Activity 1

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Definition of Moore's Law

Moore's Law, named after Gordon Moore, the co-founder of Intel, is an empirical observation made in 1965. It states that the number of transistors on a microchip doubles approximately every two years, while the cost per transistor decreases. This trend has historically driven the exponential growth in computing power, efficiency, and miniaturization of electronic devices, influencing the technology industry for decades.

Reasons Why Moore's Law Has Stopped Being True

In recent years, Moore's Law has slowed and is no longer strictly followed due to several physical and practical limitations. These limitations include:

1. Transistor Size Limits

- **Atomic Scale Limitations**: Transistors are approaching the size of a few nanometers, which is only a few atoms across. As we reach the atomic scale, quantum mechanical effects such as tunneling become significant, where electrons can pass through insulating barriers, leading to leakage currents that degrade performance and increase power consumption.
- **Fabrication Precision**: Manufacturing at such small scales requires extreme precision and control, which is increasingly difficult and costly. Variations at the atomic level can significantly affect transistor behavior and yield.

2. Power Density and Heat Dissipation

- **Power Consumption**: As more transistors are packed into a chip, the power density (power per unit area) increases. This results in significant heat generation that is difficult to dissipate efficiently. Excessive heat can damage the chip and reduce its lifespan.

- **Thermal Limits**: There are physical limits to how much heat can be removed from a chip using current cooling technologies. High temperatures can affect the reliability and performance of transistors.

3. Voltage Scaling Issues

- **Threshold Voltage Constraints**: Reducing the supply voltage to save power is limited by the threshold voltage below which transistors do not switch reliably. As mentioned earlier, the supply voltage cannot be reduced indefinitely without compromising the transistor's ability to turn on and off correctly.
- **Leakage Currents**: Lowering the voltage too much increases leakage currents, which leads to higher static power consumption, even when the device is not switching, exacerbating power and heat issues.

4. Interconnect Limitations

- **Signal Delay**: As transistor sizes decrease, the relative importance of interconnects (the wiring between transistors) increases. The delay and power consumption of these interconnects become significant bottlenecks because electrons take longer to travel through the interconnects, limiting the overall speed improvements.
- **Capacitance and Resistance**: Smaller wires have higher resistance and capacitance per unit length, which negatively affects the speed and power consumption of the circuits.

5. Manufacturing Costs and Complexity

- **Economic Factors**: The cost of developing new manufacturing processes and facilities for each new generation of smaller transistors is extremely high. The economic returns are diminishing because the cost per transistor is no longer decreasing at the same rate as before.
- **Complexity and Yield**: Increased complexity in design and manufacturing processes reduces yield (the percentage of functional chips from each wafer), making it harder to economically justify the shrinking of transistor sizes.

Conclusion

Moore's Law has driven technological progress for many decades, but several physical and practical limitations are now impeding its continuation. These include atomic-scale constraints, power density and heat dissipation challenges, voltage scaling issues, interconnect limitations, and increasing manufacturing costs and complexity. As a result, the historical rate of improvement in transistor density and cost efficiency predicted by Moore's Law has slowed, leading the industry to explore new paradigms such as alternative materials, 3D stacking, and specialized architectures to sustain progress in computing performance.