UNIVERSITI TENAGA NASIONAL

College of Engineering

Department of Electronics and Communication Engineering

Test 1 (Solution)

SEMESTER 1, ACADEMIC YEAR 2017/2018

Subject Code	:	**EEEB273**
Course Title	:	**Electronics Analysis & Design II**
Date	:	**8 July 2017**
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.**

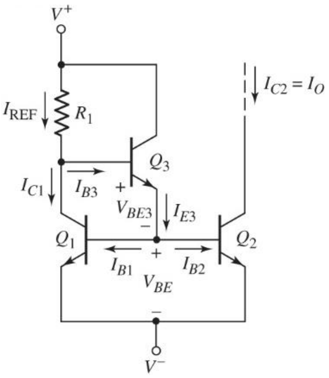
NOTE: DO NOT OPEN THE QUESTION PAPER UNTIL INSTRUCTED TO DO SO.

☺ **GOOD LUCK!** ☺

Question Number	Q1	Q2	Q3	Q4	Total
Marks					

Answers for Question 1

(i) *Three transistor current source*

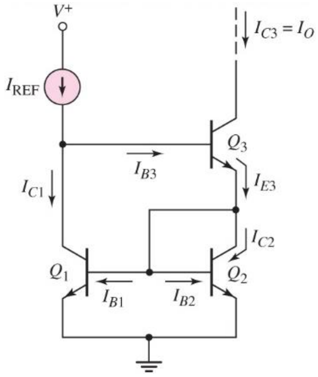


Placements of $\boldsymbol{Q_1}$*,* **Q2** *and* $\boldsymbol{Q_3}$ [2 marks]

Batteries $\mathbf{V^+}$ *and* $\mathbf{V^-}$ *labels* [2 marks]

Currents $\mathbf{I_{REF}}$ *and* $\mathbf{I_O}$ *labels* [2 marks]

Wilson current source



Placements of $\boldsymbol{Q_1}$*,* **Q2** *and* $\boldsymbol{Q_3}$ [2 marks]

Batteries $\mathbf{V^+}$ *and* $\mathbf{V^-}$ *labels* [2 marks]

Currents $\mathbf{I_{REF}}$ *and* $\mathbf{I_O}$ *labels* [2 marks]

(ii) Both three-transistor and Wilson current sources have an increased stability [1.5 marks] with smaller $\boldsymbol{I_O}$ change [1.5 marks].

(iii) For Widlar current source:

Assuming that both $\boldsymbol{Q_1}$ and $\boldsymbol{Q_2}$ are identical,

$I_{REF} \cong I_{C1} = I_S e^{\frac{V_{BE1}}{V_T}}$ [1 mark]

$I_O \cong I_{C2} = I_S e^{\frac{V_{BE2}}{V_T}}$ [1 mark]

Solving the V_{BE} voltages,

$V_{BE1} = V_T ln\left(\frac{I_{REF}}{I_S}\right)$ and $V_{BE2} = V_T ln\left(\frac{I_O}{I_S}\right)$ [2 marks]

Combining the equations for VBEs, $V_{BE1} - V_{BE2} = V_T ln\left(\frac{I_{REF}}{I_S}\right) - V_T ln\left(\frac{I_O}{I_S}\right)$ [1 mark]

Hence, $V_{BE1} - V_{BE2} = V_T ln\left(\frac{I_{REF}}{I_O}\right)$ [1 mark]

From the circuit, $V_{BE1} - V_{BE2} = I_{E2}R_E \cong I_O R_E$ [2 marks]

Combining the equations, $I_O R_E = V_T ln\left(\frac{I_{REF}}{I_O}\right)$ [2 marks]

(iv) $R_1 = \frac{V^+ - V_{BE1} - V^-}{I_{REF}} = \frac{3 - 0.6 - (-3)}{0.1m}$ = <u>54.00 kΩ</u> [1.5,1,1 marks]

$R_E = \frac{V_T}{I_O} ln\left(\frac{I_{REF}}{I_O}\right) = \frac{0.026}{0.02m} ln\left(\frac{0.1m}{0.02m}\right)$ = <u>2.092 kΩ</u> [1.5,1,1 marks]

$V_{BE2} = V_{BE1} - I_O R_E$ = 0.6 – (0.02m)(2.092k) = <u>0.5582 V</u> [1, 1, 1 marks]

Answers for Question 2

Question 2(a)

VDS2 (min) = VD2 – VS2 = -2.1 – (-3) **= 0.9V = VDS2(sat)** [2]
VDS2(sat) = VGS2 – VTN
VGS2 = VDS2(sat) + VTN = 0.9 + 0.5 **= 1.4V** [1]
From circuit, **VGS1 = VGS2 = 1.4V** [1]

Io= ID2 = $(\frac{1}{2}\mu_n C_{ox})(W/L)_2(\text{VGS2} - \text{VTN})^2$
= $(50\ \mu)(35)(1.4-0.5)^2$ = **1.418mA** [2]
IREF = ID1 = $(\frac{1}{2}\mu_n C_{ox})(W/L)_1(\text{VGS1} - \text{VTN})^2$
= $(50\ \mu)(20)(1.4-0.5)^2$ = **0.810mA** [1]

ID3=ID4=IREF = 0.810mA [1]
ID3 = 0.810mA = $(\frac{1}{2}\mu_n C_{ox})(W/L)_3(\text{VGS3} - \text{VTN})^2$
= $(50\ \mu)(5)(\text{VGS3}-0.5)^2$
VGS3 = 2.3V [2]
ID4 = 0.810mA = $(\frac{1}{2}\mu_p C_{ox})(W/L)_4(\text{VSG4} + \text{VTP})^2$
= $(20\ \mu)(10)(\text{VSG4}+ (-0.55))^2$
VSG4 = 2.562V [2]

Question 2(b)

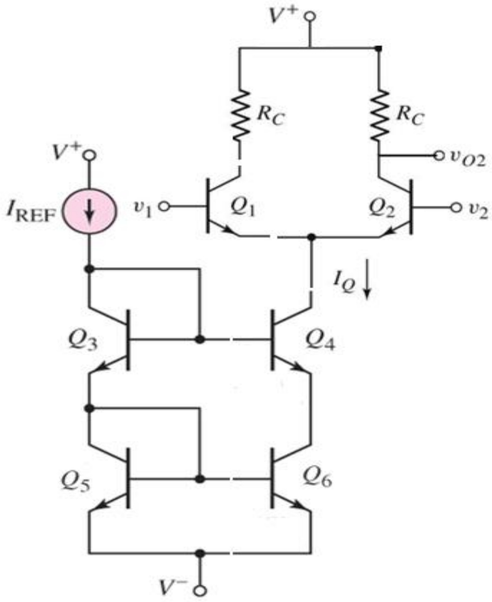
dIo = dVD2/RO [1]
dVD2 = 0.4 – (-1.6) = **2V** [1]
Ro = ro2
ro2 = 1/(λn)(ID2) = 1/(0.02)(1.418m) = **35.26kΩ** [2]
dIo =2/35.26k = **56.72uA** [1]

Question 2(c)

Io' = Io + dIo [1]
= 1.418mA + 56.72uA
= 1.475mA [2]

Answers for Question 3

(a)



Cascode CS	[2]
Supply connections	[1]
Output and reference connection of CS	[2]

(b) $I_{C2} = I_Q / 2 = 0.5\text{m} /2 = 0.25$ mA [2]

$R_C = [V^+ - v_{o2}] / I_{C2}$ [2]

$= [12 – 0.4] / 0.25m = 46.4k\Omega$ [2]

(c) $v_d = v_1 – v_2$ [2]

$v_d =$ (250 – 150) $sin\ \omega t$ μV = 100 $sin\ \omega t$ μV [2]

(d) $v_{cm} = (v_1 + v_2)/2$ [2]

= [(250+150)/2] $sin\ \omega t$ μV = 200 $sin\ \omega t$ μV [2]

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

v_o = (223) 100 $sin\ \omega t$ μV + (-10)(200 $sin\ \omega t$ μV) [2]

= (22.3m - 2m) $sin\ \omega t$ V = 20.3 $sin\ \omega t$ mV [2]

Answers for Question 4

$$V_o = \frac{\beta R_C}{2(r_\pi + R_B)}.V_d - \frac{\beta R_C}{r_\pi + R_B + 2(1+\beta)R_o}.V_{cm}$$

$$R_B = 0$$

$$\Rightarrow V_o = \frac{\beta R_C}{2r_\pi}.V_d - \frac{\beta R_C}{r_\pi + 2(1+\beta)R_o}.V_{cm} \qquad [2]$$

$$V_o = A_d V_d + A_{cm} V_{cm} \qquad [2]$$

$$A_d = \frac{\beta R_C}{2r_\pi} = \frac{g_m r_\pi R_C}{2r_\pi} = \frac{g_m R_C}{2} \qquad [2]$$

$$g_m = \frac{I_Q}{2V_T} = \frac{(0.8\text{m})}{2(0.026)} = 15.384\ \text{mA/V} \qquad [2]$$

$$r_\pi = \frac{2V_T\beta}{I_Q} = \frac{2(0.026)(100)}{(0.8\text{m})} = 6.5\ \text{k}\Omega \qquad [2]$$

$$\Rightarrow A_d = \frac{g_m R_C}{2} = \frac{I_{CQ} R_C}{2V_T} = \frac{I_Q R_C}{2(2V_T)} = \frac{I_Q R_C}{4V_T} = \frac{(0.8\text{m})(12\text{k})}{4(0.026)} = 92.3 \qquad [2]$$

$$A_{cm} = \frac{-\beta R_C}{r_\pi + 2(1+\beta)R_o} \qquad [2]$$

$$\Rightarrow A_{cm} = \frac{-\beta R_C}{r_\pi + 2(1+\beta)R_o} = \frac{-g_m R_C}{1 + \frac{2(1+\beta)R_o g_m}{\beta}} = \frac{-\frac{I_Q}{2V_T} R_C}{1 + \frac{2(1+\beta)R_o}{\beta}\frac{I_Q}{2V_T}} = -0.237 \qquad [2]$$

$$CMRR = \left|\frac{A_d}{A_{cm}}\right| = \left|\frac{92.3}{-0.237}\right| = 389 \qquad [4]$$