Lost in the Bermuda Triangle: Complexity vs. Energy vs. Performance

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June 18, 2006
WCED Panel

Microprocessor Performance Evolution

Performance = Frequency / PathLength × CPI
### Power/Performance (EPI) Evolution

**Power** = **EPI** × **IPC** × **Frequency**

- **Intel Microprocessors**
  - EPI (nj)
  - 65nm at 1.33v
  - i486 10
  - Pentium 14
  - Pentium Pro 24
  - Pentium 4 (WMT) 38
  - Pentium 4 (CDM) 48
  - Pentium M (Banias) 13
  - Pentium M (Dothan) 15
  - Core Duo (Yonah) 11
  - Core Duo (Merom) 10

**Power**: single core power (relative to i486 baseline)

**Performance**: SPECint performance (relative to i486 baseline)

**EPI**: average energy spent per instruction (in nano-joules)

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### EPI Optimization for CMP Architectures

**Power/Performance Scaling**

**EPI = 48nj**

**EPI = 10nj**

**EPI = 5 nj** (linear power scaling)

**EPI = 1 nj** (power scales at n^1.1)

**EPI = 0.5 nj** (linear power scaling)

**EPI = 0.1nj**

**EPI = 0.01nj**

**EPI: CPU Cores Prog. Accelerators Fixed Function Units**

- ~0.3 nj
- ~0.6 nj
- ~0.7 nj

**NP/DSP/GPU**

- IXP2800 ~1 nj
- TMS320C6713 ~0.7 nj
- GeForce7800GTX ~0.6 nj
- Intel Gen4 ~0.3 nj

**Power = EPI × IPC × Frequency = EPI × IPS**

**150W Power Envelope**

**EPI Throttling**

**20x Performance Increase**
Research Challenges

• **10x Reduction of Core EPI:**
  - Avoid O(n^2) and O(n^3) structures
  - Leverage heterogeneous cores/accelerators

• **Linear Power Scaling of Uncore:**
  - Provide on-demand interconnects
  - Eliminate legacy interfaces

• **2x Reduction of Design Cycle:**
  - Adopt modular design style
  - Reuse building blocks