Nanocomputing: Devices, Circuits and Architectures

Carrara Sandro, Demarchi Danilo, Graziano Mariagrazia, Piccinini Gianluca

Cursus
Génie électrique

Sem. Type

Language English
Credits 2
Session Exam Project report
Workload 60h
Hours 30
Lecture 30
Number of positions 20

Frequency
Every year

Remarque
Next time: spring 2020

Summary
Detailed overview of the circuits and systems for nanocomputation, that are expected to become one of the most promising topics in the forthcoming scenario, going beyond the ultra-scaled CMOS technologies and focusing the attention on nanoscale emerging technologies.

Content
The student will have a good overview of the novel solutions offered by the nanotechnologies. He will have an exhaustive coverage starting from the technology, passing to the devices up to the architectures. One of the training goals of the course is to give to the student a scenario form which to choose a specific topic of particular interest, that will be studied and developed for the preparation of the final Project Report.

State of the art: nanocomputing in ULTRA scaled CMOS:
- CMOS scaling trends at device levels: scaling, leakage, double-gate transistors, FinFET
- Circuit and architectural techniques: dark silicon, dynamic voltage scaling, subthreshold computation

Field coupled nanocomputing (FCN):
- A new principle: computing through field coupling and not through transport
- Devices: quantum dot cellular automata (QCA), nano magnetic logic (NML), molecular QCA, silicon based QCA
- Discussions on technology, behavior, models, energy consumption, speed, area
- Interconnections: magnetic domain walls, spin waves, molecular wires
- Designing a FCN circuit: a new design paradigm toward intrinsic pipelining
- Circuits and architectures based on FCN structures: synchronous, asynchronous, null-convention logic
- How to solve feedback problems
- Cut set retiming; solutions based on systolic arrays and interleaving

Nanocomputing based on conduction:
- molecular nanowires, molecular transistors and circuits
- gate-all-around transistore, ambipolar transistors, nano-PLA, NanoASIC
- Architectures: sea of nanoarrays for massive computation

Logic in memory:
• Devices: resistive memories, memristors, nanomagnets and magnetic memories
• Circuits: logic embedded in memory, communications and protocols
• Architectures: caches to the limit, use hic what you need nunc, search nearby what you need later

Alternative nanocomputing devices and architectures:

• Molecular computing
• Spintronic computing
• Cellular automata
• Quantum computing

BioMolecular Computing:

• DNA-based computing concepts, the Adleman experiment
• Simple logic gates based on Proteins and Enzymes
• Logic inferences by Antigen-Antibody structures
• "Computing" capabilities of biological cells

BioMemristors:

• Basic concepts about memristive devices
• How to use biomolecules for building memristors
• Device examples

Keywords
Nanocomputing; Beyond CMOS; Quantum Cellular Automata (QCA); Quantum Computing.

Learning Prerequisites
• Required courses
  Basic courses in silicon technologies and CMOS architectures.

Learning Outcomes
By the end of the course, the student must be able to:
• Conduct a project for the implementation of a device for computation at the nanoscale.

Resources
• Moodle Link
  • https://moodle.epfl.ch/enrol/index.php?id=14897