Mobile Platform Idle Power Optimization – Methodologies and Tools

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Agenda

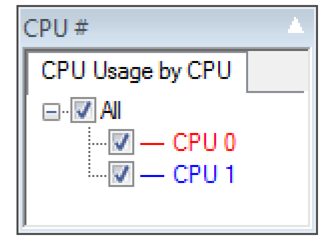
- Mobile platform energy efficiency goals
- Hardware considerations
- Software considerations
- Tools for idle power analysis

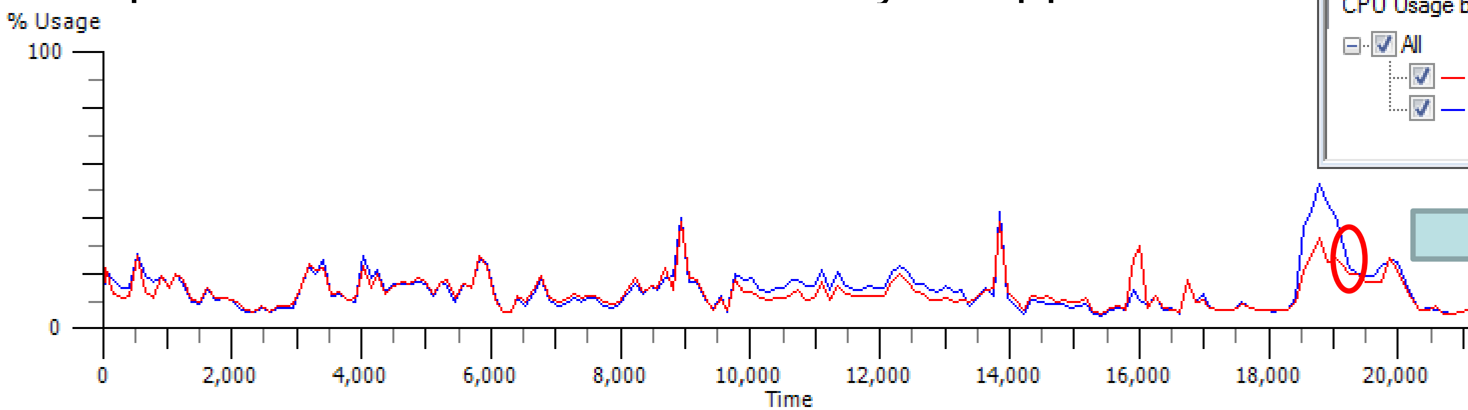
Mobile Platform Energy Efficiency Goals

Minimize power consumption while idle

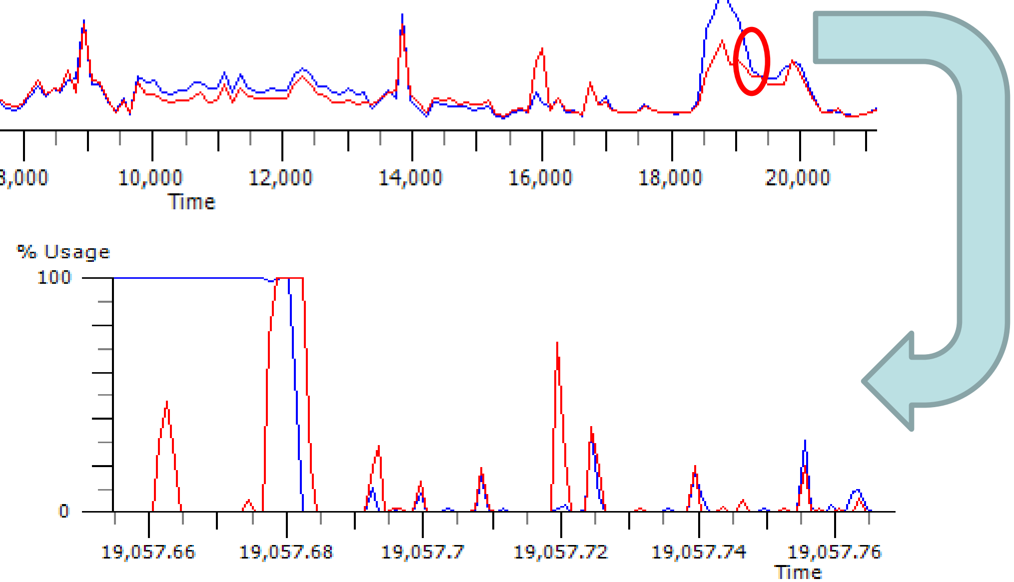
- Mobile client systems are idle (low CPU utilization) most of the time

Example: Office PC loaded with many IT applications





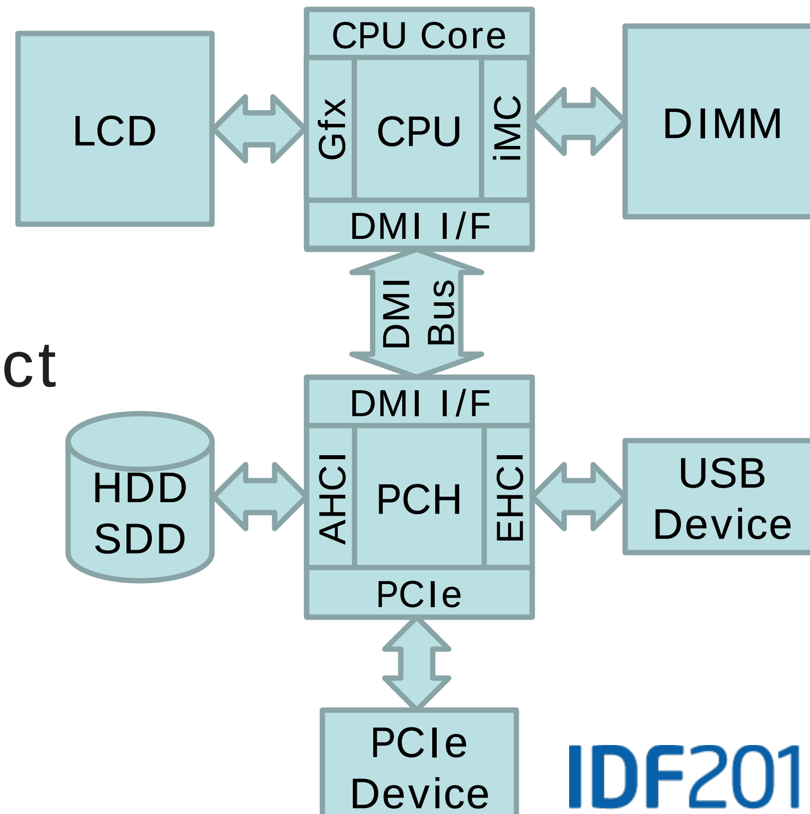
- Even with moderately busy workloads, there are a lot of low CPU utilization sections



Source: Intel Corporation

Platform Power Saving Features

- Today's mobile platform implements many power saving features
- But, many systems are not taking full advantage of them
  - Not properly configured
  - Bad component selection
  - Bad software activities
- One bad component can cause significant impact



PCIe = PCI Express* Technology

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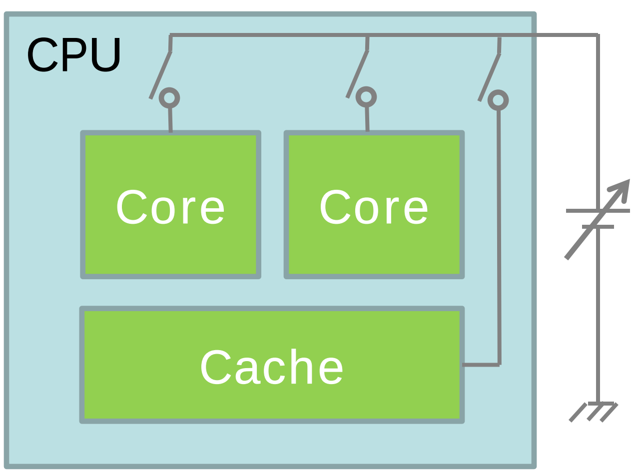
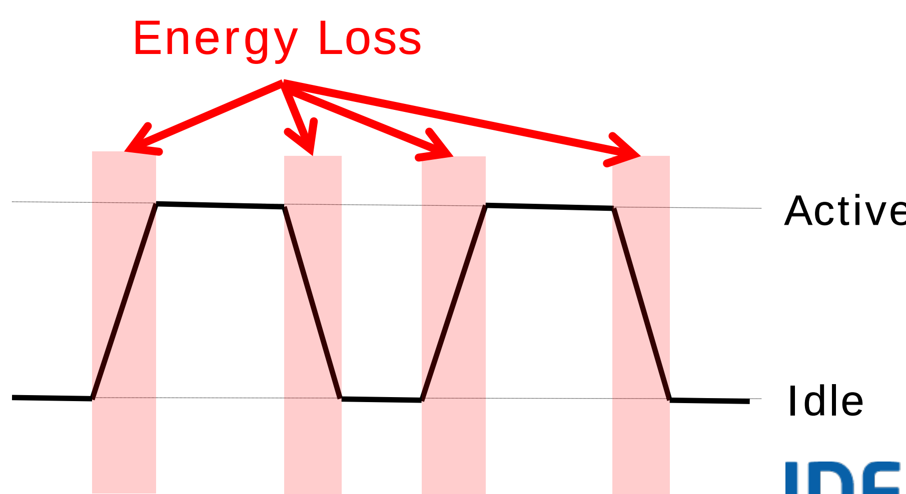
CPU Power Saving

- CPU is a well power managed component
  - Dynamic power supply voltage
    Lower voltage when CPU utilization is low
  - Power gating
    Turn off power when CPU is idle to minimize leakage
  - CPU can adjust performance/power to the workload
- But, burns energy at each idle/active transition





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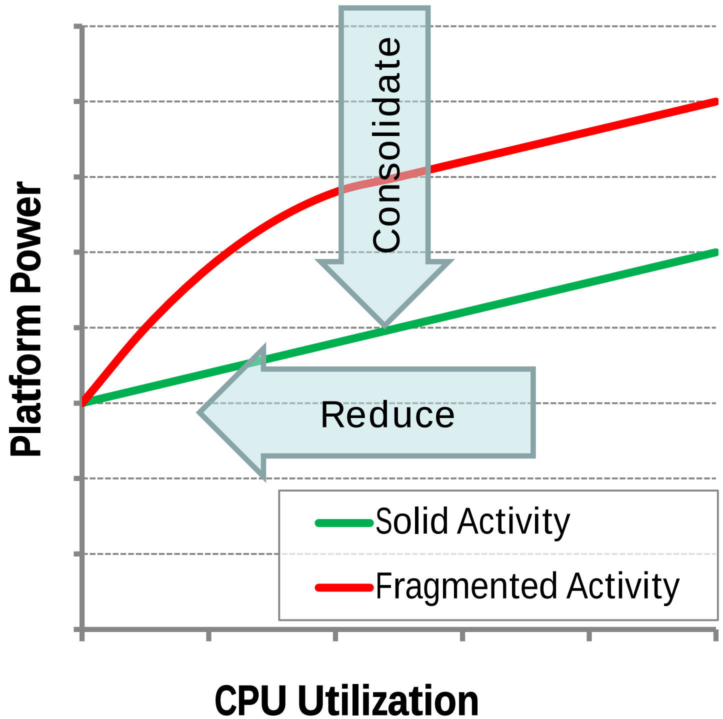
Software Impact to Platform Power

- Resource utilization (CPU cycle count) isn't the only factor
- Periodicity of the activity makes big impact
- Optimization needs to address both
- Details will be discussed in the software section



PCI Express* / SATA Power Saving

- Serial buses implement Link Power Management
  - L0s and L1 (ASPM) states for PCI Express* links
  - Partial and Slumber states for SATA links
- Maximize residency in the lower power states
- But, just setting enable bits isn't enough

  Actual residency determined by many factors
  - Traffic on the bus
  - Device and driver policy

Recommendations

- Select devices with adequate policy*
- Verify LPM state residency in the shipping configuration
- Configure driver policy if necessary

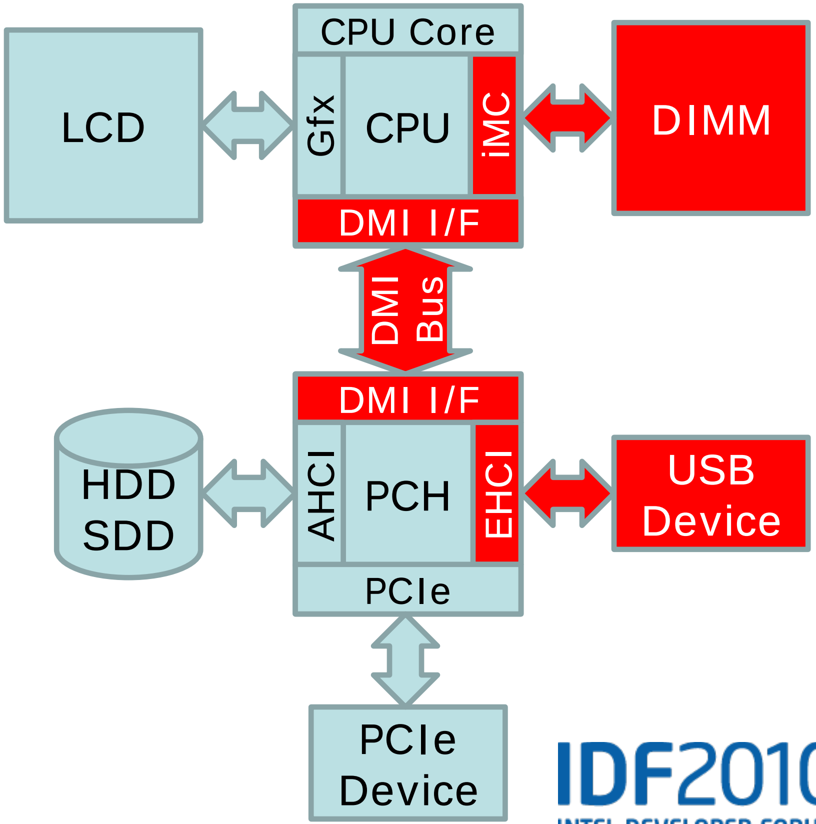
  Intel® Rapid Storage Technology (RST) has registry settings for SATA policy*

Please see the following white papers for details :

- Designing Energy Efficient SATA Devices (SATA devices)
- Energy-efficient platform devices (PCI Express* devices)

USB Device Power Saving

- USB operates on periodic polling and keeps large part of platform in active state
- USB device should implement Selective Suspend and stay in that state as long as possible



Please see the following white papers for details :
- Energy-efficient platform devices
- Making USB a more energy efficient interconnect

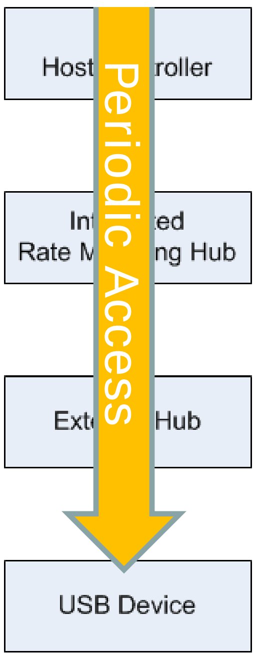
PCIe = PCI Express* Technology

USB Device Power Saving (Cont.)

- Periodic device polling diminishes the benefit of selective suspend

Recommendations

- Choose devices with selective suspend support
- Minimize access to the devices
- Place the device closer to host controller if periodic access is necessary



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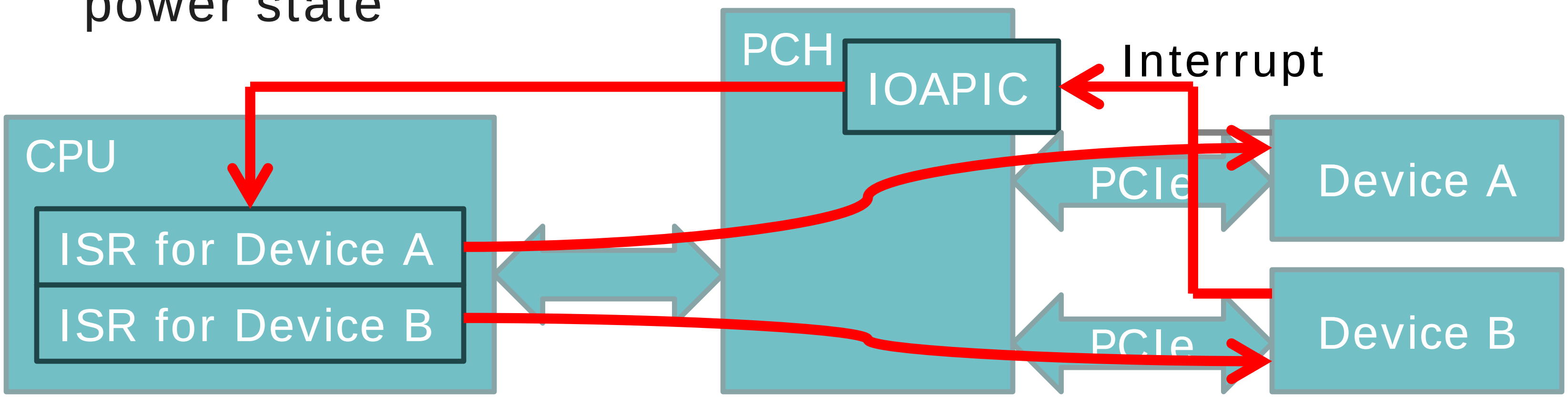
Interrupt Sharing

- Interrupt sharing increases platform activity
  - ISRs (Interrupt Service Routines) for multiple devices are executed to determine the source of interrupt
  - Each ISR accesses its hardware and wakes bus from low power state



Recommendations
- Make sure device and driver support MSI
- If not, assign dedicated line for devices with frequent interrupts

PCIe = PCI Express* Technology

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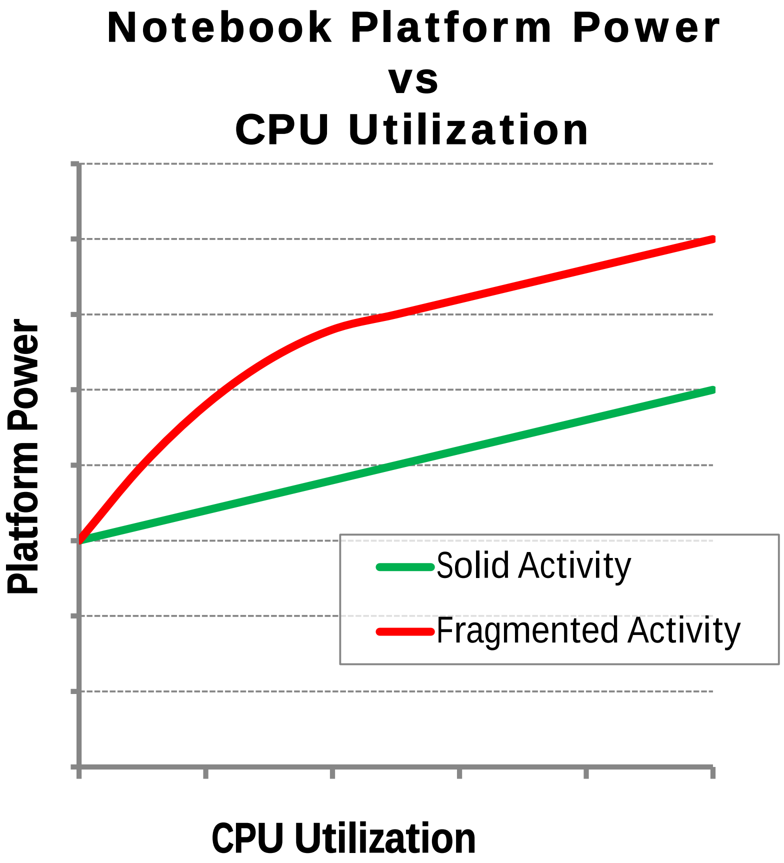
Optimize Application Behavior

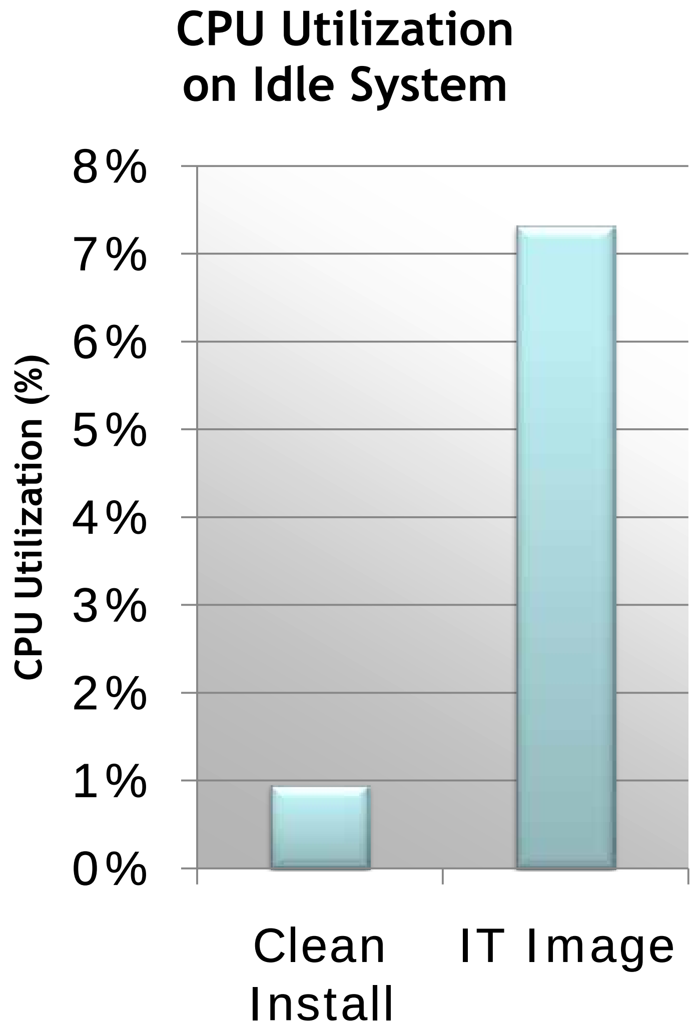
- Two major factors that determine platform power
  - Resource Utilization
    - § (e.g. CPU utilization)
  - Resource Usage Pattern
    - § Fragmented activities cause more power impact
- Focus on idle



Application Design Principles

Respect System Idle

- Idle dominates usage scenarios for client systems
  - Reducing idle power is essential for extending battery life
  - Windows* 7 made vast improvements



Source: Microsoft Corporation

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Optimize Resource Usage

- Performance improvement = power improvement
- Architect event driven designs instead of polling or spinning
  - WaitForSingleObjectEx() or SleepEx()

```
void EatBatteryLife()
{
        HANDLE sharedResource = NULL;

        //your process waits for a file to be created via:
        while (sharedResource == NULL)
        {
                waitTime++;
                sleep(1);
        }
}
```

DO NOT DO THIS

WaitForSingleObjectEx() API Usage

```
//process 1's code
void UpdateSharedResource()
{
   //set sharedResource
   sharedResource = UpdateResource();

   // Set sharedResourceIsReadyEvent to
   // signaled
   SetEvent(sharedResourceIsReadyEvent);
}
```

```
//process 2's code
void ConsumeSharedResource()
{
   DWORD dwWaitResult;

   dwWaitResult = WaitForSingleObjectEx(
            sharedResourceIsReadyEvent,
            INFINITE,
            FALSE);  // indefinite wait

   switch (dwWaitResult)
   {
      case WAIT_OBJECT_0:
      //
      // TODO: use sharedResource
      //
      break;
      default:
      return 0;
    }
}
```

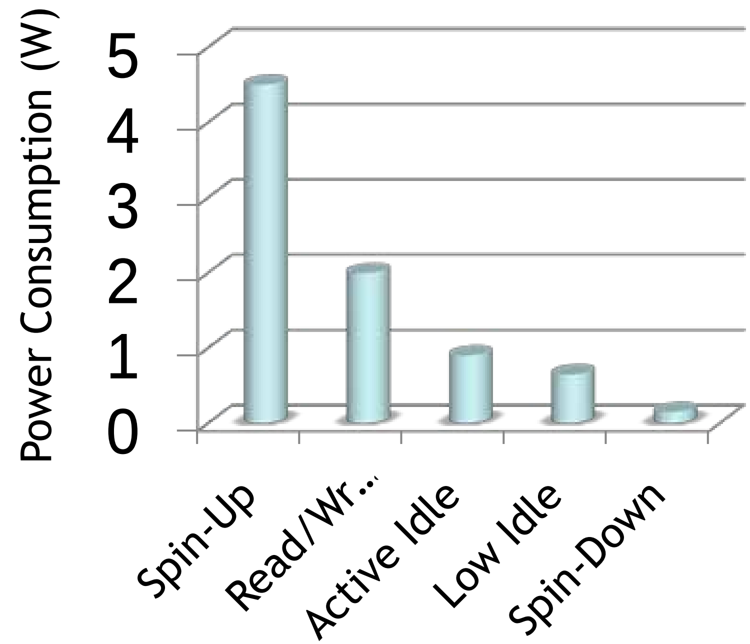
Optimize Resource Usage (2)

- Repainting GUI cascades work to graphics controller
  - 1 pixel change causes 10 VBI
  - Avoid animation icons in the system tray area
- Don't use WMI where Win32 APIs or .NET classes will suffice
  - Example: Repeated Win32_Directory enumeration vs. FileSystemWatcher class
- Choose event-driven APIs
  - Example: EvtSubscribe() instead of EventLogQuery()

Optimize Resource Usage (3)

- Assume all devices have power states
- Reduce device activity to enable low power states
  - Disk spin-down
  - Periodic, low-priority disk activity from applications should be on order of several hours
  - Batch I/Os where possible
  - Use volatile registry keys for transient information

Example HDD Power



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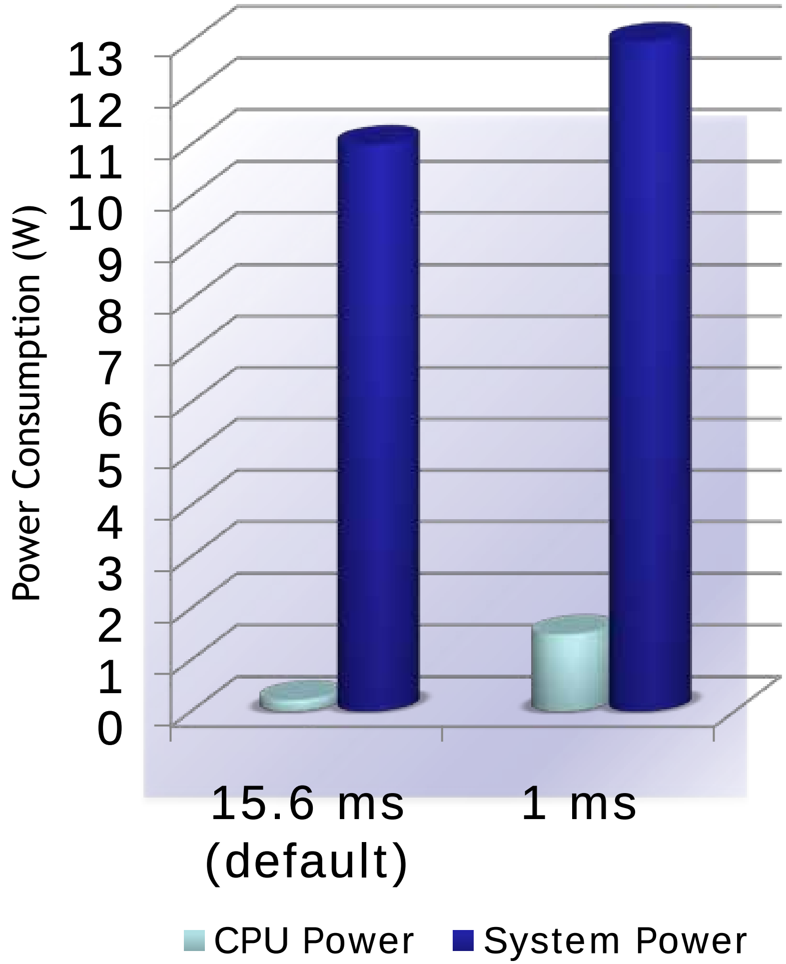
Reduce Periodic Activity

- Avoid changing timer resolution from the default setting
  - Avoid reducing by using larger buffers
  - If you want more granular timestamps, use QueryPerformanceCounter()
- Media playback should use 10ms (or larger)
  - Limit request to as little codepath as possible
- Audio playback code should use event-driven, shared-mode WASAPI*

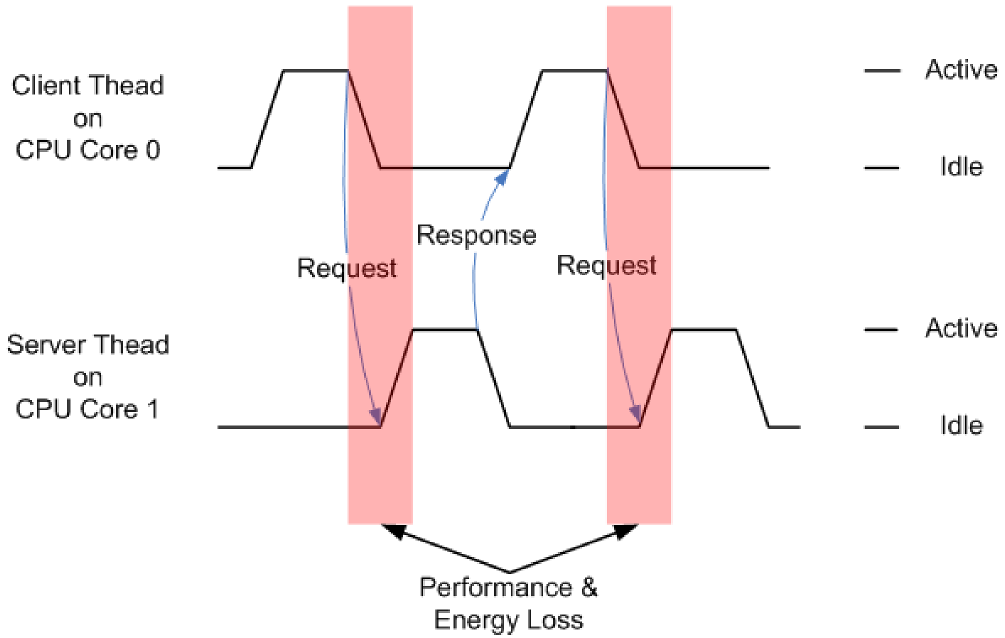


Source: Microsoft Corporation

* Please see Windows* 7 SDK sample code at
C:\Program Files\Microsoft SDKs\Windows\v7.0\Samples\multimedia\audio\

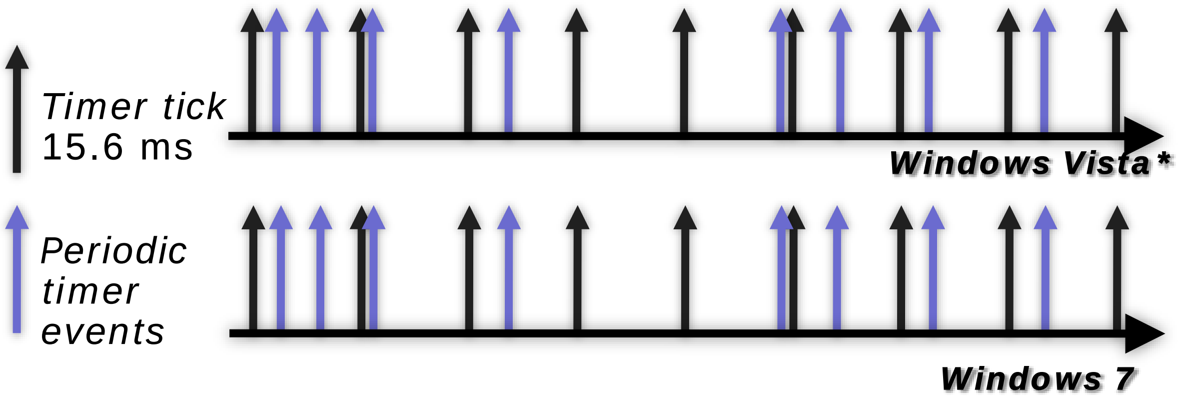
Reduce Periodic Activity (2)

- Thread ping-pong effects
  - Avoid extremely short duration 'work & signal' patterns
    - Use of RPC/COM can cause this
  - Battery Life Analyzer tool provides insight into thread behavior



Coalesce Timers

- Kernel mode and user mode timers should coalesce with other work on the system for minimum power impact
  - Need to engineer for timing tolerance
- New coalescing APIs in Windows* 7



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SetWaitableTimerEx() API

- Replace calls to SetWaitableTimer() with this API
  - More efficient than a purely periodic timer
  - Tolerance parameter should scale with the timer period

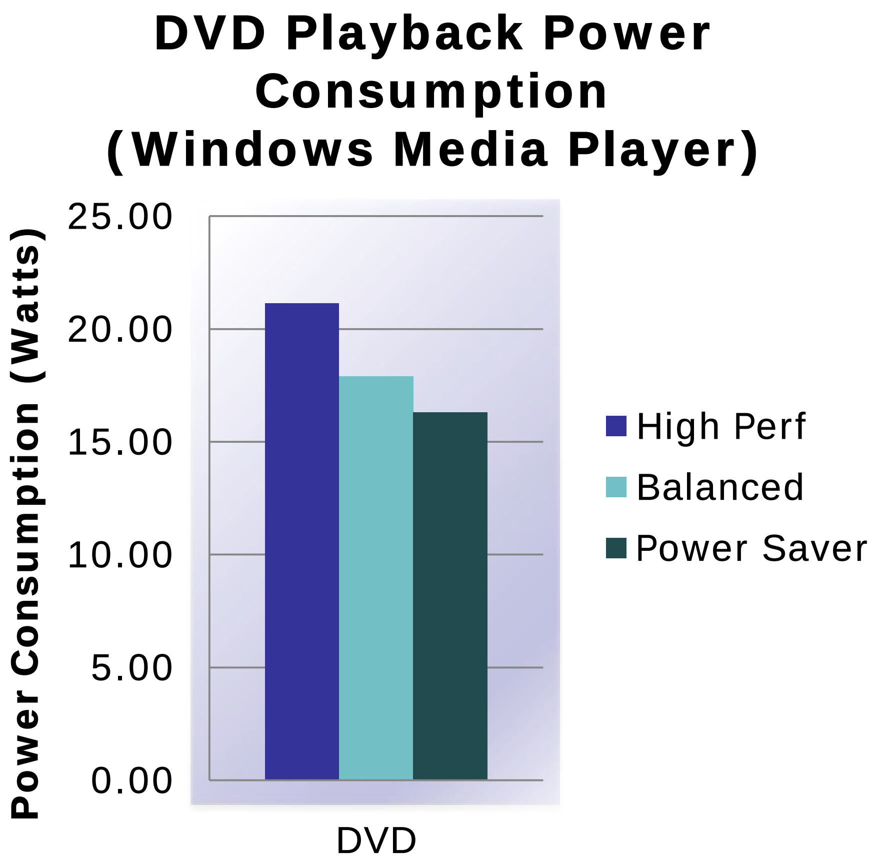
```
BOOL WINAPI SetWaitableTimerEx(
    __in     HANDLE hTimer,
    __in     const LARGE_INTEGER *lpDueTime,
    __in     LONG lPeriod,
    __in_opt PTIMERAPCROUTINE pfnCompletionRoutine,
    __in_opt LPVOID lpArgToCompletionRoutine,
    __in_opt PREASON_CONTEXT WakeContext,
    __in     ULONG TolerableDelay
    );
```

SetWaitableTimerEx() API Usage

```
void CreateAndSetPeriodicTimer()
{
   myTimer = CreateWaitableTimerEx(NULL,
                  TimerName,                   //string with chosen timer name
                  NULL,
                  TIMER_MODIFY_STATE);         //required security attribute to call
                                               //SetWaitableTimerEx

   bError = SetWaitableTimerEx(myTimer,
                  DueTime,             //UTC due time
                  10000,               //periodic timer duration is ten seconds
                  CompletionRoutinePointer,    //APC completion routine
                  ArgsToCompletionRoutine,     //completion routine arguments
                  WakeContext,         //only if waking the machine
                  1000);               //tolerable delay is one second

   //DO WORK

   bError = CancelWaitableTimer(myTimer);      //be sure to cancel periodic timers!
}
```

Bonus: Optimize for System State

- System state holds optimization potential for applications
  - Firewall application should do very little when the PC is not connected to network
- Register for power state change notifications
  - Use the callback to trigger behavioral changes



Source: Microsoft Corporation

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RegisterPowerSettingNotification() API

- Allows you to register for change notifications on power settings
- Callback is a notification to change application behavior
  - Includes new power setting value

```
void MyApp::OnInit()
{
        hACDCSource = RegisterPowerSettingNotification(m_hWnd,
                                                       &GUID_ACDC_POWER_SOURCE,
                                                       DEVICE_NOTIFY_WINDOW_HANDLE);
}
void MyApp::OnDestroy()
{
        if (hACDCSource != 0)
                UnregisterPowerSettingNotification(hACDCSource);
}
```

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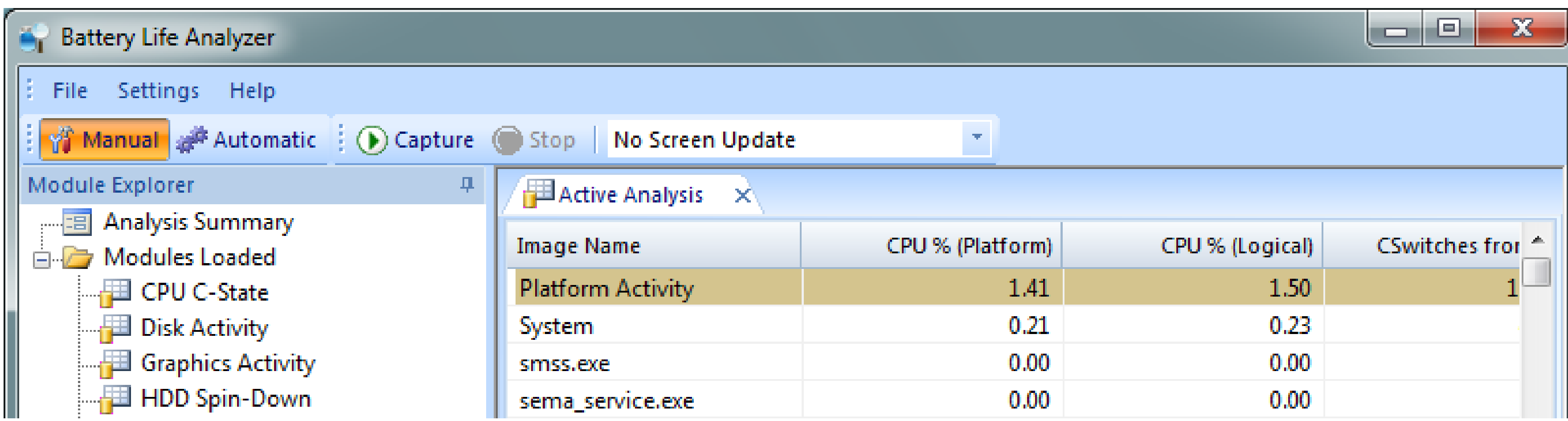
Choose the Right Tool

- Microsoft* Windows* “PowerCfg /energy”
  - OS Built-in command
  - Easy to use, suitable for identifying some common issues
- Microsoft* Windows* Performance Toolkit (xperf)
  - Built on ETW (Event Tracing for Windows) Technology
  - Good tool for deep performance / power analysis
- Battery Life Analyzer
  - New tool from Intel
  - Easy to use, suitable for identifying bad components
  - More detailed information on Intel mobile platforms
  - Built on ETW Technology

Battery Life Analyzer - Outline

- High level tool to identify battery life issues
  - Simple GUI application
  - In most cases, it takes only few mouse clicks
- Quantifies the impact of the issues
  - Where possible, power impact is estimated



Battery Life Analyzer - Features

- Hardware Analysis
  - CPU C-state residency
  - PCI Express*, SATA Link Power Management
  - USB selective suspend
- Software Analysis
  - Fine-grained CPU utilization information
  - Periodicity of the activity
  - Concurrency of multi-core activity
  - Graphics activity
  - Identify process causing HDD spin-ups

Battery Life Analyzer – CPU C-State

CPU C-State Example:

- High residency in the deepest C-state
- All software behaving well

CPU C-State

C-State Counters	Affinity Mask	Average (%)	Power Impact (W)
Package0 C0 - C1	0x0000000f	1.66	N/A (See SW Analysis)
Package0 C3	0x0000000f	1.94	0.021
Package0 C6	0x0000000f	96.40	0.000
Core0 C0 - C1	0x00000003	1.03	N/A (See SW Analysis)
Core0 C3	0x00000003	1.46	0.005
Core0 C6	0x00000003	97.52	0.000
Core1 C0 - C1	0x0000000c	1.06	N/A (See SW Analysis)
Core1 C3	0x0000000c	1.12	0.004
Core1 C6	0x0000000c	97.83	0.000

Battery Life Analyzer – SATA LPM

SATA Link Power Management

- Bad Example
  - DVD drive not entering Slumber state

SATA LPM

Controller/Drive Name	Port	% Active	% Partial	% Slumber	HIPM	DIPM	DIPM Enabled
Intel(R) 5 Series 6 Port SATA AHCI Controller (0/31/2)							
Fdfdsfdfjlkfkdlfd;fdjsfdfd	0	0.00	0.00	100.00	Y	Y	Y
Fdfdsfdfjlkfkdlfd;fdjsfdfd	2	0.00	100.00	0.00	Y	Y	Y

- Good Example
  - Same drive enters Slumber state after enabling host initiated Slumber in the registry

SATA LPM

Controller/Drive Name	Port	% Active	% Partial	% Slumber	HIPM	DIPM	DIPM Enabled
Intel(R) 5 Series 6 Port SATA AHCI Controller (0/31/2)							
Fdfdsfdfjlkfkdlfd;fdjsfdfd	0	0.00	0.00	100.00	Y	Y	Y
Fdfdsfdfjlkfkdlfd;fdjsfdfd	2	0.00	0.00	100.00	Y	Y	Y

Battery Life Analyzer – HDD Spin-up

Disk Activity Analysis

- Identify which process/routine is causing HDD spin-up

Disk Activity

Spin-up Time	Process	PID	TID	File	I/O
4:04:36.892 AM 7/27/2010	System	4	60	C:\Windows\System32\config\SYSTEM	FileIoFlush
4:14:25.552 AM 7/27/2010	taskhost.exe	1672	1944	C:\ProgramData\Microsoft\RAC\Temp\s...	FileIoFlush
4:46:34.082 AM 7/27/2010	explorer.exe	1984	2176	C:\Users\Administrator\AppData\Roami...	FileIoCreate
4:54:37.456 AM 7/27/2010	svchost.exe	824	2476	C:\Windows\CSC\v2.0.6\namespace	FileIoCreate
5:07:44.448 AM 7/27/2010	svchost.exe	792	1352	C:\Windows\system32\gpsvc.dll	FileIoCreate
5:42:04.019 AM 7/27/2010	svchost.exe	824	1640	C:\Windows\CSC\v2.0.6\namespace	FileIoCreate
5:49:37.395 AM 7/27/2010	svchost.exe	824	592	C:\Windows\CSC\v2.0.6\namespace	FileIoCreate

Stack Trace	
C:\Windows\system32\drivers\fileinfo.sys+0x000000000000adbc	
C:\Windows\system32\drivers\fileinfo.sys+0x0000000000007fff	
C:\Windows\system32\drivers\fltmgr.sys::FltReleasePushLock()	
C:\Windows\system32\drivers\fltmgr.sys::FltIsCallbackDataDirty()	
C:\Windows\system32\drivers\fltmgr.sys+0x00000000000016c7	
C:\Windows\system32\ntoskrnl.exe::IoReportHalResourceUsage()	

Summary

- Your product has a direct impact to the battery life of mobile platforms
- One bad product can ruin the customer experience
- Start looking at the impact to idle power
- Tools and more information are available from Intel and Microsoft

Call to Action

- Get tools
  - "PowerCfg /energy"
    Windows* 7 built in command
  - Microsoft* Windows* Performance Toolkit (xperf)
    Now included in Windows 7 SDK
  - Battery Life Analyzer
    Send e-mail to: BatteryLifeAnalyzer@intel.com
- Analyze your product and identify the issue
- Improve power efficiency of your product

Additional sources of information on this topic:

- Other Sessions
  - EBLS001: Interconnect Bus Extensions for Energy-Efficient Platforms
  - EBLS002: Impact of “Idle” Software on Battery Life
- White papers

  http://www.intel.com/technology/mobility/notebooks.htm
  - Designing Energy Efficient SATA Devices
  - Making USB a More Energy-Efficient Interconnect
  - Energy-Efficient Platforms – Designing Devices Using the New Power management Extensions for Interconnects
  - Energy-Efficient Platforms – Considerations for Application Software and Service

  http://www.microsoft.com/whdc/system/pnppwr/default.mspx
  - Mobile Battery Life Solutions Guide for Windows 7
  - Developing Efficient Background Processes for Windows
  - Using PowerCfg to Evaluate System Energy Efficiency
  - Windows Timer Coalescing

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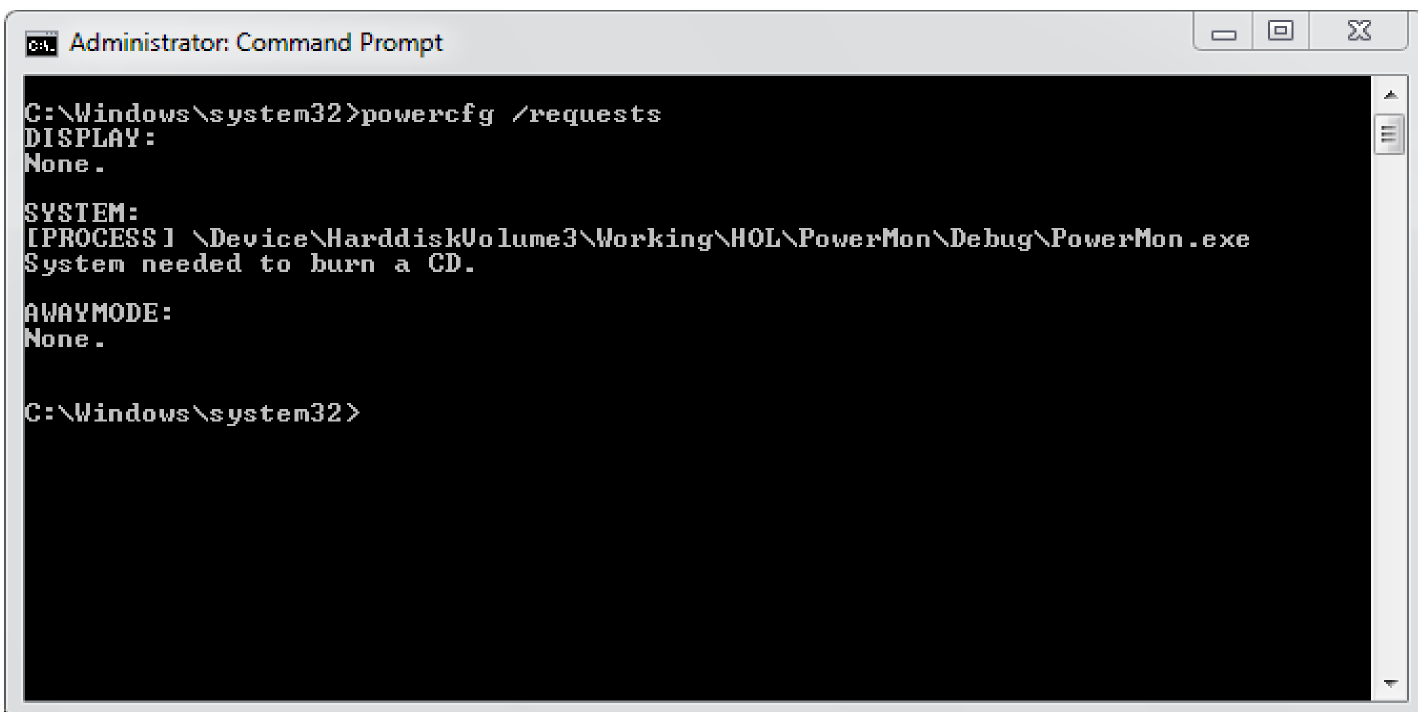
Rev. 5/7/10

Backup Slides

PowerSetRequest() API

- Replaces setthreadexecutionstate()
- Allows you to issue availability requests for monitor & system
- Allows you to create a custom, localized reason string
- Does not prevent user-initiated sleep transitions



PowerSetRequest() API Usage

```
void KeepSystemAwake()
{
    // This example uses a simple, non-localized availablity request diagnostic
    string
    POWER_REQUEST_CONTEXT SimpleRqContext;
    SimpleRqContext.Version = POWER_REQUEST_CONTEXT_VERSION;
    SimpleRqContext.Flags = POWER_REQUEST_CONTEXT_SIMPLE_STRING;
    SimpleRqContext.Reason.SimpleReasonString = L“System needed to burn a CD.";

    HANDLE SimplePowerRequest = PowerCreateRequest(&SimpleRqContext);

    // Set a system request to prevent automatic sleep
    PowerSetRequest(SimplePowerRequest,PowerRequestSystemRequired);

    //
    // Do work here...
    //

    // Clear the request
    PowerClearRequest(SimplePowerRequest,PowerRequestSystemRequired);
}
```