EC-252: COMPUTER ARCHITECTURE AND MICROPROCESSORS

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CPU Power Management for PC

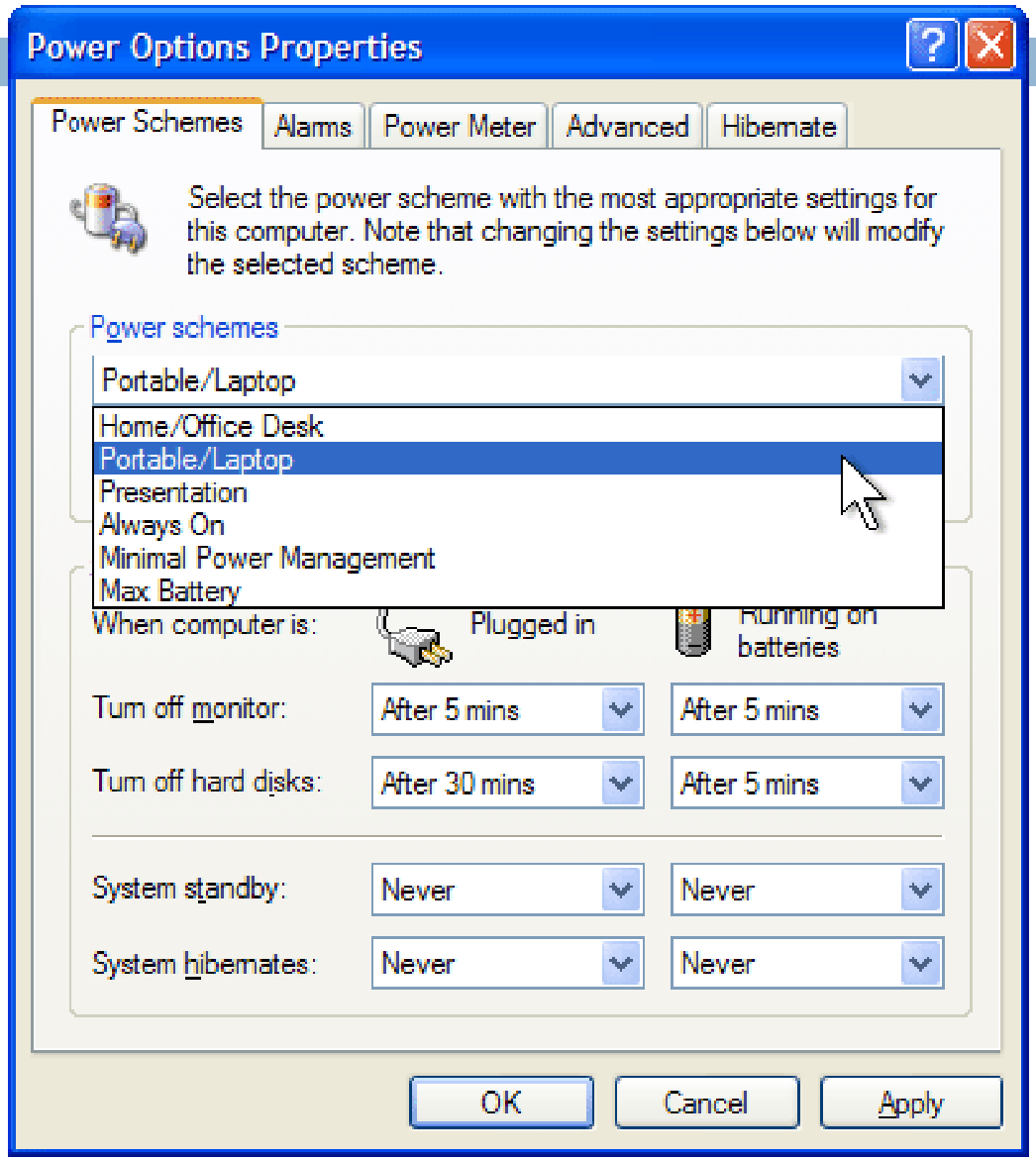
- Overclocking
  - Increase clock speeds of CPU, CPU multiplier, memory, etc
  - Pros: faster, Cons: generates more heat and noise
- Underclocking
  - CPU, GPU, memory, etc

- **Must be done Manually!!**

Power Constraint in Mobile Devices

- Mobile devices are entities with power-constraints
  - Laptops, smart phones, PDAs
- To increase the battery life, we need some power saving policy
  - Display condition adaptation (dim/ sleep)
  - Thermal condition adaptation
  - Processing condition adaptation
- User power policy
  - User choices made through control panel
- System power policy
  - Dynamic frequency scaling (depends on user power policy)

Power Options in Windows OS



Dynamic Frequency Scaling

- Automatically adjust CPU clock frequency “on the fly”
  - Objectives are to
    - Conserve power
    - reduce heat generation
- Also used in quiet computing
  - Decreases energy and cooling costs for lightly loaded machines
  - Less heat output => cooling fans are slowed down or turned off => reduces noise levels & saves more power
- Also known as CPU (dynamic) throttling

CPU Dynamic Throttling

- Relationship between power policy scheme and processor dynamic throttling policy

Power Scheme	AC Power	DC Power
Home/Office Desk	None	Adaptive
Portable/Laptop	Adaptive	Adaptive
Presentation	Adaptive	Degrade
Always On	None	None
Minimal Power Management	Adaptive	Adaptive
Max Battery	Adaptive	Degrade

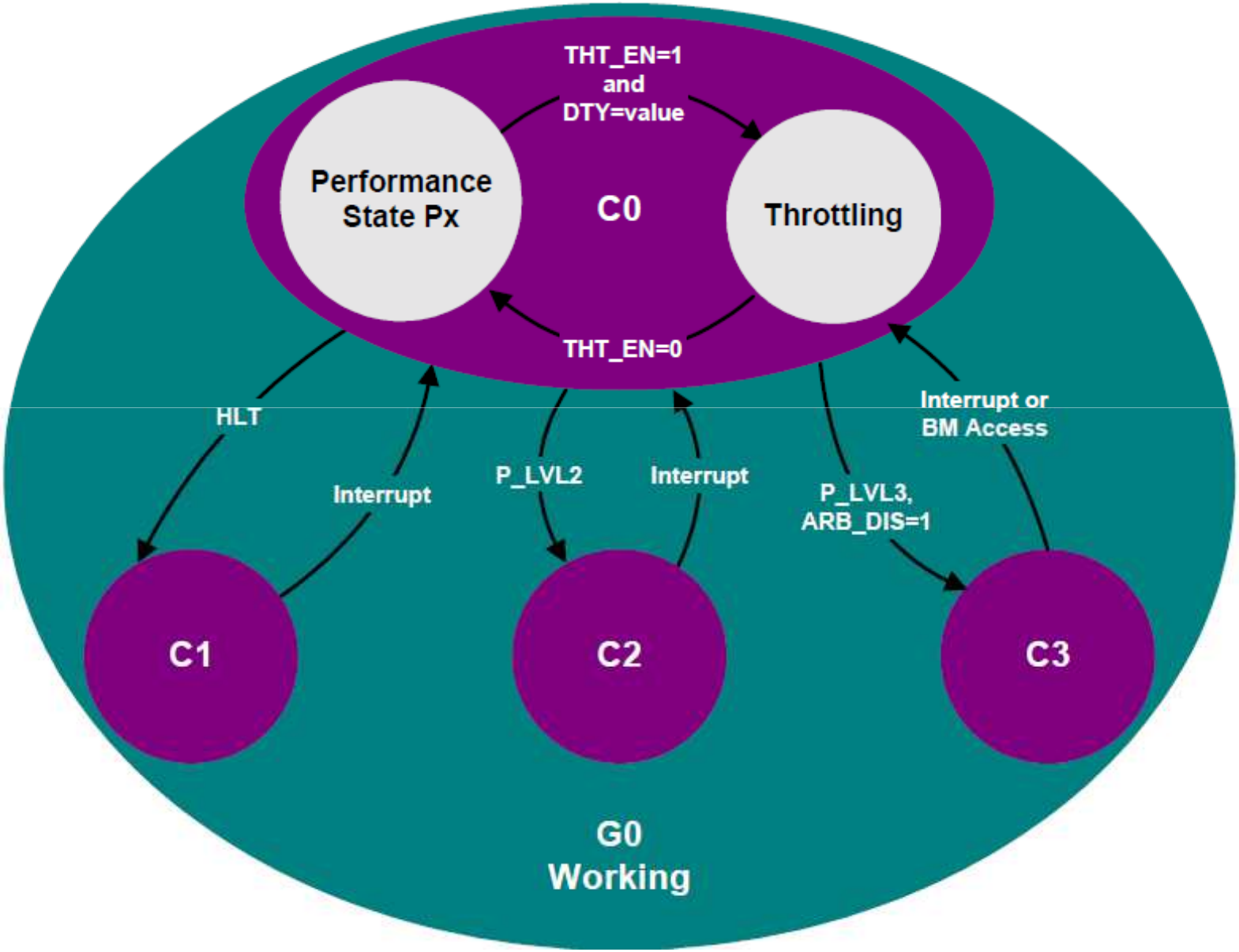
CPU Dynamic Throttle Policy

- Four operating states of the CPU
  - "None"
    - Ensures the processor is always at the highest performance state
  - "Adaptive"
    - Matches the performance state to current demand
  - "Constant"
    - Runs the processor in the lowest available frequency/voltage state
  - "Degrade"
    - Also runs the processor in the lowest available frequency/voltage state
    - Utilizes *linear stop clock throttling* if the remaining battery capacity drops below a certain threshold

Advanced Configuration and Power Interface (ACPI / ACPI 2.0)

- ACPI provides a platform-independent open standard for device configuration and power management by the operating system
  - The standard was originally developed by Intel, Microsoft, and Toshiba - later joined by HP and Phoenix
- First released in December 1996
- Latest version is "Revision 5.0," published on November 23, 2011

ACPI: Processor and Power States



Processor States

- The CPU power states *C0*-*C3*:
  - **C0** is the operating state.
  - **C1** (often known as *Halt*)
    - Not executing instructions, but can return to an executing state essentially instantaneously
    - All ACPI-conformant processors must support this power state
  - **C2** (often known as *Stop-Clock*) is a (optional) state where
    - the processor maintains all software-visible state, but may take longer to wake up
  - **C3** (often known as *Sleep*) is a (optional) state where
    - the processor does not need to keep its cache coherent, but maintains other state
    - Variants: Deep Sleep, Deeper Sleep, etc, based on how long it takes to wake the processor

Power-performance States

- While a processor operates (C0 state), it can be in one of several power-performance states P0 to Pn
  - **P0** max power and frequency
  - **P1** less than P0, voltage/frequency scaled
  - …
  - **Pn** less than *P(n-1)*, voltage/frequency scaled
- up to an implementation-specific limit of *n*, no greater than 16

Clock Speed vs. P-States

- CPU clock speed can be dynamically changed (to different *P-states)*
  - to meet the instantaneous performance needs of the operation being performed,
  - while minimizing power draw and heat dissipation

- P-states are known as SpeedStep in Intel processors and as PowerNow! or Cool'n'Quiet in AMD processors

Dynamic Freq. Scaling (in Practice)

- Intel's SpeedStep Technology
  - Allows dynamic and software controlled moderation of CPU clock speed (mainly for mobile systems)
  - SpeedStep I: used in 2nd gen. Pentium III processors
  - SpeedStep II: (aka. Enhanced SpeedStep) used in Pentium III-Mobile processors
  - SpeedStep III: adapted for Pentium 4-Mobile (M) processors
    - Pentium 4-Mobile (P4-M) emerged as the laptop version of the Pentium 4

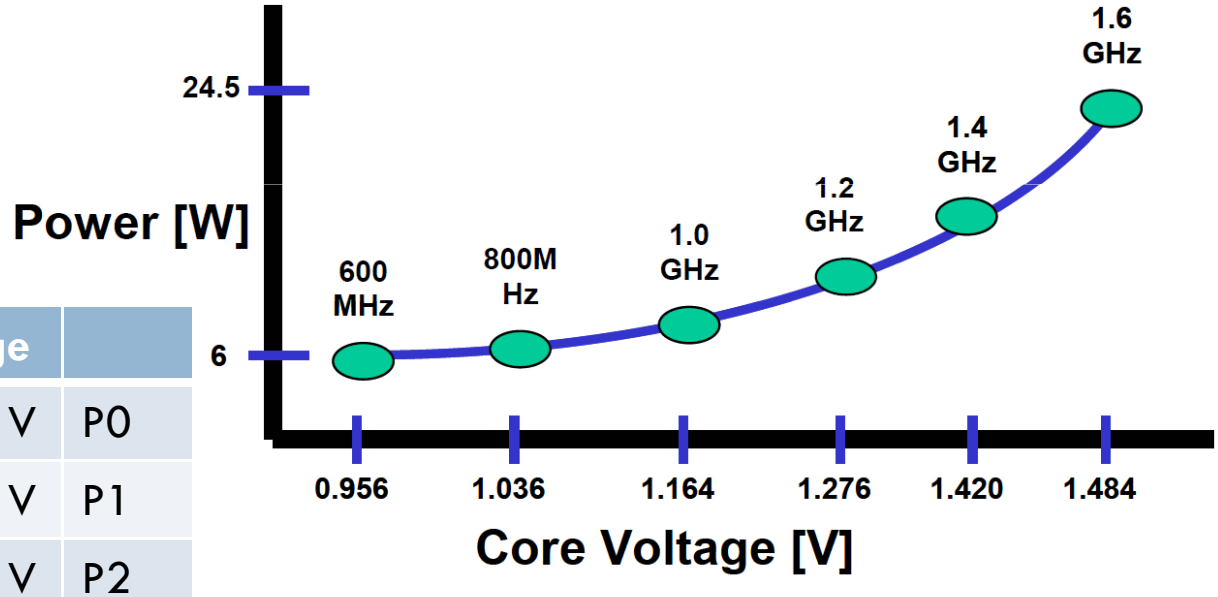
Dynamic Freq. Scaling (in Practice)

- Intel's Enhanced Intel SpeedStep Technology (EIST)
  - used with the first and second generation of Pentium M processors (family of mobile single-core x86 CPU)
  - Pentium M emerged as the new mobile processor which is a heavily modified version of the Pentium III
  - Why not modify P4?
    - P4 consumed more power and emitted more heat than any previous Intel or AMD processors

Pentium M Performance States

- Supported Performance States (P-states) for the Intel Pentium M Processor at 1.6GHz

Frequency	Voltage	
1.6 GHz (HFM)	1.484 V	P0
1.4 GHz	1.420 V	P1
1.2 GHz	1.276 V	P2
1.0 GHz	1.164 V	P3
800 MHz	1.036 V	P4
600 MHz (LFM)	0.956 V	P5



Dynamic Freq. Scaling (in Practice)

- AMD employs 2 different CPU throttling technologies
- Cool'n'Quiet technology
  - used in desktop and server processor lines
  - aim is to produce less heat => fans move slower => keeps cool and reduces noise level
- PowerNow! Technology
  - used in mobile processor line,
  - sometimes, also in desktops (e.g., AMD K6-2+)

Enhanced Intel SpeedStep Technology

- The software model behind EIST performs all mgmt. for the frequency and voltage transitions
- Microsoft* Windows* XP and the Windows Server 2003 family include complete native processor performance control to support EIST
- The native support in Windows XP and the Windows Server 2003 family consists of two components:
  - The kernel power policy manager, and
  - the processor driver

Enhanced Intel SpeedStep Technology

- The kernel power policy manager owns
  - the decision-making, and
  - the set of rules used to determine the appropriate frequency/voltage operating state
  - It may make decisions based on several inputs, such as
    - end-user power policy,
    - processor utilization,
    - battery level, or
    - thermal conditions and events

Enhanced Intel SpeedStep Technology

- The processor driver is used to make actual state transitions on the kernel power policy manager's behalf
  - The driver does not initiate frequency/voltage state transitions independent of the kernel power policy manager