Design of Digital Circuits (252-0028-00L), Spring 2018
Optional HW 1: DRAM Refresh

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Released: Monday, Mar 05, 2018

1 DRAM Refresh

A new supercomputer has a DRAM-based memory system with the following configuration:

- The total capacity is 1 ExaByte (EB).
- The DRAM row size is 8 KiloByte (KB).
- The minimum retention time among all DRAM rows in the system is 64 ms. In order to ensure that no data is lost, every DRAM row is refreshed once every 64 ms. (Note: For each calculation in this question, you may leave your answer in simplified form in terms of powers of 2 and powers of 10.)

(a) How many DRAM rows does the memory system have?

(b) How many DRAM refreshes happen in 64ms?

(c) What is the total power consumption of DRAM refresh in 64ms? (Hint: you will need to figure out how much power a refresh operation consumes. You can find useful information in the technical note by Micron `https://safari.ethz.ch/digitaltechnik/spring2018/lib/exe/fetch.php?media=tn4704.pdf`. Use the current (IDD) numbers specified in the datasheet posted on the website `https://safari.ethz.ch/digitaltechnik/spring2018/lib/exe/fetch.php?media=1gb_ddr3_sdram.pdf`. Clearly state all the assumptions and show how you derive the power numbers. You are welcome to use other data sheets as well. Make sure you specify how you obtain the power numbers and show your calculations and thought process.)

(d) What is the total energy consumption of DRAM refresh during a day?

This question is an extended version of the question on Slide 37 in Lecture 4:
Slides: `https://safari.ethz.ch/digitaltechnik/spring2018/lib/exe/fetch.php?media=onur-digitaldesign-2018-lecture4-mysteries-basics-afterlecture.pdf`.
Video: `https://youtu.be/WZeYoDkzAmc`.

2 Main Memory Potpourri

A machine has a 4 GB DRAM main memory system. Each row is refreshed every 64 ms.

(a) The machine's designer runs two applications A and B (each run alone) on the machine. Although applications A and B have a similar number of memory requests, application A spends a surprisingly larger fraction of cycles stalling for memory than application B does? What might be the reasons for this?

(b) Application A also consumes a much larger amount of memory energy than application B does. What might be the reasons for this?

(c) When applications A and B are run together on the machine, application A's performance degrades significantly, while application B's performance does not degrade as much. Why might this happen?

(d) The designer decides to use a smarter policy to refresh the memory. A row is refreshed only if it has not been accessed in the past 64 ms. Do you think this is a good idea? Why or why not?

(e) When this new refresh policy is applied, the refresh energy consumption drops significantly during a run of application B. In contrast, during a run of application A, the refresh energy consumption reduces only slightly. Is this possible? Why or why not?