

**Define Moore's law and explain why it has now stopped being true. Be sure to describe all of the physical limitations that have prevented Moore's law from continuing to be true.**

Moore's law is an observation that transistor density was doubling every two years. Smaller transistors resulted in more transistors on a chip as well as each transistor being able to switch more quickly. This led to a massive increase in the processor power available to programmers. Unfortunately this can no longer continue to be true.

One key factor is described as the "Power Wall", this describes the effect that having a higher density of transistors results in increased power consumption of the chip. On its own this is problematic as many modern devices are battery powered and don't have unlimited power to supply these chips. Even more importantly though is with increased power comes increased temperature, these chips become increasingly hard to cool to the point that they will melt if Moore's law continues.

Another factor is Denard's scaling, this describes the practice of decreasing the voltage swing of the transistors as they shrink. This has the effect of reducing the power consumption as dynamic power is related to the square of the voltage swing. But this also can't continue forever, firstly transistors have a threshold voltage below which they cannot switch. This sets a minimal voltage swing required. Noise is also a key issue in electrical systems, as the voltage swing reduces the ability to detect noise becomes more difficult. For example if the noise is  $\pm 0.5V$  then with a 5V swing the high (4.5V) and lows (0.5V) would still be able to be distinguished from each other. Whereas if the swing was only 1V then the noise could bring the low value to 0.5V which could be mistaken for the high value with noise of 0.5V.

The final physical limitation preventing Moore's law from continuing is Leakage Power. This is power used by the transistor when not switching e.g. not Dynamic Power. As transistor density increases the size of the insulators between transistors reduces. This causes more power to leak and thus becomes a larger component of the overall power. As described before power and temperature are limited and both should be reduced.