

Moore's Law is widely known for observing anecdotally that the number of transistors on a microchip doubles approximately every two years, leading to roughly exponential growth in computational power over time. As of late, the relentless progress of Moore's Law has plateaued, and it is no longer considered entirely accurate. The limiting factors primarily stem from physical constraints that impede further advancements in line with the law's original predictions. Here are the key reasons behind these limitations:

1. Temperature increases as power increases: As the power consumed by transistors increases, so does the heat generated. This is a direct consequence of the relationship between power and temperature. As transistor density increases and more transistors are packed onto a chip, the overall power consumption rises, resulting in elevated temperatures.

2. Power increases as transistor density increases: Increasing the number of transistors on a chip, as Moore's Law suggests, raises the power requirements of the circuitry. With greater transistor density, more power is needed to drive the increased number of transistors, contributing to a higher overall power consumption.

3. Voltage scaling reduces (dynamic) power consumption: One approach to mitigating power consumption is voltage scaling, which involves reducing the operating voltage of transistors. By lowering the voltage, the dynamic power consumption decreases. This technique has been instrumental in achieving power savings, particularly in earlier stages of transistor scaling.

4. Voltage scaling cannot prevent leakage power loss: Despite the benefits of voltage scaling, it is unable to address leakage power, which arises from current leakage through transistors when they are in an "off" state. As transistors become smaller, leakage current becomes more significant, resulting in increased power loss that cannot be effectively reduced through voltage scaling alone.

5. Voltage scaling is limited due to noise or threshold voltage: Voltage scaling faces limitations due to factors such as noise and threshold voltage. Noise interference becomes more pronounced at lower voltages, limiting the extent to which voltage scaling can be applied. Additionally, there is a minimum threshold voltage required to ensure proper transistor operation. Scaling the voltage below this threshold becomes impractical due to reliability concerns and the risk of compromised functionality.

These physical limitations collectively contribute to the diminishing applicability of Moore's Law. While progress in semiconductor technology continues, it necessitates innovative solutions, multidisciplinary approaches, and advancements beyond traditional transistor scaling.