# Moore's Law and Its Limitations

In 1965, Gordon E. Moore, the CEO of Intel, made an observation that the number of transistors on a microchip doubles about every two years. It was named Moore's Law several years later by the physicist Carver Mead.

In the decades that followed Gordon Moore's original observation, the Law guided the semiconductor industry in setting targets for research and development. The industry, that has been a driving force of technological and social change, and economic growth of the late 20th and early 21st centuries.

Moore's Law implies that computers, devices that embed computers, become smaller, faster, and cheaper with time.

But the Law is not eternal. Experts agree that computers should reach the physical limits of Moore's Law at some point in the 2020s. The high temperatures of transistors would make smaller circuits impossible. Because cooling down the transistors takes more energy than the amount of energy that passes through the transistors.

In a 2005 interview, Moore admitted that "...the fact that materials are made of atoms is the fundamental limitation and it's not that far away...We're pushing up against some fairly fundamental limits so one of these days we're going to have to stop making things smaller."

Continuous innovation is the cornerstone of Moore’s Law. In 2012, with its 22-nanometer (nm) processor, Intel was able to boast of having the world's smallest and most advanced transistors in a mass-produced product. In 2014, Intel launched an even smaller, more powerful 14nm chip; and today, the company is struggling to bring its 7nm chip to market.

Now the technological advances have shifted to packing more cores on a chip with simultaneous increase of performance per watt. For examples, Intel 7 process underpins the 12th Gen Intel® Core™ processors in 2022. Intel 4, an implementation of extreme ultraviolet (EUV) lithography, is manufacturing-ready in the second half of 2022. It delivers an approximate 20% increase in transistor performance per watt. Intel 3 delivers a further 18% performance per watt and will be manufacturing-ready in the second half of 2023.

One nanometer is one billionth of a meter, smaller than the wavelength of visible light. The diameter of an atom ranges from about 0.1 to 0.5 nanometers.

One of the key technical challenges of nanoscale transistors is the design of gates. As device dimension shrinks, controlling the current flow in the thin channel becomes more difficult. The physical limits to transistor scaling have been reached due to source-to-drain leakage, limited gate metals and limited options for channel material. High power dissipation is the decisive factor limiting the development of ever integrated and high-frequency integrated circuits.

**Sources:**

Moore's Law discussed by Gordon E. Moore. <https://www.youtube.com/watch?v=MH6jUSjpr-Q>.

What Is Moore's Law and Is It Still True? <https://www.investopedia.com/terms/m/mooreslaw.asp>

Intel Technology Roadmaps and Milestones <https://www.intel.com/content/www/us/en/newsroom/news/intel-technology-roadmaps-milestones.html#gs.oyte37>

Moore’s Law <https://en.wikipedia.org/wiki/Moore%27s_lawє>

Concept 1: Temperature increases as power increases.



4 pts

The response mentions this concept.



0 pts

The response does NOT mention this concept.

Concept 2: Power increases as transistor density increases.



3 pts

The response mentions this concept.



0 pts

The response does NOT mention this concept.

Concept 3: Voltage scaling reduces (dynamic) power consumption.



1 pt

The response mentions this concept.



0 pts

The response does NOT mention this concept.

Concept 4: Voltage scaling cannot prevent leakage power loss.



1 pt

The response mentions this concept.



0 pts

The response does NOT mention this concept.

Concept 5: Voltage scaling is limited due to noise or threshold voltage.



1 pt

The response mentions this concept.



0 pts

The response does NOT mention this concept.