EE 382V Semiconductor Memory Design

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Semester: Spring 2021

Course Description:

Memory technology is becoming a critical component in modern Integrated Circuits designs ranging from minute IoT, to exa-scale supercomputers to emerging Artificial Intelligence (AI), Machine Learning (ML) accelerators. The abundant data computing necessitates dense, large capacity, and energy efficient memory technologies. It is estimated that by 2040, around 1 Trillion internet connected devices will be deployed generating millions of Zettabytes (1 Zetta = 10^{21}) consuming tens of Zetta-joules of compute energy/year.

This graduate course is focused on the comprehensive discussion of semiconductor memory design from atoms to the AI. The first part of the course covers current volatile memory technologies such as Static Random Access Memory (SRAM), Dynamic RAMs (DRAM), Multi-ported RAMs, and Content Addressable memories (CAMs). The second part of the course focusses on non-volatile semiconductor memories such as Read-Only-Memories, Resistive RAM, Magnetic RAM, FLASH and 3D memories. The third part of the course covers in-memory and near-memory computing circuit techniques aimed at minimizing the data movement energy and latency cost (also called as "Memory Wall"). It also discusses applications of emerging memories in neuromorphic computing.

Course Contents:

Part-I:

1. Course introduction, Evolution of memory technologies
2. Static Random Access Memories (SRAM) – Basics of bitcell design, array peripherals
3. Advanced SRAMs: Vmin, Leakage, Reliability, New device concepts
4. High performance multi-ported SRAMs – Register files, Dual-port, multi-ported SRAMs
5. Content Addressable memories (CAM)- Binary CAMs, Ternary CAMs
6. Dynamic Random Access Memory (DRAM) – basics and peripheral circuit design, DRAM stacking
7. Embedded DRAM (eDRAM): 1T1C, and gain-cell eDRAMs

Part-II:

8. Embedded Non-Volatile Memories (eNVM): Read-Only-Memory (ROM), Programmable ROM (PROM)
9. Resistive RAM: Device technologies (OxRAM, CBRAM, 2D) and Circuits
10. Magnetic RAM: Bitcells (STT, SOT, VCMA) and Circuits
11. Special purpose memories: NV-SRAMs, Crossbar arrays
12. NOR FLASH: Device and circuits
13. NAND FLASH: devices, circuits and array architectures
14. 3D FLASH: Process Technologies and circuits

Part-III:

15. Compute-In-Memory: Case studies from SRAM, RRAM, MRAM technologies
16. Compute-near-Memory: Case studies from DRAM and FLASH technologies.
17. Memory applications in neuromorphic computing

Prerequisites: A graduate course in VLSI design or equivalent

Materials:

A collection of papers form IEEE/ACM conferences
Lecture notes

Grading:

Class Participation, Paper Readings, Critiques, Presentations: 35%
Assignments: 30%
Project: 35%