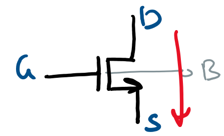
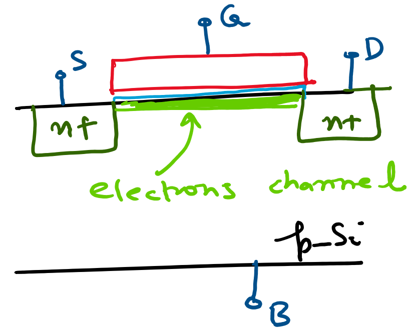
ECE 310 - Lecture 19

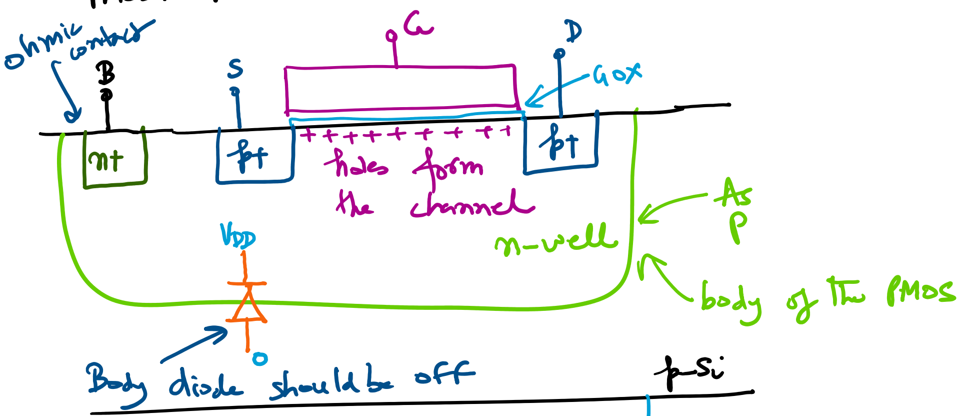
Sunday, February 25, 2018 9:26 PM

NMOSFET → NFET or NMOS in short

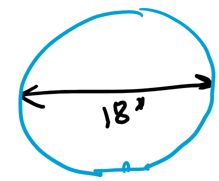


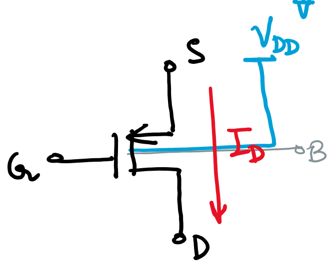


PMOSFET → PFET or PMOS



Starting material → p-doped Si

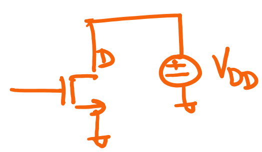




Current always flows from Source to Drain
S → D

PMOS body is connected to the highest potential on chip
↳ supply voltage, V_{DD}

V_{DD} → supply voltage



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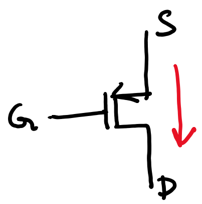
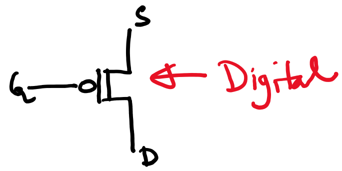
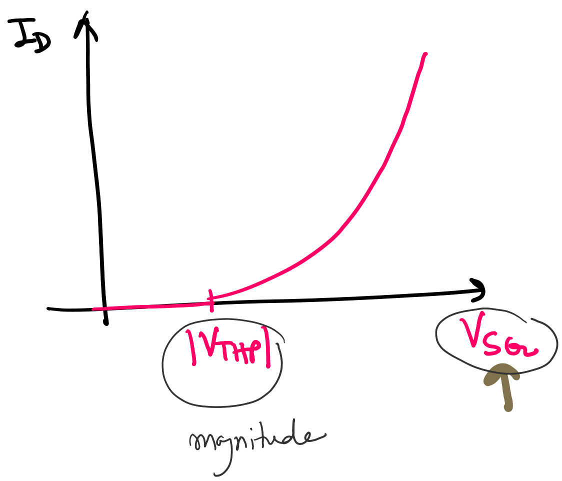
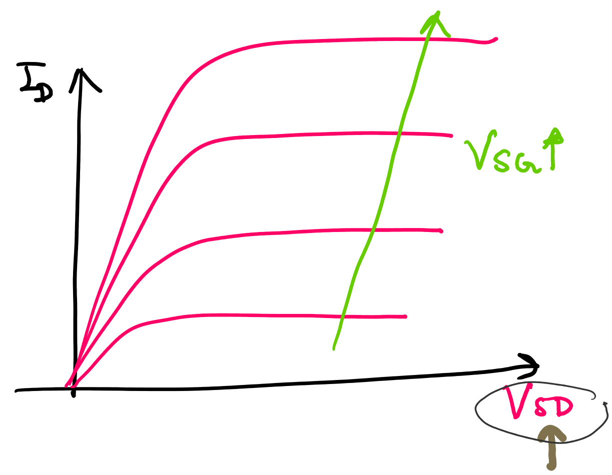


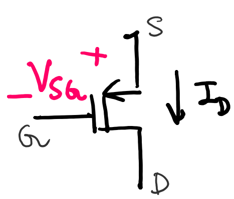


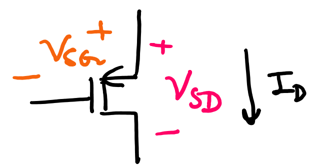
V_{THP} ← Threshold voltage
↳ −ve number

All positive convention!









We use the magnitude of $|V_{THP}|$.

$$I_D = \begin{cases} 0, & V_{SG} < |V_{THP}| \quad \text{CUTOFF} \\ \mu_p C_{ox}' \frac{W}{L}\left[(V_{SG} - |V_{THP}|)V_{SD} - \frac{V_{SD}^2}{2}\right], & V_{SD} < V_{SD,sat} \quad \text{TRIODE} \\ \frac{1}{2}\mu_p C_{ox}' \frac{W}{L}(V_{SG} - |V_{THP}|)^2, & \text{SATURATION} \end{cases}$$

TRIODE and SATURATION: $V_{SG} > |V_{THP}|$

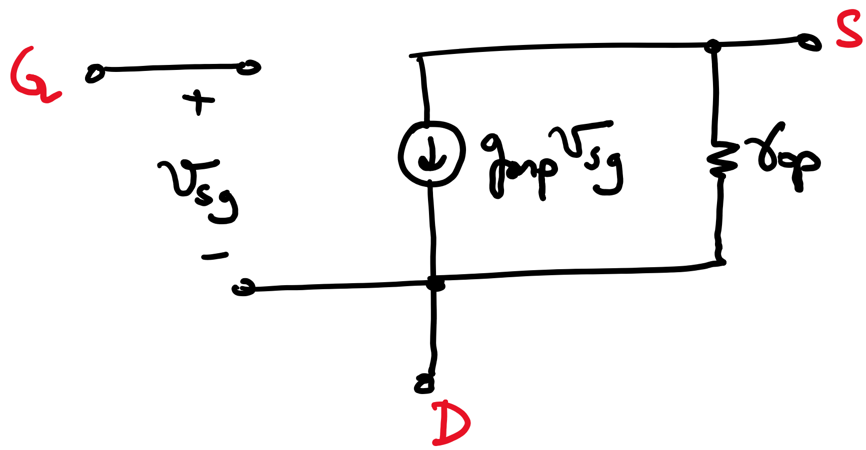
$V_{SD,sat} = V_{SG} - V_{THP}$

$V_{GS} \rightarrow V_{SG}$
$V_{DS} \rightarrow V_{SD}$ → PMOS Equations

NMOS Equations $\xrightarrow[V_{THN} \Rightarrow |V_{THP}|]{V_{GS} \to V_{SG},\ V_{DS} \to V_{SD}}$ PMOS Equations

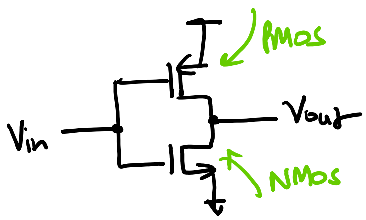
IV curves look similar

PMOS small signal model

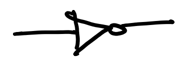


CMOS Technology : CMOS ⇒ Complementary MOS

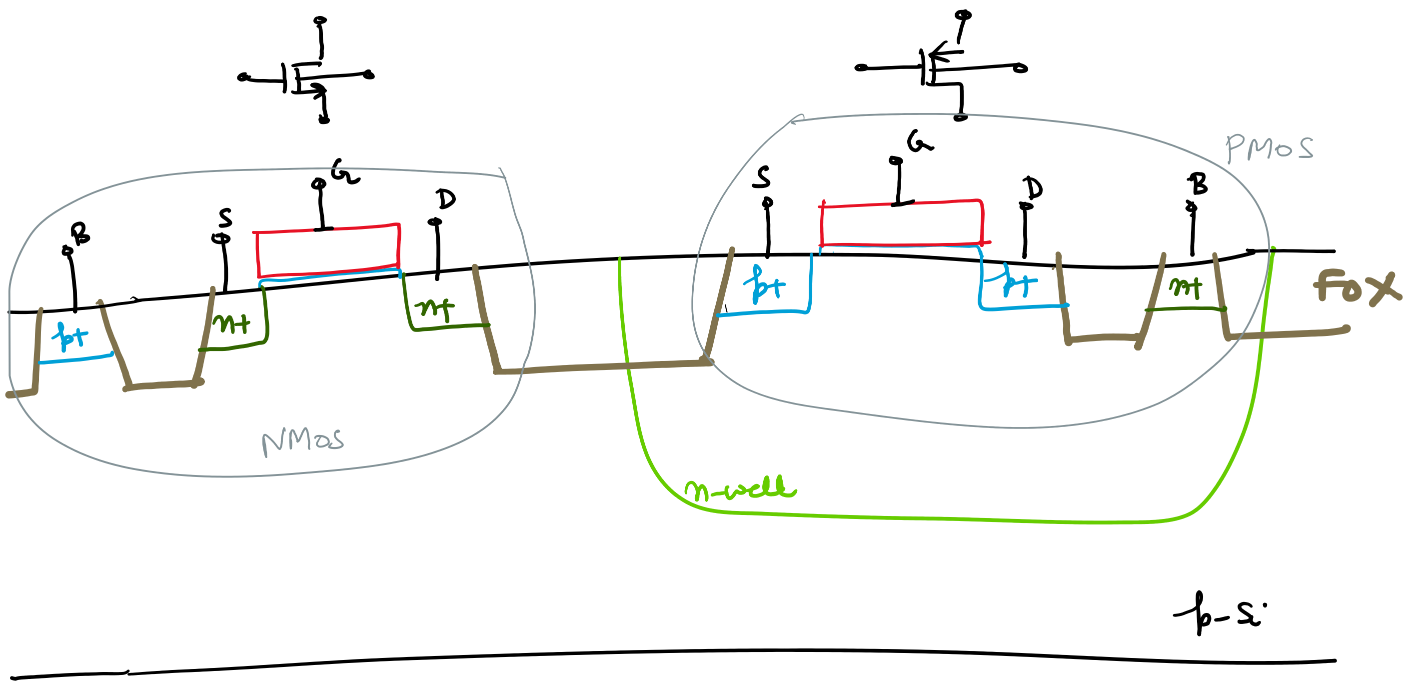
CMOS Inverter (NOT gate)



⇒



8086 from Intel



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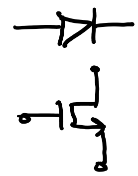
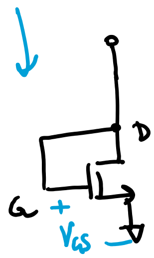
"Diode Connected MOSFETs"



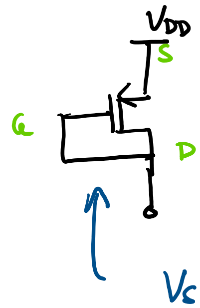


diode connected NMOS

If $V_{GS} > V_{THN} \Rightarrow$ ON

$$V_{DS} = V_{GS} > (V_{GS} - V_{THN})$$

⇒ If the NMOS diode is ON, it's always in Saturation!



Diode connected PMOS

$$V_{SD} = V_{SG} > (V_{SG} - |V_{THP}|)$$

⇒ PMOS diode is always ON in SAT.

& never in TRIODE

Chapter 16 [clone of chapter 7] of the Textbook

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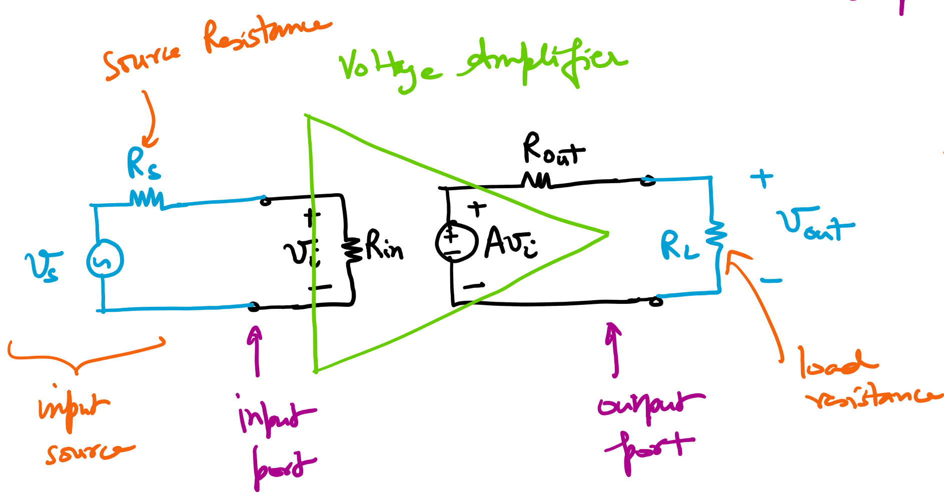
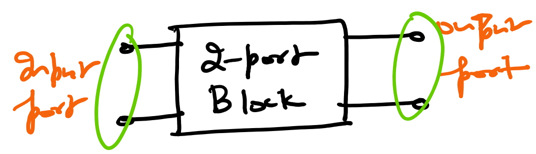
CMOS Amplifiers :

2-port Network / Block





$|A| > 1 \Rightarrow$ amplifier

Ideal voltage amplifier:

↳ At the input, the circuit must operate as a voltmeter

* sense the input voltage without disturbing the previous stage (shouldn't "load" the previous stage)

$$v_i = \frac{R_{in}}{R_{in}+R_s} \cdot v_s \quad \Rightarrow \quad R_{in} = ?$$

$$= \frac{1}{1+\frac{R_s}{R_{in}}} v_s = v_s \quad \text{if} \quad \boxed{R_{in} \to \infty}$$

↳ Similarly for an ideal voltage amplifier, we desire

$$\boxed{R_{out} \to 0}$$

all of the output voltage must appear across the load.

$R_{in} \to \infty$, $R_{out} \to 0$

$R_{in} \to \infty$

$R_{in} \to \infty$, $R_{out} \to 0$

$$v_{out} = A \left(\frac{R_{in}}{R_s + R_{in}}\right)\left(\frac{R_L}{R_{out} + R_L}\right) v_s \Rightarrow A v_s \text{ iff } \begin{array}{l} R_{in} \to \infty \\ R_{out} \to 0 \end{array}$$

* Important to estimate / analyze input & output impedances of amplifiers

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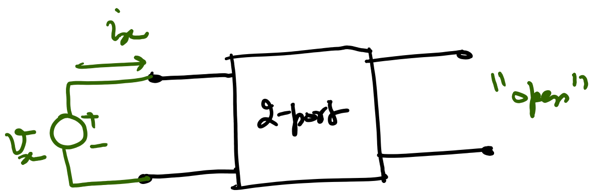
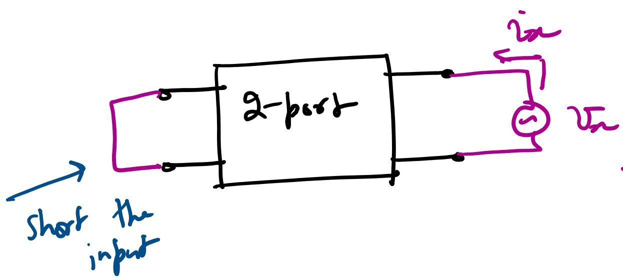
How to measure (or analyze) input and output impedances?



open the output port & find small signal $\frac{v_x}{i_x} \Leftarrow Z_{in}$

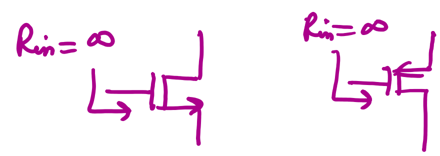
$Z_{in} \equiv R_{in} = \frac{v_x}{i_x}$ ⇐ input impedance



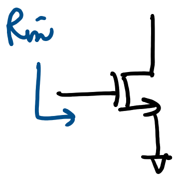
Short the input port and find small-signal $\frac{v_x}{i_x} \Leftarrow Z_{out}$

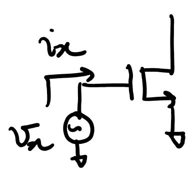
$Z_{out} \equiv R_{out} = \frac{v_x}{i_x}$

Examples



a) R_{in}

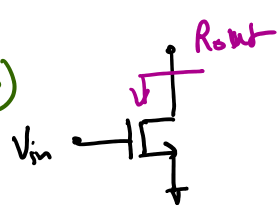


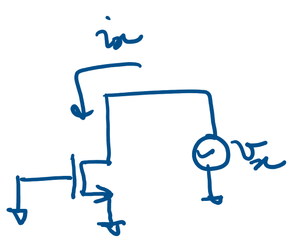


At low frequencies, gate is insulated $\Rightarrow i_x = 0$

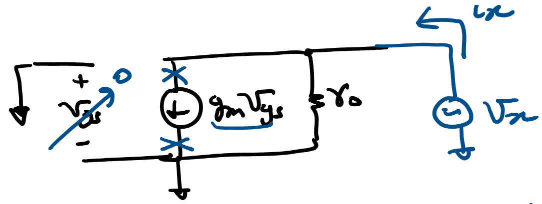
$\Rightarrow R_{in} = \frac{v_x}{0} = \infty$

b)

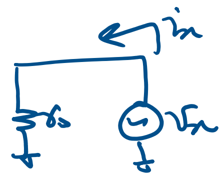




R_{out}, "looking into" the drain



⇒



⇒ $v_x = i_x r_o$

⇒ $R_{out} = \frac{v_x}{i_x} = r_o$