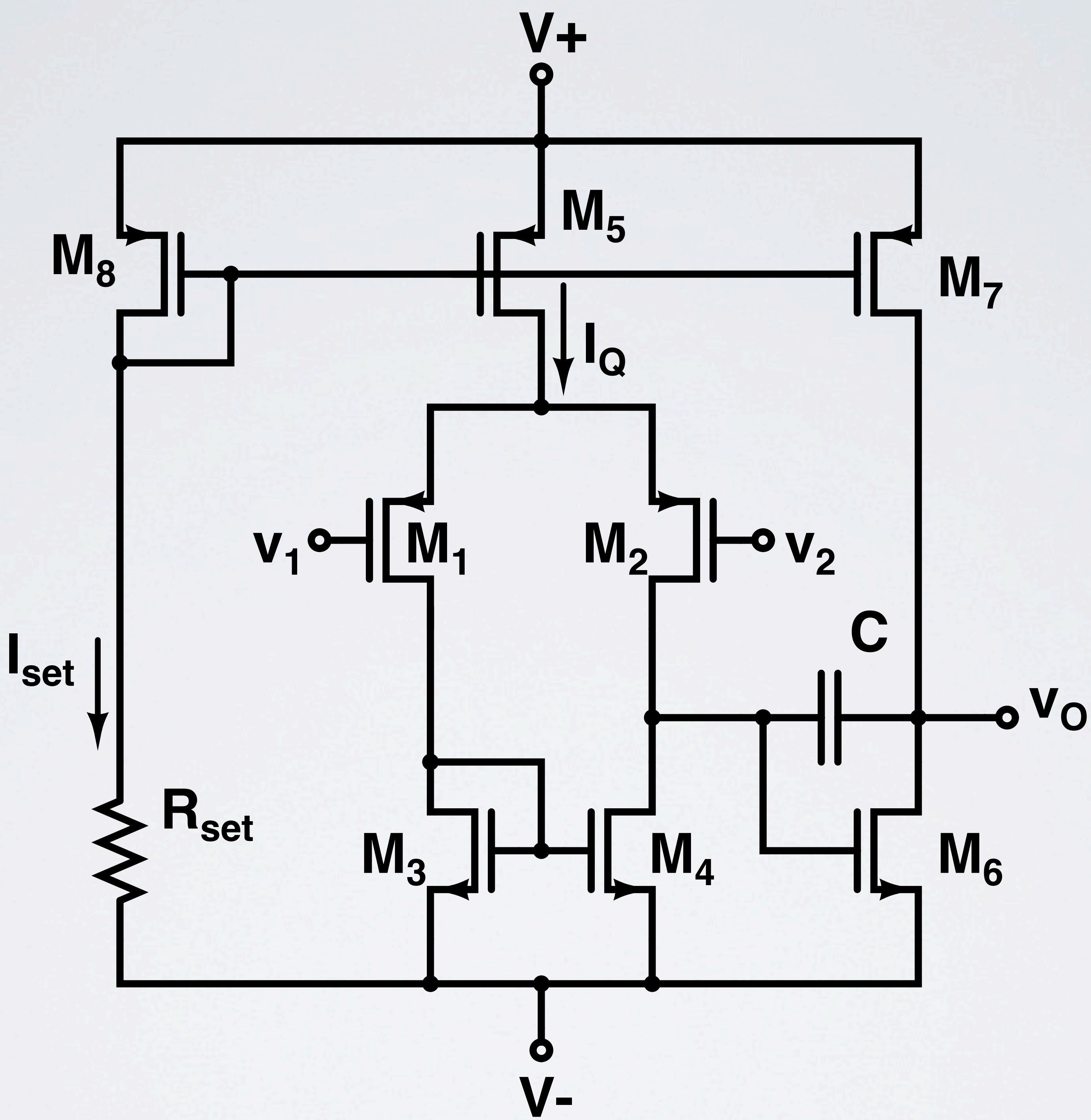
CMOS OPAMPS

INEL4202 Electronics II

MC14573



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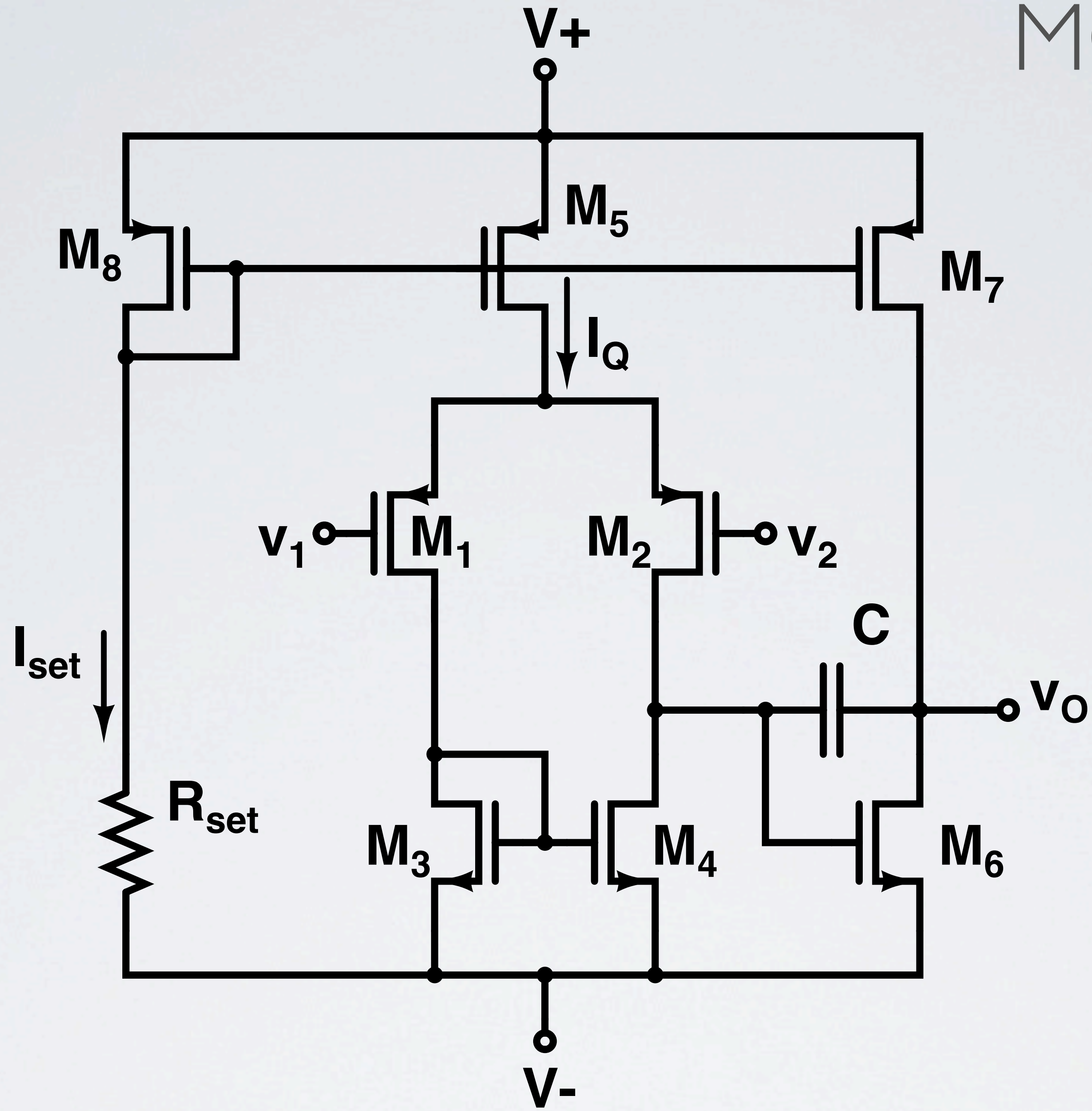

<u>Example:</u> Find DC bias current when V_{TN}=0.5V, ½$\mu_n C_{ox}$=20uA/V^2, λ_n=0.02V^{-1}, V_{TP}=−0.5V, ½$\mu_p C_{ox}$=10uA/V^2, λ_p=0.02V^{-1}, R_{SET}=225kΩ,$(W/L)_3$=$(W/L)_4$=6.25, $(W/L)_{OTHER}$=12.5, V+=5V, V−=−5V.

<u>Example:</u> Find gain.

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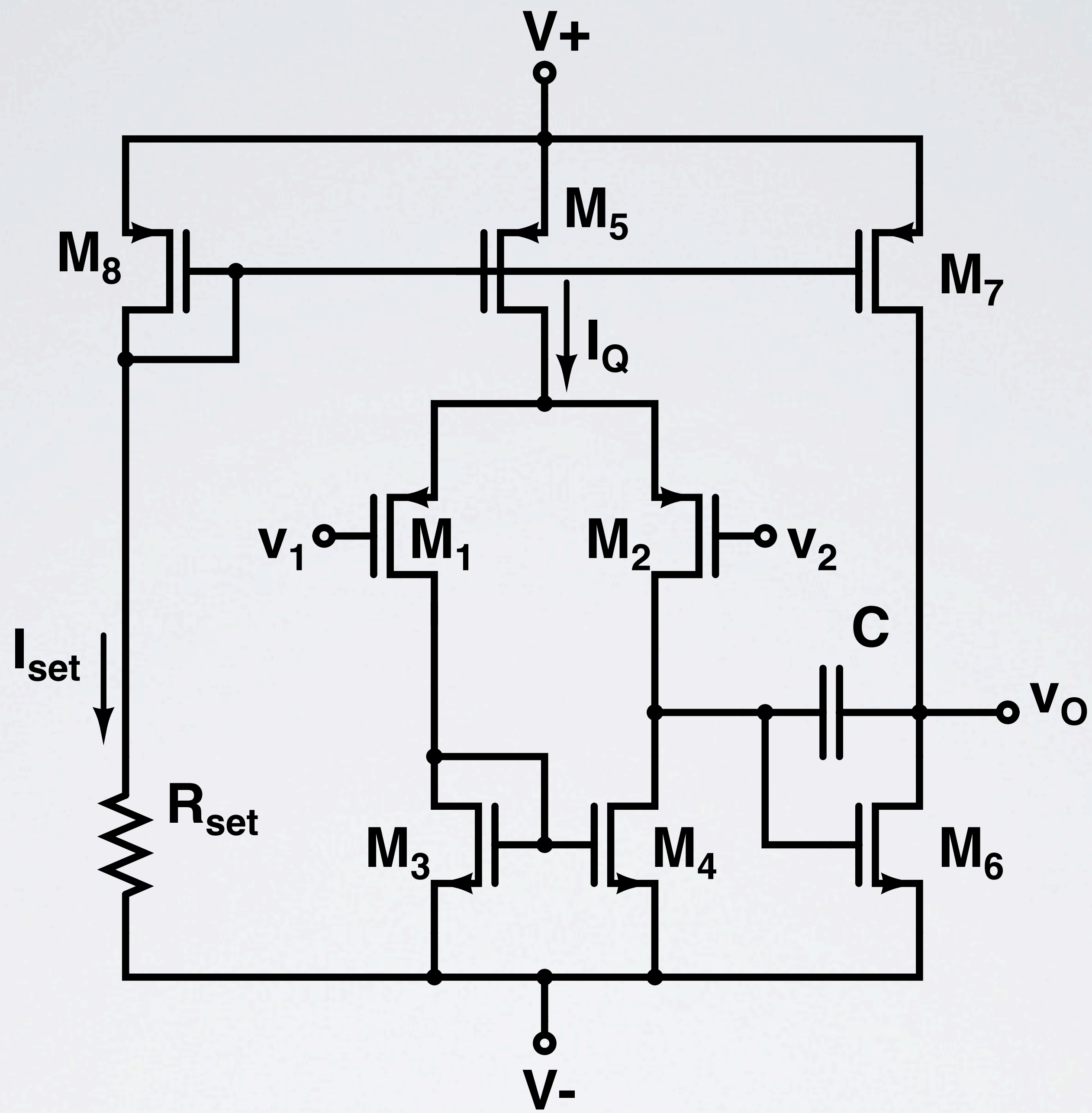
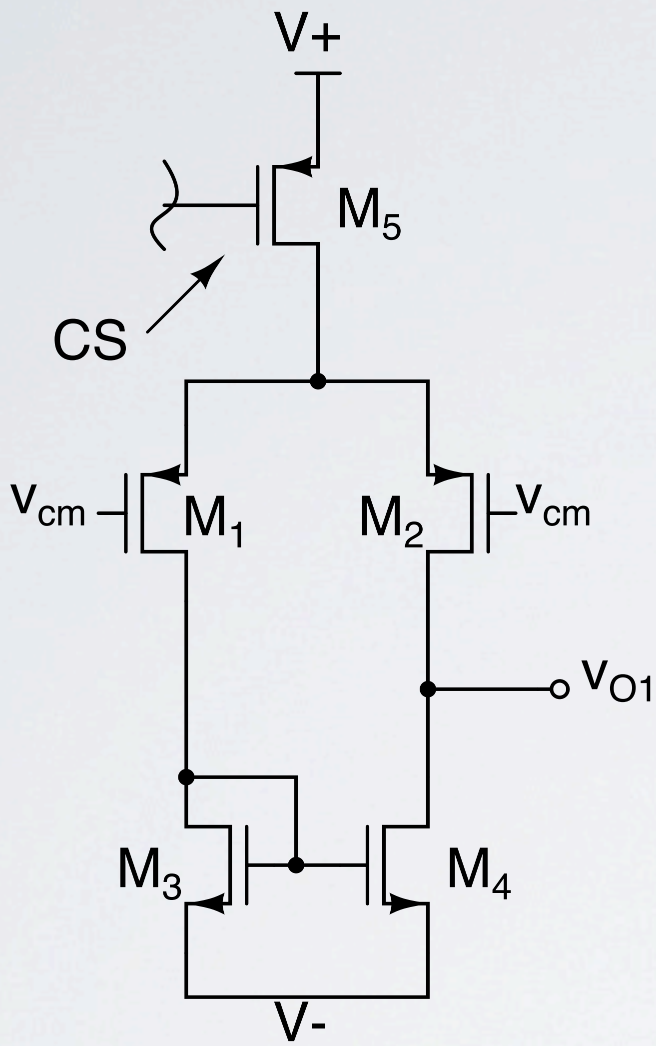
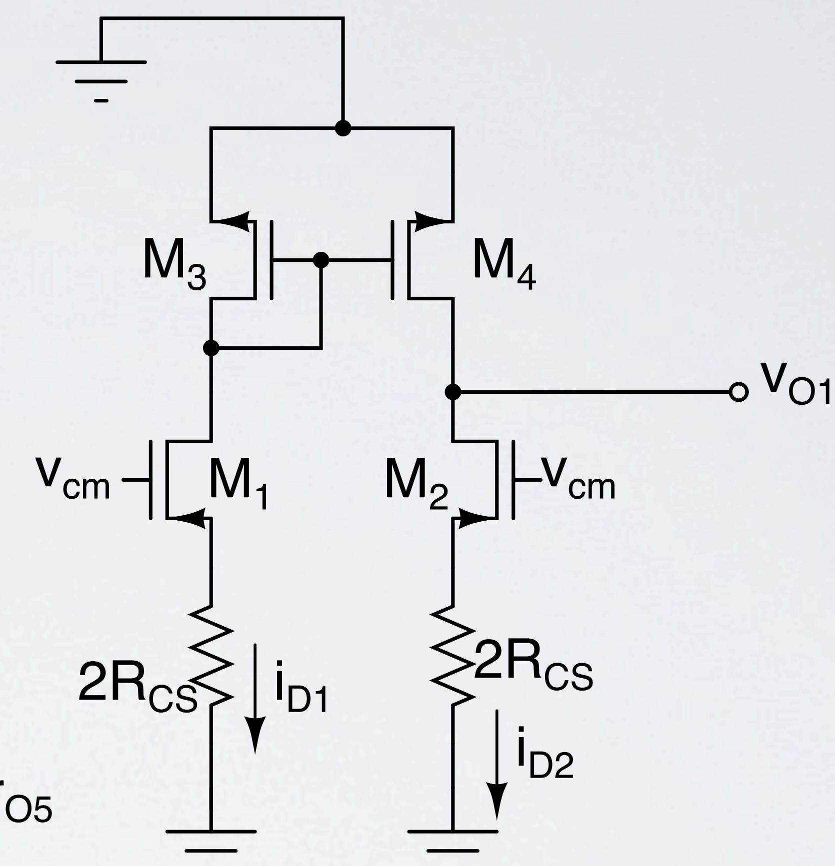


<u>Example 13.8:</u> Find DC bias current when V_{TN}=0.5V, ½$\mu_n C_{ox}$=20uA/V^2, λ_n=0.02V^{-1}, V_{TP}=−0.5V, ½$\mu_p C_{ox}$=10uA/V^2, λ_p=0.02V^{-1}, R_{SET}=225kΩ,$(W/L)_3$=$(W/L)_4$=6.25, $(W/L)_{OTHER}$=12.5, V+=5V, V−=−5V. (ANSWER: I_{REF}=39.7uA)
<u>Example 13.9:</u> Find gain. (ANSWER: A_v=(125)(125)=15,625)

A_{CM} for differential stage with active load due to and error $\boldsymbol{\varepsilon}$ in K (for example, $(W/L)_1 = (1+\boldsymbol{\varepsilon})\,(W/L)_2$)



$R_{CS} = r_{O5}$



small-signal equivalent ckt.
i_{D1} is the incremental drain current

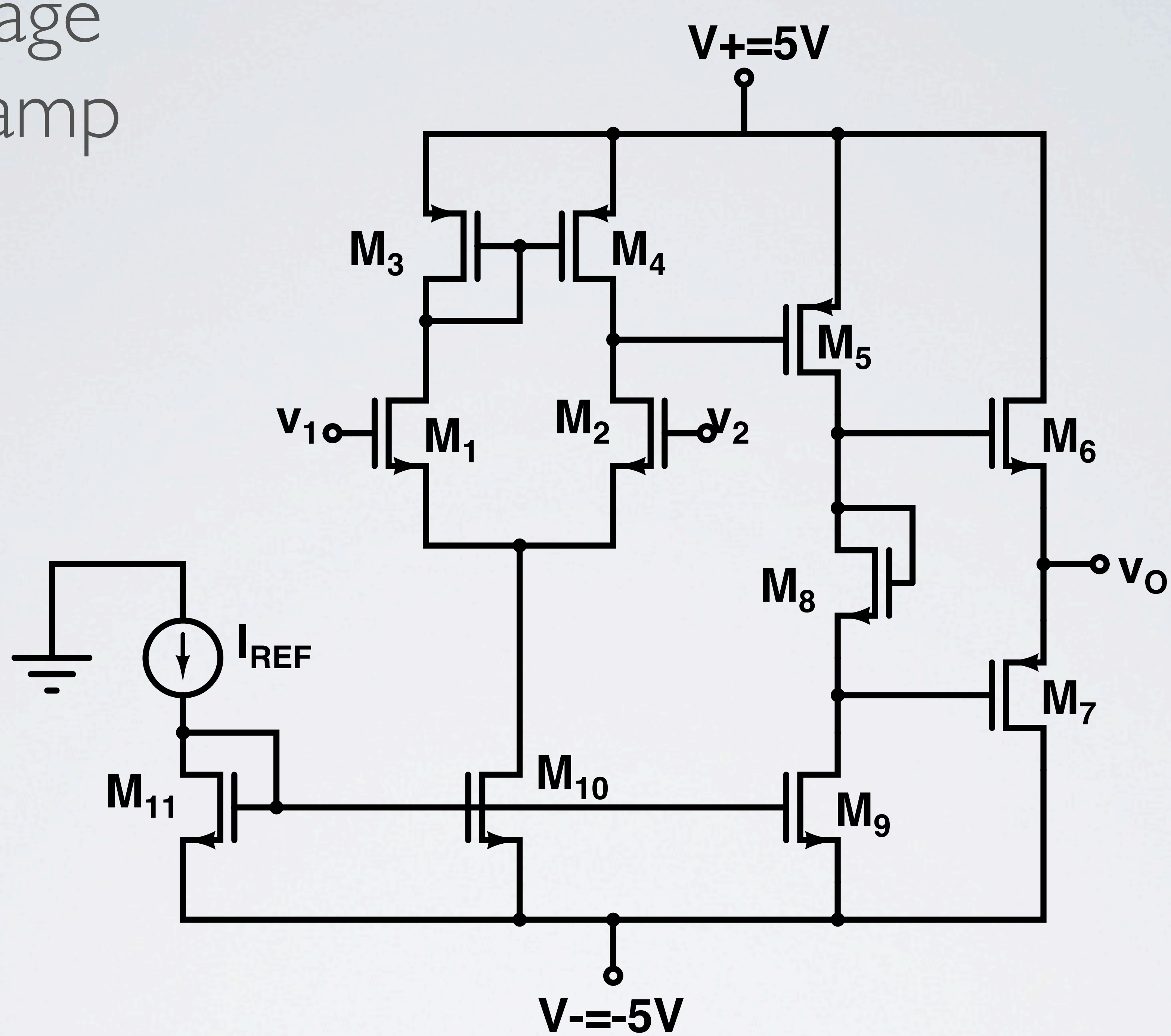
A_{CM} for differential stage with active load due to and error ϵ in K (for example, $(W/L)_1 = (1+\epsilon)(W/L)_2$)

$$
\begin{aligned}
i_{d,1} &= g_{m1} v_{gs,1} \\
v_{gs,1} &= v_{g,1} - v_{s,1} \\
v_{g,1} &= v_{cm} \\
v_{s,1} &= 2R_{CS} \times i_{d,1} \\
i_{d,1} &= g_{m1}\left(v_{cm} - 2R_{CS} \times i_{d,1}\right) \\
i_{d,1}\left(1 + g_{m1} 2R_{CS}\right) &= g_{m1} v_{cm} \\
i_{d,1} &= \frac{g_{m1} v_{cm}}{1 + g_{m1} 2R_{CS}} \\
i_{d,2} &= \frac{g_{m2} v_{cm}}{1 + g_{m2} 2R_{CS}} \\
g_{m1} &= g_{m2}\left(1+\epsilon\right) \\
i_{o,1} &= i_{d,1} - i_{d,2} = \frac{g_{m2}\left(1+\epsilon\right) v_{cm}}{1 + g_{m2}\left(1+\epsilon\right) 2R_{CS}} - \frac{g_{m2} v_{cm}}{1 + g_{m2} 2R_{CS}} \\
v_{o,1} &= i_{o,1}\left(r_{o4} \| r_{o2}\right)
\end{aligned}
$$

If $2g_{m2}\epsilon R_{CS} \ll 1$, (or equivalently, $\epsilon \ll \frac{1}{2g_{m2}R_{CS}}$)

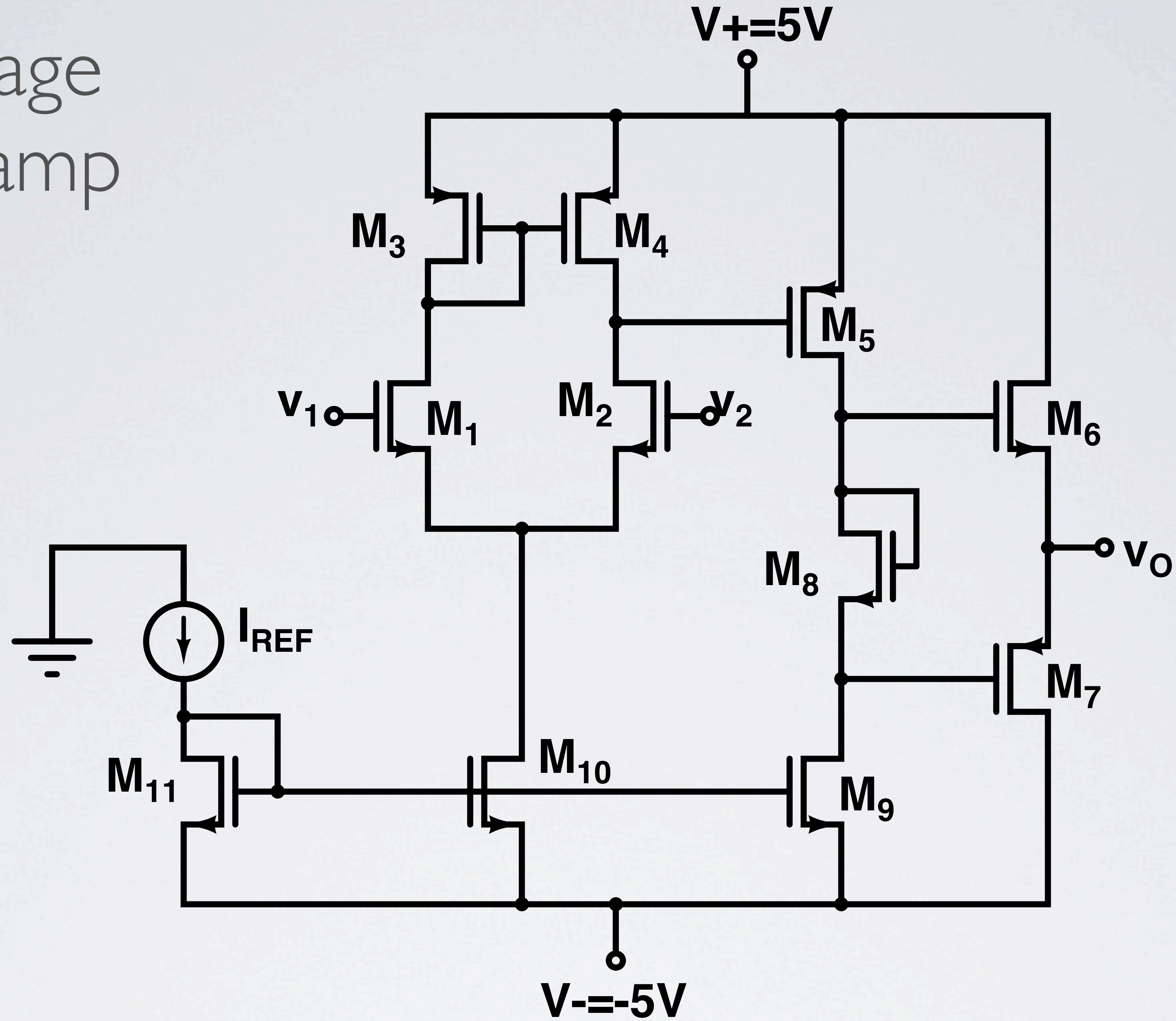
$$
\begin{aligned}
i_{o,1} &\simeq \frac{g_{m2}\epsilon v_{cm}}{1 + g_{m2} 2R_{CS}} \\
A_{cm,1} &= \frac{v_{o,1}}{v_{cm}} = \frac{g_{m2}\epsilon\left(r_{o4} \| r_{o2}\right)}{1 + g_{m2} 2R_{CS}} \Rightarrow CMRR = \frac{1 + g_{m2} 2R_{CS}}{\epsilon}
\end{aligned}
$$

Three-stage cmos opamp



Example 13.10: Find DC and AC characteristics. $V_{TN}=0.7V$, $k_n'=80uA/V^2$, $\lambda_n=0.01V^{-1}$, $V_{TP}=-0.7V$, $k_P'=40uA/V^2$, $\lambda_p=0.015V^{-1}$, $I_{REF}=160\mu A$, $(W/L)_1=(W/L)_2=15/1$, $(W/L)_3=(W/L)_4=40/1$, $(W/L)_5=80/1$, $(W/L)_6=25/1$, $(W/L)_7=50/1$, $(W/L)_9=(W/L)_{10}=(W/L)_{11}=20/1$. Select $(W/L)_8$ so that $V_{GS6}=V_{GS7}=0.85V$.

Three-stage cmos opamp



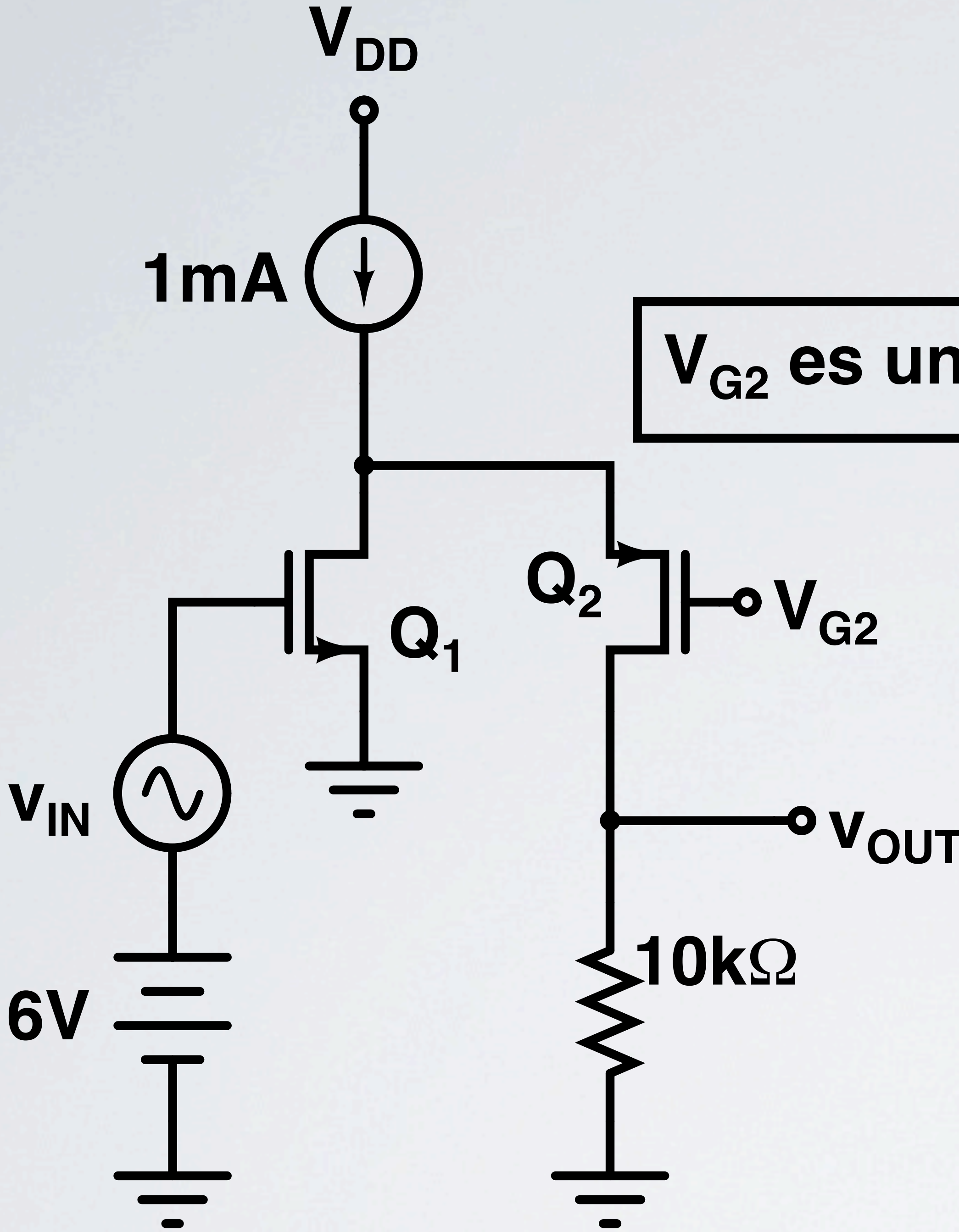
Example: Find DC and AC characteristics. V_{TN}=0.7V, k_n'=80uA/V^2, λ_n=0.01V^{-1}, V_{TP}=−0.7V, k_P'=40uA/V^2, λ_p=0.015V^{-1}, I_{REF}=160μA, $(W/L)_1$=$(W/L)_2$=15/1, $(W/L)_3$=$(W/L)_4$=40/1, $(W/L)_5$=80/1, $(W/L)_6$=25/1, $(W/L)_7$=50/1, $(W/L)_9$=$(W/L)_{10}$=$(W/L)_{11}$=20/1. Select $(W/L)_8$ so that V_{GS6}=V_{GS7}=0.85V.

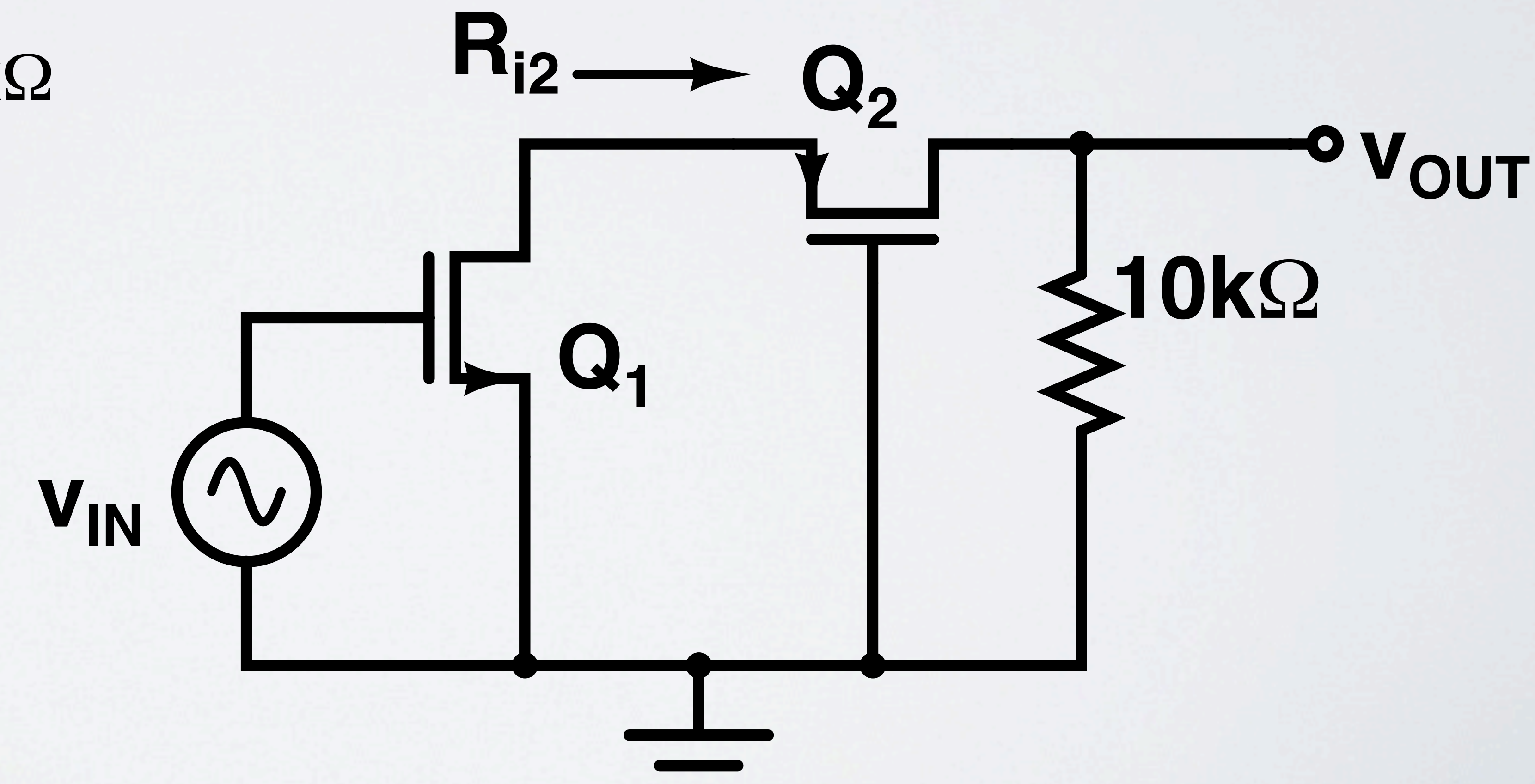
ANSWER: $(W/L)_8$ = 4; I_{D6}=I_{D7}=22.5uA; A_v=(219)(−253)=−55407 V/V.

$K_{n,p} = 20mA/V$

$V_{Tn} = -V_{TP} = 1V$

V_{G2} es un voltaje DC

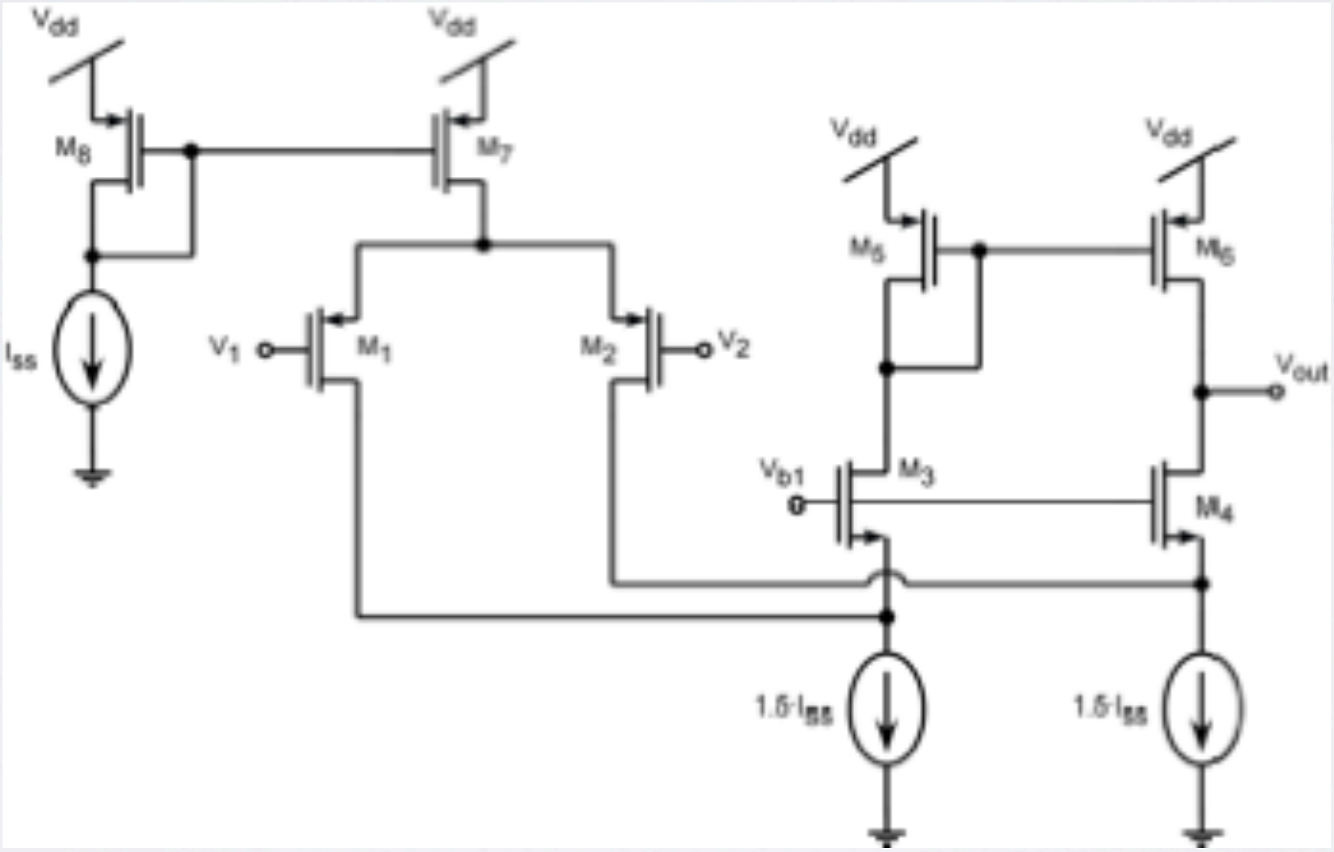




For the following CMOS amplifier, where V_{b1} and V_{b2} are DC voltages for proper operation of the circuit:

a) identify the negative and the positive terminals
b) find the expression for the differential gain $A_{id}=V_{out}/V_{id}$
c) find the expression for the differential input resistance R_{ind}
d) find the expression for the output resistance R_{out}

Assume: I_{ss} = ideal current source



III. For the following CMOS amplifier, where V_{b1} and V_{b2} are DC voltages for proper operation of the circuit:

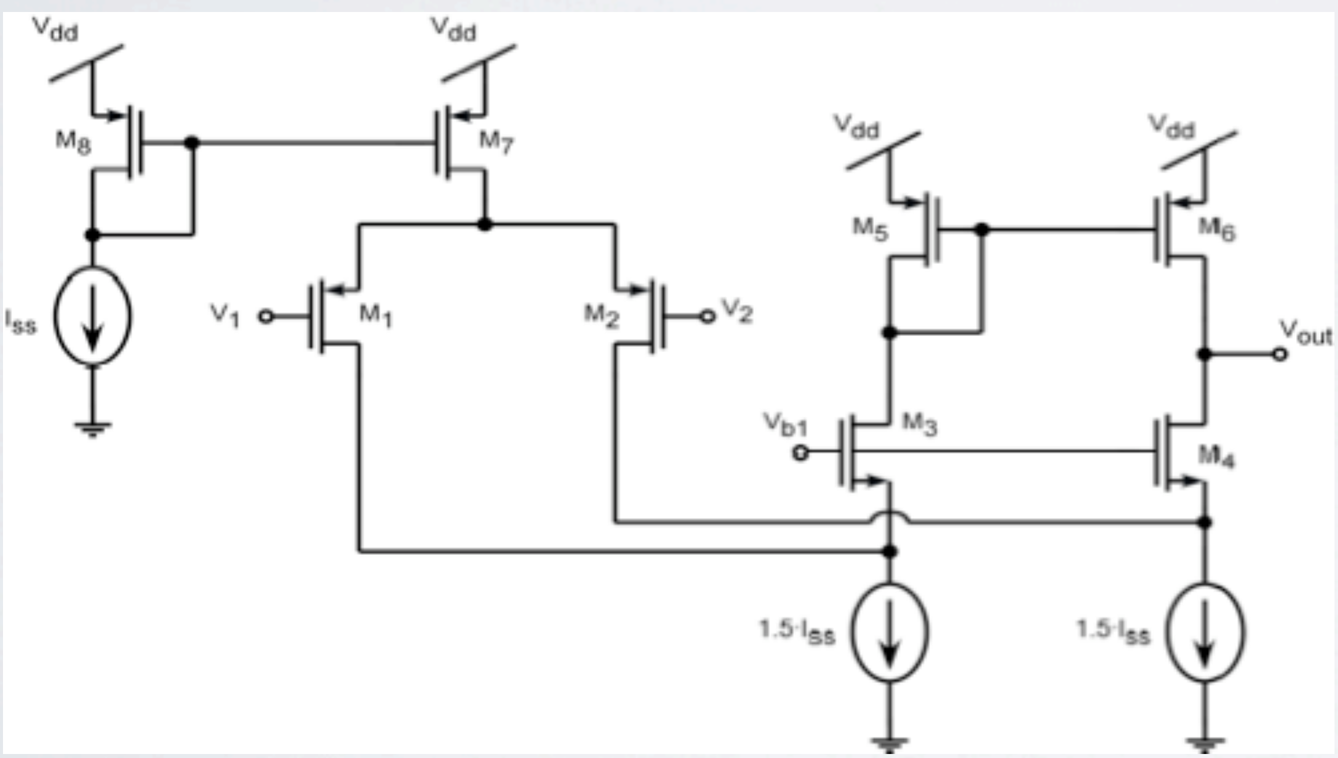
a) identify the negative and the positive terminals
b) find the expression for the differential gain $A_{id}=V_{out}/V_{id}$
c) find the expression for the differential input resistance R_{ind}
d) find the expression for the output resistance R_{out}

Assume: I_{ss} = ideal current source

a)

$v_1 \uparrow \Rightarrow i_{d1} \uparrow \Rightarrow i_{d5} \downarrow \Rightarrow i_{d6} \downarrow$

$\therefore v_1$ is + ; v_2 is -



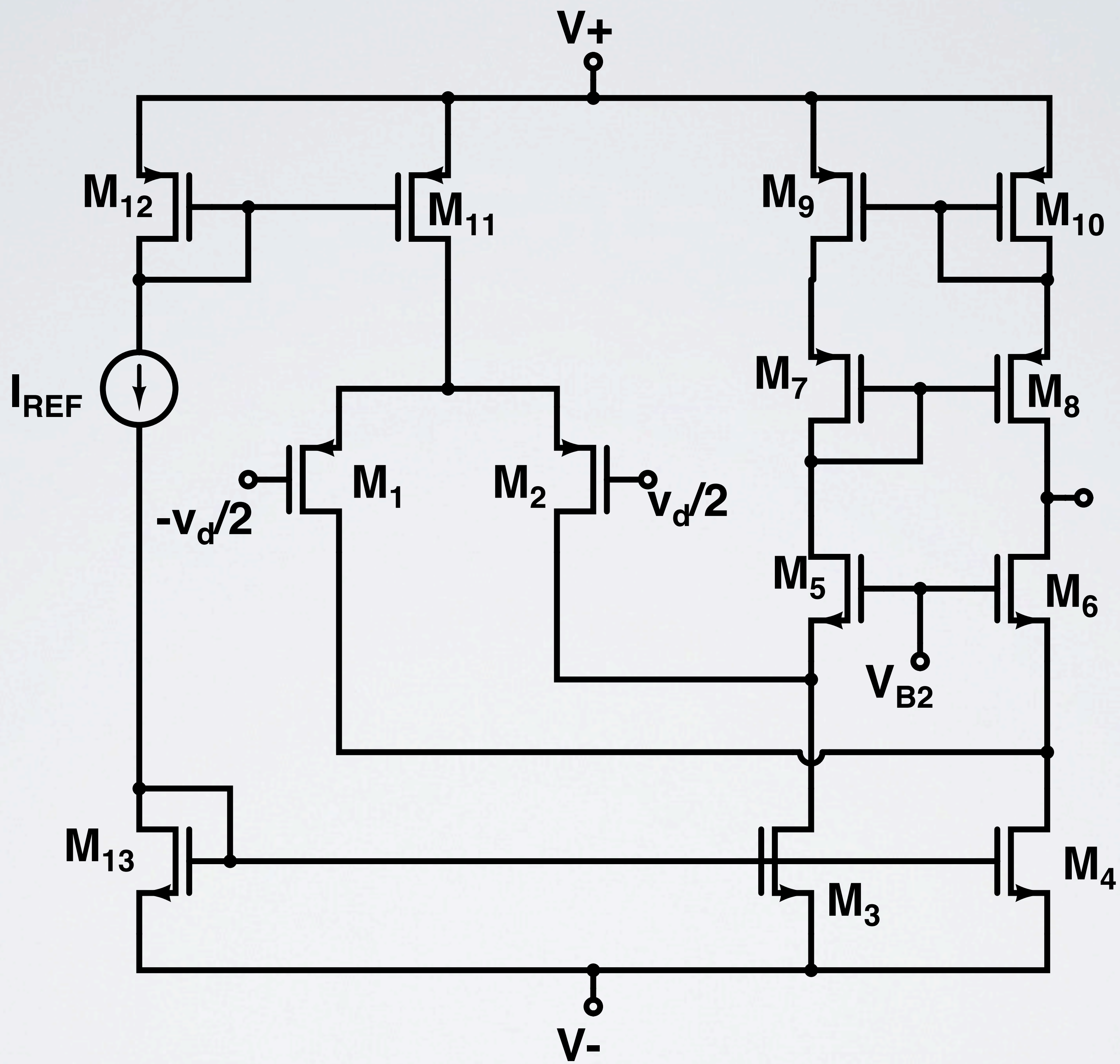
b)

$$
\begin{aligned}
A_{id} &= \frac{v_{OUT}}{v_{id}} = g_{m1} R_O \\
R_O &= r_{O6} \| r_{O4}\left(1 + g_{m4} r_{O2}\right) \\
g_{m1} &= 2\sqrt{K_P I_{SS}/2} \qquad g_{m4} = 2\sqrt{K_N I_{SS}} \\
r_{O6} &= \frac{1}{\lambda_{P6} I_{SS}} \qquad r_{O2} = \frac{2}{\lambda_{P2} I_{SS}} \\
r_{O4} &= \frac{1}{\lambda_{N4} I_{SS}}
\end{aligned}
$$

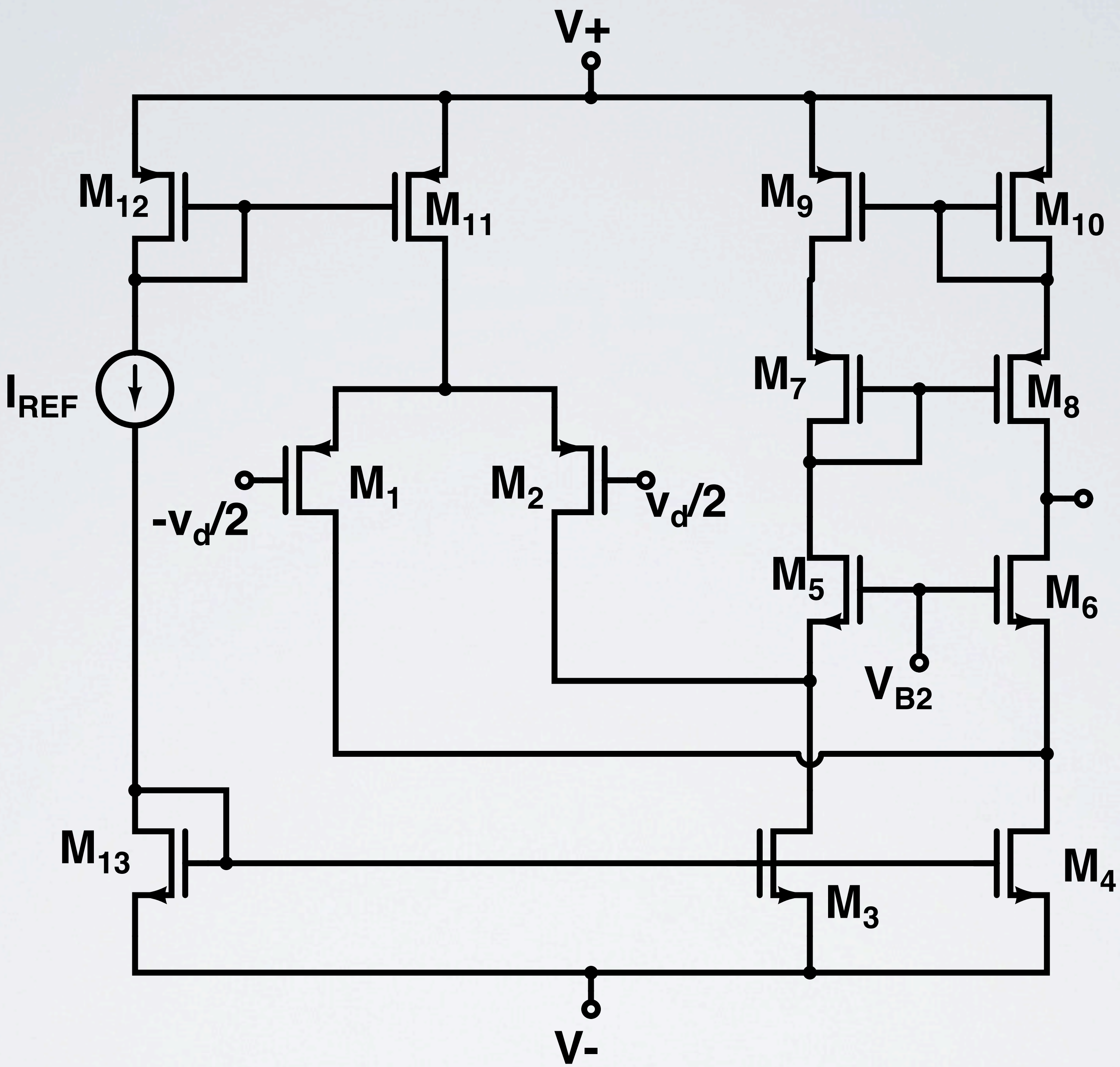
c) $R_{ind} = \infty$

d)

$$
\begin{aligned}
R_O &= r_{O6} \| r_{O4}\left(1 + g_{m4} r_{O2}\right) \\
g_{m1} &= 2\sqrt{K_P I_{SS}/2} \qquad g_{m4} = 2\sqrt{K_N I_{SS}} \\
r_{O6} &= \frac{1}{\lambda_{P6} I_{SS}} \qquad r_{O2} = \frac{2}{\lambda_{P2} I_{SS}} \\
r_{O4} &= \frac{1}{\lambda_{N4} I_{SS}}
\end{aligned}
$$



Example: I_{REF}=100uA, k_n'=80uA/V^2, K_p'=40uA/V^2,(W/L)=25, y $\lambda_n=\lambda_p=0.02V^{-1}$.
Find voltage gain.



<u>Example:</u> I_{REF}=100uA, k_n'=80uA/V^2, K_p'=40uA/V^2,(W/L)=25, y $\lambda_n=\lambda_p=0.02V^{-1}$.
Find voltage gain. (ANSWER: A_d=32000)