Energy/Power and DVFS/DFS

- Topics: Energy/Power and DVFS/DFS

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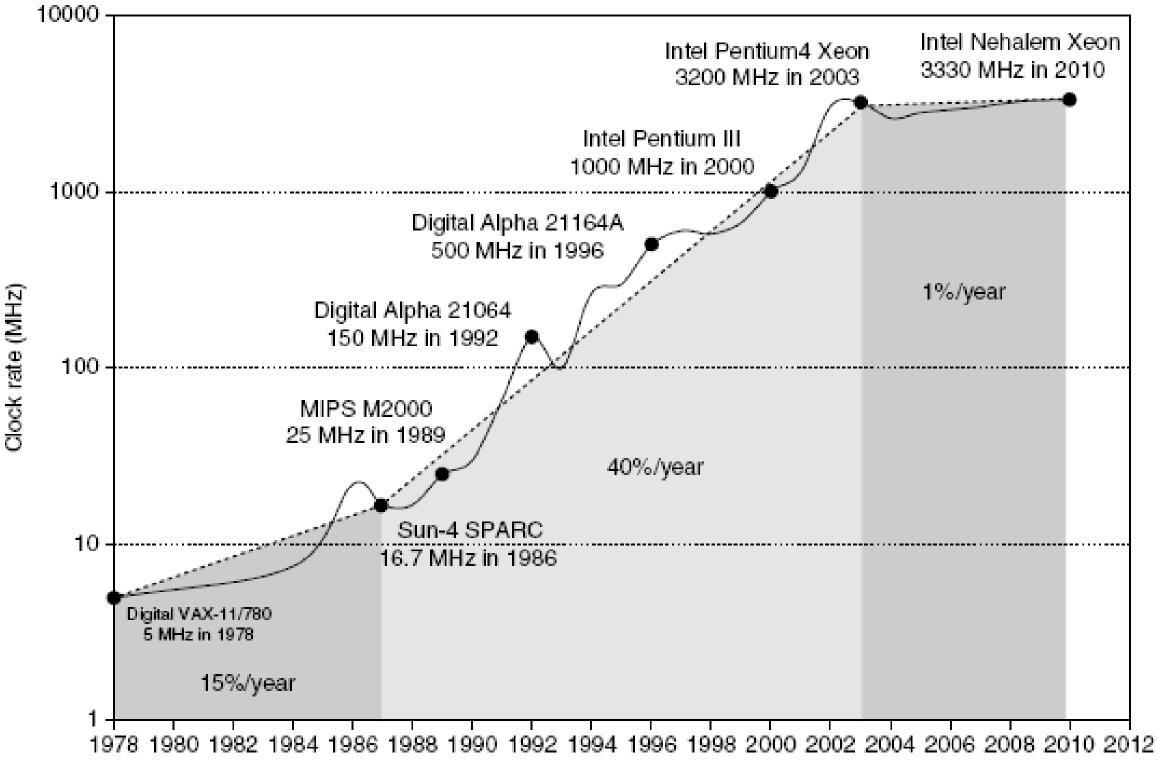
Power

- Intel 80386 consumed ~ 2 W
- 3.3 GHz Intel Core i7 consumes 130 W
- Heat must be dissipated from 1.5 x 1.5 cm chip
- This is the limit of what can be cooled by air



Power Vs. Energy

- Energy is the ultimate metric: it tells us the true "cost" of performing a fixed task

- Power (energy/time) poses constraints; can only work fast enough to max out the power delivery or cooling solution

- If processor A consumes 1.2x the power of processor B, but finishes the task in 30% less time, its relative energy is 1.2 X 0.7 = 0.84; Proc-A is better, assuming that 1.2x power can be supported by the system

Static (leakage) Power

- Power = static power + dynamic power
- Static power consumption
  - $Current_{static}$ x Voltage
  - Scales with number of transistors

Dynamic Energy and Power

- Dynamic energy
  - Transistor switch from 0 -> 1 or 1 -> 0
  - ½ x Capacitive load x Voltage^2
- Dynamic power
  - ½ x Capacitive load x Voltage^2 x Frequency switched
- Reducing clock rate reduces power, not energy

Power Consumption Trends

- Dyn power α activity x capacitance x voltage^2 x frequency
- Capacitance per transistor and voltage are decreasing, but number of transistors is increasing at a faster rate; hence clock frequency must be kept steady
- Leakage power is also rising; is a function of transistor count, leakage current, and supply voltage
- Power consumption is already between 100-150W in high-performance processors today
- Energy = power x time = (dynpower + lkgpower) x time

Problem 1

- For a processor running at 100% utilization at 100 W, 20% of the power is attributed to leakage. What is the total power dissipation when the processor is running at 50% utilization?

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- For a processor running at 100% utilization at 100 W, 20% of the power is attributed to leakage. What is the total power dissipation when the processor is running at 50% utilization?

Total power = dynamic power + leakage power
= 80W x 50% + 20W
= 60W

Problem 2

- If processor A consumes 1.4x the power of processor B, but finishes the task in 20% less time, which processor would you pick:
  - (a) if you were constrained by power delivery constraints?
  - (b) if you were trying to minimize energy per operation?
  - (c) if you were trying to minimize response times?

Problem 2

- If processor A consumes 1.4x the power of processor B, but finishes the task in 20% less time, which processor would you pick:
  - (a) if you were constrained by power delivery constraints?
    Proc-B
  - (b) if you were trying to minimize energy per operation?
    Proc-A is $1.4 \times 0.8 = 1.12$ times the energy of Proc-B
  - (c) if you were trying to minimize response times?
    Proc-A is faster

Relation b/w frequency and time

A processor's frequency is

(a) increased by 30%

(b) decreased by 40%

Find the percentage change in execution time.

Answer: (a) New time = 1/130% = 100/130 = 0.769 = 76.9%

Thus, execution time has reduced by 23.1%

(b) new time = 1/60% = 100/60 = 1.66 = 166.66%

Thus, execution time has increased by 66.66%.

Energy/Power Saving Techniques

DFS AND DVFS

Reducing Power and Energy

- **DFS: Dynamic frequency scaling** --
  - Control knob: reduce frequency
  - Result: reduces dynamic power, but increases energy

- **DVFS: Dynamic voltage and frequency scaling**
  - Control knob: reduce frequency and voltage
  - Result: reduces both dynamic and static power and energy
  - voltage drop leads to slow transistors, so frequency of operation is also reduced

Problem 3

- Processor-A at 3 GHz consumes 80 W of dynamic power and 20 W of static power. It completes a program in 20 seconds.

A. Find energy of this processor

B. Find energy on scaling frequency down by 20%?

C. Find energy on scaling freq and voltage down by 20%

Problem 3

- Processor-A at 3 GHz consumes 80 W of dynamic power and 20 W of static power. It completes a program in 20 seconds.

A. Energy = 100 * 20 = 2000 Joules

B. Energy on scaling frequency down by 20%

New dynamic power = 64W; New static power = 20W

New execution time = 25 secs (assuming CPU-bound)

Energy = 84 W x 25 secs = 2100 Joules

C. Energy on scaling freq and voltage down by 20%

New dynamic power = 41W; New static power = 16W;

New exec time = 25 secs; Energy = 1425 Joules