DEVICE PHYSICS FOR IC DESIGNERS
Physical Architecture Design

Course contents

Prerequisites

The course prerequisites include knowledge of:

- Fundamentals of quantum mechanics
- Semiconductor theory and device physics
- Fundamentals of semiconductor manufacturing process
- MOS transistor operation (square law and velocity saturated model)
- Fundamentals of digital and analog design

Additional material to refresh on some of these concepts can be provided.

Course Context

For almost 6 decades the Moore's Law, which in its latest incarnation predicts that the number of components in an integrated circuit doubles every 2years, has been the fundamental driving force of the semiconductor industry. For a great extent of time, i.e., until the MOS transistor gate reached the 0.1 micrometer (submicron) range, the secret sauce that made this empirical law so successful is known as Dennard Scaling, which lay down the rules to decrease the size of the components of a given function while increasing its operating clock frequency and reducing its power consumption.

Once the submicron dimension was reached, the insurgence of secondary effects due to the short size of the device channel and quantum effects of layers reach the atom scale, has impaired the channel control, i.e., the ability to provide a good driving current while minimizing the leakage current in OFF conditions, putting a stop to the Dennard Scaling. But the Moore's Law has been alive thanks to technology improvements, like leakage reduction and mobility improvements techniques, the introduction of new devices, like FinFET, and other technological advancements known as More than Moore.

Course Objective

The objective of this course is to provide a fundamental understanding of the various physical, technological, and economical aspects that have been keeping the Moore's Law alive for almost 60 years. Starting from a circuit designer's perspective, the various device parameters that influence the circuits performance will be analyzed, with a particular

attention on power consumption. A physical understanding of these phenomena will be provided, including elements of quantum mechanics, while trying to keep it as practical as possible. Economic and financial aspects will also be taken into consideration as they are integral part of the technology evolution. In this context, techniques on how, to estimate and manage design and production cost of integrated circuits will be provided.

Course Outline

- The semiconductor industry engine: Moore's Law, Dennard's Scaling, and beyond
- The semiconductor ecosystem: market, manufacturing and R&D,
- Digital performance metrics: timing power and area
- Short-channel effects, leakage current reduction and mobility enhancement
- Ultra-Thin Body devices: FinFET, FD-SOI, and more advanced devices
- Physical architecture design: chip performance, cost and reliability estimation
- Learning from others: chip cost analysis and estimation from information and resources available in the web

Readings/Bibliography

- The course will be based on lecture notes, and required readings that will be made available, as the course progresses.
- A list of required online videos will also be provided.
- Much of the presented material is inspired or adapted from various sources, including textbooks, conference tutorials, tutorial papers and other excellent resources available on the web, which are listed in the references section in the slides set for each lecture.

Teaching methods

- In-person lectures, taught in English, complemented by a PDF version of the lecture slides and other required readings and videos.
- Additional clarifications and/or technical discussions can be requested via email.
- Online meeting vis MS Teams or Google Meet can be arranged upon request.

Assessment methods

- The assessment will include a project assignment (in English language) that will be discussed during the oral examination.
- Like the project assignment, the examination will be held in English and usage of appropriate terminology by the student will be assessed.
- Emphasis will be place on the student ability to contextualize and argue on the topics presented during the course.

- A fundamental understanding of the material of the prerequisites is also a requirement.

Teaching tools

- In-person lectures in English language
- PDF slides of the presented material
- Required additional readings
- Required tutorial videos (available online)
- Optional readings and videos
- Clarifications and discussions via email (upon request)
- Live online meeting vis MS Teams or Google Meet (upon request)