Advanced Computer System Design (Low-power system design)

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Course Introduction

- Graduate course that covers low-power system design
- Schedule
  - Monday and Wednesday, 4:00 PM to 5:15 PM
- Instructor
  - Prof. Naehyuck Chang
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  - Phone: SNU-1834
  - Office: 301-506
- TA
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  - Office: 301-551

Course Introduction

- Homepage
  - http://elpl.snu.ac.kr/acd08/
  - Under construction
- Language
  - English
  - All the lecture, exam and (possible) presentation will be in English
  - Email inquiry to Instructor must written in English
- Evaluation
  - Attendance (25%) including quizzes and participation of the classes (questions, answers and comments)
  - Midterm (30%)
  - Final (30%)
  - Assignment (15%)

Course Introduction

- Textbook
  - There is no single textbook for this course
- References
  - DVD ROM achieves from 1994 to present for the all relevant ACM/IEEE conferences
  - TA will post some books (do not expect much from them)
- Course materials
  - PDF format slides will be uploaded one by one

Announcements

- Scheduled absent classes
  - Sept. 8 (ASP-DAC TPC)

- Possible rearrangements of classes, absent classes and/or examinations
  - Nov. 5 (DATE TPC)
  - Nov. 10 and 12 (ICCAD)

- Remote lecture is considered (depending on the internet connection available)
- Student's absences of classes
  - Can be excused for conference attendance with prior notice
  - Appropriate reading assignments will be given

About the Instructor

- Has been contributing to ACM/IEEE low-power system working society since 1999
  - Over 60 technical papers
  - IEEE Transactions on CAD associate editor
  - Technical Program Committee member of
    - DAC and ASP-DAC
    - ICCAD, ISLPED, ISQED, GLSVLSI, CODES+ISSS, PATMOS, ESTIMedia, MSE, etc.
  - Committee Member of
    - SIGDA PhD Forum, ASP-DAC Student Forum, and ACM Graduate Scholarship
  - Major contributions
    - Low-power display systems including DLS
    - Cycle-accurate energy measurement and modeling
    - Practical DVS: memory, DC-DC, heterogeneous cost function, etc.
    - Fuel-cells for portable applications

What to cover

- Device modeling and source of power consumption
  - Long-channel MOSFET model
  - Short-channel effect
  - MOS capacitances
  - Dynamic power of CMOS gates
  - Static power of CMOS gates
- Power estimation
  - Circuit-level power estimation
  - Macromodeling
  - Leakage estimation
  - Power measurement techniques
  - System-level power estimation

What to cover

- Low-power techniques
  - Low-level dynamic power
  - Architectural-level dynamic power
  - Bus encodings
  - Leakage power
  - Glitch power
  - Dynamic voltage scaling (DVS)
  - Dynamic power management (DPM)
- Thermal-aware design
- Peripheral and memory power reduction
- The lecture schedule can be changed by the instructor without notice

Why Low Power?

- Why do we want to decrease power consumption?
  - The marked wants longer battery life, higher performance and smaller size for portable devices
  - Small embedded systems with a small power source that needs to have a long life time
  - Lower power consumption decreases working temperature of the device

Why Low Power?

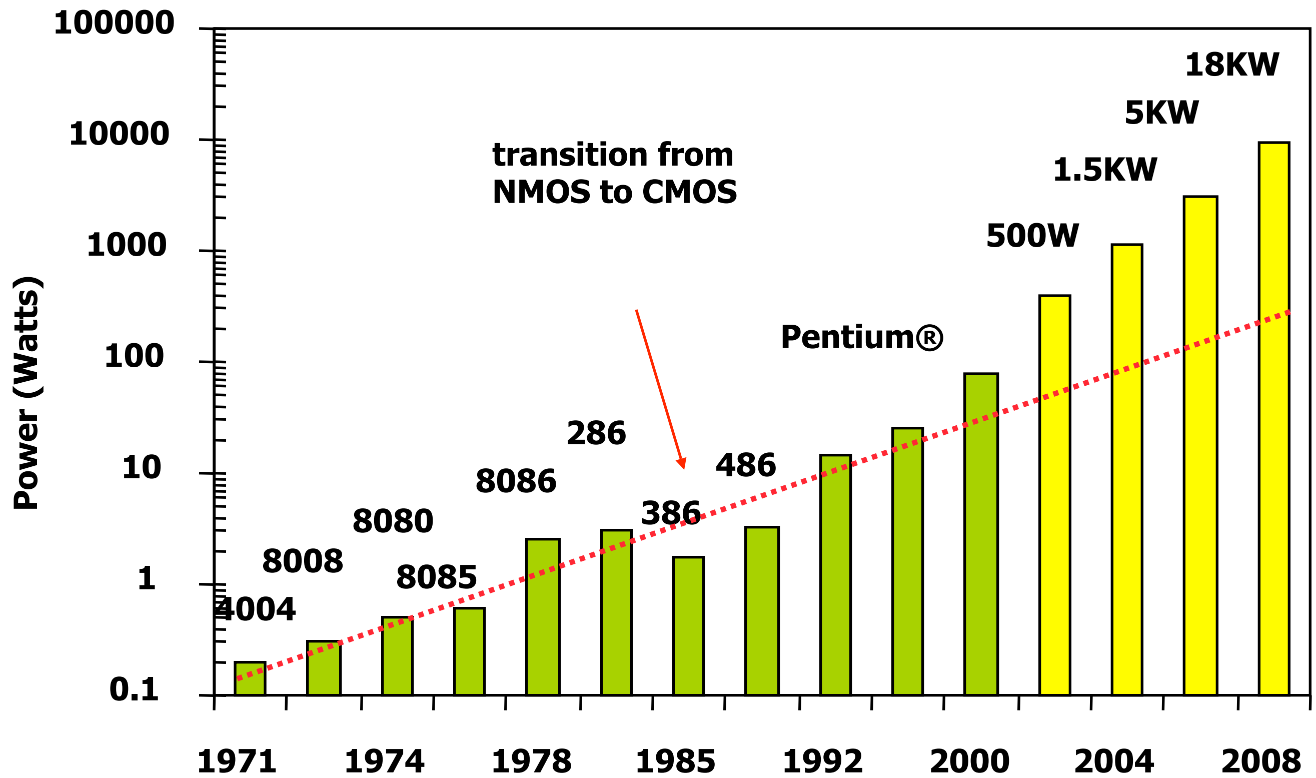
- Higher performance and longer battery life is conflicting demands
  - Sophisticated design techniques is needed to meet both of them
- Power management is one of the most critical design issues
  - Meet the demands of the market
  - Keep the working temperature at a acceptable level

Why Low Power?

- Thermal issues
- Energy issues
- Power issues

Why Low Power?

- Power delivery and dissipation will be prohibitive



Source: Borkar, De Intelâ

Why Low Power?

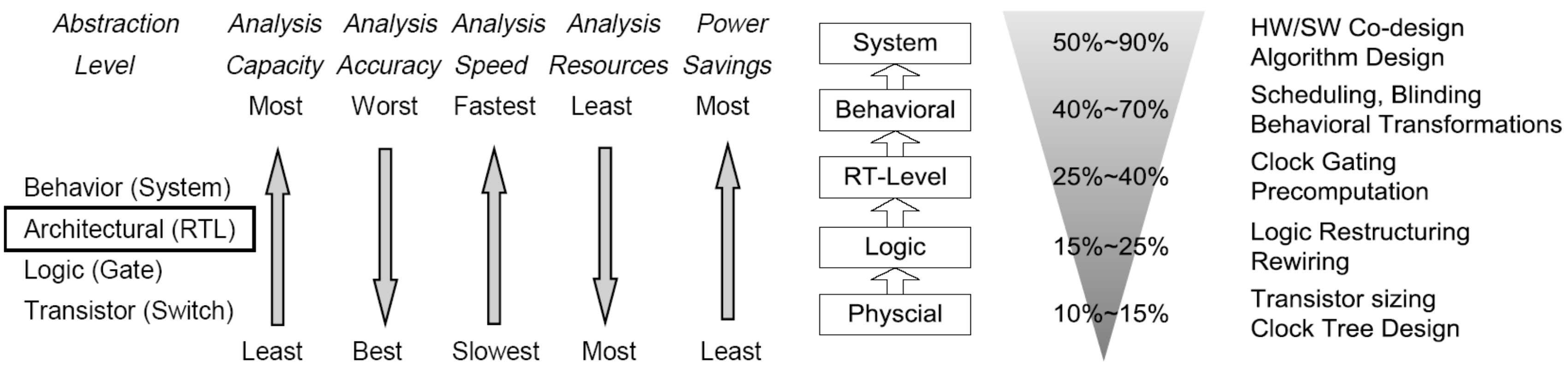
- Designing within limits: power & energy
  - Thermal limits (for most parts self-heating is a substantial thermal issue)
  - Package cost (4-5W limit for cheap plastic package, 100W/cm^2 air cooled limit, 7.5kW 19" rack)
  - Device reliability (junction temp > 125^{o}C substantial reduction in reliability)
  - Performance (25^{o}C to 105^{o}C: loss of 30% of performance)
- Distribution limits
  - Substantial portion of wiring resource, area for power distribution
  - Higher current - lower R, greater dI/dt needs more wire, decoupling capacitors
  - Package capable of low impedance distribution

Why Low Power?

- Energy capacity limits for portable applications
  - Limit of batteries
  - Energy cost
  - Energy for IT equipment large fraction of total cost of ownership

System-level energy optimization

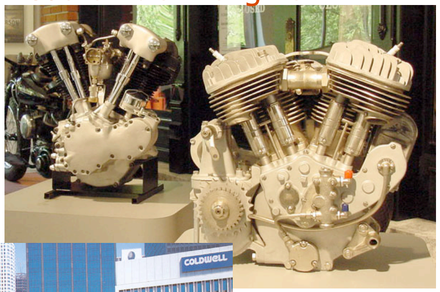
- High-level energy reduction
  - RTL or higher level
  - Suitable for complex systems
  - Higher energy gain
  - Based on high-level energy model.
    - High-level energy characterization.
  - Abstraction progressively degrades the quality of power estimation



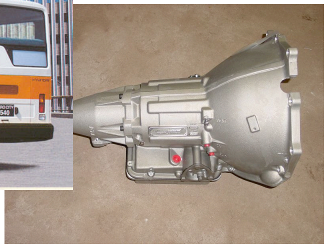
System-level energy optimization

- Low-level energy optimization
  - Has been contributing over dozens of years
  - Enhancement of devices and components
  - General solution that applicable to almost all kinds of use
  - City bus service example
    - Objective: more gas mileage
    - New buses, engine swap, aluminum bodies, new transmissions, etc.
  - In the semiconductor world
    - NMOS
    - CMOS
    - MTCMOS

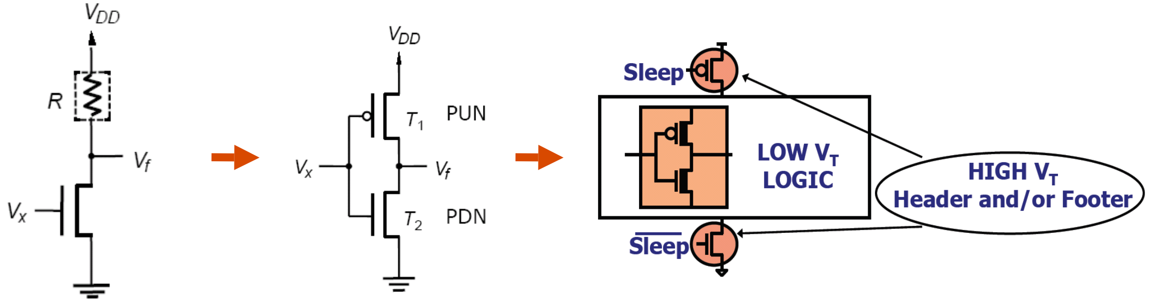
Gas-efficient engine



Light-weight bus

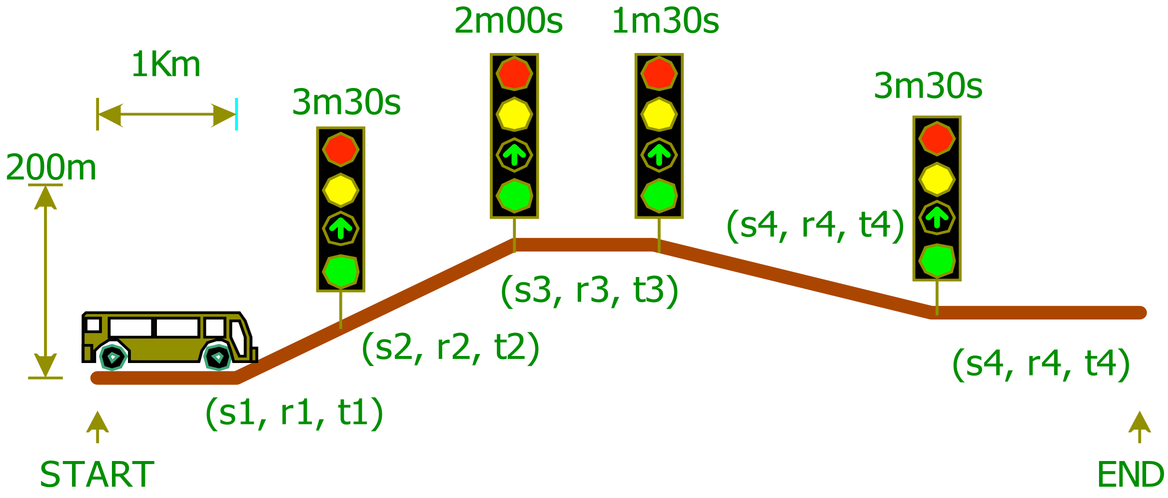


Low-loss transmission



System-level energy optimization

- System-software-level energy optimization
  - City bus service example
    - Optimal speed, engine rpm, shift position scheduling w/original hardware
      - Analysis of a target route
      - Use of component characteristics



System-level approaches give us bigger chance to minimize energy consumption!

System-level energy optimization

- Level of abstraction: **engine idle gas consumption**
  - **Model 1**: linear gas consumption per speed:
    $g = mv$
  - **Model 2**: counting idle gas consumption when $v=0$:
    $g = mv + I$
  - **Model 3**: counting engine restarting cost

Proper energy characterization is a primary concern of quality high-level power saving approach

- Applicable gas saving techniques when a vehicle is temporarily parked
  - **Technique 1**: linear gas consumption model
    - No policy when a vehicle is stopping
  - **Technique 2:** Idle gas consumption
    - Stop engine whenever a vehicle is stopped
  - **Technique 3:** Restarting cost
    - Stop engine when stopping time is more than 2 minutes for instance

Questions?

- Reading assignment
  - **High-level power modeling, estimation, and optimization**
    - Macii, E. Pedram, M. Somenzi, F.
    - **Computer-Aided Design of Integrated Circuits and Systems, IEEE Transactions on**
    - Nov 1998
      Volume: 17, Issue: 11
      On page(s): 1061-1079