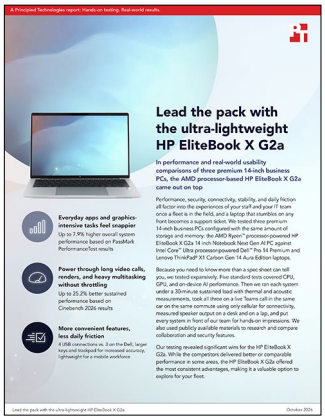


The science behind the report:

Lead the pack with the ultra-lightweight HP EliteBook X G2a

This document describes what we tested, how we tested, and what we found. To learn how these facts translate into real-world benefits, read the report Lead the pack with the ultra-lightweight HP EliteBook X G2a.

We concluded our hands-on testing on September 1, 2026. During testing, we determined the appropriate hardware and software configurations and applied updates as they became available. The results in this report reflect configurations that we finalized on June 16, 2026 or earlier. Unavoidably, these configurations may not represent the latest versions available when this report appears.

Our results

To learn more about how we have calculated the wins in this report, go to https://facts.pt/calculating-and-highlighting-wins. Unless we state otherwise, we have followed the rules and principles we outline in that document.

Table 3: Performance benchmark results. Source: PT.

Benchmark	HP EliteBook X G2a	Dell™ Pro 14 Premium	Lenovo ThinkPad® X1 Carbon Gen 14
PassMark PerformanceTest (higher is better)			
Overall PassMark rating	7,125	6,600	6,754
Cinebench 2026 (higher is better)			
CPU multi-threads score	3,405	2,476	2,621
Geekbench 6 Pro (higher is better)			
CPU multi-core score	14,051	11,583	11,370
CPU single-core score	2,907	2,739	2,726
GPU OpenCL score	26,931	23,586	23,720
Geekbench AI (higher is better)			
CPU full precision score	3,715	3,531	3,539
CPU quantized score	8,537	6,856	6,976
GPU full precision score	7,738	6,707	6,342
GPU quantized score	5,764	4,438	4,368
LM Studio (lower is better)			
Time to first token (seconds)	0.31	0.49	0.44

Table 4: Performance, thermal, and acoustic results under a 30-minute sustained Cinebench 2026 load. Room baseline noise level with all systems idle was 24.1 dBA. Source: PT.

Sustained load	HP EliteBook X G2a	Dell Pro 14 Premium	Lenovo ThinkPad X1 Carbon Gen 14
Cinebench 2026 after 30-minute sustained load (higher is better)			
CPU multi-threads score	2,979	2,519	2,378
Surface temperature under sustained load (lower is better)			
Keyboard deck (°F)	110.8	116.6	105.1
Underside of chassis (°F)	122.4	126.3	124.0
Acoustics under sustained load (lower is better)			
Noise level (dBA)	25.3	33.6	24.2

Table 5: Embedded 5G/WWAN results during a live Microsoft Teams video call, mean of three runs. Source: PT.

Cellular connectivity	HP EliteBook X G2a	Dell Pro 14 Premium	Lenovo ThinkPad X1 Carbon Gen 14
Signal strength (closer to zero is better)			
Stationary, average (dBm)	-80.0	-84.2	-87.5
Stationary, weakest 5% (dBm)	-83.0	-89.7	-104.3
Commute, average (dBm)	-78.4	-82.2	-84.4
Commute, weakest 5% (dBm)	-95.7	-100.3	-105.0
Uplink throughput, median of samples (higher is better)			
Stationary (Mbps)	1.73	0.85	0.77
Commute (Mbps)	1.92	1.05	1.03
Downlink throughput on the commute (higher is better)			
Median (Mbps)	1.97	1.96	1.99
Weakest 5% (Mbps)	0.99	0.97	0.22
Teams audio round-trip time on the commute (lower is better)			
Average round-trip time (ms)	57	60	98

Table 6: Speaker performance results on a desk and on a lap. Source: PT.

Speaker performance	HP EliteBook X G2a	Dell Pro 14 Premium	Lenovo ThinkPad X1 Carbon Gen 14
Volume lost when moving from desk to lap, 50 to 100 percent device volume (closer to zero is better)			
Best case (dB)	-2.8	-3.7	-7.1
Worst case (dB)	-3.6	-5.3	-7.5
Tonal shift between desk and lap (lower is better)			
Frequency response shift (dB)	0.056	0.474	0.373
Loudness on a lap (higher is better)			
50% volume (dB)	80.73	77.52	73.68
60% volume (dB)	82.48	80.47	75.85
70% volume (dB)	83.22	82.45	77.52
Total harmonic distortion on a lap (lower is better)			
50% volume (%)	7.62	17.46	12.36
60% volume (%)	8.70	18.22	10.77
70% volume (%)	10.66	17.61	11.15

Table 7: Battery life efficiency results in minutes per watt-hour (WHr), Balanced power mode. Source: PT.

Battery life	HP EliteBook X G2a	Dell Pro 14 Premium	Lenovo ThinkPad X1 Carbon Gen 14
Battery life efficiency (higher is better)			
UL Procyon Office Productivity Battery Life (min/WHr)	14.0	13.1	16.7
BAPCo MobileMark 30 (min/WHr)	12.6	11.1	15.3

System configuration information

Table 8: Detailed information on the systems we tested.

System	HP EliteBook X G2a Next Gen AI PC	Dell Pro 14 Premium Laptop	Lenovo ThinkPad X1 Carbon Gen 14 Intel Aura Edition
Processor			
Vendor	AMD	Intel®	Intel
Model number	Ryzen™ AI 7 PRO 450	Core™ Ultra 7 365 vPro®	Core Ultra 7 365 vPro
Core frequency (GHz)	2.0 – 5.1	1.8 – 4.8	1.8 – 4.8
Number of cores	8	8 (4 x Performance-cores, 4 x Low Power Efficient-cores)	8 (4 x Performance-cores, 4 x Low Power Efficient-cores)
Number of threads	16	8	8
L2 Cache	8 MB	Not published	Not published
L3 Cache	16 MB	12 MB Intel Smart Cache	12 MB Intel Smart Cache
AI Engine Capabilities NPU TOPS	Up to 50 TOPS	Up to 49 TOPS	Up to 49 TOPS
NPU Driver	AMD 32.0.203.314 (10/10/2025)	Intel 32.0.100.4778 (04/28/2026)	Intel 32.0.100.4778 (04/28/2026)
Memory			
Amount (GB)	32 (onboard)	32 (onboard)	32 (onboard)
Type	LPDDR5x	LPDDR5x	LPDDR5x
Speed (MT/s)	8,533	8,533	8,533
Graphics			
Vendor	AMD	Intel	Intel
Model number	Radeon 860M	Intel Integrated Graphics	Intel Integrated Graphics
Driver	AMD 32.0.22042.18001 (03/11/2026)	Intel 32.0.101.8736 (04/23/2026)	Intel 32.0.101.8724. (04/16/2026)
Storage			
Model	Phison PSEPN512GP87GT	SK Hynix PVC10	Samsung MZVL8512HFLU-00BLL
Amount (GB)	512	512	512
Type	PCIe 4.0 x4, M.2 NVMe SSD	PCIe 4.0 x4, M.2 NVMe SSD	PCIe 4.0 x4, M.2 NVMe SSD
Connectivity/expansion			
WWAN	HP 5G Sub-6 Cat19	Qualcomm Snapdragon X72 5G DW5934e	Qualcomm Snapdragon X12 4G Cat6 Modem
WLAN	MediaTek MT7925 Wi-Fi 7	Intel Wi-Fi 7 BE211	Intel Wi-Fi 7 BE211
Bluetooth	6.0	5.4	5.4
Ports	1 x HDMI 2.1 1 x stereo headphone/microphone combo jack 2 x Thunderbolt™ 4 with USB Type-C® 40 Gbps signaling rate (USB Power Delivery, DisplayPort™ 2.1) 1 x Nano SIM slot 1 x nano security lock slot 1 x USB Type-A 5Gbps signaling rate (powered) 1 x USB Type-C® 10Gbps signaling rate (USB Power Delivery, DisplayPort™ 2.1)	1 x HDMI 2.1 2 x Thunderbolt™ 4 with Power Delivery 3.1 & DisplayPort 2.1 (USB Type-C™) 1 x Nano SIM slot 1 x nano security lock slot 1 x stereo headphone/microphone combo jack 1 x USB 3.2 Gen 1 Type-A	1 x HDMI® 2.1 (supports resolution up to 4K@60Hz) 1 x Headphones / mic combo 3 x USB-C® (Thunderbolt™ 4, USB 40Gbps) 1 x Nano SIM slot 1 x nano security lock slot 1 x USB-A (USB 5Gbps)

System	HP EliteBook X G2a Next Gen AI PC	Dell Pro 14 Premium Laptop	Lenovo ThinkPad X1 Carbon Gen 14 Intel Aura Edition
Video	1 x HDMI 2.1	1 x HDMI 2.1	1 x HDMI 2.1
Battery/AC Adapter			
Type	Lithium-polymer	Lithium-polymer	Lithium-polymer
Rated capacity (Wh)	56	60	58
AC Adapter	HP 100W Wall mount USB Type-C® Halogen Free Foldable GaN adapter	100W USB-C AC Adapter	65W USB-C 90% PCC 2pin AC Adapter
Display			
OEM description	14" diagonal WUXGA WLED+LBL UWVA Anti-Glare with 5MP IR Webcam (1920x1200) (400 Nits)	14", WUXGA (1920 x 1200), Non-Touch,400 nits,AG,45% NTSC, 8 MP + IR MIPI Cam	14" WUXGA (1920 x 1200), IPS, Anti-Glare, Touch, 100%sRGB, 500 nits, 60Hz, Low Power
Size	14"	14"	14"
Resolution	1,920 x 1,200	1,920 x 1,200	1,920 x 1,200
Touchscreen	No	No	Yes
Operating system			
Vendor	Microsoft	Microsoft	Microsoft
Name	Windows 11 Pro	Windows 11 Pro	Windows 11 Pro
Build number or version	25H2 OS Build 26200.8524	25H2 OS Build 26200.8655	25H2 OS Build 26200.8524
BIOS			
BIOS name and version	HP Y88 Ver. 01.01.18 (04/23/2026)	Dell Inc. 1.3.3 (06/16/2026)	Lenovo N4OET47W (1.10) (03/30/2026)
Dimensions			
Height (inches)	0.31 – 0.56	0.66 – 0.78	0.36 – 0.64
Width (inches)	12.31	12.25	12.34
Depth (inches)	8.54	8.53	8.63
Weight (lbs) Notebook only	2.53	3.14	2.50
Weight (lbs) Notebook + Power Adapter	3.04	3.94	3.08

How we tested

Setting up the systems

Setting up and updating the OEM image

1. Boot the system.
2. Follow the on-screen instructions to complete installation, using the default selections when appropriate.
3. Set the Windows (plugged in) Power Mode to Best Performance.
4. Set Screen and Sleep options to Never:
    a. Right-click the desktop, and select Display settings.
    b. From the left column, select System.
    c. Click Power & Battery.
    d. For all power options listed under Screen and Sleep, select Never.
5. Disable User Account Control notifications:
    a. Select Windows Start, type `UAC`, and press Enter.
    b. Move the slider control to Never notify, and click OK.
6. Run Windows Update, and install all updates available.
7. Run the OEM's Support Assistant utility, and install all recommended BIOS and driver updates available.
8. Download and install the latest NPU driver:
    a. For AMD-based systems: https://ryzenai.docs.amd.com/en/latest/inst.html
    b. For Intel-based systems: https://www.intel.com/content/www/us/en/download/794734/intel-npu-driver-windows.html
9. Verify the date and time are correct, and synchronize the system clock with the time server.
10. Pause Automatic Windows Updates:
    a. Click Windows Start.
    b. Type `Windows Update settings`, and press Enter.
    c. From the Pause updates drop-down menu, select Pause for 5 weeks.

Capturing an image

1. Connect an external HDD to the system.
2. Click Windows Start, and type `Control Panel` in the search bar. Click Control Panel → System and Security → Backup and Restore (Windows 7) → Create a system image.
3. Verify that the external HDD is selected as the save drive, and click Next.
4. Verify that all drives are selected to back up, and click Next.
5. Click Start backup.
6. When you see the prompt to create a system repair disc, select No, and close the dialogs.

Restoring an image

1. Connect an external HDD to the system.
2. Press and hold the Shift key while restarting the system.
3. Select Troubleshoot.
4. Select Advanced options.
5. Select See more recovery options.
6. Select System image recovery.
7. Select the User account.
8. Enter the system password, and click Continue.
9. At the Restore system files and settings screen, select Next.
10. Verify that the external HDD is selected, and click Next.
11. Once the recovery has completed, click Finish.

Testing with PassMark PerformanceTest

Setting up the test

1. Install PassMark PerformanceTest:
    a. Download PassMark PerformanceTest from https://www.passmark.com/products/performancetest/download.php.
    b. To begin the installation, click Install.
    c. Select Accept to accept the license agreement, and click Next.
    d. After the installation is complete, deselect Launch Performance Test, and click Finish.

Running the test

1. To launch PassMark PerformanceTest, click the PassMark PerformanceTest icon.
2. To start the benchmark, click Run Benchmark.
3. When the test completes, record the results.
4. Repeat steps 1 through 3 twice more, and report the median result.

Testing with Cinebench 2026

Setting up the test

1. Download and install Cinebench 2026 from https://www.maxon.net/en/downloads/cinebench-downloads.
2. Launch Cinebench 2026.
3. Select File → Advanced benchmark.
4. From the Minimum Test Duration drop-down menu, select Off.

Running the multi-thread test

1. Launch Cinebench 2026.
2. Click Start next to CPU (Multiple Thread).
3. Record the result.
4. Wait 10 minutes before rerunning.
5. Repeat steps 1 through 4 twice more, and report the median result.

Testing with Geekbench 6 Pro

Setting up the test

1. Purchase a Pro license, and download and install Geekbench 6 Pro from https://www.geekbench.com/download/.

Running the CPU test

1. Launch Geekbench.
2. Click Run CPU Benchmark.
3. Record the result.
4. Wait 5 minutes before rerunning.
5. Repeat steps 1 through 4 twice more, and report the median result.

Running the GPU OpenCL test

1. Launch Geekbench.
2. Click Run Compute Benchmark.
3. Record the result.
4. Wait 5 minutes before rerunning.
5. Repeat steps 1 through 4 twice more, and report the median result.

Testing with Geekbench AI

Setting up the test

1. Purchase and download a Geekbench AI Pro license from https://www.geekbench.com/ai/download/.
2. Using all the defaults, run the installer, and install the benchmark.

Running the test

1. Launch Geekbench AI.
2. Enter the license key.
3. For CPU testing, select:
   - AI Framework: ONNX™
   - AI Backend: CPU
   - AI Device: processor
4. For GPU testing, select:
   - AI Framework: ONNX
   - AI Backend: DirectML
   - AI Device: graphics card
5. Click Run AI Benchmark.
6. When the test completes, record the results.
7. Wait 5 minutes before rerunning.
8. Repeat steps 1 through 7 twice more, and report the median result.

Testing with LM Studio

Setting up the test

1. Download LM Studio from https://lmstudio.ai/.
2. Run the installer, and install using all defaults.
3. Launch LM Studio.
4. Click Skip for now.
5. Select Start Local LLM service on login, and click Continue to LM Studio.
6. In the left-hand column, click Model Search.
7. In the Search bar, type `Meta Llama 3 8B Instruct`, and select the lmstudio-community version.
8. Click Download to download the Meta Llama 3 8B Instruct Q4_K_M model.

Running the test

1. Launch LM Studio.
2. Select Load a model, and choose the Meta Llama 3 8B Instruct Q4_K_M model.
3. When the model is fully loaded, in the message field, type `How can AMD Ryzen Processors in HP Elitebooks help enterprise customers deliver better user experience, productivity, performance and ROI?` and click Send.
4. When the test is complete, record the results.
5. Eject the model.
6. Delete the chat messages.
7. Open a new chat by clicking the + icon, and reload the same model.
8. Wait 5 minutes, open a new chat window, and repeat steps 2 through 7 twice more. Report the median time to first token.

Measuring thermals and sustained performance with Cinebench 2026

These tests require the following:

- A FLIR E6-XT infrared camera
- Cinebench 2026

Setting up the test

1. Download and install Cinebench 2026 from https://www.maxon.net/en/downloads/cinebench-downloads.
2. Set the Windows (plugged in) Power Mode to Balanced.
3. Launch Cinebench 2026.
4. Select File → Advanced benchmark.
5. Select File → Preferences, change the Custom Minimum Test Duration to 30 minutes, and click OK.
6. Exit Cinebench, and shut down the system.

Running the test

1. Start the thermal recorder.
2. Boot the system, and leave the system plugged in.
3. Launch Cinebench 2026.
4. Select File → Advanced benchmark.
5. Verify that the Custom Minimum Test Duration is set to 30 minutes.
6. Select CPU (Multi Thread), and click Start.
7. After 30 minutes, record the performance result and skin temperatures. Note the ambient room temperature, and use the FLIR E6-XT infrared camera to take a skin temperature photo of the keyboard deck and the underside of the chassis.
8. Repeat steps 1 through 7 twice more.

We report the median sustained Cinebench 2026 score, along with the ambient and skin temperatures we captured during that same run.

Measuring system acoustics during a Cinebench 2026 run

These tests require the following items:

- Extech SDL600 Sound Level Meter/Datalogger with SD card
- Cinebench 2026

Setting up the test

1. Place the system under test in a sound-proofed professional sound booth.
2. Set the Extech SDL600 on a tripod so that it is 2 feet in front of, and 1 foot above, the bottom of the system under test.
3. Download and install Cinebench 2026 from https://www.maxon.net/en/downloads/cinebench-downloads.
4. Set the Windows (plugged in) Power Mode to Balanced.
5. Launch Cinebench 2026.
6. Select File → Advanced benchmark.
7. Select File → Preferences, change the Custom Minimum Test Duration to 30 minutes, and click OK.
8. Exit Cinebench, and shut down the system.

Running the test

1. Boot the system.
2. Launch Cinebench 2026.
3. In the Minimum Test Duration field, select Custom (30 minutes).
4. Start the Extech SDL600 Sound Level Meter/Datalogger.
5. Click the Cinebench 2026 CPU (Multi Thread) Start button.
6. At the end of the 30-minute Cinebench 2026 run, stop the Extech SDL600, and record the average sound level (dBA) while running Cinebench 2026.
7. Shut down the system for 60 minutes, and let it return to room temperature.
8. Repeat steps 1 through 7 twice more, and report the median result.

Measuring embedded 5G/WWAN performance under a Microsoft Teams video-call workload

We compared the embedded 5G/WWAN subsystems in three commercial laptops under a live Microsoft Teams video-call workload. We tested all three systems simultaneously, in the same vehicle with the same system placement, on the same route, and at the same time, so that every system experienced identical conditions. We tested on 08/19/2026 between 9:00 AM and 5:00 PM ET in the Research Triangle Park and RDU area, using two scenarios (Multi-Location stationary and Commute mobility) and performing three runs per scenario.

We tested the following systems:

- HP EliteBook X G2a 14 inch AI PC with an HP 5G Sub-6 Cat 19 modem
- Dell Pro 14 Premium PA14260 with a Qualcomm Snapdragon X72 5G DW5934e modem
- Lenovo ThinkPad X1 Carbon Gen 14 Aura Edition with a Qualcomm Snapdragon X12, 4G LTE Cat 6 modem

All three systems used T-Mobile 5G Unlimited service. We disabled Wi-Fi on all systems for all runs, so cellular was the sole internet path.

Setting up the systems

1. Place all three systems under test in the same vehicle, using the same system placement for every run.
2. On each system, verify that T-Mobile 5G Unlimited service is active.
3. On each system, disable Wi-Fi, and confirm that cellular is the sole internet path.
4. On each system, close all applications other than OEM-installed software and the test tooling.

Scenario 1: Multi-Location (stationary)

In this scenario, we logged continuously while moving between three stationary locations near active office buildings during office hours, and we remained at each location for approximately 5 minutes.

1. On each system, launch the PowerShell network logging script, and confirm that it is sampling. The script samples approximately every 2 seconds and records cellular state and signal strength (Signal % and RSSI in dBm) via `netsh mbn`, Wi-Fi state via `netsh wlan`, Rx/Tx throughput from adapter byte-counter deltas via `Get-NetAdapterStatistics`, the active internet interface from the default route, and a location tag set by keypress.
2. Join all three systems to a single three-way Microsoft Teams video meeting, with cameras on and microphones unmuted on every system. Keep the meeting active for the remainder of the run.
3. Set the location tag to 0 (transit) by keypress, and move to Location 1, approximately 50 feet from an active office building.
4. Set the location tag to 1 by keypress, and remain at Location 1 for approximately 5 minutes.
5. Set the location tag to 0 (transit) by keypress, and move to Location 2, approximately 100 feet from an active office building.
6. Set the location tag to 2 by keypress, and remain at Location 2 for approximately 5 minutes.
7. Set the location tag to 0 (transit) by keypress, and move to Location 3, approximately 10 feet from an active office building.
8. Set the location tag to 3 by keypress, and remain at Location 3 for approximately 5 minutes.
9. End the Teams meeting, and stop the logging script on each system.
10. In the Teams admin center, export the per-participant session details for each system by navigating to Users → Manage Users, selecting the participant, and selecting the meeting.
11. Repeat steps 1 through 10 two more times, for a total of three runs.

Scenario 2: Commute (mobility)

In this scenario, we logged continuously over a driven route that simulated working during a bus commute.

1. On each system, launch the PowerShell network logging script, and confirm that it is sampling.
2. Join all three systems to a single three-way Microsoft Teams video meeting, with cameras on and microphones unmuted on every system. Keep the meeting active for the remainder of the run.
3. Drive from the office to the GoRaleigh Regional Transit Center.
4. To simulate a bus transfer, wait at the GoRaleigh Regional Transit Center for 5 minutes.
5. Drive from the GoRaleigh Regional Transit Center to RDU airport.
6. Drive from RDU airport back to the GoRaleigh Regional Transit Center.
7. To simulate a bus transfer, wait at the GoRaleigh Regional Transit Center for 5 minutes.
8. Drive from the GoRaleigh Regional Transit Center back to the office.
9. End the Teams meeting, and stop the logging script on each system.
10. In the Teams admin center, export the per-participant session details for each system by navigating to Users → Manage Users, selecting the participant, and selecting the meeting.
11. Repeat steps 1 through 10 two more times, for a total of three runs.

Calculating the results

We calculated the results we report as follows:

- For each run, we calculated the mean, median, and 5th percentile (the weakest 5 percent of samples) of each system's signal strength (RSSI, in dBm), downlink (Rx) throughput, and uplink (Tx) throughput.
- We report the mean of the three runs for each metric.
- Multi-Location results include the samples we logged in transit between locations (location tag 0).
- Downlink availability is the percentage of samples at or above 200 kbps, the minimum downlink that Microsoft documents for Teams meeting video (https://learn.microsoft.com/en-us/microsoftteams/prepare-network).
- We took Teams audio round-trip time from the per-participant session details in the Teams admin center.

Measuring speaker frequency response and total harmonic distortion (THD)

Generating the sine sweep

1. In Room EQ Wizard (REW), in the top icon bar, select Generator.
2. In the new pop-up window, select the Sweeps tab.
3. Select the Measurement tab.
4. Ensure Start freq. is set to 20 Hz and End freq. is set to 20,000 Hz.
5. Set the Length to 1M.
6. Set the dBFS amount to -2.00 dBFS to optimize the signal-to-noise ratio.
7. At the bottom, under the Save to file tab, ensure the sample rate is set to 48 kHz and the bit depth is 32-bit float.
8. To open the save window, select WAV. Name and save the file to an easily accessible location for later use. For the purposes of this methodology, we refer to this file as Sine Sweep x1.
9. Open the sweep file in Pro Tools (or DAW of choice), and ensure the session's sample rate is set to 48 kHz and the bit depth is 32-bit float.
10. Drag the file down the timeline so there are 30 seconds of silence before the sweep begins.
11. Duplicate the sweep file twice on the same track so there are three copies of the sweep.
12. Space the sweeps so there are 10 seconds of silence between each sweep.
13. Export the full timeline, including the 30 seconds of silence and the three sweeps (the total file length should be approximately 2 minutes). For the purposes of this methodology, we refer to this file as Sine Sweep x3. Ensure that the export sample rate and bit depth match the session settings (48 kHz, 32-bit float).

Setting up and calibrating the recorder system

1. Load the Sine Sweep x3 file onto the system under test (SUT).
2. Open the Sine Sweep x3 file using Windows Media Player, and ensure the application's volume is set to 100%.
3. Set the speaker volume on the SUT to 100%.
4. On a separate system connected to an audio interface and measurement microphone (the recorder system), calibrate the sound card using REW's calibration process, and load the resulting calibration file into the Soundcard calibration box in REW Preferences.
5. In Preferences, under Cal files, load the measurement microphone's calibration file (provided by the microphone manufacturer).
6. Place the SUT on a table in an enclosed sound booth, and connect it to AC power.
7. To simulate the distance and placement of a user's head, place the measurement microphone 3 feet from the SUT.
8. Measure the exact distance between the measurement microphone and the center of the device lid. Save this measurement for a later step.
9. Play the Sine Sweep x3 file on the SUT, and adjust the microphone input gain on the recorder system's audio interface so that it is high enough for a good signal-to-noise ratio but never clips (we used 80% input gain). Keep this gain setting fixed for the remainder of the test session across all devices and SUT volume steps.
10. Connect a speaker to the recorder system's audio interface output, and place it in the same enclosed sound booth.
11. Place an SPL meter directly next to the measurement microphone.
12. Using REW's tone generator, play a steady 1 kHz reference tone from the speaker, and note the SPL meter's reading of that tone.
13. In REW, select Preferences → Soundcard tab → gear icon next to the microphone's Cal entry. In the Calibration data pop-up, enter the SPL level shown on the SPL meter into REW's calibration field.
14. On the recorder system, create a new Pro Tools (or DAW of choice) session to record the playback sweeps, and ensure the session's sample rate is set to 48 kHz and the bit depth is 32-bit float.
15. Create a new track with the input set to the input channel of the measurement microphone.

Testing the systems

1. Set the speaker volume on the SUT to 50%.
2. Play the Sine Sweep x3 file on the SUT, and exit the booth during the 30 seconds of silence before the sweeps begin.
3. During the 30 seconds of silence, click Record in Pro Tools on the recorder system, and record all three sweeps.
4. Edit the recording to remove the silence before and between the three sweeps, so that each sweep file starts right before the preamble and ends right after the postamble.
5. Repeat steps 1 through 4 at the following SUT speaker volumes: 60%, 70%, 80%, 90%, and 100%.
6. Repeat steps 1 through 5 for all three SUTs. Place all devices in the same location on the table, and ensure their lids are open at the same angle for all measurements.
7. Build the surrogate lap environment using two foam rollers and microphone stands with stereo bars to hold up each end of the rollers. Adjust the height to mirror that of the desk, and use the distance measurement from step 8 of Setting up and calibrating the recorder system to determine the SUT placement on the rollers. Use this placement for all SUTs.
8. Repeat steps 1 through 5 for all three SUTs in the lap environment.
9. Export all three sweep recording files, and label each one by SUT, volume percentage, and desk or lap environment (e.g., Device1 Sweep1 50 desk). Ensure that the export sample rate and bit depth match the session settings (48 kHz, 32-bit float).

Importing the sweep recordings into REW and exporting the data

1. In REW, select File → Import → Import sweep recordings.
2. Under Stimulus, click the folder icon, and import the Sine Sweep x1 file.
3. Under Response, click the folder icon, and import the first sweep recording file.
4. Check the Apply cal files checkbox.
5. The sweep recording now appears in the file list on the left side of REW. To save the measurement as an MDAT file for future reference, click the floppy disk and pencil icon.
6. Repeat steps 1 through 5 for each of the three sweep recordings within a single volume, environment, and device combination (e.g., Sweep1, 50% volume, desk, Device 1).
7. At the bottom-left corner of the graph display, click Average the responses. This creates a new file in the file list on the left side of REW. Rename this file as the average for this device and configuration.
8. Under Graph in the REW toolbar, select 1/3 smoothing to match the technical measurement standard and align most closely with how the human ear perceives sound.
9. To save each average as an MDAT file for future reference, click the floppy disk and pencil icon.
10. To export the frequency response and SPL data, select File → Export → Export measurement as text.
11. To export the distortion data, select File → Export → Export distortion data as text. When exporting, check Set end frequency for the highest harmonic.
12. Repeat steps 1 through 11 for each configuration of each SUT, for a total of 36 sets of average MDAT files, average frequency response data files, and average distortion data files.

Calculating the results

We calculated the results we report from the exported average data as follows:

- **Loudness:** We energy-averaged each SPL response from 20 Hz to 20 kHz (10 × log10 of the mean of 10^(dB/10)). Volume lost on the lap is the lap SPL minus the desk SPL at each volume step. We report the smallest and largest loss across the 50 to 100 percent volume steps.
- **Distortion:** We took the arithmetic mean of THD from 20 Hz to 9,750 Hz. We excluded fundamentals above 9,750 Hz because their harmonics fall outside the 20 kHz sweep bandwidth and cannot be measured validly.
- **Tonal shift:** For each environment, we subtracted the 50 percent volume frequency response from the 100 percent volume frequency response and calculated the standard deviation of that difference from 20 Hz to 20 kHz. Tonal shift between desk and lap is the absolute difference between the desk and lap values.

Measuring battery life with the Procyon Office Productivity Battery Life Benchmark

Setting up the test

1. Boot the system.
2. Verify the following display and power settings:
    a. Right-click the desktop, and select Display settings.
    b. Uncheck the box next to Change brightness automatically when lighting changes, if available.
    c. Uncheck the box next to Change brightness based on content, if available.
    d. In the Scale drop-down menu, select 100%.
    e. From the pane on the left, select System.
    f. Click Power & Battery.
    g. For all power options listed under Screen and Sleep, select Never.
    h. Set Power mode while unplugged to Balanced.
    i. Under Energy Saver, disable Lower screen brightness when using energy saver.
3. Download and install Procyon.
4. Open Procyon.
5. Click Battery Life Office Productivity Benchmark.
6. Click Register.
7. Enter the license key, and click Register.
8. Click Calibrate.
9. Click Start.
10. Using a nit meter, adjust the screen brightness to as close to 200 nits as possible, and click Next.
11. Fill out the information, and click Save calibration.
12. Close Procyon.
13. Before running the benchmark, install a licensed version of Microsoft 365; open the Word, Excel, PowerPoint, and Outlook applications; and disable tips when possible.

Running the test

1. Boot the system.
2. Ensure the system is fully charged.
3. Launch Procyon.
4. Select the Procyon Battery Life option.
5. Under the Office Productivity tab, click Run.
6. When prompted, unplug the system.
7. When the benchmark completes, plug in and power up the system.
8. Record the results.
9. Repeat steps 2 through 8 twice more, and report the median result.

Measuring battery life with MobileMark 30

This test requires an X-Rite - i1Display Plus colorimeter. We performed this test in Balanced mode.

Avoiding antivirus software conflicts

MobileMark 30 is not compatible with any virus-scanning software, so we uninstalled any such software present on the PCs before we installed the benchmark.

Avoiding pre-installed software conflicts

MobileMark 30 installs the following applications, which its test scripts employ:

Productivity

- Corel WinZip 26.0 Enterprise
- Microsoft Excel 2021 Professional Plus
- Microsoft Outlook 2021 Professional Plus
- Microsoft PowerPoint 2021 Professional Plus
- Microsoft Word 2021 Professional Plus

Creativity

- Adobe® Photoshop® CC

If any of these applications already exist on the system under test, they could cause problems with the benchmark due to software conflicts. To avoid any such issues, we uninstalled all conflicting pre-installed software applications—including different versions of any of the programs MobileMark 30 uses—before we installed the benchmark.

Using the MobileMark built-in configuration tool

This tool supports three levels of configuration:

1. Only makes changes that are REQUIRED for the benchmark to run.
2. Additionally, makes changes that are RECOMMENDED for repeatable results.
3. Additionally, makes OPTIONAL changes that help ensure best results.

The configuration tool makes the following configuration changes at each of the three levels:

Level 1 - Required

- Disables User Account Control (UAC)
- Set DPI Scaling to 100%
- Disables Low Battery Actions
- Disables Network Proxies
- Disables System Sleep and Hibernate
- Disables Windows Update
- Enables Windows Search
- Disables WinSAT

Level 2 - Recommended

- Creates BAPCo power scheme
- Sets Power Plan Type to Balanced
- Sets CPU Adaptive Mode
- Disables Battery Saver Dimming
- Verifies Battery Saver Threshold
- Disables Disk Defrag
- Disables Windows Error Reporting
- Disables Windows Lock Screen
- Disables Screen Saver and Monitor Timeout
- Sets Font Smoothing

Level 3 - Optional

- Disables Battery Saver
- Disables Hard Disk Timeout
- Disables System Restore
- Ignores Laptop Lid Close
- Enables Dark Mode

We chose the official BAPCo "Run Benchmark" default as outlined in the BAPCo MobileMark 30 User Guide (https://bapco.com/wp-content/uploads/2024/04/BAPCo-MobileMark30_User-Guide-v1.0.pdf), which runs the benchmark using the Required and Recommended options.

Setting up the performance-qualified battery life test

1. On a separate PC, install the i1Profiler software from https://www.xrite.com/categories/formulation-and-quality-assurance-software/i1profiler, and connect the X-Rite - i1Display Plus colorimeter to that PC.
2. On the system under test, verify that the volume is set to 50%.
3. Verify the display is no less than 250 nits.
4. On the system under test, install MobileMark 30 with the default options.

Running the performance-qualified battery life test

1. Boot the system.
2. Launch MobileMark 30.
3. Click Run Benchmark.
4. Click Brightness Profiler.
5. Allow the white screen to warm up for 30 minutes. After 30 minutes, click Skip.
6. At the Panel Dark Luminance pop-up, to use the value that is queried from the display, select Yes.
7. Place the X-Rite - i1Display Plus colorimeter in the outlined spot on the screen.
8. On the test PC, to turn off the test overlay, press F1.
9. On the colorimeter PC, start the i1Profiler program, and select Advanced.
10. Click Display, and click Profiling.
11. Next to Luminance, click the drop-down menu, and select Measure.
12. In the drop-down menu that appears below, select Paper in booth.
13. In the box with the image that says Place your paper in the light booth, scroll down, and click Measure.
14. On the test PC, adjust the slider until the Target White luminance is met on the colorimeter PC.
15. Once the correct Target White luminance is met on the test PC, click Done.
16. The test will begin immediately. When prompted, unplug the AC power adapter.

The benchmark is complete when the PC has fully depleted its battery and is no longer operational when running on battery power.

We executed the MobileMark 30 benchmark three times on each system and took the median battery life score run as the representative performance score result for that test.

Calculating battery life efficiency

Because the systems have different battery capacities, we divided each system's median battery life in minutes from the Procyon Office Productivity Battery Life Benchmark and from MobileMark 30 by its rated battery capacity in watt-hours (WHr). We report the result as minutes per WHr.

This project was commissioned by HP

Read the report ▶

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How we created this report

A PT team, which includes the contributors we've listed and others, created this report and performed the technical work behind it. In addition to our use of some AI tools in testing, we used AI to analyze acoustic data and help generate and edit portions of the report.

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