Dell White Paper

Understanding Battery Life in Portable Computers

Gary Verdun, Technology Strategist
Office of the CTO

Battery life scores in portable computers are in many ways similar to the miles per gallon (mpg) numbers used in the automotive industry. Mpg numbers are a fair indication of how much fuel a car consumes while driving a very specific course in a very specific pattern. The consistent course and pattern make the results repeatable and allow one to compare the fuel consumption of different vehicles. The actual gas mileage that a driver achieves depends greatly on how that individual drives. Carrying heavy loads, accelerating rapidly, low tire pressure, and other factors determine actual gas mileage.

Similarly, in portable computers there are many factors that affect the amount of time a portable computer battery can deliver power before it must be recharged. Factors such as the types of applications run, system configuration, display brightness, and power management settings in the BIOS or operating system can all impact battery life significantly.

In this paper, we show how some of these variables affect battery life in a typical portable computer system, discuss the main battery-life benchmarks used by the industry, and provide guidance on ways to maximize battery life.

Battery-Life Benchmarks

Despite the difficulty in predicting battery life for an individual user, there is benefit from battery life benchmarks that provide guidance on how long a system might run on a single charge. In addition, users benefit from being able to compare one unit with another. For these reasons, most companies that sell portable computers provide estimates of battery life. In addition, industry trade magazines and Web sites such as PC Magazine, www.zdnet.com, or www.laptopmag.com provide battery-life run time figures. These figures are usually based on generally accepted

battery-life benchmarks that attempt to replicate one or more common portable computer usage models.

Battery life benchmarks exercise a system by running a particular workload using standard system settings or limitations until the battery runs out of energy and the system shuts down. The time the system was able to run from the beginning of the test at a fully charged condition until the system shuts down from lack of battery energy is the run time or battery life score for the benchmark.

Over the past few years, the number of official battery-life benchmarks has fallen, and MobileMark 2007 is now the most commonly used benchmark for most of the world. Exceptions include Japan and much of the Pacific Rim, which still use the Japan Electronics and Information Technology Industries Association (JEITA) battery run-time method.

Several other nonstandard run-time scenarios are used that generally consist of minimum or maximum power-consumption scenarios. These workload scenarios can show the maximum and minimum possible battery life that can be achieved, but are not good indicators of what a typical end user can expect under normal usage.

MobileMark 2007

http://www.bapco.com/products/mobilemark2007

MobileMark 2007 (MM07) was developed by the Business Applications Performance Corporation (BAPCo), a nonprofit consortium that develops and distributes objective performance benchmarks based on popular computer applications and industry-standard operating systems. Current members of BAPCo include AMD, ARCintuition, Dell, HP, Hitachi Global Storage Technologies, Intel, Lenovo, Microsoft, NVIDIA, Samsung, Seagate, Sony, Toshiba, and VIA Technologies.

MM07 simulates actual customer interaction with a computer by including variable-length pauses between keystrokes and certain other tasks while running standard application software. The intent of this approach is to more closely match the typing speed and workflow of typical users. This is important because today's portable computers include power management features that take advantage of these pauses to reduce the system power and prolong battery life during periods of inactivity. The inclusion of more realistic keystroke pauses allows the benchmark to better simulate the way the system would be exercised in the hands of a real-world user running similar applications.

MM07 provides testing workloads to simulate three usage models: productivity, DVD playback, and "reader" workloads.

The productivity workload emulates a mobile professional running the following applications while doing typical office worker-type tasks. The benchmark also emulates background file compression and virus detection operations.

- Adobe™ AcrobatReader 7.0
- Adobe Illustrator™ CS2
- Adobe Photoshop™ CS2
- Apple QuickTime 7.1
- Intervideo WinDVD® 8
- Macromedia Flash 8

- Microsoft® Office® 2003 Pro
- Microsoft® Project 2003
- Winzip® 10.0

DVD playback workload uses the InterVideo* WinDVD* 8.0 application to play a video DVD that BAPCo created from the open-source 3D animated short film, *Elephants Dream* (www.elephantsdream.org).

The reader workload emulates a person reading a book or other document using Adobe Acrobat Reader version 7.0.

JEITA (http://it.jeita.or.jp/mobile/e/)

The JEITA benchmark test does not attempt to simulate typical office productivity workloads. Instead, it consists of playing a Motion Picture Experts Group (MPEG) video file continuously until the portable computer shuts down due to low battery. The published number is the average of two runs; the first limits the minimum display brightness to 20 nits and the second with no minimum brightness limitation, although the backlight must be running. Over time, the MPEG video has been updated to maintain reasonable workloads for the system. This test is more similar to the MM07 DVD playback test than to the productivity test in terms of the work the system has to do during the test.

Other Non-Standard Battery-Life Tests

Other industry sources (writers, bloggers, and web sites) compare battery life using their own test procedures. The most common of these run a minimum workload such as an operating system idle condition and a maximum workload to yield minimum and maximum battery life results. These tests attempt to bracket the possible battery-life extremes—for example, a minimum battery life of 1.5 hours and maximum of 5 hours. Actual battery life falls somewhere in this wide range based on actual usage.

Comparing Standard Benchmarks

Figure 1 compares the run-time of a typical 14-inch notebook system with a 60-Whr battery on the MobileMark workloads and JEITA benchmark.

Run times range from about 5 hours for the lightest workload, MobileMark Ereader, to about 3.4 hours for the heaviest workload, MM07 DVD playback. This approximately 1.5-hour difference in run time amounts to an almost 50% increase in run time for the Ereader workload over the DVD playback workload. This comparison clearly illustrates how battery life can vary depending on the workload being run.

Your mileage will vary!

Manufacturers determine their published battery-life numbers using benchmarks like MM07. Why might your actual run time be different than the manufacturer's published battery life numbers? There are several potential contributors:

- System power management settings

- Display brightness settings
- Wireless or wired network activity
- Actual workload

System Power Management Settings Differences

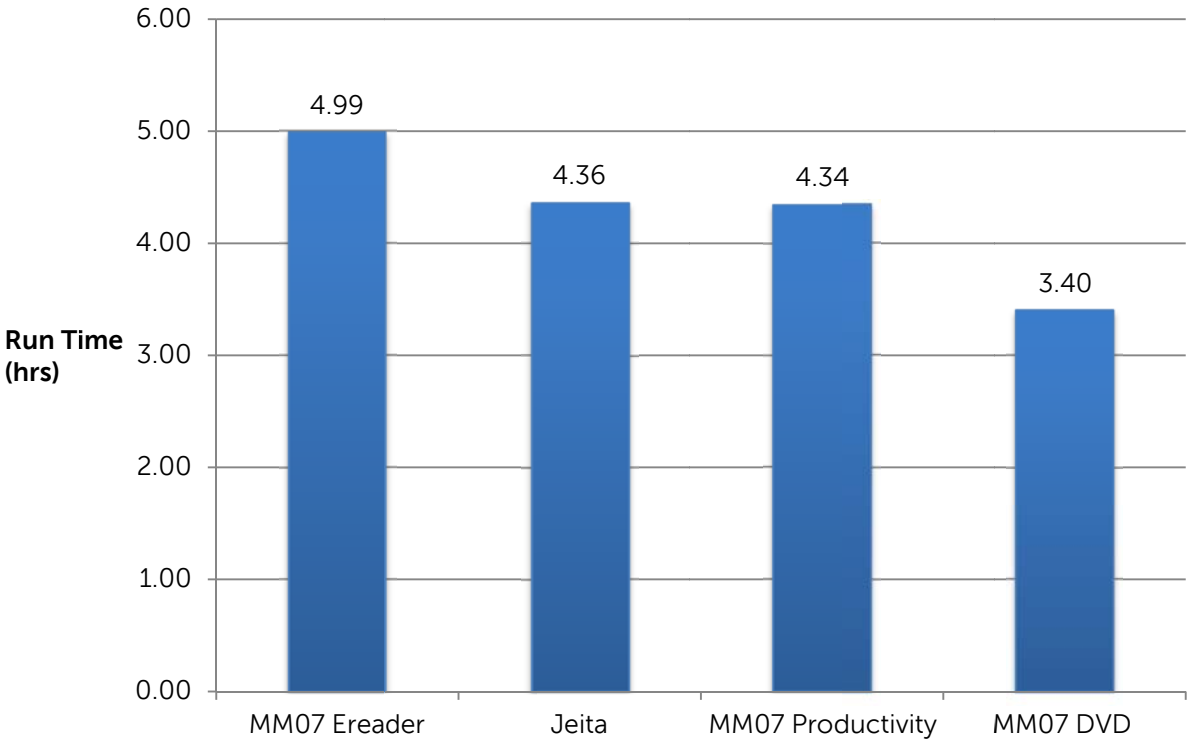
Current portable computer systems provide power-management settings through the operating system or an application running on the platform. These settings typically require a trade-off between performance/functionality and battery life. Some of the more common power management settings follow:

- Display Time Out
- Hard Disk Drive Time Out
- System Sleep/Standby Time Out
- System Hibernate Time Out
- Power Policy

Display Brightness

Most portable computer systems use backlit LCD panels. The end user controls the light output from the panel—or screen brightness—using a function key or power-management application. The backlight consumes a significant portion of total system power and, therefore, screen brightness settings have a strong impact on battery life.

Figure 1. Run Time Comparison Using MM07 and Jeita Battery Life Benchmarks



Note: These benchmarks were run on a Dell Inspiron 1545 portable computer with an Intel® Core™ 2 Duo processor running at 800 MHz. See Appendix for configuration details.

Wireless or Wired Network Activity

Most battery-life benchmarks are run with the wireless network disabled for simplicity and repeatability of results. Light wireless network activity such as e-mail or Web browsing should not impact battery life significantly. However, high network traffic such as large file downloads or streaming video reduces battery life significantly.

Actual Workload

Just as your car's gas mileage will vary if you're driving alone compared to pulling a trailer with a heavy load, notebook power usage will vary depending on your workload. In computer systems, this workload is the software running on the system such as operating system, applications, and hardware device drivers.

In the following section, we focus on the effects of workload and display brightness on battery life. We present benchmark results for a typical notebook computer system running under various workloads and brightness settings.

Effects of Workload and Brightness on Battery Life

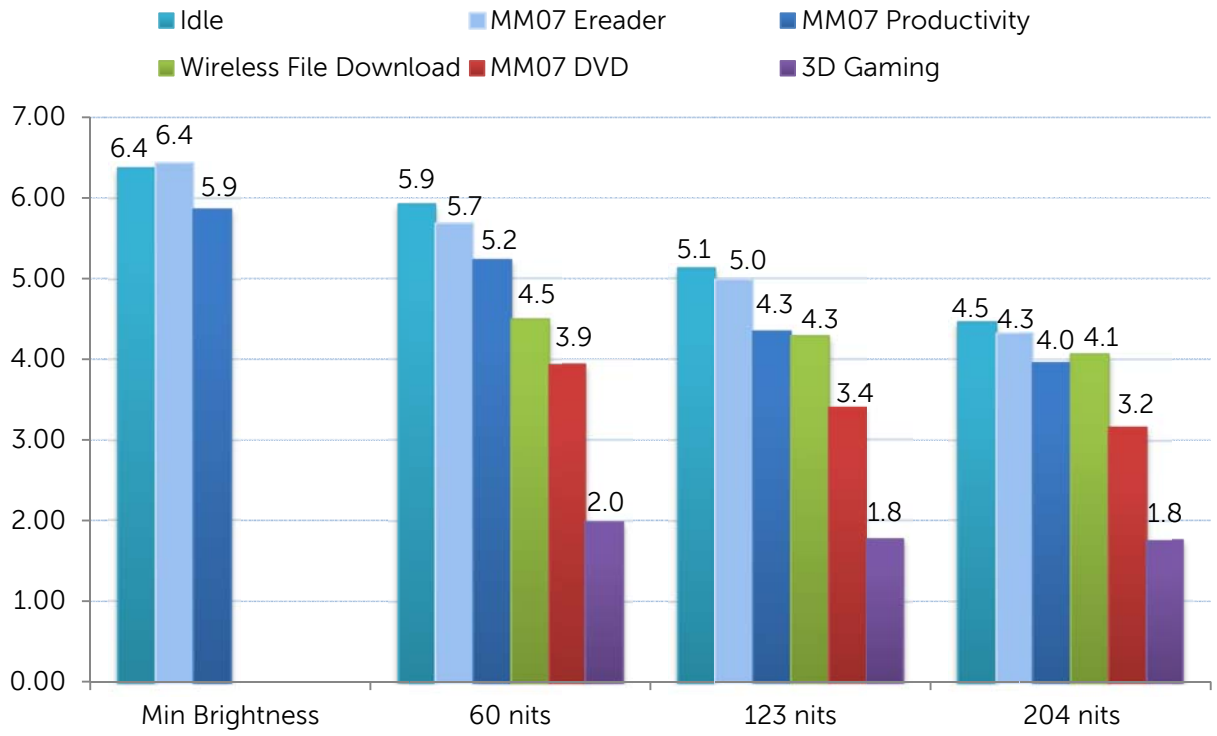
Because a notebook's battery life varies depending on the applications it's running, organizations such as BAPCo put a lot of effort into defining the workloads used in their battery-life benchmarks. The goal is to provide a consistent and repeatable level of activity on the system.

The combination of workload or application software running on the system and the keystroke pauses used in applying commands to the application determines how hard the system electronics—CPUs, graphics controllers, and so forth—must work during the test. In general, the harder the system works, the more power it consumes and the shorter the battery life. Applications such as word processing and e-mail usually have low performance requirements. In contrast, complex scientific analysis programs or 3D applications and 3D games can have high CPU and graphics performance requirements.

Figure 2 shows how workload and display brightness affect the battery life in a test system. Battery life or run time is expressed in hours and fractions of hours. The larger the number, the longer the system will operate between battery charge cycles.

Figure 2 presents MM07 Ereader, DVD playback, and Productivity benchmark results, as well as three additional benchmarks: idle, a 3D gaming workload, and a high-intensity wireless file download.

Figure 2. Run Time for Various Applications and Brightness Levels



The application/work load scenarios considered are as follows:

1. Idle – This is represented by the system having an operating system loaded and sitting at the desktop after the initial startup sequence has settled out. This is the minimum work equivalent.
2. MM07 Ereader – This is based on the average power consumed running the Mobile Mark 2007 Ereader workload.
3. MM07 Productivity – This is based on the average power consumed by the platform while running the 2–hour workload of MM07 benchmark.
4. MM07 DVD – This is the average power consumed by the platform during a 2–hour period while playing the MM07 DVD run-down video.
5. Wireless File Download – This is the average power of the system while downloading the MM07 DVD file from the internet onto the local machine using the wireless networking interface. This is a very high wireless activity workload.
6. 3D Gaming – This is the average power of the platform while running a 3D game performance benchmark. This represents a game–playing scenario or some other high-performance application.

Note: These benchmarks were run on a Dell Inspiron 1545 portable computer with an Intel® Core™ 2 Duo processor running at 800 MHz. See Appendix for configuration details.

Idle is a good indication of the minimum amount of work that can be applied to a platform because there are no active applications running on the system.

For a maximum workload, a 3D gaming application was selected, because its workload is near the expected maximum that a user could achieve running commercially available applications. 3D gaming applications stress processor and graphics subsystems and are not generally used in battery life testing. Calculating a battery life number using a 3D gaming workload would be the equivalent of determining a car's gas mileage while carrying maximum rated vehicle weight while driving up a mountain. For this test, the 3D gaming workload was set to run in a continuous loop and the power was measured until the system stopped running. Average power for this data set was then calculated and battery life calculated based upon a typical battery.

The third additional workload downloads a very large movie file over wireless connection. This workload is much more active than a typical Internet browsing scenario and is the only benchmark run with the wireless radio enabled.

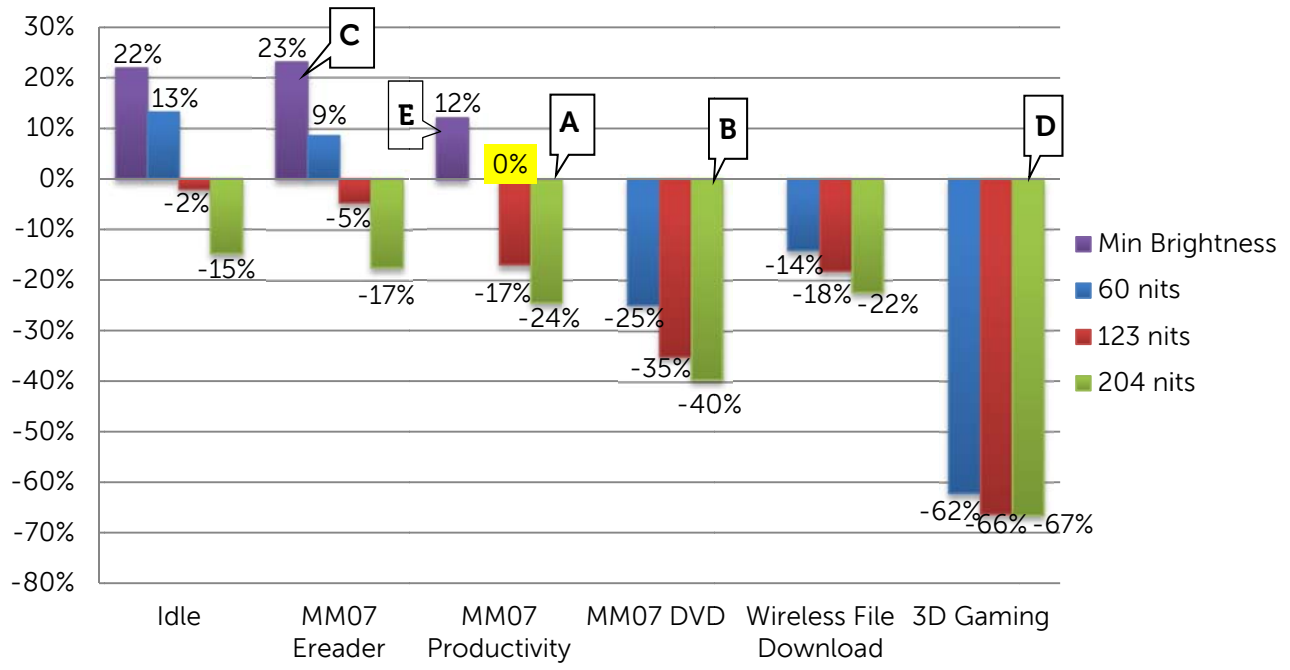
The results in Figure 2 show that varying display brightness and workload have a significant impact on battery life. As display brightness and workload increases, battery life declines. For example, look at the MM07 office productivity benchmark data. Battery life varies from 5.9 hours at minimum brightness to 4 hours at higher brightness (204 nits). The change in battery life due to workload can easily be seen by comparing the idle results to the 3D gaming results at any brightness. At 123 nits, this is 5.1 hours for idle workload to 1.8 hours for a 3D gaming workload on our test system. This difference of over 3.3 hours in battery life highlights how significant an impact workload is on battery life. The software run on a portable computer can impact battery life by 3 or more hours on a single charge.

These results also highlight the fact that no battery life benchmark can provide a completely accurate prediction of the battery run time for every user. What the end user does with the system will have a huge effect on how long the battery will last.

The benchmarks in Figure 3 address the more important question for a typical user, "How will my battery life differ from published battery life numbers?" Figure 3 shows how run time is affected by different panel brightness levels and application workloads running on the system. Differences are expressed as a percentage change in run time, compared to the typically published MM07 productivity benchmark. All data was collected using standard benchmark run rules, if required. Each bar on the graph shows how battery life might differ from this MM07 productivity score by changing panel brightness and running different workloads.

The green bar labeled A in Figure 3 shows that if you configure your notebook display at maximum brightness running typical office applications with wireless off, you could expect about 24% lower battery run time than the MM07 productivity benchmark that Dell publishes. Label B in Figure 3 shows that if you play DVDs at maximum brightness with wireless disabled, you could expect about a 40% lower battery run time than Dell's published MM07 productivity benchmark numbers. Label C in Figure 3 shows that if you primarily read

Figure 3. Percentage Change in Battery Run Time By Workload Compared to MM07 Productivity



Note: These benchmarks were run on a Dell Inspiron 1545 portable computer with an Intel® Core™ 2 Duo processor running at 800 MHz. See Appendix for configuration details.

documents with wireless disabled and keep display brightness at minimum, you could expect about 23% longer run time than Dell's published MM07 productivity benchmark numbers. Label E in Figure 3 shows that running the MM07 benchmark workload at minimum brightness would yield a 12% longer battery life.

Label D in Figure 3 above, shows the end user can reduce battery run time about 67% when compared to Dell's published MM07 productivity numbers by running high performance applications at high screen brightness levels. Label C in Figure 3 is the other extreme of reading documents at minimum brightness and is a 23% longer battery life than the published number. Users can expect to have a battery life that falls somewhere in between these two extremes.

The wireless file download test described above is intended to provide some insight into how much a very active wireless network might cause an end user's battery life to differ from the MM07 benchmark test scenarios. The results show that the battery run time for heavy file download over the wireless interface falls

between the MM07 productivity and DVD workloads. The worst-case scenario shows less than a 15% reduction in battery run time compared to the MM07 productivity workload.

The more typical user scenario of having wireless enabled, but not transferring a large amount of data, can be expected to reduce run time by less than 15%. The combination of heavy wireless file download and maximum brightness results in a battery run time about 22% less than the MM07 productivity run time. For our initial 60–nit run time of 5.2 hours, this results in about 1.1 hours less run time on this particular system.

How to Extend Battery Life

Here, we focus on the key steps that end users can take to maximize battery life. As discussed in the previous section, the types of applications run on the system have a major impact on battery life, but other factors also have an impact. The MM07 results in Figure 1 reveal significant battery life differences due to display brightness.

Reduce Display Power Consumption

The display subsystem creates the image seen on the portable computer screen. The single largest consumer of power in the display subsystem is the display lamp, which governs brightness. The brighter the lamp, the more power is consumed by the display system and the shorter the battery life. In most portable computer usage models, the display backlight consumes 30%-40% of the total system power. If the panel brightness is raised to maximum, the backlight power can approach or even exceed half the total system power.

In Figure 2, the MM07 battery life ranges from 4 hours associated with maximum display brightness to 5.8 hours at minimum brightness. These benchmark results suggest a battery-life increase of almost 2 hours associated with adjusting the brightness of the display from its highest setting to the minimum setting. Because the brightness setting has such a powerful impact on battery life, most portable computers are configured to automatically dim the display as the AC power is removed and to increase the brightness when plugged back into an AC outlet. To save even more power, display brightness can be manually adjusted using the Fn ↑ and Fn ↓ keys on Dell™ Inspiron™, Latitude™, and Dell Precision™ mobile workstation systems.

To maximize battery life, users should keep the display at the minimum brightness level required to view the display comfortably.

Operating System Settings

In addition to adjusting display brightness, users can take other steps to extend battery life, including enabling Microsoft® Windows® operating system and device power-management capabilities. For instance, you should disable all unused devices such as the integrated camera, Bluetooth® technology radio, audio, and the wired LAN when you are connected via a wireless network.

Microsoft Windows operating system settings can also have a significant impact on battery life. Windows operating systems since

Windows XP provide the ability to extend battery life by trading off power consumption and performance using "Power Schemes." These are accessible via the "Power Options" icon in the "Control Panel."

Windows XP

For best battery life, select the Portable/Laptop or Max Battery power schemes, which save power by turning off devices such as the display and hard drive during periods of inactivity, and adjusting processor power. Portable/ Laptop dynamically adjusts processor power and performance based on the demands of the application running on the system. When performance demands are low, the processor is kept in a low power and performance state. When demands are higher, the processor runs at higher power and performance levels up to its maximum capacity. In contrast, the Max Battery setting operates by forcing the processor to its minimum performance level until the battery power becomes low. At that point, the power scheme increasingly forces sleep periods on the processor, further limiting processor performance as the battery becomes more depleted. This approach can extend battery life, but there is significant performance degradation. In contrast, none of these power-saving techniques are applied under the *Always On* power scheme, which is designed for maximum performance, but results in the shortest battery life.

Windows Vista

The Windows Vista operating system provides much more control than Windows XP over processor performance. Three primary power plans are available under the "Power Options" in the "Control Panel": *Power Saver*, *Balanced*, and *High Performance*. The power saver plan maintains the processor in its lowest performance state unless the system gets very busy, at which point the processors goes into a high-performance state. This ability can save battery life in many portable systems. The Power Saver plan should yield the lowest power for very light activity levels, but the system will exhibit a noticeable reduction in performance.

The High Performance plan is intended for heavy workloads or those users who desire performance and are willing to sacrifice battery life to get it. Historically, many users have set the processor performance state or operating frequency to the maximum speed 100% of the time when they want high performance. Dell has optimized the high-performance plan to use processor performance states very aggressively to obtain nearly the same performance, while using less power than running at maximum frequency 100% of the time.

Windows 7

Windows 7 adds even more power-management controls for end users and OEMs to better optimize the user experience and power-battery life trade-off. The following settings have the greatest impact on battery life (in decreasing order):

1. Dim the display time
2. Turn off the display time
3. Put the computer to sleep time
4. Hard disk turn-off time

Shortening these time values will tend to increase the battery life of your system, but will extend the time required for the system to be ready to use after a period of inactivity.

You can change these settings by clicking the battery icon in the system tray and choosing "More power options." From here, choose "Change Plan Settings" to configure display turn-off and sleep times. Alternatively, you can choose "Change Advanced Power Settings" to configure other settings such as the hard-disk turn-off time. This setting defines how long the system is inactive before the hard-disk platter is stopped to save the energy. Dell systems are configured at 10 minutes, but you can increase your battery life by reducing this setting, given the following caveats:

- Once the platter is spun down, any disk access will take noticeably longer to execute. For example, if you launch an application, search for a file, or open a file, you will have to wait a few more seconds to see the results.
- It is possible to *reduce* battery life if this time is set too short. The platter must spin down and remain inactive for a little while to realize energy savings. The act of spinning the drive back up to speed expends more energy than keeping it spinning. If you notice the drive spinning up soon after spinning down on a regular basis, this setting should probably be lengthened.

Dell systems feature "Dell Recommended" Power Plans that are optimized to provide the best user experience. Dell operating system images have significant optimizations to provide better performance and battery life. For typical users, Dell recommends the "Balanced" power plan.

Windows Vista and Windows 7 both allow for the addition of gadgets on the desktop. Some gadgets can increase power consumption significantly, so Dell recommends disabling any gadgets you don't need when operating on battery.

Enable Device Power Management

Some system devices have built-in power management capabilities. A good example is wireless LAN devices. A wireless LAN device can consume significant power, because it maintains a minimum amount of traffic between the portable computer and nearby wireless access points at all times. Power management features built into many wireless LAN devices can be enabled to allow the portable computer's power management software to reduce power consumption of the device. These features can be enabled in the wireless device software that is installed on the portable computer.

Wireless devices in many newer portable computers also provide separate power switch controls. These are generally intended for airplane travel and disable the wireless transmitters as is required on most flights. Disabling wireless networking when not being used will also extend battery life.

System Configuration/Purchase Options

End users can also affect the battery life of a system by the options they choose during the purchase process. Some purchase options can affect battery life at the expense of other system parameters like cost, performance, or weight.

Larger Battery

If battery life is important, users should consider larger batteries, i.e., 9-cell instead of a 6-cell or 6-cell instead of a 4-cell. Each of these two cases will yield about a 50% increase in battery life on any given system.

Hard Disk Drive Speed

Another factor that can contribute to longer battery life is to select one of the lower-speed hard disk drives. A 5,400 RPM drive will consume less power than a 10,000 RPM drive, which will result in longer battery life. Disk-intensive applications will be somewhat slower with the lower-speed drives.

Solid-State Disk Drive

The lowest power permanent storage or drive option would be the solid-state disk drive. These drives do not have the spinning platter and consume much lower idle power than a standard hard disk drive, resulting in longer battery life. These drives also provide significant performance improvements over standard hard disk drives, but cost significantly more.

LED Backlight Displays

Light Emitting Diode (LED) backlights are more efficient than Cold Cathode Fluorescent (CCFL) backlights. Displays using LED backlights will provide longer battery life than CCFL backlit panels. The battery life addition will vary depending on the system, but if battery life is important select the LED backlit display.

Additional Steps

There are several additional steps that the end user can take to maximize battery life. If feasible, mute audio when running on battery power. Audio power consumption varies greatly depending on the system used, but can have a noticeable effect on battery life. In addition, install a second battery, rather than an optical drive, in the portable drive bay. This step not only increases battery capacity, but eliminates the power consumption associated with the optical drive. Programs that are run from a CD or DVD can be copied to and run from the hard drive, which typically consumes less power than an optical drive. Even if no second battery is installed, removing an unused optical drive can extend your run time.

Finally, an easily overlooked step is to ensure that your system is equipped with adequate system memory. If a computer does not have enough system memory to run the operating system and open applications, it will use the hard drive for working space in a process called "paging." This process increases activity on the hard drive. Reading from and writing to the hard drive, rather than system memory, consumes much more power.

Summary

An important first step in maximizing battery life is to choose a notebook system configured to enable long battery life. If battery life is of high importance, limit high-performance options and increase the size of the battery. It is also important to enable operating system and device power management capabilities. Further steps include disabling devices that are not used when running on battery power, and replacing the optical drive with a second battery. Finally, it is important to address the top power consumer in the system—the display. Lowering the display brightness is one

of the most effective ways to extend battery life. For this reason, most portable computers are configured to automatically lower display brightness when running on battery power.

Dell continues to drive industry initiatives and technologies that can yield power efficiencies in Dell portable products. Dell works with suppliers, technology partners, and industry groups to extend battery life through improvements in battery technology and power management, as well as by minimizing the power consumed by system components.

Summary of Actions for Extending Battery Life

- **Processor Speed** – Enabling features such as Intel SpeedStep® or AMD PowerNow!™ extends battery life by automatically adjusting the processor speed to meet system demands. These features are typically enabled by default on portable computers that support them.
- **CD, DVD, CD-RW, and Hard Drive Access Frequency** – Moving files and programs directly to the hard drive, when possible, reduces the number of devices requiring battery power. Adding more memory can also help by reducing the need to use a swap file on the hard drive.
- **Programs** – Running only the programs that are necessary reduces demands on the system processor and memory. Programs that cause intensive use of the processor and drives (such as playing a DVD movie or 3D games) can more than halve the amount of time that the computer can be used on battery power.
- **LCD Brightness** – Lowering the brightness of the LCD screen reduces the amount of power required by the screen. To adjust the brightness of the LCD screen, press **Fn** ↑ to increase the brightness or **Fn** ↓ to decrease the brightness on the LCD display panel.
- **Power Management** – Set the computer to enter Sleep when idle for short periods and hibernate when idle for long periods of time to conserve battery power when the computer is not being used.
- **System Configuration** – The options you choose when purchasing a system can have significant effect on the battery life you will get. Larger batteries, LED displays, slower spinning hard disk drives, or better yet, a solid state disk drive, can all contribute significantly to the battery life of your system.
- **Battery Age** – Rechargeable batteries used in portable computers wear out over time, just like virtually all the other batteries you use in other products. In portable computers, this usually shows up as gradually shorter run times over the life of the battery. As with most wear-out modes, the harder you use the battery, the sooner it will wear out, so those things you do to increase your run time will also extend the time before you need to buy a new battery.

Appendix

Benchmarked System Configuration	
Platform	Inspiron 1545
Service Tag/Serial Number	ROB08BH
CPU	Intel Core 2 Duo T6600
Architecture	Penryn
Multi Core Support	Enabled (Dual-Core)
CPU Frequency	2.2GHz
Chipset	Intel GM45
Memory Vendor	Hynix
Memory Type	DDR2
Memory Quantity	2GB/667MHz
Memory DIMM Count	2x1GB
HDD Vendor	WD Scorpio WD1600BEVT
HDD Size	160GB
HDD Rotational Speed	5400RPM
HDD Technology	SATA
HDD Mode	AHCI
Graphics Card	Intel GM45
Graphics Memory	32MB
Testing Video Resolution	1024x768, 32-bit
Operating System	Vista Ultimate SP1, 32-bit
File System	NTFS
Power Scheme	Dell_Methodology (Cobra 1.1.0.42)
Aero	Enabled
Panel Size	15.6" HD
Native Resolution	1366 x 768
WLAN	Intel WiFi Link 5100 AGN
Driver	Intel, 12.0.0.82 (7/8/2008)
Optical Drive Type	DVD +/- RW
BIOS	A08

Disclaimer: The performance tests and results in this document were measured using specific configurations within the Dell performance labs as of November 2010. Actual performance results will vary based on the user's system configuration, applications, and manufacturing variability. These results should be used as a relative indicator only. Buyers should consider their own usage and consult with sources of performance data such as BAPCo at www.bapco.com.