

TESTING STARTUP TIME AND VIDEO PLAYBACK BATTERY LIFE: WINDOWS 10 VS. WINDOWS 7

Microsoft is offering a free upgrade to Windows 10 to people currently running Windows 7. While the free upgrade sounds nice, you are probably staying on the sidelines until you know if the upgrade is good or bad for your PC. Will Windows 10 improve your experience, hurt your experience, or stay the same after you upgrade?

Microsoft asked Principled Technologies to find out what actually happened to devices when they upgraded to Windows 10 from Windows 7. We looked at startup performance and battery life based on video playback to see how the upgrade affects PC performance. Because Windows 7 has been out for a long time, we tested 20 Windows 7 systems sold between 2010 and 2015 on a wide variety of configurations. The systems represented nine vendors and included both laptops and desktops. Our test systems had 2, 3, 4 and 8 GB of RAM, 250 GB, 320 GB, 500 GB, 750 GB and 1TB of storage, and a mix of AMD® Sempron™ and A6 processors and Intel® Pentium®, Celeron®, Core™ i3 and Core i5 processors. This range of hardware ensured that we tested devices representative of computers that most consumers bought during this time. We first captured performance on Windows 7, upgraded to Windows 10, and then retested. Figure 1 presents the results from the Windows Assessment and Deployment Kit Full Boot and Fast Startup tests on the 20 systems in our test bed. Windows 10 was faster in every case.

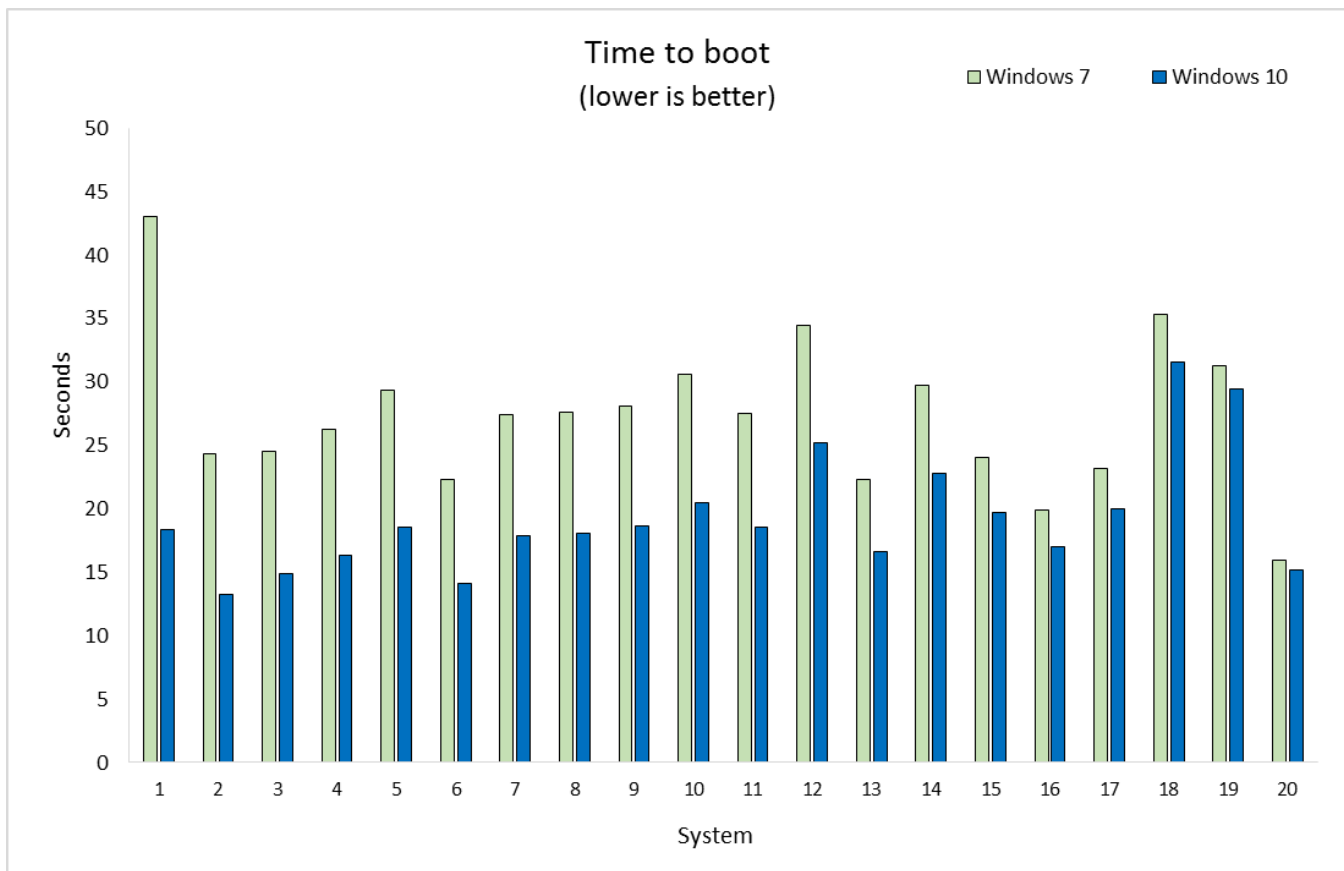


Figure 1: Upgrading Windows 7 systems to Windows 10 reduced startup times. Systems are in order from largest improvement to smallest improvement.



VALIDATED IN OUR LABS

With our 20 systems, we ran the devices through hundreds of test cycles to ensure we had enough data to feel confident in the results. Our goal was to ensure that our results represent what most users might expect to see on their devices. To meet that goal, the 20 systems went through an estimated combined 553 totals runs, with around 273 battery tests, and 280 Fullboot and FastStartup runs. Figure 2 gives an overview of the 20 Windows 7 systems we tested. For a look at exact system specs for each of the test systems, see Appendix A. If you're interested in our detailed test methodology, visit Appendix B.

System name	CPU	Storage	RAM
Acer® Aspire® E1-532-4870	Intel Pentium 3558 1.7GHz	500 GB	4 GB
Acer Aspire TC-605 (Desktop)	Intel Pentium G3250 3.2GHz	500 GB	4 GB
Acer Aspire V5-131-2629	Intel Celeron 1007U 1.5GHz	500 GB	4 GB
ASUS® K30AD (Desktop)	Intel Pentium G3240 3.1GHz	1 TB	4 GB
ASUS X401A (RGN4)	Intel Pentium B970 2.3GHz	320 GB	4 GB
Compaq Presario CQ56 (219WM)	Intel Celeron 900 2.2 GHz	250 GB	2 GB
Dell™ Inspiron™ 14 (1464)	Intel Core i3-330M 2.13GHz	500 GB	4 GB
Dell Inspiron 15R (N5110)	Intel Core i5-2410M 2.3GHz	500 GB	4 GB
Dell OptiPlex™ 3010 (Desktop)	Intel Core i5-3450 3.1GHz	500 GB	4 GB
Dell XPS™ X8700 (Desktop)	Intel Core i5-4460 3.2GHz	1 TB	8 GB
Gateway® NE56R10u	Intel Celeron B820 1.7GHz	320 GB	3 GB
HP Pavilion G62 (340US)	AMD Athlon P340 2.2GHz	320 GB	3 GB
HP Pavilion G7 (1070US)	Intel Core i3-380M 2.53GHz	500 GB	4 GB
HP ProBook 450 G1	Intel Core i5-3230M 2.6GHz	750 GB	8 GB
Lenovo® ThinkCentre® E73 (Desktop)	Intel Core i3-4130 3.4GHz	500 GB	4 GB

System name	CPU	Storage	RAM
Lenovo ThinkPad® E540	Intel Core i5-4200M 2.5GHz	500 GB	4 GB
Lenovo ThinkPad Edge E545	AMD A6 5350M 2.9GHz	320 GB	4 GB
Samsung® Series 5 NP530	Intel Core i5-2467M 1.6GHz	500 GB	4 GB
Samsung Series 5 NP535	AMD A6-4455M 2.1GHz	500 GB	4 GB
Toshiba Satellite L455D (S5976)	AMD Sempron SI-42 2.1GHz	250 GB	2 GB

Figure 2: The Windows 7 systems we tested.

As Figures 1 and 3 show, all 20 systems booted faster after we upgraded them to Windows 10 from Windows 7. Windows 10 improved user-perceived startup time by an average of 28 percent. Improvement ranged from 6 percent to as much as 57 percent faster. Please note that for our startup tests we compared user-perceived startup times, testing Full Boot on Windows 7 and Fast Startup on Windows 10. Fast Startup is a newer feature that uses a hybrid shutdown to get systems started more quickly; this feature was unavailable in Windows 7, which accounts for the different startup methods in our comparison.

Figure 3 details the times, in seconds, for perceived startup, and the percentage improvement for the Windows 10 upgrade.

User-perceived startup times			
System number	Windows 7	Windows 10	Percent improvement with Windows 10
1	43.08	18.40	57%
2	24.33	13.24	46%
3	24.52	14.91	39%
4	26.29	16.36	38%
5	29.37	18.51	37%
6	22.35	14.15	37%
7	27.44	17.86	35%
8	27.62	18.04	35%
9	28.10	18.63	34%
10	30.57	20.51	33%
11	27.54	18.59	32%
12	34.42	25.21	27%
13	22.30	16.61	26%
14	29.69	22.77	23%

User-perceived startup times			
System number	Windows 7	Windows 10	Percent improvement with Windows 10
15	24.09	19.71	18%
16	19.91	17.02	15%
17	23.14	20.00	14%
18	35.35	31.55	11%
19	31.23	29.49	6%
20	15.94	15.20	5%

Figure 3: User-perceived startup time for the systems, in seconds.

Battery life

We also tested the battery life of the 15 laptops (five systems were desktops) while playing a video. As Figure 4 shows, nine of our 15 laptops saw an increase in battery life based on video playback when we upgraded them to Windows 10 from Windows 7. Two laptops stayed the same, and four laptops had shorter battery life. Your laptop may vary.

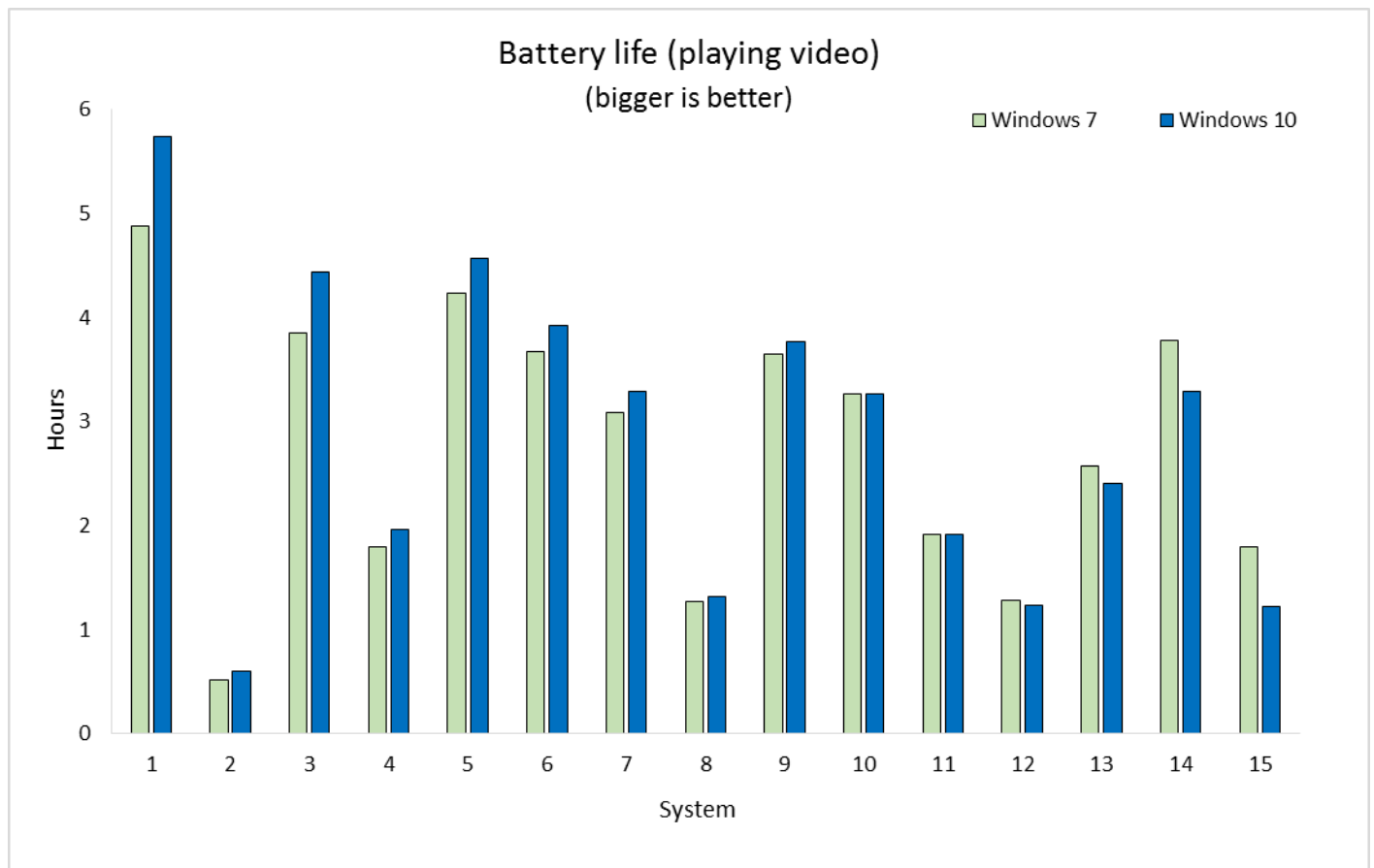


Figure 4: Battery life based on video playback when upgrading Windows 7 systems to Windows 10. Systems are in order from largest improvement to smallest improvement.

Figure 5 details the times, in hours, for battery rundown time playing a video, and the percentage improvement for the Windows 10 upgrade.

Battery life based on video playback			
System number	Windows 7	Windows 10	Percent change with Windows 10
1	4.88	5.73	17%
2	0.52	0.60	16%
3	3.85	4.43	15%
4	1.80	1.97	9%
5	4.23	4.57	8%
6	3.67	3.92	7%
7	3.08	3.28	6%
8	1.27	1.32	4%
9	3.65	3.77	3%
10	3.27	3.27	0%
11	1.92	1.92	0%
12	1.28	1.23	-4%
13	2.57	2.40	-6%
14	3.78	3.28	-13%
15	1.80	1.22	-32%

Figure 5: Battery life based on video playback for the systems, in hours.

CONCLUSION

Many factors affect PC performance, including if the hardware has the right driver package to optimize how the hardware works with the operating system. This means that user experiences vary when upgrading to Windows 10. After our Microsoft-commissioned testing of 20 Windows 7 systems picked specifically to have a wide range of ages, processors, drives, and other specs, we found that upgrading to Windows 10 improved startup times by an average of 28 percent. When we tested video playback, a battery-intensive feature, the majority of devices upgrading to Windows 10 saw better battery life (Note: Your individual results may vary depending on your device's condition). Nine of the 15 devices had improved battery life, two had the same battery life, and four had declining battery life after upgrading to Windows 10.

APPENDIX A – SYSTEM CONFIGURATION INFORMATION

Figures 6 through 10 provide detailed configuration information for the test systems. Some systems report two sets of information. This is because we had two physical systems of each kind to expedite testing. All were identical, except for any differences noted here.

System	Acer Aspire E1-532-4870	Acer Aspire V5-131	Acer Aspire TC-605	ASUS K30AD 1A
General				
Number of processor packages	1	1	1	1
Number of cores per processor	2	2	2	2
Number of hardware threads per core	1	1	1	1
Total number of processor threads in system	2	2	2	2
System power management policy	Balanced	Balanced	Balanced	Balanced
Processor power-saving option	Enhanced Intel SpeedStep® Technology	Enhanced Intel SpeedStep Technology	Enhanced Intel SpeedStep Technology	Enhanced Intel SpeedStep Technology
System dimensions (length x width x height)	15" x 10.12" x 1"	11.25" x 7.93" x 1.62"	N/A	N/A
System weight	4.66 lbs.	3.14 lbs.	N/A	N/A
CPU				
Vendor	Intel	Intel	Intel	Intel
Name	Pentium	Celeron	Pentium	Pentium
Model number	3558U	1017U	G3250	G3240
Stepping	C0	E1/L1	C0	C0
Socket type	Socket 1168 BGA	Socket 1023 FCBGA	Socket 1150 LGA	Socket 1150 LGA
Core frequency (GHz)	1.70	1.60	3.20	3.10
L1 cache	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)
L2 cache	2 x 256 KB	2 x 256 KB	2 x 256 KB	2 x 256 KB
L3 cache	2 MB	2 MB	3 MB	3 MB
Platform				
Vendor	Acer	Acer	Acer	Asus Tec
Motherboard model number	EA50_HW	Mimic	Aspire TC-605	K30AD_M31AD_M51AD_M32AD
Motherboard chipset	Haswell-Ult	Intel Ivey Bridge	Intel H81	Intel H81
BIOS Name and version	Insyde Corp V2.17(09/02/2014)	Acer V1.09 (10/30/2012)	American Megatrends P21-A4 (09/12/2014)	American Megatrends 0601 (06/09/2014)

System	Acer Aspire E1-532-4870	Acer Aspire V5-131	Acer Aspire TC-605	ASUS K30AD 1A
Memory module(s)				
Vendor and model number	A-Data Technology MIF4D2C087KZ1	Hyundai HMT451S6MFR8A-PB	Kingston ACR16D3LU1KFG/4G	Samsung M378B5173DB0-CK0
Type	PC3-12800	PC3-12800	PC3-12800	PC3-12800
Speed (MHz)	1,600	1,600	1,600	1,600
Speed running in the system (MHz)	1,600	1,600	1,330	1,330
Timing/Latency (tCL-tRCD-tRP-tRASmin)	11-11-11-28	11-11-11-28	9-9-9-24	9-9-9-24
Size (MB)	4,096	4,096	4,096	4,096
Number of memory module(s)	1	1	1	1
Total amount of system RAM (GB)	4	4	4	4
Channel (single/dual)	Single	Single	Single	Single
Hard disk				
Vendor and model number	Seagate ST500LT012-9WS142	Seagate ST500LT012-9WS142	Western Digital WDC WD5000AAKX-22ERMA0	Western Digital WDC WD10EZEX-22BN5A0
Number of disks in system	1	1	1	1
Size (GB)	500	500	500	1,000
Buffer size (MB)	16	16	16	64
RPM	5,400	5,400	7,200	7,200
Type	SATA 3.0 Gb/s	SATA 3.0 Gb/s	SATA 6.0 Gb/s	SATA 6.0 Gb/s
Controller	Intel 8 Series SATA AHCI Controller-9C03	Intel 7 Series Chipset Family SATA AHCI Controller	Intel 8 Series/C220 Series SATA AHCI Controller	Intel 8 Series/C220 Series SATA AHCI Controller
Driver	Windows 7: Intel 9.4.0.1017 (2/25/2013) Windows 10: Intel 9.4.0.1017 (2/25/2013)	Windows 7: Intel 11.0.00.1032 (11/29/2011) Windows 10: Intel 11.0.00.1032 (11/29/2011)	Windows 7: Microsoft 6.1.7601.18231 (6/21/2006) Windows 10: Microsoft 10.0.10240.16384 (6/21/2006)	Windows 7: Intel 12.8.0.1016 (8/1/2013) Windows 10: Intel 12.8.0.1016 (8/1/2013)
Operating system				
Name	Windows 7 Home Premium	Windows 7 Home Premium	Windows 7 Home Premium	Windows 7 Home Premium
Build number	7601	7601	7601	7601
Service Pack	1	1	1	1
File system	NTFS	NTFS	NTFS	NTFS
Kernel	ACPI x64-based PC	ACPI x64-based PC	ACPI x64-based PC	ACPI x64-based PC

System	Acer Aspire E1-532-4870	Acer Aspire V5-131	Acer Aspire TC-605	ASUS K30AD 1A
Language	English	English	English	English
Microsoft DirectX® version	DirectX 11	DirectX 11	DirectX 11	DirectX 11
Operating system				
Name	Windows 10 Home	Windows 10 Home	Windows 10 Home	Windows 10 Home
Build number	10240	10240	10240	10240
Service Pack	N/A	N/A	N/A	N/A
File system	NTFS	NTFS	NTFS	NTFS
Kernel	ACPI x64-based PC	ACPI x64-based PC	ACPI x64-based PC	ACPI x64-based PC
Language	English	English	English	English
Microsoft DirectX® version	DirectX 12	DirectX 12	DirectX 12	DirectX 12
Graphics				
Vendor and model number	Intel HD Graphics	Intel HD Graphics	Intel HD Graphics	Intel HD Graphics
Type	Integrated	Integrated	Integrated	Integrated
Chipset	Intel HD Graphics Family	Intel HD Graphics Family	Intel HD Graphics	Intel HD Graphics
BIOS version	2170.0	2130	2175.0	2170.0
Total available graphics memory (MB)	1,696	1,760	1,760	1,696
Dedicated video memory (MB)	64	128	128	64
System video memory (MB)	0	0	0	0
Shared system memory (MB)	1,632	1,632	1,632	1,632
Resolution	1,366 x 768	1,366 x 768	1,280 x 1,024	1,280 x 1,024
Driver	Windows 7: Intel 10.18.10.3355 (11/15/2013) Windows 10: Intel 10.18.15.4256 (7/17/2015)	Windows 7: Intel 8.15.10.2752 (5/10/2012) Windows 10: Intel 10.18.10.4252 (7/10/2015)	Windows 7: Intel 10.18.10.3574 (4/23/2014) Windows 10: Intel 10.18.15.4256 (7/17/2015)	Windows 7: Intel 10.18.14.4170 (3/16/2015) Windows 10: Intel 10.18.15.4256 (7/17/2015)
Sound card/subsystem				
Vendor and model number	Realtek High Definition Audio	Realtek High Definition Audio	Realtek High Definition Audio	Realtek High Definition Audio
Driver	Windows 7: Realtek 6.0.1.6865 (3/19/2013) Windows 10: Realtek 6.0.1.7535 (6/16/2015)	Windows 7: Realtek 6.0.1.6543 (1/3/2012) Windows 10: Realtek 6.0.1.7535 (6/16/2015)	Windows 7: Realtek 6.0.1.7231 (4/22/2014) Windows 10: Realtek 6.0.1.7535 (6/16/2015)	Windows 7: Realtek 6.0.1.7116 (12/17/2013) Windows 10: Realtek 6.0.1.7535 (6/16/2015)

System	Acer Aspire E1-532-4870	Acer Aspire V5-131	Acer Aspire TC-605	ASUS K30AD 1A
Ethernet				
Vendor and model number	Broadcom® NetLink Gigabit Ethernet	Broadcom NetLink Gigabit Ethernet	Realtek PCIe GBE Family Controller	Intel Ethernet Connection I217-V
Driver	Windows 7: Broadcom 15.6.0.6 (3/27/2013) Windows 10: Broadcom 15.6.0.6 (3/27/2013)	Windows 7: Broadcom 15.2.0.4 (2/10/2012) Windows 10: Microsoft 15.6.1.2 (1/29/2013)	Windows 7: Realtek 7.80.218.2014 (2/18/2014) Windows 10: Realtek 7.80.218.2014 (2/18/2014)	Windows 7: Intel 12.8.33.0 (5/30/2013) Windows 10: Microsoft 12.12.50.6 (3/20/2015)
Wireless				
Vendor and model number	Qualcomm® Atheros AR956x	Qualcomm Atheros AR5BWB222	N/A	N/A
Driver	Windows 7: Qualcomm Atheros Communications 10.0.0.263 (8/25/2013) Windows 10: Qualcomm Atheros Communications 10.0.0.263 (8/25/2013)	Windows 7: Qualcomm Atheros Communications 10.0.0.42 (2/23/2012) Windows 10: Qualcomm Atheros Communications 10.0.0.42 (2/23/2012)	N/A	N/A
Optical drive(s)				
Vendor and model number	HL-DT-ST GUA0N Super Multi DL	N/A	Matshita SW830	Asus GHB1N
Type	DVDRAM	N/A	DVD-RW	DVD-RW
USB ports				
Number	3	3	6	5
Type	1 x USB 3.0, 2 x USB 2.0	USB 2.0	2 x USB 3.0, 4 x USB 2.0	2 x USB 3.0, 3 x USB 2.0
Other	Media Card Reader, HDMI port	Media Card Reader, HDMI port	Media Card Reader, HDMI port	Media Card Reader, HDMI port
Monitor				
Model	N/A	N/A	ViewSonic® VG730m	ViewSonic VG730m
LCD type	HD LED-backlit	HD LED-backlit	SXGA LCD	SXGA LCD
Screen size	15.6"	11.6"	17"	17"
Refresh rate	60 Hz	60 Hz	60 Hz	60 Hz
Maximum resolution	N/A	N/A	1,280 x 1,024	1,280 x 1,024

System	Acer Aspire E1-532-4870	Acer Aspire V5-131	Acer Aspire TC-605	ASUS K30AD 1A
Battery				
Type	4-cell Lithium Ion	6-cell Lithium Ion	N/A	N/A
Size (length x width x height)	10.5" x 1.5" x 0.75"	8" x 7.5" x 1.31"	N/A	N/A
Rated capacity	37 Wh	56 Wh	N/A	N/A
Weight	0.40 lbs.	0.61 lbs.	N/A	N/A

Figure 6: Configuration information for the test systems.

System	ASUS X Series X401A	Compaq Presario CQ56	Dell Inspiron 14 1464	Dell Inspiron 15r N5110
General				
Number of processor packages	1	1	1	1
Number of cores per processor	2	1	2	2
Number of hardware threads per core	2	1	2	2
Total number of processor threads in system	4	1	4	4
System power management policy	Dell	HP Recommended	Dell	Dell
Processor power-saving option	Enhanced Intel SpeedStep Technology	Enhanced Intel SpeedStep Technology	Enhanced Intel SpeedStep Technology	Enhanced Intel SpeedStep Technology
System dimensions (length x width x height)	14.80" x 10.24" x 1.24"	14.72" x 9.70" x 1.50"	13.39" x 9.55" x 0.82"	14.80" x 10.24" x 1.24"
System weight	5.80 lbs.	5.34 lbs.	4.86 lbs.	5.80 lbs.
CPU				
Vendor	Intel	Intel	Intel	Intel
Name	Core i5	Celeron	Core i3	Core i5
Model number	2410M	900	M330	2410M
Stepping	D2	R0	C2	D2
Socket type	Socket 988B rPGA	Socket P (478)	Socket 989 rPGA	Socket 988B rPGA
Core frequency (GHz)	2.30	2.20	2.13	2.30
L1 cache	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)
L2 cache	2 x 256 KB	1,024 KB	2 x 256 KB	2 x 256 KB
L3 cache	3 MB	N/A	3 MB	3 MB
Platform				
Vendor	Dell	Hewlett-Packard	Dell	Dell
Motherboard model number	034W60	1605	System 1: 0C6HFD System 2: 0FR6M4	034W60

System	ASUS X Series X401A	Compaq Presario CQ56	Dell Inspiron 14 1464	Dell Inspiron 15r N5110
Motherboard chipset	Intel HM67	Intel GL40	Intel HM55	Intel HM67
BIOS Name and version	American Megatrends X401A1.212 (12/03/2012)	Hewlett-Packard F.15 (04/07/2011)	Dell A13 (03/29/2011)	Dell A11 (08/03/2012)
Memory module(s)				
Vendor and model number	Samsung M471B5273DH0-CH9	Hyundai HYMP125S64CR8-S6	System 1: Hyundai HMT125S6BFR8C-G7 System 2: Samsung M471B5673FH0-CF8	Samsung M471B5273DH0-CH9
Type	PC3-10700	PC2-6400	PC3-8500F	PC3-10700
Speed (MHz)	1,333	800	1,066	1,333
Speed running in the system (MHz)	1,333	800	1,066	1,333
Timing/Latency (tCL-tRCD-tRP-tRASmin)	9-9-9-24	6-6-6-18	7-7-7-20	9-9-9-24
Size (MB)	4,096	2,048	2,048	4,096
Number of memory module(s)	1	1	2	1
Total amount of system RAM (GB)	4	2	4	4
Channel (single/dual)	Single	Single	Dual	Single
Hard disk				
Vendor and model number	Western Digital WDC WD5000BPVT-75HXZT1	System 1: Seagate ST9250315AS System 2: Hitachi HTS545025B9A300	System 1: Seagate ST9500420AS System 2: Western Digital WD5000BEVT-75ZAT0	Western Digital WDC WD5000BPVT-75HXZT1
Number of disks in system	1	1	1	1
Size (GB)	500	500	500	500
Buffer size (MB)	8	8	System 1: 16 System 2: 8	8
RPM	5,400	5,400	7,200	5,400
Type	SATA 3.0 Gb/s	SATA 3.0 Gb/s	SATA 3.0 Gb/s	SATA 3.0 Gb/s
Controller	Intel Mobile Express Chipset SATA AHCI Controller	Intel ICH9M-E/M SATA AHCI Controller	Intel 5 Series/3400 Series Chipset Family 4 Port SATA AHCI Controller – 3B29	Intel Mobile Express Chipset SATA AHCI Controller

System	ASUS X Series X401A	Compaq Presario CQ56	Dell Inspiron 14 1464	Dell Inspiron 15r N5110
Driver	Windows 7: Intel 10.1.0.1008 (11/6/2010) Windows 10: Intel 11.1.0.1006 (2/1/2012)	Windows 7: Intel 9.6.2.1001 (4/13/2010) Windows 10: Intel 9.6.2.1001 (4/13/2010)	Windows 7: Intel 7.0.0.1013 (6/4/2009) Windows 10: Intel 7.0.0.1013 (6/4/2009)	Windows 7: Intel 10.1.0.1008 (11/6/2010) Windows 10: Intel 10.1.0.1008 (11/6/2010)
Operating system				
Name	Windows 7 Home Premium	Windows 7 Home Premium	Windows 7 Home Premium	Windows 7 Home Premium
Build number	7601	7600	7601	7601
Service Pack	1	1	1	1
File system	NTFS	NTFS	NTFS	NTFS
Kernel	ACPI x64-based PC	ACPI x64-based PC	ACPI x64-based PC	ACPI x64-based PC
Language	English	English	English	English
Microsoft DirectX version	DirectX 11	DirectX 11	DirectX 11	DirectX 11
Operating system				
Name	Windows 10 Home	Windows 10 Home	Windows 10 Home	Windows 10 Home
Build number	10240	10240	10240	10240
Service Pack	N/A	N/A	N/A	N/A
File system	NTFS	NTFS	NTFS	NTFS
Kernel	ACPI x64-based PC	ACPI x64-based PC	ACPI x64-based PC	ACPI x64-based PC
Language	English	English	English	English
Microsoft DirectX® version	DirectX 12	DirectX 12	DirectX 12	DirectX 12
Graphics				
Vendor and model number	Intel HD Graphics 3000	Intel GMA 4500M	Intel HD Graphics	Intel HD Graphics 3000
Type	Integrated	Integrated	Integrated	Integrated
Chipset	Intel HD Graphics 3000	Intel 4 Series Express Chipset Family	Intel HD Graphics (Core i3)	Intel HD Graphics 3000
BIOS version	2098.0	1932.0	1926.1	2098.0
Total available graphics memory (MB)	1,696	797	1,696	1,696
Dedicated video memory (MB)	64	64	64	64
System video memory (MB)	0	0	0	0
Shared system memory (MB)	1,32	733	1,632	1,32
Resolution	1,366 x 768	1,366 x 768	1,366 x 768	1,366 x 768

System	ASUS X Series X401A	Compaq Presario CQ56	Dell Inspiron 14 1464	Dell Inspiron 15r N5110
Driver	Windows 7: Intel 8.15.10.2361 (4/10/2011) Windows 10: Intel 9.17.10.4229 (5/27/2015)	Windows 7: Intel 8.15.10.2086 (2/20/2010) Windows 10: Intel 8.15.10.2702 (3/11/2013)	Windows 7: Intel 8.15.10.2104 (3/31/2010) Windows 10: Intel 8.15.10.2900 (11/26/2012)	Windows 7: Intel 8.15.10.2361 (4/10/2011) Windows 10: Intel 9.17.10.4229 (5/27/2015)
Sound card/subsystem				
Vendor and model number	Realtek High Definition Audio	Realtek High Definition Audio	Realtek High Definition Audio	IDT High Definition Audio
Driver	Windows 7: Realtek 6.0.1.6649 (5/31/2012) Windows 10: Realtek 6.0.1.7535 (6/16/2015)	Windows 7: Realtek 6.0.1.6206 (9/21/2010) Windows 10: Realtek 6.0.1.7535 (6/16/2015)	Windows 7: Realtek 6.0.1.6039 (2/2/2010) Windows 10: Realtek 6.0.1.7535 (6/16/2015)	Windows 7: IDT 6.10.0.6324 (1/25/2011) Windows 10: IDT 6.10.0.6324 (1/25/2011)
Ethernet				
Vendor and model number	Realtek PCIe FE Family Controller	Realtek PCIe FE Family Controller	Realtek PCIe FE Family Controller	Realtek PCIe FE Family Controller
Driver	Windows 7: Realtek 7.48.823.2011 (8/23/2011) Windows 10: Realtek 9.1.401.2015 (4/1/2015)	Windows 7: Realtek 7.46.610.2011 (6/10/2011) Windows 10: Realtek 9.1.401.2015 (4/1/2015)	Windows 7: Realtek 7.46.610.2011 (6/10/2011) Windows 10: Realtek 9.1.401.2015 (4/1/2015)	Windows 7: Realtek 7.46.610.2011 (6/10/2011) Windows 10: Realtek 9.1.401.2015 (4/1/2015)
Wireless				
Vendor and model number	802.11n Wireless LAN Card	Ralink RT5390	System 1: Dell Wireless-N 1520 System 2: Dell Wireless 802.11g 1397	Intel Centrino 1030
Driver	Windows 7: Ralink Technology 5.0.24.0 (4/2/2013) Windows 10: MediaTek 5.0.57.0 (5/18/2015)	Windows 7: Ralink 5.0.9.0 (11/27/2012) Windows 10: MediaTek 5.0.57.0 (5/18/2015)	Windows 7: Broadcom 5.30.21.0 (7/7/2009) Windows 10: Broadcom 5.30.21.0 (7/7/2009)	Windows 7: Intel 14.0.1.2 (12/21/2010) Windows 10: Microsoft 14.4.1.1 (1/23/2013)
Optical drive(s)				
Vendor and model number	Matshita UJ8B1	HP GT31L	Optiarc AD07585H	Matshita UJ8B1
Type	DVD-RW	DVD-RAM	DVD-RW	DVD-RW
USB ports				
Number	4	3	3	4

System	ASUS X Series X401A	Compaq Presario CQ56	Dell Inspiron 14 1464	Dell Inspiron 15r N5110
Type	2 x USB 3.0, 2 x USB 2.0	USB 2.0	USB 2.0	2 x USB 3.0, 2 x USB 2.0
Other	Media Card Reader, HDMI port	N/A	Media Card Reader, HDMI port	Media Card Reader, HDMI port
Monitor				
LCD type	HD LED-backlit	LED BrightView	HD LED-backlit	HD LED-backlit
Screen size	15.6"	15.6"	14"	15.6"
Refresh rate	60 Hz	60 Hz	60 Hz	60 Hz
Battery				
Type	6-cell Lithium Ion	6-cell Lithium Ion	6-cell Lithium Ion	6-cell Lithium Ion
Size (length x width x height)	8.43" x 2.37" x 0.87"	8.06" x 2.12" x 0.81"	10.75" x 2.12" x 0.87"	8.43" x 2.37" x 0.87"
Rated capacity	48 Wh	47 Wh	48 Wh	48 Wh
Weight	0.66 lbs.	0.67 lbs.	0.71 lbs.	0.66 lbs.

Figure 7: Configuration information for the test systems.

System	Dell OptiPlex 3010	Dell XPS X8700	Gateway NE56R10U	HP Pavilion G62-340us
General				
Number of processor packages	1	1	1	1
Number of cores per processor	4	4	2	2
Number of hardware threads per core	1	1	1	1
Total number of processor threads in system	4	4	2	2
System power management policy	Balanced	Dell	Balanced	HP Recommended
Processor power-saving option	Enhanced Intel SpeedStep Technology	Enhanced Intel SpeedStep Technology	Enhanced Intel SpeedStep Technology	AMD PowerNow!
System dimensions (length x width x height)	N/A	N/A	15.02" x 9.96" x 1.31"	14.72" x 9.70" x 1.25"
System weight	N/A	N/A	5.28 lbs.	5.50 lbs.
CPU				
Vendor	Intel	Intel	Intel	AMD
Name	Core i5	Core i5	Celeron	Athlon II
Model number	3450	4460	B820	P340
Stepping	E1/L1	C0	D2	DA-C3
Socket type	Socket 1155 LGA	Socket 1150 LGA	Socket 988B rPGA	Socket S1 (638)
Core frequency (GHz)	3.10	3.20	1.70	2.20

System	Dell OptiPlex 3010	Dell XPS X8700	Gateway NE56R10U	HP Pavilion G62-340us
L1 cache	32 KB + 32 KB +32 KB +32 KB (per core)	32 KB + 32 KB +32 KB +32 KB (per core)	32 KB + 32 KB (per core)	64 KB + 64 KB (per core)
L2 cache	4 x 256 KB	4 x 256 KB	2 x 256 KB	2 x 512 KB
L3 cache	6 MB	6 MB	2 MB	N/A
Platform				
Vendor	Dell	Dell	Gateway	Hewlett-Packard
Motherboard model number	042P49	OKWVT8	EG50_HC_HR	1444
Motherboard chipset	Intel H61	Intel Z87	Intel HM70	AMD 785GX
BIOS Name and version	Dell A13 (10/14/2014)	Dell A10 (12/08/2014)	Gateway V1.13 (10/09/2012)	Hewlett-Packard F.29 (04/07/2011)
Memory module(s)				
Vendor and model number	Hyundai HMT35U6CFR8C	Kingston K531R8-ETB	Hyundai HMT325S6CFR8C-H9, Gateway KN1GB0H0172	Kingston HP594908-HR1-ELFE, Micron 4JSF12864HZ-1G4D1
Type	PC3-12800	PC3-12800	PC3-10700	PC3-10700
Speed (MHz)	1,600	1,600	1,333	1,334
Speed running in the system (MHz)	1,600	1,600	1,333	1,066
Timing/Latency (tCL-tRCD-tRP-tRASmin)	11-11-11-28	11-11-11-28	9-9-9-24	7-7-7-20
Size (MB)	4,096	4,096	1 x 1,024, 1 x 2,048	1,024, 2,048
Number of memory module(s)	1	2	2	2
Total amount of system RAM (GB)	4	8	3	3
Channel (single/dual)	Single	Dual	Dual	Dual
Hard disk				
Vendor and model number	Hitachi HDS721050CLA362	Seagate ST1000DM003-1CH1	Hitachi HTS543232A7A384	Western Digital WD# 00BEVT-60A23T0
Number of disks in system	1	1	1	1
Size (GB)	500	1,000	320	320
Buffer size (MB)	16	64	8	8
RPM	7,200	7,200	5,400	5,400
Type	SATA 3.0 Gb/s	SATA 6.0 Gb/s	SATA 3.0 Gb/s	SATA 3.0 Gb/s
Controller	Intel 6 Series/C200 Series Chipset Family Serial ATA Storage Controller	Intel 8 Series/C220 Chipset Family SATA AHCI Controller	Intel 7 Series Chipset Family SATA AHCI Controller	AMD SATA Controller

System	Dell OptiPlex 3010	Dell XPS X8700	Gateway NE56R10U	HP Pavilion G62-340us
Driver	Windows 7: Intel 9.2.0.1011 (9/10/2010) Windows 10: Intel 9.2.0.1011 (9/10/2010)	Windows 7: Intel 12.0.0.1082 (1/22/2013) Windows 10: Intel 12.0.0.1082 (1/22/2013)	Windows 7: Intel 11.1.0.1006 (2/1/2012) Windows 10: Intel 11.1.0.1006 (2/1/2012)	Windows 7: AMD 1.2.0.164 (10/7/2009) Windows 10: AMD 1.2.0.164 (10/7/2009)
Operating system				
Name	Windows 7 Professional	Windows 7 Home Premium	Windows 7 Home Premium	Windows 7 Home Premium
Build number	7601	7601	7601	7601
Service Pack	1	1	1	1
File system	NTFS	NTFS	NTFS	NTFS
Kernel	ACPI x64-based PC	ACPI x64-based PC	ACPI x64-based PC	ACPI x64-based PC
Language	English	English	English	English
Microsoft DirectX version	DirectX 11	DirectX 11	DirectX 11	DirectX 11
Operating system				
Name	Windows 10 Pro	Windows 10 Home	Windows 10 Home	Windows 10 Home
Build number	10240	10240	10240	10240
Service Pack	N/A	N/A	N/A	N/A
File system	NTFS	NTFS	NTFS	NTFS
Kernel	ACPI x64-based PC	ACPI x64-based PC	ACPI x64-based PC	ACPI x64-based PC
Language	English	English	English	English
Microsoft DirectX® version	DirectX 12	DirectX 12	DirectX 12	DirectX 12
Graphics				
Vendor and model number	Intel HD Graphics 2500	NVIDIA® GeForce GT 720	Intel HD Graphics	AMD ATI Mobility Radeon™ HD 4250
Type	Integrated	Discrete	Integrated	Integrated
Chipset	Intel HD Graphics 2500	GeForce GT 720	Intel HD Graphics	AMD Radeon HD 4250
BIOS version	2137.9	80.28.56.0.1	2130.0	BK-ATI VER010.094.001.045 .035812
Total available graphics memory (MB)	1,696	4,096	1,326	1,405
Dedicated video memory (MB)	64	1,024	128	256
System video memory (MB)	0	0	0	0
Shared system memory (MB)	1,632	3,072	1,198	1,149
Resolution	1,280 x 1,024	1,280 x 1,024	1,366 x 768	1,366 x 768

System	Dell OptiPlex 3010	Dell XPS X8700	Gateway NE56R10U	HP Pavilion G62-340us
Driver	Windows 7: Intel 9.17.10.3040 (2/22/2013) Windows 10: Intel 10.18.10.4252 (7/10/2015)	Windows 7: NVIDIA 9.18.13.4752 (2/5/2015) Windows 10: NVIDIA 10.18.13.5362 (7/22/2015)	Windows 7: Intel 8.15.10.2653 (2/14/2012) Windows 10: Intel 9.17.10.4229 (5/27/2015)	Windows 7: ATI Technologies 8.770.2.1000 (9/19/2010) Windows 10: AMD 8.970.100.9001 (1/13/2015)
Sound card/subsystem				
Vendor and model number	Conexant SmartAudio HD	Realtek High Definition Audio	Realtek High Definition Audio	Realtek High Definition Audio
Driver	Windows 7: Conexant 8.50.14.50 (12/17/2013) Windows 10: Conexant 8.50.14.50 (12/17/2013)	Windows 7: Realtek 6.0.1.6909 (5/14/2013) Windows 10: Realtek 6.0.1.7535 (6/16/2015)	Windows 7: Realtek 6.0.1.6543 (1/3/2012) Windows 10: Realtek 6.0.1.7535 (6/16/2015)	Windows 7: Realtek 6.0.1.7404 (12/10/2014) Windows 10: Realtek 6.0.1.7535 (6/16/2015)
Ethernet				
Vendor and model number	Realtek PCIe GBE Family Controller	Realtek PCIe GBE Family Controller	Broadcom NetLink Gigabit Ethernet	Realtek PCIe GBE Family Controller
Driver	Windows 7: Realtek 7.67.1226.2012 (12/26/2012) Windows 10: Realtek 9.1.401.2015 (4/1/2015)	Windows 7: Realtek 7.67.1226.2012 (12/26/2012) Windows 10: Realtek 7.67.1226.2012 (12/26/2012)	Windows 7: Broadcom 15.0.1.0 (1/19/2012) Windows 10: Microsoft 15.6.1.2 (1/29/2013)	Windows 7: Realtek 7.46.610.2011 (6/10/2011) Windows 10: Realtek 9.1.401.2015 (4/1/2015)
Wireless				
Vendor and model number	N/A	Dell Wireless 1703	Atheros AR5B125 Wireless Network Adapter	Atheros AR9285 Wireless Adapter
Driver	N/A	Windows 7: Atheros Communications 9.2.0.514 (11/30/2012) Windows 10: Atheros Communications 9.2.0.514 (11/30/2012)	Windows 7: Atheros Communications 9.2.0.480 (1/10/2012) Windows 10: Atheros Communications 9.2.0.480 (1/10/2012)	Windows 7: Qualcomm Atheros Communications 10.0.0.67 (6/14/2012) Windows 10: Qualcomm Atheros Communications 10.0.0.212 (9/28/2012)
Optical drive(s)				
Vendor and model number	HL-DT-ST GH82N	TSST Corp SH-216DB	Matshita UJ8C0, Pioneer DVRTD11RS	HP TS-L633R
Type	DVD-RW	DVD-RW	DVD-RAM, DVD-RW	CD/DVD-W

System	Dell OptiPlex 3010	Dell XPS X8700	Gateway NE56R10U	HP Pavilion G62-340us
USB ports				
Number	10	10	3	3
Type	USB 2.0	2 x USB 3.0, 8 x USB 2.0	USB 2.0	USB 2.0
Other	Media Card Reader, HDMI port	Media Card Reader, HDMI port	Media Card Reader, HDMI port	Media Card Reader, HDMI port
Monitor				
Model	ViewSonic VG730m	ViewSonic VG730m	N/A	N/A
LCD type	SXGA LCD	SXGA LCD	LED-backlit	HD LED-backlit
Screen size	17"	17"	15.6"	15.6"
Refresh rate	60 Hz	60 Hz	60 Hz	60 Hz
Maximum resolution	1,280 x 1,024	1,280 x 1,024	N/A	N/A
Battery				
Type	N/A	N/A	6-cell Lithium Ion	6-cell Lithium Ion
Size (length x width x height)	N/A	N/A	10.68" x 2.12" x 0.75"	7.87" x 0.75" x 2.06"
Rated capacity	N/A	N/A	48 Wh	47 Wh
Weight	N/A	N/A	0.70 lbs.	0.64 lbs.

Figure 8: Configuration information for the test systems.

System	HP Pavilion G7 (1070us)	HP ProBook 450 G1	Lenovo ThinkCentre E73	Lenovo ThinkPad E540
General				
Number of processor packages	1	1	1	1
Number of cores per processor	2	2	2	2
Number of hardware threads per core	2	2	2	2
Total number of processor threads in system	4	4	4	4
System power management policy	HP Recommended	HP Optimized	ThinkCentre Default	Energy Saver
Processor power-saving option	Enhanced Intel SpeedStep Technology	Enhanced Intel SpeedStep Technology	Enhanced Intel SpeedStep Technology	Enhanced Intel SpeedStep Technology
System dimensions (length x width x height)	16.37" x 10.75" x 1.43"	14.76" x 10.09" x 0.9"	N/A	14.84" x 1.04" x 9.84"
System weight	6.12 lbs.	5.34 lbs.	N/A	5.22 lbs.
CPU				
Vendor	Intel	Intel	Intel	Intel
Name	Core i3	Core i5	Core i3	Core i5

System	HP Pavilion G7 (1070us)	HP ProBook 450 G1	Lenovo ThinkCentre E73	Lenovo ThinkPad E540
Model number	380M	4200M	4130	4200M
Stepping	K0	C0	C0	C0
Socket type	Socket 989 rPGA	Socket 947 rPGA	Socket 1150 LGA	Socket 947 rPGA
Core frequency (GHz)	2.53	2.50	3.40	2.50
L1 cache	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)
L2 cache	2 x 256 KB	2 x 256 KB	2 x 256 KB	2 x 256 KB
L3 cache	3 MB	3 MB	3 MB	3 MB
Platform				
Vendor	Hewlett-Packard	Hewlett-Packard	Lenovo	Lenovo
Motherboard model number	166A	1942	10AU002PUS	20C6008SUS
Motherboard chipset	Intel HM55	Intel HM87	Intel H81	Intel HM87
BIOS Name and version	Insyde F.66 (01/24/2013)	Hewlett-Packard L74 Ver.01.20 (07/16/2014)	Lenovo FCKT66AUS (02/09/2015)	Lenovo J9ET96WW (2.17) (12/12/2014)
Memory module(s)				
Vendor and model number	Samsung	SK Hynix HMT351S6EFR8A-PB	Ramaxel RMR5030MN68F9F1 600	Hyundai HMT451S6BFR8A-PB
Type	PC3-12800	PC3L-12800S	PC3-12800	PC3-12800
Speed (MHz)	1,600	1,600	1,600	1,600
Speed running in the system (MHz)	1,064	1,600	1,600	1,600
Timing/Latency (tCL-tRCD-tRP-tRASmin)	7-7-7-19	11-11-11-28	11-11-11-28	11-11-11-28
Size (MB)	2,048	4,096	4,096	4,096
Number of memory module(s)	2	2	1	1
Total amount of system RAM (GB)	4	8	4	4
Channel (single/dual)	Dual	Dual	Single	Single
Hard disk				
Vendor and model number	Hitachi HTS545050B9A300	Hitachi HGST HTS541075A9E680	Western Digital WDC WD5000AAKX-08U6A	Hitachi HGST HTS725050A7E630
Number of disks in system	1	1	1	1
Size (GB)	500	750	500	500
Buffer size (MB)	8	8	16	32
RPM	5,400	5,400	7,200	7,200
Type	SATA 3.0 Gb/s	SATA 6.0 Gb/s	SATA 6.0 Gb/s	SATA 6.0 Gb/s

System	HP Pavilion G7 (1070us)	HP ProBook 450 G1	Lenovo ThinkCentre E73	Lenovo ThinkPad E540
Controller	Intel 5 Series 4 Port SATA AHCI Controller	Intel 8 Series Chipset Family SATA AHCI Controller	Intel 8 Series/C220 Chipset Family SATA AHCI Controller	Intel 8 Series Chipset Family SATA AHCI Controller
Driver	Windows 7: Intel 10.0.0.1046 (9/13/2010) Windows 10: Intel 10.0.0.1046 (9/13/2010)	Windows 7: Intel 12.7.3.1001 (7/24/2013) Windows 10: Intel 12.7.3.1001 (7/24/2013)	Windows 7: Intel 13.0.0.1098 (2/5/2014) Windows 10: Intel 13.0.0.1098 (2/5/2014)	Windows 7: Intel 12.8.0.1016 (8/1/2013) Windows 10: Intel 12.8.0.1016 (8/1/2013)
Operating system				
Name	Windows 7 Home Premium	Windows 7 Professional	Windows 7 Professional	Windows 7 Professional
Build number	7601	7601	7601	7601
Service Pack	1	1	1	SP1
File system	NTFS	NTFS	NTFS	NTFS
Kernel	ACPI x64-based PC	ACPI x64-based PC	ACPI x64-based PC	ACPI x64-based PC
Language	English	English	English	English
Microsoft DirectX version	DirectX 11	DirectX 11	DirectX 11	DirectX 11
Operating system				
Name	Windows 10 Home	Windows 10 Pro	Windows 10 Pro	Windows 10 Pro
Build number	10240	10240	10240	10240
Service Pack	N/A	N/A	N/A	N/A
File system	NTFS	NTFS	NTFS	NTFS
Kernel	ACPI x64-based PC	ACPI x64-based PC	ACPI x64-based PC	ACPI x64-based PC
Language	English	English	English	English
Microsoft DirectX® version	DirectX 12	DirectX 12	DirectX 12	DirectX 12
Graphics # 1				
Vendor and model number	Intel HD Graphics	Intel HD Graphics 4600	Intel HD Graphics 4400	Intel HD Graphics 4600
Type	Integrated	Integrated	Integrated	Integrated
Chipset	Intel HD Graphics (Core i3)	4600	Intel HD Graphics 4400	4600
BIOS version	2104.0	2175.0	2177.0	2,179.0
Total available graphics memory (MB)	1,696	5,060	1,696	1,696
Dedicated video memory (MB)	64	1,280	64	64
System video memory (MB)	0	0	0	0
Shared system memory (MB)	1,632	3,780	1,632	1,632
Resolution	1,600 x 900	1,366 x 768	1,280 x 1,024	1,366 x 768

System	HP Pavilion G7 (1070us)	HP ProBook 450 G1	Lenovo ThinkCentre E73	Lenovo ThinkPad E540
Driver	Windows 7: Intel 8.15.10.2509 (8/31/2011) Windows 10: Intel 8.15.10.2900 (11/26/2012)	Windows 7: Intel 9.18.10.3324 (10/7/2013) Windows 10: Intel 10.18.15.4256 (7/17/2015)	Windows 7: Intel 10.18.14.4170 (3/16/2015) Windows 10: Intel 10.18.15.4256 (7/17/2015)	Windows 7: Intel 9.18.10.3272 (8/8/2013) Windows 10: Intel 10.18.15.4256 (7/17/2015)
Graphics #2				
Vendor and model number	N/A	AMD Radeon HD 8750M	N/A	N/A
Type	N/A	Discrete	N/A	N/A
Chipset	N/A	Radeon HD 8750M	N/A	N/A
Resolution	N/A	1,366 x 768	N/A	N/A
Driver	N/A	Windows 7: Advanced Micro Devices 13.152.1.9002 (1/21/2014) Windows 10: Advanced Micro Devices 15.200.1062.1003 (7/28/2015)	N/A	N/A
Sound card/subsystem				
Vendor and model number	IDT High Definition Audio	IDT High Definition Audio	Realtek High Definition Audio	Conexant SmartAudio HD
Driver	Windows 7: IDT 6.10.66315.0 (12/1/2010) Windows 10: IDT 6.10.6315.0 (12/1/2010)	Windows 7: IDT 6.10.6486.0 (7/5/2013) Windows 10: IDT 6.10.6486.0 (7/5/2013)	Windows 7: Intel 10.18.14.4170 (3/16/2015) Windows 10: Realtek 6.0.1.7535 (6/16/2015)	Windows 7: Conexant 8.65.17.50 (11/19/2013) Windows 10: Conexant 8.66.4.0 (5/13/2015)
Ethernet				
Vendor and model number	Realtek PCIe FE Family Controller	Realtek PCIe GBE Family Controller	Realtek PCIe GBE Family Controller	Realtek PCIe GBE Family Controller
Driver	Windows 7: Realtek 7.46.610.2011 (6/10/2011) Windows 10: Realtek 9.1.401.2015 (4/1/2015)	Windows 7: Realtek 7.73.618.2013 (6/18/2013) Windows 10: Realtek 7.73.618.2013 (6/18/2013)	Windows 7: Realtek 7.67.1226.2012 (12/26/2012) Windows 10: Realtek 7.67.1226.2012 (12/26/2012)	Windows 7: Realtek 7.73.618.2013 (6/18/2013) Windows 10: Realtek 10.1.505.2015 (5/5/2015)
Wireless				
Vendor and model number	Broadcom 4313	Intel Dual Band Wireless-AC 3160	N/A	Intel Wireless-N 7260

System	HP Pavilion G7 (1070us)	HP ProBook 450 G1	Lenovo ThinkCentre E73	Lenovo ThinkPad E540
Driver	Windows 7: Broadcom 5.60.350.23 (9/1/2010) Windows 10: Broadcom 5.60.350.23 (9/1/2010)	Windows 7: Intel 16.10.0.5 (1/28/2014) Windows 10: Intel 17.15.0.5 (2/22/2015)	N/A	Windows 7: Intel 17.0.2.5 (4/16/2014) Windows 10: Intel 17.15.0.5 (2/22/2015)
Optical drive(s)				
Vendor and model number	HP TS-L633R	HP UJ8DBD	PLDS DH16AESH	HL-DT-ST GU90N
Type	CD-DVD-W	DVD-RAM	DVD-RW	DVDRAM
USB ports				
Number	3	4	6	3
Type	USB 2.0	2 x USB 3.0, 2 x USB 2.0	2 x USB 3.0, 4 x USB 2.0	2 x USB 3.0, 1 x USB 2.0
Other	Media Card Reader, HDMI port	Media Card Reader, HDMI port	Media Card Reader, Display port	Media Card Reader, HDMI port
Monitor				
Model	N/A	N/A	ViewSonic VG730m	N/A
LCD type	HD LED-backlit	HD LED-backlit	SXGA LCD	HD LED
Screen size	15.6"	15.6"	17"	15.6"
Refresh rate	60	60 Hz	60 Hz	60 Hz
Maximum resolution	N/A	N/A	1,280 x 1,024	N/A
Battery				
Type	6-cell Lithium Ion	4 cell Lithium-Ion	N/A	6 cell Lithium-Ion
Size (length x width x height)	7.87" x 2.12" x 0.81"	10.55" x 1.75" x 0.75"	N/A	8" x 2" x 0.75"
Rated capacity	47 Wh	65 Wh	N/A	48 Wh
Weight	0.67 lbs.	0.65 lbs.	N/A	0.62 lbs.

Figure 9: Configuration information for the test systems.

System	Lenovo ThinkPad E545	Samsung Series 5 NP530	Samsung Series 5 NP535	Toshiba Satellite L455
General				
Number of processor packages	1	1	1	1
Number of cores per processor	2	2	2	1
Number of hardware threads per core	1	2	2	1

System	Lenovo ThinkPad E545	Samsung Series 5 NP530	Samsung Series 5 NP535	Toshiba Satellite L455
Total number of processor threads in system	2	4	2	1
System power management policy	Energy Saver	Samsung Optimized	Samsung Optimized	Balanced
Processor power-saving option	AMD PowerNow!	Enhanced Intel SpeedStep Technology	AMD PowerNow!	AMD PowerNow!
System dimensions (length x width x height)	14.84" x 9.64" x 1.34"	13.1" x 9.0" x 0.82"	12.4" x 8.6" x 0.69"	15.06" x 10.5" x 1.50"
System weight	5.14 lbs.	3.84 lbs.	3.22 lbs.	5.90 lbs.
CPU				
Vendor	AMD	Intel	AMD	AMD
Name	A6-5350M	Core i5	A6	Sempron
Model number	A6-5350M	2467M	4455M	SI-42
Stepping	RL-A1	D2	TN-A1	LG-B1
Socket type	Socket FP2 (827)	Socket 1023 FCBGA	Socket FP2 (827)	Socket S1 (638)
Core frequency (GHz)	2.90	1.60	2.10	2.10
L1 cache	64 KB (per core)	32 KB + 32 KB (per core)	64 KB + 64 KB (per core)	64 KB + 64 KB (per core)
L2 cache	1024 KB	2 x 256 KB	2048 KB	512 KB
L3 cache	N/A	3 MB	N/A	N/A
Platform				
Vendor	Lenovo	Samsung	Samsung	Toshiba
Motherboard model number	20B20011US	530U3BI/530U4BI/530U4BH	NP1234567890	NBWAE
Motherboard chipset	AMD K15 IMC	Intel HM65	AMD K15 IMC	AMD 780G
BIOS Name and version	Lenovo HRET24WW (1.12) (01/24/2014)	Phoenix Technologies 13XK (03/28/2013)	American Megatrends P07RAG.N53.130403 .LEO (04/03/2013)	Toshiba V1.30 (11/25/2010)
Memory module(s)				
Vendor and model number	Hyundai HMT451S6BFR8A-PB	Unknown	Unknown	Samsung M4 70T5663EH3-CF7
Type	PC3-12800	Unknown	Unknown	PC2-6400
Speed (MHz)	1,600	1,333	1,333	800
Speed running in the system (MHz)	1,600	1,333	1,349	667
Timing/Latency (tCL-tRCD-tRP-tRASmin)	11-11-12-28	9-9-9-24	9-9-10-24	3-3-3-11
Size (MB)	4,096	4,096	4,096	2,048
Number of memory module(s)	1	1	1	1

System	Lenovo ThinkPad E545	Samsung Series 5 NP530	Samsung Series 5 NP535	Toshiba Satellite L455
Total amount of system RAM (GB)	4	4	4	2
Channel (single/dual)	Single	Single	Single	Single
Hard disk				
Vendor and model number	Western Digital WDC WD3200LPVX-08V0TT5	System 1: Seagate ST500LM012 System 2: Seagate ST500LT012	System 1: Seagate ST500LT012-1DG142 System 2: Hitachi HTS545050A7E380	Western Digital WDC WD2500BEVT-26ZCT0
Number of disks in system	1	1	1	1
Size (GB)	320	500	500	250
Buffer size (MB)	8	System 1: 8 System 2: 16	System 1: 16 System 2: 8	8
RPM	5,400	5,400	5,400	5,400
Type	SATA 6.0 Gb/s	System 1: SATA 6.0 Gb/s System 2: SATA 3.0 Gb/s	SATA 3.0 Gb/s	SATA 3.0 Gb/s
Controller	AMD SATA Controller	Intel Mobile Express Chipset SATA AHCI Controller	AMD SATA Controller	Standard AHCI 1.0 Serial ATA Controller
Driver	Windows 7: AMD 1.2.1.331 (4/11/2012) Windows 10: AMD 1.3.1.277 (4/15/2015)	Windows 7: Intel 10.1.5.1001 (2/18/2011) Windows 10: Intel 10.1.5.1001 (2/18/2011)	Windows 7: AMD 1.2.1.327 (12/12/2011) Windows 10: AMD 1.2.1.327 (12/12/2011)	Windows 7: Microsoft 6.1.7601.18231 (6/21/2006) Windows 10: Microsoft 10.0.10240.16384 (6/21/2006)
Operating system				
Name	Windows 7 Professional	Windows 7 Home Premium	Windows 7 Home Premium	Windows 7 Home Premium
Build number	7601	7600	7601	7600
Service Pack	1	1	SP1	1
File system	NTFS	NTFS	NTFS	NTFS
Kernel	ACPI x64-based PC	ACPI x64-based PC	ACPI x64-based PC	ACPI x86-based PC
Language	English	English	English	English
Microsoft DirectX version	DirectX11	DirectX 11	DirectX 11	DirectX 11
Operating system				
Name	Windows 10 Pro	Windows 10 Home	Windows 10 Home	Windows 10 Home
Build number	10240	10240	10240	10240
Service Pack	N/A	N/A	N/A	N/A

System	Lenovo ThinkPad E545	Samsung Series 5 NP530	Samsung Series 5 NP535	Toshiba Satellite L455
File system	NTFS	NTFS	NTFS	NTFS
Kernel	ACPI x64-based PC	ACPI x64-based PC	ACPI x64-based PC	ACPI x86-based PC
Language	English	English	English	English
Microsoft DirectX® version	DirectX 12	DirectX 12	DirectX 12	DirectX 12
Graphics				
Vendor and model number	AMD Radeon HD 8450G	Intel HD Graphics 3000	AMD Radeon HD 7500G	ATI Radeon 3100
Type	Integrated	Integrated	Integrated	Discrete
Chipset	Radeon HD 8450G	Intel HD Graphics 3000	7500G	Radeon 3100
BIOS version	113-DVST-113	2098.0	BRO42452.006	BK-ATI VER010.094.001.031 .033844
Total available graphics memory (MB)	2,124	1,696	2,030	895
Dedicated video memory (MB)	768	64	512	256
System video memory (MB)	0	0	0	0
Shared system memory (MB)	1,356	1,632	1,518	639
Resolution	1,366 x 768	1,366 x 768	1,366 x 768	1,366 x 768
Driver	Windows 7: Advanced Micro Devices 12.102.1.8000 (4/24/2013) Windows 10: Advanced Micro Devices 15.200.1062.1002 (7/15/2015)	Windows 7: Intel 8.15.10.2622 (1/10/2012) Windows 10: Intel 9.17.10.4229 (5/27/2015)	Windows 7: Advanced Micro Devices 8.945.2.0 (4/25/2012) Windows 10: Advanced Micro Devices 15.200.1055.0 (7/6/2015)	Windows 7: ATI Technologies 8.634.1.0 (7/29/2009) Windows 10: AMD 8.970.100.9001 (1/13/2015)
Sound card/subsystem				
Vendor and model number	Conexant 20671 SmartAudio HD	Realtek High Definition Audio	Realtek High Definition Audio	Realtek High Definition Audio
Driver	Windows 7: Conexant 8.65.17.50 (11/19/2013) Windows 10: Conexant 8.54.48.0 (9/20/2012)	Windows 7: Realtek 6.0.1.6699 (8/7/2012) Windows 10: Realtek 6.0.1.7535 (6/16/2015)	Windows 7: Realtek 6.0.1.6699 (8/7/2012) Windows 10: Realtek 6.0.1.7543 (6/23/2015)	Windows 7: Realtek 6.0.1.5904 (7/28/2009) Windows 10: Realtek 6.0.1.7535 (6/16/2015)

System	Lenovo ThinkPad E545	Samsung Series 5 NP530	Samsung Series 5 NP535	Toshiba Satellite L455
Ethernet				
Vendor and model number	Realtek PCIe GBE Family Controller	Realtek PCIe GBE Family Controller	Realtek PCIe GBE Family Controller	Realtek RTL8102E/RTL8103E Family PCI-E Fast Ethernet
Driver	Windows 7: Realtek 7.48.823.2011 (8/23/2011) Windows 10: Realtek 9.1.401.2015 (4/1/2015)	Windows 7: Realtek 7.45.516.2011 (5/16/2011) Windows 10: Realtek 9.1.401.2015 (4/1/2015)	Windows 7: Realtek 7.50.1123.2011 (11/23/2011) Windows 10: Realtek 10.1.505.2015 (5/5/2015)	Windows 7: Realtek 7.3.522.2009 (5/22/2009) Windows 10: Realtek 9.1.401.2015 (4/1/2015)
Wireless				
Vendor and model number	Realtek RTL8188E	Intel Centrino Advanced-N 6230	Qualcomm Atheros AR946x	Realtek RTL8187SE Wireless LAN PCIE Adapter
Driver	Windows 7: Realtek 2007.8.201.2013 (2/1/2013) Windows 10: Realtek 2023.4.115.2015 (2/12/2015)	Windows 7: Intel 15.3.1.2 (9/30/2012) Windows 10: Microsoft 15.4.1.1 (1/23/2013)	Windows 7: Qualcomm Atheros Communications 10.0.0.42 (3/8/2012) Windows 10: Qualcomm Atheros Communications 10.0.0.321 (6/16/2015)	Windows 7: Realtek 6.9071.822.2008 (8/22/2008) Windows 10: Realtek 6.9071.822.2008 (8/22/2008)
Optical drive(s)				
Vendor and model number	HL-DT-ST GT80N	TSST Corp SU-208AB	N/A	TSST Corp TS-L633C
Type	DVD	CD/DVDW	N/A	CD/DVD-W
USB ports				
Number	4	3	3	2
Type	3 x USB 3.0, 1 x USB 2.0	2 x USB 3.0, 1 x USB 2.0	1 x USB 3.0, 2 x USB 2.0	USB 2.0
Other	Media Card Reader, HDMI port	Media Card Reader, HDMI port	Media Card Reader, HDMI port	Memory Card Reader
Monitor				
LCD type	HD LED-backlit	HD LED	HD LED	HD LCD
Screen size	15.6"	14"	13.3"	15.6"
Refresh rate	60 Hz	60 Hz	60 Hz	60 Hz

System	Lenovo ThinkPad E545	Samsung Series 5 NP530	Samsung Series 5 NP535	Toshiba Satellite L455
Battery				
Type	6-cell Lithium Ion	8-cell Lithium Ion	4 cell Lithium-Ion	6-cell Lithium Ion
Size (length x width x height)	8" x 2.06" x 0.81"	Integrated	Integrated	8.06" x 2" x 0.75"
Rated capacity	48 Wh	N/A	N/A	44 Wh
Weight	0.63	Integrated	Integrated	0.66 lbs.

Figure 10: Configuration information for the test systems.

APPENDIX B – HOW WE TESTED

Setting up the system

Downlevel OS

1. Install or recover the OEM factory image.
2. Complete the out-of-box setup procedures.
3. Run Windows Update, and install all Important Updates.
4. Copy the contents of WPT.zip to %SystemDrive%\WPT.
5. Proceed to [Preparing the System for Test](#).

Upgrading to Windows 10

Before upgrading to Windows 10, make sure that Windows Update is enabled and set to Automatic (default setting) on the current OS.

1. Insert Windows 10 DVD or USB media in the test PC, and run SETUP.EXE.
2. Follow the on-screen instructions to complete the upgrade.
3. Run Windows Update, and install all updates.
4. Launch the Store app, and install all Store app updates.
5. Check if any driver or app installation is in progress and allow the installation to complete before proceeding.
6. Proceed to [Preparing the System for Test](#). Ensure you follow these steps again after upgrading to Windows 10 because some of these options reset during upgrade.

Preparing the system for test

Make the following system changes. Repeat these steps on each system.

1. Activate Windows.
2. Turn off Automatic Windows Updates.
 - a. In Windows Search, type `Windows Update`
 - b. Click Change settings.
 - c. Select Never check for updates (not recommended).
3. Turn off UAC notifications.
 - a. In Windows Search, type `User Account Control` and select Change User Account Control settings.
 - b. Move the slider bar to Never notify.
4. Turn off the system screensaver.
 - a. In Windows Search, type `screen saver` and select Change screen saver.
 - b. From the screen saver drop-down box, select None.
5. Set Turn off the display to Never.
 - a. In Windows Search, type `power options` and press Enter.
 - b. Next to the active power plan being used, click Change plan settings.
 - c. From the Turn off the display drop-down boxes (located under On battery and Plugged in), select Never.
6. Set Put the computer to sleep to Never.
 - a. In Windows Search, type `power options` and press Enter.

- b. Next to the active power plan being used, click Change plan settings.
 - c. From the Put the computer to sleep drop-down boxes (located under On battery and Plugged in), select Never.
7. Turn off Action Center Alerts.
 - a. In Windows search, type `action center` and press Enter.
 - b. Click Change Action Center settings.
 - c. Uncheck every box, and click OK.
8. Disable Adaptive Brightness.
 1. In Windows Search, type `power options` and press Enter.
 2. Next to the active power plan being used, click Change plan settings.
 3. Click Change Advanced Power Settings.
 4. Expand the Display node.
 5. Expand the Enable Adaptive Brightness node.
 6. Set the On battery and Plugged in values to Off.
9. Set the Display Brightness and the Dimmed Brightness levels to 150 nits.
 - a. Unplug the system and open the default web browser, and open a plain white webpage by typing `about:blank` into the address bar.
 - b. Allow the display to warm for 5 minutes.
 - c. Using a Gossen® Mavolux 5032C luminance reader, set the display brightness on each system as close to 150 nits without going under.
 - d. Close the webpage.
10. Disable Keyboard Backlighting.
11. Set the system audio level to 50% by clicking the speaker icon on the taskbar and moving the slider bar to 50%.
12. Download the latest virus definition files and app update and perform a scan using the default anti-malware application.
13. Open the Disk Performance Monitor by right-clicking the taskbar and selecting Start Task Manager→Performance tab→Resource Monitor→Disk tab.
14. Run Idle Tasks.
 1. Press the Windows key.
 2. In Windows Search, type `cmd`
 3. Right-click `cmd.exe`, and select Run as administrator.
 4. In the elevated command prompt, enter the following:
`Cmd.exe /c start /wait Rundll32.exe advapi32.dll,ProcessIdleTasks`
 5. Watch the disk performance monitor and do not interact with the system until the disk activity is 0%.
 6. After the disk activity is 0%, wait 5 minutes before running the test.
15. Verify that the clock is set to the correct time.

16. During upgrade, connect Wi-Fi to an access point that has an Internet connection. During all testing, connect to an access point that does not have an internet connection. When connecting to the access point, click No on the prompt to Share and see other network devices.
17. Populate the WinSAT data store by typing the following into an elevated command prompt:
`winsat prepop`
18. Reboot the system.

Additional setup steps for Windows 7

1. Run the Win7PowerTracingKey.reg file to add it to the registry key. Reboot the machine after adding this (or add this before the final Reboot step, above).

Additional setup steps for Windows 10 (post-upgrade)

1. Disable Windows Store Updates. Run this command on an elevated command prompt:
`reg add
"HKLM\Software\Microsoft\Windows\CurrentVersion\WindowsStore\WindowsUpdate"
/v AutoDownload /t REG_DWORD /d 2 /f`
2. Follow the below instructions from an elevated command prompt to disable WU.
 - a. Unpack the disableupdates.zip archive.
 - b. Run the following commands on an elevated command prompt:
`Apply_LGPO_Delta.exe gpdelta.log
gpupdate /force`
3. Reboot system.

Measuring startup times

Assessing Windows ADK Boot Performance (Full Boot)

1. Copy and unzip the FULLBOOT_10240.zip test package on the test machine.
2. Run RUNJOB.cmd within the extracted package folder to start the test.
 - The test execution is fully automated and restarts the system in between prep and timing runs.
 - Results will be generated in the test package folder under the results sub-directory where the test package was extracted.
3. Move the results off the test system.

Assessing Windows ADK Boot Performance (Fast Startup)

1. Copy and unzip the FASTSTARTUP_10240.zip test package on the test machine.
2. Run RUNJOB.cmd within the extracted package folder to start the test.
 - The test execution is fully automated and restarts the system in between prep and timing runs.
 - Results will be generated in the test package folder under the results sub-directory where the test package was extracted.
3. Move the results off the test system.

Measuring battery life based on video playback

Local full screen video playback (FSVP) – Setting up the test

We used the following applications to play media clips locally. Verify that they are the default apps to handle the MP4 file extension:

- Windows 7: Windows Media Player
- Windows 10: Movies & TV app (latest version in the store)

Note on the number of iterations for this test: We ran this test two times, and if the variation was less than 5% we did not perform additional runs. If the variation was greater than 5%, then a third test run was performed.

1. Determine which content will be played (720p or 1080p) by checking the current screen resolution of the device.
 - On devices with screen resolutions greater or equal to 1920x1080, use 1080p3min.mp4.
 - On devices with screen resolutions less than 1920x1080, use 720p3min.mp4.
2. Copy the unzipped BatteryLife_LocalFullScreenVideoPlayback folder to C:\temp on the test machine.
3. Verify the system is 100% charged.
4. Launch and configure the PwrInfo.exe tool (see Figure 15).
 - a. Click on Configure.
 - b. Set the Refresh Interval duration to 60,000 (1 minute).
 - c. Select the checkbox next to Enable logging.
 - d. Set the path to a log file name such as: C:\temp*MachineName-OSVer-Content-Player.csv* (for example, Dell1464-Win7-720p-WMP.csv).
 - e. Press OK then minimize the PwrInfo.exe tool.
5. Start the ETW tracing script.
 - a. Start an elevated command prompt and enter the following commands:

```
cd /d c:\temp
Trace_Video.cmd
```
 - b. Minimize the command prompt window.

Opening the battery life test content in the correct media player

On Windows 7, the content should automatically playback in the Windows Media Player. On Windows 10, the content should automatically playback in the Movies & TV app.

Running the video playback battery life test

1. In the media player, enable the loop/repeat option so that the content endlessly plays until the device shuts down.
2. Maximize the playback application so that video is rendering in Full Screen mode. Verify that none of the desktop can be seen (including the taskbar).
3. Move the mouse cursor to the center of the screen, and verify that the transport controls (seek, pause, play, volume, etc.) fade away.
4. Unplug the device from AC Power, and do not interact with the mouse, keyboard, or the device until it shuts down.

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