UNDERSTANDING BATTERY LIFE IN PORTABLE COMPUTERS

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Many factors affect the amount of time that a portable computer battery can deliver power before it must be recharged. These factors include the types of applications being run and display brightness. Most companies that sell portable computers report battery life estimates for their portable computers. In addition, industry trade magazines and websites such as *PC Magazine* and **www.zdnet.com** provide battery life estimates. These estimates are usually based on well- known battery life benchmarks that attempt to replicate the way that portable computers are used in typical environments. Despite continuous improvements in these benchmarks, the estimated battery life figures they yield can differ from actual battery life experienced by users.

For example, Table 1 shows how the battery-life results can vary significantly between the two most common battery-life benchmarks: BapCo MobileMark® and Business Winstone BatteryMark®. (Two versions of the BatteryMark benchmark are presented: Ziff Davis BatteryMark 4.0.1 and Business Winstone BatteryMark 2002.) These results show as much as a 35-minute variation between battery-life results.

In this white paper, we discuss the top battery-life benchmarks, how they exercise the system, and some of the techniques used to more accurately reflect the typical keystroke patterns (including pauses) of end users. We also discuss the main factors that impact battery life and provide guidance on how users can extend the battery life of their portable computers.

Battery-Life Benchmarks

Several industry organizations maintain standardized tests or benchmarks that can be used to compare the battery life of different portable computers. These benchmarks exercise a system by running a fixed workload repeatedly until the battery forces the system to shut down. The time from the beginning of the test sequence until the system is shut down is the battery life "score" for that particular test run.

Early battery life benchmarks executed their workloads as fast as the processor could accept the commands. Keyboard input was paused several times in the command sequence to simulate idle time when the user was performing other functions. A similar approach was used in all desktop and portable system performance benchmarks during that time. A good example of this approach was the Ziff Davis BatteryMark benchmark, which ran a sequence of tests that exercised different subsystems. There were short pauses between each test and a longer pause at the end of the sequence. This process was repeated continuously as long as the battery lasted. The drawback to this approach is that it did not attempt to simulate the way that users actually type when using an application. The benchmark did not run actual user applications, nor did it properly simulate the pauses associated with tasks such as reading e-mail. Two leading battery life benchmarks attempt to better simulate actual usage models: Winstone 2004 BatteryMark and MobileMark 2002.

Benchmark	Benchmark Results
Ziff Davis BatteryMark 4.0.1	3 hours, 18 minutes
MobileMark2002	3 hours, 31 minutes
Business Winstone BatteryMark 2002	3 hours, 53 minutes

Note: Each benchmark was run three times on a portable computer and the resulting run times were averaged to minimize the impact of run variations. The power management and display brightness settings were held constant. This table presents the average results for each benchmark.

Table 1. Sample Benchmark Results

Business Winstone (BWS) BatteryMark

One of today's leading battery life benchmarks is BWS BatteryMark. The latest version is BWS 2004 Battery-Mark, but earlier versions—BWS 2002 BatteryMark and BatteryMark 4.0.1—are still common. This benchmark was developed by VeriTest for Ziff Davis Media, a major publisher of business and consumer magazines, including *PC Magazine*. The BWS BatteryMark workload is the same suite of applications that make up the Business Winstone workload:

- Lotus® Notes R5
- Microsoft® Office XP (FrontPage®, PowerPoint®, Excel, Access, and Word)
- Microsoft Project 2000
- Netscape 6.2.1
- Norton AntiVirus 2002
- WinZip 8.0

Although it consists of the same workload, BWS BatteryMark differs from Business Winstone by including pauses between tasks. The benchmark does not simulate the typing speed, including pauses, of a user.

BatteryMark reports an overall score that corresponds to the time elapsed from the beginning of the test until the system shuts down due to low-battery condition. The table of results also reports "wait time"— the time the system spent sleeping or waiting between tasks—and "active time"—the time the system spent actually doing work.

MobileMark 2002

MobileMark 2002 was developed by the Business Applications Performance Corporation (BAPCo). BAPCo is a nonprofit consortium that develops and distributes a set of objective performance benchmarks based on popular computer applications and industry-standard operating systems. Current members of BAPCo include Dell, Hewlett-Packard, IBM, Intel, Microsoft, and AMD.

MobileMark simulates actual usage models by including variable-length pauses between keystrokes and certain other tasks. The intent of this approach is to more closely match the typing speed and workflow of real users. This is important because today's portable computers usually include power management features that take advantage of these pauses to reduce the system power and prolong battery life. The inclusion of more-realistic keystroke pauses allows the benchmark to better reflect the battery life a user will experience when performing similar workloads.

Dell was very active in the development of the MobileMark benchmark, which is unique among industry battery-life benchmarks. Traditionally, battery life and performance benchmarks are run separately. The battery-life benchmark is run while the portable system is on battery power; the performance benchmark is run while the system is plugged into a power outlet. This approach can yield incomplete or misleading information because most portable computers are configured to transition to a reduced performance level when running on battery power to extend battery life. It is possible to manipulate a traditional battery-life benchmark to yield a high battery-life score by artificially reducing the performance to a level that renders the system unsuitable for real-world applications. In contrast, the MobileMark benchmark measures battery life and system performance simultaneously. For this reason, we base much of our analysis in this paper on MobileMark 2002 benchmark results.

MobileMark 2002 can be run in "productivity" workload or "reader" workload. The productivity workload mimics a mobile professional accessing e-mail and creating documents, graphics, and animation. The benchmark also mimics background file compression and virus detection operations. The following applications are used during the course of the MobileMark productivity test:

- Microsoft Word 2002
- Microsoft Excel 2002
- Microsoft PowerPoint 2002
- Microsoft Outlook® 2002
- Netscape Communicator 6.0
- WinZip Computing WinZip 8.0
- McAfee VirusScan 5.13
- Adobe® Photoshop® 6.0.1
- Macromedia Flash 5

The reader workload emulates a person reading a book or other document using Netscape Communicator 6.0. Published battery life numbers use the productivity workload because this more closely simulates the real-world usage of a typical business portable computer user.

JEITA

An additional battery-life benchmark is common in Japan and is cited in many battery specifications. The Japan Electronics and Information Technology Industries Association (JEITA) benchmark test does not attempt to simulate typical office productivity workloads. Instead, it consists of running a Motion Picture Experts Group (MPEG) video file continuously until the portable computer shuts down due to low battery. This test tends to produce unusually long battery-life scores. Because it does not simulate typical office productivity workloads, the JEITA benchmark is not used in this white paper.

Workload Effect on Battery Life

The entire test suite design of the BatteryMark and MobileMark benchmarks is based on a defined workload. This section explains why so much effort is put into defining the workload used in a battery-life benchmark.

The combination of workload and keystroke pauses determines how hard the system electronics—CPUs, graphics controllers, and so forth—must work during the test. The harder the system works, the more power it consumes and the shorter the resultant battery life. Applications such as word processing and e-mail usual-

ly have low performance requirements. In contrast, complex scientific analysis programs or 3D applications and games can have high CPU and graphics performance requirements. Figure 1 shows how power consumption can vary for a system and some of its major components while running different applications.

In this graph, each stack represents the power consumed while running a particular workload or while the system is in "Windows Idle" mode.[1] The height of each stack represents the total system power drawn from the battery. Each stack is broken down into various system components: graphics controller, hard drive, processor, audio subsystem, display subsystem, and the remaining components such as memory and core-logic chip set (labeled "Rest of system"). In this way, the graph depicts the amount of power consumed by each component under various workloads. For example, the processor consumes approximately 3 watts running MobileMark 2002, an average of 5-6 watts during DVD playback, and about 11 watts during 3DMark® 2000, a benchmark that measures 3D graphics performance.

Figure 2 shows how these power consumption variations affect battery life. This graph shows the battery life of a system with a 53-watt hour (Whr) battery that is
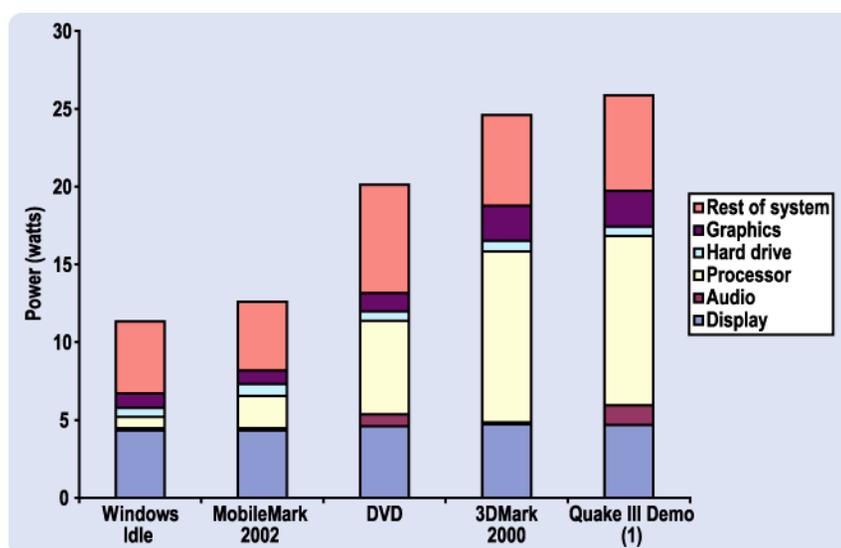
Note: These benchmarks were run on a Dell Latitude C600 portable computer with an Intel® Pentium® III processor running at 700 MHz. Although scores may differ on more-current systems, the relative power usage of various system components does not vary significantly.

Figure 1. Relative Power Consumption of Main Portable Computer Components

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1. "Windows Idle" refers to the condition of a computer system when it is first booted and the user logs onto the system, but before any programs are running.
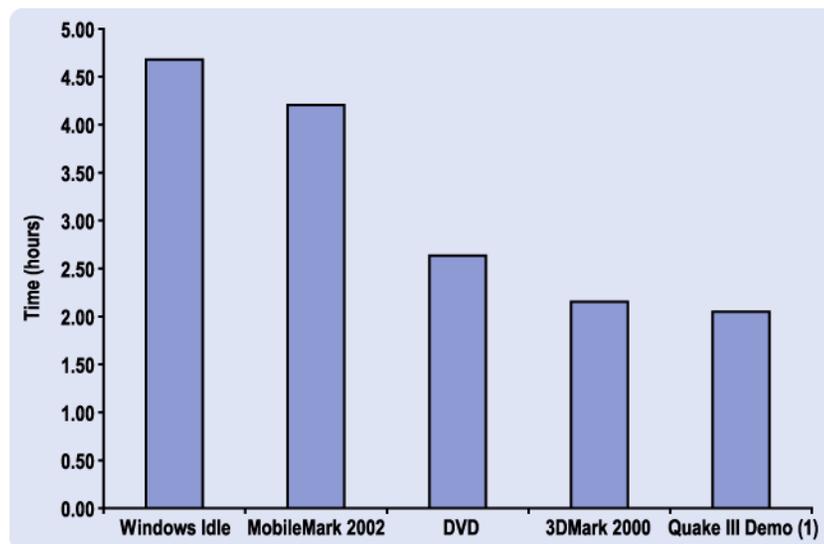
Note: These benchmarks were run on a Dell Latitude C600 portable computer with an Intel Pentium III processor running at 700 MHz.

Figure 2. Battery Life Under Different Workloads

running the workloads shown in Figure 1. It can be seen that battery life varies significantly between the 3D application workload of 3DMark 2000 at approximately 1.5 hours and the Windows operating system idle state at 3.8 hours. The heavy workload of 3DMark 2000 consumes more power, which shortens battery life. The fact that battery life varies so significantly depending on the particular mix of applications running on a portable system is one of the main reasons that the actual battery life seen by end users can vary from the estimates published in magazines or on company websites.

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 MobileMark 2002 results in Figure 1 reveal two top power consumers:

- **Display Power** — power consumed to create the image seen on the portable computer screen.
- **Rest of System** — power consumed by the remaining nonspecified electronics in the system such as the core-logic chip set and memory.

The processor is a distant third in the MobileMark 2002 results because typical business productivity applications are not compute-intensive. The mobile processors

used in most of today's portable computers usually consume only 5–8 percent of the total system power when running mainstream business productivity applications. The second top power consumer, "Rest of System," is a catch-all category for components such as the system memory and core-logic chip set that are too difficult to measure independently or do not individually contribute significantly to power consumption. The top power consumer is display power. In the next section, we discuss the impact of display brightness on the power consumed by the system.

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. Figure 3 compares the expected battery life when the display is set to minimum and maximum brightness levels.

In Figure 3, the MobileMark 2002 battery life ranges from 3 hours and 23 minutes associated with maximum display brightness, to 4 hours and 50 minutes at minimum brightness. These benchmark results suggest a battery-life increase of over an hour associated with adjusting the brightness of the display from its highest to lowest setting. Because the brightness setting has
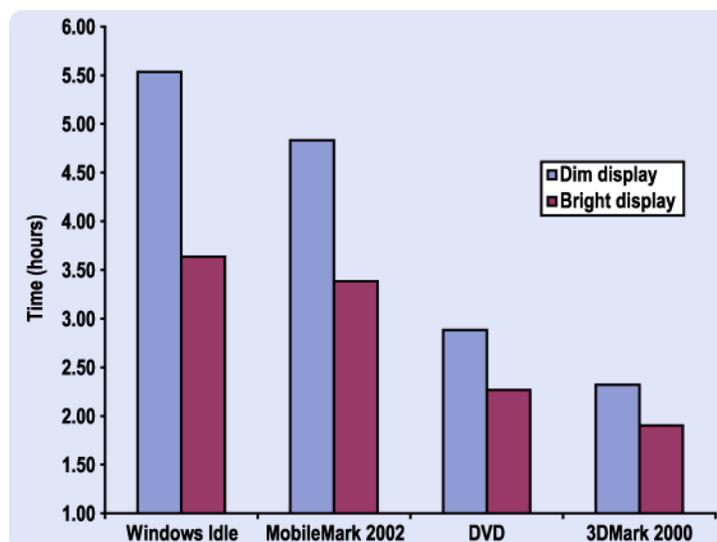
Note: These benchmarks were run on a Dell Latitude C600 portable computer with an Intel Pentium III processor running at 700 MHz.

Figure 3. Effects of Display Brightness on Battery Life

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 ↓** keys on the portable computer keyboard of Dell™ Inspiron™, Latitude™, and Dell Precision™ mobile workstation systems.

Other Power-Saving Steps

In addition to adjusting display brightness, users can take other steps to extend battery life, including enabling Windows operating system and device power management capabilities.

Enable Microsoft Windows® Operating System Features

Microsoft Windows operating system settings can have a significant impact on battery life. Current Windows operating systems 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**. 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

Brightness Settings When Running Battery-Life Benchmarks

Some portable computer manufacturers limit the maximum brightness that can be set when on battery power. This practice improves battery life, but greatly reduces the visibility of the screen under high ambient light conditions such as a brightly lit room or outdoors on a sunny day. This practice can also impact published battery life benchmark tests run by portable computer manufacturers and industry magazine test facilities. For this reason, the latest MobileMark benchmark test recommends that the display on a tested system be set to a specific brightness level or "luminance" measured in candelas per square meter (cd/m2), also known as "nits" in the U.S. The recommended level is 60 nits. Portable computer LCDs generally range from about 20 nits for the dimmest setting to a maximum brightness of 150–180 nits on some of the brightest displays currently available.

However, most magazine test facilities do not have equipment to measure the surface brightness or luminance of a display. Instead, they typically use a specific point in the range of settings provided by the manufacturer of the system such as minimum, middle, or maximum settings. When running the MobileMark benchmark, this default setting is the middle brightness setting. For this reason, the actual display brightness level of tested systems can vary significantly between computer makers, thus skewing the resulting battery life benchmark results.

Dell does not limit the maximum brightness setting on its portable computers when running on battery power. The full display brightness range is available whether the system is plugged into a power outlet or running on battery power.

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.

Current Windows operating systems also allow users to disable certain hardware devices that are not used when the portable computer is running on battery power. This is accomplished using the Windows **Device Manager** accessible in the **System** icon of the **Control Panel**. For example, a system can be configured to temporarily disable the 10/100/1000 Ethernet LAN controller when running on battery power. Or, executing the above process while on battery will cause the device to automatically be disabled in the future when the system is running on battery power.

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.

Dell QuickSet

Quickset is a software interface available on Dell notebooks since 2002 that enables easy control over key features. QuickSet makes it easy to customize settings for travel or presentations, and its power management interface provides quick access to standard or customer-defined power schemes

Using the Power Management Wizard, a customer defines settings for standby and hibernate modes, as well as power schemes that can turn off the display and hard drive, set display brightness, and define wireless activity. These schemes are customized for operation on and off battery.

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 affect on battery life. In addition, install a second battery, rather than an optical drive, in the portable drive bay. This step not only extends battery capacity, but eliminates the significant 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.

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 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 portable system that is equipped with a mobile processor designed with power management in mind. 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 when running on battery power 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.