EECS 151 Disc 5

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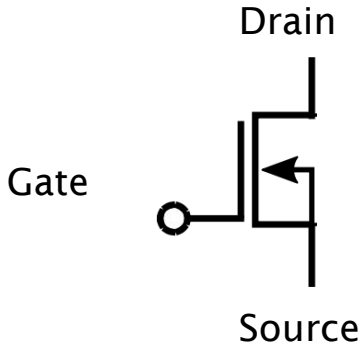
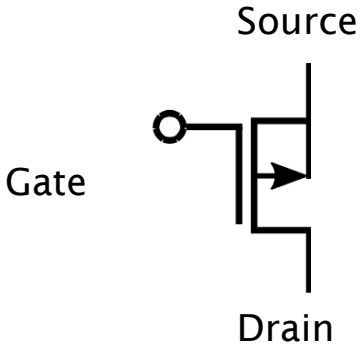
Contents

- MOS Transistors
- Switch Networks
- CMOS
- Layout
- Flip-flops

N-MOS and P-MOS

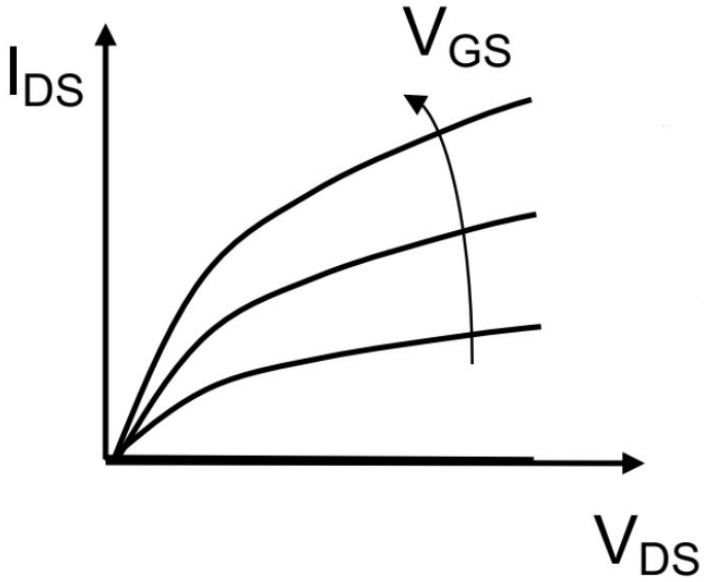


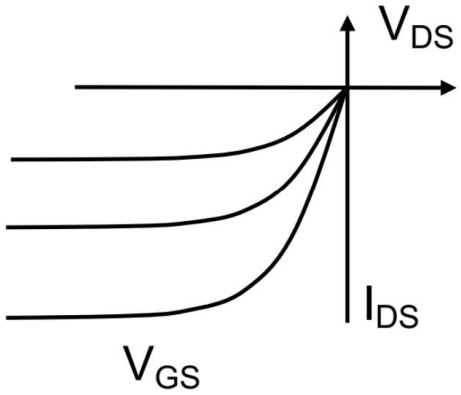
NMOS



PMOS

V-I Characteristics





PMOS works with negative voltages

Note: NMOS is stronger (more current) than PMOS. Wider is stronger.

More SPICE Simulation

.param your_param 0

.step param your_param 1 9 2

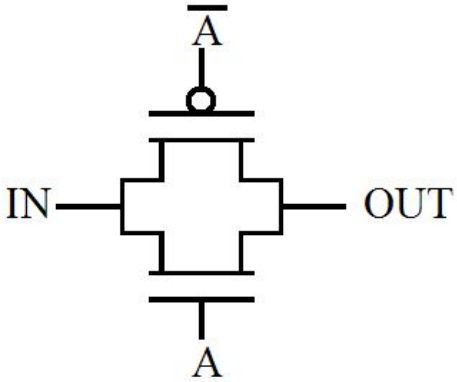
Plots each case (your_param = 1,3,5,7,9) with different colors

Can be combined with .dc to plot multiple curves

Transmission Gate

NMOS is bad at passing 1; PMOS is bad at passing 0 (why?)

Transmission gate:

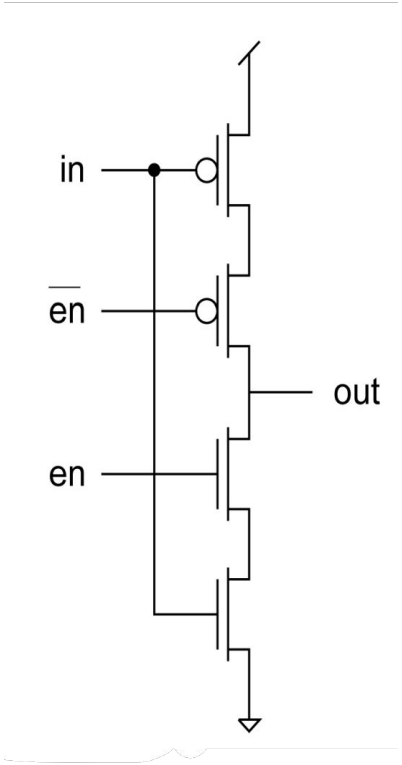


Tri-state Buffer

Transmission gates do not provide power, accumulating a load on the driver

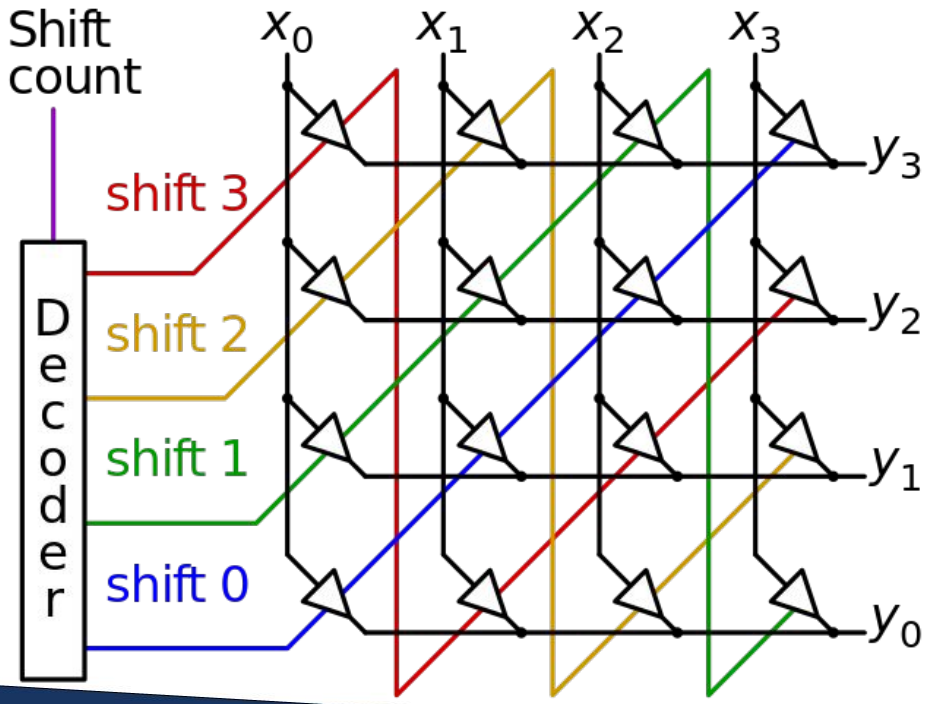
Alternative: Tri-state buffers

- Pass input to output if enabled
- Oneway
- Use a new power supply (VDD, GND)



Tri-state buffer with inverted output

Barrel Shifter



CMOS Logic

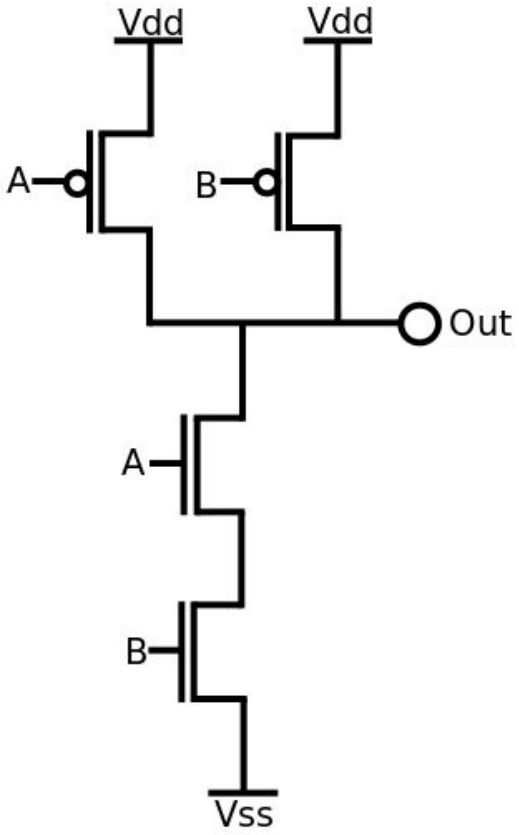
The majority of digital logic is implemented using CMOS.

- Pull-up networks : PMOS and VDD
- Pull-down networks : NMOS and GND

NAND2 Gate

Show why this is a NAND gate in two ways:

- By analyzing the PDN
- By analyzing the PUN

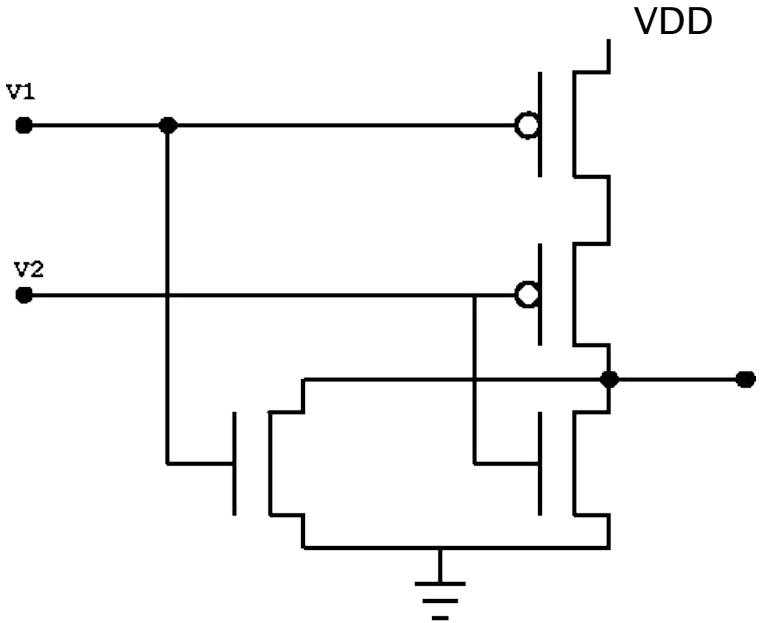


NOR2 Gate

Draw a CMOS NOR2 gate.

NOR2 Gate

Draw a CMOS NOR2 gate.



AND-OR-Invert (AOI) Gate

Draw a complex CMOS gate implementing a 2-1 AOI:

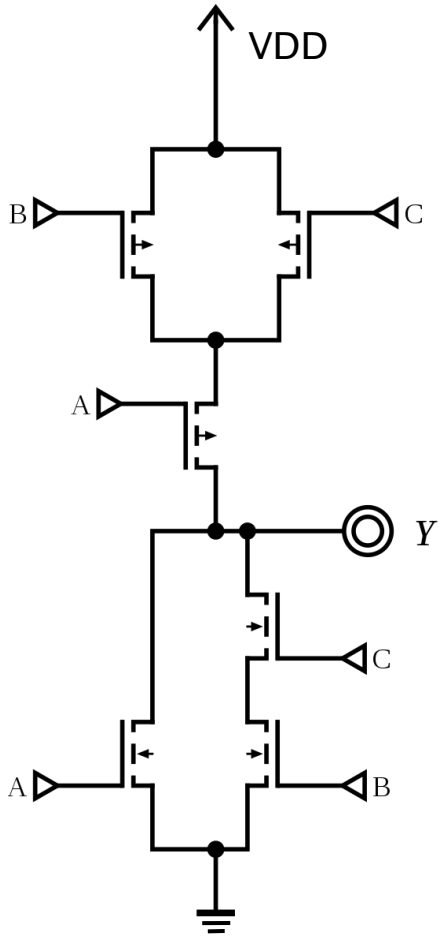
$Y = (A + B\,C)'$

(Hint: Complement the function for PDN)

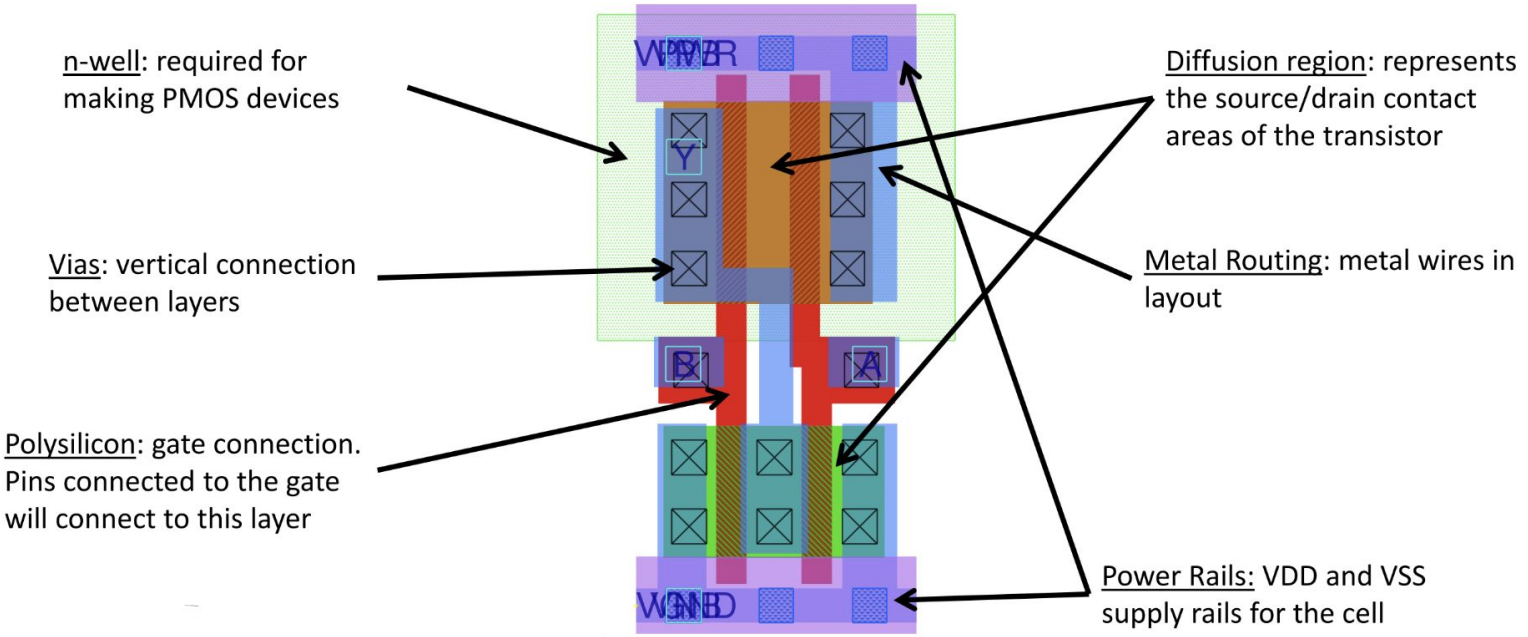
AND-OR-Invert (AOI) Gate

$Y = (A + B\,C)' = A'\,(B' + C')$

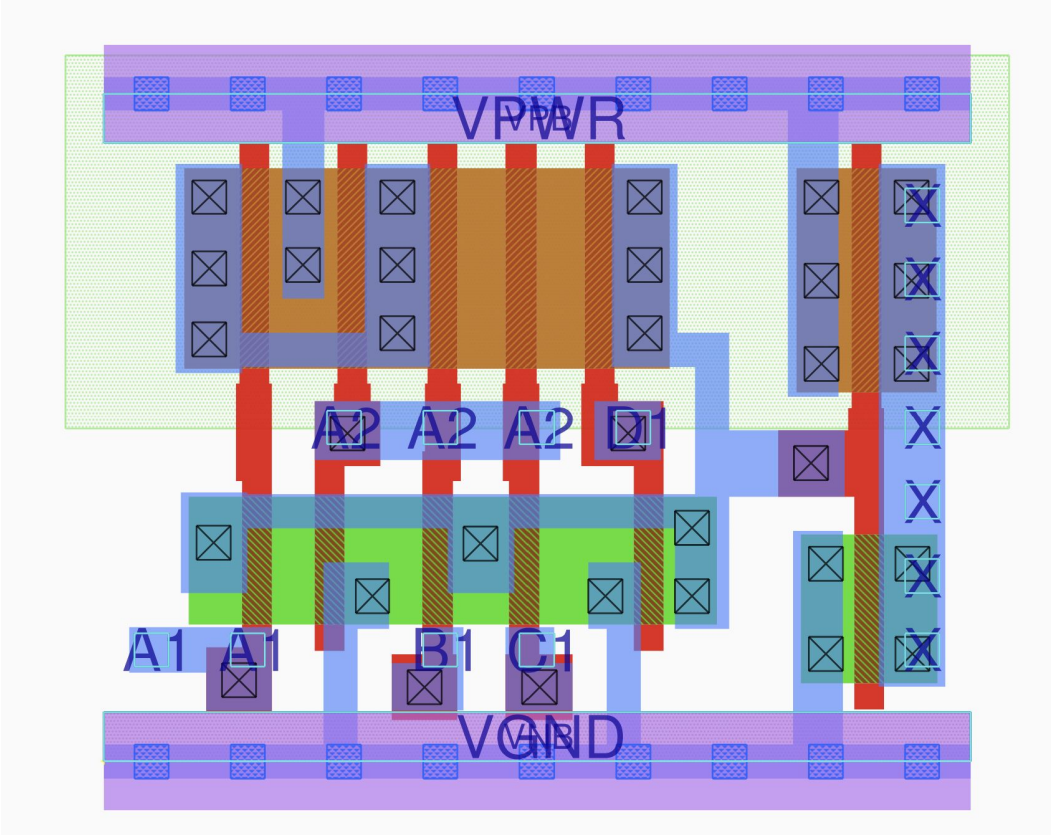
$Y' = A + B\,C$

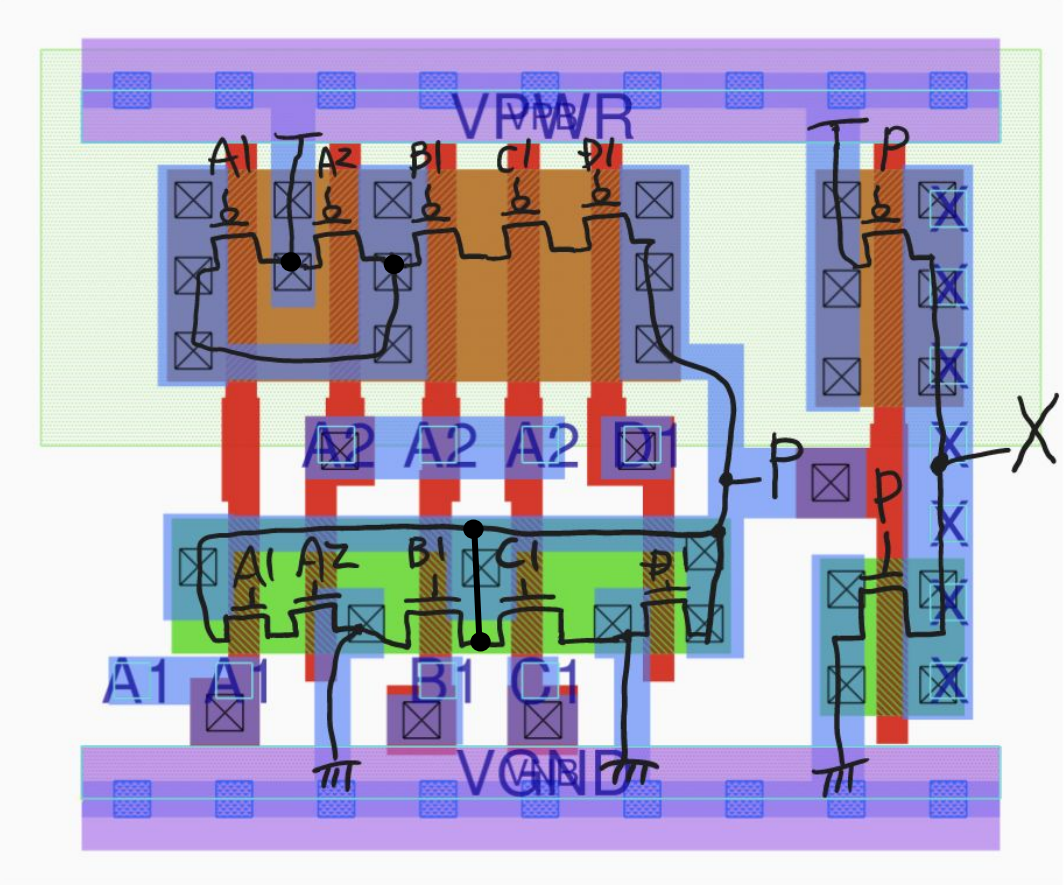


Layout

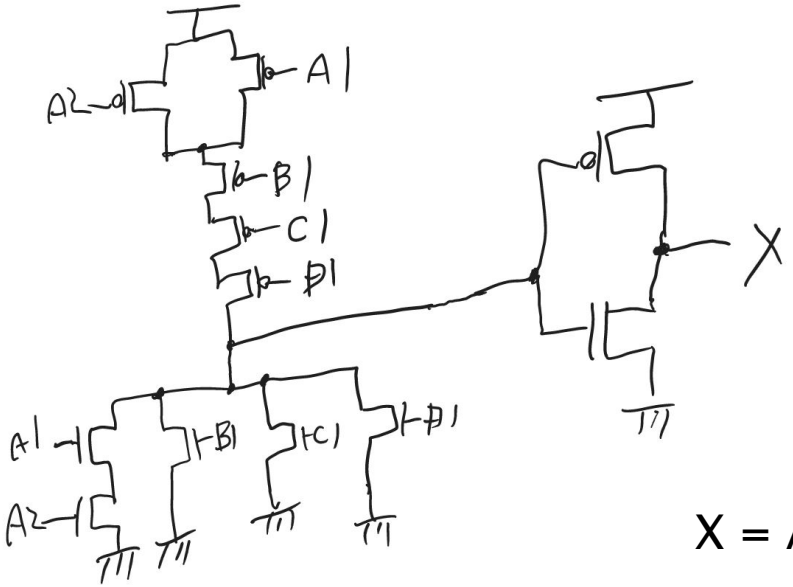

n-well: required for making PMOS devices
Vias: vertical connection between layers
Polysilicon: gate connection. Pins connected to the gate will connect to this layer
Diffusion region: represents the source/drain contact areas of the transistor
Metal Routing: metal wires in layout
Power Rails: VDD and VSS supply rails for the cell

Example



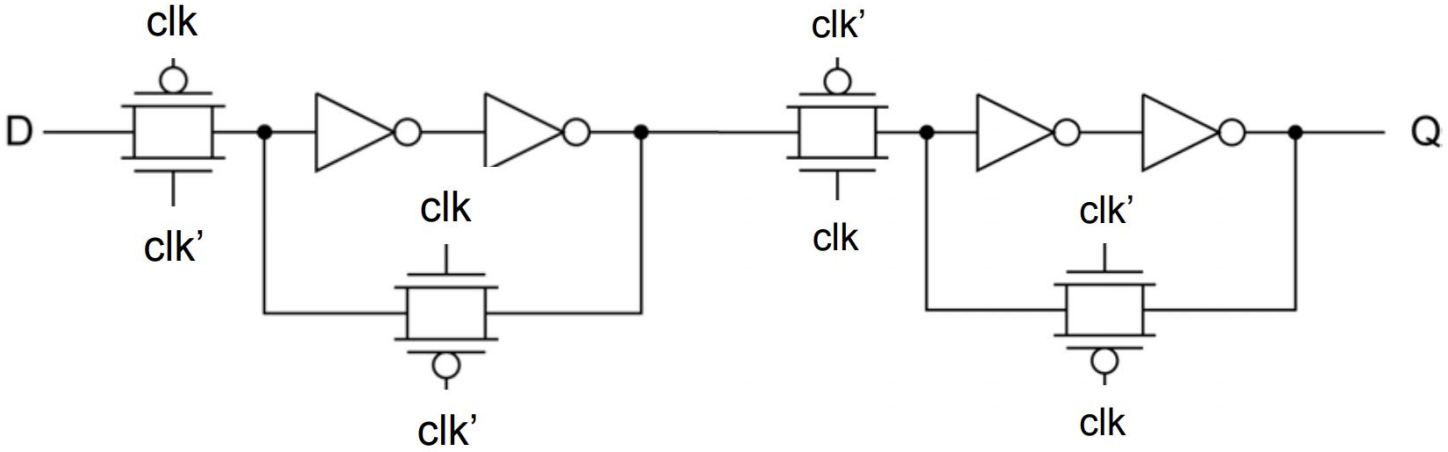

VPWR
A1
A2
B1
C1
D1
P
X
VGND

Transistor-Level Schematic



$$X = A1\ A2 + B1 + C1 + D1$$

Flip-Flops



Flip-Flops