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ECSE 310 Homework 1

1. Definitions
   1. kWh stands for kilowatt hour, a unit of energy equivalent to 3.6 Megajoules. It is the energy transmitted by a power of constant rate over a period of an hour
   2. CO2e stands for Carbon dioxide equivalent and is the standard unit for measuring carbon footprints. The impact of other gasses are expressed in CO2e to simplify calculations with a comparative amount of CO2 that would create the same amount of warming.
   3. GHG stands for GreenHouse Gas, which is a blanket term that describes any gas in the atmosphere that absorbs and re-emits heat, increasing the temperature of the earth more that it would be otherwise. GHG’s include methane, carbon dioxide and ozone.
   4. Activity factor is a constant in the equation in determining switching power dissipation. The value is meant to consider how often the gate switches as this controls charging/discharging.
   5. Dynamic Switching Energy is the energy required for constant charging voltage
   6. N-type and p-type semiconductor- Semiconductors are elements that have resistances between metals and insulators. The N-type/P-Type distinction is determined by the difference of how the semiconductor is doped with a charge. N-types are doped with a electron donor and the electrons are the majority charge carrier, whereas P-type are doped with an electron acceptor and holes are the majority charge carrier.
   7. NMOS and PMOS- These are both transistors. NMOS uses a an n-type semiconductor as a source and drain with a p-type body, and when A High voltage is applied to the gate, the transistor allows flow from source to drain. PMOS works inversely, with a P-type source and drain with a n-type body and allows flow if the gate is of low voltage.
   8. CMOS stands for Complementary metal- oxide semiconductors and is made up of both a NMOS and PMOS transistor in series with the same wire connected to both gates. The effect of this is that the input is always the inverse of the output.
   9. Local Interconnect refers to a type of scaling where the distance travelled is low, due to this R and C scale inversely with each other. The Time constant RC
   10. Global Interconnect refers to scaling when length is a long enough to influence the time constant. RC then scales with the Length RC ~ L^2
   11. Sheet Resistance- a common property used to characterize the lateral resistance of a thin film of conductor and semiconductors. This value is independent of size of the square allowing for easy comparison. It is equivalent to resistivity divided by thickness
2. Answer The following Questions
   1. Describe why capacitor and inductor can give delay: Both inductors and capacitors store energy in magnetic fields and electric fields respectively. Because energy cannot dissipated in the storage device instantaneously, there will always be delay in voltage for capacitors and current for inductors.
   2. Use a formula to explain why IBM airgap process is better (in terms of switching speed and switching energy): The airgap increases the distance between the plates and by the following equation: as d increases total capacitance decreases. The delay decreases as the parasitic capacitance decreases because the delay is proportional to capacitance each shown by the time constant equation: . The Energy held decreases as Capacitance increases as well as shown in the equation below:
   3. Why is it more convenient to use sheet resistance to model interconnects? : It is Sheet resistance is a dimensionless unit so the size of the sheet has no effect on the value of the resistance.
3. The current Leader of the Top500 supercomputer table (https://www.top500.org/lists/2017/11/ ) is the Sunway TaihuLight (National Supercomputing Center, Wuxi, China), which has a peak performance of 125\*10^15 Flop/s (“Flop/s” means floating point operations per second, which characterizes computing device performance) and a power consumption of 15,000 kW.
   1. Calculate number of computations per kWh:
   2. Given an average home consumes 11,000 KWh per year of electricity how, many homes could be run on the power consumed by this supercomputer:

* 1. Using the model for interconnect power given in class (in the notes, lecture 2.2: Interconnect (III)), extend the model to obtain equations for i) interconnect delay and ii) energy for a buffered line, where we divide the total line length L into N segments.

1. Interconnect delay:
2. Energy for a buffered line:
   1. Obtain an expression for the value of N which minimizes the delay

The derivative of Tau with respect to N should reveal the min of delay

* 1. Plot delay and energy as a function of N for the following Parameters

The Equation found for minimum delay was

The graph proves that the derived equation is correct as N = 1.18 is visibly the minimum of the line.

To find Energy Vs. N

1. The Intel 8086 microprocessor introduced in 978. It had an initial clock frequency of 5 MHz, and had 29,000 transistors, made with 3 μm technology operating at 5 V. The die size was 33 mm^2 . Assume a switching energy per transistor of 1 pJ. The design power was 1.9 W.
   1. Estimate the capacitance of the transistors from the data above
   2. Assuming an activity factor 0.1 estimate the power dissipation due to transistor switching:
   3. Given thermal design power of 1.9 W, what was the power dissipation per unit area
   4. Same tech is scaled down to 22 nm Transistors, but die size is the same. Find
      1. Number of transistors
      2. Clock Frequency

* + 1. Switch energy per transistor
    2. Total power dissipation due to transistor switching:
    3. Voltage
  1. Assuming an operating voltage of 1 V, estimate switching energy per transistor and the associated power dissipation for the chip: