Optimizing Windows Device Performance and Battery Life

Jessie Labayen
Principal Program Manager
Agenda

Performance and Power Fundamentals
Assessment Toolkit
Performance & Power Setting
Energy Estimation Engine (E3)
Start with Great Fundamentals

Fundamentals is about experiential performance, battery life and quality

Poor fundamentals impacts user satisfaction

The more features you add in your device, the more visible and important fundamentals becomes

How poor fundamentals can impact modern devices

Thin & light device with 4k/HDR display that do not deliver battery life expectations or glitch free media playback

Slow Windows Hello logon experience

Slow or glitchy App or Gaming experience

Glitchy inking experience
Optimizing for Performance
Windows Performance Process

Design for performance
Deliver consistent performance
Iterate & improve

Different focus, same approach

Software
Windows
Hardware

OEMs, ODMs

Service, App, Driver developers

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## Test Recommendations

| User experiences          | Covers end-to-end scenario that typical users will experience  
|                          | Examples: Boot, video playback, browser navigation, etc.  
|                          | **Windows Assessment Toolkit** |
| Micro benchmarks          | Specific operations in your application, service or driver that are critical to optimize for performance  
|                          | Examples: Antivirus file scan, driver load, driver init routine, etc.  
|                          | **Event Tracing for Windows** and **Windows Performance Toolkit** |
| Key performance metrics   | Relevant data needed to assess and evaluate performance  
|                          | Examples: CPU usage, disk IOs, memory usage, etc.  
|                          | **Windows Performance Toolkit** |
Event Tracing for Windows (ETW)

What is ETW
Fast, reliable, and versatile tracing framework
Dynamic trace control
(no reboot or app restart required)
Uses an efficient non-blocking buffering and logging mechanism

Instrument code
Investigate performance issues pre/post shipping
Correlate app behavior with system resources usage
Accurately measure your app operations
Responsiveness

Poor performance or responsiveness leads to lower customer satisfaction

Key areas to consider
User perception should determine performance goals
Measure the planned hardware configurations
Real-world workloads, resource constraints and software preload must be taken into account

Holistic evaluation of resource utilization
**Physical**: CPU, GPU, disk, display resolution, memory, network, battery
**Logical**: critical sections, critical resources
Example: Fast Startup

From a low power state to a responsive desktop
Boot, Fast Startup, Resume from Standby, Resume from Hibernate

Usually I/O and CPU intensive

Highly impacted by apps
Startup applications, services and logon scheduled tasks
RUN key and Startup folders entries
Includes hardware-related processes (energy saver, control panels, tray icons, etc.)
Software Preload Guidance

Don’t launch unnecessary memory resident processes
Use trigger start services and avoid having services running all the time unnecessarily
Delay start process if possible with the Task Scheduler

Optimize resource usage on app launch
Reduce CPU/disk contention and steady state memory usage
Avoid managed code in boot path

Leverage Automatic Maintenance
Perform periodic tasks like updates, scans, etc. to avoid user impact

Analysis focus
Memory footprint of processes impacting hiberfile size
Critical path analysis of logon and device initialization (bad drivers, security providers)
CPU and disk resource consumption during post-on/off

Optimizing for All Day/Longer Battery Life
Battery life & design tradeoffs

Audio offload reduces CPU power by 4-14%
Flash disks are more energy efficient
Digitizers consume energy
Saves power by turning off display engine
Low refresh rate panels reduce power by 3-5%
Larger displays consume more energy
Higher resolution consume more power
Higher battery capacity increases weight & thickness

- No audio offload
- Hard Drive
- Touch/Pen
- No Panel Self Refresh
- 60 Hz panel
- Larger Display
- Higher Resolution
- Smaller Battery

- Audio Offload
- Solid State Drive
- Non-Touch/Pen
- Panel Self Refresh
- 48 Hz - 60 Hz panel
- Smaller Display
- Lower Resolution
- Larger Battery

Shorter

Battery Life

Longer
Battery Life Planning

Power Modeling
Build power models for each device configuration
Lookup energy data on component datasheets

Partner with silicon vendors
Leverage your silicon partners’ reference design and development kits to compare component spec with actual power draw based on real world workloads

\[
\text{Est. Battery Life (hours)} = \frac{\text{Battery Capacity (Wh)}}{\text{System Power Consumption (W)}}
\]

<table>
<thead>
<tr>
<th>Scenario Workload</th>
<th>Hardware</th>
<th>Part #</th>
<th>Idle</th>
<th>Standby</th>
<th>Playback</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Platform CPU</td>
<td>Part #A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Display</td>
<td>Part #B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Input controller</td>
<td>Part #C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Memory</td>
<td>Part #D</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Storage type</td>
<td>Part #E</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wi-Fi</td>
<td>Part #F</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mobile broadband</td>
<td>Part #G</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sensors</td>
<td>Part #H</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Battery controller</td>
<td>Part #I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other parts</td>
<td>Part #J,K</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total Avg Power (mW)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Battery Capacity (Wh)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Est. Battery Life (hours)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Power Savings Checklist & Resources

Audio offload capable hardware
Audio offload saves 4-14% in power
Learn more: https://aka.ms/MXA-AudioOffload

Low refresh rate (48 Hz) and power efficient panels
When playing 24fps in full screen Media Engine based apps, refresh rate drops from 60 to 48 Hz
Saves 3-5% in power, learn more: https://aka.ms/MXA-VideoPower

Save power with Media Engine apps
Promote usage of Media Engine based playback apps with users and reviewers
Movies & TV and Netflix support power saving features

Plan ahead
Choose hardware components wisely
Keep thermals in mind along with power and performance
Windows Assessment Toolkit and Inbox Tools
Automated assessments
Performance, quality and energy efficiency (battery life) assessments and workloads that simulate real world scenarios while capturing metrics and actionable traces

Windows 10 October 2018 Update

Performance
New OOBE assessment workflow
Office Performance (Excel, Word, PowerPoint, Outlook)
Media Quality diagnostics

Power
E3 logging on all battery life workloads
PowerView (E3 results viewer) app
System Timer Resolution diagnostics
### Microsoft Office Performance Assessment

<table>
<thead>
<tr>
<th>Group by</th>
<th>Duration (Milliseconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excel_Launch</td>
<td>785</td>
</tr>
<tr>
<td>Excel_FileOpen</td>
<td>280</td>
</tr>
<tr>
<td>Outlook_Launch</td>
<td>2172</td>
</tr>
<tr>
<td>PowerPoint_Launch</td>
<td>478</td>
</tr>
<tr>
<td>PowerPoint_FileOpen</td>
<td>533</td>
</tr>
<tr>
<td>PowerPoint_SlideShowBegin</td>
<td>160</td>
</tr>
<tr>
<td>Word_Launch</td>
<td>614</td>
</tr>
<tr>
<td>Word_FileOpen</td>
<td>425</td>
</tr>
</tbody>
</table>

The analysis is complete with 1 warning and 0 issues. The overall performance metric is 665 milliseconds.
# Media Diagnostics

## Windows 10 Media Playback Quality

<table>
<thead>
<tr>
<th>Analysis complete</th>
<th>True</th>
</tr>
</thead>
<tbody>
<tr>
<td>Issues</td>
<td>3</td>
</tr>
<tr>
<td>Independent Flip is not enabled</td>
<td>1</td>
</tr>
<tr>
<td>MultiPlane Overlay is not enabled</td>
<td>1</td>
</tr>
<tr>
<td>Hardware Video Acceleration is not enabled</td>
<td>1</td>
</tr>
<tr>
<td>Total playback duration (Seconds)</td>
<td>290</td>
</tr>
<tr>
<td>Total audio glitches (count)</td>
<td>0</td>
</tr>
<tr>
<td>Total video glitches (count)</td>
<td>25</td>
</tr>
<tr>
<td>Video glitches (count)</td>
<td>4</td>
</tr>
<tr>
<td>Average frames late (count)</td>
<td>1.00</td>
</tr>
<tr>
<td>Minimum frames late (count)</td>
<td>1</td>
</tr>
<tr>
<td>Maximum frames late (count)</td>
<td>1</td>
</tr>
<tr>
<td>Sum frames late (count)</td>
<td>4</td>
</tr>
<tr>
<td>DWM schedule glitches (count)</td>
<td>21</td>
</tr>
<tr>
<td>Dropped video frames (count)</td>
<td>0</td>
</tr>
</tbody>
</table>

## Media Diagnostics Metrics

<table>
<thead>
<tr>
<th>Group by</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D Engine Activity</td>
<td>Passed</td>
</tr>
<tr>
<td>Audio Offload</td>
<td>Passed</td>
</tr>
<tr>
<td>DagKmI IndependentFlip</td>
<td>Failed</td>
</tr>
<tr>
<td>DagKmI MMIOFlipMultiPlaneOverlay</td>
<td>Stopped</td>
</tr>
<tr>
<td>Hardware Video Acceleration</td>
<td>Failed</td>
</tr>
<tr>
<td>Multimedia/Power VSyncSamplingRate</td>
<td>Passed</td>
</tr>
</tbody>
</table>
## System Timer Resolution Diagnostics

### Diagnostic Information

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greatest battery percentage decrease (%)</td>
<td>1</td>
</tr>
<tr>
<td>Greatest battery percentage increase (%)</td>
<td>0</td>
</tr>
<tr>
<td>Desktop background image name (file path)</td>
<td>C:\Windows\wallpaper\Windows8img0.jpg</td>
</tr>
<tr>
<td>Power plan name</td>
<td>Balanced</td>
</tr>
</tbody>
</table>

### Windows 10 Full Screen Media Playback Workload - Instance #1

**CPU Utilization**
- Time spent in the active C-state (%): 0.00
- Time spent in the lowest C-state (%): 0.00
- Lowest C-state (%): 0
- CPU Dynamic Timer Tick Support: Supported
- Periodic CPU sources (<100 ms interval): 6
- Periodic CPU sources (<300 ms interval): 1

**Timer Resolution Metrics**

<table>
<thead>
<tr>
<th>Query Duration (Milliseconds)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>619234.714</td>
</tr>
</tbody>
</table>

**Process**

<table>
<thead>
<tr>
<th>Group by</th>
<th>Resolution (Milliseconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>VideoUI.exe (8706)</td>
<td>2,000</td>
</tr>
</tbody>
</table>

**Actual**

<table>
<thead>
<tr>
<th>Group by</th>
<th>Resolution (Milliseconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>System</td>
<td>15,625</td>
</tr>
</tbody>
</table>
**Battery Life Media Workloads**

**New**
- Netflix on Edge
- YouTube custom

**Existing**
- Default local video
- Custom local video
- Netflix video streaming
- Movies & TV video streaming
- YouTube default video streaming
- Custom streaming
PowerView tool

Visualize powercfg /srumputil output

Compare results from different runs

Filter scenarios and block of time

Sort by hardware component power draw

Graph hardware component power draw
Assessment Toolkit Download

Where to download the ADK
https://docs.microsoft.com/en-us/windows-hardware/get-started/adk-install
Assessment Toolkit Installation

Windows Assessment Toolkit
Windows Performance Toolkit
Media eXperience Analyzer (optional)

Recommend for analyzing ETW logs generated by the Media Quality & Media Energy Efficiency workloads.
Media Quality Assessment

Running the Assessment
Configure the assessment parameters in the Windows Assessment Console (WAC) then run the assessment

Viewing results in WAC
Media Quality audio/video glitch counts in the Windows Assessment Console (WAC)
How to run a Media Quality Assessment

**Step 1**
Launch the Windows Assessment Console, click options, then New Job

**Step 2**
Select “Create a custom job”

**Step 3**
Click “Add assessments”, select the Windows 10 Media Playback Quality assessment then configure parameters and run
Windows Assessment Console (WAC)

GUI that you can use to define and launch assessment jobs and view assessment results
Windows Performance Recorder (WPR)

WPR is based on Event Tracing for Windows. It records system events that you can then analyze using Windows Performance Analyzer.
Visualize Event Tracing for Windows (ETW) events that are recorded by WPR or assessment for analysis.
Task Manager GPU Graphs

Data comes from video memory manager and GPU scheduler in the Graphics Kernel
More accurate than 3rd party utilities
Requires WDDM 2.0 or above

GPU utilization
Video memory
Per-process usage in details tab

POWERCFG

Inbox tool that is run from an elevated CMD prompt

Common switches used for power debugging/analysis

/batteryreport
Generates battery usage information

/energy
Analyzes the system for common energy-efficiency and battery-life problems

/spr
Generates a report of system power transitions over the last three days on the system, including modern standby power efficiency

/srumutil
Enumerates the entire Energy Estimation Engine data from the System Resource Usage Monitor (SRUM)

https://docs.microsoft.com/en-us/windows-hardware/design/device-experiences/powercfg-command-line-options
Performance/Power Slider
Performance & battery balance
Performance/Power slider enables users to choose the right balance between battery-life longevity and system performance.

Updates
We heard your feedback: Slider Read API support shipped in 1809
https://docs.microsoft.com/en-us/windows/desktop/Power/power-management-functions

Behind the scene levers
Lever 1: General Processor Power Management (PPM) tuning & Processor Specific tuning (Example: EPP)
Lever 2: Power throttling background applications (DC power only)
Lever 3: Thermal Management
**Scenario Profiles**
Low-latitude, low-power, constrained – dynamically applied based on workload

**Power Scheme Overlays**
Slider shown when the Balanced Power Scheme is active

**Power Schemes**
Balanced, High Performance, Power Saver, OEM Custom

**Battery Saver**
Lowest power setting

**Better Battery**
Favors power

**Better Perf**
Slightly favors performance

**Best Perf**
Favors Performance
Definitions

PPM: Processor Power Management
EPP: Energy Performance Preference (0% – 100%)
  0% favors performance, 100% favors power

Overview

Inbox PPM settings on all Intel and AMD chipsets
Inbox EPP settings only apply to devices with Intel Speed Shift
Custom OEM firmware can be tuned for each slider position

Resources

Power Settings: https://aka.ms/Config-Power-Settings
Power Slider: https://aka.ms/Perf-Power-Slider
PPM Options: https://aka.ms/PPM-Options
PerfEPP: https://aka.ms/PerfEPP

Inbox EPP Values

<table>
<thead>
<tr>
<th>Slider Position</th>
<th>AC</th>
<th>DC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery Saver</td>
<td>None</td>
<td>EPP 70</td>
</tr>
<tr>
<td>Better Battery</td>
<td>None</td>
<td>EPP 70</td>
</tr>
<tr>
<td>Better Performance</td>
<td>EPP 33</td>
<td>EPP 50</td>
</tr>
<tr>
<td>Best Performance</td>
<td>Modern Standby: EPP 25</td>
<td>S3: EPP 0</td>
</tr>
</tbody>
</table>

Notes:
- EPP values above are subject to change
- Settings which are not explicitly set are inherited from Better Performance (Balanced Plan)
Lever 2: Power Throttling

Overview
Reduces CPU power by up to 11% by slowing down background apps
User configurable only & only applies to DC power
Enabled on all 6th+ gen Intel CPUs with or without Speed Shift
Work in progress to enable on AMD Ryzen mobile CPUs

Application Control
App developers can define power throttling levels using the SetProcessInformation function: https://aka.ms/SetProcInfo

Resources
Blog: https://aka.ms/powerthrottling
Learn more https://aka.ms/Perf-Power-Slider
Lever 2: Power Throttling User Controls

Options for opting out of power throttling

Option #1: Unchecking “Reduce the work the app can do when it’s in the background” will opt the app out of power throttling

Option #2: opt all apps out by moving slider to Best Performance
Lever 3: Thermal Management

Examples of power/perf thermal settings
Thermal Management: Processor limits and other thermal settings
Acoustics: Fan speed (noise) and performance

API’s and customization
Read APIs for the slider: [https://docs.microsoft.com/en-us/windows/desktop/Power/power-management-functions](https://docs.microsoft.com/en-us/windows/desktop/Power/power-management-functions)
Energy Estimation Engine (E3)
# Power Instrumentation Solutions

<table>
<thead>
<tr>
<th></th>
<th>Fully Instrumented Devices</th>
<th>Dev Kit</th>
<th>HW Power Meter IC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost</strong></td>
<td>High ($$$,$$$$)</td>
<td>Medium ($$$)</td>
<td>Low ($)</td>
</tr>
<tr>
<td><strong>Component Flexibility</strong></td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td><strong>E3 Compatibility</strong></td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Scale</strong></td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
</tbody>
</table>

**WinHEC 2018**

**HBI: Microsoft Confidential**

For WinHEC 2018

Shared under NDA

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**Overview**

Inbox service running on all battery powered Windows 10 devices
Attributes energy usage to hardware, apps and services
Battery usage by app leverages E3 data

**Accuracy**

Improve accuracy with optional hardware power meters available from Maxim Integrated and Microchip

<table>
<thead>
<tr>
<th>E3 Configuration</th>
<th>Approximate accuracy per E3 power model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CPU</td>
</tr>
<tr>
<td>Software Estimation *</td>
<td>89% ***</td>
</tr>
<tr>
<td>Hardware Measurement **</td>
<td>&gt;98%</td>
</tr>
</tbody>
</table>

* Actual accuracy of the software estimation code path varies depending on how different the hardware power characteristics are from a device Microsoft used to generate the default inbox power profiles.

** Hardware based power monitoring chips can be included in pre-production and retail devices.

*** This varies from processor to processor, but the 89% value is based on energy data reported by Intel MSRs on recent Intel chipsets.

Note: the accuracy data above is specific to screen-on scenarios.
Power model improvements
Continued improvements in energy attribution accuracy

Enablement docs
Improving hardware power meter enablement documentation

Telemetry
E3 telemetry analysis investments
Viewing E3 Data

Battery Overview in Settings

... and a 4th option referred to as Integrated Power Consumption Measurement tool
Real-time Integrated Power Consumption Measurement with E3

Jacky Zhao
Senior Program Manager
Agenda

Feature Introduction
Solution Implementation
Live Demo
Case Study
Calibration
Call to Action
Issues and Goal

**Issues**
Traditional power instrument are complex and expensive
Limited engineers to access power data

**Goal**
Enable broader ecosystem/engineers to access power measurement
Optimize battery life in whole product development cycle
IPCM Solution Block Diagram

Power Meter and Sense Resistor integrated in target power delivery circuit

Current, Voltage and Energy data from Power Meters
Intel® Whiskey Lake HDK Launched and Available at www.hdkboards.com.
IPCM – Case Study
### Scenario-based Power Measurement

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Modern Standby</th>
<th>System Idle</th>
<th>Local Video playback</th>
<th>Online Video Playback</th>
</tr>
</thead>
</table>
| **Test Setup**    | 1. WiFi connected | 1. Airplane Mode  
2. Brightness: 60%  
3. Audio: no speaker  
4. System idle | 1. WIFI connected  
2. Brightness: 60%  
3. Audio: no speaker  
4. 1080P full screen Local video playback | 1. WIFI connected  
2. Brightness: 60%  
3. Audio: no speaker  
4. Online video stream(Edge) |
| **Power (mW)**    | **280.0** ** | **2577.1** | **3521.8** | **4055.7** |

* Tested on Intel® Whiskey Lake-U HDK with ES2 silicon. ** Need remove debug LED power, before that is 786mW.

Enable customized scenario power measurement
Power Consumption Breakdown

- Panel: 28.99%
- SoC: 24.28%
- Backlight: 8.54%
- Memory: 9.21%
- SSD: 5.65%
- Audio: 1.07%
- WiFi/BT: 0.36%
- EC: 0.52%
- Debug: 0.88%
- Others (include VR loss etc): 20.50%
## Component Scenario Power

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Modern Standby</th>
<th>System Idle</th>
<th>Local Video playback</th>
<th>Online Video Playback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Setup</td>
<td>WiFi connected</td>
<td>Airplane Mode</td>
<td>WIFI connected</td>
<td>WIFI connected</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Brightness: 60%</td>
<td>Brightness: 60%</td>
<td>Brightness: 60%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Audio: no speaker</td>
<td>Audio: no speaker</td>
<td>Audio: no speaker</td>
</tr>
<tr>
<td></td>
<td></td>
<td>System idle</td>
<td>Full screen Local video playback</td>
<td>Full screen online video stream(Edge)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1080p</td>
<td>1080p</td>
</tr>
<tr>
<td>WIFI (mW)</td>
<td>8.3</td>
<td>2.0</td>
<td>12.7</td>
<td>128.5</td>
</tr>
</tbody>
</table>

Real scenario power optimization for component vendor
Improve efficiency of power delivery circuit for OEMs

* Test set-up: Intel Whiskey Lake HDK with ES2 silicon, WiFi module (Intel Wireless-AC 9560), test duration of 10 mins.
Why need Calibration?

Sensor resistor tolerance may be up to 10%
Calibration Solution

Motherboard (power down mode)

- Sensor Resistor
- PCB & Process Resistance
- Power Meter

Calibration Module

- Switch Controller
- Constant Current Source
- MCU

Measurement PC

- Resistor Calibration Tool
- Switch Control Driver

Deployed in manufacturing line
IPCM on Whiskey Lake HDK

28 power rails
Support all power states
Report rate: 10 samples per second (single power rail)
Precision – 3% (Current ≥ 10mA)

IPCM v1.1 available on MS Collaborate
Call to Action

- Evaluate IPCM and understand the value of E3
- New features coming and more platform support
- Integrate IPCM/E3 in development boards
- Include E3 power IC in production devices for higher accuracy power data