TRANSISTORS

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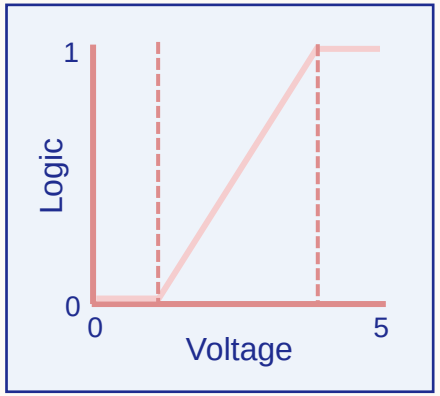
ANALOG TO DIGITAL

We've so far considered electronic signals to be discrete, either ON or OFF. In reality, these have continuous physical quantities such as voltage on a wire:

Logical 0 is represented by 0V, while logical 1 is commonly represented by 5V… *But what if the voltage was 0.0001V or 4.9999V?*

Due to the nature of electrical signals being continuous and likely to have small variances, we actually consider a (small) range of voltages as representing logical 0 or logical 1.



However, we're not interested in exact physics and so tend to abstract this continuous logic and instead think of discrete variables, where ***Vdd* (drain)** represents the voltage range that is acceptable to represent logical 1 and ***Vss* (source/ground)** represents the voltage range that is acceptable to represent logical 0.

As transistors have become smaller, Vdd has lowered, to save power and avoid overloading them!

SILICON

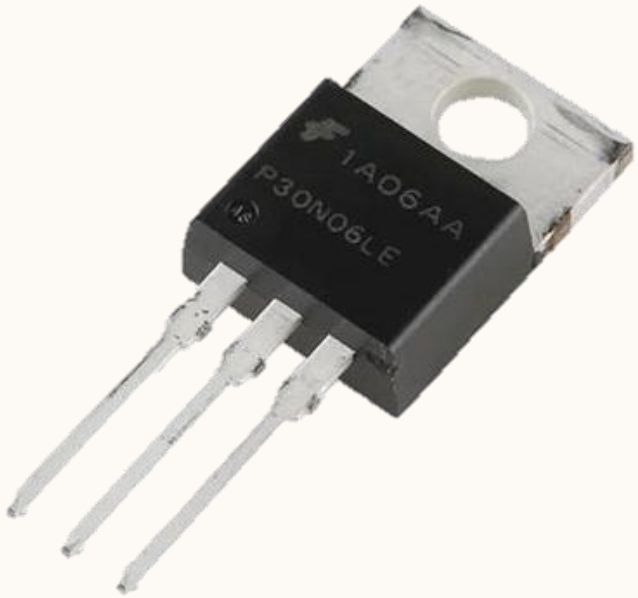
Transistors are electrically controlled switches, and they are used as building blocks in modern computers because they are cheap, small, and reliable.

There are two main type of transistors: BJTs (bipolar junction transistors) and **MOSFETs (metal-oxide-semiconductor field effect transistors)** – we'll be looking at the latter!

MOS transistors are built from Silicon, a **semiconductor** and the second most abundant element on Earth.

Semiconductors have the unique property of conducting electricity under certain conditions, while acting as insulators (blocking the flow of electricity) in others.

Impurities can be introduced, using a process called **doping**, to modify what conditions are required to create a conductive channel.



TRANSISTOR TYPES

The doping process can either gives the silicon structure extra electrons or *holes* (the absence of an electron where it could exist). These modifications will result in two distinct types of MOS transistors: p-type transistors (pMOS) and n-type transistors (nMOS).

n-type

These are modified to have **extra electrons.**

We call these negative types as electrons are negatively charged.

p-type

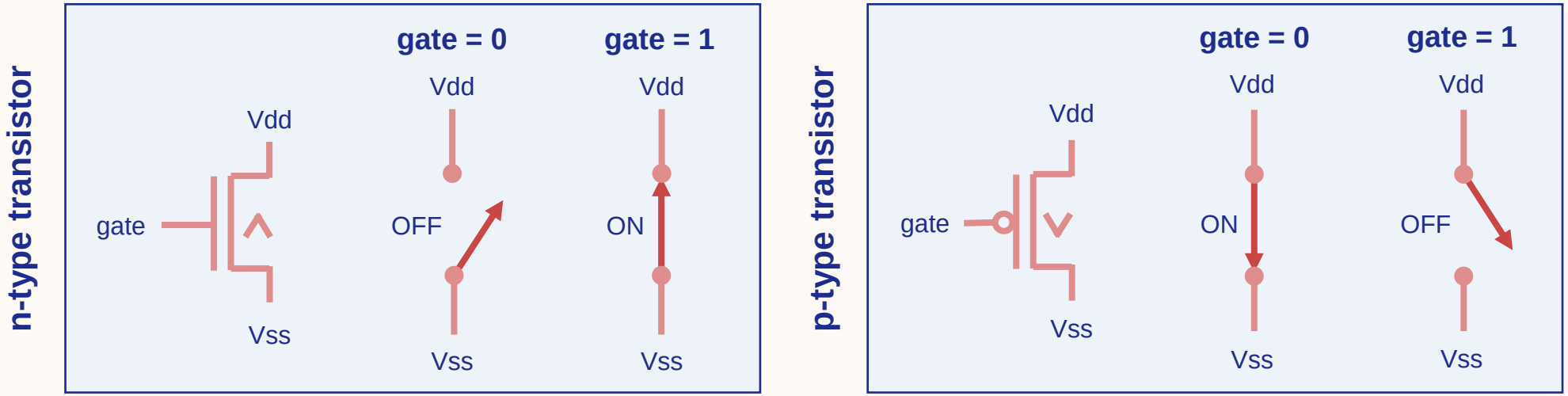
These are modified to have **holes.**

We call these positive types as the holes give a “lack of negative charge”.

N-type transistors require a Vdd/1 input to create a conductive channel (turn ON), while p-type transistors require a Vss/0 input to create a conductive channel (turn ON)…

TRANSISTOR TYPES

P-type and n-type transistors act as electrically controlled switches within a circuit – these are turned ON or OFF, depending on the gate signal:



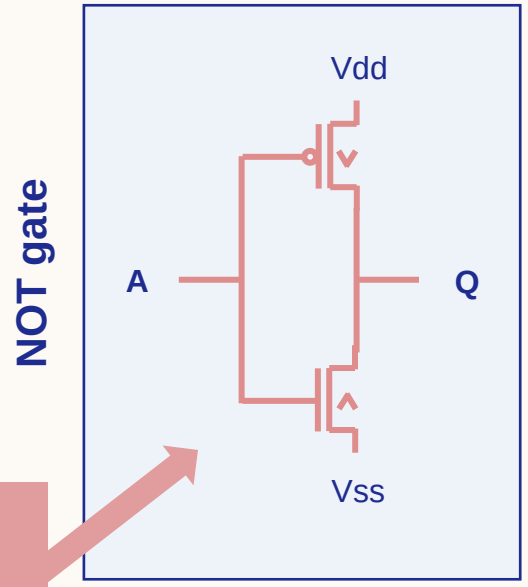
Beyond having opposing responses to the gate signal, p-type and n-type transistors also differ in terms of what type of signal they pass effectively.

Specifically, p-type transistors are effective at passing the Vdd/1 signal, while n-type transistors are effective at passing the Vss/0 signal. Each does a poor job of passing the opposite signal!

CMOS LOGIC

Within CMOS technology (which is used in most modern computers), both n-type and p-type transistors work together. N-type transistors are used to make a connection to Vss when ON, whereas p-type transistors are used to make a connection to Vdd when ON.

This complementary action allows for efficient switching in circuits, which is why CMOS stands for **Complementary Metal-Oxide-Semiconductor**…



Connection to Vss is required, as no connection = no signal!