



The science behind the report:

Improve your day-to-day experience with Windows 11 Pro laptops

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 [Improve your day-to-day experience with Windows 11 Pro laptops](#).

We concluded our hands-on testing on January 26, 2023. 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 October 24, 2022 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 <http://facts.pt/calculating-and-highlighting-wins>. Unless we state otherwise, we have followed the rules and principles we outline in that document.

Benchmark results

Table 1: Results of our benchmark testing. We conducted three runs of each test on multiple identical systems. In cases where we had three identical systems, we report the median score and Redshift time. In cases where we had two identical systems, we report the max score and, for Redshift, minimum time. See the System configuration information section for details on the identical systems we tested. Higher is better unless otherwise noted.

Results	HP ProBook 450 G8	HP ProBook 450 G6	HP EliteBook 850 G8	HP EliteBook 850 G5	Lenovo® ThinkPad® X1 Yoga G6	Lenovo ThinkPad X1 Yoga G3	Lenovo ThinkPad T14	Lenovo ThinkPad T480
PCMark 10 scores								
Overall rating	4,187	2,677	4,108	2,726	4,523	2,677	4,674	2,871
Essentials	8,966	7,875	9,494	8,491	10,185	8,536	10,381	8,227
Productivity	6,082	6,103	6,359	5,864	6,360	5,341	8,962	6,741
Digital content creation	4,920	3,106	4,976	3,116	5,074	3,106	5,495	3,275
Gaming	3,095	931	2,562	962	3,441	981	2,524	1,012

Results	HP ProBook 450 G8	HP ProBook 450 G6	HP EliteBook 850 G8	HP EliteBook 850 G5	Lenovo® ThinkPad® X1 Yoga G6	Lenovo ThinkPad X1 Yoga G3	Lenovo ThinkPad T14	Lenovo ThinkPad T480
PCMark 10 applications test scores								
Overall rating	10,470	8,815	9,903	8,686	10,554	7,854	11,279	9,083
Word	5,367	5,607	5,532	4,767	5,179	4,388	5,897	5,024
Excel	17,508	13,273	16,106	14,527	17,032	13,121	18,825	14,218
PowerPoint	11,896	8,927	10,181	9,062	13,103	7,712	13,060	10,397
Edge	10,752	9,090	10,603	9,074	10,735	8,572	11,163	9,167
SYSmark® 2018 scores								
Overall rating	1,509	1,287	1,452	1,222	1,530	1,249	1,603	1,400
Productivity	1,361	1,156	1,302	1,089	1,350	1,085	1,457	1,234
Creativity	1,743	1,451	1,680	1,409	2,013	1,487	1,935	1,624
Responsiveness	1,447	1,270	1,399	1,188	1,319	1,207	1,461	1,368
SYSmark 25 unplugged scores								
Overall rating	1,160	690	1,153	1,016	1,172	837	1,142	1,079
Productivity	1,195	721	1,229	1,058	1,197	866	1,197	1,141
Creativity	1,191	662	1,148	986	1,236	826	1,131	1,035
Responsiveness	926	687	961	983	940	784	1,020	1,039
SYSmark 25 scores								
Overall rating	1,242	1,040	1,194	1,064	1,187	970	1,253	1,096
Productivity	1,250	1,084	1,232	1,061	1,198	986	1,304	1,134
Creativity	1,331	1,021	1,234	1,075	1,266	962	1,291	1,075
Responsiveness	992	976	982	1,043	949	949	1,012	1,046
SYSmark 25 with VBS enabled scores								
Overall rating	1,242	1,003	1,122	1,064	1,191	935	1,233	1,025
Productivity	1,260	1,027	1,133	1,068	1,207	937	1,260	1,051
Creativity	1,322	1,003	1,186	1,068	1,272	940	1,277	1,010
Responsiveness	988	937	920	1,042	940	914	1,043	994
3DMark® overall ratings								
Fire Strike	3,612	1,085	2,987	1,184	4,082	1,179	3,003	1,221
Time Spy	1,400	458	1,251	474	1,491	481	1,290	495
Cinebench R23 scores								
Multi-core	4,005	3,280	4,271	2,991	5,276	3,384	6,184	3,584
Single-core	1,357	1,029	1,321	957	1,366	892	1,560	1,051

Results	HP ProBook 450 G8	HP ProBook 450 G6	HP EliteBook 850 G8	HP EliteBook 850 G5	Lenovo® ThinkPad® X1 Yoga G6	Lenovo ThinkPad X1 Yoga G3	Lenovo ThinkPad T14	Lenovo ThinkPad T480
Blender Benchmark average samples per minute								
Monster workload	35.63	27.19	34.33	26.84	39.72	29.63	45.01	29.92
Junkshop workload	18.89	15.43	18.11	15.26	19.89	13.18	25.52	17.34
Classroom workload	13.63	10.79	13.51	10.89	17.29	11.63	18.90	12.52
Maxon Redshift 3D Renderer (lower is better)								
Time (hh:mm)	5:40	6:28	5:43	6:50	N/A**	N/A**	4:39	5:44
WebXPRT 4 scores on Edge (Chromium)								
Overall score	193	153	188	149	193	136	221	164
Subscores (milliseconds, lower is better)								
Photo enhancement	395	495	410	520	396	578	351	400
Organize album using AI	2,001	2,442	2,002	2,570	2,004	2,771	1,744	2,257
Stock option pricing	129	164	135	170	131	183	113	165
Encrypt notes and OCR scan	956	1,311	996	1,326	968	1,460	848	1,173
Sales graph	289	372	296	385	288	421	255	359
Online homework	2,636	3,092	2,726	3,102	2,573	3,408	2,276	3,168
Procyon® Office Productivity Benchmark scores								
Overall rating	5,539	4,168	4,865	4,611	5,300	3,950	5,557	4,615
Word	6,594	4,472	5,289	4,680	5,621	4,308	5,932	5,551
Excel	4,910	3,980	4,690	4,277	5,001	3,772	5,366	4,342
PowerPoint	5,948	4,220	5,431	5,175	5,965	4,253	5,673	4,636
Outlook	4,317	3,875	3,557	4,136	4,183	3,144	5,021	3,572
Procyon Photo Editing Benchmark scores using Adobe Photoshop and Lightroom Classic								
Overall rating	4,888	3,512	4,568	3,608	4,842	3,390	5,170	4,018
Image retouching	5,407	3,988	4,981	4,108	4,968	3,591	5,252	4,529
Batch processing	4,419	3,094	4,190	3,169	4,720	3,202	5,090	3,565
Procyon Video Editing Benchmark scores using Adobe Premiere Pro								
Overall rating	1,669	964	1,319	1,025	2,010	1,053	1,232	1,173

*These Lenovo X1 Yoga PCs did not meet the Maxon Redshift benchmark system requirements.

Thermal testing results

Table 2: Results of our thermal testing. We conducted three runs of each test on multiple identical systems. In cases where we had three identical systems, we report the median temperature. In cases where we had two identical systems, we report the minimum temperatures. See the System configuration information section for details on the identical systems we tested. Lower is better.

Results	HP ProBook 450 G8	HP ProBook 450 G6	HP EliteBook 850 G8	HP EliteBook 850 G5	Lenovo ThinkPad X1 Yoga G6	Lenovo ThinkPad X1 Yoga G3	Lenovo ThinkPad T14	Lenovo ThinkPad T480
Hottest top surface point								
Temperature (°F)	57.0	55.0	61.8	65.3	66.0	79.3	71.7	74.8
Temperature (°C)	13.9	12.8	16.6	18.5	18.9	26.3	22.1	23.8
Hottest bottom surface point								
Temperature (°F)	80.0	74.4	71.4	74.3	67.2	95.9	97.8	95.5
Temperature (°C)	26.7	23.6	21.9	23.5	19.6	35.5	36.6	35.3

Battery life testing results

Table 3: Results of our battery life testing. We conducted three runs of each test on multiple identical systems.* In cases where we had three identical systems, we report the median time. In cases where we had two identical systems, we report the max time. See the System configuration information section for details on the identical systems we tested. Higher is better.

Results	HP ProBook 450 G8	HP ProBook 450 G6	HP EliteBook 850 G8	HP EliteBook 850 G5	Lenovo ThinkPad X1 Yoga G6	Lenovo ThinkPad X1 Yoga G3	Lenovo ThinkPad T14	Lenovo ThinkPad T480
Battery life (hh:mm)								
Local video playback	10:39:33	8:37:20	11:56:09	6:57:20	12:58:49	9:39:07	8:45:08	5:29:06
Streaming video	6:40:11	6:29:54	7:33:39	4:00:13	8:03:58	6:38:26	5:52:55	3:56:09
Zoom conference call	3:49:18	3:53:18	3:09:17	2:18:50	3:52:14	3:13:13	2:14:55	1:47:22
Web browsing	9:53:37	7:19:16	9:54:13	4:54:33	14:30:47	8:11:14	7:06:58	5:17:16
PCMark 10 battery life	8:54:00	6:07:00	9:12:00	4:27:00	15:49:00	8:30:00	6:30:00	4:02:00

*The HP ProBook 450 G6 Streaming video, Zoom conference call, and PCMark 10 battery life times are the median results from three runs on a single system because the second system's battery failed during testing.

System configuration information

HP ProBook 450 laptop information

Table 4: Detailed information on the three identical HP ProBook 450 G8 and two identical HP ProBook 450 G6 systems we tested.

Information	HP ProBook 450 G8 x3	HP ProBook 450 G6 x2
Processor		
Vendor	Intel®	Intel
Model number	Core™ i5-1135G7	Core i5-8265U
Core frequency (GHz)	2.40–4.20	1.60–3.90
Number of cores	4	4
Intel Smart Cache (MB)	8	6
Memory		
Amount (GB)	16 (built-in onboard)	16 (built-in onboard)
Type	DDR4L	DDR3L
Speed (MHz)	3,200	2,400
Graphics		
Vendor	Intel	Intel
Model number	Iris® Xe Graphics	UHD Graphics 620
Storage		
Vendor	Samsung	Intel
Model Number	MZVLQ256HAJD	SSDSCKKF256G8H
Amount (GB)	256	256
SSD type	M.2	M.2
Connectivity/expansion		
Wireless internet	Intel Wireless-AC 9560	Intel Wireless-AC 9560
Bluetooth	5.2	5.1
USB	3 x 3.1 1 x USB-C	3 x 3.1 1 x USB-C
Video	1 x HDMI	1 x HDMI
Battery		
Type	Lithium-polymer	Lithium-polymer
Size	Integrated	Integrated
Rated capacity (Whr)	45	45

Information	HP ProBook 450 G8 x3	HP ProBook 450 G6 x2
Display		
Size (in.)	14	14
Type	LED-backlit	LED-backlit
Resolution	1,920 x 1,080	1,920 x 1,080
Touchscreen	No	No
Operating system		
Vendor	Microsoft	Microsoft
Name	Windows 11 Pro	Windows 10 Pro
Build number or version	10.0.22621	10.0.19045
BIOS		
BIOS name and version	HP T88 Ver. 01.11.00	HP R71 Ver. 01.20.00
Dimensions		
Height (in.)	0.78	0.75
Width (in.)	14.15	14.37
Depth (in.)	9.20	10.11
Weight (lbs.)	3.84	4.41

HP EliteBook 850 laptop information

Table 5: Detailed information on the three identical HP ProBook 850 G8 and two identical HP ProBook 850 G5 systems we tested.

Information	HP EliteBook 850 G8 x3	HP EliteBook 850 G5 x2
Processor		
Vendor	Intel	Intel
Model number	Core i5-1135G7	Core i5-8350U
Core frequency (GHz)	2.40	1.70
Number of cores	4	4
Intel Smart Cache (MB)	8	6
Memory		
Amount (GB)	16 (built-in onboard)	16 (built-in onboard)
Type	DDR4L	DDR3
Speed (MHz)	3,200	2,133
Graphics		
Vendor	Intel	Intel
Model number	Iris Xe Graphics	UHD Graphics 620

Information	HP EliteBook 850 G8 x3	HP EliteBook 850 G5 x2
Storage		
Vendor	Kioxia	Samsung
Model Number	KXG60ZNV256G	MZVLB512HAJQ
Amount (GB)	256	512
SSD type	M.2	M.2
Connectivity/expansion		
Wireless internet	802.11ax	802.11ac
Bluetooth	4.0	4.0
USB	2 x USB-A 3.1 2 x USB-C	2 x USB-A 3.1 1 x USB-C
Video	1 x HDMI	1 x HDMI
Battery		
Type	Lithium-polymer	Lithium-polymer
Size	Integrated	Integrated
Rated capacity (Whr)	56	56
Display		
Size (in.)	14	14
Type	LED-backlit with IPS technology	LED-backlit with IPS technology
Resolution	1,920 x 1,200	1,920 x 1,080
Touchscreen	No	No
Operating system		
Vendor	Microsoft	Microsoft
Name	Windows 11 Pro	Windows 10 Pro
Build number or version	10.0.22621	10.0.19045
BIOS		
BIOS name and version	HP T76 Ver. 01.11.00	HP Q78 ver. 01.22.00
Dimensions		
Height (in.)	0.75	0.73
Width (in.)	14.15	14.60
Depth (in.)	9.2	9.91
Weight (lbs)	3.84	4.25

Lenovo ThinkPad X1 Yoga laptop information

Table 6: Detailed information on the two identical Lenovo ThinkPad X1 Yoga G6 and G3 systems we tested.

Information	Lenovo ThinkPad X1 Yoga G6 x2	Lenovo ThinkPad X1 Yoga G3 x2
Processor		
Vendor	Intel	Intel
Model number	Core i5 1135G7	Core i5 8250U
Core frequency (GHz)	2.4	1.6
Number of cores	4	4
Cache	8MB L3	6MB L3
Memory		
Amount (GB)	8 (built-in onboard)	8 (built-in onboard)
Type	DDR4L	DDR3L
Speed (MHz)	4,266	2,133
Graphics		
Vendor	Intel	Intel
Model number	Iris Xe Graphics	UHD Graphics 620
Storage		
Vendor	Hynix	Intel
Model Number	HFS256GDE9X081N	SSDPEKKF256G8L
Amount (GB)	256	256
SSD type	M.2	M.2
Connectivity/expansion		
Wireless internet	802.11ax	802.11ac
Bluetooth	4.0	4.0
USB	2 x USB 3.2 2 x Thunderbolt 4	2 x USB-A 3.1 2 x USB-C
Video	1 x HDMI	1 x HDMI
Battery		
Type	Lithium-polymer	Lithium-polymer
Size	Integrated	Integrated
Rated capacity (Wh)r	57	54
Display		
Size (in.)	14	14
Type	LED-backlit with IPS technology	LED-backlit with IPS technology
Resolution	1,920 x 1,200	1,920 x 1,080
Touchscreen	No	No

Information	Lenovo ThinkPad X1 Yoga G6 x2	Lenovo ThinkPad X1 Yoga G3 x2
Operating system		
Vendor	Microsoft	Microsoft
Name	Windows 11 Pro	Windows 10 Pro
Build number or version	10.0.22621	10.0.19045
BIOS		
BIOS name and version	Lenovo N32ET80W (1.56)	Lenovo N25ET62W (1.48)
Dimensions		
Height (in.)	0.59	0.67
Width (in.)	12.32	13.11
Depth (in.)	8.77	9.02
Weight (lbs.)	3.00	3.08

Lenovo ThinkPad T-series laptop information

Table 7: Detailed information on the two identical Lenovo ThinkPad T14 and Lenovo ThinkPad T480 systems we tested.

Information	Lenovo ThinkPad T14 x2	Lenovo ThinkPad T480 x2
Processor		
Vendor	Intel	Intel
Model number	Core i7-1185G7	Core i7-8650U
Core frequency (GHz)	3.00	1.90
Number of cores	4	4
Cache (MB)	8 L3	8 Intel Smart Cache
Memory		
Amount (GB)	16	16
Type	DDR4	DDR4
Speed (MHz)	4,266	2,133
Graphics		
Vendor	Intel	Intel
Model number	Iris Xe Graphics	UHD Graphics 620
Storage		
Vendor	Samsung	Intel
Model Number	MZVLB512HBJQ	SSDPEKKF256G8L
Amount (GB)	512	256
SSD type	M.2	M.2

Information	Lenovo ThinkPad T14 x2	Lenovo ThinkPad T480 x2
Connectivity/expansion		
Wireless internet	802.11ax	802.11ac
Bluetooth	4.0	4.2
USB	2 x USB-A 3.1 1 x USB-C	2 x USB-A 3.1 1 x USB-C
Video	1 x HDMI	1 x HDMI
Battery		
Type	Lithium-polymer	Lithium-polymer
Size	Integrated	Integrated
Rated capacity (Whr)	50	48
Display		
Size (in.)	14	14
Type	LED-backlit with IPS technology	LED-backlit with IPS technology
Resolution	1,920 x 1,200	1,920 x 1,080
Touchscreen	Yes	No
Operating system		
Vendor	Microsoft	Microsoft
Name	Windows 11 Pro	Windows 10 Pro
Build number or version	10.0.22621	10.0.19045
BIOS		
BIOS name and version	Lenovo N32ET53W (1.53)	Lenovo N24ET70W (1.45)
Dimensions		
Height (in.)	0.70	0.79
Width (in.)	12.95	13.25
Depth (in.)	8.94	9.15
Weight (lbs.)	3.33	3.63

How we tested

Setting up the systems

Creating and updating the OEM Microsoft Windows 10 and 11 images

1. Boot the system.
2. Follow the onscreen instructions to complete installation, using the default selections when appropriate.
3. Click the battery icon in the lower-right corner, and adjust the Windows Power mode (plugged in) to Best Performance.
4. Unplug the system, click the battery icon in the lower-right corner, adjust the Windows Power mode (on battery) to Best Performance, and plug in the system.
5. Set DPI scaling to 100%, and set Screen and Sleep options to Never:
 - Right-click the desktop, and select Display settings.
 - Under the Scale and layout section, for the Change the size of text, apps, and other items option, select 100%.
 - From the left column, select Power & Sleep.
 - For all power options listed under Screen and Sleep, select Never.
6. Disable User Account Control notifications:
 - Select Windows Start, type `UAC`, and press Enter.
 - Move the slider control to Never notify, and click OK.
7. Disable Virtualization Based Security:
 - Select Windows Start, type `Group Policy`, and press Enter.
 - Select Computer Configuration → Administrative Templates → System → Device Guard.
 - Double-click Turn on Virtualization Based Security.
 - Select Disabled, click Apply, and click OK.
8. Run Windows Update, and install all updates available.
9. Launch the Windows Store app, and install all Store app updates.
10. Launch each vendor proprietary utility app installed on each system, and update any drivers or BIOS files:
 - For Dell, run the Dell Command Update utility.
 - For HP, run the HP Support Assistant utility.
 - To install the latest chipset and graphics drivers available, go to either <https://www.intel.com/content/www/us/en/support.html> or <https://www.amd.com/en/support>.
11. Verify the date and time are correct, and synchronize the system clock with the time server.
12. Disable Automatic Windows Update:
 - Right-click the Windows Start button.
 - Select Computer Management.
 - Select Services and Applications.
 - Select Services.
 - Scroll down, and double-click Windows Update.
 - Click Stop.
 - From the Startup type drop-down menu, select Disabled.

Capturing an image

1. Connect an external HDD to the system.
2. Right-click desktop, and select Personalize → Home → Update & security → Backup → More options → See advanced settings → System Image Backup → 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. At Do you want 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 Shift 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.

Measuring performance with PCMark 10 benchmarks

Setting up the PCMark 10 test

1. Purchase and download the PCMark 10 benchmark from <https://benchmarks.ul.com/pcmark10>.
2. Install PCMark 10.
3. Launch PCMark 10.
4. Select Business Edition, and input the license key.
5. Close PCMark 10.

Running PCMark 10

1. Boot the system.
2. Select Windows Start.
3. Type `cmd`, and press Ctrl+Shift+Enter.
4. Type `Cmd.exe /c start /wait Rundll32.exe advapi32.dll,ProcessIdleTasks`. Do not interact with the system until the command completes.
5. After the command completes, wait five minutes before running the test.
6. Launch PCMark 10.
7. Select More Tests, and select PCMark 10 Applications.
8. To begin the test, click Run.
9. When the test completes, record the results, and shut down the system.
10. Complete steps 1 through 9 twice more, and record the median results.

Setting up the PCMark 10 applications test

1. Install and sign into Microsoft Office 365.
2. Open Microsoft Word, Excel, and PowerPoint, and verify that each application is signed into the Microsoft user account.
3. Purchase and download the PCMark 10 benchmark from <https://benchmarks.ul.com/pcmark10>.
4. Install PCMark 10.
5. Launch PCMark 10.
6. Select Business Edition, and input the license key.
7. Close PCMark 10.

Running PCMark 10 applications

1. Boot the system.
2. Select Windows Start.
3. Type `cmd`, and press Ctrl+Shift+Enter.
4. Type `Cmd.exe /c start /wait Rundll32.exe advapi32.dll,ProcessIdleTasks`. Do not interact with the system until the command completes.
5. After the command completes, wait five minutes before running the test.
6. Launch PCMark 10.
7. Select More Tests, and select PCMark 10 Applications.
8. To begin the test, click Run.
9. When the test completes, record the results, and shut down the system.
10. Complete steps 1 through 9 twice more, and record the median results.

Measuring performance with SYSmark benchmarks

Avoiding antivirus software conflicts

SYSmark 2018, SYSmark 25, and SYSmark 25 DC tests are not compatible with any virus-scanning software, so we uninstalled any such software present on the systems before we installed each benchmark.

Avoiding pre-installed software conflicts

SYSmark 2018 installs the following applications, which its test scripts employ:

Productivity

- Adobe® Acrobat® Pro DC
- AutoIT 3.3.14.2
- BowPad64-2.3.3 installer
- Google® Chrome®
- Microsoft® Excel® 2016
- Microsoft® OneNote® 2016
- Microsoft® Outlook® 2016
- Microsoft® PowerPoint® 2016
- Microsoft® Word 2016
- Windows Zip

Creativity

- Adobe® Photoshop® CC 2017
- Adobe® Lightroom® Classic CC
- CyberLink PowerDirector® 2015

Responsiveness

- Adobe Acrobat Pro DC
- Adobe Lightroom Classic CC
- Adobe Photoshop CC 2017
- CyberLink PowerDirector 2015
- Google Chrome
- Microsoft Excel 2016
- Microsoft OneNote 2016
- Microsoft Outlook 2016
- Microsoft PowerPoint 2016
- Microsoft Word 2016

SYSmark 25 installs the following applications, which its test scripts employ:

Productivity

- Adobe® Acrobat® Pro DC (15.010.20060)
- Audacity 2.3.2
- AutoIT 3.3.15.2
- Corel WinZip 24 Enterprise
- Google® Chrome®
- Microsoft Excel 2019
- Microsoft Outlook 2019
- Microsoft PowerPoint 2019
- Microsoft Word 2019
- Shotcut v19.09.14

Creativity

- Adobe Lightroom® Classic CC 2019
- Adobe Premiere® Pro CC (20.0.6)
- Adobe Photoshop® CC (13.1.5)

Responsiveness

- Adobe Acrobat Pro DC
- Adobe Lightroom Classic CC 2019
- Adobe Premiere Pro CC 2019
- Adobe Photoshop CC 2019
- Audacity 2.3.2
- Corel WinZip 24 Enterprise
- Google Chrome
- Microsoft Excel 2019
- Microsoft Outlook 2019
- Microsoft PowerPoint 2019
- Microsoft Word 2019

If any of these applications already exist on the system under test, they could cause problems with the SYSmark benchmarks 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 SYSmark 25 or SYSmark 25 DC use—before we installed the benchmarks.

Using the SYSmark built-in configuration tool

This SYSmark tool supports three levels of configuration:

- Only makes changes that are REQUIRED for the benchmark to run.
- Additionally, makes changes that are RECOMMENDED for repeatable results.
- 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

Level 2 - Recommended

- 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
- Create BAPCo power scheme
- Set Power Plan Type to High Performance
- Set CPU High Performance
- Disables Disk Defrag
- Disables Windows Error Reporting
- Disables Windows Lock Screen
- Disables Windows Pop-ups
- Disables Screen Saver and Monitor Timeout
- Disables Windows Sidebar/Gadgets
- Disables Desktop Slideshow
- Disables Windows Defender
- Disables Windows Firewall
- Set Font Smoothing

Level 3 - Optional

- Disables Hard Disk Timeout
- Disables System Restore
- Ignores Laptop Lid Close

We chose the official BAPCo Run Benchmark default as outlined in the BAPCo SYSmark 2018 User Guide http://bapco.com/wp-content/uploads/2018/10/BAPCo_SYSmark2018_user_guide.pdf, which runs the benchmark using the Required and Recommended options.

Setting up SYSmark 2018

1. Install SYSmark 2018 with the default options.

Running SYSmark 2018

1. Boot the system.
2. Select Windows Start.
3. Type `cmd`, and press Ctrl+Shift+Enter.
4. Type `Cmd.exe /c start /wait Rundll32.exe advapi32.dll,ProcessIdleTasks`. Do not interact with the system until the command completes.
5. After the command completes, wait five minutes before running the test.
6. Launch SYSmark 2018.
7. Click the Settings Gear icon.
8. Verify that the iterations are set to the default 1.
9. Verify that Conditioning Run is enabled.
10. Enter a name for the benchmark run.
11. To return to the main menu, click the Back button.
12. Click Run Benchmark.
13. When the benchmark finishes, record the SYSmark 2018 benchmark results.
14. Complete steps 1 through 14 twice more, and record the median results.

Setting up SYSmark 25

1. Install SYSmark 25 with the default options.
2. Install the latest patch, SYSmark25_Patch4_1.0.4.54 as of August 10, 2022.

Running SYSmark 25 (unplugged)

1. Boot the system.
2. Select Windows Start.
3. Type `cmd`, and press Ctrl+Shift+Enter.
4. Type `Cmd.exe /c start /wait Rundll32.exe advapi32.dll,ProcessIdleTasks`. Do not interact with the system until the command completes.
5. After the command completes, wait five minutes before running the test.
6. Unplug the system from AC power.
7. Launch SYSmark 25.
8. Click the Settings Gear icon.
9. Verify that the iterations are set to the default 1.
10. Verify that Conditioning Run is enabled.
11. Enter a name for the benchmark run.
12. To return to the main menu, click the Back button.
13. Click Run Benchmark.
14. When the benchmark finishes, record the SYSmark 25 benchmark results.
15. Plug the system into AC power, and allow the system to fully recharge.
16. Complete steps 1 through 15 twice more, and record the median results.

Running SYSmark 25 (plugged in)

1. Boot the system.
2. Select Windows Start.
3. Type `cmd`, and press Ctrl+Shift+Enter.
4. Type `Cmd.exe /c start /wait Rundll32.exe advapi32.dll,ProcessIdleTasks`. Do not interact with the system until the command completes.
5. After the command completes, wait five minutes before running the test.
6. Launch SYSmark 25.
7. Click the Settings Gear icon.
8. Verify that the iterations are set to the default 1.
9. Verify that Conditioning Run is enabled.
10. Enter a name for the benchmark run.
11. To return to the main menu, click the Back button.
12. Click Run Benchmark.
13. When the benchmark finishes, record the SYSmark 25 benchmark results.
14. Complete steps 1 through 13 twice more, and record the median results.

Enabling the VBS feature on the Windows 11 laptops

1. In the search bar, search for Core Isolation.
2. Toggle Memory integrity to On.
3. Restart your laptop.

Measuring performance with the 3DMark benchmark

Setting up the 3DMark test

1. Download the 3Dmark benchmark from <http://www.futuremark.com/benchmarks/3dmark/all>.
2. Install 3DMark with the default options by double-clicking the 3DMark installer.exe file.
3. Launch 3DMark by double-clicking on the 3Dmark desktop icon. Enter the registration code, and click Register.
4. Exit 3DMark.

Running 3DMark

1. Boot the system and wait five minutes before running the test.
2. To launch the benchmark, double-click the 3DMark desktop icon.
3. At the 3DMark Home screen, click the More Tests button.
4. Select the desired benchmark to run (i.e., Fire Strike or Time Spy).
5. Move the slider button to turn off the "Include Demo" feature.
6. Click Run.
7. When the benchmark run completes, record the results.
8. Perform steps 1 through 7 two more times for each benchmark, and report the median of the three runs.

Measuring performance with the Cinebench R23 benchmark

Setting up Cinebench R23

1. Download and install Cinebench from the Microsoft Store.

Running Cinebench R23

1. Launch Cinebench.
2. Select either CPU (Multi Core) or CPU (Single Core), and click Start.
3. Record the result.
4. Wait 15 minutes before re-running.
5. Complete steps 1 through 4 two more times.

Measuring performance with the Blender benchmark

Setting up the Blender tests

1. Download the Blender Benchmark from <https://opendata.blender.org/>.

Running the Blender tests

1. Launch the Blender Benchmark.
2. At the Welcome screen, click Next.
3. Select Blender version 3.1.0, and click Next.
4. At the Benchmark Scenes screen, click Next.
5. At the Benchmark Device screen, select the GPU option, and click Start Benchmark.
6. Record the results.
7. Wait five minutes before performing the next run.
8. Complete steps 1 through 7 four more times.

Measuring performance with the Maxon RedShift benchmark

Setting up RedShift

1. Download and install the Maxon App from <https://www.maxon.net/en/try>.
2. Click the Maxon One 14-day trial, and download and install the RedShift application.

Running Redshift

1. Open a command prompt by clicking the Windows icon on the bottom left of your desktop, typing `cmd`, and pressing enter.
2. Inside the command prompt, type `cd C:\ProgramData\Redshift\bin`, and press Enter.
3. To start the benchmark, type `RunBenchmark.bat`, and press Enter.
4. Record the results.
5. Wait five minutes before performing the next run.
6. Complete steps 1 through 5 four more times.

Measuring performance with the WebXPRT 4 benchmark

Running WebXPRT 4

1. Open the Google Chrome web browser, and go to <https://www.principledtechnologies.com/benchmarkxprt/webxprt/>.
2. Click Run WebXPRT 4.
3. At the Ready to test your browser screen, click Continue.
4. Click Start.
5. When the test completes, record the results.
6. To rerun WebXPRT, click Run Again, and click Start.
7. Record the results.
8. Complete steps 1 through 7 two more times.

Measuring performance with Procyon benchmarks

Setting up the Procyon tests

1. Download and install Procyon.
2. Open Procyon.
3. Click Office Productivity Benchmark.
4. Click Register.
5. Enter the license key for the Office Productivity Benchmark, and click Register.
6. Click Photo Editing Benchmark or Video Editing Benchmark.
7. Click Register.
8. Enter the license key for the Photo and Video Editing Benchmark, and click Register.
9. Before running the benchmarks, make sure to install licensed versions of Microsoft 365, Adobe Photoshop 22.0 or higher, Adobe Lightroom Classic 10.0 or higher, and Adobe Premiere 14.5 or higher.

Running the Procyon tests

1. Boot the system.
2. Select Windows Start.
3. Type `cmd`, and press Ctrl+Shift+Enter.
4. Type `Cmd.exe /c start /wait Rundll32.exe advapi32.dll,ProcessIdleTasks`. Do not interact with the system until the command completes.
5. After the command completes, wait five minutes before running the test.
6. Launch Procyon.
7. Click Office Productivity Benchmark.
8. Click Run.
9. When the benchmark is complete, record the results.
10. Click Photo Editing Benchmark.
11. Click Run.
12. When the benchmark is complete, record the results.
13. Click Video Editing Benchmark.

14. Click Run.
15. When the benchmark is complete, record the results.
16. Shut down the system.
17. Complete steps 1 through 16 twice more.

Measuring thermals while running a Cinebench R23 workload

Setting up the environmental heatmap test

1. Download and install Cinebench R23 from the Microsoft Store.
2. Launch Cinebench R23.
3. Select File, and check Advanced Benchmark.
4. Select File and Preferences.
5. In the Preferences popup, type 70 minutes in the Custom Minimum Test Duration field.
6. Click OK.
7. Close Cinebench.

Running the environmental heatmap test

1. Launch Cinebench. R23.
2. From the Minimum Test Duration drop-down menu, select Custom (70 minutes).
3. Select CPU (multi core), and click Start.
4. After 1 hour, photograph the top and bottom of the laptop with a FLIR E6-XT thermal camera. View the images and report the highest temperature for the top and bottom areas.
5. Stop the test, and turn off the laptop.
6. Let the laptop cool for 1 hour.
7. Complete steps 1 through 6 two more times.

Measuring battery life with a local video playback

Note: Performing this test requires the following items:

- A Gossen Mavolux 5032C USB luminance meter
- A 5-minute 1080p .MP4 (329 MB) test video
- Battery exe installed in Users directory to capture start and end times

Setting up the local video playback test

1. Turn on the systems.
2. Copy the .MP4 file to each system, and verify that the video player is set to loop the video.
3. Verify that the displays will remain on, and disable power saving options.
4. Right-click the desktop, and select Display settings.
5. Uncheck the box next to Change brightness automatically when lighting changes.
6. Select Battery:
 - Under Turn battery saver on automatically drop-down menu, verify that the default is set to 20%.
 - Uncheck the box next to Lower screen brightness while in battery saver.
7. Select Power & sleep:
 - Under the Screen heading, change both the On battery power, turn off option and the When plugged in, turn off after option to Never.
 - Under the Sleep heading change both the On battery power, turn off option and the When plugged in, turn off after option to Never.
 - Click Additional Power Settings.
 - Click Change Plan settings.
 - Click Change Advanced Power Settings.
8. Expand the Battery field:
 - Under Critical Battery Notifications choose Off.
 - Under Low Battery Notifications choose Off.

9. To bring up a white screen, open a web browser, and type `about:blank` into the address bar.
10. Unplug the systems.
11. Allow the screens to warm up for 30 minutes.
12. Use the luminance meter to adjust each screen to a brightness as close as possible to 200 nits.
13. Right-click the desktop, and select Display settings.
14. Adjust the slider bar until the luminance meter reads 200 nits.

Running the local video playback test

1. Verify that the system's battery is fully charged.
2. Launch the test .MP4 video in full screen mode.
3. Start `battery.exe` to capture start and finish battery time in Users directory.
4. Unplug the system from power.
5. When all the systems have finished, restart the system, go to Users directory, and document start and end times for each system.
6. Complete steps 1 through 5 two more times.

Measuring battery life while streaming video

Note: Performing this test requires the following items:

- A Gossen Mavolux 5032C USB luminance meter
- Battery exe installed in Users directory to capture start and end times

Setting up the streaming video test

1. Turn on the systems.
2. Verify that the displays will remain on, and disable power saving options.
3. Right-click the desktop, and select Display settings.
4. Uncheck the box next to Change brightness automatically when lighting changes.
5. Select Battery:
6. Under Turn battery saver on automatically drop-down menu verify that the default 20% is set.
7. Uncheck the box next to Lower screen brightness while in battery saver.
8. Select Power & sleep:
9. Under the Screen heading change both the On battery power, turn off option and the When plugged in, turn off after option to Never.
10. Under the Sleep heading change both the On battery power, turn off option and the When plugged in, turn off after option to Never.
11. Click Additional Power Settings.
12. Click Change Plan settings.
13. Click Change Advanced Power Settings.
14. Expand the Battery field:
15. Under Critical Battery Notifications choose Off.
16. Under Low Battery Notifications choose Off.
17. To bring up a white screen, open a web browser, and type `about:blank` into the address bar.
18. Unplug the systems.
19. Allow the screens to warm up for 30 minutes.
20. Use the luminance meter to adjust each screen to a brightness as close as possible to 200 nits.
21. Right-click the desktop, and select Display settings.
22. Adjust the slider bar until the luminance meter reads 200 nits.

Running the streaming video test

1. Verify that the system's battery is fully charged.
2. Open the web browser.
3. Navigate to <https://www.youtube.com/watch?v=i4bO7B1vyT8>.
4. Start `battery.exe` in Users directory.
5. Ensure the video is running in full screen.
6. Unplug the system from power.
7. When all the systems have finished, restart the system, go to Users directory, and document start and end times.
8. Complete steps 1 through 7 two more times.

Measuring battery life during a Zoom video conference call

Note: Performing this test requires the following items:

- A Gossen Mavolux 5032C USB luminance meter
- A 1-minute 25-second 1080p .MP4 (222 MB) test video
- Battery.exe installed in Users directory
- One external stand-alone system that plays the looped video
- One external base system that initiates the Zoom call and broadcasts the looped video to the systems under test

Setting up the Zoom video conference call test

1. Turn on the systems.
2. Copy the .MP4 file to the external stand-alone system that will play the looped video. Verify that the video player is set to loop the video.
3. Verify that the displays will remain on, and disable power saving options.
4. On the external base system and the system under test, download and install the Zoom video conferencing application from <https://zoom.us/download>.
5. Right-click the desktop, and select Display settings.
6. Uncheck the box next to Change brightness automatically when lighting changes.
7. Select Battery:
 - Under Turn battery saver on automatically drop-down menu verify that the default 20% is set.
 - Uncheck the box next to Lower screen brightness while in battery saver.
8. Select Power & sleep:
 - Under the Screen heading, change both the On battery power, turn off option and the When plugged in, turn off after option to Never.
 - Under the Sleep heading, change both the On battery power, turn off option and the When plugged in, turn off after option to Never.
9. Click Additional Power Settings.
10. Click Change Plan settings.
11. Click Change Advanced Power Settings.
12. Expand the Battery field:
13. Under Critical Battery Notifications, choose Off.
14. Under Low Battery Notifications, choose Off.
15. To bring up a white screen, open a web browser, and type `about:blank` into the address bar.
16. Unplug the systems.
17. Allow the screens to warm up for 30 minutes.
18. Use the luminance meter to adjust each screen to a brightness as close as possible to the 200 nits setting.
19. Right-click the desktop, and select Display settings.
20. Adjust the slider bar until the luminance meter reads 200 nits.

Running the Zoom video conference call test

1. Verify that the test systems' batteries are fully charged.
2. On the external stand-alone system, launch the test .MP4 video in full screen mode.
3. On the external base system launch a Zoom video conferencing call to the systems under test.
4. Start battery.exe in Users directory.
5. When all the systems have finished, restart system and go to Users directory and document start and end times.
6. Complete steps 1 through 5 two more times.

Measuring battery life while web-browsing

Note: Performing this test requires the following items:

- A Gossen Mavolux 5032C USB luminance meter
- Battery exe installed in Users directory to capture start and end times

Setting up the web-browsing test

1. Turn on the systems.
2. Verify that the displays will remain on, and disable power saving options.
3. Right-click the desktop, and select Display settings.
4. Uncheck the box next to Change brightness automatically when lighting changes.
5. Select Battery:
6. Under Turn battery saver on automatically drop-down menu verify that the default 20% is set.
7. Uncheck the box next to Lower screen brightness while in battery saver.
8. Select Power & sleep:
9. Under the Screen heading change both the On battery power, turn off option and the When plugged in, turn off after option to Never.
10. Under the Sleep heading change both the On battery power, turn off option and the When plugged in, turn off after option to Never.
11. Click Additional Power Settings.
12. Click Change Plan settings.
13. Click Change Advanced Power Settings.
14. Expand the Battery field:
15. Under Critical Battery Notifications choose Off.
16. Under Low Battery Notifications choose Off.
17. To bring up a white screen, open a web browser, and type `about:blank` into the address bar.
18. Unplug the systems.
19. Allow the screens to warm up for 30 minutes.
20. Use the luminance meter to adjust each screen to a brightness as close as possible to 200 nits.
21. Right-click the desktop, and select Display settings.
22. Adjust the slider bar until the luminance meter reads 200 nits.

Running the web-browsing test

1. Verify that the system's battery is fully charged.
2. Open the Chrome web browser.
3. Navigate to <http://weblooper.web.fc2.com/>.
4. Select Top 50.
5. Insure that the refresh time is set to the default of 30 seconds.
6. Click Start.
7. Start battery.exe in Users directory.
8. Unplug the system from power.
9. When all the systems have finished, restart the system, go to Users directory, and document start and end times.
10. Complete steps 1 through 9 two more times.

Measuring battery life using the PCMark 10 modern office benchmark

Note: Performing this test requires the following items:

- A Gossen Mavolux 5032C USB luminance meter

Setting up the modern office test

1. Purchase and download the PCMark 10 benchmark from <https://benchmarks.ul.com/pcmark10>.
2. Install PCMark 10.
3. Launch PCMark 10.
4. Select Business Edition, input the license key, and select Continue.
5. Click Update.
6. When the update is complete, close PCMark 10.
7. Verify that the display will remain on, and disable power saving options.
8. Right-click the desktop, and select Display settings.
9. Next to Change brightness automatically when lighting changes, uncheck the box.
10. Select Battery:
11. Under Turn battery saver on automatically drop-down menu, verify that the default 20 percent is set.
12. Next to Lower screen brightness while in battery saver, uncheck the box.
13. Select Power & sleep:
14. Under the Screen heading change both the On battery power, turn off option and the When plugged in, turn off after option to Never.
15. Under the Sleep heading change both the On battery power, turn off option and the When plugged in, turn off after option to Never.
16. Click Additional Power Settings.
17. Click Change Plan settings.
18. Click Change Advanced Power Settings.
19. Expand the Battery field:
20. Under Critical Battery Notifications choose Off.
21. Under Low Battery Notifications choose Off.
22. To bring up a white screen, open a web browser, and type `about:blank` into the address bar.
23. Unplug the systems.
24. Allow the screens to warm up for 30 minutes.
25. Use the luminance meter to adjust each screen to a brightness as close as possible to 200 nits.
26. Right-click the desktop, and select Display settings.
27. Adjust the slider bar until the luminance meter reads 200 nits.

Running the modern office benchmark

1. Verify that the system's battery is fully charged.
2. Boot the system.
3. Select Windows Start.
4. Type `cmd`, and press `Ctrl+Shift+Enter`.
5. Type `Cmd.exe /c start /wait Rundll32.exe advapi32.dll,ProcessIdleTasks`. Do not interact with the system until the command completes.
6. After the command completes, wait five minutes before running the test.
7. Launch PCMark 10.
8. Select More Tests, and select the Battery tab.
9. Select the Modern Office battery profile.
10. Unplug the system under test.
11. Click Run.
12. When the system powers off, reconnect the power, and boot the system.
13. Record the result.
14. Complete steps 1 through 13 two more times.

Read the report at <https://facts.pt/HxLb98U>



This project was commissioned by Microsoft.



Facts matter.®

Principled Technologies is a registered trademark of Principled Technologies, Inc. All other product names are the trademarks of their respective owners.

DISCLAIMER OF WARRANTIES; LIMITATION OF LIABILITY:

Principled Technologies, Inc. has made reasonable efforts to ensure the accuracy and validity of its testing, however, Principled Technologies, Inc. specifically disclaims any warranty, expressed or implied, relating to the test results and analysis, their accuracy, completeness or quality, including any implied warranty of fitness for any particular purpose. All persons or entities relying on the results of any testing do so at their own risk, and agree that Principled Technologies, Inc., its employees and its subcontractors shall have no liability whatsoever from any claim of loss or damage on account of any alleged error or defect in any testing procedure or result.

In no event shall Principled Technologies, Inc. be liable for indirect, special, incidental, or consequential damages in connection with its testing, even if advised of the possibility of such damages. In no event shall Principled Technologies, Inc.'s liability, including for direct damages, exceed the amounts paid in connection with Principled Technologies, Inc.'s testing. Customer's sole and exclusive remedies are as set forth herein.