# Dynamic Voltage Scaling

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## Introduction

- **Energy-constrained mobile devices**
  - Cell phones, PDAs, digital cameras, pocket PCs, and laptops are becoming commonplace
  - Mobile devices have limited battery lifetimes
- **Simple techniques**
  - Turning off (or dimming) the screen while a system is idle
  - Shutting down hard disks
  - But, reactivation of hardware take some time affecting response times of applications

# Major Sources of Power Consumption

- In laptop computers and PDAs
  - Display backlighting accounts for a large fraction of dissipated power
  - Hard drives, modem, and sound devices
  - Recent report shows that the processor subsystem accounts for nearly 60% of the energy consumed at the maximum computational load



**Energy consumption of Apple Macintosh computers**

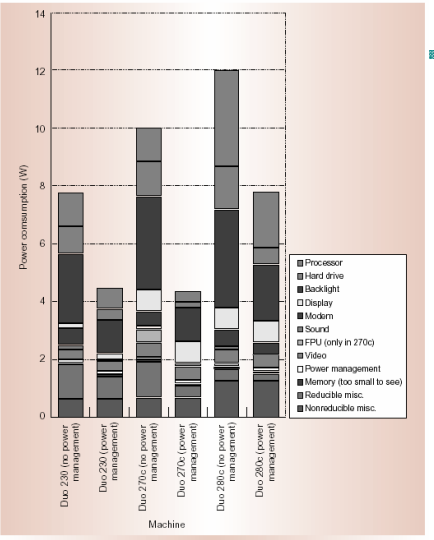


Figure 2. Power consumption breakdowns for each machine, with and without power-saving modes.

# Energy Consumption in CMOS Technology

- Power consumption per every cycle in a digital circuit
  - $P = C \cdot V^2 \cdot f$
  - C (output capacity)
  - V (supply voltage)
  - f (clock frequency)

- Energy consumption
  - $E \propto V^2$



# Dynamic Voltage Scaling (1)

- Relationship between V and f
  - $V \propto f$
  - Lowering the supply voltage increases the circuit delay
  - The clock frequency must be reduced accordingly

- Observations
  - Execution times scale linearly to the supply voltage
  - The energy consumption scales quadratically to the supply voltage

# Dynamic Voltage Scaling (2)

- **Voltage scheduling graph by Pering, et al.**
  - **{S, C, D} = {start time, execution time, deadline}**
  - **{E} = energy**

- **Optimal speed settings**
  - **Sum-of-squares optimization**
  - **Given the constraint**
    - $\sum f_i = k$
  - $\sum f_i^2$ **is minimized when**

$$f_1 = f_2 = \ldots = f_n$$

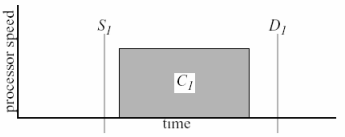


Figure 1: The Voltage Scheduling Graph

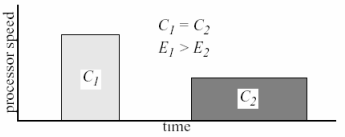


Figure 2: Task energy vs. computation



# DVS-Supporting Microprocessors

MICROPROCESSORS THAT ALLOW THE CORE OPERATE AT DIFFERENT VOLTAGES AND FREQUENCIES

| Processors | Voltage (V) | Speed (MHz) | Power Consumption (Watt) | Features |
|---|---|---|---|---|
| StrongARM SA-2 [7] | 1.30<br>0.75 | 600<br>150 | 0.45<br>0.04 | 12-fold energy reduction |
| Pentium-III [8] | 1.60<br>1.35 | 650<br>500 | 22<br>9 | SpeedStep Tech. -2 modes |
| XScale [9] | 1.6<br>0.75 | 800<br>150 | 0.9<br>0.04 | 1000 MIPS<br>185 MIPS |
| Crusoe (TM5400) [6][10] | 1.65<br>1.10 | 700<br>200 | 2<br>1 | 16 levels (33MHz/step) |
| ARM7D [4] | 5.0<br>3.3 | 33<br>20 | 0.165<br>0.033 | 185 MIPS/W<br>579 MIPS/W |
| PowerPC860 [11] | 3.3<br>2.4 | 50<br>25 | 1.3<br>0.241 | 2 modes |