Name:

Student ID Number:

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

Lecturer: Dr Jamaludin/ Dr Fazrena Azlee

Table Number:

UNIVERSITI TENAGA NASIONAL

The National Energy University

College of Engineering

Department of Electronics and Communication Engineering

Test 2 – MODEL ANSWERS

SEMESTER 2, ACADEMIC YEAR 2018/2019

Subject Code : **EEEB273/EEEB2014**
Course Title : **Electronics Analysis & Design II**
Date : **5 January 2019**
Duration : **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 (bc)	Q2 (a)	Q2 (bc)	Q3 (ab)	Q4 (a)	Q4 (b)	Total
Marks								
CO	9	3	9	3	5	9	4	

QUESTION 1 [30 marks]

Answers for Question 1

(a)

$I_O = I_{B5}$ [1]

$I_{B5} = \frac{I_{E5}}{(1+\beta)} = \frac{I_{B3}+I_{B4}}{(1+\beta)}$ [2]

Must indicate currents in Figure 1

$I_{B5} = \frac{\frac{I_{C3}}{\beta}+\frac{I_{C4}}{\beta}}{(1+\beta)} = \frac{\frac{I_{C1}}{\beta}+\frac{I_{C2}}{\beta}}{(1+\beta)}$ [2]

$I_O = I_{B5} = \frac{I_{C1}+I_{C2}}{\beta(1+\beta)} = \frac{I_Q}{\beta(1+\beta)}$ [2]

$I_O = \frac{I_Q}{\beta(1+\beta)} = \frac{0.24\text{m}}{200\times 201} = 5.97\text{ nA}$ [3]

(b)

$I_{C2} = I_{C4} = \frac{I_Q}{2} = \frac{0.24m}{2} = 0.12\text{ mA}$ [2]

$r_{o2} = \frac{V_{A2}}{I_{C2}} = \frac{100}{0.12m} = 833.3\text{ k}\Omega$ [1]

$r_{o4} = \frac{V_{A4}}{I_{C4}} = \frac{60}{0.12m} = 500\text{ k}\Omega$ [1]

$R_O = r_{o2}||r_{o4} = 833.3k||500k = 312.5\text{ k}\Omega$ [1]

$g_{m2} = \frac{I_{C2}}{V_T} = \frac{0.12m}{0.026} = 4.615\text{ mA/V}$ [1]

$A_d = g_{m2}(r_{o2}||r_{o4}) = g_{m2}(R_O)$ [2]

$A_d = (4.615m)(312.5k) = 1442$ [1]

$A_d(\text{New}) = 80\% \times A_d = 0.8 \times 1442 = 1153.6$ [2]

$A_d(\text{New}) = g_{m2}(r_{o2}||r_{o4}||R_L) = g_{m2}(R_O||R_L)$ [2]

$1153.6 = (4.615m)(312.5k||R_L)$ [1]

$R_L = 1286\ k\Omega$ [1]

(c) Use Cascode **{OR Wilson}** current source as active load. [2]

Draw the circuit incorporated in diff-amp with New Active load. [1]

Discussion: Increases output resistance of the diff-amp with new active load, help reduces the loading effect when load is connected because output resistance of Cascode configuration is βr_{O4} **{OR Wilson configuration is $\beta r_{O3}/2$}** which is at least 200X larger for Cascode **{OR 100X larger for Wilson}** than that in the circuit in Figure 1. This larger output resistance of the active load definitely will increase the differential mode voltage gain of the diff-amp. [2]

NOTE: Part (c) can have any other reasonable and logical answer!

QUESTION 2 [30 marks]

Answers for Question 2

a) State the function of each transistor M1 to M6 in Figure 1. [6 marks]

- M1 & M2: differential-pair , common-**source** amplifiers [2 marks]
- M3 to M6: cascode current mirror [2 marks], active load [2marks]

b) Calculate the voltages VGS1, VSG5 and VD1. [12 marks]

$ID1 = ½\ kn'(W/L)_1(VGS1\text{-}VTN)^2$	[1 mark]
ID1= ½ IQ = 0.3m/2 = 0.15m	[1 mark]
$0.15m = ½\ (200u)(10)(VGS1\text{-}0.8)^2$	[1 mark]
→ VGS1 = 1.1873 V	[1 mark]
$ID5 = ½\ kp'(W/L)_5(VSG5+VTP)^2$	[1 mark]
ID5= ½ IQ = 0.3m/2 = 0.15m	[1 mark]
$0.15m = ½\ (80u)(30)(VSG5\text{-}0.7)^2$	[1 mark]
→ VSG5 = 1.0536 V	[1 mark]
$VD1 = VD3 = V^+ - VSG5 – VSG3$	[1 mark]
VSG3=VSG5 = 1.0536 V	[2 marks]
→ VD1 = 5 – 2(1.0536) = 2.893V	[1 mark]

c) Calculate the differential gain of the circuit if: (W/L)1-2=10, (W/L)3-6= 30 [12 marks]

Ad=gm1x[ro2||Ro4cascode]	[2 marks]
gm1=2sqrt[(Kn1)(ID1)] = 2sqrt[0.5(200u)(10)(0.15m)] = 0.7746mA/V	[1 mark]
ro2=1/(lambdan)(ID2) = 1/(0.01x0.15m) = 666.7kOhm	[1 mark]
Ro4cascode=gm4ro4ro6	[2 marks]
gm4=2sqrt[(Kp4)(ID4)] = 2sqrt[0.5(80u)(30)(0.15m)] = 0.8485mA/V	[1 mark]
ro4=1/(lambdap)(ID4) = 1/(0.015x0.15m) = 444.4kOhm	[1 mark]
ro4=ro6	[1 mark]
Ro4cascode=(0.8485m)(444.4k)(444.4k)=167.6MOhm	[1 mark]
Ad= gm1x[ro2||Ro4] = (0.7746m)(666.7||167.6M) = 514.6.8 V/V	[2 marks]

QUESTION 3 [20 marks]

Answers for Question 3

(a)

$R_{L7} = R_{c11} \| R_{b12}$ [1]

$R_{b12} = r_{\pi 12} + (1+\beta_n) R_{b8}$

$R_{b8} = r_{\pi 8} + (1+\beta_n) R_4$

$r_{\pi 8} = \beta_n V_T / I_{C8} = (120 \text{ x } 0.026)/(\,\mathbf{1.2}\text{m}) = \mathbf{2.6}\text{ k}\Omega$ [1]

$R_{b8} = r_{\pi 8} + (1+\beta_n) R_4 = \mathbf{2.6}\text{k} + (121)(5\text{k}) = \mathbf{607.6}\text{ k}\Omega$ [1]

$I_{C12} = I_{E12}(\beta_n / (1+\beta_n)) = I_{B8}(\beta_n / (1+\beta_n)) = (I_{C8}/\beta_n)(\beta_n / (1+\beta_n))$

$= I_{C8} / (1+\beta_n) = \mathbf{1.2}\text{m} / (121) = \mathbf{0.009917}\text{ mA} = \mathbf{9.917}\ \mu\text{A}$ [2]

$r_{\pi 12} = \beta_n V_T / I_{C12} = (120 \text{ x } 0.026) / (\mathbf{9.917}\mu) = \mathbf{314.6}\text{ k}\Omega$ [1]

$R_{b12} = r_{\pi 12} + (1+\beta_n) R_{b8} = \mathbf{314.6}\text{k} + (121)(\mathbf{607.6}\text{k}) = \mathbf{73.834}\text{ M}\Omega$ [1]

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

$r_{o11} = V_{A11} / I_{C11} = 120 / \mathbf{0.3}\text{m} = \mathbf{400}\text{ k}\Omega$ [1]

$g_{m11} = I_{C11} / V_T = \mathbf{0.3}\text{m} / 0.026 = \mathbf{11.538}\text{ mA/V}$ [1]

$r_{\pi 11} = \beta_n V_T / I_{C11} = (120 \text{ x } 0.026) / (\mathbf{0.3}\text{m}) = \mathbf{10.4}\text{ k}\Omega$ [1]

$R_{c11} = (\mathbf{400}\text{k})(1 + \mathbf{11.538}\text{m}(\mathbf{10.4}\text{k} \| 0.2\text{k})) = \mathbf{1.305}\text{ M}\Omega$ [1]

$R_{L7} = R_{c11} \| R_{b12} = \mathbf{1.305}\text{M} \| \mathbf{73.834}\text{M} = \mathbf{1.282}\text{ M}\Omega$ [1]

(b)

$R_o = R_4 \| (r_{\pi 8} + Z_1) / (1+\beta_n)$ [1]

$Z_1 = (r_{\pi 12} + Z) / (1+\beta_n)$ [1]

$Z = R_{c11} \| R_{c7}$ [1]

$R_{c7} = r_{o7} = V_{A7} / I_{C7} = 60 / \mathbf{0.3}\text{m} = \mathbf{200}\text{ k}\Omega$ [1]

$Z = R_{c11} \| R_{c7} = \mathbf{1.305}\text{M} \| \mathbf{200}\text{k} = \mathbf{173.4}\text{ k}\Omega$ [1]

$Z_1 = (r_{\pi 12} + Z) / (1+\beta_n) = (\mathbf{314.6}\text{k} + \mathbf{173.4}\text{k}) / (121) = \mathbf{4.03}\text{ k}\Omega$ [1]

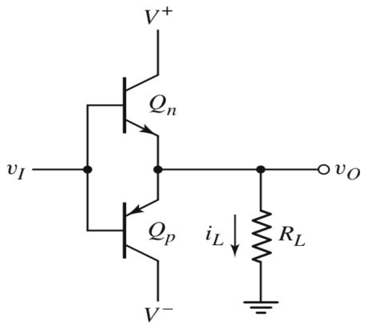
$R_o = R_4 \| (r_{\pi 8} + Z_1) / (1+\beta_n) = 5\text{k} \| ((\mathbf{2.6}\text{k} + \mathbf{4.03}\text{k})/121) = \mathbf{54.2}\ \Omega$ [1]

QUESTION 4 [20 marks]

Answers for Question 4

a) Sketch the Class B output stage. Explain the operation. **[5 marks]**

- Sketch [2 marks]



- Operation [3 marks]
  - Assume VBE(on) =VEB(on) = 0.7V:
    VO remains zero as long as -0.7 ≤VI ≤ 0.7 [1]
  - Qn conducts during the positive half of the input cycle:
    VI positive and > 0.7V, Qn turns on. [1]
  - Qp conducts during the negative half-cycle:
    VI negative and < 0.7V, Qp turns on. [1]

b) Class A

i) Calculate the maximum possible output voltage range of the circuit. **[2 marks]**

vo(max)= V^+ - VCE1(sat) =5-0.3 = 4.7V [1 mark]
vo(min)= V^- + VCE2(sat) = -5+0.3 = -4.7V [1 mark]

ii) Determine the minimum required biasing current IQ. **[3 marks]**

IQ(min) = |IL(min)| = |vo(min)/RL| [1 mark]
= |-4.7/100| = 47mA [2 marks]

iii) For -4V ≤ vO ≤ +4V. Determine the required range of the input voltage vI. **[10 marks]**

vI = vO + VBE1 [2 marks]
IC1=IE1, IE1 = IQ + IL [1 mark]
IC1 = IQ + vO/RL [1 mark]

For vO=vO(max)= +4V,

VBE1 = VT. ln(IC1/IS) = VT. ln[(IQ + vO/RL) /IS] [1 mark]
=26m . ln[(47m + (4/100))/9x10^{-15}] = 0.7774V [1 mark]
vI(max) = vO(max) + VBE1 = 4 + 0.7774 = 4.7774V [1 mark]

For vO=vO(min)= -4V,

VBE1 = VT. ln(IC1/IS) = VT. ln[(IQ + vO/RL) /IS] [1 mark]
=26m . ln[(47m + (-4/100))/9x10^{-15}] = 0.7119V [1 mark]
vI(max) = vO(max) + VBE1 = -4 + 0.7119 = - 3.2881V [1 mark]