POWER

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Why Does Power Matter?

Two big processor concerns that involve power:

- Performance
- Power consumption

Performance Effect #1

Conductivity

Semiconductors are better electrical conductors at lower temperatures

Power Consumption

More complex circuitry uses more power, generating more heat and raising the temperature

Combine these two factors

High power consumption => worse performance

Performance Effect #2

High performance computers generate LOTS of heat

Components begin melting, falling off, failing completely

Computer becomes a molten pile of junk

Could be solved by running hardware slower, but then why build it at all?

Low Power

Portable devices are popular (laptops, PDAs, etc). Some might even say they're useful.

However, if portable devices require a 10 pound battery to run for one hour, they aren't very practical.

Solutions

Spectrum of approaches

One end: Dissipate power efficiently

- Targets designs which care most about performance

Other end: Consume less power

- Targets designs which care primarily about minimizing power consumption (duh)

Dissipating Power

Heat Sinks

Fans (Air Cooling)

Liquid Cooling

Cryogenic Cooling

Consuming Less Power

Better materials

Less complex circuitry

The Papers

Analog Decoding

Digital’s Processor Design

Cray (macro water cooling)

Tuckerman/Pease (micro water cooling)

Reversible Computation

Analog Decoding

Premise: with "real" analog values, doing computation digitally can be much less efficient than doing it with analog techniques

Example problem: decoding a signal encoded over a noisy analog channel.

Analog Decoding 2

- Digital Approach
  - Convert analog signal to digital signal, and then detect/correct spurious information
- Analog Approach
  - Detect/correct spurious information, and then convert analog signal to digital signal.
- Analog approach yielded two order of magnitude improvement in efficiency

DIGITAL's Processors

Describes the basic design of the Alpha 21264, which is shared by the StrongARM 110

Versatile design, meets different objectives:

- 21264: 600 Mhz clock, up to 72 W power consumption
- SA 110: 200 Mhz clock, .5–1W power consumption

DIGITAL's Processors 2

Begin with Alpha 20264: 26W @ 200Mhz

Keep it simple, remove the fancy features

No FPU, no branch history table, simplified control

Improvements in fab process, reduce input voltage, slow down to 160 Mhz

Clocks: Use more power efficent clock latching and conditional clocks

End result: SA 110: < 500mW @ 160 Mhz

Cray

"System level" water cooling

- Entire computer is immersed in liquid
- Liquid is circulated continuously to keep the computer cool, as liquid heats it is cycled away from the system to be cooled and pumped back in
- No specific numbers on how efficiently it can dissipate power.

Tuckerman/Pease

"Chip level" water cooling

- Channels for water cooling are integrated into the design of the chip, part of the fabrication process

Power Density supported: 790 W/cm^2

Allows for compact design and good heat dissipation efficiency

Reversible Computing

Basic idea: don't discard information, since losing information translates into decreased entropy => dissipating energy

Speed vs. power efficiency tradeoff

Research

- Pendulum (MIT AI)

Currently Popular

High performance supercomputers

- typically liquid cooled a la Cray
- some older models are air cooled

Low Power

- StrongARM
- Transmeta Crusoe

Other Interesting Things

Interesting thermoelectric effects

- Thermoelectric materials which can conduct heat away from circuit when current is flowing
- Currently used for applications requiring precise temperature control (preferably cold)
  - refrigeration, lasers
- Recent material advances may make the extra expense practical for processors

Other Interesting Things 2

Cryogenic Cooling

Kryotech: desktop PCs of today can generate a lot of heat, and can be overclocked for higher performance, requiring good cooling. With these techniques, a 1 Ghz Athlon was available a few months before officially released by AMD.

Given the short lead time (only sped up the curve by a few months), probably not worth extra expense for most people