Name:

Student ID Number:

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

Lecturer: **Dr Jamaludin /Dr Azni Wati /Dr Fazrena Azlee**

UNIVERSITI TENAGA NASIONAL

College of Engineering

Department of Electronics and Communication Engineering

Test 2 – MODEL ANSWER

SEMESTER 1, ACADEMIC YEAR 2013/2014

Subject Code	:	**EEEB273**
Course Title	:	**Electronics Analysis & Design II**
Date	:	**22 August 2013**
Time Allowed	:	**1½ hours**

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	3	Total
Marks				

FORMULA FOR TRANSISTORS

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

$$g_m = 2\sqrt{K_? I_{DQ}}$$

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

Question 1 **[40 marks]**

Figure 1 shows a **MOSFET** differential amplifier circuit biased with constant current source I_Q. It is given that $V^+ = 10$ V, $V^- = -10$ V, and $I_Q = 0.2$ mA.

Also, the **NMOS** transistor parameters are: $V_{TN} = 1$ V, $k'_n = 100$ μA/V^2 and $\lambda_n = 0.01$ V^{-1}, and the **PMOS** transistor parameters are: $V_{TP} = -1$ V, $k'_p = 80$ μA/V^2 and $\lambda_p = 0.015$ V^{-1}.

a) **State** the function of each transistor M_1 to M_6 in the **Figure 1**. [10 marks]

b) **Calculate** the differential gain of the circuit if given: $(W/L)_{1\text{-}2} = 5$, $(W/L)_{3\text{-}6} = 10$. [20 marks]

c) **Calculate** the *CMRR* **(dB)** if $A_{cm} = -0.003$. [10 marks]

Answers for Question 1

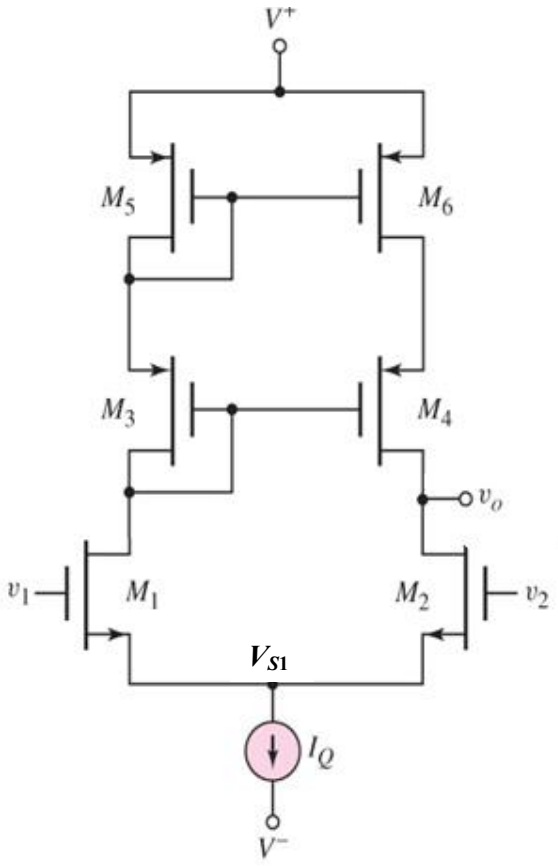

Figure 1

Answers for Question 1 (Cont.)

Question 1: Solution

a) State the function of each transistor M1 to M6 in Figure 1. [10 marks]
- M_1 & M_2: differential-pair, common-emitter amplifier [4 marks]
- M_3 to M_6: cascode current mirror [2 marks], active load [4 marks]

b) Calculate the differential gain of the circuit if given: (W/L)1-2=5, (W/L)3-6= 10 [20 marks]

$$A_d = g_{m1}(r_{O2} \| R_{O4})[4marks]$$
$$g_{m1} = 2\sqrt{K_{n1} I_{D1}} = 2\sqrt{0.5(100\mu)(5)(0.1m)} = 0.316\,\text{mA/V}[2marks]$$
$$r_{O2} = 1/(\lambda_n I_{D2}) = 1/(0.01x0.1m) = 1M\Omega[2marks]$$
$$R_{O4Cascode} = g_{m4} r_{O4} r_{O6}[4marks]$$
$$g_{m4} = 2\sqrt{K_{p4} I_{D4}} = 2\sqrt{0.5(80\mu)(10)(0.1m)} = 0.4\,\text{mA/V}[2marks]$$
$$r_{O4} = 1/(\lambda_p I_{D4}) = 1/(0.015x0.1m) = 667k\Omega[2marks]$$
$$r_{O6} = r_{O4} = 667k\Omega[1mark]$$
$$R_{O4Cascode} = (0.4m)(667k)(667k) = 178M\Omega[1mark]$$
$$A_d = (0.316m)(1M \| 178M) = 312.8V/V[2marks]$$

c) Calculate the CMRR (dB) if Acm = -0.003. [10 marks]

CMRR = |Ad/Acm| = |312.8/-0.003|	= 104.27k	[4 marks]
CMRR(dB) = 20 log(|Ad/Acm|)	= 20 log(104.27k)	[4 marks]
	= 100.3 dB	[2 marks]

Question 2 **[20 marks]**

The **Class AB** output stage is shown in **Figure 2**, with V_{CC} **= 10 V,** I_{CQ} **= 2 mA,** and R_L **= 100 Ω**. Assume Q_n and Q_p to be matched, with I_S **= 3x10^{-13} A**.

a) Determine V_{BB}. [4 marks]

b) For v_O **= 6 V**,

i. **Find** the values of i_L, i_{Cn}, i_{Cp}, v_{BEn}, and v_{BEp}. [10 marks]

ii. **Calculate** the power dissipated in Q_n and Q_p. [6 marks]

Answers for Question 2

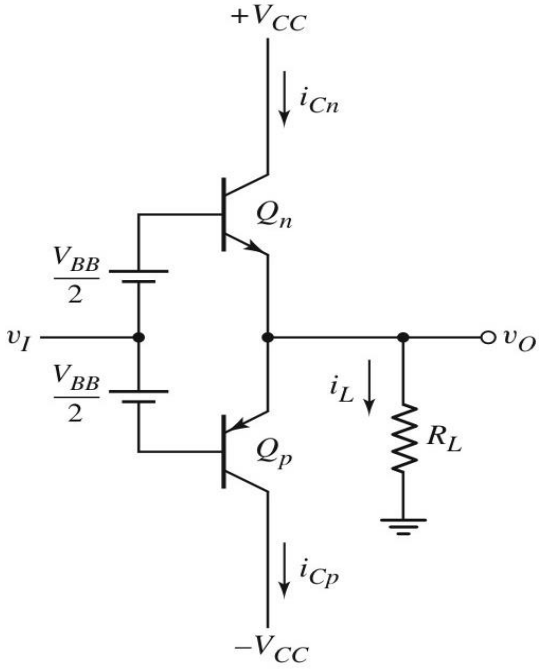

Figure 2

Answers for Question 2 (Cont.)

Question 2: Solution

a) Determine V_{BB} [4marks]

$I_{CQ} = i_{Cn} = i_{Cp}$ when $v_{BEn} = v_{BEp} = V_{BB}/2$ [2 marks]
$V_{BB}/2 = V_T \ln(I_{CQ} / I_S) = (26m) \ln(2m / 3x10^{-13}) = 0.588$ V
$V_{BB} = 2 \times 0.588 = 1.176$ V [2 marks]

b) For $v_O = 6$ V,

i. **Find** the values of i_L, i_{Cn}, i_{Cp}, v_{BEn}, and v_{BEp}. [10 marks]

$i_L = v_O / R_L = 6 / 100 = 60$ mA [2 marks]

1st iteration:
i_{Cn} å $i_L = 60$ mA [1 mark]
$v_{BEn} = V_T \ln(i_{Cn} / I_S) = (26m) \ln(60m / 3x10^{-13}) = 0.677$ V [2 marks]
$v_{EBp} = V_{BB} - v_{BEn} = 1.176$ ï 0.677 = 0.499 V [2 marks]
$i_{Cp} = I_S \exp(v_{EBp} / V_T) = (3x10^{-13}) \exp(0.499/26m) = 0.0649$ mA [2 marks]

Recalculate i_{Cn}:
$i_{Cn} = i_L + i_{Cp} = 60m + 0.0649m = 60.065$ mA [1 mark]

ii. **Calculate** the power dissipated in Q_n and Q_p. [6 marks]

$P_{Qn} = V_{CEn} \times i_{Cn}$ [1 mark]
$V_{CEn} = V_{CC} - v_O$ =10 ï 6 = 4 V [1 mark]
$P_{Qn} = 4 \times 60.065m = 240.26$ mW [1 mark]

$P_{Qp} = V_{ECp} \times i_{Cp}$ [1 mark]
$V_{ECp} = v_O$ ï (-V_{CC}) = 6 ï (-10) = 16 V [1 mark]
$P_{Qp} = 16 \times 0.0649m = 1.038$ mW [1 mark]

Question 3 **[40 marks]**

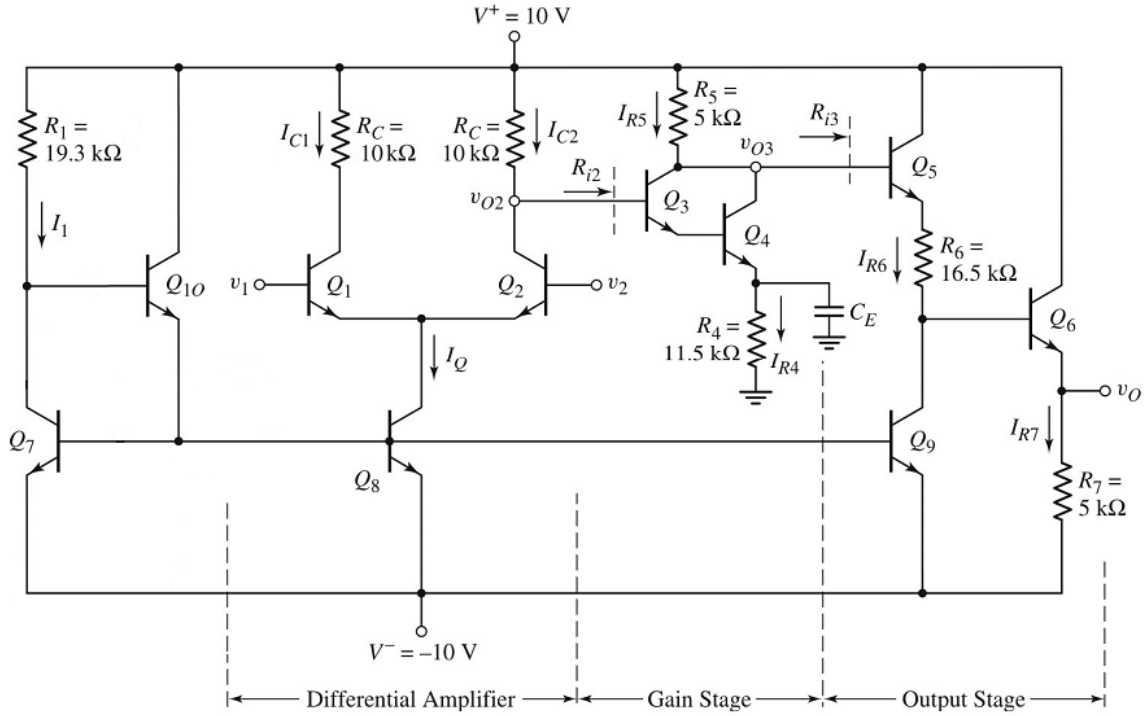

Figure 3

Figure 3 shows a design for a simple bipolar op-amp. The biasing for amplifiers in the circuit is provided by **three-transistor current sources**. The measured current through R_6 is **0.42 mA.** Study the figure carefully. **Neglect base currents**. Assume V_{BE}**(on) = 0.7 V** for all transistors.

Calculate I_1, I_Q, I_{C2}, v_{O2}, v_{O3}, and v_O. **Show all your calculation clearly** in order to get full marks. [40 marks]

Answers for Question 3

Answers for Question 3 (Cont.)

I_1 $= (V^+ - V_{BE10} - V_{BE7} - V^-) / (R_1)$ **[4]**

$= (10 - 0.7 - 0.7 - (-10)) / (19.3k) \quad = 0.9637$ mA **[2]**

Neglect base current, $I_Q = I_1 = 0.9637$ mA **[3]**

$I_{C2} = I_Q / 2 = 0.4818$ mA **[3]**

$v_{O2} = V^+ - I_{C2} R_C = 10 - (0.4818m)(10k) = 5.182$ V **[5]**

$I_{R4} = (v_{O2} - 2 V_{BE}(on)) / (R_4)$ **[4]**

$= (5.182 - 1.4) / (11.5k) \quad = 0.3288$ mA **[3]**

$I_{R5} \approx I_{R4}$ (neglecting base currents) $= 0.3288$ mA **[3]**

$v_{O3} = V^+ - I_{R5} R_5 = 10 - (0.3288m)(5k) = 8.356$ V **[4]**

$I_{R7} = (v_{O3} - 2V_{BE}(on) - I_{R6} R_6 + 10) / (R_7)$ **[3]**

$= (8.356 - 1.4) - (0.42m)(16.5k) + 10) / (5k) = 2.005$ mA **[2]**

$v_O = -10 + I_{R7} R_7 = -10 + (2.005m)(5k) = 0.026$ V **[4]**