COLLEGE OF ENGINEERING
PUTRAJAYA CAMPUS
FINAL EXAMINATION

SEMESTER 1   2018 / 2019

MODEL ANSWERS

PROGRAMME	: **Bachelor of Electrical & Electronics Engineering (Honours)** **Bachelor of Electrical Power Engineering (Honours)**
SUBJECT CODE	: **EEEB273**
SUBJECT	: **ELECTRONIC ANALYSIS AND DESIGN II**
DATE	: **September 2018**
TIME	: **3 hours**

INSTRUCTIONS TO CANDIDATES:

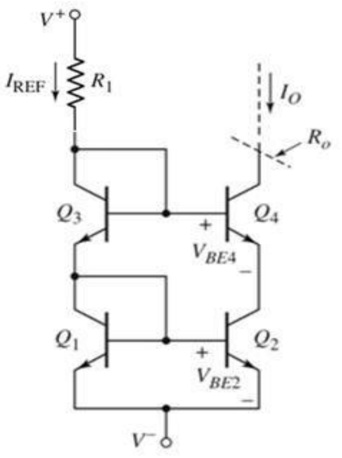
1. This paper contains **FIVE** (5) questions in **NINE** (9) pages.
2. Answer **ALL** questions.
3. Write **all** answers in the answer booklet provided. **Use pen** to write your answer.
4. Write answer to different question on **a new page**.

THIS QUESTION PAPER CONSISTS OF NINE (9) PRINTED PAGES INCLUDING THIS COVER PAGE.

Question 1 [20 marks]

Answers:

(a) **[Each component carries 0.5 marks, total 4 marks]**



(b)

$$I_{C2} = \beta I_{B2} = I_{E4} = \beta I_{B1}$$

$$I_{C4} = \alpha I_{E4} = (\tfrac{\beta}{\beta+1})(\beta I_{B1}) = I_O \qquad \rightarrow I_{B1} = (\tfrac{\beta+1}{\beta^2})I_O$$

$$I_{B4} = \frac{I_{E4}}{\beta+1} = (\frac{1}{\beta+1})(\beta I_{B1})$$

$I_{C1} = \beta I_{B1}$ and $I_{E3} = (\beta + 2)\, I_{B1}$

$I_{B3} = \left(\frac{1}{\beta+1}\right) I_{E3} = \frac{1}{(\beta+1)}(\beta + 2)I_{B1}$ and $I_{C3} = \beta I_{B3} = \left(\frac{\beta}{\beta+1}\right)(\beta + 2)\, I_{B1}$

$$I_{REF} = I_{C3} + I_{B3} + I_{B4}$$

$$\rightarrow I_{REF} = \left(\frac{\beta}{\beta+1}\right)(\beta + 2)\, I_{B1} + \frac{1}{(\beta+1)}(\beta + 2)I_{B1} + (\frac{1}{\beta+1})(\beta I_{B1})$$

$$I_{REF} = \left[\frac{(\beta^2+2\beta+\beta+2+\beta)}{\beta+1}\right] I_{B1}$$

$$I_{REF} = \left[\frac{(\beta^2+2\beta+\beta+2+\beta)}{\beta+1}\right]\left[\left(\frac{\beta+1}{\beta^2}\right) I_O\right]$$

$$\rightarrow I_O = [I_{REF}/\left[1 + \frac{4}{\beta} + \frac{2}{\beta^2}\right]] \approx I_{REF}/[1 + \frac{4}{\beta}]$$

[Each carries 0.5 marks, total 5 marks]

c) β =150, Since β is higher than 100, $\therefore$ *Approximation of* $I_O = I_{REF}$ **[1 mark]**

$$I_{REF} = \frac{V^+ - V_{BE1} - V_{BE3} - V^-}{R_1} = \frac{5-0.7-0.7-(-5)}{6\times10^3} = 1.433mA$$ **[2 marks]**

$$I_O = I_{REF} = 1.433mA$$ **[0.5 mark]**

$$R_O = \beta r_O = \beta\left(\frac{V_A}{I_O}\right) = 150\left(\frac{100}{1.433m}\right) = 10.465M\Omega$$ **[3.5 marks]**

d) $g_{m4} = \frac{I_O}{V_T}$ **[1 mark]**

$$g_{m4} = \frac{1.433mA}{26mV} = 55.128mA/V$$ **[1 mark]**

$$r_{\pi4} = \frac{\beta V_T}{I_O}$$ **[1 mark]**

$$r_{\pi4} = 150\left(\frac{26mV}{1.433mA}\right) = 2.721k\Omega$$ **[1 mark]**

Question 2 [20 marks]

Answers:

Q2a(i) Design the circuit such that $\boldsymbol{I_3}$ **= 400 uA** and $\boldsymbol{V_{CE1} = V_{CE2}}$ **= 10 V**. **[5 marks]**

Neglect the base currents;

$I_1 = I_3 = 400\ \mu A$

Using KVL, $R_1 = (V^+ - V_{BE4} - V^-) / I_1$

$R_1 = (15 - 0.7 - (-15)) / 0.4m =$ **73.25 kΩ** [1, 1, 0.5]

As $V_{CE1} = 10$ V; $V_{C1} = V_{CE1} - V_E = 10 - 0.7 = 9.3$ V

$R_C = (V+ - V_{C1}) / I_{C1} = (15 - 9.3) / (400\mu/2) =$ **28.5 kΩ** [1, 1, 0.5]

Q2a(ii) Determine $\boldsymbol{A_d}$ and $\boldsymbol{CMRR_{dB}}$ for a one-sided output at $\boldsymbol{v_{O2}}$. $\boldsymbol{A_{cm}}$ is given as **−0.113**.

[5 marks]

Find rπ,

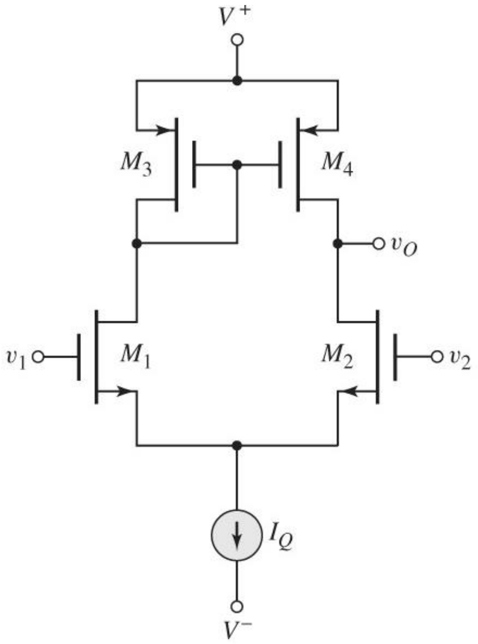
$r_\pi = \beta v_T / I_{CQ} = (100)(0.026) / 200\mu =$ **13 kΩ** [0.5, 0.5]

$A_d = \beta R_C / 2(r_\pi + R_B)$

$= (100)(28.5k) / 2(13k + 10k) =$ **62** [1, 1]

Thus, $CMRR_{dB} = 20 \log_{10} (62/0.113) =$ **54.8 dB** [1, 1]

Q2b(i) Draw an improved diff-amp for the circuit in **Figure 3**. Use **Table 1** for the transistors specification. **[4 marks]**



M3 and M4 placement [2]

PMOS type [2]

Q2b(ii) Calculate the minimum power supply voltages if the common input voltage is to be in the range of **$\pm$ 3 V**. Assume symmetrical supply voltages.

[6 marks]

$i_{D3} = K_p\,(v_{SG3} + V_{TP})^2$ [2]

$0.5\text{m}/2 = 0.25\text{m}\,(v_{SG3} - 0.4)^2$

$v_{SG3} = \mathbf{1.4\ V}$ [1]

Then, assuming that $v_{SG3} = v_{GS1}$,

$v_{DS1}(sat) = v_{GS1} - V_{TN} = 1.4 - 0.4 = \mathbf{1.0\ V}$ [2]

$v_{CM} = V_O - v_{DS1}(\text{sat}) + v_{GS1}$

$3 = (V^+ - 1.4) - 1.0 + 1.4$ ➔ **$V^+ = 4$ V and $V^- = -4$ V** [1]

Question 3 [20 marks]

Answers:

Q3(a)	I_1	$= (V^+ - V_{BE7} - V^-) / (R_1)$		[1]
		$= (10-0.7-(-10)) / (19.3k)$	$= 1$ mA	[1]
	I_Q	$= I_1 / (1 + 2/\beta)$	$= 0.990$ mA	[2]
	I_{C2}	$= I_Q / 2$	$= 0.495$ mA	[2]
	v_{O2}	$= V^+ - I_{C2} R_C = 10 - (0.495m)(10k) = 5.05$ V		[2]
	I_{R4}	$= (v_{O2} - 2\ V_{BE}(on)) / (R_4)$		
		$= (5.05 - 1.4) / (11.5k)$	$= 0.3173$ mA	[0.5]
	I_{R5}	$\approx I_{R4}$ (neglecting base currents) $= 0.3173$ mA		[0.5]
	v_{O3}	$= V^+ - I_{R5} R_5 = 10 - (0.348m)(5k) = 8.413$ V		[1]

Q3(b)	Using	$I_{C2} = 0.495$ mA, $I_{R4} = 0.3173$ mA:	
	A_{d1}	$= (g_{m2} / 2)(R_C \parallel R_{i2})$	
	g_{m2}	$= I_{C2} / V_T = (0.495mA)/(26mV) = 19$ mA/V	[1]
	$r_{\pi4}$	$= \beta V_T / I_{R4} = (200x26m)/(0.3173m) = 16.388$ kΩ	[1]
	$r_{\pi3}$	$\approx \beta\ r_{\pi4} = 200x16.388k = 3277.6$ kΩ	[1]
	R_{i2}	$= r_{\pi3} + (1 + \beta)\ r_{\pi4}$	[1]
		$= 3277.6k + (201)(16.388k) = 6571.59$ kΩ	[1]
	A_{d1}	$= (19m/2)(10k \parallel 6571.59k) = 94.85$	[1]
	A_{v2}	$\approx (I_{R4} / 2V_T)\ R_5 = (0.3173/(2x26m))(5k) = 30.5$	[1]
	A_3	≈ 1 (Output stage assume gain = 1)	[1]
	A_d	$= A_{d1}\ A_{v2}\ A_3$	[1]
		$= 94.85 \text{ x } 30.5 \text{ x } 1 = 2893.8$	[1]

OR

Q3(a)	I_1	$= (V^+ - V_{BE7} - V^-) / (R_1)$		[1]
		$= (10-0.7-(-10)) / (19.3k)$	$= 1$ mA	[1]
	I_Q	$\approx I_1$ [Since β=200 >> 1]	$= 1$ mA	[2]
	I_{C2}	$= I_Q / 2$	$= 0.5$ mA	[2]
	v_{O2}	$= V^+ - I_{C2} R_C = 10 - (0.5m)(10k) = 5$ V		[2]
	I_{R4}	$= (v_{O2} - 2\ V_{BE}(on)) / (R_4)$		
		$= (5 - 1.4) / (11.5k)$	$= 0.313$ mA	[0.5]
	I_{R5}	$\approx I_{R4}$ (neglecting base currents) $= 0.313$ mA		[0.5]
	v_{O3}	$= V^+ - I_{R5} R_5 = 10 - (0.313m)(5k) = 8.44$ V		[1]

Q3(b)	Using	$I_{C2} = 0.5$ mA, $I_{R4} = 0.313$ mA:	
	A_{d1}	$= (g_{m2} / 2)(R_C \parallel R_{i2})$	
	g_{m2}	$= I_{C2} / V_T = (0.5mA)/(26mV) = 19.23$ mA/V	[1]
	$r_{\pi4}$	$= \beta V_T / I_{R4} = (200x26m)/(0.313m) = 16.613$ kΩ	[1]
	$r_{\pi3}$	$\approx \beta\ r_{\pi4} = 200x16.613k = 3322.6$ kΩ	[1]
	R_{i2}	$= r_{\pi3} + (1 + \beta)\ r_{\pi4}$	[1]
		$= 3322.6k + (201)(16.613k) = 6661.8$ kΩ	[1]
	A_{d1}	$= (19.23m/2)(10k \parallel 6661.8k) = 96$	[1]
	A_{v2}	$\approx (I_{R4} / 2V_T)\ R_5 = (0.313m/(2x26m))(5k) = 30$	[1]
	A_3	≈ 1 (Output stage assume gain = 1)	[1]
	A_d	$= A_{d1}\ A_{v2}\ A_3$	[1]
		$= 96 \text{ x } 30 \text{ x } 1 = 2880$	[1]

Question 4 [20 marks]

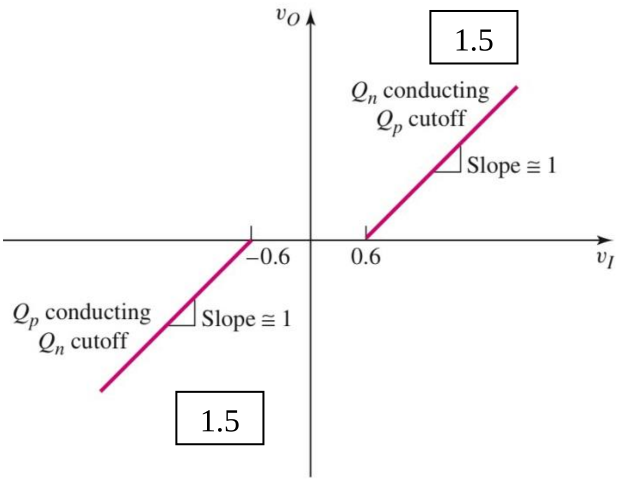
Answers:

Q4a(i)

Figure 4(a) - Approximate class-B output stage [1]

Figure 4(b) - Class-AB output stage [1]

Q4a(ii)



Q4a(iii)

$$i_{Cn} = i_{Cp} = I_S e^{\frac{V_{BB}}{2V_T}}$$ [0.5]

$$i_{Cn} = (4x10^{-13})(e^{\left[\frac{1.2}{(2)(0.026)}\right]}) = 4.210mA$$ [1]

$$P_{Qn} = P_{Qp} = v_{CE} i_C$$ [0.5]

$$v_{CE} = 12V$$

$$P_Q = (12)(4.210m) = 50.52mW$$ [1]

$$v_{O(\max)} = 12V$$ [1]

$$P_{L(\max)} = \frac{1}{2}\frac{V_p^2}{R_L} = (0.5)\left(\frac{12^2}{100}\right) = 0.72W$$ [1]

Question 4(b) [10 marks]

To calculate I_{C16}, need to determine I_{C13B}

I_{C13B} = 0.75 I_{C12} = (0.75)(0.3m) = 0.225 mA **[1 mark]**
I_{C17} = I_{C13B} = 0.225 mA **[1 mark]**

$I_{C16} \cong I_{E16} = I_{B17} + IR_9 = I_{C17} / \beta + ([I_{C17}R_8 + V_{BE17}] / R_9)$ **[1 mark]**
I_{C16} = (0.225m/200) + ([0.225mx100 + 0.7] /50k)
I_{C16} = 1.125µ + 14.45µ = 15.575 µA **[1 mark]**

Rb16 = rpi16 + (1+B)[R9 || Rb17] **[1 mark]**

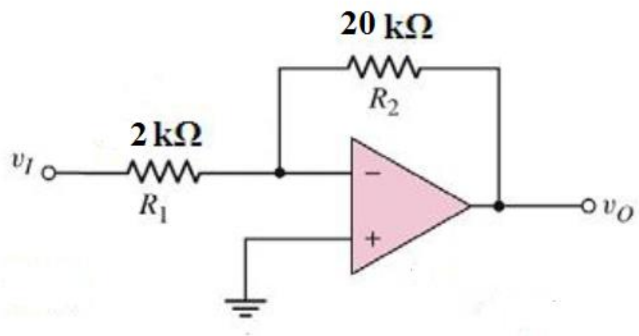
Rb17 = rpi17 + (1+B)R8 **[1 mark]**

Rpi17 = B.VT/IC17 = (200)(26m)/0.225m = 23.11 kOhm **[1 mark]**
Rpi16 = B.VT/IC16 = (200)(26m)/ 15.575u = 333.868 kOhm **[1 mark]**

So Rb17 = 23.11k + (201)100 = 43.21kOhm **[1 mark]**
50k || 43.21k = 23.17k
So Rb16 = 333.868 + (201)(50k || 43.21k] = 4.993 MOhm **[1 mark]**

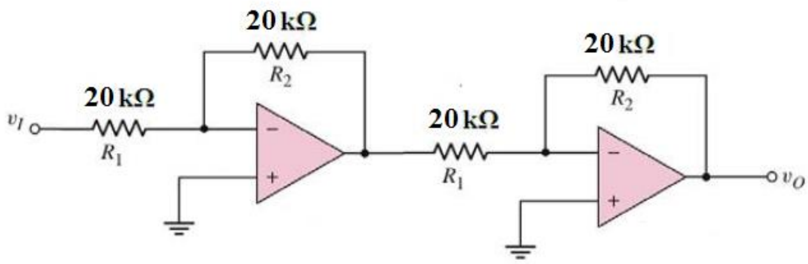
Question 5 [20 marks]

Question 5(a) [8 marks]



(i) Av = -R2/R1 = -10
R1 = R2/15 = 20k/10 = 2kOhm [1.5 marks]

Correct inverting configuration structure [1.5 marks]



(ii) Av = -R2/R1 = -1
R1 = R2/1 = 20k/1 = 20kOhm [2 marks]

Correct inverting configuration structure [2 marks]
Cascade inverting for 1st stage and 2nd stage [1 mark]

Question 5(b) [12 marks]

R2/R1 = 80k/20k = 4 **[1 mark]**
R4/R3 =85k/20k = 4.25 **[1 mark]**

Vo = [1+4][4.25/1+4.25]v_{I2} – 4v_{I1} = 4.048v_{I2} – 4v_{I1} **[2 marks]**
= 4.048(vcm-vd/2) – 4(vcm+vd/2)
=0.048vcm - 4.024vd **[2 marks]**

Hence, Ad = 4.024 **[2 marks]**
Acm = 0.048 **[2 marks]**

And CMRR = 20. Log(4.024/0.048) = 38.47 dB **[2 marks]**