boldsymbol{\beta/2}$ **[2]**

(iii) Higher output resistance by a factor of **2** **[2]**

(iv) Higher output resistance by a factor of $\boldsymbol{(1 + g_m R'_E)}$ **[2]**

Using smaller resistors in the circuit **[2]**

Can have different values for $\boldsymbol{I_O}$ and $\boldsymbol{I_{REF}}$ where $\boldsymbol{I_O}$ is smaller than $\boldsymbol{I_{REF}}$ **[2]**

For (iv) →Can use any two answers above, total 4 marks.

Answers for Question 1(b)

(i)

$I_{B1} = I_{B2}$ **[1.5]**

$I_O = I_{C2} = \beta I_{B2}$ $I_{B2} = I_O / \beta$ **[1.5]**

$I_{C1} = I_{C2}$ $I_{C1} = I_O$ **[1.5]**

$I_{E3} = 2 I_{B2} + V_{BE} / R_2$ **[1.5]**

$I_{B3} = I_{E3} / (1 + \beta)$ **[1.5]**

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

$= (2 I_O)/(\beta(1 + \beta)) + (V_{BE})/((1 + \beta)R_2)$ **[1.5]**

$I_{REF} = I_{C1} + I_{B3}$ **[1.5]**

$= I_O + (2 I_O)/(\beta(1 + \beta)) + (V_{BE})/((1 + \beta)R_2)$ **[1.5]**

$I_{REF} - (V_{BE}) /((1 + \beta)R_2) = I_O + (2 I_O)/(\beta (1 + \beta))$ **[1.5]**

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

$$I_{REF} - \frac{V_{BE}}{(1+\beta)R_2} = I_O\left(1 + \frac{2}{\beta(1+\beta)}\right)$$ **[1.5]**

(ii)

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

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

= 0.700216m + 0.000864m = 0.7011 mA **[1]**

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

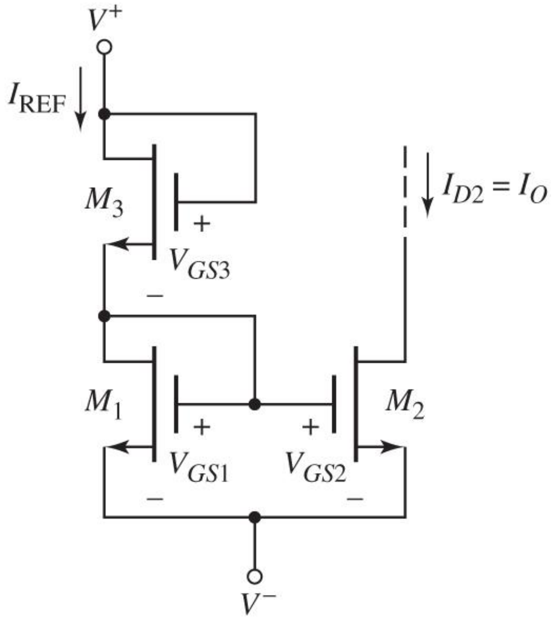
= (10 - 2(0.7)) / (0.7011m) **[2]**

= 12.27 kΩ **[1]**

QUESTION 2 [20 marks]

Answers for Question 2

Q2(a)



Placement of M_1, M_2 *and* M_3	[5]
Currents I_{REF} *and* I_O	[3]
Power supplies $\boldsymbol{V}^+$ and $\boldsymbol{V}^-$	[2]

Answers for Question 2 (Continued)

Q2(b) Using the equation, $V_{DS}(sat) = V_{GS} - V_{TN}$

$V_{DS2}(sat) = V_{GS2} - V_{TN}$

$V_{GS2} = V_{DS2}(sat) + V_{TN}$ [2]

= 0.6 + 0.4 = **1.0 V** [1]

From the RHS; solve for $(W/L)_2$ using the equation given.

$$\left(\frac{W}{L}\right)_2 = \frac{I_O}{(\frac{k_n'}{2})(V_{GS2}-V_{TN})^2}$$ [1]

= (50u)/(120u/2)[1-0.4]^2

= **2.315** [0.5]

Since $V_{GS1} = V_{GS2} = 1V$ [1]

Solve for

$$\left(\frac{W}{L}\right)_1 = \frac{I_{REF}}{(\frac{k_n'}{2})(V_{GS1}-V_{TN})^2}$$ [1]

= (100u)/(120u/2)[1-0.4]^2

= **4.63** [0.5]

For the LHS; solve for V_{GS3}.

$V_{GS3} = V^+ - V_{GS1} - V^-$ [1]

= 2.5 – 1 = 1.5 V [0.5]

Solve for

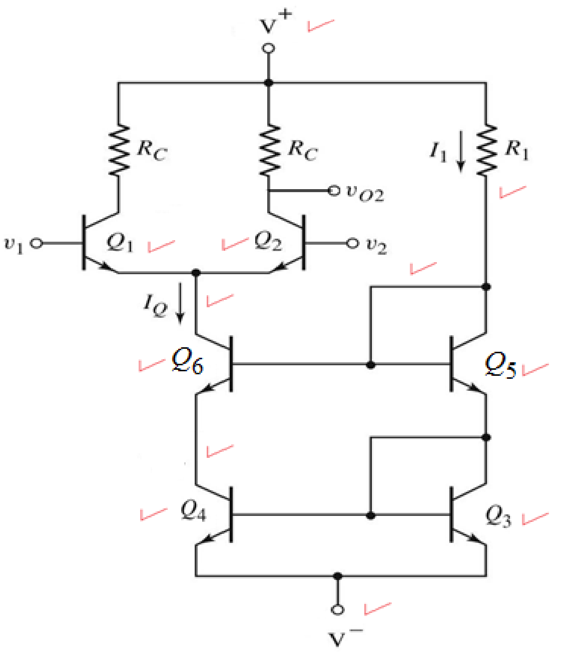
$$\left(\frac{W}{L}\right)_3 = \frac{I_{REF}}{(\frac{k_n'}{2})(V_{GS3}-V_{TN})^2}$$ [1]

= (100u)/(120u/2)[1.5 - 0.4]^2

= **1.377** [0.5]

QUESTION 3 [25 marks]

Answers for Question 3(a)



Marking:

Correct differential amplifier with Rc and inputs	[1]
E1/E2 to C6 (or C4) connection (IQ)	[1]
V+ and V-	[1]
Correct **cascode** current source connection	[1]
Correct Iref/I_1 side with diode connected transistors	[1]

Answers for Question 3(b)

(b)

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

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

$$I_{C4} = \frac{10-(1.8)-(-0.7)}{10k} = 0.89\ mA$$ [2]

$$I_{E4} = \frac{1+\beta}{\beta} I_{C4}$$ [2]

$$I_{E4} = \left(\frac{41}{40}\right)(0.89m) = 0.91225\ mA$$ [2]

$$I_{C2} = 2I_{E4}$$ [2]

$$I_{C2} = 2(0.91225m) = 1.8245\ mA$$ [2]

$$I_1 = \left(1 + \frac{2}{\beta(1+\beta)}\right)(I_{C2})$$ [2]

$$I_1 = \left(1 + \frac{2}{(40)(41)}\right)(1.8245m) = 1.826725\ mA$$ [2]

$$R_1 = \frac{V^+ - 2V_{BE} - V^-}{I_1}$$ [2]

$$R_1 = \frac{10-2(0.7)+10}{1.826725m} = 10.182\ k\Omega$$ [2]

QUESTION 4 [20 marks]

Answers for Question 4

Q4(a) Calculate the value of resistor R_C. [3 marks]

VRC = V+ - Vo2 = IC2Rc [1]

$$I_{C2} = \frac{I_Q}{2} = 200\mu/2 = 100\mu$$ [1]

VRC = 10 – 5 = 5V

So Rc = 5/100u = 50kΩ [1]

Q4(b) Find the differential voltage gain (A_d) and common-mode voltage gain (A_{cm}) for one-sided output [10 marks]

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

$$g_{m1} = \frac{I_{C1}}{V_T}, I_{C1} = I_{C2} = 100\mu$$ [1]

$$g_{m1} = \frac{100\mu}{26m} = 3.846\ mA/V$$ [1]

$$A_d = \frac{(3.846m)(50k)}{2} = 96.15\ V/V$$ [1]

Version 1

Given CMRR(dB) = 85dB = 20 Log CMRR [1]

Therefore CMRR = $10^{(85/20)}$ = 17 783 [1]

CMRR = Ad/|Acm| [2]

So |Acm| = Ad/CMRR = 96.15 / 17783 = 5.407 $\times 10^{-3}$ [2]

Version 2

$$Acm = -\frac{gmRc}{1+\frac{2(1+\beta)Ro}{r\pi+RB}}$$ [2]

Ro = ro4(1+gm4(rpi4||R2)) [0.5]

ro4 = VA4/IQ = 200/200u = 1MΩ [0.5]

gm4 = IQ/VT = 200u/26m = 7.69mA/V [0.5]

rpi4 = β4.VT/IQ = 500(26m)/200u = 65kΩ [0.5]

Ro = 15.23MΩ [0.5]

$$r_{\pi1} = \frac{\beta_1 V_T}{I_{C1}} = \frac{(200)(0.026)}{100\mu} = 52\ k\Omega$$ [0.5]

$$Acm = -\frac{(3.848m)(50k)}{1+\frac{2(1+200)15.23M}{52k}}$$

= - 1.634 $\times 10^{-3}$ [1]

Q4(c) Determine the differential-mode input resistance R_{id} and the common-mode input resistance R_{icm} [5 marks]

$R_{id} = 2r_{\pi 1}$ [0.5]
$r_{\pi 1} = \frac{\beta_1 V_T}{I_{C1}} = \frac{(200)(0.026)}{100\mu} = 52\ k\Omega$ [0.5]
So $R_{id} = 2(52k) = 104\ k\Omega$ [0.5]

Ricm = (1+B)[Ro] [0.5]
Ro = ro4(1+gm4(rpi4||R2) [0.5]
ro4 = VA4/IQ = 200/200u = 1MΩ [0.5]
gm4 = IQ/VT = 200u/26m = 7.69mA/V [0.5]
rpi4 = β4.VT/IQ = 500(26m)/200u = 65kΩ [0.5]
Ro = 15.23MΩ [0.5]
Ricm = (1+200)(15.23M) = 3.06 GΩ [0.5]

Q4(d) If the circuit is modified such that resistor R_2 is zero, will this improve the common mode rejection performance of the differential amplifier? Justify your answer. [2 marks]

If R2 is zero, the current source is now the simple 2 transistor current source, **[1/2]**

which has lower output resistance Ro than the Widlar current source. **[1/2]**

This will cause the value of common mode voltage gain Acm to increase, **[1/2]**

hence CMRR will decrease. Hence the performance will worsen. **[1/2]**