Introduction to Digital Design and Computer Architecture

2. Fundamentals of Logic Gates

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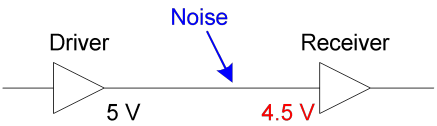
Voltage Ranges for Logic Levels

- **Logic 1 (High)**: Voltage range depends on the technology (e.g., TTL, CMOS).
- **Logic 0 (Low)**: Defined by a lower voltage range.
- **Noise Margin**:
  - Input and output voltage levels are designed with a margin to tolerate noise.
  - Ensures reliable signal interpretation.

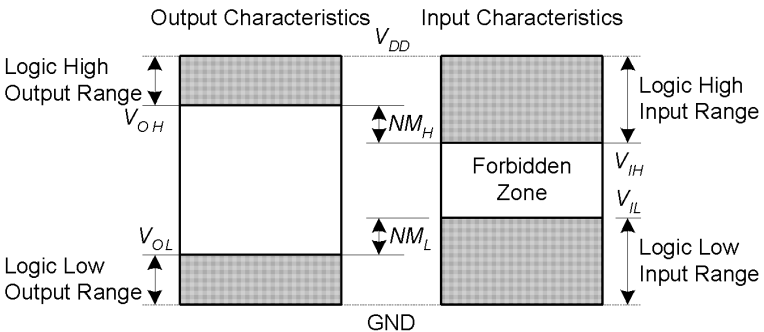
What is Noise?

Voltage Ranges for Logic Levels

- **Anything that degrades the signal**: E.g., resistance, power supply noise, coupling to neighboring wires, etc.
- **Example:** a gate (driver) outputs 5 V but, because of resistance in a long wire, receiver gets 4.5 V



Logic Levels



DC Transfer Characteristics

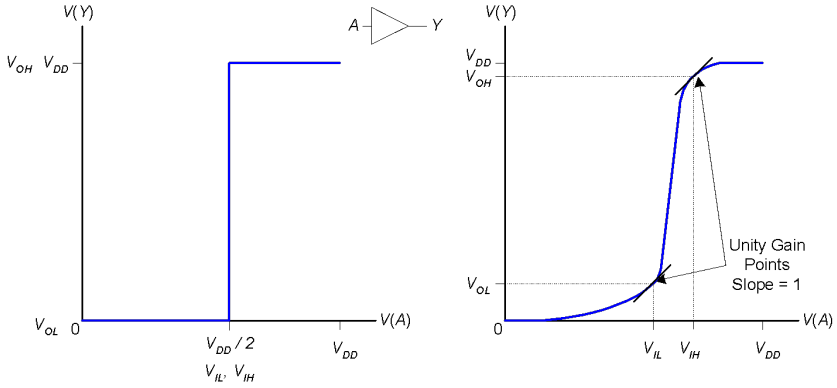


Figure: Expectation - Reality

Supply Voltage Scaling

In the 1970s and 1980s, $V_{DD} = 5V$.

- Over time, V_{DD} has decreased to protect smaller transistors and reduce power consumption.

Common Supply Voltages

3.3V, 2.5V, 1.8V, 1.5V, 1.2V, 1.0V, ...

Avoid frying tiny transistors.

Be cautious when connecting chips with different supply voltages.

BOOM!

Chips operate because they contain magic smoke

Proof: if the magic smoke is let out, the chip stops working

Conductors, and Dielectrics

- **Conductors:**
  - Materials that allow free flow of electric charge (e.g., copper, silver).
  - Have low electrical resistance.
- **Dielectrics (Insulators):**
  - Materials that resist the flow of electric current (e.g., glass, rubber).
  - Used in capacitors and to prevent short circuits.

Semiconductors

- **Semiconductors:**
  - Materials with electrical conductivity between conductors and insulators.
  - Can be modified using doping (e.g., silicon, germanium).
  - Basis of modern electronics (transistors, diodes, ICs).

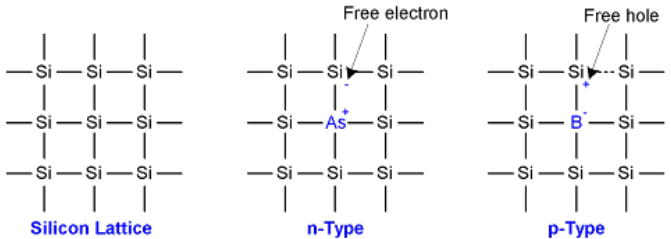


Figure: Silicon

Transistors: Tiny Switches That Power the World

Semiconductor

A tiny semiconductor device that acts like a switch or an amplifier.

The building block of all modern electronics!

- **Types of Transistors:**
  - **Bipolar Junction Transistor (BJT):** Uses electric current to control a larger current.
  - **Field-Effect Transistor (FET):** Uses an electric field instead of current to switch on and off.
  - **MOSFET (Metal-Oxide-Semiconductor FET):** The most common type, found in microprocessors and memory chips.

Why Are They Important? - They are the reason computers, smartphones, and even your TV work. - Used in everything from amplifying sound in speakers to switching billions of times per second in a CPU.

MOS Transistors

- **Metal-Oxide-Semiconductor (MOS) Transistors:**
  - Polysilicon (used to be metal) gate
  - Oxide (silicon dioxide) insulator
  - Doped silicon

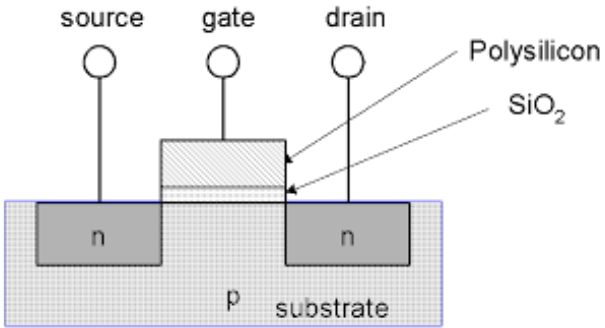
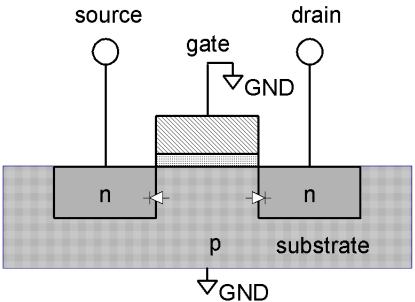


Figure: MOS Transistor Structure

nMOS

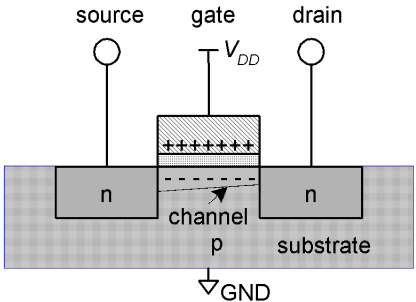
Gate = 0

- **OFF**



Gate = 1

- **ON**



pMOS

- **PMOS (P-Channel Metal-Oxide-Semiconductor) Transistors:**
  - Polysilicon gate (used to be metal)
  - Oxide (silicon dioxide) insulator
  - Doped silicon (P-type)

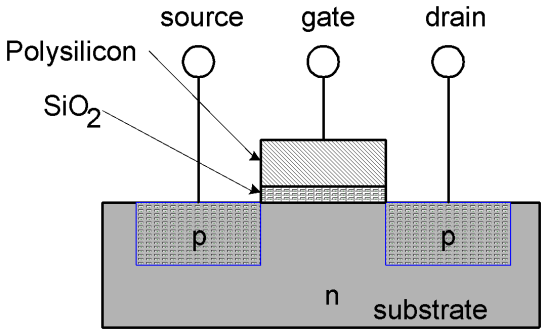
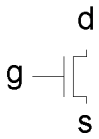
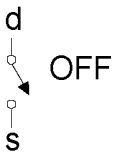
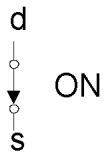
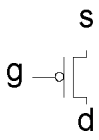
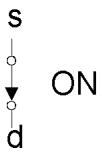
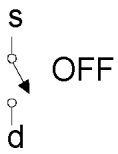


Figure: PMOS Transistor Structure

Transistor Function

		g = 0	g = 1
nMOS			
pMOS			

Logic Gates

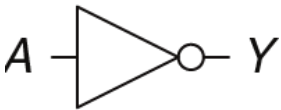
Logic gates are the fundamental building blocks of digital electronics.

They take one or more inputs and produce a single output based on a logical operation.

The most common logic gates

- AND, OR, NOT
- NAND, NOR, XOR, and XNOR

NOT Gate



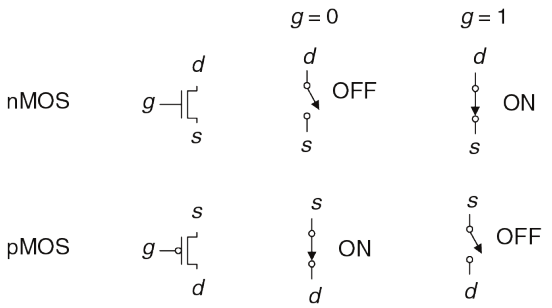
Inverts the input:

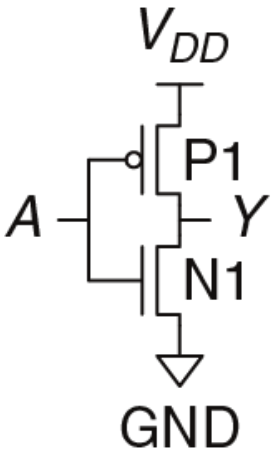
- Input 1 $\rightarrow$ Output 0
- Input 0 $\rightarrow$ Output 1

$$Y = \overline{A}$$

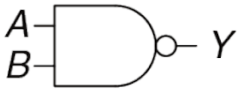
A	Y
0	1
1	0

NOT Gate





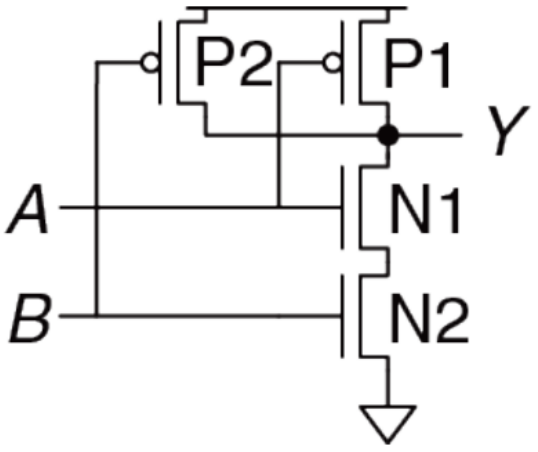
AND-NOT (NAND)



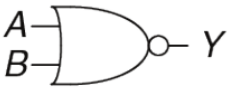
$$Y = \overline{AB}$$

A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

AND-NOT (NAND)



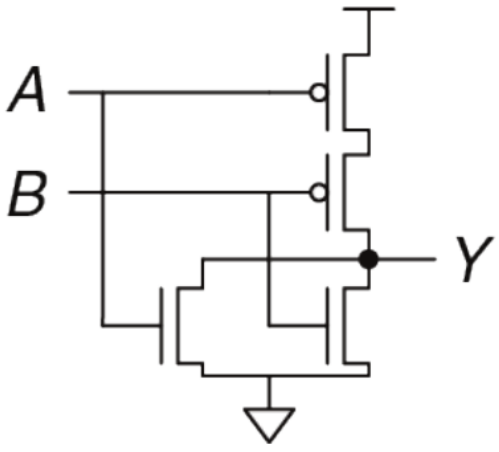
NOR



$$Y = \overline{A + B}$$

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

NOR




ВЖУХ
И КОНЕЦ ПРЕЗЕНТАЦИИ