Power and Energy Management

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EEL

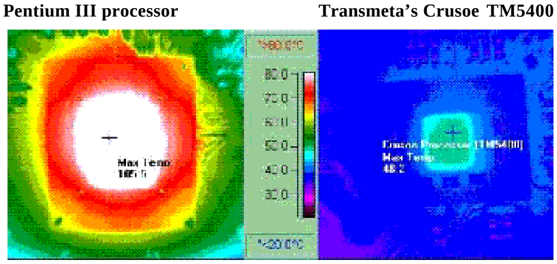
Energy Efficiency and Low-Power Lab

DARK LAB
The Systems Design and Evaluation Laboratory

Why Power/Energy Management?

- Prolong battery life
- Reduce heat dissipation
  - packaging costs and cooling
  - reliability

Pentium III processor **Transmeta's Crusoe TM5400**



Without cooling: 105C (221F) vs. 42C (118F)
running DVD application (Source: Transmeta's Crusoe processor white paper)

HW/OS/Compiler Optimizations

optimizations

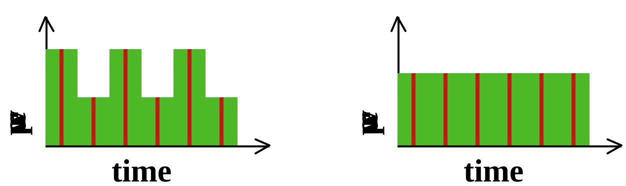
- ❑ **try to improve quality of code (may fail in some cases)**
- ❑ **optimizing compilers typically consists of multiple passes**
- ❑ **different optimization objectives:**
  - **execution time reduction**
  - **reduction in resource requirements (memory, registers)**
  - **(peak) power and energy reduction**

criteria for effectiveness of optimizations

- ❑ **safety - program semantics must be preserved**
- ❑ **opportunity - how often can it be applied?**
- ❑ **profitability - how much improvement?**

Power vs. Energy

power: activity level at a given point in time
energy: total amount of activity



same energy, different (peak) power

optimizing for (peak) power == optimizing for energy?

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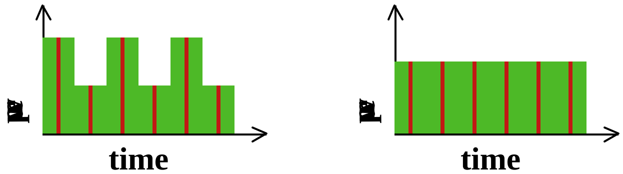

same energy, different (peak) power

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ANSWER: Not necessarily! Example: re-schedule activities

Power/Energy vs. Performance

performance: **overall program execution time**

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Power/Energy vs. Performance

performance: overall program execution time

optimizing for power/energy == optimizing for performance?

ANSWER: (a) Mostly Yes, at least for traditional optimizations that reduce overall computation and memory activity

- ❑ redundancy elimination (CSE, PRE, dead code elimination)
- ❑ strength reduction (e.g.: replace 2∗a with a+a), loop invariant code motion
- ❑ memory hierarchy (locality) optimizations (register alloc., loop interchange, loop distribution, blocking for cache)

Power/Energy vs. Performance

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ANSWER: (b) Not really, in particular for optimizations that exploit tradeoff between power/energy usage and performance

- ❑ loop invariant code motion, aggressive speculation
- ❑ blocking for cache
- ❑ DFVS, resource hibernation, remote task execution, QoR

Power/Energy vs. Performance

```
for (i=0, i<10; i++) {
  a = b* 2;
  c[i] = d[i] + 2.0;
}
```

(A)

```
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for (i=0, i<10; i++) {
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(B)

Which code is better in terms of power/energy and which in terms of performance?

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Power/Energy vs. Performance

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(B)

Which code is better in terms of power/energy and which in terms of performance?

ANSWER: It depends

- simple RISC architecture: (B)
- VLIW or superscalar architecture with empty "slots": (A)

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Power/Energy vs. Performance

You can run, but you cannot hide

- pushing instructions onto the non-critical execution path ("hiding") does not necessarily reduce energy
- higher threshold for profitability of speculation

You cannot beat hardware

- if an operation is implemented in hardware, that's the best you can do (e.g.: floating-point unit)
- need to be able to disable hardware if not in use

Keep the overall picture in mind

- performance is measured for the entire program
- power/energy should also be measured for the entire system, in addition to optimized system component

Why Compiler and not OS/Hardware?

Compiler advantages:

- low or no overhead (power/energy and performance) at program execution time
- may know about "future" program behavior through aggressive, whole program analysis.
- can better identify profitability of high overhead optimizations based on large context analysis.
- can reshape program behavior through code transformations and thereby enable optimizations.

Compiler disadvantages:

- insufficient information about runtime program behavior may lead to code of poor quality

Why Compiler and not OS/Hardware?

Possible Scenarios:

- single user environment: compiler-directed power and energy management is directly "executed" by underlying OS/HW.
- multiple user environment: power/energy application profile is used by OS to make scheduling decisions.

Syllabus

- ❑ Web site:
  http://www.cs.rutgers.edu/~uli/PowerEnergy/spring2003
- ❑ Research papers: our reading list will be constructed on the fly; possible topics (incomplete)
  - resource hibernation
  - remote task execution
  - dynamic voltage and frequency scaling
  - QoS tradeoffs
  - load concentration (servers)
- ❑ Will cover techniques from hardware, OS, and compiler, and possible interactions between them
- ❑ Students give one 30 minutes presentation