COLLEGE OF ENGINEERING
PUTRAJAYA CAMPUS
FINAL EXAMINATION

SEMESTER 2 2015 / 2016

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	**: February 2016**
TIME	**: 3 hours**

INSTRUCTIONS TO CANDIDATES:

1. This paper contains **FIVE** (5) questions in **NINE** (9) 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**.
5. Show clearly all calculations, complete with proper Unit for every parameter.

THIS QUESTION PAPER CONSISTS OF NINE (9) PRINTED PAGES INCLUDING THIS COVER PAGE.

Question 1 [20 marks]

Question 1(a) [7.5 marks]

$$R_1 = \frac{V^+ - V_{BE5} - V_{BE3} - V^-}{I_{REF}} = \frac{10 - 0.7 - 0.7 - (-10)}{0.5mA} = 37.2k\Omega \quad [1, 1, 0.5]$$

$$I_Q = \frac{I_{REF}}{1 + 4/\beta} = \frac{0.5m}{1 + 4/50} = 0.4629mA \quad [1, 1, 0.5]$$

$$R_O = \beta_6 r_{o6} = \beta_6 \frac{V_{A6}}{I_Q} = 50\frac{250}{0.4629m} = 27.003M\Omega \quad [1, 1, 0.5]$$

Question 1(b) [5 marks]

$$A_d = \frac{g_{m2} R_C}{2}$$

$$R_C = \frac{2A_d}{g_{m2}} = \frac{2(200)}{8.903m} = 44.928k\Omega \quad [1, 1, 0.5]$$

$$g_{m2} = \frac{I_Q/2}{V_T} = \frac{0.4629m}{2(0.026)} = 8.903mA/V \quad [1, 1, 0.5]$$

Question 1(c) [6 marks]

$$A_{cm} = \frac{-g_{m2} R_C}{1 + \frac{2(1+\beta_2)R_O}{r_{\pi 2}}}$$

$$R_O = 27.003M\Omega$$

$$g_{m2} = 8.903mA/V$$

$$R_C = 44.928k\Omega$$

$$r_{\pi 2} = \frac{\beta_2 V_T}{I_Q/2} = \frac{2(150)(0.026)}{0.4629m} = 16.85k\Omega \quad [1, 1, 0.5]$$

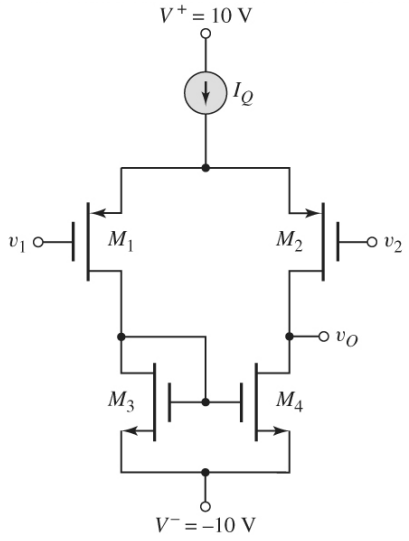
$$A_{cm} = \frac{-g_{m2} R_C}{1 + \frac{2(1+\beta_2)R_O}{r_{\pi 2}}} = \frac{-(8.903m)(44.928k)}{1 + \frac{2(1+150)(27.003M)}{16.85k}} = -0.000826V/V \quad [1, 2, 0.5]$$

Question 1(d) [1.5 marks]

Increase Ro of the cascode current source.

Question 2 [20 marks]

Q2(a)



M_3 and M_4 labels [2]

Placement of NMOS CS [2]

V_O placement [1]

Q2(b)

Based on symmetry, $V_{GS3} = V_{GS4}$; $V_{DS3} = V_{DS4}$

$$V_{GS} = V_{TN} + \sqrt{\frac{I_{REF}}{K_n}};$$ [2]

thus $V_{GS3} = V_{GS4} = V_{DS3} = V_{DS4} = 1 + \sqrt{\frac{0.2m/2}{0.1m}} =$ **2 V** [1]

$V_{SG1} = V_{SG2} = 1 + \sqrt{\frac{0.2m/2}{0.1m}} =$ **2 V** [1]

$V_{SD1} = V_{SD2} = V_{GS1}$ ï $(V_{DS3}$ ï 10) = 2 ï (2 ï 10) = **10 V** [1]

Q2(c)

$r_{On} = \frac{1}{\lambda_n I_{DQ}}$ [1] $= \frac{1}{(0.01)(0.1m)} =$ **1 MΩ** [1]

$r_{Op} = \frac{1}{\lambda_p I_{DQ}} = \frac{1}{(0.015)(0.1m)} =$ **0.667 MΩ** [1]

$A_d = g_m(r_{on} \parallel r_{op})$ [1] = (0.2)(1000k ‖ 667k) = **80** [1]

Q2(d)

$I_{D1} = I_{D2} = I_Q/2 =$ **0.1 mA** [1]

As $r_{o2} = r_{on} =$ **1 MΩ** [0.5] and $r_{o4} = r_{op} =$ **0.667 MΩ** [0.5]

Therefore, RO = $r_{o2} \parallel r_{o4}$ [2] = (1000k ‖ 667k) = **400 kΩ** [1]

Question 3 [20 marks]

Answer:

Q3(a)

$i_{E1min} = I_Q - |i_{Lmin}|$ [1]

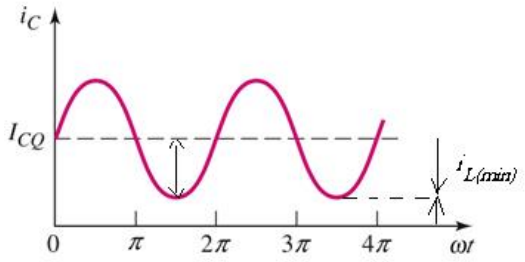
$P_L = \frac{V_p^2}{2R_L} = 50mW$ [2]

$V_p = \sqrt{2R_L P_L} = 1.581V$ [1]

$|i_{Lmin}| = \frac{V_p}{R_L} = \frac{1.581}{25} = 63.24mA$ [1]

$I_Q - i_{E1} = 0.8I_Q = |i_{Lmin}|$ [1]

$I_Q = \frac{63.24m}{0.8} = 79.05mA$ [1]



$R = \frac{0 - V_{BE_{ON}} - V^-}{I_Q} = \frac{-0.7+12}{79.05m} = 143\Omega$ [3]

Q3(b)

$I_{C1} = \frac{\beta}{1+\beta} I_{B2} = \frac{I_{C2}}{1+\beta} = \frac{1m}{61} = 16.39\mu A$ [2]

$r_{\pi 1} = \frac{(60)(0.026)}{16.39\mu} 95.18k\Omega$ [1]

$r_{\pi 2} = \frac{(60)(0.026)}{1m} = 1.56k\Omega$ [1]

$R_i = r_{\pi 1} + (1+\beta) r_{\pi 2} = 95.18k + (61)(1.56k) = 190.3k\Omega$ [2]

$r_{\pi 3} = \frac{(60)(0.026)}{5m} 312\Omega$ [1]

$R_o = 5k \parallel \left[\frac{r_{\pi 3} + 50k}{1+\beta}\right] = 5k \parallel 825 = 708\Omega$ [3]

Question 4 [20 marks]

Answer:

$A_{d1} = g_{m2}(r_{o2} \parallel r_{o4}) = 243$ [1] or Total [5]

$A_{v2} = g_{m7}(r_{o7} \parallel r_{o8}) = 272$ [1] or Total [5]

Overall gain

$A_d = [g_{m2}(r_{o2} \parallel r_{o4})]X[g_{m7}(r_{o7} \parallel r_{o8})] = 66010$ [2]

$I_{DS} = K_p[V_{SG3} + V_{TP}]^2 = \frac{V^+ - V - V_{SG3}}{R_{set}}$ [2]

$60V_{SG3}^2 - 71V_{SG} + 11.6 = 0$ [2]

$V_{SG3} = 0.987V \gg I_{DS} = 60.0\mu A$ [1, 1]

$I_{DS} = I_Q = I_{D7}$ [1]

$I_{n7} = \frac{I_Q}{2} = 30.0\mu$A [1]

Elements in A_{d1} and A_{v2}

K_{n7}	K_{p2}	g_{m2}	g_{m7}
1 *m*A/V^2 [1]	0.4 *m*A/V^2 [1]	0.2191mA/V [1]	0.4899mA/V [1]

r_{o2}	r_{o4}	r_{o7}	r_{o8}
2.218MÝ [1]	2.218MÝ [1]	1.109MÝ [1]	1.109MÝ [1]

Question 5 [20 marks]

Answers:

Q5(a)

Calculation:

A_v $= 1 + R_2/(R_{1F} + R_{1V})$ [1]

R_2 $= 250$ kq . R_{1F} is a fixed-value resistor.

R_{1V} is a potentiometer. Gain is maximum, i.e. 51, when $R_{1V} =$ **0** q .

A_{v1} $= 51 = 1 + R_2/(R_{1F} + R_{1V}) = 1 + 250k/(R_{1F} + \mathbf{0})$ [1]

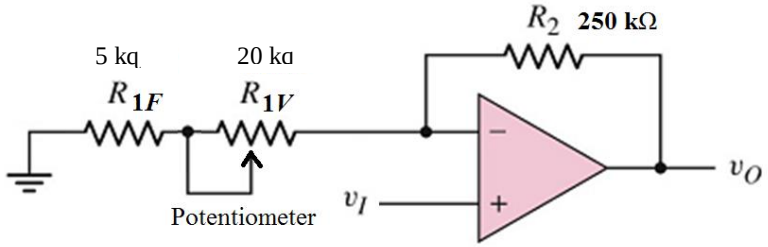
R_{1F} $= 5$ kq [0.5]

Gain is minimum, i.e. 11, when R_{1V} is maximum.

A_{v2} $= 11 = 1 + R_2/(R_{1F} + R_{1V}) = 1 + 250k/(5k + R_{1V})$ [1]

R_{1V} $= 20$ kq [0.5]

Circuit: [2]



Q5(b)

$$v_{O1} = (-R_F/R_1)\, v_{I1} + (-R_F/R_2)\, v_{I2}$$
$$= (-R_F/R_1)\, v_{I1} + (-R_F/R_1)\, v_{I2}$$
$$= (-R_F/R_1)\,(v_{I1} + v_{I2}) \quad \textbf{[3]}$$

$$v_O = (-R_F/R_1)\, v_{O1} \quad \textbf{[1]}$$
$$= (-R_F/R_1)\,(-R_F/R_1)\,(v_{I1} + v_{I2}) \quad \textbf{[1]}$$
$$= (-100k/100k)\,(-100k/100k)\,(v_{I1} + v_{I2})$$
$$= v_{I1} + v_{I2} \quad \textbf{[1]}$$

Note: Student can use any method that leads to the same answer.

$$v_O = -10v_{I1} - 5v_{I2} + 2v_{I3} + 5v_{I4}$$

Q5(c)

$\boldsymbol{R_F / R_1 = 10}$ ➔ $\boldsymbol{R_F = 10\ R_1}$ **[0.5]**

and $\boldsymbol{R_F / R_2 = 5}$ ➔ $\boldsymbol{R_F = 5\ R_2}$ **[0.5]**

So, resistor R_1 will be the **<u>smallest</u>** value. Set $\boldsymbol{R_1 = 25\ k\Omega}$. **[1]**

➔ $\boldsymbol{R_F} = 10\ R_1 = 10 \times 25\ k\Omega$ $\boldsymbol{= 250\ k\Omega}$ **[0.5]**

and $\boldsymbol{R_2} = R_F / 5 = 250k\Omega\ / 5$ $\boldsymbol{= 50\ k\Omega}$ **[0.5]**

$R_N = R_1 \parallel R_2 = 25\ k\Omega \parallel 50\ k\Omega$ $= \boldsymbol{16.667\ k\Omega}$

$1 + R_F / R_N = 1 + 250k / (16.667k)$ $= 16$

$(1 + R_F / R_N)(R_P / R_A) = (16)\ (R_P / R_A) = 2$ **[0.5]**

and $(1 + R_F / R_N)(R_P / R_B) = (16)\ (R_P / R_B) = 5$ **[0.5]**

So, $(R_A / R_B) = 5/2$. **[0.5]**

Choose $\boldsymbol{R_B = 80\ k\Omega}$, **[1]**

then $\boldsymbol{R_A = 200\ k\Omega}$ **[1]**

$R_P = (5\ R_B) / 16$ $= (2\ R_A) / 16$

➔ $\boldsymbol{R_P = 25\ k\Omega}$ **[0.5]**

$R_P = R_A \parallel R_B \parallel R_C$

➔ $\boldsymbol{R_C = 44.45\ k\Omega}$ **[1]**