UNIVERSITI TENAGA NASIONAL

The Energy University

COLLEGE OF ENGINEERING
PUTRAJAYA CAMPUS
FINAL EXAMINATION

SEMESTER 1 2019 / 2020

MODEL ANSWERS

PROGRAMME	: **Bachelor of Electrical & Electronics Engineering (Honours)** **Bachelor of Electrical Power Engineering (Honours)**
SUBJECT CODE	: **EEEB273/EEEB2014**
SUBJECT	: **ELECTRONIC ANALYSIS AND DESIGN II**
DATE	: **September 2019**
DURATION	: **3 hours**

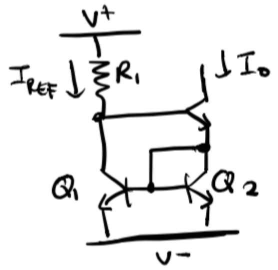
<u>INSTRUCTIONS TO CANDIDATES:</u>

1. This paper contains **FIVE** (5) questions in **EIGHT** (8) 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 EIGHT* (8) *PRINTED PAGES INCLUDING THIS COVER PAGE.

Question 1 [20 marks]

a)



Close Wilson CM – 2m.
Q_2 diode connected – 1m.
Power supply labelled – 1m.
I & Q labelled – 1m.

b) $I_{REF} = I_{C1} + I_{B3}$. – 1m

$I_{E3} = I_{C2} + 2I_{B2} = I_{C2}\left(1 + \frac{2}{\beta}\right)$ – 1m

$I_{C2} = \frac{I_{E3}}{(1+2/\beta)} = \frac{(1+\beta)}{\beta(1+2/\beta)} I_{C3} = \left(\frac{1+\beta}{2+\beta}\right) I_{C3}$ – 1m.

$I_{REF} = \left(\frac{1+\beta}{2+\beta}\right) I_{C3} + \frac{I_{C3}}{\beta}$ – 1m

$I_O = I_{C3} = \frac{I_{REF}}{1 + \frac{2}{\beta(2+\beta)}}$ – 1m.

c) $\Rightarrow I_{REF} = I_O \times \left(1 + \frac{2}{\beta(2+\beta)}\right) = 0.25m\,(1.0005)$

$= 0.25m.$ – 1m.

$\Rightarrow V^+ = I_{REF} \cdot R_1 + V_{CE1} + V^-$ – 1m.

$\Rightarrow V_{CE1} = 2V_{BE}$ – 1m.

$\Rightarrow R_1 = \frac{V^+ - (2V_{BE} + V^-)}{I_{REF}}$

$= 34.4\ k\Omega$ # – 2m.

d) $\Rightarrow \frac{dI_O}{dV_O} = \frac{1}{R_O}$

$dI_O = \frac{1}{R_O} \cdot dV_O$. – 1m

$\Rightarrow r_{o3} = \frac{V_A}{I_O} = \frac{100}{0.25m} = 400\ k\Omega$. – 1m

$\Rightarrow R_O = \frac{\beta}{2} r_{o3} = 12\ M\Omega$ – 1m

$\Rightarrow dV_O = 5 - 1 = 4V$. – 1m

$\Rightarrow dI_O = \frac{1}{12M} \times (4) = 333\ nA$ # – 1m.

Question 2 [20 marks]

Q2(a) 5 marks

$I_{D1} = I_{D2} = 150\mu A \quad V_{O2} = 3.5V$

$R_D = \frac{V^+ - V_{O2}}{I_{D1}}$ — 1m

$= 10 k\Omega$ # — 1 m.

$A_V = \frac{g_m R_D}{2} = \left[\frac{2\sqrt{K_{n1}(I_{D2})}}{2}\right] R_D$ — 1m

$= \left[\sqrt{100\mu \times 150\mu}\right](10k)$

$= 1.22 \ V/V$ — 1m.

gm = 0.245mA/v **[1 mark]**

Q2(b) 15 marks

Power dissipation = 1mW = (V^+ - V-) (IQ) [1]

1m = (20) IQ

So IQ = 0.05mA = 50 uA [1]

Currents in diff pair ID1 = ID2 to ID6 = ½ IQ = 25 uA [1]

For Vo to be 80% of power supply voltage, Vo = 0.8(10) = 8 V [1]

-8V ≤ Vo ≤ 8V

Vo(max) = 8 V = V+ - VSD6(sat) - VSD4(sat) [1]

Let all PMOS transistors in active load to be matched,

so VSD6(sat)=VSD4(sat) [1]

Vo(max) = 8V = 10 - 2.VSD6(sat) [1]

VSD6(sat) = VSD4(sat) = 1 V [1]

VSD6(sat) = VSG6 + VTP

1 = VSG6 – 0.5

VSG6 = 1.5 V = VSG4 [1]

ID4 = ½ kp' $(W/L)_4$ $(VSG4+VTP)^2$ [0.5]

25u = ½ (25u) $(W/L)_4$ $(1.5-0.5)^2$

$(W/L)_4 = 2 = (W/L)_3 = (W/L)_5 = (W/L)_6$ [1]

Vo(min) = -8 V = VDS1(sat) + VIQ(min) + V- [1]

Assume for cascode,

VIQ(min) = 2 VDS(sat) = 2 VDS1(sat) [1]

Vo(min) = -8 V = -10 + 3.VDS1(sat) [1]

VDS1(sat) = 0.67 V [0.5]

Thus,

ID1 = ½ kn' $(W/L)_1$ $(VGS1-VTN)^2$ [0.5]

25u = ½ (80u) $(W/L)_1$ $(0.67)^2$

$(W/L)_1 = 1.39 = (W/L)_2$ [0.5]

Question 3 [15 marks]

Q3(a) [5 marks]

Q3, Q4, R4, and R5 in Gain Stage make Darlington Pair amplifier **[2]**

Q5, Q9, and R6 in Output Stage make voltage level translator **[1]**

Q6 and R7 in Output Stage make Common Collector or Emitter Follower **[2]**

Q3(b) [10 marks]

$I_Q = 1.4$ mA

$I_{C2} = I_Q / 2 = 0.7$ mA **[0.5]**

$v_{O2} = V^+ - I_{C2} R_C = 14 - (0.7m)(10k) = 7$ V **[0.5]**

$I_{R4} = (v_{O2} - 2 V_{BE}(on)) / (R_4)$

$= (7 - 1.4) / (11.5k) = 0.487$ mA **[0.5]**

Using $I_{C2} = 0.7$ mA, $I_{R4} = 0.487$ mA:

$A_{d1} = (g_{m2} / 2)(R_C \parallel R_{i2})$

$g_{m2} = I_{C2} / V_T = (0.7mA)/(26mV) = 26.923$ mA/V **[1]**

$r_{\pi 4} = \beta V_T / I_{R4} = (200x26m)/(0.487m) = 10.678$ kΩ **[1]**

$r_{\pi 3} \approx \beta\, r_{\pi 4} = 200x10.678k = 2135.6$ kΩ **[1]**

$R_{i2} = r_{\pi 3} + (1 + \beta)\, r_{\pi 4}$ **[1]**

$= 2135.6k + (201)(10.678k) = 4281.88$ kΩ **[0.5]**

$A_{d1} = (26.923m/2)(10k \parallel 4281.88k) = 134.3$ **[0.5]**

$A_{v2} \approx (I_{R4} / 2V_T)\, R_5 = (0.487m/(2x26m))(5k) = 46.83$ **[1]**

$A_3 \approx 1$ (Output Stage: assume gain = 1) **[1]**

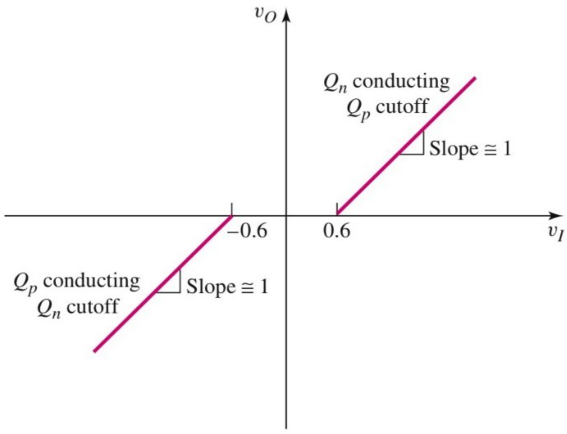
$A_d = A_{d1}\, A_{v2}\, A_3$ **[1]**

$= 134.3 \times 46.83 \times 1 = 6289.27$ V/V **[0.5]**

Question 4 [25 marks]

Q4a [5 marks]

Dead band zone:	Both transistors OFF -0.6<VI<0.6V	[1]
Positive signal:	correct linear relationship [1], correct transistor ON/OFF	[1]
Negative signal:	correct linear relationship [1], correct transistor ON/OFF	[1]



Q4b [10 marks]

i) Quiescent condition

VBB	= VBEn + VEBp	= 1.4 V	[1]
ICQ	= icn=icp=IS. exp((VBB/2)/VT))		[1]
	= (5×10^{-15}) exp((1.4/2)/26m))	= 2.463 mA	[2]

ii) Vo = -3V

IL	=Vo/RL = -3/100	= -30 mA	[1]

Icp approx. equal to IL,

i.e. Icp	= | IL |	= 30 mA	[1]
VEBp	= (VT) ln(icp/Is)		
	= (26m) ln(30m/(5×10^{-15}))	= 0.7649 V	[1]
VBEn	= VBB – VEBp = 1.4 – 0.7649	= 0.6350 V	[1]
Icn	= IS. exp((VBEn)/VT))		
	= (5×10^{-15}) exp(0.6350V/26m)	= 0.2023 mA	[1]

Recalculate icp

Icp	= icn – IL		
	= 0.2023 mA – (-30mA)	= 30.202 mA	[1]

Q4c [10 marks]

	$Iset/IQ = (W/L)_5/(W/L)_6 = (W/L)_5/4(W/L)_5$	= ¼	[1]
So	Iset = IQ/4 = 2m/4	= 0.5 mA	[1]
	VIQ(min) = VSD6(sat)	= 1 V	[1]
	VSD6(sat) = VSG6 + VTP ➔ 1 = VSG6 – 0.8		
So	VSG6 = 1.8V = VSG5	= 1.8 V	[1]
From KVL,			
	Rset = (V+ - VSG5 – V-) / Iset		
	= (20 – 1.8) / 0.5m	= 36.4 kΩ	[1]
	$Iset = ID5 = ½ kp' (W/L)_5 (VSG5 + VTP)^2$		[1]
	$0.5m = ½ (20u) (W/L)_5 (1.8 – 0.8)^2 = ID5$		
	$(W/L)_5 = 50$		[0.5]
	$(W/L)_6 = 4(W/L)_5 = 4x50$	= 200	[0.5]
	VCM(max) = V+ - VSD6(sat) – VSG1		[1]
	$ID1 = ½ IQ = ½ kp' (W/L)_1 (VSG1 + VTP)^2$		
	$1m = ½ (20u) (20) (VSG1 – 0.8)^2$		
	VSG1 = 3.0307V	= 3.0307 V	[1]
	VCM(max) = 10 -1 – 3.0307	= 5.9693 V	[1]

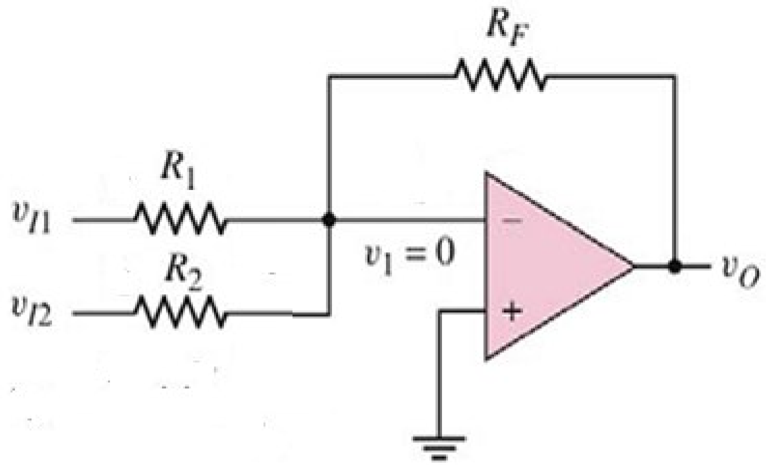
Question 5 [20 marks]

Q5(a) [6 marks]

Q5(a)(i) [3 marks]

Inverting amplifier **[1]**

$V_O = -(R_2 / R_1) V_I$ **[1]**



[1]

Q5(a)(ii) [3 marks]

Non-Inverting amplifier **[1]**

$V_O = (1 + R_2 / R_1) V_I$ **[1]**

$V_O = (1 + 25k/25k)(1.5V) = 3V$ **[1]**

Q5(b) [6 marks]

***One method: Use current analysis at non-inverting input to get V_2**

$$\frac{V_{I1}-V_2}{40k}+\frac{V_{I2}-V_2}{20k}=\frac{V_2-0}{10k} \quad [1]$$

$$\frac{V_{I1}}{40k}+\frac{V_{I2}}{20k}=\frac{V_2}{10k}+\frac{V_2}{40k}+\frac{V_2}{20k} \quad [1]$$

$$V_{I1}+2V_{I2}=7V_2 \rightarrow V_2=\frac{V_{I1}}{7}+\frac{2V_{I2}}{7} \quad [1]$$

***May use other method (e.g. superposition) to get $V_2=\frac{V_{I1}}{7}+\frac{2V_{I2}}{7}$**

[Total marks = 3]

$$V_O=\left(1+\frac{100k}{50k}\right)V_1=3\,V_1=3\,V_2 \quad \text{Virtual short!} \quad [1]$$

$$V_O=3\left(\frac{V_{I1}}{7}+\frac{2V_{I2}}{7}\right)=\frac{3}{7}V_{I1}+\frac{6}{7}V_{I2} \quad [1]$$

$$V_O=\frac{3}{7}(0.2)+\frac{6}{7}(0.3)=0.3429\,V \quad [1]$$

Q5(c) [8 marks]

$$i_1=\frac{v_{I1}-v_{I2}}{R_1} \quad [1]$$

$$i_1=\frac{[-0.65+0.05\sin\omega t\ (\mathrm{V})]-[-0.60-0.05\sin\omega t\ (\mathrm{V})]}{10k} \quad [0.5]$$

$$\rightarrow i_1=-5+10\sin\omega t\ (\mu\mathrm{A}) \quad [0.5]$$

$$v_{O1}=v_{I1}+i_1R_2 \quad [1]$$

$$v_{O1}=[-0.65+0.05\sin\omega t\ (\mathrm{V})]+[-5+10\sin\omega t\ (\mu\mathrm{A})](40k) \quad [0.5]$$

$$\rightarrow v_{O1}=-0.85+0.45\sin\omega t\ (\mathrm{V}) \quad [0.5]$$

$$v_{O2}=v_{I2}-i_1R_2 \quad [1]$$

$$v_{O2}=[-0.60-0.05\sin\omega t\ (\mathrm{V})]+[-5+10\sin\omega t\ (\mu\mathrm{A})](40k) \quad [0.5]$$

$$\rightarrow v_{O2}=-0.40-0.45\sin\omega t\ (\mathrm{V}) \quad [0.5]$$

$$v_O=\frac{R_4}{R_3}(v_{O2}-v_{O1}) \quad [1]$$

$$v_O=\frac{120k}{40k}([-0.40-0.45\sin\omega t\ (\mathrm{V})]-[-0.85+0.45\sin\omega t\ (\mathrm{V})]) \quad [0.5]$$

$$\rightarrow v_O=1.35-2.7\sin\omega t\ (\mathrm{V}) \quad [0.5]$$