



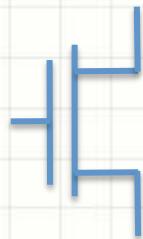
COL215 DIGITAL LOGIC AND SYSTEM DESIGN

Real Circuits :
Transistors and Gates
15 September 2017

What are logic gates made of?

Transistors

Metal Oxide Semiconductor
(MOS) transistors



N-channel
NMOS



P-channel
PMOS

Bipolar Junction Transistors
(BJT)

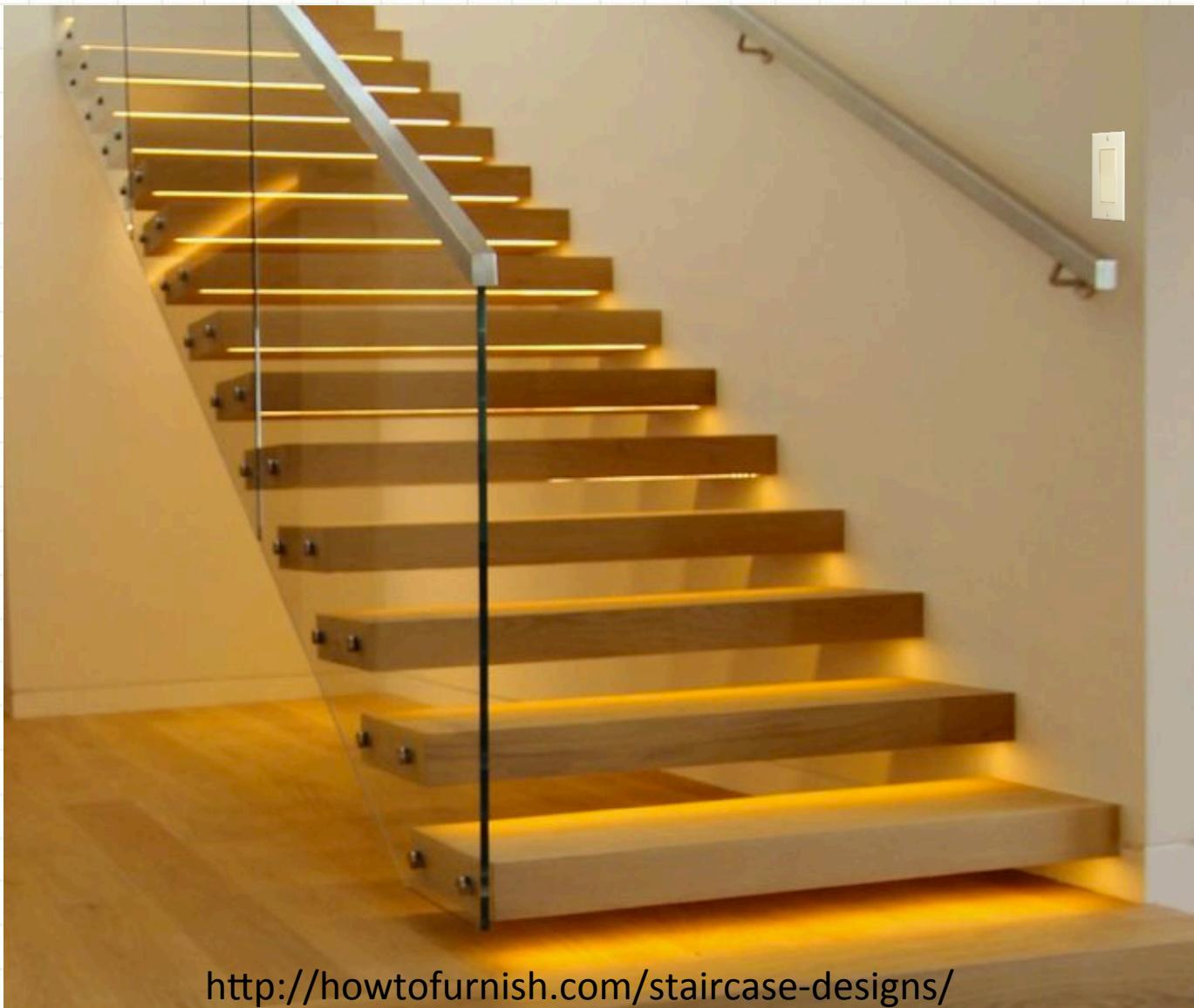


NPN



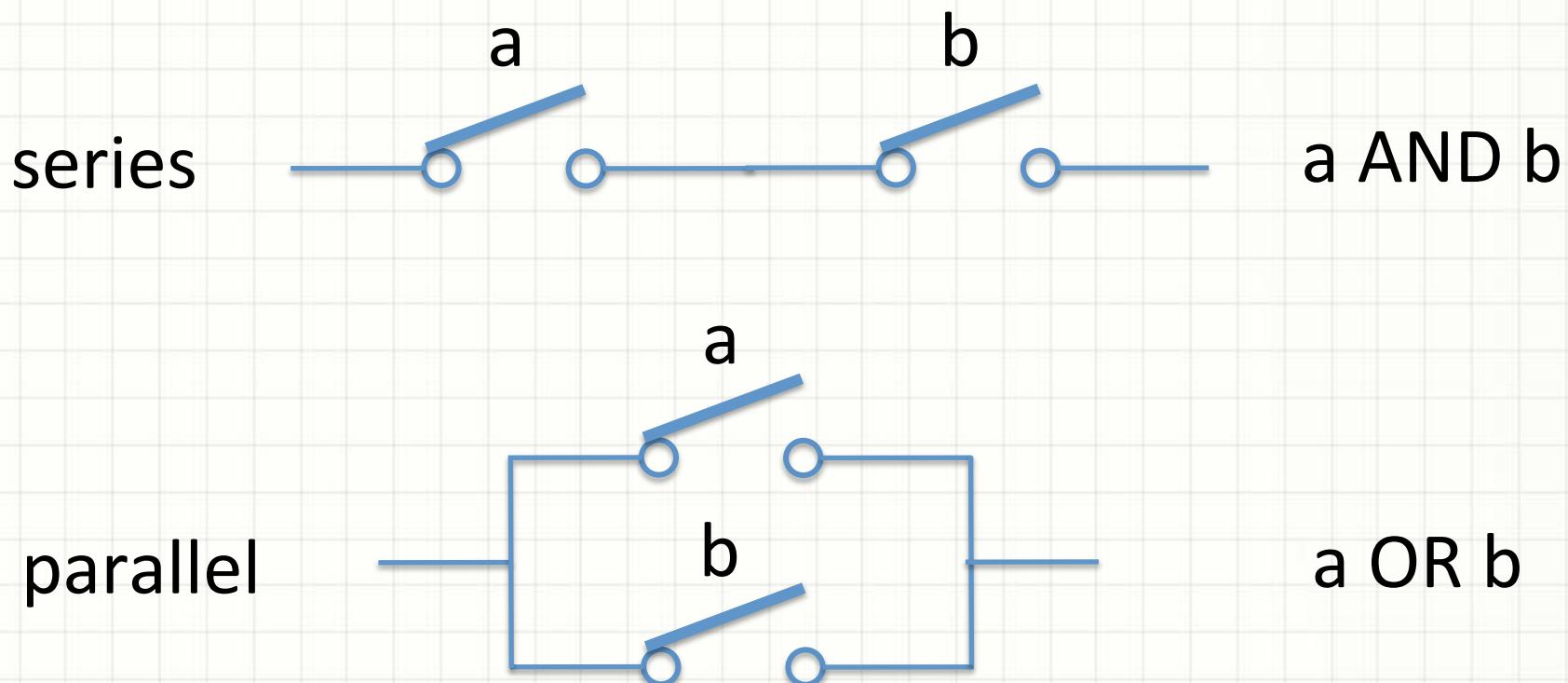
PNP

Other ways of implementing logic

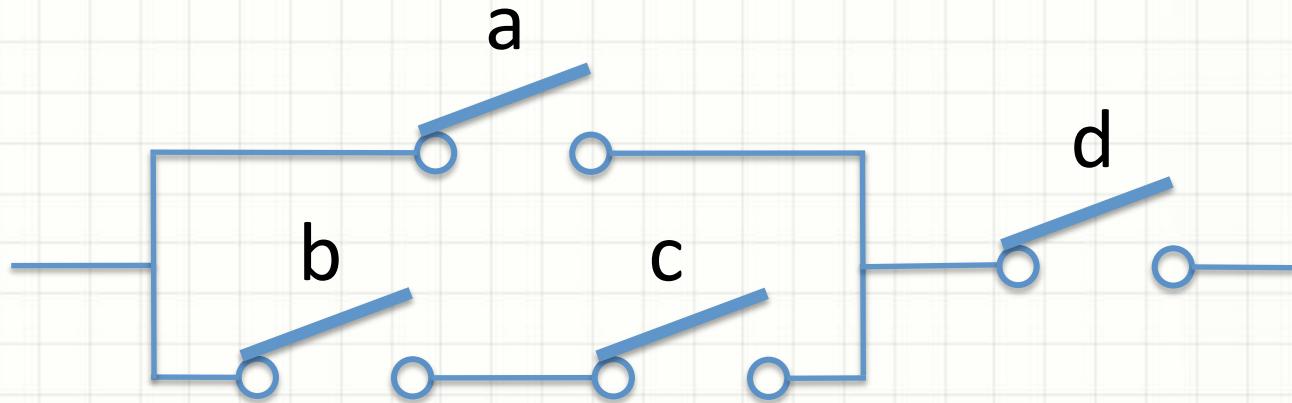


<http://howtorefurnish.com/staircase-designs/>

Series – parallel switches

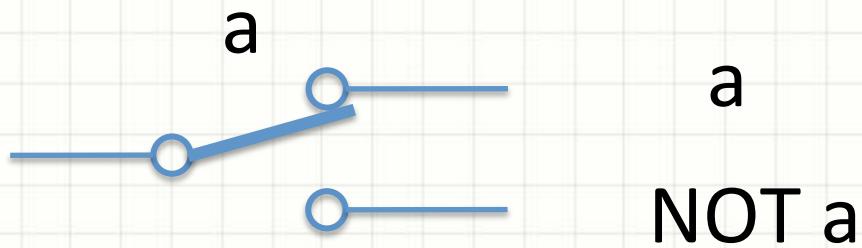


Series – parallel logic

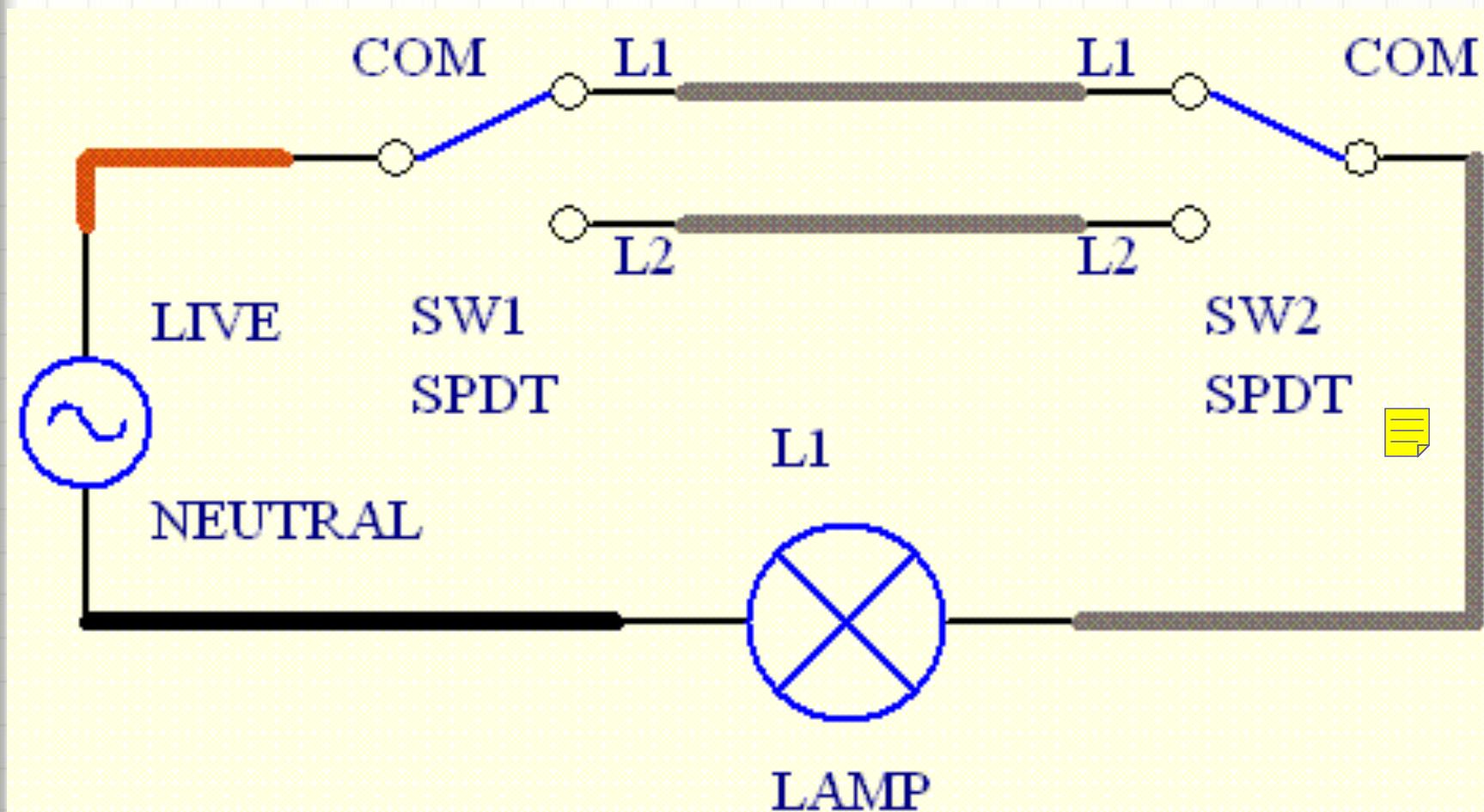


$(a \text{ OR } (b \text{ AND } c)) \text{ AND } d$

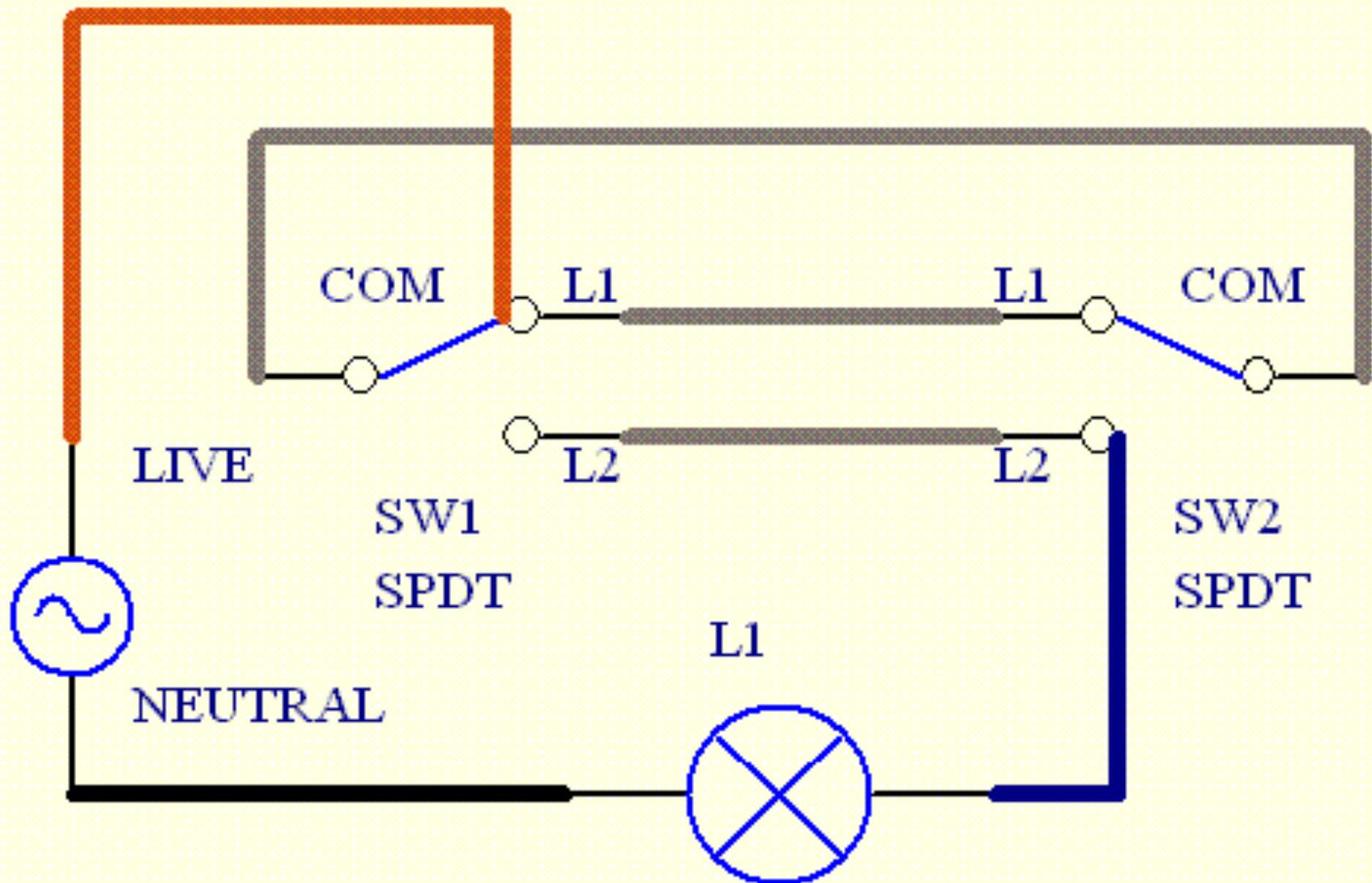
Double throw switch



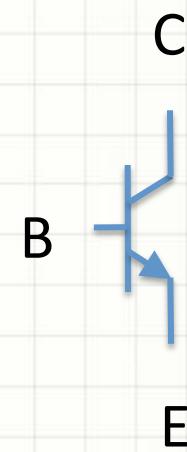
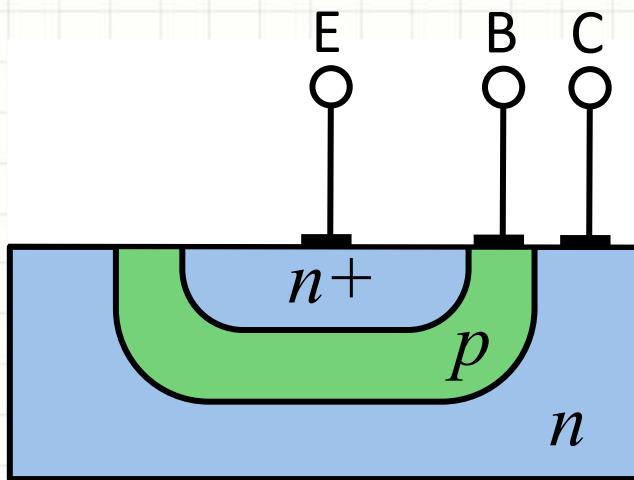
Staircase wiring



Staircase wiring

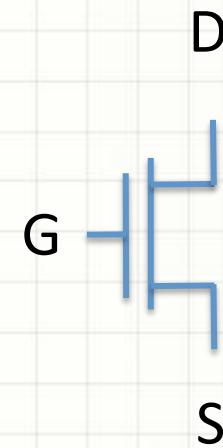
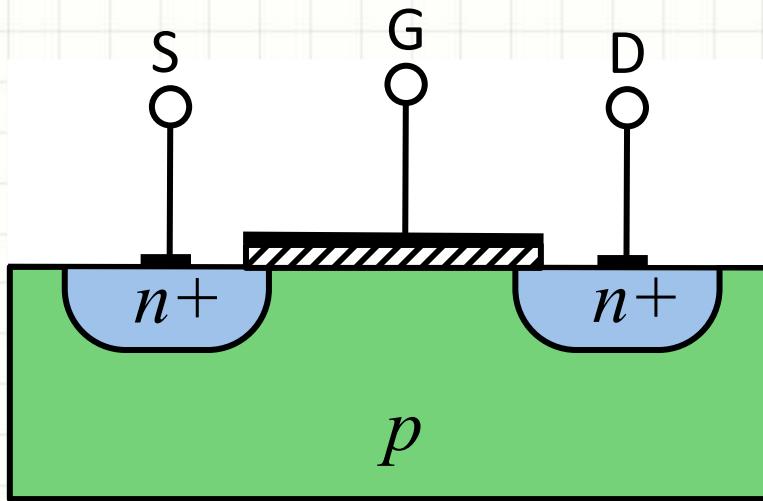


NPN Transistor



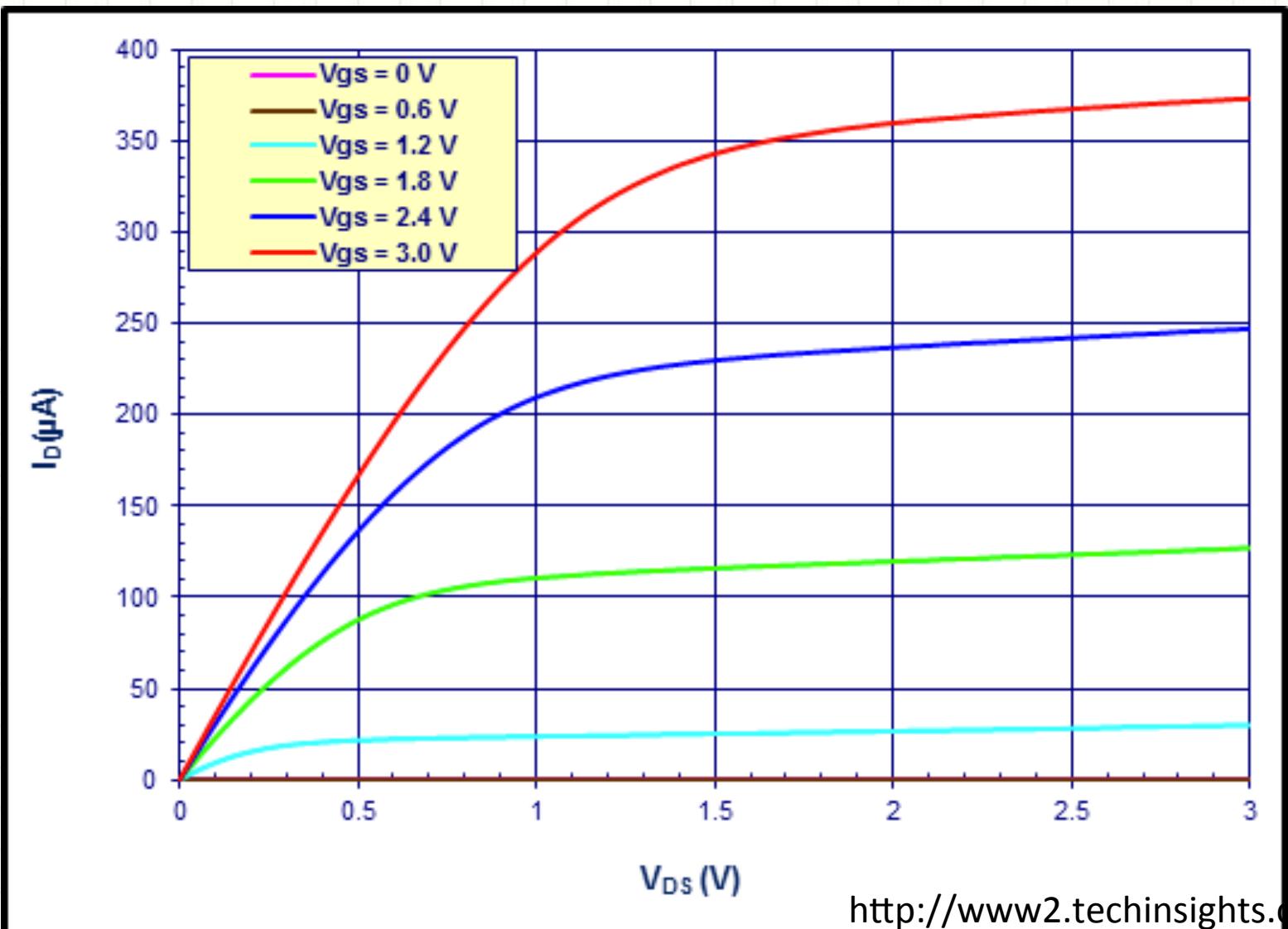
E Emitter
B Base
C Collector

NMOS Transistor

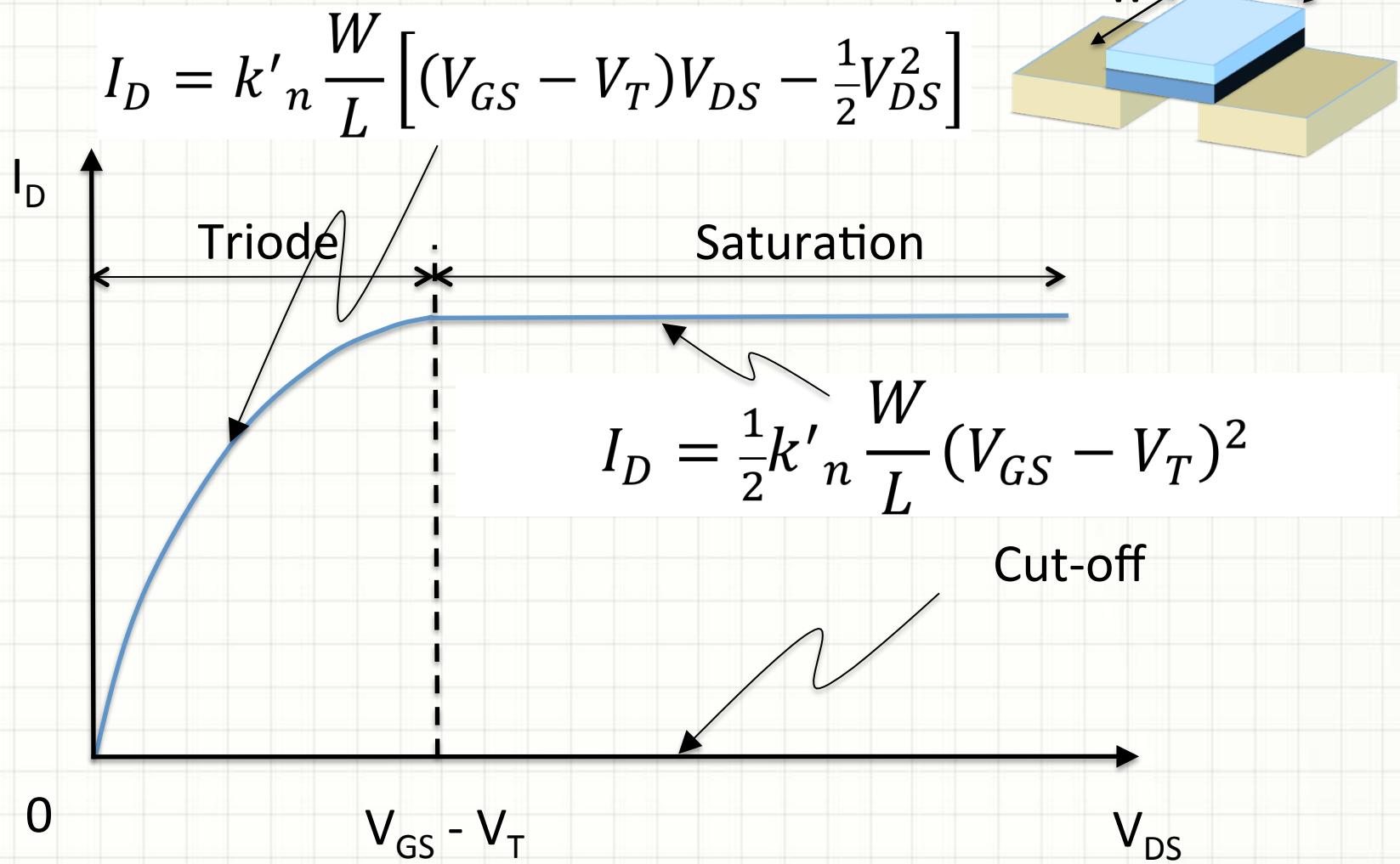


S Source
G Gate
D Drain

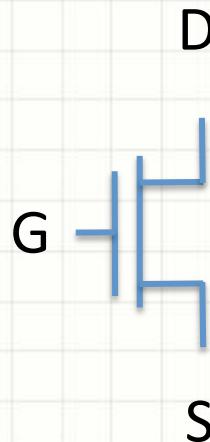
NMOS transistor V – I characteristics



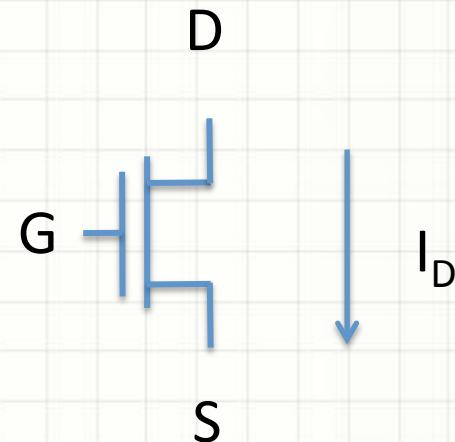
$V - I$ for a fixed V_{GS} (simplified)



NMOS Transistor Switch



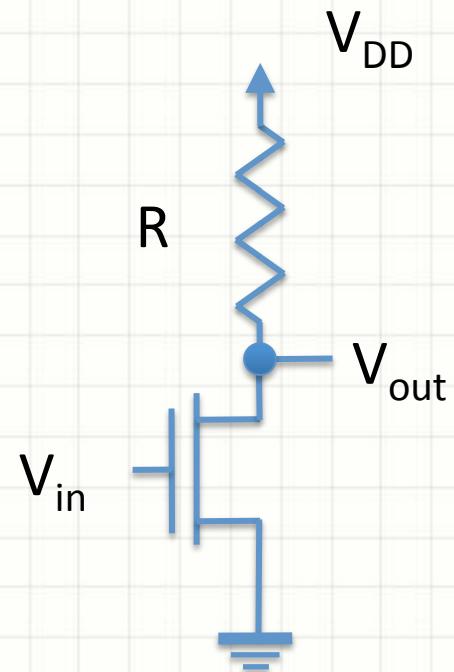
$$V_{GS} < V_T$$



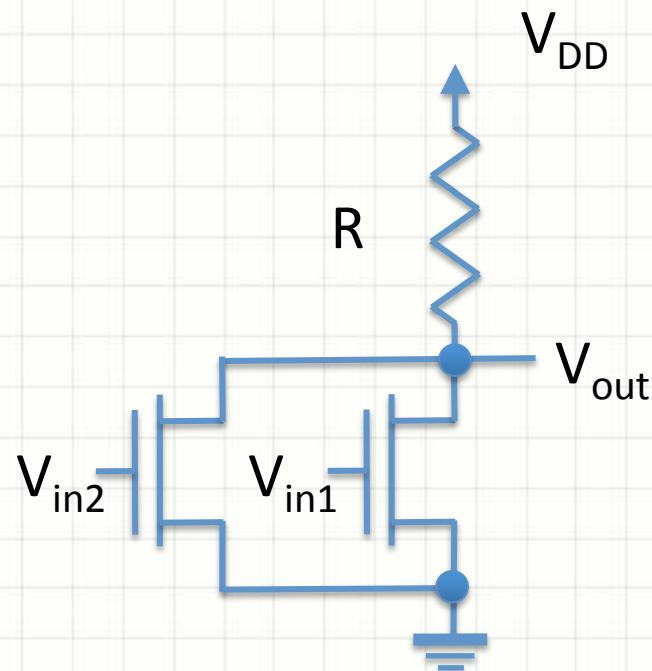
$$V_{GS} > V_T$$



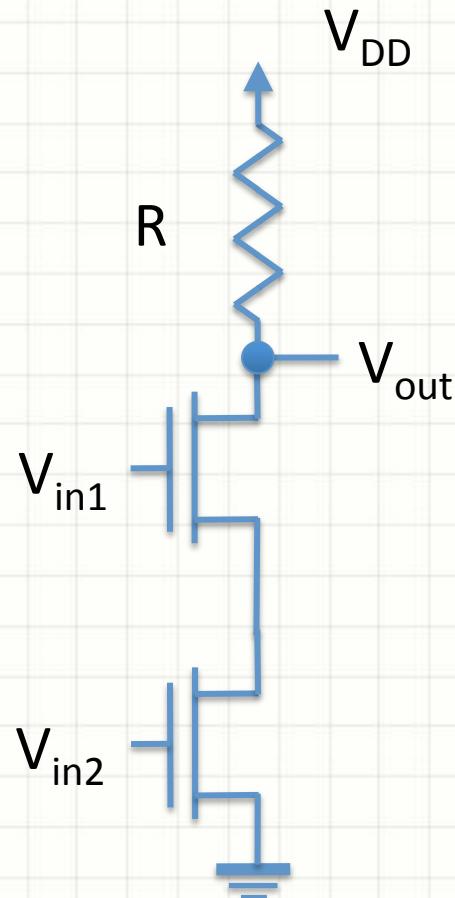
NMOS Transistor NOT gate



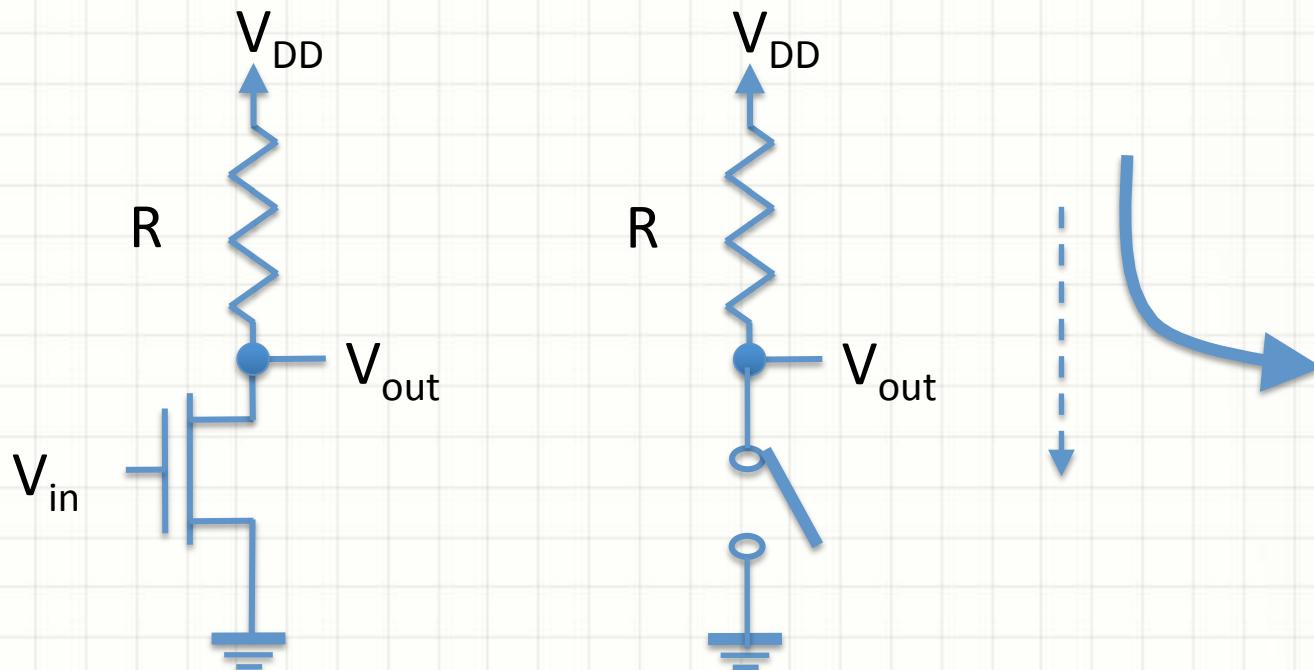
NMOS Transistor NOR gate



NMOS Transistor NAND gate

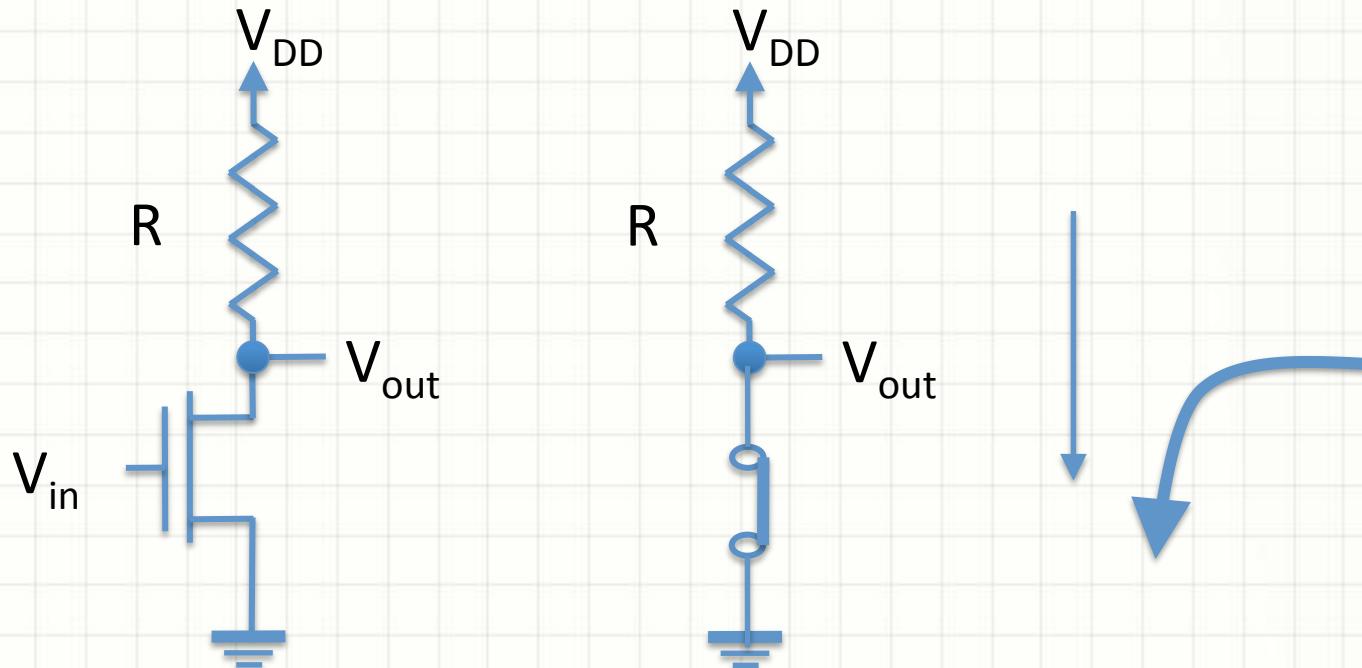


Resistor in NMOS NOT gate



Transistor OFF, R should be as low as possible

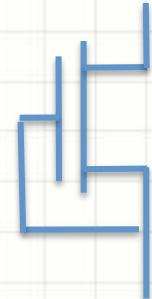
Resistor in NMOS NOT gate



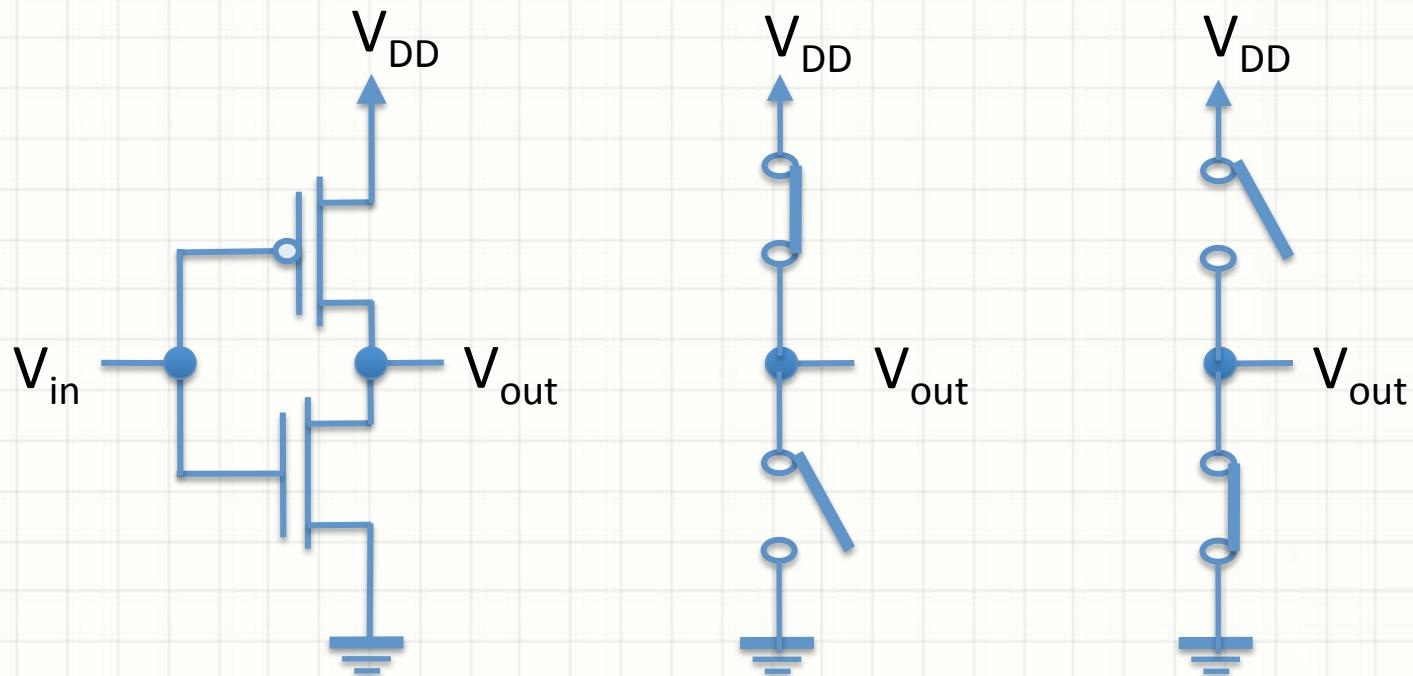
Transistor ON, R should be as high as possible

Passive and active pull up / pull down

- Passive
 - Resistor
- Active
 - Depletion mode transistor
 - Takes less silicon space

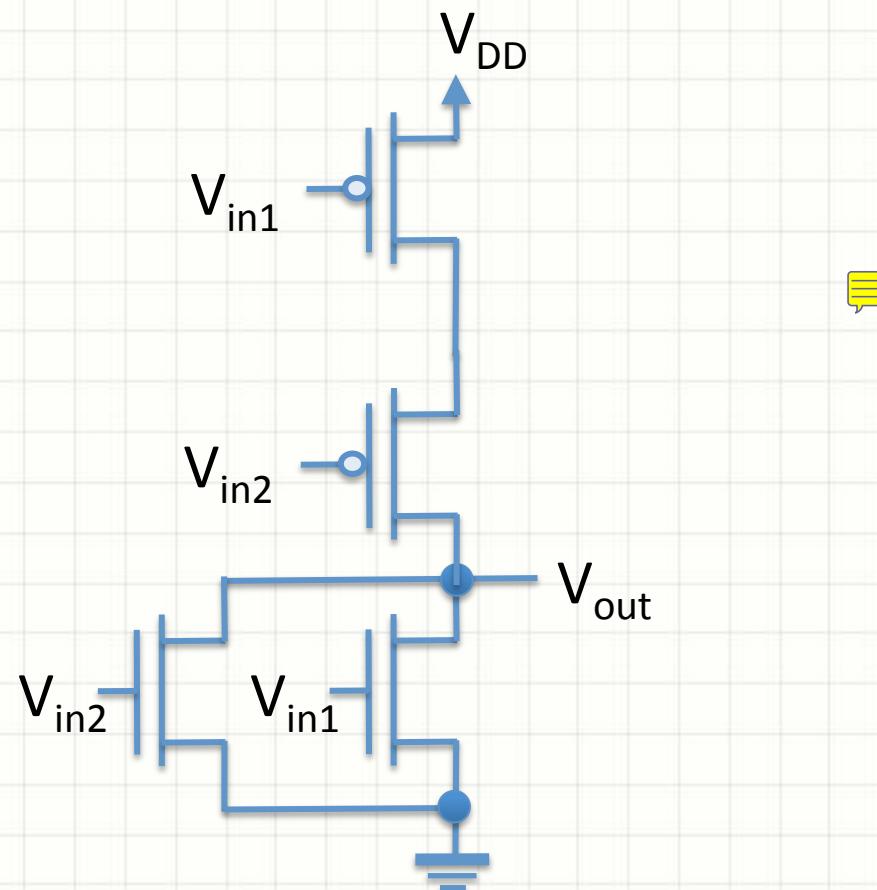


Replacing R with a switch

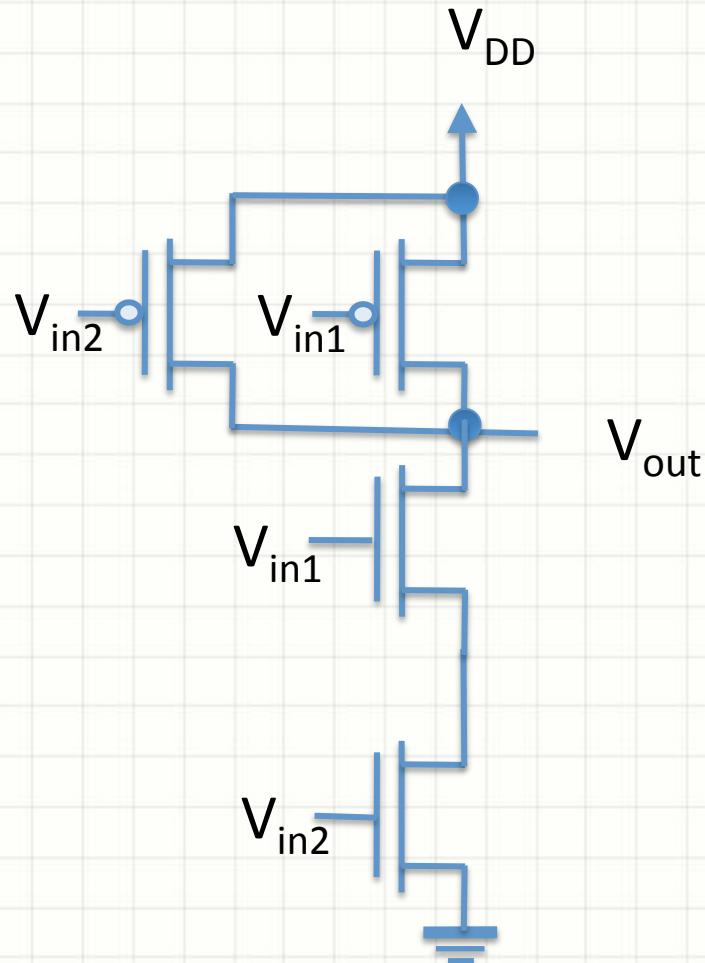


Complementary MOS (CMOS) or
Complementary Symmetry MOS

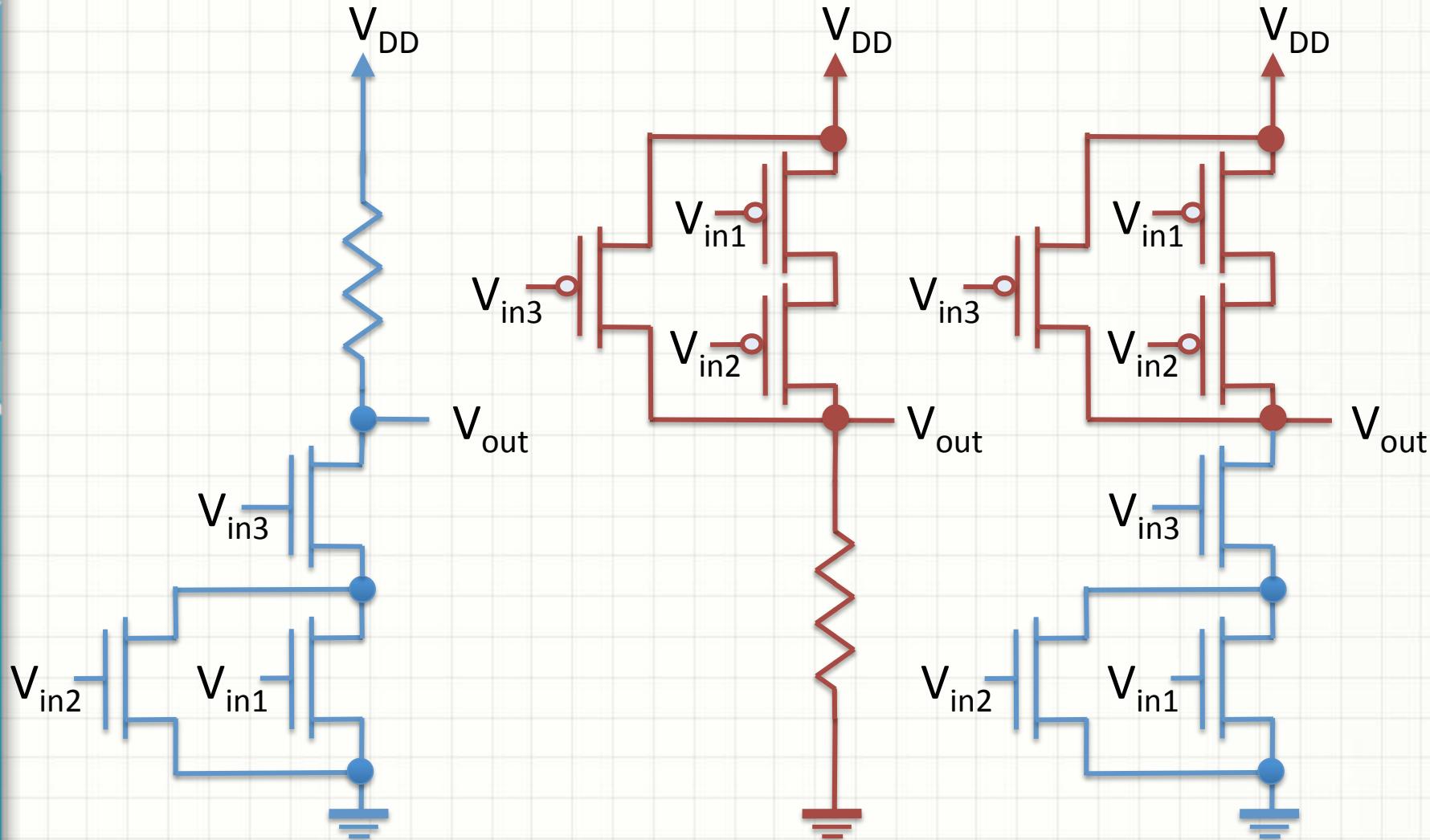
CMOS NOR gate



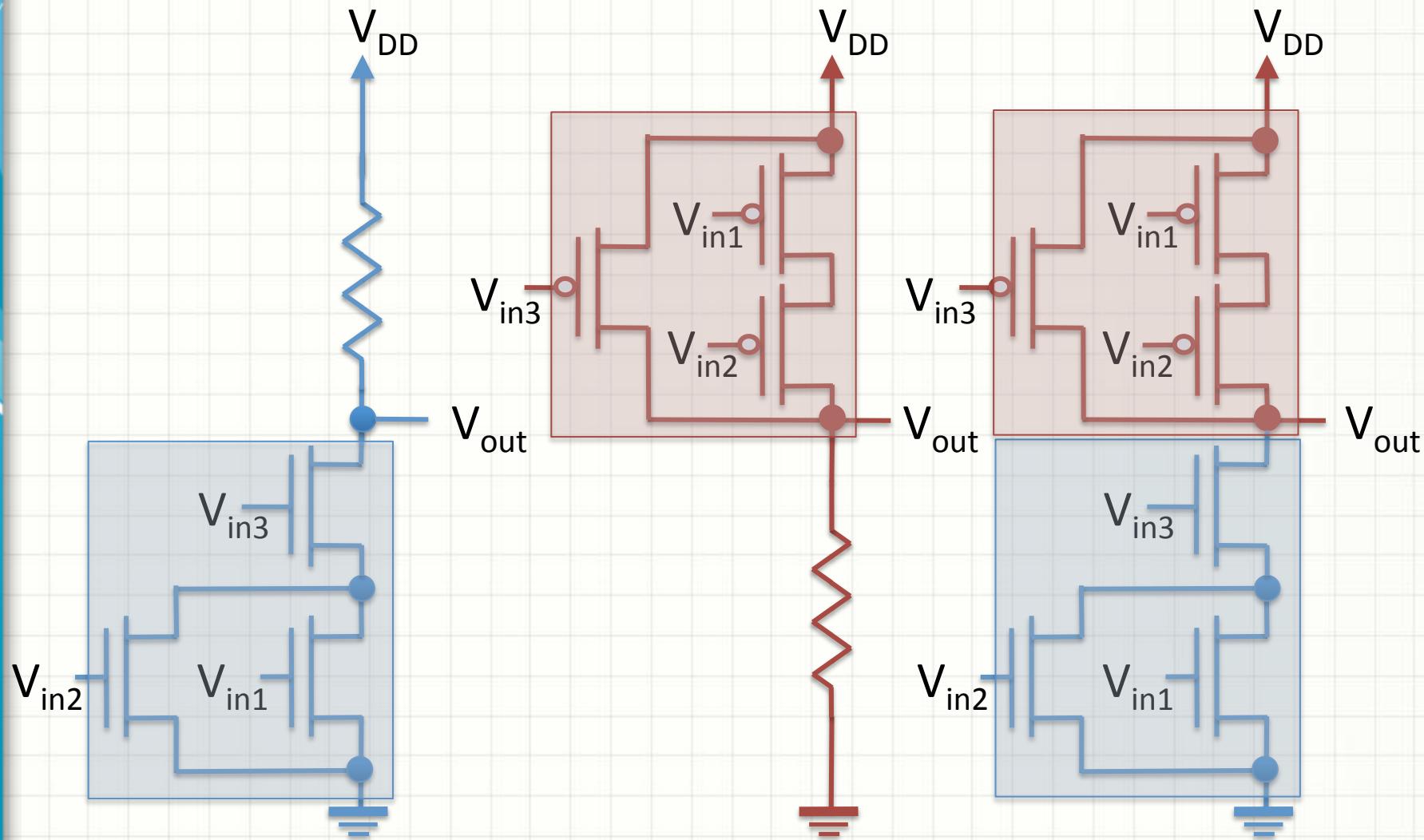
CMOS NAND gate

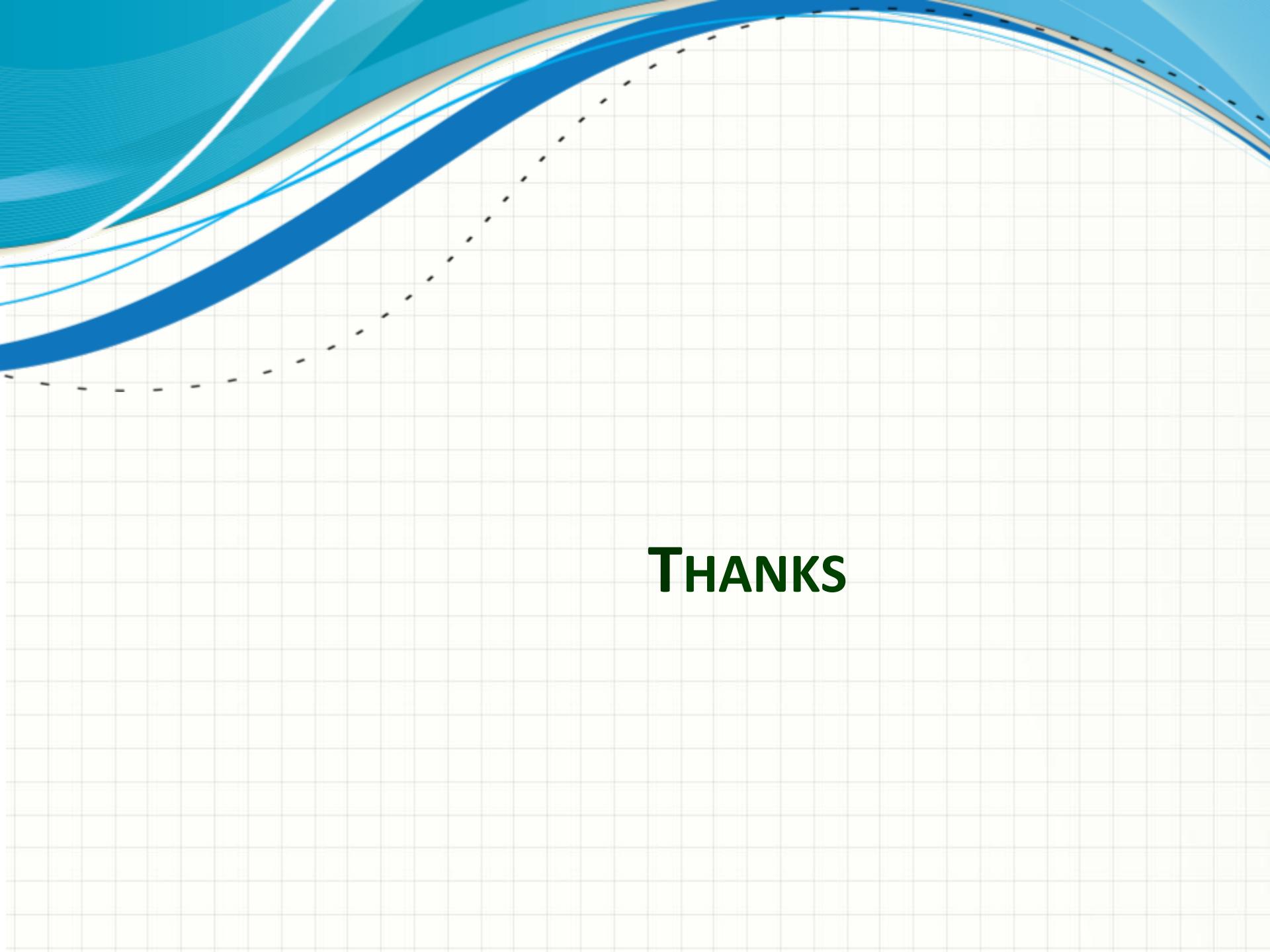


NMOS, PMOS and CMOS circuits



NMOS, PMOS, CMOS PDN and PUN



The background features a white grid pattern. Overlaid on the top left is a stylized graphic element consisting of several curved bands in shades of blue and cyan. A prominent thick blue band curves from the bottom left towards the top right. A dashed black line follows a similar path, starting from the bottom left and curving upwards and to the right.

THANKS