Name:

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Section: **01/02/03 A/B**

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UNIVERSITI TENAGA NASIONAL

College of Engineering

Department of Electronics and Communication Engineering

Test 2

SEMESTER 2, ACADEMIC YEAR 2013/2014

Subject Code	:	**EEEB273**
Course Title	:	**Electronics Analysis & Design II**
Date	:	**19 December 2013**
Time Allowed	:	**1 hour 15 minutes**

Instructions to the candidates:

1. Write your Name and Student ID number. Circle your section number.
2. **Write all your answers using pen**. **DO NOT USE PENCIL** except for the diagram.
3. **ANSWER ALL QUESTIONS.**
4. **WRITE YOUR ANSWER ON THIS QUESTION PAPER.**
5. For BJT, use V_T = **26 mV** where appropriate.
6. Use at least **4 significant numbers** in all calculations.

NOTE: DO NOT OPEN THE QUESTION PAPER UNTIL INSTRUCTED TO DO SO.

☺ **GOOD LUCK!** ☺

Question No.	1	2	Total
Marks			

<u>Question 1</u> **[50 marks]**

A **MOSFET** differential amplifier in **Figure 1(a)** is to be redesigned to use a **P-MOSFET cascode** current source, as shown in **Figure 1(b), as an active load** to replace the drain resistances (R_D). The supply voltages for the overall circuit are $V^+ = 10$ **V** and $V^- = -10$ **V**. Bias current for the differential amplifier is $I_Q = 0.3$ **mA**. The transistor parameters for the MOSFET differential amplifier pair are $k'_n = 80\ \mu A/V^2$, $\lambda_n = 0.015\ V^{-1}$ and $V_{TN} = 1$ **V**. For all **P-MOSFET** transistors in the active load, i.e. M_{11} to M_{14}, assume $K_p = 0.1\ mA/V^2$, $\lambda_p = 0.02\ V^{-1}$ and $V_{TP} = -1$ **V.**

(i) **Design** the differential amplifier to achieve a differential-mode voltage gain of $A_d = 400$, where its output v_O is a **one-sided output**. **Show clearly all your calculations**. **State clearly** all your assumptions, **if any**. Hints: You need to calculate the value of R_O also.

[40 marks]

(ii) **Calculate** output v_O if $v_1 = +0.51$ **mV** and $v_2 = -0.23$ **mV.**

[10 marks]

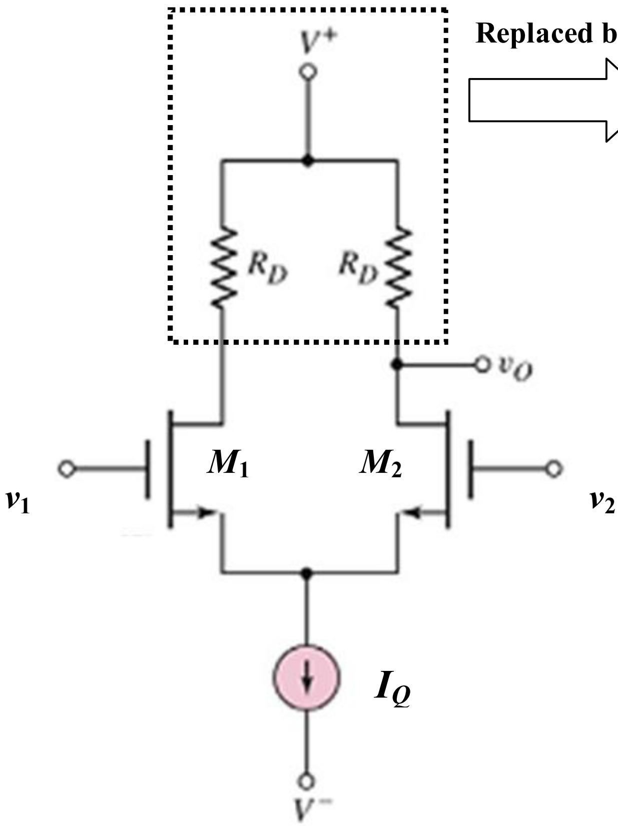

Figure 1(a)

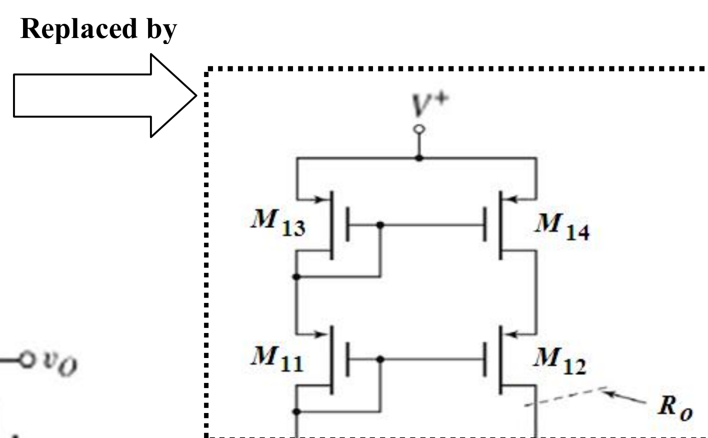

Figure 1(b)

Answers for Question 1

$$(i) A_d = g_{m2}(r_{o2} \| R_O)$$ 3

$$r_{o2} = \frac{1}{\lambda_n \frac{I_Q}{2}} = \frac{1}{0.015(0.15m)} = 444.4k\Omega$$ 3

$$R_O = g_{m12} r_{o12} r_{o14}$$ 3

$$g_{m12} = 2\sqrt{K_{p12} I_{D12}} = 2\sqrt{(0.1m)\frac{0.3m}{2}} = 0.2449 mA/V$$ 3

$$r_{o12} = r_{o14} = \frac{1}{\lambda_p \frac{I_Q}{2}} = \frac{1}{(0.02)\frac{0.3m}{2}} = 333.33k\Omega$$ 4

$$R_O = (0.2449m)(333.33k)(333.33k) = 27.211M\Omega$$ 3

$$Solution1: R_O >> r_{o2} \Rightarrow r_{o2} \| R_O \cong r_{o2}$$ 3

$$A_d = g_{m2}(r_{o2} \| R_O) \cong g_{m2} r_{o2}$$ 3

$$g_{m2} = A_d / r_{o2} = 400 / 444.4k = 0.9 mA/V$$ 3

$$g_{m2} = 2\sqrt{K_{n2} I_{D2}} = 2\sqrt{\frac{k_n'}{2}(W/L)_2 \frac{I_Q}{2}}$$ 3

$$0.9m = 2\sqrt{\frac{80\mu}{2}(W/L)_2 \frac{0.3m}{2}}$$ 3

$$(W/L)_2 = \frac{(0.9m)^2}{(80\mu)(0.3m)} = 33.75$$ 3

$$(W/L)_1 = (W/L)_2 = 33.75$$ 3

$$Solution2: r_{o2} \| R_O = 444.4k \| 27.211M = 437.26k$$ 3

$$A_d = g_{m2}(r_{o2} \| R_O)$$ 3

$$g_{m2} = A_d / (r_{o2} \| R_O) = 400 / 437.26k = 0.9147 mA/V$$ 3

$$g_{m2} = 2\sqrt{K_{n2} I_{D2}} = 2\sqrt{\frac{k_n'}{2}(W/L)_2 \frac{I_Q}{2}}$$ 3

$$0.9147m = 2\sqrt{\frac{80\mu}{2}(W/L)_2 \frac{0.3m}{2}}$$ 3

$$(W/L)_2 = \frac{(0.9147m)^2}{(80\mu)(0.3m)} = 34.86$$ 3

$$(W/L)_1 = (W/L)_2 = 34.86$$ 3

Answers for Question 1 (Cont.)

(ii)

$v_d = v_1 - v_2 = 0.51m - (-0.23m) = 0.74mV$ 3, 2

$A_d = v_O / v_d$

$v_O = A_d v_d = 400(0.74m) = 296mV$ 3, 2

Question 2 **[50 marks]**

(a) For the circuit shown in **Figure 2(a)**, the transistor parameters are $\boldsymbol{\beta} = \mathbf{100}$ and $\boldsymbol{V_A} = \infty$. The bias currents in the transistors are indicated on the figure. **Determine** the output resistance $\boldsymbol{R_O}$ of the output stage. Show clearly all your calculations.

[20 marks]

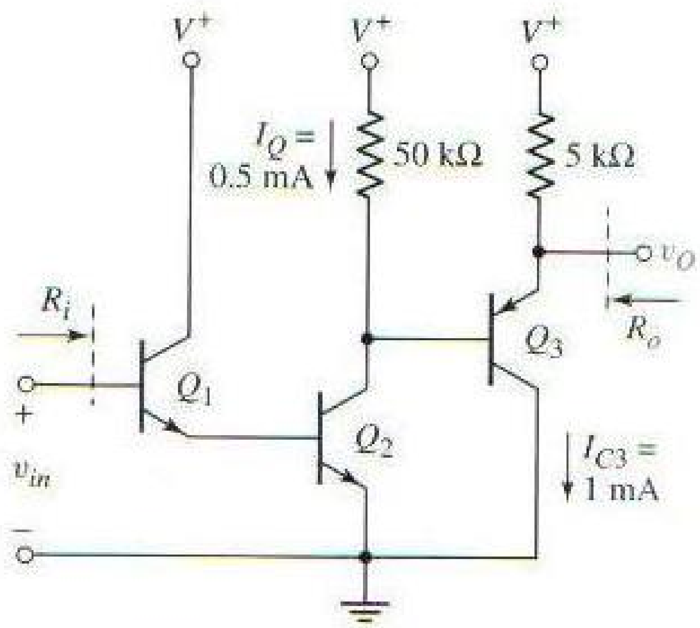

Figure 2(a)

Answers for Question 2(a)

$$R_O = 5k \left\| \frac{r_{\pi 3} + Z}{1+\beta} \right.$$ 3

$$Z = 50k \| R_{C2}$$ 3

$$R_{C2} = r_{o2} = V_{A2} / I_{C2} = \infty / (0.5m) = \infty$$ 5

$$Z = 50k \| \infty = 50k\Omega$$ 2

$$r_{\pi 3} = \beta V_T / I_{C3} = 100(.026)/(1m) = 2.6k\Omega$$ 4

$$R_O = 5k \left\| \frac{2.6k + 50k}{1+100} \right. = 0.472k\Omega$$ 3

(b) Study **Figure 2(b)** carefully. The transistor parameters are: $\beta = 180$, $V_{BE}(on) = 0.7$ V, and $V_{CE}(sat) = 0.4$ V. **Design** the output stage amplifier for maximum output swing and then calculate its **power conversion efficiency**, η. Show clearly all your calculations.

[30 marks]

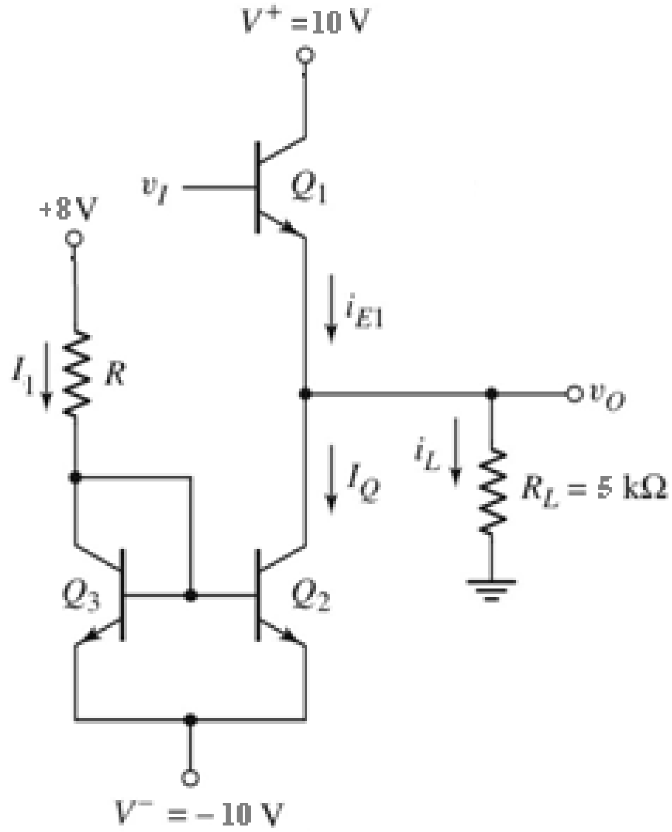

Figure 2(b)

Answers for Question 2(b)

Answers for Question 2(b) (Cont.)

$$v_O(\text{min}) = V^- + V_{CE}(\text{sat}) = -10 + 0.4 = -9.6\text{V}$$ 3

$$I_Q = |i_L(\text{min})| = \left|\frac{v_O(\text{min})}{R_L}\right| = \frac{9.6}{5\text{k}} = 1.92\text{mA}$$ 3

$$I_1 = I_Q = \frac{8 - V_{BE}(\text{on}) - V^-}{R}$$ 3

$$R = \frac{8 - 0.7 - (-10)}{1.92\text{m}} = 9.01\text{k}\Omega$$ 3

$$\eta = \frac{P_L}{P_S}$$ 3

$$\overline{P_L} = (1/2)(i_L(\text{max}))^2 R_L$$ 3

$$\overline{P_L} = (1/2)(1.92\text{m})^2(5\text{k}) = 9.216\text{mW}$$ 3

*Solution*1:

$$\overline{P_S} = I_Q(V^+ - V^-) + I_1(8 - V^-)$$ 3

$$\overline{P_S} = (1.92\text{m})(20) + (1.92\text{m})(18) = 72.96\text{mW}$$ 3

$$\eta = \frac{9.216\text{mW}}{72.96\text{mW}} = 0.1263@12.63\%$$ 3

*Solution*2:

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

$$\overline{P_S} = (1.92\text{m})(20) = 38.4\text{mW}$$ 3

$$\eta = \frac{9.216\text{mW}}{38.4\text{mW}} = 0.24@24\%$$ 3

Appendix: BASIC FORMULA

BJT

$$i_C = I_S e^{v_{BE}/V_T} \text{ ; npn}$$

$$i_C = I_S e^{v_{EB}/V_T} \text{ ; pnp}$$

$$i_C = \alpha i_E = \beta i_B$$

$$i_E = i_B + i_C$$

$$\alpha = \frac{\beta}{\beta + 1}$$

; Small signal

$$\beta = g_m r_\pi$$

$$r_\pi = \frac{\beta V_T}{I_{CQ}}$$

$$g_m = \frac{I_{CQ}}{V_T}$$

$$r_o = \frac{V_A}{I_{CQ}}$$

MOSFET

; N – MOSFET

$$v_{DS}(\text{sat}) = v_{GS} - V_{TN}$$

$$i_D = K_n[v_{GS} - V_{TN}]^2$$

$$K_n = \frac{k_n'}{2} \cdot \frac{W}{L}$$

; P – MOSFET

$$v_{SD}(\text{sat}) = v_{SG} + V_{TP}$$

$$i_D = K_p[v_{SG} + V_{TP}]^2$$

$$K_p = \frac{k_p'}{2} \cdot \frac{W}{L}$$

; Small signal

$$g_m = 2K_n\left(V_{GSQ} - V_{TN}\right) = 2\sqrt{K_n I_{DQ}}$$

$$r_o \cong \frac{1}{\lambda I_{DQ}}$$