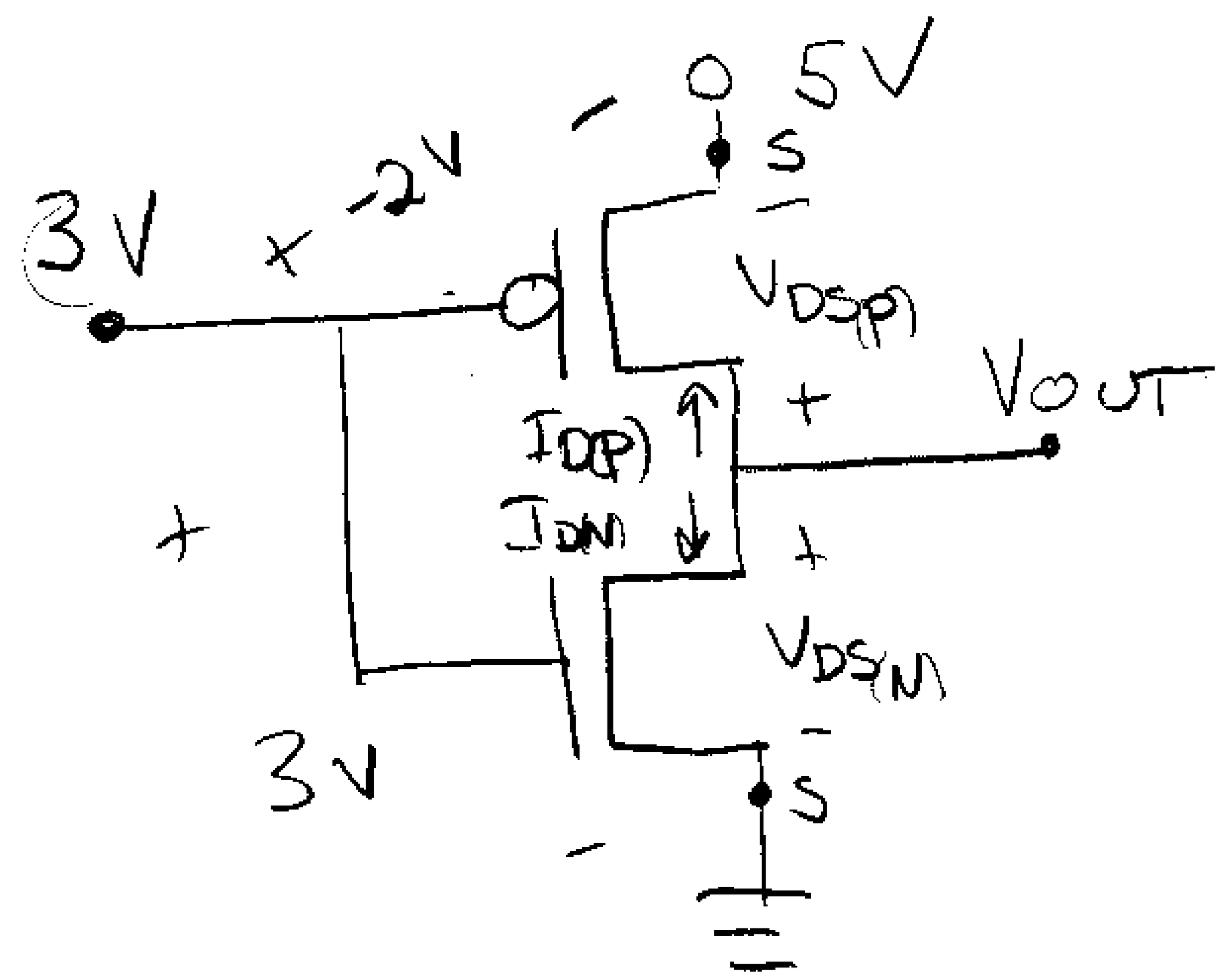
Lecture 22



$W/L\, \mu_n C_{ox} = W/L\, \mu_p C_{ox} = 1\,mA/V^2$

$\lambda_n = \lambda_p = 0\ V^{-1}$

$V_{TH(n)} = 1V \qquad V_{TH(p)} = -1V$

Find V_{OUT}.

$-V_{DS(N)} + V_{DS(P)} + 5V = 0 \qquad I_{D(P)} + I_{D(N)} = 0$

Probably Region D: NMOS triode, PMOS saturation

$I_{D(P)} = -1\,mA/V^2 \cdot \frac{1}{2} \cdot (-2V - -1V)^2 = -\frac{1}{2}\,mA$

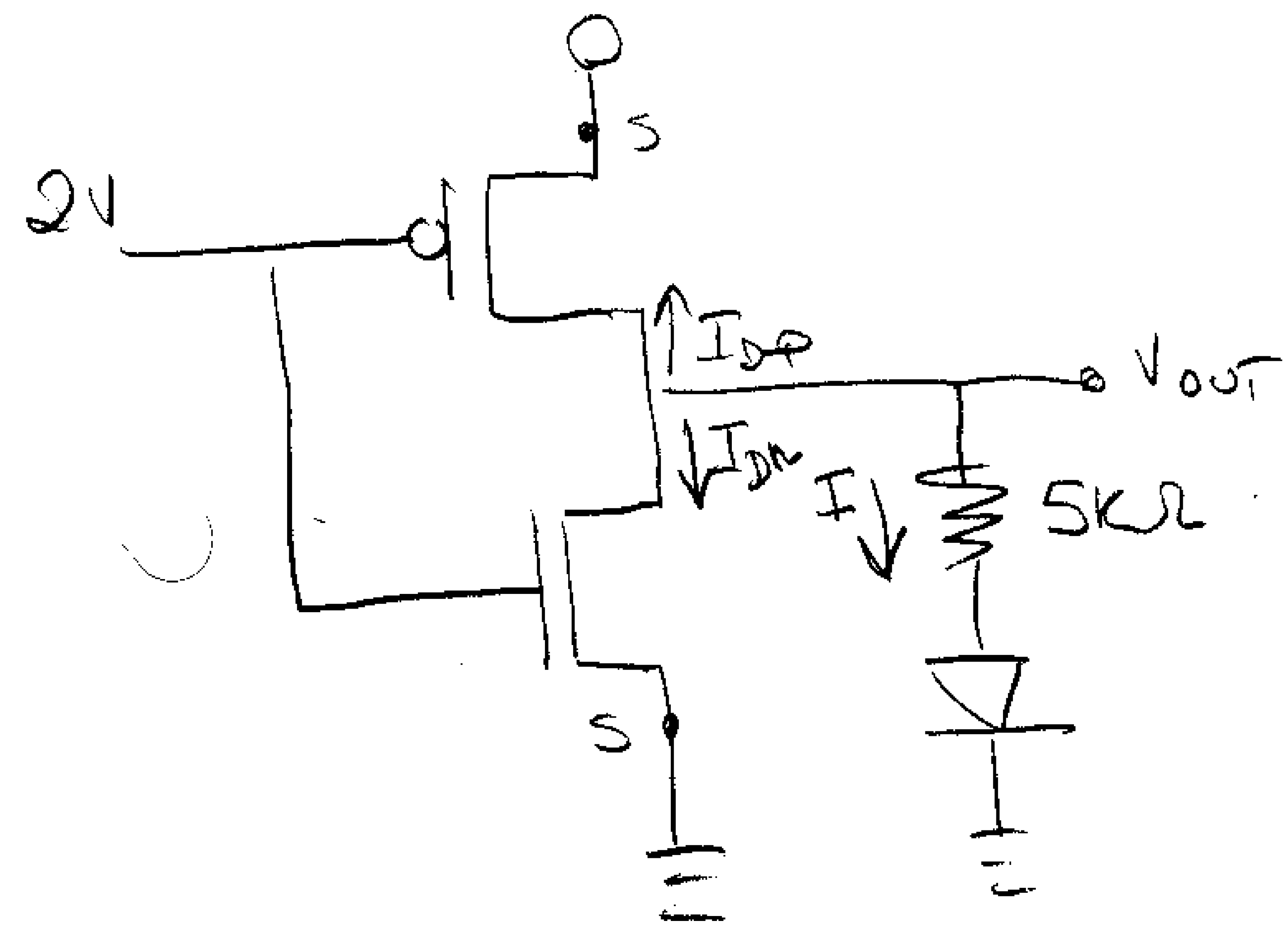
$I_{D(N)} = 1\,mA/V^2 \cdot \left(3V - 1V - \frac{V_{DS(n)}}{2}\right) V_{DS(n)}$

$= -I_{D(P)} = \frac{1}{2}\,mA$

$V_{DS(n)} = \{0.27, 3.73\} \qquad 0.27\,V$ ok for triode

$V_{DS(P)} = V_{DS(n)} - 5V = -4.73\,V$ ok for saturation

$V_{OUT} = 0.27\ V$



$V_{GS(n)} = 2V \quad V_{GS}(p) = -3V$

$-V_{DS(n)} + V_{DS(p)} + 5V = 0 \qquad I_{D(n)} + I_{D(p)} + I = 0$

$V_{DS(n)} = 5kI + 2V$ (in forward bias)

Guess NMOS in saturation, PMOS in triode

$$I_{D(p)} = -1mA/V^2\left(-3V - -1V - \frac{V_{DS(p)}}{2}\right)V_{DS(p)}$$

$$I_{D(n)} = 1mA/V^2(2V-1V)^2 \cdot 1/2 = 1/2\ mA$$

$$= -I_{D(p)} - I$$

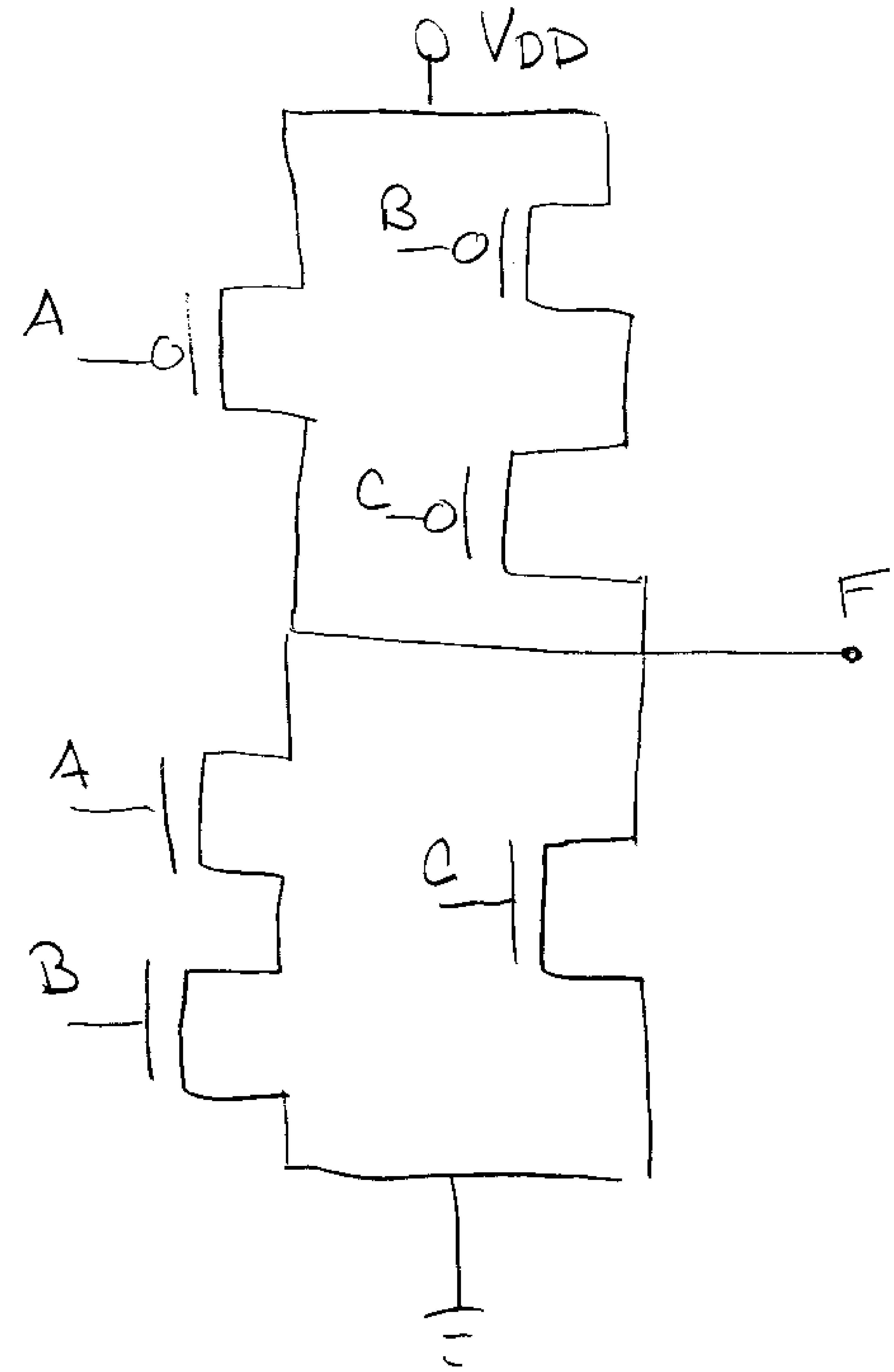
$$= 1mA/V^2\left(-2V - \frac{V_{DS(p)}}{2}\right)V_{DS(p)} - \frac{V_{DS(n)}-2}{5K\Omega}$$

$$= 1mA/V^2\left(-2V - \frac{V_{DS(p)}}{2}\right)V_{DS(p)} - \frac{V_{DS(p)}+3}{5K\Omega}$$

$V_{DS(p)} = \{-3.82, -.58\}$ For triode, need $V_{DS(p)} > V_{GS(p)} - V_{TH(p)}$ (−2V)

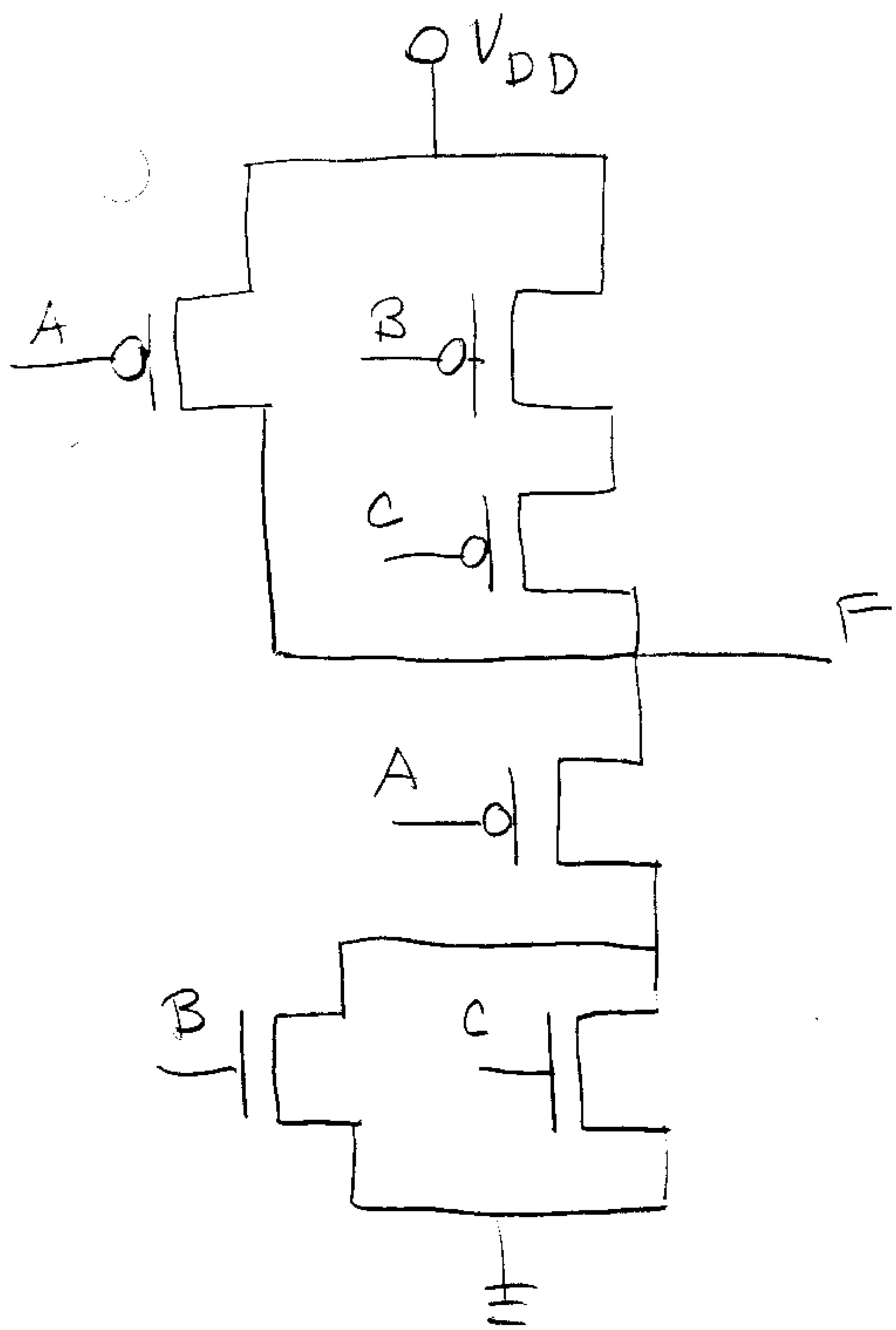
$V_{DS(p)} = -.58V \quad V_{DS(n)} = 4.42V$ ok for saturation

$I = .484mA$ ok for forward bias $\underline{V_{OUT} = 4.42V}$



Does this circuit perform a logic function?
If so, what function? (Give the Boolean expression).

No — if A = 0 and C = 1, then F is simultaneously connected to both V_{DD} & ground.



Does this circuit perform a logic function?
If so, what function? (Write the Boolean expression).

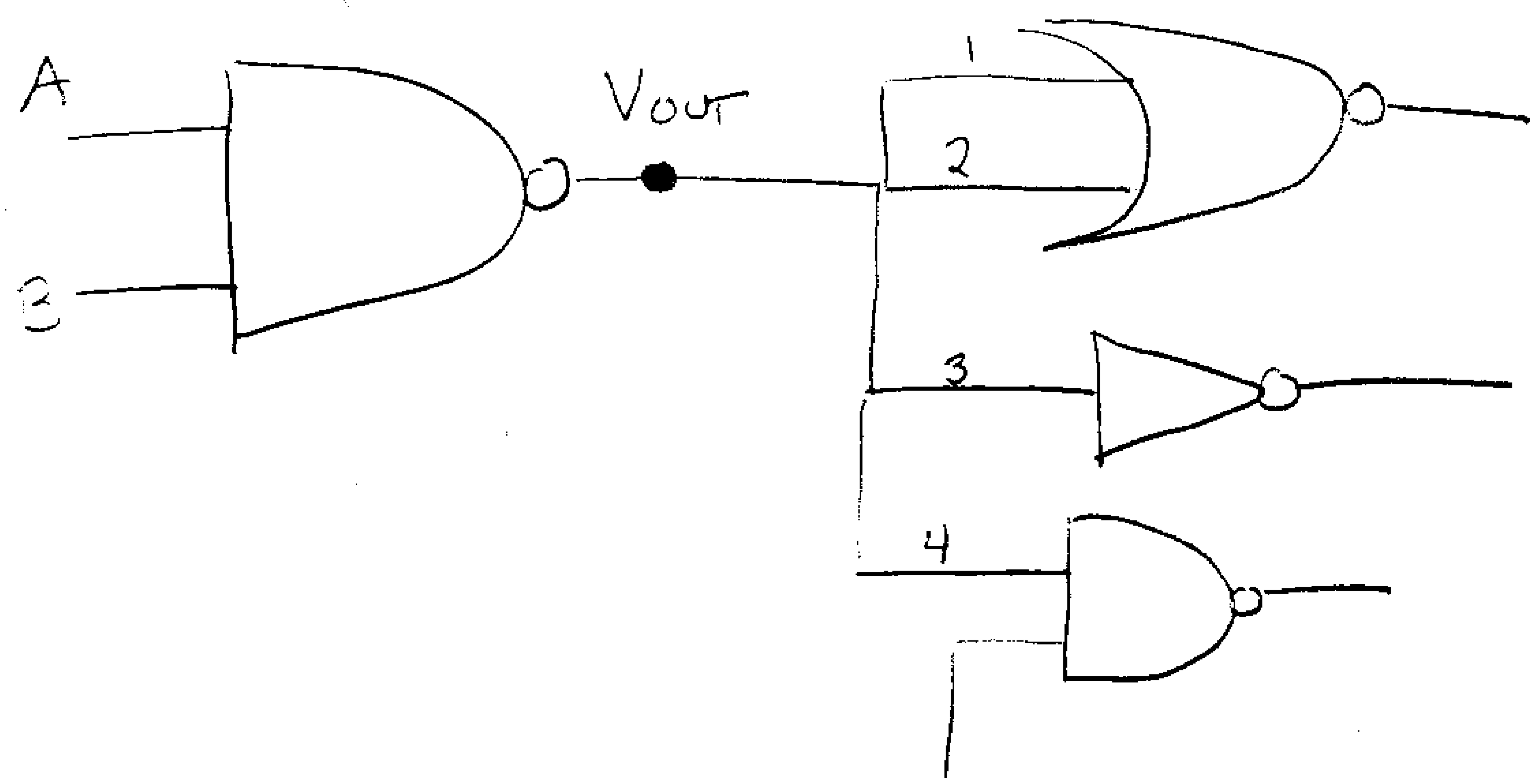
F = 0 when A = 1 and (B = 1 or C = 1)

$\overline{F} = A(B+C) \Rightarrow F = \overline{A(B+C)}$

Another way to write it:

F = 1 when A = 0 or (B = 0 and C = 0)

$F = \overline{A} + \overline{B}\,\overline{C}$ Same as above (by De Morgan).



$C_G = 20\,pF$

$R_n = 1\,K\Omega$

$R_p = 2\,K\Omega$

Logic 1 = 5 V

Logic 0 = 0 V

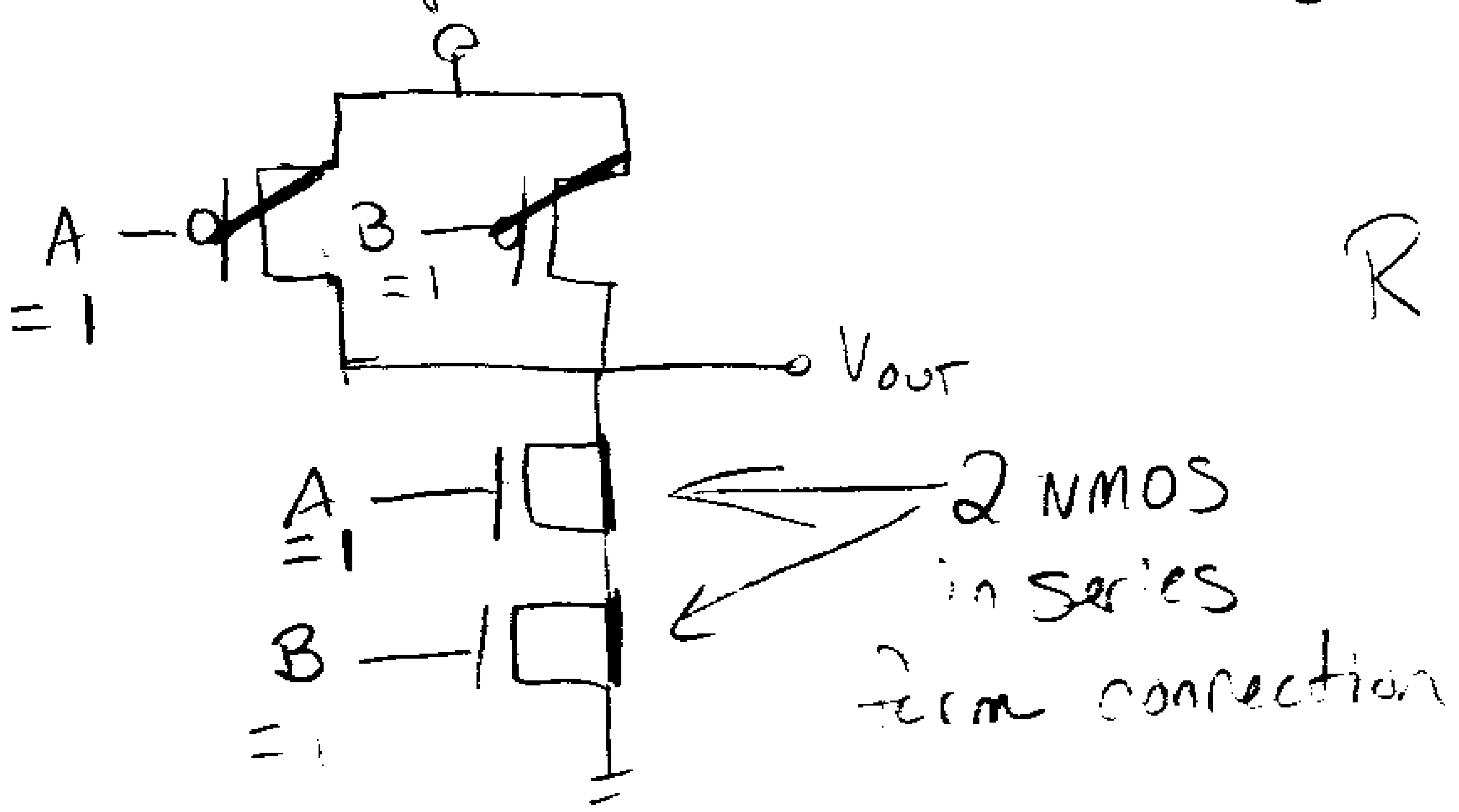
Suppose that for all $t < 0$, we had A = 1 and B = 0.

At $t = 0$, B goes (instantaneously) from 0 to 1.

Find $V_{OUT}(t)$ and t_P for the first NAND gate.

V_{OUT} connected to 4 CMOS inputs.

Each input is 2 transistor gates. $C_G = 4 \times 2 \times 20\,pF = 160\,pF$



$R = R_N + R_N = 2\,k\Omega$

$t_p = \ln 2 \cdot 2\,k\Omega \cdot 160\,pF = 222\,ns$

Before: A = 1, B = 0 ⇒ $V_{OUT} = 5V$ After: A = 1, B = 1 ⇒ $V_{OUT} = 0V$

$V_{OUT}(t) = 0 + (5-0)e^{\frac{-t}{2k \cdot 160pS}}\,V = 5e^{\frac{-t}{320nS}}\,V$