Temperature-Aware and Low-Power Design and Synthesis of Integrated Circuits and Systems

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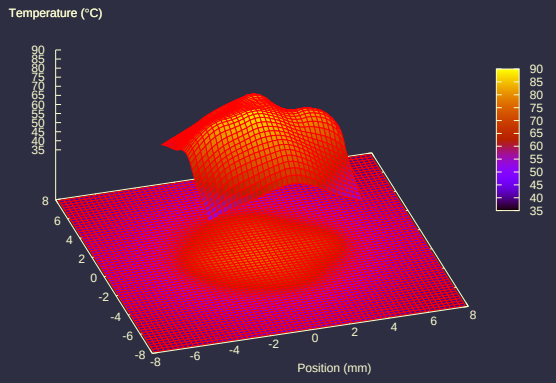

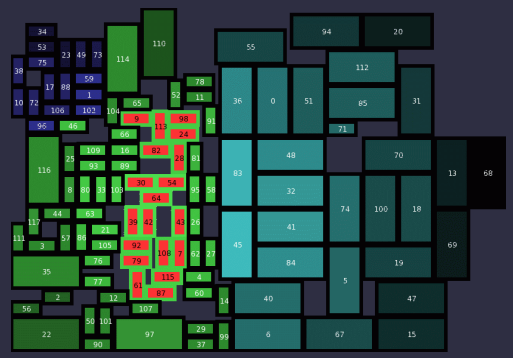

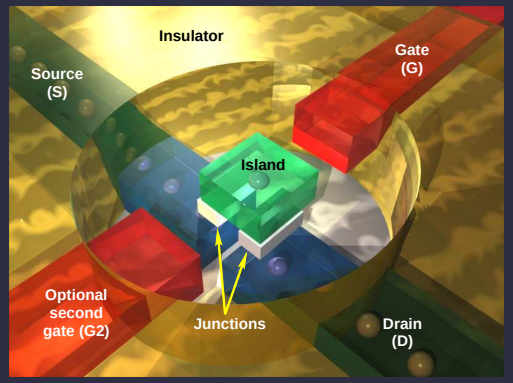

Today's goals

1. Know how to get access to the resources you'll need for this course
   - Books, computer lab, website, and mailing list
2. Understand work and grading policies
3. Rough understanding of topics we'll cover in course

Outline

Administration

- Lectures
  - Tuesdays and Thursdays from 12:30–2:00
  - Tech L158
- PDF files for some lectures will be posted to http://robertdick.org/talp

Class prerequisites

- Advanced Digital Logic Design
- Computer Architecture
- VLSI Systems Design

Topic prerequisites

- Basic electrical circuit analysis
- Digital logic design
- VLSI design
- Computer architecture

Course structure

- We will start on research projects almost immediately
- Each project will have a research, design, and presentation component
- The class meetings will be a mix of lectures and paper discussions
- Main purpose of class: Prepare students for independent research on temperature-aware and low-power design and synthesis of integrated circuits and systems

Decide office hours

I can reschedule office hours based on your comments

Person	Day	Time	Room
Robert Dick	Tuesday	2:00–4:00	L477 Tech
Robert Dick	Thursday	2:00–4:00	L477 Tech

Grading policies

Literature summaries:	10%
Exams:	15%
Mini-project presentation:	7%
Project presentation:	18%
Mini-project quality and report:	15%
Project quality and report:	35%

- Active class participation by students is strongly encouraged
- There will be two projects
  - Mini-project due approximately 1/2 through the course
  - Final project

Project

- Open to individual project goals
- Will also provide a few default projects
- Some will require teams
- Multiple people may work on the same topic and collaborate
- However, each person must describe/present his/her own work

Subscribe to mailing list

- Please subscribe to the TALP mailing list by sending a to listserv@listserv.it.northwestern.edu with no subject and a body of

  SUBSCRIBE TALP [Firstname] [Lastname]

- Useful for getting questions rapidly answered
- If you email an academic question to me, I'll will post the question and the answer to the newsgroup/mailing list but remove your name

Lab access

Depending on your project, you may need access to one or more of the following resources

- Solaris machines running HSPICE
- Linux machines running ISAC or HotSpot
- Infrared cameras
- Solaris machines running Mentor Graphics layout software

Course goals

After finishing this course you should

- Be prepared for independent research in temperature-aware or low-power design or synthesis of integrated circuits or systems
- Have a high-level understanding the major research topics in the area
- Have completed a project that can naturally be developed into substantial and novel research

Course topics

- Integrated circuit power consumption
- Power macromodeling
- Heat flow analysis
- Temperature-aware and power-aware physical design
- Temperature-aware and power-aware behavioral synthesis
- Temperature-aware and power-aware microarchitectures
- Temperature-aware and power-aware system-level architectures
- Advances in cooling technologies
- Power and temperature implications of novel device technologies
- Reliability models

Outline

Available infrastructure

- ISAC thermal analysis algorithms
- MILP optimal temperature-aware real-time scheduling formulation and CPLEX
- Integrated floorplanning and high-level synthesis algorithm
- 3-D temperature-aware floorplanning software
- M5 multiprocessor simulator instrumented with power and thermal models
- Single-electron tunneling transistor SPICE models
- User-driven laptop DVFS infrastructure
- Fast temperature-dependent leakage power estimation techniques

Modeling

- Design and fabricate an integrated circuit to determine the impact of wire density and anisotropy on thermal conductance
- Design and fabricate an integrated circuit to validate existing, or develop new, temperature-dependant wear process models, e.g., electromigration
- Use Monte Carlo techniques to develop a transistor-level macromodel that accurately considers non-equilibrium conditions between optic and acoustic phonons and integrate it within an architectural-level Fourier heat transfer analysis infrastructure

Modeling

- Model and evaluate novel cooling structures using ANSYS or COMSOL Multiphysics
- Develop and validate models for interface layers between dissimilar materials
- Develop new numerical methods for rapid and accurate steady-state thermal analysis

Design and synthesis

- Temperature-aware global routing
- New ideas in temperature-aware floorplanning (many already exist), e.g., graph-space stochastic gradient descent
- Optimal and heuristic allocation, assignment, and scheduling
- Temperature-aware reliable architectures
- Architectural evaluation of novel device technologies
- Temperature-aware test scheduling

Online management and cooling

- Predict optimal power states of system devices
- Develop novel techniques of controlling power states, e.g., camera and backlight trick
- Validate power deregulation
- Invent and test a new cooling technology

Outline

Reading assignment

- Introduction attempting to unify power, thermal, and reliability modeling
- High-level introduction to thermal problems (review for many)
  Li Shang and Robert P. Dick. Thermal crisis: Challenges and potential solutions. *IEEE Potentials*, 25(5), September 2006
- Details on impact of process scaling on power
  Ali Keshavarzi. Power-aware architectural synthesis. In Wai-Kai Chen, editor, *The VLSI Handbook*. CRC Press, 2006

Determine tentative project topics

- Due next class
- Propose a mini-project topic
- One of your two papers for Tuesday will be based on the topic
- You will need to provide evidence of the following things next week
  - Novelty
  - Potential for usefulness
  - Feasibility of evaluating idea

Next lecture

- Power consumption
- Dynamic and leakage power models
- Relationship between power and other characteristics