

Moore's Law, proposed by Intel co-founder Gordon Moore in 1965, originally observed that the number of transistors on a semiconductor chip tends to double approximately every two years, leading to exponential growth in computing power and technological advancement. However, while Moore's Law held true for several decades, it has now slowed down and is no longer strictly accurate due to various physical limitations in semiconductor technology. These limitations have prevented Moore's Law from continuing unabated. Here are the key factors contributing to the end of Moore's Law:

1. **Transistor Scaling Limits:** As transistors have shrunk to atomic scales, fundamental physical limitations have emerged, making further scaling increasingly challenging. Quantum mechanical effects, such as quantum tunneling and leakage currents, become more significant at these tiny dimensions, hindering transistor performance and reliability.
2. **Heat Dissipation:** As transistor sizes have decreased and transistor densities increased, power density has risen, leading to greater heat generation within semiconductor chips. Heat dissipation becomes a significant challenge, as smaller transistors are less efficient at conducting heat away from the chip. Excessive heat can degrade performance, reduce reliability, and lead to thermal throttling, where clock speeds are lowered to prevent overheating.
3. **Energy Efficiency:** With the end of Dennard Scaling (where power density remains constant as transistor sizes decrease), the improvements in energy efficiency that accompanied transistor scaling have slowed down. As a result, simply increasing transistor counts no longer leads to corresponding increases in performance-per-watt, making further scaling less beneficial.

- 4. Economic and Manufacturing Challenges:** The economics of semiconductor manufacturing have also become increasingly challenging. Building new fabrication facilities (fabs) capable of producing chips with smaller transistor sizes requires significant investment. The cost of designing and producing advanced semiconductor technology nodes has risen dramatically, leading to a slowdown in the rate of new technology node introductions.
- 5. Technological Innovations and Paradigm Shifts:** While traditional semiconductor scaling may have slowed, technological innovations and paradigm shifts such as the rise of specialized accelerators (e.g., GPUs, TPUs), heterogeneous computing architectures, and advancements in packaging technologies (such as 3D integration) are driving continued improvements in computing power and performance, albeit through different means than traditional transistor scaling.

In summary, Moore's Law has slowed down and is no longer strictly accurate due to various physical, economic, and technological limitations inherent in semiconductor technology. While the era of exponential transistor scaling may be coming to an end, continued advancements in computing power and performance are being driven by new innovations and approaches to hardware design.