



Desktop and notebook system processors: Time and energy savings from upgrading to current models

Executive summary

Intel® Corporation (Intel) commissioned Principled Technologies (PT) to measure and compare the performance and energy usage of a current Intel® Core™ 2 Duo processor-based desktop and notebook system against that of an older Intel® Pentium® 4 processor-based desktop system and an older Intel® Core™ Duo processor-based notebook system while running three custom application scenarios.

We tested the following desktop and notebook systems:

- Intel Core 2 Duo processor E8400-based desktop system
- Intel Pentium 4 processor 640-based desktop system
- Intel Core 2 Duo processor P8600-based notebook system
- Intel Core Duo processor T2700-based notebook system

These systems performed the following custom application scenarios:

- Copying a 499MB folder from the C: drive to the computer desktop with BitLocker enabled
- Opening all of the Intuit QuickBooks Pro 2009 Favorite Reports in QuickBooks
- Running a series of Intel-supplied multitasking tests that measure performance and energy usage

KEY FINDINGS

- The Intel Core 2 Duo processor E8400-based desktop system finished the BitLocker-encoded folder copy task 1.73 times faster, the QuickBooks Favorite Reports task 2.54 times faster, and the multitasking tests 2.62 times faster than did the Intel Pentium 4 processor 640-based desktop system. (See Figures 1 and 3.)
- The Intel Core 2 Duo processor P8600-based notebook system finished the BitLocker-encoded folder copy task 1.46 times faster, the QuickBooks Favorite Reports task 1.70 times faster, and the multitasking tests 1.33 times faster than did the Intel Core Duo processor T2700-based notebook system. (See Figures 2 and 3.)
- The Intel Core 2 Duo processor P8600-based notebook system finished the BitLocker-encoded folder copy task 1.13 times faster, the QuickBooks Favorite Reports task 2.81 times faster, and the multitasking tests 2.25 times faster than did the Intel Pentium 4 processor 640-based desktop system. (See Figure 3.)
- The Intel Core 2 Duo processor E8400-based desktop system used 77.0 percent less energy than did the Intel Pentium 4 processor 640-based desktop system. The Intel Core 2 Duo processor P8600-based notebook system used 38.1 percent less energy than did the Intel Core Duo processor T2700-based notebook system.

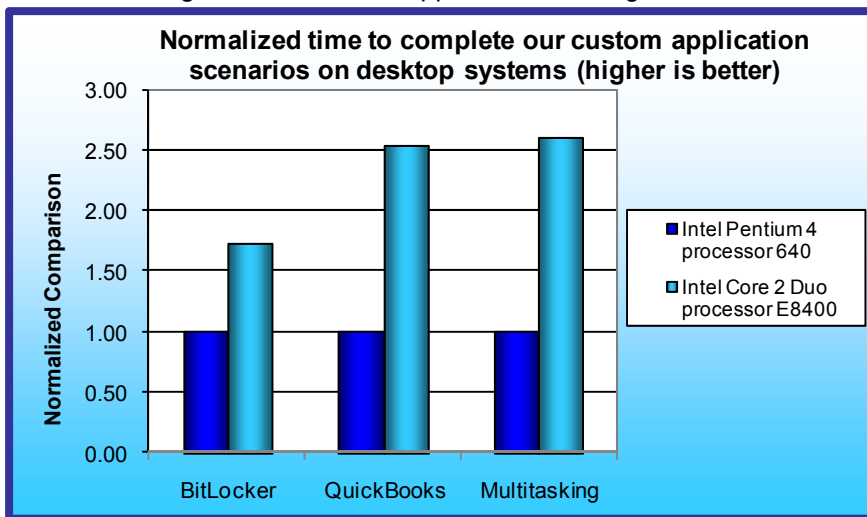


Figure 1: Median normalized time, in seconds, the desktop systems took to complete the custom application scenarios. Higher numbers are better.

We measured the increase in speed that the latest generation of Intel Core 2 Duo processors brought to our custom application scenarios. We used these test scenarios to represent realistic desktop and notebook usage.

As the Key findings state and the Test results show, the Intel Core 2 Duo processor E8400- and P8600-based systems significantly outperform the Intel Pentium 4 processor 640- and Intel Core Duo processor T2700-based systems in our custom application scenarios. The Intel Core 2 Duo processor P8600-based notebook system also significantly outperforms the Intel

Pentium 4 processor 640-based desktop system. The Intel Core 2 Duo processor E8400- and P8600-based systems use significantly less energy than the Intel Pentium 4 processor 640- and Intel Core Duo processor T2700-based systems.

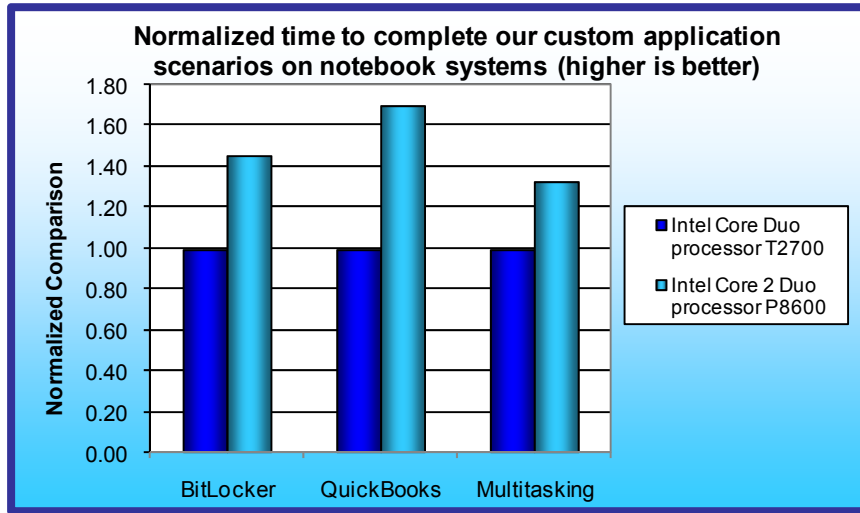


Figure 2: Median normalized time, in seconds, the notebook systems took to complete the custom application scenarios. Higher numbers are better.

Figure 2 displays the median normalized time the Intel Core 2 Duo processor P8600- and Intel Core Duo processor T2700-based notebook systems took to complete the three application scenarios. As Figure 2 shows, the Intel Core 2 Duo processor P8600-based notebook system finished the BitLocker-encoded folder copy task 1.46 times faster (11.9 seconds less), the QuickBooks Favorite Reports task 1.70 times faster (4.9 seconds less), and the multitasking tests 1.33 times faster (20.9 seconds less) than did the Intel Core Duo processor T2700-based notebook system.

As Figure 3 shows, the Intel Core 2 Duo processor P8600-based notebook system was faster than the older Intel Pentium 4 processor 640-based desktop system. The notebook finished the BitLocker-encoded folder copy task 1.13 times faster (3.5 seconds less), the QuickBooks Favorite Reports task 2.8 times faster (12.7 seconds less), and the multitasking tests 2.25 times faster (80 seconds less) than did the older desktop.

Throughout our testing, the Intel Core 2 Duo processor E8400-based desktop system used 77.0 percent less energy than did the Intel Pentium 4 processor 640-based desktop system, and the Intel Core 2 Duo processor P8600-based notebook system used 38.1 percent less energy than did the Intel Core Duo processor T2700-based notebook system. We measured energy in watt-hours using the Watts Up Watt Meter. Watts Up took energy readings during the multitasking test script runs.

In the following sections, we present the results of our tests (Test results), look more closely at our test application scenarios (Application scenarios), and give detailed information about how we actually performed the tests (Test methodology). In Appendix A, we present the configurations of the test systems. In Appendix B, we explain how to manually execute the application functions in our scenarios.

Test results

Figure 3 shows the median times, in seconds, each system took to complete each of the three custom application scenarios. We conducted each test five times and report the median time for each system.

Figure 1 displays the median normalized time the Intel Core 2 Duo processor E8400- and Intel Pentium 4 processor 640-based desktop systems took to complete the three application scenarios. As Figure 1 shows, the Intel Core 2 Duo processor E8400-based desktop system finished the BitLocker-encoded folder copy task 1.73 times faster (12.5 seconds less), the QuickBooks Favorite Reports task 2.54 times faster (12.0 seconds less), and the multitasking tests 2.62 times faster (89.0 seconds less) than did the Intel Pentium 4 processor 640-based desktop system.

Figure 2 displays the median normalized time the Intel Core 2 Duo processor P8600- and Intel Core Duo processor T2700-based notebook systems took to complete the three application scenarios. As Figure 2 shows, the Intel Core 2 Duo processor P8600-based notebook system finished the BitLocker-encoded folder copy task 1.46 times faster (11.9 seconds less), the QuickBooks Favorite Reports task 1.70 times faster (4.9 seconds less), and the multitasking tests 1.33 times faster (20.9 seconds less) than did the Intel Core Duo processor T2700-based notebook system.

Application scenarios	Desktop systems		Notebook systems	
	Intel Core 2 Duo processor E8400-based system	Intel Pentium 4 processor 640-based system	Intel Core 2 Duo processor P8600-based system	Intel Core Duo processor T2700-based system
Total time to copy folder with BitLocker enabled	17.19	29.66	26.20	38.13
Total time to open Favorite Reports in QuickBooks	7.77	19.75	7.03	11.97
Total time to run multitasking tests	55.10	144.10	64.10	85.00
Total energy used to run multitasking tests	1.31	5.72	0.72	1.17

Figure 3: Median times, in seconds, or median energy, in watt-hours, the systems took to complete the custom application scenarios. Lower numbers indicate shorter times or lower energy usage and are therefore better.

Application scenarios

We created two application scenarios, and Intel provided the third application scenario, to illustrate the benefits of an upgraded PC.

The scenarios include the following:

- Viewing results from a BitLocker-encrypted results folder
- Using QuickBooks to open a set of memorized reports
- Running the following multitasking tests: Monte Carlo running in Excel, PDF conversion in PowerPoint, batch photo processing in Photo Shop Elements, and video encoding in TMPGEnc XPress

Each of these scenarios involves one or more basic operations, such as copying a folder or opening files. The results of the scenario are the response times for each of these operations. We used realistic operations and content for all tests.

Data security Windows Vista BitLocker encryption scenario: Copying a folder on an encrypted volume

For security reasons, some IT departments use Windows Vista's BitLocker technology to encrypt hard disk partitions. A user working on a BitLocker-encrypted drive might choose to open the folder where he or she keeps a golden, unchanging version of his or her files and make a working copy on his or her desktop.

We timed:

- the folder copy from when the user right-clicks the BitLockerWorkload test folder and chooses Copy Here until the dialog box with the progress bar disappears

QuickBooks Pro 2009 Favorite Reports viewing scenario: Opening a set of memorized reports

For accounting work, some businesses use Intuit QuickBooks to review financial data. A user working with Intuit QuickBooks Pro 2009 might choose to open a set of memorized reports to view financial data.

We timed:

- the appearance of the Intuit QuickBooks Pro 2009 reports from when the user clicks Display until all the report windows are open

Multitasking tests scenario: Running a series of multitasking tests

In order to test a variety of multitasking tests (from Microsoft Office to multimedia projects), Intel provided the scripts that we used for our third scenario. A small business owner, for example, might do some business analysis, then for marketing purposes create a PDF, modify some photos, and create some videos for his or her

website. Intel designed these tests, which show how high performance systems reduce energy consumption due to their quicker completion of CPU demanding tasks.

We timed:

- the completion of the Monte Carlo simulation, the conversion of a PowerPoint file into PDF format, the batch processing of 12 photos, and the conversion of an MPG file into M2T video format from when the user clicks OK to when the applications finish

Test methodology

Setting up the test systems

To get the most accurate and repeatable results possible, start with a clean hard disk and set up all the test systems using the following procedures.

The Windows Vista installation steps below apply to all three scenarios.

Installing Microsoft Windows Vista Ultimate 32-bit edition with SP1

Use the following process to install a clean version of Windows Vista Ultimate on each system under test:

1. Install Windows Vista Ultimate 32-bit edition with SP1.
 - a. Boot to a Windows Vista Ultimate with SP1 DVD.
 - b. When prompted, press any key to boot from CD or DVD.
 - c. At the language, time, and keyboard preference screen, accept the default options, and click Next.
 - d. Click Install now.
 - e. Do not enter a Product key. Uncheck Automatically activate Windows when I'm online, and click Next.
 - f. At the Do you want to enter your product key now screen, click No.
 - g. Select Windows Vista Ultimate, and check I have selected the edition of Windows that I purchased.
 - h. Click Next.
 - i. Check I accept the license terms.
 - j. Click Next.
 - k. At the Which type of installation do you want screen, select Custom (advanced).
 - l. Click Drive options (advanced).
 - m. Select the destination Disk for the operating system.
 - n. Click Format.
 - o. Click OK at the All data stored will be permanently deleted dialog.
 - p. Once the system finishes formatting the disk, click Next.
 - q. Windows begins the install process and automatically reboots the system twice.
 - r. After the second reboot, click Next.
 - s. Fill in the Username and Password fields, and click Next.
 - t. Select a picture for the user account, and click Next.
 - u. Fill in the computer name field, choose a desktop background, and click Next.
 - v. When presented with the option to enable Automatic Updates, click Ask me later.
 - w. Select the correct time zone, date, and time, and click Next.
 - x. At the Thank you screen, click Start.
 - y. When the Windows Vista Ultimate with SP1 installation completes, log into Windows, and close the Welcome Center dialog.
2. Set the test resolution (on desktop systems only).
 - a. Right-click on the desktop.
 - b. Select Personalize.
 - c. Click Display Settings.
 - d. If the monitor resolution is not already 1280 by 1024, adjust it to that setting.
 - e. Click OK.
 - f. Click Continue.
3. Verify that Windows Automatic Updates are off.
 - a. Click Start.
 - b. Select Control Panel.

- c. Click Security.
- d. Under Security Center, select Turn automatic updating off.
- e. Select the Never check for updates radio button.
- f. Click OK.
- g. Click Continue.
4. Turn off System Restore. Doing so prevents such events from occurring during testing and affecting results.
 - a. Click Start.
 - b. Right-click Computer.
 - c. Select Properties.
 - d. Select System protection on the left.
 - e. Click Continue.
 - f. Uncheck each box under Automatic restore points.
 - g. Select Turn System Restore Off at the System Protection pop-up window.
 - h. Click OK.
5. Turn all Power Management settings to Performance.
 - a. Click Start.
 - b. Select Control Panel.
 - c. Select Appearance and Personalization.
 - d. Under Personalization, click Change screen saver.
 - e. Select (None) from the Screen saver drop-down menu.
 - f. Click the Change power settings link.
 - g. Select the High performance radio button.
 - h. Click the Change plan settings link.
 - i. Select Never for the Turn off the display and Put the computer to sleep drop-down menus.
 - j. Click Change advanced power settings.
 - k. Click Hard disk→Turn off hard disk after→Setting (Minutes), then type Never.
 - l. Scroll down, and click Sleep→Sleep after→Setting (Minutes), and type Never.
 - m. If Hybrid Sleep is an option, Click Sleep→Allow Hybrid Sleep→Setting, and select Off.
 - n. Scroll down, and click Display→Turn off display after→Setting, then type Never.
 - o. Click OK.
 - p. Click Save changes.
 - q. Close the Power Options window.
 - r. Click OK on the Screen Saver Settings.

Installing all Windows Vista SP1 Critical and Recommended Updates and driver updates

1. Run Windows Update, and download all important and optional updates (except Language Packs) through 03/10/2009.

BitLocker scenario

Preparing the drive for BitLocker

1. Launch the BitLocker Drive Preparation Tool.
 - a. Start→All Programs→Accessories→SystemTools→BitLocker→BitLocker Drive Preparation Tool.
 - b. If presented with a User Account Control dialog box, click Continue.
 - c. At the BitLocker Drive Encryption EULA, click I Accept.
 - d. At the Preparing Drive for BitLocker screen, click Continue. This may take several minutes.
 - e. At the completion of Drive Preparation, click Finish.
 - f. Click Restart Now to apply changes.

QuickBooks scenario

Installing Adobe Flash Player 10.0.22.87

Use the following process to install a clean version of Adobe Flash Player 10:

1. Install Adobe Flash Player 10.0.22.87 from http://www.adobe.com/shockwave/download/download.cgi?P1_Prod_Version=ShockwaveFlash&promoid=BIOW.

- a. Uncheck the box next to Google toolbar, and click Agree and Install Now.
- b. If an Information Bar pop-up appears, click Close.
- c. Click the gold installation bar tab ribbon, and click Install ActiveX Control...
- d. Click Continue at the User Account Control dialog.
- e. Click Install at the Security Warning dialog.
- f. Flash Player is successfully installed when the flash installation completion movie plays.

Installing Intuit QuickBooks Pro 2009

Use the following process to install a clean version of Intuit QuickBooks Pro 2009. This installation includes an automatic installation of the Microsoft .NET 1.1 Runtime.

1. Insert the Intuit QuickBooks Pro 2009 installation CD.
 - a. Click Run setup.exe.
 - b. At the User Account Control screen, click Continue.
 - c. At the downloading latest critical updates screen, select the Yes (Recommended) radio button. Click Next when finished.
 - d. At the Welcome to QuickBooks Installation Wizard screen, click Next.
 - e. Select the I accept radio button, and click Next at the License Agreement screen.
 - f. Select the One user radio button, and click Next at the Number of Users screen.
 - g. Enter the Intuit QuickBooks License Number and Product Number, and click Next.
 - h. Accept the default installation path, and click Next.
 - i. At the Optional QuickBooks Search Feature screen, select the No radio button.
 - j. At the Ready to install QuickBooks screen, click Install.
 - k. At the Installation Complete screen, click Finish.
2. After installation of Intuit QuickBooks Pro 2009 completes, configure the application for testing.
 - a. Launch the application by double-clicking the QuickBooks Pro 2009 desktop shortcut.
 - b. Click File→Open or Restore Company.
 - c. Click the Open a company file radio button, and click Next.
 - d. Select sample_product based_business.qbw from C:\users\Public\Public Documents\Intuit\QuickBooks\Sample Company Files\QuickBooks 2009, and click Open.
 - e. At the QuickBooks Information dialog, click OK.
 - f. If the application prompts you to register, click Remind Me Later.
3. Turn off automatic updates.
 - a. Click Help→Update QuickBooks...→Options.
 - b. Select No to Automatic Update.
 - c. Click Save.
 - d. Close the Update dialog.
4. Close all open windows, and then close QuickBooks.
5. Launch Intuit QuickBooks Pro 2009.
6. Verify that a single window with the title No Company Open appears.
7. Close QuickBooks.

Multitasking tests

Configuring Windows

1. Turn off User Account Control.
 - a. Click Start→User Accounts→User Accounts, and click Turn User Account Control on or off.
 - b. Uncheck the box for Use User Account Control, and click OK.
 - c. Click Yes when prompted to reboot.
2. Turn off the Windows Sidebar.
 - a. Right-click the Sidebar icon on the task bar, and choose Properties. Uncheck Start Sidebar when Windows starts. Click OK.
 - b. Right-click the Sidebar icon on the task bar, and choose Exit. If prompted whether you are sure you want to close the window, click Yes.
3. Copy the HUGI demo distribution folder to C:\Demo\HUGI. Do not change this path, as there are dependencies on this path in the demo script.

Installing the necessary programs

1. Install Microsoft Office 2007 Excel and PowerPoint components.
 - a. Insert the install CD, and choose Run SETUP.EXE.
 - b. Enter your Product Key, and click Continue.
 - c. Accept the License Terms, and click Continue.
 - d. Choose Customize install.
 - e. Click the dropdown list beside each program, and choose Not Available except for Excel, PowerPoint, Office Shared Features, and Office Tools.
 - f. Click Install Now.
 - g. Click Close.
2. Install Adobe Acrobat 9 Pro.
 - a. Double-click the install file.
 - b. Make sure that English is the chosen Language, and click OK.
 - c. Click Next on the Setup window.
 - d. Choose Install the trial version, and click Next.
 - e. Choose Typical install, and click Next.
 - f. Click Next.
 - g. Click Install.
 - h. Click Finish.
3. Install Adobe Photoshop Elements 7.0.
 - a. Double-click the install file.
 - b. Click Next on the Welcome window.
 - c. Click Accept on the License Agreement window.
 - d. Leave the default location folder, and click Next.
 - e. Click Install.
 - f. Click Finish.
 - g. Click Yes when prompted to restart the computer.
4. Install TMPGEnc 4.0.
 - a. Double-click the install file.
 - b. Choose default settings on all windows.
5. Install Autolt.
 - a. Double-click the install file.
 - b. Click Next on the Setup Wizard window.
 - c. Click I Agree on the License Agreement window.
 - d. Choose Edit the script, and click Next.
 - e. Click Install.
 - f. Click Finish.
6. Install VLC media player.
 - a. Double-click the install file.
 - b. Choose English, and click OK.
 - c. Click Next.
 - d. Click I agree.
 - e. Leave default components, and click Next.
 - f. Click Install.
 - g. Uncheck Run VideoLAN VLC media player 0.8.6d, and click Finish.
7. Install Watts UP USB Data Logger.
 - a. Double-click the WuUSBSetup file.
 - b. Click Next on the Welcome window.
 - c. Click Yes to accept the License agreement.
 - d. Click Next.
 - e. Leave the default name, and click Next.
 - f. Click Next.
 - g. Choose Typical install, and click Next.
 - h. Leave the default folder name, and click Next.
 - i. Click Next.
 - j. Uncheck Run Watts Up USB now, and click Finish.

- k. When the Windows Found New Hardware window pops up, choose Locate and install driver software (recommended).
 - l. Click Don't search online.
 - m. Click I don't have the disc. Show me other options.
 - n. Click Browse my computer for driver software (advanced).
 - o. Browse to C:\Program Files\EED\WattsUPUSB\Drivers, and click Next.
 - p. Click Close.
 - q. Repeat steps l through p to install the second driver.
8. Install Watts Up real time logger.
- a. Double click the WURealUSBsetup file.
 - b. Click Next on the Welcome window.
 - c. Click Yes to accept the License agreement.
 - d. Click Next.
 - e. Leave the default name, and click Next.
 - f. Leave the default install location, and click Next.
 - g. Choose Typical install, and click Next.
 - h. Leave the default folder name, and click Next.
 - i. Click Next.
 - j. Uncheck Run Watts Up Real-Time USB now, and click Finish.

Configuring the programs

1. Configure Office.
 - a. Open Excel 2007.
 - i. In the Privacy Options window, uncheck Search Microsoft Office Online for Help content when I'm connected to the Internet, and click Next.
 - ii. Choose I don't want to use Microsoft Update, and click Finish.
 - iii. Click the Office Button→Excel Options.
 - iv. Click Trust Center.
 - v. Click Trust Center Settings...
 - vi. Click Macro Settings.
 - vii. Choose Enable all macros, and click OK.
 - viii. Close Excel.
 - b. Open PowerPoint 2007.
 - i. In the Privacy Options window, uncheck Search Microsoft Office Online for Help content when I'm connected to the Internet, and click Next.
 - ii. Choose I don't want to use Microsoft Update, and click Finish.
 - iii. Close PowerPoint.
2. Configure Adobe.
 - a. Launch Acrobat 9 Pro.
 - i. Click Accept on the License Agreement.
 - ii. Choose I'd like to use this product on a trial-basis, and click Next.
 - iii. Click Advanced→Accessibility→Setup Assistant...
 - iv. Click Next.
 - v. Click Next.
 - vi. Uncheck Confirm before tagging documents, and click Next.
 - vii. Choose Only read the currently visible pages, and click Next.
 - viii. Click Done.
 - ix. Close Acrobat.
 - b. Launch Photoshop Elements.
 - i. Choose Organize from the main menu.
 - ii. Choose I'd like to use this product on a trial-basis on the popup window, and click Next.
 - iii. Choose No when prompted to specify a photo location.
 - iv. Click Edit→Preferences→Adobe Partner Services.
 - v. Uncheck Automatically check for services, and click OK.
 - vi. Close Photoshop.
 - vii. Check the C:\Demo\HUG\ly2 folder, and delete any files that are in it.

- viii. Re-launch Photoshop choosing Editor from the main menu this time.
- ix. Click File→Process Multiple Files...
 - x. Choose I'd like to use this product on a trial-basis on the popup window, and click Next.
 - xi. Browse to C:\Demo\HUGI\Yosemite\ for the Source location.
 - xii. Browse to C:\Demo\HUGI\Y2 for the Destination location.
 - xiii. In the Image Size section, check the boxes for Resize Images and Constrain Proportions.
 - xiv. Type 25 into the Width box, and choose percent from the pull down menu.
 - xv. In the File Type section, check the box for Convert Files to:, and select JPEG High Quality in the drop-down menu.
 - xvi. In the Quick Fix section, check the boxes for Auto Contrast and Sharpen.
 - xvii. Click OK.
 - xviii. When Photoshop finishes resizing the photos, close the application.
- 3. Configure the rest of the applications.
 - a. Launch TMPGEnc.
 - i. Enter the serial number, and type Intel in the Name space.
 - ii. Choose Obtain a license.
 - iii. Click OK in the confirmation window.
 - iv. Click Do not display this message again when you get the Quick Time warning, and click Continue.
 - v. Click Close on the News Center popup window.
 - vi. Uncheck Check URL before opening the Web browser and Connect to server at application start-up options, and click Yes on the confirmation window.
 - vii. Click Apply.
 - viii. Click OK.
 - ix. Click Close.
 - x. Close TMPGEnc.
 - b. Launch VLC media player.
 - i. Click Settings→Preferences→Video.
 - ii. Under General Video Settings choose Fullscreen video output, and click Save.
 - iii. Close the media player.
 - c. Launch Watts Up Pro Data Logger (WattRealUSB icon on the desktop).
 - i. Click Meter Settings.
 - ii. Click the Logging tab.
 - iii. Set the Logging Interval to 0 hours, 0 minutes, and 1 second.
 - iv. Click the Memory tab.
 - v. Under Memory Full Handling click Automatic.
 - vi. Click the Logged Items tab.
 - vii. Click Clear All Checks.
 - viii. Select the Watts option.
 - ix. Click Send settings to meter, and click Close.
 - x. Close the Data Logger.

Appendix A – Test system information

Figure 4 provides detailed configuration for the desktop systems we tested and Figure 5 provides detailed configuration for the notebook systems we tested.

System	HP Pavilion a6660t (Intel Core 2 Duo processor E8400-based system)	HP Compaq dc5100 MT (Intel Pentium 4 processor 640-based system)
General		
Processor and OS kernel: (physical, core, logical)/(UP, MP)	1P2C2L/UP	1P1C2L/UP
Number of physical processors	1	1
Single/dual/quad-core processors	Dual	Single
System power management policy	High Performance	High Performance
CPU		
Vendor	Intel	Intel
Name	Core 2 Duo	Pentium 4
Model number	E8400	640
Stepping	E0	N0
Socket type	Socket LGA775	Socket LGA775
Core frequency (GHz)	3.0	3.2
Front-side bus frequency (MHz)	1,333	800
L1 cache	32 KB + 32 KB (per core)	16 KB + 12 Kμops
L2 cache (MB)	6	2
Platform		
Vendor and model number	Pegatron Corporation	Hewlett-Packard
Motherboard model number	Benicia	09E0h
Motherboard chipset	Intel P35/G33/G31	Intel i915P/i915G
Motherboard revision number	1.01	0A
Motherboard serial number	IPIBL-LB	P92CBOCS5J09VV
BIOS name and version	American Megatrends Inc. 5.32 (10/23/2008)	Hewlett-Packard 786C2 v01.08 (04/17/2006)
BIOS settings	Default	Default
Memory module(s)		
Vendor and model number	Hyundai HYMP112U64CP8-S6	Micron MT8HTF646AY-53EB7
Type	DDR2 PC2-6400	DDR2 PC2-4300
Speed (MHz)	800	533
Speed running in the system (MHz)	800	533
Timing/latency (tCL-tRCD-tRP-tRASmin)	6-6-6-18	4-4-4-12
Size (MB)	2,048	1,024
Number of memory module(s)	2 x 1,024 MB	2 x 512 MB
Chip organization	Single-sided	Single-sided
Channel	Dual	Dual
Hard disk		
Vendor and model number	Western Digital WD3200AAJS	Samsung HD080HJ
Size (GB)	320	80
Buffer size (MB)	8	8
RPM	7,200	7,200
Type	SATA	SATA
Controller	Intel ICH8R/ICH9R/ICH10R/DO SATA RAID Controller	Intel 82801FB Ultra ATA Storage Controller

System	HP Pavilion a6660t (Intel Core 2 Duo processor E8400-based system)	HP Compaq dc5100 MT (Intel Pentium 4 processor 640-based system)
Controller driver	Intel 8.6.3.1004 (11/03/2008)	Microsoft 6.0.6001.18000 (06/21/2006)
Operating system		
Name	Microsoft Windows Vista Ultimate	Microsoft Windows Vista Ultimate
Build number	6001	6001
Service pack	Service Pack 1	Service Pack 1
File system	NTFS	NTFS
Kernel	ACPI-x86 based PC	ACPI-x86 based PC
Language	English	English
Microsoft DirectX version	10.0	10.0
Graphics		
Vendor and model number	NVIDIA GeForce 9300GE	Intel 82915G/GV/910GL Express Chipset
Type	Discrete	Integrated
Chipset	GeForce 9300GE	82915G/GV/910GL Express
BIOS version	62.98.29.0.14	Intel Video BIOS
Memory size (MB)	128	128
Resolution	1,280 x 1,024	1,280 x 1,024
Driver	NVIDIA 7.15.11.7556 (04/17/2008)	Intel 6.14.10.4656 (08/01/2006)
Sound card/subsystem		
Vendor and model number	Realtek High Definition Audio	SoundMAX Integrated Digital Audio
Driver	Realtek Semiconductor Corp. 6.0.1.5502 (10/25/2007)	Analog Devices 5.12.1.5410 (07/13/2007)
Ethernet		
Vendor and model number	Broadcom NetXtreme Gigabit	Realtek RTL8168C Family PCI-E Gigabit
Driver	Microsoft 10.10.0.1 (08/01/2006)	Realtek 6.214.1211.2008 (12/11/2008)
Optical drive(s)		
Vendor and model number	ATAPI DVD A DH16A6L-C	LITE-ON SOHD-16P9S
Type	DVD+RW CD-R	40x CD-R Write/DVD-ROM
Interface	SCSI	IDE
Dual/single layer	Dual	Single
USB ports		
Number	6	8
Type	2.0	2.0

Figure 4: Desktop test system configurations.

System	Lenovo T400 (Intel Core 2 Duo processor P8600-based system)	Lenovo T60 (Intel Core Duo processor T2700-based system)
General		
Processor and OS kernel: (physical, core, logical)/(UP, MP)	1P2C2L/UP	1P2C2L/UP
Number of physical processors	1	1
Single/dual core processors	Dual	Dual
System power management policy	High Performance	High Performance
Processor power-saving option	SpeedStep technology enabled	SpeedStep technology enabled
System dimensions (length x width x height)	13" x 9.5" x 1.5"	12" x 10" x 1.25"
System weight	5 lb, 4 oz	5 lb
CPU		
Vendor	Intel	Intel
Name	Core 2 Duo	Core Duo
Model number	P8600	T2700
Stepping	R0	D0
Socket type and number of pins	Socket P (478)	Socket 479 mPGA
Core frequency (GHz)	2.40	2.33
Front-side bus frequency (MHz)	1,066	666
L1 cache	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)
L2 cache (MB)	3	2
Platform		
Vendor	Lenovo	Lenovo
Motherboard model number	7417CTO	1952AF2
Motherboard chipset	GM45	Intel i945GM
Motherboard revision number	07	03
System/motherboard serial number	L3C0306	L30008590
BIOS name and version	Lenovo 2.07 (02/13/2009)	Lenovo 1.10 (08/02/2006)
BIOS settings	TPM disabled	Default
Memory module(s)		
Vendor and model number	Samsung M471B2874DZ1-CF8	Micron MT16HTF12864HY-667F1
Type	DDR2	DDR2
Speed (MHz)	1,066	666
Speed running in the system (MHz)	1,066	666
Timing/latency (tCL-tRCD-tRP-tRASmin)	7-7-7-20	5-5-5-15
Size (MB)	2,048	2,048
Number of memory module(s)	2 x 1,024 MB	2 x 1,024 MB
Chip organization	Double-sided	Double-sided
Channel	Dual	Dual
Hard disk		
Vendor and model number	Hitachi HTS722020K9SA00	Hitachi HTS541680J9SA00
Size (GB)	200	80
Buffer size (MB)	16	8
RPM	7,200	5,400
Type	SATA	SATA
Controller	Intel ICH9M/M-E Family 4 Port SATA AHCI Controller	Intel 82801 GBM/GHM (ICH7-M Family) Serial ATA Storage Controller

System	Lenovo T400 (Intel Core 2 Duo processor P8600-based system)	Lenovo T60 (Intel Core Duo processor T2700-based system)
Driver	Intel 6.9.1.1001 (2/20/2008)	Microsoft 6.0.6001.18000 (06/21/2006)
Operating system		
Name	Microsoft Windows Vista Ultimate	Microsoft Windows Vista Ultimate
Build number	6001	6001
Service pack	Service Pack 1	Service Pack 1
File system	NTFS	NTFS
Kernel	ACPI-x86 based PC	ACPI-x86 based PC
Language	English	English
Microsoft DirectX version	10.0	10.0
Graphics		
Vendor and model number	Intel GMA 4500MHD	Intel GMA 950
Type	Integrated	Integrated
Chipset	Mobile Intel 4 Express	Mobile Intel 945 Express
BIOS version	Intel Video BIOS	Intel Video BIOS
Memory size (MB)	128	256
Resolution	1,280 x 800	1,024 x 768
Driver	Intel 7.15.10.1556 (9/9/2008)	Intel 7.14.10.1437 (02/11/2008)
Sound card/subsystem		
Vendor and model number	High Definition Audio Device	SoundMAX Integrated Digital HD Audio
Driver	Microsoft 6.0.6000.16386 (6/21/2006)	AnalogDevices 6.10.1.5510 (10/04/2007)
Ethernet		
Vendor and model number	Intel 82567LM Gigabit Network	Intel Pro/1000 PL
Driver	Intel 9.52.20.0 (11/21/2008)	Intel 9.12.36.0 (12/04/2008)
Modem		
Vendor and model number	ThinkPad Modem	ThinkPad Modem
Driver	CXT 7.73.0.0 (3/28/2008)	CXT 7.62.0.0 (01/31/2007)
Optical drive(s)		
Vendor and model number	HL-DT-ST RW/DVD MU10N	HL-DT-ST DVD ROM GDR8087N
Type	DVD-ROM/CD-RW	DVD-ROM
USB ports		
Number	3	3
Type	USB 2.0	USB 2.0
Monitor		
LCD type	WXGA TFT	TFT Active Matrix
Screen size (inches)	14.1	14.1
Refresh rate (Hz)	60	60
Battery		
Type	IBM E305279 Lithium Ion	IBM E236872 Lithium Ion
Size (length x width x height)	8.75" x 2.5" x 3/4"	8" x 2" x 3/4"
Rated capacity	4840mAh/10.8V	5200mAh/10.8V
Weight (oz)	11.4	11.3

Figure 5: Notebook test system configurations.

Appendix B – Instructions for running the application scenarios

We evaluated the performance of each of the test systems on each of the three application scenarios (see the Application scenarios section for more information on them) by hand-timing the tasks in those scenarios.

We collected results for five runs of each scenario in each system configuration. We refer in this paper only to the median results of those runs on each system configuration. Lower times to complete a given function indicate better performance. We round those times to hundredths of seconds in this report.

In the following instructions, we assume you have already completed all of the setup work in the Test Methodology section.

Copying a folder on an encrypted volume (BitLocker scenario)

The applications involved

The scenario requires one application:

- Windows Vista BitLocker Drive Encryption

The data files involved

This scenario uses one folder:

- BitLocker WL, a 499MB folder with 307 files

The test process

First, prepare each system by following these steps once:

1. Copy the BitLockerWorkload directory to C:.
2. Make four copies of this directory.
3. Rename these directories BitLockerWorkload1 through BitLockerWorkload5.

Edit the group policy for BitLocker

1. Click Start, and type gpedit.msc in the Search box.
2. Press Enter.
3. If the User Account Control dialog box appears, verify that the proposed action is what you requested.
4. Click Continue.
5. From the Group Policy Object Editor screen, take the following actions:
 - a. Click Local Computer Policy.
 - b. Click Administrative Templates.
 - c. Click Windows Components.
 - d. Double-click BitLocker Drive Encryption.
 - e. Choose Control Panel Setup: Enable advanced startup options.
 - f. Change the radio button selection to Enabled.
 - g. Choose Allow BitLocker without a compatible TPM.
 - h. Choose Disallow startup key with TPM in the drop-down menu under Configure TPM startup key option.
 - i. Choose Disallow startup PIN with TPM in the drop-down menu under Configure TPM startup PIN option.
 - j. Click OK to change the group policy to use a Startup Key.
6. Click Start, and type gpupdate.exe in the Search box. Press Enter.
7. Wait for the process to finish.

Encrypt the boot partition with BitLocker on systems that do not have a Vista-compatible TPM

1. Click Start, and type BitLocker in the Search box.
2. Select BitLocker Drive Encryption.
3. If the User Account Control dialog box appears, verify that the proposed action is what you requested, and click Continue.
4. From the BitLocker Drive Encryption screen, click Turn On BitLocker on the operating system volume.
5. From the Set BitLocker Startup Preferences screen, choose Require Startup USB Key at every startup.

6. Insert a USB flash drive in the computer, if one is not already present.
7. From the Save the user Startup Key dialog box, choose the location of the USB flash drive.
8. Click Save.
9. In the Save the recovery password dialog box, the following options appear:
 - Save the password on a USB drive.
 - Save the password in a folder.
 - Print the password.
10. Choose the Save the password on a USB drive option to preserve the recovery password.
11. Click Next.
12. At the Save a Recovery Password to a USB Drive dialog, click the USB drive you desire, and click Save.
13. At the Save the recovery password dialog box, click Next.
14. From the Encrypt the selected disk volume dialog box, confirm the Run BitLocker System Check box is unchecked, and click Encrypt.
15. The Encryption in Progress status bar appears.
16. Encryption is complete when that progress bar disappears. This process required from 30 to 60 minutes on the test systems.

To execute the test, follow these instructions. You will need one stopwatch.

1. Reboot the system under test.
2. Log in.
3. Wait 2.5 minutes to be sure the system has completed booting and is in a consistent starting state.
4. Prepare the stopwatch.
5. Right-click the BitLockerWorkload n test folder, where n equals the number of the test run.
6. Drag the folder to the desktop.
7. Release the right mouse button.
8. Simultaneously choose Copy Here from the Windows pop-up and start the stopwatch.
9. Stop the stopwatch when the dialog box with the progress bar disappears.
10. Record this time as the test's result.
11. Delete the copy of the folder.
12. Repeat these steps four times for a total of five runs.

We report the time, in seconds, that the system took to make a copy of the folder on an encrypted volume. Lower times indicate faster performance and so are better.

Viewing data in Intuit QuickBooks Pro 2009 (QuickBooks scenario)

The application involved

- Intuit QuickBooks Pro 2009

The data file involved

- sample_product based business.QBB, a 7,036KB sample QuickBooks data file

The test process

First, prepare each system by following these steps once to load the test QuickBooks database:

1. Launch Intuit QuickBooks Pro 2009.
2. Click File→Open or Restore Company...
3. At the What type of file dialog box, select the Restore a backup copy radio button, and click Next.
4. At the Restore Company Backup dialog box, select the Local Backup radio button, if that button is not already selected, and click Next.
5. Browse to the sample_product based business.QBB file, and click Open. This action returns you to the Open or Restore Company Backup dialog box.
6. Click Next.
7. At the Save Company File As screen, click Save.
8. Click Yes to confirm overwriting an existing company file.

9. Click the check box beside I Understand, and click Update Now.
10. At the Update Company dialog, click Yes.
11. At the QuickBooks Information dialog, click OK twice.
12. At the QuickBooks Learning Center dialog, click Go to QuickBooks.

To execute the test, follow these instructions. You will need one stopwatch.

1. Reboot the system under test.
2. Log in.
3. Wait 2.5 minutes to be sure the system has completed booting and is in a consistent starting state.
4. Double-click the Intuit QuickBooks Pro 2009 desktop icon.
5. Click Open to open the company file (sample_product based business.qbw).
6. Click OK to close the QuickBooks information dialog.
7. At the Register Intuit QuickBooks Pro 2009 screen, click Remind Me Later.
8. Click Window→Close All to close any open windows.
9. Click Reports→Process Multiple Reports to open the Process Multiple Reports window.
10. Select Favorite Reports from the drop-down list.
11. Prepare the stopwatch.
12. Simultaneously click Display and start the stopwatch.
13. Stop the stopwatch when all the report windows are open (pay particular attention to top left report).
14. Record this time as the test result.
15. Click Window→Close All to close the reports before closing QuickBooks Pro to re-run the test.
16. Repeat these steps four times for a total of five runs.

We report the time, in seconds, that Intuit QuickBooks Pro 2009 took to load the reports. Lower times indicate faster performance and so are better.

Running multitasking tests (Multitasking scenario)

The application involved

- Microsoft Excel 2007
- Microsoft PowerPoint 2007
- Adobe Acrobat 9.1
- Adobe Photoshop Elements 7
- TMPGEnc XPress 4.0
- VLC Media Player

The data file involved

- ISMC08.pptx, a 14,795KB PowerPoint file
- MonteCarloDemo2.xlsm, a 616KB Excel file
- Yosemite, a 38,900KB folder containing 12 images
- Desert-25Mbps.mpg, a 93,817KB video file

The test process

1. Browse to C:\Demo\HUGI\HUGI-TimePowerCPU.exe, and create a shortcut of the file on the desktop.
2. Double-click the HUGI-TimePowerCPU shortcut to start the script.
3. When prompted, click OK to start the demo.
4. When the demo is finished, record the results in the results spreadsheet, and click OK to quit.
5. When the script closes all the applications, empty the Prefetch folder by clicking Start and typing Prefetch in the Search box, and press Enter. Select all the items in the Prefetch folder, and delete them.
6. Empty the recycle bin.
7. Restart the computer.
8. Repeat steps 2 through 7 four more times.

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Principled Technologies, Inc.
1007 Slater Road, Suite 250
Durham, NC 27703
www.principledtechnologies.com
info@principledtechnologies.com

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