Mobile Power Guidelines 2000

Intel Corporation

Revision 0.8

Sept. 16,1998

Test results reported within this document are not intended to offer the typical or representative workload experienced by a commercially available system. Rather they are based on a test platform design and are offered solely to assist the OEM and vendors in improving their products.

The hardware vendor remains solely responsible for the design, sale and functionality of its product, including any liability arising from product infringement or product warranty.

This document is an intermediate draft for comment only and is subject to change without notice. Readers should not design products based on this document.

ACKNOWLEDGEMENTS

We would like to extend special recognition to the following companies for their early and extensive participation in the development of the Mobile Power Guidelines: Compaq* Corporation, Dell* Corporation, Fujitsu* PC Corporation, IBM* Corporation, NEC* Computer System Division and Toshiba* Corporation.

We would like to acknowledge the following companies for their contributions and support of this document:

System Manufacturers (OEM)

Compaq Corporation
Dell Corporation
Fujitsu PC Corporation
IBM Corporation
NEC Computer System Division
Toshiba Corporation

Graphics

ATI Technologies*
NeoMagic Corporation*
S3, Inc.*
Trident Microsystems, Inc.*

Audio

Analog Devices, Inc.*
Rockwell International Corporation*
Tritech Microelectronics Ltd.*

Modem

ESS Technology, Inc.*
Pctel, Inc.*
Rockwell International Corporation
Motorola, Inc.*

Memory

RamBus Corporation*
NEC Corporation*

Power Supply

Analog Devices, Inc.
Linear Technology Corporation*
Maxim Integrated Products, Inc.*
STMicroelectronics, Inc.*

Screens

Hitachi America, Ltd.*

Storage

DVD

Hitachi America, Ltd.
Pioneer Electronic Corporation*

Hard Drive

Fujitsu Computer Products of America, Inc.*
Hitachi America, Ltd.
IBM Corporation

High Density Floppy

Iomega Corporation*

1394

Texas Instruments, Inc.*

CardBus

Texas Instruments, Inc.
Ricoh Co., Ltd.*

Table of Contents

1. Executive Summary

The demand for new features and higher performance in mobile PCs presents a challenge to the mobile PC industry. This challenge requires the developers to continue to provide system performance that meets user demands, within thermally manageable limits. Power dissipated in the interior of a full-featured notebook increased by 90% in the last three years. Looking ahead, expected system enhancements continue to challenge developers to design systems that are power efficient within the thermal envelope.

The Mobile Power Initiative is a comprehensive industry initiative that addresses these power challenges. Its goal is to lead a coordinated industry effort to deliver users future mobile PCs that are high-performance, feature-rich and power efficient. The initiative is supported by leading PC system manufacturers, component suppliers and software vendors and spans the mobile system hardware, system software and application software.

- To address application power, Intel has created power monitoring and analysis tools that help software developers identify and correct power-wasting code. In addition, the Mobile Application Software Guidelines provide recommendations for developing power-friendly software.
- To improve operating system power management, Intel, Microsoft*, and Toshiba* authored an industry power management specification called the Advanced Configuration and Power Interface (ACPI). Industry transition to this interface is well under way. In addition, the Intel® Power Management and Analysis tool measures power and latency of system devices while they are in different states using the adapter or battery power supply.
- To address platform power issues these Mobile Power Guidelines (MPG) focus on providing achievable power targets for all system components.

The Mobile Power Guidelines 2000, a key element of the Power Initiative, sets power targets for each of the components on the mobile PC platform, and provides recommendations on how to meet these targets. Based on the 1999 Guidelines, this document includes updated information on system configuration, end-user applications, and new performance targets. Key changes include significant increases in system performance and capability while keeping power consumption flat, and the addition of the mini-notebook form factor. These changes allow the guidelines to adapt to industry developments, playing a key role in power-friendly system design.

Meeting these component power targets ensures that future mobile PCs add the capabilities and performance users demand within mobile thermal limits. Hardware component vendors and original equipment manufacturers will benefit by cost reductions due to lower power components, lighter weight thermal solutions, and higher product reliability. This document discusses various techniques that can be used to achieve the power targets. Among them, voltage reduction is a significant method of reducing power.

To see the impact on power from voltage reduction, consider the following example. Unmanaged, the power consumption for the memory controller at 2.5V is expected to be approximately 2.6W (as measured by 3D WinBench* Power benchmark). Because power decreases with the square of the voltage ratio, that power can be reduced to 1.5W at 1.8V. Extended across the entire system, the principle of voltage reduction can make a major improvement on the power characteristics of the mobile PC.

Implementing these voltage and power reduction targets allows the performance improvements customers demand while keeping the overall system power within the 23 to 25 watt thermal envelope. Intel continues to monitor voltage levels and reduce where necessary in order to reduce power waste in mobile system components it manufactures. We encourage mobile computer component and original equipment manufacturers to join this trend. Those who embrace it will reap many benefits including the following:

- ➢ Lower power components
- ➢ Lower power systems

- √ Lower cost component packages
- √ More reliable components
- √ Higher performance
- √ Lower cost thermal solutions
- √ Lighter weight thermal solutions
- √ More reliable systems
- √ More room for additional features or performance

2. Introduction

New technologies and feature rich applications are promising unprecedented opportunities for mobile computer system, hardware component, and software vendors. Users expect the same high performance from their mobile computers that they enjoy on their desktops. Delivering higher performance and new features while still maintaining a thermally manageable system with good battery life poses significant challenges to the mobile computing industry.

2.1 The Challenge

As new mobile computers are introduced with higher performance and features rivaling desktop systems, the power, thermal, and battery run time challenges are growing. Power dissipation in mobile computers jumped by 90% between 1994 and 1997 and continues to rise. This rise in power consumption is now pushing the thermal power dissipation limits for full featured mobile computers and left unchecked, would threaten battery run time.

- Thermal Limitations: Although mobile PC power consumption has been increasing rapidly, cooling techniques have been evolving more slowly. Ergonomic constraints limiting mobile computer skin temperature will likely limit the maximum system power dissipation to about the same 23-25 watt level as previous generations. Actual thermal capacity varies with the physical size of the system.
- Battery Run Time: In addition to near desktop performance, mobile computer users demand longer battery run time. This will require optimizing system hardware and software for *both* high performance and low power.

Increasing power consumption, combined with system thermal power dissipation limits, and user demands for higher performance and longer battery run time are creating significant challenges. To meet these challenges the mobile computing industry must find ways to hold power within thermally manageable limits while increasing performance and battery run time to meet user expectations.

Mobile Power Initiative Addresses the Challenge

To address this power challenge, Intel Corporation has launched a Mobile Power Initiative. This initiative is a cooperative program uniting industry leaders in addressing *all areas that impact mobile PC power*: hardware, operating system, and applications. The Mobile Power Initiative addresses the following:

- Platform Power: The guidelines provide achievable power targets for all system hardware components to keep overall mobile PC power within thermal limits. They recommend methods of developing high-performance, power efficient PCs through voltage reduction and low power system design techniques. These new guidelines incorporate features and capabilities expected in mobile systems ranging from mini-notebook to full-size in the year 2000.
- Operating System: The Advanced Configuration and Power Interface (ACPI) is an industry power management specification collaboratively authored by Intel, Microsoft*, and Toshiba*. As the operating system manages resources required by applications, it recognizes which resources in the system are in use and which are idle. ACPI was developed with the objective of utilizing operating system knowledge to improve the way systems manage power. A key tool in this transition to ACPI-enabled systems is the Intel Power Management and Analysis Tool (IPMAT), which now enables power and performance measurements in battery mode.
- Application Software: The Intel Mobile Application Software Guidelines provide specific information on creating power-friendly software. In addition, the Intel Mobile Power Guidelines 2000 provide information on power monitoring and analysis tools (developed by Intel) that are available to software developers. Some application programs do not use resources efficiently and prevent idle devices from entering low power states. These tools for system analysis can help developers identify and correct power-wasting code. As a result of making power-related modifications, dozens of new applications are now power-friendly, reducing overall system power significantly. The latest version of Intel Power Monitor (IPM) includes Windows* 98 and ACPI support, further helping the effort to create power-friendly software.

The cornerstone of the Mobile Power Initiative is the Mobile Power Guidelines. These guidelines provide achievable power targets for the system hardware components to keep overall mobile PC power within thermal limits. They also provide recommendations on how to achieve these power targets. Meeting these targets is a key part of the effort to significantly increase performance and capability in 2000 while holding power flat.

This will benefit everyone in the mobile computing community. Mobile PC users will get higher performance and more power efficient systems. Hardware component vendors and original equipment manufacturers will benefit from cost reductions due to lower power components, lighter weight thermal solutions, and higher product reliability.

*Third-party brands and names are the property of their respective owners

2.2 Intended Audience

This Mobile Power Guidelines addresses all aspects of system development that impacts mobile computer power consumption. It is focused toward mobile computer OEMs, hardware component vendors, system software vendors and application software vendors.

2.3 Objective

The objective of this document is to unify the mobile computing industry with a common set of guidelines to enable continued feature and performance enhancements while keeping the system thermally manageable and maintaining good battery life.

This document sets component power targets for systems expected to be in production in mid 2000. It describes full-featured high-performance primary notebook computer systems, and mini-notebook systems intended as secondary computers. Addition of the mini-notebook configuration in these guidelines creates power targets that span the full range of PC form factors. Thin & Light systems will also exist which have a configuration and performance which is a subset of the full-size notebooks.

3. System Cooling Constraints

While notebook power consumption has been increasing rapidly, cooling techniques to remove the heat generated within the notebook have been evolving more slowly. The performance of the cooling systems in notebooks is governed by physical laws of heat convection and radiation. Therefore, a notebook with specified geometrical and configuration constraints can dissipate a finite amount of heat. The heat dissipation limit from a notebook is a function of the notebook surface area that is exposed to the air, the material characteristic (emissivity), and the skin and air temperatures.

The heat from inside of a notebook is passively dissipated by warming the outside surface (skin) of the plastic or the housing material over the ambient air and actively dissipated by using a fan and heat exchanger. Most fan designs can remove about 4 to 8 Watts of heat and the rest is passively dissipated by natural convection and radiation from the outside surface. The passive dissipation of the heat requires elevation of the notebook skin temperature over the air temperature. If there are no limits on the skin surface temperature, the passive heat dissipation limit is unbounded. Of course, such a notebook with unconstrained high skin temperatures will be unusable. Intel recommends, as a guideline, that the notebook computer skin temperature be within approximately 15 °C over the ambient air temperature. This 15 °C $\Delta T_{skin-air}$ is based on the following reasons:

- Most notebooks are typically operated in air temperatures around 25 °C, an environment that applies to most air-conditioned places. In such an environment, the skin temperature will be 25 + 15 = 40 °C. The human body temperature is normally 37.1 °C. At T_{skin} = 40 °C, our fingers or skin will not feel the notebook outer surface getting warm.
- A 15 °C $\Delta T_{skin-air}$ permits about 15 to 17 Watts of total platform power (entire notebook power minus the display power) to be managed passively in a typical notebook. Many popular applications on new processors operate in this range of platform power. If 15 to 17 Watts can be managed passively, then the fan usage in the thermal solution is minimized.
- Most notebooks are designed to 35 °C $T_{air,max}$ which corresponds to T_{skin} = 50 °C. Thus, with a 15 °C $\Delta T_{skin-air}$, the key cap temperature will be 50 °C. The bottom surface or underside of the keyboard will be slightly warmer than 50 °C. The temperature specifications for many keyboards are generally in 55 to 60 °C range and thus the keyboard operation will be at the specification limit. Similar logic can apply to other temperature sensitive components (e.g., HDD, CD-ROM) inside the notebook.

Below, estimates of the heat dissipation limits are given for two notebook sizes: full size and mini-notebook size. The thermal envelopes shown in Figures 1 to 2 make the following assumptions:

- Ambient air room temperature is 25 °C (the results are linearly scaleable/applicable to other ambient temperatures up to 35 °C).
- The bottom surface of the notebook is insulated. The top (keyboard) and side walls are used as a radiator.
- The notebook skin is made of ABS/PC plastic or painted metal chassis (emissivity = 0.95) and has an isothermal skin temperature.
- The fan/heat exchanger combination removes 8 Watts of heat from the full size notebook.
- There is no fan/heat exchanger present in the mini notebook.

Current full size notebook systems measuring 10 x 12.3 inches with base unit (excluding lid thickness) of 1.0 inch can dissipate about 25.6 Watts.[1] Figure 1 shows the total heat dissipation limit for a varying skin temperature and for a full size notebook dissipating heat in 25 °C T_{air}. The recommended ergonomic limit is then at 40 °C. The total heat dissipation power in the figures does not include the display power. Figure 2 shows the thermal limits for a mini notebook assuming a base size of 8.2 x 10.2 x 0.65 in^3. The corresponding total heat dissipating limit for the smaller notebook comes to about 11.5 W. It is noted here that the dissipation limits shown in Figures 1 and 2 apply to a typical notebook, heat dissipation from a particular notebook design can vary.

These thermal constraints show that the system power growth must be managed and action is required to reduce future notebook system power.

---

[1] Refer to Intel Application Note 584 “Notebook Thermal Design Guide for High-Powered Microprocessors” (order # 243321-001) for a detailed discussion of notebook thermal considerations.

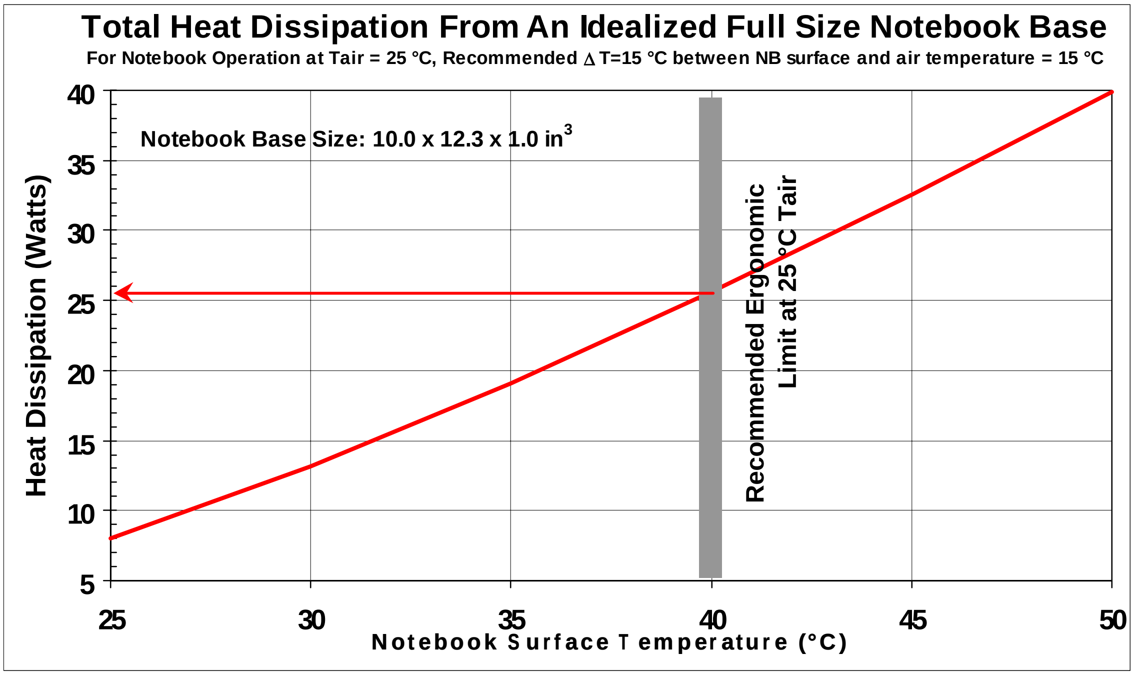


Figure 3-1 Total heat dissipation limit for a full size notebook

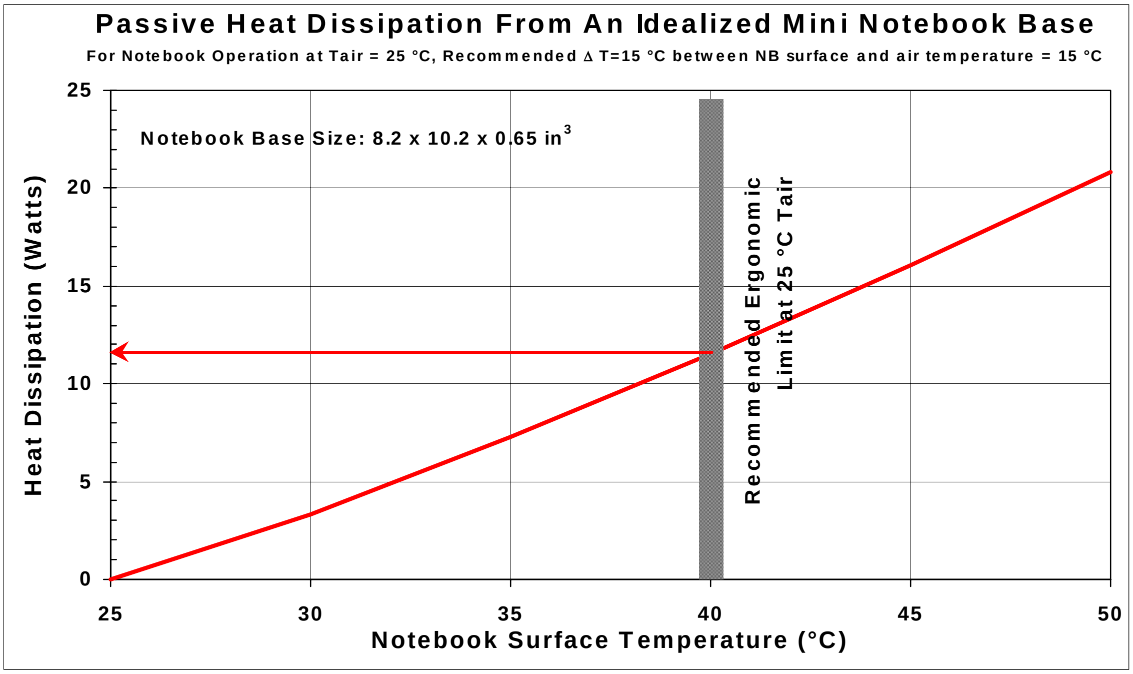


Figure 3-2 Passive heat dissipation limit for a mini size notebook

4. Power Target Method and Assumptions

This document identifies subsystem power targets designed to keep system power within the thermal and battery life constraints defined in section 5 while increasing system performance. This section describes the method and assumptions used in generating these power targets and suggests power measurement benchmarks for testing component power.

4.1 Assumptions

The following assumptions can be made regarding the achievement of stated power targets:

- Components in a mobile computer system will not all be at maximum power at the same time.
- For most subsystems power states can be defined such as active, idle, stop clock, etc. which represent the amount of power the subsystem will consume in that state.
- Total subsystem power can be represented as the sum of the subsystem power in each state times the time in each state divided by time. Input/Output (I/O) power for each bus interface can be estimated by multiplying (Capacitance x Voltage^2 x Frequency.)
- Since CMOS devices consume almost all of their power during switching, frequency can be estimated as (Bus Traffic / Theoretical Maximum Bus Traffic). I/O power for each subsystem can be estimated by adding the I/O power for each bus interface connected to the subsystem. Leakage current is increasing in low voltage CMOS devices. In low voltage devices this must be accounted for, particularly in idle and sleep states.
- Power consumption for future systems can be estimated by identifying the various power states each subsystem can be in, the percentage of time spent in each power state, and amount of data traffic flowing on each bus.
- The average power consumption of a subsystem can be represented as the sum of the power consumed in each power state multiplied by the percentage of time spent in each state.
- The average system power consumption can be represented as the sum of the average power consumed by each subsystem.

4.2 Worst Case Power Application

To define system power targets it is necessary to identify the applications that generate the worst case system power that is likely to occur in normal use. Appendix B shows system power measurements for several applications measured on an Intel evaluation board in 1997. These tests identified MPEG2 video playback as having the worst case power of the applications we tested. Extrapolating this data and factoring in significant system improvements such as multimedia enhancements, we expect the worst case power application in 2000 to be 3D game play. While this application is not expected to be the most commonly used application it is expected to be the worst case power application since it simultaneously requires a lot of CPU processing for video and audio decompression, high resolution, fast action graphics, DVD drive, memory accesses and audio playback.

For the full size system the average 3D game power target assumes that 3D game scenes are stored on a DVD drive, the hard drive is accessed occasionally, and audio is active at 30% amplifier power. An onboard LAN is connected and is predominantly idle. The CardBus slots are assumed empty. Bluetooth and fast IR are inactive.

For the mini-notebook system the average 3D game power target assumes that the game is run from the hard drive, and audio is active at 30% amplifier power. An onboard LAN is connected and is predominantly idle. The CardBus slots are assumed empty and the Bluetooth and fast IR are inactive.

4.3 Power Target Method

The subsystem power targets were defined by profiling subsystem power consumption for a current platform and then extrapolating these estimates to factor in expected performance and power consumption improvements by the year 2000.

Future subsystem power consumption was extrapolated by identifying significant power states for each subsystem (ie. active, idle - clock on, stop clock, etc.) and estimating the amount of time the subsystem will spend in each state while running the worst case power application.

Power consumption in some subsystems such as the memory controller and IO controller are related to data transfer rates. For these subsystems I/O power was estimated separately and added to the subsystem core power consumption. I/O power was calculated by estimating the capacitive load driven by the subsystem, the average switching frequency based on the clock rate and estimated data rates for each bus interface driven by the subsystem, and multiplying the capacitance and switching frequency times the switching voltage squared.

Average subsystem power is defined as the sum of the power consumed in each state times the percentage of time spent in each state.

5. System Features and Power Targets

This section describes system feature assumptions and power targets for 2000 notebook computers. 1999 feature and power figures are included in Appendix A of this document for comparison. Section 5.1 shows the system configuration assumptions. Section 5.2 proposes power targets for each subsystem and summarizes the total power dissipated in the notebook interior.

5.1 System Feature Summary

The tables below show the system configuration assumptions for 2000 systems. It describes systems from the smallest, lower end systems to full-featured systems implementing the latest technology.

Table 5-1 System Features Comparison

Mini Notebook	Full Size
Size: 8.2 x 10.2 x 1.0” (0.65” thick base)	Size: 10.0 x 12.3 x 1.5”(1” thick base)
Mobile Pentium® II processor with L2 cache or next generation	Mobile Pentium® II processor with L2 cache or next generation
Graphics Controller PCI interface 2 MB frame buffer 800 x 600 x 16 bit / pixel resolution LCD and CRT screen support Direct digital or LVDS display interface	Graphics Controller AGP 2x interface 6 MB frame buffer 1024 x 768 x 24 bit / pixel resolution MPEG2 H/W assist (Motion compensation, YUV 4.2.0) Enhanced 3D acceleration LCD and CRT dual screen support LVDS display interface TV output
10.4” Color HPA or TFT LCD Display	13.3 or 14.1” Color TFT LCD Display
Memory Subsystem 64 MB SDRAM or RDRAM memory	Memory Subsystem 96MB RDRAM memory
I/O Subsystem I/O controller with integrated timers, counters, etc. 3.3v 33 MHz PCI bus Parallel and Serial ports System Management Bus controller Universal Serial Bus controller Keyboard controller ACPI microcontroller with SM Bus system battery interface Bluetooth in base	I/O Subsystem I/O controller with integrated timers, counters, etc. 3.3v 33 MHz PCI bus Parallel and Serial ports System Management Bus controller Universal Serial Bus controller Keyboard controller ACPI microcontroller with SM Bus system battery interface Bluetooth in base
	1394 (1 S400 external port) optional
USB (1 external connector)	USB (1 external connector)
Storage media IDE/ATA33 hard drive	Storage media Floppy drive IDE/ATA66 hard drive IDE DVD
CardBus 1 power managed slot	CardBus 2 power managed slots
Soft Audio (AC’97) Sound blaster S/W emulation Wave table synthesis (downloadable samples) Combined audio/modem AFE Stereo or Mono speakers	Soft Audio (AC’97) Sound blaster S/W emulation Wave table synthesis (downloadable samples) 3D positional sound AC3 / MPEG2 decode Combined audio/modem AFE Stereo speakers
Soft Modem (AC’97) Software Datapump(V.90)	Soft Modem (AC’97) Software or hardware Datapump (V.90) (power models assume a hardware Datapump as it is worst case)
No Docking	PCI Docking
LAN on motherboard or Cardbus	LAN on motherboard or Cardbus

System dimensions used are for reference only. OEM systems will vary from the sizes shown here based on design goals and target market. In particular Thin & Light systems will exist which have a configuration and performance which is a subset of the full size notebooks. Configurations are adjusted to account for a thinner package, more limited thermal envelope and potentially reduced battery size.

Although the configuration shows optional use of RDRAM* in mini-note configuration, all power analysis for mini-note assumes SDRAM.

5.2 System Power Target Summary

Table 5.2 System Power Targets Comparison

	Mini Notebook	Full Size
	Average 3D WinBench* Power (W)	Average 3D WinBench* Power (W)
CPU & L2 Cache	5	9.5
Memory Controller	1.3	1.5
System Memory	.7	1.2
Graphics Subsystem	1.0	2.4
IO Subsystem	.6	.6
Audio	.7	1.6
Modem	.3	.4
Hard Drive	1.4	1.3
DVD Drive/CD	0	1.4
1394 Controller	0	0
CardBus	.2	.2
LAN	.4	.4
Power Supply	1.5	2.6
Charging	0	0
Cooling	0	0.5
Other	.8	1.0
Base Total	**13.9**	**24.6**
LCD	2.8	4.3
SYSTEM TOTAL	**16.7**	**28.9**

5.3 Component Features and Power Targets

5.3.1 CPU and L2 Cache

5.3.1.1 Features and Assumptions

The following CPU and level 2 cache subsystem features are assumed for systems shipping in 2000.

Mini Notebook	Full Size Notebook
Mobile Pentium® II processor with L2 cache	Mobile Pentium® II processor with L2 cache

5.3.1.2 Power Targets

The following table shows the CPU and level 2 cache power targets for systems shipping in 2000.

CPU & L2 Cache Power Target 2000			
	Peak Power (W)	**Sleep Power (W)**	**Average 3D WinBench* Power (W)**
Full Size	12	0.36	9.5
CPU utilization & bus traffic = 60%			
Mini	6	0.36	5
CPU utilization & bus traffic = 60%			

Average 3D WinBench* power represents the highest *sustained* power that a real worst-case application will draw from the CPU. The typical thermal design power (TDP typical) specification for an Intel processor is derived from sustained power measurements from worst case applications such as 3D WinBench* with margin added to account for process variations. The peak CPU power guideline represents the maximum power consumed while executing the worst case CPU instruction mix at nominal Vcc. This resembles the TDP max specification for Intel processors. These are design guidelines and should not be construed as future processor specifications.

5.3.2 Memory Controller

5.3.2.1 Features and Assumptions

The following memory controller features are assumed for systems shipping in 2000.

Mini Notebook	Full Size Notebook
• SDRAM or RDRAM interface	• Direct RDRAM interface • AGP 2x graphics interface • 1.6v or lower CPU interface

RDRAM Assumptions:

- 6 - 300 Mhz 128 Mbit Devices
- 2 Devices in the Active Pool
- 4 Devices in the Nap Pool

SDRAM Assumptions:

- 8 - 66 Mhz 64 Mbit Low Power Devices
- CKE Enabled

OPTIONAL FEATURES

ECC

NOTE: ECC will increase the Memory Controller Power and associated power supply loss by approximately 12.5%

5.3.2.2 Power Targets

The following table shows the Memory Controller power targets for systems shipping in 2000.

Memory Controller Power Target 2000			
	Peak Power (W)	**Sleep Power (W)**	**Average 3D WinBench* Power (W)**
Full Size	2.25	0.3	1.5
Utilization			67%
Mini	2.0	0.05	1.3
Utilization			67%

5.3.2.3 Design Considerations

Memory controller power can be reduced by implementing micro-level gated clocks and by disabling GTL sense amplifiers when bus is idle for Full Size systems. For Mini Note systems, power can be reduced by reducing the core voltage.

5.3.3 System Memory

5.3.3.1 Features and Assumptions

The following system memory subsystem features are assumed for systems shipping in 2000.

Mini Notebook	Full Size Notebook
• 64 Mbytes SDRAM or RDRAM* • 66 MHz interface • 3.3v core and I/O	• 96 Mbytes Direct RDRAM* • 300 MHz interface • 2.5v core • 1.8v I/O

OPTIONAL FEATURES

ECC

NOTE: ECC will increase the System Memory Power and associated power supply loss by approximately 12.5%

5.3.3.2 Power Targets

The following table shows the system memory subsystem power targets and utilization assumptions for systems shipping in 2000

Memory Power Target 2000			
	Peak Power (W)	**Sleep Power (W)**	**Average 3D WinBench* Power (W)**
Full Size	2.4	0.35	1.2
System memory utilization			50%
Mini	1.3	0.35	.7
System memory utilization			54%

*Third-party brands and names are the property of their respective owners

5.3.4 Graphics

5.3.4.1 Features and Assumptions

The following graphics subsystem features are assumed.

Mini Notebook	Full Size Notebook
• PCI-33 interface • 2 MB Frame buffer • LCD Resolution 800 x 600 x 16 bpp • CRT resolution 1024 x 768 x 16 bpp, 75 or 85 Hz • MPEG-2 playback • Direct Digital or LVDS output	• AGP-2x interface • 6 MB Frame Buffer • LCD resolution 1024 x 786 x 24 bpp • CRT resolution 1280 x 1024 x 24 bpp, 75 or 85 Hz • Enhanced 3D Acceleration, MPEG-2 Playback support, including YUV 4:2:0, Motion Compensation • LCD & CRT dual screen support • LVDS display interface • TV output

5.3.4.2 Performance Targets

The following table shows graphics subsystem performance targets for 2000. The MPEG 2 frame rate performance assumes 720 x 480 pixel resolution. The video stream is 10 Mbyte / sec. The MPEG 1 frame rate performance assumes 640 x 420 pixel resolution. 2D and 3D benchmarks are based on Winbench* 98, Native LCD panel display on at it's maximum resolution and color depth, all other displays are off.

Mini Notebook			Full Size Notebook		
2D Winbench*	3D Winbench*	MPEG2 *	2D Winbench*	3D Winbench*	MPEG2 *
100	100	30 fps	450	450	30 fps

5.3.4.3 Power Targets

The following table shows the graphics subsystem power targets for systems shipping in 2000. Average figures are based on running target application for a reasonable length of time using typical content.

Graphics Subsystem Power Target 2000			
	Peak Power (W)	**Sleep Power (W)**	**Average 3D WinBench* Power (W)**
Full Size	3.0W	0.8W	2.4W
Graphics Controller Utilization			75%
Frame Buffer Utilization			60%
Mini	1.4W	0.2W	1.0
Graphics Controller Utilization			75%
Frame Buffer Utilization			60%

5.3.4.4 Design Considerations

The graphics subsystem performance can be increased in 2000 and meet the 2000 power targets through the following power reduction techniques::

- Reduce graphic controller core voltage to 1.8 volts.
- Reduce graphic controller AGP signaling voltage to 1.5 volts
- Integrate the frame buffer
- Utilize host bus power management effectively. Allow the host bus clock to shut down as often as possible.

5.3.5 Flat Panel Display

5.3.5.1 Features and Assumptions

The following flat panel display features are assumed for systems shipping in 2000.

Mini Notebook	Full Size Notebook
• 10.4” Color HPA LCD panel • 800 x 600 x 16 bit / pixel resolution • Direct digital or LVDS interface • 120 nits panel brightness	• 13.3” or 14.1” Color active matrix LCD panel • 1024 x 768 x 24 bit / pixel resolution • LVDS display interface • 120 nits panel brightness

5.3.5.2 Power Targets

The following table shows flat panel display power targets for systems shipping in 2000.

Mini Notebook		Full Size Notebook	
Peak Power (W)	Average Power (W)	Peak Power (W)	Average Power (W)
3.05	2.8	4.75	4.3
Utilization	100%		100%

These power targets include panel logic, backlight, and low voltage signaling interface. The Peak Power is generated at initial power-on and decreases while the backlight warms-up.

For the power targets, a 14.1” panel has been assumed in the Full Size Notebook. A power savings of .5 watts may be achieved by use of the 13.3” panel. In the Full Size Notebook, a 15.1” panel may be used but it requires .5 watts of additional power as well as a possible increase to system dimensions.

In the Mini Notebook, a 10.4” HPA panel is assumed; but an equivalently sized TFT panel will provide a slight power savings. The use of a larger (11.3”) or a smaller (10”) LCD panel will result in a minor increase or decrease in power, respectively.

5.3.5.3 Design Considerations

Flat panel display power can be reduced through the following techniques:

- Reduce display logic voltage to 2.5 volts.
- Reduce refresh rate when image is static.
- Improve aperture ratio.
- Increase lamp efficiency.
- Increase light spreader sheet efficiency.
- Improve panel driver and controller efficiency.
- Improve CCFT inverter efficiency.

5.3.6 I/O Subsystem

5.3.6.1 Features and Assumptions

The following I/O subsystem features are assumed for systems shipping in 2000.

Mini Notebook	Full Size Notebook
• Timers, DMA, RTC, counters, etc. • 3.3v 33 MHz PCI bus • Super I/O controller (parallel, serial ports, floppy) • System Management Bus Controller • Universal Serial Bus controller • Keyboard controller • ACPI micro-controller with SM Bus system battery interface • Bluetooth in base	• Timers, DMA, RTC, counters, etc. • 3.3v 33 MHz PCI bus • Super I/O controller (parallel, serial ports, floppy) • Fast IR • System Management Bus Controller • Universal Serial Bus controller • Keyboard controller • ACPI micro-controller with SM Bus system battery interface • Bluetooth in base

5.3.6.2 Power Targets

The following table shows the I/O subsystem power targets for systems shipping in 2000.

I/O subsystem Power Target 2000			
	Peak Power (W)	**Sleep Power (W)**	**Average 3D WinBench* Power (W)**
Full Size	2.68	0.4	0.6
Utilization			25%
Mini	2.68	.04	.6
Utilization			25%

5.3.6.3 Design Considerations

I/O subsystem power can be reduced by implementing ACPI power management.

5.3.7 Modem Subsystem

5.3.7.1 Features and Assumptions

The following modem subsystem features are assumed for systems shipping in 2000. Full Size systems include DVD movie playback, 3D Internet gaming, and Videoconferencing capabilities.

Mini Notebook	Full Size Notebook
V.90 V.80 V.17	V.90 V.80 V.17

5.3.7.2 Power Targets

The additional power generated by the CPU for soft modem host processing is NOT included in these targets.

Modem Power Target 2000				
	Peak Power Dissipated (W)	**Suspend (wake disabled) (W)**	**Suspend (wake enabled) (W)**	**Data Transfer (W)**
Full Size				
DSP	TBD	TBD	TBD	100mw
Codec	350mW	0W	5mW	100mW
DAA	150mW	TBD	TBD	150mW
Mini				
Codec	350mW	0W	5mW	100mW
DAA	150mW	TBD	TBD	150mW

5.3.7.3 Design Considerations

For the Full Size and Mini notebooks, the following architecture is assumed in the 2000 timeframe:

- Either a MC’97 or AMC’97 (Modem Codec or combined Audio & Modem Codec defined by AC’97) Use of an AMC codec will save a small amount of power.

- A WDM modem driver with capability including:
  - V.90 data connection
  - V.80 data protocol
  - V.17 fax command set
- An international silicon DAA
- “Wake enabled” is understood to mean the modem subsystem can detect a ring and return an interrupt to the sleeping system causing it to wake. It does not include any other modem functionality such as capturing caller-id.

5.3.8 Audio Subsystem

5.3.8.1 Features and Assumptions

The following audio subsystem features are assumed for systems shipping in 2000. Full Size systems include DVD movie playback, 3D Internet gaming, and Videoconferencing capabilities.

Mini Notebook	Full Size Notebook
Wavetable Music Synthesis 3D spatialization audio	Wavetable Music Synthesis MPEG2/AC3 Decode 3D HRTF audio

5.3.8.2 Power Targets

The following table shows the Audio power targets for systems shipping in 2000.

The additional power generated by the CPU for soft audio host processing is NOT included in these targets.

Audio Power Target 2000

	Peak Power Dissipated (W)	Sleep (D3) Power (W)	Average 3D Game Power Dissipated (W)
Full Size			
Codec	350mW	0W	150mW
Amplifier	650mW/channel	0W	425mW/channel
Speaker	900mW/channel	0W	300mW/channel
Total (2 speaker channels)	3.45W	0W	1.60W
Mini			
Codec	350mW	0W	150mW
Amplifier	300mW/channel	0W	175mW/channel
Speaker	300mW/channel	0W	100mW/channel
Total (2 speaker channels)	1.55W	0W	.7W

5.3.8.3 Design Considerations

For the Full Size and Mini notebooks, the following architecture is assumed in the 2000 timeframe:

- Either a AC’97 or AMC’97 (Audio Codec or combined Audio & Modem Codec)
- A WDM audio driver and additional audio filters capable of:
  - power management
  - wave table synthesis
  - 3D HRTF processing (except for Mini-notebooks)
  - AC3/MPEG2 decode (except for Mini-notebooks)
- A Windows/NT* operating system incorporating:
  - kernel mixer
  - output sample rate converter
  - SoundBlaster emulation
- Audio amplifier

*Third-party brands and names are the property of their respective owners

- Stereo speakers - (1 Watt speakers for full size and .3 Watt for Mini-notebook) Higher power speakers may be appropriate in some systems intended for multimedia usage but the tradeoff is an increase in power. The power increase to move to 2 watt speakers is 1.25 watts in the full size or 2.5 watts peak.

For the Mini notebook, the audio subsystem architecture in the 2000 timeframe is somewhat decreased in audio software functionality. Such tradeoffs may be necessary to balance market demands with diminished manufacturing costs.

5.3.9 Storage

5.3.9.1 Features and Assumptions

The following storage subsystem features are assumed for systems shipping in 2000.

Mini Notebook	Full Size Notebook
• ATA33 HDD	• ATA 66 HDD • High Density FDD (swap bay) • DVD-ROM (4X) (swap bay)

OEMs have the option to use a rewritable-DVD drive in place of a DVD-ROM drive. For the platform power calculations, the DVD-ROM drive was used.

5.3.9.2. Power Targets

The following table shows the Storage power targets for systems shipping in 2000.

Storage Media Power Targets 2000						
	Spin Up Pwr (W)	**Rd/Wr Power (W)**	**Idle Pwr - Spin (W)**	**Standby - No Spin (W)**	**Sleep Pwr (W)**	**Ave 3D Game Power (W) Full, Mini**
F/D	5	1.25	N/A	N/A	0.15	0 / 0
High Density F/D	4	3	1.25	0.25	0.01	0 / 0
H/D	6	2.7	1	0.3	0.1	1.3 / 1.4
DVD-ROM	6	3	2	0.3	0.1	1.4 / 0
Rewritable-DVD	6	3.6	2	0.3	0.1	0 / 0
Floppy Drive Utilization					Spin Rd/Wr Idle - spin Standby - no spin	Power Off
High Density Floppy Drive Utilization					Spin Rd/Wr Idle - spin Standby - no spin	Power Off
Hard Drive Utilization					Spin	0% / 0%
					Rd/Wr	15% / 23%
					Idle - spin	85% / 77%
					Standby - no spin	0% / 0%
DVD Drive Utilization					Spin	4% / 0%
					Read	30% / 0%
					Idle - spin	5% / 0%
					Standby - no spin	61% / 0%

5.3.9.3. Design Considerations

Hard Disk Drives and DVD-ROM drives are expected to increase performance between 1999 and 2000 while not increasing power.

To help achieve lower power storage products, it is recommended that all digital CMOS logic on the device use 3.3V. An efficient regulator can be used on-board to regulate the 5V input voltage to be 3.3V for the on-board digital, CMOS logic.

IEEE1394 is not recommended for interface to internal storage devices. It cannot provide host-private access to the primary storage device. In addition, if the internal IEEE 1394 port is implemented, it will add 1 Watt of extra power to the entire platform. This power comes from 0.1W for the active port in the system, 0.1W for the active port on the device, 0.4W for the 1394a PHY on the device, and 0.4W for the 1394 Link on the device.

5.3.10 1394 Subsystem

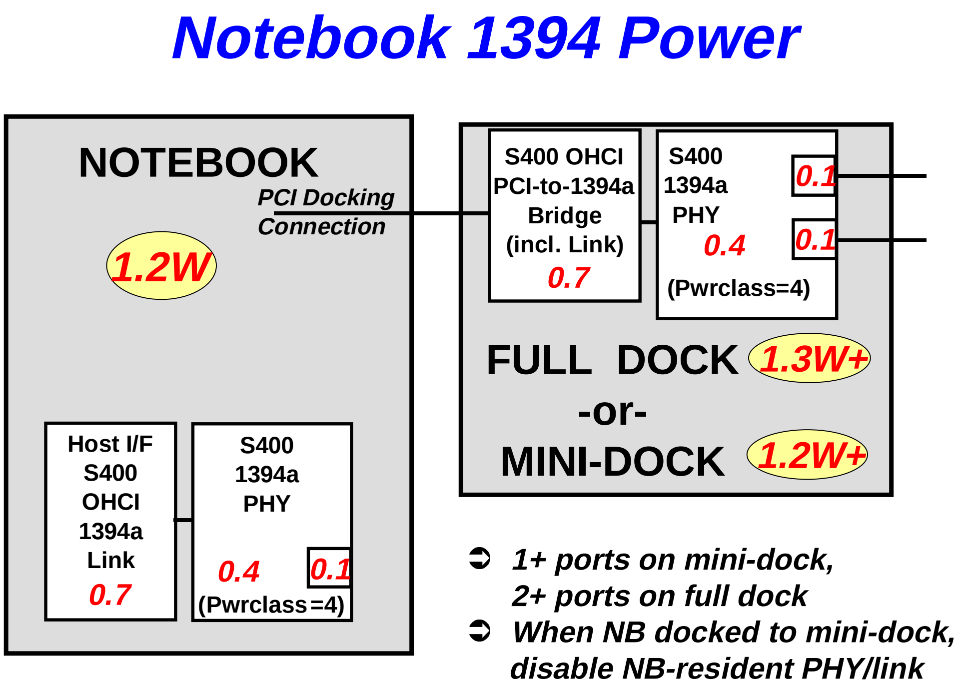


Figure 5-1 Assumed Notebook and Dock 1394 Configurations

5.3.10.1 Features and Assumptions

IEEE 1394 is an optional feature in systems shipping in 2000. The following subsystem features are assumed for systems which include 1394. Note that since the 1394 capabilities of a notebook and dock are designed to be complementary, assumed features are specified for both the notebook and the dock. It is assumed that the OEM will choose the lowest speed 1394 port that can support any required 1394 operation in order to minimize power consumption.

Mini Notebook	Full Size Notebook
• *No 1394 in this class of platform, due to cost, size, power and thermal constraints.*	• 1394-compliant PHY, power-class 4 (does not source cable power). • OHCI 1.0 (or 1.1, if available) compliant host-interface link. • One external port. (S400)

Port Replicator	Mini-Dock	Full Dock
• *Disallowed by 1394-1995 and 1394a specifications.* (Passive wire feed-through of notebook ports violates 1394 signal-repeater requirements).	• 1394a-compliant PHY, power-class 4 (may source power). • PCI-to-1394 link or PCI-to-1394 integrated PHY/link. • One or more external ports	• 1394-compliant PHY, power-class 4 (may source power). • PCI-to-1394 link or PCI-to-1394 integrated PHY/link. • Two or more external ports (for desktop equivalence).

Note that an external notebook 1394 port can be implemented either as a front-panel "walk-up" port, or as a back-panel port. In addition, if the docked notebook does not include a 1394 interface, then the dock can include a full 1394 interface (OHCI link and PHY) attached to the dock-side docking connection (usually PCI). In this configuration, the dock's 1394 interface may be powered by the dock, and dissipates heat within the dock (rather than in the notebook).

5.3.10.2 Power Targets

The 1394 subsystem is *not used* in the game-oriented analysis scenario assumed by these Power Guidelines. Thus, the 1394 power allocated to 1394 in the IMPG system power targets (Table 5.2) is uniformly 0. However, 1394 can contribute a substantial amount of power consumption while in use. The following considerations are intended to convey some understanding of 1394 power usage.

The table below shows what power allowances should be made for an active 1394 subsystem in systems shipping in 2000. Note that a single optional *internal* 1394 device is allowed for in the full dock, in order to specify worst-case system power configurations. Also, since measured suspend power levels for 1394a-compliant PHYs are not yet available, the following tables assume a consumption of 3mW per suspended PHY port. When the system is in the “sleep” state, all ports are assumed to be suspended, and both the PHY core and the link are assumed to be inactive and consuming no power. A disabled port is assumed to consume as much power as a suspended port.

To calculate the possible 1394 contribution to a 3D game power target, it is assumed that the game utilizes a DVD drive connected to the notebook via 1394. The game-related power consumption figures below account *only* for power consumed *by the 1394 interface*, not by the DVD drive itself. The game power figures presume one active host-interface port and one active interface port on the DVD drive. The “3D Game Power” column accounts for only the 1394 interface power that is *consumed within the notebook itself* (and which therefore contributes to the notebook’s thermal loading). Since 1394 bus power is approximately independent of bus utilization level (since the bus is always fully active in normal operation), the table reflects the same entries for Peak Power and for 3D Game Power.

Note that the Full Size notebook game power level is predicated on use of an *external* DVD drive, so that only the host-interface power is dissipated within the notebook. Similarly, the mini-dock power figure is based on use of an *external* DVD drive attached to the mini-dock. (Mini-docks are usually too small to include large internal devices such as DVD). Since the mini-dock configuration supports 1394 through a dock-resident 1394 bridge, the mini-dock power numbers represent power dissipated *in the dock, not in the notebook*. DVD power is dissipated outside both the notebook and the mini-dock.

In contrast, the full-dock power figures assume the use of a DVD drive that is *internal* to the dock. This reflects the most probable system configuration, as well as illustrating the impact of one internal 1394 device on a platform. In this configuration, the dock’s two external ports are assumed to be in a low-power state (suspended or disabled), and a third port on the dock’s PCI-to-1394 bridge is used to attach the internal DVD drive. The internal DVD drive is assumed to include a 1-port PHY and simple (non-OHCI) link.

In this configuration, the dock’s 1394 bridge consumes 1.26W [0.7W for the dock’s OHCI link + 0.4W for the dock’s PHY core + 0.1W for the dock port used to attach the DVD drive + 0.06W for the two suspended or disabled dock-bridge ports]. The DVD drive’s 1394 interface consumes an additional 0.9W [0.4W for the device link + 0.4W for the device PHY core + 0.1W for the single device port]. This results a total 1394 interface power dissipation of 2.16W within the dock. When all 4 1394 ports in the dock are in a low-power state (i.e. 3 dock-bridge ports + 1 DVD port), 1394 dissipates about 0.012W in the dock.

As in the case of the mini-dock, none of this power is dissipated *in the notebook*, but rather in the dock.

1394 Subsystem Power Target 2000

	Peak Power (W)	Suspend or Disable Power (W)	3D Game Power (W)
Full Size	1.2	0.003	1.2
Thin & Light	0 (no 1394)	0 (no 1394)	0 (no 1394)
Mini	0 (no 1394)	0 (no 1394)	0 (no 1394)
Mini-Dock	1.2	0.003	1.2
Full Dock	2.16	0.012	2.16

5.3.10.3 Design Considerations

The 1394 capabilities of a notebook computer are provided cooperatively by the notebook and by an associated dock. Due to power and thermal constraints, the notebook provides minimal 1394 capabilities. However, the combination of a notebook with a full dock can provide 1394 capabilities equivalent to those of a desktop system.

In most contemporary notebooks, the notebook and dock are connected through a PCI-based docking connector. Within the dock (mini-dock or full dock), a PCI-to-1394a bridge provides a host-accessible interface to one or more 1394 ports to which external devices or internal (dock-resident) devices can be connected. In this configuration, notebook-resident 1394 port(s) should be disabled

An OHCI link provides a host system with both a standard 1394 interface, and with data-buffering and DMA services. Thus, the power figures given here assume the use of an OHCI link in the notebook. When the notebook is mated with a full dock, the ensemble's 1394 capabilities are provided by the dock-resident PCI-to-1394 bridge. Thus, it is assumed that the dock also provides an OHCI link.

There are two major areas in which the designer of a mobile 1394 subsystem must make design choices:
1. Control of 1394-interface power state;
2. Selection and control of 1394 cable-power capabilities.

Design considerations for each of these appear below. Further specification details can be found in the 1394a draft standard *P1394a Draft Standard for a High Performance Serial Bus, Draft 2.0*, and implementation details may be found in *1394 Trade Association Power Specification Part 3: Suspend/Resume* and in further citations listed below.

Power-State Control
The 1394-1995 standard provides no power-management capabilities, other than issuing of Link On packets by the bus manager. In contrast, the 1394a standard includes the ability to suspend or disable ports, and the ability to control the operational and power state of the PHY core. Thus, all of the above recommended system configurations and power estimates assume the use of 1394a-compliant PHYs and links.

Relevant specification details can be found in the 1394a draft standard, and in two 1394 Trade Association guideline documents: *1394 Trade Association Power Specification Part 3: Suspend/Resume*, and *1394 Trade Association Power Specification Part 2: Power State Management".*

To reduce 1394 power consumption, it is necessary to suspend or disable ports whenever possible. Doing so can take 1394 power consumption from Watts to milliWatts. To use these capabilities properly, it is necessary to recognize how they differ. A suspended port may be brought back to its normal operating state through the occurrence of a "resume" event, such as connection of a device to that port, or arrival of a software- or hardware-induced "wake" event at that port. In contrast, a disabled port is insensitive to any such resume event. A disabled port can only be re-enabled by an explicit software command received either through another (active) port on that PHY, or through the PHY's PHY/link interface. Thus, the choice of suspending or disabling a port should be based on whether a subsequent resume is desired. In terms of power-consumption, a suspended port and a disabled port are indistinguishable, and either is in the range of a few milliWatts.

Control of the PHY-core power consumption is a complex process involving port activity, PHY registers and the PHY/link interface; it will not be treated further here. The interested reader is referred to the 1394a draft standard.

When the bus is in active use, each associated PHY and link is powered and fully operational. If the platform system software determines that the 1394 bus is not presently needed, but may be needed on short notice, it is recommended that the bus power manager suspend all ports, after preparing for reception of expected wake events. If the system software determines that the 1394 subsystem will not be needed for a prolonged period, the platform should turn off (i.e. power down) its PHY(s) and link(s). Since the notebook is a single-port bus "leaf" (end-point) in the recommended configurations, powering down the notebook's 1394 interface will not disrupt traffic on the bus. Since it is necessary to re-enumerate the bus after turning off a node, this will cause greater resume latency (hundreds of milliseconds or more) than merely suspending ports (tens of milliseconds).

Cable Power
The 1394 bus includes the capability to supply device power over an optional power-pair in 1394 cables. The 1394a draft standard defines PHY "power classes" which identify the cable-power sourcing, sinking or pass-through capabilities of a given node. This

information is transmitted by each node during the bus tree-identification process, and is thus available to a bus power manager for use in maintaining a bus “cable-power budget”.

Relevant specification details can be found in the 1394a draft standard, and in the 1394 Trade Association guideline document *1394 Trade Association Power Specification Part 1: Cable Power Distribution”* .

None of the assumed classes of notebooks implement bus-powering capability. It is recommended that the notebook platform’s host interface declare itself as a power-class-4 device (i.e. it defines its specific power characteristics in its Configuration Status Register or “CSR”, space). It is further recommended that the notebook 1394 node CSR power data characteristics be configured such that the node does not sink, source or pass power. This configuration alleviates the need to source a minimum cable power of 3.2W (3.0 W to enumerate the peer PHY, plus 0.2 W to overcome a worst-case I^2R drop in the interconnecting cable). After PHY enumeration, additional power may need to be provided to enable a cable-powered device for normal operation when sending a Link-On command to the device. Due to the modest power-sourcing capability of a notebook, using a notebook as a source of cable power is not recommended.

A mini-dock configured with 1394 capability should be implemented in the same manner as recommended for the notebook platform. The mini-dock should not sink power from or source power to the attached notebook via a notebook 1394 connection. In addition, the mini-dock should not sink power from or source power to the 1394 bus via an attached 1394 cable.

A full-dock 1394 configuration may be designed to source cable-power as either a standard power provider or an alternate power provider as described in the 1394 Trade Association Power Specification, Part 1: Cable Power Distribution. This recognizes the fact that an AC-powered dock can be built with substantially more power-supply capacity than a notebook. It is recommended that the docking-station 1394 node be designed to source cable power as a power class 4 alternate power provider with a launch voltage between 12 and 15 volts, and current capacity of 500 mA per port. Voltage, current, and power pass-through capability must be defined in the docking station's 1394 node ROM CSR space.

Device Power Models

As of this writing, the 1394a ICs on which these power guidelines are based do not yet exist, though they are far along in development. However, various PHY and link vendors have developed estimates for the expected power consumption of their devices. These make it possible to develop the generic power model which is assumed in this section:

- 1394a OHCI link @ S400: 0.4W (non-OHCI link will use somewhat less power);
- 1394a PHY @ S400:
  - PHY core (PLLS, etc.): 0.4W
  - PHY port (adder per active port): 0.1W
  - PHY port (per suspended port): 3mW

Since 1394b-compliant components may be in design in the ’00 timeframe, the following model exists for 1394b:

- 1394b OHCI link @ S800: 0.7W (non-OHCI link will use somewhat less power);
- 1394b PHY @ S800:
  - PHY core (PLLS, etc.): 0.8W
  - PHY port (adder per active port): 0.3W
  - PHY port (per suspended port): 3mW

5.3.11 CardBus

5.3.11.1 Features and Assumptions

The following CardBus features are assumed for systems shipping in 2000.

Mini Notebook	Full Size Notebook
• 1 power managed CardBus slot, includes ZV;	• 2 power managed CardBus slots; one includes ZV

The CardBus controller and CardBus slots are power managed in accordance with the "PCI Bus Power Management Specification for PCI to CardBus Bridges" included in the PCMCIA PC Card Standard.

5.3.11.2 Power Targets

The following table shows the CardBus power targets for systems shipping in 2000.

CardBus Power Target 2000			
	Peak Power (W)	**Suspend Power [wake enabled] (W)**	**Suspend Power [wake disabled] (W)**
Full Size	5.0	0.67/enabled slot	0.0
Mini	2.5	0.67	0.0

CardBus I/O cards (e.g. 100 Mbit LAN) when placed in D3 and also enabled to wake the system, via PME#, may draw up to 200mA while monitoring the network for a wake packet.

5.3.11.3 Design Considerations

System designers must ensure that all hardware requirements specified in the "PCI Bus Power Management Specification for PCI to CardBus Bridges" standard are met. System power management software must make aggressive use of the mechanisms provided.

5.3.12 Universal Serial Bus (USB)

5.3.12.1 Features and Assumptions

The following USB features are assumed for systems shipping in 2000.

Mini Notebook	Full Size Notebook
• 1 external connector	• 1 external connector

5.3.12.2 Power Targets

The following table shows the USB power targets for systems shipping in 2000.

USB Power Target 2000			
	Peak Power (W)	**Suspend Power [wake enabled] (W)**	**Suspend Power [wake disabled] (W)**
Full Size	2.5/port	0.0125	0.0
Mini	2.5	0.0125	0.0

Mobile systems are specifically allowed, by the USB specification, to define their root ports as self-powered or alternatively as bus-powered. Self-powered definition burdens the system with providing up to 2.5W/port, while bus-powered definition allows a system to support only 0.5W/port. The table above assumes a self-powered definition. The burden, on a Mini-Notebook, can be significantly reduced if they choose the bus-powered definition. This definition can also vary based on the systems power source. When attached to AC the system can choose to support a self-powered root hub, but when operating on battery choose instead to only provide a bus-powered hub.

5.3.12.3 Design Considerations

System designers should reference the Intel “USB Mobile System Design Guidelines” for design recommendations. This document can be obtained at: http://developer.intel.com/design/usb/designex/usbgl10.htm

5.3.13 LAN Controller

5.3.13.1 Features and Assumptions

The following LAN features are assumed for systems shipping in 2000.

Mini Notebook	Full Size Notebook
• LAN on motherboard or PCCard • 10/100 megabit	• LAN on Motherboard or PCCard • 10/100 megabit

5.3.13.2 Power Targets

The following table shows the LAN cache power targets for systems shipping in 2000. The LAN is 100 Base T and is assumed predominantly idle with less than 5 Mbit / second traffic. The power numbers shown are for a motherboard implementation. Substitution of a PCCard solution would add .4 watts in peak power as well as in crease the power in the PCCard controller.

LAN Power Targets 2000

	Peak Power (W)	Idle Power -Connected (W)	Idle Power - No Connect (W)	Average 3D WinBench* Power (W)
Full Size	.6	.4	0	.4
LAN utilization & bus traffic				5%
Mini	.6	.4	0	.4
LAN utilization & bus traffic				5%

5.3.13.3 Design Considerations

LAN subsystem power can be reduced by reducing the core voltage of the LAN controller as well as implementing ACPI power management techniques.

5.3.14 Power Supply

5.3.14.1 Features and Assumptions

The following power supply features are assumed in systems shipping in the year 2000.

Power Supply Features 2000
• 90% overall efficiency while running 3D Winbench*

5.3.14.3 Design Considerations

Maintaining good efficiency and transient response becomes more challenging as output voltages get lower and currents gets higher. A majority of the power losses in a typical switching power supply configured in a “buck” topology are due to resistive losses in the power path. These losses are equal to the current squared times resistance. To maintain efficiency it will be necessary to reduce the resistance in the power path. This can be accomplished by reducing the transistor on-resistance ($R_{DSon)}$, inductor resistance, capacitor effective series resistance (ESR) and eliminating the current sense resistor typically found in buck converters. Since the bulk of the current is conducted through the low side MOSFET at low output voltages, power supply efficiency can also be improved by placing two low resistance MOSFETs in parallel for the low side MOSFET.

While I^2R resistive losses dominate efficiency at high loads, reducing switching losses is also important. Switching losses can be improved by reducing the high-side MOSFET gate-drain charge and gate-source charge, and synchronous MOSFET gate-drain charge and reverse recovery time. For optimum efficiency, the high side MOSFET should be sized to balance resistive losses and switching losses. The power supply controller can reduce switching losses by reducing the dead time between high-side MOSFET and synchronous MOSFET activation.

The following tables list suggested power supply characteristics for systems shipping in 2000. The current load estimates are based on the configurations listed in Table 5.1 (System Feature Comparison). The regulation and ripple tolerance refers to the output voltage tolerance at steady state while drawing the average 3D WinBench* load listed in the table. Transient regulation refers to the total output voltage tolerance including ripple and load regulation during a worst case transition to or from maximum load. The transient regulation tolerance assumes that either the CPU core power supply is located immediately adjacent to the processor to minimize resistive and inductive losses between the power supply and the CPU.

Full Size System Power Supply Characteristics 2000						
Input Voltage		3-Cell Li+ Battery 7.5-18 V				
Output Voltage	Value	1.3 V (CPU & Cache)	1.8 V	2.5 V	3.3 V	5.0 V
	Regulation & Ripple	3.5%	3%	2%	2%	2%
Current	3D WinBench* Load	7.3 A	2 A	0.5 A	1.5 A	0.5 A
	Max. Load	11.5 A	3 A	1 A	2.5 A	2 A
Efficiency	3d WinBench* Load	**90%**				
Transient	Regulation	10%	5%			
	Response Time	2µs	2µs			

Mini-notebook System Power Supply Characteristics 2000						
Input Voltage		3-Cell Li+ Battery 7.5-18 V				
Output Voltage	Value	1.1 V		2.5 V	3.3 V	5.0 V
	Regulation & Ripple	5%		2%	2%	2%
Current	3D WinBench* Load	3.6 A		0.3 A	1.5 A	0.5 A
	Max. Load	4.8 A		0.5 A	2.5 A	2A

Efficiency	3D WinBench* Load	**90%**	
Transient	Regulation	10%	5%
	Response Time	2µs	2µs

POWER RAIL GOAL

- Remove all 12V Components from Mobile Computers top to bottom

5.3.15 Battery Charging

5.3.15.1 Features

The following battery charging subsystem features are assumed in systems shipping in the year 2000.

Battery Charging Features 2000
• Smart battery charger • Adaptive charging algorithm

5.3.15.2 Power Targets

2000 Battery Charging Power Targets			
	Peak Power (W)	**Idle Power (W)**	**Average 3D Game Power (W)**
Full Size	2.5	0	0
Mini	1.5	0	0

These charging power targets assume an adaptive charging mechanism is implemented. In this document adaptive charging refers to some form of variable charging control that senses how heavily the system is loaded and reduces heat dissipated in charging when the system is near maximum load. Adaptive charging could be implemented through a small sense resistor on the main AC adapter input and adjust charging current to keep overall system power below a maximum threshold. Since the charging voltage is high, the current would be relatively low and a small sense resistor would only dissipate about 0.1 watts at peak load. Adaptive charging could also be implemented with thermal sensors that reduce charging when the system is nearing it’s thermal limit.

6. Battery Life

This section estimates 2000 system battery life by looking at factors that affect battery life and projecting typical system power consumption and battery capacity. It also includes suggestions for improving battery life.

6.1Battery Life Factors and Assumptions

Battery life is affected by many factors including battery capacity, chemistry, discharge rate, discharge profile, temperature and charge/discharge history. These factors are briefly described and some assumptions made to enable a first order battery life estimate for the system described in this paper.

Battery capacity is the total amount of power a battery can deliver when discharged at constant current over a 5 hour period. While there are many different battery sizes in use today, 3x4 cell lithium ion battery stacks are common in many full size systems and will be used for this battery life analysis. A typical 3x4 cell lithium ion battery stack today has roughly 47 watt hours capacity. Battery capacity is continuing to increase at 5-10%/year. This trend is expected to increase through 2000. Assuming a 5%/year improvement, the same size battery in 2000 is estimated to have a capacity of about 52 watt-hours.

Discharge rate has a non-linear impact on the total amount of power a battery can deliver. A battery will deliver its full rated capacity when discharged at constant current over a 5 hour period (called a 1C discharge rate.) If a battery is discharged twice as fast (2C discharge rate) it will not deliver as much total power as it would if discharged at a 1C rate. Table 6-1 shows approximate capacity derating at various discharge rates for lithium ion batteries.

Table 6-1 Battery Capacity at Various Discharge Rates

Discharge Rate	Usable Battery Capacity (Normalized to 1C Discharge Rate)
C/5	107%
C/2	104%
1C	100%
2C	94%
4C	86%

This table is for constant current discharging. Note that discharging faster than a 1C rate decreases usable capacity more than slowing the discharge rate increases capacity. If the discharge rate is not constant, the usable battery capacity will be less than the capacity at the average rate of discharge. For example, if a battery was discharged at a pulsed rate of 2C 50% of the time and C/2 50% the average discharge rate would be 1C but the usable battery capacity would be only 99%.

Usage profile refers to the dynamically changing discharge rates a battery is subjected to during use. The usage profile will vary significantly across users and systems. To measure battery life across various systems a consistent user workload profile must be established. A benchmark, SYSmark98 for Battery Life from BAPCo, which was designed upon a business user input model will be employed for as a workload profile for this evaluation. The benchmark consists of a business software suite, Microsoft* Office 97; a game, Microsoft* Flight Simulator 98; and a web browser, Netscape*. This benchmark approximates a real usage scenario by running scripts for applications and entering data at a typing rate of approximately 48 words per minute. It also includes a 20 minute idle time after completing a loop through all seven applications since typical systems go into standby occasionally.

Battery chemistry affects peak discharge rate, thermal response, and the number of charge / discharge cycles a battery can tolerate. These all impact the useful charge a battery can deliver. Nickel Cadmium (NiCd) and Nickel Metal Hydride (NiMH) have higher peak current capabilities than Lithium ion (Li^+) chemistries but are also more sensitive to temperature. As temperature rises the internal resistance in NiCd and NiMH increases and reduces peak current capability. At room temperature and above, Li^+ peak current capacity is relatively temperature independent. Battery capacity also diminishes as batteries are repeatedly charged and discharged. This battery life analysis assumes a new, fully charged Li^+ battery pack is used and it is at or above room temperature.

6.2 Battery Life Analysis

System power design and effective power management can aid in extending battery life. If any of these ingredients are insufficiently executed then the battery life will be reduced. Reducing the battery life will diminish the usefulness of a notebook as a portable computer. This section will examine APM and ACPI implementations on a reference design intended to be typical of today's notebook configurations.

To evaluate extending battery life, power measurements were captured without power management, with APM (Advanced Power Management), and with ACPI (Advanced Configuration and Power Interface) on Microsoft* Windows* 98. The average power measurements that were captured without power management will be used as a reference. This will aid in estimating the power management efficiency of ACPI and APM for extending battery life.

6.2.1 Typical Business Notebook Model

The testing environment was based on a design configured as today's typical notebook:

Mobile Components	Description
CPU	Mobile Pentium® II 266/66MHz
North Bridge/Chipset	440BX
HDD	IDE/ATA33
System Memory	32 MB(66 MHz SDRAM)
Audio/CD-ROM	Analog SoundBlaster* Compatible / 11x
L2 Cache	512KB
Serial Controller	USB
LCD	10.4" / 800x600x16bit/pixel
Graphics Controller	PCI/2MB
Graphics/IO Bus	PCI 33MHz
Cardbus Controller	PCMCIA 3v
Speakers/Amplifier	8Ω Speakers/ 1W Amplifier
Other Peripherals	Parallel, Serial Ports

Table 6-2 Tested System Configuration

6.2.2 Battery Life Assumptions

SYSmark98 for Battery Life is a benchmark which was developed BAPCo*. It employs a workload that is intended to represent a typical business user. We use it as a workload in the measured case to understand the power used by each subsystem.

All references to power will be considered as average power. The average system power consumption includes all mobile components (CPU, HDD, etc.) and is considered to be 100%.

The sub category,” Other Electronics”, will consist of all the other peripherals not stated in the test configuration table.

Because the USB and Cardbus were not exercised significantly in this benchmark and their combined average power consumption was .1W, neither will impact the battery life analysis and will be added to the ‘other electronics’ number.

6.2.3 Power Measurements

Components	No PM	APM	ACPI
System	22.11	17.19	16.16
CPU+L2+CPU I/O	6.83	2.81	2.61
Other Electronics	5.93	5.42	5.72
*HDD/CD-ROM	2.95	2.57	2.55
LCD Back Light	1.93	1.93	1.93
North Bridge	1.52	1.51	0.86
Graphics Controller	1.15	1.15	1.17
**SubSystem I/O	0.84	0.84	0.85
System Memory	0.7	0.7	0.34
Speakers/Amplifier	.26	0.26	0.26

Table 6-3 Overall average power for all workloads in SYSmark98 for Battery Life

**HDD/CD-ROM are connected to a common IDE port; therefore,*
their average power consumption is combined.
*** SubSystem I/O is the southbridge, keyboard controller and mouse controller*

These measurements provide us with an understanding of where power is being consumed in today’s platform. They also illustrate the importance of power management software in the notebook. In this implementation ACPI was a small percentage better than APM in reducing power. ACPI is in its initial implementations today and is expected to improve as implementations are refined. These measurements will be used as a basis for projecting power in the future platform.

6.3Total System Power Estimates

To estimate system battery life, average power consumption for the entire system must be estimated. This includes the notebook base, LCD, and any peripherals plugged in that draw power from the notebook. This analysis makes the following configuration and usage assumptions:

- The system configuration is the same as shown in Table 5-1.
- There are no devices connected to the external 1394 or USB ports
- The DVD drive is not used while running the SYSMark98/BL benchmark and is in the sleep state.
- The 1394 controller is in the suspend state.
- A LAN is connected and is predominantly idle.

- The power management algorithm puts the hard drive into standby after 2 minutes and to sleep after 5 more minutes.
- The power management algorithm turns off the LCD backlight after 5 minutes of inactivity and suspends after 10 minutes.

Table 6-4 shows the estimated component utilization and power consumption while running the SYSMark98/BL benchmark for the full size system in 2000. The utilization estimates assume the time required to complete a loop through the SysMark98/BL benchmark is dominated by fixed delays associated with the input typing rate. Higher performance processors will complete tasks faster and spend more time in a low power idle state when waiting for input. Configuration differences and lower component power consumption in 2000 are also factored into the average SysMark98/BL power estimates.

Table 6-4 Estimated SYSMark98/BL for Battery Life Component Utilization and Power Consumption

	2000	
	Estimated Utilization (%)	Power (Watts)
CPU & L2 Cache	20%	3.0
Memory Controller	18%	0.6
System Memory	18%	0.7
Graphics Subsystem	40%	1.7
LCD Panel	86%	3.3
IO Subsystem	Hub 25%, KBC 75%, ACPI uCtrl 30%	0.6
Audio	15%	0.4
Hard Drive	Spin-up 1%, Rd/Wr 20%, Idle 53%, Stdby 15%, Sleep 11%	1.2
DVD Drive	0%	0.1
1394	0%	0.0
USB	0%	0.0
Cardbus	0%	0.2
LAN	5%	0.4
Power Supply		1.4
Charging	0%	0.0
Cooling	10%	0.1
Other	100%	0.7
Total SYSMark98/BL System Power		**14.3**

6.4 Battery Life Calculation

With the assumptions and total system power estimates given in the sections 6-1 and 6-4 we can calculate the average battery life with the following equation:

Average battery life ≈ ((Battery size * Discharge rate derating) / (Total SYSMark98 System Power))

Since the estimated total system power is about 27% of the nominal battery capacity in 2000, the batteries will discharge at slightly above the 1C rate. At this level we will use a derating factor of .98. This yields the following results:

Average 2000 battery life ≈ (52Watt Hours * .98) / (14.3 Watts)) = 3.56 hours

These estimates indicate the average battery life for a full size system will be slightly over 3.5 hours in 2000. Actual battery life will vary based on exact configuration, battery size and battery characteristics. Systems adhering to the mobile power guidelines will benefit from both increased performance and longer battery life since average power is held down while battery capacity is increasing.

6.5 Design considerations

In addition to designing-in lower power components, system vendors can increase battery life by tuning the system and software for lowest power consumption, and implementing aggressive power management strategies.

7. System Development Tools

Intel has available several software development tools to assist Independent Hardware Vendors (IHV's), Independent Software Vendors (ISV's) and Original Equipment Manufacturers (OEM's) in the development of ACPI compliant systems and components. All assist the developer in determining patterns of system activity and power states of various subsystems. These tools vary in the level of analysis and potential correction they provide and while some are software based, others require specified hardware and configurations. The objectives of the different tools differ also. The developer would choose the tool based on the type of analysis desired. There are 3 tools with various capabilities of examining the power consumption impact created by *applications*, *software design*, and *hardware subsystems*. They are:

- Intel Power Monitor (IPM) is used to measure power consumed by a system while running certain software applications. This enables software developers to examine and "fix" software to be more power efficient, and hardware developers to analyze and correct areas of excessive power consumption in mobile computer hardware.
- Intel Power Analyst (IPA) is used to measure power consumed by mobile computer subsystems (such as the CPU, memory, hard disk, etc.) in real time. It analyzes power consumption of the entire system as well. This is to enable developers to determine if certain applications or configurations will hold the system within power budgets.
- Intel Power Management and Analysis Toll (IPMAT) is a hardware and software tool used to help OEMs and IHVs analyze device and system power management against ACPI requirements. This enables the developer to determine proper integration of the OS to efficiently manage power as it can measure ACPI supported states for both systems and devices.

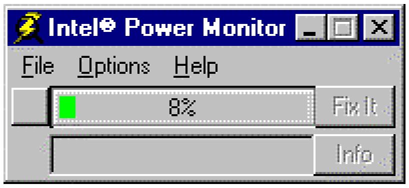
Intel's System Development Tools were created to provide additional resources for developers to measure system behavior in order to more easily identify and correct the sources of excessive power consumption in mobile PC systems. The following sections provide a detailed description of each tool's capabilities and requirements.

7.1 Intel Power Monitor (IPM)

The Intel Power Monitor (IPM) is a software analysis tool that is designed to measure the impact of applications and the operating system on the power consumed by an Intel-based computer. IPM enables Independent Software Vendors (ISVs) to develop power-efficient software applications that are mobile system-friendly, and provides Independent Hardware Vendors (IHVs) with insight into the impact of their hardware and their bundled software applications on mobile system power.

7.1.1 Standard Features, Operation, and Requirements

The Intel Power Monitor has a simple set of menus and controls. In addition to the standard title bar and menu items, there are other unique display features that give the user information about power use and activity detected in the system being tested:



CPU Activity Meter: This is a bar gauge that graphically represents processor activity as a percentage of time the CPU is not in an idle state. This display updates approximately once per second. A colored bar indicates the amount of processor activity of the software currently active:

- Green indicates low activity.
- Yellow indicates that the processor is active 75% or more of the time.
- Red indicates that the processor was unable to go idle during the last measurement period.

Application Name field: Displays the name of the application or driver most likely responsible for the processor activity. If the processor is unable to enter an idle state, the Intel Power Monitor attempts to discover the most likely cause by finding the most active application. If the application displays some well-known power-unfriendly behavior and the Intel Power Monitor has determined that it can enable a fix, the name of the offending application appears in the Application Name field and two screen buttons are enabled:

- Fix It Button: Clicking this button allows the system to perform power management for brief periods. These rest periods are so short that they are virtually undetectable to the user, but they can have a significant effect on extending the battery life.

  Fixed applications display the word "FIXED" in the title bar and the Power Monitor itself displays the number of fixed applications in its title bar.

  If the Intel Power Monitor is unable to fix an application, the button will display the word 'Ignore,' allowing the operator to tell IPM to ignore further monitoring of this application.

- Info Button: Clicking the Info button displays further information about the reported application.

The following are the requirements for the Intel Power Monitor

	Intel Power Monitor
Web site	http://developer.intel.com/ial/ipm/
Intel Contact	***See Web site***
Software	**IPM** • Cost: Complimentary • See web site to download • Available: Now!
Target System	**Pentium® Processor System (or faster)** • Windows* 95, Windows* 98, or Windows NT* 4.0 • (see web site for latest OS support)
Host System	**None**
Other Equipment	**None**

7.1.2 Evaluation of Power Use and System Activity

Power management software extends battery life by spinning down the disk, switching off the display, halting the processor, and turning off parts of your notebook computer when those parts are not performing work. Power management software usually resides in the system BIOS, but may reside in the operating system.

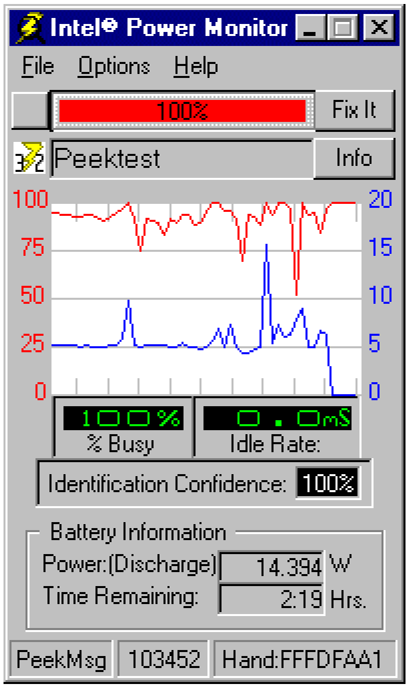
By fixing software that impedes the power management features of a notebook computer, the application developer can reduce power consumption and thereby extend battery life.

The Power Monitor helps to identify where these problem areas may exist. If the Power Monitor's CPU activity meter remains in the red for extended periods the software developer is responsible for determining if the application is performing useful work. If, for example, IPM reports 100% CPU activity while an application is waiting for an operator action, it indicates that the power demands of that application are wasteful and could be reduced.

7.1.3 Extended Display Features and Operation

The Intel Power Monitor offers an extended display mode that provides more detailed information to the Independent Software Vendors (ISVs) and Independent Hardware Vendors (IHVs).

There are several additional fields and features in the extended display. They are:



100%

Peektest

100 % — % Busy

0.0mS — Idle Rate:

Identification Confidence: 100%

Battery Information

Power:(Discharge) 14.394 W

Time Remaining: 2:19 Hrs.

PeekMsg | 103452 | Hand:FFFDFAA1

- '<u>% Busy</u>' and '<u>Idle Rate</u>' histogram: Two numeric displays, one that mirrors the CPU Activity Meter's percent busy display and a second that shows the average number of milliseconds spent in the idle state before returning to the run state during the last sample period. The histogram tracks a 90-second history.
- '<u>Identification Confidence</u>' field: This field is filled in with a percentage when an application name appears in the Application Name Display. The number represents IPM's confidence in the identification of the application or driver as the offending executable.
- '<u>Smart Battery and ACPI battery</u>' subsystem: If the notebook computer has a Smart Battery subsystem or the operating system supports ACPI Battery a 'Battery Information' section will display the rate of battery 'Power [Charge or Discharge]' and the 'Time Remaining' until empty.
- The status bar at the bottom of the window tracks additional information. The status bar operates in three distinct modes:

  <u>Normal</u>: Displays the hits, sample size and process handle (if available) of the most active application from the last sample period. In operation, you will see the sample rate vary from a low value when the system is relatively idle, to a larger number taken as the system reaches 100% non-idle for a few seconds.

  <u>PeekMsg</u>: Displays 'PeekMsg', the number of PeekMessage() calls made by the application in the last second and the process handle.

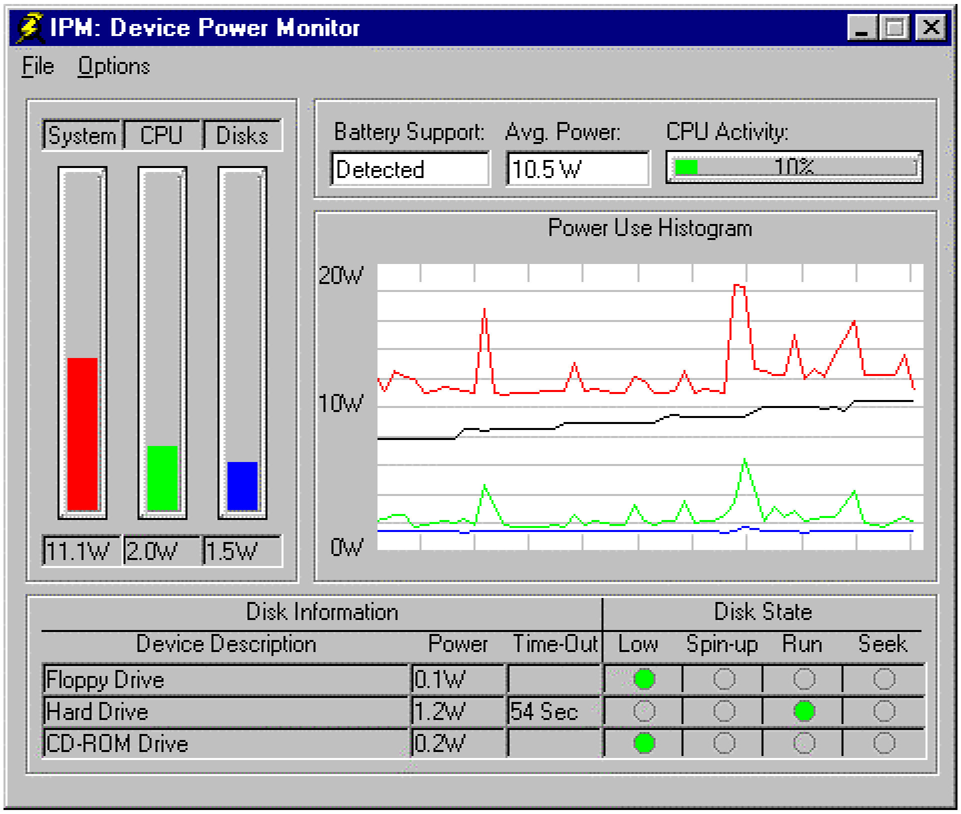
  <u>VxD</u>: Displays 'VxD' to indicate that a specific Windows* 9x driver is curtailing traversal of the system's idle chain along with the process handle.

Taking more samples-per-second allows the Intel Power Monitor to better determine the application that is the *most active*; the one that is the *most likely cause of the non-idle activity*. The extended display further assists you in evaluating the most active application as follows:

- If the Intel Power Monitor can determine the name of the application, it appears in the Application Name Display. Double-clicking the name displayed in the Application Name Display invokes the API Monitor menu.
- The API Monitor subsystem allows you to select a series of system APIs and monitor the number of times each selected API is called by the selected application.

7.1.4 Device Power Monitor (DPM) Features and Operation

The Device Power Monitor is designed to give an ISV or OEM a more detailed analysis tool for determining the impact of their software design on specific platform subsystems. Presently, the DPM subsystem supports analysis of the CPU and rotating media, such as a floppy drive, a hard drive, and a CD-ROM drive.



Battery Support: Detected

Avg. Power: 10.5 W

CPU Activity: 10%

System	CPU	Disks
11.1W	2.0W	1.5W

Disk Information			Disk State			
Device Description	Power	Time-Out	Low	Spin-up	Run	Seek
Floppy Drive	0.1W		●	○	○	○
Hard Drive	1.2W	54 Sec	○	○	●	○
CD-ROM Drive	0.2W		●	○	○	○

There are several additional fields and features in the Device Power Monitor subsystem display. They are:

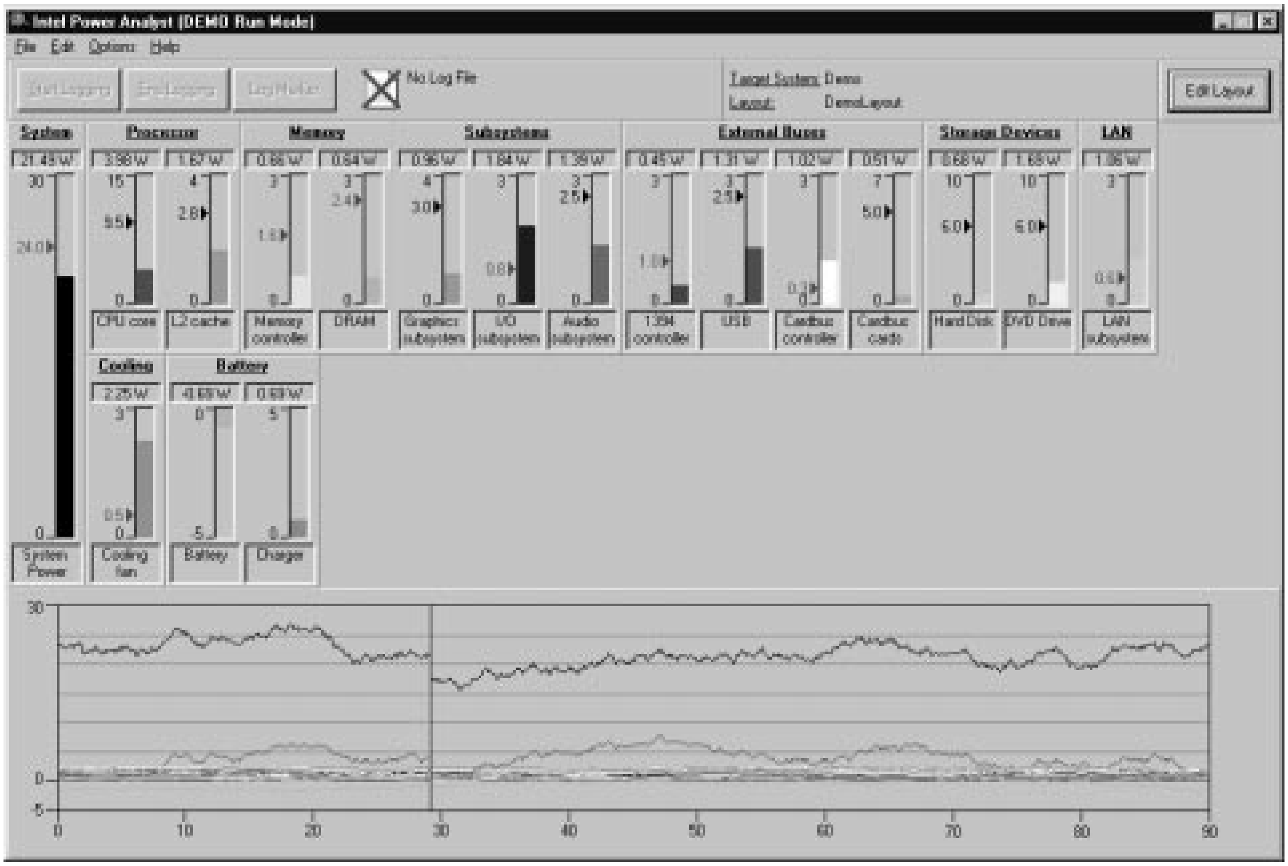
- <u>‘CPU Activity’ meter</u> (upper-right corner). Read this gauge exactly like the gauge in the main IPM window.
- <u>Text Fields</u> (immediate left of the CPU Activity Gauge) that display whether a Smart Battery or ACPI Battery has been found on this system and an ‘Avg. Power’ (Average Power) in watts.
- <u>Three Gauges</u> (left side of the display) labeled ‘System’, ‘CPU’ and ‘Disks’. These gauges display power use by the entire system and separate the CPU and rotating media into two separate power measurements. On a Smart Battery supported system, the ‘System’ gauge is a very accurate measurement of power usage. The ‘CPU’ and ‘Disks’ gauges calculate power use numbers based upon the observed behavior of your system.
- <u>Power Use Histogram</u> (right of the Three Gauges) tracks and displays the three Device Power Gauge numbers and the Average Power number. The Disk Information Display area has a line entry for each instance of rotating media found on the system.

7.2 Intel Power Analyst

The Intel Power Analyst (IPA) is a hardware tool that measures the power consumption of the various subsystems of a mobile computer, such as the CPU, memory, hard disk, and video, audio, and PC cards in *real time*. Developers of mobile PC components, systems, or operating systems can use IPA to determine if particular subsystems are within their power budgets for certain applications or system configurations.

7.2.1 Features and Operation

The IPA software shows the *real time* power measurements of many different mobile computer subsystems and devices, such as the CPU, memory, hard disk, video, and audio, as well as the total system power. Each device or subsystem has a dedicated gauge that displays the real time power consumption. In addition, the power of each device or subsystem, along with total system power, is tracked over time on a power versus time histogram.



Target System: Demo
Layout: DemoLayout

The IPA software interface has many features and options.

- Up to 31 *customizable gauges* display the real time power consumption of devices and subsystems.
- A *power versus time histogram* shows the short-term power trends of each device and subsystem.
- The user can *create data logs* with a custom sampling rate to evaluate long term power trends that can be imported and analyzed in Microsoft* Excel.

In addition, the user can set a power target for each of the power gauges. The power target and an arrow are displayed in black next to the power gauge. If the power level of the device or subsystem exceeds the user-defined power target, the color of the arrow and power number change to red to alert the operator of a potential power consumption problem.

*Third-party brands and names are the property of their respective owners

The following are requirements for the Intel Power Analyst.

	Intel Power Analyst
Web site	http://developer.intel.com/design/mobile/intelpower/tools/ipa
Intel Contact	***Contact your local Intel representative***
Software	**IPA software on Host systems** - Software is complimentary - Available Now!
Target System	**Instrumented Evaluation system** - Mobile Platform Development Kit-2; OR - Instrumented OEM system
Data Acquisition System	**Fluke NetDAQs** - Number of NetDAQs between 1 and 3 depending on number of instrumented subsystems - IPA Interface Kit-1 from Intel to connect to Target system
Host System	**Pentium® Processor System (166MHz or faster)** - Microsoft Windows* NT 4.0 with Service pack 2 or 3 - 1024 x 768 x 256 display - 10Base-T network connection to link to NetDAQs

An OEM or IHV may choose to use IPA on their own evaluation system board, rather than Intel's MPDK-2. If this is the case, the OEM or IHV system board must be instrumented for power measurement, similar to Intel's MPDK-2. For connection to the NetDAQs, the IPA Interface Kit-1 from Intel, or an OEM or IHV specific interface cabling solution must be used. The NetDAQ part number that should be ordered from Fluke depends on the choice of interface between the target system board and the NetDAQs. For more information on using IPA with your evaluation system board, contact your local Intel representative.

7.2.2 Evaluation of Power Use and System Activity

IPA uses direct power measurements from the system board to determine the power that is consumed by different mobile computer devices and subsystems. A system board that has been specially instrumented for power measurements is required, along with a data acquisition system and other hardware as indicated above. The software interface displays these measurements in the form of histograms and fluctuating bar gauges as shown previously. Each device or subsystem registers power consumption in *real time* in the IPA window.

IPA allows developers of mobile PC systems, devices, drivers, operating systems, and software applications to measure the impact of their products on total system power or individual device power. IPA allows developers to validate that their devices or systems are operating within agreed upon power targets.

*Third-party brands and names are the property of their respective owners

7.3 Intel Power Management and Analysis Tool (IPMAT)

The Intel Power Management Analysis Tool (IPMAT) is a hardware and software tool that is designed to help Original Equipment Manufacturers (OEMs) and Independent Hardware Vendors (IHVs) evaluate device capability and power management under ACPI. IPMAT helps to ensure proper integration of OS power management through ACPI providing the ability to test for supported ACPI states at both the system and device level. The tool checks the ACPI power management support of hardware, devices, drivers, and applications and the resume latencies associated with ACPI state changes. In this way it can be used to qualify and select vendors.

7.3.1 Features, Operation, and Requirements

IPMAT offers *manual, automatic* and *monitor modes* for evaluating ACPI device and system states with an option to select an individual device/driver in the system. The key features it provides to assist in evaluating power use are:

- *Interfaces to a digital power meter, data acquisition system, or mobile system battery stack* to automatically measure power and current consumed by the system under test (required only when recording power and current measurements).
- *Creates and manages a database* of baseboards, add-in cards, test configuration, PM qualifying parameters, test results and applications. The results for each test run are stored in the database and can be retrieved for a given baseboard and configuration at a later time for analysis.
- *Performs automated evaluations of ACPI integration* within the PC being tested.

The following table outlines the requirements for the entire IPMAT system: How and where to obtain the software, the necessary and optional hardware for running the tool, and the conditions of use for certain types of testing.

	Intel Power Management Analysis Tool
Web site	http://developer.intel.com/design/ipeak/
Intel Contact	***See Web site***
Software	**IPMAT software on both Target and Host systems** • See web site for details • Available: Now!
Target System	**Pentium® Processor System** • ACPI/OnNow compliant platform, devices, device drivers, and OS • Serial port, modem, or network interface and appropriate cable(s) • IPMAT software
Host System	**Pentium® Processor System (Optional, but recommended - needed for testing certain ACPI states)** • Windows* '95/'98 • Serial port to connect to watt meter and a null modem cable • A 2nd serial port, or a modem or network interface and appropriate cable(s) • IPMAT software
Power Measurement	**Power Meters(Optional - needed only for power measurement)** • **Watt Meter:** Yokogawa* WT110 • **Measurement Cable:** Yokogawa* B9017ZV (To order Watt Meter and Cable: 1-800-258-2552) **OR** • **Data Acquisition System:** Fluke* NetDAQ* • **Cabling:** IPA Interface Kit-1 from Intel to connect to Target system **OR** • **Mobile system battery stack interface** (Windows* 98 and NT*5 – ACPI)

7.3.2 Evaluation of Power Use and System Activity

The Intel Power Management Analysis Tool (IPMAT) is the first to be developed for the Power Management Toolkit. Intel's IPEAK Power Management Toolkit was developed to help PC OEMs and IHVs incorporate the Power Management initiative in product design and system integration processes. IPMAT helps to ensure proper integration of ACPI by providing the ability to test for supported ACPI states at both the system and device level.

The tool can be used to:

- Qualify power management functionality.
- Quantify power consumption.
- Test the behavior of applications participating in Global System Power Management.

8. ACPI

The Advanced Configuration and Power Interface (ACPI) is an industry specification developed to address the issues of managing power to reduce power consumption, maximize component efficiency, and preserve and extend battery life in mobile computer systems. Microsoft*, Intel and Toshiba* authored the specification but it includes contributions from Independent Hardware Vendors (IHV's), Independent Software Vendors (ISV's) and Original Equipment Manufacturers (OEM's) to ensure it meets the needs of the entire industry.

8.1 System Level Power Management

ACPI is a culmination of several breakthroughs in the area of power management. A number of technological advancements that have been made over recent years were the direct result of the identification and development of System Level Power Management. This refers to the presence of mechanisms that read the activities of a system and have the ability to monitor and change the power states of subsystems and components.

Advanced Power Management — Advanced Power Management (APM), introduced in 1991, created an interface between the Operating System and the BIOS allowing the Operating System and the Power Management code embedded within the BIOS to communicate directly. Initially APM contained interfaces to address all known problems with timer-based power management. New interfaces became necessary, however, to handle the evolution of new hardware.

Advanced Configuration and Power Interface — ACPI, introduced in 1997, is a comprehensive well-specified power management and configuration mechanism. It draws from the existing collection of power management BIOS code, APM Application Programming Interfaces (API's) and Plug and Play (PNP) BIOS API's. The ACPI specification supports an orderly transition from existing (legacy) hardware to ACPI hardware and it allows both mechanisms to exist in a single machine. Newer Operating Systems can take advantage of ACPI mechanisms and older Operating Systems can continue to operate with older mechanisms.

ACPI creates mechanisms for control of three basic functions: Platform Power Management (Hardware), Device Power Management (BIOS), and Platform Configurations (Operating System). ACPI specifies conditions, features, and design and configuration models for the development of mobile PC systems in the following areas:

- HARDWARE: ACPI specifies a fixed register space that allows the Operating System to interact with the hardware at a fixed location without a wait for the OS to be fully loaded. This interaction is important at initial boot and when a component is exiting a sleep state so that the Operating System can locate registers needed for basic operation with a minimum of overhead.
- BIOS: ACPI specifies Tables and Control Methods for BIOS. These ACPI tables describe the hierarchy of the platform the Operating System uses to manage power and configure the system. The tables are then used to create the ACPI namespace. The namespace in effect provides the Operating System with the equivalent of a block diagram of the system. This includes Buses, Devices and Control Methods. These control methods, provide a way for the Operating System to determine "current" and "possible" resources of a device. If it finds an acceptable configuration it can then "set" the device according to the possible resources.
- OPERATING SYSTEM: ACPI specifies the interfaces which allows the Operating System to perform functions such as Plug and Play and power management support.

The ACPI specification supports Motherboard devices and devices not already covered by any Bus PM or Device Class specifications. Only unique system board functions are addressed. System designers can concentrate on providing hardware and software support for non-standard and value added machine features. A range of power management features are possible for different hardware designs while using the same basic Operating System drivers.

8.2 System Power States Defined

Key to obtaining the power management objectives of ACPI, is the definition of various system states. Maximum power utilization is realized by identifying a system or component state and adjusting the power use according to levels of activity in the system. ACPI defines 4 Global or "G" states:

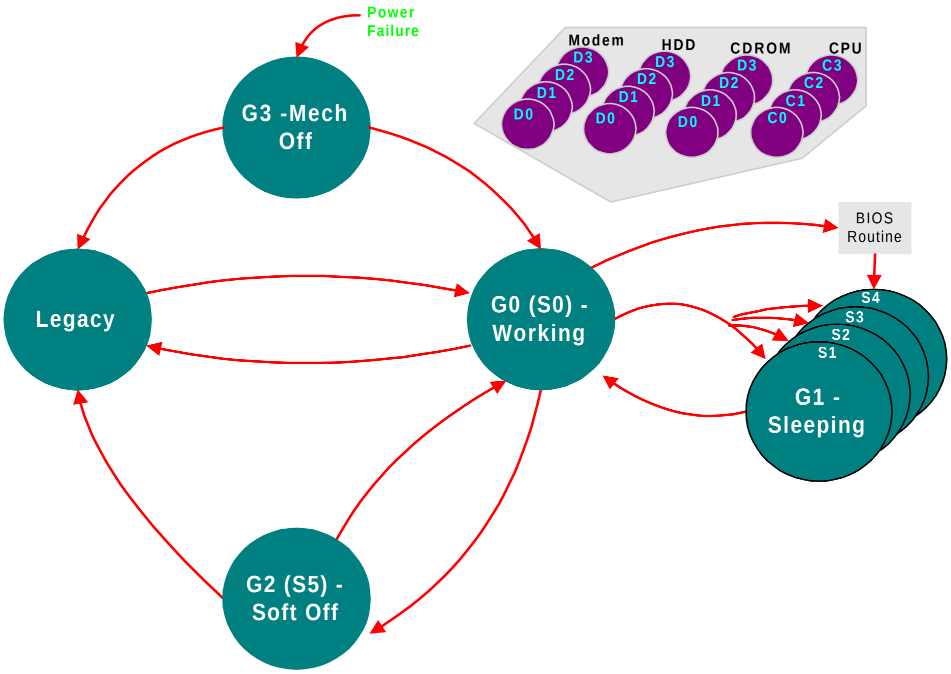


Figure 8-1ACPI State Diagram

- G0: This is the "Working" state is the PCs state where the Operating System is actively executing code. This is the same state where the system manages the device power. The device power states or ("D" states) become relevant here as the system makes requirements of devices individually and dynamically changes their states. ACPI indicates 4 device power states ranging from full working state (D0) to no power state (D3). The CPU is treated as a special device and therefore has its own unique low power states ("C" states.) The CPU power states range from full power state (C0) where instructions are being executed, to the lowest power state with increased latency.
- G1: This is the "System Sleep" state where the system is not visibly active or executing code, and "appears" to be off, although it is drawing minimal power. There are 4 defined levels of latency or sleep states ("S" states). These range from a latent sleeping state with no loss of system context to a very low power, long wakeup latency with no retention of system context except for working memory. Work can be resumed without rebooting the Operating System because both the system hardware and software save large elements of the system context. The lowest power "sleep" state in this category would require a reload of system context from a disk.
- G2/S5: This is the "Soft Off" state where the system is effectively "off" in that no device context is saved. Electrical current is still available in the system, however, so it would not be safe to disassemble the machine in this state. When this state is exited the system does a full boot to resume activity.
- G3: This is the "Mechanical Off" state where no electrical current is running through the circuitry. This state is required to ensure safety for service personnel performing maintenance or repair activities.

8.3 End User Benefits

Another primary goal of power management is to provide more capable, functional, and efficient mobile systems to the end-user. Power savings are only advantageous if the user is able to use the system more easily, for a longer period, and with minimal down time due to configuration or system stability issues. Systems that are ACPI compliant have the potential to provide a number of important benefits to the end-user:

- Mobile PCs will appear “off” and quiet when not in use but will resume full operation when required. Since the basis of the mechanisms of ACPI provides Operating System Power Management (OSPM), more consistent and reliable functioning is assured. The Operating System is now involved in controlling the power coordination across a wide range of sub-systems.
- Users will experience smarter power management and improved battery life in their mobile PCs. ACPI assures that systems are not prevented from entering low power states because a screensaver is enabled. The mechanisms of ACPI also prevent a system from performing a power management feature when it is not desired such as a screen blanking out if the system has not been accessed for a certain period.
- Mobile PCs using ACPI will provide more Plug and Play benefits to the end-user. This capability is likely to significantly reduce typical configuration and computer upgrade difficulties.

8.4 Industry Cooperative Development

Intel, Microsoft* and major BIOS vendors are all working to support OEMs to prevent or remove roadblocks to the release of ACPI compliant systems. ACPI support is now required as part of PC98 compliance. Many systems are already providing support for ACPI starting from January 1998.

Intel, Microsoft* and Toshiba* are hosting ACPI Implementation Workshops to help speed the development of ACPI compliant systems. Microsoft* is providing a Hardware Compatibility Test (HCT) that checks ACPI hardware compatibility. Intel is making available three tools for testing system power: Intel Power Monitor (IPM), Intel Power management Analysis Tool (IPMAT and the Intel Power Analyst (IPA) described earlier in this document (Chapter 7).

9. Summary

This paper proposes methods of monitoring and containing power consumption in future notebook computer systems. Through these guidelines, Intel seeks to provide developers with ways of identifying the sources of power usage in applications, components, and subsystems and proposes ways of reducing or maintaining voltage levels while maximizing system performance. Users have come to expect similar performance from mobile computers that they experience with desktop systems. To continue to provide users with capable, versatile, and powerful mobile systems, component manufacturers, software developers, and system designers will need to work together to incorporate these power considerations into future mobile system designs.

The Mobile Power Guidelines suggest ways of containing voltages to maintain or increase mobile system performance while staying within thermal limits. Vendors who embrace these guidelines will be able to offer higher performance, lower power products with more features at reduced costs. This will allow more packaging options and perhaps wider market opportunities. To realize the many potential benefits to the industry, we call upon industry leaders like you to join us in brining about the changes needed to unlock these opportunities.

Appendix A

This appendix describes system feature assumptions and power targets for 2000 notebook computers. 1999 feature and power figures are included for comparison. The following table shows the system configuration assumptions.

1999 System Configuration	2000 System Configuration
• Mobile Pentium II processor or next generation	• Mobile Pentium® II processor or next generation
• 512KB pipeline burst level two cache	• Integrated level two cache
• Graphics controller AGP 2x interface 4 MB frame buffer 1024 x 768 x 24 bit / pixel resolution MPEG2 H/W assist (motion compensation, YUV 4:2:0) Enhanced 3D acceleration LCD and CRT dual screen support LVDS or Panel Link display interface TV output	• Graphics Controller AGP 2x interface MB frame buffer 1024 x 768 x 24 bit / pixel resolution MPEG2 H/W assist (Motion compensation, YUV 4.2.0) Enhanced 3D acceleration LCD and CRT dual screen support LVDS display interface TV output
• 13.3” Color TFT LCD display	• 13.3 or 14.1” Color TFT LCD Display(14.1 used for power analysis)
• Memory Subsystem 64MB RDRAM memory	• Memory Subsystem 96MB RDRAM memory
• I/O Subsystem I/O controller with integrated timers, counters, etc. 3.3v 33 MHz PCI bus Fast IR System Management Bus controller Universal Serial Bus controller Parallel and serial ports Keyboard controller ACPI microcontroller with SM Bus system battery interface	• I/O Subsystem I/O controller with integrated timers, counters, etc. 3.3v 33 MHz PCI bus Parallel and Serial ports System Management Bus controller Universal Serial Bus controller Keyboard controller ACPI microcontroller with SM Bus system battery interface
	• Bluetooth in base
• 1 1394 walk-up port (S400)	• 1394 (1 S400 external port) Optional
• 1 USB port	• USB (1 external connector)
• Storage media Floppy Drive IDE hard drive IDE DVD-ROM	• Storage media Floppy drive IDE/ATA66 hard drive IDE DVD
• Card Bus Two power-managed slots	• CardBus Two power managed slots
• Audio SoundBlaster* S/W emulation Wave table synthesis (downloadable samples) 3D positional sound AC3 / MPEG2 decode Host controller	• Soft Audio (PCI/AC’97) SoundBlaster* S/W emulation Wave table synthesis (downloadable samples) 3D positional sound AC3 / MPEG2 decode Host controller Combined audio/modem AFE Stereo speakers
• Software modem data pump	• Hardware or Software modem data pump (Hardware used for power analysis)
• PCI Docking	• PCI Docking
• LAN on motherboard	• LAN on motherboard

Appendix B

	Estimate 1999 Power (Watts)		2000 Power Goals (Watts)
	3D Game	MPEG 2 Movie	3D Game
CPU & L2 Cache	9.5	7.9	9.5
Memory Controller	1.2	0.9	1.5
System Memory	1.4	1.4	1.2
Graphics Subsystem	2.4	2.4	2.4
IO Subsystem	0.5	0.6	0.6
Audio	1.5	1.5	1.6
Modem			0.4
Hard Drive	0.7	0.0	1.3
DVD Drive	1.4	3.0	1.4
1394 Controller	0.0	0.0	0.0
USB	0.0	0.0	0.0
CardBus	0.1	0.1	0.2
LAN	0.4	0.4	0.4
Power Supply	2.0	2.0	2.6
Charging	0.1	1.0	0.0
Cooling	0.5	0.5	0.5
Other	0.3	0.3	1.0
TOTAL	**22.0**	**22.0**	**24.6**