EE141- Spring 2002
Introduction to Digital
Integrated Circuits

Tu-Th 9:30-11am
203 McLaughlin

What is this class about?

- **Introduction to digital integrated circuits.**
  » CMOS devices and manufacturing technology.

- **What will you learn?**
  » Understanding, designing, and optimizing digital circuits with respect to different quality metrics: cost, speed, power dissipation, and reliability
Digital Integrated Circuits

- Introduction: Issues in digital design
- The CMOS inverter
- Combinational logic structures
- Sequential logic gates; timing
- Arithmetic building blocks
- Interconnect: R, L and C
- Memories and array structures
- Design methods

Interludium: Administrativia

Instructor

Jan M. Rabaey
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Office hours: 511 Cory
Tu 1-3pm
The TA’s and Reader

Dejan Markovic
Discussion + lab
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Reader
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The Web-Site

The sole source of information
http://bwrc.eecs.berkeley.edu/Classes/ee141

- Class and lecture notes
- Assignments and solutions
- Lab and project information
- Exams
- Many other goodies ...

Save a tree!
Class Admission

- Class is overenrolled
  - Class room only seats 65 + 15
  - But … videotaped
  - Also webcasted (http://webcast.berkeley.edu)
- Admission priorities
  - Graduating seniors
  - First-year grads
  - Juniors, other grads
  - Concurrent enrollment
Make sure your name is on the class roll!

Discussions and Labs

- Discussion sessions
  - We 9-10am, 293 Cory
  - We 2-3pm, 247 Cory
  - Pick any of the two (the are covering the same material)
  - One of them will be moved to another time slot (in 203 McLaughlin)
- Labs (353 Cory)
  - Mo 9-12am
  - Tu 2-5pm
  - Th 12:30-3:30pm
  - Pick the one that fits you the best (pending availability) and STICK TO IT!
Class Organization

- 10 Assignments
- A couple of design projects (1 term project)
- Labs: 6 software, 1 hardware
- 2 midterms, 1 final
  - Midterm 1: Tu, February 25, 6:30-8:00pm
  - Midterm 2: Tu, April 15, 6:30-8:00pm
  - Final: Tu. May 20, 8-11am

Grading Policy

- Homeworks: 10%
- Labs: 10%
- Projects: 20%
- Midterms: 30%
- Final: 30%
Class Material

- Lab Reader:
  Available on the web page!
  Selected material will be made available from Copy Central
- Check web page for the availability of tools

Software

- MicroMagic
  » Schematic editor: Sue
  » Layout editor: Max
  » Online documentation and tutorials
- HSPICE and IRSIM for simulation
Getting Started

- Assignment 1: Getting SPICE to work – see web-page
- NO discussion sessions or labs this week.
- First discussion sessions in Week 2
- First Software Lab in Week 3

Introduction

- Why is designing digital ICs different today than it was before?
- Will it change in future?
The First Computer

The Babbage Difference Engine (1832)
25,000 parts
cost: £17,470

ENIAC - The first electronic computer (1946)
The Transistor Revolution

First transistor
Bell Labs, 1948

The First Integrated Circuits

Bipolar logic
1960’s

ECL 3-input Gate
Motorola 1966
Intel 4004 Micro-Processor

Evolution in Transistor Count
Intel Pentium (II) microprocessor

Moore’s Law

- In 1965, Gordon Moore noted that the number of transistors on a chip doubled every 18 to 24 months.
- He made a prediction that semiconductor technology will double its effectiveness every 18 months.
Moore’s Law

Electronics, April 19, 1965.

Evolution in Complexity
Transistor Counts

Source: Intel

Moore's law in Microprocessors

2X growth in 1.96 years!

Transistors on Lead Microprocessors double every 2 years

S. Borkar
Moore’s Law - Logic Density

Shrinks and compactions meet density goals
New micro-architectures drop density

Die Size Growth

Die size grows by 14% to satisfy Moore’s Law
**Frequency**

Lead Microprocessors frequency doubles every 2 years

**Processor Frequency Trend**

Frequency doubles each generation

Number of gates/clock reduce by 25%

V. De, S. Borkar
ISLPED’99
Power

Lead Microprocessors power continues to increase

Processor Power

Lead processor power increases every generation
Compactions provide higher performance at lower power
Power will be a problem

Power delivery and dissipation will be prohibitive

Power density will increase

Power density too high to keep junctions at low temp
Power delivery challenges

High supply currents at low voltage: Challenges: IR drop and L(di/dt) noise

Not Only Microprocessors

Cell Phone

Digital Cellular Market (Phones Shipped)


Units 48M 86M 162M 260M 435M

(data from Texas Instruments)
Productivity Trends

Complexity outpaces design productivity

Challenges in Digital Design

∞ DSM

“Microscopic Problems”
- Ultra-high speed design
- Interconnect
- Noise, Crosstalk
- Reliability, Manufacturability
- Power Dissipation
- Clock distribution.

Everything Looks a Little Different

∞ 1/DSM

“Macroscopic Issues”
- Time-to-Market
- Millions of Gates
- High-Level Abstractions
- Reuse & IP: Portability
- Predictability
- etc.

...and There’s a Lot of Them!
Design Abstraction Levels

Why Scaling?

- Technology shrinks by 0.7/generation
- With every generation can integrate 2x more functions per chip; chip cost does not increase significantly
- Cost of a function decreases by 2x
- How to design chips with more and more functions?
- Design engineering population does not double every two years...
- Need to understand different levels of abstraction
Next Class

- Introduces basic metrics for design of integrated circuits – how to measure delay, power, etc.
- Brief intro to IC manufacturing and design