National Semiconductor Corporation
Technical Backgrounder

Meeting the System Control Demands of Mobile PCs

January, 1997

To create mobile PCs that deliver high performance, long battery life, light weight, and ease of use, designers need a variety of sophisticated core-logic and system-control ICs. These ICs must enable the features that end users want, while giving OEMs the flexibility to develop cost-effective, easily upgradable products.

To address these requirements, National Semiconductor Corporation now offers its Mobile System Solution family of four ICs, which combines National's recognized leadership in system I/O control and its recently acquired PicoPower core-logic and power-management technology into the only complete set of core-logic and system-control chips for implementing notebook computers and other mobile PCs. These chips also constitute the only complete chip family to support the Advanced Configuration and Power Interface (ACPI) Rev. 1.0 standard. While this comprehensive set of chips greatly simplifies design and manufacturing for OEMs, it does not lock them into using all of the chips now or in the future. The National Mobile System Solution is carefully designed to give OEMs the maximum amount of flexibility possible.

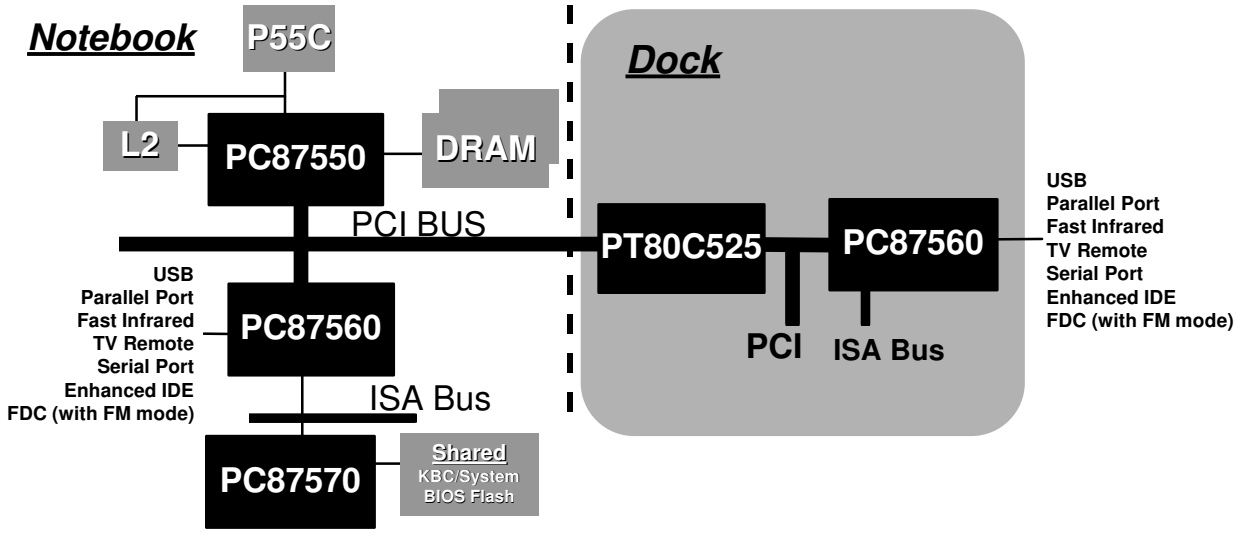

Figure 1. National Semiconductor Mobile System Solution

National's Mobile System Solution includes (Figure 1):

- The PC87550 PCI System Controller (North Bridge) — "North-bridge" functions for 5-class processors (the traditional logic chip set functions "above" the PCI bus, including L2- cache, and DRAM control, and power management controllers)

- The PC87560 PCI SystemI/O Controller (South Bridge) — "South-bridge" functions, such as system peripherals and high-performance I/O controllers (for Enhanced IDE, USB host, Universal Infrared, floppy disk, serial port, and parallel port)

- The PC87570 Keyboard and Power Management Controller — A controller for power management, keyboard, real-time clock, and system functions

- The PT80C525 (Nile-II) Advanced PCI-to-PCI Bridge Interface Controller — A PCI-to-PCI bridge that enables hot docking

Mobile PC Market Trends

The main trends in the mobile PC market include moves toward higher-performance processors, advanced power management, and increased functionality. When designing mobile PCs, OEMs are now using processors with the same performance levels as those in desktop systems. Mobile system solutions are also enabling desktop performance features such as state-of-the-art DRAM and PCI bursting. The resulting parity in performance between notebooks and desktops, coupled with better screen displays, have led many users to replace their desktop PCs with notebook PCs.

To enable users to take desktop performance on the road, extending battery life is always a crucial requirement for mobile PCs. In addition to employing advanced battery technology, OEMs use sophisticated system-level power-management capabilities in ICs to eliminate battery drain when there are no useful functions to perform.

In another trend, the PCI Bus continues to be the local bus of choice wherever possible, as the venerable ISA bus exits from the system. For the time being, however, the ISA bus remains useful for interfacing to low-cost, slow resources, such as the keyboard and the real-time clock. Docking stations can also regenerate the ISA bus for compatibility with older add-in cards.

The desktop-replacement trend has created a major requirement for high-performance docking technology. Users need to be able to dock notebook computers with resources such as large hard drives and network controllers that stay on the desktop. A "hot-docking" capability is needed so that users can connect or disconnect the notebook PC to the docking station without the need for a lengthy reboot. (PCI hot docking stations, specifically, can provide PCI slots and optional ISA slots to enable desktop expandability and flexibility.) Docking interfaces can also provide a convenient way to attach optional mobile resources, such as CD-ROM drives and high-end sound systems, to mobile PCs.

These overall trends in the mobile PC market affect system control logic in five areas:

- Performance
- Power management
- Docking
- Integration
- Flexibility

These areas overlap in many ways. For example, all of a mobile PC's functions could theoretically be integrated into one chip, but this level of integration would allow little design flexibility and would even increase cost because of high packaging expenses for the large-pin-count chip. The key to a superior PC system control chip family is to balance the requirements of each area to achieve the best overall solution.

National Semiconductor's acquisition of PicoPower technology helps meet this goal. The PicoPower product line brings industry-leading technology for north-bridge functions, hot docking, and power management. Its Mobile System Solution, National is taking advantage of these strengths as well as National's traditional strengths in SuperI/O and other highly integrated, mixed-signal solutions.

Boosting Performance

Although the major PC functions and interfaces are standardized, there is still plenty of room for system control logic designs to have a major impact on performance. National's Mobile System Solution maximizes performance in many ways. Two of the most important involve optimization of PCI utilization and the implementation of the CPU-to-memory interface.

Performance is optimized by enabling PCI bursting at rates above 100 MB per second and concurrency across the system. When the CPU accesses L2 cache, for example, any of the PCI bus masters in the Mobile System Solution can access main memory concurrently (Figure 2).

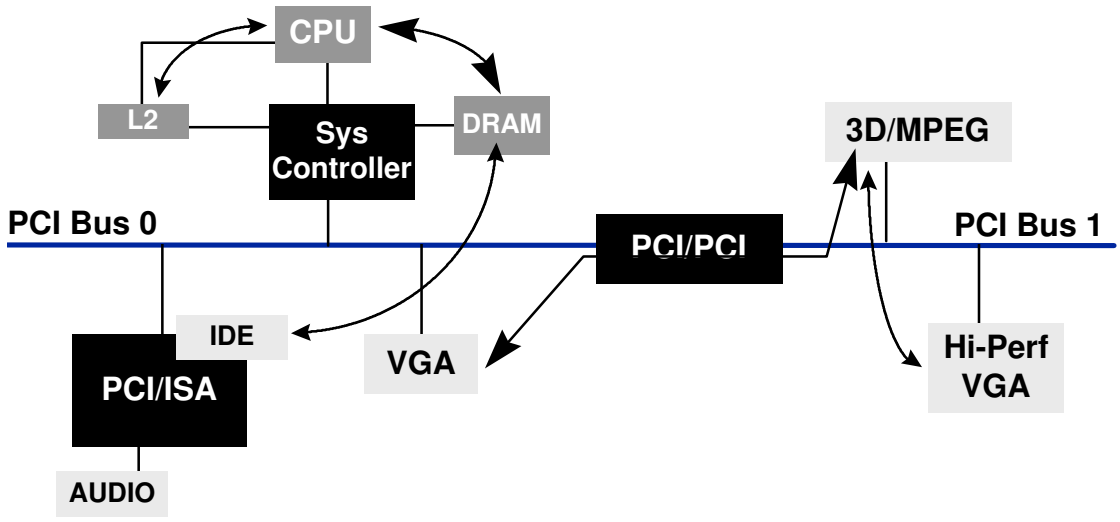

Figure 2. Concurrency Across the System

To fully optimize performance, all high-speed I/O controllers in the system must be PCI Bus masters with scatter/gather DMA capability, and the slower I/O controllers should be accessible through deferred PCI transactions (giving priority to the high-speed controllers). The PC87560 south-bridge chip implements this approach for the Mobile System Solution. The PC87560's bus-mastering I/O controllers include two Enhanced IDE channels, a USB host controller, and a Universal Infrared controller. All other I/O channels in the chip can be controlled via deferred PCI Bus transactions.

The National mobile solution also supports direct PCI-master-to-PCI-target transactions. Although the Windows operating system does not currently support such transactions, National believes that the capability will become available in the near future to provide dramatic improvements in data throughput. Today, for example, PCs rely on the CPU to move MPEG video frames from a digital video disk (DVD) into memory, and then to a graphics controller. With the National chips and an enhanced operating system, however, a PCI bus master could move an MPEG frame from the DVD directly to the graphics controller, leaving the CPU free to perform other tasks. Overlapping tasks speeds up overall execution. Additionally, the PT80C525 PCI-to-PCI bridge moves large blocks of data in bursts between the mobile PC and the docking station, and supports independent operation of the two PCI buses, thus reducing the PCI overhead for both bus segments.

As for the CPU-to-memory interface, the PC87550 north-bridge chip optimizes throughput between the CPU, L2 cache, and main memory by providing independent buffering at various stages. This buffering promotes a smooth flow of data that takes maximum advantage of the available bandwidth. The PC87550 also supports SDRAM for the highest available main-memory performance.

Extending Battery Life with Minimized Power and ACPI

Power management strategies have become increasingly important in recent years as mobile PC users demand longer battery life while CPUs consume more power. National's Mobile System Solution offers the most sophisticated power management functions yet. For the many functions that are under software control, OEMs can continue to use software that was written for previous generations of PicoPower chips, thus shortening their time to market.

The most important power management strategy available today is the Advanced Configuration and Power Interface (ACPI) standard. ACPI defines a flexible hardware interface that provides a standard way to integrate power management features throughout a PC's hardware, operating system, and application software. ACPI thus enables the PC to automatically turn on and off such peripherals as CD-ROMs, hard disk drives, floppy disk drives, and PCMCIA

cards. The National Mobile System Solution is the first logic control chip set to support this standard.

All of the chips participate in power management, but the PC87550 PCI System Controller (North Bridge) and the PC87570 Keyboard and Power Management Controller have especially vital roles. The latter packages control functions for the keyboard and real-time clock together with power-management controls. As a result, the PC87570 can power-up and power-down the entire PC (working via the PC87550) based on multiple internal and external event sources, such as the ring from the fax/modem, docking events, lifting the display, keyboard, pointing device, host command, internal timers, dedicated input pins, analog-to-digital input, low-battery alarm, and real-time-clock alarm.

While the PC is powered-down, for example, the PC87570 can re-apply power (again working via the PC87550) in response to a ring signal from a fax modem. The PC87550 can then wake up the PC within 30 to 50 msec—fast enough to obtain the Caller ID information that is available on the phone line at the first ring. This capability allows the PC to handle phone and network services without being continuously powered-up.

Another key to superior power management is the ability of the PC87550 to control the processor clock. For example, a thermal sensor connected to the PC87570 can tell it if the processor is getting too hot—critical information in a mobile PC that has a powerful processor but no cooling fan. The PC87570 can then instruct the PC87550 to throttle back the clock until the processor's temperature drops.

In most PCs that provide processor-clock throttling, the clock generator controls the clock. The advantage to using the PC87550 is that it can provide a finer level of control. The clock can be slowed gradually, so that the user rarely notices the performance difference. The ability to throttle the clock with fine granularity results in a 5- to 10-percent performance advantage overall. At the other extreme of clock control, the PC87550 has the unique ability to stop the processor clock altogether if the processor has no task to perform.

Hot Docking

A good docking technique for mobile PCs should enable hot docking or undocking at any time and with any system configuration or operating system without electrical damage or data loss. The docking technique should also provide full plug-and-play support, avoid adding extra cost or weight to the notebook itself, and furnish a level of throughput that does not degrade the notebook's overall performance.

National's PCI-to-PCI bridge approach is the only docking technique that meets these requirements, providing a far better solution than the alternatives (ISA bus and CardBus). The ISA bus can have technical problems during hot docking, has a high pin count, generally lacks the sophistication needed for high-performance docking, and does not allow implementation of a PCI bus in the docking station. A CardBus docking interface is easy to implement but has cost, convenience, and performance drawbacks.

National's SmartDock™ technology — implemented in the PT80C525 Nile-II PCI-to-PCI docking chip and supported by the PC87550 north-bridge chip — provides a superior docking PCI-to-PCI bridge. The PCI bus offers extremely high performance, but has a relatively low pin count that makes it ideal for physical connections. Using the PCI protocol, the PT80C525 Nile-II enables the mobile PC and docking-station PCI buses to operate concurrently; a master and a target on the same bus can communicate even when the other bus is busy. For legacy ISA and IRQ support, the PT80C525 allows an ISA bus in the docking station with an implementation of Distributed DMA and Serial IRQ.

Optimal Integration

Given today's semiconductor and packaging technologies, the National Mobile System Solution represents a cost-effective level of integration. It features single-chip north- and south-bridge solutions, and integrates keyboard, real-time-clock, and power-management functions into a single chip.

Further levels of integration will raise tradeoffs among factors such as package costs, process technologies, power management, and the flexibility of the solution. For example, the keyboard/real-time-clock (RTC) functions could be integrated into the south-bridge chip, but the keyboard/RTC functions work well together in a separate chip for power-management reasons: all the other chips can be powered down completely when not in use so that even leakage current is eliminated. Only the PC87570 keyboard/RTC chip needs to remain awake. Similarly, the National mobile solution does not integrate the north- and south-bridge chips into a single IC. Aside from the cost of packaging this huge chip, the integration would make it more difficult to accommodate new processors.

While there are good reasons today for this partitioning, tomorrow promises to bring system-on-a-chip demands. With a comprehensive range of PC logic functions, National Semiconductor is well-positioned to deliver a single-chip solution for mobile PCs when the market is ready.

Maximizing Flexibility

To give PC designers the greatest possible design flexibility, the National Mobile System Solution offers an open architecture. OEMs gain a choice of features and implementation strategies, with the ability to interchange chips with equivalent solutions from other vendors. Further, to provide flexibility to OEMs who use other solutions, the PT80C525 PCI-to-PCI bridge and PC87570 Keyboard and Power Management Controller will work in other system controller environments.

The solution is also designed to allow easy upgrades and product differentiation. For example, the chips permit use of 5-class processors from multiple vendors; support synchronous-burst or pipeline-burst SRAM and fast-page-mode, EDO, or synchronous DRAM; provide flexible power management support; and offer many other options.

In addition to the standard I/O functions required for mobile PCs, for example, the PC87560 south-bridge chip includes support for Distributed DMA and Serial Interrupt Request (Serial IRQ). Many PCI peripheral suppliers support these industry standards, allowing OEMs to

differentiate their product portfolios by adding additional features. Additionally, low-cost ISA peripherals can be connected to the PC87560's ISA-like bus. To simplify ISA implementations and enable Windows Plug-and-Play compatibility, the PC87560 provides many ease-of-use features such as chip selects; programmable memory and I/O ranges; positive and subtractive decoding; and legacy ISA DMA and interrupt routing.

With so many options built into the chips, OEMs can exploit a great deal of flexibility simply by using the entire set of chips. The ability to get this complete chip set from one vendor brings advantages of its own, including validation of the entire set of system functions, the ability to deal with only one vendor in purchasing, and a road map for the future that ensures support for ongoing mobile-PC enhancements, including support for next-generation 5- and 6-class processors.

# # #

National Semiconductor Mobile System Solution Features

PC87550 PCI System Controller (North Bridge)

In a 388-pin BGA package, the PC87550 includes:

- Support for Intel Pentium processors and 5-class processors from AMD and Cyrix; (optimized for Multimedia Extension (MMX) processors)
- The ability to handle processor speeds of 50, 60, and 66 MHz
- 64-bit, direct-mapped, write-through L2-cache controller
- Optimized PCI performance with PCI bursting at more than 100 MB/sec
- Independent buffering between CPU, PCI, and DRAM
- Full PCI, DRAM, and CPU concurrency
- Support for synchronous-burst or pipelined-burst SRAMs for L2-cache
- Support for SDRAM/EDO and FPM DRAMs in a mixed mode with auto detect
- Support for cache-less system design
- ACPI Rev. 1.0 compliant power management
- Proven, simple PicoPower power-management model
- Six power-down modes
- Active thermal feedback
- Active and passive power management
- CPU clock throttling and SMM/SMI support
- CPU power setting at 10% granularity
- Network and Caller ID compliant power-down mode
- SmartDock-II compliant PCI hot-docking support
- Pin- and register-compatible upgrade path to future Pentium processors, and 5- and 6-class processors from AMD and Cyrix

PC87560 PCI SystemI/O Controller (South Bridge)

In a 316-pin BGA package, the PC87560 provides:

- PCI 2.1 interface, compliant to PCI Mobile Design Guide 1.0
- 3.3V and/or 5V operation
- Power management compliant to ACPI Rev. 1.0
- PCI Bus master interface with scatter/gather DMA
    - Two channels of Enhanced IDE
    - USB host controller compliant to OpenHCI Ver. 1.0
    - Universal Infrared controller (including support for IrDA high-speed extensions)

- Deferred PCI transactions for other I/O functions
    - Floppy disk controller
    - 16550 serial port

    - IEEE 1284 parallel port

- System functions
    - Distributed DMA controller with DRQ/DACK routing
    - Serial interrupt controller with interrupt routing
    - 8254 timer

- Low-cost expansion through an ISA-like bus
    - Programmable chip selects with programmable I/O and memory ranges
    - Positive or subtractive decoding
    - Interface to keyboard controller, RTC, and system FLASH ROM

- Master and slave mode for use in mobile PC or docking station

PC87570 Keyboard and Power-Management Controller
In a 176-pin TQFP, the PC87570 offers power management, keyboard, and system control resources, including:

- 16-bit embedded RISC processor core
- Interrupt control unit
- Direct interfaces to keyboard, mouse, and internal pointing device
- Shared FLASH-memory BIOS support
- Real-time clock
- Four timers
- A/D converter with an 8-channel multiplexer
- Four 8-bit D/A converters
- ACCESS.bus interface
- Full ISA address decoder
- Programmable clock generator
- Extensive power management control capabilities
- 76 general-purpose I/O ports

PT80C525 (Nile-II) PCI-to-PCI Bridge Interface Controller
In a 176-pin TQFP, the PT80C525 Nile-II supports a high-performance docking interface and dual-ISA system design with these features:

- Full compliance with PCI Local Bus Specification Revision 2.1
- Full compliance with PCI-to-PCI Bridge Architecture Specification Revision 1.0
- Full compliance with SmartDock-II technology that enables true PCI hot docking
- Full compliance with Nile registers in transparent bridge mode
- Support for Windows 95 Plug-and-Play capabilities, including “Eject PC” icon
- Supports PCI sustained bursting beyond 100 MB/sec
- Supports concurrency across the primary and secondary PCI buses

- Supports patent pending Speculative Cycle Start technology
- Programmable transparent or visible bridge mode
- Programmable positive or subtractive decode modes for both upstream and downstream transactions
- ACPI compliance