CMOS transistors and gates

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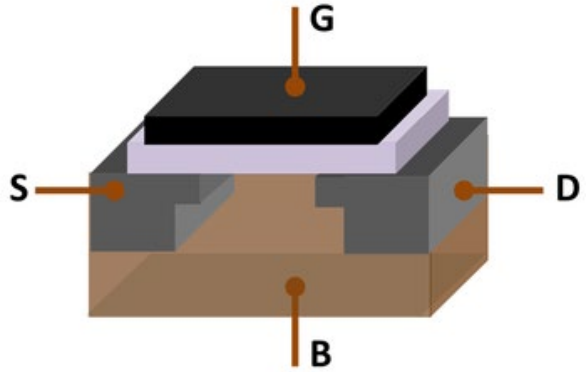
- **Metal-oxide semiconductor (MOS) transistors and gates**
  - Chapter 5, Kohavi's book

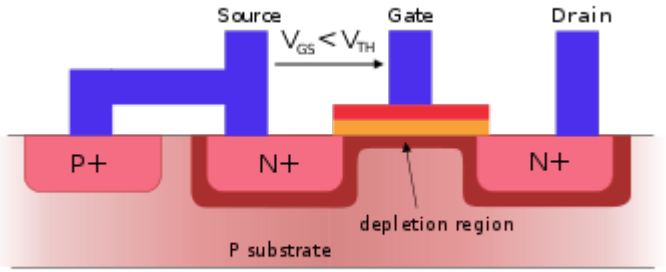
MOSFET

- The **metal–oxide–semiconductor field-effect transistor** (**MOSFET**), also known as the **metal–oxide–silicon transistor** (**MOS transistor**, or **MOS**) is a type of insulated-gate field-effect transistor that is fabricated by the controlled oxidation of a semiconductor, typically silicon.

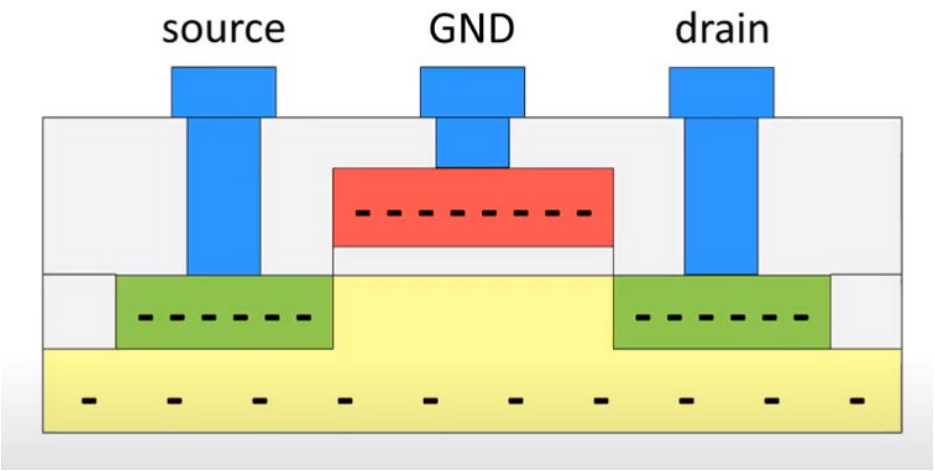


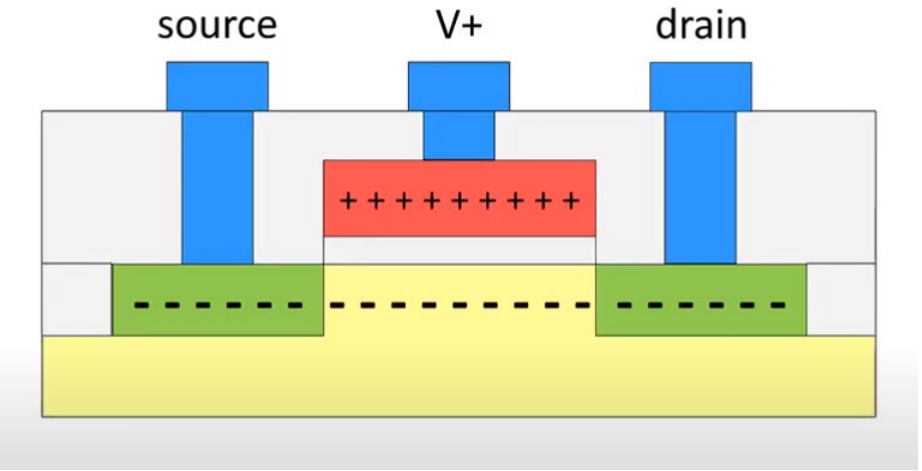
MOSFET

- The traditional metal–oxide–semiconductor (MOS) structure is obtained by growing a layer of silicon dioxide on top of a silicon substrate, commonly by thermal oxidation and depositing a layer of metal or polycrystalline silicon. As the silicon dioxide is a dielectric material, its structure is equivalent to a planar capacitor, with one of the electrodes replaced by a semiconductor.
- When a voltage is applied across a MOS structure, it modifies the distribution of charges in the semiconductor.

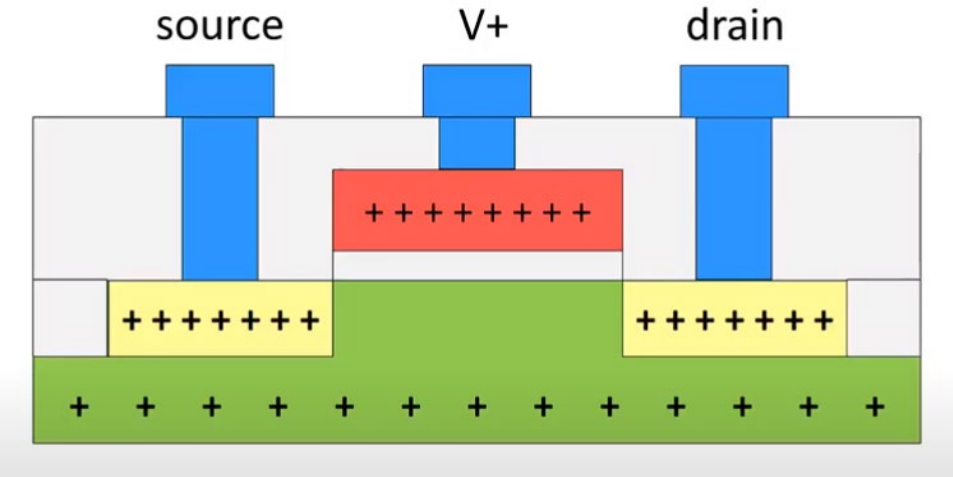


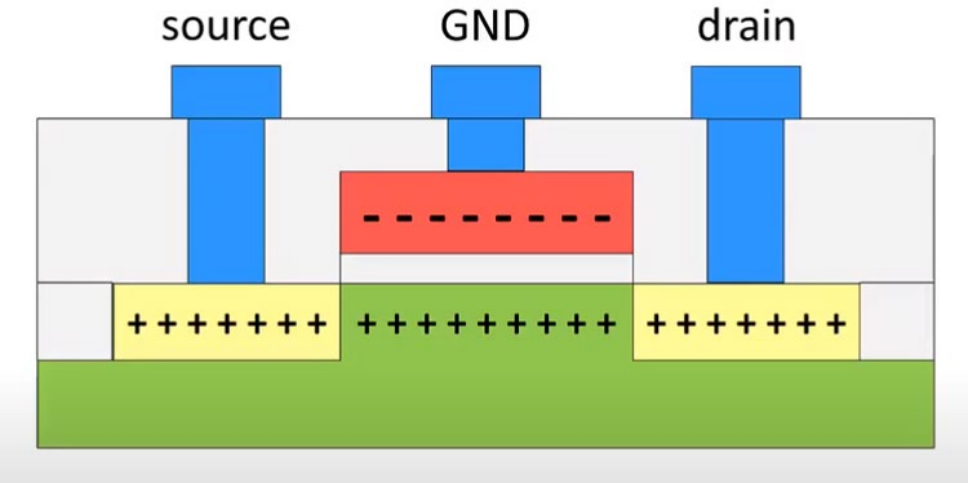
NMOS





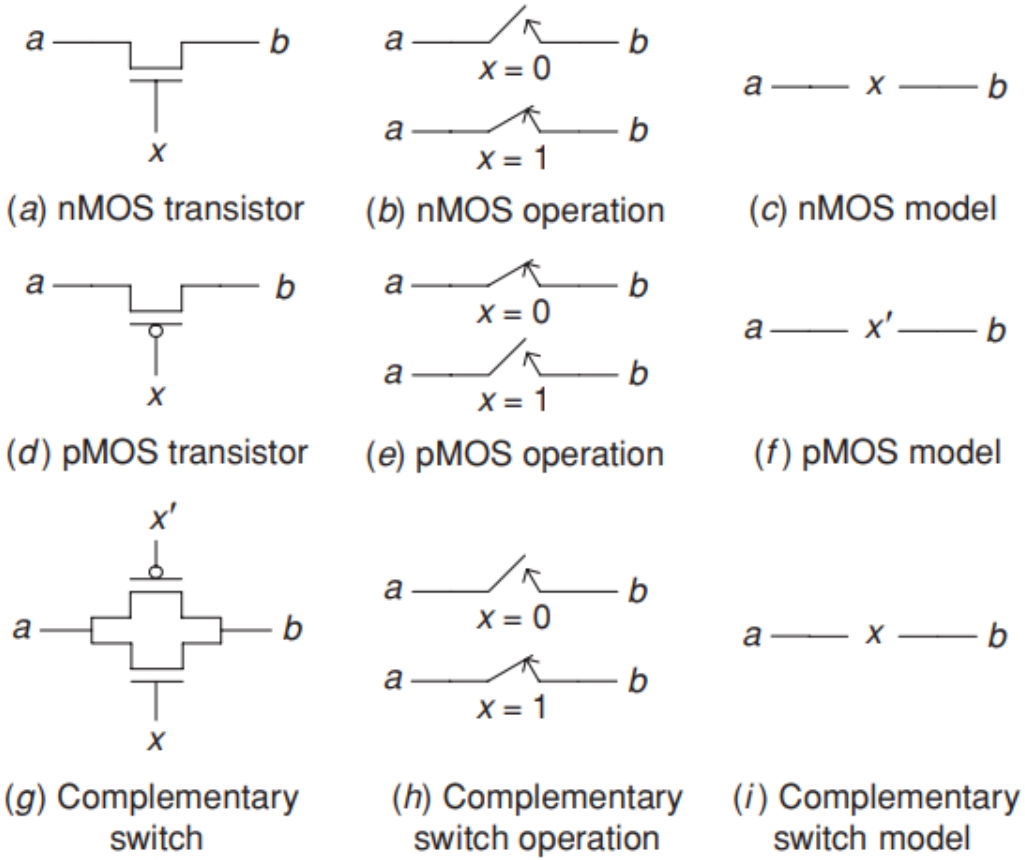
PMOS





METAL-OXIDE SEMICONDUCTOR GATES AND TRANSISTORS

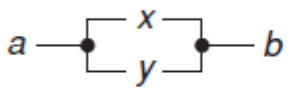
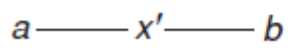
- Complementary metal-oxide semiconductor (CMOS) is the dominant technology for implementing chips.



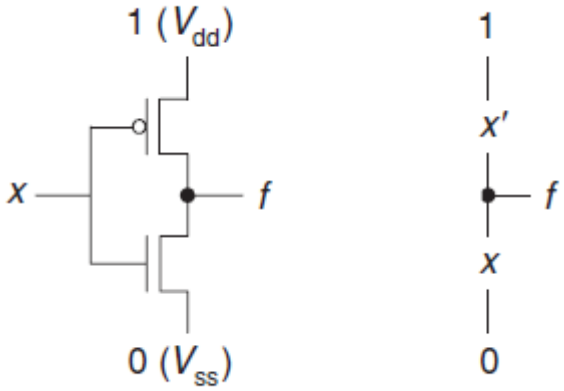
MOS CONTD.

- nMOS Transistor: The switch is open when x=0 and closed when x=1
- pMOS Transistor: The switch is open when x=1 and closed when x=0
- An nMOS transistor passes a 0 perfectly, but a 1 imperfectly.
- pMOS transistor is good at propagating a 1, but bad at propagating a 0.
- To overcome this drawback of nMOS and pMOS transistors they can be connected in parallel.
- It is called a complementary switch. This switch is closed when x = 1 since both its transistors are closed for this value.

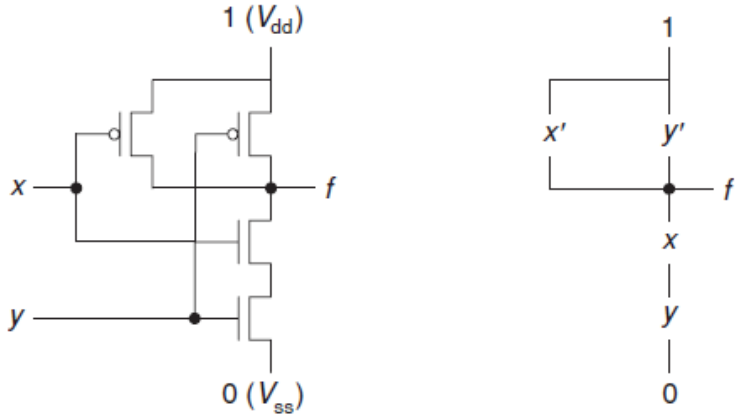
- Any switching expression can be realized by an appropriate connection of such transistors

Network	Transmission function
	$T_{ab} = x + y$
	$T_{ab} = xy$
	$T_{ab} = x'$

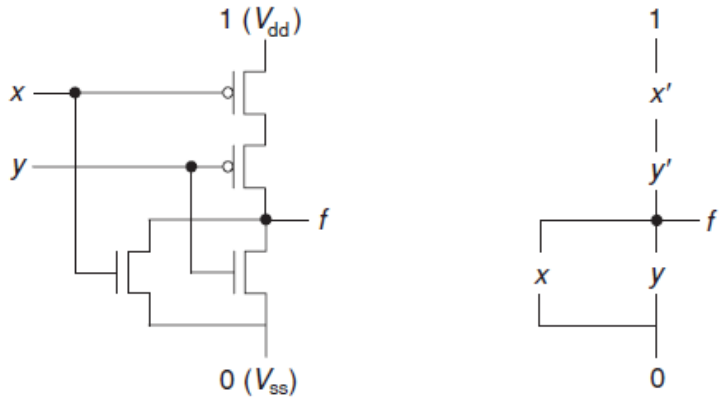
Gate realization using transistors



NOT GATE



(*a*) CMOS NAND gate and its transmission functions.



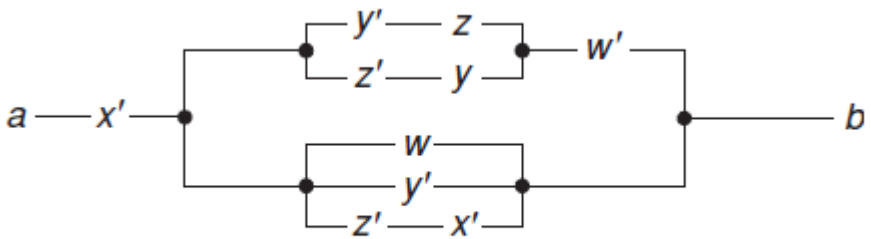
(*b*) CMOS NOR gate and its transmission functions.

Analysis of series–parallel networks

- Two MOS transistors with transmission functions x and y, connected in parallel, is x + y.
- the transmission function of a network consisting of two MOS transistors connected in series is xy.
- Since the algebra of MOS networks is isomorphic to switching algebra, the transmission function of two networks, T1 and T2, connected in series is T1T2 and the transmission function of a parallel connection of these two networks is T1 + T2.
- Utilizing these properties, we can determine the transmission function of any series–parallel network.

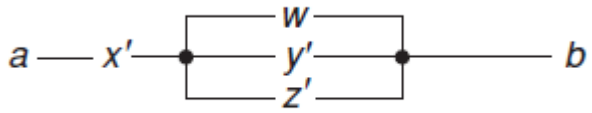
Analysis of series–parallel networks

$$T_{ab}(w, x, y, z) = x'[(y'z + yz')w' + w + y' + x'z'].$$



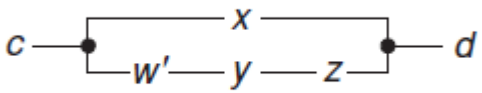
(a) $T_{ab} = x'[(y'z + z'y)w' + w + y' + x'z']$.

$$T_{ab}(w, x, y, z) = x'(w + y' + z').$$



(b) $T_{ab} = x'(w + y' + z')$.

Simplified expression

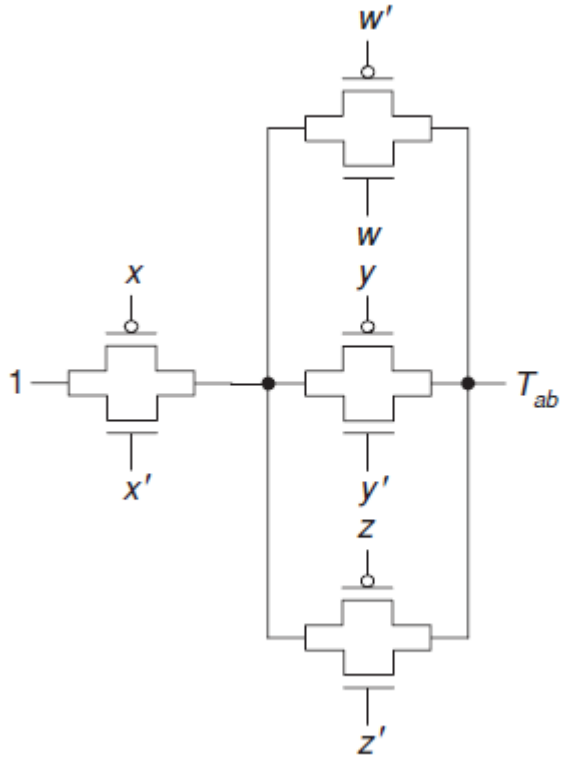


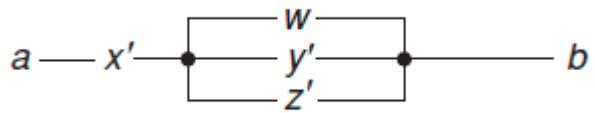
(c) $T_{cd} = T'_{ab} = x + w'yz$.

Complement

Complementary-switch-based CMOS implementation

$T_{ab}(w, x, y, z) = x'(w + y' +$



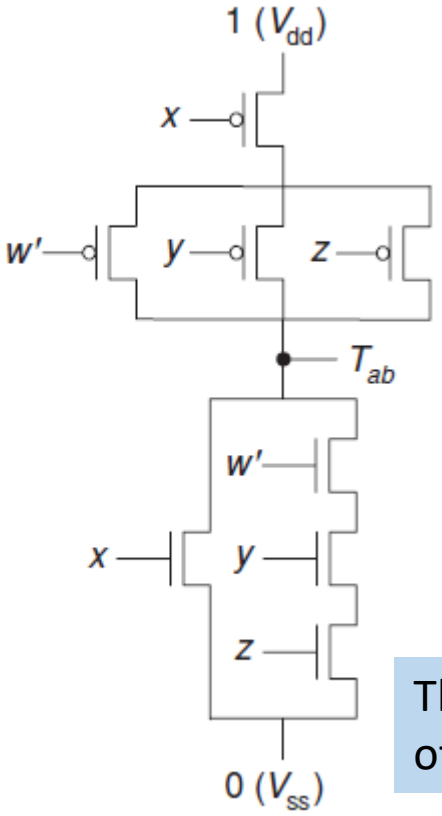


(b) $T_{ab} = x'(w + y' + z')$.

simply involves a one-to-one mapping from the network

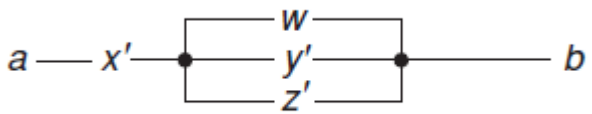
Complex CMOS-gate implementation

- A CMOS gate is said to be complex if it does not implement a primitive function such as a NOT, NAND or NOR gate.

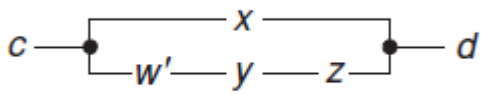


pMOS network

nMOS network



(b) $T_{ab} = x'(w + y' + z')$.



(c) $T_{cd} = T'_{ab} = x + w'yz$.

The number of transistors in complex CMOS-gate implementation of an expression is TWICE of its literal count

Synthesis of MOS networks

- Obtain the switching expression of the function
- Obtain the minimal/simplified expression
- Implement the simplified function using series-parallel network
- Simplify the network if possible (if some parallel sub-paths can be merges without changing the functionality).