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 Energy University

College of Engineering

Department of Electrical and Electronics Engineering

Test 2 – Model Answer

SEMESTER 1, ACADEMIC YEAR 2019/2020

Subject Code	:	**EEEB2014/EEEB273**
Course Title	:	**Electronics Analysis & Design II**
Date	:	**17 August 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 (abc)	Q1 (d)	Q2 (a)	Q2 (b)	Q3 (ab)	Q4 (a)	Q4 (b)	Total
Marks	20	10	8	27	20	3	12	100

QUESTION 2 [30 marks]

Answers for Question 1

Q1(a) 8 marks

DC balanced condition, VEC4 = VEC3 and VCE2 = VCE1 [1]

VEC3 = VE3 – VC3 [0.5]

VE3 = 5 V [1]

VC3=VB5 = V+ - VEB3 – VEB5 = 5 – 0.65 – 0.65 = 3.7 V [1]

VEC4 = VEC3 = 5 - 3.7 = **1.3 V** [1]

VCE1 = VC1 – VE1 [0.5]

VC1 = VC3 = VB5 = 3.7 V [1]

VE1 = VB1 – VBE1 = 0 – 0.67V = -0.67V [1]

VCE2 = VCE1 = 3.7 – (-0.67) = **4.37 V** [1]

Q1(b) 6 marks

$r_{02} = V_{An}/I_{CQ2} = V_A/(I_Q/2) = 100/(0.4m/2) = 500\ k\Omega$ [1]

$r_{04} = V_{Ap}/I_{CQ2} = V_A/(I_Q/2) = 70/(0.4m/2) = 350\ k\Omega$ [1]

$g_{m2} = I_{CQ2}/V_T = I_Q/2V_T = 0.4m/[2(26m)] = 7.692\ mA/V$ [2]

$A_d = g_{m2}\,(r_{02}//\ r_{04}) = 7.692m\ (500k//350k) =$ **1584 V/V** [2]

Q1(c) 6 marks

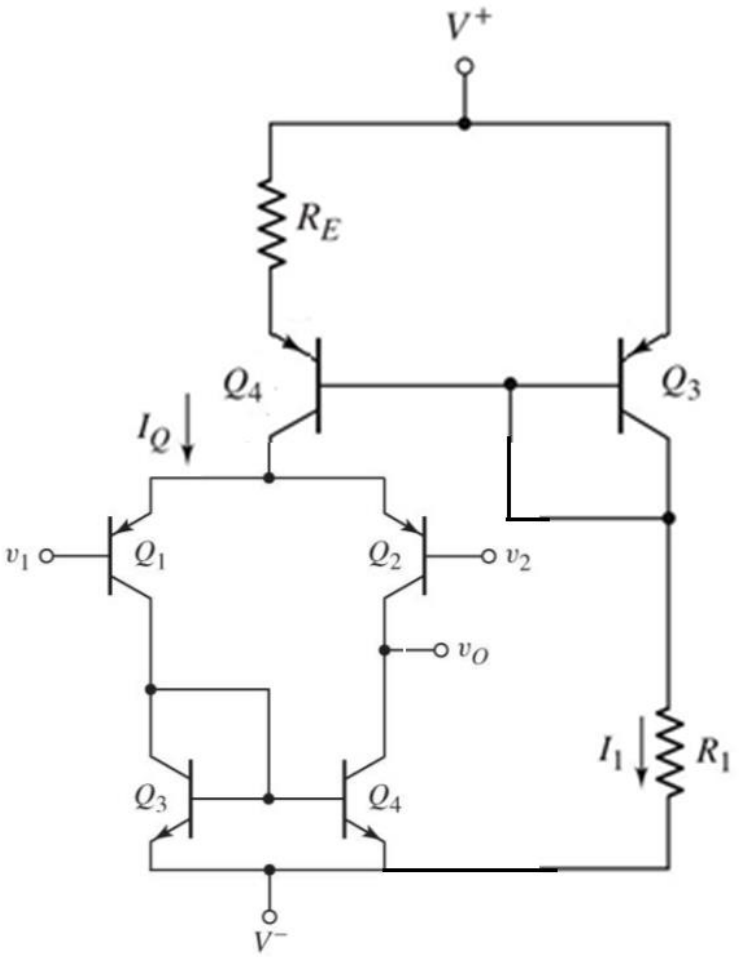
$A_d = g_{m2}\,(r_{02}\ //\ r_{04}\ //\ R_L)$ [2]

$0.9(1584) = 1425 = 7.692m\ (500k//350k//\ R_L)$ [2]

RL = 1.84 MΩ [2]

Answers for Question 1 (Continued)

Q1(d) 10 marks

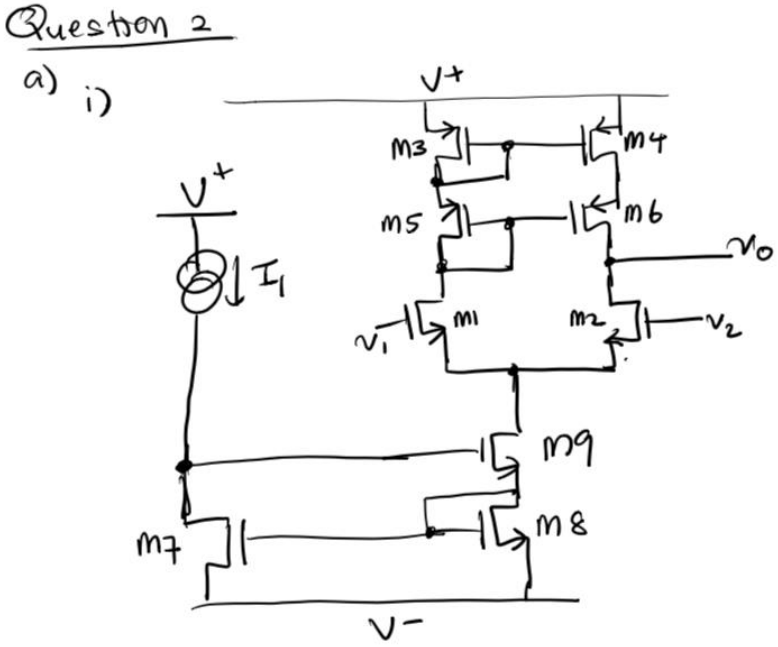


Correct pnp differential amplifier	[2]
Correct npn 2 transistor active load	[2]
Correct pnp **Widlar** current source	[2]
Correct I_1 (Iref) side with diode connection	[2]
Correct IQ current source C4 to E1/E2 connection	[1]
V+ and V-	[1]

QUESTION 2 [35 marks]

Answers for Question 2

Q2(a) 8 marks



Biasing	[2]
Diff amp	[3]
Cascode	[2]
Correct labelling	[1]

Answers for Question 2 (Continued)

Q2(b) 27 marks

b) i) $I_Q = 12.8\,mA$

$\Rightarrow I_O = \frac{I_Q}{2} = 6.4\,mA$ — 1 mark.

$\Rightarrow r_{o2} = \frac{1}{\lambda_n I_D} = 10.42\,k\Omega$ — 1 mark.

$r_{o4} = \frac{1}{\lambda_p I_D} = 7.81\,k\Omega$ — 1 mark

$\Rightarrow R_o = r_{o2} \| r_{o4} = 4.46\,k\Omega$ — 2 mark.

ii) $g_m = 2\sqrt{K_n I_D} = 2.26\,mA/V$ — 3 mark.

$\Rightarrow A_v = g_m R_o = 10.1\ V/V$ — 2 mark.

iii) $A_d = g_m(R_o \| R_L) = 6.98\ V/V$ 5 marks

iv) $CMRR = 27.7 = 20 \log \left| \frac{A_d}{A_{cm}} \right|$ — 3 marks

$|A_{cm}| = 0.288\ V/V$ — 2 mark.

v) $v_d = v_1 - v_2 = 20 \sin \omega t$ 2 marks

$v_{cm} = \frac{v_1 + v_2}{2} = 0.5 \sin \omega t$ 2 marks

$v_o = A_d v_d + A_{cm} v_{cm} = 139.5 \sin \omega t$

— 3 mark.

QUESTION 3 [20 marks]

Answers for Question 3

Q3(a) 15 marks

$I_{C7} = I_Q = 45\ \mu A$ Given

$I_{C6} = \frac{\beta}{1+\beta} I_{E6} = \frac{\beta}{1+\beta} I_{B7} = \frac{\beta}{1+\beta}\frac{I_{C7}}{\beta} = \frac{I_{C7}}{1+\beta}$ [1]

$I_{C6} = \frac{I_{C7}}{1+\beta} = \frac{45\ \mu}{121} = 0.3719\ \mu A$ [0.5]

$r_{\pi 6} = \frac{\beta V_T}{I_{C6}} = \frac{120 \times 0.026}{0.3719\ \mu} = 8.39\ M\Omega$ [1]

$r_{\pi 7} = \frac{\beta V_T}{I_{C7}} = \frac{120 \times 0.026}{45\ \mu} = 69.33\ k\Omega$ [1]

$R_i = r_{\pi 6} + (1+\beta) r_{\pi 7}$ [1]

$R_i = 8.39M + 121(69.33k) = 16.778\ M\Omega$ [0.5]

[Total for R_i = 5 marks]

$R_i = \frac{2(1+\beta)\beta V_T}{I_Q} = \frac{2 \times 121 \times 120 x 26m}{45\ \mu} = 16.778\ M\Omega$ [Optional: 2 marks]

$R_{c11} = r_{o11}[1 + g_{m11}(r_{\pi 11} || R_3)]$ [1]

$R_3 = R_2 = 2\ k\Omega$ Widlar [1]

$r_{o11} = V_A / I_{C7} = 120/45\mu = 2.67\ M\Omega$ [0.5]

$g_{m11} = I_{C7}/V_T = 45\mu/0.026 = 1.73\ mA/V$ [0.5]

$r_{\pi 11} = \frac{\beta V_T}{I_{C7}} = \frac{120 \times 0.026}{45\ \mu} = 69.33\ k\Omega$ [0.5]

$R_{c11} = 2.67M[1 + (1.73m)(69.33k || 2k)] = 11.65\ M\Omega$ [0.5]

[Total for R_{c11} = 4 marks]

$R_{b8} = r_{\pi 8} + (1+\beta) R_4$ [1]

$R_4 = 5\ k\Omega$ Given

$I_{C8} = \frac{v_o - V^-}{R_4} = \frac{0-(-10))}{5k} = 2\ mA$ [1]

$r_{\pi 8} = \frac{\beta V_T}{I_{C8}} = \frac{120 \times 0.026}{2m} = 1.56\ k\Omega$ [1]

$R_{b8} = 1.56k + 121(5k) = 606.56\ k\Omega$ [1]

[Total for R_{b8} = 4 marks]

$R_{L7} = R_{c11} || R_{b8}$ [1]

$R_{L7} = 11.65M || 606.56k = 576.54\ k\Omega$ [1]

[Total for R_{L7} = 2 marks]

Q3(b) 5 marks

$I_{C7} = (1+\beta) I_{C6} = (1+\beta)(\beta I_{B6})$ [1]

$v_{O3} = I_{C7}(r_{o7} || R_{L7}) = (1+\beta)(\beta I_{B6})(r_{o7} || R_{L7})$ [1]

$v_{O2} = I_{B6} R_i$ Given

$r_{o7} = V_A / I_{C7} = 120/45\mu = 2.67\ M\Omega$ [1]

$A_2 = \frac{v_{O3}}{v_{O2}} = \frac{(1+\beta)(\beta I_{b6})(r_{o7} || R_{L7})}{I_{b6} R_i} = \frac{(1+\beta)(\beta)(r_{o7} || R_{L7})}{R_i}$ [1]

$A_2 = \frac{(1+120)(120)(2.67M || 576.54k)}{16.778M} = 410.34$ [1]

[Total for A_2 = 5 marks]

$A_2 = (I_Q / 2V_T)\ R_{L7}$ = (45µ x 576.54k)/(2 x 26m) = 498.93 [Optional: 2 marks]

(Ignore r_{o7})

QUESTION 4 [15 marks]

Answers for Question 4

Q4(a) 3 marks

(a) Class A has low power conversion efficiency where its maximum efficiency is 25% [1.5] while Class B can reach up to 78.5% although suffering from cross-over distortion [1.5].

Q4(b) 12 marks

(b) **Class A emitter-follower** circuit

(i) $I_Q = (V^{+CS} - V_{BE}(on) - V^-)/ R$ [1]

$= (3 - 0.6 + 5) / 2k = \mathbf{3.7\ mA}$ [1]

(ii) $P_{Q1} = I_{C1}.V_{CE1}$ [1]

$= I_Q.V_{CE1} = (\mathbf{3.7m})(5 - 0) = \mathbf{18.5\ mW}$ [0.5]

$P_{Q2} = I_{C2}.V_{CE2}$ [1]

$= I_Q.V_{CE2} = (\mathbf{3.7m})(0 - (-5)) = \mathbf{18.5\ mW}$ [0.5]

$P_{Q3} = I_{C3}.V_{CE3}$ [1]

$= I_Q.V_{BE3}(on) = (\mathbf{3.7m})(0.6) = \mathbf{2.22\ mW}$ [0.5]

$P_R = I_R^2 R$ [1]

$= I_Q^2 R = (\mathbf{3.7m})^2 (2k) = \mathbf{27.38\ mW}$ [0.5]

(iii) For sine-wave output voltage (v_O) with peak value of 4 V.

Power conversion efficiency, $\eta = P_L / P_S \times 100\%$ [1]

$P_L = (V_p)^2 / (2R_L) = 0.5\ (4)^2 / 1k = \mathbf{8\ mW}$ [1]

$P_S = (V^+ - V^-)I_Q + (\mathbf{3} - V^-)I_Q$

$= (5 - (-5))(\mathbf{3.7m}) + (3 - (-5))(\mathbf{3.7m}) = \mathbf{66.6\ mW}$ [1]

$\eta = 8m / 66.6m \times 100\% = \mathbf{12.01\%}$ [1]

Or using power dissipation for Q1 and Q2 only:

$P_S = (V^+ - V^-)I_Q$

$= (5 - (-5))(\mathbf{3.7m}) = \mathbf{37\ mW}$ [1]

$\eta = 8m / 37m \times 100\% = \mathbf{21.6\%}$ [1]