Name:	**Dr JBO**
Student ID Number:	**Model Answer**
Section:	02 A/B
Lecturer:	Dr. Jamaludin Bin Omar

EEEB273 - Quiz 4
SEMESTER 2, ACADEMIC YEAR 2016/2017
Date: 8 December 2016 Time: 15 minutes .

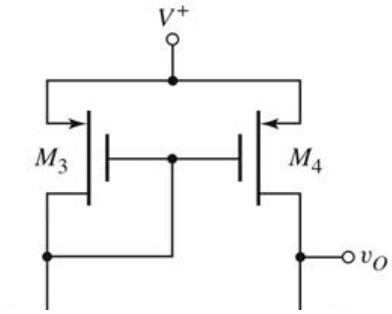
Question:

The circuit parameters for differential amplifier with active load shown in **Figure 1** are $V^+ = 5$ V, $V^- = -5$ V, and $I_Q = 250$ μA. The **NMOS** transistor parameters are $V_{TN} = 0.4$ V, $k'_n = 100$ μA/V^2, $(W/L)_n = 8$, and $\lambda_n = 0.018$ V^{-1}. The **PMOS** transistor parameters are $V_{TP} = -0.4$ V, $k'_p = 40$ μA/V^2, $(W/L)_p = 10$, and $\lambda_p = 0.02$ V^{-1}.

a) **Determine** the output resistance (R_O) of the differential amplifier. [4 marks]

b) **Calculate** the differential-mode voltage gain (A_d) and the common-mode voltage gain (A_{cm}) if ***CMRR*** of the differential amplifier is **55 dB**. [6 marks]

Answer:



; 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

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

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

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

(a)

I_D	$= I_Q / 2 = 250\mu / 2$	$= 125$ μA	[1]	
r_{o2}	$= 1 / (\lambda_n I_D)$	$= 1 / [(0.018)(125\mu)]$ $= 444.44$ kΩ	[1]	
r_{o4}	$= 1 / (\lambda_p I_D)$	$= 1 / [(0.02)(125\mu)]$ $= 400.00$ kΩ	[1]	
R_o	$= r_{o2} \parallel r_{o4}$	$= 444.44\text{k} \parallel 400.00\text{k}$ $= 210.52$ kΩ	[1]	

(b)

R_o	$= r_{o2} \parallel r_{o4}$	$= 210.52$ kΩ		
g_{m2}	$= 2\sqrt{[K_n I_D]}$	$= 2\sqrt{[(k'_n/2)(W/L)_n(I_Q/2)]}$	[1]	
	$= 2\sqrt{[(100\mu/2)(8)(125\mu)]}$	$= 0.4472$ mA/V^2	[1]	
A_d	$= g_{m2} R_o = (0.4472\text{m})(210.52\text{k})$	$= 94.144$	[1]	

; Small signal

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

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

$CMRR_{dB}$	$= 20 \log [A_d / A_{cm}] = 55$ dB	[1]
A_{cm}	$= A_d / [10^{55/20}] = 0.16741$	[2]

Name:	**Dr JBO**
Student ID Number:	**Model Answer**
Section:	02 A/B
Lecturer:	Dr. Jamaludin Bin Omar

EEEB273 - Quiz 4
SEMESTER 2, ACADEMIC YEAR 2016/2017
Date: 8 December 2016 Time: 15 minutes

,

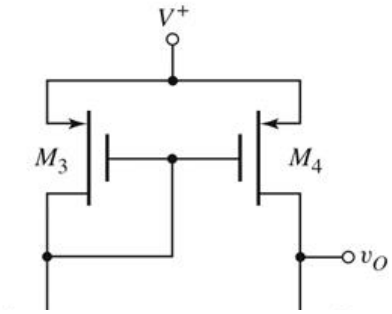
Question:

The circuit parameters for differential amplifier with active load shown in **Figure 1** are $V^+ = 5$ V, $V^- = -5$ V, and $I_Q = 250$ μA. The **NMOS** transistor parameters are $V_{TN} = 0.4$ V, $k'_n = 100$ μA/V^2, $(W/L)_n = 8$, and $\lambda_n = 0.02$ V^{-1}. The **PMOS** transistor parameters are $V_{TP} = -0.4$ V, $k'_p = 40$ μA/V^2, $(W/L)_p = 10$, and $\lambda_p = 0.018$ V^{-1}.

a) **Determine** the output resistance (R_O) of the differential amplifier. [4 marks]

b) **Calculate** the differential-mode voltage gain (A_d) and the common-mode voltage gain (A_{cm}) if ***CMRR*** of the differential amplifier is **45 dB**. [6 marks]

Answer:



; 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

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

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

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

(b)

I_D	$= I_Q / 2 = 250\mu / 2$	$= 125$ μA	[1]	
r_{o2}	$= 1 / (\lambda_n I_D)$	$= 1 / [(0.02)(125\mu)]$ $= 400.00$ kΩ	[1]	
r_{o4}	$= 1 / (\lambda_p I_D)$	$= 1 / [(0.018)(125\mu)]$ $= 444.44$ kΩ	[1]	
R_o	$= r_{o2} \parallel r_{o4}$	$= 400.00\text{k} \parallel 444.44\text{k}$ $= 210.52$ kΩ	[1]	

(c)

; Small signal

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

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

R_o	$= r_{o2} \parallel r_{o4}$	$= 210.52$ kΩ	
g_{m2}	$= 2\sqrt{[K_n I_D]}$ $= 2\sqrt{[(k'_n/2)(W/L)_n(I_Q/2)]}$		[1]
	$=2\sqrt{[(100\mu/2)(8)(125\mu)]}$	$= 0.4472$ mA/V^2	[1]
A_d	$= g_{m2} R_o = (0.4472\text{m})(210.52\text{k})$	$= 94.144$	[1]

$CMRR_{dB}$	$= 20 \log [A_d / A_{cm}] = 45$ dB	[1]
A_{cm}	$= A_d / [10^{45/20}] = 0.52941$	[2]

Name:	**Dr JBO**
Student ID Number:	**Model Answer**
Section:	02 A/B
Lecturer:	Dr. Jamaludin Bin Omar

EEEB273 - Quiz 4
SEMESTER 2, ACADEMIC YEAR 2016/2017
Date: 8 December 2016 Time: 15 minutes

;

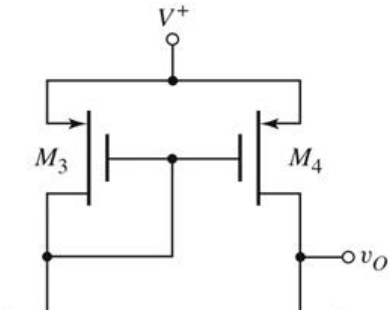
Question:

The circuit parameters for differential amplifier with active load shown in **Figure 1** are $V^+ = 5$ V, $V^- = -5$ V, and $I_Q = 250$ μA. The **NMOS** transistor parameters are $V_{TN} = 0.4$ V, $k'_n = 100$ μA/V^2, $(W/L)_n = 5$, and $\lambda_n = 0.018$ V^{-1}. The **PMOS** transistor parameters are $V_{TP} = -0.4$ V, $k'_p = 40$ μA/V^2, $(W/L)_p = 10$, and $\lambda_p = 0.02$ V^{-1}.

a) **Determine** the output resistance (R_O) of the differential amplifier. [4 marks]

b) **Calculate** the differential-mode voltage gain (A_d) and the common-mode voltage gain (A_{cm}) if ***CMRR*** of the differential amplifier is **55 dB**. [6 marks]

Answer:



; 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

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

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

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

(c)

I_D	$= I_Q / 2 = 250\mu / 2$	$= 125$ μA	[1]	
r_{o2}	$= 1 / (\lambda_n I_D)$	$= 1 / [(0.018)(125\mu)]$ $= 444.44$ kΩ	[1]	
r_{o4}	$= 1 / (\lambda_p I_D)$	$= 1 / [(0.02)(125\mu)]$ $= 400.00$ kΩ	[1]	
R_o	$= r_{o2} \parallel r_{o4}$	$= 444.44\text{k} \parallel 400.00\text{k}$ $= 210.52$ kΩ	[1]	

(d)

R_o	$= r_{o2} \parallel r_{o4}$	$= 210.52$ kΩ		
g_{m2}	$= 2\sqrt{[K_n I_D]}$	$= 2\sqrt{[(k'_n/2)(W/L)_n(I_Q/2)]}$	[1]	
	$= 2\sqrt{[(100\mu/2)(5)(125\mu)]}$	$= 0.3535$ mA/V^2	[1]	
A_d	$= g_{m2} R_o = (0.3535\text{m})(210.52\text{k})$	$= 74.43$	[1]	

; Small signal

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

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

$CMRR_{dB}$	$= 20 \log [A_d / A_{cm}] = 55$ dB		[1]
A_{cm}	$= A_d / [10^{55/20}] = 0.13236$		[2]

Name:	**Dr JBO**
Student ID Number:	**Model Answer**
Section:	02 A/B
Lecturer:	Dr. Jamaludin Bin Omar

EEEB273 - Quiz 4
SEMESTER 2, ACADEMIC YEAR 2016/2017
Date: 8 December 2016 Time: 15 minutes :

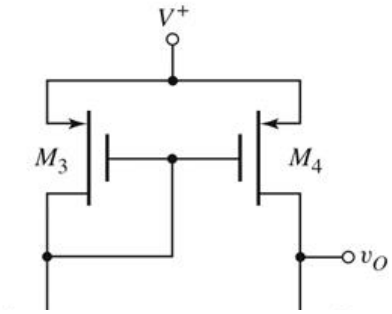
Question:

The circuit parameters for differential amplifier with active load shown in **Figure 1** are $V^+ = 5$ V, $V^- = -5$ V, and $I_Q = 250$ μA. The **NMOS** transistor parameters are $V_{TN} = 0.4$ V, $k'_n = 100$ μA/V^2, $(W/L)_n = 5$, and $\lambda_n = 0.02$ V^{-1}. The **PMOS** transistor parameters are $V_{TP} = -0.4$ V, $k'_p = 40$ μA/V^2, $(W/L)_p = 10$, and $\lambda_p = 0.018$ V^{-1}.

a) **Determine** the output resistance (R_O) of the differential amplifier. [4 marks]

b) **Calculate** the differential-mode voltage gain (A_d) and the common-mode voltage gain (A_{cm}) if ***CMRR*** of the differential amplifier is **65 dB**. [6 marks]

Answer:



; 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

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

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

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

(d)

I_D	$= I_Q / 2 = 250\mu / 2$	$= 125$ μA	[1]	
r_{o2}	$= 1 / (\lambda_n I_D)$	$= 1 / [(0.02)(125\mu)]$ $= 400.00$ kΩ	[1]	
r_{o4}	$= 1 / (\lambda_p I_D)$	$= 1 / [(0.018)(125\mu)]$ $= 444.44$ kΩ	[1]	
R_o	$= r_{o2} \parallel r_{o4}$	$= 400.00\text{k} \parallel 444.44\text{k}$ $= 210.52$ kΩ	[1]	

(e)

; Small signal

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

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

R_o	$= r_{o2} \parallel r_{o4}$	$= 210.52$ kΩ	
g_{m2}	$= 2\sqrt{[K_n I_D]}$ $= 2\sqrt{[(k'_n/2)(W/L)_n(I_Q/2)]}$		[1]
	$=2\sqrt{[(100\mu/2)(5)(125\mu)]}$	$= 0.3535$ mA/V^2	[1]
A_d	$= g_{m2} R_o = (0.3535\text{m})(210.52\text{k})$	$= 74.43$	[1]

$CMRR_{dB}$	$= 20 \log [A_d / A_{cm}] = 65$ dB	[1]
A_{cm}	$= A_d / [10^{65/20}] = 0.04185$	[2]