Name:

Student ID Number:

Section:

Lecturer: Dr Azni Wati/ Dr Jehana Ermy/ Dr Jamaludin

Table Number:

UNIVERSITI TENAGA NASIONAL

# College of Engineering

## Department of Electronics and Communication Engineering

# Test 2 – Model Answer

**SEMESTER 2, ACADEMIC YEAR 2015/2016**

| | | |
|---|---|---|
| Subject Code | : | **EEEB273** |
| Course Title | : | **Electronics Analysis & Design II** |
| Date | : | **9 January 2016** |
| Time Allowed | : | **1 hour 45 minutes** |

## Instructions to the candidates:

1. Write your Name and Student ID number. Circle Lecturer for your section.
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.**

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

☺ **GOOD LUCK!** ☺

| Question Number | Q1 | Q2 | Q3 | Total |
|---|---|---|---|---|
| Marks | | | | |

**<u>Answer for Question 1 (Cont.)</u>**

Q1(a) [6 marks]

| | |
|---|---|
| M1 & M2: Diff Amp | [2] |
| M3 ï M6: Active load | [4] |

Q1(b) [8 marks]

Vcm(max) = $V^+$ - $V_{SG5}$ ï $V_{SG3}$ ï $V_{DS1(sat)}$ + $V_{GS1}$ [1]

$V_{DS1(sat)}$ = $V_{GS1}$ -$V_{TN}$

Thus,

Vcm(max) = $V^+$ - $V_{SG5}$ ï $V_{SG3}$ +$V_{TN}$ [2]

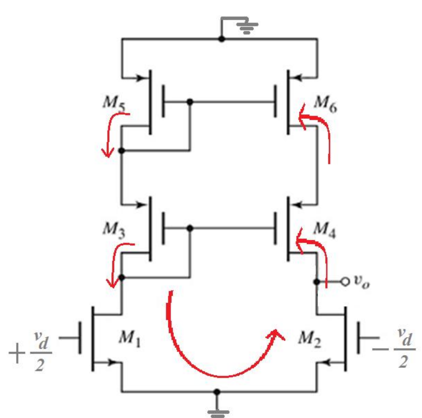
$V_{SG5}$ = $V_{SG3}$ = [1]

$$=\sqrt{\frac{I_{D5}}{K_p}}-V_{TP}=\sqrt{\frac{I_Q/2}{\frac{k_p}{2}(W/L)}}-(-1)=\sqrt{\frac{0.23m/2}{\frac{80u}{2}(10)}}+1=0.5362+1=1.5362 \quad [3]$$

Vcm(max) = 10-1.5362-1.5362+1 = 7.9276V [1]

Q1(c) [6 marks]

| | |
|---|---|
| Indicate ac grounds | [2] |
| Indicate ac currents in diff-amp | [2] |
| Labels of inputs vd/2 and ï vd/2 | [2] |



Q1(d) [8 marks]

$$g_{m4} = 2\sqrt{K_P I_{D4}} = 2\sqrt{\left(\frac{k_p^{'}}{2}\right)\left(\frac{W}{L}\right)_4 I_{D4}}$$

$$g_{m4} = 2\sqrt{\left(\frac{80\varepsilon}{2}\right)(10)(0.115m)} = 0.4289mA/V \qquad [2]$$

$$r_{o4} = r_{o6} = \frac{1}{\lambda_p I_{D4}} = \frac{1}{(0.01)(0.23m/2)} = 869.56k\Omega \qquad [4]$$

$$R_o = g_{m4} r_{o4} r_{o6} = (0.4289m)(869.56k)(869.56k) = 324.3M\Omega \qquad [2]$$

Q1(e) [8 marks]

$$A_d = g_{m2}(r_{o2} \parallel R_O) \qquad [1]$$

$$g_{m2} = 2\sqrt{K_n I_{D2}} = 2\sqrt{\left(\frac{k_n^{'}}{2}\right)\left(\frac{W}{L}\right)_2 I_{D2}}$$

$$g_{m2} = 2\sqrt{\left(\frac{100\varepsilon}{2}\right)(5)(0.115m)} = 0.3391mA/V \qquad [2]$$

$$r_{o2} = \frac{1}{\lambda_n I_{D2}} = \frac{1}{(0.015)(0.115m)} = 579.71k\Omega \qquad [2]$$

$$A_d = (0.3391m)(579.71k \parallel 324.3M) = 196.17 \qquad [3]$$

Q1(f) [4 marks]

Output resistance of diff-amp is ro2//Ro, therefore it can be changed by changing the configuration or circuit used for the active load. The larger output resistance from the active load circuit (Ro) results in larger diff-amp output resistance and vice versa. [4 marks for any logical discussions that creates Ro with diff-amp output resistance]

**Answer for Question 2**

Q2(a) [10 marks]

$$R_i = r_{\pi 6} + r_{\pi 7}(1+\beta_p) \qquad [2]$$

$$r_{\pi 6} = \frac{\beta_p V_T}{I_{C6}} = \frac{90x26mV}{0.25mA/91} = 851.76k\Omega \qquad [2]$$

$$I_{C6} = \frac{\beta_p}{1+\beta_p} I_{E6} = \frac{\beta_p}{1+\beta_p} I_{B7} = \frac{\beta_p}{1+\beta_p}\frac{I_{C7}}{\beta_p} = \frac{I_{C7}}{1+\beta_p} = \frac{0.25mA}{1+90} = 0.002747mA \qquad [2]$$

$$r_{\pi 7} = \frac{\beta_p V_T}{I_{C7}} = \frac{90x26mV}{0.25mA} = 9.36k\Omega \qquad [2]$$

$$R_i = 851.76k + (9.36k)(1+90) = 1.70352M\Omega \qquad [2]$$

Q2(b) [20 marks]

$$R_o = R_4 \Bigg\| \left(\frac{r_{\pi 8} + Z}{(1+\beta_n)}\right) \qquad [2]$$

$$Z = \frac{r_{\pi 9} + (R_{c11} \| R_{c7})}{(1+\beta_n)} \qquad [2]$$

$$R_{c11} = r_{o11}\left(1 + g_{m11}(r_{\pi 11} \| R_3)\right) \qquad [2]$$

$$r_{o11} = V_{A11} / I_{C11} = 120V / 0.25mA = 480k\Omega \qquad [1]$$

$$g_{m11} = I_{C11} / V_T = 0.25mA / 26mV = 9.615mA/V \qquad [1]$$

$$r_{\pi 11} = \beta_n V_T / I_{C11} = (120x26mV)/0.25mA = 12.48k\Omega \qquad [1]$$

$$r_{\pi 11} \| R_3 = 12.48k \| 200 = 196.84\Omega$$

$$R_{c11} = (480k)\left(1 + 9.615m(196.84)\right) = 1388.45k\Omega \qquad [1]$$

$$R_{c7} = r_{o7} = V_{A7} / I_{C7} = 60V / 0.25mA = 240k\Omega \qquad [2]$$

$$R_{c11} \| R_{c7} = 1388.45k \| 240k = 204.62k\Omega \qquad [1]$$

$$r_{\pi 9} = \beta_n V_T / I_{C9} = (120x26mV)/(1mA/121) = 377.5k\Omega \qquad [1]$$

$$I_{C9} = \frac{\beta_n}{1+\beta_n} I_{E9} = \frac{\beta_n}{1+\beta_n} I_{B8} = \frac{\beta_n}{1+\beta_n}\frac{I_{C8}}{\beta_n} = \frac{I_{C8}}{1+\beta_n} = \frac{1mA}{121} = 0.008264mA \qquad [1]$$

$$Z = \frac{r_{\pi 9} + R_{c11} \| R_{c7}}{(1+\beta_n)} = \frac{377.5k + 204.62k}{(1+120)} = 5.108k\Omega \qquad [2]$$

$$r_{\pi 8} = \beta_n V_T / I_{C8} = \frac{120x26mV}{1mA} = 3.12k\Omega \qquad [1]$$

$$R_o = R_4 \Bigg\| \left(\frac{r_{\pi 8} + Z}{(1+\beta_n)}\right) = 5k \Bigg\| \left(\frac{3.12k + 5.108k}{(1+120)}\right) = 67.08\Omega \qquad [2]$$

**Answer for Question 3**

(a) Using the formula, **(6 marks)**

$I_C = I_S \exp(\frac{V_{BE}}{V_T})$; [2]

$V_{BE} = V_T \ln\left(\frac{i_{Cn}}{I_S}\right) = (0.026)\ln\left(\frac{1m}{2\times10^{-15}}\right) = \underline{0.7004\ \text{V}}$ [2]

So, $V_{BB} = 2V_{BE} = 2(0.7004) = \underline{1.401\ \text{V}}$ [2]

(b) The power dissipated in each transistor, $P_Q$ **(3 marks)**

$P_Q = ic.v_{CE} = (1m)(5) = \underline{5\ \text{mW}}$ [2,1]

(c) When $v_O = -3.5$ V, **(12 marks)**

$i_{Cp} \cong |i_L| = |v_O/R_L| = |$ -3.5V/1kÝ $|$ = $\underline{3.5\ \text{mA}}$ [2]

$V_{EB} = V_T \ln\left(\frac{i_{Cp}}{I_S}\right) = (0.026)\ln\left(\frac{3.5m}{2\times10^{-15}}\right) = \underline{0.7330\ \text{V}}$ [2]

$V_{BE} = V_{BB} - V_{EB} = 1.40077 - 0.73296 = \underline{0.6678\ \text{V}}$ [2]

$i_{Cn} = (2 \times 10^{-15}) \exp\left(\frac{0.6678}{0.026}\right) = \underline{0.2857\ \text{mA}}$ [2]

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Then, $i_{Cp} \cong i_{Cn} - i_L = 0.2857m + 3.5m = \underline{3.7857\ \text{mA}}$ [2]

Using the new sets of values, - this is second iteration and optional. If marking first iteration only, the 4 marks will be redistributed in the above ($V_{BE}, V_{EB}, i_{CN},$ and $i_{CP}$).

$V_{EB} = V_T \ln\left(\frac{i_{Cp}}{I_S}\right) = (0.026)\ln\left(\frac{3.7857m}{2\times10^{-15}}\right) = \underline{0.73499\ \text{V}}$ [1]

$V_{BE} = V_{BB} - V_{EB} = 1.40077 - 0.73499 = \underline{0.66578\ \text{V}}$ [1]

$i_{Cn} = (2 \times 10^{-15}) \exp\left(\frac{0.66578}{0.026}\right) = \underline{0.2642\ \text{mA}}$ [1]

$i_{Cp} = i_{Cn} + i_L = 0.2642m + 3.5m = \underline{3.764\ \text{mA}}$ [1]

$v_I = v_O - v_{EB} + V_{DD}/2$ = –3.5 ï 0.7330 + 0.7004 = $\underline{-3.533\ \text{V}}$ [2]

(d) For power dissipation in: **(9 marks)**

$Q_n : P_{Qn} = i_{Cn}v_{CEn}$ = (0.2857m)[5 ï (-3.5)] = $\underline{2.43\ \text{mW}}$ [2,1]

$Q_p : P_{Qp} = i_{Cp}v_{ECp}$ = (3.7857m)[-3.5 ï (-5)] = $\underline{5.68\ \text{mW}}$ [2,1]

$R_L: P_{RL} = i_L^2 R_L = (3.5m)^2(1k) = \underline{12.25\ \text{mW}}$ [2,1]