Semiconductor Technology from A to Z

Fundamentals

CMOS vs. Bipolar 3
- ***Overview*** 3
- ***Operating Principle Compared*** 3
- ***Power Dissipation and Switching Behaviour*** 3
- ***Integration Density and Scaling*** 4
- ***Comparison Table*** 4

CMOS vs. Bipolar

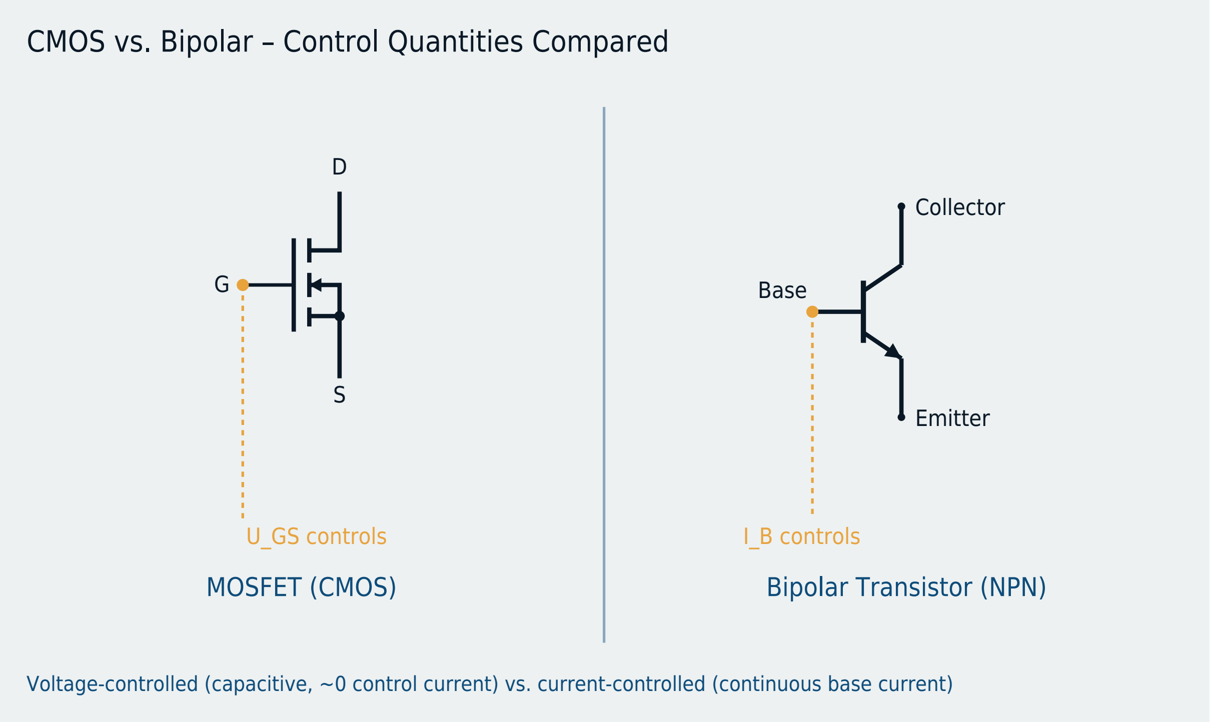
Overview

CMOS technology and the bipolar transistor represent two fundamentally different ways of controlling and amplifying electrical signals. While the bipolar transistor dominated digital electronics for decades (TTL logic), the field-effect transistor in the form of CMOS technology has almost completely displaced it since the 1980s – not because it is inherently "better", but because its properties suit mass integration far more effectively. In analogue, radio-frequency, and power applications, however, the bipolar transistor remains relevant to this day.

Operating Principle Compared

The MOSFET is a unipolar device: a voltage at the gate generates a conductive channel between source and drain via an electric field. Because the gate is insulated from the channel by an oxide layer, practically no control current flows in steady state – the MOSFET is voltage-controlled.

The bipolar transistor, by contrast, works with two types of charge carriers simultaneously (hence "bipolar"). A base current controls a much larger collector current through carrier injection and diffusion. It is therefore current-controlled and requires a continuous control current during operation.



Power Dissipation and Switching Behaviour

This difference has direct consequences for power dissipation: in CMOS circuits, an n-channel and a p-channel transistor are always switched complementarily for each logic level, so that no path conducts between supply and ground in the static state – static power dissipation is close to zero. Power dissipation here arises mainly dynamically, from charging and discharging the gate and line capacitances during switching.

Bipolar transistors, on the other hand, require a continuous base current to stay conducting, resulting in permanent static power dissipation. In return, their high transconductance (a large collector current per change in control current) often gives them higher switching speeds and better drive capability into low load impedances.

Integration Density and Scaling

The near-lossless standby behaviour of CMOS allows billions of transistors to be integrated on a single chip without total power dissipation becoming unmanageable – an advantage bipolar logic could never match at this density. A MOSFET also requires no elaborate base doping structure, making it more area-efficient and easier to scale.

Bipolar transistors continue to hold their ground wherever high current drive capability, low noise, or high cutoff frequencies are required: in RF amplifiers, power stages, and precision analogue circuits (e.g. operational amplifiers). BiCMOS processes also combine both worlds deliberately.

Comparison Table

Property	MOSFET / CMOS	Bipolar Transistor
Control quantity	Voltage (gate)	Current (base)
Input resistance	very high (capacitive)	low
Static power dissipation	~0 (at standby)	always present
Switching speed	high, capacitively limited	very high, transconductance-limited
Noise behaviour	good	partly better (at RF)
Typical application	Digital logic, memory	Analogue/RF/power electronics