Technical Brief

PowerMizer 7.0

Intelligent Power Management Technology for NVIDIA GeForce 8M Series and Quadro NVS/FX Notebook GPUs

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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. With new innovations in 3D-intensive operating systems like Microsoft's Vista®, new demands are being put on the graphics processing units (GPUs) and power management has never been more crucial.

The NVIDIA® GeForce® 8M Series and NVIDIA Quadro® NVS notebook graphics processing units employ NVIDIA PowerMizer® 7.0 - an intelligent, fully automatic power management technology aimed at providing the best balance of performance and battery life.

PowerMizer® 7.0 is the culmination of a long history of power management technology tightly integrated into NVIDIA GPUs. It enables the most efficient system-level power management and delivers increased battery life for notebook PC users. PowerMizer gives you the longest battery life whether you're playing the latest Microsoft DirectX 10.0 Shader Model 4.0-based 3D games (at smooth frame rates of unprecedented image quality), watching your favorite HD video (HD-DVD, Blu-ray or prerecorded HDTV shows), running industry-leading business applications (Microsoft® Office Suite, Lotus Notes, Bloomberg, TradeStation, Reuters), or performing routine PC tasks (e-mail, office, or Internet).

A key focus and goal of the seventh generation of PowerMizer is to provide the most intelligent and adaptive GPU power management technology possible. The latest generation achieves this by providing performance-on-demand for the user. Digital watchdogs monitor GPU utilization and are able to turn down portions of the chip that are not being used, by throttling power consumption to meet the performance needs of a specific application. When an application does require the GPU to go full throttle, it can do so immediately to ensure that maximum performance is achieved.

A key NVIDIA notebook technology, the latest version of PowerMizer 7.0, was developed as a tightly integrated element of the GeForce 8M Series, Quadro NVS, and Quadro FX notebook solutions. PowerMizer 7.0 makes it possible for the GeForce 8M Series and NVIDIA Quadro NVS notebook GPUs to deliver award-winning features and performance benefits while maintaining the longest battery life possible. The following table is a summary of techniques employed to create the most comprehensive power management solution.
Table 1. PowerMizer 7.0 Power Management Techniques

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<th>Power Efficient Design</th>
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Engineered for Comprehensive Notebook Power Management

PowerMizer 7.0 delivers numerous innovations aimed at increasing battery life:

- **CPU Offload** - The NVIDIA graphics engine has dedicated GPU hardware that efficiently runs complex geometry calculations and offloads them from the CPU. This helps extend battery life, yet delivers superior performance rendering cinematic-quality graphics. This ability directly translates to extended battery life.

- **Dedicated Video Engine** - NVIDIA Pure Video™ technology is the combination of dedicated high-definition (HD) video processors and video decode software that enables unprecedented picture clarity. Other chips use general-purpose shader hardware for video post-processing. PureVideo offloads video from the shaders and the CPU, which translates to lower power usage, better performance, and extended battery life for video playback of Blu-ray, HD-DVD, and off-air HD content.

- **On Chip Power “Watchdog”** - On chip power management circuitry designed to monitor the GPU’s utilization and throttle voltages and clocks of underutilized portions of the GPU. This automatic demand-based monitoring ensures intelligent power management is always at work. Examples are:
  - Intelligent dynamic clock scaling keeps clocks low for long battery life and automatically scales up to match an application’s task activity.
  - Aggressive dynamic clock gating turns off large not-in-use blocks of the GPU 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.
  - The shutdown of unused configuration resources saves unnecessary power consumption (for example, it shuts down a TV-out module when it’s not connected to a TV).

- **Advanced Clock Gating** - A comprehensive network of clock gating circuitry encompasses the entire GPU to ensure the utmost level of control.

- **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.

- **PCI Express Bus Power Management** - PowerMizer goes outside the GPU to vary the PCI Express bus bandwidth based on advanced bus utilization algorithms. This greatly reduces the power consumption when the PC is idle.

- **NVIDIA's ASPM** (Active State Power Management) extends the reach of PowerMizer's PCI Express link power management. By detecting the level of activity on the PCI Express link, PowerMizer can determine the optimal time to place the link into a lower power state.

- **LCD Backlight Brightness Control** - The backlight is one of the largest power consumers in a notebook PC. NVIDIA Smart Dimmer™ technology intelligently manages panel power consumption by dimming the back light whenever possible based on user preferences and activities, thereby increasing battery life.

- **Advanced Silicon Fabrication** and packaging processes, tuned specifically for notebook needs, provide the industry's lowest power operation capability—down to the latest 0.065 micron process technology, running at low voltage, and with 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.

- **ACPI** - 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. An automatic AC detection feature switches between performance mode and the user-selected battery-saving mode.

- **MXM** - PowerMizer's power management technology efficiently manages power and performance of the graphics subsystem to deliver enhanced battery life for MXM–based notebook PCs.

- **Graphical User Interface (GUI)** - The user experience has been greatly simplified in the new Windows Vista operating system. PowerMizer performance modes have been directly mapped to the Power Plans in Vista. Therefore, the user only has one location in the operating system to set and check the power modes; greatly simplifying the process.

- **Termination-Free Graphics Memory** - When PowerMizer7.0 is able to turn down the memory clocks, it determines whether to shut off the memory’s signal termination network (a great source of power consumption). In many cases, the memory clock does not have to run full bore and can thus run without the power draining termination network.
New Battery-Friendly Graphics and Video Engines

The foundation of the GeForce Go 8 Series and NVIDIA Quadro NVS/ FX notebook GPUs is the graphics engine that delivers the latest Microsoft DirectX 10.0 Shader Model 3.0–enabled true cinematic computing for users on the go. This graphics engine continues the tradition of offloading 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 include PureVideo HD, the foundation for delivering the best-of-class HD video for users on the go. PureVideo HD is comprised of video processor engines and video decode software optimized for decoding the H.264 and VC-1 format, the formats for both Blu-ray and HD-DVD. These new standards are pushing the limits of the CPU. With Pure Video HD, NVIDIA GPUs achieve 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 system-level balanced work partitions enabled by PowerMizer—and the resulting offload of these features to the more power-efficient GPUs—notebook PCs gain the longest possible battery life for 3D gaming and video playback.

By implementing this in hardware, the GPU is able to manage its resources almost immediately and thus provides a seamless balance between performance and longer battery life for the end-user.

Intelligent Power Management:
Performance on Demand

With integrated digital watchdogs built into the GPU, PowerMizer 7.0 is able to monitor the GPU’s utilization in hardware. This enables efficient algorithms to ensure that the GPU is always optimized for the current application. With the diverse array of applications spanning from simple email and word processing applications to very complex 3D gaming programs and high definition 1080p Blu-ray/HD-DVD movie playback, PowerMizer 7.0 adjusts the GPU’s performance according to the demands placed on it, in order to keep overall system power consumption to a minimum.

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

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. This ensures that very
little battery power is wasted by running harder than is necessary. In addition, performance is always maintained by being able to turn the clocks at a moments notice.

Another key feature—on-chip thermal management—enables a new level of graphics subsystem power management by utilizing on-chip temperature-sensing circuitry and built-in software driver support. Notebook PC designers can use this feature to design ultra efficient, 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, while simultaneously offering 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. The tremendous industry momentum behind this initiative indicates that MXM is on its way to revolutionizing the notebook PC market by accelerating time-to-market and enabling rapid configure-to-order manufacturing. PowerMizer 7.0 offers full support for this key initiative.

PowerMizer 7.0 uses a built-in protocol—plus associated power management software/hardware resources—to exchange power/thermal-related information between the notebook motherboard and the MXM graphics module. These features enable PowerMizer 7.0 to ensure the most robust but power-efficient implementation of MXM-based notebook PCs. So whether the NVIDIA notebook GPU in your notebook PC is a motherboard-down design or an MXM module design implementation, you’re guaranteed full PowerMizer 7.0 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 8M Series or NVIDIA Quadro NVS/FX notebook GPU driving the notebook panel is the only component fully aware of, and responsible for, driving the display on the LCD panel. This unique capability forms the basis for SmartDimmer technology, which lets users preset certain brightness-related preferences through a control panel in Windows Vista (Figure 1). It also lets the GPU manage the panel display within these limits. As a result, the GPU can reduce power consumption from one of the biggest power users in a notebook—the display panel. This reduction seamlessly delivers enhanced battery life for the user.
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 exchange for longer playing time. Automobile designers running 3D crash analysis applications may want every bit of 3D performance (with little concern for battery life) so they can run accurate simulations of automobile crashes.

In the Windows XP operating system, PowerMizer 7.0 provides a simplified user interface for power management settings.

In the new Windows Vista operating system, PowerMizer 7.0 control has been directly mapped into Vista’s Power Options Menu. There is no need for the user to manage the power from multiple control panels. With PowerMizer 7.0, the user has streamlined control topology along with the knowledge that PowerMizer is always working in the background; adaptively adjusting its power consumption based on utilization.
XP Power Management Settings

In the NVIDIA Control Panel window, users can choose between two options – Enable PowerMizer and Disable PowerMizer. These two settings provide the user everything they need for advanced power management. As illustrated in Figure 2, the control panel has been greatly simplified. Enabling PowerMizer all the time saves battery power, and reduces electrical usage if the notebook PC is plugged in. In Windows XP, you can choose to disable PowerMizer if so desired.

Figure 2. Windows XP PowerMizer Control Panel - Specifying Power Savings Modes under AC and Battery Power
Vista Power Management Settings

Power settings in Windows Vista are based on three power plans that are mapped to the two performance modes in Power Mizer 7.0, Maximum Performance and Balanced. These modes set the maximum ceiling the GPU clocks are allowed to reach. When not heavily utilized, the GPU can always go down to the lowest clock settings, therefore they have been excluded as a separate mode.

When a user goes to the Power Options menu in Windows Vista (Figure 3), they have three Power Plans to choose from. When a Power Plan is chosen, the operating system will communicate to the driver to automatically set Powermizer to the appropriate performance mode.

Table 2. Power Mode Mapping

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<th>Windows Vista</th>
<th>PowerMizer 7.0</th>
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<tr>
<td>High Performance</td>
<td>Maximum performance</td>
</tr>
<tr>
<td>Balanced</td>
<td>Maximum performance</td>
</tr>
<tr>
<td>Power Saver</td>
<td>Balanced</td>
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Typical Power Management Settings

As shown in Table 1, PowerMizer has two modes the OS can select, Balanced and High Performance. These modes set the upper limit that the GPU is allowed to operate at; however, the GPU is always allowed to go down to its lowest utilization clock setting when no applications are being run.

Balanced

The lowest power plan in Windows Vista, Power Saver, is mapped to the Balanced mode of PowerMizer 7.0. This ensures that applications perform well even when the lowest setting is chosen. **Balanced** mode covers most applications, excluding some 3D applications.

There are some instances where a GPU can operate 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 better 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.

In many cases, Balanced mode is appropriate. For example, 3D enthusiasts may select the 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 extended battery life.

Only NVIDIA provides users with such effective control over performance and battery life, backed up with the tightly integrated hardware and software PowerMizer technology incorporated into the GeForce 8M Series and NVIDIA Quadro NVS/FX notebook solutions.

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.

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.

CPU Offload Example

Figures 3 and 4 show CPU utilization when running a Blu-ray H.264 HD movie using the CPU and GPU, respectively. You can see that under the GPU video playback, 30% less CPU cycles are being used. This dramatic reduction in CPU usage means less power is being consumed by the processor, therefore system power consumption is reduced, resulting in longer battery life.

Note: Testing was conducted on an Intel Centrino based platform with 2 GHz Core2 Duo processor, and a GeForce 8600M GS, running Intervideo WinDVD8 playing a Casino Royale H.264 Blu-ray disc.
Figure 4.  Blu-ray HD Movie Playback on the CPU
Figure 5. Blu-ray HD Movie Playback on GPU

Off-loaded from the CPU to the GPU, PowerMizer dramatically lowers CPU utilization for longer battery life.
Conclusion

The NVIDIA GeForce Go 8M Series and NVIDIA Quadro NVS notebook GPUs deliver the ultimate 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 7.0, NVIDIA’s latest comprehensive and intelligent power management technology.

NVIDIA delivers comprehensive, advanced power management in our latest notebook GPUs by leveraging many technologies: dedicated graphics engine and PureVideo video architectural advancements, MXM graphics support, efficient ACPI power-states utilization, on-chip configuration/performance/thermal monitors, SmartDimmer technology, leading-edge manufacturing technologies, and active power management of the PCI Express link. NVIDIA has a tradition in the notebook PC market of advancing the frontier of the user’s graphics experience and expectation, and PowerMizer 7.0 is a key element in delivering this for our latest notebook GPUs.

Together with PowerMizer 7.0, the GeForce Go 8M Series and NVIDIA Quadro NVS/FX notebook solutions deliver the highest performance with the longest battery life, offering 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, then power consumption is reduced. If voltage is reduced, overall power is exponentially reduced also. PowerMizer 7.0 also scales the voltage.

Dynamic Clock Scaling

Power consumption is directly proportional to frequency, so the lower the frequency of the GPU, the less power consumed. NVIDIA designed the GPU to run at frequencies as low as 100 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 clocks 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 frequency to zero. According to the power equation, if frequency is zero, then power equals zero. GeForce 8M Series and NVIDIA Quadro NVS/ FX notebook 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 8M Series and NVIDIA Quadro NVS/ FX notebook GPUs use an advanced semiconductor process technology to operate at the lowest voltage of any notebook 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 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 for 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 full performance because battery life is not a concern. PowerMizer 7.0 recognizes when a machine is running on AC power and sets its performance mode to Maximum performance. Based on its monitoring circuitry, PowerMizer still conserves power when the GPU is not being taxed, resulting in lower electric costs and sparing the environment.
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