ECE 3030: Physical Foundations of Computer Engineering
Summer 2020
Homework 1—Total points 100
Due on Tuesday 6/2/2020 at 11.59am.

Q1 The following figure shows how the microprocessor clock frequency evolved over the last four decades. Note that clock frequency stopped increasing after 2005. Explain why. [10 pts]

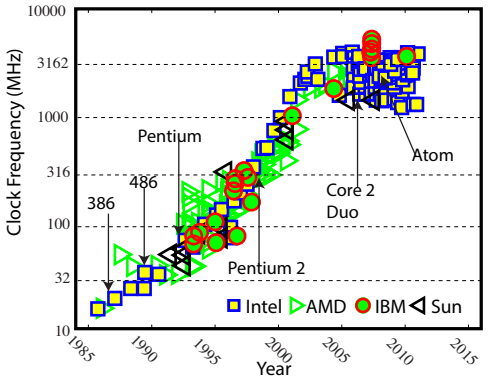

Figure 1: Ref: Andrew Danowitz et al. CPU DB: recording microprocessor history. In: Communications of the ACM 55.4 (2012), pp. 55-63.

Solution to Q1: Increase in clock frequency means increase in power density and the rate of heat generation. Increasing clock frequency beyond ∼3 GHz increases the power density beyond a sustainable limit. The power density has remained constant at ∼100 W/cm^2 since 2005 (fig. 1).

Q2 The Moore's law is an observation that the number of transistors per square area of a state-of-the-art microprocessor chip doubles approximately every two years. This has remained valid since early 1970s till now. How is that achieved while the size of the chip has remained almost the same? Why is it advantageous? [10 pts]

Solution to Q2: By making the physical dimensions of the transistors smaller and smaller, more transistors are fitted into nominally same sized chips over generations. More transistors on the same chip means more computing operations and higher performance.

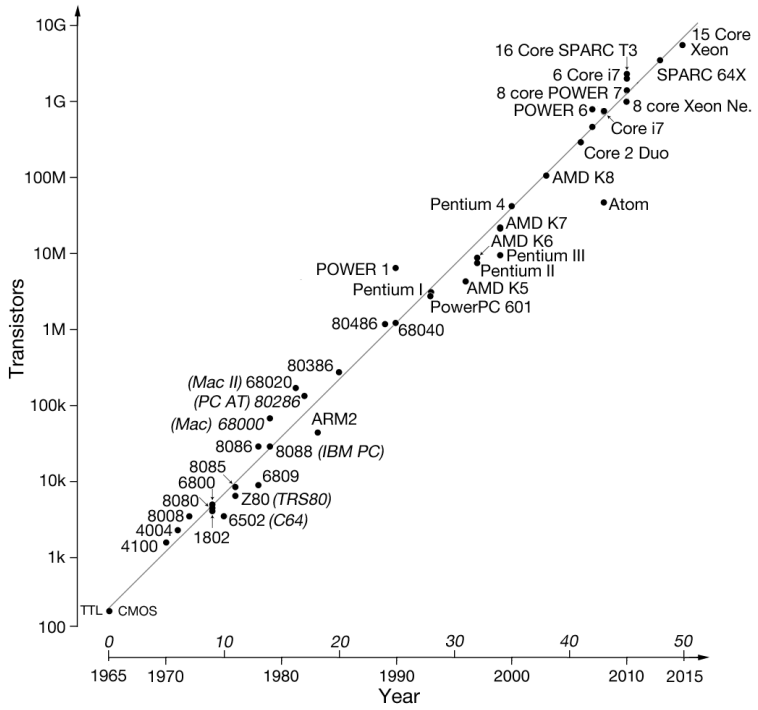

Figure 2: Ref: `https://www.elektormagazine.com/articles/moores-law`

Q3 What is the largest transistor count in a microprocessor? [Apple A12 Bionic chip has 6.8 billion transistors. There are other chips with higher transistor counts.] [20 pts]

Solution to Q3: Cerebras CS-2, powered by the Wafer Scale Engine (WSE-2) is the largest chip ever made and the fastest AI processor to date. Purpose-built for AI work, the 7-nanometer WSE-2 has 2.6 trillion transistors (`https://venturebeat.com/2021/08/24/cerebras-cs-2-brain-scale-chip-can-power-ai-mod`