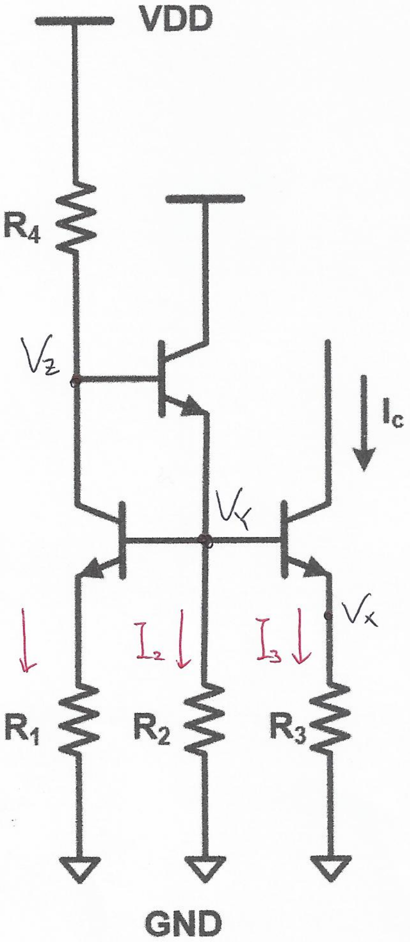
[1] Find the values of I_c. Assume that $R_1 = 1\text{k}\Omega$, $R_2 = 10\text{k}\Omega$, $R_3 = 1\text{k}\Omega$, $R_4 = 10\text{k}\Omega$, $V_{BE} = 0.7\text{V}$, $\beta = \infty$, and $V_{DD} = 10\text{V}$.



$V_x = I_c R_3 = 1k \cdot I_c$

$V_z = 1k \cdot I_c + 2 \times V_{BE} = 1k \cdot I_c + 1.4$ 5

$= VDD - I_c R_4 = 10 - 10k \cdot I_c$ 2

$11k \cdot I_c = 8.6$

$\therefore I_c = \frac{8.6}{11}\, mA$

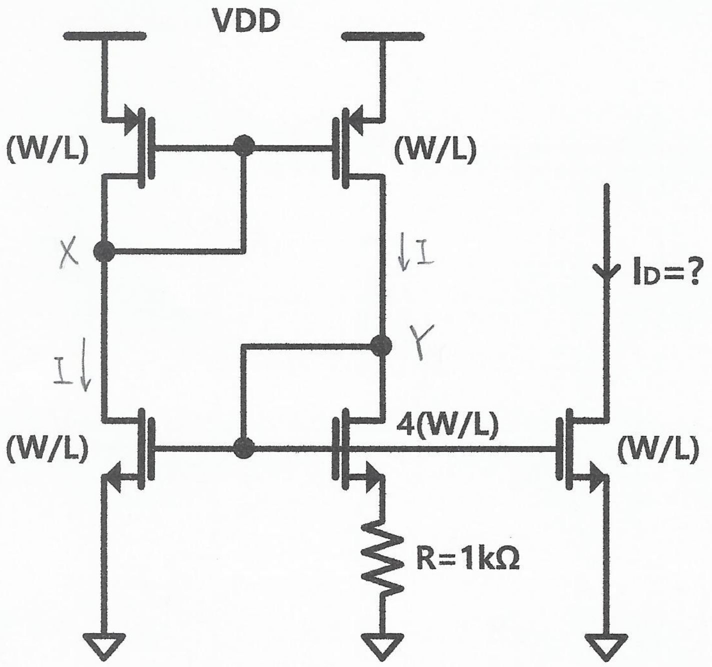
$\simeq 0.782\, mA$ 3

$I_1 = I_2 = I_3$ 로 놓고 풀 경우 0점

$(I_1 = I_3 \neq I_2)$

(같다고 가정하고 풀면 오순 발생)

[2] Find the value of I_D. Assume that $\left(\frac{W}{L}\right) = 10$, $\mu_n C_{OX} = \mu_p C_{OX} = 200\ \mu A/V^2$, $V_{th}=0.5V$, $\lambda=0$, and $V_{DD} = 2V$.



KCL @ node X : $\frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)(V_Y - V_{th})^2 = \frac{1}{2}\mu_p C_{ox}\left(\frac{W}{L}\right)(2 - V_X - |V_{th}|)^2 = I$

KCL @ node Y : $\frac{1}{2}\mu_n C_{ox}\cdot 4\left(\frac{W}{L}\right)\cdot(V_Y - IR - V_{th})^2 = \frac{1}{2}\mu_p C_{ox}\left(\frac{W}{L}\right)(2 - V_X - |V_{th}|)^2 = I$ ┘+3

위 식에 값을 대입하여 정리하면,

$$(1.5 - V_X)^2 = \overbrace{\underbrace{(V_Y - 0.5)^2 = 4\cdot(V_Y - 1000I - 0.5)^2}_{①} = 1000\cdot I}^{②}$$

① 로부터 $V_Y - 0.5 = 2(V_Y - 1000I - 0.5)$

②의 $1000I = (V_Y - 0.5)^2$을 위 식에 대입하여 정리하면, $(2V_Y - 1)(V_Y - 1) = 0$

$V_Y = 0.5$인 경우 $I = 0$이 되므로 가능한 $V_Y = 1\ (V)$ ┘+4

$\therefore I_D = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)\cdot(V_Y - V_{th})^2 = 0.25\ (mA)$ ┘+3

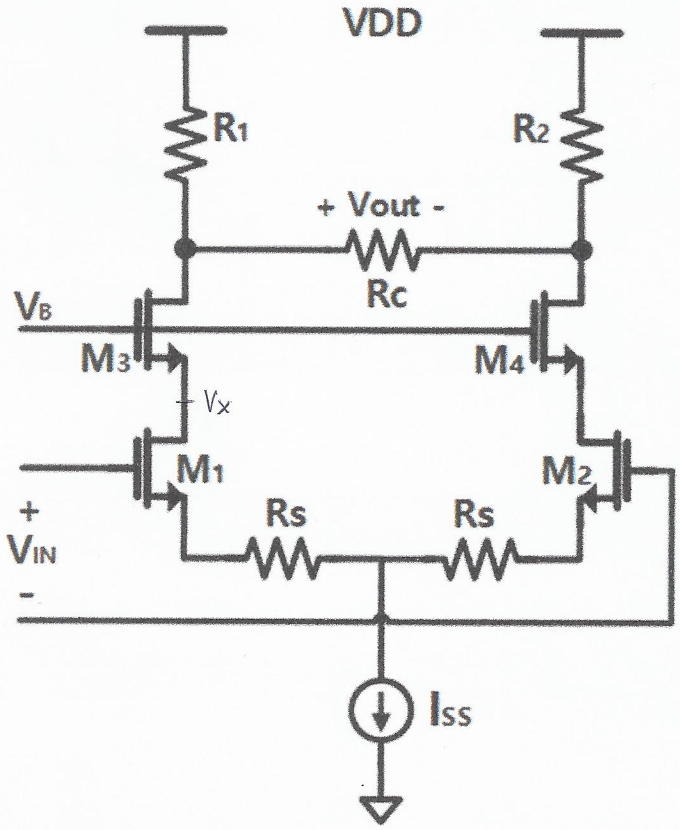
[3] For the following circuit, answer the questions.

Assume the circuit is symmetric and all MOS transistors are in the **saturation** region.

(Use $R_1=R_2=5k\Omega$, $R_C=20k\Omega$, $R_S=1k\Omega$, $V_{DD}=5V$, $I_{SS}=1mA$, $V_{thn}=0.4V$,

$g_{m1}=g_{m2}=1$ mA/V, neglect the channel legnth modulation. M_1,M_2,M_3 and M_4 are ideally identical.

The V_{IN} is the small signal with common mode voltage($V_{IN,CM}$=2V).)



✮ A번의 경우 문제에 오류가 있어 문제 채점기준은 완화하여 진행했습니다.

A. Find the V_B with the widest dynamic range of output.

원래정답 총 5점

$M_1 \to$ saturation.

$g_m = \frac{2I_D}{V_{OV}} \Rightarrow 1mA/V = \frac{2\times\frac{1}{2}\times10^{-3}A}{V_{OV}}$

$\therefore V_{OV} = 1V$.

$M_1, M_3 \to$ ideally identically

$M_1 \to V_{DS1} \geq V_{GS1} - V_{Th}$.

$\Rightarrow V_X \geq V_G - V_{Th} = 1.6V$; +2점

$V_{out} \geq V_B - V_{th}$.

$V_B = V_X + V_{ov} + V_{th}$

$= 1.6 + 1 + 0.4 = 3V$; +3점.

혹은. $V_B - V_{th} \leq V_{out}$.

$V_B \leq 2.9$ 도 정답 처리.

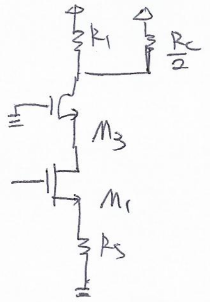
* 채점시 위의 2가지 방향으로 각각 풀이시 출제 의도를 곧장 했으면 2점(부분점수)

$V_B=2V$는 M_3가 아예 off되므로 오답.

B. Derive the expression of small-signal differential voltage gain from V_{in} to V_{out}.

Consider the channel length modulation. There is no need to find a value.

half circuit analysis



$A_V = -G_m \cdot R_{out}$

$= -\frac{g_{m1}}{1+g_{m1}R_S} \cdot \left(\frac{R_C}{2} \| R_1 \| g_{m1} \cdot g_{m3} \cdot r_{o1} \cdot r_{o3} \cdot R_S\right)$

① 부호, $\frac{V_{out}}{V_{in}} \Rightarrow ⊖$ 1점.

② $G_m \to$ 2점.

③ $R_{out} \to$ 2점 총 5점

* R_{out}의 경우 근사를 안해도 됨

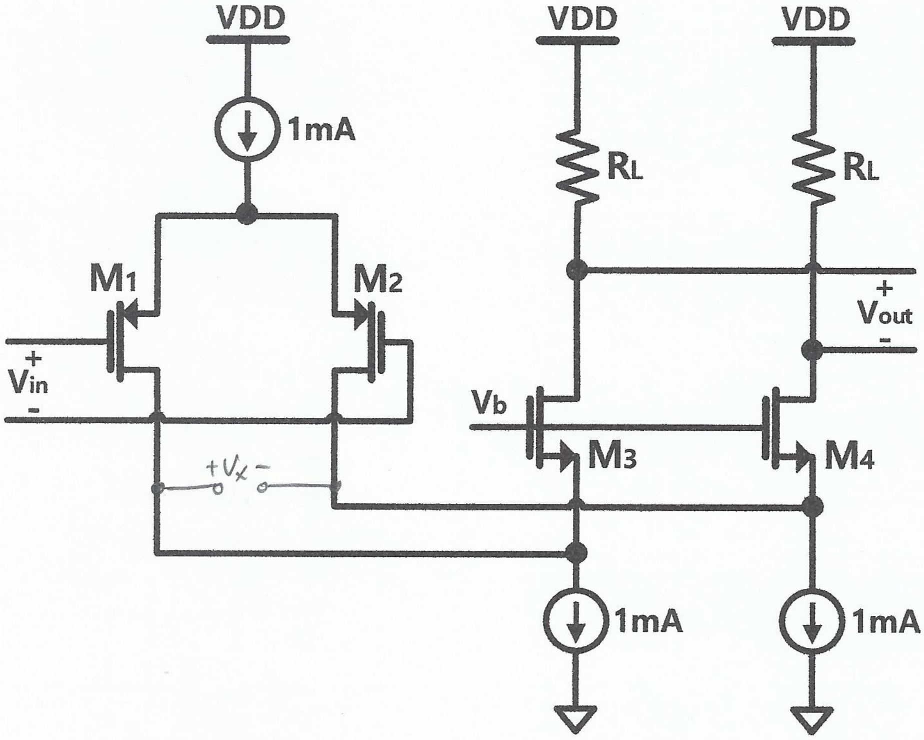
다만 channel length modulation을 고려하라 했기 때문에

$r_o = \infty$로 둔 경우는 오답

*2 stage로 나누어 푼 경우 1stage당 2점.

2stage 4점 + 부호 1점 = 5점

[4] Find the small signal gain $A_v(=\frac{V_{out}}{V_{in}})$. Assume that all transistors have the same $(\frac{W}{L})$ of 20, $\mu_n C_{ox}$ = 200 μ A/V², $\mu_p C_{ox}$ = 100 μ A/V², V_{th}=0.5V, $\lambda_n = 0.01V^{-1}$, $\lambda_P = 0.02V^{-1}$, R_L=2kΩ, and V_{DD} = 5V. Also assume that all MOS transistors are in the **saturation** region.



$$g_{m1,2} = \sqrt{2\mu_p C_{ox}\left(\frac{W}{L}\right) I_{D1}} = \sqrt{2}\ (mS)$$

$$r_{o1,2} = \frac{1}{\lambda_p I_{D1}} = 100\ (k\Omega) \quad \rfloor +1$$

$$g_{m3,4} = \sqrt{2\mu_n C_{ox}\left(\frac{W}{L}\right) I_{D3}} = 2\ (mS)$$

$$r_{o3,4} = \frac{1}{\lambda_n I_{D3}} = 200\ (k\Omega) \quad \rfloor +1$$

$$\frac{V_x}{V_{in}} = -g_{m1} \cdot \left\{ \left(\frac{r_{o3} + R_L}{1 + g_{m3} r_{o3}} \right) \| r_{o1} \right\} \quad \rfloor +4$$

$$\frac{V_{out}}{V_x} = g_{m3} (R_L \| r_{o3}) \quad \rfloor +2$$

$$\frac{V_{out}}{V_{in}} = -g_{m1} \cdot g_{m3} \cdot \left(\frac{r_{o3} + R_L}{1 + g_{m3} r_{o3}} \| r_{o1} \right) (R_L \| r_{o3})$$

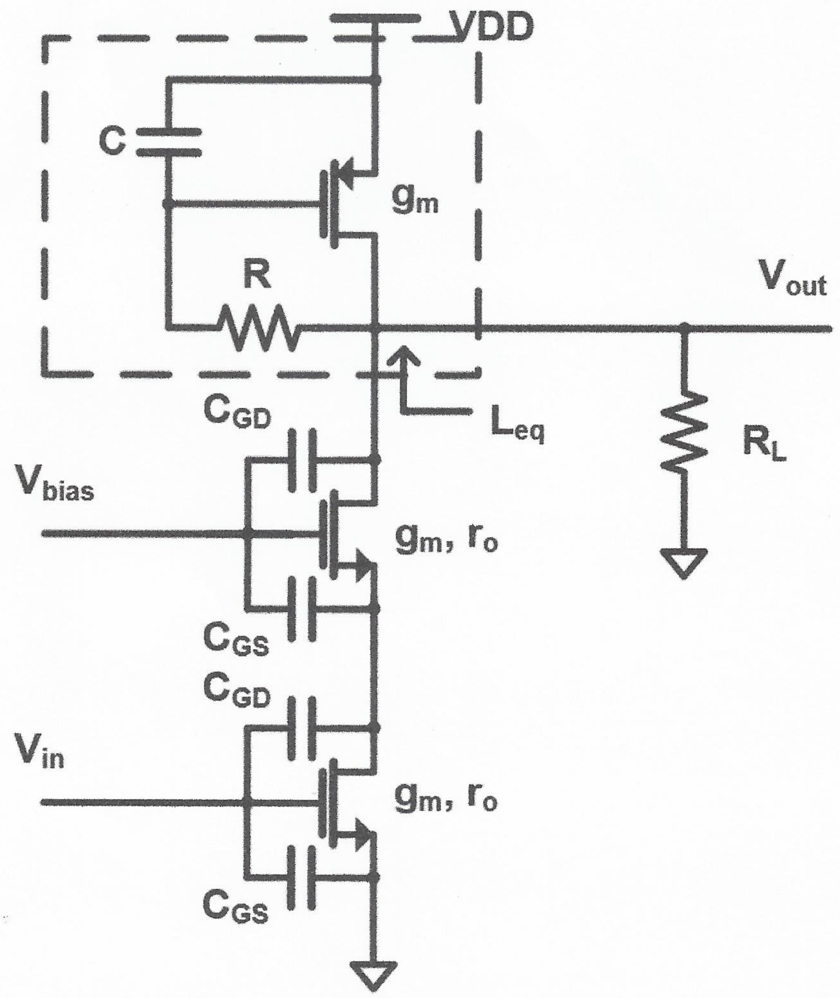
$$\approx -2.81 \quad \rfloor +2$$

gain 부호 틀릴 시 -1 점.

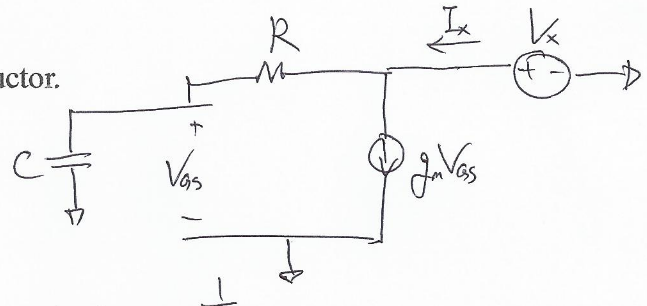
$\frac{V_x}{V_{in}} = -g_{m1} \cdot \frac{1}{g_{m3}}$ 로 근사하여 풀 경우 -2점.

단, 근사에 대한 타당한 근거가 있을 시 정답인정.

[5] For the following active inductor circuit, answer the questions.



A. Find L_{eq} of the active inductor.

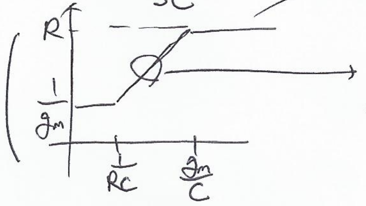


$$V_{GS} = \frac{\frac{1}{sC}}{R+\frac{1}{sC}} \cdot V_x$$

$$I_x = g_m V_{GS} + \frac{1}{R+\frac{1}{sC}} V_x = \frac{\frac{g_m}{sC}+1}{R+\frac{1}{sC}} V_x$$

3

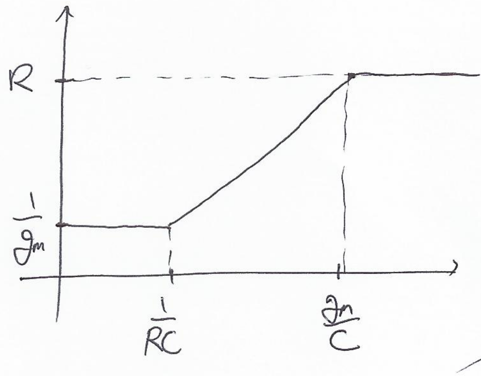
$$Z_x = \frac{1+sRC}{g_m + sC}$$



$$L_{eq} = \frac{RC}{g_m}$$

2

B. Find the frequency range where the active inductor becomes purely inductive.

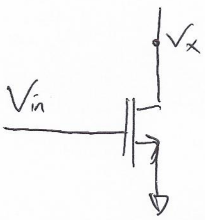


$$\frac{1}{RC} < \omega < \frac{g_m}{C}$$

2

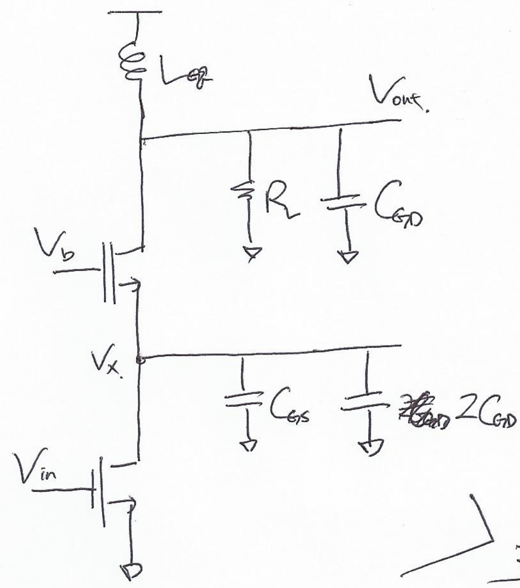
3

C. Find the transfer function of the above circuit.



$$\frac{V_x}{V_{in}} \simeq -g_m \cdot \frac{1}{g_m} = -1$$

Miller



3

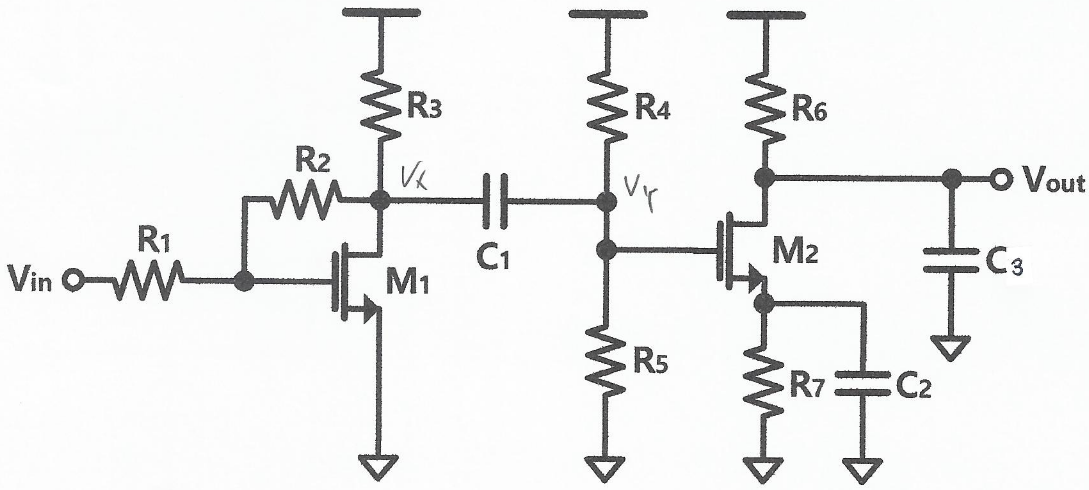
$$\frac{V_x}{V_{in}} = -g_m \left(\frac{1}{g_m} // \frac{1}{s(C_{GS}+2C_{GD})} \right)$$

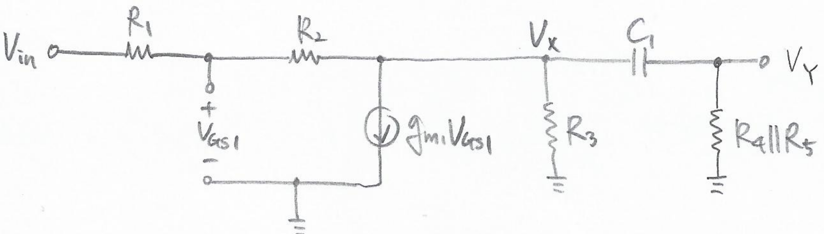
$$\frac{V_{out}}{V_x} = g_m \left(sL_{eq} // R_L // \frac{1}{sC_{GD}} \right)$$

$$\frac{V_{out}}{V_{in}} = -g_m^2 \left(\frac{1}{g_m} // \frac{1}{s(C_{GS}+2C_{GD})} \right) \left(sL_{eq} // R_L // \frac{1}{sC_{GD}} \right)$$

7

[6] For the following circuit, find the transfer function H(s) of the circuit and draw a Bode plot of H(s). Assume that $R_1=R_2=R_3=1k\Omega$, $R_4=R_5=100k\Omega$, $R_6=2.5k\Omega$, $R_7=1k\Omega$, $C_1=2pF$, $C_2=4pF$, $C_3=4pF$, $g_{m1}=2mS$, $g_{m2}=4mS$.





$$\begin{cases} g_{m1}V_{GS1} + \dfrac{V_X}{R_3} + sC_1(V_X - V_Y) + \dfrac{V_X - V_{GS1}}{R_2} = 0 \\ \dfrac{V_X - V_{GS1}}{R_2} = \dfrac{V_{GS1} - V_{in}}{R_1} \\ V_Y = \dfrac{(R_4 \| R_5)}{\frac{1}{sC_1} + (R_4\|R_5)} \cdot V_X \end{cases}$$

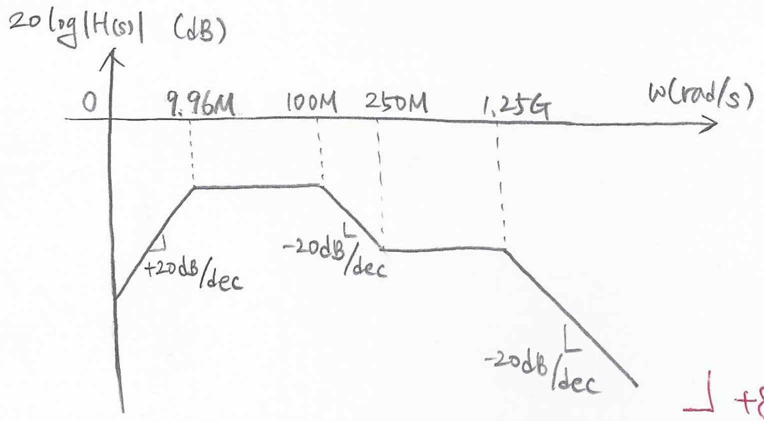
$$\Rightarrow \frac{V_Y}{V_{in}}(s) = -\frac{\dfrac{g_{m1}R_2 - 1}{R_1 + R_2}}{\dfrac{(g_{m1}R_2 - 1)R_1}{(R_1+R_2)R_2} + \dfrac{1}{R_2} + \dfrac{1}{R_3} + \dfrac{1}{\frac{1}{sC_1} + (R_4\|R_5)}} \cdot \frac{R_4\|R_5}{\frac{1}{sC_1} + (R_4\|R_5)}$$

$$= -\frac{s}{5\times10^7\left(1 + s/(9.96\times10^6)\right)}$$

한 편, $\dfrac{V_{out}}{V_Y}(s) = -\dfrac{\frac{1}{sC_3} \| R_6}{\frac{1}{g_{m2}} + \left(\frac{1}{sC_2}\|R_7\right)} = -\dfrac{2\left(1+s/(2.5\times10^8)\right)}{\left(1+s/(1.25\times10^9)\right)\left(1+s/10^8\right)}$

$$\therefore H(s) = \frac{V_{out}}{V_{in}}(s) = \frac{V_X}{V_{in}}(s) \cdot \frac{V_Y}{V_X}(s) = \frac{4\times10^{-8} \cdot s \cdot \left(1+s/(2.5\times10^8)\right)}{\left(1+s/(9.96\times10^6)\right)\left(1+s/(1.25\times10^9)\right)\left(1+s/10^8\right)}$$

+12 ($\frac{V_Y}{V_{in}}$: 8점 $\frac{V_{out}}{V_Y}$: 4점)



+8
축 및 단위 표시 −1
기울기 표시 −1
pole, zero 위치 −1 씩

[7] Fill in the table. Assume that $g_m = \infty$.

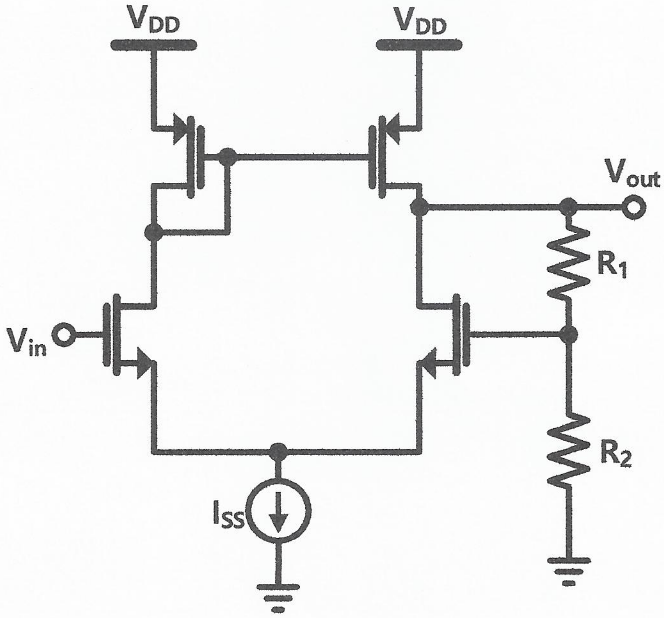


Fig A

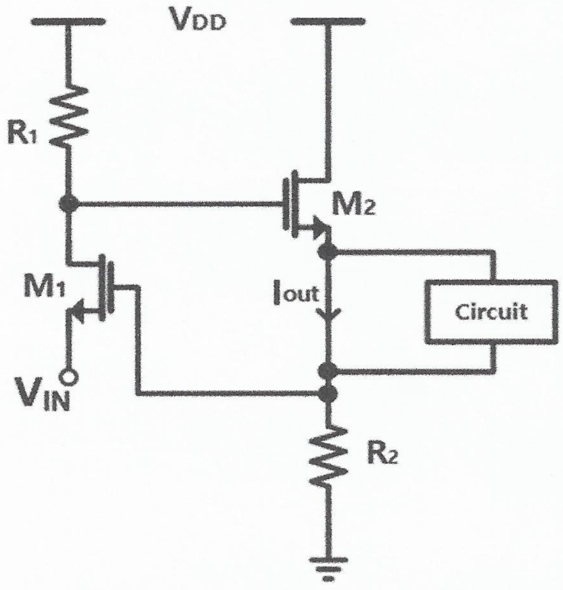


Fig B

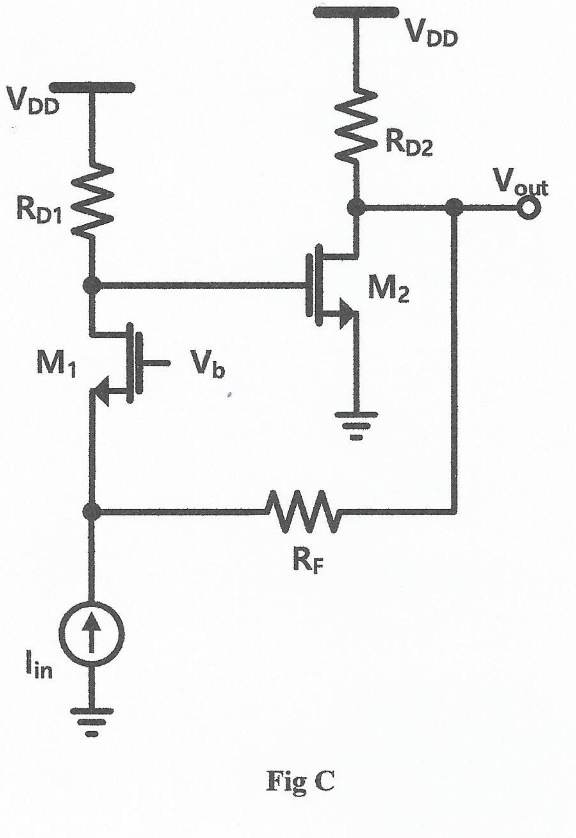


Fig C

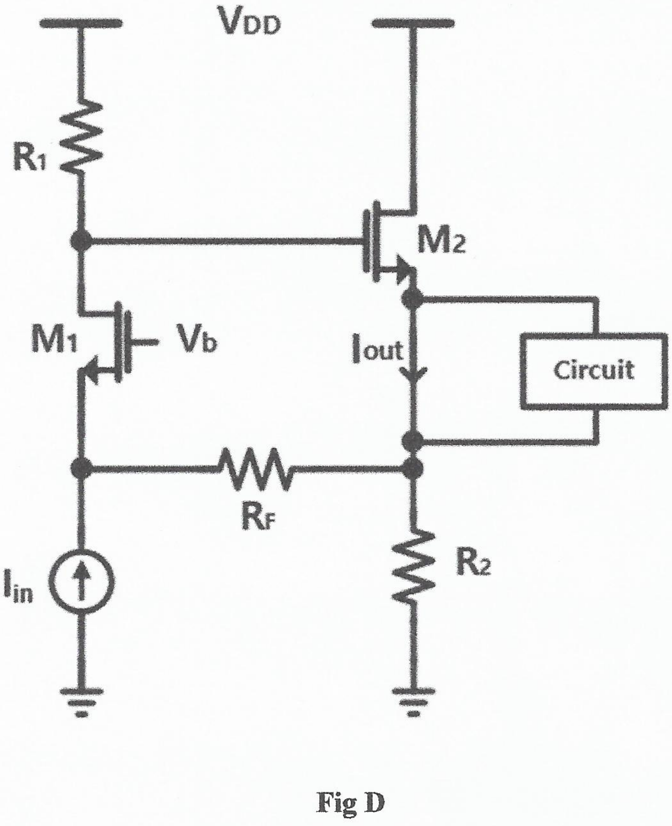


Fig D

	Fig A	Fig B	Fig C	Fig D
Feedback Topology	Voltage to Voltage	current to voltage	voltage to current	current to current
Type of Amplifier	voltage amp	trans conductance	trans impedance or trans resistance.	Current Amplifier
Open-loop Gain	∞	∞	$-\infty$	$\frac{R_1}{R_2 \parallel R_F}$
Feedback Factor	$\frac{R_2}{R_1 + R_2}$	R_2	$-\frac{1}{R_F}$	$\frac{-R_2}{R_F + R_2}$
$R_{in\text{-}open}$	∞	0	0	0
$R_{in\text{-}closed}$	∞	R_1	0	0
$R_{out\text{-}open}$	R_1+R_2. or $(R_1+R_2) \parallel r_{oN} \parallel r_{op}$	R_2	$R_{D2} \parallel R_F$ or $R_{D2} \parallel R_F \parallel r_{ON}$	$R_2 \parallel R_F$
$R_{out\text{-}closed}$	0	∞	0	$(R_2 \parallel R_F) \cdot (1 - \frac{R_1}{R_F})$

{End of Midterm }

빈칸 한개당 1점

부호 틀리면 0점

Rout-open의 경우 $r_{ON} = r_{op} = r_o$ 라 하고 채점.

ex) 즉 $(R_1+R_2) \parallel r_{oN} \parallel r_{op}$ 도 되고 $(R_1+R_2) \parallel r_o \parallel r_o$ 도 된다함.