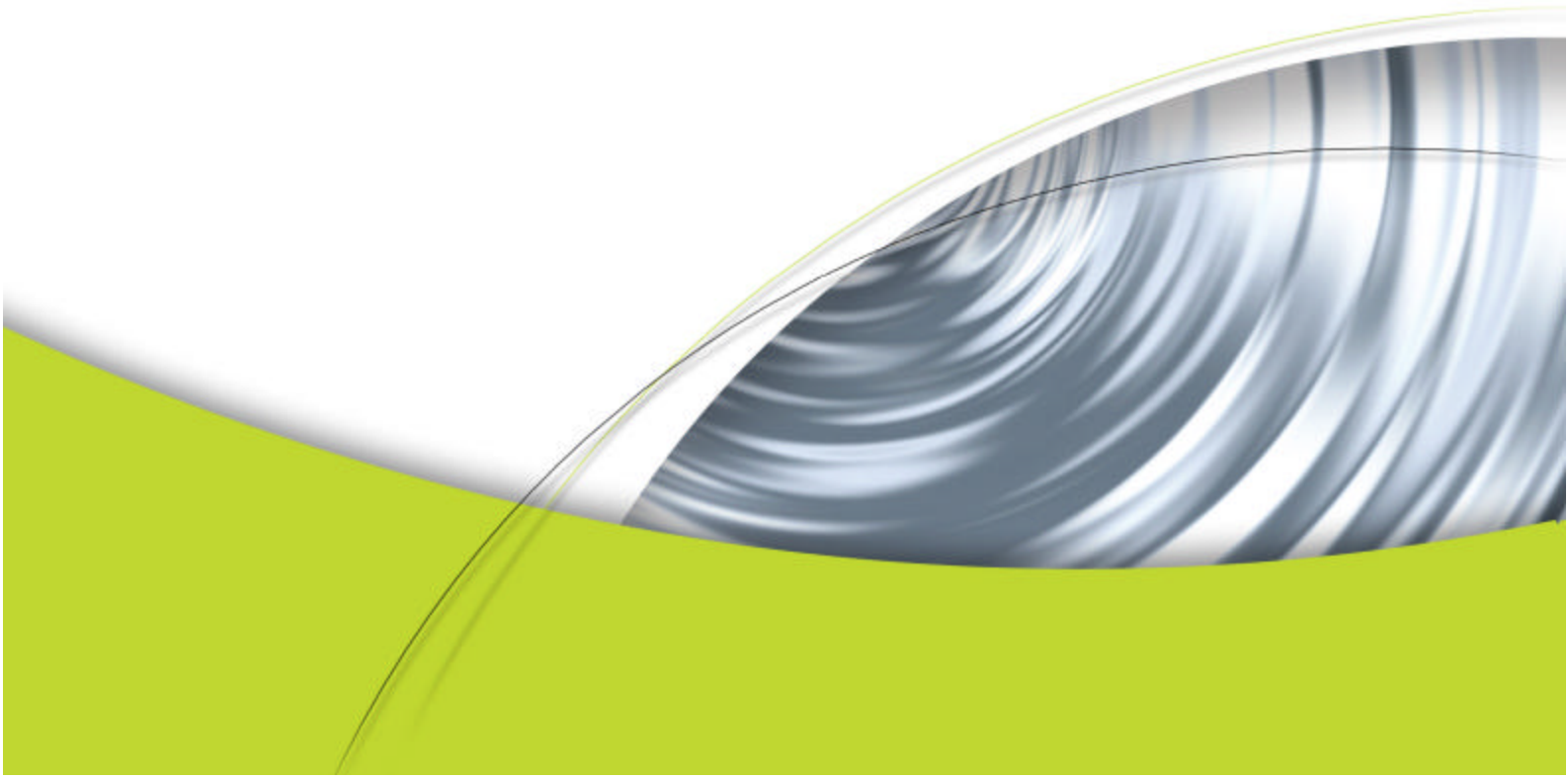


# Technical Brief

## PowerMizer 5.0

Power Management Technology for GeForce Go 6 Series and NVIDIA Quadro FX Go1400

# Table of Contents

# Introduction

The notebook PC market continues to experience explosive growth, fueled by the dramatic shift towards the “one PC” usage model. In this model, users demand the same high performance as a desktop PC, yet require the uncompromised battery life and form factor convenience of a traditional notebook PC.

The NVIDIA® GeForce™ Go 6 Series and NVIDIA Quadro® FX Go1400 graphics processing units—NVIDIA’s newest and most advanced mobile graphics processing unit GPU product families—are specifically designed to address these challenging needs. And the NVIDIA PowerMizer™ 5.0 technology is key to delivering this demanding yet crucial requirement.

PowerMizer 5.0 enables the most efficient system-level power consumption and delivers the longest battery life to notebook PC users. PowerMizer gives you the best battery performance whether you’re playing the latest Microsoft® DirectX® 9.0 Shader Model 3.0–based stunning 3D games (at smooth frame rates of unprecedented image quality), watching your newest favorite HD video (HD-DVD or prerecorded HDTV shows), or performing routine PC tasks (e-mail, office, or Internet).

PowerMizer 5.0, the latest version of PowerMizer and a key NVIDIA mobile technology, was developed as a tightly integrated element of the GeForce Go 6 Series and NVIDIA Quadro FX Go1400. PowerMizer combines many techniques: maximum CPU offload, maximum usage of ACPI low-power-states, revolutionary GPU performance-per-watt design, fully programmable on-chip video processor, leading-edge semiconductor manufacturing technologies, and MXM (Mobile PCI Express Module) support. PowerMizer 5.0 is key to enabling these mobile GPUs to deliver their award-winning features and performance benefits within the stringent constraints of a desktop notebook or workstation notebook PC.

# Engineered for Comprehensive Mobile Power Management

PowerMizer 5.0 delivers numerous innovations:

- The NVIDIA CineFX™3.0 engine has dedicated GPU hardware that greatly offloads complex geometry calculations from the CPU. This helps CineFX 3.0 extend battery life (the CPU is the biggest power consumer in a notebook PC), yet deliver superior performance rendering cinematic-quality graphics. This ability directly translates to extended battery life for 3D gaming.
- The NVIDIA PureVideo™ video processor is a revolutionary new video processor with full programmability of its own on-chip dedicated hardware resources. Other chips use general-purpose shader hardware for video post-processing. PureVideo offloads video from the shaders, which translates to lower power and extended battery life for video playback.
- Sophisticated on-chip performance and configuration monitors provide fine-grain monitoring and aggressive management of power consumption for various modules. This ability allows the enabling, demand-based level of clocking, and even shutdown of modules—all in a fully dynamic manner, ensuring extended battery life in dynamic usage-mode situations
  - Shutdown of unused configuration resources saves unnecessary power consumption (for example, TV-out module shutdown when not connected to a TV).
  - Intelligent dynamic clock scaling keeps clocks low for long battery life and automatically scales up to match application task activity.
  - Aggressive dynamic clock gating turns off large sections of the GPU not in use to achieve the lowest operating power.
  - Dynamic voltage scaling keeps voltage at the lowest level possible and only scales up voltage for the most demanding applications.
- On-chip thermal monitors deliver a higher level of thermal manageability (at both a GPU and a system level), enabling a cooler and more reliable operational environment. This also extends battery life by minimizing leakage power, which is directly proportional to operating temperatures within notebook PCs.
- Dynamic lane management for PCI Express to support low-power L0s and L1 states for 1× to 16× lanes.
- Advanced manufacturing fabrication and packaging processes, tuned specifically for mobile needs, provide the industry's lowest power operation capability (down to the latest 0.11 micron process technology, running at low voltage, and power-dissipative bare-die flip-chip packaging).
- NVIDIA Intellisample™ data compression technology minimizes the raw memory bandwidth/power required. Its low-power, self-refresh, power-down memory modes for Win-Idle reduce the power consumption of video memory. Both features are achieved without compromising graphics quality.

- Optimal usage of system-level Advanced Configuration and Power Interface (ACPI) performance states (processor and system)—driven through an efficient, balanced use of on-chip GPU resources—enhances battery life by ensuring system-level power savings.
- Automatic AC detection feature switches between performance mode and the user-selected battery-saving mode.
- Dynamic software-controlled CPU/GPU workload distribution minimizes system power with minimal user impact.
- NVIDIA SmartDimmer™ technology intelligently manages panel power consumption based on user preferences and activities. This feature is uniquely possible through the GPU because it controls the user's final visual experience.
- MXM, a revolutionary initiative to modularize mobile graphics across the notebook PC market segment, is fully supported through PowerMizer 5.0. Based on a mechanism to exchange optimum power settings between the motherboard and the MXM module, PowerMizer efficiently manages power and performance of the graphics subsystem to deliver enhanced battery life for MXM–based notebook PCs.
- PowerMizer also provides a simple, intuitive, yet powerful user interface that lets users customize their preference, balancing their particular needs between longer battery life and higher-performance usage modes. This feature enables technology to service users as they prefer—a key success factor for adoption of this capability to deliver extended battery life.

## New "Power-Efficient" Graphics and Video Engines

The GeForce Go 6 Series and NVIDIA Quadro FX Go1400 mobile GPUs include graphics engine CineFX 3.0, the foundation for delivering the latest Microsoft DirectX 9.0 Shader Model 3.0–enabled true cinematic computing for users on the go. The CineFX 3.0 engine offloads the sophisticated and extremely compute-intensive geometry and rendering calculations from the CPU to the GPU. The GPU is a far more power-efficient unit for these purposes, which enables these otherwise power-prohibitive operations to be executed within notebook power budgets.

These notebook GPUs also introduce PureVideo, a technology driven by a sophisticated new on-chip video processor. PureVideo is the foundation for delivering the best-of-class HD video playback for users on the go. PureVideo accomplishes this more power-efficiently than ever, extending battery life for video playback of older, DVD/TV content plus newer, HD-DVD/HDTV content.

Because of these architectural system-level, efficient, balanced work partitions enabled by PowerMizer—and the resulting offload of these features to the more power-efficient GPUs instead of to CPUs—notebook PCs gain the longest possible battery life for 3D gaming and video playback.

## Dynamic On-Chip Power Management Monitors

Sophisticated new on-chip configuration, performance, and thermal monitors constantly oversee usage modes, activity levels, and operational conditions of the many hardware modules in the GPU and the GPU as a whole as well. This means that automated gating/scaling and enabling/disabling of units is performed on an ongoing dynamic basis, dramatically enhancing the level of granularity of this power management scheme

Finely tuned with the "monitoring" capability is a built-in "control" capability. Tightly integrated features allow dynamic control with varying levels of granularity for clock scaling, clock gating, and supply voltage scaling.

Another key feature—on-chip thermal management—enables a new level of graphics subsystem power management by utilizing on-chip (and extensible with external) temperature-sensing circuitry and built-in software driver support. Notebook PC designers can use this feature to design ultraefficient, system-level management of performance, power, and thermal parameters.

A "performance on demand" native hardware capability ensures that only the minimal hardware elements and settings are used at any given time. This feature maximizes power savings and extends battery life, and simultaneously offers seamless performance and quality operation. Robust hardware and software design and verification of these features ensures not only extended battery life but—equally important—a reliable and predictable user experience.

## MXM Power Management Support

The Mobile PCI Express Module (MXM) is an industry initiative to modularize notebook PC graphics. As evidenced by the tremendous industry momentum behind this initiative, MXM is on its way to revolutionizing the notebook PC market by accelerating time-to-market, enabling configure-to-order manufacturing, and eventually bringing the promise of user-upgradeable notebook graphics within reach. PowerMizer 5.0 offers full support of this key, new initiative.

PowerMizer 5.0 uses a built-in protocol for exchanging power/thermal–related information between the notebook motherboard and the MXM graphics module, plus associated power management software/hardware resources. These features enable PowerMizer 5.0 to ensure the most robust yet power-efficient implementation of MXM–based notebook PCs. So whether the NVIDIA notebook GPU in your mobile PC—a GeForce Go 6 Series or an NVIDIA Quadro FX Go1400—is a motherboard-down design or an MXM module design implementation, you're guaranteed full PowerMizer benefits, for the longest battery life.

## SmartDimmer Technology

SmartDimmer—a feature uniquely manageable through the GPU—is an intelligent way to manage notebook panel power consumption (for example, it dims the panel when appropriate). The GeForce Go 6 Series or NVIDIA Quadro FX Go1400 GPU driving the notebook panel are the only components fully aware of, and responsible for, driving the display on the panels. This unique capability forms the basis for SmartDimmer technology, which lets users preset certain brightness-related preferences through a Control Panel (Figure 1) and lets the GPU then manage the panel display within these limits. As a result, these GPUs can reduce power consumption in one of the most significant and always-on power expenders in a notebook—the display panel. In turn, this reduction seamlessly delivers enhanced battery life for the user.

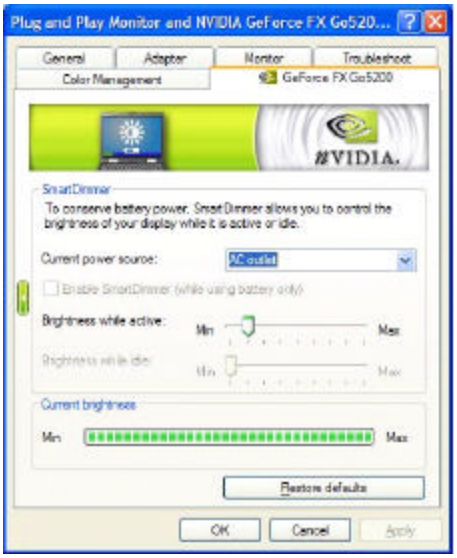



Figure 1. Controlling Brightness-Related Preferences with SmartDimmer

## PowerMizer User Interface

Users want their notebooks to operate according to their personal priorities. A student playing a 3D game on an airplane may want to reduce the frame rate in order to play longer. Or, architects running 3D design applications may want every bit of 3D performance to present a compelling walkthrough of buildings they created, with little concern for battery life.

PowerMizer 5.0 provides an intuitive user interface for power management settings that lets users choose maximum performance, maximum battery life, or a happy-medium “balanced” operating mode.

## Power Management Settings

In the Properties window, users can adjust a slider to select a battery setting that ranges from Maximum power savings to Maximum performance (Figure 2).

Because the CPU is the main power consumer in a notebook, a Balanced setting is also offered. This setting trades a small amount of performance (by offloading the CPU) for a large gain in battery life.

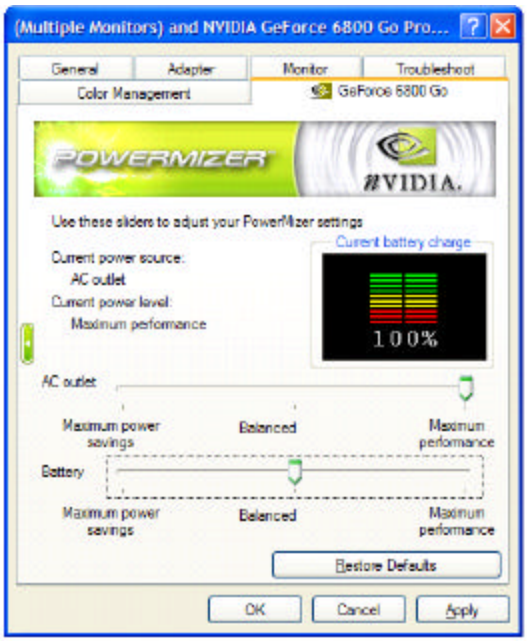



Figure 2. Specifying the Battery Mode

## Typical Power Management Settings

A built-in AC-detect mechanism lets users set a preference for battery mode or AC-power mode once. After that, the notebook automatically switches between these modes, depending on whether the notebook is plugged into a wall outlet AC source or is operating on battery power. A typical setup would have “Maximum performance AC outlet” and “Balanced” battery mode settings. Of course, this is fully adaptable based on individual preferences.

3D enthusiasts may select Balanced power savings setting, actively trading some performance for extended battery life. Why run at 120 frames per second if the display only allows 60 frames per second? PowerMizer software reduces the maximum operating frequency of the GPU to reduce the power consumed. PowerMizer also reduces the workload on both the GPU and the CPU, using a patent-pending technique. Reducing the workload in the system allows maximum battery life.

Only NVIDIA provides users with such effective control over performance and battery life, backed up with a tightly integrated hardware and software PowerMizer technology incorporated in the GeForce Go 6 Series and NVIDIA Quadro FX Go1400 GPUs.

**Note:** This control sets the "maximum" ceiling permissible based on the user's preference. PowerMizer actively manages power to lesser utilization levels, automatically delivering extended battery life while guaranteeing no visible effects to users.

## Maximum Performance

The highest performance is achieved by selecting Maximum performance. For highly demanding applications, such as design tools or 3D animation, this capability can be critical.

When Maximum performance is selected, no regard is paid to the level of CPU usage. Maximum frame rates are always achieved, even if they are too fast for the user to keep up with, or too fast for the screen to display.

Figure 3 shows CPU usage when a system is running a detailed scene of 1,000 frames. During the short test execution, the CPU utilization was 100 percent, which dropped to almost zero for the remainder of the 1:40 (1 min. 40 sec.) profiled. In Maximum performance mode, the test ran at 92 frames per second.

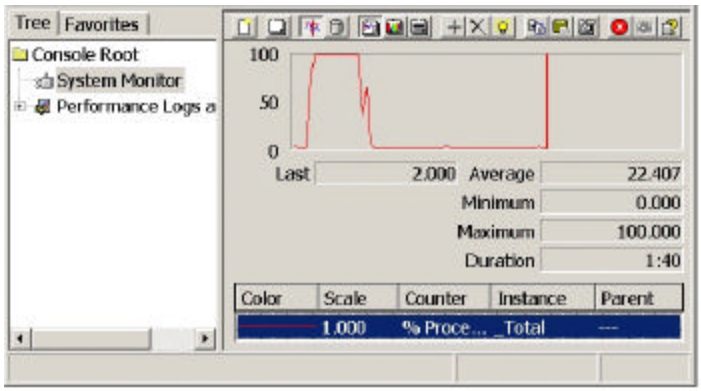



Figure 3. CPU Utilization in Maximum Performance Mode

While the test was running, the power (amps) consumed by the system was logged using a digital amp meter at 0.1 second intervals (Figure 4). The power was supplied from a 20 V source.

Power is calculated by multiplying the 1.5 A average by 20 V, which equals 30 W. When system power is measured, higher power equals shorter battery life.

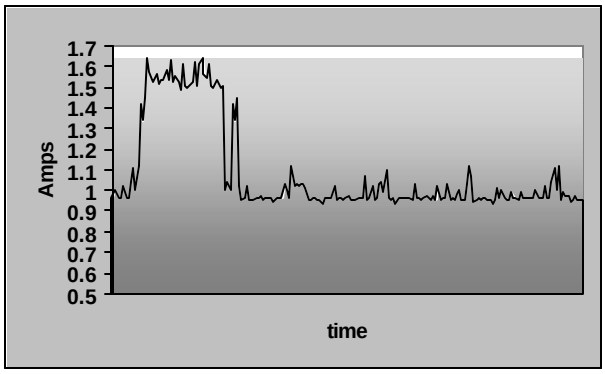
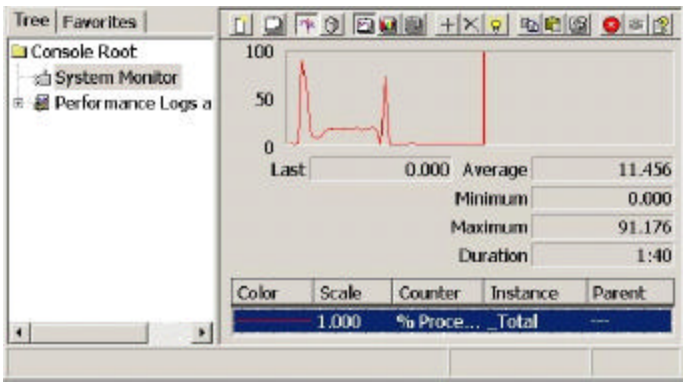



Figure 4. DC Current Used in Maximum Performance Mode

## Balanced

Sometimes the GPU runs so fast that the system is doing more work than the user can take in. To reduce power, users can select the Balanced setting, which trades frame rates for compelling performance. The Balanced mode pays particular attention to the load balancing between the CPU and the GPU. This balancing ensures that the load is placed on the GPU, which lets the CPU idle in a lower power state. During the test run (in Balanced mode), the system ran at a compelling 55 frames per second. Figure 5 shows the CPU usage for Balanced mode (rendering 1,000 frames).




Note the marked decrease in power consumption. When the CPU idles, it uses much less power, dramatically reducing power usage for the overall system.

Figure 5. CPU Utilization in Balanced Mode

Figure 6 shows the current that's drawn by the system during testing. Notice that the average power drawn is less than 1.2 A. This translates to 24 W using a 20 V power supply. The PowerMizer Balanced mode offers a balance between high performance and significant power savings—20 percent in this example. All the power saved in this mode comes from reducing the workload on the CPU.

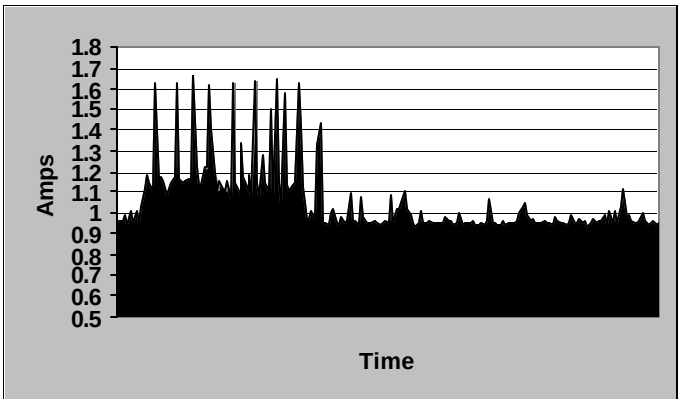



Figure 6. DC Current Used in Balanced Mode

## Maximum Power Savings

Setting PowerMizer at Maximum power savings provides the longest battery life. Clocks and voltage are held at their minimum settings to ensure the lowest power consumption. For the user who wants usable frame rates and maximum battery life, this is the ideal setting.

Figure 7 is a screenshot of the system monitor showing CPU utilization in Maximum power savings mode. This test took longer to render 1000 frames, running at 26 frames per second. Other than when the test was being loaded, the CPU utilization averaged only 10 percent.

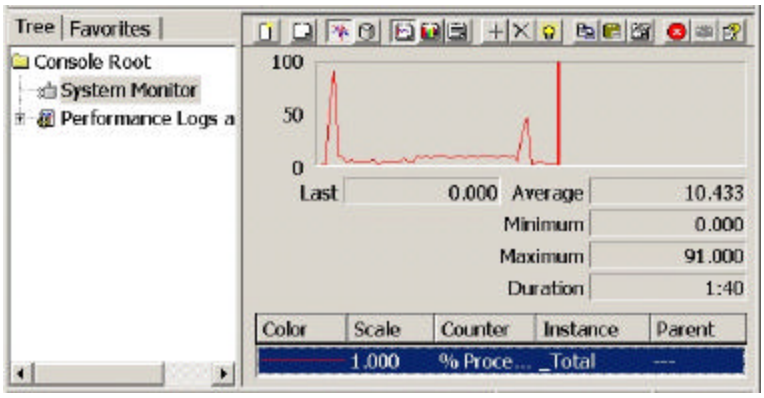



Figure 7. CPU Utilization in Maximum Power Savings Mode

Figure 8 shows the amount of power consumed when the system runs in Maximum power savings mode. The average power at 1.1 A translates to 22 W, a 25 percent savings in power. In this mode, the graphics subsystem offloads the CPU to achieve the power savings. Maximum power savings is the ideal setting for usable frame rates and maximum battery life.

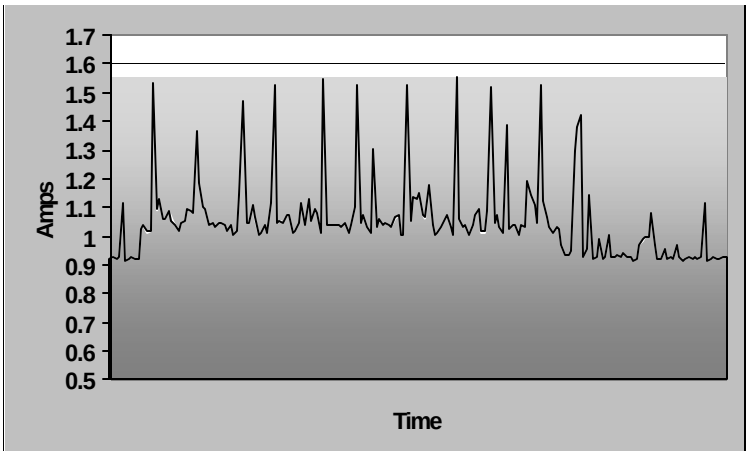



Figure 8. DC Current Used in Maximum Power Savings Mode

# Conclusion

The NVIDIA GeForce Go 6 Series and NVIDIA Quadro FX Go1400 GPUs deliver the ultimate in mobile cinematic computing for the new, unified, at-work or at-play mobile user. Breathtaking cinematic graphics and HD video quality, with industry-leading performance in a notebook PC form factor, are enabled by PowerMizer 5.0, NVIDIA's latest comprehensive and advanced power management technology.

NVIDIA delivers comprehensive, advanced power management in our latest mobile GPUs by leveraging many technologies: CineFX 3.0 graphics and PureVideo video architectural advancements, MXM graphics support, efficient ACPI power-states utilization, on-chip configuration/performance/thermal monitors, SmartDimmer technology, and leading-edge manufacturing technologies. NVIDIA has a tradition in the notebook PC market of advancing the frontier of the user's graphics experience and expectation, and PowerMizer 5.0 is a key element in delivering this for our latest notebook GPUs.

Together with PowerMizer 5.0, the GeForce Go 6 Series and NVIDIA Quadro FX Go1400 GPUs deliver the longest battery life and true mobility for notebook PC and workstation users.

# Appendix: Fundamental Power Management Techniques

At the core of power management technologies is the power equation itself:

$P = CV^2f$

The power equation describes the relationship between power (P), capacitance (C), voltage (V), and frequency (f). When you reduce any of the terms on the right side of the equation, the required power is reduced. For example, if the clock frequency is reduced, the power consumption is also reduced.

## Dynamic Clock Scaling

Power consumption is directly proportional to the frequency, so the lower the frequency of the GPU, the lower the power consumed. NVIDIA designed the GPU to run at frequencies as low as 16 MHz during the Win-Idle state, which dramatically lowers the typical power consumption.

The frequency is raised when performance is needed, and then drops back down when not needed. Many docks in the graphics subsystem—an engine clock, memory clock, and pixel clock—are carefully managed to deliver a great user experience while consuming the least amount of power.

## Dynamic Clock Gating

Clock gating is equivalent to reducing the frequency to zero. According to the power equation, if the frequency is zero, then power equals zero. GeForce Go 6 Series mobile GPUs use clock gating extensively to ensure that all the unnecessary portions of the GPU use zero power.

## Voltage Scaling

An increase in voltage results in an exponential increase in consumed power. Therefore, managing voltage is extremely important for managing power consumption. GeForce Go 6 Series and NVIDIA Quadro FX Go1400 GPUs use an advanced semiconductor process technology to operate at the lowest voltage of any mobile GPU. Other GPUs use a higher voltage at all times, or scale voltage up to deliver performance, thus shortening battery life. The finer process geometries in the NVIDIA solutions—down to a power-saving 0.11 micron low-voltage process—enable a design that can run at lower nominal voltages.

When the notebook is plugged in, the NVIDIA GPU supports increasing the voltage to operate at peak frequencies so that it delivers maximum performance. This provides desktop-equivalent performance in a notebook, without the traditional trade-off in graphics performance that has previously plagued notebooks.

## AC Power Auto Detect

When the notebook is plugged into a wall outlet running on AC power, users expect ongoing full performance because battery life is not a concern. PowerMizer 5.0 recognizes when a machine is running on AC power and uses the AC Outlet performance setting, which normally turns off performance-limiting techniques to provide maximum performance globally.

As soon as AC power is removed, PowerMizer automatically uses the Battery setting, which normally would be in Balanced or Maximum Battery Savings mode. Once set, no further user intervention is required. The PowerMizer mode can be set, whether the machine is on AC or not.

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