UNIVERSITI TENAGA NASIONAL

COLLEGE OF ENGINEERING
PUTRAJAYA CAMPUS
FINAL EXAMINATION

SEMESTER 1 2013 / 2014 – MODEL ANSWER

PROGRAMME	: **Bachelor of Electrical & Electronics Engineering (Honours)** **Bachelor of Electrical Power Engineering (Honours)**
SUBJECT CODE	: **EEEB273**
SUBJECT	: **ELECTRONIC ANALYSIS AND DESIGN II**
DATE	: **September 2013**
TIME	: **3 hours**

INSTRUCTIONS TO CANDIDATES:

1. This paper contains **Six** (6) questions in **Ten** (10) pages.
2. Answer **ALL** questions.
3. Write **all** answers in the answer booklet provided.
4. Write answer to different question on **a new page**.
5. For all calculations, assume that V_T **= 26 mV**.
6. Use at least **4 significant numbers** in all calculations.

THIS QUESTION PAPER CONSISTS OF TEN* (10) *PRINTED PAGES INCLUDING THIS COVER PAGE.

Answer for Q1: [20 marks]

$$A_d = \frac{g_m R_C}{2}$$ **[1]**

$$g_m = \frac{I_C}{V_T} = \frac{I_Q}{2V_T} = \frac{1.5\text{m}}{2(26\text{m})} = 28.846\text{ mA/V}$$ **[1, 1, 0.5]**

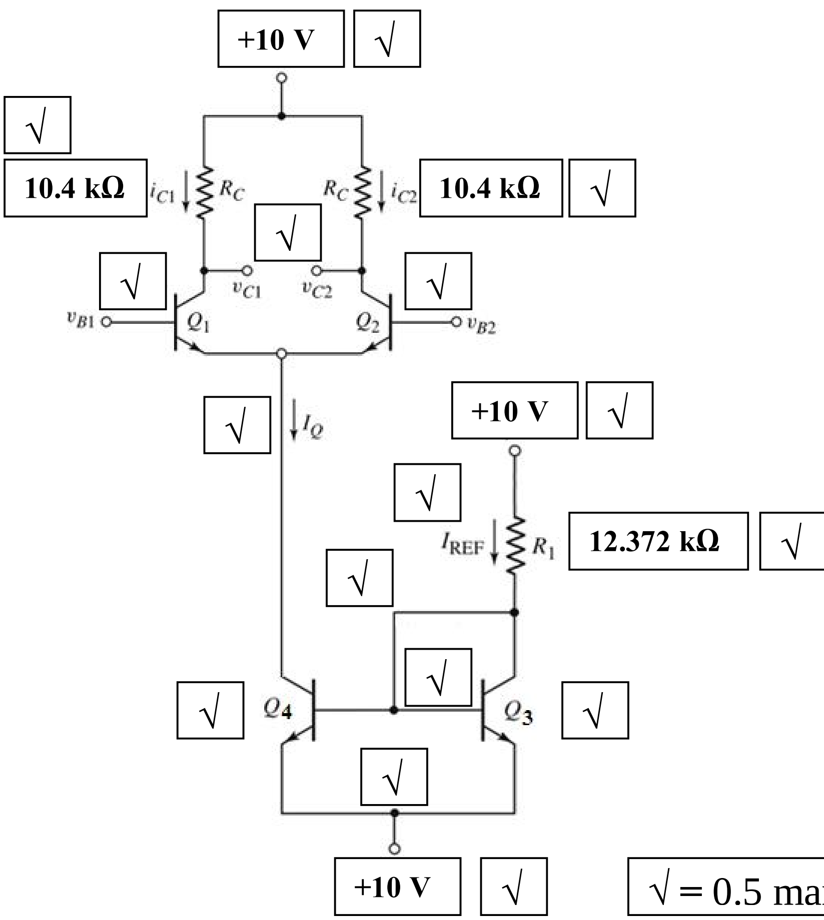
$$R_C = \frac{2A_d}{g_m} = \frac{2(150)}{28.846\text{m}} = 10.400\text{ k}\Omega$$ **[1, 1, 0.5]**

$$I_Q = \frac{I_{REF}}{1 + 2/\beta}$$ **[1]**

$$I_{REF} = I_Q(1 + 2/\beta) = 1.5\text{m}(1 + 2/50) = 1.56\text{ mA}$$ **[1, 1, 0.5]**

$$R_1 = \frac{V^+ - V_{BE}(on) - V^-}{I_{REF}} = \frac{10 - 0.7 - (-10)}{1.56\text{m}} = 12.372\text{ k}\Omega$$ **[1, 1, 0.5]**

Total = 12 marks



√ = 0.5 marks

Total = 8 marks

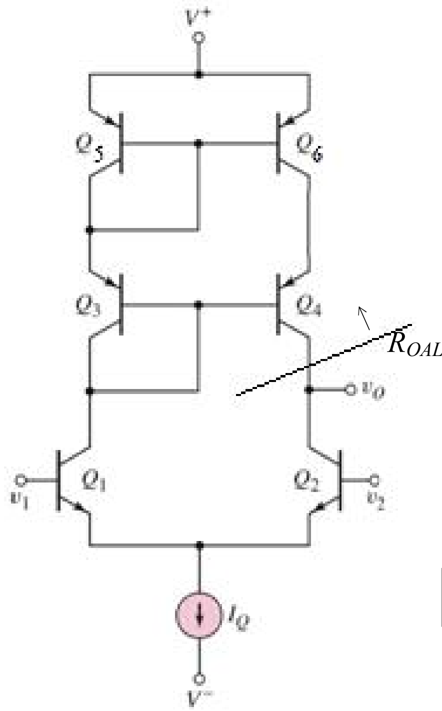
Answer for Q2: [15 marks]

Q2(a) [5 marks]

$$I_O = \frac{I_{CQ}}{2} = 0.09mA$$ 0.5, 0.5

$$r_{O4} = \frac{V_{AP}}{I_O} = \frac{100}{0.09m} = 1.111M\Omega$$ 0.5, 0.5

$$R_{OAL} = \beta r_{O4} = (150)(1.111M) = 166.7M\Omega$$ 0.5, 0.5



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Q2(b) [6 marks]

$$v_O = (g_{m2}v_d)R_O$$ 1

$$R_O = R_{OAL} \| r_{O2}$$ 1

$$r_{O2} = \frac{V_{AN}}{I_O} = \frac{120}{0.09m} = 1.333M\Omega$$ 0.5, 0.5

$$R_O = 166.7M \| 1.333M = 1.322M\Omega$$ 0.5, 0.5

$$g_{m2} = \frac{I_O}{V_T} = \frac{0.09m}{0.026} = 3.462mA/V^2$$ 0.5, 0.5

$$A_d = g_{m2}R_O = (3.462m)(1.322M) = 4578$$ 0.5, 0.5

Q2(c) [4 marks]

$$v_O = A_d v_d = (4578)(5\sin\omega t)mV = 22.89\sin(\omega t)V$$ 1, 0.5, 0.5

The total output resistance of the differential amplifier will be smaller resulting in smaller value for the small-signal voltage gain, A_d. The output voltage will be a lot smaller than 22.89 V.

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<u>Answer for Q3: [10 marks]</u>

Q3(a) [3 marks]

- Class AB has less power dissipation than Class A (or Class AB has more power conversion efficiency than Class A) [1 mark]
    - since the output stage transistors are not continuously on. [0.5 mark]
- Class AB has removed the cross-over distortion of Class B [1 mark]
    - by providing a constant bias voltage VBB across the output stage transistors. [0.5 mark]

Q3(b) [7 marks]

(i)

$v_O(\text{max}) = V^+ - V_{CE}(\text{sat}) = 10$ ï $0.2 = 9.8$ V

[1] [1/2]

$I_Q = i_L(\text{max}) = v_O(\text{max}) / R_L = 9.8 / 1\text{k} = 9.8$ mA

[1] [1/2]

(ii)

$R = (0 - V_{BE}$ ï $(-10)) / I_Q = 9.3 / 9.8\text{m} = 949$ q

[1] [1]

(iii)

$$\overline{P_L} = \frac{1}{2}\left(i_L(\max)\right)^2 R_L = \frac{1}{2}(9.8)^2(1) \Rightarrow \overline{P_L} = 48.02 \text{ mW}$$ [1/2]

$$\overline{P_S} = I_Q\left(V^+ - V^-\right) + I_Q\left(0 - V^-\right)$$ [1/2]

$$= 9.8(20) + 9.8(10) \Rightarrow \overline{P_S} = 294 \text{ mW}$$

$$\eta = \frac{\overline{P_L}}{\overline{P_S}} = \frac{48.02}{294} \Rightarrow \underline{\eta = 16.3\%}$$

[1/2] [1/2]

<u>Answer for Q4: [20 marks]</u>

<u>Calculating transistors aspect ratios:</u>

A_v(dB) = 100 dB

100 = 20 $\log_{10}(A_v)$ [2 marks]

So, A_v = 100,000 V/V [1 mark]

A_v = 100,000 = A_{d1} x A_{v2} [1 mark]

$A_{d1} = g_{m1}\ (r_{o2} \parallel r_{o4})$ [1 mark]

$A_{v2} = g_{m7}\ (r_{o7} \parallel r_{o8})$ [1 mark]

g_{m1} = 2 SQRT[$K_{p1}\ I_{D1}$] = 2 SQRT[(10u) $(W/L)_1$ (5m)]

g_{m1} = (0.4472m) SQRT[$(W/L)_1$] [1 mark]

$r_{o2} = 1/(\lambda_p\ I_{D2})$ = 1/(0.02x5m) = 10 kΩ [1 mark]

$r_{o4} = 1/(\lambda_n\ I_{D4})$ = 1/(0.01x5m) = 20 kΩ [1 mark]

$r_{o2} \parallel r_{o4}$ = 10k $\parallel$ 20k = 6.67 kΩ [1 mark]

g_{m7} = 2 SQRT[$K_{n7}\ I_{D7}$] = 2 SQRT[(20u) $(W/L)_7$ (10m)]

g_{m7} = (0.8944m) SQRT[$(W/L)_7$] [1 mark]

$r_{o8} = 1/(\lambda_p\ I_{D8})$ = 1/(0.02x10m) = 5 kΩ [1 mark]

$r_{o7} = 1/(\lambda_n\ I_{D7})$ = 1/(0.01x10m) = 10 kΩ [1 mark]

$r_{o7} \parallel r_{o8}$ = 5k $\parallel$ 10k = 3.33 kΩ [1 mark]

So, A_v = 100,000 = A_{d1} x A_{v2}

= $\{g_{m1}\ (r_{o2} \parallel r_{o4})\}.\{g_{m7}\ (r_{o7} \parallel r_{o8})\}$

= {(0.4472m) SQRT[$(W/L)_1$].(6.67kΩ)}.{(0.8944m) SQRT[$(W/L)_7$].(3.33 kΩ)}

= 8.88 SQRT[$(W/L)_1$] SQRT[$(W/L)_7$]

Since all transistor sizes are the same, $(W/L)_1 = (W/L)_7$

A_v = 100,000 = 8.88 $(W/L)_1$

Thus, $(W/L)_1$ = 11,256 = $(W/L)_{2,3,4,7}$ [2 marks]

<u>Calculating resistor Rset</u>

$R_{set} = (V^+ - V_{SG5} - V^-)/\ I_{set}$ [2 marks]

$V_{SG5} = V_{SD5} + V_{TP}$ = 1.5 + 2 = 3.5 V [1 mark]

So, R_{set} = (5 – 3.5 – (-5))/10m = 650 Ω [1 mark]

Answer for Q5: [15 marks]

Q5(a) [5 marks]

$$V_{BE10} = V_T \ln\left(\frac{I_{C9}}{I_S}\right) = (0.026)\ln\left(\frac{10x10^{-6}}{5x10^{-16}}\right) = 0.6167V$$ 1, 1, 0.5

$$R_4 = \frac{V_{BE11} - V_{BE10}}{I_{C9}} = \frac{0.65 - 0.6167}{10\mu} = 3.33k\Omega$$ 1, 1, 0.5

Q5(b) [10 marks]

$$A_{d1} = \frac{v_{o1}}{v_d} = -g_m\left(r_{o4} \| R_{act1} \| R_{i2}\right)$$ 1

$$\Rightarrow A_{d1} = -\left(\frac{I_{CQ}}{V_T}\right)\left(r_{o4} \| R_{act1} \| R_{i2}\right)$$ 0.5

$$r_{o4} = \frac{V_{AP}}{I_{C4}} = \frac{50}{5\mu} = 10M\Omega$$ 0.5, 0.5

$$R_{act1} = r_{o6} = \frac{V_{AN}}{I_{C6}} = \frac{50}{5\mu} = 10M\Omega$$ 0.5, 0.5, 0.5

Where $I_{C6} = I_{C9}/2 = 5\text{uA}$ 0.5

$$R_{i2} = r_{\pi16} + (1 + \beta_n)(r_{\pi17} \| R_9)$$ 1

Where $r_{\pi16} = \beta_n V_T / I_{C16} = (200)(0.026)/13.2\text{u} = 394\text{k}\Omega$ 0.5, 0.5

And $r_{\pi17} = \beta_n V_T / I_{C17} = (200)(0.026)/0.165\text{m} = 31.52\text{k}\Omega$ 0.5, 0.5

$$R_{i2} = 394k + (201)(31.52k \| 50k) = 394k + 3886k = 4280k\Omega$$ 0.5

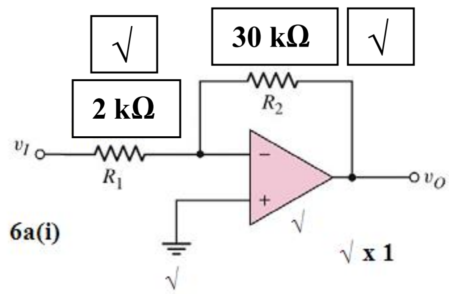
$$A_{d1} = -\left(\frac{5\mu}{0.026}\right)\left(10M \| 10M \| 4280k\right) = -(0.1923m)(2306k) = -443.4$$ 0.5, 0.5

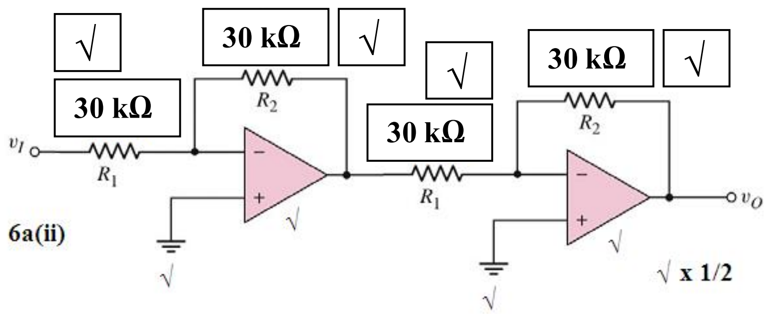
Overall amplifier gain is A_{d1} x A_{v2} x A_{v3} where A_{v3} is unity.

A_v = - (-443.4) (100) (1) = 44,340 0.5, 0.5

Answer for Q6: [20 marks]

Q6(a) [8 marks]





Q6(b) [4 marks]

$$v_O = \left(1 + \frac{R_2}{R_1}\right) v_I$$ 1

$$A_v = 20 = \frac{v_O}{v_I} = \left(1 + \frac{R_2}{R_1}\right)$$ 1

$$\frac{R_2}{R_1} = 19 \Rightarrow R_2 = 19R_1 \Rightarrow R_2 > R_1$$ 0.5

Select $R_1 = 15\ \text{k}\Omega$, then $R_2 = 285\ \text{k}\Omega$ 1, 0.5

Q6(c) [8 marks]

R_1 = 15 kΩ, R_2 = 90 kΩ, R_3 = 15 kΩ, and **R_4 = 120 kΩ**

$$v_O = \left(1 + \frac{R_2}{R_1}\right)\left(\frac{R_4 / R_3}{1 + R_4 / R_3}\right)v_{I2} - \left(\frac{R_2}{R_1}\right)v_{I1}$$

$$v_O = \left(1+\frac{90\text{k}}{15\text{k}}\right)\left(\frac{120\text{k}/15\text{k}}{1+120\text{k}/15\text{k}}\right)v_{I2} - \left(\frac{90\text{k}}{15\text{k}}\right)v_{I1}$$ [1]

$$v_O = (1+6)\left(\frac{8}{1+8}\right)v_{I2} - 6v_{I1}$$ [1]

$$v_O = 6.222v_{I2} - 6v_{I1} = 6.222(v_{cm} + \frac{v_d}{2}) - 6(v_{cm} - \frac{v_d}{2})$$ [1]

$$v_O = 6.111v_d + 0.222v_{cm}$$ [1]

A_d = 6.111, A_{cm} = 0.222 [1, 1]

***CMRR* = 20 log$_{10}$[6.111/0.222] = 28.795 dB** [1, 1]